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HARVEY BUTCHER: A PASSION FOR ASTRONOMICAL INSTRUMENTATION

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Abstract: This paper covers some aspects of the scientific life of Harvey Butcher who was the Director of the Research School for Astronomy and Astrophysics at the Australian National University in Canberra from September 2007 to January 2013. He has made significant contributions to research on the evolution of galaxies, nucleosynthesis, and on the design and implementation of advanced astronomical instrumentation including LOFAR (Low Frequency Array Radio telescope). He is well known for his discovery of the Butcher-Oemler effect. Before coming to Australia he was the Director of the Netherlands Foundation for Research in Astronomy from September 1991 to January 2007. In 2005 he was awarded a Knighthood in the Order of the Netherlands Lion for contributions to interdisciplinary science, innovation and public outreach. This paper is based on an interview conducted by the author with Harvey Butcher for the National Project on Significant Australian Astronomers sponsored by the National Library of Australia. Except otherwise stated, all quotations used in this paper are from the Butcher interview which has been deposited in the Oral History Archives of the National Library.

Keywords: Harvey Butcher, the Butcher-Oemler effect, LOFAR, Square Kilometre Array (SKA), Giant Magellan Telescope (GMT), space research

1 INTRODUCTION

Born in Salem, Massachusetts in 1947, Harvey Raymond Butcher (see Figure 1) came from a middle class family. His father was a surgeon. As a young boy his interest in astronomy was fired by reading an article on high-resolution spectra in cool stars which appeared in the *Scientific American*. This was in his high school years. He had not realised that if you make a spectrum of the Sun or the stars, you see many spectral lines, and that they tell you about the physics and the composition of the distant stars. He thought that this was amazing. He was very keen to become a professional astronomer, but his father was less impressed. "He did not encourage me to be an astronomer by any means," Butcher recalled. "He was supportive, as a father should be, but very sceptical." Nevertheless, Butcher went to the California Institute of Technology to study astronomy. Although he found the place intellectually exciting and stimulating, he also found it stressful.

He then arranged a part-time job at Mount Wilson Observatory (Figure 2), where he met a number of well-known astronomers who came to observe. His role was to help with the development of infrared photometry in one of the first surveys of the sky at infrared wavelengths (the Neugebauer-Leighton Two Micron Sky Survey). He also spent a lot of time with Allan Sandage (1926–2010; Figure 3; Lynden-Bell, and Schweizer, 2012), who was very encouraging, and very helpful. It was Sandage (described by Francis Bello in the June 1954 issue of *Fortune* magazine as the astronomer who was helping to define the age and structure of the Universe), who first suggested to Butcher that he should go 'down under' to undertake his Ph.D. studies at Mount Stromlo Observatory in Australia. Sandage was a good friend of Olin Eggen (1919–1998; Figure 4; Trimble et al., 2001), then Director of Mount Stromlo Observatory. In fact, Eggen had teamed with Sandage and Lynden-Bell and written the famous 'ELS paper' on the formation of our Galaxy which gave them a citation count of 1499, a very high figure for the 1960s. The time he spent at Mount Wilson was also the beginning of Butcher's deep interest in the designing and construction of new astronomical instrumentation to probe the secrets of the Universe. It was to remain his passion throughout his career.

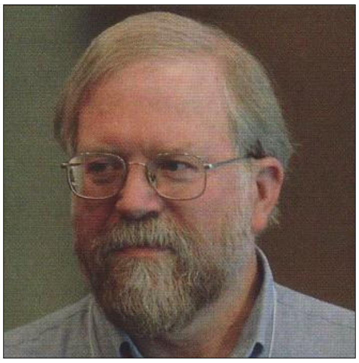

Figure 1: Harvey Butcher (courtesy: University of Virginia).

Butcher graduated from Caltech in 1969. He then took up Sandage's suggestion and went down to Mount Stromlo Observatory in February 1970 to do his Ph.D. What amazed him was that at Mount Stromlo there were no lecture courses, and students were treated almost as staff members for access to telescopes and other facilities. He had been completely fed up with sitting in lecture courses and taking exams. The idea of having four years to do nothing but

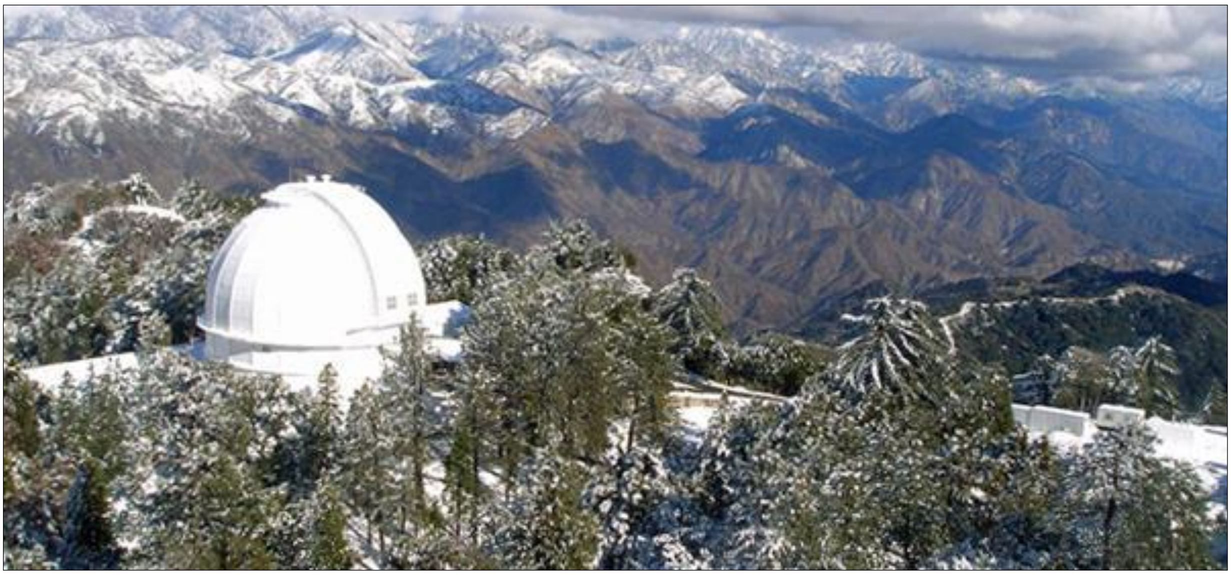

Figure 2: Mt Wilson Observatory (www.pa.ucla.edu/).

Figure 3: Allan Sandage (en.wikipedia.org).

