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Galaxy's Snacking Habits Revealed

Director's message

Warrick Couch

I write this having just returned from the 49th Annual Scientific Meeting of the Astronomical Society of Australia, which was held in Fremantle (WA) and hosted by Curtin University. As well as offering an excellent program of scientific talks, many of which were given by our young, up-and-coming researchers including PhD students, there were several significant events that also took place at this meeting.

Perhaps the most notable was the launch of the new Decadal Plan for Australian Astronomy – "Australia in the era of global astronomy" – that covers the period 2016-2025 (Figure 1). This represents the culmination of more than 18 months of very hard work that involved a large fraction or the Australian astronomy community (through their participation in the 11 working groups), as well as the heroic efforts of an editorial board who distilled down all the input from the working groups into a coherent and compelling plan. As indicated by the title of the Plan, the next decade will see Australian astronomy become even more dependent on telescope facilities that require global partnerships to fund and operate them. This is reflected in the Plan's five highest infrastructure priorities for the next decade, all of equal importance: partnership equating to 30% of an 8m-class optical/infrared telescope, partnership equating to 10% of a 30m-class optical/infrared extremely large telescope (ELT), maintenance of instrument development/construction capability at the AAO and ATNF to maximize engagement in global projects, membership of the International SKA Project and continued development of Australia's SKA pathfinder facilities ASKAP and MWA, and provision of high performance computing facilities for large-scale theoretical simulations and the processing and delivery of large observational datasets.

The first three of these priorities have a number of important implications for the AAO. In combination, they require the AAO to expand its activities in two of its key function areas: in supporting Australia's engagement in and use of

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Front cover photo Credit: Ivanhoe Girls' Grammar School Astronomy Club, Samuel Carbone (Trinity College), Travis Rector (University of Alaska) and AAO.
Caption: The 2014 Gemini Image Contest was won jointly this year by Ivanhoe Girls' Grammar School Astronomy Club (supervised by Mr Paul Fitz-Gerald) and Samuel Carbone of Trinity College (supervised by Mr William Cooper). Their proposed image was of the merging galaxy system, NGC 7727, which was subsequently observed with the Gemini South 8-metre telescope using g, r, and i filters. For more information on the Gemini Schools Image Contest, visit http://ausgo.aao.gov.au/contest.

international 8m- and (when they come on-line) ELT-class telescope facilities, and in telescope instrumentation development and construction. Given its long and distinguished track record in both areas, the AAO is well placed to do this, with the recent creation of its International Telescope Support Office (ITSO) being an important first step towards the former. Additionally, should Australia join ESO – which the Decadal Plan identifies as being the best strategic option for Australia meeting its optical/infrared needs – the AAO would need to adapt its operation to facilitate and support this membership. Although the 4m AAT is not explicitly mentioned in the above priorities, the Decadal Plan anticipates that it will no longer continue to be operated as a national facility once GMT begins operations towards the end of the decade, with the AAT operations funding then being diverted to GMT. This will certainly be a 'life-changing' event for the AAO given the operation and support of the AAT has been its primary focus since its creation.

As we enter the next decade, having access to 30% of an 8m-class telescope is without doubt the most urgent and serious need of the Australian astronomy community, with its current national access (via Gemini and Magellan) falling far short of this, amounting to just over 15%. Moreover, Australia's 6.2% share partnership in Gemini will terminate at the end of this year. To partially address this dire situation, Astronomy Australia Limited (AAL) has secured national access to the twin Keck 10m telescopes, purchasing 15 nights in each of 2016 and 2017 across the two telescopes. Combined with the 15 nights per year that AAL has purchased on Magellan in these same two years, this will take Australia's total access to just over 10% of an 8m telescope. There is clearly much more work to do in addressing this important Decadal Plan priority!

Of course we have two institutions in Australia – Swinburne University and ANU – who have addressed this deficiency in national 8m access by purchasing their own time (15 nights per year) on Keck. Indeed Swinburne has been doing this since 2008, with ANU following them in 2013. While this does not alleviate our national 8m access problem, it is noteworthy that AAL, ANU, and Swinburne have come together and reached agreement on a joint allocation process for the 45 nights of Keck time that these institutions will in total purchase in 2016 and 2017. The primary motivation here is the significant scientific and operational benefits such an arrangement is likely to yield, allowing larger-scale and more ambitious programs to be undertaken collaboratively, and greater flexibility in the use and scheduling of the time. This will see the establishment of a new "Keck Time Allocation Committee" (KTAC) that will operate separately to the Australian Time Assignment Committee (ATAC), but which will also have its secretariat provided by the AAO. More details about this important new development can be found at our new ITSO portal (www.aao.gov.au/itso).

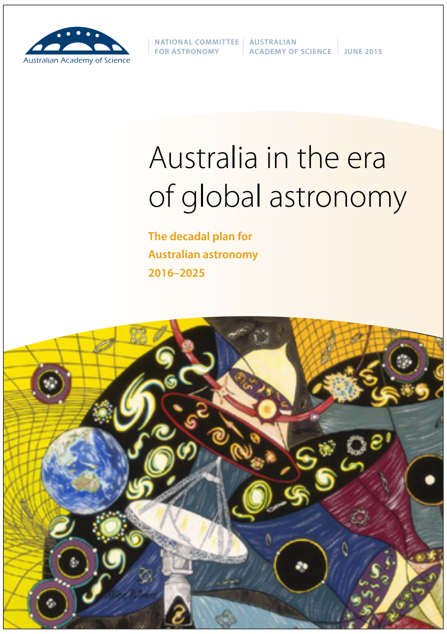


Figure 1: Cover of the Australian astronomy decadal plan 2016–2025. Available at http://australianastronomydecadalplan.org/

Finally, to return to the ASA meeting in Fremantle, it also provided a final opportunity for astronomy community input on options for the future governance of Australian astronomy infrastructure. In the last issue of the AAO Observer I mentioned that a discussion paper had been produced by a special working group of the Department of Industry & Science that examined different governance models that might provide more efficient management of astronomy infrastructure investments in the future more global environment, while at the same time ensuring the very best research outcomes. The working group has since produced a second "Options" paper that develops these models into twelve specific governance options, each of which is evaluated on the basis of the basic principles for good governance as well as the substantial feedback that had been received from the community on the original discussion paper. Ms Ann Bray, General Manager of the Science Agency Governance Branch within the Department (and who chaired the working group after the departure of Brian Boyle) attended the ASA meeting, and many astronomers who were there met with her to express their views on this second paper. The consultation process continued with the Department holding a roundtable meeting to seek the views of the key stakeholders within the Australian astronomy community (AAL, ASA, AAO, CSIRO/CASS, NCA, universities). The Department will provide advice to the Minister of Industry & Science in the coming months, seeking his direction on how this governance issue should be taken forward.

Colour Photography at the AAO — a Brief History

David Malin

If you have opened a popular astronomy or science book in the last 30 years, you have probably seen one of David Malin's colour photographs of deep-sky objects of the Southern Sky. In this article he shares with us the history of to use the AAT and the UKST for colour photography and how things have changed since the analogue days of 1975.

Introduction

A few months ago I contributed all the astronomical photographs I made at the AAO to what will be the AAO image archives. Before doing so I documented them as thoroughly as I could so, anyone interested in their origins could find them. Bringing all this material together prompted me to write this outline, which covers the ideas that led to what became the world's first series of true-colour RGB astronomical images

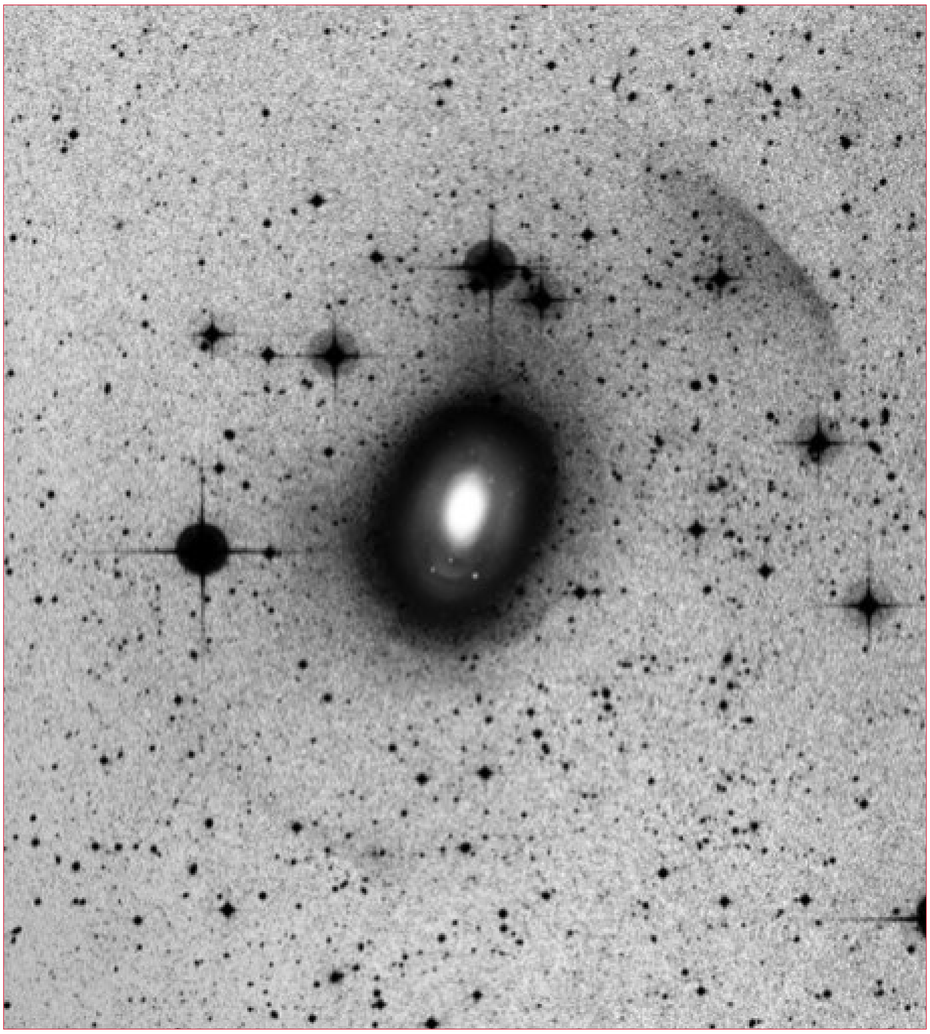


Figure 1: The negative part of this photograph is a photographically amplified image made by combining six UKST plates, revealing a faint external shell. Overlaid in register, a positive image derived from an AAT plate reveals detail of the inner shell-like structures of the galaxy using unsharp masking. NGC 1344 is classified as a normal E5 elliptical. Image width is about 20 arc min.

In the mid-1970s, when I joined the AAO, no professional observatories and very few amateur astronomers were producing or publishing colour photographs of deep sky astronomical objects. The few images that did appear were uninteresting by any standards and all were made on colour film, which was very inefficient when the exposures were long. When I accepted the AAO job in 1975, the Observatory's first director, Joe Wampler, was very keen 'to put the AAO on the map' as he put it, and together with long list of other items, he wanted me to make some astronomical images in colour to advertise our shiny new telescope.

There was no easy or obvious way to do this in 1975, and in any case I was very busy setting up the facilities for photographic observers on the AAT, who were both numerous and demanding. We tried colour film in a lash-up of a Hasselblad roll-film holder at AAT's prime focus in May 1976, with usable results, and a couple of months later I stuck large sheets of colour film on to glass plates to exploit the AAT's wide field. Again, the results were interesting but not especially striking, being rather low contrast with weird colour balance effects that were difficult to fix in pre-digital days. However, they were published with some fanfare, first in the Illustrated London News[1], and then, more surprisingly, in the Australian Women's Weekly, which was probably not quite the audience Joe had in mind. Around this time I did some long exposure tests in the lab using hyper-sensitized colour film that convinced me that we needed a different approach.

The most likely possibility was a colour separation process, where individual monochrome images taken in red, green and blue light were combined into a single colour image using yellow, magenta and cyan dyes. The movie industry's very effective Technicolor process worked this way, and there was a still-photography imbibition (dye-transfer) version of this that could produce beautiful images, widely used for display prints.

But the system was incredibly complex and needed special equipment and steady workflow to keep the numerous chemicals and ingredients fresh and up to temperature. It was utterly impractical for occasional, intermittent use in a one-person darkroom. However, a colour separation process itself was obviously worth a closer look.

Astronomers had been making colour separation negatives for a long time, though the probably were unaware of it. By using Kodak spectroscopic plates and bandpass filters to make B- and V-band (blue and green respectively) exposures for photometry, amongst other things, they had made images that have similar broadband spectral coverage to the blue – and green-sensitive layers in colour film. All that was needed was a matching R-band exposure to provide a data set for a three-colour image that might approximate to true colour. But the practical question remained; how to combine these three images photographically into a colour picture?

With hindsight, it now seems that several things came together at about the same time that led to a solution.

Darkroom techniques

In a previous life using optical and electron microscopes I had encountered photographic materials that had inherent high contrast and high density, rather like the astronomical plates I was becoming familiar with. At that time I revived and modified a little-known process I came across in the printing trade, where it was used to subtly sharpen images and adjust the tonal range in half-tone reproductions: unsharp masking. I first used it on X-ray diffraction films to extract faint lines adjacent to over-exposed ones, but soon began to use it to extract more information from astronomical plates [1] and it quickly led to some scientific discoveries. It was essentially a contact-copying process that produced a positive derivative of the negative original.

At about the same time I was experimenting with various kinds of films and equipment for copying AAT plates before they left the observatory with the observer, possibly never to be seen again. I noticed that one of the high contrast films I tried with a diffuse-light copier revealed much fainter detail than I could see on the original when the copy was under-exposed. I called that 'photographic amplification', and it too was a successful process for producing new science [3] and together with unsharp masking, uncovered two new types of galaxy [4,5]. Like unsharp masking, it was a positive-working contact printing process that worked extremely well on UK Schmidt plates, the source of much of my experimental material in the early days. Indeed many of my scientific publications have come from UKST material.

A difficulty with photo-amplification was that it increased the apparent graininess (similar to shot-noise) in the image, especially troublesome if the image was magnified. Happily, the UK Schmidt was making a sky survey, which involved taking several plates of the same field, and I soon found that combining several photo-amplified derivatives from different plates of the same object in the darkroom reduced the shot noise in just the way you might expect (Figure 1).

This was done with a simple, home-made frame intended to take 8 x 10-inch film or prints. Its only precision part was a piano hinge (Figure 2). This was placed under the enlarger in the darkroom, with a piece of photographic film or paper on a slightly adhesive surface under the light-tight hinged lid. The top of the lid was also slightly adhesive. The frame was moved around under the enlarger to select a suitable area of interest in the projected image of a film positive. A piece of photographic paper was attached to the lid and an exposure made.

On development and drying the paper carrying the newly-made negative print was re-attached to the lid, where it acted as a reference. The frame could be shifted around until the projected positive image completely cancelled out the image on the print — perfect registration! The projected image was switched off, the lid opened and an exposure made. This was repeated, using the same reference print and 'receiver' film with as many different positives as were available. With a bit of practice it was possible to combine five or so identical fields into a deep image in as many minutes. The ability to combine many images in perfect register more or less completed my basic toolkit.

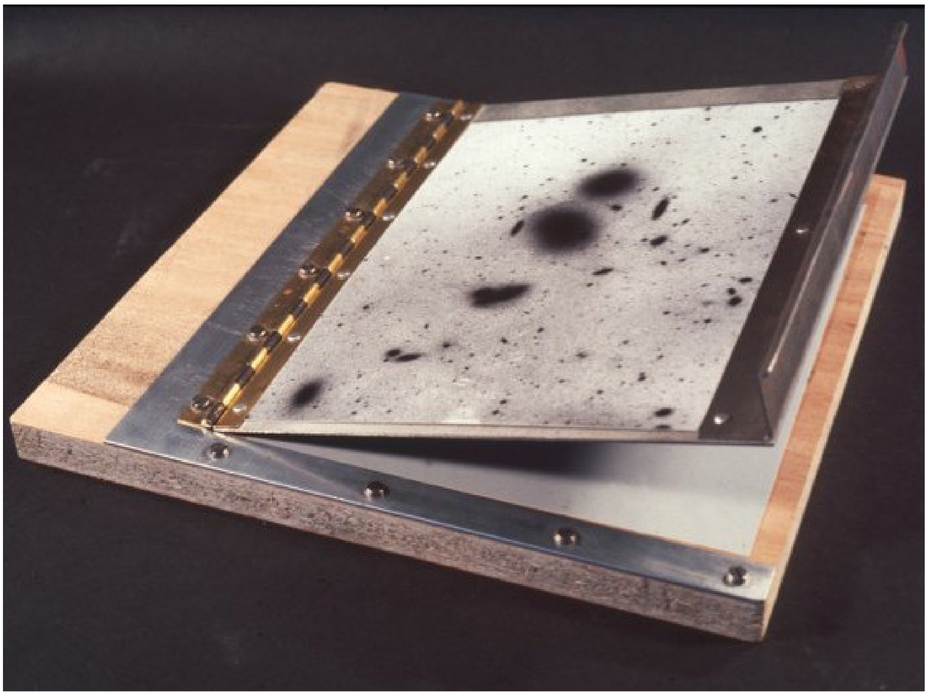


Figure 2: A simple superimposition frame for use with a photographic enlarger to combine multiple images in register. On the lid is a reference print, and beneath it a sheet of photographic paper on which several exposures can be made sequentially from different plates of the same object.

Colour photography

The invention of colour photography can be traced back to the renowned 19th century physicist, James Clarke Maxwell. In a famous demonstration at London's Royal Institution in 1861, Maxwell used three 'magic lanterns' to produce the world's first colour photograph from black and white images. He had a professional photographer take photographs of a piece of coloured cloth (the Maxwell tartan, naturally) several times through a number of colour filters. These black and white negatives were effectively colour separations, and from them the photographer made positive lantern slides. Maxwell projected the three, monochrome positives, in register, onto a white screen in a dark room, using the same colour filters over the projector lenses as used for the original negatives. He found that the red, green and blue colour separations used with the appropriate filters gave the most realistic colour representation. They still do, and this demonstration of additive photography was the world's first colour photograph. It marked the beginning of the science of colorimetry, and a deeper understanding of human colour vision, which was Maxwell's original intent.

