AAO OBSERVER

THE AUSTRALIAN ASTRONOMICAL OBSERVATORY NEWSLETTER

NUMBER 131 | FEBRUARY 2017

Cutting-edge technologies for infrared spectroscopy

Director's message

Warrick Couch

My message for the February issue of the AAO Observer always gets written towards the end of January, well into the long hot Australian summer. While this is a time when most of us feel relaxed and rested after having just had our summer holidays, for me it is also a time that brings back vivid memories of observatories and bush fires. I will never forget driving back from my holiday in Queensland in January 2003 and hearing the devastating news of Mount Stromlo Observatory being largely destroyed by a massive bush fire. And then almost 10 years to the day later, the "Wambelong" fire swept through Siding Spring Observatory (SSO) and then on through the bush and many properties between it and Coonabarabran on the afternoon and evening of 13 January 2013. The trauma and destruction that these fires caused reminds us that we have to be ever vigilant for this threat throughout the summer, making our operations at SSO not as relaxed as the short nights and holiday time mood might suggest. Indeed the Wambelong fire has led to the introduction of much stricter controls on the access to and occupation of SSO during periods of high fire danger, with the public barred access at times of extreme danger and all SSO staff being required to leave the mountain when the fire danger reaches "catastrophic" levels. The AAO also contributes to the protection of SSO and the surrounding region from bush fires by very willingly allowing a number of its staff to be available for volunteer bush fire duties during working hours, should the need arise.

As much as we want to avoid bushfires and the damage they do to life and property, it remains a fact that they have been a part of the natural cycle of ecosystems in Australia for millions of years, with many being started by lightning strikes. Many plants have adapted to bushfires to the extent that they require fire to regenerate or to release their seeds. In terms of regeneration the Wambelong fire has been no exception, with the growth of new vegetation and the regeneration

Contents

Front cover photo Credit: NGC 2018 - Supernova remnant in the LMC. Image was taken with the CACTI camera in 2dF with B, [OIII] and Hα filters. Credit: Ángel R. López-Sánchez (AAO/MQ), Steve Lee (AAO), Rob Patterson (AAO) and Robert Dean (AAO).

of fire-damaged trees in the bush that surrounds SSO being conspicuously rapid and vigorous. There has also been a parallel, if not quite so rapid 'regeneration' in the Observatory itself, having by some miracle survived the fire with all its telescopes mostly undamaged. Completion of the new ANU Lodge that replaces the one that was burnt down is now just under a month away (see the "SSO News" article). The fire station, which was also burnt down, has also been replaced by a new building. The public visitors' centre – the ANU "Exploratory" – and the public viewing gallery in the AAT dome have both undergone a much-needed revamp. Members of the public continue to flock to SSO during the annual "Starfest" open day, with last year's event being one of the best ever. And the Warrumbungle National Park next to which SSO resides has been designated an International Dark Sky Park – the first in Australia and the Southern Hemisphere!

The AAO has also undertaken significant upgrades to its two telescope at SSO, the AAT and the UKST. Having completed the construction and commissioning of HERMES on the AAT a year after the fire, the AAO's next major project has been to completely refurbish the UKST, and equip it with a new multi-fibre positioner and spectrograph (known as TAIPAN). At a cost of more than $6M, this project has not just involved a complete overhaul of the UKST telescope and dome itself, with replacement of its control systems to allow remote and semi-automated observing, but also the construction of the very first MOS system that uses the AAO's autonomous "starbug" positioner technology. The latter serves as an important 'working-on-telescope' prototype for the multi-fibre MANIFEST system the AAO is building for the 25m Giant Magellan Telescope.

Over this summer the project has entered the home straight, with the positioner and spectrograph being shipped from the AAO's laboratories at North Ryde to SSO, and assembled and integrated into the UKST telescope system. Already, the starbugs module has been successfully installed within the UKST telescope tube. Commissioning of the entire system will commence in April and is expected to be completed by July-August. The completely rejuvenated UKST will then be used to conduct two major surveys – Taipan and Funnelweb, the former being a survey of 1,000,000 galaxies that will make major contributions in cosmology and galaxy evolution, and the latter being a survey of 3 million stars that will provide critical information for future exoplanet searches and understanding the thick disk in our galaxy. As has been the case in the past, the UKST will continue to operate on a 'user pays' basis with the two survey teams covering its operations and maintenance costs. This, I am sure, will prove to be another excellent example of the AAO successfully 'reinventing' its AAT and UKST telescopes using new and innovative technologies that allow them to continue doing world-class science while at the same time see them serving as test-beds for future applications of these technologies on larger 8m-class and ELT telescopes. We look forward to having the official opening of TAIPAN later this year.

This 'reinvention' strategy also continues to pay strong dividends for the AAT. The OzDES Project reported on page 12 of this issue is a good example. Here the wide-field, high-multiplex spectroscopic capabilities of the AAT are providing significant scientific value-add to the Dark Energy (imaging) Survey being conducted on the 4m Blanco Telescope, in better understanding the physics behind the accelerating expansion of the universe, and tracking the growth of supermassive black holes over cosmic time. A particularly impressive feature of this program is that it is systematically able to obtain redshifts for SN and transient host galaxies down to r=24 mag, a limit generally considered to be beyond the spectroscopic reach of a 4m telescope. The AAT's pivotal role in last year's discovery of a large population of helium-burning stars in the globular cluster M4 that are dying much sooner than expected – thereby requiring a significant revision of stellar evolution models – and the Milky Way's oldest stars within its bulge, further underscores its continued strong scientific value and impact.

Changing gears somewhat, I would like to draw readers' attention to the article "Astronomers and Mothers: Recalibrating the Centre of their Universe" contained in this issue (page 20), which focuses on the experiences, challenges, and successes of the 5 astronomer mothers on our staff. As Director, I am particularly proud to have an article of this nature published in the AAO Observer for a number of reasons. Firstly, that we have such a high fraction (~30%) of mothers with young children amongst our research astronomy staff is, I suspect, highly significant compared to other observatories and astronomy institutions. We are particularly fortunate to have such a strong cohort of 'astronomy mums' who are so productive and do much to enrich the research culture at the AAO, despite the demands and challenges of motherhood. Their willingness to come together and share their perspectives in this way is also to be admired, given some of them are of a quite personal nature. It is also very generous in that what they have to say will, I am sure, strike a chord and be helpful to many others. Given the rather constrained public service environment in which the AAO operates, I am also proud that we can provide the financial support and flexibility in work practices to help our staff who are primary carers – be they mothers or fathers – deal with the challenges of this important role.

International Collaboration Spearheaded by the AAO Develops Cutting-Edge Technologies for Infrared Spectroscopy

Kyler Kuehn[1], Simon Ellis[1], Steve Kuhlmann[2], Hal Spinka[2], Ravi Gupta[2], Leo E. Ocola[2], Jonathan St Antoine[1], Javier Lorenzo[1], Robert Nash[1], Guohua Wei[3], Nathaniel P. Stern[3]

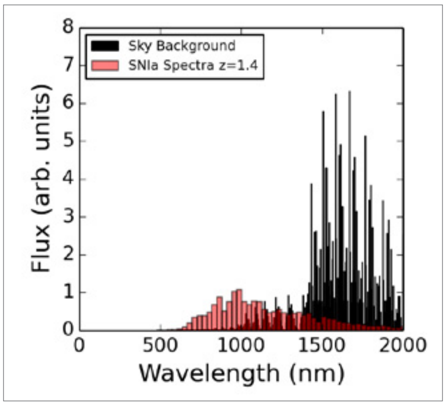
AAO Instrument Scientists Dr. Simon Ellis and Dr. Kyler Kuehn have been hard at work over the last four years developing novel technologies for future astronomical instruments. Alongside their students and a group of collaborators at Argonne National Laboratory and Northwestern University (near Chicago in the United States), Dr. Ellis and Dr. Kuehn are attempting to make near-infrared astronomy with ground-based telescopes feasible by suppressing atmospheric OH emission lines. Current instruments that attempt to observe light at wavelengths between 1 and 2 microns (slightly longer than visible wavelengths of light, which range between about 0.4 and 0.7 microns) are plagued by emission from OH molecules in the upper atmosphere that create a “forest” of lines impeding detection of light from beyond the atmosphere. Even attempts to detect light between the OH lines with high-resolution instruments are thwarted by the “wings” of the lines scattering into adjacent wavelengths and swamping any signal that might otherwise be detected [Sullivan 2012].

1 Australian Astronomical Observatory
2 Argonne National Laboratory,
3 Northwestern University

Space-based instruments do not face this impediment, of course, but orbiting observatories such as the Hubble Space Telescope or the forthcoming James Webb Space Telescope are orders of magnitude more expensive than ground-based telescopes (billions of dollars rather than millions). Additionally, space-based telescopes are substantially more difficult to maintain or upgrade, and suffer from limited lifetimes with respect to ground-based observing facilities. Furthermore, space-based telescopes suffer from significant “oversubscription” – that is, only about 1 in 10 astronomers with interesting scientific proposals are able to secure observing time on such telescopes (compare those poor odds of success to ground-based telescopes where oversubscription is usually much better; in general, about 1 in 3 proposals are successful).

Observing in the near infrared is vital for investigating a wide variety of important astronomical questions, but the starkest statement of the problem is apparent when cosmology is considered. Supernovae are used to reconstruct the expansion history of the universe, and the farther away a supernova is, the greater insight astronomers can obtain into the behaviour of the early universe. Nearby supernovae emit light that is easily observable in visible wavelengths; however, when such a supernova is, for example, 8 billion light years away, its light gets redshifted to between 1 and 2 microns – precisely the region where atmospheric OH emission is the worst (Figure 1).

Several different technologies are being investigated to accomplish this suppression; one that has been tested previously [Content et al. 2014] is the Fibre Bragg Grating (FBG).



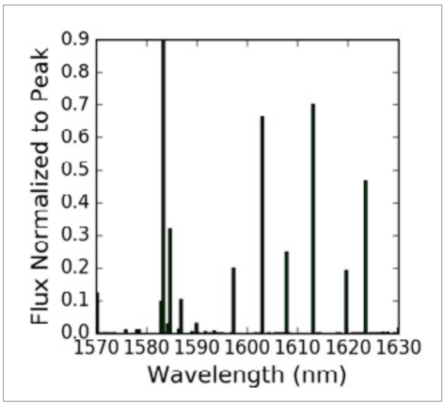


Figure 1: (Left) The spectrum of a type Ia supernova at a redshift of z=1.4 (corresponding to roughly 8 Gyr ago). More than half of its flux would be obscured from ground-based observations by OH emission from the Earth’s atmosphere. (Right) The OH emission line relative fluxes from 1570-1630 nm, normalized to the peak flux. Suppressing the emission from even a few of these lines would substantially improve the signal-to-noise of observations in this wavelength range.

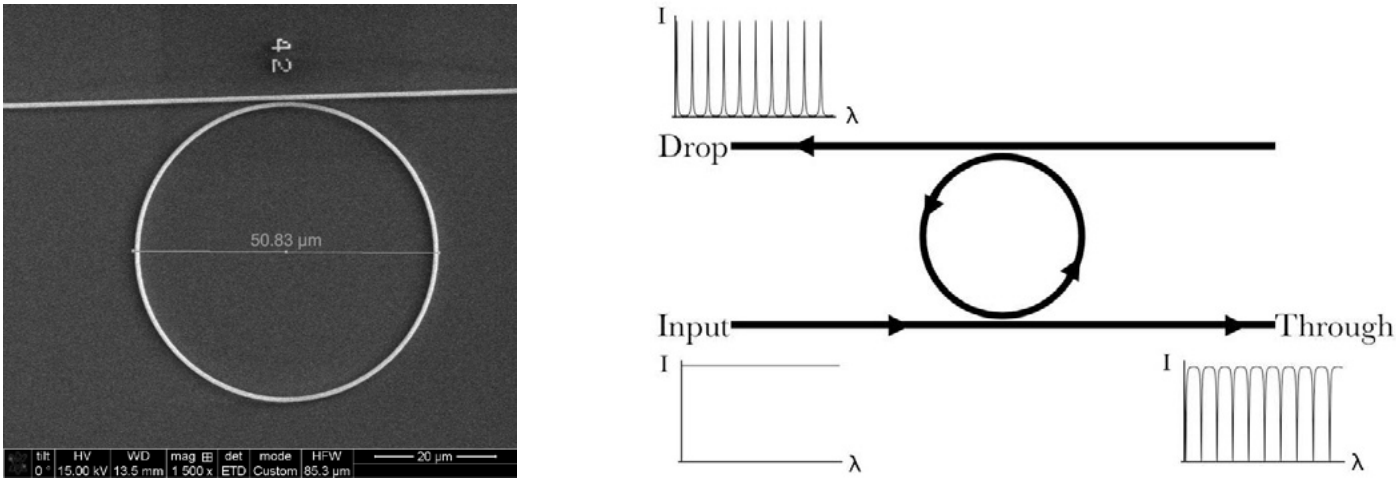


Figure 2: (Left) A silicon micro-ring resonator next to a waveguide lithographically printed on a silicon nitride wafer. (Right) Illustration of input and output waveguides on either side of a ring resonator, creating a notch filter with suppression at the through port of specified wavelengths of light.

Another promising technology – the one currently under investigation by the joint AAO-Argonne-Northwestern collaboration – is the Silicon Micro-Ring Resonator [Xu et al. 2008]. These are expected to have comparable suppression capabilities to FBGs while being easier and cheaper to produce through ubiquitous lithographic processes. Because dozens or even hundreds of rings can fit on a single silicon wafer, this technology is also more scalable than FBGs.

Ring resonator-based suppression operates by sending light through one or more waveguides coupled to a looped waveguide, as shown in Figure 2. Light from the input waveguide evanescently couples into the ring, whereupon it constructively and destructively interferes with itself until only light at the resonant wavelengths of the cavity remains. The condition for resonance is $m\lambda = nL$, where m is an integer, λ is the wavelength, n is the effective index of refraction, and L is the circumference of the ring. The resonant light couples back into the input waveguide and interferes with the input light. At each coupling from one waveguide to another there is a $\pi/2$ phase change, thus the light coupled back to the input waveguide is now π radians out of phase with the input light, and therefore the interference is destructive and effectively filters the input signal at the resonant frequencies of the ring.

Thus, a series of ring-resonators, each tuned to the wavelength of a different OH emission line, could provide a means of OH suppression.

Research into the fabrication and operation of these micro-ring resonators began independently at both the AAO [Ellis et al. 2012] and Argonne National Laboratory; the international collaboration between these organisations began in earnest when Dr. Kuehn finished his postdoctoral appointment at Argonne and took up an Instrument Scientist position at the AAO. Since then, the strengths of these organisations have complemented one another in this research area. Argonne National Laboratory possesses the Center for Nanoscale Materials (CNM) where ring resonators are fabricated (Figure 3), while AAO staff have access to facilities for testing the ring resonators at the Australian National Fabrication Facility hosted by Macquarie University. Furthermore, AAO staff also have significant experience with theoretical calculations and simulations of the ring resonators, offering insight, guidance, and feedback to the design process at CNM (Figures 4 and 5). These simulations not only determine the optimal sizes and configuration of the basic ring resonator components without the need for extensive (and expensive) trial and error, they also facilitate design of even more elaborate systems such as double rings with more complicated wavelength suppression patterns.

They also help to explain unexpected effects, such as polarization- and temperature-dependence of the suppression, that are observed during laboratory experiments.

Figure 3: Electron-beam lithography facilities at Argonne National Laboratory's Center for Nanoscale Materials.

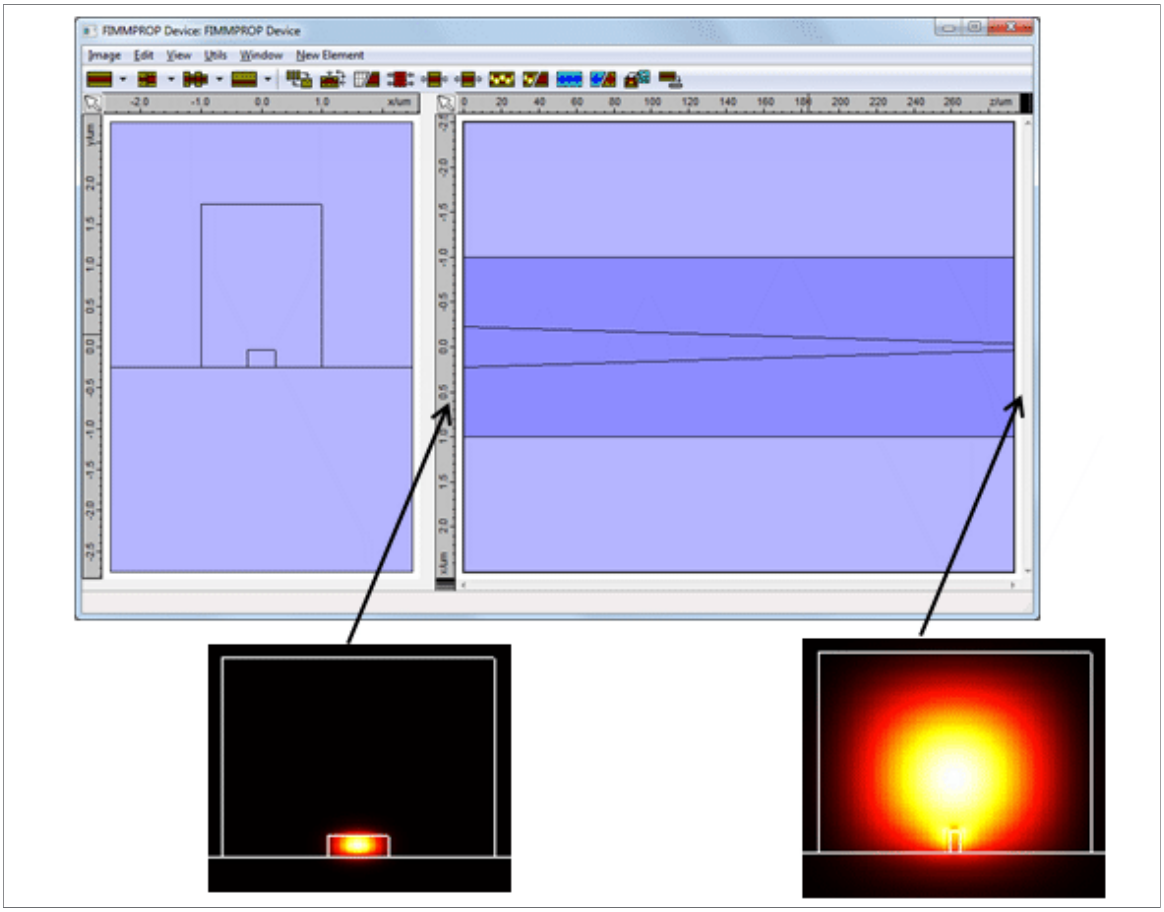


Figure 4: (Top) Side and top view of a simulated tapered waveguide. (Bottom) Side view of the initial and final distribution of the electric field as it propagates from left to right along the waveguide. Note that the field expands significantly, a desirable quality to match the (much larger) diameter of the fibre that is coupled to the waveguide. These results provided the precise sizes of the various components that would result in optimal coupling between the waveguide and the input/output fibres.

