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Australia and ESO sign a decadal Strategic Partnership

HERMES images with the Photonics Comb | 2dfdr - 20 years of evolution | Night life of Night Assistants

Director's message

Warrick Couch

Never before in writing my usual message for the AAO Observer have I been in a position to report such transformative events that have taken place over the last few months in terms of the future of Australian optical astronomy and the AAO itself.

This all started with the announcement of the Federal Budget on the evening of 9 May. Contained within the Budget was the news that as part of a new measure entitled *Maintaining Australia's Optical Astronomy Capability*, the government would fund a 10 year strategic partnership between Australia and the European Southern Observatory (ESO), involving an investment of $26.1M over the next 4 years, and a total of $120M over the next 11 years. Not only does this address one

Contents

Australia and the European Southern Observatory (ESO) have signed a 10-year Strategic Partnership. The photo shows all the signatories of the Australia-ESO agreement. From left to right: Virginia Kilborn (President of the Astronomical Society of Australia), Warrick Couch (Director of the AAO), Sue Weston (Deputy Secretary, Department of Industry, Innovation, and Science), Senator the Hon Arthur Sinodinos (Minister for Industry, Innovation, and Science), Tim de Zeeuw (Director General of ESO), Brian Schmidt (Vice Chancellor of the Australian National University), Laura Comendador (Head of the ESO Cabinet), and Patrick Geeraert (ESO Director of Administration).

Credit: Stuart Ryder (ITSO/AAO)

of the most important and urgent priorities of the current Australian Astronomy Decadal Plan – having access to the equivalent of 30% of an 8m optical/infrared telescope through a long-term partnership – but realizes a long-held ambition that the Australian astronomy community has had for more than 20 years. Indeed I well remember how close we came to joining ESO back in 1995. With ESO membership having been ranked as the highest priority for expenditure of the government's major national research facility funding, there was every expectation that it would be approved. But with a general election looming and Australia's economy being weak, the Keating cabinet decided at the last minute not to fund ESO membership, in fear that the required expenditure of tax payers' money overseas would not be a good look politically.

When Australian membership of ESO was being considered back in 1995, it was for full membership. Importantly, the 10 year "Strategic Partnership" with ESO funded through this year's Budget is both different to full membership but also provides Australia with the option of achieving it in the long-term. Moreover, it represents an excellent deal for Australia. Specifically, at a cost considerably below that of full membership, it gives Australian astronomers access to what they need most – the optical telescopes at ESO's La Silla and Paranal Observatories (LSP), in particular the 8m Very Large Telescope (VLT), consisting of four 8m telescopes as well as the world's leading optical interferometer facility (VLTI). With Australia's GDP-based share of ESO being ~7.5%, this access to the VLT realizes the Decadal Plan goal of having a 30% share of an 8m. Added to this, Australian instrumentation groups and industry will be able to compete for all contracts and work associated with LSP and its telescopes, as though Australia was a full member state. Having been involved in the negotiations with ESO, I cannot emphasize enough what an enormous attraction Australia's excellence and innovation in astronomical instrumentation is to ESO in having Australia become a strategic partner.

So that Australian astronomers could have access to the LSP facilities as soon as possible (viz from April 2018), the Department of Industry, Innovation and Science (DIIS) moved very quickly to negotiate and finalise the Strategic Partnership Agreement with ESO. On the morning of Tuesday 11 July, the agreement was signed by the Minister for Industry, Innovation, and Science, Senator the Hon Arthur Sinodinos, and the Director General of ESO, Prof Tim de Zeeuw, at the ASA Annual Scientific Meeting being held at ANU (see Fig. 1). This marks the beginning of an exciting new era for Australian astronomy, a fact that was readily appreciated and enthusiastically applauded by the 200 or so astronomers who were present at the signing.

What does the future hold for the AAO in the new ESO era? First of all, it needs to be understood that the funding of the ESO partnership by the government also relies on a new partnership between it and the research sector in funding and governing optical astronomy infrastructure – an expanded 'package' that now includes ESO as well as the AAO. The government pays for ESO and in return the research sector must now fund and govern the AAO (remembering it is currently a division within the Department of Industry, Innovation & Science, DIIS). In doing so, the looming issue of the AAO's current funding program terminating in mid-2020 is resolved. While many details are yet to be worked out and agreed upon – and there will be a lot of devil in this detail – in broad terms, this will see the AAO split into two entities: (i)The operations of the AAT and UKST, which will be funded and governed by a consortium of universities led by the ANU, and continue for a minimum of 7 years. (ii)The AAO's instrumentation capability based in Sydney, that will be primarily funded through AAL (which has committed $5M per year of its NCRIS allocation) in partnership with universities, particularly those based in Sydney who might host and co-invest in this activity. The target date for having these new arrangements in place is 1 July 2018, bearing in mind that the final two years of the AAO's current funding will be repurposed to pay for ESO.

The massive task of determining what these new arrangements will be and transitioning to them has now begun. Here DIIS will consult closely with the AAO Advisory Committee (AAOAC). An important initial step is to establish the basic principles, boundary conditions and most judicious options for establishing (i) and (ii) above. For AAT operations, this will involve an external review to be undertaken by Markus Kissler-Patig, the outgoing Director of Gemini, who will advise the ANU-led consortium on what operational models should be considered that best meet the underlying objectives of government in funding the *Maintaining Australia's Optical Astronomy Capability* measure as well as the needs of the astronomy community. For AAO-Sydney, DIIS is currently working with the AAOAC on establishing the main principles and boundary conditions in transitioning it to a national instrumentation capability. It is also in the process of forming a high-level reference group that will provide it with expert input into its planning and implementation, making sure all

Fig 1. An historic day for Australian astronomy – the Minister for Industry, innovation and Science, Senator the Hon Arthur Sinodinos, and the Director General of ESO, Tim de Zeeuw, sign a 10 year Strategic Partnership Agreement between Australia and ESO.

key stakeholders are represented.

As mentioned above, the world-leading instrumentation capability that currently resides at the AAO in Sydney (and indeed more broadly in Australia) is a strength much valued by ESO. Maintaining this capability is critical to maximizing the scientific and economic returns on the government's investment in ESO. It is also the vehicle for achieving another key government imperative in this context: to deliver a wider range of industry-focused R&D and commercial activities. Hence great care and thought is required to preserve this extremely valuable asset in transferring it to these new governance and funding arrangements, and to ensure it has every chance of thriving into the future.

Here we should not forget that the AAO's current instrumentation program is a major going concern with numerous multi-million dollar instrumentation contracts (e.g. GHOST, 4MOST), an external revenue stream this financial year of $8.6M, and a range of world-leading technologies (e.g. Starbug and Echnidna positioners, OH-suppression systems) that are certain to play a vital role in future ESO and GMT instrumentation.

Hence as well as retaining the extraordinary talent and IP that currently resides within the AAO, there are, in my view, two key

requirements critical to the survival and success of the organization going forward. Firstly, stable, long-term funding, remembering that the lifetime of telescope instrumentation projects (from concept development through construction to commissioning) is at least 5 years. Moreover, a key part of the ESO instrumentation procurement model is that the member states contribute the labour costs. Secondly, the retention of the world-renowned "AAO" brand.

Finally, I have said numerous times that another key element to the AAO's success has been it having so many talented, long-serving, and loyal staff. No one epitomizes this more than Steve Lee, who is legendary world wide for his skills as an AAT night assistant, as well as an instrument maker. On 25 July, Steve reached the amazing milestone of having worked at the AAO for 40 years, and it was a great pleasure to join the celebration of this at the AAT and acknowledge Steve's many contributions to the AAO and astronomy over this period (see Fig. 2). I am sure many users of the AAT who have had Steve as their night assistant will be equally appreciative and hold him in the same very high regard.

Fig 2. Celebrating Steve Lee's 40 years of service at the AAO.

2dFdr

20 years of evolution

Chris Lidman[1], Michael Birchall[1], Tony Farrell[1], Scott Croom[1,2], Francesco d'Eugenio[3], Andy Green[1] and Tayyaba Zafar[1]

Introduction

2dFdr is the AAO's software package for processing data from fiber-fed instruments. Originally designed to process data from the 2dF instrument (Lewis et al. 2002), it now processes data from all of the AAO's fiber-fed instruments, and is currently being updated to process data from TAIPAN, which is due to enter operations later this year.

Over the 20 years it has been in use, 2dFdr has undergone many changes. In this article, we provide an overview of the some of the more recent changes that have been made to 2dFdr, and look forward to how 2dFdr might evolve into the future.

A Brief History

The primary purpose of the original 2dF instrument was to obtain hundreds of thousands of redshifts, and the first version of 2dFdr was designed with that goal in mind. As new fiber-fed instruments were installed and as astronomers began to require more from the data, 2dFdr has had to evolve. In the period from 2004 to 2007, it received major upgrades to support the AAOmega spectrograph (Smith et al. 2004), both for the multi-object mode with the 2dF feed and the IFU mode with SPIRAL. Improvements at that time included moving from the NDF file format to FITS, removing STARLINK dependencies, and moving to GNU autoconfigure to manage the builds.

2dFdr now processes data from four AAT instruments (HECTOR with its single fiber feed, and AAOmega with its three fiber feeds: SAMI, KOALA, and 2dF) and will soon process data from TAIPAN. Legacy instruments, such as the original 2dF instrument, 6dF, and SPIRAL are still supported. Every instrument is different. 2dFdr has to be flexible enough to account for these differences and to process data that range by a factor of 40 in spectral resolution and 10,000 in flux.

The 2dFdr Working Group

Updates to 2dFdr are managed by the 2dFdr working group, which was initiated in 2014 to help speed up the development cycle. The group consists of software developers and astronomers from the AAO, and astronomers from the Australian astronomical community. The group meets once every three weeks to discuss algorithms, and set priorities.

The 2dFdr working group is open to anyone with an interest in processing data from fiber fed spectrographs to participate in the group. If you are interested, then please contact one of the authors listed above. Many of the recent changes to 2dFdr have been initiated by requests that we have received from the large survey teams, e.g. the OzDES and SAMI survey teams, and more recently, the TAIPAN survey team. The willingness of the astronomers from these teams to dig into the code is an important factor in how quickly these changes are implemented.

Recent Changes to 2dFdr

We highlight a couple of recent changes that have had a significant impact on the quality of the data processing: accurate ridge tracking and optimal extraction. Other changes, which we do not describe here, include improved cosmic ray detection, double-pass cosmic ray detection, and updated transfer curves.

RIDGE TRACKING

Ridge tracking, or tram line mapping as it is colloquially known, is the process by which the locations of the spectra on the CCD are found and then characterised with low order polynomials. These locations are then used in the flux extraction (described next). Even small offsets in the location of the tram lines, as small as one hundredth of a pixel, can leave noticeable artefacts in the reduced spectrum. Lithographic errors in the manufacturing of the CCD can result in offsets this large. 2dFdr is now equipped to map out these offsets and correct for them.

Ridge tracking requires high signal-to-noise data. Usually, the science frames do not contain enough signal, so flat fields or twilight flats are used instead. Between the time the flats and science exposures are taken, the location of the spectra on the CCD can change. This is due to evaporation of LN2 in the camera dewers. 2dFdr now computes and corrects for these offsets.

OPTIMAL EXTRACTION

Three methods are used in extracting the flux from each fiber. Simplest of all is an unweighted sum of the flux within an aperture centred on the tram line map. Slightly more complicated is to weight the pixels within the aperture according to their distance from the tram line map. The third and most complex method is a simultaneous fit to the flux in each fiber and the background. This is done column-by-column (although this need not be the case) and is called optimal extraction. Of the three methods, it is the one that produces the most accurate results yet takes the longest to run.

FUTURE WORK

Improving optimal extraction, and sky subtraction are two of the long-term priorities of the 2dFdr group. Undoubtedly, both TAIPAN, with its Nyquist-like sampling of the spatial PSF, and HECTOR with its KOALA-like fiber packing will present the 2dFdr group with new challenges.

For instruments like KOALA, which pack 1000 fibers in 4096 rows (i.e. 4 pixels per fiber), the number of fit parameters relative approaches the number of data points. This can lead to ill-conditioned matrices and erroneous results.

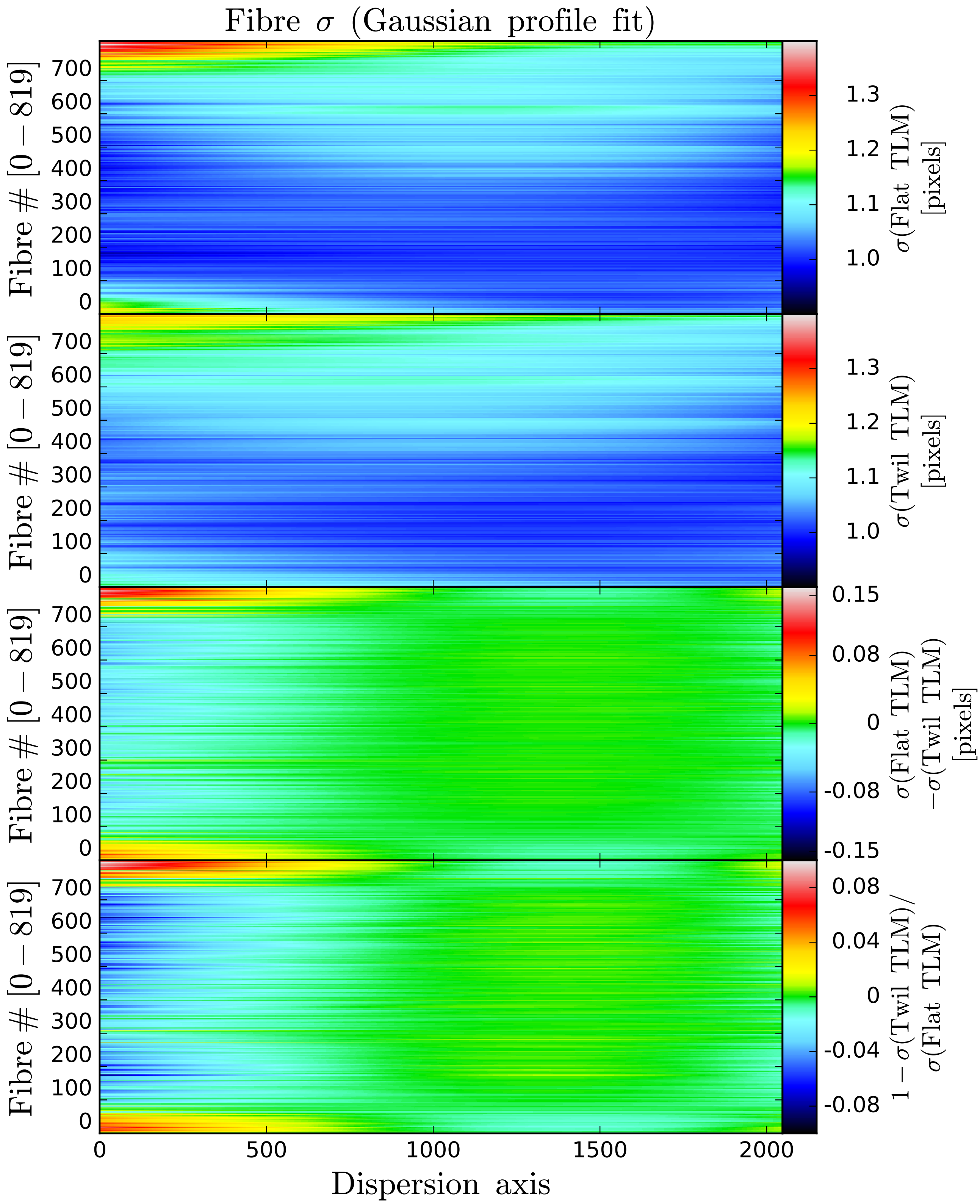

Figure 1. Comparison of the tramline fit to the blue CCD of AAOmega with the SAMI fiber feed using a lamp flat (top panel) and a twilight flat (bottom panel) illustrating the important differences between these two flat fields. Each panel shows the fiber width (sigma) as a function of fiber number (Y-axis) and pixel number along the dispersion direction (X-axis; higher pixel numbers correspond to longer wavelengths). When using the lamp flats, the value of sigma at the blue end of the CCD is biased (red regions of the diagram). This bias is noticeable for low and high fiber numbers, where the internal reflections from the spectrograph are strongest. When using the twilight flats, which have a much bluer spectrum, the fiber profile appears more uniform. The AAO is developing a new flat field system for fiber-fed instruments at the AAT. The system will result in better spectral and spatial illumination of the fibers. The flat field is used at various points in 2dFdr (tram line mapping, profile fitting and flat fielding). It is arguably the most important calibration. Results from the new flat field system will be presented in a future edition of the AAO Observer.

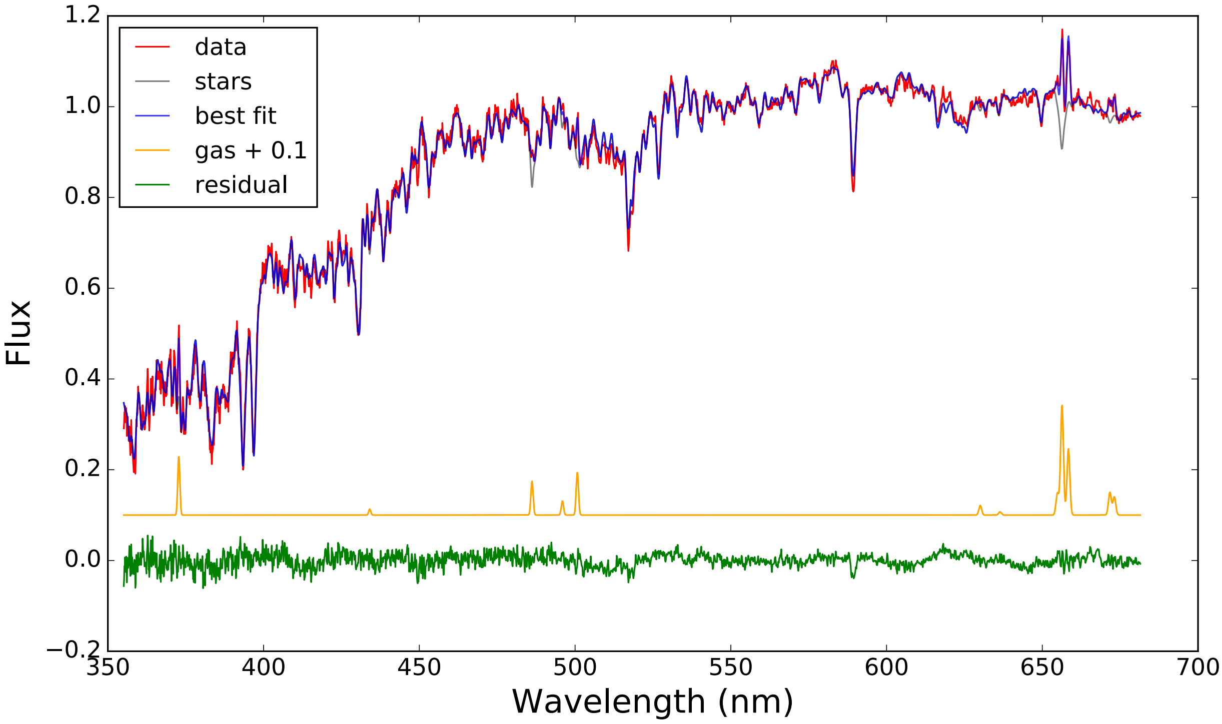

Figure 2. The average spectrum of twenty brightest cluster galaxies (in red), together with a pPXF fit (with and without emission lines in blue and grey, respectively). The emission line component is shown separately with a vertical offset in orange, and fit residuals are in green. The signal-to-noise of the spectrum is around 100 and the reduced chi-square is close to 1. Note how all of the bumps and wiggles in the data have counterparts in the fitted spectrum. The spectrum is rich in information. For example, the [NII] / H-alpha line ratio is less than one, which suggests that star formation and not AGN activity is responsible for powering the emission lines. The fit to the Mg b line at 517nm suggests this alpha element is enhanced with respect the models used in the fit. The fit to the Na line at 590nm also differs from the models.