I slowly began to appreciate that the projected red, green and blue positive images did not have to be present simultaneously, but could be overlaid sequentially by projection and thus combined on a colour-sensitive film or paper using the simple superimposition frame just described and an enlarger with an RGB filter-wheel. This was essentially Maxwell's additive photographic process updated; all that remained was to find a positive-working material to capture the projected RGB colour image. And there was one such material I was very familiar with, Cibachrome paper, manufactured by my previous employer, Ciba-Geigy. Even better, it could be processed in about 12 minutes in a darkroom using simple equipment. This was important, since both exposure and colour balance was an issue, and having materials processed by a commercial laboratory would have been an extremely tedious way to monitor progress on both fronts.

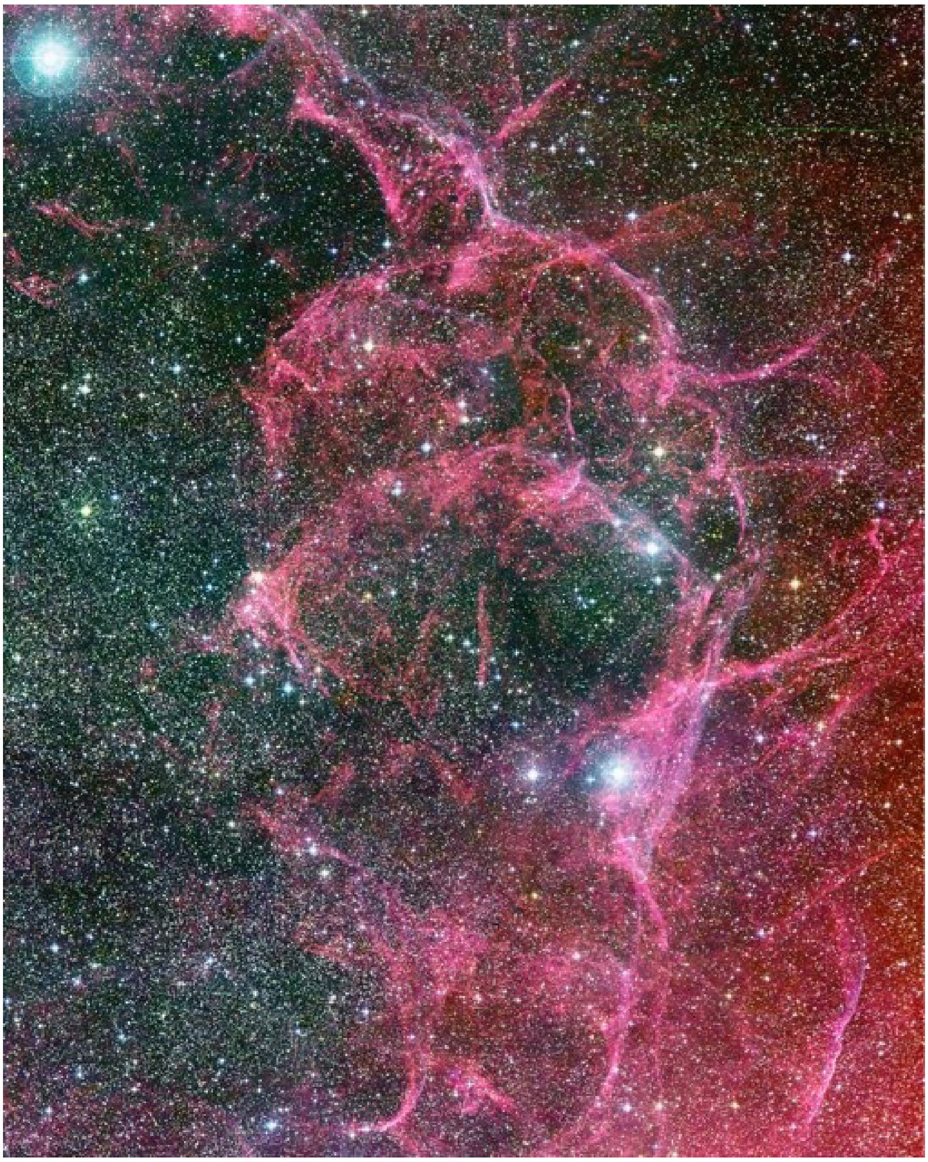


Figure 3: The Vela supernova remnant is very large and has a very low surface brightness, an ideal target for the UK Schmidt Telescope. This nebulosity was the subject of the first true-colour additive astronomical image made at the AAO, in 1978.

Although the issue of the colour balance of unseeable objects imaged in non-standard passbands remained (discussed later in this article), by September 1978 I could make 8 x 10-inch colour images from telescope plates. The first useful picture was a part of the Vela supernova remnant, far too faint to be captured on colour film, but beautifully clear on a Cibachrome print made using positive copies of a series of short exposure BVR plates taken in 1976 with the UK Schmidt Telescope (Figure 3).

Naturally, there was no time formally available for frivolities such as colour photography at the AAT, but friends at UKST proved more amendable, and a search of their archives found some existing B, V and R plates that might be usable, including some of the spectacular regions including the LMC (test plates from 1975) M8 and M20 in Sagittarius and around Eta Carinae. The images from these were enough to convince me that we had a workable process and were soon in print. By the early 1980s, AAO tricolour images were becoming widely known and published.

Despite this success, three main problems endured: how to obtain suitable RGB plates (especially from the AAT), how to achieve reliable, realistic and reproducible colour balance, and how to make mural-sized prints.

Service Observing

The plate problem was less of an issue for the photography-oriented UKST, who were keen to advertise their telescope, and who were largely independent of time allocation committees (TAC). Many of the early colour pictures were derived from UKST material, for which I was very grateful. However, things also improved at the AAO, where Don Morton had already established a 'service photography' program.

There was a demand in the astronomical community for images for science-oriented projects on southern hemisphere objects. However the telescope was scheduled in one-night blocks so one-off plates were not possible. To meet this need, during 1976 Don Morton initiated what he called 'service photography' on the AAT. Requests were solicited for proposals for short amounts of time for single or a very few plates — I think there was a two – or three-hour time limit. The intention initially was to assess these in-house for observing conditions (seeing, transparency, Moon etc.) and to schedule them in Director's time. If demand was sufficient, we could then approach the TACs for time. This was essentially the first queue-scheduled program on any large telescope as far as I am aware, and it began at the end of January 1977. The first observers were Don Morton, Louise Turtle and myself, and that year we had sufficient demand to require eight additional dark nights for prime focus photography.

Don Morton's 'reward' for the many hours spent in the prime focus cage (and many more hours spent hypersensitizing plates) was to allow the observers to take one plate for their own projects in any session. Service Observing was continued with a full schedule for almost 20 years thereafter, and as a consequence of my 'allowance', it became the source of many of the plates used for colour images. It was also possible to take useful R-band plates in both dawn and dusk twilights, which did not count as a time allocation. While a staff astronomer was initially allocated to the program, for many years I shared the observing with Steve Lee, and I recall our many nights at the telescope with great pleasure. It turned out to be an extremely efficient use of the telescope. With two experienced observers and careful planning of slews, we were gathering photons for more than 100 percent of the 'official' time (if the twilight plates were included).

Figure 4: The projected grayscale calibrator use for colour balance is shown on the corner of this image of the emission nebulae NGC 3576 and NGC 3603 (left). I was puzzled by the different colours of the nebulae, but NGC 3603 is much more distant that its apparent companion, and H-beta light has been absorbed by interstellar dust.

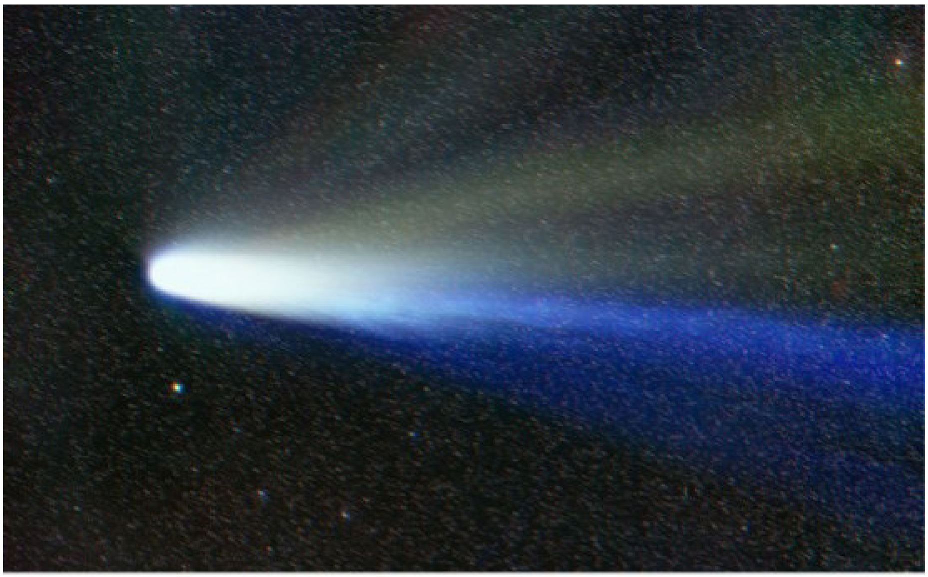
Colour Balance

I had many mentors at the AAO, and the first and most influential of these were David Allen and Paul Murdin. When I arrived at the AAO, Paul and David were planning a popular book that they modestly called Catalogue of the Universe[7], and they invited me to join them, mainly to help with illustrations. It was Paul who introduced me to the notion of blackbody radiation and its link with the colours of the stars and the colour-magnitude diagram. This book also contains the first RGB colour photograph I ever made, and the first to be published, the Vela SNR mentioned earlier. Later Paul and I went on to write another book The Colours of the Stars[8], which had many more RGB images, and it was the writing of that book that linked my conventional photographic thinking about colour balance to the more complex issues involved with colour in astronomy, not least emission line objects.

The obvious problem with colours in astronomical images is that they are on the threshold of colour vision for most people. Even then the colours are pastel hues, so there is no useful visual reference, even for saturated emission lines (for example). I was thus attempting to create photographs of objects that where hardly visible in colour, using a novel, uncalibrated system that was not intended for the purpose. To complicate matters, there was little in the literature about colour balance using an additive imaging system, except in the deeper recesses of handbooks for colour TV engineers — the only widespread additive colour system in use at the time. The language was opaque to me, and the fundamental issues they explored — conserving bandwidth and the gamut of colour CRT phosphors with weird emission spectra — were hardly relevant.

The most obvious approach was to install an optical projection system in the prime-focus (PF) camera that shone a greyscale image on to part of the plate shielded from sky photons for the full duration of the exposure. The light source could be adjusted to mean noon sunlight (like daylight colour film) and sent through the filter in use with each BVR plate, so, in theory, a neutral greyscale on a final tricolour image would ensure that we had achieved accurate and realistic colours in the astronomical object, at least for blackbody and other continuum sources (Figure 4). Fortunately, a design for such a device existed at Kitt Peak[6], but it was to be a few years before a calibrator tailored to the AAT PF camera could be made and installed.

In the meantime I built a simple lab setup with a plate camera so I could make long exposures on cut-down astronomical plates using a standard greyscale target and the same filters as on the telescope. With a tungsten source filtered to a daylight colour-temperature and lots of neutral density filters I could make colour separation tests in the lab. These were equivalent to the photometric B, V and R bands and were copied to positives and combined into colour images in the way I used telescope plates. This gave me invaluable insights into the complexities of hue, gamut and dynamic range and provided an essential calibration point. I could now be confident that our analogue RGB astronomical images were a reasonable representation of reality.



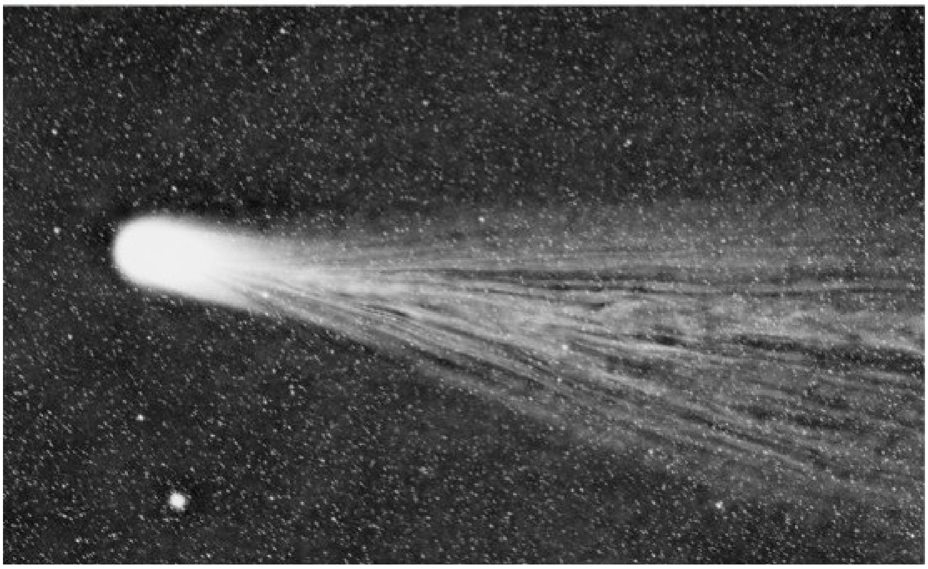


Figure 5: Comet Halley on 12 March, 1986, imaged by the UKST. The colour image clearly shows the colour difference between the ion and dust tails of the comet. The B&W picture shows fine structure in the ion tail and was made using unsharp masking on the blue-light plate of the colour composite.

Images for reproduction

There was soon a steady demand for pictures for publication, especially from the numerous authors of books for USA-based liberal arts astronomy courses and popular science and astronomy magazines. While this is a trivial issue with today's digital images, they were 20 years in the future. It was impractical to provide original Cibachrome prints for publication, so I photographed my master prints on large format transparency film and distributed them in that format way (by airmail, of course). This was adequate for book and magazine publication but there was a loss of quality, especially for large reproduction sizes.

By the mid 1980s the RGB additive process had been refined through much practice, and by then we has 100 or so colour images, and they were in high demand. This eventually led me to replaced the 8 x 10 Cibachrome as a receiver material with 8 x 10 colour negative film. This was a big step, because I could not process and proof this material in-house to monitor exposure and colour balance in near-real time. It also involved a 10,000-fold reduction of the RGB enlarger exposure times, so I was literally working literally in the dark. However, with a bit of practice it worked, and from the negatives, large (and large quantities of) prints and transparencies could be made by a commercial lab, all with a consistent colour balance. While that relieved me of a big workload I also had to revisit and recalibrate all the existing RGB colour images to make new colour negatives for them. Happily this was up and running well before Comet Halley (1985–6; Figure 5) and supernova 1987A appeared in the southern hemisphere. From the PR point of view those events were life-changing.

Other things were changing too. By 1987 I had a dumb terminal on my desk linked to the central VAX11/780 and I had an e-mail address. A year or two later I had a Macintosh MkII, no longer dumb, but very slow by today's standards. It had a 40MB HD and 2MB of memory, it ran Photoshop 2.5, and from that point imaging changed forever. However, some things we take for granted now were either not available or not readily affordable such as computer memory and storage, desktop scanners and colour printers. I soon realised the implications of the fact that digital colour images were built in RGB and that Photoshop thought in those terms too. As a result I has some monochrome positive film colour separations scanned by an external lab. I taught myself how to combine them in register in Photoshop R, G and B channels. With a minute amount of memory everything to do with images took forever, so file sizes were tiny but it worked. When combining images in software became more practical, the files themselves were stored on numerous CDs, and this let to the final iteration of the AAO's colour images.

When I retired from the AAO in 2001 I took with me the large (mostly 8 x 10-inch) film positive RGB colour separations I had derived from AAT, UKST and other telescope plates. Many had been made using unsharp masking and other analogue processes to extract the best from the originals, which (for the AAT plates) are stored in the AAT dome. I bought a good flatbed scanner and rebuilt the images in software so they all had a file size of 8,000 x 10,000 pixels. That seemed big at the time....

I was also able to create new images from this material that were not possible in the darkroom, and to remove gradients, blemishes, scratches and dust that were the bane of conventional photography, and I was able to adjust the colour balance of all of them to a common standard and a common colour space. None of that was possible pre-digital. It is this collection, plus others (star trails and the like) taken on film and scanned at high resolution that is now part of the AAO archive.

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Ionized gas in the extended UV disc of the NGC1512/1510 system

Ángel R. López-Sánchez (AAO), Tobias Westmeier, César Esteban & Baerbel S. Koribalski

How do galaxies grow and evolve? Galaxies are made of gas and stars, which interact in very complex ways: gas form stars, stars die and release chemical elements into the galaxy, some stars and gas can be lost from the galaxy, some gas and stars can be accreted from the intergalactic medium. The current accepted theory is that galaxies build their stellar component using their available gas while they increase their amount of chemical elements in the process. But how do they do this?

We have completed new, unique observations using the 2dF instrument at the 3.9m Anglo-Australian Telescope (AAT), in combination with radio data obtained with the Australian Telescope Compact Array (ATCA) radio-interferometer, to study how the gas in processed into stars and how much chemical enrichment has this gas experienced in the nearby galaxy NGC 1512.

NGC 1512 and NGC 1510 is an interacting galaxy pair composed by a spiral galaxy (NGC 1512) and a Blue Compact Dwarf Galaxy (NGC 1510) located at 9.5 Mpc (=31 million light years). The system possesses hundreds of star-forming regions in the outer areas, as it was revealed using ultraviolet (UV) data provided by the GALEX satellite (NASA) (Figure 1). Indeed, the UV-bright regions in the outskirts of NGC 1512 build an “eXtended UV disc” (XUV-disc), a feature that has been observed around the 15% of the nearby spiral galaxies. However these regions were firstly detected by famous astronomer David Malin (AAO) in 1975 using photographic plates obtained with the 1.2m UK Schmidt Telescope (AAO), at Siding Spring Observatory (NSW, Australia).

