On 27 September, the AAO obtained the first science exposures with the complete 2dF. The image shows the first configured field plate with 400 fibres for the K-selected redshift survey (K. Glazebrook, J. Huang, L. Cowie, C. Tinney) and the resulting CCD frames from both spectrographs. See page 10 for more details.
DIRECTOR’S MESSAGE
Brian Boyle

Once again 2dF dominates the AAO headlines. The September/October 2dF commissioning run resulted in the first successful observations of 400 objects with two spectrographs (see the article by Karl Glazebrook and Ian Lewis in this newsletter). This represents a tremendous achievement by all those associated with the project, and brings the 2dF to the brink of full operational status, after more than five years of intensive design, construction, testing and commissioning. Although there are major outstanding issues which still need to be addressed (most notably the re-configuration time), users can expect to see continuing progress made towards a fully-commissioned system during the next few months.

The success of 2dF has also stimulated further developments associated with robotic fibre positioners at the AAO. In this newsletter Fred Watson and Quentin Parker report on the new six-degree field (6dF) project, a proposed robotic system for the UK Schmidt Telescope which would yield an order of magnitude improvement in the number of spectra per night over that which can currently be obtained with the UK Schmidt’s FLAIR system. A design study for 6dF is now underway and is due to be completed by March 1998.

It is particularly encouraging to note that 6dF was perceived as the ‘flagship’ instrumentation programme for the UKST over the next few years by the AAT Board at their September meeting. The AAT Board also welcomed the ‘Options’ report of the UK Schmidt Telescope Panel which identified 6dF, along with a wide-field CCD facility, as major new scientific initiatives which could assure the scientific future of the UKST.

In the meantime, the interim magnetic-button upgrade to the existing FLAIR fibre system on the UKST (described by Quentin Parker in this newsletter) promises to increase the speed, efficiency and safety of the present manual fibering-up process.

The preliminary design review for IRIS-2 was held at the end of September and the outcome was generally positive. Further work needs to be done on the optical design, but the AAO’s estimates of staff resources, timescale and overall project costs were deemed to be realistic by the review panel.

The AAO is also proceeding with the purchase of a blue tunable filter for Taurus, which should be available by semester 98A. The blue Taurus tunable filter (TTF) will open up many new scientific avenues including Lyα imaging in the crucial 2<z<4.5 range, and [O ii], [O iii] and Hβ imaging at low redshifts. Full details of this instrument are given in the article by Joss Bland-Hawthorn. The success of the red TTF (see the articles by Margon and Cecil in this newsletter) augurs well for the scientific productivity of the blue TTF.

Finally, it is pleasing to note that the telescopes of the AAO have both played a significant role in defining the position of the Hubble Deep Field South (see the article on page 4). It is hoped that the AAO, alongside other major southern hemisphere observatories, can capitalise on follow-up observations of the HDF-S in the next few years, yielding yet more important observations on the nature of the distant Universe.

THE OWLS AND THE PUSSYCAT
Sandra Ricketts

Some weeks ago, AAO staff at Epping were joined by a pair of tawny frogmouths who proceeded to build a scrappy nest above the outdoor seating area. In due course two babies hatched out and their progress was watched with much interest. One morning however, one of these new observatory night owls was found on the ground, fortunately not by Thomas, the observatory cat. Mother owl did not seem particularly concerned so a representative from the Sydney Metropolitan Wildlife Service was summoned. The Wildlife Service is now raising the baby, and will return it to the observatory for release when able to fly. This may be in just a couple of weeks, as frogmouths grow very quickly.

Alas, a week later, baby owl number 2 appeared to have flown or glided to the veranda railing, and despite careful observation during the day, has disappeared (not courtesy of Thomas we hope).

Meanwhile a third baby has appeared on the branch with mother and its progress is being closely monitored. Uncertainty remains as to the quality of the parenting.

(Note for the pedantic: We know that tawny frogmouths are not owls, but the term is used for brevity and convenience).
In the last couple of years, the standard big bang nucleosynthesis (SBBN) model has been challenged by an apparent crisis between determinations of light element (D, 4He and 7Li) abundances on the one hand, and the predictions that SBBN makes for their primordial values and η (the ratio of baryons to photons). If the low D/H observations in high-redshift low-metallicity QSO absorption systems by Tytler and colleagues represent the primordial value, then the primordial helium abundance (Y_P) would have to be larger than 0.246 for concordance. Taking all of the available data, a best estimate of Y_P is 0.230 ± 0.003 (statistical). This has led to much speculation that there is an unknown systematic bias which is leading to underestimates of the He abundances in the low metallicity systems. Whether the SBBN “crisis” is due to errors in passing from observed to derived abundances, or from the present to extrapolated primordial ones, or due to a need to go beyond the standard model, surely the name of the game is very high quality abundance data of a large sample of extremely low metallicity H II galaxies.

Following Peimbert and collaborators, Y_P is best obtained from determinations of He/H, O/H, and N/H in very low metallicity H II regions. In a regression of He/H versus O/H (and N/H) the y-intercept provides an estimate of Y_P. It is clear that objects with extremely low abundances (O/H < 5x10^-5 ~ 1/25 of the solar value) carry most of the weight in the determination of Y_P. It has also been clear for many years that there are very few data points in this regime. These objects are most valuable because of their low metal content and high excitation which makes the derived Y_P value less vulnerable to the uncertainties both in a correction for neutral helium and in the extrapolation to zero metals due to unknown aspects of chemical evolution. I Zw 18 (with O/H ~ 1/50th of solar) has the lowest measured abundance of any known galaxy. Skillman & Kennicutt found identical He/H abundance (Y=0.230) in the two main components. It has been suggested that the observations of I Zw 18 should be discarded because they give the lowest value of He/H but there is no physical reason for discarding I Zw 18. On the other hand, it has been suggested that all of the other data should be disregarded (ignore the extrapolation to zero metallicity) and that the He/H in I Zw 18 should be adopted as an upper bound on Y_P. In order to determine whether I Zw 18 is a valid point or a red herring, a significant sample of galaxies with comparable or lower metallicity must be found. These objects have to be of sufficiently high surface brightness, to be able to measure precisely the weak diagnostic lines (typically 1% of Hα) to be sure that they are free from known systematics.

