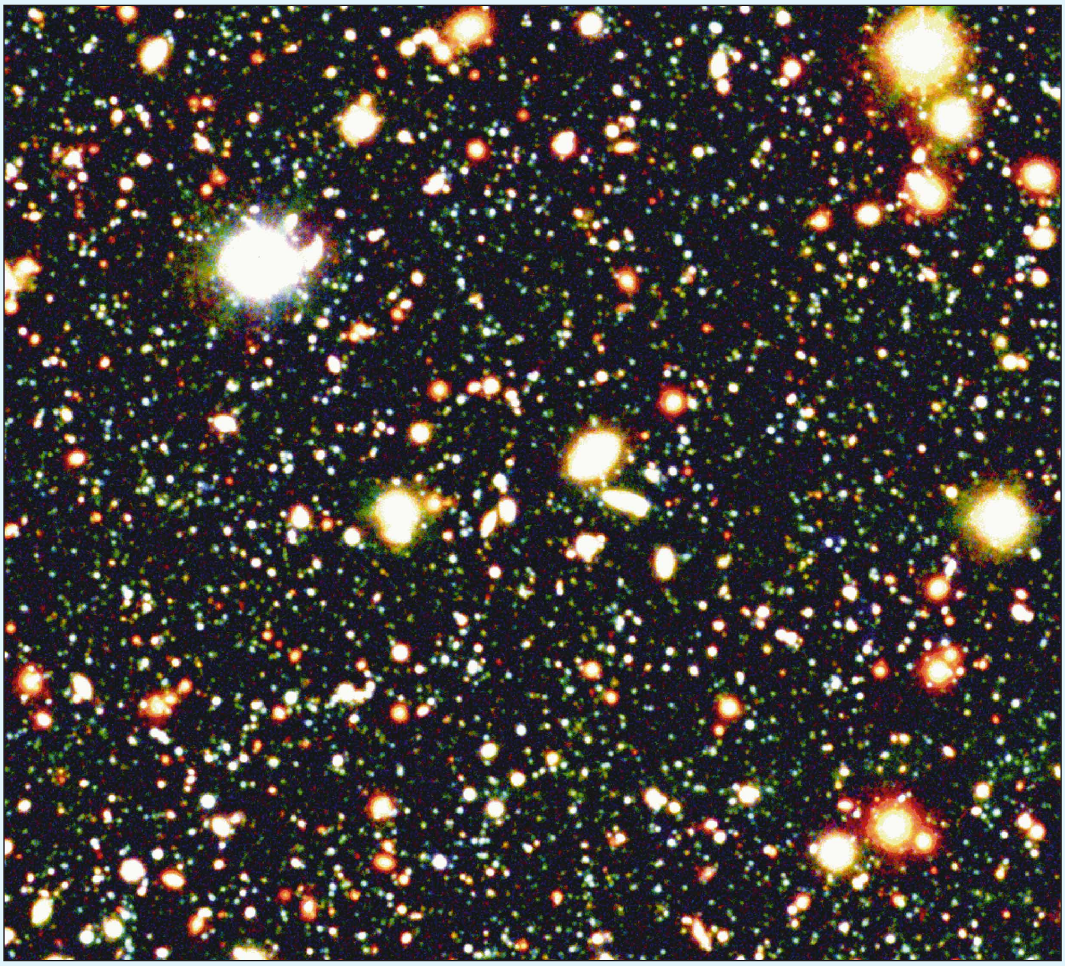
No. 3, September 2000

The Isaac Newton Group of Telescopes

NEWSLETTER



Shown above is the William Herschel Deep Field (WHDF), a 7×7 arcminute patch of sky in the constellation of Pisces observed by the WHT for a total of about 70 hours. The WHDF is the deepest ground-based image of the sky (for further information see article by Nigel Metcalfe et al. on page 3).

Message from the Director

Dear Reader,

The landscape of UK ground based astronomy is rapidly changing. This is a matter of natural evolution, and like in most evolutionary processes, at times quantum leaps are experienced. Potentially the most significant of such changes would become reality if the UK were to obtain the funds required to join the European Southern Observatory (ESO). This will profoundly change the way the UK has historically organised ground-based astronomy, and it will undoubtedly impact on the role played by the existing facilities, including those of the Isaac Newton Group of telescopes. It is good to see that a debate has been opened to discuss the future requirements in some detail, placed in the light of the UK joining ESO. In order to summarise the role that ING could play in the future of UK astronomy, an open letter was sent out to the astronomical community. This letter is reprinted on page 34. At the time of writing it is not clear what the future will bring, but I trust that various committees and PPARC will find the right balance of choices that is best for the future of UK astronomy.

In spite of the significant upheaval resulting from the potential changes in the future, work at the observatory is steadily progressing to improve the capabilities of the telescopes. The most important milestone recently has been the completion of the new infra-red camera, INGRID, for the William Herschel Telescope. INGRID has had a long and nasty

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 by the Instituto de Astrofísica de Canarias (IAC).

(Continued from front cover)

history as it was one of the projects that got trapped in the closure of the Royal Greenwich Observatory. There was no other option at that time as to transfer the project to La Palma and complete it there. One can imagine that for the observatory to take on such a fairly major project whilst retaining a clear focus on the operation of the telescopes wasn't easy. Throughout the project PPARC has been very supportive in working towards a successful completion of INGRID, for which ING is very grateful. Although later than planned, in the end commissioning of INGRID was a great success and all those involved are pleased and proud to see INGRID now delivers the science it was intended for. The impact of INGRID on the demand of the William Herschel Telescope has been felt immediately, as the oversubscription of bright time for semester 2000B has been well above that for dark time!

Development effort now focuses on the NAOMI adaptive optics system for the WHT. Progress at the Astronomy Technology Centre and the University of Durham has been very good. On La Palma engineers and astronomers are busy with the preparations for the commissioning of this complex system. It is with great anticipation that we are looking forward to 'first light' for this common-user adaptive optics system.

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

The ING Newsletter

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The ING Newsletter is published twice a year in March and September. If you wish to submit a contribution, please contact Javier Méndez (*jma@ing.iac.es*). Submission deadlines are 15 July, and 15 January.

SCIENCE

Ultra-Deep Imaging at the William Herschel Telescope

Nigel Metcalfe, Tom Shanks and Richard Fong (University of Durham)

Ultra-deep imaging observations using powerful, ground-based telescopes such as the William Herschel Telescope (WHT) have the capacity to probe the evolutionary history of galaxies back to their formation epoch. At the faintest galaxy magnitudes, we are looking out not only in distance but back in time to when the Universe was only a few percent of its current age.

Over the past few years, we have therefore used the WHT to produce the deepest ground-based image of the sky which we have called the William Herschel Deep Field (WHDF). With exposures of ~30 hrs in U and B, the resulting images reach magnitudes which are comparable to the Hubble Deep Fields (U ~ 27, B ~ 28) but covering a five times bigger area of the sky than the two HDFs combined. As well as substantial exposures in the redder optical bands from the WHT, the field has also been imaged in the near-IR with a 30 hr exposure in K from the UKIRT IRCAM3, reaching K ~ 23 in a small central sub-area and a 14 hr exposure in H from the Calar Alto 3.5-m Omega Prime camera covering the whole 7' × 7' area and reaching H ~ 23 (McCracken et al., 2000a, McCracken et al., 2000b). Table 1 summarises the current situation. Figure 1 shows an optical 'true' colour image of the WHDF.

The WHT data were taken with the Prime Focus camera using Tektronix or, more latterly, Loral CCDs. The U-band observations were much enhanced by the Loral chips, which have 3 times the sensitivity of the Tektronix at these wavelengths. Data reduction was carried out using our proprietary software (Metcalfe et al., 1991,1995).

For many aspects of the studies of high redshift galaxies, the bigger area of this Herschel Deep Field gives it a unique advantage over HST data. At intermediate redshifts ($1 < z < 3$) the larger numbers of galaxies means that they are more easily split into their various sub-populations by their colours. At high redshift, the big area means we have more chance of detecting candidates for galaxies in the redshift range $3 < z < 7$ which are within the magnitude reach of multi-object spectrographs on 8–10 m class telescopes for obtaining spectroscopic confirmation of their photometric redshift. The bigger area also has advantages for studies of high redshift galaxy clustering, aimed at understanding how structure forms in the early Universe.

Figure 2 shows the B-band galaxy counts for the WHDF compared with other data, including the Hubble Deep fields. Also shown are the predictions for a universe in which galaxies do not evolve with time, and those for which galaxies follow simple stellar population synthesis tracks (Bruzual & Charlot, 1993). Two geometries are considered, $q_0=0.05$ (open) and $q_0=0.5$ (flat). It is clear that non-evolving models underpredict the counts from quite bright magnitudes (B ~ 22). Even an open evolving model struggles to keep up with the sheer numbers of galaxies seen, although there are probably enough uncertainties in this model to 'tweak' it higher at faint magnitudes. Those who favour a closed universe have to relax the constraint that galaxy numbers are conserved (e.g. merging) or at the very least invoke a population at high redshift which has disappeared from view by the present day (e.g. fading dwarfs). The model shown is a version of the latter.

One of the main tools for scientific analysis of these data is the colour-colour diagram. It might be thought that without spectroscopy it is impossible to judge the redshifts of these faint galaxies, but Figure 3 shows this is not the case. Here, simple stellar population synthesis evolutionary tracks (Bruzual & Charlot, 1993) have been plotted for E/S0 and spiral galaxy types on top of the WHDF data. They are colour-coded by redshift. The 'hook' of galaxies toward the bottom left of the diagram is clearly identified with spirals tracking out towards redshifts of 2, whilst the prominent 'finger'

Band	Exposure (hours)	Magnitude Limit	Telescope
U	34	27	WHT
B	28	28	WHT
R	8	26.5	WHT
I	5	25.5	WHT
H	14	22.75	Calar Alto
K	1	20.5	UKIRT/Calar Alto
K sub-area	30	23	UKIRT

Table 1. Magnitude limits and exposure times for the William Herschel Deep Field.

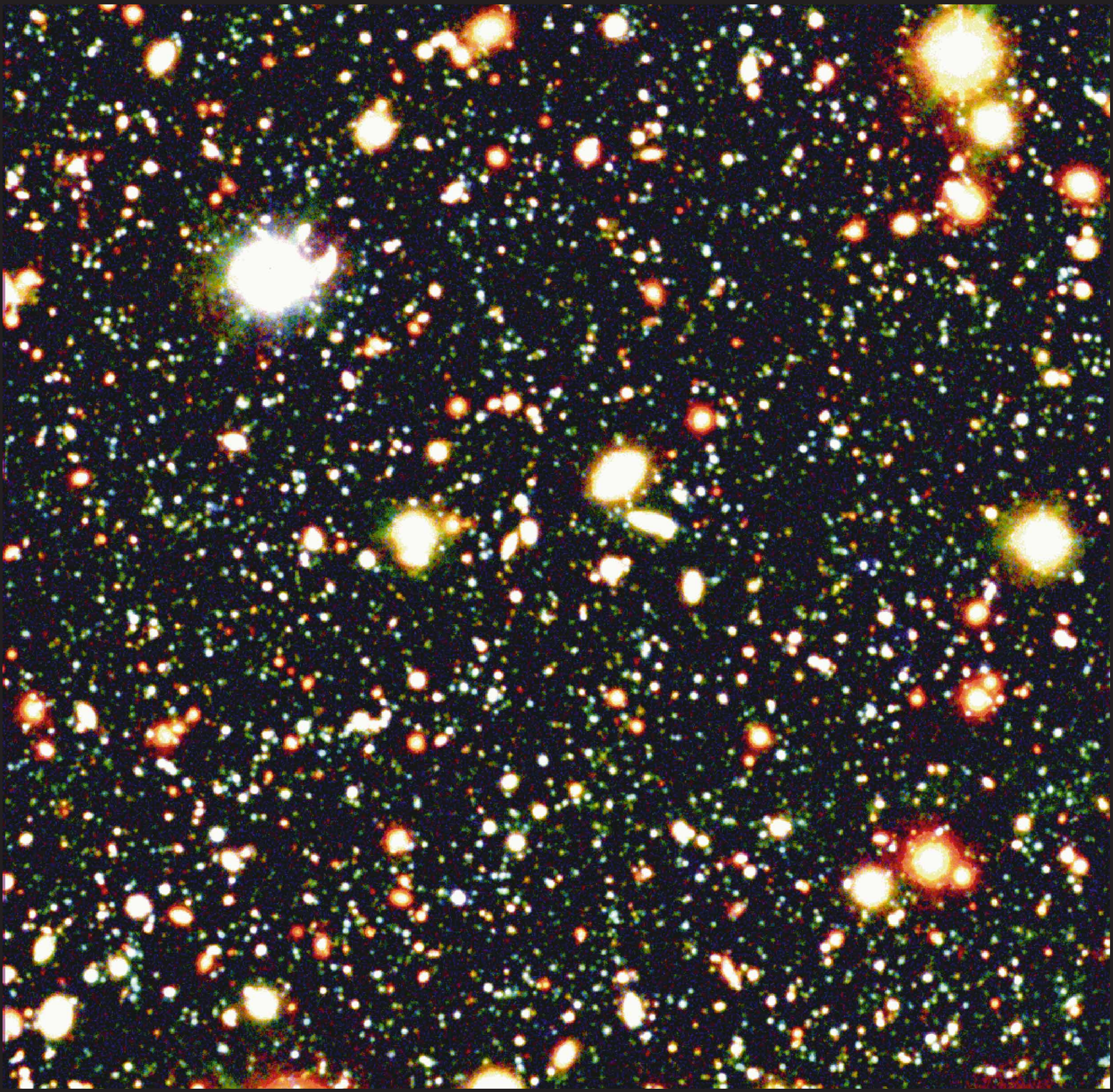

Figure 1. A ‘true’ colour image of the William Herschel Deep Field, formed by mapping U, B and R exposures onto blue, green and red respectively. The image covers 7×7 arcminutes.

pointing upwards is composed of low redshift ellipticals. Highlighted in red are those galaxies with (R–H)>3.5. These are predicted on the basis of their optical-infrared colours to be elliptical galaxies at redshifts above ~1, in agreement with their location in Figure 3. Interestingly the scatter in (R–H) (or (R–K)) for these galaxies is very high, spanning almost 2 magnitudes.

The infra-red colours are also useful for detecting clusters of galaxies. Shown in Figure 4 are 'true' colour plots of a 1.3' box from the WHDF formed by combining R, I and H images and U, B and R images. Notice the prominent string of red galaxies to the left side on the RIH plot. This is a cluster, probably with a redshift between 0.5 and 1.

To identify high redshift galaxies the photometric 'dropout' technique (e.g. Steidel et al., 1999) is perhaps the best known. This relies on the presence of a Lyman limit in galaxy spectra, shortward of which nearly all of the flux is absorbed by intervening hydrogen. When this limit is redshifted into a particular filter the galaxy becomes very faint or disappears altogether, whilst remaining relatively bright through redder filters. Figure 5 shows three examples of such galaxies identified on the WHDF; a 'dropout' from the U-filter, implying z>3, a 'dropout' from both U and B (it is still faintly visible in B, but remember that this exposure is much deeper than the others), implying z>4, and a potential R-band 'dropout', which could have a redshift above 6 !

Using the 'dropout' technique in several bands enables us to plot the number count of galaxies at various redshift intervals. These can then be compared with simple evolutionary model predictions. Figure 6 shows such a plot for z~6 galaxies selected by R-band 'dropout' — we have included points from the Hubble Deep Fields (F606W 'dropout') and also shown the numbers of spectroscopically confirmed galaxies from surveys in the literature. We also plot the counts expected on the basis of the same simple luminosity

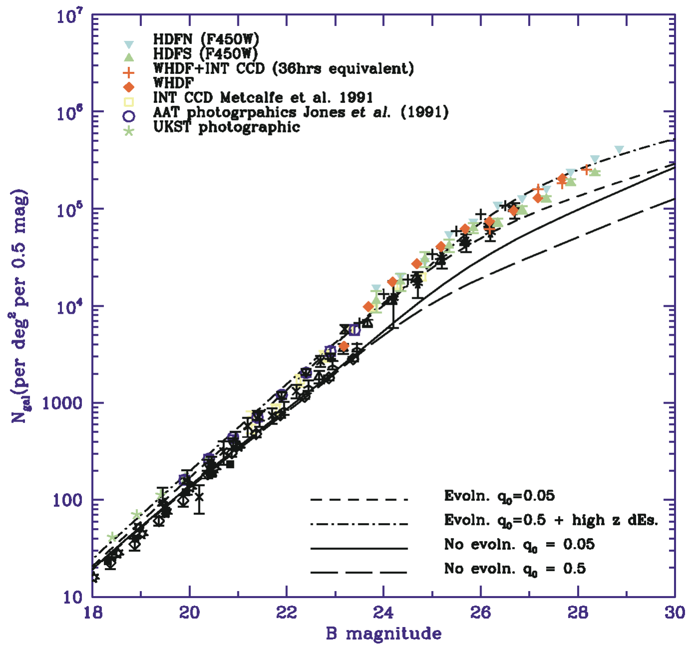

Figure 2. Differential galaxy number counts for the B-band, compared with evolving and non-evolving models for low and high q_0 . Durham counts are shown with coloured symbols; b/w symbols indicate counts from the literature.

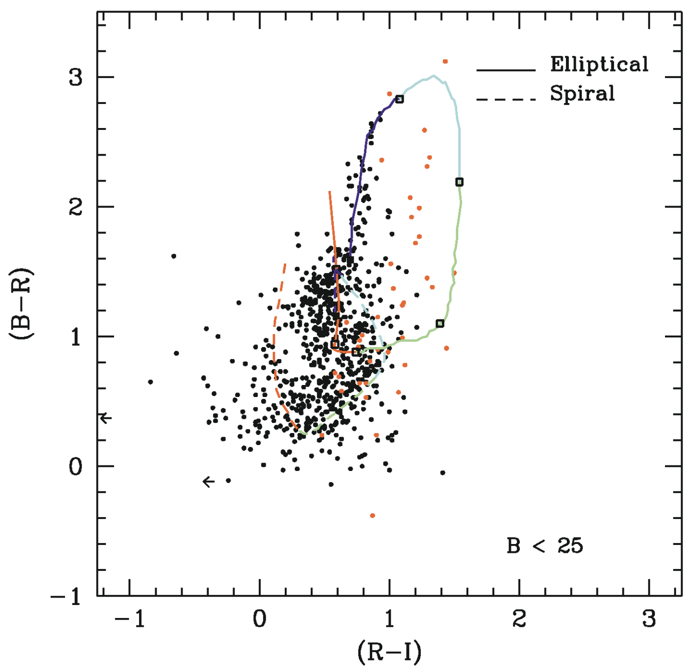

Figure 3. (B–R) versus (R–I) colour-colour plot for the WHDF, showing the predicted evolutionary tracks followed by elliptical and spiral galaxies. Colours indicate redshift range; blue z<0.5, cyan 0.5<z<1, green 1<z<2 and red 2<z<3. The red dots indicate those galaxies which are relatively bright in the infra-red ((R–H)>3.5).

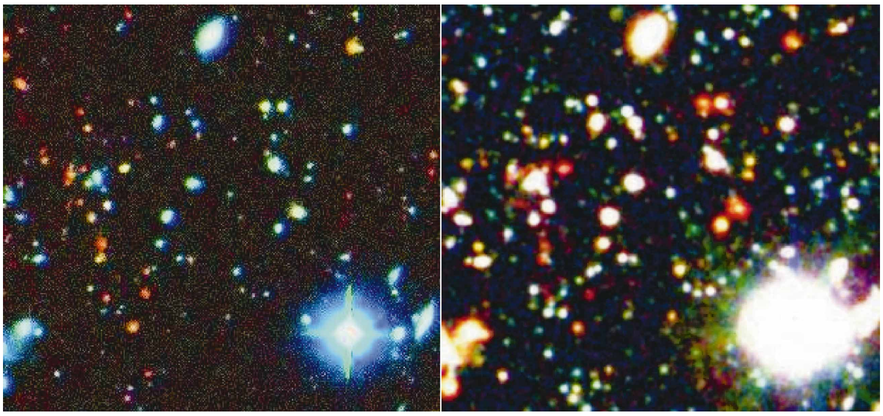

Figure 4. RIH (left) and UBR (right) 'true' colour images of a small portion of the WHDF, showing the presence of a cluster at a redshift of 0.5~1, identifiable by the presence of very red galaxies, particularly in the optical-infrared image.

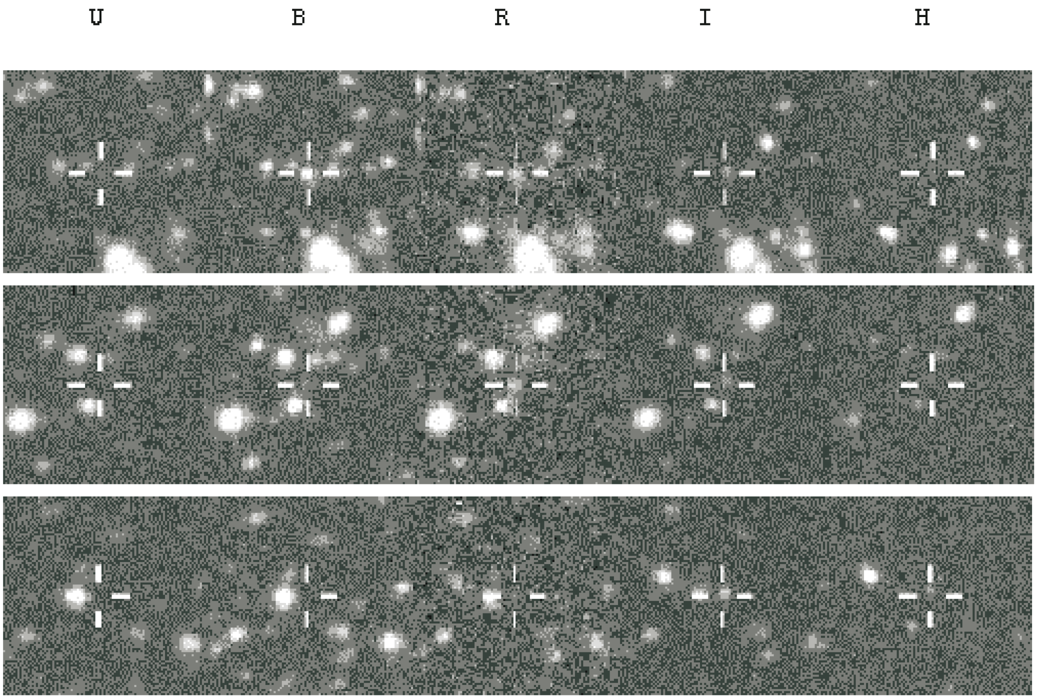

Figure 5. Top panel: An example U-dropout galaxy at B~25.0; Middle panel: A potential B-dropout galaxy with R~24.3; Bottom panel: A candidate R-dropout with I~23.8.

