In this issue Joss Bland-Hawthorn and Anthony Horton discuss their recent work on integrated photonic spectrographs. Top left: Schematic showing the basic sub-components of a modified array waveguide grating (see Bland-Hawthorn & Horton 2006 for details). Top right: Their first prototype of an integrated photonic spectrograph (IPS). Light from an optical fibre is fed in from the left; the light is dispersed within the 7.5 cm device ($R=4000$) before emerging as a continuous spectrum from the aperture on the right (black face). A lower resolution device would be smaller still. Bottom: IPS response measured with a tunable laser (hence the discrete lines) and scanning detector along the curved focal plane. A continuous spectrum has never been observed through a photonic grating because it has no application within the telecomm industry.
DIRECTOR’S MESSAGE

This bumper edition of the AAO Newsletter provides a revealing slice through the many activities in which the AAO is currently involved. First and foremost there is the broad array of science carried out with AAO facilities, both by the AAO’s Astronomy group and by our many far-flung users. On the AAT, this ranges from Zeeman Doppler imaging of the magnetic fields and starspots on young solar-type stars (p3), to measurements for galaxies in the Shapley Supercluster that yield precise relations between their masses and the ages and metallicities of their stars (p7). From the UKST, we have newly discovered supernova remnants from an Hα survey of the Galactic Plane (p12), and the final data release of the 6dF Galaxy Survey, comprising more than 120,000 galaxy redshifts over the southern sky (p16 and centrefold).

Then we have a forward look from the AAO’s Instrumentation group (p22). This lays out a pathway to the future that includes potential new AAT instruments (and upgrades to existing instruments), the ambitious WFMOS spectrograph for Gemini/Subaru, and the AAO’s role in developing future facilities such as the Giant Magellan Telescope and the PILOT Antarctic telescope. One of the Instrument Science group’s contributions is featured on the front page of the Newsletter (also p27). Following on from their development of fibre Bragg gratings for suppressing the OH airglow lines, the group is now designing and prototyping integrated photonic spectrographs. These remarkable innovations foreshadow the coming photonic revolution in astronomical instrumentation, sweepingly characterised as “instruments without optics”. Finally we have a report on the essential work of the AAO Users’ Committee (p30), which guides the operation of the Observatory and the choice of future instrumentation.

Even while this activity continues across all aspects of the AAO’s mission, we are also heavily engaged in a process of renewing the fabric and infrastructure of the Observatory. The most obvious signs of this process are the new roof on the headquarters building at Epping and the ongoing replacement of the solar cladding around the AAT and UKST domes and on the utilities buildings at Siding Spring. However these large projects are just the most visible parts of a long-term refurbishment process that will upgrade aging infrastructure, particularly at the AAT, and allow the AAO’s facilities to serve the community reliably and efficiently for another decade.

The process of renewal is also occurring amongst the personnel at AAO. We are proud that two AAO staff members have been awarded prestigious fellowships in the past year: Chris Tinney, our former Head of Astronomy, has taken up an Australian Research Council Professorial Fellowship at the University of NSW, while Joss Bland-Hawthorn, our Head of Instrument Science, will be leaving at the end of October to take up a Federation Fellowship at the University of Sydney. While we are delighted by their success, we know they will be sorely missed at the Observatory, to which they have both contributed so much over the last decade.

We are therefore very pleased to welcome Andy Bunker as our new Head of Astronomy. Andy comes to us via Oxford, Berkeley, Cambridge and Exeter, and is well known internationally for his work detecting high-redshift galaxies and studying the star formation history of the universe. On the AAT he has used CIRPASS and IRIS2 to study star-formation in galaxies at redshifts $z=1-2$, and he has plans for following up the VISTA near-infrared imaging surveys with AAOmega. His other interests include the James Webb Space Telescope project, where he is closely involved in the development of the NIRSpec near-infrared spectrograph as a tool for studying the ‘Dark Ages’, reionization and the era of the first galaxies.

The AAO is now advertising for a new Head of Instrument Science. We are seeking someone with broad interests who can bridge the gap between astronomy and instrumentation and be a creative driver for the AAO’s world-recognised R&D program in astronomical technologies. This is clearly no small task, but it is also an unusual opportunity. Last, but not least, the AAO is hiring a new Australian Gemini Scientist (and Deputy). From 1 January 2008, the Australian Gemini Office will be located at the AAO, and we are looking to recruit a senior astronomer with a strong research program involving 8-metre telescopes to lead the AAO’s drive to provide outstanding support to Australian large-telescope users.

These multifarious aspects of renewing the AAO are all part of the organization’s evolution towards becoming Australia’s national optical/IR observatory. It is a demanding but exciting process, and we look forward to providing an expanding user base with the high quality of services that we consider to be the signature of the AAO.

Matthew Colless
SPECTROPOLARIMETRY OF SOLAR-TYPE STARS WITH THE AAT
Ian Waite (USQ) and Stephen Marsden (AAO) for the AAT Zeeman Doppler Imaging team

Stellar magnetic fields

The Sun’s spots, flares, prominences and coronal mass ejections provide us with graphic demonstrations of the importance of magnetic phenomena in a stellar atmosphere. This solar magnetic activity has its origins inside the Sun. The outer convection zone of the Sun is rotating differentially (with the equator rotating faster than the polar regions), however the radiative zone of the Sun rotates as a solid body. Thus there is a strong shear that occurs between these two zones. This is called the interface layer (or tachocline) and is where magnetic fields are generated via a dynamo process. In the tachocline differential rotation wraps north-south magnetic field lines around the Sun in the direction of rotation and convective motions act to raise the magnetic fields through the convection zone to emerge at the surface. Thus the study of magnetic fields helps to underpin our understanding of the solar interior as well as its atmosphere. However, is a solar-type dynamo also in operation in other stars?

Stellar observations show us a wide range of magnetic phenomena similar to (but often much more powerful than) that evidenced by the Sun. Young solar-type stars (stars believed to have a similar internal structure to the Sun but much younger) are often rapidly rotating (rotating once every few days or less, compared to the 25 day rotational period of the Sun) and must have powerful dynamos as evidenced by the large prominences and flares they emit. Such high activity is also seen on members of evolved binaries where rapid rotation is preserved due to the tidal locking of the two stars. Active red dwarfs are also stars that display magnetic activity, even though they have no radiative zones and thus no interface layer. How does the dynamo in such stars operate? Magnetic fields occur in stars across the H-R diagram with the generation of these magnetic fields being one of the most important processes operating in a star, affecting everything from the activity level to angular momentum loss. Thus the study of magnetic fields is a key area in stellar astronomy.

Zeeman Doppler Imaging

Most measurements of stellar magnetic fields are only indirect and give us an averaged picture of the magnetic activity of a star. To understand how dynamos in other stars operate we need to observe the magnetic field across the star in as much detail as possible. Determining the distribution of magnetic fields across the stellar surface is possible using a spectropolarimetric technique referred to as Zeeman Doppler Imaging, or ZDI (Donati et al. 1989; Semel, 1989; Donati et al. 2003). ZDI has been employed at the AAT to detect and in many cases map stellar magnetic fields, so that we can understand stellar dynamos and the role of magnetism in stellar structure, energy balance and evolution.

As light passes through a magnetic field it is polarised and split. Thus by recording not only the intensity of light from a star, but also its polarisation, we can learn something about the star’s magnetic field. Figure 1 outlines briefly how ZDI works. If we have a rapidly rotating star magnetic regions on the limb of the star rotating towards us (X1) will be blue shifted and those on the limb rotating away from us (X2) will be red shifted (both due to the Doppler effect). In addition, the splitting of the light (the Zeeman effect) produces slight shifts in the observed line profiles for each magnetic region so that when the two polarisation states are subtracted from each other they produce a distinctive polarisation signature that gives the polarity of the magnetic region.

As the star rotates X2 will eventually move behind the star (and not be seen) while X1 will move across the stellar surface. Thus by observing a star during a complete rotation, information on the surface distribution of the magnetic field can be recovered. As it makes use of both the Zeeman and Doppler effects the technique is called Zeeman Doppler imaging.

Figure 1: This figure has been taken from Carter et al. (1996) and shows how the Stokes V (circularly polarised) signature is shifted (and opposite for opposite polarity) for the two spots on the stellar surface due to the Doppler effect.
ZDI observations commenced at the AAT in 1989, with the detections of magnetic fields on the RS CVn evolved binary HR 1099 (Donati et al. 1990). Since then ZDI at the AAT has been used to produce a wealth of scientific results. Some examples are:

- Measurement and mapping of magnetic fields on a range of stars (young, old, cool, warm, single, binary);
- Measurement of stellar surface differential rotation apparent in both spot features and magnetic features;
- Monitoring of the changing magnetic features on stars undergoing stellar cycles;
- First observations of the magnetic fields of extremely young stars (T Tauri stars);
- Evidence that young stars possess distributed dynamos different to the solar dynamo;
- Support for international multi-wavelength campaigns involving the Chandra spacecraft and Gravity Probe B.

**Semel polarimeter**

A specialist visitor instrument to the AAT, known as the Semel Polarimeter (also as “SEMPOL” or “SEMELPOL”), is used to measure stellar polarisation with extreme precision in order to reveal the magnetic signature. Using spectropolarimetry obtained with SEMELPOL, we can map the surfaces of stars, determine the positions of active regions and the evolution of such regions and determine the magnetic polarity of these active regions. All of this helps in the understanding of how magnetic fields are generated.

The SEMELPOL instrument is named after its designer, Meir Semel, who works at the Observatoire de Paris-Meudon, where the instrument was constructed. SEMELPOL is positioned at the AAT’s f/8 Cassegrain focus and consists of an aberration-free beam splitter and an achromatic quarter-wave plate orientated to transmit circularly polarised light. The light is then passed into a dual optical fibre, which is fed into a Bowen-Walraven image slicer at the entrance to UCLES. The quarter-wave plate can be rotated from +45° to −45° with respect to the beam splitter to alternate the polarisation in each fibre. This procedure is used to remove instrumental polarisation so that only polarisation from the star remains. For a more detailed review of SEMELPOL see Donati et al. (2003) or Semel et al. (1993).

The polarisation of light is usually expressed in terms of the Stokes parameters: Stokes I (total wave power, or intensity), Stokes Q & U (linearly polarised components) and Stokes V (circularly polarised component). In practice, only the Stokes I parameter and the circularly polarised Stokes V parameter are normally measured, and Stokes Q & U, being much weaker, are measured only for extremely magnetically active stars.

**Data reduction using ESpRIT and LSD**

ZDI observations are reduced and analysed using a dedicated pipeline processing software developed by Jean-François Donati at the Observatoire Midi-Pyrénées known as ESpRIT (Échelle Spectra Reduction: an Interactive Tool). ESpRIT software delivers robust, near-automated extraction of spectral data from the raw frames to provide Stokes I intensity and a Stokes V polarisation spectrum for a sequence of exposures.

The magnetic signatures embedded in the starlight are extremely difficult to detect. The typical Zeeman signature is very small, with a circular polarisation signature of ~0.1% of the continuum level for active stars (Donati et al. 1997). To detect these signatures we use a mathematical technique called Least-Squares deconvolution (LSD) which sums the Stokes signature in thousands of individual spectral lines into one profile to dramatically improve the signal-to-noise ratio by a factor of some thirty times compared to a single line. This is the only way to detect the Stokes V signature in any but the brightest stars. For a detailed description of the ESpRIT software package and LSD, see Donati et al. (1997).

