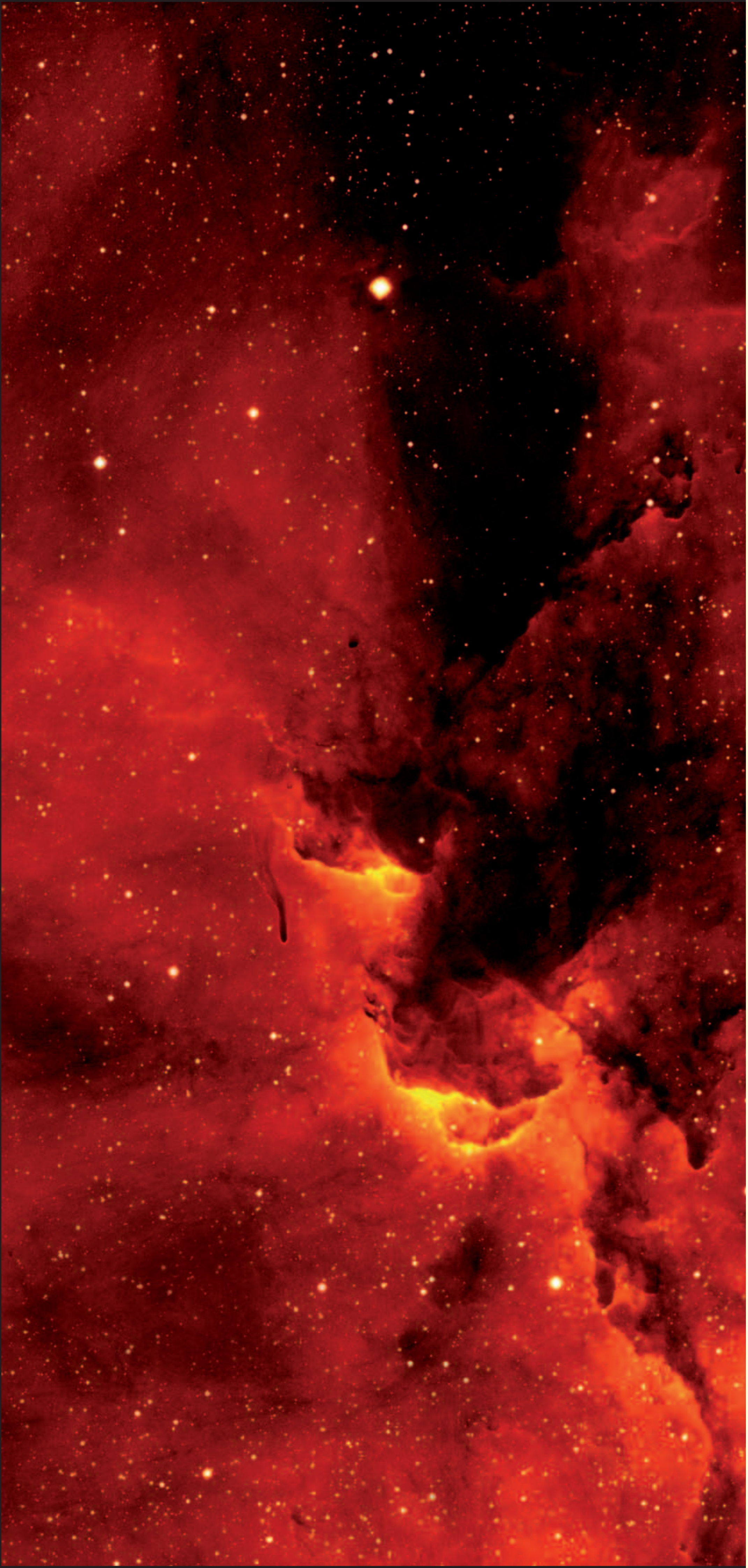
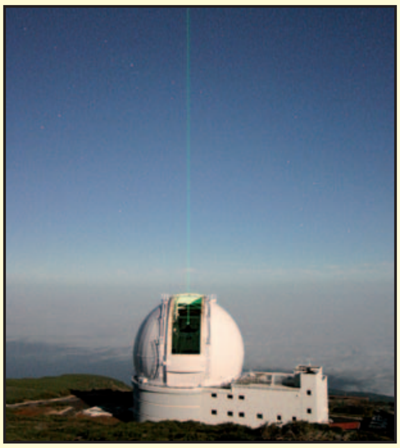


Isaac Newton Group of Telescopes

Biennial Report 2004 2005



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Front cover: IC1396 or the Elephant Trunk Nebula. Image obtained as part of the Isaac Newton Telescope Photometric Hα Survey of the Northen Galactic Plane, and it was prepared by Nick Wright, University College London. Inset: Photograph of laser test on the William Herschel Telescope as part of GLAS preparatory study. Credit: Javier Méndez.

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The ING Biennial Report is available online at http://www.ing.iac.es/PR/AR/ *or at* http://www.ast.cam.ac.uk/ING/PR/AR/.

Isaac Newton Group of Telescopes

Biennial Report

of the PPARC-NWO-IAC ING Board

2004 – 2005

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 Roque de Los Muchachos Observatory (ORM) on the island of La Palma, Canary Islands, Spain. The WHT is the largest telescope of its kind in Western Europe.

The construction, operation, and development of the ING telescopes is the result of a collaboration between the United Kingdom, 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. The remaining 5 per cent is reserved for large scientific projects to promote international collaboration between institutions of the CCI member countries.

The ING operates the telescopes on behalf of the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom, the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of The Netherlands and the Instituto de Astrofísica de Canarias (IAC) of Spain. The Roque de Los Muchachos Observatory, 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 2004-2005 Biennial Report of the Isaac Newton Group of Telescopes, on behalf of the ING Board.

The period 2004-2005 marks a new phase for the ING. The restructuring of the organization, prompted by a reduction in the level of funding, was completed in this period and at the end of this period the ING underwent a major review with a very positive outcome. These two aspects mark this period very well: despite the restructuring the ING has been able to maintain and develop a world class observatory with facilities that are high in demand and produce excellent science. The Board is very impressed with these accomplishments and wants to compliment the entire ING staff for carrying the observatory through harsh times in such an effective way.

The participation of the IAC in the ING was very important for maintaining the funding of the ING at an appropriate level. In my opinion it has accomplished even more. It resulted in a more intensive collaboration between the different ING partners, which will prove to be invaluable for the future of the observatory at the Roque de Los Muchachos.

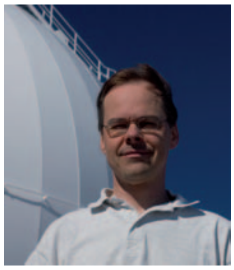
The past two years have been very productive from a scientific point of view. LIRIS, the near infrared imager/spectrograph designed and built by the IAC for the WHT, was commissioned successfully and has done exciting first science. As part of the NASA Deep Impact campaign it observed the collision between an impactor probe and the nucleus of comet 9P/Tempel1. Another new WHT instrument, OASIS, opened the area of high spatial-resolution imaging-spectroscopy. In combination with NAOMI, the adaptive optics system, it provides a unique capability for a wide range of interesting problems, ranging from the dynamics in the very centers of galaxies to spectroscopy of individual stars in star clusters or crowded regions. The laser guide star system that is now put together will open up the entire northern sky for AO assisted spectroscopy and imaging and bring to fruition a technical and science area that will prove to be very interesting and strategically important for both the ING and its communities.

But there was more: the demand for visiting instruments, all producing high quality science, remains higher than can be accommodated. The review panel recognized that the WHT is one of the few 4-m class telescopes that accommodates visiting instruments and considered this a very strong aspect in many respects: it produces excellent science and it maintains high quality instrument development within the community. The suite is quite impressive: PN.S, CIRPASS, INTEGRAL, SAURON, PLANETPOL and others to come.

The INT, now operational in a single instrument mode, as was the JKT before its retirement, continues to entertain excellent projects. Highlights are charting the environs of the Local Group galaxies Messier 31 and Messier 33 to unprecedented deep levels, the jet driven ring around Cygnus X-1 and the rings around planetary nebulae reflecting the mass loss history of the dying stellar precursor.

The Board started focusing 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 recognized. The ING community and the review panel have already made this clear, and we expect the funding agencies to come with positive formal statements soon. The pressure on funding in the presently participating countries is high and resources need to be shared with a several new initiatives in the realm of future large facilities. Yet the Board hopes, with the community that the funding agencies have the insight that maintaining a world class facility, even though consisting of modest size telescopes by modern standards, is crucial for the health of its scientific community.

INTRODUCTION



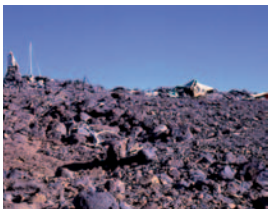
Dr. René Rutten
Director of ING

Welcome to the biennial report of the Isaac Newton Group of Telescopes for the years 2004 and 2005. The dynamics and excitement of astronomy have certainly been felt at the observatory during the last two years. As you can read in this report many scientific highlights passed the scene and important technical advances were made. This report provides an overview of the main events and summarizes the financial status and scientific output of the telescopes. The successes and achievements over the period covered by this report have only been possible thanks to the continued quality efforts of ING staff, who have shown a high level of commitment and professionalism through uncertain and sometimes difficult times.

It is now some thirty years ago that La Palma was being explored as a potential location for a new observatory in the Northern hemisphere. That choice has most certainly paid off in scientific terms. The site testing equipment in those days was not so sophisticated to today's standards and the circumstances under which the work was conducted were rather primitive. The pictures below (courtesy of site tester Thomas Gough) give an impression of the situation. Although the observatory is now well established, characterization of the observing site continues and is even stepping up pace with the advent of adaptive optics, the construction of very large telescopes such as the 10m GTC, and the possibility of construction of a future Extremely Large Telescope. In the early days analysis of star trails and of sparse meteorological measurements were the basis for initiating the observatory; now we possess an arsenal of additional tool such as DIMM, MASS, SLODAR, and remote sensing to help us decide on the quality of the atmosphere. But what remains the same is the finding that La Palma is one of the very best observing sites in the World.

The reporting years saw also intense activity on growing European collaboration between observatories in which ING was strongly involved. Under the umbrella of OPTICON a large programme to promote trans-national access to telescopes was initiated. The demand for observing programmes for the ING telescopes was so large that limits had to be imposed to prevent the scheme from running out of resources. European collaboration, not only for the construction of future large facilities, but also for existing observatories will be beneficial to European astronomy at large. ING hopes to play a key role in this as well.






Chapter 1

SCIENTIFIC HIGHLIGHTS

THE DISCOVERY OF A GALAXY-WIDE SUPERWIND FROM A YOUNG MASSIVE GALAXY AT REDSHIFT Z≈3

The formation of galaxies requires gas to cool in haloes of dark matter that collapse under gravity from the expansion of the Universe. However, cooling alone overproduces bright galaxies at the present day, so models incorporate thermal conduction, photoionisation and galaxy merging, together with additional feedback in the form of galactic-scale outflows. The latter are powered by supernovae and massive stellar winds, or by relativistic winds and jets resulting from gas accretion onto supermassive black holes. These high-velocity galactic outflows mark the termination of star formation in the most massive galaxies and deposit heavy elements in the intergalactic medium.

Although starburst superwinds have been studied in local dwarf galaxies, such as M82, observational evidence for their counterparts in young massive galaxies at high redshift has been less direct: it is unclear whether such outflows are localised to regions of intense star formation just a few kiloparsecs in extent, or whether they instead have a significant impact on the entire galaxy and its surroundings.

To observe such outflows via absorption studies a background light source is needed with a spatial extent somewhat larger than a Lyman-break galaxy stellar body or a quasar sightline. Such a source is provided by the recently discovered Lyman-α-emitting blobs (LABs), associated with Lyman-break galaxies in the SSA22 protocluster at redshift z=3.09 (seen 11.5 gigayears ago when the Universe was 20 per cent of its current age), a structure which is likely to evolve into a rich cluster of galaxies. Sizes of these LABs are around 100 kiloparsecs and Lyman-α luminosities of about 10^{44} erg s^{-1}.

The Lyman-α haloes of two of these LABs were observed using integral-field spectroscopy, which, unlike conventional

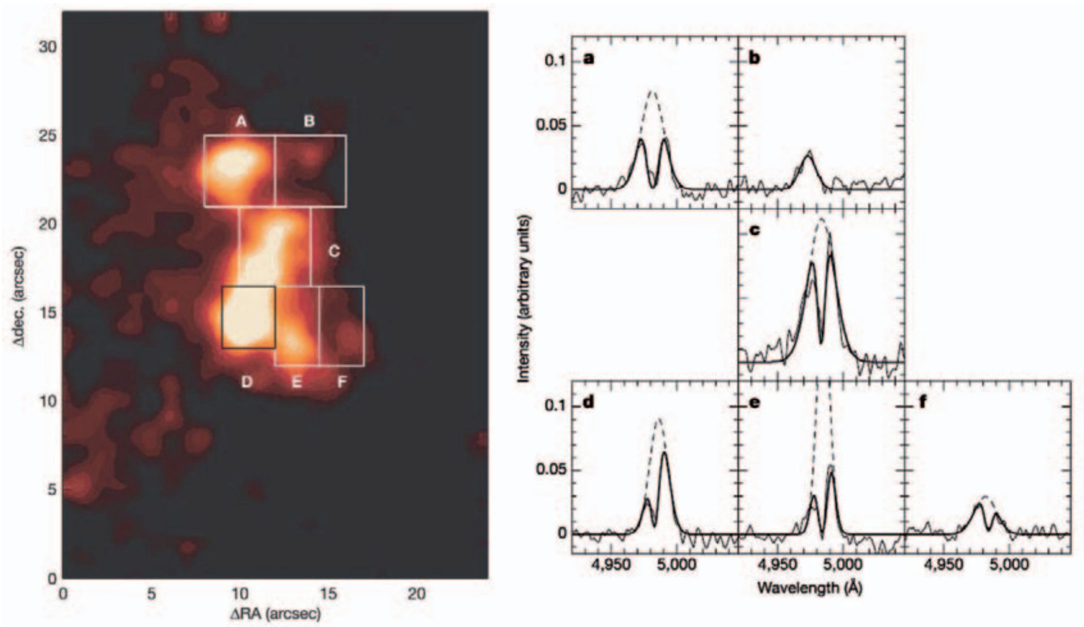


Figure 1. Left: This shows the extent of the gaseous halo of LAB-2 (10 arcsec on the sky equates to a physical distance of 76 kpc in this galaxy approximately). The image was derived from observations with the SAURON Integral Field Spectrograph, by collapsing the data cube along the wavelength direction. The labels indicate regions for which one-dimensional Ly-α emission line profiles have been extracted and shown on the right. Right: Thick solid lines are fits to a model where the intrinsic Ly-α emission (dashed lines) is partially absorbed by foreground HI.

slit spectroscopy, gathers spatially resolved spectra over a two-dimensional area. Such information is essential for a complete picture of the complex morphology of these objects. Astronomers used the SAURON Integral Field Spectrograph on the William Herschel Telescope providing moderate resolution spectra over a 41 arcsec×31 arcsec area, sampled with 0.95-arcsec lenslets.

Observations of object LAB-2 shows that its spatially extended Lyman-α line emission appears to be absorbed by neutral hydrogen in a foreground screen covering the entire galaxy, with a lateral extent of at least 100 kiloparsecs (over 300,000 light years across or about three times larger than the disk of our own Milky Way galaxy) and remarkable velocity coherence. Based on the uniformity of the absorption across the galaxy, it appears that this screen was ejected from the galaxy during a starburst several hundred million of years earlier and has subsequently swept up gas from the surrounding intergalactic medium and cooled. This provides the most direct evidence yet of a galaxy being almost torn apart by the galaxy-wide impact of high-redshift superwinds.

An absorbing shell is predicted to form when a starburst-heated hot gas bubble becomes over-pressurized relative to the interstellar medium and hence breaks out of the galactic disk, accelerates, and fragments as a result of Rayleigh-Taylor instabilities. Hot gas then escapes into the halo and forms a second shell of swept-up intergalactic medium. Evolutionary models for the Lyman-α emission from such superwinds suggest that the LAB-2 absorber is in a late phase, where the shell has cooled and slowed sufficiently to absorb the underlying emission.

Astronomers have long been puzzled about why key elements for the formation of planets and ultimately life (such as carbon, oxygen and iron) are so widely distributed throughout the Universe; only 2 billion years after the Big Bang, the remotest regions of intergalactic space have been enriched with them. The superwind observed in this galaxy shows how such blast waves can travel through space carrying the elements formed deep within galaxies.

THE ISAAC NEWTON TELESCOPE PHOTOMETRIC Hα SURVEY OF THE NORTHERN GALACTIC PLANE

Hα emission is ubiquitous in our Galaxy. It traces ionised gas of assorted nebulae such as HII regions, planetary nebulae, Wolf-Rayet nebulae, and supernova remnants. It is a strong signature of active stars, interacting binaries, very massive stars (especially supergiants, Luminous Blue Variables and Wolf-Rayet stars), Be stars, post-AGB stars, pre-main-sequence stars and so on. These objects represent important evolutionary phases which are generally short lived, and are hence few in number and difficult to find. Their discovery is therefore well worth the effort of a concerted programme and in August 2003 a major new survey project was started using the Wide Field Camera (WFC) on the Isaac Newton Telescope (INT) to do just that. It is called the INT Photometric Hα Survey of the Northern Galactic Plane, or IPHAS for short.

Its goal is to conduct an Hα survey of the entire northern Galactic Plane in the latitude range $-5° < b < +5°$, a sky area of 1800 deg^2, covering the magnitude range $13 < r' < 20$. When complete it will represent an enormous improvement over previous work. The final catalogue of IPHAS point sources will contain photometry on about 80 million objects. Used on its own, or in combination with near-infrared photometric catalogues, IPHAS will be a major resource for the study of stellar populations making up the disc of the Milky Way. The eventual yield of new northern emission-line objects from IPHAS is likely to be an order of magnitude increase on the number already known.

The next pages and the front cover of this Biennial Report show several examples of the images being obtained.

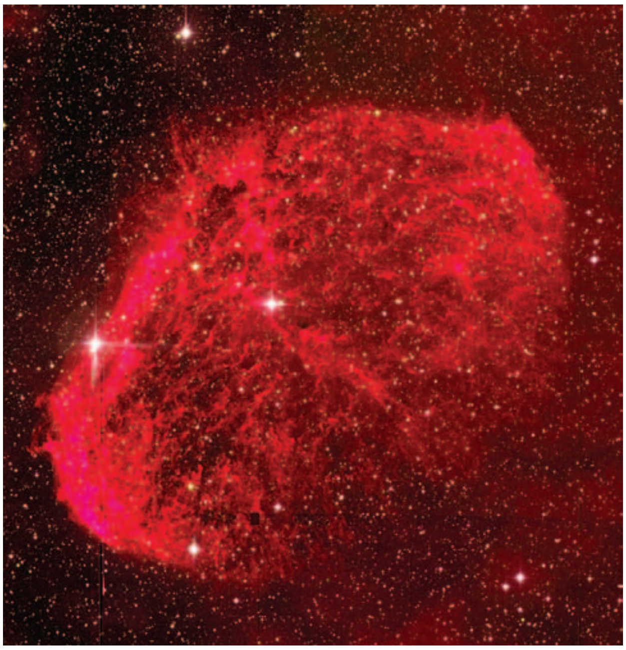
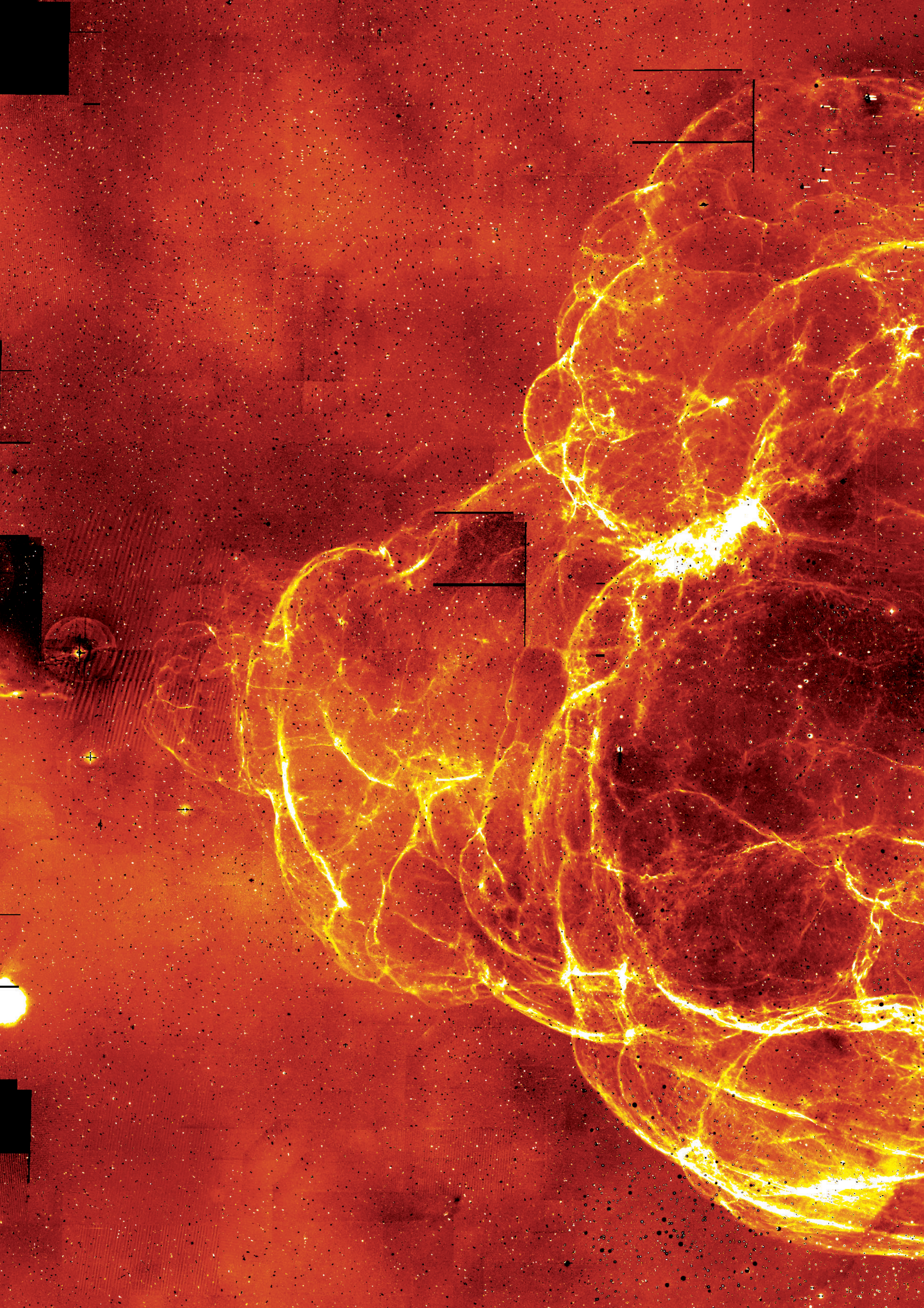
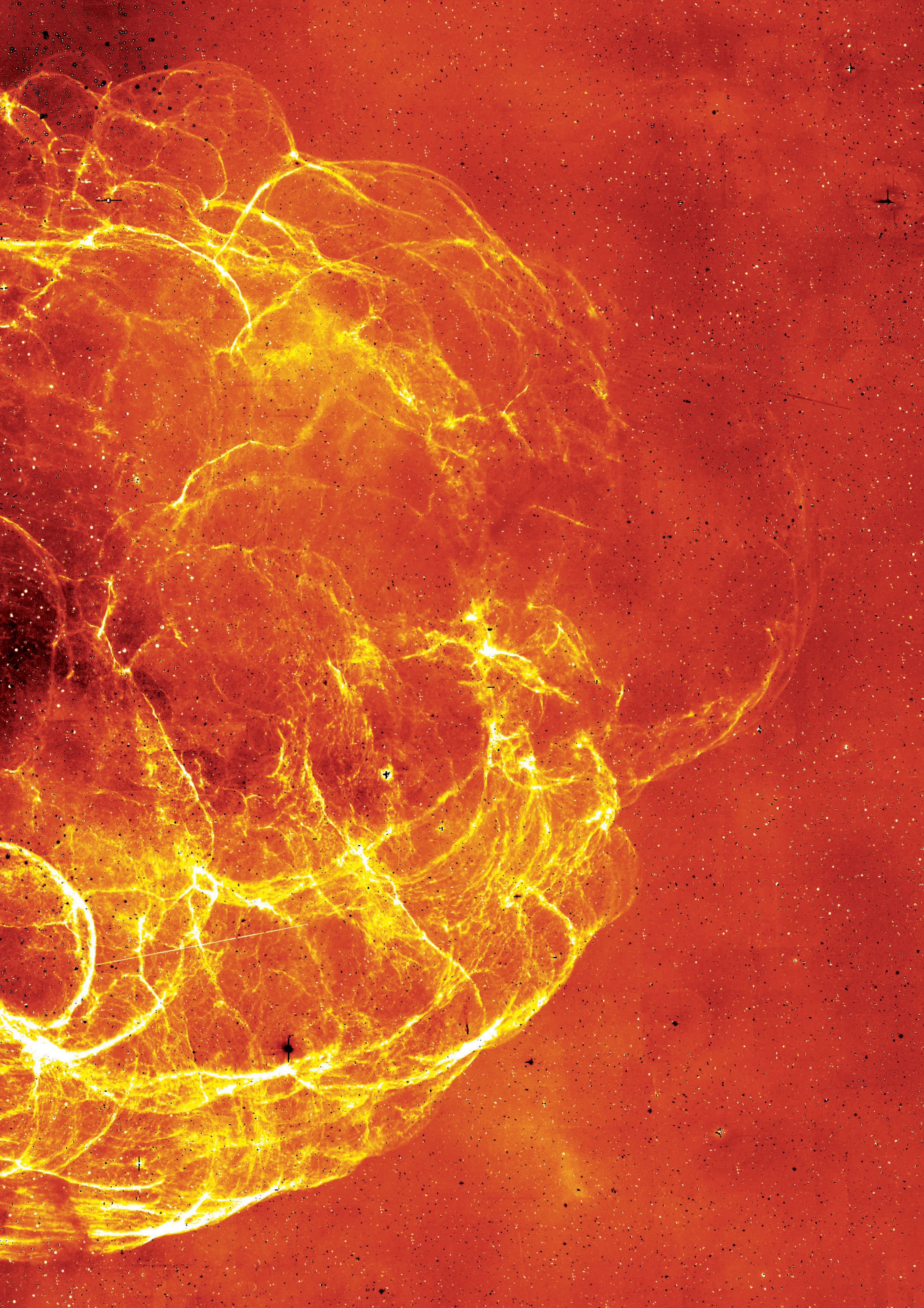


Figure 2. The crescent nebula, NGC6888, which surrounds the Wolf-Rayet star PPM 84423, seen in Hα emission by IPHAS.

Figure 3. Next two pages: a 5°×3.5° mosaic of the supernova remnant S147 in Hα. North is to the top and East to the left.





