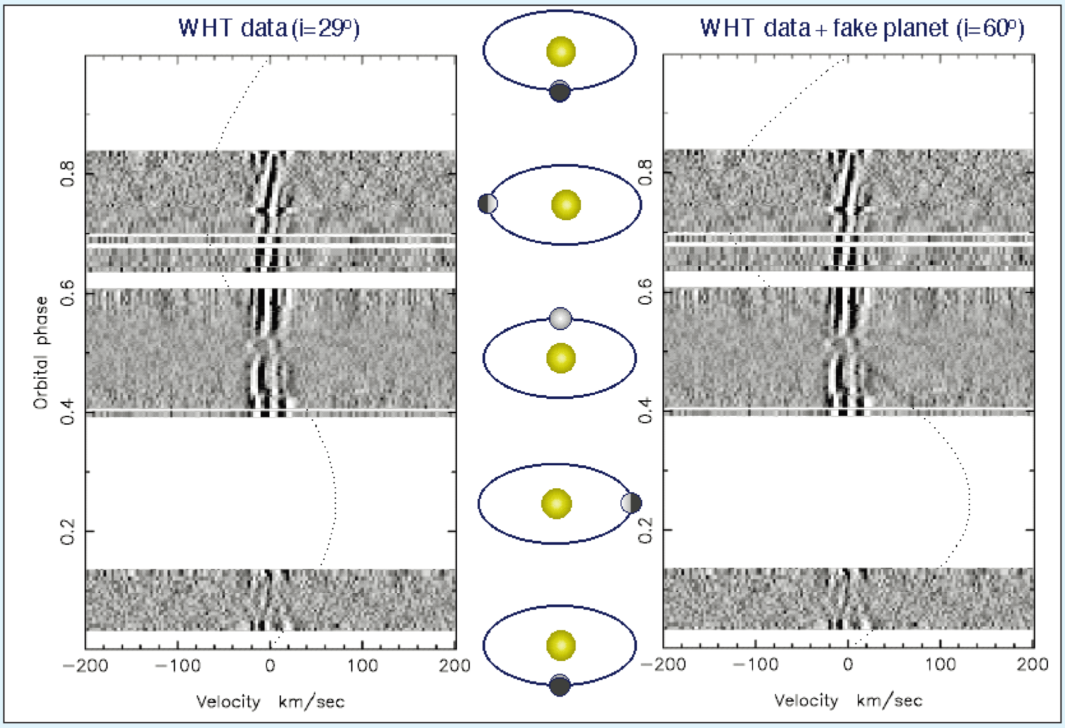
No. 2, March 2000

The Isaac Newton Group of Telescopes

NEWSLETTER



WHT Achieves First Direct Detection of an Extra-solar Planet

This grayscale phase plot illustrates the method of Cameron et al. for detecting reflected-light signatures from extra-solar planets, using data secured with the WHT + UES in 1998 and 1999. The left-hand panel shows 145 residual velocity profiles of the τ Boo system, obtained by subtracting a model of the direct starlight from the data and averaging the profiles of the ~2300 spectral lines buried in the residual spectrum. The velocity scale is in the reference frame of the star, and time increases upward. The dotted paths indicate the velocity curve of a planet orbiting with an orbital inclination of 29° (left-hand panel) and 60° (right-hand panel). The right-hand panel shows the effect of adding the simulated spectrum of a planet with 1.4 Jupiter radii and Jupiter-like reflectivity to the original spectra. The simulated planet signature appears as a dark linear feature with an amplitude about 10^{-4} of the mean stellar continuum level, crossing from positive to negative velocity at phase 0.5 when the planet is on the far side of the star. The planetary signature detected in the data is much weaker, because of the low inclination, but would follow the velocity curve shown in the left-hand panel. The "barber's pole" pattern of travelling ripples lies wholly within the residual stellar profile, is wavelength independent, and probably originates in stellar surface features (see article by Andrew Collier-Cameron on page 3).

Message from the Director

Dear Reader,

As I am writing this the Year 2000 (but not the new Millennium!) has just commenced. The telescopes passed their Y2K tests successfully well before the date change and no problems were experienced on January 1st. I hope the rest of the year will go as smoothly as that first night of the new year.

Last year 1999 ended with much excitement when in December the discovery by Andrew Collier-Cameron (St. Andrews) and co-workers of the Millennium Planet was announced to the press. For the first time ever the light of an extrasolar planet had been detected. The observations leading to this break-through were obtained with the Utrecht Echelle Spectrograph (UES) on the William Herschel Telescope.

The new year will bring many activities and exciting projects for ING. Most importantly, in a few months we hope to have the new IR

THE ISAAC NEWTON GROUP OF TELESCOPES

The Isaac Newton Group of Telescopes (ING) consists of the 4.2 m William Herschel Telescope (WHT), the 2.5 m Isaac Newton Telescope (INT) and the 1.0 m Jacobus Kapteyn Telescope (JKT), and is located 2,350 m above sea level at the Roque de Los Muchachos Observatory (ORM) on the island of La Palma, Canary Islands, Spain. The WHT is the largest telescope of its kind in Western Europe.

The construction, operation, and development of the ING telescopes is the result of a collaboration between the United Kingdom and the Netherlands. The site is provided by Spain, and in return Spanish astronomers receive 20 per cent of the observing time on the telescopes. The operation of the site is overseen by an International Scientific Committee, or Comité Científico Internacional (CCI).

A further 75 per cent of the observing time is shared by the United Kingdom and the Netherlands. On the JKT the international collaboration embraces astronomers from Ireland and the University of Porto (Portugal). The remaining 5 per cent is reserved for large scientific projects to promote international collaboration between institutions of the CCI member countries.

The ING operates the telescopes on behalf of the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of the Netherlands. The Roque de Los Muchachos Observatory, which is the principal European northern hemisphere observatory, is operated on behalf of Spain by the Instituto de Astrofísica de Canarias (IAC).

PPARC NWO

(Continued from front cover)

camera, INGRID, operational on the WHT. Secondly, if all goes according to plan, this summer the Adaptive Optics system, NAOMI, will become operational on the WHT with the exciting prospect of delivering an image quality that will be measured in small fractions of an arcsecond. It will open a completely new toolbox for ING users, with hopefully many scientific discoveries to follow. Furthermore, ING's new Data Acquisition System, based upon the latest version of the San Diego controllers, will be rolled out to all foci of the WHT, and a new unit with narrow and continuous fibres for AUTOFIB should see first light in 2000. And last but not least further laser guide star trials will be carried out to complete the study of suitability of the skies above La Palma for sodium laser guide star deployment.

As you see ING and the various collaborating groups have a busy and exciting year ahead!

In the previous newsletter I reported on the negotiations that were taking place with Spain to seek collaboration between the ING and the Spanish 10-m telescope project GranTeCan. Regretfully, too many obstacles were encountered and both the Netherlands and the UK decided to withdraw from the negotiating table. A possible future collaboration is not wholly excluded, and hopefully scientific links and technical interests common to the GranTeCan and ING will develop into strong ties between our two organisations.

Dr René Rutten. Director, ING.

The ING Board

The ING Board oversees the operation, maintenance and development of the Isaac Newton Group of Telescopes, and fosters collaboration between the international partners. It approves annual budgets and determines the arrangements for the allocation of observing time on the telescopes. ING Board members are:

Prof. T de Zeeuw, *Chairman* – Leiden
Dr. W Boland – NWO
Dr. A Collier-Cameron – St Andrews
Dr. A Mampaso – IAC, Tenerife
Prof. M Merrifield – Nottingham
Dr. P Murdin – PPARC
Prof. J Drew – London
Dr. C Vincent, *Secretary* - PPARC

The Instrumentation Working Group

The Instrumentation Working Group for ING was recently re-constituted primarily to provide scientifically informed advice on the instrumentation programme for the ING telescopes. The IWG fulfils an important function as intermediate between ING and the user community. IWG members are:

Dr. R G McMahon, *Chairman* – Cambridge
Dr. S Arribas – IAC, Tenerife
Dr. G B Dalton – Oxford
Dr. V S Dhillon – Sheffield
Dr. S F Green – Kent
Dr. K Kuijken – Groningen
Dr. N A Walton, *Secretary* – ING

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SCIENCE

WHT Achieves First Direct Detection of an Extra-solar Planet

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The last few years have seen huge advances in the quest to discover and characterise planetary systems orbiting stars other than the Sun. During the 1980s, infrared and mm-wave observations revealed a high incidence of solar system-sized dusty discs around T Tauri stars and young main-sequence stars. These both confirmed that our own planetary system originated in a flattened, rotating disc of dust and gas, and suggested that planetary systems should be commonplace around other solar-type stars. The expectation was that our own system would turn out to be fairly typical. Small rocky planets should condense from refractory dust grains in the warm inner disc. Giant planets, with cores of a few Earth masses composed of dust grains with ice mantles, could sweep up the large amounts of gas available in the outer parts of the disc.

The discovery by Mayor & Queloz (1995) of a Jupiter-mass planet ($m \sin i = 0.45 M_J$) in a 4.2-day orbit about the star 51 Peg thus came as a surprise. In the four years since then, the tally has grown to some 30 planetary candidates detected from the orbital "Doppler wobbles" of their parent stars. Even though this method has a selection bias toward high-mass planets in short-period orbits, the existence of close-orbiting giant planets and longer-period objects in highly eccentric orbits is surprising. Planetary-system formation is increasingly looking like a violent business, with dynamical interactions between discs and planets producing inward orbital migration, destabilisation of orbits and possibly ejection of planets into interstellar space.

Aside from the dynamical considerations, these discoveries provide exciting new challenges for models of the interior and atmospheric properties of giant planets at a variety of distances from their parent stars. Are they like the methane brown dwarfs, with extensive sodium and methane absorption (Sudarsky et al., 1999) at optical and IR wavelengths? Do they possess cloud decks of silicates and iron condensates (Marley et al., 1999), and if so, what optical properties would be expected of such clouds?

The idea of attempting a direct detection grew out of work one of us (ACC) has been conducting in collaboration with Jean-Francois Donati (Toulouse) on Zeeman-Doppler imaging of magnetic polarity patterns on stellar surfaces. This entails precise registration and subtraction of left-and right-circularly polarized echelle spectra, and the use of least-squares deconvolution (Donati et al., 1997) to combine Stokes V profile information from the thousands of absorption-line profiles recorded in each echellogram. The method yields composite profiles of Stokes V signatures hundreds or thousands of times fainter than the direct spectrum, with signal-to-noise ratios several tens of times greater than the best-exposed parts of each echellogram. We expect the reflected-light signature of a close-orbiting giant planet to contain the same set of lines as its parent star, but to be 10,000 to 30,000 times fainter than the direct starlight and Doppler shifted by orbital motion. We found that it should be possible to isolate the moving planet signature, provided we could first subtract an accurate model of the direct starlight from the data.

We selected τ Boo (Butler et al., 1997) as our first target. Being closer to its star than any of the other known "Hot Jupiters", the giant planet orbiting τ Boo should intercept more starlight, and hence appear brighter in relation to its star, than any of the other known planets of its class. We secured our first 4 clear nights' observations in 1998 April. We initially tried to model the direct starlight using spectra of the star taken near inferior conjunction, when the planet's dark side is turned toward us. This proved unsatisfactory: small night-to-night shifts in the position of the spectrum on the detector conspired with low-level fixed-pattern noise that could not be flat-fielded out, to give non-Gaussian noise levels greatly in excess of photon statistics. Within any given night, however, the position of the spectrum on the detector remained essentially unchanged. By constructing the template spectrum from the sum of all spectra taken on a given night, the fixed-pattern noise level was reduced to 10 – 20% of the photon noise. The penalty for this is that, on nights when the planet is near quadrature and the velocity is almost constant, the planet signature gets subtracted out along with the starlight. Accordingly, the best times to observe the planet are just before and just after superior conjunction. The planet is then at its brightest, its lines are Doppler shifted well clear of the star's lines, and its velocity is changing rapidly. These considerations dictated our observing strategy in the

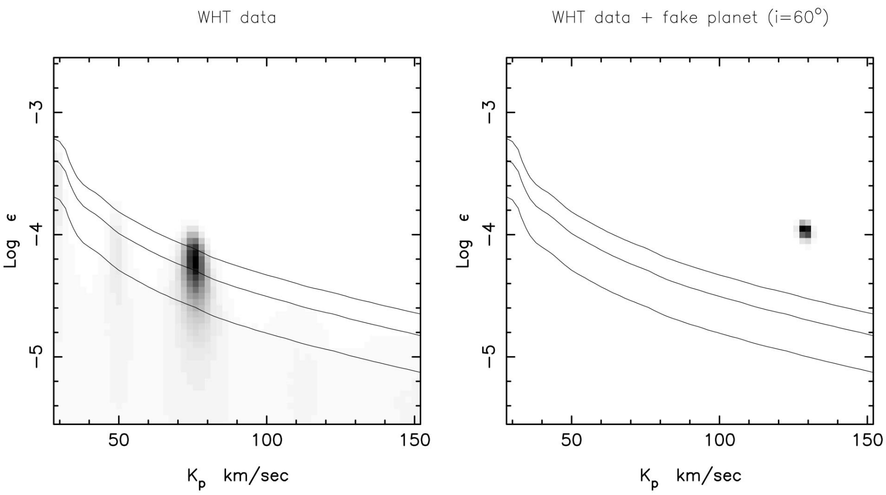

Figure 1. The relative probability map testing for the presence of a planetary reflected-light signature. For each possible value of the unknown planet-to-star brightness ratio ε, and of the planet's projected orbit velocity K_p, darker shades denote progressively better fits to the data. The solid curves show the 68.3%, 95.4%, and 99.7% upper limits above which a planet signature can be ruled out as a function of K_p. The plot shows significant evidence for a planet at projected orbital velocity K_p=74±3 kms^{-1} and face-on planet-to-star flux ratio $\varepsilon = 7.5 \pm 3 \times 10^{-5}$. Since the true orbital velocity amplitude is close to 152 kms^{-1}, the implied orbital inclination is close to 29°. In the right-hand panel, the signature of a simulated planet with Jupiter-like reflectivity, radius 1.4 times Jupiter, and orbital inclination 60° is detected at a high level of significance.

1999 season, when all observations were scheduled close to superior conjunction. To maximize the photon catch on each CCD exposure, we nodded the telescope to widen the spatial profile of the spectrum on the detector. This also allowed us to expose for longer without saturating the CCD.

By the end of the 1999 season we had amassed a total of nearly 600 spectra in 9 clear nights of observation. The S:N ratios of the deconvolved profiles were typically around 20,000, easily sufficient to detect a planet of Jovian dimensions and reflectivity if seen fully illuminated. This allowed us to place strong upper limits ruling out a Jupiter-like planet in near-edge-on orbits — and produced evidence for detection of a planet at an orbital inclination of 29° (Figure 1). A detailed investigation suggests a false-alarm probability of about 5% (Collier-Cameron et al., 1999).

We were able to construct a crude albedo spectrum for the planet, by measuring the strength of the planet signature in 6 independent subsets of the data spanning different wavelength ranges between 3850 and 6100 Å. This "spectrum" is shown in Figure 2. Curiously, the signal is only significant at wavelengths between about 4600 and 5000 Å, suggesting that strong absorption features may be present. The strength of the detection in the 4600 to 5000 Å region suggests a radius nearly twice that of Jupiter for plausible albedo values, and the inclination yields a mass 8 times that of Jupiter.

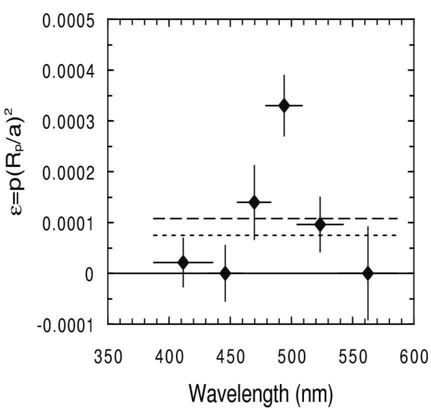

Figure 2. The wavelength dependence of the planet-to-star brightness ratio $\varepsilon(\lambda)$ at zero phase angle for τ Boo b, derived from six independent subsets of the echelle data. Signals are present between 4600 and 5000 Å but absent at other wavelengths.

At face value, our candidate detection appears to conflict with the upper limits from 3 nights of Keck data published by Charbonneau et al. (1999), who failed to see the planet at a signal level apparently half that of our claimed detection. Part of the discrepancy results from differences in the models used by the two teams to represent the angular dependence of the planet's reflectivity. We also understand that they did not compensate fully for the fact that some of the planet signal goes missing when you subtract out the direct light from the star. This is particularly important for a tilted orbit. Together these differences between the two analyses bring the results into agreement within their uncertainties.

We will seek confirmation of this detection using the WHT in the spring of 2000, this time targeting a set of orbital phases optimized for an orbital inclination near 30°. The new phasing will allow us to gather up to 16 times as many "useful" photons from the planet, as we've amassed so far. If the detection survives this more intense scrutiny, we should be able to quadruple the spectral resolution and double the S:N relative to the existing data, giving us a better chance of identifying the major optical absorbing species.

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Gamma-Ray Burst Afterglows: Surprises from the Sky

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The GRB field of astronomy has experienced a cascade of astonishing discoveries and new surprises over the past three years. In this paper we discuss some of the highlights of GRB afterglows, in which the ING telescopes have played an important role. With the new generation of GRB satellites to be launched, new exciting results are on their way, giving important insights into the nature of the progenitors of GRBs, and also into the high redshift universe.