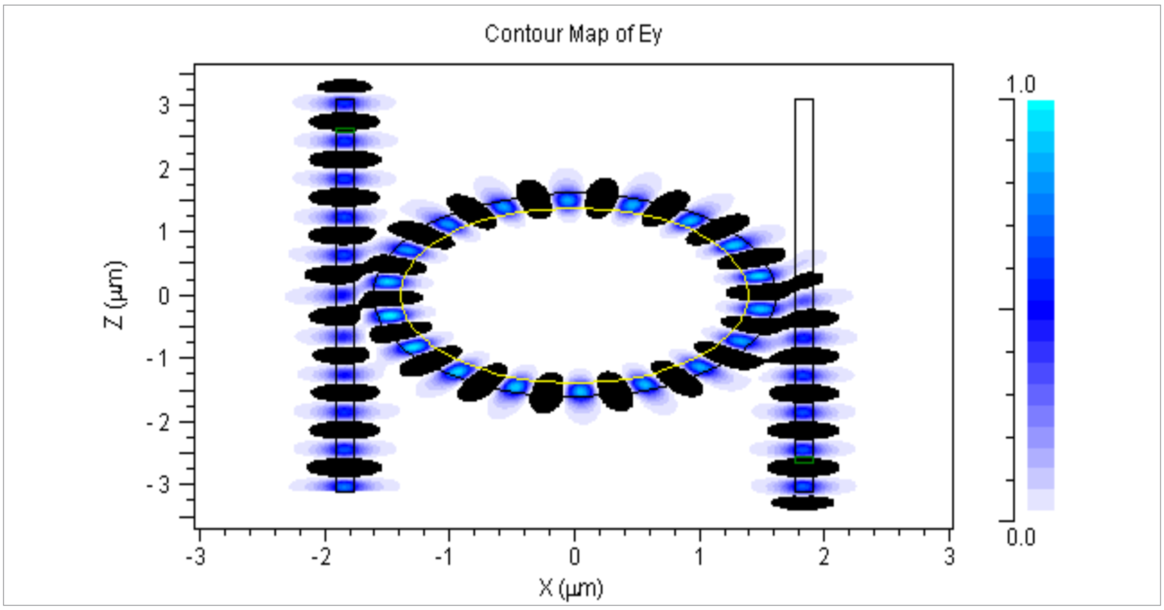
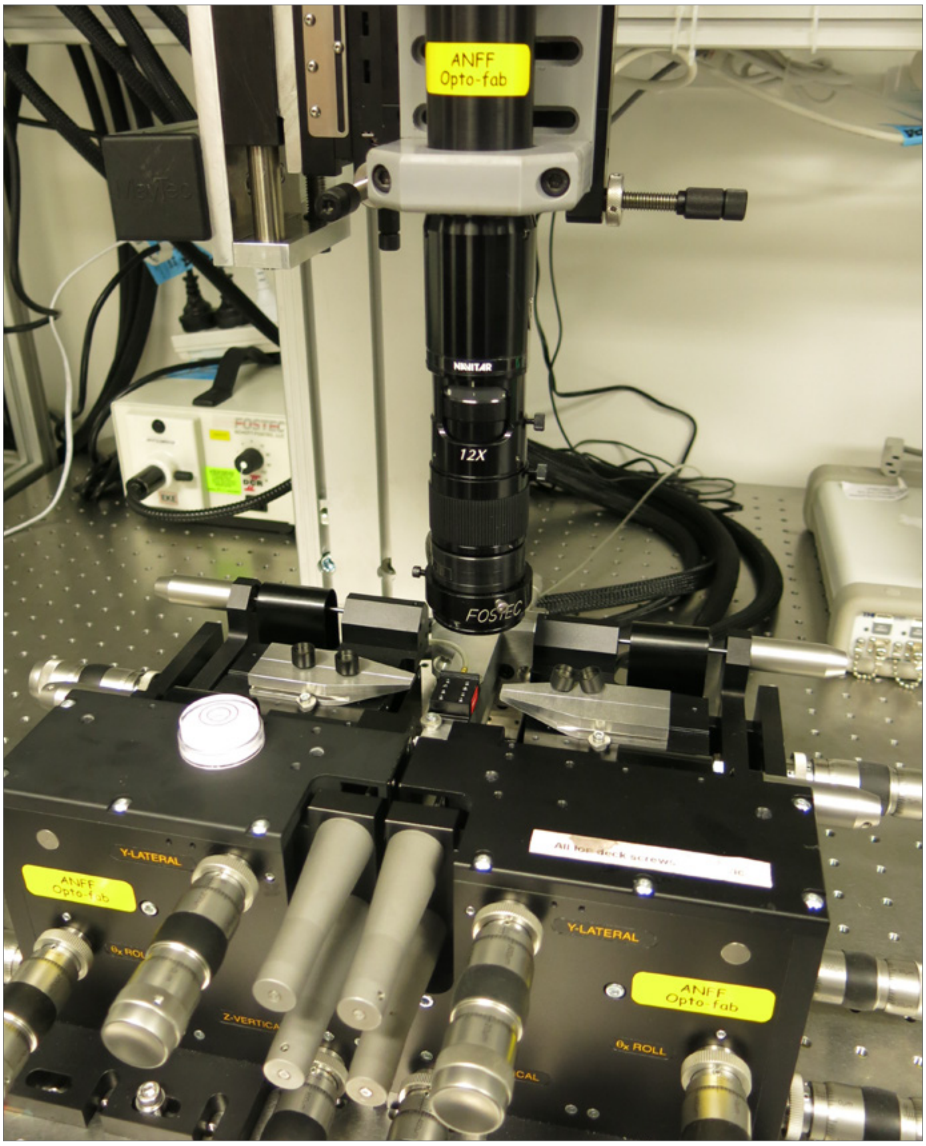


Figure 5: Simulation of the electric field propagating along the input waveguide on the left, and then separating into two components. At resonant wavelengths, the field couples strongly to the ring resonator and then to the drop port on the right, while off-resonance the field does not couple and simply propagates along the initial waveguide to the output fibre. These results showed the precise wavelengths at which suppression is expected for a given waveguide/ring geometry.

This years-long collaboration is now bearing fruit. After the initial theoretical design work and micro-ring fabrication, researchers began their experimental effort by coupling the fibres into silicon wafers using v-grooves and cantilevers in the interior of the wafer [St. Antoine 2015], as originally implemented by Galan [2012] (see Figure 6). This proved difficult to fabricate without damaging the waveguides, and even more difficult to assemble the wafer-fibre system after fabrication. Since the fibres needed to be precisely aligned with the cantilevered waveguide extending over the v-groove, uncertainties in the etching of the grooves possibly prevented the very small cantilever waveguide from being centred in the fibre. Furthermore, the etching process itself sometimes caused significant damage to the nearby waveguides, thereby preventing any transmission even in an otherwise-flawless system. On the theoretical side, possible mismatches between the modes that propagate in the waveguide and those that propagate in the fibre were also discovered. All of these factors contributed to negligible measured throughput, preventing accurate measurement of suppression for several months.



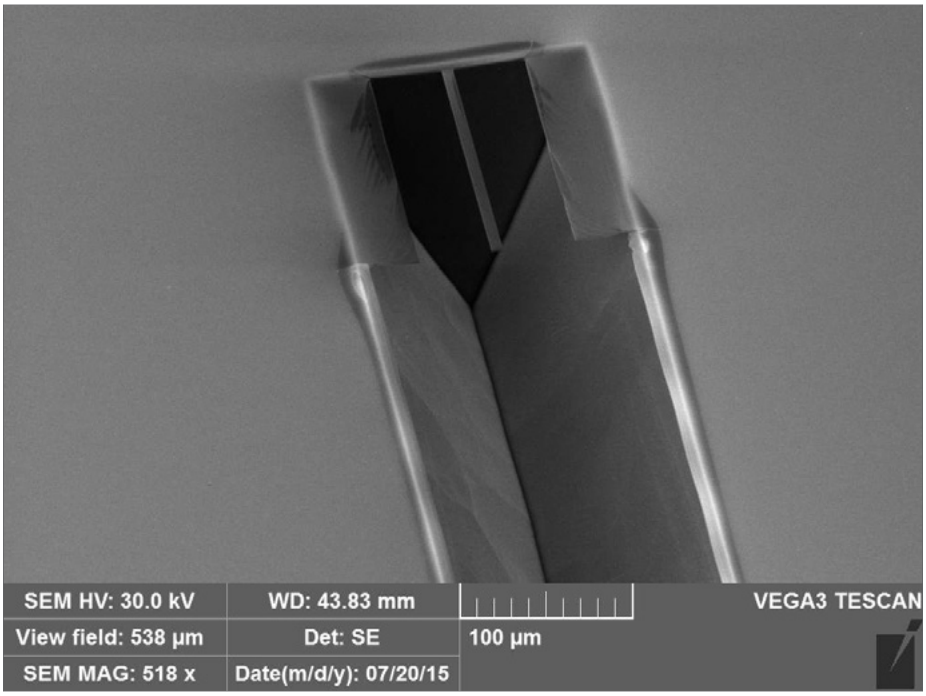


Figure 6: (Top) Precision positioning stages at the Australian National Fabrication Facility hosted by Macquarie University. The input and output fibres are secured to the grooved silver fixtures near the centre of the image, while the wafer is secured by vacuum to the central stage, immediately below the microscope lens. (Bottom) SEM scan of a v-groove into which a fibre will be glued, along with the cantilever that extends the waveguide from the bulk of the wafer into the region that will allow coupling with the fibres. This configuration with silicon waveguides proved very difficult to fabricate without damaging the waveguides, and the precariously thin cantilevers were especially easy to damage, resulting in complete loss of fibre/waveguide coupling. Currently the researchers are successfully coupling the optical fibres to the waveguides at the wafer edge.

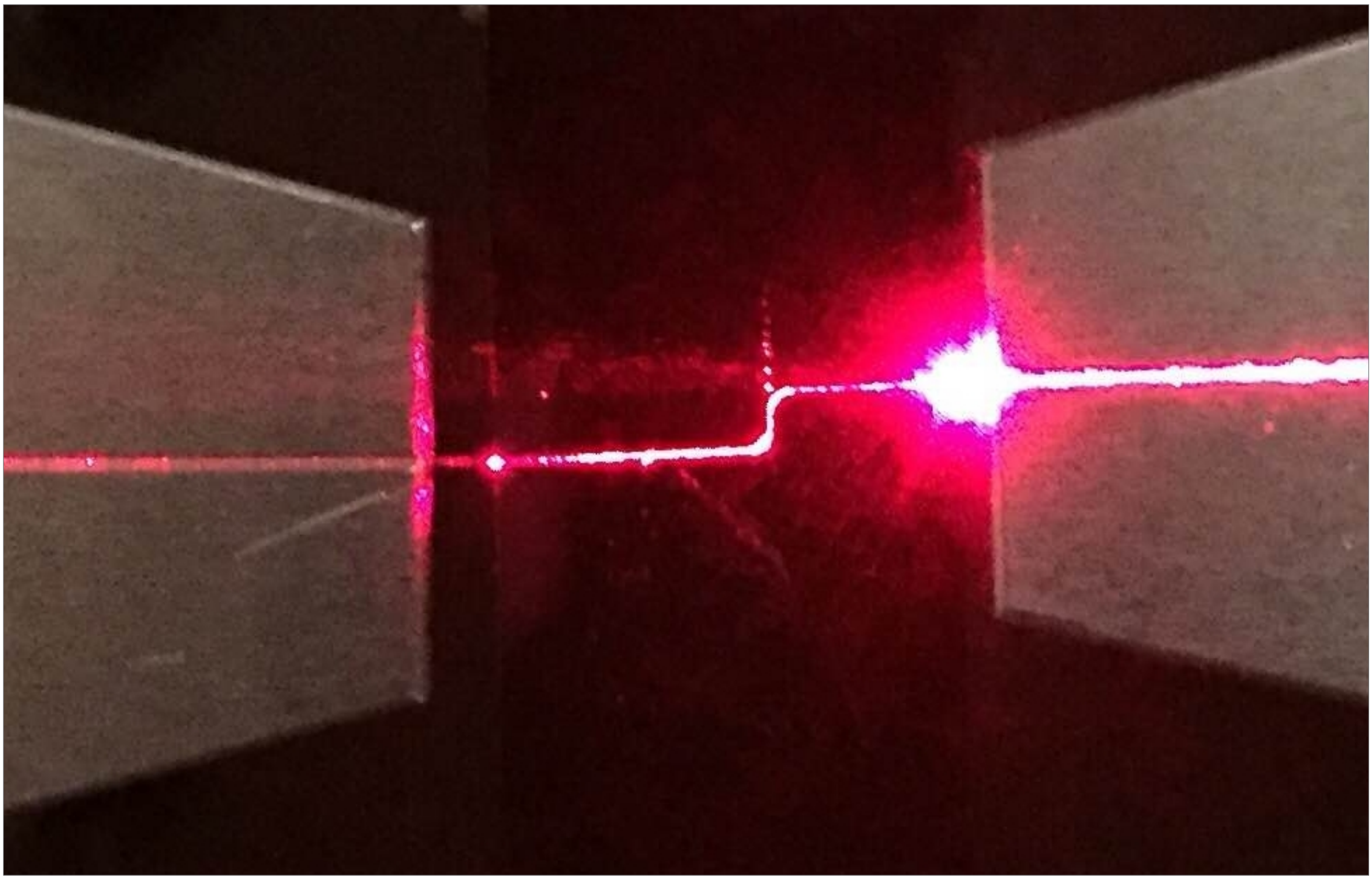


Figure 7: A zoomed-in view of fibres precisely aligned with the s-shaped waveguide on a silicon nitride wafer. Red laser light is sent into the input fibre (right), couples to the waveguide, and then proceeds through the output fibre (left).

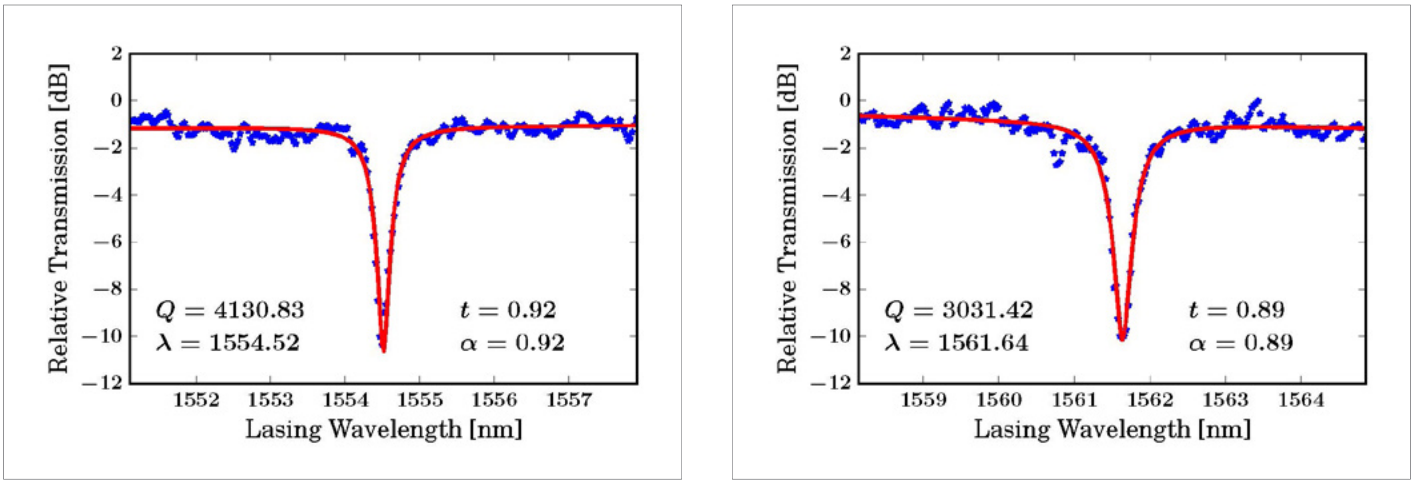


Figure 8: Measurements of the relative transmission at wavelengths near, or corresponding to, the suppression wavelength of the ring resonator. Note the 10 dB of suppression achieved at the desired wavelengths (λ=1554.5 or 1561.6 nm). Q is the "Quality" of the ring resonator, defined as the ratio of the energy stored in the ring to the energy lost per cycle. Since we do not want losses within the ring (but instead coupling to the drop port or propagation to the through port), Q factors of at least several thousand are desired. The quantity t describes the fraction of the electric field in the input waveguide that does not couple to the ring, while α is the throughput per circulation of the ring.

