

Accelerating the Rate of Astronomical Discovery: Introduction and Overview

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Special Session 5 on Accelerating the Rate of Astronomical Discovery addressed a range of potential limits to progress - paradigmatic, technological, organisational, and political - examining each issue both from modern and historical perspectives, and drawing lessons to guide future progress. A number of issues were identified which potentially regulate the flow of discoveries, such as the balance between large strongly-focussed projects and instruments, designed to answer the most fundamental questions confronting us, and the need to maintain a creative environment with room for unorthodox thinkers and bold, high risk, projects. Also important is the need to maintain historical and cultural perspectives, and the need to engage the minds of the most brilliant young people on the planet, regardless of their background, ethnicity, gender, or geography.

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1. Introduction

The 3.5 day Special Session on 'Accelerating the Rate of Astronomical Discovery' was born from a conference-bus discussion in Lithuania between Ray Norris and Clive Ruggles on what would be the most appropriate meeting to mark the International Year of Astronomy. As the public announcements regarding the 2009 IYA have emphasised, new astronomical discoveries are currently being made at an extraordinary rate, while the invention of the telescope ushered in an equally momentous "golden age of discovery" 400 years ago. We concluded that this would be an optimum occasion to review the extent to which astronomers are achieving the optimal rate of astronomical discovery. Can we identify and overcome the limits to progress? What steps can be taken to accelerate the rate of expansion of astronomical knowledge? What lessons can be learnt both from the past?

The meeting addressed a range of potential limits to progress - paradigmatic, technological, organisational, and political - examining each issue both from modern and historical perspectives, and drawing lessons to guide future progress. We were fortunate in being able to attract some internationally-renowned speakers, including four IAU Presidents (past, present, and future), pulsar discoverer Jocelyn Bell Burnell, and physicist and popular science writer Lawrence Krauss.

The meeting was divided into 12 sessions, each focussing on one particular topic, and introduced by one or two invited speakers, followed by contributed papers. This brief summary cannot possibly review every one of the many excellent papers, but instead focuses on a few highlights.

2. Back to the Future

The meeting was opened by the new President of the IAU, Bob Williams, who spoke on "Discovery and the Culture of Astronomy", and who pointed out that the astronomical discovery processes evolve slowly with time, and have no systematic procedure by which they are evaluated and modified. For example, time on major telescopes is allocated by a peer-review system, and yet arguably the most significant research conducted by the Hubble Space Telescope (the Hubble Deep Fields) were not awarded time through a peer-review process. Diversity is therefore important, and should be encouraged throughout astronomy. Furthermore, we should regularly review how we conduct the business of astronomy, and recommend change where necessary.

Historian of Science David DeVorkin introduced a historical perspective by examining what has worked and what hasn't. While no absolute answers are available, a series of case studies gave us hints to what might be most productive. We learnt that the great discoveries of the past relied not only on skill and insight, but also on the willingness to take risks, the ability to form productive collaborations, and the value of diversity and versatility.

As a case study, IAU President-elect Norio Kaifu examined the phenomenal rise of astronomy in Japan. A key factor here was the presence of visionary and inspirational leaders (including, of course, Kaifu himself, although he would be too modest to say so!). It was also important to monitor carefully the developments elsewhere, and be prepared to use cutting-edge technology to jump ahead of the international state-of-play.

The status of astronomy as a science was questioned by Lawrence Krauss. He noted that, while the last few years have produced a revolution in our picture of the Universe on its largest scales,

this revolution has also raised the question of whether cosmological concepts such as inflation and Dark Energy are in fact falsifiable. If not, then cosmology has arguably crossed the border from physics to metaphysics.

Magda Stavinschi pointed out the importance of teaching students not only about current astronomy, but also of our astronomical heritage. Knowledge of that history is essential to provide the context within which discoveries and theories can be evaluated, or major projects planned. Magda noted that "one cannot have a future without knowing one's past."

3. Creativity, Innovation, and Culture

Simon White warned us of the dangers of becoming too enamoured with big projects, billion-dollar telescopes, and the resulting intellectual bandwagons. While acknowledging the value of such projects, it is important that we do not become immersed in a corporate mentality where we fail to recognise creative ideas that depart from the juggernaut of academic orthodoxy.

Some of the greatest scientific discoveries in the past, Ken Kellermann told us, have not in fact come from testing theories, but from applying technology to broadening our view of the Universe. In fact even when telescopes have been built primarily for a particular research goal, their major discoveries are often unrelated to that goal. Knowing that is the case, we must try to make out future telescopes flexible, and, even more importantly, to ensure our minds and research processes are sufficiently flexible to recognise the unexpected.

The discovery of pulsars is a prime example of this process, and pulsar discoverer Jocelyn Bell Burnell explained the importance of having a mindset which would be receptive to bits of scruff on a chart recorder, while less prepared minds might dismiss them as unimportant. Other key factors included knowing the instrument intimately, thus being able to distinguish the exceptional from the routine, and of being in a stimulating research group in which creativity and risk-taking are encouraged.

Past IAU President Ron Ekers built on this theme to show how science instruments, both in astronomy and in other areas of science, grow exponentially and inexorably from "little science" to "big science". The ensuing change of culture raises the challenge of how to maintain creativity and flexibility in the face of the rigid and bureaucratic processes which are necessary to build a "Big Science" instrument. This challenge may be rephrased as a challenge to maintain a vigorous and nimble "Small Science" community even while developing the "Big Science" instruments which are necessary for the advance of the research field.