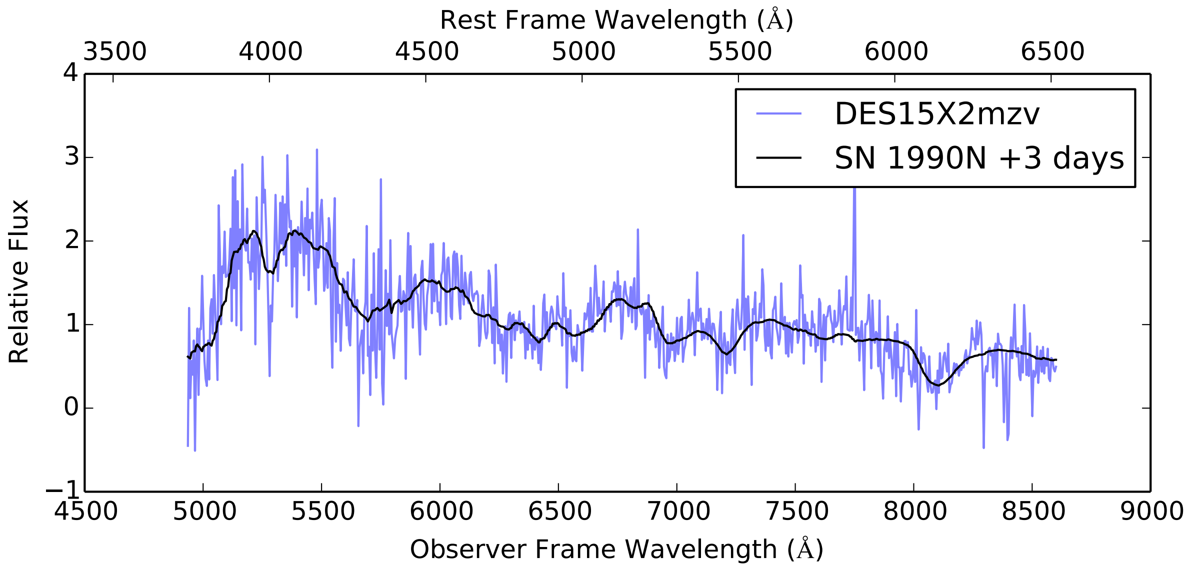

Figure 3. An AAOmega spectrum (in blue) of a Type Ia supernova at z=0.32 a few days past maximum light, showing the characteristic 'W feature' due to sulphur at 5400 Angstroms (rest wavelength) and a broad dip at 6100 Angstroms that is due to silicon. For comparison, the spectrum of a nearby supernova, SN 1990N, is plotted in black. Classifying the supernova like this one before the recent changes to 2dFdr would not have been possible. OzDES has used the AAT to confirm Type Ia SNe up to redshift z=0.6.

An alternative approach to column-by-column extraction, which is the current approach, is to fit a rectangular region, the boundaries of which are defined by the slit geometry. The advantage of this approach is that one can use fewer parameters to describe the data, leading to better conditioned matrices and more robust results.

Currently, we model the fiber profile as a Gaussian that varies in width as one moves along the tram line. In detail the fiber profile is not Gaussian. The profile tends to be boxier and has exponential-like wings. Preliminary tests suggest that one can get modest improvements with more complex profiles.

There are a number of other changes that are currently being implemented, for example: folding the heliocentric correction into the wavelength calibration, which will enable one to stack spectra taken over several nights without further interpolation; implementing super-sampled sky subtraction as an alternative to the sky subtraction algorithms that are used now, which will be especially useful for objects that are roughly at the same redshift (i.e. stars); and improved processing of the flat fields.

SCRIPTING AND PARALLELISATION

2dFdr was originally intended to reduce one night's observing, driven by a GUI. Modern surveys are producing vast quantities of data (e.g. HERMES will eventually observe 1,000,000 stars over something like 500 nights) and need to re-reduce their surveys entirely when changes to the reduction strategy are made. As a result, 2dFdr now supports a very flexible script driven interface known as "AAOrun", which can be used to spawn multiple reductions in parallel.

RESULTS

Earlier versions of 2dFdr often produced spectra that could only be reliably used to measure a redshift or a velocity. This was due, in part, to artefacts introduced during the reduction, such as negative continua, spectral discontinuities, and poor sky subtraction. Inadequate calibration frames, in particular flat fields (see Fig. 1), also played a role.

Spectra are rich in information and have many uses. For example, they can be used to infer the chemical composition of stars and galaxies, they can be used to measure kinematics of stars in galaxies, and they can be used to classify objects. Hence, one of our aims in modifying 2dfdr over the past couple of years was to produce spectra that can be used for more than just obtaining a redshift.

Figs. 2 and 3 show examples of the kinds of analyses that can now be done more reliably with the improvements that have been made to 2dFdr. The first, shown in Fig. 2, is the average spectrum of about 20 galaxies together with a best fit model. Note how the model accurately fits the data. This spectrum can be used to estimate the age of stellar population, the chemical composition of both the stellar material and the gas, and the mechanism that leads to the emission lines. The second example, shown in Fig. 3, is the spectrum of a distant Type Ia SNe. With earlier versions of 2dFdr, the spectrum of this SN would not have been classifiable, as the spectral discontinuities often seen in early data would have masked the subtle broad spectral features in these SN spectra.

The changes also enable us to obtain redshifts for objects that are many times fainter than what was typically done with 2dF and AAOmega. For the host galaxies of supernovae, OzDES reaches 90% redshift completeness down to an r-band magnitude of 24 (Childress et al. 2017), which is more complete at a fainter magnitude than the recently completed VIPERS survey on the VLT. Of course, to reach this limit with a 4m-class telescope, one needs to integrate for a long time. Some OzDES targets have now been observed for more than 100,000 seconds, yet the signal-to-noise ratio continues to improve, albeit at a rate that is slightly shallower than the theoretical limit (Childress et al. 2017).

THE 2DFDR CODE REPOSITORY, FUSION FORGE, AND THE FUTURE OF 2DFDR

The source for 2dFdr is maintained in the AAO's source code control system, but this is not available to outside users and snapshots are released outside the AAO. To provide a better working environment for the collaborative approach we need, the 2dFdr source has been moved to a more open system (FusionForge) using GIT as the source code management tool.

The public interface of the Fusion Forge web page is located at https://dev.aao.gov.au. No login is required if you wish to download the 2dFdr source code. If you wish to contribute to the development of the code, then you'll need to first create an account and, once the account is approved, send a request to join the 2dFdr project. Once that is approved, you'll be able to contribute to the code.

The development of 2dFdr is driven by the needs of its users. This is true now and it will be true in the future, irrespective of what the AAO may look like in 12 months from now. By making it easier for the community to become involved in the development of 2dFdr, we are hoping to reduce the time it takes to develop and implement new algorithms, and to encourage more users to become involved.

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Holistic Spectroscopy – Complete Reconstruction of HERMES Spectroscopic Images with the Aid of Photonic Combs

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Reduction of multi-fiber spectral images, like those from the 4-camera Hermes multi-object spectrograph, is done superficially most of the time. Rows in a two-dimensional image are collapsed into one-dimensional spectra and most contaminants, like fiber cross-talk and sky background, are only removed afterwards. This whole process discards some information and in most cases cannot retain the complex resolution profile of the original 2D spectra. It also complicates estimates of uncertainties. We find that the traditional approach of 2D spectral reduction is inadequate for multi-object surveys that require precise information from stellar spectra, e.g. measuring elemental abundances from stellar spectra or the shape function of the Lyman alpha forest lines, for example.

Over the past year, we have explored the prospect of "holistic 2D spectroscopy" where no collapse into one dimension, or even extraction, is needed at any step in the process. A related approach is extracting photometry from dense stellar fields. Instead of measuring the flux of each star independently, we model each star with a point spread function (PSF) and find the right combination of PSFs that reproduces our observed field.

This approach has not transferred into spectroscopy for several reasons: Measuring the PSF of the spectrograph is not trivial, modelling the spectra is much harder and slower than modelling point sources, and the whole regression problem is not sparse any more, as each spectrum occupies a much larger portion of the CCD than a point source would. All of these problems must be solved before holistic spectroscopy becomes a viable alternative to the traditional one-dimensional approach.

We solved the problem of measuring the PSF of the Hermes spectrograph with the aid of a photonic comb discussed in the AAO Observer last year (Kos et al, 2016). Here we pick up from that article and show some early results on the holistic reconstruction.

What We Have Learned?

A technical article on the instrument set up has been presented elsewhere (Bland-Hawthorn et al 2017, arXiV:1704.08775). Using a clever solution, where we inject the photonic comb into the 2dF fibers via a small amateur telescope (Figure 1), we can illuminate all fibers at once. This is actually not the best idea, as the peaks from neighboring fibers will overlap on the CCD. We therefore illuminate every third fiber and repeat the whole procedure three times to probe every fiber on both positioner plates. This way the peaks are nicely isolated and each peak can be analyzed without polluting flux from the neighbouring fibers. A total exposure time of 50 minutes was needed for each of three sets of exposures to get as much signal as we need for our application (few thousand counts per peak).

Parameterization and Interpolation of the PSF

We want to know how the PSF looks in any and every point in the CCD plane, so we have to interpolate the measured PSFs. In order to interpolate the PSFs, we first have to parameterize them. Parameterization by moments proved to be a good way to do it. We choose a slightly unconventional set of moments called discrete Chebyshev moments (see Bland-Hawthorn et al 2017 for a more detailed description). Discrete Chebyshev moments are convenient because they are exact (calculated from whole numbers and without any approximations), work in the original pixel space, the base functions can be tabulated and queried fast, and there always exist a finite number of moments, which means that we lose no information when converting PSFs into the moments and back. Once the PSFs are parameterized in such an orthogonal base we can interpolate each moment over the whole CCD plane. Discrete chebyshev moments are unfortunately not very intuitive. If we want to better understand the shapes of the PSFs, we can use more conventional image moments. They are not orthogonal and the inverse transformation back into the PSFs is extremely hard, so we only use them for illustration of different optical aberrations (Figure 2).

Notice that the measured moments consist of several components. The smooth transitions over the CCD plane come from the optics and variation of the optical aberrations over the field.

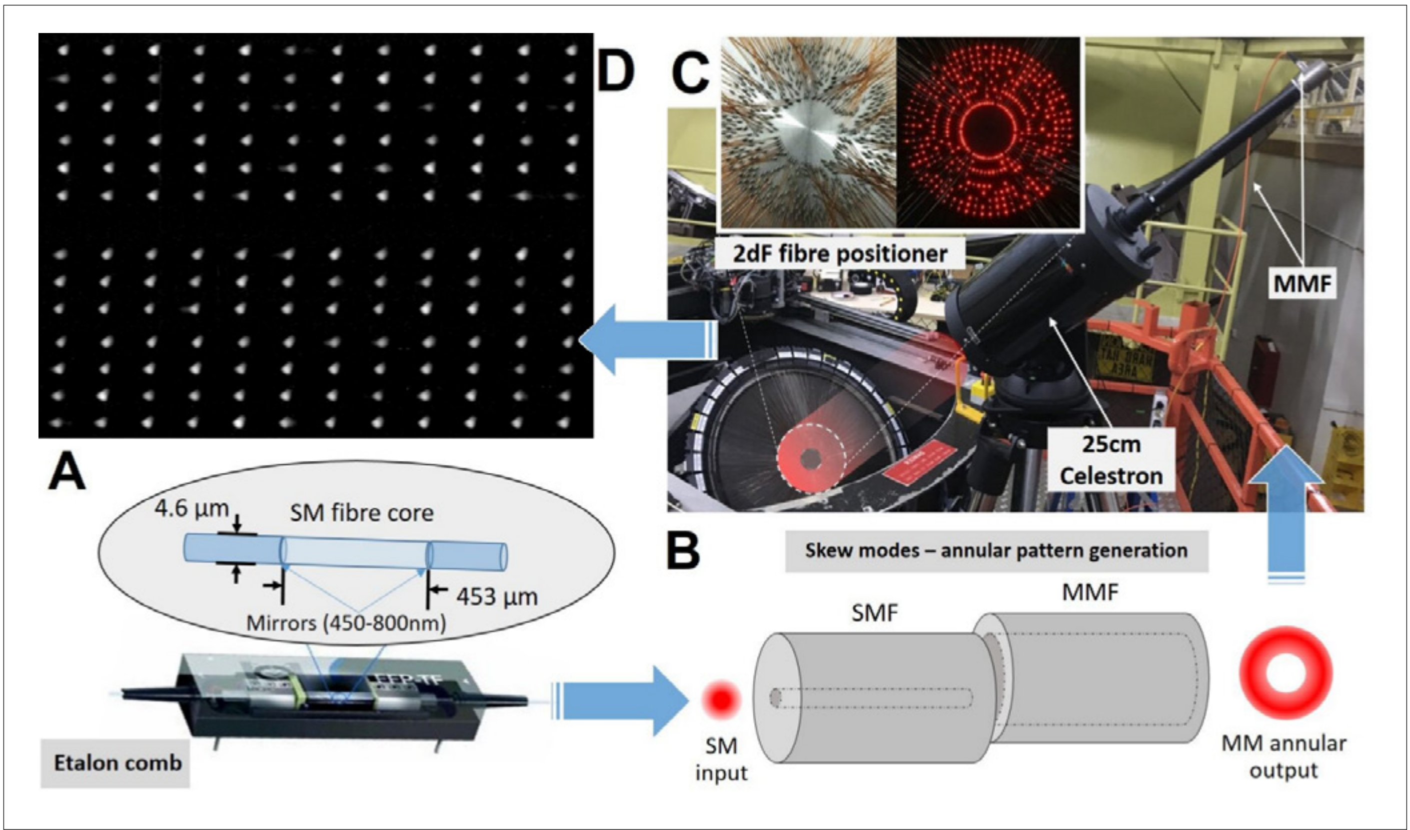

Fig 1: A fiber from the etalon (A) is coupled with a multi-mode fiber in a way that most of the light is emitted in an annulus (B). The light is then led into a 25 cm amateur telescope (C) where the light in the annulus can pass past the central obstruction of the telescope and is collected by the 2dF fibers. Panel C shows all 400 fibers positioned in the illuminated area. In the end we decided to illuminate only every third fiber at once. A corner of an image acquired this way is shown in panel D.

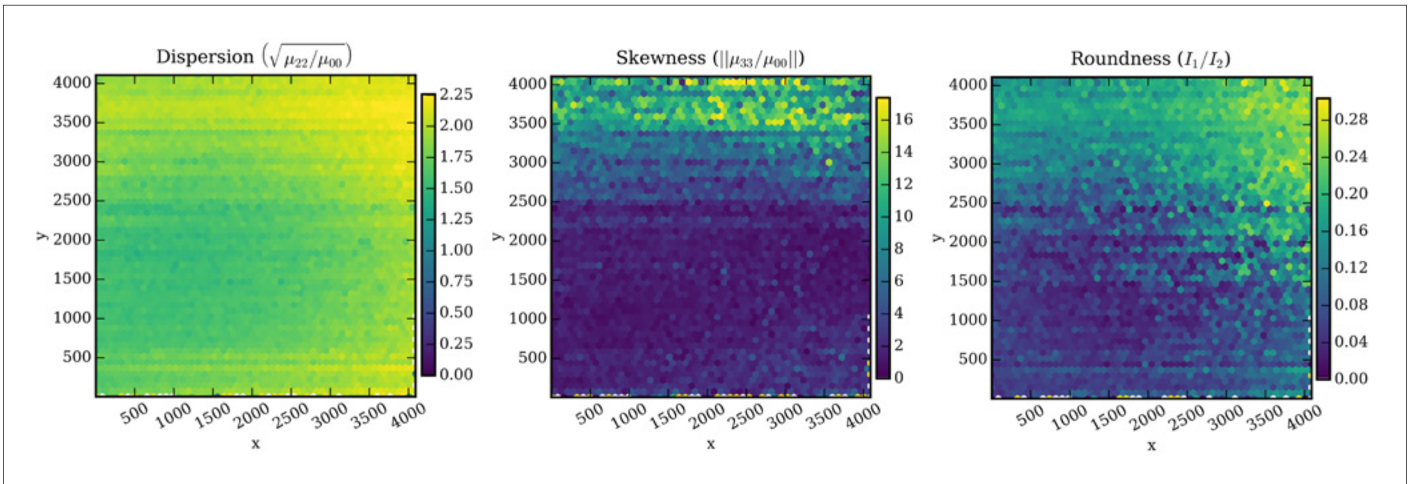

Fig 2: Image moments are used to inspect the measured PSFs, because they have physical meanings. Left to right are displayed the dispersion (size of the PSF), skewness (asymmetry of the PSFs), and roundness of the PSFs in the whole CCD plane of the green arm. Roundness is not one of the image moments but can be expressed with Hu moments, a special set of moments derived from different image moments.

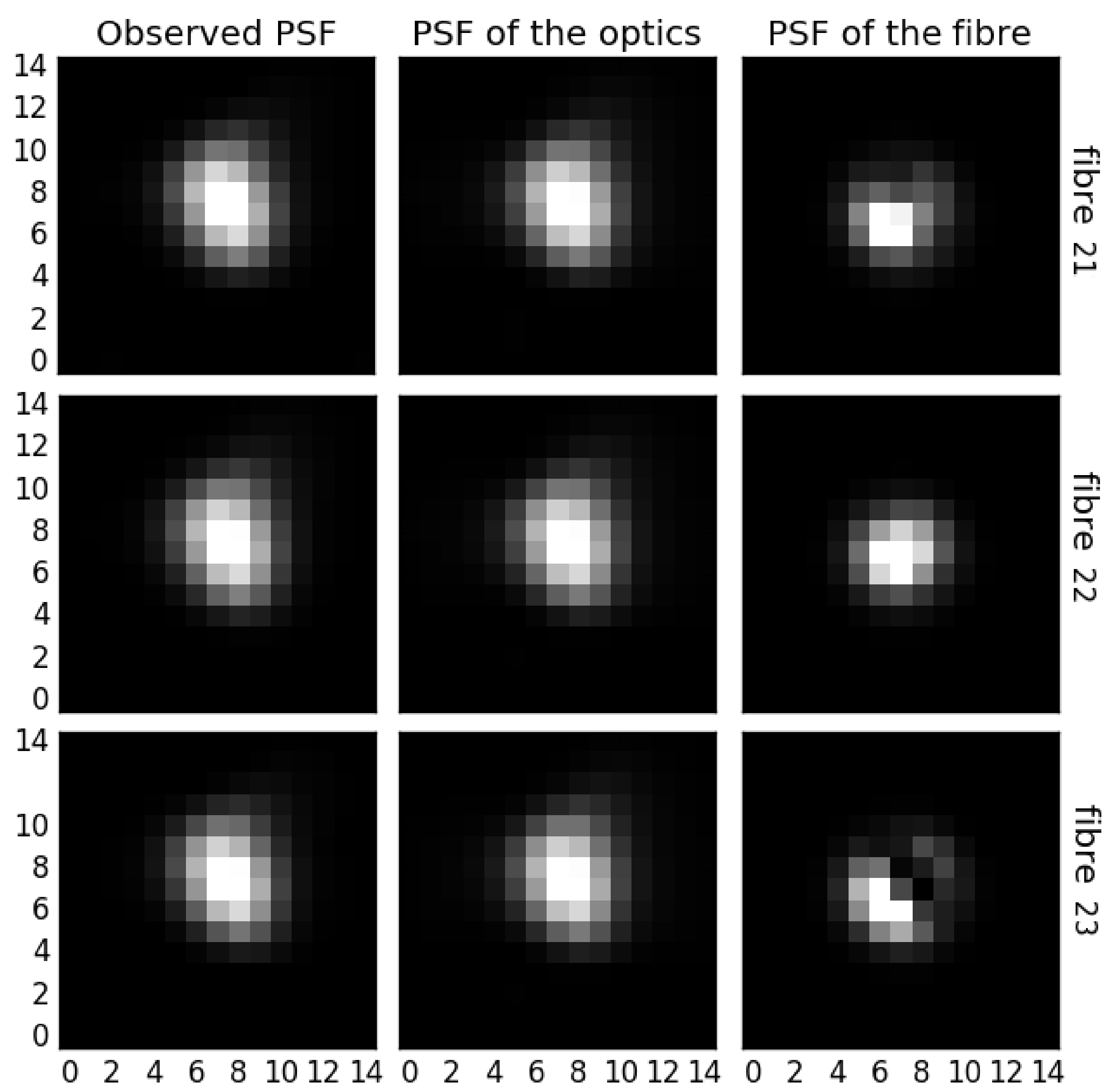

Fig 3: PSFs from three consecutive fibers in the green arm. Left column shows the measured PSF, middle column shows the optics part of the reconstructed PSF, and the right column shows the fiber part of the reconstructed PSF. The right column essentially shows the aperture of the fiber. Notice a piece of dirt or a scratch in fiber 23. Such details show that we can parameterize the PSF very well.

We can decompose this smooth component further into the linear part (contribution of the grating), and a spherically symmetric part (contribution of the rest of the optics).

There is also a component that comes from fibers. The fiber apertures are not all the same and some can be dirty or scratched, so every fiber can produce a different beam. Part of the PSF that changes from fiber to fiber is therefore attributed to fiber aperture variations (Figure 3). Such decomposition allows us to model the PSF correctly even if a fiber was moved in the CCD plane. In fact, the PSF measurements are so precise that we can reconstruct the shape of the fiber apertures, even when they are convolved with the PSF of the optics. This makes us confident that we finally understand the PSF variations well.