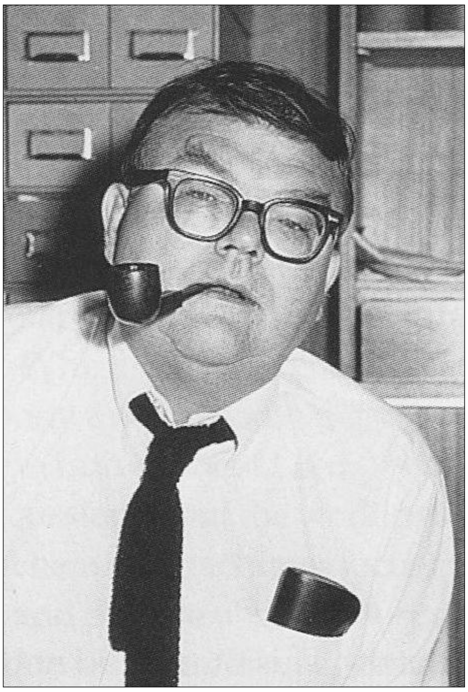

Figure 4: Olin Eggen (courtesy: Mount Stromlo Archives).

research projects was unbelievably attractive to him. In hindsight, he noted it was one of the best decisions he ever made.

2 NUCLEOSYNTHESIS

Butcher began his Ph.D. on a study of nucleosynthesis in the Galaxy under the supervision of Mike Bessell, a young astronomer who was making a name for himself in the study of stellar astrophysics, and Alex W. Rodgers (1932–1997), who was to become the Director of the Observatory in 1986. Butcher had chosen his topic before he even arrived. The theory that stars convert light elements into heavier ones via nuclear reactions had been worked out by Burbidge, Burbidge, Fowler and Hoyle (1957). They had shown that the different elements came from different nuclear processes in different stars. When Butcher came on the scene the key question was:

> Is the result the same throughout the whole history of the Galaxy, or is there evidence of secular, relative abundance evolution for elements produced by nuclear reactions under very different conditions?"

Butcher wanted to measure differential chemical abundances in dwarf stars of r- and s-process elements, which are produced in different stars and over widely-differing timescales.

However, he soon discovered that the available gratings in the 74-in Coudé spectrograph were not suitable for the work. With advice and help from Bessell and Rodgers he put together in the Coudé one of the first high-resolution Echelle spectrographs in astronomy (Butcher, 1971). What he found was that over a very large range of ages and over mean abundance levels differing by a factor of 30, basically there was very little or no measurable difference in the relative abundances (Butcher, 1972; 1975).

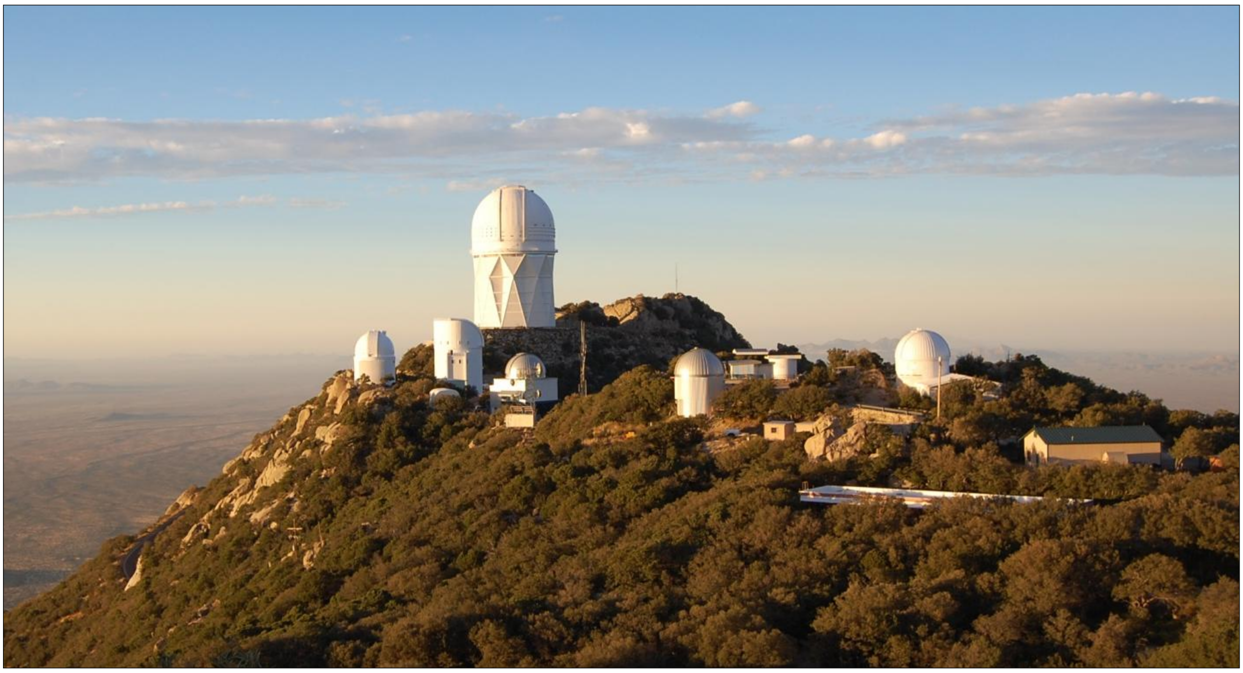

Figure 5: Kitt Peak National Observatory (www.cesl.arizona.edu/node/864).

This approach to doing research, of developing new instrumental capabilities to make new observations possible, characterized the rest of Butcher's professional career.

3 KITT PEAK

On a visit to Mount Stromlo in 1973, Peter Strittmatter from the University of Arizona in Tucson offered Butcher a job following the defence of his thesis. Butcher left Mount Stromlo in September 1974 to work at the Steward Observatory as a Bart Bok Fellow. While in Tucson he became friends with Gus Oemler and Roger Lynds at the Kitt Peak National Observatory (Figure 5), and joined them on the Kitt Peak staff in September 1976. Lynds had a particular interest in the new panoramic digital detectors and was kind enough to involve Butcher to help test and implement them on the telescope.

Oemler interested him in trying to observe the evolution of galaxies over cosmic time. They decided to try to use the new digital detectors to look at rich galaxy clusters, which were ideal targets for the relatively small fields of view of these early vidicon and Charge Coupled Devices (CCDs). He noted:

> It is hard to appreciate today that in the 1970s, received wisdom was that galaxies formed early and essentially didn't evolve visibly over recent cosmic time.

But he thought S0 galaxies (which are disc systems without any significant current star formation) might just be very old spiral galaxies in which the gas had all been converted into stars. Oemler felt that might be the case, but that probably in clusters their gas gets stripped away by the ambient cluster medium. To try to test the two hypotheses for the origin of S0 galaxies, they used the new detectors to observe what was happening. To their surprise they found lots of blue galaxies in clusters at modest redshifts, which should not have been there according to all the then-current ideas. Some of the galaxies had changed dramatically in recent cosmological times (Butcher and Oemler, 1978; 1984).

Senior astronomers were scathing about the claim and dubbed it the 'Butcher-Oemler effect'. If you had an effect named after you, he noted,

> ... that tended to mean that nobody believed it and it wasn't going to turn out to be correct in the long run. So it was not a positive thing to have a Butcher-Oemler effect at that time.

It was an unpleasant period in Butcher's life.

In the early 1980s, Barry Newell at Mount Stromlo teamed up with Ph.D. student Warrick Couch (now Director of the Australian Astronomical Observatory) to study a dozen high-redshift galaxies, taking the photometry from deep photographic plates mostly from the 3.9-m Anglo-Australian Telescope at Siding Spring Observatory. According to Couch (2006), this work made the very important step of independently confirming the Butcher-Oemler effect and showed it to be widespread and hence generally a universal property of rich, centrally-concentrated clusters at redshifts >0.2.

