The Anglo-Australian Planet Search has begun to bear fruit, with the discovery of 3 new planets, and the confirmation of 4 others. This sky map shows the position of the new planets discovered by the AAT on the sky, and an approximate comparison of their orbits with those of our Solar System. See the article on page 3 for more detail.
The next few months will see significant milestones reached in a number of major AAO projects, both scientific and technical. The 2dF QSO and galaxy redshift surveys will make their first public release of data in April/May, ahead of the June 30 2001 deadline originally agreed between the survey teams, time assignment committees and the AAT Board. The QSO survey will release the positions, redshifts and spectra for over 10000 QSOs at the beginning of April, with the release of 100000 galaxy redshifts following a month later. The timely public release of the data will provide the entire community with a tremendous opportunity to exploit the wealth of information in these ‘state-of-the-art’ surveys and add to the growing body of scientific results that are already beginning to flow from the surveys. With over 160000/16000 galaxy/QSO redshifts obtained, the redshift surveys also remain on track for reaching their final targets of 250000 galaxies and 25000 QSOs by the end of semester 01B.

Just as the 2dF surveys establish themselves as the first major extra-galactic surveys of the new millennium, the UK Schmidt will shortly embark on another – the 6dF galaxy survey. The goal of the 6dF galaxy survey is to obtain redshifts for approximately 100000 K-band selected galaxies and peculiar velocities for 15000 galaxies over the entire Southern hemisphere at a galactic latitude of greater than 10 degrees. This non-proprietal survey is due to be completed within 4 years and when complete it will be the most comprehensive survey of galaxies in the local Universe ever attempted. The 6-degree field robot positioner and fibre optic system have passed initial tests at Epping and the system is now entering on-sky commissioning tests at the UK Schmidt. The 6dF galaxy survey is due to start once commissioning is complete and we anticipate that this will be close to the original April 2001 milestone set at the outset of the 6dF project in 1998.

Another major milestone facing the AAO is the forthcoming AAT Board meeting at which the future shape of the AAT agreement beyond 2006 will be resolved. There is little doubt that with successes such as 2dF and 6dF, the AAO has developed an enviable reputation for excellence in instrumentation. Equally, the scientific productivity of the AAO has never been higher. A quick scan through the pages of this newsletter provides an excellent overview of the large range of world-class science (from planets to large-scale structure) currently being done with the AAO telescopes.

The astronomical world will be very different in 2006, as will the relative priorities of the UK and Australia. However, if the AAO continues to focus on its recognised strengths in science and instrumentation then both Australia and the UK stand to benefit from remaining in a partnership (albeit, perhaps, of a more flexible nature) that will continue to assist both nations in achieving their scientific priorities beyond 2006.

Brian Boyle

Next Issue:
If you have some recent results based on AAT or UKST data, or other items of interest, please send articles to newsletter@aaoepp.aao.gov.au by April 23, 2001. Article length can vary from 2 paragraphs to 2 pages, with preference for plain or latex text, postscript figures and postscript or tiff images.

November Issue Competition Winner: Congratulations to Helen Woods for her solution to the Instrumentation Word Scramble, identifying 19.5 out of 21 instruments.
The Anglo-Australian Planet Search has been running now for just over 3 years at the AAT. This long term program is using an iodine cell installed in the UCLES Coude spectrograph to measure high precision velocities for a sample of 200 nearby solar-type stars. This iodine cell technique is the same one that has been used so successfully at the Lick and Keck Observatories to detect the vast majority of currently known extra-solar planets.

Implemented at the AAT, the technique has been demonstrated to deliver systematic, long-term velocity precisions of 3m/s (1). Precisions at least this small are essential to the detection of Solar System analogues – or at least to the detection of Jupiter- or Saturn- analogs around other stars. Jupiter induces a velocity variation in the Sun of around 10m/s with a 12 yr period, so a clear detection of such a velocity signal requires observations at the 3m/s level.

The three years of data now in hand are now beginning to bear fruit. In December we announced (2) the detection of three new extra-solar planets, and a new brown dwarf candidate. We have also been able to independently confirm the detection of four previously detected extra-solar planets around HD134987, HD13445, HD75289 and HD17051.

The three new planets from the AAT are around HD160691 (μ Ara), HD179949 and HD27442 (ε Reticulum), while the brown dwarf candidate is in orbit around HD164427 (see Table 1).

The most interesting of these new objects is the planet orbiting ε Ret. It represents the first extra-solar planetary object to be found in a circular or near-circular orbit outside a radius of one tenth of an au. “51 Peg”ers, or hot Jupiters (like the planet orbiting HD179949) have been found now around many stars, as have giant planets in highly elliptical orbits (like that orbiting HD160691). Up until now giant planets in other solar systems have not been found in any orbits looking anything remotely like our own Solar System. ε Ret changes all that – its gas giant orbits just outside where the Earth lies in our own system.

This location immediately leads to speculation as to what the environment on satellites of the ε Ret gas giant might be like. Unfortunately, ε Ret is a K2IV subgiant, which means its bolometric luminosity will be some 6 times that of the Sun, and the flux incident at 1.26 au will be ~ 3.8 times that incident on the Earth, making it unlikely to be conducive to “life as we know it” as the saying goes. But it’s still the only system we have found which looks even remotely like the proto-typical planetary systems we envisaged before the first extra-solar planets were discovered.

With these new discoveries already in the bag, and lots of variable stars in our on-going target list, we are confident that you’ll be seeing AAT planet discoveries regularly in the years to come!

The Anglo-Australian Planet Search Team is; Paul Butler, Chris Tinney, Hugh Jones, Alan Penny and Geoff Marcy.

