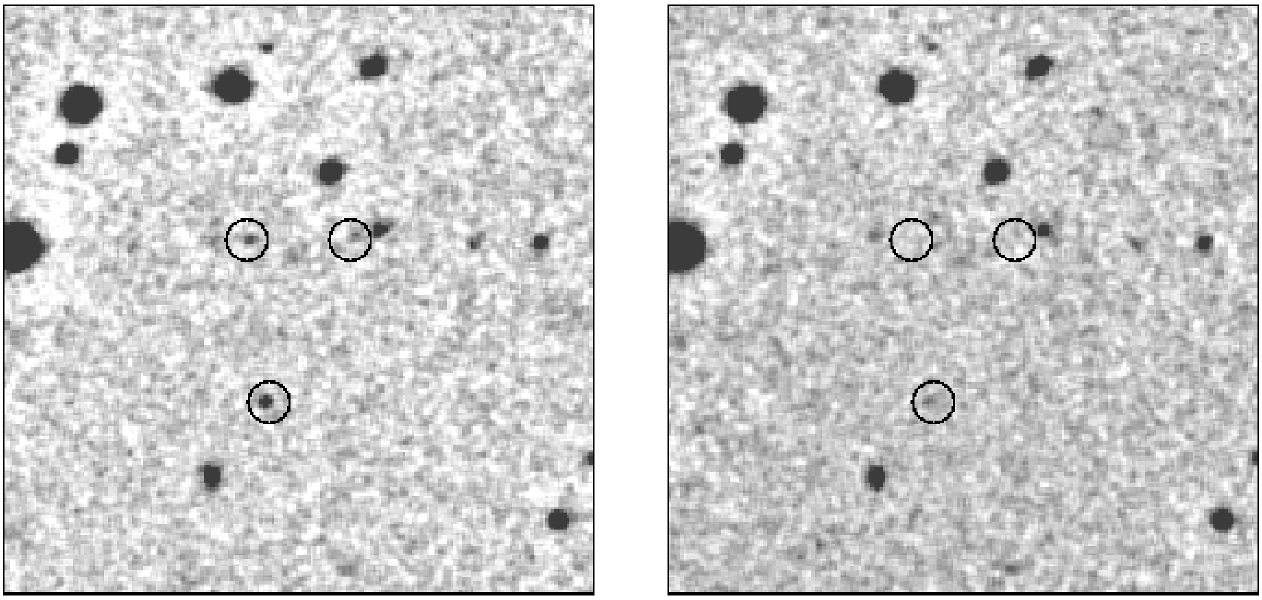
NUMBER 90 AUGUST 1999

AAO NEWSLETTER

ANGLO-AUSTRALIAN OBSERVATORY

Now you see them, now you don't!



ON OFF

Images showing three emission-line galaxies (circled) at *z* = 0.9 detected with TTF in the field of quasar MRC B0450-221. Images are shown both 'on' and 'off' the emission line [O II] λ3727. See article by Baker, et al. p3.

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DIRECTOR'S MESSAGE

It is a truth universally acknowledged that the AAO is not located on one of the world's best astronomical sites, at least as far as weather or seeing is concerned. However, the AAO perhaps receives more than its fair share of bad press as far as the prevailing climatic conditions are concerned. This is amply illustrated by the experience of the MPE team whose highly successful 2-year period of bringing their 3D instrument to (and from) the AAO has recently come to an end.

As Lowell Tacconi-Garman diplomatically acknowledges in his article in this Newsletter, the 3D team came with the belief that "the seeing is nothing to write home about". Yet, over the four semesters that the 3D team observed at the AAT approximately two-thirds of the time was clear and, of those two-thirds, the K-band seeing was one arcsecond seeing or better 60% of the time. While this may be surprising to some people, this is simply the Siding Spring long-term average. Although the "average" weather undoubtedly played its role, the more important factor in the success of 3D was undoubtedly the skill and dedication of both the 3D team and the AAO support staff. It is perhaps too infrequently acknowledged that a "benign" site like the AAO does offer the significant advantage over more "hostile" sites of being easier to work in. A benign location also makes it easier to attract the skilled technical staff that are much of the reason behind the AAO's world-wide reputation for outstanding support.

3D was an extremely positive and productive experience for all concerned: the AAO, the MPE team and the Anglo-Australian community who were able to observe with this state-of-the-art instrument. The AAO is indebted to the MPE team for bringing 3D to the telescope, and we look forward to any future opportunities which may arise to host new instrumentation from MPE or, indeed, any other group at the AAO. Other instrument groups take note of the MPE experience!

As the articles in this newsletter attest, the AAO's recent "home-grown" instruments, in particular the Taurus Tunable Filter (TTF), are also now reaching a level of maturity where much outstanding science is being produced. The discovery of a z=0.9 cluster around a radio-loud quasar (Baker et al.) and anomalous arms in a Seyfert (Cecil) are just two examples of the excellent science now being produced from TTF. As a commissioned system, 2dF continues to improve its reliability and performance. Although the redshift surveys have suffered from poorer weather than the statistical average over the past six months, they are now past 50000 galaxy redshift / 5000 QSO redshift mark, and heading for the $10^5/10^4$ galaxy / QSO redshift milestone by the end of semester 99B.

Finally, the article by Karl Glazebrook and others in this newsletter demonstrates that the AAO can be productive even on cloudy nights. They report on the innovative nod-and-shuffle sky-subtraction technique being successfully applied to 2dF observations during a night with "sub-optimal" conditions. Clearly anything that the AAO site may lack in weather conditions, it makes up for in the productivity and innovation of its staff.

Brian Boyle

Next issue:

The November issue will have a theme of **Early Results from 2dF**. So what have you been doing with all those fibres? Please tell us! Of course, articles on other recent research with the AAT and UKST are also very welcome. Contact **newsletter@aaoepp.aao.gov.au**. Contributions are due by November 1, 1999 with no penalty for early submission! Preferred formats are ascii or latex text, and postscript or gif images.

STARFORMING GALAXIES AT $z = 1$ WITH TTF

Jo Baker (Berkeley), Dick Hunstead (U Syd) & Malcolm Bremer (U Bristol)

In recent years, deep field surveys and cluster searches have indicated that galaxies were forming stars much more prodigiously at $z = 0.5 – 1$ than they are today. In a global sense, the average rate of star formation in the universe increases steadily up to $z = 1 – 2$ where it plateaus (and possibly declines again above $z \sim 3$) (Madau et al. 1998). However, little is known about the cause of the strong evolution in star-formation rate, and moreover, the redshift region $1 < z < 2$ remains poorly characterised despite the majority of stars apparently being formed at that time. A perhaps related, and equally poorly understood, evolutionary trend is the rise and fall of quasars and active galactic nuclei (AGN) from $z \sim 5$ to the present day.

To shed light on these and other issues, we have begun a programme of deep multicolour imaging of quasar fields, including narrow-band observations with the TAURUS Tunable Filter (TTF; see previous AAO Newsletters for a description). These observations aim to identify and investigate clusters of galaxies around quasars at $z \sim 1$ and beyond, and to investigate links between quasar properties and their environment.

To date TTF observations of five $z \sim 1$ quasar fields have been obtained at the AAT. The targets comprise radio-loud quasars drawn from the complete Molonglo Quasar Sample (Kapahi et al., 1998). TTF bandpasses of 8 – 10 Å FWHM were scanned in a sequence of seven steps through the wavelength of [OII] λ3727 at the quasar redshift in order to sample a typical cluster velocity range, ± 2000 km/s or so.

A detailed analysis has now been completed on the first field observed with TTF, quasar MRC B0450–221 at $z = 0.898$, including complementary *V*- and *I*-band optical imaging and follow-up spectroscopy (Baker et al., 1999). In a relatively modest total observing time (7 wavelength steps of 1000s each), 10 new emission-line galaxy candidates were identified in the TTF dataset with estimated [OII] equivalent widths greater than 70 Å (equivalent to star-formation rates of about 10 M_{sun} per year). Three obvious line emitters are shown in Fig. 1 (see Front Page). Four (out of 5 targetted) have been confirmed spectroscopically to lie at $z = 0.9$ (an example is shown in Fig. 2).

The corresponding overdensity of star-forming galaxies at $z = 0.9$ relative to the field (Cowie et al., 1997) is a factor of 10 – 20 in the 600 Mpc^3 volume sampled by TTF. The majority are consistent with bona fide $z = 0.9$ galaxies: the number density of ELG candidates peaks at the quasar redshift (and drops to approach the field density beyond 1500 km/s) and only 1 – 3 low-redshift interlopers are expected.

Most of the emission-line galaxies lie in a group offset some 200 – 700 kpc west of the quasar. Around the quasar itself, within 1 arcmin, lies an excess of red galaxies with *V–I* colours consistent with passively evolving ellipticals which tend to characterise the cores of clusters (Smail et al. 1998). Therefore, the quasar MRC B0450–221 lives in a cluster environment, characterised by the accretion of gas-rich galaxies from the overdense field onto an older cluster core. Similar studies with TTF of more quasar fields will help provide a representative picture of clusters and quasar environments at $z \sim 1$.

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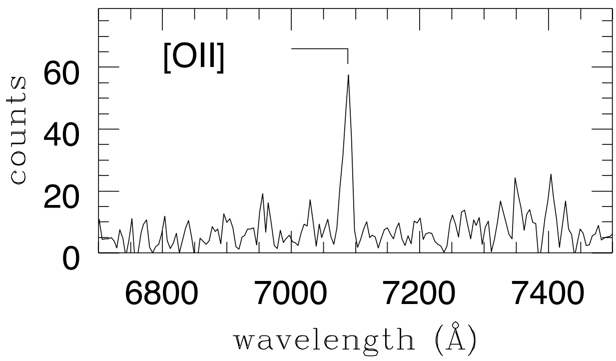

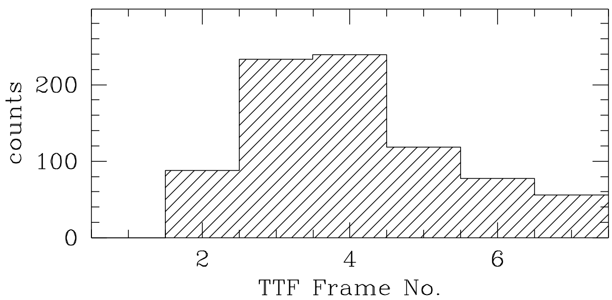

Figure 2. Left: Spectrum of an emission-line galaxy detected by TTF, showing [OII] at $z = 0.9$. Right: The counts in each TTF bin are also shown for comparison.