Afterglow highlights

GRB 970228

Twenty five years after the discovery of Gamma-Ray Bursts (GRBs), there was still a very strong debate about their distances. One camp put them in the halo of the Galaxy, the other among the most distant objects known in the universe. It was expected that the discovery of a counterpart at other wavelengths would resolve this issue. Searches for counterparts were not successful because the error boxes typically had the size of several degrees. Such positions could be refined by triangulation with the Inter-Planetary Network (IPN), but the few GRBs with such accurate positions were, with hindsight, not observed rapidly enough to give a chance of detecting afterglows. With the launch of the Italian-Dutch satellite *BeppoSAX* (near the end of 1996), which carries two X-ray Wide Field Cameras (WFCs) on board, burst positions became available with typical error circle radii of 3 arcminutes (a factor of ~4000 improvement in localisation). These positions were made available rapidly (several hours after the burst). When the second burst detected by one of the WFCs came along (GRB 970228) the team of the late Jan van Paradijs, consisting of the two former PhD students Titus Galama and Paul Groot, were ready for it. They pointed the WHT towards the WFC X-ray source position 21 hours after the burst, and on March 8, the INT was used for a follow-up image. Using these images, they were able to identify the first optical counterpart of a GRB (van Paradijs et al., 1997), which marked the beginning of a revolution in our understanding of GRBs (see Figure 1). This discovery, together with that of the X-ray afterglows discovered by our Italian colleagues with the Narrow Field Instruments (NFIs) of *BeppoSAX* is among the top 5 of major scientific breakthroughs of 1997, according to *Science*. Later HST images showed a faint nebula around the optical transient (OT), for which Keck has now been able to determine the redshift: z=0.695. These results confirmed that GRBs occur at cosmological distances and together with the fluxes received at Earth, indicated that GRBs are the most powerful photon emitters in the Universe.

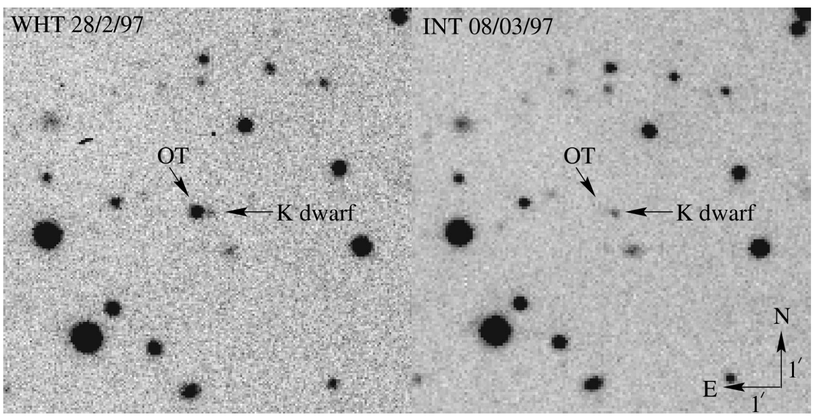


Figure 1. Discovery V band images of the first optical counterpart (GRB 970228) (van Paradijs et al., 1997). The image on the left shows the transient on February 28, 1997. The image on the right shows the transient on March 8, 1997. The optical transient is denoted by 'OT'. A late-type star (K-dwarf) is also indicated.

GRB 970508

The first OT for which the redshift was determined was GRB 970508: z=0.835 (Metzger et al., 1997). It was also the first burst for which a radio afterglow was discovered, by Dale Frail and colleagues (Frail et al., 1997), and the ING observations of this burst showed evidence for a spectral transition (Galama et al., 1998a). Titus Galama and co-workers also constructed a radio to X-ray spectrum at day 12 after the burst and showed that the observations can be understood in terms of the relativistic blastwave (or fireball) model (see Figure 2; the R-band light curve of this burst is also shown). In this model, a huge amount of energy is dumped into a compact region, which causes a relativistically expanding blast wave that sweeps up the surrounding matter. The electrons in the shock are accelerated to a power-law distribution in energy and radiate synchrotron emission. The bulk of the electrons have the Lorentz factor γ_m and radiate near the peak frequency ν_m (corresponding to γ_m). This produces the typical synchrotron spectrum shown in sections II and III of Figure 2. Section I is modified by synchrotron self absorption (frequency ν_a), and section IV is located above the electron cooling frequency (ν_c); cooling causes a steepening of the spectrum. As the blast wave slows down, the peak and cooling frequencies move to lower frequencies as a power-law in time,

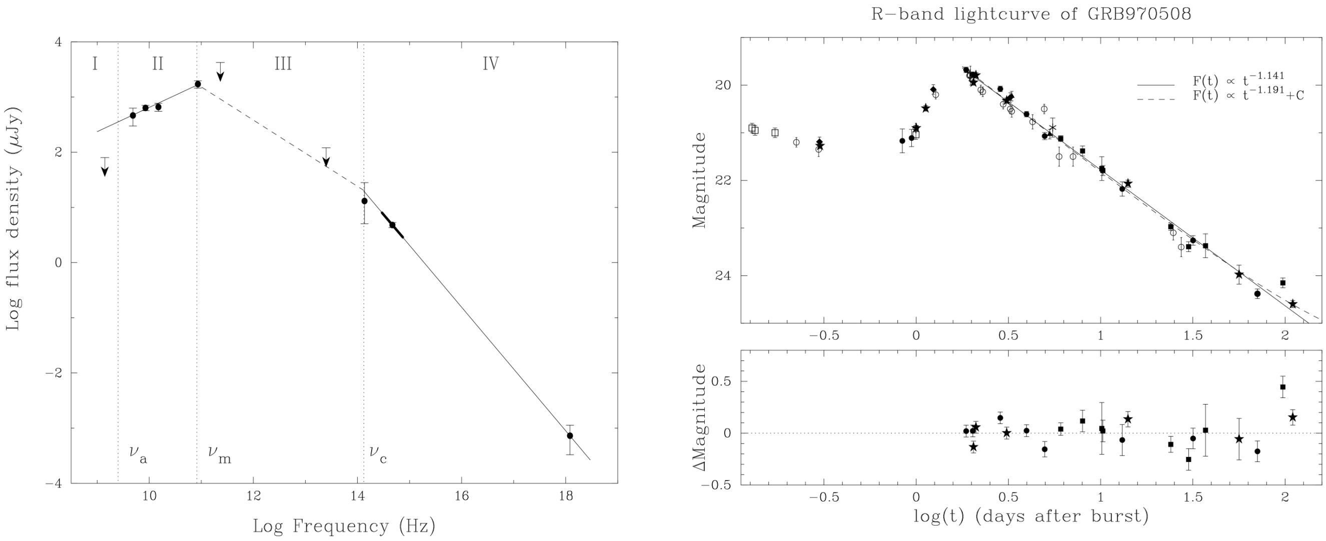


Figure 2. Left: The X-ray to radio spectrum of GRB 970508 on May 21.0 UT (12.1 days after the event). Three break frequencies are indicated, corresponding to synchrotron self-absorption, ν_a, the peak, ν_m, and the transition to rapid electron cooling, ν_c (from Galama et al., 1998b). Right: R_c band light curve of GRB 970508, based on ING data. A power law fit is represented by the solid line. Indicated by the dashed line is a fit of a power law plus a constant, $F_R = F_{R0}\, t^{\alpha} + C$. Left lower panel: the fit to the power law decay subtracted from the data. Deviations from a power-law decay are only moderate (r.m.s. = 0.15 magnitudes) (from Galama et al., 1998c).

which, together with the fact that the spectral shape is also a power-law (in distinct regions), causes a power-law decline of the afterglow.

GRB 971214

Using the Keck 10-m telescope, Shri Kulkarni and his colleagues, were able to determine the redshift of the counterpart of GRB 971214 at z=3.42 (Kulkarni et al., 1998; the most distant GRB detected so far). The implied energy output, assuming a standard cosmological model and isotropic energy release, was an amazing 3×10^{53} erg.

GRB 980425

After GRB 970228, the redshift determination of GRB 970508, which showed that GRBs come from cosmological distances, and the outstanding energy output of GRB 971214, the GRB community was waiting for the next surprise from the sky.

On Sunday April 29, 1998, two of us (Titus Galama and Paul Vreeswijk) were analysing images taken the days before with the Anglo-Australian Telescope (AAT) and ESO's New Technology Telescope (NTT). They were frantically looking for a faint stellar-like object to disappear in later frames, but couldn't find any good candidates. As Paul was on the phone with his sister, who called him up for his birthday, Titus shouted out: "Hey, what's this??? Paul, look at this!" It appeared Titus had discovered the supernova SN 1998bw (see Figure 3 and Figure 4), which marked the beginning of a revolution in not only the GRB field, but also the SN community. With our late supervisor Jan van Paradijs, we very conservatively estimated the chance of finding a supernova in the GRB error box, with the time of collapse around the time of the burst, and found it to be 10^{-4}. This being so small, the notion that some GRBs and SNe are physically related became fairly hard to reject (Galama et al., 1998d).

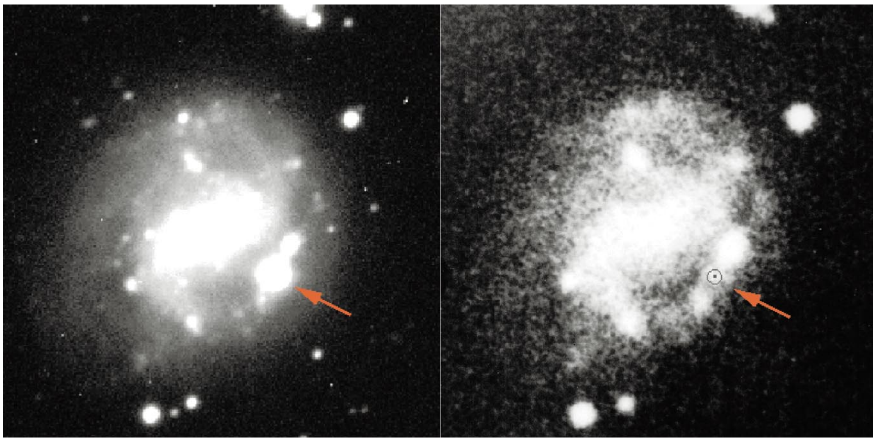
Since this discovery, more evidence for a relation between SNe and GRBs has been found. Josh Bloom and colleagues suggested that the late-time afterglow of GRB 980326 could be explained by an underlying SN 1998bw type supernova at a redshift of about unity (Bloom et al., 1999). Our team, after re-analysing just about all the available data of GRB 970228, to minimise differences in analysis by different groups, has also found evidence for a supernova contributing to the light curve of GRB 970228 (see Figure 5). These findings call for accurate determination of afterglow magnitudes, not only at early times, but especially at late times (~20–30 days after the burst), for which the WHT is very suitable. The link between GRBs and SNe was one of the ten major breakthroughs in 1999 according to *Science*.

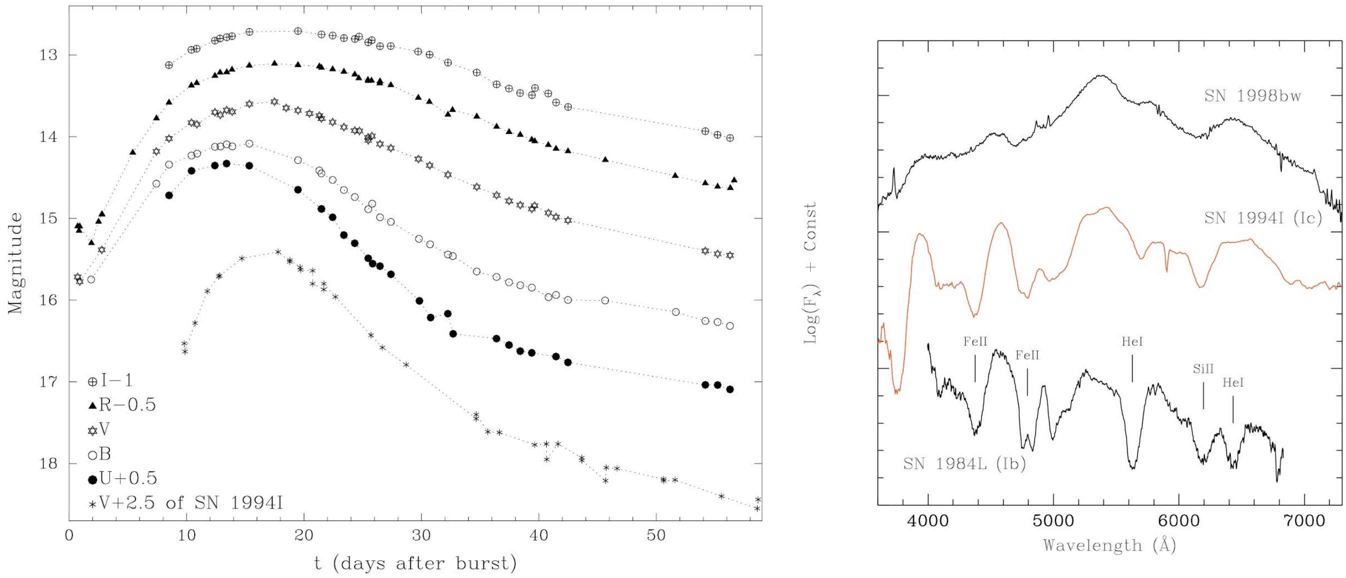
GRB 990123

After nearly two years of afterglow studies, GRBs continued to surprise the community with the discovery of the afterglow of GRB 990123. The first report was of an afterglow of R~18th magnitude, which was not very unusual at around 4 hours after the burst. However, the ROTSE team had slewed their robotic telescope to the burst position only 20 seconds after the BATSE alert and when they analysed their images at the reported position of the afterglow, they found an incredible V~9th magnitude flash, i.e. somebody with binoculars looking at the right part of the sky would have been able to see it! The total isotropic energy output of this

Figure 3. Discovery R band NTT image showing SN 1998bw in the spiral galaxy ESO 184–G82 on May 1 1998 (left) and pre-discovery (1976) UK Schmidt Telescope image of ESO 184–G82 (right) (from Galama et al. 1998d).

Figure 4. Left: UBVRI light curves of the GRB supernova SN 1998bw (GRB 980425). Time is in days since April 25.91 UT. For comparison the V band light curve of the type Ic SN 1994I is shown. Right: Representative spectra near maximum light of SN 1998bw, SN 1994I, and SN 1984L (type Ib). The overall shape of the spectrum of SN 1998bw is similar to that of a Ic supernova, although the spectral features are less pronounced (from Galama et al. 1998d).





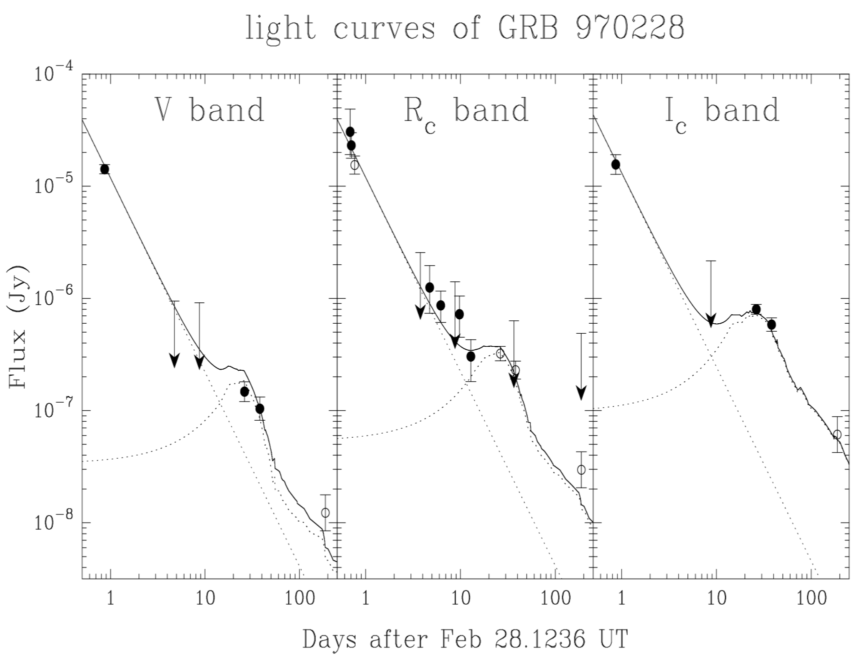


Figure 5. The V-, R_c-, and I_c-band lightcurves of GRB 970228 (log-log plot of fluxes versus time). The dotted curves indicate power-law decays, fixed at α = –1.46, and redshifted SN light curves. The thick line is the resulting sum of SN and afterglow. This, along with similar evidence for an SN component to GRB 980326 and the connection of GRB 980425 with SN1998bw, suggests that at least some classical GRBs are associated with a class of supernovae (from Galama, Tanvir, Vreeswijk et al., 1999).

burst beat that of GRB 971214: over 10^{54} erg.

Combined with the BATSE data and images taken at other telescopes, including the ING, we were able to conclude that the BATSE γ-ray burst itself, the optical flash responsible for the 9th magnitude, and the late-time afterglow, came from three distinct emission regions. Figure 6 shows that the optical flash probably smoothly connects with the late-time afterglow, which means that if OTs are caught at an early time, they may be very bright. Observations of bright afterglows should become possible with the launch of HETE-II, which will provide accurate positions of the prompt X-ray burst accompanying the GRB within a minute.

