NUMBER 111 FEBRUARY 2007

AAO NEWSLETTER

ANGLO-AUSTRALIAN OBSERVATORY

The Eye of the Serpent

IRIS2 "true colour" near-infrared image of the Serpens molecular cloud, obtained in September 2006 with the new science-grade array, from imaging in the J (blue), H (green), and Ks (red) filters. The blue butterfly-like object near the centre is the Serpens Reflection Nebula, while the yellow object just below it, surrounded by braided nebulosity, is the Young Stellar Object Ser B6 (IRAS 18274+0112). Numerous outflow and embedded sources are also visible. The images were pipeline-reduced by ORAC-DR, then processed with GIMP by Stuart Ryder.

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DIRECTOR'S MESSAGE

In the last AAO Newsletter, I noted that the AAO was awaiting the outcomes of the Australian government's Review of the Observatory. The Review Panel's report[†] made ten important recommendations for the future of the AAO. In abridged form, these are:

1. The AAO should continue in its role as the major national facility manager for optical astronomy in Australia until at least 2015.
2. The Australian Government should increase the planned recurrent funding for the AAO by $10.5 million over the five-year period 2006–07 to 2010–11.
3. Noting that the outstanding success of the AAO is based on the conjunction of research, instrumentation and facility management, maintaining this capability combination should be a priority when considering future funding for the AAO, in order to optimise delivery to the user community.
4. A new instrument should be developed which will extend the life of the AAT for use by Australian researchers and students for at least the period to 2015. The instrumentation capability of the AAO is central to its ability to deliver forefront astronomical capability to users, and in so doing ensures that the AAO retains a strongly competitive position worldwide as a builder of innovative instruments.
5. The AAO should be refurbished as necessary, with funding to address the two most critical categories of repairs of $4.1 million in the budget period 2006–07 to 2010–11.
6. The AAO should be given the broader role of a national optical observatory, managing both national and international projects, and encompassing Gemini, ELTs, Antarctic astronomy facilities and other national investments to the benefit of the Australian astronomical community.
7. An Optical Astronomy Australia (OAA) Board should be established as a statutory corporation after 2010 to own and manage national facilities where appropriate, provide leadership and coordination of optical astronomy research in Australia, undertake strategic planning, provide a point of contact with the Australian Government and international organizations, seek and distribute major facility funds, and appoint the Director and manage the AAO.
8. An Interim OAA Board should be established in 2007 with broad responsibilities to lead and manage the optical astronomy program in Australia from 2007–2010, with suitable transition arrangements as the UK's involvement in the current AAO reduces and ends in 2010.
9. Consideration should be given in the future to widening the scope of the OAA Board to that of a broader peak body for all Australian astronomy beyond 2010.
10. A further review should be held in the period 2010–11 with the purpose of developing guidance for the AAO for the period out to 2015.

The first steps towards realising this program were made on 27 November 2006, when initial outcomes of the Australian *National Collaborative Research Infrastructure Strategy* were announced. *Optical and Radio Astronomy* was one of nine capabilities that received substantial funding. Over the next 4½ years, $45 million will be injected into a variety of programs in Australian astronomy, including existing facilities such as the AAT and Gemini, new facilities such as the Square Kilometre Array and its precursors, and design and development work for the Giant Magellan Telescope and PILOT, a proposed Antarctic 2m-class telescope.

The AAO component of this broad investment plan is $10 million, of which $4.1 million will be used to refurbish and revitalise the AAT's 33-year-old systems and infrastructure, while the other $5.9 million will be used to build a new front-line instrument for the AAT. A specific instrument concept being explored is the AAOmicron near-infrared multi-object spectrograph described by Simon Ellis & Roger Haynes on page 18 of the August 2006 Newsletter, which aims to exploit both prior instrumentation developments and revolutionary new technologies. Together, these investments will help ensure that the AAT remains a reliable, efficient and scientifically potent

[†] http://www.dest.gov.au/sectors/science_innovation/policy_issues_reviews/reviews/anglo_aus.htm

telescope for at least another decade.

Just as important, however, is the proposed formation of *Astronomy Australia*, a limited-liability statutory corporation that will have overall responsibility for managing NCRIS funding for astronomy. Membership in *Astronomy Australia* will be open to all Australian institutions involved in astronomical research. If *Astronomy Australia* is effective in its role as NCRIS program manager, then, in accord with recommendations 7 & 8 of the Review Panel, it may prove to be the appropriate entity to take over the operation of the Observatory from the AAT Board after the UK's involvement with the AAO ends in mid-2010.

The next 3½ years will therefore see an organic evolution of the AAO, as it transforms itself from a bi-national, one-telescope facility into a fully-fledged national observatory supporting an array of optical and infrared facilities. Indeed this process is already underway: from 2007, the AAO will host the Project Office for the PILOT design study and work closely with the Australian GMT Project Office located at ANU, while from 2008, support activities for Australia's involvement in the Gemini and Magellan telescopes will be consolidated at the AAO. These changes, and others to follow, will present the AAO with challenges and opportunities, and we welcome both.

Matthew Colless

LARGE OBSERVING PROGRAMS ON THE AAT REQUEST FOR PROPOSALS SEMESTER 07B

The AAO aims to provide opportunities for Australian and British astronomers to make effective use of the Anglo-Australian Telescope's unique capabilities to address major scientific questions through large observing programs. These large observing programs may use any instrument, or combination of instruments, on the AAT, although the community's particular attention is drawn to the AAOmega spectrograph, which will be the world's most efficient instrument for large-scale survey spectroscopy for some years to come.

In line with previous announcements, the AAT Board (AATB) is issuing this *Request for Proposals (RfP)* for major new observing programs to commence in semester 07B (August 2007 to January 2008) or semester 08A (February 2008 to July 2008). The AATB expects large observing programs to be awarded more than 25% of the available time on the AAT in semester 07B; this fraction of time will be reviewed for subsequent semesters. The AATB encourages ambitious large programs and does not set an upper limit on the fraction of time large programs can be awarded.

All proposals will be evaluated by the Anglo-Australian Time Allocation Committee (AATAC), and should use the standard AATAC form (although with non-standard page limits). The case for the proposed large observing program must include:

1. A major, compelling and feasible scientific program. The proposal should focus on key questions that the observational data would address, but should also outline anticipated secondary uses of the data by the broader community. 'Major' in this context will generally mean programs requiring 50 nights or more (there is no set upper limit), possibly extending over several years. The science will be expected to be groundbreaking and not just incremental. Proposers need to discuss what their program will achieve in comparison with other on-going and future programs on similar timescales. *The scientific program should be described in no more than 5 pages (including figures, tables, and references).*

2. An observing strategy describing the provision of the input target sample, the detailed plan for the observations (number of nights including the standard allowance for weather, cadence of time-critical observations, and total duration of the project), the proposed instrumental setups, constraints on weather conditions or timing of observations, signal-to-noise or other figures of merit required to achieve the science goals, and any special support needed for the observations. The number of targets, required data quality, sensitivity limits and so on should all be carefully and rigorously justified. Programs requiring multiple visits to the same field should present a strategy for updating targets to achieve optimum efficiency. *The observing strategy should be described in no more than 2 pages.*

3. A management plan outlining the collaboration involved in the program, the sharing of responsibilities for scientific management; the planning of observations; the carrying out of observations; data reduction; quality control at each of these stages; data release to the AAO community and the International

Virtual Observatory; and finally, data analysis and exploitation by the proposing team. The plan should outline the roles of all team members and how members contribute to carrying out the program. Proposers may also wish to suggest a publication strategy, including the process for determining authorship. *The management plan should be described in no more than 2 pages.*

4. A project timeline including the observational and analysis aspects, with milestones and regular reviews by AATAC during the course of the program. Proposers should plan for significant public outreach, and the proposal should explain the broader impact of the project. *The timeline and outreach should be described in no more than 1 page.*

Proposers are encouraged to form broad collaborations across the Australian and British communities in support of their programs. The PIs for large programs will generally be expected to commit to the project as the main focus of their research over the program's duration.

Proposals for large observing programs should be submitted to AATAC by the standard proposal deadline of 15 March 2007.

The number of large programs to be awarded time will be determined with a clear preference for a small number of very high quality programs delivering high impact science as quickly as possible. Within these guidelines, AATAC will award time based on considerations including the relative scientific merit and impact of the large programs and standard programs, the quality of the management, publication and outreach plans, and the phasing of programs to provide a steady rollover of large programs for the longer term. A panel of independent expert referees will be asked to provide comments on the proposals; proposers will be given the opportunity to respond to the referees' comments.

There will be annual opportunities to propose large observing programs at each B semester deadline. For technically difficult or ambitious programs, proposers may wish to request time in the first semester to carry out pilot observations that will demonstrate the achievability of the program's goals and validate its observational feasibility.

Proposers are encouraged to contact the AAO Director (director@aao.gov.au) to discuss their plans in advance.

Matthew Colless
AAO Director
25 January 2007

THE AAO'S FOUNDING EXECUTIVE OFFICER

Russell Cannon

As noted in our previous Newsletter, Doug Cunliffe died last August after a long illness. Doug was head of the AAO's administration for a quarter of century, from when he was appointed as Executive and Finance Officer to the newly-formed AAT Project Office in Canberra in 1968 until he retired in 1992. Originally trained as an electrical engineer in Melbourne, Doug came to the AAO from the CSIRO Division of Mechanical Engineering.

Doug more than anybody was responsible for the AAO management style. The Observatory was a bi-national research facility, governed by an independent Board with the power to establish its own rules and procedures. The prime objective was simply to maximise the scientific output while meeting the needs of visiting astronomers. Doug's great contribution was recognised with the award of a Medal of the Order of Australia in 1990.

Two themes occur repeatedly in descriptions of Doug: that he was imperturbable and unfailingly good-humoured, and that he was a true gentleman who embodied the best features of the Australian character. "He was invariably cheerful ... his good humour more or less shamed us all into trying not to lose our tempers" (Fred Hoyle, former Board Chairman); "His sound judgement, even-handed and good-natured approach ... were major factors in the smooth running of the Project Office" (Ben Gascoigne, in 'The History of the AAO'); "Thanks to Doug's patient and friendly guidance, I was able to learn the [administrative] side of running a major scientific facility" (Don Morton, Director 1976–86); "Doug was one of those rare individuals who can and do set the tone for first-class institutions ..." (Malcolm Smith, AURA/CTIO); "Doug ... made a strong impact on me during my early visits to Sydney as a Postgrad [and contributed to] the very favourable impression of Australia ... which attracted me here" (John Webb, UNSW).

Douglas Ward Cunliffe, A.M., born Caulfield, 3 November 1927; died Sydney, 17 August 2006. He is survived by his wife Pauline whom he married in 1953; a daughter Linda and sons Ian and Russell; and six grandchildren.

THE MILLENNIUM GALAXY CATALOGUE

Simon Driver (University of St Andrews, UK), Jochen Liske (European Southern Observatory, Germany), Alister Graham (Swinburne University of Technology, Australia).

Introduction

The Millennium Galaxy Catalogue (MGC; Liske et al. 2003) is designed to provide a comprehensive resource for the study of structure in the Universe on 1–100 kpc scales, i.e. galaxies. Structure in the local Universe on >1 Mpc scales is relatively well understood, thanks to a well developed cosmological theory (ΛCDM), and extensive surveys such as the Two-degree Field Galaxy Redshift Survey (2dFGRS; Colless et al. 2001).

However, the story on the smaller 1–100 kpc scales is significantly different and structure at this level is not fully understood. This is not surprising as this scale constitutes a regime dominated by non-linear physical behaviour, where mass concentrations have decoupled from the Hubble flow, and where baryon physics becomes critical as the baryons eventually dominate over the dark matter. Numerical models are, as yet, unable to grapple with this regime until such time as the baryon physics can be comprehensively encoded. Instead, models of galaxy formation rely on semi-analytic extensions, which in turn are based on empirical data and a few key analytical recipes (see Baugh 2006).

It is therefore important to recognise that empirical datasets are currently driving our understanding of galaxy formation, with the semi-analytic models rapidly developing to accommodate new empirical studies. The MGC constitutes a breakthrough dataset in this subject and is based on the fusion of imaging data from the INT Wide Field Camera and spectroscopic data from the Two-degree Field (2dF) facility on the AAT. The imaging spans 37 sq. degrees and is deeper and higher resolution than any other comparable area survey. Although the MGC imaging is entirely B-band, overlap with the shallower Sloan Digital Sky Survey (SDSS) provides complementary *ugriz* data. About half the spectroscopic data (redshifts) are derived from archival data (2dFGRS and SDSS) and about half from our own MGCz survey (Driver et al. 2005), which was conducted primarily with the 2dF from 2001–2004. UKIRT coverage of the MGC is currently in progress.

MGCz contains 10,095 galaxies with B<20 mag and 96.1% spectroscopic completeness. The spatial resolution is sufficient to enable the comprehensive study of galaxy structure through Sersic+exponential bulge-disc decompositions using GIM2D (Simard et al. 2002). The resulting database of multi-wavelength imaging, spectroscopy and structural decompositions is unique, and constitutes the largest structural galaxy resource worldwide. All data were publicly released at the IAU General Assembly in Prague last August and are available through our website at: http://www.eso.org/~jliske/mgc. Here we briefly show six key science breakthroughs, all of which open up new avenues of research and shed new light on our empirical understanding of galaxy formation and evolution.

1. The bivariate brightness distribution

For several decades there has been debate and speculation as to whether the Universe contains large numbers of low surface brightness galaxies (LSBGs;

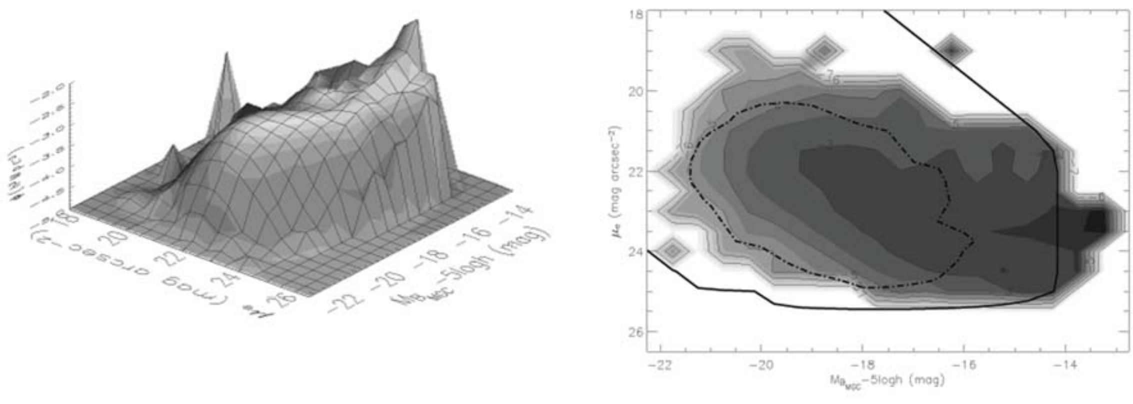

Figure 1: The space-density of galaxies as a function of luminosity and surface brightness show as a 3D representation (left) and as a 2D contour plot (right). The solid line defines the MGC selection boundary. The z-axis and contours are logarithmic and the data show a strong luminosity-surface brightness relation and also that the data ridge is well defined. Completeness only becomes an issue towards fainter luminosities.

