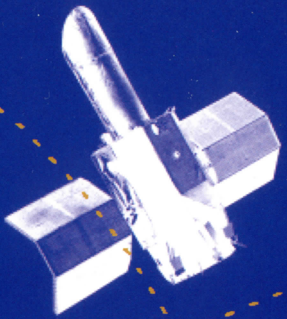
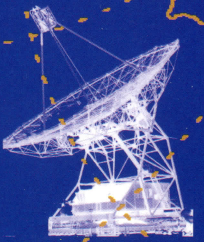


# Organizations, People and Strategies in Astronomy

Volume 1

Edited by André HECK



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# Organizations, People and Strategies in Astronomy

## Volume 1

Edited by

André HECK

## OPSA I

venngeist

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# EDITORIAL

## A Matter of Continuity

This volume is of the same vein as an earlier prize-winning series *Organizations and Strategies in Astronomy (OSA)*[1], the seven volumes of which covered – over their 150 chapters by world-class scientists – quite a number of unusual subjects in astronomy-related books. The following main themes were tackled:

– characteristics and strategies of astronomy-related organizations (globally and specifically, nationally and internationally);
– recruitment and promotional policies;
– economy of activities;
– evaluation processes (proposals, individuals, institutions, etc.);
– policies for professional publications;
– bibliometric studies;
– evolving sociology of scheduling and coordinated observing;
– communication under its diverse facets;
– series of astronomy-related conferences;
– interactions with other communities and the society at large;

together with a long list of matters covering the astronomy-related life and context, in the spirit of sharing experience.

Rather than being devoted to the publication of hard-science results, the OSA volumes described how astronomy research lives: how it is planned, funded and organized, how it interacts with other disciplines and the rest of the world, how it communicates, etc.

Thus the OSA series has been a unique medium for scientists and non-scientists (sometimes from outside astronomy) to describe their experience and to elaborate, often for the first time at such a level, on non-purely scientific matters, many of them of fundamental importance for the efficient conduct of our activities.

[1]See Heck (2000-2006) and `http://astro.u-strasbg.fr/~heck/osabooks.htm`.

As the initiator and catalyser of the series, it has been a privilege for me to interact with the various contributors. These have done their best to write in a way understandable to readers not necessarily hyper-specialized in astronomy while providing specific detailed information on their expertise and sometimes quite enlightening "lessons learned" sections.

The last paragraphs of OSA 6's and OSA 7's Forewords (resp. Cesarsky and Bonnet 2006) stated eloquently the timeliness of dealing with strategical and organizational issues, insisting on the need of pursuing such catalyzing and publishing activities. Together with encouragements and positive comments received independently, this led me to launch a continuation series while putting more emphasis on people – hence the additional word in the title: *Organizations, People and Strategies in Astronomy (OPSA).*

## A Matter of People

It is sometimes necessary to remind young students that scientific knowledge does not exist *per se*, but is the result of an evolutionary process mixing facts and theories with their confirmation or invalidation via data collected by continually improved instrumentation and analyzed by ever more sophisticated tools.

Behind all this, and behind the papers, books, colloquia, projects, experiments, organizations, successes, failures, etc., are people, with all the peculiarities of the human zoo, its bright sides, its weaknesses and its possible disabilities. This seems sometimes forgotten by the scientists themselves, and in particular by some managers of science handling their human material like pieces on a chessboard, or like equations, lines of codes or test tubes that can be manipulated at will or along mere moody whims.

Behind humans are lives, families, projects, a past and a future that must be respected. Too often in my already long professional voyage have I seen entire careers damaged by clumsy managers believing they were the only holders of the truth in a sacrosanct mission that was merely the fruit of their own ambition or of their narrow-minded approach of our job. Sometimes such misdeeds – often in a context of *faits accomplis* and absence of dialogue with the persons concerned – are no more than personal greed or intrigues in favor of family members or a coterie of cronies. I shall come back to this hereafter.

Astronomy has one of the most noble missions: understanding the universe, as well as the place and rôle of man in it. This can be ideally achieved by providing the best working environment to those serving astronomy, not only via sufficient funding and efficient equipment, but also by minimizing unnecessary pestering and interferences.

Creative people should be given special attention as they develop re-

*Figure 1.* This frontispiece of Chérubin d'Orléans' *La Dioptrique Oculaire* (1671) is extracted from the remarkable compendium by Inga Elmqvist Söderlund (2010). It gathers together about 300 frontispieces and illustrated title pages from European books on astronomy published in the $17^{th}$ century. In her own words, Elmqvist has *"undertaken to show how a frontispiece in a $17^{th}$-century astronomy book is able to invite the user to enter into a sumptuous palace or a beautiful garden, ornate with works of art, to be offered to drink from the fountain of wisdom."* Father Chérubin d'Orléans (1613-1697), or François Lasséré under his native name, is credited with the invention of the first binocular telescope, among other things. At the beginning of this book on dioptrics (in the *Epistre* directed to Colbert, King's Counsellor and Secretary of State), the author describes how astronomy and the telescope could be relevant to the society at large. The frontispiece above is signed by Jean le Pautre and Gérard Edelinck. See p. 194 of Elmqvist Söderlund (2010) for a full description. (Courtesy I. Elmqvist Söderlund)

search (often at their own expenses) outside beaten pathes and established funding channels. It requires for this a managing intelligence open to unorthodox approaches and unusual methods of work[2], often sources of dazzling syntheses and stunning advances. Providing adequate recognition is also of fundamental importance in a world of oversized egos versus modest remunerations.

A question is coming up recurrently nowadays: are we producing too many astronomers, *i.e.* more than what the society needs and/or can absorb? There are countries where, years ago, educational programs in astronomy have been multiplied in universities, putting them *de facto* in competition (*i.e.* with their survival depending on the number of students), and producing years later so many PhDs in astronomy that hundreds of applications for only a few open positions are now eating away the time of selection committee members. Would more focussed policies not have been more efficient?

## A Matter of Ethics

> *"Scientists must always remember that they are human beings first, scientists second. And adherence to ethical principles may sometimes call for limits on the pursuit of knowledge."* [J. Rotblat (2002)]

> *"The greatest pressure on the integrity of scientists are exerted at the interface between the professional practice of science and the demands by fund-awarding patrons." [...]*
> *"The Faustian bargains lurk within routine grant applications, the pressure to publish for the sake of tenure and the department's budget, the treatment of knowledge and discovery as a commodity that can be owned, bought and sold. Handling these pressures and realities is inseparable from the difficult task of being a scientist today." [...]*
> *"Researchers who falsify data, massage statistics, appropriate other people's discoveries or ideas cannot be said to be "good scientists", in either a moral or a professional sense: certainly their results are unlikely to be any good."* [Cornwell (2003)]

The above quotations convey some of the boundary conditions of our job. Everybody will certainly agree on general ethical principles, such as those hinted at by the first quotation, issued on a background of discoveries potentially leading to the development of weapons of mass destruction.

The practical application of ethical rules of all kinds seems however problematic as breaches can be recurrently observed, most of them not lethal ones, but nevertheless annoying.

[2]On creativity in arts and sciences, see *e.g.* Heck (2001).

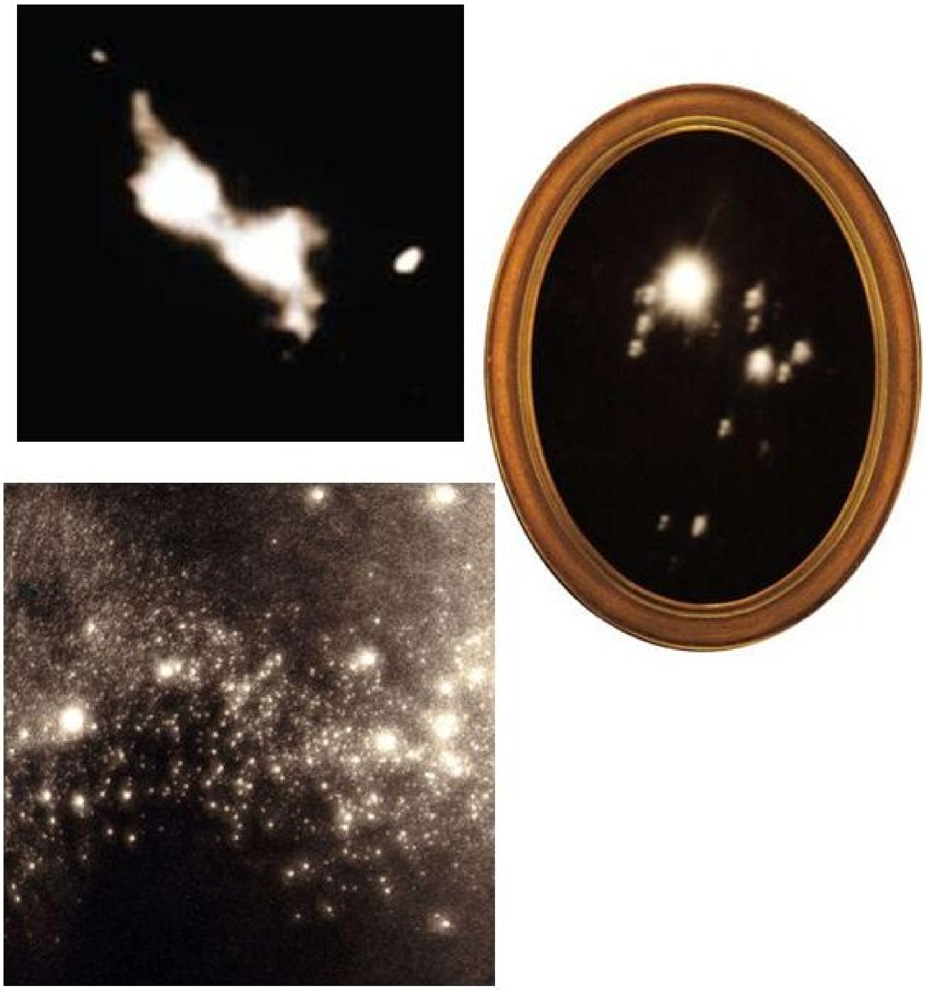

*Figure 2.* Artist Mariana Tres has an original way of sprinkling flower to fabricate false astronomical photographs. As mentioned on her web page, she *"approaches her work in a multidisciplinary manner to illuminate untold histories and events of the natural world and to playfully examine the veracity of photography, science and recorded history."* Gathered above are (upper left) the *Bikini Nebula* attributed to imaginary $19^{th}$-century astrophotographer Anabella Gaposchk, (right) an *Open Cluster in Sagittarius*, and (lower left) *Merging Stars in Cassiopaea.* Note that the modern bikini as women's swimsuit was invented by French engineer Louis Réard only in 1946, naming it after Bikini Atoll in the Pacific, the site of nuclear weapon tests in July of that year. See Nath (2007) for more details, including a pointer to a press release on Tres' artistic residency at Harvard-Smithsonian Center for Astrophysics. (Courtesy M. Tres)

In our job, ethics in publishing is perhaps the first issue we are thinking of. In my opening comments at the FPCA-II meeting (Heck 2011), I detailed a recent personal experience: unrelated bibliographical references surrepticiously added, by an editor at the level of the proofs, in a paper in principle frozen since it had been approved by a couple of referees.

At about the same time, an independent paper had been sent to the publisher by the editors of conference proceedings without me having a chance to check the proofs. Once this could be done via direct contact with the unaware publisher (embarrassed at the editors' behavior), it turned out that the original text had been altered in an unacceptable way. What went through the minds of the editors in charge of those publications? Do they believe they could be ever trusted again?

And what to say about that other case when a foreign institution extracted some material from a directory to provide it to a commercial company without proper return to the original compiler?

So ethics can still be an issue in this $21^{st}$ century, and perhaps even more so because of the flexibility and potentially easy alteration of the electronic material. For some people, digitization is an open invitation to manipulation.

Hence the need of educating students in the way research is actually carried out, properly carried out, and its results cleanly published. This is why I was very happy to see the late John Huchra tackling those issues in his column as President of the American Astronomical Society (AAS), in the society newsletters[3]. Please do have also a look at the *AAS Statement on Professional Ethics* [4]. John's untimely death prevented him from materializing his intended contribution to this volume.

Another omnipresent ethical facet is nepotism, a *de facto* taboo since it is generally overlooked by people dealing with ethics, perhaps by fear of being brought to courts or by the difficulty of proving facts. Nepotism can take different shapes, from pure nepotism securing PhD theses and/or positions for close relatives to the usage of some managerial authority to inflate artificially the achievements of next-of-kin, either personal ones or of the group they lead, for instance by aggregating contributions from outsiders.

Such misdeeds can take subtle forms, be exercised through pressure and intimidation, and have sometimes a desastrous impact on the career of brilliant scientists. For a couple of people I know, it had been necessary to move and even to expatriate themselves for pursuing a decent career (with family consequences leading up to a divorce). On fragile characters, this can have long-lasting psychological consequences, embittering the rest of their life. I have the greatest admiration for those people, loving their

[3]See, *e.g.*, *AAS Newsl.* **146** (May/June 2009) and **148** (September/October 2009).
[4]Cf. *AAS Newsl.* **151** (March/April 2010) p. 8-9.

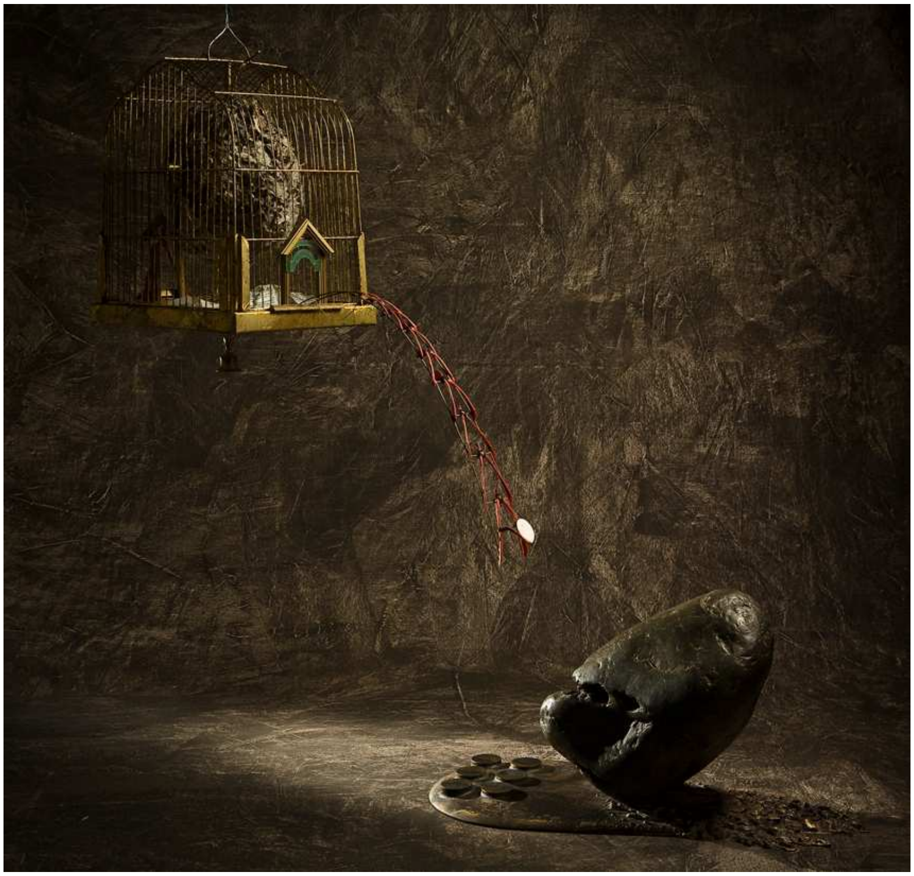

*Figure 3.* Stephanie Rayner's works have already been featured in the OSA volumes: the *Galileo's Eyelid* and the *Labyrinth* appear in OSA 4's and OSA 7's Editorials respectively. The *Dialogue Concerning the Two Chief World Systems* illustrated above is made of two separate sculptures relating to each other. It replicates the title of Galileo Galilei's 1632 book, a bestseller of the time, that led to his conviction of "grave suspicion of heresy". Says Rayner (private comm.): *"The upper left sculpture is a bird cage shaped like a Bishop's hat. I took this rusting cage and gilded it with gold leaf ..., but the rust still shows through. Inside the cage is a gold cross with a wasps' nest built around it. The wasp nest's paper structure has been incorporated with pages of the Bible. The bottom of the cage is clear so one can see wasp chewed pages of the Bible lying there and through the centre is an upside-down gold candle stick. The doors of the cage look like church doors ... and from one door there is a ladder in forced perspective made of red wishbones. The last wishbone holds a Eucharist wafer. The other sculpture is an asteroid sitting affixed to a piece of bronze. I have done nothing to that stone ... it came from the Northern lake were I found it polished and what with looks to me like a brow ridge, nose and open mouth. The rear of the bronze is rough, like debris after something has hit the earth. In the front are six circles with raised and polished surfaces that I etched with Galileo's first drawings of the Moon. These bronze Moons are of the same size as the Eucharist wafer. These two sculptures are in dialogue."* More on Rayner's works and her web site can be found at Nath (2003). (Courtesy Stephanie Rayner – Photograph by Rob Davidson)

job, dedicated to their science, maintaining quality and objectivity of work, serving the high ground of science in spite of the reprehensible attitudes they had to face.

To prevent all this, some institutions are actually preventing close relatives to work at the same place. Should that be a general rule? If it would be easy to apply it blindy for next-of-kin (possibly making life difficult for some couples), how should we deal with coteries of chronies?

I shall come back later on harassment that can also be included under ethics. It is a much broader issue than sexual harassment to which it is often reduced. By the way, in this respect, we should be careful not to build gender discrimination the other way round, keeping in mind that we should aim at a situation where ultimately the only criteria would be quality and competency, i.e. sheer quslification.

Often small ethical issues are enough to poison a working context and to hamper the successful development of a career. And we should be ambitious in countering these. Make a parallel with noise pollution: loud sources in construction and transportation systems are well identified and measures start to be taken to reduce them, but surveys consistently show that people are mostly unhappy, and sometimes getting a hell of a life, with the accumulation of petty noise sources from their neighborhood.

There is no ingenuousness here, nor excessive pessimism. Many managers are fully dedicated to their job, sometimes to the prejudice of their own scientific activities. But there is no reason to accept the questionable practices of a minority not fit nor properly trained for the job. Some of these live in the illusory confidence that hastily organized seminars have given them the keys to human handling.

## A Matter of Vision

In the OSA 6 (2006) Editorial, a pragmatic scientist was visiting an imaginary place called Weirdland, populated by Weirdies obeying rules edicted from the capital city, Weirdtown. This visitor could not help being surprized by the way the Weirdic scientists were functioning. Here are again, from his diary, a few notes falling directly under ethical considerations:
– few scientists in charge of institutions seemed to have ever been trained in management or in human resources; they often behaved in a narrow-minded "little-chief" spirit;
– the qualities of leaders were rarely a selection criterion for positions of responsibilities; the process was generally a kind of cooptation, sometimes through the formal election of a unique candidate;
– the administrative structure and the resulting burden were so heavy that highly qualified scientists avoided entering the managerial career and there-

*Figure 4.* Quite a few of Anselm Kiefer's sizeable masterpieces involve an astronomical sky made of outlined constellations with numerous identifications of astronomical objects. If the explicit stellar names are generally correct (with seldom confusions or omissions), the numerical identifiers (most on rectangular white labels) are imaginary, not respecting an increasing right-ascension sequence or overflowing in number of digits what would normally be expected from coordinate data. Note also some artistic licence with the Messier list, such as M138, since Messier compiled only 110 objects. The 560cm × 380cm work reproduced here, dated from 2001 and entitled *Himmelspaläste 2 (Bootes)* [Heavenly Palaces 2 (Boötes)], belongs to the Würth Collection (Inv. 8316). It is oil on canvas, together with emulsion, lacquer, plaster and straw. For more on Kiefer's extensively documented works, their background and their interpretations, see *e.g.* Kiefer (2011), Kiefer & Arasse (2010) and Weber (2011), to quote just a few recent publications. (Courtesy Würth Collection and Galerie Thaddeus Ropac, Paris – Special thanks to Marie-France Bertrand, Musée Würth France Erstein, and to her team)

fore ended up being regulated by less competent people;
– the personnel selection and promotion processes were most disturbing; under policies of transparency, it appeared that many decisions were in fact taken in advance of commission meetings, that applicants had frequently no possibility for appeal and no opportunity to get themselves heard;
– ethical issues were largely ignored by Weirdic scientists; ethic charters were rarely heard of or ignored; guidelines to avoid conflicts of interest and collusions seemed not to exist; close relatives or people with strong connections were sometimes holding high-ranking positions within the same organizations;
– examples abounded where immediate carreerist benefit (personal or for friends) prevailed over the long-term interest of the discipline.

These were just a few points from the visitor's diary that was holding many more comments on publications, education, evaluation, and other issues. Weirdland was a virtual world, but the list above could certainly be extended by our own observations.

In the forewords of his textbooks, Bouasse (1918) was already pointing out shortcomings and inadequacies in the professional deontology, as well as absurdities in astronomy educational policies at the very beginning of the $20^{th}$ century. Much closer to us, Koestler (1973) set up, on a dramatic background of world conflict threat, a hilarious parody of academic jetsetters attending a conference in an easily identifiable European place.

What seems to be missing with some managers, sometimes with national policies, is a long-term vision of our rôle towards the society at large. It requires managers to go beyond their personal priorities, to exercise a large dosis of humanism, to put themselves above the courtisans unavoidably surrounding them and to get an elevated perspective.

Even if, as says Owen (2009), *"hubris is almost an occupational hazard for heads of government, as it is for leaders in other fields [...] for it feeds on the isolation that often builds up around such people"*, there is no excuse to accept it among leaders of scientific institutions.

In his last annual report, the ombudsman of the French Republic had an interesting comment (Delevoye 2011, my translation): *"Authority, to be accepted, cannot be based on the sole justification of a title or an election, but will rest on the moral dimension of the person exercising it."* Should we add: rather favor the ethics of virtue than that of rules, rather favor what is correct than what is allowed?

At a time when media are hungrily exploring the effects of poor management on morale at work and investigating waves of suicides at big companies, giving them ample coverage, we should certainly do our best to avoid such an exposure in our fields, if this is not already too late (see *e.g.* Foderaro 2011).

Workplace bullying and/or mobbing[5] leading to resignations, departures, and psychological damage up to suicides are generally the result of hubristic management. I have been recurrently baffled by utterly striking lacks of dialogue, with managers making an opinion and taking decisions irremediably impacting the career of their people without even talking to them, and sometimes just on the basis of rumors or hearsay.

Some time ago, I was attending a largely historical conference together with an assemblage of past managers of institutions of all kinds, some of them with a reputation of "dictators with blood running in the corridors". But, by the time of that meeting, quite a few of them had become diminished and pitiful old men – a powerful lesson of humility!

*

*  *

## This OPSA Volume

In line with the OSA/OPSA spirit of sharing expertise, this book opens with a chapter by Chr. Veillet analyzing the evolution of observational procedures from his long stint as head of the Canada-France-Hawaii Telescope.

Several chapters are then reviewing the organization of astronomy in various parts of the world as well as international collaborations: by A. Hopkins and his colleagues at the Australian Astronomical Observatory; by M. Bode on the ASTRONET Infrastructure Roadmap; by P. Murdin on the demography of astronomy in the UK; by Chr. Impey on the workforce development and public engagement in the US; and by G. Miley on the IAU Astronomy for Development Programme.

The volume continues with a group of chapters dealing with education towards research, including the training of young astronomers, starting with a review paper by R. Snieder and collaborators, followed by Chr. Sterken's presentation of his *Scientific Writing for Young Astronomers* project. Unexpected advice to graduate students in astronomy are gathered in a short note by J. Linsky while G. Brissenden *et al.* describe a new community-based model for conducting astronomy education research and instructor professional development in the US. Staying in the same part of the world, K. Marvel details the career services of the American Astronomical So-

[5]Various definitions of *workplace bullying* as harmful boss-behavior or actions of malintent towards employees involve immediate supervisors, managers or bosses, with or without complicity of other employees. Bullying includes one of several of the following characteristics: repetition, duration, escalation, power disparity, attributed intent. *Mobbing* – a term imported in several European languages – covers all forms of bullying, including by single persons.

ciety and J. Holbrook analyzes survival strategies for African American astronomers and astrophysicists.

The contributions of Citizen Science to astronomy research are then the theme of a chapter by C. Christian and colleagues. Under the title *Accessible Astronomy*, N. Grice reviews her remarkable work of making astronomy accessible to people with all kinds of disabilities. This section ends with the presentation by J. Harvey and P. Michaud of Hawaii's annual *Journey through the Universe (JttU)* program, a flagship Gemini Observatory outreach initiative.

Then come several contributions linked to the documentation facet of our activities: U. Grothkopf sharing her extensive experience as astronomy librarian; H.A. Abt presenting the usage of h- and a-indexes in astronomy; and E. Henneken and collaborators describing the impact on discovery of the resources and tools offered by the Astrophysics Data System.

A couple of chapters are devoted to ethics in this volume: a review paper by D.R. Koepsell and a discussion of publishing practices by L. Sage.

The last group of chapters is dealing with historical aspects: J. Meadows takes the example of Rutherford Appleton Laboratory for considerations on the development of big science; A. Heck illustrates historical examples of lobbying; and J.M. Pasachoff describes the new obituary policy at the American Astronomical Society.

As in the OSA volumes, this editorial highlights several examples of astronomy-related art – one of the facets participating to the general communication process for astronomy. See the figure captions for details.

**Acknowledgments**

It has been a privilege and a great honor to be given the opportunity of compiling this book and interacting with the various contributors. The quality of the authors, the scope of expertise they cover, the messages they convey make of this book a natural continuation of the previous OSAs.

The reader will certainly enjoy as much as I did going through such a variety of well-inspired chapters from so many different horizons. I am specially grateful to the various independent readers ("referees") who ensured prompt and constructive reading of the contributions.

The Editor
*Lu Neûr Flokê*
July 2012.

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[7] `http://www.center.kva.se/bilder/Avhandling_5.pdf`

[8] See also `http://www.stephanierayner.com/` .

[9] See also a CfA Press release (21 Sep 2001) about Tres' residency there at: `http://www.cfa.harvard.edu/news/archive/tres_901.html`, as well as `http://www.reframingphotography.com/content/mariana-tres` .

*Organizations, People and Strategies in Astronomy I (OPSA I), 15-26*
*Ed. A. Heck, © 2012 Vennngeist.*

# CHANGING WORKING HABITS AT OBSERVATORIES: MORE EFFICIENCY FOR BETTER SCIENCE!

CHRISTIAN VEILLET

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**Abstract.** Moving away from the widely used model of astronomers going to the telescope to conduct their observations is a trend that is being adopted by an increasing number of facilities. Instead of degrading the data, staff-made observations are actually overall providing better results, as they use the conditions best suited to each program and are done by well-trained observers. The next step is to realize that a PhD is not at all needed to perform these observations: up to some extent, even the night selection of "what to do when" can be left to a well-trained AI-based computer. On the technical side, observing remotely without anybody at the telescope allows for a more relaxed observing environment, leading to better observations. As the telescope is now far from the operator, remote sensing is indispensable and allows for continuous and automatic monitoring, opening the door to automatic alerting when equipment shows signs of problems before they become a real failure. The reliability of the observatory improves and the time lost to failures is dramatically decreased, leading to a much lower level of stress for the technical staff. Using our experience at the Canada-France-Hawaii Telescope, we will explore the practical consequences of this evolution, not only on the performance of the observatory, but also on the changes it entails on the overall redistribution of the work within the observatory, and on the relationship between the staff and the astronomical community, culminating with the notion that an observatory is first and foremost a service provider.

*Figure 1.* Solar Observatory at Chankillo, Peru. (Courtesy Ivan Ghezzi)

## 1. The Observing Astronomer

Astronomers/astrologers have for millennia observed the heavens with their naked eyes, discovering in the variation with time of the apparent position of the Sun, the Moon, and the stars some of the fundamental cycles of their motion, from the duration of the various years (sidereal, tropical, ...) to the precession of the equinoxes, of the various lunar months to the Saros cycle. These early observers used natural or man-made features (Fig. 1) in the landscape as alignment aids, later replaced with instruments like gnomons or armillary spheres. Astronomers conducted their own observations, but were also able to tap into the recording of earlier catalogs or observations, thanks to the use of writing systems such as the Sumerian cuneiforms for Western astronomy. This access to earlier observations was key to the study of cycles and time-related phenomena. It is not much different from going back to previous observations or a star catalog when looking for the optical counterpart of a gamma-ray burst or the precursor of a supernova. With naked eye astronomy, only the location of the observer would make a difference in what could be seen of the Heavens: the observable sky depends on the observer's latitude and on the transparency of the atmosphere and darkness of the night.

The advent of the telescope in the early 1600s changed drastically the

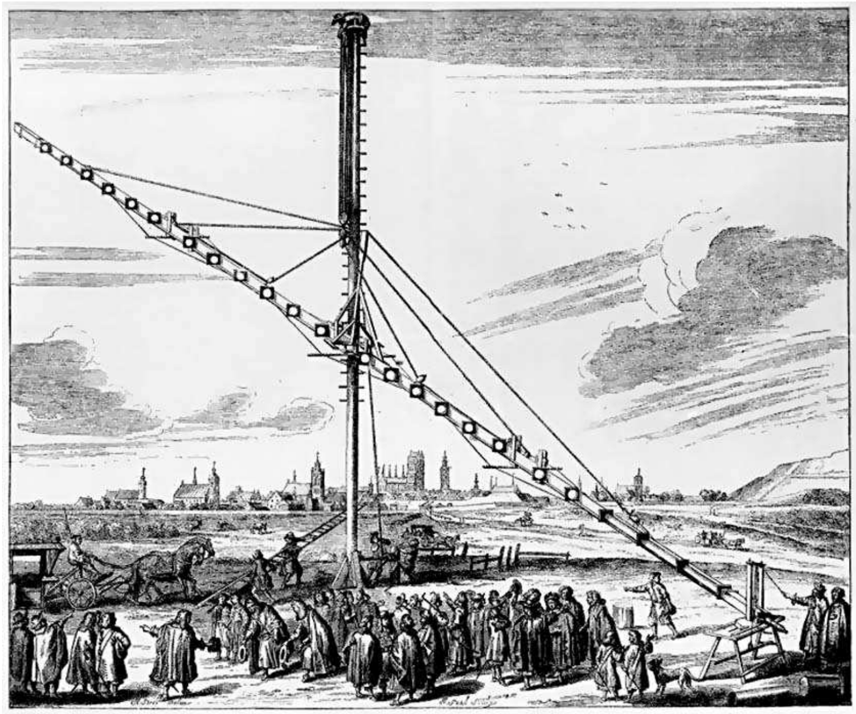

*Figure 2.* Hevelius' 46m long refractor. (public domain)

situation. If astronomers dealing with observational data wanted to make significant progress, they had to have access to these telescopes, which became quickly more and more sophisticated, therefore expensive and only accessible to a few. Photography would not come to general use before the end of the $19^{th}$ century. Therefore, for nearly 300 years, these observing astronomers had to rely on their eyes and record their observations as position measurements or as drawings. They spent countless nights at the eyepiece with the help of night assistants when the telescopes were not easily driven single-handed, like in the early days (Fig. 2) or with William Parsons' $72''$ telescope which required well-muscled workers!

For the whole $20^{th}$ century, from the early days of astronomical photography to the generalized use of CCDs or other modern detectors, astronomers kept observing themselves even though their eyes were no longer needed for the data gathering itself. Most of these astronomers would come from their own institution (an observatory or a university department) to telescopes made available to the scientific community by public or private facilities. As instrumentation evolved from basic imaging in the visible light to more complex instrumentation (spectroscopy, adaptive optics, ...) in new wavelength domains (infrared, sub-millimetric, or radio), astronomers had to learn how to observe with the instrument they intended to use, hopefully reading the user's manual before their observing run and receiving an initial support from staff at the telescope. During the run, the level of support would vary with the facility visited: more often than not, observers would be left by themselves with the assistance of a telescope operator.

In spite of much progress made over the last decade in computer-assisted instrumentation and the amazing growth of the Internet capabilities, the observing astronomer coming to the telescope for an "observing run" is still the main mode of operation at most of the major observatories. However, the availability of fast Internet connections has incited a few observatories to offer "remote" observing: the observing astronomer stays either at his/her own institution, or at a more comfortable location than the telescope itself, while having access in real time to the telescope observing environment in order to act as if at the telescope. This remote observing is more efficient than the traditional "observer at the telescope" mode, as it avoids traveling to the facility, often on long distances, saving time and money while allowing a more rested astronomer to be more efficient in a better environment.

## 2. Observing for the Astronomer... Why?

If the eyes of an astronomer at the telescope for an observing run are no longer needed to collect the data, what are they needed for?

One of the main arguments given is that the observing astronomer is faced with changing observing conditions, sometimes not suited well to the observing program. There is a need to adapt the observing strategy to these conditions in near real time by looking at the data, sometimes changing targets or moving to a backup" program.

It is true that an observing run can be plagued by poor seeing while a good image quality is required for the success of the program, or by absorption when photometric skies are needed. A full observing run can even be lost to weather! All of this leads to an inefficient use of telescope time, which the presence of the observing astronomer can only mitigate, at the price of much loss when a run is wiped out by weather. The only way to insure that observations are made under the conditions required by the observing program is to schedule them only when those conditions are met. This is done in the Queue observing scheme adopted partially or fully by many observatories: all observations requested by the users are piled up in a pool and, at any time, only those which can use the current conditions are actually executed.

In such a scheme, there is no place for astronomers at the telescope (even remotely) observing only for their own programs, but if they have the telescope full-time for their own use! Data are now always acquired in the requested conditions. The Principal Investigator (PI) of a program, no longer observing, will therefore get what was requested for. After all, space missions work in that mode at the satisfaction of their users! Another advantage is the possibility to share between programs basic information like sky flats or calibrations. A short visitor run will only get flats based on a few images, while, in Queue mode, flats will be taken in all required filters for as long as the instrument is on the sky, leading to a much better set of flats for all the programs observed during a given period.

When observing for the astronomers in queue mode, ground-based observatories are challenged by large changes in observing conditions on short time scales, something space observatories are protected from. However, the burden is on the observatory, not on the PIs.

## 3. Observing for the astronomer... Who?

We are now looking at an observing model where the observations from all programs which were allocated time are in queue, and where the PIs do not observe for themselves anymore: observations are done in service mode. We will refer to this mode as QSO (Queued Service Observing) (Veillet 2006).

For some observatories, a cheap way to handle QSO is to ask observing astronomers coming to the telescope to run the queue instead of observing for themselves, though they may have a chance to conduct some of their own observations if they pop up in the queue. Unfortunately, the savings are only local: in the great scheme of things, using an astronomer from afar, with the added cost of travels and associated expenses, is not cheap at all! It also only works for a relatively simple instrument which does not require a deep knowledge of its many modes.

An alternative solution is to ask an observatory staff astronomer with a good knowledge of the instrumentation to perform the observations for the users. This time, it is expensive for the observatory: an observatory has to run every night of the run and many astronomers would be required, as one does not want to have them only doing observations for users!

Actually, having an astronomer running the queues at night is not a good idea: it is not the best use of the skills of a scientist. In QSO mode, queues are prepared during the day relatively quickly by a staff astronomer and the work at night is limited to selecting the observations in the prepared queues according to the observing conditions. While this task requires a good knowledge of basic astronomy and observations, it does not require a PhD at all.

At the Canada-France-Hawaii Telescope (CFHT), the Service Observer

(SO) positions created at the onset of QSO only required a BA in astronomy, or physics with a minor in astronomy, ideally with already some knowledge of observation at the telescope, and with a real interest in handling observations for scientifically exciting programs on a large telescope with state-of-the-art instrumentation. All the SO recruitments, made over nearly a decade from a pool of passionate candidates, have been excellent. SOs have played a key role in the success of the observatory, accompanying the progress of the QSO mode initially limited to a single instrument toward the normal operation mode used all year long (but for a few nights with an old instrument used in classical mode).

## 4. Observing Alone?

When Service Observers started to replace observing astronomers, the observatory still needed an Observing Assistant (OA) to take care of the telescope and the overall facility while the SO was observing. The CFHT telescope is big in spite of its relatively modest mirror size, as it was conceived at the end of the 60s on a Palomar 5-m telescope model (Fig. 3). With more and more computer assistance added to the QSO mode, like an automatic slew of the telescope once an observation is selected, or automatic field acquisition and guiding setting once on a target, the role of the OA became limited to readying the observatory for observing at the beginning of the night and closing and securing it at the end of the night. During the observing itself, the OA's role was mainly to intervene and assist in case of problems. It became clear that one person, with appropriate training, could actually handle both the SO and OA duties. This would reduce the manpower needed for observing, therefore increasing the efficiency of the operations of the observatory. Unfortunately, at sites like Maunakea, safety is an issue as the working conditions are difficult (remoteness of the site and altitude) and having at least two people in the building is mandatory per the so-called "two-person rule". In order to really reduce the manpower needed at night, we had to think about not being at the telescope anymore during observing!

## 5. Nobody at the Telescope: Moving to Remote Operation

Retrofitting an old facility like CFHT to enable its remote operation is not an easy thing: after all, we are talking about a 250-ton of moving mass telescope, or a 580-ton dome, with their hydraulic drives and high-pressure oil running from the basement to the dome floor, hundreds of meters of hoses carrying glycol running all over the telescope and its instrumentation, ... Is it really feasible to replace all the monitoring carried out by an OA and all the interventions a person could do at night at the facility by


*Figure 3.* The CFHT telescope. (© CFHT)

remotely-controlled functions accessible on a screen and through the click of a mouse?

Actually, not only it is feasible, but it brings much more than just the possibility of remotely operating of the facility! An example: replacing reading a pressure gauge at the beginning of the night to check that pressure is nominal by a pressure sensor opens the possibility of continuously controlling the pressure through a script reading the value, sending a warning when a significant increase or decrease, or a significant change rate, are detected, therefore preventing a failure before it occurs! Add to the script an automatic notification through text messages on smart phones, write as many scripts for as many sensors as you deem necessary for safe operations, and you end up with technical staff faced with more advance notice of potential failures and consequently much less actual ones: the operations move from fighting fires to well-informed preventive maintenance and preemptive actions. The decrease of the amount of time lost to technical problems is now well below 2% of the clear weather, an excellent reliability for an old facility equipped with complex high-tech instrumentation. The peace of mind given to the technical staff has been a very important outcome of the move to remote operation.

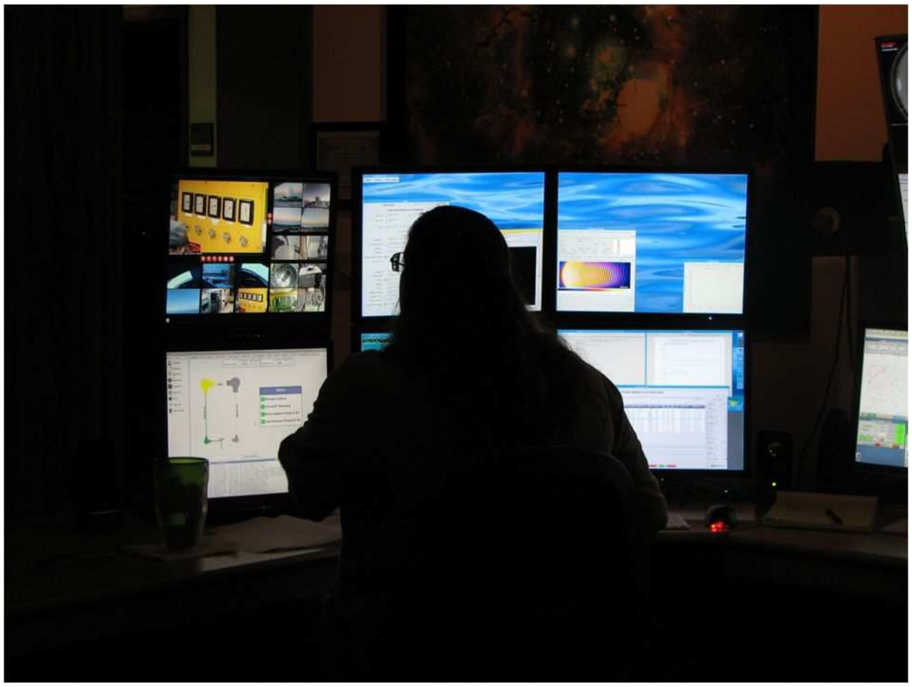

*Figure 4.* Remote Observer at the helm of CFHT from Waimea. (© CFHT)

## 6. A Single-Handed Observing Facility

Now that the telescope can be operated remotely, the stage is open for single-handed observation, which requires merging the Service Observer and Observing Assistant positions in a single one, called Remote Observer (RO). The SO contribution is the most demanding as it requires a good knowledge of astronomy. The OA duties are now greatly eased by much computer assisted functions. The training process of the OAs and SOs toward filling the newly created RO positions has been long and at times challenging, but overall very successful. CFHT is now operated at night by a single person running everything (Fig. 4). The observing is done in a much better environment: a normal level of oxygen in the brain facilitates decision-making and the easy drive to the headquarters removes the hazards of driving the summit road to the observatory at 4200m elevation.

Remote observing, especially when the telescope is at a remote site, is highly beneficial, without real technical drawbacks: most of the subsystems of the building, telescope and instrumentation are instrumented to be remotely controlled. Major failures will still happen. However, the presence, or not, of the observer at the telescope does not change the fact that they will always require the appropriate staff to go to the telescope and fix them.

## 7. A Shift in Duties for the Observatory Astronomers

Among staff astronomers' duties, the support provided to the visiting observing astronomer is critical to the scientific productivity of the observatory. As already mentioned, the degree of preparation of the visitor is highly variable and the support astronomer is often the only way to insure a successful run.

In QSO mode, the role of the staff astronomer becomes even more critical. It starts with the preparation of the so-called Phase 2, in which the PIs who are allocated observing time prepare their observation through a web-based interface, through which they detail the requirements of their scientific program, including those on the environment (image quality, sky transparency and background level, ...). The staff astronomers check the programs once entered in Phase 2. If needed, they request additional information from the PIs or propose them a better strategy. At this point, everything is ready when the time comes for scheduling the observations.

The validation of the data from the previous night and the preparation of the queues for the coming night are handled by the Queue Coordinator (QC), a role generally handled by a staff astronomer, but which can also be performed by a trained Service Observer. Data validation is greatly assisted by the near real-time assessment of the data made by the RO at the time of the observations.

The final involvement of staff astronomers in the observing process is related to data processing. At CFHT, an observatory-run data processing pipeline is mandatory for any instrument to be used in QSO mode. It makes a big difference in the usage of the data by the PIs: as data are ready for scientific analysis, there is a faster turnaround time between the data acquisition and the publication and less time is spent on non-creative work.

During this process, it is very important to maintain a good communication stream between observatory staff and PIs: observing astronomers coming to the telescope allowed a direct connection between the community of users and the observatory. Now that no one is coming anymore, this communication stream is the main link between a facility and its user base.

A last aspect of QSO operations staff astronomers, and observatory management at large, must keep in mind is that the overall queue process has to be flexible, in spite of the desired rigidity inherent to the operation of a complex facility. CFHT's experience is that maintaining flexibility has been indeed paramount to the success of QSO and to the buy-in of its users. In addition to allow for post-Phase 2 changes, as long as they

*Figure 5.* A florilege of elliptical galaxies observed using LSB (Duc *et al. 2011*. (© CFHT/CNRS/CEA)

are explained and clearly communicated, this flexibility means also to be ready to offer new modes of observing or new strategies which were not necessarily thought off when QSO started. Two striking examples: (1) The "Staring Mode" used on CFHT's Wide-Field Infrared Camera (WIRCam) enabling the observation of secondary transits of exoplanets through sub-millimagnitude precision photometry over several hours (Croll *et al.* 2010). (2) The Low-Surface-Brightness (LSB) mode (Fig. 5), used with the Wide-Field Imager MegaCam to study the extent of the halo of elliptical galaxies showing that they are far from being "dead", as they exhibit clear signs of recent merging activity (Duc *et al.* 2011).

Because these new modes were handled at the observatory level as significant additions to the overall QSO mode, they were made, once tested, readily available to all users instead of only the PI who requested them. They are therefore used for much more than what was initially intended: another way to significantly enhance the scientific potential of the observatory.

## 8. A Model for Other Facilities?

QSO is particularly well suited to observatories serving a large and diverse community. At a private telescope, there will be some reluctance to move to such a mode as users tend to think that they are entitled to coming to "their" telescope and observe themselves, and often think that they know better than anyone else how to observe for their own program. Actually, their reaction is similar to what was observed with some PIs at CFHT in the early days of QSO. In that respect, it is interesting to see that CFHT and Gemini, both open to many national communities, are observing, at least partly for Gemini, in queue mode, while the W.M. Keck observatory is only used in visitor mode.

In spite of the initial reluctance of some CFHT users, one must recognize that none of them would want the observatory to come back to the old "visitor" mode: PIs don't have to travel and learn the intricacies of the instrumentation; their observations are always taken under the right conditions, including calibrations of good quality; their data are validated and pre-processed by the observatory. For the observatory, operations in queue mode are more efficient and the overall productivity of the telescope is better, as there is better use of telescope time, with observations prioritized according to the importance of the scientific programs (as ranked by the time allocation committees).

Service observing led to the emergence of the new profession of service observer, who handles the scientific operation of the telescope at night. At remotely operated telescopes, another new position was created: remote observer, who handles the overall operation of the observatory single-handed. In the meantime, staff astronomers saw their duties evolve, with more implication in a wide range of ongoing scientific programs. They now actively participate, with much dialogue with PIs, in the preparation of the observations and their validation.

With remote observing, the technical staff has a chance to monitor the observatory with the help of computer-assisted alert systems and watchdogs, allowing more preventive actions instead of "fighting fires". The resulting peace of mind is a real relief for all involved in the operation of the observatory.

As Extremely Large Telescopes (ELTs) are contemplated, we can hope that they will operate in QSO mode: the gain in efficiency will be even larger than for any existing telescope, as the cost of a unit of observing time will be much higher as ELTs will be worth more than one billion dollar in investment only!

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# THE TELESCOPES AND PROCESSES OF THE AUSTRALIAN ASTRONOMICAL OBSERVATORY

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**Abstract.** The Australian Astronomical Observatory operates the Anglo-Australian Telescope and the United Kingdom Schmidt Telescope in Australia, as well as coordinating access for the Australian community to the Gemini, Magellan, and other international telescope facilities. We review here the processes involved within the AAO related to allocating observing time on these facilities, as well as the impact on telescope use of both the Large Program projects and the AAO's instrument program.

## 1. Introduction

The Australian Astronomical Observatory (AAO)[1] is a division of the Australian Federal Government's Department of Innovation, Industry, Science and Research (DIISR). The AAO operates the Anglo-Australian Telescope (AAT) and the United Kingdom Schmidt Telescope (UKST) at Siding Spring Observatory, near Coonabarabran in north-western New South Wales. The AAO also hosts the Australian Gemini Office (AusGO)[2], which manages the allocation of time to Australian astronomers on the Gemini

[1] http://www.aao.gov.au/
[2] http://ausgo.aao.gov.au/

telescopes, as well as on Keck, Subaru and Magellan, through time-sharing or purchase agreements.

Here we outline the processes involved in allocating time on these facilities, as well as some reflections on the impact and role of Large Program projects at the AAT and the relationship between the AAO's instrumentation program and the science programs of our users.

## 2. The Anglo-Australian Telescope

The Anglo-Australian Telescope (AAT) is a 4 m optical telescope located at the Siding Spring Observatory, near the country town of Coonabarabran, NSW, Australia. It was commissioned in 1974 by the then Anglo-Australian Telescope Board. The AAT provides world-class observing facilities with a range of state-of-the-art instruments, which are constantly being upgraded to meet the demands of the scientific community. Observing time on the AAT is highly sought-after, by international observers as well as the Australian astronomical community.

The AAT instrument suite includes the 2dF/AAOmega multi-object fibre spectrograph, the SPIRAL integral-field spectrograph, the IRIS2 infrared imaging spectrograph, and the CYCLOPS/UCLES/UHRF high-resolution echelle spectrograph. The AAO is currently building the HERMES[3] multi-object high-resolution spectrograph, to be commissioned in late 2012, along with a range of technologically innovative new instruments[4] including the GNOSIS OH-suppression fibre-feed to IRIS2, and the SAMI multi-object integral-field spectrograph system using hexabundle fibre IFUs.

### 2.1. AAT TIME ALLOCATION OVERVIEW

Observing time is allocated on the AAT through the following process.[5]

**The Proposal Call.** AAT observing time is scheduled by semester, with A Semesters running from February to July and B Semesters running from August to January of the following year. Each year, a *Call for Proposals* is announced on the first of March and September for the coming B and A Semesters respectively, for which the proposal deadlines are 15th March and 15th September.

**Proposal Submission.** All observing proposals must be submitted via the AAT online proposal form. The form requests all critical data, those necessary for technical assessment, such as instrument details and observing

[3] http://www.aao.gov.au/HERMES/
[4] http://www.aao.gov.au/instsci/
[5] Details can also be found at http://www.aao.gov.au/astro/applying.html

restrictions, as well as those necessary for statistical time allocation, such as PI and Co-I affiliations, level of observing support, and students involved. While we have fixed page-limits for the Scientific Justification section of proposal, the format is at the discretion of proposers (we do, however, have guidelines stating that densely packed, small-font and unformatted text are unlikely to improve the chances of getting observing time). Three pages are allowed for normal programs, five pages for those requesting 'Long-Term' status, and ten pages for 'Large Programs'. Long-Term programs are those which require time distributed over several semesters, although the total time request need not be large. Large Programs are those requiring 50 nights or more (there is no set upper limit), usually, though not necessarily, extending over several semesters. To be competitive as a Large Program, the scientific goals must be groundbreaking and not just incremental. In addition, only five of the ten pages allowed for the justification are to be allocated to the scientific case. The remaining pages are to be used for the observing strategy (up to two pages), the project management plan (up to two pages), and a project timeline (up to one page). Other than adhering to the page restrictions, the proposers are free to format their Scientific Justification as they wish, and are then required to upload a PDF version into the online application form.

**Technical Assessment and External Referees.** All AAT proposals submitted by the deadline are assessed for technical feasibility by AAO astronomers. The technical assessors remain anonymous, and do not contribute comments regarding the scientific merit of the proposal. The Technical Secretary collates these reports and is responsible for contacting the PI if there is a serious technical flaw. The Technical Secretary has the final say on whether a proposal is feasible, and on identifying an appropriate number of AAT nights to be allocated if awarded time.

Proposals classified as Large Programs, requesting over 50 nights of telescope time over one or more semesters, are sent to external referees to aid in assessing their scientific merit. The Technical Secretary is responsible for soliciting up to 3 referees per proposal, where the referees are experts in the proposed field of research. PIs will have the right of reply to matters raised by the referees, but the referees' identity remains strictly anonymous.

**Proposal ranking.** The Australian Time Allocation Committee (ATAC) is responsible for grading all AAT Observing proposals on their scientific merit. The ATAC members meet about 6 weeks after the proposal deadline. All proposal details and any supplementary material (e.g. referee reports) are provided to ATAC in advance of the meeting. At the meeting ATAC members discuss each proposal and assign a final grade (see next section on the grading procedure). Once the grading is complete, the Technical

Secretary prepares a draft schedule of the telescope allocations, which is then discussed with ATAC. In some cases (e.g. where two equally ranked proposals are at the cut-off) ATAC revises the relative ranking of proposals. Allocations made at the meeting are provisional only, and strictly confidential.

**Telescope Schedule.** The draft schedule and rankings are sent to the AAT Scheduler, who undertakes to publicly release the AAT schedule within one week of the ATAC meeting. This includes taking into account instrument setup nights, Director's Discretionary time and the roster of the support astronomers. Immediately before, or in conjunction with, the release of the AAT schedule, the ATAC Secretary emails all applicants giving the number of allocated nights, and general feedback, including the committee's reasons for the non-allocation of time.

### 2.2. AUSTRALIAN TIME ALLOCATION COMMITTEE

There are seven members of the Australian Time Allocation Committee (ATAC), chosen primarily from among the Australian community, and including at least one International member. In addition, a substitute member will also be appointed to take the place of any ATAC member who is unavailable for a meeting of the committee. Appointment to ATAC is usually for a 3-year term, although appointments may be for staggered terms to ensure a steady turnover in membership. Nominations to the committee will be periodically sought by the AAO Director. There will normally be no more than one representative on ATAC from any given institution.

**ATAC Meeting and grading procedure.** The committee meets twice each year, usually in the first or second week of May and November, to assess and rank proposals for the following semester. ATAC will normally meet in person in Australia, at the AAO in Sydney, but members unable to travel to Sydney are expected to participate via videoconference. Four members constitute a quorum. At the meeting the Chair (or in their absence, the Deputy Chair) presides. Allocations are made by a grading system (described below) carried out by the members present. ATAC members may also be required to vote on procedural or allocation matters. In the event of an equality of votes the Chair (or Deputy Chair, if presiding) has a casting as well as a deliberative vote.

In order to save time at the meeting, each panel member does a full science pre-grading of all the proposals beforehand, abstaining for those proposals in which a member is taking part. These 'pre-grades' are submitted to the ATAC Secretary before the meeting. Panel members are still free to change their votes at the meeting as subsequent discussion may change their opinions.

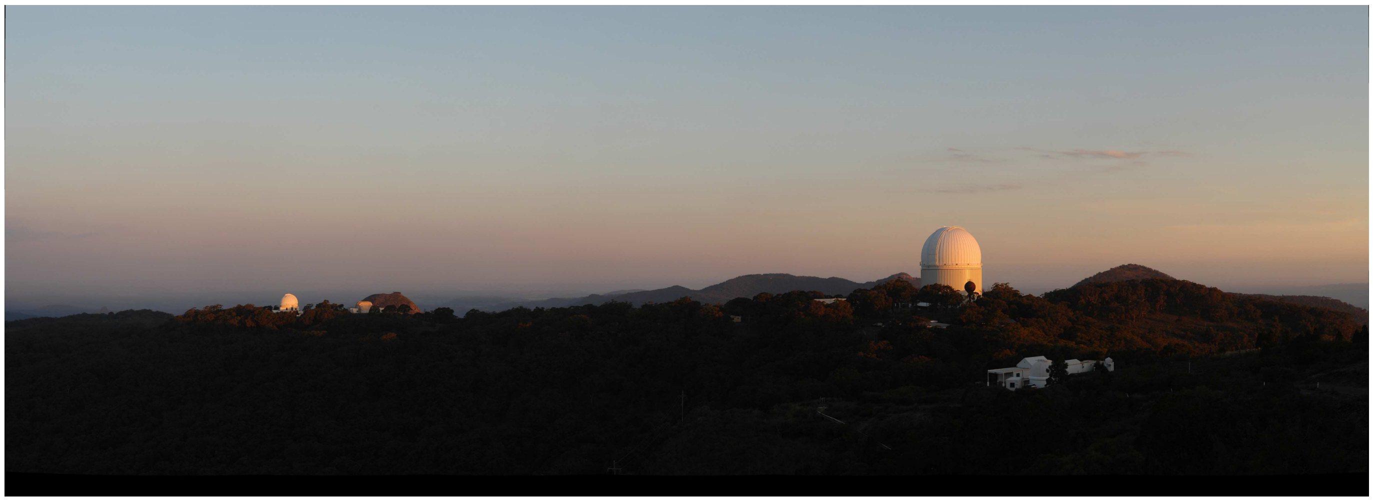

*Figure 1.* The AAT (right) and UKST (left) at Siding Spring Observatory. (Courtesy Fred Kamphues)

Committee members grade each of the proposals based on scientific merit, using the following guidelines: 5 = outstanding proposal; 4 = well above average proposal; 3 = good proposal; 2 = below average proposal; 1 = technically/scientifically defective proposal.

At the meeting, the proposals are discussed in order of their pre-grades, where the lowest pre-graded proposals are not further discussed, unless there is a sufficient dispersion in the pre-grades to warrant more investigation. The committee member assigned to a proposal gives a brief summary of the proposal, concluding with their scientific opinion of the application. The application is then discussed by the whole committee, and the final score is given in terms of the above grades. Fractional grades are permitted. Each ATAC member submits their final score anonymously to the Technical Secretary, who then determines the final averaged score.

Grades by committee members should be given on the scientific merit of the proposal, irrespective of whether dark, grey, or bright time is requested. Proposals are graded scientifically for the maximum number of nights/hours requested unless panel members feel the goals can be met in less time.

When a committee member is included in the list of applicants on a proposal, or otherwise feels they may have a conflict of interest, they must recuse themselves from the meeting during discussion and voting on that proposal.

**Responsibilities of committee members.** Each member of ATAC is expected to: (a) assess and grade each application prior to the meeting; (b) prepare a summary of the proposals allocated for presentation at the meeting; (c) collate a brief feedback statement for each proposal, based on discussion during the meeting; and (d) provide a point of contact for their constituents to communicate general issues with ATAC (although any potential matter of dispute arising from the meeting should be directed to the Chair).

In addition, the ATAC Chair (or in their absence, the Deputy Chair) is expected to: (a) oversee policy matters; (b) conduct the business at each meeting; (c) coordinate the allocation process at the meeting; (d) liaise with the ATAC Secretary and Technical Secretary over any matters arising or in development of new policies; (e) supervise the dispatch of feedback to all applicants after the meeting; and (f) liaise with the AAT Scheduler and Technical Secretary in the event of a scheduling conflict.

**The AAT Technical Secretary.** The AAT Technical Secretary is responsible for: (a) providing an updated list of available AAO instruments to the user community in advance of the application deadline; (b) supervising the receipt of ATAC applications via the online proposal form; (c) coordination of technical assessments by qualified AAO staff; (d) monitoring consistency of ATAC grades over consecutive semesters; (e) liaison with PIs prior to the meeting where there may be a serious technical problem with a proposal; and (f) providing a report to the AAO Director on over-subscription history, telescope usage, and updates on instrumentation status.

The Technical Secretary may not comment on scientific issues, unless invited to do so by the Chair, but is expected to attend the policy and scientific sessions of the ATAC meeting or at the very least be available for technical comment during the meeting.

### 2.3. ACCOUNTING FOR AAT OBSERVING TIME

The allocation of AAT time uses two parameters to balance rightful AAT share with high-quality science:

1. A specified fraction, $f_O$, of open-access time, taken out of Australia's (otherwise unconstrained) share, $f_A$, such that $f_A + f_O = 1$. The purpose of the open-access share is to foster international collaboration, as well as allowing high-ranking but internationally-dominated proposals to also use the AAT.
2. A super-majority threshold, M, used to measure the proportion of Australian involvement in a proposal. The purpose of the super-majority threshold is to ensure that time is awarded largely according to Australia's funding of the AAT's operation while still allowing (and even encouraging) some level of collaboration.

The time allocation procedure starts with ATAC ranking all proposals by scientific merit, without regard to the nationality of the applicants. The Technical Secretary then proceeds by:

- Initially drawing upon the Australian and Other time shares in proportion to the fraction of such proposers on each program. Note that nationality is determined by the location of the proposer's home institution, not by the proposer's citizenship. A proposal that is awarded $N$ nights and has $A$ Australians and $O$ Other proposers counts as $N_A$ Australian nights and $N_O$ Other nights, where $N_A = N \times A/(A+O)$ and $N_O = N \times O/(A+O)$. Then:
- If the Australian share is exhausted first, the remaining proposals are awarded time as ranked, regardless of nationality, or:
- If the Other share of AAT time is exhausted first, the remaining proposals are only awarded time from the residual Australian share if they (i) have an Australian PI and (ii) meet the super-majority criterion—i.e., if the fraction of Australians is greater than or equal to the super-majority threshold, $A/(A+O) \geq M$, rounding to the nearest whole percentage. The exception to this is when there are no qualifying pro-

posals that can make use of the remaining time due to observational constraints.

Presently ATAC adopts a Australian fraction of 70%, and an Other fraction of 30%. The Australian super-majority threshold is 67%. These fractions reflect AAT demand (based on nationality) over past semesters and will be reviewed in the context of AAT demand over future semesters.

Once time has been allocated through a first pass of all eligible proposals, any remaining time will be filled through a second pass of the list. In this instance, proposals are taken solely on the basis of rank order, and the super-majority nationality criteria no longer apply. This means that time is not charged to partner shares nor repaid in future semesters. Rather, the nights are distributed from the remaining nights irrespective of which partner's share they come from.

Note that the actual fraction of time going to Other observers is generally higher than 30% (in fact typically around 40%) because there may be Other observers on proposals that are Australian-led and with an Australian super-majority.

The AAT Scheduler will, with guidance from the Chair of ATAC, make minor adjustments to the allocations to allow for practical matters such as dark/grey/bright time demand, scheduled instrument blocks, Director's time and so on.

### 2.4. AAT SERVICE OBSERVING

The AAO operates a service observing programme at the AAT for programmes that require up to six hours of observing time. Service time is normally allocated for programs that require a small amount of data to complete a programme, to look at individual targets of interest, or to try out new observing techniques.

The ATAC sets the total number of service nights each semester. This number is set so as to equalise the oversubscription rate between service proposals and regular proposals, and is typically 8–9 nights per semester, with at least one night per semester for each of the instruments.

A call for service proposals is issued three times a year, with deadlines on 1 February, 1 June, and 1 October. The proposals are reviewed by one internal and two external referees, on the basis of scientific merit. Proposals with an average referee grade of at least 2.5 (out of 5.0) are then added to the service queue, where they remain until either the observations have been conducted or 18 months have elapsed.

On each of the service nights, an AAO support astronomer conducts observations on one or more of the programs in the queue, selecting proposals to observe on the basis of the proposal's grade and the efficiency and feasibility of conducting the observations for the given proposal at that time of year. The data is then sent to the PI of the proposal in question, while the observations are logged, and the queue is updated.

### 2.5. LARGE PROGRAMS

The introduction of a Large Program model at the AAT has had an impact on the variety and scope of projects able to be facilitated through AAT observations. Examples of AAT Large Programs include the 2dF Galaxy Redshift Survey[6], the WiggleZ Dark Energy Survey[7], the Anglo-Australian Planet Search[8], and the Galaxy And Mass Assembly (GAMA) survey[9].

Each of these programs has involved substantial collaborations, and has resulted in high-profile and significant scientific results. The AAO expects Large Programs to be awarded in total at least 25% of the available time on the AAT, and in recent semesters as much as 50% of the time has been allocated to Large Projects. By facilitating these large allocations of time, and encouraging the community to work collaboratively on major projects, the impact of a 4 m class telescope is continuing to remain as strong as many 8–10 m class telescopes, and not far behind the most productive space-based observatories.

## 3. United Kingdom Schmidt Telescope

The UK Schmidt Telescope (UKST) is a survey telescope with an aperture of 1.2 m and a very wide field of view. The telescope was commissioned in 1973 and, until 1988, was operated by the Royal Observatory, Edinburgh. It became part of the AAO in June 1988.

Originally used exclusively for survey photography, the UKST was adapted for experimental multi-fibre spectroscopy in the 1980s, and a succession of prototype systems eventually culminated in the robotic 6dF multi-object spectrograph. This provides access to up to 150 targets over a six-degree diameter field of view. It was commissioned as a common-user instrument in 2001, replacing photography as the principal operational mode of the telescope.

Until 1 August 2005, UKST operations were funded by the AAO, with the telescope being used for 6dF Galaxy Survey[10] observations, as well as common-user non-survey observations. On that date, however, the current user-pays model was introduced, under which the AAO maintains the fa-

[6] `http://msowww.anu.edu.au/2dFGRS/`
[7] `http://wigglez.swin.edu.au/`
[8] `http://www.phys.unsw.edu.au/~cgt/planet/AAPS_Home.html`
[9] `http://www.gama-survey.org/`
[10] `http://www.aao.gov.au/local/www/6df/`

cility and runs it as a cost-neutral asset. UKST users are required to pay the effective running costs for the period over which they make use of the telescope. In fact, with the exception of a very small number of Directors nights used for pilot observations, the sole user of the telescope since 2005 has been the international RAVE collaboration (the acronym stands for RAdial Velocity Experiment). The resulting RAVE[11] survey of stellar radial velocities and atmospheric parameters now comprises more than half a million spectra, which are being issued in a series of data releases.

The UKST is now owned by the Australian National University but is still operated by the Australian Astronomical Observatory. Once the RAVE survey is completed in mid-2012, collaborations interested in using the telescope will be invited to contact the AAO Director to discuss the details of proposed observing programs and the associated costs involved.

## 4. Allocation of time on external facilities

Australia has a 6.2% share in the Gemini Observatory partnership, providing about 15 nights per semester, split between the Gemini North and Gemini South 8 m telescopes. Access to a limited number of nights each semester on the Keck 10 m and Subaru 8 m telescopes is also offered by an exchange time agreement with Gemini. In addition, since 2007 Australia has purchased 15 nights per year through the Carnegie Institution for Science on the twin 6.5 m Magellan telescopes at Las Campanas Observatory to provide capabilities (e.g. high-resolution optical spectroscopy and wide-field optical imaging) not currently provided by the Gemini telescopes. The Australian Gemini Office (AusGO) within the AAO provides the interface between these facilities and Australian users, ranging from proposal submission to technical assessment, through to observation planning, assistance with data reduction, and publicising of results. The allocation of time each semester on these facilities is the responsibility of ATAC.

The process for allocating Australia's purchase of Magellan nights (nominally 8 nights in the A semester, and 7 nights in the B semester) is essentially the same as that described for the AAT, except that technical assessments are carried out by AusGO staff, and allocations are then forwarded to the Magellan Scheduler who makes best efforts to accommodate ATACs recommendations within pre-scheduled blocks of Carnegie Institution time on each Magellan telescope.

The process for allocating Australia's share of Gemini time is rather more complex. Technical assessments are carried out by AusGO staff prior to the ATAC meeting, and Principal Investigators given the chance to respond to any technical queries identified. After the ATAC meeting the

[11] `http://www.rave-survey.aip.de/rave/`

ranked proposals and their recommended allocations are forwarded to the Gemini Observatory, which carries out an iterative queue merging process between the Gemini partner countries up to and during the International Time Allocation Committee (ITAC) meeting. The top $\sim$30% (by time allocated) of proposals go into queue Band 1, for which Gemini aim to achieve a 90% completion rate; the next 30% go into Band 2, which aims to have a 75% completion rate; the next 20% go into Band 3, for which 85% of programs which are started should receive at least 75% of their time; and the bottom 20% is available for 'Poor Weather' programs that can tolerate seeing $> 2''$ and/or $> 3$ mag of extinction by clouds. ATAC may award 'rollover' status for 2 more semesters to Band 1 programs (except for Target of Opportunity programs) so as to ensure their completion.

ATAC is required to forward programs which can use the full range of observing conditions and Right Ascensions, or risk forfeiting any unfilled time in that semester. During the ITAC meeting the ATAC Chair decides whether to support Joint proposals seeking some time from Australia, even if not all the other partners from which time is being sought have supported them with a comparable ranking. 'Classical' observing time on either of the Gemini telescopes, and on the Keck or Subaru telescopes via exchange time agreements, may be awarded by ATAC in units of 10 hours = 1 night, but these are top-sliced from ATACs total allocation, reducing the size of the queue bands accordingly. A complete description of the Gemini time allocation process can be found online[12].

## 5. Instrumentation

The AAO maintains a strong and innovative instrument science program for developing ground-breaking new instruments on both the AAT and other telescopes worldwide[13]. One of the impacts of having an instrumentation program that is integrated with the observer community has been the ability to be highly responsive to (i) community needs and requirements, and (ii) new technological developments, in particular in astrophotonics. One consequence has been the ability to develop highly innovative new instrumentation (such as the HERMES high-resolution multi-object spectrograph, as well as the GNOSIS OH-suppression fibre-feeds, and SAMI hexabundle IFU fibre-feeds) with a fast turnaround time. Importantly, this is also done in the environment of a strong relationship with the observer community, ensuring that high-impact scientific results flow rapidly from the commissioning and full-scale deployment of such new facilities.

[12] `http://www.gemini.edu/sciops/observing-gemini/proposal-submission/tac-process`

[13] `http://www.aao.gov.au/astro/newinstrum.html`

It is interesting to see how the science programs of the user community are both driving, and driven by, the instrumentation program at the AAO. In particular there is now a rapidly growing community in Australia with a focus on Galactic Archaeology that seeks to exploit the HERMES instrument.

## 6. Summary

This article has summarised the facilities offered by the Australian Astronomical Observatory and the procedures by which these resources are allocated under an open, competitive and peer-reviewed process. Both the facilities and the procedures have been developed over a long period in response to the scientific requirements of the user community (both Australian and international) and in an ongoing effort to optimise the scientific productivity and impact of the observatory. This evolutionary development has, both due to historical contingencies and by playing to emerging strengths, naturally led the AAO towards a specialisation in wide-field multi-object spectroscopy and large-scale survey programs. This particular focus exists, however, in the context a full-function telescope/instrumentation suite that caters to the very broad scientific needs of the entire community of optical/infrared astronomers in Australia. As those needs evolve in future, the AAO will develop new facilities and procedures so that it continues to serve its users and produce high-quality science.

*Organizations, People and Strategies in Astronomy I (OPSA I), 39-53*
*Ed. A. Heck, © 2012 Venngeist.*

# THE ASTRONET INFRASTRUCTURE ROADMAP: A STRATEGIC PLAN FOR ASTRONOMY IN EUROPE

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**Abstract.** The ASTRONET Infrastructure Roadmap represents a pioneering venture for Europe in long-term planning of astronomical endeavour. It aims thereby to maintain and strengthen Europe's rôle in astronomy internationally over the next 10-20 years. In this review, I first describe the background to ASTRONET. This is followed by an outline of the development of a Science Vision, and then the Roadmap itself. Details are given of the working methods used and the conclusions reached, which include not only those regarding future facilities but also areas such as theory, computing, laboratory studies, human resources, industrial impact and public engagement. Gaps and opportunities in our proposed provision are outlined before addressing the next steps for the ASTRONET programme as a whole.

## 1. What is ASTRONET?

ASTRONET was founded by the major European funding agencies and initially funded from the European Commission Framework 6 programme at the level of 2.5M Euros over five years from September 2005 (we shall refer to this as ASTRONET-1 below). The success of the programme has led to its continuation under Framework 7 at 1.6M Euros for a further four years from January 2011 ('ASTRONET-2'). ASTRONET is an ERA-Net coming under the initiative 'Integrating and Strengthening the European Research Area' (ERA). It is coordinated by CNRS/INSU, with Jean-Marie Hameury as project manager, and the ASTRONET-1 Board was chaired by Johannes Andersen of NOTSA during the phase of the project that included the development of both the Science Vision and Roadmap, and is now chaired by Ronald Stark of NWO. At the time of writing, it comprises 11 primary Contractors (mainly national funding agencies, plus ESO) together with 21 Associate member organisations (again, mainly national funding agencies, plus ESA) and a further two nations represented as Forum members. Further information, publications and updates on progress of the initiative can be found on the project's website[1].

The funding agencies decided to form ASTRONET for the following over-riding reason: large projects proposed for the next 10-20 years in astronomy and astro-particle physics require investments of several billion Euros. The EU only provides for a few percent at most of this cost – the funding agencies and other government organisations would be expected to meet the rest. ASTRONET was thus established to help national funding agencies to take science-based, rational, coordinated decisions for the long term benefit of European astronomy – and, at a higher level, to help unlock further necessary resource for our science in Europe. We are therefore effectively prototyping a counterpart of the US Decadal Surveys for Europe, but with a wider remit and in a rather more complex environment. Hence this is a very ambitious undertaking. The ASTRONET Roadmap also complements that of the European Strategy Forum on Research Infrastructures (ESFRI) in that (i) it is a valuable input for the ESFRI committee, (ii) it has a much broader scope across astronomy (although of course focussed on that field), and (iii) it contains a prioritised list of projects.

Activities within ASTRONET-1 from 2005 were organised under five main headings:

- Preparation of a common Science Vision for the next 20 years (published in September 2007[2]).
- Establishment of a Roadmap of infrastructures to address the Science Vision (published in November 2008[3]).
- Networking, including the integration of new participants (ongoing) and the production of a Report on the Management of European Astronomy (published by ASTRONET in July 2007).
- Coordinated Actions, which required work towards launching a common call for proposals with a common or joint budget (launched, and successful proposals are underway under the title 'Common Tools for Future Large Sub-mm Facilities').
- Implementation, including specific actions arising (see the last section of this article for the development of this under ASTRONET-2).

[1] `http://www.astronet-eu.org/`
[2] See de Zeeuw & Molster (2007).
[3] See Bode et al. (2008).

