AAO OBSERVER

THE AUSTRALIAN ASTRONOMICAL OBSERVATORY NEWSLETTER

NUMBER 128 | MARCH 2016

OzDES reaches the half way mark

200000 stars observed by GALAH | Siding Spring hosts 1000 for StarFest | A three-headed globular cluster

Director's message

Warrick Couch

As AAO Director, the commencement of a new year comes with a mixture of anticipation and reflection, both in wondering about what challenges lie ahead for the organisation, and in taking stock of what was achieved in the previous year.

In terms of the AAO functioning as an observatory, 2015 was another year of significant achievement both scientifically and in instrumentation. As highlighted in this & the previous issue of the AAO Observer, as well as in media releases, there were numerous scientific discoveries of note made by our AAT and international 8m telescope users. In addition, the large flagship surveys being conducted on the AAT – SAMI, GALAH, OzDES, and 2dFLens – all made significant progress, publishing key results, and in the case of 2dFLens, reaching its completion. (Here I note that I intend to continue the AAO's policy of making up to 50% the time on the AAT available for large survey programs, with the remaining 50% available for smaller PI-science programs.)

In instrumentation, large strides were taken in developing a working on-telescope "starbug" positioning system, with the construction of the Taipan positioner module for the UKST. In the international arena, the AAO successfully progressed its construction of the Gemini High resolution Optical SpecTrograph (GHOST) through the preliminary and critical design phases, made significant progress on the design of the kilo-fibre "Echidna" spine positioning system (AESOP) for 4MOST on ESO's VISTA 4m telescope, and ramped-up its engagement with the National Astronomical Observatory of Japan in the development of the GLAO-fed multi-object near-infrared spectrograph, ULTIMATE, for the 8m Subaru telescope. Another highlight of 2015 was a significant growth and diversification in the AAO's outreach activities, particularly in the use of social media, through the initiatives of Dr Amanda Bauer.

Within the broader landscape of the AAO being a national research facility that operates as a division of the Federal

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Front cover photo credit: The view through the repaired shutter of the UKST, Steve Chapman.

Department of Industry, Innovation, and Science, 2015 was also an eventful year. It was one that demonstrated that the AAO's place within a large government department is, at times, an advantageous one in terms of funding, with it receiving an additional $3 million from the Department, over and above its recurrent operating budget. This funding will pay for 8 metre telescope access (managed by AAL on behalf of the Australian astronomy community), a number of major AAO instrumentation projects, and the operation of the AAO's International Telescope Support Office (ITSO).

While very welcome, such funding is unpredictable, with the AAO relying more on annual allocations of NCRIS funding from AAL to cover expenditure items of this nature (as well as the ongoing maintenance of the AAT). However, 2015 proved to be a bit of a roller coaster year for the NCRIS scheme as a whole, with there initially being uncertainty as to whether it would be funded in the 2015-2016 financial year, which in turn resulted in the allocation for astronomy (via AAL) not being confirmed and the exact amount known until 6 weeks before it started. When it was confirmed, AAL was able to allocate just over $1 million of NCRIS funding to the AAO to upgrade the 2dF positioner and HERMES spectrograph on the AAT; to cover the additional costs associated with the ITSO supporting the new national Keck time; and to continue the Antarctic PLATO program (in partnership with UNSW and China).

From a government policy point of view, 2015 was also a year in which the Industry, Innovation and Science portfolio gained prominence through being identified as the most important agenda of the new Turnbull government. What this meant in practice was revealed in the multi-billion dollar "National Innovation and Science Agenda" announcement made in early December. Contained within this announcement were 24 new initiatives that addressed important issues such as the provision of secure long-term funding for research infrastructure; increasing collaboration between industry and universities; incentivising investment in research and innovation; and boosting the ability of CSIRO, universities, and other research organisations to commercialize their research. Included within these were two measures that are particularly significant for Australian astronomy: Firstly, the future funding of NCRIS being secured for the long term, with $1.5 billion being allocated to it for the next 10 years. This will ensure much needed funding stability and certainty for national research infrastructure, where for the astronomy capability (which is just 1 of 27 that receive NCRIS funding) it will allow AAL to plan accordingly for its investment in Australian astronomy research facilities. Secondly, the provisional allocation of $294M over the next 10 years for Australia to meet its obligations to the construction and initial operation of Phase 1 of the SKA. While this is subject to a successful conclusion being reached to the current SKA Convention negotiations and the development of a satisfactory business case, it nonetheless puts in reach the funding needed for one of the key priorities of the new Australian *Astronomy* Decadal Plan (2016-2025) to be realised.

Overall, therefore, 2015 was a very positive year for the AAO, Australian astronomy, and the national science and research sector more broadly. However, as we look ahead to 2016 and beyond, some major challenges and uncertainties remain. In the context of the new Decadal Plan, there remains the urgent and very important priority of securing significant and long-term access to international 8-metre class optical/infrared telescope facilities (the goal being the equivalent of 30% of a single 8 m telescope). Even with the future long-term funding of the NCRIS scheme now being assured, it is not at all clear that the allocations AAL receives will be sufficient to fund such access (in addition to meeting its other funding priorities). In reality, a separate new funding allocation (as per the recent SKA announcement) is required to at least cover the capital buy-in associated with Australia becoming a significant share partner in an 8-m class facility.

Another major issue still under consideration is the future governance of Australian astronomy infrastructure. This is being handled by a special working group established by the Department of Industry, Innovation and Science. Discussions and consultations took place with the Australian astronomy community and its key stakeholders last year on the various governance models/options proposed by this group. The process has (at the direction of the Minister) entered a new phase in which two specific options are being evaluated in much greater detail by the working group, whose terms of reference and membership have been significantly expanded. The two options being considered both involve consolidation of optical and radio astronomy into a new entity, one being a subsidiary company of CSIRO, and the other being a corporate Commonwealth entity. Detailed implementation plans that include a cost-benefit analysis, risk assessment, identification of issues around funding and cost recovery, and elucidate roles and responsibilities of the new entity, are expected to be delivered for each of these options by this coming April. Yet again, there will be much interest in the outcomes that emerge at this next milestone, as also what decisions are made in response.

Finally, one of the many important legacies left by my predecessor, Matthew Colless, was the "AAO Forward Look to 2015" document that provided a very detailed forward plan for the Observatory over the last 4 years (2012-2015). With this period now having come to an end and the plan largely implemented, it is time to develop a new plan that sets the strategic directions of the AAO over the next 5-10 years. This is also timely given the commencement of the new Decadal Plan, which in many ways sets the strategic agenda for the AAO over the next decade, as detailed in my message in the last issue of the AAO Observer. The production of a new strategic plan for the AAO is well advanced, and I look forward to being able to present it to the community in a few months time.

OzDES reaches the half way mark

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OzDES is a large survey at the AAT, using the 2dF fibre positioner and AAOmega spectrograph to observe tens of thousands of sources in the 10 deep fields of the Dark Energy Survey. OzDES has just completed its third observing season, and is now half way through its allocation of 100 AAT nights. To date, OzDES has obtained the redshifts of about 20,000 sources, and has spectroscopically confirmed over 100 supernovae. In this article, we describe the OzDES survey, and present some sample spectra that illustrate the quality of the data that OzDES is obtaining.

DES and OzDES

The Dark Energy Survey (DES) is using DECam, a 3 square degree imager mounted on the CTIO 4m Blanco Telescope, to image almost a quarter of the Southern Hemisphere. DES, which started taking data in 2013, consists of a wide survey, covering approximately 5,000 square degrees, and a deep survey, which repeatedly images 10 fields with a weekly cadence over a 6 month period.

The main aim of DES is to understand the physics behind the accelerating expansion of the universe. It does this using four astronomical probes: galaxy clusters, the large scale distribution of galaxies, weak lensing and Type Ia supernovae. The data being obtained by DES is also being used to study a wide variety of astronomical objects [1], from Trans-Neptunian objects in our solar system, on to the most distant quasars in the universe.

The scientific grasp of DES is broadened and strengthened with spectroscopic followup of sources discovered by DES. However, as DES is purely an imaging survey, the spectroscopy needs to be obtained with other facilities. The 2dF positioner and AAOmega spectrograph is the ideal instrument to obtain these data. As can be seen in Fig. 1, the FoV of DECam is well matched to the patrol field of the 2dF positioner on the AAT. OzDES uses 2dF to observe tens of thousands of sources in the DES deep fields. One of the novel features of OzDES is that it observes the 10 DES fields on a roughly monthly cadence over the time the DES fields are visible from the AAT. This allows us to monitor sources (e.g. AGN or supernovae) with time-lapse spectra. Additionally, we can obtain redshifts for objects that are usually too faint (as faint as r=24) for a 4-m class telescope such as the AAT, by simply re-observing objects until the redshifts are obtained.

OzDES has two main scientific goals. The first goal is to constrain the dark energy equation-of-state parameter and its evolution with time by combining host galaxy redshifts of about 2,000 Type Ia supernovae measured with the AAT with distance estimates of these supernovae from light-curves obtained with DECam. The second goal is to map out the growth in supermassive black holes, from 12 billion years ago to the present today, using AGN reverberation mapping [2].

At the same time, OzDES is observing transients that happen to be bright enough to observe at the time OzDES takes data (to date, OzDES has published 16 Astronomical Telegrams announcing the discovery of 100 supernovae). 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, luminous red galaxies, RedMaGiC galaxies [6], and faint AGN. OzDES is also obtaining spectra of hundreds of stars in the DES fields to help with the calibration of the spectroscopy and the cross-calibration of the DES and SkyMapper photometric systems.

Improvements in processing data from 2dF + AAOmega

Some of the objects in OzDES are 100 times fainter than the night sky, so accurately removing the night sky from spectra is critically important. For data taken with 2dF, this is achieved by positioning 25 fibres in areas where there are no objects. The spectra that are extracted from these 'sky' fibres are combined, and then subtracted from object spectra,

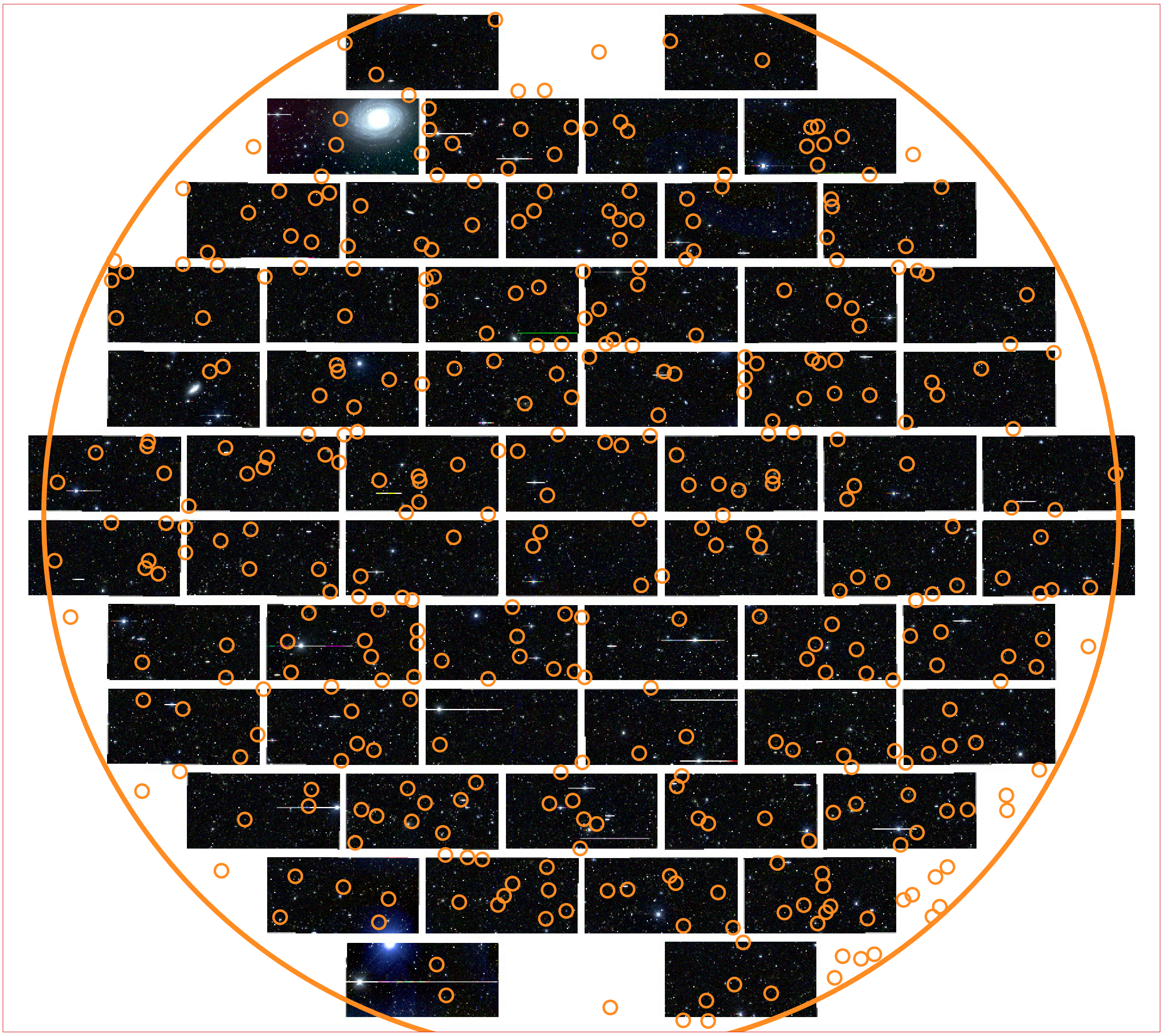

Figure 1: The 2.1 degree diameter field-of-view of the 2dF patrol field (large orange circle) overlaid on top of a DECam image with its 60 CCDs. Small orange circles mark the location of objects targeted by OzDES during one of its runs. Figure taken from [7]

which contain contributions from the sky and the objects themselves.

