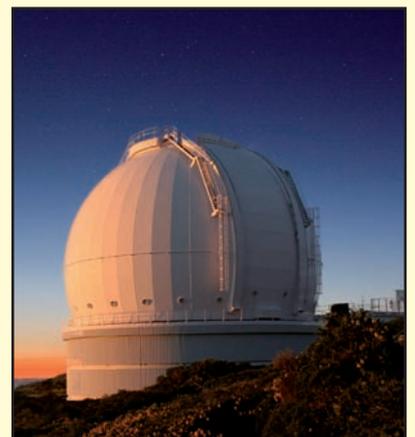




ISAAC
NEWTON
GROUP
OF
TELESCOPES

*Biennial
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2006
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Front cover: The Milky Way from the site of the William Herschel Telescope. Credit: Nik Szymanek. Inset: Photograph of the WHT at sunset. Credit: Nik Szymanek.

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ISAAC NEWTON
GROUP OF TELESCOPES

Biennial

Report

of the STFC-NWO-IAC ING Board



2006 – 2007

ISAAC NEWTON GROUP



William Herschel Telescope



Isaac Newton Telescope



Jacobus Kapteyn Telescope

OF TELESCOPES



The Isaac Newton Group of Telescopes (ING) consists of the 4.2-metre William Herschel Telescope (WHT), the 2.5-metre Isaac Newton Telescope (INT) and the 1.0-metre Jacobus Kapteyn Telescope (JKT). The ING is located 2350 metres above sea level at the Observatorio del Roque de los Muchachos (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 are the result of a collaboration between the United Kingdom, The Netherlands and Spain. 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, the Netherlands and the Spanish Instituto de Astrofísica de Canarias (IAC). 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 Science and Technology Facilities Council (STFC) of the United Kingdom, the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of The Netherlands and the IAC of Spain. The ORM, which is the principal European northern hemisphere observatory, is operated by the IAC.

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FOREWORD



Prof. Thijs van der Hulst
Chair of the ING Board

It is a pleasure to write this foreword to the 2006-2007 Biennial Report of the Isaac Newton Group of Telescopes, on behalf of the ING Board.

The period 2006-2007 was one of consolidating the efforts started several years ago to prepare for operating a world-class facility with a budget which at best is stable. In parallel, the discussion intensified with the partners (STCF, NWO and the IAC) on how to continue to operate the ING at the appropriate level after 2009 when the current agreement comes to an end. Despite these difficult circumstances the ING has been able not only to maintain a world-class observatory with facilities that are high in demand and produce excellent science, but also has developed and completed new facilities such as the Laser Guide Star system, GLAS, opening an new area of science and expertise. The Board is very impressed with these accomplishments and wants to compliment the entire ING staff for carrying the observatory through continued harsh times in such an effective way. It clearly shows the motivation and dedication of all involved.

The past two years have been very productive from a scientific point of view. LIRIS, the near infrared imager/spectrograph designed and built by the IAC for the WHT, is in high demand and producing excellent science. The same statement can be made for the other new instrument OASIS now routinely available at the WHT in combination with NAOMI, the adaptive optics system. Its capabilities will be greatly enhanced with the laser guide star system, GLAS, successfully developed and installed and almost ready for routine observing. GLAS opens up the entire northern sky for Adaptive Optics (AO) assisted spectroscopy and imaging. It is the final step in a strategic development to bring the WHT to the forefront of AO and to bring to fruition a science area that will prove to be very interesting and strategically important for both the ING and its communities. Outside interest in these capabilities is already quite strong.

Another asset of the WHT, accessibility for visiting instruments, continues to prove itself. The demand for visiting instruments, all producing high quality science, remains higher than can be accommodated, and over the last two years we saw INTEGRAL, SAURON, PN.S, PLANETPOL, FASTCAM, GHaFaS (IAC's new Fabry-Perot imager), and ULTRACAM use the WHT, many several times. A new, very valuable and exciting addition in this respect will be the very-high-resolution fibre-fed spectrograph HARPS-NEF, a Harvard planet-finder (complementing the NASA Kepler mission) which will probably come to the WHT and also be available to the general ING community. Negotiations were conducted in 2007 and will be completed early in 2008.

The INT, initially operational in a single instrument mode with the WFC, but now a dual instrument facility again with the IDS back on-line, continues to entertain excellent projects. Use of the INT for large scale surveys has led to the recent first data release of the (H-alpha, r, i) survey of the galactic plane, IPHAS, providing a fascinating view of the northern galactic plane.

The Board continued to focus its attention on the future of the ING past 2009 when the present contracts between the funding agencies, NWO, PPARC and the IAC terminate. The high potential of the ING, in particular the WHT, is widely recognised. The partner countries are close to an agreement with the IAC and NWO continuing to support the ING at the current level past 2009, and the STFC indicating that it will continue supporting the ING, though at a reduced level. With the imminent contract with Harvard for the use of the WHT for HARPS-NEF, it will be possible to find sufficient funding to continue the ING past 2009. The Board and Director have put continued efforts into finding a constructive way forward and it is gratifying to see that a very positive solution is within reach.

INTRODUCTION

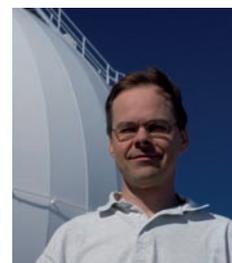
Welcome to the bi-annual report of the Isaac Newton Group of Telescopes. This report is prepared at a time where the observatory finds itself at a crossroads. On the one hand, the telescopes, after more than 20 years of successful operation continue to deliver excellent science and new opportunities, while on the other hand we live in uncertain and turbulent times when funding for continued operation of the telescopes is under pressure.

But if history is our guide to the future, with the WHT having contributed to over 1500 science papers in refereed journals and having played an important role in shaping a generation of scientists, my expectation is that also in future years the ING telescopes will provide a valuable resource to astronomers. Also during the past two years the ING telescopes contributed to exciting research fields ranging from trans-Neptunian objects, through exo-planets and brown dwarfs, to gamma-ray bursters, galaxy formation and evolution, as you can read in this report.

The positive outlook onto the future is underpinned by the prospects of exciting new scientific potential offered by recent and planned developments at the WHT. Just to mention a few highlights: recently a Rayleigh laser beacon was completed that greatly enhances the sky coverage of the adaptive optics system, thus providing Adaptive Optics survey capability. A new imager and low-resolution spectrograph, ACAM, is in an advanced state of development for the WHT, and together with the Center for Astrophysics and Geneva Observatory we are advancing the development of an extremely stable high-resolution spectrograph that will be in operation in 2010 and will have a major impact in the search for extra-solar planets, and ultimately even Earth-size planets.

Developments at the ING must be seen in a wider, European perspective. During the last few years, ideas have been developed to facilitate collaboration on medium-size telescopes across Europe. It is generally recognised that these telescopes remain a valuable scientific resource, but at the same time financial realities make it difficult to maintain and develop them. Cooperation must be the answer. Such a long-term vision of creating a pan-European facility in which the ING will play a central role is strongly endorsed by the partners in the ING and actively pursued in the OPTICON network. Hopefully in the next few years we will see this become a reality.

And at the end of the day, literally, the domes open and photons are being collected with the aim of unveiling the physics of the universe around us. This is only possible thanks to the continued effort from the team of committed, enthusiastic, and competent people forming the ING, day-after-day, night-after-night. Our team is prepared for the future.



Dr. René Rutten
Director of ING

Chapter 1

SCIENTIFIC HIGHLIGHTS

OUTFLOWS FROM AGNS ORIGINATE AS DISK WINDS ORBITING A SUPER-MASSIVE BLACK HOLE

Most galaxies undergo an active phase, during which a central super-massive black hole generates vast radiant luminosities through the gravitational accretion of gas. Winds launched from a rotating accretion disk surrounding the black hole are thought to play a critical role, allowing the disk to shed angular momentum that would otherwise inhibit accretion. Such winds are capable of depositing large amounts of mechanical energy in the host galaxy and its environs, profoundly affecting its formation and evolution, and perhaps regulating the formation of large-scale cosmological structures in the early Universe. However, observational verification that AGN outflows originate as disk winds has proven elusive.

Using the ISIS spectrograph in its spectropolarimetric mode on the WHT, a team of astronomers was able to obtain the first observational evidence that indeed outflows from active galactic nuclei originate as winds from rotating accretion disks surrounding a super-massive black hole. The evidence came from observations of the quasar PG 1700+518 and some of the results can be seen in Figure 1.

A GIANT OUTBURST TWO YEARS BEFORE THE CORE-COLLAPSE OF A MASSIVE STAR

For the first time, astronomers witnessed a double stellar explosion at exactly the same position on the sky, suggesting the death of a massive star.

SN 2006jc was discovered in UGC 4904 on 2006 October 9. The early spectrum was that of a hydrogen-poor event with strong, narrow He I emission lines superimposed on a broad-line spectrum of a type Ic supernova. In 2004, an optical transient was reported which, when retrospectively compared with the SN 2006jc discovery images, appeared to be spatially coincident with the supernova. The 2004 transient was much fainter than SN 2006jc and it remained visible for only a few days after discovery. Given the new

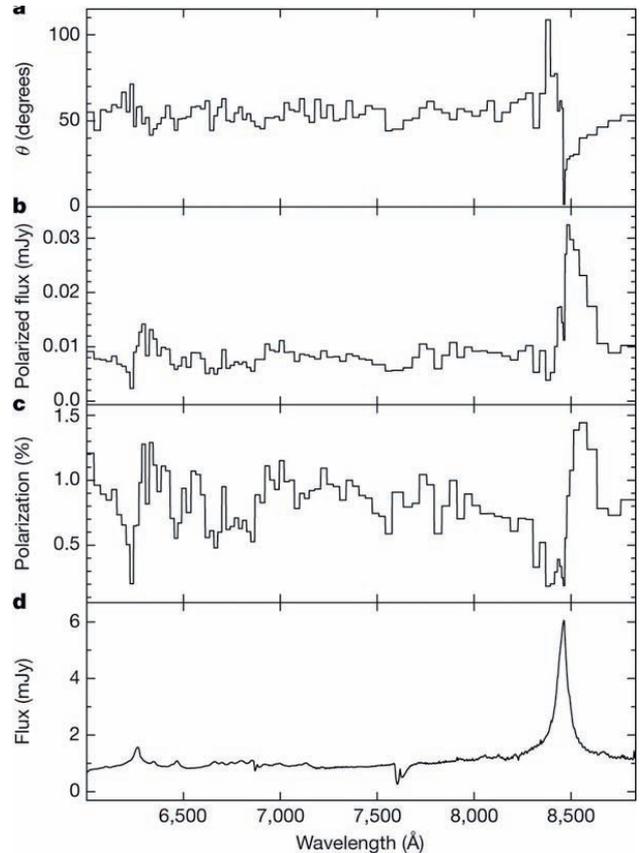


Figure 1. The polarisation data for the BAL quasar PG1700+518. The data were obtained using ISIS spectrograph on the WHT, at a spectral resolution of 3.4 Å. The polarisation data have been re-sampled into bins with an error of 0.1% in degree of polarisation. a) The position angle of polarisation, θ ; b) the polarised flux spectrum in mJy; c) the degree of polarisation as a percentage; and d) the total flux spectrum in mJy. Note the large change in polarisation position angle across the broad H α emission line, which reverses direction at the line peak. In polarised flux, the broad emission line is redshifted with respect to the wavelength of the peak in total flux. Adapted with permission from Macmillan Publishers Ltd: *Nature* (S. Young et al., 450, 74), copyright 2007.

bright supernova discovery, the nature of this transient, named UGC 4904-V1, became intriguing.

A global collaboration of astronomers analysed the images containing the two transients using differential astrometry of 21 nearby stars, and found that UGC 4904-V1 and SN 2006jc were indeed coincident to within the uncertainties. So they decided to follow-up and study SN2006jc with a

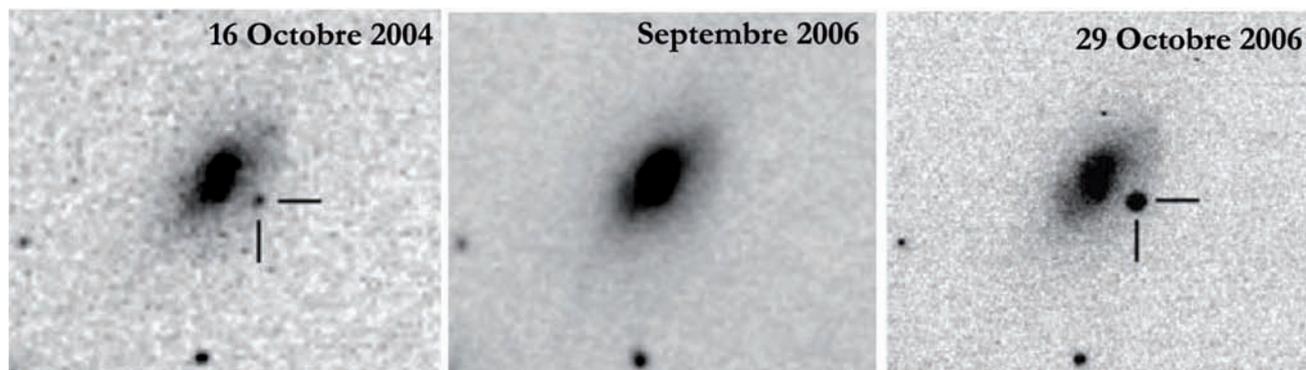


Figure 2. Sequence of images of UGC 4904 rebinned to a pixel scale of 0.53 arcsec. Left: detection of UGC 4904-V1 on 2004 October 16. Middle: another image obtained on 2006 September 21 showing no transient detection. Right: R-band frame taken on 2006 October 29. The two transients are coincident to within 0.1 arcsec, and the total error budget is 0.3 arcsec. Adapted with permission from Macmillan Publishers Ltd: *Nature* (Pastorello, A. et al., 447, 829), copyright 2007.

wide range of large telescopes, among them the WHT and its ISIS spectrograph.

The most likely explanation for the 2004 explosion is a giant outburst of a very massive star like Eta-Carinae, and only the most massive stars can produce this type of outburst. So the 2006 supernova must have been the death of the same star, possibly one that was 50 to 100 times more massive than the Sun. It turns out that SN2006jc is a very weird supernova – unusually rich in the chemical element helium, which supports the idea of a massive star outburst, followed by death.

THE MOST DETAILED IMAGE EVER PRODUCED OF THE ROSETTE NEBULA

Compiled from data taken from IPHAS, the Isaac Newton Telescope Photometric H α Survey of the Northern Galactic Plane, astronomers produced a new image of the Rosette Nebula (NGC 2237) which is thought to be the most-detailed ever produced. The image spans four square degrees, about twenty times the size of the full moon.

The Rosette Nebula is a vast cloud of dust and gas spanning 100 light years and lying about 4500 light-years away. Inside the nebula lies a cluster of bright massive stars (NGC 2244), whose strong stellar winds and radiation have cleared a hole in the nebula's centre. Ultraviolet light from these hot stars excites the surrounding nebula, causing it to glow.

Star formation is still active around the nebula, as proven by the presence of a very young infrared star (AFGL 961) still in its final stages of formation. It is thought that the young massive stars in the nebula will one day blow all the gas and dust away. The centre of the Rosette Nebula is about 1.8 degrees below the Galactic Plane, the glow from

which can be seen at the top left (north eastern) corner of Figure 3.

Due to its large angular size, most large telescopes are unable to capture the entire nebula in one exposure and therefore the highest resolution images have been limited to small areas. IPHAS is in the process of imaging the entire Galactic Plane and members of the survey team were able to combine almost 200 individual CCD images to make this large and detailed H α image.

Even more detailed images of the central parts of the Rosette Nebula have also been prepared by the IPHAS team, including an image of dense dust lanes where star formation may still be ongoing.

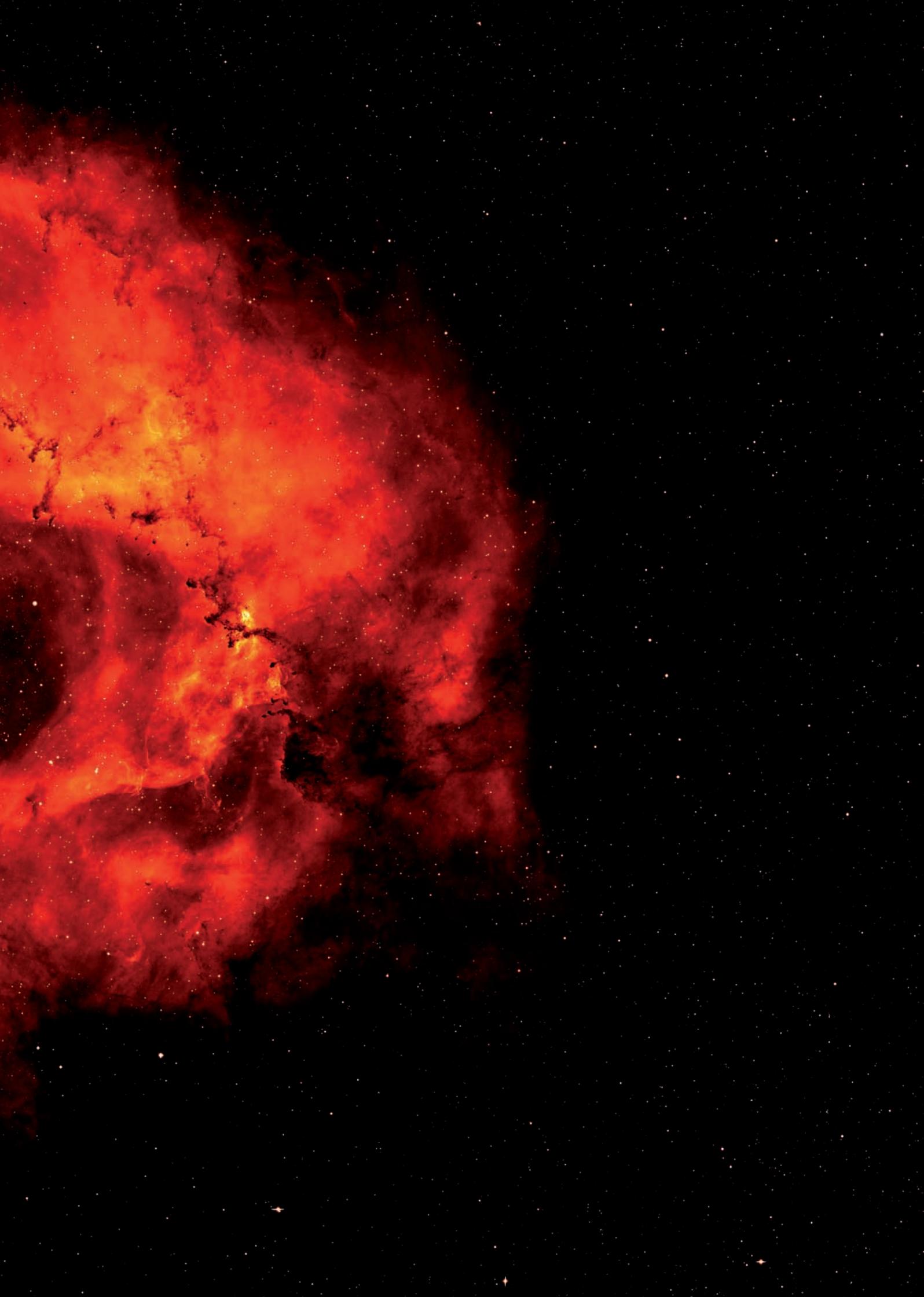
IPHAS is a photometric imaging survey of the entire Northern Galactic Plane at three different wavelengths, using the Wide Field Camera on the INT to cover an area of 1800 square degrees. The survey will soon be followed by VPHAS+, a complementary Southern Galactic Plane survey using telescopes in the southern hemisphere.

THE TRANS-NEPTUNIAN OBJECTS 2005 FY₉ AND 2003 UB₃₁₃ ARE SIMILAR TO PLUTO

The discovery of two large trans-Neptunian objects (TNOs) 2003 UB₃₁₃ and 2005 FY₉, with surface properties similar to those of Pluto, provided an exciting new laboratory for the study of processes found in Pluto and Triton: volatile mixing and transport; atmospheric freeze-out and escape, ice chemistry, and nitrogen phase transitions.

Figure 3. Next two pages: The Rosette Nebula as seen in H-alpha light. Image size is 126x115 arcminutes, 1 arcsecond per pixel. North is up, east is to the left. Image credit: Nick Wright (University College London) and the IPHAS collaboration.





2005 FY₉ is the third brightest known TNO, after 2003 UB₃₁₃ and Pluto. The size of 2005 FY₉ is approximately 0.7 times that of Pluto. The semi-major axis of its orbit is 46 AU, the perihelion distance is 39 AU and the inclination of the orbit is 29°. These values are typical of the classical TNO family.

Visible spectroscopy of 2005FY₉ was obtained using the ISIS spectrograph on the WHT, and near-infrared spectroscopy was obtained using the NICS spectrograph on the TNG. The complete visible and near-infrared spectra were compared with the spectrum of Pluto and that of pure methane ice and it was found that the spectra of both TNOs are very similar. They are dominated by strong absorption bands produced by methane ice. In fact, the absorption bands in the spectrum of 2005 FY₉ are deeper than in the spectrum of Pluto, as a result of the larger abundance of methane ice in 2005 FY₉. Also the colour of the surface of the TNO (indicated by the slope of the spectrum) is red, similar to that of Pluto. This shows the presence of complex organic compounds in the surface.

Until now only one known TNO, Pluto, showed the presence of strong methane ice absorption bands in its spectrum. However, apart from 2005 FY₉, these bands were also recently observed in the spectrum of the largest yet known TNO, 2003 UB₃₁₃, as shown in the Figure 5. The near infrared spectrum of 2003 UB₃₁₃ is very similar to that of 2005 FY₉.

The visible spectrum of 2003UB₃₁₃ shows very prominent absorption bands from solid CH₄. The icy-CH₄ bands are significantly stronger than those of Pluto and slightly weaker than those observed in the spectrum of 2005 FY₉. A shift relative to the position of the bands in the spectrum of laboratory CH₄ ice is observed in the bands at larger wavelengths, but not at shorter wavelengths, which can be explained by a vertical compositional gradient. Purer methane could have condensed first, while 2003 UB₃₁₃ moved towards aphelion during the last 200 years: as the atmosphere gradually collapsed, the composition became more nitrogen-rich due to the fact that most volatile components condensed and CH₄ diluted in N₂, present in the outer surface layers.

THE YORP EFFECT DETECTED ON NEAR-EARTH ASTEROID 2000 PH5

The Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effect is believed to alter the way small bodies in the solar system rotate. YORP is a torque due to sunlight hitting the surfaces of asteroids and meteoroids and warming their

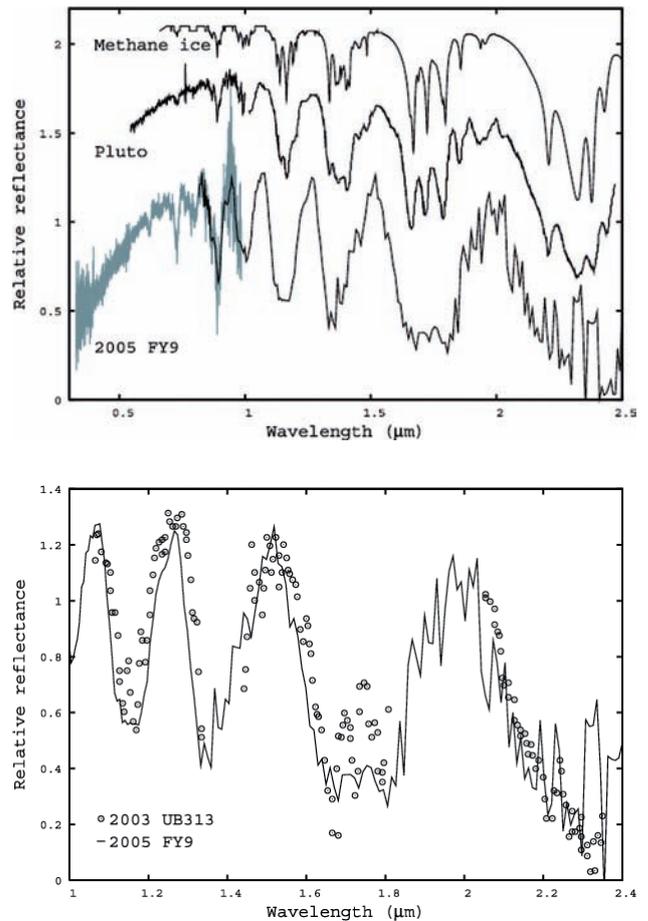


Figure 4. Top: The spectrum of 2005 FY₉ compared with the spectrum of Pluto and that of pure methane ice. Notice the strong methane ice absorption bands present in the spectrum of both TNOs. Bottom: Near infrared spectrum of 2005 FY₉ compared with that of TNO 2003 UB₃₁₃. The similarity of both spectra shows that the surface composition of the two objects must be similar (figure from Licandro et al., 2006, A&A, 445, L35).

surfaces, leading to a gentle recoil effect as the heat is emitted. By analogy, if one were to shine light on a propeller over a long enough period, it would start spinning.

Although this is an almost immeasurably weak force, astronomers believe it may be responsible for spinning some asteroids up so fast that they break apart, perhaps leading to the formation of binary asteroids. Others may be slowed down so that they take many days to rotate once. The YORP effect also plays an important role in changing the orbits of asteroids between Mars and Jupiter, including their delivery to planet-crossing orbits. Despite its importance, the effect has never been seen acting on a solar system body, until now.

Using extensive optical and radar imaging from powerful Earth-based observatories, astronomers have directly

observed the YORP effect in action on a small near-Earth asteroid, known as (54509) 2000 PH5.

Shortly after its discovery in 2000, it was realised that this asteroid would be the ideal candidate for such a YORP detection. At just 114m in diameter, it is relatively small and so more susceptible to the effect. Also, it rotates very quickly, with one day on the asteroid lasting just over 12 Earth minutes, implying that the YORP effect may have been acting on it for some time. With this in mind, the team of radar and optical astronomers undertook a long term monitoring campaign of the asteroid, with the aim of detecting any tiny changes in the spin-rate.

Over a 4 year time span, astronomers took images of the asteroid at a range of telescope sites including the INT. With these facilities the astronomers measured the slight brightness variations as the asteroid rotated.

They found that the asteroid is rotating faster by 1 millisecond every year, which is caused by the heating of the asteroid's surface by the Sun. Eventually it may spin faster than any known asteroid in the solar system. Figure 5 shows the change of the rotational period over the years.

COMET 17P/HOLMES OBSERVED WITH THE EYES OF THE INT

On the night of the 23rd of October 2006, Comet 17P/Holmes underwent an outburst that increased its brightness by a factor of a million during the following days.

The INT pointed to the comet just after sunset on the night following the outburst, and it detected a highly centralised condensed coma with no signs of a tail. The coma had

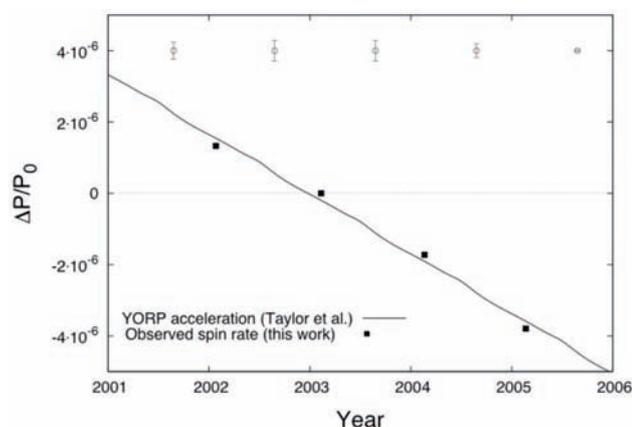


Figure 5. The observed spin-rate was seen to change from year to year (black dots). The solid curve is the expected theoretical YORP strength derived from the 3-D shape model (figure from Lowry et al., 2007, *Science*, 316, 272).



Figure 6. INT image of comet 17P/Holmes processed to show the inner coma structure. Credit: T Naylor / A Fitzsimmons / C Brunt / ING.

extended out to 37,000 km from the nucleus, and the outer edge was almost perfectly circular. This distance implied that the dust was moving at least 0.2 km per second (800 km per hour) from the central nucleus. Image processing showed that the material was currently leaving the comet towards the South East.

Figure 6 shows an expanding circular cloud of gas and dust emanating from the nucleus, together with a brighter cloud of material.

FIRST OBSERVATIONAL EVIDENCE OF A DEAD CATAclySMIC VARIABLE

A long-standing and unverified prediction of binary star evolution theory is the existence of a population of white dwarfs accreting from substellar donor stars. Such systems ought to be common, but the difficulty of finding them, combined with the challenge of detecting the donor against the light from accretion, means that no donor star to date has a measured mass below the hydrogen burning limit.

A binary star system in which a white dwarf accretes material from a companion is called a cataclysmic variable (CV). Every kilogram of material that falls onto the white dwarf gains the energy equivalent of a few kilotons of TNT. Much of this energy is released as ultraviolet or X-ray radiation. Many CVs have been identified from this highly variable, short-wavelength light produced by rapid mass transfer onto the white dwarf. However, most CVs should have evolved through this violent phase to become a "dead CV" with a low-mass companion that can support

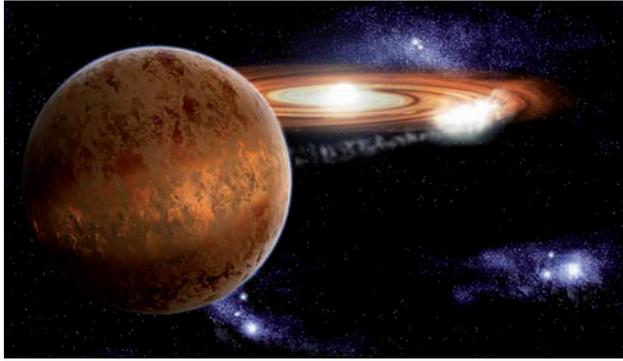


Figure 6. Artist's impression of SDSS 1035+0551. The hot white dwarf is the same size as the Earth, yet its mass is the same as our Sun. The brown dwarf is about the same size as Jupiter, but much more massive. The gravity of the white dwarf pulls gas from the brown dwarf; this gas spirals down onto the surface of the white dwarf, like water down a plughole, forming an accretion disc of hot gas around the white dwarf. Where the falling gas from the brown dwarf hits the accretion disc, it creates a hot spot. The position of this hot spot depends on the masses of the two stars. The authors precisely timed when the white dwarf and hot spot were eclipsed by the brown dwarf. This allowed them to measure the location of the hot spot, and infer the masses of the two stars. Credit: Stuart Littlefair/Science.

only weak mass transfer. Extensive efforts to confirm this long-standing prediction have failed to identify any CVs that have clearly survived the rapid mass transfer phase of their evolution.

A team of astronomers using ULTRACAM on the WHT reported for the first time the unambiguous detection of a dead CV from a direct mass measurement of the low-mass companion in the CV SDSS 103533.03+055158.4 (SDSS 1035 for short).

The orbital period of SDSS 1035 is only 82 min, so small features such as the white dwarf are eclipsed in less than a minute. To accurately measure these rapid changes of brightness in such a faint star, they used ULTRACAM, an instrument that uses CCDs to measure the brightness of CVs and other rapidly varying stars. The data quality is impressive and leads to a mass for the companion accurate to about 4%. This is good enough to show convincingly that they were observing a genuine dead CV because the companion is well below the limit of 0.072 solar masses, after which a star cannot sustain nuclear reactions in its core. Objects that are born with masses below this limit are known as brown dwarfs.

A typical CV is smaller than the Sun, so there is a good chance that the orientation of the binary is such that the companion eclipses the white dwarf once every orbit as seen from Earth. This will lead to an apparent dimming of

the CV every orbit during the few minutes that the companion blocks the light from the white dwarf. SDSS 1035 is an eclipsing CV, so there is a wealth of information to be gleaned from the changes in brightness during the eclipse. These show, for example, that the mass transferred from the low-mass companion forms a disc around the white dwarf with a bright spot on its outer edge due to the inflowing material.

A GASEOUS METAL DISK AROUND A WHITE DWARF

As the main-sequence stars hosting planetary systems evolve through the red-giant stage, they swell up and destroy planets and asteroids out to many hundred solar radii. However, a team of astronomers found a metal-rich gas disk around a moderately hot and young white dwarf.

The mass of the white dwarf implies a relatively massive main-sequence progenitor of ~4 to 5 solar masses, which will have expanded to a radius of ~1000 solar radii. It is therefore impossible that the material making up the present-day disk has survived the giant phase at its current location; it must instead have been brought inward from outside a distance of 1000 solar radii.

The white dwarf SDSS J122859.93+104032.9 (henceforth SDSS 1228+1040) was identified as a moderately hot 0.77 solar-mass white dwarf, but noted very unusual emission lines from the Ca II 850- to 866-nm triplet, as well as weaker emission lines from Fe II at 502 and 517 nm. The line profiles of the Ca II triplet display a distinct double-peaked morphology, which is the hallmark of a gaseous, rotating disk. Time-resolved spectroscopy and photometry do not reveal any radial velocity or brightness variations. These data exclude the possibility that SDSS 1228+1040 is an interacting white dwarf binary, in which an accretion disk around the white dwarf forms from material supplied by a nearby companion star. Furthermore, the absence of Balmer and helium emission lines implies that the gaseous disk around SDSS 1228+1040 must be extremely deficient in volatile elements, which independently rules out an interacting binary nature for this object.

A dynamical model of the double-peaked emission lines constrains the outer disk radius to just 1.2 solar radii. A possible origin of such dust disks is the tidal disruption of either comets or asteroids. Asteroids appear to be more likely candidates because they can explain the large amount of metals accreted by the white dwarfs from the dusty environment, as well as the absence of hydrogen or helium. Furthermore, the radius derived from the

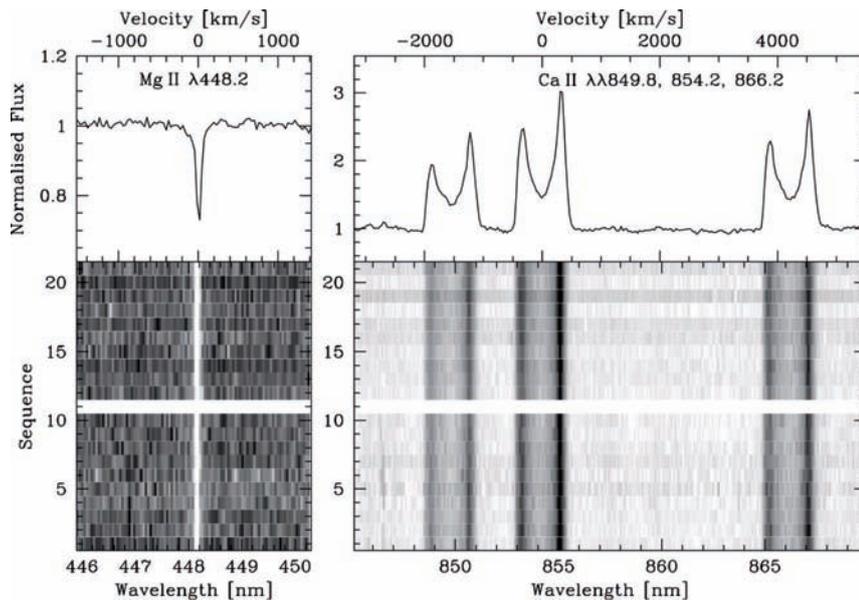


Figure 7. Time-resolved spectroscopy of SDSS 1228+1040. Medium-resolution spectroscopy of SDSS 1228+1040 was obtained with the double-arm spectrograph ISIS on the WHT. Two sets of 10 consecutive spectra each were obtained. The bottom panels show the two time series of spectra, each extending over 1.7 hours, centered on the calcium emission triplet (right) and the magnesium absorption line (left). The normalised average spectra are shown in the top panels. Radial velocities are given in the upper axes with respect to CaII 854 nm (right) and MgII 448 nm (left). The radial velocity of the MgII line is stable to within ± 4 km/s over time scales of 20 min to 1 day. Additional time-series photometry obtained with the Wide-Field Camera at the INT shows the star at constant brightness within ± 0.01 mag (figure from Gänsicke et al., 2006, *Science*, 314, 1908. Reprinted with permission from AAAS).

dynamical model is compatible with the tidal disruption radius for a rocky asteroid.

Although the detection of asteroid debris around SDSS 1228+1040 represents a possible link to the existence of planetary systems around their main-sequence progenitor stars, modelling the excess infrared luminosity provides no direct information on the geometric location and extension of the dust, impeding a more detailed understanding of the nature and origin of the circumstellar material.

But certainly the infrared excess found around metal-polluted white dwarfs hotter than 15,000K suggests that the radiation field of these hot white dwarfs causes sublimation of a dust disk and the case of SDSS 1228+1040 demonstrates that planetary debris material can be detected around younger and hotter white dwarfs in the form of gaseous disks. Furthermore, the detection of a metal-rich debris disk around this relatively massive white dwarf indicates that the formation of planetary systems can take place also around short-lived massive stars.

THE LEAST-MASSIVE BROWN DWARFS IN THE PLEIADES

A search for low-mass brown dwarfs in the Pleiades open cluster has led to the identification of the least massive cluster members: BRB 28 and 29 have masses of the order of 25 Jupiter masses, and they were confirmed as cluster members from HK_S photometry and proper motion measurements using the Long-slit Intermediate Resolution Infrared Spectrograph (LIRIS) on the WHT.

This discovery will help to constrain evolutionary models for L-type brown dwarfs and to extend the study of the cluster mass function to lower masses. The existence of such low-massive brown dwarfs and their frequency in relation to higher mass stars might indicate the presence of planetary-mass bodies floating freely in the Pleiades.

FIRST DETECTION OF RUBIDIUM IN ASYMPTOTIC GIANT BRANCH STARS

A long debated issue concerning the nucleosynthesis of neutron-rich elements in Asymptotic Giant Branch (AGB) stars is the identification of the neutron source. Low- and intermediate-mass stars (1 to 8 solar masses) evolve towards the asymptotic giant branch (AGB) phase after the completion of hydrogen and helium burning in their cores, before they form planetary nebulae, ending their lives as white dwarfs. Basically, an AGB star is composed of an inert carbon-oxygen (C-O) core surrounded by a He-rich intershell and an extended H-rich convective envelope. Nuclear energy release is dominated by the H shell and interrupted periodically by thermonuclear runaway He-shell "thermal pulses" that initiate a series of convective and other mixing events. Strong mass loss enriches the interstellar medium (ISM) with the products of the resulting complex nucleosynthesis. During this thermally pulsing AGB (TP-AGB) phase, stars originally born O-rich (reflecting the ISM composition) can turn C-rich ($C/O > 1$) as a consequence of the "dredge-up" of processed material from the bottom of the convective envelope to the stellar surface.