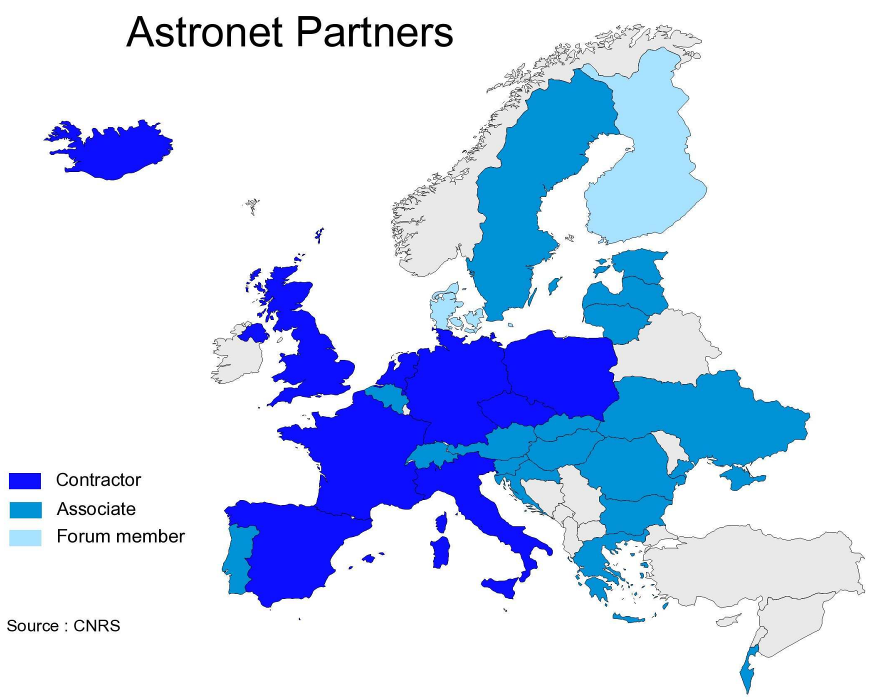


*Figure 1.* Map showing the current extent of the ASTRONET partnership. (© CNRS)

## 2. Developing the Science Vision

The brief here was to look broadly at key science questions in all of astronomy for the next two decades, with NWO of the Netherlands as the lead agency. It was recognised very early in the process that a great deal of material already existed and thus it was that maximum use was made of available documents (e.g. national strategic plans, ESA's Cosmic Vision report, joint ESO-ESA reports, scientific cases for new facilities). It was also vital to involve a broad, knowledgeable and well respected cross-section of the science community. In the end around 50 people were direct members of the Science Vision Working Group and its four thematic panels. The working group chair was Tim de Zeeuw (now Director General of ESO). Wider community input was solicited via a web-based discussion forum and an open symposium. The latter event was held in Poitiers in January 2007 and was attended by over 200 astronomers from all over Europe and beyond.

The Science Vision exercise was divided into four key questions, each addressed by a specialist panel, these being:

A. Do we understand the extremes of the Universe?
B. How do galaxies form and evolve?
C. What is the origin and evolution of stars and planetary systems?
D. How do we fit in?

Within each key question were developed a number of specific goals, with up to seven under each heading. Overall, the Science Vision was developed in sufficient detail to allow the identification of generic capabilities of the facilities needed to deliver the Vision[4]. This was then to be the basic starting point of the Infrastructure Roadmap, as we will now describe.

## 3. Developing the Roadmap

Here, the brief was to assemble a plan for the infrastructures that will enable European astronomy to deliver the Science Vision, with the STFC of the UK as the lead agency and the current author as the Roadmap Task Leader. We therefore naturally took the Science Vision as the point of departure. Our remit was very broad, covering both ground and space-based facilities, plus the Virtual Observatory, (super)computing, theory, human resource issues, outreach, education and training and industrial links. We were to incorporate existing plans (of ESO, ESA etc.) as far as possible, and have a global perspective. Overall, we were to attempt to fit this within reasonable budgetary envelopes and schedules. The process of developing the Roadmap got underway in earnest in the Autumn of 2006. The motivations and modes of operation are described in detail in Chapters 1 and 2 of the final report (Bode et al. 2008), which, together with an Executive Summary, is available from the ASTRONET website.

As with the Science Vision, the task of developing the Roadmap was undertaken by specialist panels, reporting to a working group. The panels were organised under the following headings (with the relevant chapters of the final report indicated in each case):

A. High energy astrophysics, astro-particle astrophysics, gravitational waves (Chapter 3)
B. UVOIR and radio/mm astronomy (Chapter 4)
C. Solar telescopes, solar system missions, laboratory studies (Chapter 5)
D. Theory, computing facilities and networks, virtual observatory (Chapter 6)

[4]pdf versions of both the Science Vision and Infrastructure Roadmap can be downloaded from `http://www.astronet-eu.org/`

E. Education, rcruitment and training, public outreach, industrial links (Chapter 7)

The first three panels effectively covered facilities in the main, and the latter two some additional critical underpinning infrastructure in its widest sense, and the broader impact of our work on society in general. The panels comprised up to twelve members each, with selection being based primarily on relevant expertise, but bearing in mind a reasonable spread of nationality and gender. Each panel reported to the Working Group whose membership comprised the chair and co-chair of each panel together with ten members at large who assisted the panels with their work. Overall however, the task of the working group was to synthesise the recommendations of the panels into the final Roadmap, ably aided and abetted by the Assistant Scientists (Maria Cruz of Liverpool JMU and Frank Molster of NWO) and chaired by the current author. Altogether, over 60 scientists, plus educators and journalists on Panel E, were members of the panels and working group.

## 4. Working Methods

From March 2007 until October 2008 around 40 meetings of the panels and working group were held. Most of these were face-to-face, but Panel D in particular, rather fittingly, held several virtual meetings via teleconference. Panels A to C identified well over 100 facilities which might be evaluated in the roadmapping exercise. As part of this, a questionnaire was sent to all of them, generating an almost complete return by early July 2007 (the full list of facilities surveyed can be found in Appendix IV of the final report). An evaluation template was formulated and then completed by each assigned panel rapporteur for each facility. Evaluation criteria were developed to give first-pass rankings, then each facility was further discussed, further information gathered as appropriate, and initial judgements refined (for example in the light of the ESA Cosmic Vision first call results which were available to the panels in October 2007). In parallel with this, the ASTRONET Science Vision was launched in September 2007.

The main focus of the Roadmap is of course on future facilities (but well-defined major upgrades and significant operational prolongations were also included). Only facilities with a significant European content (in terms of a likely funding requirement) and well enough developed to be able to be judged adequately were included. We had to set some lower bound to the 'scale' of projects to be scrutinised, and decided upon a European funding requirement of greater than 10M Euros capital cost and/or greater than 10M Euros operational cost over five years (unless there were a special reason to lower this limit in a particular case). Finally, only those facilities where a major European funding decision was expected to be required from

2009 onwards were included.

Broad categories of prioritisation were used for initial ranking of facilities: High, Medium and Low, with only High priority projects normally discussed in detail in the final report; other facilities were included for 'context' and some smaller scale current facilities have been grouped. It was recognised that a large facility may on average address more Science Vision questions than a smaller-scale example, but the smaller one may very cost-effectively address a sub-set of important science questions. Therefore projects were sub-divided into cost categories: Small (10M-50M Euros); Medium (50M-400M Euros), and Large (greater than 400M Euros). These mapped to some extent onto the previous US Decadal Survey for ground-based projects (the latest Decadal Survey for Astronomy and Astrophysics[5] being published in August 2010) and the original ESA Cosmic Vision 'M-class' and 'Flagship (L-class)' designations for space-based missions, including instruments. We also utilised a timescale division (to full operation) as follows: Short-term (<2015); Medium-term (2016-2020); Long-term (>2020) and assigned each project a current Technology Readiness Level. The evaluation criteria we used (in decreasing weight) were Scientific Impact (particularly in relation to delivering the Science Vision), Competition/Uniqueness, European Involvement, User Base and Industrial Relevance. This evaluation gave us a first-pass ranked list of projects in each of Panels A-C.

The terms of reference for Panels D and E were naturally somewhat different from Panels A, B and C. Specific questions from these panels were included in the questionnaire sent to facilities, but D and E also undertook considerable additional information gathering as detailed in Chapters 6 and 7 of the final report. Panel D then gave members responsibility for specific areas within their remit and Panel E sub-divided into several task groups. Information exchange with other panels took place throughout the process, both directly and through the working group.

The roadmapping process was not without cognizance of, and inputs from, other organisations and initiatives with an important role in the future shape of astronomy in Europe. For example, the working group included representatives of ESO and ESA, plus the EC-funded Integrated Infrastructures Initiatives (I3s) OPTICON and RadioNet. In addition, the EuroPlaNet initiative had representation on Panel C (and on the working group in the initial phases)[6]. Information exchange with the astro-particle

[5]See `http://sites.nationalacademies.org/bpa/BPA_049810`

[6]On those intitiatives, see contributions in the earlier *Organizations and Strategies in Astronomy (OSA)* series (Ed. A. Heck, Springer, Dordrecht): for OPTICON, the chapter by G. Gilmore in OSA 2 (2001), pp. 83-102; for RadioNet, the chapter by A.G. Gunn in OSA 7 (2006), pp. 171-180; for EuroPlaNet, the chapter by M. Blanc and the EuroPlaNet

ERA-Net, ASPERA, included round-table meetings with ASTRONET. Finally, links with ESFRI were gradually strengthened as the ASTRONET initiative progressed.

In order to meet the deadlines set at the start of the project, activity was intense between the constitution of the working group and panels in early 2007 and the delivery of the final report in November 2008. An important milestone was then a meeting with the agencies in London in February 2008 where our initial findings were presented for a 'sanity check' in terms of, for example, funding envelopes and competing national aspirations. Further work ensued on the draft, which was then released for public consultation in early May 2008, at which point a web-based forum was also made available to the community to post their comments. As with the Science Vision, the centrepiece of the consultation was an open symposium, held over four days in June 2008 in Liverpool, which was attended by around 300 participants. The consultation period then ended in July 2008. The final panel and working group meetings were subsequently held to amend their conclusions in light of the consultation. Responses to all comments made were posted on the web forum following the launch.

## 5. Priorities and Recommendations

### 5.1. GROUND-BASED PROJECTS

Among the *large scale* ground-based infrastructure projects, two emerged as clear and equal top priorities due to their potential for fundamental breakthroughs in a very wide range of scientific fields, from planetary systems (including our own) to cosmology:

– The European Extremely Large Telescope (E-ELT), a 40m-class optical-infrared telescope being developed by ESO as a European-led project. The E-ELT passed its Phase B final design review in September 2010 with a decision on construction planned for December 2011.
– The Square Kilometre Array (SKA), which is to be the world's most capable radio telescope. Led from the international Project Office at Jodrell Bank, the SKA is being developed by a global consortium with an intended European share of up to 40%. It will be built in phases of increasing size, area, and scientific power, with final site selection between Australia and South Africa in 2012, detailed design envisaged to start in 2013 and construction of Phase 1 from 2016.

It was concluded that although the E-ELT and SKA are very ambitious projects requiring large human and financial resources, they can both be

Coordinating Team in OSA 7 (2006), pp. 155-170. (Ed. Note)

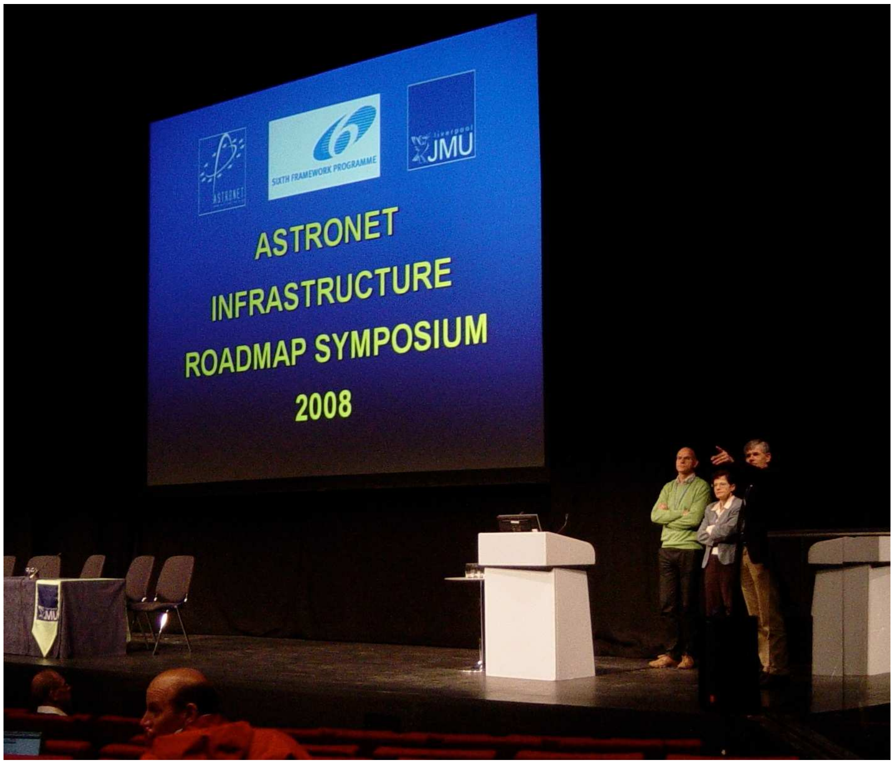


*Figure 2.* The culmination of the community consultation on the Roadmap was the Symposium held in Liverpool in June 2008. Here Thijs van der Hulst (Univ. Groningen) of the main Working Group chairs a discussion on the development of software, computing and the Virtual Observatory following a presentation by Francoise Combes (Obs. Paris) and Paolo Padovani (ESO), chair and co-chair of Panel E respectively. (© M. Bode)

delivered via an appropriately phased plan, as detailed in Chapter 4 of the report.

Three outstanding projects were identified in the *medium scale* category. In descending order of priority these comprise:

– The 4m European Solar Telescope (EST) to be built in the Canary Islands.
– The Cerenkov Telescope Array (CTA), a high-energy gamma-ray 'true' observatory.
– The proposed underwater neutrino detector, KM3NeT.

In addition, in terms of the highest priority *small scale* project, a working group has been established to study the options for the provision of a Wide-Field Multiplexed Spectrograph for massive surveys on a 4-10m-class optical telescope. This group is expected to provide its report imminently, with important input from that of the ETSRC (see below), but it has already sparked several initiatives internationally to deliver such an instrument.

### 5.2. SPACE-BASED PROJECTS

The working group and panels independently agreed with the 2007 round of selection of Cosmic Vision missions for the initial study phase made through the ESA Advisory Structure. The final choice of missions by the standard ESA procedure, which tracks changes in mission scope and cost and possible mergers with, or replacement by other European or international projects, was therefore broadly supported. Within this framework, the roadmap priorities, including some non-ESA missions, are set out below.

Among the *large-scale* missions:

- The gravitational-wave observatory LISA and the X-ray observatory XEUS/IXO were ranked together at the top.
- Next were the proposed TandEM and Laplace missions to the planets Saturn and Jupiter and their satellites. Of these, Laplace became the joint Europa Jupiter System Mission (EJSM-Laplace – with NASA and JAXA) and was selected to proceed to the next stage by the ESA process in early 2009 to compete with IXO or LISA for the next L-mission slot.

  However, the US National Research Council (NRC) subsequently released Decadal Surveys for both astronomy and planetary science[7]. While both surveys recommended continued cooperation with ESA, and ranked highly all three L-class mission concepts, none of them was ranked as top priority in the corresponding survey. The US budget outlook also became known in February 2011, and in ESA's recent discussions with NASA it became clear that it is quite unlikely that any of the L-class mission candidates can be implemented as a joint Europe-US mission in the planned timeframe of the early 2020's. Instead, ESA has begun a rapid definition effort to identify new science goals and mission concepts in the fields of gravitational wave astronomy, X-ray astronomy, and exploration of the Jupiter system. These should be implemented as part of an ESA-only or ESA-led mission to be launched in the early 2020's for a cost to ESA of about 850M Euros, with additional national contributions from ESA member states. The ESA Science Programme Committee will be considering the path forward for the new-style L-missions at their February 2012 meeting, after

[7]See `http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412` for the latter

the ongoing rapid study phase. Overall, this illustrates the fact that the very largest scale projects often inevitably rely on global co-operation to come to full fruition, but it also emphasises the strength of Europe's capability when those co-operative endeavours don't go strictly to plan.
– ExoMars was ranked highly as well, just below TandEM/LAPLACE, but does not compete directly with the other science missions as it belongs to a different programme within ESA (Aurora).

The longer-term missions Darwin (search for life on 'other Earths'), FIRI (formation and evolution of planets, stars and galaxies), and PHOIBOS (close-up study of the solar surface) were also deemed very important. However, they still require lengthy technological development, so it was regarded as premature to assign detailed rankings to these three missions at this stage.

Among *medium scale* investments:

– GAIA science analysis and exploitation (an approved Horizon 2000 Plus astrometric mission) was judged most important.
– Within the proposed new projects in this category, the dark energy/dark matter mission Euclid was ranked highest, followed by Solar Orbiter (a joint project with NASA). At the ESA Space Science Advisory Committee (SSAC) in January 2010, both were selected for further study towards the selection of the first two missions that will proceed to launches expected in 2017-18.
– Next in the ASTRONET rankings, with equal rank but different maturity, are Cross-Scale (magnetosphere), Simbol-X (a non-ESA X-ray project), PLATO (exoplanet transits) and SPICA (a far-infrared observatory – led by JAXA). Of these, PLATO has been selected for further study by ESA in the M-class missions and SPICA has also been endorsed to proceed to the definition study phase, but as ESA is a minor partner to JAXA, it is being treated separately from the other approved Cosmic Vision missions. However Cross-Scale was not selected and funding for future development of Simbol-X was not secured by its international partners.

– Below these in the ASTRONET rankings was Marco Polo (a near-Earth asteroid sample return), which was also not selected by the ESA process to go forward to the next stage of the Cosmic Vision programme for 2017-18 launches. However, the revised mission, Marco Polo-R, is now one of the 4 M-class missions selected in the 2011 round of submissions to proceed to the next stage of assessment for a launch in 2020-22.

By their nature, there were no small scale space projects under consideration for inclusion in the Roadmap.

## 5.3. THE RÔLE OF EXISTING FACILITIES

In space, several current missions are so successful that an extension of their operational lifetimes beyond those already approved is richly justified on scientific grounds. In a constrained environment, however, the selection of the missions that can be extended within available funds should be based on the scientific productivity of the mission and, for ESA-supported missions, the overall balance in the ESA programme. Recommendations on mission prolongations are summarised in Chapter 8 of the final report.

On the ground, the existing set of small to medium-size night-time optical telescopes is a heterogeneous mix of national and common user instruments, equipped and operated without overall coordination. This is inefficient in the era of 8-10m telescopes and ASTRONET therefore appointed a committee (the European Telescope Strategy Review Committee – ETSRC) to review the future rôle, organisation, and funding of the European 2-4m optical telescopes within the context of the Roadmap. The final ETSRC report is available via the ASTRONET website. As mentioned above, a working group has been established to investigate the provision of a Wide Field Multiplexed Spectrograph on a 4-10m class optical telescope, building on some of the work of the ETSRC, and due to report imminently. A review of Europe's existing radio telescopes is also now underway as SKA development gathers pace and is due to report on a similar timescale. That for mm/sub-mm facilities will be undertaken shortly after, followed later by a review focusing on the optimum exploitation of our access to 8-10m class optical telescopes as we enter the era of the E-ELT, and the rationalisation of ground-based solar telescopes as we move into the EST era. These reviews will help Europe to establish a coherent, cost-effective complement of medium-size facilities required to augment the major new facilities.

## 5.4. THEORY, COMPUTING AND DATA ARCHIVING

It is acknowledged that the development of theory and computing capacity must go hand in hand with that of observational facilities. Systematic archiving of properly calibrated observational data in standardised, internationally recognised formats will preserve this precious information obtained with public funds for future use by other researchers, creating a Virtual Observatory. The Virtual Observatory will enable new kinds of multi-wavelength science and present new challenges to the way that results of theoretical models are presented and compared with real data. The Roadmap therefore proposes continued development of the Virtual Observatory, including recommending planning for the provision of a public, VO-compliant archive with any new facility.

The Roadmap also proposes that a 'virtual' European Astrophysical

Software Laboratory (ASL – a centre without walls) be created to accelerate developments in this entire area on a broad front. The ASL would coordinate and raise funds for software development and support, user training, postdoctoral positions within a programme of pan-European networks, and set standards. It is proposed that the ASL would select a few highly competitive astrophysics projects per year to send proposals to the top-tier, pan-European high performance computing centres to help ensure a significant share of CPU hours at the petascale level for astronomy. The report also makes recommendations on the development of novel data grids by exploiting the popular appeal of astronomy in order to get CPU owners to donate spare CPU cycles, or by initiating a classical market in such cycles. The ASL could have a rôle in coordinating this activity. An ASL Committee has now been established, chaired by Matthias Steinmetz of Potsdam, to coordinate the implementation of this initiative.

### 5.5. LABORATORY ASTROPHYSICS

The report stresses the need to enhance support for laboratory astrophysics – including the curation of solar-system material returned by space missions in a proposed European Analysis and Curation Facility. The report also proposes the establishment of a Technical Fellowship Programme and of new European networks stimulated by Joint Calls between the agencies, as pioneered by the call undertaken in the current ASTRONET project. To take these initiatives forward, a European Task Force for Laboratory Astrophysics has been formed, chaired by Louis d'Hendecourt (Univ. Paris-Sud) and Jonathan Tennyson (UCL). The Task Force is cognizant of the international dimension, and in particular conclusions drawn in this area in the latest US Decadal Survey, and will report in 2012.

### 5.6. EDUCATION, RECRUITMENT, OUTREACH AND INDUSTRIAL LINKS

Ultimately, the deployment of skilled humans determines what scientific facilities can be built and operated as well as the scientific returns that are derived from them. Recruiting and training the future generation of Europeans with advanced scientific and technological skills is therefore a key aspect of any realistic roadmap for the future. Conversely, astronomy is a proven and effective vehicle for attracting young people into scientific and technical careers, with benefits for society as a whole, far beyond astronomy itself.

The Roadmap identifies several initiatives to stimulate European scientific literacy and provide European science with the human resources it needs for a healthy future, drawing on the full 500-million plus population of the new Europe. The proposed initiatives include among others:

– Enhanced training of teachers in astronomy – this has now been taken up for implementation by IAU Commission 46 under the auspices of the Network for Astronomy School Education (NASE), chaired by Rosa Maria Ros of the Technical University of Catalunya.
– Inclusion of astronomy more widely in national curricula – this is an action likely to be followed up in ASTRONET-2 (see below).
– New or enhanced educational portals – these are being created in several languages and are to be hosted on the website of Universe Awareness (UNAWE, an organisation also associated with the IAU).
– Establishment of a standardised European communication portal for media, educators, interested people and others – this has now been implemented[8].
– Appropriate funding and recognition of outreach activities – again something that should be followed up in ASTRONET-2.
– Creation of an international network of experts in technology transfer – there has been some subsequent progress on the national scale, but the international initiative still needs pursuing.
– Enhanced scientific exploitation of facilities – the issue has been taken up with the European Research Council, but also requires the attention of the various national funding agencies to ensure that Europe maximises the scientific output of its facilities.

### 5.7. TECHNOLOGY DEVELOPMENT AND INDUSTRIAL SPIN-OFF

Technological readiness, along with funding, is a significant limiting factor for many of the proposed projects, in space or on the ground, and key areas for development are identified in the Roadmap in each case. However, astronomy also drives high technology in areas such as optics and informatics. Maintaining and strengthening a vigorous and well coordinated technological R&D programme centred on promising future facilities and in concert with industry is therefore an important priority across all areas of the Roadmap. The required technology development and industrial applications are summarised in Chapter 8 of the final report.

## 6. Perceived Gaps and Opportunities in Europe's Future Observational Capability

Inevitably, the roadmap process revealed several gaps in future provision where some of the questions posed in the Science Vision may not be fully addressed. We briefly outline these here:

[8] `http://www.portaltotheuniverse.org/`

- Small-scale and fast-track space missions – while our prioritisation of facilities naturally focussed on the medium to large scale space missions, we recognise the opportunities afforded by smaller projects as a crucial part of a balanced future programme.
- High Energy Astrophysics – Panel A identified various areas of instrumentation that are strongly called for in the Science Vision but are not yet programmatically ready, and/or do not yet provide large improvements over existing experiments at affordable cost. One such area is 0.1-10 MeV imaging and spectroscopy and another is all-sky monitoring in both X-rays and $\gamma$-rays.
- UV Astronomy – there is a pressing need for a successor to IUE in terms of a dedicated FUV/EUV astronomy mission. Panel C also identified the need for an (E)UV Solar mission with X-ray capabilities.
- Optical/IR ground-based interferometry over kilometric baselines – this is a natural successor to VLTI.
- mm-submm Astronomy – European access is required here to a large aperture single dish with array detectors on an extremely high site. There is also a requirement for further CMB polarisation studies post-Planck.
- Radio spectral imaging of the Sun – such imaging at centimetre to metre wavelengths is essential in particular in furthering our understanding of physical processes in the solar corona.
- Arctic and Antarctic sites – these offer special opportunities for the development of astronomy and their further exploration and development are encouraged.

## 7. Next Steps and Concluding Remarks

It was very pleasing to see the ASTRONET project continue into its next phase through the provision of Framework 7 funding. The main objectives here are to:

- Establish a permanent mechanism for planning and coordination in European astronomy.
- Follow-up and implement the Roadmap, thus ensuring the construction of the new facilities that are needed to keep Europe at the forefront of scientific knowledge and at the same time optimise existing programmes in scientific as well as financial terms.
- Narrow the scientific and – in particular – technological gaps between the European countries.
- Establish a regularly updated data base with key information on the financial and human resources available to astronomy in all European

countries, as well as the structure and governance of astronomical research in each country.

This will allow several of the initiatives mentioned above to come to full fruition, with ASTRONET acting as a facilitator and champion, and also enable the updating of the Science Vision and the Roadmap. Towards the end of this period, preparations will start for a full revision of the Roadmap itself.

The Roadmap is a pioneering venture for Europe, and a complex and challenging task. Its implementation will however help to maintain and enhance Europe's leading rôle in addressing what are foreseen as the major questions in our area of science. It will also enhance the scientific and technical capability of Europe at all levels and aid collaborations with our wider international partners on some of the largest-scale, global projects over the next two decades. We have a job to do to persuade our political masters to provide adequate funding to realise our goals, but having brought our own house in order, we have some powerful and compelling arguments in our favour to help them to decide to do so.

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# THE DEMOGRAPHY OF ASTRONOMY IN THE UNITED KINGDOM

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**Abstract.** This article is about the universities and the people involved in astronomy in the United Kingdom, including their numbers, their age, gender and ethnicity, where they study or work, and their career structures.

## 1. Introduction

In a previous article (Murdin 2006), I summarised the history, the scope and the organisation of British astronomy. In this article, I concentrate on demographic issues of the present day, 2011. I limit the geographical scope of my article to the United Kingdom (UK), which both has a centralised, overall organisational structure and comprises four nations with various degrees of self-government, namely England, Scotland, Wales and Northern Ireland. Research is regarded as a UK activity but education is national – the distinctions are somewhat reminiscent of those in Germany between the *Bundesrepublik* and the *Länder*, or in the USA between the Federal government and the individual states. I do not limit the scope of 'astronomy', which in this article includes planetary sciences, solar and solar-terrestrial physics, as well as cosmology and astrophysics. I rely for many figures on the *Demographic Surveys* by the Royal Astronomical Society (RAS) of the UK astronomical community, the most recent for 2010 available to me at the time of writing in draft form (McWhinnie 2011).

## 2. Universities

Astronomy research in the UK is carried out almost entirely at universities and the bulk of the astronomy population (90-95%, depending on definition) is at a university. Universities have research as one of their two core activities, the other being higher education, with 'enterprise' (business connections, outreach) being a third, being given greater emphasis now by the Government. UK universities and the Government are very positive about the interaction between the two core activities of teaching and research, on the one hand because of the mutual intellectual stimulation that exists between student and teacher, which benefits both endeavours, on the other because research in universities is both productive and cost effective, because many of the paid staff are young and therefore inexpensive, and the overheads of research are shared with teaching.

As a result of the concentration of astronomy in universities, the demography of astronomers in the UK is based mainly around academic criteria and is most readily described in terms of university status, progressing through academic career stages. Fig. 1 shows the stages of a typical academic career in England (with an individual in Scotland starting one year earlier), flanked by parallel career paths to which (and, more infrequently, from which) an individual might transfer at any stage.

The overall structure of higher education in the UK is evolving as a result of the Bologna process by which Europe is unifying its higher educational qualifications to make them comparable across Europe to enhance mobility between countries. The standard framework for training under the Bologna Accord is 3 + 2 + 3 years for a first degree at bachelor's level, a further degree at master's level and a research degree at doctoral level. The current norm for training in England is now best characterised as 4 + 4 years for a first degree at master's level and a research degree. But the state of affairs in the UK is evolving and some universities provide three year degrees, and additional one or two year courses so that students can readily make the transition from another system to theirs. The structure is currently overcomplicated, with almost everything differing from nation to nation within the UK, from university to university and from course to course (a fact in itself demonstrating the need for standardisation).

As at August 2010, there were 115 universities in the UK (Table 1),

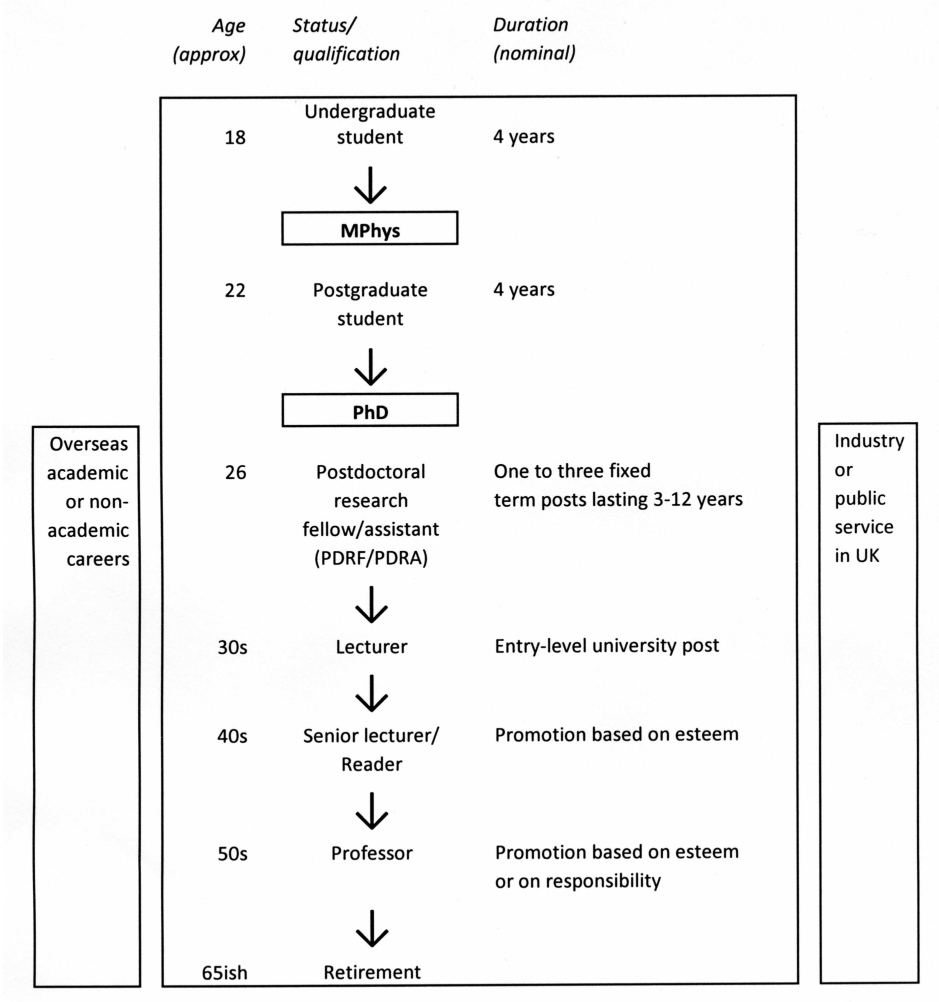


*Figure 1.* A nominal astronomical career path in England.

where 'university' means an organisation with the word in its title. Federal institutions such as the University of Wales and the University of London, and the Open University, are counted as one university for the purpose of Table 1, which needs to be interpreted with caution as a result of this rather mechanical selection procedure. The power of an organisation to award degrees, both as the result of a taught course or as the result of research, is regulated in the UK by law. Up to 1992 universities operated only under Royal Charters, i.e. individual constitutional documents defining an organisation's purpose, structure and powers, and authorised into law by

TABLE 1. Universities in the UK

| **Country** | **Number of Universities** | **Fraction of the population of the UK living in that country** |
|---|---|---|
| England | 89 | 84% |
| Scotland | 14 | 9% |
| Wales | 10 | 5% |
| Northern Ireland | 2 | 3% |
| Total in the UK | 115 | 100% |

the monarch. Under the Further and Higher Education Act 1992, it is now the Privy Council, i.e. the body that (in the language of historic constitutional principles that underlie some aspects of state bureaucracy in the UK) 'advises the monarch in her duties as Head of State', which approves the use of the word 'university' (including 'university college') in the title of an institution of higher education. The Privy Council does so on the basis of an analysis by a Government agency, the Quality Assurance Agency for Higher Education, showing whether the institution is a well-founded, cohesive and self-critical academic community that can demonstrate firm guardianship of its standards.

A university can, as it pleases, offer courses at the levels and in the subjects that it wants to teach and research. It may structure itself how it wishes into colleges, faculties, schools, institutes and/or departments (all these are referred to hereafter as a 'department'). Astronomy is taught and/or researched at 48 universities (where here and subsequently I do differentiate between the colleges of the University of London, and similar cases where the organisation is to a large extent independent academically from others). Astronomy has its home typically in a department of physics, or of physics and astronomy, or of mathematics. A minority of universities have a standalone department of astronomy, or teach or research astronomy in association with some other physical science or engineering subject.

A few of the older universities have names without the word 'university' in them, like Imperial College, London, and a small number are named after people (founders or benefactors). Most typically, the name is of the form 'University of [Location]' or '[Location] University', and [Location] is usually a city. This is an indication of the fact that the 48 universities where astronomy is studied, and therefore astronomers, are distributed broadly in correlation with the population, with good geographical diversity.

A number of UK universities have formed groups with common interests, including so-called ‘mission groups’. The ‘Russell Group’ is an association of the 20 largest research-intensive universities, with its name reflecting the fact that it traditionally met at the Russell Hotel, London. The ‘1994 Group’, founded in that year, consists of 19 smaller research-intensive universities, formed in response to the formation of the Russell Group to balance its consolidated influence as the British ‘Ivy League’. These 39 universities include nearly all the universities where astronomy is studied (those universities in these two groups where astronomy is not studied limit themselves to a narrow, specialist group of subject areas, like the London School of Economics). Most of the remainder of the 48 astronomy universities belong to the University Alliance, formally launched in 2007, and comprising 23 universities which emphasise a balanced portfolio of research, teaching, enterprise and innovation as integral to their missions, i.e. they have a business-friendly stance, often with a high proportion of science and technical courses. Thus, astronomy is a subject taught and researched primarily within the 62 more active universities in the UK.

## 3. Taught degrees in astronomy

In the UK (see Fig. 1) a student typically enters university at age 18 (17 in Scotland) as an ‘undergraduate’, intending to progress and ‘graduate’ with a university qualification or ‘degree’. Up to recently, the degree would have been at bachelor’s level (a three or four year course in England and Scotland respectively), but it is now more typically at master’s level (in a further year’s study that is usually completely integrated into the previous bachelor’s level course). Except for the Open University (see below), which is ‘open’, each university controls the entrance of students through quality criteria, i.e. on the basis of the applicant’s academic record of examinations in school, and, especially in cases where the applicant has been disadvantaged and underachieved, on the basis of an estimate of the potential of the student to do well in the degree course in the intended subject. Because of the selection criteria, it is not usual for a student to drop out of a degree courses. Up to now, the total number of students in each university has been ultimately controlled by the UK Government through the total funding which it supplies, except for the University of Buckingham, which is the only independent university in the UK, accepting no Government funding; but it has no astronomy activity, indeed nothing at all in the physical sciences. But the number of students in each course has been controlled by the way the university divides this money to departments and courses (depending on demand and capacity). Students apply to the universities and courses that they select through a centralised system run by the Universities and Colleges Admissions Service (UCAS) – selection and agreement is directly between the student and the university, UCAS is purely administrative and coordinating. UCAS covers fulltime courses at nearly all universities in the UK, but notably has nothing to do with courses at the Open University (see below).

In the heyday of the welfare state in the UK (say 1950-1980), university education was provided to a rather small fraction of the population (of order 10%) at no charge to the student. It was financed through Government funding direct to universities, and students received grants to help with living expenses. As stated, entry to university was through merit, although performance in the examinations was helped by the school education received and was therefore strongly correlated with family circumstances. University education was thus not only for personal development and a training to enter intellectually-based professions, it was also an engine for social mobility, although a flawed one, and a way of driving development in the professions through the ability of their meritocracy.

In recent years, university education has been provided to a growing fraction of the population, with consequent strain on public finances, and consequent financial pressure by Government on universities. The Government has demanded ever greater efficiencies – larger classes, longer teaching hours, consolidated courses – and now spends half as much per student as twenty years ago. Taken together with the expansion of the numbers of students, some would say that this has led to reduced standards of education. The efficiency process has delivered the affordability that the Government has needed to help fund the delivery of higher education to a wider fraction of the population, but the money required to fund higher education has nevertheless increased dramatically. This has led to the governments of England and Northern Ireland gradually to withdraw funding from students and to require the student to pay fees[1].

Thus, in the years immediately before and up to 2011, the cost of attendance at a course was paid for partly through money supplied from centrally gathered tax funds, partly by funds gathered by the university from other sources, and partly (except in Scotland and Wales) by the student. The maximum that a student had to contribute in 2011 in England and Northern Ireland was GBP 3,375 p.a. Loans were available from the Government at reduced interest to cover the cost of tuition; loans were also available to cover living costs (currently reckoned at GBP 5,500 p.a., GBP 7,700 p.a. in London) with outright grants also available on a sliding scale depending on family income. Loans start to be paid back only when the new graduate is employed with a wage above a certain limit, which approximates to the median income in the UK.

[1]Scotland and Wales, however, maintained the principle of free university education, but required non-Scottish or non-Welsh students, respectively, to pay fees.

From 2012 the maximum tuition fee for an undergraduate course will greatly increase to GBP 9,000 p.a. – most universities that teach astronomy will charge the maximum, or near. In Scotland and Wales, the devolved Government intends to continue to pay student fees, although the universities in these countries are concerned about the further financial pressure that will result, and fear the effect of underfunding. For students resident outside the EU, fees are uncontrolled and can be up to about GBP 20,000 per year, depending on course (law, dentistry, medicine and laboratory subjects like physics being among the more expensive). For reasons of European mobility, fees of EU students are regulated by EU law, and such students receive the same treatment as English, Northern Irish, Welsh or Scottish students respectively – curiously, since the EU laws on mobility have no validity within a member state, students resident in England who wish to study in Scotland (and similarly) will be disadvantaged relative to, say French or German students, and have to pay fees, but of course they can always choose to study in France or Germany (say), on French or German terms.

About 36% of young people (40% of young women and 32% of young men) in the UK now go to a university. Fifty years ago a degree course may have been discussed in terms of social mobility, as well as personal development. Nowadays, a degree course is most commonly discussed as the gateway to a good career, as well as personal development.

The discussion of a good career in this context often centres on one that is well paid, presumably because this is more quantitative and objective than job satisfaction. The median differential in pay between a university graduate in Physics and Astronomy and someone who stopped studying science just before he or she would have gone to university is about GBP 5,000 per year. The additional lifetime earnings for physics and astronomy graduates over non-graduates are at least GBP 100,000 (the comparable figure for graduates in history, English and the like is considerably less). Of course, a significant fraction (about a third) of these extra earnings is remitted back to the Government in income tax, more than the cost of the education.

There is considerable concern about the effect on this analysis of the new system of student payment, in which it will be common to leave a university course with a debt for fees alone of GBP 35,000, accruing interest (albeit at a low rate). With the living costs, the debt might be so large that paying it back over 30 years with interest could cost as much as GBP 140,000. This will certainly take the shine off the additional lifetime earnings, possibly wipe them out, and therefore greatly reduce the financial attraction of a university education, especially for young people from less-affluent social classes. In spite of the post-war principles of universal education, the UK is a country with a relatively poor and worsening record of social mobility, compared with European countries in general and the USA. The UK Government intends that an augmented system for grants and bursaries will improve access to university education by those whose families cannot otherwise afford it and thus increase social mobility, but many fear that the new system of loans for fees for university education, which start a student into a career with a substantial debt, will do the reverse.

I have spelled out these financial and social considerations because they bear on the position of astronomy as a taught subject in UK universities. As well as personal inclination, considerations of cost and future employability greatly influence the student's choice of degree subject. As a result, astronomy is not sought after as a degree subject *on its own*, even if astronomy is a good training in interdisciplinary applied science. Students are more likely to opt for a subject that, it is believed, will lead more directly to a good job. At the same time, students are also more strongly attracted to astronomy as a subject to study for their personal satisfaction than many other sciences. Their ideal is to undertake a course that provides opportunities to study a bread-and-butter science with a future job in mind, with some flavoursome jam on top, like astronomy.

Because university education operates to a greater or lesser degree as a market, student choice is the driver of the courses that universities offer. It is expected that, as a result of the intensification of the arrangements by which students pay for their own education, there will be further changes in the courses that universities offer, but few people confidently forecast how this will affect astronomy. The effect of student choice up to now has been that astronomy is now typically offered at UK universities only in association with other subjects – 'Physics and astrophysics', for example.

Indeed, the experience of university physics departments is that a strong astronomy component to a physics degree course is attractive to students. The Institute of Physics has reported a survey of eight Russell Group universities that suggested that over 50% of first year and nearly 75% of final year physics undergraduates cited astronomy or astrophysics as being of significant interest in attracting them to their physics programme. This is the reason why some universities name their 'physics and astronomy' courses in such a way as to make them, it is hoped, even more attractive – 'physics with cosmology', for example.

Reasons like these underlie the recent steady expansion of astronomy in UK universities. Since the 1970s, one new astronomy group has been added to UK universities on average every year or two, a process still on-going. It is fortunate that these economic pressures are consistent with the view of many astronomers that astronomy has changed from a discipline with its own methodology and circumscribed subject matter to applied physics, mathematics and/or chemistry and is best studied as a multidisciplinary science, not as a standalone science.

Data on university applications are collected by UCAS. In 2010, after a period of some years of decline or stagnation, there were more applications and acceptances to study a course with physics in its name than for ten years, with 25,500 applications and 4,500 acceptances (each applicant can apply for up to 5 courses but of course will ultimately be accepted by at most one). It is not known why there has been an upsurge of applications to study physics; perhaps in response to the Government message ('science good', if not quite with the corollary 'arts bad') students are turning further from 'soft' subjects to 'hard' subjects with good employment prospects, leavened by more enjoyable components, like astronomy. Certainly, the physics community, led by the Institute of Physics, has put a lot of effort into making physics more attractive.

The definition used by UCAS includes any course with 'physics' in its name, including, say, 'engineering with physics'. If we restrict the definition of a physics course to one that is predominantly in physics, the number of physics undergraduates in English universities is about 9,700 (HEFCE 2010), i.e. about 2,600-3,000 entries per year. The undergraduate population in England is 1,020,000.

40 universities offered an undergraduate course with some sort of an astronomy component identified in its name, and there were 4,200 applications for entry to these courses with 700 acceptances (Massey 2011). Probably most of the students accepted to study what I am continuing for simplicity to call simply 'astronomy' overlap with those who will study physics, so more than 15% of undergraduate physics students study astronomy in significant quantity.

## 4. Postgraduate research

The main route in the UK to a career in astronomy is through an undergraduate degree in physics (or mathematics or similar) followed by postgraduate training, which for a doctorate in the UK lasts in principle 4 years, but in practice sometimes longer. The main output is a thesis describing a research project carried out under the supervision of an academic member of the university. If all is well, the student is awarded a doctorate of philosophy (PhD) or other further degree. It is during the period of postgraduate training that the student may develop the knowledge, skills, independence and determination necessary for sustained independent research in astronomy, and builds up the evidence that may gain the student a post in an astronomy research group, or, if not, another equivalent employment.

Over 40 universities offer postgraduate opportunities and have active research groups whose members individually supervise the research of postgraduate students. This is about the same, perhaps even a larger number than offer undergraduate courses. This is possible because astronomy in the UK is set up with a number of centralised research facilities (telescopes, etc.) offered competitively for common use. Thus members of even a small group of astronomers at a university, perhaps even a single individual, can have access to world-class equipment and pursue cutting-edge research even if the university affords minimal infrastructural support for scientific research or teaching, such as laboratories. This enables an astronomer in even a small group within a physics or mathematics department to supervise PhD students, even if there is no support there for teaching astronomy at an undergraduate level. The students in their turn learn by accompanying their supervisor in his or her endeavours.

These circumstances constitute another good reason why astronomy is attractive to newer universities: a small university can gain a high-profile share of a research activity at a high standard through the employment of a small number of the right people, without the requirement to provide expensive equipment on campus.

Postgraduate research in British universities is financed by a 'research council' which receives a block grant from central government and subdivides the money to finance various subjects and programmes, some money centrally directed by the research council but much given to universities for individual projects, in response to proposals received. The research council responsible for astronomy is the Science and Technology Research Council (STFC). The expansion of astronomy, for reasons directly connected with the market system for education that the Government has developed, placing the choice of course of study in the hands of the student and the incentive to respond to this in the hands of the universities, has placed a strain of severe competition on STFC as it seeks to satisfy the increasing demand by astronomers for support and facilities. This has placed upward pressure for resources on the Government. One paradoxical response by the Government is to propose to limit, through top-down direction, the range of universities carrying out research, in astronomy as in other subjects. One recent suggestion by the minister for universities is to limit the number of research intensive universities to about twenty, more than halving the number that exists at present.

The largest bloc of astronomy PhD students in the UK is supported by grants from STFC, which pays tuition fees to the university and provides a living allowance to the student. The allowance, tax free, was recently increased considerably and seems to support an adequate student lifestyle. The number of grants is controlled under a quota system; in general, grants are awarded only to students who have achieved first class honours in a relevant undergraduate degree, or the next lower grade, known as an 'upper second class', abbreviated 2(i). Additionally, students can be funded by individual universities, self-financed or financed by other sources, including sources overseas. Because the training scheme has recently moved from a 3-year PhD to, more typically now, a 4-year PhD, and everyone knows that money is in short supply, the grant given by STFC to the university to pass on to the student is sufficient to last 3.5 years, not 4. Universities typically provide 4-year training to as many students as they can afford and as the research project and the preparedness of the student demands. There are always significant numbers of students supported from outside the main Government-sponsored system.

In recent years, up to 2009, the number of PhD students in astronomy being financed by STFC was about 150 students starting their studies per year. In 2010 the number was 132 and, according to STFC's financial plan, it will soon further decrease and plateau at 120-125. Since the training is typically for 4 years, the total number of mostly STFC-financed students in 2010 was about 490. According to the RAS Demographic Survey for 2010, there were 1060 PhD students in astronomy. The survey data were compiled in the winter of 2010/11, in the first months of the academic year, at the annual peak of PhD student numbers, with some students finishing off their theses after the time during which they are financed has run out. This might augment the number of STFC-supported and formerly-STFC-supported students by 10-20%, i.e. up to about 600. It follows that over 40% of PhD students in astronomy in the UK are financed by non-STFC sources.

By far most postgraduate students are full-time and 70% are domiciled in the UK, 30% outside the UK (half from the EU and the remainder in small numbers from many other countries).

## 5. Fixed-term post-doctoral researchers

The first position taken up by a newly-qualified astronomer with a doctorate, if he or she stays in astronomy, is typically as a fixed-term researcher. In making a grant to a university researcher to carry out specified projects, the STFC often provides funds for post-doctoral research assistants (PDRAs) to help with the research. Additionally STFC has funds available for research fellowships, competitively awarded to the most promising individual young scientists. In addition there are a number of fellowships (PDRFs) available from individual universities and colleges, the Royal Society, the Royal Astronomical Society, the EU, various charitable sources and foundations, etc. Such awards are made for a specified term of years – typically three. The Bologna process envisages that training will extend into the post-doctoral period, and it is often the case that post-graduates will receive training in transferable skills, i.e. skills that will equip the individual for employment both inside and outside astronomy research. This is seen in the UK as more and more essential, since the reality is that most PDRAs/PDRFs will not, in the long term, sustain an academic career in astronomy.

In 2010 there were about 450 PDRAs/PDRFs in astronomy in the UK. According to the RAS Demographic Surveys, this is about the same as in 2003; the number probably peaked between then and 2010, being brought back down from a high by the recent financial stringency. The number in 1998 and 1993 was about 410 and 320 respectively.

In the recent survey, 38% of PDRAs/PDRFs were foreign nationals, a larger proportion than were PhD students. 27% were from other EU countries, 2% from the USA and 9% from elsewhere. 30% of PDRAs/PDRFs obtained their PhD from outside the UK. The attraction of the UK to foreign nationals who want to research in astronomy is a mixture of the vigour of the science in the UK (second in output only to the USA), a desire (if they are not native English speakers) to exploit and develop the professional English-language skills that they will already have acquired and an attitude by UK astronomers to employ the best people as PDRAs/PDRFs without regard to nationality. Working against the latter principle is an increasingly difficult stance by UK immigration policy against economic migrants from outside the EU, although there are various exemptions for the well-qualified.

PDRAs/PDRFs are lucky enough to spend nearly all their time on research. They seem to reckon themselves adequately paid, almost exactly at the median wage in the UK, although this wage is less than they might have earned at the same career stage in some industrial positions.

## 6. Permanent posts

The entry level into the permanent academic staff of a university is Lecturer, with the name indicating the more important responsibility (certainly more time consuming, judging by the RAS Demographic Survey) of the appointee, namely, teaching, although of course research is of comparable weight. A few individuals are appointed to permanent research or technical staff positions, without teaching responsibilities. ‘Permanent’ is the customary adjective but is now too strong: there are increasing number of posts filled on the basis of there being continuing money available, and the concept in the UK of university ‘tenure’, the right to continued employment in the same job at a university until death or retirement, has weakened considerably. ‘Indefinite’, ‘open-ended’ or ‘continuing’ are more appropriate adjectives than ‘permanent’.

As the individual gains age, responsibility and reputation, he or she may be promoted to Senior Lecturer or Reader (terminology differs from university to university; hereafter both referred to as 'Senior Lecturer'). An individual may then be selected through competition for an established 'chair' (as the post of professor may be called) or another position which has some structural or organisational responsibilities. Alternatively, an individual may be offered personal promotion to the rank of Professor. This promotion does not always come with an increase in pay, but it may be part of a package offered as an inducement by a university to an astronomer to transfer away from his current post.

This phenomenon, reminiscent of footballers' transfers from team to team (but on a reduced financial scale), is more frequent at regular intervals, at the times of the Government's periodic evaluation of universities, which influences the grants that it gives out to support university work other than teaching. Formerly known as the Research Assessment (RA) exercise, it is now called the Research Excellence Framework (REF), run jointly by the Higher Education Funding Councils for the four nations (like the one for England, HEFCE). The REF will take place in 2014, and will evaluate the output in the period 2008-13 of selected staff in post at the end of 2013. It is widely expected that there will be a migration of people with a good publications record in relevant years to other universities before the crucial census date, as universities respond to this market pressure on their funding. The next RAS Demographic Survey may well find that a number of professors of astronomy were created as a result of transfers taking place in the years 2011-2013.

The data from the RAS surveys for the numbers of permanent posts in universities are shown in Table 2. The erratic changes in totals since 1993 may be in part real and in part sampling differences between the surveys: in particular the 2003 survey was notably incomplete. Nevertheless there appears to have been a real increase since the 1990s, due to a mixture of reasons. I have already noted the continued establishment of new astronomy groups in universities (see above), although much of the increase appears to have been in universities where astronomy groups have been established for some time. Some of the growth is due to the closure after 1998 of the astronomical research functions of two research council institutes, the Royal Greenwich Observatory and the Royal Observatory, Edinburgh, and the reduction and merger of their technical operations. A number of astronomers were absorbed into universities in that process. There remain less than 100 staff in astronomy outside the universities compared to 400 or so before 1998.

Another feature of the 2010 figures is the rebalancing towards senior status positions: the doubling of the number of professors is particularly

TABLE 2. Permanent astronomy staff in UK universities

| | 1993 | 1998 | 2003 | 2010 |
|---|---|---|---|---|
| Professors | 78 | 98 | 104 | 227 |
| Senior lecturers | 100 | 97 | 105 | 160 |
| Lecturers | 101 | 117 | 74 | 111 |
| Technical staff | 129 | 78 | 35 | 70 |
| Research staff | | 20 | 8 | 50 |
| Totals | 408 | 410 | 326 | 618 |

notable. This is probably due to the introduction of the schemes for personal promotion and appointment of professors on merit.

In 2010, 78% of permanent staff were British, 12% from other EU countries and 2% from the USA. 41% do not have children, comprising 27% of professors and 62% of lecturers. In general in the UK, 40% of UK university graduates aged 35 are childless and that at least 30% will stay that way, so the astronomy population seems to be typical in this respect.

All three grades of academic staff (Professor, Senior Lecturer and Lecturer) reported that they spend over a third of their time on research (between 35% and 39%). The teaching load (undergraduate and postgraduate) varied inversely with administrative load: Lecturers spend 41% of their time teaching and 13% in administration respectively, Senior lecturers 37% and 17%, Professors 28% and 21%. All grades spent 4-5% of their time on outreach.

## 7. Gender demography

The proportion of females among postgraduate students in astronomy is about 34% (2011). Given a goal of gender equality, this is a considerable improvement on the 1998 figure of just over 20% (Tadhunter 2000), but still well short of the goal. The proportion of female staff of different status is as shown in Table 3. As with other academic subjects in UK universities, the proportion of women decreases with both age and seniority of status, and is larger in fixed term positions than in permanent positions. However, astronomy is apparently more female-friendly than physics. Changes in the population of astronomers are driven by the young intake but take place in the population as a whole on a generational timescale. The male-preponderance presumably reflects the mid-time at which the population was formed, as well as a systematic tendency for females to drop out of the

TABLE 3. Proportion of females

| Grade | Astronomy | Physics |
|---|---|---|
| Professor | 7% | 5% |
| Senior Lecturer/Reader | 16% | 11% |
| Lecturer | 28% | 20% |
| Permanent Research staff | 10% | }17% |
| Fixed Term research staff | 27% | |
| Permanent technical staff | 30% | |
| Fixed term technical staff | 20% | |
| Postgraduate students | 34% | 19% |

career pipeline or to rise up against a glass ceiling.

## 8. Ethnic demography

The only data known on the ethnicity of astronomers in the UK is data collected in 2010 by the RAS Demographic Survey 2011. 95% of permanent staff and 97% of fixed term staff describe themselves as white. The figures for the UK population as a whole are rather contentious and often not free from the political bias of the source, but objective figures are available in the official census by the UK Office of National Statistics. 86% of the UK population described themselves as white in the 2001 census. The 2011 census figures are not yet available, but are likely to show a higher proportion of non-white people. It is clear that non-white people are considerably under-represented in the population of astronomers in the UK; from the scant data on this subject that is available, this is true of many countries.

## 9. Career development

Here is a very simple model of the astronomy population in the UK: The total number of permanent academic staff is roughly 600, the number of postgraduate students about 1000. There are 450 PDRAs/PDRFs. The time that an individual spends in each of these stages of a nominal career is, let us say, 4 years as a PhD student, 6 years as a PDRA and perhaps as long as 40 years, say 20 years on average, as an academic. If the system is closed to outside sources and sinks (it is not) and if the system is in steady state (astronomy has been expanding), it would follow that 25% of postgraduate students would become PDRAs/PDRFs, and half of them would then go on to enjoy a university career in astronomy. Overall about 10% of PhD students would go on to enjoy an academic career in astronomy.

Actual figures for 2009, established from a survey by the STFC of the PhD students of astronomy that the STFC financed, and who completed their studies 10-14 years earlier (STFC 2010), are as follows[2].

46% of the former students who responded were working in universities, 27% in the private sector and 23% in other government or public sector organisations. Of those employed in universities, 32% were lecturers or senior lecturers and a third were working outside the UK. In the private sector, about three quarters worked in business or financial services: in investment banks, money market traders, fund management companies and companies providing management consultancy services. Former students also worked for large business systems companies and a minority worked in manufacturing companies. Of those working in the public sector, half worked in UK or international research establishments. A common feature of all these roles was that they require high-level mathematical, computer modelling and information technology skills which are key components of most astronomy PhDs. Most of the remainder were working in organisations that did not undertake research directly, such as central or local government and schools or colleges. Unmentioned in the survey were careers in school teaching, journalism or astronomy outreach, e.g. at a planetarium; these positions have been of less interest to someone with a PhD in astronomy, although there are a number of such people, perhaps an increasing number, doing a good job in those careers in the UK.

Further to develop the simple model above, of the progression of those scientists who set out on an academic career in astronomy, in conjunction with the standard ages of people who follow the nominal career of Fig. 1, it would follow that the age distribution would have a peak at young ages (PhD students, aged say 22-25), stepping down to a shoulder at a height of one-third peak for PDRAs/PDRFs (aged say 26-32), stepping down again to about 10% of peak (permanent staff, aged say 33-63).

The actual age distribution shows a triangular shape, declining almost monotonically and linearly from people who are in their early twenties to those about to retire aged 70. Thus individuals appear to leave an astronomy career in the UK at a constant rate per year. There is no known survey data of their destinations. Statistically, mortality and ill-health would be minor factors. Observation suggests that a number of those leaving UK astronomy migrate to academic posts overseas, for example to posts in overseas-based international organisations like the European Southern Observatory or to academic posts in other countries, like the USA, Germany, Australia, or South Africa. Some presumably shift to other, completely different parallel careers, whether in academia, public service or industry.

[2]The figures were, apparently, not corrected for any selection bias in the responses, e.g. university employees might be more readily located and more likely to respond.

It is rare for a person to be appointed to a permanent academic post before the age of 30, and staff in their late thirties are equally likely to be in permanent or fixed term posts; but some people in fixed term posts are in their forties and a few even in their fifties. It follows, since the age of a newly-qualified PhD is perhaps 27, that on average a person newly appointed to a permanent academic post would have had at least one, on average three, and perhaps more fixed-term PDRA/PDRF posts of three years duration. The people in these fixed-term positions are however at a time of their lives when family responsibilities, potential or de facto, are growing.

In general, PDRAs/PDRFs are realistic about the career that they could try to take further. Some never intended that they should take up an academic career in the UK in the long term. Some have seen what an academic career in astronomy entails, particularly the work-ethic of long hours, a salary that is perceived to be mediocre compared with the rumoured bonuses available in banking careers, the mobility and the flexibility of location that is necessary in the early years. They reject such a career, and move to something with a more conventional work-life balance.

For others, getting a permanent job in astronomy is a strong objective. They see as worthwhile rewards the constant intellectual challenge and the self-fulfilment that comes with understanding a problem in astronomy; they see the opportunity for travel, the sense of belonging to a global community and the respect that their peers give to an astronomer. They like what they see of the life lived by their more established colleagues.

In principle, there is no limit to the number of fixed-term posts that an individual may hold, although the older such a person becomes the more problematic is the next position. There have been some attempts to limit the number of positions or the maximum age at which a research council would permit a PDRA/PDRF to be employed, but these were illegal as well as paternalistic, and abandoned. However, EU employment legislation has reduced the distinction between fixed-term and permanent appointments in the rights of employment that accrue, and the distinction has become less crucial.

## 10. Part time study of astronomy

The Open University (OU) was established in 1969 to provide part-time or distance-learning for people wishing to achieve a university education in that way – typically adults who have for one reason or another have not taken the usual route at the usual time, perhaps for reasons of health or family circumstances. The OU's degree course is modular with units at different levels (correlating with the years of a conventional degree course) and weights. Successfully completed modules can be assembled, in a number of configurations, into a Certificate (mostly Level 1 study), a Diploma (mostly Level 1 + 2 study) or ultimately, after at least six years, into a Degree (Level 1 + 2 + 3 study). The degree is awarded either in a particular subject or in a broad range of subjects selected by the student within some given criteria of level and distribution. The OU has 250,000 students enrolled at any one time (about 50,000 outside the UK).

Astronomy modules are amongst the most, if not the most popular science courses at the OU, with 3,500 students enrolled in 2010 in at Level 1 (roughly equivalent to a conventional first year undergraduate course), 1,000 at Level 2, and 260 at Level 3, or 4,770 in total. The total enrolled in physics was 2,713. Taking account of the weighting of the courses, the total numbers were 595 and 970 full-time equivalent students respectively for astronomy and physics.

Following in the OU model, there are now university-level distance-learning courses in astronomy given from a collaboration of Liverpool John Moores University and the University of Central Lancashire. The units can be built up into a Degree or a Certificate of Higher Education, a qualification reckoned to be degree-level but not of the same scope as a degree.

Astronomy is also a subject which can be studied at school with an examination at the end of the course which is part of the General Certificate of Secondary Education (GCSE), taken typically at age 16. The examination can also be taken by adults on completion of a course at a college of further education, typically through evening courses. The number of people who take this examination has risen by a factor of ten over the last twenty five years to over 2,000 candidates in 2009, after a big increase in the numbers of educational institutions offering GCSE Astronomy, from its start when it was mainly taken by sixth formers in private residential schools. The National Curriculum taught in all schools requires school pupils to learn some astronomy, including basic things about the sun, earth, moon and the solar system.

Astronomy education in the OU and in schools is thus making some progress to widen the educational base in the UK and making a contribution to social mobility.

## 11. Amateur astronomy and public education

In Britain today there are over 10,000 amateur astronomers, probably more. This number is estimated from the membership of the 200 known amateur societies, which run meetings programmes and sometimes operate amateur observatories with star parties. The national amateur astronomical societies are the British Astronomical Association (BAA), with a membership of

3,000 amateur astronomers, and the Society for Popular Astronomy (SPA), with a similar sized membership of astronomy beginners, which has evolved out of a society directed specifically at young people. The principal amateur astronomy magazines in Britain are *Sky at Night* and *Astronomy Now*, with circulations reputed to be in the mid 20,000's. These amateur activities constitute an informal system of continuing professional development for large numbers of people who are likely to be in jobs with technical content.

There are large static planetaria at public education centres for astronomy in Armagh, Bristol, Chichester, Dundee, Glasgow, Greenwich, Isle of Wight, Jodrell Bank, Leicester, Liverpool, Sidmouth, Southend, Stockton, and Todmorton, some with active public observatories. Leicester is home to the National Space Centre (NSC), a major educational venture associated with Leicester University's Department of Physics and Astronomy. NSC has considerable success in attracting school students, especially the Challenger Learning Center, where it is possible to simulate space travel. There are important astronomy educational centres at the locations listed above, at the Spaceport on Merseyside, and elsewhere. Liverpool John Moores University is the home of the National Schools Observatory which, through the Liverpool Telescope, delivers inspirational astronomy to school children.

These facilities are greatly in demand by school teachers who understand the motivational power of astronomy for their students, and its ability to sugar-coat what the students may regard as the bitter pill of science-learning that they have to swallow, but who feel less than fully competent to teach space/astronomy studies. Indeed, the small number of school teachers teaching physics who have a degree-level qualification in physics is a matter of national concern, so these facilities provide a powerful complement to the study of physics in schools. The total throughput of people through these facilities is millions per year, the throughput of school children in the hundreds of thousands. For example, of the 2 million visitors to the Royal Observatory, Greenwich in 2008, 14,500 were school children in organised parties. 208,000 people per year visit the National Space Centre, of which 52,000 are school children; 100,000, 80,000 and 45,000 people each year visit the Merseyside Spaceport, the Jodrell Bank Visitor Centre, and the Armagh Planetarium, respectively, with similar proportions of school children.

Astronomy is recognised as an important educational activity by the BBC exercising its public service remit. Each episode of a recent BBC-TV series *Wonders of the Universe*, presented by Prof. Brian Cox, was watched by 6 million people (including on the Internet). The Open University also funds and provides material for significant astronomy programming on the BBC, including *The Cosmos: a Beginner's Guide*, presented by Adam Hart Davies. For 50 years, amateur astronomers have been catered for by a regular monthly programme *The Sky at Night*, presented by Patrick Moore, probably the world's longest running TV series with the exception of news programming, with about 2 million viewers. Astronomy stories are often (perhaps as often as daily) presented in one national newspaper or another and in radio and TV news programmes, typically as an upbeat item in an otherwise rather depressing assembly of general news about politics, the economy, crime and catastrophes. It is probable that a significant fraction of the population of the UK comes into contact with modern astronomy several times per year.

All this educational activity in astronomy is known from opinion surveys to be an important influence in attracting young people to science, and influencing the acceptance of the place of science in everyday activities by the population at large. This is recognised as such at Government level. This accounts for some of the support given to high-profile research astronomy by Government sources. Amateur astronomy is recognised as a component of continuing professional development for adults and its broad appeal has regularly figured in enquiries by the members of parliament who form the Parliamentary Committee on Science and Technology, who recognise astronomy's economic impact in raising competence in science and technology (House of Commons Science and Technology Committee 2011).

## 12. The future

Astronomy has established itself in the UK as a science in which the country excels. The science has its own scientific value, but its research output is sometimes described as taking place in 'blue skies', without results that are directly relevant to the economy. Of course, astronomy has direct economic value in the development in industry of cutting-edge technological capacity, spinning out from projects such as space instrumentation. Science and technology in the UK are acknowledged as having economic value to the 'knowledge economy', and have been favoured in Government spending accordingly, even after the economic downturn arising from the banking crisis of 2008; while most Government funding in the UK has been cut back starting in 2010, spending on science has remained broadly constant. It will be a continuing challenge to astronomers to demonstrate to Government that astronomy in particular has economic impact, because Government grants for research are increasingly being awarded on this basis, in addition to scientific merit. Both scientific merit and 'impact' figure in the REF, for example, and in the award of research grants by STFC.

Astronomers have, as a community, welcomed the role that their subject-matter gives them to be scientists who can inspire, motivate, attract and scientifically educate a wide range of people, particularly the young. In this nationally relevant goal, the astronomical community has been particularly successful, although from some of the demographics it seems that we could do better. It seems likely that the consequent economic impact that results from a broadly-based, scientifically well-educated, self-confident work-force is the largest economic impact that astronomy could possibly generate. The challenges are further to demonstrate this practical outcome, while at the same time maintaining scientific integrity, and structuring the participation in astronomy of the younger members of the UK academic community of astronomers, especially women and the ethnic minorities, in such a way that they embrace their probable future outside astronomy, while maintaining their enthusiasm and the standard of achievement in their early studies.

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# ASTRONOMY IN THE UNITED STATES: WORKFORCE DEVELOPMENT AND PUBLIC ENGAGEMENT

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**Abstract.** Astronomy workforce development and public engagement in the United States are described. The number of professional astronomers has grown by about a third in the past 25 years, to about 4000. Only one in four are faculty in an academic setting; the rest work in a wide range of public and private research institutes. PhD production has remained steady at about 200 per year. Women account for roughly half of BSc degrees and a third of PhD degrees, but their participation declines to about 10% at the level of full professor. Minorities are underrepresented by a substantial factor at all levels of the profession. In terms of public engagement, astronomy has unique advantages associated with its visual appeal and the large and active amateur astronomy community. The are 1400 public planetaria in the U.S., with another 110 in schools and universities. Astronomers have made good use of new media such as blogs and podcasts and social networks, but the biggest impact has been in the area of citizen science, where people with no technical background contribute directly to a research project by, for example, classifying galaxies. The International Year of Astronomy and the remarkable success of the Galileoscope have inspired large numbers of people to appreciate astronomy, contributing indirectly to the professional vitality of the field.

## 1. Introduction

Astronomy has a singular status among all sciences in the awareness of the general public. Throughout its long history it has been twined with culture through stories told about stars and planets, and it has been embedded in daily life through its importance for navigation and time-keeping. From the time of the Copernican Revolution, astronomy has shaped our sense of our place in a vast and ancient universe. In the modern age, astronomy is one of the most vital sciences, with discoveries spurred by sophisticated space observatories and large new ground-based telescopes. Part of its popularity is its instant visual appeal; images from the Hubble Space Telescope have attained iconic status around the world. Astronomy is simultaneously big and small sciencecutting edge facilities cost billions of dollars, but CCDs are cheap enough that a legion of amateur astronomers participates, and they can generate publishable research. The public feels ownership over the subject in a way that benefits the profession and its practitioners.

This article will give an overview of the development of an astronomical workforce and the modes by which astronomers engage with the public. Space is too limited for details, which can be pursued through references at the end. The focus is the United States, but professional astronomy is a highly collaborative "village" of 10,000 people, with projects and meetings drawing from many countries. The same is true of public engagement. The ubiquity and reach of the Internet, and the rise of English as the dominant second language, mean that astronomy outreach can be truly international. The US community goes through an important process every ten years called the Decadal Survey (National Research Council 2010). Sponsored by the National Academy of Sciences, each decadal survey harnesses a broad swathe of the community in preparing a report that summarizes the state of the profession and sets funding priorities for the succeeding ten years. This type of high-stakes consensual exercise is rare in any scientific field.

## 2. Workforce Development

The world does not have, and probably does not need, a large number of astronomers. The economic benefits of astronomy are largely indirect and the "currency" of the field is primarily intellectual. In challenging economic times, it can be difficult to defend investment in work that is motivated by expanding the understanding of the universe we live in. Yet it is a pursuit that exemplifies our capacity for abstract thought and separates us from all other species on the planet. At its best, astronomy is both inspirational and humbling.

### 2.1. DEMOGRAPHICS OF ASTRONOMERS

The best gauge of the number of professional astronomers in the US is the count of full members of the American Astronomical Society. This has risen from just under 3000 in 1984 to 4000 in 2009 (Fig. 1). There are

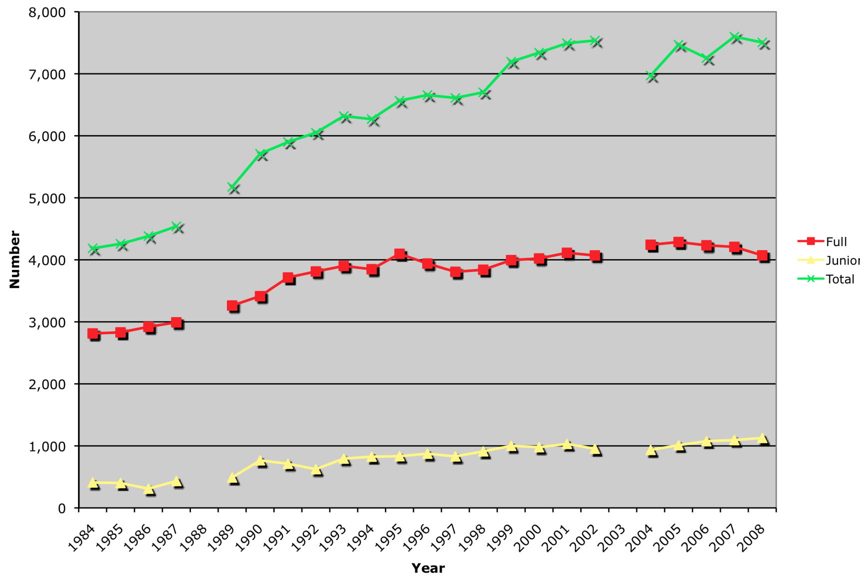


*Figure 1.* Membership of the American Astronomical Society from 1984 to 2009, including members inside and outside the United States. Growth was 33% during a period when the US population increased by 25%. (Courtesy Kevin Marvel and the AAS)

also 1000 junior members, typically astronomy students, and 2500 "other" members, consisting of an assortment of teachers, professionals in related fields, and amateur astronomers (American Astronomical Society 2005). This total probably grows to 9000 if others who do not necessarily self-identify as astronomers, such as relativists, cosmologists and astro-particle physicists, are included. Globally, the International Astronomical Union has a membership of 10,000, roughly a quarter of who are from the US.

Most astronomers work in academic settings and their jobs involve a mix of teaching and research (Fig. 2). Then come research institutes associated with universities and observatories (e.g. CARMA, Carnegie, CSO, LBT, Kavli, Keck, SAO). About one in six astronomers either works for the government (NSF, NASA, NRL, USNO) or in federally-funded research and development centers operated by NASA (e.g. Ames, Goddard, Kennedy, JPL, Marshall) or the NSF (Gemini, NAIC, NSO, NOAO, NRAO, NSO). The non-profit category includes old and illustrious planetaria (Adler, Griffith, Hayden), and there is a smattering of astronomers in industry and the military. Among the large cohort of academic astronomers, many are on soft money or have adjunct faculty status so have little job security. Academic astronomy suffers from the constrained resources that hamper public universities all over the US.