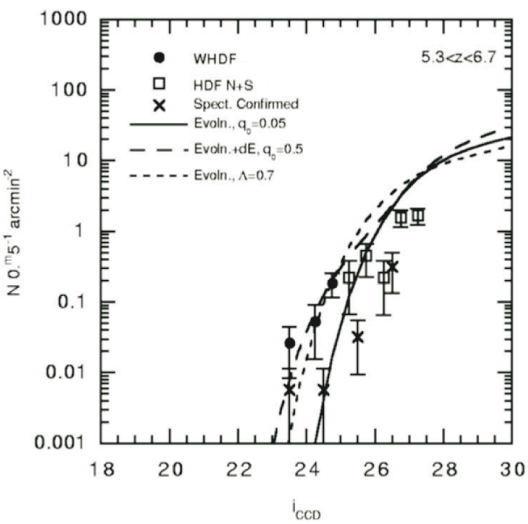

Figure 6. Numbers of R-band 'dropout' potential z~6 galaxies, together with the handful of spectroscopically confirmed such objects, compared with the predictions of simple luminosity evolution models.

evolution models as used in Figure 2. These models reproduce well our own data, and that of Steidel et al., at lower redshifts, z~3.

It is remarkable how well these simple models match this ultra-high redshift data. The fact that a population of spectroscopically confirmed z~6 galaxies have already been identified and that even larger numbers of R dropout candidates exist in both the Herschel and Hubble Deep Fields indicates that significant numbers of luminous galaxies were already extant at these redshifts, pushing the epoch of formation of giant galaxies back even earlier.

Looking to the future, we return to the WHT later this year with the aim of using the new mosaic camera to image in R, I & Z to look for R-band dropouts to fainter magnitudes and over a wider area. Such candidates will be ideal targets for the GMOS spectrograph on the new GEMINI-N 8-m telescope.

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Discovery of a Type Ia Supernova Progenitor

P. F. L. Maxted, R. C. North and T. R. Marsh
(University of Southampton, Department of Physics and Astronomy)

In April of this year we were awarded 13 nights of INT time to look for binary subdwarf-B (sdB) stars. The properties of these stars strongly suggest they are composed almost entirely of helium and have masses close to 0.5 solar masses (Saffer et al., 1998). We suspected that many of these stars would be short period binary stars, and we were right. We found 22 binary stars from a sample of 42 sdB stars from the Doppler shifts in the Hα line, only one or two of which were previously known. However, despite this important result, this observing run will be remembered for the two hours we spent observing one particular sdB star, KPD 1930+2752, because it turned out that this star could be an important step in answering some of the biggest questions in observational cosmology.

We decided to observe KPD 1930+2752 because a paper appeared by Billères et al. (2000) presenting photometry of this star suggested it is a binary with an orbital period of only $2^{h}\,17^{m}$. The photometry was taken to look for pulsations with periods of a few hundred seconds, a phenomenon now observed in several other sdB stars. Pulsations were detected in KPD 1930+2752, but superimposed on the complex multi-periodic pulsations is a quasi-sinusoidal signal with a period of about an hour. Folding the data on twice this period shows the typical light curve of a star distorted by the presence of a close companion, i.e., an ellipsoidal variation with two maxima and two unequal minima. To confirm this interpretation, radial velocity measurements were needed to look for the Doppler shift of the star as it orbits its unseen companion star. We were in an ideal position to make these observations, so we observed KPD 1930+2752 over one orbit on the morning of April 17th.

The expected radial velocity shift is very easily seen in the raw data (Figure 1) and shows the sinusoidal shape expected for a circular orbit. What is surprising is the large amplitude of the motion (350 km/s). KPD 1930+2752 is a very typical sdB star with a mass close to 0.5 solar masses so the mass of the companion must be at least 0.97 solar masses. A normal star of this mass is too large to fit into such a short period binary, so the companion is almost certainly a white dwarf star. If we assume the orbital plane of the binary is edge-on to our line-of-sight, we can predict the size of the ellipsoidal variation we should see based on our measured radial velocity amplitude, the measured surface gravity of the sdB star and the orbital period. This gives a very good fit to the observed light curve (Figure 2), so the inclination must be close to this assumed value and the mass of the white dwarf is not much higher than the minimum value of 0.97 solar masses. A white dwarf of this mass are thought to be composed of degenerate carbon and oxygen.

Massive white dwarfs in binaries are prime candidates for the progenitors of Type Ia supernovae. The observed properties of Type Ia supernovae put very strong constraints on the progenitors, particularly the complete absence of hydrogen and helium in the spectrum just after the explosion and their appearance in old stellar populations such as elliptical galaxies. Models of exploding white dwarfs are, naturally, very uncertain, but it appears likely that a massive white dwarf composed of carbon and oxygen will explode if it accumulates a layer of helium and then exceeds the Chandrasekhar limit. A proposed mechanism for build-up of helium on a massive white dwarf is steady thermonuclear burning of hydrogen due to accretion from a normal star. The observed counterparts to these binaries are the 'super-soft sources' which are identified by the soft X-ray flux emanating from the hot surface of the white dwarf. However, it appears that the majority of Type Ia supernova cannot be due to super-soft sources because the mass transfer rate must remain within a narrow range for a sufficiently long time to build up sufficient helium. At lower accretion rates the hydrogen does not burn steadily, but is ejected in a series of nova explosions. At higher accretion rates the mass transfer is Eddington-limited. It also appears that super-soft sources are not sufficiently long-lived to give supernova explosions in elliptical galaxies (Leibundgut, 2000).

The competing model to super-soft sources has been the double degenerate scenario, in which the companion to the massive white dwarf is a lower mass white dwarf composed mostly of helium. In this scenario, the mass transfer occurs when gravitational radiation drives the two white dwarfs into contact. The difficulty with this model has been the lack of any observed counterparts. This is not surprising given that only 1 in 500 white dwarfs needs to be a progenitor to explain the observed rate of galactic supernovae and far fewer than 500 white dwarfs have been studied in sufficient detail to reveal whether they are potential supernovae.

The possibility of a helium star companion to a white dwarf has not been widely considered as a source of Type Ia supernovae, but KPD 1930+2752 is clearly a very promising candidate. Gravitational radiation will drive the sdB star and the white dwarf together within 200 million years, at which point the white dwarf will accrete the sdB star and exceed the Chandrasekhar mass. The result of our search for binary sdB stars becomes important in this regard because many of them will have white dwarf companions, though not all will be as massive as the companion to KPD 1930+2752. We intend to continue our observations of these stars to determine the companion mass distribution and the period distribution. The space density of sdB stars is quite well determined, so we will then be able to say whether there are enough binaries like KPD 1930+2752 to explain the observed rate of Type Ia supernovae in our Galaxy.

The true nature of Type Ia supernovae has become an important question for observational cosmology because they are used as standard candles and can be observed at redshift as high as z ~ 1. Observations of these distant supernovae has recently led to claims that the expansion of the Universe is accelerating (Riess et al., 1998, Perlmutter et al., 1999). This conclusion is the result of Type Ia supernovae at high redshift being about 30% too bright compared to a non-accelerating Universe model. This has led to intense debate over the possibility that the properties of Type Ia supernovae has evolved so as to mimic an accelerating Universe. A clear answer to this question will not be possible until the identity of the progenitors is determined. The discovery of KPD 1930+2752 is an important step in our understanding of this most fundamental question.

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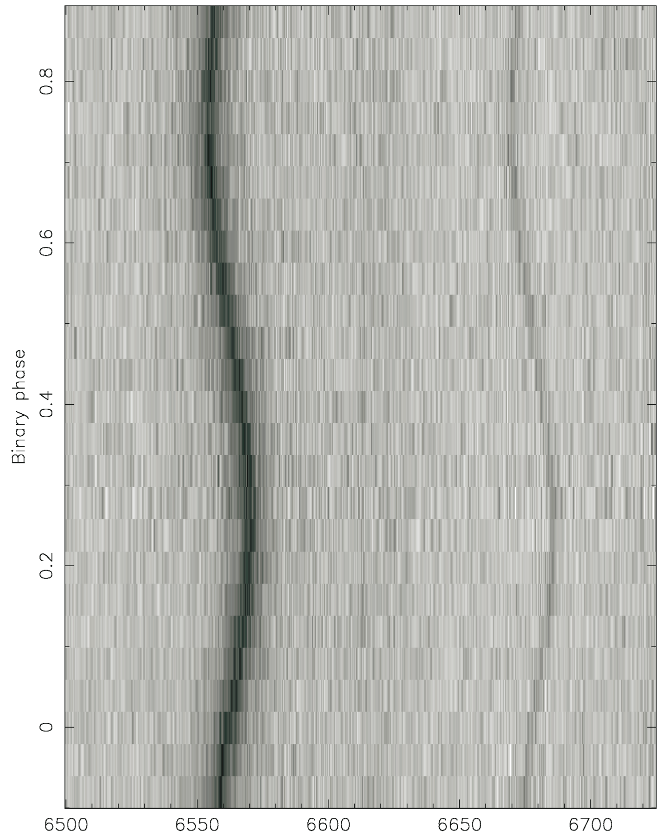

Figure 1. Raw spectra from KPD 1930+2752. The radial velocity shift is very easily seen (x-axis in angstroms).

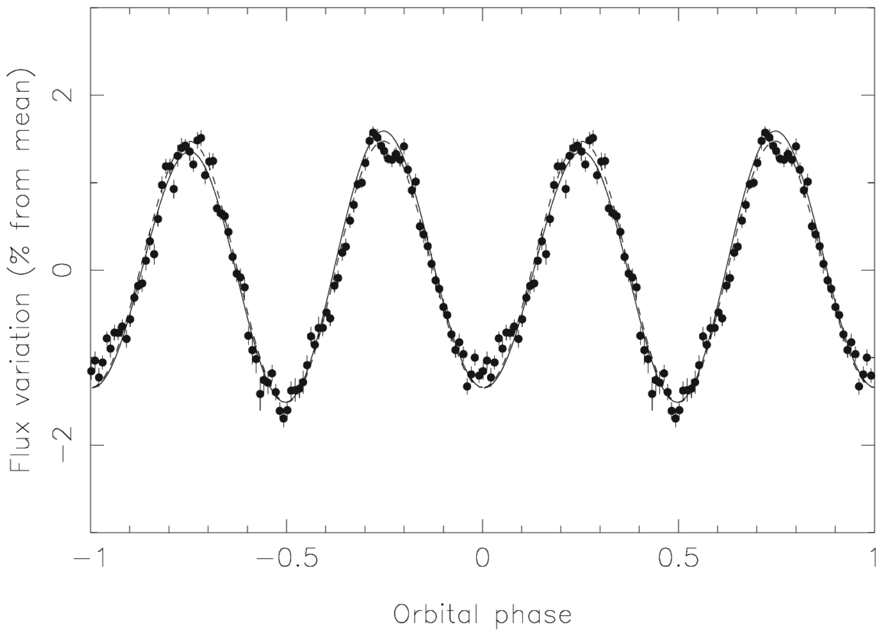

Figure 2. The light curve of KPD 1930+2752 after removal of the signal due to pulsations from Billères et al. (2000) with a model light curve (solid line) for the ellipsoidal variability assuming an inclination of 90°. The model light curve excluding Doppler boosting is shown as a dashed line.

WHT Measures Speed of Surface Vibrations on Stellar Corpses

Simon Jeffery (Armagh Observatory) and Don Pollacco (Queen's University of Belfast)

Using the William Herschel Telescope, Drs. Simon Jeffery and Don Pollacco have adapted a technique to measure how fast stellar surfaces vibrate, and have applied it to two of the Galaxy's newest class of pulsating stars. The results will appear shortly in the *Monthly Notices of the Royal Astronomical Society* (Jeffery & Pollacco, 2000).

Stellar remnants, the garbage of the Galaxy, include an enormous variety of stars, ranging from very cool supergiants to superhot white dwarfs and neutron stars. Most stars shine because nuclear reactions deep inside release huge amounts of energy as hydrogen is converted to helium. When the hydrogen fuel runs out, the star picks up a one way ticket to oblivion. But first, they attempt a brief nuclear comeback as they convert helium into carbon and other heavy elements.

Extraordinarily common examples of stars having a final nuclear fling are the subdwarf B stars. These are the nearly naked helium cores of low mass stars. They are smaller than hydrogen-burning stars, but larger than white dwarfs — the ultimate stellar corpse. Their surfaces are six times hotter than the Sun. It was a considerable surprise when the light output from some of these stars was discovered to vary with periods between 200 and 500 seconds (Kilkenny et al., 1997, O'Donoghue, 1999). These stars are now known either as subdwarf B variables — sdBV stars for short — or EC 14026 variables, after the first one discovered which had the catalogue number EC 14026–2647.

The sdBV light curves are very complicated, with a few to several tens of simultaneous frequencies. Such 'multiperiodic' oscillations are attributed to non-radial pulsations. These are vibrations of the stellar surface rather like the vibrations of a drum skin or a bell, where many different modes resonate at the same time. As the stellar surface moves up or down it cools down or heats up and hence becomes fainter or brighter. Adding up the effects of all the simultaneous vibrations over the visible hemisphere produces small changes in the light emitted towards the Earth. The same thing happens on the Sun, where thousands of simultaneous vibration occur, but the sdB vibrations have a much larger amplitude.

Light variations only provide an indirect view of the movement of the stellar surface. In many pulsating stars, such as Cepheids, the surface motion can be detected directly by measuring its speed towards or away from an observer. This is much easier when the pulsation amplitude is large and only one period is present, as in classical Cepheids. However, it is very important because it allows the mass of the star to be measured and it helps to explain why these stars pulsate. As soon as their discovery was announced, we wanted to know if the surface motion could also be measured for pulsating subdwarf B stars.

We set out to test this idea in 1997, obtaining our first observations with the William Herschel Telescope in 1998 October. Stellar surface velocities are measured using the Doppler effect. As the surface moves outwards, and hence towards the observer, its light is blue-shifted. These Doppler shifts were measured with a spectrograph called ISIS. A special feature of ISIS allowed us to make a continuous sequence of Doppler measurements with very short exposure times. Using conventional methods to read out the ISIS detector would have taken nearly as long as collecting the starlight, making the observations 50% efficient or less. 'Continuous mode' enabled us to reach efficiencies of over 80%. In just 10 hours of observing over two nights, we obtained 2600 spectra of PB 8783 and KPD 2109+4401, two sdB stars of the 13th magnitude.

We added all the spectra from each star together to make a template (Figure 1), and then measured the Doppler shift of every spectrum relative to its template. This was converted to a velocity. We then looked to see whether the velocity data showed any of the same periods as the light curves measured previously (O'Donoghue et al., 1998, Koen, 1998, Billères et al., 1998). Even with the WHT and our novel techniques, the measured velocities contain a lot of noise. We therefore had to use Fourier analysis to search for periodic variations. Specifically, we were looking for the *amplitude* of any variations with the same frequencies as those seen in the light curve.

Expecting only to find frequencies of the largest amplitude light variations, we were surprised to find some of the smaller light variations also showing up in the velocity data (Figures 2 and 3). Altogether, we identified two pulsation frequencies in KPD 2109+4401 and five in PB 8783, with amplitudes between 1.1 and 2.7 km/s. Some of these are probably a combination of two or more of the frequencies found in the light curve.

Like the light curve, each velocity measurement is an average of the projected velocity over the visible hemisphere. Every point on the surface will have a velocity which is the sum of motion due to several different vibrations which interfere with one another either constructively or destructively. The challenge now is to build a model of the non-radially oscillating surface which can uniquely reproduce the observed velocity and light curves.

Several sdB stars, including some EC 14026 variables, are also binaries. The spectrum of a main-sequence F star can be seen superimposed on that of PB 8783 (Figure 1). An additional surprise was that the average velocity of the sdB stars drifted slowly during our observing run. When we measured the sdB and F star in PB 8783 separately, we found the drifts to be in opposite directions (Figures 3 and 4). This could not be a systematic error; we may have stumbled on the reflex motions of the two stars as they orbit one another with a period of between 0.8 and 3.7 days. It was satisfying to find that pulsations are only seen in the sdB star and *not* the F star! Although KPD 2109+4401 shows no other evidence of having a companion, the drift of 9 km/s over 5 hours in our data may be the first evidence that it, too, is a binary.

High-speed spectroscopy with 4 m-class telescopes has proved to be a very powerful tool for exploring non-radial stellar oscillations. We have already extended the technique by observing with both the William Herschel and Anglo-Australian Telescopes — one after another — in order to improve the frequency resolution. We also intend to explore its application to other non-radially pulsating stars.

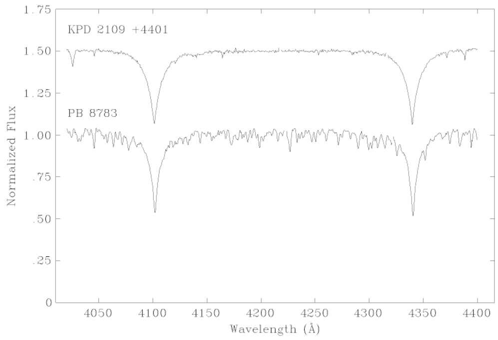

Figure 1. The mean spectra obtained for two pulsating sdB stars KPD 2109+4401 and PB 8783. The latter is a binary star; the faint spectrum of an F star can be seen superimposed on the sdB spectrum, which is completely dominated by broad hydrogen lines.

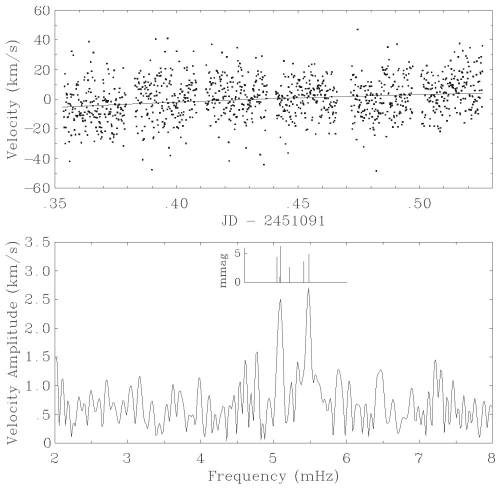

Figure 2. Radial velocities and amplitude spectrum of KPD 2109+4401 from WHT high-speed spectroscopy on 1998 Oct 4. A least squares solution to the slowly varying velocity component is shown in the top panel (solid line). The bottom panel shows part of the velocity amplitude spectrum. The inset light amplitude spectrum is taken from Koen (1998).

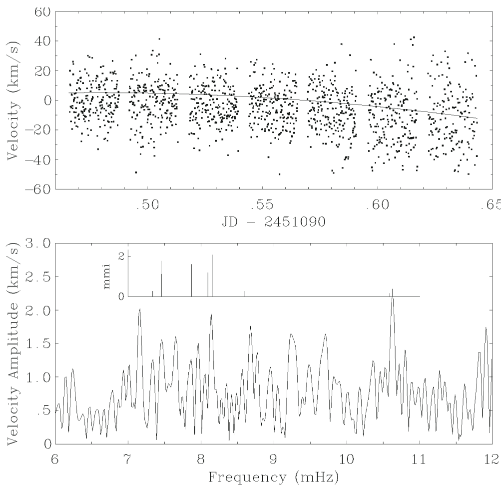

Figure 3. Radial velocities and amplitude spectrum of the sdB star in PB 8783. The least squares solution to the slowly varying velocity component is shown in the top panel (solid line). The inset light amplitude spectrum is taken from O'Donoghue et al. (1998). mmi denotes parts-per-thousand and 1 mmi equals 1.086 mmag.

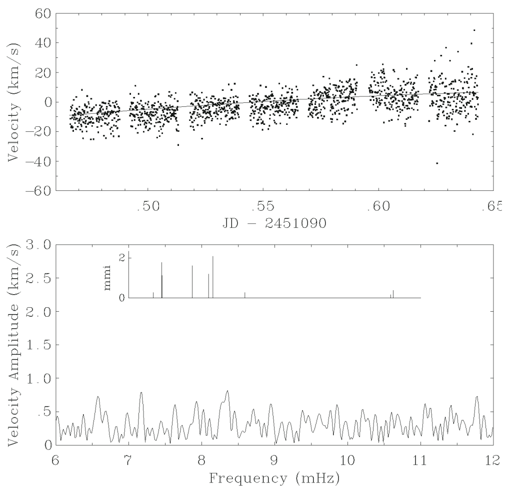

Figure 4. As Figure 3 for the F star in PB 8783.