Mixing of protons into the He-rich intershell during the TP-AGB phase leads to reaction chains producing free

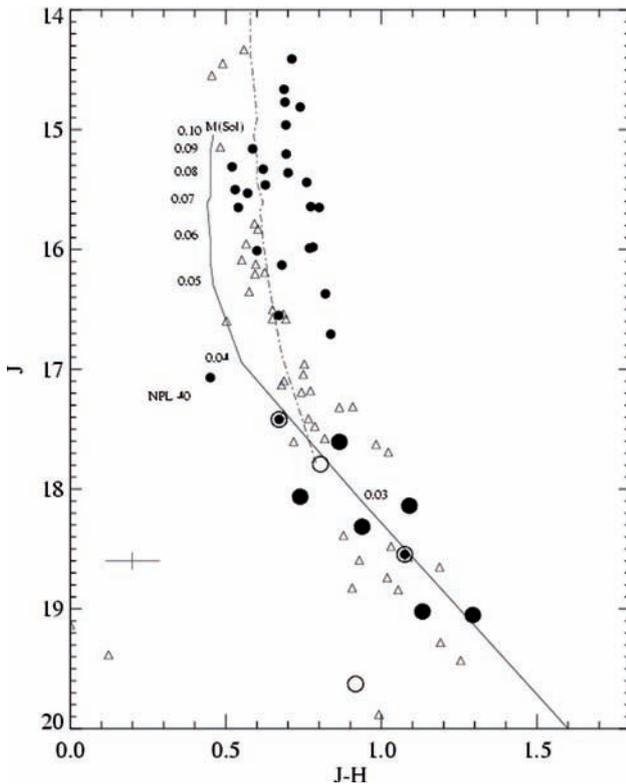


Figure 8. *J* versus *J-H* colour-magnitude diagram for all Pleiades very low-mass star and brown dwarf candidates of the survey with lithium abundance or proper motion consistent with membership (filled circles) (figure from Bihain et al., 2006, *A&A*, 458, 805).

neutrons, which allow production of neutron-rich elements such as Rb, Sr, Y, Zr, Ba, La, Nd, and Tc by slow neutron capture on iron nuclei and other heavy elements (the s process). There are two possible chains for the neutron production: $^{13}\text{C}(\alpha, n)^{16}\text{O}$ and $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$. The ^{13}C neutron source operates at relatively low neutron densities and temperatures in TP-AGB stars during the inter pulse period. The ^{22}Ne neutron source operates at much higher neutron densities and requires higher temperatures, which are achieved only while the convective thermal pulse is ongoing.

In the more massive AGB stars where these high temperatures are more easily achieved, the s-process elements are expected to form mainly through the ^{22}Ne reaction that also strongly favours the production of the stable isotope ^{87}Rb (because of the operation of a branching in the s-process path at ^{85}Kr that modifies the isotopic mix between ^{85}Rb and ^{87}Rb).

Unfortunately, the Rb isotope ratio cannot be measured in stellar sources even with the help of very-high-resolution spectra, because the lines are too broad, and thus it is difficult to use this parameter as a neutron density

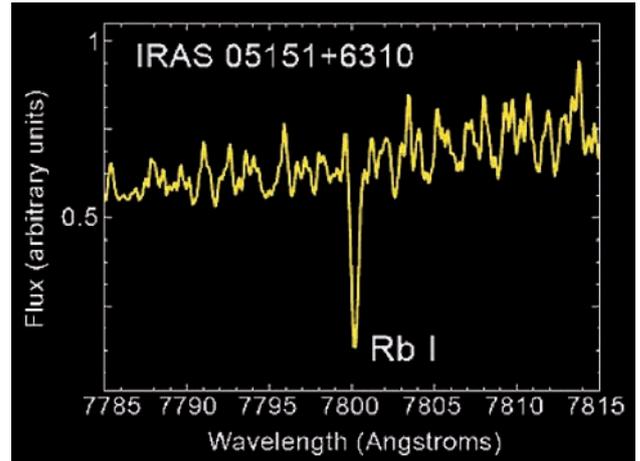


Figure 9. Rubidium line at 7800Å as detected by the UES spectrograph on the WHT in BW Cam, one of the AGB stars observed in this study. Credit: IAC/ESA.

indicator. As an alternative, the total Rb abundance can be used. The theoretical prediction is that the relative abundance of Rb to other nearby elements produced by the s-process, such as Zr, Y, and Sr, is a powerful indicator of the neutron density at the s-process site and, as such, is a good discriminator of the operation of the ^{13}C versus the ^{22}Ne neutron source in AGB stars.

A team of astronomers using the Utrecht Echelle Spectrograph (UES) on the WHT reported for the first time intermediate-mass (4 to 8 solar masses) AGB stars in our Galaxy that are Rb-rich as a result of overproduction of the long-lived radioactive isotope ^{87}Rb . This represents direct observational evidence, predicted theoretically 40 years ago, that the slow-neutron capture process following the $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$ reaction must be the dominant neutron source in these stars.

Because huge amounts of Rb-rich processed material can be transferred to the interstellar medium by massive AGB stars, this result has also relevant implications for the Rb primeval solar nebula abundance.

Radioactive dating studies of primitive chondrites assume that the initial conditions are known and that the oldest components of chondrites evolved without external exchange of Rb. The results of this research, however, suggests that the initial abundance may have been altered by a nearby population of massive AGB stars during the early evolution of our Solar System, and consequently, the Rb abundance measured in primitive meteorites should be considered only as a qualitative measure of antiquity.

THE MEDIUM-RESOLUTION INT LIBRARY OF EMPIRICAL SPECTRA

A project aimed at improving the existing tools for extracting stellar population information using the optical region of composite spectra was started by a team of astronomers mainly using the IDS spectrograph on the INT. Although the main motivation of this work was to use this new calibration to study the stellar content of galaxies using spectra of unresolved stellar populations, it was anticipated that the material could also be useful in other areas of astronomy.

This included a new stellar library (MILES – the Medium-resolution Isaac Newton telescope Library of Empirical Spectra), a set of homogeneous atmospheric parameters, a redefinition and recalibration of spectral-line indices, empirical fitting functions describing the behaviour of indices with stellar parameters, and stellar population model predictions.

A comprehensive spectral library with medium-to-high resolution and a good coverage of the Hertzsprung–Russell (HR) diagram is an essential tool in several areas of astronomy. In particular, this is one of the most important ingredients of stellar population synthesis, providing the behaviour of individual stellar spectra as a function of temperature, gravity and chemical abundances.

Unfortunately, the empirical libraries included in this kind of models up to now, contained few stars with non-solar metallicity, compromising the accuracy of predictions at low and high metallicity. This problem has usually been partially solved by using empirical fitting functions, polynomials that relate the stellar atmospheric parameters (T_{eff} , $\log g$, and $[Fe/H]$) to measured equivalent widths. These functions allow the inclusion of any star required by the model (but within the stellar atmospheric parameter ranges covered by the functions), using a smooth interpolation.

However, the new generation of stellar population models go beyond the prediction of individual features for a simple stellar population, and they attempt to synthesise full spectral energy distributions (SEDs). In this case, the fitting functions cannot be used, and a library of stars covering the full range of atmospheric parameters in an ample and homogeneous way was urgently demanded. Moreover, although the evolutionary synthesis codes do not require absolute fluxes, the different stellar spectra must be properly flux calibrated in a relative sense so that the whole SED can be modelled. This, however, is quite

difficult to achieve in practice, due to the wavelength-dependent flux losses caused by differential refraction when a narrow slit is used in order to obtain a fair spectral resolution.

Another important caveat in the interpretation of the composite spectrum of a given galaxy is the difficulty of disentangling the effects of age and metallicity. Due to blending effects, this problem is worsened when working at low spectral resolution, as is the case when low-resolution stellar libraries are used. There are a few studies that have attempted to include spectral features at higher resolution. However, predicting such high-dispersion SEDs is very difficult owing to the unavailability of a library with the required input spectra.

Whilst the new generation of large telescopes are already gathering high-quality spectra for low- and high-redshift galaxies, the stellar population models suffer from a lack of extensive empirical stellar libraries to successfully interpret the observational data. At the moment, the available stellar libraries have important shortcomings, such as a small number of stars, poor coverage of atmospheric parameters, narrow spectral ranges, low-resolution and non-flux-calibrated response curves.

The MILES library overcomes some of the limitations of the previous libraries. The new library covers the spectral range 3525–7500 Å at spectral resolution of 2.3 Å [full width at half-maximum (FWHM)]. The spectra of 985 stars with metallicities ranging from $[Fe/H] \sim -2.7$ to $+1.0$ and a wide range of temperatures were obtained using the IDS spectrograph on the INT over a total of 25 nights in 5 different runs.

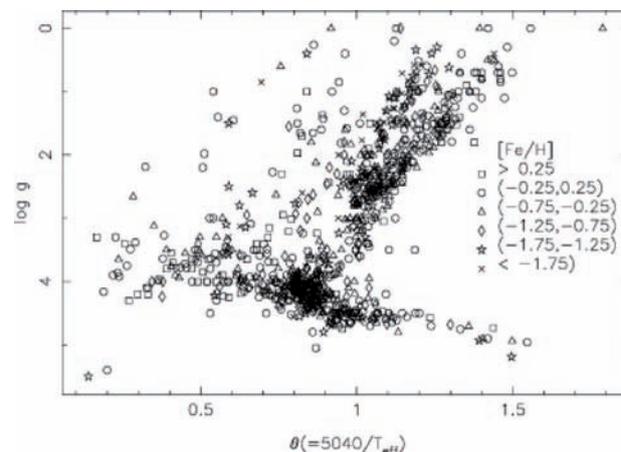


Figure 10. Gravity–temperature diagram for the library stars. Different symbols are used to indicate stars of different metallicities, as shown in the key (figure from Sánchez-Blázquez et al., 2006, MNRAS, 371, 703).

SHORT TIME-SCALE VARIABILITY IN THE FAINT SKY VARIABILITY SURVEY

There is a wide range of photometrically variable systems in the Universe. The range of time-scales on which these systems vary, is as wide as the physical processes that produce their variability. For example, we have intrinsically variable stars, where the variability is caused by changes in their internal structure or atmospheres that vary with time-scales of minutes to years. Other stars show variability because they rotate and their surface is inhomogeneous, for example, because of star spots, or because they form part of a binary or multiple system and their revolution around the centre of mass of the system results in changes in the detected flux due to the changing aspect of a non-isotropically emitting surface or eclipses.

This is also the case for planets orbiting stars. The time-scale of the variability in this case is dictated by the orbital parameters of the system and can range from seconds to years. Near-earth objects (NEOs), such as asteroids, also show variability as they rotate and are non-spherical.

We find photometric variability in extragalactic objects as well, such as quasars, where the variability is probably the result of material being accreted by the central engine, or 'one off' systems, such as gamma-ray bursts (GRBs) or supernovae (SNe) where the variability is produced by intrinsic changes in the structure of an astronomical object that take place only once.

The study of variability provides important information about the physical nature of the variable objects, leads to the discovery of new classes of objects, helps to study the physical structure of stars, for example, pulsating stars, allows us to obtain information on Galactic structure through the use of variables such as RR Lyrae as standard candles, and is the key to determining extragalactic distances through the use of standard candles, such as Cepheids and Type Ia SNe.

Most of our knowledge of variability is based on the study of apparently bright sources, which naturally selects members of intrinsically bright populations. At present, little is known about variability of intrinsically fainter populations, because in bright samples they are lacking altogether or are only represented by a few members.

The Faint Sky Variability Survey (FSVS) was one of the programmes of the INT Wide Field Survey and it was designed to account for this deficit by studying two unexplored regions of the variability space: the short time-

scale variability region (down to tens of minutes) and the intrinsically faint variable sources (down to $V = 24$ mag) at mid and high Galactic latitudes. The FSVS also contains colour information for all targets, giving us the option of positioning objects in the colour-colour diagram, as well as finding the variability time-scales and amplitudes that characterise them. The main aims of the FSVS are thus to obtain a map of a region of the Galaxy (~ 21 deg²) in variability and colour space, to determine the population density of the different variable objects that reside in the Galaxy and to find the photometric signature of up-to-now unknown intrinsically faint variable populations.

The full FSVS data set consists of 78 Wide Field Camera (WFC) fields, covering an area in the sky located at mid and high Galactic latitudes ($-40 < b < -21$, $15 < b < 50$, $89 < b < 90$). For each field, they took one set of B -, I - and V -band observations on a given photometric night. Photometric variability observations were taken with the V filter on several consecutive nights. On average, fields were observed 10–20 times within one week in the V band. Exposure times were 10 min with a dead time between observations of 2 min. This observing pattern allows one to sample periodicity time-scales from $2 \times (\text{observing time} + \text{dead time})$ (i.e. 24 minutes) to twice the maximum time-separation of observations (which ranges from 3 to 13 days). All fields were re-observed years later to determine proper motions.

A V -band variability analysis of the point sources in the FSVS on time-scales from 24 min to tens of days showed that about one per cent of the point sources down to $V = 24$ are variables. Of these, about 50 per cent show variability time-scales shorter than 6 h, 22 per cent show variabilities between 6 h and 1 d, 20 per cent between 1 and 4 d and 8 per cent show periods longer than 4 d. The total number of variables is dominated by main sequence sources. The distribution of variables with spectral type is fairly constant along the main sequence, with 1 per cent of the sources being variable, except between spectral types F0 and F5, where the fraction of variable sources increases to about 2 per cent. For bluer sources, above the main sequence, beyond the blue cut-off at $(B-V) < 0.38$, this percentage increases to about 3.5. About a third of the total number of short time-scale variables found in the survey were not detected in either B or/and I band. These show a similar variability time-scale distribution to that found for the variables detected in all three bands.

The observed variability is likely to be the result of pulsations, binarity and stellar rotation as well as intrinsic flaring activity in the case of main sequence stars. One RR

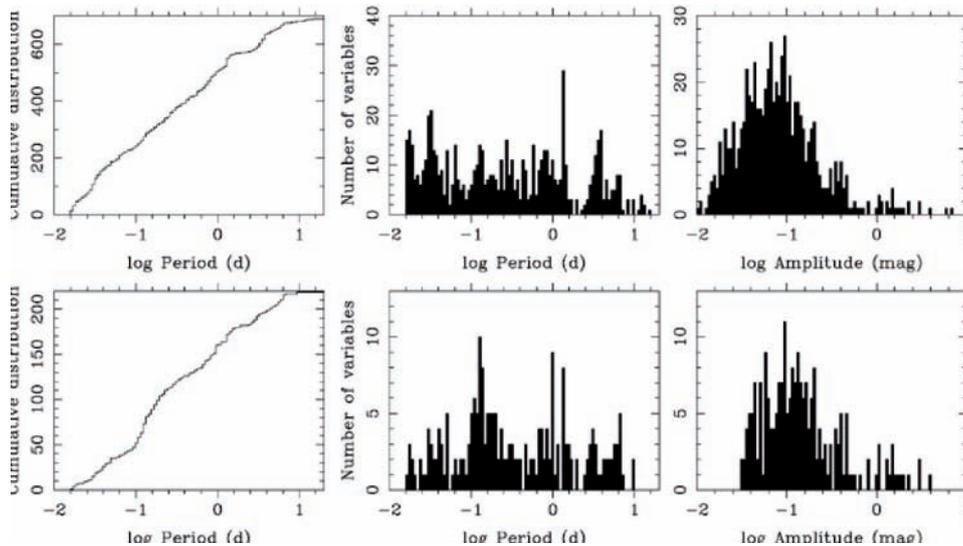


Figure 11. Histograms showing the cumulative period distribution (left hand panels), the period distribution (middle panels) and the amplitude distribution (right-hand panels) for the short-term variable point sources in the FSVS. Top panels: the 689 out of 744 sources with accuracies in the periods and amplitudes of the order of 30 per cent or less. Bottom panels: sources where the error in their periods and amplitudes is of the order of 10 per cent or less (figure from Morales-Rueda, 2006, *MNRAS*, 371, 1681).

Lyr candidate found is the furthest known in the Galaxy and could allow the determination of the mass of the Milky Way.

The highest space densities of variables found in the FSVS (i.e. 17 deg⁻²) show periods below 12 h. These include CVs, RR Lyr stars, and other short-period pulsators, such as δ Scuti stars. They find a density of four variables per deg² centred on a 1 d period which includes longer-period CVs, RR Lyr and other pulsators, like γ Doradus stars and Population II Cepheids. A space density of two variables per deg² at 3.75 d includes some longer-period CVs, γ Doradus stars, Population II Cepheids and longer-period pulsators, such as subdwarf B stars. At 12.75 d, they also find two variables per deg². These would be mainly binaries with those orbital periods and Population II Cepheids.

The FSVS is complete down to $V=22$ for CVs in the minimum period (80 min), as long as they show variability amplitudes of the order of 0.4 mag. It is complete down to $V=22$ for periods between 80 min and 1 d in a 17.82-deg² area of the survey, as long as the amplitude of the variability is at least 0.7 mag. This includes most RR Lyr stars.

NEW PLANETARY NEBULAE DISCOVERED BY IPHAS

The INT/WFC Photometric H α Survey of the Northern Galactic Plane (IPHAS) is currently mapping 1800 degrees² of the Northern Galactic plane (a band between $b = -5$ to $+5$ degrees) in three filters using the INT Wide Field Camera. The survey is an international collaboration of 15 institutes. A narrow-band H α and two Sloan filters (r' and i') are used for matched 120, 30, and 10 s exposures, respectively, spanning the magnitude range $r'=13$ to 20

mag for point sources. IPHAS is the first fully-photometric H α survey of the Galactic plane. It will discover around 40,000 new emission-line stars, including young stars (T Tau, Herbig AeBe stars, etc.), evolved stars (post-AGB, LBVs, etc.) as well as binaries (CVs, symbiotic stars, etc.) in addition to thousands of extended nebulae such as Planetary Nebulae (PNe), H-H objects, HII regions, SN remnants, etc.

Two systematic searches for PNe are currently conducted on the IPHAS data. Extended PNe are searched visually from continuum subtracted mosaics of IPHAS data while the compact PNe search is based on IPHAS catalogue information. The first step to select compact PN candidates is to filter out all objects which are too close to the borders of the CCDs or to the areas of bad pixels, as well as sources which are not classified as stars or extended objects. Also a first cut in the $r'-H\alpha$ plane is made removing all objects with $r'-H\alpha < (r'-H\alpha)_{\text{median}} + 1$, which removes the majority of the stellar locus objects. They also remove sources where the positional match between individual images is worse than 0.65 arcsec. Together with the visual search for extended PNe they expect to find a total of 500–1000 new Galactic PNe.

The discovery of the first new PN from this survey is an unusual object located at a large galactocentric distance and has a very low oxygen abundance. The so-called "Príncipes de Asturias" nebula shows an intricate morphology: there is an inner ring surrounding the central star, bright inner lobes with an enhanced waist, and very faint lobular extensions reaching up to more than 100".

Another example is the Ear Nebula shown in Figure 13. The exposure times amounted to 50 minutes in H α and 30

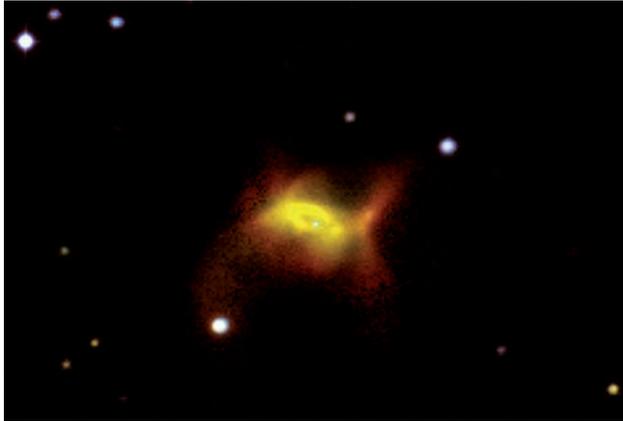


Figure 12. The "Príncipes de Asturias" nebula or IPHAS PN-1. Credit: Antonio Mampaso, Romano Corradi and the IPHAS Collaboration.



Figure 13. The Ear Nebula is one of the new PNe discovered by IPHAS. This is a two-colour image, red for $H\alpha$ and green for $[O III]$. North is to the right and East is to the top. Credit: Laurence Sabin, Nick Wright and the IPHAS Collaboration.

minutes in $[O III]$. The nebula was confirmed to be a relatively old planetary nebula using the ISIS spectrograph on the William Herschel Telescope.

A WHIRLPOOL IN THE WAKE LEFT BY A DYING STAR

The central star of Sharpless 2-188 is 850 light years away and it is travelling at 125 kilometres per second across the sky. Observations show a strong brightening in the direction in which the star is moving and faint material stretching away in the opposite direction.



Figure 14. A combined image showing the bright regions and the faint regions behind the bright arc of the Sharpless 2-188 nebula (figure from Wareing et al., 2006, MNRAS, 366, 387).

The astronomers compared the predictions from a simulation in three-dimensions of the movement of a dying star through surrounding interstellar gas with observations of the planetary nebula Sharpless 2-188 taken as part of the IPHAS survey. They believe that the bright structures in the arc observed ahead of Sharpless 2-188 are the bowshock instabilities revealed in the simulations, which will form whirlpools as they spiral past the star downstream to the tail.

IPHAS INITIAL DATA RELEASE

The IPHAS collaboration, together with the Cambridge Astronomical Survey Unit (CASU) and the Astrogrid Virtual Observatory (VO) announced the availability of the IPHAS Initial Data Release (IDR).

The IPHAS IDR is a photometric catalogue of more than 200 million objects coupled with associated imaging data covering about 1700 square degrees in three colours. The survey is aimed at revealing large scale structure in our local galaxy, and also the properties of key early and late populations making up the Milky Way.

The object catalogues and data quality control parameters have been ingested in a Sybase Relational Database Management System. The access to the primary data products has been implemented through use of standard VO publishing interfaces as provided by the Astrogrid system.

BROWN DWARFS AND ISOLATED PLANETARY-MASS OBJECTS

Using data from a deep infrared survey of the young σ Orionis open cluster, astronomers searched for low-mass objects in the central region down to 6 Jupiter masses and studied their mass distribution.

The survey was built from data taken with the Wide Field Camera on the INT and ISAAC on VLT's UT1 Antu. Deep I - and J -band images of a 0.22deg^2 region close to the cluster centre were obtained, reaching limiting magnitudes of $I\sim 24.1$ and $J\sim 21.8$ respectively. The LIRIS infrared spectrograph and imager on the WHT was also used to obtain some deep images in the H and K_s bands. And follow-up of candidates was performed using data from the 2MASS survey, the Spitzer Space Telescope, and other telescopes.

The survey yielded 30 very young cluster low-mass objects, among them brown dwarfs (BDs) and isolated planetary-mass objects (IPMOs). By studying their mass spectrum, or counting the number of objects per mass interval, the astronomers found a rising mass spectrum in the mass interval 0.11 to 0.006 solar masses implying that IPMOs could be as frequent as our Sun.

They found no direct evidence for the presence of an opacity-mass limit for objects formed via fragmentation and collapse of molecular clouds implying that BDs and IPMOs probably form as an extension of the low-mass star formation process. Any possible mass cut-off would lie below 0.006 solar masses or 6 Jupiter masses.

Another interesting result of their research is that almost half of the studied BDs harbour protoplanetary discs.

A LOW-MASS PRE-MAIN-SEQUENCE ECLIPSING BINARY SYSTEM

Eclipsing binaries are a special class of spectroscopic binaries, systems where the components are so close together that they cannot be separated by imaging. In an eclipsing binary, the system is edge-on as seen from the Earth, so one star passes in front of the other every half orbit, causing the total light emitted to dim in a periodic fashion. By measuring the shape of these eclipses in a light curve of the system, astronomers can derive the radii of the stars in the binary.

The binary system JW 380, located in the very young Orion Nebula Cluster (ONC), was identified using time-series

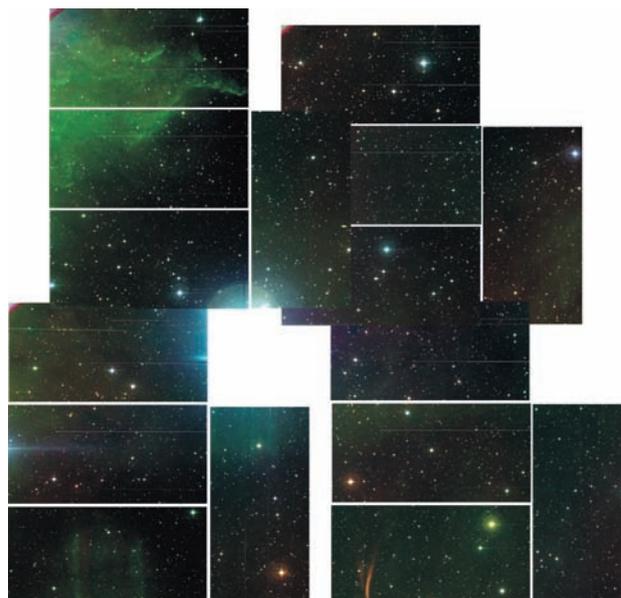


Figure 15. Colour composition of the σ Orionis open cluster (North is up and East to the left) from images taken using the Wide Field Camera on the INT.

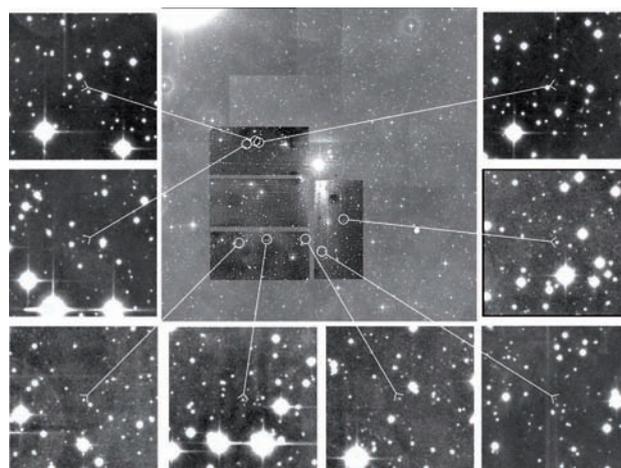


Figure 16. Mosaic of I -band images centred on σ Orionis taken with the Wide Field Camera on the INT showing the location of some of the low-mass objects. North is up and East to the left. The size of each Wide Field Camera frame is about 11×22 arcmin². The background image is from DSS-2-IR.

imaging observations taken with the Wide Field Camera on the INT. These observations were part of the Monitor project, a large-scale survey searching for eclipsing binary and transiting extrasolar planet systems in a number of young open star clusters.

Follow-up spectroscopic observations obtained using the FLAMES fibre-fed spectrograph on the VLT UT2 and the NOAO Phoenix spectrograph on Gemini-South were used to derive the radial velocities and hence component masses of the stars, as well as to confirm the system's membership in the ONC.



Figure 17. Colour composition of a Wide Field Camera image of the Orion Nebula. Credit: Jonathan Irwin.

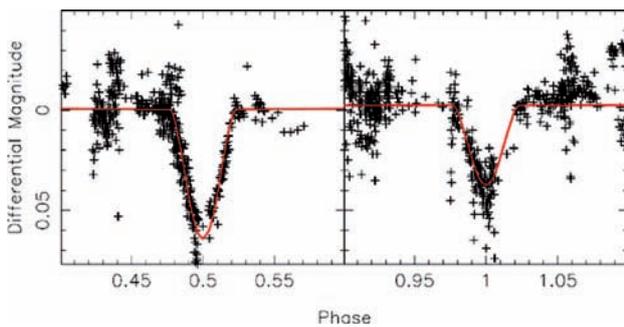


Figure 18. Eclipses in the light curve of JW 380 (figure from Irwin et al., 2007, MNRAS, 380, 54).

From these data, the astronomers were able to obtain accurate empirical measurements of both the masses and the radii of the component stars of JW 380. The star system comprises of a pair of 0.26, 0.15 solar-mass pre main sequence stars, with measured radii of 1.2 and 0.9 solar radii respectively.

This is the second eclipsing binary identified in the ONC. The first was announced during 2006 and contains two brown dwarfs, or "failed stars", systems which are too cool to burn hydrogen into helium. JW 380 contains instead two M-dwarf stars of 3-4 times heavier mass. By identifying eclipsing binaries spanning a range of masses and ages, it is possible to map the evolution of stellar radius with age empirically, which can then be compared to models of stellar evolution to help understand how stars evolve.

The observations confirm the predictions of theoretical models that low-mass stars are "bloated" at these

extremely young ages because they are still contracting in the stages between birth and arrival onto the main sequence. Comparing the measured radii with the model predictions indicates an age of 2-3 Myrs, consistent with existing estimates for the ONC.

A third component in the system is also visible in the spectroscopic observations. This may be physically associated with the binary, making a triple star system with the third component in a wide orbit. This will be the subject of future follow-up observations to derive its orbital parameters.

The present result is part of the Monitor Project, a large-scale photometric survey of nearby open clusters and star-forming regions, aiming to measure time-series photometry for >10,000 cluster members over >10 deg² of sky, to find low-mass eclipsing binary and planet systems. Peak rms accuracy over the entire data set is better than ~2 mmag using aperture photometry, with rms <1 per cent over ~4 mag, in data from 2- and 4-m class telescopes with wide-field mosaic cameras, among them, the INT Wide Field Camera.

A STRONGLY-IRRADIATED TRANSITING GAS-GIANT EXOPLANET

The SuperWASP cameras are wide-field imaging systems sited at the Observatorio del Roque de los Muchachos and the Sutherland Station of the South African Astronomical Observatory. Each instrument has a field of view of some ~482 square degrees with an angular scale of 13.7 arcsec per pixel, and is capable of delivering photometry with accuracy better than 1% for objects having $V \sim 7.0-11.5$. The systems, while designed to monitor fields with high cadence, are capable of surveying the entire visible sky every 40 minutes. Depending on the observational strategy, the data rate can be up to 100 Gb per night. A robust, largely automatic reduction pipeline and advanced archive is used to serve data products to the Wide Area Search for Planets (WASP) consortium members. The Isaac Newton Group of Telescopes is a member of the WASP consortium and the design of the SuperWASP cameras was inspired by the early success of the CoCAM series of cameras designed and built at the ING from 1996 to 1998, one of which was responsible for the discovery of the so-called Sodium Tail in Comet Hale-Bopp 1995.

The first planets discovered by SuperWASP were WASP-1b and WASP-2b in 2006. WASP-1b was named as "Garafia-1" after the name of the municipality that hosts the Observatorio del Roque de los Muchachos, and both were

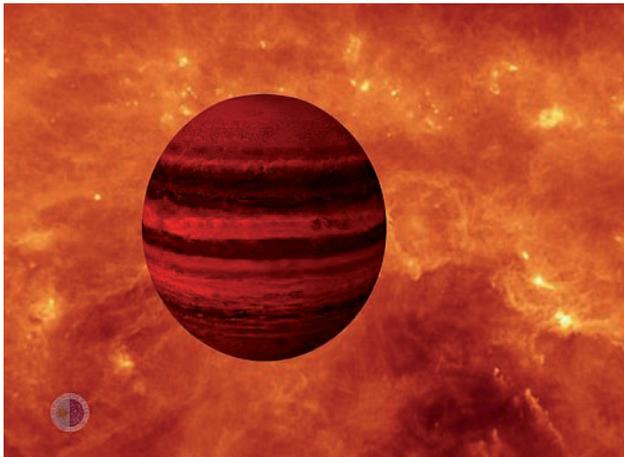
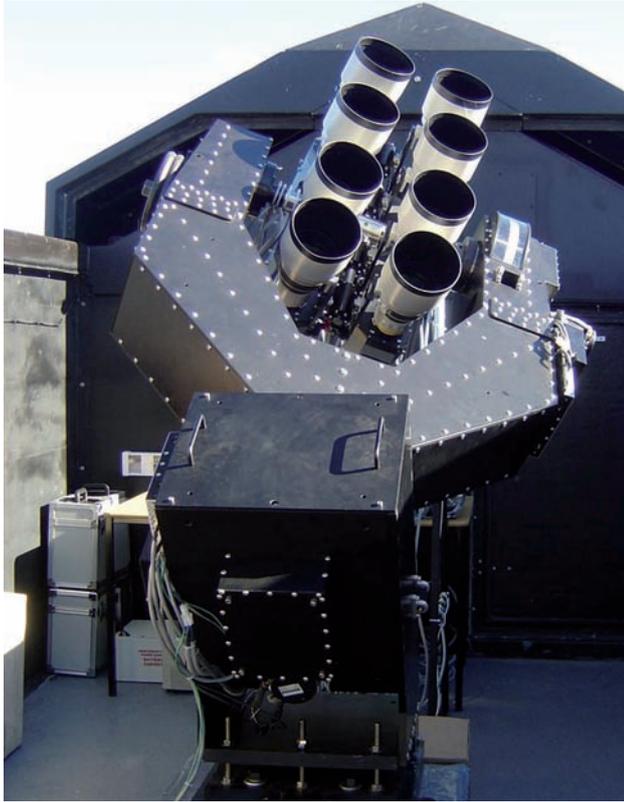


Figure 19. Top: SuperWASP-N cameras at the Observatorio del Roque de los Muchachos. Credit: David Anderson. Bottom: WASP-3b is one of hottest extrasolar planets ever detected. Credit: artist impression by IAC's multimedia service.

actually the first ever exoplanets discovered at the observatory.

Following this success, the WASP and SOPHIE collaboration announced the discovery of three more exoplanets: WASP-3b, WASP-4b and WASP-5b. WASP-3b was one of the hottest exoplanets discovered until then. At a temperature of more than 1700 degrees Celsius, WASP-3b has the potential to place stringent constraints on exoplanet atmospheric models. The discovery of the three transiting

planets was named 'the 6th most important scientific discovery of 2007' in Time Magazine's Top Ten List.

The first transits of WASP-3b were detected by the SuperWASP cameras and they were then confirmed by the IAC80 telescope at the Observatorio del Teide, Tenerife, as part of the Canarian Observatories' International Time Programme for 2007, and by the University of Keele's 60-cm telescope. The discovery confirmation, using the radial velocity method, came from data obtained with the SOPHIE spectrograph on the Observatoire de Haute Provence's 1.93m telescope.

Observations made with the adaptive-optics system NAOMI+INGRID on the WHT were used to exclude the possibility of a nearby eclipsing-binary system being the cause of the transits. WASP-3, the host star, lies at approximately 220 parsecs or 720 light years and no companion stars were found to lie within 45 astronomical units of WASP-3.

THE AXISYMMETRIC WIND OF THE POST RED SUPERGIANT IRC +10420

IRC +10420 is an extremely luminous star that inhabits the so-called yellow void on the HR diagram between the red and blue supergiants. There is considerable evidence that the star is evolving rapidly away from the red supergiant (RSG) phase toward the luminous blue variable (LBV) or Wolf-Rayet (W-R) phases. As such, this object represents a potential link between the key post-main-sequence mass-losing stages and is therefore considered extremely important for the study of massive stellar evolution.

The star has been observed to gradually increase in temperature from ~6000 to ~9200 K in the last 30 years and the material the star has recently ejected may be the precursor to a LBV/W-R nebula. These nebulae are often axisymmetric, but it is unclear how these nebulae are formed. Hydrodynamic studies have shown that axisymmetric morphologies can arise from either an axisymmetric wind in the LBV/W-R phase, or a spherically symmetric wind blowing into a slower axisymmetric wind ejected in the RSG phase. As wind axisymmetry may be linked to rotation, which itself plays an important role in the evolution of a massive star, and as IRC +10420 appears to be somewhere between the LBV/W-R and RSG phases, determining the true geometry of the star's present-day wind may provide insight into the formation mechanism of the bipolar nebulae of massive stars. Furthermore, it may also provide clues as to the role of rotation in its

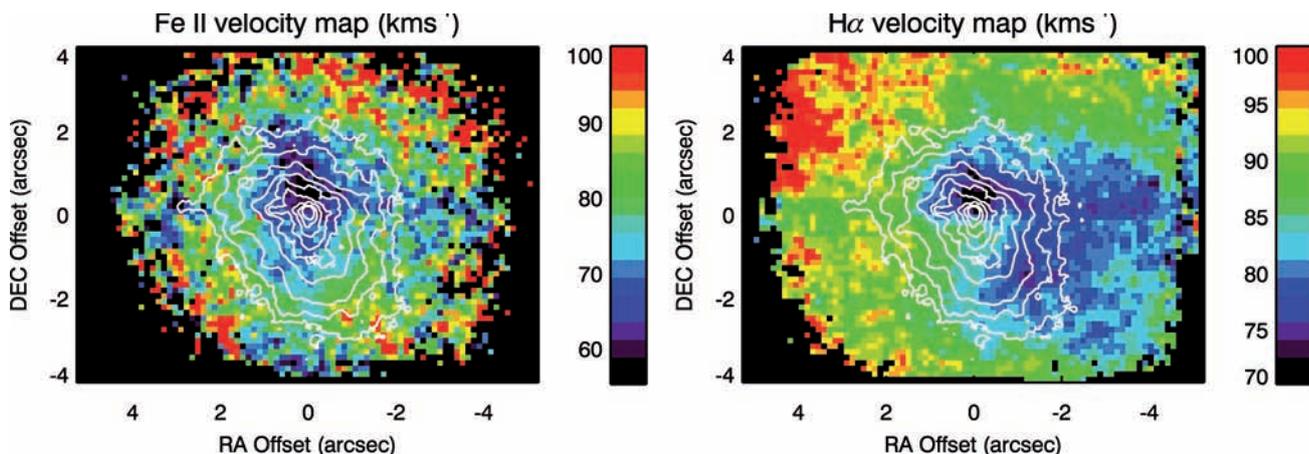


Figure 20. Velocity maps, as determined from Gaussian fits to the emission lines. The images are overlaid with a contour map of the B-band HST image. Images are heliocentric corrected, and colour bars to the right of each plot show the velocity scale. The two maps show different behaviour: the Fe II map shows lower velocities in the centre and higher velocities in the outer regions; while the H α map shows the lowest velocities in the southwest and the highest in the northeast. (Extracted from Davies et al., 2007, ApJ, 671, 2059).

subsequent evolution and the connection to other classes of massive star.