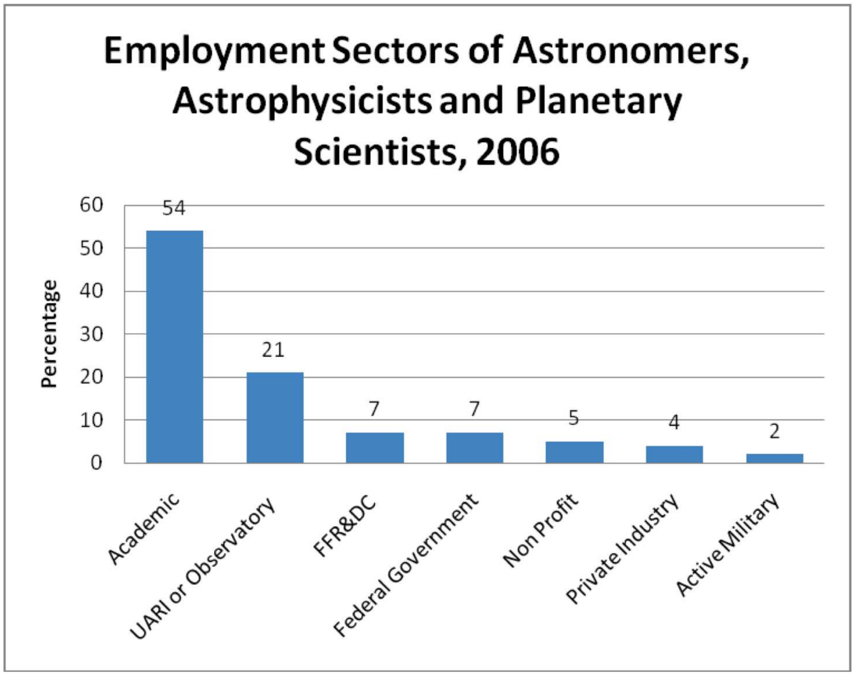


*Figure 2.* Employment in astronomy and closely related fields, from a random sample of 705 member of the American Institute of Physics and affiliated societies. UARI's are University-affiliated research institutes like NASA centers and National Observatories. FFR&DCs are Federally-funded research and development centers like JPL and Los Alamos Laboratory. (Courtesy Rachel Ivie and the AIP Statistical Research Center)

## 2.2. THE TRAINING OF ASTRONOMERS

Astronomy is a relatively small academic field. Between 1997 and 2006 the number of astronomy BSc degrees doubled from 170 while PhD degrees were steady at about 200 per year (Fig. 3). By way of comparison, the 350 BSc and 200 PhD degrees in astronomy awarded in 2006 is far less than the 16,000 BSc degrees and 3700 PhD degrees in other physical sciences or the 90,000 BSc degrees and 7700 PhD degrees in life and agricultural sciences (National Science Foundation 2011). Astronomy has close ties to physics so these numbers are underestimates, since students can pursue physics degrees with a specialization in astronomy. About 3/4 of these graduates are US citizens or permanent residents and 90% stay in the US after graduation (Ivie 2010).

The next part of the standard career path has benefited from government investment in major research facilities over the past twenty years. After the PhD, most astronomers look for a postdoctoral fellowship or a fixed-term

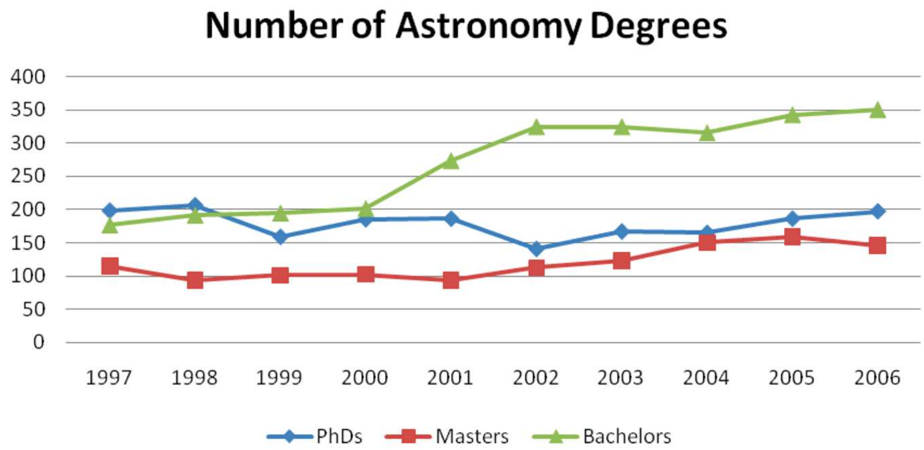


*Figure 3.* Astronomy degrees earned in the United States from 1997 to 2006. Masters degrees include those earned en route to a PhD The rise in Bachelors degrees was caused by physics departments adding the option of a double major. (Sources are the NSF for the PhD, the National Center for Education Statistics for the MSc, and the AIP for the BSc)

research position. Using the metric of positions advertised in the AAS Job Register, the number of such positions has doubled in the past ten years and $^2/_3$ of all PhD recipients take such a position (Fig. 4). Eight years after PhD, 85% of astronomers have long-term or permanent jobs, half in research and half in administration or teaching. In the US there are 1700 faculty positions, with 35% in astronomy departments and 65% in physics departments. Assuming no growth in that sector and replacement after 35 years, that implies there will only be academic employment in the future for 1/4 of astronomy PhD recipients (Ivie 2010). On the other hand, the unemployment rate for people with degrees in astronomy and astrophysics is very low, about 1% (American Astronomical Society 2005).

## 2.3. DIVERSITY AND DIVERSIFICATION

Astronomers are still mostly male, white, and relatively old, although there are trends making the profession more diverse. There has been slow and steady success in attracting women into astronomy, with a rise from 10% to 30% in the percentage of women receiving BSc degrees from 1966 to 2001 and a rise from 5% to 22% of women receiving PhD degrees over the same period (Fig. 5). Gender parity is much better than in physics but markedly worse than in biology. The American Institute of Physics workforce surveys show the diminishing fraction of women through the ranks of astronomy, from 45% with MSc degrees and 28% with PhD degrees

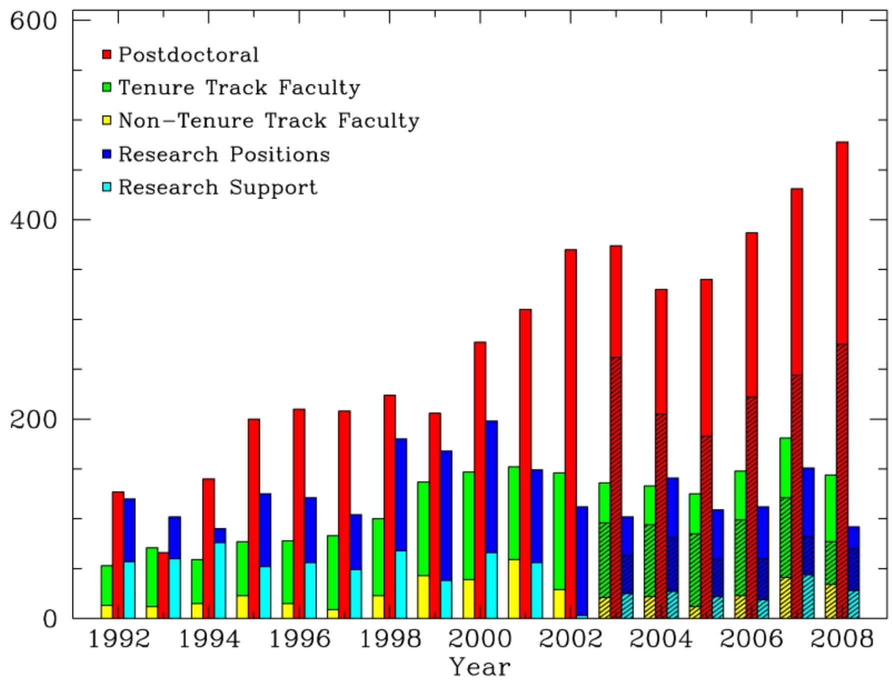


*Figure 4.* Data from the American Astronomical Society Job Register, showing the number of postdoctoral (red), faculty (green/yellow), and research (blue/cyan) positions advertised from 1992 to 2008. After 2002 the shaded regions of the histograms show the portion of the jobs that were in the US Faculty positions are divided into tenure track (green) and non-tenure track (yellow) and research positions are divided into research (blue) and support (cyan). (Courtesy Kevin Marvel and the AAS)

to 28% assistant professors and 11% full professors (quoted in Kinney *et al.* 2011). Under-representation of minorities is even worse, as they form 25% of the US population but only 2-3% of astronomy PhD recipients and under 1% of faculty (American Institute of Physics 2011). Moreover, the number of minority PhD awards has not changed in 25 years (Fig. 6). On gender, there is at least a sign that the pipeline is finally inching towards parity. The fraction of women in the most junior cohort of the AAS, 18-23 years old, is now 60% (Marvel 2009).

Alongside diversity, the astronomy profession must adapt to a changing work landscape by diversifying. It is already the case that a majority of PhD astronomers do not work in academia or in research labs. Pressure on funding will grow since most comes from the small discretionary part of the federal budget; the success rate for individual investigator grants from the Astronomy Division of the NSF has dropped from 50% in 1990 to 25% in 2010 (Ulvestad 2011). Some of this diversification is happening because

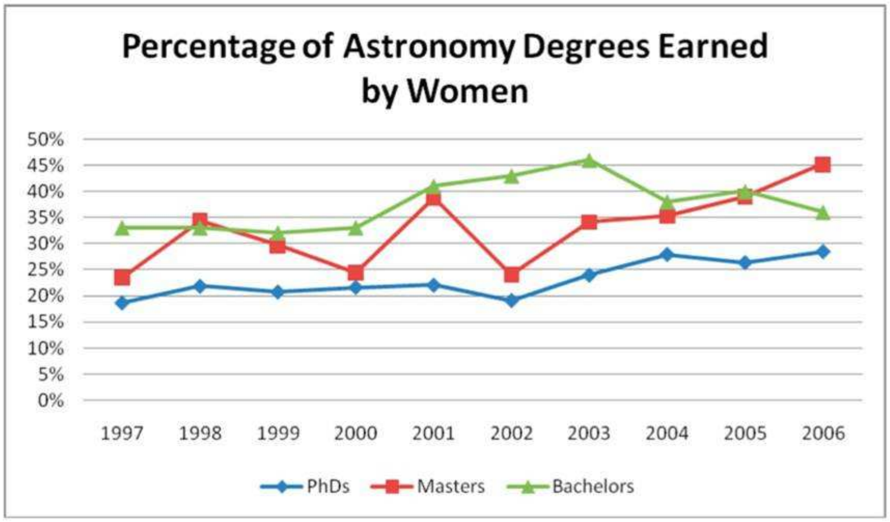


*Figure 5.* The percentage of astronomy degrees earned by women from 1997 to 2006. Explanation and sources of data are as for Fig. 3.

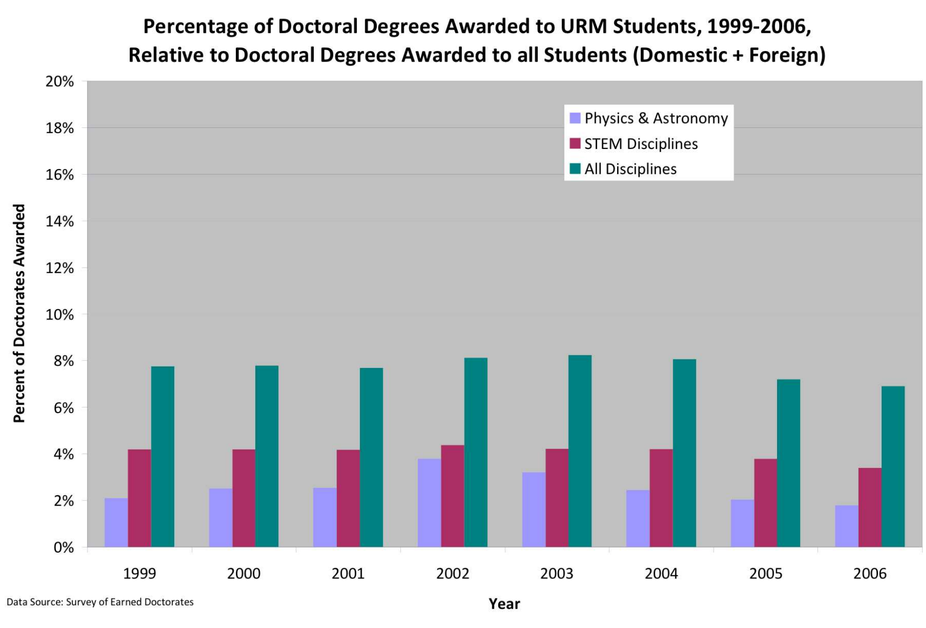


*Figure 6.* Percentage of doctoral degrees awarded to under-represented minorities. (National Science Foundation Survey of Earned Doctorates)

of central roles of data handling and computation in modern research. Any skills in these areas play into job growth associated with the data-intensive projects such as SDSS and LSST. Science policy and project management are other career niches open to astronomy graduates. There are also new opportunities for astronomers trained in education and pedagogy to help address low levels of US science literacy, as noted in a recommendation of the Astro 2010 survey (National Research Council 2010). Science literacy is tracked by the NSF in biannual surveys with an instrument that includes several astronomy questions (National Science Foundation 2010).

## 3. Public Engagement

Astronomy has unparalleled power to capture the imagination. It starts with an awareness of planet Earth, one of what may be a billion habitable worlds in the Milky Way galaxy, whose manmade structures and divisions melt away when seen from the perspective of space. In many branches of science, there is a high barrier to public appreciation because of the edifice of formal knowledge required to appreciate research results. Astrophysics is also an intimidating discipline, but astronomy can leverage the visceral impact of a Hubble Space Telescope image of the Eagle Nebula or a WMAP panorama of the infant universe.

### 3.1. TRADITIONAL MODES

The science museum is not dead. Despite the surge in online modes of engagement with information, the traditional science center has kept pace by offering more hands-on experiences and using cutting edge technology like immersive visualization and personal handheld museum "assistants." People only spend 10% of their lives in formal education settings, but in the US in 2008, 60 million people were served by 350 science centers and museums. Another 14 million students attended as part of school groups (Bell *et al.* 2009). About one in four Americans visit a science center each year, a rate lower than libraries, zoos or general museums, and one that depends strongly on level of education (Fig. 7). Almost a half of these science centers include planetaria and there are a total of 1400 across the country, plus another 1100 located in schools and universities. Most are small; only 70 have dome diameters larger than 15 meters (Fortson & Impey 2009). An increasing majority now use digital projection.

Traditional media are not dead. The National Science Foundation tracks the way the American public gets its news and science information, and while the Internet almost trebled as a primary source of science and technology information between 2001 and 2008, eclipsing magazines and newspapers in 2003, it still lies significantly below television (Fig. 8). Print science

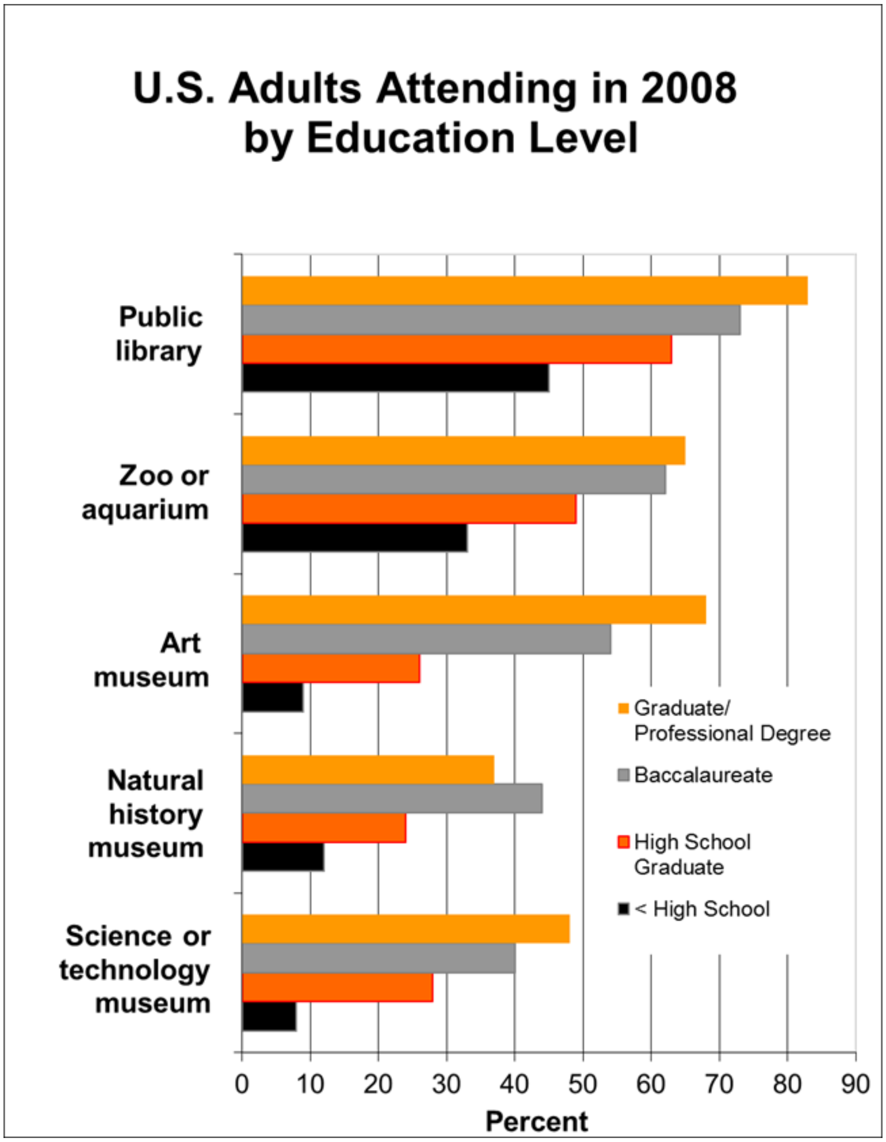


*Figure 7.* Percentage of members of the public who attended particular institutions at least once in 2008. The science museum category includes planetaria. Data is divided by highest level of education. (National Science Foundation's Science and Engineering Indicators 2010)

journalism is in retreat as newspapers retrench, reducing science coverage and laying off writers (Brumfield 2009). One barometer for astronomy is a drop by 50% from 1998 to 2008 in the attendance at AAS winter meetings of member of the traditional press (Fortson & Impey 2009). New media outlets for science have risen, but not enough to compensate and there are natural concerns over accuracy and consistency of coverage (e.g. de Cemir 2010). A generation of American astronomers was inspired by Carl Sagan's seminal TV series Cosmos in 1980. Astronomy continues to have a strong presence in TV programming on cable stations, in a steady string of IMAX movies, and in Hollywood's continuing infatuation with space themes, which includes five of the top ten grossing movies of all time.

### 3.2. INTERNET AND NEW MEDIA

Among Americans under the age of 30 the Internet is already the primary source of science information and that will soon be true of all Americans (Horrigan 2006). Astronomy has ridden the "wave" of the Internet very well, as the number of Internet users has more than doubled in the past decade. Astronomy features in 8% of the top 100 blogs and 24% of the top 50 podcasts. There are six online forums about astronomy with over 10,000 members, topped by Bad Astronomy/Universe Today, with nearly 50,000, followed by Cloudy Night with 30,000 and Astronomy.com with 28,000. No astronomy web sites make it into the top 1000 most popular; NASA's main site comes closest, with an Alexa rank of 752 in June 2011 and 9 million unique monthly visitors. It is impossible to reliably estimate but it is likely that the largest online access to astronomy occurs from a subset of the 350 million people viewing Wikipedia articles each month. Corporate heavyweights Microsoft and Google have spurred engagement with astronomy, the former via an application called World Wide Telescope which facilitates the creation of scripted tours of the sky and astronomical objects, the latter via instant access to maps of the night sky, the Moon, and Mars.

Social media have also been important in spreading astronomy. Facebook and MySpace have 500 and 13 groups respectively using astronomy as a keyword. However, only ten of these groups have more than a hundred members, and while Facebook users install 20 million apps a day, only 14 astronomy apps are available. On Flickr, the most popular photo sharing site, there are about 1000 groups dealing with astronomy, hosting 85,000 photos. Overall on the site there are roughly 3 million photos dealing with astronomical themes. YouTube is the dominant web site for sharing video content, adding a days' worth every minute. About 20,000 videos have a keyword of astronomy and there are 45,000 playlists with astronomy as a keyword. As of 2009, only 27 of these videos had 100,000 views (all the data in this section comes from Cominsky and Gay, quoted in Fortson & Impey 2009). Like other scientists, astronomers are still learning how best to operate in the rapidly-evolving new media landscape.

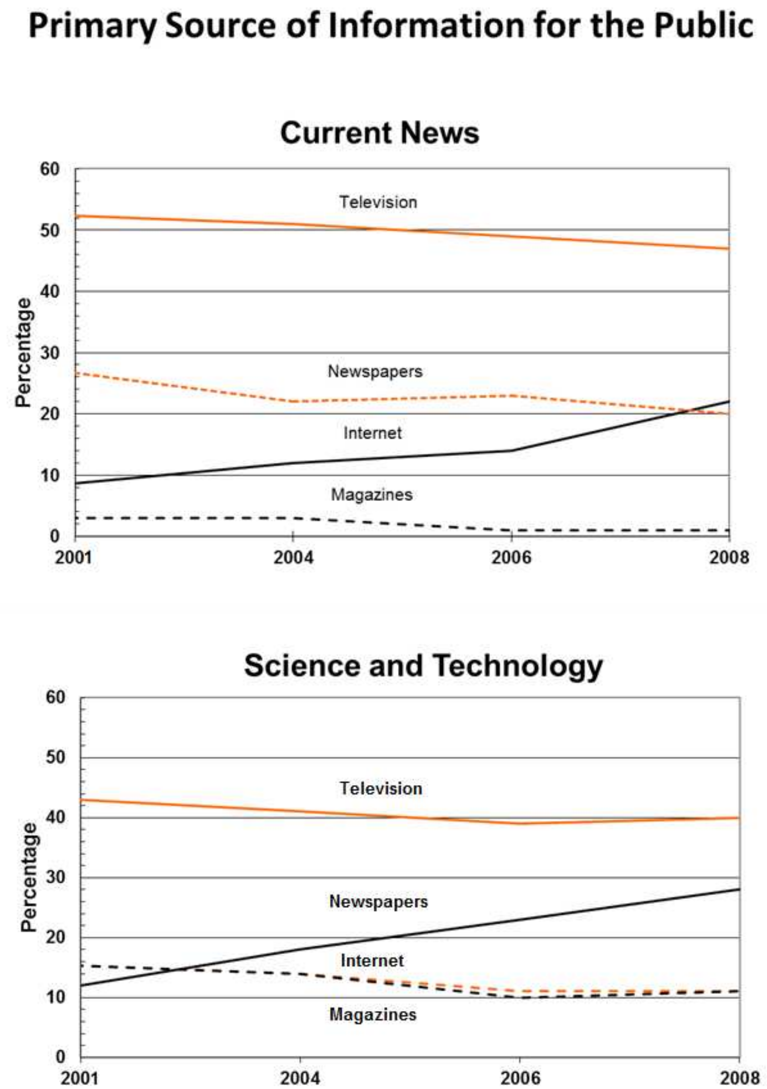


*Figure 8.* Primary source of information for the public about current events and science and technology from 2001 to 2006. Based on usage patterns, the growth of the Internet as a source of science information continues a steady rise. (National Science Foundation's Science and Engineering Indicators 2010)

## 3.3. THE CITIZEN SCIENTIST

Astronomy has been in the vanguard of a movement called citizen science, where members of the public are harnessed as volunteers to do research

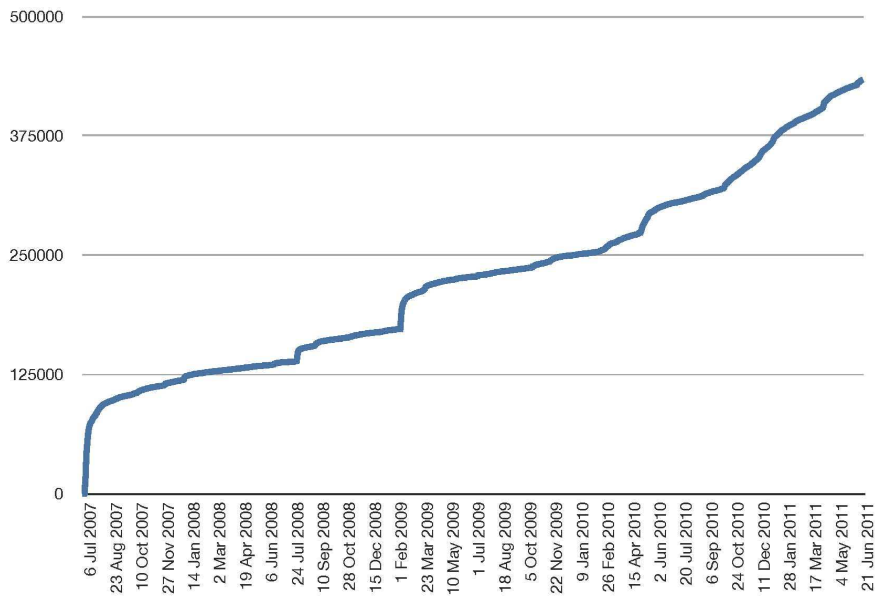


*Figure 9.* Number of users registered with `http://www.zooniverse.org/` since the launch of the first project, Galaxy Zoo, in 2007. Not all registered users classify, and not all classifications come from registered users. Large or rapid jumps in numbers are associated with launches of new projects and associated media coverage. (Courtesy Chris Lintott)

(Hand 2010[1]). They might make observations, analyze data, or do computer reductions or simulations, in every case under the guidance of scientists or within a framework defined by scientists. SETI@home was the first project to engage the public in scientific analysis, in this case the search for radio signals from intelligent aliens, but the public's role was essentially passive, with their desktops harnessed in a massive distributed computing project. Galaxy Zoo is more indicative of the future of citizen science (Fig. 9). In just the first two years of this project, 250,000 volunteers carried out 100 million classifications of galaxies from the Sloan Digital Sky Survey, with an accuracy and reliability that was, in the aggregate, equal to the efforts of professional astronomers (Raddick *et al.* 2009). By drawing the public into the enterprise, projects like Galaxy Zoo, and its extension into other fields, called Zooniverse, help to increase the understanding and acceptance of astronomical research.

[1]See also the specific chapter on citizen science (by Christian *et al.*) in this volume. (Ed. Note)

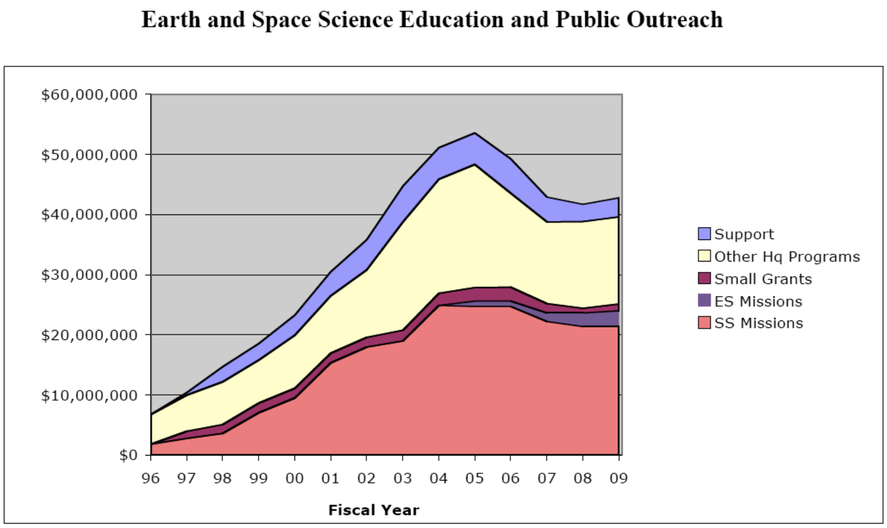


*Figure 10.* Total NASA budget for Earth and Space Science Education and Public Outreach from 1997 to 2009. The blue Support wedge is Science Mission Directorate personnel costs and other support costs. ES is Earth Sciences and SS is Space Sciences. (Courtesy NASA)

Public engagement in astronomy got an enormous boost in 2009 with the International Year of Astronomy, which celebrated the 400th anniversary of Galileo's first observations. One of the most inspired spin-offs from the IYA was the Galileoscope, an improved version of his original spyglass made with modern materials. Over 100,000 Galileoscopes were sold in 2009 and more generally the IYA improved the already-strong relationship between professionals and the 250,000 amateur astronomers in the US CDDs have become powerful and cheap enough that dedicated amateurs contribute in many research projects. Education and Public Outreach (EPO) have federal government support as well, spurred by NASA's decision to dedicate 1% of the cost of all space and astronomy missions to these activities (Fig. 10) and NSF funding at a level of 6-7% of the total for research grants. NSF's "broader impacts" criterion for merit review of proposals has contributed to a sea change in attitudes. Many professional astronomers are committed to public engagement in their work.

## 4. Summary

Astronomy is in a golden age of discovery, with progress on everything from the demographics of exoplanets to the state of the universe in the first tiny fractions of a second after the big bang. Despite its vitality, the profession is unlikely to grow in the United States due to the increasing cost of facilities and large projects and the pressure felt by universities to cut costs and teach more efficiently. Training in astronomy should be complemented by technical, educational, computational and managerial skills, to allow graduates a greater range of career options. Astronomy is held in high regard by the public, which indirectly benefits the profession overall. The most exciting ways to increase public engagement involve social media and citizen science on the Internet. Low science literacy is a significant societal problem and astronomers have an opportunity and an obligation to help raise the science awareness and understanding.

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# THE IAU ASTRONOMY FOR DEVELOPMENT PROGRAMME

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**Abstract.** Astronomy is a unique tool for international development because it combines cutting-edge technology with fundamental science and has deep cultural roots. The International Astronomical Union regards furthering the exploitation of astronomy for sustainable global development as an important part of its mission.

To realize these aspirations the IAU has developed an ambitious strategic plan for the period 2010 – 2020. This plan, "Astronomy for the developing world: Building from IYA 2009", endorsed by the IAU General Assembly in 2009, envisages a substantial increase in IAU educational and development activities during the next decade.

This article will discuss the content of the plan, the processes that led to its creation and adoption and the setting up of the IAU Global Office of Astronomy for Development at the SAAO in Cape Town, South Africa. We shall also describe the activities envisaged in the plan and argue that such a program is important for its own sake and necessary to generate funding for the next generation of astronomical research facilities.

## 1. Introduction – Astronomy for International Development

> *"It is important to maintain a basic science competence in 'flagship' sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future – the view that we are a second-class nation, chained forever to the treadmill of feeding and clothing ourselves".* – South African Department of Science and Technology, White paper on Science & Technology Policy (1996)

### 1.1. BACKGROUND

The IAU has long regarded fostering astronomy in developing countries as an important part of its mission. During the past two decades the IAU has conducted a range of educational and outreach activities under the auspices of its Commissions 46 and 55. These activities were directed mainly towards stimulating astronomy at university level. The success of the International Year of Astronomy (IYA 2009) and the increase in the scope and size of astronomy outreach activities inspired a review IAU activities and the development of a new strategic plan for the next decade. As IAU Vice President for Development and Education, I was privileged to be author of this plan and responsible for its implementation.

In this article, I shall first describe the outline the unique aspects of astronomy as a tool for furthering education and capacity building throughout the world. After commenting on the present global state of the astronomical research and education and I shall describe some activities that have been carried out by the IAU in recent years. I shall then outline the processes that led to the development of the new strategy, discuss the content of the Plan and the present state of its implementation, including the setting-up of a small office to coordinate the activities at the South African Astronomical Observatory (SAAO) in Cape Town, South Africa.

### 1.2. UNIQUENESS OF ASTRONOMY FOR HUMAN CAPACITY BUILDING

As illustrated in Fig. 1, the front cover of the IAU Decadal Strategic Plan, astronomy provides an inspirational and unique gateway to technology science and culture, three fundamental characteristics of developed nations.

- Astronomy is an important driver for the development of *advanced technology*, such as the most sensitive detectors of light and radio waves and the fastest computers. The need to study the faintest objects possible requires sophisticated electronics and extreme-precision adaptive optics as well as state-of-the-art engineering and innovative software algorithms. Astronomy has played an important role in the development of space technology that has opened up the Universe for study across the whole electromagnetic spectrum and driven developments in miniaturization. Modern optical and radio telescopes are among the most advanced machines ever built and are outstanding educational vehicles for becoming familiar with the latest complex technology.
- The Universe provides an inexpensive laboratory for *scientific studies* of extreme conditions that are inaccessible on Earth. Stars and galaxies are environments that have produced the chemical elements around us and formed organic molecules, the building blocks of life. During the

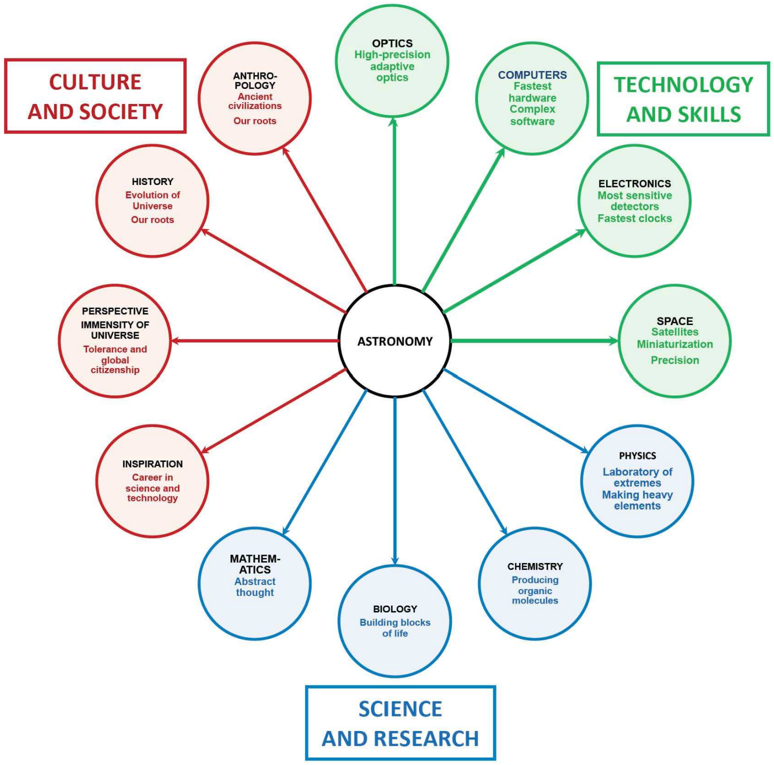


*Figure 1.* Schematic reproduction of cover of the IAU Strategic Plan, illustrating that astronomy is a unique tool for capacity building.

last century astronomical studies have led to new discoveries in physics, chemistry and biology and to the creation of the new sciences of astrophysics, astrochemistry and astrobiology. Because of its mathematical basis, astronomy is also an excellent tool for teaching mathematics. Access to several of the most sophisticated astronomical facilities and data archives are open to all. Hence astronomy enables scientists in every country to become involved in forefront scientific research at very little cost.

- Astronomy also contributes substantially to modern *culture* and is relevant to several topical issues of present-day society.
  - Astronomers are the ultimate historians. Large telescopes are "time machines" that routinely provide pictures and other information about of the observable Universe close to its "birth", 13.7 billion years ago. Unravelling the history of the Universe has been a

crowning achievement of humankind during the last half-century.

- One of the most important societal functions of modern astronomy is as a tool for education in the broadest sense. Because it is one of the most approachable of sciences, and one that consistently fascinates young people, astronomy is an excellent vehicle for introducing science and technology to children. The accessibility of the sky, the beauty of cosmic objects and the immensity of the Universe are inspirational and provide a perspective that encourages internationalism and tolerance. The excitement of astronomy has stimulated large numbers of young people to choose a career in science and technology, thereby contributing to the "knowledge economy" of many countries.

### 1.3. FROM THE CRADLE TO THE GRAVE

These various characteristics make astronomy an important tool for education and capacity building at all levels "from the cradle to the grave".

- *Primary education* (ages 4-10).
  The early formative years are crucial in the development of the human value system. At these ages children can readily appreciate and enjoy the beauty of astronomical objects and can learn to develop a 'feeling' for the vastness of the Universe. The sky and the Universe can excite young children and stimulate their imaginations. Exposure to inspirational astronomical themes can help broaden the minds and stimulate a world-view. Furthermore, astronomy is an excellent and exciting introduction to the scientific method and the concept that nature can be interrogated by rational means.
- *Secondary education* (ages 11-18).
  Astronomy is an outstanding medium for stimulating the interest of secondary school students in science and technology. The Universe and space travel are fascinating subjects in their own right. These topics can be integrated into physics, chemistry, biology and mathematics teaching and provide a link with technology and engineering studies. Recently, educational networks of telescopes have been developed that enable school children throughout the world to do astronomical observations by means of the Internet and introduce children to exciting scientific research.
- *Tertiary/University education and research training.*
  The link with astronomy is a frequent reason for young people to choose to study the physical sciences at University and the study of astronomy provides an excellent preparation for many careers in technology and management. Astronomy deals with material, which is much denser and

much sparser than anything that can be produced on Earth. Analysing phenomena under the extreme conditions that are present in astrophysical objects develops problem-solving abilities. Furthermore, modern astronomical research is often carried out in international collaborative teams, which by necessity develops managerial and people skills.

- *Research capabilities and infrastructures.*
  Much modern astronomical research requires facilities that are too expensive even for individual developed countries to build and operate. The realization of such facilities has frequently necessitated large international collaborations. Nevertheless, many of the largest astronomical telescopes and satellites and their archival treasures can be used by astronomers throughout the world, no matter where they are based, providing an easy and relatively inexpensive entry for developing countries into inspirational and visible world-class international research.
- *Public outreach.*
  Astronomy is the most approachable of all sciences for the general public. Compare the relative attention that astronomy receives in the newspapers and other media of most countries with that devoted to most other sciences. Everybody can gaze at the sky and appreciate its beauty. The evocative images produced by modern telescopes fascinate, whereas stories about exotic cosmic objects and the evolution and origin of our Universe can inspire, entertain and stretch the imagination. Information about the state of the Universe in the distant past has deep implications about the roots and future of our species. Astronomy provides an ideal introduction for teenagers to the creative excitement of the exact sciences and frequently stimulates students to embark on a scientific career. The adventure of astronomy is a popular ingredient of adult education program

## 2. Why a New Strategic Plan?

> *"Education is a human right with immense power to transform. On its foundation rest the cornerstones of freedom, democracy and sustainable human development."* – Kofi Annan

### 2.1. PREVIOUS ACTIVITIES BY THE IAU COMMISSIONS

Prior to 2009 the IAU education and development activities focused on universities, research and outreach. These were carried out through two commissions of its members. Commission 46 is concerned with "Astronomy Education and Development" and Commission 55 is devoted to "Communicating Astronomy with the Public". Within Commission 46 four "Program Groups" were involved with furthering astronomy in the developing countries. These program groups were the "World Wide Development of Astronomy (WWDA)", "Teaching for Astronomy Development (TAD)", the "International Schools for Young Astronomers (ISYA)" and "Exchange of Astronomers". The main activities carried out by the program groups were visits by astronomers to developing countries and organising schools for young astronomers. The coordination and implementation of all the activities were carried out on a purely voluntary basis. This was a limitation on the size and scales of the programmes. The advent of IYA2009 changed this dramatically.

### 2.2. IYA2009: THE INTERNATIONAL YEAR OF ASTRONOMY

The UN-proclaimed IAU-UNESCO International Year of Astronomy 2009 (IYA2009)[1], initiated by the Executive Committee was the largest science education and public outreach event ever and reached hundreds of millions of people in 148 countries. IYA2009 was a global effort to "help the citizens of the world rediscover their place in the Universe through the day- and night-time sky, and thereby engage a personal sense of wonder and discovery." Reports from the IYA2009 network (148 countries, 40 international organisations and 28 global projects) show that at least 815 million people worldwide were reached by IYA2009 activities. Star parties, public talks, exhibits, school programmes, books, citizen-scientist programmes, sciencearts events, IYA2009 documentaries and parades.

Astronomy is a special discipline for science outreach in that it has hundreds of thousands of amateur practitioners throughout the world. Collaboration between the professional and amateur astronomers was one of several factors that were responsible for the huge success and large outreach of IYA2009. Other factors included (i) the bottom-up and inclusive nature of the activities and (ii) a small office that provided professional coordination for the activities of volunteers. These will be important aspects of future IAU educational and development programmes.

### 2.3. ROAD TO THE IAU ASTRONOMY FOR DEVELOPMENT PLAN

The advent of IYA2009 was an opportune time to review the educational strategy of the IAU and develop a long-term plan for the post-IYA era.

There are several reasons why such a decadal plan was needed. First, technology is changing. The widespread access to the Internet and the future availability of remotely operated telescopes for education are two of many new opportunities that can be exploited. Secondly, several new

[1] `http://www.astronomy2009.org/news/updates/1108/`

astronomy-based programs have been instigated for education at the primary and secondary levels. We realised that coordination and focusing of the various IAU and non-IAU programs can produce a program that as a whole is greater than the sum of its parts. Thirdly, to augment efforts in this area a substantial amount of additional funding is needed. An ambitious and well-founded strategic plan is a prerequisite for any attempt to solicit additional funding.

In late 2007 the IAU Executive Committee therefore embarked on an exercise designed to produce a plan for ratification at the 2009 IAU General Assembly. First, we obtained input from a wide range of experts and stakeholders. An informal "brainstorming" meeting was held in Paris from 28-30 January 2008 to provide input to the Plan. Participants included representatives of IAU Commission 46 and its Program Groups, of non-IAU global astronomy education programmes, including the Japanese Tripod, ODA programme, the IYA Cornerstone 11/ Africa Plan, the Las Cumbres Observatory telescope network, Global Hands on Universe and Universe Awareness. In addition, several members of the IAU Executive Committee were present. As a result of this meeting the first draft of a plan was written. During the next year, this Strategic Plan went through several additional drafts, with input obtained from stakeholders such as the United Nations Office for Outer Space Affairs (UNOOSA), the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). Finally, the IAU Press Office, with the help of the ESO Education and Public Outreach Department, produced an illustrated version of the Plan for distribution.

The IAU Strategic Plan was approved by the IAU Executive Committee on 7 April 2009 and endorsed by two resolutions at the IAU General Assembly at Rio de Janeiro on 13 August 2009.

## 3. Digression – State of World Astronomy Development

*"Fanatic ethnic, religious or national identifications are difficult to support when we see our planet as a fragile, blue crescent fading to become an inconspicuous point of light against the bastion and citadel of the stars."* – Carl Sagan

Before discussing the content of the new IAU Strategic Plan it is instructive to survey the state of astronomy research and general education around the world, i.e. the theatre in which the plan must operate.

### 3.1. RESEARCH

An overview of the state of astronomy development was given by Hearnshaw (2007), who classified countries into various groups, using the GDP as a classification parameter. Here I shall use updated data supplied by Hearnshaw (2008) and adopt a slightly modified classification scheme, based purely on the state of astronomy in the countries. For the purposes of discussing world astronomical development, it is convenient to divide countries into the following groups:

Group 1A. “Developed astronomy research countries A”.
These are IAU member states with $> 4$ IAU members per million population, indicative of a thriving astronomy research community.

Group 1B. “Developed astronomy research countries B”.
These are IAU member states that participate in or host front-line astronomy research facilities, but that have less than 4 members per million population.

Group 2. “Emerging astronomy research countries”.
These are IAU member states with between 0.5 and 4 IAU members per million population that do not participate in front-line astronomy research facilities. They are targets for stimulating growth of their astronomical research.

Group 3. “Developing astronomy research countries”.
These are countries that do not adhere to the IAU, but have at least one individual IAU member, indicative of limited involvement in astronomical research. They are targets for stimulating growth of their astronomical research.

Group 4. “Potential developing astronomy research countries”.
These are countries with well-developed tertiary education that neither adhere to the IAU nor contain individual IAU members. They are targets for stimulating the establishment of astronomy-oriented research groups.

Group 5. “Underdeveloped astronomy countries.”
These are countries that do not adhere to the IAU or contain individual IAU members whose tertiary education is only weakly developed. They are targets for stimulating the dissemination of astronomy education within their schools.

A summary of the present state of astronomical development in 152 countries as a function of their region is given in Figs. 2. For each region the number of countries and the number of inhabitants that fall into each of the above classifications are shown.

About two thirds of the world’s population inhabits Group 1 countries that are developed in astronomical research. However, many of the “developed” astronomy countries in Group 1B have large populations and within

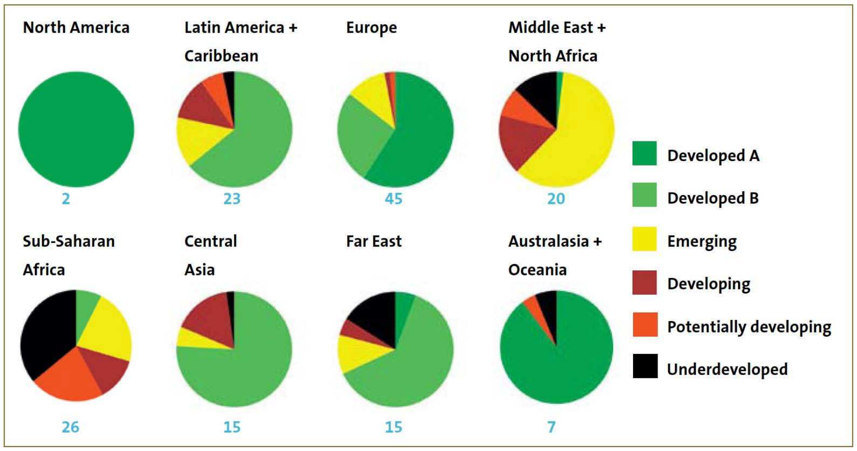


*Figure 2.* Astronomy research development by region. Populations in millions that inhabit countries at various stages of development in different regions of the world. The plots were compiled on the basis of data from Hearnshaw (2008, private communication). The numbers of countries included in each region are indicated in blue. A number of conclusions follow from these statistics.

these countries there are often substantial regional variations in the degree of astronomy development.

There is considerable disparity from region to region. The region that has the largest populations in the least developed astronomical groups is Sub-Saharan Africa.

As to be expected, there is a strong correlation between astronomical development and gross domestic product (GDP), with poorer countries generally being less developed in astronomy.

### 3.2. EDUCATION

The state of the educational infrastructure must be an important factor in determining the detailed strategy for astronomy development, particularly in the areas of school education and public outreach. The global distribution of educational index is illustrated in Fig. 3.

Since not all UN member states chose provide the necessary statistics, the data is not complete. Nevertheless, they provide a useful basis for planning future initiatives for programs directed at stimulating astronomy in primary and secondary and tertiary education.

Countries can be divided into three broad categories based on their Education Index: high, medium, and low. As is the case with astronomy research development, Sub-Saharan Africa has the largest number of least developed countries as measured by their educational index.

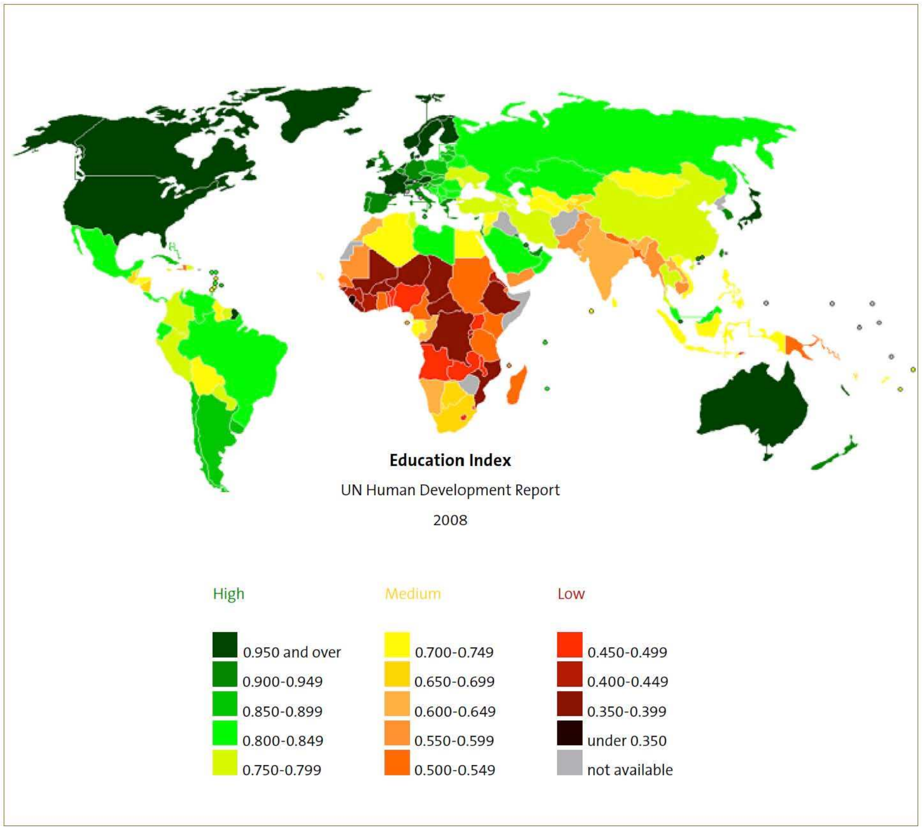


*Figure 3.* Global distribution of educational index. The educational index is defined by E = 2/3 (L) + 1/3 (C), where L is the literacy rate and C is the combined gross school enrolment ratio. This is taken from the 2007/2008 edition of the UN Human Development Report (2007, ISBN978-0-230-54704-9).

## 4. Building on the IYA – The IAU Strategic Plan 20102020

> *"Education is the great engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mineworker can become the head of the mine, that a child of farm workers can become the President of a great nation."* – Nelson Mandela

### 4.1. THE STRATEGY

The new IAU plan[2] is a bottom-up plan of action for the next decade to use astronomy as a tool for capacity building throughout the world. It contains a vision, goals to be achieved during the next decade, a strategy for achieving these goals and a blueprint for implementation.

The long-term vision of the plan is that eventually all countries should participate at some level in astronomical research and that all children throughout the world will be exposed to knowledge about astronomy and the Universe. Specific goals for the next decade are (i) to raise the level of astronomy development of as many countries as possible by one or more categories (Section 3.1) and (ii) to include aspects of astronomy in the primary and secondary education of as many children as possible.

The "meat" of the plan is a strategy consisting of several components.

- *A strategic phased integrated approach.*
  This includes primary, secondary and tertiary education, research and public science outreach. The strategy will be based on the future potential for astronomy research and education in each country, using objective data, augmented by advice from experts in the region
- *Special attention to Sub-Saharan Africa.*
  Because of its relative underdevelopment, sub-Saharan Africa will receive special attention.
- *Using IYA2009 as a springboard.*
  Several IYA global cornerstones will be continued and supported, after the IYA has finished. Examples of activities that have been adopted by the IAU include the Galileo teacher training program, UNAWE and the Galileoscope. Also, the huge network of IYA contacts that has been built up in IAU member states and other countries is a valuable resource that will be used for future capacity building activities.
- *Enlarging the number of active volunteers.*
  We shall recruit vigorously among our ∼10,000 members and augment the pool of member volunteers by doctoral students, postdoctoral trainees and talented non-member experts on pre-tertiary education and outreach, including amateur astronomers. It is hoped that expatriates will play an important role.
- *Initiation of new activities*, such as semi-popular lectures on inspirational topics at the high school and long-term institute twinning between established astronomy institutes and university departments in less developed countries.
- *Creation of a small Global Office of Astronomy for Development (GOAD).*

[2] http://iau.org/static/education/strategicplan_091001.pdf

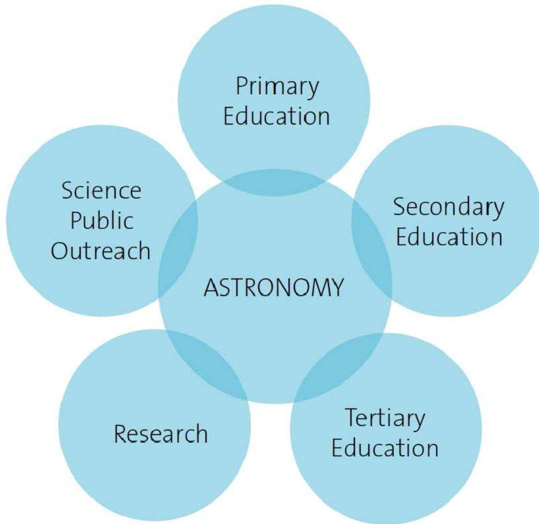


*Figure 4.* Elements of astronomy development. Fundamental ingredients of development to which astronomy can make a unique contribution. The mix of activities will be tailored to the needs of each country and region.

Mobilizing large number of volunteers and implementing new programs need professional coordination, as was demonstrated during the coordination of IYA2009.

- *Increasing regional involvement.*
  The bottom-up IYA2009 approach will be continued, with a substantial degree of decentralization. This will involve the appointment of regional development coordinators and the designation of regional "institute nodes". It is envisaged that the regional coordinators will coordinate development efforts throughout their geographical region.
- *Exploiting innovative techniques.*
  Where possible we shall explore innovative approaches to education and development, including the internet and new tools, such as archives, robotic telescope networks and the "Astro-bus" a mobile science centre pioneered by La Cité des Sciences in Tunis that contains a planetarium and a small telescope and reaches children and the public in rural Tunisian villages.
- *Evaluation and assessment* will be an essential part of the plan.

### 4.2. PLANNED ACTIVITIES

The core of the planned strategy is to expand existing IAU activities and initiate several new ones. Planned activities to be carried out under the auspices of the Strategic Plan (Table 1) include the following:

4.2.1. *Primary and secondary education*

- *Teacher training.*
  Teacher training at primary and secondary levels is a crucial element of national development. During the last few years the IAU has organized teacher-training courses in several countries. It is planned to rationalise and expand these activities during the next decade. Outreach to teachers in the developing world will involve the preparation and translation of materials, the provision of training courses and harnessing global technological resources in the service of primary and secondary education. It is envisaged that the use of expatriates for such activities will be expanded during the implementation of the Plan.
- *Inspiring disadvantaged children (Universe Awareness).*
  The IAU web site[3] uses the beauty and grandeur of the Universe to inspire young children from ages 4 to 10 years, particularly those from an underprivileged background. The perspective given by astronomy is used to broaden children's minds, awaken their imagination, encourage curiosity in science and stimulate global citizenship and tolerance. Although UNAWE was only founded five years ago, it is already active in more than 40 countries and comprises a global network of almost 500 astronomers, teachers and other educators. Besides developing educational material and training teachers, UNAWE enables the exchange of ideas and materials through networking and interdisciplinary workshops. The European Union (EU) has recently granted 1.9 million Euros to support the 6-country EUNAWE project in Germany, Italy, The Netherlands, South Africa, Spain and the UK. In some countries UNAWE has worked closely with the UNESCO network of schools.
- *Global Hands-On Universe (GHOU)* is an educational program that enables secondary school students to investigate the Universe while applying tools and concepts from science, mathematics, and technology. Using the Internet, GHOU participants around the world request observations from an automated telescope or download images from a large image archive, and analyse them with the aid of user-friendly image processing software.

4.2.2. *Tertiary/university education and building research capacity*

- *Capacity-building visits by scientists and engineers.*
  With a view to developing capabilities in astronomy teaching and/or research in countries that have little experience in astronomy visits

[3] `http://www.iau.org/`

TABLE 1. Some of the activities envisaged in the strategic plan

| **Development Phase** | **Activity** |
|---|---|
| Primary and secondary education | Teacher training |
| | Universe Awareness |
| | Global Hands on Universe |
| Tertiary/university education and research capacity | Capacity-building visits by astronomers and engineers |
| | National schools for undergraduates |
| | Regional schools for postgraduates |
| | Long-term (sustainable) institute twinning |
| Public outreach | Semi-popular inspirational lectures in astronomy and related technology |
| | Exploitation of fixed and mobile planetaria |

are made by IAU experts to assess the situation and encourage the development of astronomy courses at undergraduate level, or the setting up of small astronomy research groups.

- *National Schools for undergraduate students.*
  For several years the IAU has had a programme to assist a country or group that has little or no astronomical activity, but which wishes to enhance its astronomy education significantly. Highly successful national training schools in several countries have been given under the auspices of this programme. Funding permitted, it is intended to enhance and intensify these activities.
- *Regional schools for postgraduate students.*
  The IAU International Schools for Young Astronomers (ISYA) has been a highly successful IAU activity for several years. It exposes PhD students from developing regions to the latest cutting-edge science and techniques. Since the inception of ISYA in 1969, 20 ISYAs have been organized in more than 20 countries and have provided education for almost 1000 students. Recent locations include Argentina, Morocco, Mexico, Malaysia and Thailand. Presently these schools are held annually, with partial funding from the Norwegian Academy of Science and Letter During the next decade the ambition of the IAU is to increase the number of such regional schools.
- *Long-term (sustainable) institute twinning.*
  Another new planned activity is a long-term program for "twinning" between developed astronomy institutes and institutes and university

departments where astronomy is less developed. The goal is to provide guidance in setting up astronomy courses and building up an astronomy research capability. The rationale for this program is that such an association can provide needed continuity and focus for sustainable astronomy development.

4.2.3. *Public outreach*

- *Semi-popular inspirational lectures in astronomy and related technologies.*
  An endowed lecturer program will be a major new initiative to promote interest in astronomy and science in developing countries. The goal of such a program is to facilitate excellent and inspiring semi-popular lectures, thereby enhancing worldwide public interest and understanding in astronomy and the Universe. The target audience will be secondary school students, university students and members of the public.
- *Planetaria and small telescopes – Japanese ODA Program.*
  In order to promote education and research in developing nations, the Government of Japan has been providing developing nations with high-grade astronomical equipment under the framework of the Official Development Assistance (ODA) cooperation program since 1984. Instruments donated included university-level reflecting telescopes, as well as modern planetaria used for educational purposes, together with various accessories. By the end of 2007 Japan will have provided 7 telescopes and 20 planetaria to 22 developing nations. In order to ensure effective use of these instruments, the Japanese Government provides follow-up technical training through the Japan International Cooperation Agency (JICA). In return, the recipient countries are expected to provide housing and infrastructure for the instruments. The IAU Strategic Plan envisages working closely with the ODA programme during the next decade to exploit planetaria for science outreach to public in developing countries.

4.3. ORGANISATION OF THE ACTIVITIES.

The Plan foresees a substantial expansion of programmes, and funding, together with a large increase in the number of volunteers. Building on the IYA model, the focus will be on a demand-driven coherent mix of sustainable activities. This will require a more suitable organisational structure that can be provided by the present purely volunteer approach of the IAU Commissions.

To (i) rationalize the activities, (ii) reflect the increasing emphasis on pre-tertiary education and (ii) enable the scale and scope of activities to

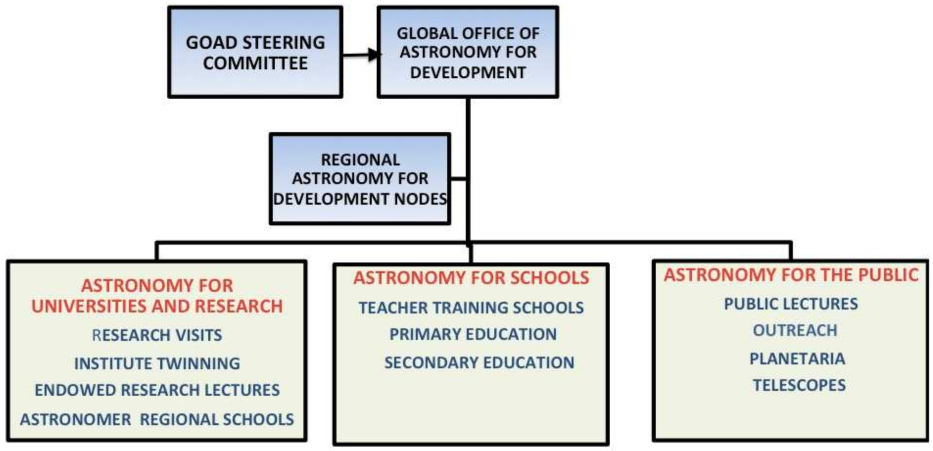


*Figure 5.* Organogram showing the activity task forces. The IAU Strategic Plan foresees that future astronomy for development activities will be coordinated in these three sector task forces.

be expanded, the Strategic Plan envisages (as shown in Fig. 5) that "three global task forces will be set up to coordinate and carry out activities in the various areas of astronomy development, (i) primary and secondary education, (ii) tertiary/university education and research and (iii) public outreach." According to the SP, the strategy for each of these task forces will be determined by agreement between the task force, the global development office and the regional coordinators, or the relevant institutes or authorities in the developing country. In accordance with the IYA model, the activities will be bottom-up and demand-driven by the regions, with large task forces providing the necessary global expertise.

## 5. Status of the IAU Strategic Plan

> *"Human history becomes more and more a race between education and catastrophe."* – H.G. Wells

### 5.1. THE GLOBAL OAD

The Strategic Plan covers a ten-year period and will be implemented gradually, in accordance with the available funding and (wo)man power. The first crucial step is to set up of a small Global Office of Astronomy for

*Figure 6.* The South African Astronomical Observatory, the institute that was selected to host the IAU Office of Astronomy for Development (OAD). This office will coordinate IAU capacity building activities globally and begun operations in March 2011. (Credit: South African Astronomical Observatory)

Development to coordinate the activities. IAU funds alone were insufficient to support such an office and a substantial amount of external funding was needed. In late 2009 the IAU instigated a call for proposals to host this office. Forty letters of intent were received followed by 20 full proposals. In May 2010, the IAU Executive Committee selected the South African Astronomical Observatory (Fig. 6) to host the GOAD. The successful proposal is co-funded by the South African Department of Science and Technology through the National Research Foundation. On 30 July 2010 the President of the South African National Research Foundation, Albert van Jaarsveld and the General Secretary of the IAU, Ian Corbett, signed an agreement to initiate the Global OAD. The Office will be overseen by a 6-member Steering Committee, with equal representation by IAU and NRF nominees.

After a competitive global recruiting process, Kevin Govender was appointed as first Director of the Global OAD from 1 March 2011. The IAU Global Office of Astronomy for Development was inaugurated by Naledi Pandor, the South African Minister for Science and Technology on 16 April 2011.

### 5.2. TRANSITION TO IMPLEMENTATION – THE FIRST YEAR

Now that the Global OAD has been set up, we are ready to begin the transition to implementing the Strategic Plan. Our goal will be to have the basis of the new organizational structure up and running by the Beijing General Assembly of the IAU in August 2012. The first year will be a learning experience and will be approached pragmatically. Among the initial tasks that will receive attention by the Global OAD are:

- *Increasing the number of volunteers.*
  Recruitment will occur both within the IAU and amongst interested postdocs and other non-IAU members (e.g. teachers) with relevant expertise, who could contribute usefully to the implementation of the Plan. Expatriates volunteers will be given special attention.
- *Securing external contributions to the SP.*
  There is considerable interest in the Plan globally and we shall investigate whether external organisations would be willing to contribute to implementing the plan in a useful way.
- *Setting up the activity task forces.*
  We expect to begin setting up the sector task forces during the first year. The structure and organization of these task forces will depend on the number of volunteers available.
- *Establishing regional nodes.*
  Following a workshop at the Global OAD, we envisage that an Announcement of Opportunities for regional nodes will be distributed.
- *Fund raising.*
  During 2011, the GOAD would investigate possible sources of funding and prepare for an active fund-raising campaign.

## 6. Final Remarks

> *"But there was another reason why astronomy was so prominent in ancient and medieval science. It was useful in a way that the physics and biology of the time were not."* – Steven Weinberg, Missions of Astronomy, New York Review of Books, October 22 2009

The IAU Strategic Plan for Development is an ambitious blueprint for using astronomy as a tool for capacity building. No scientific union has ever before attempted to implement an educational programme on such a scale. An obvious question that arises is why should the professional astronomical community become involved in such a venture? My answer is to cite reasons of morality and of expediency. Facilities needed to carry out frontier astronomical research become more expensive every year. The willingness of society to fund these magnificent machines sets an ultimate limit of what can be achieved. The decision of whether or not to construct a billion-dollar astronomical research facility is inevitably a political one. By devoting a tiny fraction of astronomical resources to global development and education, we enhance the image of astronomy as a whole and make politicians more receptive to research proposals. Mobilizing astronomy in the service of global development is a cost-effective strategy for researchers. By mobilizing large numbers of talented and creative scientists, engineers and teachers in the service of society globally, the IAU Plan will be a cost effective spinoff of one of the most profound adventures of our civilization the exploration of the Universe.

From the earliest times astronomy has had a profound effect on human development and has been of enormous benefit to society. The IAU Strategic Plan will continue this role of astronomy as a practical discipline in the present age. Hence our slogan for the IAU decadal plan is "Exploring our Universe for the Benefit of Humankind".

## Acknowledgements

It is a pleasure to thank everybody who provided input and feedback into developing the IAU Strategic Plan. John Hearnshaw provided the data on which Fig. 2 is based. I particularly thank Kevin Govender and others for their visionary blueprint for astronomy education in outreach in Africa, that was in many ways a model for the IAU Plan. Participants at the informal meeting in Paris in January 2008 that led to the development of the Plan include Catherine Cesarsky, Ian Corbett, Michèle Gerbaldi, Jean-Pierre De Greve, Roger Ferlet, Kevin Govender, Ed Guinan , John Hearnshaw, Karel van der Hucht, Larry Marschall, Carolina Ödman, Paul Roche, Rosa Ros, Kaz Sekiguchi, Magda Stavinschi and Bob Williams. I am also indebted to the large numbers of astronomers and others who devoted large amounts of time and effort to astronomy development activities that have laid the basis for the planned expansion. Catherine Cesarsky and Bob Williams as past-President and President of the IAU have given exceptional support to these activities.

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# TEACHING GRADUATE STUDENTS THE ART OF SCIENCE

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**Abstract.** Graduate students traditionally learn the trade of research by working under the supervision of an advisor, much as in the medieval practice of apprenticeship. In practice, however, this model generally falls short in teaching students the broad professional skills needed to be a well-rounded researcher. While a large majority of graduate students considers professional training to be of great relevance, most graduate programs focus exclusively on disciplinary training as opposed to skills such as written and oral communication, conflict resolution, leadership, performing literature searches, teamwork, ethics, and client-interaction. Over the past decade, we have developed and taught the graduate course *The Art of Science*, which addresses such topics; we summarize the topics covered in the course here. In order to coordinate development of professional training, the Center for Professional Education has been founded at the Colorado School of Mines. After giving an overview of the Center's program, we sketch the challenges and opportunities in offering professional education to graduate students. Offering professional education helps create better-prepared graduates. We owe it to our students to provide them with such preparation.

## 1. Introduction, the Need for Professional Training

Graduate school is aimed at preparing scientists and engineers to be the scientific professionals of the future. Those graduating, with either MSc or PhD degrees, pursue a career in a variety of areas of employment – in academia, industry, or government. Unsurprisingly, graduates with such advanced degrees ultimately attain high-level positions with their employers. Sometimes such positions are in the research field in which students have studied, but often the professional life sooner or later extends beyond the specialistic research in which the students are trained (Golde & Dore 2001). Even those pursuing a continuation of their research after graduation usually experience a change in their daily activities as they acquire progressively more responsibility such as in leadership of research groups. This suggests that graduate programs should prepare students to assume broad professional roles that go beyond those of the specialized individual researcher: universities aim to educate the professionals of the future and should educate students accordingly.

One might question the extent to which graduate students are, in practice, adequately prepared for carrying out their research while in graduate school. Where do students, for example, learn how to successfully choose a research topic, prepare a research plan, work effectively with an advisor, do a literature search and archive results, manage their time, and communicate effectively? One might hope that students learn such skills from their advisors and by being part of a research group, but how well are they in fact learning such skills in this way?

The mechanism for educating graduate students is essentially a medieval system wherein the pupil (the student) works with the master (the advisor) for several years. Once the master decides that the pupil has learned her new trade, the time has come to award the graduate degree. This is, of course, a caricature of graduate school, but it is one with a grain of truth. In practice, while students focus on research and disciplinary classes, some of them receive frequent and excellent coaching from advisors and team-members. Many graduate students, however, lack adequate mentoring in professional skills. This often leads to a loss of time in graduate school, needless frustration and discouragement, and an overly narrow preparation for a future career. As stated by Cassuto (2011):

> *"It amounts to this: Graduate school is professional school, but most PhD programs badly neglect graduate students' professional development. We spend years of their training ignoring that development, and then, only at the last moment when students are about to hit the job market, do we attend to their immediate professional needs."*

This view of graduate school might, in fact, be overly optimistic since it assumes that graduate students who are near the end of graduate training are actually taught professional skills. That might not even be the case.

The National Institutes of Health (NIH) carried out a study to determine the effectiveness of professional training given to graduate students and postdoctoral fellows supported by NIH (Mervis 2011, NIH 2011). The report identifies the need for adequate professional training. Berg (NIH 2011) writes in his role as director of the National Institute of General Medical Science:

> *"Ultimately, a healthy biomedical and behavioral research enterprise requires that government, academia, industry and other partners work together toward common goals that recognize the essentiality of high-quality mentoring and career guidance for the next generation of scientists. Our future, the future of discovery, and the utilization of such discovery for the benefit of humankind depend on it."*

This quote expresses that adequate mentoring and training of young researchers goes beyond the interest of individual researchers; the effectiveness of the whole research endeavor and its potential impact on society might depend on the degree to which young researchers are adequately prepared beyond the confines of their specific scientific field. Clearly there is a need to focus on the professional education of young researchers.

## 2. Are Graduate Students Being Adequately Trained?

Few systematic studies have been conducted that quantify to what extent the needs of graduate students for professional training are met. The American Institute of Physics carried out an "initial employment survey" among physics PhDs with first jobs in the private sector and who graduated in 2007 or 2008 (Ivie 2011). This survey showed that 98% of the graduates stated they work with their new employers on teams, 67% regularly speak in public, and 63% work with clients. This raises the question "Have these students been adequately trained in graduate school in the 'soft' areas such as team-work, oral communication, and client interaction?"

We asked a mix of MSc and PhD students in different stages of their graduate studies their views about the value of a range of professional skills including communication, conflict resolution, leadership, carrying out literature surveys, and teamwork. A large majority of the graduate students acknowledged the importance of broad professional training in general, e.g., written and oral communication, ethics, and leadership. Moreover, employers consider such skills to be essential to advancement of their young professionals and, by extension, to the success of their organization.

In our roles of advisor and dean of graduate studies, we discovered that the adaptation of students from different cultures to the work style in the

USA can take a considerable effort of the student and the advisor. Interestingly, NIH identifies the creation of a diverse workforce as one of five priority items; the NIH report (2011) states that *"diversity is an indispensable component of research training excellence, and it must be advanced across the entire research enterprise."* We currently are developing a 1-credit graduate course that helps students better understand cross-cultural issues that can arise in graduate school.

We also asked graduate students what they believe to be the most efficient method for delivering professional training. Surprisingly, students thought that interaction with advisors was the least effective way to provide such training. This is in striking contrast with the notion that the advisor is the person most important in helping their students grow to become young professionals. This suggests that those graduate students have not perceived the mentoring they experience to be of particular value to their professional growth. This does not mean, of course, that mentoring and advising is unimportant; rather, it reflects the fact that interactions with advisors currently often fall short of inspiring acquisition of general professional skills. Coaching academic faculty – training the trainers – might have fundamental value for increasing the effectiveness of academic advising and benefitting the professional growth of young researchers.

To advance their professional skills, students have the greatest preference for seminars or workshops, or to incorporate elements of professional training into regular courses. These two approaches are perceived to require their smallest investment of time, and therefore represent for them the most sensible options given the pressure they are under to finish a graduate degree in a limited amount of time. This preference for time-efficient options is, in practice, reinforced by some advisors who question the merit of broad stand-alone professional training. This attitude among academic advisors might be a result of their not having received formal professional education themselves.

Incorporating elements of professional education into disciplinary courses is not only time-efficient, it also has the merit of placing professional skills in the context of the discipline chosen by the student. One might question, however, how easy this option is to realize in practice because many disciplinary courses are already overloaded with content judged most pertinent to advancing students' research; moreover, teachers often have neither the interest nor the skills to broaden the scope of their disciplinary classes to include aspects of professional education.

In order to help students develop effective research habits and grow into professional researchers, one of us (RS) developed in 2002 the course *The Art of Science* at the Colorado School of Mines (CSM). In the next section we give an overview of topics covered in that course. Despite its relatively small size, CSM now offers six different graduate courses for professional training of graduate students. Furthermore, in order to coordinate these courses and to foster new initiatives for professional education of graduate students, CSM has founded a Center for Professional Education. We describe the scope of this center in more detail in Section 5.

## 3. The Art of Science

The course *The Art of Science* started at a modest scale, with about five students in the first year. Currently the class attracts about 60 students per year, which is about 25% of the graduate students that enter CSM each year. The class is taught to students from all departments. Several departments have made this graduate course mandatory for their students because they have found students to be more effective in their research after they have taken this class.

The growth in the enrollment in the course might be attributed to a combination of factors; one is that the class, which started out as a 3-credit course, was subsequently shortened to being a 1-credit one. This reduction in time-investment for the course was appreciated by students, and it also made advisors more receptive to their students 'sacrificing' some research time to take this class. This reinforces the conclusion of Section 3 that it is important that professional education for graduate students be offered in a manner that is time-efficient.