References

Table 1: Details of planets and brown dwarf candidate discovered at the AAT

<table>
<thead>
<tr>
<th>Parent Star</th>
<th>M sin(i) (M_jup)</th>
<th>Orbit Period (days)</th>
<th>Semi-Major Axis (au)</th>
<th>Eccentricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD179949 (in Sagittarius)</td>
<td>0.84</td>
<td>3.1</td>
<td>0.045</td>
<td>0.05</td>
</tr>
<tr>
<td>HD160691 (μ Ara)</td>
<td>1.86</td>
<td>743</td>
<td>1.6</td>
<td>0.62</td>
</tr>
<tr>
<td>HD27442 (ε Reticulum)</td>
<td>1.26</td>
<td>426</td>
<td>1.1</td>
<td>0.02</td>
</tr>
<tr>
<td>HD164427 (in Telescopium)</td>
<td>46</td>
<td>109</td>
<td>0.46</td>
<td>0.55</td>
</tr>
</tbody>
</table>
SCIENCE HIGHLIGHTS

SEARCHING FOR RECENT STAR FORMATION IN GAS-RICH ELLIPTICALS/S0s

Annette Ferguson, Thijs van der Hulst (Kapteyn Institute, Groningen) & Jacqueline van Gorkom (Columbia)

A physical understanding of the processes which govern and regulate large-scale star formation in galaxies is essential for all models of galaxy formation and evolution. Although the star formation properties of disk galaxies across the Hubble sequence are now well-documented (yet the underlying physics is poorly understood), there remains a paucity of information about the frequency and nature of star formation in the earliest types of galaxies, namely the ellipticals/S0s. As recently reviewed by van Gorkom (1997), Knapp (1999) and Sadler (2000), there is now evidence that a significant fraction of field ellipticals/S0s actually contain substantial amounts of cold interstellar gas, observed in both atomic and molecular form. Gas morphologies range from extended (i.e. several tens of kpc) disks and rings to fragmented shells; in most cases, the gas continues on well beyond the bulk of the stellar light. With typical gas masses ranging from $10^8 - 10^9 \, M_\odot$ (and sometimes even higher), it appears these gas-rich early-types contain just as much cold gas as star-forming dwarfs/irregulars and even some large spirals. Furthermore, the peak gas column densities in these systems ($N_H \sim 10^{20} - 10^{21} \, cm^{-2}$) are comparable to those seen in the outer parts of spirals, and in LSB galaxies, where low level massive star formation is often observed (Ferguson et al. 1998a, van der Hulst et al. 1993). This begs the obvious question: is the gas in present-day ellipticals/S0s also star-forming?

We have begun a survey with the AAT and the Taurus Tunable Filter to search for the signatures of recent massive star formation — i.e. Hα emission from HII regions — within a sample of ~35 ellipticals/S0s known to have extended HII and/or CO disks, rings and shells. Our survey has the sensitivity to detect HII regions ionized by only a few massive stars ($L_{H\alpha} \sim 10^{37} \, erg \, s^{-1}$, comparable to Orion) and measure star formation rates of $\geq 10^4 \, M_\odot / yr$. Our sample is drawn largely from the ongoing HII studies of van Gorkom, Schiminovich & van der Hulst as well as an extensive search of the literature. Galaxies span a range in absolute magnitude (low-luminosity to giant Es) and morphological appearance (peculiar vs normal) and display gas kinematics varying from ordered rotation along either the major or minor axes (or neither) to completely unsettled motions. Figure 1 shows Hα continuum-subtracted and continuum images of 3 of the 7 ellipticals imaged during our first TTF run in Jul/Aug 2000. Star-forming sites in these galaxies range from a few isolated knots (eg. NGC 1210, NGC 5266) to very active disks (eg. Arp 230); almost all other systems imaged show some level of star formation activity as well. By increasing our sample size, we will be able to better quantify the frequency, distribution and rates of star formation in present-day ellipticals/S0s and ultimately, through analysis of the relationship between star formation and interstellar medium properties, will gain fresh insight into the nature of the star formation law in diverse and extreme physical environments. More observations are scheduled this semester at both the AAT and WHT.

Discovery of HII regions in gas-rich ellipticals also provides a major breakthrough towards addressing a separate issue, namely the origin of the gas itself. The irregular distribution and kinematics of the gas in many cases, coupled with the faint tidal features sometimes seen and the gas masses involved, are suggestive of a merger/accretion origin, but whether the victims of this process are small gas-rich dwarfs, or large spirals remains unclear. Furthermore, one cannot yet rule out these gaseous features as being due to ‘late primordial infall’ or that some of the gas is actually a result of mass-loss from stars in the elliptical itself. A powerful discriminant between different theories is the gas-phase chemical abundance, a quantity that can be derived in a relatively straightforward manner from the emission-line spectra of (even faint) HII regions. Determining the mean level of enrichment in these gas features, as well as searching for the signature of abundance gradients and/or intrinsic metallicity dispersion, will be of fundamental importance. Newly-discovered HII regions will therefore be excellent targets for future chemical abundance studies with large ground-based telescopes.

References

Morganti et al 1997 AJ 113 937
van der Hulst et al 1993 AJ 106 548
Figure 1: A mosaic of continuum and Hα continuum-subtracted images of galaxies observed during our Jul/Aug 2000 TTF run. NGC 5266 (top) is exceptional in containing a disk of $>10^{10} M_\odot$ of regularly-rotating H I (Morganti et al. 1997). A few isolated knots of Hα emission are detected in the extended H I, as well as an inner ring of compact star-forming regions. Interestingly this ring is oriented perpendicular to the major axis of the H I, but aligned with the minor-axis dust lane. NGC 1210 (middle) is a shell elliptical with ~ $6 \times 10^9 M_\odot$ of regularly-rotating H I, which does not appear to have settled into a disk (Schiminovich et al. 1997). A few isolated H II regions are detected in the main body of the galaxy, as well as one associated with an outer gas shell. There may also be some nuclear emission. Arp 230 (bottom) is also a shell elliptical: despite having less gas (~ $2 \times 10^9 M_\odot$) than the others, it has by far the most star formation. The very luminous H II regions, like the gas, are concentrated in a settled rotating disk, which is oriented perpendicular to the optical major axis (much akin to the inner disk of Cen A).
THE HELIX NEBULA REVISITED — A PLANETARY NEBULA THE SIZE OF THE MOON

Quentin Parker (ROE), David Malin (AAO), Sue Tritton (ROE) & Malcolm Hartley (AAO)

The Helix (NGC 7293) is a planetary nebula located about 450 light years away in the constellation Aquarius (RA 22:30; Dec −20:48) making it probably the closest such nebula to the Sun (but see AAO Newsletter No.94, p9). It is one of the most striking and well known planetary nebulae (PNe) and, as far as we are aware, the only such object for which a ground-based parallax observation could be made. Despite this, its distance remains uncertain with estimates varying from 85 to 590 light years (e.g. see Acker et al., 1992, in the Strasbourg-ESO catalogue of Galactic Planetary Nebulae).