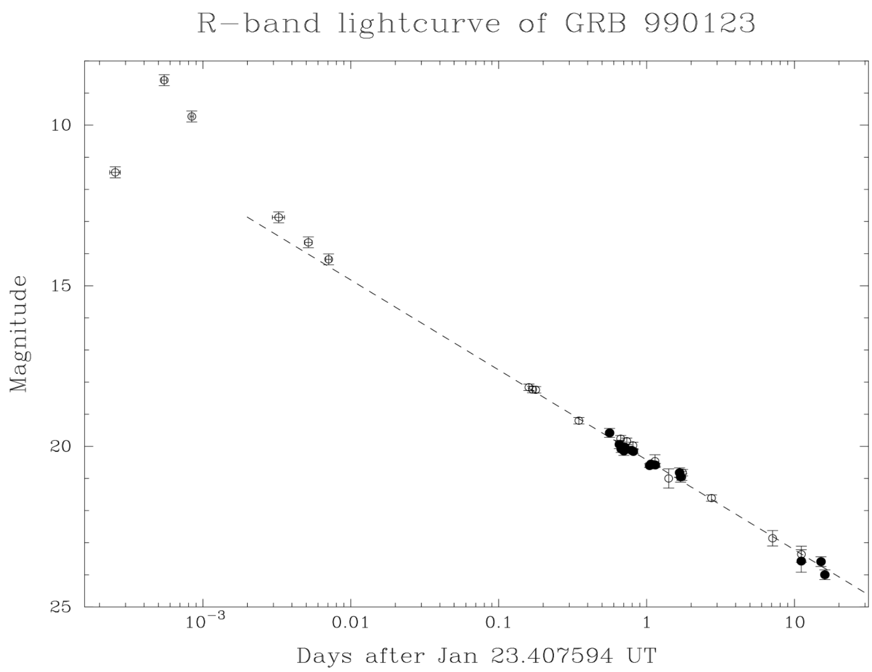


Figure 6. R-band light curve of the afterglow of GRB 990123, including our WHT and INT data. The filled circles indicate results of our observations. The open circles are data taken from the literature. The dashed line indicates a power law fit to the light curve (for t>0.1 days), which has exponent –1.12 ± 0.03. Also included are the ROTSE data. The power law fit is extrapolated backward (from Galama et al., 1999).

GRB 990510

In the past year many bursts went off at Southern declinations. With the first unit of the Very Large Telescope in use, our team was able to determine the redshifts for three afterglows (two are actually lower limits, since only absorption features are detected and these could in principle be caused by an intervening cloud in the line of sight): GRB 990510, GRB 990712 and GRB 991216.

For GRB 990510 we also studied the evolution of the metal absorption lines (see Figure 7). We found no evidence for a change in the equivalent width of the MgII feature, suggesting that the atoms responsible for the absorption are not in the immediate vicinity of the site of the explosion (Vreeswijk et al., 1999).

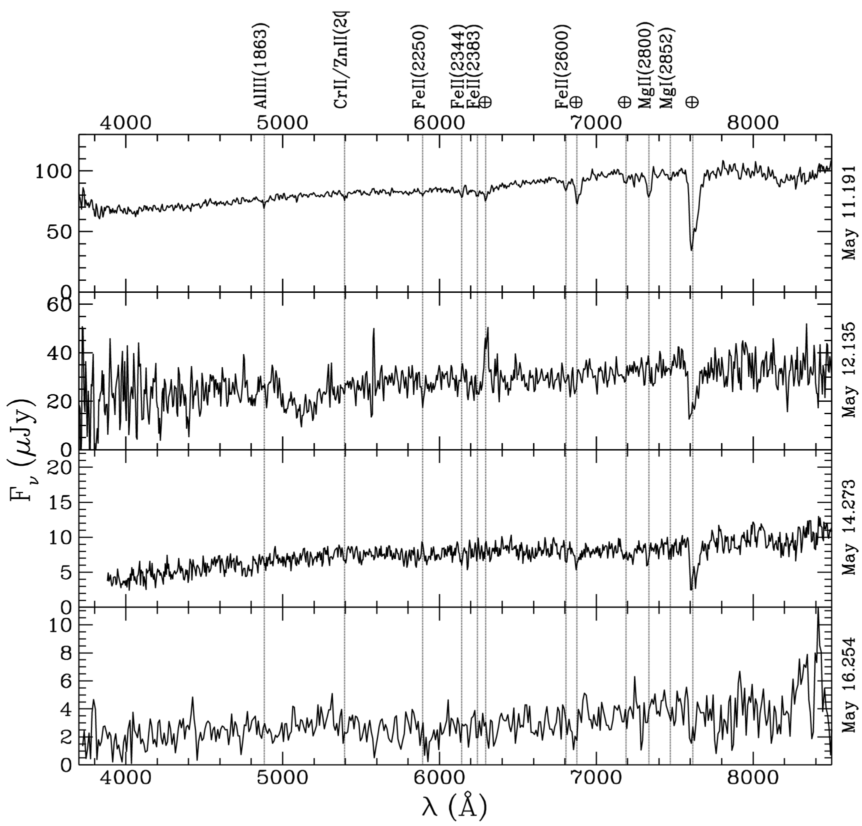


Figure 7. VLT/FORS1 spectra of the afterglow of GRB 990510, from 0.8 to 5.9 days after the burst, plotted over the wavelength range 3700-9300Å. Several absorption features are indicated with the broken lines, putting the absorber redshift at z = 1.619 ± 0.02, which is most likely the host galaxy of the burst (From Vreeswijk et al., 1999).

Future prospects

The combination of their power and their large distances, makes GRBs extremely interesting as possible probes of the high redshift Universe. When we have a vast sample of redshifts available, and we find more evidence that GRBs are directly related to the formation of massive stars, they can be used to trace the star formation rate up to the very early Universe. And just like quasars, they can be used to study the chemical composition of the intergalactic medium. In several GRB afterglow spectra, multiple absorption systems have been detected through the identification of redshifted UV metal lines. When these GRBs were caught, they were typically fainter than R = 20. With the launch of HETE–II (expected date of launch: 23 Jan. 2000), however, it will become possible to catch GRB afterglows when they are still very bright, at R ~15–16. This is due to the fact that HETE will be able to make an accurate position available immediately (less than one minute), whereas the WFC positions of *BeppoSAX* typically are available after 4 hours. At that brightness, high signal-to-noise, high resolution spectroscopy will become feasible. For some bursts it may even become possible to catch them when they are brighter than R = 10, but this requires an automated activation procedure of the telescopes. ESO is already investigating the possibilities of automated activation of the VLT, and hopefully other observatories will follow.

Coming from cosmological distances, GRBs have the possibility of being gravitationally lensed. Although this possibility is estimated to be less than 0.1% (Blaes & Webster, 1992), with 3 bursts per day going off over the whole sky, detecting a lensed GRB is just a matter of time. With the clear variability that GRBs display, the time lag should be easy to determine, and assuming a mass model for the lensing galaxy or cluster, one will be able to estimate the value for H_0 (as has been done for several lensed variable quasars).

Following up GRB afterglows has pushed traditional ground-based observing into a new mode of operation — of frequent and substantial overrides. Thanks to the support of the time-allocation committees and observatory staff, and goodwill of the large majority of observers, this has actually worked very successfully. Without the target-of-opportunity possibility, many of the above mentioned exciting discoveries would not have been possible. Clearly, in the longer term, a move towards queue / reactive scheduling will benefit both GRB astronomers and the rest of the community.

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The Sakurai Object: A Case Study in Advanced Stellar Evolution

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In 1996 Y. Sakurai, a Japanese amateur astronomer, discovered what was originally described as a nova in Sagittarius. Spectroscopy soon after discovery indicated the Sakurai Object to have a cool hydrogen-deficient photosphere —quite unlike that of a normal nova explosion— and the only similar object being Nova Aql 1919 (Lundmark, 1921). With the detection of a faint and ancient planetary nebula around the star, it was clear that this was not like a typical nova but was probably a highly evolved single star undergoing some form of rather exotic evolution. In fact the Sakurai Object (now known as V4334 Sagittarii) has become one of the most intriguing objects in stellar astrophysics and promises to be a rosetta stone to our understanding of the evolution of ancient stars.

To understand why stellar astronomers were excited by Sakurai's discovery we must review some history. Hazard et al. (1980) discovered that the inner regions of the planetary nebula Abell 78 had material that strongly emitted [O III] and [N II] but emission from hydrogen was absent —the conclusion being that this object was hydrogen-deficient. Since then a number of other similar objects have been identified, the study of which, has led to new physics being developed —mass loading into a stellar wind (e.g. Hartquist et al., 1986), with application in many other branches of research. Theories developed to account for the odd physical properties of these systems and other hydrogen deficient stars, involved either merging binary white dwarfs (Webbink, 1984) or else a delayed helium shell flash (Iben et al., 1983). This later phenomena results from the small possibility that a shell flash (as experienced by stars ascending the AGB) may be delayed until the post-AGB star has almost become fully degenerate,

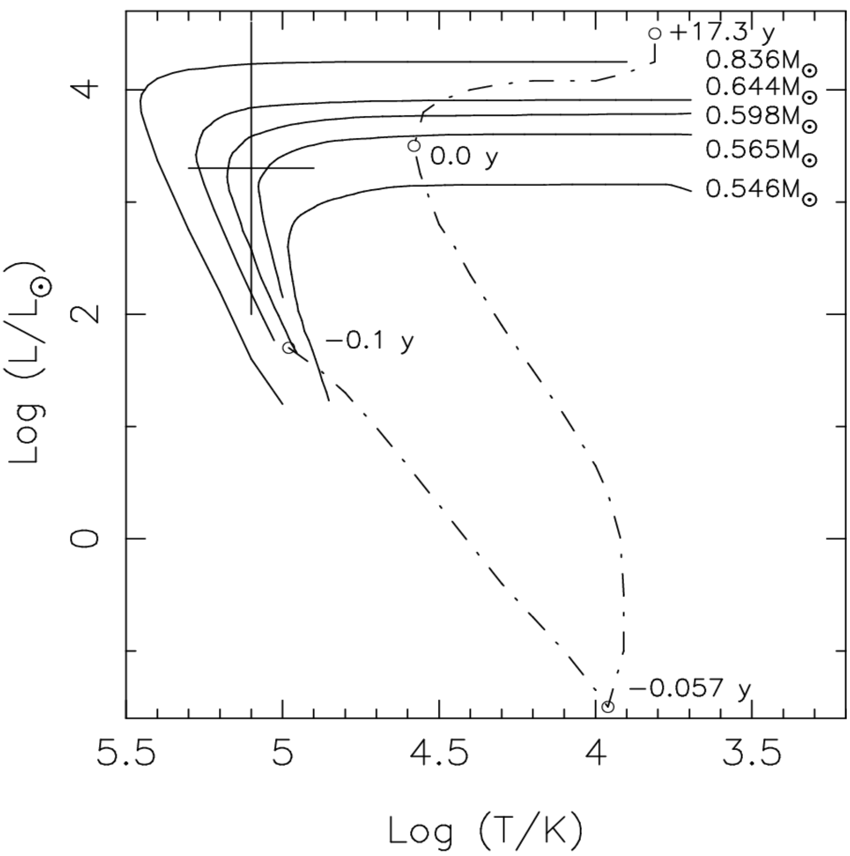

Figure 1. The position of the Sakurai Object prior to its shell flash derived from a model of the nebula ionisation (Pollacco, 1999). The solid lines are evolutionary tracks for post-AGB stars, while the broken lines represents the expected evolutionary track for a star suffering a helium shell flash. The Sakurai Object is currently positioned towards the top right of this diagram (high luminosity, and low temperature), but is heavily obscured by circumstellar dust.

albeit with a relatively massive envelope. Although exotic physics was necessary, it did seem that the strange abundance patterns produced by mixing during the shell flash could be related to the observed values (although the evolutionary timescales seemed far too short to explain some classes of hydrogen-deficient stars).

One of the hydrogen-deficient objects discovered is the central knot in Abell 58. Ford (1971) noted the apparent coincidence in position between this object and Nova Aql 1919 —a highly unusual, very slow nova. Although the nova has long since faded from view it had been given the designation V605 Aquila. However, Seitter (1987) obtained deep spectra of the central knot in Abell 58 and also found superimposed an extremely reddened continuum with V~22. The only features visible in her spectra were [C IV] 5801/11 Å emission, indicative of a strong wind and usually seen in Wolf-Rayet carbon stars. If the 1919 event was a shell flash then this object gives us the first indication of evolutionary timescales —less than 70 years from pre-white dwarf to red supergiant and back to hot central star!

So this is where the Sakurai Object fits in: it is the first observational test of this theory. In the 5 months following its discovery its surface abundance of hydrogen diminished by more than 0.7 dex and its temperature by several hundred degree's Kelvin per month. Furthermore, mixing of the envelope brought *s* process enhanced material to the surface (Asplund et al., 1999). During the first few months of 1997 the stellar temperature had diminished to the point where molecular (swan) bands had appeared and as dust formation started the whole photospheric spectrum became reddened and washed out. Evolution of the light curve resembled that of V605 Aql (as far as we can tell anyway) and eventually as massive amounts of dust were generated the object became heavily obscured in the optical (V~22), while it remains bright in the IR. All measurements taken over the last year suggest the photosphere/dust shell is still cooling. As for the future, we expect the similarity to V605 Aql to continue but with the benefit of modern detectors we will gain real insight to the rate and nature of evolution of the central star as it becomes hotter as well as the development of its wind and its interaction with its environment.

The Sakurai Object is the subject of an ongoing long-term monitoring campaign using the ING telescopes. The next few years promise much as it continues its evolution casting 'light' on many hitherto unobserved areas of evolution.

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TELESCOPES AND INSTRUMENTATION

The One Eye that Sees All: Integral Field Spectroscopy with SAURON on the WHT

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In 1999, a new and unique integral-field spectrograph, SAURON, made its debut at the WHT. SAURON has a large field of view and high throughput, and was developed as a private instrument in a collaborative effort between groups at Observatoire de Lyon, Leiden Observatory, and the University of Durham for the systematic study of the stellar and gaseous kinematics and the line-strength distributions of nearby early-type galaxies.

Galaxy dynamics and integral-field spectroscopy

Many elliptical galaxies and spiral bulges are triaxial and/or display multiple kinematic components. Triaxiality leads to velocity structures that are difficult to map with traditional long-slit spectroscopy. Furthermore, the central few arcseconds are often 'kinematically decoupled': the inner and outer regions appear to rotate around different axes. This makes two-dimensional (integral-field) spectroscopy of stars and gas essential for determining the internal structure of these systems, and for understanding their formation and evolution.

Substantial instrumental effort has gone into high-spatial resolution spectroscopy with slits (e.g., STIS on HST), or in small areas (e.g., the integral-field units (IFUs) TIGER and OASIS on the CFHT), to study galactic nuclei. By contrast, studies of the large-scale kinematics of galaxies still make do with long-slit spectroscopy along at most a few position angles. Therefore, the galaxy dynamics groups at the Observatoire de Lyon, Leiden Observatory, and the University of Durham joined forces to build SAURON (Spectroscopic Areal Unit for Research on Optical Nebulae), an IFU optimized for studies of the kinematics of gas and stars in galaxies, with high throughput, and most importantly, with a large field of view.

SAURON

The optical layout of SAURON is illustrated in Figure 1. A filter selects a fixed wavelength range, after which an enlarger images the sky on the heart of the instrument, the lenslet array (Figure 2). Each lenslet produces a micropupil. After the collimator, the light of each micropupil is dispersed by a grism, and a camera then images the resulting spectra onto a CCD. The CCD is rotated slightly to avoid overlap of adjacent spectra. This design is similar to that of the prototype IFU TIGER, which operated on the CFHT between 1987 and 1996 (Bacon et al., 1995), and of OASIS, a common-user IFU for use with natural guide star adaptive optics at the CFHT. Table 1 summarizes the basic specifications of SAURON.

The SAURON optics are optimized for the wavelength range 4500–7000 Å. Currently only one filter and one grism are available, for the range 4810–5400 Å. This allows simultaneous observation of the OIII and Hβ emission lines to probe the gas kinematics, and a number of absorption features (the Mg b band, various Fe lines and again Hβ) for measurements of the stellar kinematics (mean velocity, velocity dispersion, and the full line-of-sight velocity distribution), and the line

Spatial sampling	0.26″		0.94″
Field of view	9″ × 11″		33″ × 41″
Spectral resolution (FWHM)	2.8 Å		3.6 Å
Instrumental dispersion (σ)	70 km/s		90 km/s
Grism		514 lines/mm	
Spectral sampling	0.9 Å/pix		1.1 Å/pix
Wavelength coverage		4810–5400 Å	
Calibration lamps		Ne, Ar, W	
Detector		EEV12 2148 × 4200	
Pixel size		13.5 μm	
Efficiency (optics/total)		~35% / 14%	

Table 1. SAURON specifications.