SCIENCE WITH WFI WORKSHOP

The AAO, RSAA & University of Melbourne will be holding a workshop commencing after lunch on Oct 14 and through Oct 15. The venue will be the RSAA's Mt Stromlo headquarters. This meeting will discuss in detail the scientific opportunities offered by the 8K x 8K Wide Field Imager (WFI) which will be commissioned on the SSO 1-m telescope later this year, and the AAT early next year.

WFI will provide fields of 33' x 33' on the AAT at 0.23"/pixel and 52' x 52' at 0.4"/pixel on the SSO 1-m. These wide fields will permit a whole new class of survey science to be undertaken at both facilities, and it is the exploration of these scientific opportunities that is the aim of this workshop.

Presentations will be made of the capabilities of WFI, and key speakers will be invited to review prospects in a number of selected scientific areas. Following this, attendees will be asked to present specific projects they have in mind. As a key aim of this meeting is to make plans for strategic large-scale surveys, it will be essential for speakers to present specific project details (i.e. survey areas, locations, passbands, depths, etc) so that overlaps and commonalities can be identified. Commonality with surveys involving IRIS2's wide field (7.7' x 7.7') JHK capabilities will also be explored.

So get thinking about your WFI projects!

Those interested in attending should contact Gary Da Costa (gdc@mso.anu.edu.au), Michael Drinkwater (m.drinkwater@physics.unimelb.edu.au) or Chris Tinney (cgt@aaoepp.aao.gov.au) before October 1. A brief description of the presentation attendees would like to make would be appreciated.

Descriptions of WFI and its capabilities can be found at www.aao.gov.au/local/www/cgt/wfi/wfi_pfu.html and msowww.anu.edu.au/observing/wfi/index.shtml

TRACKING THE TWISTED JETS IN NGC 4258

Gerald Cecil (SOAR Project/NOAO)

We have used the red TTF at the WHT to study the famous "anomalous arms" which extend in the radio for 10 arcmin across the nearby Seyfert galaxy NGC 4258 (M106). These observations are part of an on-going programme with the AAT, CFHT and WHT to understand extended narrow-line regions in active galaxies. NGC 4258 is an important target because it hosts an accretion disk whose properties are exceptionally well constrained by embedded water masers (Miyoshi et al. 1995). Proper motions of the masers have been used recently to establish an entirely geometric distance to the galaxy that is accurate to a few percent (Herrnstein et al. 1999) The disk inclination and warp is very well constrained, and the disk is in Keplerian rotation about a black hole of mass $4x10^7$ M_{sun}.

The anomalous arms were first detected in Hα, but are also prominent in radio synchrotron and X-rays. ROSAT imaging spectroscopy (Cecil, Wilson & De Pree 1995) established that the X-ray spectrum is thermal, and characteristic of high-speed (~400 km s^{-1}) shocks within a few tens of arcseconds of the nucleus. Such shock velocities are also consistent with the emission-line spectrum (Cecil, Morse & Veilleux 1995) and oscillatory kinematic deviations from disk motion (Cecil, Wilson & Tully 1992). The arms therefore likely arise from shock excitation as jets flow near the comparatively dense ISM of this spiral galaxy. In the radio, the jets span the visible extent of the galaxy (Fig. 1c) but their orientation is unconstrained. Given the large gas velocities, there is no reason to expect that the arms remain in the galaxy disk.

With a few minutes remaining at the end of another program, we used the TTF for a 20-min Hα exposure (Fig. 1a,b) with a bandpass of 14 Å, followed by a broad-band 2-min exposure to record starlight for subtraction. It is impressive that, despite full moonlight, the TTF images reveal jet/ISM interactions at much larger radii than hitherto reported (marked in Fig. 1a,b). This is a tribute to the high efficiency of the TTF even when working with a narrow bandwidth.

From the spatial extent of the gas and its flux, we infer recombination times much shorter than the dynamical time of the outflow (t_{rec} < 80,000 sqrt(f) years, with f the gaseous filling factor) and gas densities expected in the galaxy disk n_e ~ 1.4/sqrt(f).) The implications are that the flow is still active and splashes back onto the galaxy disk at large radii. This would arise if the jets became mass loaded by entrainment during their initial flow through the disk. The TTF is sensitive enough to obtain the fluxes of other spectral lines and to constrain velocities of the gas along the newly revealed jet strands. We hope to obtain these observations soon. In this way we will form a comprehensive, 3D view of the flow from the black hole to the edges of the galaxy to finally crack this dynamical puzzle.

A full description of these data is available on the Astro-ph preprint server.

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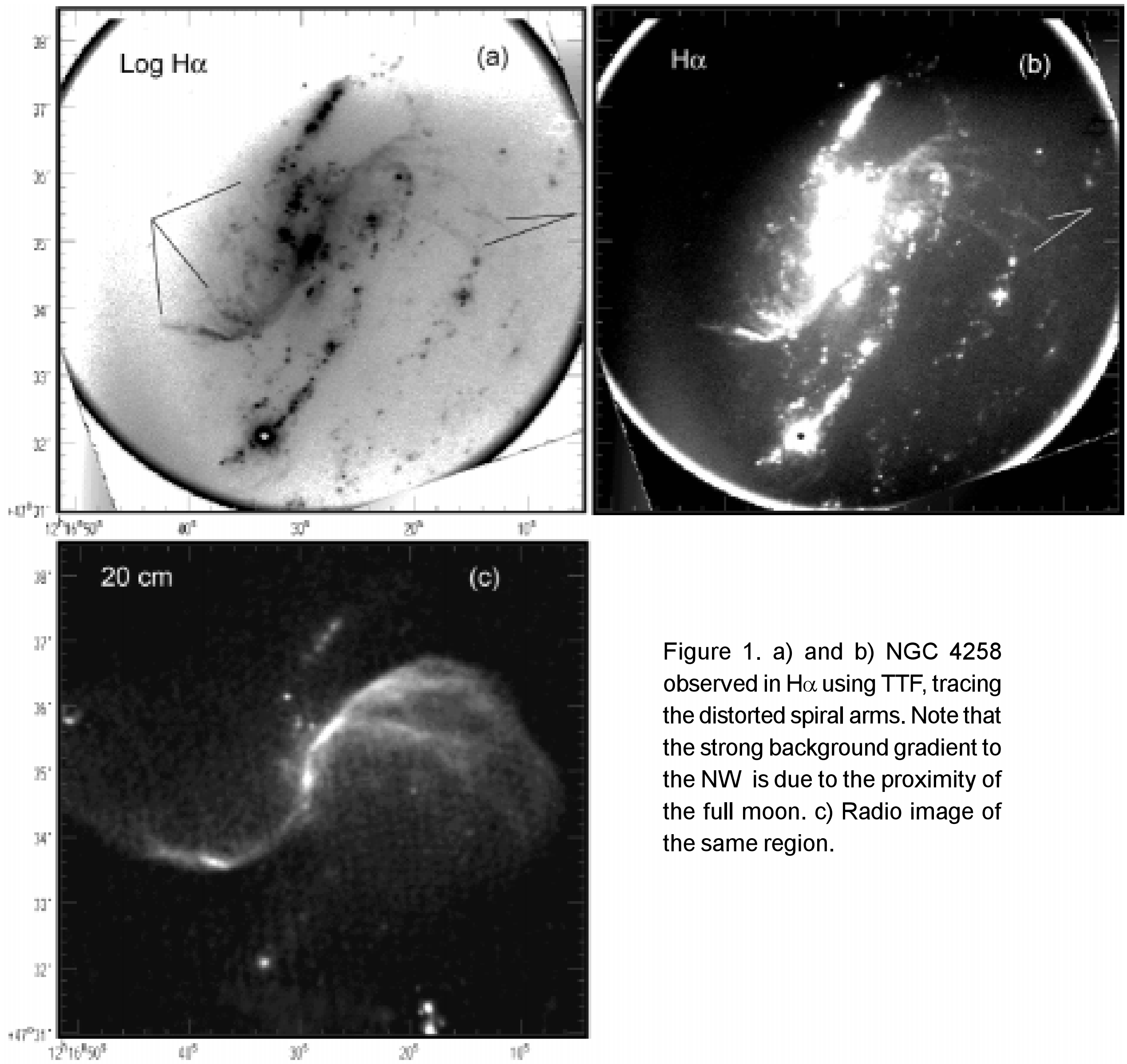

Figure 1. a) and b) NGC 4258 observed in Hα using TTF, tracing the distorted spiral arms. Note that the strong background gradient to the NW is due to the proximity of the full moon. c) Radio image of the same region.

2DF GALAXY REDSHIFT SURVEY: AN UPDATE

Ian Price, Matthew Colless (ANU) & Terry Bridges (AAO) for the 2dF Galaxy Redshift Survey

It's been over a year since the last news about the 2dF Galaxy Redshift Survey (see article by M. Colless in the April 1998 issue), so we thought we would give a brief update of the project. The 2dF GRS is a consortium, largely of Australian and UK astronomers, that aims to observe the spectra and measure the redshifts for 250,000 galaxies. The galaxy sample is magnitude limited at 19.45, and was selected from UK Schmidt plates scanned by the APM. The galaxies selected are in two contiguous strips, one in each of the North and South galactic caps, and in 100 random 2dF fields in the South galactic cap. The 2dF GRS is integrated with the QSO Redshift Survey (see article by Croom et al. in the July 1998 Newsletter for more information about the QSO RS).

In semesters 1998B and 1999A an additional ~41000 redshifts were measured, taking the total of unique redshifts to ~50000 as of July 1999. This makes the 2dF Galaxy Redshift Survey the largest of its kind, with twice the number of measured redshifts as the Las Campanas Redshift Survey. The current map of the galaxy distribution clearly shows large scale structure in the local universe. This is illustrated in the cone plot of Figure 1 (Back Page), where redshift is plotted against RA for the observed galaxies. The blank wedges in this figure result from currently incomplete sampling, and do not reflect the galaxy distribution.

The effect of clustering in the galaxy distribution can be seen through the dynamic component of the measured redshifts. Analysis of the redshift space distortion (Figure 2, Back Page) clearly shows the 'finger of god' effect which results from the peculiar velocities of galaxies in cluster potentials. This is demonstrated in Figure 3 by the increase in the correlation function on small scales along the line-of-sight. The anisotropy of the correlation function provides an estimate of $\beta = \Omega^{0.6}/b \cong 0.5$.

Observations in the coming semester will soon fill in gaps in the observed field distribution, providing large contiguous regions with high redshift completeness. This will allow preliminary analysis of large scale structure, and provide constraints on the density of the universe and the nature of dark matter.

For more information about the 2dF GRS, see our WWW page at: http://msowww.anu.edu.au/~colless/2dF/ and for the 2dF QSO Redshift Survey see: http://msowww.anu.edu.au/~rsmith/QSO_Survey/qso_surv.html.