Most of the latest searches of low metallicity galaxies were conducted on Schmidt objective prism plates, searching for strong emission lines (particularly [O III] 5007Å) and therefore biased against the lowest metallicity objects.

Recently we developed a new method to identify candidates by inspecting the low S/N spectra from redshift surveys like Durham/UKST and Stromlo/APM and selecting those whose line ratios correspond to the expectations for a low abundance H II region; in the first run for this project (AAT, RGO spectrograph, last August) in just two nights we discovered five new extremely metal-poor H II galaxies (out of nine candidates observed). One of them, with metallicity about that of I Zw 18 and T_e ~25000K, is the hottest H II region known (see figure). In these two nights at the AAT we have doubled the number of known extremely low metallicity H II galaxies, the list of which took almost 30 years to build.

Figure: AAT spectrum (4500s) of the lowest metallicity galaxy found in our August 96 run
Over the past few months, the AAT and the UKST have been involved in a search for a suitable QSO which will lie at the centre of the Hubble Deep Field South (HDF-S). The HDF-S follows on from the success of the first Hubble Deep Field, and observations are due to begin in October 1998. As before, deep images will be made with the Hubble Space Telescope in a number of bands, and the data will be made available to the community. However, the HDF-S differs in two significant ways from the original HDF. First, it will (obviously) be located at southerly declinations. Second, it was decided that it should contain a QSO with $z>2$, enabling the relationship between the high redshift galaxies identified in the HDF-S and the absorption lines in the spectrum of the HDF-S QSO to be studied.

The requirement that the HDF-S be located in one of the HST’s Continuous Viewing Zones and that the field be in a region of relatively low galactic extinction with no bright stars, dramatically reduced the area in which to identify a suitable QSO. In total, only 12 small ($1 \times 1$) fields were initially selected by the STScI as suitable for the HDF-S, and it came as no surprise that no appropriate QSO was previously known in any of these fields.

Fortunately, one of these areas (SF-03A) was located in the UK Schmidt field 146 which had an archival IliaJ objective prism plate (UJ9697P) available. Mike Irwin used the APM in Cambridge to digitise this plate, and the prism plate spectra of objects located in the HDF-S were analysed by Paul Hewett using his Prism Reduction Software. One outstanding candidate was identified: a bright ($B = 17.5$) object with an estimated redshift of $z = 2.25$. The optical image of this QSO, taken from the second epoch sky survey, is shown in figure 1. The co-ordinates of the object are $\alpha(2000)=22^h 33^m 37.6^s$, $\delta(2000) = -60^\circ 33' 29.6"$.

Ian Lewis, Joss Hawthorn and Ray Stathakis then observed this candidate with 2dF during morning twilight on 1997 April 6. Its spectrum (see figure 2) shows the strong emission lines of C IV and C III], giving a precise redshift of $z = 2.245$. Follow-up 20cm radio observations of the field surrounding this QSO by Ray Norris revealed that it was not a strong radio source ($S_{20cm} < 3$ mJy), but that a relatively strong radio source ($S_{20cm} = 146$ mJy) was located 10 arcmin from the QSO. Despite initial concerns that the bright radio source might limit the noise level attainable in deep radio observations of this field, the relatively bright optical magnitude for the QSO, and the consequent ease with which high resolution spectra could be obtained, led the STScI to adopt this QSO as the choice for the HDF-S.

During August, Jeremy Bailey, Bob Carswell, Phil Outram and Jessica Chapman obtained UCLES observations of the QSO over the wavelength range 3500–5000Å, comprising the region of the QSO spectrum from the Lyman continuum break to the C IV emission line. These data are currently being reduced and, in the true spirit of the HDF, will be made available to the community as soon as possible. Further deep radio observations of this field are also planned.

The identification of the HDF-S QSO is an excellent demonstration of the power of UKST archival material, and of the inter-dependence between many Australian-based facilities, e.g. UKST, AAO and ATNF. The rapid
and willing response of many astronomers to carry out observations in their own time has also been a major factor in the success of this campaign. Astronomers with access to Southern Hemisphere observatories can now look forward to capitalising on the next Hubble Deep Field.

**NARROWBAND TIME SERIES PHOTOMETRY WITH TTF: THE ODD SPECTRUM OF THE X-RAY STAR V2116 OPH**

Bruce Margon, Eric Deutsch (U. Washington), Joss Bland-Hawthorn (AAO)

The spectra of the optical counterparts of compact galactic X-ray sources tend to be unusual, but even amongst this select group, V2116 Oph, the counterpart of GX1+4 (=X1728–247) is exotic. This classical, intense X-ray binary, observed for 25 years, is projected very close to the galactic center, and is probably truly at a ~10 kpc distance, as the inferred X-ray luminosity is then 6x10\(^37\) erg s\(^{-1}\), near the Eddington limit. On the basis of an early suggestion by Glass & Feast (1973), the object was optically identified with a V=18.7 star with an exceptionally unusual spectrum, resembling that of a symbiotic star (Davidsen et al. 1977). The optical spectrum of the object, now known as V2116 Oph, has shown higher excitation emission lines than any other known X-ray star; for example, [Fe x] (I. P. = 235 eV) and [Ar XI] appear. There is also extremely strong H\(\alpha\) emission. The spectrum appears to be markedly time variable on scales from minutes to years; in recent epochs, the highest excitation lines have disappeared (Chakrabarty & Roche 1997), but the enormously strong H\(\alpha\) emission remains.

The symbiotic-like optical spectrum of V2116 Oph directly shows the presence of a red giant, of type near M6 III, via numerous prominent molecular bands in the near IR. This fact alone suggests that we may be viewing the system at a very special, short-lived stage, when the normal primary is passing through a quite brief phase of its evolution. However, this point is made even more vivid by the X-ray behaviour. GX1+4 is an X-ray pulsar, with the initial observations of the early 1970s yielding a coherent X-ray period of about 130 s, slow, although not inordinately slow, for X-ray binaries. Continued X-ray observations revealed an enormous X-ray period derivative, with values of P' = dP/dt~3 s yr\(^{-1}\) reported (Laurent et al. 1993 and references therein). This is the fastest spin-up rate for any known X-ray pulsar. The characteristic age, P/P' ~40 yr, confirms that this is an amazingly rapidly evolving object. More recent X-ray observations show that the X-ray P' has reversed sign, although the modulus remains very large (Laurent et al. 1993, Chakrabarty et al. 1997). It seems clear that in GX1+4 we have the chance to observe an X-ray pulsar undergoing rapid evolution.