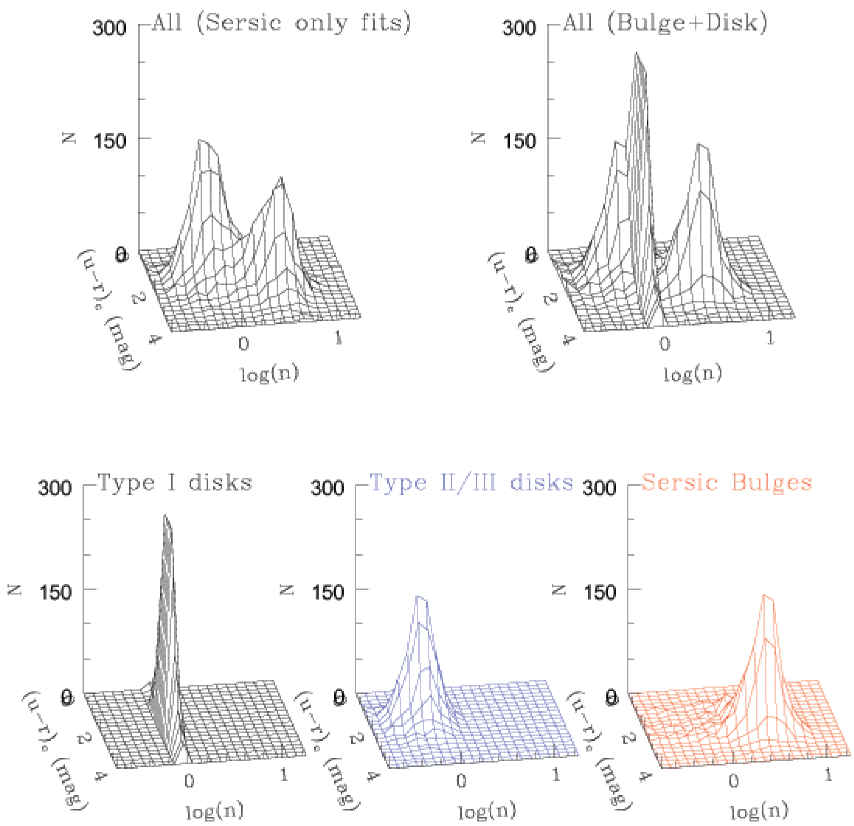

Figure 2: The observed distribution of galaxies shown on a colour-concentration (log Sersic index) grid. The bimodality seen in the global properties (upper left) becomes even more apparent when the galaxies are separated into bulge and disk components (upper right). The lower panels show the distinct structures consisting of exponential discs (lower left), truncated discs (lower centre) and central spheroidal structures (lower right).

see review by Impey & Bothun 1997). The MGC was the first optical study to resolve this issue through a bivariate brightness analysis (Driver et al. 2005) which reveals that while LSBGs are extremely numerous these systems are exclusively low luminosity galaxies (dwarfs), and contribute a negligible amount to the total integrated B band luminosity density and stellar mass budget (see Fig. 1). The question does however remain as to whether the neutral gas component and dark matter component in these systems are also negligible. To address this we hope to survey the MGC at 21cm with xNTD to obtain both gas and dynamical mass estimates.

2. Galaxy bimodality

Galaxy bimodality has to some extent been recently rediscovered (Strateva et al. 2001). However the MGC data enables us to clearly demonstrate (see Fig. 2) that galaxy bimodality is due to the two component nature of galaxies, and not two galaxy types (Driver et al. 2006; Driver, Liske & Graham 2007). The two components are a red, old, spherical, concentrated (as measured by the Sersic index) component, and a blue, young, diffuse, and extended flat component, i.e. spheroids and disks. The strong division between these two components in the concentration-colour plane, at least for luminous systems, argues for two clear epochs and modes of galaxy formation, whereby bulges form early (either via direct collapse or via rapid merging), followed by a second slower phase of disc formation (splashback, infall and accretion).

3. The supermassive black hole mass function for early and late type galaxies

Existing estimates of the SuperMassive Black Hole (SMBH) mass function are based on either the mass-sigma relation or the mass-luminosity relation. The former can be difficult to measure, problematic to implement, and costly in terms of telescope time. Previous attempts to implement the latter have either neglected late-types entirely by colour cuts or by adopting some questionable constant bulge-to-total flux ratio for these systems. By using the mass-bulge concentration relation of Graham & Driver (2007) we have constructed the most robust SMBH mass function to date (Graham et al. 2007) for both early- and late-

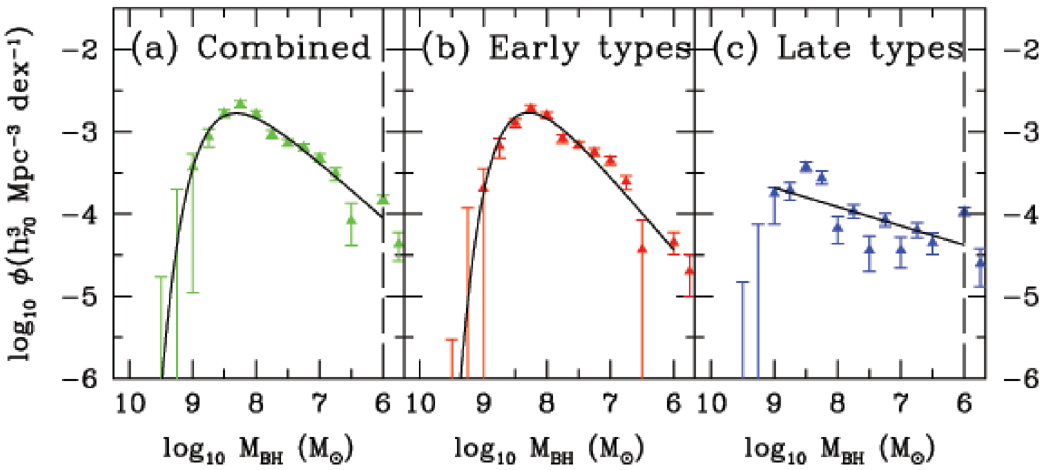

Figure 3: The supermassive black hole mass functions for all galaxy types (left), early-types (centre) and late-types (right). The early-types dominate the total SMBH mass function throughout.

type galaxies based on a sub-sample of ~2000 high-signal-to-noise galaxy bulges and ellipticals (see Fig. 3). A key conclusion is that ~0.01% of the baryons are currently locked up in SMBHs at the centres of galaxies.

4. Dust attenuation of bulges and discs

Looking at the characteristic turnover luminosity (L*) of bulges and discs versus inclination we have identified dramatic attenuation-inclination relations for each component (Driver et al. 2007a). Fitting sophisticated dust models (Tuffs et al. 2004) which incorporate the 3D geometrical distribution, grain composition and clumpiness, has enabled us to also constrain the face-on attenuation for bulges and discs. The rather shocking result is that in the B-band only 63 per cent of the photons produced in discs actually emerge from the galaxies. The situation is even worse for bulges: only 29 per cent of the B-band photons produced by bulge stars manage to escape to the IGM. For a single galaxy the total B-band internal dust attenuation can be anything from 0.2 to 2.5 mag depending on inclination (i) and bulge-to-total ratio (see Fig. 4). This has severe implications for estimates of the nearby luminosity function, luminosity density, and stellar mass estimates as well as for comparative evolutionary studies to higher redshift samples drawn from HST.

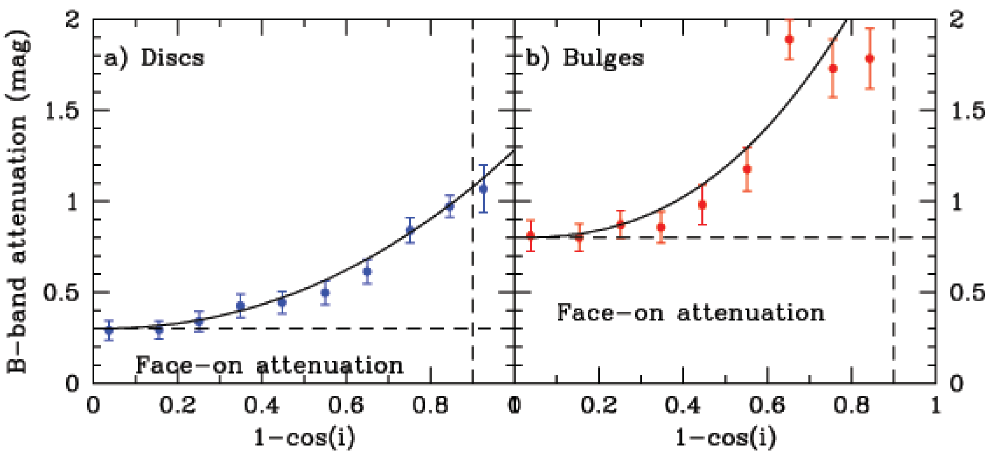

Figure 4: Dust attenuation in the B band for galaxy discs (left) and bulges (right) versus inclination (i). The inclination dependence is empirically derived and the face-on attenuation based on detailed dust models.

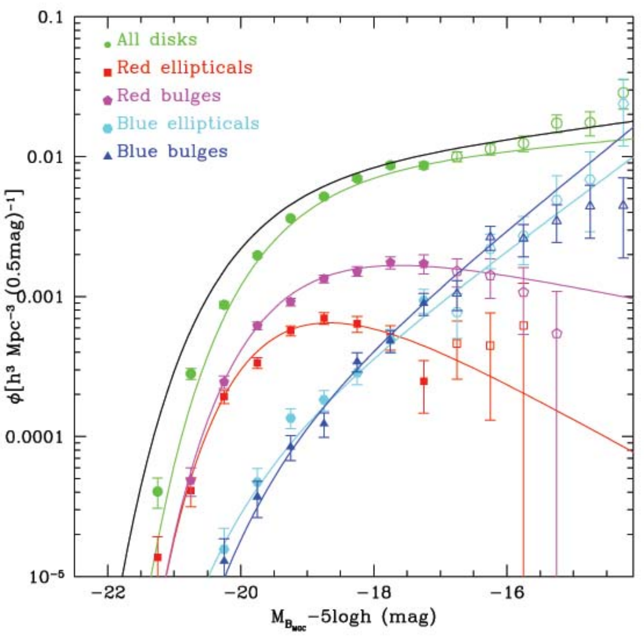

Figure 5: The luminosity functions (crude proxies for stellar mass functions) for the distinct galaxy components. It is clear that distinct structures occur over distinct luminosity ranges. The explanation for this is not yet clear.

5. The luminosity function of bulges and discs

It is possible (Driver et al. 2007a,b, see Fig. 5) to derive independent luminosity functions for bulges and discs, before and after dust correction, and convert this to stellar mass. In doing so we find that 60% of the baryons in the form of stars exist in galactic disks, 10% in ellipticals, and 27% in classical bulges (the remainder are in low luminosity blue spheroidal stellar systems). This is important for theories of galaxy formation based on hierarchical merging, which generally predict that a much higher fraction of stars should reside in spheroidal structures (i.e., merger products). That the majority of the stellar mass is in extended discs, which are dynamically unstable to major mergers, implies that while the merger mechanism is important it is a minor player compared to the disc formation mechanism – which is presumably driven by infall, splashback and accretion.

6. The global B-band luminosity function

The two key aims of the 2dFGRS were to quantify the large scale structure in the Universe and to measure the galaxy luminosity function. It is the combination of these two measurements which can be used to effectively constrain cosmological parameters (see Cole et al. 2005). The MGC cannot address the former because of its limited size, but can and has revised the latter (Driver & Liske 2007). Primarily because of dust attenuation, the MGC reveals that the B-band luminosity function reported by the 2dFGRS (Norberg et al. 2002) requires significant revision (a 10 σ shift). Fig. 6 shows the rather dramatic progression of the B-band galaxy luminosity function as one incorporates a variety of factors. By far the most crucial is the impact of correction for internal dust attenuation previously ignored in these types of studies.

Summary

The MGC is providing a clearer picture of the types of structures which exist, their frequency, and their mass/luminosity dependence, on the 1–100 kpc scale. The MGC results to date point firmly towards a two-stage process of galaxy formation with early and rapid formation of the giant spheroids followed by the slower quiescent process of disc formation. As is often the case, more questions are raised than resolved, most

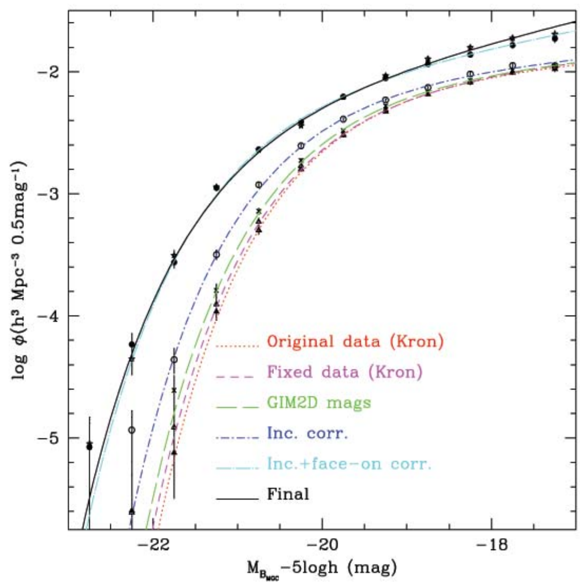

Figure 6: The impact of dust attenuation on the global B band galaxy luminosity function. Note that the original data agrees extremely well with that derived by the 2dFGRS which also ignored dust attenuation. Clearly dust is playing havoc in our optical based studies.

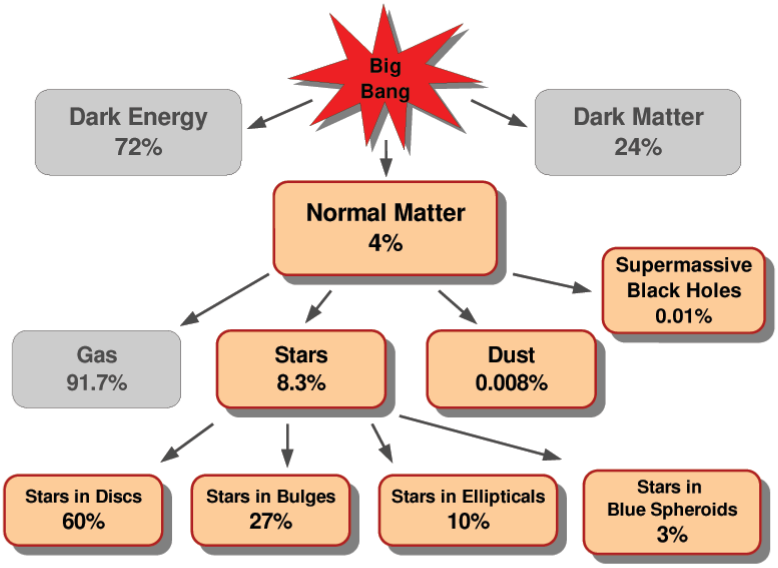

Figure 7: Today's cosmic inventory of the baryons formed in the Big Bang. We see that the largest processed component is in the form of stars that predominantly reside in galaxy discs, these are not easily preserved during major merger events.

notably whether spheroid formation at lower luminosity is continuing today, as evidenced by the abundance of low luminosity blue ellipticals identified at the survey limits.

Plans are afoot (GAMA; Driver, Peacock, Liske, Baldry) to massively expand the MGC program to a K-band flux-limited survey with 10x larger area, greater depth, spatial resolution, spectral resolution and broader wavelength coverage (UV-radio). The main motivation is to enable a study of all of the above as a function of environment, to consider the full spectral energy output for each galaxy component, and to enable a detailed study of intermediate scales (100 kpc – 1 Mpc). This latter aspect is key to placing further constraints on dark matter via the halo mass function.