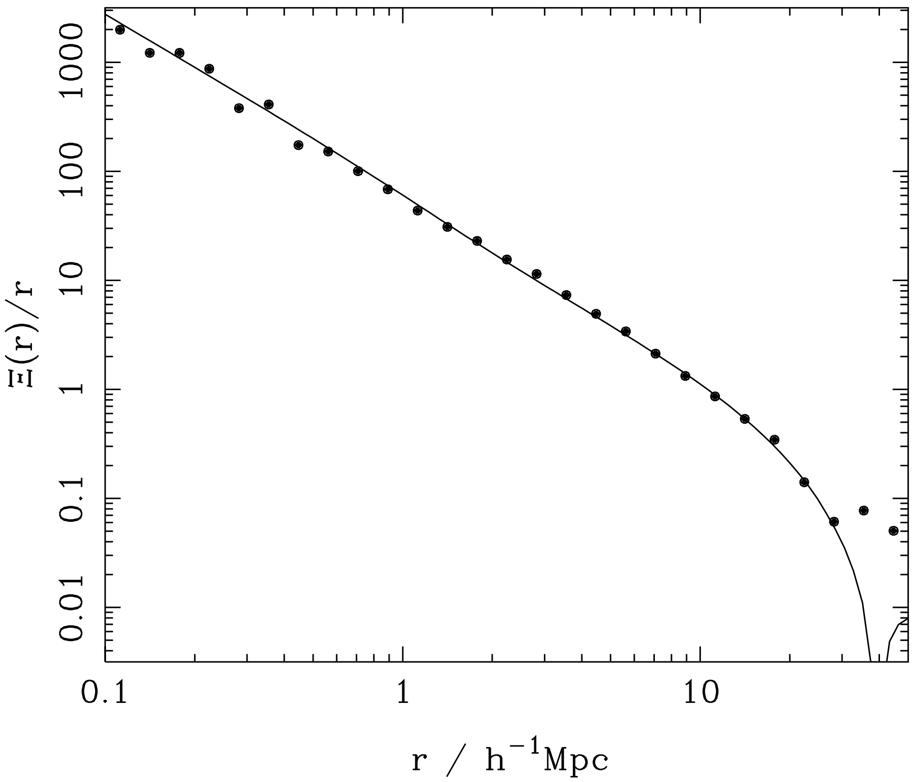

Figure 3. The projected real-space correlation function. The solid line shows the prediction from the APM galaxy survey angular correlation function.

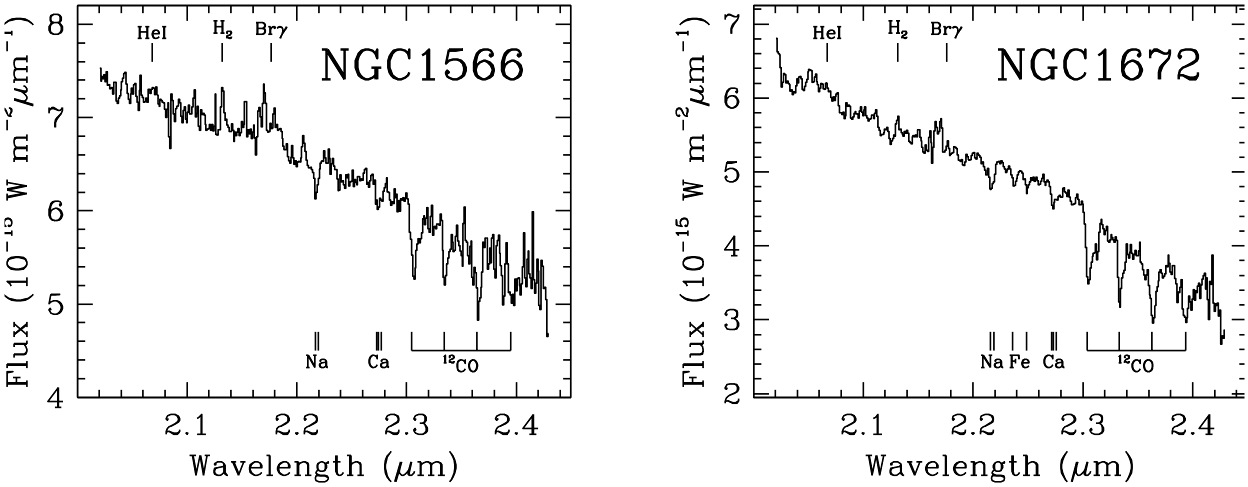

Figure 1. The nuclear spectrum of the Seyfert 1 NGC 1566 (left) and the Seyfert 2 NGC 1672 (right), obtained with 3D on the AAT. Note that both galaxies show strong stellar absorption lines in their spectra.

MPE'S NEAR–INFRARED IMAGING SPECTROMETER 3D AND THE AAT, Or How We Spent the Winter During the Summer and Vice Versa

Lowell Tacconi-Garman (MPE)

During Semesters 97B through 99A those among you with keen eyes will likely have noted the invasion of the AAT by "the Germans." This unruly pack brought with it a most suspicious instrument, with the even more suspicious name 3D + **ROGUE**. The staff at the AAT are likely still asking themselves: Who were these invaders, and what could they possibly have in all those wooden shipping crates?

As it turns out "the Germans" were a team of people (myself, Jack Gallimore (now at NRAO), Stephan Anders, Frank Eisenhauer, Jens Jansen, Sabine Mengel, Eva Schinnerer (now at CalTech), Rafael Sosa-Brito, and Niranjan Thatte) from the *Max-Planck-Institut für extraterrestrische Physik* (what a mouthful!) located in Garching, Germany. In late 1996 we were approached by both Russell Cannon and Stuart Lumsden with the enticing idea of bringing MPE's 3D instrument to the AAT and offering support for non-MPE users, in exchange for guaranteed nights. We were a bit apprehensive to take them up on their offer, since (1) we had seen a cartoon of the AAT depicted as a rain bucket, (2) the seeing at the AAT was rumoured to be nothing to write home about, and (3) those *huntsmen*! However, we were convinced that this offer was too good to turn down, and we set about working out the fine points of the agreement. Early on, MPE's guaranteed nights were targeted for a Key Program of observations of Seyferts, ultraluminous IRAS galaxies (ULIRGs), and sources discovered as part of the European Large Area ISO Survey (ELAIS), some results of which are shown below.

Our first run was in November of 1997, but already in early October we had our first exposure to Australian wildlife (or lack thereof). It was only a few days before

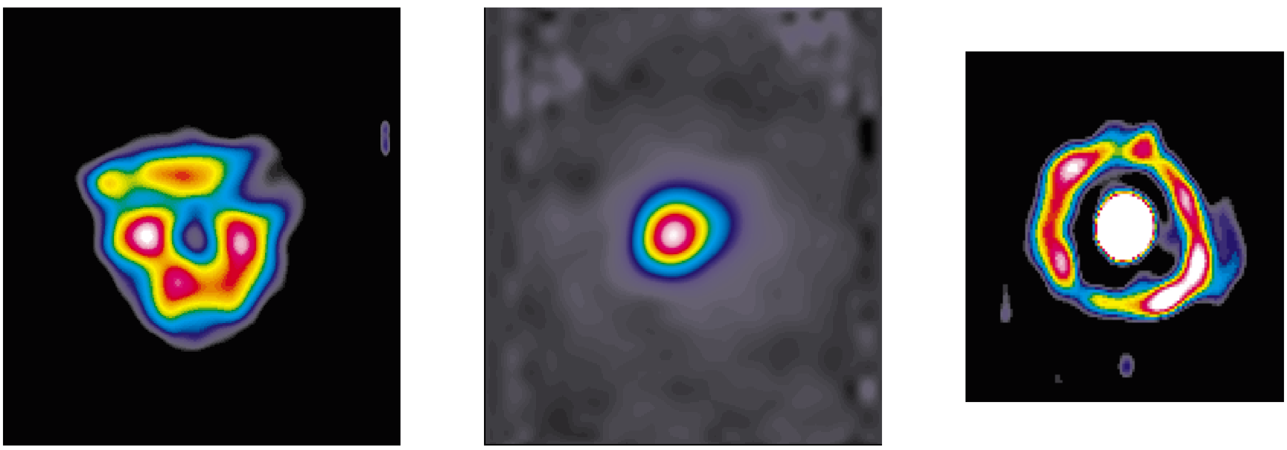

Figure 2. The results of the decomposition of the K–band emission from the Seyfert 1 NGC 7469 into its stellar (left) and nonstellar (middle) components (images are 8 arcsec on a side). For comparison, we show on the right the K–band map (Genzel et al. 1995) made with the MPE speckle camera SHARP (image size is 6.4 arcsec on a side). The ring shown in the right panel is due to star formation.

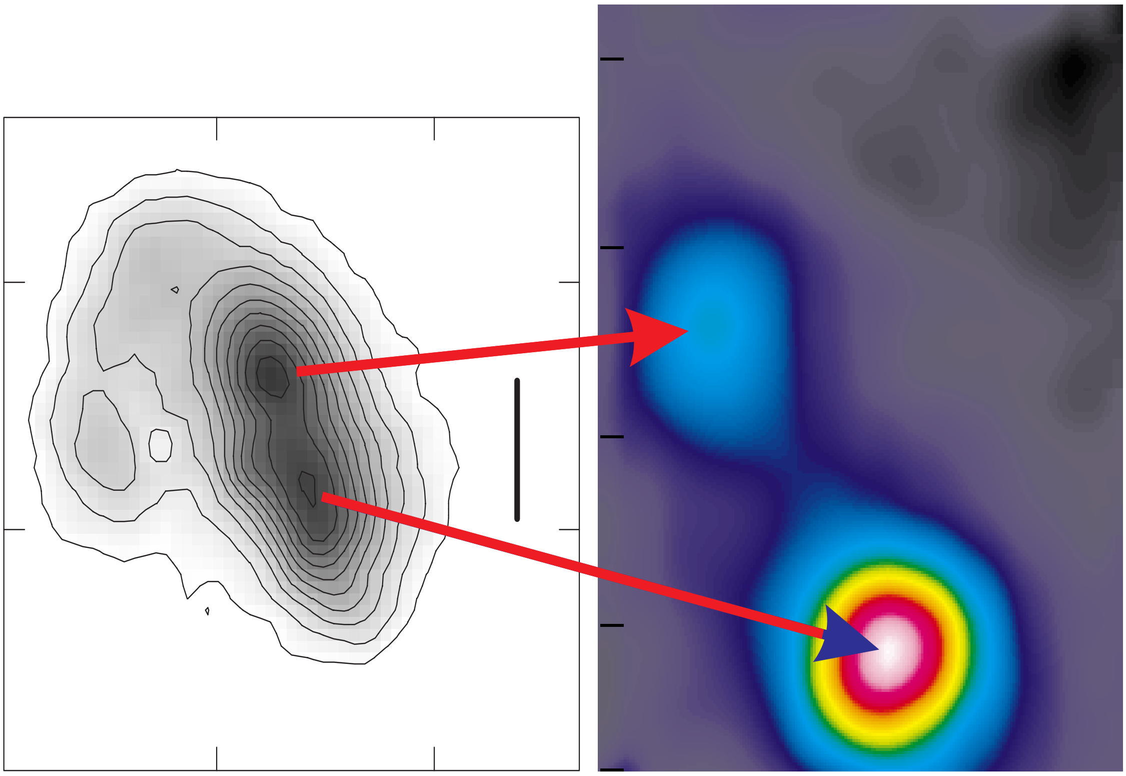

Figure 3. (left) R–band image of IRAS 06206–6315 from Duc et al. (1997). The bar represents 5 arcsec. (right) The K–band image obtained with 3D on the AAT in October 1998 under conditions of one arcsec seeing. Note that the southern nucleus is much redder than the northern nucleus.