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Now You See It and Now You Don't ! Comet LINEAR Blows Up in Full View of the JKT

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It's quite something to be able to observe regularly at somewhere like the Roque de los Muchachos Observatory. As a schoolboy I had visited the Isaac Newton Telescope at Herstmonceux no less than four times, before it was moved to La Palma. During these visits had dreamed of one day using it and, when I finally did, in 1985, it was to observe Comet Halley, which was something very special for me.

When I was assigned the time in La Palma on the JKT, I gave thanks for my extraordinary luck that the observations (a programme of quasar microvariability observations) were scheduled exactly at the perihelion of Comet LINEAR, or C/1999 S4 (LINEAR) as it is correctly known. This would be able to get data on the comet at the start of each night without interrupting the main programme. At the time I hoped that Comet LINEAR might become a reasonable spectacle. Never did I imagine that I would have a front seat for an amazing spectacle — but not the one that I had expected.

There has been something odd about Comet LINEAR right from the start. Comet LINEAR really is a first-time object from the Oort Cloud, despite the fact that the latest orbit from the Minor Planet Center seems to show it in a strongly closed orbit. In fact, it has fallen in from about 1 light year out, well into the outer part of the cloud. However, it has never behaved like a new comet. One expects an object like Comet LINEAR to be extremely gassy and brighten fast at large heliocentric distance, something that it did not do. In fact, apart from a short period before perihelion the brightening rate was always below average. According to HST observations taken three weeks before perihelion, the comet has very unusual composition. Rather than 80% water ice and about 10% CO ice, the proportion of CO ice is about 20 times lower, which explains the slow brightening at large distances from the Sun, as CO is the dominant volatile at these distances. The comet thus brightened only very slowly initially.

Again, although only the HST observations have been widely published, it seems that small fragments have been expelled from the nucleus for some months. Had this been more widely known it might have been realised that this comet was an extraordinarily fragile body compared to most comets. This made the comet a candidate to break-up at perihelion, the moment when the insolation is not just much greater, but also changes direction very rapidly, causing enormous thermal stresses on the comet's nucleus.

On July 23rd, the first night of the JKT run, the comet was in the throes of a minor outburst, and had reached magnitude 6, and was showing a quite spectacular tail. The JKT's CCD has a field of view of some 11 arcminutes and even in the short exposures that the comet's rapid motion allowed, the streamers flowed across the diagonal of the chip and out of the field, being at least 15 minutes long. In fact, the comet was so bright and condensed that observing it was a real problem. It saturated badly in a 5-second exposure. In the end, exposures of just 2 seconds with the R (red) filter were required.

On July 24th, a German astronomer visiting the Roque asked permission to visit the telescope with his girlfriend during the observations. I prepared to show them a spectacular comet. To my enormous chagrin, there was almost no tail to be seen. Much longer exposures could also be taken without getting near saturating. At the time the alarm bell did not ring, but it should have done.

On July 25th things started badly. There was a power failure shortly before sunset and all the computers went down. A lot of ING staff battled to get the systems up again. At 9:30 pm the control system was still not working and the observations were in great danger of not being made. Shortly afterwards, despite network problems and a slow system response, the TCS and ICS could be brought up, although with some missing tasks. In fact, it was not until 11:15 pm that everything was truly up and running again, by which time the comet would have set on the telescope. Thanks though to the efforts of Peter van der Velde and other, anonymous staff, and the advice of Neil O'Mahoney on the INT, the critical observations of the comet were saved.

To avoid wasting valuable time the comet was positioned on the chip as soon as it was too late to take flat fields. Even the very first images, with the sky half way to saturating the CCD, were enough to show that something odd was going on. The comet's inner coma was no longer teardrop shaped (the solar wind flowing around the comet's head causes this shape). In fact, the comet looked rhomboidal. As the sky darkened, it became clear that the innermost coma had a shape like a short, fat cigar.

My first thought was "Shoemaker-Levy". It looked just like those first images of Comet Shoemaker-Levy 9 after it was discovered. Now this kind of thing happens so rarely that my second thought was "too much imagination! Shut up or you'll make a fool of yourself!". I passed the images to Brian Marsden (an old and very respected friend) and waited for a reaction, with a copy to the CometLinear.com website, adding a "PS" saying that it looked like the comet was breaking up. Caution though caused me to ask for that comment not to be used in the Web. Next day I also discussed the observations with Javier Licandro, my Ph.D., who was planning to observe the comet that night in the infrared on the TNG. Neither Brian, nor Javier were impressed.

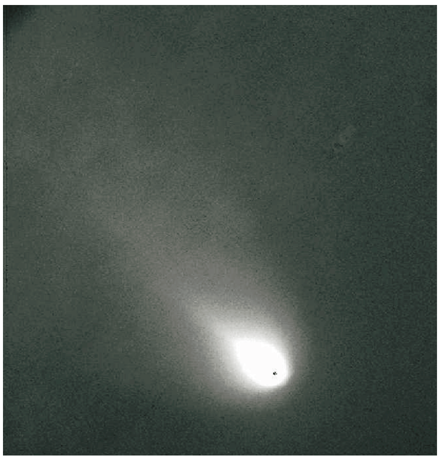
"Maybe I am getting excited about nothing", I thought. Both commented that the comet had been expelling small fragments and that this was probably just another such event. That night though, July 26th, would be decisive. If it was a fragment, it should be clearly visible, separated from the nucleus. If it was a fragmentation, then there should be a "string of pearls" effect, as in Shoemaker-Levy 9.

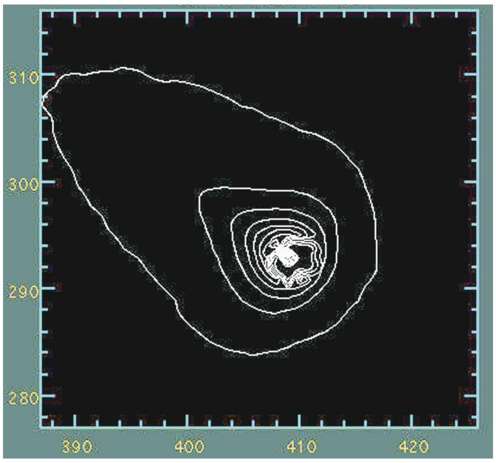
With some excitement, the telescope was pointed again as dusk fell. Was it all a mistake? Would the comet look normal again? The first very ghostly images showed that the comet was even more elongated than previously. All kinds of contour maps and 3-D surface maps were tried, looking for sub-nuclei, but none could be seen. At this point I was convinced that the comet had fragmented. But would anyone else be? I sent the images off to Brian again but, very unusually, did not get a response — in fact because the Minor Planet Center was preparing its latest batch of Minor Planet Circulars and absolutely swamped with work!

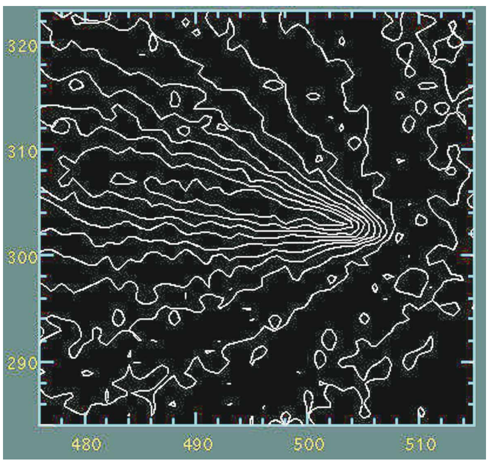
Estimating the size of the "cigar" I was able to get an idea of its expansion velocity — about 40 m/s. This is so slow that the cloud had to be of fairly heavy fragments of solid matter. In contrast, gas would expand perhaps as much as 50 times faster. It also led to the rather disconcerting conclusion that the break-up must have happened the previous evening — if only the comet could have been followed for a couple of hours before it set...

Once again, on the 27th, the telescope was swung to the comet during dusk in high expectation. Javier was now convinced that something very odd was happening and we made bets at dinner what it might be. By then I was convinced that the comet had completely broken up. We even speculated whether or not it would still be there to observe. It was, but even more extended and now much fainter. Several local amateurs sent in magnitude estimates suggesting that the comet had faded suddenly and was now a lot less condensed. This was consistent with a dying comet.

The elongation of the comet was increasing at a steady rate and there was still no hint of the string of pearls. This was it! After seeing two or three images come down from the camera I called Brian at his office and described what I was seeing. "I guessed that it might be you", he said. Brian pointed out that Comet Bennett, in 1974, had broken up in much the same way and added, encouragingly,







Figures 1–4. From top to bottom and from left to right: 1) JKT R-band image of Comet LINEAR on 23rd July. The central condensation showed the typical 'teardrop' form; 2) Contour levels of the comet's coma on 23rd August; 3) Raw JKT R-band image of Comet LINEAR on 26th July. The central condensation is now strongly elongated, with a very flat brightness distribution. Coma's brightness had also faded and its length increased; 4) Contour levels of the comet's coma on 26th August. The unusual elongated shape was the first evidence of the comet's complete break-up.

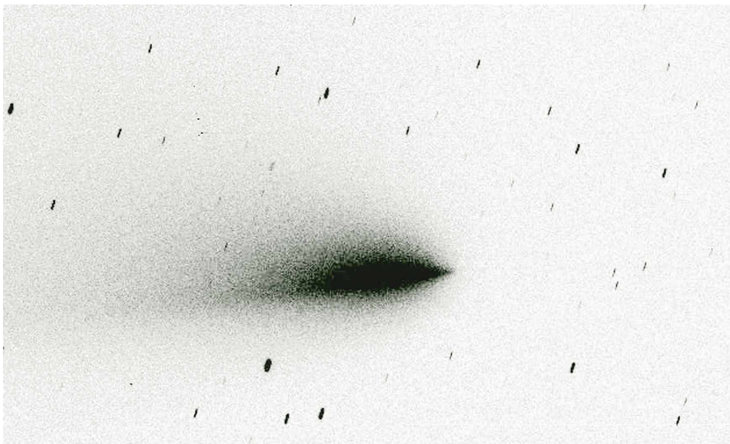



Figure 5 (left). This image, obtained on 1 August with the WFC on the INT, covers a field of view of 22 arcminutes and is processed to show the faint tail of the comet, which extends well beyond the edge of the field of view. Figure 6 (right). This another image, obtained on 1 August, is a 100-second exposure with the WFC on the INT. This section of the full image measures 4.5 arcminutes, equivalent to 110,000 km at the comet. This image is processed to show faint details in the coma of the comet. No features are seen in the image, which implied that no significant individual fragments more than a few metres across still emit gas. This demonstrates the catastrophic disruption of the nucleus.

"it's time that we put something out on this. Send something in, but don't stop observing". To avoid distractions, a long sequence of observations was programmed into the computer in several filters so that the only intervention required would be to re-centre the comet in the field occasionally as it moved.

Being cynical about such things and worried about being scooped, I prepared a note for the IAU Circulars with all haste. Within an hour, mostly taken up with resending the text twice because it arrived unreadable, the circular was out. Although a set of radio observations of the comet received top billing on that particular circular, the data was out and the JKT had beaten a lot of bigger and more costly telescopes to the draw.

Some astronomers were sceptical initially, but the following day confirmatory observations were published from three groups (Filipenko, Nakano & Javier Licandro's TNG observations). Images and e-mails came in from all around the world. An American amateur called Jim Vail had observed the initial stages of the break-up without recognising it; Ian Griffen in New Zealand obtained a wonderful confirmatory image. Since then the comet has faded dramatically. Visually, it dropped three magnitudes in about 5 nights and, in the JKT images, the inner core has got bigger and bigger and its surface brightness has dropped constantly until it barely registered in a 20 second JKT exposure in B or Z on the 31st.

Service observations of the Comet on August 1st proved scientifically very important indeed. With some American astronomers still doubting that the comet had even been disrupted and making highly negative statements to the press about the ING data, Romano Corradi and Neil O'Mahoney were able to take deep exposures of the comet with the Wide Field Camera on the INT. These were difficult observations with the comet low in twilight, but were deep enough to show that no large fragments of the nucleus had survived.

With a 5σ limiting magnitude of R=22.0, B=22.7, the absolute magnitude of the fragments could be no brighter than H=25. For icy fragments that are outgassing strongly the limiting size is just a few metres. Totally iceless fragments could be much larger as large as a few hundred metres in diameter, although the existence of such inactive fragments would suggest strongly that the death of the comet was due to exhaustion of volatiles.

The JKT and INT observations did however demonstrate that active fragments of some size had to exist given that the comet maintained a very sharp "spear-point" shape. It was thus evident that faint and unresolved fragments continued existing at this tip. This prediction was announced on IAUC 7474 and confirmed when the HST took a very deep integration of this area of the comet's head finding a number of faint cometessimals, the brightest of which was about 2 magnitudes fainter than the INT limiting magnitude. Further images with the VLT showed that there were at least a dozen detectable nuclei, although all of them were very faint indeed and unreachable to existing northern hemisphere telescopes.

This has been one of the very few occasions when the break-up of a comet has been followed in such detail. The results show that the nucleus, at least of Comet LINEAR, is far more fragile than had been suspected. This holds enormous implications for future space missions such as Deep Impact, which plans to launch a penetrator at the nucleus of 9P/Tempel 1. Already people had feared that the nucleus might not have the solidity to stop the penetrator, which could simply go straight through and come out the other side. Comet LINEAR will do little to calm such fears, even if it is probable that this was a particularly fragile object. ¤

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Lithium Trail Leads Back to the Big Bang

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Studies of lithium with the high resolution spectrographs UES and UCLES on the WHT and AAT have revealed a slow but steady rise in the Galactic lithium abundance from the earliest stars in the halo of the Galaxy up until the epoch at which the old disk population formed. After this period, prolific Li nucleosynthesis is apparent. Long-standing uncertainties over the contributions of galactic chemical evolution and the destruction of Li can now be addressed, and the primordial lithium abundance and ultimately the universal baryon density Ω_B can be inferred more reliably. The observations may also help clarify the roles of AGB stars and novae in more recent periods of galactic chemical enrichment.

Introduction

Studies by many workers following Spite & Spite's (1981, 1982) discoveries of an almost uniform Li abundance in the old stars of the Galaxy (e.g. Rebolo, Molaro, & Beckman, 1988) supported the interpretation of this abundance as the primordial one, at worst "hardly altered" (Spite & Spite, 1982). This interpretation required that any depletion of the stellar surface Li from a higher initial abundance be minimal. While ample evidence existed of Li destruction in *some* stars, the lack of a spread in halo dwarf Li abundances provided empirical evidence that destruction may have been minimal in these objects (e.g. Boesgaard & Steigman, 1985).

Classical stellar evolution models (e.g. Deliyannis, Demarque, & Kawaler, 1990) fitted this interpretation, showing that Li destruction in metal-deficient dwarfs with shallow surface convective zones would be minimal ($\lesssim$0.05 dex). However, the same models failed to explain numerous Population I star observations, and an alternative class of models possessing extra mixing implied that considerable Li depletion as high as 1 dex could have occurred in the halo stars. Other dissenting voices were heard. Deliyannis, Pinsonneault, & Duncan (1993) argued that there was a non-negligible spread in the Li abundances of the halo dwarfs that would not be consistent with a perfectly primordial composition. Thorburn (1994) found an even greater intrinsic spread $\sigma \simeq 0.10$ dex, and moreover claimed, as did Norris, Ryan, & Stringfellow (1994), that the abundances depended on both T_{eff} and [Fe/H]. Such dependences were contrary to the notion of a unique Li abundance in the halo stars, and thus undermined the association of the observed Li abundance(s) with the primordial one.

The Intrinsic Spread of ^{7}Li

Ryan, Norris, & Beers (1999) set out to obtain a highly homogeneous data set on a sample occupying only a narrow range of T_{eff}, [Fe/H], and evolutionary type. Restricting their sample to 6000 K $\lesssim T_{eff} \lesssim$ 6400 K and $-3.5 \lesssim$ [Fe/H] $\lesssim -2.5$, applying double-blind data analysis techniques, obtaining multiple high-resolution, high-S/N UCLES observations of the targets, and using multiple temperature indicators to minimise random errors, they achieved a formal abundance error as low as σ_{err}= 0.033 dex per star. These results have considerably higher precision than most previous Li measurements (for which typically $\sigma_{err} \simeq 0.06-0.08$ dex).

Excluding one previously known ultra-Li-deficient star, the objects exhibited a total observed spread σ_{obs}= 0.053 dex, considerably less than that found by Thorburn (1994). However, this 0.053 dex was found to be dominated by an underlying metallicity dependence, and the spread of the Li abundances about this trend is a mere σ_{obs} = 0.031 dex, and Gaussian in form. This corresponds to the spread in Li abundance *at a given metallicity*. Comparing this with the formal measurement errors of σ_{err} = 0.033 dex leads to the conclusion that the intrinsic spread in the stars must be negligible.

The very narrow spread of Li abundances constrains the impact of extra-mixing in so far as extra-mixing models predict a spread in the final Li abundances of a population of stars. The rotationally-induced mixing models of Pinsonneault et al. (1999) suggested that Li depletion by ~0.2–0.4 dex existed. As Figure 1 shows, the new data with their narrower spread (at a given metallicity) rule out rotationally-induced mixing models that exhibit even 0.1 dex median depletion. Previous results that gave contrary conclusions can be understood as arising from a mixture of stars having different metallicities and by poorer quality data.

The Underlying Li vs [Fe/H] Trend

Although Li GCE during the halo-forming era has often been ignored, we should not be surprised that it exists. With modern CCDs and large aperture telescopes, even small levels of ^{7}Li enrichment can be measured. Moreover, it is consistent with recently measured ^{6}Li abundances (Smith, Lambert, & Nissen, 1993,1998; Hobbs & Thorburn, 1997; Cayrel et al., 1999, Deliyannis & Ryan, 2000).

To examine Li GCE, Ryan et al. (2000b) obtained UES and UCLES data on 18 halo stars with

–2.0 ≲[Fe/H]≲ –1.0, in the same temperature range as the metal-poor sample, and compared the abundances with several GCE models. The Fields & Olive (1999a, b) model includes the most likely Population II sources of Li, the ν-process in supernovae and GCR spallation, and the models of Romano et al. (1999) incorporate many Population I sources, primarily the ν-process, AGB stars, and novae. Figure 2 shows the hybrid; it provides a reasonable fit to the data over the history of the Galaxy from [Fe/H] = –3.5 to –0.6. Mismatches at the highest metallicities may be due to the exclusion of the newly studied cool bottom processing of Li, and/or to sizeable uncertainties in the theoretical Li yields of novae.

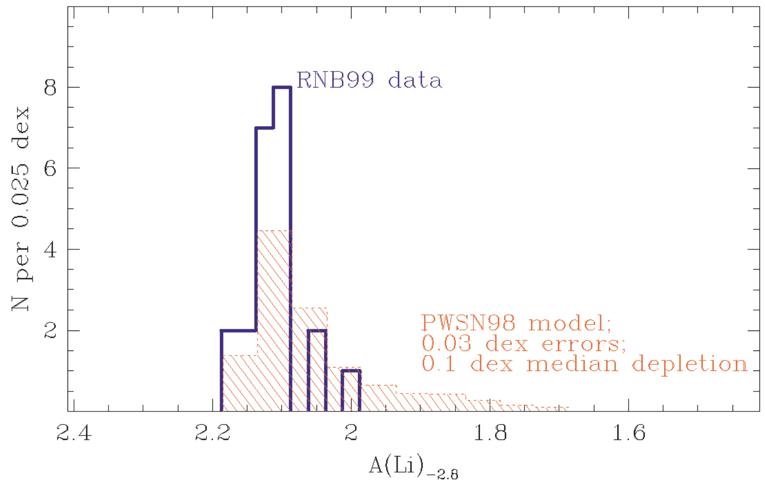

Figure 1. Spread in Li abundance A(Li) (at a given metallicity [Fe/H] = –2.8 after compensation for the [Fe/H] dependence of Li), compared with predictions for a rotationally-induced mixing model exhibiting a median depletion of 0.1 dex. The absence of stars in the tail of the theoretical distribution indicates that this particular model overestimates Li destruction.

The Primordial Li Abundance and Uncertainties

The new constraints on the stellar destruction of Li and its production over Galactic history permit a new calculation of the primordial Li abundance taking into account a wide range of random and systematic uncertainties. Beginning with the observed abundance for the most metal-poor stars, we apply corrections for the inferred GCE contribution (with uncertainties) and for stellar depletion. Uncertainties in the stellar temperature scales remain one of the largest sources of error, and in this analysis we adopt the zero-point of the IRFM scale of Alonso, Arribas, & Martínez-Roger (1996). We associate an uncertainty of ±0.08 dex with this choice, in recognition of the remaining difficulties in the temperature scales for halo dwarfs. These and the other effects lead us to infer a primordial abundance $A(Li)_p = 2.09^{+0.19}_{-0.13}$ dex, where the uncertainties resemble 2σ limits (Ryan et al., 2000a). The baryon-to-photon ratios corresponding to this range are in excellent agreement with those inferred from estimates of the primordial He abundance, but the range of deuterium measurements published in recent years present more of a challenge. Disfavoured high D/H values($\sim 20\times10^{-5}$) are compatible with the He and Li values, whereas the lowest values ($\sim 3.4\times10^{-5}$) are barely so. However, even slightly larger D/H values around $\sim 5\times10^{-5}$ are in tolerable agreement with the ^{7}Li and ^{4}He values (Ryan et al., 2000a). In any event, the inferred baryon density range,

$$\Omega_B = \frac{0.02-0.04}{(H_0/63\ \mathrm{kms^{-1}Mpc^{-1}})^2},$$

continues to lie 10 times below the value of Ω_M inferred from recent cosmological studies (e.g. Efstathiou et al., 1999).