Finally, the cosmic inventory (Fig. 7) provides a summary of our estimate as to where the baryons produced in the Big Bang reside today. It is known that at a redshift of ~1500 they were in a uniform diffuse neutral state and their movement from that phase to the one shown in Fig.7 is essentially the highly non-linear process of galaxy formation. It is expected that repeating the type of analysis performed on the MGC at higher redshift (with JWST) and to finer levels of complexity will eventually provide the empirical scaffolding from which the final model of galaxy formation will hang. In the meantime significant work needs to be done to complete our zero redshift census.

We would like to especially thank all of the staff at the Anglo-Australian Observatory for their professionalism and dedication in bringing about the 2dF facility and making it such a leading instrument.

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ASTEROSEISMOLOGY WITH UCLES

Tim Bedding (U. Sydney) for the UCLES asteroseismology team

The past few years have seen great progress in measuring oscillations in solar-type stars, thanks to the tremendous velocity precision being developed for hunting planets. On the AAT, UCLES with the iodine cell plays a vital role in measuring stellar oscillations, not least because the longitude of the AAT makes it central to obtaining temporal coverage that is as continuous as possible. Multi-longitude observations reduce the once-per-day aliasing that is a big problem for single-site observations.

Measuring stellar oscillations is a very elegant experiment in physics. A star is a gaseous sphere that oscillates in many different modes when excited. The oscillation frequencies depend on the sound speed inside the star, which in turn depends on properties such as density, temperature and composition. The Sun oscillates in many modes simultaneously and comparing the mode frequencies with theoretical calculations (helioseismology) has led to significant revisions to solar models (e.g. Christensen-Dalsgaard 2002). The recent revision of solar abundances poses a new challenge (see Asplund 2004) in which helioseismology is sure to play an important role.

Measuring oscillation frequencies in other stars (asteroseismology) allows us to probe their interiors in exquisite detail and study phenomena that do not occur in the Sun. We expect asteroseismology to produce major advances in our understanding of stellar structure and evolution, and of the underlying physical processes.

The difficulty in observing solar-like oscillations lies in their tiny amplitudes (less than a metre per second). Thanks to the Doppler precision provided by spectrographs such as UCLES, UVES and HARPS, the field of asteroseismology has finally become a reality. Here we summarise the recent results by our group, in which UCLES has been central.

1. α Centauri A & B: our nearest neighbours

Our two-site observations with UVES and UCLES of both components of the α Cen binary system (G2 V, K1 V) were extremely successful (Butler et al. 2004, Bedding et al. 2004, Kjeldsen et al. 2005). As shown in Fig. 1, oscillations are clearly visible in the time series of α Cen A, with a precision comparable to that obtained on the Sun by the SOHO spacecraft.

The noise floor at high frequencies in the Fourier

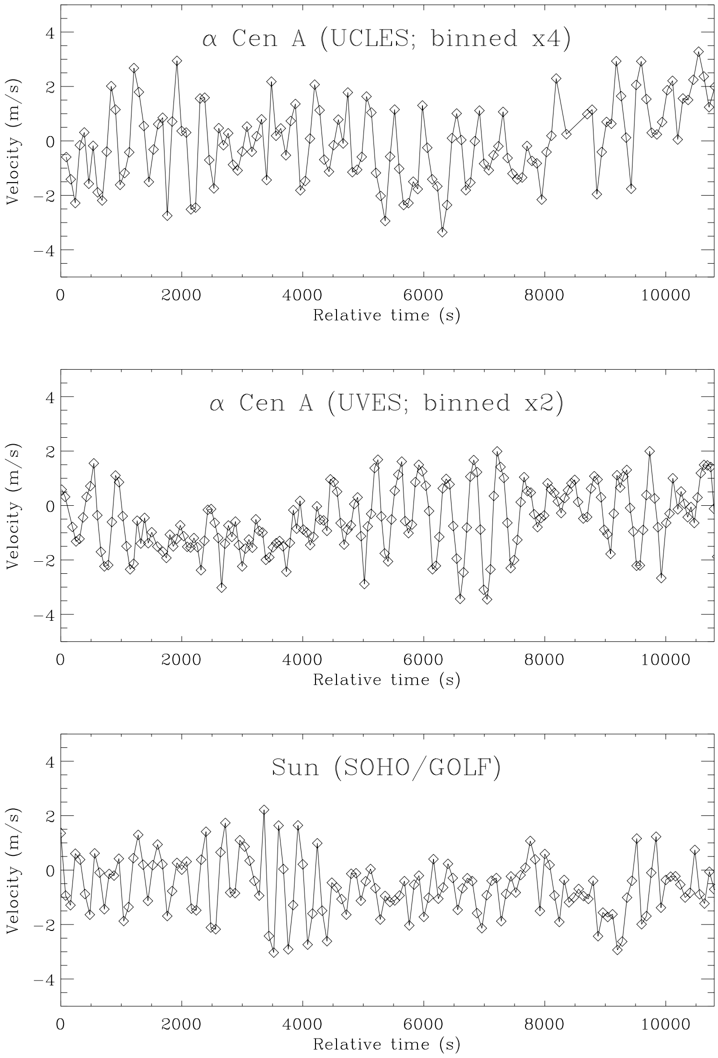

Figure 1: Velocity measurements of α Cen A from UCLES and UVES (top two panels), in which oscillations are clearly visible in the time series. The precision is comparable to that obtained by the SOHO spacecraft for the well-known 5-minute oscillations in the Sun (bottom panel). See Butler et al. (2004, ApJ 600, L75).

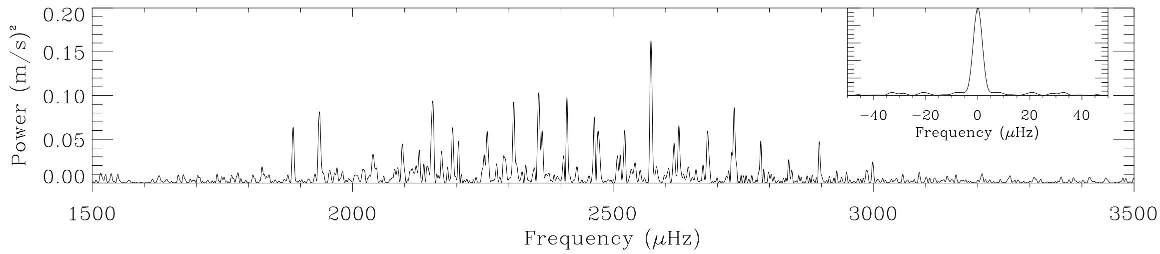

Figure 2: Power spectrum of oscillations in α Cen A, from velocity observations with UCLES and UVES. The inset shows the spectral window (the response to a pure sine wave), with the frequency scale expanded by a factor of 5. Figure from Bedding et al. (2004, ApJ 614,380).

spectrum is below 2.0 cm/s, making these the most precise observations of stellar velocities ever obtained (see Fig. 2). The power spectra yielded 42 oscillation frequencies in α Cen A and 37 in α Cen B, with degrees l = 0, 1, 2 and 3. We are particularly interested in the so-called small separations between modes with l = 2 and 3 and those with l = 0 and 1. In the A component these should reveal the effects of a possible convective core and allow us to estimate its size. This will be the first direct test of the extent of core overshoot, an issue that is vitally important in stellar evolution models.

2. ν Indi: an old metal-poor star

We made the first application of asteroseismology to a metal-poor object, namely the subgiant star ν Indi ([Fe/H] = –1.4). We measured velocities with UCLES at the AAT and CORALIE on the 1.2-m Swiss telescope on La Silla, Chile. We were able to detect oscillations and infer the large frequency separation. Combining with the location of the star in the H-R diagram and comparing with standard evolutionary models, we were able to place constraints on the stellar parameters (Bedding et al. 2006).

The results are shown in Fig. 3, which plots the parameters of ν Ind (effective temperature, radius, mass and age) for three different choices of the mixing-length parameter. The thin error bars show the range of each parameter based on classical measurements alone (luminosity and temperature), while the thick bars include the constraint provided by our measurement of the large

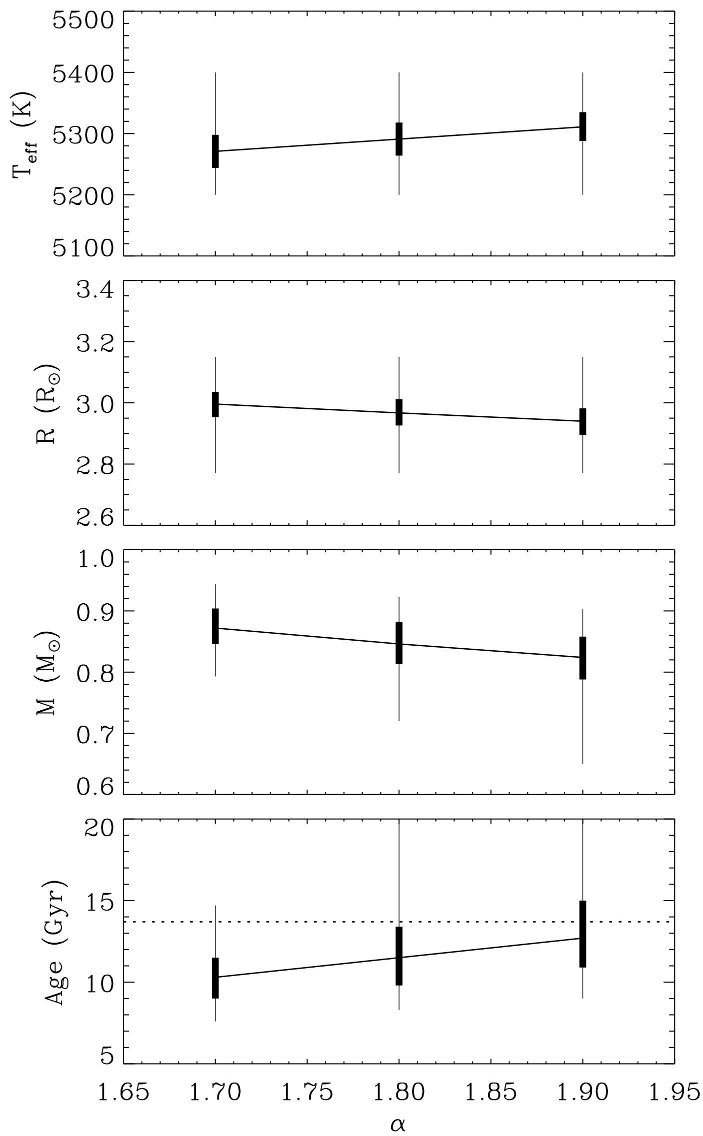

Figure 3: Parameters of ν Ind for three different choices of α, the mixing-length parameter. The thin error bars show the range of each parameter based on classical measurements alone (luminosity and temperature), while the thick bars include the constraint provided by our measurement of the large frequency separation of the oscillations. The dashed line at an age of 13.7 Gyr indicates the upper limit set by age of the universe from cosmology. Figure from Bedding et al. (2006, ApJ 647, 558).

frequency separation of the oscillations. The dashed line at an age of 13.7 Gyr indicates the upper limit set by age of the universe from cosmology. Our results confirm that ν Ind has a low mass (0.85 ±0.04 M_{SOL}) and is at least 9 Gyr old. Analysis of the full set of oscillation frequencies (Carrier et al., submitted to A&A) should allow a test of stellar evolution theory in a low-metallicity star, which is an important step in verifying age determinations for the oldest stars in the Galaxy.

3. β Hyi: a subgiant with mode bumping

β Hydri is a bright southern subgiant that is slightly more massive and much more evolved than the Sun. This was the star we chose five years ago for our first attempt to perform asteroseismology with UCLES, from which we obtained the first clear evidence for solar-like oscillations in any star (AAO Newsletter, Feb 2002, issue 99; Bedding et al. 2001). These single-site observations allowed us to measure the large frequency separation but did not produce unambiguous identification of individual modes. Meanwhile, theoretical models for β Hyi (Fernandes & Monteiro 2003, Di Mauro et al. 2003) have indicated the occurrence of mode bumping, which goes a long way toward explaining our earlier difficulty in mode identification. Mode bumping is an important complication with subgiants in which mode frequencies are shifted from their usual almost-regular spacing by effects of gravity modes in the stellar core. The shifts arise from a strong abundance gradient in the hydrogen-burning shell, just outside the helium core. Quantifying such effects should provide information about the properties of the convective core, including any mixing beyond the region that is convectively unstable (so-called core overshoot). Thus, mode bumping is extremely exciting because it provides a very sensitive measure of conditions in the core (Christensen-Dalsgaard et al. 1995), but it does mean that observations must be as continuous as possible to minimise complications from aliases in the Fourier spectrum.

We recently carried out a dual-site campaign on β Hyi with UCLES at the AAT and HARPS on the ESO 3.6-m telescope (Bedding et al., submitted to ApJ). We confirmed the earlier detection of oscillations and were able to identify nearly 30 modes, including some which show the clear effect of mode bumping (see Fig.4).

We used the large frequency separation of β Hyi to infer the mean stellar density to an accuracy of just 0.6%. Combining this with the angular diameter measured with the Sydney University Stellar Interferometer (SUSI) gives a direct estimate of the stellar mass, to an accuracy of 2.7% (J. North et al.). This is probably the most precise mass determination of a solar-type star that is not in a binary system, illustrating the power of combining asteroseismology and interferometry.

Modelling of the full set of oscillation frequencies in β Hyi should allow us to constrain the two convective parameters: the mixing length and the amount of core overshoot. This will be a crucial test of stellar evolution models in a regime beyond that of the Sun and other main-sequence stars. After a long wait, the field of asteroseismology is finally underway and UCLES at the AAT is playing a crucial role.

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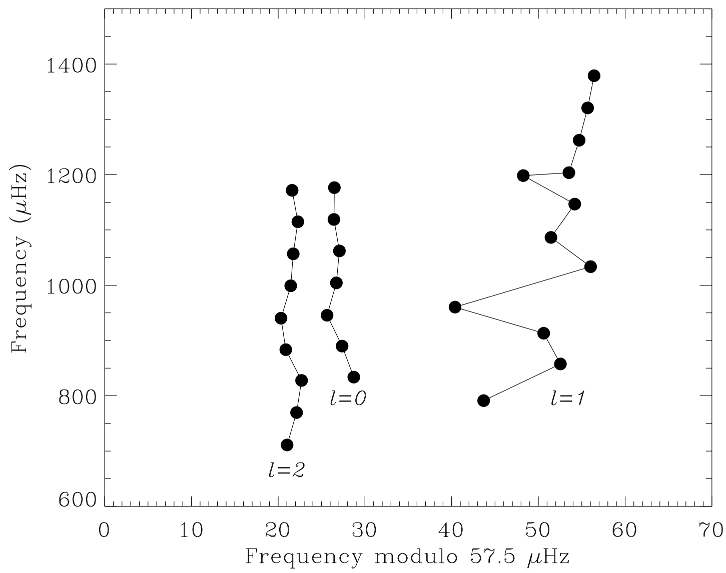

Figure 4: The so-called echelle diagram of oscillations frequencies in the G2 subgiant star β Hyi, based on observations in 2005 with UCLES and HARPS. The measured frequencies are stacked modulo the large frequency separation, and so form nearly vertical ridges. The small separation (between l=0 and 2) measures the core composition. The strong deviations from vertical alignment in the l=1 modes indicate departures from a regular spacing that are due to mode bumping. Figure from Bedding et al. (submitted to ApJ).

