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Stellar Astrophysics

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Abstract: Michael Bessell has been the most cited author at the Research School of Astronomy and Astrophysics at the Australian National University for the past 12 years and is one of 33 Australian Citation Laureates for work carried out between 1981 and 1988.

He is internationally recognized for his work in photometry and his filter systems have become standard filters in use at most observatories throughout the world. His research interests include the study of the evolution of different mass stars and the build up of elements in these stars, searches for the most metal-poor stars, searches for proto-planetary disks and proto-planets and brown dwarfs through a study of young M dwarfs, temperature calibration of stars, astronomical photometry and instrumentation. He has made significant contributions in each of these areas of astronomical research.

Keywords: Standard photometric systems, stellar evolution, AGB stars, M dwarfs

EARLY LIFE

Michael Bessell grew up in a home where there was always talk at the dinner table about education and the 'politics of the teaching profession.' His grandfather who was a headmaster was the President of the Tasmanian Teacher's Federation and he knew 'not only Joe Lyons but also all the socialist members of Parliament while his father was the Secretary of the Workers Education Association.' So in this environment it was natural that they believed 'that the only way for people to achieve in the world was to gain a good education.' This philosophy was instilled in Bessell at a very young age. According to Bessell, 'my parents brought us up to have the idea that the only way to succeed was to do well at school.' He attended government schools and for his secondary education he attended Hobart High School, a selective high school.

As a young boy he read 'lots and lots of books and our family had a great respect for books.' Interestingly he read books on archaeology. 'I can remember looking through the Illustrated London News and seeing pictures of scientists at work digging up tombs from different places and so I always had the idea of being a scientist even though I wasn't sure what a scientist was.' He was also curious about how things work. The mechanical advantage that pulleys and levers provide fascinated him. 'I was fascinated by the idea of the way pulleys and levers worked and how people could master the environment by using them.' Algebra and mathematics held a similar fascination for him. 'The idea that you let X be something and you could solve for it, really came as a wonderful idea and I was forever solving problems after this.'

INTEREST IN ASTRONOMY

His interest in astronomy came later. It was fired by Bart Bok, the then Director of the Mount Stromlo Observatory who according to Bessell, 'was an amazing publicist and enthusiast. It was Bok's aim I think in life to speak to as many people in Australia as possible about astronomy.' He attended some of his lectures at university and was 'absolutely fascinated by his showmanship and the fascinating pictures that he would show.' 'That is what stimulated a great interest of my doing astronomy.'

He went up to the University of Tasmania for his undergraduate studies on a teacher's scholarship. It was natural for him he said to go into teaching. 'My grandfather was a teacher, my mother was a teacher and my aunts were teachers.' However, this was to change in his honours year when for his honours project he did a radio astronomy project under Ellis, the professor of physics who was very well known for his 'mathematical theories of the ionosphere.' At the time he was studying in the physics department there were two other well known physicists, viz: F.D. Cruickshank and Hans Buchdahl. Cruickshank was 'very famous for his invention of paraxial coefficients of optics.' According to Bessell 'this for the first time enabled people other than the scientists at Zeiss to make lens systems. And people who graduated through the physics department at the University of Tasmania went on to found optic companies in America to build cameras for the U2s. It led to a whole lot of work during the war of designing optics and they were able reproduce these Zeiss patents from first principles.' Buchdahl was famous for his work on the theory of general relativity and later moved to the Australian National University.

For his project he measured the galactic radio radiation at 1.5 and 2.5 Megahertz. This work along with observations made with another student, Michael Waterworth led to his first paper in *Nature* (Ellis et al. 1962). The article appeared under the names of Ellis, Waterworth and Bessell. It happened that Fred Hoyle was visiting Tasmania at that time and he reviewed their observations and gave them an explanation of the phenomena. It was this 'first chance to meet Fred Hoyle, a well known British astronomer'. He was most impressed with Hoyle.