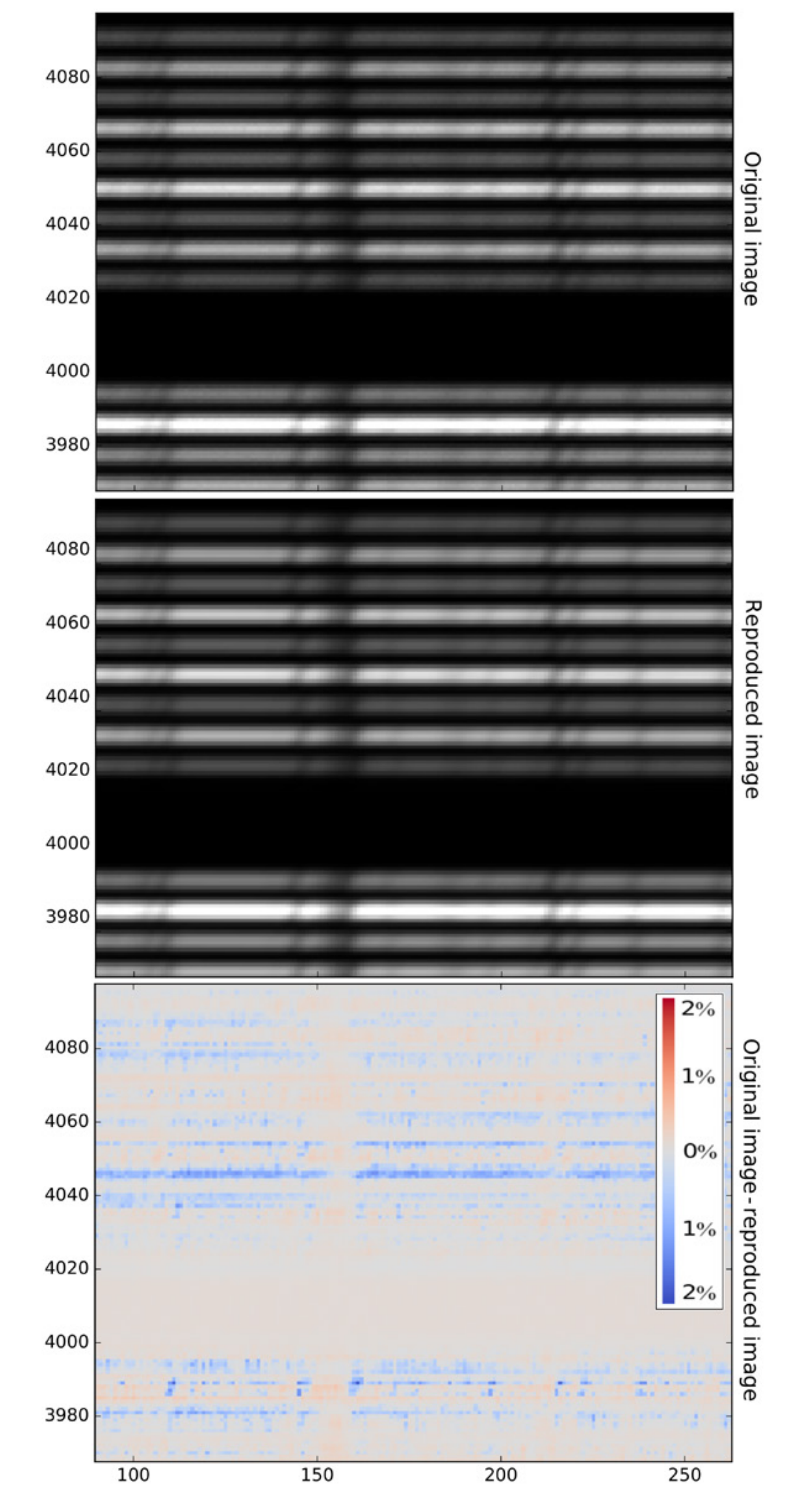

Fig 4: Details in the original (top) and reproduced (middle) images with the difference between the two (bottom). The extreme corner of the CCD is shown here with some of the most prominent absorption lines. The bottom shows percent residuals per pixel with no convolution for the instrument response profile.

Reproducing a Spectrum

Because we are not extracting the spectrum in the 2D spectroscopic reduction, we must use a (one dimensional) template spectrum that we convolve with the known PSF to produce a two-dimensional image. We can do so for every fiber. Such a reconstructed image is then compared with the target observed image and the whole process is repeated until the set of templates that best reproduce the real image are found.

Twilight flats are images where every fiber yields a solar spectrum. If done while the sky is bright enough, they will be almost free from any sky emission lines and any other background light. Such spectra are a great starting point also because we know very well what template to use, what is the radial velocity, and that the spectrum is identical in every fiber. There are, unfortunately, some quantities that must be measured. First, templates come as normalized spectra and the observed spectra have a somewhat complicated continuum, influenced by the telescope, fibers, and instrument transmissivity and blaze function. This is hard to measure with our comb, as the power between peaks varies a bit. We therefore measured the continuum on the observed 2D spectra and renormalized the template. Second, the tramlines must be measured, so we can tell along which curve to reconstruct the spectrum from each fiber. Third, the wavelength calibration must be known. The spectra are obviously reproduced in the pixel space, so the template's wavelengths must first be inverted. We measure all three quantities in the traditional way, as we would in a normal extraction and reduction process. They can, however, be left as free parameters while the reconstruction is done iteratively until optimal tramlines, continuum, and wavelength calibrations are found.

In Figure 4, we show a reproduced twilight image and the residuals from the original image. We can reproduce the solar spectrum with almost perfect accuracy. Residuals are driven by the measured continuum and telluric absorptions which we did not include in the model (see also Figure 5).

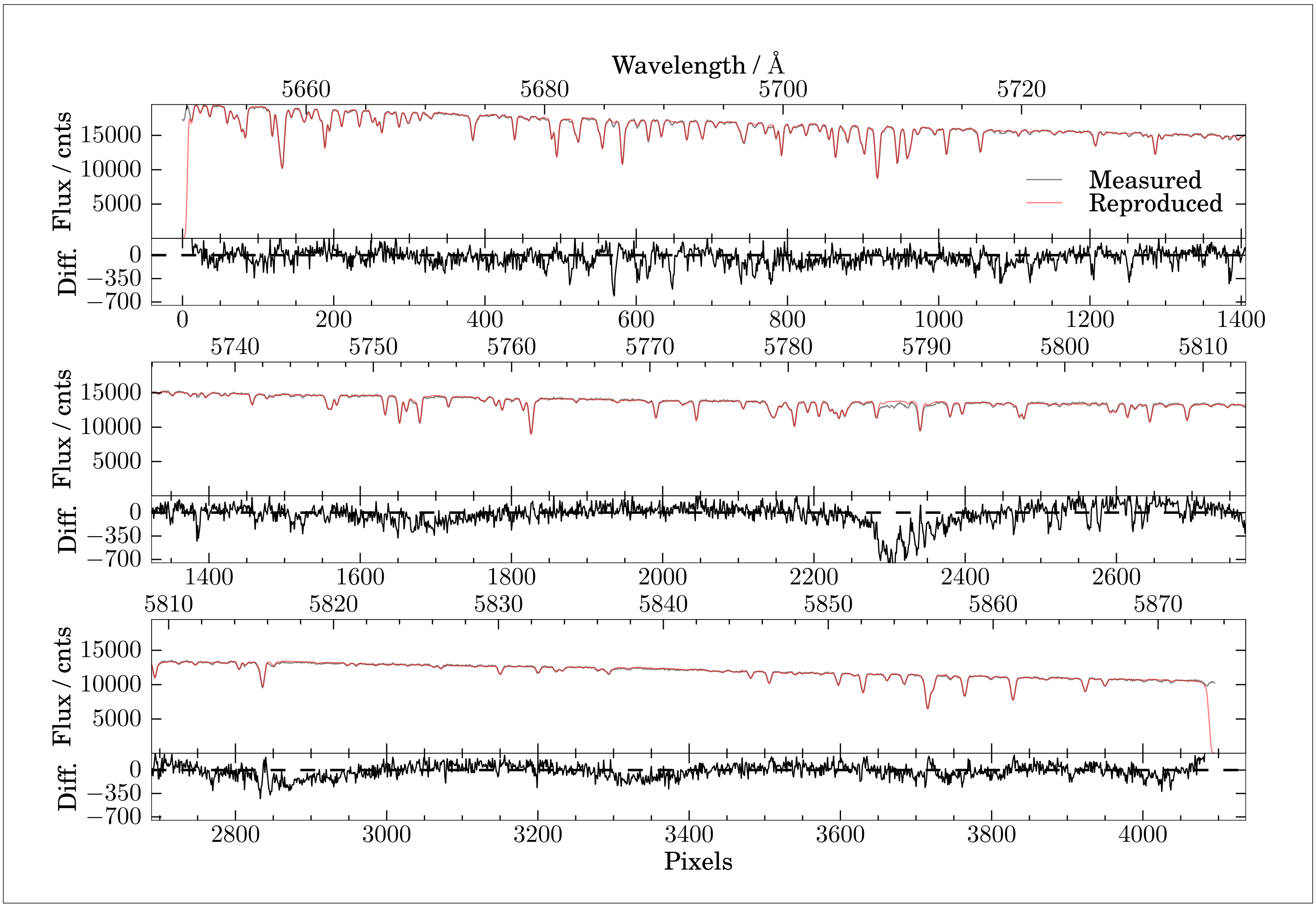

Fig 5: How well the original and reproduced spectra match is easiest to show on extracted 1D spectra. Gray and red lines show the spectra extracted from the original and reproduced images, respectively. The difference is plotted with a black line below the two spectra. The whole spectral range is sliced into three regions for clarity. Note the telluric band at 579 nm. Telluric bands have not been included in the model, so this one stands out. There are also a few lines with incorrect parameters that do not reproduce well, a typical fault in synthetic spectra. Otherwise the difference is dominated by noise and sometimes mismatched continuum.

Uncatalogued, faint telluric absorption bands (~ 1% flux) seen in the residuals are a great demonstration of the advantage of the forward modeling approach. These features are overlooked in traditional reduction as they are too weak to be measured and can only be picked up in the analysis phase. Apart from the telluric absorption lines and global continuum, residuals are kept well below 0.5%, limited by the signal to noise ratio of the observed image. The best matching solar template has a resolving power of around 32000 or more, significantly more than 28000, the nominal resolution of Hermes. This is, as expected, due to the optical distortions that smooth out the PSF during the collapse into a 1D spectrum.

The Future

We are currently working on reproducing stellar spectra on science images taken by the GALAH survey and will soon incorporate the methods we are developing into our reduction pipeline. GALAH will be the first spectroscopic survey to benefit from holistic 2D spectroscopic analysis which we believe is crucial to the success of the survey goals, in particular chemical tagging. The SAIL labs are developing a more powerful photonic comb that will use the dome screen in order to illuminate the primary mirror directly. This will allow the photonic comb to be used as a standard calibrator during the course of an observing run.

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Veloce: Australia's new planet hunter

Duncan Wright (AAO/UNSW)

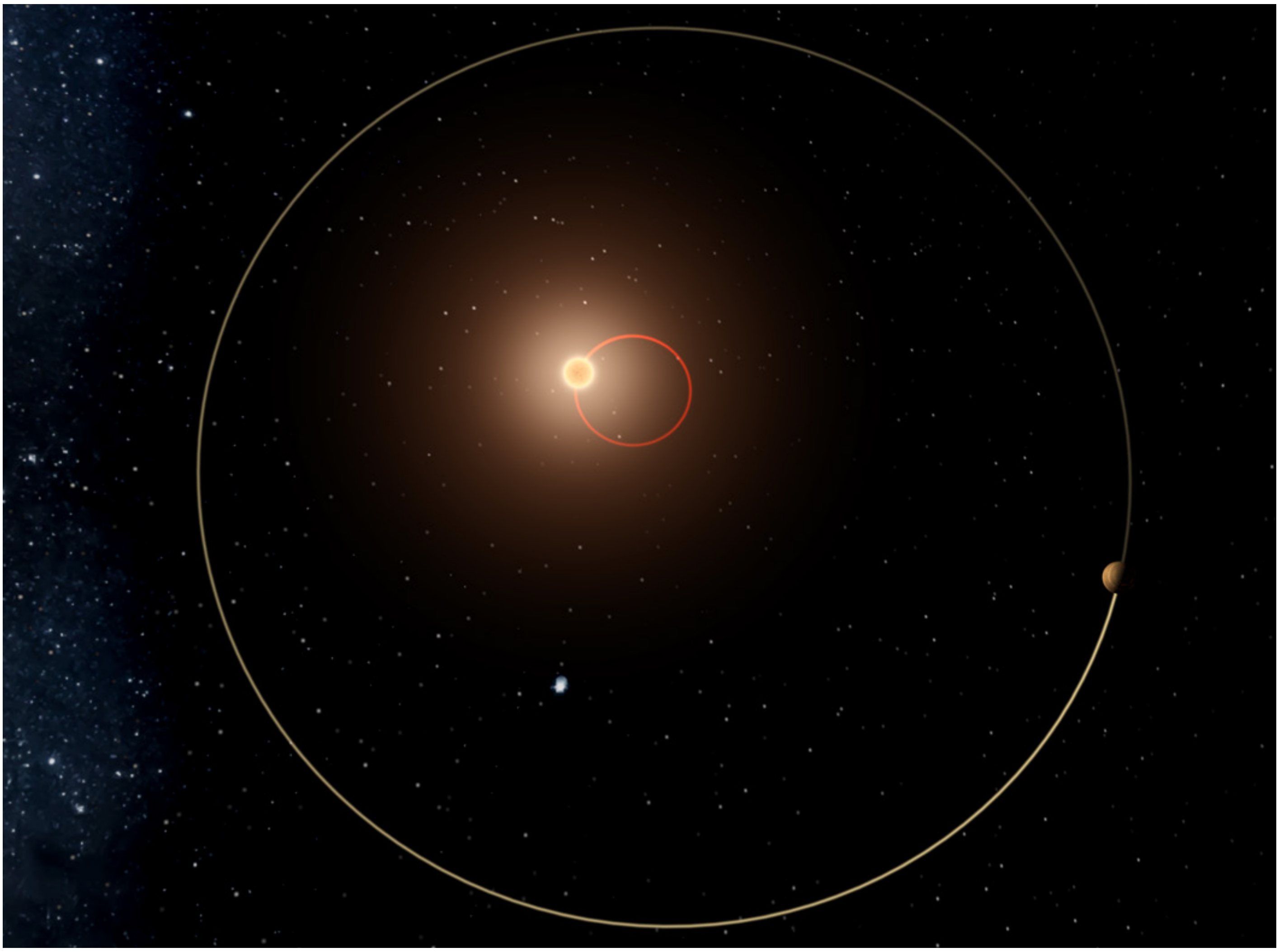

Figure 1: A top down view of a simulation of a simple one planet (Hot Jupiter) system with the orbits shown for the planet (orange) and star (red). A star-planet system orbits about the combined centre of mass (or system barycentre). Because the star is many times more massive than the planet its orbit is much smaller, and its speed in that orbit much slower than for the planet.

Veloce is the new high-resolution spectrograph for the Anglo-Australian telescope that will be installed and commissioned in early 2018. Veloce will be looking for planets around nearby stars, in particular around low-mass stars called M-Dwarfs. It will observe one star at a time, and break up the starlight into its colours and use the red wavelengths (~580 – 930nm) to measure the velocity of the star moving toward or away from the Earth i.e. along the line of sight.

Discovering planets

When a planet orbits a star, the star is also moving because they are both orbiting around the star-planet system's centre of mass (see figure 1). Because the star is much more massive than the planet the system's centre of mass is much closer to the star, which means the star has to move in a small orbital ellipse in the same amount of time as the planet (further away from the centre of mass) has to move in a large orbital ellipse. The result is that the star moves at a much slower speed in its orbit than the planet. This motion of the star due to the orbiting planet can be detected as a periodic change in the velocity of the star as it travels around the orbit, but it is a challenging measurement to make with the necessary precision. As an example, the speed of the Earth in its orbit is about 30 kilometres per second, but the speed of the Sun due to the Earth's orbit (ignoring the influence of the other planets) is about 10 centimetres per second – too small to detect with current instrumentation. It is the speed of the planet hosting star that we are measuring with a spectrograph and, to date, the most precise spectrographs can achieve a velocity precision for a star of a little better than 1 metre per second, about the speed of a person walking slowly.

Veloce: one of the most precise spectrographs in the world

Veloce will also achieve better than 1 metre per second velocity precision, but at a much lower cost than comparable spectrographs thanks to some new technologies and innovations i.e. a laser comb calibration system (see figure 2), simple but precise temperature and pressure controls, and a compact modern design (an asymmetric white-pupil design).

The temperature and pressure controls will keep the output from Veloce extremely stable. Combining this with the laser comb, which produces a dense set of known peaks in the light spectrum (see figure 3) that are used to very accurately calibrate the spectrograph, will allow the detection of super-Earth mass planets orbiting nearby M dwarf stars.

Some thirty of such nearby planets have been detected with high-resolution spectroscopy in recent years, many with orbital velocity amplitudes of ~1-5 metres per second, but many more are expected in the next few years with the advent of the NASA Transiting Exoplanet Survey Satellite (TESS), launching next year. Veloce will be well placed to confirm and follow up the most interesting TESS targets. With both planet radius (from TESS) and mass (from Veloce) we will know the planet's bulk density and we can then begin to study in depth those exoplanets that will be the best targets for habitability and atmospheric investigation for the foreseeable future.

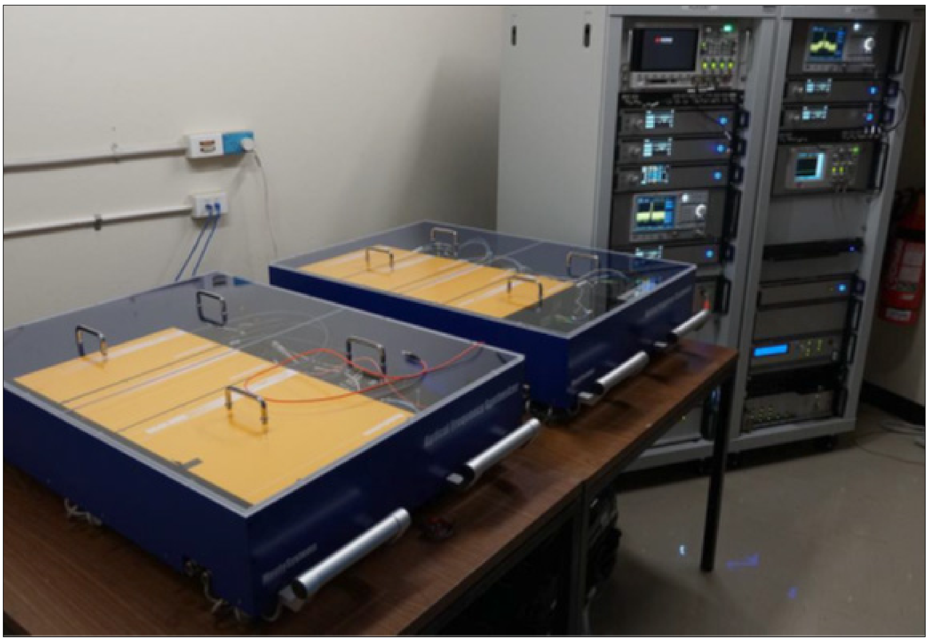

Figure 2: The Menlo systems laser comb, recently arrived at the AAT.
Credit: Anthony Horton, AAO

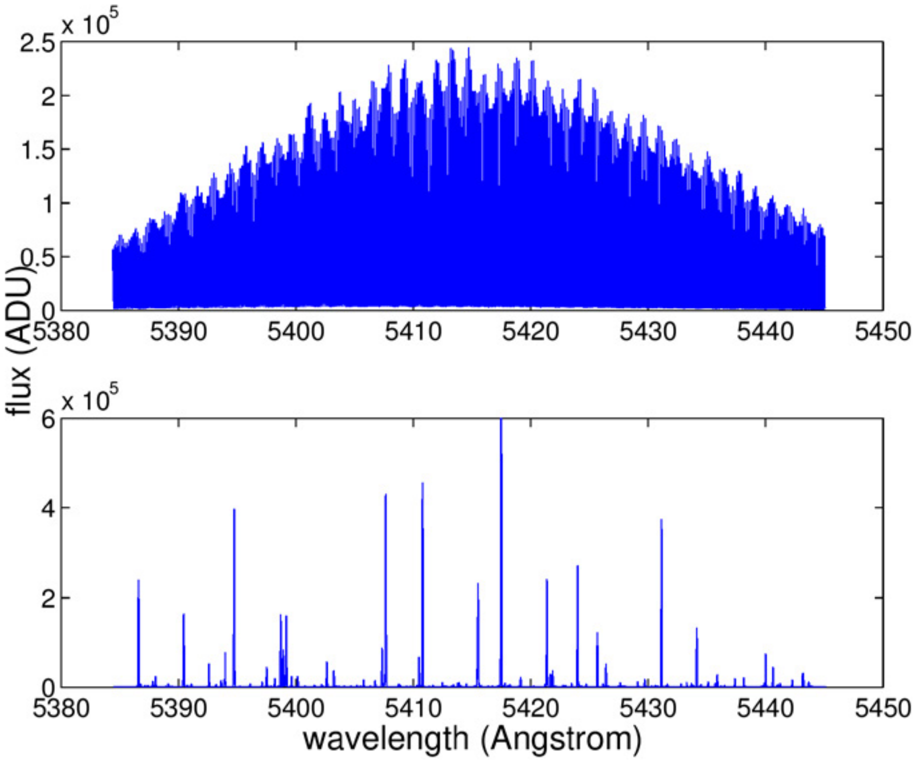

Figure 3: A small region observed by the ESO spectrograph HARPS using a Menlo systems laser comb similar to the Veloce laser comb (top). The same region as above but for a standard Thorium-Argon arc lamp traditionally used for spectrograph calibration (bottom). Note the extremely high density and even spacing of the laser comb spectrum compared to the lamp spectrum.