With a giant primary and any reasonable assumption for the mass of the secondary (presumably a neutron star), the system orbital period must be of the order of one or more years. Although we would very much like to understand the basic parameters of this unusual system, simply extracting even the period will not be easy. Searches for periodic variations in the X-ray pulse timing residuals are foiled by the large, irregular torque derivatives noted above. Normal radial velocity spectroscopy of the optical lines will be difficult; the expected variations are very small compared at least to the very broad H\(\alpha\) emission.

In principle the detection of an optical analogue to the X-ray pulses could yield an elegant and accurate radial velocity solution. If the ionising radiation is reprocessed to visible light at a location in the system fixed with respect to the barycentre, and the recombination times are short compared to the pulse period, the resulting optical pulses can be searched for periodic modulation due to orbital motion. If the reprocessing surface is physically larger than the light travel time in one pulse cycle, phase mixing may dilute the pulse amplitude greatly, but working in the Fourier domain provides far more potential sensitivity than standard radial velocity spectroscopy. This technique has of course been applied decades ago, with great success, to the X-ray pulsar HZ Her/Her X-1 (Middleditch & Nelson 1976).

Here we discuss an innovative attempt at the AAT to obtain high signal-to-noise radial velocity measurements, and thus to elucidate the system parameters. The second strongest emission line in the optical spectrum of V2116 Oph is a rare and remarkable one, namely extremely prominent O I \(\lambda 8446\). This line has been reported in a small number of very interesting objects ranging from Seyfert galaxies to occasional odd stars. In some objects, the great observed strength relative to other common species must be explained by some type of preferential emission mechanism. Grandi (1975, 1976) suggested that pumping by an intense Ly\(\beta\) radiation field, in a coincidence not dissimilar to the famous Bowen mechanism which enhances [O III]/N III in nebulae and X-ray stars, may be responsible. Detection of the expected 11287\(\bar{\nu}\) line in the Seyfert I Zw I at the expected strength relative to \(\lambda 8446\) (Rudy et al. 1989) provides elegant confirmation...
of this hypothesis. O $\lambda$8446 has also been reported at great strength in the symbiotic star V1016 Cyg (Rudy et al. 1990), and again the presence of the 11287Å line at comparable strength confirms that Ly$\beta$ pumping is the mechanism.

Although the source of the exciting Ly$\beta$ in V1016 Cyg may not be obvious, the source in GX1+4 most surely is: V2116 Oph is known to be irradiated by 100,000 solar luminosities of (directly observed) ionising radiation. As the X-radiation from GX1+4 is steadily pulsed, with typical pulsed fractions of 0.4, it is possible that the O $\lambda$8446 emission in V2116 Oph may also be strongly modulated with the (currently) 120 s period of the X-ray source. Thus we have begun a program to search for periodic modulation of emission lines in V2116 Oph, especially in this curious O $\lambda$ feature. Although success is certainly not assured (the line may originate from a circumstellar nebula, for example, rather than a region sufficiently small to preserve the pulse phase), in principle the pulse amplitude could be far higher in a suitable emission line than in broadband light. (We also note in passing a negative search for periodic H$\alpha$ pulsations many years ago by Krzeminski & Priedhorsky 1978).

An elegant way to obtain very high throughput, linear photometry in a narrow bandpass at arbitrary wavelength is to use the charge-shuffle mode of the TTF. On one night in July 1997, we repeatedly imaged V2116 Oph using the TTF on the AAT through a 6" by 3' slit, rotated to include the X-ray star plus one brighter and one fainter nearby companion. Each slit image is exposed for 12 s before charge is shuffled 10 pixels down the chip. This is done 102 times before the chip is filled and read out, a quite efficient protocol as each shuffle consumes only 1 s, a delay time selected to avoid burning out the shutter. Figure 1 displays two of the five separate exposures obtained on the partly-cloudy night of mediocre seeing. Within each strip, V2116 Oph is the bright object below; the brighter reference star is the object on the top of each strip.

The TTF was tuned to a bandpass of 7 Å (90% filter transmission) at 8446Å; the pixel size was 0.594"/pix. A TTF scan across the line in wavelength space, prior to the time series, ensured that the strong O $\lambda$ emission line was indeed present and detected. In the figure, the time direction runs horizontally in each strip. Note the effect of clouds during the time series, as well as the degradation in seeing (2–4") through the night.

A preliminary analysis of the data, using differential photometry on the nearby reference stars, reveals that despite the constantly variable clouds and poor seeing conditions, we may set an upper limit of ~3% (full-amplitude) on periodic $\lambda$8446 oscillations at the X-ray frequency. This value is comparable to the amplitude of continuum oscillations reported by Jablonski and colleagues in broadband optical light on some nights. Therefore we are already able to rule out an enhancement of the pulsation amplitude in O $\lambda$, at least at the time of our observations. Although substantial further observations of this complex system are needed to unravel its nature, the unique utility of TTF in charge shuffle mode for narrow band time-series photometry of faint objects is already very clear.

References


MOVING MIRRORS AROUND A SUPERMASSIVE BLACK HOLE

Gerard Cecil (SOAR Telescope Project)

The energy flow from the central black hole of a quasar is poorly understood, yet is expected to profoundly influence the evolution of the assembling galaxy. While the early life of an active galaxy remains outside our reach, the energy flow itself can be studied much closer...
to home. The ionized gas in the circumnuclear “narrow-line” regions (NLRs) of Seyfert galaxies exhibits lumpy emission-line profiles that extend over several thousand km/s even when resolved spatially in many nearby systems. The profiles are a complex convolution of the gas spatial and density distributions, ionization gradient, reddening distribution, and gaseous velocity field. IR, optical, and UV spectrometers have sufficient spatial resolution and sensitivity to disentangle these parameters.