**Recent observations of two active young solar-type stars**

Collaborative ZDI research between the University of Southern Queensland (USQ) and the AAO is focused on a better understanding of the magnetic activity and dynamos of young and rapidly rotating solar-type stars. This research should also help provide a more complete picture of our Sun’s early evolution, activity and effects on our planetary system including the Earth. Recent AAT observations of young solar-type stars include the detection of magnetic fields for the stars HD 106506 and HD 1411943. Both stars are very young and rapidly rotating and are in the pre-main sequence phase of their evolution. This means that they are much more swollen (larger) than the Sun and are still contracting down to the main-sequence (upon which the Sun lies). These observations are part of a study to see how the evolutionary state of a star affects the magnetic activity and dynamo processes. The data are...
HD 106506 is a late F/early G star, and thus is slightly more massive than the Sun. It is a very rapid rotator, with a projected rotational velocity (v\text{sin}i) of 81 km s\textsuperscript{-1}, has an apparent visual magnitude of 8.49, and is located approximately 126 pc away. Observations made of this star over Easter 2007 with SEMELPOL at the AAT have resulted in the detection of its magnetic field (see Figure 2a) and we have so far reconstructed a map of the starspots on its photosphere (Figure 2b). The flattened polar projection shown in Figure 2b was generated using the Stokes I information only (i.e. no polarisation information) which recovers just the brightness (or spot) features (not the magnetic features) and shows a large spot feature at high latitude as well as mid- to low-latitude spot features. HD 106506 thus exhibits a giant spot region encircling the pole. A polar spot is common on spot maps of rapidly rotating solar-type stars and is very different from the spots seen on the Sun (which are restricted to near the equatorial regions). The exact reasons why rapidly rotating stars have polar spots are still not fully known, but it is believed that the increased Coriolis force, due to the rapid rotation, may have the effect of deflecting the spot features to higher latitudes as they erupt through the star’s convection zone.

Figure 2: (a) LSD profiles for one observation of HD 106506 taken at the AAT. The upper profile is the Stokes V (circularly polarised) LSD profile, the middle profile is the Null (or Noise) LSD profile and the bottom profile is the Stokes I (Intensity) LSD profile. Note that the Stokes V and Null profiles have been shifted upwards and multiplied by 25 to improve clarity. The two large “bumps” in the Stokes V profile indicate the presence of magnetic fields on the stellar surface, while the Stokes I profile shows small “bumps” in the bottom of the profile due to the presence of spots on the stellar surface. (b) Map of the spot features on the active young solar-type star HD 106506. This is a flattened polar projection down to −30° latitude with the equator marked as a bold line. The data was obtained at the AAT during Easter 2007. This diagram shows a major spot feature at high latitudes near and at the star’s pole, as well as smaller spot features at lower latitudes. Even the smallest detected spot features are many times the size of sunspots. Tick marks around the image indicate stellar rotational phases for the observations used to generate the map.

Figure 3: Stokes V profiles for HD 141943. The thin lines show the observed Stokes V signatures while the thick lines show the fitted profiles used to produce the maps in Figure 4. The number to the right of each profile shows the rotational phase at which the observation was taken.
However, the real power of SEMELPOL is its ability to reconstruct the magnetic field from the polarisation signatures. This is demonstrated for the young pre-main sequence sun-like star, HD 141943. This early G star has strong chromospheric emission and moderately rapid rotation ($v\sin i = 34$ km s$^{-1}$) and is 133pc away with an apparent visual magnitude of 7.87. ZDI observations of HD 141943 during the Easter 2007 run at the AAT showed the unmistakable signature of large-scale magnetic fields in the observed Stokes V profiles (see Figure 3). From these profiles the surface magnetic structure of HD 141943 has been reconstructed (Figure 4). Figure 4 shows a spherical projection of the surface of this star showing not only the surface spot structure, but the radial, azimuthal and meridional magnetic field reconstructions. As was seen on HD 106506, the spot map of HD 141943 also shows a large polar feature, with extensions or separate spot features extending across a wide range of latitudes. The magnetic field of HD 141943 is very different to that of our modern-day Sun. The azimuthal field map shows large regions of surface azimuthal field. Such large, near-surface regions of azimuthal magnetic field are again often seen on young rapidly-rotating stars. A solar-type dynamo would normally restrict these azimuthal magnetic fields to the tachocline, the area between the radiative and the convective zones. However the presence of these large-scale fields on (or near) the surface of HD 141943 could indicate that a non-solar-type dynamo may be operating throughout the entire convective zone.

**Conclusion**

Zeeman Doppler Imaging results such as those discussed here (and others such as measurements of surface differential rotation and prominence mapping studies) are important in constraining models of stellar magnetic dynamos and their role in the stellar interior. They have shown that the magnetic field pattern of rapidly rotating stars is vastly different to that of the Sun, indicating that a different dynamo mechanism may be generating the magnetic fields in such stars.

ZDI at the AAT has had a long and productive history and continues to produce new results furthering our understanding of stellar magnetic activity and stellar evolution, including the early evolution of our Sun.

**Acknowledgements**

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**References**


Figure 4: Zeeman Doppler Imaging results for the young sun-like star HD141943 using data taken at the AAT over Easter 2007. The spot map (upper-left) shows a large polar active region but with spot activity also evident at lower latitudes. The magnetic maps shown in this figure are separated to indicate three different components of the stellar surface magnetic field: Radial (field in/out of the star), Azimuthal (E-W field), and Meridional (N-S field). Red and blue colours indicate positive and negative field polarity.
**AN AAOMEGA SURVEY OF GALAXIES IN THE SHAPLEY SUPERCLUSTER**
Russell Smith (Durham), John Lucey (Durham), Mike Hudson (Waterloo)

**Introduction**

Since the peak of cosmic star-formation activity at $z \approx 2$, the key process in the evolution of galaxies has been a progressive extinguishing of activity as they lose or exhaust their gas and subsequently fade into the “red and dead” population.

Attempts to observe and account for this “quenching” process are currently among the most active research areas in extragalactic astronomy. The bi-modal colour distribution of galaxies, with a tight “Red Sequence” of passive galaxies separated from a “Blue Cloud” of star-forming systems, has been revealed in unprecedented detail by the Sloan Digital Sky Survey (e.g. Baldry et al. 2006). Galaxy surveys at higher redshift ($z=0.3–1.2$) are characterising the luminosity and stellar-mass distributions of the star-forming and quiescent galaxies, and tracing the build-up of the red population over cosmic history (e.g. Bell et al. 2004; Faber et al. 2005; Bundy et al. 2006). Studies of distant galaxy clusters find deficits of faint red members relative to local clusters, suggesting the low-mass galaxies continued to form stars well after the giant ellipticals were quenched (e.g. De Lucia et al. 2007; Stott et al. 2007).

On the theoretical front, matching the very homogeneous properties of the red population was one driver for the current push to incorporate AGN feedback into galaxy formation models (e.g. Croton et al. 2006; Bower et al. 2006). An alternative to studying galaxy populations at higher redshifts is to infer the quenching history from today’s Red Sequence galaxies. Working with nearby galaxies enables detailed spectroscopic analyses where the characteristic stellar ages and chemical abundances can be deduced from the strengths of certain absorption features. Until recently, such studies were typically based on rather small galaxy samples (e.g. Kuntschner et al. 2001) or else used the composite information from large galaxy surveys to infer average properties at the expense of knowing the dispersion of those properties (Nelan et al. 2005; Bernardi et al. 2006). Moreover, many studies have been effectively limited to very luminous red galaxies, >0.5$L^*$ (e.g. Thomas et al. 2005). On balance, however, these programmes concur in finding that less massive galaxies have younger luminosity-weighted stellar ages than the classical giant ellipticals. Qualitatively, this average behaviour, which implies significant growth in the faint red population over the past ~8Gyr, is consistent with the quenching trends identified at higher redshift (e.g. see Smith 2005).

The above emphasises the importance of studying faint Red Sequence galaxies to understand the evolution of galaxy populations. Some early steps in this direction were made by Mobasher et al. (2001) and Caldwell, Rose & Concannon (2003). The observations described here aim to probe this faint regime with high-precision measurements for individual galaxies, to resolve the level of variation in formation history at given mass. While pushing to lower luminosities, we also need to maintain large sample sizes and high signal-to-noise ratios as required for precise stellar age estimates.

The efficient way to obtain large numbers of galaxy spectra is to target intrinsically densely-populated areas of the sky, i.e. galaxy clusters, and use multi-object spectroscopy to observe many galaxies simultaneously. To probe further down the luminosity function, we are forced to study nearby clusters, where the dense cores cover sky areas >1 deg$^2$. Thus, substantial galaxy samples cannot be observed in reasonable timescales with current instrumentation on 8m telescopes, which are limited to 0.1 deg$^2$ fields of view.

With its large multiplex factor, wide field-of-view, high throughput and great stability, AAOmega is the world’s most efficient instrument for deep spectroscopic studies of low-redshift cluster galaxies. We are undertaking a comprehensive spectroscopic survey of galaxies in the Shapley Supercluster ($z=0.045$) using AAOmega, supported by optical, infrared and ultraviolet imaging data from other telescopes. This article summarises the first phase of our work; for more details, see Smith, Lucey & Hudson (2007).

**AAOmega observations**

Spectroscopic observations were obtained on the nights of April 26 and 29, 2006. Target galaxies were drawn from a magnitude limited (R<18) sample from the photometric catalogue of the NOAO Fundamental Plane Survey (NFPS, Smith et al. 2004). The catalogue covers the central 40×40 arcmin$^2$ region in each of the three clusters Abell 3556, Abell 3558 and Abell 3562. Two AAOmega fibre configurations were employed, with substantially overlapping fields of view. Fibres were assigned to some 60% of the ~700 targets.

In the blue arm of the spectrograph, the 580V grating was used, with a nominal resolution of 3.5 Å FWHM from 3700–5800 Å, covering most of the best-calibrated optical absorption lines. In the red arm, we used the 1000R grating, to measure nebular emission at H$\alpha$,
The age-sensitive Balmer lines can be contaminated by nebular emission from AGN or star formation activity. To identify galaxies affected by contamination, we measure emission line equivalent widths for Hβ, [OIII] 5007, Hα and [NII] 6583, after first removing the best-fitting stellar template from among a suite of high-resolution stellar population models. (Careful treatment was necessary also to remove the atmospheric absorption band at 6670–6955 Å, which coincides with redshifted Hα and [NII] in Shapley!)

Some 30% of the sample galaxies show Hα emission down to 0.5 Å equivalent width, including 20% of galaxies on the red sequence. Emission-line ratio diagnostics show that the blue galaxies predominantly have emission from star-formation. Among red sequence galaxies, Hβ/[OIII] varies by a factor of ~100, with a strong luminosity dependence such that the most luminous objects are LINER-like, while the ratios in faint objects are consistent with star-formation (Figure 2). As a result, the constant ratio Hβ/[OIII] = 0.6–0.7, as often assumed in elliptical galaxy studies (e.g. Trager et al. 2000), over-corrects emission contamination in very luminous galaxies, and seriously under-corrects the contamination of faint objects. Contrary to previous claims (e.g. Kuntschner et al. 2001), it is a poor correction, even (perhaps especially) in a statistical sense.