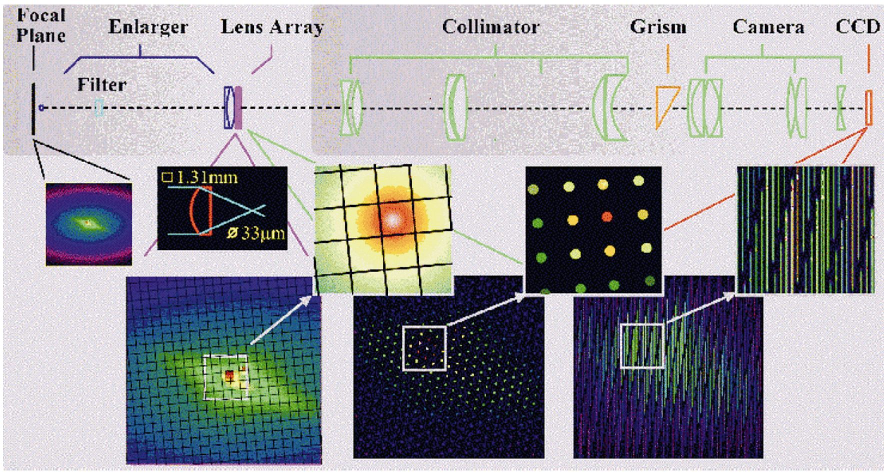
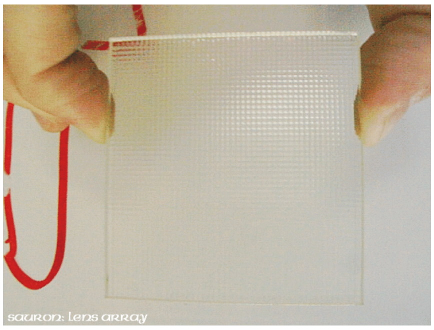
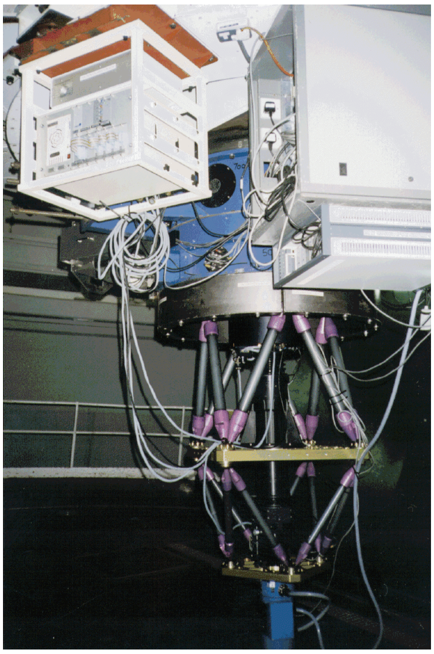


Figure 1 (top). Optical layout of SAURON.

Figure 2 (bottom). The SAURON lenslet array is made of fused silica, and consists of over 1600 square lenslets, each 1.35 mm on the side.

Figure 3 (right). SAURON mounted on the Cassegrain port of the WHT.





strengths (age, metallicity, and abundance ratios).

A new feature of SAURON compared to existing IFUs is the ability to do simultaneous sky subtraction. This is achieved by means of an extra enlarger which observes a patch of sky 1.7 arcmin away from the main field, using about 100 lenslets.

Each of the lenslets normally images 0.94 × 0.94 arcsec on the sky. This undersamples the typical seeing at La Palma, but provides essentially all one can extract from the integrated light of a galaxy over a remarkably large field of view, 33×41 arcsec, observed with a filling factor of 100% (1500 lenslets). SAURON therefore does justice to its name, as its mythical predecessor was also known as 'The one eye that sees all'.

SAURON contains a mechanism for switching to another enlarger, resulting in a 9×11 arcsec field of view, sampled at 0.26 × 0.26 arcsec. This mode can be used in excellent seeing to study galactic nuclei with the highest spatial resolution achievable at La Palma without adaptive optics.

The total throughput of SAURON, including atmosphere, WHT and detector, is 14%.

The mechanical design of SAURON is similar to that of OASIS; it is light and strong, and minimizes flexure. Figure 3 shows the instrument mounted on the Cassegrain port of the WHT. SAURON weighs less than 300 kg, as compared to about 1500 kg for ISIS, which normally occupies this port. In order not to have to rebalance the WHT when SAURON is mounted, four counterweights totalling 580 kg are bolted on with the instrument: these are visible as a steel ring surrounding the top of SAURON. The dewar, made available by the ING, can be seen at the very bottom of the photograph.

The plan to develop SAURON was hatched in the summer of 1995, and the first work started in late spring 1996. The instrument was completed in January 1999. This fast schedule was possible because SAURON is a special-purpose instrument with few modes, and because much use could be made of the expertise developed at Observatoire de Lyon through the building of TIGER and OASIS. While SAURON was constructed as a private instrument, plans are being developed to make it accessible to a wider community.

Commissioning the Eye

SAURON was commissioned on the WHT in early February of 1999, during time shared with the ESA STJ team (see *ING Newsletter*, **1**, 13). In the preceding days, the instrument was checked, together with the software to run it, and the interface to the WHT environment. We paid particular attention to the optical alignment of SAURON and the detector, to be sure that the spectra were aligned accurately with the columns of the CCD.

The instrument performed very well from the moment of first light, on February 1. We modified an internal baffle slightly, to avoid some residual light leak between the main field and the sky part. A small tilt of the filter removed an unwanted ghost image. The slow read-out of the CCD led to some inefficiencies, but this is being fixed by the ING.

Figure 4 presents some calibration data taken during commissioning. Panel a) shows a small part of an exposure with the grism taken out, which produces an image of the micropupils. Panels b) and c) show spectra obtained with the internal

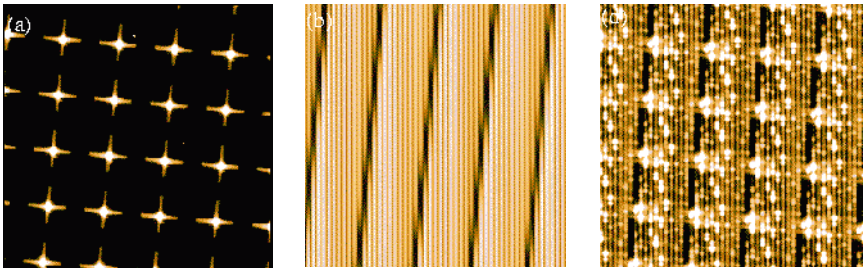


Figure 4. Examples of various SAURON calibration measurements, taken during commissioning. Each panel shows only a small part of the entire CCD frame so that details can be seen. a) Micropupil image taken with the grism out. Each dot is the diffraction pattern from one square lenslet. b) Continuum image using the tungsten lamp. c) Neon arc.

tungsten and neon lamps, respectively. The former shows the nicely aligned continuum spectra, while the latter shows the emission lines used for wavelength calibration.

Data Analysis

Each SAURON exposure produces a CCD frame containing about 1600 individual spectra. These are extracted by means of an optimal algorithm based on a full optical model of the instrument. The resulting data cube is reduced in the standard manner, archived, and analysed by means of a set of programs modelled on the XOASIS package.

We have developed a special pipeline, fittingly called Palantir, to analyse the SAURON data cubes in a very systematic manner. The first module of Palantir removes the instrumental signature, the cosmic rays, and also does the wavelength and flux calibration and the sky subtraction. The second module allows merging of individual exposures and mosaicing of different pointings for the same object. Measurement of the kinematic quantities and the line strengths is then done with dedicated algorithms. The reduced data is archived at Leiden Observatory, and will be made public in due course.

First Results

Figure 5 shows results from the first SAURON observing run (February 14–20, 1999). Reconstructed total intensity, stellar Mg b line strength, mean velocity and velocity dispersion, and emission-line gas intensity and velocity maps are presented for the E6 galaxy NGC 3377. The stars show a striking rotating disk pattern with a spin axis misaligned ~10º from the photometric minor axis. The Mg b isophotes seem to follow the continuum light. A comparison with the Hβ isophotes will reveal whether this galaxy contains a younger stellar disk. The gas also reveals non-axisymmetric structures and motions. These results are based on a total of only four 30 min exposures (no spatial binning was applied). The large angular extent of the maps should be noted.

During our run in October 1999, we observed the E3 galaxy M32 to test the high-resolution mode. Figure 6 shows the integrated intensity and the mean velocity field of the central region of M32, derived from a single 45 min exposure with good seeing. The velocity field is very regular, is consistent with axisymmetry, and has a peak amplitude of about 50 km/s. Individual velocity measurements are accurate to a few km/s. The velocity dispersion in M32 is significantly smaller than the SAURON instrumental dispersion, except in the inner few arcseconds (e.g., van der Marel et al., 1998), and we do not show this here.

Figures 5 and 6 also illustrate a key advantage of integral-field spectroscopy over traditional aperture and long-slit spectroscopy: by integrating the flux in each spectrum, the surface brightness distribution of the galaxy is recovered. As this is derived from the same spectra that are used to obtain the kinematics and line strengths, there is never any doubt about the relative location of these measurements and the galaxy morphology.

The SAURON project: structure of E/S0/Sa Galaxies

We built SAURON to measure the intrinsic shapes and internal velocity and metallicity distributions of early-type galaxies, and to gain insight into the relation between the stellar and gaseous kinematics and the stellar populations in spheroids. Our strategy is to study a representative sample of nearby ellipticals, lenticulars, and early-type spiral bulges. The SAURON data are combined with high spatial resolution spectra of the nuclei, and interpreted through state-of-the-art dynamical and stellar population modelling.

Our sample was constructed as follows. We first compiled a complete list of accessible E/S0 galaxies and Sa bulges for which SAURON can measure the stellar kinematics: $-6° \le \delta \le 64°$ (zenith distance), $cz < 3000$ km s^{-1} (spectral coverage), $\sigma > 90$ km s^{-1} (spectral resolution). The objects span a factor 50 in luminosity ($M_B < -18$) and cover the full range of environment, nuclear cusp slope, rotational support, and apparent flattening. The galaxies were then divided into six categories (E/S0/Sa; field/cluster) and a representative sample of 72 objects was selected to populate the ellipticity versus absolute magnitude planes homogeneously (Figure 7). Based on our two observing runs in 1999, we hope to complete the observations of the entire sample by early 2002.

The detailed measurements will be compared with fully general galaxy models constructed by means of Schwarzschild's numerical orbit superposition technique (e.g., Cretton et al., 1999). The dynamical modelling uses all appropriate imaging and spectral data that are available, including HST and OASIS

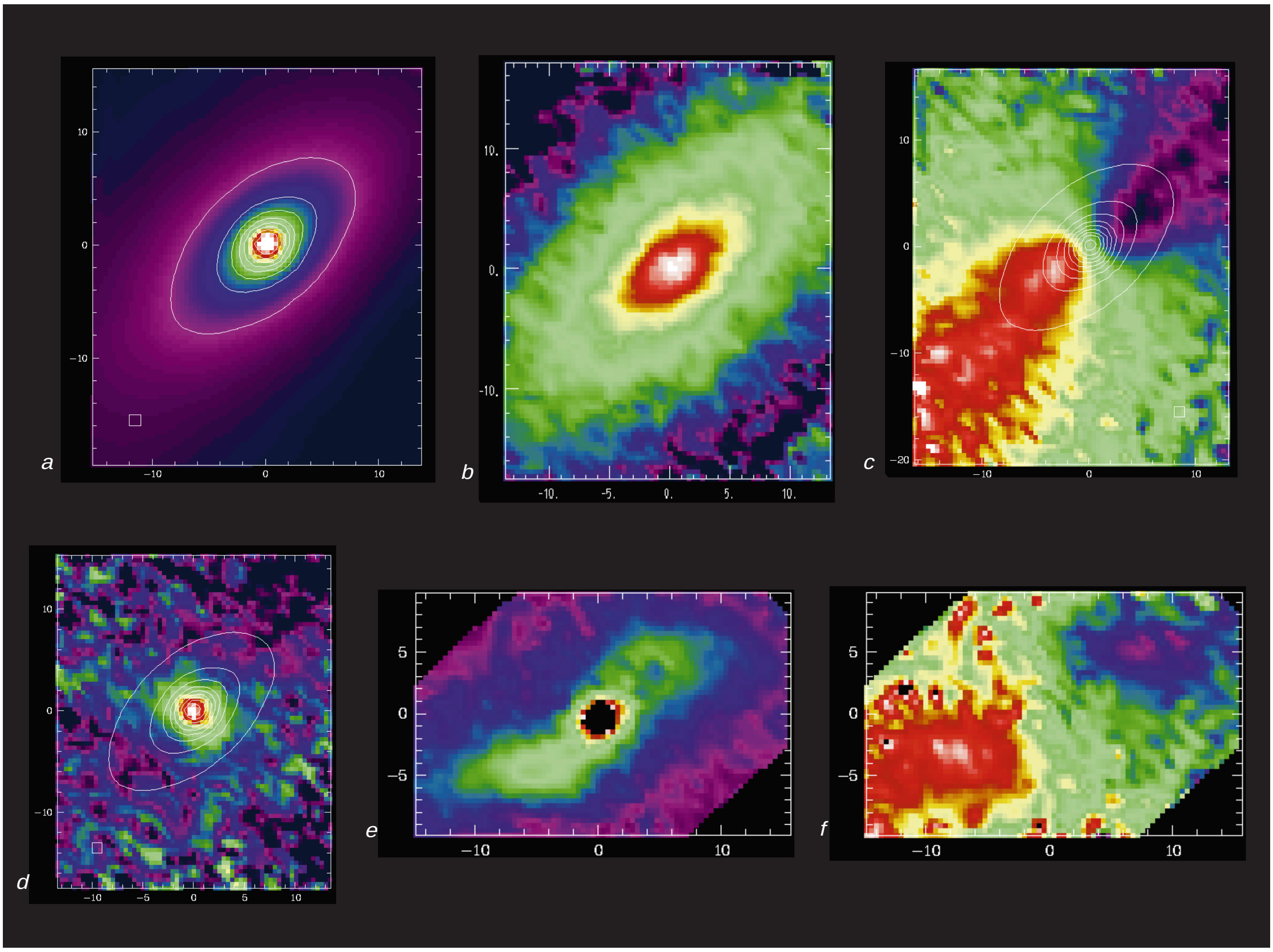


Figure 5. SAURON measurements of the E6 galaxy NGC 3377. Each pixel is 0.94″×0.94″ and the FOV shown is 30″×39″. a) Reconstructed total intensity. b) Stellar Mg b index. c) Stellar mean velocity. d) Stellar velocity dispersion. e) Gas total intensity ([OIII] λ5007). f) Gas mean velocity.

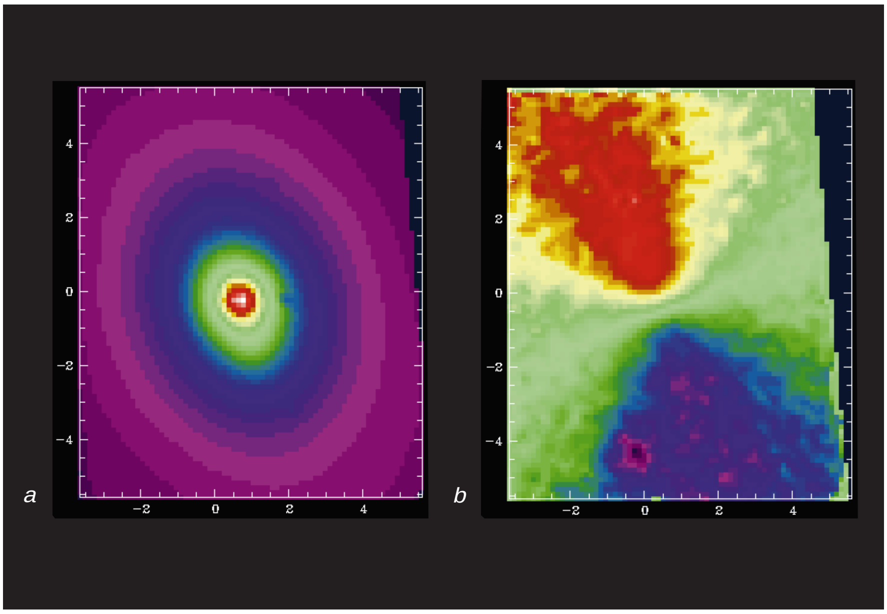


Figure 6. SAURON measurements of M32. a) Reconstructed total intensity. b) Stellar mean velocity. The FOV is 9″×11″, and the spatial sampling is 0.26″×0.26″.

spectra to constrain the mass of a central black hole. When combined with the constraints on the stellar populations derived from the line-strength distributions (Kuntschner & Davies, 1998), this will shed new light on the fundamental connections between the large and small scale dynamics, the formation (and existence) of supermassive black holes and galactic nuclei, and the history of metal enrichment in early-type galaxies.

It is a pleasure to thank René Rutten, the ING staff, in particular Tom Gregory, and Didier Boudon and Rene Godon for enthusiastic and competent support on La Palma. The SAURON project is made possible through financial contributions from NWO, the Institut National des Sciences de l'Univers, the Université Claude Bernard Lyon I, the universities of Durham and Leiden, and PPARC.

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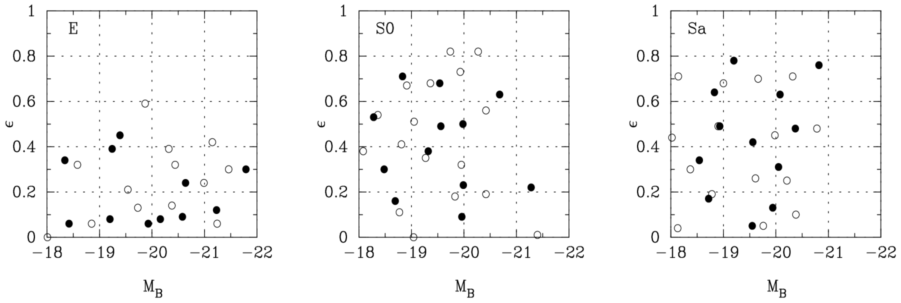

Figure 7. Distribution of E, S0, and Sa galaxies in the SAURON sample in the plane of ellipticity ε versus absolute blue magnitude M_B. Open circles: field galaxies. Solid circles: cluster galaxies.