we were due to ship essentially an entire lab* to the AAT in our time–tested wooden shipping crates when someone at our institute made the offhand remark that it was surprising that we were able to use wooden crates at all. A quick bit of checking with the appropriate authorities confirmed that there was the potential of transporting non-indigenous critters from Germany to Australia (that is, other than the astronomers). This really put us into panic mode, as everything was "go for liftoff" with no time to spare for box fumigation . In the end, a letter on MPE letterhead did the trick.

After arriving at the telescope we settled into our home away from home and set about reassembling the combined 3D/ROGUE instrument (for information about 3D and ROGUE see http://mpe3d.mpe-garching.mpg.de/3D.html and its associated links). 3D then saw "first AAT light" on the night of 07/08 November 1997. On that particular night, after aligning everything and doing the necessary first night tests, we started in on the Key Program by turning our attention to the Seyfert 1 galaxy NGC 1566. Under what we at the time considered uncharacteristically good AAT seeing 0.6 arcsec, we obtained slightly less than a half hour of R=1000 K–band data. These data were supplemented two nights later in 0.5 arcsec seeing, and the resulting K-band spectrum from the inner 1 arcsec is shown in Figure 1 (left), along with the nuclear spectrum of the Seyfert 2 NGC 1672 (right; also obtained as part of the Key Program). These Seyfert data, along with others, are presently being analysed and will be included as part of the Ph.D. Thesis of Rafael Sosa-Brito. The efforts to date in the analysis of the Seyfert data have concentrated on isolating the stellar versus non-stellar contributions to the nuclear emission (Figure 2).

As an example of Key Program ULIRG data, we present in Figure 3 (right) a K–band image of IRAS 06206–6315. Figure 3 (left) shows an R-band image of the same source (from Duc et al. 1997). In Figure 4 we show the resulting seeing-weighted spectra of the southern nucleus (left) and the northern nucleus (right). A noteworthy result is that though neither nucleus exhibits a broad Pα line which would indicate the presence of nuclear activity, the southern nucleus does show prominent [Si VI] emission normally attributed to AGN.

In addition to our own observations, we also supported (and continue to support through our website) a wide variety of non-MPE led projects which are feverishly being worked on at a number of places in the U.K., Australia, and the U.S. Some examples of these projects are: Meadows and Crisp (JPL) have observed the night side of Venus in H and K to determine the horizontal and vertical distribution of water vapour through the middle and lower Venus clouds with unprecedented global spatial coverage and high spectral resolution; Hoare et al. (Leeds) have studied shocked gas around young H II

* "So **that's** what they had in all those boxes!"

regions; Meikle et al. (IC) have monitored the evolution of the ejecta and circumstellar material around Supernova 1987A; Lumsden et al. (now at Leeds) have obtained spectra of Seyfert 2 galaxies to complement near-IR polarimetry in order to test the Unified Model for AGN; Appleton et al. (Iowa) have explored the nature of the ISM in the highly segregated CO / H I disk of Arp 118; Crowther et al. (UCL) have observed the WR starburst galaxy NGC 5253; and Burton et al. (UNSW) have investigated the photodissociation region of NGC 2023 by measuring the variation in H_2 line ratios.

This wealth of data was made possible by the friendly and thoroughly professional support we received from the AAT staff, as well as the very cooperative weather. Indeed, in spite of the fact that certain staff members welcomed our return as a sure sign of a return to rainy weather, we were, on the whole, very pleased with the weather. Over the four semesters that we observed at the AAT, something like two-thirds of the time was unfettered by clouds. And, perhaps even more surprising to us was that of those two thirds, about 60% was arcsecond or better seeing. But, *oh*, those huntsmen!

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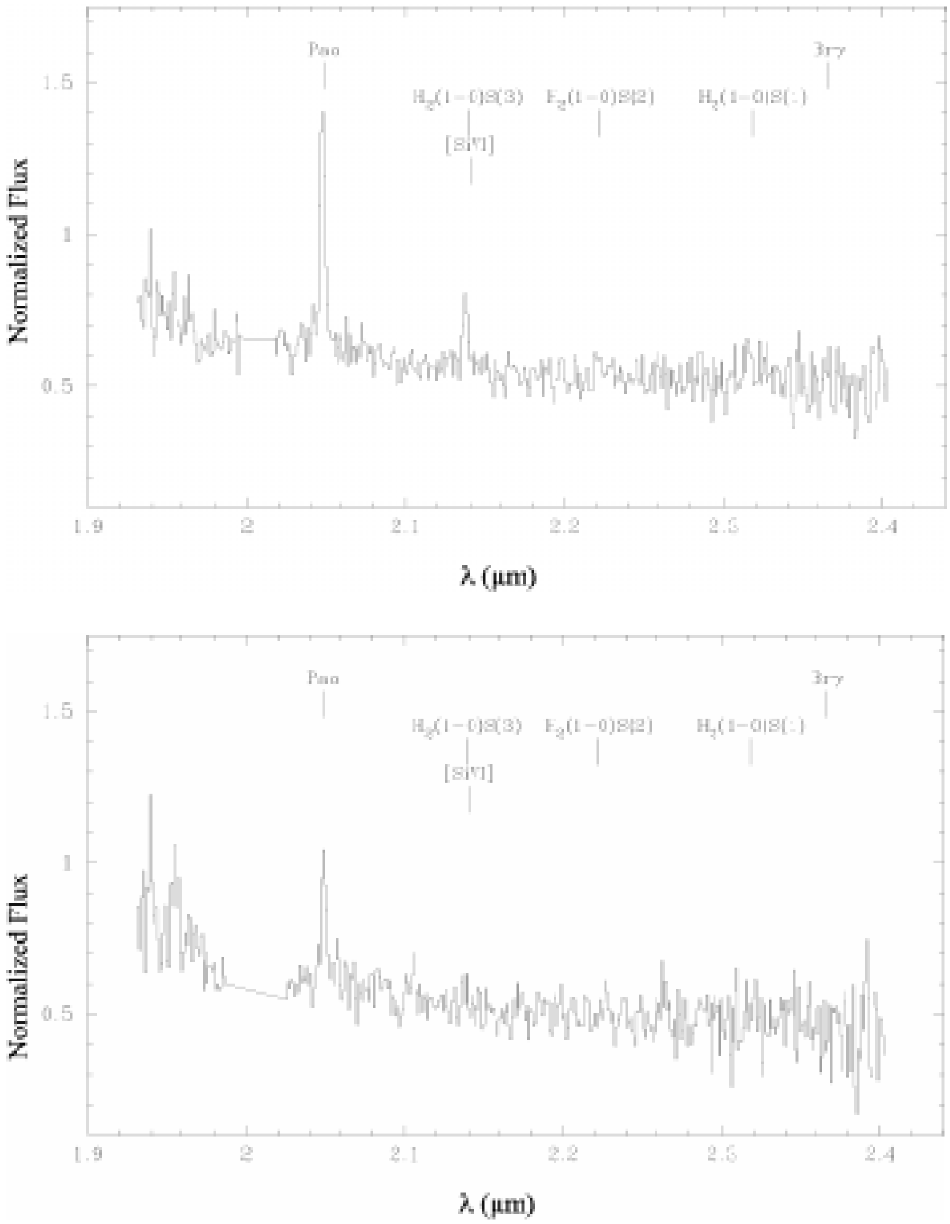


Figure 4. The seeing–weighted spectra of the two nuclei of the ULIRG IRAS 06206–6315. The upper panel shows the spectrum of the southern nucleus, while the lower panel shows the spectrum of the northern source. The wavelengths of some common NIR lines are marked for the redshift of this source. The features at 2 μm are due to the atmosphere. Neither component shows a very broad Pα line, though the northern source is substantially bluer than the southern source.