### 3.1. COURSE CONTENT

The curriculum of the class, including its homework exercises, can be accessed online[1]. The course currently covers the the following topics, that range from the philosophical to the rather nuts-and-bolts applied:

- What is science?
- Making choices
- The advisor and thesis committee
- Questions drive research
- Giving direction to your work
- Turning challenges into opportunities
- Ethics of research
- Using the scientific literature
- Communication
- Publishing a paper
- Time management
- Writing proposals

[1] `http://inside.mines.edu/~rsnieder/Art_of_Science_curriculum.pdf`

– The scientific career
– Applying for a job

Each of these topics is covered in much more detail in the textbook (Snieder & Larner 2009) (see Fig. 1) that grew out of this class; here we give just an overview of each of the topics in the course.

**What is science?**

Given the breadth and depth of the topic of the philosophy of science, one could readily teach a separate full course on the scientific method. For students who are almost always pressed for time, however, it is useful to restrict the class to material that has immediate and practical implications for their research. Science is based on logic; a statement that is inconsistent with logic might well be interesting or beautiful, but it cannot be considered part of science. Science nevertheless often makes its largest advances based on such non-logical, ill-defined abilities as creativity, inspiration, insight, and intuition, and the seemingly unscientific activity of play. And, then there's the fortuitous element – serendipidity. Successful scientists appreciate the great paradox that science is an activity that, while a description of nature dependent on logic, often moves forward through pathways that are not logical at all! Although students are generally aware of this paradox in at least a vague and unarticulated way, it helps students be more creative in their research when the existence of this paradox is highlighted. Introducing students to the intuitive part of science and its value gives them license to venture into tapping into their creative, perhaps illogical, talents (Schwartz 2008). It is the combination of the logic and the intuitive creative talents that makes science a true art, hence the course title *The Art of Science*.

**Making choices**

Students face many decisions in their choice of graduate program, advisor, research topic, and future career path. The need to make choices, of course, continues after graduate school as well; whenever confronted with having to select what is hoped will be a good decision, it is essential to be well informed. One part of being informed is to get the information from the right people. When choosing an advisor, for example, it is not only important to talk with potential advisors, it also pays off to talk with their students, especially former students, as well. Making the right choice of research topic has far-reaching implications for success in graduate school and satisfaction in later career and life. A suitable research topic must be innovative and doable, it must match the research facilities and the time that are available, and it should also offer the promise of instilling a passion in those doing the research. We teach students the concept of the "S-curve of development" wherein a research field goes from initiation stage through

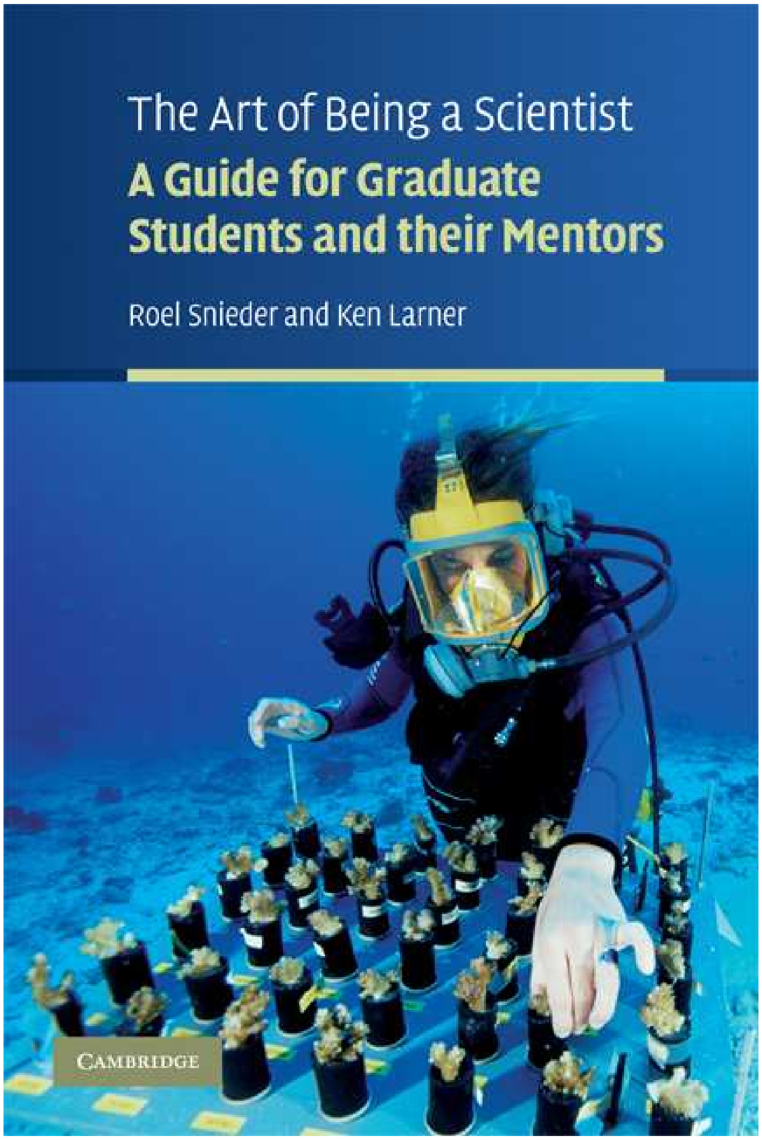


*Figure 1.* Cover of the book *The Art of Being a Scientist.*

exponential growth to maturation. Having (1) an awareness of differences in challenges and opportunities that these three stages present, (2) a recognition of the stage a particular line of research is currently in or might soon enough be in , and (3) an understanding of which stage of research best matches the student's technical, creative, and emotional strengths can assist in making the right choice of research topic.

### The advisor and thesis committee

The advisor is a central person in the career of a graduate student. Not only does the advisor need to sign off on specific stages of graduate study, of more consequence is the essential role that the advisor ideally plays in mentoring the graduate student towards scientific independence. The perfect advisor is a creative and respected researcher, a dedicated mentor (Vesilind 2001), she challenges the student but provides support when needed, has ample time, and has financial resources and infrastructure for the research. Clearly that perfect advisor is hard to find. The situation is, in fact, even more complicated. Different students need different types of advisors. The insecure over-achiever needs, for example, a different style of supervision than does an overconfident self-starter. As students change over time – and they should change as they grow through the graduate program – the style of advising that works best for them will also change. Given that the 'perfect advisor' is an illusion, a student's task is to try to make an optimal choice, one that likely involves some degree of compromise, rather than a perfect choice. In *The Art of Science*, we aim to help students by making them aware of the elements that could be part of the choice and by giving them ideas for going through the process of choosing an advisor. Students, moreover, need to learn how to make effective use of their advisor (Kearns & Gardiner 2011). Related to this is their use of the thesis committee. Many graduate students see this committee just as a machine to provide signatures, but with the right outlook (of both the student and the committee), the committee can play a valuable role as sounding board for crucial choices in a student's research and education.

### Questions drive research

An interesting exercise is to pose graduate students the following assignment. *Please complete the following sentence in not more than 20 words: "The main question I want to address in my research is ..."* It might be surprising to find that many students have difficulty in completing this sentence. That difficulty arises because they lack clarity on the very research question they aim to address. But how can one expect to find an answer if it is not clear what the question is? It is fundamental that students understand the significance of asking questions in research. Some of these questions are major overlying ones, some are more specific with a focus on a particular practical problem. The 'right' questions are ones that almost automatically lead to actions in research. The best start at asking the 'right' question comes from asking lots of them – both 'good' ones and 'stupid' ones, simple ones and bold ones. It can take courage and imagination to ask bold questions. The question "What would be the consequences if the speed of light were the same for all observers?" posed by Einstein is at first sight nonsensical, yet it changed our world-view because it led to the theory of special relativity. In the course, we offer students ideas for generating research questions, ideas that range from writing them down as they arise during the day (or night), to talking with others (students don't often enough recognize one another as a resource), and to free association. The questions thus generated form a natural basis for making a work-plan for the research project.

**Giving direction to your work**

A quote from Lewis Carroll states that *"If you don't know where you are going, any road will take you there."* The purpose of setting *goals* is to clearly define where you are heading and what you want to achieve. Without articulating goals, random events or other people are likely to define the way in which our life and career unfold. Students should learn that if they don't define where they are headed, somebody or something else will (indeed, also should researchers and people in general). But setting goals is not all; one also needs to be aware of *process*. What is the value of reaching a goal in graduate studies when the process of getting there is not attractive? Clearly the process of doing research must have its rewards as well. This offers a second perspective on giving direction to our work: being process-oriented. Ultimately a third perspective can come to the fore: what is the *meaning* of our work? What does our work mean to us, to the scientific community, to other people, and to the world? Whose life is touched or improved by my work? The key in setting direction is to reconcile goals, process, and meaning. This is not easy, and many of us never get to that point, but being aware of these complementary aspects of our work is an indispensable first step.

**Turning challenges into opportunities**

Research is challenging. One challenge that is bound to arise – often – is being stuck. There are, roughly speaking, two reasons for being stuck. The first is having insufficient clarity on the research question that one aims to address or on the path that one intends to take to address those questions. This problem can be paralyzing and needs to be fixed as soon as possible using the techniques described in the section on posing questions. The second reason for being stuck is that something is 'wrong' in the sense that one's understanding is incomplete. While frustrating, this source can actually be highly positive because it can be a precursor to gaining new insights (Kuhn 1962). Not a small aspect of his approach to research, Lord Kelvin emphasized *"When you are face-to-face with a difficulty, you are up against a discovery."* Students need to learn what activities help them in getting unstuck. For some of us, for example, running is an activity that is conducive for getting new insights when these are needed. By developing an awareness of activities that are helpful in getting unstuck, students can become more effective in getting out of seeming impasses they invariably will encounter. In the course, we also discuss the role that play and serendipity have in opening new avenues of thought and for research.

**Ethics of research**

The ethics of research is often seen in the restricted sense of "responsible conduct in research." That view of research ethics focuses on issues such as honesty, avoiding plagiarism, and appropriate sharing of authorship – important issues that students need be aware of. In practice one often cannot repeat and verify experiments done by others nor can one easily chase down all possible antecedents to reported research. Students therefore must recognize the extent to which the advancement of science is founded on trust. Moreover, students need to be made aware that honesty and preservation of one's reputation is especially challenged when economic interest lies at the heart of a scientific or engineering endeavor. Yet there is more to research ethics than the need for honesty. It is through dissent that science moves forward beyond current understanding; science cannot advance when everyone is in agreement and is satisfied with current viewpoints. In his wonderful book "Science and Human Values," Bronowski (1956) emphasizes that science is underpinned by honesty and advanced by dissent. Yet, as illustrated in the parody of Oxman et al. (2004), not every scientist has developed the skills to disagree respectfully and express dissent in a constructive way.

Apart from these issues of how research is carried out, it is essential to the growth of a student into a mature and contributing researcher to gain the insight that research is not value-free. In this highly technological age, science has the potential to affect society and the lives of others either negatively or positively; often a given scientific advance can have both positive and negative ramifications. A heightened awareness of such potential consequences can be a valuable guide toward choices in research whose impact on society and its environment is positive.

**Using the scientific literature**

Research projects should begin with a solid literature search. Students sometimes skip or minimize this step and, as a result, either duplicate work of others or make their work unnecessarily difficult by failing to take advantage of the insights of others. Over the years, the scientific literature has grown so much that it is difficult to keep pace with. Students need to learn how to use the powerful electronic tools available for searching the literature effectively. Furthermore, it is important to develop a modern data base of references: such a database makes it possible to retrieve papers easily and to generate a bibliography at the end of papers or a thesis with the touch of a few buttons. In the course, we make our students aware of free database programs such as Zotero[2], Mendeley[3], and Jabref[4]. As a homework exercise, students must choose a system for managing bibliographic information and show that they have started using the program of their choice. We have found that without the reinforcement of such an exercise, although the class tends to be interesting to students, it might not lead to helpful behavioral change. Nevertheless, not all approaches for keeping up with the literature ought to rely solely on electronic tools and information technology. A journal club, for example, with stimulating discussions on research among colleagues, can be a great aid to maintaining awareness of current research.

**Communication**

Career advancement for a scientist, whether working in academia, industry, or government, can be governed largely by the young researcher's ability to communicate, both orally and in writing. We emphasize that, *effective* communication is difficult. For both oral and written communication of research, perhaps the most difficult skill to learn is to place oneself in the shoes of the reader or listerner. This skill is essential for setting the level and tone of the communication needed to reach the audience and peak its interest. In oral presentations, one must be aware of the short attention span of most audiences (Medina 2008), indeed the relatively short time available to convey research and results that could well have taken a year or more for the presenter to have generated and understood. Young researchers need to resist the temptation of over-feeding the audience with material that, despite the availability of modern projection resources, is poorly readable (Benka 2008, Payne & Larner 2008). An effective way we've found for teaching students the do's and don'ts of oral presentation is to show them a spoof presentation in which the teacher does everything wrong, and to discuss what is amiss in this presentation afterwards. Because few of us can give an outstanding presentation while improvising, students need to expect that preparing for an effective oral presentation is hard work that requires extensive rehearsals, the audiences for the rehearsals consisting of both colleagues who familiar with the work and those who are not. Moreover, the friendliest of rehearsal audiences has members who care enough about the success of the final product to offer in-depth critiques of both the content and details of presentation style. Similarly, any well-written manuscript usually has gone through many revisions that often rely on the input from caring colleagues who act as severe proofreaders, in essence the

[2] `http://www.zotero.org/`
[3] `http://www.mendeley.com/`
[4] `http://jabref.sourceforge.net/`

first line of reviewers. Also, before embarking on the writing, both students and advisors can save much time by decoupling the content of a paper from its style. This can be done effectively by first developing an outline that is so detailed that the content and flow of the paper are virtually predetermined. Once this is done, the 'only' thing that needs to be done is to formulate this content into words[5]. Our next advice is to 'blast away' in putting words on paper, with little concern for either the audience or word choice. Then comes the essential next step: revise, revise, revise – progressively choosing wording and writing style aimed at increasing clarity for author's intended reader.

**Publishing a paper**

Obvious as it is that publishing of a paper starts with the choice of a journal, junior graduate students are often unaware of the differences in scope and quality of journals. We discuss the impact, so to speak, of the *impact factor* as well as other considerations to take into account when choosing a journal. Examples include the readership of the journal, the speed of publication, the cost of publication, and the journal's reputation. As mentioned in the previous section on communication, when planning a paper for publication it is essential to know the audience for whom a paper has been written. Students should understand the mechanics of the review process and be aware of opportunities to steer that process, for example by suggesting names of reviewers and associate editor who might be best suited to handle the manuscript, people who are especially knowledgeable about the subject of the paper and who can be counted on to treat the work fairly. Also, knowing how best to respond to reviews, particularly those that might seem at first unduly critical, can be an art in itself. Students need to learn to take the comments of reviewers seriously, without being carried away by indignation when a review at first sight feels unduly critical. The comments of reviewers more often than not are a great help in improving a manuscript; they can point out segments of a paper that are in need of further clarification not only for them but for the intended readership. Students, however, also need to know that they, as authors, are allowed to deviate from the suggestions of reviewers if they can convey their reasons for disagreement. Always, the author should respond to specific concerns raised by reviewers in a cover letter to the editor, stating point-by-point how they have addressed the concerns, including those about which the author was not in agreement with the reviewer and therefore were not incorporated in the revised version of a manuscript.

[5]Most students have learned this in high school, but seem to have forgotten this by the time they are in graduate school. Many advisors have forgotten this as well, with the result that they unnecessarily grind their way through repeated lengthy drafts to

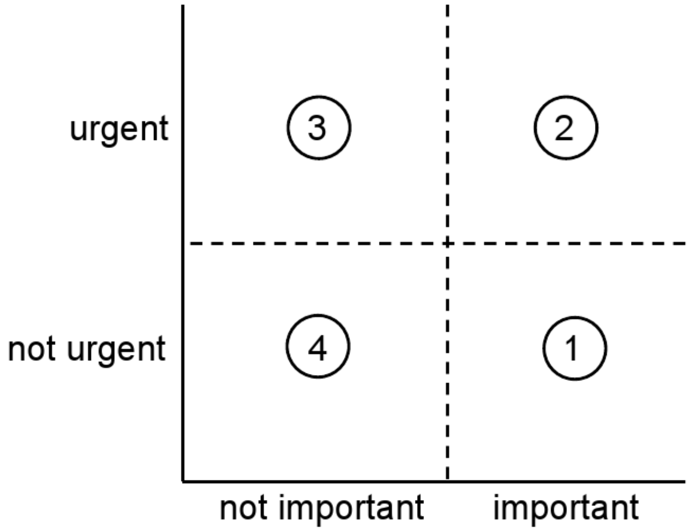


*Figure 2.* A categorization of activities. (adapted from Covey 1990)

**Time management**

Many of us feel as though there is not enough time for all that we have to do. This is, however, an illusion because, for everyone, a day always has 24 hours, and a week seven days. Nothing will change these basic facts. The feeling of not having enough time results from our trying to do too many things in a given amount of time. The word 'time-management' therefore is a misnomer; the difficulty actually boils down to one of 'activity-management'. This is not just a semantic distinction; students need to learn that is essential to make choices about which activities to spend their time on, and which not. It is illuminating for students to consider the diagram in Fig. 2, adapted from the book of Covey (1990). Roughly speaking, all of our activities are either important or unimportant, and they are either urgent not urgent. This is, of course, an oversimplification because both importance and urgency vary on a sliding scale, but for the moment we make this simple distinction. Given the criteria of urgency and importance, each of our activities fits into one of the four quadrants of Fig. 2. Many of us make the mistake of confusing urgency with importance with the result that the important activities tend to fall by the wayside to urgent, but actually less important, ones. As a homework exercise, students monitor their activities for a week and insert into the diagram of Fig. 2 each activity, with the time spent on it. Students also insert into the diagram activities that

discover that they disagree with the main structure and content of the manuscript.

they would have liked to do, but did not find time for. After that, they analyze the way in which they have spent their time, and make a plan for improvement, if needed. We discuss in class that saying "no" is essential in activity management, and discuss why this often is so difficult. Learning how to gracefully say "no" is an important skill, and we give suggestions for ways in which to offer alternatives to requests, or directives, from superiors. (When we say "yes" to a request, we are often saying "no" to something else that we might otherwise do.) We also point out that, useful as they often are, electronic tools such as cellphones, email, and the internet, they can also be a severe distraction. We caution students to be the master of these tools, rather than their slave.

**Writing proposals**

Regardless of whether a scientists or engineer works in academia, industry, or government, writing proposals is an integral part of her job because one must, in general, explain why time and resources need to be expended on research. Every proposal starts with the choice of to whom the proposal is to be submitted, and one needs to be informed in order to make this choice wisely. When writing a proposal it is essential to stick to the guidelines given by the funding agency. Such guidelines include tangible issues such as the length of the proposal, as well as less tangible ones such as the specific points that must be addressed in the proposal. One should also be aware of the way in which proposals are handled. Many junior researchers do not realize that members of a review panel often are faced with having to read more than 1,000 pages of proposals. These panel members obviously don't have the time to do this; hence a proposal, starting with the abstract, must make a favorable first impression. As scientists we often feel the urge to be complete in our proposals, and explain all facts and details that we feel are important to us. This, however, is not what reviewers, panel members, and program managers are looking for. They seek a concise description of the state of research in a field, the research question that one aims to address in order to advance the research field, the research methodology used, the competency and facilities of the research team, and the proposed time-line and deliverables.

**The scientific career**

In order to make the right choices for one's career (choices again), the key, as before, is to be informed. We discuss the structure of the academic career and its opportunities and hurdles, such as the tenure process. Students should know that the nature of the tenure process varies significantly among universities and that the degree of fairness of the tenure process varies much as well. A useful and practical guide for best practices in tenure evaluation is available online[6]. The choice of employment in academia versus industry or government is a major one for graduates. Because their training takes place at universities, many students in science have apparent familiarity with the university work environment, but limited understanding of what it means to work in industry or government. In the class we aim to give them insight into differences and similarities that might be expected. As a homework exercise, students interview four researchers, preferably from different types of employers, with the goal of gaining greater insight into the choices available to them. We also discuss gender issues. Despite many efforts, there still exists a gender disparity in engineering and in the higher ranks of scientists. We point out several mechanisms that have brought about gender bias. (Did you find the use of the word "she" instead of "he" in this chapter strange, or even disturbing?) Balancing professional and personal life is a challenge in the scientific career; we find that students are keen to discuss this topic. For female students the topic of combining motherhood and family responsibilities with a successful career is of particular interest.

**Applying for a job**

The application for a job begins with identifying several potential employment opportunities. As with all choices, one first must gather facts. For this, students should rely not only on recruiters and human resource managers, but also hear the opinion of employees and former employees. An appropriate and well-constructed letter and curriculum vitae are essential, and job seekers need to keep in mind that the relevant information must be made easily accessible for overloaded search-committee members and managers. During an interview, the person seeking employment should be pro-active. This can make the interview more useful as a fact-finding tool; moreover, a pro-active attitude usually is viewed favorably by people conducting interviews. Also, because promotions and significant salary increases are infrequent events once an individual is employed, it is important to negotiate before accepting a job offer. Although the class includes no time to cover negotiation in depth, we do point out the different styles of negotiation: win-win, win-lose, and (hopefully never) lose-lose. The job application process should aim for making an optimal match between employer and employee, which obviously calls for seeking a win-win strategy. Some industrial employers are unduly restrictive in the rights granted to their employees, for example by insisting on long-term non-compete agreements after employees leave the organization to work elsewhere. In order to avoid unpleasant surprises when starting at a new job, the job appli-

[6] `http://www.acenet.edu/bookstore/pdf/tenure-evaluation.pdf`

cant should be clear about all conditions of appointment *before* accepting a position (Larner 2002).

### 3.2. TEACHING *THE ART OF SCIENCE*

Since 2002, we have offered *The Art of Science* as a graduate course at CSM, and have also given this class as a short-course at numerous universities that include Stanford University, Tohoku University (Sendai, Japan), Delft University of Technology (Delft, Netherlands), Australian National University (Canberra, Australia), and King Abdullah University of Science and Technology (Jeddah, Saudi Arabia, Fig. 3). We have also presented *The Art of Science* as a short-course for the research laboratories of ExxonMobil, Saudi-Aramco, and Shell.

The class has consistently received positive reviews from students. One student commented that

> "The Art of Science *was an eye opener for me. It made me think of my career and my life differently. It gave me energy and ideas to restart and continue when I am stuck."*

When teaching physics courses, we never had a student say that our course changed their view of career and life! Having a far-reaching impact on students is an important aspect of offering a class such as *The Art of Science*. An anonymous student at an international university wrote in an evaluation that

> *"I am glad I found this course early in my academic career. If only my university had required faculty members to come to your class! Thank you for putting all the things together which otherwise probably would have taken me years and many unfortunate incidents to figure out."*

This comment expresses that taking a class such as *The Art of Science* can save graduate students much time. This feedback recurs often in evaluations. Students often express regret that they had not taken the class earlier because that might have saved them time by being more efficient and by avoiding time-consuming mistakes. Taking a 1-credit class in the practice of science does take some time out off a busy schedule, but the increased efficiency and effectiveness in doing research, and in communicating that research, can readily make up for the time investment. The student comment above also indicates the wish that faculty members would attend course. This points to a need for training faculty to teach the skills needed for being an effective scientist. Although most faculty members are dedicated to advance research together with their students, much could be gained by training academic faculty in mentoring.

In numerous lectures about teaching *The Art of Science*, we typically have received a response from faculty along the lines "it would be great


*Figure 3.* Discussion during a break in the short-course *The Art of Science* at King Abdullah University of Science and Technology (KAUST). (Courtesy Marie-Laure Boulot, KAUST Winter Enrichment Program)

to offer a course like this in our department." The reality, though, is that developing and offering such a class takes time of faculty who are already struggling with their workload. We aim to reduce the time needed to start teaching a course such as the *Art of Science* by making our curriculum and homework exercises available, as examples, in the book (Snieder & Larner 2009) and through the internet[7] . Following are several options for offering this type of graduate education.

- The most straightforward scenario is to offer the class as either a departmental or interdepartmental course. This option requires a dedicated faculty member who is able and willing to champion such a course. For this scenario to work, the department or institution must recognize the value of such an educational initiative.
- One can broaden disciplinary courses to include elements of professional training. We have found that this option actually is most preferred by students who have not taken the 1-credit course. It does, however, require dedication of teachers to make time available to include professional training in their disciplinary courses; not every teacher has the skills or the time available in her course to offer such traininig.

[7] `http://inside.mines.edu/~rsnieder/Art_of_Science_curriculum.pdf`

– It is possible to share the teaching load by offering the class in the form of a reading group or seminar that is led, in turn, by different faculty members. This reduces the workload for individual faculty members and it might help create a greater involvement from faculty members. This scenario also makes it possible to draw upon the strengths of different faculty members.

Offering such training in any of these forms requires time of students and teachers. We do believe, however, that because of the improved the efficiency that students gain, it helps them ultimately to save time. Perhaps more important, it helps students to become more creative and more efficient researchers.

## 4. The Center for Professional Education

Currently the graduate program of the Colorado School of Mines includes the following courses for professional development:

1. The Art of Science
2. Introduction to Research Ethics
3. College Teaching
4. Advanced Science Communication
5. Academic Publishing
6. Professional Oral Communication

Given the small size of the school, the breadth of this course-offering speaks to the dedication of the school to professional training of graduate students. The class "Introduction to Research Ethics" was developed in response to the requirement of the National Science Foundation (NSF) that undergraduate students, graduate students, and postdoctoral fellows, receive training in research ethics.

In order to coordinate and facilitate professional education we have founded the Center for Professional Education[8] at CSM. Initially, the Center serves primarily graduate students, but over time might extend its activities to undergraduate education as well. The Center coordinates educational activities that include courses for broad professional development of students, seminars and workshops for students and faculty, and a speaker series. The Center brings together faculty dedicated to educating graduate students who are well prepared for the workforce, and acts as a nucleus for writing proposals to support initiatives for professional education, including new methods of delivery. Activities of the Center are directed not only toward helping graduate students, but also toward providing assistance and

[8] `http://cpe.mines.edu/`

support to faculty so they might improve their advising skills. The Center can serve a number of purposes.

*1. Develop more rounded graduates.* Graduates compete with highly qualified graduates from other institutions for positions in academia, industry, and government. As such, graduates strive to find ways to distinguish themselves from the competition. While technical competence remains the most valued aspect of graduates, students can distinguish themselves through development of professional skills.

*2. Advertise educational activities.* The presence of the Center makes it possible to advertise our activities for professional education. This helps, for example, in recruiting top-level graduate students and in soliciting external support through foundations for graduate education and research contracts. Advertising the possibility of gaining professional skills could be particularly helpful in attracting top-level international students.

*3. Support new proposals.* Pressure has been increasing for generating proposals to the NSF, NIH, and other funding agencies that require broader education for graduate students. The presence of an active Center with a broad offering of courses strengthens proposals that must include elements of professional education.

*4. Conduct research on education in professional development.* The Center will engage in education research in professional development by initiating and coordinating such a research effort, and by helping to solicit funding for such research activities.

*5. Ease the task of advising students.* Much of the time spent advising students tends to be devoted to disciplinary discussions that are at the core of the research experience. Training graduate students in professional development helps them be more effective in their research, in interacting with their advisor, in improving their interaction with their advisor, and in developing essential oral and written communication skills. Such training makes the task of advising easier, and hence reduces the workload of advisors.

*6. Initiate new activities and bring the relevant faculty together.* The Center is a nucleus to bring together faculty with a passion for professional development and to coordinate their efforts toward the creation of new initiatives and improvements of existing efforts. The current course offering does not cover all areas in professional development that are relevant for graduate students. By organizing seminars, and workshops, and by initiating the development of new courses, the Center serves to expand the scope of professional education.

## 5. Conclusion, Challenges and Advantages of Professional Graduate Training

In offering professional education to graduate students, we have encountered a number of challenges. First, teaching aimed at encouraging change in the behavior of students to make them more effective scientists, does not necessarily lead to such behavioral change. Most teachers know the phenomenon that students who have learned certain material in class are unable to use that material a semester later. This also holds for professional training. In order for material to stick with students, it must be repeated and reinforced regularly. For professional training it takes the dedication of the academic advisor, or refreshing the experience in other courses, to provide such reinforcement. Second, it takes an effort to get graduate students and their advisors to buy into professional education because the time needed for such education at the outset appears to them to decrease the time available for research. Our impression is that professional education makes students more efficient in their studies and research, even taking into account the time needed for the professional training. In the absence of hard data to substantiate this claim, however, it can be difficult to convince others of the value in devoting time for such professional training. This is aggravated by the fact that not all scientists appreciate the relevance of teaching and learning topics beyond disciplinary skills in their narrowest sense. Third, it does take resources, in particular time, to offer a broad professional education. Realistically, the required time and other resources are made available only when the institution acknowledges the importance of professional education.

Professional graduate training offers a number of advantages for students. First, being better prepared for scientific work can help minimize unnecessary frustration and loss of time both in graduate school and beyond. Second, it can help increase both the quality and quantity of the scientific work done in graduate school. Third, students learn skills to become better collaborators and to work more effectively with advisors. Fourth, such training should help students communicate their research more effectively. Fifth, broad professional training helps students be better prepared for the job market, and, sixth, it helps students to be better scientists.

Advantages also accrue to academic departments and their faculty members who offer professional training. Such training helps students to be more effective in their work, thus reducing the workload of advisors. For example, we discovered in our research group (the Center for Wave Phenomena[9]) that offering students a class on academic publishing in combination with tutoring to improve their writing skills saved a large amount of time for ad-

[9] `http://cwp.mines.edu/`

visors assisting students to write their thesis and publications. Moreover, offering an attractive program of professional education can help attract better students. As is generally appreciated, the quality of students is essential for the well-being of an academic research group; raising the level of incoming students elevates the scientific creativity and productivity of the whole group. Last the requirement of funding agencies to offer professional training is growing rapidly. The recent report of NIH (2011) points in this direction. Both NIH and NSF now require training in research ethics. The 'broader impact' criterion of the National Science Foundation is becoming increasingly important, and large programs such as the Integrative Graduate Education and Research Traineeship (IGERT) of NSF require professional education. Having an institutional program for professional education in place not only helps to offer such training, it obviates the need for individual faculty members to develop such training, and it increases the chances of success in funding of proposals.

More than any other reasons for offering professional education to graduate students, we owe it to our students to give them the best preparation possible to be the professionals of the future. Graduate students ought not be viewed as cheap labor to help us in our research; rather, the primary purpose of a graduate program is to educate young researchers who carry the torch of science forward and assure the continuity of the scientific endeavor in the best possible way. We should prepare them for this work as well as we can.

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# THE "SCIENTIFIC WRITING FOR YOUNG ASTRONOMERS" (SWYA) PROJECT

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**Abstract.** This paper describes the origins of the *Scientific Writing for Young Astronomers* (SWYA) project, and presents a short overview of the contents of the SWYA Schools organised in 2008 and 2009. The scope and the future of the SWYA teachings is documented.

## 1. Introduction: The SWYA project

Courses in scientific writing abound at many universities, and are sometimes included in the curriculum of a doctoral training program. These courses are mostly of a generic character (*i.e.*, they are offered in a faculty-based context), yet very few discipline-specific scientific writing courses are being put up. Some detailed tutoring in written and in oral scientific communication for astronomy students was presented by Kurtz (2006) and by Sterken (2006) as an experiment in the framework of a workshop for PhD students that was organised in 2005 in Pécs (Hungary), see Sterken & Aerts (2006).

In 2007 the Board of Directors of *Astronomy & Astrophysics* (A&A) and *EDP Sciences*, the Publisher of A&A, decided to organise an entire School on the various aspects of scientific writing and publishing in astronomy, *viz.*, a three-day teaching event on key aspects of scientific writing. A first *Scientific Writing for Young Astronomers* (SWYA) School was thus organized in 2008, and a second one in 2009. The Schools were financed by A&A and by *EDP Sciences*, who also provided all logistic support.

## 2. The purpose of the SWYA School

The purpose of the SWYA project was twofold:

1. to teach young PhD students how to express their scientific thoughts and results through adequate and efficient written communication, and
2. to discuss the operation of A&A as an example of an international peer-reviewed journal in astronomy.

Questions, such as

- what makes one author a good communicator and another a poor one,
- how to communicate scientific results through adequate scientific writing,
- how does the editorial process of a journal function, and why need scientific papers be refereed

(and many more) were dealt with in depth.

## 3. The SWYA School venue, format and audience

The schools took place in Hotel and Conference Center *Aazaert* in the city of Blankenberge, on the North Sea coast of Belgium. That (scientifically) uneventful location was selected on the basis of its very attractive out-of-season accommodation prices, its excellent conference facilities, and because the entire hotel facility was reserved solely for SWYA participants.

Shortly after releasing the first announcement in 2007, we saw that the overwhelming response would soon lead to an oversubscription factor of more than 100%, so attendance was consequently restricted to beginning PhD students, with a maximum of two participants from a same institute. At the same time, we strove for a 50/50 gender balance of the student population. Finally, about 65 students were accepted for the first event (2008), and a similar number participated in the second School one year later.

Both Schools were directed by C. Sterken, and involved more than half a dozen additional lecturers, among which some A&A Editors (Claude Bertout, Thierry Forveille and Steve Shore), A&A Language Editors (Joli Adams and Martine Usdin) and external lecturers (Uta Grothkopf from the *European Southern Observatory*, Laurent Cambrésy from the *Centre de Données astronomiques de Strasbourg*, and Jean-Marc Quilbé from *EDP Sciences*). The format of both events was chosen to be a combination of the open and traditional classroom type, with teachers stimulating student interest by their own lecturing performance. In addition, the SWYA 2009 School included hands-on sessions, during which groups of students received interactive tutoring from the A&A language editors.

## 4. The SWYA Proceedings

Most lectures were published in full in the SWYA Proceedings (Sterken 2011a, 2011b) as Volumes 49 and 50 in the *EAS Publications Series*.[1] The organization of these Proceedings, though not a faithful record of the lectures, closely reflects the structure of the Schools. The books contain papers about the editorial office and the Editors, the Publisher, the business models in journal publishing, the journal A&A, the refereeing process, bibliometric databases, and library services. They also comprise papers about how to write a good scientific paper, what are the norms of ethical behaviour in science (including the dangers and pitfalls of plagiarism), and technical tutoring on communicating scientific results through graphics. One aspect of this collection of papers is the apparent redundancy or overlap between the chapters: such redundancy is unavoidable, since each lecturer's approach is from a different viewpoint: editor, referee, author, and publisher.

Part 1 (EAS 49)

This Volume contains a set of seven lectures that deal with diverse aspects related to scientific writing, *viz.*,

- the history and operations of the journal Astronomy & Astrophysics,
- the A&A Editors' views of the publishing process,
- the role of the Publisher,
- two chapters on language editing,
- one chapter on library services in astronomy, and
- one paper explaining the use of databases – in particular *VizieR* and *SIMBAD* – in the context of preparing scientific papers.

The first three papers of this Volume are presented by Editors – past and present – of A&A. The first paper starts with a brief historical introduction, followed by a review of the scope, editorial process, and production organization of A&A, including the economic model of the Journal, and some current issues in scientific publishing. This paper is immediately followed by a paper on the history of A&A, by one of the first Editors-in-Chief of the Journal. Then follows a chapter that explains the functioning of scientific journals from the editorial side of the process, with emphasis on the interaction between the three parties: the author(s), the Editors, and the referees. The chapter explains how this proceeds, and discusses editorial criteria – scientific, archival, and ethical – and how these have evolved historically and consensually.

Then follows a paper on the role of the Publisher, describing the various facets of the publishing activity, including the daily work of a dedicated

[1] `http://www.eas-journal.org/`

team of professionals that guarantees the timely production of this weekly astronomy journal.

Two articles deal with language editing: the first reviews the general advantages of editing the English expression, and describes both the aims of this effort and its place in the full publication process. That paper is followed by a detailed *Guide* to language editing that serves as a reference for any non-native user of the English language.[2]

The remainder of the Volume is dedicated to technical support in the broadest sense, *viz.*, to astronomy libraries as providers of information, and to databases at the *Centre de Données astronomiques de Strasbourg* (CDS). Special attention is given to the two most important information tools in astronomy: the *NASA Astrophysics Data System* (ADS) and the `arXiv` e-print server, in addition to an introduction to bibliometric studies. The last paper presents the succession of processes leading published data to the CDS databases, and focusses on the strategy that ensures a high level of quality.

Part 2 (EAS 50)

Whereas Part 1 carries guidelines and examples for publishing in academic journals, the three papers in the second Volume are aimed at supplying guidelines to PhD students and postdoctoral fellows to help them compose scientific papers for different forums (journals, proceedings, thesis manuscripts, etc.). These papers cover the information that was presented in about 9 to 10 lectures in both SWYA Schools, and include several examples and case studies in astronomical context, in addition to many examples from scientific enquiry in a much broader sense.

The first paper copes with the preparation of manuscripts, with the handling of copyrights and permissions to reproduce, with communicating with editors and referees, and with avoiding common errors. More than two dozen FAQs (on authorship, on refereeing, on revising multi-authored papers, etc.) are answered.

The second paper is entirely dedicated to communication with graphics, *i.e.*, to all facets of visual communication by way of images, graphs, diagrams and tabular material. Design types of graphs are explicated, as well as the major components of graphical images. The basic features of computer graphics are explained, and also concepts of color models and of color spaces (with emphasis on color graphics for viewers suffering from color-vision deficiencies). Special attention is given to the verity of graphical content, and to misrepresentations and errors in graphics and in associated basic statistics. Dangers of dot joining and curve fitting are discussed, with

[2]The full guide is available at
`http://www.aanda.org/images/stories/doc/english-guide.pdf`

*Figure 1.* Students and lecturers of the first SWYA School (2008), in front of St Rochus church in Blankenberge (Belgium). Photo courtesy Taavi Tuvikene.

emphasis on the perception of linearity, the issue of nonsense correlations, and the handling of outliers. The remainder of the chapter illustrates the distinction between data, fits and models.

The main theme of the third paper is truthful communication of scientific results, and hinges on the pillar that every scientist daily comes across: **ethics** – involving two major aspects of research, *viz.*, the measurement of scientific value, and the enforcement of proper conduct in research and in scientific writing. Scientific misconduct in the broadest sense is discussed by category: researcher misconduct, author misconduct, referee and grant-reviewer misconduct. But also publisher misconduct, editorial misconduct and mismanagement, and research supervisor misbehavior are dealt with. The overall signatures of scientific misconduct are focussed on, as well as the causes and the cures. This is followed by a Section devoted to whistle-blowing.

## 5. The scope and the future of the SWYA teachings

It is not evident to assess whether SWYA has reached its goals, but several students provided useful feedback that will be helpful for improving our performance when the time comes. The following points were taken from the feedback from a poll that was organised by EDP at the end of SWYA 2009:

- we received a "beyond curtain" look on publishing, from a different position than from the author's viewpoint;
- to learn how a paper is refereed explains the time needed to publish a paper;
- we learned a lot about the editorial process of A&A and other main journals;
- we learned how to structure a scientific paper;
- the sessions on databases and library services were excellent, and very useful;
- the session on language editing was very useful for non-native English speakers;
- the session on bibliometrics was very valuable;
- the information about graphics was very practical;
- several lectures enabled us to immediately use the knowledge acquired;
- the school was informative, beneficial, friendly, and pleasant in many points, and
- the school was a place for exchange and learning, and should carry on.

So it seems that many students found the initiative informative, useful, encouraging, and adviceful. The answers confirm what was evident to every lecturer: our youngest students seem not to know the difference between the Editor and the Publisher, they are ill-informed about the role of the referee, they have no clue about the work done by many invisible people in the process of verifying their work and in bringing their manuscripts to print, and many even think that we can do without Editors and Publishers altogether. The answers make it clear that SWYA was very helpful in remediating this lack of knowledge.

Some students also indicated that they found these 2.5-day schools too short, others desired more practical instruction on typesetting with LaTeX, or a more intensive teaching of the English language. Obviously, these calls for more intensified training can only be met in dedicated language classes and via technical training courses, which fall beyond the scope for which SWYA was originally set up.

Several students also expressed that SWYA taught them some unanticipated elements of scientific education, what led some of them to share their hopes and concerns with the lecturers (either during the sessions, or via private contacts later on).

Another very strong feedback signal consisted of the numerous expressions of appreciation for the very open and positive social atmosphere that prevailed throughout the duration of each school. Because of the fact that we basically had the hotel all to ourselves, this environment led to many discussions among participants (and lecturers), and intense exchanges of writing and research experience before and after the lessons, as well as over dinner, or during an evening stroll on shore. Such freewheeling exchanges of ideas was most beneficial to the students, and to the lecturers. It thus seems that we made the right choice in bringing together very young PhD students in a non-competitive ambiance so different from the workshop and conference atmosphere that some of them already had experienced.

Whether there will be future SWYA Schools depends, above all, on the availability of sponsoring capacity: whether or not this kind of schooling will continue in this format, entirely depends on the initiative of the main sponsor *EDP Sciences*. Nevertheless, the petition to go on with the SWYA project was very heartwarming.

Although the SWYA project was conceived for young astronomers, the School reaches much further than just the young astronomy student, as many general issues related to technical, scientific, and social aspects of scientific writing were addressed. The Proceedings, in particular, are meant for a much wider audience that includes graduate and seasoned students, as well as postdoctoral fellows and thesis supervisors in about any discipline of the exact sciences. The elaborate discussions on bibliometry also widen the readership to scientometrists and science administrators.

## Acknowledgements

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# UNEXPECTED ADVICE FOR BEGINNING GRADUATE STUDENTS IN ASTROPHYSICS

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**Abstract.** My experience is that beginning graduate students in astrophysics have unrealistic views of how to negotiate the complexities of graduate school and to prepare themselves for a professional career in astrophysics or some other field. This chapter describes my unexpected advice to students beginning with why they should not plan to write a thesis. Other advice concerns how to find and work with a research supervisor, writing and other skills needed for their research, and the need to be creative and when necessary controversial.

As a long time participant in the academic world, I have been asked by many beginning graduate students for advice in negotiating the complexities of graduate school and selecting a research topic for their thesis. Students generally expect that my advice would be to master the core courses in the astrophysics curriculum, do well in the comprehensive exam, choose a research advisor from a list of available people, and write a great thesis.

I generally surprize and often disturb them by responding that they are asking the wrong questions. The world of academia and the skills valued by the real world after graduate school are very different from their preconceived views. Since I have provided the following unexpected advice many times, I thought that it was appropriate to write down my "off the wall" suggestions for the benefit and perhaps amusement of others.

**(1) Most important advice: do not write a thesis**

The first question that students usually ask is what would be a good thesis topic. I generally respond by asking the student how many people will actually read their thesis. My guess is that the list consists of the author, hopefully the thesis committee members, the author's parents, and likely nobody else – perhaps a grand total of eight. Furthermore, if their Vita contains a publication list consisting of only their not yet completed unpublished thesis, no potential employer will be interested. Students often respond that after they graduate, they will become serious about writing papers for publication in the scientific journals based on their thesis research, but my experience is that after graduation, most people have other responsibilities and little time or desire to convert their thesis work into journal papers. Often, the thesis research never sees the light of day. So, why write a thesis?

Universities require that graduate students submit and defend a thesis in order to receive their PhD degree, but most universities do not require that the thesis consist only of not yet published research. I encourage students to write up their research as a series of papers on the same or similar topics and submit these papers to the refereed journals in a timely way.

When about six interesting papers have been refereed and published or at least submitted, I then suggest they write a short introductory chapter and submit a "thesis" consisting of the introductory chapter and the published papers. Since most or all of the "thesis" has been appropriately refereed, the thesis committee has little alternative to accepting it. As they say in chess, "check mate."

**(2) How to select and deselect a research supervisor**

Finding a research supervisor is a two-way street in which faculty members look for graduate students and graduate students look for appropriate faculty members. I advise students to take the initiative by reading recent papers published by different faculty members and deciding which topics look exciting and which faculty members are active in interesting fields.

Serious homework can avoid getting into dead-end topics that provide no excitement. When you have made your decision, go to the faculty member, mention that his or her research area is really exciting, and ask for a research assistant position. This usually works unless there is no money for such a position. Whether the potential advisor is male or female should not be a reason for selection.

Despite your best efforts, you may find that the chemistry with your advisor and/or the research topic is a failure. If so, then inform your advisor in a timely way so that he or she can find a new research assistant. Then repeat the process to find a new advisor.

**(3) Don't worry – you can become a real expert**

Students sometimes think that they could never master a research topic at anywhere near the level of experts in the field. I believe that this lack of self-confidence is unwarranted. For many, if not most, research topics, achieving a level of mastery approximating that of the experts should require an intelligent and industrious student to read the literature and work on the data and theory for a year or at most two years. You can do it. Furthermore, the experts have many responsibilities that occupy their time, whereas a graduate student can devote most of his time to understanding the topic. So, have no concern, you can become an expert.

**(4) Develop unique tools**

Whether one is an observer or a theoretician, it is critically important to develop new and more powerful tools for conducting your research. Such tools include data analysis software and semi-empirical modeling codes for observers and theoretical models and associated software for theoreticians. Often such tools may already exist, but to use them as "black boxes" does not develop your own skills. It is better to write your own software or significantly modify existing codes to understand what is real signal and what is noise. Tools that you develop can be valuable for many years in the future.

**(5) Astrophysics is a literary profession**

When I mention that astrophysics is a literary profession, students think that I have forgotten that astrophysicists write scientific papers, not novels. I then point out that the only way that we present our scientific results for consideration by the community is by what we publish in the journals and what we say at scientific meetings. Thus there is a premium on developing excellent writing and speaking skills. Some students are disappointed when they hear this because they have concentrated on developing their scientific and mathematical skills rather then their writing skills often because they do not think that they can ever write well.

Since writing skills must be learned, it is worthwhile to take a class in scientific writing or even creative writing and have available a textbook on writing style. However, there is no alternative to writing papers and proposals to develop and refine these skills. The more that you write, the better your writing will be. Don't be afraid to start.

The same is true of speaking skills. Presenting your research at seminars and teaching the occasional undergraduate level class can be very helpful. My experience is that developing excellent writing and speaking skills also develops better logical thinking. You do not really understand a topic unless you have written about it and taught it before a skeptical audience.

Although most papers and meetings these days are in English, it is helpful to become multilingual. Most native English speakers are deficient in this regard, thereby losing critical ability to communicate with many of their colleagues. Proficiency in two or more languages leads to better writing and speaking skills in all of the languages.

**(6) Become a graphic artist**

When I ask students what they should do first when writing a scientific paper, they usually respond by saying that they will first write the introduction, or an outline, or perhaps the abstract. I suggest that a far better approach is to first create the figures which contain the results of the paper in graphical form. Well-constructed figures with captions that explain the various data and assumptions tell most of the story of the paper. The text ties together the figures and explains their significance. When the figures are complete, the text can be written very easily.

Figures in journal articles contain data, fits to the data, and models both theoretical and semi-empirical. In addition to such traditional-style figures, authors should include artistic representations (i.e., cartoons) showing the physical principles underlying the models. This is a way of clearly showing the reader what is important for understanding the results described in the paper. I therefore encourage students to develop graphic artist skills. There are many software programs available for making such figures.

**(7) Be creative and controversial**

Most research topics use a standard set of assumptions and analysis techniques. Just because these assumptions and analysis techniques are adopted by most people working in the field does not make them right or even good approximations. It is important to look at things from a fresh perspective.

Be creative. When more and better quality data become available, the old assumptions often are no longer viable. When modeling a set of observations, it is usually better to include the physics approximately rather than including only some of the physics exactly. If you are convinced that your new approach is right, then do not be afraid of being controversial. This will attract attention to your work.

**(8) Writing proposals for fun and profit**

Many astronomers dread writing proposals requesting support and observing time. This is a bad habit to acquire. Instead one should view proposal writing as an opportunity to tell an exciting story. The proposal can describe a scientific journey in the quest for new insights. If you write about the science that you wish to do as an exciting journey, the reviewers of your proposal can get caught up in the excitement.

**(9) Develop your teaching skills**

While academic positions generally require teaching the next generation of students, graduate programs do not usually prepare students for teaching. Again, initiative on your part is essential. Volunteer to teach a laboratory or recitation section and ask your advisor for the opportunity to teach his class when he is traveling. Pay attention to how the best teachers prepare and deliver their lectures. Where there are mentoring programs to improve the teaching skills of faculty, try to participate even though you are a graduate student.

**(10) Prepare for the non-academic world**

Each year there is usually only one academic position for every 4.5 PhD degrees awarded to astrophysics majors and graduates in related fields who do research on astrophysics topics. While there are also positions at observatories, national facilities, and some private corporations with connections to astrophysics, many new PhDs will eventually find themselves doing something other than astrophysics. Given this reality, students should be prepared and look positively on using their skills in different areas. A graduate program is a good time to learn how to think rationally, develop a wide range of skills, learn how to present your results, and be creative.

Many employers in the business and government world value these skills. Work in the non-academic world can be very rewarding both financially and in terms of your sense of accomplishment.

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# ASTRONOMY CATS

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**Abstract.** The Center for Astronomy Education's (CAE's) NSF-funded Collaboration of Astronomy Teaching Scholars (CATS) Program is a grassroots multi-institutional effort to increase the capacity for astronomy education research and improve science literacy in the United States. Our primary target population is the 500,000 college students who each year enroll in an introductory general education (a breadth requirement for non-science majors) Earth, Astronomy, and Space Science (EASS) course (Fraknoi 2001, AGI 2006). An equally important population for our efforts is the individuals who are, or will be, teaching these students.

In this chapter, we will briefly discuss the goals of CAE and CATS, the varied personnel that make up the CATS collective, the diverse projects we've undertaken, and the many challenges we have had to work through to make CATS a success.

## 1. Goals of CAE and CATS

CAE in Steward Observatory at the University of Arizona, lead by Ed Prather and Gina Brissenden, is devoted to improving teaching and learning in general education EASS courses by conducting investigations into students' beliefs and reasoning difficulties, and instructors' implementation difficulties related to teaching EASS. The results of this work are used to inform the development of proven instructional strategies and assessment materials for use in the EASS classroom. These research-validated instructional strategies and assessment materials are prominently featured during our professional development CAE *Teaching Excellence Workshops* for general education EASS instructors (Prather *et al.* 2009 and the references therein). The goal of these professional development workshops is to increase the pedagogical content knowledge of instructors and improve the effectiveness of their classroom implementation abilities.

To create sustainability and broaden the national impact and scope of our work, the leadership of CAE, in cooperation with other leaders in astronomy education and research (Chris Impey, Univ. Arizona and Kevin Lee, Univ. Nebraska), developed the NSF-funded Collaboration of Astronomy Teaching Scholars (CATS) Program. The primary goals of CATS are to:

1. increase the number of general education EASS instructors conducting fundamental research in discipline-based education;
2. increase the amount of research-validated curriculum and assessment instruments available for use in general education EASS courses; and
3. increase the number of instructors developing and conducting their own CAE *Teaching Excellence Workshops.*

## 2. The CATS Collaborative

The broader CAE community is approximately 3000 members strong and growing. But creating a community this large does not happen immediately or effortlessly. How this community came to be is probably best understood by stepping back in time to look at pivotal milestones along the way.

It was our desire to foster a population of EASS instructors who cared deeply about the learning occurring in their classes, and who were motivated to conduct research on the effectiveness of their own instruction. We also wanted to create a larger community of instructors that would lend support, advice, council, and wisdom, to each other.

We knew the instructors who would be willing to do their own research would also have spent a few semesters trying one or more of the interactive learning strategies in their classroom, and would be eager to know how well it was working. These same instructors were also often active participants in our online academic community of practice listserv, `Astrolrner@CAE`.

However, before we could expect inexperienced EASS instructors to try new curriculum in their class, they would first need to feel confident about their ability to effectively implement the curriculum in their courses. It was for this reason that we created our CAE *Teaching Excellence Workshop* series, which debuted in 2004. The participation-based workshops have provided EASS instructors with the experiences they needed to become familiar with best practices when using classroom proven curriculum (Prather

& Brissenden 2009). All workshop participants were also invited to join `Astrolrner@CAE` in an effort to expand their professional development experience beyond the workshop setting. To date, we have conducted hundreds of workshops, in over half of the US states, Puerto Rico, Canada, and France.

Our workshops have been attended by thousands of current and future (grad students and postdocs) college EASS instructors, as well as hundreds of middle school and high school teachers. The success of these workshops has been greatly facilitated by the strong relationships CAE has developed with professional societies such as the American Astronomical Society, the American Association of Physics Teachers, and the Astronomical Society of the Pacific. These societies help promote our workshops, as well as provide venues for them to be held. Their endorsement of our workshops also provides a certain *gravitas* to the notion that working to become a better instructor is valued. A surprising outcome to us is that about 25% of our Tier I (or "introductory") workshop attendees participate in a second Tier I workshop. And of these 2-time Tier I participants, about 35% attend a Tier I workshop three or more times.

Before we could create our CAE *Teaching Excellence Workshops*, designed to help train instructors to become effective implementers of active engagement instructional strategies, so they would become motivated to do research, we first had to develop and validate a suite of instructional strategies and assessment materials to get the whole thing started – which we began way back in 2000 (Prather *et al.* 2009 and the references therein).

Over the last decade, through CAE's programmatic evolution described above, we had grown our community of practice to approximately 3000 members, and were finally ready to select scholars to participate in the *CATS Fellowship* program. The *CATS Fellowship* program provides leadership opportunities for instructors who have made significant pedagogical contributions to the CAE *Teaching Excellence Workshops* and who have consistently participated in and elevated the scholarly nature of discussions on the `Astrolrner@CAE listserv`. It is through the collaborative work done by *CATS Fellows* that the goals of the CATS program would be achieved.

There are over 50 *CATS Fellows* involved in one or more of the many CATS collaborative research and professional development projects. These *CATS Fellows* represent senior and junior faculty, adjunct instructors, postdoctoral researchers, as well as graduate and undergraduate students. They come from 4-year institutions that primarily focus on research; from 4-year liberal arts colleges; and from 2-year community colleges. The *CATS Fellows* also represent an incredible geographical diversity (Fig. 1). Through the geographical and experiential diversity represented by the participants

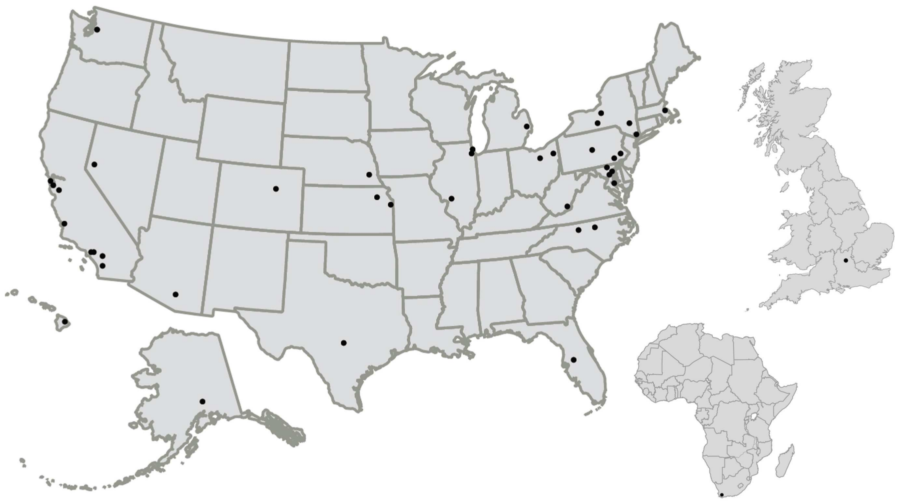

*Figure 1.* Dots represent the location of a *CATS Fellow*, or group of *CATS Fellows*, who span the United States, Canada, England, & South Africa.

in the *CATS Fellows* program, we have substantially increased the likelihood that the voices of all stakeholders in the EASS teaching and learning community are being heard and their needs met.

## 3. Our Diverse Projects

When we wrote our grant to the NSF Course Curriculum and Laboratory Improvement (CCLI) Phase III Centers Program to create CATS, we had already identified several projects we believed were necessary to help move the college general education EASS teaching community forward. Our decisions as to which instructional strategies and assessment tools were in need of development, and which research investigations should be pursued, came from conversations with participants from the CAE *Teaching Excellence Workshops*, from the input of leaders from EASS professional societies, and from discussions occurring on our `Astrolrner@CAE` academic listserv. We also informed these decisions from the outcomes of the Physics Education Research community that were positively impacting that community to improve teaching and learning in physics (McDermott & Redish 1999 and the references therein). The particular interests of individuals within the broader CAE community who would become our *CATS Fellows* identified additional new directions for CATS collaborative research and professional development.

Following is a small sample of the research projects and professional development programs that highlight the collaborative nature of CATS, along with some of our research results. Our hope is that this sample helps to demonstrate a bit more about the complexity of CATS:

*3.1 An investigation into the teaching and learning that occurs in reformed college general education EASS courses using the Light and Spectroscopy Concept Inventory (LSCI)*

Perhaps the largest of the CATS research projects involved pre- and post-instruction testing of approximately 5000 students, from over 70 individual classes, taught by nearly 40 different instructors at more than 30 different colleges. Students were asked to answer the 26 conceptual questions presented in the Light and Spectroscopy Concept Inventory (Bardar *et al.* 2007). In addition, students were asked to complete 15 demographic questions. Phase I of our analysis involved an investigation into the relationships between class sizes, type of institutions, amount of course time spent using interactive learning strategies, and course-averaged student learning gains. Our findings have provided important insights as to which of these factors correlates with students' learning. We found that all general education courses start with approximately the same level of content understanding related to the topics of the LSCI (pre-instruction scores = 24%±2%).

Much to our surprise we found that the class-averaged normalized gain scores were independent of class size or type of institution – demonstrating that students' achievement is possible no matter where you go to school or how big (or small) your class. We found that statistically, classes with higher levels of interactive engagement (IAS>25%) on average did much better at improving student understanding. However, there were several classes that had a significant amount of class time dedicated to the use of interactive teaching methods but also had very little change in student achievement (Figs. 2-4). This result starts to illustrate how critical an instructor's implementation ability is to the success of a classroom, even when proven instructional strategies are being used (Prather *et al.* 2009 and the references therein)!

Phase II of this work focused on the student responses to our 15-question demographic survey. A multivariate regression analysis was conducted to determine how ascribed characteristics (personal, demographic and family characteristics), achieved characteristics (academic achievement and student major), and the use of interactive learning strategies are related to the individual student learning gains in these classes. The results show dramatic improvement in student learning with the increased use of interactive learning strategies even after controlling for individual characteristics. In addition, we found that the positive effects of interactive learning strategies apply equally to men and women, across ethnicities, for students with all levels of prior mathematical preparation and physical science course ex-

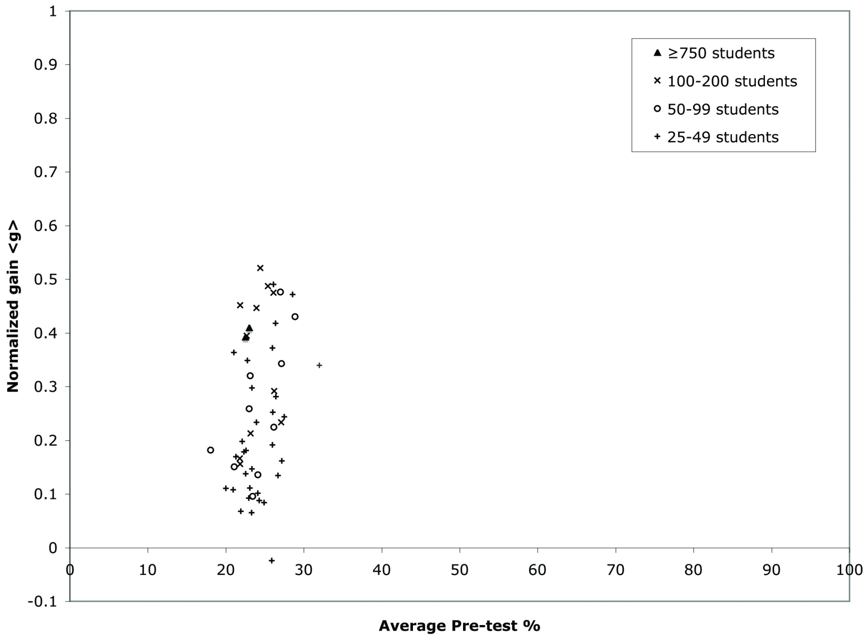


*Figure 2.* This graph displays the class-averaged normalized gain <g> score vs. the class-averaged pre-test score identified by class size. Note that the averaged pre-test score is 24%±2% for all classes regardless of class size and that it is possible to achieve higher learning gains regardless of class size.

perience, independent of GPA, and regardless of primary language. These results powerfully illustrate that all students can benefit from the effective implementation of interactive learning strategies (Rudolph *et al.* 2010).

Phase III is an ongoing investigation using Item Response Theory to independently analyze changes in students' inherent reasoning abilities, and to determine the inherent difficulty and discrimination of the items in the LSCI itself.

Beyond the 70 instructors and 5000 students that contributed to this work, the three phases of this investigation have been the collaborative efforts of 4 faculty members, 2 graduate students, and 7 undergraduate research assistants from 4 different universities and colleges. A major component of one dissertation in Astronomy Education Research has come from this work.

*3.2 An investigation of the conceptual and reasoning difficulties students have with learning cosmology, and the effectiveness of a Lecture-Tutorial approach to teaching cosmology*

Over the past three years more than 10 instructors from as many different institutions have worked together on an investigation into students'

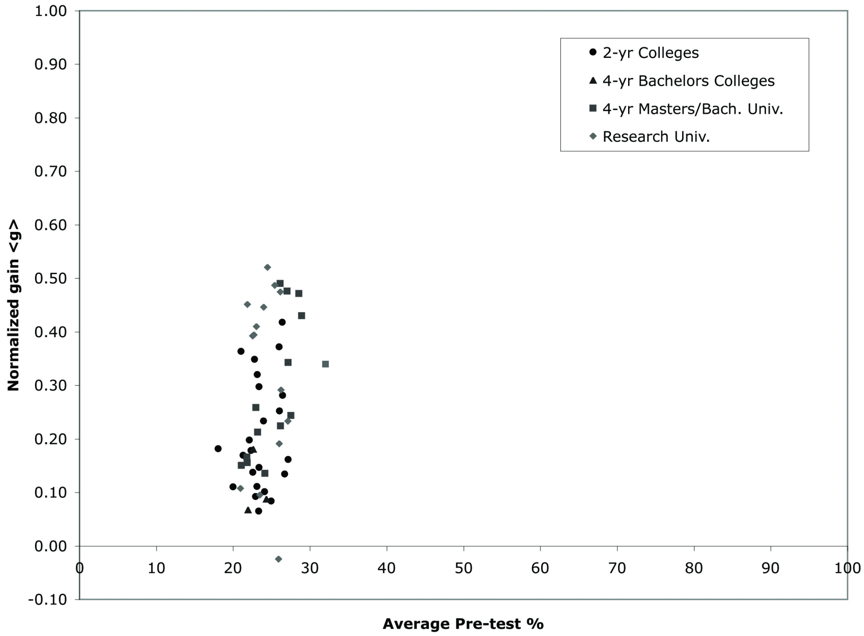


*Figure 3.* This graph displays the class-averaged normalized gain <g> score vs. the class-averaged pre-test score identified by type of institution. Note that the averaged pre-test score is 24%±2% for all classes regardless of type of institution and that it is possible to achieve higher learning gains regardless of type of institution.

conceptual and reasoning difficulties in cosmology. To date, we have analyzed the written responses to a set of open-ended conceptual questionnaires from over 2000 students enrolled in classes at institutions all across the United States. The research questions investigate students' ideas on the Big Bang, the expansion and evolution of the Universe, and the evidence for dark matter. The findings from these investigations informed the development of a new suite of cosmology Lecture-Tutorials that are designed to increase students' understanding of these commonly taught cosmology topics. These Lecture-Tutorials have gone through several semesters of classroom testing in an iterative process to assess their effectiveness on student learning and to address the challenges to implementation brought up by the *CATS Fellows* who are trying them out in their classrooms. Ongoing systematic research has provided significant evidence to document that these new Lecture-Tutorials help students achieve larger learning gains than lecture alone over these challenging cosmology topics.

### *3.3 Development and validation of the Question Complexity Rubric (QCR) for use with the creation of a national archive of Think-Pair-Share (TPS) questions*

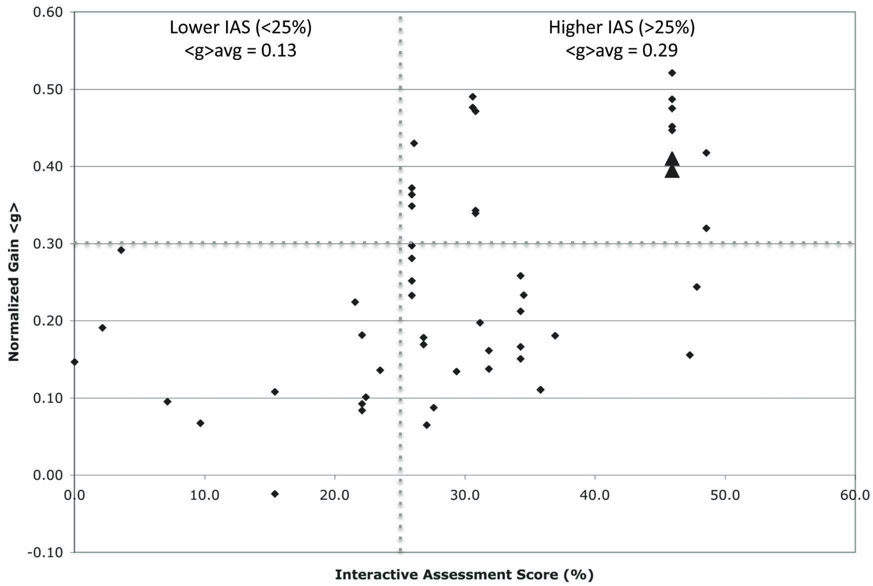


*Figure 4.* This graph displays the class-averaged normalized gain <g> score vs. the class's Interactive Assessment Score (% of class time taught interactively). Note that only classes with an IAS >25% were able to achieve normalized gain <g> scores above 0.30 and that there is a statistically significant difference in learning gains between the Lower IAS classes (<25%) and Higher IAS classes (>25%). Also note that simply because a class had an IAS >25% was no guarantee of higher gains.

This project will generate a community-based national archive with hundreds of topically and hierarchically sorted, cognitively-challenging questions that are intended to supplement an instructor's implementation of TPS or for other assessment purposes (i.e. exams and homework) for use in EASS classrooms. In addition, this project is developing and validating the Question Complexity Rubric (QCR). The QCR is being created so that members of the EASS teaching and learning community will have a tool that allows them to assist us with ranking questions in this archive, based on the item's conceptual complexity and intellectual rigor. The online question archive system provides users with the utility to (1) use the QCR to score questions, (2) search for and download questions based on topic and/or QCR score, and (3) add their own questions to the archive. Early results involving more than 20 *CATS Fellows* established a set of calibration questions that are used to determine the effectiveness of the QCR. Pilot studies found that participants scored the calibration questions identically 70% of the time, and were within one QCR score of the item average for 96% of all calibration questions. This work is ongoing and has seen a dramatic increase in participation from the greater CAE community.

*3.4 Development and validation of the Solar System Concept Inventory (SSCI)*

The SSCI has been developed to assess students' conceptual and reasoning abilities regarding topics commonly taught in a college general education solar system course. The topics included on the SSCI were selected through a collaborative process involving several prominent planetary scientists from around the US, who identified the key concepts most commonly addressed in a solar system course taught at the general education level. SSCI topic domains include formation mechanisms, planetary interiors, atmospheric effects, and the properties of small solar system bodies. National multi-institutional field-testing has been going on for three years and has involved nearly 2500 students and 17 instructors from 10 different institutions. After each round of testing, a group of instructors from multiple institutions around the country worked together to analyze the data and revise or eliminate underperforming questions. Each question was examined using a combination of point-biserial (discrimination), percent correct (on the pre-test and post-test), and item difficulty to determine if the question was properly differentiating students' understanding while also ensuring the question was not too conceptually easy or difficult to answer. The final version of the SSCI is now available and being used to assess students' understanding in many classrooms across the US.

*3.5 An investigation into participant conceptual understanding of science topics related to investigations of Citizen Science (CS)*

In the US, Citizen Science (CS) is an increasingly popular and very efficient way to help scientists with the reduction and analysis of data. CS activities provide members of the public with raw data and asks them to identify, label, categorize and sort science mission data so that scientists can continue their research using refined data-sets. Zooniverse is an institution that creates CS programs. Our international collaboration with Zooniverse is currently running two assessment programs designed to investigate whether there is a connection between the level of participation in Zooniverse Citizen Science activities and the development of conceptual understanding of the topics and tasks addressed in the CS activity.

Beginning efforts focused on the creation of two multiple-choice concept inventories designed in collaboration with mission scientists from the Sloan Digital Sky Survey (SDSS) and Lunar Reconnaissance Orbiter (LRO) and other content experts. One inventory is designed to investigate students' understanding of concepts related to the properties of galaxies, and the second instrument focuses on students' understanding of lunar cratering.

We have analyzed nearly 5000 responses from over 3500 users. The low-level participants, defined as participants who have tagged and labeled fewer than 100 images, received an average score of 41% on the Lunar Cratering Concept Inventory whereas high-level participants, those who processed over 600 images, score an average of 58%. While the initial results show significant differences between low-level participants and more experienced users, this work is ongoing and will begin using different methodologies of participant sampling and data analysis.

### *3.6 A long-term study of science literacy and attitudes toward science among non-science majors*

Over the last 20 years we have gathered over 10,000 questionnaires from students in general education classes at CAE's home institution. The questions come from an instrument used by the National Science Foundation to test basic scientific knowledge. Along with a standardized measure of "science literacy," the instrument has students respond to statements about science, technology, and pseudoscience on a Likert scale. The rich data set has allowed powerful statistical analyses of relationships between science knowledge and attitudes towards science. Overall, there is little gain in science literacy during an undergraduate career, spanning 2-3 general education science classes. Moreover, beliefs in pseudoscience are poor indicators of science literacy, indicating that non-scientific thinking persists alongside science knowledge. Factor analysis also shows little correlation between religious beliefs and science literacy.

This work is being extended through a mixed-methods study that uses longitudinal assessment data of student combined responses to several different concept inventories and science literacy surveys along with student one-on-one interview data. This research program elicits the input of the broader EASS teaching community about their own beliefs and attitudes about what is important for general education students to understand about the nature of science and the role in society. This multi-year, multi-institutional work will inform our understanding of how different instructional environments affect students' science literacy, their attitudes and beliefs about learning science, their thoughts on the role of science in society, and the ability of EASS courses to improve students' critical reasoning and evidence-based reasoning abilities.

### *3.7 A Situated Apprenticeship Approach to Professional Development*

Over the past several years members of CAE and the *CATS Fellows* program have provided *Teaching Excellence* professional development workshops to more than 2000 current and future EASS faculty (grad students and postdocs). The goal of these workshops is to provide participants with training in best practices for the effective implementation of interactive learning strategies. What makes these intensive two-day, 16-hour workshops particularly unique is that participants are required to actively practice their teaching while the other workshop participants evaluate the implementation of the person teaching. This active-engagement and participation-based professional development framework is called Situated Apprenticeship (Prather & Brissenden 2009). There is now a cadre of more than 10 *CATS Fellows* who serve as co-presenters during the *CAE Teaching Excellence Workshops* held at national meetings. In addition a group of *CATS Fellows* have created five *CAE Regional Teaching Exchange* programs designed to expand the efforts of CAE and CATS to instructors in their part of the country.

## 4. Challenges and Making It Work

Accomplishing the goals of the CATS program has required developing new models for collaborative, discipline-based research. While CAE, in Steward Observatory at the University of Arizona, is the activity hub of CATS, CATS is made up of over 50 collaborators, spread geographically across the country. They run the gamut of experience in education research from undergrads to tenured faculty. Several of our CATS projects have been, and are, the subject of PhD dissertation research as well as undergraduate research projects.

In the United States, we have an expression to describe the difficulty of getting a group of people to stay focused working together on a task all the way to completion: "It's like herding cats." Given the number of collaborators involved in CATS, the range of research experience, and the number of projects going on simultaneously, there probably isn't a better phrase to describe what CATS has felt like. Yet, one of the most rewarding aspects of our collaboration has been the degree to which everyone in CATS has (in US baseball terms) "stepped up to the plate" and generously contributed their valuable time and resources to ensure the success of the diverse and challenging research and professional development programs undertaken.