Finally a breakthrough occurred when the wafers were changed from (Si/SiO2) to (Si3N4). The latter is more red-sensitive, allowing alignment of the fibres and waveguides with visible (red) light which is subsequently changed to infrared for quantitative testing (Figure 7). Additionally, the refractive index of Si3N4 is lower, so the waveguides can be larger (and more easily fabricated) while still allowing only a single mode to propagate (a requirement for efficient coupling between the waveguides and the fibres). Additionally, the coupling mechanism was changed from fibres glued into v-grooves in the interior of the wafer to lensed fibres precisely aligned (with digitally-controlled six-axis stages) at the carefully smoothed edges of the wafers. And so, measurable narrow-band suppression of near-infrared light was finally achieved (Figure 8). In this case, 10 dB of suppression with a width of less than 1 nm has been measured at two different wavelengths – one centred at 1554.5 nm, the other at 1561.6 nm – for a single ring resonator. The system is also very efficient, with approximately 90% or better self-coupling (t, the fraction of the electric field in the input waveguide that does not couple to the ring) and approximately 90% or better throughput per circulation of the ring (α).

The next steps for the project are to improve the performance of the entire system by increasing suppression from each ring, developing more suitable substrates for infrared transmission (by, e.g., returning to Si/SiO2), fabricating multiple rings in series to suppress additional OH lines, and precisely controlling the system's temperature so that the wavelengths that are suppressed do not shift as ambient temperature varies. Control of the polarization of the input light will also be important, as the TE and TM modes can be propagated or suppressed differently.

Finally, the entire ring resonator system will be packaged into a suitable format for on-sky testing at the Australian Astronomical Observatory's telescopes at Siding Spring Observatory. The project will culminate in the construction of a spectrograph operating in the 1-2 micron wavelength range that removes (nearly) all of the OH emission lines, offering clear observations despite the intervening atmosphere.

In the coming years, we expect to achieve the detection of pristine stellar and galactic spectra at near-infrared wavelengths, opening up a new window on the universe and offering unprecedented scientific insights into a wide variety of astrophysical phenomena.

Acknowledgements:

We gratefully recognize the contributions from the fabrication staff at Argonne's Center for Nanoscale Materials, including Dave Czaplewski, Ralu Divan, and Christina Miller. We also acknowledge the contributions of numerous students working at Argonne National Laboratory, specifically: Daniel Davies, Katarzyna Pomian, James Derkacy, and Ariel Matalon. The Australian Astronomical Observatory is an agency of the Australian Department of Industry, Innovation, and Science. Argonne National Laboratory is a facility of the United States Department of Energy.

References

Sullivan, P. and R. Simcoe, "A Calibrated Measurement of the Near-IR Continuum Sky Brightness Using Magellan/FIRE", PASP 124:922 (2012)

Content, R. et al., "PRAXIS: low thermal emission high efficiency OH suppressed fibre spectrograph", Proc. SPIE 9151 (2014)

Xu, Q., D. Fattal, and R. G. Beausoleil, "Silicon microring resonators with 1.5-μm radius," Optics Express 16, p. 4309 (2008)

Ellis, S., et al., "Potential applications of ring resonators for astronomical instrumentation", Proc. SPIE 8450 (2012)

St. Antoine, J., "Characterisation and design of fiber to waveguide coupling", Master's Thesis, Bishop's University (2015)

Galán, J.V., Ph.D Thesis, Departamento de Comunicaciones, Universidad Politécnica de Valencia (2010)

Easy reduction of KOALA data using new Python scripts

Ángel López-Sánchez, AAO/MQU
KOALA/AAOmega instrument scientist
Angel.Lopez-Sanchez@aao.gov.au

KOALA, the Kilofibre Optical AAT Lenslet Array, is a wide-field, high efficiency, integral-field unit (IFU) designed for use with the bench mounted AAOmega spectrograph on the AAT. KOALA has 1000 hexagonal lenslets arranged in a rectangular array. The field of view is selectable between either 15.3 x 28.3 arcsec with 0.7" spatial sampling (narrow mode) or 27.4 x 50.6 arcsec with 1.25" sampling (wide mode, see Figure 1). To achieve this, KOALA uses a telecentric double-lenslet array fed by interchangeable fore-optics. The IFU is mounted at the f/8 Cassegrain focus and feeds AAOmega via a 31m fibre run. Hence, KOALA benefits from all the flexibility of the reconfigurable AAOmega spectrograph. The double beam spectrograph provides user selectable wavelength coverage and resolution using a series of movable, interchangeable gratings.

Individual KOALA frames are easily reduced by 2dFdr, the AAO's generic data reduction package for all the observatory's fibre-based spectrograph. 2dFdr takes raw files from the telescope and extracts wavelength calibrated spectra for each lenslet of the integral-field unit. For KOALA data, 2dFdr is currently able to apply some fibre chromatic and total response correction, detector response correction (flat-fielding) and sky subtraction using blank sky regions within an individual observation.

More information about KOALA, including the KOALA Observing Manual and a description of the data reduction process, can be found on the KOALA webpage https://www.aao.gov.au/science/instruments/current/koala/overview

KOALA has been offered at the AAT since 2014. However, obtaining the well-reduced combined data has not been a trivial process, particularly because of the (few) dead lenslets it possesses (see Figure 1). Therefore, it is recommended to slightly offset the field between individual frames (and take at least 3 of these) when observing. This means individual science frames can't be directly combined using 2dFdr. Furthermore, unlike 2dF, KOALA does not include any system to correct for atmospheric differential refraction, meaning that there might be a spatial offset between the blue and the red part of the spectrum with the same lenslet.

We are currently developing new Python scripts that combine and/or mosaic observations of a single source, correct for atmospheric differential refraction and also deal with the spatial rebinning of the data onto a square spatial grid (i.e. cubing). We expect these scripts to be completely functional by Semester 17A. Additionally, some programs may need spectrophotometric flux calibration. This step will be later included in our Python scripts but it can be already achieved using standard IRAF routines.

As an example, here we show the KOALA data obtained for the Blue Compact Dwarf Galaxy (BCDG) POX 4. We obtained 3 x 30 min exposures in the wide field following the offsets with positions a – > b – > d (see the Manual, we have also developed a Python script that provides offsets between spaxels for a given position angle) using the 580V grating in the blue arm (3650 – 5700 Å) and the 1000R grating in the red arm (6300 – 7500 Å) of the AAOmega spectrograph. The individual science frames were reduced using 2dFdr following the standard process.

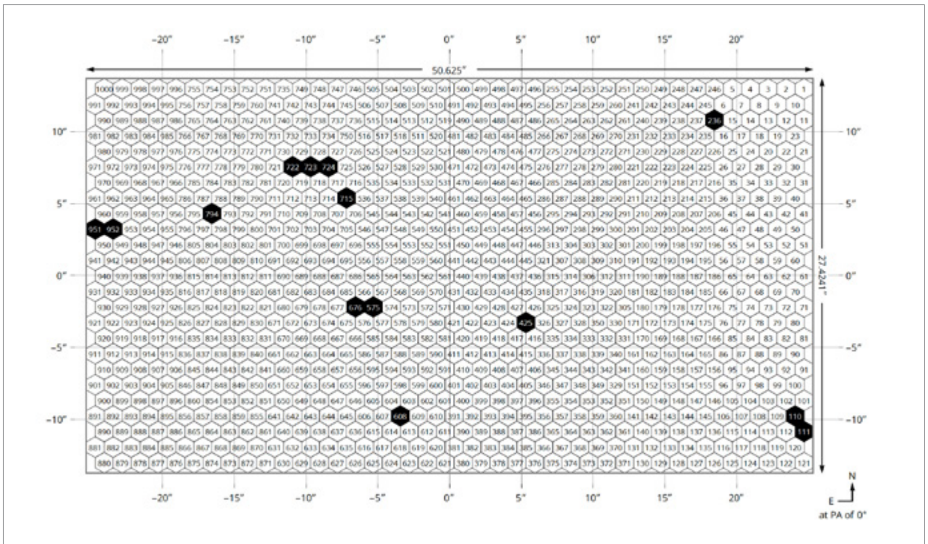
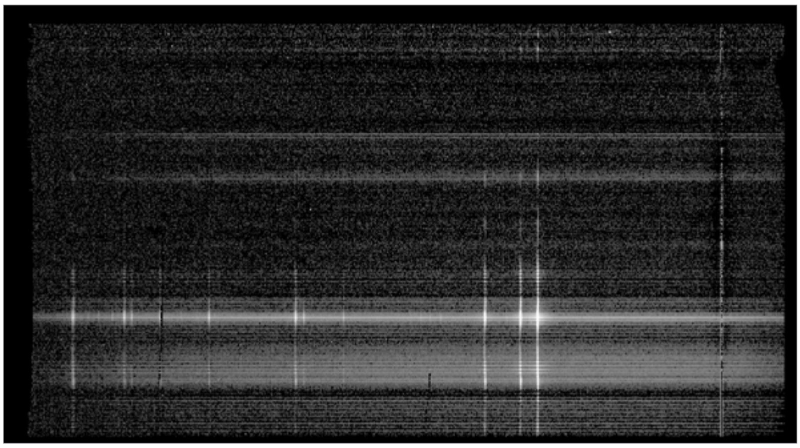
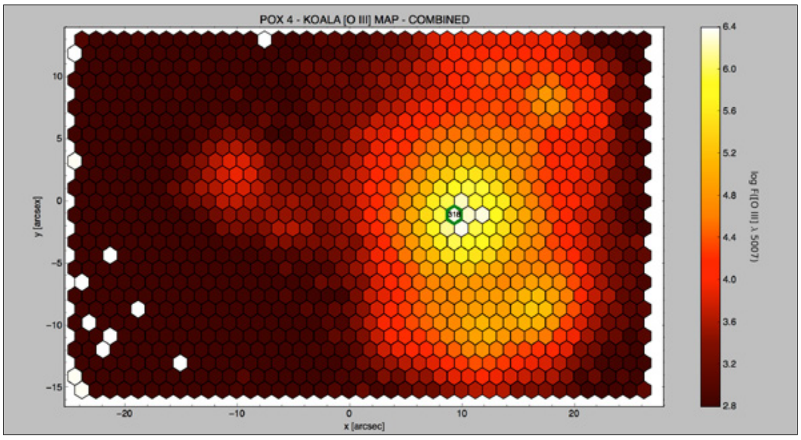


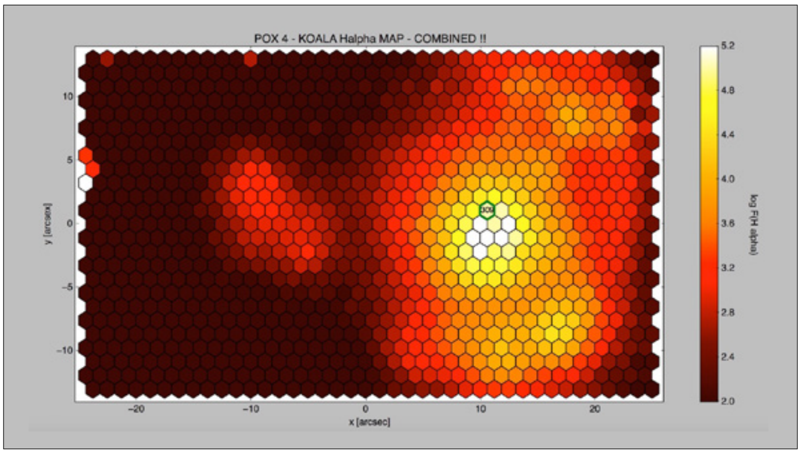
Figure 1. Layout of KOALA Lenslets for the wide field of view configuration (1.25" sampling). The 14 dead fibres/lenslets (as known on December 2016) are shown in black. The field is oriented such that at position angle of 0°, the long axis is east-west. The position angle is measured north-through east.



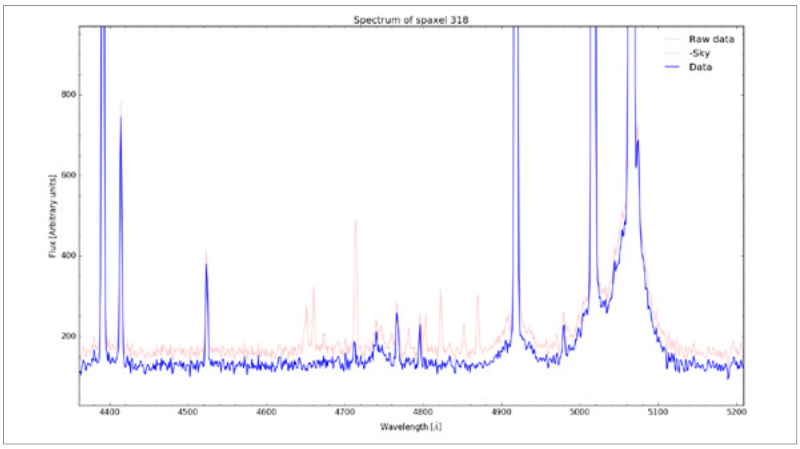
2.



3.



4.



5.

This gives resulting fits files with a size of 2048 (spectral axis) x 1000 (spaxels). Then we run the new Python scripts to produce a combined file. The resulting fits file has a size of 2048 (spectral axis) x 1107 (spaxels). The additional 107 spaxels are created as a consequence of now having a slightly larger field of view. This file is shown in Figure 2.

Our Python scripts for combining KOALA data also provide tools for plotting maps (as examples, see Figures 3 and 4 with the maps of the [O III] 5007 and Hα emission in POX 4), localizing spaxels, plotting spectrum (see Figure 5) and more, including velocity maps and plotting spectrum of a region, plus additional features that we're developing.

In summary, the combination of 2dFdr software and the new Python scripts can provide a ready-to-analyze KOALA science frame in few minutes. Our Python scripts are still under development but they will be functional for Semester 17A. Everyone can apply for KOALA time at the AAT by regular or service (less than 6 hours) mode. Do not hesitate to contact me if you are interested in using this powerful instrument.

Figure 2. Combined data for 3 x 1800 s exposures of POX 4 using the 580V grating and the wide field. The resulting fits file has a size of 2048 (spectral axis) x 1107 (spaxels). Bright (and some faint) emission lines are clearly seen in this Figure.

Figure 3: Map of the [O III] 5007 emission in POX 4 resulting of combining 3 x 1800 s exposures using our new Python scripts. Spaxel 318 is identified (see its spectrum in Figure 5).

Figure 4: Map of the H-α emission in POX 4 resulting of combining 3 x 1800 s exposures using our new Python scripts. Spaxel 309 is identified.

Figure 5: Wavelength-calibrated (but not flux-calibrated) spectrum of spaxel 318 (POX 4 centre) resulting from combining 3 x 1800 s exposures using our new Python scripts. The red line shows the combined raw data, the thick blue line is obtained by subtracting the sky contribution (in green color, can not be seen in this plot). The quality of the AAOmega spectrum reveals plenty of details on this spaxel: from faint high-excitation lines of He II and [Ar IV] to broad components underlying the bright, narrow H-β and [O III] lines. Also note that the second-left bright emission line corresponds to the auroral [O III] 4363 line. Data from López-Sánchez et al. (in prep).

News from OzDES

Chris Lidman[1], Tamara M Davis[2], Samuel Hinton[2], Janie Hoormann[2], Paul Martini[3], Bonnie Zhang[19,20], Filipe B. Abdalla[4], Jacobo Asorey[2], Manda Banerji[5], Rahul Biswas[6], Elizabeth Buckley-Geer[7], Chris D'Andrea[10,8], Aurelio Carnero[9], Daniela Carollo[19], Michael Childress[10], Karl Glazebrook[11], Julia Gschwend[9], Stephanie Jouvel[12], Anthea King[13], Alex Kim[14], Kyler Kuehn[1], Geraint Lewis[15], Huan Lin[7], Edward Macaulay[8], Anais Moller[19], Jeremy Mould[11], Dale Mudd[3], Bob Nichol[8], Ray Norris[16] Andreas Papadopoulos[8,22], David Parkinson[2], Eduardo Rozo[17], Eli Rykoff[17], Nick Seymour[18], Rob Sharp[19], Flavia Sobreira[6], Natalia Eire Sommer[19], Mathew Smith[10], Rollin Thomas[14], Brad Tucker[19,20], Syed Uddin[20,23], William Wester III[4], Fang Yuan[19]

The Australian Dark Energy Survey (OzDES) is using the 2dF fibre positioner and AAOmega spectrograph on the AAT to obtain the redshifts of thousands of sources in the 10 deep fields of the Dark Energy Survey. OzDES has just completed its fourth observing season, and is now two-thirds of the way through the survey. To date, OzDES has obtained the redshifts of around 25,000 sources, and has spectroscopically confirmed over 150 supernovae. In this article, we provide an update on the two main OzDES programs: using Type Ia Supernovae to measure the expansion history the universe, thereby constraining dark energy, and using reverberation mapping to measure the growth of supermassive black holes in AGN over the past 12 billion years.