It is also one of the largest PNe on the sky with an apparent diameter of 16 arc minutes being typically reported in the optical. Furthermore, deep wide field photographic imaging with the AAT and UKST in broad band colours has also previously shown that its halo extends to about 28 arc minutes, which is co-incidently the apparent size of the full moon on the sky.

Two 3-hour H-alpha exposures using the UK Schmidt Telescope were taken of this nebula during September 2000. These were taken both for publicity purposes and to see if targeted wide-field narrow-band imaging can reveal additional information for such bright PNe. These have now been combined photographically by one of us (DFM) to produce amplified derivatives to show the faintest features. Inspection revealed several structures which we believe are new. The maximum extent of the outermost detected features is also now shown to be about 50 arcminutes in a NE to SW direction across the image.

The figure below, which is about 66 arcminutes on a side, gives the new amplified photographic derivative from the combined deep H-alpha images together with the
SCIENCE WITH THE WFI - PARALLAXES FOR L-DWARFS
Chris Tinney

The arrival of a prime focus imager at the AAT which will see frequent service is particularly exciting for one specific branch of imaging science – CCD astrometry.

As has become more widely understood in recent years, CCDs make nearly ideal devices for astrometric measurements. Their matrix of pixels is defined to phenomenally high precision and regularity by their manufacture; they sit in a temperature controlled environment; and they have their QE peak in the red, where the atmosphere is best behaved. So unlike photographic plates, which are almost invariably precision-limited by the scanning process adopted, CCD astrometry (as long as you count enough photons) can be carried out at a precision limited only by the atmosphere.

And that doesn’t just mean “one tenth of the seeing size” as most astronomers assume – in fact the current limit to which a relative position (i.e. a small angle on the sky) can be measured at a good site is around 1 mas, or 1/500th of the seeing. You just have to observe objects bright enough that you can count 250,000 photons.

The biggest problems for CCD astrometry are actually complex optics (which almost invariably bend, flex or otherwise change over the course of time, resulting in variable astrometric distortion patterns), and changing instrumentation (for much the same reasons). WFI, fortunately, sits behind a fairly weak set of optics (the triplet corrector) at the AAT prime focus, meaning we can expect its astrometric performance to remain constant over many years.

We have therefore begun an astrometric program which aims to measure parallaxes for a sample of 50 very low-mass stars and brown dwarfs of the new extremely red* “L” spectral class. Our sample has been selected from the 2MASS southern database, and evenly spans the whole of the new spectral class from objects like very late M-dwarfs, to objects near the transition to methane “T” dwarfs. By scheduling individual nights on each WFI run (and using small periods of twilight observing kindly provided by willing WFI observers) we will be able to observe each target several times a year over a two year period – more than sufficient to determine the distances to these objects which we expect to all lie within about 25pc (i.e. > 40ms parallaxes).

The result will be the first complete and empirical definition of the colour-magnitude diagrams for the brown-dwarf cooling extension to the H-R diagram – an essential set of parameters for the currently poorly understood atmospheres of these new “L” type objects.

*Brown dwarf astronomers laugh at the “Extremely Red Objects” of extragalactic astronomy – compared to the optical-IR colours of L and T dwarfs, these galaxies should really be renamed MROs, or “Marginally Red Objects”
STRANGERS IN THE NIGHT
Scott Croom for the 2dF QSO Redshift Survey

Introduction

The major redshift surveys with the 2-degree Field are coming to completion this year (weather permitting!). The galaxy survey now has redshifts for over 150,000 galaxies, and the QSO survey has measured redshifts for over 16,000 QSOs. It's clear that the major goals of the surveys, which are mostly focussed on measurements of large-scale structure, are in sight.

However any survey which aims to observe many thousands of objects will also turn up a few things which at first may have been unexpected. In particular, the 2dF QSO Redshift Survey (2QZ), as well as finding many thousands of QSOs, also obtains spectra for a large number of other objects which masquerade as QSOs in the photometric section of the catalogue. The 2QZ was based on the selection of point sources with blue colours (in u-b and b-r) from photographic plates (Smith et al. 2001; Smith 1998; Croom 1997). Initial predictions were that ~55% of the candidates would turn out to be QSOs, while the remainder would be blue galactic stars and compact star-forming dwarf galaxies, and this has been shown to be the case in the subsequent observations. Within the stars, QSOs and galaxies, a number of peculiar objects (peculiar at least to an astronomer who spends most of their time looking at QSOs) have been unearthed, and it is these which this article will focus on.

Striking Stars

Approximately 28% of the 2QZ catalogue are galactic stars. The vast majority of these are galactic sub-dwarfs, mostly with A, F or G spectral classifications, which have moved into the colour selection limits of the 2QZ by photometric errors. About 15% of the stars are hot white dwarfs showing the typical broad hydrogen Balmer absorption of the DA white dwarf class. Also found are

Figure 1. Some of the peculiar stars found in the 2QZ. a) a DQ white dwarf b), a cataclysmic variable and, c) a white dwarf or A star + M star binary system.
~ 50 DBs dominated by neutral helium. A rarer object is shown in Fig. 1a. This is a DQ white dwarf, a cool white dwarf with strong molecular carbon (Swan) bands. A second rare class is cataclysmic variables (CVs), binary systems with accretion onto a white dwarf. So far ~10 of these have been found in the 2QZ, with an example shown in Fig. 1b. In fact the spectrum plotted here is one of two CVs found in the same 2dF field (a total of over 300 fields have been surveyed to date).

The last of the galactic oddballs presented here is shown in Fig. 1c. The two spectra are of the same source, as a small fraction of our sources is observed twice to allow us to check the reliability of our identification procedure. The bottom spectrum was observed on the 20th September 2000 and shows a blue continuum with broad Balmer absorption. This could be either be a DA white dwarf or possibly a hot A-star. The top spectrum is the same object observed two days later (offset by +300 counts to separate the two spectra in the blue). There are two obvious changes: first there are now strong narrow Balmer emission lines, second there is also now a strong red continuum including weak TiO bands. At the blue end the continuum and absorption features remain unchanged. Emission lines could be produced by a flaring M-dwarf, however that couldn’t cause the rapid change in continuum emission. An alternative is that the system is eclipsing; this rules out the blue star being a white dwarf, as it would then have a radius ~0.01 R⊙ too small to obscure an M-dwarf. If the blue source is not a DA white dwarf, but an A-star, then it could eclipse the M-dwarf. However then the fact that the two stars are of similar brightness poses another problem. Clearly further observations will be needed to test the eclipsing hypothesis.

