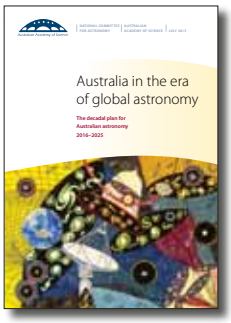
Australian astronomy is going global



Ragbir Bhathal considers Australia's ambitious decadal plan 2016–2025, and finds that its global approach follows naturally from Australian astronomy's growing world profile.

Australian astronomers have released their decadal plan for astronomy for the years 2016 to 2025 (Australian Academy of Science 2015). It is an ambitious plan that takes into account their limitations, advantages of location, expertise and world standing in the international world of astrophysics. They have called it, appropriately, *Australia in the Era of Global Astronomy*. The global approach is a reflection of the Australian government's push to open up Australia to the world (Office of the Chief Scientist 2014). In fact, over the past few years, policy makers both in government, industry and the universities have begun to realize that to survive in the highly competitive digital age of the 21st century Australia has to embrace globalization because markets, skills, knowledge and scientific research are increasingly moving on a global scale.

"The plan is for international cooperation and partnerships with major players"

What's the plan?

The decadal plan spells out the science drivers and instruments that astronomers will use to answer a series of ambitious questions about the universe. The questions are among those of concern to astronomy globally: How did the first stars and galaxies transform the universe? What is the nature of dark matter and dark energy? How do galaxies form and evolve across cosmic time? How do stars and planets form? How are elements produced by stars and recycled through galaxies? What is the nature of matter and gravity at extreme densities?

To answer these questions, the plan outlines a strategy that encompasses international cooperation and partnerships with major players in global astronomy in the US and Europe. There are five infrastructure priorities, which are given equal weight: a significant (30%) partnership in an 8 m class optical/infrared telescope; a smaller role in a next-generation extremely large telescope; continuing development of Square Kilometre Array precursor instruments and SKA membership; instrument development for global projects; and high-performance computing for large theoretical simulations and data handling.

Global goals

Australian astronomers have been working within the international community for several decades. The transition to global science started in the late 1950s when American astronomer Bart Bok became the director of Mount Stromlo Observatory, where he established an international graduate school (De Vorkin 1978). Olin Eggen (director from 1966 to 1977) introduced new instrumentation to Mount Stromlo Observatory and the astronomical community and took a leading part in Australia's first foray into a bilateral project, the Anglo–Australian Observatory. This was a joint project between the Australian and British governments and their astronomers (Gascoigne *et al.* 1990) and now forms the backbone of the Australian Astronomical Observatory. In 1961, the Parkes Radio Telescope was opened, owing a debt to the generosity of the Carnegie Institution and the Rockefeller Foundation (Robertson 1992). This most versatile instrument has been involved in some major contributions in astrophysics through the HI Parkes All-Sky Survey (HIPASS) and observations of millisecond pulsars and is now being used to search for gravitational waves. And the 1980s saw the commissioning of the Australia Telescope (now the the Australia Telescope National Facility), a brainchild of Bob Frater (Bhathal *et al.* 2013).

Jeremy Mould, with his considerable experience of big science projects such as the Hubble Space Telescope, introduced the concept to the Australian astronomical community in the 1990s. His appointment of Brian Schmidt to the staff of Mount Stromlo Observatory was a stroke of brilliance. Schmidt had the audacity, at the age of 27 and as a newly minted PhD, to lead the international High-Z Supernova Search Team. In the 2000s, the appointments of Penny Sackett and Harvey Butcher as directors of Mount Stromlo Observatory furthered the ideas of big science by getting Australian astronomy involved in the Giant Magellan Telescope (Bhathal 2015). Their astute decision positioned the community for a leadership role in the new

1 Artist's impression of the Giant Magellan Telescope being built in Chile for completion in 2025, and in which Australia plays a key role. (GMTO)

generation of extremely large telescopes. Brian Schmidt's world standing was confirmed with the award of the Nobel Prize in 2011 (Bhathal *et al.* 2013). Now that he is vice-chancellor of the Australian National University, we will see a concerted push to globalization. Since the 1940s, Australian astronomers have been part of significant developments in astronomy and astrophysics, recorded succinctly by Longair (2006) in his excellent account of the development and history of astrophysics and cosmology from 1900 to 2005. The names of Australian astronomers stand alongside a whole host of influential global astrophysicists from Aaronson to Zwicky.

Big science, big surveys

Large sky surveys have become increasingly significant as a source of statistical information about astronomical objects, opening up new areas of scientific exploration. In the 1990s and early 2000s, Australian astronomers were involved in four large surveys, HIPASS led by Lister-Stavely Smith and Rachel Webster (Putman *et al.* 1998), the 2dF Galaxy Redshift Survey (Peacock *et al.* 2001) and the 6dF Galaxy Survey (Jones *et al.* 2004) led by a group of leading British and Australian astronomers (Richard Ellis and Matthew Colless were co-PIs on the 2dFGRS while Colless was PI on the 6dFGS) and the High-Z Supernova Search team (Schmidt *et al.* 1998). Warrick Couch and Brian Boyle were members of Saul Perlmutter's Supernova Cosmology Project.