DES and OzDES

The main aim of the Dark Energy Survey (DES) is to understand the physics behind the accelerating expansion of the universe. It does this using four astronomical probes: galaxy clusters, large scale structure, weak lensing and Type Ia supernovae (SNe Ia). The data obtained by DES are also being used to study a wide variety of astronomical phenomena [1].

DES is an imaging survey using DECam, a 3 square degree imager mounted on the CTIO 4m Blanco Telescope in Chile. It consist of a wide field survey covering a quarter of the Southern sky, and a transient survey that repeatedly images 10 deep fields with a weekly cadence over a six month period every year. DES has just completed its fourth year of operations.

The scientific grasp of DES is broadened and strengthened with spectroscopic followup. The 2dF positioner and AAOmega spectrograph on the AAT is the ideal instrument for the followup, as the field-of-view of DECam is well matched to the patrol field of the 2dF positioner. OzDES uses 2dF and AAOmega to observe tens of thousands of sources in the 10 DES deep fields.

One of the novel features of OzDES is that it observes these fields on a roughly monthly cadence over the time these fields are observed in Chile. This allows us to monitor sources spectroscopically (e.g. AGN), and to obtain redshifts for objects that are usually considered to be too faint (as faint as magnitude r=24) for a 4m class telescope such as the AAT, by simply continuing to observe them until the redshift is obtained.

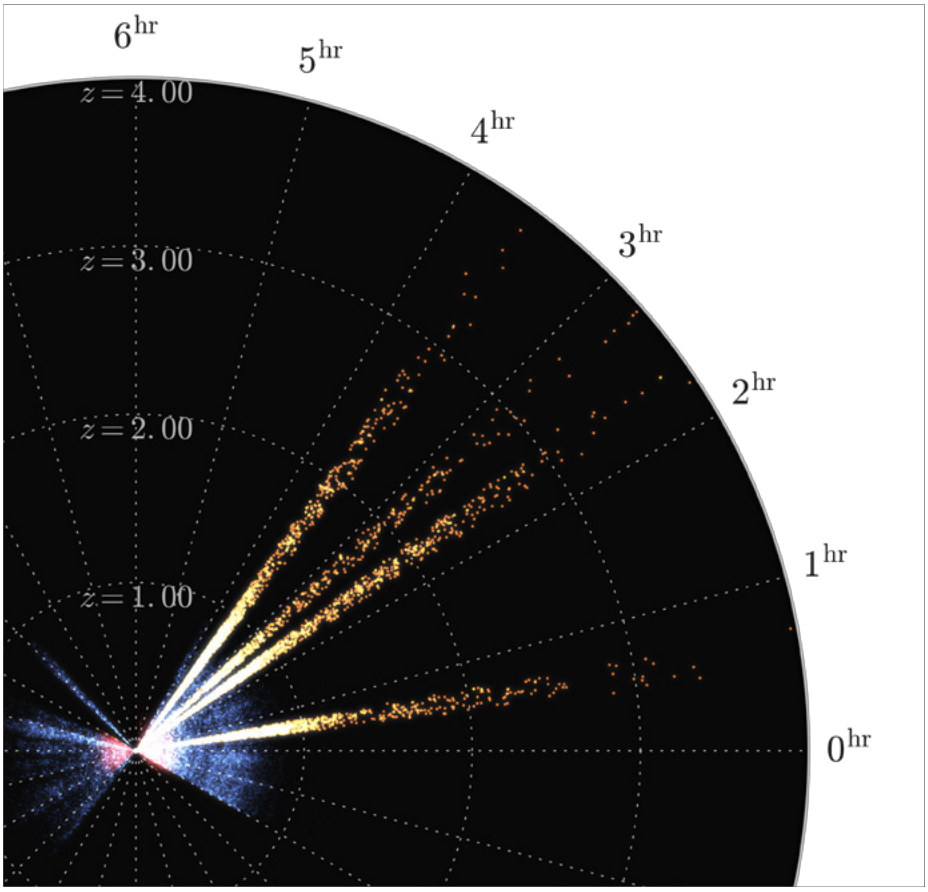


Figure 1. A plot showing the redshift reach of OzDES survey in yellow compared to 2dFLenS [7] in blue and the 2dF Galaxy Redshift Survey [8] in pink. Most of the OzDES sources below redshift z=1.2 are galaxies, whereas most of the sources above this redshift are AGN.

OzDES has two main scientific goals. The first goal is to constrain the dark energy equation-of-state parameter and its evolution with time using the SN Ia Hubble diagram. The second goal is to map out the growth in supermassive black holes, from 12 billion years ago to the present, using AGN reverberation mapping [2].

OzDES is also obtaining redshifts for thousands of other sources, including radio galaxies from the ATLAS radio survey [3-5], galaxies in clusters and groups, and redMaGiC galaxies [6]. Fig. 1 shows a cone plot of the OzDES survey, compared with two other well known AAT surveys.

SN Ia Cosmology

The number of Type Ia supernova that have been used to constrain the expansion history of the universe has grown from a few dozen in the late 1990s to over a thousand today. The Supernova Legacy Survey (SNLS) and the SDSS-II Supernova Survey [9,10] have contributed more than half of these supernovae.

The DES survey will produce 5 times as many supernovae as the SNLS and SDSS surveys combined. Typing all of them spectroscopically, as was done in SNLS and SDSS, is not practical. Instead, typing will be done by combining high quality multi-colour light curves obtained with DECam, together with a redshift of the host galaxy that is obtained with the AAT. The advantage of this approach is that the host redshift can be obtained at any time. Furthermore, since the 10 DES fields are repeatedly targeted, one can obtain redshifts of galaxies that are usually much too faint for the AAT.

To date, OzDES has obtained the redshifts of almost 4,000 galaxies that hosted a transient of some type over the past four years. Only about half of the transients are SNe Ia. The rest are mostly AGN, or SNe of other types. By deliberately targeting the host galaxies of a broad range of transients, we will be able to better discriminate between a transient that is a SN Ia and a transient that is not.

OzDES is also observing transients that happen to be bright enough to observe at the time OzDES takes data. So far, OzDES has classified over 150 supernovae, most of which are SNe Ia. The AAT has spectroscopically classified more DES SNe Ia than any other telescope in the world, as can be seen in Fig 2.

After four years of effort, the DES SN sample is now large enough to provide competitive constraints on dark energy. We are taking a staged approach to the analysis.

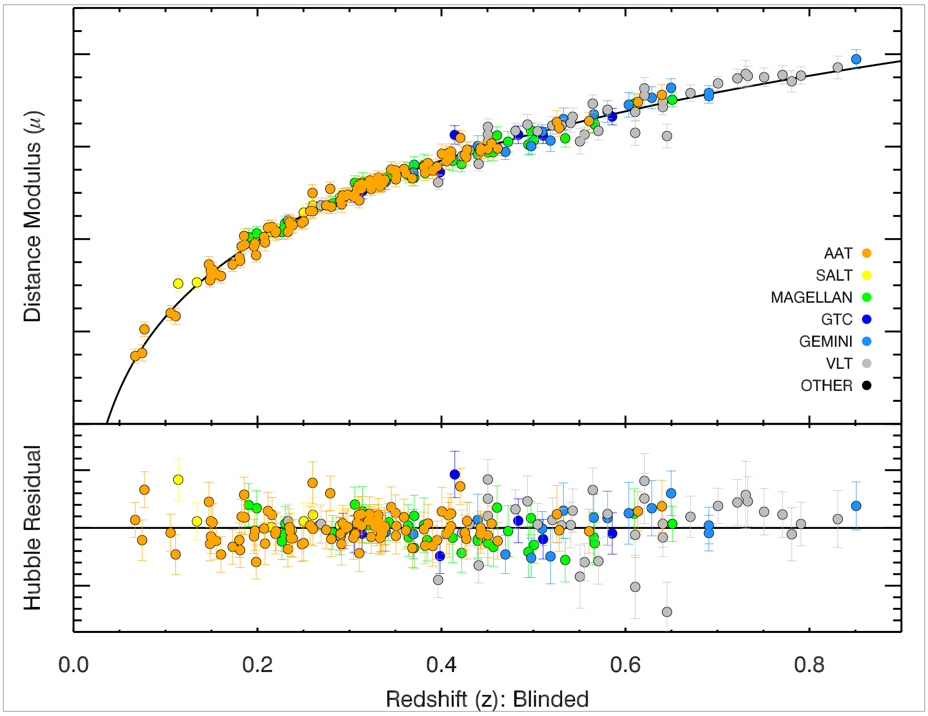


Figure 2. A Hubble diagram containing over 200 SNe Ia from the first three years of DES. SNe Ia from the AAT are in coloured in orange. As part of the blinding process a hidden function has been applied to slightly warp the redshift axis. Under ideal conditions, the AAT can spectroscopically confirm SN Ia up to redshift z=0.6.

We have combined the spectroscopically confirmed SNe shown in Fig. 2 with a sample of nearby SNe from the CfA and CSP surveys to create a sample of about 500 SNe Ia. This is similar to the number of SNe Ia used in the in the Joint Lightcurve Analysis (JLA, [11]), which has provided some of the tightest constraints yet on the dark energy equation of state parameter.

We are pursuing a number of approaches to deriving constraints from this sample of 500 SNe Ia. This includes the approach that was developed for the JLA sample, as well as newer approaches [12]. As is now standard in cosmology, all our analyses are blinded. In other words, the answer is hidden until the analysis is complete and the methods thoroughly tested.

Once we have developed the tools to analyse this sample of 500 spectroscopically confirmed SNe Ia, we will turn our attention to the full DES sample, which will be available at the end of 2018 and will be an order of magnitude bigger.

Reverberation Mapping

Reverberation mapping is a technique that uses the time delay between the line and continuum emission in AGN as a way to measure the mass of the central black hole. The continuum emission emitted from the inner regions of the AGN illuminates the gas clouds orbiting the black hole, which form what is known as the broad line region (BLR). This radiation ionises the gas in the BLR leading to the formation of broad emission lines. A time delay is observed due to the fact that the continuum radiation is emitted at a radius on the order of light days from the black hole as opposed the emission lines which are formed at a radius of light months/years. If the BLR is in virial equilibrium within the gravitational field of the black hole, the combination of this time delay along with the velocity of the orbiting gas determined by the width of the emission line can be used to measure the mass of this supermassive black hole.

The OzDES reverberation mapping program is regularly monitoring 771 AGN with a monthly cadence. With these data, it is possible to monitor the variability of the strength of the emission lines formed in the BLR with H-beta being the prominent line observed in low redshift sources and MgII and CIV seen in high redshift AGN.

Using these lines OzDES will be able to measure time lags in AGN with redshifts up to z~4. The continuum light curves are obtained through DES observations of these sources with a weekly cadence and will be used with the OzDES data to measure the time lag and in turn the mass of the central black hole for approximately 40 percent of the monitored AGN. The expected performance of the OzDES reverberation mapping program when compared to existing survey data is shown in Fig. 3. The OzDES reverberation mapping program will not only be able to significantly increase the number of AGN for which we have direct lag measurements but will also extend these measurements to AGN at higher redshifts.

There is a relationship between the radius of the BLR and the luminosity of the AGN. This radius-luminosity relationship makes it possible to determine the radius of the BLR and in turn the black hole mass using single epoch observations.

Because OzDES will significantly extend the number of measured time lags in high redshift AGN, it will be possible to study the effect of using different lines on the radius-luminosity relationship providing a way to obtain more accurate black hole mass estimates using single epoch observations. OzDES will also be able to be used to test the idea that AGN can be used as standard candles for cosmology.

Concluding Remarks

OzDES has now used two-thirds of the time that was allocated to it, and is well on its way to obtaining the data it needs. By the end of the survey, we expect to obtain host galaxy redshifts of around 2,500 Type Ia supernova, and spectroscopically classify over 200 of them. OzDES is also making significant progress in monitoring almost 800 AGN. We look forward to reporting on the results from OzDES in future editions of the AAO Observer.

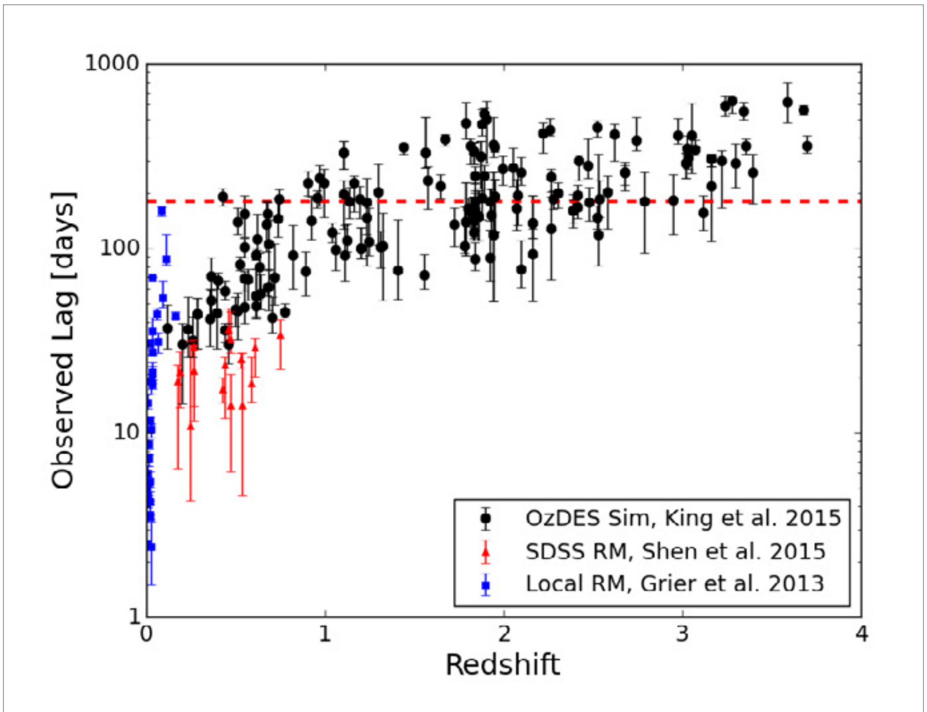


Figure 3: Simulated time lags of AGN observed by OzDES plotted against the real redshift. Plotted in red and blue are real lags from observations of local AGN and AGN from SDSS [13,14].

References

[1] Dark Energy Survey Collaboration 2016, MNRAS, 460, 1270
[2] King et al. 2015, MNRAS, 433, 1701
[3] Hales et al. 2014, MNRAS, 441, 2555
[4] Middleberg et al. 2008, AJ, 135, 1276
[5] Norris, R. et al. 2006, AJ, 132, 2409
[6] Rozo, E. et al. 2016, MNRAS, 461, 1431
[7] Blake, C. et al. 2015, MNRAS, 462, 4240
[8] Colless, M. et al. 2001, MNRAS, 328, 1039
[9] Astier, P. et al 2006, A&A, 447, 31
[10] Friemann, J. A., 2008, AJ, 135, 338
[11] Betoule, M. et al. 2014, A&A, 568, 22
[12] Rubin, D. et al. 2016, ApJ, 813, 137
[13] Shen, Y. et al. 2015, ApJS, 216, 4
[14] Grier, C. J, et al. 2013, ApJ, 764, 47

Institutes

1 AAO
2 University of Queensland
3 The Ohio State University
4 University of Chicago
5 University College London
6 Argonne National Laboratory
7 Fermi National Accelerator Laboratory
8 University of Portsmouth
9 Observatorio Nacional de Rio Janiero / Laboratorio interinstitucional de e-Astronomia
10 University of Southampton
11 Swinburne University of Technology
12 Institut de Ciencies de l'Espai (IEEC/CSIC)
13 University of Melbourne
14 Lawrence Berkeley National Laboratory
15 University of Sydney
16 CSIRO Astronomy and Space Science
17 SLAC National Accelerator Laboratory
18 ICRAR
19 Australian National University
20 ARC Centre of Excellence in All Sky Astrophysics (CAASTRO)
21 University of Oslo
22 European University Cyprus
23 Purple Mountain Observatory

From SSO to SOFIA

Stuart Ryder (International Telescopes Support Office, AAO)

It has long been a dream of mine to fly on board NASA's Stratospheric Observatory For Infrared Astronomy (SOFIA). A project begun a decade ago using IRIS2 on the AAT ultimately made this possible.

Back in 2004, astronomer Peter Barnes (then at the University of Sydney, now at the University of Florida) and his team launched the CHaMP (Census of High– and Medium-mass Protostars) project, the first large-scale, unbiased, uniform mapping survey at sub-parsec-scale resolution of 90 GHz line emission from massive molecular clumps in the Milky Way. To find these clumps, he used complete surveys of a large portion of the southern Galactic Plane in Vela, Carina, and Centaurus (300° > l > 280°) and (−4° < b < +2°) in four molecular spectral lines in the 3 mm waveband made with the 4 m Nanten telescope. He then made higher resolution follow-up observations of 300 of these clumps (Barnes et al. 2011; data available from http://www.astro.ufl.edu/~peterb/research/champ/) using the 22 metre Mopra antenna, just down the road from Siding Spring Observatory.