HUNTING DOWN BENCHMARK BROWN DWARFS WITH IRIS2

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Introduction

Brown dwarfs (BDs) are generally cool (<2300K), and therefore faint, sub-stellar objects. Complex chemistry occurs within their atmospheres, such as the production of water vapour, dust and methane. These poorly understood sources of opacity make it hard to determine properties such as metallicity, gravity and effective temperature via spectral fitting. The discovery of benchmark brown dwarfs, where properties can be measured or inferred independently of spectra (Pinfield et al. 2006) will provide unprecedented test beds for the models, and could facilitate the spectroscopic measurement of fundamental BD properties. This would allow the substellar initial mass function and formation history to be measured for the field population, revealing all their fundamental implications for star formation theory.

We are currently undertaking a search for BDs as binary companions to white dwarfs and subgiants, in an attempt to discover benchmark systems, where these stars may provide accurate age and composition constraints for the brown dwarf companion. Subgiants evolve rapidly across the H-R diagram, and have long been acknowledged as excellent "chronometers". High mass white dwarfs will have short lived progenitor stars and the cooling age will be an excellent proxy for the binary age.

A Survey for Brown Dwarf Companions to Subgiants

These are ideal primaries for our purpose because their age can be accurately constrained due to the short amount of the total lifetime spent in this evolutionary phase, and because they haven't undergone any mixing or dredging up of materials, which occurs later on during the giant phase. This means that accurate age and metallicity can be measured for a subgiant and inferred for a brown dwarf companion since these properties should be common for binary components.

We are currently embarking on a deep NIR imaging survey using IRIS2 to search around subgiants. This allows candidate brown dwarfs as faint as J=20 to be detected out to distances of 160pc for L-dwarfs (BDs of T_{eff}~2300–1300K) and 40pc for T-dwarfs (T_{eff}~1300–800K).

Our survey technique places the field of view of IRIS2 just above and just below each target so that the subgiant is positioned just off the edge of the array in each case. This allows near complete imaging around the subgiant, while avoiding problems associated with bright PSF wings and diffraction spikes, enabling BD companions to be found out to 20,000AU from the subgiant. Our subgiant sample was taken from the Hipparcos catalogue of stars. They were selected from colour-magnitude diagrams by comparison to theoretical isochrones (Giradi et al. 2000). Figure 1

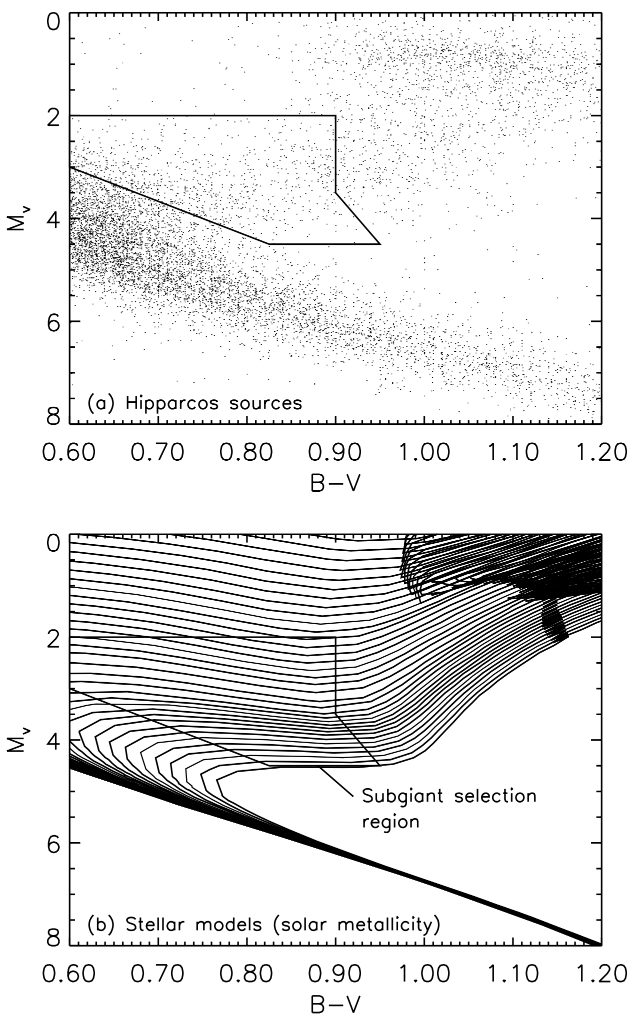

Figure 1. Top: Mv, B-V diagram of Hipparcos stars. Bottom: theoretical isochrones from Girardi at al. (2000). The subgiant selection box is indicated in both plots.

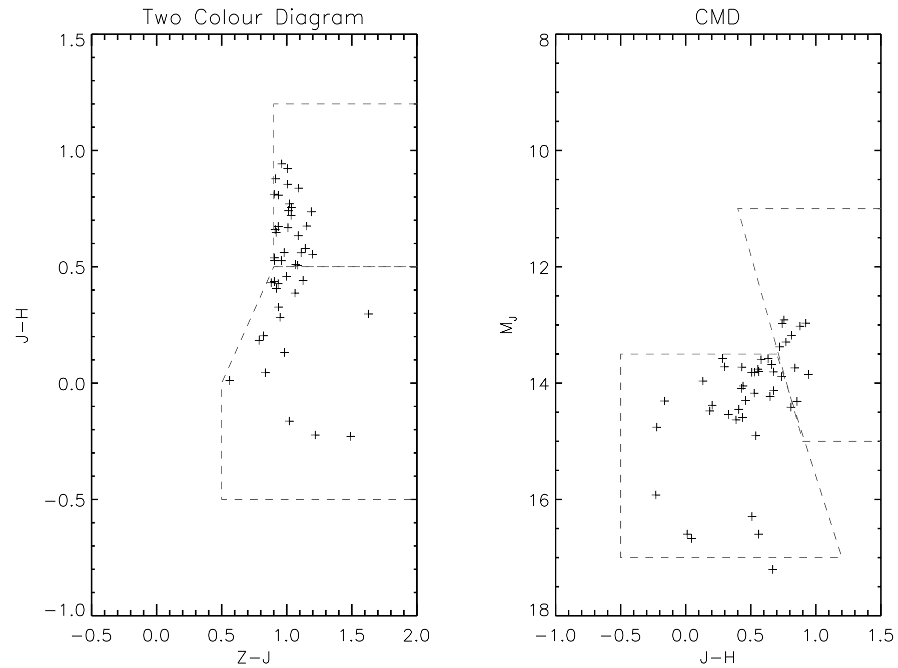

Figure 2. Left: two-colour plot ; and right: CMD of BD candidate binary companions. Red dashed areas are occupied by L-dwarfs, blue dashed areas are occupied by T-dwarfs. L/T transition objects occupy the red two-colour box and the blue CMD box.

shows the selection box that we used to pick our subgiant sample.

Eight nights of observing in December 2005 allowed 70 subgiants to be surveyed. Analysis of these images has revealed ~40 new BD candidates. These were selected from their positions on a two-colour diagram and a colour-magnitude diagram, so that their NIR colours are consistent with being BDs, and their brightnesses are consistent with being at the same distance as the subgiant. The selection regions are shown as dashed boxes on the two-colour and colour-magnitude diagram in Figure 2.

Wide Brown Dwarf Companions to White Dwarfs

We also aim to use white dwarfs in a similar way to the subgiants, to determine the age of a brown dwarf companion. BD companions to white dwarfs are rare, and only 3 are known to date, GD165B (Zuckerman & Becklin 1992), GD 1400 (Farihi & Christopher 2004) and WD0137-349 (Maxted et al. 2006; Burleigh et al. 2006), with the widest system having a separation of 120AU. It is commonplace for BDs to exist in wide binaries to main sequence stars at separations of 1000–5000AU (Pinfield et al. 2006; Gizis et al. 2001). However when a star sheds its envelope as it moves into the white dwarf phase we may expect brown dwarf companions to migrate outwards (Burleigh, Clarke & Hodgkin 2002) to separations of ~4000–20,000AU. Some may be broken apart quite rapidly by gravitational interactions with other stars, but some could survive.

We carried out a search of 2MASS and SuperCOSMOS in the south (Day-Jones et al. 2006) and identified 8 white dwarf/ L-dwarf binary candidates. Of these one was confirmed as a common proper motion binary containing a white dwarf candidate and an ultra-cool dwarf (UCD) candidate (late M or early L) from images taken during service time with IRIS2 in July 2006 (Figure 3). The white dwarf candidate can clearly be seen in the optical and gets fainter moving towards the NIR, whereas the UCD is not visible in the optical but gets a lot brighter in the NIR. The spectrum of the ultra-cool component was also taken earlier in September 2006 with IRIS2. Spectral ratios and a comparison to template spectra were made (Figure 4), revealing a UCD of spectral type M9±1. The white dwarf candidate is being followed up in DDT on the VLT. The nature of the system suggests the distance to the pair is 35–44pc, giving a binary separation of 3000–4000AU. If confirmed, which seems likely, this system would be the widest binary system of its type by an order of magnitude.

Building on this work

With the discovery of the prototype wide UCD-WD binary system almost certain, we plan to expand our search for such binaries to the UKIRT Infrared Deep Sky Survey. We expect to identify many in the 4000 sq degrees of the Large Area Survey (combined with

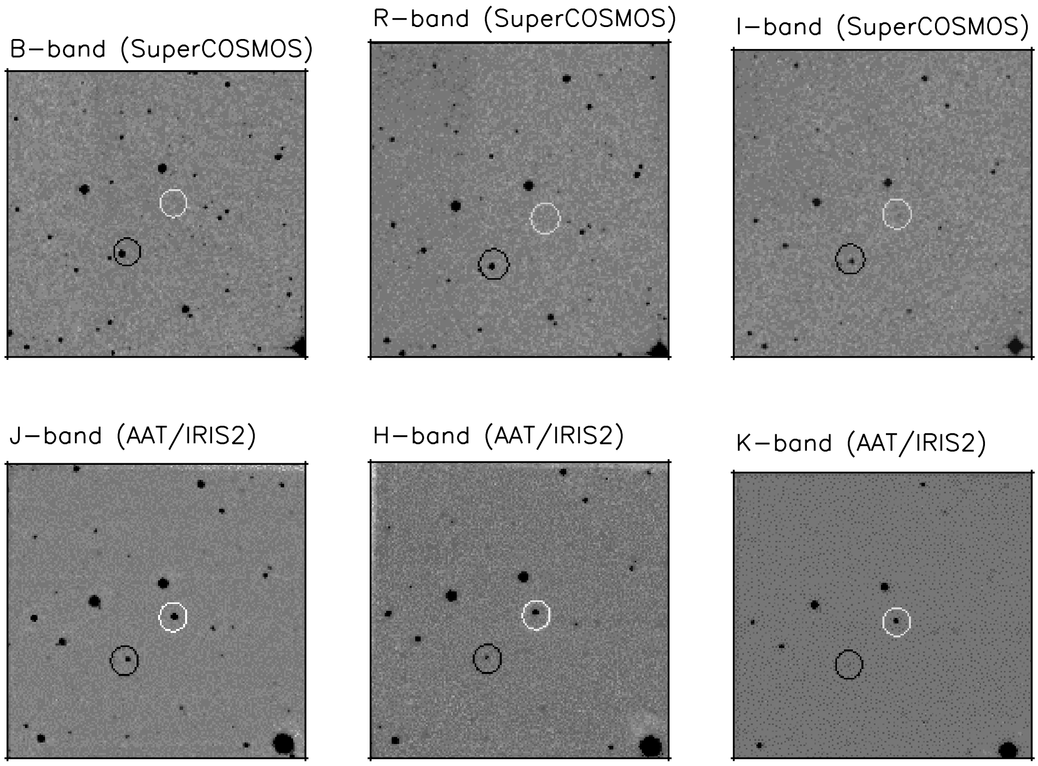

Figure 3: SuperCOSMOS and IRIS2 images of the white dwarf (white circles) and the UCD (black circles) common proper motion pair. The white dwarf can be seen in the optical (B,R,I and just visible in the J and H bands) and the UCD can be seen in the NIR (J, H & K bands).

Sloan), and can single out those containing high mass white dwarfs and so establish well constrained ages for these benchmark brown dwarfs.

We also plan to build on our initial IRIS2 search for benchmark brown dwarf companions to subgiant stars. Following up our candidates with methane imaging and second epoch broad-band observations will allow us to confirm T dwarfs and common proper motion companions in general. Infrared imaging around our full subgiant sample in both the south and the north should allow us to reveal a large sample of benchmark brown dwarfs with well constrained age and composition.

Discoveries made using IRIS2, and surveys like UKIDSS should thus take brown dwarf astronomy into a new domain, where the substellar IMF and formation history of the disk population can be accurately measured. Such knowledge would undoubtedly be extremely revealing for our understanding of the nature of brown dwarfs.

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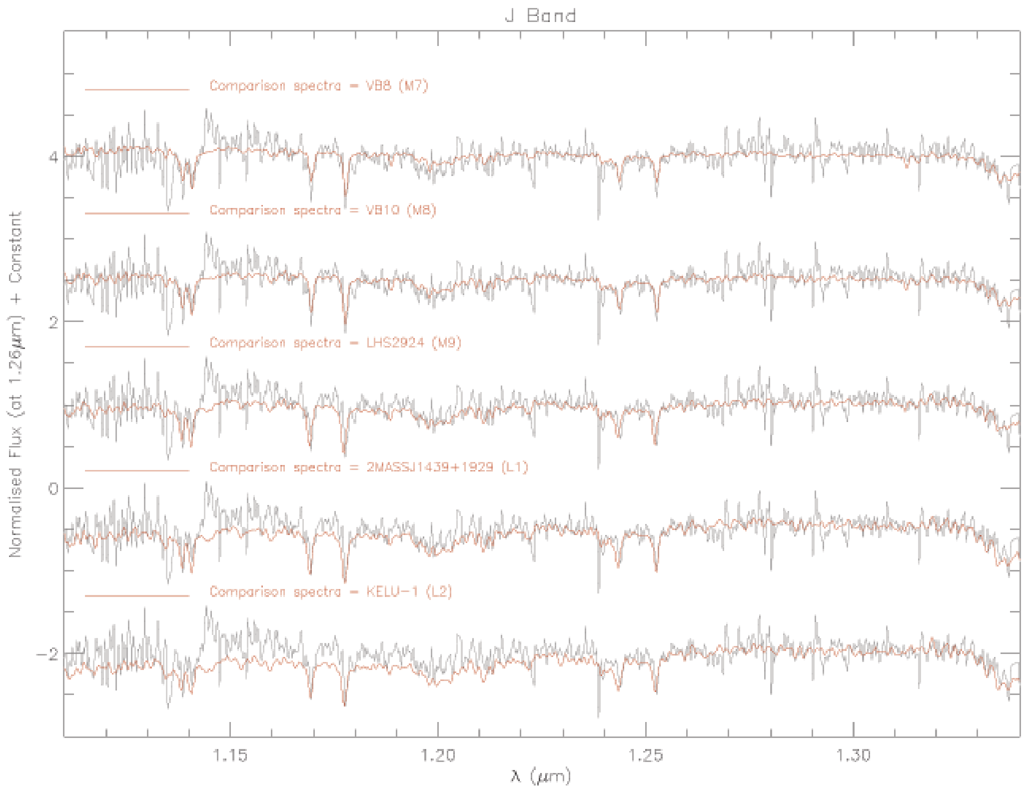

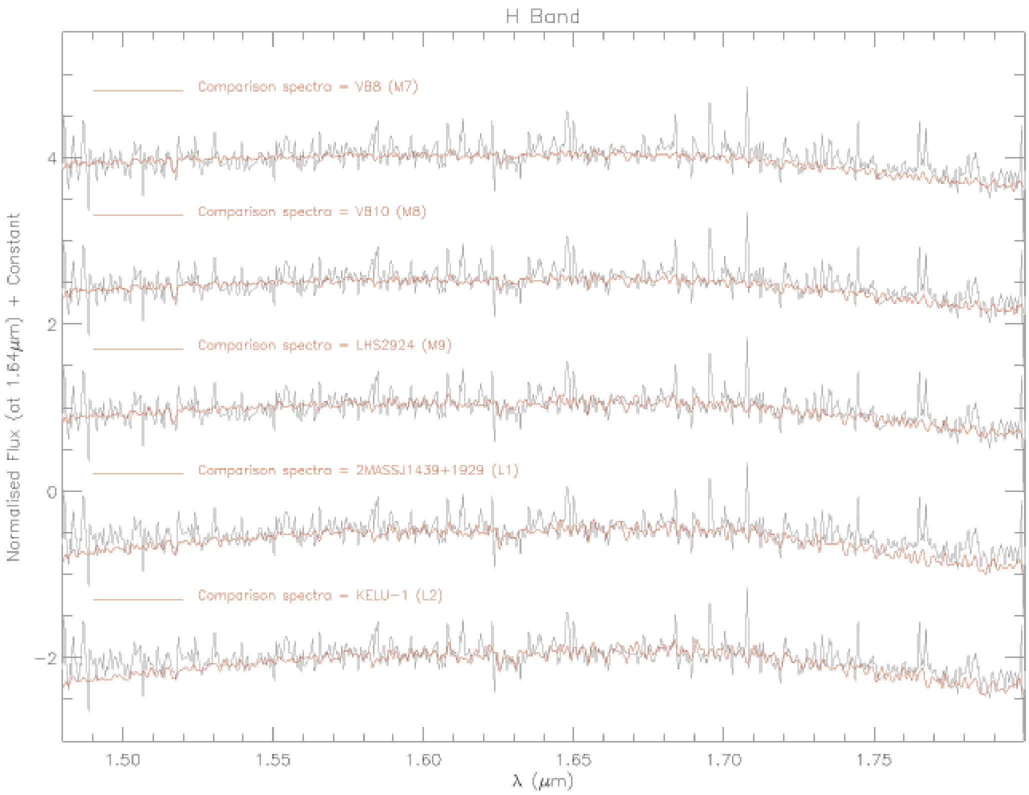

Figure 4a: J band spectra of UCD, normalised at 1.26 μm and 4b: H band spectra, normalised at 1.64μm. Both are overplotted with template spectra from M7-L2.