Further confirmation came several years later. Butcher noted that, "Gus Oemler found that Zwicky had seen the phenomenon visually on his photographic plates from Palomar." Fritz Zwicky (1898–1974) was often right, and that gave Oemler the courage to continue to lobby

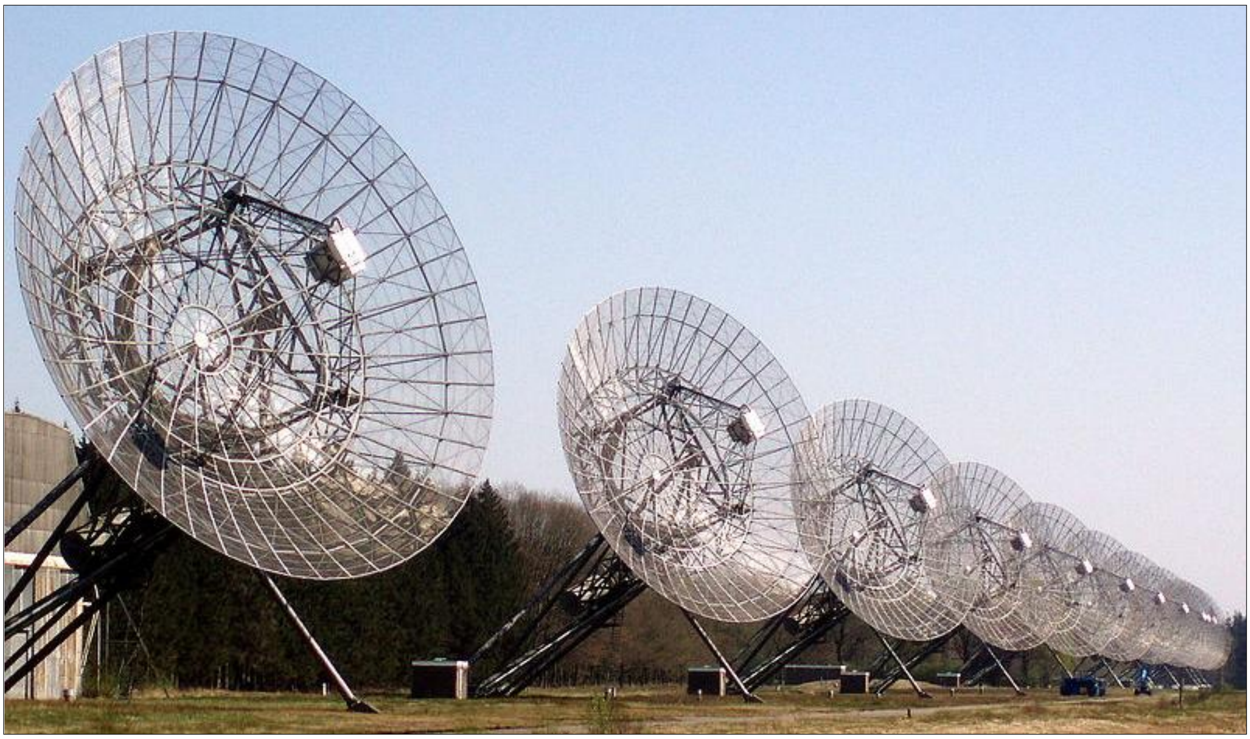

Figure 6: The Westerbork Synthesis Telescope at the Westerbork Radio Observatory (en.wikipedia.org).

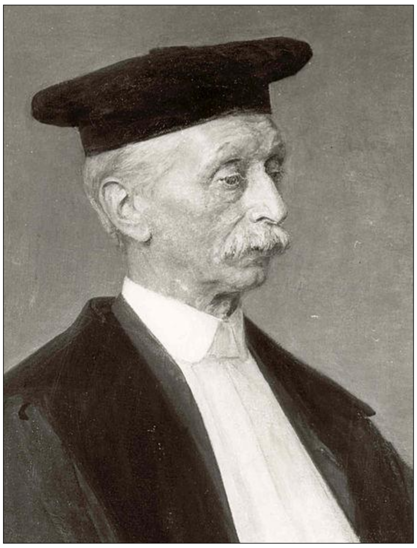

Figure 7 (left): The Kapteyn Astronomical Institute at Groningen University (www.astro.rug.nl/~weypaert/zernike_gebouw.gif).
Figure 8 (right): Jacobus Kapteyn (en.wikipedia.org).

his colleagues about the reality of the evolution. Today, undergraduate astronomy textbooks carry a description of the Butcher-Oemler effect.

Butcher stayed at Kitt Peak until September 1983. While there, he worked to perfect CCD detector systems and spearheaded their use for imaging and multi-aperture spectroscopy for observing very faint high-redshift galaxies. He also was project scientist for several new observing instruments, including an early spectrograph for obtaining spatially-resolved spectra at resolutions approaching the diffraction limit.

4 IN THE NETHERLANDS

By 1983 Butcher had moved to a position at Kitt Peak where he was influential in determining policy, but even so he decided that it was time to try something new. Earlier, in November 1982, because of his expertise in astronomical instrumentation, he had a visit from Professor Dr Harry van der Laan, Chairman of the Dutch National Committee on Astronomy as well as Chairman of the Board of the Netherlands Foundation for Radio Astronomy (ASTRON). At that time ASTRON operated the Dwingeloo and Westerbork Radio Observatories (Figure 6), managed a university grants program, and was the Dutch centre for developing a new optical observatory on La Palma (in the Canary Islands), together with the U.K. and Spain. Van der Laan represented the community in negotiations with the British on the development of the Isaac Newton Group of telescopes on La Palma and the James Clerk Maxwell sub-millimetre telescope in Hawaii. At the time, the Dutch astronomers were setting up an inter-university working group at the Kapteyn Observatory in Roden (just south of Groningen), whereby technical staff from Groningen and Leiden were seconded to the group, but they needed someone to lead the effort. That person would also have a full professorship at the Kapteyn Astronomical Institute at Groningen University (Butcher, pers. comm., 18 November 2013).

Van der Laan asked Butcher to consider a job in the Netherlands specifically to help out in a collaboration with the U.K. to build a new observatory on La Palma. Butcher's instrumentation background was what motivated them to offer him a professorship at the Groningen University. He moved to Groningen (Figure 7) in October 1983. Groningen has long had a strong reputation in astronomy. Between 1878 and 1921 Jacobus C. Kapteyn (1851–1922; Figure 8) was at Groningen and because of the rather poor conditions in the low, coastal country, he set up an astronomical laboratory. The purpose of the laboratory was to reduce observations obtained by him and his colleagues overseas. It was only after WW II that the Dutch astronomers moved in a big way into radio astronomy, which has no hindrance from the weather. The drive was spearheaded by Jan Oort (1900–1992; Figure 9) at Leiden (van Woerden and Strom, 2006).