These surveys not only provided new insights into the nature and structure of the universe, but also a high number of citations, which boosted the international profile of Australian astronomy, including Schmidt's Nobel Prize in 2011. They also boosted Australian instrumentation expertise. The 2dF and 6dF surveys used new instrumentation (the multi-fibre spectrograph) developed at the Anglo–Australian Observatory under the influence of British astronomers to allow large numbers of spectra to be obtained in a single exposure. Ellis and Keith Taylor were largely the parents of 2dF, while 6dF was largely the work of Fred Watson; both were supported by Russell Cannon, then AAO director.

"Australia was involved in the early days of the discovery of dark matter in galaxies"

Australia was involved in the early days of the discovery of dark matter in galaxies. Kenneth Freeman is credited with being the first to point out in print (Freeman 1970) that some spiral galaxies must have an outer halo of dark matter (van Albada *et al.* 1985). This led indirectly to the MACHO project, which used the refurbished Great Melbourne Telescope to probe the content of our galactic dark halo. A team of US astronomers led by Charles Alcock and Chris Stubbs joined forces with Freeman and a group of Mount Stromlo astronomers for MACHO, which ran from 1992 to 1999 and showed that dark matter did not consist of the relatively large objects that the team had looked for. The nature of dark matter and dark energy remains one of the major unsolved problems in astrophysics of the 21st century. In fact, it has become one of the key programmes of the US decadal plan 2010. Their Wide-Field Infrared Survey Telescope (WFIRST), which is planned to be launched in 2020, will be used to find out the effect of dark energy on the evolution of the universe. Dark energy will also be investigated by them with the ground-based Large Synoptic Survey Telescope.

Australian astronomers are already involved in world-class science in the priority fields identified by the decadal plan. For example, Freeman and Joss Bland-Hawthorn of the University of Sydney founded the new field of galactic archaeology – reconstructing the evolution of our galaxy using the remnants of ancient stars – which has become an active research area. The discovery of pulsars led to the compilation of the Australia Telescope National Facility Pulsar Catalogue of 2003, listing almost 1500 pulsars of which 90 are members of binary systems. Richard Manchester has a long and distinguished record of studying pulsars, having discovered over half of them with his colleagues. And Matthew Bailes from Swinburne University discovered fast radio bursts – flashes of radio energy whose origin remains uncertain – with the Parkes Telescope.

A strong astronomical community

The Australian astronomical community is strong across a range of research fields, with major international awards going to staff at Mount Stromlo Observatory and Swinburne University. Mount Stromlo Observatory also excels in high technology.

Australian astronomy's decadal plan for 2016–2026

The decadal plan identifies five top-level science infrastructure priorities. These priorities are equally weighted as part of an overall astronomy capability:

- Partnership equating to 30% of an 8 m class optical/infrared telescope.
- Continued development and operation of the Square Kilometre Array (SKA) precursors, the Australian SKA Pathfinder (ASKAP) and the Murchison Widefield Array (MWA) at the Radio-astronomy Observatory (MRO), and membership of the SKA telescope.
- Partnership equating to 10% of a 30 m class optical/infrared extremely large telescope, such as the Giant Magellan Telescope (GMT);
- Capability within the national observatories (the Australian Astronomical Observatory and the Australia Telescope National Facility) to maximize Australia's engagement in global projects through instrumentation development for these and other facilities.
- World-class high-performance computing (HPC) and software capability for large theoretical simulations, and resources to enable processing and delivery of large data sets from these facilities.

The Advanced Instrumentation and Technology Centre (AITC) was established in 2006 and has already established itself as an international high-technology instrument provider, building the GMT Integral Field Spectrometer (GMTIFS) and designing Laser Tomography Adaptive Optics (LTAO) for the Giant Magellan Telescope. It is also working with EOS Space Systems and other organizations in space-based instrumentation. The expertise developed at the AITC will be valuable in the global astronomy strategy of the decadal plan.

Innovative high-technology instrumentation projects are also underway in Western Australia. The Murchison Widefield Array (MWA), a low-frequency precursor for the Square Kilometre Array (SKA), led by Steven Tingay from Curtin University, is being used to study the epoch of ionization, galactic science and time-domain astrophysics. Another innovative instrument is the Sydney–AAO Multi-object Integral-field Spectrograph (SAMI) which began a survey in 2013 to study 3400 galaxies. The establishment of the SKA in the silent environment of the Shire of Murchison (population 113) will begin a new era for astrophysics.

