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Some aspects of the scientific development and astronomical research of Warrick Couch

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Abstract

Warrick Couch was appointed the Director of the Australian Astronomical Observatory in April 2013. He was elected a Fellow of the Australian Academy of Science in 2009 for making "pivotal contributions to our understanding of the evolution of galaxies in rich clusters and the effects of galaxy environment on their evolution and for his appointment as the primary investigator in an international team that, despite intense competition, secured one of the first allocations of observing time with the Hubble Space Telescope," according to the Academy. He was awarded an Australian Citation Laureate for 1991–1998, and is recognised as a "Highly Cited" researcher with over 20,000 citations. He previously held positions of Head of School of Physics at the University of New South Wales and Distinguished Professor at Swinburne University of Technology. He has also held the positions of the Australian Gemini Scientist and the Australian Extremely Large Telescope Project Scientist and was the Chair of the Anglo-Australian Telescope Board and a Member of the International Gemini Board. This paper discusses some aspects of his scientific development and astronomical research based on an interview the author conducted with him in 2006. It covers the period up to May 2006.

Introduction

Born in New Zealand, Warrick Couch came to Australia in the late 1970s to do his postgraduate studies at the ANU's Mount Stromlo and Siding Spring Observatories on a British Commonwealth Scholarship. Apart from a three year period spent working as a postdoctoral fellow in the UK, he has remained in Australia, making it his home. He came from a middle class family with lots of books in the house and parents who were very keen on him learning to play the piano. They made sure that he had lessons "pretty much through all my years in primary and secondary school." As a young boy he said, "I read a lot of detective stories and adventure novels." He did not read any science fiction books but enjoyed reading the science textbooks at school. He tinkered with mechanical things and played with Meccano sets and was also interested in wood work. At school "mathematics was his strong point" and he also developed a great interest in physics. It is rather surprising that he did not show much interest in astronomy as a young boy. "I don't think I ever had quite the curiosity that my father had. I didn't have the great interest in the stars that I developed later in life, particularly when I was a university student." His father was a surveyor in the Lands & Survey Department before becoming involved in geodetic computing, hence his father's interest in astronomy. However, his father was one of the influences in Couch wanting to do a science degree at university. "In those days", he said, "a science degree was quite highly respected. In New Zealand in the early seventies, which is when I left high school and went to university, science was seen as a very attractive option, and I was very keen to pursue it."

Victoria University

He went to Victoria University in Wellington because it offered "a very good science course." It was an exciting time for him to be at university, he said, "It was a time when we just had a change of government in New Zealand from a conservative government for many years to a Labour government, and student politics was thriving at that point. It was also the time of the Vietnam War". Like many a student at that time he was involved in student protests. This included protests against the "tours of racially-selected rugby teams from South Africa to New Zealand." That did not distract him from his studies. He went on to major in physics rather than mathematics. He went into physics, he said, probably for the wrong reasons. "I chose it because most of my friends decided to do it. And we'd established a wonderful camaraderie in the first year. Friends not just locally from the Wellington area, but all round New Zealand". He had some very good lecturers, such as Professor David Beaglehole who came from a distinguished family of scientists and intellectuals. He taught him physics in his first year, which really inspired him to continue on with physics into higher years.

It was in his honours year that he turned to astrophysics under the influence of Joe Trodahl and Denis Sullivan. They gave an introductory course in astrophysics and "that's when I got really excited about it and turned to astrophysics and astronomy." Trodahl offered him a Masters research project which involved using a new piece of equipment, a photometer that Trodahl and Sullivan had designed and built. He took it down to Mount John Observatory in the South Island of New Zealand to carry out measurements on Delta Scuti type variable stars. He then took the data, in particular the observed colour variations, using stellar atmosphere models to infer the variations in the surface temperature and gravity in their atmospheres." Astronomers in New Zealand have a very strong traditional interest in variable stars, including the distinguished amateur astronomer, Frank Bateson, who ran an extremely successful variable stars program.