Siriusly, a newly identified intermediate-age Milky Way stellar cluster

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We confirm the reality of the recently discovered Milky Way stellar cluster Gaia 1 using spectra acquired with the HERMES and AAOmega spectrographs of the Anglo-Australian Telescope. This cluster had been previously undiscovered due to its close angular proximity to Sirius, the brightest star in the sky at visual wavelengths. Our observations identified 41 cluster members, and yielded an overall metallicity of [Fe/H]=-0.13 and barycentric radial velocity of 58.30 km/s. These kinematics provide a dynamical mass estimate of 13000 solar masses. Isochrone fits to photometry indicate that Gaia 1 is an intermediate age (3 Gyr) stellar cluster. Combining the spatial and kinematic data we calculate Gaia 1 has a circular orbit with a radius of about 12 kiloparsec, but with a large out of plane motion: up to 1 kiloparsec. Clusters with such orbits are unlikely to survive long due to the number of plane passages they would experience.

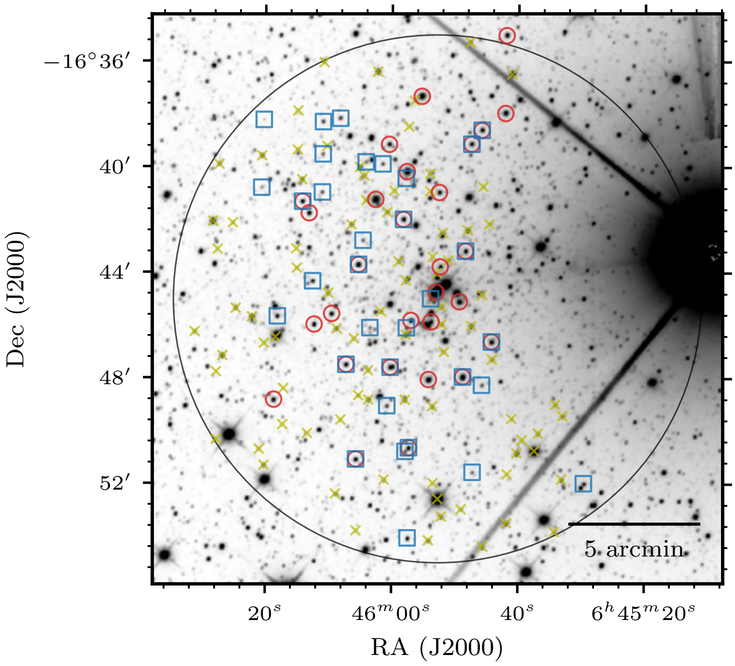

Figure 1: Sky distribution of the identified members (red circles: HERMES; blue squares: AAOmega) on the un-WISE W1 image. Indicated with yellow crosses are field stars within 10-arcmin that were also observed. The large circle shows 10-arcmin around the cluster centre. The radial extent of the cluster is not clear as the exclusion zone around Sirius in our observing strategy (and also in 2MASS) has limited our ability to identify how far east the cluster extends on the sky.

Introduction

The ESA Gaia mission has the goal of constructing the largest and most precise 6D space catalogue ever made. It is measuring the positions, distances, space motions and many physical characteristics of some one billion stars in our Galaxy and beyond.

Koposov et al (2017) took advantage of a number of unique capabilities of Gaia (i.e., no weather and sky brightness variations; low-to-no spurious detections; excellent star/galaxy discrimination) to search for stellar overdensities using a modified method they had previously applied with great success to ground-based surveys. Their search of the Gaia catalogue identified 259 candidate overdensities, of which 244 had clear associations with previously known clusters and dwarf galaxies. Of the unknown overdensities, two were statistically significant enough to warrant quick publication: Gaia 1 and Gaia 2. Of particular note is Gaia 1 which is located only 11 arcmin from Sirius (though their physical separation is 4 kpc), the brightest star in the night sky. This cluster likely would have been previously identified had it not been for this proximity, which has hidden its existence from astronomers.

Beyond the novelty of being previously undiscovered, the cluster parameters estimated indicate that Gaia 1 is an interesting target in its own right due to its being on the border between open and globular clusters. It is about 1 kpc out of the plane of the Galaxy, which might suggest it is an open cluster. The photometry shows a populated red clump region, indicative of an intermediate age, metal-rich cluster (Girardi 2016). However, the available photometry can only provide so much information, with a complete picture of the cluster's chemistry and kinematic only possible when the photometry is combined with spectroscopy.

Observations

Gaia 1 was observed with two of the spectrographs of the 3.9-metre Anglo-Australian Telescope over three nights: on the night of 2017 February 15 with the four-armed high-resolution HERMES spectrograph; and on the nights of 2017 February 24 & 26 with the two-armed AAOmega spectrograph. For all the observations, the light was fed to the instruments using the 392-fiber Two-Degree Field (2dF) optical fiber positioner top-end.

Gaia 1 has an angular extent of about 15 arcminutes and the centre of Gaia 1 is located only 10 arcmin from the V=-1.5 Sirius system (Figure 1). This meant we had two main concerns when observing Gaia 1: that diffraction spikes from Sirius could coincide with fibers; and that the scattered light from Sirius could be so large as to overwhelm the light from the target stars which are 13–18 magnitudes fainter. The extent and brightness of the diffraction spikes from Sirius were difficult to predict, so our primary mitigation method was to simply avoid placing fibers within 10 arcmin of Sirius. To reduce the scattered light from Sirius we used the 2dF plate that was coated black, and the field was centred on Sirius, with the cluster off-centre. Placing the cluster off-centre does have the trade-off of reducing the number of targets that can be observed, as the fibers of 2dF have a maximum allowed offset from their radial positions, and cannot be placed across the centre of the plate.

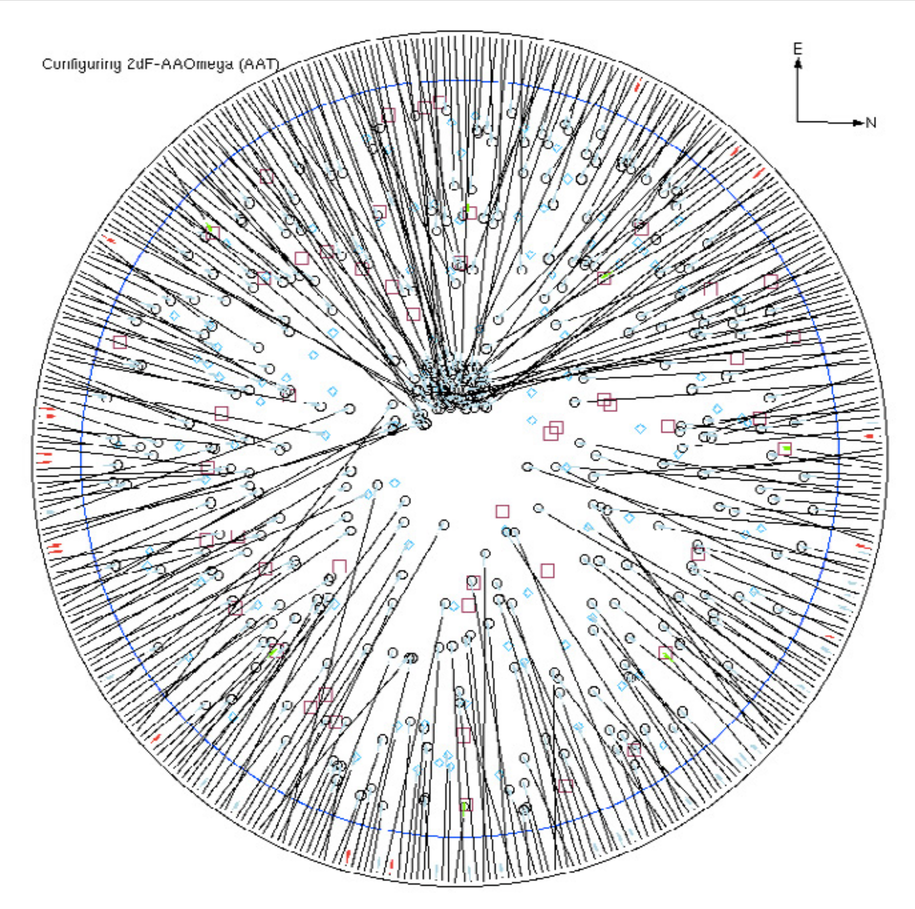

Figure 2: Black circles potential targets to observe, red squares are the fiducials, blue diamonds are the sky positions, and the black lines indicate the fibers Arrangement of the fibers on the 2dF plate. Black circles indicate potential targets to observe, red squares are the fiducials, blue diamonds represent the sky positions, and the black lines indicate the fibers. The empty zone in the middle of the plate is the zone of exclusion around Sirius.

Stellar parameter determination

For the stars observed with HERMES, the barycentric radial velocity was measured independently from the spectra of the blue, green, and red cameras by cross-correlating the observed spectra with a template of the cool giant Arcturus. Stellar parameters were determined from the high-resolution spectra with the classical method of measuring equivalent widths. For the 27 stars with reliable metallicity values, we find an average metallicity (and standard deviation of the sample) of [Fe/H]=-0.13±0.13.

For the red AAOmega spectra, the near-infrared calcium triplet (CaT) lines at 8498.03, 8542.09 and 8662.14 Å were used to measure the barycentric radial velocities of the stars and to estimate their metallicity. Combining the results from the AAOmega and HERMES datasets we find that the systemic radial velocity and dispersion of the cluster is 58.30±0.22 km/s with a dispersion of 0.94±0.15 km/s.

From the CaT method, for the 11 stars photometrically identified as clump members, and observed with AAOmega, we derive a metallicity of [Fe/H]=-0.20±0.15.

Orbit

The positional information was combined with kinematic information to estimate a probable orbit for the cluster. None of the stars identified as members were bright enough to be part of the Tycho-Gaia Astrometric Solution (Lindegren et al. 2016), but 42 member stars were in the UCAC5 proper motion catalog (Zacharias et al. 2017). Only stars with magnitude u<15 were used as for stars fainter than this the proper motions errors become very large. There were nine stars that made this magnitude cut.

We computed the orbits of the cluster using the galpy code (http://github.com/jobovy/galpy; Bovy 2015) and the recommended simple Milky-Way-like potential with the default parameters . The cluster orbit was integrated forward in time for 1 Gyr with 1 Myr resolution, for 10000 random realizations varying the inputs with Gaussian errors. In Figure 3, for clarity, a subset of 100 of these realizations are shown.

The median value of the orbital parameters was found for the 10000 realizations, with uncertainty ranges given by the 16th and 84th percentile values: the maximum and minimum Galactic distance achieved by the cluster are r_{max}=13.8±1.4 kpc and r_{min}=11.4±0.2 kpc; the largest distance out of the Galactic plane, z_{max}=1.1±0.4 kpc; and the eccentricity of the orbit e=0.09±0.04. The uncertainties in these orbital parameters are primarily driven by the uncertainty in the proper motions, with a much smaller contribution from the uncertainty in the distance. There was a negligible contribution from the uncertainty in the radial velocity and position of the cluster. The Gaia DR2+ results should improve the precision to which the cluster's orbit can be calculated by providing accurate and precise proper motions.

The present day finds Gaia 1 at about two-thirds of its maximum distance out of the Galactic plane. Vande Putte et al. (2010) investigated the orbits of Galactic open clusters and found that most clusters are in quasi-periodic crown orbits like that of Gaia 1. They further classified clusters based upon their z_{max} and radial quantity. For Gaia 1 the radial quantity is η=0.19±0.09. It would be expected that clusters that formed in the disc of the

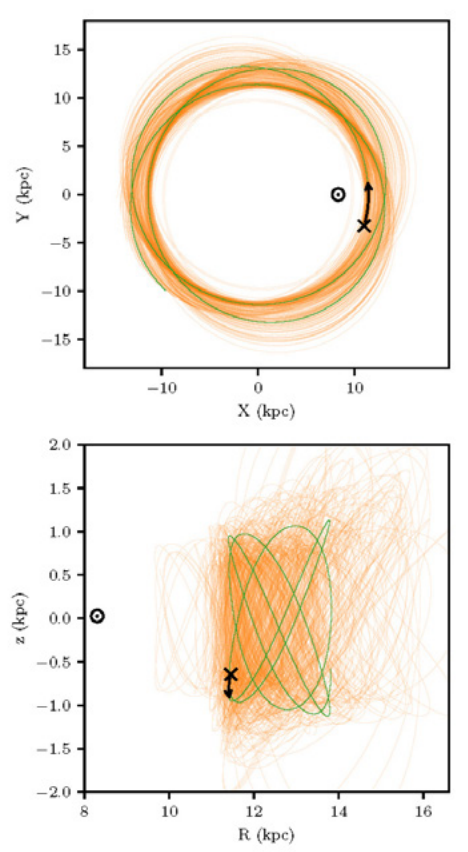

Figure 3: Projection of the orbit of Gaia 1 integrated forward in time using galpy. The green line shows the orbit using the best values found for the cluster, and the fainter orange lines show the orbits of the random realizations. The black arrow indicates the direction of motion for this `best' orbit from the starting position. The currently observed position of Gaia 1 is marked with a cross, and also shown is the present day of the Sun. For clarity, only 100 of the 10000 random realizations are shown.

Galaxy would have low η, and Vande Putte et al. (2010) found 80 per cent of the 439 clusters had η<0.28, and 90 percent of clusters had z_{max}<0.35 kpc. Although Gaia 1 has a circular orbit like the majority of open clusters, it has a large maximum distance out of the Galactic plane; over 3 times the scale height of the thin disk.

Numerical simulations of open cluster orbital evolution have shown that it is possible for the spiral arms of the Galaxy to have a large vertical effect on clusters, giving them large out-of-plane excursions (>200 pc), though these orbits tend to be chaotic (Martinez-Medina et al. 2016). Martinez-Medina et al. (2017) investigated the survival of such high-altitude open clusters, and find that clusters in the plane of the disk and clusters with relatively large vertical motions (z_{max}>3.5 kpc) tend to have the longest lifetimes. This is because the clusters experience the tidal stresses associated with disk crossings never (in the case of clusters in the plane) or rarely (in the case of high-altitude clusters). The clusters with the shortest lifetimes (with respect to an identical cluster on an in-plane orbit) have z_{max}~600 pc. Gaia 1, with z_{max}≅1.1 kpc, is in a region of orbital parameter space which should be quite detrimental to its long-term survival. In its present orbit it makes nine plane crossings every gigayear, for a total of over 30 in its 3 Gyr lifetime.

It is therefore surprising to find Gaia 1 in its present orbit at the present day. This suggests that either it has recently moved into this orbit, perhaps after an interaction with a spiral arm, or that it has experienced significant mass loss in the past, and is now on the verge of complete destruction. Significant mass loss in the past would tend to support the association of the extratidal stars we find with radial velocities, metallicities and photometry consistent with Gaia 1. Higher precision radial velocity measurements could help to clarify whether Gaia 1 is in virial equilibrium or whether it is in the process of disrupting.

Conclusions

We have presented the first spectroscopic observations of stellar cluster Gaia 1, which was recently discovered by Koposov et al. (2017). Although initially these observations were carried out to investigate the novelty of a cluster that had previously been blocked from our view by glare from Sirius, these observations have shown Gaia 1 is an interesting target in its own right, being relatively metal-rich and intermediate age cluster with a mass of about 13000 solar masses..

Both low and high-resolution spectra are consistent with the cluster having a metallicity of – 0.13. Orbital modelling shows that Gaia 1 has a circular orbit but a large motion out of the plane of the Galaxy, and is currently found 640 pc below the plane of the Galaxy and could travel as much as z_{max}=1.1±0.4 kpc out of the plane. Such an orbit could result in the cluster experiencing over 30 plane passages during its lifetime, which means that Gaia 1 could have a large stellar stream associated with it that is waiting to be discovered.

Further Reading

The full article can be read at http://arxiv.org/abs/1703.03823

Acknowledgements

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The kinematic morphology—density relationship at the AAT

S. Brough (University of New South Wales), J. van de Sande (University of Sydney), M. Owers (AAO/Macquarie University), P. Oliva-Altamirano (Swinburne University) and the SAMI Team

In astronomy 'morphology' refers to the shapes of galaxies – whether they have spiral structures like the Milky Way, or more egg-like structures like elliptical (or early-type) galaxies. Early-type galaxies can also be classified with a kinematic morphology which describes the orbits of the constituent stars. The orbits can either be either correlated, making the galaxy rotation-supported ('fast-rotating galaxies'; the stars do not collapse under gravity because they are rotating and cannot shed angular momentum), or the stars have disorded radial orbits so the galaxy is pressure supported ('slow rotating galaxies'; stars falling into the centre are balanced by stars that are travelling out the other side). The kinematic morphologies are parametrised with the spin parameter, λ (Emsellem et al. 2007).

The ATLAS^{3D} team examined the relationship between kinematic morphology and galaxy environment (density) for the first time (Cappellari et al. 2011; Cappellari 2016). They observed that there are few slow-rotating early-type galaxies, relative to the total number of early-type galaxies, in the most sparse (lowest density) environments. However, the fraction of slow-rotating galaxies more than doubles in the densest region of the Virgo cluster. This relationship has since been studied in seven additional galaxy clusters (D'Eugenio et al. 2013; Houghton et al. 2013; Fogarty et al. 2014, Scott et al. 2014). These authors all find that the fraction of slow-rotating galaxies increases with increasing environmental density.

There is also a known relationship between galaxy mass and kinematic morphology such that the highest mass, more luminous galaxies are also more likely to be slow-rotating galaxies (e.g. Jimmy et al. 2013; Veale et al. 2016). However, because of the small samples available to date it has not been clear whether galaxy mass or environment have a stronger effect on kinematic morphology.

The SAMI Galaxy Survey

The SAMI Galaxy Survey (Bryant et al. 2015) will observe ~ 3600 galaxies in a range of environments including eight galaxy clusters (Owers et al. 2017) using the SAMI instrument (Croom et al. 2012) on the AAT. This is the largest sample of cluster galaxies available to date and allows us to disentangle the dependence of kinematic morphology on galaxy mass and environment.

In Brough et al. (2017) we have analysed the kinematic morphology – density relationship for 315 early-type galaxies in the 8 SAMI galaxy clusters. The 8 clusters span a cluster mass range of $14.2 < \log(M_{200}/M_{\odot}) < 15.2$. Cluster member galaxies were observed within the inner regions of the clusters. The galaxy stellar masses observed range from $10.0 < \log(M*/M_{\odot}) \leq 11.7$. We classify these galaxies as fast or slow rotators depending on their spatially-resolved stellar kinematics (van de Sande et al. 2017). We analysed the fraction of slow-rotating galaxies as a function of galaxy environment and stellar mass. We also examined the distribution of spin parameter itself as a function of both galaxy environment and stellar mass.

We find that the fraction of slow-rotating galaxies depends on environmental density and radial position in the cluster but depends more strongly on galaxy mass (Figure 1). We also examine the spatial distribution of the slower-rotating galaxies in each cluster in Figure 2. The slow-rotating galaxies (red) are generally located in the cluster centres and those few that are located outside are generally associated with substructure in the galaxy distribution (Abell 85, 119 and 2399).

Once any dependence on galaxy mass is removed from the distribution of spin parameter (corrected for inclination), no significant relationship with local cluster environment remains (Figure 3).

We conclude that the orbits of the stars in the cluster galaxies are more affected by the galaxies' mass, rather than by the environment in which they are found and that the reason the slow-rotating galaxies are found in more dense environments is because dynamical friction causes more massive galaxies to move to those environments. Similar results have since been found by analysis of an independent dataset (Veale et al. 2017).

Is the Centre a Special Position?

In Oliva-Altamirano et al. (2017) we asked whether the massive galaxies that sit in the centres of clusters, central galaxies, have similar kinematic morphologies to the early-type galaxies in the ATLAS^{3D} sample, or if they follow a different relationship with stellar mass and environment. We used new observations made with the SPIRAL instrument on the Anglo-Australian Telscope of 5 galaxies selected from the Sloan Digital Sky Survey C4 Cluster Catalog (Miller et al. 2005) as well as 10 galaxies observed with the VIMOS integral-field unit on the Very Large Telescope (Jimmy et al. 2013) and the 7 central galaxies from previous cluster studies (D'Eugenio et al. 2013; Houghton et al. 2013; Fogarty et al. 2014, Scott et al. 2014). We re-analysed these data to form a homogeneous sample covering a wide range of galaxy stellar masses, $10.9 < \log(M*/M_{\odot}) \leq 11.7$, and cluster masses, $12.9 < \log(M_{200}/M_{\odot}) < 15.6$. With these data we found that the probability of slow rotation for central galaxies increases as galaxy stellar mass increases (Figure 4), consistent with the general early-type galaxy population. We were also able to analyse the effects of environment, through cluster mass, and found that the probability of slow rotation does not depend significantly on cluster mass (Figure 5).

These results suggest that the orbits of the stars in the central galaxies are not affected by the galaxies' positions at the centres of these massive systems.