First Sodium Laser Beacon at La Palma

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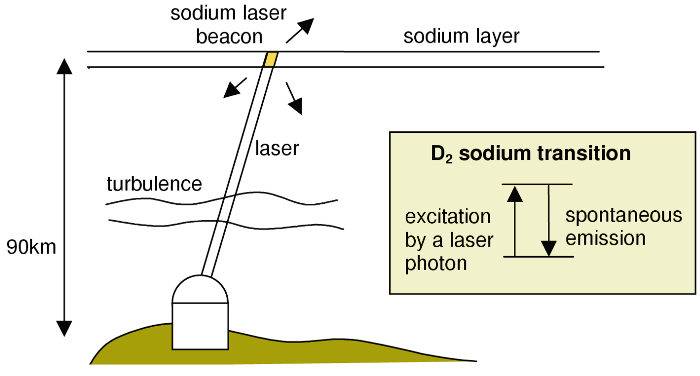
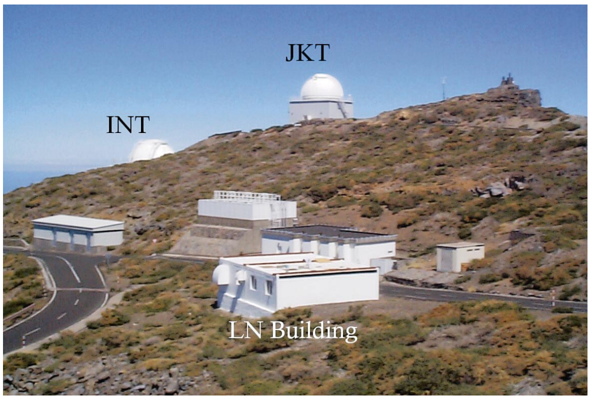
In the ING Newsletter No. 1, an ongoing project to implement an adaptive optics system on the WHT was described. Called NAOMI (Nasmyth Adaptive Optics for Multiple Instrumentation), this system will be capable of eliminating, to a large degree, the image degrading effects of atmospheric turbulence.

As with any adaptive optics system, NAOMI will rely on measuring light from a relatively bright reference object, or "guide star", close to the desired target in order to make the necessary correction. At visible wavelengths, however, it is often not possible to find a sufficiently bright star in the neighbourhood of the astronomical region of interest. One would like to be able to simply dial-up a guide star exactly where it is needed, and this is possible with the use of a "sodium laser beacon".

At an altitude of 90 km, well above the troublesome turbulence (which rarely reaches beyond 25 km altitude), is a 15 km thick layer of sodium atoms which, just as in a sodium lamp, can be excited to spontaneously emit light. To achieve this from the ground we can use a laser tuned to an absorption wavelength (589.0 nm) of the sodium atoms. The excited region of atoms creates a bright spot in the sky, the sodium laser beacon, which can be used as the guide star for an adaptive optics system (Figure 1).

A Laser Guide Star (LGS) system is being planned for the WHT to compliment the NAOMI system. In preparation, the Applied Optics group at Imperial College London has been investigating some practical aspects of creating and using sodium beacons for adaptive optics. Amongst these is a study of the sodium layer dynamics at La Palma using observations of an experimental sodium laser beacon. We have built a laser system which launches a 25 cm diameter, diffraction limited beam from the liquid nitrogen building located roughly midway between the JKT and the WHT (Figure 2). Part of the laser beam is directed through a small sodium oven and by measuring the absorption we can lock the (tuneable) laser output to precisely the correct wavelength





Figures 1 and 2. Left: A laser, tuned exactly to the D2 transition of sodium, can be used to excite the sodium layer at 90 km altitude. The beacon thus created can be used as the guide star for an adaptive optics system. Right: The Liquid Nitrogen (LN) building which houses the laser. The beam is launched through a hole in the roof.

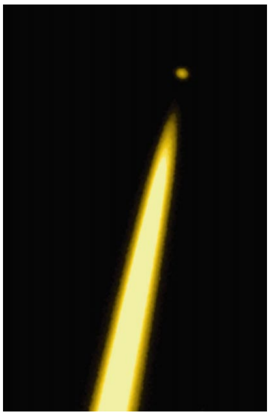


Figure 3. A pseudocolour image of the laser scattering taken with a small telescope 3 m away from the laser launch. The small spot at the top is the sodium laser beacon.

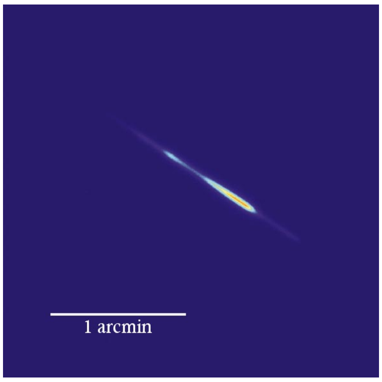


Figure 4. A pseudocolour image of the resonant backscatter from the sodium layer as viewed from the JKT at midnight 22 September 1999.

for resonant excitation of the sodium layer. The light scattered from our laser beam is shown in Figure 3, an image taken in September 1999 from a 20 cm Meade telescope 3 m away from the launch. Above the long streak of Rayleigh backscatter the sodium beacon is clearly visible. With only the slightest detuning of the laser wavelength the sodium spot disappears.

Observing the sodium beacon from the JKT, some 160 m away, gives a different perspective. Figure 4 shows the long streak through the sodium layer created by the laser, with brighter emissions from those parts of the layer more abundant with sodium. Analysing the profile of these images allows us to measure fluctuations in the sodium density profile above La Palma, on both minute-to-minute and season-to-season time scales. In September 1999 we recorded some very interesting profiles. Figure 5 depicts one night's data (22 September) and shows large, slow variations in the shape and total area of the sodium profile, as well as a sporadic event of high sodium concentration, lasting about 15 minutes, in the upper part of the layer. While it is not certain what drives the dynamics of the sodium layer, these variations must be taken into account when designing a laser guide star adaptive optics system.

The results shown here represent only part of our sodium monitoring campaign, which will also encompass observations in January, April, and June 2000 in order to measure seasonal variations in the layer. Along with our other related studies, this work paves the way for the construction of a laser guide star system for the WHT. Our present laser (an argon ion pumped ring dye laser) will not be used for this purpose as its 400 mW output power cannot produce a bright enough beacon for an adaptive optics system. With a more powerful laser system working in conjunction with the NAOMI adaptive optics system, the WHT will be placed in a highly competitive position against the larger 8 m class telescopes whose larger diameter makes the use of laser guide stars less effective.

Further information about this and other related research can be found at *http://op.ph.ic.ac.uk/*. ¤

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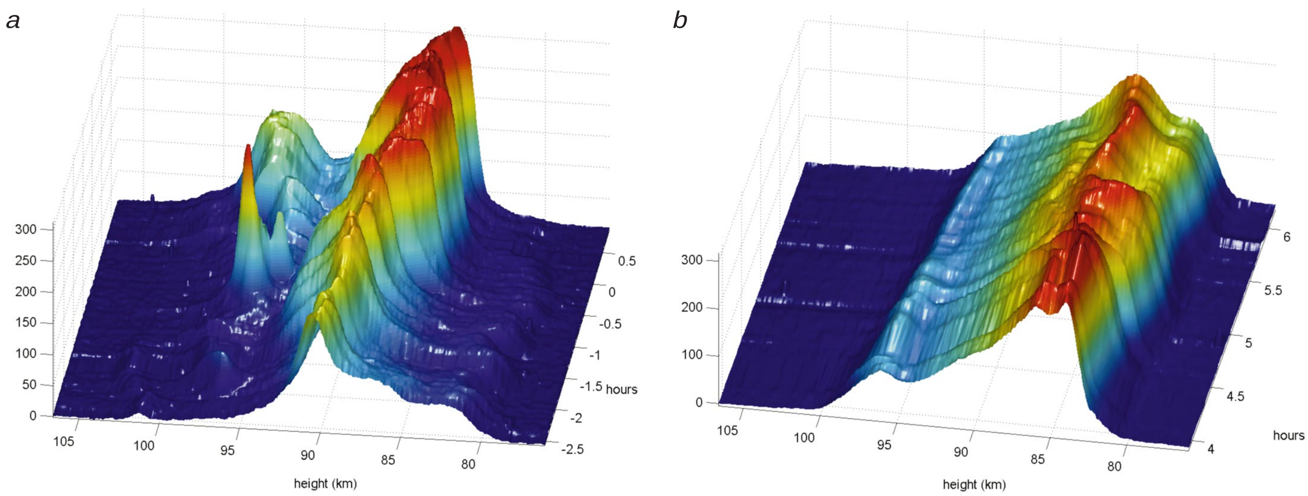


Figure 5. Relative sodium density measured on 22 September 1999. (a) and (b) are early and late parts of the night, respectively. Time is indicated in hours from midnight.

M33 Galaxy

This image of Messier 33 was obtained with the mosaic CCDs of the Wide Field Camera at the INT telescope. The authors are L. Magrini and M. Perinotto (University of Florence, Italy), R. Corradi (ING), and A. Mampaso (IAC). The image is a composition of frames taken in three narrow bands: the green colour represents the galaxian emission in a filter centred on the [OIII] nebular line at 500.7 nm, red is the Hα hydrogen emission at 656.3 nm, while blue is mainly stellar light taken through a continuum filter centred at 555.0 nm (Stromgren Y). In only one observing night, and with two positionings of the telescope, it was possible to cover the whole galaxy which has a size of approximately one degree in the sky.

The main scientific goal of these observations was to search for planetary nebulae in this nearby galaxy. They are recognised as emission-line objects with generally intense [OIII] and Hα lines, negligible continuum emission, and a point-like appearance (1 arcsec corresponds to about 4 pc at the distance of M33). 134 newly discovered planetary nebulae were selected, but these observations also contain a large amount of information about other ionised nebulae, such as HII regions, supernova remnants, Be stars, symbiotic binaries, Wolf-Rayet stars, LBVs, etc. Their excitation status can be estimated by using the ratio between the [OIII] and Hα emission. Results concerning the search for planetary nebulae are in press on the *Astronomy and Astrophysics Journal* (Magrini et al., 2000).

Romano Corradi (rcorradi@ing.iac.es)

The Half Arcsecond Programme (I)

C. Packham[1], R. W. Wilson[2], M. Azzaro[1], N. O'Mahony[1], S. Fine[1], D. Gray[1], V. Reyes[1], C. Martín[1]

[1]: Isaac Newton Group
[2]: ATC, Astrophysics Group, Cavendish Laboratory (soon to join the astronomical instrumentation group at Durham)

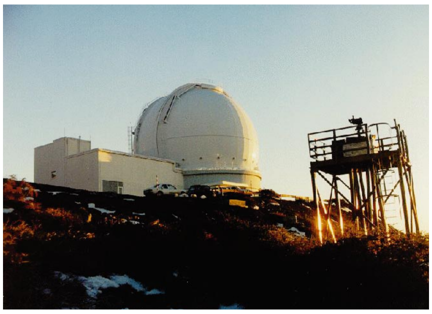


Figure 1. The ING DIMM tower near the WHT.

Over the last three years, the Half Arcsecond Program (HAP) has found some important and surprising results. These results, recently published in the MNRAS (Wilson et al., 1999, **309**, 379), are summarised on the HAP WWW site (*http://www.ing.iac.es/hap/haphomepage.htm)* and a short summary of the key conclusions follows.

The HAP was started by the ING in 1993 in order to optimise the image quality of the WHT, especially in preparation for NAOMI, the natural guide star adaptive optics system due to be commissioned in mid-2000 (see ING Newsletter No. 1). The goal of the HAP is to eliminate non-atmospheric degradations of the WHT's image quality, so that the measured image width for the WHT will be as close as possible to the intrinsic (site) seeing value.

Two main sources of image degradation can be distinguished in addition to the atmospheric seeing: (1) imperfections of the telescope itself, including tracking and focus errors and other optical aberrations, and (2) turbulence effects such as convection at the primary mirror and mixing of air at different temperatures in the light path, collectively referred to as dome seeing or artificial seeing.

An Early Result

One of the first problems identified by the HAP was the presence of two plumes of turbulent warm air flowing into the optical light path above the primary mirror. These were clearly visible in defocused (pupil) images from the WHT. The plumes emanated from the supporting fork structure of the primary mirror, heated by oil warmed during its lubricating passage around the WHT structure. It was clear that the WHT image quality suffered from this turbulence and that an engineering solution was required to reduce the temperature differential between the fork structure and dome air. Hence in September 1996 an oil cooling plant was installed to reduce and track the temperature of the telescope bearing oil to within a fraction of a degree of the dome air temperature. Subsequent pupil images showed the turbulent air plumes were eliminated, and also that heating of the air in the dome was significantly reduced during both night and day.

A Targeted but Sensitive Approach

Having removed the obvious contribution to dome seeing, more sophisticated and quantitative seeing measurement techniques were required to search for more subtle effects. In order to reduce the seeing of the WHT to that of the site, it was first necessary to accurately determine the site seeing. In October 1994 a Differential Image Motion Monitor (DIMM) was installed on a tower near the WHT (see Figure 1). A DIMM measures the seeing via the differential motion of stellar images and hence is unaffected by wind shake, poor tracking, focus, etc. and therefore gives an unbiased estimate of the atmospheric seeing. In fact the DIMM measures the Fried parameter (r_0) or spatial coherence length of starlight. For the standard (Kolmogorov) theory of atmospheric turbulence this is related to the seeing FWHM for a large telescope (in the absence of other aberrations) by:

$$FWHM = 0.98\, l \,/\, r_0 \qquad (1)$$

where *l* is the wavelength of observation. Hence the accuracy of the DIMM seeing estimates depends on the validity of the standard seeing model at the site.

The DIMM has been used by ING to provide an extensive set of seeing data for the WHT site. The results of the monitoring campaign between October 1994 to August 1998 are displayed in Figure 2, which shows median site seeing at the WHT to be 0.69 arcseconds, in good agreement with other surveys carried out at other sites on the Roque by collaborators at the IAC.

Initial attempts to measure the seeing obtained inside the WHT made use of the Cassegrain autoguider, but several subtle effects blunted the effectiveness of this approach. However, a set of observations based around the JOSE (Joint Observatories Seeing Evaluation) wavefront sensor, installed in preparation for NAOMI, was in progress at the WHT between 1995–1998. JOSE is a Shack-Hartmann sensor equipped with a fast readout CCD. The pupil of the WHT is re-imaged onto a lenslet array, so that sections of the aperture ~50cm in diameter are imaged separately onto the detector. The CCD camera records images of the spot pattern continuously at frame rates of typically 100Hz for a

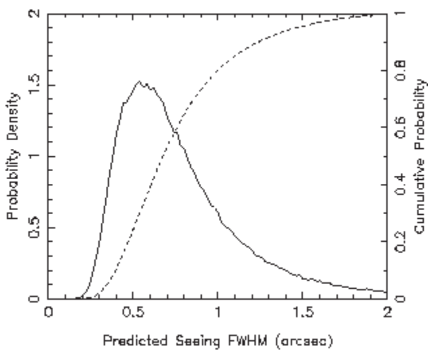


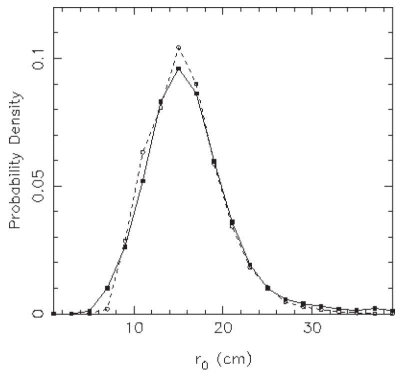
Figure 2. DIMM seeing measurements.

few tens of seconds, so that the temporal development of the wavefront distortion can be analysed. Centroids are measured relative to the mean spot location for each data sequence, so that static perturbations are ignored. The measurements are therefore unaffected by fixed (or very slowly varying) optical aberrations such as telescope defocus, but are sensitive to changing distortions due to atmospheric and dome turbulence. As for the DIMM, JOSE gives a measure of r_0, which can be translated to the seeing FWHM via equation 1. Correlating the JOSE (internal) and DIMM (external) seeing measurements provides a powerful diagnostic of WHT dome seeing.

JOSE/DIMM Correlation

By collating JOSE and DIMM observations to form an integrated data set, it is possible to compare statistics of the seeing inside the WHT to the site seeing. In Figure 3 measured values of r_0 from DIMM observations (4500 measurements[a] on 18 nights) and contemporaneous JOSE observations (2998 measurements) are plotted. Clearly there is no significant offset in the distribution of r_0 between JOSE and DIMM.