MOUNT STROMLO OBSERVATORY

For his PhD he went to the Australian National University's Mount Stromlo Observatory where Bart Bok was a professor of physics. It was Bessell said, 'the only place really in Australia to do optical astronomy' at that time. His topic was on variable stars and it was a field in which he was to become an international authority. Variable stars are stars whose luminosity changes. By studying variable stars astronomers are able to find important aspects of a star's mass, its radius and temperature. His particular variable stars were called Dwarf Cepheids and Delta Scuti stars. These stars, he said, 'had been discovered quite recently and they had periods between one and about four hours.' Some of them had large amplitudes of up to half a magnitude and 'light curves which resembled the famous RR Lyrae stars which are found in globular clusters.' The stars he had chosen for his study 'were unknown and they were not in clusters and hence people didn't know what their luminosity was.' 'They didn't know what evolutionary stage they were at and it was a fascinating thesis to try and work out what these stars were', according to Bessell. Others who had studied them considered them to be similar to the very old and low mass RR Lyrae stars, but this made very little sense because most of them had very low motions like the Sun and stars which are more massive than the Sun. What he discovered was 'that people were measuring the effective gravity by fitting the energy distribution and it turns out that there was an error in the fundamental calibration of the energy distribution of Alpha Lyrae.' He was able to correct 'this error in the energy distribution, correct gravities for the stars and show that they had mass of one and half times that of normal main sequence stars which happened to be evolving through the instability strip.' This work got him interested in the energy distribution of stars, model atmospheres of stars and the fundamental importance of getting the calibrations right. This also meant obtaining fundamental data for stars. It is interesting to note that the instrument (photoelectric scanner) that he used for his work is now on display at the Museum of Applied Arts and Science in Sydney.

AT YERKES OBSERVATORY

He spent sometime at Yerkes Observatory to work as an associate with Bob O'Dell who had been appointed the new Director of the Observatory. He was involved in commissioning a new spectrograph that was being built for that telescope and also carrying out a research program on symbiotic stars. While there he also had the opportunity of meeting Chandrashekar who was the editor of the Astrophysical Journal and a Nobel Prize winner. One of the benefits he derived by being at Yerkes was that he was able to meet quite a number of astronomers who were working in various fields, such as the spectral classification of stars. 'So meeting these people and being associated with them I think gave me a much broader interest in the kind of stellar physics which I was interested in.'

In 1969 he was appointed a Research Fellow at the Mount Stromlo Observatory at the Australian National University. He has remained there ever since and was eventually appointed to a professorship in 1998. He came back to Australia because it was 'a research only position and that was very attractive position to come back to.'

HIGH CITATIONS

He has a track record of highly cited publications and was awarded the Institute of Scientific Information, Australian Citation Laurette. One of the papers he wrote in 1979 while he was at Kitt Peak generated the most of his citations (Bessell 1979). He had gone to Kitt Peak because one of his students, Harvey Butcher, Jeremy Mould and Garth Ellingworth were there. Butcher is now the Director of the Mount Stromlo and Siding Spring Observatories. Butcher, he said was 'doing some exciting things with new image area detectors. He was also looking at other detectors.' It became obvious to him that one of the problems with the photometric detectors that were being used was that they were very poorly calibrated and the northern hemisphere 'standards were really quite terrible.' In South Africa Cousins had been carrying out excellent work in setting up standards for photometric observations. Unfortunately the northern hemisphere astronomers were not aware of his work.