The geometry of IRC +10420's wind has been the topic of much discussion over the last ~20 years, yet a consensus remains elusive due to contradictory evidence. The confusion was complete when astronomers using HST long-slit spectroscopy, utilised the star's reflection nebula as a tool with which to view the H α emission from different angles. With the slit aligned along the long axis of the nebula, they showed that the velocities of the two peaks in their H alpha profile were uniform. This was inconsistent with a circumstellar disk or a bipolar outflow, and led to the conclusion that the star showed no evidence of axisymmetry in the present-day wind. However, they only observed two slit positions, each roughly parallel to the long axis of the nebula and separated by 0.5 arcsec.

With integral-field spectroscopy using NAOMI+OASIS on the WHT, another team of astronomers improved on the data with spatially resolved spectroscopy across the whole of the inner nebula. To investigate the present-day mass-loss geometry of the star, they studied the appearance of the line emission from the inner wind as viewed when reflected off the surrounding nebula and they found that, contrary to previous work, there is strong evidence for wind axisymmetry, based on the equivalent width and velocity variations of the H alpha and Fe II 6516Å lines. They attribute this behaviour to the appearance of the complex line profiles when viewed from different angles and they also speculate that the Ti II emission originates in the outer nebula in a region analogous to the Sr filament of η Carinae, based on the morphology of the line emission. Finally, they suggest that the present-day axisymmetric wind of IRC +10420, combined with its continued blue-

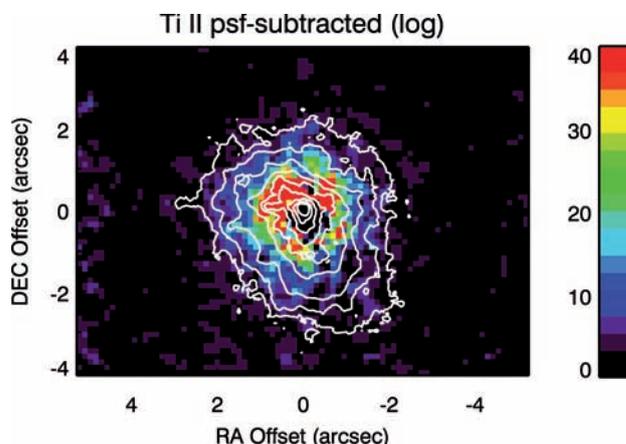


Figure 21. Continuum-subtracted, PSF-subtracted image of IRC +10420 in the light of Ti II, scaled in units of σ above the sky background. The image is overlaid with a contour map of the B-band HST image. Contrary to similar maps of the H α and Fe II emission, the Ti II emission does not trace the morphology of the reflection nebula (figure from Davies et al., 2007, ApJ, 671, 2059).

ward evolution, is evidence that the star is evolving toward the B[e] supergiant phase.

THE MILLENNIUM GALAXY CATALOGUE

The Millennium Galaxy Catalogue (MGC) is a survey of over ten thousand giant galaxies, each comprising of up to 10 billion stars as well as bulges, discs and super-massive black holes. The imaging data were obtained using the Wide Field Camera on the INT. The survey was able to determine how much of the Universe's matter is locked away in black holes, some of which are one million billion times more massive than the Earth. By adding up each key component it is found that the Universe has used about twenty percent of its original fuel reserves.

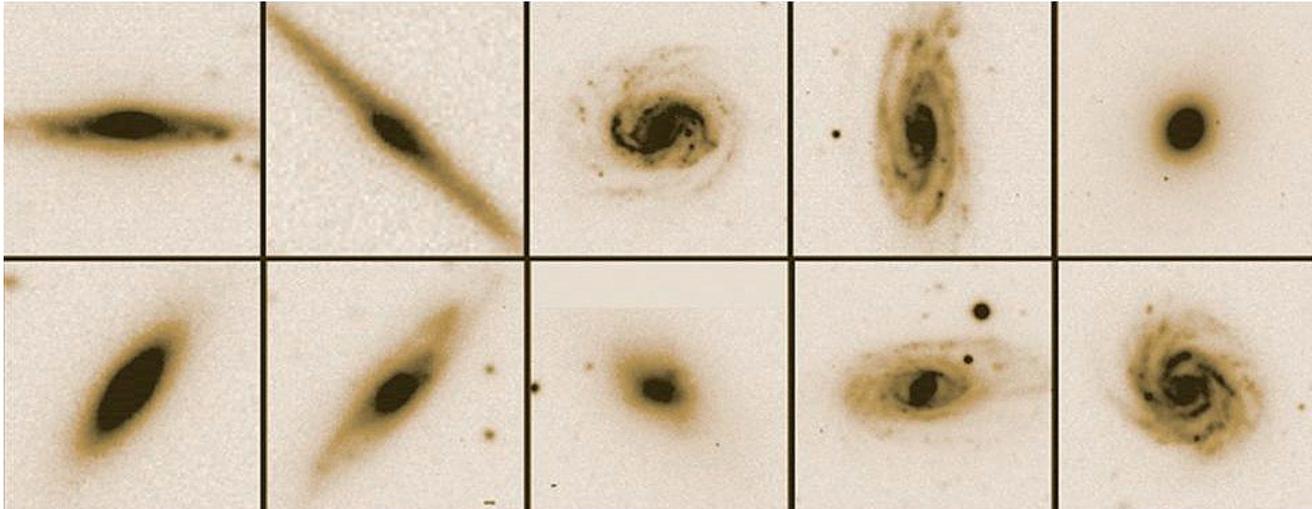


Figure 22. Sample images from the Millennium Galaxy Catalogue (figure from Driver et al., 2007, MNRAS, 368, 414).

Tracking down what happened to normal matter dating back to the Big Bang 14 billion years ago has remained one of the most important goals for cosmologists for many years. The new survey reveals that about 20% is locked up in stars, a further 0.1% lies in dust expelled from the massive stars (and from which solid structures like the Earth and man are made), and about 0.01% is in the form of super-massive black holes. The remaining 80% is almost completely in gaseous form lying both within and between the galaxies and constitutes the reservoir from which future generations of stars may form. So the Universe will be able to form stars for approximately a further 70 billion years after which it will start to go dark.

The MGC was able to focus on the structures in which stars are arranged inside galaxies so their main components could be studied separately. The survey is the first to catalogue reliable information on the distances, sizes, colours and shapes of both the bulge and disc components of so many galaxies. On average it was found that half the stars in the Universe lie in the central bulges of galaxies, while the other half are found in discs surrounding the bulges. By measuring the concentration of stars in each galaxy's bulge, the super-massive black hole mass at the heart of each galaxy could also be determined.

FROM SPIRALS TO SMOOTH DISKS

Over the past several billion years the predominant shape of disc galaxies in clusters has changed from a spiral to a smooth disk. Theory suggests that this change occurs when two galaxies of unequal mass merge and gravitational effects pull gas to the galaxies' nucleus, sweeping away the spiral structure and leaving behind a smooth, barren, thickened disk known as a lenticular

galaxy. However, galaxies orbiting in clusters move at high speeds and in random directions, which should mean that the conditions needed for these slow interactions rarely occur. Instead, multiple rapid encounters between galaxies, known as 'galaxy harassment', are dominant but these types of fast encounters cannot easily form the smooth disks.

Astronomers using imaging data from the JKT compared eight examples of populations of galaxies falling towards the centres of galaxy clusters with control samples of galaxies far from the clusters. They found that the infalling galaxies in the cluster were predominantly distorted in shape and had higher than normal rates of star formation. Between a half and three-quarters of these galaxies were very close by to another galaxy or appeared to be merging with a companion galaxy, which suggested that

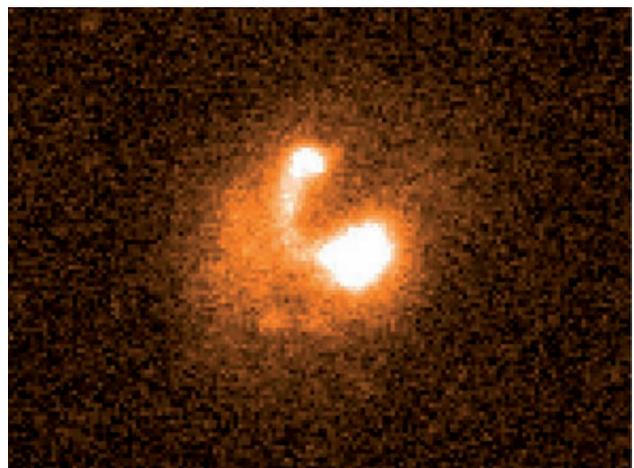


Figure 23. R-band image of CGCG 538-043 in Abell 347 ($z=0.019$) obtained with the JKT. This image resolves the galaxy into an interacting pair of galaxies. Credit: C. Moss, C.F. Thomas, P.A. James, Astrophysics Research Institute, Liverpool John Moores Univ.

interactions and mergers are more common in galaxies falling into the cluster than in the control sample. The results suggest that the conditions needed for slow galaxy interactions and mergers are more likely to occur in galaxies falling into a galaxy cluster compared to the general population of galaxies outside clusters.

And this may explain the mystery of how spiral galaxies in clusters are transformed over time into smooth disks: the slow-motion conditions needed for the transformation are indeed occurring among populations of galaxies falling towards the cluster centre.

Since infalling of galaxies into clusters was greater in the past, such interactions and mergers may have contributed significantly to the transformation of the past population of cluster spirals to lenticular galaxies in present-day clusters, explaining why clusters today have so few spirals and so many lenticular galaxies.

ANDROMEDA X: A NEW DWARF SPHEROIDAL SATELLITE OF M31

In hierarchical cold dark matter (CDM) models, large galaxies like the Milky Way and M31 form from the merger and accretion of smaller systems. Such models, while successful at large scales, predict at least 1–2 orders of magnitude more low-mass dark subhalos at the present epoch than the observed abundance of dwarf galaxies. This discrepancy, the “missing satellite” problem, is one of the most serious obstacles for matching CDM theory to observations.

A number of solutions have been proposed to address the problem, at least qualitatively. These range from the possibility that small galaxies somehow inhibit star formation, making them essentially invisible, to the prospect that they are surrounded by more unseen dark matter than first thought. All of these solutions aim to resolve the discrepancy between theory and observation by creating models that predict fewer directly observable satellites.

A complementary observational approach would be to place more stringent constraints on the faint end of the galaxy luminosity function, but attempts to do so are hampered by the low surface brightness expected of galaxies in that regime. The advent of wide-field CCD surveys such as the Sloan Digital Sky Survey (SDSS) has made it possible to detect stellar structures with extremely low surface brightness, and in 2004 astronomers discovered the two faintest galaxies ever seen – UMajor

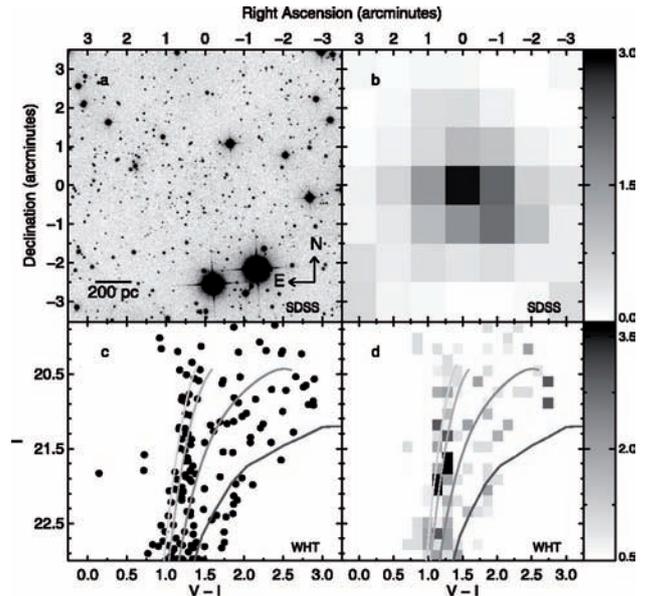


Figure 24. Andromeda X as seen by the SDSS and WHT: (a) Sum of SDSS *g*, *r*, and *i* images centered on And X. (b) Spatial density of presumed SDSS “blue” red giant stars in the same area, binned $1' \times 1'$ FWHM Gaussian. The gray-scale bar to the right indicates the significance of the spatial overdensity, in units of the background standard deviation. (c) De-reddened WHT CMD of stars within $2'$ of the center of And X with fiducial sequences overplotted for Galactic globular clusters with metallicities of (left to right) $[Fe/H] = -2.2$ (M15), -1.6 (M2), -0.7 (47 Tuc), and -0.3 (NGC 6553), shifted to a distance modulus of 24.47. (d) De-reddened WHT Hess diagram of stars within $2'$ of the center of And X, minus the area-scaled Hess diagram of a control field. The data are binned by 0.15 mag in $(V-I)$ and I . The gray-scale bar indicates the number of stars in each bin. Overplotted fiducials are as for (c) (figure from Zucker et al., 2007, *ApJL*, 659, 21).

around our Milky Way and Andromeda IX (And IX) around our nearest large galactic neighbour, Andromeda. These finds suggested that the missing satellite problem may actually be less dire than originally thought.

Since the discovery of And IX, astronomers have been using SDSS photometry of M31 and its surroundings to identify possible M31 companions for deeper observations on other telescopes. Using data from PFIP on the WHT, a team of astronomers reported the discovery of a new dwarf spheroidal companion to M31, Andromeda X (And X), comparable in luminosity to And IX. They estimated its distance and other physical properties, and found that And X has a de-reddened central surface brightness of $\mu_{V,0} \sim 26.7$ mag arcsec $^{-2}$ and a total apparent magnitude of $V_{tot} \sim 16.1$, which at the derived distance modulus $(m-M)_0 \sim 24.12-24.34$, yields an absolute magnitude of $M_V \sim -8.1 \pm 0.5$. These values are similar to those of And IX.

And X is comparable in size, surface brightness, and apparent magnitude to And IX, and, despite the uncertainty

in its distance, And X appears to be somewhat lower in luminosity. So astronomers concluded that And X is a new extremely faint dSph companion of M31. The earlier discovery of And IX raised the question of whether such low-luminosity galaxies were a rarity in the Local Group or whether And IX was the tip of an iceberg, one of a large population of faint satellites that have thus far remained undetected. And X's discovery, along with the recent discoveries of numerous other faint dwarfs around the Milky Way and M31, suggests that the latter scenario is closer to the truth —that M31 and the Milky Way have a large number of low-luminosity satellites.

NON-CIRCULAR MOTION AND A GALACTIC WIND IN THE CENTRAL REGION OF M100

Departures from regular rotation, such as winds, elongated orbits or streaming motions, provide useful information about the dynamics and history of galaxies. To identify kinematical distortions and to infer how they relate to the gravitational potential, different techniques such as velocity field fitting or Fourier analysis can be used. However, to obtain reliable results these tools must be used in combination with 2D kinematical data of high spatial resolution. Integral-field spectroscopy (IFS) is an observational technique especially suited for kinematical studies that can be applied to nearby galaxies, such as M100 (NGC 4321), to obtain velocity maps with detailed spatial information.

The inner region of M100 has been extensively studied at different wavelengths, which has revealed some interesting irregular features. On the one hand, the inner region of this galaxy shows a peculiar morphology that is quite different in the optical and in the NIR. In the optical

(broad-band), the structure is dominated by two spiral arms and an oval-shaped region of enhanced star formation, while the NIR shows an inner bar aligned with the large-scale stellar bar and a pair of small arms emerging from its ends. Whether there is a single bar or two nested bars that just happen to be aligned has been a greatly debated issue. On the other hand, non-circular motions observed from $H\alpha$ data, have been interpreted as the kinematical signatures of gas streaming along the inner part of the bar, and of dense wave streaming motions across a two-armed mini spiral. Relevant pattern speeds of this galaxy have been measured at a larger scale by different methods. Recently, data obtained on the inner region of M100 using SAURON at the WHT confirmed that the star formation ring is formed by young stars, but they also revealed a low gas velocity dispersion compared to the surroundings.

Astronomers using INTEGRAL on the WHT observed the central 2.5 kpc of M100 and obtained data on the stellar and ionised gas velocity fields to analyse the symmetries of the departures from pure rotation and to estimate the nuclear bar pattern speed. Fourier analysis of the velocity residuals obtained by subtracting an axisymmetric rotation model from the $H\alpha$ velocity field indicates that the distortions are global features, generated by an $m=2$ perturbation of the gravitational potential and can be explained by the nuclear bar. This bar has been previously observed in the near-infrared but not in the optical continuum dominated by star formation. The detection of the optical counterpart of this bar in the 2D distribution of the old stellar population and its analysis using the Tremaine–Weinberg method, allowed the determination of the pattern speed of the inner bar, obtaining a value of $\Omega_b = 160 \pm 70 \text{ km s}^{-1} \text{ kpc}^{-1}$. This value is considerably larger than the one obtained when a simple bar model is considered.

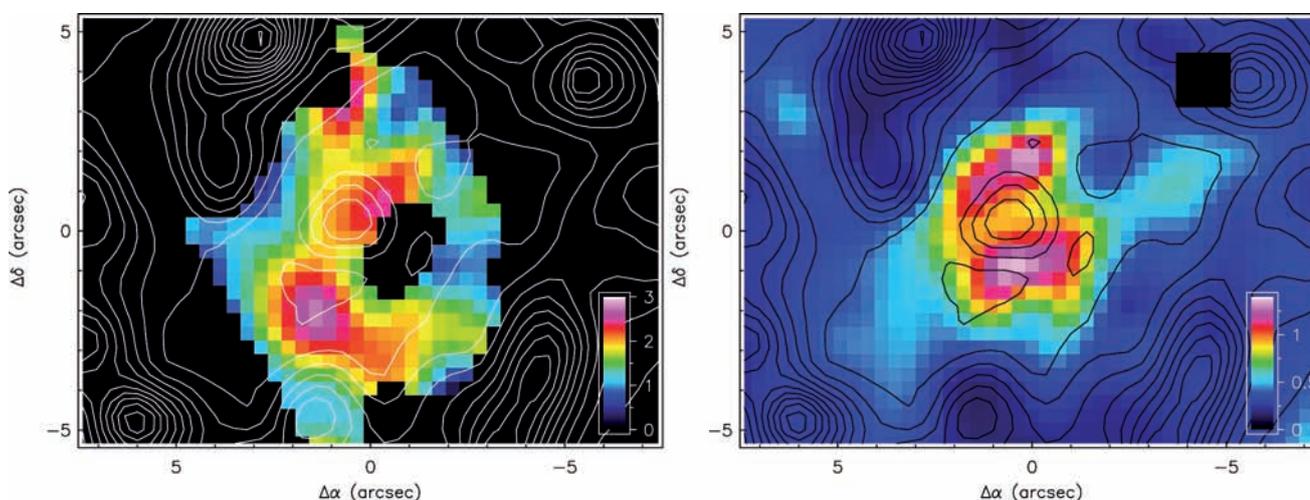


Figure 25. $[NII]/H\alpha$ line ratio for the wind (left) and Galactic (right) components. Contours show intensity of galactic $H\alpha$ emission (figures from Jiménez-Vicente et al., 2007, MNRAS, 382, L16).

Galactic winds are one of the main mechanisms by which galaxies expel metals, dust, cosmic rays, magnetic fields, etc. to the intergalactic medium. This feedback makes winds an important phenomenon in our global understanding of galaxies. These winds are usually associated with galaxies with strong nuclear activity or with starbursts, which are powerful enough to feed the winds. However, very little is known of this phenomenon in quiescent, inactive galaxies. M100 is a nearby galaxy with low nuclear activity and a moderate star formation rate of a few solar masses per year. Despite this apparent quiescence, astronomers using INTEGRAL on the WHT found an unexpected fast wind emanating from its nuclear region.

They used a new approach based on integral field spectroscopy which allows both the detection of absorbing material throughout the field of view and the production of a map of the distribution and kinematics of the absorbers. In addition, they could discriminate kinematically the ionised component of the outflowing material and to produce maps for the distribution and kinematics of this hotter phase of the wind. This approach provides a unique simultaneous global view of these two phases of a galactic wind.

The primary evidence of the wind is the presence of blueshifted interstellar NaD absorption lines. The velocity field of the absorbers show a clear rotation pattern but which is globally blueshifted ($\sim -115 \text{ km s}^{-1}$) with respect to the systemic velocity of the galaxy. The emission lines also present a blueward component arising from the ionised gas phase of the galactic wind. The velocity field of the ionised gas wind component shows no evidence of rotation but exhibits a pattern that can be interpreted in terms of the projection of an outflowing cone or shell. The wind component has $[\text{N II}]/\text{H}\alpha$ ratios of about 1.8, typical of shock ionisation.

The ionised component of the wind can be identified with an expanding shell of shocked gas, and the neutral component with disc gas entrained in the wind at the interface of the expanding shell with the galactic interstellar medium. The galactic wind seems to be driven uniquely by the nuclear starburst. The analysis indicates that a non-negligible fraction of the wind material might escape to the intergalactic medium (IGM). In this case, if the wind detected in M100 were representative of similar phenomena in other galaxies with low to moderate activity, the current estimates of metal and dust content of the IGM might be drastically underestimated.

THE METALLICITY GRADIENTS OF M 33

The galaxy M33 (NGC 598) is the third-brightest member of the Local Group. Its proximity, its large angular size, and its intermediate inclination make it particularly suitable for studies of spiral structure, interstellar medium (ISM), and of stellar populations. Being a late-type spiral galaxy, it has a rich population of H II regions. Observations with the INT, covering an area of approximately 0.6 square degrees, produced the most complete catalogue of H II regions in this galaxy.

ING's Local Group Census project (LGC) obtained new imaging observations of M33. These new deep data cover about 2 square degrees and are allowing discovery of a conspicuous number of new H II regions at large galactocentric distances. The existence of chemical abundance gradients in M33 was known long ago, but their origin, shape and magnitude are still open issues.

Using AF2 on the WHT, a team of astronomers investigated the chemical and physical properties of a large sample of H II regions of different sizes, galactocentric distances and excitations in order to study their behaviour through the disk.

In total, they analysed optical spectra of 72 emission-line objects in M33, including mostly H II regions, but also five supernova remnants and two candidate planetary nebulae. Direct determination of electron temperature was possible for 15 H II regions by the measurements of the $[\text{O III}]$ 436.3 nm line and in three of them using the $[\text{N II}]$ 575.5nm line. For the 14 H II regions with a determined electron temperature and with detection of both $[\text{O II}]$ and $[\text{O III}]$ lines they derived chemical abundances.

They also collected oxygen abundances from young stars presented in a large number of objects representative of the present time interstellar medium metallicity to draw a complete picture of the shape and magnitude of the metallicity gradient, and they found the best fit to the data using two different slopes, corresponding to the central regions $R < 3 \text{ kpc}$ ($-0.19 \pm 0.08 \text{ dex kpc}^{-1}$) and outer regions $R = 3 \text{ kpc}$ ($-0.038 \pm 0.015 \text{ dex kpc}^{-1}$). The shallower outer gradient is in agreement with several new works and it can be explained by invoking a slow continuous accretion of the disk of M33 from the intergalactic medium that continues to the present time.

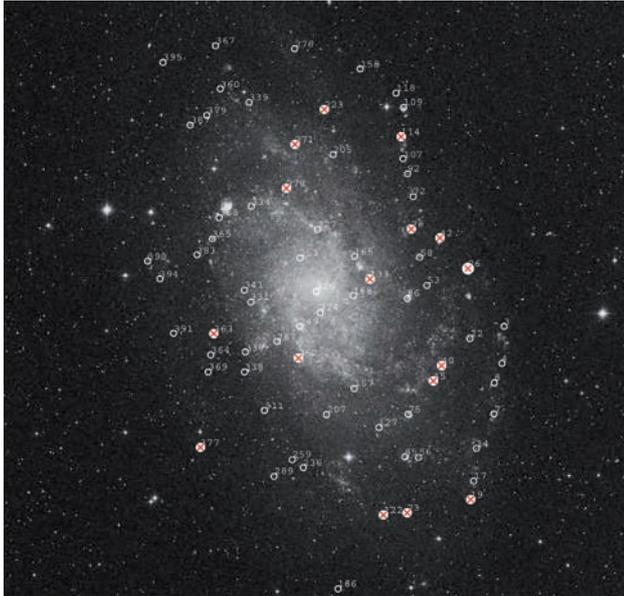


Figure 26. M33 DSS 1°×1° image indicating the location of the 72 observed emission-line objects (North is up and East to the left). HII regions with measured chemical abundances are marked with a cross (figure from Magrini et al., 2007, A&A, 470, 865).

THE SAURON PROJECT

SAURON (Spectroscopic Areal Unit for Research on Optical Nebulae) is a panoramic integral-field spectrograph built for the WHT by groups in Leiden, Lyon and Oxford. SAURON can record 1577 spectra simultaneously, with full sky coverage in a field of 33×44 arcmin and it was used to measure the kinematics and line strength distribution for a representative sample of 72 nearby early-type galaxies (ellipticals, lenticulars, and Sa bulges, in clusters and in the field).

In parallel with the data taking, the team developed a number of tools that are the key to analysing all the resulting maps, and in particular they built an elaborate software pipeline to reduce and analyse the data which produces full 2D maps of velocity from both stellar absorption lines and ionised gas emission lines, of velocity dispersion and of line ratios.

SAURON saw first light at the WHT in 1999. The entire survey was completed in 2003, and the instrument continued operations in the following years. Up to 2007, the SAURON collaboration had published more than 10 research papers covering different aspects of the research. What follows is a summary of the papers published in 2006 and 2007.

A study dealing with the fundamental plane of early-type galaxies showed that the scatter in the mass-to-light ratio vs. galaxy mass relation was extremely small, and that

small ellipticals in their central regions have almost no dark matter.

A second paper showed that early-type galaxies contain large amounts of ionised gas, in many cases in regular, stable orbits, but in other cases showing signs of infall.

A third paper provided 2D absorption line strength indices for the elliptical and S0 galaxies in the survey. Another work provides velocity and velocity dispersion fields for gas and stars in the 24 early-type spirals of the SAURON survey. A major result is that many of these objects have central disks dominating the light there. The kinematics of gas and stars and absorption line strength maps for a large fraction of these galaxies, and a number of newly discovered kinematically decoupled cores, were presented in another paper.

Two-dimensional stellar kinematics of 48 representative elliptical and lenticular galaxies revealed that early-type galaxies appear in two broad flavours, depending on whether they exhibit clear large-scale rotation or not.

A kinematical analysis of the orbital distribution of elliptical and lenticular galaxies kinematics within about one effective (half-light) radius showed that of two classes, the slow rotators are more common among the most massive systems and are generally classified as ellipticals from photometry alone. Those in the analysed sample tend to be fairly round, but can have significant kinematical misalignments, indicating that as a class they are moderately triaxial; the fast rotators are generally fainter and are classified as either elliptical or lenticular. They can appear quite flattened and do not show significant kinematical misalignments (unless barred or interacting), indicating that they are nearly axisymmetric and span an even larger range of anisotropies.

A number of the fast rotators show evidence for containing a flattened, kinematically distinct component, which in some cases counter-rotates relative to the main galaxy body. These components are generally more metal rich than the galaxy body. All these results support the idea that fast rotators are nearly oblate and contain disc-like components. The role of gas must have been important for their formation. The slow rotators are weakly triaxial. Current collisionless merger models seem unable to explain their detailed observational properties.

The absorption-line strength maps of a sample of 24 representative early-type spiral galaxies, mostly of type Sa, showed that the central regions of Sa galaxies contain at least two components: a thin, disc-like component, often

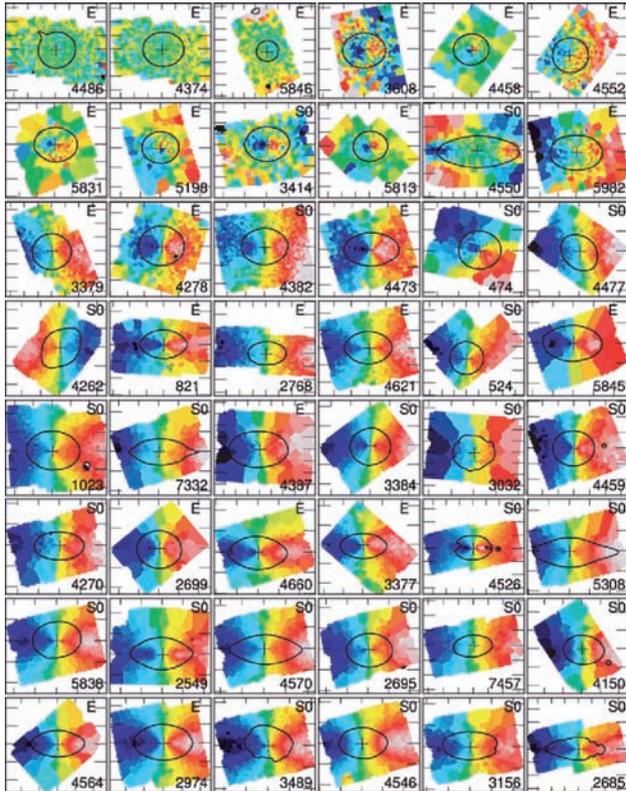


Figure 27. Example of SAURON project analysis: stellar velocity fields for 48 elliptical (E) and lenticulars (S0) galaxies, the global outer photometric axis being horizontal. Colour cuts were tuned for each individual galaxy as to properly emphasise the observed velocity structures. A representative isophote is overplotted on each thumbnail as a black solid line, and the centre is marked with a cross. Slow rotators are galaxies on the first two rows. NGC numbers and Hubble types are provided in the lower-right and upper-right corners of each panel, respectively. Tick marks correspond to 10 arcsec (figure from Emsellem et al., 2007, MNRAS, 379, 401).

containing recent star formation, and another, elliptical-like component, consisting of old stars and rotating more slowly, dominating the light above the plane. These components together form the photometrically defined bulge, in the same way as the thin and the thick disc co-exist in the solar neighbourhood. In this picture, part of the bulge, the thicker component, formed a very long time ago. Later, stars continued to form in the central regions of the disc, rejuvenating in this way the bulge through dynamical processes. This picture is able to explain, in a natural way, the heterogeneous stellar populations and star formation characteristics that we are seeing in detailed observations of early-type spiral galaxies.

THE PLANETARY NEBULA SPECTROGRAPH PROJECT

The confirmation in the 1970s that dark matter dominates the mass of the universe came from dynamical studies of spiral galaxies. In these systems, the H I gas disks offer the ideal diagnostic, since their extended nature allows one to probe very large radii where dark matter begins to dominate, and their cold disk-like structure ensures that the material is following approximately circular orbits, removing a major ambiguity in the study of its dynamics.

A similar study of elliptical galaxies would be invaluable, as it would address basic questions such as whether the dark matter halos around these systems are similar to those around spirals, suggesting that the difference in observed morphology is just a matter of chance, or that there are more fundamental differences between them. Unfortunately, the paucity of neutral hydrogen gas in ellipticals makes such a study observationally difficult.

The main object of the Planetary Nebula Spectrograph (PN.S) project is to determine whether or not the dark matter halos which are inferred to be present around spiral galaxies are also present in ellipticals. Earlier investigations, often based on the kinematics of a few tens of planetary nebulae, suggested that ellipticals contained significantly less mass than expected by the Cold Dark Matter (CDM) model of dark matter halos. The PN.S is specialised in the collection of the required planetary nebulae data and in 2003 a paper published in *Science* showed a preliminary analysis of three galaxies which supported the earlier findings.

In the consecutive years the project team continued to collect the data on a sample of 12 ellipticals, and by the start of 2006 had almost completed this process, and had begun analysing the data using an improved pipeline.

The first analysis to be published, which included all the technical data needed to scrutinise the data-reduction process for errors or biases, was that of the galaxy NGC3379, in which they obtained radial velocities for 214 planetary nebulae. The main conclusion of this work was that, barring the presence of a significant disk population hidden by a special viewing angle, disturbing the modelling of the planetary nebulae kinematics, the dark matter component within 5 effective radii cannot be greater than 40% of the total mass, whereas the CDM model predicts twice this.

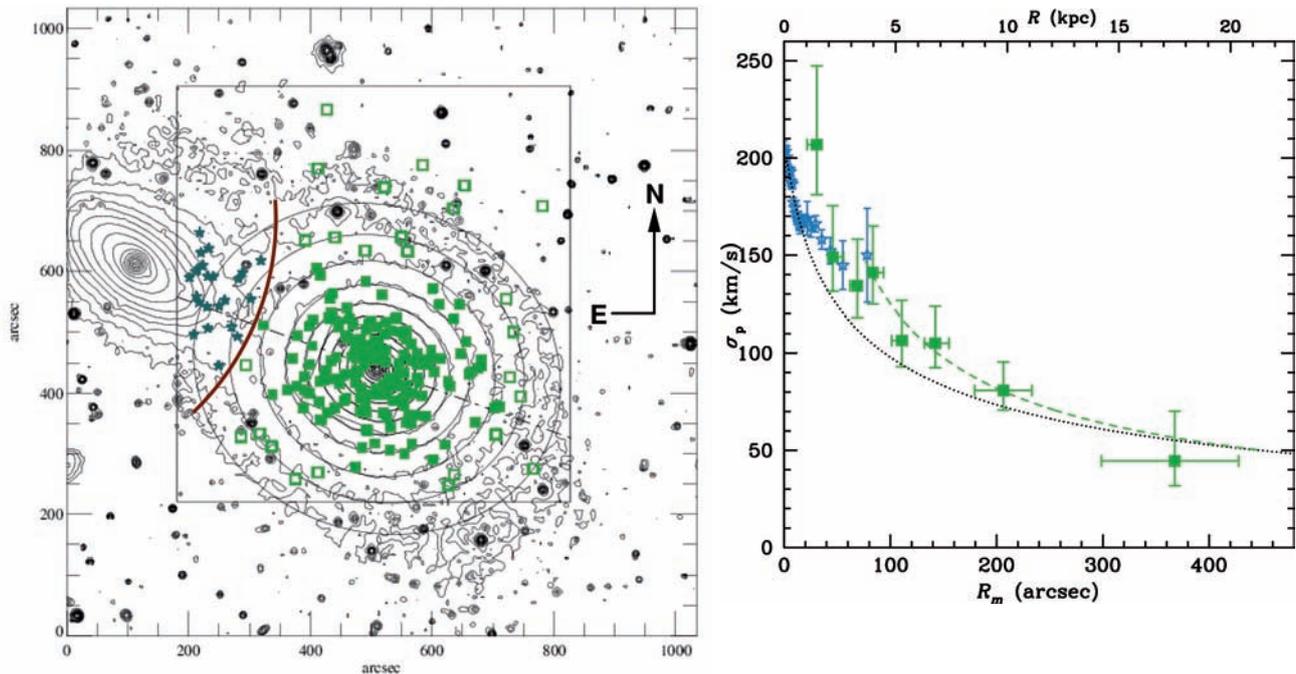


Figure 28. Left: I-band image with the locations of detected PNe and the field of the PN.S observation marked. The thick arc marks the division between the two galaxies for assigning membership to PNe, so squares are members of NGC 3379 while stars are members of NGC 3384. The filled symbols for NGC 3379 are used for objects that lie within the isophotal radius out to which the entire galaxy has been mapped. Right: Projected velocity dispersion profile for NGC 3379, showing data from stars (stars) and PNe (squares), plotted on linear axes. Dashed lines show a power-law fit at large radii, while dotted lines show an isotropic constant mass-to-light ratio model (figures from Douglas et al., 2007, ApJ, 664, 257).

DISCOVERY OF ULTRACOMPACT DWARF GALAXIES IN THE VIRGO CLUSTER

Compact dwarf galaxies are an established constituent of the population of lower luminosity galaxies, alongside the more numerous dwarf irregular, dwarf elliptical, and dwarf spheroidal galaxies. Among compact dwarfs, early-type compact elliptical galaxies such as M32, showing early-type galaxy spectra, are rare, and only very few examples have been found. Blue compact dwarfs show active star formation superposed on an older, low surface brightness component and have a broad range of sizes, including a very small proportion with effective radii as small as 300 pc.

Using follow-up data from the Wide Field Camera on the INT, astronomers discovered nine ultracompact dwarf galaxies (UCDs) in the Virgo Cluster, extending samples of these objects outside the Fornax Cluster. The newly found UCDs are comparable to the UCDs in the Fornax Cluster, with sizes $\sim < 100$ pc, $-12.9 < M_B < -10.7$, and exhibiting red absorption-line spectra, indicative of an older stellar population. The properties of these objects remain consistent with the tidal thrashing model for the origin of UCDs from the surviving nuclei of nucleated dwarf elliptical galaxies disrupted in the cluster core, but can also be explained as objects that were formed by mergers of star clusters created in galaxy interactions.

The discovery that UCDs exist in Virgo shows that this galaxy type is probably a ubiquitous phenomenon in clusters of galaxies; coupled with their possible origin by tidal thrashing, the UCD population is a potential indicator and proof of the formation history of a given cluster.

KINEMATICS OF THE ANDROMEDA GALAXY

Observations of the distribution of stellar velocities in the solar neighbourhood of the Milky Way reveal a wealth of complex structure. For a dynamical entity such as the Galaxy, this structure is as fundamental as the spatial arrangement of its stars, and should contain a wealth of information as to the system's current state, as well as archaeological clues as to how it formed. Unfortunately, such data from a single locality are difficult to interpret in terms of the global structure of the Galaxy. Although kinematic observations of more distant stars in the Milky Way have been made, the complexity of disentangling the geometry of our own Galaxy makes such data difficult to interpret. An obvious next target is therefore the Milky Way's nearby sister system, the Andromeda galaxy, M31.

However, studying the detailed kinematics of stars in even a nearby external galaxy is quite challenging. In fact, the first problem arises from its very nearness: M31 subtends such a large angle on the sky that many spectroscopic

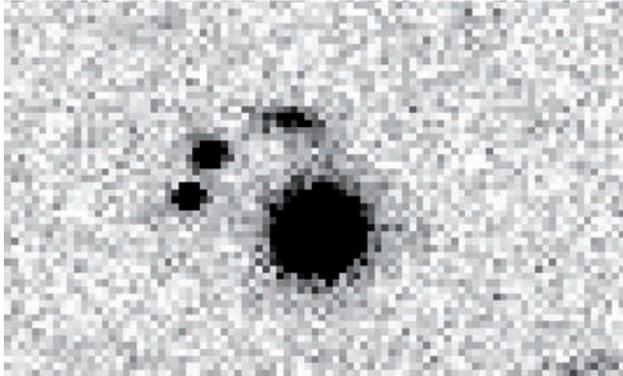


Figure 29. Region around Virgo UCD 6 is shown based on a 25 minute B-band integration with the INT Wide Field Camera (figure from Jones et al., 2006, *AJ*, 131, 312).

instruments are unable to survey the whole system within a realistic time. Further, even at what by extragalactic standards is a very modest distance, obtaining high-quality spectra of individual stars is challenging; it is only relatively recently that the requisite observations of even bright red giant branch (RGB) stars have been made.