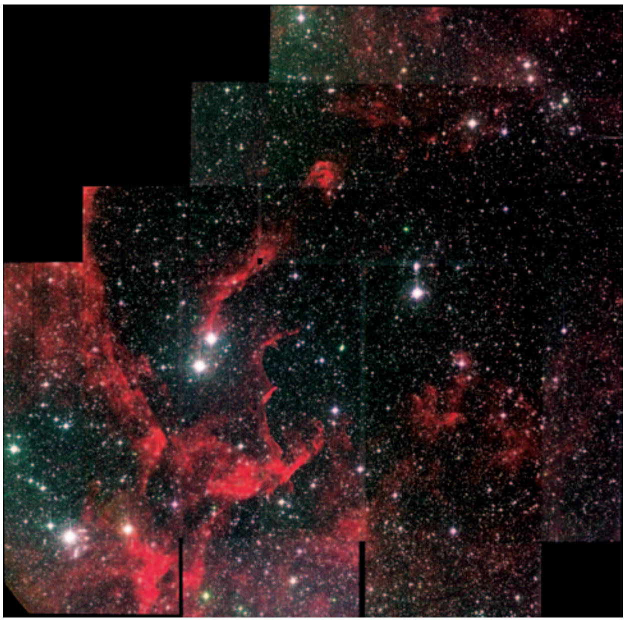


Figure 4. Filamentary Hα emission in Cygnus. The colour scheme is red for Hα, blue for the Sloan r' band, and green for Sloan i' band. As this is a significantly reddened region, as well as nebulous, there are many stars coming through strongly in the i' band, appearing here as a background of green stars.

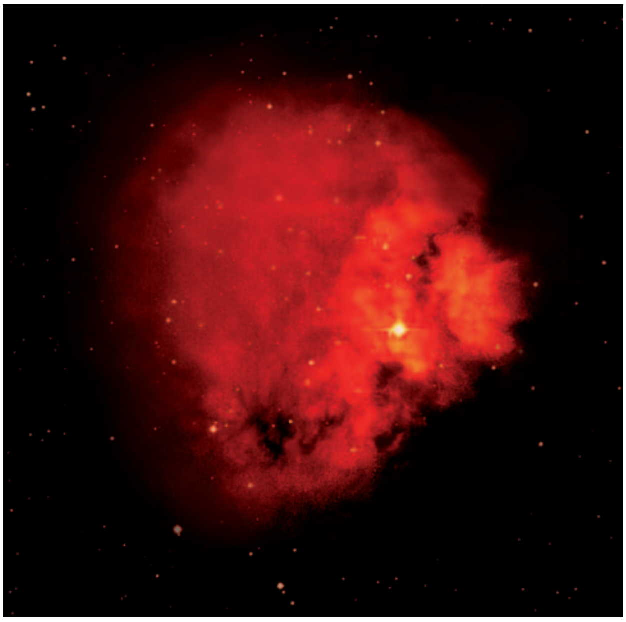


Figure 5. Sh2-242 is a small HII Region on the edge of a molecular cloud that lies just southeast of the supernova remnant Simeis 147 in the constellation of Taurus. There is evidence that this molecular cloud may contain a young stellar cluster of newly-born stars. Field of view is approximately 10×10 arcmin. North is down and East to the right.

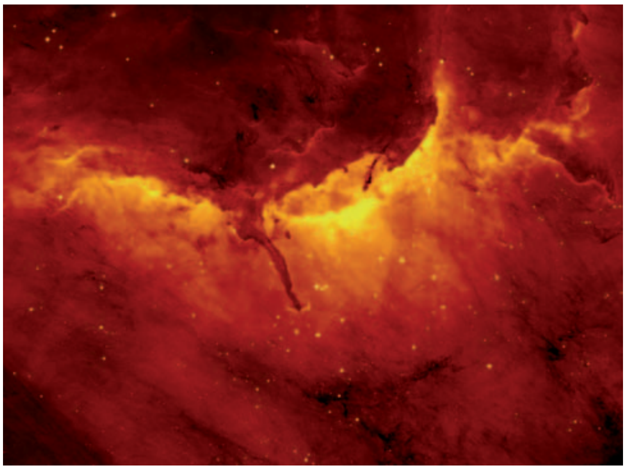


Figure 6. The Pelican Nebula is a massive nebula in the constellation of Cygnus. It lies close to the North American Nebula, the two being separated by a giant dust cloud. This image shows the main ionization front of the Pelican Nebula which makes up the head and neck of the Pelican. Recent observations have identified many new Herbig-Haro objects in this area, including two that can be seen in this image, the first on the far right hand side and the second at the end of the dust column in the second. Field of view is approximately 25×15 arcmin, North is to the left, East is down.

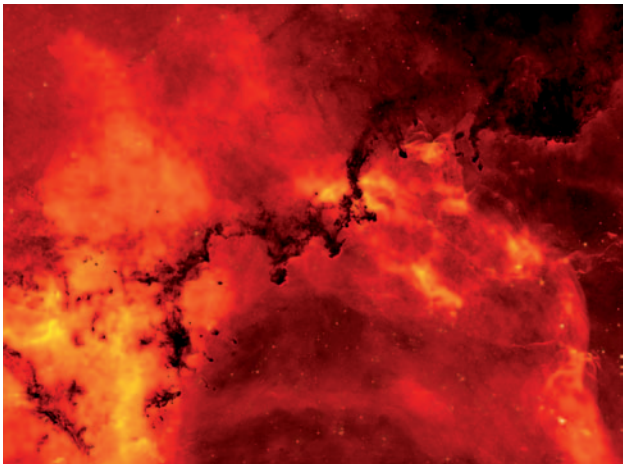


Figure 7. Dust lanes in the centre of the Rosette Nebula. Field of view is 30×20 arcmin, north to the left, east is down.

Figure 8. Sh 2-188 is a wind blown planetary nebula in Cassiopeia. It is a perfect example of a strong interaction between a planetary nebula and the interstellar medium. It shows a single arc-like structure with a faint, thin arc behind it. Also visible is a longer, wide arc extending away from the nebula itself. Recent studies have shown this shape to be due to the motion of the planetary nebula through the interstellar medium at a velocity of 125 km s^{-1}. Field of view is 22 × 22 arcmin, North is up, East to the left.

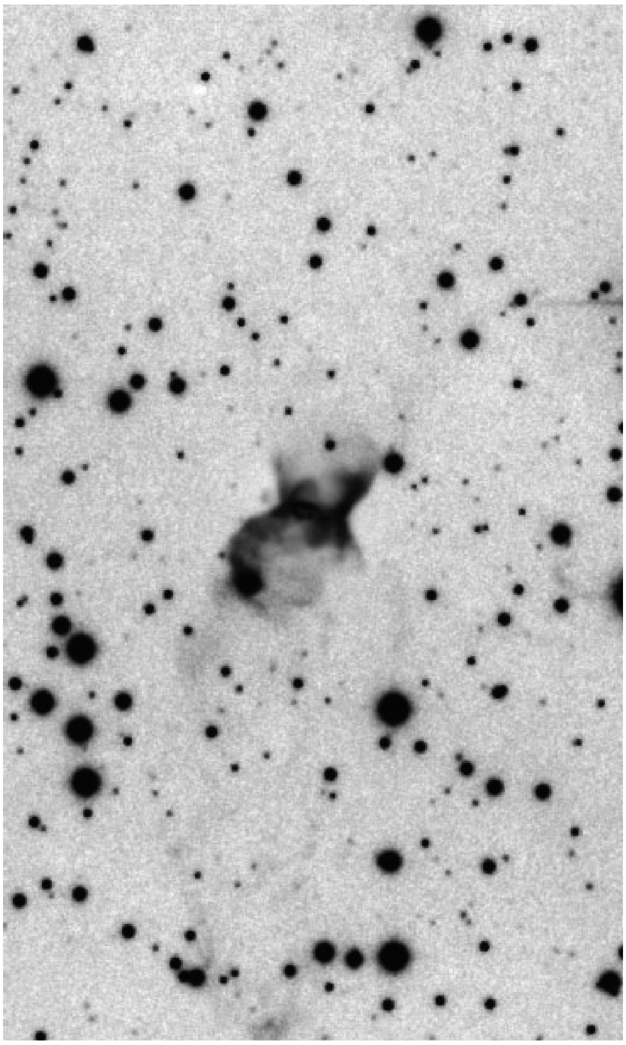


Figure 9. The newly discovered planetary nebula PN 126.62+1.32, the "Prince of Asturias" (named after the wedding of the Spanish Prince), is a rare quadrupolar nebula (central region), with extended fainter lobes extending over 16 arcminutes from the central star.

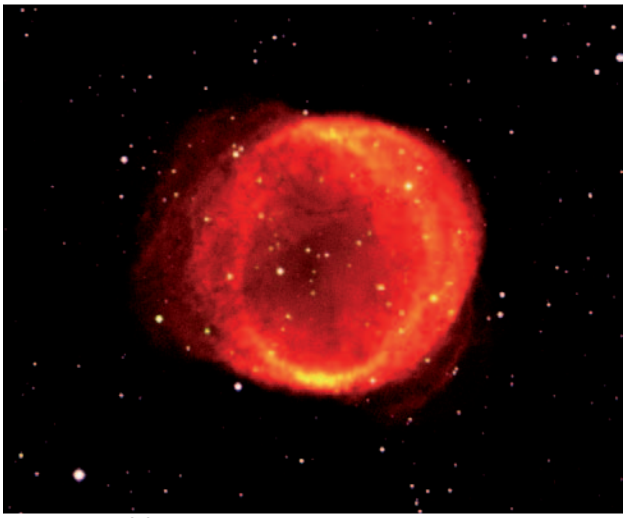


Figure 10. NGC 6781 is a small bubble-shaped planetary nebula. It is approximately 2 light years across and shows some structure in the centre similar to that seen in the Helix Nebula. Field of view is 6×6 arcmin.

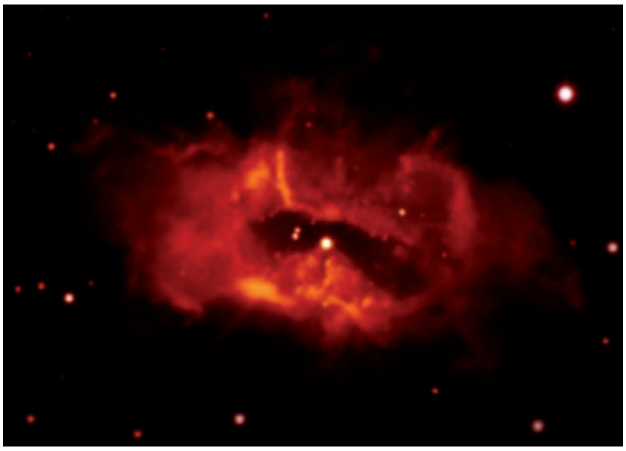


Figure 11. Sh 2-71 is quite an irregular planetary nebula. The central star is a variable star, and this may explain the strange shape of the nebula itself. Field of view is 4×3 arcmin.

THE COMPANION STAR TO TYPE IA TYCHO BRAHE'S 1572 SUPERNOVA

The brightness of type Ia supernovae, and their homogeneity as a class, makes them powerful tools in cosmology, yet little is known about the progenitor systems of these explosions. They are thought to arise when a white dwarf accretes matter from a companion star, is compressed and undergoes a thermonuclear explosion. Unless the companion star is another white dwarf (in which case it should be destroyed by the mass-transfer process itself), it should survive and show distinguishing properties.

Tycho's supernova is one of only two type Ia supernovae observed in our Galaxy, and so provides an opportunity to address observationally the identification of the surviving companion.

A team of astronomers carried out an imaging and spectroscopic survey using ISIS, UES and the Auxiliary Camera on the WHT of the central region of Tycho's supernova remnant, around the position of the explosion. The analysis of the data excluded red giants as the mass donor of the exploding white dwarf. However, they found a type G0–G2 star, similar to our Sun in surface temperature and luminosity (but lower surface gravity), moving at more than three times the mean velocity of the stars at that distance, which they claim to be the surviving companion of the supernova.

Tycho G is a star of type G0-G2 IV located at the distance of Tycho SNR and it moves in space at 136 km s^{-1}, which is a factor of over 3 larger than the mean velocity of the surrounding stars (Tycho G's metallicity in Fe and Ni are similar to solar values and therefore it can´t be a halo star). Its low surface gravity can also be interpreted as a consequence of mass stripped by the impact of the supernova explosion.

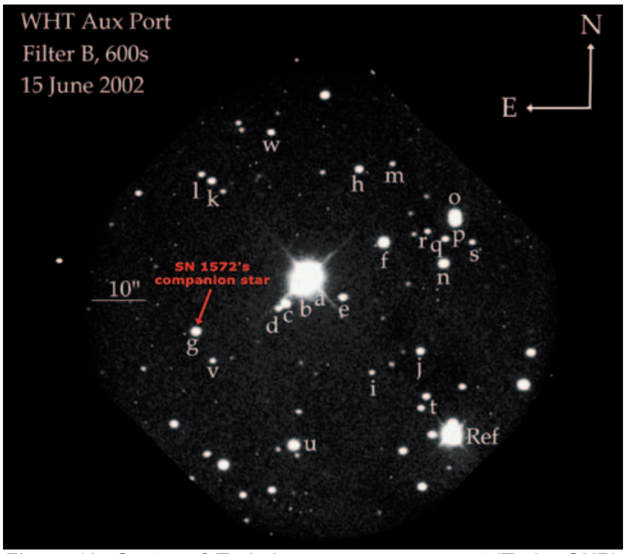


Figure 12. Centre of Tycho's supernova remnant (Tycho SNR). The star marked as 'G' is the one identified as the companion star of Tycho Brahe´s 1572 supernova. Since the supernova explosion in 1572, Tycho G has moved 2.6 arcseconds south on the sky.

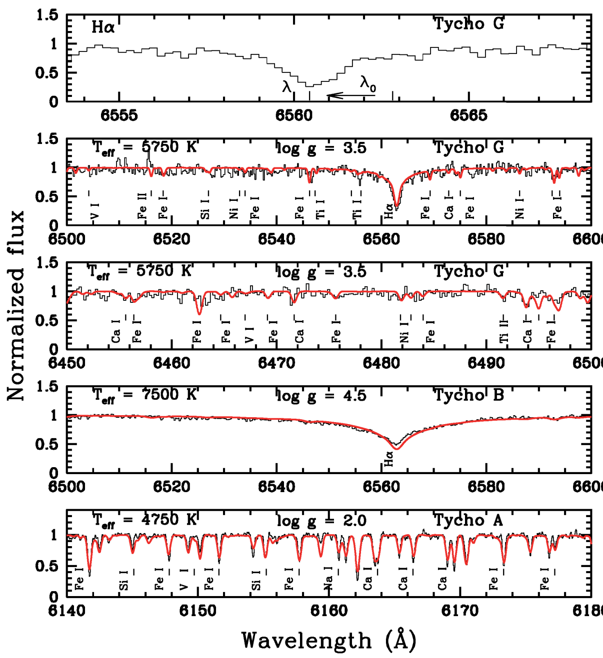


Figure 13. The spectra shown here are of the candidate star for the companion to SN 1572 (Tycho G), a red giant (Tycho A) and main-sequence star (Tycho B). Spectra were obtained at the WHT with UES and ISIS. The upper panel shows the observed spectrum near Hα. This line is blueshifted, implying a peculiar radial velocity exceeding about 3 times the velocity dispersion for its stellar type.

THE LARGEST KNOWN PLANETARY NEBULA ON THE SKY

The vast majority of Planetary Nebulae in our own Galaxy have been identified via wide-field narrow-band Hα surveys or through wide-field low-resolution slitless spectroscopic surveys, with both techniques attempting to isolate objects showing very high equivalent width emission lines that are characteristic of PNe.

Examining the results of an automated search of the Sloan Digital Sky Survey (SDSS) spectroscopic database for emission lines from putative high-redshift sources, one particular galaxy showed an unambiguous emission line detection with a somewhat weaker feature to the blue. The emission line pair was immediately identifiable as emission from [OIII] 4959, 5007. Not an entirely unexpected occurrence but the unusual feature of the detection was that the wavelength of the detection placed the emission at essentially zero radial velocity. Querying the output of the emission line search for similar detections produced more spectra showing a similar signature. All of the objects possessing [OIII] emission occurred in an approximately circular region with a diameter of ~1.5°, with not a single detection anywhere else on the sky. Investigation of SDSS spectra of stars, quasars and even sky fibres revealed further detections, all concentrated in the same region of sky.

A series of checks fairly rapidly eliminated the majority of instrumental artifacts or transient phenomena as the cause of the emission. Combining spectra beyond the boundaries of the region where [OIII] emission was detected produced clear detections of [OIII] emission extending over a region more than 2° in diameter. A smaller number of individual spectra also showed the presence of emission from Hα and [NII] 6548, 6583. The spatial distribution of the individual emission line detections revealed clear trends and composite spectra, made up from objects contiguous on the sky, confirmed the trends and even allowed the detection of [SII] 6718, 6732.

Narrowband imaging of the central part of the region was carried out using the WFC on the INT. The results were unambiguous, with excellent agreement between the surface brightness distribution evident in the INT images and the emission line detections from the SDSS spectra. A striking feature of the images was the presence of a well-defined arc-like feature, perhaps suggestive of some form of shock. A search of the region using SIMBAD revealed the presence, close to the region with the

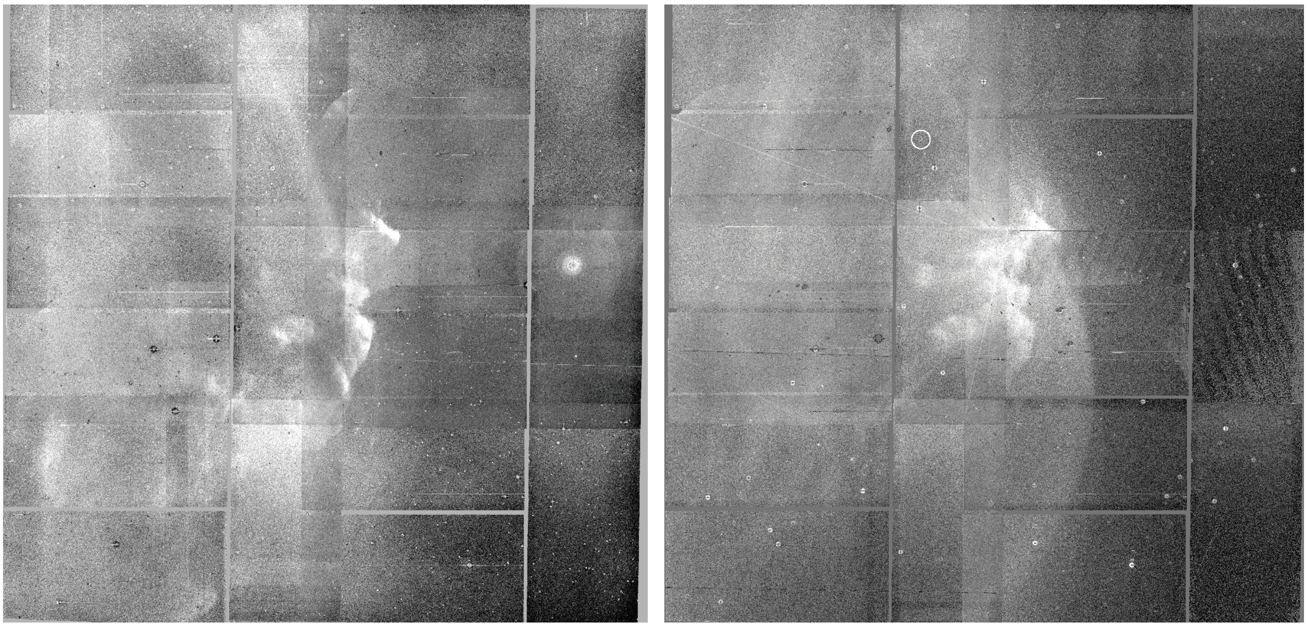


Figure 14. The left hand panel shows a mosaic of 6 INT WFC continuum–subtracted pointings in Hα+[NII] while the right panel shows the equivalent for [OIII]. The images are approximately 0.8° on a side with North to the top and East to the left. The location of the white dwarf PG1034+001 is indicated by a circle in the [OIII] image. Emission with complex structure is evident in the central regions of the images in both passbands. A well–defined arc, or boundary, is visible at center–right in the [OIII] image.

strongest [OIII] emission, of a very nearby, extremely hot DO white dwarf (PG 1034+001). The location of the white dwarf clinched the identification of the emission region as a PN.

The diameter of more than 2° makes the object the largest known PN on the sky. The spectroscopic distance estimate of 155+58 pc means the PN is certainly the second closest known and a parallax distance could confirm the nebula as the nearest PN to the Solar System. The unambiguous detection of a PN associated with a non-DA white dwarf is also a first. The PN is certainly old, an estimate of the expansion age and a kinematic age estimate, derived from extrapolating the observed proper motion of PG 1034+001 back to the origin of the radius of curvature of the arc feature, both suggest an age of ~100,000 years. The strongly enhanced [NII] emission evident along the south western boundary of the PN is also indicative of the interaction of an old PN with the surrounding interstellar medium.

FIRST DETECTION OF A PROGENITOR STAR FROM A NORMAL TYPE II-P SUPERNOVA

Supernova 2003gd was discovered on 12.82 June in the nearby spiral galaxy M74. From observations carried out using the ISIS spectrograph on the WHT, it was shown to be a type II–plateau (II-P) SN that was discovered about 87 days after explosion. A team of astronomers also observed its gradually fading light for several months using the INT.

The progenitors of type II-P SNe have long been thought to be red supergiant stars with initial masses greater than 8 to 10 solar masses that have retained their hydrogen envelopes before core collapse. This model accounts for the 2- to 3-month-long plateau phases seen in the lightcurves of SNe II-P, the existence of hydrogen P-Cygni profiles (which are indicative of an optically thick expanding atmosphere) in the early time spectra, and the estimated physical parameters of the expanding photosphere such as velocity, temperature, and density. Stellar evolutionary calculations are consistent with this picture, in which stars with initial masses in the range of 8 to 25 solar masses reach the end of their nuclear burning lives when they are red supergiants.

Only two progenitors of unambiguous SNe have been directly identified and yielded estimates of luminosity, temperature, and mass. These are the progenitors of the peculiar type II-P SN 1987A, which was a blue supergiant, and the IIb SN 1993J that arose in a massive interacting binary system. The expected red supergiant origin for the common type II-P SNe has so far eluded direct detection. The fortuitous coincidence of a type II-P SN occurring in a nearby galaxy that has high-quality prediscovery images available has allowed the direct determination of the physical parameters of a SN progenitor for only the third time.

Figure 15. Isaac Newton Telescope image of M74 (NGC 628) with inset (top) showing pre-explosion star (enhanced) from a Gemini image and (bottom) SN2003gd after it exploded from Isaac Newton Telescope when the supernova was 6 months old.

The galaxy M74 was observed with the HST about 200 days before the estimated explosion date of SN 2003gd of 18 March 2003 (with an uncertainty of about 21 days). This galaxy was also observed about 310 days before the explosion by the Gemini Telescope. An approximate position for the SN was estimated from images obtained using the Auxiliary Port Camera of the WHT and precise differential astrometry from HST images. Astronomers identified an object in the pre-explosion HST and Gemini images that is coincident with SN 2003gd.

This is the first detection of a progenitor star from a normal type II-P SN, which is the most common type of SN (by volume) in the Universe. It is a red supergiant, which is consistent with the models of single stellar evolution. Recently, there have been attempts to identify the progenitors of three nearby type II-P SNe by the same method as followed with SN 2003gd. Although these have failed to detect an object, they have been able to set restrictive upper mass limits. Mass limits of the progenitors were estimated to be 15 solar masses for SNe 1999em and 2001du and 12 solar masses for SN 1999gi. These three SNe and 2003gd are all spectroscopically very similar and appear to be a common, homogeneous class of type II. Stellar evolutionary models and theories of the SNe lightcurve and spectral evolution have long predicted that red supergiants should be the progenitors of SNe type II-P.

However, there is a quantitative discrepancy now appearing between the masses that have been derived for these four SNe II-P and the mass required to support the long plateau phase with normal expansion velocities. Consistently high ejecta masses have been derived for a large sample of 13 SNe II-P in the range of 17 to 56 solar masses, quite different from the low masses that the direct method suggests. However, the three SNe with excellent monitoring data and direct mass limits do show agreement, which is strong evidence that the common type II-P SNe originate in stars with masses between 8 and 15 solar masses.

A PANORAMIC DEEP VIEW OF THE STELLAR HALO OF ANDROMEDA GALAXY

The structure of the outer regions of galaxies is a key area in which to look for fossil remnants of the accreted masses from which the galaxies that we see today are thought to be built. The importance of these regions has increased in recent years as cosmological theories of structure formation become more exact in their predictions, and the observational instrumentation required to conduct these detailed analyses becomes more sophisticated.

Currently composed of 165 individual pointings of the INT Wide Field Camera (WFC), the M31 halo survey consists of photometry for over 7 million sources, on a photometric system accurate to 2% over ~40 square degrees on the sky, in some places probing the halo of Andromeda out to 6° (~80 kpc). Observations of 800–1000 seconds in the Johnson *V* (*V′*) and Gunn *i* (*i′*) passbands are deep enough to detect individual RGB stars down to *V′*= 0 and Main Sequence stars down to *V′*=–1. This unique dataset has provided, for the first time, a panoramic deep view of the stellar halo of a giant galaxy thought to be similar to our own Milky Way.

Despite exhibiting a near pristene disk, M31's halo is full of substructure and points to a history of accretion and disruption. The most obvious piece of substructure is the giant stellar stream (visible in the south-east). This extends to near the edge of the survey — a projected distance of some 60 kpc. In fact, by examining the systematic shift in the luminosity function of the stream as a function of galactocentric radius, a length much greater than 100 kpc is found. The similarity of the colour of this feature with the loop of material at the north of the survey suggests it seems likely that the northern feature is an extension of the stream, after it has passed very close to the centre of the potential of M31.

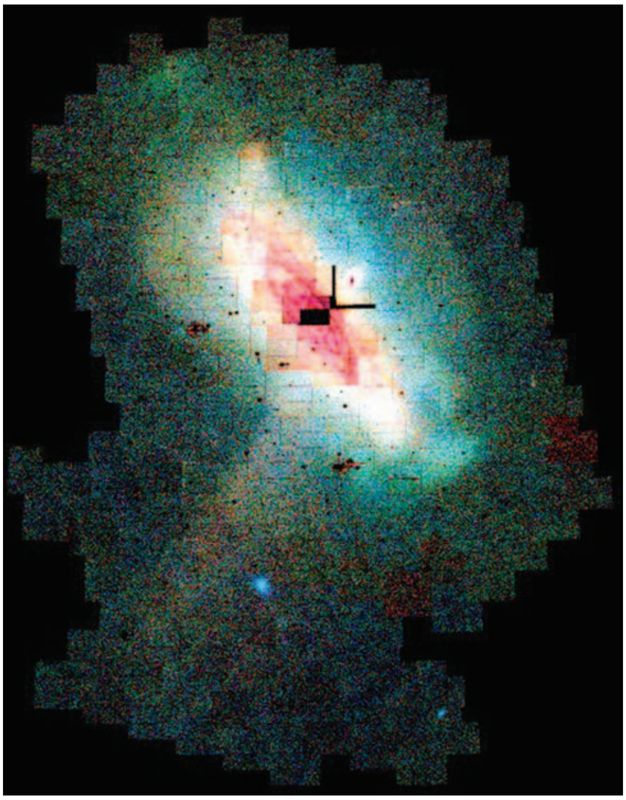


Figure 16. A multi-colour mosaic of the INT WFC survey of M31, involving 165 individual pointings over 40 square degrees of the sky, which shows the inhomogeneity of this system. Metal-poor/young stars are coded blue whilst metal rich/older stars are coded red. The (colour-dependant) substructure is obvious, and surprising given the pristene nature of the Galactic disk. The dwarf galaxies Andromeda I & III are visible at the bottom left of this figure; the newly discovered dwarf spheroidal, Andromeda IX, is just visible at the top left as a small blue dot. NGC 205 is also visible in this figure, at the right-hand side of the disk This spectacular image shows in amazing detail the wealth of information that the INT is helping to reveal about the structure of this previously invisible region of galaxies.