Having ascertained the gas content and physical conditions, the next step was to compile a systematic picture of the pre-Main Sequence evolution of young embedded star clusters, as well as the ionised and warm molecular gas excited by stars still in the process of forming. To do this Peter and I launched the IR-CHaMP survey using IRIS2 on the AAT to image these clumps in broad-band J, H, and Ks filters, as well as the narrow-band Brγ, H_2 1–0 S(1), H_2 2–1 S(1), and 2.3 μm continuum filters. Over the course of 16 nights in semesters 2011A and 2012A we managed to image 76 of these clumps in all 7 filters. Among other things these data demonstrated for the first time a significant correlation between HCO^+ line emission from cold molecular gas and Brγ line emission of associated nebulae (Barnes et al. 2013).

The most spectacular result however was the discovery of large-scale gravitational infall in the massive protostellar cluster BYF73 (Barnes et al. 2010). This clump has a mass of ~2 × 10^4 $M_\odot$, a luminosity of 2–3 × 10^4 $L_\odot$, and a diameter of ~0.9 pc. From radiative transfer modelling, we derived a mass infall rate of ~0.03 $M_\odot$ yr^{-1}, amongst the highest on record. The near-infrared K-band imaging (Fig. 1) shows an adjacent compact H II region and IR cluster surrounded by a shell-like photodissociation region showing H_2 emission.

In order to understand how BYF73 has been able to overcome factors such as turbulence, magnetic fields, and rotation to undergo such rapid infall we need measurements of the coolant lines of [O I], [O III], and [C II] in the far-infrared wavelength region from 60–150 μm. Such wavelengths are heavily absorbed by the Earth's atmosphere, and with the demise of satellites like Herschel, our only option is the Stratospheric Observatory For Infrared Astronomy (SOFIA: https://www.sofia.usra.edu/), operated by NASA and the German Aerospace Centre DLR. SOFIA is a modified Boeing 747SP with a 2.5 metre telescope mounted in the back section of the plane. Normally based out of NASA's Armstrong Flight Research Centre in Palmdale, California, SOFIA spends part of each southern winter operating out of Christchurch International Airport in New Zealand to allow access to the Magellanic

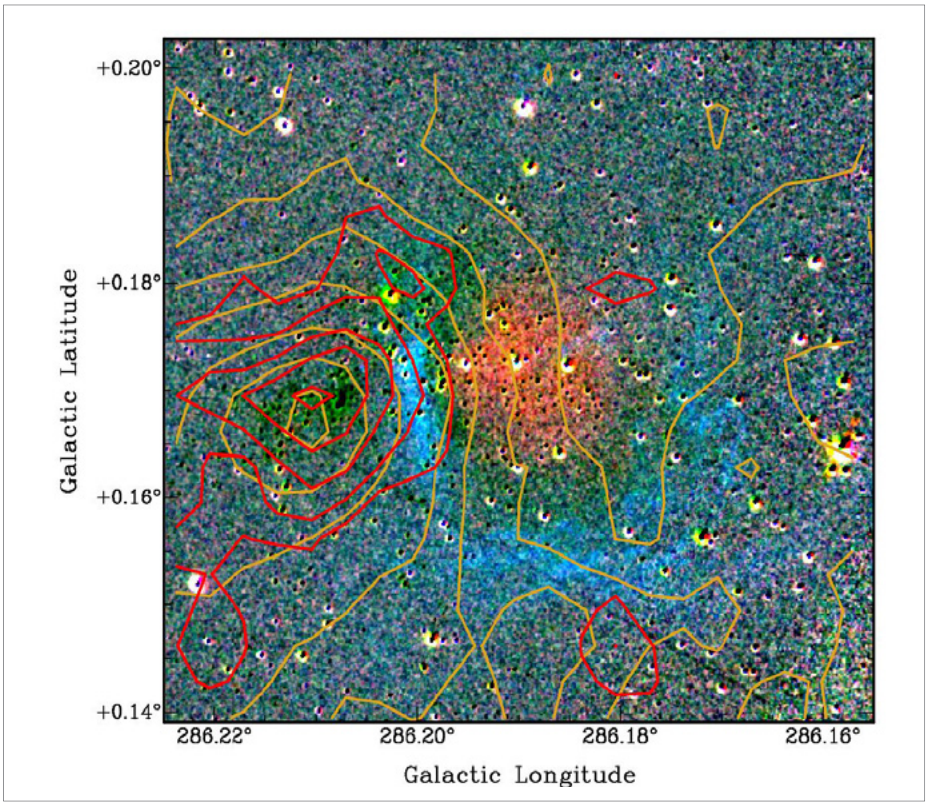


Fig. 1: Pseudo-colour image from Barnes et al. (2010) of BYF73 in K-band spectral lines. Here Brγ is shown as red, and H_2 S(1) is shown as green (v = 1 → 0) and blue (v = 2 → 1). Contours are overlaid from Mopra HCO^+ (gold) and $H^{13}CO^+$ (red) integrated intensities.

Fig. 2: SOFIA flies into Christchurch, New Zealand for the start of its southern deployment in June 2016. The bulge in the rear section is due to the hatch cover which slides open in flight to expose the 2.5m telescope to the sky. Image credit: NASA.

Clouds and other southerly targets. For 2016's southern deployment, Peter and I applied for and were granted 3 hours with the FIFI-LS integral field spectrograph to map these lines in BYF73. Although PIs are not required to be present on-board while their observations are taken, they and their Co-Is are welcome to participate as Guest Observers provided there are sufficient seats available on each flight. Fortunately I had the opportunity to accompany Peter and his PhD student Rebecca Pitts on both of our scheduled flights (or "missions" in NASA-speak).

Into the stratosphere

Obviously SOFIA has the big advantage that it can fly above the weather. However, like any ageing aircraft it requires regular servicing and checks, and shortly after its arrival in New Zealand in June 2016 (Fig. 2) a crack was discovered in one of its engine pylons. This placed all the following missions, including ours, in doubt. Fortunately the dedicated support team were able to get a replacement engine and mount flown out from the US, change it out on the freezing tarmac in Christchurch, and get SOFIA back in the air within 2 weeks, just as the FIFI-LS series of missions was about to begin. I arrived into Christchurch on 30 June and went straight to the Operation "Deep Freeze" Antarctic support facility at the airport, which is where SOFIA flight operations are based. We were given an extensive safety and egress briefing before being taken out onto the apron for a familiarisation tour of the aircraft. The rear 1/3 or so of the fuselage is taken up with the telescope cavity behind a large bulkhead, in which the telescope itself floats on

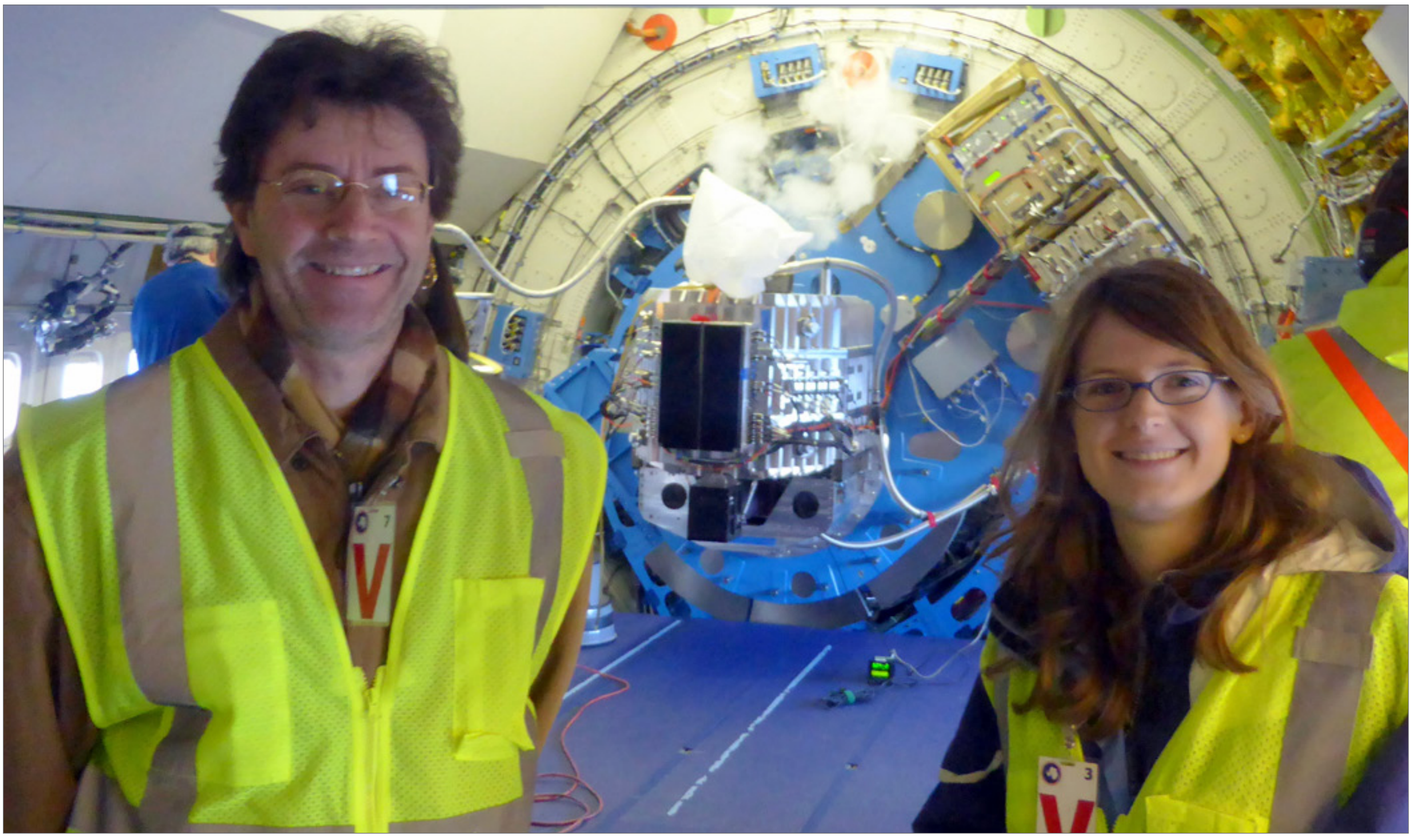


Fig. 3: Peter Barnes and Rebecca Pitts (University of Florida) standing in front of the FIFI-LS instrument, with the telescope itself located behind the white bulkhead. Note the rather spartan interior, which makes for a noisy working environment.

a gyro-stabilised spherical bearing, counter-balanced by the instrument which sits within the pressurised front section of the cabin where the mission crew and astronomers sit (Fig. 3).

Because the telescope can only point between 20° and 60° in elevation, and ±3° in azimuth, SOFIA's flight path for each 10 hour mission at altitudes between 39,000 and 45,000 feet consists of several legs tracking particular objects, starting and finishing near Christchurch. As an example, Fig. 4 shows the flight path for our first mission on 1 July, which saw us take off just after sunset; fly northwest across the Tasman Sea while climbing to cruise altitude and opening the hatch over the telescope cavity; fly a long 3 hour leg south while mapping the Galactic centre; turn east then northwest to observe two other targets; spend most of the homeward leg towards New Zealand observing our target BYF73; then finish up with a calibration target before commencing our descent over the southern alps and arriving back into Christchurch at 3:30am.

With ⅔ of this flight spent observing other people's targets, what would we do in the meantime? The long track on Sgr A* took us as far as 63° south, putting us right under the auroral circle. We were fortunate to enjoy excellent views of the aurora australis from the upper deck with all the lights turned out, similar to the photo in Fig 5 taken on a later flight by Dr Ian Griffin, Director of the Otago Museum. Notice the auroral curtain arcing over the horizon, reminding us that the aurora is a 3D phenomenon.

Finally it was time for our own observing leg to begin. Although the strict flight plan prevents us from spending any longer on our target than allocated, we were able to optimise the time spent at each wavelength setting based on real-time analysis of the data. Thanks to excellent support from the SOFIA crew, in particular Randolf Klein from USRA and Christian Fischer from the Deutsches SOFIA Institut (DSI), we got clear detections of all the major coolant lines and their variation across BYF73. As Fig. 6 shows Peter was extremely happy with the results, which called for a celebratory Tim Tam for all the crew.

Fig. 4: Flight path for our first SOFIA mission.

Fig. 5: View of the aurora australis from SOFIA's upper deck as photographed on a subsequent flight. Image credit: Ian Griffin, Otago Museum.

Back to earth

One of the other rare opportunities that SOFIA affords is the chance to ride in one of the cockpit jump seats for take-off or landing, and on my second mission I was lucky enough to do so on take-off. It took me back to the time 30 years earlier when as an undergraduate student at the University of Canterbury in Christchurch I had done the same thing on SOFIA's predecessor the Kuiper Airborne Observatory, a C-141 Starlifter aircraft with a 1 metre telescope.

In addition to flight safety, NASA takes education and public outreach very seriously, and our second mission included a number of journalists and educators. You can see footage of our flight, including an in-flight interview with me at http://tinyurl.com/jfo873r. I'm extremely grateful to NASA and to Peter for affording me this opportunity, and hope to be back in the stratosphere for more CHaMP follow-up in the future!

References

Barnes, P. J., et al. 2010, MNRAS, 402, 73

Barnes, P. J., et al. 2011, ApJS, 196:12

Barnes, P. J., et al. 2013, MNRAS, 432, 2231

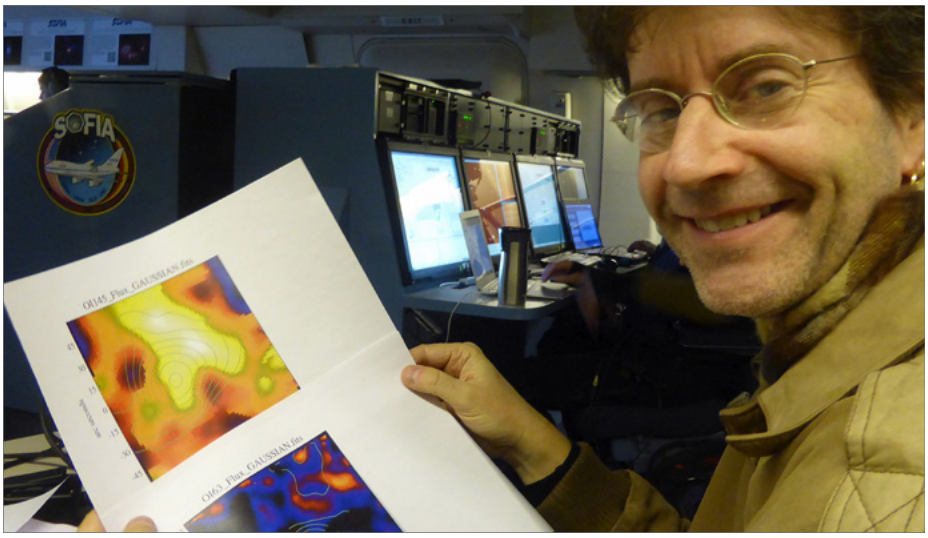


Fig. 6: A very happy PI shows off his FIFI-LS data while on descent back to Christchurch.

Scl-1013644: a star with unusual abundances in the Sculptor dSph galaxy

Carolina Salgado (ANU)

Through the study of metal-poor stars it is possible to discover clues concerning the formation history of the Milky Way and its companion satellite galaxies. Recently, carbon-enhanced metal-poor (CEMP) stars have received special attention in this context due to their possible connection to the chemical composition of the gas from which the first stellar generations formed. These carbon rich stars, defined by possessing [C/Fe] > 0.7 (Aoki et al. 2007), i.e., a carbon-to-iron abundance ratio at least five times higher than the value for the Sun, have a frequency of occurrence that increases with decreasing overall metallicity. CEMP-stars are found mostly in the Galactic Halo but they have also been discovered in the dwarf spheroidal (dSph) satellite galaxies of the Milky Way. Among the CEMP-stars, the largest subgroup are the CEMP-s stars that show a relative excess of heavy elements, such as Barium, that are produced by the slow neutron capture nucleosynthesis process. CEMP-s stars make up approximately 80% of the CEMP-star population and the current hypothesis for their origin is that the star we see today is the product of mass transfer from a carbon-enhanced asymptotic giant branch star in a binary system.

In the Sculptor dSph galaxy three CEMP-stars are currently known: one is a CEMP-no star (Skuladottir et al. 2015), i.e. a CEMP-star that does not show any excess of neutron capture heavy elements, while the other two are CEMP-s stars (Lardo et al. 2016). We have been studying the Scl dSph galaxy through investigating CH and CN band-strengths, and Na line strengths, in samples of Scl red giants. We have spectra, centered at 4300 Å, for 45 Scl stars from observations with the Gemini-South telescope and the GMOS-S multi-object spectrograph, and spectra for 161 stars, centered at 6050 Å, that were observed with AAT using the 2dF multiobject fibre positioner and the AAOmega dual-beam spectrograph. These spectra allow us to analyze the region of the G-band of CH (λ ~ 4300 Å) and of the CN-bands at λ ~ 3880 and 4215 Å. The AAOmega spectra also allow investigation of the strength of the BaII line at λ ~ 6140 Å, which provides information on s-process element abundances.