Different emission-line species diagnose local conditions, and can be used to deconvolve the profile distributions in a model-dependent way. Most of the diagnostic lines are in the optical and UV. To constrain these quantities, my collaborators (most notably J. Hawthorn of the AAO) and I are examining several nearby active galaxies, using a combination of high-resolution filter-band imaging and spectroscopy on HST, and area spectrophotometry with Fabry-Perot (FP) spectrometers in both hemispheres. We hope to extend this program to X-ray imaging spectroscopy with AXAF.

Fig. 1 (on the back cover) shows a spectral grid obtained on NGC 1068 at the AAT during the last observing season. The profile variations are complex over ~35 arcsec, but can be decomposed into the kinematic systems uncovered in other analyses, most notably our own work from Mauna Kea 7 years ago. At each location, several dynamical systems superimpose along our line of sight and the full spatial coverage of the FP allows us to isolate and map each one. “Clean” regions can be identified where a single system predominates, and are natural targets for Taurus Tunable Filter (TTF) imagery to flux fainter lines diagnostic of gaseous excitation and temperature. With its larger passband yet perfect cancellation of the adjacent starlight, the TTF has an enormous efficiency advantage if the goal is line fluxes rather than spatio-kinematic maps.

Our observations have concentrated on [O III]λ5007 for maximum sensitivity, but we have also mapped Hα (blended with [N II]) to estimate the ionized gas mass. The high degree of kinematic symmetry, evident in the regions of double-peaked profiles in Fig. 1, lead to kinematic models that constrain unobservable dimensions of the phase space and so allow us to deproject measured radial velocities into the frame of the galaxy. This exercise constrains the kinetic energies of the outflow and, ultimately, the dynamical origins of the clouds.

75% of the circumnuclear flux is distributed in a cone of ~80° opening angle that is embedded in a cylindrical, diffuse halo with FWHM >1200 km/s. A kinematic model of the high-velocity gas suggests that the gas flow is directed above the large-scale disk, illuminated in the center-darkened cone. The cone axis coincides, in projection, with the linear radio “jet” contoured in Fig. 1. At larger radii, soft X-rays extend along this axis (Wilson et al. 1992) and may trace a weakly collimated “nuclear superwind”. A superwind has also been invoked to explain the kinematics of H I absorption SW of the nucleus (Gallimore et al. 1994), and its dense manifestation at the base of the cone is a plausible medium to scatter and hence polarize nuclear light.

The kinematics of the diffuse halo is an interesting finding of the AAT observations. There is no radio emission down to low levels in these faint (compared to the bright nuclear clouds) regions; emission-line intensities are <1% of the peak. It is a tribute to the low-readout noise of the AAT CCD controllers that the kinematics of this gas can be mapped reliably. An average profile can be summed over regions (delineated in Fig. 1) E and W of the nucleus. (The ability to post facto-bin faint line-emission is of course one of the main advantages of FP.) The profiles again span >1000 km/s, and are essentially identical on either side of the nucleus. We summed and scaled the nuclear flux to verify that these profiles are intrinsic to the galaxy, not nuclear light scattered in TAURUS-2.

The symmetry is puzzling because it does not follow any rotational or outflow motion that has been mapped elsewhere in the circumnuclear region. The radial variation of the kinematic line of nodes in the galaxy disk swings through many different position angles, because of strong bar-induced motions. All of these motions would be expected to show some degree of antisymmetry diametrically across the nucleus. A simple explanation is that the disk gas here is almost stationary, and that the profiles represent the intrinsic nuclear emission profile that is reflected by (slowly) “moving mirrors” in the galaxy disk. We may therefore be measuring exactly the nuclear light seen by the disk gas in these regions. Which of the several bright nuclear knots illuminates this disk gas is an open question. The scattering efficiency is high, ~1% of the observed nuclear flux.

One model-dependent explanation for the abrupt edge of the NLR is that the emitting filaments are confined by the wind, and expand to become optically thin as the wind dilutes at larger radii. Along with localized jet/ISM interactions, the superwind is also a plausible global accelerator of the high-velocity filaments. Without going into details (developed most recently by G. Bicknell and M. Dopita at ANU), the filaments may be molecular cloud cores that have become entrained and
accelerated in the jet and supernova. In our kinematic deprojection, these clouds are expanding from the nucleus at up to 1600 km/s relative to systemic velocity, implying Mach numbers $u/c_s \sim (10–20)$ and perhaps strong shocks. Cooling columns and gas densities are large enough for shocks to be radiative.

Because of the high velocities, the bulk of the line flux from these shocks would be emitted in the UV. To constrain shock parameters, we are awaiting a grid of STIS spectra that span the brightest NLR emission. These observations, delayed by problems with the HST NICMOS camera, are time-consuming even with STIS. The recently announced Cosmic Origins Spectrograph — the 2002 HST instrument — will be at least 5 times more efficient than STIS for these line observations, so will permit UV studies of other NLRs or of NGC 1068 at higher spectral resolution. A particularly powerful aid to deconvolution will be to compare the detailed emission-line profiles of various UV species.

**References**


**DIFFERENTIAL ROTATION AND MAGNETIC POLARITY PATTERNS ON AB DOR**

Andrew Cameron (St Andrews), Jean-Francois Donati (Observatoire Midi-Pyrenees), Meir Semel (Meudon)

**Introduction**

Since early 1992 we have used both conventional and Zeeman - Doppler imaging to advance our understanding of large-scale fluid circulation in the convective zone of the rapidly rotating, pre-main sequence K0 dwarf AB Doradus, and its effect on stellar dynamo geometry. In the longer term, we are monitoring global changes in the overall activity levels, coupled with latitude drifts of the principal active belts. Within a given year, we use starspots as tracers of surface differential rotation patterns, in order to learn how rotation and convective-zone depth control the large-scale fluid circulation pattern. Our workhorse instrument has been UCLES all along, but in the last couple of years we have linked ACC’s AB Dor programme to the Zeeman-Doppler imaging work of JFD, MS and their collaborators. We now use the Semel polarimeter, mounted at the Cassegrain focus, to feed starlight analysed for opposite circular polarization states along a pair of optical fibres to the UCLES slit area. We use Zeeman-Doppler imaging to track the evolving magnetic polarity distributions on active cool stars throughout their activity cycles.