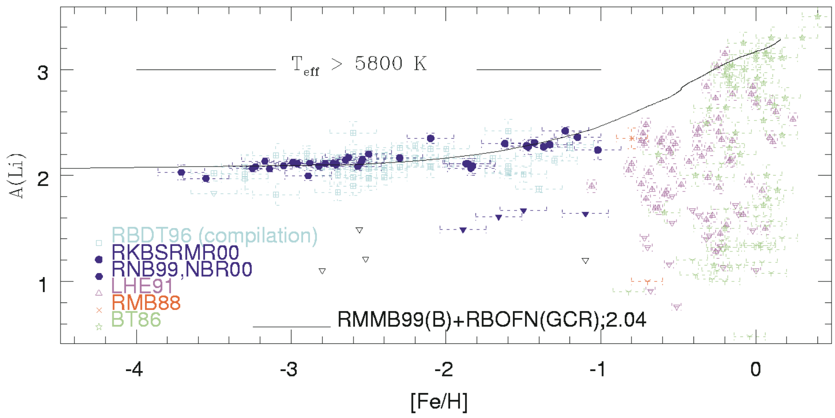

Figure 2. Evolution of Li with metallicity. Observations are for halo stars having T_{eff}>5800 K, to avoid lower-mass stars with Li depletion and to reduce the heterogeneity of the sample, and Population I stars from sources indicated. The model (solid curve) is a hybrid using the Population II contribution of Fields & Olive (1999a, b; Ryan et al., 2000a) with Population I evolution from Romano et al. (1999).

Acknowledgments

This work represents collaborations involving Prof J. E. Norris (Australian National University), Dr T. C. Beers (Michigan State University), Dr K. A. Olive (University of Minnesota), Dr B. D. Fields (University of Illinois at Urbana-Champaign), Dr T. Kajino (National Astronomical Observatory of Japan), Ms. D. Romano (SISSA, Trieste), Dr. F. Matteucci (University of Trieste), and Ms K. Rosolankova (The Open University, & St Hilda's College, Oxford), whose contributions are gratefully acknowledged.

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Photometric Redshifts: A Comparison of Methods

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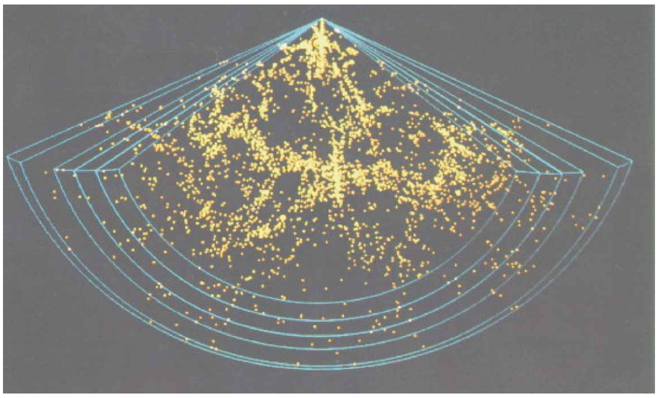
The advantages of being able to accurately extract red-shifts from photometric data is of great importance when wanting to complete large scale surveys of the night sky. In an exposure of minutes, rather than the hours needed for spectroscopy, we are able to gain colour data from a great number of astronomical sources at once. This is especially apparent with the advent of large format panoramic cameras such as the INT WFC, MegaCam at the Canada-France-Hawaii Telescope (CFHT) and, in the future, VISTA (Visible & Infrared Survey Telescope for Astronomy). If this data can then be used to accurately calculate the distribution of galaxies with red-shift, the large scale structure of the universe can be more readily determined.

Views of large scale structure have revolved around the 'Swiss cheese' analogy. Geller and Huchra (1989) showed that clusters of galaxies themselves tend to form in bubbled patterns enclosing empty regions measuring hundreds of millions of parsecs across (see Figure 1). The Swiss cheese model has also been explored by Moore et al. (1992), but consists of a 'meat-ball' distribution in a void background (see Figure 2).

There are two techniques that can be used when wanting to carry out red-shift calculations from photometric data; template fitting and the use of a training set. The first technique was initiated by Baum (1962) and later developed by Koo (1985) and Loh & Spillar (1986b). More recently Bolzonella et al. (2000) have published a very flexible method using the standard Spectral Energy Distribution fitting technique, which has been made into the publicly available code *hyperz*, (see *http://webast.ast.obs-mip.fr/hyperz/*). The second method has been developed by Connolly et al. (1995) by training a relation between galaxy colours and red-shifts via linear regression. Plotting the results of broadband photometry against red-shift showed a strong correlation of red-shift with UBRI colours up to approximately z = 0.6. Figure 3 depicts red-shift data as a function of three broadband colours. Blue dots correspond to zero red-shift galaxies, and red to a red-shift of 0.5. Each colour distinguishes red-shift intervals of approximately Δz = 0.1.

Before we continue to use photometric red-shift methods for further investigations we will compare the two techniques. In order to do this we have selected a 9 deg^2 area in the Elais N1 region. The data has been collected as part of the ING's Wide Field Survey (WFS) campaign in the Ug'r'i'z band-passes and reduced via the ING/CASU WFS pipelines (see *http://www.ast.cam.ac.uk/~wfcsur/pipeline.html*). Object catalogs have



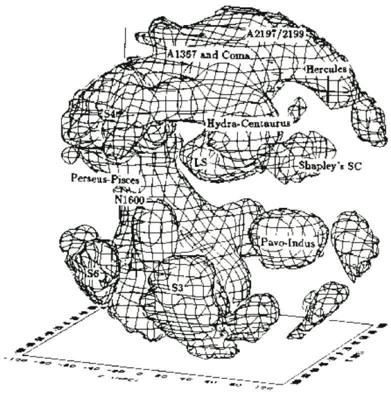


Figure 1 (left). Distribution of ~4000 galaxies in red-shift space, Geller and Huchra (1989). Figure 2 (right). Distribution of galaxies within 100 Mpc of the Milky Way, Moore et al. (1992).

been produced and formatted for use with the two methods. The method of Connolly et al. (1995) requires the use of UBRI magnitudes to which the Ug'r'i' were corrected using Fukugita et al. (1996). Magnitudes were also corrected for the effects of atmospheric extinction at the La Palma site (King, 1985). An estimation of reddening was made using Schlegel et al. (1998). The 4096×4096 pixel Lambert projection of dust in the North Galactic Pole was obtained via *ftp* to Berkeley (*ftp deep.berkeley.edu*). Using the available IDL interface, an estimation was made and averaged over the Elais region centred at RA 16 10 00 DEC +54 30 00 (J2000). E(B–V) was then converted to the required band-passes.

This same method of magnitude correction was also used for the *hyperz* code. However, a colour correction was not needed as the code allows you to map in the response of the filters used. *Hyperz* also accommodates the use of all the Ug'r'i'z wave-bands.

A simple way of testing the methods described is to compare the photometrically determined redshifts with those from direct spectroscopic measurements. Extensive searches of NED and LEDA found fifteen galaxies in the sampled Elais area with predetermined red-shifts. Once these red-shifts have been determined plots of z_{spec} against z_{phot} can be made and compared.

Galaxies exhibit a wide variety of morphological types, it's not certain that we can see all of them across the colour ranges, especially faint dwarf galaxies. Looking through the catalogs showed that more sources were present in the g' and r' bands than the U due largely to the poorer limiting magnitude reached in U. These extra sources could not be used with the Connolly method as it does not accommodate null detections. The result is a lower galaxy count (more so at the higher red-shifts). The *hyperz* method facilitates for effects such as age-metallicity links, the reddening law, flux decrements in the Lyman forest and the cosmological parameters H_0, Ω_0, Ω_Λ when building the synthetic spectra, these null detections are therefore accounted for here.

The mosaic nature of the WFC creates gaps between each chip in the array. Dithering the images or rotating the array on the sky are methods which can be used in order to remove these gaps, but these were not used for the Elais region. Our sample area includes many of these gaps which run all over the region. If it is assumed that the distribution of galaxies within these regions follow that of the hole sample then an estimation of the missing galaxies can be made.

At present we have surveyed the 9 deg^2 area using the training set method of Connolly (1995). Figure 4 shows the distribution of the galaxy red-shifts and reflects the increase of galaxies with volume and the sensitivity limit of the survey. Comparison of predetermined galaxy red-shifts with these photometric

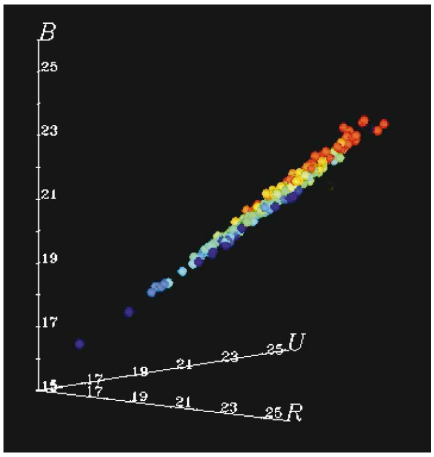


Figure 3. Three broadband colours as a function of red-shift, Connolly et al. (1995).

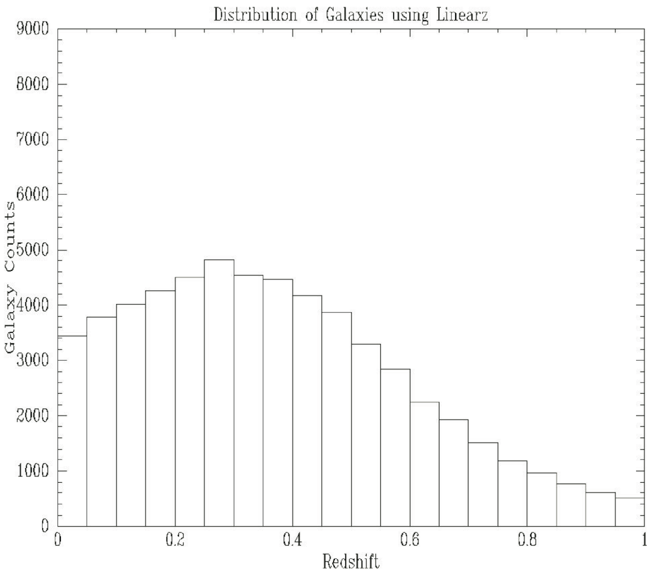


Figure 4. Distribution of galaxy red-shifts within the 9 deg^2 sampled area.

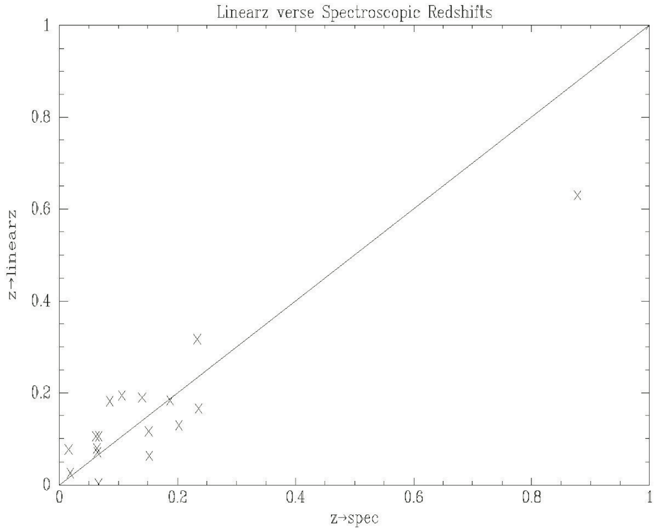


Figure 5. Plot of linear red-shifts against spectroscopic redshifts for objects in the Elais N1 region.

red-shifts (see Figure 5) suggest that the Connolly relation may need to be trained further to accommodate the different colours used. The dispersion in the fit is $\delta z=0.086$ compared to a $\delta z=0.057$ noted by Connolly et al. (1995).

In the near future we will have surveyed the entire 9 deg^2 area using both methods. Further plots of z_{spec} versus z_{phot} will show which method produces more accurate red-shift data, this method then being used to carry out red-shift surveys with INT data and to investigate areas such as the large scale structure more readily.

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TELESCOPES AND INSTRUMENTATION

First Light of INGRID on the WHT !

René Rutten and Gordon Talbot (ING)

The popularity of competitive IR imaging led to the development of a new IR imager for the WHT, called INGRID: the Isaac Newton Group Red Imaging Device. INGRID was conceived both as a moderately wide field imager as well as the prime detector to take high resolution images with the future adaptive optics system. This instrument was recently commissioned, with great success. INGRID saw its first light on the telescope in March 2000. Coincidentally, the first observations with INGRID occurred a little after the 200th anniversary of the discovery of infrared light by Sir William Herschel.

With the advent of INGRID the WHT possesses a powerful state-of-the-art IR imager for wavelengths between 0.8 and 2.5 micron. At the heart of INGRID is a 1024 × 1024 pixel HgCdTe “Hawaii” array from Rockwell. Its field-of-view is a luxurious 4.3 by 4.3 arcmin, which makes it very attractive for moderately wide-field imaging and small scale survey activities. The corresponding pixel size in the Cassegrain focus is 0.24 arcsec, designed to sample the typical good seeing conditions well.

INGRID has a closed-cycle cooler as well as a liquid nitrogen tank to achieve the required low temperatures of 77 Kelvin for the detector and the optics. The closed-cycle cooler is essentially a single-stage refrigeration unit whereby the heat is taken away through high pressure helium pipes that run from the telescope to a heat exchange unit and pump outside the telescope building. Liquid nitrogen is used to achieve fast cool-down of the instrument and when INGRID has to work under minimum vibration conditions, for instance when used in conjunction with the adaptive optics system.

INGRID will be deployed at two focal stations: at the (folded) Cassegrain focus and at the Nasmyth focus, integrated with the NAOMI adaptive optics system.

In the Cassegrain focus INGRID is mounted on the side of the Acquisition and Guiding unit together with other Cassegrain mounted instruments such as the ISIS spectrograph or

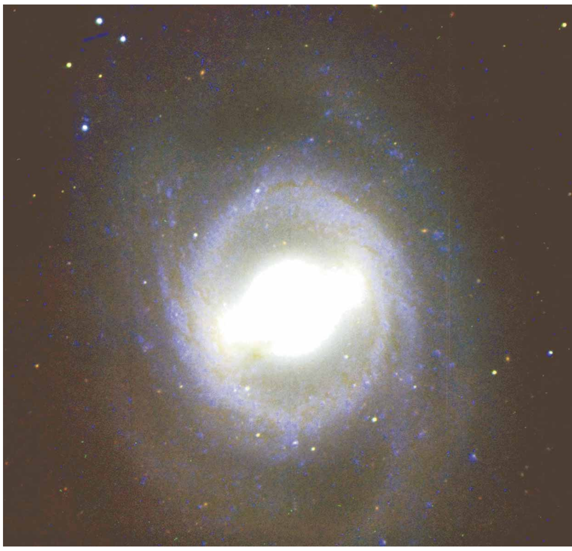

Figure 2. This false colour image, acquired on the first nights, shows the morphology of the barred spiral galaxy Messier 95. Young stars and sites of current star formation show up as blue regions, with the inner ring featuring prominently. The infrared light, measured with INGRID, traces dustlanes in the galaxy, and the older stellar populations. The dust lanes, lacking blue emission, are seen as brownish red in the image; the bar is made up of old stars and shows up as white. Picture credit: Johan Knapen (ING and University of Hertfordshire).

Figure 1. The proud INGRID commissioning team of engineers and astronomers (and the Tasmanian Devil Mascot) in the WHT control room during the first successful observations.

Figure 3. INGRID mounted on one of the WHT folded Cassegrain foci (top right). The instrument on the Cassegrain focus is SAURON. Picture credit: Rainer Girnstein.

visiting instruments such as SAURON. A flip mirror reflects light from the telescope into INGRID. At the opposite side of the A&G unit there is the Auxiliary port optical camera. The standard Cassegrain instrumentation package therefore makes a very powerful setup, combining optical spectroscopy with optical and IR imaging without the need of an instrument change. It is our intention to have the instrument available as much of the time as possible at Cassegrain. But there will of course be periods when INGRID will be used for adaptive optics observations in the Nasmyth focus.

The INGRID optics consist of warm collimating fore-optics that are interchangeable to accommodate the f/11 Cassegrain focus and the much slower adaptive optics focus. There are two filter wheels and a pupil-stop wheel. A pupil imager is foreseen as well to allow accurate alignment, particularly for adaptive optics, but this option is not commissioned yet. Available filters are broadband Z, J, H, K and K-short, and narrow band H continuum, [FeII], Bracket-gamma and K continuum. More narrow band filters are on order. At the time of writing the large volume of commissioning data is still being worked on. A preliminary users manual and other information can be found at: *http://www.ing.iac.es/Astronomy/IR/INGRID/*

Development of INGRID has been an interesting experience, with many ups-and-downs. The instrument got tangled up in the closure of the Royal Greenwich Observatory, which resulted in significant delays as people left and priorities shifted. In the end there was no alternative as for ING to complete the instrument in-house, on La Palma. With assistance from the Astronomy Technology Centre in Edinburgh and the Spanish Instituto de Astrofísica de Canarias on Tenerife the ING, thanks to the huge amount of effort and enthusiasm of everyone involved, brought the instrument to fruition. Despite the tribulations it is satisfying to note that INGRID took its first glance of the universe only

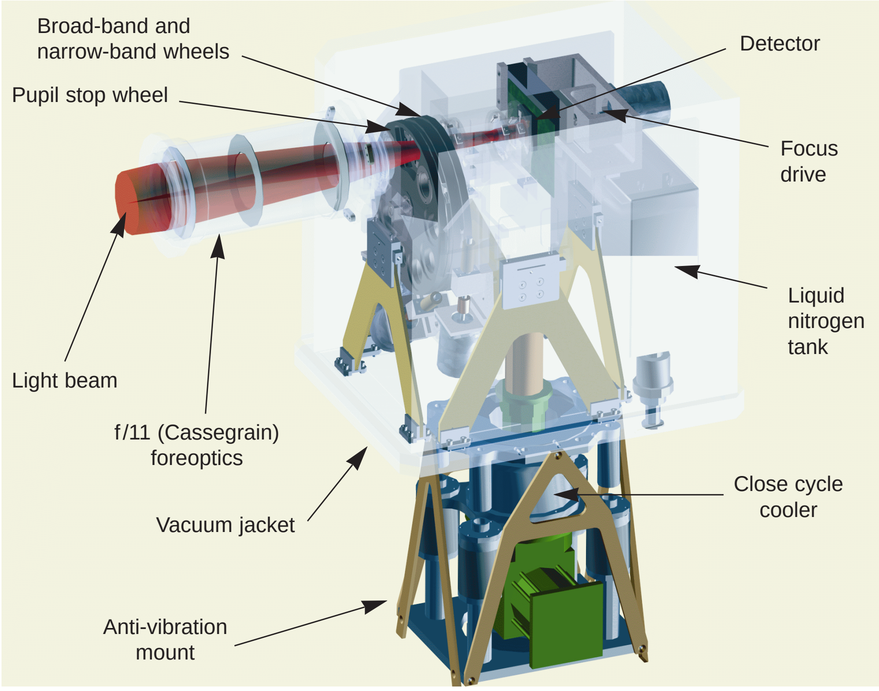

Figure 4. A 3-D transparent model of INGRID showing in red the light beam from the telescope focusing on the infrared detector. Picture credit: Paul Jolley (ING).

minutes after opening the dome on the first commissioning night. This marked the start of an almost faultless commissioning run.

Funding for INGRID has come from PPARC's instrument development line, and PPARC have been most supportive during the difficult development phase.

The success and popularity of this new instrument may be measured from the immediate science exploitation shortly after commissioning, and from the many requests to use INGRID during the following semester. This has led to an oversubscription of UK bright time on the WHT for semester 2000B of more than a factor 6 (!), something we've never seen before.

Two early science examples obtained with INGRID are shown in the accompanying pictures: Figure 5 shows observations of the massive galaxy cluster Abell 2218 with various gravitational arcs around the most massive galaxies. The second example, Figures 2 and 6, is that of the relatively nearby galaxy M95, combining optical and IR images, bringing out star-forming regions and detailed galaxy morphology.

Although having been commissioned in the Cassegrain focus, INGRID is not finished yet. First of all at the time of commissioning INGRID's data acquisition system was a stand-alone system controlled from a Unix Sparc station. The final system will have a higher level of integration with other parts of the observing system and more functionality built in (such as windowing).

Also one component of the collimating fore optics will need to be replaced. The aspheric lens in the original design turned out to be very difficult to manufacture to the tight tolerances, and therefore a backup lens was used instead. Now the aspheric lens has been delivered and, if passed acceptance testing, we plan to install it early next year. This will provide somewhat better image quality, but more importantly, the K-band thermal background is expected to be lower.

And of course INGRID is still awaiting commissioning with the NAOMI adaptive optics system in August and September.