The system has a lot of diffuse gas, as revealed by radio observations in the 21 cm HI line conducted at the Australian Telescope Compact Array (ATCA) as part of the “Local Volume HI Survey” (LVHIS) and presented by Koribalski & López-Sánchez (2009). The gas follows two long spiral structures up to more than 250,000 light years from the centre of NGC 1512. That is about 2.5 times the size of the Milky Way, but NGC 1512’s optically visible disc is about 3 times smaller than our Galaxy’s! One of these structures has been somehow disrupted recently because of the interaction between NGC

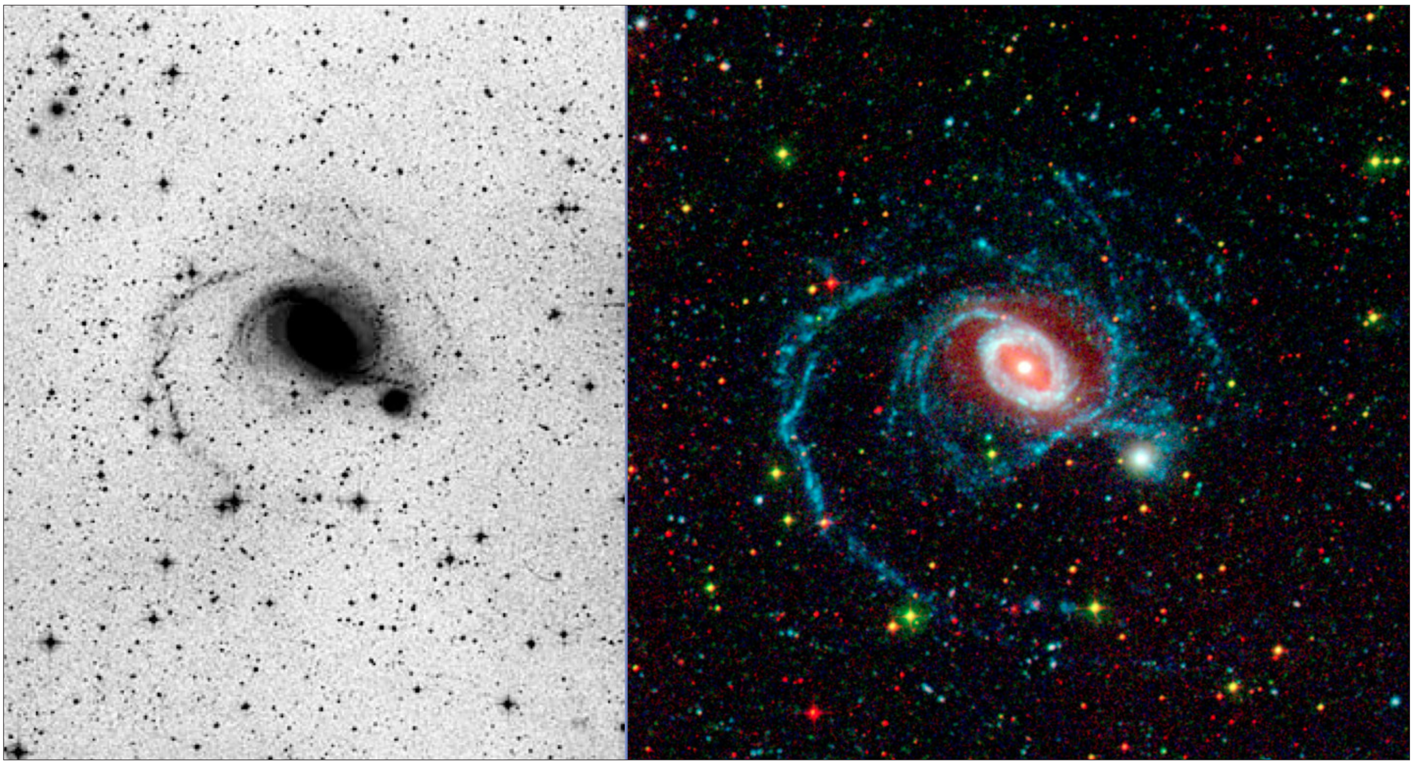


Figure 1. Deep images of the galaxy pair NGC 1512 and NGC 1510 using optical light (left) and ultraviolet light (right).
Credit: Optical image: David Malin (AAO) using photographic plates obtained in 1975 using de 1.2m UK Schmidt Telescope (Siding Spring Observatory, Australia). UV image: GALEX satellite (NASA), image combining data in far-ultraviolet (blue) and near-ultraviolet (red) filters

1512 and NGC 1510, that it is estimated started around 400 million years ago.

Our study presents new, deep spectroscopic observations of 136 genuine UV-bright knots in the NGC 1512/1510 system using the powerful multi-fibre instrument 2dF and the spectrograph AAOmega, installed at the AAT (Figure 3 shows example of the spectra acquired). 2dF/AAOmega is generally used by astronomers to observe simultaneously hundreds of individual stars in the Milky Way or hundreds of galaxies. Without considering observations in the Magellanic Clouds, it is the first time that 2dF/AAOmega is used to trace individual star-forming regions within the same galaxy, in some way forming a huge "Integral-Field Unit" (IFU) to observe all the important parts of the galaxy.

The AAT observations confirm that the majority of the UV-bright regions are star-forming regions. Some of the bright knots (those which are usually not coincident with the neutral gas) are actually background galaxies (i.e., objects much further than NGC 1512 and not physically related to it) showing strong star-formation activity. Observations also revealed a knot to be a very blue young star within our Galaxy.

Using the peak of the H-alpha emission, the AAT data allowed us to trace how the gas is moving in each of the observed UV-rich region (their kinematics), and compare with the movement of the diffuse gas as provided using the ATCA data (Figure 4). The two kinematics maps provide basically the same results, except for one region (black circle in Figure 4) that shows a very different behaviour. This object might be an independent, dwarf, low-luminosity galaxy (as seen from the H-alpha emission) that is in process of accretion into NGC 1512.

The H-alpha map shows how the gas is moving following the optical emission lines up to 250000 light years from the centre of NGC 1512, that is 6.6 times the optical size of the galaxy. No other IFU map has been obtained before with such characteristics.

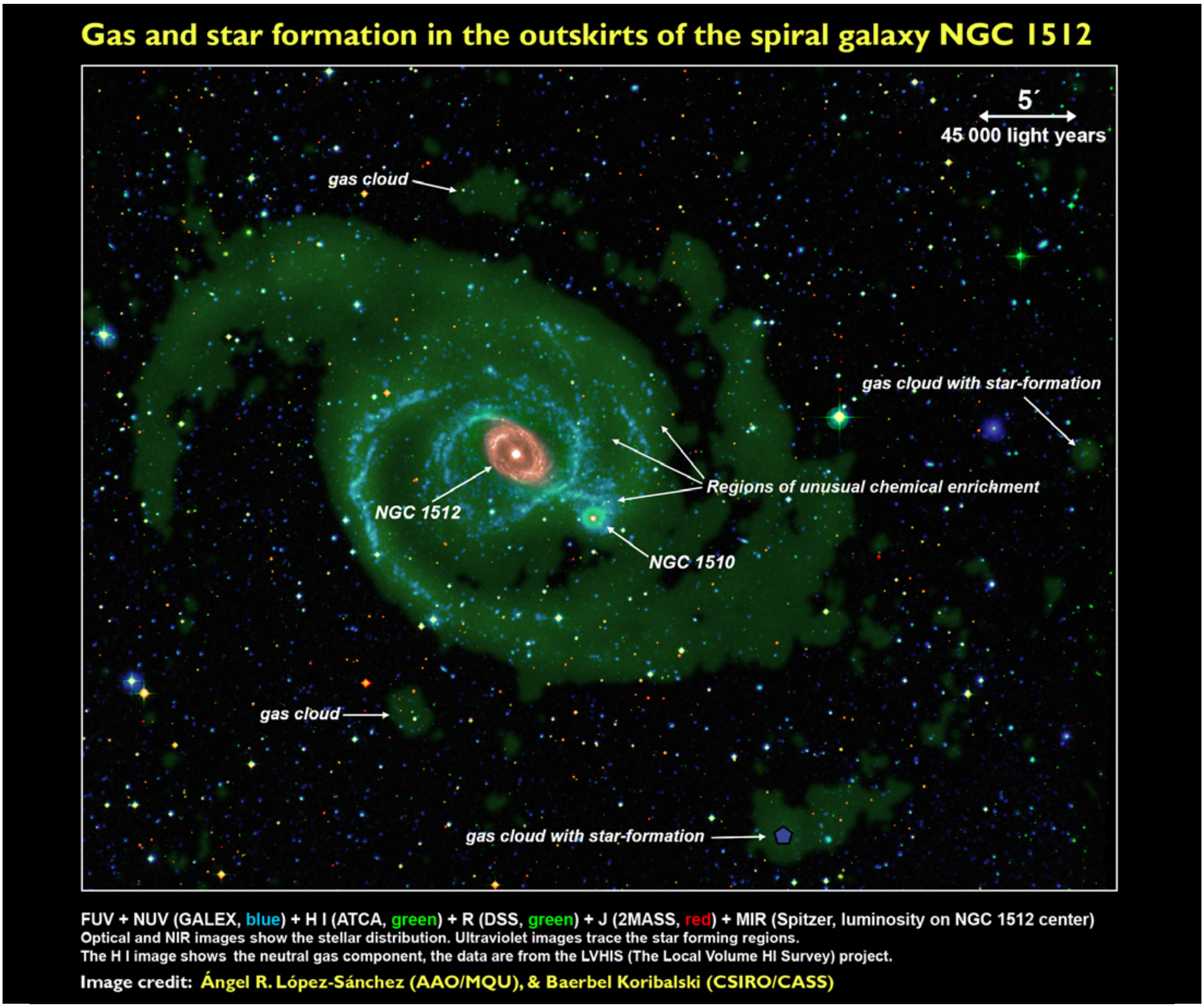


Figure 2. Multiwavelength image of the NGC 1512 and NGC 1510 system combining optical and near-infrared data (light blue, yellow, orange), ultraviolet data from GALEX (dark blue), mid-infrared data from the Spitzer satellite (red) and radio data from the ATCA (green). The blue compact dwarf galaxy NGC 1510 is the bright point-like object located at the bottom right of the spiral galaxy NGC 1512.
Credit: Ángel R. López-Sánchez (AAO/MQ) & Baerbel Koribalski (CSIRO).

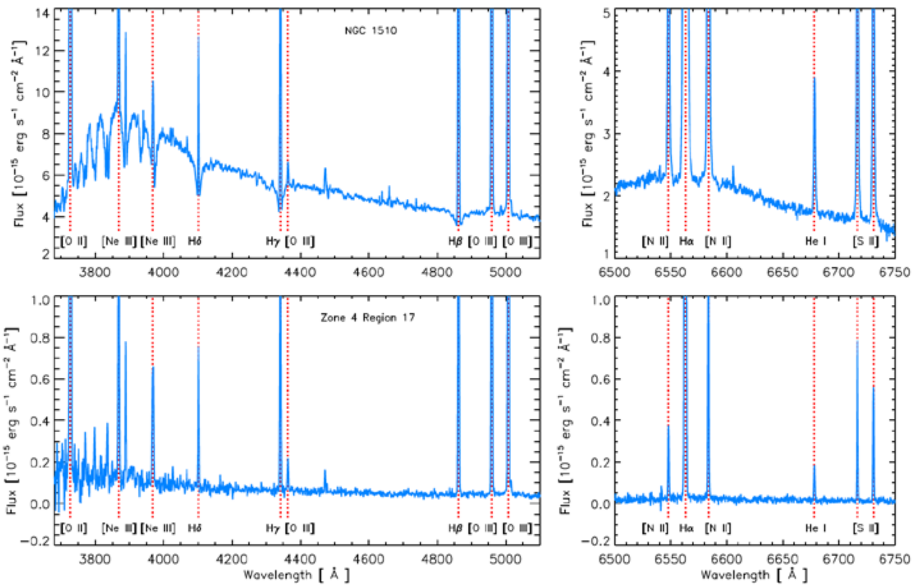


Figure 3. Two examples of the high-quality spectra obtained using the AAT. Top: spectrum of the BCDG NGC 1510. Bottom: spectrum of one of the brightest UV-bright regions in the system. The important emission lines are labelled.
Credit: López-Sánchez et al. 2015 MNRAS, 450, 3381

Using the emission lines detected in the optical spectra, which includes H I, [O II], [O III], [N II], [S II] lines (lines of hydrogen, oxygen, nitrogen and sulphur), we are able to trace the chemical composition – known in astronomy as the “metallicity”, since to an astronomer all elements which are not hydrogen or helium as defined as “metals” – of the gas within this UV-bright regions. Only hydrogen and helium were created in the Big Bang. All the other elements have been formed inside the stars as a consequence of nuclear reactions or by the actions of the stars (e.g., supernovae). The new elements created by the stars are released into the interstellar medium of the galaxies when they die, and mix with the diffuse gas to form new stars, that now will have a richer chemical composition than the previous generation of stars. Hence, tracing the amount of metals (usually oxygen) within galaxies indicate how much the gas has been re-processed into stars.

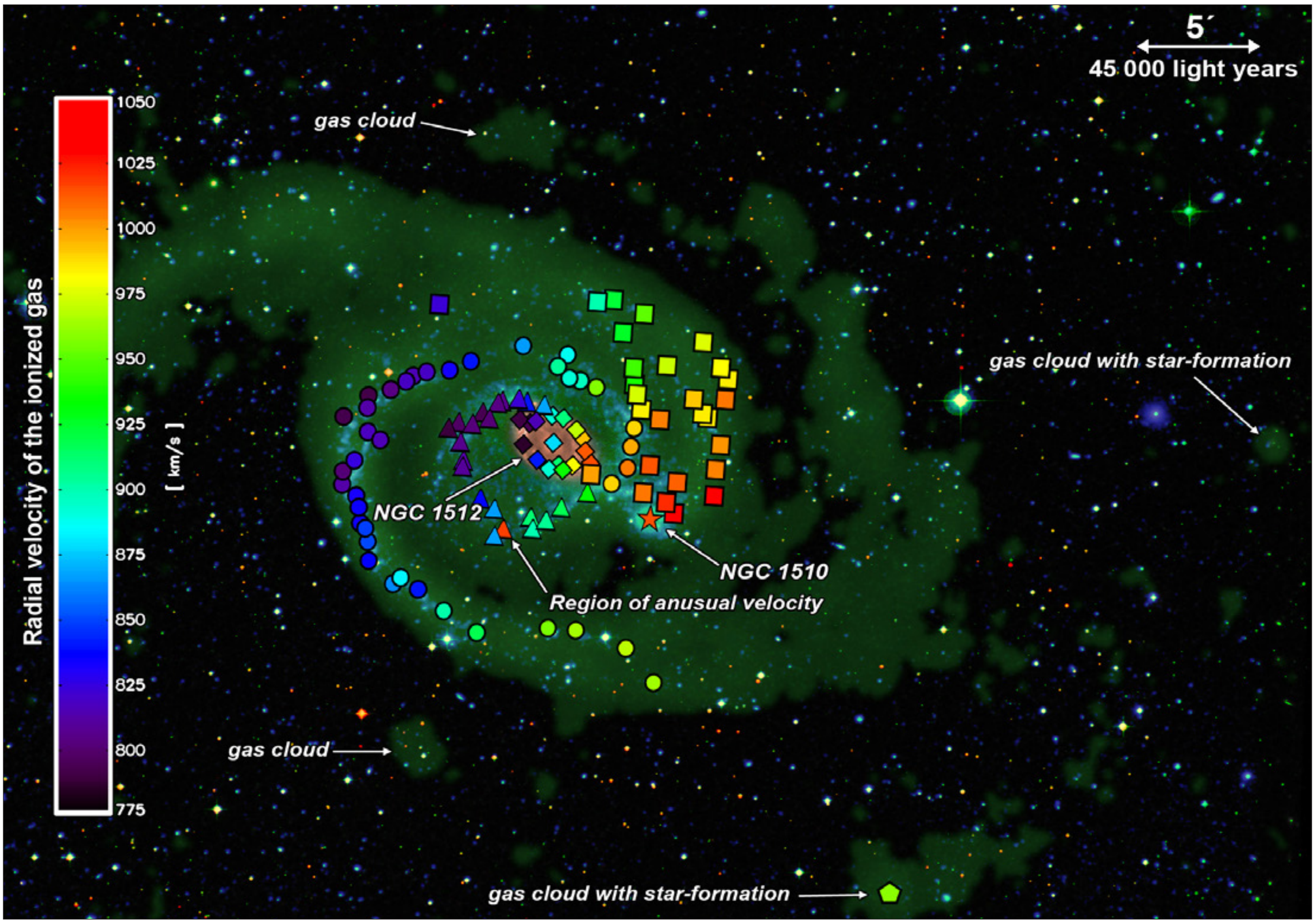


Figure 4. Map showing the velocity field of the galaxy pair NGC 1512 / NGC 1510 as determined using the H-alpha emission provided by the AAT data. This kinematic map is almost identical to that obtained from the neutras gas (HI) data using the ATCA, except for a particular region (noted by a black circle) that shows very different kinematics when comparing the maps.
Credit: López-Sánchez et al. 2015 MNRAS, 450, 3381

The "chemical composition map" or "metallicity map" (Figure 5) of the system reveals that indeed the centre of NGC 1512 has a lot of metals (red diamonds), in a proportion similar to those found around the centre of our Milky Way galaxy. However the external areas show two different behaviours: regions located along one spiral arm (to the left in Figure 5) have low amount of metals (blue circles), while regions located in other spiral arm (to the right in Figure 5) have a chemical composition which is intermediate between those found in the centre and in the other arm (green squares and green triangles). Furthermore, all regions along the extended "blue arm" show very similar metallicities, while the "green arm" also has some regions with low (blue) and high (orange and red) metallicities. The reason of this behaviour is that the gas along the "green arm" has been very recently enriched by star-formation activity, which was triggered by the interaction with the Blue Compact Dwarf galaxy NGC 1510 (blue star in the map).