Most astronomers had been 'brought up to believe that broadband photometry using very wide bands of 800 Angstroms was impossible to do high precision work with.' The Europeans, Stromgren and a lot of Americans assumed that the 'only way you could do high precision work was to use narrowbands.' Bessell was able to disprove this assumption. 'I started to observe Cousins' standards using both northern hemisphere broadband standards. Cousins' standards were five times more precise than the northern hemisphere broadband standards. So I realised that it was not the broadband that was the problem it was just the lousy work that the northern hemisphere astronomers had been doing.' Butcher encouraged him to write a paper about this and to 'provide transformations between other photometric systems' and to also say what he considered 'to be the best photometric system to use.' He did this and had over 972 citations for his paper (Bessell 1979). He went on to write other papers after that, again going into more detail on the problems with the northern hemisphere red photometric system. His work expanded into 'trying to understand the bands used for photometric systems so that we could synthesise them with model atmospheric fluxes and do synthetic photometry and from spectral photometric observations of galaxies and quasars and everything else.' 'And to do that,' he said, 'you have to reverse engineer standard photometric systems and so it all kind of tied it all up over a period of 20 to 25 years (Bessell & Brett 1988, Bessell 1990, Bessell 2005)'. He worked in this area up to the time that photoelectric photometry reached its zenith. It has now more or less vanished. It has been taken over by CCDs and it is very likely that 'all photometry will be done by survey telescopes.' The main advantage of the CCD is that one is 'able to do multiple objects. Furthermore, the CCD is completely linear.'

About the time when this period came to an end the Sloan Survey had made its appearance. Similarly the Hipparcos Catalogue was also released about the same time. According to Bessell, 'For the first time with the Hipparcos Catalogue the whole sky was covered with observations which are well standardized, going to very faint magnitudes.' However, with a new photometric system one has to work out how the old photometric systems relate to the new photometric systems. Bessell wrote a paper on Hipparcos colours and found that there were some problems with the Hipparcos photometry. He is now involved with building the Skymapper telescope at Siding Spring with Brian Schmidt. According to Bessell, 'Brian Schmidt plans to map the sky with a system similar to the Sloan system but with better sensitivity to measure the abundances and effective gravities of stars. He believes that we are going to be the first group that will provide the necessary precise standards for planned southern hemisphere large telescope surveys'. The Skymapper survey will be taking snapshots. 'We will have a single CCD which will take an image of the sky. Then move the telescope and another image of the sky will be taken. So all stars in an image will have precisely the same image profile. And so Brian Schmidt believes we will be able to do much better photometry in this way than any other survey has ever been able to do.' Skymapper will have a seven degree field of view and will also give very precise positions as well as photometry.

Bessell's work on long period variables in the Magellanic Clouds led to an important identification with respect to the Asymptotic Giant Branch (AGB) stars and new insights into stellar evolution (Wood et al. 1983). AGB stars refer to the last nuclear-burning stage in the evolution of stars after they leave the main sequence. According to Bessell, 'stars in this stage are burning helium and hydrogen in shells surrounding a core of carbon and nitrogen.' 'One of the interesting things about this time of its evolution,' he continued, 'is that this kind of burning is very unstable and it can flare up and drop back down again. During the inter pulse periods material can be dredged up to the surface and when we look at the atmospheres of these stars we can see the elements that are being created deep inside these stars. So these stars are actually a primordial source of carbon and nitrogen and also some of the heavier elements, such as lead and uranium.' Along with Peter Wood he found another interesting thing about stellar evolution. They were able to work out 'what mass stars turn into supernovae and which stars turn into white dwarfs.' This was not known until the work carried out by Wood and Bessell. Bessell's work on AGB stars was a big breakthrough in AGB evolution.