One major challenge we have faced in coordinating CATS has been to keep each project collaborator working in unison and remain continuously engaged. In addition to their CATS responsibilities, each participant typically has other research, teaching, academic, departmental, and university responsibilities. These many other demands make effective communication and adherence to meeting and project deadlines difficult yet extremely important. Frequent collaborative team meetings held in person, or virtually via phone conference calls, Skype, and the like are key to keeping team members engaged, focused, well informed and on task. Frequent team meetings serve to establish participant responsibilities and deadlines, help to inform members as to where they are falling behind, and identify potential roadblocks, which might stand in the way of progress. There is also the successful planning and executing of workshops, national and international meeting planning, writing timely research articles, etc. Finally, you and your collaborators will have additional questions related to executing research protocols, analyzing and interpreting data, etc. related to each project. Specific tips to make communication more effective and efficient include:

– Be respectful of the deadlines of your project and the time constraints of your collaborators. By meeting all deadlines you acknowledge that your collaborators and their many responsibilities are important. By missing deadlines you likely adversely affect the progress of your collaborators and delay the completion of the project.
– Respond to email and phone messages in no less than 48 hours whenever possible, to ensure your collaborators know you are aware of their requests, contributions or questions.
– Let your collaborators know in advance if you will be unavailable due to travel, vacation, or other professional responsibilities. Provide an automated "away from my office" reply if you know your travel will keep you from being able to respond in a timely manner.
– Make no assumptions about the time constraints, beliefs or availabilities of your collaborators. Be as clear, direct, and specific with any communication regarding all meetings, research questions, or other concerns, delivered via email, during a virtual meeting, or in person. A great deal of time and resources are wasted and frustrations can be avoided when collaborators communicate their ideas and needs timely and explicitly, with language that treats each team member with compassion and respect.

An additional challenge we have faced has come from the lack of resources available to CAE to manage and coordinate all the research collaborations and programmatic tasks for a group the size of CATS. First, and foremost, collaborators have to get paid and reimbursed. The time involved with managing the independent contracts with individuals, and subcontracts with other institutions, has been enormous. Then layer onto this the amount of time and resources it takes to coordinate all aspects of multi-institutional research investigations, planning professional development workshops for faculty, organizing collaborator group meetings, or arranging registration and travel for professional society meetings for the whole group ...

In the end, an important lesson we have learned though our Collaboration of Astronomy Teachings Scholars program is that our most precious resource is time and that we never seem to have enough of it.

## Acknowledgements

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# AAS CAREER SERVICES

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**Abstract.** The American Astronomical Society provides substantial programs in the area of Career Services. Motivated by the Society's mission to enhance and share humanity's understanding of the Universe, the AAS provides a central resource for advertising positions, interviewing opportunities at its annual winter meeting and information, workshops and networks to enable astronomers to find employment. The programs of the Society in this area are overseen by an active committee on employment and the AAS Council itself. Additional resources that help characterize the field, its growth and facts about employment such as salaries and type of jobs available are regularly summarized and reported on by the American Institute of Physics.

## 1. Introduction

The American Astronomical Society is the largest professional organization for research astronomers in North America and, barring the International Astronomical Union, the World. The AAS provides many services to its members, to astronomy and to affiliated disciplines. The mission of the AAS is to enhance and share humanitys scientific understanding of the Universe. The detailed mission and vision statement of the AAS may be found on its web site[1].

The Society accomplishes its central mission through the following broad goals:

[1] http://aas.org/about/mission_and_vision

1. **The Society, through its publications[2], disseminates and archives the results of astronomical research.** The Society also communicates and explains our understanding of the universe to the public.
2. **The Society facilitates and strengthens the interactions among members through professional meetings[3] and other means.** The Society supports member divisions representing specialized research and astronomical interests.
3. **The Society represents the goals of its community of members to the nation and the world.** The Society also works with other scientific and educational societies to promote the advancement of science.
4. **The Society, through its members, trains, mentors and supports the next generation of astronomers.** The Society supports and promotes increased participation of historically underrepresented groups in astronomy.
5. **The Society assists its members to develop their skills in the fields of education and public outreach at all levels.** The Society promotes broad interest in astronomy, which enhances science literacy and leads many to careers in science and engineering.

Some direct examples of services or activities executed by the AAS to accomplish these goals include publishing the *Astronomy Education Review, Astrophysical Journal, Astrophysical Journal Letters, Astrophysical Journal Supplement Series* and the *Astronomical Journal*; organizing major meetings in the field of astronomy (the two annual meetings of the Society, annual meetings of its various divisions and, new in 2011, providing logistical support for astronomy meetings not organized by the AAS or its Divisions); disseminating timely information about the field to its members through an electronic newsletter and monthly emails as well as via the Society web page; lobbying on behalf of the discipline and related sub-disciplines with the US Congress, administration and agencies; coordinating activities in the area of astronomy education; awarding prizes and other recognition for research or service work in or for the discipline; providing a press release distribution system and press conferences at annual meetings; organizing volunteers to accomplish various activities through topical committees or working groups (e.g. Committee on the Status of Women in Astronomy or

[2]See e.g. Milkey, R.W. 2006, The Scholarly Journals of the American Astronomical Society, in *Organizations and Strategies in Astronomy 7 (OSA 7)*, Ed. A. Heck, Springer, Dordrecht, pp. 241-261. (Ed. note)

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Working Group on Laboratory Astrophysics) and; providing various career services, which I detail in this chapter.

The motivation for providing career services is rooted in our central mission, and justified through our goals (outlined above). An easy way to consider the Societys activities is that a well-informed, well-networked workforce helps to ensure a vibrant and efficient scientific discipline. We attempt to tailor our services in this area to accomplish the goals of the Society, while doing so at the lowest possible cost and in the most efficient way.

In this article, I outline the various Career Services that the Society provides, a bit of the history of each of these services and some sense of the future direction for these services in the coming years. The AAS website contains links to all AAS career services and resources[4].

## 2. The AAS Job Register

The AAS Job Register[5] began in 1979 as a simple listing of jobs in a sequential format along with appropriate contact information for applicants to use to apply for each position. Initially, there was no charge for a job listing and the Society absorbed all costs for the processing and dissemination of the Job Register. The motivation for starting the Job Register was that the job situation, meaning the availability of positions generally, was fairly bleak. There were few openings and a large number of applicants (driven, in part, by the large investments by NASA in basic research connected to the human space program, ultimately declining in the mid to late 1970s, with drastic results on young people who had been drawn to astronomical research due to the excitement of the space race).

Some simple policies put in force at the outset are in force today, the job listing must be *bona fide*, meaning it must be truly an open job with no pre-selected candidate; the AAS plays no part in the job seeking or negotiating process other than publishing the position description; and the position must be open for at least thirty (30) days. The reason for these simple rules is primarily to prevent the Job Register from being used to claim that a full and open search was undertaken for a position, when in fact, the position was hard-wired for a particular candidate.

In the mid-1980s, the Society began charging a small fee to employers for the publication of their Job announcement, primarily to offset the printing and distribution of the Job Register, but even with the fee, the costs exceeded the revenue. As the popularity of the Job Register grew, the fee had to be increased to cover a larger fraction of the staff time required to

[4] `http://aas.org/career`
[5] `http://members.aas.org/JobReg/JobRegister.cfm`

manage, produce and disseminate the Job Register. By 1990, the cost was just more than USD 100,000 per year to produce, edit and distribute the Register.

In 1993, the Society moved the Job Register from a fully print-format publication to a fully on-line publication. After assessing commercially available solutions, it was decided to develop a customized solution in house, which would provide greater flexibility and customization. During a short transition period, the Job Register appeared both in print and online formats; those who requested print could still receive it. Meanwhile, an email alert system was set up that allowed distribution of the job titles newly published each month to be distributed to opt-in subscribers. This service is still in place today. A 250-word posting limit was also imposed to save costs and attempt to encourage brief job descriptions.

Just prior to the conversion to the online version, it took just over half an FTE (Full Time Equivalent, a measurement of the level of staff effort necessary to accomplish a task) to process the job ads, copyedit the ads, invoice and bill the advertisers and prepare and distribute the Job Register. The conversion to an online-only Job Register was primarily undertaken to reduce costs and increase the ease of distribution, as many publications were already online by that time (the Societys journals moving fully online in the late 1980s); it was clear the Internet and Web would be a primary mode of future communication and the Job Register must be accessible using these new communications tools.

With the reduced costs, the small net profit that resulted from the conversion began to be used to bring speakers to AAS meetings on career-related topics, ultimately to offset a fraction of the salary of a staff member dedicated to employment issues (the Associate Executive Officer for Public Policy and Employment Policy Programs, a now defunct position) and undertake other efforts in career services. Due to US tax law, revenues from the Job Register are considered unrelated business income and are subject to tax, although the AAS is a tax-exempt organization. The Society pays this tax each year, but only on the net proceeds after subtracting expenses related to career services, following standard practice in this area with the advice and guidance of qualified tax accountants and legal counsel.

Today, the Job Register is run using a database driven system to receive the Job announcements from employers, process payments for the publication of the ads and handle the subsequent online posting. The 250-word limit has been lifted, but a fee per word is charged for ads with more words than this limit. The current cost for a posting for one month is USD 190.00, with USD 0.25 charged for each word beyond 250. The Register is published monthly on the first of the month. Submissions are due no later than the $15^{th}$ and must be paid for in full by the $25^{th}$ of the month prior to the ad

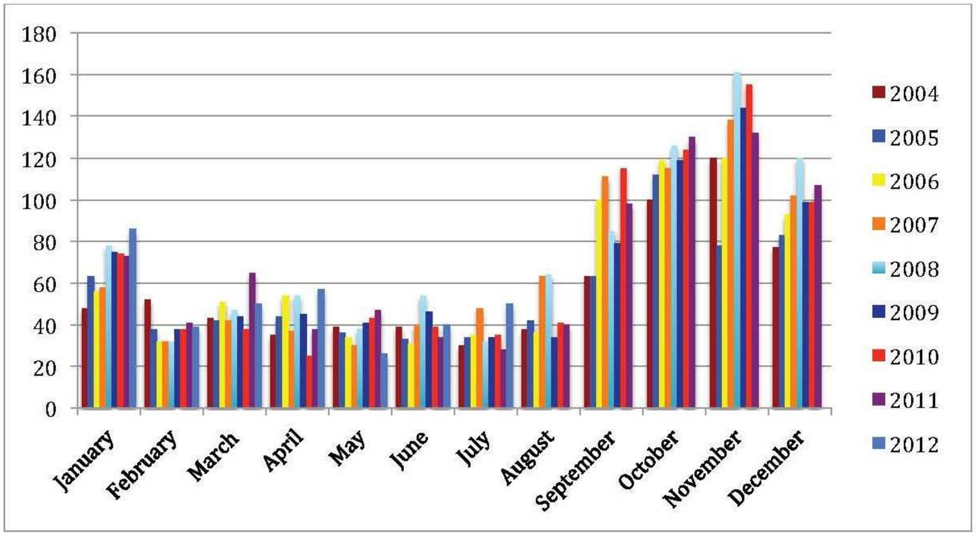


*Figure 1.* New jobs published by month in the AAS Job Register since 2004. Note that jobs listed for multiple months are counted only in the month they appear. All job types are included in this figure, permanent, postdoc, temporary, etc.

appearing online.

The number of jobs posted month-to-month varies due to the academic job cycle, but the year-to-year pattern has remained constant for years. A histogram showing the number of jobs published each month from 2004-2010 is shown in Figure 1.

A snapshot of the current Job Register is shown in Figure 2. The design and features of the Job Register web page have evolved over time in response to both job seekers and employers with the guidance of the Committee on Employment. Jobs are grouped according to defined categories, but advertisers may select the category for their job. Multiple categories are not allowed. Each job entry is for a unique job, except for the rare case of an employer being unsure how many positions may be available.

The Job Register is currently published once per month. Some online job listing sites are 'live' in that as soon as a job announcement is submitted, paid for and approved, it appears online. This system is detrimental and interruptive to the working life of a job seeker, many of whom are either graduate students or postdocs trying to get research done. The AAS has opted to publish only once per month to minimize the number of times a job seeker has to review the posted jobs. Having a live site would require daily review for new postings, or notification any time a new posting went live. Although not immediately appreciated by Job Seekers or Employers, once

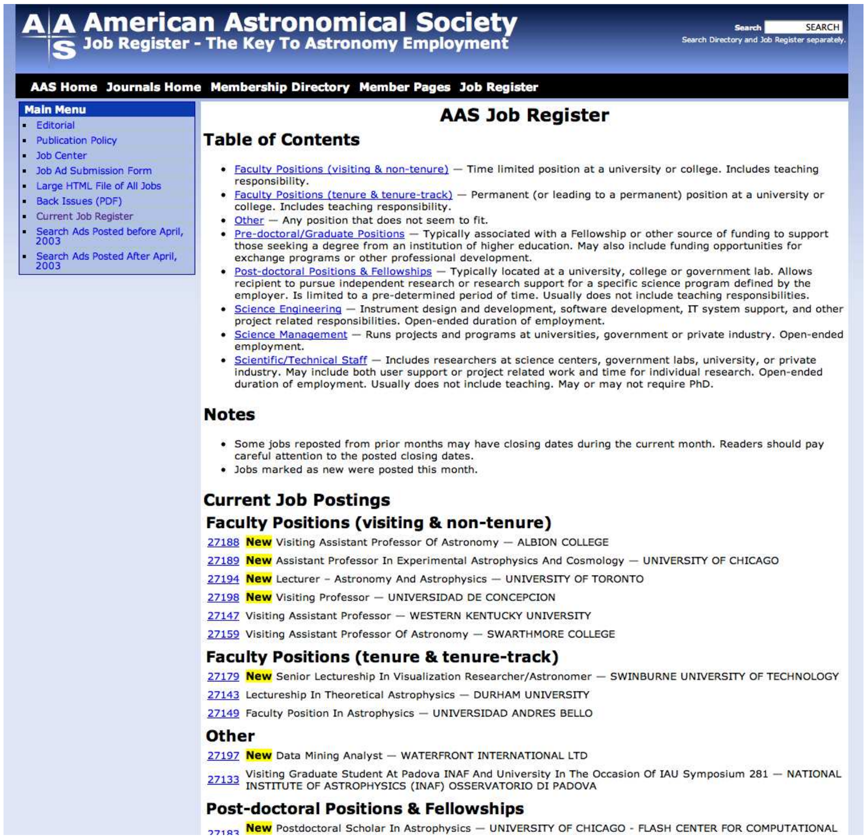


*Figure 2.* Snapshot of the current AAS Job Register.

the rationale for the once-a-month posting is explained, nearly everyone approves of the policy.

## 3. The AAS Job Center

The AAS has long had a so-called “Job Center” at its annual meetings. The Job Center serves as both a “live” posting of the current Job Register listings and as a way to connect job seekers with employers for either informal or formal interviews. The center is usually set up on the exhibit floor of the AAS Meeting hall. It consists of poster boards with the current Job Register listings, tables and chairs, a message board and books of resumes of job seekers attending the meeting. Usually located nearby, interview rooms are available for use by employers.

In the early 2000s, the Job Center was shifted to occur only at the winter meeting. This step was taken due to the very low number of job seekers or employers participating at the summer meeting Job Center. We do not anticipate having a Job Center at the summer meeting in the future, as the recruitment cycle has not shifted from its established fall-winter focus, with the winter AAS meeting falling in early January, near the peak of recruitment activity and demand in May/June remains low for this kind of service.

## 4. AAS Career Workshops

The AAS has regularly organized both sessions and workshops related to employment and career development at its annual meetings. At the 2010 winter meeting of the Society, five workshops were held ranging in topic from specific advice on interviewing, job seeking and resume writing to giving good oral presentations. Most workshops have a nominal registration fee, which helps offset the costs of holding the workshop (supplies, photocopies of materials, audiovisual support, etc.) as well as motivating workshop registrants to attend the sessions once registered. To ensure the workshops and their content are valued by participants, we carry out surveys of participants to assess both the content and the presenters. These surveys help us establish new workshops, use alternate presenters and ensure high quality workshops in the future. Included here is a typical comment from one of our longer-running workshops:

> "Even though the winter AAS meeting has been over for nearly a month, I am writing to thank you for including the career workshop in the schedule (Advancing Your Career in Astronomy: Identifying and Seizing Opportunities, Learning and Honing Professional Skills). The presenters discussion on the skills needed to become a successful astronomer with a good reputation was extremely valuable.
> As a student in the middle of my graduate career, I learned tips that will be useful throughout the various stages of my work with respect to reputation, networking, and career development. It was, however, the one-on-one career consultations that were exceptional. Her suggestions on improving a CV have been useful, and the career advice she gave me was honest, unbiased, personalized, and well considered. In twenty minutes she instilled me with confidence in my decisions and future; I am exceedingly grateful for having the opportunity to meet with the presenter one-on-one."

## 5. The AAS Committee on Employment

The AAS Committee on Employment, initially established in 1971 as the Committee on Manpower and Employment in Astronomy, was subsequently renamed the Committee on Employment in June 1988. The committee is now charged to facilitate the professional development and employment of astronomers at all career stages and on all career paths, and to promote balance and fairness in the job market. The Committee typically has between seven and ten members, from a range of career backgrounds, including academics and those working for the government and industry. Council appoints volunteer members for three-year terms and the chair serves year-to-year with reappointments as chair possible.

Bart Bok, who served on Council at the time, chaired the initial committee. The committee was formed after Executive Officer Hank Gurin (who served from 1969-1979) presented a report to the AAS Council about a job placement service he had been running informally through the Executive Office (himself and an assistant). The report submitted by the newly formed committee at the San Juan meeting of the AAS in 1971 recommended the establishment of an active placement service similar to a new Job listing service run by the American Institute of Physics, which ultimately became the Job Register, along with a variety of other recommendations related to expanding the range of employment opportunities for students of astronomy. Two recommendations made by this committee at the time that stand out, as they relate to problems with us still today, were the education of graduate students in astronomy as to their realistic job prospects and the limiting of graduate students in astronomy due to overproduction of PhDs.

Currently, the Employment Committee meets roughly monthly by teleconference to discuss ways to accomplish its charge. The committee serves several vital roles, including envisioning new services or programs, developing suggested speakers for AAS meetings, overseeing existing career services programs and providing advice to the Council on issues of employment policy. Recently, the committee has worked with the Statistical Research Center of the American Institute of Physics and other AAS committees to develop surveys of the career path for early-career astronomers (a longitudinal survey) and a survey of the astronomy job market (following up with Job Register posters to determine how positions were filled and by whom).

Additionally, the committee has undertaken the recruitment and editorial review of articles for the AAS Newsletter relating to astronomy careers. All but the current version of the AAS Newsletter is available for free[6].

The committee also recently undertook the reinvention of the Non-Academic Astronomers Network[7], meant to be a service that can connect astronomers working outside of academia and to provide a resource for students and postdocs seeking information on opportunities outside of academia.

[6] `http://aas.org/publications/newsletter_archive.php`
[7] `http://aas.org/career/nonacademic.php`

## 6. Statistics Gathered by the AAS or by the AIPs

Astronomy is a complex field, with many different types of employment available from University professorships to staff astronomers to planetarium staff. Tracking the discipline in any reliable way is a challenge, especially given the size of the AAS Executive Office, which is small. Over time, we have come to rely heavily on the help and assistance of the American Institute of Physics Statistical Research Center. This group of highly trained statisticians and survey experts help track the disciplines of physics and astronomy and provide many valuable reports, all of which are available online[8]. The AIP helps track the number of minorities working in our discipline, the number of faculty and where they are located, the typical salaries received by those employed in astronomy and many other relevant statistics.

## 7. Other Miscellaneous Activities Related to Career Services

The AAS Council has passed and reaffirmed a statement relating to the postdoctoral selection process in the United States, focused mainly on the so-called 'named' postdoctoral fellowships. This was done to ensure an even playing field among the various fellowships and to prevent the early offer of a position to particularly well-qualified applicants by a single institution. This policy is detailed on the Job Register publication policy page and on the AAS Council Resolutions page. The text of the resolution is included below.

> **On the Postdoctoral Application and Selection Process**
> **Adopted June 1988, Kansas City, MO; Reaffirmed May 2003, Nashville, TN; Reaffirmed January 2006, Washington, DC**
> The AAS Council is concerned about the procedures in the postdoctoral application and selection process. The postdoctoral experience now includes almost all recipients of the Ph.D. in Astronomy and Astrophysics. In recent years, deadlines for application and selection of postdoctoral appointments have advanced in the year and there is strong competition for new graduates.
> To insure an orderly and fair postdoctoral appointment procedure, the AAS Council recommends that the deadline for decisions on postdoctoral offers will not be required earlier than February $15^{th}$ of a given year.

The AAS has also been concerned for many decades about the number of under-represented groups working in our discipline. To help focus attention on this issue and the importance of improving the distribution of people

[8] `http://www.aip.org/statistics`

within the field, the AAS Council adopted a resolution on under-represented groups and endorsed the so-called Baltimore Charter[9].

> **On Women, Under-Represented Groups and the Baltimore Charter**
> **Adopted 11 January 1994, Washington, DC**
> "Recognizing the principle that the inclusion of women and other under-represented groups in the ranks of professional astronomers is important and highly desirable, the American Astronomical Society is committed to addressing issues of attitude and procedure that negatively impact any groups. The American Astronomical Society supports the goal of the Baltimore Charter, which is to promote a culture in which both women and men can realize their full potential in scientific careers. We recognize that there are many differences in the institutional structure of astronomical organizations, and that no single strategy is likely to be suitable to all of them. We do, however, urge all astronomical programs to formulate strategies that will enable them to realize the goal of the Baltimore Charter. We note that the AAS has already modified its bylaws to reflect commitment to this goal."

## 8. Conclusions

The AAS Career Services program has grown stochastically since the hiring of a full-time Executive Officer in the late 1970s. As staff time and resources have become available and the goals in this area have been clarified, the programs and services have expanded logically over time. The recent strategic planning exercise, undertaken by the Council from 2006 to 2009 and supported by an ongoing review and revision of the strategic plan, will guide the development and implementation of future programs. Right now, the combination of a comprehensive Job Register with the other programs and services combined with an engaged and supportive Employment Committee providing oversight and guidance allow the Society to efficiently provide Career Services at a low cost with significant impact. As long as there are jobs in astronomy, the Society will provide Career Services designed to support and enhance the careers of individual astronomers and the institutions that seek to employ astronomers to expand our shared knowledge of the Universe.

[9] `http://www.stsci.edu/stsci/meetings/WiA/BaltoCharter.html`

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# SURVIVAL STRATEGIES FOR AFRICAN AMERICAN ASTRONOMERS AND ASTROPHYSICISTS

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**Abstract.** The question of how to increase the number of women and minorities in astronomy has been approached from several directions in the United States including examination of admission policies, mentoring, and hiring practices. These point to departmental efforts to improve conditions for some of the students which has the overall benefit of improving conditions for all of the students. However, women and minority astronomers have managed to obtain doctorates even within the non-welcoming environment of certain astronomy and physics departments. I present here six strategies used by African American men and women to persevere if not thrive long enough to earn their doctorate. Embedded in this analysis is the idea of 'astronomy culture' and experiencing astronomy culture as a cross-cultural experience including elements of culture shock. These survival strategies are not exclusive to this small subpopulation but have been used by majority students, too.

## 1. African American History in Astronomy

Since 1955 only forty African Americans have earned doctorates in astronomy, astrophysics, or physics doing an astronomy dissertation. Considering the American Astronomical Society[1] has 7000 members and the Bureau of Labor Statistics lists 1500 employed astronomers, depending upon which number you consider to be a true estimate of the number of astronomers

[1] http://www.aas.org/

and considering that three African American astronomers are deceased, then African Americans make up 2.47% or 0.53% of the PhDs (Bureau of Labor Statistics 2008, American Astronomical Society). The statistics given by the Nelson Survey of the top 40 astronomy departments in the USA show that 1% of the faculty are African American which is 6 faculty out of 594 faculty for 2007 (Nelson 2007a&b). Other minorities found in the Nelson Survey are 1.2% for Hispanic faculty which is 7 faculty, and 7.1% for Asian faculty which is 42 faculty. Increasing the number of women and minorities in astronomy has been a goal for more than thirty years. 94 women faculty out of 594 are part of the 2007 survey which is 15.8%.

The American Astronomical Society (AAS) has attempted to address this imbalance through the creation of a women's group (Committee on the Status of Women 2009) and a minority group within AAS (Committee on the Status of Minorities 2002). Each of these has a newsletter that is freely available online that includes qualitative and quantitative studies about women and minorities in astronomy (Committee on the Status of Women, 1999; Committee on the Status of Minorities, 2001). These groups are meant to provide support for these minority astronomers and the newsletters are to share the latest research and opinions about diversifying astronomy.

Approaches to studying African American's success in the sciences has focused on the students as empty vessels which need to be filled with something that they are lacking, such as stronger math preparation, taking physics in secondary school, and completing a research project (Harding 1991; Harding 1998; Pearson Jr 1985; Hrabowski & Pearson Jr 1993; Pearson Jr & Bechtel 1989; Pearson Jr & Fechter 1994; Pearson Jr & Pearson 1985; Lewis 2003; Lewis *et al.* 2002; Lewis & Connell 2005; Lewis & Collins 2001).

My approach has been to consider African Americans success in astronomy as successfully navigating astronomy culture through framing it as a cross-cultural experience, moreover, as two cultures coming together with elements that conflict with each other.

Disciplinary cultures in academia have been explored by social scientists for some decades and studies of the cultures of scientists in the United States and other parts of the world have increased with the creation of departments focused on the history and philosophy of science and science and technology studies (Bourdieu 1990). Thus, the idea of an astronomy culture is consistent with these studies of other academic cultures. The issue with my cross-cultural approach is that African American culture is not monolithic: there are class, regional, occupational, and familial differences. Thus, the cultural conflicts experienced by individual African American students will differ from student to student.

## 2. Culture Shock

Culture Shock is defined as: “a sense of confusion and uncertainty sometimes with feelings of anxiety that may affect people exposed to an alien culture or environment without adequate preparation” (Dictionary.com 2011a) and similarly as “a state of bewilderment and distress experienced by an individual who is suddenly exposed to a new, strange, or foreign social and cultural environment.” (Dictionary.com 2011b). The literature on culture shock focuses on cross-cultural encounters whereas I am considering it for intra-cultural encounters: the encounter with astronomy culture. Without examining specific events, individual agency, or external events, culture shock posits that an individual will go through a cycle of positive and negative feelings towards a new culture that is predictable. Culture shock was first formulated by the anthropologist Kalervo Oberg (Oberg 1954).

He describes the four stages of culture shock as the Honeymoon phase, the Negotiation phase, the Adjustment phase, and the Mastery phase. The most anxiety and unhappiness occurs during the Negotiation and the Adjustment phases. The Negotiation phase has to do with learning to communicate, adjusting to new cultural norms, and as a result having feelings of loneliness and homesickness. The Adjustment phase concerns building new strategies and problem solving techniques to navigate the new culture as well as language acquisition: the new culture begins to make sense during this phase. Until the Mastery phase, the phase where the new culture is now normal, there is still anxiety that can be prolonged as long as the feeling of not understanding the culture remains.

## 3. Astronomy Culture Insider and Outsider, Personal and General

I was a student of physics and astronomy earning advanced degrees culminating in a PhD in astronomy and astrophysics in 1997. As a student assistant I worked on the Hubble Space Telescope, spent time at the Jet Propulsion Laboratory, and between my masters and by PhD I worked at NASA Goddard Space Flight Center. These experiences define me as an astronomy culture ‘insider’, but since 1997 I have focused on the social and cultural aspects of astronomy as an anthropologist of astronomy, thus I am also an astronomy culture ‘outsider’ (Naples 1996; Harding 1991; Collins 1986). My research and activist activities keep me circulating in and through astronomy communities throughout the United States and internationally, allowing me to utilize and explore my insider and outsider status.

## 4. Data Collection

The data that I used to formulate the six strategies for survival was collected largely informally, gleaned from conversations and discussions that I had with astronomers over the last twenty years. For the International Year of Astronomy 2009, I produced a film 'Hubble's Diverse Universe' in which I interviewed eight other African American and Hispanic American astrophysicists (Holbrook & IYA 2009; Tapia 2009; Holbrook 2009). In many of the interviews we discussed ideas and opinions about how to increase diversity within astronomy and we talked in detail about their own experiences in astronomy and as astronomers. I screened the film in physics and astronomy departments across the United States and after each screening there was discussion.

Also, I had the opportunity to meet with students in a semi-confidential setting where we discussed issues including some of these survival strategies. As part of the American Physical Society's Gender Equity Conversation task force (Committee on the Status of Women in Physics, 2009), which focuses specifically on increasing the number of women in physics, the clash of cultures emerged as an element during the workshops that we conducted. Many of the elements paralleled those in astronomy. In June 2010 with my mentor's encouragement, I wrote down the six survival strategies because they were important for the interviews that we were conducting with women and minority astronomers for our current research project (Traweek 2009; Guillen 2010).

## 5. The Six Survival Strategies' Broader Relevance

Once formulated, the six survival strategies were sent to various African American astronomers and some women astronomers and I collected their feedback. The women astronomers commented that these strategies applied to them as well and to others that they knew. The African American astronomers provided details of which strategies that they used. Next, the six survival strategies were presented to a group of aspiring black South African students in Cape Town in Fall 2010. They provided feedback on which strategies they were already using to navigate astronomy culture. In summary, the six survival strategies have been validated by individual astronomers either as strategies that they use or that they have seen used by others. Therefore, the six survival strategies are relevant beyond the African American community extending to majority students, women, and in international contexts.

1. *Oblivious*

   A person who tends to be oblivious to what is happening around them is using the first of the survival strategies. To be completely unaware of racist and sexist undertones and overtones is an effective strategy for surviving in a hostile environment. This could be an unintended strategy with a biological cause such as a form of Asperger syndrome, or it could be a behavior learned early on to ignore negative social interactions in favor of focusing exclusively on schoolwork.

As a person who travels through foreign cultures, I find that because I am American, I can be oblivious to the subtle racism found in other cultures. As a result, my life is better and less stressful when I am abroad. Such obliviousness is the result of being a stranger.

Another note, people who are aware of the sexism and racism often find their oblivious colleagues annoying because, well, they are oblivious. Especially annoying is when they insist that racism, sexism, and hostility do not exist. Instead it should be acknowledged that they could be employing a very successful survival strategy.

2. *Strong Familial Support*

   A family that is supportive can greatly aid students who are experiencing hardships as astronomy students. Family member can serve as a personal cheering section for the student reminding them that their family believe in them and believe that they can do astronomy, survive astronomy, and become an astronomer. Family members can also provide financial support that may allow the student to study full time without the distraction of having to be a teaching assistant during the time they are preparing for their qualifying exams. However, most acknowledge that it is the emotional support provided by their families that is the most important.

   The astronomy culture found in the United States is such that family is considered to be a distraction from doing astronomy. Having a family, unless you are a man with a partner who is the primary caregiver, is perceived negatively. The connection that minority students have with their families is considered negatively as well. Minority students are encouraged to move away from their family. Indicating that within astronomy, the support provided by family is not acknowledged, nor is recognition given to the fact that such families produced the students who are now in astronomy therefore they must have been doing something right.

3. *Strong Departmental Support*

   A mentor who believes that the student is capable of succeeding and helps them to succeed can help a student survive the most hostile environment. Similar to familial support, the mentor becomes a cheering section for the student. A mentor who is an astronomer who will actually say to other faculty in their department *"You cannot treat my* *student this way"* is every minority student's dream. Such a strong mentor who is willing to stand up to the rest of their department can transform a hostile environment by their actions, by forcing the hostile factions to not be blatant about their hostility. Ideally, students want the entire department to support them and believe in them, but just one person can compensate for this lack.

4. *Divinely Inspired*
   In many ways religion is a taboo subject in astronomy. Some would argue that 'the creative design' debate has made this more so the case. Nonetheless, some minority students feel that they are studying astronomy because it is their calling, i.e. it is the reason that they were put on the earth and born at this moment in time and space. Doing astronomy or being an astronomer could be more or less divine in their mind, for example thinking that they have a gift for doing astronomy, to feeling or believing that the Gods want them to become an astronomer for some divine purpose. Some level of divine purpose gives students a resilience needed to survive being an astronomy student. Thus, when bad things happen such as racist encounters or simply facing challenging new material, those that are divinely inspired know that the racists cannot deter them from becoming an astronomer and know that they are destined to master the material.
5. *Disconnect*
   A student may have the point of view that the environment that they are experiencing in graduate school or as college students is not the same as the environment that they will eventually be working in as an astronomer. The immediate culture may be so foreign, hostile, strange, etc, that they feel no connection and thus can consider themselves to be above the fray. *"These people are weird and I am not really one of them."* This is probably the equivalent of full blown culture shock, where the new culture is too strange, foreign, and repulsive to engage. In response, their education then becomes a transaction of goods and services rather than an acculturation process. They learn astronomy rather than how to be an astronomer. They are in survival mode where the process of getting a PhD becomes something to get through as quickly as possible. This disconnect allows them to distance themselves and thus be less impacted by a hostile environment. *"The haters cannot drive me out of astronomy."*
6. *Therapy and Medication*
   Getting an advanced degree can be an extremely stressful experience, and there is a sixth way to survive – therapy with or without chemical intervention. Asking professors today how graduate students in their generation dealt with the stress, many revealed that they drank a lot

of alcohol – a form of self-medication. Many graduate students in all disciplines today end up on antidepressants. However, if being divinely inspired is a taboo discussion, then being on antidepressants falls into another magnitude of taboo. Nonetheless, therapy has provided a positive and safe venue for some African American astronomy students to discuss their struggles with someone who neither is judgmental nor disbelieving.

## 6. Discussion

I continue to discuss these survival strategies with women and minority astronomers and I am mindful of adding to the list, but thus far no new strategies have been suggested. Many admit to using a blending of many of these strategies rather than relying on just one or two. On the other hand, these strategies are born in response to conflict or hostility and thankfully not every African American astronomer has had that experience.

Going back to having a supportive departmental mentor being what every student really wants, there is the expectation that this is the right of every student in astronomy. As professors, mentoring is part of their job description. But, as one African American astrophysicist said, *"Before meeting [my mentor], before sort of joining his department, the mentors, well, they were called mentors,"* implying that all mentors are not created equal. Isolation is a common experience among minority astronomy students and a dedicated mentor can do a lot to remove that sense of isolation. Isolation is often the first indication that a student is unhappy and considering dropping out of astronomy.

If the four phases of culture shock are layered onto the experiences of African American astronomy students, then the expectation is that they will be the most likely to consider abandoning astronomy during the Negotiation and Adjustment phases as they are struggling to learn the language, the norms, and how to navigate astronomy culture. The survival strategy of disconnect seems to arise during these two phases.

## 7. Conclusions

Survival strategies among women and minority astronomy students are varied but all can lead to successfully navigating what can be a very hostile and unsupportive environment. Thus, I am careful not to rank these strategies or place value judgments on them, for example considering which strategies are more or less healthy. However, I think it is fruitful to discuss these strategies in astronomy communities especially if departments are serious about being more inclusive, not just inclusive to African Americans but to all non-majority students.

I see two things that can be considered by astronomers that could move astronomy culture towards being more inclusive. First, astronomers need to acknowledge that the experience of individual students is not the same, and that this is especially true for women and minority students. What can be a healthy supportive environment for one student can be hostile and detrimental to another student. Acknowledging this difference is important and can lead to focusing on the individual needs of students allowing more to succeed. Second, returning to the survival strategies, astronomers can lend support to some of these strategies and change their departmental culture to make sure that other of these strategies are less often utilized. For example, professors should be on the lookout for non-majority students who are isolating themselves and be ready to offer support and encouragement at this crucial point.

There is no simple solution or band-aid that will suddenly increase the number of women and minority astronomers and diversify astronomy; however, analyzing astronomy culture and individual experiences may catalyze a cultural change that may bring such a goal within reach.

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# CITIZEN SCIENCE: CONTRIBUTIONS TO ASTRONOMY RESEARCH

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**Abstract.** The contributions of everyday individuals to significant research has grown dramatically beyond the early days of classical birdwatching and endeavors of amateurs of the $19^{th}$ century. Now people who are casually interested in science can participate directly in research covering diverse scientific fields. Regarding astronomy, volunteers, either as individuals or as networks of people, are involved in a variety of types of studies. Citizen Science is intuitive, engaging, yet necessarily robust in its adoption of scientific principles and methods. Herein, we discuss Citizen Science, focusing on fully participatory projects such as *Zooniverse* (by several of the authors CL, AS, LF, SB), with mention of other programs. In particular, we make the case that citizen science (CS) can be an important aspect of the scientific data analysis pipelines provided to scientists by observatories.

## 1. Introduction

Over time, the term "citizen science" has changed. Previously, it was most often associated with the activities of individuals who contributed extensive observations, engaged in data collection related activities, and enjoyed camaraderie while producing both modest and significant contributions to the advancement of science. Currently, several permutations of the definition of citizen science encompass not only a love of the natural world, but also other concepts such as the "democratization of science" including the formation of public policy by increasing public engagement in science. In this paper we refer to "citizen science" as the voluntary participation of individuals, many of whom may have no scientific training in scientific research. Their activities, such as visual observations, measurements, computations, or other investigations, contribute as an aggregate to original research goals. Specifically, the criteria used herein to define citizen science are:

- Non-expert participation: Scientific projects initiated by professionally trained researchers but participated in by volunteers without professional-level training in a relevant research area (and hence excluding self-funded researchers operating essentially as independent professionals).
- Many individuals: Involves networks of numerous individuals contributing to a specific set of goals, such that there are significantly more volunteers than professionals, usually by several orders of magnitude.
- Original Research: Research tasks that can significantly benefit from or are only possible through activities of a large number of humans.

This last attribute is important when considering citizen science in the context of data processing and analysis.

For the purpose of this paper, we adopt a definition that emphasizes the active involvement of a large group of individuals to achieve real research objectives with measurable outcomes. Citizen scientists in this context are genuine collaborators in the resulting research, and in some cases, their activities are fundamental to studies of the physical universe as well as providing key components in improving automated data analysis and machine learning. For this paper, we highlight the relationship of citizen science to astronomical observatories and professional astronomy with the confidence that many of these principles broadly apply to other sciences.

We also caution that many activities and programs that are educational and may contribute to scientific research are not considered as citizen science in our context. For example, we are not discussing the "traditional" citizen activities carried out by amateur astronomers who discover supernovae, monitor variable stars and so on, because the extent and scope of these activities are beyond the purpose of this paper. Other examples that are not under our umbrella of citizen science include science projects specifically designed for students as educational exercises or activities that mimic or reproduce scientific results or methods, or individual student projects assisting professional researchers. We also will not address distributed computing activities that involve individuals, or more accurately, their computers along the lines of *SETI@home* [1], in performing computational tasks for scientists.

This definition does, however, include a very wide range of projects. While many are simple classification tasks, complex scientific tasks also can be undertaken by citizen scientists. A welldeveloped, fairly involved example is Fold.it, a game-like experience in which participants develop new models of protein folding. The user can glean much scientific insight because opportunities for increasing understanding are cleverly embedded in the mechanics of gameplay, and a score that reflects the energy state of the protein is awarded[2].

## 2. Zooniverse Citizen Science

One of the largest collections of citizen science projects is the *Zooniverse* [3] that arose out of the *Galaxy Zoo* project, initiated in 2007 (Raddick *et al.* 2010). The idea behind *Galaxy Zoo* was to engage citizen scientists in ex-

[1] `http://setiathome.berkeley.edu/sah_about.php`

[2] See Cooper *et al.* (2010), as well as *Protein Folding* at `http://fold.it/portal/` and `http://folding.stanford.edu/`

[3] `http://www.zooniverse.org`

amining almost a million galaxies contained within the Sloan Digital Sky Survey (SDSS) to create simple classifications for each object from their visual appearance as spiral or elliptical. These morphological classifications provide important statistical insights regarding the dynamical states, angular momenta, and star-formation properties of galaxies, which greatly aid our understanding of galaxy formation and evolution, the effects of environment, and fundamental cosmology. Automated classification algorithms can provide some information but, to date, the human eye and judgment remain superior analysis tools for morphology. Selecting galaxies by appearance rather than other characteristics such as color, brightness, etc. establishes a specific sample for different types of ensuing studies. Public response was extremely positive and ultimately *Galaxy Zoo* and *Galaxy Zoo 2* gathered over 60 million classifications. Several new research investigations have been spawned, and many papers published[4].

The *Zooniverse* has been expanded into other areas, so far mostly astronomy related but some beyond that discipline. The successor to *Galaxy Zoo 2* includes high resolution Hubble Space Telescope (HST) data from several programs including one of the observatory's *Treasury Programs*[5] to enable citizen scientist classifications of distant galaxies from a deep survey, and thereby contributing an additional dimension to galaxy morphology studies. *Galaxy Zoo: Hubble* is enabling direct examination of changes in the galaxy population from early in cosmic history until now.

Other astronomically related *Zooniverse* projects include the *Milky Way Project*: visual scrutinizing infrared images of the Milky Way galaxy to identify bubbles of material and contribute to the understanding of star formation environments and stellar collapse; *Solar Storm Watch:* spotting explosions on the Sun and tracking them across space to Earth, and *Galaxy Zoo Mergers:* selecting simulated models that best match images of real merging galaxies.

Thus, *Zooniverse* projects are based on human interpretation of complex phenomena through activities that cannot be thoroughly automated. This interaction with data is sometimes called *human computation.* Many *Zooniverse* projects provide tiers of training from simple to more complicated so citizen scientists can accomplish the tasks successfully and advance in expertise. *Zooniverse* projects, available through a web browser, are generally not dependent upon *when* or *where* the participant does the analysis. This contrasts with many other historical and current data collection activities that depend upon the location and timing of amateur

[4]See Lintott *et al.* (2009 & 2011), as well as a full set of references at `http://www.galaxyzoo.org/published_papers`

[5]`http://archive.stsci.edu/hst/tall.html`

contributions (cf. Budburst[6], Community Collaborative Rain, Snow and Hail[CoCoRaHS[7]], Coral Reef Alliance[8], eBird[9], Globe at Night Dark Skies Awareness[10], Christmas Bird[11]) and numerous others (including International Occultation Timing Association[12], Monarch Watch[13], SciSpy[14], and SKYWARN[15]).

## 3. Key Advantages – Why is citizen science a significant component of large dataset analysis?

The kinds of citizen science activities employed by *Zooniverse* projects are primarily an attempt to deal with the flood of data being produced in astronomy, especially by increasingly automated large-scale surveys. Specifically, the *Zooniverse* allows a distributed community of volunteers to analyze professionally collected data.

**Scalability.** The first advantage of citizen science is its scalability. In a prescient paper, Lahav *et al.* (1995), discussing the then forthcoming Sloan Digital Sky Survey, noted that *"Classifying very large data sets is obviously beyond the capability of a single person"*. Distributing data to large numbers of individuals and collecting classification results for any given project could be a daunting management challenge, and so automated processes were seen as the most pragmatic solution.

Two circumstances have helped to greatly improve the practicality of citizen science. First, the adoption of public data sets and archives adhering to agreed-upon formats allows ready access to the data by a broad community. Second, the rapid development of communications technology in the last fifteen years, and resulting pervasion of the Internet in everyday life, enables very large numbers of volunteers to be engaged on a project. By dramatically scaling up the number of people available to work on a problem, citizen science eases the problem of the data flood by alleviating the reliance solely on automatic classifications, which often do not yet perform as well as the human techniques they were intended to replace.

Typically in the *Zooniverse*, such projects see a large spike in traffic just after activation, although sustained attention is achievable. For example, in

[6] `http://neoninc.org/budburst/`
[7] `http://www.cocorahs.org/`
[8] `http://coral.org/`
[9] `http://ebird.org/content/ebird/`
[10] `http://www.darkskiesawareness.org/gan.php`
[11] `http://birds.audubon.org/christmas-bird-count`
[12] `http://www.occultations.org/`
[13] `http://www.monarchwatch.org/`
[14] `http://scispy.discovery.com/`
[15] `http://www.nws.noaa.gov/skywarn/`

the *Planet Hunters* project[16] originated in December 2010, participants look for transits in data from NASA's Kepler satellite. In May 2011, five months after launch, *Planet Hunters* was still attracting activity that amounts to the equivalent of 51 Full Time Equivalent staff[17]. *Galaxy Zoo* alone has recorded more than 150 million classifications over nearly four years.

This enormous effort would be largely wasted if it produced results that were not useful to scientists. Careful design and testing is required prior to project initiation in order to ensure that the time invested by citizen scientists is fruitful. To this end, many citizen science activities have standalone tutorials, and some (including the original *Galaxy Zoo* and NASA's *Stardust@home*, which asked participants to identify dust grains in videos of aerogel retrieved from the Stardust mission to Comet Wild-2) even insist that a test is completed before allowing participation. Instead, the *Zooniverse* adopts a particularly effective system by incorporating participant guidance into the classification process (see Fig. 1). Careful weighting of users (Lintott *et al.* 2008) can be used to identify volunteers who perform particularly well when compared to expert data. This has the critical advantage of allowing different weightings to be used on the same database of classifications, extracting different user behaviors *post hoc* as may be required. This is analogous to weighting various automated algorithms or tuning software based processes for the particular science being pursued.

Further efficiencies can be achieved through a judicious choice of images to be considered. The *Galaxy Zoo Supernovae* project[18] aims to rapidly assess candidate transients supplied by the Palomar Transient Factory (PTF) (Law *et al.* 2009). Once data is uploaded, subscribing volunteers receive an alert asking for their help in assigning a score to each candidate according to answers offered for simple questions, as illustrated in Fig. 1 (adapted from Smith *et al.* 2011). This score not only calculates the final result, but also the priority with which candidates are presented for further inspection, ensuring that robust results can be obtained rapidly. This near real time intervention in data collection will be increasingly important as survey size continues to increase and rapid decisions need to be made as to what to follow up or even record, for example in transient object surveys.

**Serendipity.** A second key advantage of human classification is that it preserves the opportunity for serendipitous discovery. Humans involved in a classification task will continue to look for unusual objects. Further, it has been seen that the interplay of the science team and citizen scientists can be multifaceted and can follow unexpected and quite fruitful trajectories

[16] `http://www.planethunters.org`
[17] 1 FTE = 2080 hours a year = 52 weeks @ 40 hours a week.
[18] `http://supernova.galaxyzoo.org`

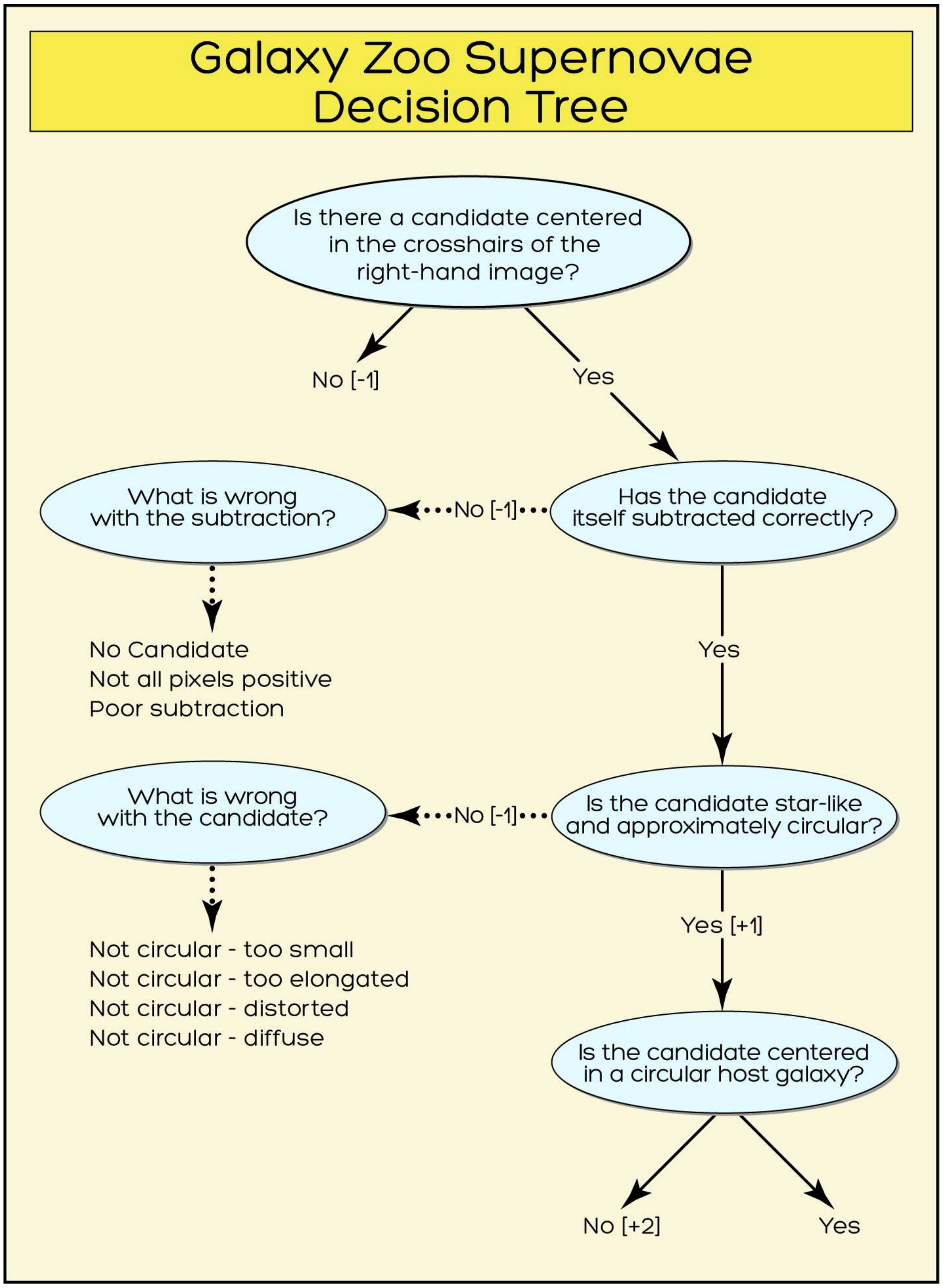


*Figure 1.* Decision tree and scoring scheme for Galaxy Zoo Supernovae. (adapted from Smith *et al.* 2011)

that might be quite different than the original research goals. For example, *Galaxy Zoo* volunteer Hanny van Arkel spotted an unusual, and previously unknown, object, which became known as Hanny's Voorwerp[19]. This object was followed-up by studies using several ground-based observatories, the Swift satellite, and with HST by the Hubble Heritage Team[20]. These studies indicate that Hanny's Voorwerp is a unique example of a quasar light echo. A vast, twisted filament of gas is observed to be illuminated by the powerful beam of a quasar that existed in the center of IC 2497 until recently, but is no longer active. The HST campaign, in particular, suggested that gas outflow from the spiral galaxy IC 2497 is interacting with a nearby part of the filament, producing star formation.

Another remarkable unforeseen occurrence involved a self-organized group of *Zooniverse* volunteers who identified, and then systematically searched for members of a new class of compact galaxies, known as "Galaxy Zoo Peas" (Cardamone *et al.* 2009) for their characteristic strong green color in the SDSS images. These galaxies have star formation efficiencies more commonly associated with Lyman-break galaxies at redshifts of z$\sim$2-3. In this case, the citizen scientists were able to make significant progress in investigating the "Peas" using tools provided both by *Galaxy Zoo* and the SDSS itself. Building tools and systems that encourage this higher-level behavior is an important part of citizen science development as it offers both interest for advanced users and a valuable route to discovery for the citizen scientists as well as their professional collaborators.

**Relation to Machine Learning.** A third important advantage is the ability of citizen science projects to produce large training sets that can be used to improve machine learning approaches. As well as the benefits of size, there is some evidence (e.g. Banerji *et al.* 2010) that the richness of the training sets, which include not only definitive answers but also quantitative estimates of difficulty of classification, can lead to significant improvement in automated techniques.

Tasks can be divided between machine and citizen to take advantage of their different capabilities. The supernova project discussed above is a simple example, in which the PTF's pipeline is responsible for identifying potential supernovae that are then assessed by volunteers. In the future, these two modes will become more integrated in real time, with observatory pipelines deciding which data to pass to humans based on an assessment of the data being received. For example, training sets could be generated on the fly hour-by-hour as sky conditions and instrument performance changes

[19]See Lintott *et al.* (2009), as well as The Galaxy Zoo and Hanny's Voorwerp (2008) at `http://www.ing.iac.es/PR/SH/SH2008/zoo.html`

[20]`http://hubblesite.org/newscenter/archive/releases/2011/01/`

or the proportion of candidates passed to humans could vary as the number of volunteers waxes and wanes over the course of a day. Alternatively unusual images could be flagged for human follow-up according to some preset criteria. Extensive development of methods to balance decisions made by several different machine learning techniques has already taken place, and should be easily adapted to include citizen scientists as a classification option.

This vision, in which appropriate citizen science projects could form a natural part of an observatory's data reduction pipeline is ambitious, and demands some agility and adaptability on the part of observatory facility scientists and engineers, but the key advantages of citizen science outlined above make it imperative if we are to continue to make the most of the data available.

One of many methods for measuring the success of citizen science in terms of research productivity is the suite of case studies of serendipitous discoveries that came about due to the activities of the volunteers, mentioned above. Other measures that are commonly used to access science productivity relate to publications. Consider that *Galaxy Zoo* has only been in operation for approximately 3 years; it is remarkable that 21 refereed papers and nearly 500 citations have resulted from the citizen science work. In addition, three of the top 100 SDSS papers in the last three years are from *Galaxy Zoo*. The citizen science research, while small, has contributed to about 2-3% of the SDSS publications to date (although SDSS publications have amassed over a considerably longer period of time). Citizen science activities have a great potential to grow and contribute more significant results to astronomical research.

## 4. Techniques, Tools and Infrastructure – How to make CS happen?

Distributed data analysis of the kind discussed in this chapter is only possible thanks to the widespread availability of the World Wide Web. The fate of the original *Galaxy Zoo*, which was overwhelmed by demand for much of its first day, illustrates the need to choose tools appropriate to accommodate the spikes in traffic received by many citizen science projects.

Commercial cloud computing delivers a solution for web applications with unpredictable traffic. Load balancing and auto-scaling tools supplied by brokers such as Amazon Web Services ensure that new servers can rapidly and automatically be made available whenever necessary. A modular implementation of the application, in which a database and application layer communicates with a thin website layer *via* a RESTful Application Programming Interface (API) makes this scaling easier, and helps make code reuse between projects more viable. This structure can also support alternative presentations of an interface, with encouraging results. *Tiny-planets.com* (a commercially developed educational site for 5-7 year olds) hosts a version of *Zooniverse's Moon Zoo* interface; Warner Brothers have developed a version of the *Milky Way Project* to tie in with their "Green Lantern" film; and the *Galaxy Zoo* iPhone app has seen an increase of two orders of magnitude compared to the web browser version in the number of classifications *per user*; impressive, even given the likely selection effects in participation that are operating.

In addition to the main site, tools which encourage communication between the volunteers and the project scientists and developers are of vital importance in attracting and sustaining a community. Much of the serendipitous science from *Galaxy Zoo* came from a basic forum, and a new "Talk" tool that can be more closely integrated with the process of classification itself has been developed and released[21]. The ultimate goal of such tools should be to bring questions and interesting discoveries to the scientists' attention only when expert input is necessary, reducing the time needed for appropriate mentoring while still ensuring nothing gets lost. For more one-way communication, most citizen science projects use blogs to keep the community informed about the progress of research.

## 5. Citizen Science and Observatories

Astronomical observatories, especially those with federal funding, provide access to facilities including observational equipment and data capture primarily for scientific research. In order to maximize the science return on the funding investment, open data policies are implemented, delivering access to archives for a wide community. In addition, it is the practice of current observatories to implement facility pipeline processing for calibration and instrument characteristic removal, populating the archives not only with raw observations but higher-level science data. Experience has shown that observatories that do accommodate robust archives and data analysis pipelines and tools enjoy remarkable productivity (Apai *et al.* 2010).

Traditionally, there has not been any routine relationship between professional observatories and citizen science. There have been isolated examples of public participation and the integration of amateur activities into science research, but observatories have not adopted citizen science contributions as routine business. With the growing emphasis on large, complicated datasets, as well as the acquisition of survey data that cover a significant portion of the sky, additional analysis resources may be required. Experience with the *Zooniverse* has demonstrated that citizen science can

[21] `https://github.com/zooniverse/Talk`

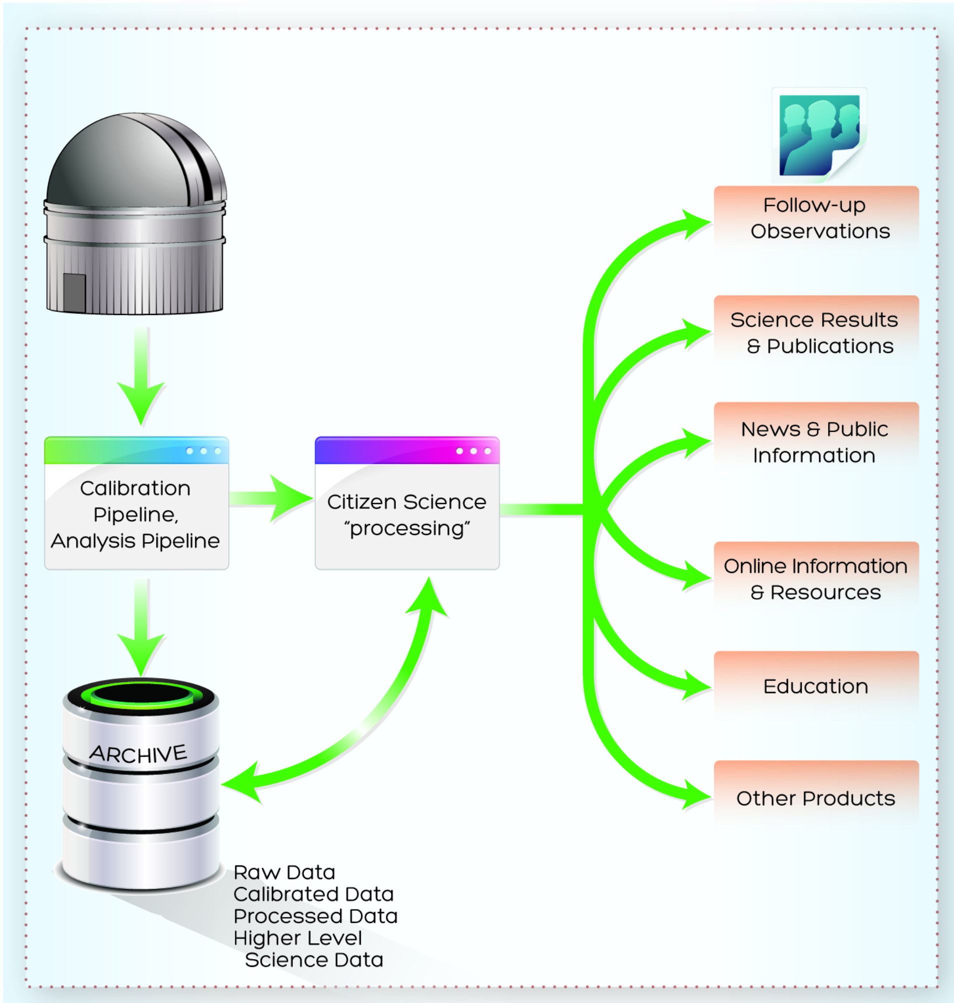


*Figure 2.* Notional flow of data processing for astronomical observations, including standard pipelines, archive, and Citizen Science analysis pipeline. (© STScI)

make a contribution. Thus, the addition of a citizen science infrastructure to the data analysis pipeline may be valuable and, in fact, advisable, in order to improve science productivity for specific types of data and research problems. For example, as shown in Fig. 2, data flows from the observatory to the systems that provide data quality checking, calibration, data analysis pipeline processing and the production of higher-level science data products. Output data and products are deposited in the observatory archive and can be delivered to a citizen science project. The citizen science "pipeline" produces additional information that can be merged with the other data products, and stored in the archive.

Of course it is possible for curators of large private datasets also to make use of citizen science as an additional analysis tool, but one should note that a by-product of restricted data access policies is that the public user (as well as members of the science community) become disinterested in the data. This creates a situation where many talented analyzers/scientists (unaffiliated with the data) do not spend time contributing to challenging research studies related to the proprietary data. This sort of restriction also has a dampening effect on the potential for serendipitous and spontaneous citizen-led discovery and research.

In order for a research topic to benefit from unique human cognitive abilities exercised by a collective of many individuals it must engage and challenge the participants by ensuring that they work with real scientific data, information, and resources. Citizen science pipelines must be designed with care to be the most beneficial for both the science teams and the citizen scientist. The implementation of citizen science contributions necessarily involve the scientists with a vested interest in the research goal. *Zooniverse* experience demonstrates that citizen participants are highly motivated not only by contributing to research, but also by having a connection to the research team.

It is clear that citizen science volunteers need appropriate infrastructure and tools. Access to imagery and visualization of sky locations can also be an engagement tool, promoting a sense of ownership for the individual, even if the analysis is of some other sort of data product (for example, a light curve). Some individuals will accomplish further investigations, confer with other citizen scientists, and will report back on their individual work, if the appropriate forums are available. This does imply that the research team or the observatory must make a modest investment in citizen science infrastructure, services, and tools to achieve success.

To maximize the contribution of the "citizen science module" (Fig. 2) in the data analysis pipeline, individuals must find the activities in several ways. For example, the *Galaxy Zoo Hubble* project created as a follow-on to the SDSS-based *Galaxy Zoo* was advertised through both the *Zooniverse* and HST's HubbleSite.org. This latter site is the main public interface to HST and has myriad resources including activities, information, and interactive modules. The majority of citizen scientists participated through the *Zooniverse*, but the clientele of HubbleSite also participated. Thus coordination between the main citizen science portal and the observatory portal was fruitful and cast a wider net for participation.

## 6. Summary

Citizen Science, as we use the term in this chapter, provides a professionalized manner in which any individual can contribute to substantive, authentic scientific research. In particular, the *Zooniverse* projects have demonstrated that research projects can significantly benefit from large numbers of participants in cases especially where human cognitive abilities can supplement automated data analysis.

Initial results have shown that for observatories collecting large, sometimes complicated and also survey type datasets, *Zooniverse* methodology produces robust results as well as serendipitous discoveries. Specifically, citizen scientists have contributed to the results from the large SDSS sky survey, the concentrated transient/planet finding studies from the NASA Kepler mission, characterization of lunar craters and features from the Lunar Reconnaissance Observatory, and the galaxy morphology studies from HST Treasury programs, to name a few.

Selection of projects is critical if we are not to waste the time of volunteers or to fail to meet the goal of providing authentic engagement with research. Basic data analysis task should, where possible, be automated rather than thoughtlessly passed to citizen scientists. Instead, by incorporating the potential to support citizen science into a standard pipeline as illustrated in Fig 2, it should be possible to allow scientists with a need to use the resources of volunteers to rapidly prototype, test and launch a project at whatever level is necessary.

The presence of an existing community of engaged citizen scientists also allows for the possibility of "career" development for the citizen scientists themselves. As discussed above, engagement is possible at many levels of task from simple classification, to investigation of interesting objects and eventually to follow-up or detailed work. This progression to higher level tasks will be a necessary part of adapting citizen science for the long term as automation of basic data analysis continues, driven in part by the results of the citizen science projects themselves.

Reflection upon the growth and success of this type of citizen science has led us to believe that it could be quite beneficial to integrate citizen science analysis "modules" (projects) into an observatory pipeline in some form. Citizen science will continue to grow and evolve along its own trajectory. Observatory personnel would be wise to monitor citizen science techniques for possible adaptation to standard high level data processing. Certainly when new sky survey observatories are planned, citizen science contributions should be considered from the outset. One instance is the planning for the Large Synoptic Survey Telescope (LSST[22]). While citizen science is

[22] `http://www.lsst.org/lsst`

not yet fully integrated into the data analysis pipeline, it is planned that data from the LSST pipeline will be available for citizen science projects.

It also has not escaped our notice that astronomical citizen science makes a significant contribution to public understanding of science, with a growing potential for formal and informal science education. Our focus here, however, is the significant impact that citizen science is having on scientific research.

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# ACCESSIBLE ASTRONOMY: ASTRONOMY FOR EVERYONE

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**Abstract.** In this chapter, Noreen Grice, an astronomy educator, describes her expertise in making astronomy accessible to people with disabilities.

## 1. Disability Statistics

According to the United States Census, 54 million Americans or about one out of every five citizens are living with a disability. Worldwide, the United Nations and various international organizations estimate that more than 500 million people are disabled. People who do not have a disability and are "temporarily able" may require assistance later in life due to age-related health conditions.

Although there are different interpretations of the word disability, it is often associated with a limitation of physical or mental abilities, including mobility, vision, hearing, communication and learning. People living with a severe disability may require augmentation and assistive technology to fulfill basic life needs, while others may only need limited assistance to participate in school, work or other events.

## 2. My Involvement with Accessibility

In 1984, I was an astronomy major in my senior year of college, working part time in the planetarium at the Boston Museum of Science. One afternoon, a group of blind students came to my planetarium show. A manager told me to help the students to their seats.

This was a pre-recorded program, so I welcomed everyone to the planetarium and pressed a button on the computer to start the show. At the end of the show, I wondered what these blind students thought of the planetarium, so I asked them. They said, "It stunk." That was the first time I realized that astronomy and the planetarium were not very accessible.

I began work immediately to create accessible resources, starting with tactile images. After a few meetings with people from the Perkins School for the Blind and the Massachusetts Association of the Blind, I used hand tools to etch tactile images from plastic pages. After a month of continuous effort, I had created a spiral bound book of tactile images to accompany all of the planetarium shows at the Museum. At least, blind visitors would have a resource that they could borrow during the planetarium shows.

Next, I began writing the text for a new astronomy book that would be specifically designed for blind readers. I called the book *Touch the Stars*. As I composed the text, I imagined that many tactile images would accompany it including constellations, phases of the moon, eclipses, nebulae and galaxies. However, in the mid 1980s, technology to mass-produce tactile images did not exist. Primitive methods, such as gluing string to cardboard, were used to individually make touchable pictures. So, I graduated from college, put the book away in a box, and headed to California for graduate school.

## 3. Creating Resources to Make the Universe More Accessible

Two years later, I returned to the Boston Museum of Science with an M.S. in astronomy. Through a small grant, I purchased a state-of-the-art Braille embosser. I began designing artwork with an Apple IIE computer and mass-producing tactile astronomy images to go along with all of the planetarium shows. Because the Braille paper was so inexpensive, visitors could keep the images after the planetarium show. Many visitors told me after the programs that they never knew what these space-related objects looked like before. The tactile images provided a great conversation starter and helped me understand how to simplify and improve my designs.

With the Braille embosser, I was finally able to design the tactile images for my book. The Museum of Science supported my work and published *Touch the Stars* in 1990. The book was such a success that it was expanded into second and third editions in 1994 and 1998.

In 1999, I was contacted by a NASA educator who had seen a copy of *Touch the Stars* in a bookstore in Chicago. He said that it was too bad something like that didn't exist for the Hubble Space Telescope images. And that began my work on *Touch the Universe: A NASA Braille Book of Astronomy*!

I collaborated with the NASA educator and a teacher of the blind in Colorado. As I designed prototype tactile images, students at the Colorado School for the Blind reviewed them. The students were surprised that I

*Figure 1.* An amateur astronomer shows a child how a telescope works by providing a tactile tour of the telescope. (Photo credit: Andrew Cheng, Texas Astronomical Society of Dallas)

wanted their opinion of my tactile images and the teacher observed that, at first, their comments were neutral because they didn't want to be critical. However, the teacher explained that I was asking them to be very critical so the tactile pictures would be very useful. Then, they expressed what they really liked and disliked.

The students asked me to reduce some of the "tactile clutter" that I designed into the images. I learned from these students that "less is more." That is, when you simplify a tactile image, it is easier for the tactile reader (especially a person who has limited experience with tactile images) to imagine the picture in their mind. When a sighted person examines a picture, they look at the whole image and then examine the details. A tactile reader must examine the details and piece it together in their mind. This was a powerful concept for me. Based on student and teacher comments and suggestions, I continued to make changes in the tactile images until they were deemed "accepted."

I organized *Touch the Universe* as a voyage of discovery, starting from Earth orbit, traveling through the solar system, our galaxy and outward to the most distant image taken by HST at the time, the Hubble Northern Deep Field. Tactile codes were assigned to distinguish different components of the images. On the facing page was a caption for each image. For example, the caption for The Ring Nebula image includes, "The true colors in this image indicate different layers of gases: helium (blue), oxygen (green), and nitrogen (red). The outline of the outer layer of cool nitrogen is represented by a dotted texture, the middle hot layer with oxygen has a texture of parallel lines, and the very hot center area of helium, with a star, has no texture."

Originally, I had planned to duplicate the images one by one at home on plastic sheets; however, the project received a lot of media attention and Joseph Henry Press became the publisher. The final images were printed in color on paper and embossed with metal plates like a greeting card, with text pages in print and Braille. The book was published in 2002, the same year the $4^{th}$ edition of *Touch the Stars* was available.

Shortly after *Touch the Universe* was published, a solar scientist at NASA was interested in creating a tactile book about the Sun. This started me working on a new tactile book entitled *Touch the Sun: A NASA Braille Book*. The vivid tactile images for this book were silkscreened and vacuum-formed (thermoform) onto plastic pages. Joseph Henry Press published *Touch the Sun* in 2005.

Also in 2005, I wrote a book about learning the Moon's phases. Entitled *The Little Moon Phase Book* (with its Spanish counterpart *El Pequeño Libro de las Fases de la Luna*), this features tactile naked eye and glow-in-the-dark tactile telescopic views of the moon during the different lunar phases. The *Little Moon Phase Book* also includes a text description of why the phases of the moon occur that corresponds to the tactile images in the book. The motivation behind this book was a simple resource that sighted or blind people could use to look at the moon, turning the pages until the tactile image matched what they saw. People who could not see the moon visually could still observe it by touch and read about the phases. *The Little Moon Phase Book* was produced (in English and Spanish) by Ozone Publishing using a tactile silkscreen technology.

My third NASA book dealt with observing the universe through different wavelengths. As co-author on *Touch the Invisible Sky: A Multi-Wavelength Braille Book Featuring Tactile NASA Images*, I wrote sections of the text and designed the tactile images in sets, comparing color/tactile views of an object at four different wavelengths.

One of the focus groups that reviewed the text and tactile images from this book included students and adults who were blind or had low vision, at the National Federation of the Blind's Youth Slam. As we discussed the images, one student who had low vision commented about the bright colors in a galaxy image. Immediately, one of the adult mentors said, "The pictures are in color? You mean sighted people can use our book too?" I found

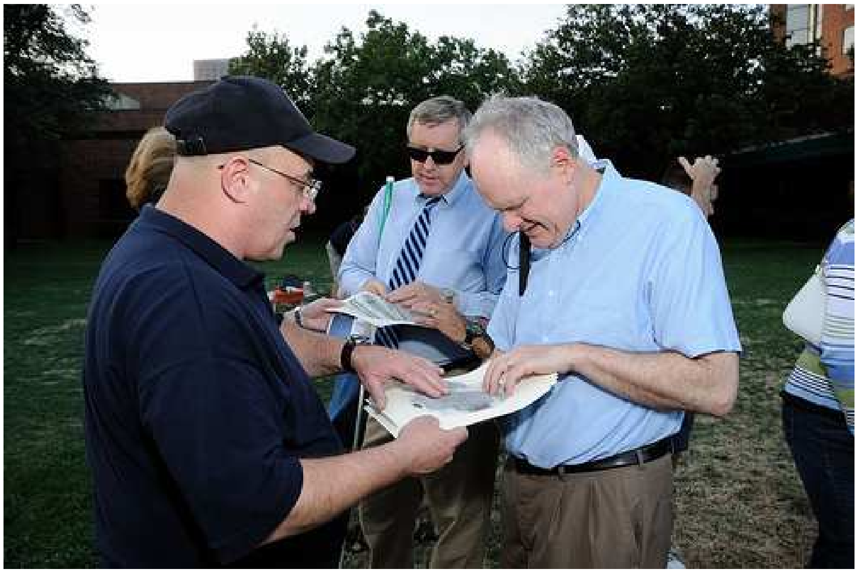

*Figure 2.* An amateur astronomer verbally describes an image as a visitor examines the image by touch. (Photo credit: Andrew Cheng, Texas Astronomical Society of Dallas)

this to be incredibly profound because my goal had been to create books with accessible text (in print and Braille) and accessible images (in color and touchable) that students could use together. Rather than reproducing books for students who were blind, I had been designing books that could be used by everyone from the start. Another strength of this book was that since no human can see beyond visible light, all readers were blind to other wavelengths. Everyone would be learning and experiencing the images together. Ozone Publishing released *Touch the Invisible Sky* in 2007.

## 4. A Guide to Accessible Astronomy Places

Although my books have been focused on providing tactile access to the cosmos, I have also received training in assistive technology for people with a variety of disabilities. For my latest book, I decided to write a guide for making astronomy available to people through mobility access, non-visual access, non-hearing access, and non-verbal communication access.