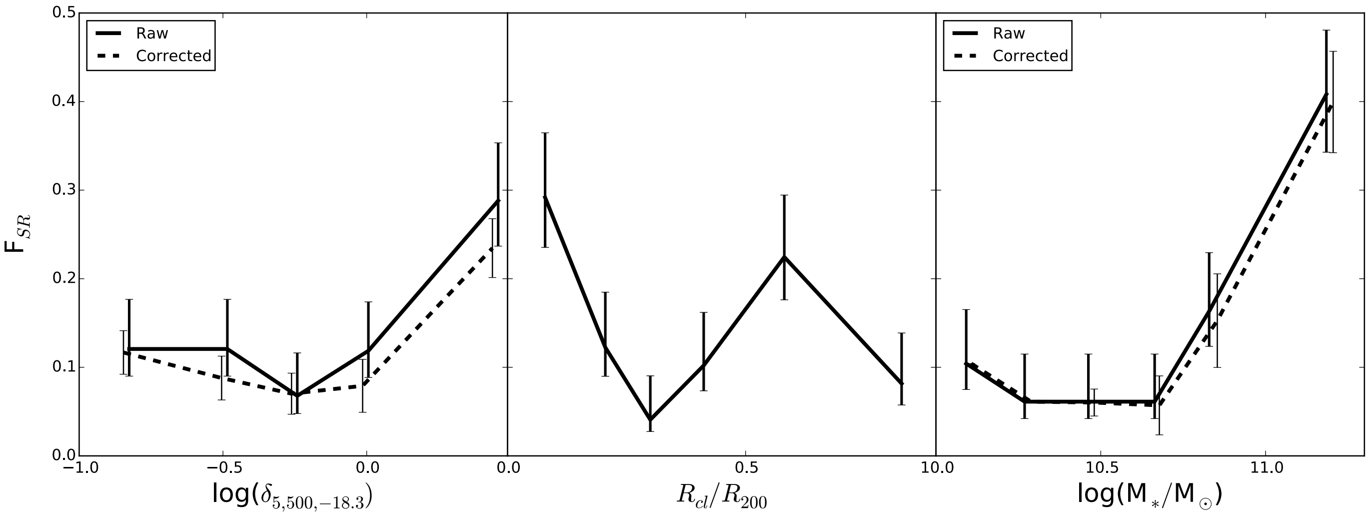

Figure 1: Fraction of slow rotators, F_{SR}. The left-hand panel shows F_{SR} as a function of environmental density, δ. We observe an increasing fraction of slow rotators with increasing density. The middle panel shows F_{SR} as a function of radial position in the cluster, R_{cl}/R_{200}. The fraction of slow rotators increases with decreasing radius. Interestingly there is a 'bump' at $R_{cl}/R_{200}\sim 0.6$ due to substructure in four of the clusters. The right-hand panel shows F_{SR} as a function of stellar mass, M∗. We observe that the fraction of slow rotators increases with increasing stellar mass.

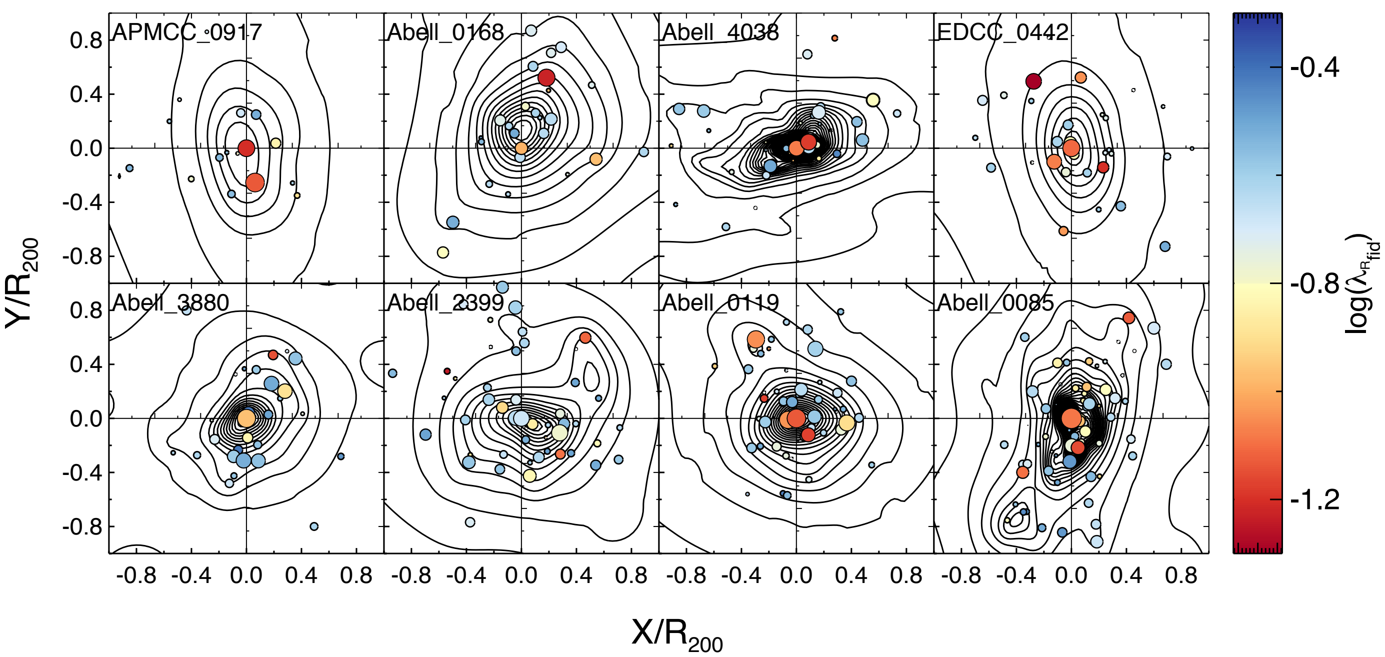

Figure 2: The spatial distribution of the observed early-type member galaxies in the 8 clusters. The point sizes indicate stellar mass and the colours indicate spin parameter, λ. The black contours show galaxy isopleths that are adaptively smoothed. The slow-rotating galaxies (red) are generally associated with the cluster centres and substructure.

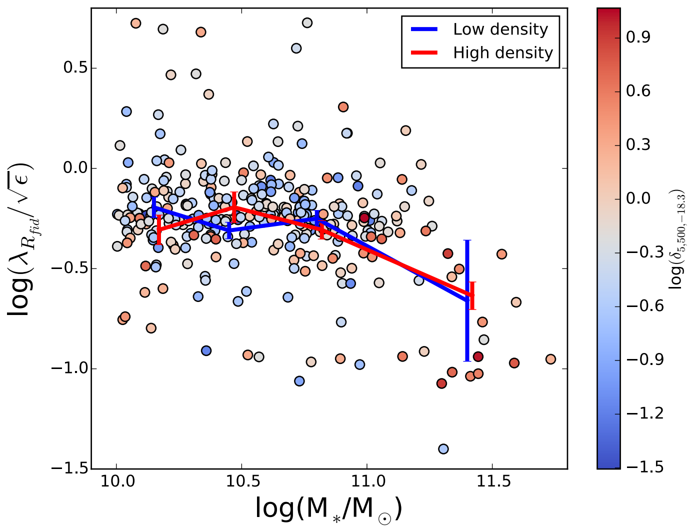

Figure 3: The distribution of inclination-corrected spin parameter, $\lambda/\sqrt{\varepsilon}$, as a function of stellar mass, $M_\odot$, with colours showing environment density, δ. The lines show mean corrected spin parameter as a function of stellar mass for the lower and upper quartiles of density. The corrected spin parameter does depend on stellar mass, but that relationship is not significantly different between the most and least dense environments.

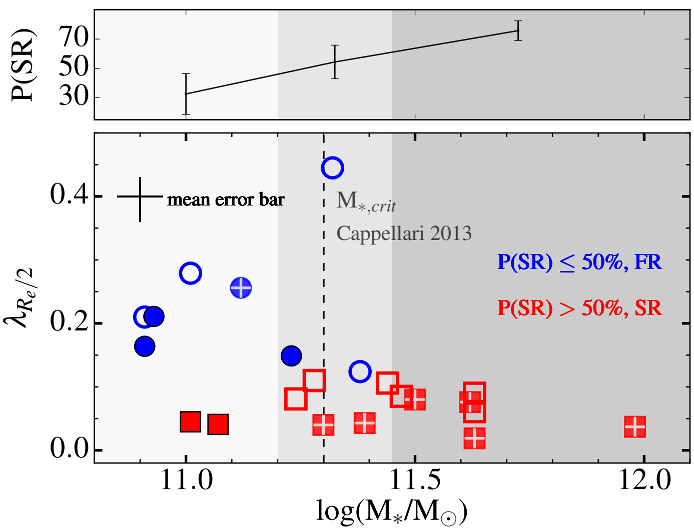

Figure 4: The lower panel shows spin parameter, λ, as a function of galaxy stellar mass, $M_\odot$. The dashed line represents the critical mass from Cappellari (2013). Representative measurement uncertainties are shown at the top of the lower panel. The upper panel shows the mean probability of slow rotation, *P*(SR), per stellar mass bin (shaded regions). The mean *P*(SR) error bars are the standard errors on the mean. The P(SR) increases with increasing stellar mass.

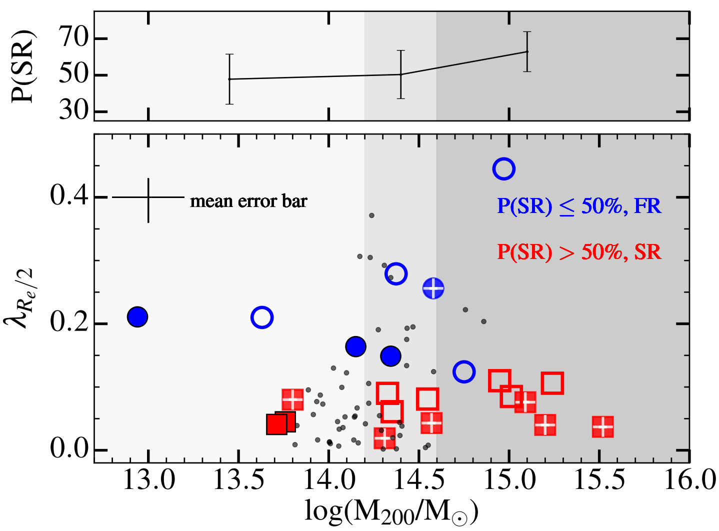

Figure 5: The lower panel shows spin parameter, λ, as a function of cluster mass, $M_{200}/M_\odot$. Representative measurement uncertainties are shown at the top of the lower panel. The upper panel shows the mean probability of slow rotation, *P*(SR), per cluster mass bin (shaded regions). The mean *P*(SR) error bars are the standard errors on the mean. There is a weak trend of increasing *P*(SR) with increasing cluster mass; however, it is not statistically significant.

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Supernova 1987A illuminates after 30 years

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and Amanda Bauer (LSST)

30 years ago, on 23rd February 1987, humans witnessed the first supernova explosion visible to the unaided eye in almost 400 years. The event provided an unprecedented opportunity for the 3.9metre Anglo-Australian Telescope (AAT), which went on to play a key role in the study of Supernova 1987A.

The stellar outburst seen in 1987 on Earth resulted from the explosion of a massive star called Sanduleak -69° 202 in the Large Magellanic Cloud, one of our closest galaxy neighbours and only visible from the southern hemisphere. Light from the explosion had taken 170,000 years to travel through space before hitting terrestrial telescopes.

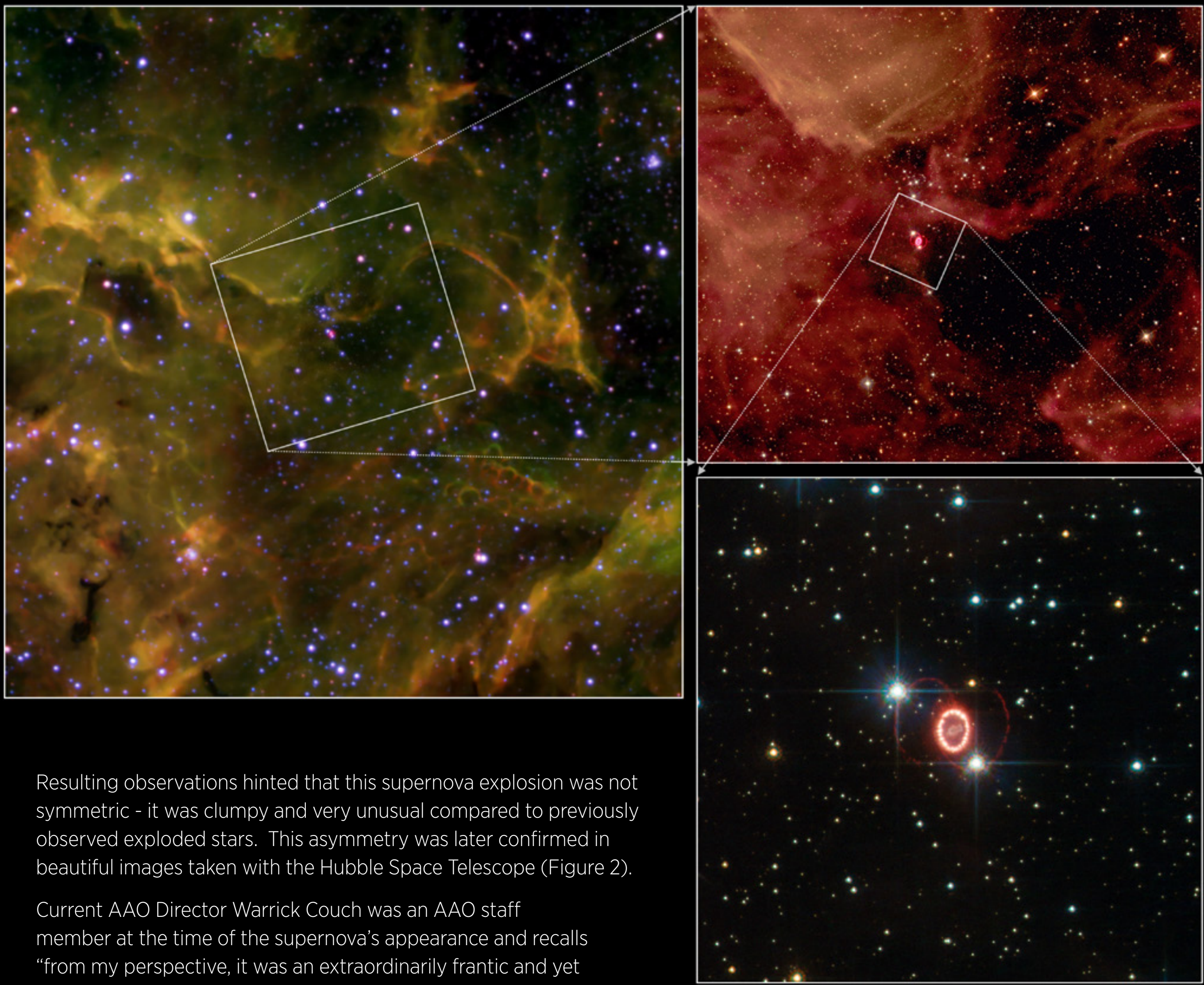
Once alerted to news of the supernova in February 1987, astronomers and engineers working at the Australian Astronomical Observatory immediately devised plans for how to make the best observations with the AAT. Observing the supernova became a top priority for the next three weeks, the assumed time that it would remain bright.

But just in case the supernova continued to be visible, AAO's Peter Gillingham rapidly assembled a very high resolution "Wooden Spectrograph", since no telescope in the southern hemisphere at the time had this type of technology available to take advantage of observing such a rare, bright supernova. With luck, Supernova 1987A remained observable for several months after it exploded.

Figure 1: Detail of the new CACTI AAT image of the neighbourhood of SN1987A

A new image of the neighbourhood around Supernova 1987A in the Large Magellanic Cloud, taken with the 3.9m Anglo-Australian Telescope.

Credit: Ángel R. López-Sánchez (AAO/MQU), Steve Lee, Robert Patterson, Robert Dean and Jennifer Riding (AAO) & Sarah Martel (UNSW / AAO).



Resulting observations hinted that this supernova explosion was not symmetric - it was clumpy and very unusual compared to previously observed exploded stars. This asymmetry was later confirmed in beautiful images taken with the Hubble Space Telescope (Figure 2).

Current AAO Director Warrick Couch was an AAO staff member at the time of the supernova's appearance and recalls "from my perspective, it was an extraordinarily frantic and yet exhilarating time as the Observatory used its entire armoury of skills, inventiveness, and high-tech instruments to capture this remarkable and rapidly evolving event with the AAT."

What does the neighborhood around Supernova 1987A look like today? AAO astronomer Angel Lopez-Sanchez captured a wide-field image of the region on 16th February 2017 with the new CACTI camera on the AAT (Figure 2). The image shows the remnant of Supernova 1987A, with the pink glow of its hydrogen gas, and filaments of gas and dust that stretch over 300 light years to either side.

The new image also reveals a group of pearl-like bubbles, 110 light years away from the explosion site. These bubbles are a sign of youth, indicating this fertile stellar nursery continues to form new stars.

We also prepared a 40 second animation that shows a zooming into the SN1987A remnant in the Large Magellanic Cloud. This animation, that is available on our YouTube channel (https://www.youtube.com/watch?v=hMb_A4l6WtY), uses 4 images: the full view of the Tarantula Nebula, as seen by the AAT years before the explosion on 23 February 1987, a new image of the neighbourhood of the supernova obtained with the new CACTI camera at the AAT, and wide and deep images obtained with the Hubble Space Telescope showing the asymmetry of the SN 1987A remnant.

Figure 2: The neighborhood and the remnant of SN 1987A.

Top left: New image around the remnant of SN 1987A in the Large Magellanic Cloud taken with the 3.9m Anglo-Australian Telescope.

Credit: Ángel R. López-Sánchez (AAO/MQU), Steve Lee, Robert Patterson, Robert Dean and Jennifer Riding (AAO) & Sarah Martel (UNSW / AAO).

Top right: Wide Hubble Space Telescope image of the central area, data collected between 1994 and 1997.

Credit: Hubble Heritage Team (AURA/STScI/NASA/ESA).

Bottom right: Deep Hubble Space Telescope image obtained in 2011 showing the asymmetric structure of the SN 1987A remnant.

Credit: ESA/Hubble & NASA.

New Horizons for Australian Astronomers

Fred Watson (AAO)

Many readers of this newsletter will know that Australian astronomers have long coveted the idea of our nation being affiliated with ESO, the European Southern Observatory. A near-success two decades ago fell victim to budget pressures in the run-up to the 1996 federal election, relegating the issue to a fond hope in the bosoms of optical astronomers on both sides of the European-Antipodean divide. But with almost breathtaking swiftness, there has now been a shift in the fortunes of those ambitions. Behind-the-scences negotiations have given way to a blaze of publicity at the ASA's Annual Scientific Meeting in Canberra, where Senator the Hon Arthur Sinodinos (Commonwealth Minister for Industry, Innovation and Science) and Professor Tim de Zeeuw (ESO Director General) exchanged signatures on 11 July 2017 (see Director's message).

What exactly does the deal involve? While current fiscal realities prohibit full membership of ESO, the ten-year strategic partnership that Australia will formally enter on 1 January 2018 provides long-term access to the world's most comprehensive

Above: Prize for Australian astronomers. A sunset portrait of the four 8.2-m Unit Telescopes of ESO's VLT at Paranal. Also visible are three of the four 1.8-metre Auxiliary Telescopes that can be combined with the larger telescopes for interferometric work in the VLTI mode.

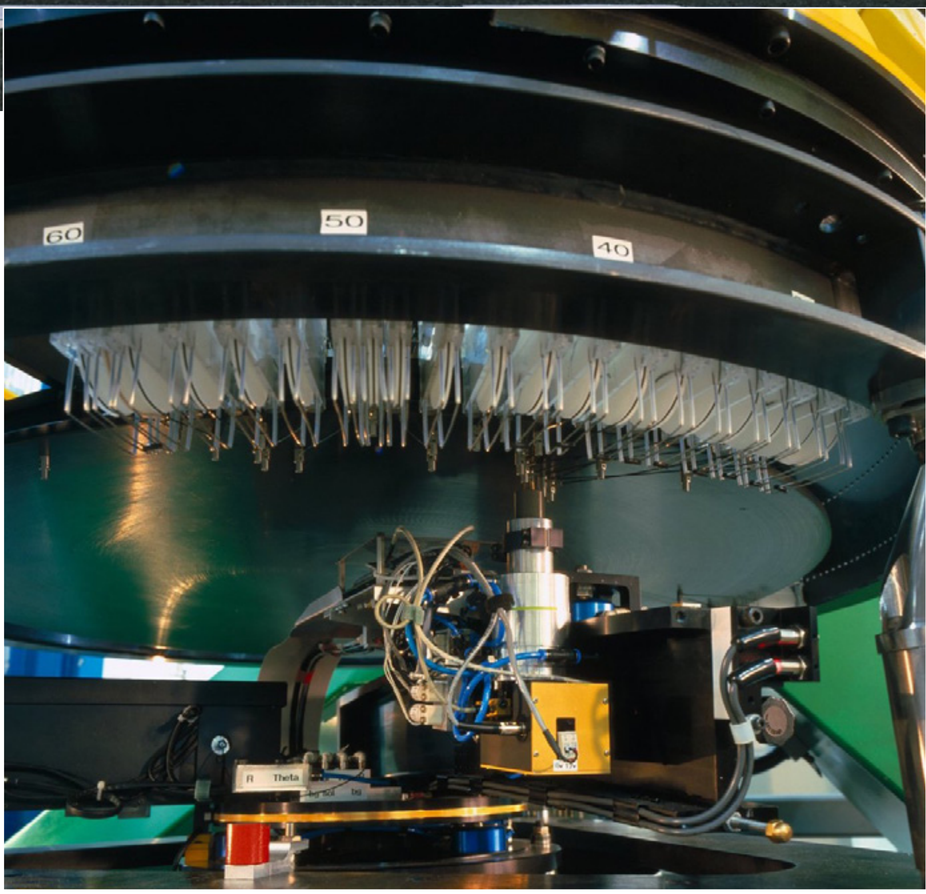
Credit: Juan Carlos Muñoz-Mateos (Staff member at ESO)..

suite of optical astronomy facilities, located in northern Chile at La Silla and Cerro Paranal. Here, atmospheric conditions are exquisitely matched to the requirements of ground-based optical astronomers.