Finally, it's worth mentioning the 'heroes' of INGRID: Chris Packham played a key role as project scientist. He has recently taken up a post at the University of Florida, but will be back to observe with 'his' INGRID. Mechanics and optical alignment work was largely carried out by Kevin Dee, Paul Jolley, Mariet Broxterman and Bart van Venrooy. Sue Worswick (ATC) and Richard Bingham (UCL) helped address various optics-related problems and queries. Peter Moore (with assistance from Derek Ives at the ATC) brought the detector under control, and Simon Rees, Matthieu Bec, Guy Rixon, Robert Greimel and Marti Pi i Puig (IAC/GTC) ensured that there was software to control the instrument and the detector. Also we should not forget the efforts initially at the Royal Greenwich Observatory, where Simon Craig (now ATC) was project manager and Keith Thompson (now Stanford) was project scientist when INGRID was kicked off. ¤

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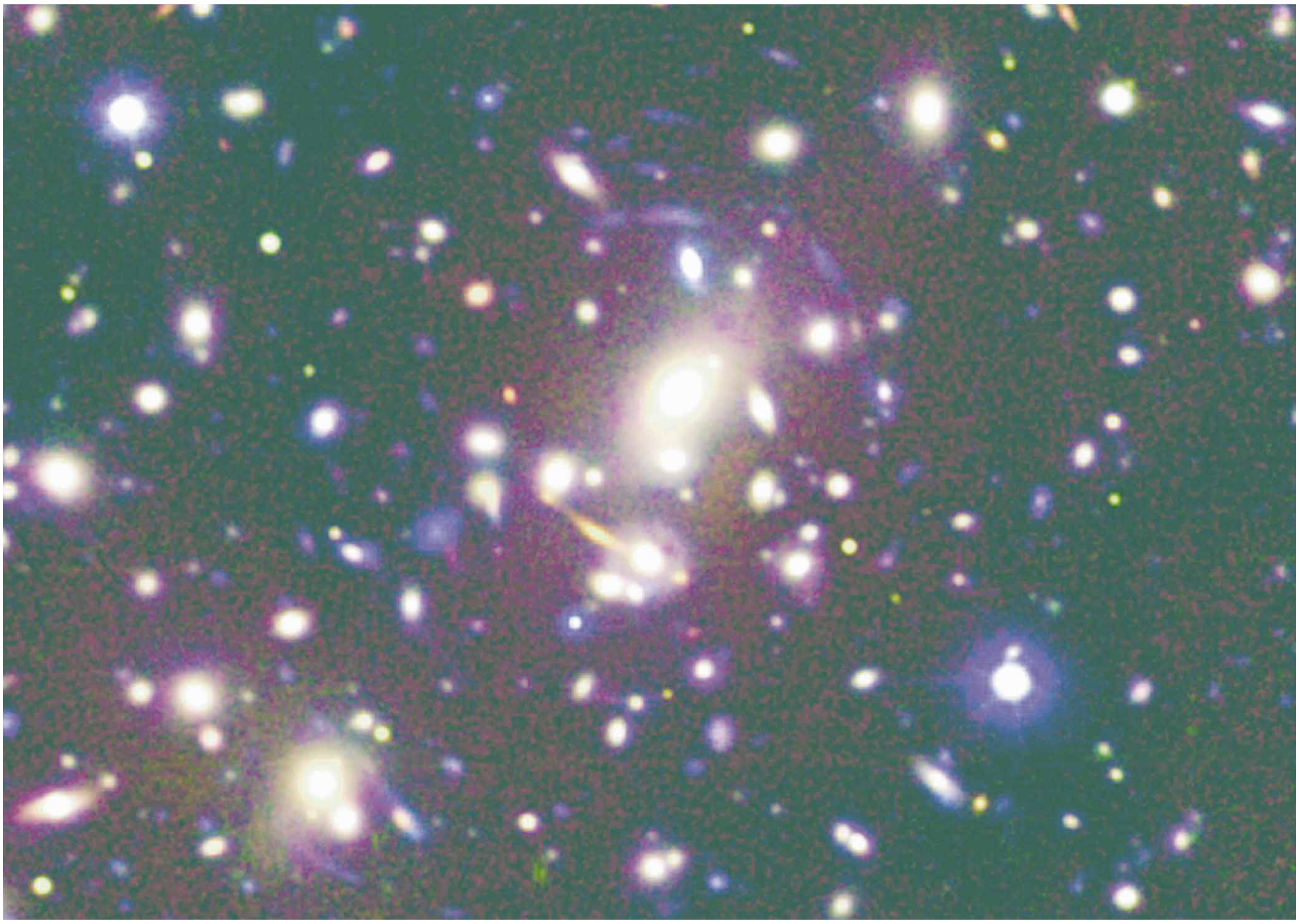

Figure 5. This image is a combination of a blue (B-band) frame acquired using a CCD on the WHT Cassegrain focus with two near-infrared exposures in the J- and K-bands obtained with INGRID with the B (0.4 µm), J (1.2 µm), and K (2.2 µm) images coded as blue, green and red. The field of view of this image is 3 arcminutes, corresponding to 2 million light years across at the distance of the cluster. The INGRID exposure times totalled 4 hours in J and 2.5 hours in K under good sky conditions (better than 0.8 arcsecond seeing). Picture credit: Ian Smail (University of Durham) and Chris Packham (ING).

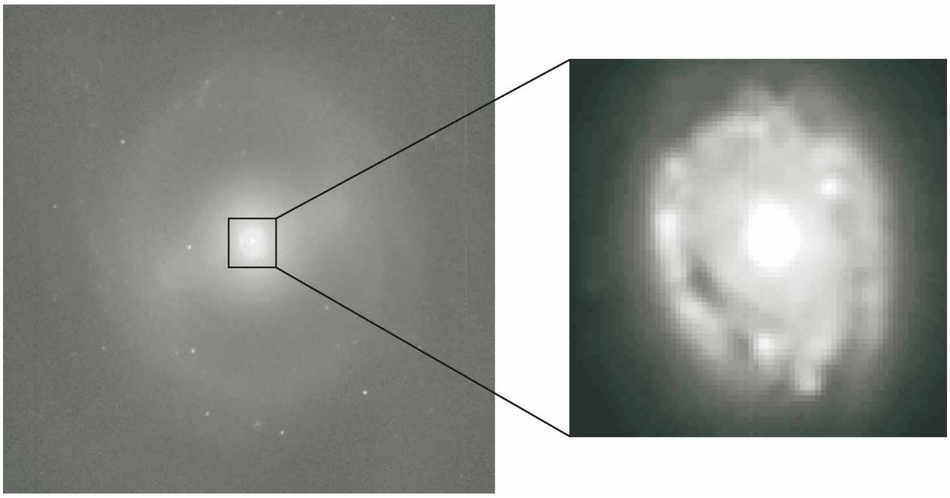

Figure 6. The image on the left is an INGRID J-band image of M95. The inset on the right shows the nuclear ring of enhanced star formation (see also Figure 2). Picture credit: Johan Knapen (ING and University of Hertfordshire).

NAOMI Progress

René Rutten and Gordon Talbot (ING)

NAOMI has just arrived on La Palma after a long and tortuous trip from Durham to Portsmouth, to Bilbao, to Cádiz and finally to the Canary Islands, sailing the Bay of Biscay and the Atlantic. The Nasmyth Adaptive Optics system for Multi-purpose Instrumentation, NAOMI, is the common-user adaptive optics system for the William Herschel Telescope and its arrival on La Palma heralds the start of an intense commissioning period. Prior to this, an immense amount of work has been carried out over the past few years in the design, manufacture and testing of all parts of the system that build up the complex equipment. Teams from the University of Durham and the UK-ATC (and in the early days also from the RGO) have converted the original concept into a reality of hardware and software. The following weeks will have to prove that NAOMI is ready to sail the skies.

In brief, NAOMI will deliver an adaptive optics corrected focus and is situated in the GHRIL (Ground Based High Resolution Imaging Laboratory) Nasmyth focus. The specification of the system focuses on delivering diffraction limited image quality with high Strehl ratios at IR wavelenghts. The specification and technical performance of NAOMI is expected to be of such high quality that, in combination with the stable sky over La Palma very significant improvements in image quality will also be delivered in the future at visible wavelengths. NAOMI is funded from PPARC's instrument development line.

NAOMI is not really an instrument in its own right, as alone it will not deliver science. It will be used in conjunction with the INGRID IR camera to deliver diffraction limited IR images. Further future developments include the addition of a coronagraph and (very likely) the addition of an optical integral field spectrograph. These instruments will provide astronomers with state of the art tools for observations at the highest possible spatial resolutions.

Initially NAOMI will rely on finding natural guide stars on which to measure the wavefront distortions. We hope that in the future a laser guide star system will come into operation to open up nearly the full sky to adaptive optics correction at optical and near IR wavelengths.

The accompanying pictures show NAOMI arriving on La Palma on 4 August and transport to GHRIL. ¤

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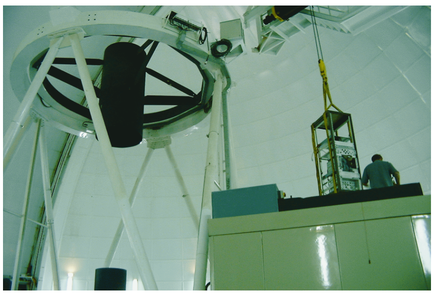


Figures 1–8. From top to bottom and from left to right: 1) NAOMI arrives in the port of La Palma; 2) Alan Chopping and Raúl Concepción proudly show the NAOMI cargo; 3) Arrival at the observatory; 4) First stop at the INT; 5) NAOMI is transported to the WHT; 6) Carefully lifted to the instrument platform; 7) Set up at GHRIL, its new home; 8) Some of ING staff helping during first setup in the GHRIL room.

S-Cam Update – Novel Capabilities for Resolving Old Problems !

Nicola Rando (ESA) and Peter Moore (ING)

In a previous article in this newsletter (*ING Newsletter*, No. 1, p. 13) we presented the novel Superconducting Tunnel Junction detector (STJ). A novel technological advance ready to open up the skies for new discoveries. Since then much work has been done by the team at ESA to improve S-Cam and the third run of this camera has been successfully completed.

The main changes in S-Cam 2 concern the increased resolving power (now of order 8 at 500 nm), the higher maximum count-rate sustained by each of the electronics channels (now equal to 5 kHz), a simplified setup and alignment procedure and a number of improvements in the Graphical User Interface software. The camera design is based on a bottom loading ^{4}He cryostat hosting an adsorption ^{3}He cooler. A dedicated optical collimator unit interfaces the camera focal plane to the Nasmyth focus of the Ground High Resolution Imaging Laboratory (GHRIL) of the WHT.

A plate scale of 0.6 arcsec/pixel was selected to match the telescope point spread function (typically around 1 arcsec). The optical unit is based on a reflective section and on a lens objective. Two filter wheels are available with neutral density and narrow band filters. The front-end electronics is based on 36 charge sensitive preamplifiers and related shaping stages working at room temperature: these allow to individually bias and read-out each STJ of the array. Optimised shaping stage filters allow to maximise the signal to noise ratio without penalising the count-rate capability of the electronics (now increased to 5 kHz/channel). Each channel has a peak detection unit and an analog to digital converter which allow us to perform pulse height analysis on each detected photon. Every event is then associated with a highly accurate time of arrival provided by a commercial Global Positioning System receiver. The electronics system is controlled via a dedicated data acquisition computer, which is then interfaced with a remote control PC. Such a control PC functions as Graphical User Interface and allows the remote control of the main instrument functions (from the telescope control room), including the array operating parameters. The data storage takes place on the same unit, which also provides some limited data analysis capability (data 'quick-look' functions).

As a consequence of the high detector responsivity and detection efficiency, the rejection of thermal infrared photons is crucial for the camera performance, directly influencing the resolving power of the instrument. While the expected sky background flux at the Nasmyth focus does not represent a major problem (with an expected integral number of counts of order 50 counts per second, per pixel), the thermal radiation emitted by warm parts in the field of view of the array would affect the system performance. In order to minimise this degradation mechanism, adequate IR filters must be used. In this latest configuration, S-Cam 2 adopts two KG2 glass filters of different thickness, cooled at a temperature of 12 and 2 K respectively. A third silica element is located in front of the focal plane array and maintained at 0.32 K. The optical entrance window of the cryostat is sapphire, with standard ARC's on one side and a multi-layer IR filter on the opposite side. Mainly due to the presence of these filters, the overall camera throughput in the nominal band-pass is of order 25%. Further development work is ongoing in order to improve the efficiency of the IR filters.

In December 1999 and April 2000 a series of astronomical demonstration campaigns were completed at the WHT focusing on the astronomical exploitation of the camera rather than on engineering aspects. The campaigns demonstrated stable operations from all the 36 elements of the array and a performance level

S-Cam 2 Characteristics

Band-pass: 350 – 650 nm (at 10% photon collection efficiency)

Provided data per detected event: Wavelength, arrival time, pixel identification

Resolving power ($\lambda/\Delta\lambda$ (fwhm)): Of order 10 at 300 nm

Event time accuracy: 5 µsec (absolute time reference via GPS)

Maximum count rate: 5 kHz / pixel

Camera field of view: 4.0 × 4.0 arcsec^2 (plate scale = 0.6 arcsec / pixel)

Instrument installation: Nasmyth focus (f / 11) – William Herschel Telescope

Observation time: In excess of 10 hours (cooler hold time)

Camera focus adjustment: Via telescope secondary mirror and dedicated optical unit

Camera guiding: Auto-guider

Filter wheel: 2 sets of 8 filters on 2 independent wheels

On-line data analysis: 'Quick-view' software installed on control PC

Data storage format: FITS format (via control PC) fully equivalent to what was recorded in the laboratory during the integrated system testing. One of the first astronomical objects observed during these campaigns was UZ For, one of a class of short-period binary systems known as polars or AM Her stars. The two stars which constitute this binary system are very different: a low-mass dwarf star cooler than our sun but which is still burning hydrogen in its core, and a much smaller stellar remnant known as a white dwarf. White dwarfs, the evolutionary end-point of a sun-like star, typically contain about as much mass as our own sun, but squeezed into a volume about the size of the Earth. In the case of polars, they are also highly magnetised, with surface magnetic field strengths ranging from 10 to 70 MG. The two stars are so close that they may orbit around each other in only a few hours, with matter being drawn off the ordinary dwarf star onto the surface of the white dwarf, giving off X-rays in the process. The white dwarf rotates synchronously with the binary period and its strong magnetic field prevents the in-falling matter from forming an accretion disk. Such systems are ideal candidates for study with S-Cam since they display a rich variety of spectral and temporal variations in the optical, due to the emission, absorption and occultation effects of the various system components: the dwarf star, accretion stream, and hotspot. While this makes them interesting from an astrophysical point of view, the requirement to combine high time-resolution with medium resolution spectroscopy has made them difficult to study using traditional dispersion spectroscopy/CCD techniques. S-Cam's combination of energy sensitivity and millisecond timing capability —plus its exceptional detection efficiency— make it highly suited to the study of these binaries. Figure 1 shows an S-Cam observation of the eclipse transition of this 127 minute binary UZ For in three energy bands (low, medium and upper). The energy bands were defined by dividing the full energy range into three bands (i.e. wavelength) intervals. The low energy band extends from 1800 nm to 620 nm; the medium energy band extends from 620 nm to 525 nm and the high energy band from 525 nm to 215 nm. It should be noted that the S-Cam photon collection efficiency at wavelengths longer than 750 nm and shorter than 325 nm is below 1%, while it peaks at 525 nm, just above 25%. The data, provided by all the pixels of the array, have been rebinned into 3 second time intervals for the sake of clarity. The eclipse corresponds to the white dwarf passing behind the normal dwarf star, which itself contributes very little light. The extremely sharp eclipse transition demonstrates that most of the emission is coming from a hotspot on the surface of the white dwarf. Just after the onset of the eclipse, a ledge-like structure is seen in the light curve that persists for a few seconds before falling off less sharply; this is probably the contribution from the white dwarf's photosphere.

In conclusion, the capability to provide simultaneously imaging, arrival time and spectro-photometric information make Superconducting Tunnel Junctions a good candidate for the next generation of detectors for optical astronomy. Ta-Al based devices have demonstrated single photon counting capability at wavelengths longer than 2 μm and responsivity ranging from 10^4 to 10^5 e^-/eV at an operating temperature of 0.3 – 0.5 K. On this basis, 6×6 Ta arrays with 25×25 μm^2 pixels have been fabricated and successfully operated in the visible, UV and X-ray regime, showing uniform performance and demonstrating the possibility to perform multichannel operations. The detectors do not have any significant cross-talk between adjacent pixels, while the Josephson current of the pixels can be satisfactory minimised at a common magnetic field intensity.

The instrument has now demonstrated its capability of producing astronomically relevant data. The typical camera applications capitalise on the specific characteristics of Superconducting Tunnel Junction detectors, with particular emphasis on the time resolution and simultaneous spectro-photometric capabilities (e.g. study of time variable objects, such as pulsars and binary systems). Despite the presently limited FOV and the modest spectral resolution, S-Cam 2 has provided valuable astronomical results during a series of observations conducted at the WHT.

The camera design has continued to evolve in parallel with the detector array development, with particular regard to larger array formats and innovative read-out schemes, allowing a significant enlargement of the related FOV. While larger format arrays can be produced within the limits of the present fabrication technology, the current front-end approach may require significant changes in order to read-out in excess of 10×10 elements. Parallel development activities are ongoing in order to determine alternative read-out schemes, thus opening the way to considerably larger format arrays. Additional development work is underway in order to improve further the wavelength resolving power by using more effective IR filters and/or by modifying their configuration inside the cryostat. In addition, the migration to lower energy-gap superconductors, with a commensurate increase in resolving power is now under study. Finally, a considerable effort is being invested in simplifying the instrument operations, by limiting the need for cryogenic liquids and by adopting innovative cryogenic technologies. Such changes will allow the operation of future generations of this type of camera at remote observation sites as common user facilities.

Further information on STJ detectors and S-Cam can be found at the following URLs:

http://astro.estec.esa.nl/SA-general/Research/Stj/STJ_main.html

http://astro.estec.esa.nl/SA-general/Astronews/37-html/an37.html#stj

ftp://astro.estec.esa.nl/pub/sciproj/dmartin_ltd8.pdf

We acknowledge the key contribution of other members of the Astrophysics

Division of ESA, at ESTEC. In particular J. Verveer and S. Andersson who provided engineering support during the instrument development and at the telescope, and P. Verhoeve and T. Peacock for the optimisation of the detector performance and its detailed evaluation. The astronomical observations performed with S-Cam and the data interpretation have been carried out by F. Favata and M. A. C. Perryman, supported by A. Reynolds. ¤

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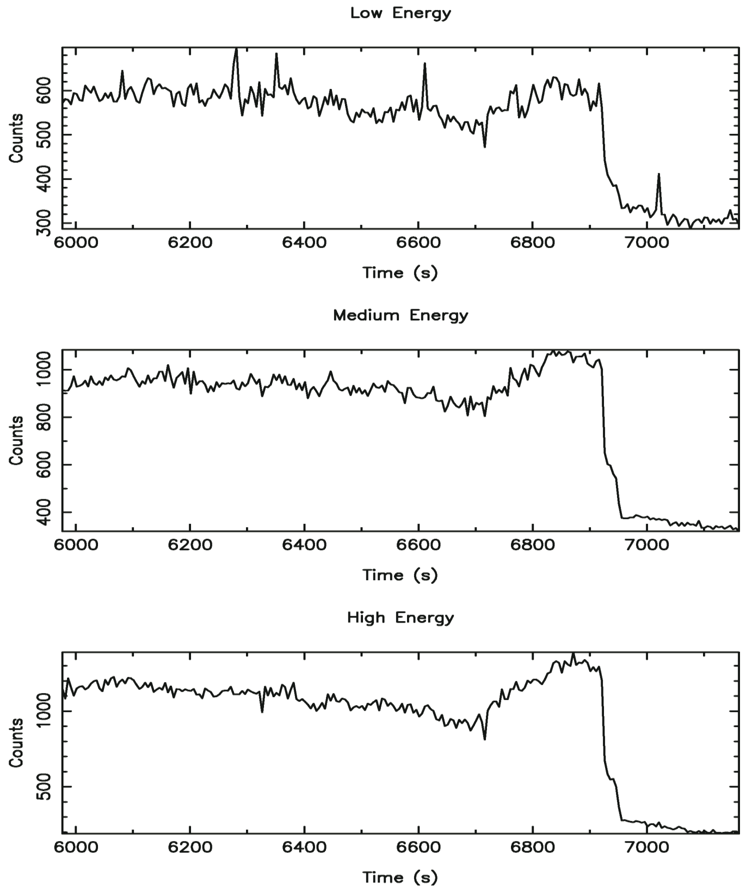

Figure 1. Eclipse transition of the binary UZ For in three energy bands (low, medium and upper). The low energy band extends from 1800 nm to 620 nm; the medium energy band extends from 620 nm to 525 nm and the high energy band from 525 nm to 215 nm. The counts were provided by all the 36 elements of the array, without any filtering procedure.

INTEGRAL: A Simple and Friendly Integral Field Unit Available at the WHT

Begoña García-Lorenzo[1], Santiago Arribas[2] and Evencio Mediavilla[2]

[1]: Isaac Newton Group of Telescopes (ING); [2]: Instituto de Astrofísica de Canarias

Integral-field spectroscopy (IFS) has merited much attention in recent years due to its advantages with respect to classical *sequential* 2-D spectroscopic techniques (e.g., long-slit scans, Fabry-Perot) when studying relatively small extended objects. IFS is able to *simultaneously* obtain a spectrum for each spatial sample of a two-dimensional field.

Most of the advantages of the IFS technique are direct consequences of the simultaneity when recording spatial and spectral information. Indeed, there is no need to worry about the differential atmospheric refraction, nor to adapt the slit width (spectral resolution) to the seeing conditions. The configuration of IFS makes unnecessary an accurate centering of the slit. The simultaneity does not only imply a more efficient way to observe but, more importantly, it guarantees a great homogeneity in the data. Several implementations of the IFS technique have been developed, based in the use of fibres, microlenses, micro-mirrors, or mixed solutions.

Early implementations of fibre projects at the Roque de los Muchachos Observatory were led by Peter Gray more than a decade ago. During all this time, the WHT has played an important role in the development of the IFS. Several fibre IFS instruments have been built (HEXAFLEX, Arribas et al., 1991; 2D-FIS, García et al., 1994, and now INTEGRAL, Arribas et al., 1998a). More recently SAURON (de Zeeuw et al., 2000), which is based on the microlenses approach has also been successfully used at the WHT. Future projects include TEIFU and OASIS, which combine the advantages of IFS and AO.

INTEGRAL

INTEGRAL is used in combination with the WYFFOS spectrograph (Bingham et al., 1994), and it is mounted in the Nasmyth 1 platform (GHRIL) of the WHT (see Figure 1).