A second large stellar stream candidate has also been identified with the INT WFC photometry. The visible part of this feature is some 15 kpc long. The progenitor of this feature appears to be the satellite galaxy NGC 205. This object has long been known to be tidally perturbed but it is only now that the full extent of its disruption is becoming clear. Considerable amounts of other substructure exists in addition to these streams.

The other spiral in the Local Group, the Triangulum Galaxy (M33), has also been surveyed with the INT WFC. The structure of this galaxy is striking in comparison to M31: the lack of substructure is immediately obvious. It appears that not all spiral galaxy haloes need look like M31. There is then the question of the M31 dwarf satellite galaxies. The homogeneous nature of the data has allowed

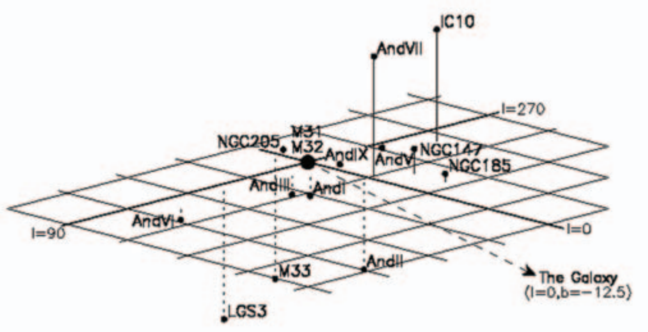


Figure 17. The distribution of the satellite galaxies of M31, as derived from the INT WFC photometry of these objects. The coordinate system is an M31–centric system. The plane is the plane of the disk of M31, and each cell corresponds to 100 kpc×100 kpc. l is a longitude measured around the disk of M31, such that l=0 is the longitude of the Galaxy. b is a latitude, measured from the disk of M31. Solid lines indicate objects located above the plane of the disk, while dashed lines indicate objects below the plane of the disk. A clear tendency for the satellites to lie on the near side of M31 can be observed, and suggests an intriguing correlation between the M31 satellites and our own Galaxy.

accurate and internally self-consistent distances and metallicities to be measured for each of these galaxies. For the first time, the three dimensional spatial distribution of these objects, has reliably probed and revealing that far from being isotropically distributed and unbiased indicators of the potential of Andromeda, there are strong indications that these objects are preferentially located on the near side of Andromeda, towards the Galaxy.

A NEW POPULATION OF STAR CLUSTERS IN THE HALO OF M31

As part of the INT WFC survey of M31, a search for globular clusters in a large part of the halo has been carried out. Globular clusters systems are valuable tools for the study of the evolution of their host galaxies, acting as chemical and dynamical probes. Specifically, most globular clusters are believed to be old objects, and thus provide clues to the earliest epochs of galaxy formation history.

Three extended, luminous globular clusters were discovered during this search for classical clusters. Although having globular-like colours and luminosities, they have unusually large half-light radii, ~30 pc (compared to typical values between 1 and 7 pc) and they are hundreds of times less dense — the distances between the stars are, therefore, much greater. They lie at projected galactocentric distances of ~15 to ~35 kpc. These objects begin to fill the gap in parameter space between (negligible dark matter) classical globular clusters and (dark matter dominated) dwarf spheroidals, and are unlike any clusters found in the Milky Way, or elsewhere to date.

The fields visually investigated included the whole INT Wide Field Survey of M31, an area far into the halo, and an additional region south along the Andromeda Stream, and towards M33, making a total area of more than 40 deg^2. The survey consisted of *V'*- and Gunn *i'*-band images reaching limiting magnitudes of *i'*=23.5 and *V'*=24.5, and taken in average seeing of 1.2 arcsec. These images were processed by the INT-WFS pipeline provided by the Cambridge Astronomical Survey Unit, which includes tools for astrometry, photometry and object description and classification.

The extended M31 clusters have no known analogues in the Milky Way, where such clusters would certainly have been discovered if they existed, unless hidden by the plane of the Galaxy. This suggests that they could hold important clues to the differing formation histories of these galaxies. If these clusters were not born with their present morphology then one may speculate that they are the stripped cores of cannibalized dwarf spheroidal galaxies, or the products of cluster mergers perhaps themselves created in a previous interaction of a gas-rich companion with M31.

RINGS IN THE HALOES OF PLANETARY NEBULAE

The end-point of the evolution of solar-type stars is essentially determined by the onset of a strong stellar wind, which, in a few hundred thousand years completely removes the star's gaseous envelope, thereby removing the fuel that has previously maintained the thermonuclear energy source in its interior. This phenomenon occur during a (second) phase in which the star becomes a red giant, the so-called the Asymptotic Giant Branch (AGB) stage. In the last million years of the AGB, the red giant is dynamically unstable and pulsates with typical periods of few hundred days: a prototypical star in this phase is Mira in Cetus. The mechanical energy of the pulsations pushes large amounts of material far away enough from the core of the star for it to cool down and condense into dust. This newly formed dust is further accelerated out of the gravitational bounds of the star by the pressure of the radiation coming from the hot stellar remnant. Gas, which is coupled to dust by collisions, also leaves the star in this process.

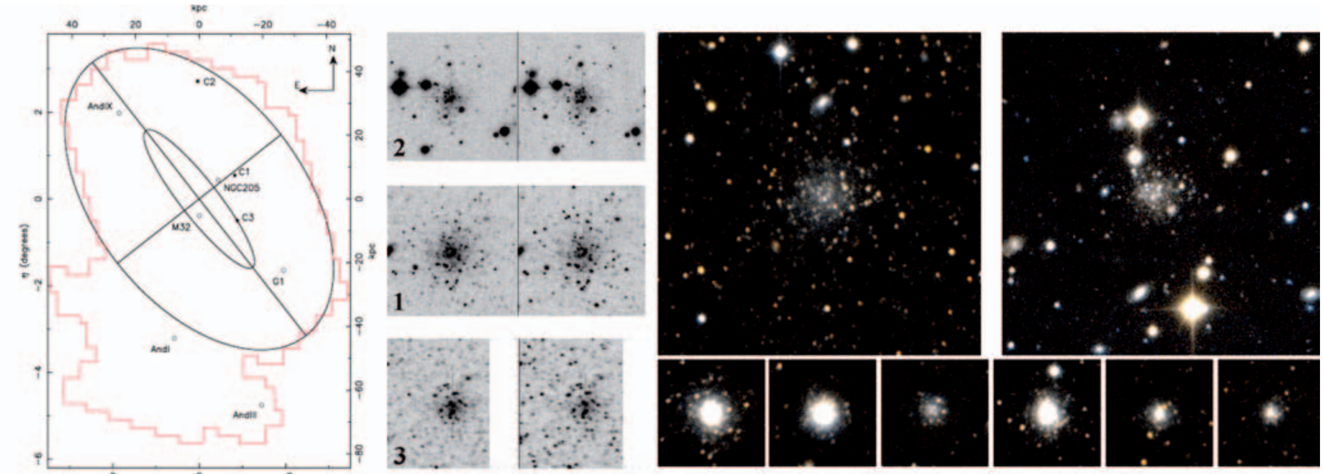


Figure 18. The location of the new extended globular clusters in relation to major landmarks of the M31 system (open circles), and the survey area (red dotted outline). The ellipses represent a 2° radius disc aligned and tilted to the inclination of M31 and an oblate halo of axial ratio 0.6 aligned along the major axis. The kpc scales correspond to a distance to M31 of 780 kpc. To the right, V- and i-band images of the new luminous 'extended' clusters, from the INT–WFS images. Each image is 1 × 1 arcmin^2, with north up and east to the left. Cluster 3 is a partial image as it lies on the edge of an INT–WFS field. Right: Images of two of the newly discovered clusters. Below them are examples of M31's normal globular clusters, which have similar luminosities but whose stars are much more concentrated together (and hence the images of the globular clusters are saturated in the centres of the clusters).

In the last hundred thousand years of the AGB, this mass loss process is so strong that the star is completely surrounded by a thick, expanding dust shell that makes it very difficult to observe what is going on inside it. One way to recover valuable information about this critical phase of stellar evolution is to study the progeny of AGB stars, i.e. planetary nebulae (PNe). These are nothing but the ejected AGB envelopes, heated by the radiation of the hot stellar core, and therefore emitting at the specific wavelengths (emission-lines) typical of the gas that they are composed of.

PNe are fantastic laboratories in which to study a variety of physical phenomena, for example, in the past many aspects of atomic and molecular physics have been addressed by studying PNe. More recently, PNe have become laboratories for investigating the (hydro)dynamical formation of shock waves produced by collisions between stellar winds, with the consequent formation of thin gaseous shells, and bipolar flows or jets which closely resemble those observed in other type of stars or in the nuclei of active galaxies. If we understand the formation of the complex and spectacular shapes displayed by PNe, a lot can also be understood about the very late AGB evolution.

An observational highlight in the investigation of the shapes of PNe came from the HST images of the Cat's Eye, which revealed the presence of a series of shells in the inner regions of its halo. They appeared to be produced by mass ejected from the star in a series of

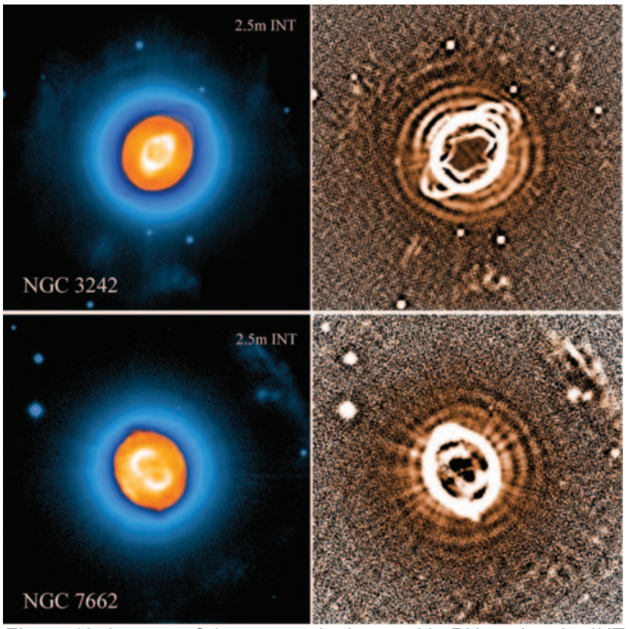


Figure 19. Images of rings recently detected in PNe using the INT WFC. Left: [OIII] images. Right: the same images processed to enhance the rings.

pulses at about 1500 years intervals during the last 20,000 years of the AGB evolution. Each shell contains about one hundredth of the mass of the Sun, i.e. approximately the mass of all the planets in the Solar System combined. When projected in the sky, these shells appear as "rings" (or sometimes "arcs") composing a sort of "bull's-eye" pattern.

Discovery of these rings came as a surprise, as mass-loss modulation on a timescale of 1000 years was not predicted by theory (compare with the 100 times longer timescale of the recurrence of thermal pulses). First, it was thought that rings were a rare phenomenon, but recent observations taken mainly with the Wide Field Camera of the INT, have instead shown that these structures are likely the rule rather than the exception. They are thus of general relevance to understanding the large mass loss increase that characterises the end of the evolution of a star like the Sun.

Several mechanisms have been proposed for the formation of these rings. They include binary interaction, magnetic activity cycles, or stellar pulsations caused by instabilities in the hydrogen burning shell inside the AGB envelope. Another possibility is that gas is ejected smoothly from the star, and rings are created later on due to formation of hydrodynamical waves in the outflowing material that are caused by a complex coupling between gas and dust. In any case, it is clear that any AGB mass loss theory should now confront the evidence that these rings are frequently found in PNe, and thus contain important information relating to the very late evolution of a large fraction of stars in the Universe.

THE DEEP IMPACT EVENT AT THE ING TELESCOPES

The NASA Deep Impact mission was due to collide with a comet in order to reveil the composition and constitution of comets and thereby provide better insight into these bodies that go back to the early phases of the formation of the Solar System. The mission consisted of two spacecrafts: an impactor, weighting 364 kg, and a flyby spacecraft for observing the impact and relaying data from the impactor. The main goal of the mission was to study the interior and outer layers of a comet. Until the impact, very little was known of the internal structure and the physical evolution of the outer layers of a comet nucleus. Most of what we know relies primarily on theoretical models. The relationship between the coma's composition and the nucleus composition is also uncertain. Even if the coma is formed by material from the nucleus, there are several physical and chemical processes that rapidly affect the material ejected from the nucleus.

Comets are remnants of the early stages of the formation of our Solar System and thus contain the most pristine material from that era, as well as clues to its subsequent evolution. Whatever evidence we have into their internal composition comes either from remote observation and modelling of the dust and gases that are lifted off the surface, or from in-situ analysis of data from recent spacecraft flybys. Deep Impact was designed to provide a first look at the interior of a comet by striking the surface to expose the material underneath the opaque crust.

The target comet was comet 9P/Tempel 1. This is one of a class of comets known as the Jupiter-family of comets, most of which are believed to have formed in the trans-Neptunian region. These objects have low inclination orbits and typically take less than 20 years to orbit the Sun. Their orbits are strongly influenced by Jupiter, hence their name. 9P/Tempel 1 orbits the sun once every 5.5 years, and the Deep Impact encounter was scheduled to take place at perihelion, when the comet was at 1.5 and 0.9 Astronomical Units from the Sun and Earth, respectively.

Deep Impact was designed so that much of the mission-critical science would be done from Earth-based telescopes. These facilities would observe the comet before, during, and after impact. This was an unprecedented coordinated observational campaign, which included over 550 whole or partial nights of observation using 73 ground-based telescopes at 35 observatories. These facilities would observe the comet's evolution in wavelength regimes and timescales inaccessible to the spacecraft.

The Roque de Los Muchachos Observatory played a substantial role in this campaign. Observations started in 2000. But the interesting part of the game started on July 2nd, 2005. From July 2nd to July 10th a campaign involving three telescopes of the observatory, the WHT, the TNG and the NOT was conducted. LIRIS at the WHT was used from July 3rd to 7th to obtain near infrared images in the *J* and *K* bands and near infrared spectra. Also another group used the INT and the Liverpool Telescope to follow the activity of the comet from July 1st to 7th. The five largest telescopes of the Roque de Los Muchachos Observatory were used simultaneously to track an astronomical experiment in an unprecedented way.

On July 3rd, 2005 the Deep Impact impactor probe successfully separated from its mother craft onto a trajectory that would plunge the probe into the nucleus of comet 9P/Tempel 1 at a velocity of 10 kms^{-1}. At 05:44:36 UT on July 4th the impactor collided with the comet producing an impact of 19 GJ of kinetic energy and excavating a crater shaped by gravity.

The first aim of the campaign was to study the dust ejected by the impact by using the high S/N images obtained in the visible and near infrared, and the spectra in the near

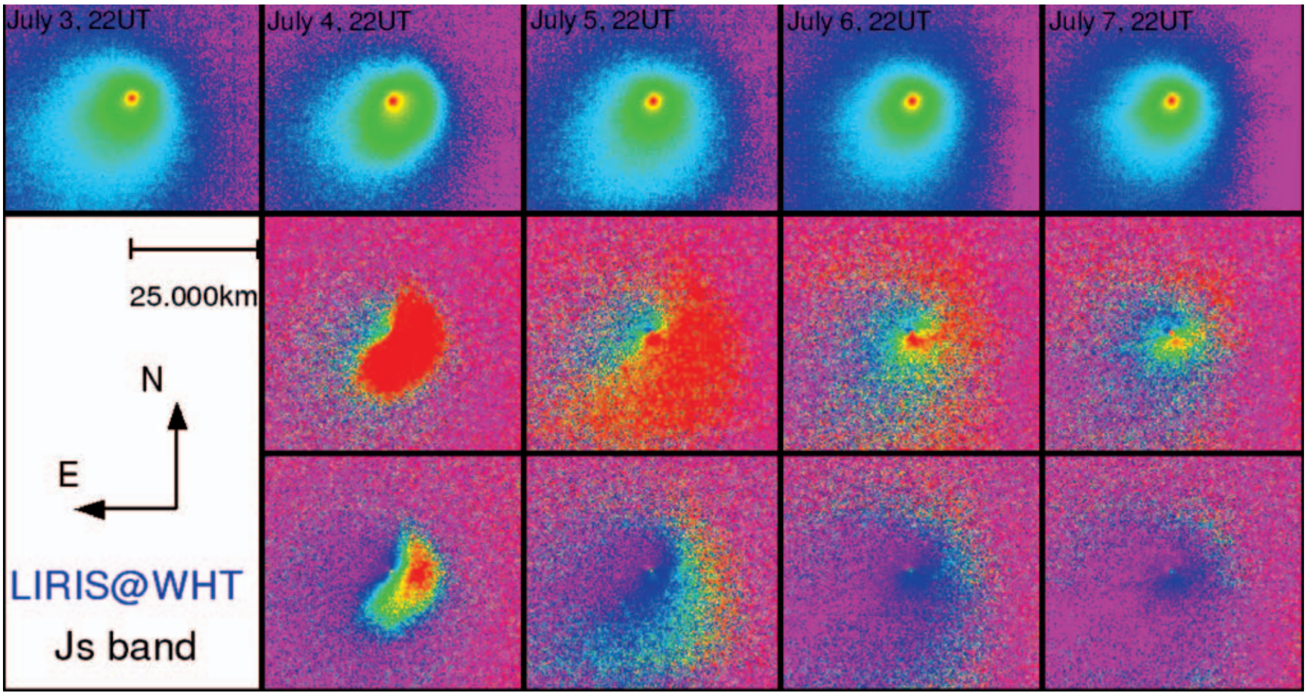


Figure 20. First row: Sequence of calibrated near-infrared J-images of the dust coma of comet Tempel1 obtained with LIRIS at the WHT. Notice the changes in the images from July 3rd (pre-impact) to July 4th (taken 16 hours after the impact). Second row: Post-impact J-images processed to show only the dust ejected by the impact. Each image has been divided by the pre-impact one obtained on July 3rd. The evolution of the ejecta cloud is clearly seen. Third row: Same as 2nd row shown in a different flux scale.

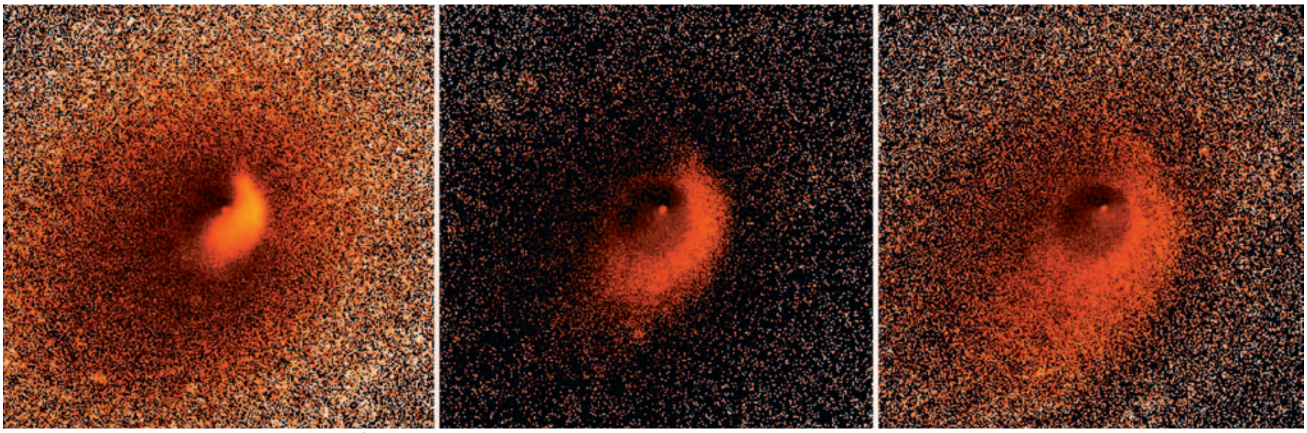


Figure 21. These dramatic images of the expanding and dissipating ejecta plume were obtained by dividing the July 4th, 5th, and 6th coadded images of the comet by the pre-impact image on July 3rd. North is up and East to the left. The plume expands mostly into the South-Western quadrant, and appears to be decelerating at a non-uniform rate. The dust particles at the leading edge of the plume, are expanding at a rate of ~210 ms^{-1} (±10%) on July 4th (measured at a Position Angle of 225°). The field of view in every image is 190×190 arcsec, which is equivalent to ~123,000×123,000 km at the comet.

infrared where there are many features due to gas emission. The evolution of the intensity and colour of the dust gives important information on the size of the ejected grains, like their size distribution and ejection velocities. The second aim of the campaign was to measure possible variations of the gas emission by means of visible spectroscopy, to detect any possible new activity in case the impactor penetrated deep enough to meet the fresh ices below the dust mantle. This would evaporate part of them and expose ices to the sun-light generating a new active area.

The impact produced an ejected cloud of dust and the observers were able to obtain a set of excellent images, in particular, in the *R* and *J* bands. At these wavelengths the images were sampling the reflected sunlight by the dust in the coma. The spectra also showed that the gas contribution was very low in particular in the near infrared. Some conclusions about the dust cloud ejecta follow: the dust ejected by the impact formed a semi-circular expanding cloud that extended from position angles (PA) 145° to 325°; assuming an albedo typical of cometary grain size, and from the flux of the dust ejecta, an

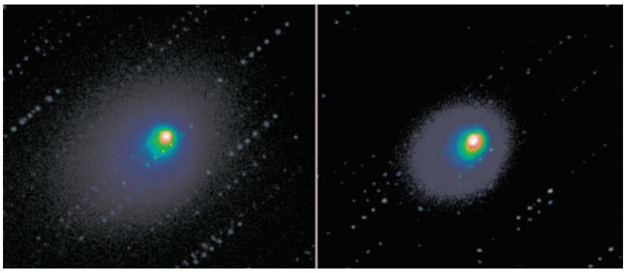


Figure 22. When comet Tempel1 came into view from La Palma, some 16 hours after the Deep Impact probe struck the comet, observes were able to start tracking the target comet with the INT. Both images above are a combination of 7×20 second Sloan-Gunn r' (red) filter images which isolate the dust component of the coma. The image on the left was taken on July 3rd between 21:56 and 23:03 Universal Time, about 7 hours before impact. The image on the right was taken between 22:08 and 23:56 UT on July 4th, 16 hours after probe impact. The comet was seen to increase in brightness by a factor of two —as measured in the central pixel— before and after the impact as seen from this location. Even in these images the effects of the impact can be seen by the changing coma shape between the two images. North is up and East to the left. The field of view in both images is 340×340 arcsec, which is equivalent to ~220,000×220,000 km at the comet.

estimation of a total mass of dust ejected of $\sim 10^6$ kg (equivalent to about 10 hours of normal comet activity) can be derived; the orientation of the ejecta proves that the impact happened below the orbital plane of the comet; the position of the leading edge of the dust cloud present on the July 4th images show that it expanded outward at a projected speed of about $200 \pm 20\,\mathrm{m\,s^{-1}}$ (though varying with azimuth).

In the following days the shape of the cloud changed because of the effect of solar radiation pressure that moved the dust particles to the tail of the comet (PA=110°). The maximum projected distance in the sunward direction, achieved on July 7th, was 30,000 km. By July 9th most of the ejected dust was moved to the coma and the comet looked like as in the pre-impact phase. The ejected dust is diluted in the comet tail.

The study of the structures of the dust coma in high S/N images provided also very interesting results. The comet presented some dust structures in the pre-impact phase that indicate that the nucleus had some particularly active regions. These structures remained after the impact, thus these active regions were not affected. And the new structures observed after the impact on July 4th rapidly disappeared and none remained at a high S/N level after a few days.

The observations from the INT were very important for completing the time base coverage of the comet as it fell below the sky from the primary observing site at Mauna

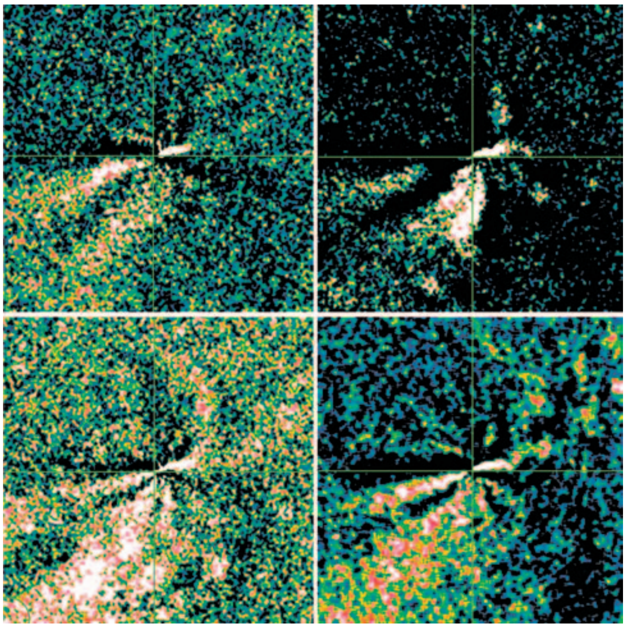


Figure 23. Larson-Sekanina image processing techniques were applied to the coadded r'-filter coma images from four of the nights to reveal the dramatic changes in the structure of the dust coma that resulted from the impact. Before impact on July 3rd (upper left panel), three jet structures can be seen to be emanating from the comet's nucleus. On July 4th, just 16 hours after probe impact, the intensity of the jet/coma structures in the West and Southern direction increase dramatically (upper right panel). North is up and East to the left. On July 5th, new curved structures can be seen in the North-Western quadrant (lower left panel), possibly made visible by the extra material ejected into the coma from the impact. The structures seem to return to their pre-impact status on July 6th (lower right panel). The field of view in every image is 95×95 arcsec, which is equivalent to ~62,000×62,000km at the comet.

Kea, Hawaii. The observing slot ran from July 1st to July 7th, 2005. A period which overlapped the Deep Impact encounter allowed the observers three nights pre-impact and four nights post impact observing. The strategy was to use the Wide Field Camera to obtain image mosaics up to 5 million kilometres along the projected anti-solar direction to look for ion-tail features that may have been produced as a result of the impact.

The post impact observations quickly revealed that no such ion features were present, which was subsequently confirmed by other observers performing similar programs. With this in mind it was decided to focus on deep optical imaging of the central gas and dust coma through *UBVr'i'O+* filters. When the comet was imaged on July 4th, about 16 hours after the impact, the comet was seen to have increased in brightness by a factor of two — as measured in the central pixel— compared to the July 3rd pre-impact levels. Some dramatic changes were seen in the dust coma. The Deep Impact event did not create a new period of sustained cometary activity, and in many ways the artificial impact resembled a natural outburst.

In conclusion, the impact was an impulsive event that affected the dust mantle of the comet. A large amount of dust was ejected into the coma in a very short time. In no more than 5 days this dust dissipated. Also, if the impactor reached the fresh-ices below the dust mantle, it did not excavate enough to expose a sufficient amount of ices to create a new region sufficiently active to be easily detected.

A JET-POWERED BUBBLE FORMED IN THE GAS AROUND BLACK HOLE CYGNUS X-1

Galactic black holes undergoing accretion are thought to emit the bulk of their power in the X-ray band by releasing the gravitational potential energy of the infalling matter. At the same time, they are capable of producing highly collimated jets of energy and particles flowing out of the system with relativistic velocities that travel into the surrounding medium.

Black Hole X-ray Binaries (BHXBs) are the essential laboratories for understanding the overall physics of the accretion process in these systems, and have provided us with a wealth of understanding of, for example, the properties of the accretion disc. In comparison, the energy and matter content of the jets produced by BHXBs are not well constrained because they are radiatively inefficient.