Mount Stromlo Observatory

When he arrived at Mount Stromlo Observatory in Canberra, he found that students did not commence their PhD projects straight away but instead "spent their first year doing several smaller projects under the supervision of different staff members." "I did two projects, one with Ken Freeman, who was wonderful to work with, and the other with Peter Wood. Peter was good to students, very helpful, and a great mentor as well." He also got to work with John Norris. They were all doing research on globular clusters and at that time Mount Stromlo Observatory was a 'mecca' for "globular cluster people", according to Couch. During his first year, he met Barry Newell who had worked in the US at Kitt Peak Observatory and had got to know Harvey Butcher and Gus Oemler who had done some pioneering work on distant clusters of galaxies with a new imaging camera. Butcher was to become the Director of the Research School of Astronomy and Astrophysics from 2007 to January 2013 which runs Mount Stromlo and Siding Spring Observatories. They had found that these distant clusters, which were at a redshift of 0.4 (considered to be high in those days), had many blue galaxies in them. This was quite unexpected because "all the observations that had been taken over many decades of similar rich clusters at low redshift had shown that all the galaxies in these systems were generally red and there were very few blue spiral galaxies. Blue colours generally indicate galaxies that are forming stars." This result, which came to be known as the "Butcher-Oemler" effect (Butcher and Oemler 1978, Butcher and Oemler 1984), was controversial and greeted with considerable caution at that time.

This controversy motivated Newell to suggest that a lot more work needed to be done to verify the effect. He saw an exciting opportunity to do more of this work in Australia on the new 3.9-metre Anglo-Australian Telescope. After having weighed up all the possibilities as to which PhD project to undertake, Couch decided to work with Newell on "this distant cluster project." This involved a detailed photometric study of a sample of a dozen high redshift clusters, the photometry being derived from deep photographic plates mostly obtained with the AAT. As such, Couch was very privileged to work with David Malin, whose world-leading techniques for hyper-sensitizing plates and deriving uniform and accurate photometry from them were critical to the success of the project. According to Couch, "his thesis made the very important step of independently confirming the Butcher-Oemler effect and showing it to be a wide-spread and hence generally universal property of rich centrally-concentrated clusters at redshifts beyond 0.2 (Couch 1982)".

Research on galaxies and clusters

Despite these advances in verifying the Butcher-Oemler effect, there were still questions to be answered regarding the nature of the blue galaxies in these clusters. Some astronomers were questioning as to whether these blue galaxies were actually members of the clusters. Could it be the case that the galaxies are superimposed in front of the cluster or actually lie behind the cluster? According to Couch, "with photometric studies, you had to use statistical methods to actually determine whether the blue galaxies were members of the clusters. There were still some uncertainties with that particular approach". He was able to pursue these questions further when he took up a post-doctoral fellowship at the Physics Department at the University of Durham in the UK. A young and up-and-coming astrophysics group at Durham had recently been established under Dick Fong, who had moved out of particle physics to start afresh in astrophysics. It had attracted a number of innovative astronomers, such as Richard Ellis, Tom Shanks and Ray Sharples. Brian Boyle, who was to become the Director of the Australia Telescope National Facility from 2003 to 2009 (now Director Astronomy Australia Ltd.), joined the Durham group as a PhD student later. While Couch worked with all these people, his most fruitful collaboration was with Ellis, who was interested in clusters and galaxy evolution. It was to be a very productive, rewarding, and long-lasting relationship.

The main focus of the research Couch undertook with his Durham colleagues was to better understand the physical properties of the distant cluster blue galaxy populations. This involved the development and application of several new and innovative techniques, in particular the use of narrow and intermediate band filters to better characterize the galaxies' spectral energy distributions, and the utilization of the world-first optical fibre fed multi-object spectrograph on the AAT. The latter made it feasible to simultaneously gather good quality spectra for significant samples of these faint galaxies in distant clusters (Couch 1983). According to Couch, "that revealed something quite interesting that we hadn't expected. These galaxies were not blue because they were just forming stars in the fairly sort of pedestrian way that we see in nearby spiral galaxies, like our Milky Way. But that the galaxies had undergone quite a dramatic star formation event. The star formation had occurred in what we call a burst. For some reason the star formation switched on. It was very vigorous for about a period of a billion years or so and then all of a sudden it got cut off. We were not expecting this and it really pointed to some sort of a 'star burst cycle' as we called it. For some reason the galaxy switched on, formed stars at a great rate for a certain short period of time, and then got cut off' (Barger, et al. 1996)". He and Ray Sharples developed the first detailed model which "quantified this behaviour and also explained the changes in the galaxies' spectral and photometric properties that accompanied it."