Access to the four 8.2-m telescopes of ESO's VLT at Paranal is an important prize for Australian astronomers, whose requirements for time on telescopes in this class have been highlighted in successive Decadal Plans for Australian Astronomy – including the current one (2016-2025). Historically, such access has been granted by relatively short-term financial agreements with institutions other than ESO. These arrangements have provided little opportunity to influence the design and procurement of advanced instrumentation for the telescopes, an area in which Australia has particular expertise. The new deal with ESO explicitly aims to capitalise on that know-how, with promised benefits not only for technologically-adept institutions such as AAO, but for partners in Australian universities and industry.

Technology is only one of the reasons ESO is keen on Australian involvment, however. Another – also highlighted in successive Decadal Plans – is the high-impact science carried out by Australian astronomers. As that well-worn (if faintly aggressive) metaphor has it, Australian astronomical research has long punched above its weight – and our scientific clout can only be increased by the new facilities now becoming accessible. The complete suite of instrumentation open to Australian astronomers is summarised in the table below, and fuller details are available at https://www.eso.org/public/teles-instr/ .

With Australian astronomers now eligible to compete for time alongside astronomers based in ESO member states, there are already a number of useful online resources available.



There's an ESO twitter feed specifically for us at https://twitter.com/ESO_Australia, while a neat video introduction to ESO's time allocation process is accessible at https://www.youtube.com/watch?v=K4GHhcbYNXU&feature=youtube (but don't let the oversubscription statistics put you off...). Help is also available from the International Telescopes Support Office at AAO (https://www.aao.gov.au/itso/home or by email at itso@aao.gov.au).

Excluded from the new partnership is ESO's Atacama Large Millimetre Array (ALMA) at the Llano de Chajnantor site near San Pedro de Atacama. Access to this 5,100-m high submillimetre facility has lower priority for Australian astronomers than access to 8-m class optical telescopes. Likewise the 39.3-m European Extremely Large Telescope (E-ELT), currently under construction at Cerro Armazones (near Paranal), is excluded because of Australia's established participation in the proposed 22-m Giant Magellan Telescope, also in northern Chile. At the conclusion of the agreement in 2028, however, Australia will have the opportunity to enter into full membership of ESO, with access to both ALMA and E-ELT. While it is difficult to chart the financial landscape that will then prevail, there is optimism that this will be a real possibility.

The Government's initiative in forging the partnership with ESO has been widely praised within the Australian astronomical community. The jury is still out, however, on a concomitant change which, at present, is in the process of formulation. As explained in the Director's message, it heralds the biggest makeover in AAO's 43-year history, with its key functions moving from the government sector to the research sector,

Above: Hot off the press... a teaser for Australian astronomers. This exquisite image of the planetary nebula IC4406 was obtained at first light of ESO's new Adaptive Optics Facility (AOF) on UT4, using the MUSE integral field spectrograph. The faint shell structures have not previously been seen.
Credit: ESO

VLT (4 x 8m)				Interferometer	4m-VISTA	2.6m-VST	La Silla Telescopes	
UT1	UT2	UT3	UT4	VLTI	VISTA	VST	4m-NTT	ESO-3.6m
NACO	FLAMES	SPHERE	HAWK-I	AMBER	VIRCAM	OmegaCAM	SOFI	HARPS
KMOS	X-shooter	VIMOS	SINFONI	PIONER	—	—	EFOSC2	—
FORS2	UVES	VISIR	MUSE	GRAVITY	—	—	—	—

(Table courtesy Tayyaba Zafar)

and a separation of telescope operations and the Observatory's technology and facilities base in Sydney. Once again, it is fiscal reality that dictates the need for this transformation. Without it, the Observatory's finances would have cascaded over a precipitous funding cliff in 2020. With it, the requirements of the Decadal Plan in maintaining the key functions of the AAO can be met.

By the time the next edition of the AAO Observer appears, details of the new structure should be well-established, with a clear time-line for it to be implemented. And there are good prospects that the AAO's well-known and well-respected branding will survive the metamorphosis – as it did last time. As someone remarked back then, 'The AAO is dead: long live the AAO...'

Further reading

https://www.science.org.au/files/userfiles/support/reports-and-plans/2015/astronomy-decadal-plan-2016-2025.pdf

http://minister.industry.gov.au/ministers/sinodinos/media-releases/new-investment-advanced-manufacturing-and-research-infrastructure

http://www.anu.edu.au/news/all-news/anu-welcomes-access-to-telescopes-at-premier-site

Watson, Fred & Colless, Matthew, 2010. 'The AAO is dead: long live the AAO!' Astronomy & Geophysics, 51, 3.16 (https://www.aao.gov.au/files/AAO_transition_AG_article.pdf)

Left top: As if to tantalise Australian astronomers, the distant summit of Cerro Armazones is beautifully framed by one of the VLT Auxiliary Telescopes and the purple glow of the 'belt of Venus', just before sunrise at Paranal. Armazones will host the European Extremely Large Telescope, excluded for now from the strategic partnership.

Inset: Getting our own back. The OzPoz fiber positioner was built by the AAO for the VLT's FLAMES multi-object spectrograph. It was an early example of AAO expertise in instrumentation finding its way to other astronomical facilities, and is likely to be repeated under the new strategic partnership.

Credit: ESO

Successful BBC and ABC Stargazing Live TV events at Siding Spring Observatory

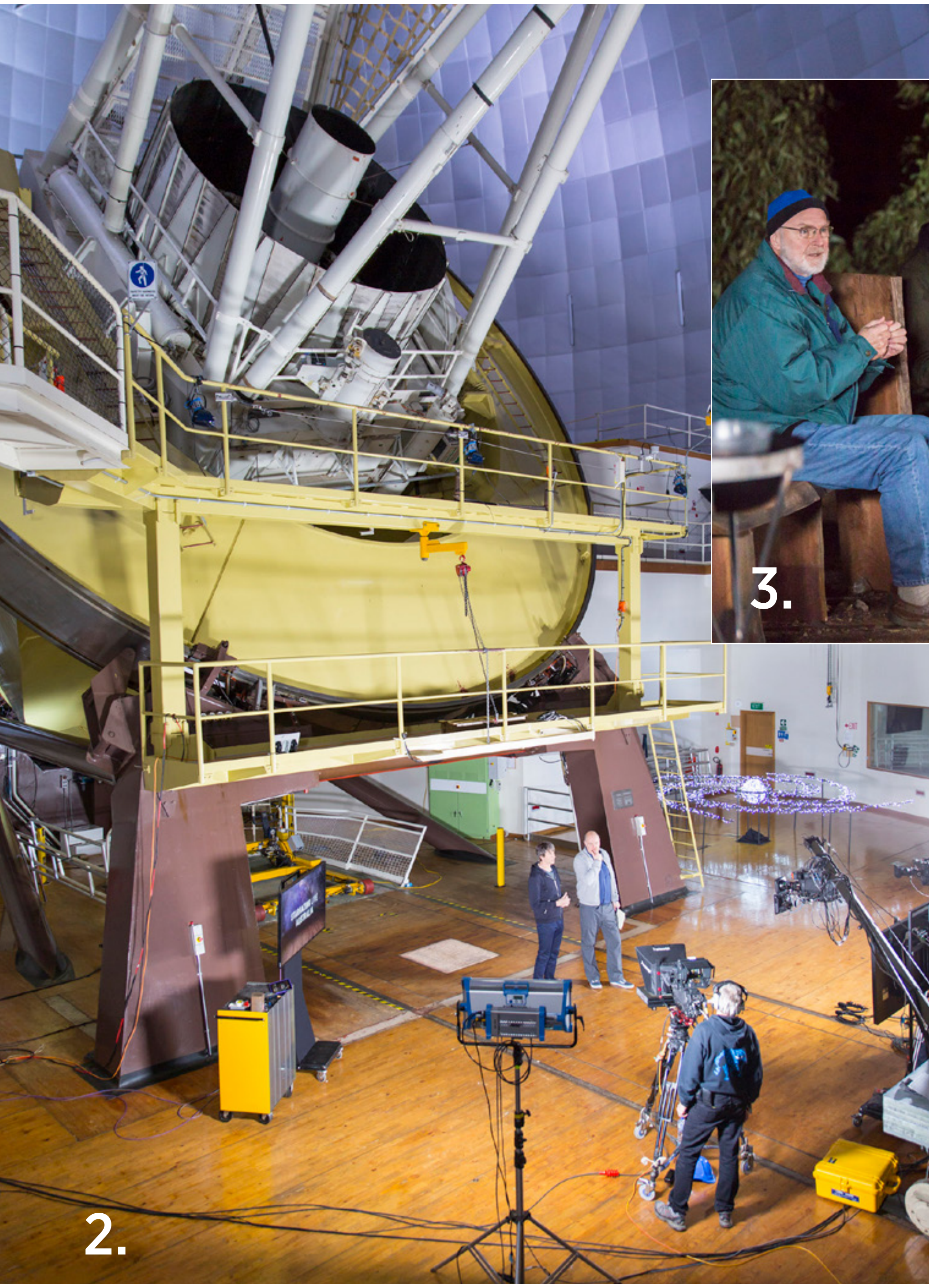
Ángel R. López-Sánchez (AAO/MQU)

Colorful lights in the dome of our Anglo-Australian Telescope in preparation for the Stargazing Live TV shows.

During two weeks in late March and early April 2017, famous physicist and TV presenter Professor Brian Cox co-hosted two "Stargazing TV" shows transmitted live from Siding Spring Observatory on the BBC and on the ABC. The stage of these major TV events was our Anglo-Australian Telescope, (AAT) at Siding Spring Observatory, on the edge of the Warrumbungle National Park near Coonabarabran, NSW.

BBC Stargazing Live shows at Siding Spring Observatory were transmitted on the early morning of Wednesday 29th, Thursday 30th and Friday 31st March 2017 (evenings of the previous days in the UK). BBC Stargazing Live TV shows were hosted by Professor Brian Cox and TV presenter and comedian Dara Ó Briain,


3.


2.

Main: The Keyhole Nebula. Image taken as part of the "ABC Stargazing Live" TV at the Siding Spring Observatory (NSW, Australia), 4 – 6 April 2017. Data taken on 3rd April 2017 using the CACTI camera in 2dF at the 3.9m Anglo-Australian Telescope. Color image using B (12 x 60s, blue) + [O III] (12 x 60s, green) + Hα (12 x 60 s, red)filters.

Credit: Ángel R. López-Sánchez (AAO/MQU), Steve Lee (AAO), Robert Patterson (AAO), Robert Dean (AAO) and the Night Assistant at the AAT: Wiston Campbell (AAO).

Inset: Prof. Brian Cox and TV presenter Julia Zemiro hosted the #StargazingABC Live TV shows.

Credit: Ángel R. López-Sánchez (AAO/MQU).

2: Rehearsals for BBC Stargazing Live TV shows at the ground floor of the AAT.

Credit: Ángel R. López-Sánchez (AAO/MQU).

3 AAO astronomer David Malin is interviewed by Prof. Brian Cox and Dara Ó Briain during BBC Stargazing Live TV shows.

Credit: Ángel R. López-Sánchez (AAO/MQU).

with the participation of biologist and BBC presenter Liz Bonnin and Broome-based amateur astronomer Greg Quicke (who was very popular in social media, receiving the nickname of #SpaceGandalf).

#StargazingABC live episodes were telecast the following week (Tuesday 4th, Wednesday 5th and Thursday 6th April 2017). Hosts Professor Brian Cox and TV presenter Julia Zemiro were joined by astronomers to inspire Australia to explore our Universe and tackle astronomy's most intriguing questions. Astronomer Lisa Harvey-Smith (CSIRO) also participated as TV presenter for the #StargazingABC shows.

AAO's Fred Watson, Steve Lee and David Malin were interviewed several times during the ABC and BBC Stargazing Live shows.

For #StargazingABC first episode, the Milky Way, AAO astronomers Ángel López-Sánchez and Steve Lee prepared a new astronomical color image using data taken with the CACTI auxiliary camera of the AAT, which was broadcast in the episode.

This image shows diffuse gas and dust in the heart of the Carina Nebula. The bright star is Eta Carinae, a massive double star at the end of its live that will soon explode as a supernova. The "Keyhole" is the dark cloud in the centre of the image.

Both Stargazing Live ABC events were very successful. #StargazingABC live episodes reached 2.7 million viewers across metro and regional Australia. They also had a huge impact in social media. The first ABC TV episode reached over 240K people and had more than 8K reactions in Facebook, comments and shares, similar numbers to those obtained with ABC TV's New Year's Eve Family Fireworks stream. Regarding Twitter, the #StargazingABC hashtag reached 18.4 million users and produced 16.8K tweets from 6.3K unique contributors. 12.8K of these tweets were produced during the broadcasts, making #StargazingABC trend no.1 in Australia.

Inset: Sarah Brough (UNSW) in Antarctica.
Credit: Wynet Smith

Where will your career take you?

Sarah Brough (University of New South Wales)

In December 2016 the AAO supported me to attend the first Homeward Bound expedition – a 3-week leadership course for women in science which took place onboard a ship in Antarctica!

How does something like this even come about? Homeward Bound started for me with a seemingly innocuous email in August 2015: the monthly update from the Early and Mid Career Researcher Forum of the Australian Academy of Science. It mentioned a project to take 76 female scientists from around the world to Antarctica in December 2016, learning state-of-the-art leadership & strategic skills along the way.

My long-term love of penguins and the work I have being doing to support and encourage women in science (as Chair of the Astronomical Society of Australia's Inclusion, Diversity And Equity in Astronomy chapter; https://asa-idea.org) encouraged me to apply, even though the deadline was short, the application had to be in video form and it would mean being away from my now 4½ year old son for 3½ long weeks. Only a few weeks later I found out I had been accepted; this was really happening!

In the year leading up to our departure we took various tests to understand our thinking and behavioural styles as well as our emotional intelligence (4MAT; LSI and MSCEIT tests) and were privileged to discuss the results with development coaches who volunteered their time to help us on our journey as leaders. We also started to get to know one another through monthly teleconferences; small project teams and Australian state-based meetings as well as active Slack and Facebook pages.

In December 2016 76 women covering a range of ages and nationalities and science backgrounds – social scientists, mathematicians, geologists – as well as 5 film crew, our 2 expedition leaders: Greg Mortimer and Monika Schillat, and 6 faculty including the indomitable Fabian Dattner whose vision, drive and determination brought us all to this place in time, all descended on a hotel in Ushuaia, at the southern tip of Argentina.

Our home for the next 3 weeks was the class 1C icebreaker M/V Ushuaia, operated by Antarpply. We were very lucky with the

Main: Gentoo Penguin.
Credit: Sarah Brough

weather and the notorious Drake Passage crossing was notably calm so we started work early. The philosophy behind our on-board lessons was that the best leaders know themselves, so we were encouraged to understand our own behaviour. We used the tests we had taken before the trip to understand our thinking and behavioural styles as well as our emotional intelligence. We saw that we all looked for the same things in a leader: someone with a constructive, human-focussed style and a lack of aggressive or passive defensive responses. It made me realise how much some of my thinking styles hold me back but also gave me tools to reframe those styles.

We thought carefully about our own values as leaders, our motivations in wanting to be leaders, as well as defining what we saw leadership to be. I saw that not everyone has the same values or motivations in their leadership aspirations.

We thought about our current visibility in our communities and what we wanted that visibility to look like in the future. I realised I want to be more visible outside of the Australian astronomical community, sharing my expertise with a broader audience. Finally, we prepared personal strategy maps to plan how we would move forwards after leaving the ship.

There was also Symposium@Sea – three-minute presentations from everyone. This allowed us to see the 'expert' side of one another and practise how to communicate to the four different learning styles we had identified. I was inspired to find a topical analogy between the unseen 90% of the galaxies that I study and the 90% of icebergs that is underwater.

Our lessons were intermixed with daily landings in the Antarctic. I got used to the routine of changing into many layers ready for briefing by our Expedition Leader before going and then off onto the adventure that the landing would bring. Experiencing the cold (around 1°C), the cacophony and stench of penguin colonies (Adélie, Chinstrap, and Gentoo - Main photo), as well as the beauty of the Antarctic colours and the cat-like seals snoozing everywhere (Photo 2). We saw many whales and enjoyed beautiful rocks, glassy water, mountains criss-crossed with snow as well as the peaceful sounds of water and the less peaceful sounds of ice. There was also fun – we slid down snow-covered hills, running back to the top of the hill from the bottom just to do it again.

Human mixing was encouraged: Landing with people we had not spoken to yet, getting up and sitting somewhere else in the lounge room we worked and socialised in. Trying to talk to everyone became the norm. With those conversations came nuggets of thought and insights into different ways of thinking. Slowly we got to know one another and to have deeper conversations. I was having a steady stream of insightful, life-changing conversations with this awesome group of women (Photo at the end of the article).

Back Home

I have now been home for 6 months, so what has my Homeward Bound experience meant for me so far?

I now have the widest, most supportive network you can imagine and we are all still there for each other. This international cheer team has allowed me to take the step outside of my comfort zone I envisaged on board: increasing my visibility as a scientist. I have taken part in several public events ranging from video-conferencing with high school students in the Hunter Valley, to a panel discussion on the nature of time in Sydney.

Developing my personal strategy map onboard gave me specific objectives to focus on to achieve an overarching goal. This consideration makes it easier now to answer the always difficult question of whether to seek out or accept a particular opportunity.

I have also changed workplace, saying goodbye to the AAO and joining the School of Physics at University of New South Wales in January. In joining a new group and taking on new challenges I feel more confident in my leadership skills, and less hesitant in facilitating a variety of opinions into a workable consensus for all.

I could not have had this experience without the support of the Australian Astronomical Observatory, an amazing organisation for whom I am very proud to have worked for over seven years.

The Homeward Bound program provided a unique opportunity for Sarah to experience leadership training of a completely different style to that available within the AAO and the Department of Industry, Innovation and Science. The AAO places a high value on the professional development of our staff, and this was clearly a chance for us to support Sarah's growth as a future leader of our community. I have recognised the value of the program since Sarah's return in many ways. Sarah has long had significant potential as a research leader and manager, as well as being a leader of positive change in our community. This has been crystallised through her experience with Homeward Bound. While Sarah always showed a high level of self-confidence and clearly defined personal goals, her capacity in these areas has increased, and she is demonstrably conducting herself as a leader. She has benefited from the time to reflect on her goals, to refine and develop these, and to put clear plans in place to achieve them. Sarah's newly-formed and strong personal and professional networks, arising from among the program participants, give her a source of support and a resource that she can draw on as her career evolves. With her move from the AAO to UNSW shortly after her return, Sarah has had the opportunity straight away to put into practice many of the leadership skills she has developed. It is very pleasing to see her stepping up to this challenge, and I look forward to continuing to work with her in the future as she takes on major leadership roles in our community.