Planetary nebulae (PNe) have long been recognised as a potentially simpler dynamic tracer of the stellar population. Stars evolve very rapidly but quite gently from the RGB phase to become PNe, so the kinematics of these two populations should be essentially identical. Further, the presence of strong emission lines in PNe make them quite easy to identify, and render the measurement of their Doppler shifts fairly trivial.

More than 20 years ago, astronomers reported on kinematic measurements of 34 PNe in M31, but it was not until recently with the development of wide-field multi-object spectrographs that it has become possible to start to obtain the large samples necessary for dynamical studies. Even with such instruments, these studies involve both narrow-band imaging to identify candidate PNe and subsequent spectral follow-up, and this complex two-stage process has limited astronomers' enthusiasm for such projects. However, the recently commissioned Planetary Nebula Spectrograph (PN.S) on the WHT has reduced this process to a single stage, simultaneously identifying PNe and measuring their velocities.

Astronomers have therefore used this instrument to carry out a deep kinematic survey of PNe over $\sim 6 \text{ deg}^2$, covering the bulk of M31's visible area. They obtained a catalogue of positions, magnitudes and velocities for 3300 emission-line objects found by the PN.S. Of these objects, 2615 are found likely to be planetary nebulae (PNe) associated with M31. With the exception of the very central, high surface brightness region of M31, this survey is complete to a

magnitude limit of $m_{5007} \sim 23.75$, 3.5 mag into the PN luminosity function.

The calibrated data were checked for internal consistency and compared with other catalogues, in particular one made from observations previously obtained using AF2 on the WHT and narrow-band imaging with the Wide Field Camera on the WHT. This comparison survey had produced a sample of 723 PNe in the disc and bulge of M31. Velocities were determined using the $[\text{O III}] \lambda 5007$ emission line. Rotation and velocity dispersion were measured to a radius of 50 arcmin (11.5 kpc), resulting in the first stellar rotation curve and velocity dispersion profile for M31 out to such a radius. The kinematics were consistent with rotational support at radii well beyond the bulge effective radius of 1.4 kpc, although the data beyond a radius of 5 kpc were limited.

The luminosity function of the surveyed PNe is well matched to the usual smooth monotonic function. The only significant spatial variation in the luminosity function occurs in the vicinity of M31's molecular ring, where the luminosities of PNe on the near side of the galaxy are systematically ~ 0.2 mag fainter than those on the far side. This difference can be explained naturally by a modest amount of obscuration by the ring. The absence of any difference in luminosity function between bulge and disc suggests that the sample of PNe is not strongly populated by objects whose progenitors are more massive stars. This conclusion is reinforced by the excellent agreement between the number counts of PNe and the R-band light.

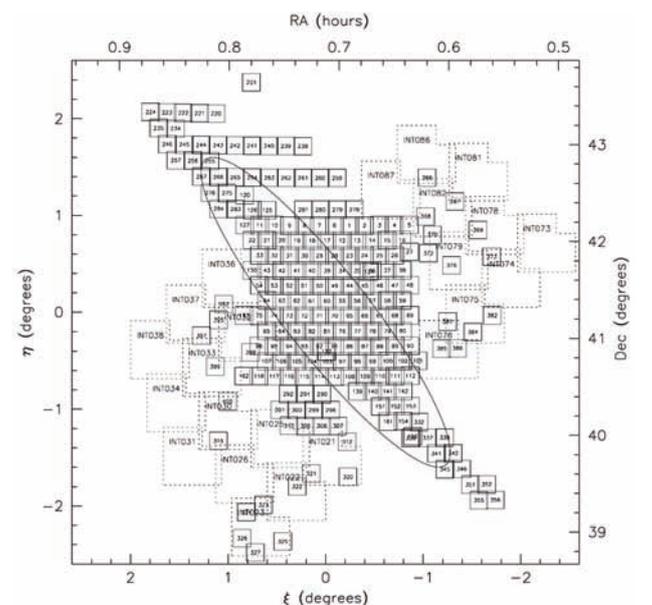


Figure 30. Fields observed in M31. The small square fields are PN.S field locations; the larger fields with dotted outlines are the INT WFC fields. The ellipse marks a 2° (27.4 kpc) disc radius (figure from Merrett et al., 2006, *MNRAS*, 369, 120).

The number counts of kinematically selected PNe also allows to probe the stellar distribution in M31 down to very faint limits. There is no indication of a cut-off in M31's disk, out to beyond four scale lengths, and no signs of a spheroidal halo population in excess of the bulge out to 10 effective bulge radii.

A preliminary analysis of the kinematics of the surveyed PNe shows that the mean streaming velocity of the M31 disc PNe reveals a significant asymmetric drift out to large radii. Their velocity dispersion, although initially declining with radius, flattens out to a constant value in the outer parts of the galaxy. There are no indications that the disc velocity dispersion varies with PN luminosity, once again implying that the progenitors of PNe of all magnitudes form a relatively homogeneous old population. The dispersion profile and asymmetric drift results are shown to be mutually consistent, but require that the disc flares with radius if the shape of its velocity ellipsoid is to remain invariant.

THE POINT-AGAPE SURVEY

The POINT-AGAPE (Pixel-lensing Observations with the Isaac Newton Telescope-Andromeda Galaxy Amplified Pixels Experiment) survey is an optical search for gravitational microlensing events towards the Andromeda galaxy (M31). As well as microlensing, the survey is sensitive to many different classes of variable stars and transients.

The POINT-AGAPE collaboration monitored M31 for three seasons (1999-2001) with the Wide Field Camera on the INT. In each season, data were taken for one hour per night for roughly 60 nights during the six months that M31 was visible. The two 33×33 arcmin² fields of view straddle the central bulge, northwards and southwards.

The galactic dark matter may be partly composed of compact objects (e.g., black holes, faint stars, brown dwarfs, jupiters) that reside in halos and are popularly called MACHOs ("MASSive Compact Halo Objects"). Observations toward the Magellanic Clouds by the first generation of microlensing surveys yielded important constraints on the Milky Way (MW) halo. The EROS collaboration obtained an upper limit to the contribution by MACHOs to a standard MW halo. Also, according to the MACHO collaboration, the optical depth toward the Large Magellanic Cloud is too large by a factor ~5 to be accounted for by known populations of stars. This excess is attributed to MACHOs of mass ~0.4 solar masses (in the mid-range of mass for main sequence stars).

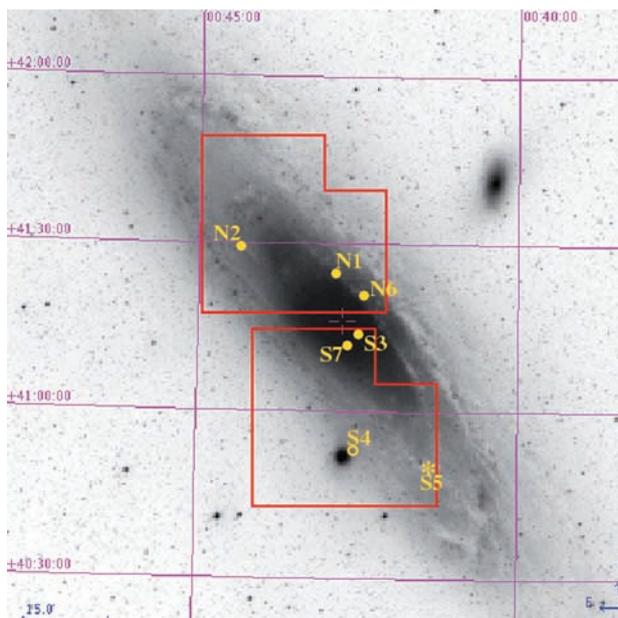


Figure 31. The boundaries of the observed fields are marked as red lines, and the centre of M 31 is a cross. Circles mark the positions of the 6 microlensing events detected. The open circle (S4) corresponds to an event seen toward M32. The star (S5) indicates the position of a binary event candidate (figure from Calchi Novati et al., 2005, A&A, 443, 911).

M 31, being both nearby and similar to the MW, is a suitable target for such a search. It allows observers to explore the MW halo along a different line of sight. It has its own halo that can be studied globally, and its high inclination is expected to give a strong gradient in the spatial distribution of microlensing events. However, the latter feature, which was at first believed to provide an unmistakable signature for M 31 microlensing halo events, seems to be shared, at least to some extent, by the variable star population within M 31.

A high-threshold analysis of the 3 years of data yielded 6 bright, short-duration microlensing events, which are compared with a simulation of the observations and the analysis. The observed signal is much larger than expected from self lensing alone and the astronomers conclude, at the 95% confidence level, that at least 20% of the halo mass in the direction of M 31 must be in the form of MACHOs if their average mass lies in the range 0.5-1 solar masses. This lower bound drops to 8% for MACHOs with masses ~0.01 solar masses.

In addition, they found a likely binary microlensing candidate with a caustic crossing. Its location, some 32 arcmin away from the centre of M31, supports the conclusion that they were detecting a MACHO signal in the direction of M31.

The POINT-AGAPE survey also yielded the identification of 20 classical novae (CNe) candidates observed over three seasons in M31. CNe were detected both in the bulge region as well as over a wide area of the M31 disc. Nine of the CNe were caught during the final rise phase and all are well sampled in at least two colours. The excellent light-curve coverage allowed the astronomers to detect and classify CNe over a wide range of speed class, from very fast to very slow. Among the light curves is a moderately fast CN exhibiting entry into a deep transition minimum, followed by its final decline. The CN catalogue constitutes a uniquely well-sampled and objectively-selected data set with which to study the statistical properties of CNe in M31, such as the global nova rate, the reliability of novae as standard-candle distance indicators and the dependence of the nova population on stellar environment.

A catalogue with the locations, periods and brightness of 35,414 variable stars in M31 was produced as a by-product of the microlensing search. The variables were classified according to their period and brightness. Rough correspondences with classical types of variable star (such as Population I and II Cepheids, Miras and semi regular long-period variables) were established. The spatial distribution of Population I Cepheids is clearly associated with the spiral arms, while the central concentration of the Miras and long-period variables varies noticeably, the brighter and the shorter period Miras being much more centrally concentrated.

A crucial role in the microlensing experiment is played by the asymmetric signal – the excess of events expected in the southern or more distant fields as measured against those in the northern or nearer fields. It was initially assumed that the variable star populations in M31 would be symmetric with respect to the major axis, and thus variable stars would not be a serious contaminant for measuring the microlensing asymmetry signal. However, it was found that all the variable star distributions are primarily asymmetric because of the effects of differential extinction associated with the dust lanes.

A PANORAMA OF ANDROMEDA AND TRIANGULUM HALOS

The outskirts of galaxies hold fundamental clues about their formation history. It is into these regions that new material continues to arrive as part of their ongoing assembly, and it was also into these regions that material was deposited during the violent interactions in the galaxy's distant past. Moreover, the long dynamic timescales for structures beyond the disk ensure that the

debris of accreted material takes a very long time to be erased by the process of phase mixing, which in turn means that it is possible to detect many of these signatures of formation as coherent spatial structures.

Much theoretical effort has been devoted in recent years to understanding the fine-scale structure of galaxies, as researchers realised that cosmological models could not only be tested with the classical large-scale probes, such as galaxy clusters, filaments, and voids, but also with observations on galactic and subgalactic scales. Indeed, it is precisely in the latter regions that the best constraints on cosmology are expected to be placed in the coming decades. The Λ CDM cosmologies, in particular, are now sufficiently well developed theoretically that the Local Group provides a means of directly testing and constraining these theories, by observing the profiles of density, age, and metallicity of the structure and substructure predicted to be found in the outer parts of galaxy disks and in galaxy halos.

Andromeda, like the Milky Way, is a canonical galaxy and a laboratory for examining in close detail many of the astrophysical processes that are investigated in the more distant field. Studying Andromeda and Triangulum in the Local Group has the advantage that it affords us a view free from the problems that plague Galactic studies due to our position within the Milky Way, yet their location within the Local Group allows us to resolve and study individual stars and deduce population properties in incomparably greater detail than is possible in distant systems.

Andromeda is the closest giant spiral galaxy to our own and the only other giant galaxy in the Local Group. In many ways Andromeda is the “sister” to the Milky Way, having a very similar total mass, having shared a common origin, and probably sharing the same ultimate fate when they finally merge in the distant future. However, there are significant differences between these “twins.” M31 is slightly more luminous than the Milky Way, and it has a higher rotation speed and a bulge with a higher velocity dispersion. M31 possesses a globular cluster system with ~500 members, approximately 3 times more numerous than that of the Milky Way.

The disk of Andromeda is also much more extensive, but is currently forming stars at a lower rate than the Galaxy. There are indications that the Milky Way has undergone an exceptionally low amount of merging and has unusually low specific angular momentum, whereas M31 appears to be a much more normal galaxy in these respects. Although possibly the consequence of low number statistics, it is

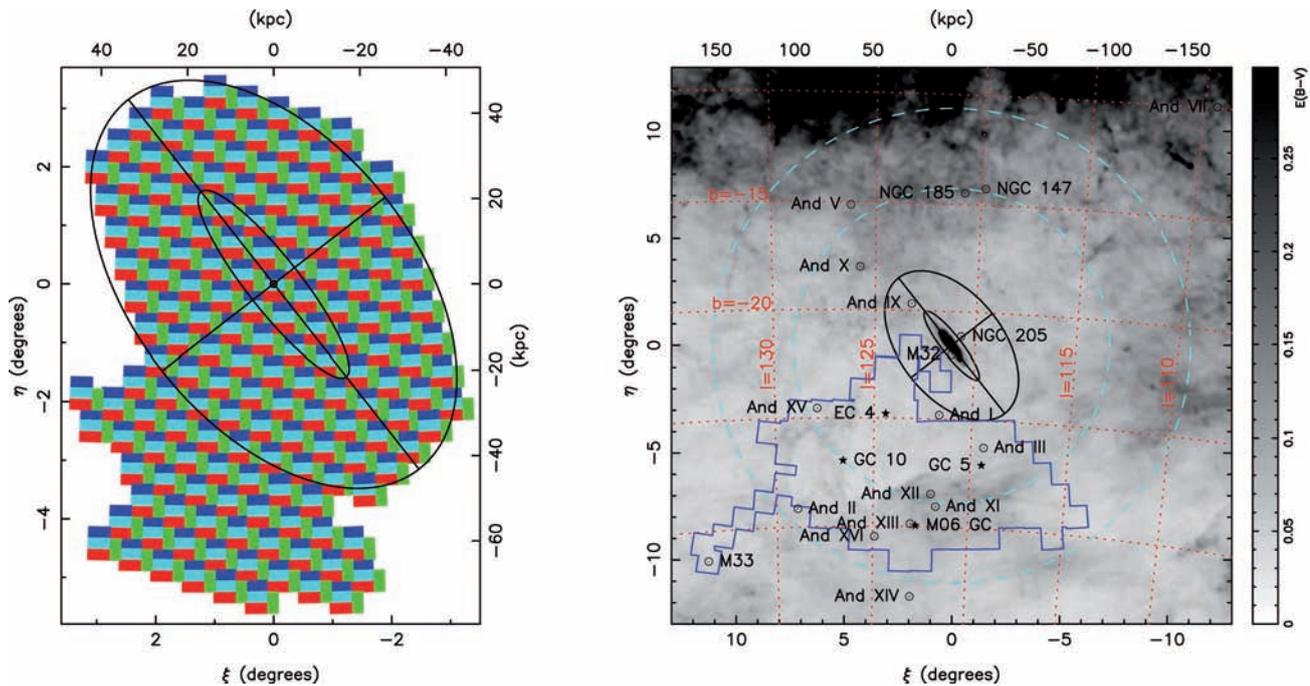


Figure 32. Left: coverage of the large panoramic survey of M31 with the INT Wide Field Camera, in standard coordinates (ξ , η). The inner ellipse represents a disk of inclination 77° and radius 2° (27 kpc), the approximate end of the regular H I disk. The outer ellipse shows a 55 kpc radius ellipse and the major and minor axes are indicated with straight lines out to this ellipse. This map is constructed from a total of 164 INT WFC individual pointings. Right: survey region (irregular blue polygon) overlaid on a schematic diagram of M31 and surrounding Local Group structure. Note that the survey extension along the M31 minor axis reaches M33 and therefore probes the halos of both these disk galaxies. In addition to the ellipses reproduced on the left-hand figure, the two concentric dashed circles show projected radii of 100 and 150 kpc. A grid in Galactic longitude and latitude has been marked. The extinction over the surveyed region is also shown (figures extracted from Ibata et al., 2007, ApJ, 671, 1591).

tempting to attribute significance to the fact that Andromeda has a compact elliptical (M32) and three dwarf elliptical galaxies (NGC 205, NGC 147, NGC 185) among its entourage of satellites, as well as no star-forming dwarf irregulars (dIrrs) within 200 kpc, whereas the Milky Way has no ellipticals but two dIrrs. However, it is perhaps in their purported halo populations that the differences between the two galaxies are most curious and most interesting.

If Andromeda is the twin of the Milky Way, the Triangulum galaxy (M33), with a mass ~ 10 times lower than either of these two giants, is their little sister. M33 is the third brightest galaxy in the Local Group and probably a satellite of M31. The relatively undisturbed optical appearance of M33 places strong constraints on the past interaction of these two galaxies, although it should be noted that the gaseous component is extremely warped.

In order to study in more detail the halos of both the Andromeda and Triangulum galaxies, astronomers performed a deep photometric survey of the Andromeda galaxy, conducted with the Wide Field Camera of the INT and MegaCam on CFHT, that covered the inner 50 kpc of the galaxy and the southern quadrant out to ~ 150 kpc and included an extension to M33 at >200 kpc. This is the first

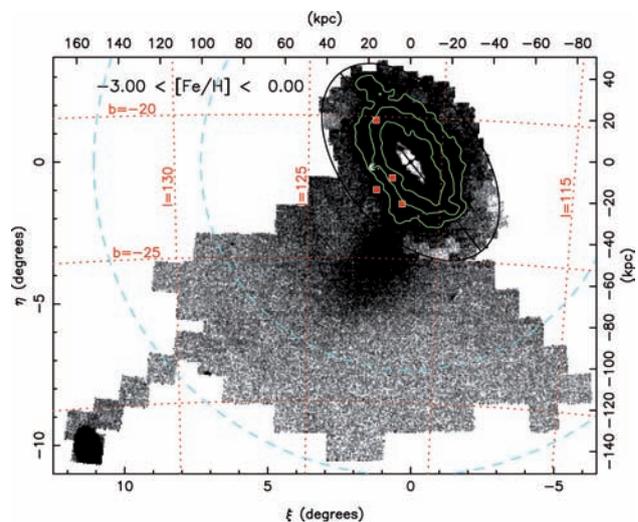


Figure 33. Matched filter map to the limiting depth of the INT survey ($i_0=22.8$ for $S/N\sim 10$). The contours show the approximate location of the surface brightness levels 27, 28 and 29 mag arcsec $^{-2}$ respectively (figure from Ibata et al., 2007, ApJ, 671, 1591).

systematic panoramic study of this very outermost region of galaxies. They detected a multitude of large-scale structures of low surface brightness, including several streams, and two new relatively luminous dwarf galaxies: And XV and And XVI.

Significant variations in stellar populations due to intervening stream-like structures are detected in the inner halo. Underlying the many substructures lies a faint, smooth, and extremely extended halo component, reaching out to 150 kpc, whose stellar populations are predominantly metal-poor. They find that the smooth halo component in M31 has a radially decreasing profile that can be fitted with a Hernquist model of immense scale radius ~ 55 kpc, almost 4 times larger than theoretical predictions. If it is symmetric, then the total luminosity of this structure is $\sim 10^9$ solar luminosities, again similar to the stellar halo of the Milky Way.

This vast, smooth, underlying halo is reminiscent of a classical “monolithic” model and completely unexpected from modern galaxy formation models. M31 is also found to have an extended metal-poor halo component, which can be fitted with a Hernquist model, also of scale radius ~ 55 kpc. These extended slowly decreasing halos provide a challenge and strong constraints for further modelling.

ECLIPSING BINARIES AND CEPHEIDS IN THE ANDROMEDA GALAXY

Cepheids are probably the most studied variable stars. Their large amplitudes and intrinsic luminosities make them easily detectable in most photometric variability surveys. In addition, their well-known period-luminosity (P-L) relationship has made these variable stars one of the main cornerstones in deriving extragalactic distances. The importance of Cepheids for distance determination stands in contrast with the relative lack of additional information on the specific characteristics of extragalactic Cepheids and the possible corrections because of their particular properties (i.e., metallicity).

A clear example is the Andromeda galaxy (M 31), where the first identification of Cepheids was already performed by Hubble in 1929. After the observations of Baade & Swope in 1965, few efforts have been dedicated to further analyse the Cepheid population in M 31.

This trend has changed in recent years with the emergence of new observational capabilities. Several variability surveys have started to study the stellar content in M 31 and other Local Group galaxies, obtaining large samples of Cepheids with accurate photometry. The detailed study of the observed Cepheids has emphasised the importance of an issue that was usually overlooked in most photometric studies, the effect of blending. It has been proposed that the magnitude of Cepheids may be affected by the light of unresolved companion stars (i.e.,

blends). The effect of blending is somewhat different from crowding or confusion noise, since companion stars appear to be in the same point-like source. Therefore, even when achieving perfect point-spread function modelling, blending can still be present. The effect can be the same as in spectroscopic binaries, where the individual components cannot usually be resolved from ground-based images.

With the goal of obtaining accurate distance determinations to the Andromeda Galaxy, and constraining the age and evolution of the Universe, astronomers started a project to use eclipsing binaries as distance indicators to M 31. Eclipsing binaries have been proved to yield direct and precise distances that are essentially assumption-free. To do so, high-quality photometric and spectroscopic data were needed. As a first step in the project, broad band photometry (in Johnson *B* and *V*) was obtained in a region ($\sim 34' \times 34'$) in the north eastern quadrant of the galaxy over 5 years.

The data, containing more than 250 observations per filter, generated a catalogue with 236,238 objects with photometry in both *B* and *V* passbands. This catalogue is the deepest ($V < 25.5$ mag) photometric survey obtained so far in the studied region and it contains 3964 identified variable stars, with 437 eclipsing binaries and 416 Cepheids.

The most suitable eclipsing binary candidates for distance determination were selected according to their brightness and from the modelling of the obtained light curves. The resulting sample includes 24 targets with photometric errors around 0.01 mag. Detailed analysis (including spectroscopy) of some 5-10 of these eclipsing systems should result in a distance determination to M 31 with a relative uncertainty of 2-3% and essentially free of systematic errors, thus representing the most accurate and reliable determination to date.

The resulting sample of 416 Cepheids is the most complete in M 31 and has almost the same period distribution as the David Dunlap Observatory sample in the Milky Way. The large number of epochs (~ 250 per filter) has permitted the characterisation of the pulsation modes of 356 Cepheids, with 281 of them pulsating in the fundamental mode and 75 in the first overtone.

The findings show that the blending contribution is as important as the metallicity correction when computing Cepheid distance determinations to M 31 (~ 0.1 mag). Since large amplitude Cepheids are less affected by blending,

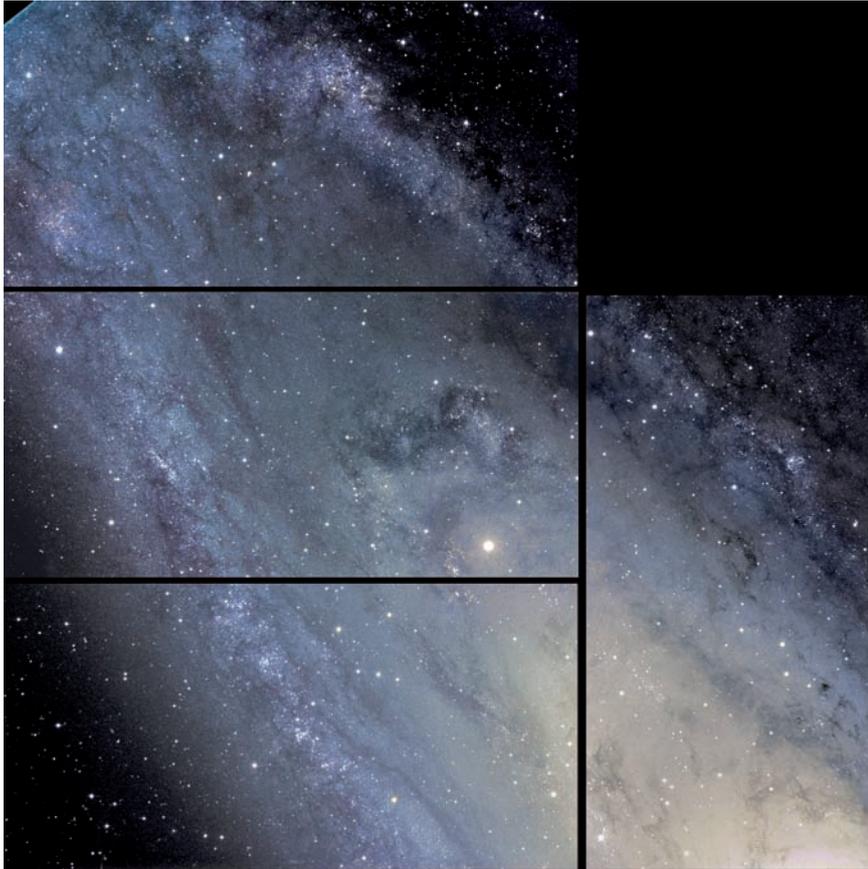


Figure 34. This INT Wide Field Camera composite image in B and V bands of the Andromeda Galaxy centered at R.A.=00h44m46s and Dec.=+41°38'20" shows the field of view used in the present study. (Credit: F. Vilardell, I. Ribas and C. Jordi, final image preparation by N. Szymanek)

they used those with an amplitude larger than 0.8 mag to derive a distance to M 31 of $(m-M)_0=24.32\pm 0.12$ mag.

PROBING COSMIC EVOLUTION WITH GAMMA-RAY BURSTS

Gamma-ray bursts (GRBs) are very bright flashes of radiation, which are detected approximately 100 times per year by satellites. For a long time it was a mystery as to where these flashes originated from and how they were produced. In 1997 astronomers using the WHT discovered that GRBs show a so-called "afterglow": radiation in other wavelengths following the gamma-rays. This afterglow can be studied with telescopes from the Earth, and allowed astronomers to find that GRBs originate in the violent deaths of massive stars, in star-forming galaxies far away.

GRBs have proven to be excellent probes of the distant Universe. The high luminosities of GRB afterglows allow absorption line studies of the interstellar medium at high redshift up to redshifts larger than 6. The decrease in brightness of GRB afterglows means that a rapid response is essential, the afterglow can be "caught" when it is still bright. To exploit this benefit, the override programmes on the WHT and the INT are ideal for responding rapidly.

Early in the morning of February the 6th, 2006 a GRB was detected by the Swift satellite. The GRB was at that time high in the sky over La Palma and the weather was good. Within 15 minutes the NOT was pointed towards this burst by the Danish GRB follow-up group. Using ALFOSC a bright optical afterglow was discovered in the R band. Directly after the detection had been made, a low-resolution spectrum was acquired using the same instrument. The latter spectrum rapidly determined the redshift of GRB 060206 at $z=4.048$. Meanwhile, the WHT had been alerted through a collaboration of the NOT and WHT, involving GRB follow-up teams from the Netherlands, the United Kingdom and Denmark. Starting at just 1.6 hours after the burst a medium-resolution spectrum could be obtained using the WHT's ISIS spectrograph.

The combination of the NOT and WHT data provided a unique window on this afterglow. The low resolution and broad wavelength coverage of the NOT spectrum allowed an accurate determination of the column density of neutral hydrogen (H I), redshifted to optical wavelengths. The better resolution of the WHT spectra meant an accurate study of metal lines in the spectrum was possible. A large number of metal lines are found in the spectra, including (forbidden) fine-structure lines. Based on the

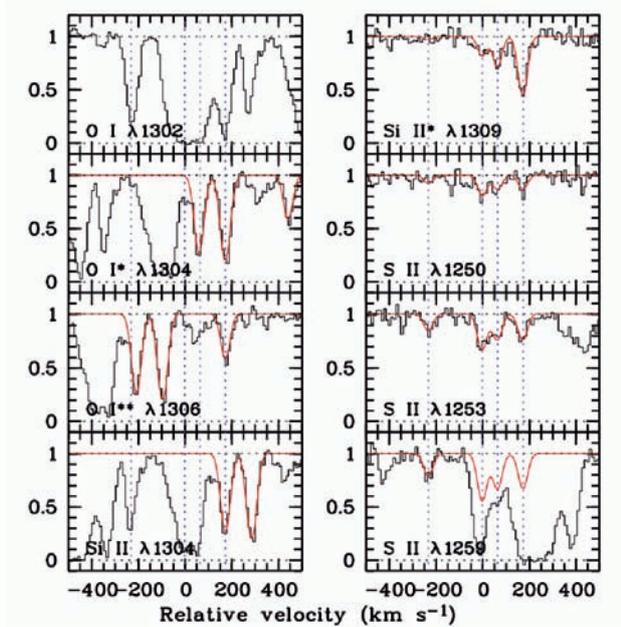


Figure 35. Portions of the ISIS spectrum showing the O I, O I*, O I**, Si II, Si II* and S II lines. It is clearly visible that there are four discrete velocity components, with velocity differences of up to $\sim 500 \text{ km s}^{-1}$.

measurement of the neutral hydrogen column density and the metal content from weak, unsaturated singly-ionised sulphur (S II) lines, a metallicity of $[\text{S}/\text{H}] = -0.84 \pm 0.10$, or ~ 0.14 times solar metallicity, was derived. This is in fact one of the highest metallicities measured from absorption lines at redshift around 4. From the very high column densities for the forbidden singly-ionised silicon (Si II*), and neutral oxygen (O I* and O I**) lines, the researchers infer very high densities in the system, significantly larger than 10^4 cm^{-3} .

The high-resolution spectra also allow the astronomers to study the kinematics of the absorption systems. Several different, discrete velocity systems can be distinguished, with velocities of up to 500 km s^{-1} . Most surprisingly however, was the tentative detection of molecular hydrogen in the ISIS spectrum. This is the very first detection of molecular lines in an optical GRB afterglow spectrum. Especially remarkable is the fact that this possible detection has been achieved with a 4-metre telescope, proving that medium size telescopes can compete when response times are short.

U AND B NUMBER COUNTS FROM THE GOYA SURVEY

The Galaxy Origins and Young Assembly (GOYA) survey is designed to study the formation and evolution of galaxies with the aim of learning about the epoch and the

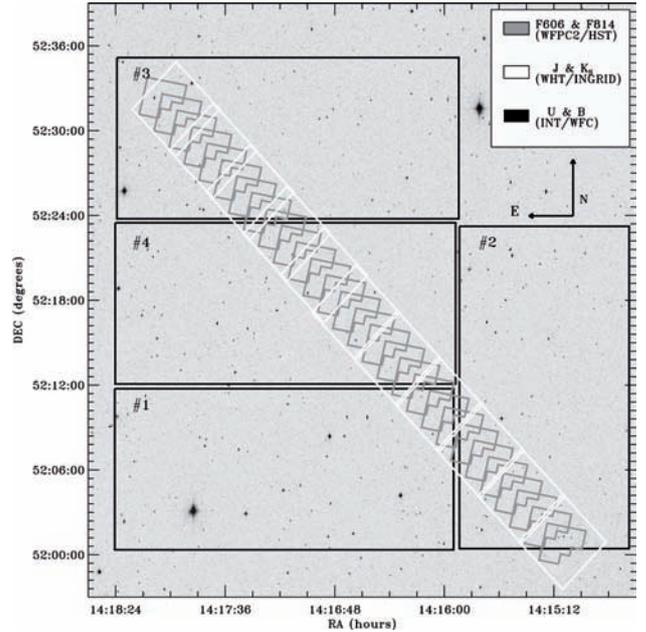


Figure 36. Observations of the GOYA Survey in the GWS region over a DSS image. The 28 HST WFPC2 pointings defining the GWS in F606W and F814W are shown in gray, while J and Ks WHT INGRID fields are shown in white. The GWS runs diagonally across the wide $45' \times 45'$ field marked in black, which corresponds to the INT WFC field (U and B data). Numbers in black indicate positions and orientations of the four chips of WFC (figure from Eliche-Moral et al., 2006, ApJ, 639, 644).

mechanisms by which galaxies assembled the bulk of their stars and acquired their present structure and dynamics. For this, a near-infrared/optical observational program using some of the most powerful ground-based telescopes and public data is being conducted to map 0.5 square degrees of high-latitude sky. As the main scientific motivation behind the design of EMIR (a NIR cryogenic multi-slit spectrograph for the 10.4m GTC at Observatorio del Roque de los Muchachos), GOYA emphasizes the use of near-infrared observations, which sample the optical rest-frame spectrum of galaxies at very high redshifts.

The GOYA photometric survey is a multicolour survey in six broadband filters (U, B, V, I, J, K_s) with target depths of $U=B=V=I=26$ and $J=K=22$ (AB magnitudes). Its principal aim is to generate a galaxy database for sample selection and characterisation for subsequent NIR spectroscopy with EMIR.

The U and B imaging came from observations carried out with the INT Wide Field Camera and covers the Groth-Westphal Strip (GWS). The GOYA Survey has also reduced and analysed data over this field in NIR filters from WHT INGRID (J and K_s) and in visible filters from HST WFPC2 (F606W and F814W). Originally, the GWS field

was defined as 28 HST WFPC2 pointings extended along a 45' strip. It has an area of ~ 150 arcmin² of sky. Compared to other existing optical-NIR surveys, GOYA offers a notable increase in the depth times area product in several filters, compiling complementary photometry in six optical-NIR bands and morphological and surface brightness information from high-resolution HST WFPC2 images.

Counts were derived over the magnitude ranges $18.0 < U < 25.0$ and $19.5 < B < 25.5$. These wide ranges (7 magnitudes in U and 6 magnitudes in B) result from the combination of wide area and depth of the survey. In both bands, the number counts are in good agreement with other studies that cover fainter and brighter magnitudes. When combined with K_s number counts, the data provide strong constraints on galaxy formation models, due to the presence of a knee at $K_s=17.5$ in the NIR counts and the absence of such a feature in blue passbands.

Adopting a Λ -dominated cosmological model, a simple number count model (including luminosity evolution and a galaxy number evolution) accurately reproduces the observed counts in U , B and K_s in a consistent way. Extensive modelling suggests that only by assuming a moderately low formation redshift for the dominant NIR population (elliptical galaxies) does the model reproduce the $K_s=17.5$ knee. Reproducing the lack of a knee in the U and B counts, subsequently requires the adoption of a moderate optical depth for all galaxy types, including elliptical galaxies. Neither of the two assumptions are at odds with current ideas on galaxy formation and evolution in hierarchical universes.

THE STAR FORMATION RATE AT REDSHIFT ONE

The quest for giving the first global view of the history of star formation in the Universe, as a key element in understanding galaxy assembly, commenced around 10 years ago. To date, many quantitative attempts to measure the global star formation history have been based on optical measurements and have thus suffered from having to use different indicators of star formation in various redshift bins, redshifted into the optical.

These various indicators not only have uncertain relative calibrations but are also affected differently by dust extinction. Commonly used star formation rate (SFR) indicators are ultraviolet (UV) continuum luminosity, which can be heavily dust extinguished, and nebular emission lines such as H alpha and [O II], (the latter of which is strongly dependent on metallicity and ionisation state).

Longer wavelength estimators relying on far-infrared (FIR) or radio luminosity are insensitive to dust obscuration and yet have their own caveats.

The Universe at redshift $z \sim 1-2$ is believed to be one of the most active epochs in galaxy formation and evolution. Indeed, it is inferred to be the epoch at which large elliptical and spiral galaxies are assembled and therefore may also be the period of peak star formation in the Universe. Yet, the Universe at this epoch is still neither well studied, nor well understood. Observations have long been hampered by the difficulties of observing objects at these redshifts in the visible wavebands. At redshift $z \sim 1$, key diagnostic spectral features are redshifted out of the optical into the near-infrared (near-IR), which is a difficult regime to work in, and the rest UV Lyman alpha line is not accessible in the optical until around redshifts $z \sim 2.5$. The redshift range $z \sim 1-2$ has hence traditionally been dubbed the spectroscopic 'redshift desert'. Furthermore, there is certainly evidence that the SFR was much higher in the recent past ($z \sim 0.5$), compared to the current epoch. However, it is still unclear whether at redshifts of one and beyond, the star formation density plateaus, declines, or perhaps continues to increase.

A team of astronomers have used the Cambridge Infrared Panoramic Survey Spectrograph (CIRPASS) mounted on the WHT with the aim of addressing the true star formation history of the Universe at redshifts $z = 0.7-1.5$, through H alpha measurements of a large sample of galaxies. CIRPASS is a near-IR fibre-fed spectrograph operating between 0.9 and 1.67 μm and it can operate with 150 fibres with the ability to simultaneously observe up to 75 targets (in object/sky pairs). CIRPASS work with one of two modes – with an Integral Field Unit or in multi-object mode (CIRPASS-MOS). CIRPASS-MOS was used at the Cassegrain focus of the WHT to observe 62 objects at a time in the Hubble Deep Field-North. The fibre size corresponds to ~ 1.1 arcsec at the WHT (which is approximately comparable to the expected seeing convolved with typical galaxy profiles, at least for compact galaxies). CIRPASS-MOS demonstrates a powerful new technique for studying distant galaxies, and this is the first successful example of near-IR multi-object spectroscopy of high-redshift galaxies.

Stacking the spectra in the rest frame, to infer a total SFR for the field, they find a lower limit (uncorrected for dust reddening) on the SFR density at redshift $z = 1$ of 0.04 solar masses per year and Mpc^{-3} . This implies rapid evolution in the SFR density from $z=0$ to 1 which is proportional to $(1+z)^{3.1}$.