Relativistics jets are a common feature of accreting black holes on all mass scales, ranging from supermassive black holes at the centres of active galactic nuclei to stellar-mass black holes in X-ray binary systems within our own Galaxy. Whereas the inflow of hot gas can be very efficient in producing light (up to 40% of the accreted material may be transformed into energy and radiated away in the form of optical/ultraviolet/X-ray photons), the same is not true for the synchroton-emitting outflow, whose efficiency might be lower than a few per cent. Estimating the total — radiated plus kinetic — power content of the jets, and hence their importance with respect to the accretion process in terms of energetics, is a primary aim of high energy astrophysics.

Attempts at measuring the jet power from radio luminosities are riddled with assumptions about its spectrum and radiative efficiency. However, the jet power can also be constrained by analysing its interaction with the surrounding interstellar medium (ISM). Synchrotron radio lobes associated with jets from AGN are commonly used as accurate calorimeters of the power×lifetime product of the jets, a method only very recently applied to jets from stellar mass black holes.

In 2004, very deep low radio frequency observations of the field of Cyg X–1, a 10-solar-mass black hole, resulted in the discovery of a shell-like structure which is aligned with the resolved radio jet of this BHXB. This radio shell has been interpreted as the result of a strong shock that develops at the location where the collimated jet impacts on the ambient ISM. Models of jet-ISM interactions predict a shell of shocked compressed ISM visible via bremsstrahlung emission, containing a bubble of relativistic synchrotron-emitting plasma. The spectrum of the shocked shell should be approximately flat from radio to much higher frequencies and possess spectral lines in emission. To test this, the Cyg X–1 jet-blown nebula was consequently observed at optical wavelengths with the Wide Field Camera of the INT.

The shell of the nebula is clearly visible in a 100-minute Hα image (a lower limit of m=23.1 arcsec^{-2} from the nebula was calculated from the observations). The researchers claim that an emission mechanism with a flat spectrum, such as bremsstrahlung, plus excess flux possibly due to line emission, as expected in the case of radiative shock, can explain the radio and optical data obtained. However, the spectrum is inconsistent with that of optically thin synchrotron radiation. This, therefore, is the first detection of a thermal shell of gas that is shocked by its interaction with a jet of a Galactic black hole.

The discovery of this large-scale (~5 parcsecs in diameter) ring-like structure surrounding Cygnus X-1 that appears to be inflated by the inner radio jet, imply that low-luminosity stellar-mass black holes as a whole dissipate the bulk of the liberated accretion power in the form of "dark", radiatively inefficient relativistic outflows, rather than locally in the X-ray-emitting inflow, whose key signature is the eventual energization of the ambient medium. So for decades astronomers have been severely underestimating how much power black holes pump back into the universe instead of merely swallowing material across their event horizons.

The discovery team ruled out the possibility that the ring might be the low-luminosity remnant of the supernova that spawned the black hole. Since Cygnus X-1 moves in the sky along a trajectory that is roughly perpendicular to the jet, it cannot possibly have been located in the centre of the ring.

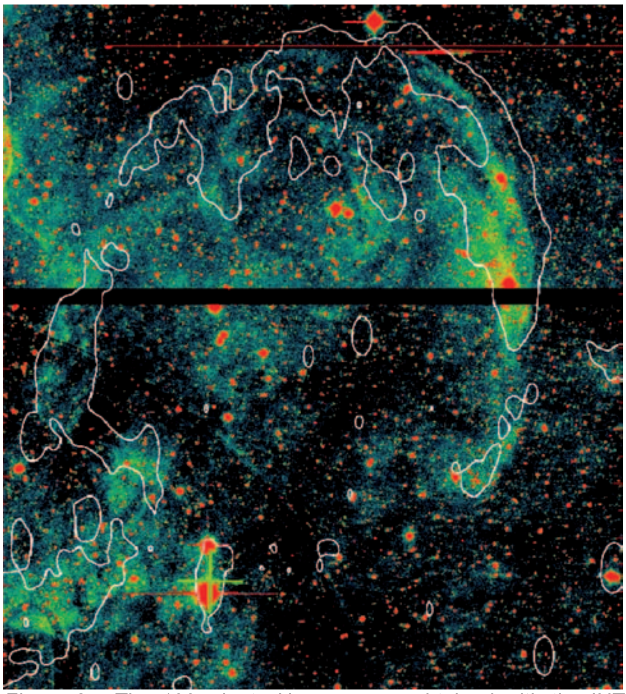


Figure 24. The 100-minute Hα exposure obtained with the INT WFC of the field of Cyg X–1 (the black hole is depicted by the cross on the bottom-left) and the ~5.5 arcmin jet-blown nebula. 3σ radio contours are overplotted in white.

This profitable technique has potential for constraining the jet power associated with other BHXBs if further jet-blown nebulae are identified. With the confirmation of this jet-ISM interaction associated with Cyg X–1, it is clear not only that there may be an undiscovered population of jet-blown bremsstrahlung nebulae associated with BHXBs, but also that these nebulae may easily be found with simple wide-field red-optical imaging.

HIGHLY ATTENUATED SUPERNOVAE IN THE NUCLEAR REGIONS OF STARBURST GALAXIES

A handful of nearby supernovae (SNe) with visual extinctions of a few magnitudes have recently been discovered. However, an undiscovered population of much more highly attenuated (A_V>10) core-collapse supernovae (CCSNe) is likely to exist in the nuclear (central kiloparsec) regions of starburst galaxies. For instance, in the nuclear regions of M82 and other nearby starburst galaxies one core-collapse supernova is expected to explode every 5–10 years. Furthermore, in luminous infrared galaxies (LIRGs) such as the interacting system Arp299 (NGC 3690+IC 0694) at least one CCSN can be expected every year. The high dust extinction means that optical searches for such SNe are unlikely to be successful.

By observing in the near-IR *Ks*-band the extinction is strongly reduced, making searches for such dust obscured SNe look feasible. Making use of this advantage, astronomers have been carrying out a near-IR *Ks*-band search campaign for SNe obscured by dust in the nuclear regions of nearby starburst galaxies with the WHT since 2001. Initially, the search started using INGRID near-IR imager. In 2004 observations with LIRIS commenced. By that time, the search had only produced the detection of a possible SN in old images making any follow-up observations and definite confirmation of this SN impossible. They estimated that the lack of SN detections from the INGRID SN search database indicated an average extinction towards the nuclear SNe exceeding A_V=10. Such high extinctions would certainly be expected for most of the SNe within the nuclear regions of starburst galaxies such as M82.

Already on the first run LIRIS observed a SN, SN 2004am, within the nuclear regions (~500 pc) in M82. The discovery of this event, however, had already been reported just one day before the observations. The 0.89-1.53-μ LIRIS spectrum showed broad hydrogen lines demonstrating that this was a type II event. The LIRIS *JHKs* images showed a moderately reddened source exactly coincident with a bright starburst knot within the nuclear regions of M82. The optical-near-IR colours also showed that the extinction towards this SN was A_V~5.

Later observations with LIRIS in 2005 produced discoveries of subsequently confirmed SN events in the interacting luminous infrared galaxy Arp 299 (distance ~45 Mpc) and in the nearby starburst galaxy NGC 2146 (distance ~13 Mpc). Both Arp 299 and NGC 2146 have high expected CCSN rates of ~1–2 and ~0.2 SNe per year, respectively, as indicated by their far-IR luminosities. SN 2005U with *Ks*=16.2 was discovered 1.3 kpc from the *Ks*-band nucleus A of Arp 299 and it was classified as a type II SN. The near-IR colour estimated from the LIRIS images gave an extinction of A_V~4. SN 2005V was also discovered by LIRIS on the same night. It had a magnitude of *Ks*=13.8 and it was located 330 pc from the *Ks*-band nucleus of NGC 2146. It was spectroscopically classified as a type Ib/c SN, about 1–2 weeks past maximum brightness. The near-IR colours from LIRIS indicated an extinction of A_V~3–4 towards SN 2005V.

The combined INGRID and LIRIS SN search database includes images for 40 nearby starburst galaxies, on

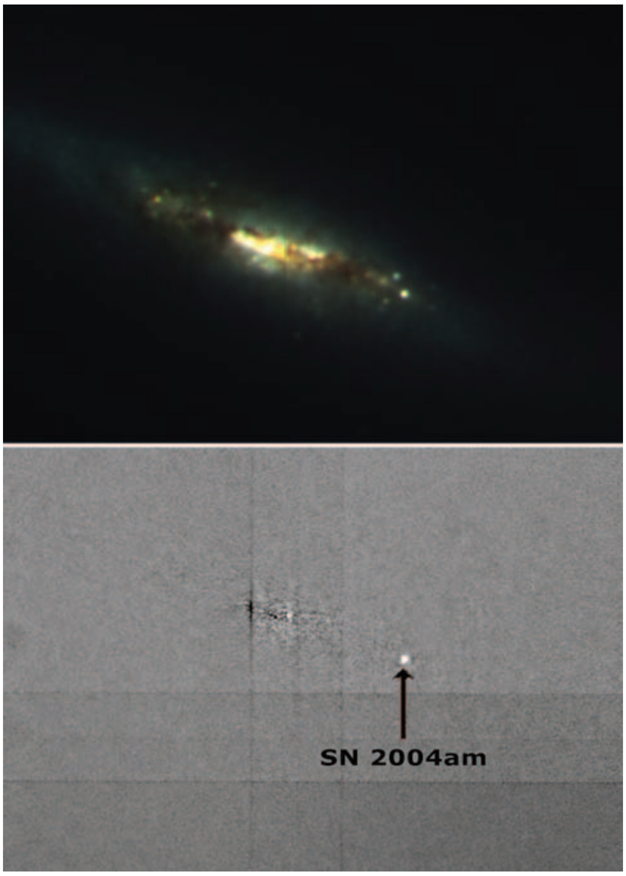


Figure 25. Top: JHKs LIRIS image of M82 (+SN 2004am) observed on 2004 Nov 25. Bottom: The result of alignment, image matching and subtraction between LIRIS Ks band images from March 2004 and November 2004. Note that by this time the SN had already dimmed considerably.

Figure 26. JKs LIRIS image of Arp 299 (+SN 2005U) observed on 2005 Jan 30.

Figure 27. JHKs LIRIS image of NGC 2146 (+SN 2005V) observed on 2005 Jan 30.

average observed ~4.3 epochs per target. Although several CCSNe have now been discovered in starburst galaxies at near-IR wavelenghts, they are all extinguished by only a few magnitudes in A_V. The expected population of highly extinguished supernovae within the nuclear regions of starburst galaxies therefore still remains unrevealed.

A DARK HYDROGEN CLOUD IN THE VIRGO CLUSTER

Simulations of cold dark matter models predict far more dark matter halos than are observed as galaxies. For this reason, it has been hypothesized that there must exist dark matter halos that contain no stars. The advent of neutral hydrogen multibeam systems has allowed surveys of large areas of sky to be carried out with much higher sensitivity than has been possible in the past, thus allowing sources to be detected by their gas content alone rather than their stars and opening up the possibility of finding truly isolated clouds of extragalactic gas with no stars.

A recent deep neutral hydrogen survey of the Virgo Cluster (VIRGOHI) using the multibeam system on the Lovell Telescope has covered 32 deg^2 and detected 31 sources, of which one of them, VIRGOHI 21, does not have an optical counterpart. There have been several previous claims of the detection of isolated clouds of extragalactic gas with no stars in them, but subsequent analyses have either revealed the optical counterparts or shown that the gas is mereley debris from nearby visible galaxies. Many other detections of HI clouds have been associated with nearby optically bright galaxies, but VIRGOHI 21 cannot be so easily explained.

Following detection, VIRGOHI 21 was observed at the Arecibo Telescope and the Very Large Array (VLA). From the HI flux astronomers calculated an HI mass of $10^8 M_{solar}$ and a velocity width of ΔV_{20}=220 km s^{-1}. From the speed it is spinning VIRGOHI 21 is a thousand times more massive that could be accounted for by the observed hydrogen atoms alone, and from the Tully-Fisher relation,

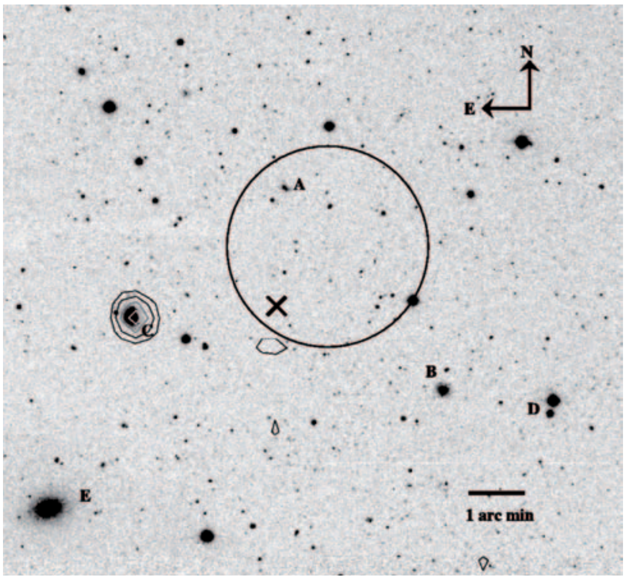


Figure 28. INT B-band optical image of the field of VIRGOHI 21. The cross marks the weighted center of the HI detection, and the circle shows the size and position of the central Arecibo beam.

Figure 29. The ellipse shows the region of sky where the dark cloud was found on a colourful image from INT data.

a galaxy with this velocity width would be expected to be 12 mag or brighter.

Deep optical CCD images in *B*, *r'*, and *i'* bands with the INT were obtained, reaching surface brightness limits of 27.5, ~27.0 and 25.8 mag arcsec^{-2} respectively. On the *B*-band frame, an object of 10" scale or larger at this surface brightness limit should have been detected. This is more than 100 times dimmer than the central surface brightness of the disks of typical spiral galaxies and dimmer than any known massive low surface brightness galaxy or than the lowest surface brightness dwarf galaxy.

For many years astronomers have been measuring the way in which stars and galaxies move. These measurements indicate that there must be far more matter in the Universe that can be accounted for by the visible light we see. This 'dark matter' still holds many mysteries for astronomers — is it well mixed up amongst the stars, or is it separate from the stars? Another puzzle is that the current ideas about how galaxies form predict that there should be many more galaxies in the Universe than are visible to us. So, these two ideas —dark matter and the lack of galaxies— have led to predict that there must be unseen 'dark' galaxies hidden in the Universe. Finding a dark matter galaxy is an important breakthrough because, according to cosmological models, dark matter is five times more abundant than the ordinary (baryonic) matter that makes up everything we can see and touch.

The members of the discovery team conclude that in the very nature of things it would be difficult to make an indisputable claim to have found a dark galaxy, particularly when past claims to that effect have quickly been ruled out by subsequent observations (either of a dim underlying galaxy or of bridging connections to nearby visible companions). Nevertheless, VIRGOHI 21 passed all of the careful tests the astronomers were able to set for it, using the best equipment currently available.

Dark galaxies are thought to form when the density of matter in a galaxy is too low to create the conditions for star formation. The observations of VIRGOHI 21 may have other explanations, but they are consistent with the hydrogen being in a flat disc of rotating material, which is what is seen in ordinary spiral galaxies.

MOST OF THE GROWTH OF SUPERMASSIVE BLACK HOLES IS OBSCURED BY DUST

Supermassive black holes underwent periods of exponential growth during which we see them as quasars in the distant Universe. Quasars are some of the brightest objects in the Universe and are seen by the light emitted as gas and dust spiral into the black hole. They are situated in the inner-most regions of galaxies and can consume the equivalent mass of between ten and a thousand stars in one year. It is believed that all quasars are surrounded by a dusty ring which hides them from sight on Earth in about half of cases.

The summed emission from these quasars generates the cosmic X-ray background, the spectrum of which has been used to argue that most black-hole growth is obscured. There are clear examples of obscured black-hole growth in the form of 'type 2' quasars, but their numbers are fewer than expected from modelling of the X-ray background. Objects surrounded by dust are hard to see in visible light, so the astronomers looked at infrared wavelengths. Using NASA's Spitzer Space Telescope data, they selected objects that have mid-infrared and radio emissions characteristic of quasars, but which are faint at near-infrared and optical wavelengths.

The researchers found 21 examples of lost quasars in a relatively small patch of sky. All of the objects were confirmed as quasars in radio wavelengths and using the ISIS spectrograph on the WHT. This new population of obscured quasars are hidden behind the dust of the galaxy itself rather than just by a dust ring. The presence of lots of dust in a galaxy indicates that stars are still forming there.

Therefore, this population of distant type-2 quasars, which is at least comparable in size to the well-known unobscured type-1 population, is responsible for most of the black-hole growth in the young Universe and, throughout cosmic history, black-hole growth has been concentrated in the dusty, gas-rich centres of active galaxies. This is in good agreement with predictions from the X-ray background and implies, from comparisons between the integrated luminosity density of quasars (both type-1 and type-2) and the local space density of relic black holes, that black-hole growth occurs in short, efficient spurts in the cores of forming galaxies.

THE INT/WFC SURVEY OF THE MONOCEROS RING

The formation and evolution of galaxies remains one of the big questions in astronomy. In the currently favoured Λ cold dark matter model (ΛCDM), galaxies are built up over time via accretion of smaller systems. One firm prediction of this model is that this accretion of smaller systems should still be ongoing and that the Milky Way halo should contain a large number of satellite systems. It has been suggested that, given the model, there are too few satellites actually within the Milky Way halo.

The tidal dismemberment of a dwarf galaxy as it falls through the Milky Way halo is a slow process, with extensive streams of tidal debris existing for long periods of time. While ancient remnants have been identified in our own Galactic neighbourhood, more extensive surveys of the Galactic halo have concluded that there is only a single, major ongoing accretion event, that of the Sagittarius dwarf galaxy. While this accretion event is adding mass to the Galactic halo and provides an important probe of the shape of the dark matter potential, the lack of other major accretion events is somewhat disconcerting given the predictions from the ΛCDM.

The recently discovered Monoceros Ring (MRi, or the One Ring) can be interpreted as an additional ongoing accretion event within the Milky Way. Investigating the density and extent of this structure is important when trying to fully understand the impact this type of event is having on the evolution of our Galaxy both in the past and into the future. If the MRi is instead the outermost edge of the Milky Way, mapping the outer reaches of the disc will provide insight into the past of the Milky Way.

Astronomers used the INT Wide Field Camera to continue a campaign to detect this stellar population around the Galactic plane, mapping out the extent of the MRi in the region of Galactic longitudes l =61°–150° with 10 pointings in symmetric pairs above and below the plane of the Galaxy spanning 90° about the equator of the Milky Way.

This ongoing survey has yielded three detections of the ring in the region l, b = (118°, 16°), (150°, 15°) and a tentative detection at (150°, -15°). Galactocentric distance estimates to these structures gave ~17, ~17 and ~ 13 kpc, respectively. These are combined with a re-examination of the field observed with the INT WFC in 2003, (123°, -19°), showing the position of the halo is not in accordance with the model and possibly represents another detection of the ring. The Galactocentric distance to this feature is estimated at ~21 kpc. This provides evidence that the ring may be wrapped around the Galaxy more than once.

These detections also lie very close to the newly discovered structure in Triangulum-Andromedae hinting at a link between the two. The remaining six observed fields are apparently non-detections although in light of the new models, closer inspection reveals tentative structure.

With the overdensity of M giant stars in Canis Major being claimed both as a progenitor to the MRi and alternatively a manifestation of the Milky Way warp, much is still unknown concerning this structure and its connection to the MRi.

Both detections and non-detections support a complex picture of the MRi. In particular, those detections above the plane suggest the MRi has an extended stream tracing an arc ~17 kpc from the Galactic Centre, while the detections below the plane, reveal a tentative detection of the Triangulum-Andromedae region in the background of the (123°, -19°) region and also the presence of a foreground stream. Lying roughly in the plane of the Milky Way, the MRi may represent a unique equatorial accretion event which is contributing to the thick disc of the Galaxy, or alternatively, the MRi may be a natural part of the disc formation process.

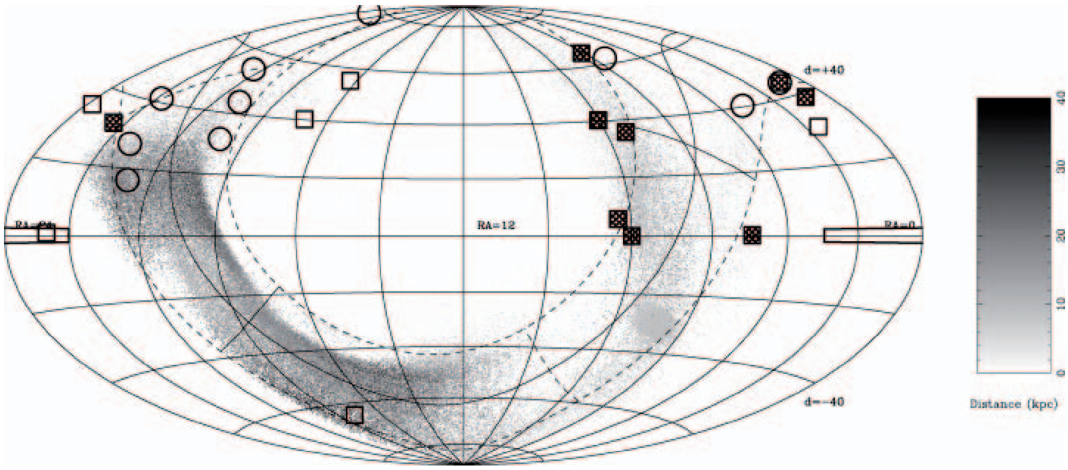


Figure 30. Aitoff projection of the sky, illustrating the locations of the fields obtained for this current survey. The projection is in equatorial coordinates, with the Milky Way equator (b= 0°) shown as a solid black curve accompanied by the dashed curves which mark out Galactic latitudes of b=±20°. The Galactic Centre (l= 0°) and anticentre (l= 180°) are shown as solid bars crossing the Galactic equator. The points represent the prograde model for the destruction of the Canis Major dwarf with the grey-scale showing the Galactocentric distance (kpc) of the points, as shown in the side bar. The dense knot located below the Galactic equator represents the final location of the progenitor used in the simulation. The symbols in the plot are represented as follows: the circles represent the location of the fields in this survey; the squares represent the fields associated with the M31 survey, with the hashed squares being confirmed detections of the ring and empty squares being non-detections.

Chapter 2

OPERATION, MAINTENANCE AND DEVELOPMENTS

TELESCOPE OPERATION

During the two-year period 2004/05 covered by this report, the ING telescopes again performed very well, with downtime figures due to technical problems averaging only 2.3% and 1.5%, 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 34%.

Day-to-day telescope operations support is carried out by a dedicated Operations Team, taking responsibility for the telescopes and associated infrastructure. Efforts of day-time and night-time support activities concentrate on the WHT. 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. Many observing teams visit the telescopes every year. The INT, in contrast, operates in a much simpler fashion and is a single-instrument facility. The 1-m JKT does not host science observations anymore, but is now regularly being used for measuring the atmospheric turbulence profile above the observatory using the technique of SCIntillation Detection And Ranging (SCIDAR) led by the IAC.

At night a telescope operator in always present on the WHT to assist the scientists in taking the observations. ING's team of astronomers acts as the primary contact for visiting scientists. They assist visitors in taking the observations and in carrying out observations in service for the community.

The year 2005 marked the end of an important reorganisation that was the result of a phased reduction of operating cost of the observatory. These measures unavoidably had an impact on the service delivered to the visiting astronomers, but the strong focus on the operation of the WHT has meant that a continued high level of service and flexibility could still be offered to the community of users.

Adaptive optics observations are gradually becoming more important. The advent of the laser guide star system in the near future will drastically enhance the scientific potential and hence likely increase the interest in the use of adaptive optics further. In order to ensure optimal scientific use of the best seeing periods for adaptive optics observations the observing programme at night must be of a flexible nature. The expectation is that during certain periods of the year the WHT will be operated in such queue-scheduled mode.

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 around the turn of the decade after having been in force for 30 years. Leading up to this date discussions between the various international partners are under way on how best to adapt and continue with the formal structure in order to prepare the wider observatory for the future. In parallel with these discussions, ideas have further matured on potential further collaboration between telescope groups at the observatory, building on the successful collaboration that already exists with the Italian 3.5-m Telescopio Nazionale Galileo (TNG).

Together with the international agreements also the telescope facilities advance in age. One of the first telescopes at the ORM was the INT. In February 2004 that telescope had been in operation on La Palma for 20 years. An impressive period of two decades of continuous operation that has resulted in many important discoveries and well over 1100 papers published in scientific journals.

INSTRUMENTATION

An important development for the WHT was the commissioning and first science operation of the intermediate resolution IR spectrograph and imager, LIRIS, that was built by the Instituto de Astrofísica de Canarias. This instrument, based on a 1024 by 1024 pixel Hawaii array detector operates in the Cassegrain focus of the telescope and allows high quality imaging and multi-

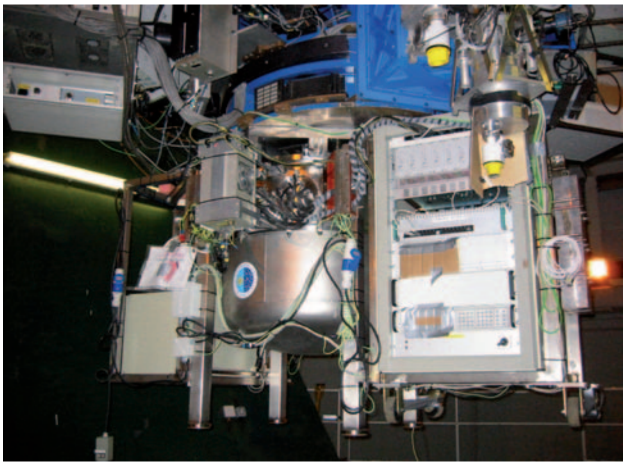


Figure 31. LIRIS mounted in the Cassegrain focus of the WHT.

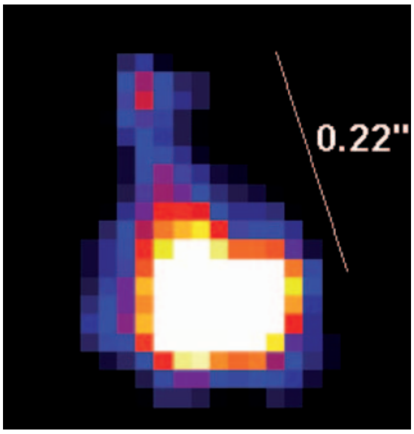


Figure 32. I-band image of a close binary star with the NAOMI Adaptive Optics system using the OASIS integral field spectrograph.

object spectroscopy at near IR wavelengths. Following extensive testing LIRIS was taken into operation during the summer of 2004 as a common-user instrument. The science projects carried out with this instrument are diverse and include distant galaxies, stellar populations, brown dwarfs and planetary nebulae, showing the potential of this instrument for the community of users. In particular the possibility of using multi-object masks offers a potential that is currently a rare feature at other telescopes.

Since its commissioning LIRIS has become one of the most popular instruments on the WHT. Its multi-slit mask mode is particularly popular as it offers a huge multiplex advantage over classical long-slit spectroscopy and is therefore very efficient. Many spectra of for instance galaxies in distant clusters can be observed at the same time. Also during the year the polarisation module was commissioned in LIRIS, offering imaging polarimetry at infrared wavelengths.

Development work at the ING has focussed on the Adaptive Optics (AO) instrumentation suite, an extensive and rather complex set of instruments that permanently occupies one of the Nasmyth foci at the WHT. The Adaptive Optics system itself, NAOMI, has been in operation for four years now. It feeds three science instruments: the infra-red imager INGRID, the coronagraph OSCA, and the optical integral field spectrograph OASIS. The latter is the most recent addition to the AO capability through a collaboration with the Observatoire de Lyon, France.