**Signal enhancement**

High S:N ratios, high spectral resolution and high time resolution are the keys to successful stellar surface imaging. Dark features on the stellar surface produce bright “bumps” in the rotation profiles of photospheric lines. The amplitudes of these bumps rarely exceed a few tenths of a percent of the continuum level, but the rates at which they drift across the stellar rotation profile reveal the precise locations of the spots that cause them. Imaging magnetic fields is even tougher. For typical active-star field strengths of a few hundred Gauss, the Zeeman effect produces such tiny wavelength shifts between opposite circular polarization states, that the difference between oppositely-polarized spectra (the Stokes V spectrum) contains signatures with peak-to-peak amplitudes of about 0.1 percent of the continuum signal level. We have made a major advance with the introduction of least-squares deconvolution (LSD) as a way of extracting both rotational and Zeeman profile information from the 1500 to 2000 photospheric lines that are recorded simultaneously on a typical UCLES spectrum (Donati et al. 1997). This allows us to achieve signal-to-noise ratios of order $10^4$ in the Stokes V profile of AB Dor, and of order 1500 for the unpolarized profiles, using 800 s and 200 s exposure times respectively.

**First maps of stellar differential rotation**

The combination of Doppler imaging and LSD has allowed us to map the surface of AB Dor’s spots and magnetic fields in unprecedented detail. Our first two ZDI runs in 1995 December (Donati & Collier Cameron...
Figure 2: Reconstructed images of stellar surface brightness (top), and the radial (centre) and azimuthal (bottom) magnetic field components.

1997 and 1996 December (Donati et al 1998) produced data sets spanning several nights, with excellent repeatability in the fine surface detail. We found starspot activity at nearly all stellar latitudes. This allowed us to map the differential rotation pattern for the first time on a star other than the Sun, using an updated version of the spot-tracking methods employed by early solar observers nearly four centuries ago! By cross-correlating constant-latitude slices in maps taken four nights apart, we discovered that AB Dor’s equator rotates faster than the high-latitude regions by about one part in 220. Given AB Dor’s 12.4 h rotation period, this means that the equator “laps” the poles every 110 days or so. This is almost identical to the solar lap time: a rather surprising result, since AB Dor rotates nearly 50 times faster than the Sun.

Strong azimuthal fields

Our pilot Zeeman-Doppler imaging studies of AB Dor revealed a mainly radial field at high latitudes, with an alternating east-west sectoral polarity structure. The 1995 and 1996 ZDI maps show two partial belts of strong (~500 G) azimuthal magnetic field, of a kind not seen on the Sun. JFD and his colleagues have also found similar belts of azimuthal field in the RS CVn binary HR 1099 and the young main-sequence star LQ Hya (Donati 1998).

A new dynamo puzzle

It is almost universally accepted that the solar dynamo is confined to an overshoot layer at the base of the convective zone. If this was the case for AB Dor as well, we would expect magnetic flux tubes (expelled from the convective zone by both Coriolis and buoyancy forces) to emerge almost radially from the stellar photosphere. As a significant fraction of the magnetic flux observed on AB Dor is found to be roughly horizontal, we speculate that AB Dor (and other rapid rotators on which similar horizontal field features are detected) trigger a distributed dynamo, operating throughout the entire volume of the convective zone. This suggestion would explain at the same time why low-latitude spots — which should be absent on rapid rotators according to the latest flux-tube eruption models of DeLuca et al. (1997), assuming a solar-like overshoot layer dynamo — are observed in abundance on AB Dor and other similar rapid rotators.

By continuing to monitor the magnetic geometry of this enigmatic star from year to year, we stand a good chance of learning how such a dynamo would behave. Watch this space!

2DF UPDATE: FIRST 400 FIBRE SCIENCE DATA
Ian Lewis and Karl Glazebrook

Hardware status (5/10/97)

Both fieldplates of the 2dF positioner are fully populated with 40 fibre retractors each with a nominal 10 spectroscopic fibres. There are a number of broken fibres or missing prisms bringing the total available fibres down to about 380 for each fieldplate.

Both spectrographs are under partial remote control (shutter, grating rotation, hartmann shutters). The camera focus is under much more limited control and requires the connection of a PC at prime focus access. The filter wheels are not yet commissioned and it is unlikely that they will be available until next semester as they require the camera focus to be completely automated. All the reflecting optics have been recoated with protective aluminium as tests showed that the boosted silver coatings had not lived up to their promise in the blue region of the spectrum.

The first of the new remotely controlled 2dF power supplies has been debugged and commissioned and is now in operation on the spectrographs. This was more important than using it on the positioner due to the inaccessibility of the spectrograph electronics while on the telescope.

Due to the rush to get onto the sky with 400 fibres, the back illumination shielding has not been set up properly, making fibre configuration while observing impossible. However the mainly long exposures required from the scheduled science during this run meant that this has not been a serious problem.

With both cameras now in use, the engineering CCD in camera #1 has been replaced by the science device. The newly commissioned camera #2 now uses the engineering device. We are refining our techniques for focusing the spectrographs; spectrograph #1 is already proving to be easier to focus with the science grade CCD, as the field flattener was designed for the radius of curvature of this device rather than that of the engineering CCD.

All the changes described above have taken the full resources of the observatory for the last two months and have prevented much active work on the 2dF positioner (for reasons of physical access to the hardware as well as available effort), so the fibre positioning speed remains at about 20 seconds/fibre, although this is expected to reduce in the very near future.

Future work

The recent observing run has allowed us to identify a number of problem areas that require attention before the next run. These are the reliability of the grating rotation, the back illumination shielding, the spectrograph shutters and the gripper jaw encoder. These four areas probably account for most of our 2dF hardware problems during the run.

A very high priority will also go to working on the robot positioner to improve its operating speed. Much of the ground work for an increase in speed has already been done and will be tested in full operation during the two weeks of down time.

The two spectrograph cameras will undergo extensive testing during the next two weeks including the testing of the camera focus mechanisms and (hopefully) the integration of the camera focus into the full 2dF control system.