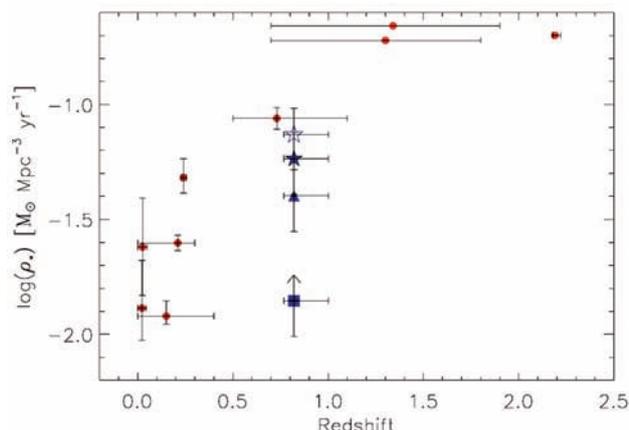


Figure 37. Star formation rate densities determined from $H\alpha$ measurements only and with reddening corrections. The authors used their own reddening corrections where applicable. The uncorrected data points are shown with a square and triangle. Reddening-corrected points are shown for the Milky Way law (filled star) and a Calzetti law (open star) (figure from Doherty et al., 2006, MNRAS, 370, 331).

This successful application of multi-object fibre spectroscopy to observe high-redshift galaxies constitutes a powerful technique, and the success of this multi-object spectroscopic survey bodes well for larger surveys with future instruments such as EMIR on Gran Telescopio Canarias.

DISCOVERY OF THE MOST MASSIVE GALAXY LENS

There have been many optical giant arcs discovered, caused by the lensing effects of massive galaxy clusters and their central galaxies. But, few optical rings have ever been found, despite theoretical predictions that they should be abundant.

Using data from the Sloan Digital Sky Survey (SDSS) Data Release 5 (DR5), astronomers found the largest optical Einstein ring known, an almost complete ($\sim 300^\circ$) Einstein ring of diameter $10.2''$, more than 5 times the size of previously-known optical rings. Further imaging follow-up with the Wide Field Camera on the INT revealed a "horseshoe" shape with three brightness peaks, and thus the name "Cosmic Horseshoe".

The lensing galaxy itself is an interesting object, it is a member of a rare population of Luminous Red Galaxies (LRGs). These are the largest and most massive galaxies in the universe, and they are also believed to host massive black holes. This deflecting galaxy has a line-of-sight

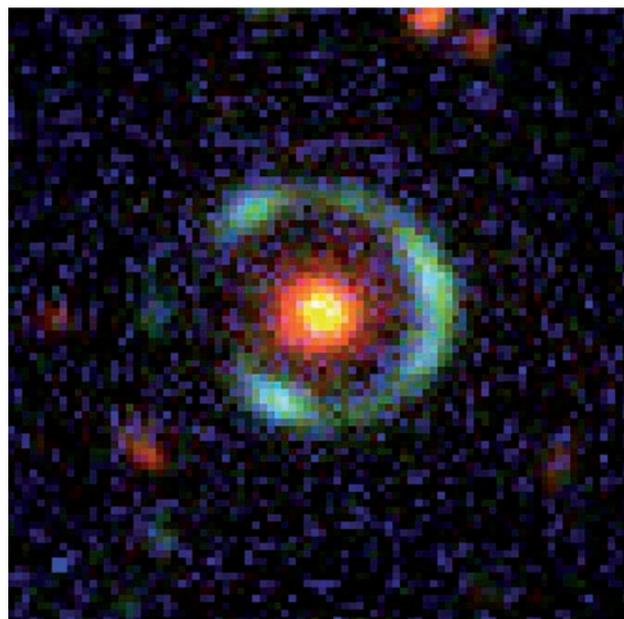


Figure 38. INT WFC u, g, i composite of the Cosmic Horseshoe from follow-up data (figure from Belokurov et al., 2007, ApJ, 671, L9)

velocity dispersion in excess of 400 km s^{-1} and a redshift of 0.444, while the source is a star-forming galaxy with a redshift of 2.379. From its colour, luminosity, and velocity dispersion, they argue that this is the most massive galaxy lens hitherto discovered.

OTHER SCIENTIFIC HIGHLIGHTS BRIEFLY

The kinematics of diffuse ionised gas in the disk halo interface of NGC 891

The properties of the gas in halos of galaxies constrain global models of the interstellar medium. Kinematical information is of particular interest since it is a clue to the origin of the gas. From Fabry-Pérot TAURUS II observations at the WHT of the kinematics of the thick layer of the diffuse ionised gas in NGC 891, the rotation curve of the halo gas could be determined. $H\alpha$ data cubes show much higher angular resolution than in the H I 21cm line. The velocity information of the diffuse ionised gas extracted from the data cube is compared to model distributions to constrain the distribution of the gas and in particular the halo rotation curve. The astronomers find that the scale length of the H alpha must be between 2.5 and 6.5 kpc. Furthermore they find evidence that the rotation curve above the plane rises less steeply than in the plane. This is all in agreement with the velocities measured in the H I (Kamphuis et al., 2007, A&A, 468, 451).

The European Galactic Plane Surveys (EGAPS): IPHAS and UVEX

The European Galactic Plane Surveys (EGAPS) will, for the first time ever, map the complete galactic plane, (10×360 degrees), down to 21st magnitude in u' , g' , r' , i' and H alpha and partly in He I 5875. It will complete a database of ~ 1 billion objects. The aim of EGAPS is to study populations of short-lived stellar and binary phases in our Galaxy and combine these population studies with stellar and binary evolutionary codes to vastly improve our understanding of crucial phases of stellar evolution. Target populations include Wolf-Rayet stars, planetary nebulae, white dwarfs (in binaries), cataclysmic variables and other mass-transferring binaries. EGAPS uses the INT+WFC for the Northern Hemisphere and will use the VST+Omegacam in the Southern Hemisphere. The Northern red survey (IPHAS, using r' , i' , and Halpha) started in 2003 and is complete. The northern blue survey (UVEX; u' , g' , r' and HeI) started in June 2006. Early results include the detection of a number of rare planetary nebulae, cataclysmic variables, red-dwarf white-dwarf binaries in clusters, a possible AM CVn candidate, and a deep photometric and spectroscopic investigation of the Cyg X region. EGAPS will revolutionise the field of galactic stellar astrophysics by completing the first ever fully digital, multicolour deep survey of the Galactic Plane (Groot et al., 2006, 26th meeting of the IAU, Joint Discussion, 13, 54.).

Kinematics of the ultracompact helium accretor AM Canum Venaticorum

AM Canum Venaticorum stars (AM CVn stars in short) are interacting binary stars whose mass, mainly helium, is constantly flowing from one star to the other. What makes these objects special is their ultra-compact nature. They consist of two degenerate, hydrogen-deficient stars, which means that these binaries have extremely short orbital periods, from about one hour down to only a few minutes. Their ultracompact nature makes them the strongest known sources of gravitational waves that can potentially be detected with the future ESA/NASA cornerstone satellite mission LISA, the Laser Interferometer Space Antenna. Until now, only a few exotic AM CVn stars were known. Of crucial importance for expanding the known population has been the advent of wide-field surveys such as the SDSS. In order to further improve the statistics of the sample, a number of dedicated wide-field sky surveys were designed and started, among them, IPHAS and UVEX on the INT. In addition to population studies, some astronomers embarked on a project to study individual systems in detail, using phase-resolved spectroscopic

techniques. One of the main questions to address was how these binaries are formed. Theoretically, no fewer than three different formation channels have been proposed to contribute to the AM CVn population, but which of these channels actually produce AM CVn stars, and in what numbers, has been a long-standing problem.

Using ISIS on the WHT, a team of astronomers was able to weigh the stars of the AM CVn binary, and showed that they are more massive than previously thought. This has important consequences for their formation and evolution. In addition, these observations allowed them, for the first time, to accurately predict the gravitational-wave signatures of these binary stars and they have shown that the known short-period AM CVn stars are the first solid candidates for detection with a LISA-type instrument. These stars will thus be of crucial importance to test and calibrate such a gravitational-wave detector, as well as directly test the predictions from General Relativity concerning the emission of gravitational waves from binary stars (Roelofs et al., 2006, MNRAS, 371, 1231).

A composite H II region luminosity function in H α of unprecedented statistical weight

Statistical properties of H II region populations in disk galaxies yield important clues to the physics of massive star formation. Previous studies have shown that there might exist a dual slope in the luminosity function (LF) of H II regions, with a well defined break at a specific luminosity, but the lack of a sufficient statistical base has prevented a conclusive result. One approach can be increasing the statistical weight by deriving a general form of the LF from

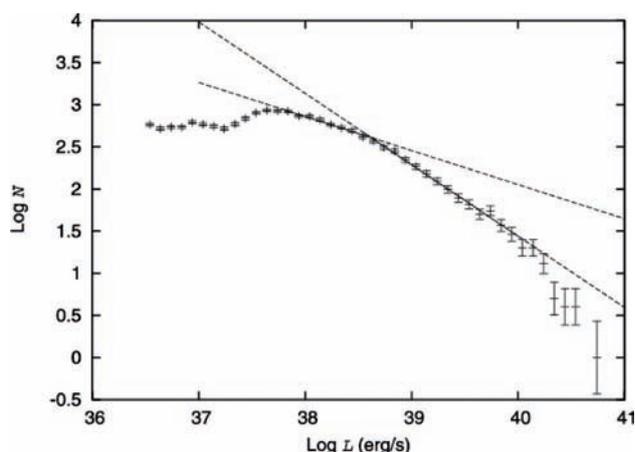


Figure 39. LF made from the combined H II region catalogues of 53 nearby spiral galaxies. The large number of H II regions allows plotting the LF in steps of 0.1 dex. The best double-slope fit is indicated by the lines, where dashes show extrapolations beyond the range over which the best fit has been made (figure from Bradley et al., 2006, A&A, 459, L13).

a sample of nearby spiral galaxies. For this reason, a team of astronomers obtained H α images of a sample of 53 spiral galaxies using the JKT, and after photometric calibration, the galaxies were summed to form a total LF comprising 17,797 H II regions. The new LF shows a clear two slope power law behaviour, with a significantly steeper slope for the high luminosity branch. This can be modelled by assuming that the high luminosity regions are density bounded, though the scenario is complicated by the inhomogeneity of the ionised interstellar medium. The break, irrespective of its origin, is of potential use as a distance indicator for disc galaxies (Bradley et al., 2006, A&A, 459, L13).

Massive star formation in the central regions of spiral galaxies

Enhanced nuclear activity in disk galaxies, in starburst or AGN form, appears to be an integral part of their evolution. Both forms of activity have been observed to co-exist and are a clear manifestation of the symbiotic evolution of galactic centres and their host galaxies. The observed tight correlation between the masses of the central black holes and the velocity dispersions in the surrounding bulges provides the most direct evidence for this evolution and yields important clues on the dynamics, structure, and evolution of galaxies.

To initiate and to maintain the AGN or nuclear starburst activity, gas inflow must be stimulated from the disk to the central regions – a process which must be accompanied by a substantial loss of angular momentum in the gas. Theoretically, this leads to the suggestion that gravitational torques acting through galactic bars or galaxy interactions are involved. Massive star formation can be convincingly traced by the accompanying H α emission and is very easily observed with standard telescopes and cameras. H α is mainly produced in the H II regions surrounding massive B and O stars, although shocks and non-stellar activity can also lead to H α emission.

Using 73 images of galaxies obtained with the AUX camera of the WHT, a team of astronomers studied the morphology of the H α emission in the circumnuclear, two kpc radius regions, as well as from the nucleus *per se*. The circumnuclear area that was chosen is large enough to incorporate most nuclear rings. For most of the galaxies, no H α imaging was available and the spatial resolution was mostly below one second of arc. They confirmed that late-type galaxies have a patchy circumnuclear appearance in H α , and that nuclear rings occur primarily in spiral types Sa-Sbc. They identified a number of previously

unknown nuclear rings, and confirmed that nuclear rings are predominantly hosted by barred galaxies. Other than stimulating nuclear rings, bars do not influence the relative strength of the nuclear H α peak, nor the circumnuclear H α morphology. No significant influence of the presence or absence of a close companion on the relative strength of the nuclear H α peak, nor on the H α morphology around the nucleus, was found (Knapen et al., 2006, A&A, 448, 489; Sarzi et al., 2007, MNRAS, 380, 949).

The water ice rich surface of (145453) 2005 RR43: a case for a carbon-depleted population of TNOs?

Spectroscopic and spectrophotometric studies show that about 70% of Trans-Neptunian Objects (TNOs) present a mantle of complex organics on their surfaces. Long term processing by high energy particles and solar radiation on icy bodies, induces the formation of organic species in their outer layers, resulting in a mantle that covers the unprocessed original ices. Until recently, the only case of a TNO with a surface covered basically by a thick layer of water ice was Charon, and it has been considered an intriguing case because of the need of a resurfacing mechanism like cryovolcanism or collisions with micro-meteorites. Recently, it has been showed that other TNOs also have surface composition similar to Charon and are located in a narrow region of the orbital parameters space. The existence of a population of TNOs with Charon-like surfaces and similiar orbital parameters needs to be explained, as it can have a strong impact on the knowledge of the trans-neptunian belt formation theories and/or resurfacing mechanisms. A study of the surface composition of the TNO (145453) 2005 RR43 using ISIS on the WHT showed that this object is indeed a member of such a population (Pinilla-Alonso et al., 2007, A&A, 468, L25).

DE CVn: a bright, eclipsing red dwarf-white dwarf binary

Large gaps remain in our knowledge of binary stellar evolution that not only affect our understanding of evolved compact binaries, but also of phenomena such as supernovae type Ia explosions, the rate of mergers between neutron stars, and the number of gravitational wave sources in our Galaxy. The poorly understood physics of the common-envelope (CE) phase results in considerable uncertainty in binary evolution models. During the evolution of a binary, the more massive star turns into a giant. When the initial orbital period is small enough, the envelope of the giant will encompass the secondary star. The secondary and the core of the giant will spiral in towards each other in a CE. When the envelope is expelled, a close binary, consisting of the core

of the giant (which will evolve towards a white dwarf) and the unevolved secondary star may emerge. The CE phase is expected to be very short, lasting less than ~ 1000 years, and therefore is virtually impossible to observe directly.

To study the effects of this phase, it is best to focus on objects that have most probably undergone a CE phase in their past. These are identified with binary systems containing at least one stellar remnant, where the current orbital separation is smaller than the radius of the giant progenitor, usually with orbital periods shorter than 1 day. Close white dwarf-red dwarf binaries must have passed through a common-envelope phase during their evolution. DE CVn is a detached white dwarf-red dwarf binary with a relatively short (~ 8.7 h) orbital period. Its brightness and the presence of eclipses make this system ideal for a more detailed study. From photometric and spectroscopic observations of DE CVn using ULTRACAM and ISIS on the WHT among other instruments, a team of astronomers found that the mass of the white dwarf is 0.51 solar masses, its effective temperature is 8000 K, and it has a hydrogen-rich atmosphere (DA-type). The red dwarf has a spectral type of M3V and its mass is 0.41 solar masses. The astronomers reconstructed its evolution and found that the progenitor of the white dwarf was a relatively low-mass star of less than 1.6 solar masses. The current age of this system is $3.3\text{--}7.3 \times 10^9$ years, while it will take longer than a Hubble time for DE CVn to evolve into a semi-detached system (van den Besselaar et al., 2007, A&A, 466, 1031).

Echoes from the companion star in Sco X-1

When the accreting compact object in an interacting binary is a neutron star or a black hole, the potential well is so deep that the infalling gas is heated to more than a million degrees Kelvin, producing abundant X-rays. These objects are therefore called X-ray binaries, and part of the observational work has concentrated on the so-called ultra-compact X-ray binaries (UCXBs). They are the X-ray binary cousins of the AM CVn stars and are also promising sources of gravitational wave radiation.

Low-mass X-ray binaries (LMXBs) are interacting binaries containing a low-mass donor star transferring matter on to a neutron star or black hole. Mass accretion takes place through an accretion disc, and with temperatures approaching $\sim 10^8$ K. In these binaries optical emission is dominated by reprocessing of the powerful X-ray luminosity in the gas around the compact object which usually swamps the spectroscopic features of the weak companion stars. In this scenario, dynamic studies have classically been restricted to the analysis of X-ray

transients during quiescence, where the intrinsic luminosity of the donor dominates the light spectrum of the binary.

Sco X-1 is the prototype LMXB and also the brightest persistent X-ray source in the sky and it has been the target of detailed studies since its discovery. Simultaneous X-ray and ULTRACAM optical data of Sco X-1 were obtained to cover the full 18.9-h orbital period in 12 snapshots, yielding 16.1 ks of X-ray data and simultaneous optical photometry in three different bands. For the first time, astronomers were able to isolate the emission line contributions from the mass donor star that correspond to X-ray variations with a delay that is consistent with the light travel time between the X-ray source near the neutron star and the irradiated face of the donor star that directly contributes to the emission (Muñoz-Darías et al., 2007, MNRAS, 379, 1637).

Searching for the lowest mass galaxies: an HI perspective

In the currently favoured cosmological models, structure evolves, by gravitational instability, from small, primordial, fluctuations in the dark-matter distribution. In this framework, galaxies form by the cooling of gas captured inside the dark-matter halos. In normal-sized galaxies, this cool gas will form stars, making the galaxy visible in optical light. However, various physical processes may prevent the cooling of the gas, and therefore the formation of stars. Such halos would remain dark in optical light. One possibility is that small galaxies are not heavy enough to condense the gas to densities high enough for star formation to occur. It may also be the case that the radiation of the first large objects formed in the universe keeps the gas in small galaxies ionised. Finally, it is conceivable that if a few stars form in a small galaxy, supernovae will expel the remaining gas, halting further star formation.

One possibility to test these various hypotheses is to study the neutral gas content of very small galaxies. The various theories about what may happen to the gas when small galaxies form, make different predictions for the gas content. For example, if all the gas is expelled, there may be a lower limit to the size of galaxies. On the other hand, if galaxies are too small to compress the gas so that stars can form, one should find very small galaxies that are dark in the optical but are detectable in neutral hydrogen because they consist solely of gas. Such systems are dubbed "dark galaxies".

So far, blind extragalactic surveys of neutral hydrogen have failed to detect a population of dark galaxies.

However, this may be due to these surveys not being sensitive to objects smaller than $10^{7.8}$ solar masses of H I and hence they may not be able to find the small, dark H I clouds predicted by some theories. To answer the question of whether a significant population of gas-rich, low-luminosity, low-surface brightness, or even dark galaxies, exist, it is necessary to reach lower H I masses. In order to achieve this, a new blind H I survey using the WSRT telescope of 90 square degrees in the constellation of Canes Venatici (the so-called "CVn survey") was designed to be sensitive to objects with HI masses down to below 10^6 solar masses.

To be able to study the optical properties of the detections, the smaller galaxies were also observed with the INT WFC where images of the objects were made in different colours. These observations show that all objects detected in H I have clear counterparts in the optical. Therefore, the data do not give any indication that, even when going to lower H I masses, dark H I objects exist (Kovac, 2007, "Searching for the lowest mass galaxies: an H I perspective", PhD thesis, Rijksuniversiteit Groningen; Kovac et al, 2005, "The faint end of the H I mass function", IAU Colloquia, 198, 351).

The ING Override Programme and Gamma-Ray Bursts

The ING Override Programme continues to produce a significant number of papers, in particular in the field of Gamma-Ray Bursts. During 2006 and 2007, the following papers were published using data from a wide variety of instruments (PFIP, LIRIS, ISIS, INGRID, AUX and WFC): Castro-Tirado et al., 2006, "GRB 051028: an intrinsically faint gamma-ray burst at high redshift?", *A&A*, 459, 763; De Ugarte Postigo et al., 2006, "GRB 060121: Implications of a Short-/Intermediate-Duration Gamma-Ray Burst at High Redshift", *ApJ*, 648, L83; Fynbo et al., 2006, "Probing cosmic chemical evolution with gamma-ray bursts: GRB 060206 at $z = 4.048$ ", *A&A*, 451, L47; Levan et al., 2006, "Infrared and Optical Observations of GRB 030115 and its Extremely Red Host Galaxy: Implications for Dark Bursts", *ApJ*, 647, 471; Castro-Tirado et al., 2007, "The dark nature of GRB 051022 and its host galaxy", *A&A*, 475, 101; Ruiz-Velasco et al., 2007, "Detection of GRB 060927 at $z = 5.47$: Implications for the Use of Gamma-Ray Bursts as Probes of the End of the Dark Ages", *ApJ*, 669, 1; Curran et al., 2007, "GRB 060206 and the quandary of achromatic breaks in afterglow light curves", *MNRAS*, 381, L65).

New Milky Way Companions

The known satellite galaxies of the Milky Way all lie within ~300 kpc, and their brightest stars are resolvable from

ground-based telescopes. Thus, it is possible to acquire an enormous wealth of data on their stellar populations, making the satellite galaxies important objects in many fields of astrophysics. They have also emerged as a battleground in near-field cosmology. Using data from the SDSS, astronomers have found 5 new satellites of the Milky Way, one of which was followed-up with the Wide Field Camera on the INT. So far astronomers accept 14 mini-galaxies as Milky Way satellites, (the dwarf irregulars, Large and Small Magellanic Clouds and 12 dwarf spheroidals), although sometimes the distinction between star clusters and dwarf galaxies is ambitious. The possible disrupting satellites, Canis Major and Virgo, overdensities and the already absorbed dwarf known as the Monoceros Ring, are other structures related to this research (V. Belokurov et al., 2007, "Cats and Dogs, Hair and a Hero: A Quintet of New Milky Way Companions", *ApJ*, 654, 897).

Discovery of a cluster of galaxies behind the Milky Way

Rich clusters of galaxies have been successfully used as tracers of large-scale structure formation and evolution, which has allowed the setting of constraints on various cosmological parameters. In the past, the majority of rich clusters was first identified in the optical and later observed in X-rays. However, with the advent of large and deep X-ray surveys, X-ray observations have become one of the most useful techniques for discovering clusters of galaxies, especially for intermediate and high-redshift systems. On the other hand, X-rays may also be useful for detecting clusters near the Galactic plane, where the increasing number of stars and extinction makes the optical identification of background galaxies difficult. Following this approach, astronomers reported the discovery of Cl 2334+48, a rich cluster of galaxies in the Zone of Avoidance, identified in public images from the XMM-Newton archive, and followed up using optical images with the Wide Field Camera on the INT (Lopes de Oliveira et al., 2006, "Discovery of a cluster of galaxies behind the Milky Way: X-ray and optical observations", *A&A*, 459, 415).

The RAPid Temporal Survey (RATS)

The intensity of stellar objects can vary on a wide range of time-scales, ranging from seconds to months to years. A large number of projects now exist whose aim is to detect such varying sources. The reasons for this are many, but include the search for extrasolar planets and interacting binary stars. Most of these surveys are sensitive to time-scales longer than a day. It is only recently that such surveys have been sensitive to shorter term time-scales. For instance, the Faint Sky Variability Survey on the INT

has a large survey area and it was sensitive to variations only as short as ~24 min. In principle the SuperWasp project is sensitive to variations on time-scales as short as a few minutes. However, it is sensitive to relatively bright objects, $V \sim 7-15$.

Why is it important that we extend the parameter search down to periods shorter than 10 min? Recently a new class of object has been discovered in which coherent intensity variations have been detected on time-scales of ~10 min or less. It is thought that these systems are interacting white dwarf–white dwarf pairs which have no accretion disc, and the observed period represents the binary orbital period. As such, they are expected to be amongst the first sources to be detected using LISA, the planned gravitational wave observatory.

These systems are at the short end of the period distribution of white dwarf–white dwarf binaries, or AM CVn systems. For orbital periods less than 80 min, the secondary (mass-donating) star cannot be a main-sequence star. Furthermore, for periods shorter than 30 min, the secondary must be a helium white dwarf.

The aim of the RApid Temporal Survey (RATS) is to discover objects whose optical intensity varies on time-scales of a few minutes to several hours. The prime aim is to discover interacting ultracompact binary systems – systems consisting of two degenerate (or semi-degenerate) stars orbiting around a common centre of gravity – with binary orbital periods of less than ~70 min. The pilot survey data was obtained using the INT and the Wide Field Camera. It covered 3 deg^2 and reached a depth of $V \sim 22.5$. Nearly 50 sources were found to show significant intensity variations and none were previously known variable objects. However, only four objects showed modulations which varied on periods of approximately 1 h or less, one being a subdwarf B star and the other three are likely to be SX Phe stars. (Ramsay and Hakala, 2005, "RApid Temporal Survey (RATS) – I. Overview and first results", MNRAS, 360, 314; Ramsay et al., 2006, "RApid Temporal Survey (RATS) – II. Followup observations of four newly discovered short-period variables", MNRAS, 371, 957).

Exploration of the Kuiper Belt by High-Precision Photometric Stellar Occultations: First Results

Astronomers report the first detection of hectometre-size objects by the method of serendipitous stellar occultation using ULTRACAM on the WHT. This method consists of recording the diffraction shadow created when an object crosses the observer's line of sight and occults the disk of

a background star. One of the detections is most consistent with an object between Saturn and Uranus in size. The two other diffraction patterns detected were caused by Kuiper Belt objects beyond 100 AU from the Sun and hence are the farthest known objects in the solar system. These detections show that the Kuiper Belt is much more extended than previously believed and that the outer part of the disk could be composed of smaller objects than the inner part. This gives critical clues to understanding the problem of the formation of the outer planets of the solar system (Roques et al., 2006, "Exploration of the Kuiper Belt by High-Precision Photometric Stellar Occultations: First Results", AJ, 132, 819).

The MEGA survey

The Microlensing Exploration of the Galaxy and Andromeda (MEGA) survey uses several instruments and telescopes, among them, the Wide Field Camera on the INT, to detect microlensing towards the nearby Andromeda galaxy, M 31, in order to establish whether massive compact objects are a significant contribution to the total mass budget of the dark halo of M 31. The MEGA observations with the INT spanned four observing runs in the first three seasons. The data were acquired jointly with the POINT-AGAPE collaboration although the data reduction and analysis were performed independently. Using a fully automated search algorithm, astronomers identified 14 candidate microlensing events. The results from the survey are compared with theoretical predictions for the number and distribution of events. For most models, the observed event rate is consistent with the rate predicted for self-lensing - a MACHO halo fraction of 30% or higher can be ruled at the 95% confidence level. The event distribution does show a large near-far asymmetry, hinting at a halo contribution to the microlensing signal. Two candidate events are located at particularly large projected radii on the far side of the disk. These events are difficult to explain by self-lensing and only somewhat easier to explain by MACHO lensing. A possibility is that one of these is due to a lens in a giant stellar stream. (J. T. A. de Jong et al., 2004, "First microlensing candidates from the MEGA survey of M 31", A&A, 417, 461; J. T. A. de Jong et al., 2006, "MACHOs in M 31? Absence of evidence but not evidence of absence", A&A, 446, 855).

The Angstrom Project Alert System

The Angstrom Project is undertaking an optical survey of stellar microlensing events across the bulge region of the Andromeda galaxy (M 31), using a distributed network of

2-m class telescopes, among them, the INT and the Wide Field Camera. The Angstrom Project Alert System (APAS) was developed to identify candidate microlensing and transient events in real time, using data from robotic telescopes. This is the first time that real-time microlensing discovery has been attempted outside of the Milky Way and its satellite galaxies. The APAS is designed to enable follow-up studies of M31 microlensing systems, including

searches for gas giant planets in M31, and other transient events. In addition to the new observing data, the APAS uses archive data from the POINT-AGAPE dark matter microlensing survey of M31 (M. J. Darnley et al., 2007, "The Angstrom Project Alert System: Real-Time Detection of Extragalactic Microlensing", ApJ, 661, L45).

Chapter 2

OPERATION, MAINTENANCE AND DEVELOPMENTS

TELESCOPE OPERATION

During the two-year period 2006/07 covered by this report, the ING telescopes again performed very well, with downtime figures due to technical problems averaging only 2.2% and 2.9%, on the William Herschel Telescope (WHT) and the Isaac Newton Telescope (INT), respectively. These figures are well below the target value of a maximum of 5 percent technical downtime. Observing time lost due to poor weather over the same period averaged 19.8%.

The technical downtime figures must be seen in the light of significant cost savings and reduction of personnel that have taken place over the past few years. Moreover, both the WHT and the INT are now in their third decade of operation, but remain operationally very reliable and effective thanks to our programme of planned maintenance, combined with initiatives to continuously seek modernisation of systems in order to improve longevity, maintainability, and increase of scientific return.

Telescope maintenance covers a wide range of activities, but one particularly important event has been the aluminising of the WHT primary mirror, bringing the mirror back to a near-pristine state. In between aluminising runs the mirrors are regularly inspected and cleaned using CO₂ snow and in this way the efficiency of the largest optical component is kept at the highest levels.

Day-to-day telescope operations support is carried out by a dedicated Operations Team, taking responsibility for upkeep of the telescopes and associated infrastructure. Efforts for day-time and night-time support activities concentrate on the WHT where many observing teams visit every year. On this telescope five common-user instruments are supported, one of which is the complex adaptive-optics suite. Also, several visiting instruments were supported at the WHT during the reporting period. The INT, in contrast, operates in a much simpler fashion and has only two facility instruments. On this telescope in 2006 the Intermediate Dispersion Spectrograph was refurbished and put back in operation in response to popular demand from the user community. The 1-m Jacobus Kapteyn Telescope no longer hosts science observations, but is now regularly

being used for measuring the atmospheric turbulence profile above the observatory by the IAC. At night, a telescope operator is always present at the WHT to assist the scientists in taking the observations. ING's team of astronomers acts as the primary contact for visiting scientists and also provides introduction and training at the telescope. They also assist visitors in taking the observations and in carrying out observations in service for the community. Astronomy support on the INT is now competently taken care of by students.

Apart from common-user instruments, various visitor instruments were used, including two new instruments (see the section on Instrumentation). The visiting instruments were: INTEGRAL, the integral-field fibre bundle feeding the WYFFOS spectrograph, led by the IAC; PLANETPOL, the very high accuracy polarimeter led by the University of Hertfordshire; PN.S, which is a slitless spectrograph for detection of planetary nebulae led by the University of Groningen; SAURON, the large field integral-field spectrograph led by the University of Leiden; and ULTRACAM, the high-speed triple-band imager led by the University of Sheffield. The two new visiting instruments, both led by the IAC and described on more detail below are GHaFaS, a Fabry-Perot imager, and FASTCAM, which is a dedicated very high speed optical imager for high spatial resolution observations ('lucky imaging'). Besides these visiting instruments, experimental activities also continued to exploit the telescope. A team from the Universities of Arcetri and Durham continued testing novel co-phasing techniques on a segmented mirror, using a pyramidal wavefront sensor, potentially an important technology for future Extremely Large Telescopes.

Most of the observing nights at the telescopes are used in classical visitor mode where the scientific team is present to carry out the observations. But in April of 2007 the WHT was used for several nights in queue-scheduled observing mode where observations are dynamically scheduled and executed by observatory personnel. For the observatory this was a novelty, with an intensive period of planning and observing. The outcome of the strongly oversubscribed period was highly successful with a nearly 100% success rate on the top tier set of proposals. Based on this success

and on what was learned, it is anticipated that further blocks of queue-scheduled observing time will be planned.

2006/07 was marked by further developments of the Adaptive Optics (AO) instrumentation suite, in particular the commissioning of the GLAS Rayleigh laser guide star beacon. The advent of the laser guide star system is expected to greatly enhance the scientific potential of adaptive optics. This development ties in well with the intention to extend queue-observing at the WHT, in order to exploit the good seeing required for AO observations.

ING continued its active participation in the OPTICON programme funded by the European Union to share access to telescopes across Europe. This initiative has as its primary aim opening national observing facilities to scientists from other nations who do not have access by right. Over the 5 year period of this programme on the WHT, 29 nights have been funded under this scheme, while the INT participates with 38 nights. Although only a small fraction of the total observing time, it does represent a significant resource and has inspired cross-border collaborations, and, more importantly, may lead to pan-European collaboration and coordination of these research infrastructures.

In 2007 the WHT celebrated its 20th operational anniversary, and later that year the 1,000,000th CCD science exposure was obtained. During these two

decades, the WHT has contributed data to some 1500 science papers published in refereed journals, and to many important discoveries.

In view of the above historical note, it is worth recalling that the presence of the Isaac Newton Group of Telescopes at the Spanish Observatorio de Roque de los Muchachos (ORM) is secured under international agreements. These agreements will be up for renewal in 2012 after having been in force for over 30 years.

INSTRUMENTATION

The GLAS Rayleigh laser beacon for Adaptive Optics

The year 2007 was marked by the completion and commissioning of the GLAS Rayleigh laser guide star project as part of the Adaptive Optics system at the 4.2-m William Herschel Telescope. Adaptive Optics techniques allow ground-based observers to obtain spatial resolutions a tenth of an arcsecond, by correcting the image blurring introduced by the Earth's atmosphere. The common-user AO system, NAOMI, located on one of the Nasmyth platforms, is performing well. The resulting image sharpness delivered by AO not only carries the advantage of distinguishing finer structure and avoiding source confusion in dense fields, but also allows observations to reach significantly fainter objects, as the sky background reduces with the square of the angular resolution. A main

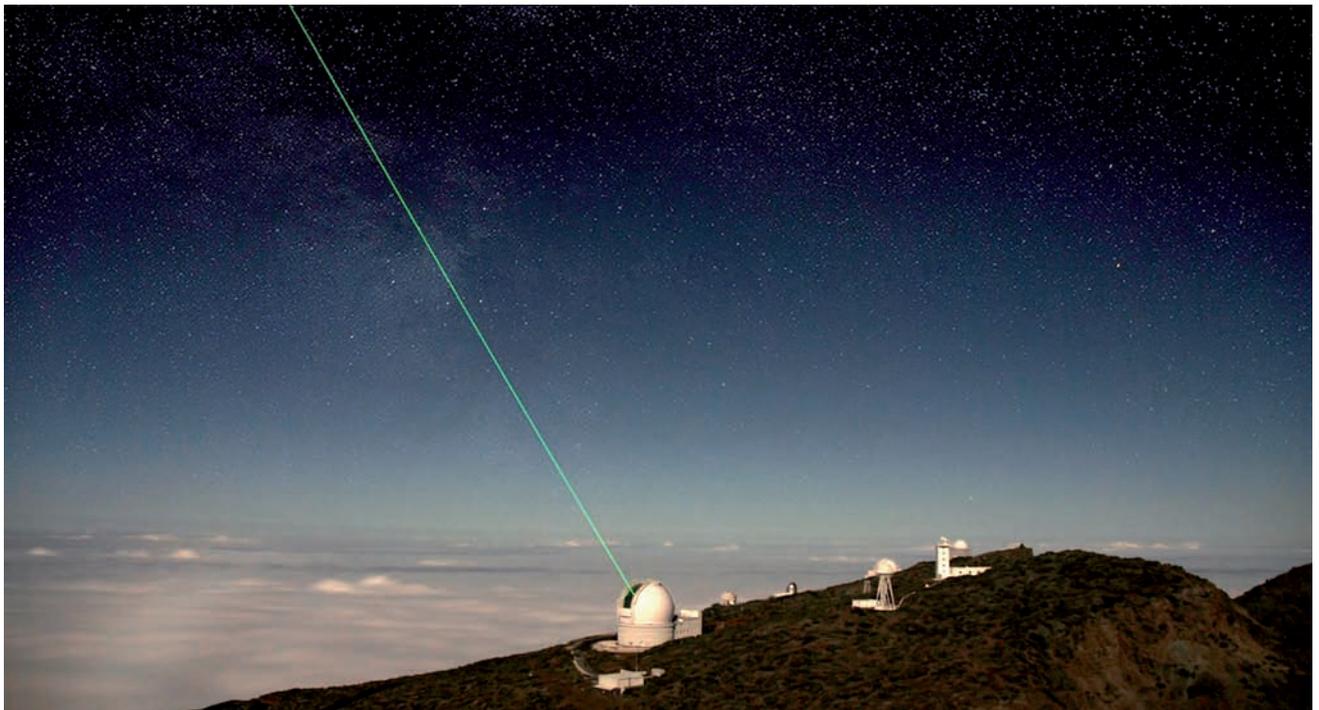


Figure 40. The GLAS laser beam emerging from the WHT.

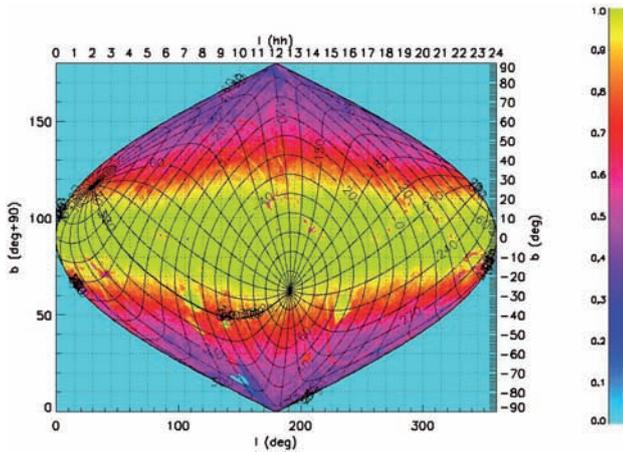


Figure 41. Sky coverage predictions based on achieving an $R=17$ limit for the tip-tilt natural guide star and a 2 arcmin patrol field. (courtesy Remko Stuik, Leiden).

practical limitation for classical AO is the need for bright guide stars to measure the wavefront distortions. By using an artificial laser guide star, this limitation is largely avoided, allowing objects almost anywhere on the sky to be studied with AO. In particular, it opens up the possibility of observing faint and extended sources, and will enable observations of large samples, unbiased by the fortuitous presence of nearby bright stars. With a laser guide star facility, a 4-m class telescope situated on a good observing site like La Palma is highly competitive.

The GLAS Rayleigh laser system is designed to work in conjunction with existing AO equipment and ancillary instrumentation and infrastructure at the WHT. A 25W pulsed laser is projected to 15 km altitude from a launch telescope mounted behind the secondary mirror. The Rayleigh back-scattered light is detected by a dedicated wavefront sensor system to measure the wavefront shape from the laser guide star, and provide corrections to the deformable mirror of the AO system. A Pockels cell range-gate system that is synchronised with the laser pulses selects the height and duration of the laser return signal from the atmosphere.

The key reason for building the GLAS laser system is to improve sky coverage for AO observations. Although the laser will guarantee the presence of a bright point source for high-order wavefront sensing, correcting the low-order tip-tilt mode still relies on the presence of a natural guide star. This then poses a limitation on sky coverage. Predicted sky coverage for GLAS is shown in the diagram below and indicates a dramatic improvement over natural guide star adaptive optics.

Example results from the 2007 commissioning are shown below and indicate a promising future for science exploitation.