The OASIS adaptive-optics assisted integral field spectrograph was taken fully into operation during the reporting period. The spectrograph works in the optical wavelength range and offers a wide variety of spectral

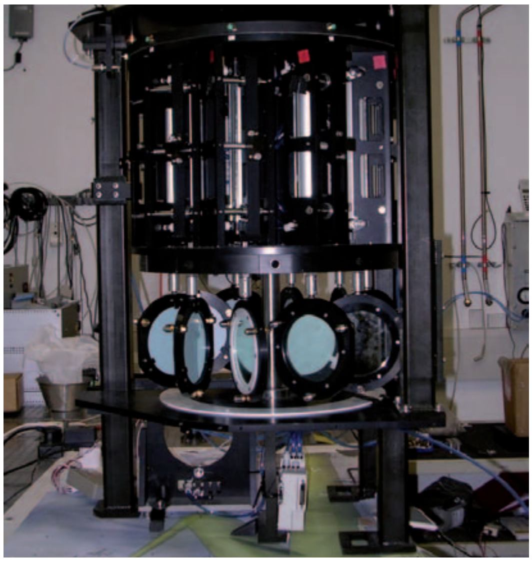


Figure 33. The automatic dichroic filter changer unit.

modes. Also optical imaging can be conducted with this system, and best images achieved so far have been those of a close binary system, achieving 0.1 arcsecond image width in the *I* band.

The OASIS spectrograph supports a wide choice in bandwidth and resolution. OASIS competes for photons with the wavefront sensor, and in order to have the best possible throughput to both OASIS and the wavefront sensor a range of dichroic beam splitters is available to pre-select the wavelength range of interest. The dichroic reflects the appropriate waveband into OASIS while the remaining photons are used for wavefront sensing. Until recently manually changing dichroic filters posed a significant operational overhead, and therefore an automated system was designed and built to swap dichroics in and out of the beam in a fast, accurate, and efficient manner. This dichroic changer was commissioned during the reporting period and is currently in full operation.

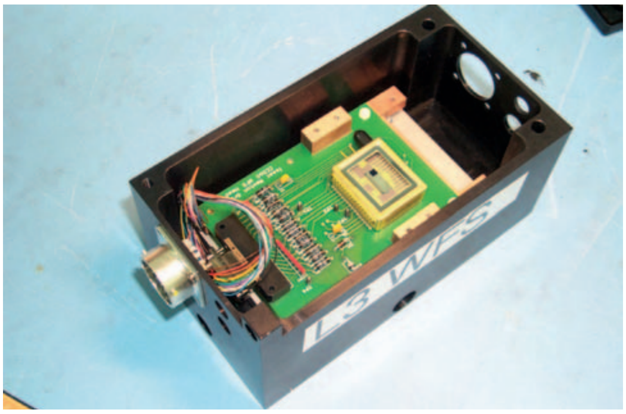


Figure 34. The Low-Light-Level CCD that will be deployed as wavefront sensor in the AO system. The actual CCD chip is the tiny black square in the yellow enclosure.

Natural guide star adaptive optics is largely limited by the availability of stars bright enough to measure the wavefront distortions on that are induced by the Earth's atmosphere. Measurement and correction of the wavefront distortions has to take place in the shortest possible time in order to generate the best results. However, short exposure times (milliseconds) also imply that few photons are available and hence bright stars are required to generate sufficient signal-to-noise. Also in the case of NAOMI this is a limitation for effective and broad scientific use of the instrumentation. Being able to detect fainter stars would help ease the situation. At very faint signals the detector read noise becomes an important factor, and therefore a project is under way to install a zero-read noise CCD in the existing wavefront sensor. For faint guide stars the nearly zero read noise from this new detector is expected to improve the detection efficiency of the system by at least a factor of two.

The ultimate solution for finding bright enough guide stars is to create an artificial 'star' that can be used as a wavefront sensor source. Such artificial source can be created using a strong, well collimated laser beam that is aligned with the main telescopes. Laser light that is back scattered from high in the atmosphere can then be used as an artificial point source suitable for wavefront sensing. In 2004 a project was initiated to create such laser beacon based on Rayleigh back scatter from an altitude of about 20km above the observatory. This project, listening to the Dutch acronym GLAS, for (translated) Ground-layer Laser Adaptive optics System, will work in conjunction with the NAOMI instrument as well as with the existing science cameras.

The scientific advantages of GLAS are potentially huge as such a laser guide star system will amplify the fraction of sky available to adaptive optics observations at visible and infrared wavelengths from a few percent to nearly 100%. In terms of astronomical research, this translates into radical progress as it opens up high spatial resolution observations from the ground to nearly all types of science targets, making possible the observations of faint and extended sources, and enabling observations of large samples, unbiased by the fortuitous presence of nearby bright stars. In combination with the existing instrumentation the WHT will offer a highly competitive facility to the astronomical community, exploiting a window of opportunity before similar capability will exist on 8-m class telescopes.

The system design of GLAS was fully completed in 2005. At the heart of the system will be a 515nm green laser of about 30W. This laser will be mounted at the top of the telescope. Its light beam will travel to the centre of the telescope, behind the secondary mirror, where it will be injected into a beam launch telescope. There the laser beam will be expanded to about 35cm, and subsequently projected into the atmosphere where it will be focussed at a distance of 20km. The diagram below gives a good impression of what this part of the system will look like once installed at the WHT. Expectation is that the laser system will be commissioned in 2006.

Existing instruments remain competitive through the continuous upgrade and improvement of its components. Therefore, apart from the major new instrument developments mentioned above, there have also been a wide range of enhancements to instruments, all with the aim to improve the scientific capability and operational

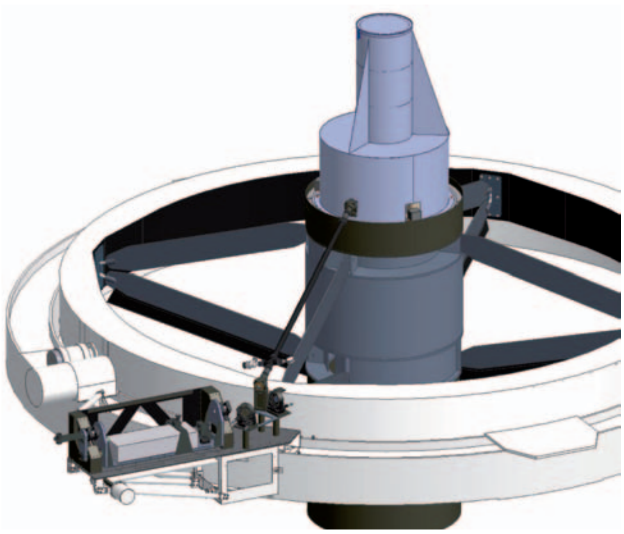


Figure 35. Top ring of the WHT, with shown in the front the laser unit inside a cradle. Laser light will travel through an evacuated pipe to the centre of the telescope, where it will be projected into the atmosphere by the beam launch telescope that is located behind the secondary mirror.

Figure 36. WYFFOS long camera.

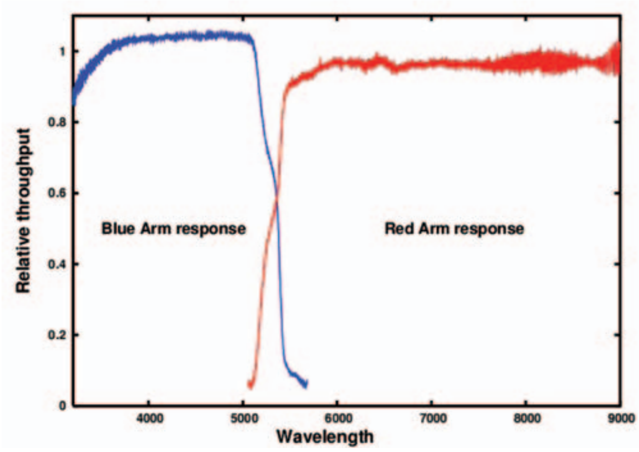


Figure 37. Response curve of the new dichroic of the ISIS spectrograph.

efficiency. An important milestone was achieved with the successful commissioning of the WYFFOS long-camera. This new camera to the fibre-fed WYFFOS spectrograph has the advantages over the original camera that it accommodates a larger number of fibres, has an external focus permitting change of detector, and provides a somewhat higher spectral resolution than the previous camera. The camera was built by the ASTRON institute in the Netherlands.

Apart from the hardware changes for the WYFFOS instruments, there have also been very significant upgrades of the software. In particular the software responsible for setting up the multiple fibre module, AUTOFIB, that feeds WYFFOS has seen major modernization, resulting, amongst other things, in a drastic reduction of the fibre setup time.

Also the venerable ISIS spectrograph has seen important advances with the acquisition of a new dichroic filter that splits light between the red and blue optimized spectrograph arms. The new dichroic possesses a sharper cut between the wavelength ranges at a wavelength that is appropriate for most science programmes, and also features a smoother response. A small but very significant upgrade that has helped the efficiency of the instrument as a whole.

The WHT remains very popular with university groups who build dedicated instruments to find answers to specific astronomical questions. The infrastructure and support offered by ING greatly assists the exploitation of visiting instruments. For that reason over the years many instruments have been deployed in this way and during the reporting year no less than six different visiting instruments came to the telescope. New instruments that had not been to the WHT before were the CIRPASS multi-object IR spectrograph and PLANETPOL, capable of extremely high accuracy polarimetric observations. A brief description of these two new visiting instruments follows.

CIRPASS is a near-IR fibre-fed cooled spectrograph, designed and built by a team from the University of Cambridge. The acronym stands for the Cambridge Infra-Red Panoramic Survey Spectrograph. CIRPASS can take either an integral field fibre bundle or a multi-object fibre bundle. The latter was used at the WHT. A plug-plate system of pre-drilled holes allowed the acquisition and observation of many galaxies simultaneously, thus providing a huge multiplex advantage. The observations focussed on the star formation rates in distance galaxies such as those found in the Hubble Deep Field.

The second visiting instrument new to the WHT was PLANETPOL, from the University of Hertfordshire (UK). The key objective of this instrument is to detect and characterise scattered light from planets around distant stars. Starlight scattered on the surface and in the atmospheres of extra-solar planets causes a weak but characteristic polarization signal. PLANETPOL is designed to detect such very weak signals and has already proven it can achieve that demanding goal.

The WHT also keeps attracting experimental activities. Arguably the most exciting set of experiments relate to the future development of extremely large telescopes. The future telescopes will have segmented primary mirrors and a very significant and costly problem is the control of the segments in order to keep them aligned at all times to a fraction of a wavelength. Of course this problem has been solved by existing segmented telescopes such as the Keck twins on Hawaii and the GTC on La Palma, but for future ELTs the problem is much more severe and costly. Therefore alternative methods are being

Figure 38. The CIRPASS IR spectrograph (blue cabinet) being positioned on the moving platform at the base of the WHT. Light from the Cassegrain focus is fed through a large bundle of fibres to the spectrograph.

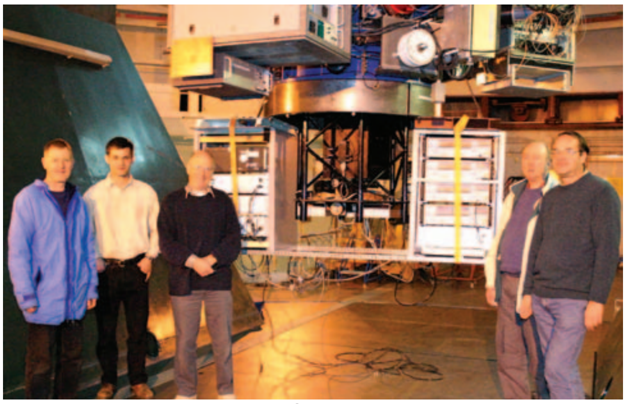


Figure 39. The PLANETPOL instrument mounted in the Cassegrain focus of the WHT, together with the team of scientists.

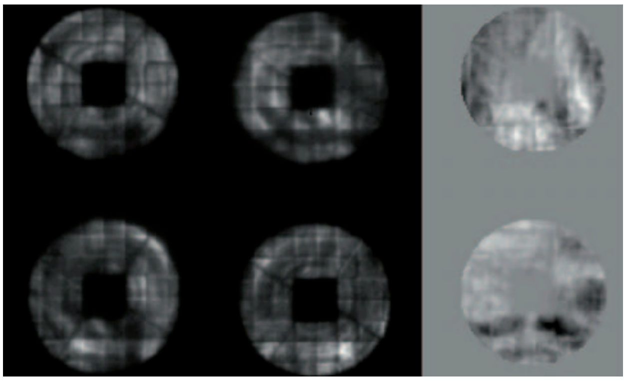


Figure 40. Picture of WHT telescope pupil as see through the pyramid wavefront sensor. The resulting mirror flatness over the controlled subset of mirror elements was better than 10nm.

considered to determine the phase difference between the segments by optical means, in a fast way, and by using starlight. The results of such measurement can then be used to mechanically control the relative position of the mirror segments.

Theoretical work by the group in Arcetri, Italy showed the feasibility using a novel technique of the pyramid wavefront sensor, but this required testing under real conditions as proof-of-concept. This idea inspired collaboration with groups from Durham, UK to use the deformable mirror of the NAOMI adaptive optics system which happens to have individual segments that can be controlled, thus serving as a tiny prototype of a future giant telescope. The experiments were very successful and have proven that the concept is indeed viable.

Another very successful experimental activity that was hosted by the ING falls in the field of astronomical site characterization. In past years researchers from the University of Durham had developed a novel method to measure atmospheric turbulence. This method of Slope Detection and Ranging, or SLODAR, had been extensively tested on the WHT and was so successful in measuring turbulence profiles in the lower atmosphere that a portable unit was designed. This unit would be deployed at different observatories as a site testing tool in preparation for the future construction of extremely large telescopes. First tests were carried out on La Palma, hosted by the ING.

Figure 41. First deployment of the SLODAR equipment.

INFRASTRUCTURE

The LIRIS IR spectrograph was commissioned during the reporting period. LIRIS, being a complex cryogenic instrument, requires particular care also when it is not mounted on the telescope. For that reason a dedicated 'parking' area was constructed in the basement of the WHT. In this enclosure the instrument can be kept cold and connected to the network and ancillary equipment for monitoring and control. Furthermore, a mobile, deployable clean room has been acquired that can be installed in the aluminizing area. The prime purpose of this acquisition was for LIRIS in case the instrument needs to be opened up, but it will be equally useful for similar operations on other instruments.

An important milestone was reached with the full modernization of the detector controller infrastructure. Not only the science detectors, but also all TV and autoguider systems now operate on the basis on SDSU controllers while data acquisition runs through ING's ULTRADAS software system. Having a uniform infrastructure for these systems offers significant advantages for maintenance, while at the same time performance of these modern systems is much better.

Steady progress was made on installation of a higher bandwidth data link between the Mayantigo office building at sea level and the observatory site, culminating in an order-of-magnitude enhancement. Also the connection of the observatory to the Internet improved drastically. This improvement has meant, amongst other things, that archiving of scientific data in Cambridge is now automated and does not require posting of tapes or disks anymore.

Over the years ING has been making steady progress in tracking and implementing the latest CCD detector technologies. Activities include the use of low-light-level CCDs for wavefront sensing as well as for high speed spectroscopy, optimized coatings to reduce fringing at long wavelengths, and testing of surface treatment techniques also to reduce fringing.

A low-key activity has been the step-wise improvement to the WHT control room, in order to make it a more friendly work environment, including new furniture, additional possibilities for computer connections, and improvements in lighting, computer screens and insulation from the somewhat noisy electronics cabinets.

Figure 42. Lifting of primary mirror of the Nordic Optical Telescope in preparation for aluminizing.

During the reporting period both the INT and WHT primary mirrors were re-aluminized. Also mirrors from partner telescopes at the observatory make use of ING's experience and infrastructure. The past two years both the mirror of the Nordic Optical Telescope and of the Liverpool Telescope were aluminized by ING.

Early in the reporting period the SUPERWASP experiment, led by the Queen's University Belfast and hosted by the ING was officially inaugurated. The installation consists of a number of wide-field cameras on a robotic mount, located in an automatic roll-off roof enclosure. The main scientific aim of this experiment is the detection of planets around stars through their occulting effect when the planet transits the stellar surface. The inauguration event was carried out, very appropriately, by remote control; the mayor of the municipality of Garafía where the observatory is located, Mr. José Peñate, commanded the instrument to move and cut a red ribbon.

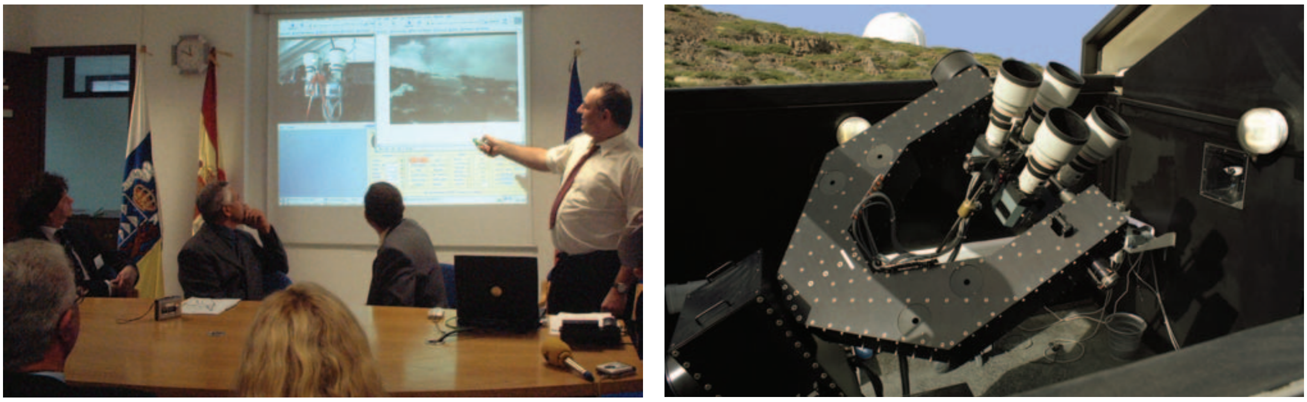


Figure 43. Left: SuperWASP inauguration by remote control. Right: Enclosure open of SuperWASP and WHT dome in the background.

Chapter 3

USE OF OBSERVING TIME AND SCIENTIFIC PRODUCTIVITY

USE OF TELESCOPE TIME

The available observing time on the ING telescopes is allocated 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 to British astronomers to the PPARC Panel for the Allocation of Telescope Time (PATT), and to 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 way to obtain small sets of observations, which would not justify a whole night or more of telescope time. On the WHT several nights per semester are set-aside especially for this purpose. During those nights, ING support astronomers perform observations for several service requests.

Stand-down and discretionary nights are used for major maintenance activities, commissioning of new instruments, enhancements, calibration and quality control tests, etc., and partly for astronomy, for example, as compensation for breakdowns or for observations of targets of opportunity.

The way the available observing time on the ING telescopes has been shared in 2004 and 2005 is summarised in Table 1.

USE OF INSTRUMENTATION

Figure 44 shows the allocation of nights per instrument on the WHT in 2004 and 2005. As in previous years, the ISIS spectrograph was the most popular instrument, taking up some 40% 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, the high-speed multi-CCD camera ULTRACAM, the near-IR multi-object spectrograph, CIRPASS, and the PLANETPOL photo-polarimeter. The INTEGRAL coherent fibre feed to the WYFFOS spectrograph is effectively operated as a private

	WHT		INT	
Time allocation	**2004**	**2005**	**2004**	**2005**
UK PATT	139	130	174	163
NL PC	49	56	61	63
SP CAT	77	78	104	100
ITP	8	14	8	14
TNG time share	10	11	—	—
Service	19.5	17	—	—
Instrument Builder's Guaranteed Time	17	19	0	0
Stand-down and discretionary (including commissioning)	46.5	40	19	25
Total	366	365	366	365

Table 1. Number of nights allocated from Semester 2004A to 2005B. Service include UK and NL service time, and SP CAT includes Spanish service time.

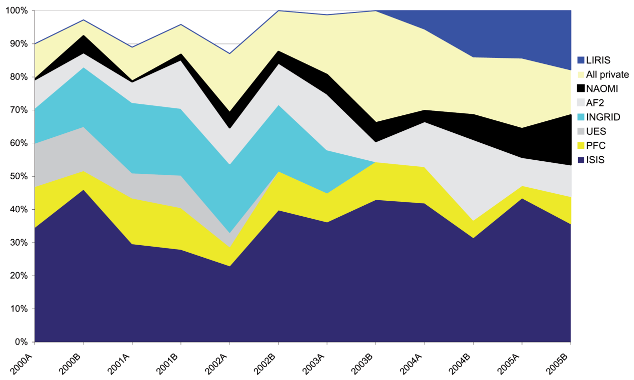


Figure 44. Use of WHT's instrumentation per semester.

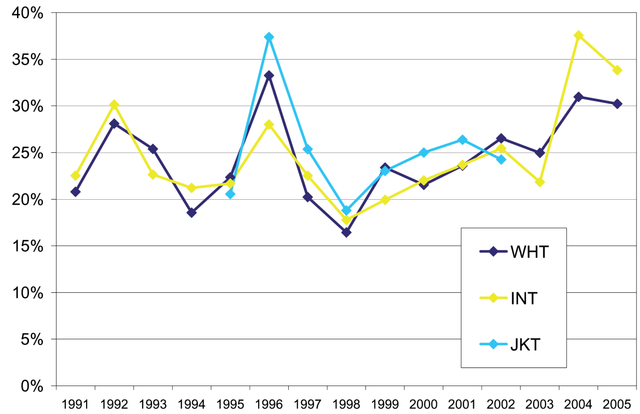


Figure 46. Weather downtime per year.

instrument as well. In particular the ULTRACAM and PLANETPOL instruments enjoyed much interest.

On the INT, dark time periods were exclusively used for CCD imaging with the Wide Field Camera, as the INT was solely dedicated to wide field imaging programmes.

TELESCOPE RELIABILITY

During the year 2004 and 2005 the ING telescopes again performed very well, with downtime figures due to technical problems averaging at 3.4% and 1.5% in 2004 and 1.5% and 1.4% in 2005 for the WHT and the INT respectively. These figures meet the target value of a maximum of 5% technical downtime. Down time due to poor weather averaged 35% in 2004 and 34% in 2005. The historical trends of technical down time and weather down time are plotted in Figures 45 and 46. Figure 47 shows the seasonal average.

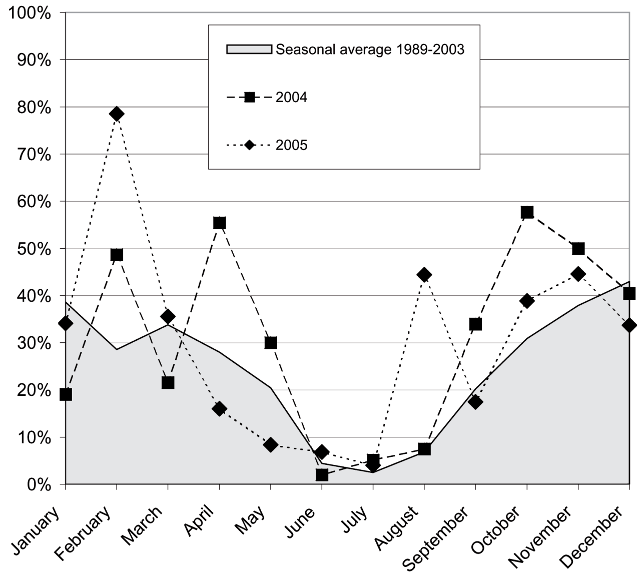


Figure 47. WHT's monthly weather downtime.

SCIENTIFIC PRODUCTIVITY

An important metric 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 E) is 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 most journals are now published electronically and often have quite sophisticated search engines associated with them and it is therefore appropriate to conduct the search with the help of these facilities.

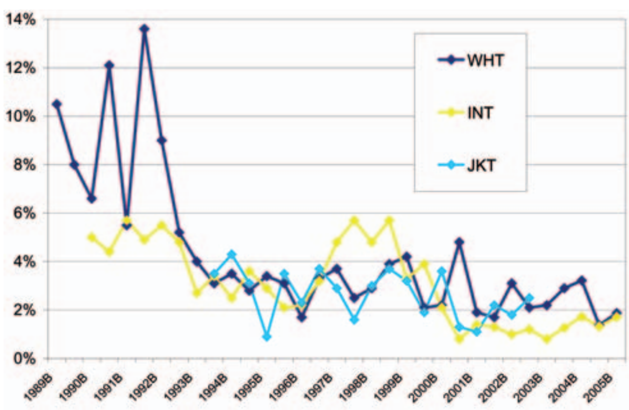


Figure 45. Technical downtime per semester.

Our selection process identifies papers that make direct use of observations obtained with the ING telescopes, in order to qualify. Papers that refer to data presented in earlier papers (derivative papers) are not counted.

When we analyse ING publications for the five years between 1995 and 1999 inclusive it can be seen that more than 95% of articles are published in a small number of core journals. These core journals consist of the British journal *MNRAS*, the American journals *Astrophys J*, *Astrophys J Letters*, *Astrophys J Suppl*, *Astron J* and *PASP*, plus the European journal *Astron Astrophys* (including the now defunct A&AS). We also include *Nature* and *Science* as core journals due to their perceived high impact. Journals making up the remainder of publications are widely spread among such journals as *Icarus* and the *Irish Astronomical Journal* to name a few. The bibliography for the years 2004 and 2005 was compiled from only the core journals listed above for reasons of efficiency. Search engines were used to select papers and the resulting list of papers visually inspected to ensure that they satisfied the selection criteria described above.

An analysis of these numbers follows (see Figures 48 to 52 and Table 2). Note that if a paper makes use of more than one telescope we count that paper for each telescope. Also, concerning perceived nationality we use the nationality of the first author's institution although in a few cases two 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 instrument, with 42% of all publications during the reporting period. The number of papers from visitor instruments on the WHT also remained significant, with 16 papers over two years.

On the INT the papers are split very evenly between IDS spectrograph and the Wide Field Camera as might be expected from the split of observing time between these instruments, roughly 50-50.

Concerning the nationality of the first author's institution, there is little change, at least considering the fluctuations from year to year. The UK share is steady 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, emphasizing the international character of the observatory and the high level of international collaboration between research groups.

THE ING ARCHIVE

All data taken with the ING telescopes is archived in the UK, at the Institute of Astronomy, Cambridge. The data archive is managed by the Cambridge Astronomy Survey Unit.

Archival data from the ING telescopes is made available to anyone upon request, after a one-year proprietary period.

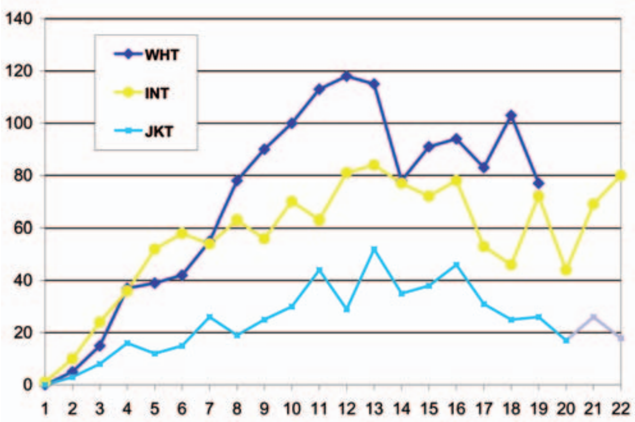


Figure 48. Number of refereed papers per telescope from first light year.