The JOSE wavefront sensor data allows the validity of the standard turbulence model for the WHT site to be examined. Figure 5 shows the mean (relative) distribution of rms Zernike mode strengths for the seeing-induced wavefront aberrations at the WHT focus. The data are plotted against their theoretical values for the Kolmogorov turbulence model (Noll, R. J., 1976, *J Opt Soc Am*, **66**, 207). Clearly the measured distribution is close to theoretical expectation, so that the DIMM and JOSE seeing FWHM predictions are valid. In fact the data show evidence for an outer scale of turbulence (i.e. upper limit to the scale of the seeing aberrations) with a mean value of approximately 15 m. As a result the DIMM and JOSE predictions may



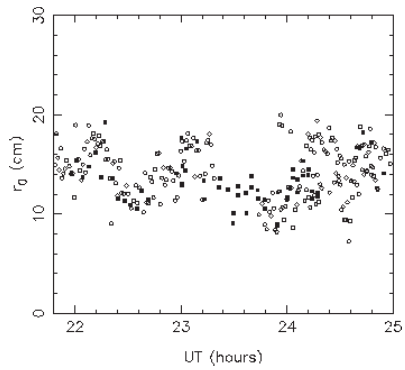


Figure 3 (left). Normalised probability distributions for contemporaneous JOSE (solid line) and DIMM (broken line) r_0 measurements determined from measurements on 18 nights between 1995 May and 1998 August.
Figure 4 (right). Example of contemporaneous JOSE (filled squares) and DIMM (open circles) r_0 measurements.

somewhat over-estimate the WHT seeing at long wavelengths (R-band and longer), since equation 1 assumes an infinite outer scale.

Seeing arising from excess mirror or dome temperature is likely to be described poorly by the Kolmogorov model (Bridgeland, M. T., Jenkins, C. R., 1997, *MNRAS*, **287**, 87), with excess power in aberrations on small spatial scales (high order Zernike modes). Hence this analysis also suggests that there is no strong dome seeing contribution at the WHT. A similar analysis of JOSE data before oil cooling was implemented showed excess power on small scales, consistent with artificial seeing from the turbulent air plumes.

Conclusions

It is important to consider why the WHT does not appear to suffer from artificial seeing. It is generally accepted that excess temperature of the mirror, dome or support gives rise

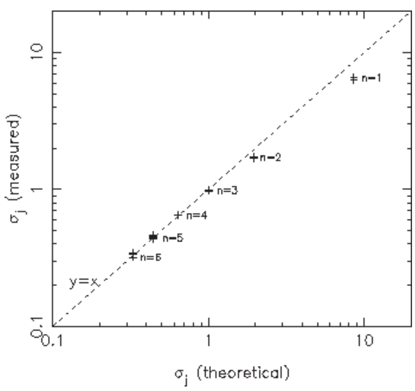


Figure 5: Zernike Modelling of JOSE Data.

to artificial seeing. Figures 6 and 7 show the summation of several years data obtained during observing nights for the dome minus external air temperature and mirror minus dome temperature respectively. Figure 6 shows that large dome temperature excesses are very rare. Calibration of the temperature sensors has shown a drift in the external thermometer by ~1.5 K over the several years of operation and hence in reality the 1 K offset suggested by Figure 6 is even smaller. Large primary mirror temperature offsets are more frequent, but the differential is >2 K for only ~25% of observing time. We speculate that such a large offset occurs only during rapid weather changes where the large thermal inertia of the (thick) primary mirror retains excess thermal energy for one or two nights, but that the atmospheric seeing will in that case be sub-optimal due to rapidly changing weather conditions. It also seems that under normal circumstances, the considerable thermal inertia and good insulation of both the primary mirror and dome air mass prevent the mirror from absorbing significant heat from the air during the daytime, leaving it close to the air temperature of the previous night.

The fact that no significant artificial seeing in the WHT has been detected after cooling the WHT's oil is certainly against common perception of the WHT seeing. In part this is due to reliance on the WHT's autoguider for seeing information. The autoguider

(a) We wish to thank the IAC seeing group for providing some DIMM measurements useful for our analysis.

has an independent focus, optical aberrations and several other 'features', and so gives only an approximate (and certainly pessimistic) estimate of the true WHT seeing.

In the absence of dome seeing, the remaining tasks for the HAP at the WHT are to optimise the tracking and focus of the telescope. The power spectrum of image motion measured by the JOSE sensor reveals a spike due to the known oscillation of the WHT support structure at 2.7Hz. Whilst this resonance contributes little power on average, the oscillation can have a significant effect on image width if it is strongly excited, for example by wind buffeting of the telescope structure. In future it may be possible to monitor the telescope drive encoders automatically, and to alert the observer to excess tracking errors at high frequencies. A significant contribution to the image FWHM at the WHT (as for all telescopes) may result from imperfect focus. Current methods for estimation of the optimum focus are limited by the inherent variability of the site seeing. Improved methods to focus and to track the focus of the WHT are under investigation.

In the next issue of the ING newsletter we will discuss the HAP at the INT and the future of the HAP.

HAP Publications:

1. Wilson, R. W., O'Mahony, N., Packham, C., Azzaro, M., 1999, "The seeing at the William Herschel Telescope", *MNRAS*, **309**, 379.

2. Packham, C., O'Mahony, N., Wilson, R. W., 1998, "Recent developments in the Half Arcsecond Programme", *New AR*, **42**, 431.

3. Azzaro, M., Breare, M., 1998, "Some meteorological parameters affecting the image quality of the WHT on La Palma", *New AR*, **42**, 471.

4. O'Mahony, N., Packham, C., Wilson, R. W., Rutten, R., 1997, "Characterisation and Optimisation of Seeing at ING Telescopes", 23rd IAU General Assembly, Kyoto. ¤

Chris Packham (cp@ing.iac.es)

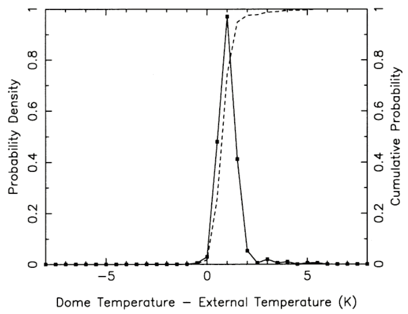


Figure 6. Dome-External Air Temperature Difference.

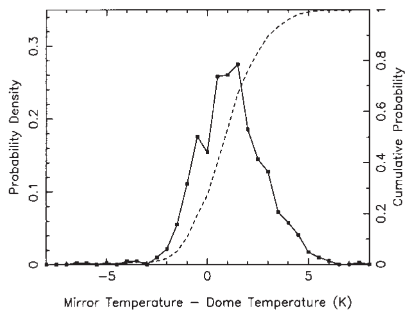


Figure 7. Mirror-External Air Temperature.

WHT Millenium Upgrade

Gordon Talbot (Head of Engineering, ING)

The Isaac Newton Group have embarked on a comprehensive upgrade of the William Herschel Telescope (WHT), involving replacing and enhancing many systems. The programme embraces a number of projects, and all ING engineering groups are contributing. The upgrade directly supports the NAOMI adaptive optics system and INGRID IR imager but also brings performance and reliability improvements to the WHT in support of other instruments. Previous, recent improvements include an Alpha computer based Telescope Control System (TCS), the introduction of 4k×2k EEV–42 detectors and improved dome seeing through oil cooling.

The programme includes:

– New Observatory Control System to replace the existing Instrument Control System for improved performance, ease of maintenance and development, further increased commonality between subsystems and reduced maintenance costs. Initially the system will support ING's new data acquisition system, ULTRADAS, for faster CCD readout, and the implementation of the 4k×4k two chip EEV–42 mosaic for use at prime focus and on UES. Instrument control will then be implemented sub-system by sub-system using DRAMA and EPICS (channel access) with appropriate mimic displays until all focal stations and instruments are converted. This project will build on basic control to provide more complex modes of observing —such as automatic guide star acquisition. Finally it will provide an efficient queue-observing tool to automate service observing.

– New autoguider. This will be a DRAMA based system similar to the INT system, replacing the existing FORTH based system that runs on unreliable, obsolete and irreplaceable hardware.

– New acquisition TV system will replace the existing, obsolete system with a modern supportable system that offers improved performance. Initially implemented as a stand-alone system the ultimate aim is to integrate with other telescope systems.

– Faster CCD readout through the ULTRADAS system. This embraces the production of a new data acquisition system (DAS), and its implementation for all science detectors at ING using the San Diego State University SDSU-2 CCD controller. Principle gains from the project are faster readout speed, and improved reliability —from both the DAS system and CCD controller— together with reduced maintenance requirements. The system will ultimately use a

PCI interface between the CCD controller and DAS computer, however due to delivery delays it is initially being implemented using an S-BUS card. With the S-BUS interface the system produces typically a threefold decrease in un-windowed readout cycle time over previous ING systems, with the PCI interface this will improve to sixfold, potentially offering an overall 5% increase in telescope observing time. The project is currently being expanded to include infra-red detectors, first in support of INGRID, and eventually the LIRIS spectrograph being developed by the IAC. ULTRADAS has been commissioned on the INT Wide Field Camera and WHT Prime Focus 4k×4k 2 chip mosaic.

– A new UNIX based Guide Star Server will be implemented. This work has been placed at the UKATC (to begin in FY 2000/2001) and it is expected it will be based on the porting of an existing system.

– The above improvements will remove several obsolete, failing and unsupportable systems, including the Network Interface Units (NIUs) and Data Management System (DMS) both dependent on bespoke hardware and software and both the causes of much lost time while requiring a large support effort.

– Improvements to GHRIL (Ground based High Resolution Imaging Laboratory) for NAOMI which include:

  – Reducing telescope vibration by tuning and modifying the oil damping system with extra dampers near to the bearing surfaces.

  – A new cooling system with glycol lines routed through the telescope to an external heat exchanger. This system was installed and operated for the last ELECTRA adaptive optics run. Extension is planned to the UES cooler — thus removing a further source of vibration in the telescope structure and heat within the dome.

  – A new optical bench for NAOMI. The previous two ELECTRA runs identified that the original, although adequate for other instruments was insufficiently damped for NAOMI and so will be replaced.

  – Improved access for instruments, including NAOMI through a roof hatch.

  – Improvements to GHRIL seeing by re-coating and adding CaF_2 windows to the infrared de-rotator. The windows will prevent airflow through the unit, eliminating turbulence in the light path and stopping the deposition of dust on the reflecting surfaces. Additionally, once the sealed unit is fitted, airflow within the optical bench room will be studied in an effort to understand and improve local seeing.

  – Improvement in telescope tracking/positioning ready for NAOMI, by the elimination of glitches seen by ELECTRA

After only 11 years of operation the WHT is still a young telescope. These measures ready it for common user adaptive optics, will offer better performance for observers together with improved reliability/reduced maintenance operation. In short they take it into the new millennium, and as they are being implemented over the next two years, fit in with either 2000 or 2001 as defining the start of the next millennium. ¤

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New Instrumentation for the WHT

René Rutten (Director ING)

In order for the William Herschel Telescope to keep offering the best possible instrumentation in the future, it is important that new ideas and instruments are developed. For that reason, in June 1999 an announcement was sent out inviting novel ideas for new instrumentation for the WHT to be brought forward. The following four proposals for new instruments were received:

– Bacon (Lyon): *OASIS — an Adaptive Optics (AO) optimised integral field spectrograph.*

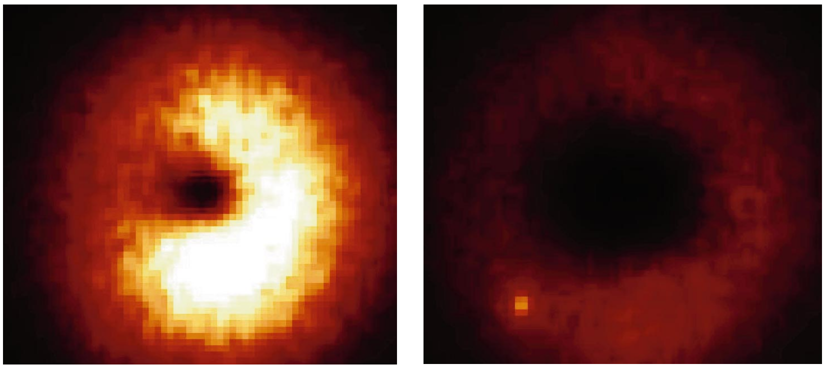

Figure 1. Simulated H-band coronagraphic PSFs with a secondary star 1.0 arcsec away from the central object (Δm= 7m) without (left) and with adaptive optics correction (right). The diameter of the focal plane stop was 1.0 arcsec and the uncorrected seeing was ~0.7 arcsec.

– Doel (UCL, London): *Coronagraph for the NAOMI AO system.*

– Sharples (Durham): *MOSAIC – Multi-Object Spectrograph with Adaptive Optics Image Correction.*

– Vick (ATC, Edinburgh): *High-resolution spectral imaging facility for the NAOMI AO system.*

Each of these proposals was of high quality, which made it difficult to set priorities. It is noteworthy that all four proposals focus on adaptive optics, which is conceived as a key development area for the WHT.

Following a review by the Instrumentation Working Group (IWG) the ING Board discussed the various submissions and recommendations in December 1999, and I will present here what the outcome was.

The ING Board considered that the proposal by Doel et al. to build a coronagraphic unit to work with NAOMI should be supported on the shortest possible time scale. Examples of science areas where the coronagraph would be particularly useful are the study of brown dwarfs and substellar companions, proto-planetary disks around young stellar objects, QSO host galaxies, and mass outflow from objects such as symbiotic stars and luminous blue variables.

This development has a clear set of science applications and can be delivered at a modest cost. This instrument would be able to exploit the capability of NAOMI with natural guide stars, as it will be used in the investigation of faint sources around bright objects. It would help increase the early scientific impact of NAOMI.

The proposal by Bacon et al. to deploy an existing instrument, OASIS (currently available on the CFHT) on the WHT with NAOMI was considered extremely attractive. OASIS is a state-of-the-art and unique integral field spectrograph using a lenslet array. Its design allows very fine spatial sampling to take full advantage of an Adaptive Optics system. The instrument is fully developed and operational, but would have to be adapted to work with NAOMI. An assessment is being undertaken to see whether both systems can be made compatible.

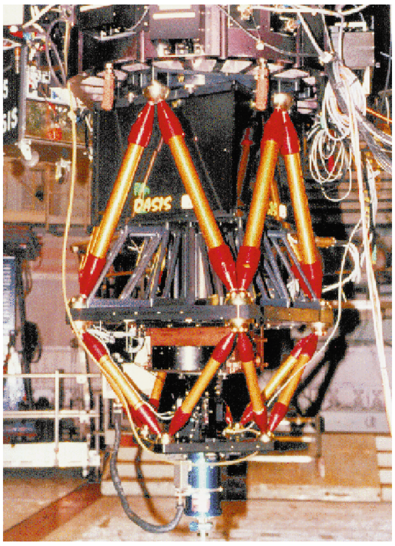

Figure 2. OASIS on the CFHT.

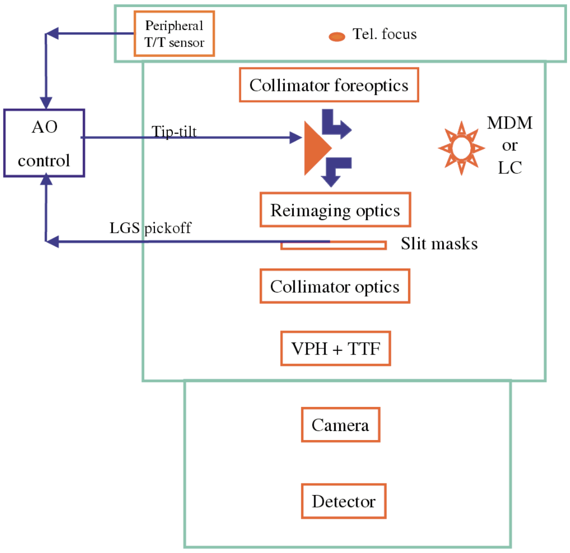

Figure 3. MOSAIC layout.

OASIS is a versatile spectrograph allowing a wide range of science projects to be carried out, and therefore it is anticipated that the interest in its exploitation will be large.

The MOSAIC proposal by Sharples is for an AO-corrected multi-object spectrograph and imager for the WHT Nasmyth focus. This system is distinct from the NAOMI AO system and would have its own (restricted conjugate) AO system, which aims to achieve not so much the best possible image quality over a small field, but instead aims for significant improvements in image quality over a wide field. The AO feature in combination with a multi-object spectrograph would present important gains over existing facilities, and be unique.

MOSAIC would have an important impact on the WHT. It would be mounted at the Nasmyth focus where currently UES is mounted. (UES would have to be positioning elsewhere and fed by a fibre from MOSAIC). The AO correction would also involve installing a Rayleigh laser system to generate the artificial guide star.

Clearly this instrument would have great potential and potentially keep the WHT competitive next to the 8-m class telescopes. MOSAIC, with its laser system and own AO hardware is a comparatively complex instrument that would require a major investment. Technical and performance aspects, as well as its impact on telescopes operation will need to be studied further.

LDSS and TAURUS on the WHT

A second announcement-of-opportunity was issued also in June 1999 asking interested parties to adopt the existing common-user instruments: the Low Dispersion Survey Spectrograph, LDSS, and the Fabry-Perot imaging spectrograph, TAURUS, as private instruments.

The reason to retire these less-used instruments as common-user facilities was driven by a combination of financial and operational pressures. Rather than just decommissioning the instruments they were offered to interested groups in the user community to take on as private instruments. In this way the instruments could be retained for the continued use by the astronomical community, but no longer be a burden on the observatory, which is faced to have to take care of a growing number of instruments under ever tighter financial constraints.