ACAM: A New Wide-Field Cassegrain Imager and low-resolution spectrograph for the WHT

ING has long wanted to improve the imaging capability at the Cassegrain focus of the WHT. Having a readily available imager at that focus carries with it important advantages for scientific exploitation, for reasons of flexibility of scheduling and fast response. The existing Auxiliary port camera fulfils this role to some extent but is limited in its field of view and its use of filters. ING is therefore designing a wider field imager, ACAM (Auxiliary-port CAMera), to replace the existing AUX port imager. ACAM was proposed and plans for its construction were

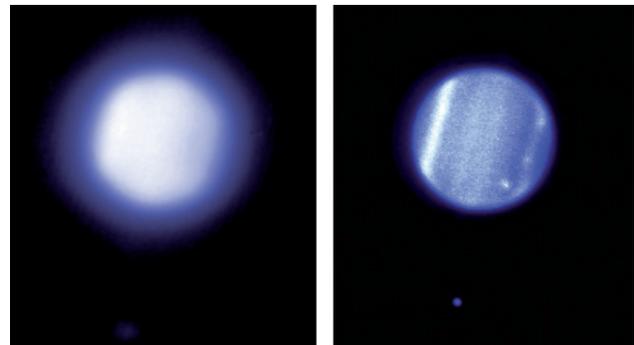


Figure 42. H-band images of Uranus with GLAS and adaptive optics correction off (left) and on (right). The faint object at the bottom is the moon Miranda.

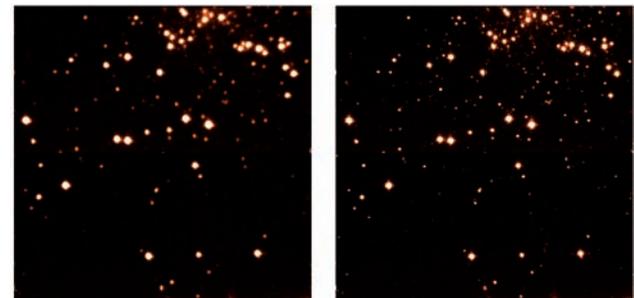


Figure 43. Uncorrected and laser-corrected images (left and right, respectively) of a region in the globular cluster M15. The increased sharpness and brightness of the stars in the right hand image demonstrate the clear enhancement in image quality.

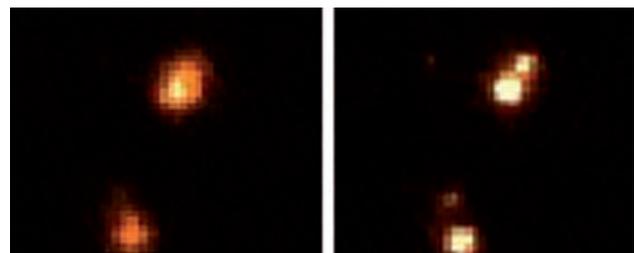


Figure 44. A zoom into one small section reveals how what appears to be two stars in the uncorrected image are actually four stars.

developed during the period covered by this report. In summary, it will offer high-throughput imaging over an 8 arcmin field of view, and low-resolution spectroscopy on axis. The gain in area is illustrated below.

The factor 20 increase in imaging area, and the added functionality (narrow-band filters, high-throughput spectroscopy) will make it possible to carry out science programmes which have not previously been possible with the WHT. Examples of science programmes which will benefit from ACAM include supernova and gamma-ray burst fast response imaging and spectroscopy, exoplanet transit photometry and spectroscopy, and narrow-band emission-line imaging of low-redshift galaxies (using e.g. ING's collection of TAURUS filters). The synergy with the ISIS spectrograph and the LIRIS near-IR spectrograph and

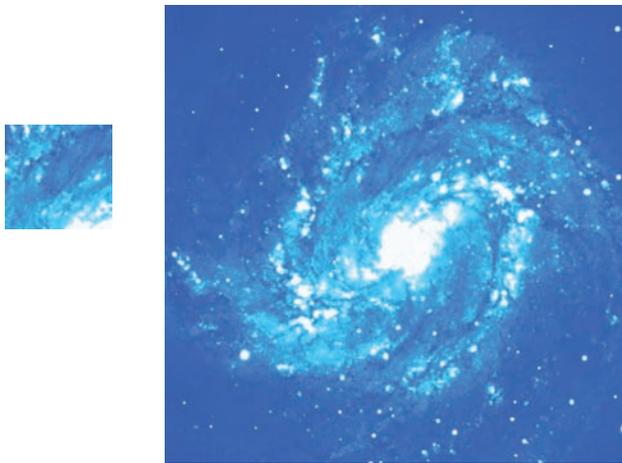


Figure 45. M81, as it would be imaged by cameras with fields 1.8 and 8 arcmin across (representing aux-port and ACAM).

imager is particularly powerful, as switching between these instruments will be quick and easy.

The challenge of the optical design was to deliver good image quality across the whole field of view, and at all optical wavelengths, without compromising the throughput. The final 7-lens design was agreed in late 2007, and most of the manufacturing took place in 2008. The detector will be a 2kx4k CCD with peak QE~0.9 and very low fringing. Commissioning is expected mid-2009.

The WHT as planet hunter: the HARPS-NEF instrument

In 2006 an important activity was initiated that may well define a significant part of the scientific future of the WHT. In that year, work began on planning the construction of a high-resolution extremely stable spectrograph by the Center for Astrophysics in Cambridge and the Geneva Observatory. The intention was expressed to place and exploit this instrument at the WHT.

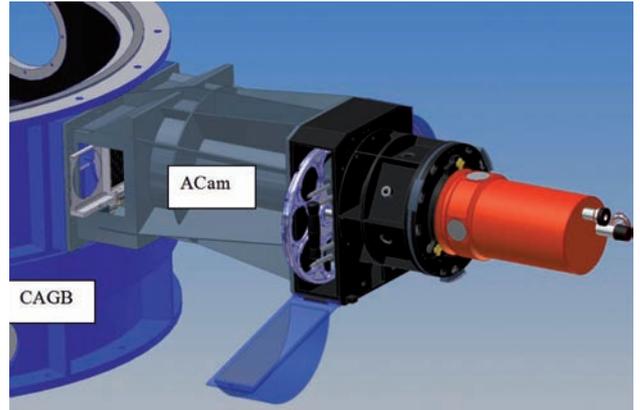


Figure 46. ACAM instrument design model shown mounted in the Cassegrain A&G box.

The HARPS-NEF instrument is a close twin of the HARPS instrument on the ESO-3.6m telescope. It is a high-resolution echelle spectrograph, where great care has been taken to achieve remarkable wavelength stability. This allows radial velocity measurements better than 1 meter per second, which is required in the search for extra-solar planets that approach the mass of the Earth. The development is intimately linked to the NASA Kepler mission, which will provide exoplanet candidates from transit light curves over a large field in the Cygnus / Lyra region. HARPS-NEF is expected to provide important follow-up spectroscopy for this.

Instrument enhancements

ING also continuously searches for ways to improve existing instrumentation. A few examples are given here.

On the ISIS spectrograph a 1k x 1k pixel Low-Light-Level CCD (L3CCD or EMCCD) was developed and commissioned as a new detector option. The detector, QUCAM, achieves close to zero read noise through electron multiplication. Furthermore, as a frame-transfer detector it is fast and can expose several times per second, with very little dead time, and is thus ideal for photon-limited observations of time-variable spectral features.

The LIRIS near-IR spectrograph optics were enhanced with high-resolution J and K-band grisms providing spectral resolutions of over 3000. A matched H-band high-resolution grism will be acquired and installed at a later date. This work was funded and executed by the LIRIS team from the IAC, where the instrument was built.

After a few years of inactivity, the INT's Intermediate Dispersion Spectrograph, IDS, was brought into service again in a response to a strong expression of interest from the community. The instrument was cleaned, and all



Figure 47. Two general-purpose L3CCD heads, with at the right the operational 1k x 1k pixel QUCAM CCD.

mechanisms checked and brought back to life. The main improvement was replacement of the obsolete Westinghouse acquisition camera with a WHT-style CCD head. Astronomical characterisation was carried out and showed throughput to be at least as good as in the past. The IDS is now in very good shape, and following rearrangement of the control computers the system can be conveniently operated by a single observer. Since its re-introduction the instrument has been in heavy demand.

Visiting instruments

Apart from the development of new and existing common-user instruments, the WHT again saw much activity with visiting instruments, including two new ones.

First light of the Galaxy H-alpha Fabry-Perot System, GHaFaS, took place in 2007 at the Nasmyth focus of the WHT. GHaFaS is a new generation Fabry-Perot interferometer, whose chief and powerful advantage over traditional systems of this kind is the high sensitivity photon counting detector. This instrument is built by a team from the Université de Montréal, with partners at the Observatoire de Marseille and the Instituto de Astrofísica de Canarias.

At the heart of instrument is the detector, based on a micro-channel plate which gives a huge electron gain once the incoming photon has been detected at a photoelectric input surface. The system has very fast readout, no readout noise, and is especially advantageous for extended objects of moderate to low surface brightness.

GHaFaS produces high-resolution line profile maps over its full 4 x 4 arcminutes field of view. Observations of nearby and distant galaxies, interacting galaxy pairs, and a planetary nebulae were obtained with great success in order to put the instrument through its paces.

A second visiting instrument to the WHT Nasmyth focus was FASTCAM, developed and built by the Instituto de Astrofísica de Canarias (IAC) and the Universidad Politécnica de Cartagena (UPCT). FASTCAM is an imaging camera that takes very short exposures in the optical wavelength range. By selecting the data least affected by the atmospheric turbulence, FASTCAM can produce very high-resolution images. The instrument had been tested previously on other telescopes, and was then deployed at the William Herschel Telescope.

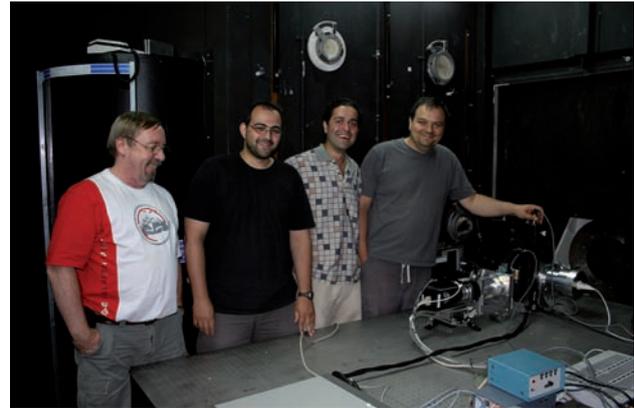


Figure 48. Some members of the GHaFaS first-light team. From left to right: C. Carignan, O. Hernández, K. Fathi, and J-L. Gach at the Nasmyth focus of the WHT.

FASTCAM consists of an EMCCD detector with optics designed to provide a pixel scale of 0.019 arcsec, an atmospheric dispersion corrector, and a filter wheel with narrow and broad band filters. Fast recording and on-line image analysis allows selection and combining of thousands of short exposures without interruption, with negligible overhead. Specially designed software allows direct inspection of the resulting images in real time. Close binaries with separations as small as 0.067 arcseconds in the R band have been resolved.

INFRASTRUCTURE

To complement ING's AO laser beacon development, a stand-alone instrument was brought into operation in 2007 to provide information on turbulence in the atmosphere as a function of height. Thanks to a collaboration with Cerro Tololo Inter-American Observatory, a Multiple Aperture Scintillation Sensor, MASS, was acquired. This instrument, attached to a small commercial telescope, provides on-line measurement of the atmospheric turbulence profile above the observatory. It is located on a small tower just outside the WHT, together with the seeing monitor. This tool is very useful for AO observations as it allows the observer to decide whether or not turbulence in the atmosphere will



Figure 49. Part of the commissioning team at the WHT, and FASTCAM set up at the Nasmyth focus on the WHT.

allow efficient Adaptive Optics observations. In particular when using the GLAS laser beacon the height of predominant atmospheric turbulence is very important.

Internet network connection at the observatory was greatly enhanced at the end of 2007. Through an investment by the IAC a Gigabit connection network was realised between the observatories at La Palma and also at Teide observatory on Tenerife. The onward connection to mainland Spain was also enhanced through improved bandwidth delivered by the RedIRIS academic network.

For the long-term maintainability of instruments, obsolete technology sometimes must be replaced and modernised. In this respect, a phased replacement of some older control systems was initiated. The prime-focus platform controls were upgraded with programmable logic controllers, providing better reliability and maintainability. Such changes sometimes also provide also operational advantages, for example through much improved response times from the filter wheel in the prime-focus imaging unit. In a similar vein, the WYFFOS spectrograph and the INTEGRAL fibre feed control software were migrated to a Unix platform. Another important and long-running task has been the upgrade of all science CCD systems to generation 3 SDSU controllers. This task was completed in 2007.

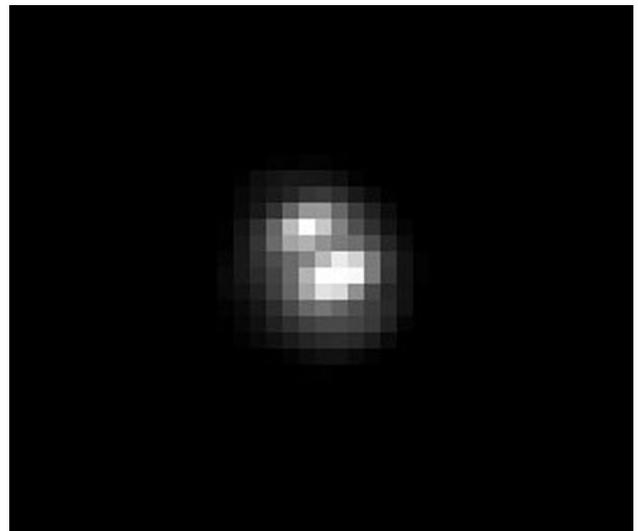


Figure 50. This R-band image shows the result of combining the best 5% of a series of 8000 images obtained for the binary star COU 292 ($V=8.4$ and 8.7 magnitudes respectively). Based on available orbital information an angular separation of 0.07 arcsec was expected. The binary was resolved and an angular separation of 0.067 ± 0.007 arcsec could be measured. Credit: FastCam commissioning team.

Attention has been paid to the work environment for observers at night. The INT control room was made a more comfortable place to work for visiting astronomers, and measures were taken to reduce noise in the WHT control room. Furthermore, reorganisation of the ING web site was begun to provide a uniform design and layout and improve readability.

Chapter 3

USE OF OBSERVING TIME AND SCIENTIFIC PRODUCTIVITY

USE OF TELESCOPE TIME

The available observing time on the ING telescopes is divided between British, Dutch and Spanish time allocation committees, the CCI International Time Programmes (ITP), service and discretionary nights, and scheduled stand-down and commissioning time.

The ING Board has delegated the task of time allocation for British astronomers to the PPARC Panel for the Allocation of Telescope Time (PATT), and for Dutch astronomers to the NFRA Programme Committee (PC). It is the responsibility of the Instituto de Astrofísica de Canarias (IAC) to allocate the Spanish time via the Comité para la Asignación de Tiempos (CAT). For committee membership see Appendix I.

The aim of the ING service observing programme is to provide astronomers with a rapid and flexible tool for obtaining small sets of observations, which would not justify a full observing run. On the WHT several nights per semester are set-aside for this purpose. During these nights, ING support astronomers perform observations for service requests. During semester 2006A to semester

2007B, including a special call for adaptive-optics proposals in semester 2007A, 123 service proposals (total time 445 hours) were received, and 73 of those service proposals (total time used 257 hours) were completed.

Stand-down and discretionary nights are used mainly for major maintenance activities, commissioning of new instruments, enhancements, calibration and quality control tests, etc., and occasionally for observing science targets, for example, as compensation for time lost to technical problems or for observations of targets of opportunity.

The way the available observing time on the ING telescopes has been shared in 2006 and 2007 is summarised in the table below.

USE OF INSTRUMENTATION

The figure on the next page shows the allocation of nights per instrument on the WHT in 2006 and 2007. As in previous years, the ISIS spectrograph was the most popular instrument, taking up some 35% of the scheduled observing time. Visiting instruments on the WHT during this period include the SAURON integral field spectrograph, the planetary nebula spectrograph, PN.S,

Time allocation	WHT		INT	
	2006	2007	2006	2007
UK PATT	135	129	158	164
NL PC	49	53	67	63
SP CAT	80	82	100	100
ITP	14	14	17	18
TNG time share	11	8	—	—
Service	13	27	—	—
Instrument builder's guaranteed time	1	—	—	—
Stand-down and discretionary time (including commissioning)	62	52	23	20
Total	366	365	366	365

Table 1. Number of nights allocated from semester 2006A to 2007B. Service include UK, NL and SP service time, and SP CAT includes Spanish service time on the INT.

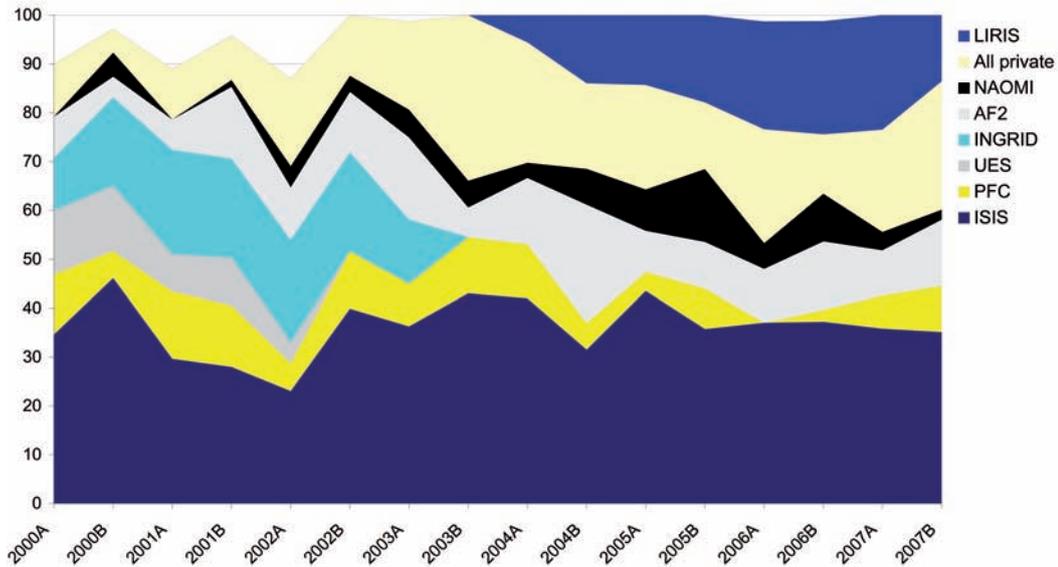


Figure 51. Percentage of use of WHT's instrumentation by semester. LDSS and TAURUS were decommissioned around 2000. NAOMI was first offered in semester 2000B and it is used in combination with INGRID, OASIS or OSCA. INGRID was not offered at the Cassegrain focus from semester 2003B. UES was decommissioned in semester 2002B. INTEGRAL was not offered during semester 2002B and is a visiting instrument from 2003A. LIRIS was first offered in 2004A.

the high-speed multi-CCD camera ULTRACAM, the PLANETPOL photo-polarimeter, the INTEGRAL coherent fibre feed to the WYFFOS spectrograph, and most recently, the GHaFaS Fabry-Perot imager. In particular there was much interest in ULTRACAM.

On the INT, the Wide Field Camera was used 73% of the time, while the Intermediate Dispersion Spectrograph, which came back into operation in August 2006, was used 27% of the available time.

TELESCOPE RELIABILITY

During 2006/07 the ING telescopes again performed very well, with downtime figures due to technical problems averaging at 1.5% and 2.3% in 2006A and B, and 2.8% and 3.5% in 2007A and B for the WHT and the INT respectively. These figures are well below the target value of a maximum of 5% technical downtime. Downtime due to poor weather averaged 20.5% and 25.9% in 2006 and 20.2% and 20.1% in 2007 for the WHT and the INT respectively. The historical trends of technical down time per semester and weather down time per year and month are plotted in the accompanying figures.

SCIENTIFIC PRODUCTIVITY

An important measure of the success of the ING telescopes is the number of publications published in refereed journals and for this reason the ING Bibliography (see Appendix I) is

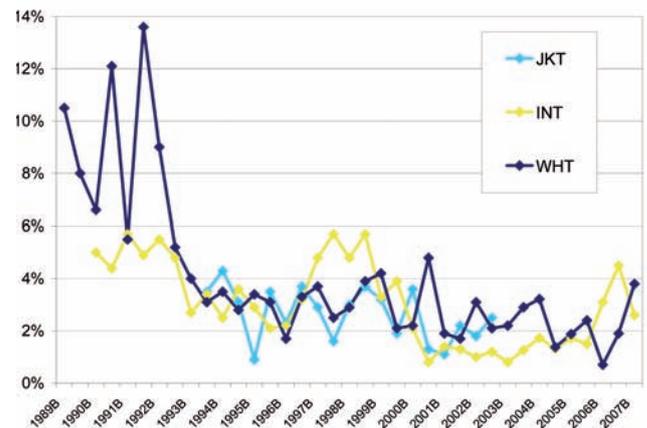


Figure 52. Technical downtime per semester.

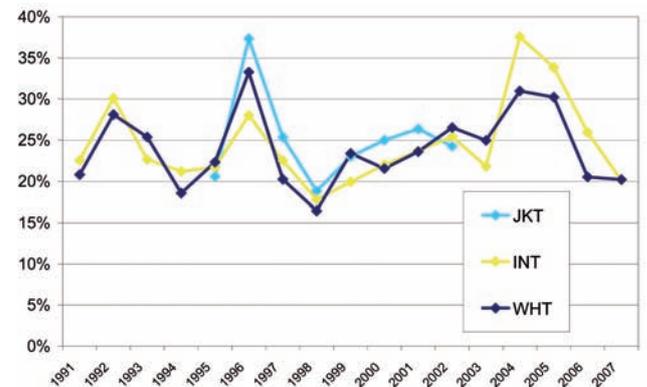


Figure 53. Weather downtime per year.

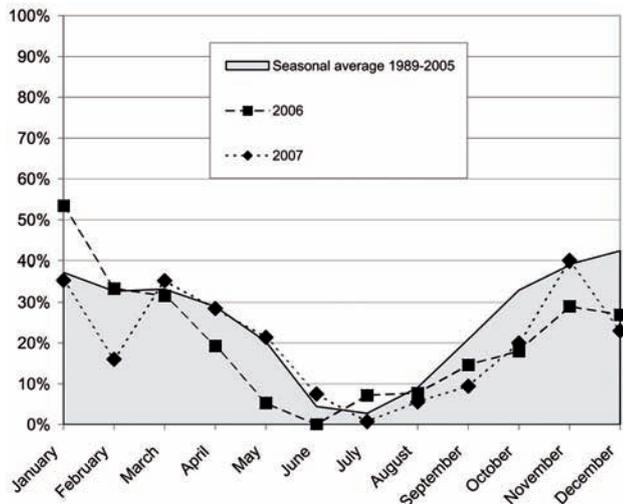


Figure 54. WHT's monthly weather downtime.

updated annually. Traditionally, this bibliography has been compiled by visually scanning all articles in many journals and identifying those which make use of data from our telescopes. However electronic publishing and sophisticated search engines make this task easier. Our selection process identifies papers that make direct use of observations obtained with the ING telescopes, in order to qualify for our publication list. Papers that refer to data presented in earlier papers (derivative papers) are not counted.

More than 95% of ING publications for the five years between 1995 and 1999 inclusive were published in a small number of core journals: the British MNRAS, the American ApJ, ApJL, ApJS, AJ and PASP, the European A&A, and Nature and Science. The remaining publications are dispersed among many other journals, e.g. Icarus and the Irish Astronomical Journal. The bibliography from 2002 onwards was compiled from only the core journals listed above, for reasons of efficiency. Search engines were used to select papers and the papers in the resulting list were checked to ensure that they satisfied the selection criteria described above.

An analysis of these numbers for 2006/07 follows. Note that if a paper makes use of more than one telescope we count that paper for each telescope. The nationality is taken to be that of the first author's institution, although in a few cases two or more institutions are credited. Similarly, if a paper makes use of more than one instrument, that paper is counted against each instrument.

Of all the available instruments on the WHT, the ISIS spectrograph remains the most productive, contributing to 40% of all publications during the reporting period. The

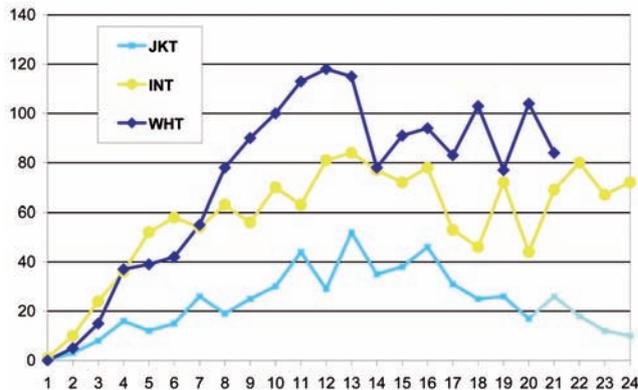


Figure 55. Number of refereed papers per telescope from first light year.

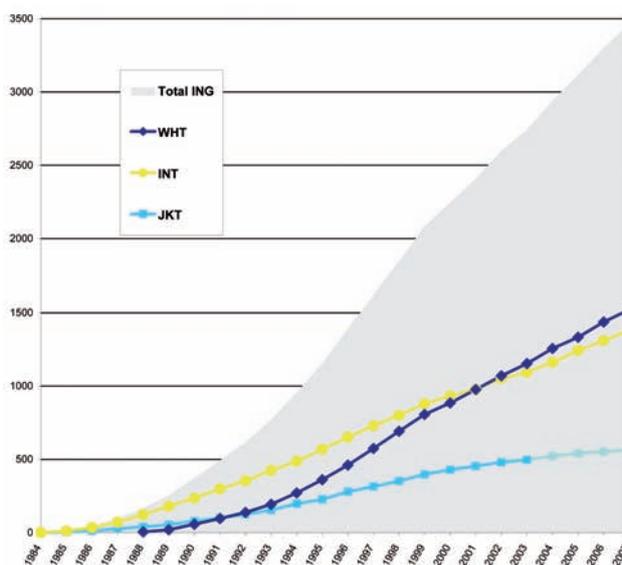


Figure 56. Cumulative number of refereed papers per year.

Year	WHT	INT	JKT	Total
1984	—	1	—	1
1985	—	10	3	13
1986	—	24	8	32
1987	—	36	16	52
1988	5	52	12	69
1989	15	58	15	88
1990	37	54	26	117
1991	39	63	19	121
1992	42	56	25	123
1993	55	70	30	155
1994	78	63	44	185
1995	90	81	29	200
1996	100	84	52	236
1997	113	77	35	225
1998	118	72	38	228
1999	115	78	46	239
2000	78	53	31	162
2001	91	46	25	162
2002	93	72	26	191
2003	82	44	17	143
2004	103	69	26	198
2005	77	80	18	175
2006	104	67	12	183
2007	84	72	10	166
Total	1521	1382	563	3466

Table 2. Number of refereed papers per year and telescope.

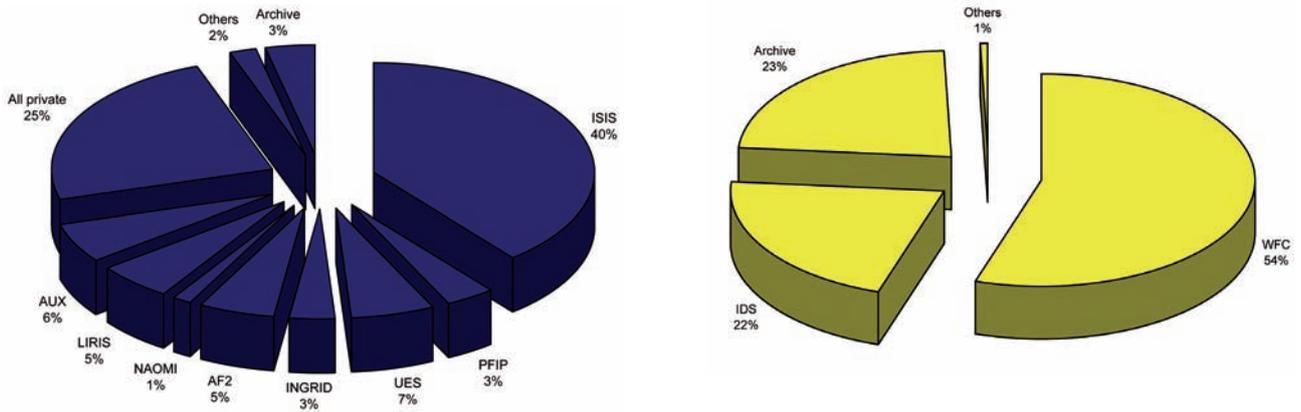


Figure 57. Left: Use of instrument data in WHT refereed papers in 2006 and 2007. Archival papers made use of data from the ING archive. Right: Use of instrument data in INT refereed papers in 2006 and 2007. Archival papers include data from the ING, INT WFS or IPHAS

number of papers from visitor instruments on the WHT also remained significant, with 24% of the papers.

On the INT the papers are split between the WFC and the IDS spectrograph, in roughly the same ratio as the split in observing time between these instruments. Data from the ING archive, particularly from the WFS and IPHAS archives, have contributed significantly to the scientific productivity of the INT.

The distribution of the nationalities of the first author's institution changes little from year to year. The UK share is steady at around 40%, and the Spanish share about 20%. The NL share also showed little systematic change. Interestingly, about one third of the papers have a first author from other countries, emphasising the international character of the observatory and the high level of international collaboration between research groups.

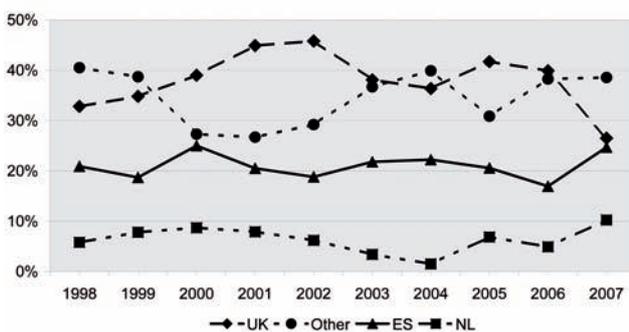


Figure 58. Evolution of the nationality of first author's main institution in refereed papers that used data from the ING telescopes.

THE ING ARCHIVE

All data taken with the ING telescopes are archived in the UK, at the Institute of Astronomy, Cambridge. The data archive is managed by the Cambridge Astronomy Survey Unit. The total amount of (compressed) data stored has passed the 26 Tb mark.

Archival data from the ING telescopes are made available to anyone upon request, after a one-year proprietary period. The number of archive retrieval requests increased significantly in 2006 and 2007, with over 700 requests for retrieval of more than 40000 data sets. The historic trend of the archive requests can be seen in the accompanying figure. This level of archive use underlines the importance of the ING archive as a general tool for astronomy research.

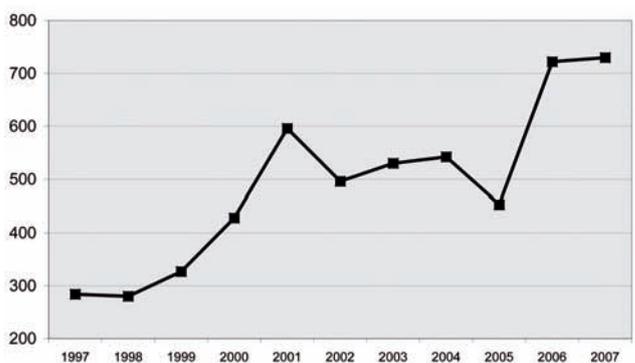


Figure 59. Number of ING archive requests per year.

Chapter 4

IN-HOUSE RESEARCH

During 2006 and 2007, the research productivity of the ING Astronomy Group, as measured by publication rate, was maintained at its previous high level, was approximately 100 papers in refereed journals. A complete list of these papers is included in Appendix F. Appendix G shows the research seminars given at ING by visiting astronomers or staff members.

As in previous years, an important aspect of the research effort is that ING staff continue to be closely involved with on-going research programs which rely on observations carried out on our telescopes. One example is the ING's very active role in the INT/WFC H alpha survey of the north Galactic plane (the IPHAS survey), which involves five ING staff astronomers (Corradi, Greimel, Lennon, Leisy and Skillen) and several ING students.

An outstanding example of the synergy of telescopes of the Observatorio del Roque de los Muchachos is the search for extrasolar planets driven by the SuperWASP facility, in which Skillen is deeply involved. This project started in 2004 and it is discovering a number of new extrasolar planets, many of which have been confirmed by follow-up imaging and spectroscopy with the ING telescopes.

Moreover, Benn is P.I. of the project "The nature of quasar outflows" which was awarded the International Time Programme for 2007.

Further enhancement of the international visibility of the ING was provided by two major international conferences organised in 2006 and 2007.

More of these and other activities are described below.

INDIVIDUAL RESEARCH ACTIVITIES

In a search for rare white dwarf populations using SDSS Stripe 82 repeat imaging, Bramich and collaborators have discovered 8 new candidate ultracool white dwarfs, which probe the earliest star formation in the Galactic disk. From the same data, they have also discovered 10 new candidate halo white dwarfs, useful as probes of the

earliest star formation in the proto-Galaxy and for testing of the age of the oldest stars. Bramich's interest in extra-solar planet research has led to the discovery of a pre-main sequence eclipsing binary in the Orion nebula cluster with two sub-solar-mass components. These are rare systems that can be used to help constrain theories of star formation and stellar evolution. Bramich is currently developing a new method for difference image analysis, which promises to be more powerful and robust than the standard method, and with many fewer input parameters.

Benn used WHT/ISIS to investigate the physics of the absorbers in broad-absorption-line (BAL) quasars. By deriving true column densities (eliminating the effect of covering factor) for different ions, it was possible to estimate the ionisation parameter at different absorbers. This constrains the distance of the absorbers from the nucleus, which is currently uncertain by several orders of magnitude, limiting our understanding of the impact of the outflow on the quasar and its environment.

Benn was awarded most of the La Palma international time (2007-8) on the WHT, TNG, INT, NOT and Mercator telescopes, to carry out a more ambitious campaign aimed at understanding the physics of BAL quasars. This work is in collaboration with Arav (Virginia), Barker (Sheffield), Carballo, González and Jiménez (Santander), Ellison (Victoria, Canada), Holt (Leiden), Mack and Montenegro (Bologna) and others. The team has also obtained Keck and VLT time for this project.

Corradi studied several aspects of Galactic and extragalactic planetary nebulae (PNe). In the Galaxy, significant progress has been achieved in the search for new PNe in the Galactic Plane. Preliminary results in the area from 18 to 20 hours in right ascension show that the IPHAS survey will likely triple the number of known PNe. This will allow us to build a magnitude-limited sample of objects, and to discuss fundamental properties such as the stellar death rate in the Galaxy. In addition, the increased sample will allow us to study in more detail, critical phases such as the fast transition between red giants and PNe, which is short and therefore quite rarely observed. Together with his former PhD student Santander, now a

support astronomer at the ING, the role of binary interactions in the late stages of stellar evolution has been investigated by means of high quality (e.g. HST and VLT) observations of nebulae around symbiotic Miras. They illustrate the complex mass loss history and physics from these stars. Outside the Galaxy, PNe are nowadays used as reliable tracers of the luminosity, dynamics, and distances of any stellar system. Corradi contributed to the calibration of the use of PNe as luminosity indicators in all type of galaxies, through a comprehensive study of PNe in the Local Group, and a thorough comparison with population synthesis models.

An ING visiting scientist, Klaus Fuhrmann, continued spectroscopic analyses of all stars within 25 pc, north of the declination -15 deg, and down to absolute visual magnitude $M_V=6.0$, which corresponds to approximate spectral type K2 V. Since the defined sample of $N\sim 350$ stars is volume complete, it allows for an unbiased investigation of the local stellar populations, the extremely old ($\tau > 12$ Gyr) thick disc and the much younger thin disc ($\tau < 8$ Gyr). The local normalisation of the former population turns out to be 20%, which, along with its considerable chemical enrichment level, implies that the thick disc must be a massive component of the Milky Way Galaxy, a major source of baryonic dark matter. Its star-burst like formation history particularly challenges the hierarchical cold-dark-matter-dominated formation picture for spiral galaxies. Another focus of Fuhrmann's research is on model atmosphere analyses of exoplanet host stars. Comparison with the above volume-complete nearby star sample suggests that the usual claim that exoplanet host stars are metal-rich, is only a weak effect, if any, restricted to the 0.1 dex level.

Leisy participated in the IPHAS survey group, searching and studying ionised nebulae in the Galactic disc. In addition, together with Corradi he has been studying the physics and chemistry of extragalactic planetary nebulae. Most of them were discovered through an INT narrow-band survey of the Local Group. Follow up spectroscopy at several 8m telescopes allowed to accurate determination of their chemical abundances. These are used both for studying stellar evolution and chemical yields in stellar populations with metallicity different from the Galaxy, and for determining the chemical history of the parent stellar populations.

As a member of the Supernova Cosmology Project and The Physics of Type Ia Supernova Explosions (RTN) collaboration, Méndez participated in observations for both projects on the telescopes at the Observatorio del Roque

de los Muchachos Observatory, and also collaborated with the SDSSII Supernova Survey. Méndez became a member of the teaching panel of a master degree on science journalism and science, technology and environmental communication organised by University Carlos III, Madrid, and started a research network on science communication called "Red Elipsis".

Skillen, in collaboration with Pollacco (QUB), commissioned a major upgrade to the SuperWASP computing infrastructure. A sophisticated weather station and environment monitoring system allows the facility to now operate robotically under computer control. The inaugural season of SuperWASP observing yielded light-curves for some 6.7 million stars with V magnitudes in the range $\sim 8-15$, comprising ~ 1.3 billion photometric data points in total. Although these light-curves encompass a wide range of interesting variable star phenomena, the main focus of SuperWASP is to uncover the small, $\sim 1\%$ periodic dips typical of 'hot Jupiter' exoplanets as they transit the discs of their host stars.