NOVA VELORUM 1999

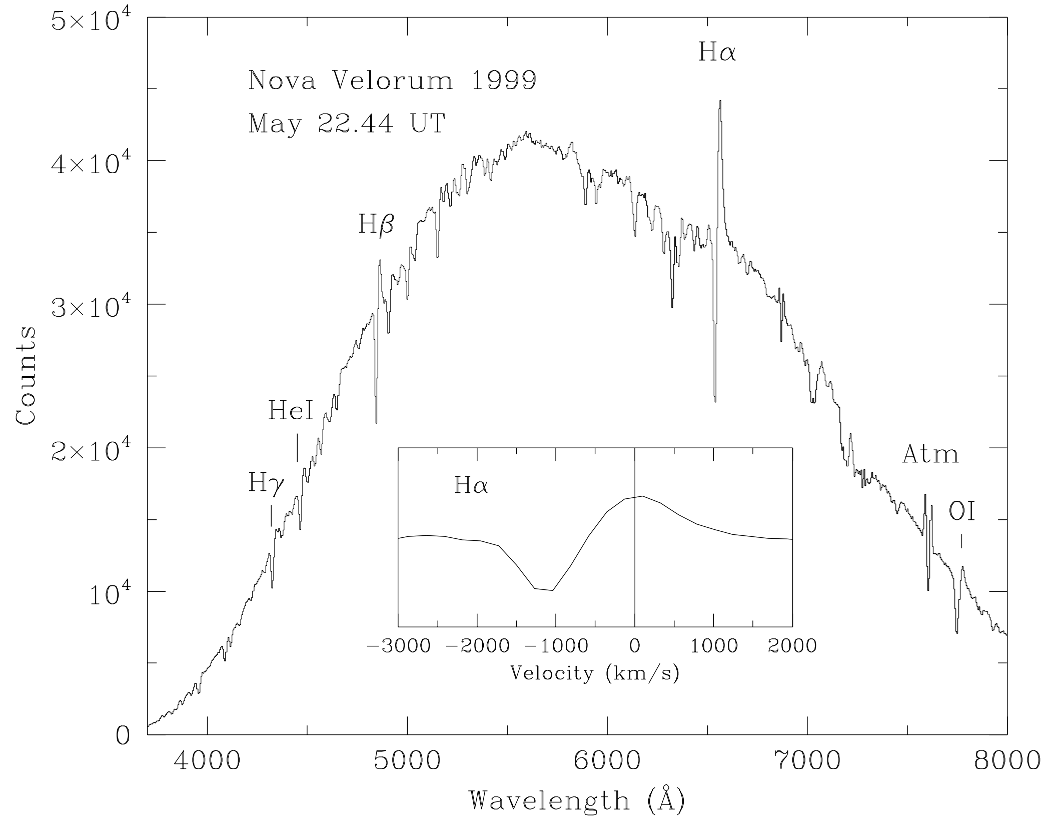
Steve Lee

Coincidence can play a big part in observing as we found out on the night of May 22 this year. The night was a bit on the bright side for a good 2dF redshift survey run and the little bits of cloud floating past were a serious limitation. An exposure was just finishing and deep discussions about what could be done in the marginal conditions was underway when the telephone rang. It was Peter Williams, a keen amateur astronomer and also an old friend of mine. Not wishing to be outdone by my recent discovery of a comet (which matched his discovery of C/1998 P1 last year) he'd just found a new star in the constellation of Vela – probably a nova, but you couldn't be sure. Could we help?

I took the details and posed the question to the observers – "can we squeeze in time to confirm a 3rd magnitude possible nova?" Ian Lewis and I adjourned outside armed with a Norton's star atlas to check on the candidate star and weather. The conclusion was that the star was definitely real and that the weather was too poor for observing given the amount of moonlight.

The hardest problem was finding it with the FPI – Peter's coordinates weren't good enough and after 10 minutes of hunting around we were ready to give up. I rang Peter back and he gave me a different set of numbers from another amateur in Perth. These proved equally poor but as a last resort I set the telescope to the mean of their offerings and bingo – one very bright star. Getting a star this bright down one of 2dF's fibres is no problem, but getting an exposure short enough with a low dispersion grating would be harder. After a couple of saturated frames, we found by stopping the mirror down to an indicated 2.5-m and taking a 1 second exposure we could get a useful spectrum. The resulting spectrum was carefully eyeballed – it was only a nova, no blinding supernova this time – and an e-mail to the CBAT was dispatched.

I rang Peter back to congratulate him and let him know that he could relax again. A few hours later, IAU circular number 7176 was issued with Peter's discovery and our observations. Instant gratification! And all because of a little cloud and moonlight.



Spectrum of Nova Velorum 1999 taken at the AAT using 2dF. The spectrum has not been corrected for instrumental response. The strongest features are identified, all with P-Cygni line profiles (i.e. blue-shifted absorption and redshifted emission). These profiles are observed when material is ejected from the star. The inset shows the Hα line in relative velocity units, showing maximum absorption at around -1200 km/s with wings extending to ~ -2000 km/s. (Ray Stathakis)

LDSS++ MODES WITHIN TAURUS-2

Joss Hawthorn & Karl Glazebrook

In May, we carried out tests at the telescope to see if VPH grisms can be usefully operated within TAURUS-2. If successful, this would permit tunable imaging and multi-slit spectroscopy within a single instrument. The 400 lines mm^{-1} grating (790 nm blaze) was placed in a special holder in the pupil in conjunction with a GG475 order sorting filter. After placing a microslit mask at the focal plane, the instrument was illuminated with monochromatic lamps. As expected, LDSS++ generally outperforms TAURUS-2 for multi-slit spectroscopy over the full field. However, VPHs do have important uses within TAURUS-2.

TAURUS-2 has fewer optical surfaces than LDSS++ and suffers radial aberrations beyond the 8 arcmin field. We also identified a few regions at 3 arcmin radius where some of the red arc lines have closely grouped, multiple images. This phenomenon is still being investigated. LDSS++ has superior spectroscopic performance with a more even focus over the 500-900 nm range.

In 1996, it was originally proposed (see http://www.aao.gov.au/local/www/jbh/ttf/taurus++.html) to upgrade the TAURUS-2 optics to allow for TTF and LDSS++ modes within the same instrument. This preceded both ATLAS (proposed spectrograph for the AAT) and OSIRIS (Grantecan), and helped lay the foundations for these later developments. However, the TAURUS/LDSS upgrade path is no longer being pursued since it is largely superseded by the ATLAS development.

Compared to LDSS++, VPHs within TAURUS-2 have few advantages over LDSS++. Firstly, TAURUS-2 has a slowly declining transmission out to 1 micron whereas the LDSS++ transmission falls rapidly beyond 750nm. Secondly, TAURUS-2 can be operated by one observer in that, unlike LDSS++, all filter wheels are under automatic control and do not require an extra observer in the Cass cage.

Like LDSS++, all of the nod & shuffle modes are available to TAURUS-2. High quality, low resolution (R ~ 900) spectra were obtained for nebular sources in the LMC. These will be posted on the TTF web page along with the test images. The multiple images may indicate that the full field should only be used for multi-slit spectroscopy within a restricted spectral (e.g. UBVRI) window, although this requires another test.

The inner 5 arcmin TAURUS-2 field has broadly comparable performance to LDSS++. There are numerous science cases that could benefit from having the microslit capability in addition to TTF imaging.

As a postscript, since TAURUS-2 is frequently on the telescope, it is particularly flexible for 'target of opportunity' override programmes. Furthermore, these tests show that TAURUS-2 is also an excellent test bed for future spectrographs which incorporate both TTFs and VPH grisms.

NOD AND SHUFFLE – PERFECT SKY-SUBTRACTION WITH 2DF? Or How to Amuse Yourself on a Cloudy Night...

Karl Glazebrook, Joss Hawthorn, Tony Farrell, Lew Waller, John Barton & Ian Lewis

Readers of the AAO Newsletter may have followed with interest the use of the novel 'nod and shuffle' mode for sky subtraction first proposed some years ago (J. Hawthorn, AAO Newsletter 75). Recently the implementation of this technology has been astoundingly demonstrated by us with the LDSS++ project (see the Nov 1998 Newsletter). In this mode CCD charge shuffling is used to store a sky spectrum for each 'microslit'; as this is observed through exactly the same slit and exactly the same pixels and in exactly the same time frame, near perfect sky subtraction results.

Encouraged by this success we determined to demonstrate nod and shuffle sky-subtraction with other systems, in particular for the 2dF fibre spectrographs. Fibres are notorious for difficult sky-subtraction because of the problems in correcting the fibre spectra for the different fibre responses. Using nod and shuffle we should observe the sky through the same fibres and hence get high-quality sky-subtraction. We embarked upon an experiment of this mode with 2dF on the service night of 23rd July, 1999. As it was a bright night with 70% lunar phase we thought it would present a particularly interesting challenge to the removal of the background! (Normally good sky-subtraction is impossible with 2dF in these conditions).

The Experiment

The 2dF system was not designed for nod and shuffle observing so some fudging was required to adapt it for this mode. Firstly we disabled the second spectrograph and camera completely, as nod and shuffle currently only works for one CCD. Secondly we had to create spare, unilluminated space on the CCD to store the shuffled spectra. The scheme we chose is illustrated in Figure 1(a). We disabled alternate retractors – i.e. left the fibres parked and masked the parked positions with a specially made wooden mask. This creates unilluminated areas which can then be used to store the charge during the shuffle as shown in Figure 1(b).

For our experiment we decided to go for broke and configured a field full of bright galaxies only 23 degrees from the gibbous moon. Unfortunately for us the weather did not co-operate and we could only dimly see the moon through the thick cloud. We could not even detect our guide stars so galaxies were out of the question.

Nevertheless although we could not hope to get spectra of objects we could at least try to prove that the subtraction worked, and in fact for this the shocking background of thick cloud back-illuminated by the moon was ideal. For our experiment we nodded the telescope between an ‘object’ and a 7 arcsec offset ‘sky’ position every 30 seconds throughout a half hour exposure in the standard LDSS++ mode.

After some coddling we persuaded 2dFDR to reduce the data and the results are shown in Figure 2. The sky-subtraction was first done in the standard 2dFDR mode where some of the fibres are used as ‘sky fibres’ and the median sky is subtracted from the data after throughput correction. Then to compare we removed the sky using the shuffled data by simply subtracting the image shifted by the correct number of pixels and then re-reduced the data with the 2dFDR sky-subtraction turned off.

The results speak for themselves. The raw cloudy sky spectrum (no subtraction) peaks at about 8000 ADU at 7000 Å. (This is about 40 times the dark, clear sky background!). The normal sky-subtraction shows horrid systematic variations at the ± 200 ADU level (2.5%). But the shuffled subtraction is perfectly flat apart from a few cosmic rays (we only did one exposure so there was no opportunity for clipping them). There is only a slight DC offset from zero, we attribute this to a slowly varying scattered light gradient across the chip.

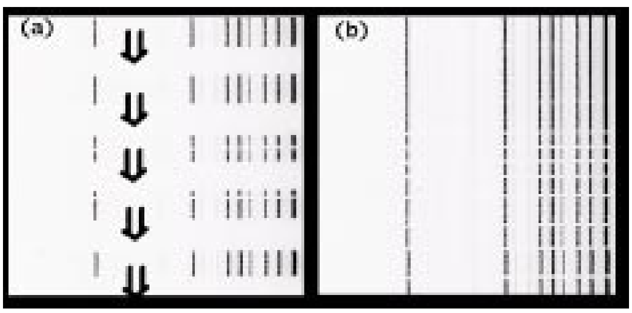


Figure 1. (a) Raw arc spectra through 2dF with alternate retractors (groups of ten fibres) masked out. This creates gaps which the spectra can be shuffled in to while observing. (b) The result of a shuffled exposure – the gaps are filled in. Sky is removed by subtracting the data which fills in the gaps.