**Extra-galactic Weirdos**

Now we’ll move a little further afield. Most of the sources in the 2QZ are extra-galactic, ~ 55% QSOs and ~ 10% narrow-emission-line galaxies. A number of rare or remarkable QSOs and NELGs (or a combination of both) have been found. Some of these are shown in Fig. 2. In Fig. 2a we show the first supernova found by 2dF: SN 2001O discovered on the 23rd January 2001 (Boyle et al. 2001). It is found in a galaxy with strong star formation (indicated by the strong [O ii], [O iii] and Balmer emission lines). The broad spectral features of [O ii], [O iii] and Si ii indicate that this is a Type-I SN close to maximum brightness. Observations in the next few weeks should allow us to ascertain whether it is a Ia or a rarer Ic. The Ic could be a stronger possibility because of the high star formation rate in the galaxy.

Moving out a little in redshift we find our second extra-galactic oddity (Fig. 2b). This spectrum shows the narrow lines of a NELG at z = 0.35 (dotted lines), but also the broad lines of a QSO at z=2.11 (dashed lines). This is a foreground NELG and a background QSO. As the alignment of the two must be very close for the light of both to go down a 2dF fibre, this source is a candidate gravitational lens.

The spectrum in Fig. 2c is also a composite spectrum, but this time the lines indicate equal redshifts for both components. In the blue there is broad Mg ii emission typical of QSOs, while in the red there is [O ii], [O iii] and Hβ emission coupled with an absorption of the higher order Balmer lines and Ca ii, H and K. This is reminiscent of the post-starburst QSO found at the Keck telescope following up 2QZ and NVSS cross-matches (Brotherton et al. 1999). In that object a strong A-star spectrum was seen, indicating a recent (~ 400 Myr) starburst. The spectrum in Fig. 2c has lines more typical of an F/G star, so the age of the starburst will be significantly greater. However, there is also strong [O i] (which wasn’t seen in the Brotherton et al. object), indicating ongoing star formation. The 2QZ contains ~ 10 sources of this type which should help us to constrain the star formation properties of QSO host galaxies.

The last of this instalment of weirdos is the extreme broad absorption line (BAL) QSO shown in Fig. 2d. Approximately 5% of the QSOs in the 2QZ show evidence of broad absorption, however this spectrum is by far the most heavily absorbed. There are large absorption bands in Si iv, C iv and Al iii blue-wards of the approximate location of the emission lines (with such features an accurate redshift is almost impossible to determine). This is similar to some of the BAL QSOs found in the FIRST radio survey (Becker et al. 1997). It is unlikely that objects which absorbed any more than this would fall into our sample, as they become increasingly red, whereas the 2QZ selection was based on blue colours.

**Finally**

The first release of 2QZ data will occur at the beginning of April 2001. In this release will be the catalogue and spectra for over 20000 sources (of which over 10000 will be QSOs) from the most complete regions surveyed to date. I hope this article has encouraged some readers to investigate the data when released, not just for the QSOs, but also for the myriad other interesting objects which lurk within a data set of this size. It is worth noting that all of the objects discussed above were discovered through manual checks (and double checks!) of the spectra, after automated routines had classified the majority of “normal” sources. For further information see the 2QZ web page at www.2dfquasar.org.
References
Brotherton, M. S., van Breugel, W., Stanford, S.A., Smith, R.


Figure 2. Some of the peculiar extra-galactic sources found in the 2QZ. a) SN 2001O, b) a candidate gravitational lens, c) a post-starburst QSO, d) an extreme broad absorption line QSO.
DIFFERENTIAL IMAGING WITH RUGATE FILTERS

Joss Bland-Hawthorn (AAO), Sonia Cianci & John O'Byrne (U. Sydney)

After several years of development and design, we now have our first high performance rugate filter to be commissioned at the AAT in June (see Offer & Bland-Hawthorn 1998, MNRAS 299, 176). This filter – the first of its kind for astronomical use – produces two narrow transmission bands at 490 nm and 660 nm. The measured transmission profile is illustrated on the right.

The filter will allow us to perform exquisite differential photometry of nearby spirals on both the Hα and Hβ lines. Differential imaging allows us to obtain two bands essentially simultaneously by switching between the two spectral lines in synchrony with charge shuffling on the CCD. The systematic error between the bands, induced by instrumental and atmospheric effects, is greatly reduced. Note that the filter bands are slightly offset to the red to allow us to go after galaxies redshifted by up to 2000 km s⁻¹. A small tilt will allow us to observe objects at zero redshift.

The rugate filter, when used with the TTF, should enable us to see very subtle variations in extinction or ionization across each galaxy in our sample. We require these observations in part to understand why ultraviolet images of spirals show occasional anti-correlations with our TTF Hα images of the same objects (see Cianci 2000, AAO Newsletter 94.)

The multiband design is crucial to allow differential imaging between widely spaced spectral bands. The TTF, like any disperser, has a periodic response in wavelength. To single out one order, we normally use a pre-filter whose bandpass is less than the free spectral range defined by the plate separation. But that only works when all the wavelengths to be imaged fall within the pre-filter bandpass. How are we to undertake differential imaging on bands which are very widely separated?

A beautiful solution comes from realizing that what is observed through the TTF at the detector is a convolution of the pre-filter with the periodic comb (Airy function). If the order is chosen correctly, the blue band can be placed beside the red band in Z-space without overlap, i.e. order confusion. (Z is the electronic variable used to tune the TTF.) It turns out that there are in fact many available TTF orders within the range m = 4 and m = 40 where this is indeed true. In other words, we can perform differential imaging over a wide range of spectral resolutions. Note that a pre-filter which stretched from Hβ to Hα could only be used at the lowest resolution (R<100) if order confusion is to be avoided. For a more detailed discussion, see Cianci, Bland-Hawthorn & O’Byrne, 2000, SPIE 4008, 1368.

OBSERVING AT THE AAT

Helen Woods & Stuart Ryder

In previous years, students have not been permitted to observe at the AAT unsupervised. As a result of discussions with both PATT and ATAC, the AAO wishes to announce that with the prior written permission of the Director, suitably experienced students may in future observe without their supervisor being present at the telescope. Supervisors who feel that their students may qualify to observe on their own should seek formal approval well in advance of the run, by sending e-mail to director@aaoepp.aao.gov.au.