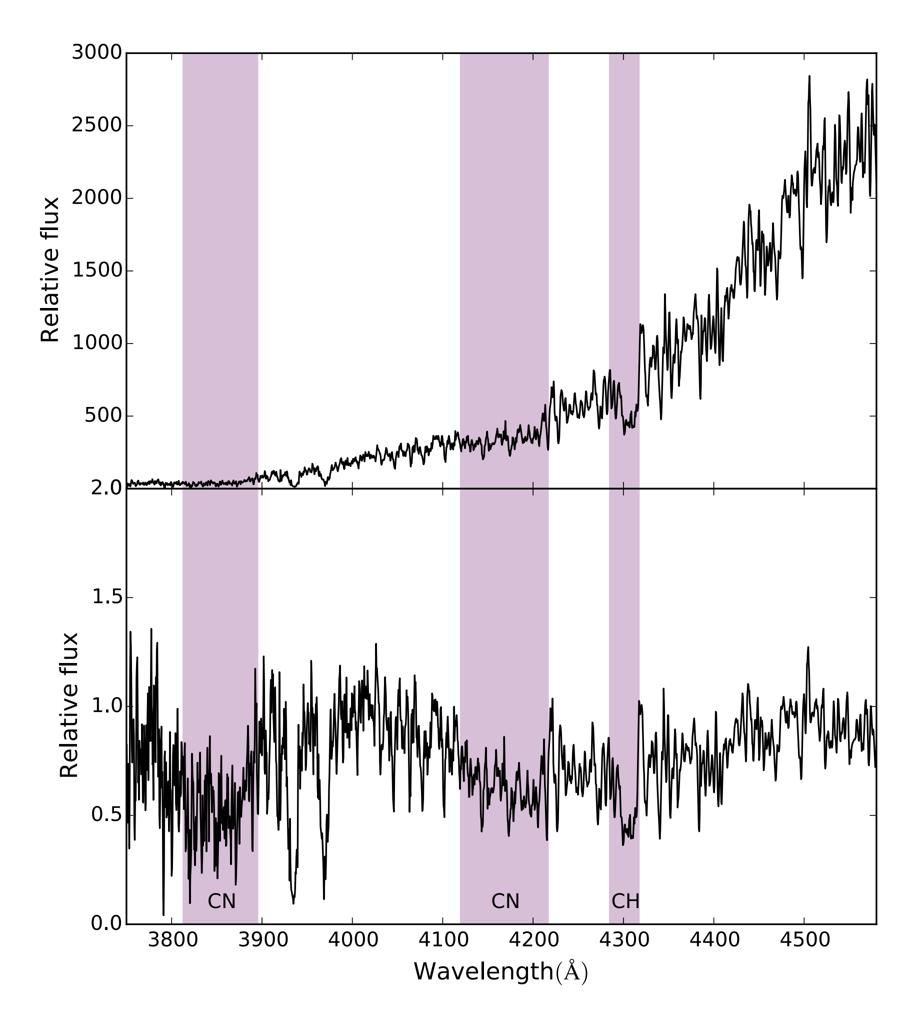


Figure 1: Upper panel: Observed GMOS-S spectrum of Scl-1013644. Lower panel: Normalized spectrum of Scl-1013644. The locations of the CH (λ 4300 Å) and CN (λ 3883, 4215 Å) bands are marked

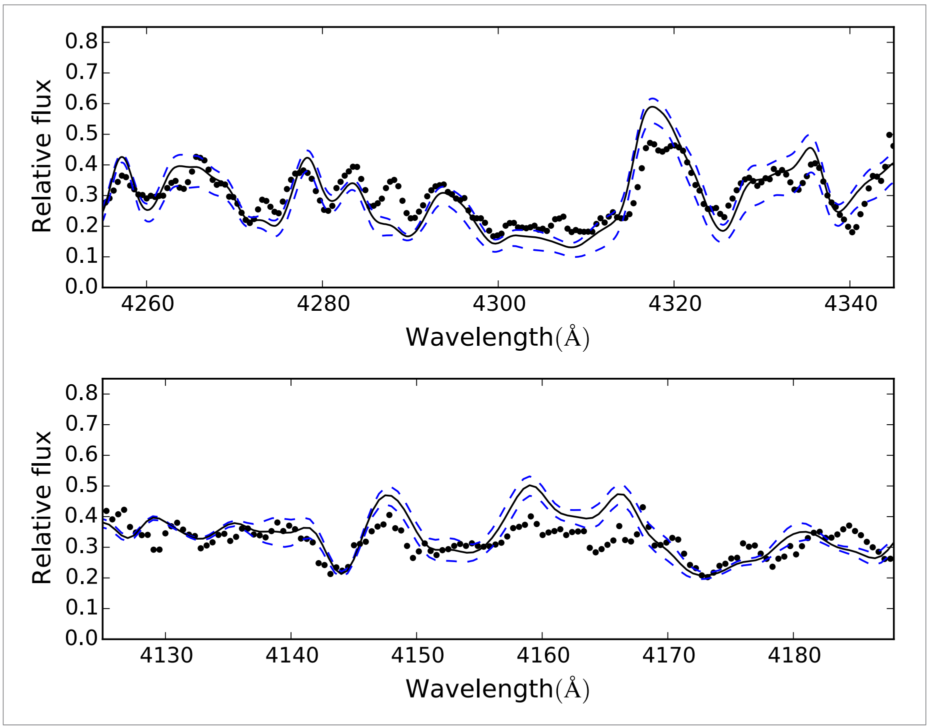


Figure 2: Spectrum synthesis of CH (top panel) and CN (bottom panel) features for Scl-1013644. In both panels the observed spectrum is represented by dots. Upper panel: The solid line represents the best abundance fit with [C/Fe] = +0.8 and [O/Fe] = +0.7. The dashed blue lines show carbon values ±0.15 dex about the central value. Lower panel: The solid line represents the best abundance fit with [C/Fe] = +0.8, [O/Fe] = +0.7 and [N/Fe] = –0.3. The dashed blue lines show nitrogen values ±0.2 dex from the best fit.

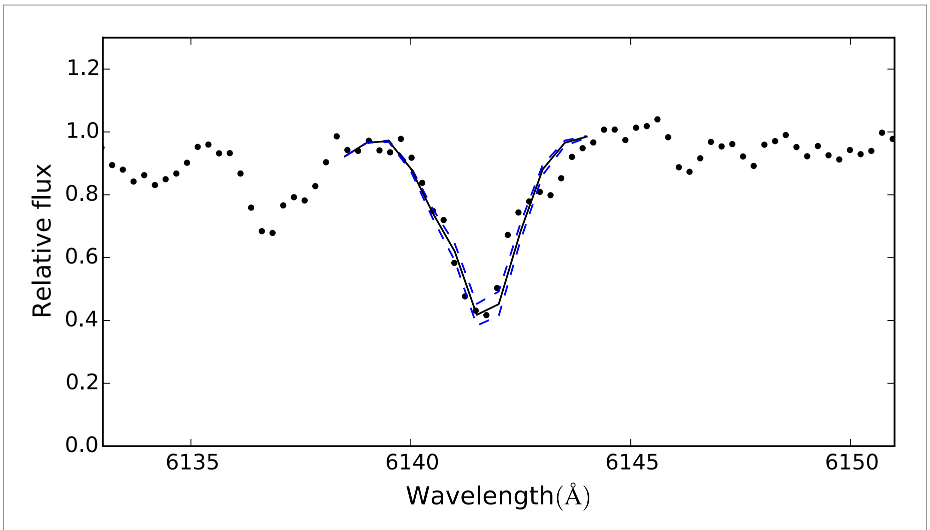


Figure 3: Spectrum synthesis of the λ 6141.7 Å BaII line for Scl- 1013644. The observed spectrum is represented by dots. The solid line represents the best fit which has [Ba/Fe] = +2.1. The dashed blue lines show barium values that differ by ±0.15 from the best fit.

In Figure 1 we show the GMOS-S spectrum of the Sculptor red giant star Scl-1013644. This star is a confirmed Scl member that has been previously identified as being relatively rich in heavy elements (Geisler et al. 2005). The figure shows that the CN and CH molecular bands are extremely strong in the spectrum of this star, allowing its classification as a CH-star. We have then used spectrum synthesis techniques applied to the observed blue and red spectra to derive the abundances of carbon, nitrogen and barium in the star. Figures 2 and 3 show the best fits of the synthetic spectra to the observations; details describing the fitting process can be found in Salgado et al (2016). We find for this star [C/Fe] = +0.8, [N/Fe] = -0.3, and most significantly, [Ba/Fe] = +2.1 dex. This latter value is consistent with the barium abundance found by Geisler et al. (2015). Our derived carbon-to-iron abundance ratio lies marginally above the limit of Aoki et al. (2007) for classification as a CEMP-star. Consequently, Scl-1013644 becomes the fourth CEMP-star known in the Sculptor dSph, and the high [Ba/Fe] value indicates that it is a CEMP-s star. The unusual abundances most likely have their origin in a binary-star mass-transfer process.

References:

Aoki et al 2007, ApJ, 655, 492

Lardo et al 2016, A&A, 585, A7

Geisler et al 2005, AJ, 129,1428

Salgado et al. 2016, MNRAS, 463, 598

Skúladóttir et al. 2015, A&A, 574, A129

Astronomers and Mothers: Recalibrating the Centre of their Universe

Amanda Bauer[1], Tayyaba Zafar[1], Caroline Foster[1], Gayandhi De Silva[1], & Sarah Brough[1]

Amanda Bauer wearing her 3 month old daughter while speaking at an international conference. (Credit: IAU)

While always changing, the Universe evolves much more slowly than a human lifetime. Humanity has only existed for a small blip of the life of the Universe and yet society has evolved immensely. Motherhood is an essential part of human society, and we must acknowledge in the workplace that with a child comes responsibilities and adjustments to every parent's life. Just as all galaxies are unique, so are motherhood stories. In this article, we take a break from showcasing astronomy at the AAO to focus on some of the unique astronomers who do the research.

[1] Australian Astronomical Observatory

The editor, Tayyaba Zafar, asked recent mothers at the AAO to share some of their experiences, challenges and success stories. AAO astronomer mothers relate the various solutions they have created, with the assistance of the AAO, to manage the often conflicting demands of their careers and motherhood.

Navigating a New Course

When Sarah Brough announced her pregnancy in July 2012 there had not been a pregnant member of staff at the AAO in a decade, let alone one with instrument support duties. With the encouragement and assistance of AAO management, she assigned 2 deputy instrument scientists oversight of her observing and support duties whilst on leave. They were luckily able to continue in that role upon her return to work 11 months later, because she initially found it impossible to work nights.

However, she found that returning to work part-time and being unable to contribute a full-time load completely knocked her self-confidence. It took her many months to regain that confidence and feel like a valued member of the research community again. She admits "this was probably in my own head, but it felt very real to me at the time. Looking back I should have reached out more to other astronomer mums in the community as I now know that this is a common experience and I didn't need to feel so isolated."

While Sarah could not travel in the first 2 years of her son's life, she was able to access the AAO Return To Work grant scheme. With this financial support she organised a major international conference in February 2015, bringing many international astronomers to Sydney to discuss the latest research in her field. This helped reinvigorate her research in what could otherwise have been a crisis point in her career.

Returning to work

Access to long maternity leave is a privilege enjoyed by most women at the AAO, but integrating back into the astronomy community after being away for long leave can be challenging. Many mothers take advantage of AAO's flexible working policy and return to work part-time, working a few days a week, instead of jumping back to full-time right away. Adjusting to a reduced workload comes with a few common challenges, even as it affords better work-life balance.

Working part-time requires a mental adjustment to reduce expectations of oneself after working so many hours for so long before having a baby. As one mother puts it, "Thankfully, my supervisors stepped in and emphasized that a full-time output was not required and that I should adjust my expectations of myself to be in line with my workload. This has meant giving up sitting on certain committees and pushing back on requests for "extra-curricular" activities. Things are much better now and I'm proud to say I've survived the return to work turmoil."

Alongside adjusting to being at work again, one mum describes her exhaustion from frequent night wakings and constant guilt over leaving her child with a "stranger" at daycare. That guilt is compounded by the many daycare germs, which inevitably go around the family and diminish work productivity. Thankfully, this situation does improve over time as immune systems strengthen and relationships grow between the child and the daytime carers.

Single parenting

The demands and challenges of single parenting can seem insurmountable at times, especially to career-driven people. But the situation is not unique among AAO astronomy mothers. With strength, support, and determination, they are doing their best to make it work.

When Tayyaba Zafar arrived at the AAO from her previous post in ESO, Germany she was pregnant and felt overwhelmed about being in a new country, a new workplace, and preparing for the arrival of her first baby. The AAO, which had never dealt with such a situation before, swiftly worked to help.

"I received a fantastically warm welcome from my new colleagues, such as a baby shower and a meal train after my baby's birth," Tayyaba said.

One of the major challenges she faced was not being entitled to paid maternity leave since the workplace agreement only allows maternity leave after 12 months service. With an infant and no support at home, Tayyaba had to come back to work right away. She worried about not doing justice to her role as a mother and felt guilty about not meeting work expectations either.

To alleviate these issues, the AAO sponsored her Permanent Residency in order to allow access to social safety nets for her and her baby. Tayyaba shared that "this provided incredible relief to our precarious situation. While it did not replace maternity leave, I was able to use half pay leave and flex-time to spend 6 weeks at home after giving birth, to adapt to my new role as a mum."

Starting back at work when her baby was 6 weeks old was exhausting, and she sometimes felt overwhelmed by caring for her baby and lacking energy. The AAO continued its support in the form of flexibility. "I was regularly reminded that I could work from home if needed, for instance if my son was sick or if we had had a terrible night. This made me feel valued. It gave me a lot of confidence and the ability to balance work life and motherhood."

Another major challenge has been that Tayyaba's job involves telescope support duties, which require stretches of several nights in a row staying up all night. The situation seems almost impossible for a breastfeeding single parent to achieve. Tayyaba was able to take on this responsibility due to several levels of support: the AAO deferred her observing duties for 6 months, she was then able to support observations remotely from the North Ryde office, her mother was able to visit, and her observing schedule was carefully blocked over a single month rather than scattered across the semester.

She states that "the individual and collective support and flexibility of the AAO helped me immensely to navigate the path of being a mother and continuing my career."

Working and travelling with babies

Astronomers notoriously travel all over the world to attend conferences and workshops to promote their research, and to keep up to date with the latest results. Amanda Bauer intended to take long maternity leave before returning to work part time, but was then invited to present at a big conference in South America, to be held just a few months after her baby was born.

"I couldn't pass up the opportunity to give an invited keynote talk to an important audience, despite still being on maternity leave, so I accepted the invitation. The AAO and the Department supported me to return to work for two weeks, giving me time to prepare for the conference, travel and attend."

It was a tight timeline to get all of her daughter's official documents processed for the trip, but everything came together in time. At the conference, she was not sure how welcoming people would be about bringing her infant along, but she had informed the organisers well in advance.

"I quickly realised that most people were thrilled to have a tiny participant join the proceedings! People offered to help, and many shared their personal stories, describing challenges of getting to conferences due to having children, that I never would have heard without having my tiny person present."

Many people, mostly women, struggle dealing with these issues, and it's done quietly, behind the scenes, without anyone knowing the additional strain they go through just to be present at events like these.

Amanda certainly faced challenges having an infant with her, compounded by not having a support person along. "I wasn't able to do the evening events or socialising, which I was sad to miss, and my fatigue grew with each day. I didn't make it to as many sessions as I would have without my infant with me, but I also noticed just how many people were completely distracted by their computers and not paying attention anyway."

There were many fascinating discussion sessions, including one on how best to present astronomy to audiences outside major cities. "At the beginning of the breakout session, I was the only woman in the room, and I was breastfeeding in the back. After a while, my daughter started to get restless, so I made sure I contributed my thoughts to the group before I took her out into the hallway."

The conference organised to have all talks live-streamed online. Amanda suggests that if an organisation goes through the effort to live-stream, then also set up a separate room at the venue to show the videos there as well. "This would be beneficial for my situation, but also in case people show up late and don't want to disrupt by entering the room, or if someone is waiting for a phone call, etc."

Amanda's talk was on Day 4 of the conference, by which time she had many offers from people willing to hold her baby while she spoke. But to her pleasant surprise, her daughter fell asleep in her carrier. "I wore her while I gave my 40 minute keynote presentation!"

While she successfully survived her first conference with a baby, Amanda intends to take a support person in the future, which should be possible with resources offered by the AAO that she can apply to use.

While children and partners can potentially experience the enriching benefits from travel, bringing family on work travel isn't always financially or logistically possible. The necessity and frequency of travel required for an astronomy career does add significant pressure to the rest of the family. One AAO astronomer mum says, "I have a very supportive partner, and he has requested that my travel be restricted to a maximum of one week per month."

Growing up: Changing Demands

The requirements of parenthood are not over after giving birth or raising a toddler. The demands of changing nappies and sleepless nights are exchanged with educational concerns and the social wellbeing of impressionable young people.

Gayandhi De Silva arrived at the AAO in 2010 with an 18 month old toddler and a 5 year old starting Primary school.

Today, Gayandhi has an energetic 8 year old and a pre-teen entering High School. She says "worrying about the sleeping routine and childcare hygiene seem so trivial compared to contemplating if I am guiding them correctly in their education. Will they fall into the wrong track? Will they be able to find work? Will they be strong enough to deal with failure, social mistreatment or a broken heart?"