THE FORMATION OF CLUSTER EARLY-TYPE GALAXIES

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Introduction

The dominant model of galaxy formation involves the hierarchical growth of structure in a ΛCDM universe; small objects form first and undergo mergers building up more massive objects. Within this framework of galaxy formation, the merger history of an early-type galaxy can fall anywhere between two extremes: mergers could occur early-on and rapidly, with subsequent passive evolution (this is essentially the classical view of early-type galaxy formation – the monolithic collapse scenario; Eggen et al. 1962); alternatively the galaxy could experience a more extended history of mergers (the hierarchical merging scenario; Searle & Zinn 1978).

The question of which scenario is most applicable to the formation of cluster early-type galaxies is undecided. The high relative velocities of cluster galaxies are thought to prevent late merger activity and argue against an extended hierarchical merging scenario, while stellar population studies have consistently shown a significant age spread amongst cluster early-types that is difficult to reconcile with a near-instantaneous monolithic collapse scenario.

Here we summarise the results from a substantial spectroscopic study of the stellar populations in cluster early-type galaxies that addresses this issue.

Observations and Reductions

The sample of galaxies used in this study was drawn from four low-redshift clusters (Coma, A1139, A3558, and A0930 at $\langle z \rangle = 0.04$), and one intermediate-redshift cluster (A0370 at $z = 0.374$). Observations were made using 2dF on the AAT and FLAMES on the VLT, and spectra were obtained for ~450 galaxies from which redshifts (z), velocity dispersions (σ), and Lick indices (Burstein et al. 1984; Trager 1997 and references therein) were measured. Standard methods were used to calibrate the indices to the Lick system (e.g. see Kuntschner 2000). Using a χ^2 method (Proctor et al. 2004) coupled with up-to-date stellar population models incorporating variable element abundances (Thomas et al. 2003), mean luminosity-weighted ages (t), metallicities ([Z/H]), and α-element abundance ratios ([α/Fe]) were estimated from the strengths of the Hβ, Mg*b*, and Fe5335 indices for ~120 galaxies. These data allowed us to investigate in detail the stellar populations of early-type galaxies in low-z clusters and track the evolution of cluster early-type galaxies over 30% of the Hubble time.

Scaling Relations

The strengths of most metal-sensitive indices are found to correlate with σ, while the strength of Hβ, the only age-sensitive index measured, is found to be anti-correlated. Ignoring the fact that all indices are sensitive at some level to changes in age, [Z/H], and [α/Fe], the simplest interpretation of these correlations is that more massive galaxies are older and more metal-rich than less massive galaxies.

The Mg-σ and Hβ-σ relations have been well studied, and the relations found in this study are consistent with

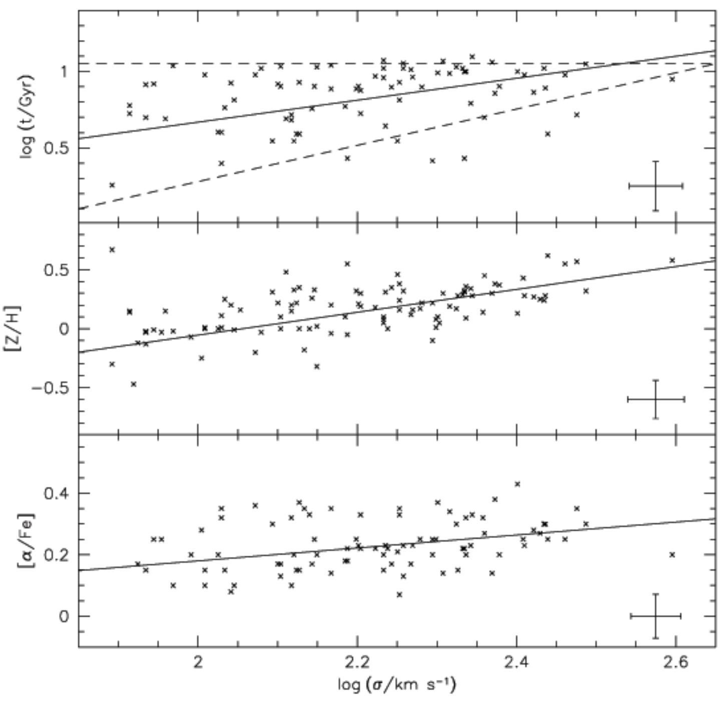

Figure 1: The variation of logarithmic age (top), [Z/H] (middle), and [α/Fe] (bottom) with σ. Mean error bars are given in the lower right corner of each panel. The solid lines in each panel are our fits and the dashed lines in the top panel are for illustrative purposes only. Note, only galaxies for which reliable error estimates could be obtained were used to calculate the fits.

those found in the literature. Inconsistent results have been found regarding the ⟨Fe⟩-σ relation (⟨Fe⟩ ≡ (Fe5270+Fe5335)/2), with most previous studies having found at most only a weak correlation, whereas we find a strong, highly significant correlation between ⟨Fe⟩ and σ, consistent with that found by Kuntschner et al. (2001). The change in [Z/H] with σ implied from the ⟨Fe⟩-σ relation is less than half that shown by the Mg-σ relation, and implies that the abundance ratios also vary as a function of σ.

The above results are confirmed when the variations of the stellar population parameters, derived from several indices jointly, are examined as a function of σ (Figure 1). The top panel shows the relation between logarithmic age and σ. The two quantities are found to be moderately correlated at the 2σ level. The correlation appears to be driven by the youngest galaxies at a given σ – i.e. at all σ there exist galaxies with old stellar populations, but the age of the youngest galaxy increases with σ. This result is consistent with the concept of down-sizing (Cowie 1996), where the typical mass of a star-forming galaxy increases with *z*.

The relation between [Z/H] and σ is shown in the middle panel. The two quantities are highly correlated at a significance level greater than 5σ. [α/Fe] and σ are found to be moderately correlated at a 3σ significance level, as shown in the bottom panel. α-elements are produced mainly by SNII while Fe-peak elements are produced mainly by SNIa. Since there is a delay between the onsets of these two types of SN (with SNII occurring within tens of millions of years of a burst of star-formation and SNIa only occurring after about 3 Gyr), the ratio of α-elements to Fe provides an indication of the star-formation timescale.

Taken as a whole, the above three relations imply that more massive galaxies are on average older, formed their stars in a shorter and more intense burst, and are more metal-rich than less massive galaxies.

Stellar Population Parameter Distributions

We estimated stellar population parameters for 103 galaxies from our four low-*z* clusters. The distributions of ages and [Z/H] in each of the four clusters are found to be consistent with being drawn from the same distribution. There is, however, a significant difference between the [α/Fe] distributions in Coma and A3558. The median [α/Fe] in Coma is 0.2 dex while in A3558 it is 0.32 dex. Using the linear relation between [α/Fe] and log(*t*) (Thomas et al. 2005) we find that, on average, galaxies in the Coma cluster formed their stars on timescales <1 Gyr while those in A3558 have a remarkably short star-formation timescale of <200 Myr. Semi-analytic models predict that star-formation should occur more rapidly in regions of high density (De Lucia 2006) – both Coma and A3558 are extremely rich clusters, and in such environments the median [α/Fe] is expected to be large. However, Coma is known to have substructures related to on-going accretion of a galaxy group, and such accretion, if accompanied by extended periods of star-formation, could lower the median [α/Fe]. Both A0930 and A1139, which are relatively poor clusters, are found to be more consistent with Coma than A3558.

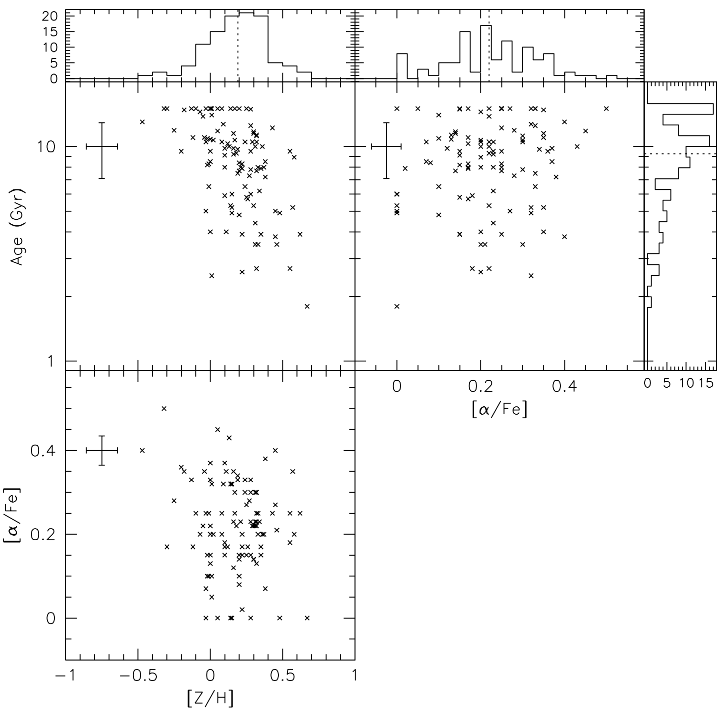

Figure 2: The distributions of the stellar population parameters in our four low-*z* clusters. Mean error bars are given in the top left corner of each panel. Marginal distributions are shown for each parameter in which the median value is shown as a dotted line.

The combined data from all four clusters (Figure 2) is found to have a mean age of ~9.2±0.5 Gyr, a mean [Z/H] of ~0.19±0.02 dex, and a mean [α/Fe] of 0.22±0.01 dex. Errors on these quantities were estimated via Monte Carlo

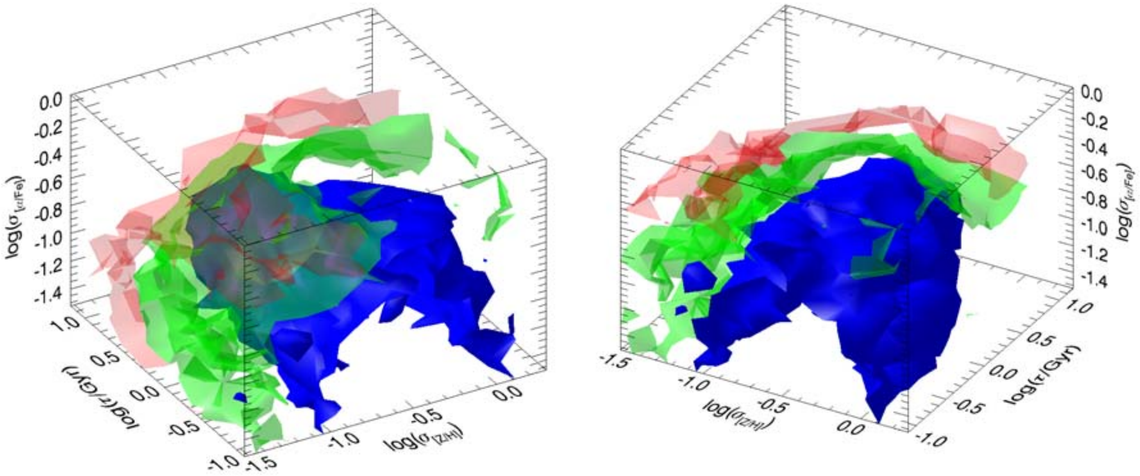

Figure 3: The 3D confidence contours on the e-folding time for the ages and the Gaussian scatter in [Z/H] and [α/Fe] generated from the numerical simulations described in the text. The blue, green, and red surfaces are the 1σ, 2σ, and 3σ confidence contours.

simulations taking into account the observational errors in the indices. Most of the galaxies exhibit old ages, but a small number of galaxies are found to have younger ages, possibly due to a recent episode of star formation. The [Z/H] are found to be almost exclusively super-solar. Looking at the marginal distributions, the ages follow an approximately exponential distribution, while the other two parameters' distributions are approximately Gaussian.

There are ~12 galaxies which have t≈15 Gyr and six galaxies which have [α/Fe]≈0. The galaxies with extremely old ages possibly suffer from nebular Hβ emission in-fill, which weakens the strength of the Hβ index and leads to older estimated ages. The galaxies with solar [α/Fe] are extremely interesting and will be discussed later.

Numerical simulations were performed to determine the amount of *intrinsic* scatter present in each of the stellar population parameter distributions. The method used is as follows. We begin by selecting a range of *e*-folding times for the exponential age distribution, and a range of scatters for both the [Z/H] and [α/Fe] Gaussian distributions, with the median [Z/H] and [α/Fe] used as the distribution means. Then, for a given combination of *e*-folding time and scatters, we generate a model consisting of 10,000 combinations of stellar population parameters. These combinations were converted to Hβ, Mg*b*, and Fe5335 index strengths using the Thomas et al. models, and these in turn were perturbed using errors drawn from the observed galaxies' index error distributions. Stellar population parameters were then estimated from these perturbed index strengths using precisely the same method used on the actual data. The model distribution was lightly smoothed, and the likelihood statistic of the observed galaxy distribution was calculated. Probabilities were estimated from Monte Carlo simulations. The process was repeated for all combinations of *e*-folding times and scatters. Figure 3 shows the 3D confidence contours generated from these simulations, while slices through the 3D confidence contours parallel to the *t*-[Z/H] plane are shown in Figure 4.