For sky subtraction to work well, all aspects of the data processing prior to the sky subtraction must be performed correctly. This includes unbiased extraction of the flux in the fibres, accurate modeling of the complex pattern of scattered light in both the red and blue cameras of AAOmega, and accurate flat fielding.

The AAO has invested considerable time in improving the 2dF data reduction pipeline (hereafter 2dfdr) over the last couple of years. Tram line mapping is now more accurate, and the extraction of the flux from the fibres and the modeling of the scattered light are done simultaneously by solving a system of linear equations.

Improvements are nevertheless still possible and we are actively investigating these. For example, the spatial profile of the fibre is currently modeled as a Gaussian. A more accurate model would include the broad wings present in the profile and the fact that the fibre is resolved. The disadvantage of moving from a Gaussian is that the equations involving some of the more complex profiles no longer become linear and more parameters need to be fit. This leads to more computation, and perhaps less stable solutions if care is not taken. We expect that much of this work will be extremely useful for other instruments, e.g. KOALA, where the spacing between fibres is about two-fifths of the spacing used in 2dF, and for future instruments such as Hector.

Another critical aspect in the processing of data from 2dF + AAOmega is flat fielding. It is an aspect that we did not fully appreciate when we first started taking data with 2dF + AAOmega, as we had assumed that standard flats would be sufficient. Standard flats, which we refer to as flap flats, are taken by illuminating a pair of flaps that fold in front of the corrector. Because of the properties of the material of the flaps, the nature of the illumination, and the proximity of the flats to the image plane, the resulting flats imprint a wavelength dependent response that varies from fibre to fibre. This can lead to very poor sky subtraction, which is especially noticeable when the background flux is high due to the presence of the moon. It also leads to the classic dichroic discontinuity, which has often been a feature in spectra taken with AAOmega. To avoid this, we use dome flats to correct the flap flats. It is a technique that is commonly used elsewhere and is often called an illumination correction.

To perform the illumination correction, we process the data taken with the flap flats and the dome flats in the same way. We then divide the extracted dome flat by the extracted flap flat, smooth the result along the wavelength direction to produce the illumination correction, and then multiply this correction into the extracted flap flat. This enables us to keep the high signal-to-noise ratio that the flaps flat provide and yet remove the wavelength dependent response that the flap flats would imprint into to the data if they were used without being corrected.

We have found that we do not need to take dome flats for every setup. One dome flat per field plate per run is sufficient. Dome flats appear to be stable over a period of several months, so one can use dome flats that were taken weeks or months before or after an observing run to correct the flap flats, something that we have done if the dome flats for a particular OzDES run had not been taken. Nevertheless, we do not recommend this, as the availability of fibres (due to breakage or repair) can change over this timescale.

Redshifting

We have developed a new software package called Marz [8], which improves on the previously used runz software. It uses an adapted version of the Autoz fitting algorithm [9], extended to a wider range of object types and optimised for the low signal-to-noise spectra of OzDES. Marz is a web application, so needs zero installation, and works simply by dragging and dropping an appropriately formatted fits file into the website (http://samreay.github.io/Marz/). The software makes a first pass at redshifting all the spectra, and then provides tools for interactive confirmation or correction of the automatic redshifts. It can be used not only for redshifting but as a general tool for inspecting and visually typing spectra.

Sample spectra from OzDES

As a demonstration of the quality of the data that OzDES is obtaining, we show a number of OzDES spectra for three classes of objects.

SUPERNOVAE

While most of the supernova redshifts will come from the redshifts of their hosts, it is important to spectroscopically confirm a subsample of the supernovae, and reject objects that are misclassified as supernova from DES photometry, e.g. AGN. The aim of this work is to determine how to maximize the purity of Type Ia supernova in the photometrically selected supernova sample, while minimizing the contamination from other types of transients.

Over the last three observing seasons, OzDES has spectroscopically confirmed over 100 supernovae. In the third season alone, OzDES confirmed 63 supernovae. The factor of four improvement over the first two years is in part due to improvements in the processing of AAOmega data that were described earlier. Under good conditions, the AAT can now spectroscopically confirm SNe Ia up to z=0.5 in a few hours of integration.

While the majority of the supernovae observed by OzDES are Type Ia supernovae, there are a number of core collapse SNe and a handful of super-luminous supernovae, including a super-luminous supernova at the record redshift of 1.89. A selection of OzDES spectra are shown in Fig. 2.

COADDED SPECTRA

It is now well established that the properties of SNe Ia correlate with the properties of their hosts. For example, SNe Ia in galaxies that are more actively forming stars appear to be better standard candles, and SNe Ia in more massive hosts are brighter than SNe Ia in less massive hosts after correcting for the relationships between SN luminosity, colour, and light curve width.

While the impact of these correlations is not large enough for them to significantly bias the value measured for the dark energy equation-of-state parameter from current data sets, it is expected that it will be important to include these correlations in future SN datasets.

Furthermore, since it is easier to get the redshift of a galaxy that is bright or has emission lines, the DES SN sample will be biased towards SNe Ia that are hosted by galaxies that are massive and actively forming stars. The bias will be a function of redshift.

Hence, it will important to understand the galaxy host population in future SN cosmological analyses. While some properties can be obtained from broad band photometry, spectra lead to a richer set of properties. However, the galaxies targeted by OzDES are as faint as r=24, so the signal-to-noise ratios are typically one. While this is sufficient for determining redshifts, it is insufficient for measuring other quantities of interest, such as the star formation rate, and the ages and metallicities of the stellar populations in these galaxies. For these kinds of measurements, one requires signal-to-noise ratios of 10 and above.

An approach to obtaining higher signal-to-noise ratios is to stack spectra. An example is shown in Fig. 3, where we stack the spectra of several hundred LRGs (luminous red galaxies) in the redshift interval $0.7 < z < 0.75$. The signal-to-noise ratio of the co-added spectra is over 30. All the features in this spectrum are real, as can be deduced by comparing the data with the model. For this particular example, one gets a good estimate of the age, metallicity and the α/Fe ratio of the stellar population. One even sees evidence for low amounts of star formation.

In fitting the stacked spectrum, we used a modified version of the Penalised Pixel Fitting software (pPXF; [12]) to fit the stacked spectrum. The pPXF code determines the stellar kinematic parameters from a galaxy spectrum by simultaneously solving for the optimal template, as determined by the linear combination of Single Stellar Population (SSP) templates from the MILES library [13], and the velocity offset and convolution required to match the absorption spectrum. During the fitting, the optimal template is modulated by a 10th order multiplicative polynomial to account for flux calibration uncertainties. The code is modified to allow for the simultaneous fitting of emission lines, which are modelled as Gaussians in the non-linear part of the pPXF code, along with the underlying stellar continuum. This means that formal uncertainties on the best-fitting parameters can be determined for the emission lines. In Fig. 3, the stacked spectrum is shown in black, the best-fitting optimal template in red, the emission lines in blue and the residuals from subtracting the best-fitting continuum+emission line model form the stacked spectrum are shown as green diamonds. The fits demonstrate that the rich array of bumps and wiggles seen in the spectrum are indeed real features, while there is emission detected for the [OII]3726, 3728 and [OIII] 4959, 5007 doublets and a hint of emission filling the Hβ (4862) absorption line, indicating the existence of ongoing star formation or AGN activity. In the future, this method of stacking will be useful for determining the mean underlying stellar population parameters of supernova hosts, as well as the gas-phase properties.

RARE AGN

OzDES has observed thousands of AGN over the three years it has been taken data. Perhaps the most unusual AGN that we have uncovered so far is a very rare FeLoBAL AGN with post starburst features.

Typically, quasars are confirmed via the presence of strong broad and/or narrow emission lines in their spectra. As the name suggests, broad absorption line (BAL) quasars also possess broad absorption troughs in their spectra in addition to the normal emission lines. These absorption troughs occur on the blue side of the rest wavelength of the emission line, implying that there is intervening material along the line of sight to the central source that is moving away from it.

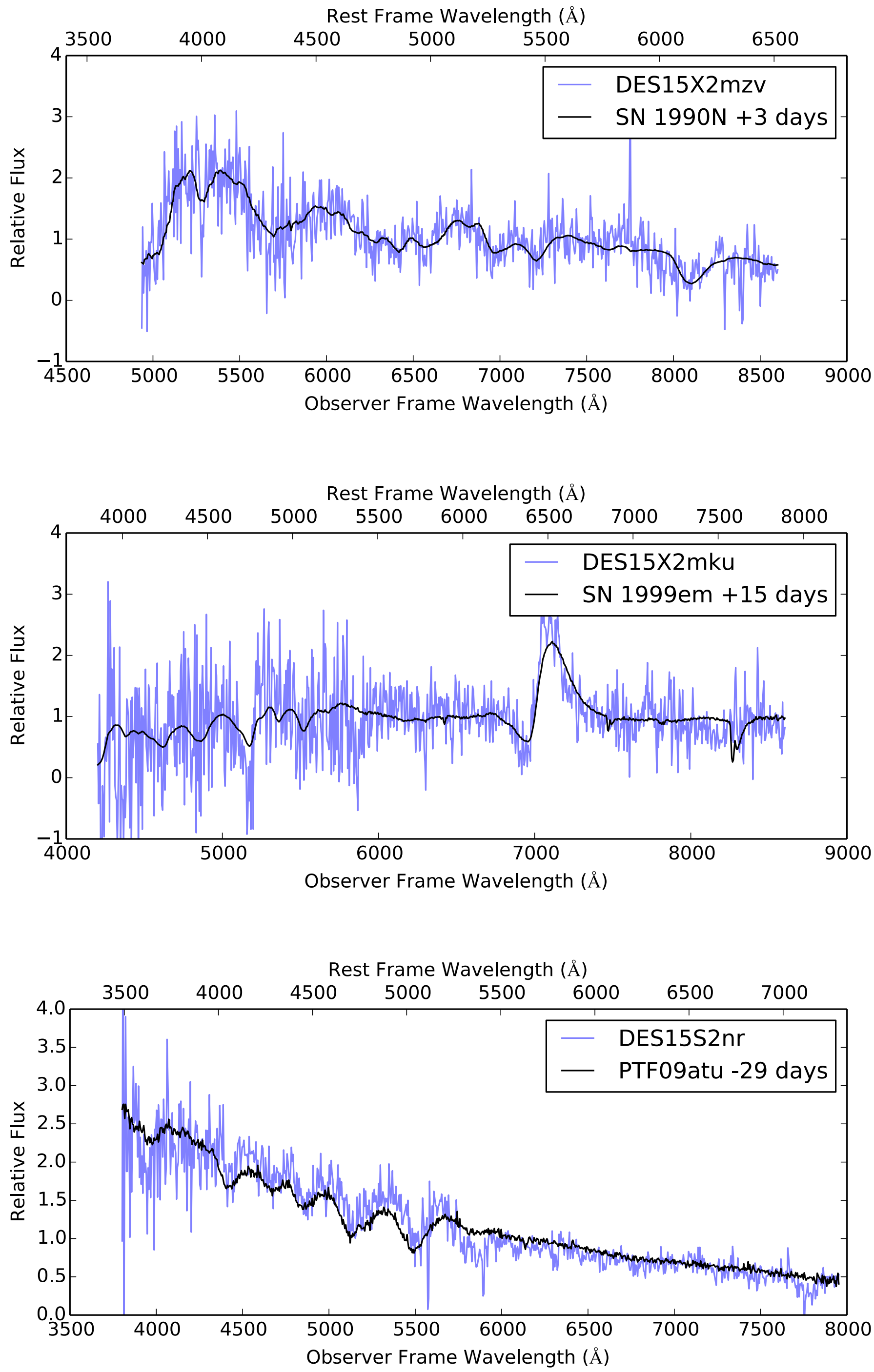

Figure 2: A selection of 3 supernovae from the 100 supernovae that have been spectroscopically confirmed by OzDES.