When combining the available ultraviolet and radio data with the new AAT optical data it is possible to estimate the amount of chemical enrichment that the system has experienced. This analysis allows us to conclude that the diffuse gas located in the external regions of NGC 1512 was already chemically rich before the interaction with NGC 1510 started about 400 million years ago. That is, the diffuse gas that NGC 1512 possesses in its outer regions is not pristine (formed in the Big Bang) but it has been already processed by previous generations of stars. The data suggest that the metals within the diffuse gas are not coming from the inner regions of the galaxy but very probably they have been accreted during the life of the galaxy either by absorbing low-mass, gas-rich galaxies or by accreting diffuse intergalactic gas that was previously enriched by metals lost by other galaxies.

In any case this result constrains our models of galaxy evolution. When used together, the analysis of the diffuse gas (as seen using radio telescopes) and the study of the metal distribution within galaxies (as given by optical telescopes) provide a very powerful tool to disentangle the nature and evolution of the galaxies we now observe in the Local Universe.

Further Reading

Á. R. López-Sánchez, T. Westmeier, C. Esteban, and B. S. Koribalski. "Ionized gas in the XUV disc of the NGC1512/1510 system", 2015, MNRAS, 450, 3381. Published in Monthly Notices of the Royal Astronomical Society (MNRAS) through Oxford University Press.

Available online at http://doi.org/10.1093/mnras/stv703

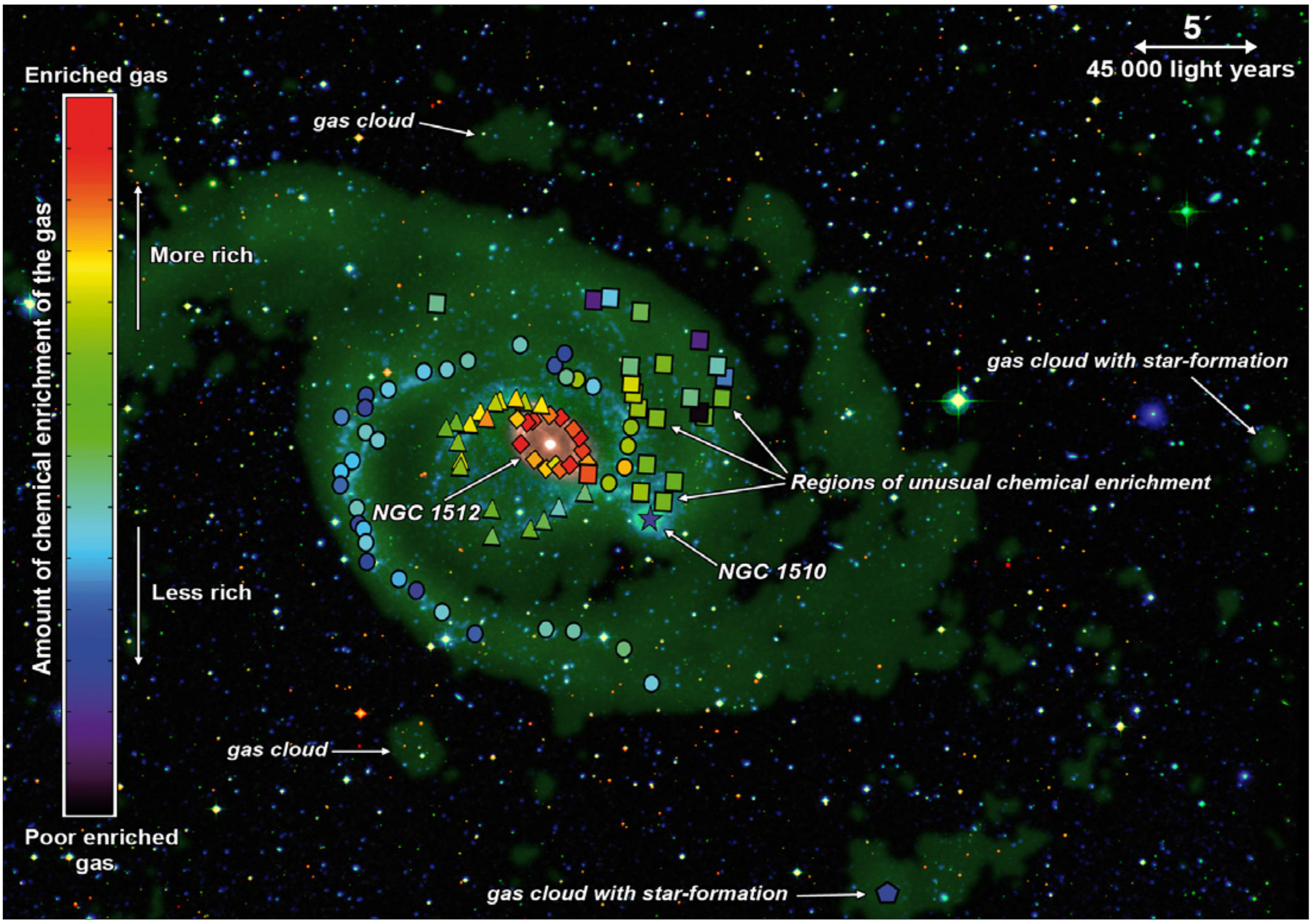


Figure 5. Metallicity map of the NGC 1512 and NGC 1510 system, as given by the amount of oxygen in the star-forming regions (oxygen abundance, O/H). The colours indicate how much oxygen (blue: few, green: intermediate, red: many) each region has. Red diamonds indicate the central, metal rich regions of NGC 1512. Circles trace a long, undisturbed, metal-poor arm. Triangles and squares follow the other spiral arms, which is been broken and disturbed as a consequence of the interaction between NGC 1512 and NGC 1510 (blue star). The blue pentagon within the box in the bottom right corner represents the farthest region of the system, located at 250 000 light years from the centre.
Credit: López-Sánchez et al. 2015 MNRAS, 450, 3381

Confirming the reality of binary open clusters with UCLES and HERMES

Gayandhi De Silva (AAO, University of Sydney), Giovanni Carraro (ESO), Valentina D'Orazi (INAF-Padova), Varvara Efremova (AAO), Hayley Macpherson (AAO), Sarah Martell (UNSW)

It is widely accepted that stars form in some form of a star cluster. The current model of the global star formation hierarchy is that giant molecular clouds fragment into cloud cores, producing stellar complexes, stellar associations and open clusters, which dissipate into individual stars. The exact mechanisms that takes place between the stages of molecular cloud and star cluster is not completely understood, and it is likely there are different paths that lead to the formation of different systems of clusters. One such possibility is binary or multiple star cluster formation. These are clusters that formed at similar times, in similar sites, from a common parental gas cloud.

Such primordial binary clusters are transient in nature, making them difficult to identify. One or more of the clusters could disperse; the pair could merge or separate into two bound clusters depending on factors such as cluster size, separation, strength of tidal forces and encounters with giant molecular clouds. The identification is further complicated because some candidate binary clusters could simply be optical doubles due superposition along the line-of-sight, or effects of Milky Way disk dynamics could place two un-related clusters in pairs in the same place in the Galaxy.

If two clusters formed at about the same time and site, then they should have similar ages, motions and chemical properties, assuming no major contamination events (e.g. supernovae) taking place during the cluster formation timescales. Binary clusters caused by tidal capture may show common motion, but the chemical properties and ages are likely to be different. For any optical doubles we expect both the motion and chemical composition to be different between the two clusters. So the aim of this research is to identify chemically and dynamically similar clusters.

In the Large and Small Magellanic Clouds at least 10 percent of the known clusters are thought to be in pairs, possibly triggered by interactions between the two systems. Binary clusters have been seen in other violent environments such as the Antennae galaxies and M51. The merger of larger binary cluster systems has been suggested as a possible explanation for the formation of massive globular clusters such as ω Centauri. Of the Galactic open clusters, 10% have been proposed to be in binary or multiple systems. However most studies attempting to confirm primordial binary open clusters in the Milky Way have had negative outcomes, with the only confirmed primordial binary system being h + χ Persei.

We carried out a spectroscopic study on the candidate binary cluster pair NGC 5617 and Trumpler 22. From photometric data, we determined that both clusters have a similar age of about 70Myrs and share a similar heliocentric distance of about 2.1 kiloparsecs. Figure 1 shows a 60x60 arcmin field around the cluster pair. Notice that the open cluster Pismis 19 is visible in the same field of view, but this cluster is older and located further from these two clusters and simply lie along the line of sight, so would be neither chemically or dynamically linked to NGC 5617 and Trumpler 22.

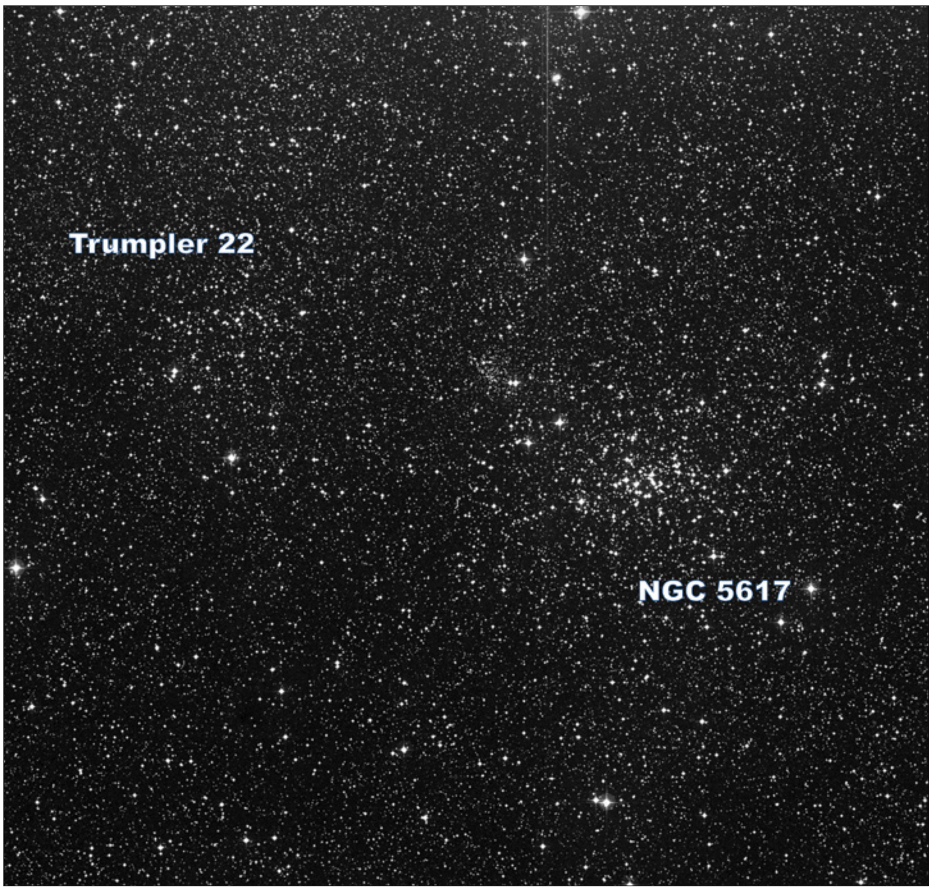


Figure 1: 60 x 60 arcmin Digitized Sky Survey image showing the cluster pair in the constellation Centaurus. The bright star α Centauri is located above NGC 5617 just outside the field of view of the image. An unrelated open cluster Pismis 19 can also be seen between the two binary clusters.
Credit: Digitized Sky Survey

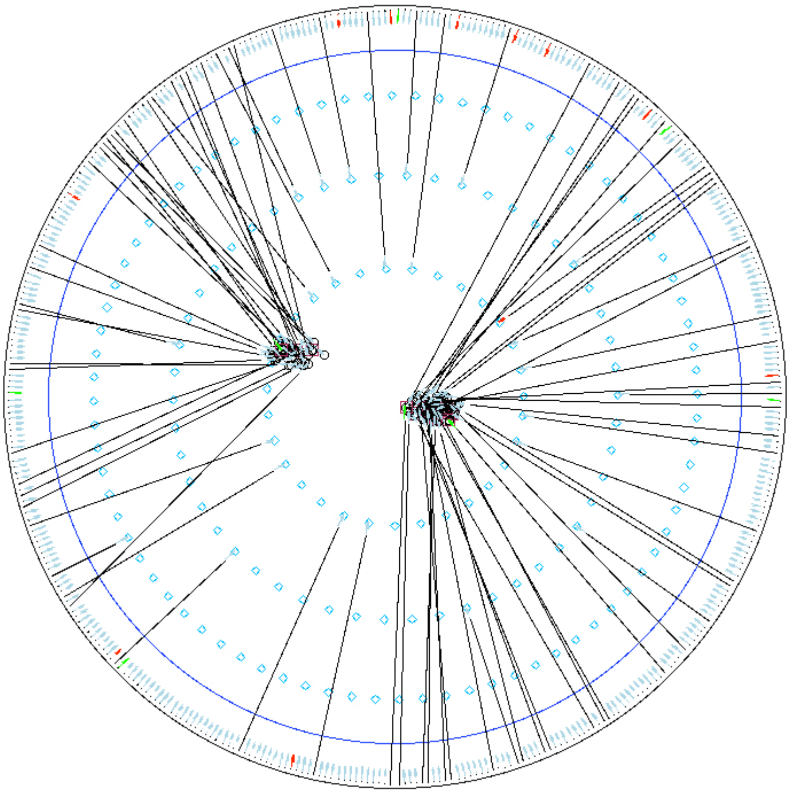


Figure 2: 2 clusters in 1 observation: 2dF plate configuration of the candidate binary open clusters for observation with HERMES. Each black line represents a fibre positioned onto the 2dF plate.

We collected spectra of candidate members of the binary open clusters using the AAT's University College London Echelle Spectrograph (UCLES) and the High Efficiency and Resolution Multi-object Spectrograph (HERMES) via service observing programs. High-resolution (spectral resolution or R~30,000) spectra were collected for 6 bright stars in the two clusters with UCLES. The 2-degree field of view and multi-object capability of HERMES allowed us to obtain high-resolution (R~28,000) spectra for a further about 50 stars in both clusters in a single exposure. Figure 2 shows the fibre configuration used by HERMES.

The data were reduced using a combination of Iraf reduction routines and the AAO's 2dFdr package. The resulting spectra were used to measure the radial velocities (RV) of the stars by cross correlating against a template spectrum. The RV analysis identified we had observed 6 non-members in Trumpler 22 and 4 non-members in NGC 5617 as their RV values deviated from the clusters' mean velocities. The heliocentric radial velocities of the two clusters were measured to be very similar, with the mean RV = −38.46 ± 2.08 km/s for Trumpler 22 and mean RV = −38.63 ± 2.25 km/s for NGC 5617. This confirms the two clusters have a common motion.

Despite the large sample of spectra collected, only 4 cluster members could be used for spectroscopic stellar parameter and abundance analysis. The bulk of the stars were either too hot or rotating too rapidly, which results in their spectral line features being unusable for the spectroscopic analysis used. A high fraction of hot stars and rapid rotators is expected in young clusters such as Trumpler 22 and NGC 5617.

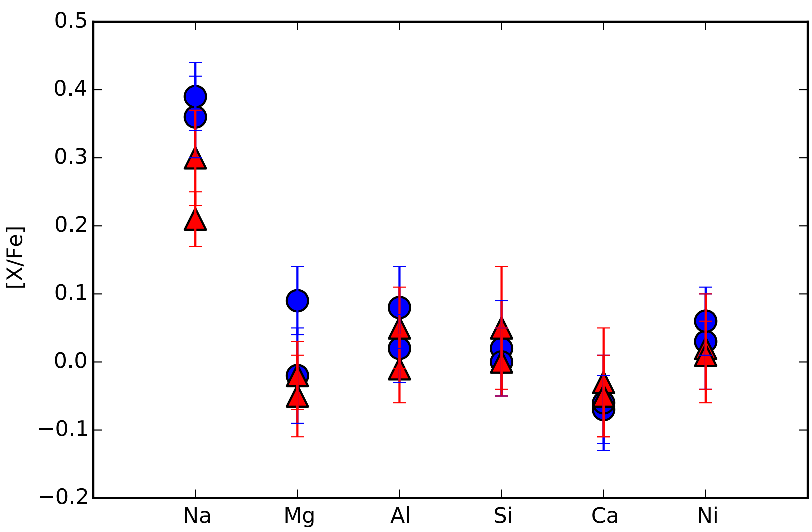


Figure 3: The measured abundance pattern of the two clusters. Red triangles show the abundances of stars of NGC 5617 and the blue circles are stars of Trumpler 22.

Of the stars with measurable spectral features, most were the non-members as determined by the RV analysis.

Abundances of Fe, Na, Mg, Al, Si, Ca and Ni were measured in 4 stars (2 in each cluster) using the MOOG abundance analysis code with Kurucz model atmospheres based on spectral line equivalent widths. The typical errors on the derived stellar parameters are 50K in effective surface temperature, 0.1 dex in surface gravity and 0.1 dex in micro-turbulence. We find that both clusters share very similar elemental abundances with mean [Fe/H] = – 0.18 ± 0.02 dex. Figure 3 shows the individual abundances, where blue circles are the members of Trumpler 22 and red triangles are the members of NGC 5617.

The presented evidence is indicative of a common chemical enrichment history of these two clusters. Together with common motions, location and ages we confirm that NGC 5617 and Trumpler 22 are a primordial binary cluster pair in the Milky Way. An expanded search for more primordial binary or multiple open clusters will help determine the primordial binary cluster fraction in the Galaxy and provide further insight into the star formation mechanisms.

Further Reading

De Silva et al. "Binary open clusters in the Milky Way: photometric and spectroscopic analysis of NGC 5617 and Trumpler 22". Accepted for publication in MRNAS, 2015.

Refereed preprint available at http://arxiv.org/abs/1507.03230.