These simulations provide us with a great deal of information regarding the intrinsic scatter in each of the stellar population parameters, which we summarise here. Firstly, it is difficult to constrain the *e*-folding time. This is due to small uncertainties in index strengths translating to large changes in the age estimate, combined with relatively large observational errors in the Hβ index. Although models with small values of *e*-folding time are not ruled out, we find that our data is most consistent with the model having τ ~900 Myr. Secondly, small scatters in [Z/H] ($\sigma_{[Z/H]}$<0.1) are strongly ruled out, as are large scatters ($\sigma_{[Z/H]}$>2). We find the model with $\sigma_{[Z/H]}$~0.3 is the most consistent with our data. Finally, large scatters in [α/Fe] ($\sigma_{[\alpha/Fe]}$>0.3) are also strongly ruled out. Models with low scatters in the [α/Fe] are not ruled out, but we find that the most consistent model is that with $\sigma_{[\alpha/Fe]}$~0.07.

The intrinsic scatters in the [Z/H] and the [α/Fe] distributions found in the above simulations are consistent with the correlations found between σ and these two parameters – since both these quantities scale with σ and since the galaxies in our low-*z* cluster sample have 80≤σ≤400 km s^{-1}, we would expect both these quantities to have some intrinsic scatter. The

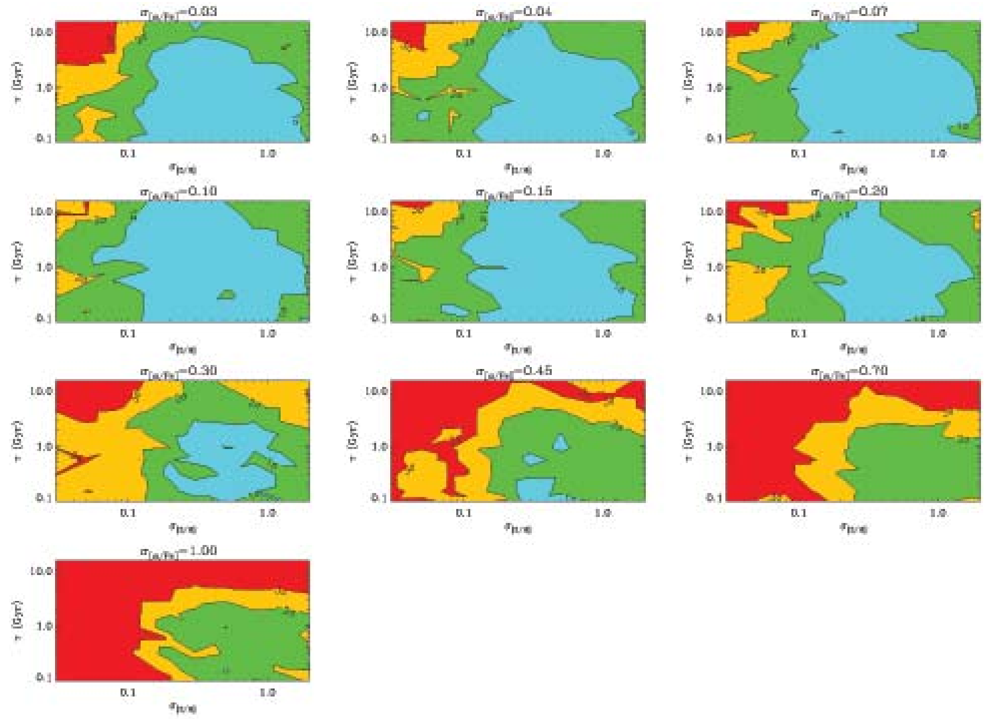

Figure 4: Slices, parallel to the *t*-[Z/H] plane, through the 3D confidence contours shown in Figure 3. The value of the [α/Fe] scatter used to generate the model is shown at the top of each panel.

correlation between age and σ is only marginal, yet the above numerical simulations indicate a spread in ages greater than that caused by our observational errors, implying a genuine range in the stellar population ages that is not significantly correlated with galaxy mass.

If cluster early-type galaxies formed via the monolithic collapse model then this age spread requires an explanation. One possibility is that most stellar population models do not take into account the contribution of UV sources to the integrated light from a galaxy. Contributions to the mid-UV flux from old, metal-poor stars (Maraston & Thomas 2000) or to the far-UV flux from old metal-rich stars (De Propris 2000) can lead to galaxies appearing ~5 Gyr younger than they really are. This would amplify any spread in ages and possibly account for the spread that we see.

Of course the straightforward explanation of the age spread is that some cluster early-type galaxies formed via the hierarchical merging scenario (with at least some of the mergers being 'wet' and resulting in star-formation), or at least have not evolved purely passively since their formation was completed at high *z*. A small fraction of stars produced in a more recent star-formation episode, induced by a merger or some other process such as harassment (Moore et al. 1998), would contribute a disproportionate amount to the total luminosity causing the galaxy to appear younger (see the frosting models by Trager et al. 2000). The fact that late star-formation results in lowering [α/Fe], which is inconsistent with the high [α/Fe] found for most early-type galaxies, has been used as an argument against such a frosting model (Maraston & Thomas 2000). Recalling the six galaxies estimated to have [α/Fe]≈0, we find that five of these six galaxies also have ages <6 Gyr. It seems plausible that these five galaxies may have undergone an episode of star-formation <6 Gyr ago and consequently have lower [α/Fe]. The existence of these galaxies, while not ruling out the UV sources as the cause of the lower ages for some of the younger galaxies, shows that at least some cluster early-type galaxies did not form all their stars in a monolithic collapse but had some level of later star-formation that frosted the older stellar population with younger stars.

The Stellar Populations in A0370

Stellar population parameters were estimated for 12 galaxies from our intermediate-*z* cluster, A0370. The stellar population parameter distributions are shown in Figure 5.

We find that the galaxies in A0370 have a median age of 4.1±2.6 Gyr, a median [Z/H] of 0.41±0.13, and a median [α/Fe] of 0.15±0.09. Two-sample 2D KS testing shows that the distributions of both [Z/H] and [α/Fe] in A0370 are consistent with those found in our low-*z* clusters. The age distributions, however are found to be significantly different. The difference between the

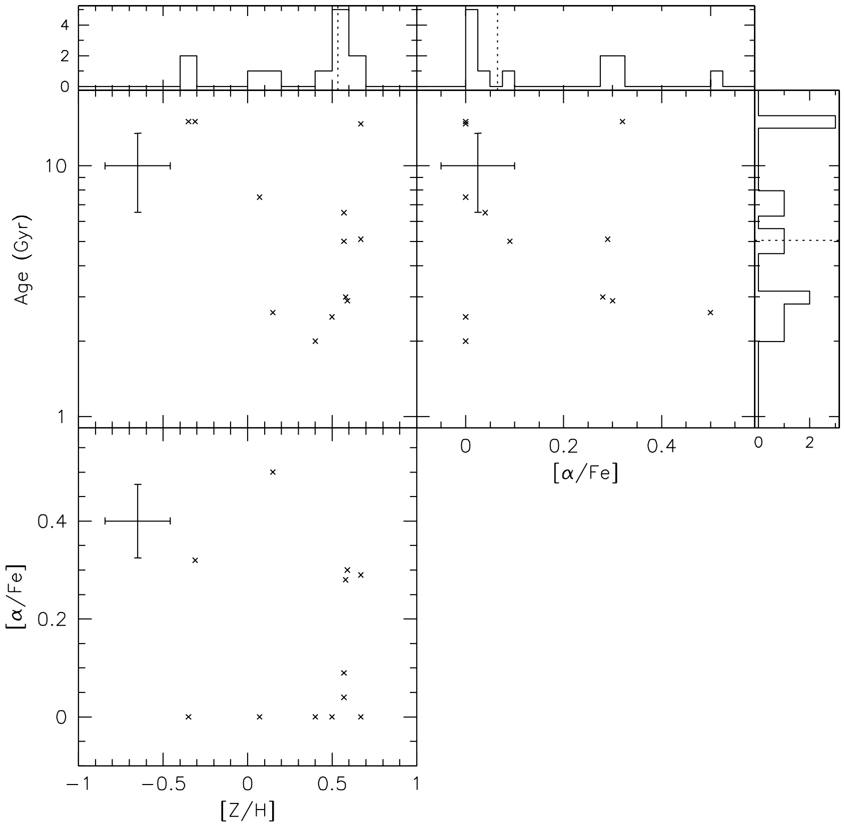

Figure 5: The distributions of the stellar population parameters in our intermediate-*z* cluster, A0370. Mean error bars are given in the top left corner of each panel. Marginal distributions are shown for each parameter and the median value is shown as a dotted line.

mean age of our low-*z* cluster galaxies and that of the A0370 galaxies is ~5 Gyr, which is approximately the difference in look-back time between *z*=0.04 and *z*=0.374. If this age difference is taken into account, then the distributions are found to be consistent. These results suggest that, on average, the galaxies in our low-*z* clusters are passively evolved versions of those in A0370.

In conclusion, we find that the age and [Z/H] distributions in our four low-*z* clusters are remarkably similar, but that the distributions of [α/Fe] are not, with the differences possibly due to the varying richness of the clusters. [Z/H] and [α/Fe] are found to scale with galaxy mass, with more massive galaxies being more metal-rich and forming their stars in shorter, more intense bursts. Age is only marginally correlated with galaxy mass, but we find that at all σ there exist old galaxies, and that the mass of a typical star-forming galaxy is found to increase with *z*. Small amounts of intrinsic scatter are found for each of the stellar population parameters; for [Z/H] and [α/Fe] this is most likely due to their correlation with σ. The scatter in age is in a small part due to its relation with σ but possibly also due to some galaxies experiencing a more recent episode of star-formation, which lowers their estimated age. Finally, we find that the low-*z* cluster galaxies are, on average, consistent with being passively evolved versions of the galaxies in A0370.

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EXAMPLES OF NEW EVOLVED PLANETARY NEBULAE FROM THE SUPERCOSMOS H-ALPHA SURVEY

Jayne Birkby (AAO UK Summer Vacation Scholar/Durham University), Quentin Parker, Brent Miszalski, Agnes Acker & David Frew (AAO/Macquarie University, ULP, Strasbourg & Perth Observatory)

Planetary nebulae (PNe) are a common but cosmically brief phenomenon that occurs in the late phases of stellar evolution for low- to intermediate-mass stars (1 to 8 M_{SOL}). The precise mechanisms that produce the intricate and beautiful shapes of PNe are still poorly understood, but in simple terms, a PN is just a rearrangement of previously ejected matter from an evolved progenitor star that may or may not have a close binary companion, a model known as the Interacting Stellar Winds (ISW) model (e.g. Kwok, 2000).

Once the remnant central star becomes hot enough ($T \sim 2.5 \times 10^4$K), it emits most of its energy as UV radiation. The resultant hard radiation field photoionises the atoms in the previously expelled gaseous shell which leads to the emission of recombination and collisionally-excited forbidden spectral lines. The most prominent of these lines are the Hα 6563Å line and, in the absence of appreciable extinction, the usually stronger [OIII]$\lambda\lambda$4959, 5007 forbidden lines.

However, PNe become rapidly unobservable due to the combination of a typical expansion velocity of ~25kms^{-1}, the decreasing low density of the gas (10^2 – 10^4 cm^{-3}) and the declining luminosity of the central star (M_v = –3 to +5) as it descends into the white dwarf phase. The decrease in emission yields a mean PN lifetime of only ~10^4yrs (Zijlstra & Pottasch, 1991). Unsurprisingly, this makes many PNe hard to find without large area, highly sensitive, narrowband surveys (sampling one of the strong emission lines), which probe to faint limits across much of the Galactic Plane.

Fortunately, the advent of the AAO/UKST Hα survey of the Southern Galactic Plane (Parker et al., 2005) provides just such a dataset. Indeed, careful visual examination of the original survey fields, supplemented after 2003 by access to the digital survey data, has led to 900+ new Galactic PNe being uncovered. These have been reported recently in the Macquarie/AAO/Strasbourg Hα Planetary Nebula Project (MASH) catalogue: Parker et al. (2006)[1]. Despite this 60% increase in known Galactic PNe (the most significant incremental addition in 100 years) the full potential of the on-line survey data (the SuperCOSMOS Hα survey or SHS) had not been fully realised. Despite the gain in depth made possible by the AAO/UKST Hα Survey, MASH has omitted numerous compact 'star-like' PNe along the southern plane due to the initial discovery techniques employed not being sensitive to faint, point-like emitters. A number of very low surface brightness, large, evolved candidate PNe have also been overlooked. This new work will go a long way to addressing the currently under-represented highly evolved and young PNe in both the MASH and all previous catalogues.

This summer AAO research project was designed specifically to tackle the issue of missing, large, low-surface brightness PNe candidates using improved techniques to uncover additional sources from the digital SHS data. This was greatly aided by the functionality offered by the DS9 visualisation software[2] and plugins developed by one of us (BM) to facilitate efficient multi-wavelength image comparisons and cross-checking with SIMBAD.

Although full digital resolution (10μm/0.67" pixel) data from the SHS can be downloaded from the survey web site, this is time-consuming for large area searches. Fortunately, each SHS survey field is also available in blocked-down form (a factor of 16 in each dimension) as individual FITS files which still incorporate an accurate World Co-ordinate System (WCS) in the FITS header. Frew and Parker (2005) had already examined the blocked down Hα images looking for extended, low-surface brightness nebulosities, but for this project quotient images were created by dividing the blocked down full field Hα data by the matching short-read (SR) counterpart (the blocked-down SR data was not previously available). The entire 233 survey fields were re-examined in this form. The blocking has the effect of enhancing low surface brightness features and, with the ability to directly tweak the contrast in the quotient images, many promising new large-scale PNe candidates have been uncovered. Of course, spectroscopic follow-up is required to properly characterise the nature of many of these new candidates, though comparisons with MSX and 2MASS data are also useful, as is the identification of possible blue central star candidates from examination of the existing on-line SuperCOSMOS B_J images. Colour composites using the Hα/SR and B_J SuperCOSMOS images were also created for the candidates and three of the most promising are presented here.