*Everyone's Universe: A Guide to Accessible Astronomy Places* is really two books in one. The first half of the book is an educator's guide to making astronomy accessible at star parties and observatories. In the past, it was assumed that if you wanted to look through an observatory telescope, you had to walk up a steep spiral staircase. Or, you had to have enough vision to see the object in the eyepiece or be able to speak with the tele-

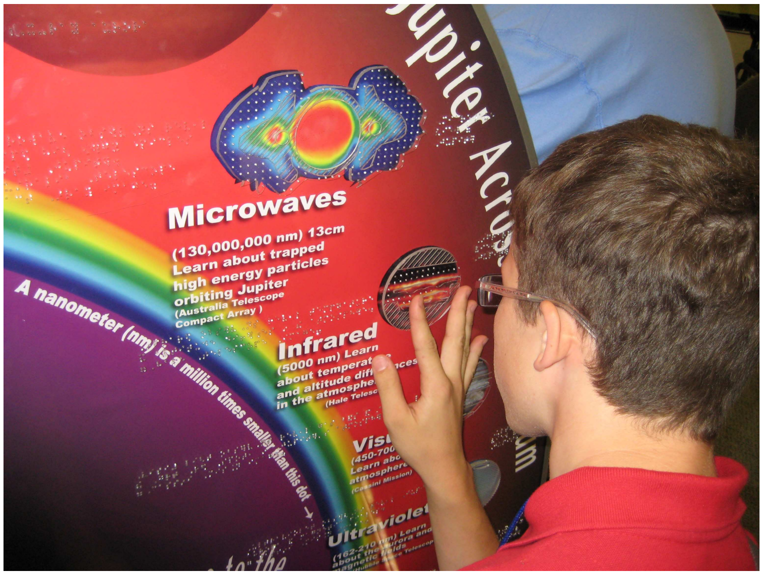


*Figure 3.* A visitor explores tactile graphics on a NASA exhibit designed by Noreen Grice. (Photo credit: Noreen Grice)

scope attendant. Not anymore! This book describes strategies and resources that make observing not only accessible for a person with a mobility, a visual, a hearing or a communication disability, but also more convenient for everyone else.

The second part of the book is a friendly travel guide within the United States (plus the Thinktank Museum in England) that highlights observatories and planetariums that offer accessible features. These might include an extended eyepiece for people in wheelchairs, tactile images for visually impaired, assistive listening systems or captioning for people with hearing impairments and communication boards for people who communicate non-verbally.

*Everyone's Universe* was published in 2011 and has the potential to change the way people perceive disabilities and enhance the access and participation of this underserved population. Then, it really will be everyone's universe.

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# GEMINI OBSERVATORY TAKES ITS LOCAL COMMUNITIES ON AN EXPANDING JOURNEY THROUGH THE UNIVERSE

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**Abstract.** Currently in its $7^{th}$ year (2011) Hawaii's annual Journey through the Universe (JttU) program is a flagship Gemini Observatory public education/outreach initiative involving a broad cross-section of the local Hawai'i Island astronomical community, the public, educators, businesses, local government officials, and thousands of local students. This paper describes the program, its history, planning, implementation, as well as the program's objectives and philosophy. The success of this program is documented here, as measured by continuous and expanding engagement of educators, the community, and the public, along with formal evaluation feedback and selected informal verbal testimony. The program's success also serves as justification for the planned adaptation of a version of the program in Chile in 2011 (adapted for Chilean educational and cultural differences). Finally, lessons learned are shared which have refined the program for Gemini's host communities but can also apply to any institution wishing to initiate a similar program.

## 1. Introduction

The Journey through the Universe program as managed and implemented by the Gemini Observatory[1,2] is modeled after the national Journey

[1] http://www.gemini.edu/
[2] http://www.gemini.edu/journey

through the Universe (JttU) program founded in 1999 by National Center for Earth and Space Science Education (NCESSE[3]). The program, now entering its $8^{th}$ year (2011) on the Big Island of Hawai'i, has experienced sustained (and sustainable) growth during its tenure in Hawai'i and has matured into a well-established and well-recognized (locally and nationally) educational program[4]. The program's key elements include:

- Astronomy and observatory staff educators/presenters who share their work and career passions in local classrooms (average of 5000+ participating students at over 300 classrooms per year);
- Teacher and master teacher workshops based on educational modules[5] that are aligned with state and national education standards (four modules with average of 100+ teachers participating in workshops each year);
- Parent, student, and public science events (average of 1,730 participants/year);
- Community business/education partnership opportunities providing volunteer assistance (~24 "Ambassadors" per year help observatory staff educators/presenters). 29 local business partners (2011, see Table 1) provide additional resources i.e. t-shirts, food, prizes etc.);
- Guest lecturers and educators from institutions beyond Hawai'i (NASA, NSF, Lunar Science Institute, etc.) who participate in many events and activities in order to broaden exposure and diversity for the experience of local students and the public.

All of these elements are combined to create an educationally focused, event/fun-filled week during the annual "Journey Week" – an expanded 10-day "week" that is the core of the JttU program[6]. During the past seven years this program has evolved based on evaluations, feedback and other informal input and continues to grow in new directions as described herein.

## 2. History

The JttU program originally took root under the leadership of Jeff Goldstein of the National Center for Earth and Space Science Education (NCESSE) as a national network of communities sharing a common goal of bringing science, technology, engineering and mathematics (STEM) researchers into local classrooms to share their passion for scientific exploration. The original JttU program began in 1999 and ran under NCESSE until 2006. During this period its reach grew into 13 communities across

[3] http://ncesse.org/
[4] http://www.gemini.edu/images/pio/jttu/NSTA_article.pdf
[5] http://journeythroughtheuniverse.org/program_overview/po_co.html
[6] http://www.gemini.edu/journey

TABLE 1. All community partners participating in JttU in the 2011 implementation of the program.

| |
|---|
| Bank of Hawai'i |
| Big Island Toyota |
| Business – Education Partnership |
| Caltech Submillimeter Observatory |
| Canada-France-Hawai'i Telescope |
| Ctr for Astronomy & Physics Ed. Research |
| DOE Hilo/Laupahoehoe/Waiakea Complex |
| Gemini Observatory |
| Hawai'i Island Chamber of Commerce |
| Hawai'i Island Economic Development Board |
| Hawai'i Tribune-Herald |
| 'Imiloa Astronomy Education Center |
| James Clerk Maxwell Telescope |
| Japanese Chamber of Commerce & Industry |
| Joint Astronomy Centre |
| KTA Superstores |
| KWXX |
| Mauna Kea Observatories Outreach Committee |
| NASA Infrared Telescope Facility |
| NASA Lunar Science Institute |
| National Radio Astronomy Observatory |
| Rotary Club of Hilo Bay |
| Smithsonian Submillimeter Array |
| Subaru Telescope |
| Thirty Meter Telescope |
| United Kingdom Infrared Telescope |
| University of Hawai'i at Hilo |
| UH Hoku Ke'a and 2.2 Meter Telescopes |
| UH Institute for Astronomy |

the US[7]. Only a small fraction of this original network of communities is still active in the program since core funding of the program was discontinued in 2005. After 2005 participating communities were left to pursue continuation of the program on a self-funded, ad-hoc basis.

Gemini Observatory joined the JttU network in 2004 and, in part due to the significant outreach and educational resources available at Gemini as well as the significant community of observatories on Mauna Kea at large, provided a model community for the effective integration of this program.

[7] http://journeythroughtheuniverse.org/lc_network/lcn_cnm.html

The combination of a well-coordinated community of observatories[8] with common outreach objectives, and a local department of education anxious to explore new and innovative ways to establish partnerships that would impact students, provided a formula and environment for sustained success that would outlive the original JttU program at NCESSE. The legacy of the original JttU program continues to thrive on Hawai'i Island and is, and will continue to be, implemented in a manner that attracts and affects learners of all ages and engages observatory researchers and staff in ways that are fun, educational, and inspirational for everyone involved.

In summarizing the history of this program, it would be unfair to not recognize the similarities (and differences) between the JttU program and Project Astro[9] which continues (2011) under the management and oversight of the Astronomical Society of the Pacific[10]. While the two programs established themselves during similar timeframes, Project Astro is based on a commitment for scientists to visit classrooms four times in a given year whereas JttU is based on a high-impact week of programming and classroom visits that engages the entire community and relies on the relationship established between researchers and teachers to foster and facilitate future follow-up visits. Finally, because the JttU program meets so many of the criteria and goals of a Project Astro site, the Hawai'i JttU program is considered an "adjunct" Project Astro site and JttU staff participate fully in the annual Project Astro site-leaders workshops[11].

Due to the successful history of JttU in Hawai'i, the program is expected to continue and grow in new and innovative directions that will keep the program fresh and relevant for the future. Many of these visions are discussed in Section 10 of this paper.

## 3. Programmatic Objectives

The JttU program as currently implemented in Hawai'i has three primary institutional objectives for the Gemini Observatory – these are to:

- Connect and engage learners with educators, scientists and engineers in an effective, lasting, and relevant manner;
- Engage the local community at all levels; and
- Foster an environment where students can pursue STEM careers and find local support and role models for their advancement.

[8] `http://www.mkooc.org/`
[9] `http://www.astrosociety.org/education/astro/project_astro.html`
[10] `http://www.astrosociety.org/`
[11] `http://www.astrosociety.org/education/astro/about/involved.html`

Likewise, the local Department of Education (North Hilo/Laupahoehoe/Waiakea Complex[12]) has additional stated objectives for the program, which are to:

– Heighten awareness of science in classrooms;
– Help students meet the Hawai'i Content and Performance Standards and national standards;
– Provide rigor, relevance and relationships in curriculum, instruction and assessment;
– Tap into the rich resources that are available in the Hilo community;
– Improve teaching staff in content fields. Provide professional development, in-service training sessions, networking and articulation amongst educators, scientists, and community members who can help improve teaching;
– Educate parents and the community in the space science enterprise.

## 4. Putting It All Together

The JttU program is remarkably multi-faceted. Often, when individuals unfamiliar with the myriad elements that make up the JttU program are exposed to all of its components they respond that they had no idea how much was involved, and how many elements need to come together to make the program work. The following discussion summarizes the program while offering a brief overview and sampling of each element that makes up the Gestalt of JttU.

The core of JttU is the annual Journey Week (JW), JW consists of an extended week (typically 10 days) during which the entire local community is engaged and students, teachers and the public are offered opportunities to learn directly from researchers and observatory staff in an environment that is fun and education-focused. At its most elemental level, a JW consists of master and classroom teacher workshops, presentations in classrooms (see Fig. 1), workshops for classroom presenters (generally observatory scientists/engineers), public science events (see Fig. 2), media programming, community and business appreciation events and opportunities for community members to participate and learn about the work of scientists, engineers and other staff who support and advance the science of astronomy in Hawai'i.

Specifically, the following elements comprise the core of a JW:
<u>Astronomers, Engineers and Staff in Classrooms:</u> Astronomy educators are recruited from the observatories on Mauna Kea, University of Hawai'i at Hilo, 'Imiloa Astronomy Education Center[13], NASA and other observato-

[12] `http://165.248.6.166/data/complexarea.asp?key_complexarea=10`
[13] `http://www.imiloahwaii.org/`


*Figure 1.* Peter Michaud, Gemini Observatory, demonstrating carbon dioxide mirror cleaning during a classroom visit. (© Gemini Obs.)

*Figure 2.* Journey through the Universe Galileo workshop for participating teachers in the 2011 program. (© Gemini Obs.)

ries from across the country and the world. Astronomers, scientists and engineers are often not equipped to visit classrooms and share their personal journeys which led them to their professional heights. The astronomer's workshop, prior to JW, aids scientists and engineers in planning for classroom presentations and provides opportunities for dialogue with teachers regarding the most engaging discussions and activities for them to share with students (see Fig. 3).

Teacher Workshops and Educational Modules: The national JttU program produced (and still provides) "educational modules" that include lessons for both master teachers and all participating classroom teachers (see Fig. 4). Although the lessons meet the National Science Standards, the Hawai'i JttU education team also aligned the modules with the Hawai'i State Science Standards[14]. The Hawai'i Department of Education (DOE) invested significant resources utilizing master science teachers to align all four modules that now are rotated on a four-year cycle designed to foster conceptual understanding through activities that seamlessly integrate content and process in order to facilitate engaging, inquiry-based learning.

[14] http://standardstoolkit.k12.hi.us/index.html

*Figure 3.* Subaru Telescope's Kumiko Usuda, Astronomer, demonstrates to the students the various wavelengths of light. (© Subaru Obs.)

Ambassadors: Ambassadors accompany the visiting scientists and engineers in classrooms, introducing them to the students and assisting with demonstrations and hands-on activities shared with students. The ambassador group is extensive and comes from highly diverse backgrounds including: physicians, former teachers, car dealership owners, bankers, and local university astronomy students to identify just a few.

Family Science Events: The local community embraces the annual science lecture/talks presented by distinguished astronomers and educators (see Fig. 5) as part of the JW. These public presentations are augmented by educational, hands-on activities and are attended by thousands of learners of all ages from our local community. In past years they have also fostered partnerships with the local mall, the University of Hawai'i at Hilo Theatre, downtown Hilo theatres and the 'Imiloa Astronomy Center.

Chamber of Commerce Business Appreciation: The local Hawai'i Island Chamber of Commerce and Japanese Chamber of Commerce join together annually and sponsor a thank-you celebration for our scientist/engineer classroom presenters, DOE staff, ambassadors and businesses (see Fig. 6). This is the Chamber(s') way of expressing their gratitude for making STEM


*Figure 4.* Journey through the Universe 2011 teacher workshop at 'Imiloa Astronomy Education Center. (© Gemini Obs.)

education exciting and engaging and inspiring our students. The community is deeply invested in the JttU program and our governor's, mayor's and state representatives' offices attend the event or send representatives and produce proclamations of support[15].

Community Support: JttU has received financial support from many local businesses including the Bank of Hawai'i, Thirty Meter Telescope, Hawaii Island Economic Development Board, Hilo Toyota, both the Hawai'i Island and Japanese Chamber of Commerces, and the Business-Education Partnership to name just a few. In 2011 the NASA Lunar Science Institute[16] offered monetary support and allowed their own educators and scientists to participate in classroom visits.

Media Coverage/Promotions: Local media, radio, and newspaper offer thousands of dollars worth of free advertising for JttU events and strongly promote the program's message of science outreach to the community. Promotion of JW includes banners in our local airports and every participating school as well on main intersections going into the base facilities of the observatories. The schools place JttU information on their billboards and

[15] http://www.gemini.edu/journey
[16] http://lunarscience.nasa.gov/


*Figure 5.* Kevin Caruso creates a spacesuit for a young student during a Journey through the Universe Family Science day. (© Gemini Obs.)

*Figure 6.* Former Gemini Observatory Director, Doug Simons, speaks before the Chamber of Commerce event as a thank you celebration for the astronomers, DOE staff, teachers and ambassadors participating in the program. (© Gemini Obs.)

websites in order to promote the scheduled scientists and engineers who will be visiting their schools.

## 5. Countdown to a Journey Through the Universe Week

All of these key elements converge during the annual JW and must be coordinated and planned well in advance, thus, a typical JW plan begins immediately after the previous year's activities. The "timeline" that follows provides a context for planning and hints at the magnitude of the required effort:

JW MINUS 11 MONTHS:
As one JttU year ends, the next year is put in motion within the next 30 days. Based on the post-JW "issues" and "lessons learned" meetings, and evaluations submitted from the astronomers, teachers, principals, and ambassadors, the JttU team continues to make improvements and recommendations to improve the program. The Hawai'i Department of Education and Gemini's Public Information and Outreach staff meet to determine the 10 days during which JW will take place in the subsequent year. Venues are then booked for the workshops and family science events.

JW MINUS 9-10 MONTHS:
The Department of Education and Gemini Public Information Office contracts with lead educators who will conduct workshop for the astronomy educators, master teachers and general classroom teachers. Gemini's PIO

office sends out thank-you letters with a JttU annual report attached. This annual report includes samples of materials produced, bios on the astronomy educators, highlights from the website, all media coverage including headline stories, brochures, newspaper and radio ads[17].

A JttU website is established for the following year and it is updated regularly as details are solidified. Because this is a primary source of information for the public as well as JttU team-members, it is critical that this information is updated in a timely fashion.

JW MINUS 7-8 MONTHS:

JttU partners, including local businesses, are asked to provide monetary support for next year's JttU program. Personal contact is required as they are investing resources and want to understand its impact. The funding must be in place early since commitments are required for venues, materials, contracted services, etc.

JW MINUS 6 MONTHS:

Recruitment of local, national, and international astronomy educators begins. Intent forms are sent out to all scientists that have participated in the program before or have expressed an interest in joining the JttU team. This form confirms days when participants are available for classroom presentations and which grades they would prefer (although requests are not guaranteed). The local Department of Education office begins interactions with their district's schools and confirms which teachers and classes will be participating in the following year. It should be noted that this is not a trivial task since JttU engages an average of 19 schools and over 350 classrooms annually. It typically takes three months before final schedules are confirmed.

Presentations are provided for local Rotary Clubs, Chamber of Commerce and any business that is considering providing monetary support for the JttU program.

JW MINUS 4-5 MONTHS:

Local Chamber of Commerces meet with JttU team members to discuss plans for the annual appreciation event they will hold for the astronomy community, businesses, and Department of Education participants. The governor, mayor, senate and house offices are asked to send a formal proclamation and a representative to the event.

This timeframe is also when a significant "media blitz" begins. Radio stations are contacted and the quantity of free public service announcements is determined and recording studio facilities are secured to tape the "spots." The local newspaper's editor is also contacted and a commitment is agreed

[17] http://www.gemini.edu/images/pio/jttu/JTTU.pdf

upon for the contribution of ad space, after which graphic design begins on ad production. A JttU t-shirt (unique for each year) is designed for distribution to all participating school principals, master teachers, scientists, and engineers, and ambassadors. A new design is also created each year for banners placed at schools as well as JttU "conference" bags that are distributed at workshops.

JW MINUS 3 MONTHS:
Banners are provided to our local airport and placed at strategic locations so all visitors and residents will have advance notice about upcoming JttU programs. Participating schools hang their banners and promote JW on the billboards and other highly visible locations. All resource materials are purchased including binders that are "populated" with relevant information for each astronomy educator and ambassador. The information included in these binders includes phone contacts for classroom teachers, schedules, and specifics such as where parking is located at schools.
Schedules for up to ten talks presented at the family science events are finalized and all observatories are advised of these events and asked to participate if desired.

JW MINUS 2 MONTHS:
Astronomy educators receive notification of assigned classrooms and information binders are distributed. Presenters can contact their assigned teachers and develop their presentations. An astronomy educator workshop provides classroom presenters with opportunities to ask questions of education experts and presentations from the past are shown along with resource materials and discussions on suggested outcomes. The local Department of Education administrative staff work with participating schools on various JttU events held during the upcoming JW. Programs are designed and printed for family science events.

JW MINUS 1 MONTH:
Leaders from the JttU team meet weekly during the month prior to JW. All team members are expected to devote 100% of their time to assure that events run smoothly and all reasonable problems are anticipated. Most pending invoices are committed or paid at this time and businesses are notified of the JW schedule to assure their attendance at family/public events. Speakers are contacted and given an opportunity to visit venues where their talks will take place. As one of the many personal touches, supporters gather to make almost 200 lei for participants. These little details have a disproportionate impact and are greatly appreciated – as indicated in evaluations and informal responses by participants.

JW BEGINS:
During the JW three workshops are held; one for the master teachers, one

*Figure 7.* Journey through the Universe Family Science Event at Border's Book Store featuring Inge Heyer. (© Joint Astron. Ctre)

for classroom teachers, and another for astronomy/science educators. Also, one family science event is held during the weekend prior to the period of classroom visits. Although the program grows each year, an average JttU year brings over 50 astronomy/science educators into over 370 classrooms (see Figs. 7 & 8). During JW the community is abuzz with excitement and students tell families and friends about the scientist who visited their classroom. The result is that JttU is talked about at dinner tables, social events and anywhere people gather, making it difficult for anyone living on the east side of the Big Island to not be touched by the program. As the last day approaches all participants are extremely gratified by the knowledge that they made a difference – our *keiki* (the Hawaiian word for children) and our community are much richer for the experience.

## 6. Resources

Each year, to accomplish the myriad programmatic elements identified in the previous sections, the JttU team, led by the Public Information and Outreach Office[18] of the Gemini Observatory, brings together a diverse set

[18] http://www.gemini.edu/pio/?q=pio

*Figure 8.* Students, their teachers and school administrators participate in a solar system walk during Journey through the Universe week in 2011. (© Gemini Obs.)

of individuals all of whom are instrumental in implementing the program. These include (but are not limited to):

– Mauna Kea observatories outreach staff and managers;
– Local Department of Education administration and support staff;
– Local informal science educators;
– University of Hawai'i at Hilo educators;
– Local business leaders;
– Individual volunteers from business and community (ambassadors);
– Observatory engineers, scientists and other interested staff.

In addition to these human resources, many other monetary, services, and non-human (tangible) resources are provided by community and business partners (see Table 1 for a complete list of local businesses participating in Journey in 2011). Resources sponsored by local business include:

– Media (newspaper/radio) promotional donations;
– Prizes, gifts and t-shirts;
– Food and refreshments;
– Facilities;
– Transportation;
– Guest accommodations.

An additional level of human resources are required for logistics and planning that are provided on a regular basis, including (estimated):

– Gemini Public Information and Outreach Staff: 0.95 FTE
– Department of Education Staff & Teachers: 0.90 FTE
– University of Hawai'i at Hilo: 0.05 FTE

The resources assembled for JttU in east Hawai'i to support STEM education are also much appreciated by local educators as expressed by the local Department of Education District Superintendent of the Hilo/Laupahoehoe/Waiakea District Complex Valerie Takata:

> *"This grassroots effort of the education entity, astronomy centers, and the business community working together toward common goals has been absolutely stellar. What an amazing opportunity for all of us to tap the resources within our community and to make a difference! We are investing in our students, teachers and communityand in our future; therein lies the potential and strength."*

## 7. Evaluation and Metrics

JttU is evaluated and metrics assessed each year based on evaluation instruments originally developed by the national JttU program[19].

Participation in a post-workshop questionnaire is required for all teacher and astronomer education workshop attendees and these are collected at the end of each workshop. These instruments[20] assess the quality and effectiveness of the presenters and the workshop content; the perceived quality of the educational materials; and the workshop's logistical arrangements and comfort of the venue. The questionnaires ascertain both quantitative and qualitative data and allow for open-ended commentary.

In addition, each classroom teacher who hosts a scientist, engineer or other staff presenter is required to complete an evaluation of the presenter as well as other key aspects of the JttU classroom program.

All evaluation data is compiled each year and used to improve the program in future years. In addition, an annual "Lessons Learned" meeting is held to solicit input from key staff, teachers and others involved in the implementation and execution of the program. Some of the results of these sessions are presented in the next section of this paper.

Another key metric of JttU success is simply the sustained engagement of educators, participating scientists and engineers, as well as the community at large. Tables 1 & 2 present some of these key data that illustrate this metric and reveal the success of the program in terms of impact and overall engagement of a diverse cross-section of our community over a sustained period of time.

[19] http://journeythroughtheuniverse.org/program_overview/po_as.html
[20] http://www.gemini.edu/eval

TABLE 2. Key data from JttU over seven years of implementation (2005-2011). These data reflect the sustained interest and participation of the community in JttU and provide an indication of the magnitude of the program's impact to a relatively small community in East Hawai'i (population ∼50K).

| | Astron. Educ. | Amb. | Schools | Students | Classrms Visited | Teachers Trained | Public Events Partcpts |
|---|---|---|---|---|---|---|---|
| 2005 | 7 | 10 | 17 | 5000 | 115 | 134 | 2000 |
| 2006 | 11 | 12 | 21 | 8000 | 370 | 134 | 550 |
| 2007 | 33 | 15 | 18 | 8012 | 300 | 110 | 760 |
| 2008 | 43 | 21 | 21 | 7409 | 332 | 102 | 900 |
| 2009 | 45 | 27 | 21 | 8010 | 353 | 105 | 1700 |
| 2010 | 35 | 24 | 18 | 5833 | 330 | 137 | 3000 |
| 2011 | 47 | 35 | 18 | 6483 | 310 | 110 | 3200 |

Finally, while evaluations and participation data make up the core of JttU metrics, the value of verbal testimony by teachers and participants cannot be understated. The following statement by Christine Copes, Master Teacher at Hilo's Waiakea Elementary School captures the spirit that many local educators bring to the program:

> *"I have benefited both professionally and personally for the Journey program, from the quality of the teacher workshops to the connections with world-class scientists and educators. When students are given the opportunity to engage in relevant, exciting, and age-appropriate science and astronomy activities, they remain attentive, focused and involved. Because of this involvement, they comprehend the content, and very often follow up with the quest for more information on the science topic."*

## 8. Best Practices and Lessons Learned

Over the course of JttU in Hawai'i many lessons have been learned and mistakes made. For example, when JttU classroom visits began, it was common to hold presentations for 100-200 students in an auditorium setting. At that time there were essentially no limits on the number of students allowed in a single presentation. However, it became obvious that quantity was not conducive to a quality experience for students and now (whenever possible) no more than two classes (60 students maximum) are allowed at a single presentation.

Another adaptation based on lessons learned in Hawai'i involves the four education modules originally provided by the JttU national program. This curriculum library includes inquiry-based, hands-on lessons for elementary, middle, and high school classes (see Footonote 5 in Section 1). The Hawai'i JttU district educator supervisors determined early in the implementation of JttU that the modules needed to be aligned with the Hawai'i State Science Standards to be effective, useful and most importantly, used by local teachers. A considerable effort assured this alignment and the four modules are now rotated through the program on a four-year cycle. Furthermore, since teachers are better suited to present these lessons from curriculum, the observatory classroom presenters were encouraged to develop their own presentations, independent of the JttU education curriculum module themes. This resulted in observatory staff presenting even more inspiring and personalized presentations and developing their own lessons/activities and better allowing them to share how they became interested in science and relate better to students and teachers.

Originally, scientists from the observatories went into classrooms without any encouragement or mechanism for contacting their classroom teachers in advance. However, the partnership and bond formed when the astronomy educator and teacher have an opportunity to discuss specific subjects in advance is highly beneficial. When the astronomy educators know in advance what particular state science standards are most appropriate their presentations can become more relevant and valuable to teachers and students. This simple exchange allows teachers to more easily justify taking a day of "regular" lessons and replacing it with a JttU classroom presentation without losing valuable content standards teaching time. Teachers also have the opportunity to invite the visiting science educators back into the classroom for further instruction on their topics.

Many observatory staff (not only astronomers) expressed a strong desire to go into classrooms but had no previous experience with K-12 students. Others felt that their work would not be interesting to students. In order to address these concerns, and encourage a diverse cross-section of observatory staff to participate in JttU, a system now exists in which new observatory staff participants can partner with a more experienced "mentor" who has participated in the JttU program in previous years. This provides new participants with the confidence to address a classroom of elementary students and also expanded our network of classroom educators to include engineers and observatory support staff at all levels.

Finally, the idea of asking for funding to support JttU at any level is critical. While it is difficult to ask businesses or even the local chamber of commerce to support our activities financially, there is no better way to inspire loyalty, commitment and buy-in to a program than to make an investment of resources  financial or otherwise. We believe that this is a significant component of the JttU program in Hawai'i and a key reason why this program is so successful and continues to be sustainable and even grow year-to-year.

## 9. Adaptation to Other Communities

The JttU program in Hawai'i is unique. It is widely acknowledged that there is an abundance of scientists available to participate in the program on the island of Hawai'i as there are 12 well-staffed observatories on Mauna Kea. However, in most communities there is a local (or nearby) university or college along with an amateur astronomy club that would likely be willing to work with their local educators. As is commonly stated, astronomy is a "gateway science" and can be easily integrated into physics, biology, engineering, chemistry, mathematics and other disciplines. Most communities, both large and small, have the resources to establish a sustainable variation of the JttU program that reflects their own strategic needs in STEM education and focuses on their strengths and even local geo-physical/political environments.

This is why Gemini is currently (2011) implementing a variation of the JttU program in our host community (La Serena) in Chile. While the planned (pilot) program is significantly different (and much smaller – for now) than the program in Hawai'i, it integrates the core model of scientists and engineers interacting directly with the community, students and teachers[21].

## 10. Future Plans

As plans develop for the 2012 JttU program in Hawai'i expansion into a partnership with the University of Hawai'i at Hilo School of Pharmacology and their undergraduate chemical engineering program. JttU 2012 will likely see the addition of at least two University of Hawai'i at Hilo professors from the Engineering and Pharmaceutical Departments. It is also proposed that JttU's master teachers be offered a one-week course in basic engineering concepts prior to JttU 2012. Local education advocate Jim Kennedy, (who also serves as the head of the Workforce Development Board for the County of Hawai'i) states, *"This is a great example of the sort of self-starting, outside the traditional boxes, collaboration of community resources that the Workforce Investment Board is seeking to encourage."*

The possibilities of adding other STEM resources that are available in a community are as limitless as the boundaries one sets in defining the content of our universe!

[21]`http://www.gemini.edu/node/11609`

## 11. Summary and Conclusions

The JttU program in Hawai'i is the Gemini Observatory's flagship outreach program at the Gemini North facility in Hilo Hawai'i. It has proven, by its sustained growth and expansion into new partnerships and content directions, to resonate with our local education, business, and general publics and is expected to continue to impact our local community for many years to come.

The model it provides for other communities is viable and adaptable for a wide variety of circumstances and resources. With seven years of delivering JttU to the Hawai'i community, it is obvious that the program not only fills a need but has also produced a valuable resource for educators and parents that will guide and inspire the next generation of explorers.

*"After seven years of experiencing Journey classroom presentations firsthand and now enrolled at UHH to obtain my astronomy degree, it was great to be back in the classroom inspiring and taking the role of the educator during Journey through the Universe week."*
[Kellen Bello, University of Hawai'i at Hilo student and JttU alumnus]

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# TIME FLIES WHEN YOU'RE HAVING FUN – TWO DECADES IN AN ASTRONOMY LIBRARY

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**Abstract.** In this chapter, I will explore how life and work has changed during the past 20 years in a specialized astronomy library. After a description of some major developments, I will describe where observatory libraries stand today, and where they might be going.

## 1. Introduction

Friday afternoon is my preferred time of the week. Not only because of the obvious reason that the weekend is about to begin. There's more to it. On Fridays around 5 pm, colleagues at my institute start to go home, the usual busy roaming around of people slowly settles down, and it is getting quiet all around. At that time I like to walk through our library. It is a nice moment to enjoy the peaceful atmosphere, walk through the aisles, and think about the potential the library holds for new features we might offer our library users in future. This moment also allows me to think back of how things were one or even two decades ago.

I started my work as Head Librarian of the ESO Libraries in April 1991. At that time, it was not very common for libraries to use computers, let alone have access to e-mail. At ESO Garching, the library was equipped with exactly one vt100 terminal, located in a remote corner of the library. Still, the fact that there was access at all to what later turned out to be the internet was already quite an achievement. The ease with which electronic mail made it possible to contact colleagues abroad, especially in the US, fascinated me as it solved the problems of high telephone bills as well as long delays in getting responses via snail mail.

A first application of computers in libraries had been created a few years before by my predecessor, Edith Sachtschal: a relational database with entries for bibliographic data and order details to help the librarians handle journal subscriptions. At that time, and for some years to come, the database served mostly as a template from which necessary lists were printed and then filled-out manually, for instance with prices and durations of journal subscriptions. I remember well that one afternoon maybe half a year after I had started at ESO I was sitting at my desk, finishing the last entries in such lists. I looked around, found that everything was in order, and thought to myself: "There's nothing else to do for today." That was the last time such a thought even vaguely crossed my mind ever since.

Soon after, a development started that can without hesitation be described as an information revolution. Basically all work areas in libraries were affected, and even more importantly, the role and importance of research libraries at large. But let's go step by step.

## 2. The Early and Mid-90ies

Since the foundation of ESO, libraries had been established where the astronomers were, namely at the ESO headquarters (since 1980 in Garching) as well as at the observing site on top of the mountain La Silla in Chile. In 1994, the latter was moved to the ESO office in Vitacura, Santiago. The collections in both libraries were geared towards the astronomers and their needs for research and observations. Like in many other observatories, the concept of exact library opening hours was not applied as astronomers needed access to books and journals also during night hours, for instance for immediate consultation of star catalogues during their observations. The idea of making information resources easily accessible has traditionally been more important for us than the application of strict library rules.

Besides books and journals, preprints traditionally played a vital role in keeping astronomers informed about latest findings in their field of research. Many astronomers regularly checked the newest preprints that had arrived in our library from all over the world and were displayed on the library shelves. After a month, they were moved to the storage where we kept them for another year. After that time, it was assumed that they had been published in journals or conference proceedings.

Despite the focus on our own collections, it was also possible to provide documents to the library users which had not been purchased by us. However, the interlibrary loan of those years was organized in a different way, and it could take a few weeks before a requested article arrived. Of course, such a delay would be unacceptable today.

In the mid-90ies, services such as Archie, Gopher, and Veronica appeared

– names that are basically forgotten today, but which can be described as very early versions of online search engines[1]. Soon, the potential of these tools for libraries became obvious as they enabled us to search an increasing number of library catalogs and other databases that helped us to answer requests from library users. It was a logical consequence to take the initiative to convert also our own card catalog into machine-readable format. The online catalog project started in 1992 and was made available to the public in November 1993. While access was first available through a telnet link, we moved to a web-based interface as soon as this technology became available. Indeed, the library pages were among the first ones on the newly established ESO web site. The oldest entry in the internet archive 'Wayback Machine'[2] for the `eso.org` domain dates from Dec. 3, 1996, and it already includes a link to the library pages[3].

The possibility of handling processes entirely online had not yet become available, but the internet started to emerge and play an increasingly important role in the daily work of librarians. In astronomy, the mid-90ies brought forward the first electronic journals, earlier than in most other subject areas. With them, one of the largest reengineering processes in libraries began.

At first, publishers experimented with a variety of formats that complemented print journals. Microfiche, diskettes, tapes and the like were an attempt to port publications to an electronic format. However, they were all offline, non-connected containers of information and hardly provided advantages compared to paper, except in some cases a better index that allowed readers to find appropriate content easier.

In fact, there was a concern – mainly expressed by librarians – from the beginning, a problem that still has not fully been solved: how can we make sure that the content stored on electronic media will be accessible in decades or even centuries from now? Print material does not require any decoding except language skills; other than that, it can safely be assumed that our and future generations will be able to read text. On the other hand, the situation is very different for electronic publications. Without the appropriate reading devices the content is lost – and who would be able to guarantee that such devices will be available even after a few years? The fast emergence and disappearance of microfilm, floppy disks, and other storage devices seem to indicate that much of the technology that was introduced

[1] See for instance Wikipedia: Web search engine, `http://en.wikipedia.org/wiki/Web_search_engine`

[2] `http://www.archive.org/web/web.php`

[3] ESO homepage as of Dec. 3, 1996: `http://web.archive.org/web/19961218231549/http://www.eso.org/`

during these years was not really thought-through from an archival point of view.

After a few years of experimenting, the first generation of e-journals had stabilized. With better search capabilities built into electronic journals, it became possible to find an exact word, name or object that was mentioned somewhere in an article, but wouldn't have been indexed in the old days. Full-text searching quickly became and still is one of the major advantages of electronic over print publications.

Availability of online journals regardless of the time a researcher wanted to consult them as well as accessibility from anywhere were other intriguing features. In the early days user ID and password and later verification by IP address coupled with VPN (virtual private network) connectivity enabled users to search, read, and download e-journals as if they were physically in the library even though they actually may have been attending a conference abroad or working from home.

From a librarian's point of view, the fact that we did not have to deal anymore with claiming journal issues that had not arrived or the need to locate misshelved or even stolen volumes was a nice facet of e-publications. Instead, we were now troubleshooting technical problems in case access was interrupted.

A major paradigm shift occurred because of the new acquisitions model of electronic publications. While we were used to obtain books and journals and make them available in our libraries to the users, publishers introduced new purchasing models for e-journals. Each journal now required a contract between the publisher and the library, and often access to the scientific content was granted by publishers for a limited time, namely only for the duration of the license. This idea was much closer to the concept of renting material than actually buying it. Librarians obtained specific legal knowledge in order to negotiate the best possible conditions for their users and to provide seamless and convenient access to publications. Publishers introduced an additional difficulty: in an attempt to deal with each library individually and prevent librarians from sharing best strategies, publishers would often prohibit open discussions of contract conditions and price quotes among colleagues. Nevertheless, librarians found ways and opportunities to discuss these matters and help each other, even without explicitly mentioning the exact subscription fee a publisher requested or confidential license clauses.

One of the main problems that came with electronic publications was the strain they put on library budgets. While print was still requested by our library users, e-journals were equally needed, so both formats had to be subscribed in parallel, of course at higher prices than one medium alone. To make things worse, the need to maintain double subscriptions for print as well as electronic versions came at a time when most library budgets were considerably shrinking due to worldwide economic problems.

Regarding contract negotiations with publishers, ESO's status as an intergovernmental organization created a very specific legal situation. Many libraries had teamed up with their neighbor institutions or other national organizations to form so-called consortia that gave them a stronger position during negotiations with vendors. As ESO does not fall under any specific national rules and regulations, we typically could not join such consortia, but were facing contract discussions on our own. Fortunately, advice and best practices were shared on librarians' mailing lists from where we could learn about effective strategies.

## 3. 2000 and Onwards

About 15 years after the advent of online journals, electronic format has basically replaced print. Non-electronically available information has become marginalized. In particular the capabilities of today's search engines have led to the assumption among users that online search results will be complete. Information resources that are not at least indexed, if not available in full-text, are often not taken into account, simply because users don't expect them to exist.

Over time, ESO has published many books, reports, and newsletters. In order to make these historic documents available to the wider community, the library started a digitization campaign in 2008. Documents for which ESO owns the copyright included back issues of ESO's magazine *"The Messenger"*, the *Annual Report*, published since 1964, a large number of conference proceedings and some other publications that marked milestones in ESO's history. Also some technical reports were scanned and made available via the library catalog, on the library's "historical documents" page[4] and through the web pages of the ESO Public Outreach Department[5]. Of special interest are those in-house reports that are by now out of print, but are still requested by scientists and engineers. For the conference proceedings, we started a project with the NASA ADS team: we provided spare copies of proceedings volumes, and ADS took care of the digitization. Today, the full-texts of most ESO conference proceedings published during 1983 and 2002 are available online to interested readers[6].

[4] `http://www.eso.org/sci/libraries/historicalbooks.html`

[5] See for instance `http://www.eso.org/sci/publications/messenger/`

[6] `http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?version=1&warnings=YES&partial_bibcd=YES&sort=BIBCODE&db_key=ALL&bibstem=ESOC.&year=&volume=&page=&nr_to_return=3000&start_nr=1`

The digitization project tied in very well with the concept of the Open Access (OA) movement in academia which promotes free online access to scientific literature[7]. In this context, the word "free" (of charge) typically refers only to the readers; most of the current OA business models have shifted the costs from readers (subscribers) to authors (institutions). Typically, publishers now provide authors with an option to pay a one-time fee in order to publish their article open access while the remainder of papers in the same issue may still be available only through a subscription or via pay-per-view. The advantage still is that all articles published under an open access model are available to the entire scientific community.

The open access concept also comprises author self-archiving, be it on the researchers' web pages or in an institutional or subject-related repository like astro-ph/arXiv[8]. By now, most publishers allow authors to deposit their manuscripts on the web, provided that they mention where the article has been published. However, self-archiving by individual authors neglects two crucial topics: retrievability (i.e., papers will not be found through central search engines) and preservation (because manuscripts are much more prone to be lost over time unless researchers migrate them regularly to newer technologies).

In comparison with other subject areas, the OA situation in astronomy is relatively favorable, even though still not perfect. Besides an estimated 80% submission rate of manuscripts to the arXiv e-print server, the core journals (*A&A*, *AJ*, *ApJ/ApJS*, *MNRAS*, *PASP*) apply so-called delayed open access. Full-texts are currently made available two to three years after publication. National and institutional mandates requiring that scientists deposit final peer-reviewed manuscripts in digital archives will probably bring the delay down to only one year soon.

The acquisitions policy for journals at ESO has now practically been changed from print plus electronic to e-only. Whenever possible, we only subscribe to the electronic version, especially for those journals from which individual articles are easy to obtain through document delivery or specific purchases directly at the publishers' sites. There are some exceptions from this rule though. For instance, we will obtain the core astronomy journals (i.e., *A&A*, *ApJ*, *ApJS*, *AJ*, *MNRAS*) on paper for as long as they are published. Being a library specialized in astronomy, we regard it as our mission to purchase and archive these journals also on paper. Let the publishers and the astronomy community decide when the end of the paper era has come![9]

[7] `http://en.wikipedia.org/wiki/Open_access_(publishing)`

[8] `http://www.arxiv.org/`

[9] As a side note it should be mentioned that as of mid-2011, the *MNRAS Letters*, *ApJ Letters* as well as certain parts of *A&A* are exclusively available in electronic format. For

The situation is a bit different for books. For a few years, we have been trying to promote the use of electronic books. A major book publisher in astronomy, Springer, has marketed their e-books platform to which we have been subscribing since 2005. At the same time, we reduced the purchases of print books by Springer to basically zero. At least almost, as we still buy specific books if the requesters really prefer print. Needless to say that our book vendors were not amused to see our acquisitions drop from about 600 new titles (by Springer and other publishers) per year, typically obtained for the library in Garching as well as our branch library in Santiago de Chile, to approx. 250 purchases. But many library users are happy with the easy search and retrieval mechanisms (including Google Books where Springer titles can be found) and the exemplary download, print, and storage capabilities provided by Springer.

On the other hand, the current reading devices, i.e., reading on screen or e-book readers with which we also experiment at ESO, do not seem to convince the majority of readers. At present, electronic format is still best suited for content that is not read cover-to-cover, for instance conference proceedings from which users typically select one or a few chapters, but hardly read the entire volume. With regard to textbooks, the search options are convincing in order to locate specific sections, but users typically still prefer the print edition for reading. It will be interesting to see how e-book readers will evolve in the near future and whether perhaps five years from now we will hardly remember why we considered books on paper useful. The user experience will also largely be shaped by better and more user-friendly Digital Rights Management (DRM) systems as those currently embedded in digital content often limit the use and efficiency of e-books for readers to such an extent that they are prevented from normal use of electronic books. In the long run, it can be hoped that such restrictive DRM software will not survive in the e-books market.

## 4. Space

Space is a critical issue for practically all libraries these days. With fewer users visiting the physical collections and an increasing number of publications being available online, management might erroneously think that the need for library space diminishes – despite the large amount of paper that still arrives every day in our library offices. At ESO, we are in the lucky position to occupy central places in the institutes, even on two levels, both in Garching and Santiago. While the site collection at La Silla was closed in August 2009 to become an "e-only library", so far we had to fight only moderately for the space allocated to us in the two main locations. On the

some time, paper has already been phased out for these sections.

other hand, an extension to the existing square meters of course is out of the question.

In Garching, we tried to confront the problem of limited storage by reducing the amount of bound journal volumes that we store. For many years, we enjoyed the luxury of subscribing to, and archiving, journals outside of our core subject areas astronomy and optics, for instance titles in computer technology and high-energy physics. As such journals are held by many university and state libraries, it is fairly easy to obtain specific articles through document delivery services, typically even within only a few hours. This situation prompted us to donate many of our journal volumes to interested libraries or, in some cases, to discard them.

We preferred this seemingly drastic measure to off-site storage which would have been possible under certain conditions. Retrieving a specific volume from a storage located away from our library would take in the best possible case one day – too long compared to the two to three hours it takes to receive a document through interlibrary loan or document delivery. In addition, it has to be taken into consideration that also off-site storage is expensive and should only be used for items that are precious and worth the expenditure. Hence, we decided to dispose of many volumes. This is a sign of the paradigm shift that is going on in many libraries from purchasing books and journals "just in case" someone might ask for them towards a "just in time" approach whereby documents are obtained and provided in a timely manner when they are actually requested.

After the non-core journal volumes had been removed, we started to rearrange books and journals on shelves in order to store them in a more compact way. We freed several meters of shelf space and finally were even able to completely dismantle a large shelf. The space we gained has been transformed into a meeting area that invites astronomers to meet for their regular coffee meetings, discussion groups, or presentations. We experienced considerable demand for this enhanced work area and actually encountered situations where two "competing" groups would have liked to hold their meetings at the same time.

A nice side-effect of these meetings is that once participants are in the library, it is easy for them to stop by our office for a moment to request a document, comment on a book they read, or ask for advice regarding the use of retrieval tools. All this can also be done by e-mail, but a face-to-face conversation once in a while still is much more personal and efficient.

## 5. Productivity Measures

During the past decade, an increasing number of astronomy librarians have become involved in productivity measures at their institutes, in particular bibliometric studies that can help to evaluate the productivity and impact of telescopes and instruments or of specific observing programs. In addition, such studies hold important information regarding the acceptance of instruments by the user community and can provide guidelines for future observing facilities.

For many years, Angelika Treumann, my colleague for more than 15 years in the ESO Library Garching, has visually inspected printed journal articles in order to spot any mentioning of ESO facilities as well as authors affiliated with ESO. Initially, the lists she compiled were printed in the *ESO Annual Report* in order to create a record of the scientific output from ESO's observing facilities and staff. Later, this compilation of bibliographic records developed into a specialized database. After Angelika's retirement, her successor, Christopher Erdmann, skillfully used contemporary programming tools and techniques (PHP, Javascript, XML, SQL, etc.) to convert the existing database into a tailored, complex system. Today, this system comprises a semi-automated full-text search tool (FUSE) and a content management system (the ESO Telescope Bibliography, or telbib) (Erdmann & Grothkopf 2010). FUSE allows us to retrieve selected papers (i.e., those published in approx. a dozen refereed astronomy journals) via the NASA ADS Abstract Service[10], convert the PDFs to text, and scan the texts for ESO-defined keywords. If keywords are detected, FUSE shows them in context in a list which is then inspected by the librarians to determine whether the paper indeed should be included in our telescope bibliography, or whether it was a false hit (Fig. 1).

Telbib and FUSE are essential tools in coping with the ever increasing number of refereed papers that have to be scanned every year[11]. After Chris Erdmann had left ESO in 2010 to take up his new position as the Head Librarian at the Harvard-Smithsonian Center for Astrophysics (CfA), Silvia Meakins has become the new technology expert in the ESO Library. Together we continue to enhance both systems and implement new features, tailored to the specific needs which allow us to improve our workflow and derive new metrics from the telbib knowledge base (see for instance Grothkopf & Lagerstrom 2011). For an overview of currently available information in telbib as well as tags assigned by the librarians, see the screenshot of the "Edit Paper" feature in telbib (Fig. 2).

In the meantime, several other observatories have asked us for permission to use FUSE for their own bibliographies. We have provided the software to libraries in the US (including STScI, Gemini, Subaru, CFHT, and the Carnegie Observatories), South Africa, India, and Argentina. A large

[10] `http://adswww.harvard.edu/`

[11] The number of refereed papers checked has increased from approx. 7,800 in 2007 to approx. 9,400 in 2010.

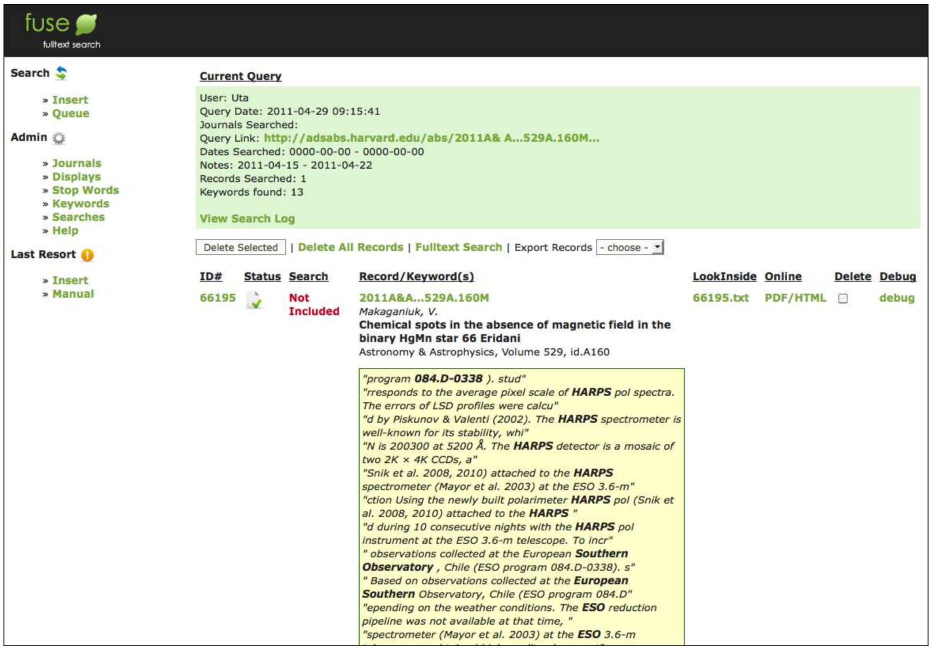


*Figure 1.* Screenshot of FUSE, the ESO Full-text Search tool. ESO-defined keywords are highlighted in context. (© ESO)

user base is desirable as all libraries can add further modules if they wish and thus make the system even better in a joint effort. Last year, a Google Group has been set up, initiated by the compilers of telescope bibliographies at the Chandra Archive, STScI, and ESO, to provide a forum to exchange best practices for maintaining bibliographies, to develop recommendations for using cross-facility bibliometrics, and to share solutions to common problems[12].

## 6. Building a Librarians' Network: LISA

Astronomy libraries worldwide can be characterized in a variety of ways. Often they are very specialized and rather small and have only one or two librarians. They are geographically dispersed and not rarely located in remote areas. The total number of astronomy libraries worldwide is below 300, so it is a relatively small community. And, most importantly: the community of astronomy librarians is extremely well connected.

Before I joined ESO, I worked at a biology institute at the University of Hamburg. Work methods and processes vary from one subject area to

[12] http://groups.google.com/group/astrobib/

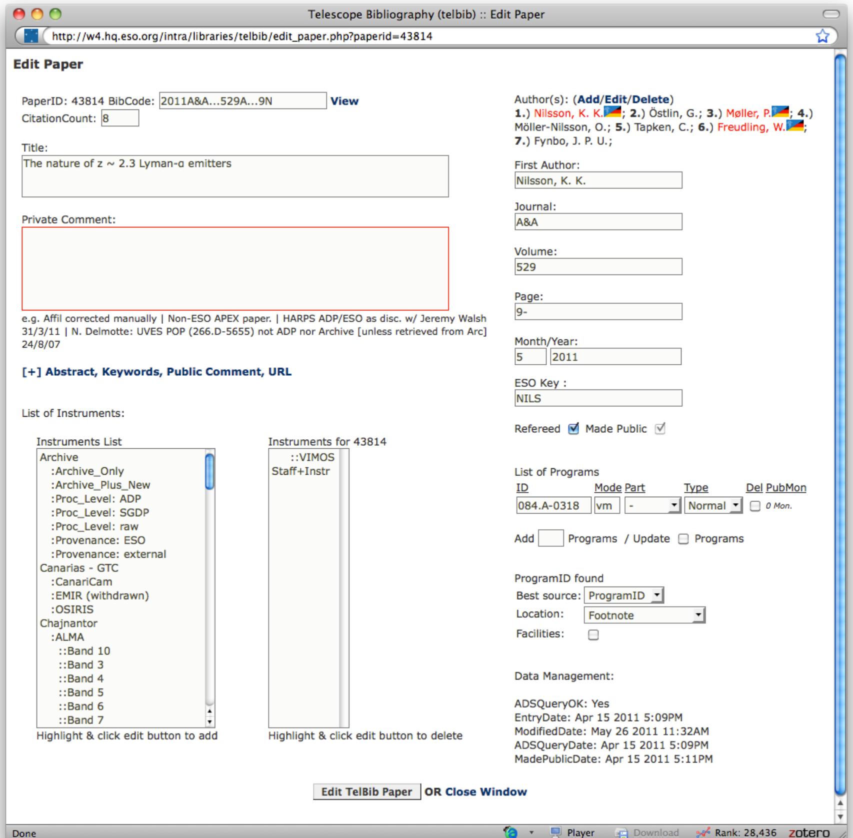


*Figure 2.* Screenshot of the "Edit Paper" interface of the ESO Telescope Bibliography (telbib). Bibliographic information, citations, keywords and abstracts are imported from the ADS; program IDs, observing mode, program type and tags describing the astronomical instruments used as well as other information like authors affiliated with ESO are assigned by the librarians. (© ESO)

another, and I had not been familiar with the tools and techniques used in astronomy. Soon I found out that in astronomy getting acquainted with the procedures is easy thanks to a large network of colleagues who are always willing to answer questions, provide help and advice, and share experiences. I owe a big *Thank You* to Sarah Stevens-Rayburn, Ellen Bouton, Brenda Corbin, Marlene Cummins, and Robyn Shobbrook, who were at that time the librarians at STScI, NRAO, the US Naval Observatory, the Astronomy Library of the University of Toronto, and the Anglo-Australian Observatory (now Australian Astronomical Observatory). Without their guidance, I would not have been able to understand the mechanisms of astronomy libraries so fast.

Astronomy is an excellent example to show how cooperation across borders leads to better service. While our own libraries may be located remotely and be limited in number of books and journal subscriptions, help regarding finding a specific article, learning about best practices, or sharing experience about new information retrieval tools is only an e-mail away (if sent to an astronomy librarians' mailing list).

Even better than communication through e-mail is to meet personally. In 1988, astronomy librarians held their first international meeting which was initiated, promoted and implemented most notably by Brenda, Ellen, and Sarah. At that time, nobody was expecting that such a conference, called *Library and Information Services in Astronomy (LISA)*, would be repeated. However, LISA developed into a series of meetings and is now held every three to four years. Librarians, astronomers, computer specialists and publishers get together to discuss the state of the art in information maintenance and retrieval, latest techniques and technologies, and the future of librarianship. An overview of past LISA conferences, conference logistics and topics and how they have changed over time can be found in Corbin & Grothkopf (2006) and on the LISA homepage[13]. Jill Lagerstrom gives an excellent summary of the most recent conference, LISA VI which was held in Pune, India, in 2010. In her article "Astronomy Librarian – Quo Vadis?" Jill describes important themes from LISA VI in the context of the overall situation of astronomy librarianship (Lagerstrom & Grothkopf 2011).

## 7. Marketing libraries and their services

In times when most of the content is available online, it is obvious that fewer users enter the physical library to find the information they need. During recent years, marketing and advertising services has become an important topic among librarians. How can we catch the attention of researchers so that they notice us as a service entity? How can we position ourselves in our institutes as the information department?

One option is to talk to potential users early on. For some time, ESO has been conducting so-called induction classes. These are half-day sessions for newly hired staff during which the main departments of the organization are introduced. The library routinely takes part in these classes. We present the library staff in Garching and Santiago (where our colleague Maria Eugenia Gómez has been taking care of the library for more than 25 years), explain the most important research tools and resources, and emphasize our availability for questions and advice. Participation in the

[13] `http://www.eso.org/sci/libraries/lisa.html`

induction courses allows us to meet all new staff personally and, very importantly, immediately gather (and answer) the first questions they may have. From their first day at ESO, our new colleagues will this way have an idea who to turn to when they have questions or need information.

Within the organization, a strong web appearance is a necessity as we need to be present where our users are, and that often means in the virtual world. In addition, we are implementing collaborations with the outreach department in order to include the libraries in ESO-related information displayed in the entrance area as well as in the context of the ESOcast, ESO's series of video podcasts.

A fantastic experience was the participation in the SWYA (Scientific Writing for Young Astronomers) schools which were organized by Christiaan Sterken and the publisher of the journal *Astronomy & Astrophysics (A&A)*, EDP Sciences. SWYA-1 and 2 were held in 2008 and 2009, respectively, and were each attended mostly by students who had just started their PhD thesis[14]. At both schools, I was invited to give presentations on library services, impact measures, and literature management systems. I enormously enjoyed the opportunity to show the students how libraries may help them with tricks and tips regarding the use of search engines beyond the obvious one-line query or assist them in finding literature and information relevant for their thesis. More important than teaching were the conversations and informal talks that took place before and after lectures. Because of the particular set-up of the hotel in Blankenberge, Belgium, where the schools took place, lecturers and students spent three days together during which many professional and also some personal questions were discussed, maybe even solved. Presenting librarians as the human interface to information retrieval early in the careers of astronomers has been very fulfilling; I am sure that some of the students who attended the schools went away with a changed impression of libraries, knowing that librarians are their allies in their quest of turning information into knowledge.

At the other end of the spectrum, librarian consultants have become relatively common on publishers' boards. They play a crucial role in mediating between readers/authors, publishers, and librarians in order to make publications better readable, accessible, and in general more worthwhile for all partners involved in the publishing process[15]. In astronomy, basically all publishers have invited librarians onto their boards which in many cases

[14]For a more detailed description of the SWYA schools, see the chapter by C. Sterken in this volume.

[15]For more information, see the section on Publishers Relations of the Special Libraries Association/Physics-Astronomy-Math division (SLA/PAM) at `http://pam.sla.org/bulletin/publishers-relations/`

has led to close collaboration and much better understanding of the various viewpoints.

## 8. The role of the ESO Library

So, where do small, specialized research libraries like the ESO Libraries stand today? What is our role in a scientific world that focuses on direct, immediate access to information, where the users of information resources increasingly bypass the physical library, and where the librarians' role is in danger of becoming invisible?

"Todo cambia" – everything changes – is one of my favorite songs by Mercedes Sosa. The lyrics, written by Julio Numhauser when he was in exile in Sweden, are melancholic, yet the music is so joyful that it invites us to sing along or even get up and dance, just as "La Negra" did so many times during her concerts[16]. The political meaning of the song aside, I often feel that we librarians should do the same: recognize the changes that are happening, understand what they mean to us, and then dance along.

Perhaps this is easier said than done, but every adaptation to change starts with a look at what *was*, what *is*, and what we hope *will be*. We all know well how our work procedures looked like in the past. But where are we now? Who are our allies? What can we offer, and to who?

At ESO, library users come from a large variety of groups. First and foremost, scientists, students, post-docs, and scientific visitors come to mind. We make sure they have access to all information sources they need for their work, and we continuously amend library services in response to changing requirements. In the context of bibliometric studies, we often cross-check our findings regarding specific papers in the telescope bibliography with instrument scientists and other astronomers interested in this topic in order to make sure that the tags we assign and decisions on inclusion or exclusion of papers are correct.

The second largest group of library users are the ESO engineers and technical specialists who need specific standards and technical documents, especially during times of telescope planning and construction. Other user groups include the ESO outreach department, administration, the legal office as well as ESO employees in general for whom we sometimes purchase amateur astronomy books. Last not least, we provide help and advice to (mostly European) astronomy libraries through interlibrary loan, suggestions regarding library services and procedures, or exchange of ideas and procedures.

[16]Videos of Mercedes Sosa performing can be found on YouTube, see for instance `http://www.youtube.com/watch?v=In5TjoaYMRs`

All these groups can be our allies and collaborators for whom we offer a variety of services and with whom we cooperate on a number of projects. These can be characterized as follows:

- Astronomers and engineers: librarians provide an information center with rapid and seamless access to historical and current collections, both locally and networked. Many libraries have initiated and maintain digital repositories for papers and data produced at their respective institutes.
- Instrument scientists and management: we collaborate on policies for telescope bibliographies and extend current activities to future (perhaps international) projects. Librarians develop and maintain productivity measures for staff, projects, and facilities and build digital systems to provide access to statistics.
- Data archivists and virtual observatory specialists: librarians who are in charge of telescope bibliographies close the loop from observations and archived data to published results in order to obtain the highest scientific return from observations; they work with data archive specialists to assure that the research output is tracked as completely and comprehensively as possible and as needed.
- Outreach and public relations: there is a noticeable increase in the involvement of librarians in outreach activities, e.g., through conference preparation, maintenance of meeting-related web pages, linking of press releases with corresponding papers in telescope bibliographies, and preparation and realization of exhibitions, to name just a few.
- Other information specialists worldwide: through involvement in professional organizations, we foster collaboration among observatory librarians and telescope bibliographers on regional, national, and international levels. Active exchange of expertise through mailing lists, conferences, and other means of communication leads to a tight network of professional contacts that ultimately result in even better service for library users.
- Astronomers from the wider community: we establish contacts among librarians and astronomers in our own institutes and observatories as well as in the wider community through events and collaborations, e.g., the IAU Working Group Libraries[17].
- Consultancy and training: librarians play an important role in their institutes to increase the information literacy of PhD students and young researchers. They are external consultants for journal publishers and lecturers at writing schools for astronomy students and as such mediate between scientists, publishers, and information providers.

[17] http://www.eso.org/sci/libraries/IAU-WGLib/index.html

Involvement in many different projects and collaboration with a variety of other departments will without doubt increase the library's visibility and emphasize its role as an information and technology center. This is not meant to say that libraries should embark on all kinds of activities regardless of their aim and purpose. One should always keep an eye on the mission of the library as well as the organization as a whole to make sure all efforts are in line with these overall goals.

With these guidelines in mind, we will monitor upcoming information retrieval tools, evaluate them to understand whether they might be of use to our library patrons, and implement those that provide new functionalities or easier access. This requires not only knowledge of the technologies, but also the vision to understand how new tools might fit into a changing work environment of astronomers and engineers. Last, but certainly not least, it is essential to talk to our users (and also those who currently *do not* use the library) to learn about their wishes and suggestions. The result of such communication can then be used to enhance library services, to mediate between astronomers and publishers or service providers, and in general to establish an information, learning and knowledge center that our users like to consult whenever they need advice.

## 9. "I like books" – A Mixed Blessing

If we were to ask library users which item symbolizes libraries, a large fraction of them would probably say "books", thinking of large hardcover volumes. During recent years, it happened often that library users and visitors came into our office to talk about scientific information and libraries. On such occasions, sooner or later the paradigm shift from print to electronic resources becomes a topic. "I like libraries" the visitor would typically say, "the smell of books is so nice, and I love to feel the paper when I turn pages." Politely, I would smile and nod in agreement – but only for a short moment. While librarians are of course happy about everybody who appreciates the print collection, this is only part of the story. The library of today is so much more than just a book repository. Libraries should not only be seen in their function as archives where tons of (increasingly old) paper are stored, or as a refuge for those who regret that the days are gone when scientists would find latest information in the paper preprints displayed in the library. Libraries have made a quiet, but constant transition to become information centers that handle all kinds of knowledge containers, from paper (which without doubt is still around) to electronic media (like CDs or DVDs), to networked resources. In many institutes, libraries are the information hub and the first contact point for scientists and engineers when they look for information needed for their work.

Please don't misunderstand me – I *do like* books. At home, the walls of my apartment are lined with book shelves. There's nothing better than books to create a cozy, relaxed atmosphere. Yet, for libraries printed information is only one part of what characterizes them. Rather than being mentally affiliated with archival tasks, I would prefer library users to see us as the information and media center that provides whatever information is necessary, in whatever format. The concept of "making accessible" has become more important than storing printed items, and a complete in-house collection has evolved into information retrieval on servers located around the world.

## 10. Finally: A Confession

Finally, I have a confession to make. I remember the moment 20 years ago when I learned that ESO had selected me as the new Head Librarian. I was thrilled and happy, but at the same time also shocked. Shocked by the fact that of all possible subject areas, I should from now on work in an *astronomy* library. With a father who had been a physics school teacher and a brother who is a mathematician, it seems that all the genes in our family that are responsible for the capability to understand sciences and technology had happily bypassed me and settled with another family member. I always had been much more interested in literature, languages, and social sciences. In high school, I dropped chemistry from the curriculum as soon as this was an option. Even worse, I had started my studies in library school with the idea of working in a public library where I would provide fiction and non-fiction literature to adults and children, organize readings, and be able to reach out to the community with offers for special user groups. In short, my professional plans had been quite the opposite of where I ended up.

Little did I know! Shortly after I took up work at ESO, I began to understand that science libraries in general, and observatories in particular, are far from being boring and dull. Librarians in small science libraries are fortunate to be in close contact with their user community which are typically scientists and engineers, and therefore also in close contact with research and technical developments. Especially in observatories, where scientists are engaged in the quest for the origin and the destiny of the universe it is easy to be intrigued – after all, the big questions of where we come from and where we are going are nowhere closer to a scientific response than in astronomy.

We astronomy librarians are also very fortunate because we work in a technologically advanced environment where many developments like access to databases, availability of e-journals, extensive text-mining, and others have been implemented much earlier than in other subject areas. Sometimes

I am asked whether I would like to change job now that I have spent 20 years in the same institution. My answer has been and always will be the same: if the environment around you and the technologies you apply in your daily work evolve constantly, there is no need to change job, because you are changing *with* the job. I can honestly say that the ESO Libraries provide a work environment more fulfilling, challenging and even entertaining than I could have ever imagined.

## Acknowledgements

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# THE H- AND A-INDEXES IN ASTRONOMY

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**Abstract.** Astronomers can compute h-indexes using either the Science Citation Index (World of Science) or the Astrophysical Data System (ADS). These two data systems sample different sets of publications. We compare the different results from these and the advantages and disadvantages of each. Because the Hirsch h-index is a steep function of time, their values for young and old astronomers cannot be compared. We define an a-index that is constant with time. Whether the h-index or a-index is more indicative of important research depends upon how one accredits the citation counts of authors in multi-author papers. We list current mean h- and a-indexes for astronomers in four countries. We conclude that on the average, individual astronomers in France, Germany, the UK, and USA are doing equally well in research importance but those in the first three countries are still not producing as much research as those in the USA, relative to total populations.

## 1. Introduction

How does one evaluate the accomplishments of an individual scientist? One can count his or her papers, but not all papers are equally important; some scientists publish many trivial papers while others may write just a few that are frequently quoted. Or one can note his or her papers that receive the largest numbers of citations, but if those papers were written by many authors, the individual's share of the credit may be small. Or one can count the total citations to all of a person's papers but it may not be fair to compare a person who published many major papers in his/her career with a person who published a few very outstanding papers.

Jorge Hirsch (2005), a physicist at the University of California, San Diego, proposed a rapid method of evaluation that allows for the productivity of many important papers. His h-index is defined as the number of papers that have received that number or more citations to each. For example, if a person has published 40 papers that each received 40 or more citations to date, then his or her h-index is 40. The h-index is generally easy to compute because the on-line version ("Web of Science") of the Science Citation Index (SCI) or the Astrophysics Data System (ADS) allows a person's papers to be arranged in the order of decreasing citations to date. Hirsch discussed the various ways in which a person's publications can be evaluated (total number of papers, total citations, number of outstanding papers, etc.); he commented on the disadvantages of each. He set up the equations relating these parameters and applied his h-index to physicists, primarily.

This method, although generally easy to compute, has three disadvantages, namely:

1. It is biased against young people whose papers have not yet been published long enough to accumulate many citations. However, Hirsch found that, to a first approximation, an h-index will increase linearly with time since the beginning of a publication career, so junior and senior scientists can be compared by the differing rates of growth of their h-indexes.
2. It is biased for scientists who work in large teams unless one divides the number of citations for a paper by the number of authors. For instance, the first Sloan Digital Sky Survey paper (York 2000) has received 2877 citations to date, but it has 144 authors. Should each author be given credit for 2877 citations or for $2877 \div 144 = 20$ citations? Hirsch acknowledges this problem. The ADS allows one to sort papers either by "citation count" (e.g. 2877 for the above paper) or by "normalized citation count" (e.g. 20 citations per author in that example). This allocation may not be fair to the author(s) who do most of the work in a multi-author paper. Unfortunately there is no consensus regarding the ordering of authors' names and their relative contributions to the research.
3. It is biased for people working in popular fields (currently galaxies and cosmology in astronomy). For instance, Hirsch reports that h-indexes up to 190 are possible in biology, but in physics the record is 110. Thus h-indexes for individuals generally should be compared only with those of other people in the same field.

Hirsch found that in physics an $h = 12$ should be considered enough to secure university tenure, 20 is a sign of success after 20 years of research, 40 indicates an outstanding scientist likely to be found only at major research centers, and 45 is typical for a person elected to the National Academy of Sciences. What numbers are typical for astronomers?

## 2. Comparison of SCI and ADS Counts

Astronomers have two sources of data about the published papers, namely the SCI and ADS. Unfortunately these two sources give results that are significantly different and each has advantages and disadvantages.

For the SCI the advantages are:

1. SCI includes many journals in other sciences (chemistry, mathematics, general science) not sampled by ADS.
2. SCI is limited to about 8000 reliable journals that are available to most scientists.
3. SCI is limited to published papers.
4. Results from SCI can be compared with Hirschs results and other studies.

The disadvantages are:

1. The subscription rate for SCI is expensive.
2. Because it includes scientists in many different fields, there is often a confusion of names and initials. That means that for astronomers with family names and initials similar to those of other scientists (called homographs), the lists of their papers includes those of others and must be separated. This can usually be done by using the "Analyze" option wherein papers are separated by fields of research. Hirsch mentions that his statistics do not include some authors complicated with homographs.

The ADS has the following advantages:

1. It is free to all users.
2. It is limited to astronomers and, largely, to astronomical journals so there is less confusion of names.
3. It gives immediately the total number of citations to all of a person's papers. One can click on "Astronomy and Astrophysics" or "Physics and Geophysics"; the default position for the latter includes the former.
4. It allows one to sort papers by "normalized citation count" in which the citation count is divided by the number of authors.

The ADS has these disadvantages:

1. It includes material that is often not wanted, such as unpublished papers (e.g. astro-ph), abstracts (only) of papers given at meetings, papers given at conferences whose publications may be difficult to find, errata, editorials, etc. That material can be either in the articles listed by author and in the citations to those articles. I recommend that

users select the option "All refereed articles" when compiling lists of substantial papers.

2. A spot check indicates that it will have a confusion of names (homographs) in 5-10% of the time, but because one does not know which 5-10%, one needs to scan visually each list of papers to see if they come from more than one author. Homographs are likely with names like Davis, Smith, and Jones, but can occur for less common names.

Both sources have problems with the forms of the names that will give the full data for substantial papers. For SCI one must give the full initials to reduce the confusion with other scientists (with no comma after the family name) or use an asterisk (e.g. G* Smith) to recover papers written using both one or two initials. For ADS giving the full initials may fail to include papers published with the first name only. For instance, for the fictitious name (but based on a real person) "Roger D. Smith", searching under "R. Smith", "Roger Smith", or "Roger D. Smith" will yield all of his papers, but "R.D. Smith" will not. One must be careful in using these sources because one can easily obtain partial or excessive information without realizing it.

I compared the SCI and ADS results obtained for 81 astronomers who are members of the National Academy of Sciences (NAS). I used the "All refereed papers" option in ADS. I did not include five names for which the homographs made separation with others difficult to disentangle. It turned out that the difference in h-indexes was h(SCI)– h(ADS) = -1.0 $\pm$0.8 (mean error in the mean), i.e. no significant difference in mean h-index. However, some individual h-indexes differed by as much as 32 (80 in SCI, 48 in ADS) due, in this case, to an astronomer who wrote and had citations to many papers in physics and chemistry. The mean error in h-index per individual was $\pm$7.0 or $\pm$15%. Therefore it seems safe to compare the average h-indexes in SCI and ADS for a large number of astronomers, but definitely not for individuals. Therefore stay with one database.

To continue this comparison of results from SCI and ADS for 81 astronomers in the NAS, their highest number of citations per paper agreed in the mean at $C_{max}$(SCI) – $C_{max}$(ADS) = -13$\pm$28 (error in the mean), but the mean scatter for individual astronomers is $\pm$247 citations or $\pm$34.4%, i.e. not good. The mean number of papers differed by n(SCI) – n(ADS) = -28$\pm$11 but the error for individuals is $\pm$100 papers or $\pm$59.0%, i.e. not good. Therefore do not use interchangeably data from the two data sources.

## 3. The a-Index

A major problem with using the h-index is that the counts from young and old researchers cannot be compared. The h-index increases rapidly with time, but it is laborious to determine h-indexes for times other than the present. The changes with time are shown in Fig. 1. The values of the h-indexes at decadal intervals increase linearly, within their statistical errors, as Hirsh noted.

Abt (2012) found that if the h-index is divided by the number of decades, or fractional decades, the result is statistically constant with time. Those are shown in Fig. 1 for the same four astronomers. He called the result the "a-index" for "age-independent". For the 12 astronomers discussed by Abt (2012), Fig. 2 shows that the a-index is correlated with the slope of the h-index with a cross-correlation coefficient (cc) of 0.932. Like the h-index, it is not well correlated with the total number of papers (cc = 0.868) or with the total citations (cc = 0.876).

In Fig. 2 we see that the astronomers with high, medium, and low h-index slopes have high, medium, and low a-indexes, respectively. However, the scatter is disturbing. It turns out the scatter is mostly due to an uncertainty in how to allocate the citation credit for multi-author papers. Therefore we cannot tell whether the slopes of the h-indexes or the a-indexes are better measurements of productivity.

## 4. Comparison of Four Countries

Whereas the USA dominated over most other countries in the development of astrophysics during much of the $20^{th}$ century, other countries have been catching up. I collected data for 2011 for the first 106-119 individual 2009 IAU members in France, Germany, UK and the USA. I tried to eliminate homographs (identical family names and initials). The results are shown in Table 1.