The tendency of our processes to quash creative thought was also noted by Catherine Cesarsky who noted that decadal plans, visions, and roadmaps are helpful, at least to foster the inception of large projects, which undoubtedly foster first-rate science. But the resulting orthodoxy can also quench originality, and amplify bandwagon effects, so that time allocation committees discriminate against original, risky, or unorthodox projects.

Eric Feigelson reviewed the importance of cross-disciplinary research, discussing the successes, challenges and opportunities. He showed that cross-disciplinary approaches have led to significant advances in astronomy, and that cross-disciplinary researchers make profound, revolutionary transformations in our thinking. If the paths of cross-disciplinary astronomy are groomed,

and talented scientists tread them in a spirit of creativity, then we can envision a blossoming of astronomy in new areas.

The influence of society on astronomical discovery was discussed by George Miley. Paradigm-changing observational facilities have become so sophisticated and expensive that they require global funding. As a result, funding decisions are inevitably political, and astronomy needs to inform these decisions using broad-based arguments, such as those in the new IAU strategic plan, which outline astronomy's benefits to society. Participation in such activities is a cost-effective way for astronomers to stimulate funding for astronomical research. On the other hand, such developments tend to stifle nonconformity amongst astronomers, which may affect future astronomical discoveries.

Clive Ruggles argued that astronomy would benefit from the mutual awareness and comprehension between modern astronomy and cultural world-views such as "indigenous cosmologies", whose goals, like those of science, are to make sense of the cosmos. The necessary links require modern astronomers to understand and respect both the heritage and the non-western frameworks of thought that give rise to these cultural perspectives. One of the most obvious potential benefits could derive from common attitudes towards the natural heritage of astronomy, namely dark skies.

4. Data and Information

Our current growth is measured not only in the size of the instruments but also in the Terabytes of data, the Teraflops required to process them, and new tools for data access, enabling new modes of astronomical discovery. George Djorgovski shared his vision of how these new ways of accessing data are fomenting a revolution affecting every stage of the research endeavour. We must be prepared for even our fundamental scientific methodology to change, and we must expect new areas of research, such as time-domain astronomy, to become increasingly significant.

Francoise Genova explained how the tools and processes of the Virtual Observatory can enable these far-reaching changes, and will facilitate the growth of our "knowledge infrastructure".

The impact of information science on astronomy was explored by Ray Norris, who pointed out that current astronomers are largely drawn from privileged backgrounds, and exclude those proto-Einsteins who are held back by their background or unconventionality. Web 2.0 and its successors could enormously raise the intellectual resources available to astronomy if we could figure out how to build a bridge to tap into these unrecognised intellects which are undoubtedly out there, not only in developing countries but perhaps in our own patent offices.

5. Education and Opportunity

Rajesh Kochhar noted a declining interest in basic science, and a shift away from physical sciences towards life sciences, and argued that research needed to be closely linked to education. In developing countries, the development of a tradition of training and mentoring of the finest young minds to conduct top-quality research is arguably more important than conducting the research itself.

On the other hand, Patricia Whitelock showed how South Africa is successfully using astronomy, and developing new telescopes such as SALT and Meerkat, as a tool for national human

development. In particular, the National Astrophysics and Space Science Programme is overcoming the legacy of apartheid to raise the level of science engagement and education amongst young Africans, and help them participate in the process of research and discovery.

Any doubt about the excitement that can be found in a presentation on education was quashed by a memorable presentation by Julieta Fierro, who alerted us to the opportunity of raising the scale and standard of our outreach projects. As well as demonstrating the importance of outreach and education, and demonstrating some novel ways to engage our audiences, she stressed how outreach must be taken seriously rather than being an after-thought: it must be interesting, diverse, simple, pertinent, and peer reviewed.

6. Panel Discussion and Conclusion

The meeting finished with a lively panel discussion in which some of the speakers were invited to answer questions from each other and from the floor. Prominent in the ensuing discussion was the role of large strongly-focussed projects and instruments, designed to answer the most fundamental questions confronting us. Such instruments continue to be immensely successful both in answering the questions for which they were designed, and just as importantly, by probing regions of the observational parameter space that have not yet been observed. Both these approaches are important, and new instruments need to be designed to address both. To do so, they must be used by people who understand the instruments intimately, and are able to recognise the difference between a new discovery and an instrumental artefact.

Against the need for such focussed projects must be balanced the need to maintain a creative environment with room for unorthodox thinkers and bold, high risk, projects. We must be wary of conservative time allocation processes and funding agencies, of bandwagon effects, and the stifling of those who venture outside the box. We must also be wary of a "one-size-fits-all" approach: while the meeting emphasised the importance of cross-fertilisation and multi-wavelength approaches, we also need people who have very deep knowledge in their own particular field or technique.

Also important are the need to maintain historical and cultural perspectives, and the need to provide opportunities so that disadvantaged students can participate in astronomy. We want to provide universal access to information, while avoiding drowning great discoveries in a sea of unrefereed insignificant publications.

Perhaps the greatest area of common ground is the need to invest in the education and engagement of the scientists of the future. It is important that we train our students to understand their instruments as well as their science, to teach them to think nimbly, and not necessarily follow the well-funded bandwagons. But we must also recognise the millions of potential brilliant scientists of the future who are currently prevented from entering the arena of science either because of social or financial needs, or because, like Einstein, they don't quite fit the model of a good mainstream student. We have the technology to reach them, but we do not yet have the processes to do so.

The challenge to astronomy is to find ways to engage the minds of the most brilliant young people on the planet, regardless of their background, ethnicity, gender, or geography. By doing so we can not only accelerate astronomy, but we can generate real benefits to wider human society.

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