Absorption indices and the index-σ relations

Broad-band colours are degenerate with respect to age and metallicity: old metal-poor galaxies can have colours identical to those of younger, but more metal-rich, systems. To break this degeneracy, we use the system of spectroscopic absorption indices as developed by the Lick group (e.g. Trager et al. 1998). In particular, we exploit the age sensitivity of the hydrogen Balmer lines, and the metallicity sensitivity of a range of lines primarily tracing Mg, Fe, C and N.

The Lick indices from Hδ A,F to Fe5406 were measured on the flux-calibrated spectra, at the native spectral...
resolution. The indices \( \text{Mg}_1, \text{Mg}_2, \text{Fe}5270 \) and \( \text{Fe}5335 \) are not used, since at the redshift of Shapley, they are contaminated by the 5577 Å sky emission for a large fraction of the galaxies. The measured absorption line indices are corrected for velocity broadening, and from the native resolution to the Lick resolution of ~9 Å using a new procedure which (a) allows for the variation in the corrections as a function of spectral type and (b) avoids any smoothing of the observed spectrum, hence preserving the noise characteristics of the data.

Figure 3 shows the correlations of selected line indices with velocity dispersion (the index-\( \sigma \) relations) for 232 supercluster members selected to have very low H\( \alpha \) emission (EW<0.5 Å). Of these, 34 have measured velocity dispersions consistent with zero and are shown at an arbitrary \( \sigma \) at the left of the figure. Index-\( \sigma \) slopes are fitted to the remainder of the sample.

The slopes of the index-\( \sigma \) relations can be predicted from stellar population models (e.g. those of Thomas et al. 2003), if we assume scaling relations of the form \( \text{Age} \propto \sigma^x, [\text{Z/H}] \propto \sigma^y, [\alpha/\text{Fe}] \propto \sigma^z \). Conversely, the slopes of these scaling relations can be determined by attempting to reproduce the index-\( \sigma \) slopes for a non-degenerate set of indices (e.g. Nelan et al. 2005; Smith et al. 2006).

Fitting for the slopes of nine index-\( \sigma \) relations (H\( \delta \), H\( \gamma \), H\( \beta \), CN\(_1\), Fe4383, Mgb5177, Fe4668, Fe5015 and Fe5406), in comparison to the Thomas et al. models, we recover:

\[
\text{Age} \propto \sigma^{0.52\pm0.06}, [\text{Z/H}] \propto \sigma^{0.34\pm0.04}, [\alpha/\text{Fe}] \propto \sigma^{0.23\pm0.04}.
\]

The quoted errors are the formal uncertainty in the fit. Repeating the exercise using different subsets of indices in the fit, we estimate the systematic errors in the exponents to be 0.10 for age, 0.07 for [Z/H] and 0.06 for [\alpha/\text{Fe}].

The age-\( \sigma \) scaling relation is consistent with that obtained by Nelan et al. (2005) from similar analysis of the NFPS. It implies that even if the most massive red galaxies formed at very high redshift, the faint red population became quiescent only at recent epochs. In particular, a large fraction of today’s red sequence galaxies at M*>2 were forming stars, and hence blue, at z<0.5. The implied deficit of faint red galaxies as a function of redshift, agrees quantitatively with the observed evolution in the red sequence luminosity function (Stott et al. 2007; De Lucia et al. 2007).

**The Age-Metallicity-Mass relations**

To move beyond the average scaling relations, we have to ‘invert’ the stellar population models, i.e. determine the values of age, [Z/H] and [\alpha/\text{Fe}] that reproduce some set of observed indices, on a galaxy-by-galaxy basis. This analysis is presented in Smith, Lucey & Hudson (2007b, in preparation). Here, we present results derived from inversion using indices H\( \beta \), Fe5015 and Mgb5177. For the faintest galaxies in the sample (R>17), the median formal errors are ~25% in age, 0.08 dex in [Z/H] and 0.07 dex in [\alpha/\text{Fe}].

Figure 4 shows the relationship between age and metallicity for three intervals in \( \sigma \). On average, both age and [Z/H] increase with increasing \( \sigma \), as expected.
from the index-σ slope analysis summarised above. However, at fixed $\sigma$, they are anti-correlated: galaxies that are younger than average for their mass are also more metal rich than average. The sample populates a plane (the so-called “Z-plane”) described by $[Z/H] = 0.66\pm0.04 \log \sigma - 0.68\pm0.04 \log t - 0.64\pm0.08$, with scatter ~0.1dex in $[Z/H]$. This is approximately the same relation obtained by Trager et al. (2000) from a much smaller sample of mostly giant elliptical galaxies. The distribution of galaxies is approximately aligned with the age-metallicity degeneracy track (i.e. the “three-halves” rule of Worthey et al. 1994), so that the reddening effect of higher metallicity compensates for the bluer colours expected of younger populations. This “conspiracy” helps to preserve the small scatter around the colour-magnitude and index-σ relations, while concealing a large degree of age variation among galaxies of given mass. As usual in such work, the age and metallicity errors are anti-correlated, because H$_{\gamma}$ has some sensitivity to metallicity as well as to age. The error ellipses are oriented in approximately the same direction as the age–metallicity relation itself, but we can confidently resolve the intrinsic relation (cf. Kuntschner et al. 2001), since measurement errors account for only ~20% of the observed variance. The existence and slope of the age-metallicity anti-correlation at fixed mass is of crucial importance in understanding the star-formation history of the galaxies prior to quenching. In Smith, Lucey & Hudson (2007c, in preparation), we describe a simple self-enrichment model for the precursors of today’s red sequence galaxies, and show that the rate of metallicity growth required to fit the Z-plane agrees quantitatively with the evolution observed in the metallicity-mass relation for star-forming field galaxies (e.g. from Erb et al. 2006).

Conclusions

This article has summarised the first phase of a survey of galaxy properties in the Shapley Supercluster region. The programme is now being combined with the Shapley Optical (imaging) Survey (SOS; Mercurio et al. 2006). Morphological information from SOS will enable a study of the interplay of structural parameters with the stellar populations. Selecting targets from SOS yields an extended spectroscopic target sample, for which first observations were obtained in May 2007. The expanded survey will probe into the lower-density regions between and beyond the cluster cores, to investigate the environmental dependence of star-formation and enrichment histories in the richest low-redshift supercluster.
Figure 4: The Age-Metallicity-Mass relations. The black points and red ellipses show the estimated and 1σ confidence intervals for galaxies in each of three intervals in velocity dispersion. The rest of the sample is shown in grey/yellow for reference. The arrow indicates the direction in which the median age and metallicity move with increasing mass. The heavy black line (same in all panels) indicates the direction of the age–metallicity degeneracy: movement parallel to this line generates no change in galaxy broadband colours.

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References

A NEW LIGHT ON OPTICAL SUPERNOVA REMNANTS
Milorad Stupar (Macquarie University), Quentin Parker (Macquarie University/AAO), Miroslav Filipovic (University of Western Sydney)

Introduction
Historically, investigation of Galactic supernova remnants (SNRs) started with optical observations at the beginning of the last century, when the first serious observations of remnants from supernovae like the famous Kepler and Tycho examples were undertaken with the Palomar telescope. Later, with the expansion of radio astronomy, radio detection and imaging took the leading role in the studies of SNRs which are, by their nature, non-thermal and easily registered in the radio regime. In the 1960s and 1970s investigations of Galactic SNRs expanded into the field of X-rays, first with sounding rockets and later with satellites. This work continues today with the Chandra and XMM-Newton X-ray space telescopes (Ballet 2003) though radio observations remain the most widely used mechanism of study.

So far 265 supernova remnants have been identified in the Galaxy (Green 2006), mostly on the basis of radio observations at different frequencies. A browse of Green’s Catalogue shows that only 17% of SNRs have been recognised in optical light, mostly through detections in narrow-band Hα or [OIII] filters. An even smaller fraction have direct optical spectroscopic observations.

Bearing in mind this discrepancy between the number of radio/X-ray and optical observations of Galactic SNRs we undertook a comprehensive search for possible optical identifications of both known and new remnants in the UKST/AAO Hα survey of the Southern Galactic Plane (Parker et al. 2005).

Firstly, we checked for optical detection of known remnants using the factor of 16 blocked down survey data available as FITS images for each field. These blocked survey field images are sensitive to large scale coherent but low surface brightness nebulosities. We also directly inspected the original Tech-Pan survey films archived in the Plate Library of the Royal Observatory Edinburgh as finer scale fragmented emission structures at full resolution could be better detected. Features and filaments identified in this way were recorded and the associated digital data of the regions of interest were then downloaded at full 0.67 arcsecond/pixel resolution from the SuperCOSMOS Hα survey web page which hosts the digitally transformed films of this survey (http://www-wfau.roe.ac.uk/sss/halpha/). Once we confirmed that an Hα filament or...
emission cloud does not belong to any existing catalogue object like a H\textsc{ii} region or planetary nebula (PN), the object was selected for further spectroscopic observations.

**New optical supernova remnants**

Our search for possible new Galactic SNRs detected in the blocked down UKST/AAO H\alpha survey data resulted in the discovery of about 80 filaments and emission nebulosities (see examples in Figure 1) varying in size from a few arcmin (Parker, Frew & Stupar 2004) to a few degrees. About 60 of these objects have been spectroscopically observed and 21 objects subsequently classified as a new Galactic supernova remnant candidate.

Confirmatory spectral observations were undertaken over five observing runs from 2003 to 2006 using both the Double Beam Spectrograph (DBS) on the 2.3m telescope of Mount Stromlo and Siding Spring Observatory (MSSSO) and the CCD spectrograph attached to the 1.9m Radcliffe telescope of the South African Astronomical Observatory (SAAO). The observations were performed with a range of resolutions from ~7 Å, to provide primary classification spectra, up to ~1.1 Å in the red, for accurate radial velocity measurements. For SNR spectral classification we followed the scheme of Fesen, Blair & Kirshner (1985). For a SNR the intensity ratio of the \([\text{S}\text{ii}]\) doublet lines at 6717 and 6731 Å to H\alpha is a key diagnostic and should be > 0.5, indicating the presence of shocked material. Other forbidden lines of \([\text{O}\text{i}]\) at 3727 Å, \([\text{O}\text{ii}]\) at 4959 and 5007 Å, \([\text{O}\text{i}]\) at 6300 and 6364 Å and \([\text{N}\text{ii}]\) at 6548 and 6584 Å are also strong in SNR optical spectra, as are the main Balmer lines. The ratio of \([\text{S}\text{ii}]//H\alpha > 0.5\) also separates SNRs from H\textsc{ii} regions and planetary nebulae.

Alongside the positional check of new SNR candidates against H\textsc{ii} regions and planetary nebulae and possible connection with nebulae around Wolf-Rayet stars (which also have optical spectra similar to SNRs), we found that 11 out of 21 new SNR candidates have some connection with radio sources. These radio sources had no previous association with a SNR however. The H\alpha association with the radio emission was checked at four frequencies from four radio surveys: the 843 MHz SUMSS survey (Cram, Green & Bock 1998), the 1400 MHz VLA NVSS survey (Condon et al. 1998), the PMN survey at 4850 MHz (Condon, Griffith & Wright 1993) and the Parkes 2400 MHz survey of the Southern Galactic Plane (Duncan et al. 1995).