[1] http://vizier.u-strasbg.fr/vizier/MASH/

[2] http://hea-www.harvard.edu/RD/ds9

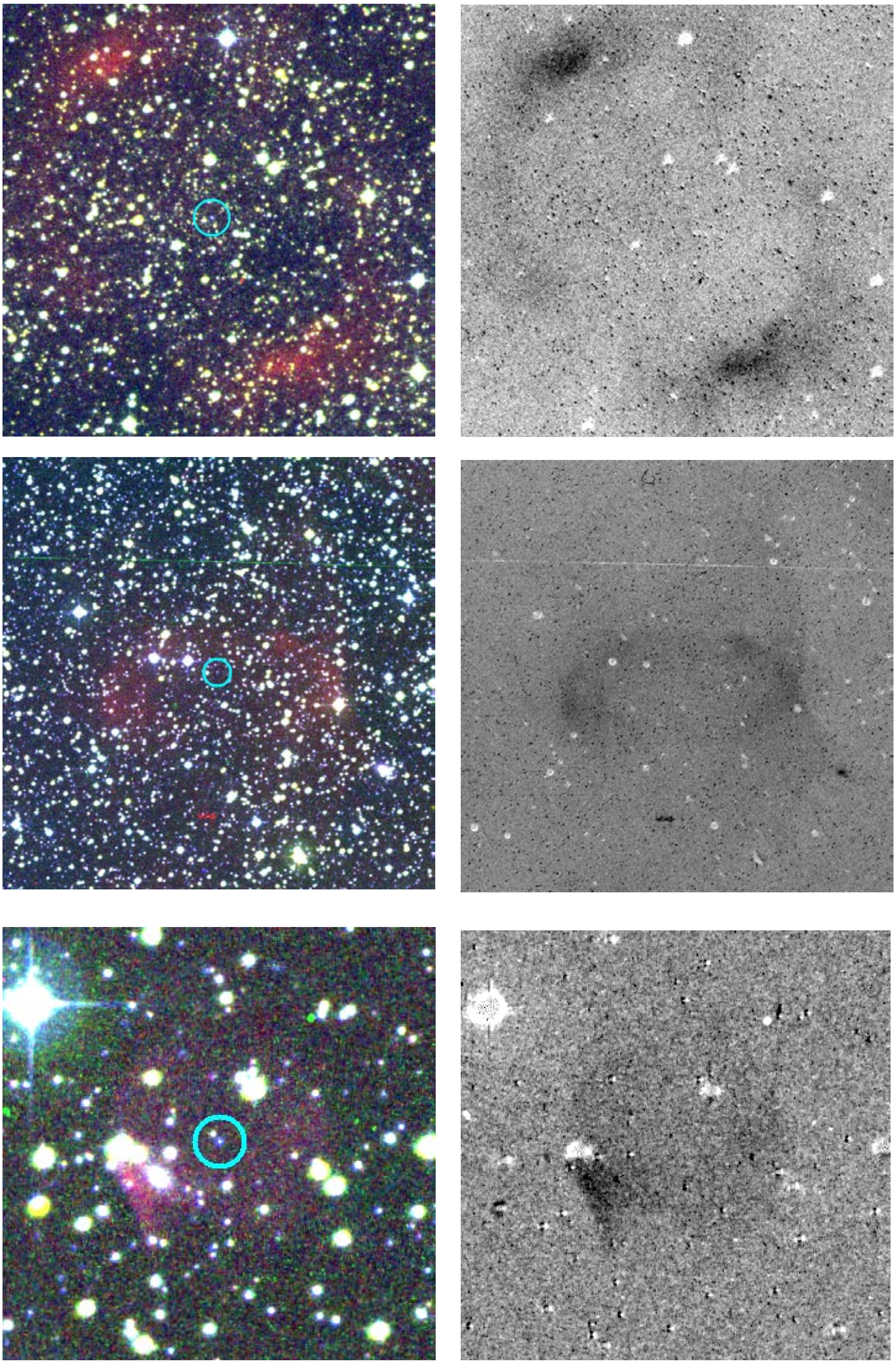

Figure 1. Three, large, extended PN candidates found in the SHS data. Left-hand images are RGB composites in Ha, SR and B_J band. The right-hand images are the Ha/SR quotients needed to see the full extent of the nebulae. Each has an obvious central blue star. Top: BMP1808-1406, middle: BMP0733-3108 and bottom: BMP0844-2736.

Three highly evolved nearby PNe, each displaying an obvious central blue star candidate, are shown in Figure 1. BMP1808-1406 has an elliptical morphology in the RGB image but enhancement in the quotient image indicates a more bipolar structure with two lobes expanding out from a central star candidate. The quotient image also reveals a light band running from north-west to south-east across the nebula, possibly indicative of a dust lane obscuring the true morphology of the candidate. For this reason, BMP1808-1406 carries a classification of 'Ear' for an elliptical, asymmetric and ring-like PNe candidate following the morphological prescription of the general MASH catalogue. The nebula visible in the quotient spans roughly 7.7', making it a particularly large PN candidate. BMP0733-3108 is another ring-like structure in the RGB image but the quotient again reveals a more robust bipolar morphology with lobes extending to the north and south. The nebula spans around 7.9', making it the largest candidate in this new MASH compilation without spectroscopic follow-up.

In summary, the visual scanning technique of the digital data developed throughout this project has been highly effective at locating faint, extended PN candidates, though some more compact emitters were also found. A fuller exploitation of all 233 SHS fields for new compact PNe is the subject of a separate project by Miszalski and is the basis for the MASH-II catalogue (Miszalski, Parker & Acker, in preparation) where 400+ new compact PNe candidates have been uncovered.

A substantial fraction (~200–300) of the new MASH-II PNe candidates are expected to be true PNe and are currently the focus of follow-up spectroscopy. Around 10–20% of these are likely to be the faint, highly evolved or nearby PNe that were the subject of this project. They will further constrain the local PN luminosity function and may also provide better modeling data for the new Hα surface brightness-radius relation developed by David Frew (e.g. Frew & Parker, 2005). The technique reported here has also had success in uncovering non-PNe, including nearly 200 various unidentified emission objects, for which a separate catalogue has been compiled.

References

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SUMMER STUDENTS

The AAO runs a student program which allows UK and Australian undergraduates to spent 8–12 weeks working here during their respective summertimes. The current southern hemisphere students are James Gill (University of Tasmania), Christina Blom (University of Cape Town) and Ricky Dunbar (University of Adelaide).

James has been working with Quentin Parker on the cataloguing and measuring of diagnostic emission lines (e.g. S II $\lambda\lambda$6717, 6731) in flux calibrated optical spectra of several hundred planetary nebulae (PNe). These objects were drawn from the recently published Macquarie/AAO/Strasbourg H-alpha survey. The aim of the project is to use line ratios to estimate line of sight extinction and to determine the temperature, electron density and chemical abundances of the planetary nebulae gas. The study will also include an investigation into the detailed spectral characteristics of bipolar PNe like RCW24 and RCW69 which have enhanced N abundance, characteristic of Type I objects.

Christina has been using IRIS2 J and K band images to search the outer disks of the galaxies NGC300 and NGC7793 for C stars, under the supervision of Simon Ellis and Joss Bland-Hawthorn. Her first challenge was to reduce the images using IRAF. The standard ORAC-DR pipeline routines struggled to produce a high quality frame from the chopped and nodded observations with which to flat field the data. An investigation into the reasons for this is ongoing and its results can hopefully be used to refine the pipeline. Christina will use the distribution of the C stars she unearths to build an understanding of how the disk of each of these galaxies has evolved.

Ricky worked with Heath Jones and Matthew Colless on Brightest Group and Cluster Galaxies (BCGs) from the 6dF Galaxy Survey (6dFGS). The positions and redshifts for 400 of the most luminous galaxies from 6dFGS were compared to known galaxy clusters and cluster-like structures within 6dFGS itself. Supported by visual inspection, around 80 BCGs were identified with clusters and a further 80 galaxies in apparent isolation, but having a similar range of bright luminosities. The BCG and control samples were found to have similar distributions in mass, luminosity, (B-R) colour, mass-to-light ratio and average surface brightness. It is hoped the two samples, selected without any prior knowledge of clustering, will reveal new insights into the formation and evolution of BCGs and the special environments in which they reside.

IRIS2 RECENT DEVELOPMENTS

Stuart Ryder (AAO)

IRIS2 Web page and S/N Calculator Updates

The IRIS2 Web pages and utilities have undergone a bit of a revamp. The main changes are:

- A discussion of imaging strategies has been added to the "Imaging Observations with IRIS2" page (http://www.aao.gov.au/AAO/iris2/iris2_cal.html).
- Information contained within the old "Wavelength Formats and Calibration Details" page has now been incorporated within the "Spectroscopic Observations with IRIS2" page (http://www.aao.gov.au/AAO/iris2/iris2_wave.html).
- The old IRIS2 astrometric distortion page has been merged with the "Flexure, Focus, and Distortion" page (http://www.aao.gov.au/AAO/iris2/iris2_focus.html).
- The imaging and spectroscopic count rates, zero-points, and long-term average sky brightnesses have been re-determined with the "Mark 2" science-grade array. The relevant sensitivity tables and on-line Signal-to-Noise Calculators have been updated accordingly. The main change from previous calculations is a reduction in *J*-band signal-to-noise ratios of ~30%, due mainly to a higher average sky brightness than initially assumed.
- Signal-to-Noise estimates are now provided for IRIS2's increasingly-popular *Z*-band filter. Note the passband of this filter is closer to the WFCAM *Y* filter than to the SDSS *z′* filter (see http://www.ukidss.org/technical/instrument/filters.html for further information).

Transforming IRIS2 Photometry to Other Photometric Systems

The *J, H, K,* and *K*s filters within IRIS2 are the same MKO infrared filters as those defined in Tokunaga, Simons, & Vacca (2002). Only a preliminary transformation to the MKO system is available for the Mark 1 science-grade array in use between March 2002 and April 2005, based on observations of only a handful of UKIRT Faint Standard stars over 3 separate nights in July 2002 (see http://www.aao.gov.au/AAO/iris2/iris2_cal.html#Transforms). For the Mark 2 science-grade array in use since May 2006, a more complete set of transformations to other systems has been derived from observations on the night of 2 Sep 2006 of UKIRT Faint Standards FS 140 and 144; NICMOS standards S279-F, S024-D, S071-D, S808-C, and S889-E; and LCO red stars L547 and BRI2202. The zero-points (magnitude of a star in the MKO system giving 1 ADU/s in a 10" diameter aperture at 1 airmass), extinction (mag/airmass), and colour terms for this night are given by the following relations:

$$J_{MKO} = 22.58 - 2.5 \log (I / t) - 0.076 (X - 1) - 0.002 (J - K)_{MKO}$$

$$H_{MKO} = 22.79 - 2.5 \log (I / t) - 0.048 (X - 1) + 0.038 (H - K)_{MKO}$$

$$K_{MKO} = 22.35 - 2.5 \log (I / t) - 0.090 (X - 1) + 0.003 (J - K)_{MKO}$$

$$Ks_{2MASS} = 22.37 - 2.5 \log (I / t) - 0.097 (X - 1) - 0.009 (J - Ks)_{2MASS}$$

where I = total integrated ADU in 10" aperture;

t = integration time in seconds;

and X = airmass of observation.

Although included in the MKO filter set, the *K*s magnitude scale is not defined in the MKO system, so 2MASS colours are used instead. Transforms to the 2MASS system are given by:

$$J_{MKO} - J_{2MASS} = -0.03 - 0.03\,(J - Ks)_{2MASS}$$

$$H_{MKO} - H_{2MASS} = -0.01 + 0.05\,(H - Ks)_{2MASS}$$

$$K_{MKO} - Ks_{2MASS} = -0.01 - 0.01\,(J - Ks)_{2MASS}$$

The difference between IRIS2's *K*s magnitudes and 2MASS *K*s magnitudes is found to be <0.01 over the full colour range.

Transforms to the LCO system are given by:

$$J_{MKO} - J_{LCO} = -0.02 - 0.05\,(J - K)_{MKO}$$

$$H_{MKO} - H_{LCO} = -0.02 + 0.06\,(H - K)_{MKO}$$

$$K_{MKO} - K_{LCO} = 0.00 - 0.03\,(J - K)_{MKO}$$

Transforms to other systems can be derived with the help of Leggett et al. (2006).

When absolute photometric accuracy is paramount, we still recommend observers determine their own extinction corrections each night, and when transformation to other infrared photometric systems is required, that a suitable colour range of standards be observed to calibrate their own data.

ORAC-DR and Starlink

With the demise of the Starlink project in mid-2005, observatories including the AAO and the Joint Astronomy Centre (JAC) in Hawaii, which both have large investments in data reduction pipelines built around Starlink infrastructure, were faced with the issue of how to maintain these pipelines. Fortunately, the JAC has taken on maintenance of the Starlink Software Collection, and has recently released an enhanced version, “Keoe (Vega)” for 32-bit and 64-bit Linux machines, as well as Macs running OS X 10.4 (see http://www.jach.hawaii.edu/software/starlink). The ORAC-DR package for IRIS2 has been tested with data from the Engineering, Mk1, and Mk2 science-grade arrays, and found to perform appropriately, i.e. bad pixel masks and linearity corrections appropriate to each array and read mode are applied automatically. Users of the last Starlink project release (Spring 2004) or earlier are strongly encouraged to upgrade to this latest release.

One particular benefit of this new Starlink/ORAC-DR release is the inclusion of an _ADD_AUTO_ASTROMETRY_ primitive. Currently, all IRIS2 images are corrected for astrometric distortion (due to the camera optics) before being aligned and combined into a mosaic. The mosaic's World Coordinate System (WCS), which converts pixel coordinates to Right Ascension and Declination, has typically been good to ~5" or so, depending on when and where the telescope pointing was last checked. Both the IRIS2 recipes JITTER_SELF_FLAT and CHOP_SKY_JITTER now call this _ADD_AUTO_ASTROMETRY_ primitive, which uses SExtractor to detect objects in the mosaic, downloads 2MASS Point Source Catalogue objects from the CDS server, then correlates them and applies a new astrometric solution using a 4-coefficient model. Future enhancements may include photometry matching as well, which would then allow for automated zero-point, extinction, and sky brightness monitoring. We wish to thank Brad Cavanagh at JAC for implementing this new capability in ORAC-DR.

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ECHIDNA IN HAWAII

Scott Croom (U. Sydney), Gabriella Frost, and Jurek Brzeski (AAO)

Introduction

As we write this, the AAO-built Echidna has touched down safely in Hawaii, en route to the Subaru Telescope. This completes the construction phase of the instrument.

It's been about eight years since Subaru Telescope commissioned the AAO to start working on a novel concept that 'gave life' to Echidna. For the Echidna team, these eight years have been filled with extreme dedication, excitement when things were happening and lots of frustration when the stubborn 'creature' would not behave itself. As expected with such a novel concept, the moments of frustration were many, but then so were the moments of joy when, one after another, the big issues and small issues were turning into history.

Echidna and FMOS

FMOS Echidna is the fibre positioning system for the prime focus of the Subaru Telescope. It makes use of a unique technology to position 400 fibres in a field-of-view of 30'. The two FMOS infrared spectrographs have been built in Kyoto and Oxford, while the AAO was responsible for the construction of the prime-focus corrector (already commissioned at Subaru) and the fibre positioning system – Echidna.

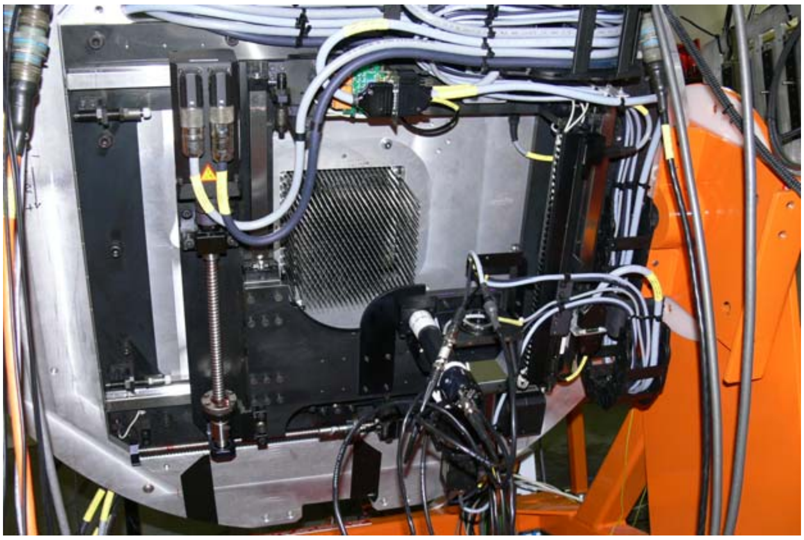
The Echidna positioner uses piezo-electric actuators to position 400 spines, which each contain an optical fibre. Each spine sits on a magnetic mount which is attached to the top of a piezo-electric actuator tube. Applying a repeated saw-tooth voltage across the piezo allows the spine to be stepped across its field of view (which is approximately 7.2mm in radius). All 400 spines can be moved at once, under software control, via a set of switching boards which allow individual spines to be addressed. The target is to configure a field in less then 10 minutes, with maximum 10 micron fibre positioning radial error. The fibre allocation efficiency should be at least an 85% yield for 400 targets randomly positioned within the field.