Top: A Type Ia SN at z=0.32 a few days past maximum light, showing the characteristic 'W feature' due to sulfur at 5400 Angstroms (rest wavelength) and a broad dip at 6100 Angstroms that is due to silicon.

Middle: A Type II SN at z=0.09, showing broad Hα. We chose these two because they were observed together in a single 2dF configuration.

Bottom: A rare super-luminous supernova at z=0.22. The first super-luminous supernova was discovered about 10 years ago [10], and only a few dozen are now known. For all three supernovae, the matches with nearby supernovae were obtained using Superfit [11].

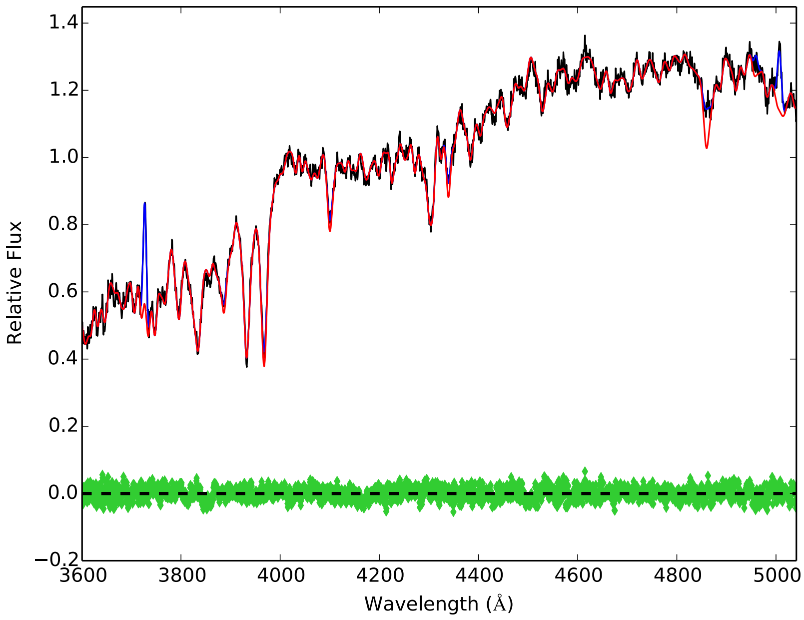

Figure 3: The co-added spectrum of 300 LRGs (in black), together with a fit (in red and blue). Residuals are in green. The mean magnitude of the LRGs that went into this spectrum was r=22.5. Note how all the bumps and wiggles in the data have counterparts in the fitted spectrum (see text for further details).

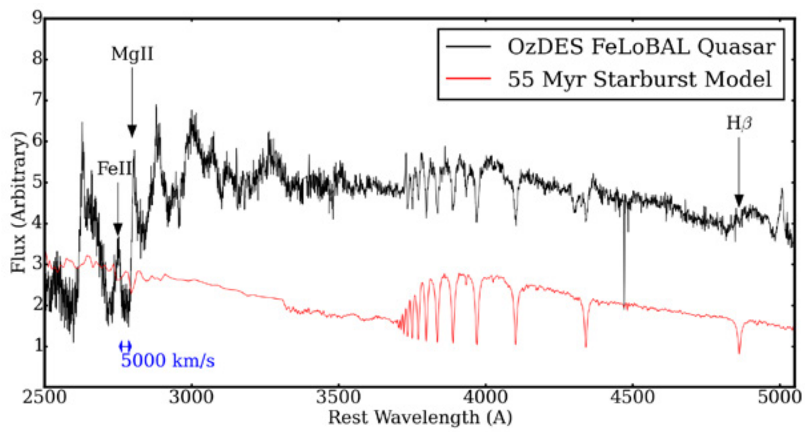

Figure 4: The OzDES spectrum of a z=0.6 FeLoBAL AGN with post-starburst features. The QSO emission features from MgII, FeII, and Hβ all have broad absorption features from outflowing gas that extend over 5000 km/s. The spectrum of an unreddened 55 Myr old starburst is shown in red, and contributes approximately half of the flux over most of the rest-frame visible spectral range.

Often, these troughs are several thousands to several tens of thousands of kilometers wide, implying that some of this gas is moving at quite high velocities. Alternatively, the absorption may arise from material produced by an outward moving shock originating from the central black hole as it collides with a clump of material along our line of sight. There are several kinds of BAL quasars, characterized by the strength of the ionization potential necessary to produce the species of ions seen. The most common are HiBALs, or high ionization BAL quasars, where the absorption is seen from highly ionized atoms, most commonly CIV (with an ionization potential of around 48 eV). These are present in approximately a quarter of all optically selected quasars. Less common, only about 3% of optically selected quasars, are LoBALs, or low ionization BALs. These have absorption in MgII, with a more modest ionization potential of around 7.6eV. Rarer still are FeLoBALs, which are LoBALs that also have absorption from FeII and FeIII, with similar potentials to MgII. These are present in only about 0.3% of optically-selected quasars. There are also only about a dozen known quasars that possess some broad absorption in Balmer lines. The object we have discovered and are monitoring with OzDES has signs of absorption in Hβ and iron in addition to magnesium. To make it even more noteworthy, it is also the first BAL quasar with evidence of a post-starburst host galaxy, shown in Figure 4. The strength of the stellar absorption lines and spectral shape around 4000A suggests that the galaxy had a star formation episode that ended about 55 Myr ago. If we believe that the starburst in this system was terminated by the energy injection from central black hole as it developed its BAL features, this object provides a unique opportunity to place a lower bound on the quasar lifetime, and provides new insights on how the presence of a quasar affects its host galaxy's growth.

Concluding Remarks

OzDES has now used half 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 the redshifts of over 2,500 Type Ia supernova, spectroscopically identifying over 200 of them. OzDES is also making significant progress in monitoring over 800 AGN and finding several rare objects. We look forward to reporting on the results from OzDES in future editions of AAO Observer as the OzDES data set becomes complete.

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GALAH SURVEY UPDATE: 200,000 HIGH-RESOLUTION SPECTRA

Sarah Martell (UNSW), Gayandhi de Silva (AAO) and the GALAH collaboration

The Galactic Archaeology with HERMES (GALAH) Survey had its second observing anniversary in November 2015. With solid experience in 2dF+HERMES, observing is a smooth process. Data reduction is reliable, with new data automatically reduced the day after they are taken. A new direction in the data analysis has driven significant progress, with initial stellar parameters produced along with the data reduction. The process for determining final stellar parameters and detailed abundances will use a combination of classical line-profile analysis and machine learning. These results will enable the GALAH team to produce exciting high-impact publications, and we have begun showing preliminary results at conferences. This article will give an overview of GALAH status in each of these areas.

Observing program – serious progress

GALAH is one of the four Large Programs ongoing at the AAT, using the 2dF fibre positioner and the HERMES spectrograph to take high-quality, high-resolution spectra for 360 stars at a time, with a goal of observing one million stars in the Milky Way. With these data we will be able to study the history of star formation, chemical enrichment and stellar migration in the Milky Way, and use it as a model for understanding spiral galaxies in general. Our data set will be the largest and most detailed collection of stellar abundances ever assembled, since HERMES spectra allow us to determine abundances of as many as 29 different elements for each star. Many other aspects of stellar and Galactic astronomy can also be explored using GALAH data; see de Silva et al. (2015) for an overview.

GALAH observational progress, considered per on-sky minute, is excellent, with efficient observers and fully filled fields. Our average data rate of 4.2 stars per observing minute is lower than the ideal value of 4.8 (360 science targets per field, observed for 60 minutes with 15 minutes of overhead) mainly because of the accommodations we make for poor seeing conditions (an extra 20 minutes of exposure time for seeing between 2″0 and 2″5, and an extra 60 minutes for seeing above 2″5).

We are making rapid progress through our target catalogue, including a large number of stars in the K2 asteroseismic fields and a set of several thousand bright stars likely to be in the first data set released by the Gaia space mission. Figure 1 shows a map of our target fields in equatorial coordinates as of September 2015, with unobserved fields in grey, completed survey fields in pink, K2 fields in magenta and bright star fields in blue. All survey fields with right ascension between 23 and 3 hours have been observed. As of the end of 2015, GALAH has observed 212664 stars in survey fields including, 46874 K2 stars, 6289 bright stars and a further 1530 stars in the pilot survey.

Data analysis – making the most of the data

Following data reduction, we make a preliminary determination of stellar parameters (effective temperature, surface gravity and overall metallicity) and radial velocity by normalizing the reduced spectra and matching them against a large grid of synthetic spectra. Based on these parameters, we also make an initial estimate for distance, using the methodology developed for the RAVE Survey (described in Zwitter et al. 2010).

The resulting normalized spectra and initial parameters then go through a three-step process to derive final parameters and individual abundances. In the first step, a subsample of stars that is representative of the full data set is analysed using the well-known SME pipeline (Valenti & Piskunov 1996) modified for GALAH data. Stellar parameter determination with SME is relatively slow, typically 15 minutes per star, so we will not use it for our full data set. Instead, the second step is to use SME results for the subsample as a training set for The Cannon (Ness et al. 2015); a data-driven machine-learning algorithm. The Cannon is extremely quick, and will be able to return accurate stellar parameters for the full data set within a few hours based on early trials. In the third step, final Cannon stellar parameters are returned to SME for deriving individual elemental abundances. With the final stellar parameters established, SME can quickly measure individual line strengths and determine abundances for individual elements.

Figure 2 shows preliminary stellar parameters for nearly 200,000 stars (left panel), SME stellar parameters for the 14,000 stars in the representative data set (centre panel, colour-coded by metallicity), and Cannon stellar parameters for the same 14000 stars (right panel, same colour coding).

The use of machine learning in the derivation of stellar parameters is GALAH's response to a challenge faced by all large survey projects: being able to process such a large volume of data in a reasonable amount of time. It is also one of several ways in which the GALAH team is pushing beyond classical analysis of our data; the development of practical methods for chemical tagging will be another opportunity to bring techniques from statistics and data science into astronomy.

We are exploring statistical techniques for automatic spectral classification, originally using Locally Linear Embedding (as was done in the RAVE survey; Matijevic et al. 2012) and more recently using t-distributed Stochastic Neighbour Embedding (t-SNE; originally introduced in van der Maaten & Hinton 2008). These techniques are particularly good at identifying outliers, and we will use the t-SNE results to identify stars with peculiar spectra, such as double-lined spectroscopic binaries and stars with emission lines, as well as stars that are rare in our disk-dominated data set, like white dwarfs and extremely metal-poor stars.

UPCOMING MILESTONES – WATCH THIS SPACE!

2016 will be an important year for GALAH. We anticipate our first public data release will be our bright star sample in mid-2016. These stars will also have distances, proper motions and radial velocities from Gaia published at around the same time. We will meet that important data set with complementary information to enable novel chemodynamical and cartography studies, and to build interest in the capabilities of GALAH data.

While GALAH data covers a large scope of astronomical information, the data also provide vital information relating to the health and performance of the instrument. Determining throughputs of fibre fed instruments such as 2dF+HERMES or 2dF+AAOmega is not trivial and requires large homogeneous data samples. Using 2 years of GALAH data, our team has carried out a thorough analysis of fibre-to-fibre variations in the 2dF+HERMES system (Simpson et al., 2016 submitted). The results indicate that it is extremely important to continue monitoring the throughputs of the fibres as the GALAH survey progresses to measure impacts of the planned HERMES intervention, the upgrades to fibre cables and 2dF.

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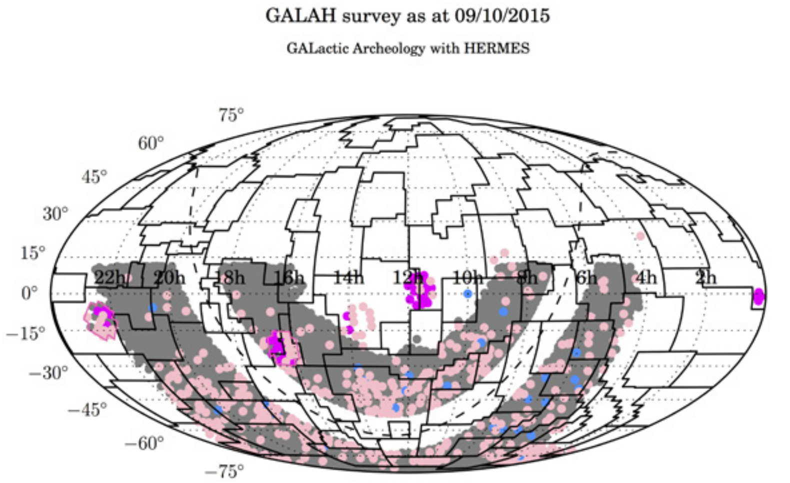

Figure 1: GALAH observing progress to date in survey and K2 fields. Colour coding is explained in the text.