Table 1 presents the diagnostic spectral line ratios for our newly identified Galactic SNRs. The ratios of all major emission lines in the red part of the spectrum are presented together with the equivalent diagnostic lines in the blue. Y means that the line is present;

<table>
<thead>
<tr>
<th>Name</th>
<th>R.A</th>
<th>δ</th>
<th>[Nii]/H\alpha</th>
<th>[Sii]/H\alpha</th>
<th>[Sii]</th>
<th>[Oii]</th>
<th>[Oii]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J2000.0 h m s</td>
<td>J2000.0 ° ' &quot;</td>
<td>6717/6731 Å</td>
<td>3727 Å</td>
<td>4959 Å</td>
<td>5007 Å</td>
<td>6300 Å</td>
</tr>
<tr>
<td>G253.0+2.6</td>
<td>08 25 54 -33 26 09</td>
<td>0.88</td>
<td>0.76</td>
<td>1.25</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G243.9+9.8</td>
<td>08 28 58 -21 57 43</td>
<td>0.65</td>
<td>0.89</td>
<td>1.65</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>G283.7-3.8</td>
<td>10 05 23 -60 17 07</td>
<td>1.27</td>
<td>1.22</td>
<td>4.11</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G288.7-6.3</td>
<td>10 26 40 -64 41 13</td>
<td>0.46</td>
<td>0.54</td>
<td>0.93</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G281.9+8.7</td>
<td>10 41 04 -48 48 49</td>
<td>1.2</td>
<td>3.79</td>
<td>1.26</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G288.3+4.8</td>
<td>11 07 19 -55 05 00</td>
<td>0.75</td>
<td>1.88</td>
<td>1.45</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G289.7+5.1</td>
<td>11 17 02 -55 17 11</td>
<td>0.60</td>
<td>1.38</td>
<td>1.40</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G289.2+7.1</td>
<td>11 18 35 -53 18 01</td>
<td>0.71</td>
<td>1.80</td>
<td>1.29</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G292.0+4.4</td>
<td>11 41 42 -57 20 00</td>
<td>0.65</td>
<td>0.97</td>
<td>1.40</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G303.6-5.5</td>
<td>12 56 31 -57 30 21</td>
<td>0.58</td>
<td>0.74</td>
<td>1.22</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G306.7+0.5</td>
<td>13 23 35 -62 05 41</td>
<td>0.55</td>
<td>0.85</td>
<td>1.36</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G308.4+2.4</td>
<td>13 35 16 -59 56 33</td>
<td>1.39</td>
<td>1.09</td>
<td>1.39</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G315.1+2.7</td>
<td>14 33 25 -57 35 30</td>
<td>0.95</td>
<td>0.76</td>
<td>1.41</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G332.4+0.6</td>
<td>16 13 01 -50 21 59</td>
<td>1.12</td>
<td>1.02</td>
<td>1.20</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G343.4+3.6</td>
<td>16 43 03 -40 37 44</td>
<td>0.81</td>
<td>0.59</td>
<td>1.35</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G332.5-5.6</td>
<td>16 42 17 -54 28 33</td>
<td>2.25</td>
<td>1.82</td>
<td>1.21</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G329.9+7.8</td>
<td>16 43 14 -58 00 15</td>
<td>1.77</td>
<td>1.18</td>
<td>1.27</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G351.1+4.9</td>
<td>17 03 14 -35 29 51</td>
<td>1.95</td>
<td>0.64</td>
<td>1.06</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>G348.2-1.8</td>
<td>17 21 49 -39 51 26</td>
<td>0.81</td>
<td>0.91</td>
<td>1.38</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G347.4-11.5</td>
<td>18 04 39 -45 30 59</td>
<td>1.18</td>
<td>1.06</td>
<td>1.46</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>G18.7-2.2</td>
<td>18 33 07 -13 38 52</td>
<td>0.72</td>
<td>1.33</td>
<td>1.34</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
N means that the line is not detected and, for reasons of simplicity, only one slit position is given per object although some objects have two or more spectra (and slit positions).

It is clear from Table 1 that all 21 objects are well inside the criteria for SNR spectral signatures as given by Fesen, Blair & Kirshner (1985). This is based not only on the [S\text{II}]/H\alpha criterion but also the presence of other diagnostic lines in the red and blue part of the spectrum. Though not listed in Table 1, the Balmer lines were present in all spectra. The [O\text{I}] lines at 6300 and 6364 Å, whose strength is also indicative for SNR classification, were also detected, but due to the strong presence of these lines in the night sky spectrum, sky subtraction couldn’t be done properly as the velocity differential was too low. These lines were not used for further analysis.

Additional support for classification of these new objects as Galactic SNRs comes from the fact that 11/21 objects have X-ray sources in the immediate vicinity and 3 candidates may also have an associated pulsar. A deeper analysis of these objects (Stupar 2007) confirms that we have identified 18 new Galactic supernova remnants. Furthermore, our optical spectra have also, for the first time, verified that G288.7-6.3, G315.1+2.7 (see Figure 2) and G332.5-5.6 (Parker, Frew & Stupar 2004), previously registered as merely candidate SNRs from extant radio observations, are in fact bona-fide new Galactic remnants.

**First optical light of known Galactic SNRs**

The high sensitivity and resolution of the Tech-Pan films used for production of the UKST/AAO H\alpha Survey of the Southern Galactic Plane motivated us to search for possible detection of H\alpha filaments and diffuse emissions connected with known Galactic SNRs discovered as non-thermal radio sources. This resulted in the first detection of optical counterparts for about 30 known Galactic remnants.

These new optical counterparts are registered as the usual irregular forms of filaments or diffuse clouds. An example for the case of G15.1-1.6 is shown on the back page, where we have an excellent match of the optical and radio emission. The optical emission is inside the radio borders with both corresponding to each other at peak emission.

The DBS on the 2.3m MSSSO telescope was also used to produce the preliminary optical spectra of known Galactic SNR G4.2-3.5 shown in Figure 3 with the radio contours overlaid on the H\alpha image. The spectra were taken across the bright, north-east filament and are shown in Figure 4. The spectra show a high [S\text{II}]/H\alpha ratio of ~1.7 and extremely strong [N\text{II}] at 6584 Å, which indicates both a likely SNR identification and a different Galactic (or possibly local) nitrogen abundance. The blue spectrum for G4.2-3.5 is shown on the left where the strongest lines are [O\text{II}] at 3727 Å and [O\text{III}] at 5007 Å.

With this number of new optical detections of known Galactic SNRs, we can now say that about 30% of the 265 known Galactic SNRs (Green 2006) have detected optical emission. We have increased this fraction...
by ~12%. Furthermore, the discovery of 21 new optically detected SNRs has added 8% to the total number of registered remnants in our Galaxy. Future work will include estimates of the spectral characteristics of all the optically registered Galactic SNRs with several slit positions along the visible optical emission structures planned.

References

Cram, L.E., Green, A. J., Bock, D. C.-J., 1998, PASA, 15, 64
Parker, Q.A. Frew, D.J., Stupar, M., 2004, AAO Newsletter, 104, 9

Figure 4: Pilot 1-D flux calibrated blue and red spectra of known Galactic SNR G4.2-3.5. In the blue (left), the strongest lines are [OII] at 3727 Å and [OIII] at 5007 Å, while in the red (right), the strongest line is [NII] at 6584 Å. The very high ratio of [SII]/Hα (~1.7) clearly classifies the object as a SNR.

Figure 3: Hα and short red quotient image of known Galactic SNR G4.2-3.5, which shows the optical detection of this SNR for the first time. The Hα filaments are parallel to the radio contours from the PMN 4850 MHz survey (contours 0.02 – 0.12 Jy/Beam). The spectra shown in Fig. 4 were taken across the brightest N-E filament in the upper left corner.
**THE 6DF GALAXY SURVEY AND ITS FINAL REDSHIFT RELEASE**

Heath Jones (AAO), Matthew Colless (AAO), Mike Read (Edinburgh), Will Saunders (AAO), Tom Jarrett (IPAC/Caltech), Tony Fairall (Cape Town), Quentin Parker (AAO/Macquarie) and the 6dFGS Team

In spring 2007 the final tranche of redshift data from the 6dF Galaxy Survey will be released, thereby completing the redshift component of the project. The 6dF Galaxy Survey (6dFGS; Jones et al. 2004, 2005) is a combined redshift and peculiar velocity survey spanning the 17000 sq. deg. of southern sky unobscured by our own Galaxy (|b| > 10 deg.). Observations were carried out using the Six Degree Field (6dF) fibre-fed multi-object spectrograph at the UK Schmidt Telescope (UKST) over 2001–2006. The main survey targets were selected to give near-complete samples with \((K, H, J, r, b) < (12.65, 12.95, 13.75, 15.60, 16.75)\), and these were supplemented with 11 additional special-interest samples. Ultimately, 136k spectra were obtained from an initial target list of 179k sources, which yielded around 120k clear redshifts. The 6dFGS website (http://www.aao.gov.au/local/www/6df/) gives ongoing survey information.

Aspects unique to 6dFGS are its near-infrared selection, wide angular coverage, and dedicated peculiar velocity survey. All of these attributes make it an ideal survey for conducting a census of galaxy mass in the nearby universe, as well as large scale bulk motion. Peculiar velocities aside, the redshift survey of 6dFGS is comparable to the highly successful 2dF Galaxy Redshift Survey (2dFGRS; Colless et al. 2001) and the Sloan Digital Sky Survey (SDSS; York et al. 2000) in terms of size and coverage. While the median redshift of 6dFGS (z = 0.054) is roughly half that of SDSS and 2dFGRS, its areal coverage exceeds both surveys several times over. Its co-moving volume is roughly equivalent to 2dFGRS and its larger fibre apertures (6.7 arcsec) ensure substantially greater spectroscopic coverage of individual galaxies than the others. Finally, since the 6dFGS sample is nearer, it furnishes large numbers of targets bright enough for the peculiar velocity survey. The nearer redshifts also obviate the need for significant evolutionary corrections, unlike the higher redshift Sloan and 2dFGRS samples. Like those surveys, its legacy will be a permanent public database, which will be unique in its combination of scope, depth and southern aspect. The complementary 2MASS Redshift Survey (2MRS; Huchra et al., in prep, Erdogan et al. 2006a), uses the 6dFGS in the south to provide a shallower all-sky redshift survey of 23k galaxies to \(K = 11.25 (z = 0.02)\).

Incremental public data releases for 6dFGS in 2002, 2004 and 2005 have seen the survey used in a wide range of applications beyond the main survey aims. The First Data Release (DR1, March 2004) alone yielded new redshifts for approximately 250 southern Abell clusters (\(z < 0.1\)) without any previous redshift (Andernach et al. 2005). Other examples include: studies of large scale structure (Flenor et al. 2005, 2006, Proust et al. 2006, Radburn-Smith et al. 2006, Doyle & Drinkwater 2006), luminosity and stellar mass functions (Jones et al., in prep., Jones et al. 2006), the influence of local density and velocity distributions (Erdogdu et al. 2006a,b, Inoue & Silk 2006), as well as galaxy groups and their properties (Brough et al. 2006a,b, Forbes et al. 2006, Firth et al. 2006, Kilborn et al. 2006). The 6dFGS has also been used in the study of special-interest samples such as extragalactic radio sources (Sadler et al. 2006, Mauduit & Mamon 2007, Mauch & Sadler 2007) and infrared luminous galaxies (Hwang et al. 2007). Future surveys with next generation radio telescopes such as MIRANDA and SKA (Johnston et al. 2007) will also benefit from the legacy of 6dFGS, as they probe comparable volumes in HI with the benefit of prior redshift information across most of the southern sky.