Four proposals were received as a result of this announcement. The proposal by Richard Bower (Durham) to adopt LDSS and by Richard McMahon (Cambridge) to adopt TAURUS were considered the strongest on the basis of their science case and ideas for developing the instruments further. The ING Board decided that these instruments would transfer to Durham and Cambridge respectively as private instruments. Both PIs indicated the possibility that the instrument may be used on other telescopes in the future. Both proposers also indicated interest in collaborating with other groups on future use of the instruments. Therefore from now on anyone interested in using either LDSS or TAURUS should contact Richard Bower or Richard McMahon, respectively. ¤

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The New WHT Mosaic Camera

Simon Tulloch (ING)

Work on this camera started at the RGO in Cambridge shortly before its closure and was continued at the ATC in Edinburgh and subsequently ING. The design incorporates two EEV42-80 CCDs mounted in a standard 2.51 Oxford Instruments cryostat normally used for single chip cameras. This camera therefore has the same mechanical interface to the telescope and could in principle be used at any port where a single chip camera is normally used. In practice it will be dedicated for use at Prime Focus (PF) and at UES on the WHT.

At prime focus this camera will double the field of view of the telescope with no vignetting from either the existing filter wheel or corrector. At UES the benefits will be from the EEVs smaller pixels (0.20″/pixel) and better blue response compared to the existing SITe detector. The EEV mosaic is marginally bigger than the SITe but since the UES output is already heavily vignetted in the outlying areas of the image, this will offer no advantage.

The camera performed well during its first science run at PF at the end of September 1999 and obtained the images that accompany this article. Some problems due to stray light were highlighted during this run and are currently being solved by the addition of extra baffling around the PF filter wheel. Some images obtained close to the celestial equator seemed to suffer some degradation due to a number of horizontal streaks extending across the full width of the images. These were later identified as geostationary satellites! Final commissioning at UES will start in late January 2000.
The CCDs were mounted on an invar baseplate that was ground flat to ±5µm accuracy. Subsequent measurement of the CCD surfaces, using an instrument developed at the RGO, showed that all pixels lay within 20µm of an optimal plane. The slight defocus that this will introduce into the small regions of the image furthest from the optimal plane, does not exceed 0.1 pixels. The physical gap between the CCDs was minimised by the use of PTFE shims. These allowed the devices to be close butted without actually touching. Once the chips were firmly screwed down to the base plate the shims were removed. The gap between adjacent image areas is only 39 pixels: approximately 1% of the total image width.

The camera was designed and built by Simon Tulloch. Dave Gellatly at the RGO was responsible for some initial mechanical design work and the ATC Mechanical Workshop was responsible for the machining.

The camera is now available as a common user instrument at Prime Focus and at UES on the WHT. ¤

Simon Tulloch (smt@ing.iac.es)

PF Performance Summary

Pixel scale: 0.24″/pixel
Field of view: 16.4′ × 16.4′
Pixel size: 13.5µm square
Image size: 4096 × 4100 pixels
Readout time: 54 s
Readout noise: 6 e^- rms
Gain: 2.2 e^-/adu for chip #1
2.0 e^-/adu for chip #2
Quantum efficiency:

	380 nm	400 nm	650 nm	950 nm
CCD1	62%	78%	75%	14%
CCD2	67%	81%	76%	13%

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(All the images on this page are credit to Simon Tulloch and Nik Szymanek)

Figure 1. BVR image of M33 Galaxy using the new 2-detector WHT prime focus camera. Exposure time was 10s.

Figure 2. 10s exposure of the Horse Head nebula with the new prime focus camera on the WHT.

Figure 3. Again as before but now combining B, V, and R images. Only one detector is shown.

Figure 4. The star-formation region M42, also known as the Orion nebula. Shown here is a 10s exposure true-colour image on the new WHT prime focus camera. The gas and dust in the nebula emits light because it is irradiated by nearby emerging stars.

Figure 5. The new WHT prime focus camera contains two EEV-42-80 thinned CCDs butted along their long axes to provide a 4K x 4K pixel mosaic. Each pixel is 13.5 μm square. A single detector comprises 2148 x 4128 pixels in total including 50 x-underscan, 50 x-overscan and 28 y-overscan pixels. The active area of the mosaic measures 55.8 x 55.35 mm, with a 0.53 mm gap between the chips. Both chips have two working amplifiers giving 3–4 electrons noise.

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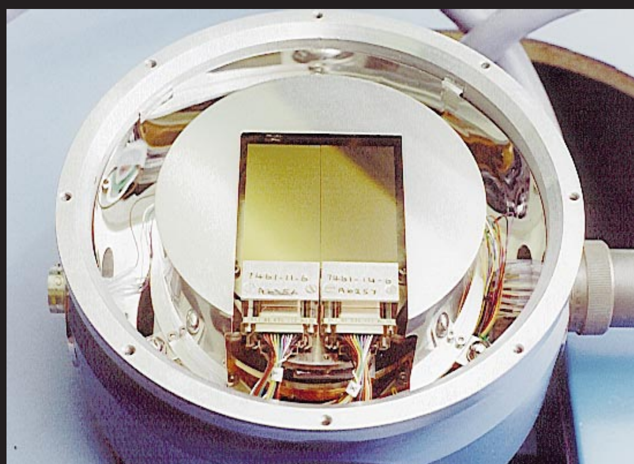

OTHER NEWS FROM ING

Y2K at the ING

Gordon Talbot (Head of Engineering, ING)

The year 2000 (if not the true millennium) is now with us, and like the rest of the world, the ING has not been brought to its knees by the 'Millennium Bug'. However, this cannot just be ascribed to good fortune —or that the Y2K problem was mere hype— it was because of the efforts of many of ING's staff.

During 1998 and 1999 the ING followed a planned programme of investigation, assessment, correction and testing of systems to ensure readiness for the year 2000.

All systems at ING were assessed including not only the telescopes but also the infrastructure and administration. Once the priorities of safety of people then protection of equipment were satisfied the major effort was in ensuring that our three telescopes would operate and return scientific data in the year 2000, bearing in mind that they are scheduled for operation 365 nights of the year.

To operate, the telescopes rely on a computer network of over 200 devices with thousands of lines of bespoke code using many operating systems and languages. Key systems are real-time telescope/instrument controls and astronomical data acquisition. Additionally astronomical data processing and archiving are essential to maintain operations. There is continuous development and replacement of systems, which vary in age from those being installed now to some over ten years old. ING are self reliant in engineering and have a six strong Computer Facilities Group and eight strong Control Software Group who are familiar with our systems and used to providing all maintenance and upgrades.

Prior to 2000 all three telescopes were successfully tested for compliance and showed that they were able to operate, point and track with dates in the new century. Much preparatory work was needed in updating operating systems, applying our own and manufacturers' patches and replacing non-compliant systems. A great deal of time was also spent isolating systems for testing.

A plan was drawn up and followed for operating over the year-end and arrangements made to have the necessary staff available. Uniquely at ING a complete night's closure for observing was scheduled for 31 December, followed by observing on all three telescopes in service mode on the nights of 1 and 2 January.

This was mainly on the grounds of safety, in case of failure to external services —principally communications— but also to minimise travelling problems for observers. However during the day of 1 January a full engineering team was on the mountain top re-testing system operation, beginning with safety related systems. Apart from our weather web-site, which was back on line the same day, no Y2K faults were found.

Since then no other date related problems have emerged. However, some systems, particularly instruments that have not yet been used, will be checked prior to scheduled use, although most have already passed Y2K tests last year. We will continue to be vigilant throughout the year as problems could still emerge.

I would like to thank all ING staff who have contributed to our smooth rollover into 2000 AD, especially those working on the network and telescope software on tight schedules for the overnight telescope tests.

Overall, so many of ING's staff were involved that I can't name them here for lack of space. Additionally support and advice was received from within PPARC.

Finally a last thought, perhaps now we should send a time capsule forward to 9999 AD warning of the imminent 'Y10K problem'. ¤

Gordon Talbot (rgt@ing.iac.es)

[INGNEWS] Mailing List

[INGNEWS] is an important source of breaking news concerning current developments at the ING, especially with regard to instruments.

You can subscribe to this mailing list by sending an email to majordomo@ing.iac.es with the message *subscribe ingnews* in the body. Please leave the subject field and the rest of the body of the message empty.

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These are the subjects of the last messages sent to the list:

24 August
– 'First issue of the ING Newsletter'

8 September
– 'Submitting Large Proposals'

News from the Computing Facilities Group

Nick Johnson (Head of CFG, ING)

The Computing Facilities Group starts 2000A eagerly anticipating the arrival of its Digital Video Disc (DVD-R) libraries. During 2000A, these 400 disc towers will be integrated into the ING archiving system and increase our on-line storage capacity ten fold. The DVD library will operate in parallel with our CD library and pick up the increased number of images generated by our UltraDAS computers and SDSU controllers. Capacity will be doubled again in 2000B with the addition of a device to flip the DVDs over and allow writing to both sides of the disc giving 9.4 GB of data storage per disc.

Computer systems performed without errors through the famous Y2K event. Our detailed planning and testing was apparently thorough, and we are delighted at the results of the hours spent in designing and building new network services. At the same time, we have almost completed the last telescope's conversion to new managed data network cabling. Finally, the ING network has ceased to be a bottleneck to system performance.

During the last days of 1999B we completed migration of all users and applications to a unified Solaris environment. This has altered procedures for visiting astronomers to use our computers with guest accounts. Tighter security management and faster user administration mean we can respond to requests with better efficiency. But we always welcome as much advance notice from visitors as possible. Please complete the form on *http://www.ing.iac.es/~cfg/pub_notes/visiting_astronomer_request.htm* to ensure CFG knows all about your IT needs before you arrive here. Thanks for your continued help with this. ¤

Nick Johnson (nrj@ing.iac.es)

Personnel Movements

Don Pollacco has left ING after several years of service. Don has been a key person in the development of fibre-based instruments at ING. In particular his efforts on improving the AUTOFIB and WYFFOS systems has been highly appreciated. He is leaving behind an important gap which will be difficult to fill. We thank him for his efforts and wish him well in his new job at Queen's University Belfast.

Also **Daniel Folha** left at the end of his tour on La Palma to return to the University of Porto. Many thanks to Daniel for his excellent support, and welcome to **Paolo Garcia** who is taking up the vacant position left by Daniel.

Begoña García and **Thomas Augusteijn** have taken up vacant positions as Support Astronomers. Both are highly experienced in observational astronomy and we are very pleased that they decided to join ING. Prior to coming to La Palma Begoña worked at the Instituto de Astrofísica de Canarias, whilst Thomas was working at the European Southern Observatory in Chile.

Romano Corradi and **Johan Knapen** also joined the Astronomy Group as research fellows. Their key task will be to strengthen the research environment at ING. Romano was working at the Instituto de Astrofísica de Canarias before taking up his position at ING, and Johan is on leave of absence from the University of Hertfordshire.

Kenny Britton and **Ermano Villani** filled temporary posts in the Site Services and Mechanical Engineering groups, respectively. Both have left ING at the end of their term after helping the groups through a very busy period. We wish both of them well in their future career.

Vicente Reyes temporarily filled the post of Telescope Operator during absence of **Neil O'Mahony**. Vicente returned to his previous business, while we welcome Neil back on La Palma.

Other Recent ING Publications

Annual Reports

Available at http://www.ing.iac.es/PR/annualreports_index.html

Technical Notes

– *No 124. ING Bibliography and Publication Rates (1999),* S F Sánchez, January 2000.

Available at http://www.ing.iac.es/~manuals/man_tn.html

Manuals

– *Observers Guide to the JKT and JAG-CCD Camera. Version 4.06,* J Telting, January 2000.
– *INT and JKT TCS Users' Manuals. Version 2.0,* R Laing and M Fisher, October 1999.
– *WHT TCS Users' Manual. Version 2.0,* R Laing, M Fisher and R Clark, December 1999.

Available at http://www.ing.iac.es/~manuals/manmain.html

In-house Research Papers

Available at http://andromeda.roque.ing.iac.es/~sanchez/ingpub/index.html

CAUP at ING

Daniel Folha (CAUP)* and Teresa Lago (Director CAUP)

*Ex-CAUP Support Astronomer at ING

Centro de Astrofísica da Universidade do Porto (CAUP), Portugal, is a scientific private association of the University recognised by the government as an institution of public utility. It started its activities in October 1990. Its objectives include the promotion and support of Astronomy through research, education at undergraduate and graduate levels, as well as the popularisation of Astronomy.

In 1997 the University of Porto, PPARC and NWO signed a Cooperative Agreement concerning the participation in the ING. Within the terms of this agreement signed in Porto, the researchers of CAUP have the right to use the JKT during 28 nights per year. In addition, they have access to the other telescopes, within the ING, under the same conditions of scientific competition as the astronomers of the United Kingdom and the Netherlands. As a reciprocal part of the agreement, CAUP maintains one resident astronomer at La Palma, integrated within the ING team. The possibility of CAUP's participation in the programmes of instrumental development associated with the ING telescopes is also provided for.

The agreement was implemented in February 1998. Since then, three astronomers associated with CAUP have worked at La Palma. The regular replacement of CAUP's astronomer brings an added value component for CAUP, namely the training of the astronomers in the management and operation of telescopes and their scientific instrumentation. Therefore this is an important complement to other facilities available to the astronomers associated with CAUP. Namely, the access to ESO facilities under the agreement of cooperation between Portugal and ESO, signed in 1990.

A view of the Centro de Astrofísica da Universidade do Porto (CAUP).

La Palma – A Personal Experience

During most of 1999 I was based in La Palma, serving as CAUP's support astronomer at ING. My task consisted of providing support on all three telescopes and various instruments, namely the JAG-CCD camera on the JKT, the WFC and IDS on the INT and UES, ISIS and Auxiliary Port imaging on the WHT. I replaced my colleague Antonio Pedrosa upon his return to Porto and I have recently been replaced by Paulo Garcia, the current CAUP astronomer in La Palma. To smooth the handover of CAUP astronomers an overlap of approximately two weeks is granted for two consecutive astronomers.

Having only used infrared instrumentation prior to my arrival at ING, becoming a support astronomer in an optical observatory meant that a very steep learning curve had to be followed. Fiddling with filters, gratings, dichroics and so on and so forth for every run, is certainly something one does not do with cooled instrumentation used for infrared observations. The help of other ING astronomers, and engineers, to whom I take this opportunity to publicly thank, made those initial times a lot easier although not less stressful. With practice, more in depth knowledge of the various systems and instruments was achieved, leading to a better service to the observatory and visiting astronomers. As a final result, I believe I am now a proficient optical, as well as infrared astronomer. Although I should leave those at ING under whose supervision I worked, as well as those whom I supported, and the future, to be the judges.

Another important point of my presence at ING was having had the opportunity to meet many people from different backgrounds. From astronomers working in various areas of astronomy, to engineers taking care of observatory equipment or bringing new instrumentation to commission. It was a pleasure to meet them all and be able to discuss many aspects of their work.

For our institution, having wider access to telescope time is, obviously, one of the goals of the PPARC-CAUP agreement. Since the start of semester 98A, when the agreement became effective, observations with ING instrumentation were done for a number of projects lead by CAUP astronomers. As examples, using JKT's JAG-CCD, a study of oscillations in roAp and δ Scuti stars; with UES and IDS, high resolution spectra of T Tauri stars were obtained in order to learn more about the properties of their strong emission lines; with IDS, low spectral resolution data was taken, again of a sample of T Tauri stars, this time to investigate their excess continuum emission. These observing programmes have been developed within CAUP's Stellar Astrophysics group, which goal is a better understanding of the formation, structure and evolution of low-mass stars.

Beyond having access to telescope time, cooperation proposals have already been advanced regarding CAUP's participation in programmes of instrumental development associated with ING telescopes. Yet, the path is open to many other possibilities in the sharing of new cooperative adventures in this field. ¤

Daniel Folha (dfmf@astro.up.pt)

Seminars and Talks given at ING

Visiting observers are politely invited to give a seminar at ING. Talks usually take place in the sea level office in the afternoon and last for about 30 minutes plus time for questions afterwards. Astronomers from ING and other institutions on site are invited to assist. Please contact Johan Knapen (knapen@ing.iac.es) for more details. These were the seminars and talks given in the last six months:

13 September
Quasar Host Galaxies, S Sánchez (ING)

16 September
Gemini Introductory Talk, I Hook (UK Gemini Support Group)

22 September
Present and Future Laser Guide Star Developments for the WHT, C Dainty (Imperial College London)

27 October
Forever Blowing Bubbles... White Dwarfs, Supernovae and Local Interstellar Space, M Barstow (University of Leicester)

4 November
Triffid Optical Observations of Isolated Neutron Stars, Andy Shearer (University College Galway)

22 November
The Background and Status of the SALT Project, David A H Buckley (South African Astronomical Observatory)

10 February
The Formation of Multiple Shells in Planetary Nebulae, R Corradi (ING)

15 February
Mid and FIR Spectral Energy Distribution of Two Active Galaxies: NGC 6090 and NGC 7582, J Acosta (Instituto de Astrofísica de Canarias)

21 February
The Stellar Content of Elliptical and Spiral Galaxies from Near-Infrared Spectroscopy, P James (Liverpool John Moores University)

28 February
WHT-Integral Field Spectroscopy combined with HST-imaging of Central Regions of Galaxies, S Arribas (Instituto de Astrofísica de Canarias)

A Big Effort (and a Big Crane) Solves a Big Problem

Kevin Dee (Head of Mechanical Engineering, ING) and Gordon Talbot (Head of Engineering, ING)

During the night of 20 February 1999 there was a major failure of the top dome shutter mechanism on the Isaac Newton Telescope, which potentially could have either left the telescope exposed to the elements (in winter!) or rendered the telescope unusable (shutter stuck closed) for a considerable period. The first priority was to make sure the telescope would be left in a safe condition, but this did not prevent that night's observing taking place.