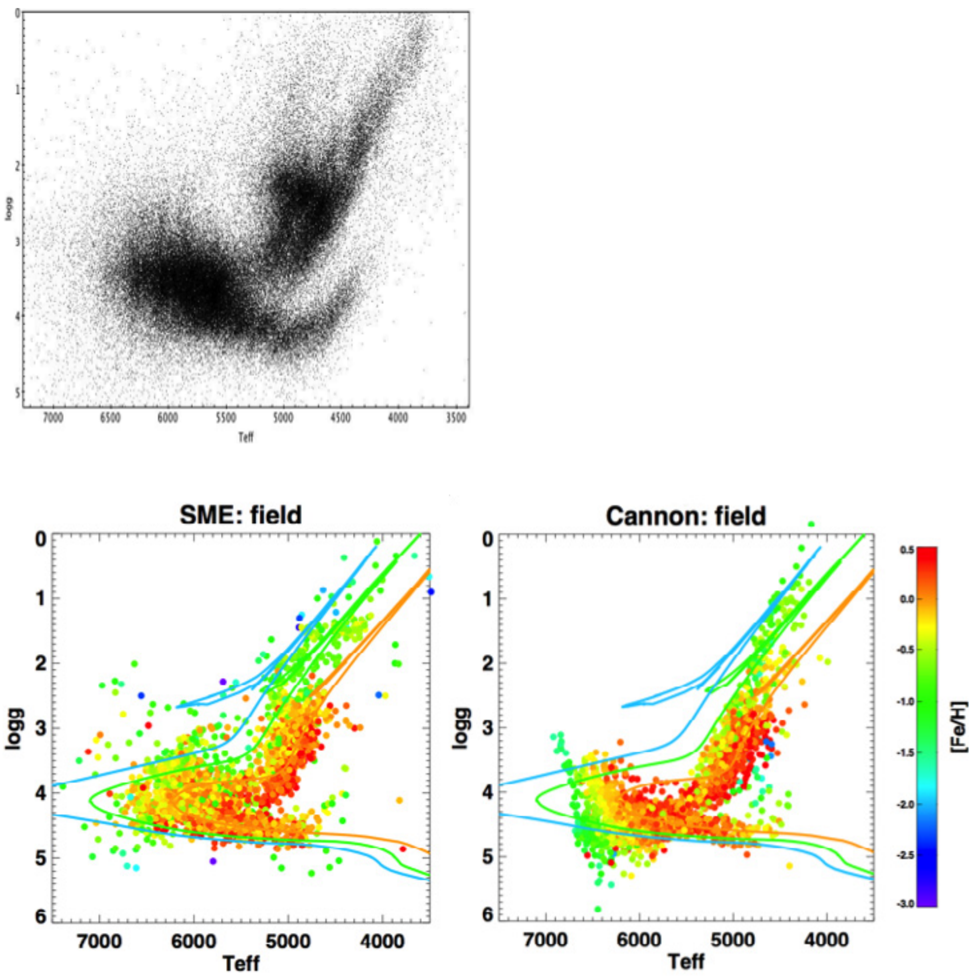

Figure 2: Stellar parameters from GUESS (top) for ~198,000 stars from the most recent up-to-date data reduction, SME (bottom left) for ~14,000 stars, and The Cannon (bottom right) for ~14,000 stars from early reductions. The SME and Cannon results are colour-coded by metallicity, with isochrones of varying metallicity overplotted with the same colour coding. SME and Cannon results will improve further with new science quality reductions that better handle continuum correction e.g. in turn-off stars. We are continually refining the finer details of the analysis using subsets of the data (e.g. star clusters, representative survey fields, and stars in common with other surveys)

A Cerberus Cluster: three populations of stars in the globular cluster NGC1851

Jeffrey Simpson (AAO)

Globular clusters are large, dense spherical conglomerations of stars, with about 150 orbiting our Milky Way galaxy. They have complex chemical and dynamical histories, which are not yet fully understood. Spectroscopic observations have shown that there are correlations and anti-correlations between various light element (e.g., carbon, nitrogen) abundances of stars, while there is little to no variation in the abundance of elements like iron. In addition, these abundance patterns are observed for stars of all evolutionary stages of the stars, requiring that most of the abundance patterns be part of the material from which the stars formed, rather than being something that has happened after the star was born. These basic properties have yet to be reconciled within a single accepted pollution model.

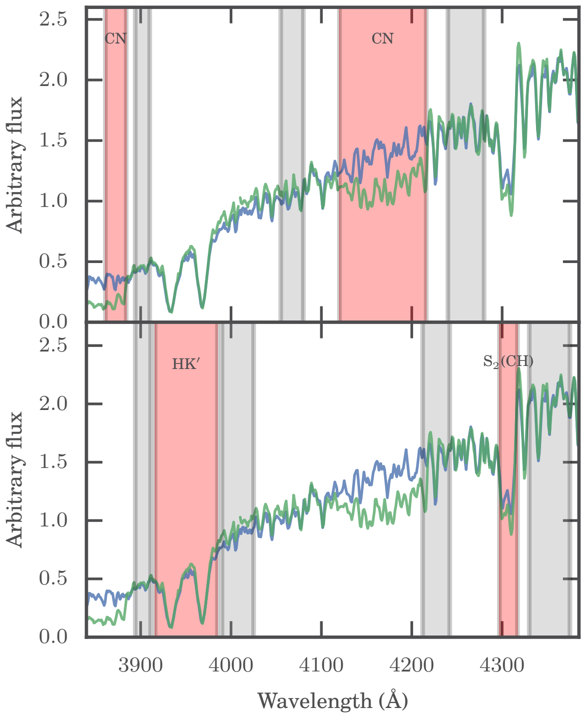

Figure 1: Examples of spectra for two stars. Both stars have very similar temperatures, but have very different CN band strengths. Also indicated are the regions of the spectra sampled for determining the spectral indices. Areas in red are the CN, CH, or calcium (HK') sensitive regions, while those in grey are the continuum regions.

The variations in light elements are thought to be the result of high temperature hydrogen burning in the interior of stars. There are a number of proposed astrophysical sites where this would be taking place: intermediate mass AGB stars; fast rotating massive stars; massive binaries; supernovae. All face problems related to the mass budget of the cluster formation, and that the assumed progentitors of clusters, young massive clusters, do not appear to be undergoing the same gas expulsion and star formation that would be required under the currently proposed models.

As part of a continuing research project to determine the chemical properties of globular cluster stars, we have observed about 100 stars of the cluster NGC1851 with the AAT's AAOmega spectrograph. Their spectra have been used to determine stellar indices and elemental abundances via matching of observed spectra to synthetic spectra. Spectral indices are a measure of the strength of a given spectral feature with respect to surrounding continuum regions. They are a well-used method for analyzing the chemistry of stellar atmospheres, in particular for investigating carbon and nitrogen abundances of stars via the CH and CN molecular features. Examples of our spectra and the regions sampled for the spectral indices are shown in Figure 1.

Inhomogeneity of CN and CH was one of the first indications that the previous paradigm of globular clusters being a simple stellar population was incorrect. In the case of NGC1851, the fact that there are CN-weak and CN-strong stars has been known for many years. Recently it has emerged that NGC1851 is not bimodal, like some other clusters, but exhibits multi-modal behaviour of its CN band strengths (Campbell et al 2012).

We were able to confirm that there is clear multi-modal behaviour of the CN band strength (Figure 2). This confirms that there are at least three peaks in this distribution, with hints of a very CN-rich population with a band strength of about 0.8 magnitudes. Also shown in the top panel of Figure 2 is the distribution found by Campbell et al (2012). They found evidence of four peaks. Their sample of 17 stars was much smaller than our sample and it would appear that one of these peaks (0.25) is the result of small number statistics, though there still appears to be an excess of stars in our data in the gap between the two populations.

There were 75 stars for which we determined carbon and nitrogen abundances directly. In Figure 2 we combine our results with theirs to present a full set of carbon, nitrogen, oxygen and sodium for the cluster.

We confirm the expected correlations and anticorrelations of light elements in the cluster: sodium & nitrogen and oxygen & carbon are correlated, while sodium & oxygen and carbon & nitrogen are anti-correlated.

The stars in Figure 3 have been coded with their population membership from their CN index strength. The two largest groups are found in distinct regions on the sodium-oxygen plot, which suggests that they are the first and second generations of stars in the cluster. The CN-weak group is very distinct in its sodium abundance with little mixing with the other populations, while the CN-richer groups are more mixed. There is only a very slight trend in their nitrogen abundances with respect to sodium.

Navin et al (2015) identified 13 previously unidentified cluster members using the radial velocity of the stars. We were able to confirm using chemical abundances and spectral indices that these stars are in fact cluster members. All exhibit line strengths consistent with all the other known members. Four of these stars have large angular distances from the cluster, indicating they are potentially lost from the gravitational well of the cluster, so-called extra-tidal stars.

These results indicate NGC1851 is a more complex object than other globular clusters. We plan to analyse spectra acquired with the AAT's HERMES spectrograph to determine abundances of more chemical abundances for these stars, in particular rubidium and lithium. These elements may hold the key to understanding this complex object.

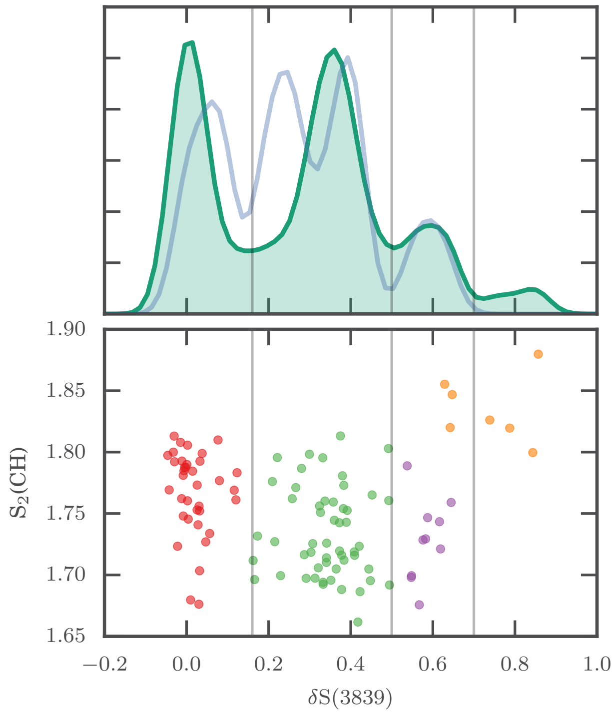

Figure 2:
(Top) A KDE (green line and shaded region) plot of the CN [δS(3839)] band strength for the cluster stars. The blue line is the distribution found by Campbell et al (2012).
(Bottom) the CN strengths against the CH band strength. There are no obvious populations in the CH except for the group of stars with both strong CH and CN. The colour coding is used in Figure 3.

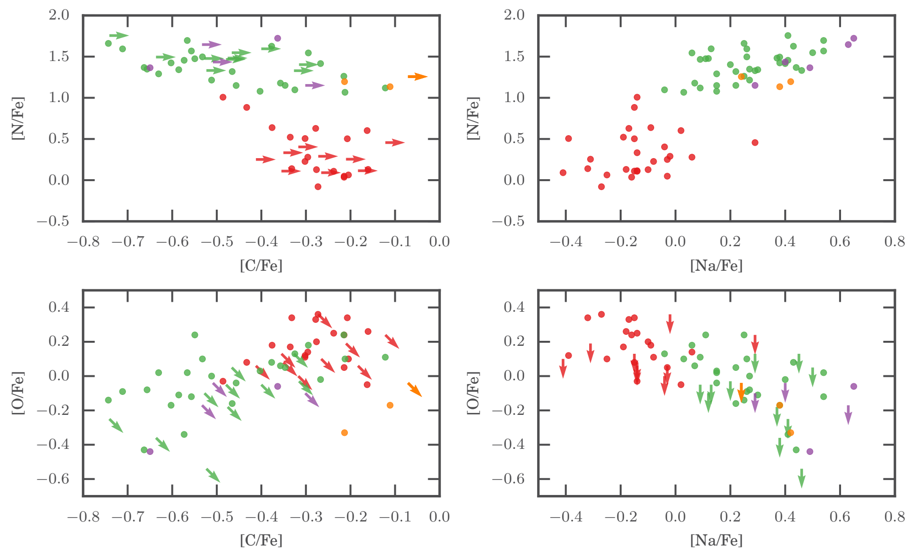

Figure 3: Carbon, nitrogen, oxygen and sodium abundances for our sample of NGC1851 stars. Points with arrows are those for which only an upper or lower limit could be determined. There is clear separation between the main two populations of stars.