There are no direct flights to Coonabarabran at present with the closure of Yanda Airlines. It is possible to fly to Dubbo and travel the remaining 1.5 hr trip by taxi or hire car. See the AAO web pages for the latest information.
**IRIS2 UPDATE**

Chris Tinney & the IRIS2 Team

Integration and testing of IRIS2 is proceeding apace, as the Observatory targets its scheduled first visit to the telescope at the end of Semester 01A. Observations will be attempted initially in ‘Shared Risks Service Observing’ (or SRSO) mode, followed by scheduled service programs in shared risks mode.

SRSO proposals should be submitted via the usual AAT service observing process - the next deadline is March 15. For IRIS2 SRSO there is no limit to the amount of time which may be requested, and the proposals will be ranked by the usual service observing process. Selection of proposals for execution will be made by the IRIS2 commissioning team, based on observing conditions and the capabilities of IRIS2 at the time. Several ATAC/PATT proposals have also been awarded shared risks time at the end of 2001A, and will be executed in service mode by the IRIS2 commissioning team.

Broadband (JHK) and narrow-band ([FeII], H2 ν=1-0 S(1), Br gamma & continuum filters are available, and a range of filters are on order) imaging at f/8 will be available, as will f/8 spectroscopy in the J, H and K bands at R≈1500. R≈2400 grisms are also on order. See the IRIS2 web pages at [http://www.aao.gov.au/local/www/cgt/iris2/iris2.html](http://www.aao.gov.au/local/www/cgt/iris2/iris2.html) for initial sensitivity estimates.

**BLUE SCIENCE WITH THE TTF**

Joss Bland-Hawthorn

If all goes well in April, the AAT will have a new high performance EEV 4K x 2K CCD at its disposal. The outstanding feature of the EEV chip is its excellent blue quantum efficiency compared to the MITLL arrays. At 450 nm, the EEV QE is close to 90%, a threefold increase over MITLL2a.

This augurs well for a new ‘blue science’ initiative with the BTTF. Steidel (2000, SPIE 4005, 22) gives several good reasons for favouring the blue over the red for chasing after high redshift galaxies and, in particular, the ‘spectroscopic desert’ at z≈1.3–2.5. The night sky is orders of magnitude darker in the blue compared to the red and the sky spectrum is relatively featureless in absorption and emission. For galactic studies, there are few if any deep [OII] emission line images of galactic or extragalactic nebulae. There is a slew of diagnostic absorption/emission lines arising from C, N, O, Si, S, Mg and Fe, to name a few.

The EEV response is to the BTTF what the MITLL3 array is to the RTTF – a perfect match. The BTTF transmission with wavelength is mirror symmetric with the RTTF transmission when reflected about 650 nm. Remarkably, the EEV QE response is mirror symmetric with MITLL3 in just the same way. The cross-over of the TTFs at Hα allows this line to be observed with either device, a crucial design consideration given that Hα is the single most important ‘normalizer’ or diagnostic line in the optical.

In order to assist telescope applications for 2001B, the TTF calculator has been upgraded to include the preliminary QE response and characteristics of the EEV. The early tests reveal the EEV to be a cosmically clean device, with good charge transfer properties and low dark current. The read noise is expected to be somewhat higher than for the MITLL arrays.

The available BTTF blocking filters are shown at the TTF web site. There may be funds for additional filters. Prospective observers should contact jbh@aaepp.aao.gov.au for details on filter purchases and calibration issues.
OPTIMAL SKY SUBTRACTION WITH FIBRE SYSTEMS
Russell Cannon

The bright-of-moon period in January 2001 afforded a rare opportunity to carry out comparative tests of different methods of sky subtraction using both the AAO’s fibre-fed systems, 2dF and SPIRAL. The basic question was to see how much better one can do using special techniques like beam-switching and ‘nod and shuffle’ (N&S), compared with conventional observing where a subset of the fibres is used to measure the sky. What is the best way of pushing fibre spectroscopy to fainter limits or higher precision? We need this information both to exploit the existing instruments properly and to plan the next generation (the AAOmega project).

The answer seems to be, as in most of astronomy, that it all depends what you are trying to measure and what is limiting your accuracy. It depends on how bright your targets are relative to the sky; on whether you are trying to measure faint quasi redshifts, stellar absorption line strengths or specific spectral features that may be contaminated by strong night sky emission lines; and it depends on the wavelength range you are looking at, and at what resolution. It also seems that the answer may be different for the independent multi-fibre 2dF system compared with the Integral Field Unit (IFU) SPIRAL.

Essentially, you want as accurate a sky spectrum as possible and to subtract it from the target object; this entails making two measurements and calibrating out any systematic differences between them. Astronomical complications arise since the sky has a mixture of continuum and sharp emission line features, the latter in particular often being time-variable, while faint objects may contaminate the supposed ‘sky’ measurement. Instrumental problems include variation of the profile (point spread function) across the field of view, scattered light in the spectrograph which can upset the relative throughput calibration of object and sky fibres; and errors in the wavelength calibration. All of these effects lead to imperfect cancellation of the sky. Scattered light can also enter into the process directly, in that it may contaminate both the object and sky measurements, but not equally; this is particularly a problem if a mixture of bright and faint targets are observed simultaneously with 2dF, or when observing a bright galaxy with SPIRAL.

For many purposes, the Nod & Shuffle technique pioneered at the AAO offers an almost perfect solution. The technique has been described in previous Newsletter articles (Bland-Hawthorn and Barton, No. 75, October 1995; Glazebrook, No. 87, November 1998) and in a recent paper by Glazebrook and Bland-Hawthorn (PASP 113, 197, 2001), where it was used with the multi-slit system LDSS++. The identical optical path is used for both object and sky measurements, and the rapid switching minimises any temporal variations. The only features which may not cancel perfectly will be those due to scattered light from the target itself; this can be a limitation of N&S in observations where the target signal level is significant, but not in completely sky-dominated data. Tests of sky versus sky lead to virtually perfect cancellation, with the noise following simple photon statistics (Glazebrook et al., Newsletter No. 90, August 1999). Thus N&S must often be the best way of obtaining faint sky-limited spectra.