Andrew Hopkins, AAO

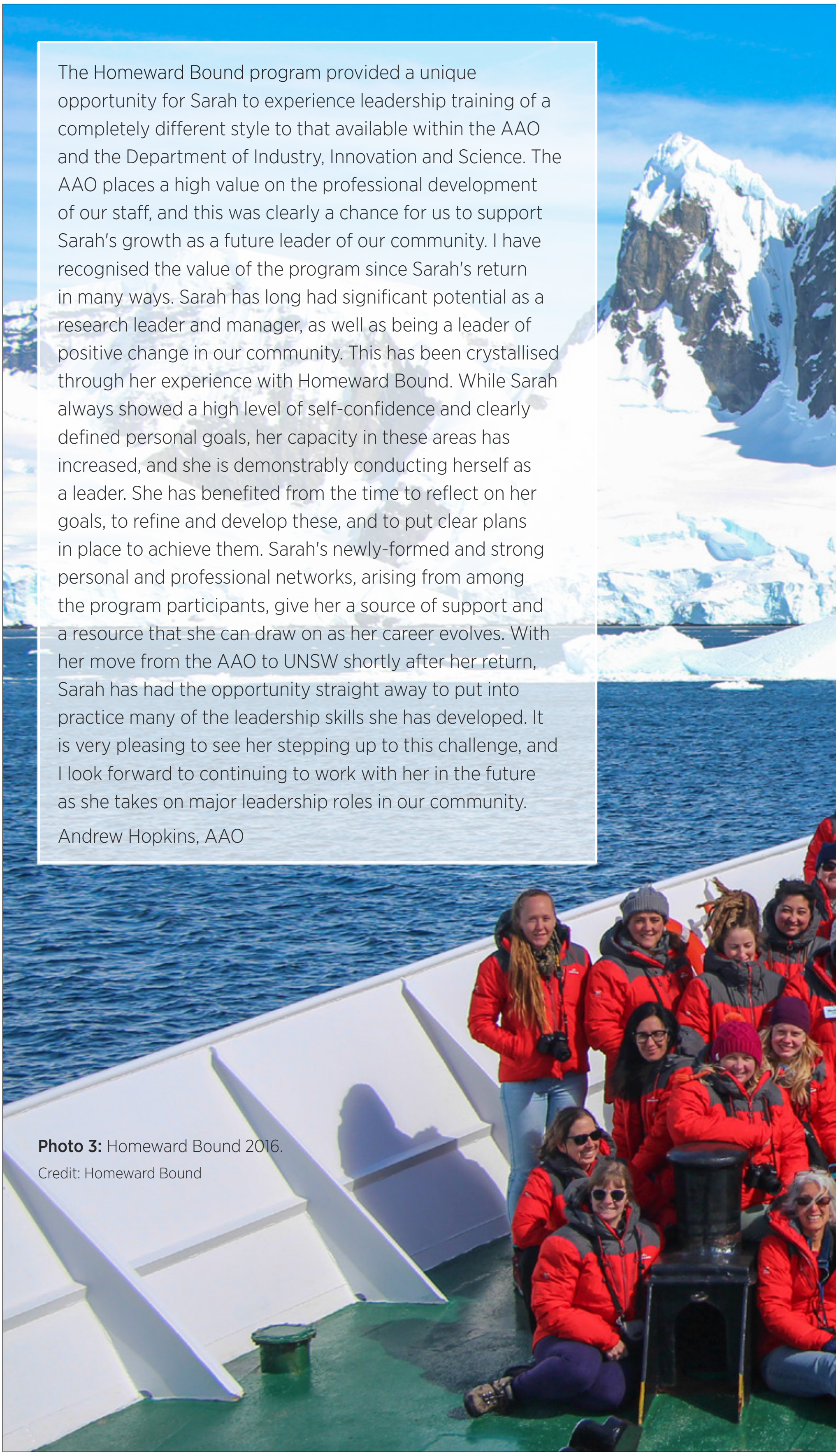


Photo 3: Homeward Bound 2016.
Credit: Homeward Bound

Figure 1: A rare occasion whereby all five-night assistants are working day shift. From left to right: Steve Chapman, Jennifer Riding, Steve Lee, Kristin Fiegert, Winston Campbell

Night Life at the AAT: The Night Assistants Perspective

Steve Lee, Winston Campbell, Kristin Fiegert,
Steve Chapman, Jennifer Riding (AAO)

Night assistants have always been an integral part of observing at the AAT. They are there to make the astronomers' observation go as smoothly, efficiently and as trouble-free as possible. A night assistant, as the name implies, works through the night from sunset to sunrise, making for some very long winter nights. At the AAT, there are five of us and a shift lasts seven days, so for one week in five our lives get turned upside down. This article will hopefully give you an insight into what it's like to be an AAT night assistant.

Turning Nights into Days

Our first challenge as a night shift worker is turning nights into days. When you are part of the day crew it is life as usual and your thoughts are about work and what you are going to do when you get home. When you are working nights it's all about the sleep. Sleep is the most important thing. It's amazing what sleep deprivation does to the human brain, just ask any shift worker about the silly mistakes that happen at 3am. So how do the night assistants do it?

Starting shift is much easier for us than returning to days. The first night is the most painful with only a nap before shift but after a night's observing sleep comes easily. The worst part is trying to return to days. It's not a matter of staying up after night shift (talk about road safety trying to drive home!), a couple of hours sleep is required before some semblance of humanity has returned.

The key to sleeping during the day is making it as dark as night. The new lodge has dark rooms but Winston Campbell chooses to go home instead. Luckily, he lives on the mountain. To make his bedroom light-tight, he has installed an extra cover over his window to keep the sunlight out. He also makes sure he doesn't see the sun until he's ready to get up. These sentiments are shared by all the night assistants.

Nights Fantastic

Working nights in the middle of nowhere has its advantages. The night sky is full of fantastic objects and weather checks are the perfect excuse to enjoy the gorgeous skies above. We've all seen more fantastic sunsets and sunrises than one could ever expect in a lifetime – although that usually means that there is a bit of cloud around to turn an ordinary sunset into a memorable one.

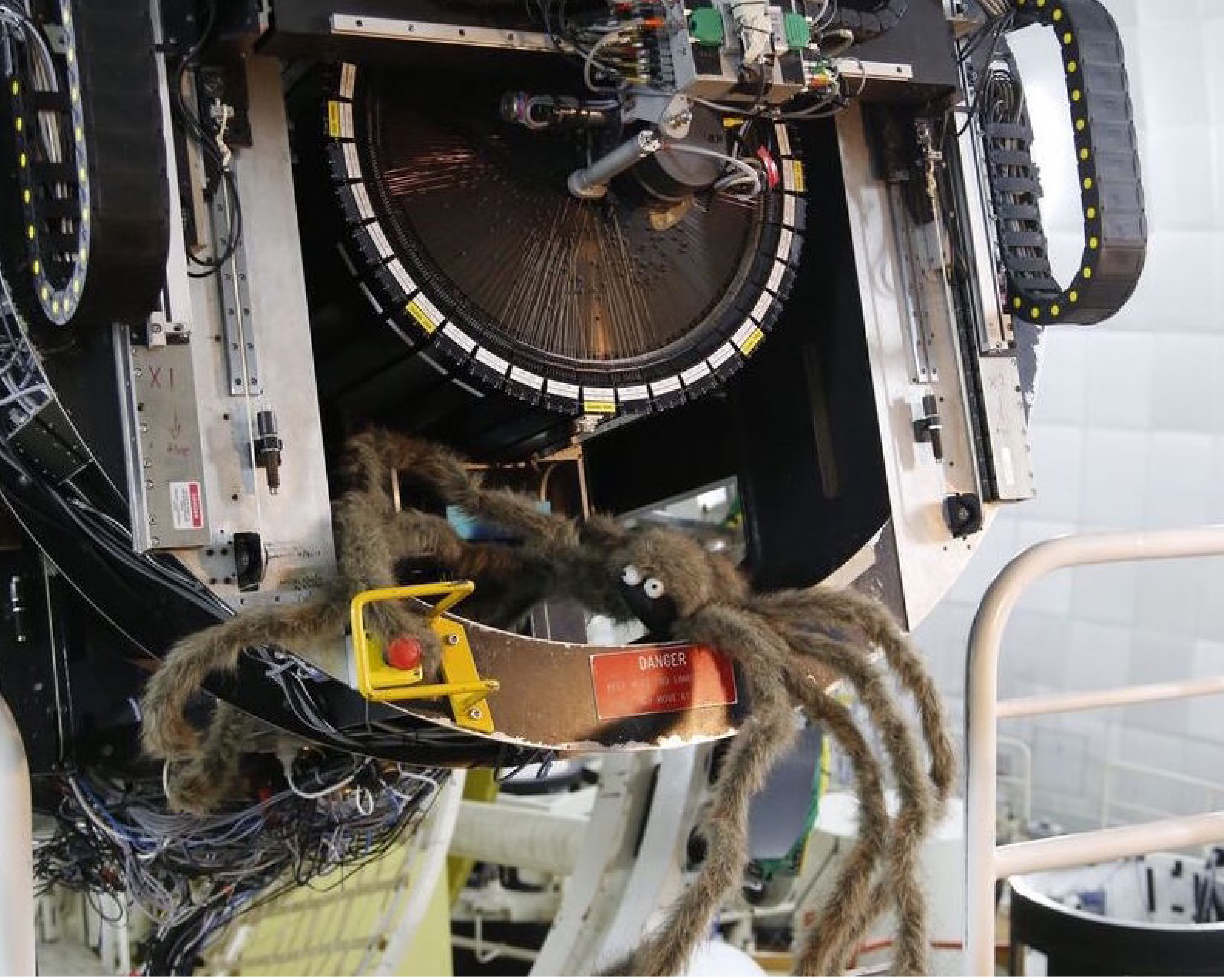


Figure 2: A typical example of a 2dF bug. A regular visitor of the AAT.

If you want pictures, just ask Steve Chapman (Chappy), you can always tell when he's on shift because his facebook page fills with sunset shots.

The AAT catwalk is a wonderful observing platform. It is the favourite part of the job for Steve Lee. Steve's seen moonbows (a rainbow illuminated by the Moon rather than the Sun) as well as many green flashes at sunrise. He loves following the gegenschein and tracing the zodiacal band under the beautifully dark skies that we have. He's seen amazing lightning displays (but unfortunately that also implies bad weather around) and meteor showers too.

Then there's the moon. Winston's two favourite effects involve clouds, reflection and diffraction. Thin high cloud causes an ice ring at 22° around the moon to appear whilst thin low cloud creates a lunar corona, a colourful diffraction ring around the moon. He's also rather fond of the way clouds sink into the valleys around the AAT although it usually means we have to close the dome soon as cloud rises to become foglike.

Kristin Fiegert likes the emu in the sky and recently became acquainted with venus' belt (thanks Fred Watson). She also finds the shadows cast by starlight rather special. If you're ever observing with Kristin and a plane flies overhead, she'll tell you its name and destination.

Finally, there's always the planets. Chappy and Kristin have helped Angel Lopez-Sanchez use twilight time (too bright for science) to image various planets and nebulae using 2dF's FPI camera. A selection of these shots are on display in the AAT control room.

When Things Go Not Quite Right

During the night it may appear the night assistant is not doing much related to telescope operations and that's our hope too. A smoothly running night means that the weather is clear, the seeing good, there is no fire danger, the guiding software is working, the telescope is tracking, the shutter is open and the instrument is collecting superb data. The problem with complex, one-of-a-kind instruments is that sometimes things go not quite right. These things can be as simple as 2dF misplacing a button right up to there's a storm coming, the dome is open, there's no power and the generator won't start. There are many things that go wrong during the night, some more traumatic than others. Here are a couple of events that cover the whole gamut of nightly experiences that the NA encounters.

2dF has bugs. Literally. Kristin remembers a time when the 2dF robot lost a button during positioning and upon inspection found that the button had been placed on a ladybird. Finding bugs (or pieces of bugs) on 2dF is nothing new and can be a real problem when they end up in the fiber retractors. Besides insects, there always seems to be at least one huntsman on the 6th floor.

There's another issue with 2dF: it's afraid of the dark. 2dF has two modes of operation, a day mode where nothing goes wrong and a night mode where the tumbler freezes (well, it is cold up here) or it no longer wants to talk to the spectrograph. It's times like these that having a night assistant around is a good thing to bring 2dF back into line. It's just unfortunate it won't repeat the fault until the next time the lights go out.

Another favourite of the AAT is weather. There is only one thing more frustrating for an observer or a night assistant than watching the rain. Winston recalls a time when after two nights of clouds it cleared up just in time for the telescope's old drive system to fail. The poor astronomer lamented his choice to not become a plumber.

Before the days of wireless, monitors and computers were wired from the telescope to the control room. Cables on a moving, turning object have a nasty habit of getting all tangled up and occasionally, whilst slewing to an object a monitor or a computer would start sliding across the desk in the control room. It takes a quick thinker to stop the telescope and not dive for the monitor.

Staying in Touch

When your day is not the same as everyone else's it is easy to lose touch with your friends and colleagues, and they lose contact with you. Those working through the day don't see you and think you're on holidays for a week. Winters are particularly bad as there is not a lot of time to do anything other than sleep and work. Kristin notes that during winter there's no point going home after a day's sleep as it is almost time to return to work. She misses her husband but perhaps not the housework. Instead, she makes herself a cup of tea and reads a book before going on shift. Returning to day shift always feels like you're coming back after a long break.

Perhaps the worst thing about night shift is missing Christmas. The AAT schedules observations for every night of the year (excepting aluminising week) meaning Christmas is spent with observers – which has been Chris Lidman these past few years. It's not all bad; welcoming in the morning watching a sunrise with a glass of champagne can make Christmas a special day up at the AAT too.

Through the Ages

Since the commissioning days of the telescope there have been about two dozen people who have been AAT night assistants. This is actually a small number when you consider that during the commissioning days and very early scheduled use of the telescope almost all the technical staff were used as night assistants at one time or another. Night assisting in those early years was very different, with the night assistant working a normal day and then staying up for the remainder of the night operating the telescope. This was only done for one night – for obvious reasons – but this gruelling shift schedule was carried on for several years.

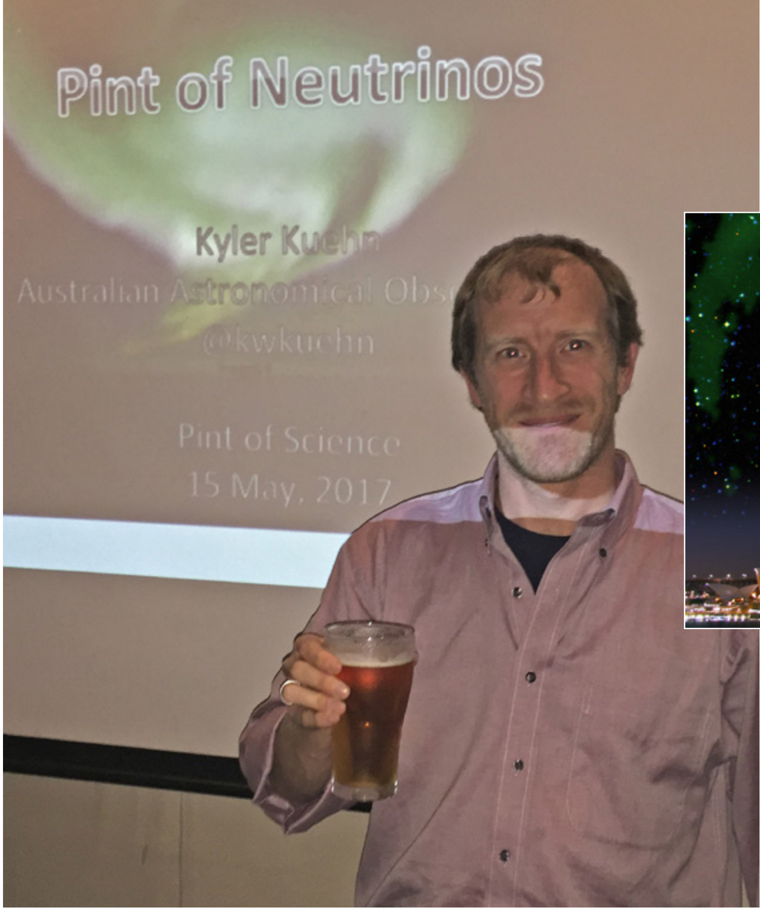
In 1976, when operations had settled down and most of the bugs worked out of the system, it was decided that a dedicated team of night assistants would be employed to operate the telescope. They were to be called Telescope System Operators rather than night assistants, but the name never stuck. First to be employed was Chief Night Assistant Tom Cragg and he would oversee the recruitment of the remaining team. Next were Steven Lee, then Kevin Cooper and finally Frank Freeman. Those three (Tom didn't usually work nights, but did the day shift for infrared observations), plus Gordon Schafer (from the original group of night assistants) remained the stable night assisting team for some 20 years and helped build a reputation for the AAT as one of the most productive and easily used telescopes around. A review article of early AAT operations commented that telescope operations were overseen by "a cheerful and well informed night assistant" a term, which stuck for a very long time.

Tom's plan for night assistants was that they would have a role in the observatory during the day, as well as working the telescope at night. At the time, other observatories simply had a day crew and a separate night crew, which could lead to problems. This philosophy is still followed today; with new night assistants being employed because of what skills they can offer beyond the ability to stay awake at night. These skills are usually things like electronics and computing, but the skill set of the night assistant is quite diverse, covering most areas of AAT operations.

Steve, who has been a night assistant for 40 years, tells people that while on paper he's still doing the same job, the job has changed around him over the years, reflecting the changing instrumentation and observing techniques at the AAO. And he still loves it.

Closing the Dome

Hopefully you have a better idea about some of the benefits and challenges of night assisting. If you're not an astronomer we invite you to come up and visit our telescope and have a look at the incredible science being done at the AAT. If you're an astronomer, we encourage you to come up to site, try out the new lodge and enjoy our skies. And bring tim tams. Night assistants love tim tams.



Above: Poster of Sydney's "Atoms to Galaxies" for Pint of Science Australia 2017.
Credit: Ángel R. López-Sánchez (AAO/MQU).

Left: Kyler Kuehn during his talk for the "Pint of Science" festival,
Credit: Rebecca Brown (AAO).

AAO joins organization of International Science Communication Festival "Pint of Science"

Ángel R. López-Sánchez (AAO/MQU)

In 2017 the Australian Astronomical Observatory joined the international Science Communication festival Pint of Science. The festival started in the UK and runs every May in over 150 cities across 12 different countries, including Australia. This year Pint of Science took place in 13 cities across Australia (including Sydney) over 15, 16 and 17 May 2017.

The Pint of Science festival aims to promote Science and Science Communication in a very relaxing atmosphere: in a pub with a drink. It brings scientists to a local pub to discuss their latest research and findings with the public.

The Australian Astronomical Observatory joined CSIRO, the ARC Centre of Excellence CAASTRO, and the Spanish Researchers in Australia-Pacific (SRAP) association as a sponsor of Sydney's Pint of Science Festival in 2017. Our astronomer Ángel López-Sánchez (AAO/MQU) co-led the organization of the "Atoms to Galaxies" talks.

These sessions included talks about Physics, Maths, Chemistry and Astronomy and were hosted at Bar Cleveland, in Surry Hills.

Sydney's "Atoms to Galaxies" program (which was the largest for Pint of Science Australia 2017) included talks about applied maths, search for exoplanets, explore quantum computing, play with the light, learn the origin of the chemical elements, map distant galaxies and challenge the laws of Physics.

The first night, "Elements in Space", included talks by AAO astronomer and engineer Kyler Kuehn, who talked about astronomy neutrinos presenting the work he conducted in Antarctica for his PhD Thesis, and by AAO and Macquarie University astronomer Ángel López-Sánchez, who transported the audience to distant stars and galaxies to know when and how the atoms that compose our body were created.

In the third night, "Decodifying the Light of the Cosmos", AAO astronomer and eResearch administrator Simon O'Toole described how we use the light collected by optical telescopes to search for planets around other stars, with the ultimate aim of finding an "Earth 2.0".

Astronomers George Hobbs (CSIRO), Luke Barnes (University of Sydney) and Baerbel Koribalski (CSIRO), as well as physicists Dr. Sergio León-Saval (University of Sydney) and Prof. Jason Twamley (Macquarie University), and mathematician Emi Tanaka (University of Sydney) completed the "Atoms to Galaxies" program.

Besides organizing Sydney's "Atoms to Galaxies" talks for Pint of Science Australia 2017, the Australian Astronomical Observatory was also present in the "Tech me out!" session Space Oddities on Wednesday 17th May. AAO's optical engineer Rebecca Brown gave the talk "Capturing the Light of the Universe", where she summarized the technologies used in optical telescopes, how they work and what we can learn, including example technologies developed at the AAO.

"Stargazing in the Calyx", new Science Communication Event series at Sydney's Botanic Gardens

Ángel R. López-Sánchez (AAO/MQU)

In June 2017 the Australian Astronomical Observatory (AAO) started a new Science Communication collaboration with historic Sydney's Royal Botanic Gardens. The events "Stargazing in the Calyx" combine a short talk given by an astronomer followed by a stargazing session with amateur telescopes.

The first of these events was held on Monday 19th June 2017. It was so successful that the following "Stargazing in the Calyx" session, scheduled on Tuesday 4th July, was sold out in just 8 minutes after the tickets were available.

The organization of these events have received hugely positive feedback, both about the venue (the brand-new "The Calyx" building at Sydney's Botanic Gardens) and the atmosphere (people enjoyed dinner with drinks under the stars) and the entertaining and knowledgable talks about the Southern Sky (given by AAO and Macquarie University astronomer Ángel López-Sánchez).

Besides some clouds and Sydney's light pollution, participants really enjoyed the views of planets Jupiter and Saturn and the Moon through the telescopes, as well as observing globular cluster Omega Centauri and the famous "Jewel Box" star cluster in the Southern Cross, as well as learnt to recognize the constellations of the winter nights in the southern hemisphere. Some of the telescopes were kindly provided by CSIRO, Sydney University, Macquarie University and some amateur astronomers who were also invited to these events.