In the standard configuration three fibre bundles (see Figure 2 for their main characteristics) are simultaneously connected at the entrance *pseudoslit* of the WYFFOS spectrograph. The bundles can be easily interchanged at the focal plane, with an overhead of a few seconds. Hence, depending on the prevailing seeing conditions and/or spatial requirements, the instrument can be easily optimised for the scientific program. The bundles can also be oriented to the desired sky position angle.

For any particular grating the spectral resolution depends on the fibre bundle. This is a direct consequence of the different sizes of the fibres. Table 1 lists the mean spectral resolution and linear dispersions for different gratings and bundles.

Due to the fact that the fibre bundles are directly connected to the focal plane without the need of pre-optics (optical derotator, focal enlarger/reducer, etc), INTEGRAL + WYFFOS is relatively efficient (1 count/s/Å for a 15 mag object at λ = 5000 Å). The focal ratio degradation (FRD) produced by the fibres is used to convert the f/11 input from the telescope to the f/8 of the WYFFOS collimator. As WYFFOS is a very suitable instrument, overheads are minimal. More details on the instrument are found in Arribas et al. (1998a, b).

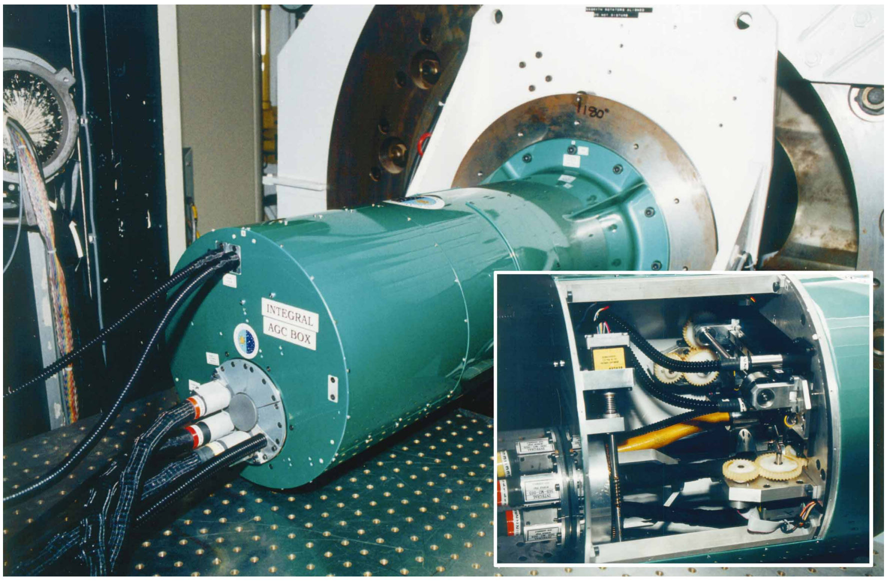

Figure 1. Acquisition, calibration and guiding structure of INTEGRAL.

First Results

INTEGRAL is being used in a number of scientific programs. We give here some examples of recent results obtained with INTEGRAL in different research areas:

- Gravitational lenses (Mediavilla et al., 1998) (Figure 3).
- Detection of faint companions (Arribas et al., 1998b) (Figure 4).
- The study of the circumnuclear region of ultraluminous infrared galaxies (Colina et al., 1999) (Figure 5).
- Structure and dynamics of blue compact dwarf galaxies (García-Lorenzo et al., 2000) (Figure 6).
- The study of the circumnuclear region of active galaxies (García-Lorenzo et al., 1999) (Figure 7).
- The inner regions of M31 (del Burgo et al., 2000).
- X-ray sources in the core of globular clusters (Charles et al., 2000).
- The kinematics of shells in galaxies (Balcells et al., 2000).

What we show here is just a sample of a larger list of projects using INTEGRAL.

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Bingham, R. G., Gellatly, D. W., Jenkins, C. R., & Worswick, S. P., 1994, *SPIE Proc.*, **2198**, 56.

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Colina, L., Arribas, S., & Borne, K. D., 1999, *ApJ*, **527**, L13.

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García, A., Rasilla, J. L., Arribas, S., & Mediavilla, E., 1994, *SPIE Proc.*, **2198**, 75.

García-Lorenzo, B., Arribas, S., & Mediavilla, M., 2000, in Proceedings of "Imaging the Universe in Three Dimensions: Astrophysics With Advanced Multi-Wavelength Imaging Devices", in *ASP Conf. Series*, **195**, 325.

García-Lorenzo, B., Cairós, L. M., Caon, N., & Vílchez, J., 2000, in Proceedings of "The Evolution of Galaxies I. Observational Clues", to be published in *ASP Conf. Series*.

Mediavilla et al., 1998, *ApJL*, **503**, 27.

de Zeeuw, P. T. et al., 2000, *ING Newsletter*, **2**, 11. ¤

Begoña García (bgarcia@ing.iac.es)

	1200 g/mm	600 g/mm	316 g/mm	300 g/mm	Echelle (order 5)
Resolution STD1 (Å)	2.8	6.0	11.8	11	–
Resolution STD2 (Å)	2.8	6.0	11.8	12	–
Resolution STD3 (Å)	4.8	9.8	19.4	12	1.22
Linear dispertion (Å/pix)	1.4	3.1	5.9	19.6	0.35
Spectral coverage (Å)	1445	3140	5837	6144	358

Table 1. Performance of INTEGRAL+WYFFOS combining each fibre bundle with different gratings.

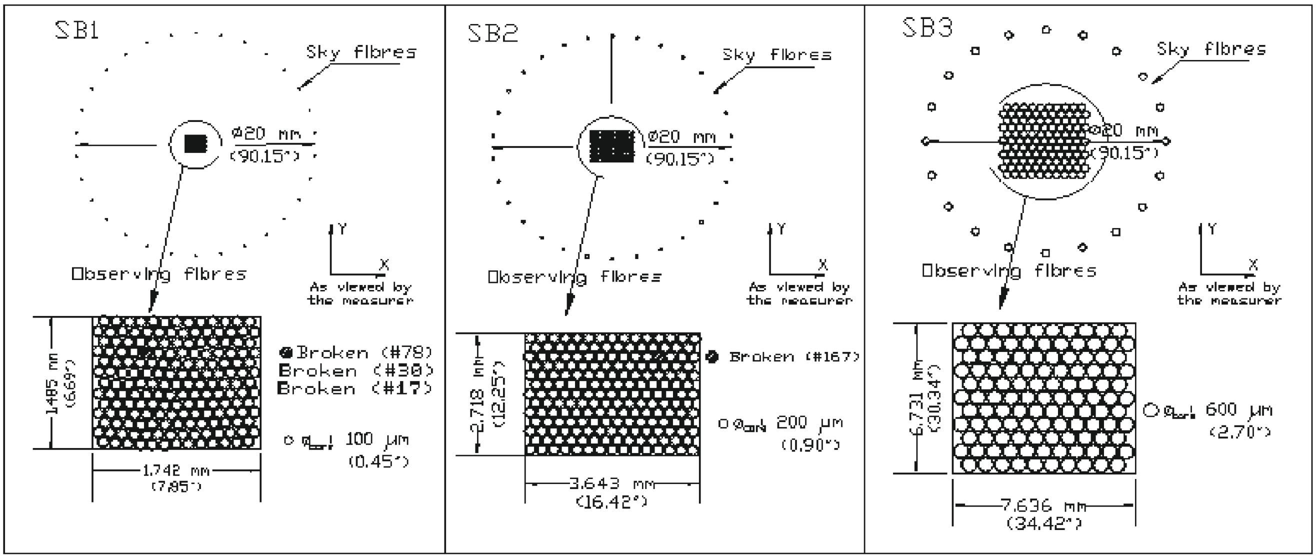


Figure 2. Configuration of the three standard bundles of INTEGRAL at the focal plane of the telescope. Note that the external ring of fibers is intended to collect the sky background simultaneously to the object observations.

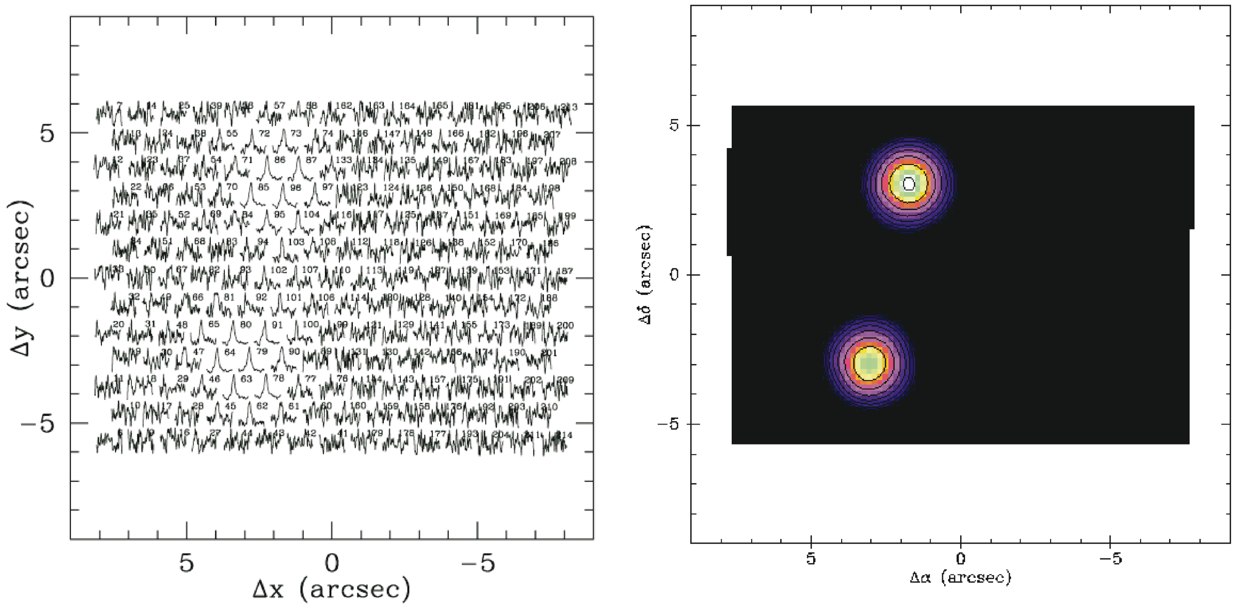


Figure 3. Gravitational lens system Q 0957+561 as observed with INTEGRAL. The picture on the left corresponds to the two-dimensional distribution of the 205 spectra obtained simultaneously with INTEGRAL in the 4500–4700 Å wavelength range (the observed range is much larger). The continuum map (right) is done integrating the flux of the spectra in the 4500–4700 Å wavelength range. The two point-like sources corresponding to the QSO compact images appear well resolved with a separation of 6.17 arcsec, in very good agreement with the distance inferred from the HST images (6.17 arcsec) (courtesy of Veronica Motta).

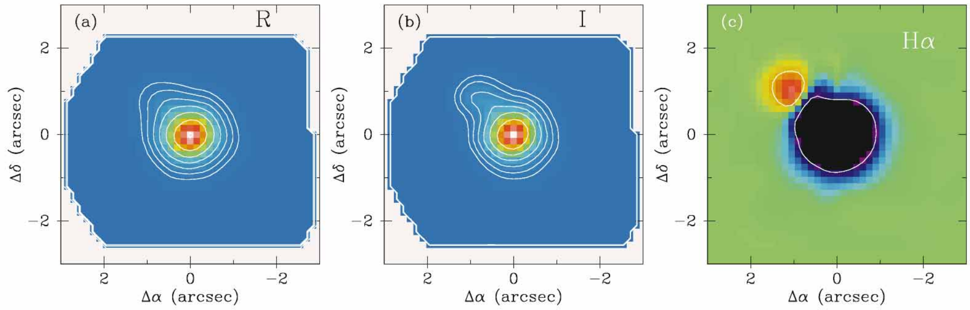


Figure 4. Reconstructed images from INTEGRAL spectra (in R, I, and Hα) of the binary system HD 167605 A+B. This system is formed by two close (~1″) stars of about 5 magnitudes of difference in flux. Due to their different spectral type it is possible to select a posteriori *a 'filter' to increase the contrast between both objects. These results were obtained with a new technique, Equalized Integral Field Spectroscopy, as explained in Arribas et al. (1998b).*

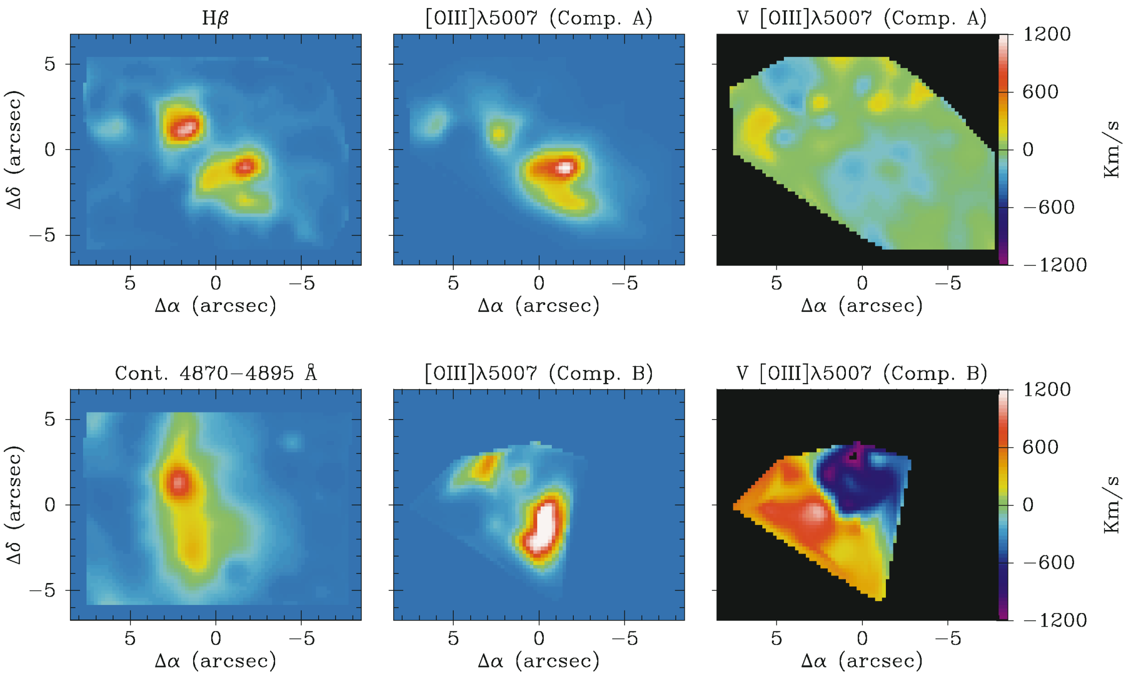


Figure 5. Images of several spectral features and ionised gas velocity fields generated from the INTEGRAL spectra of the ultraluminous infrared galaxy Mrk 273. Note the different morphology between the Hβ and the continuum. The two kinematically distinct components (A and B) could be well separated (by gaussian fits), being their associated velocity fields very different. While one component (A) is rather calm, the other indicates the presence of a strong outflow (more details in Colina et al., 1999).

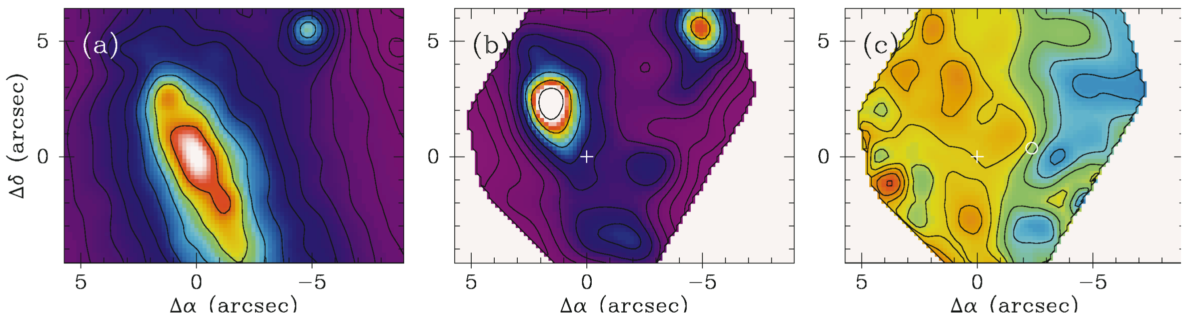
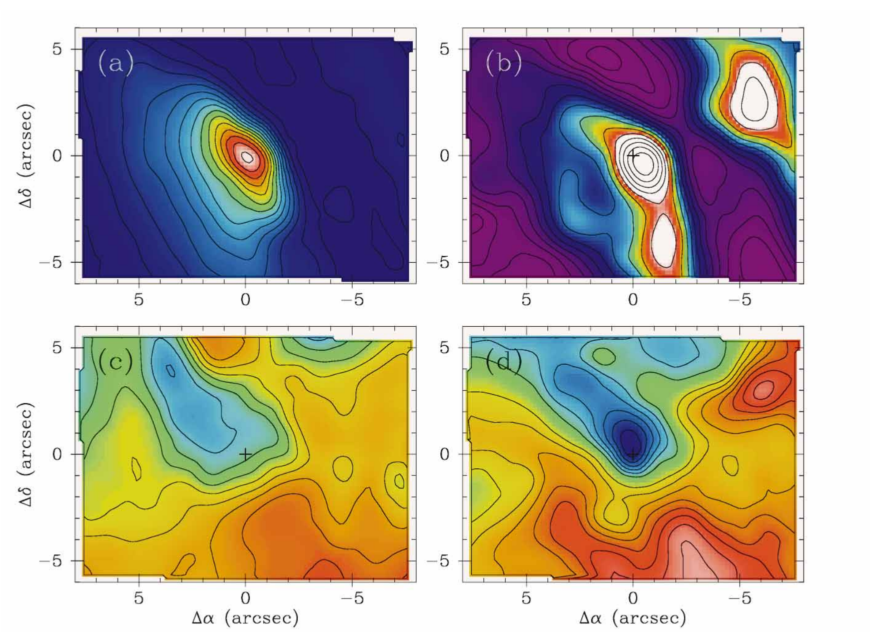


Figure 6. The inner region of the blue compact galaxy Mrk 370 shown by INTEGRAL. (a) Reconstructed continuum in the spectral range of the V filter passband; (b) [OIII]λ5007 intensity map; (c) Velocity field of the ionised gas inferred from different emission lines. A white cross marks the optical nucleus. The kinematic centre is indicated by a white circle.

Figure 7. INTEGRAL observations of the Seyfert galaxy NGC 2992. (a) Reconstructed continuum map; (b) Integrated line intensity map of [OIII]λ5007; (c) Stellar velocity field inferred from Mg I b lines; (d) Velocity field of the ionised gas inferred from cross-correlation in the range 4940–5100Å, including the [OIII]λλ4959, 5007 emission lines. Isovelocity lines expand from 2100 to 2500 km/s with steps of 20 km/s in both velocity maps. The black cross marks the optical nucleus position.



Fibre Feeding the UES

Nicholas A. Walton (ING), Andrew Collier-Cameron (University of St. Andrews) and Meir Semel (DASOP, Obs. Paris-Meudon)

This report summarises the recent successful deployment of a fibre feed to the Utrecht Echelle Spectrograph (UES). The main advantage of this feed, as opposed to the conventional Nasmyth direct feed, is that the starlight is spread along the slit, reducing sensitivity to flat field errors, and allowing increased integration times on bright objects. The prototype setup, which uses a 33-m fibre and is optimised for wavelengths around 5500Å, gives throughput at least as good as conventional slit spectroscopy with the more efficient of the UES de-rotators between 5000 and 6000Å. There is significant attenuation of the light below 5000Å, but this could be improved significantly by using a shorter fibre with better blue transmission.

1. Introduction

UES is mounted at the Nasmyth platform of the 4.2-m WHT. In normal use it is fed by light passing through one of two de-rotators onto the slit unit. Historically the full field de-rotator suffered from poor throughput. A new high throughput de-rotator was commissioned in December 1997, offering throughputs of ~95% over the wavelength range 300–1100 nm. For details see the ING web pages at *http://www.ing.iac.es/~crb/wht/derot.html*.

In normal use the light from a point source falls on the slit, with unavoidable slit losses. In good seeing, the point source will project to only two or three pixels in the spatial direction. For bright objects this can limit the maximum exposure times obtainable, due to saturation on the peak pixels. It is possible to widen the spatial profile by defocusing the telescope, but this increases slitlosses. In the normal case this may not be a problem. However, for programmes studying bright sources, but looking for underlying effects from, for example, faint companions, obtaining the maximum light from the source is imperative, especially for temporal studies.

The work of Cameron and collaborators involves the detection of reflected light signatures of extra-solar planets. It is important to maintain observing efficiency by spreading starlight along the slit. This allows increased exposure times before saturation occurs, and minimises flat fielding errors. In the normal use of UES, this spreading of the light is achieved by using the auto-guider to move the star up and down the slit during the exposure. The disadvantage is that the spatial profiles vary between exposures. Also, the method is not robust to poor weather conditions, where the auto-guider can lose the star during the dithering at times of poor transparency (the auto-guider integration time needing to be short). Finally the optical paths followed by the science and calibration light are different, resulting in displacements between them of up to 3 pixels on the detector. This introduces difficulties when flat-fielding to high precision.

An alternative method of feeding UES is by employing an image slicer to spread the starlight along the slit. This could be a direct feed from Nasmyth, but this would involve a significant re-design of the UES Acquisition and Guidance (A&G) unit. The approach described here, employing a fibre feed from the Cassegrain focus of the WHT, only involves the removal of the UES A&G unit.