Computer analysis by the WASP Consortium of the well-sampled light curves of roughly one million of these stars brighter than 13th magnitude identified some 100 high-priority candidates. In an increasingly productive collaboration of the WASP Consortium with teams from Geneva, Marseille and Paris, the discovery of three exoplanets, WASP-1b, 2b (see accompanying figure) and 3b was subsequently confirmed in follow-up spectroscopy

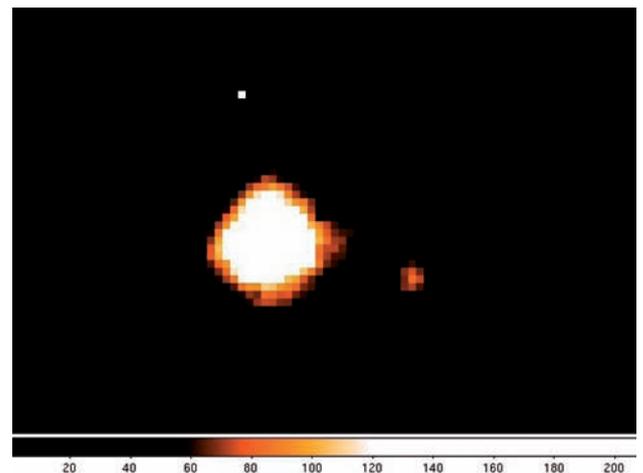


Figure 60. The host star of WASP-2b has a stellar companion 2.7 magnitudes fainter at H, located 0.7 arcsecs away. A deep eclipse of a faint companion could mimic an exoplanet transit in photometry, in which the two are not spatially resolved. In-transit and out-of-transit photometry on AO corrected images taken with NAOMI/INGRID show that the faint companion does not undergo deep eclipses, and therefore it is not the origin of the observed transits.

using the stabilised spectrograph SOPHIE on the OHP-1.9m telescope, France.

Skillen initiated a project on the WHT and NOT, in collaboration with Benn (ING) and Pollacco (QUB), for monitoring the transits of known exoplanets. Their aim was to detect other, low-mass planets in these systems from their gravitational perturbation on the times of transit by the known exoplanet.

RR Lyrae stars, as metal poor, evolved standard candles, can be used to trace the primordial stellar population of the galactic halo, if their kinematical properties are known. In collaboration with Barnes, Jeffery and Montemayor (University of Texas), Skillen completed a study to determine high-precision centre-of-mass radial velocities of a sample of field RR Lyrae stars, using echelle spectroscopy at the McDonald Observatory.

Rix has published an ApJ paper in collaboration with Pettini (IoA), Steidel (Caltech) and others on the recently discovered, proximate damped, Lyman alpha system (PDLA) towards the quasar Q2343-BX415.

Interest in this relatively neglected population of absorbers has been revived in recent years by the realisation that the environmental differences between PDLAs and the better studied 'normal' (intervening) DLAs, can give insight into galaxy formation in a quasar environment. What made this particular object so interesting was the coincidence in redshift (to within a few hundred km/s) between the absorbing gas and the background quasar.

Rix and her collaborators performed a detailed study of the chemical and physical properties of Q2343-BX415's PDLA, finding a metal enrichment comparable to normal DLAs and in stark contrast to the supersolar metallicity determinations previously reported for some proximate high ionisation systems. Their study of the kinematics showed that high ionisation gas is not only situated close to the quasar but is also infalling. Meanwhile the neutral gas was found to be receding from the quasar at $\sim 160\text{km/s}$ which, combined with a distance estimate based upon the ionisation and excitation state of the gas, presented the intriguing possibility that we are witnessing a shell of gas outflowing from the quasar host galaxy. Such outflows are routinely observed in star-forming galaxies at comparable redshifts and are thought to play a crucial role in galaxy feedback.

Rix and Pettini have now initiated a project to search for a subset of PDLAs for which the absorbing gas is exactly coincident in redshift with that of the quasar, as seen for

Q2343-BX415, and therefore likely to be associated with either the quasar's host galaxy, or a nearby galaxy forming in the same group.

In her role as 'XOasis package support' for the ING's OASIS instrument, Rix was also involved in a research project with Lennon and Parker (1-year ING student) to study the circumstellar properties of the Luminous Blue Variable (LBV) P Cygni. This project exploited adaptive-optics 3D spectroscopic observations from the WHT's OASIS+NAOMI instrumentation suite.

ORGANISATION OF SCIENTIFIC MEETINGS

Corradi, with assistance from ING's Astronomy and Administration groups, organised, on the island of La Palma, two international conferences: "The nature of V838 Monocerotis and its light echo", held from May 16 to 19, 2006, and "Asymmetrical Planetary nebulae IV", held from June 18 to 22, 2007.

The 2002 outburst of V838 Monocerotis, and its highly peculiar, fast evolution toward a very low photospheric



Figure 61. Poster for the conference "The Nature of V838 Mon and Its Light Echo".

temperature and a hypergiant size, was one of the most puzzling events in stellar astrophysics in recent years. With the goal of shedding light on this phenomenon, 50 astrophysicists from all over the world met on La Palma in 2006. They contributed to a lively conference, in which the nature of the outbursting source (a thermonuclear runaway in a massive star? merging of two low-mass stars? capture of one or several planets?), and the cause of the spectacular light echo observed around it, was debated. The conference was also an excellent opportunity to foster cooperation and coordination of future observational and modelling efforts, which are needed to shed further light on this rare object.

The conference organised in 2007 was the fourth meeting of the "Asymmetrical Planetary Nebulae" series devoted to understanding the variety of shapes displayed by planetary nebulae, and their implications to stellar evolution.

The importance of the phenomenon was highlighted by extensive CCD imaging surveys taken more than 20 years ago, but a satisfactory understanding of the cause of the sudden switch to an anisotropic mass loss mode at the end of stellar evolution is still missing.

120 astronomers met on La Palma to present the latest observational data and theoretical models. As an overall result of the conference, the role of binary systems in producing the observed mass loss geometries was further strengthened, and, following ample discussion sessions, a wide international collaboration aimed at producing a robust observational effort to demonstrate it, has been set up.

Finally, a users' meeting at NAM 2006 "Astronomy from La Palma: Developments and Future Directions" was organised, including 8 poster presentations by astronomy staff members.



Figure 62. Poster for the conference "Asymmetrical Planetary Nebulae IV".

Chapter 5

PUBLIC RELATIONS

In 2006 and 2007 thousands of visitors were shown the WHT, many as part of the annual observatory open days during the summer, but also through a large number of group visits. In total over the two years more than 6000 people visited the telescopes. These activities help strengthen the ties between the observatory and the public in general, and in particular, on the island of La Palma. VIP visits included the science ministers from Spain and the Netherlands, the director general of UNESCO, the Education and Science Commission of the Spanish parliament and Mr Lembit Opik, member of UK parliament.

ING has been very active in public outreach activities during the reporting period. Some of these activities were developed under the auspices of the OPTICON coordination network funded by the European Union. Activities included participation in the European Science Week organised on La Palma and dedicated to Einstein's theory of relativity. The participants visited the WHT and learned out about the observational aspect of special and general relativity.

There have also been many scientific outreach activities, including the organization of a well-attended 4th conference on "Asymmetrical Planetary Nebulae", in collaboration with the Instituto de Astrofísica de Canarias and the Nordic Optical Telescope and a conference with the title "The Nature of V838 Mon and Its Light Echo" in collaboration with the Istituto Nazionale di Astrofisica and the Instituto de Astrofísica de Canarias. Furthermore, ING collaborated in the organisation of the IAU Symposium 241 on "Stellar Populations as Building Blocks of Galaxies". We also collaborated with the organisation of the Starlight conference organised by UNESCO on La Palma, and with the events organised around first light of the 10.4m GTC telescope.

During the reporting period, more than 60 press releases based on results obtained using the ING telescopes were issued by ING or other institutions. Good examples of these include the announcement of the release of the Millennium Galaxy Catalogue and the first results from the IPHAS survey, the use of the first ground-layer adaptive-



Figure 63. The first use of a ground-layer adaptive-optics system for general astronomical observations was widely covered in the press. Spectacular photos such as the one shown here were used to disseminate the news. Credit: Tibor Agocs.



Figure 64. Some of the scenes from the filming of the series “Armageddon -- The Longest Night” at the INT.

optics system for general astronomical observations and the images of the exploding comet 17P/Holmes from the Isaac Newton Telescope.

Other press activities included assisting TV teams filming at ING, and of particular impact was the scientific docudrama “Armageddon — The Longest Night”, produced by ZDF, Discovery Channel and France-3. The

two-chapter series is about the collision of a comet with the Earth and its consequences.

We continued with the production of graphical and multimedia material for use with PR activities: photographs, digital video movies and 3D panoramic views of the telescopes, examples of which can be seen in the accompanying figures.



Figure 65. The WHT at sunset and waning Moon.

Appendix A

THE ISAAC NEWTON GROUP OF TELESCOPES

The Isaac Newton Group of Telescopes (ING) consists of the William Herschel Telescope (WHT), the Isaac Newton Telescope (INT) and the Jacobus Kapteyn Telescope (JKT). The WHT, with its 4.2m diameter primary mirror, is the largest in Western Europe. It was first operational in August 1987. It is a general purpose telescope equipped with instruments for a wide range of astronomical observations. The INT was originally used at Herstmonceux in the United Kingdom, but was moved to La Palma in 1979 and rebuilt with a new mirror and new instrumentation. It has a 2.54m diameter primary mirror and is mostly used for wide-field imaging and spectroscopy. The JKT has a primary mirror of 1.0m diameter and it was mainly used for observing relatively bright objects. Both the INT and the JKT were first operational in May 1984. The JKT ceased science observations in August 2003 and now it is regularly being used for measuring the atmospheric turbulence profile above the observatory.

The WHT has an altazimuth mount with a $f/2.5$ parabolic primary mirror. The WHT is of classical Cassegrain optical configuration. The paraboloidal primary mirror is made of a glass-ceramic material (Cervit) having near-zero coefficient of expansion over the operating temperature range. Instruments can be mounted at the corrected $f/2.81$ prime focus, $f/11$ Cassegrain focus, or either of two $f/11$ Nasmyth foci. The primary mirror is made of a glass-ceramic material (Cervit) having near-zero coefficient of expansion over the operating temperature range, and it weighs 16.5 tonnes. When not operating at prime focus, a convex hyperboloidal secondary mirror, made of Zerodur, 1.0m in diameter, directs the light through a central hole in the primary mirror to the main instrumentation mounted at the Cassegrain focus beneath the primary mirror cell. The telescope also incorporates a third main mirror, a flat, angled at 45 degrees, which can be motor-driven into position at the intersection of the axes, above the primary mirror, so that the light from the secondary is diverted sideways through one of the altitude bearings to the Nasmyth platforms.

The INT has a primary mirror with a focal ratio of $f/2.94$. It uses a polar-disc/fork type of equatorial mount. Instruments can be mounted at the corrected $f/3.29$ prime or $f/15$ Cassegrain foci. The optical system of the INT is a conventional Cassegrain with a paraboloidal primary mirror and a hyperboloidal secondary. It weighs 4.4 tonnes and it is made of Zerodur.

The JKT has a parabolic primary mirror of diameter 1.0m and a focal length of 4.596m. It weighs 215kg. It is equatorially mounted, on a cross-axis mount. The JKT has two optical configurations: Harmer-Wynne and Cassegrain. The former uses a $f/8$ spherical secondary and the latter a $f/15$ hyperbolic secondary. The two optical systems share the same parabolic primary mirror. At present only the Cassegrain configuration is available and instruments mount at the Cassegrain focus.

The following table shows each telescope's location:

	Latitude	Longitude	Ground floor height
WHT	28° 45' 38.3" N	17° 52' 53.9" W	2332m
INT	28° 45' 43.4" N	17° 52' 39.5" W	2336m
JKT	28° 45' 40.1" N	17° 52' 41.2" W	2364m

The ING operates the three telescopes on behalf of the Science and Technology Research Council (STFC) of the United Kingdom, the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of the Netherlands, and the Instituto de Astrofísica de Canarias (IAC) of Spain.

The ING is located at the Observatorio del Roque de los Muchachos (ORM), on the island of La Palma, Canary Islands, Spain. The ORM, which is the principal European northern hemisphere observatory, is owned by the Instituto de Astrofísica de Canarias. The operation of the site is overseen by an International Scientific Committee, or Comité Científico Internacional (CCI). Financial and operational matters of common interest are dealt with by appropriate subcommittees.

The observatory also includes the 3.6m Telescopio Nazionale Galileo, the 2.5m Nordic Optical Telescope, the 2.0m Liverpool Telescope, the 1.2m Mercator Telescope, the 60cm telescope of the Swedish Royal Academy of Sciences, the wide-field imaging facility SuperWasp, the Automatic Transit Circle, the 0.97cm New Swedish Solar Telescope, the 45cm Dutch Open Solar Telescope, and the atmospheric imaging Cherenkov 17m Magic Telescopes. Under construction are a twin to the 17m Cherenkov telescope, MAGIC-2, and the 10.4m Gran Telescopio Canarias.

The observatory occupies an area of 1.89 square kilometres approximately 2350m above sea level on the highest peak of the Caldera de Taburiente National Park, in the Palmeran district of Garafia. La Palma is one of the westerly islands of the Canarian archipelago.

The site was chosen after an extensive search for a location with clear, dark skies all the year round. All tests proved that the Roque de Los Muchachos is one of the best astronomical sites in the world. The remoteness of the island and its lack of urban development ensure that the night sky at the observatory is free from artificial light pollution. The continued quality of the night sky is protected by law. The mountain-top site has a remarkably stable atmosphere, owing to the local topography. The mountain has a smooth convex contour facing the prevailing northerly wind and the air-flow is comparatively undisturbed, allowing sharp and stable images of the night sky.

Many of the state-of-the-art telescope and instrument components are custom-built. New instruments are designed and built by technology groups mainly in the United Kingdom, the Netherlands, and Spain, with whom the ING maintains close links, and by astronomers and engineers working at ING.

THE INTERNATIONAL AGREEMENTS

The international agreements by which the Roque de Los Muchachos and the Teide Observatories were brought into existence were signed on La Palma on 26 May 1979. The participant nations at that time were Spain, the United Kingdom, Sweden and Denmark. Later other European countries also signed the agreements. Infrastructural services including roads, communications, power supplies, as well as meals and accommodation facilities, have been provided by the Spanish side. In return for the use of the observatory and its facilities, all foreign user institutions make 20 per cent of time on their telescopes available to Spanish observers. Representatives of the participant institutions meet together as the International Scientific Committee, or Comité Científico Internacional (CCI).

The inauguration of the Canary Islands observatories took place on 29 June 1985 in the presence of the monarchs and members of the Royal Families of five European countries, and the Presidents of another two.

THE ING BOARD AND THE DIRECTOR'S ADVISORY COMMITTEE

The PPARC, the NWO and the IAC have entered into collaborative agreements for the operation of, and the sharing of, observing time on the ING telescopes. The ING Board was set up to oversee the operation of this agreement, to foster and develop collaboration between astronomers of the United Kingdom, the Netherlands and Spain, and to ensure that the telescope installations are maintained in the forefront of world astronomy. In particular, the ING Board oversees the programme of instrumentation development, determines the programme of operation and maintenance of the installations, approves annual budgets and forward estimates and determines the arrangements for the allocation of observing time.

The Director's Advisory Committee (DAC) assists the observatory in defining the strategic direction for operation and development of the telescopes. It also provides an international perspective and acts as an independent contact point for the community to present its ideas.



Figure 66. Members of the ING Board (2006).

TELESCOPE TIME AND DATA OWNERSHIP

The construction, operation, and development of the ING telescopes are the result of a collaboration between the United Kingdom, the Netherlands and Spain. The site is provided by Spain, and in return Spanish astronomers receive 20 per cent of the observing time on the telescopes. A further 75 per cent is shared by the United Kingdom, the Netherlands and the IAC. The remaining 5 per cent is reserved for large scientific projects to promote international collaboration between institutions of the CCI member countries. It is intended that this time be used for the study of one, or a few, broad topics each year by several telescopes. This time is allocated by the CCI.

It is the responsibility of the IAC to make the Spanish time available to Spanish institutions and others, via the Comité para la Asignación de Tiempos (CAT). The ING Board has delegated the task of time allocation to British and Dutch astronomers to the PPARC Panel for the Allocation of Telescope Time (PATT) and the NFRA Programme Committee (PC) respectively. All the above agreements envisage that observing time shall be distributed equitably over the different seasons of the year and phases of the moon.

Notwithstanding the above, any astronomer, irrespective of nationality or affiliation, may apply for observing time on the ING. Astronomers who are working at an institute in one of the partner countries should apply through the route appropriate to their nationality or the nationality of their institute.

Time is allocated in two semesters, from 1 February to 31 July (semester A) and from 1 August to 31 January (semester B). Decisions on time allocations are made on the basis of scientific merit and technical feasibility of the proposed observations.

ING policy is that data belong exclusively to those who collected them for a period of one year, after which they are available in a common archive for all astronomers (<http://archive.ast.cam.ac.uk/ingarch/>). It may be used at any time for engineering or instrumental investigations in approved programmes carried out to improve facilities provided at the observatory.

Service observations which are made by Support Astronomers at the request of others are similarly treated. However, calibration data may well be used for more than one observation and may therefore be available for several groups. It may happen that identical or similar service observations are requested by two or more groups. Requests which are approved before the data are taken may be satisfied by requiring the data to be held in common by the several groups. It is up to them how they organise themselves to process it, analyse it, relate it to other work, and eventually publish it.

Requests for observations from programmes already executed on the telescopes should be made to the ING Archive. This is the policy whether or not the data were obtained under UK, Dutch, Spanish or International Time, or by service requests.

Appendix B

TELESCOPE INSTRUMENTATION

The design of the WHT allows great flexibility in instrumentation as this telescope facilitates fast and easy switching between the Cassegrain and Nasmyth foci. For this reason, and to take advantage of the large light collecting power of the telescope, operation and developmental efforts focus on the WHT. Also visiting instruments, i.e. instruments built and used by external groups for their own use, are welcomed at the WHT and have attracted a great deal of attention. The INT is equipped with two instruments, the Wide Field Camera and the Intermediate Dispersion Spectrograph.

A broad functional division in instrumentation capability between the WHT and INT is as follows:

William Herschel Telescope	Optical spectroscopy and spectro-polarimetry over a range of resolving powers Imaging polarimetry IR spectroscopy Multi-object spectroscopy Integral field spectroscopy Optical and infrared imaging High spatial resolution imaging Coronagraphy
Isaac Newton Telescope	Optical imaging Optical and intermediate-resolution spectroscopy

The following table summarises the common-user instruments which were available during 2006 and 2007:

Focus	Instrument	Detector	
William Herschel Telescope			
Cassegrain	Double-arm spectrograph (ISIS)	EEV and Marconi CCDs	
	Auxiliary port camera (AUX)	Tektronix CCD	
	IR imager and spectrograph (LIRIS)	Rockwell HgCdTe array	
Nasmyth	Adaptive optics instrumentation: NAOMI / INGRID / OSCA NAOMI / OASIS	Rockwell HgCdTe array MIT/LL CCD	
	Prime	Prime Focus Imaging Camera (PFIP)	2 × EEV CCD
		Autofib Fibre Positioner (AF2) and WYFFOS spectrograph	2 × EEV CCD
Isaac Newton Telescope			
Cassegrain	Intermediate-resolution spectrograph (IDS)	EEV CCD	
Prime	Wide Field Camera (WFC)	4 × EEV CCDs	

Appendix C

STAFF ORGANISATION

DIRECTORATE

René G. M. Rutten, *Director*

ADMINISTRATION GROUP

Mónica Abreu (from 12/09/2006)
Consuelo Barreto
Angeles Cortés
Les Edwins, *Head of Administration* (to 15/05/2007)
Lourdes González
Juan Martínez, *Head of Administration* (from 16/05/2007)
Yasmín Rodríguez (from 22/08/2006)
Peter van der Velde (to 07/09/2006)

Students:

Katherine Jacob (to 21/08/2007)
Vanda Jones (to 21/07/2006)
Emma Tomlinson (from 03/09/2007)

ASTRONOMY GROUP

Chris Benn
Daniel Bramich (to 04/12/2006)
Romano Corradi
Robert Greimel (to 31/12/2006)
Pierre Leisy (to 31/08/2007)
Danny Lennon, *Head of Astronomy* (to 01/12/2007)
Javier Licandro (to 31/12/2007)
Javier Méndez
Roy Østensen (to 15/06/2006)
Samatha Rix
Pablo Rodríguez (from 01/11/2007)
Mischa Schirmer (to 31/10/2007)
Ian Skillen

Students:

Sarah Barker (from 17/09/2007)
Paul Behrens (to 31/08/2006)
Andrew Cardwell (to 03/02/2006)
Samantha Hickey (to 07/09/2006)
Marie Hrudkova (from 01/09/2006 to 07/09/2007)
Ian Hunter (from 01/09/2006 to 05/09/2007)
Tina Liimets (from 03/09/2007)
Richard Parker (to 31/08/2006)
Laurence Sabin (to 31/08/2006)
Miguel Santander (from 01/10/2006 to 30/09/07)
Marica Valentini (from 27/09/2007)

ENGINEERING

Gordon Talbot, *Head of Engineering* (to 31/12/2006)

Don Abrams, *Head of Engineering* (from 01/01/2007)

COMPUTING GROUP

Don Abrams, *Head of Computing* (to 31/12/2006)
Craig Bevil
Frank Gribbin
Luis Hernández
Gary Mitchell
Sergio Picó
Juan Piñero
Simon Rees (to 26/01/2007)
Jure Skvarc

TELESCOPES & INSTRUMENTATION GROUP

Nikolas Apostolakos (to 27/09/2007)
Tibor Agocs (from 25/10/2006)
Marten Blanken (to 31/08/2006)
Diego Cano, *Head of Telescopes & Instrumentation*
Tom Gregory (to 20/02/2007)
Paul Jolley (to 28/02/2007)
Carlos Martín
Olivier Martin
Andy Ridings
Simon Tulloch

OPERATIONS TEAM

Alan Chopping
Raúl Concepción
Kevin Dee, *Head of Operations* (to 18/09/2006)
José Miguel Díaz
Michiel van der Hoeven
David González
David Goodman (from 28/08/2006 to 31/12/2006)
Amado Guillén
Roberto Martínez
José Carlos Pérez
René Pit
Jürg Rey, *Head of Operations* (from 01/01/2007)
Servando Rodríguez

Telescope operators:

Andrew Cardwell (from 03/02/2006)
José Norberto González
Juan Carlos Guerra
Neil O'Mahoney

Appendix D

TELESCOPE TIME AWARDS

The UK Panel for the Allocation of Telescope Time (PATT), the Dutch NL ASTRON Programme Committee (PC), the Spanish Comité para la Asignación de Tiempos (CAT), the Telescopio Nazionale Galileo's Time Allocation Committee (TNG-TAC) and the Comité Científico Internacional (CCI) made time awards to the following observing proposals in 2006 and 2007. The principal applicant, his or her institution or university, the title of the proposal, and the proposal reference are listed below. Semester A runs from February to July and semester B from August to January.

SEMESTER 2006A

William Herschel Telescope

UK PATT

- Aigrain (IoA), Spectroscopy of transit candidates in the M50 Open Cluster, W/2006A/44.
- Allard (Hertfordshire), Probing the vertical structure of nuclear bars, W/2006A/61.
- Benn (ING), The nature of BAL outflows in quasars, W/2006A/13.
- Dobbie (Leicester), Constraining the initial mass-final mass relation using Praesepe white dwarfs, W/2006A/1.
- Fitzsimmons (QUB), The March 12th/13th stellar occultation by Pluto, W/2006A/43.
- Gaensicke (Warwick), The cataclysmic variable period gap: fact or myth? W/2006A/29.
- Hewett (IoA), Imaging and spectroscopy of galaxy-galaxy gravitational lenses from the SDSS, W/2006A/2.
- Jameson (Leicester), Brown dwarf stars in Melotte 111 in the Coma Berenices open star cluster, W/2006A/26.
- Jarvis (Oxford), Spectroscopic confirmation and investigation of a sample of high-redshift Lyman-alpha nebulae, W/2006A/15.
- Keenan (QUB), A search for binarity in B-type post-AGB stars, W/2006A/21.
- Knapen (Hertfordshire), Origin and evolution of bars in SO and spiral galaxies, W/2006A/60.
- Knigge (Southampton), Spectroscopic reconnaissance of faint emission line stars discovered by IPHAS, W/2006A/55.
- Levan (Hertfordshire), Probing the high redshift universe with GRBs, W/2006A/46.
- Littlefair (Sheffield), On the evolutionary status of short period cataclysmic variables, W/2006A/57.
- Lucas (Hertfordshire), PLANETPOL polarimetry of the hot Neptune planet 55 Cnc e, W/2006A/11.
- Marsh (Warwick), The first eclipsing AM CVn star, SDSS J0926+3624, W/2006A/8.
- Marsh (Warwick), Angular momentum loss and exchange in white dwarf/main-sequence binary stars, W/2006A/53.
- Merrifield (Nottingham), Determining the dynamics of round elliptical galaxies using the Planetary Nebula Spectrograph, W/2005A/37.
- Page (MSSL), Star formation, cosmic downsizing, and the AGN luminosity function, W/2006A/59.
- Pettini (IoA), Characterising the metal and dust abundances of DLAs at $0.6 < z < 1.2$, W/2006A/3.
- Pinfield (Hertfordshire), Confirming and studying brown dwarf companions at wide separation, W/2006A/35.
- Sansom (Lancashire), Star formation histories and age distributions across cD galaxies, W/2006A/27.
- Skillen (ING), A search for low-mass planets in the TrES-1 system, W/2006A/32.
- Tadhunter (Sheffield), Ultraluminous infrared galaxies: quasars and radio galaxies in the making? W/2006A/12.
- Tadhunter (Sheffield), Fast neutral outflows in radio galaxies: a major source of feedback in galaxy formation? W/2006A/16.
- Vink (ICL), The geometry and strength of B supergiant winds, W/2006A/22.
- Watson (Sheffield), Imaging star-spots on the secondary stars in cataclysmic variables, W/2006A/28.
- Wilkinson (IoA), Hunting for tidal tails in the globular cluster NGC5466, W/2006A/17.
- Wilman (Durham), The Lyman-alpha haloes of sub-mm galaxies: exploring superwinds and feedback at $z=3$, W/2006A/7.

NL PC

- Besselaar (Nijmegen), Follow-up of DB+dM binary systems, w06an004.
- Cappellari (Leiden), Dark matter in early-type galaxies: stellar line-of-sight velocity-distribution at 5Re using SAURON, w06an007.
- Emonts (Kapteyn), Fast neutral outflows in radio galaxies: a major source of feedback in galaxy formation? w06an015.
- Ham (Nijmegen), Optical and NIR spectral eclipse mapping of accretion discs, w06an005.
- McDermid (Leiden), Mapping the nuclear regions of early-type galaxies with OASIS, w06an001.
- Merin (Leiden), Optical spectroscopy of a new young stellar population in Serpens, w06an018.
- Morales (Nijmegen), Close binaries in the Faint Sky Variability Survey, w06an002.
- Nelemans (Nijmegen), Testing common-envelope theory and SN Ia progenitor models with double white dwarfs, w06an010.

- Serra (Kapteyn), Stellar populations in HI-rich early-type galaxies, w06an016.
- Snellen (Leiden), Detection of direct thermal emission from the exoplanet TrES-I, w06an011.
- Starling (Amsterdam), The physics of short bursts and relativistic blast waves, w06an012.
- Wijers (Amsterdam), Probing the high redshift Universe with GRBs, w06an014.

SP CAT

- Arribas (STSCI), INTEGRAL study of very luminous infrared galaxies, WHT9/06A.
- Arribas (STSCI), INTEGRAL spectroscopy of HD209458b: a new method to study exoplanetary atmospheres, WHT10/06A.
- Barrado (LAEFF), SEDs and variability in brown dwarfs of the 5 Myr Collinder 69 cluster, WHT12/06A.
- Cairós (IAC), Mapping young and old stars in star-forming dwarfs with INTEGRAL, WHT35/06A.
- Cardiel (CAHA), Properties of dry galaxy mergers and the origin of early-type galaxies, WHT47/06A.
- Casares (IAC), Determining system parameters of a soft X-ray transient in outburst, WHT16/06A.
- Castro-Tirado (IAA), The physics of gamma-ray bursts in the SWIFT era (ToO), WHT3-A/06A.
- Gómez (IAC), A NIR systematic study of the spectroscopic properties of CCSNe, WHT14/06A.
- Kehrig (IAA), The problem of metal pollution in low metallicity HII-galaxies, WHT34/06A.
- Martín (IAC), Follow-up of the first UKIDSS ultracool dwarf candidates, WHT13/06A.
- Mediavilla (IAC), Photometric and spectroscopic variability of gravitational lenses, WHT56-C/06A.
- Mollá (CIEMAT), Stellar populations in the nuclear region of barred spiral galaxies, WHT45/06A.
- Negueruela (Alicante), A survey of blue stragglers in young open clusters, WHT2/06A.
- Padilla (IAC), Searching for baryonic matter at supercluster scales, WHT49/06A.
- Rodríguez (IAC), Unraveling the role of the SW Sextantis stars in the evolution of cataclysmic variables, WHT22-A/06A.
- Shahbaz (IAC), Ultra-compact X-ray binaries: the endpoints of binary stellar evolution, WHT21/06A.
- Zapatero (LAEFF), Near-infrared imaging polarimetry of young brown dwarfs, WHT30/06A.
- Zurita (IAC), The origin of the optical variability in the X-ray transient V404 Cyg, WHT27/06A.

SP SAT

- Acosta (IAC), Infrared catalogue of low-luminosity polarimetric standards, WHT15/06A.
- Balcells (IAC), The GOYA deep infrared survey, WHT43/06A.
- Machado, LIRIS GT.
- Najarro (IAC), Massive stars in galactic obscured massive clusters: MASGOMAS, WHT38/06A.

TNG-TAC Time Share

- Bardelli (OA Bologna), Detailed merging dynamics of A2061: creating shocks and radio relics, T8.
- Ferraro (Bologna), Probing the cluster dynamics: the radial distribution of blue stragglers, T33.
- Trevese (Roma), Investigating the nature of low luminosity active galactic nuclei (LLAGN), T16.
- Zaggia (OA Trieste), Hunting for cores of dwarf spheroidal galaxies in the external Milky Way halo, 05B/T69.
- Zaggia (OA Trieste), Hunting for disrupted cores of dwarf spheroidal galaxies in the external Milky Way halo, T76.

ITP

- Peletier (Kapteyn), MAGPOP - The star formation history of dwarf galaxies, ITP4.

Instrument Builders' GT

- Bacon (Lyon), OASIS GT.

Isaac Newton Telescope

UK PATT

- Alonso (IAC), Searching for hot Neptunes using the field star transit method, INT9/06A.
- Beckman (Open), The links between bars and star formation: an advanced survey, INT6/06A.
- Beckman (Open), Calibration of the HII region luminosity function as an extragalactic standard candle, INT10/06A.
- Castro-Tirado (IAA), The physics of gamma-ray bursts in the SWIFT era (ToO), INT1-I/06A.
- da Rocha (Göttingen), Intra-group light in Hickson compact groups, INT3/06A.
- Kiss (Konkoly Observatory), A comparative study of extinction and infrared emission in dark clouds, INT4/06A.
- López (IAC), Diffuse light in galaxy groups, INT5/06A.
- Martín (IAC), A pilot survey for very low-mass brown dwarfs and free-floating planets in Upper Sco, INT11/06A.
- Rebolo (IAC), Searching for baryonic matter at superclusters scales, INT8/06A.

- Ruiz-Lapuente (Barcelona), Supernovae at $z=0.05-0.35$: studying the nature of dark energy (II), INT2/06A.
- Vázquez (IAC), Observing convection in solar-type stars, INT7/06A.
- Viironen (IAC), New planetary nebulae found by the IPHAS survey, INT12/06A.

NL PC

- Groot (Nijmegen), The northern galactic plane UV-excess survey: UVEX, i06an001.
- Kovac (Kapteyn), The optical counterparts of the smallest gas-rich galaxies, i06an005.
- Oosterloo (Bonn), Warps in low surface brightness galaxies, i06an004.
- Snellen (Leiden), Practical astronomy for 2nd year students, i06an003.

SP CAT

- Alonso (IAC), Searching for hot Neptunes using the field star transit method, INT9/06A.
- Beckman (Open), The links between bars and star formation: an advanced survey, INT6/06A.
- Beckman (Open), Calibration of the HII region luminosity function as an extragalactic standard candle, INT10/06A.
- Castro-Tirado (IAA), The physics of gamma-ray bursts in the SWIFT era (ToO), INT1-I/06A.
- da Rocha (Göttingen), Intra-group light in Hickson compact groups, INT3/06A.
- Kiss (Konkoly Observatory), A comparative study of extinction and infrared emission in dark clouds, INT4/06A.
- López (IAC), Diffuse light in galaxy groups, INT5/06A.
- Martín (IAC), A pilot survey for very low-mass brown dwarfs and free-floating planets in Upper Sco, INT11/06A.
- Rebolo (IAC), Searching for baryonic matter at superclusters scales, INT8/06A.
- Ruiz-Lapuente (Barcelona), Supernovae at $z=0.05-0.35$: studying the nature of dark energy (II), INT2/06A.
- Vázquez (IAC), Observing convection in solar-type stars, INT7/06A.
- Viironen (IAC), New planetary nebulae found by the IPHAS survey, INT12/06A.

ITP

- Peletier (Kapteyn), MAGPOP - The star formation history of Dwarf Galaxies, ITP4.

SEMESTER 2006B

William Herschel Telescope

UK PATT

- Aigrain (IoA), Spectroscopy of eclipse candidates in the M50 open cluster, W/2006B/22.
- Bosma (Observatoire de Marseille), Deep K-band surface photometry of low surface brightness galaxies, W/2006B/26.
- Bower (ICC), The SAURON Deep Survey: exploring Lyman-alpha haloes of massive galaxies at $z=3$, W/2006B/13.
- Christian (QUB), Toward doubling the sample of known large extrasolar planets: SuperWASP candidates, W/2006B/20.
- Georgakakis (ICL), Determining the bright-end of the QSO X-ray luminosity function at $z>3$, W/2006B/10.
- Harries (Exeter), The circumstellar geometry of Classical T Tauri stars, W/2006B/51.
- Hughes (Hertfordshire), Resolving the critical ambiguities of the super massive black hole masses-stellar velocity dispersion relation, W/2006B/14.
- Irwin (IoA), Low-mass membership, rotation and binarity in M34, W/2006B/34.
- Jarvis (Oxford), Spectroscopic confirmation and investigation of a sample of high-redshift Lyman-alpha nebulae, W/2006B/6.
- Jeffries (Keele), Binary statistics and the formation of low-mass stars and brown dwarfs, W/2005B/50.
- Keenan (QUB), Evidence for star formation in galactic haloes: a B-type star in M 31, W/2006B/3.
- Levan (Hertfordshire), Probing the high redshift universe with GRBs, W/2006A/46.
- Lucas (Hertfordshire), PLANETPOL polarimetry of Upsilon Andromedae b, W/2006B/45.
- Marsh (Warwick), The ultra-low luminosity cataclysmic variables stars from the SDSS, W/2006B/60.
- Matsuura (QUB), Infrared emission from transiting extra-solar planets, W/2006B/52.
- Naylor (Exeter), A new method of determining ages of pre-main-sequence stars, W/2006B/42.
- Noordermeer (Nottingham), Understanding the origins of lenticular galaxies using their planetary nebulae, W/2006B/21.
- Pettini (IoA), The nature of DLA galaxies traced through spin temperatures: the optical survey, W/2006B/5.
- Pettini (IoA), Metals in intermediate redshift DLAs: the missing link in the chemical evolution history of the universe, W/2006B/30.
- Pollacco (QUB), Search for substellar companions to stars with extrasolar planets, W/2005B/23.
- Skillen (ING), A Search for low-mass planets in the TrES-1 System, W/2006A/32.
- Smith (Sussex), Starspot mapping of the secondary star in the dwarf nova RU Peg, W/2006B/59.
- Tanvir (Hertfordshire), The physical nature of gamma-ray bursts, W/2006B/55.
- Vidrih (IoA), Spectroscopic survey of the "Field of Streams" dissecting the Galactic halo, W/2006B/48.
- Vink (Keele), The geometry and strength of B supergiant winds, W/2006B/1.

- Ward (Durham), The coronal lines as diagnostics of AGN outflows, W/2006B/57.
- Young (Hertfordshire), Uncovering quasar nurseries: spectropolarimetry of OH megamaser galaxies, W/2006B/46.

NL PC

- Cappellari (Leiden), Dark matter in early-type galaxies: stellar line-of-sight velocity distributions at large radii using SAURON, w06bn002.
- Coccato (Kapteyn), Understanding the origins of lenticular galaxies using their planetary nebulae, w06bn004.
- Horrobin (Amsterdam), In search of the true effective temperature of T Tauri stars, w06bn012.
- Jonker (SRON), Phase resolved photometry of the msec X-ray pulsar IGRJ00291+5934, w06bn001.
- Kleijn (Kapteyn), A comprehensive study of X-shaped radio galaxies, w06bn003.
- Merin (Leiden), Optical spectroscopy of a new young stellar population in Perseus, w06bn010.
- Nelemans (Nijmegen), Using peculiar binaries to study common-envelope evolution, w06bn009.
- Rottgering (Leiden), Reliability of photometric redshifts for radio galaxies in the XMM-LSS field, w06bn011.
- Schnerr (Amsterdam), Magnetic fields and accretion in the young Herbig Ae/Be stars, w06bn005.
- Serra (Kapteyn), Stellar populations in HI-rich early-type galaxies, w06bn006.
- Starling (Amsterdam), The physics of relativistic blast waves in Gamma-ray Bursts, w06bn007.
- Wijers (Amsterdam), Probing the high redshift Universe with GRBs, w06bn008.

SP CAT

- Beasley (Complutense), Globular clusters of M31 in the K band, WHT40/06B.
- Campo (Alicante), Accurate light curve and color indices of TNO 2004 XR190 (Buffy), WHT20/06B.
- Casares (IAC), Determining system parameters of a Soft X-ray transient in outburst, WHT9/06B.
- Gallart (IAC), Stellar populations in the dwarf galaxy LGS3: probing the reionization epoch, WHT46/06B.
- García (IAC), Truncation of star formation in early-type galaxies of Hickson compact groups, WHT7/06B.
- García (IAC), 3D spectroscopy of HII regions. Physical characteristics of the ionised gas, WHT25/06B.
- Girart (IEEC), Characterisation of the magnetic field in the star-forming region NGC 1333 IRAS4A, WHT10/06B.
- Gómez (IAC), NIR systematic study of spectroscopic properties of the CCSNe, WHT15/06B.
- González (IAC), Spectropolarimetry of SW Sex systems, WHT29/06B.
- Gutiérrez (IAC), Optical counterparts of Ultra Luminous X-ray Sources, WHT44/06B.
- Herrero (IAC), Luminous Blue Stars Along the Spiral Arms of M33, WHT42/06B.
- López (IAC), Star-forming regions in starbursts galaxies with tidal streams, WHT27/06B.
- Martín (IAC), K-band spectroscopy of the most massive stars in UCHII regions, WHT32/06B.
- Martín (IAC), Chromospheric activity and improved parameters for the first BD eclipsing binary, 77-MULT.
- Negueruela (Alicante), A survey of blue stragglers in young open clusters, WHT19/06B.
- Pérez (IAC), A WYFFOS/AF2 survey of SWIRE far-infrared sources, WHT37/06B.
- Rebolo (IAC), The Pleiades L-dwarf sequence: a benchmark for the Substellar Astronomy, 113-MULT.
- Rodríguez (IAC), Unravelling the role of the SW Sextantis stars in the evolution, 47-MULT, 0.5D.
- Shahbaz (IAC), HS2331+3905: a cataclysmic variable in its final days, WHT39/06B.