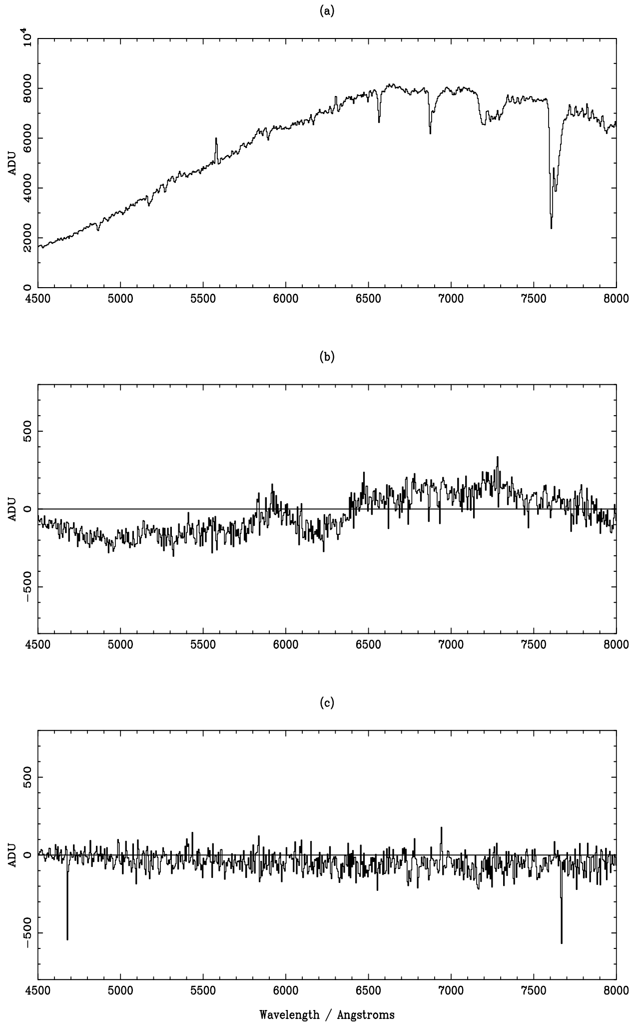


Figure 2. Cloudy sky spectrum. (a) Raw spectrum, before subtractions. (b) After standard fibre subtraction, note systematic residuals at several percent level. (c) After nod and shuffle subtractions.

One well known problem with fibre systems is that the scattered light background ruins one’s estimate of fibre throughputs and hence reduces the precision of the sky-subtraction. In the shuffled case however it makes no difference – it just shows up as a pedestal. We note that the noise level in the shuffled-subtracted spectrum is 70 ADU at 7000 Å, and since the gain is 2.79 electrons/ADU it is easy to work out that this is exactly the number expected from Poisson statistics (x sqrt(2) for the subtraction).

Where This Is Going

We believe this experiment conclusively demonstrates that nod and shuffle mode can remove the problems of sky-subtraction associated with fibres. Of course we had no doubt from our previous LDSS++ experiments that this would work, but it is nice to demonstrate it with an actual fibre system.

This is important for the next generation of fibre spectrographs, especially on 8-m telescopes (e.g. the Subaru FMOS concept and VLT/OzPoz), where one wishes to observe way below even the dark sky. If nod and shuffle mode is designed in, for example by buying enough pixels, it could be made very convenient.

But what about future use with 2dF? Right now it is extremely impractical. A mask must be taped on the parked fibres, which inhibits configuring and must be removed to set up fields. The control system must be hacked in all kinds of hairy ways which requires expert help at the telescope. And of course you only get to use 1/4 of the fibres (though we could get this up to 1/2 with suitable software/hardware effort) and have to spend half your time observing sky.

So this can not be offered for routine 2dF observing. However we ARE interested in trying this further, especially for compelling scientific programs. The method could prove very powerful for ultra-faint targets distributed over a wide field which require very long exposures. Interested parties should contact the AAO Director for permission well in advance of the telescope TAC rounds. It would be possible some Director's time could also be made available if the project was rated highly enough in order to cover the overheads of commissioning this mode. After all it would be nice to observe something more exciting than moonlit clouds...

2DF SERVICE OBSERVING

Russell Cannon, Terry Bridges, Ian Lewis

Four nights have been allocated to 2dF service observing since that option became available a year ago. Though only one of these nights was mostly clear, useful data have been obtained for six of the 13 programmes submitted prior to June. Four more could have been done if the weather had been better; three have not yet been attempted. The successful programmes were two studies of kinematics and star formation in the LMC; one looking at the kinematics and metallicities of stars in the Galactic Bulge; a search for binary red giants in the LMC, involving several short observations on different dates; looking for lithium in low mass stars in an open young cluster as a check on rotation and mixing; and a study of high redshift galaxy clusters. The preponderance of stellar programmes is accidental; most of the outstanding programmes involve extragalactic targets.

The wide range of astronomical programmes, and the fact that viable projects can be completed in two hours or less of exposure time, illustrate the versatility and power of 2dF. Service is a very efficient way of observing with 2dF since a little time can yield an awesome amount of data, while the complexity of the instrument makes it difficult for an occasional observer to use. Also, the targets and most observing parameters have to be specified well in advance, the observer has little scope to make changes at the telescope, and for many purposes the **2dFDR** pipeline data reduction system gives users an adequate final product.

We therefore encourage more users to submit short service proposals. Because grating changes are not feasible during the night (establishing optimal focus is too difficult and time-consuming), we need to have some over-subscription in order to construct a viable program on any given date. For the same reason, applicants are strongly urged to be as flexible as possible in their choice of gratings, and should note that there are other strict constraints on what is required for 2dF service proposals, as set out on the AAO WWW pages (http://www.aao.gov.au/local/www/service/INFO/2df_service_notes.html): a maximum of 3 hours total elapsed time, meaning about 2 hours directly on targets; good fiducial stars and pre-selected sky positions; and configurations which can be easily constructed at the telescope from input *.fld files

As a result of the oversubscription of 2dF, larger programmes are not always optimally scheduled, and an hour or two at the start or end of nights can be unsuitable for the programme due to Hour Angle or sky brightness constraints. Service proposals could in principle be attempted at this time, adding to the allocated service time and improving observing efficiency. In fact, since all PATT 2dF programmes are now done in service mode following the appointment of Terry Bridges to the AAO staff (see last Newsletter), it no longer makes much sense to separate the large and small proposals. PATT has recognised this and decided that in future **all** UK 2dF requests will be assessed by the full AAT TAG. Applications will be made at the same time as for larger proposals and on the same form (http://www.aao.gov.au/local/www/sll/applications/PATT-applications.html). On the Australian side the distinction between service and full proposals will continue as before, but applicants are reminded that they must state clearly when they submit similar proposals under both schemes.

Applicants should also be aware that service proposals are rigorously assessed, both scientifically and technically, and have to be fully competitive with the larger mainstream proposals. Although they should be shorter than for standard applications, the cases must be complete; applicants must explain clearly what they expect to achieve and why it is important.

NEW GRATING NOW AVAILABLE AT THE AAT

Ian Lewis and Karl Glazebrook

As mentioned in the last newsletter we recently took delivery of a new low dispersion diffraction grating blazed for the red end of the spectrum (known as the 316R grating). This grating was mounted in a grating cell during June, commissioned during the July 2dF run and is now available for general use.

The 316R grating was chosen specifically to be paired with our existing 270R grating for use with 2dF where it is advantageous to have two gratings of each type to allow similar instrument setups for both spectrographs. However this grating is also compatible with the RGO, SPIRAL and FLAIR spectrographs.

We have not had time for exhaustive efficiency measurements but in the figure we plot some initial estimates of the relative efficiencies of the low dispersion red gratings compared to the 300B gratings in a restricted wavelength range. These figures agree with the test measurements delivered with the grating by the manufacturer.

If you are planning to use these gratings please bear in mind their poor performance shortward of 4500 Å and remember that an order sorting filter is usually required for central wavelengths greater than about 6900 Å depending on the type of target object being observed.

Further technical details on AAO gratings are available on the AAO WWW pages (http://www.aao.gov.au/local/www/ras/gratings/gratings.html).

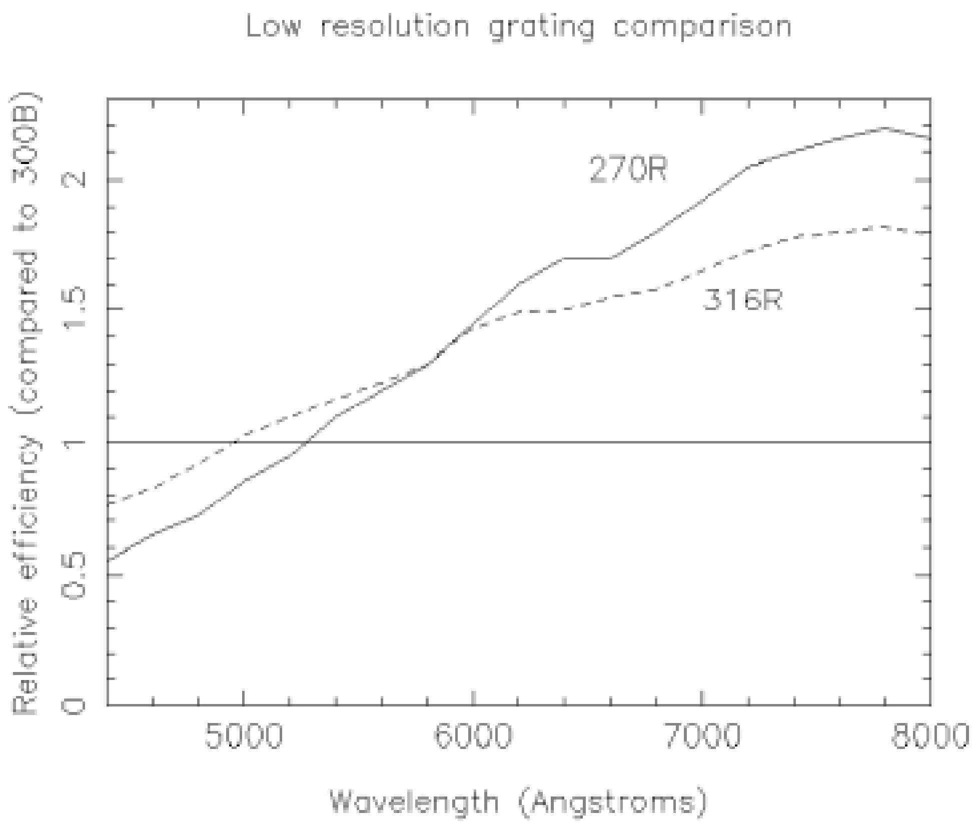
IRIS SURVIVES

Chris Tinney

The plan to decommission IRIS in 99B, announced in previous Newsletter articles, has been abandoned as IRIS parts will not be used in the construction of IRIS2. IRIS will therefore be available to observers in semester 00A.

Note that IRIS will be classified as a visitor instrument. While every effort will be made to mount IRIS and make it operational, observers will be responsible for providing their own support. They must arrive at the telescope several days in advance of their run to confirm IRIS operations and to allow staff time to rectify any faults.