**Final 6dFGS Redshift Release**

The 6dFGS Online Database (http://www.wfau.roe.ac.uk/6dFGS) is maintained by the Wide Field Astronomy Unit of the Institute for Astronomy at the University of Edinburgh. The creation of an Australian mirror-site (based at the AAO) will coincide with the final redshift release. Data are grouped into 15 inter-linked tables consisting of the master target list, all input catalogues, and their photometry. Users can obtain FITS and JPEG files of 6dFGS spectra, 2MASS and SuperCOSMOS postage stamp images in JHK and \(b_f\) where available, and a plethora of tabulated values for observational quantities and derived photometric and spectroscopic properties. The database can be queried in either its native Structured Query Language (SQL) or via an HTML web-form interface. Fuller descriptions are given in Jones et al. (2004) and at the database site.

Database tables can be queried individually or jointly. Alternatively, positional cross-matching (R.A. and Dec.) can be done between database sources and those in a user-supplied list uploaded to the sites. Search results can be returned as HTML-formatted tables, with each entry linked to individual GIF frames showing the 6dFGS spectrum alongside its \(b_f\)/JHK postage stamp.
images. Individual object FITS files of the same data can also be accessed in this way. Most 6dFGS spectra consist of two halves, observed separately through different gratings, and subsequently spliced together to join around 5600 Å. Figure 1 shows examples of the way data are presented in the database.

Long database returns can also be emailed to the user as a comma-separated variable (CSV) ASCII file. Furthermore, the FITS files of all objects found through a search can be emailed to the user as a single tar file under a tarfile saveset option. Separate downloads in the form of ASCII files are also available from the database web site. These include a master catalogue of the original target lists (incorporating the 2dFGRS and ZCAT (Huchra et al. 1992) literature redshifts not in the database proper), as well as a CSV file of the spectral observations. Final completeness maps (calculated from the revised target lists, after 2MASS and SuperCOSMOS magnitude revisions) will be made available at a future date.

All of the changes previously implemented for the Second 6dFGS Data Release (DR2; Jones et al. 2005) have been retained, with some modifications. In particular, some fields rejected from earlier releases on technical grounds have been fixed and included. The final data span observations from May 2001 to January 2006 inclusive. New changes include:

1. Revised 2MASS Names: Between the creation of the initial 6dFGS target list in 2001 and the final 2MASS XSC data release in 2004, the 2MASS source designations changed by the last two digits in both the R.A. and Dec. components of the source name. We have updated the database with the new 2MASS names while retaining the old ones for reference.

2. Revised 2MASS Photometry: The JHK total magnitudes used to select 6dFGS sources were also revised by 2MASS between 2001 and 2004. These new values have been put into the database while the old magnitudes used for 6dFGS target selection have been kept.

3. Revised SuperCOSMOS Photometry: The SuperCOSMOS magnitudes used by 6dFGS were also revised between 2001 and 2004. The updating of these
The 6dFGS View of the Local Universe

The 6dF Galaxy Survey covers the entire southern hemisphere to within 10 degrees of the Galactic plane. The map below shows the sky in Galactic coordinates with \((l,b) = (300,0)\) at the centre.
Graphic: H. Jones (AAO), T. Jarrett (IPAC/Caltech).

Galactic Plane image courtesy of 2MASS.
values for the final release has been more comprehensively done than was the case for DR2 due to improvements in our matching algorithm. Historical $b_r-K_s$ magnitudes have been retained as per the definitions created for DR2.

4. Redshift Completeness: The 2MASS and SuperCOSMOS photometry revisions have imparted a small but important scatter between the old and new versions of $b_r$,$J_HK_s$, especially $b_r$,$K_s$. They have a non-negligible impact on estimates of 6dFGS redshift completeness at the faint end. New target lists have been compiled using the revised magnitudes, the completeness estimates were recalculated, and the results are presented in Jones et al. (2007, in prep.).

5. Fibre Cross-talk: Instances of fibre cross-talk, in which bright spectral features from one spectrum overlap with an adjacent one, have been reviewed and are flagged in the database for the first time. Cross-talk is an uncommon occurrence (occurring in approximately 1 percent of all spectra), and it only affects the redshifts for spectra with fewer real features than false ones.

6. Highest Redshift Sources: Very occasionally, spurious features due to cross-talk or poor sky-subtraction led to erroneously high redshifts. All sources with $z > 1$ were re-examined and re-classified (and/or re-redshifted) where necessary. Notable examples of high redshift 6dFGS sources are the candidiate double QSOs g0114547-181903 ($z = 2.524$) shown in Figure 1(b) and g2052000-500523 ($z = 1.036$).

7. Orphan Fields: The final data release includes (for the first time) data from 29 orphan fields, which are flagged. These are fields that, for various reasons, are missing either the V or R half of the spectrum. They have a reduced redshift yield because of the restricted access to redshifted spectral features.

8. Re-examination of All Q = 2 Spectra: A re-examination of all previously-classified redshift quality $Q = 2$ sources has been carried out to improve the identification of $z \sim 1$ QSOs. (See Jones et al. 2004 for a description of the redshift quality Q scale.) Many QSOs were poorly identified in the early stages of the survey due to the absence of suitable QSO templates for redshifting.

9. Image Examination of All Q = 6 Sources: Initially 6212 sources were classified as redshift quality $Q = 6$ (i.e. Galactic sources with $z = 0$) on the basis of their spectra and redshifts alone. Once spectral and imaging data were assembled in the 6dFGS database (side-by-side for the first time), it became straightforward to check their spectral classifications against the postage-stamp images. Several redshift misidentifications were found which were subsequently re-redshifted and updated.

10. Anomalous $K$–$z$ Sources with $Q = 3, 4$: The $K$–$z$ relation was used to identify anomalous redshifts ($Q = 3, 4$; i.e. reliable extragalactic redshifts) outside the envelope normally spanned by this relation at typical 6dFGS redshifts. The hundred or so objects deemed to have anomalous $K$–$z$ values were re-examined and re-redshifted where necessary.

11. Correction of Slit-Vane Shifted Fields: Midway through the survey it became apparent that the magnetically-held vane supporting the spectrograph slit was shifting occasionally between exposures. The resulting spectra from affected fields show a small wavelength offset (between 0.75 and a few Å), dependent on fibre number. Instances of shifting were found by comparing the wavelength of the [O]5577.4 Å sky line (as measured from the 6dFGS spectra) to its true value. A search found 125 affected fields able to be fit and redshift-corrected in this way. Those galaxies with slit-vane corrected redshifts are flagged with the correction size.

12. Correction for Template Offset Values: Various tests comparing 6dFGS redshifts to independent measurements found small systematic offsets in the case of a couple of redshift templates. Corrections have been applied to redshifts from these templates for the final release.

13. Telluric Sky Line Subtraction: For the final release we have re-spliced spectra and incorporated telluric absorption line removal.

The changes discussed above are outlined in more detail in the paper accompanying the final redshift release for the 6dFGS (Jones et al., in prep). Prospective 6dFGS database users are urged to consult this paper, as well as those of the earlier data releases (Jones et al. 2004, 2005) for a comprehensive coverage of the 6DF Galaxy Survey.

Large Scale Structures in the Southern Sky

The wide sky coverage of the 6dF Galaxy Survey affords the most detailed view yet of southern large-scale structures out to $cz \sim 30000$ km s$^{-1}$. The 6dFGS improves upon the sky coverage of the all-sky PSCz survey (Saunders et al. 1990), and goes 1.5 mag deeper than the 2MRS. While prominent southern structures such as Shapley, Hydra-Centaurus and Horologium-Reticulum have received attention in their
own right over recent years, an equally detailed large-scale census of connecting structures (and the voids between them) has remained unavailable until now.

The double-page spread on pages 18 – 19 shows the $z < 0.2$ universe as seen by 6dFGS in the plane of the sky, projected in Galactic coordinates. Familiar large-scale concentrations such as Shapley are immediately obvious, and several of the major structures have been labelled. At $z < 0.02$, filamentary structures such as the Centaurus, Fornax and Sculptor walls interconnect their namesake clusters in a manner typical of large structures generally. At $z \sim 0.006$ to 0.01 the Centaurus wall crosses the Galactic plane Zone of Avoidance (ZoA) and meets the Hydra wall at the Centaurus cluster. The Hydra wall then extends roughly parallel to the ZoA before separating into two distinct filaments at the adjacent Hydra/Antlia clusters, both of which extend into the ZoA. Behind these, at $z = 0.01$ to 0.02, is a separate filament incorporating the Norma and Centaurus-Crux clusters, and encompasses the Great Attractor region (Woudt et al. 2004, Radburn-Smith et al. 2006, and references therein). Beyond these, at $z = 0.04$ to 0.05, lies the Shapley Supercluster complex, a massive concentration of clusters thought to be responsible for 10 percent of the Local Group motion (Raychaudhury et al. 1989, Reisenegger et al. 2000, Bardelli et al. 2000) or even more (Quintana et al. 1995, Drinkwater et al. 1999).

Figure 2 shows an alternative projection of these structures as conventional radial redshift maps, cross-sectioned in declination. The plot has been limited to $z < 0.05$ to show the innermost redshifts in detail. The empty sectors correspond to the ZoA. Through Figure 2 we can confirm the extended filaments previously seen in the sky view, now seen bridging the main complexes at $(\alpha, \delta, z) \sim (13.5 \text{ hr}, -30 \text{ deg}, 0.05)$ to the smaller one at $(13.8 \text{ hr}, -30 \text{ deg}, 0.04)$, and on to lower redshifts, all the way down to Hydra-Centaurus.

Erdogdu et al. (2006a) have used spherical harmonics and Wiener filtering to decompose the density field and predict the velocity field of the 2MRS ($z < 0.05$). The
correspondence between the largest-scale superclusters and voids seen in both surveys is clear. Our southernmost projection (−90 deg < d < −60 deg; not shown in Figure 2) does not confirm the three tentative superclusters of Fairall & Woudt (2006), although this region is where 6dFGS coverage is sparsest, with low completeness between 0 hr and 6 hr and around the pole (poor sky coverage), and at 11 hr to 17 hr (ZoA). Projection effects are also evident, due to the wide R.A. span of single fields at polar declinations.

Work is currently underway cataloguing new clusters and groups from 6dFGS using a minimal spanning tree algorithm (Fairall et al., in prep.). At the same time, a preliminary list of ~500 void regions has been compiled as a reference for future work on under-dense regions. The results of these and other 6dFGS analyses will be reported in future editions of the AAO Newsletter.

References


STATUS OF THE AAO INSTRUMENTATION GROUP – PATHWAY TOWARDS THE FUTURE

Sam Barden (Head of Instrumentation, AAO)

It has now been four years since I took over the helm of the Instrumentation Group here at the AAO. Ever since I first arrived, I have been working hard to keep the group funded and viable. Thanks to the efforts of the Australian funding agencies, the AATB, the Director, the Executive Officer, and my excellent team, I am pleased to report that we are now entering a period of relative stability in our funding and are much better positioned to focus on projects with strategic value to the Australian astronomical community. I present here the current set of projects that our group is pursuing and, in particular, discuss the options that we are studying for a new instrument for the AAT.