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StarFest at Siding Spring Observatory attracts over 1000 visitors

StarFest

During the long weekend in October 2015, we held another successful StarFest extravaganza that many people around the region, and even the world, have grown to look forward to.

The astronomical institutions at Siding Spring Observatory (SSO) join together under the banner of StarFest to plan this action-packed weekend.

Festivities opened Friday night at the Coonabarabran Bowling Club with the sold out Science in the Pub. ABC Science presenter Robyn Williams and host Fred Watson welcomed panel members Dr Amanda Bauer (AAO), Professor Naomi McClure-Griffiths (ANU), Professor Victoria Meadows (University of Washington), and Dr Vanessa Moss (University of Sydney) to discuss key topics in astrophysics—from Pluto's planetary status to supermassive black holes spiraling around each other.

Open Day at the Observatory welcomed over 1000 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 the sunshine, the extensive family-friendly events, and presentations throughout the day. Donations collected at the 2015 event went to the Westpac Rescue Helicopter Service.

A highlight of the weekend was Professor Victoria Meadows' Bok Lecture. The former NASA scientist visited all the way from the USA to talk about "NASA's Search for Life Beyond the Solar System." Professor Meadows shared her ideas on one of the most intriguing questions in human history: are we alone in the Universe?

For videos of the science presentations and information about the next event in October 2016, visit the StarFest http://www.starfest.org.au/ website.

The main entrance to the huge AAT dome.
Credit: Celine d'Orgeville

StarFest

Top: A Smoking Ceremony official begins Open Day outside the newly refurbished Siding Spring Observatory Exploratory

Credit: Pete Poulos

Inset: Panelists prepare to talk about all aspects of space at the sold out Science in the Pub event.

Credit: Peter Brookhouse

Below: Understanding the mass of the Sun at StarFest Open Day.

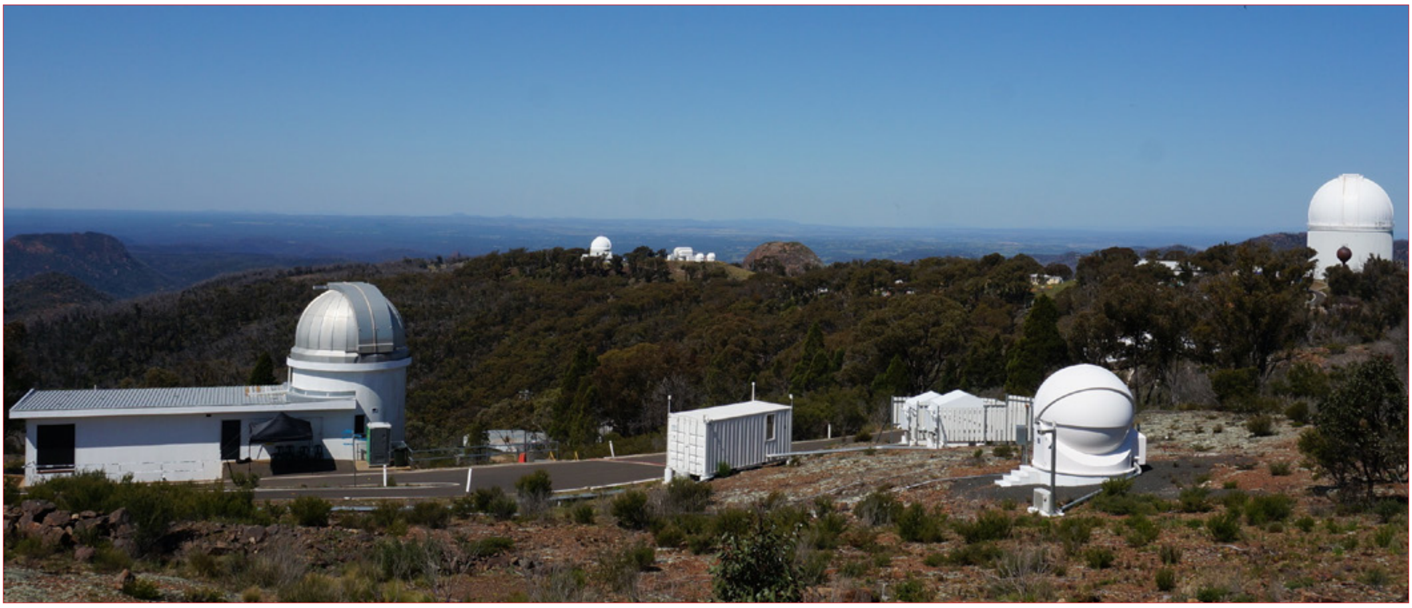
Credit: Celine d'Orgeville

Top: Prof Victoria Meadows gives her Bok Lecture "NASA's Search for Life Beyond the Solar System" at the Coonabarabran Bowling Club.

Below: Enthusiastic questions for Prof Meadows after her Bok Lecture.

Credit: Peter Brookhouse

StarFest



Top: A beautiful day to visit the telescopes on Siding Spring Observatory.

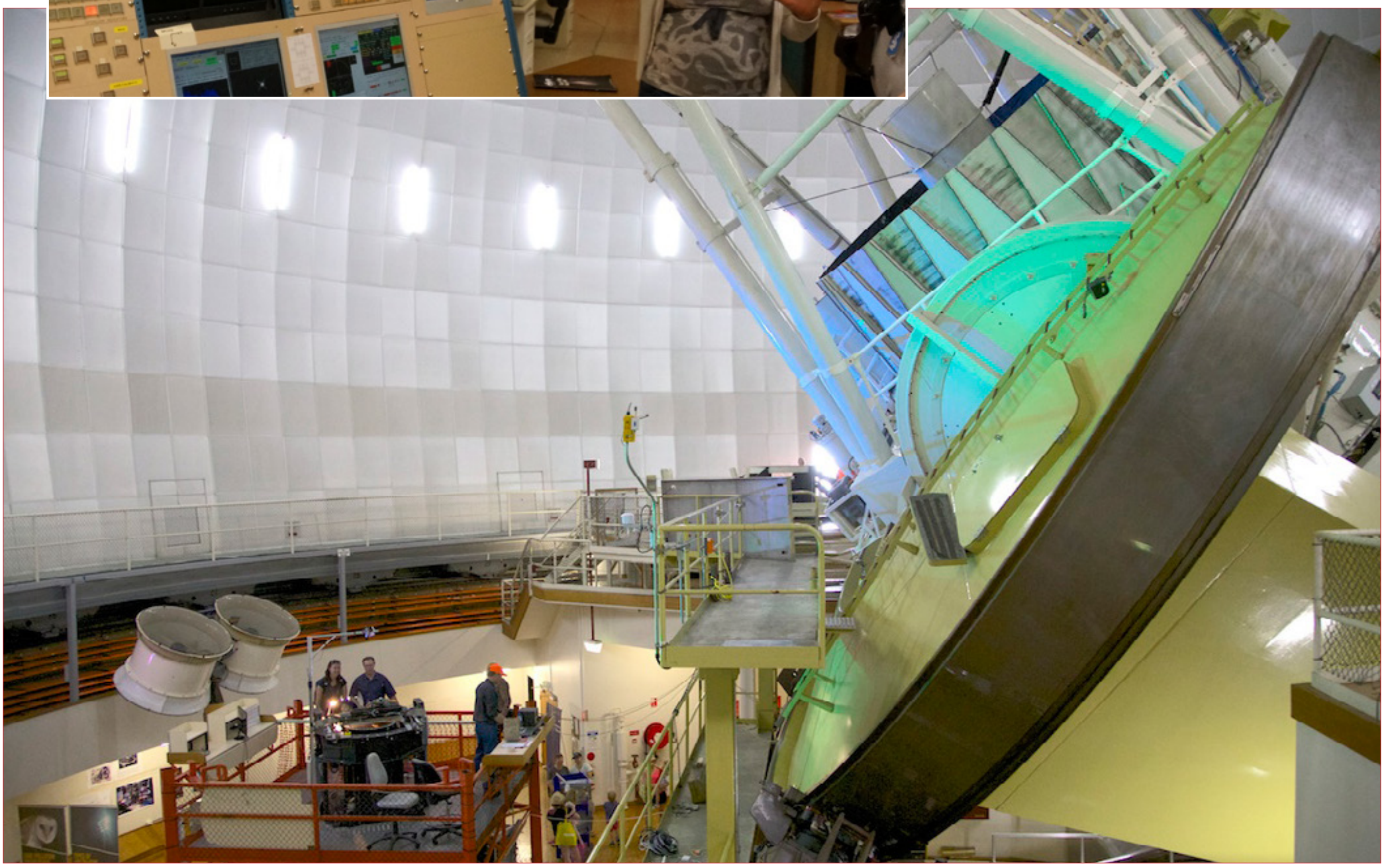
Credit: Celine_dOrgeville

Inset: AAO's Amanda Bauer stands in front of the main control desk of the AAT.

Credit: Celine d'Orgeville

Below: Guests viewed the AAT up close and watched a demonstration of the Two Degree Field (2dF) Instrument set up beside it.

Credit: Steve Lee



Astronomy for the future:
ADASS and *.Astronomy* conferences shape the path

by Nuria Lorente and Amanda Bauer

.Astronomy 7 participants in character at the conference venue: the Justice & Police Museum, Sydney CBD. **Credit:** Andy Green

The way astronomy is done is changing. As astronomical data sets, research collaborations, telescope apertures and sophistication all increase, our reliance on software and data infrastructure also increases. To accommodate this evolution we must adapt, and recognise the growing requirement of expert effort for software development, the computing infrastructure that supports it, and our methods to meaningfully engage with broad audiences on the significance of research results.

There are few conferences dedicated to bringing together astronomers, engineers, data scientists, and educators to discuss ways to improve the state of the field, yet two major international meetings were held back-to-back for the first time in Sydney, Australia in late 2015.

The *Astronomical Data Analysis Software and Systems (ADASS) XXV* ran from 25-29 October with two AAO staff members, Keith Shortridge and Nuria Lorente, taking leading roles on the organising committee. The 7th conference in the *.Astronomy* series was held the following week in Sydney, 3-6 November 2015, led by AAO Astronomer and Outreach Officer Amanda Bauer. This was the first time either ADASS or *.Astronomy* had been held in the Southern Hemisphere and, in fact, the first *.Astronomy* event to take place outside of the USA or Europe, after its initial conference in the UK in 2008.

CONFERENCE GOALS

The ADASS (http://adass.org) annual conference provides a forum for scientists and engineers interested in the algorithms, software and software systems employed in the acquisition, reduction, analysis and dissemination of astronomical data. A primary aim of the conference is to foster communication between developers and users with a range of expertise in the production and use of software and data analysis. The conference series, running annually since 1991, is driven by an international Program Organising Committee who typically serve for a handful of years, providing continuity across meetings and ensuring that the conference keeps up with the changing needs of the community and advances in technology.

The *.Astronomy* (http://dotastronomy.com) conference series aims to build a dynamic and creative community of scientists and educators to exploit the potential offered by modern computing and the internet in the era of data-driven astronomy. Rather than scientific questions, the focus is on innovative use of the web to develop new research tools, and to communicate with a broad audience through online platforms and innovative engagement resources. *.Astronomy* provides scientists, developers and science communicators an opportunity to showcase their ideas and skills outside their institutes or research areas, and help them get credit for their work.

ADASS XXV was well attended, with 300 registered participants. **Credit**: Keith Shortridge

ADASS Format and Highlights

ADASS XXV (http://www.caastro.org/event/2015-adass) commenced with the now well-established Sunday tutorial, this year on software tools for X-ray astrophysics. This was followed by a reception at the picturesque Sydney Observatory, where Elaine Sadler, director of CAASTRO – meeting host and major sponsor – opened the meeting. The formal part of the conference included 12 invited and 47 contributed talks, 126 poster presentations, 5 focus and 11 booth demonstrations, 5 Birds of a Feather (BoF) sessions (see box), and a poster sparkler session.

BoF: BIRDS OF A WHAT?

An unique and long-standing part of the ADASS meeting are the Birds of a Feather (BoF) sessions. These are plenary discussion sessions proposed before the start of the conference and run by participants, on topics of interest to the community. They can take various forms: a short introductory talk followed by an hour (or more!) of discussion, panel sessions, or small group discussions feeding back to the whole group. The aim is to tailor the format to the timely topic at hand, and to encourage active participation.

The keynote presentation was given by Brian Schmidt (ANU), who described the change, over the last generation, of the way we develop software in astronomy: from the "Hero" model (picture a lone instrumentalist astronomer writing telescope, instrument, or data reduction software against the clock, writing for speed and function, sometimes at the expense of maintainability), to a Collaborative model with multi-skilled teams comprised of astronomers, engineers and data scientists.