The next "Stargazing a the Calyx" event is scheduled on Tuesday 3rd of October. We expect they will be repeated each 1 or 2 months.

Main: People enjoying the view of the sky through amateur telescopes during the “Stargazing in the Calyx” science communication event at Sydney’s Botanic Gardens on Tuesday 4th July 2017.

Credit: Christina McGhee (Sydney’s Botanic Gardens).

Inset: AAO/MQU astronomer Ángel López-Sánchez giving his talk “Introduction to the Southern Sky” as part of the “Stargazing in the Calyx” event at Sydney’s Botanic Gardens on Monday 19th June 2017.

Credit: Christina McGhee (Sydney’s Botanic Gardens).

"The Story of Light: Surveying the Cosmos", in Vivid Sydney Ideas 2017

Ángel R. López-Sánchez (AAO/MQU)

Following the success of our sold-out Event "The Story of Light – The Astronomer's Perspective" for ViVID Sydney Ideas 2015, and "The Story of Light – Deciphering the data encoded on the cosmic light", the Australian Astronomical Observatory (AAO) continued the collaboration with ViVID Sydney Ideas 2017 organizing "The Story of Light – Surveying the Cosmos".

This successful science communication event was held at the Powerhouse Museum (Sydney) on Sunday 4th June 2017. Having an audience of 300 people, it was sold out more than two weeks before the event.

"The Story of Light – Surveying the Cosmos" was connected to the 2017 Southern Cross Astrophysics Conference: "Surveying the Cosmos, the Science from massively multiplexed surveys", that was held in Luna Park, Sydney, between 5th and 9th June 2017.

In this event, five professional astrophysicists discussed how astronomers map the Cosmos using the big data collected with optical and radio telescopes by large astronomical surveys.

How do astronomers explore the Universe? Astrophysicists use extremely sensitive telescopes and instruments to collect the light emitted by stars, gas and galaxies. The analysis of this data provides the information needed to unlock the mysteries of the Cosmos.

However, this is not an easy task. Over the last two decades large international collaborations have been formed with the aim to map the skies, catalogue celestial objects, extract their properties and perform statistical analyses. These large astronomical surveys are now providing major advances in our understanding of the Cosmos at all scales, from searching for planets around other stars to detecting gravitational waves.

Australia is at the forefront of these collaborations thanks to the unique instruments at the Anglo-Australian Telescope (AAT) and the development of radio-interferometers such as the Australian SKA Pathfinder (ASKAP).

Image: Panel members and MC of AAO's "The Story of Light – Surveying the Cosmos" Science Communication event for Vivid Sydney Ideas 2017. From left to right: Katie Mack, Alan Duffy, Simon O'Toole, Tara Murphy and Ángel López-Sánchez.

Credit: Duncan Wright (AAO/UNSW).

The panel members were Dr. Simon O'Toole (Australian Astronomical Observatory), who talked about surveying stars and exoplanets, Dr. Ángel R. López-Sánchez (Australian Astronomical Observatory / Macquarie University), who discussed how we survey the galaxies, A/Prof. Tara Murphy (University of Sydney / CAASTRO), who invited us to survey the invisible Universe, and Dr. Katie Mack (University of Melbourne), who talked about surveying the deep Universe. The event was hosted by famous astrophysicist and science communicator A/Prof. Alan R. Duffy (Swinburne University).

After short (15 minutes) talks, the panel answered questions about the Universe and challenging Physics questions as the nature of the dark matter and the dark energy. They also received some more philosophical questions that engaged the audience.

Image: Poster for the AAO's "The Story of Light – Surveying the Cosmos" Science Communication event for Vivid Sydney Ideas 2017.

Credit: Ángel R. López-Sánchez (AAO/MQU).

Southern Cross Conference 2017

Jeffery Simpson (AAO)

Above: The Southern Cross conference group photo.

Credit: Ángel R. López-Sánchez (AAO/MQU)

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 in Australia with the aim of attracting international experts with wide ranging skills to discuss a particular astrophysical topic. The 2017 conference was on the results of massively multiplexed surveys across the electromagnetic spectrum and at all scales of the cosmos.

Large astronomical surveys have been key to many of the major advances in our understanding of the cosmos at all scales over the last two decades. This conference focused on the scientific returns from massively multiplexed surveys: in terms of the number of targets that are observed simultaneously, and massive in the number of objects observed in totality. Australia has often been at the forefront of these types of surveys, with a key development being the start of regular scientific observations with the Two-Degree Field instrument on the Anglo-Australian Telescope in 1997. The 2017 Southern Cross Astrophysics Conference included a retrospective on such surveys.

The next decade will see an explosion in the output from these surveys across all astronomical facilities and scales. Highlighting just a few: APOGEE, GALAH and Gaia-ESO will have observed nearly two million Milky Way stars to help to understand the fossil record of the assembly of our Galaxy; OzDES and DESI will chart the role of dark energy in the expansion history of the universe by observing over 30 million galaxies and quasars; WEAVE and 4MOST will map the kinematic and chemical substructure in the Milky Way, enhancing the scientific legacy of Gaia's census of our galaxy, study the detailed properties of intermediate-redshift galaxies, and characterise the objects found in the next-generation radio surveys; WALLABY will map HI across the entire sky measure the HI properties of about 600,000 galaxies and derive their distances, HI masses, total masses and dark matter content; and EMU will increase the number of known radio sources by a factor of about 30.

This conference brought together a wide cross-section of the international astronomical community with the aim of facilitating discussion of the scientific achievements of massively multiplexed surveys. This conference also offered an opportunity to summarise the lessons that have been learnt in the past to help maximise the scientific return in the future.

ITSO Corner

Stuart Ryder (International Telescopes Support Office, AAO)

ESO access and the future of ITSO

On 11 July 2017 the Australian Government signed a 10 year Strategic Partnership agreement with the European Southern Observatory (ESO) - see the article on p. 25. In addition to providing opportunities for Australian instrumentation groups and industry through ESO contracts, Australian astronomers will gain access to all the ESO telescopes operated at the La Silla and Paranal Observatories (with the exception of APEX). Australian astronomers will be able to apply for time on the same basis as other ESO member countries starting in Period 101, for observing time in April – September 2018. The proposal deadline for Period 101 is noon CET on Thu 28 September 2017 (9pm AEST on 28 Sep).

In preparation for this major new opportunity ITSO and AAL have been arranging "community days" in the major capital cities, supported by ESO staff who are expert in the Phase 1 and Phase 2 processes and the ESO instrumentation. It is important to note that ESO's Observing Programmes Committee (OPC) operates rather differently from ATAC or KTAC, in that proposals are assessed by one of the 13 Expert Panels, whose members are likely to be more familiar with the theme of your research.

Unlike the other observatories that ITSO supports, ESO provides complete support for its users, covering everything from proposal handling, technical assessment, Phase 2 preparation, data reduction pipelines, and even arranging and paying for observer travel to Chile. As such ITSO's role in supporting this ESO access is still being worked out, but it is expected that ITSO will assist ESO in promoting the Call for Proposals; continuing to run annual workshops and symposia; and serve as a point of first contact for urgent ESO enquiries, being much closer in time zone to our users than either ESO Garching or ESO Santiago. Outside of ESO there is still an ongoing need for ITSO support of Magellan access (through 2020B), Subaru access (through 2018B), and the time exchange access to the Blanco telescope. The community needs to be aware however that the amount of NCRIS funding available to support all this access, including for reimbursement of observer travel, will likely be significantly reduced or eliminated altogether in the ESO era.

Semester 2017B

A total of just 5 Gemini proposals were received by ATAC for Semester 2017B, perhaps not too surprising in light of the fact 2017B is Australia's final semester as a limited-term partner in Gemini. There were 2 proposals for Gemini North, and 3 for Gemini South, with the available time oversubscribed by 1.5. ATAC nominally had 2 nights on each telescope to allocate in 2017B. ATAC's top-ranked programs requested 3 nights on Gemini South, and 1 night on Gemini North, which Gemini kindly agreed to schedule.

Magellan demand in 2017B rebounded significantly from the unexpected drop in demand in 2017A, with 10 proposals seeking 20 nights for an oversubscription of 2.5. There was an even balance in demand between the Baade and Clay telescopes, but ultimately one program seeking 1 night of MegaCam time on Clay was awarded 2 nights with IMACS on Baade to balance out the allocations, with the remainder of nights going to MIKE and FourStar programs. There were 3 Blanco proposals, all for DECam, with an oversubscription of 1.6. The range of nights and lunations available in 2017B was heavily reduced due to Dark Energy Survey requirements.

A total of 25 proposals were received by KTAC in 2017B, up slightly on 2017A. There were 11 proposals for Keck 1 and 14 for Keck 2, with Keck 1 time oversubscribed by 2.2, and Keck 2 by 1.5. There was much interest in the new Keck Cosmic Web Imager (KCWI) optical integral field spectrograph on Keck 2. In Semester 2018A AAL will not be contributing any nights to the KTAC pool, while ANU and Swinburne will be contributing ~6 nights each. The AAL Board has asked ITSO to continue supporting the KTAC time allocation process in 2018A, but without travel support for scheduled programs. Ongoing efforts by KTAC aimed at addressing unconscious bias (e.g., moving the usual cover sheet information identifying the PI and investigators to the back of the proposal; holding a pre-grading discussion about unconscious bias) appear to be working in that:

- 7/25 (28%) of proposals had female PIs, while 5/18 (28%) of allocated programs have female PIs;
- 9/25 (36%) of proposals were from senior (tenured) PIs, while 8/18 (44%) of allocated programs have senior PIs.

ITSO staff changes

ITSO was delighted to welcome Dr Devika Kamath as the new ITSO/Macquarie University Joint Lecturer in Astronomy at the end of March 2017. Devika completed her PhD at the Australian National University's Research School of Astronomy & Astrophysics (RSAA) in 2013 on the topic of AGB and post-AGB stars. Since then she has been a postdoctoral researcher at the Institute of Astronomy at KU Leuven in Belgium. Devika has extensive experience in optical spectroscopy, nucleosynthesis, and stellar interferometry. Welcome Devika!

In mid-July we bid farewell to Dr Caroline Foster-Guanzon, the ITSO Research Fellow since June 2013. Caroline has been awarded an ASTRO-3D Research Fellowship based at the University of Sydney, where she will apply her skills in optical integral field spectroscopy to exploiting the SAMI Galaxy Survey. We are grateful for all the excellent service Caroline has provided to ITSO for the past 4 years, and look forward to seeing her around the AAO frequently in the future.

2017 ITSO Science Symposium

The 2017 ITSO Science Symposium was held at RSAA on Mt Stromlo from 16–18 May 2017. There were 45 registrants, and 36 speakers presenting results from their recent use of one or more of Gemini, Magellan, Keck, and the Blanco telescopes. The symposium was particularly timely in light of the announcement the previous week that Australia would enter into a Strategic Partnership with ESO. Many of the talks were recorded for the benefit of those not able to be present in person, and these are now available via the symposium web site at https://www.aao.gov.au/conference/ITSOsci2017.

Participants at the 2017 ITSO Science Symposium on Mt Stromlo.
Image credit: Ryan Ridden-Harper (ANU).

News from North Ryde

Tayyaba Zafar (AAO)

On 8th March, International Women's Day was celebrated at the AAO where the research highlights of its female staff were presented in a colloquium over the morning tea. AAO is a member of the Athena Swan Science in Australia Gender Equity (SAGE) program. The female staff at the AAO submitted their promotional material through Katrina Sealey (chair of our SAGE Self Assessment Team) to SAGE to profile the AAO.

The AAO has nominated Rebecca Brown (see Figure) to participate in the SAGE Symposium 2017 'Super STEM communicator' workshop as part of Science & Technology Australia's "Superstars of STEM" program. "Superstars of STEM" is Science & Technology Australia's new national program designed to create new role models and remove stereotypes by building strong public profiles for a diverse range of Australian women scientists over the course of a year.

The AAO Library was temporarily used as an instrumentation lab in order to assemble the fiber feed for the TAIPAN spectrograph (see inset). The TAIPAN instrument will be mounted on the UK Schmidt telescope at Siding Spring Observatory and will be used for the TAIPAN survey.

We have had five distinguished visitors at the AAO over the last 6 months. The first was Prof Hans-Walter Rix (Max Planck Institute for Astronomy) who visited the AAO in March. He worked on the GALAH Survey with Daniel Zucker and analysed the stellar populations in our Milky Way Galaxy using the APOGEE and Gaia programs. Another distinguished visitor was Prof Denis Leahy (University of Calgary), who visited the AAO from March to June. Prof. Leahy was hosted by Andrew Hopkins to work on the connection between star formation, supernovae, and supernova remnants. Our Shaw visitor, Prof. Annette Ferguson from the University of Edinburgh, visited the AAO in April. Hosted by Daniel Zucker, she worked on the structure of our Milky Way and M31 galaxy and Funnelweb stellar surveys.

Our most recent distinguished visitors were Prof Katherine Blundell from Oxford University and Prof Hugh Jones from the University of Hertfordshire. Prof Blundell visited the AAO (both North Ryde and SSO) in May, working primarily with Steve Lee on the Global Jet Watch Project she leads, and the related science of stellar mass black holes. Prof Jones, who visited in July, worked with Simon O'Toole on exoplanet science.

Our latest batch of winter fellowship students have already started. Working with Tayyaba Zafar is Sophie Dubber (Univ. of St. Andrews, UK); working with Micheal Goodwin is Prerak Chapagain (Univ. of New Orleans, USA); working with Lee Spitler and Anthony Horton is Brittany Howard (Univ. of Victoria, Canada); working with Jon Lawrence and Barnaby Norris is Enrico Biancalani (Univ. of Bologna, Italy); working with Kyler Kuehn and Simon Ellis is Iuliia Fomicheva (Moscow Institute of Physics and Tech., Russia); and working with Chris Lidman is Elise Beaufils (MINES ParisTech, France).

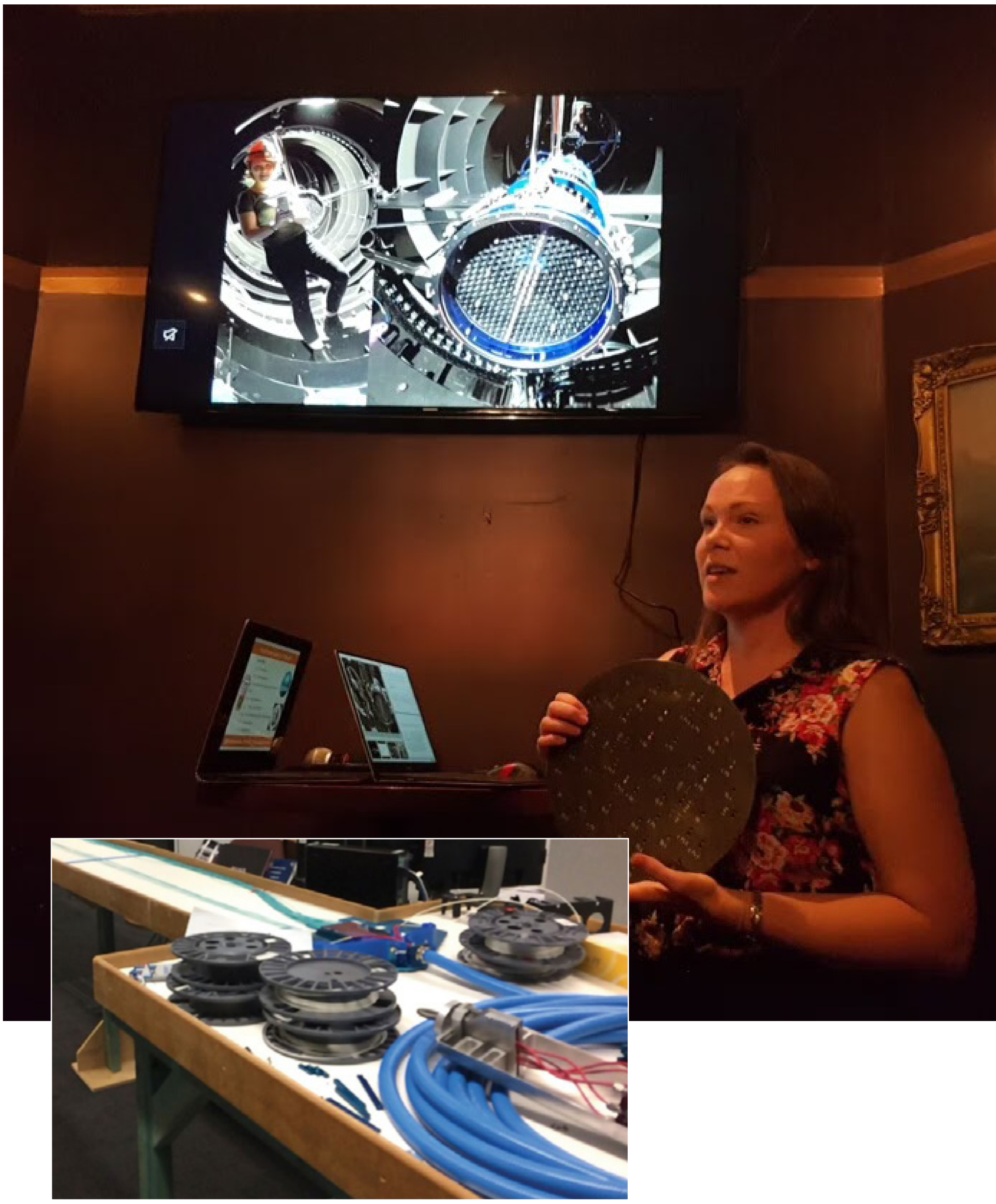


Figure 1: Rebecca Brown at the "Pint of Science" event is describing to an audience of pub-goers about fiber optic positioners which are used at the telescopes for multi-object spectroscopy.

Inset: TAIPAN Instrument fiber cable assembly at the AAO North Ryde Library

Letter from Coona

Zoe Holcombe (AAO)

Hi everyone,

Quick update on what's going on at the AAT.

SSO Lodge Opening.

Four and a half years after the original lodge was burnt down in the Jan 2013 fires the new SSO Lodge was officially opened on the 23rd June. It offers 18 private ensuite rooms, combined library/ lounge, fully equipped kitchen dining area and a large seminar room with spectacular views over the Warrumbungle National Park. The new Lodge was opened by Prof Brian Schmidt (ANU Vice-Chancellor) and the RSAA Director Matthew Colless.

New Staff member Shannon Wood

Shannon started in his new role as one of our electronics technicians at site on the 10th July. Shannon moved up to Coona on the Sunday from Wollongong with his wife and 2 young kids and started work on the Monday! We threw him straight into the action in doing an instrument change. Shannon studied at the University of Wollongong coming out with a bachelor in engineering and mechatronics. In his last job he was working with touch screen technology for a technology start-up company in Sydney. He was developing multiuser computer products for business and education.

Please welcome Shannon when you see him.

Until next time

Zoe Holcombe

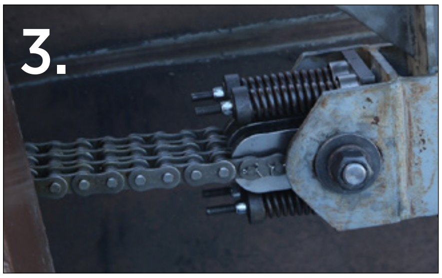
Site Projects

Zoe Holcombe (AAO)

Shutter Chain Replacement

The existing shutter chain and sprockets have been in service for over 10 years and are worn and under rated for the load of the 20 tonne shutter. The chains were successfully replaced over five days in early July, by Townsville Engineering Industries (TEI). We were fortunate to have dry (but very cold) weather over the changeover period, so tarps were not required to cover the shutter opening, and observing could take place each night.

1. Sprocket Removal
2. Heating a new sprocket prior to fitting on the gearbox shaft.
3. New chain fitted to new anchor points (top of shutter).
4. A new chain segment is ready for feeding down the shutter to the lower anchor point.

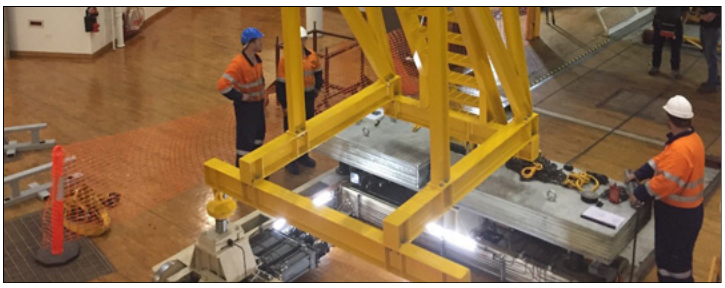


Bogie Refurbishment

The dome bogies were last serviced in 1984 and require the replacement of worn bearings and bushes, as well as re-tensioning the four suspension springs. TEI were awarded the contract for refurbishing the 32 in service bogies as well as the spare bogie.

TEI designed and manufactured an innovative bogie removal frame which utilises the mirror trolley to raise and lower the bogies from the dome rail. The bogies are lowered to the ground floor for refurbishment on site.

To date 26 of the 33 bogies have been completed.



The illuminated dome of the Anglo-Australian Telescope and the Milky Way during the ABC Stargazing Event in April 2017.

Credit: Ángel R. López-Sánchez (AAO/MQU)

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