Recent History and Current Path

Over the past couple of years, the Instrumentation group has seen the successful commissioning of the AAOmega spectrograph (AAO Newsletter 109, February 2006 and AAO Newsletter 110, August 2006), the delivery of the FMOS/Echidna fibre positioner (AAO Newsletter 111, February 2007), and involvement in the Gemini WFMOs effort (AAO Newsletter 105, July 2004 and AAO Newsletter 107, February 2005).

Unfortunately, the WFMOs effort has been on hold for over a year since the Gemini Board halted the concept studies in May 2006. However, we were recently invited by Gemini to resubmit our proposal for a new design effort that will commence in the latter part of this year and continue through mid-2008 for a Conceptual Design Review in advance of the November 2008 Gemini Board meeting. The AAO is collaborating with the same team as before (University of Durham, Johns Hopkins University, Rutherford Appleton Laboratories, NOAO, University of Oxford, and the University of Portsmouth) and looks forward to restarting this effort.

Although we are still firmly committed to the pursuit of making WFMOs a reality within the Gemini observatory, we are not dependent on that project for our financial future and we are now looking at a variety of options to ensure that new science capabilities are enabled on a reasonable timescale for our community. Funds from the NCRIS scheme for the development of a new instrument for the AAT are currently being used to look at a variety of instrument options. As indicated previously (AAO Newsletter 110, August 2006), one concept being explored is a non-thermal infrared
channel for AAOmega, called AAOmicron. Other funds were secured to explore WFMS alternatives and we are looking at scaled back WFMS-like capabilities for the AAT as other possible options. The table shows the various new AAT instrument options that we are currently considering. A community workshop will be held on 9 November to receive input on which options are preferred (see below for further details).

New Instrument for the AAT

AAOmicron Study

We are continuing to explore the scientific and technical viability of a non-thermal IR channel that can be fed by the AAOmega fibres. This AAOmicron concept will cover a wavelength range of 0.9 to ~1.7 microns in a single-channel spectrograph based on utilisation of AAOmega component design and VPH gratings. The conceptual layout is shown in Figure 1 and the capability was summarised in AAO Newsletter 110.

If chosen, AAOmicron will open up a new wavelength regime for relatively high target multiplex over the full 2 degree field of view.

HRMES Study

In order to enable a start to the WFMS Galactic Archaeology Survey in advance of WFMS on Gemini/Subaru, it is necessary to create a facility that provides quite high resolving power for multi-object spectroscopy. As one possible option for the new AAT instrument, we are pursuing an echelle grating based spectrograph design (HRMES – High Resolution Multi-Object Echelle Spectrograph, pronounced “Hermes”) that works in single order to provide the ~30k resolving power required to properly determine chemical abundances. We hope to make use of existing AAOmega component designs where possible.

If chosen, HRMES will open up a new resolution regime in the optical for relatively high target multiplex over the full 2 degree field of view.

Starbugs Development

For both AAOmicron and HRMES, we must be wary of the remaining expected lifetime for the existing 2dF positioner, which has already seen a decade of heavy usage. We could invest further effort to refurbish that positioner, however configuration times would still be significant even if we were to replace 2dF with a different pick and place gantry robot. Rather, we prefer to explore implementing a new technology that we call Starbugs (see discussion of roving robot technology in the special IAU AAO Newsletter, July 2003) in which each fibre is on its own inexpensive autonomous positioner.

The Starbugs technology is good for the relatively low density of apertures of the existing AAOmega spectrograph and the proposed AAOmicron and HRMES concepts, but is not capable of high density applications such as desired for the WFMS-A implementations. For that we turn to the Echidna technology developed for the FMOS instrument on Subaru and proposed as the positioner technology for WFMS on Gemini/Subaru (See Figure 3).

WFMS-A

A subset of the Aspen science objectives for WFMS can be achieved on a 4-metre class telescope such as the AAT with a sufficiently high density MOS capability. For example, a 9000 square degree, z~1 redshift survey could be accomplished in about 300 nights of AAT time if the multiplex capability were increased by a factor of four over 2dF.

WFMS-A serves as one possible fall back position in case the Gemini implementation of WFMS fails to mature or to remain timely. A WFMS-A facility could be collecting data 2 to 3 years in advance of the likely timescale for the Gemini WFMS.

The WFMS-A study is looking at a variety of implementation scenarios. The baseline option maximises the fibre density and enables a more optimised Dark Energy survey to take place. It includes a 1600 fibre feed with an Echidna positioner replacing the existing 2dF robot (Figure 3). The 2dF corrector will still be utilised, but possibly with a modified rear element to enhance the coupling efficiency. The AAOmega spectrograph will be split into three single-
<table>
<thead>
<tr>
<th></th>
<th>AAOmicron + AAOmega fed by 2dF or Starbugs</th>
<th>HRMES + AAOmega fed by 2dF or Starbugs</th>
<th>WFMOS-A AAOmega Baseline</th>
<th>WFMOS-A Optimal AAOmega + HRMES</th>
</tr>
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<tr>
<td><strong>Wavelength regime</strong></td>
<td>0.37–1.7µm</td>
<td>0.37–0.95 µm</td>
<td>0.37–0.95 µm</td>
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<td><strong>Low Resolution</strong></td>
<td>1300</td>
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<td><strong>Low Res Wavelength Coverage</strong></td>
<td>Full optical and near IR bands</td>
<td>Full optical band</td>
<td>0.3 µm</td>
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<td><strong>High Resolution</strong></td>
<td>11000</td>
<td>11000–AAOmega 30000–HRMES</td>
<td>11000</td>
<td>11000–AAOmega 30000–HRMES</td>
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<tr>
<td><strong>High Res Wavelength Coverage</strong></td>
<td>~70 nm @ R11k</td>
<td>~70 nm @ R11k ~10 nm @ R30k</td>
<td>~35 nm @ R11k ~10 nm @ R30k</td>
<td>~35 nm @ R11k ~10 nm @ R30k</td>
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<tr>
<td><strong>N-targets</strong></td>
<td>400 (2dF) 540 (Starbugs)</td>
<td>400 (2dF) 540 (Starbugs)</td>
<td>1600</td>
<td>1600</td>
</tr>
<tr>
<td><strong>Positioner Technology</strong></td>
<td>2dF or Starbugs</td>
<td>2dF or Starbugs Echidna</td>
<td>Echidna</td>
<td>Echidna</td>
</tr>
<tr>
<td><strong>Configuration Time</strong></td>
<td>~1 hour with interchangeable field plates (2dF) ~10 minutes (Starbugs)</td>
<td>~1 hour with interchangeable field plates (2dF) ~10 minutes (Starbugs)</td>
<td>5–10 minutes</td>
<td>5–10 minutes</td>
</tr>
<tr>
<td><strong>Comment</strong></td>
<td>Uses existing AAOmega and feeds new AAOmicron IR spectrograph</td>
<td>Uses existing AAOmega and feeds new HRMES spectrograph</td>
<td>AAOmega is transformed into 3 single channel spectrographs</td>
<td>AAOmega is transformed into 3 single channel spectrographs with a set of new HRMES spectrographs</td>
</tr>
<tr>
<td><strong>Expense Category</strong></td>
<td>Fundable with existing NCRIS funds. Starbugs positioner would require additional funds</td>
<td>The HRMES channel might be covered by the NCRIS funds. Starbugs positioner would require additional funds.</td>
<td>Significant cost likely to require international partnership with Australia holding majority share.</td>
<td>Will require international partnership to fund with Australia likely to retain minimal 50% share.</td>
</tr>
</tbody>
</table>
channel spectrographs with components used from the existing instrument and duplicate components fabricated as required. Figure 4 shows how 3 single-channel AAOmega spectrographs might fit into the West Coude room of the AAT. The cost of this instrument could possibly be funded in large part from Australian sources, but may require additional funds through international collaboration. Unfortunately, this option does not enable a sufficiently high resolution mode for the Galactic Archaeology survey.

The WFMOS-A Optimal design adds in a proper high resolution channel so that both Dark Energy and Galactic Archaeology surveys can be conducted with the facility. The addition of the high resolution channel, probably based on the HRMES concept described above, would add significant cost and will require greater involvement by international partners to get the instrument fully funded.

Community Workshop

A community workshop is scheduled for Friday 9 November at the AAO Epping laboratory to discuss the various options for a new AAT instrument, to receive your input into the science objectives and requirements, and to prioritise these options. Further details on the workshop will be posted on the AAO website and
broadcast through the ASA email exploder. The AAO will likely make a final decision on which option to pursue by the middle of 2008.

Other Efforts of the Instrumentation Group

CYCLOPS, MOS-UCLES, SPIRAL Upgrades

In addition to the various options for a new instrument on the AAT, the AAO Instrumentation Group is exploring a variety of smaller projects to enhance current AAT capabilities. Three studies are currently underway to determine design approach and costing:

- CYCLOPS: a fibre image slicer feed for the UCLES and UHRF facility.
- MOS-UCLES: a fibre feed from 2dF for multi-object observations with UCLES.
- SPIRAL Upgrade: a proposal to double the areal coverage of the SPIRAL IFU for AAOmega.

The current effort will scope out each of these ideas so that they can be evaluated and prioritised for future funding.

PILOT

Management and technical support are being provided by the AAO for the ongoing PILOT feasibility and design study of a 2m-class Antarctic telescope. This is funded by NCRIS and led by the University of New South Wales. The objectives of this study are to determine the technical issues and costing associated with implementation of a 2m-class telescope at Dome C as a pathfinder for larger optical and IR telescopes.

IIA-HESP

The Instrumentation Group has developed a design and costing for a High-resolution, Echelle Spectro-Polarimeter (HESP) for the Indian Institute of Astrophysics in Bangalore, India. The instrument will go on the 2m Himalayan Chandra Telescope and will provide resolving powers of R=30k and 60k with complete spectral coverage for two channels (2 simultaneous polarimetry modes or object-sky mode) from 370–900 nm. The AAO is partnered with KiwiStar Optics and PrimeOptics in this effort.

GMT and ELT studies

Our group also remains poised to initiate instrument design studies for the GMT as it ramps up its Design Development Phase.

Staff Changes

The instrumentation group has also seen some significant staff changes at the management level. Although Chris Evans formally retired at the end of 2005, he has remained engaged on a part time basis but will likely pursue full retirement later this year. Gabriella Frost has also decided to move on this year after her successful completion of the AAOmega project and delivery of the Echidna positioner to Subaru. We have recently hired two new project managers to replace Chris and Gabriella. They are William Rambold, who started at the end of 2006, and David Ward, who started in May of this year. William will be spearheading the WFMOS and new AAT instrument efforts. David is managing the PILOT study and will head the effort on the CYCLOPS study and the HESP design.

Concluding Comments

The AAO Instrumentation Group is looking forward to a period of stability and one in which we are creating real instruments while continuing to conceptualise future facilities. We anxiously await your input to the selection of which instrument to build for the AAT!
INSTRUMENTS WITHOUT OPTICS: AN INTEGRATED PHOTONIC SPECTROGRAPH

Joss Bland-Hawthorn and Anthony Horton (AAO)

In 2006 we introduced a new concept to astronomy, the integrated photonic spectrograph, that has the potential to solve the problem of spiralling costs in building future astronomical instruments (Bland-Hawthorn & Horton 2006). The envisaged device is ideally matched to a diffraction-limited or near-diffraction-limited focus. The light can be manipulated over much smaller baselines than in conventional spectrographs. The light is launched into an integrated photonic circuit, being dispersed over a region of order ~1 cm rather than the hundreds of centimetres associated with conventional spectrographs. In certain respects, the concept of an integrated photonic spectrograph already exists within photonics and telecom research groups, although in order to achieve a device that is suitable for astronomy, a significant amount of research and development is required.