The following day, a Sunday, a full team went to the telescope and effected a temporary repair, using spares already held. Again no observing time was lost.

It was decided after inspection that a longer term solution was needed. What was found was that the mechanism over the last 15 years 'hard labour' had bored through the casing, so at a cost of 25,000 pounds it was decided to replace all units and include a set of strategic spares for the future. After research the units were sourced from the original supplier.

While they were being delivered two nights/three days (24–26 August) were allocated in semester 2000B to carry out the work, with as much preparation as possible done off the telescope.

To carry out the work the largest crane on La Palma was hired (see photographs) to lift the half-tonne units.

A major concern was naturally the safety of those carrying out the work, due to the exposed location on top of a concave dome 30 metres above the

ground. After a risk analysis a safe system of working was introduced, involving first of all physically securing the several tonne dome shutter, to prevent it descending, while the mechanisms and cables were removed. Staff working outside the handrailed areas were secured by 'bosuns chairs' safety harnesses.

After long hours the team from the Mechanical and Site Services groups completed the work within the allocated period and handed the telescope back for observing on the third night.

It is to everyone involved's credit that from the problem occurring in February until its permanent repair six months later, no observing time was lost — what could have been a long outage was averted.

So the INT dome shutter is now ready for the next fifteen or more years service. ¤

Kevin Dee (kmd@ing.iac.es)

TELESCOPE TIME

Applying for Time

Danny Lennon (Head of Astronomy, ING)

It is important that applicants for telescope time familiarise themselves with the latest news on instrumentation and detector combinations on offer, as well as with our scheduling restrictions. PPARC issue the PATT newsletter electronically, about one month before application deadlines, which contains up-to-date information on instrument availability. However for the very latest news always refer to the ING web pages, homepage *http://www.ing.iac.es*, where application forms and style files may also be obtained. The ING's scheduling constraints were summarised in the first issue of the ING Newsletter and will not be repeated here, please refer to that issue, which is also available on our Public Information web pages. Applications should be submitted by email only, by the appropriate deadline and no earlier than one month before that deadline, to *ingpatt@ing.iac.es*.

What's new

The 2-chip CCD mosaic, consisting of two 4k×2k EEV detectors, was successfully commissioned on the prime focus of the WHT, see the article by Simon Tulloch in this issue for further details. Commissioning on UES is due to be completed in early 2000, no problems are foreseen. One of the important advantages which this will offer over the 2k×2k SITe detector is an increased maximum resolving power of 80,000. However, due to fringing problems with the EEVs in the red, the SITe will remain the detector of choice with UES if one is working beyond about 6000Å. Some testing will be done to quantify the fringing problem with the EEVs on UES during commissioning.

INGRID commissioning slipped from January 2000 (99B) into March 2000. The 99B commissioning slots were re-allocated to three PATT 2000A proposals (P/2000A/4, 6 and 8), many thanks to Tom Marsh and Sean Ryan for coming out at very short notice for these observing runs. NAOMI commissioning, using INGRID, is now scheduled for June and July in semester 2000A. Prospective users of INGRID should keep a check on its homepage at:
http://www.ing.iac.es/IR/INGRID/ingrid1_home.htm,
or contact Chris Packham for the latest information. For the latest on NAOMI, please contact Chris Benn. Note that the slippage in INGRID has also had a knock-on effect for small fibres on AF2, and they will now not be commissioned in 2000A.

As discussed by René Rutten in this issue, both LDSS and TAURUS were withdrawn as common-user instruments, and offered to the community for adoption. Both instruments received bids and indeed LDSS is back on the WHT as a visitor instrument in 2000A. Anyone interested in using LDSS in future semesters should contact Richard Bower at Durham (*R.G.Bower@durham.ac.uk*). It seems likely that TAURUS will also be adopted, subject to the successful completion of some ongoing discussions.

In the last issue we proposed two possible ways of reducing operational costs of the JKT, either by providing a day-time introduction only or providing night-time support using students. We settled on the latter solution and night-time support on the JKT is now provided mainly by Rachel Curran and Dan Batcheldor. Rachel and Dan are undergraduates from Hertfordshire University, on a one year placement scheme, and besides providing JKT support are working on science projects supervised by ING astronomy staff. (Dan is working a project concerning supernovae environments supervised by Nic Walton, while Rachel's project is on the use of radio galaxies to probe the dust in spiral galaxy disks and is supervised by Chris Benn.)

Service

The service program is now managed by Ian Skillen, the ING Scheduler and Technical Secretary to PATT. Service users with time-critical programs in particular are reminded that there is no guarantee of a program being carried out on a particular service night. Time-critical observations are carried out on a best efforts basis only. This is due to a number of factors, among them instrument availability, grade and nationality (we aim for a balance between all three allocation panels). For time-critical observations, especially for those where it is possible to predict the frequency of events, it might be better applying for an over-ride proposal through the normal PATT/NL channels. At present, time-critical service proposals do not have over-ride status on service nights, or indeed any other night, while approved over-ride programs can over-ride service nights, as well as UK and NL scheduled nights.

Service users are also reminded that the time limit of INT and JKT programs has now been increased from three to five hours. ¤

Danny Lennon (djl@ing.iac.es)

Telescope Time Awards Semester 2000 A

ITP Programmes on the ING Telescopes

– Barcons (Santander), *An XMM international survey — AXIS: the origin of the hard X-ray background*
– Pérez-Fournon (IAC), *Optical and near-infrared follow-up of the European large area (ELAIS) and ISOCAM Lockman Hole (ILHS) ISO surveys*

William Herschel Telescope

UK PATT

– Bower (Durham), *Galaxy evolution in poor clusters*
– Burleigh (Leicester), *The mass distribution, magnetic field function and origin of magnetic white dwarfs*
– Cameron (St Andrews), *The albedo spectrum of the giant exoplanet orbiting τ Boo*
– Clements (Cardiff), *Arp 220 integral field spectroscopy: supporting CHANDRA observations*
– Davies (Durham), *Mapping early type galaxies along the Hubble sequence*
– Haswell (OU), *Outbursts in black hole X-ray transients: coordinated WHT/RXTE/HST observations* (99A, long-term)
– Jeffery (Armagh), *Asteroseismology of pulsating subdwarf B stars and a DB white dwarf*
– Jeffries (Keele), *The true lithium abundance in halo stars*
– Kleyna (IoA), *Dark matter in the UMi and Draco dwarf spheroidal galaxies*
– Knapen (Herts/ING), *Star formation in arm and interarm environments in spiral galaxies*
– Knapen (Herts/ING), *Hα survey of nuclear star-forming rings in spirals*
– Mathieu (Nottingham), *Dynamics of superthin galaxies*
– Maxted (Southampton), *Testing theories of common envelope evolution with double degenerates*
– Merrifield (Nottingham), *Mapping elliptical galaxy mass distributions using gravitational redshift*
– McHardy (Southampton), *Deep R-band imaging of very deep XMM survey fields*
– McMahon (IoA), *Probing the ionization state of the universe at $z>5$*
– Morales-Rueda (Southampton), *What distorts the radial velocity curves of accretion disks?*
– Pettini (IoA), *The large-scale structure of galaxies at redshift $z\approx3$*
– Pollacco (QUB), *Restarting the fast wind in the Sakurai object (V4334 Sagittarii)*
– Rawlings (Oxford), *The cosmic evolution of radiosources using the TEXOX 1000-radiosource redshift survey (99B, long-term)*
– Rawlings (Oxford), *Evolution of $z\sim1$ 6C galaxies: discerning the role of the radio source*
– Refregier (IoA), *Measuring the cosmic shear arising from large-scale structure*
– Ryan (OU), *The primordial lithium abundance*
– Sarre (Nottingham), *Search for diffuse band carriers in the circumstellar shell of IRC+10°216*
– Serjeant (ICSTM), *Optical wide field imaging of CHANDRA/ISO/UK sub-millimetre survey area*
– Skillen (ING), *Rapid observation of gamma–ray burst optical afterglows*
– Smail (Durham), *A joint WHT/HST survey of the galaxy populations within lensing clusters*
– Storey (UCL), *H-deficient knots as the cause of spatial abundance variations in planetary nebulae*
– Tadhunter (Sheffield), *The physics of the narrow line region in powerful radio galaxies*
– Tanvir (Herts), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients*
– Terlevich (Birmingham), *The triggering mechanism for the Butcher-Oemler effect*
– Walton (ING), *Lambda – Omega: The low redshift Type Ia SN connection*

NL NFRA PC

– van den Berg (Utrecht), *High-resolution spectroscopy of two blue straggler binaries in M67*
– Best (Leiden), *Emission line gas inside and outside CSS radio sources: determining the origin of the gas*
– Best (Leiden), *Evolution of $z\sim1$ 6C galaxies: discerning the role of the radio source*
– Bézecourt (Kapteyn), *R and Z band imagery of cluster A2219 for the determination of photometric redshifts*
– Douglas (Kapteyn), *Planetary nebulae in Virgo cluster galaxies*
– Kregel (Kapteyn), *The stellar velocity distribution in the thin disk of NGC 5529*
– Luu (Leiden), *Rotational properties of Kuiper Belt objects*
– Pickering (Kapteyn), *Near-IR imaging of low surface brightness galaxies*
– Vreeswijk (Amsterdam), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients*
– van der Werf (Leiden), *Distant submillimeter galaxies – their nature and their redshift distribution*
– de Zeeuw (Leiden), *Mapping galaxies along the Hubble sequence*

SP CAT

– Aretxaga (INAOE), *The QSO – host galaxy luminosity relationship at z=2*
– Cairós (IAC), *Infrared photometry of blue dwarf galaxies: the low surface brightness component*
– Colina (IFCA), *Integral field spectroscopy of ultraluminous infrared galaxies*
– Colina (IFCA), *A study of galaxies under star formation at high redshift*
– Díaz (UAM), *Determination of the velocity dispersion in starforming circumnuclear regions*
– González (IAC), *Star formation history in galaxies from mid-infrared measurements*
– Israelian (IAC), *Searching for the evidence of supernova events in the low mass X-ray binary systems Her X-1 and Cyg X-2*
– López (IAC), *Kinematics of the nuclear bar of NGC 5850*
– Pérez (IAA), *Stellar dynamics and circumnuclear structure in isolated galaxies*
– Pérez-Fournon (IAC), *Mach disks and bow shocks in NGC 4258: testing the role of mechanical energy in AGN NLR's*
– Rodríguez (IAC), *Fe abundance in blue compact galaxies*

Isaac Newton Telescope

UK PATT

– Benn (ING), *Extinction of background radio galaxies by foreground spirals*
– Croom (ICSTM), *A photometric redshift survey in deep X-ray fields*

Important Dates

Deadlines for submitting applications

UK and NL PATT:
31 March, 30 September

SP CAT:
1 April, 1 October

ITP:
30 June

Semesters

Semester A:
1 February – 31 July

Semester B:
1 August – 31 January

– Ellis (IoA), *Comparisons of star formation diagnostics in the local and intermediate redshift universe*
– Howarth (UCL), *Colliding winds in massive close binaries*
– Keenan (QUB), *Identification of hot stars in globular clusters*
– Maxted (Southampton), *Are sub-dwarf B stars the result of common-envelope evolution?*
– McMahon (IoA), *A public near IR imaging survey on the INT*
– Morales-Rueda (Southampton), *Spectroscopy of dwarf novae in outburst (99B, long-term)*
– Naylor (Keele), *Does magnetic activity drive mass transfer in cataclysmic variables?*
– Stetson (DAO), *Helium burning variables in Ursa Minor and Draco dwarf spheroidals*
– Tanvir (Herts), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients*
– Terlevich (Birmingham), *The photometric properties of galaxy groups*
– Watson (Leicester), *Wide field imaging for the XMM serendipitous sky survey*

NL NFRA PC

– Jimenez (Kapteyn), *A much-improved stellar library for stellar population synthesis*
– Orosz (Utrecht), *Atmospheric parameters of subdwarf binary stars*
– Tschager (Leiden), *The optical hosts of young radio sources – redshifts (3)*
– Vreeswijk (Amsterdam), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients*

UK/NL WFS Programmes

– Dalton (Oxford), *The Oxford deep WFC imaging survey*
– Davies (Cardiff), *Multi-coloured large area survey of the Virgo cluster*
– Driver (St Andrews), *The Millenium galaxy catalogue*
– McMahon (IoA), *The INT wide angle survey*
– Groot (Amsterdam), *The faint sky variability survey*

SP CAT

– Aparicio (IAC), *The north-west tidal current in Sagitarius*
– Caon (IAC), *The environment's influence on the ionised gas in elliptical galaxies*
– González-Serrano (IFCA), *Redshifts of bright galaxies from the Westerbork radio survey*
– Hammersley (IAC), *A deep multi-wavelength survey of the galactic plane*
– Marín (IAC), *Globular cluster systems in Coma*
– Martínez-Delgado (IAC), *Structure of tidal residuals in the Ursa Minor galaxy*
– Nebot (Barcelona), *Physical parameters of the open clusters NGC 1817, NGC 1807 and NGC 2548*

– Pérez-Fournon (IAC), *Near-infrared imaging of a deep CHANDRA X-ray survey*
– Rosenberg (IAC), *Galactic globular cluster relative ages and the Milky Way formation (II)*
– Vazdekis (Durham), *Horizontal branch effects in the spectra of globular clusters*
– Vega (IAC), *Search for galaxies with orthogonal rotating bulge and disk*
– Vílchez (IAA), *An Hα survey of the Coma and A1367 Clusters*

Jacobus Kapteyn Telescope

UK PATT

– James (LJMU), *A survey of star formation in the local universe*
– Knapen (Herts/ING), *Star formation in arm and interarm environments in spiral galaxies*
– Norton (OU), *Photometric study of the newly discovered intermediate polar 1WGA J1958.2+3232*
– Seigar (Gent), *Optical properties of the disks of spiral galaxies*
– Shahbaz (Oxford), *Probing the accretion disc in SW Sex type stars*
– Sorensen (ING), *The binary frequency in planetary nebula central stars: short period objects*
– Tanvir (Herts), *Rapid imaging of GRB error boxes and spectroscopy of GRB–related optical/IR transients*
– Tsapras (St Andrews), *A search for planetary anomalies on high amplification microlensing events*
– Walton (ING), *Lambda – Omega: the low redshift Type Ia SN connection*
– Warren (ICSTM), *Remote halo blue horizontal branch stars and the mass of the Milky Way (99B, long-term)*
– Woolf (Armagh), *Photometry of pulsating helium stars*

NL NFRA PC

– van den Berg (Utrecht), *Photometric monitoring of an X-ray blue straggler in M67*
– van der Hulst (Kapteyn), *R-band imaging of galaxies in the WHISP sample*
– Pickering (Kapteyn), *B-band imaging of LBS galaxies*
– Vreeswijk (Amsterdam), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients*

SP CAT

– Delfosse (IAC), *Accurate optical and infrared photometry of field very low mass stars and brown dwarfs*
– de Diego Onsurbe (IAUNAM), *Spectral characterisation of quasar microvariavility*
– Nebot (Barcelona), *Physical parameters of the open clusters NGC 1817, NGC 1807 and NGC 2548*

Abbreviations

AAO	Anglo-Australian Observatory
CAT	Comité para la Asignación de Tiempo
CfA	Harvard-Smithsonian Centre for Astrophysics
DAO	Dominion Astrophysical Observatory (Canada)
DIAS	Dublin Institute for Advanced Studies
ESTEC	European Space Technology Centre
HST	Hubble Space Telescope
IAA	Instituto de Astrofísica de Andalucía
IAC	Instituto de Astrofísica de Canarias
IAUNAM	Instituto de Astronomía de la Universidad Nacional Autónoma de México
IC	Imperial College London
ICSTM	Imperial College of Science, Technology and Medicine
IFCA	Instituto de Física de Cantabria
INAOE	Instituto Nacional de Astrofísica, Optica y Electrónica (Mexico)
IoA	Institute of Astronomy
ITP	International Time Programme
LJMU	Liverpool John Moores University
MSSL	Mullard Space Science Laboratory
MSSSO	Mount Stromlo and Siding Spring Observatories
NBST	National Board of Science and Technology of Ireland
NFRA	Netherlands Foundation for Research in Astronomy
NL	The Netherlands
OAN	Observatorio Astronómico Nacional (Spain)
OU	Open University (UK)
PATT	Panel for the Allocation of Telescope Time
PC	Programme Committee
QUB	Queen's University of Belfast
RAL	Rutherford Appleton Laboratory
SP	Spain
STScI	Space Telescope Science Institute
UAM	Universidad Autónoma de Madrid
UCL	University College London
UCLAN	University of Central Lancashire
UK	The United Kingdom
WFS	Wide Field Survey

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SCIENCE

TELESCOPES AND INSTRUMENTATION

OTHER NEWS FROM ING

TELESCOPE TIME

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Service Programme	*Ian Skillen*	425463	wji
WHT Manager	*Chris Benn*	425432	crb
INT Manager	*Thomas Augusteijn*	425433	tau
JKT Manager	*Thomas Augusteijn*	425433	tau
Instrumentation Scientist	*Nic Walton*	425440	naw
Engineering Operations Manager	*Clive Jackman*	425446	cwmj
Freight	*Juan Martínez*	425414	juan