September/October observing

For the first time we have been observing scheduled allocations of science time in service mode. This is the first step to requesting observers to come out to assist in their observations, which we hope will occur by the end of this semester.

We made the first observations with 400 fibres and two spectrographs on 27th September on the first of the scheduled science nights (see image on front cover and http://www.aao.gov.au/local/www/2df/news.html). However this night and subsequent nights were seriously affected by weather and CCD controller hardware problems.

Notes for future observers

Please make all possible efforts to obtain the 2dF manual and prepare your 2dF configurations well in advance of your scheduled run (check your dates!!) even if AAO staff will be doing the observing for you. Please read chapters 3–6 of the 2dF manual carefully and prepare input catalogues (*.fld files) in the ASCII format specified, split up so that there are no more than 2000 objects per file (i.e. don’t expect us to do position/mag/colour/etc. selection for you as this involves science choices). Due to the pressures of observing and commissioning work it may not be possible to validate the files until just before configuration; correct format will avoid possible loss of time.

Ideally observers should obtain the ‘configure’ software (available from http://www.aao.gov.au/2df/observer.html) and prepare an object allocation (*.sds files)
themselves. This ensures the format is correct and that a reasonable number of object, guide fibre and sky fibre allocations are possible. It is advisable to always fetch the latest version as the default fibre tables will change between 2dF runs, and we will be updating the software as we find bugs and make improvements.

Files should be sent to the 2dF mailing account (twodfobs@aaocbn.aao.gov.au) at least a week in advance of the scheduled nights. This will allow us time in case of email problems and also to query possible configuration issues. Binary files should use standard MIME attachments or be unencoded.

Please note that grating changes during the night are time consuming and could result in up to 30–45 minutes of lost time. Order sorting filters should become available in semester 98A. There is currently no facility to allocate fibres for each spectrograph separately so the only available configuration will be to have identical gratings in both spectrographs.

We will be performing observations with 2dF in service mode up to and including the December/January run. For the late January run we expect to be requesting that scheduled observers send one experienced observer to the AAT for the duration of the run. This latter mode of operation will probably extend into the 98A semester.

**AAO SERVICE NEWS**

Jessica Chapman

Several successful service nights have recently been held at the AAT with RGO data taken by Raylee Stathakis (ras@aaoepp.aao.gov.au) on 22nd September and CCD imaging data taken by Chris Tinney (cgt@aaoepp.aao.gov.au) and Robert Sharp on 5th and 6th October.

The AAO service pages on the web have been extended to include a table giving a *Service Proposals Status Summary*. This lists all service proposals received after August 1996 and gives information on their current status and the dates of any observations taken.


The next deadline for service proposals is **November 15th**.

**COUDE SUPPORT AT THE AAT**

Jessica Chapman

Following the recent arrival of Paul Butler at the observatory, we have made some changes to support for the coude facilities. Paul Butler has now taken on the role of instrument scientist for the UCL echelle spectrograph (UCLES). Paul has extensive experience of high resolution echelle spectroscopy and will be using UCLES for a large scale search for planets around nearby stars. Jessica Chapman continues as instrument scientist for the Ultra High Resolution Facility (UHRF) and welcomes any enquiries on this unique instrument which provides a spectral resolution of up to one million.

**TTF DEVELOPMENTS**

Joss Bland-Hawthorn (AAO)

The different observational modes of the TTF are described in a recent paper by J. Bland-Hawthorn & D.H. Jones (1997; astro-ph/9707315). To date, this instrument has worked successfully in the R and I bands. The blue TTF (370–650nm) is now on order and should be here by January 1998. The characteristics match those of the red TTF, i.e. 6–60Å bandpass over the full wavelength range. Once again, the instrument is designed to work with conventional broadband (U,B,V) blockers for low resolution work, and intermediate band blockers for high resolution work (<20Å). Now is the time to stake your scientific claim, although there is a catch. If you need further encouragement, see the brief report on ‘Observational Cosmology with the TTF’ in AAO Newsletter no. 81. Note that TTF coverage from 370–960nm means that Ly₅ can be tracked to z=7, [OⅡ] to z=1.8, Hβ to z=1, [OⅢ] to z=0.9, and Hα to z=0.5.

The catch is that presently we have no intermediate blockers for high resolution work. These are specified to have a 150–250Å bandpass, a 5-cavity response profile with 95% transmission, and a 12mm circular diameter. These are manufactured by Barr Associates and cost in the range of US$1500–2200 each. In your PATT or ATAC application, please indicate whether you have funds for specific filters that you will need for your project. Delivery times are 2–3 months at present.

*We emphasize that proposing to use the TTF is easy.* With the Tek 1Kx1K CCD, the total TTF throughput (TTF+CCD+telescope) is 30% (600–700nm), 25% (800nm) and 13% (900nm). The anticipated
performance in the blue is 20% (400nm) and 25% (500nm). A TTF signal/noise calculator is currently under development.

It now seems highly likely that the new MIT-LL 4Kx2K CCDs will be available for use with the TTF in the next observing season. For comparison, the Tek 1Kx1K CCD camera gives a pixel scale of 0.59"/pix (f/8) or 0.32"/pix (f/15), compared with 0.37"/pix (f/8) or 0.20"/ pix (f/15) for the MIT-LL devices. The latter will allow for the full field to be shuffled in concert with frequency switching. Advantages of the new detectors include smaller pixels, lower read noise, and higher system throughput beyond 700nm (deep depletion CCD).

For most projects, the analysis is straightforward. The TTF produces a stream of discrete images. A suite of IRAF procedures developed by D.H. Jones now exists. Standard object-finding packages (e.g. Sextractor) can be run in real time at the telescope, and are sufficiently reliable to track variations in atmospheric conditions during the night. You should be able to walk away with reduced data!

Finally, the new MIT-LL deep depletion CCD will give both LDSS and TAURUS-2 a major advantage for astronomical observations in the red. It has become clear that the TTF produces excellent target lists for LDSS multi-slit observations. We have looked at ways to achieve faster turnaround times between TTF observations and cutting LDSS multi-slit masks. One week turnaround times are now feasible with the milling machine at Mount Stromlo.