Brian Schmidt (ANU): "Astronomy (along with High Energy Physics) - thanks to this community - has done a better job integrating data and making it accessible across our discipline than any other community". **Credit:** Andy Green

This year Andre Schaaff (CDS) and Kai Polsterer (HITS) ran a very popular BoF on cost-effective immersive visualisation, and introduced the meeting to Google Cardboard – a technology which employs the user's smart-phone as the screen on a simple stereoscopic viewer which, together with a game controller and the VOVR software allows users to explore multi-dimensional data sets. The questions that the BoF explored included whether it is worth developing new tools for 3D immersive visualisation, which audiences and applications are they most suited for, and whether the draw of immersive tools is largely novelty and technical, and tools employing 2D screens are still the best approach for research (Schaaf & Polsterer, 2016).

Anne Raugh (U. Maryland) flies through the data space using the Virtual Observatory Virtual Reality (VOVR) and VROne stereoscopic viewer. **Credit:** Helen Sim

An advantage of the long history of ADASS is its ability to continue formal discussions from one year to the next. The "Future Data Formats" BoF (Shortridge, 2016), organised this year by Keith Shortridge (AAO) and Jessica Mink (SAO), was for many years the "FITS" BoF. In the last decade it has slowly migrated from a discussion on the FITS standard – its state and future evolution, to a broader discussion on astronomical formats in general. What do we need across the entire field, what is required by specific sub-communities, and where we think the future will take us? Milestones on the progress of data formats during the year included the publication of a special section in *.Astronomy* and Computing on data formats (A&C vol 12, 2015), and the formation of an astrodataformat community discussion forum.

Another recurring BoF theme is that of software reuse, citation and credit. Alice Allen (ASCL) orchestrated this year's BoF on "Improving Software Citation and Credit", which produced a list of recommendations on software citations. This is aimed at software authors, researchers, ADS, and publishers represented in the Software Publishing Special Interest Group, as well as the broader community (Allen et al., 2016).

A new and topical BoF on "LSST and Australia" (Brough et al., 2016) was organised by Sarah Brough (AAO). Its objective was to initiate communication between members of the international Large Synoptic Survey Telescope (LSST) community and Australian astronomers with an interest in LSST, to exchange information about LSST data and to build understanding of the LSST data capabilities and challenges within the Australian community.

Following the long-standing ADASS theme of archives and virtual observatories, Amr Hassan (Swinburne), Andy Green (AAO) and Yeshe Fenner (AAL) ran a BoF discussion on "Building the Astronomical Data Archives of the Future". This took the form of a panel session with several subjects being discussed, including strategies for providing user-friendly access to large datasets, the design of Big Data tools, archive cross-matching, improving integration across astronomical archives, automated data pipelines, multi-dimensional visualisation, and a forward look at astronomical archives for the next decade.

A topic which generated considerable interest was the so-called "bring the code to the data" model of processing, where researchers load and run their processing software onto a server which has access to the data archive, rather than download potentially large datasets onto a local machine for processing. There was considerable enthusiasm for this model; it was agreed that a major challenge is in dealing with security roadblocks (in the form of access across institutional firewalls) and that this requires further attention.

"Building the Astronomical Data Archives of the Future" panel: Simon O'Toole (AAO), Jessica Chapman (CASS), David Ciardi (LSST), Richard White (MAST), Tamas Budavari (SDSS), Amr Hassan (Swinburne), Christian Wolf (ANU), Yeshe Fenner (AAL). **Credit:** Andy Green

Amanda Bauer welcomes .Astronomy 7 participants and acknowledges the event sponsors. **Credit:** Andy Green

.Astronomy Format and Highlights

.Astronomy (http://dotastronomy.com/events/seven/) employs a uniquely open and participant-driven format, and differs from most astronomy conferences in that it focuses on methods, tools and technology rather than a particular scientific question.

In the era of large surveys, where all areas of astrophysics face similar data processing and analysis challenges, this opportunity attracts participants from a wide range of research areas, who may otherwise have little interaction in their day-to-day work. In addition, the web has allowed *.Astronomy* participants to open up the process of scientific research to a wide audience, blurring the lines between research, education and public engagement.

The conference runs for 3-4 days, with under 60 participants in order to keep the full group engaged. Applicants are selected based on their interests and skills to ensure a diverse range of ideas and voices are represented in the discussions; technical skills are not essential for participation. The pre-arranged formal *.Astronomy* presentations take place during morning sessions on two days, followed by afternoons of “unconference” sessions, where topics are suggested and voted on during the day by the participants. Leaders of unconference sessions are expected to moderate the discussion, rather than simply present their work or ideas, and report main conclusions back to the entire group at the end of the day.

Nuria Lorente speaks at .Astronomy 7. **Credit:** Andy Green

An entire day of .*Astronomy* is dedicated to a Hack Day for hands-on creation and collaboration (see box).

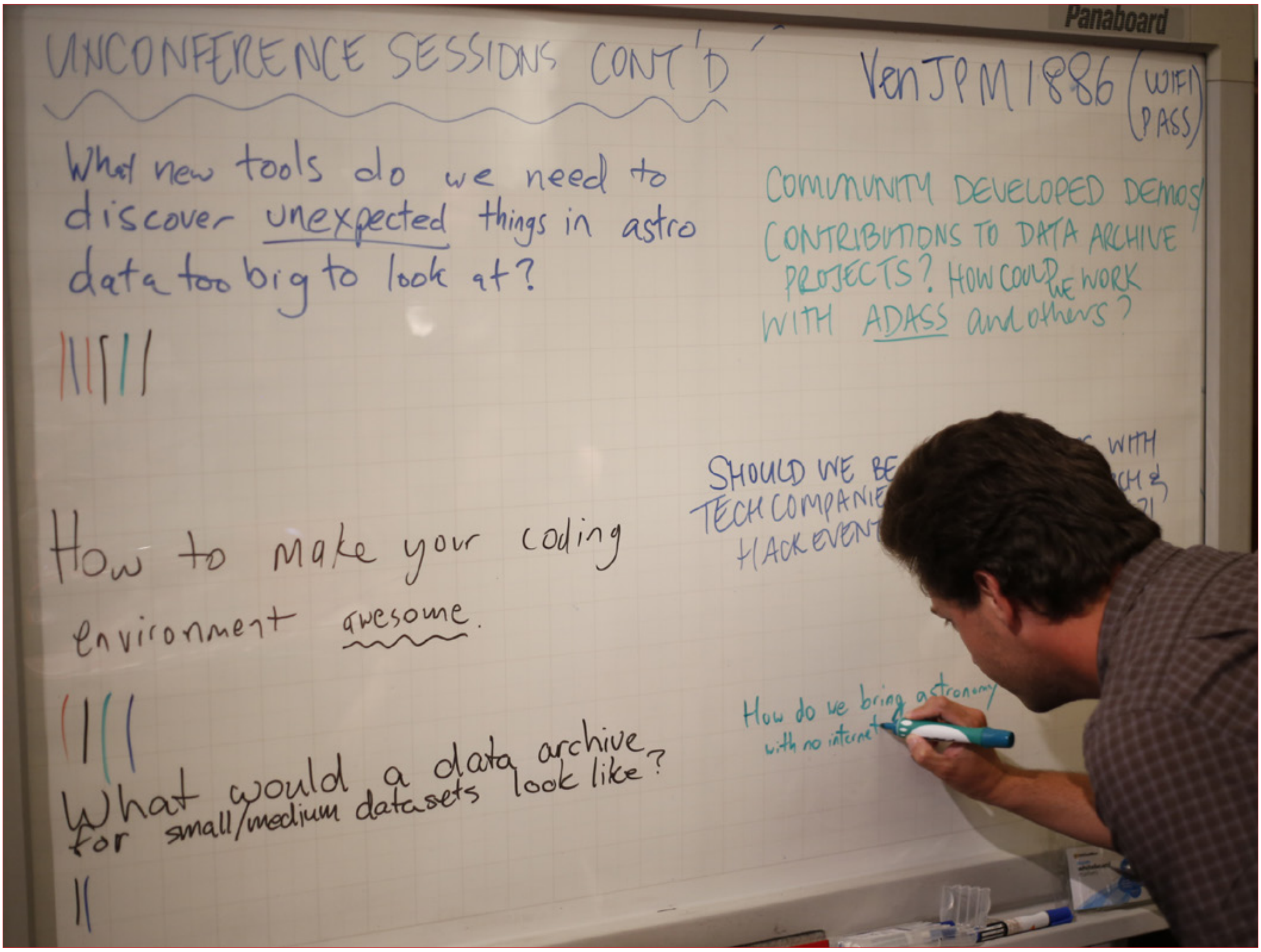
Recurring themes for Hack projects and "unconference" sessions (Simpson et al. 2013) include: Citizen Science, Visualisation, improving access to the literature (Arxiv, NASA ADS), Machine learning and classification, Data archiving and Virtual Observatories, Web-based public engagement, Web-based educational tools, goofy projects for fun, and much more.

In 2015 we introduced ".*Astronomy* Day Zero", a day of introductory tutorials on commonly used tools during the .*Astronomy* Hack Day. This day is optional and aims to help those participants who feel insufficiently skilled to fully participate in the Hack Day. You can download the Day Zero Guide (http://dotastronomy.com/wp-content/uploads/2016/01/DotAstro7_DayZero_Guide.pdf) put together by Arna Karick, or read the LIVE Blog post (http://dotastronomy.com/blog/2015/11/live-blog-astro-7-day-zero/).

.*Astronomy 7* featured a cross-disciplinary talk by Alice Williamson (Uni Sydney) who spoke about the Open Source Malaria – A New Way of Finding Medicines. Tom Robitaille discussed Astropy and the open-source revolution in .*Astronomy*, which tied nicely into the themes presented the week before at ADASS. Kirsten Gottschalk showed off very nice .*Astronomy* education mini-websites: fun (and useful) ways to showcase data. And AAO's Nuria Lorente spoke about important, yet challenging ways that software development occurs from the different perspectives of astronomers and engineers.

WHAT IS A HACK DAY?

A Hack Day is an entirely freeform day reserved for hands-on collaboration on new ideas, technical or artistic projects, based around networked technologies and the web. The Hack Day concept is common in the tech community and has been recently adopted in many areas of society: healthcare, transport, government services, and climate change, amongst many others. .Astronomy hosted the first astronomy-themed Hack Day and now they are a feature of several major conferences (the American Astronomical Society (AAS) meetings, the UK National.Astronomy Meeting (NAM), and the SPIE conference on Astronomical Telescopes and Instrumentation) and even within some University Departments.



Suggestions for unconference sessions during .Astronomy 7. **Credit:** Andy Green

"Radio Yourself" photo of Amanda Bauer playing her musical Hack Day project at .Astronomy 7.
Credit: Andy Green

One fun project completed during the *.Astronomy 7* Hack Day is Radio Yourself (http://kirstengottschalk.github.io/) (created by Kirsten Gottschalk/ ICRAR) where you can apply radio filters to a photo of yourself.

Jennifer Piscionere took a survey and created a nice visualisation of "The life cycle of astronomers" (http://jpiscionere.github.io/Sequences_sunburst.html). Several participants worked together to develop Robo-ph: an automatic podcast that reads the daily astro-ph abstracts (subscribe using iTunes: File> Subscribe to Podcast https://twitter.com/robo_ph)

There are several past Hacks that continue to grow and develop. Some examples include Astrometry.net, a web tool that automatically finds celestial coordinates for your astronomical images (http://nova.astrometry.net/), Chromoscope, which lets you interactively explore our Milky Way Galaxy in a range of wavelengths from gamma-rays to the longest radio waves (http://www.chromoscope.net/), and D3PO, a project designed to allow an astronomer, with no specialized data visualization skills, to make an interactive, publication-quality figure that has staged builds and linked brushing across plots (http://d3po.org/).

CONCLUSIONS

Software, technology and novel ways of dealing with data have always been important in astronomical research. As datasets continue to grow and expert effort is needed to manage and develop software and infrastructure, it becomes crucial to acknowledge this work.

A significant outcome from the *.Astronomy* and ADASS community is the ability to publish software in refereed journals. In 2013, Astronomy & Computing was launched, the first refereed journal dedicated to publishing astronomical software papers. Most recently, in early 2016, new software publishing categories have been added to The Astrophysical Journal and the Astronomical Journal. This marks an important change in the field, particularly for Early Career Researchers, who spend considerable amounts of time developing software, but whose career progression is often not properly rewarded for it.

Other impacts from these conferences include developing new methods to meaningfully engage with broad audiences about the science being done. As examples, several citizen science projects using astronomical data have been initiated during *.Astronomy* Hack Days and new 3D data visualisation techniques have expanded through collaborations built by participants at ADASS and/or *.Astronomy*.