There are several photonic devices that show promise for astronomy, in particular, the photonic array waveguide grating (AWG) and the photonic echelle grating (PEG). Different parts of the evolving story can be found across a dispersed literature in optics, photonics, quantum electronics and communications journals. The technology emerged from the constant demand for increased bandwidth in the telecommunications industry. The early fibre optic networks were based on data transfer at a single laser frequency in single-mode fibres (with multimode fibres finding occasional use in the last stages of the network). By 1995, it was clear that the projected need for much higher data rates would require dense wavelength division multiplexing (DWDM), i.e. independent data streams carried by many contiguous wavelength channels. A key requirement of DWDM is the ability to disperse the multiband signal within a specific input fibre or a set of input fibres into separate output channels and the ability to switch signals between input and output channels. This gave rise to the remarkable AWG router.

The first such device was invented by M. Smit (1991) in the Netherlands. These are now commercially available in various incarnations. AWGs were actually preceded by echelle gratings and came into being as a result of manufacturing difficulties with PEGs, and indeed we have concentrated our efforts on these devices. The two most basic configurations are called “symmetric” (Figure 1; Smit 1991) and “anti-symmetric” (Figure 2; Adar et al. 1993) AWGs. In our 2006 paper, we derive the basic parameters of an AWG presented by Kok et al. (2003) as a worked example.

Telecomm AWG routers are not suitable for astronomy. We are currently engaged in development work in order

Figure 1: Symmetric 1×N array waveguide grating (Smit 1991). A single input fibre feeds light into the first slab waveguide (mux) that in turn directs the light onto an array of parallel waveguides. The parallel channels define a phased array and thus behave like a grating. On output, the grating produces interference in the second slab waveguide (demux). The system is designed so that different spectral channels are carefully imaged onto distinct output fibres.
to produce AWGs that have characteristics relevant to astronomy. The first such device is shown in the top right of the figure on the front cover. The AWG comprises input and output fibre ports, a multiplexer (mux) feeding a parallel array of closely spaced, single mode waveguides that in turn feed a demultiplexer (demux). The input and output fibre ports are single-mode for the most part, although multimode operation is also possible. The input waveguide transports a range of wavelengths into the first slab waveguide (mux). The numerical aperture of the input fibre spreads out the light within the mux, but the light is directed onto the waveguide array. The number of channels in the waveguide array is limited by the width of the illumination pattern. Both the mux and demux are 2D waveguides with precisely manufactured concave edges defined along a Rowland circle (front cover, top left). The concave boundaries have a specific focal length and serve to focus the light onto the exit ports. Constructive interference arises from the careful positioning of the input/output ports with respect to the phased waveguide array.

A commercially packaged device is an integrated circuit of order several centimetres in size, incorporating both mux and demux at either end of a waveguide array, with pigtails at both ends (input/output ports) to allow communication with the outside world (Figs. 1 and 2). This is quite different from our device that has a single input fibre, and a continuous spectral output (front cover, top right), i.e. the output fibres have been removed.

Commercial AWGs conform to industrial standards, ease of mass production and general applicability. The number of parallel waveguides is usually much larger than required by the measured finesse in these devices. They are not highly optimised devices in the sense of astronomical gratings. For example, in a conventional AWG, the output ports sit along a Rowland circle in order to bypass the primary sources of optical aberration. However, it is possible to design an AWG that produces a flat focal plane, an arrangement more suited to astronomical detectors.

The spectral output from our integrated photonic spectrograph is shown in the lower figure on the front cover. The spectral response was measured with a tunable laser and scanning detector along the curved output face of the AWG; a continuous spectrum has never been measured photonically because this has no application within the telecomm industry. The individual spectral channels are shown over the spectral window 1525 – 1570 nm; the effective spectroscopic resolution of our first device is close to R=4000. The insertion loss within the AWG is about 2 dB, i.e. an overall throughput of about 60–65% at peak transmission.

We can now envisage multimode devices with R=250, 500, 1000 and 2000; flat blaze envelopes and broader spectral responses; flat output focal planes and integrated linear detectors, or even stacked devices illuminating IR arrays. But all of these will require significant investment before we are in a position to

Figure 2: Anti-symmetric 1×N array waveguide grating (Kok et al. 2003). The phased array is in 3 sections: the first section inserts an extra 60µm of path length but this is compensated for in the third section such that the overall path length difference between branches is determined solely by the straight middle section (the dashed lines are construction lines used in a design software package). This device is discussed in detail by Bland-Hawthorn & Horton (2006).
integrate hundreds of these onto circuit boards for future instruments. Individual devices will be expensive, but the cost per device will drop by orders of magnitude once many devices are integrated together.

We note with interest that F.G. Watson (1995) envisaged that it would ultimately be possible to integrate a miniaturised spectrograph with an astronomical fibre, although a device that can operate with a large core fibre (~100–200µm diameter) has yet to be considered in detail. We consider such a device to be a "micro-spectrograph" and these may look quite different to an integrated photonic spectrograph. Our view is that the mass production of micro-machined devices is a developing market that may ultimately lead to efficient micro-spectrograph devices for astronomy.

**The Future**

There are several factors that argue in favour of miniaturising spectrographs in the years ahead (Bland-Hawthorn & Horton 2006). At or near the diffraction limit, the focused spot is independent of the telescope aperture, and has a size that is compatible with photonic devices. If the light can be efficiently coupled into the device, it can remain within the device and be manipulated by it, before being imaged at the detector. The light does not need to see an air-glass boundary again. The cross-talk performance of telecomm devices already indicates that light scatter, birefringence and polarisation effects can be managed to a high degree. Instruments based on integrated circuit technology will be more easily scaled to larger sizes, cheaper to mass produce, easier to control, and much less susceptible to vibration and flexure. Conventional optical design is now replaced by photonic engineering supported by a billion dollar R&D investment.

In recent years, there have been significant advances in achieving efficient suppression of the OH night sky emission using fibre Bragg gratings embedded within optical fibres (Bland-Hawthorn et al. 2004). The night sky problem is widely viewed as one of the fundamental limitations to carrying out observational cosmology on large telescopes in the decades ahead. In order to exploit this technology, light needs to be concentrated into optical fibres. If we are to go to the trouble of concentrating light into small fibre cores, it makes sense to use these fibres as pre-filters to R=250–2000 photonic gratings. We see this as a very exciting synergy between two developing technologies.

Integrated photonic spectrographs will have other major advantages. Wide-field surveys continue to dominate astronomy and astrophysics, and will do so for decades to come. With the advent of AO correction, "wide field" takes on new meaning. We can talk about an AO-corrected, wide field if the sampled format involves thousands or tens of thousands of pixels on a side, regardless of the size of the sky field (Bland-Hawthorn 2006). Thus, wide-field positioning systems will continue to dominate astronomy for any level of AO correction. We can now envisage autonomous robotic positioners ("starbugs"; McGrath & Haynes 2006) carrying a stack of tiny spectrographs fed by a microlens array that sees the sky at the top of the stack.

Arguably, the greatest prospect from producing a viable "spectrograph on a chip" would be to realise a million element IFU – the so-called MEIFU concept – first envisaged by Content, Morris & Dubbeldam (2003). These already exist on target planes within particle accelerators that make use of bundles with $10^6$ or more optical fibres. We envisage a million fibres feeding a thousand circuit boards, each with a thousand "integrated photonic spectrographs" illuminating linear IR detectors integrated onto the boards, all of the boards assembled into a cabinet the size of a fridge.

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AN ALTERNATIVE DICHROIC BEAM Splitter FOR AAOMEGA
Rob Sharp (AAO)

As we go to press, AAOMEGA is completing its first observing run using an alternative wavelength dichroic beam splitter between the red and blue arms of the spectrograph, which operates at 6700 Å. A detailed assessment of performance is under way, but first impressions are that the new beam splitter, manufactured by “Optical Coating Associates” in Adelaide, performs well.

This optic is an alternative to the original dichroic rather than a replacement. The original beam splitter cuts over at 5700 Å, which is well matched to the capabilities of AAOMEGA, giving continuous wavelength coverage, at low resolutions, from the fibre cut off in the blue at 3700 Å out to 8500 Å in the red (with a small overlap at the change-over). However, this red limit is set by the physical size of the red CCD, and the usable observational wavelength range with the 385R grating continues on into the ever denser forest of OH air-glow lines out to 9500 Å before the CCD response becomes poor.

For the WiggleZ Dark Energy Survey project (Glazebrook et al. 2007 arXiv:astro-ph/0701876) an extension of 1000 Å to redder wavelengths provides valuable additional redshift identification information. For example, the Hβ/[OIII] lines can be recovered for many targets which would otherwise only present [OII] emission (at higher redshifts, when Hβ falls beyond 9500 Å, the [OIII] doublet is marginally resolved by AAOMEGA even at low resolution). Using the original dichroic, the WiggleZ project would have had to incur an unfortunate gap in the spectral coverage between 5700–6700 Å if the system had been tuned to these redder wavelengths. With this in mind the decision was taken by the WiggleZ team to donate a new dichroic beam splitter to AAOMEGA, with a cut over at 6700 Å.

The new optic is available with all AAOMEGA gratings and for any observing program, although the size and location of the optic in the AAOMEGA beam means that changeover between the two alternate elements is a complex task which can only be accomplished as an afternoon set-up task and with adequate advance notice to observatory staff.

Users interested in proposing to use the new dichroic should contact Rob Sharp (rgs@aao.gov.au) for further information on the optic until a full characterisation can be made available using the August 2007 data.

AAT SERVICE OBSERVING
Heath Jones (AAO)

For many years the AAO has offered service observing as a part of AAT operations. Scientists affiliated with any institution worldwide are welcome to apply with programmes seeking up to six hours of observing time. Service proposal deadlines occur four times each year on March 1, June 1, September 1, and December 1. Service time can be sought for any of the current AAT instruments (AAOMEGA, IRIS2, SPIRAL, UCLES and UHRF).

Service time is ideal for programmes that require a small amount of data to complete a programme or to try out new observing techniques. New proposals are graded by a three-member panel, a process that takes 3–4 weeks, before being accepted into the service queue for that instrument. After a proposal has been refereed, the AAO advises the PI of the average grade assigned by the referees. This grade is then used (along with observational constraints) to plan the execution of service nights, the dates for which are set several months in advance. The amount of service time per instrument scheduled each semester is adjusted to yield a similar level of over-subscription to that of regular AAT proposals (typically a factor of 2–3). Service proposals expire after a period of 18 months, but can be resubmitted at any time.

Further information about AAT service observing can be found at http://www.aao.gov.au/local/www/service/service.html. Submitting a proposal is as easy as filling in an online proposal form with observation details and a short scientific justification. Upcoming service nights and tips for maximising your chances of getting observations can also be found at the website. The current status of each instrument queue can be found at http://www.aao.gov.au/local/www/service/STATUS/service_status_index.html.