Perhaps the most exciting phase of these studies was the period where they exploited the exquisitely high spatial resolution of the Hubble Space Telescope (which was a factor of ~10 higher than that achieved in the best seeing conditions on ground-based telescopes, the latter reducing the distant cluster galaxies to fuzzy amorphous blobs in optical images) to determine, for the first time, the morphologies of the blue cluster galaxies. They were fortunate enough to receive many hundreds of orbits of Hubble Space Telescope time to pursue this project, and one which developed into a strong collaboration with Alan Dressler and Gus Oemler at the Carnegie Observatories in Pasadena, and Harvey Butcher in the Netherlands. The upshot of this was that they were able to produce a catalogue of morphological types in ten distant rich clusters of galaxies (Smail, et al. 1997). "We found that there was a mixture of galaxies in these clusters. There were certainly galaxies that we recognized very well from the nearby universe – a mixture of elliptical galaxies, S0 galaxies and spiral galaxies. But additionally, and this was a crucial discovery in terms of these blue evolving galaxies, a significant sub-set of these galaxies were quite abnormal in a number of different ways. The most conspicuous and dramatic were galaxies involved in a merger where you had two galaxies coming together and coalescing. And we caught them in the act. We also discovered that many of the spirals had a very ragged appearance, in that they were not as well structured and organised as the ones we see nearby. These were extremely important findings because it was the first ever study that had been done of the morphology of clusters and galaxies at these distant redshifts. We were seeing directly what the detailed morphological structure of galaxies was some five to eight billion years ago! Indeed that is one of Hubble's most important legacies in that it has revealed the morphology of galaxies in the distant, high redshift universe, in quite remarkable detail."

The Hubble Space Telescope observations also led to another important serendipitous discovery, the detection of "beautiful gravitational arcs" in the fields of the distant clusters. This meant the Hubble images served a dual purpose – to not only provide information on the morphology of the cluster galaxies, but to allow the distribution of the underlying, mostly dark matter in the clusters to be mapped and even more distant galaxy populations to be brought into view through the gravitational lensing effects that were observed. As such, they decided to target the rich cluster Abell 2218 (Kneib, et al. 1996), which was already a well known lensing cluster. Their Hubble image of this cluster turned out to be spectacular, and has become known world-wide as the most famous gravitational lensing picture that has ever been taken. To fully exploit all the information that was contained within it, John Paul Kneib, a young post-doctoral lensing expert from France was hired, and he "did all the modelling of the lensing features that were observed, using them to quantify and map the dark matter content of the clusters and then, in turn, to derive the distances and luminosities of the more remote galaxies that were being lensed by the cluster."

Couch's work was not just confined to studying the blue galaxy populations in distant clusters. In his paper on spheroidal populations in distant clusters (Ellis et al. 1997), the attention was focused on studying the red galaxies in these systems, which were thought to be dormant in star formation for many billions of years and hence very old. According to Couch, "There are various techniques for doing this, but we used the approach of measuring the scatter in the combined ultraviolet and optical colours of these galaxies. Such colours are quite diverse in galaxies forming stars, with their scatter only slowly decreasing over several billion years after star formation has ceased. This behaviour can be quantified using galaxy population models, allowing 'age' measurements, or rather the time since the last epoch of major star formation, to be made from the observed scatter. What we confirmed was that these objects had been around for a very long time. Probably they would have been formed at least beyond redshifts of two or three. This is important to know because that puts important constraints on models of galaxy formation. At the time there were models suggesting that galaxies could have formed as recently as a redshift of one. In particular, the hierarchical models for galaxy formation had galaxies forming continuously right through from the Big Bang until now through mergers and accretion. I think we were able to address those sorts of questions that were raised by those models."