**FLAIR NEWS**

Quentin Parker (FLAIR scientist)

Several important developments are currently underway which will significantly alter the way that FLAIR operates. These upgrades should be in place by the end of the year and available for Semester 1998A.

The most important of these will be the commissioning of an interim magnetic-button type fibre-positioning system. This will replace the rather messy and time-consuming UV curing cement process with magnetic button ferrules that will nevertheless retain much of the existing semi-automated positioning arrangements. An improved faster Z-drive, a software upgrade and the elimination of UV glue application and curing times should reduce the fibering burden from 4–6 hours to 2–3 hours.

Coupled with the significant changes to the fibering process are improvements with the spectrograph configuration control. We will shortly have remote control of spectrograph focus, hartmann shutter, grating rotation together with telescope RA,DEC fine motion control and FLAIR plateholder rotation — all from the comfort of the FLAIR console control (which doubles as the UKST common room!).


**FLAIR II TO 6DF**

Fred Watson and Quentin Parker

The UKST is entering a crucial phase in its life. With the exception of the new Hα survey, the major photographic surveys are nearing completion. Nevertheless, the UK Schmidt still has the highest information-gathering capability of any telescope in the world, and its wide field-of-view can be effectively exploited by imaging or spectroscopy. In order to reap fully the benefits of the wide field in the era of 8-m telescopes, new instrumentation must be developed.

A proposal that has found favour among the astronomical community is for a multi-fibre spectroscopy system similar to the existing FLAIR II, but with fully automated fibre positioning. Equipped with 150 fibres, such a system would offer a factor of 10 increase in efficiency over the present system for large-scale spectroscopic survey astronomy. For a fairly modest cost, it would provide the UKST with a facility that is as unique among 1-m class instruments as 2dF is among 4-m telescopes. To highlight this complementarity the proposed new system has been given the name 6dF.

Several major new large-scale projects have been put forward to take advantage of the UKST’s unique capabilities for wide-field multi-object spectroscopy. However, without 6dF, none would be really practical in terms of timescales, efficiency and cost-effectiveness. A few such projects are:

1) an all southern sky galaxy redshift survey to B<17 (100 000 galaxies);
2) a J or K-selected southern sky galaxy redshift survey (e.g. from DENIS or 2MASS data) of a well defined volume of the local Universe;
3) galaxy velocity dispersions — kinematics of galaxy clusters, distance estimates. 6dF could make a major impact in this area as fewer than 3000 galaxies currently have optical velocity dispersion estimates;
4) the bright end (B<19.0) of the quasar luminosity function;
5) possibilities for many large-scale stellar population
and kinematical studies in the Galaxy and Magellanic Clouds based on DENIS/2MASS data, the new UKST Hα survey and other surveys;

6) follow up observations to all sky surveys performed in other wavebands where the surface density of objects are a few per square degree at the optical magnitude limits of 6dF (e.g. from satellite missions such as ROSAT, IRAS and FAUST).

Further details of the science case and associated technical details can be found at: http://msowww.anu.edu.au/~colless/6dF/. However to emphasise the power of the proposed 6dF system we present in figure 1 a plot of the estimated time required by various current or planned multi-object spectroscopy systems to observe the 120 000 galaxies that will comprise a complete optical sample to B=16.5 and a complete NIR sample to J=13.7 based on DENIS data over the southern sky. 6dF is by far the most effective means to undertake such a survey.

Technical aspects of 6dF

6dF is a major upgrade to the existing FLAIR system. As currently envisaged, it consists of a set of three interchangeable fibre plateholders, each with its own 150-fibre bundle, which can be loaded into the telescope by means of the photographic plateholder elevator. Each fibre bundle terminates with a standard slit unit that locates in the (existing) floor-mounted intermediate-dispersion spectrograph.

The principal component that differentiates 6dF from FLAIR II is the automated fibre positioner. It will be designed to reconfigure a field of 150 fibres entirely automatically in about an hour, compared with the 6 hours or so currently required to set up 97 fibres semi-manually.

It is intended to locate the fibre positioner in its own enclosure in the dome to ensure the fibres are positioned at the same ambient temperature as the observations are made, and to minimise plateholder handling. It will take the form of a table onto which each plateholder can be located. A robotic fibre gripper will then move over the plateholder under computer control, positioning each fibre in turn with an accuracy of 10 micrometres (0.67 arcsec). As with 2dF, machine vision will ensure that this accuracy is achieved by means of iterated positioning of the fibres. Unlike 2dF, the time constraint is not critical, with up to 24 seconds being permitted for each fibre move.

The fibres will be attached to the field plate by the usual method of magnetic buttons. They will retract into the body of the plateholder like the existing FLAIR II fibres, but with the important difference that they will self-retract rather than requiring to be pushed in manually. Space restrictions in the Schmidt’s focal surface mean that innovative solutions must be sought for the retractor design; experimental work in this area is already under way.

The provision of several plateholders offers a ‘double-buffer’ capability analogous to that used with 2dF. While one plateholder is being used in the telescope, a second can be reconfigured. It is the shortest exposure time envisaged with 6dF (about an hour including overheads) that determines the minimum fibre set-up time. The point of having a third plateholder is to allow repeated observations of the same field over a period of time (e.g. in time-resolved spectroscopic programmes), or to have a back-up field for changing weather conditions.

Plateholders can be interchanged in the telescope in a matter of a few minutes with FLAIR II; the same will be true of 6dF. FLAIR II practice will probably be followed in the choice of fibre diameter. A value of 100 micrometres (6.7 arcsec) has proved to be suitable for a very wide range of projects, even though it was originally chosen to be well-matched to the diameter of B=17.5 galaxies.

While the technology used in the 6dF positioner will differ in many respects from that employed in 2dF (due to the steeply-curved focal surface of the Schmidt), the basic engineering concepts are similar, and therefore familiar ground to AAO engineers. Likewise, the software design will follow established principles. A modification of the existing CCD data acquisition system will be required in order to include fibre positional data in the CCD headers.

Current status

Although 6dF is currently only partially funded, it is now

![Graph showing spectroscopic success rate vs. S/N ratio](image-url)
the subject of a Phase A study being carried out within the AAO. The AAT Board has requested that the completed study be presented at its next meeting (March 1998).