Discovery of seventy new *CoRoT* BEER binaries with AAOmega

Tsevi Mazeh, Lev Tal-Or, Simchon Faigler (Wise Observatory, Tel Aviv University, Tel Aviv, Israel)

The BEER algorithm (Faigler & Mazeh 2011) analyzes stellar light curves for the BEaming, Ellipsoidal, and Reflection photometric modulations caused by a short-period orbiting companion. Out of the three effects, the beaming effect is a relativistic modulation of the observed intensity of a source of light, induced by the motion of the source relative to its observer. It is typically of very low amplitude, and can be detected mainly in light curves from space-based photometers. Unlike eclipsing binaries, all three effects are not limited to edge-on inclinations (where the two stars actually transit each other along our line-of-sight).

Applying the algorithm to wide-field accurate photometric surveys performed from space offers an opportunity to find non-eclipsing binaries. It widens the window for detecting intrinsically rare systems, like brown-dwarf and compact-objects as companions to main sequence stars.

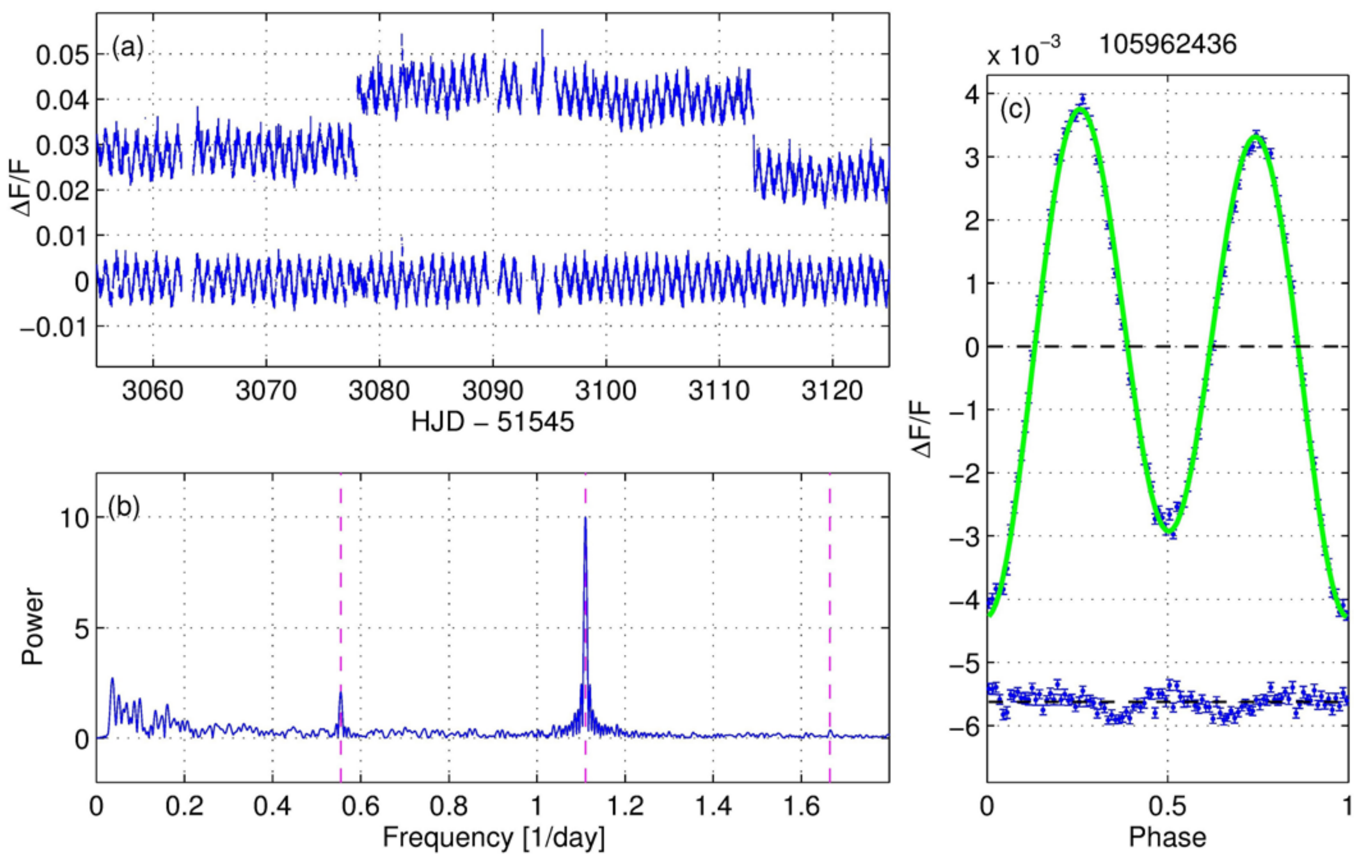


Figure 1: BEER light curve analysis of *CoRoT* 105962436 (a) A 70-day long part of the *CoRoT* white light curve, normalized by its median. For clarity, the original light curve was shifted upward by 0.03 relative to the cleaned and detrended one. (b) The power spectrum of the detrended light curve. Vertical dashed lines mark the first three harmonics of the candidate orbital frequency.

(c) Phase-folded and binned light curve (blue) and the best-fit BEER models assuming a circular orbit (green). The residuals were shifted downward for clarity.

CoRoT was a French and ESA space mission that obtained over 150,000 continuous stellar light curves with time span of tens to hundreds days with a photometric precision of 0.1 percent per measurement. We applied the BEER search to five *CoRoT* fields and identified 481 non-eclipsing binary candidates, with periodic flux amplitudes of 0.5-87 millimagnitudes. Figure 1 shows one example, *CoRoT* 105962436, of BEER detection of the three modulations.

Optimizing the AAOmega fibre-allocation, we managed to acquire 6-7 medium-resolution spectra of 281 candidates in a seven-night campaign on the AAT, allocated through the OPTICON program. Analysis of the red-arm AAOmega spectra yielded a radial-velocity precision of about 1 km/s.

The radial velocities obtained by AAOmega confirmed the binarity of seventy BEER candidates. Figure 2 shows the obtained spectrum of *CoRoT* 105962436, and the Two Dimensional Correlation analysis (TODCOR) that identified two stellar components in the observed spectrum. Figure 3 presents the double-lined orbital solution of the system.

This is the first time non-eclipsing beaming binaries are detected in *CoRoT* data, and we estimate that a total of ~300 such binaries can be detected in *CoRoT* long-run lightcurves.

Further Reading

L. Tal-Or et al. “BEER analysis of Kepler and *CoRoT* light curves III. Spectroscopic confirmation of seventy new beaming binaries discovered in *CoRoT* light curves”. Accepted for publication in A&A.

Preprint available at http://arxiv.org/abs/1505.04570

Acknowledgements

We are deeply thankful to Gary Da Costa and Simon O’Toole for their help with preparing the AAOmega proposal and observations. We are grateful for the invaluable assistance of the AAOmega technical staff and support astronomers. Particularly, we thank Sarah Brough for her help with preparing, performing, and reducing the observations.

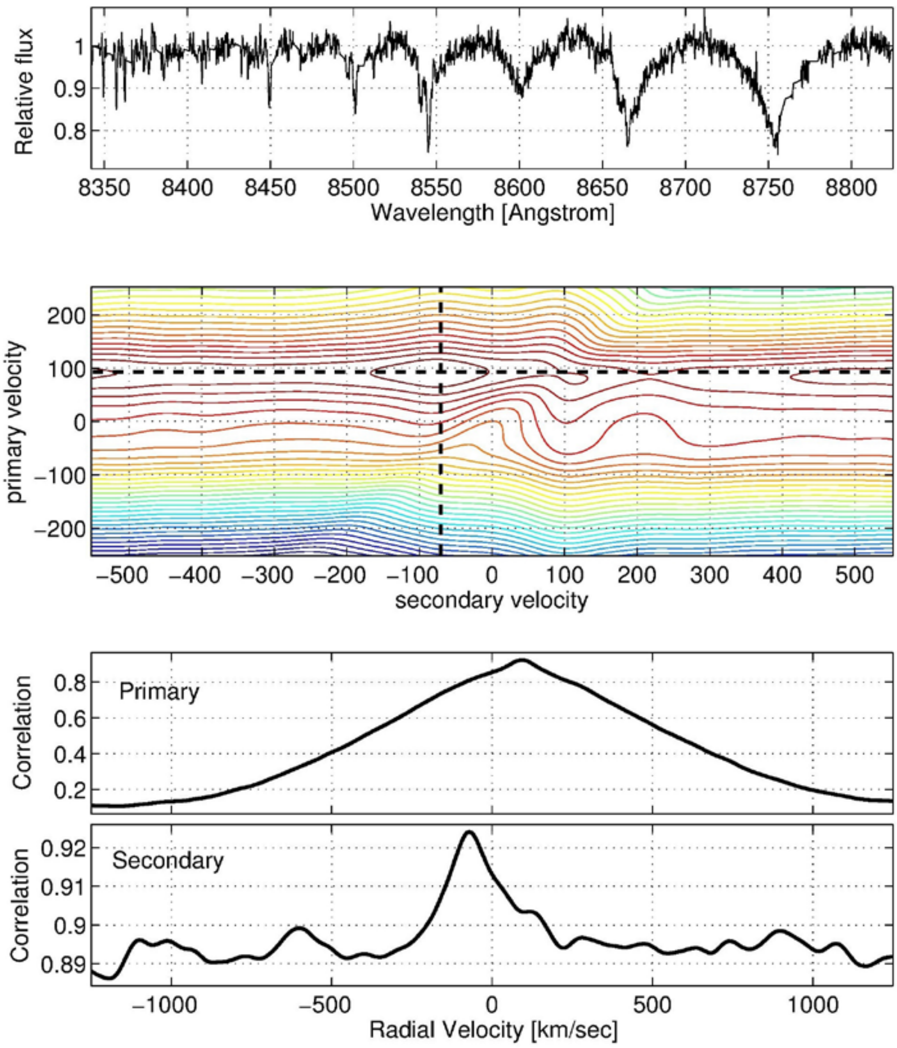


Figure 2: Upper panel: Red AAOmega spectrum of *CoRoT* 105962436. Middle panel: Contour map of the TODCOR two-dimensional correlation function for that spectrum as a function of the primary and secondary radial velocity. The black dashed lines run through the correlation peak. Bottom panel: primary and secondary cuts through the two-dimensional correlation peak.

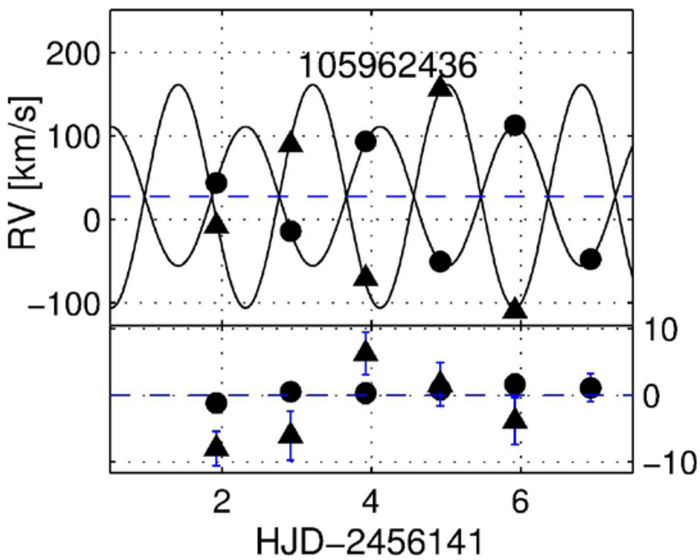


Figure 3: Derived RVs and the best-fit Keplerian model of *CoRoT* 105962436.

Unveiling Exoplanet Atmospheres: Hot Jupiters with IRIS2

George Zhou (ANU), Daniel Bayliss (Geneva Observatory, ANU), Lucyna Kedziora-Chudczer (UNSW), Chris Tinney (UNSW), Jeremy Bailey (UNSW), Graeme Salter (LAM)

The atmospheres of "hot Jupiters" are nothing like the planets in our own Solar System. Hot Jupiters are gas giant planets orbiting extremely close to their host stars, typically with orbital periods of just a few days. Consequently they receive intense irradiation from their host star, and this in turn governs the key characteristics of their atmospheres.

The intense irradiation of hot Jupiters causes them to glow brightly in the infrared. If the planet passes behind its star from our line-of-sight, the star blocks the infrared glow of the planet. To us, this occultation is observed as a dip in the flux of the entire system: a secondary eclipse event (the primary eclipse event is when the planet transits the star). By measuring the magnitude of this extremely small dip in the flux, we can directly measure the temperatures of hot Jupiters' atmospheres (Figure 1).

However, these secondary eclipses are extremely difficult to detect, as the fractional change in flux is at most just 0.3 percent. This has meant that to date only a handful of hot Jupiters have been measured in eclipse at the near-infrared wavelengths from the ground. Measuring the eclipse requires extremely precise infrared photometry over an entire eclipse duration (typically about 5 hours). The hot Jupiters that have previously been observed from the ground have been selected to yield the maximum signal to allow us to detect the eclipse. However this selection causes a bias in our understanding, making it difficult for us to draw robust conclusions on the atmospheric characteristics of the hot Jupiter population.

We have started a program using IRIS2, using the IRIS2 infrared imager on the AAT to measure the secondary eclipses of a selected set of exoplanets. The principle aim of the project is to provide a set of self-consistent temperature measurements to probe the diversity of hot Jupiter atmospheres.

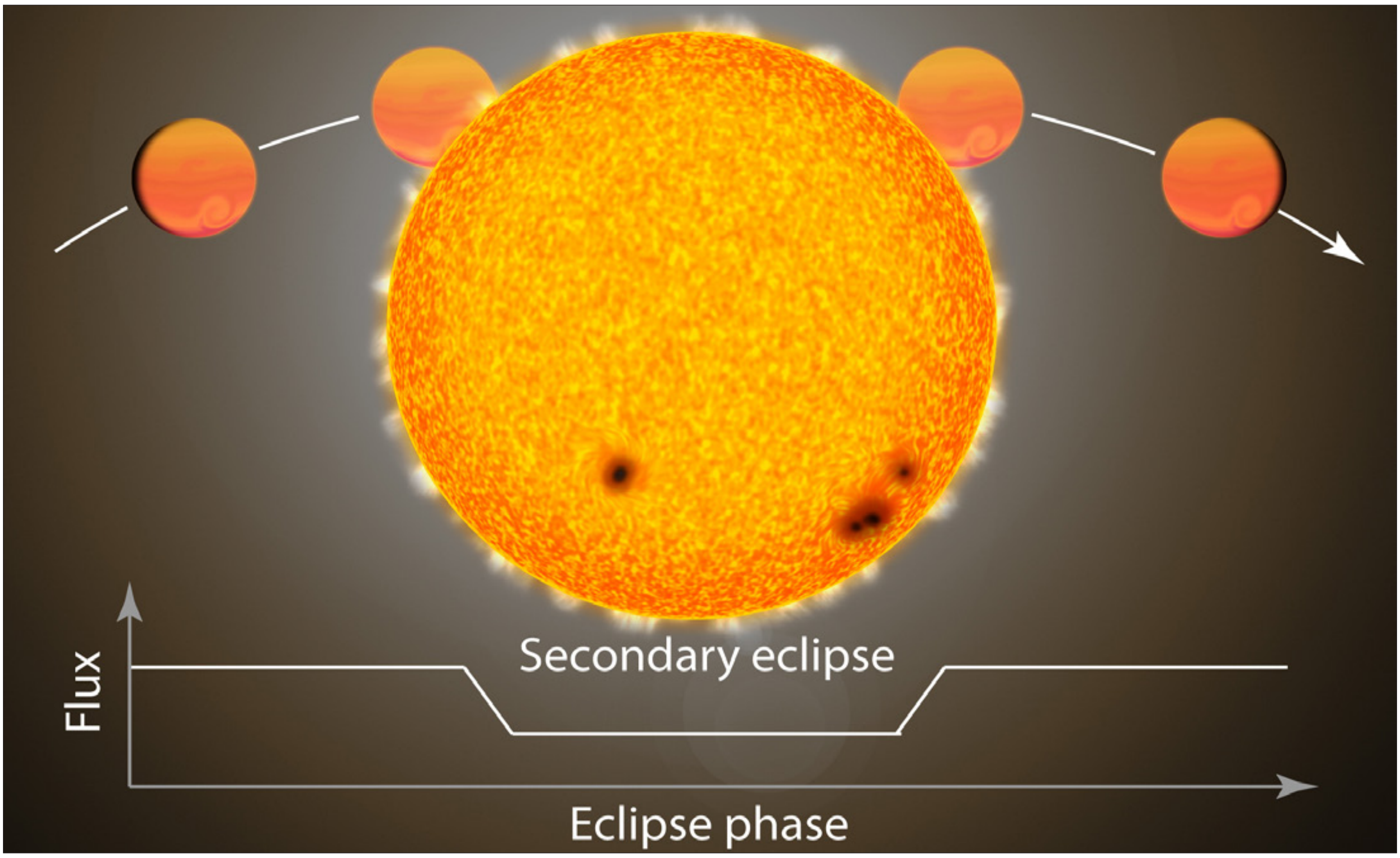


Figure 1: Hot Jupiters are highly irradiated, and thus are bright in the infrared. A secondary eclipse occurs when the planet is occulted by the star, leading to an overall drop in the flux we receive from the system. Due to the small flux ratio between the planet and the star, hot Jupiter occultations induce a fractional drop of less than 0.3%.

The AAT-IRIS2 combination turns out to be one of the best facilities in the world for secondary eclipse measurements. In fact, our observations show a photometric precision **better** than the 8.2-metre Very Large Telescope (VLT) for the same star with the same planetary secondary eclipse signal (Zhou et al. 2014). This remarkable precision is a combination of factors unique to AAT-IRIS2. First, the AAT is one of the largest equatorially mounted telescopes in the world, ensuring a constant optical path through an eclipse observing sequence (i.e. with the AAT there is no pupil rotation). This eliminates one of the largest components of systematic noise which is present in all observations made using alt-az telescopes, such as the VLT. Second, the excellent tracking and guiding of the AAT means we can keep the target star on the same pixel throughout the observations, minimising the effect of pixel-level systematics (which are severe for infrared detectors). And finally, IRIS2 has a wide field-of-view (7.7x7.7 arcmin) compared to other infrared cameras on equatorial telescopes, enabling a large number of comparison stars to be available in any given field – crucial for our relative photometric measurements.