Prospective applicants are encouraged to consult all of these web pages and to contact service@aao.gov.au with any queries.
The Anglo-Australian Observatory Users’ Committee (AAOUC), as part of its July meeting this year, organised a Science Symposium as a means of obtaining an overview of the breadth and depth of scientific output from the AAO. We invited a selection of speakers to represent a range of ongoing or recent research projects utilising AAO facilities, and the symposium was held in the ATNF Lecture Theatre. The speakers were:

- Angela Cotera “IRIS2 and Spitzer”
- Chris Tinney “The Anglo-Australian Planet Search”
- Stephen Marsden “Stellar magnetic fields with the AAT”
- Tim Bedding “Asteroseismology with UCLES and friends”
- Scott Croom “The WiggleZ BAO Survey: a status report”
- Rob Sharp “IFU Science with SPIRAL”
- Alistair Edge “The 2SLAQ Survey”
- Fred Watson “The RAVE survey”

The AAOUC was very impressed with the extent and quality of the scientific research presented and by the eagerness of these researchers to showcase their results for the community. The event was a great success and we plan to continue to hold a Science Symposium in future years to accompany our July meetings. The AAOUC thanks all the speakers for their contributions, and gratefully acknowledges the support of the AAO and the ATNF in coordinating and hosting the event.

As part of its remit, the AAOUC aims to consult widely with the user community to establish priorities for various operational initiatives of the AAO. Prior to the July meeting of the AAOUC this year, in addition to the usual interactions of the AAOUC with the community, we also conducted an online survey to solicit user feedback and input. The anonymous survey was conducted through the free online survey site http://www.advancedsurvey.com/ and resulted in 66 participants, quite evenly distributed between very frequent and occasional or potential users. The AAOUC warmly thanks the user community for participating in the survey.

Overall the users provided positive and supportive feedback regarding the AAO, its operations and instruments, and especially its personnel and the support they provide to the users. Some specific outcomes included:

- The resources in the Calls for Proposals, and the telescope and instrument documentation were almost unanimously rated highly, as was the introduction at the telescope and observing assistance.
- The service observing at the AAT was very strongly supported, with AAOmega, IRIS2 and UCLES the primary instruments used. About two-thirds of respondents were happy with the amount of service time being offered, and the remaining third indicated that increasing the amount of service time would be valuable.
- A majority (19/28) was in favour of allowing a small fraction of time during the night (from 1–5%) for obtaining seeing measurements.
- There was almost unanimous support for a new instrument, although preferences for what this should be varied greatly.

Many of the comments reflected support for upgrades of existing instruments, particularly UCLES, an option strongly supported by the AAO and the likely focus of a future Australian Research Council Linkage Infrastructure, Equipment and Facilities (LIEF) proposal. Readers should note that the AAO is particularly keen to obtain community input to best inform its decision regarding the next major instrument to be developed for the AAT, and will be holding an open workshop on 9 November 2007 to solicit such input.

The AAOUC felt that the survey has provided a valuable source of input to inform the discussions at the recent AAOUC meeting, although we recognise that with 40 questions it was a very long survey. We feel that a much smaller survey, conducted annually (or perhaps every two years), with questions targeting timely issues or those of particular relevance, would be extremely worthwhile and would aid the AAOUC in identifying areas of user concern, or in highlighting community consensus, to pass on to the AAO for subsequent action.

A list of the current members of the Users’ Committee can be found at www.aao.gov.au/about/aaouc.html.
SUMMER STUDENTS
Paul Dobbie, Stephen Marsden, Heath Jones

At the time of this newsletter going to press, two out of the three northern hemisphere summer students are well into their stays at the AAO and the third has recently arrived.

John MacLachlan from the University of St. Andrews is working with Paul Dobbie on the photometric identification of candidate white dwarfs in the Sloan Digital Sky Survey data release 6 with red excesses consistent with their having late-type companions or dust disks. Less than a handful of white dwarfs with L dwarf or later companions have been unearthed to date while 5 degenerates have been found to possess dust disks which could be the remnants of tidally disrupted Asteroid or Kuiper belt analogues. The aim of this work is to identify new examples of these types of systems which can ultimately be studied in greater detail to refine binary evolution models and potentially to provide further insight into the origins of dust disks.

In July Emma Small arrived at the AAO from the University of Liverpool in the UK to undertake a student fellowship. Emma’s project involves the mapping of the surface spots on an extremely rapidly rotating star. Spots on the surface of stars are formed via the eruption of magnetic fields through the stellar surface and thus the study of these spots can tell us a great deal about how stars generate magnetic fields.

The star which Emma is studying has the glamorous name of R88A and is located in the young open cluster IC 2602, also called the Southern Pleiades. R88A is very young (approximately 1/100th the age of the Sun with an age of 30–50 million years) and is one of the most rapidly-rotating solar-type stars known. The star completes a full rotation in just 0.2 days which is over 100 times faster than the Sun. The results from this project will enable us to determine what effect (if any) ultra-rapid rotation has on the generation of magnetic fields.

UK summer student Una Karahasanovic will be visiting the AAO from late August until October. She is working with Matthew Colless and Heath Jones on the properties of massive galaxies, both in and out of clusters. It is hoped that differences between the two samples will yield insights into how these galaxies form, and how big a role environment plays in building massive galaxies generally. Una is visiting the AAO from the University of Oxford.

LETTER FROM COONABARABRAN
Rhonda Martin

Firstly, we would like to welcome our new OH&S Projects Manager, Doug Gray, to the fold. Doug, from Britain, has been in Australia for about twelve months and has been working in Dubbo since his arrival – in fact, his family is still there for the present and Doug is doing a weekend commute. It tickles us that he considers the 144 km to Dubbo as a virtual trek; to the locals, it is a doddle, just something we do before something important, like shopping. Doug is not impressed with the weather – he reckons he left England to find some sun but instead spends his time swaddled to the ears in freezer jacket and jumpers.

After his last observing run Paul Butler took his didgeridoo home with him and it immediately started to rain, something we had been requesting from him for some time. It would seem that the didge was the jinx – not only has it rained but snowed as well, every drop of moisture very welcome – except by observers, of course.

The removal of all asbestos from Siding Spring is proceeding with a vengeance. One afternoon an orange Site Office arrived and then suddenly there were other mobile offices, and fencing, and a great deal of equipment, and lots of competent-looking men. There is also Monty, a small white dog who is the construction site mascot. The roof has already been ripped off the Utilities Building. I bet the men are glad it is cool – their protective clothing would be almost unbearable in the summer. As if waiting for them, winter arrived with a vengeance. It has already snowed once, for a whole day, and rained, and last night ice built up on the dome, and the site fences held so much ice they were in danger of blowing away on the savage wind. All plants were encased in ice. Later in the morning I espied Doug looking hopefully at a small patch of blue, hoping for some sunshine. That was just before the fog came down.

Next to be done is the UKST and then the mammoth task which is the AAT. That will be something to see. There is no doubt that this whole event has been very disruptive to our comfortable routines, from parking quite a distance away to having to eat our lunch elsewhere, but, it is fascinating to watch – it is always interesting watching other people work – and this crew is very competent indeed. Asbestos is always a worry and although there is no immediate danger to staff, it will be a relief when it is completed.
NEW LOCATION FOR AAT DATA ARCHIVE

As of July 2007, the Cambridge Astronomical Survey Unit Data Centre is the host of the AAT data archive. Previously, requests for archival data were handled by the AAO. Now, any non-proprietary AAT observation acquired since the 1st January 1990 can be retrieved by simply submitting the relevant query constraints via the webform at http://archive.ast.cam.ac.uk/arc-bin/wdb/aat_database/observation_log/make. Users will then be notified by email when their request has been completed and will be provided with instructions detailing how to retrieve the data.
EPPING NEWS
Sandra Ricketts

Once again we have had several departures and arrivals: Chris Tinney left us for an ARC Professorial Fellowship at the University of NSW, and we have since welcomed Andy Bunker, the new Head of Astronomy. Andy introduces himself at right. Gabriella Frost was farewelled at a well-attended lunch and is replaced by David Ward, who has recently joined us as Instrument Project Manager.

Chris picked a good time to leave, as while the long-awaited and much needed replacement of the roof on the Massey building at Epping was being carried out, Sydney finally received the sort of rainfall it has been awaiting for some considerable time! Major leaks occurred on the first floor, the worst-affected offices being Chris's old one and that of Sam Barden.

The library was also rained on, and the librarian was exceedingly grateful for all the help in moving some hundreds of books to a drier spot, and in covering all the shelves with sheets of plastic. We seem to have dried out now, and are enjoying the sight of new ceiling tiles. Most astronomers have been able to return to their offices after scattering to various locations on the ground floor. And the library has been unwrapped, so material can once again be found without rummaging under sheets of black plastic. At least I always knew when someone was looking for something as this could be quite a noisy process!

Major congratulations go to Joss Hawthorn, who has been awarded a prestigious ARC Federation Fellowship. Joss will move to the University of Sydney on 31 October 2007 to continue his development of photonic technologies for astronomy. However we expect we will still see a lot of him, as he will be visiting regularly in his new role as AAO Distinguished Fellow.

NEW HEAD OF ASTRONOMY
Andy Bunker

I have just joined the AAO as the new Head of Astronomy. I started my career as a student at Oxford, and in 1996 moved to Berkeley, California to work on the NICMOS camera for the Hubble Space Telescope, and also data from the Keck Telescopes in Hawaii. I then spent 5 years at the Institute of Astronomy in Cambridge, and for the past 3 years I have been on the physics Faculty at the University of Exeter. The Head of Astronomy position at AAO offers new challenges and great opportunities – and New South Wales seems a great place to live; I have just moved from the British summer to Australian winter – with no discernible difference in the weather.

My scientific background is in high-redshift galaxies; I am interested in developing techniques to identify some of the most distant galaxies yet found, and to use these to explore galaxy evolution over 90 per cent of the history of the Universe. Currently we have a large sample of galaxies at redshift 6, within a billion years of the Big Bang and seen at a critical era in history when the Universe transitions from being mostly neutral gas to highly ionized. What “fries” the Universe is still an open question, and one that new telescopes and instruments will explore over the next decade. I am on the instrument science team for the ESA NIRSpec spectrograph which will fly on the James Webb Space Telescope (the successor to Hubble). This has the potential to find galaxies within this “epoch of reionization”, and to address whether the ionizing photons from OB stars in star-forming galaxies are the culprit for reionization. I am also interested in charting the history of star formation, and to explore this I have used multi-object near-infrared spectroscopy on the AAT with IRIS2 and also the CIRPASS visitor spectrograph (built by the Institute of Astronomy in Cambridge).

The AAO has always been scientifically very active, helped by the cutting-edge instrumentation it has built. As well as the AAT and UKST, there is also access to the Gemini and Magellan telescopes, putting Australian astronomy in a very strong position. It is certainly an exciting time to join the AAO staff, with decisions soon on the next major instrument for the AAT, and Australia’s share of AAT time increasing as the UK ramps down involvement.

I am very happy to join the science team at the AAO, and am looking forward to continuing to explore the high-redshift Universe, and to taking on new challenges as the AAO moves forward.
PHOTOS OF THE GREAT FLOOD  by Sandra Ricketts
The known Galactic SNR G15.1-1.6 seen for the first time on the appropriate image of the UKST/AAO Hα Survey of the Southern Galactic Plane. There is an excellent match between the optical emission and overlaid PMN 4850 MHz radio contours (between 0.1 and 0.37 Jy/beam).