Proposers should be aware, however, that there are only a few niche areas in which IRIS remains scientifically competitive with facilities offered elsewhere, and that there have been few time allocations outside those niches in recent years.



6DF UPDATE

Fred Watson & the 6dF Project Team

The 6dF robotic fibre-positioner for the Schmidt Telescope has achieved a number of milestones over the last few months. During May, Critical Design reviews were held for the mechanical and electronic design of 6dF, both with satisfactory outcomes. A software CDR will follow later in the year.

Fabrication work on the (r,theta) and gripper mechanisms continues in parallel with OzPoz, while components are now being manufactured for the field-plate units. These units are specific to 6dF, and will be interchangeable between the positioner (for fibre configuration) and telescope (for observing). They contain not only the field-plates themselves, but the 154 fibre retractors and a rotation mechanism – all within the compass of a standard Schmidt plateholder. Because the field-plates must match the focal curvature of the telescope with a high degree of precision, some hand-finishing is required, and this is being undertaken in the Epping workshop.

Budget pressures on the instrument have necessitated a de-scoping from three field-plate units to two, a reduction that will have minimal impact on survey operations. On the other hand, significant gains will be made if a proposal to replace the existing CCD chip is implemented, as recommended by ACIAAT at its recent meeting. The instrument is still on track for a commissioning phase starting at the end of next year.

Meanwhile, the 6dF Galaxy Survey Advisory Group is preparing a draft survey plan for submission to the AAT Board at its next meeting. The group has international representation (from Australia, UK, USA and France) and is chaired by Matthew Colless (ANU). Its survey plan will contain recommendations on the best strategies for the two galaxy surveys that 6dF will undertake (redshift survey and peculiar velocity survey). Such issues as survey specification and management, telescope time requirements and quality assurance are being considered. Input catalogues for the survey will be drawn from the 2MASS and DENIS all-sky near-infrared surveys currently underway.

Finally, like most things to do with the AAO, 6dF is attracting media attention, and a team from the ABC's 'Quantum' show has just completed filming a short segment on the instrument for their next series of programmes.

More information on 6dF can be found at:
http://msowww.anu.edu.au/~colless/6dF/

H-ALPHA SURVEY

Quentin Parker (IfA, U Edinburgh)
& S. Phillipps (U. Bristol)

Summary

The AAO/UKST H-alpha survey uses probably the world's largest optical interference filter to undertake a survey of ionised gas with an unprecedented combination of coverage, resolution and depth. Scanning of the films with SuperCOSMOS and the provision of an on-line atlas will likely be the prime method of data release to the astronomical community.

Basic Points

- The AAO/UKST H-alpha survey is non-proprietorial and is the only new, fully supported AAO/UKST photographic survey.
- There are 233 fields in the galactic plane H-alpha survey and an additional 40 in the Magellanic Clouds together with the associated short red (SR) exposures.
- The survey is being undertaken on non-standard 4-degree field centres due to the physical nature of the interference filter (has a circular aperture on a square substrate) to ensure adequate field to field overlap.
- This is the first ever UKST survey whose prime method of dissemination is intended to be in the form of a digital atlas from SuperCOSMOS pixel data.

Important Timescales

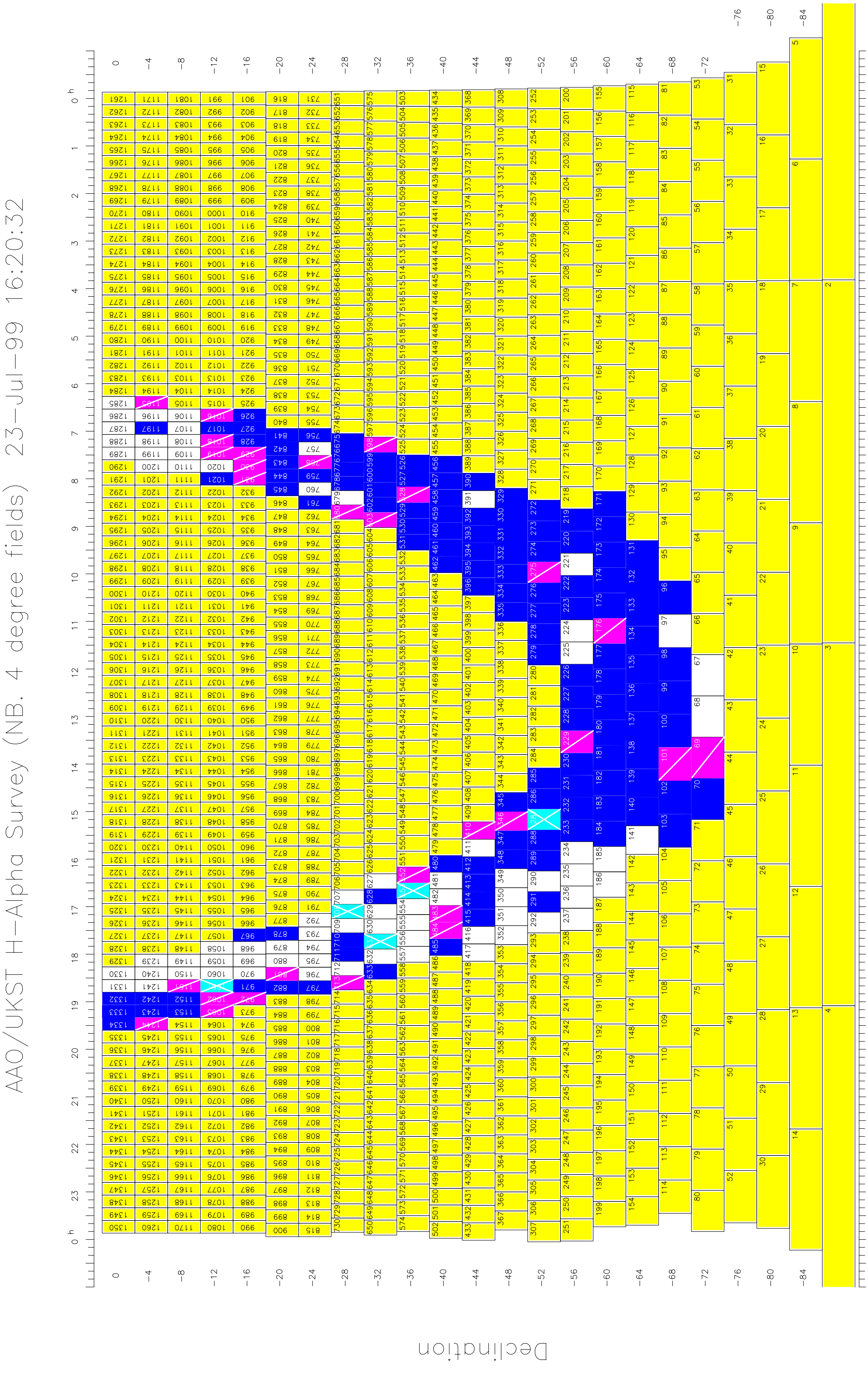
There are 4 distinct but overlapping H-alpha survey phases:

1) The H-alpha survey observational phase (July 1997-late 2000)
2) The SuperCOSMOS scanning phase (1999-2001 anticipated)
3) The digital data calibration process (2000-2001)
4) Release of on-line digital survey products to the community (2000-2001)

Current estimates put survey completion by late 2000 if current progress is maintained.

Current H-Alpha Survey Status

- A total of 320 survey field exposures have been taken as of 23/7/99 comprising H-alpha and SR pairs (usually taken consecutively).
- 126 (54%) of the initial 233 fields of the main survey area are now covered to 'a' grade as of 23/7/99 with H-alpha/SR pairs.
- 155 fields (67% of survey) are covered to a+b grade.
- 73 fields remain with no H-alpha/SR exposure pairs.


AAO/UKST H-Alpha Survey (NB. 4 degree fields) 23-Jul-99 16:20:32
Declination

- 57% of the 40 fields in the Magellanic Clouds survey are complete to 'a' grade as of 25/1/99.

A map of the current survey status is given in the accompanying figure.

Scientific Projects Currently Underway

The survey is currently supporting 5 PhD students (3 in Australia and 2 in the UK) and 1 French postdoc currently based at the UKST. There is plenty of scope for further PhD projects. A variety of different programmes are already underway which have resulted in a range of new discoveries. Several papers and articles have already appeared, some are in press and several more are in preparation.

Most of these results are from simple visual scans of the survey material which bodes well for the provision of SuperCOSMOS digital data to the community at large. The discovery or large numbers (>500 so far) of new planetary nebulae (Parker et al, in preparation) is of particular note, as is the discovery of significant numbers of supernova remnants (Walker et al, PASA, submitted) and Herbig-Haro objects (Mader et al, MNRAS, in press). The useful insights gained from combining the AAO/UKST H-alpha survey with related surveys is described by Russeil and Parker (1999, A&A, submitted). Some of the most important on-going projects are indicated below:

Planetary nebulae project (Parker, Hartley, Russeil, Morgan, Beaulieu & Phillipps)

Galactic Plane SNR project (Walker, Zealey)

Large scale Galactic Plane study (Phillipps, Parker, Precious + consortium)

LMC stacking project (Morgan, Parker, Cannon)

MC emission line objects (Morgan, Parker, Filipovic)

Extragalactic fields project in Virgo & Fornax (Edmunds, Phillipps, Cannon, Parker)

The Monoceros/Orion region and cf with CO maps (Masheder, Mader, Wilson & Zealey)

Herbig-Haro objects in Orion (Mader, Zealey, Parker & Masheder)

Community Access

As the only major new non-proprietorial AAO/UKST photographic survey and the only one undertaken with a narrow-band interference filter there is a responsibility to ensure timely access to this unique new survey material. The strategy for quality control, scanning, calibration and dissemination methods of the survey data products are important issues that are currently being addressed so that a high quality survey can be released to the community in a timely fashion.

However, several important areas need to be agreed on. These include:

- Appropriate scanning priority for ensuring timely SuperCOSMOS measures of the survey material.
- Realistic timescales for release of calibrated data products.
- Dissemination strategy for data products e.g. via incremental release of completed survey zones after proper quality control and integrity checks.
- Specification of suitably sized survey zones for release.
- Methods of data release – how the community will access the data.
- Form of data products. Apart from the provision of a calibrated digital H-alpha atlas this could include associated SR magnitudes, I-band magnitudes or a 2/3 colour on-line matched pixel data product.

The community is invited to respond to any of the above issues. It is unlikely that a film atlas of the H-alpha/SR survey will be produced but copies of particular survey fields or regions may be possible on request .