These factors make it possible for us to use AAT-IRIS2 to survey the atmospheric properties over a wide range of hot Jupiters.

To date, we have successfully measured the secondary eclipses of 8 planets with IRIS2 (Zhou et al. 2014, 2015), of which three examples of eclipse light curves are shown in Figure 2. Eclipses as shallow as 0.1% have been measured at 3-sigma significance, demonstrating our ability to probe the atmospheres of mildly irradiated planets.

These observations have allowed us to register day-side temperatures for these planets in the range of 1500 – 3000 K. These early results will be supplemented with a total of 45 planets, whose eclipses should be within the detection limits of IRIS2, and 35 planets from the Northern hemisphere via the NEWFIRM instrument on the KPNO 4 m Mayall telescope. This will form the largest collection of near-infrared secondary eclipse measurements available, allowing the most complete look into the atmospheres of the hot Jupiter population.

Interestingly, we are finding a diverse range of atmospheric properties for these hot Jupiters. The day-side brightness that we measure is dependent on the amount of irradiation received by the planet, and the amount of heat transported away from day-side to the night-side of the planet. The efficiency of day-night heat transport characterises the atmospheric circulation properties of the hot Jupiters, - effects including the strength of global winds, or the presence of jet streams. We can determine this heat circulation efficiency by comparing the measured temperatures, obtained from secondary eclipses, with those predicted by thermal equilibrium (e.g. Cowan & Agol 2011). By combining our results in the KS band (2.1 microns) with those in the mid-infrared from the Spitzer Space Telescope (3.6 – 8.0 microns), we can probe how efficiently the heat is transported at different heights of a planetary atmosphere.

Our results show that the strength of the day-night heat transport "does indeed" depend on both the level of irradiation received by the planet, and the depth of the atmosphere we probe. For the most irradiated planets, the top of their atmospheres (viewed at longer wavelengths) exhibit strong day-night temperature differences, while deeper down (viewed at shorter wavelengths) we find a more thermally mixed environment. In these hottest planets the heat redistribution to the night side is slow compared with efficient radiation of heat away from the day-side. This leads to the large day-night temperature difference at the top of the atmosphere. For more mildly irradiated planets, the day-night temperatures are relatively uniform at different atmospheric depths.

The next step is to make secondary eclipse detections at a variety of near-infrared wavelengths (e.g. J, H, KS) for the same planets. In these wavelengths many interesting molecules, such as water, have absorption bands. We can build up a low-resolution spectrum to help model the physical structure and composition of the planetary atmosphere (e.g. VSTARS, Bailey & Kedziora-Chudczer, 2012). For example, simple models predict that some of the most irradiated planets should have thermal inversions, like the stratosphere of Earth. Early observations suggest that this is not the case for these hot Jupiters. Our survey will help understand the factors that influence the structure of hot Jupiter atmospheres.

References

Bailey & Kedziora-Chudczer, 2012, MNRAS, 419, 1913
Cowan & Agol, 2011, ApJ, 729, 54
Zhou et al. 2014, MNRAS, 445, 2746
Zhou et al. 2015, MNRAS, submitted

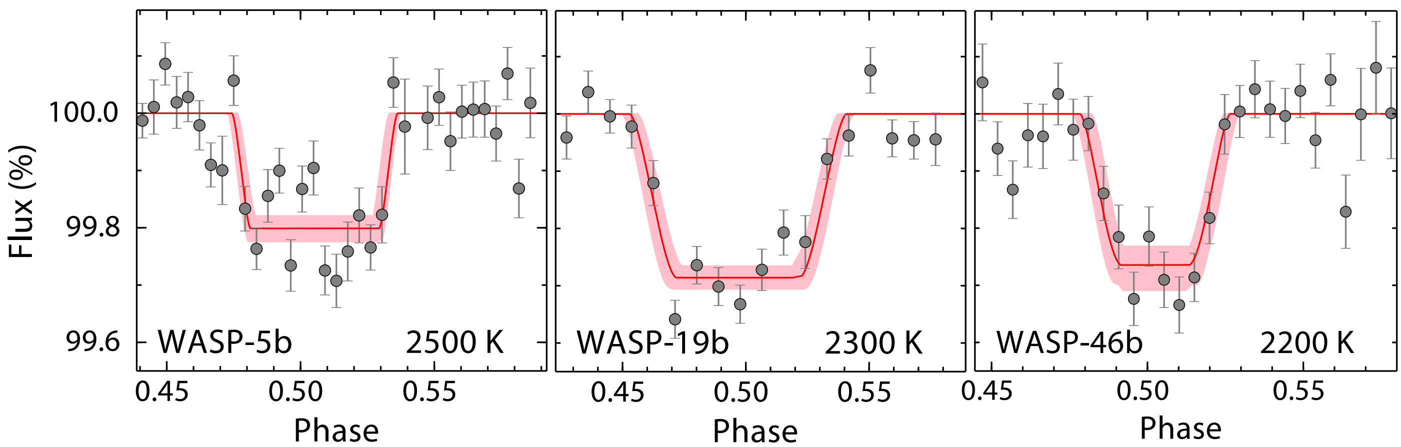


Figure 2: AAT-IRIS2 secondary eclipses light curves for three hot Jupiters from our observations in 2014/2015. The grey points show the photometric measurements, at 10 minute bins. The best fit models are plotted in red, and the pink regions encompass 68% of the allowed models. The high precision light curves from IRIS2 allow us to precisely constrain the day-side temperatures of these hot Jupiter atmospheres.

Taipan Takes Shape

Kyler Kuehn, Nick Staszak, David Brown, Rebecca Brown, Scott Case, Michael Goodwin, Urs Klauser, Jon Lawrence, Nuria Lorente, Slavko Mali, Rolf Muller, Vijay Nichani, Naveen Pai, Keith Shortridge, Julia Tims, Minh Vuong, Lew Waller, Ross Zhelem

For several years, the AAO has been developing and refining the robotic fibre-positioner technology of the Starbugs [1,2], and very soon these efforts will come to fruition on the TAIPAN instrument. Scheduled to begin observations for the TAIPAN survey [3] on the UK Schmidt Telescope (UKST) in 2016, the TAIPAN instrument will initially consist of 150 Starbugs distributed evenly across a 6 square degree field of view.

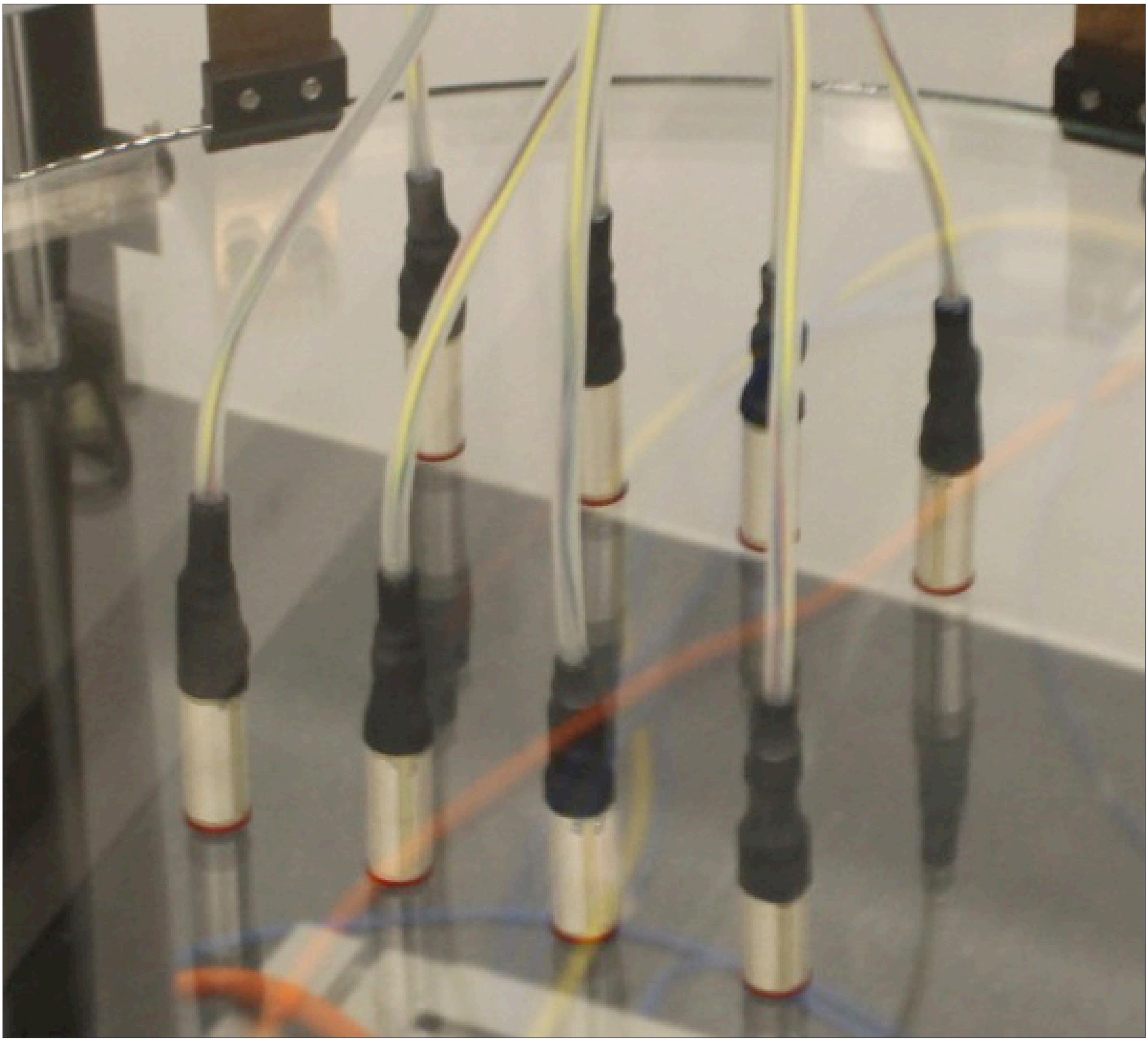


Figure 1: Eight Starbugs being tested in the AAO Optics Laboratory.
Credit: Michael Goodwin

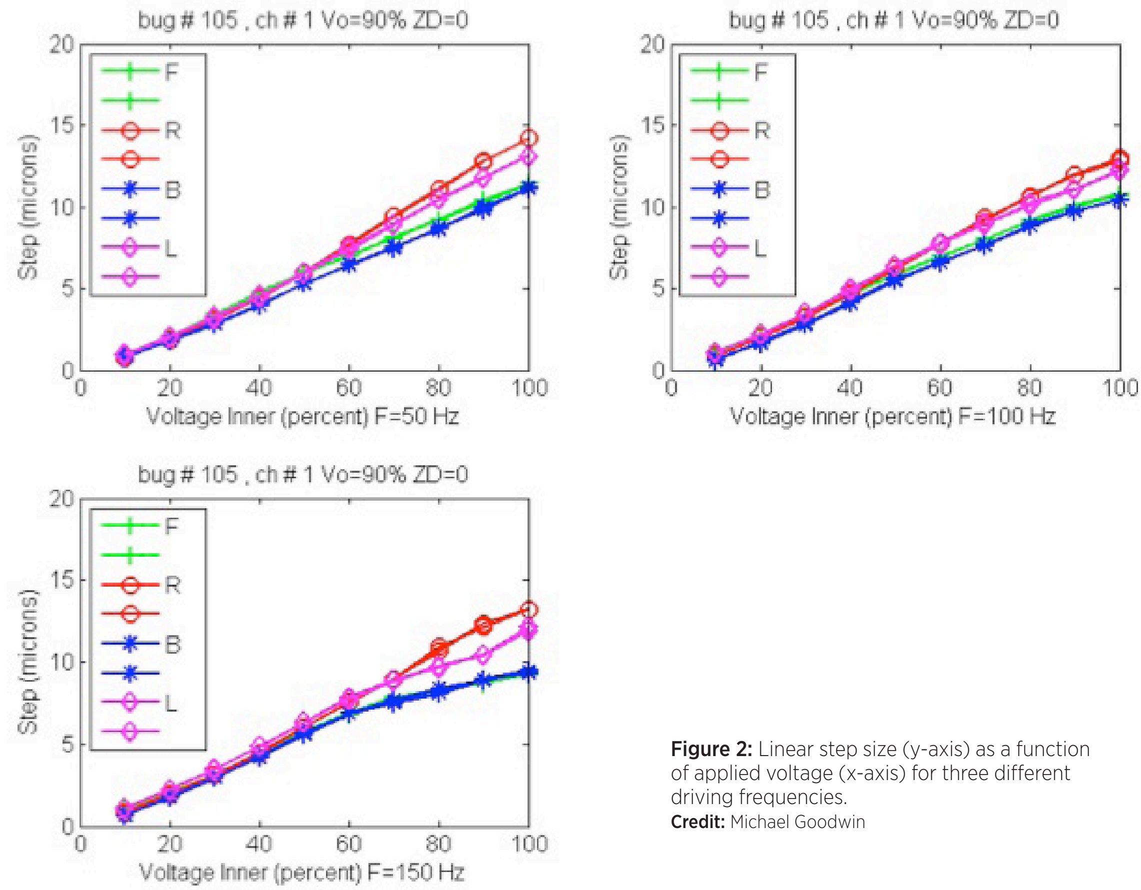


Figure 2: Linear step size (y-axis) as a function of applied voltage (x-axis) for three different driving frequencies.
Credit: Michael Goodwin

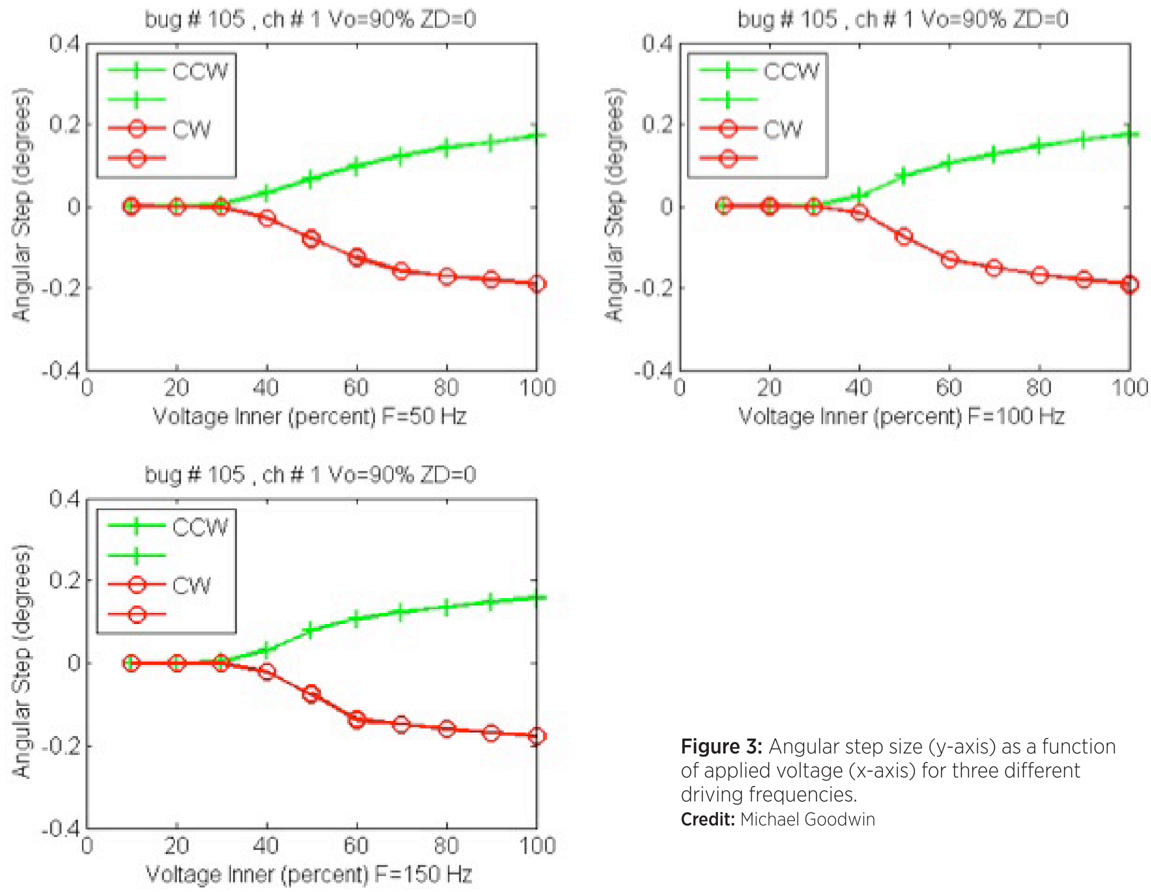


Figure 3: Angular step size (y-axis) as a function of applied voltage (x-axis) for three different driving frequencies.
Credit: Michael Goodwin