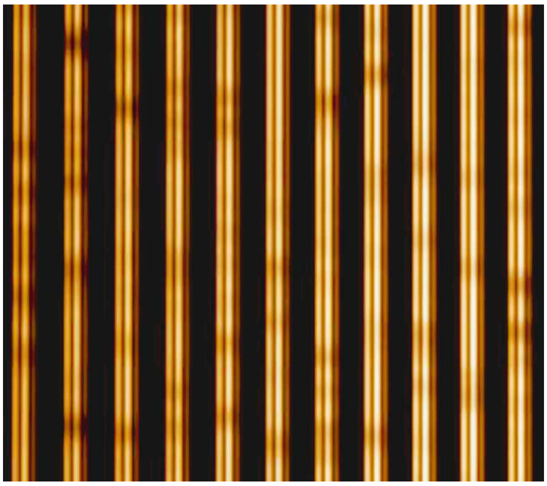
2. The UES Fibre-Feed

The prototype fibre feed developed for the WHT consists of the same fibre and image slicer designed and built by Semel's team at the Paris Observatory, Meudon. The primary use of the system has been for circular spectropolarimetry with the Semel visitor stellar polarimeter (Semel et al., 1993, *A&A*, **278**, 231), and later with UCLES at the AAT for Zeeman-Doppler imaging campaigns (e.g. Donati et al., 1997, *MNRAS*, **291**, 658). The fibre feed described here is also similar to the fibre link developed for ESPaDOnS, see: *http://webast.ast.obs-mip.fr/magnetisme/espadons.html*, the fibre-fed Echelle spectro-polarimeter deployed at the CFHT. The probe for mounting the fibre on the ISIS dekker slide was also designed and built at Meudon by F. Rigaud.

The input end of the fibre is located in a mount which fits in to the dekker slide within the slit unit of the WHT's ISIS spectrograph. The entrance aperture to the fibre projects to a circle with a diameter of 1.3 arcsec on the sky.

The fibre is run from the Cassegrain to Nasmyth foci of the WHT. At the exit end, the image slicer is mounted on a beam attached to the UES de-rotator mounting ring. Prior to installation of the image slicer, the UES de-rotator and and A&G unit are removed, to enable direct access to the UES slit assembly. The starlight is sliced such that three slices are projected into UES. There is no material slit, the projection of the sliced images at the slit position at the correct f number replaces the usual spectrograph slit. Figure 1 shows how the resulting echellogram appears at the detector.

In this interim deployment, the fibre feed system is based on one optimised for a 2000Å bandpass centred on 5500Å. The fibre is a low-OH H-treated fibre produced by Ceram-Optec (see *http://www.ceramoptec.com/*) (with 100/110 micron core/cladding diameters).



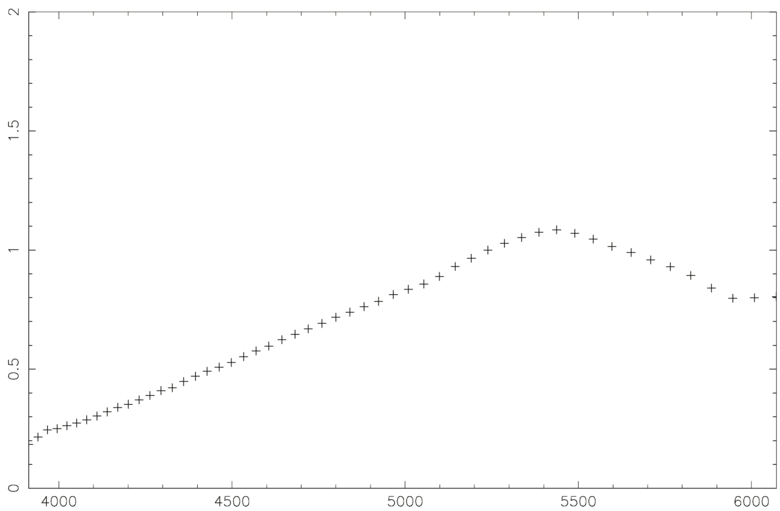


Figure 1 (left). This shows part of a UES exposure of τ Boo obtained with the fibre feed — the orders appear striated because of small gaps between the three slices from the input fibre. Figure 2 (right). The average relative transmission for different Echelle orders between an exposure taken with the fibre, and one taken through the de-rotator (see text for full description). These are plotted as function of wavelength in Angstroms.

2.1. System Efficiency

An exposure was acquired through the high throughput de-rotator of τ Boo with a 1 arcsec slit width and 4.5 arcsec slit length, the star being dithered up and down the slit during the length of the exposure.

A second exposure was obtained with the fibre feed system, with a 1.3 arcsec entrance aperture. Both exposures were taken in similar conditions (sky transparency, seeing and airmass at time of exposure).

The relative counts between the two exposures are shown in Figure 2. Allowing for the uncertainty in the seeing profiles on the two nights, it appears that the throughput of the fibre is comparable to that of the conventional slit long-ward of 5000 Å. However, blue losses are more severe, of order 75% at 3850 Å. This is as expected, due to the system not presently being optimised for good transmission in the blue.

2.2. Stability

The flat fields and stellar spectra were found to occupy the same spatial location on the CCD, indicating that there was no misalignment of the stellar and calibration beams in UES. However, there was a steady drift of the spatial profile through the night, amounting to some 75 microns in 14 hours. The drift had a steady nature, indicating that it was caused by the known poor thermal control of the UES enclosure.

3. Future Upgrades

The fibre-feed described here is still experimental in nature. However, initial results were encouraging, and it proposed to employ this system in October and November 2000 as part of a planet monitoring campaign.

Modifications that are being implemented include a second fibre fed directly from the WHT's Cassegrain A&G calibration unit. This calibration unit has the provision of fibre feeding light directly into this second fibre. This will allow direct injection of calibration ThAr and tungsten light at much higher intensities. Thus time needed for calibration exposures will be much reduced.

In order to improve the throughput, the fibre length from the Cassegrain to UES is being optimised to the shortest possible length, reducing the 33-m used in May 2000 down to approximately 10-m in October 2000. Further options include changing the size of the fibre, employing fibres with better transmission in the ultraviolet, and optimising the coatings in the slicer optics.

4. Opportunities for UES

This experimental fibre feed to UES could open the way to radical changes to UES itself. With the ING's increased emphasis on developing Adaptive Optics instrumentation and wide field multi-object spectroscopy, the pressure on the WHT's two Nasmyth platforms is increasing.

As a result of the ING's Announcement of Opportunity for new instrumentation (see IWG WWW pages), a wide field optical image corrected multi-object spectrograph, MOSAIC (Sharples et al., *Proc. SPIE*, **4008**, 2000, in press), was proposed. If constructed this instrument could be mounted at the Nasmyth platform currently occupied by UES. MOSAIC would contain an integrated AO system with a Rayleigh laser beacon. One option would enable an AO feed to be fibre fed to UES, allowing images of 0.2 to 0.3 arcsec at 6500 Å to be injected into UES.

In this case UES would be moved to a thermally and gravitationally stable location beneath the WHT. This would have potential advantages, as already described above for the feed, and for improved instrument stability.

5. Concluding Remarks

The advantages of the fibre system are that the slit profile is stable and that the calibration arc and flat field spectra are much more accurately aligned with the stellar spectra on the CCD than is the case with conventional slit spectroscopy. The poor blue throughput of the fibre fed system will be improved by further optimisation including the use of better 'blue' fibres and reducing the length of the fibre.

Further information about the fibre feed to the UES can be obtained from the UES instrument specialist, John Telting (jht@ing.iac.es).

More general information about instrumentation developments at the ING can be found under the Instrumentation Developments area of the ING web pages at *http://www.ing.iac.es/Astronomy/*, or from the ING Instrumentation Scientist, Nic Walton. ¤

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UltraDAS and ING FITS Headers

Nicholas A. Walton and Guy T. Rixon (ING)

The new data acquisition system for the ING, the UltraDAS (see Rixon et al., *Proc. SPIE*, **4009**, 2000, in press), is being implemented for use with all ING detectors. The UltraDAS development is a key component of the ING's new observing system, the philosophy of which is described in Walton et al., 1998, *Proc. SPIE*, **351**, pp. 197–208.

The UltraDAS was first commissioned on the INT's Wide Field Camera (WFC) in August 1999, resulting in much improved readout speeds. It has subsequently been released for use with the two chip EEV mosaic used with the WHT's UES and PFC and most recently with both detectors (EEV42 and TEK) of the INT's IDS. The WHT's ISIS spectrograph will be converted to use the UltraDAS by the end of 2000.

Along with the introduction of UltraDAS, the format of the FITS data product that the ING provides has changed. The main impact that the visiting observer will see is that their data will now be in the so-called Multi-Extension FITS format (MEF).

This paper describes the ING UltraDAS version s9.1 and later.

1. UltraDAS

The UltraDAS generates FITS files on disk as its final product. The UltraDAS produces one FITS file per observation. Where one camera produces data from multiple readout-amplifiers, detectors or detector controllers, only one observation is deemed to have taken place; one run number is issued and all the pixels go into one FITS file.

Hence, in the case of the INT's WFC, with an array of four CCDs, the data from all four CCDs is contained in one file with a unique run number. This is a change from the case with the old data acquisition system where one exposure would have generated in this case four individual image frames, each containing the data from just one of the array CCDs.

The UltraDAS produces FITS files as defined by issue 2.0 of NASA's standard (NOST 100-2.0 —see *http://fits.gsfc.nasa.gov*). All observations are stored in FITS files with image extensions, even if there is only one image per file. One image extension is produced for each contiguous raster in the output.

The reference document describing the ING FITS headers is available on-line at: *http://www.ing.iac.es/~docs/ins/das/ins-das-26/ins-das-26.html*.

1.1. The UltraDAS Structure

The primary HDU, or Header Definition Unit, has the following structure:

1. Mandatory descriptors, such as SIMPLE and BITPIX, with NAXIS set to zero to indicate no associated image.

2. The run packet (where a packet is a set of descriptors from the same source), written by UltraDAS.

3. Packets of descriptors from outside UltraDAS (e.g. from the instrument control system (ICS), telescope control, etc).

4. A packet of descriptors detailing the timing of the integration (usually from inside UltraDAS, but may come as a packet from the ICS).

5. A packet describing the state of the camera from inside UltraDAS.

6. A HISTORY descriptor marking the end of the header written to file by UltraDAS.

7. The END descriptor.

Each image extension has the structure:

1. Mandatory descriptors for image extension.
2. INHERIT.
3. Channel packet.
4. Integration packet.
5. END.
6. Image.

The number of image extensions is determined by the number of detectors in the array, the number of windowed readouts, etc. In the simplest case, there is one image extension per output amplifier.

The pixels may be in any FITS format. Typically, CCD pixels are recorded as signed 16-bit integers BITPIX=16, BZERO=32768, BSCALE not present). IR images are typically stored as 32-bit floating numbers (BITPIX=32, BZERO not present, BSCALE not present).

1.2. Image Extensions

This use of image extensions was developed by the NOAO for the cameras at KPNO (based on FITS image extensions as proposed by Ponz et al. (1992) — see *http://fits.cv.nrao.edu/documents/standards/image.ps*) and is an emerging de-facto standard for multi-channel cameras. ESO uses MEF format for WFI@2.2m, MEF is also offered at the CFHT with the CFH12K camera. However, the generalisation to multiple windows has been devised specifically for ING.

Some FITS keywords are provided to match the conventions of IRAF and the NOAO conventions; some are traditional at ING. This means that some data are duplicated.

The INHERIT keyword comes from the STScI convention on inheritance of HDUs, as described in NASA's user guide to FITS (see *http://fits.gsfc.nasa.gov/*). The keyword, which takes the Boolean value T, states that the extension HDU to which it applies should inherit non-conflicting descriptors from the primary HDU. Thus, if one channel of the observation is extracted to a separate file, it carries with it all the relevant information from the primary HDU. To make this scheme work, there must not be an image following the primary HDU.

For keywords contained in the both the primary HDU and the image extensions, the value set in the extension takes priority. Take for example the case of INGRID, the ING's IR detector. The keyword EXPTIME in the primary HDU would represent the total exposed time. Each extension might contain individual non-destructive reads, the EXPTIME associated with any extension would then be the exposed time up-to that point.

At the time of writing, UltraDAS does not use other FITS extensions such as tables. It may do so in later releases.

1.3. Timing Information

With the new UltraDAS (from version s9.1) the recording of timing information in the FITS headers has changed. This is to accommodate the use of UltraDAS with infra-red detectors, where exposure timing information is required in the individual extensions.

Thus the timing keywords, EXPOSED, ELAPSED and UTSTART, now appear in the image extension headers. But, in order to ensure backwards compatibility, these keywords are duplicated in the primary HDU, with the following rules being followed:

1. The timing keywords always appear in the main HDU.

2. If the detector has a shutter controlled by the DAS (i.e. all but INT WFC), then the timing keywords also appear in the extension HDUs.

3. The cards in the extensions override the cards in the main HDU (normal inheritance).

4. The times in the main HDU are the ruling times for the observation as a whole; e.g. in an INGRID run, the start of the first integration and the longest integration of any image in the file.

5. The times in the extension HDUs are specific to the associated image.

1.4. World Coordinate System

Each image has a primary world co-ordinate system (WCS). The primary WCS reserves space in the header in which data-reduction software may later write celestial coordinates. The primary WCS defines the positions of images in detector (pixel) coordinates in the focal plane. The WCS arrangements are described in the channel packet. There is no "WCS packet" covering the whole camera.

Background, upon which the UltraDAS WCS specification is based, can be found in the ING software document INS-DAS-19: Coordinate Systems for UltraDAS (at *http://www.ing.iac.es/~docs/ins/das/ins-das-19/ins-das-19.html*). Also, the NRAO information page (and links therein) on 'Representation of World Coordinate Systems in FITS' at *http://www.cv.nrao.edu/fits/documents/wcs/wcs.html* has useful information.

2. Data Image Sizes

The introduction of UltraDAS (version s9.1 and greater) sees some changes to the CCD data package size. The existing detectors have the same number of active pixels as always. However, in some cases the format of the electronically added bias and over-scan regions have changed.

For instance, TEK5, a detector now in use with the INT+IDS, has 1024×1024 active pixels. Before July 2000, it appeared in a image of size 1124×1124, the extra pixels being bias and over-scan regions. Its new size is 1100×1040, the bias regions having changed. Observers are asked to be aware of this.

Further, when binning OR windowing any particular CCD, the readout characteristics MAY change. This could mean a change of gain and noise characteristics. However, for most detectors, windowing or binning will not change the selected readout speed (per pixel). These details will be available on the ING Detector www pages.

3. Handling Multi-Extension Format Files

As stated previously the UltraDAS produces FITS format data files. The visiting astronomer typically receives a copy of these files on tape (DAT) or via ftp.

3.1. IRAF

IRAF is able to handle multi-extension fits data. For example, IRAF provides a full package for handling mosaic data array's — `mscred`. The IRAF guide to this gives a fuller description of how IRAF handles MEF data — see the guide to the NOAO MOSAIC data handling software at *http://iraf.noao.edu/scripts/irafhelp?mscguide*.

A brief example:

```
cl> imhead r200546[0] l+
```

would give a full listing of the FITS header of the primary HDU of that run.

```
cl> imhead r200546[1] l+
```

however, would only list the FITS headers of the primary HDU and the first image extension, as the INHERIT=TRUE keyword is set.

3.2. STARLINK

Full support for MEF files is not yet available in Starlink software, although work to correct this position is underway.

People who wish to reduce their data using Starlink, need to use one of three possible workarounds. The first is to use the IRAF `mscsplit` task (within the `mscred` package) to split MEF files into separate images. The second is to use the IRAF `fxsplit` task within the `fitsutil` package, this splits a MEF file into single FITS files. These can then be converted to Starlink's NDF format with the CONVERT tasks: FITS2NDF or IRAF2NDF. The third method involves converting the whole MEF to NDF format (using FITS2NDF) and then extracting individual NDFs using the KAPPA command NDFCOPY.

In the near future (with a release date tentatively set for end 2000) fuller support for MEF data will be available. A new FITS2NDF convertor will allow the extraction of specific image extensions into single NDFs and a new version of GAIA will provide native access to MEF extensions (images and tables).

At that time all Starlink applications will also allow automatic on-the-fly conversion for selecting specific MEF extensions. This means you will be able to use commands like:

```
% stats 'ingmef.fits[1]'
```

to get statistics for the first image extension of ingmef.fits.

For updates on the Starlink software referred to above please contact Peter Draper, P.W.Draper@durham.ac.uk, or see his WWW home page at *http://star-www.dur.ac.uk/~pdraper/*.

4. Closing Remarks

The introduction of the UltraDAS will bring significant benefits to the visiting astronomer. Readout times are much reduced, now being silicon limited in most cases. Hence observing on-sky efficiencies are maximised. Further one system will be available to control ALL of ING's optical and infra-red detectors, this simplifying use for observers and reducing operation support costs.

Further information about this topic can be obtained from the UltraDAS project scientist, Nic Walton (naw@ing.iac.es).

More general information about instrumentation developments can be found under the Instrumentation Developments area of the ING web pages at *http://www.ing.iac.es/Astronomy/*

Thanks to Peter Draper for providing information on the use of STARLINK software to handle ING MEF data. ¤

Nic Walton (naw@ing.iac.es)

OTHER NEWS FROM ING

The Isaac Newton Group of Telescopes and ESO

René Rutten (Director, ING)

In view of the discussion that is taking place to look at the impact of the UK joining ESO, I summarise the strategic development of the ING relevant to this. The potential benefits for the UK astronomy programme in joining ESO are very substantial, and the prospect of increased funding for astronomy centred around an ESO membership can only be welcomed. The changes that have been taking place at ING in recent years and the role in particular that is foreseen for the WHT fit very well into the future UK astronomy programme that embraces ESO. The key aspects of this are briefly presented below.

Current status of ING and its development strategy

The ING comprises three telescopes that are operated at a cost to PPARC of 2.9M pounds per annum (this figure covers the full cost of running the observatory, excluding small enhancements and instrument development projects). In recent years very substantial cost savings have been delivered, culminating in the closure of the RGO which has meant that ING now exists as an independent PPARC organisation. ING now is a lean, cost-effective and well organised observatory which delivers good value for money to the community.

Science output of the telescopes, in particular that of the WHT, is high by international standards. Both the quantity of papers based on data from ING, and their resulting science impact (measured by the number of papers published in Nature or as citation index) is very high. The WHT is simply the most productive 4-m class ground based telescope in the world ! (for details see *http://vela.ing.iac.es/About-ING/Strategy/strategic_issues.html*).

The current rationalised suit of instruments provides a powerful and balanced range of capability to the astronomical community. In particular the WHT is well equipped with relevant instrumentation to enable topical research. It satisfies the need for a versatile 4-m class optical/IR telescope as identified in PPARC's strategy for ground-based astronomy. Important for the future of the WHT is its complementary and supporting role for 8-m class telescopes and other new facilities such as VISTA.

The current development programme for the WHT focuses on Adaptive Optics and associated instrumentation, and exploitation of the wide field in the prime focus. The WHT will shortly have one of the world's most powerful AO systems, delivering excellent image quality at optical and IR wavelengths. Importantly, instrumentation optimised for AO exploitation will be available (near IR imaging, integral field spectroscopy, and coronographic capability). In this way the WHT will remain competitive next to the 8-m telescopes for several years on a world-class site. Strategically the importance of developing Adaptive Optics techniques and gaining experience in this area can not be overstated. It has become clear that the 8-m class telescopes and future generations of even larger telescopes will heavily rely on Adaptive Optics. Through the exploitation of Adaptive Optics and laser guide star technology on the WHT the UK has the opportunity to assume a leading role in this field and capitalise on past investments.

Future potential of ING and the La Palma site

The strategy for the UK to join ESO aligns perfectly with the prospect of developing the La Palma site into a truly European Northern Observatory. Currently the Canarian observatories (La Palma and Teide) host a large number of European countries, combining various solar and night-time telescopes. The advent of the 10-m GranTeCan and the 17-m MAGIC Cherenkov telescope projects positions La Palma as one of the few world-class observatory sites in the world. La Palma is proven to be an excellent observing site and recognised to be amongst the best in the world. The WHT instrument development strategy is now focusing on exploiting the excellent natural seeing through Adaptive Optics, to reach diffraction limited images in the IR at high Strehl ratios and 0.2 arcsec images at 0.6 micron. The La Palma site is particularly well placed for this, not only for the known excellent seeing conditions, but also for its principally low-altitude atmospheric turbulence which is favourable for adaptive optics exploitation. Therefore the WHT would be the ideal testing ground for AO systems for larger telescopes.

In the short to medium term, the Spanish 10-m GranTeCan, a Keck-type telescope currently under construction, offers the potential for collaboration and ultimately for the UK community to gain more access to large telescopes in the northern hemisphere. The ING will play an enabling role in this through setting up formal and informal collaborations for the science exploitation and operation of this facility. Although no firm commitments have been established to date, the potential for important scientific gains through participation in GranTeCan remains. Participation in GranTeCan would also allow the UK astronomers and engineers to gain valuable hands-on experience in segmented mirror technology and position the UK well for future development of any Extremely Large Telescope.

The development of the La Palma observatory in a European context is currently being discussed at various levels:

– A joint European operation of medium sized telescopes may well emerge as the future umbrella required to retain the INT and JKT. A reduced share for the UK in these smaller telescopes would imply a cost saving to PPARC.

– A common approach to develop a European Northern Observatory centred on La Palma is actively being pursued. A common approach in the scientific exploitation and operation of the various facilities would provide better possibilities to bid for European Community funds.

– La Palma is a very serious competitor as site for a future ELT in the north, as it is the only viable site in Europe. To win political support for large new investments to build such a telescope as a European project on European soil may well become a key argument.