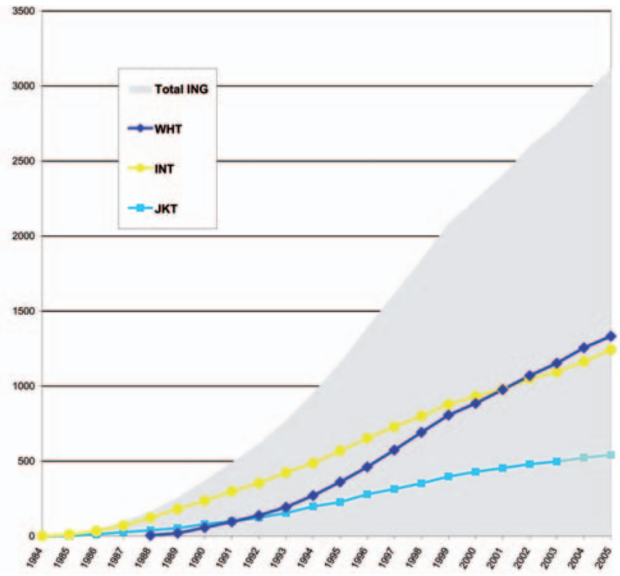


Figure 49. Accumulative number of refereed papers per year.

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
Total	1333	1243	541	2743

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

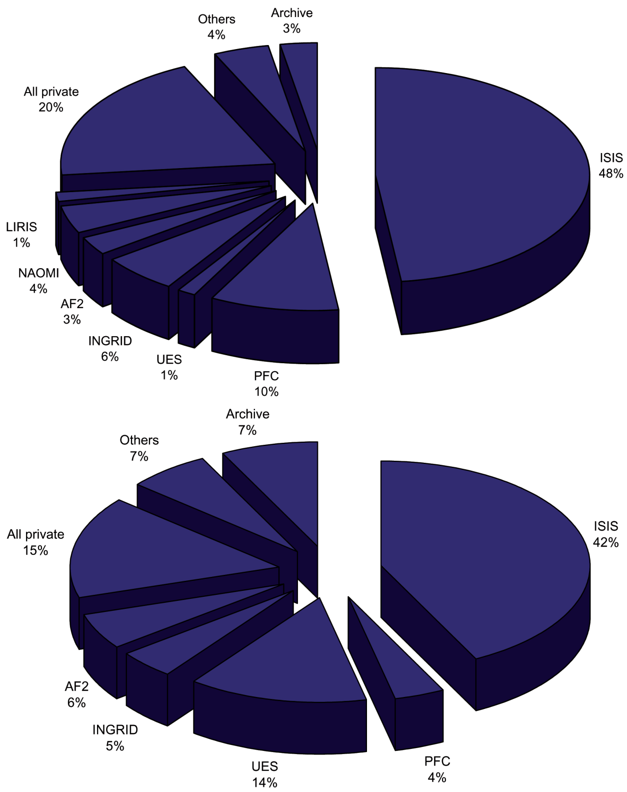


Figure 50. Top: Use of instrument data in WHT refereed papers in 2004. Archival papers made use of data from ISIS, PFIP, UES, INGRID and AUX. Bottom: The same in 2005. A total of 12 papers resulted from data obtained on service nights in both years.

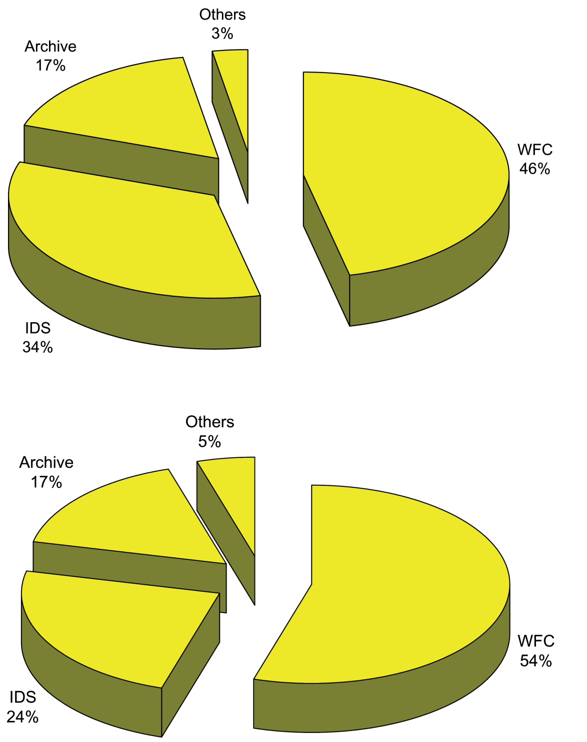


Figure 51. Top: Use of instrument data in INT refereed papers in 2004. Archival papers made use of data from the PFIP, WFC and IDS. Bottom: The same in 2005. A total of 6 papers resulted from data obtained on service nights in both years.

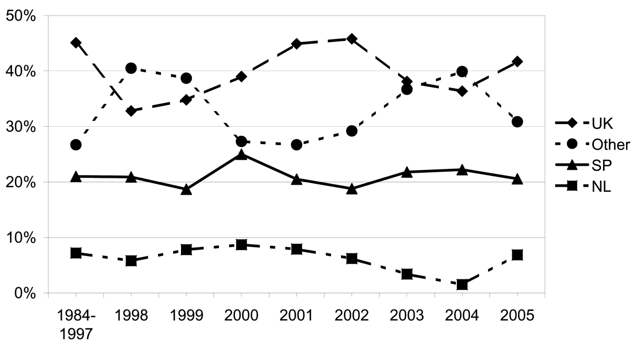


Figure 52. Evolution of the nationality of first author's first institution in ING refereed papers.

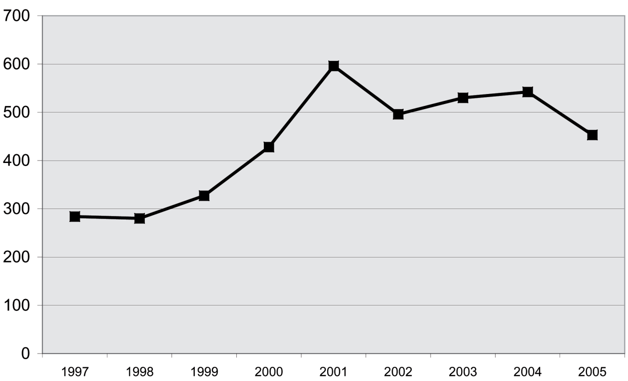


Figure 53. Number of ING archive requests per year.

The number of archive retrieval requests has remained high over the past two years, with over 500 requests per year, for retrieval of more than 40,000 data sets. The historic trend of the archive requests can be seen in Figure 53. This level of archive use underlines the importance of the ING archive as a general tool for astronomy research.

Chapter 4

IN-HOUSE RESEARCH

The in-house research effort at ING comprises 1 full-time equivalent (FTE) from its recurrent operational budget, an additional 2 FTEs contributed by PPARC. This effort is distributed amongst 9 members of the Astronomy Group which includes the Head of Astronomy, 6 support astronomers and 2 PPARC research fellows. In addition to these staff there is an additional research astronomer (Dr. Evans) funded through a PPARC Postdoctoral research grant award to Dr. Lennon.

During the years 2004 and 2005, ING staff's research productivity, as measured by publication rate was maintained at its previous high level, publishing approximately 200 papers in various scientific publications, approximately 50% of these appearing in refereed journals. A complete list of these papers is included in Appendix F. As in previous years, an important aspect of the research effort is that ING staff continue to be closely involved with on-going research programmes which are heavily dependent on observations carried out on our telescopes. An important example of this synergy is ING's very active role in the INT/WFC Hα survey of the north Galactic plane (the IPHAS survey, PI: Prof. Drew), which involves 6 ING staff (Corradi, Greimel, Lennon, Leisy, Skillen and Evans) and makes use of their expertise with the Wide Field Camera, for the survey, and with AF2, for the spectroscopic follow-up. An excellent example of collaboration with other facilities on the Roque de Los Muchachos Observatory is typified by Ian Skillen's involvement with the SuperWASP facility, this project kicked off in 2004 and aims to carry out an ultra-wide-angle survey of the northern sky. In addition Licandro co-ordinated a multi-telescope monitoring campaign focused on Deep Impact, more of these and other activites are discussed below.

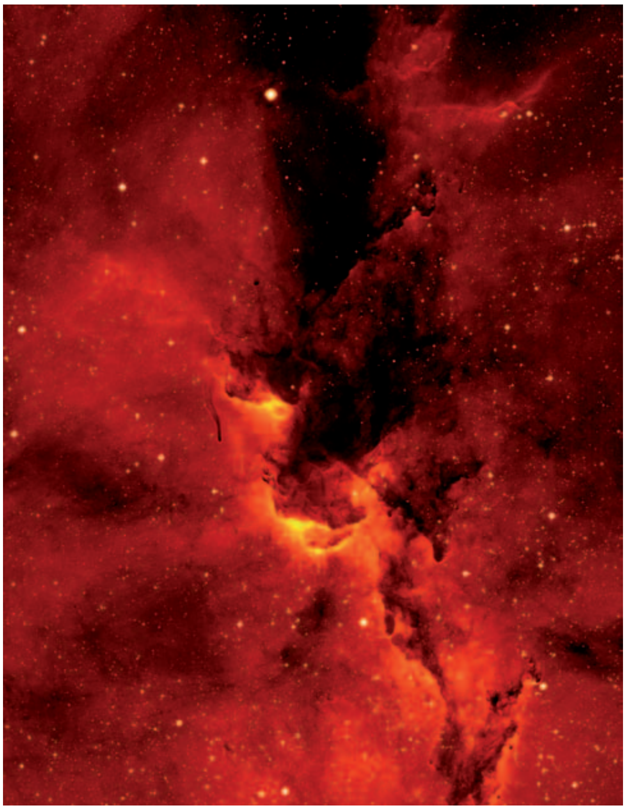


Figure 54. IC1396, the Elephant Trunk Nebula, is a giant cloud of gas and dust is illuminated by a massive central star whose radiation is triggering star formation throughout the region. This image was obtained as part of the IPHAS survey. Field of view is approximately 15×20 arcmin, North to the left, East is down.

INDIVIDUAL RESEARCH ACTIVITIES

Benn investigated the properties of the most radio-luminous broad-absorption-line (BAL) quasar known (1624+3758), discovered during his earlier INT search for high-redshift radio quasars. The quasar is highly unusual, with prominent FeII UV191 1787-A emission, a broad detached BAL trough, and the second-largest radio rotation measure known. This suggests that the quasar is intrinsically unusual (probably due to an exceptionally high accretion rate and also a high Eddington ratio), rather than merely viewed at an unusual angle, as has often been posited to explain the peculiar properties of BAL quasars. This work was carried out in collaboration with Carballo and González (Santander), Holt (Sheffield), Vigotti and Mack (Bologna), and Perley (NRAO). He also co-supervised (with Ellison, Victoria, Canada) an investigation by Russell (1-year student at ING) into quasar damped-Ly-α absorbers (DLAs), finding that there is an excess at low velocities (v<6000 km s^{-1}) relative to the quasars, i.e. the properties of the DLAs can be used to constrain clustering near high-redshift quasars.

In collaboration with Furness (1-year ING student), Schirmer (ING) and Sánchez (Calar Alto), Benn obtained a sample of z~4.5 Ly-α galaxies from a deep imaging search at the INT. This is the first stage of a search for the expected dramatic decline in galaxy counts marking the epoch of re-ionisation.

Sánchez and Benn published an analysis of astronomical productivity by country (a follow-up to their earlier analysis of the scientific productivities of telescopes worldwide).

Corradi studied several aspects concerning Galactic and extragalactic planetary nebulae (PNe). A significant result was the detection of systems of concentric rings around the main bodies of the nebulae (previously known only in few PNe) around a large fraction of the PNe that were properly imaged. This implies that the mass loss modulation producing the rings in the last 10,000–20,000 years of the AGB evolution must be a rather ubiquitous phenomenon, and therefore should be included in any physical model describing the critical mass loss that takes place in this phase.

A thourough study of the dynamics of the multi-polar nebula Mz3 was performed, showing an enigmatic system of 4 distinct outflows with different degrees of collimation. At present, none of the existing theories can explain such a complex mass loss behaviour from an evolved star.

Concerning extragalactic PNe, their search using the observation from the Local Group Census survey was nearly completed, and follow-up spectroscopy with the aim of determining their chemical properties was presented for the nearby spiral galaxy M33. This extends our knowledge of the galaxy's chemical content at intermediate ages of its evolution.

Greimel has worked with Augusteijn (NOT) on the selection of red dwarf-white dwarf binaries from the SDSS. He is also involved in the Hα survey of the Milky Way (IPHAS) and its follow up observations. Together with Corradi (ING), Viironen and Mampaso (both IAC) he participated in the compact PN search; together with Steeghs (CfA), Drew and Unruh (both ICL) he defined the Hectospec and AF2 follow up observations. He also defined the IPHAS variable star candidate list of which follow up observations have started in collaboration with Robb (Victoria, Canada).

Lennon, together with Evans (postdoc) and Trundle (PhD student) completed the most definitive study to date of massive star wind terminal velocities in the Small Magellanic Cloud. This work was based on extensive allocations of HST/STIS observing time, and the same

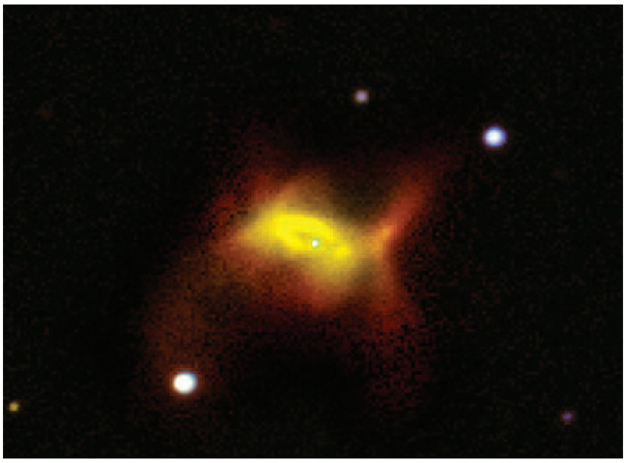


Figure 55. The newly discovered Planetary Nebula PN 126.62+1.32, the 'Prince of Asturias', is a rare quadrupolar nebula and it was discovered using IPHAS data.

data were used to present a comprehensive atlas of ultra-violet spectra of metal-poor massive stars. The use of this atlas for synthesizing the UV spectra of high-redshift star forming galaxies was also a highlight of this project (in collaboration with Rix), as was its use to investigate the nature of the super star clusters in NGC1705-1.

Trundle & Lennon published a comprehensive study of B-type supergiants in the Small Magellanic Cloud, uncovering a serious discrepancy between observed and theoretical mass-loss rates with important implications for our understanding of mass-loss in luminous blue variables, and the physics of mass-loss in these kinds of stars. They also also found very high surface nitrogen abundances in these stars, typical enhancements being an order of magnitude higher than the pristine SMC nitrogen abundance.

Evans published the first results of a 2dF survey of massive stars in the Small Magellanic Cloud, this seminal paper providing a rich dataset comprising 4161 spectra, mostly of B and A giants/supergiants. He has also published several core papers on detailed analyses of massive OB stars in the Magellanic Clouds which were instrumental in revising their effective temperature scale. Lennon & Evans also spent considerable time working on the 'VLT-FLAMES Survey of Massive Stars', a Large VLT project which will ultimately produce, as part of its brief, detailed analyses of approximately 1000 OB stars in the Galaxy and the Magellanic Clouds. Evans is the lead author on the first two consortium papers submitted to *A&A*, while there are several other papers in preparation or already submitted.

Evans and Lennon also continued their involvment in large scale spectroscopic surveys with contributions to the IPHAS follow-up spectroscopy, completing the preliminary classification of several thousand spectra in selected IPHAS fields (with student intern Mansura Jaigirdar), and contributed to the formulation of a large programme aimed at surveying the Magellanic Clouds.

Rix has published a pioneering paper that promotes the use of new metallicity indicators, based on iron absorption features, for measuring the chemical enrichment of high redshift star-forming galaxies. This work was based mainly on theoretical synthetic spectra, and she has now turned her attention to applying them to observed spectra. Rix has also pursued her work on quasar absorption line systems. In 2004 she was the co-author on a paper that quantified the possible impact of dust from intervening galaxies on QSO absorber statistics.She is now collaborating with Pettini (IoA) in a project to study the detailed physical and chemical properties of a proximate damped Ly-α absorber.

In her role as ‘XOasis support’ for the ING’s OASIS instrument, Rix is 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 exploits adaptive-optics 3D spectroscopic observations from the WHT’s OASIS +NAOMI instrumentation suite.

Leisy continued his study of extragalactic planetary nebulae (PNe). He published two articles about new PNe candidates in Local Group (LG) Galaxies and one about the abundance determinations of 180 PNe in the LMC and SMC. A search for fainter PNe, hopefully also very metal poor, has been started in the SMC and the bar of LMC, as well as in other Local Group galaxies with the Local Group Census survey (with the WFC and the ESO 2.2m WFI).

Many new candidates have been found in several galaxies, and most of them are already spectroscopically confirmed. The main goal is to produce catalogs of emission line objects, and then to do spectroscopic follow-up, mainly of PNe and HII regions. The main goals are to determine abundances and to confirm membership of some of the candidates lying very far away from their parent galaxy centers (with high resolution spectroscopy at the WHT/AF2 for example). Four Local Group galaxies (Sextans A and B, IC1613 and NGC3109) have also been observed with the VLT/FORS2 and and time was awarded on Gemini North to observe some additional northern galaxies.

These spectra are used to derive chemical abundances, both to better understand the stellar evolution of intermediate mass stars and the chemical evolution of galaxies in the Local Group and beyond. The very important effects of nuclear processes at low metallicity will help to better constrain what happened during the first stages of the formation of the first galaxies.

Licandro carried out a spectral (visible and near-infrared) survey of trans-neptunian objects (TNOs) and related icy minor planets, and also studied the physics of cometary comae. He was also the P.I. of the international campaign at the ORM in support of the Deep Impact mission. Comet 9P/Tempel 1 was observed for several months before the impact with the TNG, and during 10 days around the impact, from July 2 to July 10, was observed simultaneously with the WHT, TNG and NOT telescopes. Images in the visible and near-IR low and high resolution spectra in the visible and near-IR, were obtained. The data, still under analysis, offer a unique opportunity to study the properties of the dust ejected by the impactor (amount of dust ejected, size distribution, etc), and to study also the gas produced after the impact.

The visible and near-IR spectra of several TNOs, Centaurs and comet nuclei were obtained during 2004-2005. Particularly important is the discovery that the surface of TNO 2005 FY9, the third largest known TNO, is very similar to that of Pluto. The spectrum is dominated by the strong methane-ice absorption bands. The observed bands are deeper than those in Pluto's spectrum, which is indicative of a larger fraction of methane-ice and/or methane-ice with larger particle size in the surface of this bright TNO. This study reveals that 2005 FY9 is an excellent candidate to be the second. known TNO with a bound atmosphere (Pluto is until now the only case of a TNO with atmosphere).

Other important results are those revealed by the study of the spectrum of TNOs Quaoar and 2002 TX300, using

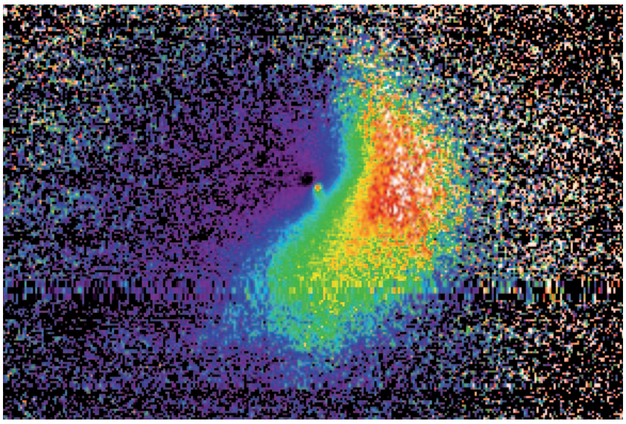


Figure 56. J-band image of comet Tempel 1 obtained using LIRIS on the WHT on July 4th, 2005. The image is the division of July 4th by July 3rd images. A clear jet structure is visible in South-West direction (on the image, North is up, East is left). The field of view of the image is 50×50 arseconds on sky which corresponds to about 32,000 kilometres at the distance of the comet.

scattering models. Both large TNOs present interesting surface properties. Quaoar presents a large fraction of cristaline water-ice on the surface, and clear indications of other volatiles, probably methane-ice. 2002 TX300 present the strongest ever observed water ice absorption bands, it spectrum is similar to that of Charon. This is the first Charon-like TNO observed. The spectra of all these large TNOs reveal that their study is very important to understand the resurfacing processes that make that large TNOs exhibit fresh volatiles in their surface.

Méndez and colleagues completed the search for the companion star to Tycho SN 1572, which followed the publication of a paper in Nature (P. Ruiz-Lapuente et al., 2004, *Nature*, **431**, 1069). The research team found a subgiant star, named as 'Tycho G', whose proper motion was too high for its Galactic location and in the range of the expected gained momentum at the supernova time. This and other features led the discovery team to conclude that Tycho G was the companion star to Tycho SN at the time of the explosion. Méndez also continued to participate in observations for and preparation of papers by the Supernova Cosmology Project, the Physics of Type Ia Supernova Explosions (RTN) and the European Supernova Consortium (ESC) collaborations. He also researched the history of the ING, and participated in the organisation of several international conferences and in public outreach activities.

Østensen is continuing his work with the ING Adaptive Optics group, where his work has focused on characterisation of AO performance. In his research he has continued his ongoing work on pulsations in subdwarf B-type stars, discovering a number of new pulsators as well as several interesting short period binary sdB+dM systems (in collaboration with Solheim, Oslo and Oreiro, IAC). In collaboration with Telting (NOT) he has presented the first evidence of line profile variations in an sdB star from time resolved spectroscopy. He has also undertaken a survey of spectroscopic subdwarf B binaries with NAOMI in order to put the different evolutionary scenarios proposed for these stars to a test.

Other projects in this field include mining the Sloan Digital Sky Survey for spectroscopic and photometric data on new and known subdwarf stars, and spectroscopic model fitting of sdB stars and sdB stars in binary systems (with Heber, Bamberg).

Østensen has continued to develop a complete database system for hot subdwarf stars, bringing together results from the numerous blue star surveys into one searchable databank that has now been released for public use. Østensen also organized the 2nd Meeting of Hot Subwarf Stars on La Palma during 2005.

Schirmer continued his work on the selection of galaxy clusters using weak gravitational lensing techniques. Such a mass-selected sample of galaxy clusters is of great cosmological interest, since clusters of galaxies indicate the highest dark matter density peaks in the Universe, and therefore retain a memory of the initial conditions for structure formation. From a 20 square degree survey 30 candidate galaxy clusters have been selected, and Mischa applied for multi-object spectroscopy time for further detailedinvestigation. If confirmed, these clusters will form the currently largest sample of mass-selected dark matter haloes. The main collaborators in this project are Matturi (Padova), van Waerbeke (UBC Vancouver) and Schneider (Bonn). The same survey data forms the basis of several other projects Mischa is involved in, such as studies of the dark matter haloes of galaxies (Kleinheinrich et al.), populations of Lyman-break galaxies at various redshifts (Hillebrandt et al.), the galaxy dark matter bias (Simon et al.) (all University of Bonn), or a census of tidal tails (Pohlen et al., IAC).

Within the framework of ING, Leisy and Schirmer are searching for planetary nebulae in Local Group galaxies and beyond, significantly improving their detection efficiency by means of sophisticated data reduction schemes. Together with Chris and Furness he participates in the search for Lyman-break galaxies at redshifts of 4 and beyond. Other of his projects encompass the identification of unknown gamma-ray sources in the Galaxy (La Palombara et al., Milan), X-ray emitters in NGC 300 (Carpano, Tübingen) and the search for the missing mass of the Crab Supernova remnant, which has been an unsolved mystery for more than two decades. Deep Hα images have recently been obtained by Lundqvist et al., and first results look very promising.

Skillen in a collaboration with Pollacco and Todd (QUB), Bell (RAL) and Augusteijn (NOT), is conducting an ongoing photometric search for eclipsing binary systems in local group galaxies. Approximately one hundred new systems have been discovered in each of M31, IC 1613 and NGC 6822. Selected systems will be followed up spectroscopically to determine accurately their physical parameters and hence distances. The goal of this project is to investigate the impact of the physical environment on standard candles within the Local Group, and to reduce the uncertainty in the determination of the Hubble Constant to within 5%.

The SuperWASP facility was inaugurated and fully commissioned in 2004, in collaboration with Pollacco (QUB) and the WASP Consortium. The WASP project is an ultra-wide-angle photometric survey with a precision of better than 1% of stars in the magnitude range 7–13, with the primary goal of discovering exosolar planet transits. It will also provide an unrivalled census of variable stars over the northern sky; the resulting archive will be exploited for a variety of science goals, ranging from the discovery of exosolar planets to aspects of stellar pulsation, binarity and galactic structure. A programme, in collaboration with Barnes (Texas), to determine high precision (0.4 km/s) radial velocity curves of galactic Cepheid stars from echelle spectroscopy, has now been completed.

SCIENTIFIC CONFERENCES

Rutten organized the 'Workshop on Adaptive-Optics Assisted Integral-Field Spectroscopy' at the Hotel H10 Taburiente Playa in Los Cancajos on La Palma during May 9–11 2005. Integral-field spectroscopy and Adaptive Optics (AO) techniques are an increasingly important tool in astronomy. A number of integral-field spectrographs are in operation around the world, and AO instruments are proliferating and becoming a standard feature of in particular the largest ground-based telescopes. The combination of integral-field spectrographs and AO is still a relatively unexplored area where the potential benefits for astronomy are huge. For that reason, a number of projects are under way or are being proposed that will take advantage of the most recent technological developments in these areas. The most prominent scientific prospects are expected to be in the areas of study of the dynamics of the central regions of elliptical galaxies and active galactic nuclei, spectroscopy of gravitationally lensed high-redshift galaxies, star formation regions and outflow of evolved stars, and the dynamics of crowded stellar fields.

The advent of a new facility instrument at the 4.2m William Herschel Telescope, the OASIS Integral Field Spectrograph, working in conjunction with the NAOMI AO system prompted the holding of a workshop covering this area. Moreover, the ING laser guide star facility (GLAS) which is currently under development, will open up nearly the full sky to AO exploitation. This implies a huge new potential for AO assisted spectroscopy to be carried out on large samples of objects, as there no longer will be the restriction of having to have a nearby bright guide star.

The workshop focused on the scientific achievements and prospects of AO-assisted integral field spectroscopy, promoting discussion and sharing of experiences and ideas. The outcome prompted new collaborations and ideas for observing programmes, while at the same time it provides the observatory with scientifically inspired advice on how to maximally exploit the exciting possibilities of AO at the William Herschel Telescope. The proceedings were published in Rutten, R. G. M., Benn, C. R., Méndez, J., 2006, *New Astronomy Reviews*, **49**, 487.

Østensen organized the '2nd Meeting on Hot Subdwarf stars and related objects' at the Real Club Náutico de Santa Cruz de La Palma during June 6–10 2005, a collaborative venture between the ING and NOT. Hot subdwarf stars are extreme horizontal branch (EHB) stars and pre-white dwarf stars. The EHB stars are core helium-burning stars with extremely thin hydrogen envelopes, and form the majority of bright stars in surveys for extremely blue objects, where they are classified as subdwarf-B (sdB) stars. They also appear in the colour-magnitude diagrams of some globular clusters as an extension of the blue tail formed by classical horizontal branch stars, though it is not clear why some clusters show this feature and other do not. The pre-white dwarf stars are related to the sdBs, but have exhausted their capacity to burn helium in the core. Many of the brightest hot subdwarfs in the field are of this class, and they are classified as sdO stars.