Butcher was to live in the Netherlands for over twenty-five years, taking out Dutch citizenship. Shortly after he arrived in Groningen, a solar physics group reported the first observations of global oscillation modes in the nearby star Alpha Centauri, which indicated significant departure from model predictions. If correct, this would have consequences for the then-open solar neutrino problem, as well as age estimates for stars, the Galaxy and possibly the Universe. Such global oscillations in the Sun are excited by convection and the equivalent in other stars held out a promise of being able actually to measure the interior structures and evolutionary stages for individual stars. Here was a chance to build on work done for La Palma with the Queensgate Instruments Company, to develop a very stable Fabry-Perot Interferometer and design and implement one of the first stellar seismometers (Butcher and Hicks, 1985). Observations with the 3.6-m European Southern Observatory Telescope on Cerro La Silla, Chile, were compared with model predicttions for Alpha Centauri and found to be in agreement (Pottasch, Butcher and van Hoesel, 1992). In the meantime, the solar neutrino problem was resolved with new neutrino physics rather than the structure of the Sun. Butcher decided to move on to other investigations.

In Groningen, Butcher also explored the possibility of using stellar abundances to develop a radioactivity chronometer for the Galaxy. The idea was

> ... to see whether I couldn't find a long lived radioactive element that I could measure. The Galaxy was thought at the time to be over 15 Gyr old, so I needed an atomic species having a single unstable isotope with a comparable half-life with which to develop a chronometer, with thorium being the obvious choice.

He used the sensitive Coudé spectrograph at the 3.6-m telescope at ESO La Silla to measure its abundance relative to stable elements in stars of different ages (Butcher, 1987). He did not find any variation over the age range of his sample stars, and concluded that perhaps the Galaxy was rather younger than people in stellar evolutionary circles had been thinking.

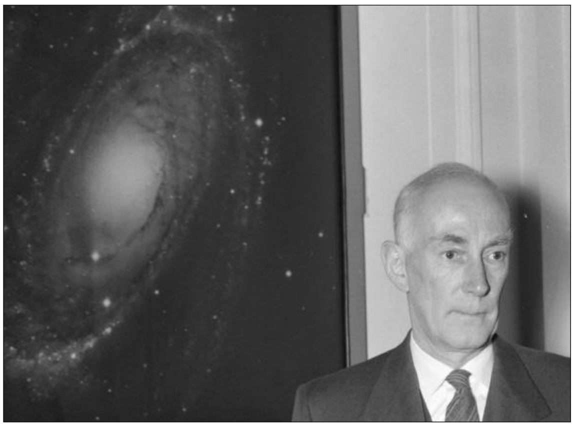

Figure 9: The visionary Dutch astronomer, Jan Oort (en. wikipedia.org).

5 INVOLVEMENT WITH ESO

In the mid-1980s, Butcher became involved at the European Southern Observatory (ESO) in developing the scientific specifications for what would become the Very Large Telescope or VLT (see Figure 10). The design of an efficient, high-resolution stellar spectrograph was a major challenge and led to the development in Groningen of an innovative prototype instrument, later called FRINGHE, a heterodyned holographic spectrometer (Douglas, Butcher and Melis, 1990). The idea was to image the Fourier Transform of the spectrum onto a two-dimensional CCD detector, thereby to gain both throughput (Jacquinot) and multiplex (Fellgett) advantages. It was a way of making a cheap, quite high-resolution spectrometer for the VLT. They tested the concept and it worked well. But the available detectors were relatively small, so the wavelength coverage that one could achieve in a single integration was also limited. In the end, ESO chose a conventional, much more expensive solution, Utraviolet and Visual Echelle Spec-

Figure 10: ESO's Very Large Telescope at Cerro Paranal, showing the buildings that house the four 8.2-m telescopes, which can be used individually or as an interferometer (en.wikipedia.org).

trograph (UVES), giving wider wavelength coverage.

6 ASTRON

By 1991 Butcher was again looking for a change, but with his family settled in the Netherlands the options were limited. He was offered the Directorship of the Netherlands Foundation for Research in Astronomy (ASTRON), a Government-financed National Research institution in Dwingeloo that specialised in radio astronomy but was starting to develop visible-light instrumentation as well. He would spend September 1991 to January 2007 managing ASTRON.

Dutch astronomers were divided at the time as to whether future investments should focus on optical astronomy using facilities at La Palma and ESO, or on radio astronomy, which would at least allow new forefront facilities to be located in the country. The compromise reached was for modest investments in both.

Early ideas for a high sensitivity HI telescope emerged in ASTRON in the 1990s, led by Jan Noordam, Ger de Bruyn and Robert Braun (Ekers, 2012; Noordam, 2012; pers. comm., 23 January 2014). A brief review of the Square Kilometre Array (SKA) from its pre-1990 roots and the global vision which emerged, at the Very Large Array (VLA) 10th anniversary meeting in 1990, to the major international project we have today is given by Ron Ekers (2012). Ekers was a strong proponent for the continued exponential growth in the collecting area (or sensitivity) of radio telescopes based on the discovery arguments of U.S. historian of science, Derek de Solla Price (1963). He argued that to maintain the exponential growth it was necessary to continually introduce new technology as refining existing technology plateaued out. By 1993, the idea of the SKA came under serious discussion in the Netherlands. Butcher ensured that Dutch R & D at ASTRON would focus on the necessary technologies and scientific development. These included the development of aperture and focal plane phased array detection, new correlator approaches, and a long-term enhancement programme for the Westerbork Radio Telescope.

Butcher also took the initiative to develop a Memorandum of Understanding (MOU) for international collaboration in the technology needed to build the SKA, and this agreement was signed by eight institutions from six countries in 1997 (Ekers, pers. comm., 23 January 2014).

One of the major outcomes of the ASTRON program was the Low Frequency Array (LOFAR). It is only possible to provide a brief early history of LOFAR in this paper. A longer more comprehensive history of LOFAR is being prepared by the author and will be published as a separate paper. According to Butcher (pers. comm., 18 November 2013) and van Haarlem (pers. comm., 18 November 2013), the early history of LOFAR is complex as it grew out of discussions of the SKA project and also involved a number of different groups (the Naval Research Laboratory, MIT's Haystack Observatory and the National Radio Astronomy Observatory in the USA, and the Commonwealth Scientific and Industrial Research Organisation in Australia). In 1997, following an Oort Workshop of science drivers for the SKA held in Leiden, George Miley, Professor of Extragalactic Astronomy at the University of Leiden

> ... suggested it as a way of bridging the gap to the SKA and using phased array technology already under development at ASTRON at the time. (van Haarlem, ibid.).

Butcher noted that the politics of science in the Netherlands was such that it was desirable to get U.S. partnership as it was seen by the Dutch government as a stamp of approval. He approached U.S. astronomy groups, such as the NRL. However, this situation changed rather dramatically when 9/11 took place in the U.S. Butcher (pers. comm., 18 November 2013) noted that "... it became politically unimportant all of a sudden in the Netherlands to have U.S. partners; the best partners would all be European."