Apart from the strategic future potential of the La Palma site, the fundamental capability of the WHT as a versatile facility on an excellent site must not be overlooked. Even in the era of 8-m class telescopes the need for the WHT is clear: Complementary and preparatory observations for large telescopes, for VISTA, and for space missions will be in increasing demand. Furthermore, there are important areas of research that do not require the very largest available collecting area, or require large amounts of observing time that will not easily become available on the largest facilities. Without access to a high-quality facility like the WHT these science areas would be seriously compromised, and the exploitation of Gemini, VLT and VISTA would be undermined.

Epilogue

There are important opportunities ahead on La Palma and the need for a well-equipped 4-m class telescopes on a world-class northern site like La Palma must be obvious. If the UK were to join ESO the case to retain a strong interest in ING would only strengthen. In this respect it is worth learning from the direction being taken by other European countries that have had a very clear focus on ESO for many years: they continue to strongly support their northern hemisphere medium sized optical/IR telescopes. The UK finds itself in a fortunate position of owning the very best telescopes of this class located on the very best observing site in Europe !

La Palma – 16 June 2000. ¤

René Rutten (rgmr@ing.iac.es)

Personnel Movements

Chris Packham, who has been a support astronomer for several years, will exchange the subtropical island in the Canarian Archipelago for the tropical and humid environment at the University of Florida. Chris has been a key player in the development of the new IR camera for the WHT, INGRID, as well as for the seeing programme. We wish him well in his future career.

Bart van Venrooy and **Mariet Broxterman** returned to the Netherlands after 5 years at ING. For both of them the excellent work carried out on various projects at ING had opened new opportunities, which they seek to exploit in their home country.

For **Scott Hunter** the beaches on La Palma weren't big enough and he decided to take up a post in the desert of Saudi Arabia. Scott's friendly presence at the observatory and skills as Personnel Officer will be missed.

Nick Johnson returned to the UK to forward his career outside the astronomy arena. We thank Nick for his important contribution in modernising ING's computing infrastructure, which has layed the foundation for future IT requirements.

Nicole Pirotte returned to her home country after more than 7 years at the observatory. Her efforts have been much appreciate by observatory staff and their families.

Mathieu Beck will in the future deploy his software skills on the Gemini telescope. His significant contribution to various projects at ING has been much appreciated.

Ken Froggatt has left the island after completion of the organisation of the RGO/ING drawing archive. His work will benefit ING for many years to come.

Crown Prince of Spain Observes at the William Herschel Telescope

Javier Méndez (Public Relations Officer, ING)

On 2 June the Crown Prince of Spain, His Royal Highness Don Felipe de Borbón visited the observatory on La Palma to lay the first stone of the Spanish 10-m telescope GranTeCan. This important event was celebrated under the cloudless Canarian skies with many important spectators present. The night before His Royal Highness visited the William Herschel Telescope not only to witness observing and meet astronomers, but also to carry out observations himself ! He took an image of the nearby Whirlpool galaxy Messier 51 with the Prime Focus Camera. This was a memorable event for all those present and ING.

The accompanying pictures were taken during the visit on 1 June to the WHT and the 'First Stone' ceremony of the GranTeCan Telescope the following day. ¤

Javier Méndez (jma@ing.iac.es)

Arriving at the observatory. Picture credit: IAC.

HRH Don Felipe in the WHT dome. Chris Benn (WHT Manager) explains the telescope optics and instruments. Picture credit: Fotos Dalda.

During the visit, HRH Don Felipe showed his interest in astronomy by asking many questions. The visiting group also included Francisco Sánchez (Director IAC), José Miguel Rodríguez (GranTeCan Project Scientist) and Román Rodríguez (President of the Canary Islands). Picture credit: Fotos Dalda.

Following the visit to the dome, HRH Don Felipe met the observer for the night, Prof Richard Ellis, in the control room. Picture credit: Fotos Dalda.

Richard Ellis explaining his observing programme to look for the Cosmic Shear to HRH Don Felipe. Picture credit: Fotos Dalda.

Chris Benn presents HRH Don Felipe with a collection of discovery images from the ING telescopes. Picture credit: Fotos Dalda.

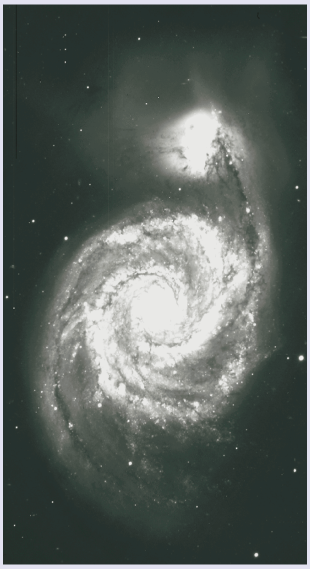


Image of M51 Galaxy obtained by HRH Don Felipe using the new mosaic Prime Focus camera on the WHT. The image was a 300s exposure through the B filter.

10-m GranTeCan telescope 'First Stone Ceremony'. The dome of the WHT is visible in the background. Picture credit: IAC.

Shown on the next page is the Whirpool, or M51, Galaxy. This is a 'true-colour' composite of B, V and R images obtained with the WHT Prime Focus Camera. The B image is the one acquired by HRH Don Felipe. Picture credit: Javier Méndez and Nik Szymanek.

ING Welcomes Young Cornish Astronomers

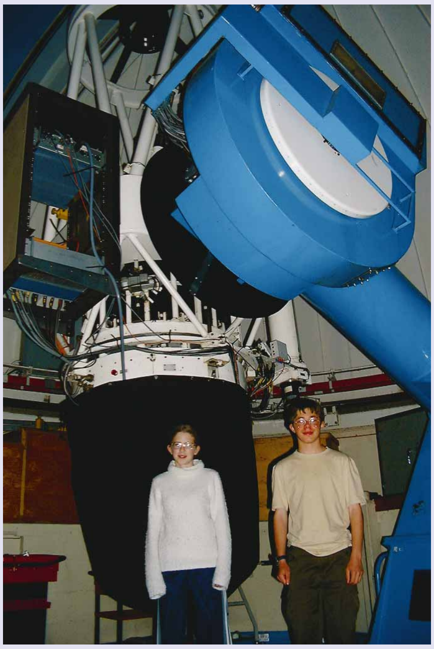
Michael Willmott (Cornwall Schools Astronomy Project) and Javier Méndez (ING)

In mid June, young Cornish astronomers Amanda Willmott (14) and Aaron Shrimpton (13) travelled to the Roque de Los Muchachos Observatory to work with ING astronomers on an observational programme at the 1-m Jacobus Kapteyn Telescope (JKT). Amanda and Aaron are both members of the Cornwall Schools Astronomy Project, a pioneering scheme organised by some local science teachers to give pupils the chance to study for GCSE Astronomy out of school hours by means of a virtual classroom environment. Having realised the potential of such a group of youngsters and the use of the JKT for educational purposes, ING allocated time on a discretionary night on the JKT, and invited Amanda and Aaron to La Palma.

Acclimatising themselves quickly to the altitude (2350m), they toured the various locations, including the William Herschel and Isaac Newton telescopes, before concentrating on their own programme. Under expert tutoring, they were fully involved at all stages of the observational programme. On the first day, they undertook preliminary work, which included checking position, apparent diameters and magnitude of candidate objects, and determining the position and suitability of possible guide stars for each of these objects. During the following night, they initially assisted in an ongoing programme monitoring microlensing events associated with the Galactic Bulge in an attempt to discover extra-solar planets around other stars. For their own work, they used the SITe2 CCD, with a variety of filters, to obtain multiple images of a planetary nebula (M27), a globular cluster (M15) and a spiral galaxy (NGC7331). In the JKT control room, they specified the location of the guide stars to the control system, then initiated the CCD image taking and monitored progress until a successful conclusion at 5am. The following evening, they worked with an astronomer, using a series of data reduction procedures to enhance the images, by compensating for electronic noise and different sensitivities between pixels, and removing the effects of cosmic rays. They have now returned to the UK with their results, and can continue to work on their data.

This visit was an outstanding success, and demonstrated what can be achieved when youthful enthusiasm and hard work meets with skilful guidance and expertise at an international location of renowned and groundbreaking facilities. Both pupils were extremely grateful for everyone's hard work which made their visit possible, and especially for ING astronomer's unstinting commitment. ¤

Javier Méndez (jma@ing.iac.es)



From top to bottom: 1) Amanda and Aaron inside the JKT dome; 2) 'True-colour' image of M27 Planetary Nebula obtained by the young astronomers. Combining images taken with different filters allow students to learn about the meaning of colours in astronomy; 3) Amanda, Aaron and their tutor at the JKT control room.

Other Recent ING Publications

Other ING publications are available on-line at the URLs below. For internal documents please visit the ING Intranet web pages or contact the relevant people on the last page:

Annual reports: *http://www.ing.iac.es/PR/annualreports_index.html*

In-house research papers: *http://roque.ing.iac.es/~sanchez/ingpub/*

Manuals: *http://www.ing.iac.es/~manuals/*

Press releases: *http://www.ing.iac.es/PR/press/*

Technical notes: *http://www.ing.iac.es/~manuals/man_tn.html*

Seminars 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 given in the last six months:

10 March. *Circumnuclear Regions of Barred Spirals*, D. Pérez Ramírez (Hertfordshire)

14 March. *The Low Surface Brightness and Dwarf Galaxy Populations in Nearby Clusters*, J. Davies (Cardiff)

21 March. *High Redshift Radio Galaxies as Probes of the Early Universe*, M. Villar-Martín (Hertfordshire)

27 March. *The Nature of Early Type Galaxies: The SAURON Project*, R. Davies (Durham)

7 April. *The Close Environment of Z CMa*, P. Garcia (ING)

19 April. *Sleuthing Mass Loss from Cool Stars*, A. Dupree (Harvard)

10 May. *Pulsational Constraints on the Evolution of Helium Stars*, S. Jeffery (Armagh)

15 May. *Transits and Reflections: Characterising Extra-solar Planets*, A. Collier-Cameron (St. Andrews)

19 May. *All About OASIS*, A. Parisi (Lyon)

23 May. *Magnetised Accretion-Ejection Structures*, J. Ferreira (Grenoble)

26 May. *Gamma-ray Burst Afterglows*, P. Vreeswijk (Amsterdam)

29 May. *The Planetary Nebula Spectrograph for La Palma: Measuring and Modelling Galaxy Kinematics*, N. Douglas & A. Romanowsky (Groningen)

31 May. *Recent Progress in Understanding the Origin of the Hubble Sequence*, R. Ellis (Caltech)

16 June. *Photometric Redshifts: An Estimator for Galaxy Density*, D. Batcheldor (Hertfordshire and ING)

4 July. *Cygnus A: Understanding the Most Powerful Radio Galaxy in the Local Universe*, C. Tadhunter (Sheffield)

17 July. *Stellar Populations in Early-Type Galaxies*, R. Peletier (Nottingham)

20 July. *Scientific Productivity of Large Telescopes*, C. Benn and S. F. Sánchez (ING)

26 July. *Finding Binary Subdwarf B Stars*, P. Maxted (Southampton)

9 August. *Introduction to Observatories in China*, J. Hao (Beijing)

17 August. *The Polychromatic Laser Guide*, R. Foy (CRAL/Observatoire Astronomique de Lyon)

22 August. *Physical Properties of Distant Minor Planets*, J. Davies (Joint Astronomy Center, Hawaii)

30 August. *Dust Extinction at Large Radii in Spiral Galaxies*, R. Curran (Hertfordshire and ING)

News from the Computing Facilities Group

Don Carlos Abrams
(Head of Computing, ING)

We have recently completed the successful installation of the 100Mbs-1 computer network in the JKT. With only two non-critical areas remaining on the old network, this milestone effectively signifies the completion of the 100Mbs-1 network between the three telescopes. Not only is the improved bandwidth welcomed but the managed network has proven to be tremendously successful in reducing downtime due to network faults. The CFG would like to thank the Electronics Group and Site Services for their invaluable help throughout the network migration from the old to the new.

Although the DVD library has suffered from a number of hardware and software issues, after receiving replacement components and newer versions of the software the project to integrate the system with ING's operations is proceeding. CFG are very optimistic about DVD technology.

Two new RAID systems have been installed within the ING; one in the WHT and the other in the INT. Each system currently houses six 18Gb disks configured to appear as one device. The systems will eventually be used in conjunction with UltraDAS during which time the amount of available disk space will increase significantly. ¤

Don Carlos Abrams (don@ing.iac.es)

News from the Roque

René Rutten (Director, ING)

Regular visitors to the Observatory will have noticed that the skyline there is changing. Close to the building of the Isaac Newton Telescope a new dome has appeared for the Belgian Mercator telescope, operated by the University of Leuven. This is a 1.2-m telescope with a science focus on asteroseismology and photometric monitoring of various objects such as active galactic nuclei, gamma-ray bursters, X-ray transients and supernovae. As the building is nearly finished, and the telescope will be shipped to La Palma this summer, first light for this telescope is only months away.

Another near neighbour of the INT will be the 2-m Liverpool robotic telescope. Ground breaking for this telescope is expected to start shortly. A composite picture of what the site around the ING telescopes will look like from above is shown in the accompanying picture.

The most impressive development is that of the construction of the 10-m GranTeCan by Spain, which is taking place on the western part of the observatory grounds. The activity around this large new facility is intense. Ground preparation is well under way and in the very near future we should see the telescope enclosure grow rapidly. Building progress can be followed live with the GTC web-cam at *http://www.gtc.iac.es/webcam_s.asp*

Another large facility that is expected to change the looks of the observatory in a very dramatic way is that of the German-led MAGIC telescope. This huge 17-m diameter Cherenkov telescope with a segmented primary mirror will not have an enclosure. The telescope will be constructed in the same area as where currently the HEGRA experiment is located, close to the entrance to the observatory site. Also for that reason the MAGIC telescope will have a dramatic visual impact once erected. ¤

[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.

Once subscribed, you can subscribe a colleague by sending to majordomo@ing.iac.es the command *subscribe ingnews your_colleague's_address*. To unsubscribe from [INGNEWS] send to majordomo@ing.iac.es the command *unsubscribe ingnews*. More information on [INGNEWS] can be found on this web page: *http://www.ing.iac.es/Astronomy/science/bulletin/*

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

10 March
– NAOMI, INGRID, S-CAM and 2000B

27 March
– INGRID First Light !

12 June
– International Time Programmes

16 June
– ING and ESO

25 July
– The ING's Wide Field Survey: 2nd Announcement of Opportunity

ING Astronomy Software News

Robert Greimel (Astronomy Software, ING)

Dear Observers,

When you go observing it is often interesting to know which software is available at the telescope. At the ING IRAF is used for quick look and (pipeline) data reduction. We do however also provide up to date installations of the following other major data reduction packages: Starlink, ESO-MIDAS, GIPSY and IDL.

Besides these large packages there are many smaller but not less important software packages that are also available for your use. You can find a list on the WWW at *http://www.roque.ing.iac.es/~astrosw/* . This web page also contains other information that you might find useful for your observing run. If you have any software requests regarding your observing run, please don't hesitate to contact me. ¤

Robert Greimel (greimel@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 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

This is a busy year for the ING. We had the very successful commissioning of INGRID and are looking forward to its first full semester of operation which is about to get underway. It was gratifying to see the high demand for this instrument, and in semester 2000B this led to bright time being oversubscribed by more than a factor of six! At the same time the pressure on dark time dropped to around two. Clearly INGRID is set to be one of the most important components of the ING's instrumentation suite.

This summer sees the commissioning of NAOMI which arrived on La Palma in early August. Work will continue on NAOMI into September when commissioning is due to be completed, with the first science runs being scheduled towards the end of 2000B.

The new vastly improved data acquisition system, UltraDAS, was successfully implemented on the IDS detectors making the INT our first all-UltraDAS telescope. The change in FITS format however appears to have caught some observers by surprise, for which we apologise. To rectify this Nic Walton (UltraDAS Project Scientist) and Guy Rixon (UltraDAS Software) have reproduced in this newsletter an article they have written to explain how to deal with the new format. During the course of this year it is expected that UltraDAS will be extended to the ISIS detectors on the WHT. Its debut there is eagerly awaited as it will replace the old and faltering data acquisition system on that instrument which is a significant contributor to WHT down-time.

Finally, the much awaited second Announcement of Opportunity for Wide Field Survey proposals was released, deadline September 30th 2000. Full details can be found at *http://www.ing.iac.es/Astronomy/science/wfs/WFCsur.announce.html*.

Visitor Instruments

The ING has seen a number of important visitor instruments receiving time on the INT and WHT over the years; CIRSI, S-CAM, MOMI and SAURON to name but a few. As is normal in such cases the observing team is allocated a contact person before they or their equipment come out, usually, but not necessarily, the Support Astronomer. In general instrument setup and testing goes well, however there have been a few problems after some observing runs primarily concerning identification and shipment of equipment to the owners' institution. These problems generally occur when the observing team leave site immediately after their observing run before equipment is properly packed away and labelled.

In an attempt to alleviate this problem we now ask all owners of such equipment to designate one member of their observing team as being responsible for the supervision of the packing and shipment of their equipment. This person will be responsible for signing-off packages for shipment off-island and should remain on-site until the relevant paperwork is completed, a Contents Identification Form. ¤

Danny Lennon (djl@ing.iac.es)

Important Dates

Deadlines for submitting applications

UK PATT and NL NFRA PC:
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

Telescope Time Awards Semester 2000 B

For observing schedules please visit this web page:
http://lpss33.ing-slo.iac.es:8080/cgi-bin/schedules.pl

ITP Programmes on the ING Telescopes

- Barcons (IFCA), *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

- Barstow (Leicester), *Metal abundances and the temperature scale of hot H-rich white dwarfs.*
- Benn (ING), *Adaptive-optics imaging of QSO host galaxies* $1<z<3$.
- Bower (Durham), *The High Redshift INGRID Cluster Survey.*
- Cameron (St Andrews), *Spectroscopic detection and characterisation of extra-solar planets.*
- Cropper (MSSL), *High Time-Resolution, Energy-Resolved Photometry of Magnetic Cataclysmic Variables.*
- Dhillon (Sheffield), *Mass-transfer stability in semi-detached binary stars.*
- Haswell (OU), *Outbursts in black hole X-ray transients: coordinated WHT/RXTE/HST observations* (99a, long-term).
- Hynes (Soton), *Pinning Down Spectral Variability in A0620–00: Advective Flow or Accretion Disk?*
- Ivison (UCL), *Star-Forming Galaxies in High-Density Environments in the Early Universe.*
- Ivison (UCL), *A Multi-Colour Search for Galaxies in High-Density Environments in the Early Universe.*
- Knapen (Herts/ING), *Star formation in arm and interarm environments in spiral galaxies.*
- Lucas (Herts), *A Search for the bottom of the IMF with Adaptive Optics.*
- Metcalfe (Durham), *A Photometric Search for* $z>4.5$ *Galaxies.*
- Morales-Rueda (Soton), *What distorts the radial velocity curves of accretion discs?*
- Naylor (Keele), *How many brown dwarfs are there?*
- Perryman (ESTEC), *Physical conditions of isolated neutron stars.*
- Pettini (IoA), *The Large Scale Structure of Galaxies and the Intergalactic medium at* $z{\sim}3$.
- Pinfield (QUB), *The white dwarf initial-final mass relation and the age of Praesepe.*
- Pollacco (QUB), *Restarting the fast wind in the Sakurai object, V4334 Sagittarii* (00a, long-term).
- Rawlings (Oxford), *The cosmic evolution of radiosources using the TEXOX 1000-radiosource redshift survey.*
- Ryan (OU), *The Primordial Lithium Abundance.*
- Skillen (ING), *Rapid Observation of Gamma-Ray Burst optical afterglows.*
- Smail (Durham), *Disentangling the ERO Population: A Survey with INGRID of Archival WFPC2 Fields.*
- Smartt (IoA), *Quantitative spectroscopy of luminous blue supergiants in M33.*
- Steeghs (Soton), *Calcium emission from quiescent accretion discs.*
- Storey (UCL), *Extending the diagnostic power of planetary nebulae — ultra-deep UV spectra of NGC 7027.*
- Tadhunter (Sheffield), *Intrinsic and jet-induced emission line kinematics in radio galaxies.*
- Tadhunter (Sheffield), *The nature of the far-IR/sub-mm excess in powerful radio galaxies.*
- Tanvir (Herts), *The metallicity dependence of the Cepheid Period-Luminosity relation.*
- Tanvir (Herts), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients.*
- Terlevich (IoA), *Probing abundance discontinuities and local enrichments in young starburst galaxies.*
- Vazdekis (Durham), *Accurate mean luminosity-weighted age determination for early-type field galaxies.*
- Warren (ICST), *Remote halo blue horizontal branch stars and the mass of the Milky Way.*

NL NFRA PC

- Bottema (Kapteyn), *The distribution of dark matter in late-type Spiral Galaxies.*
- van Kerkwijk (Utrecht), *Is the Anomalous X-ray Pulsar 4U 0142+614 a Magnetar or an Accretor?*
- Kregel (Kapteyn), *Dynamical stability of the thin disk of NGC 891.*
- Oosterloo (NFRA), *The origin of the gaseous halo of NGC 2403.*
- Orosz (Utrecht), *A dynamical study of the pulsating binary subdwarf B star KPD 1930+2752.*
- Rutten (ING), *The distance to cataclysmic variables.*
- Tschager (Leiden), *The Optical hosts of faint compact-steep-spectrum radio sources - REDSHIFTS.*
- Vreeswijk (Amsterdam), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients.*
- van Woerden (Kapteyn), *Distances of HVC Anticenter complexes and of HCV complex H.*
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Abbreviations:

CAT	Comité para la Asignación de Tiempo
ITP	International Time Programme
NFRA	Netherlands Foundation for Research in Astronomy
NL	The Netherlands
PATT	Panel for the Allocation of Telescope Time
PC	Programme Committee
SP	Spain
UK	The United Kingdom
WFS	Wide Field Survey

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