It is expected that following the Phase A study, the fibre positioner could be completed within two years. An accurate cost estimate will emerge from the study; it is likely to be in the region of $A350k. The funding to build 6dF is likely to come from a combination of AAO sources and third parties, for whom appropriate levels of guaranteed time on the instrument will be negotiated.

It is clear that, despite the advent of powerful multi-object systems like 2dF and SDSS, the existing FLAIR II has remained competitive for certain types of project due to its combination of very wide field and available fibre numbers. To fully realise the science potential of 6dF, it must be ready by 1999/2000 before imaging surveys like DENIS need to look elsewhere to obtain spectroscopic follow-up data.

The scientific potential of a fully automated replacement for FLAIR II is high. The time is right to exploit the niche that 6dF can offer, building as it does on the existing strengths and expertise of the AAO.

We thank Matthew Colless for the figure.

NEWS FROM EDINBURGH

Return of Plates to ROE Plate Library

The Plate Library at ROE is the archive for all UKST plates (including those taken since the telescope became part of the AAO). About half of the requests for UKST material can be satisfied from existing material. This has several benefits for the telescope operation. The number of requests for UKST material which can be satisfied is greatly increased if new plates are only required when there is no existing plate. The pool of plates available to users is maximised if existing plates can readily be accessed. In some cases users are able to check the practicality of their programme before requesting new material. Users who have plates at their institution are therefore asked to return plates to Edinburgh as soon as they have finished using them. It is possible for such plates to be held in the ROE Plate Library but kept “on loan” to the original user; in these cases the plates would not be loaned to another user without the original applicant being contacted in the case of a possible conflict of scientific research.

Another reason for getting plates returned to Edinburgh is to prevent their being lost. Many plates are now listed in our computer database as “missing” as we are no longer able to contact the original borrower who may have moved away. Happily, some plates thought to be lost reappear. In the past year or so plates have “mysteriously” reappeared from Canada, China, Chile, London and even from a cupboard in ROE itself! So, if you find 14 inch square plates with no obvious owner, please contact us to see if they are UKST plates; if so, we will send a suitable container for their safe return.

Sky Surveys and Atlases

The UKST was, and is, involved with the production of a variety of sky surveys and atlases. The table below gives the status of the major “all sky” surveys. Many of these are being produced as atlases on film or glass. The copying of the SERC J atlas was done at ESO and completed in 1992. A few sets were still available fairly recently. The EJ glass atlas is complete and has been sent to seven customers. The EJ film atlas will be completed this year. The ER glass atlas is now over 50% complete and production of the film atlas will start shortly. The I/SR atlas of the Milky Way and Magellanic Clouds was copied onto film but there are no plans, at present, to reproduce the high latitude I survey (although individual films can be made). There are also no plans to copy the SES survey — again individual copies can be made. Copies of the EJ film atlas are still available and orders are now being taken for the ER film atlas — please contact us for details.

Many atlases have been, and are being, scanned by various measuring machines and the digitised data made available to the astronomical community on a CD-Rom or via the Web. These data are ideal for many purposes for which hard copies (film/glass/paper) have been used in the past. For example, finding charts can easily be produced from these data. However, there are many reasons for having the original (or atlas) material available. The resolution of the widely available digitised data is generally poorer than on film copies and, in some cases, even finding charts do not show the detail seen on the films. The films also show a much larger area of sky than can be seen easily in images made from digitised data; 40 square degrees compared with a maximum of about half a degree — useful for checking extended features. The discovery of new objects such as supernovae remnants, planetary nebulae (still being identified on POSS-II), very LSB galaxies etc. needs to be done either from the original material or by checking this to confirm the digitised data.
El Niño, they say — goodie, goodie — lots of nice observing with an El Niño. Nice clear nights, nice dry weather — beaut seeing! Well now, in the last six weeks Coonabarabran has had over 12" rain — good rain mind you, just at the right time for crops and grass but not terribly good for observing. Where’s this El Niño Effect ask disgruntled observers as they peer at the pouring rain and stumble around in the fog.

‘Who cares?’ mutters John Stevenson as he buys snorkels in job lots and shows his sheep how to use them. It’s an odd fact but true that his lambs have been born with webbed feet and go ‘riddip’ instead of ‘baa’. So all the farming types are floating around as they see the burgeoning of a perfect spring. This last little spate was caused, of course, by 2dF, although it was noticeable that the weather cleared up as soon as Joss Hawthorn left. It used to be Gary da Costa who brought the rain but it seems we can start bottling up Joss and selling him to drought-ridden areas of the world. It is quite something to stand on the catwalk of the AAT and watch the lightning flaring over the Warrumbungles and then diving inside just as the wind hammers on the dome with stunning force. Still, last night was superb for Taurus, and it is looking good for the near future as well, and according to the experts, El Niño is still a pretty powerful option so observers may have a super summer after all.

2dF is definitely old hat now, with IRIS2, and 6dF and other wonderful acronyms being bandied about. There are still not enough hours in the day for the technicians as they keep the AAO on the ‘leading edge of technology’, a much abused phrase which is nevertheless true here.

We are sad to advise that Kevin Cooper is not well, and we are thinking of him and wish him well. So, there you are — apart from the incredible weather, it has been a very quiet quarter, with lots of work done and future planning in full swing.

‘Drat these sheep’ says John. ‘I don’t know, I go to the trouble of getting them snorkels and they breathe out when they should breathe in and they reckon the face masks don’t fit properly. Maybe I’ll give it up and teach them how to use a telescope instead!’ Riddip!
Taurus spectra of NGC 1068. These spectra were mapped from a stack of Taurus-2 CCD images taken in sub-arcsecond seeing over 3.5-hours, span 1250 km/s, are shown superimposed on an HST continuum-subtracted [O III] PC image and with VLA 6 cm contours, and are scaled to the same intensity in each box. We used an etalon with high finesse, large free-spectral range, and optimized interference coatings for use near [O III]λ5007. The delineated regions are discussed in the text. Fabry-Perot data have a reputation for being hard to reduce, yet these raw data are shown as they were when we walked away from the AAT. See page 6 for details.