In order to stimulate the economy, in 2002, the Dutch government decided to invest in 'knowledge infrastructure'. LOFAR fitted nicely into the scheme of things and in December 2003 it received a grant of €52 million (Butcher, ibid.). However, according to van Haarlem (pers. comm., 18 November 2013), "... the funding in the Netherlands, was closely tied up with the development of physical infrastructure in the Netherlands." As a result, the collaboration with the former partners who had insisted on a radio quiet location in the Southern Hemisphere ended. New partnerships were entered with Germany, France, the UK and Sweden. The International LOFAR Telescope (ILT) has been running since 2010. Apart from stations in the Netherlands (see Figure 11), it has stations in Germany (5), France (1), the UK (1) and Sweden (1). Poland has plans to join the consortium. Rene Vermeulen is the Director of the ILT.

The SKA was subsequently shared between Australia/New Zealand and South Africa. One of the outcomes was the successful establishment of the Murchison Widefield Array (MWA) located in Western Australia (Tingay, et al., 2013). According to Ekers (pers. comm., 23 January 2014),

> ... the MWA project began when the U.S. (MIT) and Australian partners left LOFAR. Despite the breakup of the initial LOFAR collaboration, Harvey had a huge and positive impact on the International SKA project through his involvement in the OECD and the IAU working group on large scale facilities.

LOFAR is one of the world's largest radio telescopes having sensitivity in the frequency domain 15–240 MHz, where the ionosphere causes major imaging difficulties. The problem with conventional radio telescopes has been that much of the cost is in the steel of the giant dishes that move. The cost of steel is not going down with time, so such mechanical systems are and will stay very expensive. Jan Noordam and Jaap Bregman at ASTRON pointed the way to the solution and LOFAR followed their advice, whereby the costs are shifted much towards electronics and software. That means, Butcher (2011) noted, that

> ... because of Moore's law, it'll get cheaper with time rather than more expensive. And so the idea was to build a telescope with no moving parts, in which the pointing and focusing is done in software, and with the antennas very low to the ground to mitigate RFI. The resulting instrument is much less expensive than conventional designs at long wavelengths and will continue to decrease in cost at any radio wavelength as technology advances.

In fact, the cost benefit and the use of new technology in a pathfinder for the SKA was a major motivation to build the telescope, and it is also making high-quality observations at these frequencies possible for the first time.

LOFAR has an ambitious science program in four fundamental applications: the epoch of reionization; extragalactic surveys and their exploitation to study the formation and evolution of clusters, galaxies and black holes; transient sources and their association with high-energy objects such as gamma-ray bursts; and cosmic ray showers and their exploitation to study the origin of ultra-high energy cosmic rays (Röttgering, 2006).

Butcher received a Knighthood in the Order of the Netherlands Lion in 2005 for interdisciplinary science, innovation and public outreach achieved in LOFAR.

7 SECOND COMING

In September 2007, almost 33 years after he had finished his Ph.D. at Mount Stromlo Observatory, Butcher returned as its Director. About four and a half years earlier, in January 2003, the Observatory had been engulfed in fires that were so severe that they left a trail of devastation that had never been seen before. Only the charred remains of the once-magnificent telescopes stood as silent witnesses in their burnt-out domes, and the $4 million Near Infrared Field Spectrograph (NIFS) that was undergoing final testing before being shipped to the

Figure 11: Harvey Butcher with one of the LOFAR antennas (after Schilling, 2004).

Gemini North Telescope in Hawaii was turned into a blackened melted mass. According to Penny Sackett (2013), the Director at that time,

> When the damage was assessed it was clear that we had lost all our research facilities—that is, all our research telescopes on the mountain, all our library facilities and our workshop where we had built instruments for our telescopes and telescopes for other organisations.

It was a difficult time for Sackett and a lesser person would have probably thrown his/her hat in and walked away. Instead she stood her ground and did an excellent job in organising the reconstruction of the main buildings and getting the Observatory back on its feet before she left in May 2007 to take up the position of Chief Scientist of Australia.

On his arrival in September 2007, Butcher (Figure 12) began where Sackett had left off. He built on the foundations that Sackett had laid after the fires. On reviewing the Observatory's programs and facilities Butcher found two internationally-significant projects that had begun dur-

Figure 12: Harvey Butcher and Sydney Observatory Manager Toner Stevenson at Mt Stromlo (www.Sydney observatory.com.au/2011/toner-reports ...).

Figure 13: Professor Mike Dopita and WiFeS (info.aiaa.org/ Regions/Int/Sydney/Web%20Pages/Past_Events.aspx).

Figure 14: Professor Brian Schmidt's Skymapper Telescope at Siding Spring (info.aiaa.org/).

ing the Sackett years and were under construction: Michael Dopita's Wide Field Spectrograph (WiFeS–see Figure 13) and Brian Schmidt's 1.35-m SkyMapper Telescope (Figure 14). Both were highly innovative projects. Butcher reasoned that placing the WiFeS on the 2.3-m telescope would give it a new lease of life for 6–8 years, until international competition caught up with it.

The SkyMapper project was to be used for producing a map of the southern sky with a telescope, using detectors and filters that promised to revolutionise the field of galactic archaeology. The Near-Infrared Integral-field Spectrograph (NIFS) and the Gemini South Adaptive Optics Imager (GSAOI) projects led by Peter McGregor were doing very well on the 8-m Gemini telescopes overseas. Butcher found that not only were senior staff scientifically productive, but they were clearly very capable of leading ground-breaking new international projects at the highest level. He felt that in concert with scientific discovery, the instrumentation program would be the way forward to resurrect the Observatory's international reputation after the fires. It was time, he believed, to focus on strategy.

Butcher began by working out a five year plan. He talked extensively to staff, both academic and technical/operational, and by December 2007 he had drawn up a plan that built on the foundations laid by Penny Sackett. The priorities for his directorship were:

> First, to recruit new, young researchers of the highest international standing by using the ARC Fellowship programs and the School's endowment funds. Second was to complete the construction, commissioning and scientific exploitation of the new SkyMapper (Southern Sky Survey) and Wide Field Spectrograph (WiFeS) instruments. And third, the realization of the [full financial] participation in a major international project to develop a next generation very large telescope, assumed to be the Giant Magellan Telescope (GMT).

One of the first things he did was to devise plans to recruit high-profile Postdoctoral Fellows and mid-career researchers. The first of the Fellows was Chiaki Kobayashi, an expert in the numerical simulation of galaxy evolution. Butcher also enticed two mid-career astronomers to come back to Mount Stromlo. One was Martin Asplund, who had left in 2007 to assume the Directorship of the Max-Planck Institute for Astrophysics in Garching, Germany. The other was Lisa Kewley, a Stromlo graduate who was working in the U.S.A. Both returned in 2011. He also began a program to attract good students to take up honours and Ph.D. studies at Mount Stromlo, very much as Bart Bok did when he was the Director decades earlier (see Bhathal et al., 2014).