Distant supernovae studies

In 1989, Couch was involved in the first ever discovery of a Type Ia supernova at cosmological distances, in this case at a redshift of 0.3 (Norgaard-Nielsen et al. 1989). According to him, "people had been trying to find supernovae at redshifts beyond 0.2 and 0.3. We were very fortunate to be the first ones to do so". This led to his collaboration with the astronomers who were involved with the Supernova Cosmology Project (Perlmutter et al. 1999) which was led by Carl Pennypacker and Saul Perlmutter from the University of California, Berkeley. The goal of this project was to detect high redshift Type Ia supernovae and use them to measure the cosmological parameters, in particular the value of the cosmic deceleration parameter, q_0. Their work on the cosmological parameters had implications for the nature and structure of the universe. Their results produced a new paradigm for the nature of the change in the rate at which the universe was expanding. According to Couch, "I remember very well how cosmology changed over the course of our distant supernovae campaign. At the beginning of it all, the standard model at the time was a universe which was flat, because all the theorists were telling us that the universe had gone through an inflationary period, which forced it to be flat. But any concept of there being a cosmological constant, with the implication that the universe's expansion was speeding up, was just not even contemplated. Rather, everyone subscribed to the view that the energy content of the universe was all tied up in matter, the gravitational effects of which caused the expansion to slow down over time, and there was not any dark energy." But this was about to change as they began discovering more and more high redshift Type Ia supernovae out to redshifts as high as one. Being quite precise 'standard candles', these objects "could do a much better job of constructing the Hubble diagram, resulting in the discovery of this quite remarkable and unexpected result," he said. They found that the universe was accelerating, with the implication that "dark energy" was causing this acceleration. In fact, the rival group led by Brain Schmidt from the Australian National University had also come to the same conclusion pretty much at the same time, based on their own distant Type Ia supernovae search. According to Couch, "I remember meeting Brian and we were comparing the results of the two teams, which were pointing very much to the same thing. It was a remarkable result. And I remember Brian saying this is such a scary thing and we don't really want to believe it, but our team is basically coming to the same conclusion." The accelerating universe was a major discovery, and was subsequently recognized as such by the award of the Shaw Prize to the leaders of the two teams, and the 2007 Gruber Cosmology Prize to all the members the two teams and more recently the award of the 2011 Nobel Prize in Physics to Perlmutter, Schmidt and Reiss (Schmidt, et al. 1997).

Couch has an excellent record of high citation rates for his publications. He attributes this to having worked in teams. "Most of my papers involve collaborations and I think this is the key part of my strategy." "I also think picking areas where you can make an impact is so important, and I guess I have been very fortunate to work with the right people and be in the right place at the right time and have access to major new telescopes, instruments and technologies." His papers with Richard Ellis and his collaborators with the Hubble Space Telescope made a huge impact. Some of his earlier papers, based on data obtained with the Anglo-Australian Telescope, also had a significant impact. According to him, "this was because we were the first groups to use optical fibres to observe many galaxies at one time in a cluster and therefore build up a much more detailed set of spectroscopic observations. This allowed us to understand in more detail what is going on in these clusters."

He is actively involved with the 8-metre Gemini telescopes and the next generation of "extremely large telescopes" (ELTs). In fact, he was the Australian Project Scientist for both these telescopes. The ELTs are envisaged as optical infrared telescopes "that will have an aperture of somewhere between two to three times that of the current eight and ten metre telescopes. So we are talking about a 20 or 30 metre telescope. They will undoubtedly be ground-breaking and broad ranging in terms of their scientific capabilities." According to him, "It is extremely important that Australia gets involved in an ELT project if it is to maintain its excellence in optical/infrared astronomy, and we are looking to do so at this current time." In their Decadal Plan for the 2006-2015 period, Australian astronomers have given the highest priority to three things: development and prototyping of the Square Kilometre Array (SKA), membership of an ELT, and increased access to 8-metre class telescopes. According to Couch, "one of the main strengths of Australian astronomy is that it is a very cohesive research community which, at the same time, has a healthy amount of diversity and yet strong synergy between the different areas, particularly between optical and radio astronomy. I think in the next five to ten years our main challenges are going to be in terms of maintaining that excellence."

Conclusions

As to his major achievements to date (May 2006), he said, "he was pleased with his achievements at the University of New South Wales in seeing the School of Physics through a difficult process of "regeneration and generational change." "Compared with a lot of my colleagues whom, I think, would be content to simply stay put in their comfort zone, I have been very eager and fortunate to become involved in new projects and initiatives, such as Gemini and ELTs." This paper has reviewed some aspects of the life and astronomical research of Warrick Couch up to May 2006. A subsequent paper will review his scientific work from June 2006 to 2013.

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