SP SAT

- Acosta (IAC), Infrared catalogue of polarimetric standards of low luminosity, WHT22/06B.
- Machado (IAC), LIRIS GT.
- Najjarro (IEM), Massive Stars in Galactic Obscured Massive Clusters: MASGOMAS, WHT5/06B.

TNG-TAC Time Share

- Leone (OAC), Detecting magnetic fields in planetary nebulae, and understanding their role in the nebular shaping, T15/06B.
- Magrini (OA), The chemical content of Local Group galaxies: the dwarf irregular galaxy IC1613, T36/06B.

ITP

- Drew (ICL), An IPHAS-based exploration of stellar populations in the northern Milky Way, ITP06-4.

Isaac Newton Telescope

UK PATT

- Irwin (IoA), Searching for planetary transits in the Orion Nebula Cluster, I/2006B/17.
- Irwin (IoA), Spectroscopic follow-up of eclipse candidates in M50 and the ONC, I/2006B/20.
- Maxted (Keele), New fast-rotating young stars from the SuperWASP survey, I/2006B/18.
- Maxted (Keele), Testing models for the progenitors of Type Ia Supernovae (SNe Ia), I/2006B/28.

- Pollacco (QUB), Eclipsing Binaries in nearby galaxies - tools to recalibrate the Cepheid PL relationship, I/2006B/3.
- Pollacco (QUB), Sifting the SuperWASP extra-solar planet candidates, I/2006B/9.
- Southworth (Warwick), Constraining stellar theory using detached eclipsing binary stars in open clusters, I/2006B/1.
- Street (QUB), Classification of New Low-Mass Brown Dwarf and Stellar Binaries, I/2006B/22.
- Tanvir (Hertfordshire), The physical nature of gamma-ray bursts, I/2006B/32.

NL PC

- Groot (Nijmegen), The European Galactic Plane Surveys (EGAPS): North, i06bn002.
- Wijers (Amsterdam), Probing the high redshift Universe with GRBs, i06bn005.
- Groningen students.

SP CAT

- Barrena (IAC), Photometric characterisation of galaxy clusters with diffuse radio emission and confirmation of high-redshift ($z \sim 1$) clusters with low X-ray emission, INT6/06B.
- Beckman (Open University), Calibration of the HII region luminosity function as an extragalactic standard candle, INT17/06B.
- Beckman (Open University), A deep H-alpha study of the warm ionized gas in M33, INT27/06B.
- Castro-Tirado (IAA), The diversity of gamma-ray bursts in the SWIFT era, 29-MULT/06B.
- Crespo (Complutense), Spectroscopic follow-up of flare stars with high temporal resolution, INT16/06B.
- Morales (LAEFF), Exploring the different Initial Mass Functions in the Lambda Orionis SFR, INT3/06B.
- Negueruela (Alicante), Making an OB association in Cassiopeia, INT15/06B.
- Ortiz (IAA), Short-term variability in the Trans-Neptunian Belt, INT1/06B.
- Ribas (IEEC), Direct determination of the distance to M31 from eclipsing binaries, INT12/06B.
- Ruiz-Lapuente (Barcelona), Supernovae from SDSSII: light curves, INT5/06B.
- Shahbaz (IAC), A movie of an unstable accretion disc in YZ Cnc, INT22/06B.
- Simón (IAC), Detailed modelling of Galactic HII regions, 37-MULT/06B.
- Simón (IAC), Distribution of rotating velocities of massive stars in Galactic clusters, INT25/06B.

SP SAT

- Caballero (IAC), The substellar populations in young clusters and stellar associations: I. The Orion Belt and Praesepe, INT23/06B.
- Vílchez (IAA), Deep H-alpha imaging of clusters of galaxies in the WINGS survey, INT9/06B.

ITP

- Drew (ICL), An IPHAS-based exploration of stellar populations in the northern Milky Way, ITP06-4.
- Peletier (Kapteyn), The star formation history of dwarf galaxies, ITP06-1.

SEMESTER 2007A

William Herschel Telescope

UK PATT

- Cappellari (Oxford), The SAURON Complete Survey (SCS) of early-type galaxies, W/2007A/3.
- Bunker (Exeter), Star formation at redshift ~ 2 , W/2007A/37.
- Gaensicke (Warwick), The cataclysmic variable period gap: fact or myth?, W/2007A/13.
- Hough (Hertfordshire), Spectropolarimetry of the major outer solar system satellites, W/2007A/36.
- Keenan (QUB), A search for binarity in B-type post-AGB stars, W/2007A/4.
- Keenan (QUB), The iron abundance of the globular cluster post-AGB star Barnard 29, W/2007A/24.
- Knapen (Hertfordshire), Origin and evolution of bars in SO and spiral galaxies, W/2007A/17.
- Knigge (Southampton), Spectroscopic reconnaissance of emission line stars discovered by IPHAS, W/2007A/27.
- Levan (Hertfordshire), GRBs, their nature and use as cosmological probes, W/2007A/32.
- Lowry (QUB), An unprecedented survey of the physical properties of Jupiter family cometary nuclei, W/2007A/20.
- Marsh (Warwick), Mass ratios of short period cataclysmic variable stars, W/2007A/19.
- Mattila (QUB), Unifying models of core-collapse supernovae - linking progenitor star and SN evolution, W/2007A/21.
- Merrifield (Nottingham), The PN.S elliptical galaxy survey, W/2007A/22.
- Napiwotzki (Hertfordshire), Testing common envelope theory and SN Ia progenitor models with double white dwarfs, W/2007A/33.
- Pinfield (Hertfordshire), Photometric followup of T/Y dwarf candidates from UKIDSS LAS YJ-only searches, W/2007A/30.
- Rawlings (Oxford), Spitzer-selected QSOs at high redshift, W/2007A/38.
- Smith (Oxford), A Search for Lyman break galaxies around a high redshift Lyman-alpha blob, W/2007A/7.

- Southworth (Warwick), The ultra-low luminosity cataclysmic variables stars from the SDSS, W/2007A/8.
- Symeonidis (Oxford), Determining star formation rates in $z > 0.7$ galaxies, W/2007A/14.
- Tadhunter (Sheffield), The nature of red quasars: young and hungry?, W/2007A/15.
- Wilkinson (IoA), New Milky Way satellite galaxies? Spectroscopic confirmation with AF2/WYFFOS, W/2007A/9.

NL PATT

- Curran (Amsterdam), Probing the high redshift Universe with GRBs, w07an002.
- Douglas (Groningen), Outer kinematics of nearby early-type galaxies with the PN.S, w07an009.
- Jonker (SRON), WHT follow-up observations of LOFAR transients, w07an008.
- Larsen (Utrecht), Extragalactic globular clusters in the near-infrared - Did early-type galaxies suffer recent star formation?, w07an010.
- McDermid (Leiden), The SAURON Complete Survey (SCS) of early-type galaxies, w07an001.
- Nelemans (Nijmegen), An infra-red search for the cool components in AM CVn binaries, w07an016.
- Nelemans (Nijmegen), Testing common-envelope theory and SN Ia progenitor models with double white dwarfs, w07an013.
- Oliveira (Leiden), Optical spectroscopy of a new young stellar population in Serpens, w07an006.
- Peletier (Groningen), Completing a large NIR stellar library at $R=2000$ for stellar population synthesis, w07an015.
- Snellen (Leiden), TNG observations of the spectroscopic transit of the new exoplanet HD189733, w07an005.
- Werner (SRON), Study of the interaction between the central radio source, the galaxy, and the intracluster medium in the cluster of galaxies MKW 3s, w07an004.
- Wijers (Amsterdam), Testing for achromatic breaks in Gamma-ray Burst afterglows, w07an003.

SP CAT

- Casares (IAC), Determining system parameters of a soft X-ray transient in outburst, 4-WHT1/07A.
- Castro-Tirado (IAA), Diversity of gamma-ray bursts in the SWIFT era, 20-WHT10/07A.
- Eiroa (Autónoma de Madrid), Circum(sub)stellar disk variability in young, embedded BDs. A pilot case, 70-WHT29/07A.
- Esteban (IAC), Recombination lines of heavy elements in HII regions, 63-WHT26/07A.
- García (CSIC), INTEGRAL study of very luminous infrared galaxies, 83-WHT38/07A.
- González (IAC), Characterisation of transient X-ray binaries in quiescence, 91-WHT42/07A.
- González (IFC), The nature of the luminous unusual radio quasar 1413+4505, 97-WHT49/07A.
- González (IFC), The nature of the luminous unusual radio quasar 1413+4505, 97-WHT50/07A.
- Hernán (IAC), LIRIS spectroscopy of Spitzer/IRS ULIRGs at $z \sim 1$, 92-WHT43/07A.
- Lorenzo-Cáceres (IAC), Mapping the stellar dynamics and populations of doubled-barred galaxies with SAURON, 22-WHT11/07A.
- Martín (IAC), An observational test of the physics of dust grains in L dwarfs, 51-WHT23/07A.
- Martínez (IAC), Kinematics of the tidal stream of the Galactic anticentre, 17-WHT6/07A.
- Negueruela (Alicante), A survey of blue stragglers in young open clusters, 29-WHT16/07A.
- Padilla (IAC), Searching for baryonic matter at supercluster scales: Corona Borealis, 64-WHT27/07A.
- Pérez-Fournon (IAC), The quest for a complete understanding of AGN: cluster environments, 96-WHT46/07A, 96-WHT47/07A, 96-WHT48/07A.
- Rodríguez (IAC), The role of the SW Sextantis stars in CV evolution, 25-WHT14/07A.
- Villar (Complutense), LIRIS multi object spectroscopy of an H α selected sample at $z=0.8$, 33-WHT18/07A.
- Zapatero (IAC), Brown dwarfs around low-metallicity stars - 2nd epoch, 61-WHT25/07A.

SP SAT

- Beckman (IAC), High resolution bidimensional kinematics of entire galaxies using Fabry-Pérot interferometry, 73-WHT32/07A.
- Najarro (IEM), Massive stars in galactic obscured massive clusters: MASGOMAS, 74-WHT33/07A.
- Pérez (IAC), Spectrophotometric calibration of OTELO fields, 77-WHT35/07A.
- Sánchez-Béjar (IAC), Optical spectroscopic confirmation of brown dwarfs in Upper Scorpius, 66-WHT28/07A.

TNG-TAC Time Share

- Clementini (INAF Bologna), Stellar Archaeology in the Milky Way halo: variable stars and stellar populations in the Canes Venatici I dSph, T43/07A.
- Leone (INAF Catania), Detecting magnetic fields in planetary nebulae, and understanding their role in the nebular shaping, T39/07A.

ITP

- Drew (ICL), An IPHAS-based exploration of stellar populations in the northern Milky Way, ITP06-4.
- Peletier (Groningen), The star formation history of dwarf galaxies, ITP06-1.

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UK PATT

- Anderson (Liverpool), A stellar population test of SNIa progenitor models, I/2007A/1.

- Christian (QUB), Sifting the SuperWASP extra-solar planet candidates, I/2007A/11.
- Drew (ICL), IPHAS - the INT/WFC photometric H-alpha survey of the northern galactic plane, I/2007A/12.
- Feltzing (Lund Observatory), Two new Milky Way dSph galaxies? Characterisation of their stellar population, I/2007A/7.
- Ferreras (King's College London), From voids to clusters: A journey through the star formation history of early-type galaxies, I/2007A/2.
- Fitzsimmons (QUB), Rotation rate changes in the NEO population - defining the YORP effect, I/2007A/4.
- Levan (Hertfordshire), GRBs, their nature and use as cosmological probes, I/2007A/14.
- Marsh (Warwick), Subdwarf-B stars: tracers of binary evolution, I/2007A/13.
- McGroarty (NUI Maynooth), Influence of parsec-scale outflows from young stars on molecular clouds, I/2007A/18.
- McMahon (IoA), The highest redshift $z > 6$ quasars and the coolest T/Y dwarf stars, I/2007A/19.
- Ramsay (MSSL), Determining the space density of ultra-compact binaries, I/2007A/8.
- Ripepi (INAF - Capodimonte), Stellar archeology in the Milky Way halo, I/2007A/15.
- Street (QUB), Classification of more new low-mass brown dwarf and stellar binaries from SuperWASP, I/2007A/10.

NL PC

- Curran (Amsterdam), Probing the high redshift Universe with GRBs, i07an002.
- Groot (Nijmegen), The European Galactic Plane Surveys (EGAPS): North, i06bn002 [sic].
- Jonker (SRON), WHT follow-up observations of LOFAR transients, w07an008.
- Snellen (Leiden), Practical astronomy for 2nd year students, i07an001.
- Verheijen (Groningen), Deep wide-field imaging of two galaxy clusters at $z=0.2$, i07an006.
- Wijers (Amsterdam), Testing for achromatic breaks in Gamma-ray Burst afterglows, i07an003.

SP CAT

- Barrena (IAC), Photometric characterisation and morphology of radio and X-ray diffuse emission galaxy clusters, 87-INT12/07A.
- Caballero (Heidelberg), Optical spectroscopy of sigma Orionis cluster member candidates, 93-INT13/07A.
- Casares (IAC), The northern Galactic Plane UV-excess survey: UVEX, 3-INT2/07A.
- Casares (IAC), Determination of system parameters and masses in High Mass X-ray Binaries: LS 5039 and 4U 2206+54, 36-INT7/07A.
- Castro (IAC), The buildup of halos of large cluster galaxies, 16-INT4/07A.
- Castro-Tirado (IAA), Diversity of gamma-ray bursts in the SWIFT era, 20-INT5/07A.
- Mampaso (IAC), IPHAS: the INT/WCF photometric H-alpha survey of the northern galactic plane, 48-INT8/07A.
- Martínez (IAC), Fossil records of the hierarchical formation of the Milky Way, 11-INT3/07A.
- Munari (Osservatorio di Padova), A deep photometric study of V838 Monocerotis, 67-INT9/07A.
- Pérez-Martín (Granada), How the time-scales determine the presence or lack of AGN in barred galaxies, 1-INT1/07A.
- Ribas (IEEC), The spectral energy distribution of COROT eclipsing binaries, 85-INT11/07A.

SP SAT

- Vílchez (IAA), Deep H-alpha imaging of clusters of galaxies in the WINGS survey, 80-INT10/07A.

ITP

- Drew (ICL), An IPHAS-based exploration of stellar populations in the northern Milky Way, ITP06-4.

SEMESTER 2007B

William Herschel Telescope

UK PATT

- Begum (IoA), Determination of chemical abundance of nearby faint dwarf irregular galaxies, W/2007B/39.
- Burleigh (Leicester), Metallic gas disks around hot white dwarfs, W/2007B/25.
- Cappellari (Oxford), The SAURON Complete Survey (SCS) of early-type galaxies, W/2007A/3 [sic].
- Edge (Durham), Spectroscopy of supernovae from the final SDSS-II campaign, W/2007B/53.
- Fitzsimmons (QUB), Uranus and its satellites at high spatial resolution, W/2007B/57.
- Gaensicke (Warwick), The cataclysmic variable period gap: fact or myth?, W/2007B/5.
- Geach (Durham), Tracking accelerated black-hole growth and star-formation in a $z=3.1$ protocluster, W/2007B/41.
- Harries (Exeter), The circumstellar geometry of Classical T Tauri stars, W/2007B/44.
- Jarvis (Hertfordshire), The nature and abundance of high-redshift Lyman-alpha nebulae, W/2007B/2.
- Jeffries (Keele), Age spreads and sequential star formation investigated with rotation rates in Cepheus OB3b, W/2007B/15.
- Keenan (QUB), A search for binarity in B-type post-AGB stars, W/2007B/1.

- Kurtz (Lancashire), A test of a new theory for the DB gap, W/2007B/21.
- Lane (Sydney, Australia), The Monoceros Ring/Canis Major Stream: a kinematic test of origin, W/2007B/182.
- Levan (Hertfordshire), GRBs, their nature and use as cosmological probes, W/2007A/32 [sic].
- Marsh (Warwick), Eccentricities in subdwarf-B star orbits, W/2007B/8.
- Marsh (Warwick), Angular momentum loss in white dwarf binary stars, W/2007B/27m.
- Mathioudakis (QUB), Radiative hydrodynamic processes of flares in fully convective stars, W/2007B/26.
- Mattila (QUB), Unifying models of core-collapse supernovae - linking progenitor star and SN evolution, W/2007B/28.
- Merrifield (Nottingham), The nature of galaxy thick disks from planetary nebula kinematics, W/2007B/37.
- Noordermeer (Nottingham), Understanding the origins of lenticular galaxies using their planetary nebulae, W/2007B/13.
- Pinfield (Hertfordshire), Follow-up of late T and Y-dwarf candidates from UKIDSS, W/2007B/29.
- Pollacco (QUB), The detection of Earth-mass planets in exoplanetary systems, W/2007B/50.
- Rowell (IoA), Spectroscopic Identification of ultracool white dwarfs, W/2007B/6.
- Silvotti (Osservatorio Astronomico di Capodimonte), A giant planet orbiting a hot evolved star, W/2007B/38.
- Southworth (Warwick), Sharpening the spike: the cataclysmic variable period minimum, W/2007B/54.
- Watson (Sheffield), Searching for starspots on cataclysmic variables below the period gap, W/2007B/30.
- Watson (Sheffield), Testing contact binary-star evolution: eclipse mapping of HH95-79, W/2007B/31.

NL PC

- Aerts (Nijmegen), Asteroseismology of PB8783: testing Roche lobe overflow models for sdB star formation, w07bn005.
- Curran (Astronomical Institute 'Anton Pannekoek'), Investigating the physical parameters of Gamma-ray Bursts via SEDs, w07bn001.
- Curran (Astronomical Institute 'Anton Pannekoek'), Gamma-Ray Bursts and the high redshift Universe, w07bn002.
- Hatch (Leiden), Witnessing the interaction between the AGN and the galactic gas at the centre of cooling flow clusters, w07an011.
- Hatch (Leiden), Ultra-deep spectra of the brightest cooling flow nebula, w07bn012.
- Jonker (SRON), High resolution spectra of the likely nearby low-mass X-ray binary IGRJ 00335+6126, w07bn008.
- McDermid (Leiden), The SAURON Complete Survey (SCS) of early-type galaxies, w07an001 [sic].
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SP CAT

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SP SAT

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TNG-TAC Time Share

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ITP

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UK PATT

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NL PC

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ITP Allocations

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Appendix E

ING BIBLIOGRAPHY

Below are listed research papers which were published in refereed journals in 2006 or 2007, and which make direct use of data from ING telescopes. The list includes papers based on data from the ING archive. It excludes papers which merely refer to data presented in earlier papers. This bibliography was compiled from only the refereed journals *MNRAS*, *ApJ*, *ApJL*, *ApJS*, *AJ*, *PASP*, *A&A*, *Nature* and *Science*, although many other publications have appeared elsewhere, notably in workshop and conference proceedings and in PhD theses. For every paper the following information is given: author/s, year, title, journal (in italic), volume (in bold), first page, nationality of the first institution of the first author (in brackets, using the standard ISO abbreviations) and instruments used (in parentheses, please refer to the acronyms and abbreviations listed in the last pages of this biennial report). If the data came from one of the ING data archives then this is shown in the instrument field as follows: “archive” refers to the ING archive, “WFS” refers to the INT Wide-Field Survey archive, and “IPHAS” refers to the archive of the INT/WFC photometric H α survey of the northern Galactic plane. If the observations were obtained as part of an ING service or override proposal, then this is shown as “service” or “O/R” respectively in the instrument field.

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6. E. Noordermeer, J. M. van der Hulst, 2007, "The stellar mass distribution in early-type disc galaxies: surface photometry and bulge-disc decompositions", *MNRAS*, **376**, 1480. [NL] (WFC, JAG-CCD, service:JAG-CCD)
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Appendix F

ASTRONOMY STAFF RESEARCH PUBLICATIONS

The following includes all refereed and non-refereed publications of ING astronomers in the years 2006 and 2007. It is sorted by year and in alphabetical order (ING author appears in *italic* and **bold**).

2006

1. Alvarez-Candal, A., **Licandro, J.**, 2006, "The size distribution of asteroids in cometary orbits and related populations", *A&A*, 458, 1007.
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3. **Benn, C.**, 2006, "NAOMI/OASIS on-sky performance", *New Astron Rev*, 49, 625.
4. Bernkopf, J., **Fuhrmann, K.**, 2006, "Local subgiants and time-scales of disc formation", *MNRAS*, 369, 673.
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6. Buzzoni, A., Arnaboldi, M., **Corradi, R. L. M.**, 2006, "Planetary nebulae as tracers of galaxy stellar populations", *MNRAS*, 368, 877.
7. Campins, H., Ziffer, J., **Licandro, J.**, Pinilla-Alonso, N., Fernández, Y., L., de León, J., Mothé-Diniz, T., Binzel, R. P., 2006, "Nuclear Spectra of Comet 162P/Siding Spring (2004 TU12)", *AJ*, 132, 1346.
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Appendix G

SEMINARS

Date	Title	Speaker	University / Institution
2006			
24 Jan	The QSO HE1013-2136 ($z=0.785$): tracing the ULIRG - QSO connection towards large look-back times?	J. Heidt	Landessternwarte Heidelberg
3 Mar	Dwarf elliptical galaxies in clusters: near InfraRed perspectives	S. Zibetti	MPE, Germany
6 Mar	Cosmological Inflation	D. Paraficz	NOT
9 Mar	Formation, evolution and multiplicity of brown dwarfs and giant exoplanets	J. A. Caballero	ING
21 Apr	The chemical composition and the evolution of the Galaxy: halo, thick disk, and bulge	R. Gratton	Padua Observatory, Italy
27 Apr	High redshift Ly-alpha emitters in the GOODS-S field	K. Nilsson	ESO
5 Sep	The search for extrasolar planets: study of line bisectors and its relation with precise radial velocity measurements	A. Fiorenzano	TNG
11 Dec	The Tunable Heterodyne Infrared Spectrometer THIS	G. Sonnabend	Cologne, Germany
18 Dec	Recent developments around the European Extremely Large Telescope project	R. Rутten	ING
2007			
16 Jan	New tip-tilt system for GLAS	J. Skvarc	ING
5 Feb	Astronet: A Science Vision for European Astronomy	D. Lennon	ING
1 Mar	Spins and Origins of Near-Earth Objects	A. Fitzsimmons	QUB
8 Mar	Constraints on supernova progenitors from local stellar populations	J. P. Anderson	Astrophysics Research Institute, LJMU
16 Aug	Transiting extrasolar planets	M. Hrudková	ING and Charles University, Czech Rep.
16 Aug	Rotation and massive star evolution	I. Hunter	ING and QUB
16 Oct	Properties of the Broad Line Region of quasars at $z\sim 0.3$	R. Decarli	Istituto Nazionale di Fisica Nucleare, Italy
23 Oct	ULTRASPEC: High-speed spectroscopy with zero readout noise	V. Dhillon	Sheffield University
6 Nov	Observational Evidence for Radiative Grain Alignment	B-G Andersson	SOFIA/USRA, USA

Appendix H

FINANCIAL STATEMENT

The funds approved by the international partners through the ING board totalled 2705kEUR. The observatory requested a portion of 465.5kEUR of the previously 'banked' money with PPARC. In addition 217.5kEUR were carried forward as unspent from 2005/06. Also, during the year funds were received from the EU and repayment services. Thus, the total cash budget available increased to 3507kEUR. Financial year 2006/07 saw an important increase in local salaries because vacancies arising from UK contracted staff were filled by recruitment on local contracts. The balance of expenditure against revenue at the end of the year showed an overspend of 115kEUR. This cash overspend largely arises from earlier delivery of certain items under the Enhancements Programme, in particular work carried out on the GLAS project. Details of the allocation and expenditure between the various activities is set out in the table below.

Financial year 2006/2007

Budget centre	Allocation kEUR	Expenditure kEUR
Operations		
Administration and management	50	37
Astronomy support	75	76
Conferences	5	-5
Engineering support	239	294
Local staff	1605	1602
ORM operations	730	696
Sea-level infrastructure and services	200	207
Students	22	18
SUBTOTAL	2926	2925
Enhancements and developments	581	697
TOTAL	3507	3622

The funds approved for Financial Year 2007/08 by the international partners through the ING board totalled 3102.5kEUR. The observatory requested a portion of 300.0kEUR of the previously 'banked' money with PPARC. The overspend of the previous year, 115.0kEUR, was accounted as negative income this financial year. Also, during the year funds were received from the EU, repayment services and support of research. Thus, the total cash budget available increased to 3580kEUR. Financial year 2007/08 saw an increase on local salaries because the policy to fill vacancies by recruitment in local contracts continued. The major investments under the Enhancements Programme have been on GLAS, CCDs and ACAM. The balance of expenditure against revenue at the end of the year showed a small overspend of 44kEUR. Details of the allocation and expenditure between the various activities are set out in the table below.

Financial year 2007/2008

Budget centre	Allocation kEUR	Expenditure kEUR
Operations		
Administration and management	35	29
Astronomy support	68	64
Conferences	5	1
Engineering support	243	247
Local staff	1700	1787
ORM operations	719	670
Sea-level infrastructure and services	220	206
Students	20	18
SUBTOTAL	3010	3022
Enhancements and developments	570	602
TOTAL	3580	3624

Appendix I

COMMITTEE MEMBERSHIP

ING BOARD

Prof T van der Hulst (to 10.2007)	Chairperson	University of Groningen
Prof J Hough (from 10.2007)	Chairperson	University of Hertfordshire
Dr S Berry (from 05.2007)		STFC
Dr P Crowther (to 05.2007)		University of Sheffield
Dr G Dalton		University of Oxford
Prof A Fitzsimmons (from 10.2007)		Queen's University Belfast
Dr R García López		IAC
Dr R Stark		NWO
Dr C Vincent (to 05.2007)		STFC
Ms D Telfer (to 05.2007)	Secretary	STFC
Ms M Cooper (from 05.2007)	Secretary	STFC

DIRECTOR'S ADVISORY COMMITTEE

Prof M McCaughrean	Chairperson	University of Exeter
Dr M Balcells		IAC
Dr P A James		Liverpool John Moores University
Dr N Tanvir		University of Leicester
Dr E Tolstoy		University of Groningen

ING TIME ALLOCATION GROUPS

UK Panel for the Allocation of Telescope Time (PATT)

Dr R D Jeffries (to 08.2007)	Chairperson	University of Keele
Dr R Oudmajer (from 09.2007)	Chairperson	University of Leeds

ING TAG:

Dr D Pollacco (from semester 2005B)	Chairperson	Queen's University of Belfast
Dr C Conzelice (from semester 2007A)		University of Nottingham
Dr M Jarvis (from semester 2005B)		University of Oxford
Dr J Knapen (locum for AS, 2006A only)		University of Hertfordshire
Dr C Knigge		University of Southampton
Dr M Page (from semester 2005B)		University College London
Dr G Ramsay (from semester 2008A)		Armagh Observatory
Dr A Sansom (to semester 2006B)		University of Central Lancashire
Dr M Sarzi (locum for MP, 2007A only)		University of Oxford
Dr S Smartt (to semester 2004B)		University of Cambridge
Dr P Wheatley (to semester 2007B)		University of Leicester
Dr I Skillen	Technical secretary	ING

NL ASTRON Programme Committee (PC)

Prof M Franx (from 09.2005)	Chairperson	University of Leiden
Dr H Röttgering (to 09.2005)	Chairperson	University of Leiden
Dr M Franx (from semester 2006A)		University of Leiden
Dr N Jackson (from semester 2006B)		University of Manchester
Dr M Verheijen (from semester 2005B)		Kapteyn Institute
Dr M Hogerheijde (to semester 2007A)		University of Leiden
Dr R Wijers (to semester 2006B)		University of Amsterdam
Dr T Oosterloo (to semester 2006B)		ASTRON
Dr S Trager (to semester 2007B)		University of Groningen
Dr J Kaastra (to semester 2008A)		SRON
Dr B Brandl (to semester 2008A)		University of Leiden
Dr L Kaper (from semester 2007B)		University of Amsterdam
Dr B Stappers (to semester 2007B)		ASTRON
Dr G Nelemans (from semester 2007A)		University of Nijmegen
Dr S Larsen (from semester 2008A)		University of Utrecht
Dr F van der Tak (from semester 2007B)		SRON

Dr R Strom (locum for Stappers, 2008A)

ASTRON

SP Comité de Asignación de Tiempos (CAT)

Dr J A Belmonte
Dr J M Vilchez

Chairperson
Vice Chairperson

IAC
IAA

Dr J A Acosta Pulido
Dr M Centurión
Dr G Yepes
Dr J.A López Aguerri
Dr J.A. Muñoz Lozano
Dr J Beckman
Dr J M Paredes
Dr G Stasinska
Dr E Martín Guerrero
Dr D Martínez Delgado
Dr F Najarro
Dr D Montes
Dr I Domínguez
Dr L Bellot
Dr M J Arévalo

IAC
Trieste Observatory
Universidad Autónoma de Madrid
IAC
Universidad de Valencia
IAC-CSIC
Universidad de Barcelona
OBSPM
IAC
IAC
DAMIR
Universidad Complutense de Madrid
Universidad de Granada
IAA
IAC

Appendix J

ADDRESSES AND CONTACTS

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ING's sea-level office: Mayantigo building; C/ Alvarez de Abreu, 70, 2nd floor; E-38700 Santa Cruz de La Palma; Canary Islands; Spain.

ING at Observatorio del Roque de los Muchachos: Tel: +34 922 405 500 (residencia's reception); +34 922 405 559 (WHT control room); +34 922 405 640 (INT control room); +34 922 405 585 (JKT control room).

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Director	Don Carlos Abrams	421	director
Head of Administration	Juan Martínez	418	juan
Head of Astronomy	Chris Benn	432	crb
Head of Engineering	Don Carlos Abrams	450	don
Head of Operations	Michiel van der Hoeven	467	mvdh
Head of Computing	Craige Bevil	422	cb
Head of Telescopes & Instrumentation	Diego Cano	404	dcano
Public Relations	Javier Méndez	464	jma
Telescope Scheduling	Ian Skillen	439	wji
Service Programme	Javier Méndez	464	service
WHT Manager	Chris Benn	432	crb
INT Manager	Pablo Rodríguez	441	prguez
Personnel	Chelo Barreto	417	chelo
Health and Safety	Jürg Rey	453	juerg
Freight	Lourdes González	413	lourdes

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Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO). P.O. Box 93138; 2509 AD Den Haag; The Netherlands; Tel: +31 (0)70 34 40 640; Fax: +31 (0)70 38 50 971; URL: <http://www.nwo.nl/>.

Instituto de Astrofísica de Canarias (IAC). C/ Vía Láctea s/n; E-38200 La Laguna; Canary Islands; Spain; Tel: +34 922 605 200; Fax: +34 922 605 210; URL: <http://www.iac.es/>.

Enquiries about the operation of the Roque de Los Muchachos Observatory can be made to the Instituto de Astrofísica de Canarias (IAC), see address above. Enquiries about observing time on the ING telescopes allocated by the Panel for the Allocation of Telescope Time (PATT) should be made to the executive secretary, PATT, at the STFC address given above, or for Dutch time to the chairperson of the Programme Committee (PC), email: nfra_pc@astro.rug.nl. Enquiries about the share of time at the disposal of Spain should be made to the Comité para la Asignación de Tiempos (CAT), at the IAC address given above. Enquiries about the international time scheme should be made to the Secretary, CCI, at the IAC address given above.

Appendix K

ACRONYMS AND ABBREVIATIONS

ASP Conf Ser	Astronomical Society of the Pacific Conference Series
A&A	Astronomy and Astrophysics Journal
A&A Suppl	Astronomy and Astrophysics Journal Supplement Series
AJ	Astronomical Journal
Astron Soc Pac Conf Ser	Astronomical Society of the Pacific Conference Series
ApJ	Astrophysical Journal
ApJS	Astrophysical Journal Supplement Series
Astrophys Space Science	Astrophysics and Space Science Journal
AU	Astronomical Unit (1.496×10^8 km)
AUTOFIB	Autofib Fibre Positioner
AF2	Autofib Fibre Positioner
Aux	Auxiliary Port at the WHT Cassegrain focus
Bull Am Astron Soc	Bulletin of the American Astronomical Society
Cass	Cassegrain focus
CAT	Comité para la Asignación de Tiempos (Spanish panel for the allocation of telescope time)
CCD	Charge-Coupled Device
CCI	Comité Científico Internacional (International Scientific Committee) for Astrophysics
CfA	Harvard-Smithsonian Centre for Astrophysics
CIRSI	Cambridge Infra Red Survey Instrument
CIRPASS	The Cambridge Infrared PANoramic Survey Spectrograph
DAS	Data Acquisition System
DIAS	Dublin Institute for Advanced Studies
DIMM	Differential Image Motion Monitor
ESA	European Space Agency
ESTEC	European Space Technology Centre
FastCam	High spatial resolution camera
FWHM	Full Width Half Maximum
GHaFaS	Galaxy Halpha Fabry-Perot System
GHRIL	Ground Based High Resolution Imaging Laboratory
GLAS	Ground-layer Laser Adaptive optics System
GRACE	GRound based Adaptive optics Controlled Environment
GranTeCan	Gran Telescopio Canarias
GT	Guaranteed Time
HST	Hubble Space Telescope
IAA	Instituto de Astrofísica de Andalucía
IAC	Instituto de Astrofísica de Canarias
IAU	International Astronomical Union
IAU Circ	IAU Circular
IAUNAM	Instituto de Astronomía de la Universidad Nacional Autónoma de México
IC	Imperial College
ICS	Instrument Control System
ICSTM	Imperial College of Science, Technology and Medicine
IDS	Intermediate Dispersion Spectrograph
IFCA	Instituto de Física de Cantabria
IMAFF	Instituto de Matemáticas y Física Fundamental, Madrid
INAOE	Instituto Nacional de Astrofísica, Óptica y Electrónica, Mexico
Inf Bull Variable Stars	Information Bulletin on Variable Stars
ING	Isaac Newton Group
ING Newsl	ING Newsletter
INGRID	ING Red Imaging Device
Int Astron Union Symp	International Astronomical Union Symposium
INT	Isaac Newton Telescope
INTEGRAL	Integral field fibre feed for WYFFOS
IoA	Institute of Astronomy
IR	Infrared
Irish Astron J	Irish Astronomical Journal
ISIS	ISIS double spectrograph
ITP	International Time Programme
JAG	JKT Acquisition and Guiding Unit
JKT	Jacobus Kapteyn Telescope
JOSE	Joint Observatories Seeing Evaluation programme
JSC	Joint Steering Committee
LAEFF	Laboratory for Space Astrophysics and Fundamental Physics
LDSS-2	Low Dispersion Survey Spectrograph

LIRIS	Long-Slit Intermediate-Resolution Infrared Spectrograph
LJMU	Liverpool John Moores University
MARTINI	Multi-Aperture Real Time Image Normalisation Instrument
MES	Manchester Echelle Spectrograph
Mem Soc Astron Ital	Memorie della Società Astronomica Italiana
MNRAS	Monthly Notices of the Royal Astronomical Society
MOMI	Manchester Occulting Mask Imager
MPIA	Max Planck Institute of Astrophysics
MSSL	Mullard Space Science Laboratory
MSSSO	Mount Stromlo and Siding Spring Observatories
Musicos	Multi-Site COntinuous Spectroscopy (fibre spectrograph on the INT)
NAOMI	Natural guide star Adaptive Optics system for Multiple-Purpose Instrumentation
NBST	National Board of Science and Technology of Ireland
New Astron	New Astronomy Journal
New Astron Rev	New Astronomy Review
NRAL	National Radio Astronomy Laboratory
NWO	Nederlandse organisatie voor Wetenschappelijk Onderzoek
OAN	Observatorio Astronómico Nacional
OASIS	OASIS Integral Field Spectrograph
ORM	Observatorio del Roque de los Muchachos (Roque de los Muchachos Observatory)
OSCA	OSCA Coronagraph
PASA	Publications of the Astronomical Society of Australia
PASP	Publications of the Astronomical Society of the Pacific
PATT	Panel for the Allocation of Telescope Time
PF	Prime Focus
PFC	Prime Focus Camera
PFIP	WHT's Prime Focus Imaging Platform
Planet Space Sci	Planetary and Space Science Journal
PlanetPol	High Sensitivity Polarimetre for the Direct Detection and Characterisation of Scattered Light from Extra-solar Planets
PN.S	Planetary Nebula Spectrograph
PP	People's Photometer
PPARC	Particle Physics and Astronomy Research Council
Proc	Proceedings
QMW	Queen Mary and Westfield College
QUB	Queen's University Belfast
RBS	Richardson-Brealy Spectrograph
Rev Mex Astron Astrof	Revista Mexicana de Astronomía y Astrofísica
Rev Mex Astron Astrof Conf Ser	Revista Mexicana de Astronomía y Astrofísica Series de Conferencias
RGO	Royal Greenwich Observatory
RAL	Rutherford Appleton Laboratory
SAT	Spanish Additional Time
S-Cam	Super-conducting tunnel junction Camera
SAURON	Spectrographic Areal Unit for Research on Optical Nebulae
SLODAR	SLOpe Detection And Ranging
Space Sci Rev	Space Science Reviews
SPIE	Society of Photo-optical Instrumentation Engineers
STFC	Science and Engineering Facilities Council
STScI	Space Telescope Science Institute
TAC	Time Allocation Committee
TAG	Time Allocation Group
TAURUS-II	TAURUS Fabry-Perot spectrograph or imager
TCS	Telescope Control System
TNG	Telescopio Nazionale Galileo
TRIFFID	Galway/DIAS Image Sharpening Camera
UCL	University College London
UCLAN	University of Central Lancashire
UCM	Universidad Complutense de Madrid
UES	Utrecht Echelle Spectrograph
UKIRT	United Kingdom Infrared Telescope
ULTRACAM	Ultra-fast, triple-beam CCD camera
WHIRCAM	William Herschel Infrared Camera
WFC	Wide Field Camera
WFS	Wide Field Surveys with the WFC
WHT	William Herschel Telescope
WYFFOS	Wide Field Fibre Optics Spectrograph
ZAMS	Zero-Age Main Sequence



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