Over the past decade, the main areas of astronomical research have been extragalactic astronomy, galactic astronomy, instrumentation and stellar astronomy. The weakness in theoretical astronomy that was identified in the 1990s (Bhathal & White 1991) has been corrected, and theoretical and computational astrophysics has risen to prominence in the past decade. In fact, in 2014 about 40% of the astronomers identified with the subdiscipline of theoretical and computational astrophysics (Australian Academy of Science 2015). Darren Croton and Jarrod Hurley from Swinburne University and Cath Trott from ICRAR (International Centre for Radio Astronomy Research) are the torch bearers in theoretical astrophysics. Croton uses both simulations and large data sets to study the formation and evolution of galaxies. He is also involved in the highly experimental online eResearch Laboratory aptly called the Theoretical Astrophysics Observatory.

The past few years have witnessed a change in the size and composition of the astronomical community. The community size has increased by about 25% over the past decade and there has also been a substantial increase in the number of astronomers from overseas – a trend that was started by Bok in the 1950s. This augurs well for the decadal plan for the globalization of Australian astronomy. The success of the postgraduate programmes has led to a large rise in the number of PhD students in astronomy – a positive step but also a cause of unease among some postgraduates who envisaged a long and fruitful career in astronomy, but may have to find jobs outside astronomy. That transition is part of the decadal plan, which recommends: "A set of transferable skills should be developed as part of the astronomy PhD programme, to provide highly skilled graduates for roles in the wider community. Universities should offer postgraduate and early-career courses that teach lateral skills, including expertise in managing large data sets, programming in languages in demand by industry, training in industry practices, professional project and management skills."

Women in astronomy

The number of women in astronomy has remained fairly steady at about 20% over the past decade. In the 1990s, there was only a handful of women astronomers in Australia, five in full-time jobs and two in part-time, tenured positions. Rhonda Jones, a former deputy-vice chancellor at James Cook University, ascribed the low numbers of women in the physical sciences and engineering to the perceived "maleness of these subjects" and an environment with a "locker room mentality" (Bhathal 1999). Today, women hold influential senior positions in Australian astronomy, such as Elaine Sadler, director of CAASTRO (ARC Centre of Excellence for All-Sky Astrophysics). But the decadal plan is critical of the progress of female participation in Australian astronomy and wants the community to adopt principles and practices "that aim for at least 33% female representation at all levels of Australian astronomy by 2025".

As for the future, there will be major developments and discoveries when the SKA and the GMT come online. There may even be a conceptual shift in their thinking about the universe if the nature of dark matter, dark energy and gravitational waves are discovered. Australian astronomers realize that to achieve their ambitious goals they need to have an integrated approach that encompasses the universities, AAO and ATNF. That is the objective of the decadal plan. But it has been released at a time when the Australian government is undertaking a major cost-cutting exercise in government programmes including education and research. It will require the greatest diplomacy and highly tuned persuasive powers to enable the astronomers to answer some of the fundamental questions about the universe we live in. ●

AUTHOR

Ragbir Bhathal is lecturer at School of Computing, Engineering & Mathematics, Western Sydney University, and visiting fellow at Research School of Astronomy & Astrophysics, Australian National University. He is writing a new book, *Mount Stromlo Astronomers: the Endless Frontier.*

ACKNOWLEDGMENTS

The author thanks Ken Freeman and Matthew Colless for their valuable comments, which are very much appreciated.

REFERENCES

Australian Academy of Science 2015 *Australia in the Era of Global Astronomy: the Decadal Plan for Australian Astronomy 2016–2025* (Australian Academy of Science, Canberra) http://bit.ly/1P4Mfc5

Bhathal R 1999 *Profiles: Australian Women Scientists* (National Library of Australia, Canberra)

Bhathal R 2015 *Astron. & Geophys.* **56** 1.19

Bhathal R & White G 1991 *Under the Southern Cross: a Brief History of Astronomy in Australia* (Kangaroo Press, Kenthurst)

Bhathal R *et al.* 2013 *Mount Stromlo Observatory: from Bush Observatory to the Nobel Prize* (CSIRO Publishing, Collingwood)

De Vorkin D 1978 *Oral history transcript: Dr Bart Bok* (Am. Ins. Phys.)

Freeman K C 1970 *Astrophys. J.* **160** 811

Gascoigne S C B *et al.* 1990 *The Creation of the Anglo-Australian Observatory* (Cambridge University Press, Cambridge)

Jones D H *et al.* 2004 *Mon. Not. R. Astron. Soc.* **355** 169

Longair M 2006 *The Cosmic Century: a History of Astrophysics and Cosmology* (Cambridge University Press, Cambridge)

Office of the Chief Scientist 2014 *Science, Technology, Engineering and Mathematics: Australia's Future* (Australian Government, Canberra)

Peacock J A *et al.* 2001 *Mon. Not. R. Astron. Soc.* **355** 747

Putman M E *et al.* 1998 *Nature* **394** 752

Robertson P 1992 *Beyond Southern Skies: Radio Astronomy and the Parkes Telescope* (Cambridge University Press, Cambridge)

Schmidt B *et al.* 1998 *ApJ* **507** 46

van Albada *et al.* 1985 *Astrophys. J.* **295** 305