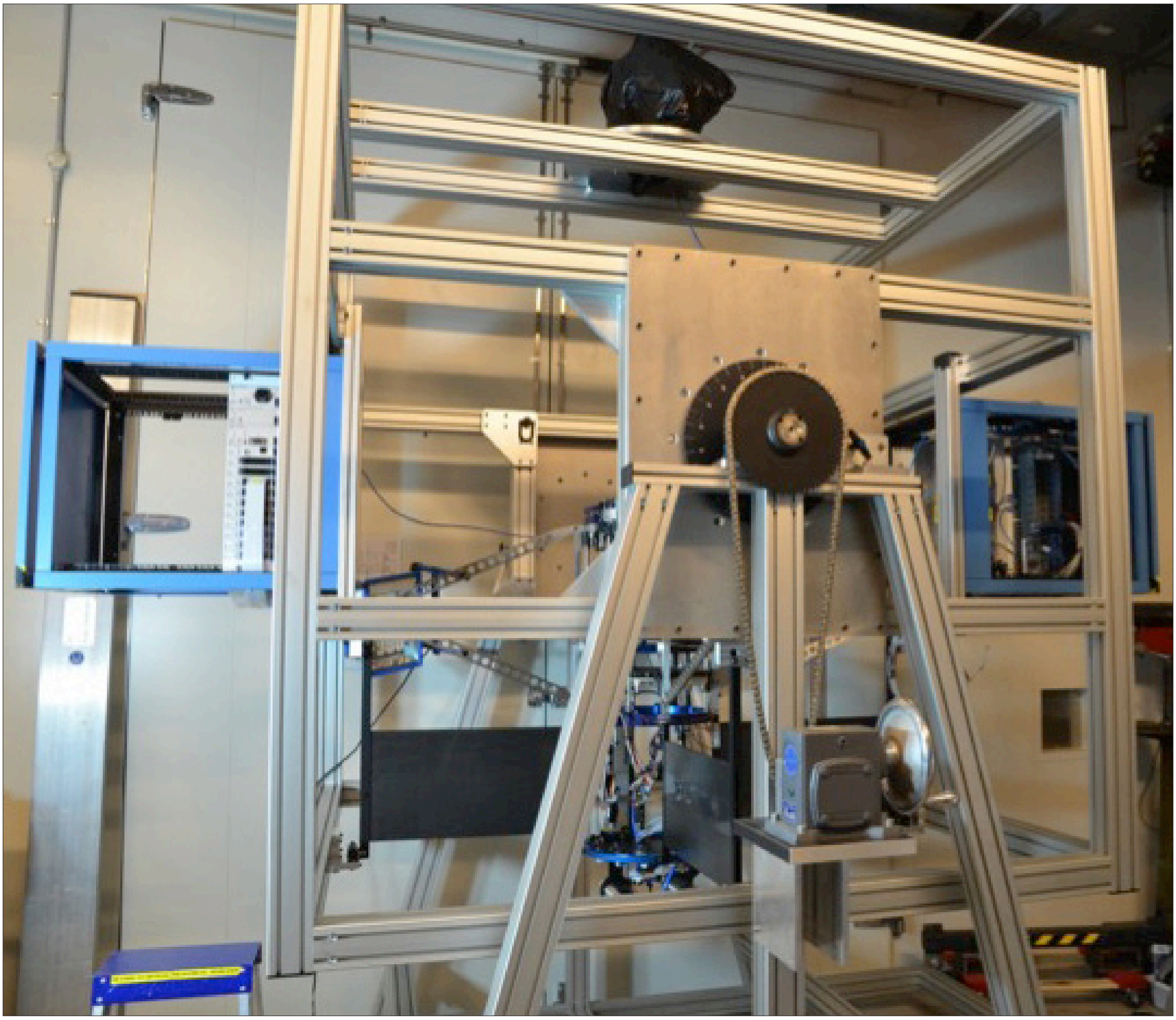


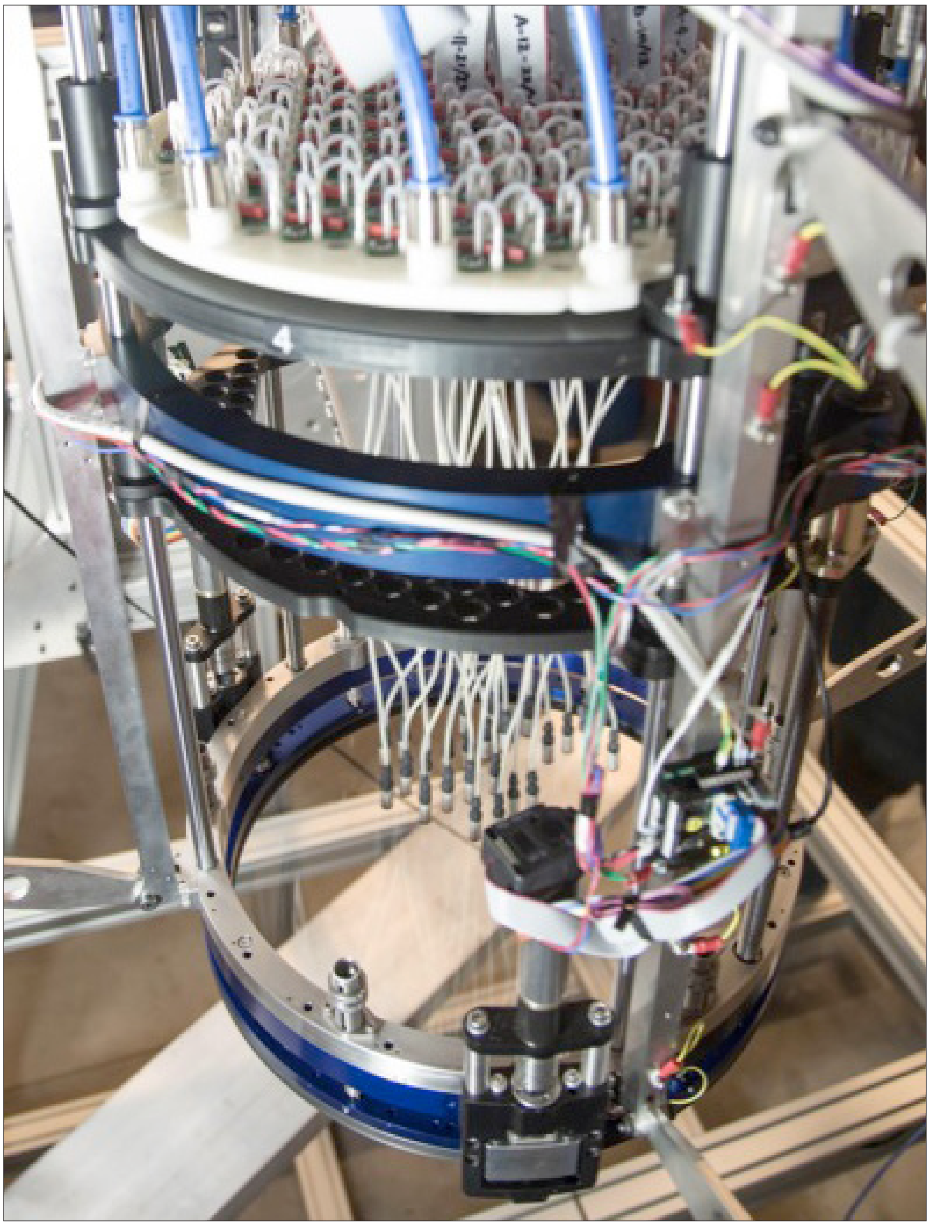
Figure 4: The TAIPAN Integrated Test Facility, capable of rotating to allow the investigation of Starbug performance at any orientation.
Credit: Nick Staszak

Currently, about half of the full complement of Starbugs has been constructed, and about half of those has been fully tested on the 8-Bug Test Rack in the AAO North Ryde Optics Laboratory (Figure 1). These tests include measurement of six different positioner motions (forward/backward linear motion, left/right linear motion, and clockwise/anticlockwise angular motion) as a function of applied voltage and driving frequency. Results show that the Starbugs are meeting or exceeding the strict performance requirements of the TAIPAN instrument (Figures 2 and 3 for details).

Another important milestone that has been achieved recently is the assembly of the primary TAIPAN optomechanical structure and vacuum adhesion system, soon to be moved into the Cleanroom/Integration Laboratory, also at the AAO's North Ryde facilities (Figures 4, 5, and 6). The current state of the instrument is the result of research and development that ambitiously addressed the following design challenges: connector density and voltage limitations, mechanical reliability and construction repeatability, field plate residues and scratching, and metrology stability.

This milestone is a celebration of having conquered these and many other design challenges faced while prototyping a futuristic technology.

Work on the complex Starbug closed-loop Metrology system and Control Software is also well underway, with precise control of individual Starbugs (i.e., positioning to within a few microns) occurring routinely, and testing of an increasingly larger phalanx of Starbugs planned for the latter half of 2015.



TAIPAN will also benefit greatly from the upgrades currently underway on the UKST, including refurbishment of the telescope and dome motors and control system, as well as the installation of the TAIPAN spectrograph (incorporating two new highly sensitive CCD cameras from Spectral Instruments). Once all of these separate components are completed and tested, they will be shipped to Siding Spring Observatory, where installation and commissioning will begin in early 2016. And then the TAIPAN survey will commence!

References

[1] Gilbert, J., et al., AAO Observer (February 2012)

[2] Kuehn, K., et al., AAO Observer (August 2014)

[3] Hopkins, A., et al., AAO Observer (August 2014)

[4] Brown, D., et al., Proc. SPIE 9151, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation, 91511A (August 7, 2014)

Figure 5: TAIPAN, the view from above: 24 Starbugs installed on the glass field plate that will sit at the focal surface of the UKST. The top of the image shows the complicated vacuum and high-voltage electrical wiring required for operation.
Credit: Nick Staszak

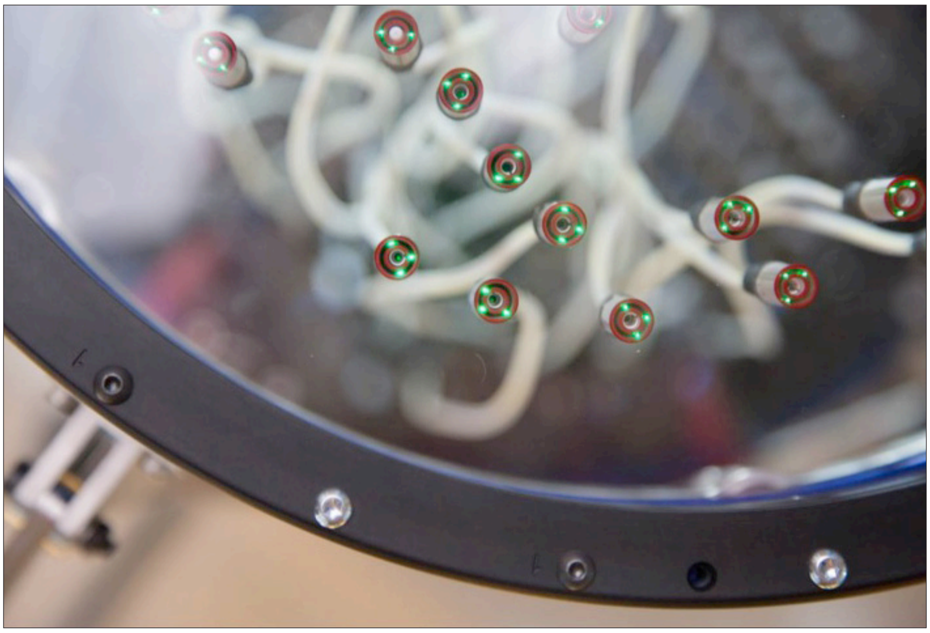


Figure 6: TAIPAN, the view from below: some of the 24 Starbugs installed on the glass field plate, with the Metrology fibres illuminated to allow closed-loop tracking of their positions.
Credit: Andy Green

Southern Cross Astrophysics Conference VIII: "Multiwavelength Dissection of Galaxies"

Ángel R. López-Sánchez AAO/MQ (SOC & LOC Chair)

The Southern Cross Astrophysics Conferences, which are jointly supported by the Australian Astronomical Observatory (AAO) and the CSIRO Astronomy and Space Science (CASS), are held annually around Australia with the aim of attracting international experts with wide ranging skills to discuss a particular astrophysical topic. The conference "Multiwavelength dissection of galaxies", which was held at the Crown Plaza Hotel in Coogee Beach, Sydney between 24th – 29th May 2015, was the 8th of the Southern Cross Conference Series. This Conference focused on galaxy evolution, combining resolved optical/near-infrared integral field spectroscopy data with other multiwavelength properties (from X-ray to radio) of nearby galaxies plus giving the view of what is known in our Milky Way.

Indeed, the number of studies of galaxies using integral field spectroscopy (IFS) is rapidly increasing as a consequence of surveys such as ATLAS-3D, CALIFA, SAMI (that is conducted at the AAT), or MANGA. IFS techniques allow to spatially resolve internal properties of galaxies with unprecedented detail, and therefore they are providing key clues for understanding the structural components of galaxies, their star-formation activity, kinematics, stellar populations, metal distribution, and nuclear activity, as well as how galaxies evolve with time. Nevertheless, for a complete picture of how galaxies work it is crucial to use other multi-wavelength results, targeting galaxies in X-ray, ultraviolet, infrared, and radio frequencies. In particular, HI radio-surveys such as HIPASS, LVHIS, THINGS, Little-THINGS, ALFALFA, HALOGAS or WALLABY are essential to trace the neutral gas content of galaxies, as the 21 cm HI radio data provide key information about how the cold gas in converted into stars and galaxy dynamics. At the same time we are notably increasing our knowledge of the structure and composition of the Milky Way. This is possible thanks to the combination of very detailed observations of individual stars (such those coming from the RAVE survey conducted at the 1.2m UKST or the on-going GALAH survey at the AAT using the new high-resolution HERMES spectrograph), detailed analyses of Galactic nebulae, large field studies of the interstellar medium, and surveys searching for the diffuse gas with and around our Galaxy.

Hence, the aim of the "Multiwavelength dissection of galaxies" Conference was to bring together international experts in both Galactic and extragalactic astronomy to discuss the different components of a galaxy: stars, gas, dust, and dark matter, and where these components are found within and around galaxies, from both an observational (from radio to X-rays, but with a fundamental optical IFS component) and a theoretical point of view (from the most recent simulations of galaxy assembly to models reproducing the chemical evolution of galaxies), with the final objective of getting a better understanding on the processes that rule the evolution of the galaxies.

Around 120 astronomers all around the globe attended to this Conference. In five days we had 94 talks, including 27 invited talks and a Summary talk, and 26 poster contributions. Highlight invited talks were given by Rosemary Wyse (The Structure of the Milky Way), Naomi McClure-Griffiths (Neutral gas in and around the Milky Way), Baerbel Koribalski (Diffuse gas in and around galaxies), Christy Tremonti (Measuring Gas Accretion and Outflow Signatures with MaNGA), César Esteban (Ionized gas in the Milky Way), Evan Skillman (The Chemical Properties of the ISM of Nearby Galaxies), Sarah Martell (Introduction to the GALAH Survey), Geraint Lewis (Galactic Archeology in the Local Group), Alessandro Boselli (The dust emission properties of nearby galaxies after Herschel), Jakob Walcher (News about the interstellar medium in galaxies from the CALIFA survey), Stas Shabala (Resolving the mysteries of AGN feedback:radio jets, galaxies and citizen science), Joss Bland-Hawthorn (Near Field Cosmology), Martin Asplund (The Gaia-ESO survey), Richard Bower (The EAGLE Universe), Lisa Kewley (SAMI Science) and Molly Peeples (A Multiwavelength View of the Circumgalactic Medium).

We also organised a "Poster Contest": participants were asked to vote for their 2 favourite posters, and they got a short (10 minutes) talk during the last session of the Conference. The winners were two PhD students: Christina Baldwin (Macquarie University, Australia, with the poster "Early-Type Galaxy Stellar Populations in the Near-Infrared") and Manuel Emilio Moreno-Raya (Universidad Complutense Madrid and CIEMAT, Spain, with the poster "Dependence of SNe Ia absolute magnitudes on the host galaxies elemental gas-phase abundances").

We have compiled the scientific presentations at the Conference Webpage:

http://www.aao.gov.au/conference/multiwavelength-dissection-of-galaxies

Furthermore, participants were very active in Twitter, that followed the hashtag of the Conference #MDGal15, allowing a wider diffusion of the main results speakers were presenting. We have also compiled all tweets in a Storify for each day, they are available in our website.

Besides the scientific talks, participants enjoyed the social events we organised for the Conference, including a Welcome Cocktail Cruise on Sunday 24th May (delegates enjoyed not only the great views of Sydney Harbour but also a starry sky and the famous ViVID Lights Sydney Festival), a Wine Tasting event on Tuesday 26th, an outdoors barbecue and a visit to Sydney Observatory and Stargazing on Wednesday 27th May, and the Conference

Dinner on Thursday 28th May, which was held at the Spanish restaurant "Postales" in famous Martin Place, Sydney. Furthermore, the AAO organised the Public Event "The Story of Light: The Astronomer's Perspective" on Sunday 24th May at the Powerhouse Museum (Sydney). This event, which was fully booked, was included as part of the ViVID Festival and connected the International Year of Light 2015 with our Conference (see article on page ***).

Overall, we considered it was a great Conference and some important and controversial research topics were actually discussed during those five days, generating new ideas and projects, and many new collaborations between participants (even between Galactic and extragalactic astronomers) started there.

Finally, I would like to thank the impeccable organisation of the staff at Crown Plaza Hotel, as everything worked very smoothly and we didn't have any problems at all during our Conference. In particular, coffee breaks and lunches were very well attended, and we really enjoyed a great quality food. Of course, I also must thank all the members of the LOC and the SOC committees for their invaluable help organising this Conference. In particular, I would like to thank Helen Woods (AAO) for her enormous effort and Andrew Hopkins and AAO's Director, Warrick Couch, for their strong support to this meeting.

Scientific Organizing Committee (SOC)

Joss Bland-Hawthorn (USyd, Australia, Rob Crain (Liverpool John Moores U., UK), Scott Croom (USyd, Australia, Gayandhi De Silva (AAO, Australia), César Esteban (IAC, Spain), Ken Freeman (ANU, Australia, Rosa González-Delgado (IAA, Spain, Andrew Hopkins (AAO, Australia, Helmut Jerjen (ANU, Australia, Lisa Kewley (ANU, Australia), Baerbel Koribalski (CASS, Australia), Sarah Martell (UNSW, Australia), Ángel R. López-Sánchez (AAO/MQ, Australia, Chair, Sebastián Sánchez (UNAM, Mexico, Christy Tremonti (UWM, USA), Lourdes Verdes-Montenegro (IAA, Spain)

Local Organizing Committee (LOC)

Amanda Bauer (AAO), Julia Bryant (AAO/USyd), Gayandhi De Silva (AAO), Jenny Ghabache (AAO), Andrew Green (AAO), Andrew Hopkins (AAO), Megan Johnson (CASS), Ángel R. López-Sánchez (AAO/MQ, Chair, Manuel Moreno-Raya (CIEMAT, Spain), Josh Marvil (CASS), Paolo Serra (CASS), Tye Young (ANU), Helen Woods (AAO)

Conference Photo: The majority of the participants to the "Multiwavelength Dissection of Galaxies" meeting, 24th – 29th May 2015. The background is an image of the Southern sky showing the Southern Cross and the Pointers.
Credit: Conference Photo: Andy Green (AAO), Background image & composition: Ángel R. López-Sánchez (AAO/MQ).