As astronomy faces the challenge of extracting new knowledge from exabyte-scale survey data, developing new skills and sharing them across research disciplines will be crucial for continued success. The ADASS and *.Astronomy* conferences are instrumental in increasing the profile of these important areas. They bring together people from a large cross-section of the astronomical community to engage in dialogue, learn about the latest projects and technologies, and collaborate on interesting projects potentially outside their official research.

.Astronomy 8 will be held in Oxford, UK from 20-23rd June 2016. Follow along online with **#dotastro** or http://dotastronomy.com/events/eight/

At the end of ADASS XXV AAO's Nuria Lorente took over as Chair for the next 5 years, from ESA's Carlos Gabriel. ADASS XXVI will be hosted by the Trieste Astronomical Observatory (OATS) of the Italian national Institute of Astrophysics (INAF), and will be held in Trieste, Italy on 16-20 October 2016 (http://www.adass2016.inaf.it). Find more information on adass.org, or follow **#astroadass** on twitter.

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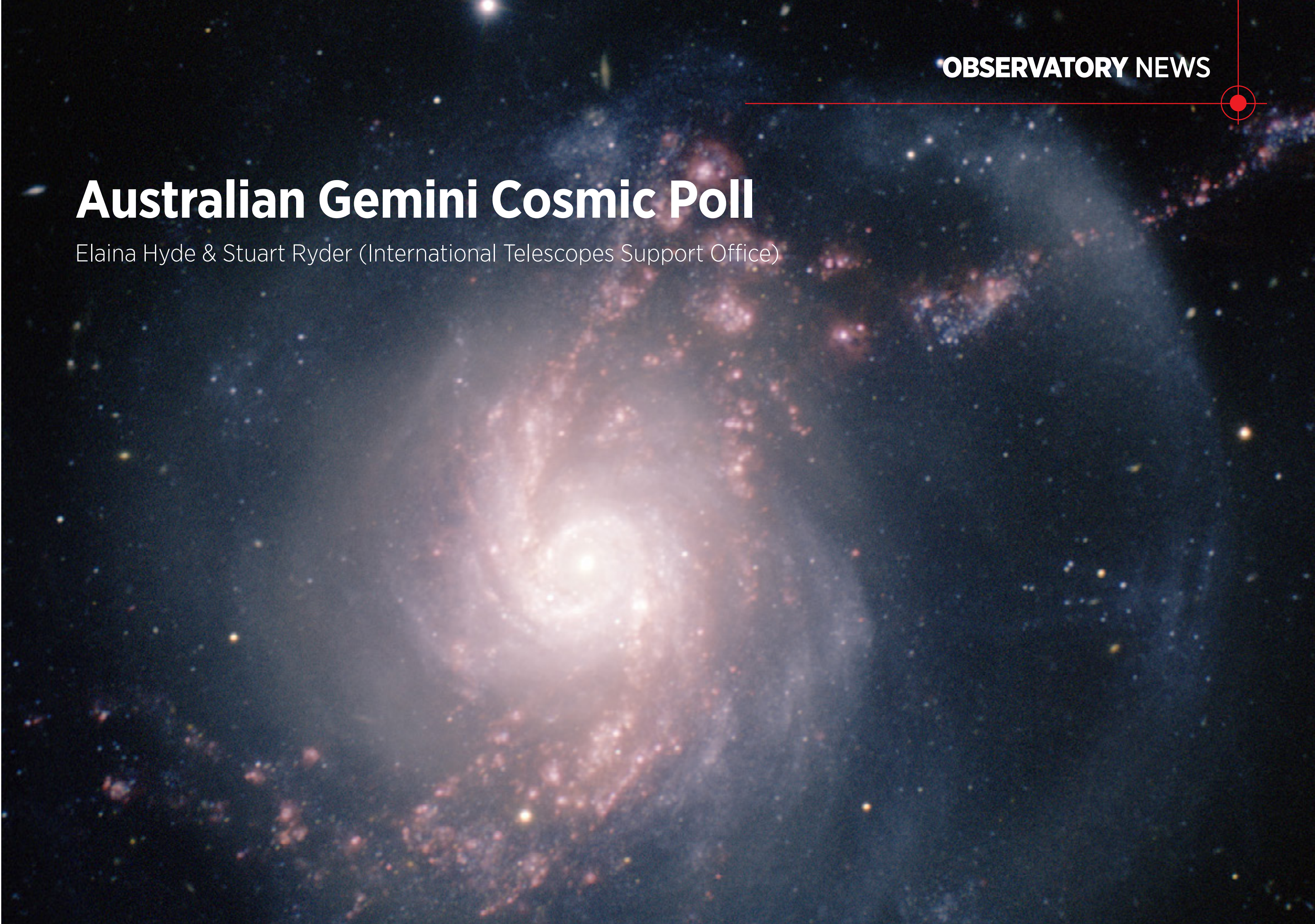
Australian Gemini Cosmic Poll

Elaina Hyde & Stuart Ryder (International Telescopes Support Office)



In November and December of 2015 the International Telescopes Support Office (ITSO) at the AAO ran the Australian Gemini Cosmic Poll event. Unlike the contests of previous years aimed at school students and amateur astronomers, the goal this time was to have the public choose which type of object the Gemini North Telescope would observe. In a spirit of intense, but friendly rivalry, each of the 4 current ITSO staff members chose one category of object to promote via a short video. These videos and the original poll can be found at http://www.thinkable.org/competition/32.

After 2 weeks of voting, the winning category was the 'individual galaxy' (promoted by Elaina Hyde) which means a galaxy that is not currently interacting with any other major galaxies, for example one like our own Milky Way galaxy. To maintain public interest in the event while observations of one of the 4 suitable individual galaxies were done in the queue, we held a 'Live from Gemini' event with Peter Michaud and André-Nicolas Chené at Gemini North. The whole session is on the AAO YouTube channel at: https://youtu.be/JLOgWs5v1fI and the Gemini blog of the event is at http://www.gemini.edu/blog/2015/12/10/partnering-with-aao-for-live-from-gemini/

Ultimately it was the galaxy NGC 3310 that was observed by Gemini North. As with previous Gemini contests we were fortunate to have Travis Rector at the University of Alaska, Anchorage to help us with the data reduction and colour processing. The final image (Fig. 1) shows that NGC3310 is even more spectacular than we imagined!

It turns out NGC 3310 has a lot of gas. The pink colour brought about through the use of a Hα filter highlights the ionized hydrogen (H II) regions where stars are forming. Despite appearing to be isolated, NGC 3310 is in fact a 'starburst' galaxy, meaning many new bright and massive stars are being formed. All this star formation may have been triggered by a collision with one of its past neighbours. From Hubble Space Telescope measurements we know NGC 3310 is 46 million light years away.

NGC 3310 is thought to be 50,000 light years wide, which is only about half the size of our Galaxy, the Milky Way. It was perhaps described best by the NASA Astronomy Picture of the Day website (http://apod.nasa.gov/apod/) who said that NGC 3310 has a "star forming party" going on.

Thanks to everyone who voted in this year's Cosmic Poll, for helping us to close out 2015 and the era of Australia's full partnership in the Gemini Observatory (see ITSO Corner on page 24), with this wonderful image of NGC 3310. We also have many people to thank for helping to make this Cosmic Poll happen: to Ben McNeil at thinkable.org for hosting the poll; Gemini Observatory for the live event and for observing the galaxy so soon after the poll closed; and to Travis Rector for helping with the image processing. To get a higher resolution image or to read the whole story you can visit our 2015 Cosmic Poll summary website at https://www.aao.gov.au/news-media/news/cosmic-poll-2015

Gemini North/GMOS composite image of the nearby galaxy NGC 3310, containing images taken with SDSS g', r', i', and Hα filters. Note the plume of stars, and asymmetric diffuse envelope suggestive of a recent past interaction. Image credit: AAO International Telescopes Support Office, Gemini Observatory/AURA and T.A. Rector (University of Alaska, Anchorage)

ITSO CORNER

Stuart Ryder (International Telescopes
Support Office, AAO)

The end of an era

31 December 2015 marked the end of Australia's time as a full partner in the international Gemini partnership. Australia joined Gemini back in 1998, with the first time allocations made in Semester 2001A. Over the next 30 semesters a total of 739 Gemini proposals were received by ATAC, of which 440 were allocated queue time and a further 25 were allocated classical nights on Gemini (or Subaru via a time exchange program). The average oversubscription factor over that time was 2.0. Almost 2/3 of these programs got 80% or more of the data they asked for under the conditions they required, thanks to the flexibility offered by Gemini's queue mode.

Among the most tangible Australian contributions to Gemini are two instruments, the Near-infrared Integral Field Spectrograph (NIFS) and the Gemini South Adaptive Optics Imager (GSAOI). NIFS was commissioned in 2005, and has just notched up its 100th publication. Not bad for an instrument that had to be rebuilt from scratch after the first nearly-complete version was destroyed in the Canberra bushfire of 2003! GSAOI was shipped to Gemini South in late 2006, but commissioning did not get underway until almost 5 years later when the Gemini Multi-Conjugate Adaptive Optics system (GeMS) and its 50 W laser were finally ready. NIFS has shown that even ultra-compact dwarf galaxies contain super-massive black holes in their cores, while GSAOI has delivered the deepest and most accurate photometry of crowded fields for any ground-based telescope. Both are a fine testament to the late Peter McGregor and his team at ANU. Australian astronomers were instrumental in driving the implementation of "nod-and-shuffle" mode with GMOS, which enabled one of Gemini's highest-impact programs, the "Gemini Deep Deep Survey".

Other notable Australian contributions to Gemini include:

- the Australian Gemini Undergraduate Summer Studentship (AGUSS) program which since 2006 has seen 23 Australian undergraduate students spend their summer at Gemini South, carrying out research projects with Gemini staff and becoming excellent ambassadors for Gemini within the Australian community.
- the Australian Gemini School and Amateur Astronomy Contests, which since 2009 have inspired school students and more recently amateur astronomers to suggest targets to image with GMOS, resulting in some awesome colour pictures of galaxies and nebulae.
- a Joint Proposals Database, established and operated by the Australian Gemini Office, which enables the sharing of one technical assessment for joint proposals, thereby improving collaboration and efficiency across the partnership.
- with the participation of Gemini staff, running two very successful Observational Techniques workshops in 2011 and 2014, with a legacy of on-line talks and tutorials.

Of the almost 1800 Gemini papers in refereed journals about 15% have at least one Australian-affiliated author. This is a good outcome considering Australia's share in Gemini was just 6.2%, and reflects the joint, collaborative nature of many of the programs allocated time. This works out at 1 Gemini paper with Australian involvement for every 8 hours of Gemini time used. Gemini data from Australia has contributed to the PhD theses of 45 students.

Although Australia is no longer a full member of the Gemini partnership, this is not the end of Australian engagement with the Gemini Observatory by any means. Astronomy Australia Limited (AAL)'s purchase of 7 classical nights on Gemini in 2016 makes Australia a "limited-term" partner in Gemini alongside Korea. Though Australia is no longer represented on the Gemini Board or its Science & Technology Advisory Committee, Australia does still have a presence on the Operations Working Group and the Users Committee for Gemini. Plus we still have more to contribute, in particular an upgrade to the GeMS wavefront sensor system later this year, and the Gemini High-resolution Optical SpecTrograph (GHOST) in 2017/18.

Proposal Statistics

A total of just 5 Gemini proposals seeking a total of 6 nights were received by ATAC for Semester 2016A, well down on the numbers in past semesters. This was to be expected in light of the much diminished access that Australia has in 2016, including no queue time, no exchange time, no target-of-opportunity, or joint proposals. There were 3 proposals for Gemini North, and 2 for Gemini South. Under the terms of Australia's limited-term partnership, ATAC has 7 classical nights to allocate in 2016, shared about evenly between semesters 2016A and 2016B, between Gemini North and Gemini South, and across lunations. Ultimately ATAC elected to allocate 1 night with GNIRS on Gemini North to Christina Baldwin, and 2 nights with GeMS+GSAOI on Gemini South to Erik Kool. Both Christina and Erik are PhD students at Macquarie University, who will get a unique opportunity for some "hands-on" experience with Gemini.

Magellan demand in 2016A was also well down on the record numbers of 2015B, perhaps due to applicants targeting their proposals towards the new joint Keck time allocation program in 2016A (see below). Nevertheless the oversubscription was still a healthy 2.4, with demand well-balanced between the Baade and Clay telescopes.

KTAC

While ITSO's Gemini workload has been winding down, this has been more than compensated for by the new challenges of supporting Australian community access to the W. M. Keck Observatory's twin 10-metre telescopes in Hawaii. After AAL was able to secure a total of 15 nights per year on Keck from Semester 2016A onwards, the two Australian institutions which currently enjoy similar levels of access (Swinburne University of Technology and the ANU) agreed to pool all 45 nights per year of Keck time into one integrated time allocation process. The joint Keck Time Allocation Committee (KTAC) consists of 2 members appointed by Swinburne (Glenn Kacprzak and Michael Murphy), 2 from ANU (Lisa Kewley and Martin Asplund), 2 appointed by AAL from the Australian community (Gayandhi De Silva and Nicholas Scott), and 1 external member (Lynne Hillenbrand from Caltech). Stuart Ryder, with valuable assistance from David Fisher (Swinburne) serves as Technical Secretary.