However, N&S does have two drawbacks: it involves spending half the observing time making sky measurements, and it depends on having clean sky positions. Ultimately, the limit may be set not by photon statistics but by unseen faint objects in the sky channels. For a single-channel system spending equal time on source and sky is the optimum faint-object strategy, but for multi-fibre systems it should be better to put a subset of the fibres on sky; using just 40 of 2dF’s 400 fibres on sky should yield a simultaneous mean sky spectrum with only a sixth of the noise level of each individual sky fibre, while giving 90% rather than 50% observing efficiency. Moreover, having many sky fibres means that a median filter (as used in the 2dF data reduction software) will minimise the effect of any faint contaminating stars. The basic question then becomes: at what point do the systematic errors involved in using different fibres exceed the random errors due to the higher noise in N&S data?

During January we were able for the first time to get real data using Nod & Shuffle with both SPIRAL and 2dF. In addition, we took data in full (or cross) beam-switching mode; with SPIRAL this simply meant moving the target between the two halves of the rectangular field of view, with 2dF it involved creating a special configuration with pairs of equally-spaced fibres for every target. We even managed to get some 2dF data in combined beam-switching and N&S mode, although that was more as a demonstration of technical virtuosity than a practical observing technique (the yield of fibres on targets became rather low!).

Most of these data are still being analysed and we are not yet ready to make definitive statements. However, several general points are already clear. With SPIRAL, Nod & Shuffle works superbly. There was virtually perfect cancellation of night sky lines across the entire CCD frame, and the structure of galaxy or nebular emission lines which happened to land on strong sky lines was immediately recovered. The N&S technique also avoided...
almost all of the problems with scattered light which limit the accuracy of continuum night sky subtraction in conventional modes. As a bonus, one bad column on the CCD (which actually affected about six adjacent pixels) also disappeared. By comparison, SPIRAL observations taken in ‘conventional’ mode are difficult to analyse, since it is hard to define pure sky fibres and harder still to eliminate intensity or profile variations across the field. This becomes particularly evident when the data for many spatial pixels are combined; low-level systematic errors may dominate the results.

By contrast, although both N&S and beam-switching worked with 2dF, it is not obvious that they offer much advantage. Certainly at the moment full N&S is not a sensible option, since it can be run with only one CCD and involves masking off 119 of the remaining 200 fibres. A further factor of two is lost since half the time is spent on sky, so the final yield is only one eighth of a full 2dF field.

Cross-beam-switching was much better in this respect and should be almost as good as N&S in terms of sky cancellation, but here it became apparent that the problem of contamination in the sky fibres may outweigh the improved cancellation. It was also a difficult technique to set up, involving a complicated configuration. The conclusion here seems to be that to push fainter than the current large redshift surveys (which are for galaxies with B < 19.5 and QSOs with B < 21), at least in the blue-yellow spectral regions, conventional observing with ~10% of fibres allocated to sky is probably the best way to go at least one magnitude fainter, using four hours of integration per field rather than 40–60 minutes as with the GRS. However, beam switching may come into its own for working in the near-IR, where night sky emission lines dominate and fringing becomes significant, or for special purposes such as spectroscopy of the sodium D-lines in Galactic stars, which are often contaminated by terrestrial emission.

All of the observations described above involved a lot of work from several members of the SPIRAL and 2dF observing teams, and technical support staff in Coonabarabran and Epping. Fuller details will be reported as they become available.

WFI AND PFU

Chris Tinney

WFI+PFU has now been through three observing runs on the AAT, and we are gaining valuable experience with WFI, which we share with the ANU’s Research School of Astronomy & Astrophysics. Although a manual for WFI operations is not yet available, prospective observers will find a set of web pages at http://www.aao.gov.au/local/www/cgt/wfi/wfi_pfu.html and in particular a continually updated record of WFI’s performance at http://www.aao.gov.au/local/www/cgt/wfi/commission_plan.html

PFU is now substantially commissioned. The filters for use with WFI now reside in dedicated holders, with filter name bar-codes on them which are read at every PFU initialisation. These filter names are then passed back to WFI so that every observation is now coded with the unique filter name of the filter actually used. Shutter exposure has been shown to be uniform at the specified <1% level for exposures of 2s or longer. The shutter time delivered seems to be approx 18ms less than that requested, however once we are convinced this offset is constant with time, observers will be able to correct their data to provide timing to very high precision. Exposures of the moon have been acquired using effective times as short as 17ms.

The operating temperature of WFI itself has been increased to a relatively warm 183K, in order to reduce the effects of poor serial charge transfer in two CCDs. This results in science-grade image quality across the mosaic, though at the cost of increased dark current. Unfortunately, this dark current is not complete so observers must be aware that dark frame acquisition is a critical part of WFI observing.

Gains of the CCDs are between 1.5 and 2 e^-/adu, and read-noises in the only available read speed are between 4 and 6 e^- . Non-linearity is similar to that seen in the AAO’s other MITLL CCDs. If observers keep their exposures below 30,000 adu above bias, then non-linearity will always be less than 0.5%. Polynomial linearity corrections have been derived, though observers for whom this issue is important will want to check them with their own linearity calibration.

The entire mosaic is read, displayed and transferred to in just under 60s, by the 8 independent channels of the SDSU2 controller system. Single CCDs can be read alone, but do not speed up the read-out process.

Experience is still being gained with the data processing of WFI images. Observers should certainly acquire both
bias and dark frames, and both should be used in processing. Skyflat fields seem to work at the 2–3% peak-to-peak level, and users of other mosaics elsewhere have found the construction of ‘dark sky’ flats from their data to be essential. WFI will probably be no different. Fringing in the i and z bands (and in the band for CCD1) is at a level of about 3–5% of sky (in dark sky conditions). So for riz, both twilight sky and dark sky flats will be essential (you need the twilight sky flats so you can disentangle the additive fringe corrections from the multiplicative dark sky flat field). Observers should be warned that with a 0.5 degree field of view there is no such thing as a blank part of the sky, so you need to use large (30") non-redundant nods in acquiring your twilight sky flats to remove bright stars.

At the time of writing, the built-in guider CCDs of WFI have not been tested in anger. Unfortunately, the guider CCDs (when turned on) seem to inject a low-level dark current (50–100 adu/1800s) into the edge of the WFI mosaic. Given this, the time required to acquire guide stars before each exposure, and the AAT’s superb tracking over 5–10 minutes, it is unlikely most observers will choose to guide.