The Story of Light – The Astronomer's Perspective

Amanda Bauer (AAO)
All photos–Angel Lopez-Sanchez (AAO/MQ)

Almost everything we know about the Universe comes from light emitted by stars and gas, and we took the opportunity during this year's VIVID Sydney festival to tell the public about it! In May 2015 we held an event called *The Story of Light – The Astronomer's Perspective*, as part of our annual Southern Cross Conference Series, and inspired by the International Year of Light and Light Technologies 2015.

The event took place at the Powerhouse Museum on Sunday 24th May as part of Sydney's popular VIVID Ideas festival, which meant that tickets sold out very quickly and we happily attracted a broader audience than usual.

The event brought together four enthusiastic, professional astronomers to describe how we use light and light-based technologies to uncover exciting mysteries of the Universe and improve our understanding of cosmology, exoplanets, the Search for Life and more.

The afternoon began with an entertaining welcome by host Dr Justine Rogers, UNSW Law Lecturer and regular among Sydney's stand-up comedy circuit. Justine offered a perfect warm up for the event by sharing her love of facts and humour with the audience.

The AAO's Prof Fred Watson began the science discussion with a presentation on what light is and how we experimentally made these discoveries over the last many centuries.

Next Prof Joss Bland-Hawthorn from the University of Sydney described several light technologies. He started by introducing the technique of spectroscopy, then moved onto photonics, an area of development his team has pioneered. He finished by explaining that future generations of telescopes will require many lasers to work together in adaptive optics systems to obtain crisp images of the night sky.

CSIRO's Keith Bannister gave an entertaining description of the basic principles of radio astronomy. He shared his love of fourier transforms, described how wifi was invented and patented by CSIRO's John O'Sullivan, and introduced the next generation of radio telescopes being built in Australia, including the Square Kilometre Array (SKA).

I rounded out the presentation portion of the afternoon by showing how all these technologies and observations of different types of light have been used to shape our understanding of galaxy formation theory.

1

The final session included a panel discussion lead by Dr Rogers taking questions from the audience. A particular highlight for me was Keith Bannister's clear explanation of the recent result that the microwave in the Parkes Radio Telescope kitchen has been tricking astronomers with false signals for years! If a hungry astronomer opens the microwave door while the microwave is still actively working, a blast of energy is sent out which the Parkes dish can be sensitive to!

The two things that stuck with me at the end of the event were a greater appreciation for how much Australia has contributed to worldwide technology development and astronomy research over the last 50 years, and also, eat with patience, astronomers!

Figure 1: Host Justine Rogers introduces the panel at The Story of Light – The Astronomer's Perspective.

Figure 2: The panel members are (L to R) Amanda Bauer, Keith Bannister, Joss Bland-Hawthorn, Fred Watson, and host Justine Rogers.

Figure 3: Fred Watson speaks to the crowd.

Figure 4: My turn to explain what different types of light tell us about galaxies.

Figure 5: The crowd enjoys the show.

ITSO Corner

Stuart Ryder (International Telescopes Support Office, AAO)

Proposal Statistics

A total of 37 Gemini proposals were received by ATAC for Semester 2015B, a jump of 40% over the numbers in recent semesters. There were 16 proposals for Gemini North; 11 for Gemini South; 8 for both Gemini North and South; and two Subaru exchange time requests. Including exchange time requests the oversubscription for Gemini North surged to 3.7 in 2015B; while demand for Gemini South also rose to 2.8. The new GRACES facility on Gemini North, providing a long-sought high-resolution optical spectroscopy capability via a fibre-link to the ESPaDOnS spectrograph at CFHT, proved particularly popular with the Australian community. ATAC allocated time to 18 queue programs in 2015B, including 6 joint proposals. Three programs had observing condition constraints and scientific rankings which made them suitable for allocation into the Poor Weather Queue.

Magellan demand in 2015B also showed a significant increase over 2015A, with 17 proposals received and an oversubscription of 5.6, the highest ever. IMACS, FIRE, FourStar, and the new multi-fibre spectrograph system M2FS were the most popular instruments, and the balance in demand between Baade and Clay was much improved over recent semesters.

ITSO road show

Part of the growth in demand for Gemini and Magellan time in Semester 2015B may be attributed to Stuart Ryder's recent "road show" of major user institutions around Australia to highlight impending changes and new capabilities. He gave presentations at the AAO (9 March), Swinburne University of Technology (11 March), the University of Western Australia (12 March), the University of Queensland (13 March), the University of New South Wales (16 March), and the ANU's Research School of Astronomy & Astrophysics (24 March). This was also a good opportunity to hear feedback from our community on what services they would like to see ITSO provide in the future.

Transition from AusGO to ITSO

As part of the ongoing transition from the former Australian Gemini Office to the new International Telescopes Support Office, all e-mail concerning Gemini, Magellan, Keck, or DECam access should now be directed to itso@aao.gov.au. E-mail to ausgo@aao.gov.au will continue to be forwarded to this new address in the short term. Also, keep an eye out for the new ITSO web portal at http://www.aao.gov.au/itso which will replace the existing AusGO web site.

International Telescope Access in 2016A

In Semester 2016A, ITSO will be supporting the following observing time on international telescopes:

- 3–4 classical nights on the Gemini telescopes, possibly with a "mini-queue" of smaller programs.
- 8 classical nights on the Magellan telescopes.
- 7–8 classical nights on the Keck telescopes, allocated by a new joint Keck time allocation committee which will assess proposals seeking time from one or more of the AAL, ANU, or Swinburne pools of nights.
- 5 nights with DECam on the Blanco 4 m telescope on Cerro Tololo, via a time exchange agreement with the AAO.

Please keep an eye on the ITSO web site, the AAO Facebook (https://www.facebook.com/AustralianAstronomicalObservatory)

and Twitter (@AAOastro) accounts, and the Astronomical Society of Australia membership e-mail exploder for the respective Calls for Proposals, and please get in touch with us if you have any questions about how to use or apply for time on these facilities.

AGUSS

The Australian Gemini Undergraduate Summer Studentship (AGUSS) program offers talented undergraduate students the opportunity to spend 10 weeks over summer working at the Gemini South observatory in La Serena, Chile, on a research project with Gemini Staff (Figure 1). They also assist with queue observations at Gemini South itself, and visit the Magellan telescopes at Las Campanas Observatory. Thanks to extra funding from AAL, we will be able to support three AGUSS students in 2015/16 instead of the usual two. Applications close on Monday 31 August 2015; please refer any interested students to http://www.aao.gov.au/science/research/students/gemini for details on how to apply.

Figure 1: 2014/15 AGUSS student Rhiannon Gardiner at Gemini South.

Figure 2: Participants at the second day of the 2015 Australian Gemini, Magellan, and Keck Science Symposium.

2015 Australian Gemini, Magellan, and Keck Science Symposium

Following the first very successful Australian Gemini and Magellan science symposium in 2012, ITSO hosted a similar event on 21 & 22 May 2015 at the AAO in Sydney. This meeting also featured Australian science being conducted with the Keck telescopes, in recognition of the fact that our users at Swinburne University of Technology as well as at the Australian National University already enjoy access to these telescopes, as will the entire Australian community from 2016. Participants were introduced to the full "smorgasbord" of instrumentation they will have access to on Gemini, Magellan, and Keck from next year. There were 24 speakers, 6 of whom are PhD students, and a total of 36 participants over the two days (Figure 1). Presentations are available from the Program tab of the meeting web page at https://www.aao.gov.au/conference/itso-symposium-2015.

Future & Science of Gemini Observatory Meeting

A meeting on the "Future & Science of Gemini Observatory" was held in Toronto, Canada from 14–18 June 2015 (http://www.gemini.edu/fsg15). Although Australia will no longer be a full member of the Gemini partnership after 2015, it will retain some access thereafter, and has a stake in ongoing instrumentation projects including GHOST and the GeMS wavefront sensor upgrade. Stuart Ryder and Andy Sheinis from the AAO gave talks at the meeting, and ITSO provided travel subsidies to assist Chris Tinney (UNSW), Sarah Sweet (ANU), and Rob Bassett (Swinburne) in attending and giving talks on their research using Gemini. Stuart Ryder represented the interests of Australian users at the Users Committee for Gemini meeting on 19 June.

Recent Science Highlights

RSAA astronomer Dr Brad Tucker was part of an international team which used the Kepler planet-hunting satellite to watch 3 Type Ia supernova events unfold in their entirety from before the onset of explosion. These light curves show no signature of the supernova ejecta interacting with nearby companion stars, indicating that each was the result of a merger of a white dwarf with another white dwarf, or other compact object. Central to this study was early-time spectroscopy in target-of-opportunity mode with the Gemini telescopes that confirmed the Type Ia nature of these events. For full details see Olling et al. 2015, Nature, 521, 332.

In recent months there have been two papers which have made use of Director's Discretionary Time on Gemini to quickly confirm and follow up Australian-led discoveries:

- Kim et al. used DECam time in July 2014 obtained as part of the AAO/NOAO time swap program to identify a stellar overdensity in Indus. Within 3 months they had acquired GMOS-S imaging and compiled a colour-magnitude diagram which confirmed that this object, designated Kim 2, is the most distant Milky Way globular cluster yet known, at over 100 kpc. See Kim, D., Jerjen, H., Milone, A., Mackey, D., & Da Costa, G. 2015, ApJ, 803:63.
- Allison et al. used commissioning data from the Boolardy Engineering Test Array (BETA) of ASKAP to conduct a blind search for the 21cm line in a continuous redshift range between z=0.4–1.0. They detected absorption at z=0.44 towards the radio source PKS B1740−517 which had no known redshift. Within a month of this discovery they had obtained a GMOS-S spectrum which confirmed the redshift and that the absorption is intrinsic to the host galaxy. They also found broad, double-peaked [O III] and [O I] emission lines in the Gemini spectrum, pointing to outflowing ionised gas. See Allison, J., et al. 2015, MNRAS, submitted (arXiv:1503.01265).

News From North Ryde

Jeffrey Simpson (AAO)

Ángel López-Sánchez took the lead in organizing of the latest Southern Cross Astrophysics Conference with the topic this year of “Multiwavelength Dissection of Galaxies”. As the title implies, this covered everything from gas and dust in our own Galaxy to the large-scale structure of the Universe, across every part of the electromagnetic spectrum.

Amanda Bauer was selected as one of the “Top 5 under 40”. ABC Radio National in conjunction with UNSW uncovered the very best early career researchers. Amanda was the only physical scientist selected and became a "Scientist in Residence" at the ABC. There she produced a segment for Radio National entitled "Journey to the edge of a forming galaxy". You can listen to her here: http://www.abc.net.au/radionational/programs/scienceshow/journey-to-the-edge-of-a-forming-galaxy/6645602

A lone worker protection dongle has been implemented for when working alone at North Ryde. For the astronomers, this comes in the form of a sensor that detects if you are lying back too far in your chair. Certainly makes sure there is no sleeping on the job while remote observing.

Staff Changes

Since the last Observer we have welcomed **Jeffrey Simpson** (talking about myself in the third person here) as a new Research Astronomer for a three-year appointment. This is Jeffrey’s first postdoctoral position and he is tasked with providing support for the AAO’s high resolution spectrographs HERMES and UCLES as well as being the editor of the AAO Observer.

The AAO is developing the AAT node of the All Sky Virtual Observatory (ASVO) project, which required two new database engineers. **Lloyd Harischandra** is a database software engineer and previously worked at University of Western Sydney in their eResearch group. The other position was filled by **Andy Green** who decided to move ‘sideways’ from his position as an AAO research astronomer.

Iraklis Konstantopoulos and **Millie Maier** have left us to take up jobs outside of astronomy research. We wish them well in their new endeavours.

Quentin Parker (held a joint AAO/Macquarie Uni position) departed Australia to take up a position as the Head of Physics & Astronomy at the University of Hong Kong. Quentin had been with the AAO for many years, and had played a significant role in building, maintaining and growing the links between AAO and Macquarie, in addition to major surveys including RAVE as a key highlight, among many other achievements.

Winter Students

We have a full complement of winter student fellows with us. **Maria Hammerstrøm** (Oslo) and **Jenifer Millard** (Cardiff) are working with **Lee Spitler** and **Anthony Horton** on the Huntsman Eye project. **Rhys Poulton** (Sussex) is working with **Chris Lidman** on the growth of massive galaxies. **Puttiwat Kongkaew** (Santa Cruz) is working with **Jessica Zhang** and **Michael Goodwin**. **Ioana Ciuca** (Durham) is working with **Sarah Brough** on measuring the environments in which galaxies live.

Letter From Coona

Zoe Holcombe

Hello from SSO,

February

Planning for this year’s StarFest began by finding some fantastic people to do "Science in the Pub" and the Bok Lecture. The line-up for Science in the Pub will be: Robyn Williams (host), Fred Watson, Amanda Bauer, Naomi McClure-Griffiths, Vanessa Moss and Vicki Meadows.

Vicki Meadows will deliver the Bok Lecture on the Sunday and will share her thoughts on “NASA’s Search for Life Beyond the Solar System”.

For more information check out our Facebook Page “StarFest Siding Spring” and also www.starfest.org.au

White out: The AAT is over there... somewhere

March
The month started with the annual aluminising of the AAT mirror. A few big days of work were put in by all staff at the AAT and the mirror was once again ready for another 12 months of work.

We then had a major problem with the AAT Dome Shutter with the arch girder developing a major crack where there had already been delamination and stress. All observing was suspended and contractors made themselves available to fix the problem straight away. We erected 2 huge tarpaulines over the shutter, which required staff to scale the dome from the outside. We also took on extra work over the weekend to get the job done so observing could resume in just under two weeks.

The Advisory Committee made its annual visit to site, and we had the usual big spread for lunch and I also made Coconut Crème Brulee and Chocolate Mousse for the ladies from North Ryde and a few from Canberra (brownie points!)

So all up March 2015 was HUGE for the AAT staff, big pat on the back to all.

May
We welcomed Shane Paul to the team of mechanical technicians, Shane has come from Melbourne and brings with him his wife Amie and 18 month old son Sam.

We had elections for our new health and safety representatives, Glenn Zaneson and Deputy Raelene Suckley have taken on these positions.

The new kitchen area on the first floor was completed, Darren Mathews has done a great job and it is so much better than the area we had for coffee before. The area will make catering for meetings so much easier and also a good place to sit down and have a chat on the lounges. Come and check it out when you're here next.

Martin Oestreich, from the Electronics Team left the AAO and we wish Martin all the best for the future.

July
Eliot Young gave the staff here at the AAT a very insightful talk on Pluto. This is the second time the AAT staff has had the opportunity to hear about Pluto: last year we had Dr Amanda Gulbis. The staff here always enjoy listening to visiting astronomers inform us about what they are doing at night.

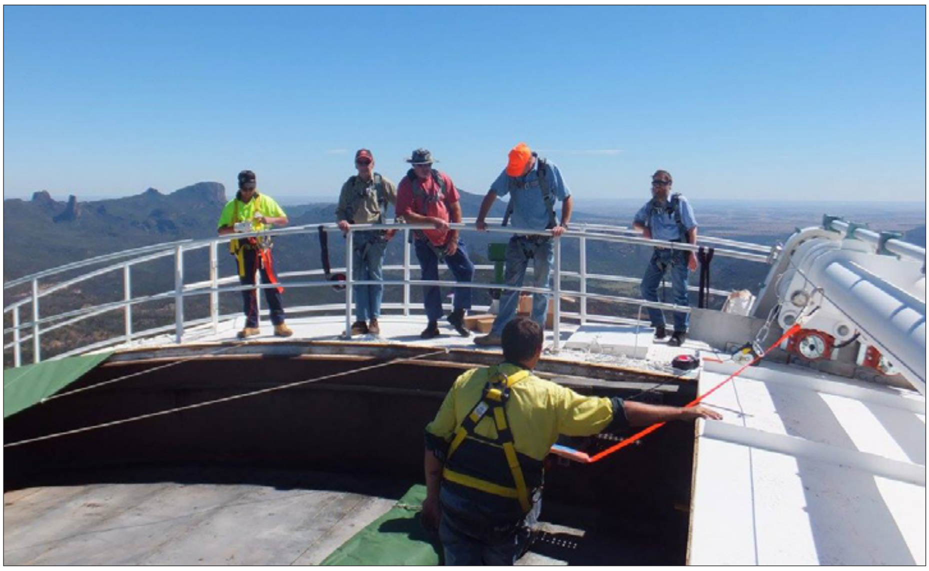
July has been very wet and we have seen snow at least 3 times this month, the worst was Sunday 12th where the mountain completely froze up and saw tree branches snapping due to the weight and wind and ice on the mountain road [Editor: In our last Observer, Zoe was very excited by the first snow she had ever seen in Coona]. The best fall we had was on the 17th though.

By the time we got to site some of it had melted but we still got to have photos and play. A reminder to all to take care on the mountain road this time of year as we have also had a fair bit of black ice.

So that is all the news from SSO, until next time.

Zoe

Little people on the dome: During the dome shutter repair, it was necessary to erect 2 huge tarps over the shutter to protect the interior of the dome from the elements.



Safety first: SSO staff and contractors get a great view while repairing the dome shutter and arch girder.

Above: The Moon, Venus, Jupiter, Regulus and the SkyMapper dome at sunset from the AAT catwalk on 19 July 2015.

Below: The Moon, Venus, Jupiter and Comet C/2014 Q1 (PANSTARRS) from the AAT catwalk on 19 July 2015.

Images provided by Steve Lee with a Canon 6D and 24-105mm lens.

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Published by the Australian Astronomical Observatory
PO BOX 915, North Ryde NSW 1670, AUSTRALIA

AAO Sydney
Telephone: (02) 9372 4800
Fax: (02) 9372 4880

AAO Siding Spring
Telephone: (02) 6842 6291
Fax: (02) 6842 2266

Email: director@aao.gov.au

www.aao.gov.au