He has been involved in the study of metal or heavy element abundance in stars. About twenty years ago he discovered CD-38 245 which was the most deficient star ever formed (Bessell & Norris, 1984). It was deficient by a factor of 30,000 with respect to the Sun. It implied that it was formed soon after our Galaxy came into existence. So a study of the abundances of the elements in its atmosphere can tell us about the kind of stars that were formed in the very first generation of star formation. About eighteen years later Bessell's group discovered HE 0107-5240 (Christlieb et al. 2004, Bessell et al. 2004). This is a very low mass star with iron abundances as low as 1/200 000 of the solar abundance of iron. It had implications for the study of star formation theory and the synthesis of chemical elements in the early universe. According to Bessell, 'interestingly enough these stars, even though they were low in iron, they were very high in carbon, oxygen, nitrogen and sodium. And there seems to be an explanation for this.' 'So what we believe', he said, 'is HE0107-5240 was formed from the supernova ejecta of very massive 25 solar mass first generation supergiant formed soon after the Big Bang. It produced a lot of carbon and nitrogen through normal chemical evolution of hydrogen and helium so it had an outside envelope of carbon, nitrogen and oxygen. This was ejected partly with stellar winds and then the star underwent a massive supernova explosion but there was so much envelope on top of the star that the supernova did not completely break out. A lot of the material got remixed and reprocessed but only a little was ejected. Most of it fell back into a black hole. So you have a 25 solar mass star which ends up as a 20 solar mass black hole. A lot of the carbon, nitrogen and oxygen was expelled in the interstellar medium but only a very small percentage of iron escaped.'

Bessell has worked on stars varying from O stars to M stars. In fact, the whole width and depth of the main sequence. Whilst hunting for the coolest and oldest white dwarfs on the Anglo Australian Telescope 'we found many M dwarfs and a lot of M sub-dwarfs which had never been seen before. This led to publications on the properties of M dwarfs and the discovery of extremely metal-deficient low mass stars.' Because of his knowledge of M dwarfs he was invited by Inseok Song and Ben Zuckerman from the University of California to collaborate with them on the study of young stars which will enable imaging and spectroscopic studies of the origin and early evolution of planetary systems (Zuckerman & Song 2004). Beta Pic was a very interesting star that had recently been discovered to have a duty disk around it, but because it was an isolated A star noone knew its age or what evolutionary stage it was at. From the work they did together they found another 30 stars which according to Bessell, 'were sharing the same space motions as Beta Pic and so in effect it gave us a mini cluster.' They were then able to get an age for the cluster or the moving group on the basis of the luminosities of the pre-main sequence M stars that they had found. This gave them the age of Beta Pic. 'This makes it much more interesting from an evolutionary point of view because we can now understand its history', he said.

Apart from his research work he has also served as a consultant for astronomy for New Zealand. In 2002 he did a review of New Zealand's capability to build a spectrograph for SALT (Southern African Large Telescope). He visited New Zealand and inspected the facilities in Christchurch, Auckland and Wellington to asses whether they had the background and the capabilities to build scientific instruments. He found they did and 'wrote a very positive appraisal of that possibility and that enabled them to take that to the Vice-Chancellor of the University of Canterbury and get his support for the University joining SALT with a hope that other universities would join in. Unfortunately the other universities did not take up the offer so the University of Canterbury has now joined SALT but the rest of the New Zealand astronomers have not.' In 2004 the New Zealand Ministry of Research and Science invited him to review New Zealand's need for a national observatory because Carter Observatory, which was the national observatory, was unable to continue doing active research and wished to become a charitable trust concentrating on astronomical outreach. One of the issues was that the University of Canterbury's Mount John Observatory was performing most of the functions of a national observatory but was 'receiving nothing from the government for performing that role.' Bessell pointed out in his report that 'it was very difficult for a single astronomer or a single physicist within a department in New Zealand to get much support for astronomical research. A national observatory could provide the kind of support and encouragement for joint collaborations that would be good for New Zealand science and education. It would stimulate the same kind of growth in astronomical interest that Australia certainly has had over the last 20 years.' The government is still considering the report.

Bessell is a very active and productive researcher and thus it is interesting to find out what is his research strategy. 'I have been very lucky in my research in being in the southern hemisphere and having access to front line instrumentation and having a reasonable amount of observing time for most of my projects. I also have very good colleagues many of whom are theoreticians. I have also visited different observatories and talked with many people there and was able to either get ideas from them or work with them on interesting projects. So it is a kind of synergy of interacting and encouraging others to collaborate, of creating and fostering the networking of astronomers around the world.'

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