The sensitivity of WFI has now been measured on sky for a range of filters, and these numbers have been fed into the AAO CCD Imaging Calculator (http://www.aao.gov.au/cgi-bin/pfcalc.pl) which should be used to estimate exposure times for WFI proposals. At g and V WFI has sensitivity only slightly poorer than the TEK. At r performance is almost identical, while at i sensitivity is almost 60% higher. Similar excellent performance is expected at z. B band sensitivity, on the other hand, is almost a factor of three down on the TEK. In other words WFI is a superb red-sensitive wide field array, but has compromised performance in the blue.

The AAO’s EEV CCD (which it is hoped to commission in April) will fill the gap of blue-sensitive imaging over a single 2Kx4K field – though for surveys WFI (with 8 times the area) will still be the most efficient imager.

The only downside to WFI’s performance has been its reliability. At the time of writing roughly 4–5% of exposures are terminated during readout by an, as yet unidentified, controller problem. RSAA is trying to identify the resources to track down this bug. In the meantime AAT WFI observers should be aware that they will lose exposures during the night until this issue can be resolved. This is yet another reason why splitting your sky limited exposures into 5–10 minute chunks is a good idea.

Finally, once again we have to thank staff at both the RSAA and AAO for their Herculean efforts in making WFI+PFU a working concern – in particular Peter Young, Ian Price and Bob Dean without whom the last two observing runs would never have taken place!
Local News

**Markus Billerwell:** On arrival at the AAO I began working with the IRIS2 crew to determine why the stepper motors were not operating correctly in cryogenic conditions. It took 8 weeks of testing and analysis until the problem was solved — a great relief to all involved. During that time I spend a week at the AAT working with David Lee on SPIRAL — it was a very enjoyable and eye opening experience and I hope to return some time in the future. On completion of the IRIS2 stepper motors I began work on a piezo driver card for the Echidna project. This work involves reverse engineering which requires the construction of a schematic diagram from a visual observation of the driver card.

**Rosalind Wang:** While a Summer Student at the Anglo-Australian Observatory, I have worked with Geraint Lewis on the feasibility of astrometric measurement of gravitational microlensing (i.e. measuring the movement of the centroid position as the source star moves behind a lens(es)). Ever since 1986, when Paczynski proposed the term 'microlensing' to describe the gravitational lensing effects whose unresolved micro-images are separated in the order of microarcseconds, there has been a flurry of observations of microlensing events. To date, there are several hundred detections of the amplification of a source star's light due to the lensing effect of the foreground lens. All the announced events are however of photometric measurements, i.e. the amplification of the source star's magnification. This is because currently no instrument is sensitive enough to measure the position of the micro-images. With the launching of the Space Interferometry Mission in June 2006 ([http://sim.jpl.nasa.gov/](http://sim.jpl.nasa.gov/)) and the full deployment of the craft in 2011, it will be possible to measure the location of the centre of light (light centroid) to the required accuracy.

The major part of my project was to develop a computer code to simulate the microlensing events of a binary lens system. The positive detection of binary events will give us a better idea of the percentage of binary stars in the Galactic halo. A binary event is very different from a single lens event, as the source star will be microlensed to give 3 or 5 microimages depending on the source star's position with respect to the lens. With photometric measurements, similar light curves are produced for a wide range of different lens-source systems due to degeneracy. However, astrometric measurements can differentiate between these systems as the associated centroid deviations vary greatly. Also, for a great number of binary lens systems, the associated light curves are basically indistinguishable from that of a single lens system, but their astrometric shifts clearly show the unique signature of a binary lens event. Therefore, the measurement of astrometric shift as well as photometric deviation of a microlensing event will greatly increase our chance of identifying a binary system and working out the associated parameters of the system.

**Katie Noakes:** My time here at the AAO has been a great experience. There are not many 20 year old, 3rd year Mech. Engineering/Maths students who can say that they have played a part in instrumentation for one of the biggest telescopes in the world. I've been working on the Echidna multi-object fibre positioner for FMOS which is going to be located at the prime focus of the 8.2-m Subaru telescope. More specifically, I've been doing testing to determine the most appropriate materials to be used for certain parts of the Echidna ball-spine prototype. The people at the AAO have made me feel so welcome and have gone out of their way to make my stay here a pleasant one. Thank you to everyone for giving me this opportunity.
Michelle Doherty: I have been working on a project with Dr Terry Bridges which will involve searching for planetary transits in the globular cluster 47 Tucanae using the Wide Field Imager (WFI). Ken Freeman (Mount Stromlo), and Penny Sackett (Groningen) are also involved with the project. This cluster has already been the target of a similar search carried out using the Hubble Space Telescope. No planets were found in the HST search, but those observations were focused on the core of the cluster and we believe that if planets are to be found, it will probably be in the less crowded outer regions of the cluster. The WFI search will also probe a higher fraction of stars closer to the Sun’s mass than the HST search. Radial velocity searches have already found “Hot Jupiters” around solar type stars and it is planets such as these which are expected to produce a transit signal.

My eight weeks here at the AAO were therefore spent struggling with IRAF, wrestling with WFI data reduction, and swearing at the computer. (Oops! I mean producing a Colour Magnitude Diagram (CMD) of 47 Tucanae.) A good CMD is a necessary tool for this project, for if planets are detected it is desirable to know as much as possible about the star they are orbiting. The CMD will also help in determining cluster membership (and thus stellar size, which is important for the transit study), via colour and magnitude selection of cluster stars against the background of galactic and SMC stars.

The data from the Wide Field Imager instrument consists of mosaic images from 8 CCD chips and in total has a field of view almost 1 degree square. So far, I have completed an instrumental CMD for 6 of the chips. The results are consistent with previously published CMDs of the cluster and show very clearly the main sequence turnoff and just below. This is the main region of interest for the planet search as smaller dwarf stars are the most likely ones to show detectable transits. The SMC giant branch is also clearly visible.

From left to right: Markus, Michelle, Rosalind and Katie.
LETTER FROM COONABARABRAN
Rhonda Martin

2dF has finally let us down - as a rainmaker that is! There was once a time when we could rely on this marvellous machine and plan accordingly – get in stores, check the boats, train the doves to fly out and look for dry land, that sort of thing. But not any more it would seem – not unless Gerry Gilmore is the observer and even more so when accompanied by Rosie Wyse!

Australia has been in the grip of a heat wave with temperatures in the 40s and 50s (one place was 56 degrees celsius!) and staff were totting up the days until 2dF went on the telescope. Even the local Coonabarabranites, who usually use a lot of bad language when they hear of 2dF usage as they splash about their daily lives, were demanding it be put on the telescope, NOW!