The first noticeable result is that that USA is an older population with a mean year for the first published papers of 1973.1 compared with 1978.9 for the other three countries. This is partly because the USA has no IAU members whose first papers were published in the $21^{st}$ century, compared with an average of 6 (5.0%) for each of the other three countries. Because values of the h-index increases each year, the longer publication times of the American astronomers easily explains the marginally larger mean value of the h-index for the Americans.

However, the larger mean value of the a-index for the first three countries suggests that the (younger) European astronomers are catching up to the Americans. An alternate explanation is that younger astronomers strongly tend to work in teams (the average number of authors per paper has been steadily increasing), so the younger European astronomers have the advantage of getting credit for team research. For the 16 European IAU astronomers whose first papers were published in the $21^{st}$ century, the average number of authors per paper was $9.3 \pm 1.7$. Compared with $4.4 \pm 0.6$

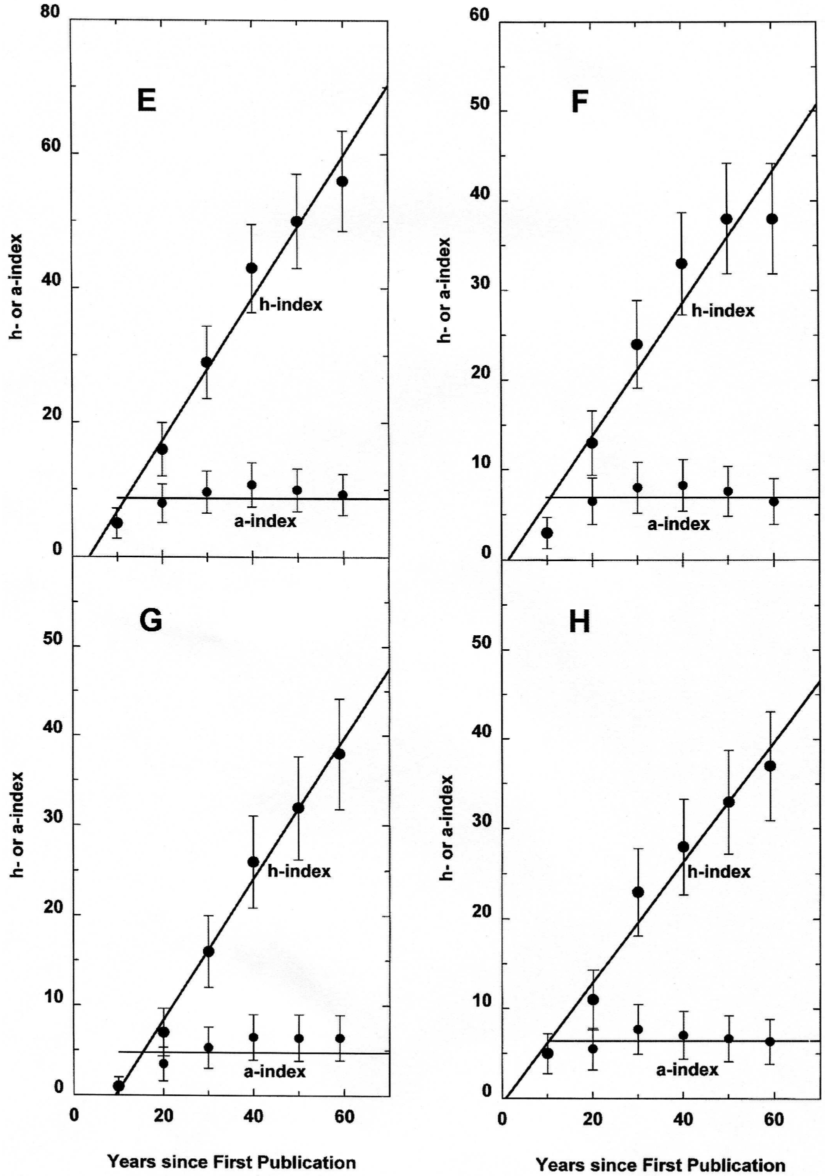


*Figure 1.* The h- and a-indexes are plotted with time, namely the number of years since the authors published their first papers. The four panels are for four astronomers whose maximum h-indexes are 56 (for astronomer E) to 37 (for astronomer H). (Reprinted with permission from Scientometrics)

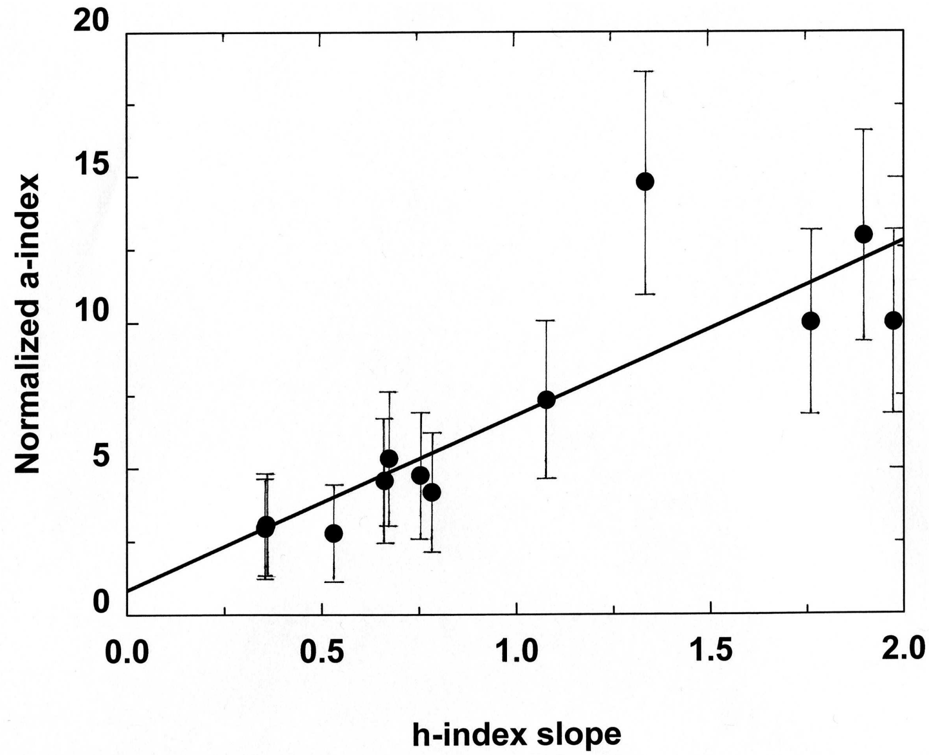


*Figure 2.* For 12 American and European astronomers near the ends of their careers, their a-indexes are plotted against the slopes of their h-indexes. The cross-correlation coefficient is 0.932. The lack of a better correlation is attributed to uncertainties of how much credit to give individual authors of multi-author papers. (Reprinted with permission from Scientometrics)

authors per paper during 1990-1995 for those three European countries, we see that the recent astronomers shifted strongly toward team research. Therefore the higher values of the mean a-indexes for the three European countries compared with the older USA astronomers is due to the former engaging more heavily in team research.

A recent study of the publication output of European and American astronomers (Abt 2010) showed that the amount of astronomical publication in Europe and the UK lagged behind that of the USA by 12 years, relative to their populations. How can we reconcile this lag with the evidence above that the quality of the former is now comparable to that of the USA? The answer is that the American papers are longer. Currently the *Astronomical Journal* and *Astrophysical Journal* papers average 13.7 and 12.1 pages per paper, respectively, compared with 7.5 pages per paper for *Astronomy and Astrophysics*. In addition, the American papers in 2009 contain far more

TABLE 1. Mean h- and a-indexes for IAU members in four countries

| **Country** | **Year of first paper** | **Mean h-index** | **Mean a-index** |
|---|---|---|---|
| France | 1979.2±1.1 | 21.1±1.1 | 8.0±0.6 |
| Germany | 1978.6±1.3 | 24.2±1.3 | 8.7±0.6 |
| UK | 1978.9±1.4 | 23.5±1.5 | 9.0±1.1 |
| USA | 1973.1±1.1 | 24.5±1.5 | 7.1±0.5 |

on-line material than the others.

We conclude that the individual astronomers in the major European countries and the United Kingdom are doing as well qualitatively as the average American but collectively they are not producing as much astronomical research as the Americans relative to their total populations.

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# THE ADS IN THE INFORMATION AGE – IMPACT ON DISCOVERY

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**Abstract.** The SAO/NASA Astrophysics Data System (ADS) grew up with and has been riding the waves of the Information Age, closely monitoring and anticipating the needs of its end-users. By now, all professional astronomers are using the ADS on a daily basis, and a substantial fraction have been using it for their entire professional career. In addition to being an indispensable tool for professional scientists, the ADS also moved into the public domain, as a tool for science education. In this paper we will highlight and discuss some aspects indicative of the impact the ADS has had on research and the access to scholarly publications.

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## 1. Introduction

Why do scientists publish? First and foremost, because they want to share their findings and further science. Essential to this process is the ability for other people to (efficiently) discover these publications. The process of information discovery has changed dramatically over the last two decades. Remember the days of spending hours in a library, paging through A&A Abstracts, catalogs and tables of contents? Sometimes a publication had to be retrieved via Inter Library Loan, adding more time to the discovery process.

A lengthy discovery process not only means a long journey before finally acquiring enough fuel to set the first step towards your goal, it also means that the discovery process is a significant portion of the cost of employing a scientist. Back then it was virtually impossible to answer the question "what is the most popular paper on X among people interested in X?" or to find a set of review papers on this subject (within a reasonable amount of time). Ease of access is therefore essential for efficient information discovery.

When the digital revolution of the Information Age culminated in the birth of the Internet, followed by the World Wide Web, the ingredients were there to take information discovery to a new level. At this time, communication started to change from paper to electronic, and this in turn created a fundamental change in society. Information in electronic form resulted in a big shift in ease of access. But just ease of access is not enough. In order to discover information efficiently, you need tools to explore this electronic universe. The combination of ease of access and (powerful) tools for information discovery are central to the process of transferring knowledge. In astronomy, the ADS has been central and pivotal in this digital revolution.

It is difficult to objectively quantify the absolute impact of the ADS (or any online service, for that matter), but we will highlight a number of facts that will illustrate aspects of the impact of the ADS. Firstly, the ease of access, combined with the powerful query capabilities of the ADS, has had a direct impact on the scientific process in the form of the amount of time gained that researchers otherwise would have spent going to a library, physically finding an article, Xeroxing it and returning to their office.

Also, access through the World Wide Web means that communities that historically had little or no access to the scholarly literature, now have access to at least basic meta data, scanned articles, Open Access literature and full text through e-prints in the arXiv repository (with which the ADS is synchronized every night). Thirdly, by diversifying its holdings, the ADS provides the astronomy community not only with the essential core journals, but also with publications from the ever-expanding periphery.

Fields that seemed to have no overlap with astronomy and astrophysics in the past, suddenly become relevant and core journals for those fields start to have content that should be available to astronomers and astrophysicists. Next, through its digitization efforts, the ADS has created access to rare and historical publications. Finally, another measure of impact is the fact that the existence of the ADS, and other electronic resources, has had a direct influence on the publication process itself. We will visit these various modes of impact in more detail in the following sections.

## 2. Impact of the ADS on Astronomy

### 2.1. EFFICIENCY OF ASTRONOMICAL RESEARCH

It seems reasonable to assume that an increased efficiency in discovering information will translate into researchers being better informed because, among other things, they will get exposed to a broader range of information sources per search effort. To what level researchers are informed will most certainly influence the quality of their research. The increase in efficiency, using the ADS, is most dramatic for more complex, but still realistic queries. For example, finding review papers on a given subject, or the most popular papers among people also interested in a given subject is a matter of just seconds, using the ADS "Topic Search". Doing this type of literature research in a traditional, "paper" library would easily take hours. But also compared to other electronic resources, using the ADS will result in increased efficiency and better results. The increase in efficiency becomes even more pronounced in those cases where the ADS provides links to additional sources of information (like SIMBAD, NED, VizieR and on-line data).

In order to quantify the increase in efficiency, Kurtz *et al.* (2000) developed a metric, based on the concept of equivalent research time gained. The physical retrieval of an article ("overhead") was estimated to be 15 minutes on average, in the "paper age". Using the ADS virtually removes this overhead, therefore resulting in a gain of roughly 15 minutes research equivalent time when an article is downloaded. Kurtz *et al.* (2000) further estimate that downloading an abstract, citation list or reference list gains one third of the time of an entire article (5 minutes). Based on the worldwide combined ADS logs from March 1999, Kurtz *et al.* (2000) found that the impact of the ADS on astronomy is 333 FTE (Full Time Equivalent, 2000 hour) research years per year. In a later study Kurtz *et al.* (2005a) found that, based on the 2002 ADS usage logs, an increase in efficiency of astronomical research by 736 FTE researcher equivalent years, or about 7% of all research done in astronomy. If we apply this to the current logs (extrapolating from the Jan 2011 logs to a full year) and just the four main astronomy journals (*ApJ*, *A&A*, *MNRAS*, *AJ*), we arrive at a number of 985 FTE research years per year. Whatever the exact interpretation of an FTE researcher year is, the impact of the ADS on astronomy, and science in general, is clearly substantial.

Another example of contributions to increased efficiency are the services *myADS* and *myADS-arXiv*, providing the scientific community with a one stop shop for staying up-to-date. In 2003 the ADS introduced a notification service, *myADS*, which uses sophisticated queries (2nd order operators) to give users a powerful tool for staying current with the latest literature in their sub fields of astronomy and physics. The *myADS-arXiv* service ("daily myADS") provides a powerful and unique filter on the enormous amount of bibliographic information added to the ADS on a daily basis, as it gets synchronized with arXiv. In essence *myADS-arXiv* is a tailor-made, open access, virtual journal (see Henneken *et al.* 2007a). The *myADS*

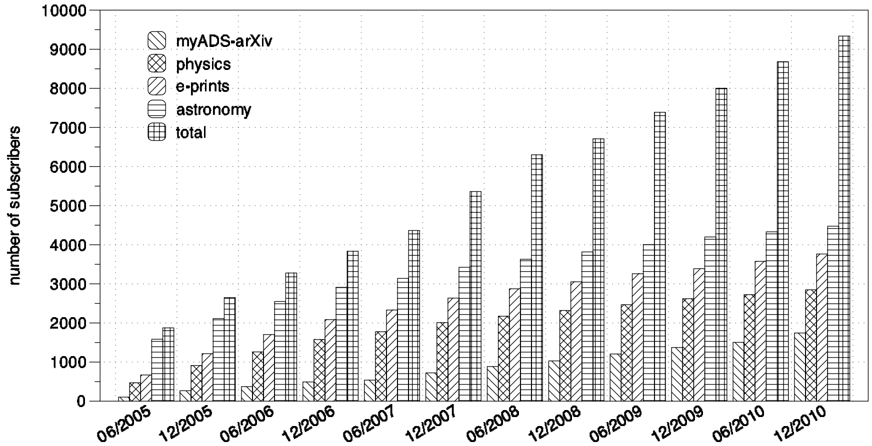


*Figure 1.* The number of myADS and myADS-arXiv users over time.

services automate an obvious need for most scientists: answering questions like "Who is citing my papers?" and "What are recent, most popular and most cited papers in my field?". Automating these queries and providing an alert service saves time. The popularity of these services is reflected in the steady growth of the number of *myADS* and *myADS-arXiv* users (see Fig. 1).

## 2.2. WORLDWIDE ACCESS AND SOCIOLOGICAL IMPACT

In 2002, the Harvard-Smithsonian Center for Astrophysics Visiting Committee reported that the ADS *"empowered astronomy research in underdeveloped countries and small institutions"* (From Report of the CfA Visiting Committee 2002). In November of 2005, the United Nations General Assembly commended the ADS for "the mirror sites of the NASA-funded Astrophysics Data System (ADS) ... had been enthusiastically accepted by the scientific community and had become *important assets for developing countries* ..." (excerpt from UN 2005). The ADS has been instrumental in helping to bridge the "Digital Divide" (see e.g. ITU 2007) for astronomical research. In Henneken *et al.* (2009) we showed that increased Internet access, in particular in Least Developed Countries (UN definition), has resulted in increased ADS usage. In that publication we examined readership in a particular region as a function of GDP per capita (GPC), because science and technology depend heavily on available budgets. Fig. 2 (taken from that paper) shows the relation between normalized GPC and normalized usage for a specific region. The definition for the region "Least Developed Countries" was taken from UN (2008). The numbers have been normalized

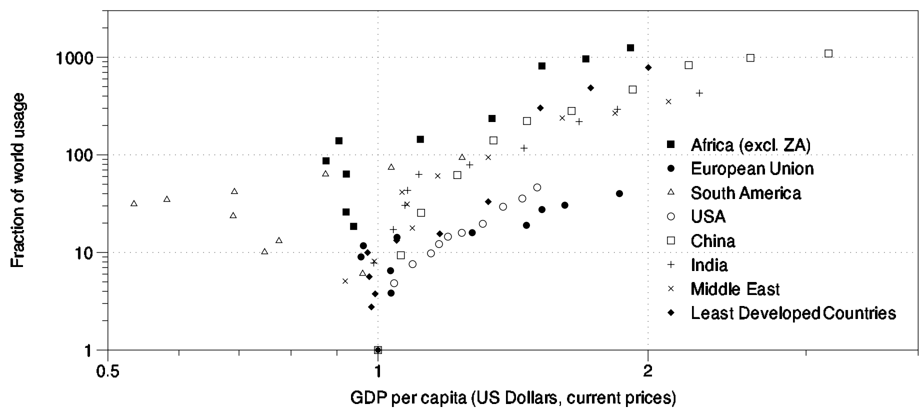


*Figure 2.* The fraction of world usage for a number of regions as a function of GDP per capita for that region. Both quantities have been normalized by their value in 1997.

with respect to the 1997 level, so the diagram shows a relative growth with respect to 1997. The general evolution in this diagram is up and to the right, as time progresses. The data used to construct Fig. 2 were taken from the ADS logs, the "Earth Trends Database" (WRI 2008), the "World Economic Outlook" (IMF 2008) and the "World Statistics Pocketbook – Least Developed Countries" (UN 2007).

Our logs show that growth in world usage is clearly driven by regions with the biggest potential. High- and middle-income regions have reached a saturation level in the density of Internet users, causing normalized ADS usage to increase at a slower rate. Clearly, the biggest potential is in low-income regions. There is a rapid increase in Internet user density in these regions, and a similar rapid increase in the number of ADS users. This indicates that the new potential is being used and in this sense there is a bridging happening of the "Digital Divide", at least from the ADS perspective.

Another metric for impact is the level of penetration in the scientific community. In other words: how many people are using the ADS regularly (10 or more times per month)? Fig. 3 shows that this number of regular users is still increasing.

In Henneken *et al.* (2009) we showed that usage by regular ADS users has a median that is fairly constant at about 21 reads per month. This is an indication for the fact that all frequent ADS users on average use the ADS on a daily basis. Initially this meant that all professional astronomers use the ADS daily, but by now there must be a growing group of professionals outside astronomy (for example physicists and engineers). This is also indicated by the fact that the current number of frequent ADS users

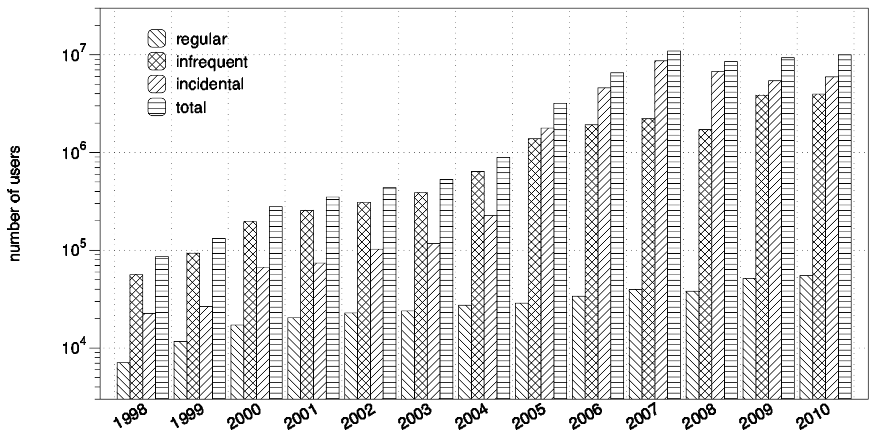


*Figure 3.* The number of ADS users of various types over time.

is significantly larger than the number of professional astronomers in the world (the IAU currently has just over 10,000 individual members, and there were about 17,000 different authors listed in the main astronomy journals in 2010).

Usage data also indicate another type of impact: the ADS has become a public service. ADS usage has changed qualitatively over time. The distribution of reads over users has changed, specifically the ratio of frequent to infrequent users has changed considerably over time. We feel that the strong increase in infrequent users has an impact on the science education of the general public. Between 35% and 40% of all ADS use actually comes from links external to the ADS. The Google, Google Scholar and Bing search engines are the largest sources, but the ADS is also linked to by thousands of static pages. For instance, Wikipedia has more than 17,000 links to the ADS. While some of the page views are scientists using Google to find a reference, the vast majority are generated by the general public.

## 2.3. DIVERSIFICATION AND EXPANSION OF HOLDINGS

In order to stay relevant for its core users, the ADS holdings must accurately reflect the complexity of the fields these people are working in. During the lifetime of the ADS, new fields emerged in astronomy and astrophysics, and existing fields became more complex, reflected in more diffuse boundaries with fields that historically had a tenuous connection with astronomy at best. The holdings of the ADS evolved accordingly. The number of journals has increased significantly over time and we currently have over 1.8 million records in our astronomy database, distributed over more than 4,500 journals.

Our digitization efforts are another aspect of the diversification of the ADS holdings. All the major astronomy journals have been scanned back to Volume 1, and they have recently been re-scanned to capture grey scale and color content. Now the ADS is focusing on scanning publications with high scientific impact and that are not otherwise available online. We have also been collaborating with librarians and observatories to digitize series of historical publications that are difficult to locate and obtain. The impact of this effort is considerable: were it not for their availability in ADS, much of this content would be simply out of the reach of researchers, librarians, and the general public. Consider, for instance, the content that ADS has digitized in collaboration with the CfA library, which consists of almost 900,000 pages of historical observatory publications. During 2009 alone, more than 1 million articles were downloaded from this collection. In other words, many historical publications have been given a new life thanks to the digitization efforts of the ADS. That this historical material is being read can be illustrated by looking at the obsolescence function of reads. The ADS logs from March and April of 2011 indicate a reads rate for historical publications of about 1.2 reads per paper per year, which agrees with the results found in Kurtz *et al.* (2005b).

### 2.4. TRENDS IN THE ELECTRONIC PUBLICATION PROCESS

It seems almost unavoidable that the presence of the ADS would also have had an impact on the actual products of the scientific community, specifically publications. Ease of access is very likely to have an impact on the actual writing process, in the sense that publications can probably be classified as being "published before the introduction of the World Wide Web" and "published after the introduction of the World Wide Web". One way of finding classifications is to represent publications as nodes in an relational network. An obvious example is the citation network: articles A and B are directionally connected when "A cites B". This network turns out to have a very specific trend: high densification over time, i.e. non-linear growth. This is shown in Fig. 4, showing the relation between the number of nodes and the number of edges in the network.

One implication is that, in an average sense, bibliographies have increased in length over time. This becomes abundantly clear in Fig. 5 which shows the average number of references in bibliographies as a function of publication year.

When an overall linear trend is subtracted (represented by "x" in Fig. 5), a deviation from this trend is observed from the mid to late 1990s on. One could argue that the ease of access, offered by web services like the ADS,

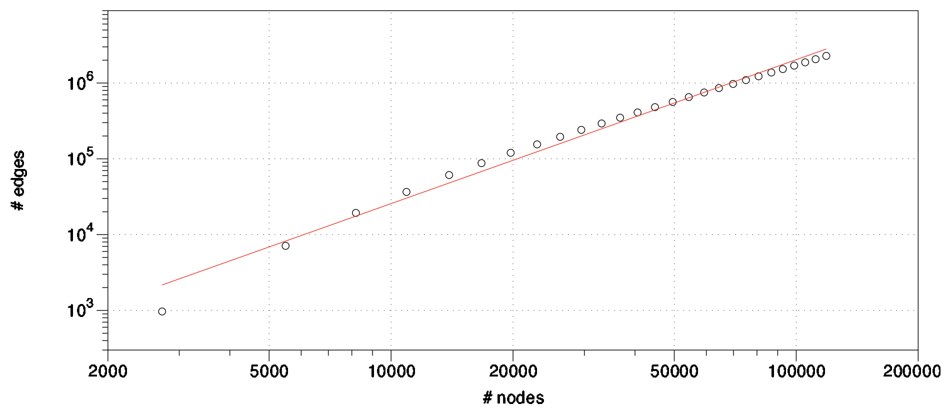


*Figure 4.* Number of nodes versus the number of edges in the citation network of the major astronomy journals in the period 1980-2006.

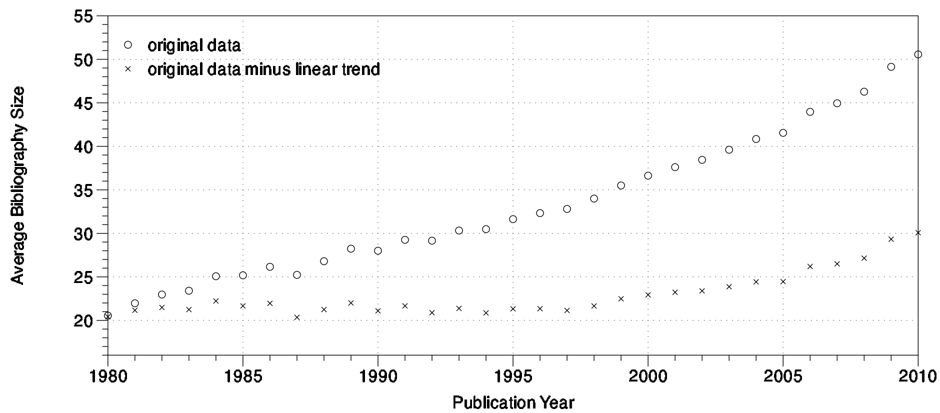


*Figure 5.* The average number of references in bibliographies in the main astronomy journals.

results in more citations (on average). Clearly, the ADS is not the only source for bibliographic information, but since our data set consisted solely of the major astronomy journals and the ADS has 100% penetration in the astronomical community, it is very likely that the ADS contributed significantly to the observed trend.

The ADS also has had impact on the study of trends in the (electronic) publication process and in how literature is being used. Michael J. Kurtz has contributed significantly to our understanding of e.g. usage and citation bibliometrics (see e.g. Kurtz *et al.* 2000 and Kurtz *et al.* 2005b&c) and the discussion of the the influence of Open Access (see e.g. Kurtz & Henneken 2007 and Henneken *et al.* 2007b).

## 3. The Future ADS

How is the ADS moving into the future? According to some, the Information Age is over and we are moving into the Imagination Age, where creativity and imagination are becoming the primary creators of economic value, as opposed to thinking and analysis (see e.g. King 2007). Whatever "age" we are in, there will remain a desire with individuals to be able to transfer information freely and to have instant access to information that would have been difficult (or even impossible) to retrieve previously. But there is definitely a new trend. It is becoming more and more common that we are faced with data collections of such magnitude and complexity, that conventional data and information discovery models brake. We need innovative ways to explore an enormous, rapidly expanding data universe. Not too long ago gigabytes seemed like a lot. The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) project is expected to produce several terabytes of raw data per night!

The ADS holdings will never come close to these amounts of data, but in our case it is the complexity of the data that requires our attention, and also the more complicated demands (and perhaps expectations) of people using the ADS. Therefore, in order to stay relevant for its end-users, the ADS has to innovate and develop new ways to explore the literature universe. We are doing exactly that in our test environment "ADS Labs", where we expose our users to new technologies and prototype services. For example, the "streamlined search" allows users to find publications that are review papers for the subject they are interested in.

Where in the "classic" approach the user had to have knowledge about what he/she is looking for and how to find it, the new streamlined search in "ADS Labs" offers a means to specify beforehand what a user is looking for. In addition to this, the results will be displayed in a different way. We use faceted filtering allowing our users to explore the literature by filtering collections of records by a particular property or set of properties. This is an efficient way to quickly focus on a particular subset of records, from the results of a broad search. In this way, we provide the user with a custom information environment. We feel that this approach results in an even more efficient information discovery environment than the classic approach. In addition to this, the abstract page now also includes recommendations.

These recommendations are based on publication similarity, in combination with article usage information from people who use the ADS frequently. The inclusion of recommendations to the usual citations and references links adds an element of serendipity to the usual activity of searching and browsing the literature. In addition to the new abstract search, ADS Labs also offers a full text search that includes current full text for all main astronomy journals. This mode of searching add a whole new dimension to information discovery, hitherto not available.

## 4. Concluding Remarks

We discussed a number of metrics for the impact of the ADS. These metrics are indicators for the impact of the ADS has on efficiency of information retrieval (essential for both research and scholarly communication), popularization of astronomy and the publication process itself (both in production and understanding). On all levels, the impact of the ADS has been significant. This impact has also been expressed in the form of recognition by peer organizations and prizes bestowed upon ADS staff.

It has been widely recognized (Fabbiano *et al.* 2010) that in this era of data-intensive science, it is critical for researchers to be able to seamlessly move between the description of scientific results, the data analyzed in them, and the processes used to produce them. As observations, derived data products, publications, and object metadata are curated by different projects and archived in different locations, establishing the proper linkages between these resources and describing their relationships becomes an essential activity in their curation and preservation. The ADS, in collaboration with the VAO, the NASA archives, and the SIMBAD project, is leading the effort of better integrating and linking the research literature with the body of heterogeneous astronomical resources in the VO, allowing users as well as applications to easily cross boundaries between archives. This endeavor has been named Semantic Interlinking of Astronomical Resources (Accomazzi & Dave 2011), and is funded by the Virtual Astronomical Observatory Data Curation & Preservation project. By maintaining its traditional role, but introducing innovations in its querying capabilities, and by taking on this new role in the inter-linking of information sources, the ADS intends to keep playing a central, pivotal role within the astronomical community.

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# SOME ETHICAL CONSIDERATIONS IN ASTRONOMY RESEARCH AND PRACTICE

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**Abstract.** Research ethics as an applied field has evolved due to a number of contentious and public lapses in ethical judgment over the past hundred years. But the main principles underlying good, ethical behavior in all of the sciences are rooted in what Robert Merton calls the ethos of science. Values and virtues, including the universal nature of its underlying objects, communal nature of scientific research, the necessity for individual disinterestedness on the part of researchers, and science's nature as organized skepticism, provide a foundation for conducting ethical research. Scientific integrity, the relation between basic science and the general public, and the social role of science all argue for adopting virtues, guiding behavior, and pursing science in ways we can now characterize as ethical in themselves. Being a good scientist and doing good science overlaps significantly with being a good person.

## 1. Introduction

Science was once deemed to be a field apart from ethics, having little-to-no nexus between the two. Science, after all, looks into objective reality, uncovering natural phenomena by measurement, experiment, and the accumulation of corroborating evidence. Ethics, on the other hand, seems to change according to the age, differs among cultures, and cannot be measured, observed, or quantified with any known precision or instruments. But science has suffered at times for these conceits, and for individual and collective groups of scientists who have in some cases flouted social conventions, ethics, or morals. Prominent cases in which scientists have engaged in academic fraud, waged public disputes with colleagues or competitors, plagiarized, falsified, or otherwise damaged their reputations and that of science itself, become etched upon the public's images of science as a field, and upon sub-fields within it. Yet science is a public pursuit, largely dependent upon the public's support, either directly or indirectly, and impacting the public in many ways as its discoveries filter up into our institutions and technologies.

Ethics is the study of "the good" and applied ethics has evolved most recently as a response to lapses in ethical judgments by those involved in sciences most directly impacting upon humans. Despite long standing philosophical disputes about the nature of the good, and its theoretical origins, in medical and research ethics, some basic guiding principles have emerged to guide and judge conduct or misconduct when it occurs. Included among these principles are a general value of beneficence, or the desire to help rather than harm, the preservation of human autonomy and dignity, the pursuit of justice, and avoiding ill intent. In other fields of research, not directly involving human subjects, these and other basic principles can help to ensure that not only does good science gets done, but science gets done in accord with the good[1].

Over the past few decades, numerous rather public and embarrassing lapses of ethics on the part of scientists, engineers, and other professionals and academics charged with academic study on the public's dime have encouraged the development of standards and norms that help to regulate and discourage bad behavior. Fields such as chemistry, physics, and basic sciences once thought immune to the errors of applied sciences like medicine and engineering, have faced the need for soul-searching in light of ethical lapses. No professional or academic endeavor, it seems, is entirely immune from errors or even evils. Conflicts of interest, the cut-throat nature of academic departments and projects, or just bad judgment can result in real harms to both the public and professions (Macrina 2005).

While most of the ethical issues that confront researchers in astronomy are similar or identical to those of other academic fields, there may be unique issues that confront astronomers. But sound ethical principles, tried and tested, and applied in courses and reviews regarding research integrity, can help guide most of those conducting astronomical research to avoid ethical pitfalls. While many might question the value of such study, or the use of such principles, consider the nature of basic science, its dependency upon the public's largess, and the duties owed to other members of the profession to maintain high ethical standards and to support its continued honor and virtue. Moreover, astronomy as a field overlaps with a number of

[1]See generally Koepsell (2009).

other fields and practices, including space exploration and commercialization, climate science, and applied physics. Researchers doing work in any basic science must consider the impact and role their research plays in a broader economic and social sphere, and gauge their actions and intentions accordingly.

Policy-makers, investments, and individual choices outside of academia depend upon work within the academy. We are all thus obliged to be mindful not only of conducting ourselves according to good ethical research practices for their own sake, but also because it matters to the world at large. Let's consider below some of the core issues involved in maintaining scientific integrity, and look at a few examples of how they may apply to research in astronomy. As well, we will look more generally at some unique duties or values associated with astronomical research and practice.

## 2. Scientific Integrity

Over the past few centuries, scientific practice has developed institutions and norms that are meant to collectively advance the conduct of research, and enrich the public store of knowledge. The scientific method depends upon some core values, including honesty and openness regarding the outcome and methods of research. According to Robert Merton, science is an inherently democratic institution, and embodies the following values: universalism, communalism, disinterestedness, and organized skepticism[2].

These values are necessary elements of the scientific method. Universalism respects that the objects of science are the same everywhere. There is no special science of the US, vs. other nations, nor of one race over another. Science seeks to uncover universal truths. It is also a necessarily communal activity. Even while research programs pursue their research sometimes behind closed doors, to enter into the scientific realm, results and methods must eventually be shared, and thus become subject to testing. Scientists must remain disinterested in the results of their study, lest they be emotionally vested in such a way that their reporting becomes skewed, either intentionally or unintentionally. Finally, scientists must constantly challenge and doubt the finality of their searches for the truths underlying nature, and be prepared to overturn cherished and accepted beliefs about past studies. Science depends upon these values, which have been said to make up the ethos of science itself.

Even before codes of ethics were developed and adopted by universities, institutes, and professions, the ethos of science, generally accepted and understood, pushed scientists to behave honestly and openly. Without these cornerstones of research integrity, a scientist's discoveries were suspect, and

[2]See Chap. 13 of Merton (1973): "The Normative Structure of Science".

his or her reputation prone to challenge. Being a good scientist, whose discoveries were useful and respected, and whose contributions to the body of scientific knowledge would endure, meant necessarily being a good scientist ethically-speaking. This is true today, but we have more concrete historical examples than a hundred years ago that help to illustrate this point, and we have codified the ethos into an ethics.

Being a good researcher and being a good human being often overlap, but there are some particular duties that arise out of the institutions of science, that we will look into more deeply in the pages ahead. Specifically, science is a socially-constructed institution that has no governing body, no central oversight, and no real codified or legal rules that apply to all scientists (although recently, some have attempted to promote such a universal code, it has only been sporadically adopted[3]).

While various fields have developed their own professional organizations, accrediting bodies, and other means of providing some direction to their "members", science as a whole remains more or less self-governing, and scientists, who conduct their research generally due to the largess of states and their citizens, may yet be guided (and generally are) by what we will call the ethos of science. As the most successful endeavor yet undertaken by humans to uncover the laws and parts of the universe, this ethos has been implicit in the methods and history of the sciences for centuries. Today, we can use it as a foundation also for discussing the ethical duties and implications of scientific research in general, and in the following pages, astronomical research in particular.

## 3. Research Conduct

Scientific programs are typically not conducted by isolated individuals. Rather, research is conducted in teams, or at least by individuals loosely connected through broader social and political networks. Ethical conduct depends upon a number of tacit virtues, collectively agreed upon, and manifest by some of the ethos described by Merton. Namely, researchers should be forthright about the bases for their "own" work, where it depends (as most research does, as even Newton acknowledged long ago) upon the work of others. Research misconduct can occur whenever researchers do any number of obviously unethical things, such as misrepresent data, fail to properly acknowledge sources or methods, etc. indeed, any actions that tend to undermine the confidence that an objective peer would have in the research or findings of another, were those actions known, ought to be avoided merely

[3]See, e.g., "A Universal Ethical Code for Scientists", 2007, UK Govt. Office for Science, `http://www.berr.gov.uk/files/file41318.pdf`. See also "The Great Beyond: Hippocratic Oath for scientists" (*Nature*, 12 Sep 2007).

as a practical matter. Of course, the motivations for misconduct, and the degrees to which certain acts may arise to unethical as opposed to merely negligent, differ from case to case. Allegations of manipulating or improperly referencing the source of data date back even to the time of Ptolemy. Up through the middle ages, Ptolemy's catalogue of stars and constellations was referenced and relied upon by generations of astronomers, navigators, and scientists. Yet the accuracy and originality of his contributions have since been cast into doubt (Evans 1987).

Critics as long ago as Sir Isaac Newton recognized that observations claimed to have been made by Ptolemy could not have been made where he claimed they were made. Thus, the accuracy of the observations themselves were cast into doubt. While there are clearly many grounds on which to challenge Ptolemy's inferences, including for instance his geocentric theory of the solar system, mere observations of the positions of stars ought to be uncontroversial. Yet his reliance upon unnamed sources clouds the veracity of his work in general, and tarnishes his work as a scientist. It also may have adversely affected generations of those who relied upon his observations. If, as seems likely, Ptolemy merely borrowed some likely reliable observations from another, attribution would have been the appropriate scientific and ethical course.

This is important because not only is it ethically wrong to claim as one's own work the work of another, but because scientists must leave a clear research trail for other researchers to check their work. Without such a trail, many countless hours of work may be duplicated or wasted.

Of course, the modern astronomer is in a much more precarious position when it comes to misappropriating or faking sources or data. It may have taken centuries for Newton *et al.* to catch onto various discrepancies in Ptolemy's accounts, but modern science moves much more quickly. The pressures of academic tenure and promotion, the need to publish, to achieve quickly, and the achieve security tend to impel researchers even now to cut corners, and in the worst cases, to commit fraud, but prominent cases of getting caught, as well as the impact such fraud has upon the ethos and perception of the sciences, ought to steer modern scientists away from such risks.

Even failure to abide by a minimal standard of care, as opposed to outright fraud, risks undermining one's own and the profession's integrity. Witness, for example, the failure of NASA scientists to covert from metric to English measurements when transferring data to the Mars Climate Orbiter resulted in the total loss of the USD 125 million spacecraft in 1999. This sort of negligence reflected badly upon NASA, wasted taxpayer dollars, and meant that valuable scientific data would not be obtained for years. Failing to properly abide by the findings of various calibration instruments during the construction of the Hubble Space Telescope's primary mirror meant a costly, and dangerous repair mission.

The stresses of due dates, monetary constraints, the pressure to publish, demands of various stakeholders, and other similar common stresses in academic research can strain the judgment of any researcher. Remaining true to the principles and duties of good research, and the virtues of a good researcher, in the face of these pressures, can help to avoid future harms. Among these principles and virtues are those associated with the ethos of science discussed above. Being open about one's sources and attributing correctly, leaving a clear trail, being honest, cooperative, and careful. Below we will discuss some specific and touchy areas of research etiquette and conduct that have ethical implications, and about which a fair amount of angst can arise.

## 4. Authorship

A frequent issue that arises in academia with ethical implications and impact regards the issue of authorship. Who counts as an author? All too frequently, authors are named on papers where no overt acts of authorship occurred. This may be because the named person was responsible for securing funding, or because of a sense of duty within a hierarchy to name the person who provides some oversight in a department, or for other understandable but insufficient reasons to grant authorship.

A good measure, however, is asking whether the named person actually contributed to writing the paper, either through developing the ideas, doing critical research and analysis, or the nuts and bolts of stringing the words together in a meaningful way. Mere copyediting does not amount to authorship, nor does a discussion around a water cooler regarding the progress or scope of the research. Rather, ask whether without the person to be named would the paper as conceived and written be possible. Some hand in both the conception and realization of a paper warrants a claim of authorship. The order of authorship differs according to professional custom, but typically first authors do most of the actual writing, middle-named authors are involved in the research, drafting and editing, and last named authors are conceptually responsible for the paper, even if they haven't written most of it. All authors ought to be involved in the drafting process to some degree, combing through it, providing corrections, actually writing parts, but at the very least reviewing it.

The ethics of authorship revolves around the notion of responsibility. If one benefits by being a named author, in that authorship typically promotes a career, bolstering a CV, leading to promotion or tenure decisions, etc., then one ought to have a vested interest in the accuracy or the paper and its impact upon the field. Recent controversies that ended up in shame and discrediting of various researchers could have been avoided had the named authors been actually, conceptually, or editorially involved in authorship. The stem cell scandal involving South Korean scientist Hwang Woo-suk resulted in jail time, loss of licenses, fines, and of course lost time and money due to research fraud (Rusnak & Chudley 2006). An apparently ground-breaking research paper published in Science had to be rescinded, and doubts were cast upon his previous papers in that and other journals. Researchers with only the most tangential connections to the study itself were named as co-authors, and had to clear their names, explain their lack of oversight and knowledge, and disclaim responsibility for the fraud. Had all named authors been actually involved as discussed above, reputations would not have been jeopardized, and the chain of responsibility for the fraud would have been more clear.

Ultimately, the decision to name someone as an author imports presumptive responsibility for that author. The reward for publishing includes a duty to stand by what is published, and the responsibility to account for any failures, intentional or otherwise, that result from published research. Researchers pressed with naming a dubious collaborator as a co-author must ask themselves and the person to be named not only whether they played a conceptual or editorial role in the paper, but also whether they can take actual responsibility in case of some failure. The public and other scientists have a right to expect no less from those who benefit through the institution of scientific publishing.

Aside from the issue of authorship itself, those engaged in any form of research ought to credit others where credit is due. Authorship decisions may have long-standing implications, and disputes have waged for generations about the roles of co-researchers, and whether they were properly credited. These disputes become especially important when Nobel Prizes are at stake, as in the case of Watson, Crick, Wilkins, and Franklin. While everyone knows who Watson and Crick were, and some know of Wilkins, Rosalind Franklin has recently been argued to have been just as critical in the discovery of the structure of DNA as the other three, and was perhaps just as deserving of Nobel recognition. In astronomy, a similar dispute continues to brew regarding the discovery of the very first pulsars, and whether Jocelyn Burnell-Bell, who was a graduate student working for Antony Hewish and who made the first actual observation of a pulsar, should have shared in the Nobel Prize with her advisor Antony Hewish (Overby 2008).

## 5. Conflicts of interest

Another issue that either raises or precipitates ethical issues in modern research concerns conflicts of interest. Where a researcher may be beholden not just to the virtues and aims of the ethos of science, in other words when he or she is not "disinterested" in the outcome of the research, a conflict of interest may result. Conflicts of interest may not necessarily impede research, nor cause it to go astray or wrong, but they run the risk of undermining the confidence of the public or other members of the profession. The nature of modern science inevitably raises more frequent potential conflicts as scientists and academics, forced to seek funding and support beyond their institutions, are often in the position now of serving multiple masters. While ideally maintaining a clear idea of the researchers disinterest in the outcome of the research would help alleviate potential conflicts, in the real world we all have interests in more mundane matters, like remaining employed, keeping funders happy, advancing our careers, and feeding our families. Remaining mindful of the potential for conflicts, however, and keeping the sources of money and trail of overlapping or conflicting duties transparent, can help maintain confidence in results and professional integrity.

Just as most institutions do not require avoiding such conflicts entirely, so too it is clear that good ethical practice in the real world may at best only require openness. Impartial arbiters, once apprised of the various potentially conflicting duties, can sort out whether, if something goes wrong, the source of the error or fault lies with the conflicts. A prominent example of how complex endeavors may lead to conflicts is the oft-cited instance of the Challenger disaster. Because NASA was answering to the executive branch, under various political pressures for a timely launch, and because Morton Thiokol was under similar political pressures, the decision to launch may have been predicated upon the wrong interests, rather than the most clear ethical duty to maintain the safety of the crew and integrity of the system.

Ultimately, researchers wishing to avoid the perils of conflicting interests need firstly to be aware of their potentially occurring. Be mindful of how owing duties to various parties may affect the production, translation, or dissemination of research. Be aware of the existence of various interested parties, and be transparent about them. In the long term, the methods of science itself will sort out whether conflicts have skewed results, or prejudiced a study. A researcher can best avoid the taint of future possible findings by being open about his or her awareness of the potential conflict, and taking pains to avoid even the appearance of bias due to potentially conflicting duties.

## 6. IP and Data

Intellectual property (IP) and rights and responsibility related to data are incompletely overlapping issues. Ordinarily, intellectual property rights do not attach to data sets since copyright and patent are meant to protect original expressions of ideas. The data accumulated through scientific study is observational. In its best instances, it reflects the world that exists, even while researchers might then go on to represent that data in new and original manners. Natural laws and phenomena themselves cannot be protected by IP, but the original uses and depictions of those laws and phenomena may be. Even so, researchers must be mindful of existing protections on such original expressions, either in publications or in the form of patented methods or machines, and ensure that they do not violate any legal rights that might exist. IP cases are costly and difficult to defend, and may hinder research for years while they are sorted out[4].

The use and misuse of data itself poses another sort of challenge. Aside from legal issues such as non-disclosure agreements, privacy concerns, and contractual restrictions that may arise in complex research scenarios, data itself must at some point be revealed in accord with the proper methods and ethos of science. It must be handled carefully, and attempts to massage, obfuscate, or otherwise manipulate data are treated harshly if uncovered by the scientific community at large. Claims of rights and restrictions over the dissemination of data or other attempts to prevent full access and investigation of data sets ultimately reflect poorly on those who choose less open paths in their research.

But being a good researcher also means respecting the need for some secrecy and not disclosing during the course of a research project, motivated by the perfectly reasonable desire to be the first to publish on a topic. Researchers who steal or destroy data in order to get ahead, to promote their careers or destroy those of others, not only violate the most basic tenets of the ethos of science, but also behave unethically. Science is a meritocracy, and sometimes luck helps. But good research and discovery is rewarded by status in the profession. Academic environments have too often been poisoned by competitiveness of the worst sort, where merit is attacked by guile, rather than competing in the open realm of discovery and invention.

Originality of thought and scientific rigor in experiment are the mechanisms for moving ahead in science, and these move us ahead as communities not only of similarly-minded researchers, but also as a species. Theft, misappropriation, or excessive secrecy, mistrust or guile, may result in temporary personal advances, but ultimately hinder our progress both materially and

[4]See generally Koepsell (2011).

ethically. Data can be reasonably concealed or otherwise protected during the course of a research project, but must be reported honestly at its conclusion. Without this sort of transparency, the scientific method itself is undermined.

## 7. Duties to Society

Increasingly, we are becoming aware that no area of science is an island unto itself. Even the most theoretical fields of research have some broader impact, if only because most basic research remains publicly-funded, and the pot of public money available for such research is increasingly threatened. Scientists doing research on the heavens are not immune from social considerations inherent in their research. Space observation and exploration take their toll not only upon the taxpayer's wallets, but also pose issues for our daily lives both now and into the future. With each launch of space-based telescope, or construction of earth-bound observatories, there is, for instance, not only generally some public expenditure, but also some environmental consequence. Whether it's contaminants from rockets or clearing land for construction, astronomical science makes an impact upon the environment. Our duties to others in general, as expressed by centuries of ethical theory, are typically recognized as including avoiding conscious harms, or at least minimizing them where harm is necessary for some other, more important reason.

While scientists sometimes work oblivious to societal repercussions, increasingly various fields are adopting codes of behavior that recognize their wider societal impact. Mindful that they work largely at the whim of the public, a sense of a reciprocal duty to others upon whom they ultimately depend, as well as guarding of reputations, help to motivate modern researchers to heed the impact of their work on their neighbors and society at large. While codes and rules are certainly helpful, a well nurtured sense of moral or ethical duty properly heeded can help avoid unnecessary and painful harms and their repercussions.

Astronomical research has a direct impact on areas of growing societal concern, and environmental consequences may come from or be influenced by the proper conduct of the study not only of other bodies in the solar system, but of earth itself. Political disputes about global warming affect us all, and these disputes depend upon accurate and responsible collection and interpretation of data, modeling of planetary climates, and analogies to other planetary climates both past and present. While many might wish to stay out of the political fights, good science warrants thorough and dispassionate research and theory free from political or emotional pressures. Misuse or manipulations of science for political ends, no matter their placement upon the political spectrum, offends the ethos of science, and degrades the nature of scientific research. It may also harm people.

Whatever the truth of the premise of anthropogenic climate change, current and future generations deserve the highest degree of scientific work in uncovering and interpreting data. Policy-makers are often politically motivated, and corporations are driven by profit, but scientists must be guided by a passion only for the truth, regardless of profit or politics. Recent stories regarding the discussion and possible manipulation of climate data, by scientists with clearly-expressed motivations to influence the public debate, have undermined public confidence in climate scientists, and perhaps set back attempts to curb behaviors that may contribute to climate change. In so doing, these researchers, by failing to remain disinterested, have hurt their cause. If they are right about the nature of climate change, they have harmed much more than a cause.

Astronomical research may also have implications for peace and justice. The exploitation of natural resources in space involves issues of fair distribution. International treaties already prohibit "owning" parts of the Moon, and future exploration of the solar system will likely involve the cultivation of valuable mineral resources, harvesting of strategic elements, or other similar goals. On Earth, we have attempted to define parts of the world that cannot be freely exploited, noting that there are things that we call "the commons" whose use impacts the potential or even right to use by everyone. Astronomers will be essential in future plans to locate and exploit the solar system's natural resources, and may well be drawn into debates regarding the existence of some extraterrestrial commons, and the justice of awarding exploitation rights to some while denying them to others.

The development of astronomical instruments may also have so-called "dual use" implications, as extremely powerful mirrors and lenses can possibly be used in space-based weapons, or sensing devices can pose a threat to our privacy or individual liberties. Just as nuclear technologies have both benign and belligerent uses, so too do many of the essential technologies behind space observation and exploration. These potential dual uses must be recognized, and scientists and engineers pursuing them should take responsibility for guarding against their harmful use, even while vigorously pursuing and realizing their scientifically valuable uses. Individual responsibility taken today can help to avoid future legal and moral culpability for the harmful uses of technology gone astray.

Finally, astronomy has long had an impact upon religious belief, and societies have had to confront, sometimes rather violently, the challenge that astronomical truths have posed to long-cherished beliefs and faiths. Galileo's famous prosecution and sequestration resulted from his accurate account of astronomical observations. Copernicus's studies and the eventual uncensored publication and dissemination of confirming study ultimately led the Catholic Church to back down and admit that the Earth was not the center of the solar system. Believers were shaken, faiths challenged, and society tested. But society has survived, and moved forward, and faiths remain. Added to the list of sciences that challenge religious faith is biology, and even now disputes rage in politics regarding the implications of Darwin's theory of evolution. Some continue also to challenge the observation that the universe and Earth are more than 6000 years old.

How should a scientist respond to those who argue that science undermines their right to religious freedom, or merely unfairly challenges their faith? Is there a duty to respect everyone's beliefs, or to tread lightly when it comes to revealing observations or studies that impact cherished belief systems? The ethos of science says no. Science and faith must at some point conflict where observations do not agree with revelation. Disinterested scientists must separate their own faith systems from observation and interpretation of empirical data if they are to remain true to the methods of science.

Similarly, they must remain disinterested in the effect of their study on the beliefs of others. Even while there is a duty to not discriminate against others due to their differing faiths, and to respect the rights of others to believe whatever they want consistent with John Stuart Mill's "liberty principle" (the right to freedom ends where it causes harm to others), there is no right to hold a belief without the inconvenience of challenge (Mill 1910). Challenging one's faith because it does not hold up against evidence causes no harm to the believer. Faith properly construed does not depend upon evidence. This is what makes it faith rather than science. Science, on the other hand, recognizes its fallibility and its mutability in light of the evidence, and depends upon constant challenge[5]

Respect for others means that challenges to faith must be civil, backed by evidence, and done only with the intention to pursue science, as opposed to the intent to cause harm. But adherence to the ethos of science, and scientific integrity and ethics demands that truths be revealed, despite their potential effects on believers. We are all entitled, after all, to our own opinions and beliefs, but we are not entitled to our own truths.

Truth is itself a good, and the uncovering of the truths underlying nature is the fundamental goal of science. Other fields may seek the exploitation of those truths to various ends, involving their own ethical duties and responsibilities, but scientists observing nature must seek to hone their models of the universe, its laws and phenomena without regard for political or religious ends. In their roles as researchers, at least, the values expressed by

[5]Elegantly argued by Stephen J. Gould (1997) who described science and religion as "non-overlapping magesteria".

Merton in delineating the ethos of science may serve as a useful guide for ethical conduct.

Ultimately, science is a social phenomenon, and scientists are a part of a broader society. The proper conduct of scientific research in every one of its branches reflects upon its role in society, and effects its perception by the broader public. Ethical conduct can be complicated as duties and obligations multiply, and as motivations become cloudy or conflict. Remembering the ultimate role of science in society, and the manner by which it best proceeds, can help to sort out some if not all of the ethical issues that may arise, and will help to ensure the smooth progress not only of individual subfields in science, but of science in general as a means to achieving human progress.

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# ETHICS IN SCIENTIFIC PUBLISHING

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**Abstract.** We all learn in elementary school not turn in other people's writing as if it were our own (plagiarism), and in high school science labs not to fake our data. But there are many other practices in scientific publishing that are depressingly common and almost as unethical. At about the 20 percent level authors are deliberately hiding recent work – by themselves as well as by others – so as to enhance the apparent novelty of their most recent paper. Some people lie about the dates the data were obtained, to cover up conflicts of interest, or inappropriate use of privileged information. Others will publish the same conference proceeding in multiple volumes, or publish the same result in multiple journals with only trivial additions of data or analysis (self-plagiarism). These shady practices should be roundly condemned and stopped. I will discuss these and other unethical actions I have seen over the years, and steps editors are taking to stop them.

## 1. Introduction

The starting point for a discussion of ethics within astronomy should be the American Astronomical Society statement of ethics policy[1]. All astronomers should read that and follow the principles therein, which broadly fall into three categories: 1) plagiarism and attribution, 2) conflicts of interest, and 3) civil and professional behaviour. Although the policy document breaks it down a little more finely than that, these three broad categories will serve my purpose, which is to illuminate the policy with examples, and to explain some of the reasons why these policies should be followed.

[1] http://aas.org/ethicsPolicy

Readers should bear in mind that although editors often hear about ethical violations first, we often have little or no legal standing to act because we are not employers/supervisors, unless the violation is directly relevant to the peer review of a particular manuscript. Even referring a case back to an employer for action can involve many consultations with a lawyer, which we will do when necessary.

## 2. Plagiarism and self-plagiarism

Plagiarism is using other people's text and saying it is your own. I have come across a few instances of that over my years at *Nature*, but despite the ease with which content can be cut and pasted, it is gratifyingly rare. The instances I have seen involved authors who were not native English speakers using text from the introductions of other papers. Plagiarism is a deep ethical violation, but it is easily caught by commercial software used by publishers, and has been rare in astronomy. I hope it stays that way.

Self-plagiarism, on the other hand, while not rampant, is fairly widespread. Authors re-use their own text, seemingly unaware that the material should be in quotes, with the original source identified. The problem in this area is the many shades of grey. For example, is it all right to use text from the justification section of an observing (or grant) proposal in the introduction of a paper? My personal position is that yes, it is fine, because the observing/grant proposal is in the direct path of accomplishing the scientific objectives, and because the full contents of the proposals are in general not publicly available (usually, it is just abstracts that are available). But what about an unrefereed conference proceeding? My strong recommendation is no, because this is publicly available, usually in a volume, and often on `arxiv` as well. I therefore feel that re-using text from such a source is not an acceptable practice. Publishing the same (or almost the same) conference proceeding in multiple places also is unacceptable. Taking text from a conference proceeding that appeared in a peer-reviewed journal is unacceptable. The text should be rewritten so that not a single sentence remains unchanged.

Pasting text from one's own published papers is wrong, and I have contacted editors of other journals when I have come across instances of this. Authors might argue that it is different to copy introductory material than interpretation and conclusions, but in general editors do not see it that way. It is completely unacceptable under all conditions, as it is attempting to gain credit for work that was not done – and that is at the core of why plagiarism is very unethical.

A very troubling practice is to publish a paper and then, a year or so later, add a trivial amount of new data and/or discussion, and present it as a ‘new’ result, in general without reference to the earlier paper. This is deeply unethical. It is also easily caught by editors.

## 3. Proper attribution of credit

Science builds upon the work of others, and the correct attribution of credit for that earlier work is important.

It is common practice in some parts (both geographical and discipline) of our community to grant authorship to any member of a collaboration, even if someone has contributed little or nothing to that specific paper. This is becoming a worry with the increase in the number of large collaborations – sometimes hundreds of people. In particular, this tends to downplay the critical roles played by students and postdocs, who in general do the bulk of the work. *Nature* has had in place a system for about two years requiring authors to specify who did what on any given paper, but we have found ourselves thwarted in the intent by the memoranda of understanding of various collaborations, which prohibit such specificity. There are several concerns. First, it is important that critical individual contributions be highlighted, so that future hiring and prize decisions be based upon a clear and transparent understanding of who did what. The present opacity will inevitably lead to hiring and prize decisions being based on back-room conversations, as in the ‘bad old days’ of chummy science. It is grossly unfair to students and postdocs. Secondly, if in the future aspects of the data collection and analysis are shown to be suspect or fraudulent, it needs to be clear just who did what, so that the source of the suspicious part of the paper is clear. Authors may be under the impression that bland statements dilute responsibility, but that is not how editors look at the situation. To us, a statement of “every author contributed significantly to this paper” not only is patently false, but invests each and every author with total ownership of the paper. If one aspect of the work is tainted, than all authors are tainted to the maximum extent.

Attribution through accurate referencing also is an important obligation for any author. At something like the 20 percent level, editors are seeing authors deliberately not citing their own previous work, in order to make the new manuscript seem more exciting. There also is a disturbing pattern of failing to cite relevant work by others. This is easily caught through the SAO/NASA Astrophysics Data System (ADS), and in fact editors always check this before sending papers to referees. When relevant work by others is not cited, there is a natural inclination to pick one of the authors of the neglected work as a referee.

## 4. Conflicts of interest

It is almost always the case that the best judge of a person's work will be a competitor, because the competitor will be aware of the nuances, observational techniques and recent activity in the field. So competitors are not excluded in a blanket way from consideration as referees (of observing or grant proposals, or of papers). But there are circumstances where it is best to recuse one's self from refereeing. If actively working on a competing paper, one should decline to referee a manuscript about the same subject. There are several reasons for this. First of all, if you take a long time refereeing the paper you are open to the charge that you are deliberately delaying publication of the competitor's paper (this usually does not apply to observing and grant proposals, because reports are due on a specified timescale). Secondly, you could be open to the charge of lifting ideas from the competitor's proposal or paper. In both cases, such actions might be entirely innocent, but why leave yourself vulnerable? If you have already submitted a competing paper, then there is less potential for conflict, but the editor should certainly be informed of the situation so that he/she can assess the situation.

An abuse of privileged information – such as using data from a paper you are refereeing to advance your own work, perhaps through a request for director's discretionary time, is a conflict of interest. I have seen authors lie about the dates on which data were collected, to cover up the unauthorized use of privileged information.

If you have a close and ongoing collaboration with someone, it is a conflict of interest to referee a proposal or paper from that person, mainly because of the worry about a lack of objectivity. But here there are many shades of gray. If the collaborator is one of 40+ authors, and you know that he/she had little to do with the paper, then I do not see a conflict of interest. Simply because a person was a former student (or supervisor) does not imply a conflict of interest. But a romantic relationship (past or present), especially a covert one, is a conflict of interest, because of the loss of objectivity. (One of my worst experiences as an editor involved an undeclared and covert relationship between an author and referee that had been ended just before the submission of a paper, where – on paper – the referee was a logical choice.)

Whenever a person has a financial stake in the outcome of a decision, he or she should recuse themselves entirely from the decision-making process. This is a source of great concern to me, because of the way funds for some projects are allocated. Certain agencies have made it a practice to distribute funds in such a way as to essentially guarantee that people have a stake in the continued funding of a project. While providing money for analysis as part of a grant of observing time seems an elegant way to get the science done, I feel that it inappropriately introduces conflicts of interest. It is one thing to be a 'stakeholder' with an interest in seeing a particular telescope built. It is quite another to see that telescope as a source of future grant money. I do not have an answer for this difficult situation, but I feel that we should be aware of it, and sensitive to the fact that we are almost entirely publicly funded and that considerable trust is placed in us to allocate funds appropriately.

## 5. Civil and professional behaviour

We were told as children that "you catch more flies with honey than with vinegar", but some people in the field need reminding of that. I feel that the whole field has become markedly less collegial than it was 20 years ago, at least partially because of trends toward larger collaborations and less time at the telescope.

We should always treat others with respect. That does not mean we cannot have disagreements over interpretation and policy, but it does mean that we should listen to what others say, consider the concerns they have, and if it is a matter of fact – apply the scientific method to determine who is correct. The wonderful thing about science is that it is inherently self-correcting, at least over time. Differences over policy can be debated, but it is unhelpful to assume that someone on the other side of a debate does not also have the long-term interests of the field in mind. Pay attention to their point of view.

It is particularly important for more senior members of the community to set a good example, and to train their students and post-docs in appropriate behaviour towards others.

## 6. Some final thoughts

There are some overall guiding principles behind an ethics policy.

We should not claim credit for work we did not do, and we should always give appropriate credit to the efforts of others.

Outside of the often necessary constraints of anonymous peer review, we should aim to be as transparent as possible about how we do and present our science.

We should not abuse our positions for personal gain.

Finally, if you ever find yourself in a situation where the ethical choice is unclear, ask yourself: If someone else did to me what I am contemplating doing, how would I feel?

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# BIG SCIENCE AND ITS PROBLEMS: THE DEVELOPMENT OF THE RUTHERFORD APPLETON LABORATORY

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**Abstract.** Research establishments have to cope with a continually changing environment. Available funding and research imperatives change with time. The question is how an establishment can remain viable throughout these changes. The Rutherford Appleton Laboratory provides an interesting case study of one establishment that has managed to survive and flourish for over fifty years despite the problems. The Rutherford Laboratory was set up in the 1950s to provide facilities for high-energy physics in the UK. By the 1970s, the need for a British accelerator had declined because of the facilities offered by CERN. The Rutherford Laboratory therefore branched out into other areas of particle physics. A major development at the end of the 1970s saw the Appleton Laboratory merged with the Rutherford Laboratory. The Appleton Laboratory had started life as an ionospheric research station. With the dawn of the space age, it became involved in satellite tracking. The growing demands of space research strained its resources and the merger with the Rutherford Laboratory was intended to strengthen its capabilities, especially in dealing with NASA. The combined Rutherford Appleton Laboratory is now the main government research establishment in physics-related areas in the UK. The joint Laboratory has proved very adaptable: the research emphasis now differs greatly from the original motivations for either component part.

## 1. Introduction

'Big science' had become a well-established phrase by the 1960s. It reflected a trend in science which had been greatly encouraged by developments during the Second World War. The characteristic features of big science are a large central facility – a particle accelerator, for example – which acts as a research focus both for the staff of the institution where the facility is situated and for visitors. Running the facility requires the participation of support staff who can call on a range of skills. Similarly, external users typically consist of groups of researchers, the members of which can also call on a variety of skills. All this entails the expenditure of large sums of money. So 'big science' has come to be defined as something requiring big facilities plus big staff complements plus big budgets. Such costly facilities typically involve either direct or indirect funding from the government.

Exactly how this is provided varies from country to country. In the United States, for example, some large facilities have been established at universities; in Germany, many have come under the Max Planck research institutes; in the UK, the preferred placement has been in government research establishments. In the immediate aftermath of the Second World War, such facilities mainly encompassed research centres devoted to some aspect of nuclear physics. The growth of space research since the 1950s has added another area of big science.

In a sense, astronomy predates both of these as a big science. Large telescopes used by visiting observers go back a century. The difference was that the visiting observers were often individual researchers, rather than groups. This has changed in recent decades, and observational astronomy can now be reckoned a part of big science. The interesting question is what happens to such facilities if the needs of researchers change and the facility loses its previous importance. The history of the Rutherford Appleton Laboratory in the UK provides useful insights into possible answers to this question[1].

## 2. Creating a National Facility

Discussion of the need for a national particle accelerator in the UK began in the 1950s. The idea was not universally welcomed. A number of universities already possessed accelerators, and they foresaw that a central facility would reduce the likelihood of further such university-based accelerators being developed in the future. Moreover, some feared that the ultimate result would be an increased central control of research activities in the field. But it was the question of future costs that clinched the argument. A document that went to the British government in 1956 contained the following key statement:

> *"Given the cost and complexity of the necessary machines and the limited resources available, the needs of universities for the larger machines can hardly be met in the future on the basis of separate provision for each university or even each major university. The setting up of a new*

[1] For a detailed history of the Laboratory, see Meadows (2009).

*research institute for the use of universities and other organisations working in the field would appear to be the best alternative."* (Litt 1979, p. 14)

This alternative had been pushed hard by John Cockroft. He was not only one of the most respected nuclear physicists of the time, he had also pioneered the creation of an Atomic Energy Research Establishment [AERE] at Harwell, near Oxford, immediately after the war. He believed that it would be advantageous to build the proposed new establishment also at Harwell, with the difference that, whereas activities at AERE were classified as confidential, the new establishment would encourage open publication. His advice was accepted. This made at least some university physicists suspicious that the new establishment would have its policy controlled by AERE: a suspicion that was enhanced when the new establishment recruited staff from AERE. The problem was made worse by the fact that many nuclear physicists resided in the north of the UK and were unhappy at having their major facility situated in the south. The latter objection was solved in the 1960s by setting up a separate establishment at Daresbury in the north of England. The suspicions of AERE gradually died down as the new facility – named the Rutherford High Energy Establishment in memory of Ernest Rutherford – developed its programme.

The proton synchrotron at the Rutherford Establishment – called 'Nimrod' – came into operation in the 1960s. Meanwhile, during the 1950s, planning had been going ahead for a new European nuclear facility, labelled CERN, near the Swiss frontier. The intention was to build there a much more powerful accelerator than that planned for the Rutherford Establishment. The result was that, from the start, British particle physicists divided their time between the Rutherford Laboratory (as it soon became) and CERN. Fortunately, the characteristics of the British accelerator made it more useful for certain types of experiment than the CERN accelerator. Internationally, there was some idea that, as new accelerators were required, they should be distributed to different countries. So there was the possibility that the UK might gain an additional accelerator that way. A panel was set up to assess the various sites that were put forward.[2] In the end the sensible option was taken, and it was decided to concentrate all the international machines at CERN.

By the 1970s, the Rutherford accelerator was coming to the end of its useful life. In the years since its creation, it had become increasingly clear that British particle physicists would be focussing their main research interests on CERN in the future. Tentative plans for a new British accelerator that had been drawn up were therefore scrapped. The question now was

[2]Its comment on the suggested British site was: "It can be very depressing to live in a place where the sun seldom shines." (Goldsmith & Shaw 1977, p. 51)

what would happen to the Rutherford Laboratory. It was making a valuable research contribution as the UK centre for developing detection equipment for accelerators at CERN and elsewhere. It also acted as the UK centre organising British research at CERN. Yet, without an accelerator of its own, it seemed to have lost its raison d'être.

## 3. Change of Focus

Particle research after the Second World War had gone off in a number of different directions. One was the use of neutrons as a tool to explore the structure of all types of material. In Britain, research on this topic initially depended on using a neutron beam from one of the Harwell reactors. However, this approach proved increasingly outdated, and British researchers had to make use of a new neutron beam facility at Grenoble. In view of its successful cooperation with CERN, the Rutherford Laboratory took over the job of developing equipment and coordinating UK/European activities in this new area. Senior staff at the Laboratory now pointed out that by cannibalising parts from other machines – some at the Rutherford Laboratory and some elsewhere – and using existing buildings, a new type of neutron beam source could be created in the UK on the cheap. The core component would be another proton synchrotron, but this one would be used to provide neutrons via collisions between the protons and a target. The proposal was given official backing, and the facility was opened by the then Prime Minister, Margaret Thatcher, in 1985, at which point it received its current title ISIS. ('Isis' is not an acronym : it is the name given to a local stretch of the river Thames.) In this ingenious way, the Laboratory replaced an aging machine by a new one with a bright future. Moreover, while Nimrod had been essentially a national facility, ISIS rapidly became an international centre for neutron diffraction research. With various updates, ISIS continues as a major international facility today.

Meanwhile, the 1970s saw other developments. Interest in the applications of lasers was growing in the research community. Low-power lasers were relatively cheap, but high-power lasers were another matter. The British government therefore decided to set up a national centre to develop high-power lasers and to provide university access to them. The Rutherford Laboratory had the necessary infrastructure and management in place to handle both complex technology and visiting researchers, so it was decided to site the new laser facility there. Similarly, the field of microelectronics was developing rapidly in the 1970s, but the equipment needed for microcircuit technology was expensive. Again, it was decided to fund a central facility at the Rutherford Laboratory. Both of these new developments fall under the heading of 'big science'. The work of the Laboratory particularly emphasized the design and construction of instrumentation. From the viewpoint of both staff and management, expansion into these new fields made good sense.

## 4. New Acquisitions

The diversification of activities at the Rutherford Laboratory described above came from the establishment of new centres and facilities at the site. The 1970s also saw major changes in the Laboratory's work via the absorption of other, already existing bodies. In 1961, the Atlas Computer Laboratory was established: it shared the Rutherford Laboratory site, but was an independent entity. Its creation reflected official recognition of the fact that the most powerful computers were too expensive for each individual university to buy, so that a central facility was needed. (The word 'Atlas' in the title was the name of the first powerful computer bought by the new Laboratory.) The problem was that the cost of computing power was dropping rapidly. Universities were acquiring increasingly powerful computers, while the central facility found it difficult to update its computer provision in a comparable way. As the national focus for computing in the UK, the Computer Laboratory was under pressure to buy a British computer. By the 1970s, however, IBM were producing considerably more powerful computers than anything available in the UK.

While the Computer Laboratory was trying to find a way out of this impasse, the Rutherford Laboratory was allowed to purchase its own computer from IBM. The result was that, the Computer Laboratory had to obtain time on the Rutherford computer, rather than vice versa, as had originally been planned. The Atlas computer was switched off in 1973, at a time when government funding of science was being squeezed. Various options were floated, but the final decision was to merge the Atlas Computer Laboratory with the Rutherford Laboratory and to upgrade their computing facilities together. Not all the staff of the Computer Laboratory were happy with this conclusion. They believed that a separate 'National Computer Centre' should have been established: after all, the Rutherford Laboratory's focus was on the development of instrumentation, which was not seen as a significant interest for the Computer Laboratory. There was also some opposition from user groups, who feared the takeover might be geared to the interests of the Rutherford Laboratory. As the review panel that investigated the future of the Computer Laboratory reported:

> *"We were all impressed by the need for any proposed arrangement to maintain the confidence of the non high energy users of these facilities and of the need to make it clear to them that they would not take second place to the physicists currently being catered for by the Rutherford*

*Laboratory."*[3]

The Rutherford Laboratory management tried hard to allay these fears. They were helped by the growing diversification of activities away from high-energy physics at the Laboratory itself. In subsequent decades, and especially after the growth of networking, the Laboratory's role in computing became generally accepted. By the time of the take-over, it had become evident that the next major advance in computing would be networking. In assuming the Computer Laboratory's role to assist universities, the Rutherford Laboratory found that it now became the focus for university networking. In recent years, this has proved advantageous for two of the Laboratory's particular interests – space science and high-energy physics. The volume of data flow in these two fields has become so large that it has been necessary to set up dedicated computer 'grids' to handle it. Because of its background in networking, the Laboratory has proved to an important focus for the development of such grids.