8 GIANT MAGELLAN TELESCOPE

Penny Sackett, the previous Director, had signed up the Australian National University (ANU) to the Giant Magellan Telescope (GMT) project in 2006. It is a billion-dollar project with full operations planned from ~2020. The effort currently is a collaboration of ten partner institutions: seven in the U.S.A. (Harvard University, Carnegie Institution, University of Chicago, University of Arizona, University of Texas at Austin, Texas A&M and the Smithsonian Astrophysical Observatory), all of which have built and operated large telescopes previously; one in Korea (the Korea Astronomy and Space Sciences Institute, a Government-run centre); and two in Australia (the ANU, and Australia Astronomy Ltd). However, at the time the ANU could contribute only a limited amount to show its commitment to the project. Unexpectedly, the Global Financial Crisis (GFC) in 2008 was a blessing in disguise for Mount Stromlo astronomers. In response to the GFC the Australian Federal Government set up the Educational Investment Fund (EIF) as part of an economic stimulus package to not only tackle the long-standing chronic need of Australian universities for additional and upgraded infrastructure but also to improve education generally.

Butcher saw an opportunity and proposed full participation in the GMT to the Vice-Chancellor, Ian Chubb. Somewhat to his surprise, Chubb enthusiastically agreed to have ANU propose the project, and in fact went on to chair the Mount Stromlo delegation at the formal interview with the evaluation panel. The ANU proposal was for A$88.4 million, to include A$65 million as their contribution to the international project (i.e. to be sent to the project office in Pasadena and yield a 5% access for ANU researchers plus 5% access through Astronomy Australia Ltd. for the whole university community, including ANU).

The EIF proposal was successful, and a contract was signed with the Government on 10 February 2010. Butcher (pers. comm., 18 November 2013) later noted: "This I view as probably my most important and enduring achievement as Director." It is a valuable complement to the Federal Government's investment in the SKA.

Butcher's next priority was engineering. With his long experience in technology management, he revitalized the engineering group and pursued opportunities for building instruments for the GMT (Figure 15). He used A$21.4 million from the grant to complete a new wing of the Advanced Instrumentation Technology Centre (AITC). This will enable it to do R&D so as to compete for large international engineering projects.

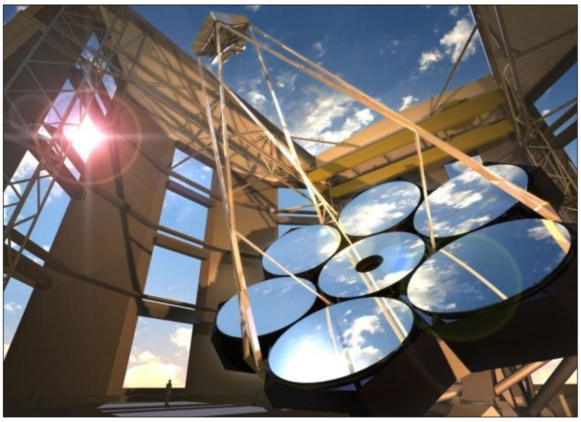

Figure 15: The Giant Magellan Telescope (www.gmto.org/Resources/GMT-1-large.jpg).

The completion of the AITC with funding from the EIF–GMT grant allowed Mount Stromlo not only to appoint new engineering staff but also to compete for one of only two or three first-light scientific instruments. Peter McGregor (Figure 16) led a team, with systems engineer Simon Parcell, to propose and win an instrument, the Giant Magellan Telescope Integral-Field Spectrograph (GMTIFS), that essentially is an evolution and combination of the NIFS and GSAOI instruments previously built for the Gemini observatories. The international evaluation panel organized by the GMT project office judged it the best-prepared and most convincing of the six or seven instruments proposed.

The aim of GMTIFS is to allow medium-resolution spectra to be taken of galaxies in the early Universe, of the surrounds of black holes and of exo-planet systems. It will map such objects in the near infrared at the highest spatial resolution possible with the GMT (diffraction limited or as close as achievable—in any case delivering some ten times sharper images than the Hubble Space Telescope can take). GMTIFS relies on a functioning adaptive optics system on the telescope, and because of this Butcher early on made the decision to have Mount Stromlo involved in adaptive optics technologies, and to compete for contracts to help design and build the adaptive optics system on

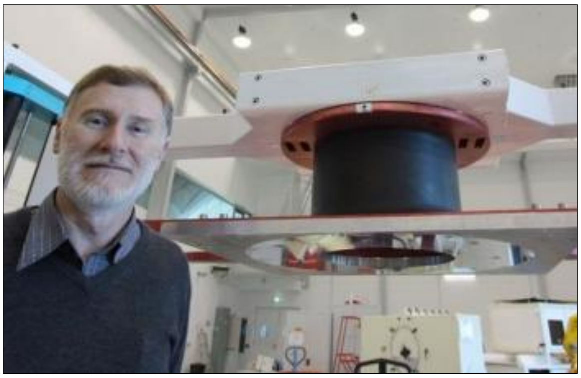

Figure 16: Professor Peter McGregor inside the massive new instrument assembly hall at Mt Stromlo (sciencewise.anu.edu.au/articles/astronomy%20opportunity).

the GMT. In that way he felt they could best guarantee that GMTIFS would end up scientifically productive at the earliest possible stage. He recruited adaptive optics specialists from overseas—Rod Conan from Canada and François Rigaut and Celine D'Orgeville from France, via Chile, as well as system engineers, project managers and optics specialists—to complement his existing in-house expertise.

Since Mount Stromlo did not have an established reputation in adaptive optics, he needed to build a working system to show that his team could really perform. He was aware that the EOS-Space Systems company at Mount Stromlo was involved in satellite laser ranging measurements. They had developed an ability to detect and monitor the orbits of space debris to unprecedented accuracy, which they hoped to turn into a profit-making business (saving commercial and military satellites from collisions with space debris). He came to the conclusion that the Observatory's effectiveness could be dramatically improved if they implemented an adaptive optics system on the EOS-Space Systems laser ranging telescope. He entered into a MOU on 10 November 2009, jointly to invest and work together to develop an adaptive optics demonstrator system on the 1.8-m EOS-Space Systems (EOS-SS) telescope at Mt Stromlo. From the Observatory's side Butcher reasoned, it would also demonstrate their capability to deliver on a potential contract for parts of the adaptive optics system on the GMT. As part of the ANU contribution Butcher agreed to host the EOS-SS R&D team at the AITC. The contract was signed on 29 August 2011.

As soon as the EIF-GMT was granted Butcher did a stock-take and critical analysis of the financial affairs of the Research School of Astronomy and Astrophysics. He realized that in the long term it would be unrealistic to expect the School to finance the technical program from the School's operating budget. He had to find a solution to this problem, which would become acute following the expiry of the EIF-GMT grant in 2014. The solution came from the new Australian space initiative announced by the Federal Government.

9 SPACE RESEARCH

On 12 November 2008, the Government released its report, *Lost in Space? Setting a New Direction for Australia's Space Science and Industry Sector*. The report recommended a return to investment in a national space effort, in particular to train a new generation of engineers with knowledge of space technologies and satellite operations.

Realizing that the engineering protocols, tools and test facilities would be very similar to what the Observatory would need for GMT instrumentation, Butcher thought this could be the way to acquire additional funding. He subsequently spent a great deal of his time following the EIF award, networking into the space community. And he agreed with Government to use some of the EIF funding to provide a national engineering capability at Stromlo, not only for GMT and astronomy but also for space research.