The AAO is planning to celebrate the 25th Anniversary of the inauguration of the AAT with a few events. The major event will be a dinner at Coonabarabran on Saturday 16 October 1999. The plan is to invite original project staff, current and previous Board members, Secretaries, Directors, staff who have made a significant contribution, as well as current staff.

I have tracked down many of the original project staff but there are still a few people I can't find. If you have any information about Ken Hall, Cheryl Christiansen, David Murray, Chris Nixon, or Heather Thomson please let me know.

Roger Bell ph 02 9372 4865 or by email rb@aaoepp.aao.gov.au

LETTER FROM COONABARABRAN

Rhonda Martin

'You've gone and put that 2dF-thingy on your telescope, haven't you?' growled a rather disgruntled local.

'Um, yes, but how did you guess?' I answered, cautiously looking around for an escape route.

'Because of the bloody weather – it's a dead giveaway – gales, and rain and more plurry rain. We haven't had a decent winter since you built that, that thing! Now where the hell have you got to ......?' but I had already discreetly disappeared around a corner.

'It used to be true' I thought ruefully, 'that 2dF brought rotten weather', but as the weather gods became accustomed to this competitor for weather control they relented somewhat, admitted it to their ranks and from thereon enjoyed its reflected glory.

'Still', I thought, listening to the howling gale outside, 'he certainly has a point this week!' Sydney, battered by hail in April, has now been drenched and blown by incredible gales. Coonabarabran did not get the rain, but the wind! O my!

Travelling to the telescope showed the road covered in yellow, the result of a night's howling wind which stripped every slightly elderly needle from the pines and branchlets from everything else. Parked in the forecourt of the AAT, 18 metres from the closest building, forlornly stood a dumpster skip. This rather unattractive piece of necessary equipment weighs in at 180 kg, empty! It is not on wheels, but skids! The wind had jockeyed it away from its position and left it for us to find — not a bad little breeze, but all the fault of 2dF?

One of the most interesting places at the AAT is the 3rd Floor, repository of all sorts of dead equipment, all of which is dear to the heart of Bob Dean. Bob has been fighting a valiant rearguard action for years, but the time has come, we must have more space, and things must GO! Wayne is considering sending in a bulldozer but it might not fit in the lift. He also has a wily opponent in Bob – as Wayne pushes mouldy equipment out one door, Bob will rescue it, give it a quick coat of paint, and slip it back in by another door. As a sweetener, he can keep one model of each species, but all the other 547 specimens have to go.

Wayne grew a little apprehensive when he spotted an obdurate Bob slipping up the back stairs with what looked like personnel mines and a machinegun, but surely there are enough of us to subdue him, and there is only one of him – isn't there?

And what do we do with the bodies of lost tourists? Many times they have slipped into the building, but they never left! Is Wayne in for a horrid shock or two when he moves an ancient Interdata? Will the bones of someone's granny greet him when he lifts the operation manual for an abacus?

O, by the way – the metal emu mentioned in the last Newsletter is now sporting a football club's beanie and scarf. It looks a darn sight warmer than I am right now!

AAT ARCHIVE

Ray Stathakis & Dionne James

The AAT archive database (http://www.aao.gov.au/archive/archive.html) is now complete from late 1993 to the present. IPCS spectra and prime focus photography from 1974 to 1993 are also included. Current observations are automatically added to the database on the next day, and header information from older epochs is added as the data are transferred from tape media to CDROM.

Thanks to the easier access, the archive has been well used, with the equivalent of six months of observations requested in 1998. 40% of users were at institutions outside Australia and the UK, indicating that the archive is extending the user base of the AAT as well as significantly increasing its efficiency.

Data can be requested through the archive database, or directly to archive@aaocbn.aao.gov.au for older data. Note that data younger than two years are available only with permission of the observers. Data collection is via ftp for small data sets, or CDROM.

A new project has started to provide on-line access to reduced data from 2dF past the proprietary period. Data will be included from the first science run in September 1997. Please note that data for the 2dF Redshift Survey **will not** be included at this stage.

Access will be via the archive database. At present searches can be made on general image characteristics such as field centre. Searches on individual object parameters will be enabled sometime next year. As instrumental setups such as high resolution observations in the blue have proved difficult to reduce, raw data will still be available for those unhappy with the 2dFDR reductions.

Clearly it's going to be a big job to reduce all non-survey 2dF observations. If, after publication, observers are willing to provide their reduced data we would be most grateful and will reference their work from the database. If you are able to help, or have queries, please contact Ray at ras@aaoepp.aao.gov.au.

EPPING EVENTS

Ray Stathakis

We've had so many staff arrivals and departures here at Epping it's been like Central Station. We've not even been able to keep up with the traditional welcome BBQs, though departures have been duly recognised with enjoyable, if somewhat sad, lunches at the El Rancho. In May we bid farewell to Coral Cooksley, long time aide to David Malin who handled the many requests for photographic material. We wish her well in her new post as the External Relations Officer at the School of Nursing, UTS and welcome her replacement, Katie Powell.

Personnel officer Greta Simms is now off on maternity leave, after the birth of Benjamin, a petite 9 lbs. Receptionist Belinda O'Brien is also on maternity leave, still awaiting the event at the time of writing. We wish both mothers much joy and at least some sleep. In the meantime Carolyn Hampele and Jeroo Mody are ably holding the fort.

Dave Hanes has completed his six month visit from Queen's University, Canada after a fruitful period of research and collaboration. It's British summer student time again, with three students at Epping: Davienne Monbleau, Clive Dickenson and Catherine Heymans. I'm sure they'll get a lot out of their experience if they survive the rigours of the user room air conditioning. Staff astronomer Paul Butler is about to depart after two years as instrument scientist for UCLES. His main interest here has been the establishment of the Anglo-Australian Planet Search using UCLES on the AAT, which has been notable for its cloud-attracting properties. Paul is moving to the Carnegie Institute Department of Terrestrial Magnetism, but he promises regular visits as the Planet Search continues.

Some shifting of furniture has been needed to squeeze in two new staff members working on instrumentation for the new generation telescopes. Roger Haynes arrived in June to work as an instrument scientist on GIRMOS, a multi-object infrared spectrograph intended for GEMINI. Ivan Baldry is here for six months to develop OSIRIS with Joss Hawthorn. OSIRIS is a low resolution spectrograph with TTF-like capabilities intended for the GRANTECAN 10-m telescope at La Palma. Other new staff include Niki Frampton who started in May as a software engineer working on 6dF, Dwight Horiuchi who joins Neil in the mechanical workshop and Shane Tan who is working as a contract draughtsman on the IRIS2 and OzPoz projects.

LIBRARY NEWS

Sandra Ricketts

Quite a number of new books have been received in the library since the last newsletter. Most are still to be found on the display shelves. A list of books received in the library in the preceding three months is emailed each quarter. If you would like to receive this list, please contact the librarian: lib@aaoepp.aao.gov.au.

Preprints received in the library each month are listed on the library's web page at: http://www.aao.gov.au/AAO/library/preprintsreceived.html – or simply click on the preprints area of the floor plan on the web page.

CROSSWORD COMPETITION

We are pleased to announce that the winner of the crossword competition in the May issue is Ian Howarth of University College, London. Ian wins a David Malin photograph of his choice.

Thanks are due to all who entered the competition.

The solution is printed on the right.

L	O	O	K	I	N	G			A	T	T	H	E	
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E		E		B		N		U		Y		M		U
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I		A		H		T		S		R		T		V
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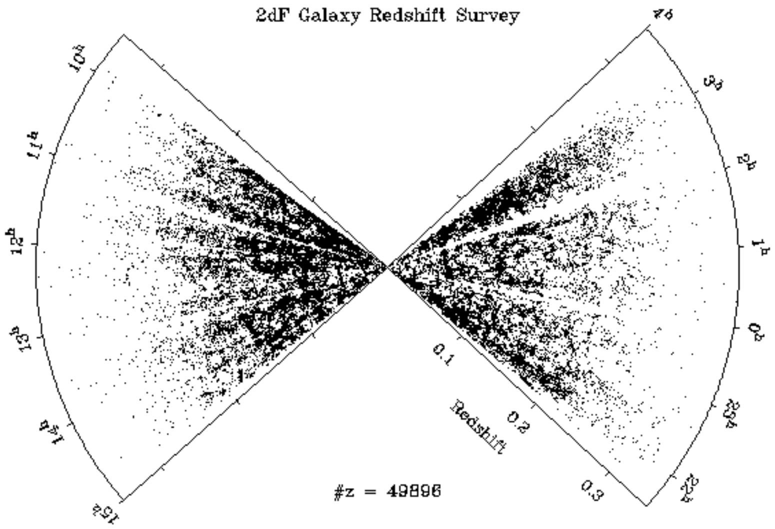

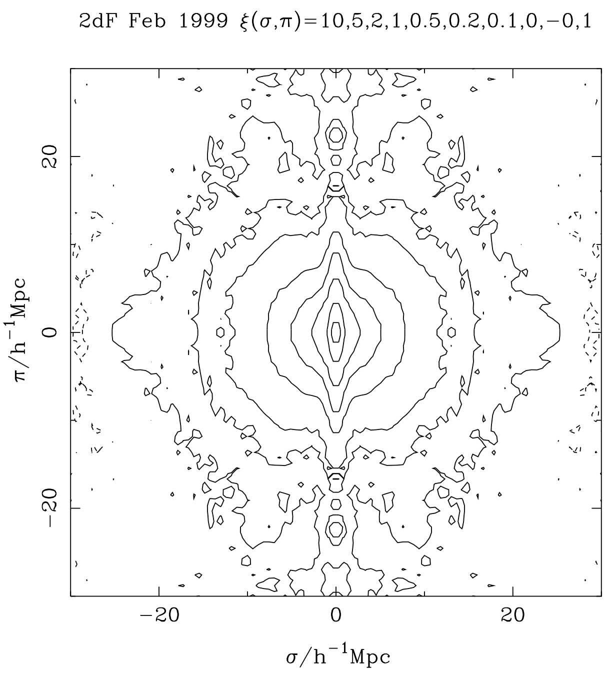

Current progress of the 2dF Galaxy Redshift Survey (see also article p6). Figure 1: The distribution of observed galaxies at z < 0.35. Galaxies in the NGP are collapsed in declination onto the plane of the celestial equator. Galaxies in the SGP are collapsed in declination onto the d = –30° cone. The spoke-like structure is due to the irregular distribution of observed 2dF fields. Figure 2: The redshift-space correlation function. The correlation function is assumed symmetric about both axes. The elongation of the contours along the line-of-sight (s = 0) on scales less than 10 Mpc is due to the peculiar velocities of cluster galaxies.

editor RAY STATHAKIS editorial assistant SANDRA RICKETTS

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