Hot subdwarf stars and their relatives are believed to be important contributors to the hitherto mysterious UV upturn phenomenon in early-type galaxies; and a comprehensive investigation on this issue is being performed by the Galaxy Evolution Explorer (GALEX). The formation of EHB stars remains, in general, a matter of debate. Recent results for Galactic EHB stars show that the majority are close binary stars, so mass transfer and mass loss due to interactions between the stars clearly play a role. EHB stars are an excellent tool for studying evolution in close binary stars. Some EHB stars shows p-mode pulsations with periods of a few minutes and some others show g-mode pulsations with periods on the order

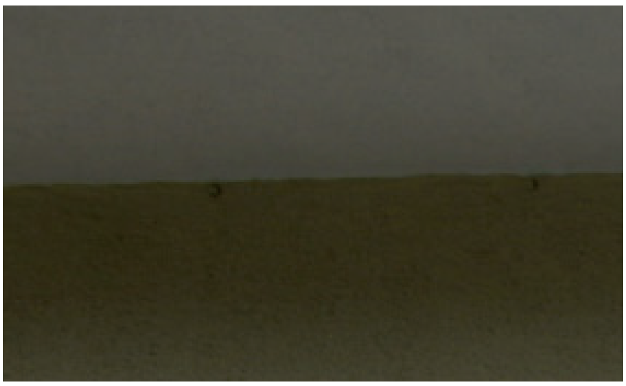


Figure 57. Group photograph of participants to the workshop on 'Adaptive-Optics Integral-Field Spectroscopy'.

of hours. Asteroseismology can be used to measure fundamental parameters for these stars directly. Hot subdwarf stars are also a laboratory for studying the effects of diffusion, weak stellar winds, radiative levitation and gravitational settling. These processes are seen to affect the peculiar composition of their atmospheres and also play a role in the driving mechanism for pulsations and, perhaps, the subsequent evolution of the star.

The meeting was divided into sessions that covered a broad range of topics related to the hot subdwarf stars. They were: evolutionary models and the UV-upturn phenomenon; hot subdwarfs and hot HB stars in the field, clusters and galaxies; atmospheric properties of hot subdwarf stars; hot subdwarfs in binary systems; asteroseismology of sdB stars.

Eight half day sessions were completed during the meeting, with three sessions dedicated to asteroseismology, two sessions for atmospheric properties and the remaining topics filling one session each. 58 participants from all over the world attended the meeting, almost half again as many as at the first meeting. The proceedings are to be published in journal *Baltic Astronomy*, Volume 15.

Figure 58. Announcing poster of the 2nd meeting on 'Hot Subdawrf Stars and Related Objects'.

Danny Lennon organized a Royal Astronomical Society Specialist Meeting 'Science from La Palma —Looking Beyond 2009' in collaboration with Evans (ING) and Drew (ICL). The meeting was held at Burlington House, Piccadilly, London, on 14 October 2005. In 2009 the international agreement setting up the Roque de los Muchachos Observatory on the island of La Palma will have been in existence for a period of 30 years. In the near future the United Kingdom will have to make a decision on whether or not to withdraw from that agreement and PPARC, through its ownership of the Isaac Newton Group of Telescopes, has the responsibility of deciding on the UK's involvement in the observatory beyond 2009. As part of the decision making process, and in support of the UK's overall strategic re-evaluation in astronomy, the ING was reviewed during 2005. It was therefore thought timely to assess recent scientific achievements from the Roque de los Muchachos, and to consider what role the observatory might have beyond 2009. The meeting was attended by approximately 100 astronomers from around the UK, and was structured to allow two morning sessions of science talks with contributors from various fields in astronomy. This was followed in the afternoon by a series of strategy talks, culminating in a half-hour discussion on the future of the ING.


Figure 59. The meeting 'Science from La Palma —Looking Beyond 2009' was held at the lecture theatre of the Geological Society at Burlington House, Piccadilly, London.

Chapter 5

PUBLIC RELATIONS

As in previous years thousands of visitors were shown the WHT and the INT, many as part of the annual observatory open days during the summer, but also through a large number of official visits, of which as much as 40% were schools. In total, ING welcomed 8206 visitors (5656 in 2004 and 2550 in 2005) in 317 tours. Some of our visitors in the reporting period were the Spanish and Dutch ministers of Science and Education and the Spanish astronaut Pedro Duque.

Coinciding with the fiesta of La Bajada de la Virgen de Las Nieves, a new model for organising tours on Open Days in order to reduce the impact on the observatory operations was tested in 2005. Visitors were asked to book online their tours well in advance. The total number of visits per open day was reduced from previous years while increasing the number of days to five.

All these activities help strengthen the ties between the observatory and the public on La Palma. Moreover, apprenticeships for a small number of technical students from La Palma have been hosted by the ING, providing further added value of the observatory to the local community. And ING also helped the foundation of the "Sociedad de Estudios Generales de la Isla de La Palma", a local society devoted to general research of La Palma.

ING continued to provide young highschool students with first contacts with professional telescopes and hands-on experiences, through the participation in night observing. One of the initiatives we supported was "WINT", a Dutch national competition for young students organised by the NOVA school. Students had to prepare their own observing programmes and the winners were awarded with two nights on the INT. Another example was from the Marlborough school from the UK, which organised a trip for 5 students and teachers to join the observer at the INT for two nights.

Other public activities included the participation of several ING astronomers in the La Palma summer university and in the celebration of the European Science and Technology Week in 2004 and 2005. The public outreach group of OPTICON has members from the CCI institutions

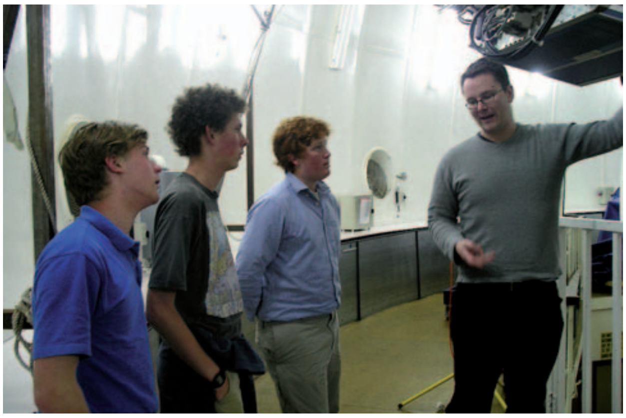


Figure 60. Top: Students at the INT control room during WINT observations. Bottom: Students from Marlborough School paying attention to the explanations given by the INT observer.

and was set up to promote the organization of common public activities at the Canarian Observatories. Apart from the support to the organization of visits to the ORM and the Open Days in summer, the group has also printed a collection of brochures for each astronomical facility in Spanish and in English and it has organized a traveling exhibit that has been displayed at the airport terminals.

Finally, ING also gave support to the inauguration of SuperWASP and for making public the results from Deep Impact at the ING telescopes.

ING has been particularly active on scientific outreach activities during the reporting period. A workshop on "Adaptive-Optics Assisted Integral-Field Spectroscopy" was organised on La Palma (9–11 May 2005) which

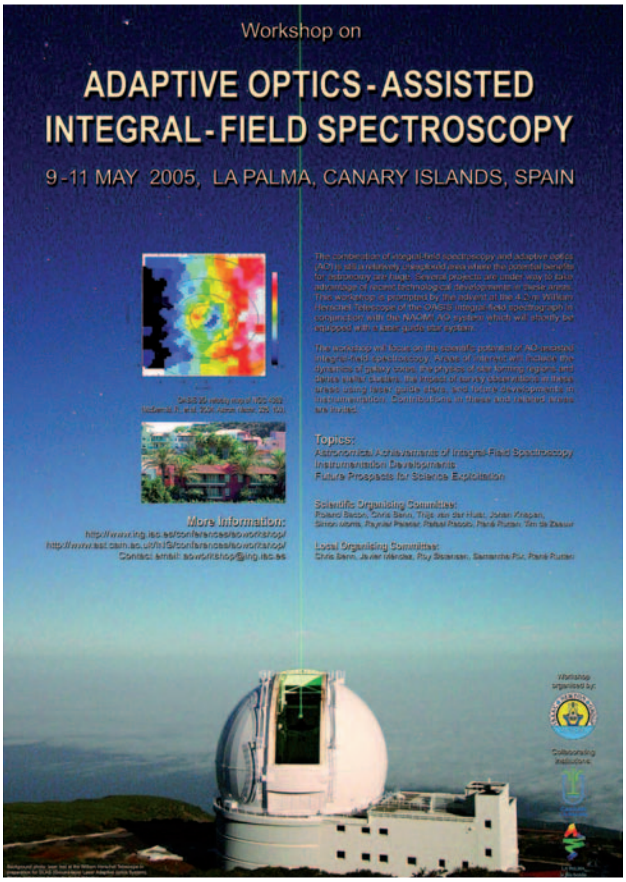


Figure 61. Announcing poster of the workshop on 'Adaptive-Optics Assisted Integral-Field Spectroscopy'.

attracted some 60 participants from around the world. This workshop was inspired by the availability of the OASIS integral field spectrograph on the WHT and of the plans to develop a laser guide star system as well. The proceedings were published in: René, R. G. M., Benn, C., Méndez, J., 2006, *New Astronomy Reviews*, **49**, 487. A joint Isaac Newton Group and Nordic Optical Telescope Conference on "Hot Subdwarf Stars and Related Objects" took place also on La Palma (6-10 June 2005), again with over 60 participants. The proceedings were published in: Østensen, R., 2005, *Baltic Astronomy*, **15**. Both conferences included a public talk and a press conference. And finally a dedicated session focussing on the scientific achievements and the future of the ING was held in London under the auspices of the Royal Astronomical Society.

Four issues of the ING Newsletter and the Biennial Report 2002–2003 were launched in the reporting period. Also remarkable is the large number of requests for using the images and photographs from our public archives in magazines, books, web sites or exhibitions in museums. The production of new public astronomical images is of vital importance to continue satisfying this high demand.

Thanks to the collaboration of the observers, we have been able to make available beautiful images, some of which have been awarded the 'NASA Astronomy Picture of the Day' recognition.

A total of 31 press releases have reflected the most relevant research highlights of our scientific production. These press releases were prepared by ING or other institutions and they were based on results from data obtained at the ING telescopes or achieved by ING astronomers. Other contacts with the press included TV teams from Spain, Germany or Ireland that filmed scenes for scientific series or documentaries at the telescopes.

Figure 62. Top: Image of M81 galaxy obtained using the Wide Field Camera on the INT. Bottom: NGC 7271 galaxy as observed with the Prime Focus camera on the WHT. Both images were incorporated to ING's public archive of images.

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. It ceased science observations in August 2003 and now it is regularly being used for measuring the atmospheric turbulence profile above the observatory. Both the INT and the JKT were first operational in May 1984.

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, just above the primary mirror, so that the light from the secondary is diverted sideways either 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 one uses a f/8 spherical secondary and the latter one 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 Particle Physics and Astronomy Research Council (PPARC) 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 Garafía. La Palma is one of the westerly islands of the Canarian archipiélago.

The site was chosen after an extensive search for a location with clear, dark skies all the year around. 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-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

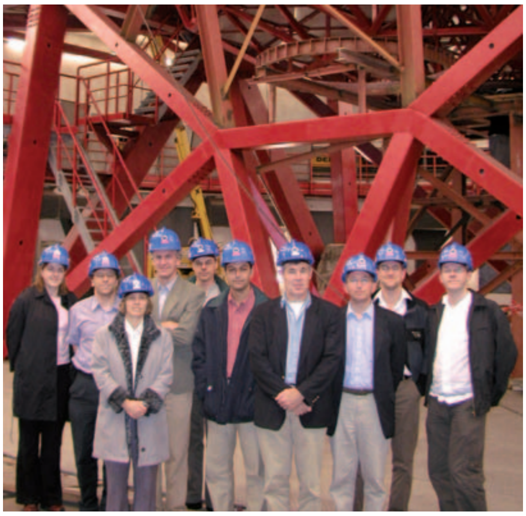
The international agreements by which the Roque de Los Muchachos and the Teide Observatories were brought into existence were signed on La Palma on 26 May 1979. The participant nations at that time were Spain, the United Kingdom, Sweden and Denmark. Later other European countries also signed the agreements. 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.



The ING Board at the Gran Telescopio Canarias.

TELESCOPE TIME AND DATA OWNERSHIP

The construction, operation, and development of the ING telescopes is 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 belongs exclusively to those who collected it for a period of one year, after which it is 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 in common to 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, analyse, relate to other work, and eventually publish the data.

Requests for observations from programmes already executed on the telescopes should be referred to the original owners of the data, and/or to the data archive. This is the policy whether or not the data were obtained by PATT, NFRA PC, or CAT scheduled astronomers, or by service requests.

Appendix B

TELESCOPE INSTRUMENTATION

The design of the WHT allows great flexibility in instrumentation as this telescope allows fast and easy switching between the Cassegrain and Nasmyth foci. For this reason, and to take advantage of the large light collecting power of this 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 welcome at the WHT and have attracted a great deal of attention. The INT is equipped with only one instrument, the Wide Field Camera. A broad functional division in instrumentation capability between the WHT and INT is as follows:

William Herschel Telescope	Optical pectroscopy and spectro-polarimetry over a wide range of resolving powers
	Imaging polarimetry
	IR spectroscopy
	Multi-object spectroscopy
	Areal spectroscopy
	Optical and infrared imaging
	High spatial resolution imaging
	Coronography
Isaac Newton Telescope	CCD imaging

The following table summarises the common-user instruments which were available during 2004 and 2005:

Focus	Instrument	Detector
William Herschel Telescope		
Cassegrain	ISIS double spectrograph	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	Rockwell HgCdTe array
	NAOMI / OASIS	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		
Prime	Wide Field Camera (WFC)	4 × EEV CCDs

Appendix C

STAFF ORGANISATION

DIRECTORATE

R. G. M. Rutten, *Director*

ADMINISTRATION

E. C. Barreto
L. I. Edwins, *Head of Administration*
N. L. González
L. A. Lawler (until 23.10.2005)
J. Martínez
B. van der Elst (to 31/03/2004)
P. v. d. Velde

Students:
E. C. Barnett (until 20.08.2004)
V. H. Jones (from 09.09.2005)
J. Keable (from 20.09.2004 to 19.08.2005)

ASTRONOMY

C. R. Benn
R. Corradi
R. Greimel
P. Leisy
D. J. Lennon, *Head of Astronomy*
J. Licandro
J. Méndez
R. Østensen
S. Rix (from 01.06.2004)
M. Schirmer (from 01/03/2004)
W. J. I. Skillen
A. Zurita (to 31/01/2004)

PPARC Postdoc:
C. Evans (from 14.01.2002 to 14/10/2005)

Students:
P. Behrens (from 26.08.2005)
A. Cardwell (from 29.08.2005)
J. Furness (from 01.09.2004 to 30.08.2005)
A. García (from 01.09.02 to 31.08.2004)
S. Hickey (from 05.09.2005)
M. Jaigirdar (from 01.09.2004 to 29.08.2005)
F. Monterrey (05.2003)
D. Mislis (from 06.10.03 to 13.09.2004)
R. Parker (from 26.08.2005)
D. Russell (from 11.08.03 to 11.08.2004)
L. Sabin (from 19.08.2005)
S. Simon (from 01.10.2004 to 30.09.2005)
N. Styles (from 15.09.03 to 31.05.2004)

ENGINEERING

R. G. Talbot, *Head of Engineering*

Computing

D. C. Abrams, *Group Leader*
D. Armstrong (to 30.04.2004)
R. Bassom (to 30.06.2005)
C. Bevil
S. Goodsell (to 31.07.2004)
F. J. Gribbin
L. Hernández
G. F. Mitchell
A. d. Paz (from 20.09.2004 to 19.12.2004)
S. Picó (from 01.09.2004)
J. Piñero
S. G. Rees
J. Skvarc (from 05.01.2005)

Note: During the period covered by this report the Computing Facilities and the Software Groups joined to a new group, the Computing Group.

Telescopes & Instrumentation

N. Apostolakos (from 01.10.2004)
C. Benneker (to 30.09.2004)
M. Blanken
D. Cano (from 01.09.2004), *Group Leader*
T. S. Gregory
A. K. Hide (to 30.04.2004), *Group Leader*
M. v. d. Hoeven
C. W. M. Jackman (to 15.03.2004)
P. D. Jolley
O. Martin (from 09.05.2003)
A. Ridings
S. M. Tulloch

Student:
N. Apostolakos (to 30.09.2004)

OPERATIONS TEAM

A. K. Chopping
J. R. Concepción
K. M. Dee, *Head of Operations*
J. M. Díaz
D. González
A. Guillén
D. Gray (to 26.09.2004)
R. Martínez
J. C. Pérez
R. Pit
J. Rey (from 01.08.2004), *Group Leader*
S. Rodríguez

Student:
J. Hutchinson (from 14.05.2004 to 14.09.2004)

Telescope Operators

J. N. González
J. C. Guerra (from 01.08.2004)
C. Martín
N. O'Mahoney

Appendix D

TELESCOPE TIME AWARDS

The UK Panel for the Allocation of Telescope Time (PATT), the Dutch NFRA Programme Committee (PC), the Spanish Comité para la Asignación de Tiempos (CAT) and the Comité Científico Internacional (CCI) made time awards to the following observing proposals in 2004 and 2005. 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 2004A

William Herschel Telescope

UK PATT

– Charles (Southampton). Determining system parameters of a soft X-ray transient in outburst. W/2004A/36
– Charles (Southampton). The mass donor in SS43. W/2004A/56
– Harries (Exeter). Spectropolarimetry of symbiotic binaries. W/2004A/6
– Haswell (OU). Accretion disc precession in AM CVn. W/2004A/49
– Hodgkin (IoA). Spectroscopic identification of very low-mass stars and brown dwarfs in young open clusters. W/2004A/54
– Jarvis (Oxford). Quantifying the space density of radio-loud quasars at z>5. W/2004A/19
– Jeffery (Armagh). PG1544+488 and other helium-rich subdwarfs: binaries, mergers or bizarre. W/2004A/45
– Keenan (QUB). The space density of B-type stars in the Galactic halo. W/2004A/3
– Lucas (Hertfordshire). PLANETPOL polarimetry of Tau Boo Ab. W/2004A/27
– Marsh (Warwick). ULTRACAM observations of detached white dwarf/M dwarf binary stars. W/2004A/35
– Meikle (ICL). Direct detection and study of supernovae in nuclear starbursts. W/2002B/56 LT
– Meikle (ICL). Detailed study of the physics of nearby Type Ia supernovae. W/2003B/2 LT
– Merrifield (Nottingham). Determining the dynamics of round elliptical galaxies using the Planetary Nebula Spectrograph. W/2003A/38 LT
– Miller (Oxford). A deep survey for cluster-lensed QSOs from SDSS and 2QZ. W/2004A/58
– O'Brien (Leicester). Optical identification of ultra-soft X-ray sources — searching for extreme accretion. W/2004A/32
– Østensen (ING). Resolving sdB binary systems with Adaptive Optics. W/2004A/46
– Rawlings (Oxford). FLAGS — understanding the starburst-AGN connection. W/2004A/17
– Roques (Observatoire de Paris). Search for small Kuiper Belt objects by stellar occultations. W/2004A/38
– Smail (Durham). A Lyman-break survey in the SCUBA/BLAST region. W/2004A/8
– Smith (Sussex). Mapping the surface of the secondary stars in cataclysmic binaries. W/2004A/50
– Snellen (IoA). The space-density of high redshift FRI radio galaxies (II). W/2004A/23
– Vink (ICL). Searching the environments of Herbig Be stars for clusters and discs. W/2004A/39
– Wilkinson (IoA). Dark matter in the Sextans dwarf spheroidal. W/2004A/2

NL NFRA PC

– Cole (Groningen). Calcium triplet spectroscopy of Galactic open clusters. w04an005
– Douglas (Groningen). Determining the dynamics of round elliptical galaxies using the Planetary Nebula Spectrograph (PN.S). w04an012
– Groot (Nijmegen). The missing link of cataclysmic variable evolution in the Sloan Digital Sky Survey? w04an013
– Groot (Nijmegen). High speed spectral eclipse mapping of accretion disks in cataclysmic variables. w04an014
– Groot (Nijmegen). High speed spectral eclipse mapping of accretion disks in cataclysmic variables. w04an017
– Nagar (Groningen). Sub-kiloparsec kinematics in Seyferts and non-active galaxies — a comparative study. w04an006
– Perryman (ESTEC). Testing the relation between magnetic field strength and QPO frequency in polars. w04an003
– Perryman (ESTEC). The optical counterparts of radio pulsars. w04an004
– Quirrenbach (Leiden). Line bisector variations for K giant stars with possible planetary companions. w04an015
– Roelofs (Nijmegen). Measuring directly the anticipated tidal deformation of the accretion disk of AM CVn. w04an010
– Röttgering (Leiden). Multi-object spectroscopy of radio sources in the Bootes Deep Field. w04an008
– van der Klis (Amsterdam). Comparing a neutron star with two black hole transients in quiescence. w04an002
– Wijers (Amsterdam). The nature of Gamma-Ray Bursts and their use as cosmological probes. w04an011

SP CAT

– Alonso (IAC). Adaptive Optics observations of candidates to transiting extrasolar planets. W29/2004
– Beckman (IAC). Vertical structure of nuclear bars in double-bar galaxies. W11/2004A
– Beckman (IAC). Evolution of galactic star formation: the morphologic method. W37/2004A
– Casares (IAC). Echo tomography of fluorescence lines in Sco X-1. W35/2004A
– Casares (IAC). Determining system parameters of a Soft X-ray transient in outburst. W36/2004A
– Castander (IEEC). Spectroscopy of pairs of quasars in the line-of-sight: a study of the proximity effect. W39/2004A
– Castro-Tirado (IAA). The nature of Gamma-Ray Bursts (GRBs). W33/2004A
– Díaz (UAM). Spectrophotometry of the brightest HII galaxies from the SDSS. W23/2004A
– Erwin (IAC). How many galactic bulges are imposters? W5/2004A
– González (IAC). Searching for the evidence of a supernova event in the LMXB V404Cyg. W21/2004A
– Gutiérrez (IAC). Systems with anomalous redshifts. W19/2004A
– Martín (IAC). Spectroscopic identification of very low-mass stars and brown dwarfs in young open clusters. W3/2004A
– Martínez (Valencia). Properties of the haloes around field elliptical galaxies. W30/2004A
– Pascual (UCM). Physical properties and chemical abundances of the population of current star-forming galaxies at z=0.24. W16/2004A
– Pérez (IAA). Massive stellar clusters in nearby disc galaxies. W40/2004A
– Pohlen (IAC). A test of the bar-peanut connection in a bulge-less galaxy. W7/2004A
– Rebolo (IAC). Direct detection of giant exoplanets and brown dwarfs around young nearby stars. W17/2004A
– Ruiz (Barcelona). Supernovae at z=0.35–0.65: a study of the nature of the dark energy. W1/2004A
– Santander (IAC). The origin of extended nebulae around symbiotic stars. W20/2004A
– Vazdekis (IAC). Ages and metallicities of S0 galaxies along the Colour-Magnitude relation. W25/2004A

Spanish Additional Time

– Balcells (IAC). U-band deep survey for COSMOS and OTELO. W9/2004A
– Cepa (IAC). The OTELO project: deep BVRI survey of Groth and SIRTF-FLS fields. W27/2004A

TNG-TAC

– Fasano (Padova). Star formation and morphological evolution of galaxies in nearby clusters with WYFFOS. T064

Isaac Newton Telescope

UK PATT

– Alton (CEA Saclay). The dust-to-gas ratio of the intergalactic gas in the M81 group. I/2004A/1
– Cotter (Oxford). A complete investigation of low-redshift radio galaxies and their cluster environments. I/2004A/20
– Davies (Cardiff). Satellites in nearby galaxy halos (M101). I/2004A/3
– de Blok (Cardiff). Deep BVRI surface photometry of core-dominated low surface brightness galaxies. I/2004A/12
– Drew (ICL). IPHAS — the INT/WFC photometric Hα survey of the northern galactic plane. I/2004A/8
– Feltzing (Lund). A differential study of the metallicity distribution functions in three northern dwarf spheroidal galaxies. I/2004A/9
– Fitzsimmons (QUB). Rapid-response astrometry of potentially hazardous asteroids. I/2004A/6
– Helmi (Groningen). Star streams and High Velocity Clouds in the Milky Way halo. I/2004A/23
– Hewett (IoA). Faint planetary nebulae around hot white dwarfs. I/2004A/11
– Jarvis (Oxford). A wide-field search for Ly-α haloes: A pre-requisite for massive galaxy formation. I/2004A/17
– Jarvis (Oxford). Quantifying the space density of radio-loud quasars at z>5. W/2004A/19 [sic]
– Snellen (IoA). The space-density of high redshift FRI radio galaxies. I/2004A/5

NL NFRA PC

– Aragon (Groningen). Measuring galaxy spin alignments along a void-intersection filament near AWM3. i04an007
– Braun (NFRA). The STARFORM/Hα survey: Probing the recent history of star formation in spirals. i04an003
– Habing (Leiden). Monitoring of Asymptotic Giant Branch stars in Local Group Galaxies. i04an001
– Oosterloo (NFRA). The mass distribution in extremely warped disk galaxies. i04an006
– Röttgering (Leiden). A survey for Ly-α emission line halos and the properties of z>2 proto-clusters. i04an008
– Wijers (Amsterdam). The nature of Gamma-Ray Bursts and their use as cosmological probes. w04an011 [sic]

UK/NL WFS Programmes

– Casares (IAC). The orbital parameters of XTE J1859+226. I10/2004A
– Castro-Tirado (IAA). The nature of Gamma-Ray Bursts (GRBs). W33/2004A [sic]
– Deeg (IAC). Sample definition for exoplanet detection by the COROT space craft. I13/2004A

– Erwin (IAC). The outer disks of S0 galaxies: clues to disk evolution. I3/2004A
– Gómez-Flechoso (UEM). Constraining the shape of the Milky Way dark matter halo with the Sgr tidal stream. I12/2004A
– Gutiérrez (IAC). Searching for Sunyaev-Zeldovich Clusters. I8/2004A
– Hammersley (IAC). A deep multi-wavelength survey of the Galactic Plane. I9/2004A
– Leisy (IAC/ING). IPHAS — the INT/WFC photometric Hα survey of the Northern Galactic Plane. I4/2004A
– López (IAC). Quantitative morphology of Hercules galactic supercluster. I1/2004A
– López (IAC). Tracing the intracluster light in Virgo Cluster. I2/2004A
– Mampaso (IAC). Planetary nebulae and the intergalactic stellar population in the intragroup medium. I6/2004A
– Vázquez (IAC). Stellar and solar oscillations. I5/2004A

Spanish Additional Time

– Herrero (IAC). Detecting the population of blue massive stars to 5 Mpc for OSIRIS. I11/2004A
– Vílchez (IAA). An Hα search for star-forming galaxies in nearby clusters. I14/2004A

SEMESTER 2004B

ITP Programmes on the ING Telescopes

– Gäensicke (Warwick). Towards a global understanding of close binary evolution. ITP7