The fibres from Echidna are fed to two OH suppression spectrographs via a fibre connecting system built in Durham. Each spectrograph takes 200 fibres. These allow observations from 0.9 to 1.8 microns at either a low resolution mode (R~700) covering this whole band or at higher resolution (R~2400).

FMOS Science

The huge multiplex gain and the OH suppression of FMOS will enable a range of science from studies of nearby sub-stellar objects to large-scale structure in the high redshift Universe.

The spatial and mass distribution of the lowest mass stars and brown dwarfs will give us clues to the understanding of the initial mass function (IMF) in the Galaxy. There are likely to be more than 200 field brown dwarfs per square degree to a limiting magnitude of H = 22.5 mag. NIR spectra of these objects at high resolution (R=1500~3000) can be used for detailed spectral classification and for accurate determinations of metallicity and temperature.



Inside the fully assembled Echidna, the spines (in the middle of the picture) are waiting for the first light.

In order to investigate the processes and physical mechanisms of star formation, infrared observations of highly obscured objects in molecular clouds are essential. Even without intra-cloud absorption, a majority of young stellar objects have spectra which intrinsically peak in the H-band, and have large Paschen-β to Bracket-γ line ratios; so that physical information can be recovered through J- and H-band spectroscopy.

The NIR coverage of FMOS allows the study of the kinematics and metallicity of stellar populations in the vicinity of the Galactic centre, and the wide field of view allows current studies of the Milky Way's halo to be extended to more distant components at fainter limiting magnitudes. These data should yield powerful insights to the star formation history and formation process of the Milky Way as well as Local Group galaxies.

A next step for studying galaxy evolution and formation with 8m class telescopes is to probe star formation in a quantitative way at redshifts $z>1$. At these redshifts many optical lines serving as vital indicators of star formation history are redshifted to NIR bands. In this context, multi-object NIR spectroscopic observations with enhanced sensitivity through OH suppression will play an important role. FMOS is also ideally suited to the spectroscopy of extremely red objects (EROs). A systematic study of the large-scale structure traced by galaxies at higher redshift ($z>1$) would effectively exploit the 30' FMOS field-of-view. This field-of-view corresponds to about 45 Mpc (comoving) at $z=2$ and will allow us to study large volumes (> 10^7 Mpc^3) at early epochs.

X-ray surveys for AGN with Chandra and XMM-Newton provide a relatively unbiased view of activity out to a redshift of about 5 or even larger. Spitzer is also proving to be very effective at selecting AGN on the basis of their mid-infrared photometry, irrespective of any obscuration. A large fraction of both X-ray and Spitzer selected sources are heavily obscured and faint in optical bands. This means that spectroscopic follow-up observations with FMOS are indispensable in determining redshifts for optically faint sources as well as probing their nature via spectral lines which have been redshifted out of the optical bands.

Where next for Echidna?

Jurek and Rolf have now arrived in Hilo and have been reunited with Echidna to re-assemble it and perform a few tests to assess its integrity after shipping. This will be followed by a significant testing and integration stage, which will take place at sea level, before the instrument is shipped to the summit of Mauna Kea. On-sky commissioning is currently planned to start in August 2007, but there is a risk it may be delayed. This depends on the completion of other FMOS subsystems and the scheduling of the Subaru Telescope.

After many years during which Echidna has played a significant part in our lives, we are all looking forward to seeing the (first) light.

The FMOS Echidna team: Gabriella Frost, Peter Gillingham, Scott Croom, Jurek Brzeski, Scott Smedley, Rolf Muller, Tony Farrell, Lew Waller, Ed Penny, Greg Smith, John Dawson, Michael Birchall, Roger Haynes, Urs Klauser, Stan Miziarski.

Some past team members have moved on over the years, but we haven't forgotten their valuable contributions: Anna Moore, Jason Griesbach, David Correll, Dwight Horiuchi, Neal Schirmer, Reuben Barnes.

NOTES FROM AATAC

Martin Asplund, AATAC chair (RSAA, ANU)

The last AATAC meeting on November 1–2 (period 07A) was a first: we experimented with having a video-conference with the Australian members gathered at AAO headquarters in Sydney and the UK constituency in Sussex. It worked very well in spite of some late evenings/early mornings, respectively, because of the time difference. This technique will be employed also for some future meetings, although the May 2007 meeting will take place with everyone in Sydney as large program proposals will be discussed (see further below).

The demand for AAT time continues to be very healthy. In total some 60 proposals were submitted for 07A . The total oversubscription was around 3 after subtracting the time already allocated to approved programs with long-term status from previous semesters. However, there were large variations between the requests for bright, grey and dark time for the Australian and UK shares with some combinations having oversubscription factors as high as 5. This is clearly a sign of a strong observatory with front-line instrumentation on a internationally-competitive telescope. It is particularly pleasing to note the continued increase in proposals from outside the Australian and UK communities.

The competition for AAT time in 07A was probably a bit stiffer than in the previous few semesters, both judged from the oversubscription factor and the cut-off grade for approved programs. While one possibility is that AATAC was more generous this time with the grading, a purely subjective impression is that in general the quality of approved programs in 07A was somewhat higher than in the past. One reason is certainly the high demand for AAOmega since it has now proven its worth with actual observations, but it might also be a purely statistical fluctuation. For the UK community, of course, the declining partner share is making it more difficult to get time and unfortunately it will become worse from 07B when the share is expected to drop to around 25%. While the approval of large programs does contribute, it is not the driving factor, as is evident from the fact that no new large programs were considered in 07A and the over-subscription rate as well as cut-off grade in 06B were somewhat lower.

To date three large programs have been approved by AATAC (the standard Anglo-Australian Planet Search: 32 nights/year; a dedicated super-Earth search by the same team: 48 contiguous nights in 06B/07A; and the WiggleZ baryon acoustic oscillation study: ~50 nights/year). A new round of large program applications will be considered for 07B. Given the recommendation by the AAT Board to have >25% of the AAT time for such large programs (without any specified upper limit), there is room for at least one more large program to be approved in 07B; the already approved programs amount to ~20% of the AAT time from 07B and AATAC is keen for this number to be 30–50% in the long-term.

To optimize the chances for success when applying for AAT time, a few obvious but unfortunately often overlooked rules of thumb are worth keeping in mind.

- A general problem is that the background and motivation for the project could be better described for the non-expert; why is this an important problem in modern astronomy? It should be remembered that most of the AATAC members will not be an expert in that particular field (the seven AATAC members need to cover all areas in astronomy from solar system to cosmology) and thus it is essential that the proposal provides the broader perspective.
- It is good to avoid contrived and/or unfamiliar acronyms (in particular if, say, ISM stands for intermediate stellar mass – yes, this has indeed happened in AATAC proposals).
- Careful justification of the sample size is needed (applies equally well if it is only one object or for 1000 objects).
- The applicant needs to provide the necessary details to enable a check on the exposure time estimates etc.
- Don't try to squeeze too much into the 3 page science and technical case – often brevity is a virtue (in particular for AATAC members reading ~60 proposals!).
- Furthermore, it should be noted that only black-and-white figures are used in the material reviewed by AATAC and it is essential that these reproduce well and are easily understandable.

Travel and Subsistence (T&S) is not normally awarded for AAOmega 2dF MOS time allocated by AATAC to UK-based PIs, as these observations are conducted by the 2dF/AAOmega Fellow or other AAO staff. However, where a compelling case can be made that real-time interaction with the applicant at the telescope would strongly benefit the efficiency or success of the program, the Deputy Chair of AATAC may recommend T&S support where appropriate. UK-based applicants who wish to be considered for such support MUST indicate this at the time of application in Section 5 of the AATAC application form, and justify their request in the technical case of the proposal. T&S for AAOmega/2dF is still expected to be the exception rather than the norm, and the final decision on whether such support can be offered rests with the Chair of PATT.

Finally, I note that supplementary material such as submission of preprints and unsolicited progress reports will no longer be considered and that only text responses to technical assessment queries will be accepted from now on.

AATAC meets by video-conference, 1 November 2006. Sitting around the table are the Australian members (L to R) Peter Tuthill, Rachel Webster, Erwin de Blok, and Martin Asplund. On the screen are the UK members at the University of Sussex (L to R) Seb Oliver, Yvonne Unruh, and Gaitee Hussain (sitting in for Jacco van Loon). Picture courtesy of Stuart Ryder.

LETTER FROM COONABARABRAN

Rhonda Martin

One thing about a drought, it makes for good observing so there are a lot of happy observers around, if not the locals. We have relied on Paul Butler for ages to bring rain when he arrives here, but of late he has let us down in this regard – we reckon his playing of his didgeridoo in the dome scared the rain spirits away!

Mind you, as this is being written (and Paul is here as we speak) we have been struck with wild storms and dare we say it? …. Rain! Not all that much in total as the monsoon struggles to make its way south, but better than nothing. Maybe Paul left his didge at home! During a particularly wild storm whilst I was huddled in a corner under three frantic dogs, Rob Patterson was blithely watching the lightning from his doorway when his chimney fell off. Considering this storm twisted trees like celery stalks, blew down power lines and flooded buildings I think he may have been very lucky – perhaps this is the revenge of the rain spirits for the playing of that didge.

Deadlier, though, were the fires started by lightning strikes a month or so ago, and then again last week. The poor Pilliga was up and raging again and it was while AAT staff were having a look from the catwalk at the eight fires along the eastern horizon that we actually saw one start! Just a puff of smoke to start but an hour later it was off and running and by sunset was north of town and moving fast. Wayne Clarke nearly lost his home and winery but his son turned up in time (Wayne was away fighting other outbreaks) to help his mother attack this fire and all they lost was one paddock. Others closer to that first puff of smoke were also fighting to save their homes. Bob Dean, John Collins and Andre Phillips from UNSW have reason to be thankful to the wonderful local fire brigades, the little helicopters that darted to the fire fronts with dangling buckets of water taken from nearby farm dams, and the sky crane 'Delilah', who became a star in her own right, entertaining crowds of people at the water works as she sucked up 9 tonnes of water in 44 seconds, releasing it along the fire front.

The only person to have a camera at the AAT during this drama was Allan Lankshear and some of his pictures are below.

Then there was Comet McNaught. This is the 31st comet discovered by Rob and was being touted in the media as the best in twenty years, but remembering the splendour of Comet Hyakutake in 1996 I initially found this one a bit of a disappointment. Because it was so close to the western sun it was difficult to see, which is a shame, and the dense smoke of yet more bushfires hindered viewing even more, although it did make for some great sunset shots. But then the comet came good – it became quite splendid with its tail spread across the sky. Rob McNaught took some beautiful pictures which can be seen on his web page, as did quite a few amateurs. The trig point at Siding Spring became quite crowded at times as people jostled for position but the comet has just about gone now, and a moon nearing full doesn't help.

Our John Stevenson has retired after almost 23 years at the AAO. As his farewell party, John requested a Golden Dome night and this duly went into operation. Quite a few came from Epping to wish him well and although the traditional acts were a bit light on (people seem to have become very shy) it was a very pleasant night, very comfortable, and John and Anna enjoyed themselves. We all did, actually. John's traditional gift from AAT and UKST staff was a beautiful model of the telescope, lovingly created by Mick Kanonczuk. It was a stunner. A 3D painting by a local artist was his gift from the AAO in general – all in all, very satisfactory.

Delilah in action

Fire at night

EPPING NEWS

Sandra Ricketts

Since the last newsletter we have been pleased to welcome three new staff members: William Rambold, the new instrument group project manager, Paul Dobbie, Research Astronomer and Stephen Marsden, Research Fellow

In this issue, we let them introduce themselves as follows:

William: In the middle of November last year I moved to Australia to take up the challenging position of project manager for the AAO instrumentation group. Two years ago, after more than 25 years working as an electronics/ software/instrumentation engineer and manager for the Dominion Astrophysical Observatory (HIA) in Canada as well as the Canada-France-Hawaii and Gemini Observatories in Hawaii, I decided to retire to a small, remote island off the west coast of Canada. A good idea at the time, but the work was just too interesting to leave behind. Instead of fishing and tending my garden as planned I yielded to temptation and did contract work from my little office in the woods, helping groups at the University of Florida and NOAO write proposals for new Gemini and Thirty Meter Telescope instruments.

All was well until I saw the advertisement for a project manager at the AAO. The prospect of working at the AAO with its exciting instrumentation program, experiencing all that Sydney has to offer and having a whole new continent to explore (not to mention the chance to leave the perpetual West Coast Rain behind) was enough to convince me to come out of retirement and get a real job again! I am now settled happily in Asquith and have come to enjoy my morning and evening reading time on the train. Since arriving at the AAO I have been made to feel at home and have come to appreciate the friendly atmosphere and beautiful setting here. Now, I just have to get used to driving on the other side of the road…

Paul: At the beginning of the year my family and I moved to Sydney so that I could start a new job at the AAO as a Research Astronomer. For the last 11 years we have been based in Leicester, where I completed my PhD and two postdocs investigating hot white dwarfs and brown dwarfs. At the time of writing this brief introduction I have only been here for 4 weeks but already I am getting into the swing of things, having begun the role of editing the AAO newsletter and also learning to apply insect repellent to myself each morning to avoid being bitten by the Epping fauna at coffee time. Over the next few months, I will be providing support for AAOmega observations (or, since many are performed in service mode, actually taking data for some of you). In the coming semesters my support role is likely to extend to include other instruments. I'm looking forward to the fresh challenges offered by this new position and getting to know my new colleagues and the wider AAO community.

Stephen: Starting in February 2007 I am taking up the position of Research Fellow at the AAO. Part of my responsibilities will involve acting as a support astronomer at the AAT and I am looking forward to getting to know the AAO staff and the wider user community of the AAT. As there will be a new face around the AAO in the coming months I suppose that I should describe a bit about what I have been up to before coming to the AAO.

Having completed my PhD in Australia (using a large amount of AAT data in my research) I have spent the last 2.5 years working as a postdoc at the Institute of Astronomy at ETH in Zurich. During this time I have been working with NASA/Stanford on optical support for the Gravity Probe B satellite mission. This has involved using the technique of Doppler imaging on high-resolution spectra of IM Peg (the guide star for the satellite) to map its surface spot structure in order to determine what (if any) effect the surface features have on the guiding of the satellite. This has tied in very well with my personal research interests which involve the study of surface spot and magnetic features on young rapidly rotating solar-type stars and what this can tell us about how magnetic fields are generated in these stars.

I have been a frequent observer at the AAT for a number of years and I have always been impressed with the level of professionalism and helpfulness of the AAO staff. This is something that I hope to be able to help contribute to during my time at the AAO.

New arrivals of course tend to follow departures, and in the last 6 months we have said farewell to Denis Whittard and Greg Madsen. Greg departed quietly, but Denis left with a bang, having fallen into a rubbish skip two weeks before his scheduled retirement. He has now recovered from his broken ribs! Rhonda has written on the previous page about John Stevenson's retirement, but we also enjoyed John's presence here at Epping for a farewell barbecue

And we congratulate Stuart Ryder on his marriage to Marilena Salvo in Italy last September. (Photos can be seen on Stuart's home page!)

Echidna and team members prior to its delivery to Hawaii

Dr. Masayuki Akiyama (Subaru Telescope) witnessed the final system tests in December, 2006. Echidna is being tested at 60 degrees attitude. Satisfied with the results are (from left): Rolf Muller (senior electronics technician), Masayuki Akiyama, Peter Gillingham (instrument scientist/project engineer), Gabriella Frost (project manager), Scott Smedley (software engineer) and Jurek Brzeski (mechanical engineer)

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