Gayandhi admits that despite being a person who wrote a PhD thesis while breastfeeding, "I now know I cannot write a paper while addressing the above issues. I cannot afford to multi-task at dinner time, as it may be my only opportunity to find out the happenings at school. I cannot rely on another carer (even family members) to be their psychological stability. I need to have the time, energy and mental space to help them get over changes, failure and fitting in, and most importantly to spend quality time being my child's best friend."

Working as a research astronomer at the AAO has helped her in many ways, directly and indirectly, to face these challenges. Examples include being encouraged to host international conferences rather than traveling overseas away from family. Her advisors and mentors have helped in identifying financial resources and writing the successful applications.

It was at Gayandhi's request several years ago that the AAO began the process of setting up remote observing from Sydney, which is now very popular and routinely carried out.

The AAO's initiative to allow flexible working hours also benefits Gayandhi. "The freedom to work from home enables me to attend a school concert, for instance, without wasting otherwise productive time driving to and from the office. Starting work late on some days enables me to attend a morning class activity that clearly boosts my child's confidence."

Gayandhi emphasizes that the "approachable and understanding nature of my peers and supervisors is undoubtedly a major positive factor. I am not looked upon as having an extra burden of being a mother, but rather as one of a group of people with various different challenges, who can understand and foster a supportive workplace community."

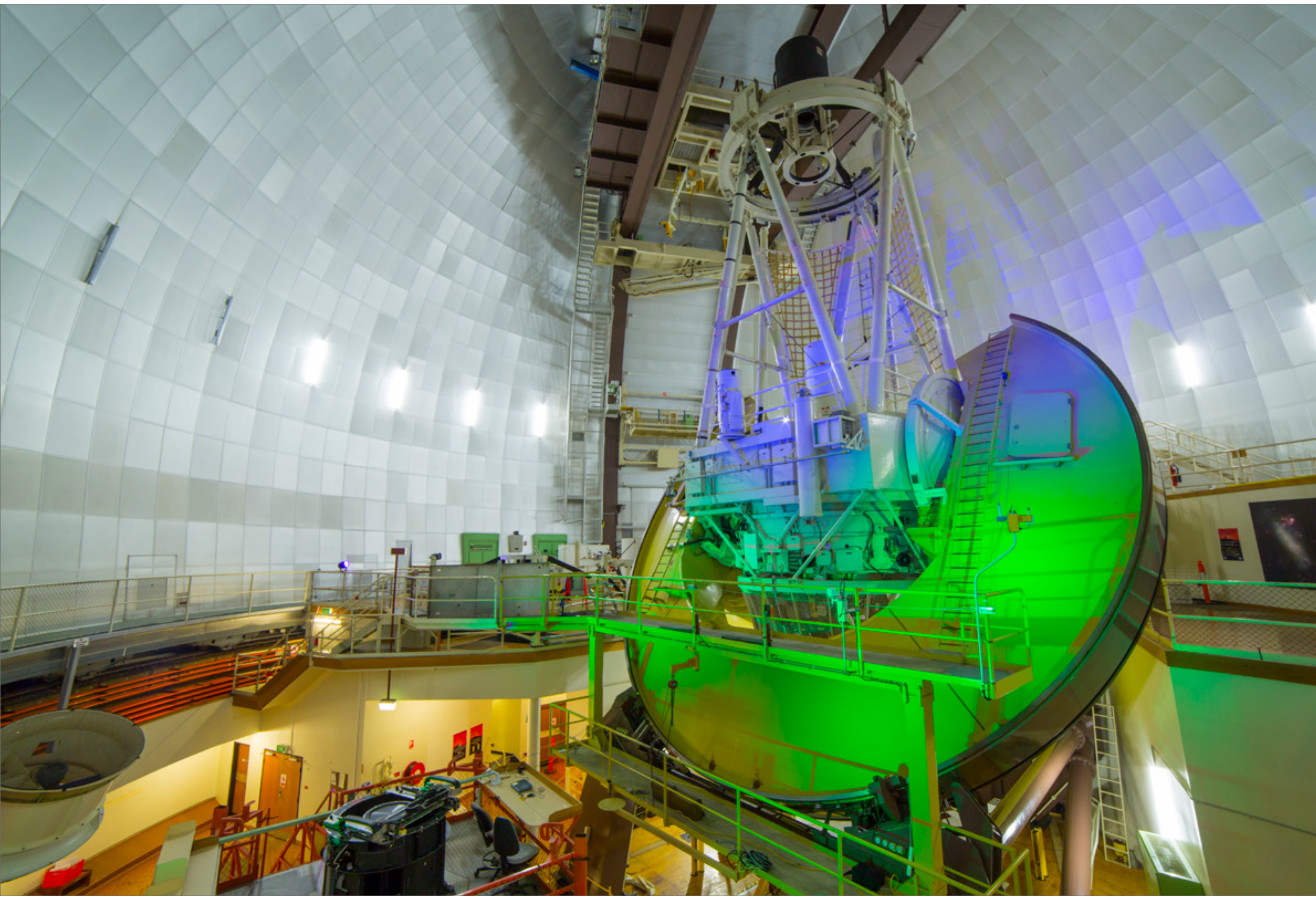
AAO's flexibility is critical for success

There is no single solution for all the unique challenges that mother's face when returning to their career after time away for family. There is however one critical theme that has emerged from our interviews with mothers at the AAO: flexibility.

Flexibility includes working from home, maintaining flexible daily working hours and scheduling, encouraging family-friendly meeting times (between 10am and 2pm where possible), and working part-time with output expectations that reflect those hours.

The truth about flexible working conditions is that they benefit everyone in the organisation, not just working mothers, by adapting to individual life circumstances. Feeling valued for individuality promotes confidence in one's abilities, dedication to the organisation, and enjoyment in life activities outside work. This in turn develops an inclusive and understanding workplace culture, which benefits employees from varied backgrounds and family situations, and promotes diversity.

As much as we love studying every aspect of our beautiful Universe, it's the supportive atmosphere and flexible policies within the AAO that enhance our experience as mothers and benefit ourselves as astronomers.



Above: The 4metre Anglo-Australian Telescope (AAT) lit up for Open Day at Siding Spring Observatory during StarFest. Photo Credit: Ángel López-Sánchez (AAO/Macquarie)

StarFest 2016

by Amanda Bauer

During the long weekend in October, we held the annual StarFest extravaganza in collaboration with ANU and other astronomical institutions at Siding Spring Observatory.

Festivities opened Friday night at the Coonabarabran Bowling Club with the sold out Science in the Pub. Host Fred Watson welcomed panel members Dr Ángel López-Sánchez (AAO/Macquarie), Professor David Malin (AAO), Dr Elisabete da Cunha (ANU), and Mr Brad Moore (iTelescope) to discuss Art versus Science in astronomical photography. The evening ended as always with original songs performed by the evening's host, Fred Watson, and Dr Amanda Bauer.

Despite a chilly Saturday, Open Day at the Observatory welcomed nearly 2000 visitors who toured the major telescope facilities, saw demonstrations of technology being developed by AAO, experienced the big telescope up close, explored the telescope's control room, listened to science talks by leading astronomers, and launched water rockets outside! Guests enjoyed extensive family-friendly events and a mobile planetarium throughout the day.

Open Day also saw the official opening of the new Timor Fire Station on Siding Spring Mountain by the NSW Rural Fire Service. Director Warrick Couch spoke at the event on behalf of the AAO, and staff member Wayne Clarke (captain of the Timor fire brigade) accepted a plaque and flag to mark the opening.

A highlight of the weekend was Dr Amanda Bauer's Bok Lecture. AAO's Dr Bauer took the audience on a journey from the beginning of our Milky Way Galaxy just after the Big Bang to the Galaxy's distant future, when stars stop forming and its supermassive black hole slowly evaporates away.

Record funds raised over the weekend were donated to the NSW Volunteer Rescue Association.

To watch videos of the science presentations, and to make plans for your StarFest trip next year, visit the StarFest http://www.starfest.org.au/ website.

Above: Dr Amanda Bauer (AAO) gives her Bok Lecture on The Life and Times of our Milky Way Galaxy. Photo Credit: Steve Chapman (AAO).

Right: Science in the Pub panel (L-R): Dr Ángel López-Sánchez (AAO/Macquarie), Dr Elisabete de Cunha (ANU), host Prof Fred Watson (AAO), Mr Brad Moore (iTelescope), and Professor David Malin (AAO). Photo Credit: Steve Chapman (AAO).

Above: Exploring technology and watching demonstrations on the AAT dome floor during StarFest Open Day. Photo Credit: Ángel López-Sánchez (AAO/MQ)

StarFest

Right: Siding Spring Observatory featuring the big white dome of the AAT during Open Day. Photo Credit: Steve Chapman

Below: Opening the new Timor Fire Station on Siding Spring Mountain by the NSW Rural Fire Service. Director Warrick Couch (far right) spoke at the event on behalf of the AAO. Pictured are (L to R) Steve York (Asst Commissioner), Ron Nash, Wayne Clarke (AAO), Corey Phillip, Christine Allard (ANU), Steve Loane (Warrumbungle Shire Council General Manager), Peter Shinton (Mayor), Warrick Couch (AAO).

StarFest Wrap Up

By Zoe Holcombe & Amanda Bauer

StarFest 2016

StarFest opened on Friday night with the SOLD OUT Science in the Pub at the Coonabarabran Bowling Club. The topic up for discussion was Art Versus Science in astronomical photography, hosted by Fred Watson with panel members Dr Ángel López-Sánchez (AAO/Macquarie), Professor David Malin (AAO), Dr Elisabete de Cunha (ANU) and Mr Brad Moore (i-telescope). The evening concluded as always with original songs performed by Fred Watson and Dr Amanda Bauer (AAO).

Open Day commenced at 9:30am on the Saturday 1st October. Despite the chilly weather we had over 2000 visitors who toured the major telescope facilities. They saw demonstrations of technology being developed by the AAO, experienced the big telescope up close, explored the telescope's control room and listened to science talks by leading astronomers. They even launched water rockets outside! Visitors enjoyed extensive family-friendly events and the mobile planetarium throughout the day. During the day, the new Siding Spring Fire Shed was officially opened by the NSW Rural Fire Service, with AAO Director Warrick Couch speaking at the event. Wayne Clarke, staff member and member of the RFS, also accepted a plaque and flag to mark the opening.

On Sunday Dr Amanda Bauer delivered the 2016 Bok Lecture and took the audience on a journey from the beginning of our Milky Way Galaxy just after the Big Bang to the Galaxy's distant future, when stars stop forming and its supermassive black hole slowly evaporates away.

Over the whole weekend all the ticket sales, raffles and donations were given to the local Volunteer Rescue Squad. The total was $5631.10.

The StarFest committee would like to thank all the AAO staff who gave up their long weekend to help out at various events, especially Open Day as it's a very long day but as you can see well worth it when our numbers keep going up. The only problem now is we need to find more parking for 2017 and more help.

Top & Above: The 2016 Bok Lecture and Science in the Pub. Credit: Steve Chapmans

Above: AAO Starfest, AAT Open Day 2016. Credit: Ángel López-Sánchez

ITSO CORNER

Stuart Ryder (International Telescopes Support Office, AAO)

Semester 2017A

A total of 8 Gemini proposals were received by ATAC for Semester 2017A. There were 3 proposals for Gemini North, and 5 for Gemini South, with oversubscriptions of 2.6 and 3.7, respectively. Under the terms of Australia's limited term partnership, ATAC has a total of 7 classical nights to allocate across 2017A + 2017B, shared close to evenly between Gemini North and Gemini South. ATAC opted to allocate three nights in 2017A: two to PhD student Erik Kool (Macquarie University) to use GeMS+GSAOI to continue his search for supernovae in Luminous Infrared Galaxies; while one night on Gemini North went to Lucyna Kedziora-Chudczer (UNSW) to use GNIRS to observe Jupiter's aurorae coincident with closest approach by the Juno spacecraft.

Magellan demand in 2017A was well down on that in 2016B, with 6 proposals seeking just 9 nights for an oversubscription of 1.1. This was all the more surprising given that Astronomy Australia Ltd (AAL) had recently announced that Australian Magellan access has now been secured through to Semester 2020B. All but 1 proposal requested instruments on the Clay telescope, so 1 program requesting time on MegaCam was switched to IMACS on Baade to meet scheduling requirements. The remaining time went to MIKE programs.

ITSO now manages the CTIO Blanco time exchange program that used to be handled by the AAT Technical Secretary. No NCRIS funds are used to secure this access (a straight swap of 5 nights on the Blanco 4m telescope in Chile for 5 nights on the AAT), but travel support for scheduled observers is provided by ITSO on the same basis as for Keck, Magellan, or Gemini. There were 4 proposals, all for DECam, with an oversubscription of 1.9. Six half-nights went to Jeff Cooke's Deeper, Wider, Faster program, and 4 half-nights to Brad Tucker's follow-up of Kepler supernova fields.

A total of 23 proposals were received by KTAC in 2017A, the same number as received in 2016B. There were 12 proposals for Keck 1 and 11 for Keck 2, with Keck 1 time oversubscribed by 2.2, and Keck 2 by 1.4. Total dark time was oversubscribed by 3.4, grey time by 0.3, and bright time by 2.2. There was one proposal received in the KTAC Large Program category. Demand for MOSFIRE was well down on previous semesters, possibly due to uncertainty over how long the instrument would be out of service following the optical misalignment event sustained in September (MOSFIRE is currently expected to be re-commissioned in Feb 2017). KTAC met on 25 October to rank the 2017A proposals. Due to high demand across the partnership for OSIRIS time in May following the detector upgrade, one KTAC program with a provisional allocation was not able to be scheduled, but a total of 16 other programs were scheduled.

Following the installation of a dedicated ISDN backup internet link in August, RSAA is now an approved "mainland" remote observing site for the Keck telescopes. Qualified remote observers can now choose between RSAA or Swinburne to carry out their observations from Australia, with ITSO reimbursing any domestic travel costs incurred.

ITSO Road Show

In the 3 week period between 29 Aug and 19 Sep 2016 ITSO staff Stuart Ryder, Caroline Foster, and Elaina Hyde undertook a "road show" of all 16 AAL member institutions, presenting an overview of all the ITSO-supported facilities on offer in Semester 2017A, as well as highlighting the range of other services ITSO provides to the community. In all some 300 people attended these presentations. It was great to have the opportunity to meet personally with so many of our users and potential new users, and the road show clearly stimulated a number of new proposal submissions in 2017A from traditionally under-represented institutions. ITSO expects to carry out a similar road show each year to brief the community on the latest telescope access offerings.

KTAC Review

In August 2016 AAL conducted a review of the KTAC joint time allocation process, with input from ITSO as well as the other KTAC partners Swinburne University and the Australian National University. ITSO thanks those who took part in the KTAC user survey for their input. The review concluded that there are already benefits to the community from a joint national Keck access program, even after only two semesters of the program. The benefits include greater flexibility and efficiency in scheduling nights; the ability to accommodate larger programs than any one partner could sustain alone; and increased institutional collaboration. It recommended continuation of the KTAC program, together with some improvements including:

- introducing a new category of Large Programs;
- reducing the turnover in KTAC membership due to appointees not being available on scheduled meeting dates;
- increasing awareness among KTAC members of unconscious bias.

As a first step towards addressing the unconscious bias issue, the KTAC Chair Michael Murphy convened a videoconference of KTAC members in advance of the pre-grading of 2017A proposals to raise awareness of many types of cognitive bias, and how it can affect merit-based processes. As part of this discussion KTAC agreed that in future proposals should be presented to them with the science case first (with any information identifying the PI removed), and the usual cover sheet information including list of investigators and institutions placed at the end. From Semester 2017B the AAO's Lens proposal system will be used to submit the Keck cover sheet and separate scientific + technical case, which Lens will then merge in the preferred order. It is notable that in Semester 2017A, 5/23 (22%) of all PIs were female, while 5/16 (31%) of successful PIs were female, a significant turnaround from earlier semesters.

Fig. 1: Participants at the AAO for the Australia–Japan workshop for collaborative science with Subaru, along with a number of remote participants joining in from Japan and the Subaru headquarters in Hawaii. Image credit: Stuart Ryder.

Subaru access

ITSO is looking forward to adding yet another fabulous facility to our portfolio. The National Astronomical Observatory of Japan and AAL have reached in-principle agreement to collaborate during 2017 and 2018 to benefit both Australian and Japanese astronomers. Australia will provide financial support, technical contributions, and 4 nights on the AAT in exchange for 10 nights on the Subaru 8.2 m telescope on Mauna Kea. The telescope access will be available during Semesters 2018A, 2018B, and 2019A. The technical contributions will include a design study associated with enhancements to Subaru's adaptive optics system. ITSO and ATAC will handle the observer support and time allocation processes. The first Call for Proposals for Australian access to Subaru in Semester 2018A is expected to be issued in Aug 2017.

To help develop collaborative links between the Australian and Japanese astronomical communities, a joint workshop was hosted by the AAO on 15 Dec 2016. The focus of the workshop was on joint projects that would make use of current and future instruments on the Subaru telescope. The workshop was sponsored by AAL and ITSO, and organized by Chris Lidman and Julia Bryant. About 40 people attended the workshop, either in person or remotely (Fig. 1). They listened to 16 speakers talk about a range of projects. The talks are available from the workshop web page at https://www.aao.gov.au/conference/JapanAustralia2016.