Another merger, of even greater significance, occurred at the end of the 1970s. The Appleton Laboratory was a government institution which had been set up after the First World War with the prime aim of using radio waves to investigate the Earth's upper atmosphere. With the advent of the space age at the end of the 1950s, it became involved in the use of balloons, rockets and satellites for exploring the upper atmosphere. NASA was keen on having access to a satellite tracking ground station in the UK, and the Appleton Laboratory was seen as the appropriate body to run such a station. The Laboratory now became designated as the central UK body for managing space projects and operating the related facilities. Its involvement in space science expanded rapidly, putting an increasing strain on its resources, and raising the fear that it might not be able to fulfil all of its commitments.

In particular, there were fears that its role as NASA's partner in the UK might be affected. One of the main problems was the relatively small size of the Appleton Laboratory. At the end of the 1970s, it had some 300 staff, only a quarter of the number employed at the Rutherford Laboratory. The government therefore took the decision to merge the Appleton Laboratory with the Rutherford Laboratory, encouraging the latter to expand its activities in space research. (The Rutherford Laboratory had already devoted some effort to building and running space-related equipment.) Several Appleton Laboratory staff were unhappy with this decision. Indeed, a number refused to move, either leaving, or taking early retirement. The Rutherford management made a considerable effort to be accommodating – including a change in the management structure – and most of those who transferred

[3]SRC-Atlas Computer Laboratory Report of Council Working Party [ALP 6-73], 1973, p. 7.

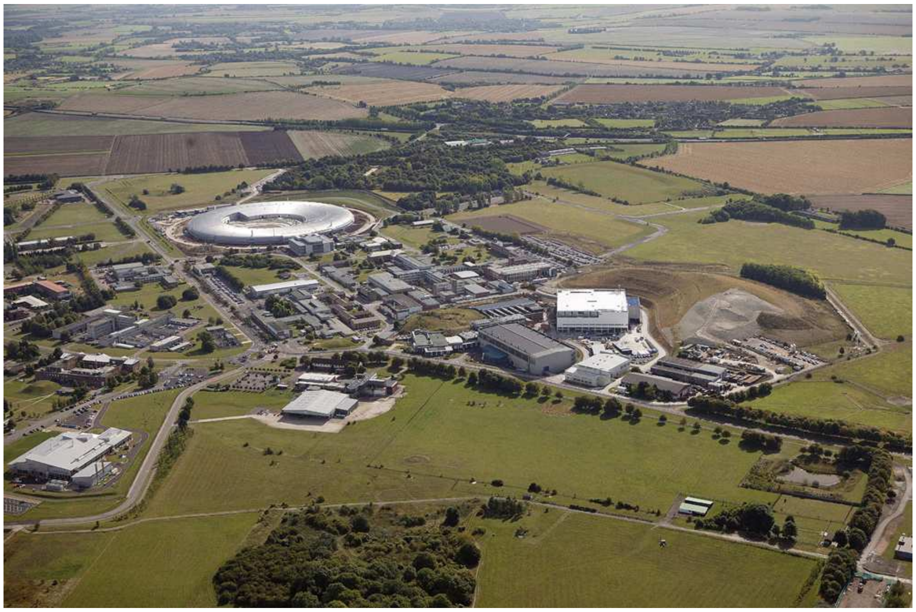

*Figure 1.* Aerial view of Rutherford Appleton Laboratory. The large silver-coloured building hosts the DIAMOND light source that started operations in 2007. It represents the single largest UK scientific investment over the past 40 years. (Courtesy RAL)

thought a reasonable attempt had been made to welcome them. The problem was that every research establishment has its own culture and needs, and these can take longer to merge. One of particular importance in the Rutherford-Appleton merger related to instrumentation. This was a prime focus of interest at both establishments, but there were differences in approach. The staff at the Rutherford Laboratory produced instrumentation to very high levels of accuracy, but not usually with stringent limits on weight and size, as was essential for space experiments. Again, this was a problem that disappeared with time and experience.

These mergers raised the staffing complement at the renamed Rutherford Appleton Laboratory to over 1,600, only a tenth of whom were involved in high-energy physics, the original purpose of the Laboratory. It was now the major focus for big science activity involving physics in the UK across a range of fields. The so-called 'Matthew principle' was coming into operation[4]. This pulling power is well reflected by the DIAMOND story. When its synchrotron reached the end of its life, the Daresbury Laboratory, like the Rutherford Laboratory, was faced with the question of what

[4]'Unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath.' (The Gospel according to St. Matthew Chapter 25, verse 29. See Merton, 1968)

to do next. Like the Rutherford Laboratory, it decided to branch out in a new direction. The Daresbury synchrotron produced considerable amounts of radiation from the electrons that it accelerated.

By the early 1970s, this radiation was being used for an increasing range of experiments. The staff at Daresbury therefore proposed the creation of a new machine designed specifically to produce synchrotron radiation. This was approved, and the new synchrotron came into service in 1980. By the 1990s, it was clear that this machine, in turn, would soon need to be replaced by an updated model. Staff at Daresbury therefore began work on designing the proposed new machine. The problem proved to be finding the funding. The financial logjam was eventually broken when a major UK charity – the Wellcome Trust – agreed to contribute part of the cost of construction. However, this led to an immediate complication. The Trust, and soon the government, felt that the Rutherford Appleton Laboratory would provide a better home for the new facility, not least because of the range of activities that was already supported there. Proponents of Daresbury were naturally dismayed, and mounted a vigorous campaign to overturn this decision, but, in the end, they were unsuccessful. DIAMOND was built at the Rutherford Appleton Laboratory site – it opened in 2007 – and the staff at Daresbury were left to seek what they might do next.

## 5. The Factors Involved in Success

Government-supported research establishments in the UK became the subject of a sweeping review in the 1990s. The question was whether any of them might be either privatised or closed. It was soon clear that history and prestige were not enough to rescue an establishment from adverse judgement. Thus it was decided in 1998 that the Royal Greenwich Observatory should be closed. This was a shock to the astronomical community, for the Observatory had existed for over 300 years, and had traditionally been seen as the premier astronomical establishment in the UK. However, its activities overlapped appreciably with those of the Royal Observatory Edinburgh. It was thought more efficient to have a single agency to manage use of astronomical facilities worldwide, and the ultimate assessment was that this could be done better by the Observatory at Edinburgh. The Rutherford Appleton Laboratory came out of the review much more successfully. In terms of selling the Laboratory, no potential buyer could be identified for such a large and diverse establishment, and other options – such as the universities running the facilities – were likely to prove more expensive for the Treasury than the existing provision. At the same time the facilities at the Laboratory were so widely used that closure was not an option. In consequence, the Rutherford Appleton Laboratory continued (and continues today) as the leading 'big science' centre in the UK.

Analysing the history of the Rutherford Appleton Laboratory reveals a range of problems from which 'big science' establishments can suffer, along with some indication of ways in which these problems can be alleviated. A basic one relates to the establishment's 'niche' position – the particular research field for which the establishment provides services. Two problems can arise from this. The first is that the niche field declines in importance; the second is that other bodies appear which overlap the research niche of the establishment. In the case of the Nimrod accelerator, both problems appeared. The type of experiments that the accelerator could encompass declined in importance, and CERN provided better facilities. Two responses to this problem seem possible – to find a new niche, or to expand to cover several niches. With ISIS, the Laboratory pursued the first option. At the same time, smaller niches – lasers and microelectronics – were occupied. These were too small to deserve an establishment of their own, but they complemented the interests already existing in the Laboratory. (It obviously helps the creation and retention of new niches if there is some degree of synergy between them.) The Laboratory now began to evolve into a general big physics establishment, rather than remaining a niche one. The addition of the Atlas Computer Laboratory and the Appleton Laboratory extended very significantly the niches covered. Indeed, the attraction of the Rutherford Laboratory as a centre for supporting university research led it into areas which were not big science at all. For example, it became the home of the Energy Research Support Unit, which was particularly concerned with the use of wind power.

General establishments have the advantage that decline of one of the niches they cover does not necessarily mean decline of the whole establishment. The disadvantage is that, unless the establishment is a major player, expanding niches may be diverted to competing establishments. The Rutherford Appleton Laboratory is now large enough to dominate the national scene, and to be the natural focus for international cooperation. Consequently, the latter problem is not currently pressing. But flexibility is still important. The Laboratory is no longer acquiring other niches at the rate it did in the 1970s and 1980s. What it has done is to respond to government pressures on research to concentrate on topics that may have future applications. By the end of the 1990s, the Laboratory was collaborating with over 120 commercial companies, and in the past decade it has been involved in the creation of a number of new companies. The drawback to this changed emphasis is that the Laboratory has two functions – to assist university researchers and to carry out its own research activities. There has, of course, always been the potential for conflict here, especially over the division of research funding between the universities and the Laboratory. Currently, university researchers in the UK are under the same pressure as the Laboratory to produce applicable research, and see the Laboratory as a possible competitor. With government funding now tight, getting the correct balance between its two functions is possibly the most sensitive problem facing the Laboratory. However, most of its users agree, whether reluctantly or not, that had the Appleton Laboratory not come into existence, it would have certainly been necessary to invent it.

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# HISTORICAL EXAMPLES OF LOBBYING: THE CASE OF STRASBOURG ASTRONOMICAL OBSERVATORIES

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**Abstract.** Several astronomical observatories have been established in Strasbourg in very differing contexts. In the late $17^{th}$ century, an observing post (scientifically sterile) was put on top of a tower, the Hospital Gate, essentially for the prestige of the city and the notoriety of the university. In the $19^{th}$ century, the observatory built on the *Académie* hosting the French university was the first attempt to set up in the city a real observatory equipped with genuine instrumentation with the purpose of carrying out serious research, but the succession of political regimes in France and the continual bidding for moving the university to other locations, together with the faltering of later scholars, torpedoed any significant scientific usage of the place. After the 1870-1871 Franco-Prussian war, the German authorities set up a prestigious university campus with a whole range of institutes together with a modern observatory consisting of several buildings and hosting a flotilla of excellent instruments, including the then largest refractor of the country. This paper illustrates various types of lobbying used in the steps above while detailing, from archive documents largely unexploited so far, original research on the two first observatories.

## 1. Introduction

Lobbying can be defined in various ways. My acception here will be a simple, general one: influencing people (including public officials) for or against a specific cause. We all "lobby" in a way or another in our life and especially in the context of our career: for securing a position for ourselves or others, for ensuring the success of an application for funding or observing time, for supporting the progress of ideas, projects, policies, etc.

Lobbying can be carried out by individuals, openly or behind the scenes (as or through *éminences grises*), or by groups, by organizations, and even by states. Targets can be individuals, groups, organizations and countries via their governing bodies. Exact motivations for lobbying are not always explicit. They can be understood at best by a good perception of all their ins and outs, and especially of the socio-historical context of the time.

While detailing original historical research, this paper will offer various examples of lobbying linked to successive astronomical observatories established in Strasbourg:

- a dual lobbying (military and scientific) by a $17^{th}$-century scholar to ensure funding for a study trip in Northern Europe;
- the lobbying initiated by the same scholar for establishing an observing post on top of a tower in the city walls and in the course of which the only arguments recorded in the proceedings were the prestige of the city and the notoriety of the university; this facility has been unproductive;
- insistent lobbying, including a modern approach (audit, etc.), to set up an observatory equipped with genuine instrumentation and the purpose of carrying out research on top of a university building, the $19^{th}$-century French *Académie*; some adverse lobbying and the succession of political regimes in France prevented any scientific output before the Franco-Prussian War of 1870-1871 at the outcome of which Strasbourg became German;
- political lobbying at the highest level in Germany leading, as a consequence of the conflict just mentioned, to a new university in the city, including a multi-building observatory equipped with a whole range of excellent instruments and the then largest refractor in the country;
- international lobbying establishing a local astronomical data facility as a center of excellence on the world stage.

The archive documents mentioned in this paper are referenced as ADBR (for the *Archives Départementales du Bas-Rhin*), AdP (for the *Archives de Paris*), AVCUS (for the *Archives de la Ville et de la Communauté Urbaine de Strasbourg*), DK-RA (for the Danish Royal Archives) and DK-RB (for the Danish Royal Library), followed by the folder number and/or corresponding date. Translations are mine.

## 2. Strasbourg "First" Observatory

### 2.1. THE HOSPITAL GATE

Strasbourg Hospital Gate is one of the very few extant remnants of the old city walls. It houses today a water tank (no longer in use) for the adjacent hospital, as well as a small meeting room, a few offices and storage areas for some hospital services. The tower features at its top a *lanternon* (turret lantern), identified as the first astronomical observatory of the city built in the second half of the $17^{th}$ century. Local historians and amateur astronomers have been repeating this over and over in all kinds of publications, often quoting each other and without proper historical referencing.

Going back to original documents in archive vaults, I therefore decided to investigate that *lanternon* in the context of the time and from the point of view of a professional astronomer interested in the inventive progress of our science, as opposed to the stand taken by some historians more attracted to, say, anecdotical facets of astronomy or an amateur's perspective.

The historical complex of Strasbourg Hospital Gate, most likely built in the first half of the $14^{th}$ century, has been described by others (see *e.g.* Waton *et al.* 2000, as well as the references therein). The current paper is concerned only with the inside, higher tower, the only element remaining today. I obtained the authorization to visit the turret several times with the assistance of the hospital security team. It is in reasonably good shape if one ignores a layer of pigeon excrement and the bodies of a few dead birds. This octagonal turret has an approximate diameter of 265cm, each side offering a rectangular window (twelve squares) of about 75cm $\times$ 100cm, with a base about 85cm above the floor, topped by a half-circular structure in seven glass elements (total height of about 75cm). The roof of the *lanternon* is an octagonal pyramid with a basis located at about 50cm above the window top (approx. 310cm above the floor). From a 1m level at the center of the octagon[1], this roof induces a dead angle of about 80° around the zenith, reduced by slightly more than half by moving from window to window[2].

The trap closing the access of rather narrow and steep stairs has now disappeared, but the traces and notches of hinges are still visible. From collected representations (sketches, drawings, photographs), the general aspect of the tower did not change over the centuries. Fig. 1 compares a current view with a 1671 pen-and-inch sketch by Johann Jacob Arhardt (ca 1613-1674) showing the top of the tower shortly before it be covered with the turret. The structure visible then on the terrace is likely a shelter (perhaps for watchers, equipment or access stairs).

## 2.2. JULIUS REICHELT

Visitors of an exhibition set up in 2009 by Strasbourg's City Archives[3] could see quite an interesting document: the obituary of a local mathematician,

[1]A reasonable low level for positioning the eye on an astronomical instrument at that time (remember that people were shorter then).

[2]The usage of an instrument (quadrant, sextant, optical device) must be forgotten in those extreme positions.

[3]On the theme *"Les Strasbourgeois et la Mort du Moyen Âge à nos Jours"* (People from Strasbourg and Death, from the Middle Ages till Nowadays), Feb-Jun 2009.

Julius Reichelt (1637-1717)[4]. For what is of interest here, let us retain: his birth on 5 Jan 1637 in Strasbourg; his enrollment as student on 16 Oct 1644 [*Matricula Scholae Argentoratensis 1621-1721*]; his graduation as Doctor of Philosophy on 26 Apr 1660; his nomination as Professor of Mathematics in 1667[5]; his repeated deanship; and his death in Strasbourg on 19 Feb 1717 – at the age of eighty, in line with the fact that astronomers and associated scientists seem in general to enjoy a particularly long life (Heck 2008).

Shortly after his graduation, Reichelt lobbied to secure funding for a study trip in Northern Europe. He attempted to get the academic and city authorities to jointly agree on the financing: the former because they saw in Reichelt the possible next occupant of a Chair of Mathematics vacant since the death of Jakob Bartsch (1600-1633) [see *e.g.* AVCUS V44/68]; and the latter because of military information (especially on fortifications) the scholar could bring back from such a trip [see *e.g.* AVCUS 1AST426 (22 Oct 1661)]. Interestingly, only scientific motivations appear on what seems to have been a save conduct [AVCUS V46/53], possibly to facilitate his passage through the various states crossed.

This duality of approach by scientists seeking funding has nothing exceptional, even nowadays. For instance, in the 1960s-1970s, solar scientists put forward the possible ozone depletion in the upper atmosphere by the first commercial jets to obtain the funds required by the launch of scientific balloons. The upper terrestrial atmosphere and the Sun were then studied spectroscopically by the same instrumentation.

Between 1939 and 1945, under the code name *Sonnengott* (Sun God), the Third Reich air force, the *Luftwaffe*, heavily invested in solar research, as well as in establishing a chain of solar observatories. The study of solar activity was then assumed to allow reliable daily predictions for determining the best frequency bands for long-distance military radio communications. During the six years of the conflict, the German solar research grew (quoting Seiler 2007) *"from a provincial backwater to the forefront of this science"*, thanks basically to the joint effort of two men: Hans Plendl (1900-1991) and Karl-Otto Kiepenheuer (1910-1975)[6]. Examples could be multiplied.

[4]Obituary by Johann Kaspar Khun (1655-1720), sometimes spelled Kuhn. [Document referenced as AVCUS 1AST446/50 (21 Feb 1717).]

[5]Berger-Levrault (1892), echoed by several $20^{th}$-century sources, mentions 1673, which is incompatible with original documents [see *e.g.* AVCUS 1R150 (12 Aug 1667)], confirmed by an anonymous compilation of professors dated 1765 [AVCUS 1AST344/28].

[6]They supported scientists during the war, for instance by securing positions away from the front lines, but also by obtaining substantial subsidies for investigations of a definite intrinsic interest, but of a reduced utility for the *Luftwaffe* – something that did not remain without consequences when, towards the end of WWII, the Nazi authorities realized that the money spent for establishing solar observatories here and there in Europe was totally out of proportion with the actual contribution of these to the war effort.

## 2.3. REICHELT'S TRIP IN NORTHERN EUROPE

Reichelt's obituary [AVCUS 1AST446/50 (21 Feb 1717)] is typical of times in which he lived in that importance came from the people one had the opportunity to meet (or to listen to). Khun lists a series of high-profile scientific and military personalities whom Reichelt would have met – an impressive assemblage for a recently graduated young man taking apparently his first trip abroad. Probably one must see in such a listing a stylistic contraction of contacts established (perhaps only claimed or attempted) by Reichelt in the course of his life.

Among others are mentioned Jan Hudde (or Huddenius, 1628-1704), mathematician from Amsterdam; Johannes Hevelius, astronomer from Gdańsk (see below); Andreas Concius (1628-1682), mathematician from Königsberg; militaries and specialists in fortifications like Axel Vrop (or Urup, 1601-1671), the Hoffmann brothers[7], as well as Hendrik Ruse (or Baron Rusenstein, 1637-1679); the cartographer Johannes Meyer (1606-1674); the physician and physicist Rasmus Bartholin (1625-1698) and the Danish astronomer Villum Lange (or Gulielmus Langius, 1624-1682, see hereafter); the librarian Adam Olearius (1601-1674), attached to the Duchy of Schleswig-Holstein-Gottorp and known for his trips to Persia.

According to the obituary, the regions visited by Reichelt were Holland, Holstein, Jutland, Denmark and Prussia. Very few documents remain from this trip, but a couple of them can be usefully exploited here. Thus Copenhagen was at the time a city surrounded by walls and its commandant kept a register of all foreigners entering the town through the four gates. Reichelt was recorded clearing Copenhagen's *toldbod* (customs) on 12 Aug 1666 together with a few other travellers coming from Gdańsk.

Copenhagen's *Rundetårn* (Round Tower), built between 1637 and 1642, belongs to the *Trinitatis* complex, designed to provide the students of the time with a church and a university library, together with an astronomical observatory. Used by the University of Copenhagen until 1861, the observatory on top of the Round Tower is the oldest European observatory still operational (nowadays only for non-professional observing). Ole Rømer (1644-1710) has been one of the prestigious users of the Round Tower, but

[7]Born in Lubań (Silesia), Gottfried Hoffmann (ca 1631-1687) studied in Leipzig and Strasbourg before entering service for the Danish Crown in 1648. He was following an elder brother, Georg who also studied in Leipzig and Strasbourg before entering the Royal Danish service in 1643, probably after some experience in fortifying several European cities. He died in 1666. In 1667/68, Reichelt attempted to get Gottfried Hoffmann as military engineer for Strasbourg, but his salary demands were too high (Westerbeek Dahl 1992 and personal comm.) [see also AVCUS 4R20 (01 May 1668)]. Strasbourg was counting its pennies as exemplified also hereafter.

his determination of the speed of light was made during his stay at Paris Observatory between 1672 and 1681.

Reichelt arrived in Copenhagen roughly a quarter of century after the completion of the Round Tower. It was then managed by Villum Lange, assisted by Rasmus Bartholin who was one of Ole Rømer's teachers. Bartholin described the double-refraction phenomenon. He is also known for his observations of a 1665 bright comet. The observatories located at the top underwent several mutations over the centuries (see *e.g.* Gykdenkerne & Barnes Darnell 1990), but all configurations benefited from the large terrace which allowed for the observation of the whole sky and the accommodation of large instruments. In Copenhagen, Reichelt stayed (at least for some time) with Simon Paulli, the King's physician, as mentioned in letters to Dean Balthasar Scheid[8] [DK-RB Thott 498-2] in a house at 3 Endeløsstraede since destroyed by fire. Those letters also confirm Reichelt's contacts with Johannes Hevelius (1611-1687) in Gdańsk.

An excellent observer, Hevelius is seen nowadays as the founder of selenography, but he had many other contributions to the progress of astronomy. Interestingly, he *de facto* established standards for the confirmation of discoveries of celestial objects and phenomena. While he preferred non-optical instruments (sextants, etc.) for precise astrometric measurements, Hevelius built refractors for mapping the Moon as well as for other observations. The focal lengths of those described in his book *Machina Coelestis* (1673) could reach 50m and contained open tubes to reduce flexing and wind problems. His observatory, *Stellaeburgum*, rebuilt several times after destructive fires, was visited by monarchs as well as by famous astronomers, such as Edmund Halley 1656-1742). In 1661, Hevelius became a member of the Royal Society. His books include some correspondence with European astronomers, but there is no trace of Julius Reichelt ...

## 2.4. BACK IN STRASBOURG

As said above, Reichelt became Professor of Mathematics in Strasbourg in 1667, after his return from Northern Europe. The reality of his teaching can be taken from the following comment by Schang & Livet (1988):

> *"Often, failing an available specialist, the same professor was teaching several matters, even very differing ones. In the 17$^{th}$ century, Reichelt, the author of a treatise of arithmeric in use at the Gymnasium until 1738, gave history courses next to public courses of mathematics. [...] For the physicist, Aristotle's work was still the starting basis, at least until the 18$^{th}$ century. [...] Geography did not deserve special teaching: it could be combined with the* mathesis *to which cosmography be-*

[8]Balthasar Scheid (Strasbourg, 1614-1670) has been Rector in 1655, 1660 and 1670.

*Figure 1.* The top of Strasbourg Hospital Gate before its covering by a *lanternon* (1671 pen-and-ink sketch by Johann Jacob Arhardt) and nowadays (© Cabinet des Estampes, reproduced with permission, & A. Heck). The structure visible on the ancient terrace is likely a shelter. The motivations recorded in the archives for the turret lantern were the prestige of the city and the notoriety of the university.

> *longed. The teaching of mathematics, in spite of the emphasis given by Dasypodius[9], remained rather elementary, at the level of the four fundamental operators of arithmetic and, as far as geometry was concerned, at the interpretation of Euclid's books. As to cosmography, as we could see from a perusal of school manuals, it was remaining faithful to Ptolemy. Copernicus was suspicious to theologians and Galileo was reeking heresy."*

[9]Conrad Dasyposius (1531-1601), mathematician remembered mainly for his design of Strasbourg's famous astronomical clock.

The first part[10] of Reichelt's booklet entitled *Elementa Astronomica & Geographica in usum Gymnasii Argentoratensis* (1688) deals with astronomy, but the chapter headings are indeed very conservative.

After his return from Northern Europe, Reichelt is seen through the archives as lobbying for establishing a covered observatory on top of one of Strasbourg's towers. An important document [AVCUS 4R24 (24 May 1672)] records a session of the city's *Conseil des XIII* (Small Senate) including a proposal by Reichelt for a *specula astronomica* (astronomical observatory) on one of the towers around Saint Elizabeth Gate *"... for the love of studying mathematics ..."*. Mention is repeatedly made of the money brought in by the supposedly wealthy students who should be attracted by such a facility and of the overall prestige resulting for the university.

Various members of the Senate supported the proposal, but Stettmeister Bernhold[11] – who apparently burnt his fingers over budgetary excesses related to the edification of the *theatrum anatomicum* (anatomy amphitheatre) – insisted on setting a binding limit to the funding.

A fortnight later, on 10 Jun 1672, the matter went to the *Conseil des XXI*, the main City Council [AVCUS 1R155]. The reputation of the city and of the university are the only arguments appearing in the records. The need for a quick decision was emphasized. It took place at another session of the *Conseil des XXI* [AVCUS 1R155 (1 Jul 1672)]. After considering other towers (Goltersturm, Saint Elizabeth Gate, both Pulvertürme, a tower near the Saint Etienne bridge, ...), it was decided that the top of the inner tower of the Hospital Gate complex was most suitable for the intended structure.

But the estimated costs were thought to be too high and, after various arguments were exchanged, the facilities were scaled down and the *Verordnete Herren* only released 300 Guilders, instructing the scholar to come to terms with the contractors. This ditty is a familiar one, and was obviously already sung at that time. The renown of the city and the reputation of the university would be safe since they would have an observatory, but it would have no terrace. At no moment, the scientific goals of the observatory and its possible instrumental endowment have been discussed.

Later on, nothing seems to have been recorded about this observatory, except some maintenance requests in the *Bauherren* registers. A list (dated 1719?) of mathematical instruments and machines constituting Reichelt's legacy [AVCUS 1AST334/12] does not include any advanced optical instrument. A few decades later, one of Reichelt's successors, Jean-Jérémie Brackenhoffer (1723-1789), produced quite a negative review of the equipment

[10] 57 pages (out of the 142 pages of a 13cm × 21cm manual).

[11] Philipp Albrecht von Bernhold (or Bernold, 1631-1677) was *Stettmeister*, *i.e.* the city's main magistrate, on several occasions.

of the observatory including then "a 16-feet[12] focal-length astronomical refractor" virtually useless according to his description [AVCUS AA2647[13]].

In hindsight, a scientific facility can be valued from its contributions to the progress of knowledge, which can only be at its best level if the users of the facility can take advantage of an *ad hoc* instrumentation. For Strasbourg's *specula astronomica*, the emphasis put on the prestige of the city and on the renown of the university, as well as economic considerations, resulted in a minimal observatory. This observing post did not take part to the spectacular developments that were occurring in European astronomy at the time and could not position itself for the subsequent phases, as much spectacular.

This is confirmed by the absence of the Hospital Gate in the compilations of astronomical contributions and advances published in reference works of the time. Lalande is the only one who makes a mention of it, and seems to rectify an oversight with a brief mention in his Volume 4 (1781): *"Strasbourg – M. Brackenhoffer, able professor of mathematics, has there an observatory & instruments"*. For pleasant it might appear, that mention is little factual; it does not speak of any constructive observations; and it gives no details of the instrumentation (or even if it was operational).

### 2.5. A MISSED OPPORTUNITY

After having reviewed, in various archives, tens of documents related to Julius Reichelt, it remains difficult to figure out the exact personality of that gentleman. Although he had obviously been a gifted student, the evolution of astronomy and of the instrumentation of his time seem however to have passed well over his head. No significant advance nor inventive initiative in the scientific and military realms seems to be credited to him. He indulged himself in traditional teaching, not echoing the progress he should have been witnessing – or hearing about – in astronomy. Even if his aspirations for the lantern turret of the Hospital Gate were frustrated by economic considerations, his inspiration, as recorded, for gaining this observatory seems to have been motivated by no scientific interest.

Throughout its history and its genesis, the top of the Hospital Gate can be considered as a likely place where some astronomical observations were conducted by local scholars in charge of elementary astronomy teaching[14].

[12]Inches and feet mentioned in this paper are French ones (respectively 27.07mm and 324.84mm).

[13]Document dated from 1773, today unavailable from the archives. A transcription can however be found in Lacroute (1959-60).

[14]There was no actual *astronomer* associated with Strasbourg universities before the creation of the current Wilhelminian Observatory at the end of the $19^{th}$ century (Heck 2005a).

There is, however, no authoritative indication that the top of the Hospital Gate was the first location used for astronomical observing in the city, or that it was the only one used for that purpose at its time. Conversely, claims in popular works on possible other earlier observing places have to be disregarded as we did here. Their authors never answered our requests for documentation/substantiation of their claims.

The erection of the Hospital Gate *specula astronomica* was undoubtedly due to Julius Reichelt's efforts in successfully lobbying the local authorities after his return from Northern Europe. We have seen how the *Rundetårn* (Round Tower) in Copenhagen, completed a few years before his visit, might have inspired him. On the basis of financial considerations, the Strasbourg magistrates opted for a minimal configuration, which prevented the installation of a terrace that would have enabled the observation of the whole sky, including the zenith area where the atmospheric transparency is best. The reduced space within the turret and the parcelling of windows certainly made extensive observations of the rotating sky difficult, and the size of the instruments had necessarily to remain greatly inferior to the telescopes that Reichelt had seen – or at least heard of – while in Gdańsk. In the numerous archival documents that I perused, I found no indication that Reichelt ever advocated advanced optical instruments, remaining consistent with his traditional teaching.

While decisive observational advances were taking place in other European cities at that time, the History of astronomy does not mention anything else for Strasbourg than records of celestial phenomena visible from all (comets, etc.). My conclusion is that the top of the Hospital Gate was probably used only for rudimentary observing of bright celestial objects or phenomena relatively low on the horizon. The opportunity was then missed to establish Strasbourg as a center of observational astronomy.

## 3. Strasbourg "Second" Observatory

### 3.1. THE FRENCH *ACADÉMIE*

In the previous section, I described the genesis of an astronomical observing post, a turret lantern, located at the top of Strasbourg Hospital Gate in the second half of the $17^{th}$ century, built merely for the prestige of the city and for the notoriety of the university. This facility did not leave any trace in the progress of astronomical knowledge.

After the turmoil of the French Revolution, the Napoleonic reorganization restructured the higher education nation-wide. My investigations were then directed towards another unexplored observatory said to have been erected on the roof of a building nicknamed *Académie* (formerly an orphanage) and housing the university faculties from 1828 onwards.

One of the first gold nuggets found in the local archives confirmed my own conclusions on the Hospital Gate observatory: *"The old tower, established over one of the city gates that, during three centuries, did not provide any acceptable observation, must be counted as zero in the current state of astronomy"* – an excerpt from a letter dated May 1810 [ADBR 1TP/SUP226, May 1810] by Chrétien Kramp (1760-1826), Dean of the Faculty of Sciences since July 1809.

Once more, this contradicts hasty conclusions such as those of a recent paper hinting at the $17^{th}$-$18^{th}$ centuries as a kind of golden age for astronomy in Strasbourg. In a manifestation of what can be called regional chauvinism, a coterie of local historians, generally amateur ones, often disregard basic principles of genuine historical research: through in-bred reciprocal quoting without returning to the original sources and documents; by misperceiving events and by failing to put them in the appropriate context of the time; and, particularly for our concern here, by a lack of *ad hoc* professional scientific expertise and competence.

Therefore, instead of wasting space as well as the readers' time in mentioning and debunking those papers, I take the deliberate stance here of quoting only reliable works and original sources. Thus for the detailed history of the $19^{th}$-century French university, please refer to the well-documented masterpiece by Livet(1996).

### 3.2. MOVING THINGS

The man who started moving things for building in Strasbourg an astronomical observatory worth its name has been mentioned earlier. The biography of Chrétien Kramp[15] is available from most local resources.

For what is of interest here, let us retain: his birth in Strasbourg on 10 Jul 1760; his graduation as Doctor of Medicine on 22 Dec 1785; his nomination in 1796 as Professor of Chemistry and Experimental Physics at the Central School (*École Centrale*) of Aix-la-Chapelle and in 1798 as Professor of Physics and Chemistry at the similar establishment in Cologne[16]. After graduating as Doctor of Sciences in 1809, Kramp came back to Strasbourg as Professor of Applied Mathematics and served also as Dean of the Faculty of Sciences until his death in 1826.

[15]In some biographical compilations, Kramp's first name appears as being Chrétien-Charles. In fact, his birth record [Paroisse protestante Temple Neuf et Cathédrale, B1754-1762/1075] mentions *Christian* while his death record [ADBR D1826/947] states *Chrétien*, first name also used by Bedel (1826) in his obituary. As to the numerous archival documents I perused, Kramp appears everywhere with the title *Doyen* [Dean] or *Prof.* Himself signs with his only surname and no initials. Note the occasional spelling *Krampp* as in Berger-Levrault (1892).

[16]Respectively Aachen and Köln, then within the Napoleonic empire.

With his local authority and good connections in Paris, Kramp lobbied[17] for a really operating observatory on top of the building that was going to accommodate the university faculties, equipped with a terrace, an opening roof and good instruments, the jewel of which was ultimately going to be a 132mm meridian refractor with a Cauchoix objective doublet.

His letter mentioned above on the zero value of the Hospital Gate tower as an astronomical observatory was addressed to Jean-Baptiste Joseph Delambre (1749-1822) who, among other charges, was Treasurer of the Imperial University in Paris since 1808. It goes on in the same vein about the available instruments: *"The same must be said of the few old and defective instruments located there; a very mediocre 8″ telescope is all that would be worth retaining."*

In November 1810, Kramp addresses a memoir to the Mayor of Strasbourg [ADBR 1TP/SUP226, 4 Nov 1810] criticizing the old tower and stressing the need for something better. In an undated document, likely from 1811 [ADBR 1TP/GEN108], things get more precise: *"The new observatory would be on the roof of the [future] building housing the faculties and would be made of a cylinder, 12′ in diameter and 5 to 6′ high, covered with a mobile dome."*

But Kramp is not waiting for the observatory to conduct observations. He goes with his students on the city walls after having secured an ad hoc authorization from the Military Commander for those nightly activities, as well as the blessing of the University Rector recommending caution and appropriate supervision to prevent abuses from the supposedly turbulent fellows [ADBR 1TP/SUP89, 25 May 1811].

### 3.3. THE *ACADÉMIE* BUILDING

In the course of the following years, Kramp continues pressurizing successive authorities[18], tirelessly explaining the need for a good observatory in

[17]The above excerpt from the May 1810 letter speaks of "three centuries" while, if the Hospital Gate Observatory has been built some time after 1672 (cf. first section of this paper), it was not yet 150 years old when Kramp wrote his letter. Was the Hospital Tower used as an observatory before the construction of its *lanternon*? Nothing however proves it in spite of unwise (undocumented, non-referenced) declarations of some modern popularizers. According to Kramp himself, there was no trace of such activities. I rather believe that, in good lobbyist, Kramp put some emphasis in his argumentation and that the three centuries have to seen as the one when the *lanternon* was built ($17^{th}$), the intermediary $18^{th}$ and the $19^{th}$ century when the letter was written.

[18]Napoleon's rule ended in 1814 and was followed by the so-called *Restauration* (Louis XVIII from 1814 to 1824 and Charles X from 1824 to 1830) with the exception of the Hundred Days (*Cent Jours*) when Napoleon re-took power (20 Mar – 22 Jun 1815). The *Monarchie de Juillet* (Louis-Philippe) lasted from 1830 to 1848 and was followed by the Second Republic from 1848 to 1852 and the Second Empire (Napoleon III) from 1852 to 1870, terminated by the Franco-Prussian War at the outcome of which Strasbourg

Strasbourg equipped with appropriate instrumentation. He acquires small instruments (such as a 6 ″ telescope) and accessories (globes, etc.). Things are slowly moving in the minds of his interlocutors as testified by various 1819 letters from the Rector directed to Kramp (such as *"we should now investigate without delay how to get a proper observatory"* [ADBR 1TP/SUP99, 26 Aug 1819]) and to military authorities investigating the suitability of one of the towers used as a prison [ADBR 1TP/SUP89, 15 Sep 1819] or the possibility to deviate traffic (inducing vibrations) from under the Hospital Gate and to reshape its upper stories [22 Dec 1819].

Three years later, the picture frame is set: the municipality agrees to host the faculties in the building of the *École du Travail*, an old orphanage[19] belonging to the city. Finally in 1824, there is a green light from all sides for putting an observatory on that building and the University Rector formally resquests Kramp to take care of the project and to submit plans as soon as they would be approved by his Faculty of Sciences.

Blueprints [AVCUS 1A119-120] from Architect Jean-Nicolas Villot (1782-1857) show the *Académie* façade with the observatory sticking out of the back as well as a floor layout of the main building and of the dependences detailing the intended distribution of the various laboratories, lecture rooms and other quarters.

### 3.4. CARRYING THE TORCH FURTHER

As mentioned in Sitzmann (1909), the multiplication of Kramp's activities undermined his health and diminished his intellectual abilities towards the end of his life. His name disappears indeed from the archives in the early 1820s. But support continues to be provided to the observatory project, including from unlikely characters. For instance in 1825, the Rector was lobbied by a former military surgeon, François Bonaventure Meunier[20] (1779-1838), now Professor of Hygiene and Medical Physics at the Faculty of Medicine, who fancied the observing facility for medical applications of meteorology[21], as well as for what sounds to be playing with camera oscura

became German.

[19]For the history of this establishment, see *e.g.* Hitter (1993), Jordan (2008) and Sablayrolles (1975-76).

[20]Sometimes spelled Meulnier. He is also known for having advocated a lightning rod on the cathedral. There is a discrepancy about his birth date: Berger-Levrault (1892) mentions 8 Jun 1779, followed by Livet (1996), while Wieger (1885) and Mantz & Héran (1997) see him ten years older: 1769. The latter ones appear to be correct. Meunier was born in Layer (Jouvençon) in the Saône-et-Loire *département* and not in Laye (Berger-Levrault 1892), nor in Layes (Wieger 1885), these latter indications leading to some confusion with the current commune of Layes-sur-le-Doubs in the same *département*.

[21]The spreading of diseases was not yet fully understood at the time. Meunier was mixing medicine with meteorology, astronomy, etc. It is interesting to note that Louis

and electricity [ADBR 1TP/GEN107, 2 Jan 1825].

Kramp died (13 May 1826) before seeing his baby operational. He was replaced by a chemist as Dean and by Ambroise Nicolas Sorlin (1773-1849) as Professor of Applied Mathematics in charge of astronomy. Sorlin is harshly judged by historians of the French university (Livet 1996), basing their opinion on a comment by Rector Cottard: *"Sorlin's retirement [in 1847] was a blessing for science."* I cannot agree with such a blunt view: through the archives, Sorlin is seen as quite active in his first years, getting the meridian refractor operational, filing requests, complaining about deterioration of the observatory and trying to improve the overall situation.

Born in Paris on 1 Feb 1773, graduated Doctor in Sciences in 1822, Sorlin took over the chair of applied mathematics in Strasbourg on 27 Nov 1826. The first appearance of his name in the local archives is in the signature of a letter to the Rector [ADBR 1TP/GEN107 (11 Jun 1827)], reporting the severe damage by a strong storm to the observatory and to the laboratory underneath where astronomical instruments were stored.

The same letter includes the first mention of a meridian instrument. It is quite likely that in Paris Sorlin met or at least heard of his almost exact contemporary, the optician Robert Aglaé Cauchoix (1776-1845) whose name in turn appears in an 1828 inventory listing *"an achromatic objective of five inches in diameter from Mr Cauchoix, made of two glasses and intended for a meridian refractor"* [ADBR 1TP/SUP252].

Several other important pieces from Sorlin's times are worth mentioning here:

• A series of blueprints dated 1828 [AVCUS 843W94], also from Architect Villot, provide very interesting details: the observatory is an irregular octagon with an inside width between 540 and 570cm, and an inside height of 325cm; it is covered with zinc; the light enters through 18 casement windows, one serving as a door enabling access to a terrace going around the observatory; the elevation is sufficient for preventing any chimney or close building to mask the horizon; there is an opening in the roof along the meridian which is closed by four planks covered with zinc and fixed with hinges and a hook. Compare to the Hospital Gate Observatory, the improvements are significant: more space inside, existence of a terrace, roof opening and allowing to observe the zenithal area where the atmospheric transparency is best. Fig. 2 shows the observatory as represented in the 1836 plan-relief of Strasbourg.

• With the aim of identifying improvements to be brought to the observatory, Sorlin successfully managed to get an expertise from the *Bureau des Longitudes* in Paris. This remains as a most interesting report [ADBR

Pasteur (1822-1895), pioneer of microbiology, taught (chemistry) later on in that very *Académie* building (1849-1854).

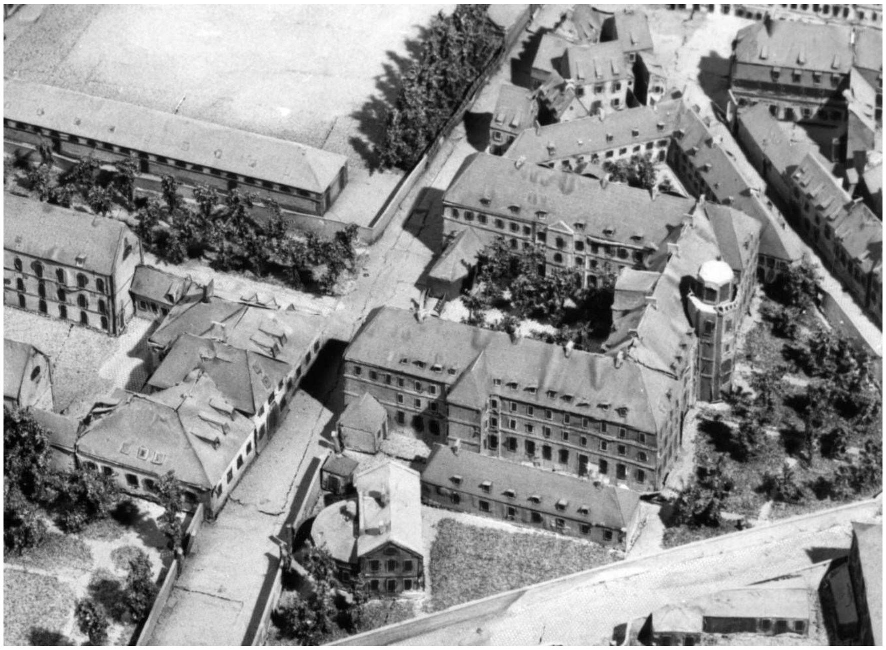

*Figure 2.* Close view of the main U-shaped *Académie* building from the 1836 plan-relief of Strasbourg. The observatory is visible over the cylindrical tower protruding from the back side. The result of an insistent lobbying including an audit by an outside body, it has been the first attempt to have in Strasbourg a real observatory equipped with genuine instrumentation. (© *Inventaire du Patrimoine*, reproduced with permission)

1TP/SUP9, 31 Mar 1829], signed by the then Bureau Secretary François Arago (1786-1853). Here are a few excerpts:
*"From the instruments used for measuring angles currently at Strasbourg Observatory, there is none suitable for astronomical observations. [...]*
*"The observatory is rather well equipped in terms of refractors: ordinary refractor of 2 ′ $^1/_2$, a polyalde refractor from Mr Cauchoix, an excellent refractor of 4 ′ from Munich and finally an objective of 5 ″ made by Mr Cauchoix, still unmounted. Mr Sorlin proposes to adapt it to a meridian refractor to be built and to be established on pillars. [...]*
*"We do not think that an observatory located so high and resting over such a broad arch would be of great stability.*
*"Conclusions. From the examination of premises so little in favor of an observatory from which we received the plans, we think that the only instruments that could be installed there with some benefit would be: a meridian refractor, an astronomical pendulum and a portable refractor suitable to observe the solar eclipses, the stellar occultations, as well as the immersions and emersions of the satellites of Jupiter. Given the impossibility to estab-*

*lish a parallactic machine in such a confined space, that portable refractor should be equipped with a circular micrometer enabling the local observers to follow comets with some success."*

• Letters [ADBR 1TP/GEN107, 28-29 Jul 1829] between the Mayor, the Rector and Lieutenant-Colonel Epailly shed some light on the origin of the pillars used for supporting the meridian refractor: the military commander suggests to recover two pillars from Bastion IX located just outside the city walls (roughly West of the city) where they had supported another instrument used for establishing a map of France[22].

### 3.5. WINDING DOWN

As he fell ill later on, Sorlin asked for replacement and early retirement, generating an abundant correspondence which might have triggered irritation from administrative authorities and the harsh appreciation quoted above. Pierre Joseph Étienne Finck (Lauterbourg, 1797 – Strasbourg, 1870) stood in for Sorlin in 1842 and fully took over in 1847. Sorlin died in Batignolles [AdP V3E/D1375] near Paris on 25 Dec 1849. Apparently more oriented towards mathematics, Finck did not leave any significant trace linked to the observatory. He was intellectually diminished in his later career.

In parallel to all this, the archives reveal continual attempts to move the university elsewhere: professors unhappy of the *Académie* location, just outside the city walls, but too far away for them; city authorities wanting to recover the building for other purposes; and the military (especially the cavalry) having an eye on it because of the vast nearby training grounds. Thus a permanent cloud of uncertainty hovered over the *Académie* observatory.

The *coup de grâce* came from Xavier-Dagobert Bach (Soultz, 1813 – Marlenheim, 1885[23]), a mathematician taking over as Dean of the Faculty of Sciences in 1866. In a document on a possible transfer [ADBR 1TP/GEN108 (26 Nov 1867)], he wrote: *"I am not requesting a new observatory, which would be quite expensive, but a terrace where portable instruments could be installed when some interesting celestial phenomenon could be observed"* – in other terms, back to the situation a century earlier when observational astronomy in Strasbourg was treated by scholars on a, say, amateurish level.

Bach's unfavorable disposition towards practical astronomy was implicitly confirmed at the outcome of the Franco-Prussian War when Strasbourg

[22]See also Yvon-Villarceau (1866), p. 321.

[23]Most biographical compilations provide erroneous elements from that scholar: Bach is born in Soultz in the Haut-Rhin *département* (and not in Soultz-sous-Forêts in the Bas-Rhin *département*) on 16 Jun 1813 (and not on 13 or 15 Jun) and his death record in Marlenheim is dated 9 Oct 1885 (and not 1 Oct).

became German and he wished to be reassigned to a Faculty inside France *"with a full teaching of mathematics ... as it would be excessively difficult to take charge of a chair of applied mathematics"* (Livet 1996).

### 3.6. INSTRUMENTATION AT THE *ACADÉMIE*

A few words on the available instrumentation are in order and we can follow its evolution through several inventories. Thus all what Kramp is listing in August 1818 [ADBR 1TP/SUP252] are two globes (celestial and terrestrial, $1\,'$ in diameter) and a catadioptric telescope ($6\,''$ in diameter, $5\,'$ of "focus"). Specific instruments are regularly petitioned through the budgets presented by the Faculty of Sciences, but there is no certain indication whether or when these were acquired.

Reliable documents are available a few years later, when Sorlin prepares his audit by the *Bureau des Longitudes*. An inventory dated 1828 [ADBR 1TP /SUP252] includes the globes just mentioned for Year 1811, an achromatic telescope ($3\,'$) for Year 1827 and Cauchoix's $5\,''$ achromatic objective doublet for Year 1828. Another report [ADBR 1TP/SUP9 (10 Dec 1828)] includes also an achromatic refractor ($2\,'\,{}^1/_2$, mediocre objective), a polyalde refractor from Cauchoix (good) and another refactor from Munich ($4\,'$, excellent). It precises the cost of Cauchoix's doublet (2500 Francs) and insists on the urgent need for a mounting and pillars to make the meridian operational.

The notes accompanying the budget prepared by the Faculty of Sciences for 1830 [ADBR 1TP/SUP252 (19 May 1829)] bring also their share of information: 2500 and 4500 Francs have been granted respectively for the meridian objective and for the instrument mounting *"that will be the most beautiful of France after that of the grand royal observatory in Paris. That passage instrument must be delivered in Strasbourg on next 15 December, and the box must be opened in the presence of the Faculty who will examine the instrument conditions, all damage remaining under the responsibility and charge of Artist Cauchoix to whom the mounting had been entrusted."* Follows an estimate of the cost for the masonry and counterweight mechanism for the final installation, as well as the urgent need in books and journal collections *"to be at the level of Paris and at least of Berlin, given the frequent visits by German erudites*[24]*."*

A last piece worth mentioning here is an inventory marked 1843 [ADBR 1TP/SUP261] including new elements such as a refractor from Franckhofer

[24]No detail, however, on such visits emerged so far from the archives. Was it then sheer bluff from the Faculty?

[sic[25]], a Gregorian telescope, a Galilean refractor, a micrometric refractor from Rochon[26] and a "vitro-cristalline" refractor from Cauchois [sic].

### 3.7. ANOTHER MISSED OPPORTUNITY

Strasbourg's so-called second observatory has been the first real attempt to set up in the city an actual observatory equipped with genuine instrumentation with the purpose to carry out serious research.

It involved all steps of modern procedures such as a long and persuasive lobbying fighting systemic inertia from all parties involved, an appropriate site research, an audit from outsiders, etc. The succession of political regimes in France[27] slowed down the whole process. The repeated attempts to move the university (and its observatory) elsewhere, as well as the lack of interest in observational astronomy from scholars in the second half of the $19^{th}$ century prevented effective productivity of the facility. To my knowledge, there is no record in the astronomical literature of observations carried out in the *Académie* facility.

After the Franco-Prussian War (1870-1871), the new German university used the building for a decade. Instrumentation was recovered, including the meridian instrument equipped with the Cauchoix objective doublet.

In the course of my investigations, I had the opportunity to visit the *Académie* building (today a professional school). The layout is still the $19^{th}$-century one, including markings of the time (such as *"Rectorat"*). The central attic where the observatory was based, or rather its underneath laboratory, is today a documentation centre for the students and the necessitated reinforcement of the floor is hiding any possibly remaining trace. In a backstage room, I noticed however quite old stairs that might have been those leading to the observatory floor. The observatory itself has totally disappeared. In lieu of it today is a small pyramidal roof.

## 4. The Wilhelminian Observatory

At the outcome of the Franco-Prussian war of 1870-1871, France lost Alsace and Moselle. As often in the course of History, the new German authorities decided to make a showcase of the newly acquired region and in particular of its capital Strasbourg. New spacious and structured quarters were built, still called today the Wilhelminian Quarters from the name of the new masters, the Emperors Wilhelm I (1797-1888) and Wilhelm II (1859-1941) who ruled until the end of World War I.

[25] In fact, Joseph von Fraunhofer (1787-1826). The refractor from Munich mentioned earlier is certainly the same instrument.

[26] Abbot Alexis-Marie de Rochon (1741-1817).

[27] See Footnote 18.

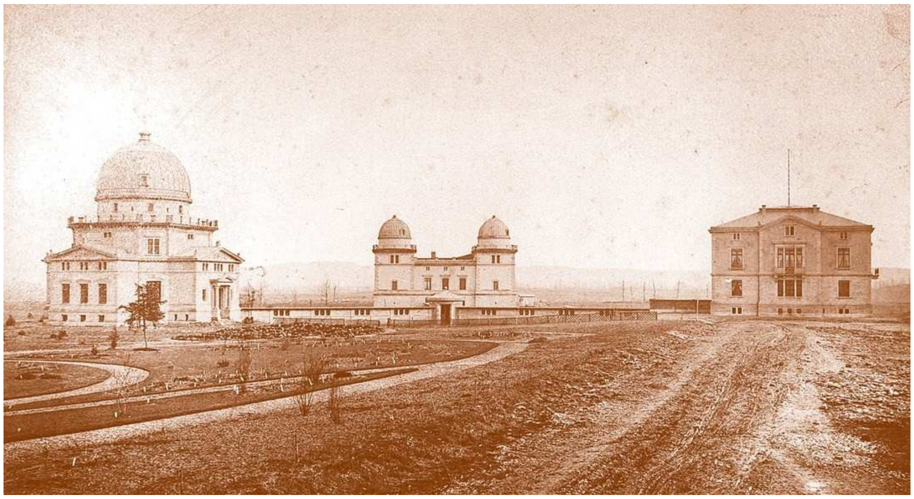

*Figure 3.* View around 1880 of the *Kaiserliche Universitäts-Sternwarte Straßburg*, the Wilhelmian observatory, showing (left) the dome of the Large Refractor, (center) the two smaller domes on a building housing also two meridian rooms, and (right) the Director's residence. The covered corridors linking the buildings are also visible. A few pathes and young trees of the Botanic Garden are visible in the left foreground. The traces left by cartwheels on the right mark the future Universitätsstraße. The Imperial University including this observatory was the result of a deliberate political will from Berlin to have in Strasbourg a strong educational outpost. (Courtesy Strasbourg Obs.)

The new city expansion included a modern university campus with an astronomical observatory. The construction of the latter took place between 1877 and 1880, with an inauguration in September 1881 celebrated with a General Assembly of the Astronomische Gesellschaft. August Winnecke (Hildesheim, 1835 – Bonn, 1897), the first Director of that observatory, was also Secretary of the German professional society.

From the start, the observatory consisted of several elements connected by covered corridors (Fig. 3). The most emblematic building, the Big Dome, was positioned at the end of a double line of university institutes. It was completed by a residential building for the Director, including offices, and an observational unit with two smaller domes and two meridian rooms.

In the first volume of the *Annalen der Kaiserlichen Universitäts-Sternwarte in Strassburg* (1896), Ernst Becker (Emmerich am Rhein, 1843 – Freiburg, 1912), the second German Director, described the buildings and the instruments they were housing. The initial instrumentation included the 132mm Cauchoix passage instrument recovered from the French *Académie* observatory and put in the West meridian room. A 160mm meridian instrument was purchased from Repsold and assigned in 1880 to the East meridian room. A 76mm heliometer by Utzschneider & Fraunhofer was acquired in 1877 from the Ducal Observatory in Gotha. In 1874, it was part of an expedition to the Kerguelen Islands for the transit of Venus with a team from Gotha. For the following transit in 1882, it went to Bahía Blanca (Argentina) with a team from Strasbourg.

The Large Refractor, a 487mm telescope, was built in 1877 by Merz (Munich) with a mounting manufactured by Repsold in 1880. The instrument was then the largest in Germany. The Northern smaller dome was equipped with a 136mm altazimutal refractor built by Merz & Repsold in 1879. As to the Southern dome, it was hosting a 162mm refracting telescope manufactured in 1876 by Reinfelder & Hertel (Munich).

The German *Inventar* of the observatory lists numerous other instruments among which a 162mm comet seeker built by Merz in 1876 with an altazimuthal mounting set on a mobile chair. Other comet seekers, small refractors and various instruments were part of the sizable equipment in those initial times. As to the astrophysical instrumentation (and to the exception of an astrophotometer from Gotha Observatory), it is essentially under Julius Bauschinger (Fürth, 1860 – Leipzig, 1934), the third German Director, that the observatory acquired spectroscopic, photographic and photometric devices.

For the history of the Wilhelminian observatory and of its subsequent evolution (French in 1919, German during World War II, then French again), interested readers are invited to refer to an edited volume (Heck 2005a) as well as to the bibliographical pointers it offers.

As explained in various papers (see e.g. Heck & Witt 2012), the underlying motivations for the new German university in Strasbourg were essentially political, under direct instructions from the *Reichskanzler* Otto Eduard Leopold von Bismarck (1815-1898), as recorded in the proceedings of the *Reichstag* session of 24 May 1871, formalized by a law passed on 20 Apr 1872 (see e.g. Hausmann 1897 and Jonas *et al.* 1995). From a report on the re-organization of Strasbourg university dated 3 Oct 1871, the reasons for including an astronomical observatory are of the same political vein:

> *"Even if the necessity of an observatory at all universities has to be questioned, one must take into consideration that, for Strasbourg, there is a strong political interest to create not only a military, but also an educational outpost as strong as possible."*
> (Bericht die Reorganisation der Universität in Strassburg betreffend [ADBR 12AL8])

The motivations behind the choice of Winnecke as the first Director are not fully detailed, but he was definitely a second choice as the first person approached was Johann Karl Friedrich Zöllner (1834-1882) who declined the offer (see e.g. Duerbeck 2005 and Wolfschmidt 2005). Winnecke's initial plans were to put the observatory North of the city, in Schiltigheim, away from the mist and frequent fog in the proximity of the Rhine and Ill rivers (fog also mentioned by Winterhalter 1891), but he was convinced to stay near the other institutes on the university campus (Hausmann 1897, Jonas *et al.* 1995). Attempts to reduce the temperature effects were made by using "gas flames" in Winter and, in Summer, water running over the large dome (covered by zinc) from its top. It is doubtful however that such a spectacular procedure was routinely used (Heck 2009).

## 5. Final Remarks

More examples of lobbying related to Strasbourg Observatory could certainly be brought forward. For instance, in an earlier paper (Heck 2005b), I described the genesis of the data center installed at Strasbourg Observatory in 1972. Initially called *Centre de Données Stellaires* (Stellar Data Center), it was renamed *Centre de Données astronomiques de Strasbourg* (Strasbourg astronomical Data Center) in order to retain the acronym CDS when its scope of activities were broadened to non-stellar data. In a subsequent paper (Heck 2006), I described its progressive penetration on the world scene, mainly in the 1980s, to which I was privileged to actively participate. Please refer to those papers for details, illustrations and references.

CDS was established through excellent relationships between European astronomers pushing for such a facility in the late 1960s, within an international context where the creation of such centers was felt increasingly urgent, motivating even the creation of an *ad hoc* working group at the 1970 General Assembly of the International Astronomical Union in Brighton. The move concurred also with the desire to reinforce Strasbourg Observatory within a policy of regionalization in France.

The second CDS Director, Carlos Jaschek (Buenos Aires, 1926 – Salamanca, 1995), multilingual and with an extensive international network, multiplied working relationships and international agreements, particularly with so-called Third-World and Eastern European countries when the Cold War was still an acute reality. With my participation in 1977 to the foundation of the European observatory for the International Ultraviolet Explorer (IUE) at Vilspa (Spain), CDS data became a reference[28], even more so when I was put in charge of the scientific operations. Accurate positions of the observed objects were critical for the spacecraft pointing as its safety was paramount. Later on, Vilspa became the first international station (Jan 1981) connected to CDS' Simbad database when it became operational.

[28]With Jean Jung (1944 – ), first CDS Director, as PhD supervisor when he was still at Paris Observatory, I had been de facto the first scientific user of CDS data, even before the center's official existence.

Conversely, when I joined Strasbourg Observatory in 1983, I could use all my contacts in the space agencies, and particularly at NASA, to "sell" Simbad and the related CDS services worldwide. Lobbying was then most frequently done at personal expenses, by Jaschek or myself, leaving guests with the best souvenirs of local gastronomy.

If one of the basic lobbying principles is that only good products or causes can be "sold" sensibly and sustainably – beyond developing and maintaining excellent contacts, fostering confidence from people, acting persistently, helping luck with gentle touches of bluff, developing flexibility to foreign cultures, exercising (away from both arrogance and toadyism) top-level respectful diplomacy helped by well-trained acute intuitions – in all this, trust and credibility are certainly essential and complementary virtues.

One of my most cherished recollections is a NASA meeting convened (Aug 1987) on the future of the space data collected by the agency. What seemed at first to be one of those standard meetings where to present CDS and SIMBAD turned out quickly of unusual importance with the presence of major project leaders and NASA's Director of Astrophysics. With a talk scheduled in the late afternoon, it became a real fight with jetlag to re-tailor in real time the presentation of SIMBAD emphasizing the differences with the individual papers on space logs and catalogs filling in the agenda, insisting on the integrated-database character, and clearing any possible suspicion of chauvinism by praising, as a Belgian, that French-based jewel.

The next morning, with typical American efficiency, a NASA Headquarters' official shook hands in an elevator of the hotel and, between the ground and third floors, declared they were going to support a link between CDS and the Astrophysics Data System (ADS) being set up, as well as to likely complete the arrangements by installing an adequate machine[29] at Strasbourg Observatory and even possibly putting at our disposal a couple of yearly grants. This was an open door to CDS/SIMBAD's spreading in North America and beyond. From then on indeed again, the critical political decision having been acquired, the story became only technical.

Lobbying can be best appreciated in the socio-historical context where it has been exercized. If human nature remained much the same over centuries (at least in terms of astuteness, to say it nicely), the procedures employed have evolved with time. The cases described in this paper show how the dramatic changes resulting from the French Revolution or the nationalist movements in $19^{th}$-century Germany had a decisive influence, not to forget the skrinking of the planet in the last decades of the $20^{th}$ century due to spectacularly improved communication means and travelling capabilities.

[29]French institutions were not free then to purchase the computers they wanted.

Finally, as to the motivations behind lobbying, they can be, as illustrated above, of a very differing nature. Sometimes, they can be barely rational[30] or even totally others than those expressed in official reports[31].

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[30]See for instance the chapter by Jack Meadows in this volume citing *"It can be very depressing to live in a place where the sun seldom shines"* as an objection to a British site proposed for an accelerator.

[31]The location selected in the 1960s for a meridian instrument in the French Pyrenees proved to be inadequate, but it was in fact near a thermal city appreciated by the wife of one of the key decision-makers (Rousseau & Heck 2009).

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# NEW OBITUARY POLICY FOR THE AMERICAN ASTRONOMICAL SOCIETY

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**Abstract.** The American Astronomical Society has a permanent website with obituaries of nearly all its members who have died since 1990. The Vice Chair of the Historical Astronomy Division (HAD) is tasked with selecting authors and editing the obituaries, which are posted by the AAS headquarters staff on a site[1] linked to the top-level AAS page[2]; an alphabetical index appears at the Historical Astronomy Division's site[3], which is linked from their top-level page[4]. The HAD was asked to be in charge of obituaries by the AAS Council in 1990. Most obituaries are in the vicinity of 800 words, but longer essays are allowable for selected individuals.

## 1. Introduction

In 1984, historian John Lankford harangued that essential information about deceased astronomers was being lost to historians. His piece, "A Crisis in Documentation: The Decline of the Obituary as a Source for the History of Modern Astronomy," appeared in the *Bulletin of the American Astronomical Society*, then a print publication (Lankford 1984). He provided statistics of obituaries over past twenty-year intervals and listed desiderata.

The Historical Astronomy Division (HAD) of the American Astronomical Society (AAS) was asked in 1990 by the AAS Council to be in charge of obituaries. Most obituaries are in the vicinity of 800 words, but longer

[1]http://aas.org/baas/obits/all
[2]http://aas.org/
[3]http:/had.aas.org/obits.html
[4]http:/had.aas.org/

essays are allowable for selected individuals and the new, electronic format of not only the obituaries but also the entire *Bulletin* allows more text and more photographs.

## 2. The Current Situation

Since 1991, obituaries have been printed in the *Bulletin of the American Astronomical Society*. As of 2011, that publication is strictly online. The online nature of the obituaries now allows them to be expanded beyond the titular limit of 800 words each, and to include pictures in color as well as links to other online obituaries (from newspapers, for example) or other biographical information.

The Vice Chair of the Historical Astronomy Division (HAD), currently me, has the task of selecting authors of the obituaries and of editing the selected information (Pasachoff 2011). The results are then passed on to AAS Headquarters in Washington for posting on the web by the Director of Communications, currently Judy Johnson, and the Membership Communications Manager, currently Crystal Tinch. They also notify the Vice Chair of HAD of members' deaths, which occur, unfortunately, at a fairly steady weekly rate[5]. The transition from the previous Vice Chair (Jarita Holbrook, now HAD Chair) to the current Vice Chair left an overlap of solicited but not yet submitted obituaries and a backlog of postings resulting from the paper-to-electronic transition, which required methods of posting to be reconsidered at AAS Headquarters.

The obituaries are posted, as they become available, by the AAS headquarters staff at a site[6] linked to the top-level page[7]; a list appears at the Historical Astronomy Division's site[8], which is linked from their top-level page[9]. At present, there are over 500 obituaries posted. At the Historical Astronomy Division's site you can find an alphabetical list of obituaries, including name, birth and death years, and the publication information in the (formerly print and currently online) *Bulletin*. All the obituaries since 1990 have been available on NASA's Astrophysics Data System (ADS), hosted at the Smithsonian Astrophysical Observatory by the High Energy Astrophysics Division at the Harvard-Smithsonian Center for Astrophysics[10]. For

[5]The rate corresponds roughly to the calculation of 5,000 AAS members (now 7,500) with an average lifetime of 100 years, or 50 deaths per year; of course, there were fewer members in the past though the average lifetime at present and in the past is substantially less than 100 years.

[6]`http://aas.org/baas/obits/all`

[7]`http://www.aas.org/`

[8]`http:/had.aas.org/obits.html`

[9]`http:/had.aas.org/`

[10]`http://adswww.harvard.edu/`

*Figure 1.* This photograph accompanying the obituary of Brian Marsden (1937-2010), late of the Harvard-Smithsonian Center for Astrophysics, charmingly shows him during his graduate-student days at Yale. The caption reads "Brian leaning on his bicycle during their years as graduate students at Yale. (Photo by Gene Milone)."

the last few years, the AAS has not included the obituaries in the online version of the *Bulletin*, so they were available only via ADS.

Obituaries are limited to former members, the list of which includes some distinguished foreign associates. Occasional exceptions can be made by the Obituary Committee, which includes the Vice-Chair of the Historical Astronomy Division (me), the American Astronomical Society's Executive Officer (Kevin Marvel) and President (Debra Elmegreen).

The main website[11] also includes a link to obituaries; as of this writing, it also displays a list of the ten most recently posted. The link[12] shows, in reverse chronological order names, date of the decease, and the date of publication of the obituary. The list can easily be alphabetized by clicking on the column head. All obituaries are now posted on the AAS website.

Though the *Bulletin of the American Astronomical Society* is now

[11] `http://aas.org/`
[12] `http://aas.org/baas/obits/all`

strictly online, the AAS office will provide bibliographical reference material for each obituary under the name(s) of its author(s).

## 3. Permanence

The question often exists these days between the permanence of digital data (on line, on DVDs, on hard drives, in the "Cloud," etc.) and print. The American Astronomical Society's *Astronomical Journal*, for example, published by the Institute of Physics (UK), promises that the Supplemental Data supplied by my co-authors and me for our paper about the transit of Venus (Pasachoff *et al.* 2011) will be available for 100 years. I have replied that we hope that the data are available to scientists preparing to observe the next transit of Venus, which won't occur for over another 105 years, in 2117, and that I hope that they could extend the guarantee to at least that date. We have been looking at observations printed in the *Philosophical Transactions of the Royal Astronomical Society* from the transit of 1761, 250 years ago, and even at the report of observations of the transit of Mercury of 1661, printed by Hevelius (1662) along with the first printed report of Jeremiah Horrocks's observations of the transit of Venus of 1639, 372 years ago. The images of comets in the *Nuremberg Chronicle* (1493) from 520 years ago, however, though assigned to real dates, turned out to be stylized rather than accurate (Olson & Pasachoff 1989a&b), even though some had been referred to as actual images.

With this issue of centuries-long future accessibility in mind, I recently received a suggestion from Ronald Shorn, formerly a *Sky & Telescope* editor (Shorn 2011). He wrote: "Glad to read that the obits are now recorded on 'electronic' media, presumably in some computer memory ... Speaking from hard won experience, that resource is, and will be, a godsend to anyone working on the recent history of astronomy ... There is another reason for this missive, which is to encourage recording of this information in more permanent format(s). I can't help thinking that, if this were the 1960s, the data would be recorded on punch cards (remember them?). Alternatively, one could use the latest 18-inch diameter, 1-inch thick spinning magnetic discs (remember them too?). As of 2011 both of these media are, or will soon be, lost, for nobody is making the equipment to read them. This trend will no doubt continue ... What to do? The optimal solution would be to find a smooth, very tall, very very wide granite cliff and carve things into it. This should preserve information for at least 5,000 years, but the AAS probably couldn't afford the expense. Possibly some printed books would be useful."

I responded that "Solar Dynamics Observatory sends down about 1.5 TB a day. If we have 1 sq mm per byte, then 1 TB = $10^{12}$ bytes = $10^6$ mm square = 1 km square of mountain cliff needed per day per TB, and roughly 25 km square of cliff face needed per year." The need for cliff storage for AAS obituaries would be much less, given perhaps 100 obituaries at 1 MB each, or 100 MB per year. At 1 sq mm per byte, then we would need only $10^8$ sq mm or a 10 m square per year, which could be easily accommodated on a variety of cliff faces. Present and future technologies could write with much smaller areas, even 0.3 nm square per letter[13]; the nanotechnology emphasis can be traced back to a 1959 lecture by Richard Feynman[14], "There's Plenty of Room at the Bottom." The Planetary Society[15] has flown the list of members into space, and often additional names, on at least 13 different spacecraft that flew to a variety of solar-system objects (Moon, Mars, Jupiter, comets, asteroids, Pluto)[16]. Perhaps, to ensure their long-term survival, the AAS should emulate the Society to arrange periodically for the obituaries to be flown into space on some compact media.

## 4. Comments

A hurdle that has to be often overcome is the fact that recently deceased individuals are often retired, and that the AAS directory therefore shows home addresses and does not reveal their former institutions, which would give clues to how to find suitable individuals to ask to write or supervise obituaries. It would be helpful if the AAS *Membership Directory*, or at least a master file at AAS headquarters, included former institutions (perhaps submitted voluntarily as the result of a routine request, at least for retired members), which would require nontrivial programming changes for the online version. This associated institution's name could also be added to the yearly print directory (which, for the moment, survives, since a new one, the *2011 Membership Directory*, arrived during the week of this writing, mid-2011). The former addresses are not easily available at AAS Headquarters, though the librarian at the US Naval Observatory is among those who have offered to refer to old Directories, an indication that the decision to phase out hard copies of things can lead to future deprivation.

In my finding an appropriate person to write an obituary, I have often made use of NASA's Astrophysical Data System[17].

Overall, the task of writing an obituary has been readily accepted, though the submission of the actual obituaries is not often prompt. As

[13] http://www.nature.com/nnano/journal/v4/n3/full/nnano.2008.415.html http://www.sciencedaily.com/releases/2009/01/090130154918.htm from 2009

[14] http://www.its.caltech.edu/~feynman/plenty.html

[15] http://www.planetary.org/

[16] http://www.planetary.org/programs/projects/international_mission_participation/messages/namesinspace.html

[17] http://adswww.harvard.edu/

the old, standard joke goes, "Of course, if you want your own obituary to be accurate, fully informative, and timely, you can and should write it yourself." This humorous comment led to the suggestion above, and its subsequent adoption, that some standard biographical information can be requested, perhaps at membership renewal time, to be put voluntarily on file, and possibly even with the name of one or more colleagues or former students who would be desirable obituary writers.

We can hope that the astronomers and historians of the future will find the AAS obituaries to be interesting and valuable.

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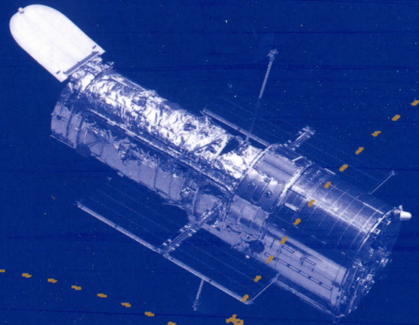


## Organizations, People and Strategies in Astronomy

### Volume 1

**André Heck (Editor)**

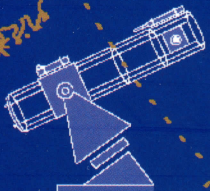
This OPSA I volume is in the line of the earlier prize-winning series Organizations and Strategies in Astronomy (OSA), with more emphasis on people. Rather than being devoted to the publication of hard-science results, these books described how astronomy research lives: how it is planned, funded and organized, how it interacts with other disciplines and the rest of the world, how it communicates, etc.

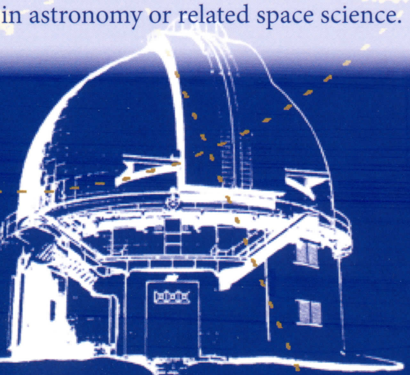
Thus the OSA/OPSA volumes have been and are a unique medium for scientists and non-scientists (sometimes from outside astronomy) to describe their experience and to elaborate, often for the first time at such a level, on non-purely scientific matters, many of them of fundamental importance for the efficient conduct of their activities. The volumes cover a large range of fields and themes: in practice, one could say that all aspects of astronomy-related life and environment are considered in the spirit of sharing specific expertise and lessons learned.

The chapters of the present volume are dealing with socio-dynamical aspects of the astronomy (and related space sciences) community: working habits, characteristics of organizations,demography of astronomy, workforce development, astronomy for the developing world, accessibility to astronomy for disabled persons, education and training to research, research communication, publication studies, public outreach, ethics, evaluation and selection procedures, career policies, strategies for minorities, contemporary history, and so on.

The experts contributing to this volume have done their best to write in a way understandable to readers not necessarily hyperspecialized in astronomy while providing specific detailed information and sometimes enlightening 'lessons learned' sections.

This volume will be most usefully read by researchers, teachers, editors, publishers, librarians, sociologists of science, research planners and strategists, project managers, public-relations officers, plus those in charge of astronomy-related organizations, as well as by students aiming at a career in astronomy or related space science.





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