In its 2009–2010 Budget, the Government announced the establishment of a Space Policy Unit which would oversee the A$48.6 million Australian Space Science Program's four years of activity. However, it specifically excluded funding for astronomy since the Government felt that astronomers had received enough support, for the SKA and GMT projects. Nevertheless, Butcher cleverly used his contacts to get the Research School to participate in and acquire funding from five projects: Antarctic Broad-Band, led by Aerospace Research Pty. Ltd.; Australian Plasma Thruster, led by ANU Physics; Space Debris Detection and Monitoring Systems, led by EOS-Space Systems Pty. Ltd.; Greenhouse Gas Monitor, led by VIPAC Engineering & Scientists Pty. Ltd.; and GRACE Follow-on, led by ANU Earth Sciences and Physics. These collaborations would establish Mount Stromlo and the AITC as an important player in the space research field, and hopefully lead to larger projects in the future.

10 SIDING SPRING OBSERVATORY

Butcher's next priority was Siding Spring Observatory. His view was that the ANU telescopes would have a useful research life of perhaps another five to seven years, or at least until the SkyMapper Southern Sky Survey could be completed. At that point, unless budget increases were forthcoming, ANU would be forced to abandon the site. He therefore undertook four initiatives.

First, he convinced ANU to transfer responsibility for site maintenance to its Division of Facilities and Services, which had formal responsbility for the basic maintenance of the other university buildings and grounds. The transfer left the Research School responsible only for its own operational telescopes—the 2.3-m and the 1.35-m SkyMapper.

Second, he arranged for the original team of engineers led by Herman Wehner, who had worked with Don Mathewson (the Director of the Observatory from April 1979 to May1986) to dedesign and build the 2.3-m telescope (see Mathewson, Hart, Wehner, Hovey and van Harmelen, 2013), to return from retirement and refurbish the instrument (see Figure 17). In particular, its drive system electronics, originally devel-

Figure 17: The team that originally designed and built the 2.3-m Telescope and came out of retirement to refurbish the instrument. From left to right: Professor Don Mathewson, Hermann Wehner, John Hart, Gary Hovey and Jan van Harmelen (after Mathewson et al., 2013).

oped by Gary Hovey, had run out of spare parts and could no longer be kept in regular, reliable operation. With a very minimal budget but a great deal of dedication and intimate knowledge of the system, the team brought the telescope system back to a state at which it might remain operational for another five to seven years.

Third, a conviction that learning to observe hands-on with small telescopes is important to the education of young astronomers led Butcher to attract several other research institutions to Siding Spring. To the Anglo-Australian Observatory (AAO), University of New South Wales instruments and the Las Cumbres Faulkes telescope would be added facilities from Korean, Polish and several more U.S. institutions. Siding Spring would become an international observatory, similar to, if smaller in scale than, the Mauna Kea Observatory on Hawaii or the Roque de los Muchachos Observatory on La Palma. Each new facility would contribute to communal site maintenance costs but otherwise enjoy a rent-free site; in exchange, each would grant ANU astronomers a level of observing access. Even when the Research School would have to abandon its own facilities, its students would be able to carry out projects at Siding Spring.

Finally, the Anglo-Australian Agreement between the British and Australian Governments would come to an end on 30 June 2010, providing an opportunity to reorganise activities at Siding Spring. The 3.9-m telescope and headquarters in Sydney would henceforth be called the Australian Astronomical Observatory (still with the initials AAO and same logo!) and become a Division of the Department of Innovation, Industry, Science and Research of the Australian Federal Government. Its new purpose would be to operate observing facilities for Australian astronomers and support Australian access to international observatories. Butcher proposed that it would be logical, given the AAO mission and its transition to an all-Australian organisation, for the Government to consider taking over the operation and maintenance of all national facilities at Siding Spring. After all, the AAO would likely remain far and away the largest facility and have the most staff on the site, hence would have the most to lose when the ANU could no longer manage the site at an appropriate level. Butcher even proposed that rather than duplicate engineering and office facilities, the new AAO could move to Canberra and co-locate with the Research School at Mount Stromlo. Unfortunately, the senior echelon at the ANU would not consider relinquishing management control of the Siding Spring campus and the astronomical community feared that ANU might come to dominate the AAO program, so neither proposal gained support.

The future of the Siding Spring Observatory was advanced during the Butcher years, but was not fully resolved.

During Butcher's Directorship the main thrust of the scientific research programs was in galactic archaeology (content and evolution of galaxies), observational cosmology (content and evolution of the whole cosmos) and the astrophysics of stars, planets and black holes. The group of academic researchers at the Observatory could be compared with the best anywhere in the world. They reaped the recognition they deserved.

Brian Schmidt (Figure 18) topped the list of researchers at Mount Stromlo by being awarded the 2011 Nobel Prize for Physics, jointly with U.S. astronomers Adam Riess (Johns Hopkins University) and Saul Perlmutter (University of California, Berkeley) for their ground-breaking research on the accelerating Universe (Bhathal, 2012). It was almost 96 years since an Australian had won a Nobel Prize in Physics—the first and only other Nobel was won by the father and son team, William and Lawrence Bragg, for their work on X-ray crystallography (Jenkin, 2008).

Ken Freeman (Figure 19) is probably the most prolific author of high-quality papers at Mount Stromlo, and indeed of the whole astronomical community in Australia. He has been a trend-setter in several areas of astronomy and astrophysics. With Joss Bland-Hawthorn of the University of Sydney, he is celebrated as the father of the field of 'galactic archaeology' and is recognised as an early proponent of the theory

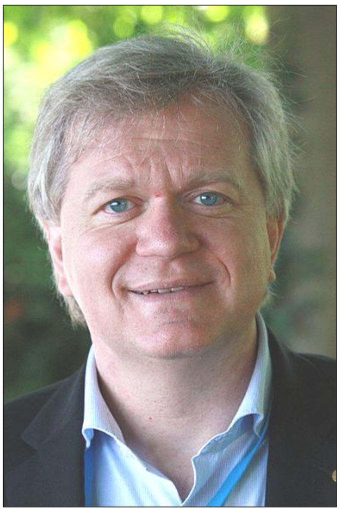

Figure 18: Professor Brian Schmidt (en. wikipedia.org).

that dark matter must form a large fraction of the mass of galaxies. He is a Fellow of the Australian Academy of Science and the Royal Society of London and in 2012 was awarded the prestigious Prime Minister's Prize for Science for his entire *oeuvre*. In January 2013 the Australian Academy of Science awarded him the Matthew Flinders Medal. Also in January 2013 he was awarded the prestigious Henry Norris Russell Lectureship by the American Astronomical Society in recognition of a lifetime of seminal contributions to astronomy, including work on the structure and dynamics of galaxies including our Galaxy.

Butcher (2011) noted:

> In 2009 we were placed number 10 in the world in space science by the Thomson-Reuters citation ranking—ahead of Cambridge, UC Berkeley and Harvard. At the start of 2012 Mount Stromlo Observatory and the Research School were supporting an Australian Research Council Centre of Excellence, two ARC Laureate Fellows, three ARC Future Fellows, an ARC Research Fellow, a DECRA Early-Career Fellow, 17 ARC Discovery grants, an ARC-LIEF grant and a major EIF grant worth $88.4 million. The Observatory has two Fellows of the Royal Society of London and memberships of the national academies of the U.S., Netherlands and Spain, as well as the Australian Academy of Science.