Sighs of relief as 2dF was hoisted onto its perch and lots of gazing into a hard, blue sky. One day went past, then two, and then a week! Still that brazen sky, and gasps of disbelief as people ventured into the oven that was home. Nearly three weeks went by and everyone had given up hope when Gerry and Rosie arrived, and it happened; that ‘thunder of an army, the steady, drumming rain’ that all Australians love. Gerry sighed, and looked resigned – it tends to happen whenever he travels half-way around the world to get here. Rosie looked positively mutinous – she also had travelled a long way. Trouble is, things were a bit over-done and the north of the state promptly disappeared under a great deal of water – we understand that Moree actually sank into its beautiful black soil and hasn’t been seen since.

We offered grateful thanks to Gerry and Rosie and promised them superb weather and fantastic seeing for their next run. Trouble is, we will probably need more rain by then!

FAREWELL GORDON!

Gordon Schafer will retire from the AAO at dawn, March 15, just over 28 years after joining the AAO on the 19th of February, 1973. Gordon is the longest serving AAO employee, commencing his employment with the AAO working with the consultant engineers to build the Telescope.

Gordon was appointed when the dome was virtually complete and before the telescope erection started, with the specific role of keeping the dome in good working order. He was so easily able to cope with this task (a tribute to the dome’s engineering as well as to his capacities) that he very soon took on a vital share of the mechanical work associated with the telescope itself. Gordon liked nothing better than jobs like removing the declination drive gearbox and stripping it down to see why it made a mysterious regular clunk at high speed.

Peter Gillingham tells of an episode during their earliest days together, when the dome shutter chain broke and the dome could not be closed. “Early on a Saturday evening, I was lowered down the rear of the dome, outside the dome skin but inside the shutter, to view the broken links. Lowering went easily but raising me turned out to be a different matter. With the friction between the cable and the dome skin, the hand operated winch wasn’t up to the task. However, although I missed a favourite TV episode, I never doubted that Gordon’s ingenuity and good sense would get me out in one piece before midnight.”

Currently he supervises the mechanical workshop at site and is an AAT night assistant. Gordon’s encyclopaedic knowledge of the telescope and his plain talking interpretations of problems will be sorely missed. Gordon and Rae will be retiring to the Central Coast to enjoy the Pacific Ocean and be closer to children and grandchildren. We wish them both all the best for the future.
OBSERVATORY NEWS

We had a hectic December at the AAO, with the departure of four fixed term staff. Serge Ivanoff finished his contract as a software programmer for the PFU/WFI project and has headed to the UK. Carolyn Hampele once again departed, this time for the financial sector. Ivan Baldry took up a Post Doc at Johns Hopkins after working with Joss Hawthorn in a range of projects including OSIRIS and AAO. After several years as programmer with the IRIS2 project, Anthony Dunk leaves us to work closer to home on the NSW Central Coast. His new work will concentrate on 3D mapping with a Geology group.

Arrivals included Helen Sim, who will now act as public relations officer for both the AAO and ATNF, and Jason Griesbach who joins us from the U.S. to work as an electronics engineer on the FMOS/Echidna project. We've had the usual bevvy of summer students come and go - see page 16. Fraser Clarke is visiting for a month to work with Chris Tinney on weather in brown dwarfs. He is partway through a PhD at Cambridge supervised by Chris Tinney and Simon Hodgkin.

Congratulations to Bob Dean who is this year's recipient of Coonabarabran's Certificate of Recognition for Community Service. The award recognises Bob's outstanding contribution to community life in fields as diverse as WAR-FM, Rotary and the new Telecentre.

CROSSWORD COMPETITION
Keith Shortridge

Send a copy of the completed crossword to the Librarian, AAO (lib@aaepp.aao.gov.au), to arrive before 30 April 2001. The first correct entry drawn then will receive a copy of a photo by David Malin of their choice. The winner will be announced in the May issue.

Across
1. Cast steel, then manage an optical instrument. (This is ‘one’.) (9)
6. Chew steadily – I leave a city near ESO base. (5)
9. Alternatively, a child for Kane’s star. (5)
10. Inform our loveless Scots lad he’s an Earthling. (9)
11. See 29 down.
12. Virginia, to look sullen shows courage. (6)
14. Fled before church, love, to hacienda. (6)
15. Saw something in the distance and Desmond wept. (8)
18. Got pin in, confused, deciding to take part. (6-2)
20. French one jumbled up with dome at site of French ‘one’. (6)
23. Commercial break, all at sea. (6)
25. To beat being not at home before game. (3-5)
27. Oil! Oh – I move around election for the masses. (3,6)
28. Cancel yearly book – it’s missing the first letter. (5)
30. When it’s dark, close a junction. (5)
31. Rapidly turn East without being cowardly. (9)

Down
1.8. One plus one, then fifty plus fifty, in Switzerland makes ‘one’. (3,7,4)
2. Final batter to endure British Isle. (4-3)
3. Songfest hit snag on being rearranged. (9)
4. Went faster than within stout ranks. (3-3)
5. Headless fella sang jazz. (4)
6,13. So many ‘one’s here ANU make a muddle. (5,3)
7. In East Africa, precipitation rises above Jedi. (7)
11. Where ‘one’ twin is built on a corn crop he damaged. (5,6)
13. See 6 down.
16. About 516 sheets encrust something unhealthy. (5,4)
17,22. I’m Cupid, I’d disrupt ‘one’ site in France. (3,2,4)
19. Go, mix gin in a state of rotation. (7)
21. International relaxation when a catch heads East. (7)
22. See 17.
24. Don’t sink, wave aloft. (5)
26. Sounds like a girl led poor Yorick. (4)
29,11. ‘One’ location where Californian city rascal has a nasty start. (3,8)
A WFI Image of the Moon

This image of the Moon was acquired on the AAT with the Wide Field Imager (WFI) and the AAO’s Prime Focus Unit (PFU) on 2 February 2001 by Chris Tinney, Fraser Clarke and Gordon Schafer. It was taken in the U (ultraviolet) passband in a 0.1 second exposure in roughly 1–1.5" seeing about 40 minutes after sunset. Each panel of the image is 2048x4096 pixels in size, to produce a total image size of 8192 x 8192 pixels, at an image scale of 0.246"/pixel.