This workshop was the first of a series of similar workshops that will occur throughout the coming year. The next workshop will be the Subaru International Partnership Science and Instrumentation Workshop, which will be held in Japan from 22–24 March 2017.

Fig 2: 2016/17 AGUSS students Grace Lawrence (second from right) and Daniel Muthukrishna (far right) at a workshop dinner with (from left) Miguel Roth (legal representative for the LSST), Romano Corradi (Director of Gran Telescopio Canarias), and Alexandre Roman Lopes (Associate Professor, University of La Serena). Image credit: Grace Lawrence.

AGUSS 2016/17

The Australian Gemini Undergraduate Summer Studentship (AGUSS) program offers talented undergraduate students the opportunity to spend 10 weeks over summer working at the Gemini South observatory in La Serena, Chile, on a research project with Gemini staff. They also assist with queue observations at Gemini South itself, and visit the Magellan telescopes at Las Campanas Observatory. The 2016/17 AGUSS program once again attracted 10 × more applicants than there were positions available. The lucky recipients were Grace Lawrence (Swinburne University of Technology) and Daniel Muthukrishna (University of Queensland). Grace and Daniel arrived in Chile on 6 December, and straight away joined with colleagues from Korea and Chile for a workshop on symbiotic stars (Fig. 2). In a first for the AGUSS program, they took the opportunity to present highlights from their research at the Chilean Astronomical Society's annual meeting in Maitencillo in late-Jan 2017.

2017 ITSO Science Symposium

The 2017 ITSO Science Symposium will take place at the ANU's Research School of Astronomy & Astrophysics on Mt Stromlo from 16–18 May 2017. Following the previous ITSO Science symposia in 2012 and 2015, this meeting will feature the research being conducted with all the international telescopes supported by ITSO. The Symposium will feature invited and contributed talks from leading Australian users of the Gemini, Magellan, Blanco, and Keck telescopes and is open to everyone, not just current users. Students and early-career researchers in particular are encouraged to attend, and travel subsidies will be available. There will be no registration fee, and lunch, morning and afternoon teas will be provided. To register, please visit the symposium web site at https://www.aao.gov.au/conference/ITSOsci2017.

Winter Studies hit the target

Lizzie Elmer (University of Nottingham)

Lizzie Elmer with the 2dF robot (Credit: Erik Tollerud)

Sending off my application to the AAO for a summer studentship was a shot in the dark. I wanted to do something totally different before returning for my fourth and final year studying Physics at the University of Nottingham, and what could be more different than living and working on the other side of the world? I couldn't believe it when I was offered the fellowship and responded with a yes within half an hour.

When I landed at Sydney airport, I was more than a little apprehensive about what I had let myself in for by accepting my student fellowship. Suddenly living on the other side of the world for three months seemed a lot more daunting than it had while I was safely in England! I had given myself a few days to settle into my accommodation and get over my jet lag, and then found myself heading to the North Ryde offices of the AAO for my first day. Before I knew it I found myself sat at a desk with a new email address and a pile of reading to help me get started on my project.

The project I worked on was to program a Target of Opportunity mode for the 2dF – AAOmega instrument. This is an override mode so that if a priority astronomical event happens during the night, like a supernova explodes or there's a gravitational wave event, the target can be viewed within a few minutes. The whole way through my project, my supervisors (Chris Lidman and Tony Farrell) were always on hand to answer the smallest questions and give me encouragement. With their help, I managed to have a completed version of the code ready for testing by halfway through my 12 weeks. After this there were sky tests to organise and documentation to write up, as well as having a mini project to help Chris prepare a catalogue for his observing time.

In late July, the two other student fellows and I were given the opportunity to visit the AAT in person. We were driven up by Chris, given a safety induction and access to the telescope control room, and then we were allowed to sit in on the night time observing! We were very lucky that while we were there the skies were perfectly clear, and I was overwhelmed by just how many stars were visible when there was no light pollution. As a Londoner, I always thought the stars from the English countryside were pretty impressive but they paled to nothing next to seeing the Milky Way above Siding Spring Observatory.

While on site, Chris organised for us to have tours around many of the telescopes on site at Siding Spring. Given the size of the site, I felt like we had seen every type of telescope possible by the end of our stay! My favourite (other than the AAT of course!) was the iTelescope set up. This was a building containing 25 smaller telescopes that could be controlled remotely by amateur astronomers. I loved that there was a facility on site that was accessible to those outside of the research community. We also had the chance to explore some of the local bush and take in some of the breath-taking views of the Warrambungle National Park, and Doug Gray (the site manager) enlisted the help of the three of us for the incredibly complex job of helping him build a new bookshelf.

Back in Sydney, everyone in the office was friendly and welcoming. I got into the habit of joining in the morning and afternoon tea breaks organised by the tea and biscuit club, so quickly felt like I was part of what was going on. One of the best parts for me was the organised 'Ladies who Lunch' once a month. I loved hearing about the developments in diversity awareness and what experiences the women in the office had had in a very male-dominated field. I also enjoyed the colloquia organised weekly where speakers from various institutions would present what they were researching. I had the chance to give a short talk on my own project towards the end of my internship. Although this was a little nerve racking, my project was really well received and it was great to see that I had been working on something people really wanted.

As I finished the code for my project fairly quickly, we were able to get some service time on the AAT to test the software while I was still in the country; seeing the tab on the telescope's user interface that would run my code was very exciting! Unfortunately, it was cloudy on the night but I got the chance to control the telescope and run the software with the dome shut. When the software ran it was a relief to see that it didn't break the robot or the telescope!

Although I had to leave Australia before the final tests were completed, I already felt like I had achieved so much in my 12 weeks! I had written functional code for the Target of Opportunity mode, and I had contributed enough to one of Chris's observing runs to warrant being named as co-author on some future papers published by the XXL collaboration. The icing on the cake came in the middle of one of my lectures back in Nottingham: the Target of Opportunity mode worked! Containing that excitement for the rest of the lecture was definitely a challenge!

Working at the AAO for 12 weeks was an absolutely incredible experience. I learnt so much just by listening to people talk about their research, and it has helped me know for sure that I want to start a career in astronomy. Thank you to everyone for being so helpful and making me feel so welcome.

Ann Savage, 1946–2017

Fred Watson and Russell Cannon (AAO)

Ann Savage at the UKST 30th anniversary celebration in January 2004.

The world of astronomy is much the poorer for the passing of Ann Savage, who lost a brave battle with cancer on 9 January 2017. Ann played a major role in the astronomical life of both the UK (where she was born and raised) and her adopted country of Australia.

Ann grew up in Kent, and demonstrated an early interest in science and mathematics. As a school-leaver, she decided against the university place she had been offered, instead taking a junior post at the Royal Greenwich Observatory (RGO), Sussex, in December 1964. A little over four years later, Ann married the love of her life, Richard, who had been gently wooing her since their schooldays.

It was during those early years that Ann showed the first signs of the determination and tenacity that characterised her career. As a day-release student, she obtained a degree in applied physics, followed by an MSc in astronomy from the University of Sussex, and, in 1972, embarked on a PhD degree studying quasars, initially under the then-Director of RGO, Margaret Burbidge. On Margaret's departure from RGO soon afterwards, Ann gladly took up a request for a UK student from John Bolton, Director of the Parkes Radio Telescope. This brought Ann and Richard to Australia in 1974.

Ann's PhD research was carried out at Parkes from 1974 to 1977, and sits among the pioneering studies of quasars. John Bolton's specific problem was to identify optical counterparts to the many new radio sources in the Parkes 2700 MHz catalogue. Quasars, being compact radio sources and very bright optically, were ideal for tying together the radio and optical reference frames. The UK Schmidt Telescope (UKST) Southern Sky Survey was just getting underway and could provide a corresponding deep optical map. The third essential ingredient was the AAT, which came on line in 1975 and could confirm which stellar images had the characteristic spectra of high redshift quasars.

A second problem was the existence of QSOs (Quasi-Stellar Objects) which looked like quasars but were not strong radio sources. Ann's main topic was to measure the sky density of these poorly-understood objects. She spent many tedious hours comparing photographic plates and radio-telescope overlays, eventually completing her thesis in the Parkes maternity hospital, where her son Robert was born. Throughout Ann's life, quasars remained almost as close to her heart as her sons.

Following her PhD studies, Ann took up a position at the UKST, which at that time was an independent British facility operated by the Royal Observatory, Edinburgh (ROE). After three years, she transferred to the home institution in Scotland, but in 1986, moved back to Australia to take up the role of Astronomer-in-Charge, a key position in maintaining the scientific work of the telescope. This included the photographic sky-surveys, objective-prism surveys and pioneering multi-fibre spectroscopy, all of which she enthusiastically supported. She also contributed to the smooth transfer of UKST operations from ROE to the AAO in 1988. Her 150 publications in the ADS database give a measure of her scientific breadth and productivity.

Ann and Richard's passion for scuba-diving led to Ann's first brush with ill-health, when damage to her middle ear caused debilitating illness. By 1993, she was on long-term sick leave, eventually retiring on ill-health grounds in 1995.

Ann and Richard chose to make Coonabarabran their retirement home, and loved their property, Holly Farm, on the Binnaway Road. For the next two decades, they participated actively in many aspects of Coonabarabran life, and Ann became a well-known figure in the community, legendary as much for her fruit cake as her astronomy. It was in 2013 that Ann was diagnosed with cancer, and underwent a lengthy and difficult period of treatment.

Ann will be remembered for her dogged determination to get things done, and for the impact she made both on astronomy and in the community. She is survived by Richard, their sons Robert and Ross, and their families. It was with both laughter and tears that family and friends gathered in Coonabarabran to farewell Ann in a thoughtful ceremony on 13 January, just as she had requested. It was Ann's wish that we should not be gloomy about her passing—but we will all miss her.

Above: The famous 'Ann plate', taken on 22 Dec 1974, when Ann was visiting the AAT control room as Patrick Wallace was testing the new telescope's control software. The plate became symbolic of the 'dawn of a new era of instrumentation.'

News from North Ryde

Tayyaba Zafar

Our latest batch of summer fellowship students have arrived. Working on Huntsman array project with Lee Spitler and Anthony Harton are Ankit Shrestha (Univ. of Wollongong), Taylah Beard (Macquarie Univ.), and Bernanda Telalovic (Univ. of Sydney); working with Micheal Goodwin are Eben Brebner (UNSW-Mechanical Engineering), Timothy Tat Mun Chin (UNSW-Mechatronics Engineering), and Mark Bakovic (Macquarie Univ.-Physics).

We welcome Liz Mannering who joined us full time as a User interface specialist to work on the AAO data central project. We bid farewell to Julia Tims, Nicholas Stazsack and Jenny Ghabache. Julia Tims joined AAO in 2011 and contributed to the management of the MANIFEST, KOALA, TAIPAN, AST3_NIR projects and also worked for the development of the GHOST proposal. Nicholas Stazsack worked here as a mechanical engineering and optical systems manager. Jenny served as the administration and information management officer. Our Future fellow astronomer Sarah Brough has also left AAO in January to take up her position as an associate professor at UNSW. Sarah joined AAO in 2009 and worked as a Research Fellow, a Research Astronomer, and lastly as an ARC Future Fellow. She also performed her role as an instrument scientist for the AAOmega. Her research includes galaxy evolution, brightest cluster galaxies, galaxy environmental dependence and mass assembly.

Lastly, the Australian Research Council announced the grant funding outcomes for 2017, and AAO staff have been awarded three different grants, among which the grant for HECTOR is outstanding for continuing the development of this important instrument.

SSO News

By Zoe Holcombe

Hello AAO

Thought I would give you some updates on various projects that are going on at the AAT this quarter plus an over view on other activities that have been happening.

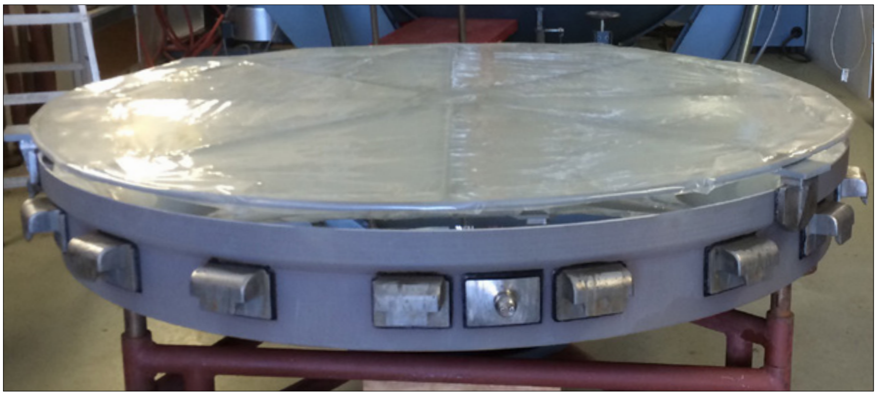
2fd Simulator

The 2dF Modernisation project's goal is to update the hardware and control system of the robotics to facilitate the long term reliability and supportability of this important AAO facility. The 2dF simulator is an important component of the project allowing offline test and development opportunities that are simply not feasible on the 2dF instrument given the telescope schedule and risk to the system. The project team reports that the 2dF simulator gantry and drive electronics have been running in X1,X2 and Y under engineering control. The Z axis is manufactured and is being integrated into the control system. Drawings and models are mostly complete and manufacturing is underway for the theta and gripper axes. System and software architecture are currently under review with the goal of rationalising the system by reducing complexity, reducing dependancy on legacy systems and migration to modern design approaches. The new invar field plates are nearing completion in the Oxford University Department of Physics workshop. The new field plates' dimensional stability, flatness and additional embedded fiducial fibres should all contribute to improved positioning performance.

Above: Shane and Chris McCowage working on 2df Simulator.

UKST Mirror Aluminising

In late November in preparation for the Starbugs arrival we aluminised the UKST Primary Mirror. The Primary Mirror was last aluminised 8 years ago. A lot has changed in 8 years. Thank goodness the chamber hasn't and with thanks to Fred Watson's detailed notes the chamber was again pumping away. It was another opportunity for Steve Lee and Wayne Clarke to impart their wisdom to the new generation aluminising team featuring Ben Wilkin, Jenny Riding and Shane Paul. Jenny, Ben and Shane showed good enthusiasm learning the correct procedures relating to Aluminising. When the Mirror was removed from the telescope it was partially covered with oil so the team were a little nervous. When the chamber opened after aluminising there were a few deep sighs...... It was a success. The UKST mirror is back.



Right & Below: Steve Lee also cleaned the UKST corrector plate which had been accumulating grime during all the re-construction work that's been going on.

October

2016 StarFest was another HUGE success and the StarFest committee are already looking into 2017. I have written a separate article in the magazine on this. Please have a read.

November

Planning Day this year saw the North Ryde crew come and experience what it's really like working at the AAT, and experience an instrument change. 2df needed to come off the telescope and HIPPI to go on. We started the morning with a safety induction by Doug Gray, were given AAT buddies and a very fashionable hard hat for the day. The first part of the morning only a few people were needed so the other half went over the ANU Lodge for a tour. After this we had morning tea and then everybody was on hand to get the fibre out of the telescope and wrapped up. We then got to experience what can go wrong – so we had an early lunch. After this we finished the instrument change and then the HIPPI team gave us a talk on what they are doing. The day finished with Warrick giving a talk and we left on the school bus, which looked flasher than usual and had air-conditioning!

That evening we went to Pilliga Pottery for dinner. We all had a very nice night, the food was good and the company also.

The next morning I made myself available at the bus to make sure all the North Ryde staff were on the bus, we didn't want to leave anyone in Coona this time.

Above: 2016 Planning Day dinner at Pilliga Pottery.

Above: AAO Admin Team

Big thanks to the Planning Day committee, I look forward to what you're going to do for next year's Planning Day to beat the fun of this year's.

December

The AAO WHS Committee put all the hard work over the last year into ComCare's hands in getting an audit done. The audit was done over 2 days at North Ryde with Zoe and Neville spending a lot of time answering ComCare's questions and a lot of documentation was given. The outcome of the Audit will be known to us by the end of December or start of January but in my eyes I think we did very well considering where we were at the start of 2015. ComCare will then come and visit the AAT in 2017 where more auditing will take place.

Above: The almost completed new ANU Lodge at SSO (middle and bottom) that replaces the old Lodge that was destroyed in the 13 January 2013 bushfire (top).

SSO Lodge Nearing Competition

The new Lodge at Siding Spring Observatory is nearing the stage where ANU staff will be able to move in to their new offices in early February 2017. The handover of the 18 ensuite bedrooms and hospitality areas will occur at the end of February. This will be followed by a 'defect and trail' period for most of March, with the first guests to use the new Lodge being a BBC television crew at the end of that month. A call for Expressions of Interest has been put out to the local community for operators of the Lodge and its café hospitality services.

After the January 2013 bush fire the Lodge unfortunately did not survive and re-building for the new Lodge started in late November 2015. Many memories exist of the old Lodge and there are sure to be many more once astronomers and staff are back on-site using the new facilities.

See you next time

Zoe.

Above: The Anglo-Australian Telescope is ready for the Open Day celebrations at Siding Spring Observatory on Saturday 1st October 2016.

Image provided by Ángel R. López-Sánchez (AAO/MQ).

EDITOR: Tayyaba Zafar

DESIGN AND PRODUCTION: Communications Branch, Corporate Network, Department of Industry and Science

ISSN 0728-5833

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

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

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

Email: director@aao.gov.au

Australian Government
Department of Industry, Innovation and Science

www.aao.gov.au