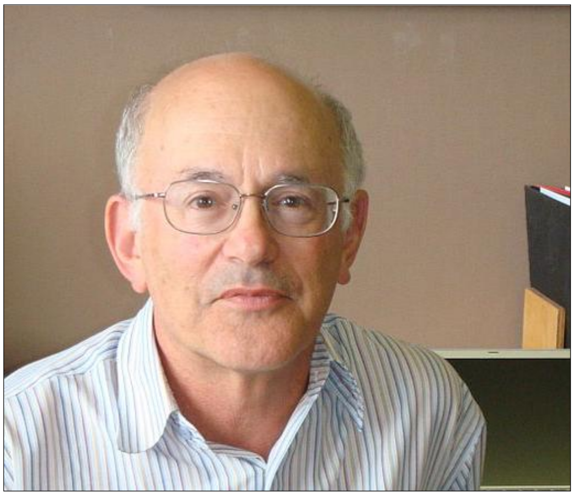

Figure 19: Professor Ken Freeman (en.wikipedia.org).

In January 2013, Butcher retired from the position of Director of the Mount Stromlo Observatory, after nearly five and a half years at the helm. Ken Freeman (2013), a senior member of the academic staff at the Research School of Astronomy and Astrophysics, has this to say about Butcher's directorship:

> He left Stromlo stronger than he found it. The place is scientifically more vibrant than it was, and the morale is generally very good.

His major achievement as the Director of the Observatory was to achieve full participation in the international Giant Magellan Telescope, and he placed the Observatory in a position to reap the benefits of discoveries in the era of very large telescopes by this and future generations of Mount Stromlo astronomers.

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12 REFERENCES

Bello, F., 1954. The young scientists. *Fortune*, June, 142–148, and 172–182.

Bhathal, R., 2012. Profile: Brian Schmidt. *Astronomy & Geophysics*, 53, 1.13–1.15.

Bhathal, R., Sutherland, R., and Butcher, H. 2014. *Mt Stromlo Observatory. From Bush Observatory to the Nobel Prize*. Melbourne, CSIRO Publishing.

Burbidge, E.M., Burbidge, G.R., Fowler, W.A., and Hoyle, F., 1957. Synthesis of the elements in stars. *Reviews of Modern Physics*, 29, 547–650.

Butcher, H.R., 1971. An Echelle grating for the 74 inch Coudé. *Publications of the Astronomical Society* *of Australia*, 2, 21–24.

Butcher, H.R., 1972. Studies of heavy-element synthesis. I. Separation of r- and s- process abundances. *Astrophysical Journal*, 176, 711–722.

Butcher, H.R., 1975. Studies of heavy-element synthesis. II. A survey of e-, r- and s- abundances. *Astrophysical Journal*, 199, 710–717.

Butcher, H.R., and Oemler, A., 1978. The evolution of galaxies in clusters. I. ISIT photometry of Cl 0024+1654 and 3C 295. *Astrophysical Journal*, 219, 18–30.

Butcher, H.R., and Oemler, A., 1984. The evolution of clusters in galaxies. V. A study of populations since z ~ 0.5. *Astrophysical Journal*, 285, 426–438.

Butcher, H.R., and Hicks, T.R., 1985. A Fabry-Perot based seismometer. In Gough, D. (ed.). *Proceedings NATO Advanced Research Workshop*. Cambridge, Cambridge University Press. Pp. 347–357.

Butcher, H.R., 1987. Thorium in G-dwarf stars as a chronometer for the Galaxy. *Nature*, 328, 127–131.

Butcher, H.R., 2004. LOFAR: the first of a new generation of radio telescopes. *Proceedings of the Society of Photo-Instrumentation Engineers*, 5489, 537–544.

Butcher, H.R., 2011. Interview with Ragbir Bhathal for the National Oral History Project on Significant Australian Astronomers on 18 November 2011, National Library of Australia, Canberra.

Couch, W., 2006. Interview with Ragbir Bhathal for the National Oral History Project on Significant Australian Astronomers on 23 May 2006, National Library of Australia, Canberra.

De Sola Price, D.J., 1963. *Little Science, Big Science*. New York, Columbia University Press.

Douglas, N.G., Butcher, H.R., and Melis, W.A., 1990. Heterodyned, holographic spectroscopy: results with the FRINGHE spectrometer. *Astrophysics and Space Science*, 171, 307–318.

Ekers, R., 2012. The history of the Square Kilometre Array (SKA) – born global. In Garrett, M.A., and Greenwood, J.C. (eds.). *Resolving the Sky – Radio Interferometry: Past, Present and Future. Proceedings of the RTS 2012 Conference*. Manchester. Published on-line in the Proceedings of Science.

Jenkin, J., 2008. *William and Lawrence Bragg, Father and Son: The Most Extraordinary Collaboration in Science*. Oxford, Oxford University Press.

Lynden-Bell, D., and Schweizer, F., 2012. Allan Sandage. *Biographical Memoirs of the Fellows of the Royal Society*, 58, 245–264.

Mathewson, D.S., Hart, J., Wehner, H.P., Hovey, G.R., and van Harmelen, J., 2013. The Australian National University's 2.3m New Generation Telescope at Siding Spring Observatory. *Journal of Astronomical History and Heritage*, 16, 2–28.

Noordam, J.E., 2012. The dawn of SKAI: what really happened. In Garrett, M.A., and Greenwood, J.C. (eds.). *Resolving the Sky – Radio Interferometry: Past, Present and Future. Proceedings of the RTS 2012 Conference*. Manchester. Published on-line in the Proceedings of Science.

Pottasch, E.M., Butcher, H.R., and van Hoesel, F.H.J., 1992. Solar-like oscillations on α Centauri A. *Astronomy and Astrophysics*, 264, 138–146.

Röttgering, H.J.A. et al., 2006. LOFAR: opening up a new window on the universe. In Klockner, H-R, Jarvis, M., and Rawlings, S. (eds.). *Cosmology, Galaxy Formation and Astroparticle Physics on the Pathway to the SKA*. Oxford, Oxford University Press. Pp. 1–9.

Sackett, P., 2013. Interview with Ragbir Bhathal for the National Oral History Project on Significant Australian Astronomers on 15 January 2013, National Library of Australia, Canberra.

Schilling, G., 2004. LOFAR: a giant radio telescope takes shape. *Sky & Telescope*, 16 September.

Tingay, S.J., Goeke, R., Bowman, J.D., et al., 2013. The Murchison Widefield Array: The Square Kilometre Array precursor at low radio frequencies. *Publications of the Astronomical Society of Australia,* 30. e013 (6 pages).

Trimble, V., Cowley, A., and Harwick, D., 2001. Olin J. Eggen (1919–1998). *Publications of the Astronomical Society of the Pacific*, 113, 131–135.

Woerden, H. van, and Strom, R.G., 2006. The beginning of radio astronomy in the Netherlands. *Journal of Astronomical History and Heritage*, 9, 3–20.

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