A total of 34 proposals were received by KTAC in its inaugural semester. There were 21 proposals for Keck I; 12 for Keck II; and 1 for time on both Keck I and II. The oversubscription for Keck I was 3.3, while for Keck II it was 1.8. The oversubscription for AAL, ANU, and Swinburne nights was 3.1, 1.8, and 2.6 respectively. Total dark time was oversubscribed by 2.6, grey time by 1.1, and bright time by 3.7. OSIRIS and ESI were the most requested instruments, while DEIMOS and NIRSPEC had the fewest requests.

One of KTAC's goals is to encourage collaborative proposals within the existing and newer Australian Keck user community, so as to leverage more time and enable more ambitious programs than any one partner could have achieved alone. Ignoring international collaborators, about ¼ of proposals involved Swinburne users only, another ¼ ANU only, and just 15% did not involve ANU or Swinburne. One-third of proposals involved astronomers from 2 of the 3 partners, and just 1 proposal involved investigators from all 3 partners.

After ranking all proposals on the basis of scientific merit, and allocating available nights from each partner as requested, a total of 16 programs were able to be scheduled, including some requiring half-night allocations. As with Magellan programs allocated time by ATAC, ITSO will be providing travel support to KTAC PIs, although some with recent experience on Keck will be able to observe remotely from Swinburne or from ANU.

The joint KTAC process will be evaluated by AAL after Semester 2016B, and any changes or improvements to policies or procedure will be implemented for 2017A. Anyone with feedback on the inaugural round is welcome to pass this along to either the KTAC Chair Michael Murphy (mmurphy@swin.edu.au), and/or their AAL member representative.

ITSO Staffing

On 29 September Dr Elaina Hyde commenced work on a casual basis as the ITSO Information Officer. Her primary task initially is a major revamp of the ITSO web site to enhance the range of facilities covered and make it easier for astronomers as well as members of the public to find the information they seek. She organised the 2015 Australian Gemini Cosmic Poll (see separate article) and has also been prolific in her social media postings, using the **#ITSOaao** hashtag to distinguish ITSO-related content.

Dr Richard McDermid, the joint ITSO/Macquarie University Lecturer in Astronomy, has been awarded a prestigious Australian Research Council Future Fellowship. This will allow him to spend the next 4 years focusing on his research into galaxy formation and evolution, which depends heavily on the use of 8m telescopes. Congratulations Richard!

AGUSS

The Australian Gemini Undergraduate Summer Studentship (AGUSS) program offers talented undergraduate students the opportunity to spend 10 weeks over Southern Hemisphere 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. Thanks to extra funding from AAL, we have been able to support three AGUSS students in 2015/16 instead of the usual two. The successful applicants (shown in Figure 1) were:

- Samuel Hinton from the University of Queensland, working with Ricardo Salinas on a study of the globular cluster system of the nearest elliptical galaxy to us, Maffei 1.
- Deeksha Beniwal from the University of Adelaide, working with Blair Conn on reconstructing the star formation histories of open clusters in the Third Galactic Quadrant.
- Benjamin Courtney-Barrer from the Australian National University, working with Morten Andersen on determining the age of the supermassive Galactic star cluster GLIMPSE 1.

2016 Observational Techniques Workshop

Following the highly successful Observational Techniques workshops held in 2011 and in 2014, ITSO will be hosting a similar event from 3–6 May 2016 at the AAO in Sydney. As with the previous workshops the focus will be on generic methods, rather than on particular instruments or telescopes. However with Australian access to Keck increasing as our Gemini access decreases we will be featuring Keck's capabilities more widely. In addition to talks by local and international experts on everything from photometry to integral field spectroscopy to tweeting about your research, there will be hands-on tutorials and social events. Registration will open shortly via the workshop web page at https://www.aao.gov.au/conference/OTW2016. Space is limited and although everyone is welcome to participate, preference will be given to graduate students and early-career researchers. For further information please contact the Workshop convenor Caroline Foster-Guanzon (cfoster@aao.gov.au).

Figure 1: The 2015/16 Australian Gemini Undergraduate Summer Studentship recipients – (left to right) Samuel Hinton, Deeksha Beniwal, and Benjamin Courtney-Barrer.

Meet and greet

Tayyaba Zafar

I was born and grew up in Lahore, Pakistan and being in the educational hub of Pakistan I went to the best institutions. Although my father wanted me to be a civil servant, my obsession always was to get a PhD in Physics but could not make up my mind in which particular subject. Among the various Physics applications, during MSc Physics in Pakistan, I was more interested in particle physics and acquired a strong background in particle physics, quantum field theory and the theory of general relativity. I scored the highest marks in MSc Physics Punjab province wide and was immediately hired as a lecturer by the University of the Punjab, Lahore and served there for one and a half years. Astrophysics hadn't been taught as a subject at that time in Pakistan. During the lectureship, while going through library shelves, I found some interesting astrophysics books and the reading developed my understanding and fascinated me by the vastness and beauty of the Universe.

I started applying for PhD positions worldwide, however, landing finally in Denmark was a coincidence. In 2007, I met with the Danish Ambassador at a seminar and he suggested that I apply for Danish vacancies as well. Coincidentally, a PhD vacancy at the Dark Cosmology Centre, University of Copenhagen was open. I was short-listed and after a written test and an interview for the position, I was selected. Copenhagen not only gave me exposure to the world but also my astrophysics journey started from there. For my PhD, I worked on interstellar medium (ISM) studies of Gamma-ray bursts and quasars and mostly conducted dust extinction studies. Ever since I have been attracted to the obscured Universe, at the same time never limited myself to a narrow range of topics.

After defending my PhD thesis in 2011, I moved to the Laboratorie d'Astrophysique de Marseille, France for my first postdoc and worked there mostly on ISM studies of intervening absorbers along the sightlines of bright quasars. In 2013, I started a European Southern Observatory (ESO)-Germany fellowship, providing me scientific independence and opportunity to work at the 8-m world-class telescopes in Atacama Desert, Chile. Under the ESO banner I supported Very Large Telescope (VLT) and worked with various instruments, mostly spectrographs. Visiting the Paranal Observatories was a great experience, however, I started looking for long-term positions and came across the AAO Research Astronomer position advertisement.

I was interviewed and offered the AAO position and to commence this I left ESO-fellowship one year ahead of my time. AAO surveys always perform meaningful science and pioneer various astrophysical studies. This is my first ever exposure to the Australian scientific community. I started working at the AAO in November 2015 and I am an instrument scientist for AAOmega spectrograph for which I am now trained. I have worked with multi-object spectrographs before, but working with 400 fibres is a great experience. I am looking forward to listening to the robot chirps over five years and being part of the amazing AAO science.

Jeffrey Simpson

I have been at the AAO for just over a year now, but have missed the chance to talk about myself in the pages of the AAO Observer. I am originally from New Zealand, where I did my undergraduate and PhD at the University of Canterbury. My PhD was an interesting time with several thousand earthquakes striking Christchurch while I was doing it, including a major one that shut down the university for two months.

After becoming involved with the GALAH survey, I became a 'fly-in/fly-out' astronomer, working from home in NZ but visiting Australia regularly in the employment of Macquarie University. After about six months of this, I convinced everybody it would make more sense to move to Australia full-time. I was fortunate enough to get this current job at the AAO, because I don't think my wife would have appreciated another international move after only six months in Australia.

My major research interests are chemical abundances of globular clusters and their chemistry (read page 11). I am also heavily involved in the GALAH survey and supporting HERMES..

News From North Ryde

Jeffrey Simpson

We ended 2015 welcoming a new astronomer into our midst: Tayyaba Zafar. Tayyaba takes over as the instrument scientist for AAOmega from Sarah Brough. You can read more about Tayyaba on Page 26. Other new staff include Elaina Hyde as the ITSO Information Officer (Page 25), and Daniel Zucker who is re-joining the AAO following the conclusion of his Future Fellowshop at Macquarie University.

The instrumentation group had a very well received design review for GHOST at Gemini. Although Australia is no longer a full partner in Gemini, the AAO continues to have an active involvement with instrumentation design and construction (as discussed in ITSO Corner; page 24).

We have hosted successful workshops for the GALAH and TAIPAN surveys. Both workshops saw astronomers, engineers, and computer scientists coming together to discuss the results and upcoming activities. For TAIPAN and FunnelWeb (which will also be using the TAIPAN spectrograph) the latter half of the year will be an exciting time as the spectrograph and Starbugs fibre positioner are integrated together on the UKST.

Our social media engagement is continuing to go from strength-to-strength. Our Twitter account (@AAOAstro) has over 2000 followers now. We continue to get many great questions and comments during our weekly #AskAAO sessions where a different person takes control of the account for an hour to tweet about their research, work and exciting science.

As we do every year, a number of undergraduate students are undertaking fellowships at the AAO during the summer. Melissa McIntosh is working with Jeffrey Simpson & Gayandhi De Silva on finding open cluster stars in the GALAH survey; Brendan Reinhart and Joshua Calcino are working with Anthony Horton and Lee Spitler on the Huntsman Telescope project; Andrew Zic is working with Tayyaba on compares different approaches to inferring the dust content in galaxies.

Finally, we temporarily said goodbye to Amanda Bauer who has just started her maternity leave. Good luck with the baby!

SSO News

By Zoe Holcombe

I hope everyone enjoyed their Christmas and New Year break and are ready for 2016. Quick wrap up of what happened here at site towards the end of 2015.

September

Wade Sutherland is now a fully qualified electrician. Wade has been doing his apprenticeship with the AAO for 4 years. The Social Club held a BBQ to help Wade celebrate his achievement. Well done Wade.

The Mechanical Team are very busy at the moment with changing rollers on the shutter, getting the mirror trolley ready for aluminising and looking into new chains for the main shutter as they are very worn. Also Darren Stafford and Shane are working on the 2df simulator, for which the wire for the gantry has just been fitted.

October

The annual StarFest activities kicked off with Science In The Pub, we had just under 300 attend the evening with Amanda Bauer, Vicki Meadows, Naomi McClure-Griffiths and Vanessa Moss on the panel and Robyn Williams and Fred Watson MCing the evening. Open Day saw a huge number of visitors to site once again and the weather was amazing. The weekend concluded with Vicki Meadows doing the Bok Lecture on the Sunday. All money raised from the weekends tickets sales, donations and raffles went to the Westpac Helicopter Service ($5013.10) which services the Coonabarabran area quiet frequently and actually did a fly over the Bowling Club Friday evening to pick up a young boy, from the hospital, who had come off his motorbike into a fence. The boy was flown to Tamworth Hospital in a stable condition. No one has ever had to pay for this service when flying with the Westpac Chopper.

November

We made our way down to the big smoke for the AAO Planning Day. With a few staff having to stay behind for UKST commitments we boarded the McWhirter Express for North Ryde (guitars and all!). The Coona staff had a great time at North Ryde and enjoyed the dinner on Tuesday Night at Darling Harbour, then it was back on the bus back to Coona with Rajni and Maryam joining us.

The UKST work continued with Peter Mack finishing the Dome Controls and other work progressing along.

Doug Gray left us for a well-deserved break back to the UK for a month with family. Doug kept in contact regularly with staff letting us know how good the UK weather was (not) and how good the UK beer was too. I think by the time Doug got back he was well and truly over rain though!

December

The NEW ANU Lodge has commenced with the dongars disappearing one day, to make way for a lovely new Lodge to appear late 2016. Observers and staff can still get accommodation on site at Bingar and House 3, though there could be some noise coming from the lodge area with construction happening. The area is fully fenced off and no one is allowed in this area without approval. If you need to go in the area please speak to ANU Site Manager first.

January

Shane and Amy Paul welcomed their baby girl on the 2nd, Emma Paul was born at 3.50am weighing 3.495kg and 51cm. Mum and Bub are doing well and brother Sam is very excited.

Katrina Harley is leaving us again on the 15th for maternity leave. Katrina is due at the end of February, and Millie is looking forward to having someone to play with. Also a BIG congratulations on your engagement.

That will leave me in Katrina's position again and I'm looking forward to filling in for her until she returns in February 2017.

That's all the news from SSO, until next time, BYE!
Zoe

The Sydney site for the successful attempt to break the Guiness World Record for the "Most People Stargazing Across Multiple Sites in a Country" on Friday 21 August 2015 (Angel Lopez-Sanchez).

Australian Government
Department of Industry, Innovation and Science

EDITOR: Jeffrey Simpson

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

ISSN 0728-5833

Published by the Australian Astronomical Observatory
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