William Herschel Telescope

UK PATT

– Bunker (Exeter). Star formation at redshift ~1. W/2004B/56
– de Blok (Cardiff). Deep K-band surface photometry of low surface brightness galaxies. W/2004B/30
– Dhillon (Sheffield). ULTRACAM observations of the transiting extrasolar planet HD209458b. W/2004B/14
– Dufton (QUB). Spectroscopy of h+c Persei to support VLT/FLAMES survey of the Magellanic Clouds (payback). W/2003B/3
– Gaensicke (Warwick). HS2331+3905: A cataclysmic variable in its final days? W/2004B/37
– Hirtzig (Meudon). Titan’s surface and atmosphere: in-depth diagnostic via spectro-imagery. W/2004B/69
– Jeffers (St Andrews). High-resolution Doppler imaging of RS CVn SV Cam. W/2004B/33
– Jeffery (Armagh). Mode identification from multicolour photometry of the pulsating sdB star PG 0014+067. W/2004B/44
– Knigge (Southampton). Spectroscopic reconnaissance of candidate emission line stars discovered by IPHAS. W/2004B/71
– Kotak (ICL). Optical spectroscopic study of the physics of nearby Type Ia Supernovae. W/2004B/16
– Kotak (ICL). Optical spectroscopic study of the physics of nearby Type Ia Supernovae. W/2004B/17
– Leven (Leicester). GRBs as cosmological probes. W/2004B/60
– Littlefair (Exeter). The quiescent accretion disc in the dwarf nova IP Peg. W/2004B/31
– Lucas (Hertfordshire). PLANETPOL polarimetry of Upsilon Andromedae b. W/2004B/6
– Marsh (Warwick). Stochastic Variability of Accreting White Dwarfs. W/2004B/21
– Marsh (Warwick). Magnetism in “non-magnetic” cataclysmic variable stars. W/2004B/66
– Maxted (Keele). Eclipsing binaries in open clusters — spectroscopy. W/2004B/40
– McLure (IoA). Exploring the connection between bulge/black-hole mass and radio luminosity from z=0 to z=2. W/2004B/34
– Meikle (ICL). Late-time study of the nearby type IIP Supernova 2004am. W/2004B/38
– Meikle (ICL). Direct detection and study of supernovae in nuclear starbursts. W/2002B/56 LT
– Merrifield (Nottingham). Gravitational redshift in M32 and the properties of its stellar population. W/2004B/39
– Nelemans (IoA). Testing common envelope theory and SN Ia progenitor models with double white dwarfs. W/2004B/47
– Royer (Leuven). A complete survey of the Wolf-Rayet content of M33. W/2004B/28
– Smith (Hertfordshire). The high and low ionization broad-line region in quasars. W/2004B/5
– Tanvir (Hertfordshire). The physics of short bursts and relativistic blast waves. W/2004B/51
– Vink (ICL). A search for evidence of accretion in Herbig Be stars. W/2004B/4
– Wilkinson (IoA). Dark matter in the Sextans dwarf spheroidal. W/2004B/70

NL NFRA PC

– Aerts (Nijmegen). Asteroseismology of the pulsating sdB star PG 0014+067. w04bn015
– de Zeeuw (Leiden). Mapping the nuclear regions of SAURON early-type galaxies with OASIS. w04bn006
– Franx (Leiden). Infrared Spectroscopy of restframe Optically Red Galaxies at high redshift. w04bn008
– Groot (Nijmegen). Spectroscopic reconaissance of emission line stars discovered by IPHAS. w04bn013
– Groot (Nijmegen). The UV-excess and White Dwarf binary population in the Faint Sky Variability Survey. w04bn014
– Groot (Nijmegen). The missing link of Cataclysmic Variable evolution in the Sloan Digital Sky Survey? w04bn016
– McDermid (Leiden). Black hole masses from gaseous and stellar kinematics using OASIS+NAOMI. w04bn007

– Nelemans (Nijmegen). Testing common envelope theory and SN Ia progenitor models with double white dwarfs. w04bn004
– Nelemans (Nijmegen). The masses of millisecond pulsars. I. Identification of suitable white dwarf companions. w04bn005
– Quirrenbach (Leiden). Line bisector variations for K giant stars with possible planetary companions. w04bn011
– Trager (Groningen). The stellar populations of gas-selected early-type galaxies. w04bn003
– Wijers (Amsterdam). GRBs as cosmological probes. w04bn009
– Wijers (Amsterdam). The physics of short bursts and relativistic blast waves. w04bn012

SP CAT

– Arribas (STScI/IAC). The potential of Integral Field Spectroscopy detecting extrasolar planetary features: INTEGRAL observations of HD209458b. W28/2004B
– Cairós (IAC). Multiwavelength studies of metal-poor Blue Compact Dwarf Galaxies: unveiling their evolutionary state. W33/2004B
– Casares (IAC). Determining system parameters of a soft X-ray transient in outburst. W2/2004B
– Castro-Tirado (IAA-CSIC). The nature of Gamma-Ray Bursts (GRBs). W36/2004B
– Colina (IEM/CSIC). INTEGRAL study of very luminous infrared galaxies. W4/2004B
– Exter (IAC). Searching for chemical inhomogeneities in planetary nebulae (PNe). W18/2004B
– Gallego (UCM). The evolution of the star formation rate density of the Universe up to z=0.8. W45/2004B
– González (IAC). Probing the evidence of a supernova event in the black hole binary A0620-00. W12/2004B
– Hatzidimitriou (Creta). Identification of optical counterpart X-ray sources in M33. W5/2004B
– Iglesias (Marseille). Galactic stellar formation in nearby clusters. W21/2004B
– Magrini (Firenze). The chemical composition of HII regions in M33. W16/2004B
– Martínez (Valencia). The mass and the extension of the haloes of elliptical galaxies. W10/2004B
– Martínez-Delgado (IAC). Does M31 have as many satellites as predicted by Cold Dark Matter theory? W37/2004B
– Miranda (IAC). Fluorescence processes in astrophysics: the excitation of OI 8446. W20/2004B
– Santander (IAC). The dynamic structure and evolution of Nova Persei 1901 remnant. W6/2004B
– Shahbaz (IAC). Infrared spectroscopy of black hole X-ray transients: accurate mass determinations. W34/2004B
– Vazdekis (IAC). Using late-type spirals as a probe of galaxy formation. W39/2004B
– Zurita (Granada). Spectroscopic identification of Hα emitters discovered by IPHAS. W30/2004B

Spanish Additional Time

– Balcells (IAC). The GOYA sample. Photometric characterisation of high-redshift galaxies. W46/2004B
– Cepa (IAC/ULL). The OTELO project: Deep B,V,R,I survey of SA68 and VIRMOS-0226 fields. W22/2004B
– Corral (IAC/GTC). Luminous blue stars in M33. W51/2004B
– Herrero (IAC). Detecting the population of blue massive stars to 5 Mpc for OSIRIS. W50/2004B
– Manchado (IAC). LIRIS GT

TNG-TAC

– Boschin (Trieste). Radio-halo clusters and cluster mergers: a homogeneous dynamical analysis of a large Northern sample. T29
– Fasano (OAP). Star formation and morphological evolution of galaxies in nearby clusters with WYFFOS. T12
– Galleti (Bologna). The Globular Cluster system of M31: a radial velocity survey for 86 candidates and the M31 total mass. T37

Instrument Builder's Guaranteed Time

– Bacon (Lyon). OASIS. GT Type A
– Bacon (Lyon). OASIS. GT Type B

Isaac Newton Telescope

UK PATT

– Aigrain (IoA). Searching for planetary transits in the Orion Nebula Cluster. I/2004B/19
– Dowsett (IoA). A systematic study of AGN within distant galaxy clusters. I/2004B/18
– Drew (ICL). IPHAS: the INT/WFC photometric Hα survey of the northern galactic plane. I/2004B/10
– Jarvis (Oxford). A wide-field search for Lyman-α haloes: A pre-requisite for massive galaxy formation? I/2004A/17 LT
– Littlefair (Exeter). How long do young stars remain locked to their discs? I/2004B/14
– McMahon (IoA). Photometric calibration of the XMM-Newton Serendipitous Survey Imaging Program. I/2004B/23
– Murphy (IoA). Testing CDM with galaxy rotation curves at large impact parameters. I/2004B/4
– Rawlings (Oxford). Tracing star-formation in two forming superstructures. I/2004B/7
– Vlahakis (Cardiff). The optically-selected SLUGS: A systematic survey of the Local Submillimetre Universe. I/2004B/13

NL NFRA PC

– Aragon (Groningen). Measuring galaxy spin alignments along the Pisces-Perseus ridge in the vicinity of A262. i04bn001
– Braun (NFRA). The STARFORM/Hα survey: Probing the recent history of star formation in spirals. i04bn004
– Groot (Nijmegen). IPHAS: the INT/WFC photometric Hα survey of the northern galactic plane. i04bn006
– Groot (Nijmegen). A HeI survey of the Galactic Plane: The AM CVn population. i04bn007
– Helmi (Groningen). The role of minor mergers in the build up of the Milky Way halo. i04bn003

SP CAT

– Barrena (IAC). Photometric and morphologic characterisation of galactic clusters with diffuse radio and X-ray emission. I7/2004B
– Beckman (IAC). The links between bars and star formation: An advanced survey. I10/2004B
– Castro-Tirado (IAA-CSIC). The nature of Gamma-Ray Bursts (GRBs). W36/2004B [sic]
– Deeg (IAC). Sample definition for exoplanet detection by the COROT space craft. I9/2004B
– Leisy (IAC/ING). IPHAS: the INT/WFC photometric Hα survey of the northern galactic plane. I6/2004B
– López (IAC). Diffuse light in compact galactic clusters. I5/2004B
– Negueruela (Alicante). Optical counterparts to Newton-XMM sources in open clusters. I3/2004B
– Rosenberg (IAC). Formation and evolution of the Milky Way (III): The Galactic disc. I8/2004B

Spanish Additional Time

– Barrado (LAEFF-INTA). Exploring the different IMFs in the Lambda Ori SFR. I1/2004B
– Herrero (IAC). Detecting the population of blue massive stars to 5 Mpc for OSIRIS: making a complete sample of M33 population. I11/2004B
– Vílchez (IAA). A Deep search for star-forming galaxies in nearby clusters. I4/2004B

SEMESTER 2005A

ITP Programmes on the ING Telescopes

– Gänsicke (Warwick). Towards a global understanding of close binary evolution. ITP7.

William Herschel Telescope

UK PATT

– Ahmad (Armagh Observatory). Parameters of hot subdwarfs of the double-lined spectroscopic binary — PG 1544+488. W/2005A/46.
– Bailey (AAO). A high precision polarization survey of bright stars. W/2005A/10.
– Blundell (Oxford). A complete spatial and dynamical study of the microquasar SS433. W/2005A/52.
– Bower (Durham). The Lyman-α haloes of SCUBA galaxies: exploring super-winds and feedback at z=3. W/2005A/21.
– Christian (Queen’s University Belfast). ISIS characterisation of variable stars from the SuperWASP survey. W/2005A/36.
– Dobbie (Leicester). A rigorous examination of the evolutionary status of SDSS hot DB white dwarfs within the DO/DB gap. W/2005A/5.
– Gänsicke (Warwick). SW, Sextantis stars — totally normal? W/2005A/31.
– Hewett (IoA, Cambridge). Imaging of spectroscopically selected gravitational lenses from the SDSS. W/2005A/19.
– Hough (Hertfordshire). Circular spectropolarimetry of DIBs. W/2005A/7.
– Jarvis (Oxford). Spectroscopic redshifts for the first radio galaxy sample selected at 74 MHz. W/2005A/8.
– Keenan (Queen’s University Belfast). The space density of B-type stars in the Galactic halo. W/2005A/6.
– Knigge (Southampton). Spectroscopic reconnaissance of candidate emission line stars discovered by IPHAS. W/2005A/39.
– Kosroshah (Birmingham). A membership study of the nearest fossil group. W/2005A/17.
– Kurosawa (Exeter). The clumpy nature of O supergiant stellar winds. W/2005A/42.
– Levan (Leicester). Probing the high redshift universe with GRBs. W/2005A/53.
– Lucas (Hertfordshire). PLANETPOL polarimetry of Tau Boo Ab. W/2005A/20.
– Magrini (Firenze, Italy). The chemical content of nearby galaxies: GR 8. W/2005A/29.
– Merrifield (Nottingham). Determining the dynamics of round elliptical galaxies using the Planetary Nebula Spectrograph. W/2005A/37.
– Pettini (IoA, Cambridge). The nature of DLA galaxies traced through spin temperatures: the optical survey. W/2005A/3.
– Pozzo (ICL). Late-time study of the very nearby Type IIP SN 2004dj. W/2005A/13.
– Tadhunter (Sheffield). Ultraluminous infrared galaxies: quasars and radio galaxies in the making? W/2005A/1.
– Tanvir (Hertfordshire). The physics of short bursts and relativistic blast waves. W/2004B/51 LT.
– Wilkinson (IoA, Cambridge). Dark matter at the edge of the Sextans dwarf spheroidal. W/2005A/35.

NL PATT

– Cappellari (Leiden Observatory). Dark matter in early-type galaxies: stellar line-of-sight velocity-distribution at $5R_e$ using SAURON. w05an005.

– Douglas (Kapteyn Institute). Determining the dynamics of round elliptical galaxies using the Planetary Nebula Spectrograph (PN.S). w05an014.
– Franx (Leiden Observatory). Infrared spectroscopy of restframe optically red galaxies at high redshift. w05an006.
– Groot (Nijmegen). High-resolution eclipse mapping of accretion disks in cataclysmic variables. w05an004.
– Helmi (Kapteyn Institute). Building up the Milky Way halo via accretion of small satellites. w05an017.
– McDermid (Leiden Observatory). The central black hole in NGC 4486A: measuring the mass and environment with OASIS+NAOMI. w05an023.
– Roelofs (Nijmegen). Measuring directly the anticipated tidal deformation of the accretion disk of AM CVn. w05an012.
– Wijers (Amsterdam). The physics of short bursts and relativistics blast waves. w05an013.
– Wijers (Amsterdam). Probing the high redshift universe with GRBs. w05an020.

SP CAT

– Beckman (IAC). Basic properties of the nuclear bars in galaxies with double bar. W39/2005A.
– Cairós (IAC). Near infrared mapping of blue compact dwarf galaxies: disentangling the starburst and the old stars. W33/2005A.
– Casares (IAC). Determining system parameters of a Soft X-ray transient in outburst. W1/2005A.
– Eiroa (Autónoma de Madrid). IMF to the subestellar limit in extremely young pre-main sequence clusters: Serpens. W14/2005A.
– González (IAA). Finding an evolutionary link between radio galaxies and very luminous infrared galaxies. W8/2005A.
– Gorgas (Complutense de Madrid). The star formation history of elliptical galaxies in different environments. W52/2005A.
– Licandro (IAC/ING). The Deep Impact experiment. W19/2005A.
– López (IAC). Studying the dynamics and origin of nuclear bars. W38/2005A.
– López-Martín (IAC). Identifying and characterising the counterparts to ULXs. W30/2005A.
– López-Sánchez (IAC). Star formation zones in starburst galaxies with tidal streams. W51/2005A.
– Mediavilla (IAC). Photometric and spectroscopic variability of gravitational lenses. WL2/2005A.
– Mollá (CIEMAT, Madrid). Stellar populations in cooling flow cluster galaxies. W22/2005A.
– Pérez (Autónoma de Madrid). Propagation of star formation in apparently compact blue galaxies. W29/2005A.
– Rodríguez (Vigo). Physical parameters and chemical abundances in hot type O subdwarfs. W26/2005A.
– Shahbaz (IAC). The origin of the optical variability in the black hole X-ray transient V404 Cyg. W50/2005A.
– Zapatero (LAEFF-INTA). Brown dwarfs around poor metallicity stars. W21/2005A.
– Zeilinger (Institute for Astronomy, Viena). Ram-pressure stripping in Virgo cluster galaxies and their extraplanar ionised gas. W56/2005A.

Spanish Additional Time

– Balcells (IAC). GOYA deep infrared survey. W41/2005A.
– Hammersley (IAC). Visible spectroscopy of the GTC standards. W31/2005A.
– Herrero (IAC). Detecting the population of blue massive stars to 5 Mpc for OSIRIS. W40/2005A.
– Martín (IAC). A search for brown dwarf candidates in three young open clusters for GTC follow-up. W3/2005A.

WHT–TNG Time Share

– Jeffers (Observatoire Midi-Pyrenees, France). Starspot tracking on the W Ursae Majoris system 44 Boo. W/2005A/24 [on the TNG].
– Quirrenbach (Leiden Observatory). Line bisector variations for K giant stars with possible planetary companions. w05an001 [on the TNG].
– Trevese (Roma). Investigating the nature of Low Luminosity Active Galactic Nuclei (LLAGN). T15 [on the WHT].

Instrument Builders' Guaranteed Time

– Bacon (CRAL-Observatoire, Lyon). GT Type A.
– Bacon (CRAL-Observatoire, Lyon). GT Type B.
– Manchado (IAC). LIRIS GT.

Isaac Newton Telescope

UK PATT

– Burleigh (Leicester). Faint planetary nebulae around hot white dwarfs. I/2005A/8.
– Coates (MSSL). Wide-field imaging of Comet 9P/Tempel during the Deep Impact collision. I/2005A/11.
– Drew (ICL). IPHAS — the INT/WFC photometric Hα survey of the northern galactic plane. I/2005A/7.
– James (Liverpool John Moores). Star formation history of dwarf galaxies in the Virgo cluster. I/2005A/6.
– Jarvis (Oxford). A wide-field search for Lyman-α haloes: A pre-requisite for massive galaxy formation? I/2005A/2.
– Mackey (IoA, Cambridge). A survey for dwarf galaxy remnants around outer halo globular clusters. I/2005A/1.
– Ramsay (MSSL). RApid Time Survey — exploring a new temporal parameter space. I/2005A/3.
– Zeilinger (Institute for Astronomy, Viena). Ages and metallicities of dwarf ellipticals in clusters at z=0.04. I/2005A/5.

NL PATT

– Aragon (Kapteyn Institute). Measuring galaxy spin alignments along a void-intersection filament near AWM3. i05an007.
– Franx (Leiden Observatory). Practical astronomy for 2nd year students. i05an005.
– Groot (Nijmegen). IPHAS — the INT/WFC photometric Hα survey of the northern galactic plane. i05an001.
– Kovac (Kapteyn Institute). The optical counterparts of the smallest gas-rich galaxies. i05an006.
– Röttgering (Sterrewacht Leiden). Ly-α emission line halos and the properties of z>2 proto-clusters. i05an002.

SP CAT

– Beckman (IAC). The links between bars and star formation: An advanced survey. I9/2005A.
– Castro-Tirado (IAA-CSIC). Physical characterisation of Gamma-ray bursts (GRBs) in the SWIFT era. W25/2005A [sic].
– Deeg (IAC). Sample definition for exoplanet detection by the COROT spacecraft. I11/2005A.
– Hatziminaoglou (IAC). Deep imaging in SWIRE ELAIS N1 and N2 fields. I1/2005A.
– Iglesias (Laboratoire d'Astrophysique de Marseille). The impact of starbursts in the halos of dwarf galaxies. I6/2005A.
– Leisy (IAC/ING). IPHAS — the INT/WFC photometric Hα survey of the northern galactic plane. I3/2005A.
– López (IAC). The luminosity function of galaxies in Hercules supercluster. I10/2005A.
– Martínez (Valencia). Dwarf galaxy population around isolated galaxies and in small groups. I4/2005A.
– Martínez-Delgado (Max-Planck-Institut fur Astronomie, Heidelberg). Two new ultra-faint Milky Way companions. I13/2005A.
– Zurita (Granada). Global morphology of star formation: Local calibration. I7/2005A.

Spanish Additional Time Allocations

– Rebolo (IAC/CSIC). Subestellar populations in young clusters and stellar associations: I. Orion Belt and Praesepe. I8/2005A.
– Vílchez (IAA). Deep Hα imaging of clusters of galaxies in the WINGS Survey. I12/2005A.

SEMESTER 2005B

ITP Programmes on the ING Telescopes

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

William Herschel Telescope

UK PATT

– Bosma (Observatoire de Marseille), Deep K-band surface photometry of low surface brightness galaxies. W/2005B/28.
– Chappelle (Liverpool), The role of gravity upon ultracool dwarf dust formation. W/2005B/18.
– Chrysostomou (Hertfordshire), Verifying the absence of jets from “misaligned” T-Tauris in the Taurus-Auriga molecular cloud. W/2005B/59.
– Fender (Southampton), Echo-mapping a Quiescent Black Hole. W/2005B/75.
– Hatch (IoA), Investigating the effects of the Perseus ICM on a supersonically infalling galaxy. W/2005B/38.
– Hodgkin (IoA), Spectroscopy of Transit Candidates in the Orion and M34 Clusters. W/2005B/53.
– Hough (Hertfordshire), PLANETPOL polarimetry of Upsilon Andromedae b. W/2005B/48.
– Huxor (Hertfordshire), Metallicity and Radial Velocity Determinations of Newly Discovered M31 Halo Globular Clusters. W/2005B/52.
– Jeffries (Keele), Binary statistics and the formation of low-mass stars and brown dwarfs. W/2005B/50.
– Leigh (Liverpool), Spectroscopic detection and characterisation of the planet orbiting upsilon Andromeda. W/2005B/10.
– Levan (Leicester), Probing the high redshift universe with GRBs. W/2005B/46.
– Littlefair (Sheffield), J1702+3229 — a CV in the period gap with an evolved secondary. W/2005B/66.
– Lucas (Hertfordshire), Determination of the primordial incidence of binarity in Orion Brown Dwarfs. W/2005B/55.
– Marsh (Observatoire de Marseille), The nature of the white dwarfs in long period cataclysmic variables (CVs). W/2005B/32.
– Nandra (ICL), The AGN luminosity function at z=3. W/2005B/26.
– Napiwotzki (Leicester), Testing common envelope theory and SN Ia progenitor models with double white dwarfs. W/2005B/47.
– Naylor (Exeter), Does star formation take a long time? W/2005B/67.
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NL PATT

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SP CAT

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Spanish Additional Time

– Acosta (IAC), Catalogue of infrared polarimetric standards of low luminosity. WHT47/05B.
– Balcells (IAC), The GOYA survey. Photometric characterisation of high-z galaxies. WHT14/05B.
– Bergond (IAA), Globular cluster populations of well defined isolated galaxies. WHT46/05B.
– Hammersley (IAC), Visible spectroscopy of the GTC standards. WHT50/05B.
– Manchado (IAC), LIRIS GT.
– Martín (IAC), Preparation for GTC follow-up of brown dwarf candidates in young open clusters. WHT4-A/05B.

WHT–TNG Time Share

– Benn (ING), The nature of BAL outflows in quasars. T60.
– Leone (OA Catania), Detecting magnetic fields in planetary nebulae, and understanding their role in the nebular shaping. T41.
– Zaggia (OA Trieste), Hunting for cores of dwarf spheroidal galaxies in the external Milky Way Halo. T69.

Instrument Builders' Guaranteed Time

– Bacon (Lyon). GT Type A.
– Bacon (Lyon). GT Type B.

Isaac Newton Telescope

UK PATT

– Burleigh (Leicester), Faint planetary nebulae around hot white dwarfs. I/2005B/9.

– Drew (ICL), IPHAS — the INT/WFC photometric Hα survey of the Northern Galactic Plane. I/2005B/10.
– Fender (Southampton), Jet-blown optical nebulae from black hole X-ray binaries. I/2005B/4.
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NL PATT

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SP CAT

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Spanish Additional Time Allocations

– Herrero (IAC), Detecting the blue massive star population to 5 Mpc for OSIRIS. INT10/05B.
– Ruiz (Barcelona), Supernovae at z=0.05–0.35: studying the nature of the dark energy (II). INT15/05B.
– Vílchez (IAA), Deep Hα imaging of clusters of galaxies in the WINGS survey. INT14/05B.

Appendix E

ING BIBLIOGRAPHY

Below is the list of research papers published in 2004 and 2005 that resulted from observations carried out at the telescopes of the Isaac Newton Group. The data used in these papers was obtained as part of an observing programme or by mining one of the ING archives. The selection process identifies papers that make direct use of observations obtained with the ING telescopes, in order to qualify. Papers that refer to data presented in earlier papers (derivative papers) are not counted. This bibliography was compiled from only the refereed journals *MNRAS*, *Astrophys J*, *Astrophys J Letters*, *Astrophys J Suppl*, *Astron J*, *PASP*, *Astron Astrophys*, *Nature* and *Science*, although many other publications have appeared elsewhere, notably in workshop, conference proceedings and PhD theses. For every paper the following information is given: author/s, title, journal, volume, first page, nationality of the first institution of the first author (between brackets), used instrument (between parentheses) and the ING Archive as the data source or Service if obtained on a service night when this was credited in the paper.

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Appendix F

ASTRONOMY STAFF RESEARCH PUBLICATIONS

The following includes all 102 refereed and non-refereed publications of ING astronomers in the year 2004 (50 refereed journal papers and 52 non-refereed papers in conference proceedings or other publications), and all 84 refereed and non-refereed publications in the year 2005 (37 refereed journal papers and 47 non-refereed papers in conference proceedings or other publications). It is sorted by year and in alphabetical order (ING author appears in italic and bold).

2004

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4. *Benn, C. R.*, Blanken, M., Bevil, C., Els, S., Goodsell, S., Gregory, T., Jolley, P., Longmore, A. J., Martin, O., Myers, R. M., ***Østensen, R.***, Rees, S., ***Rutten, R. G. M.***, *Söchting, I.*, Talbot, G., Tulloch, S. M., "NAOMI: adaptive optics at the WHT", *Proc SPIE*, 5490, 79.
5. Binzel, R. P., ***Licandro, J.***, Serra-Ricart, M., de León Cruz, J., Pinilla-Alonso, N., "Comet C/2003 WT_42 (LINEAR)", *IAU Circ*, **8270**, 1.
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9. ***Corradi, R. L. M.***, "Planetary Nebulae Morphology According to Padre Angelo Secchi", *ASP Conf Ser*, **313**, 25.
10. ***Corradi, R. L. M.***, "Multiple, Coeval and Hubble-Like Bipolar Outflows", *ASP Conf Ser*, **313**, 148.
11. ***Corradi, R. L. M.***, "Discussion Session on Nebulae Around Symbiotic Stars", *ASP Conf Ser*, **313**, 558.
12. ***Corradi, R. L. M.***, "The Bull's Eye Pattern in the Cat's Eye and Other Planetary Nebulae", *ING Newsl*, **8**, 10.
13. ***Corradi, R. L. M.***, Sánchez-Blázquez, P., Giammanco, C., Mellema, G., Schwarz, H. E., "New Rings in Planetary Nebulae Haloes", *ASP Conf Ser*, **313**, 290.
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15. ***Corradi, R. L. M.***, "Stellar paleontology using planetary nebulae", *Mem Soc Astron Ital*, **75**, 73.
16. Crowther, P. A., ***Evans, C. J.***, "CNO Abundances in Magellanic Cloud OB Supergiants", *IAU Symposium*, **215**, 218.
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21. ***Evans, C. J.***, Crowther, P. A., Fullerton, A. W., Hillier, D. J., "Quantitative Studies of the Far-Ultraviolet, Ultraviolet, and Optical Spectra of Late O- and Early B-Type Supergiants in the Magellanic Clouds", *Astrophys J*, **610**, 1021.
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Appendix G

SEMINARS

Date	Title	Speaker	University / Institution
2004			
3 Feb	LAMOST Telescope and Instrumentation: Concept, Technologies and Progress	D. Yang	Nanjing Institute of Astronomical Optics and Technology
20 Feb	Circumstellar Matter in PNe and Other Evolved Stars	H. E. Schwarz	CTIO-NOAO-AURA
4 Mar	Search for extrasolar planets with SARG	S. Desidera	Padova Observatory
12 Mar	Planetary Nebulae in the Local Group	L. Magrini	Dipartimento di Astronomia e Scienza dello Spazio, University of Firenze
6 Apr	Helium-rich subdwarf B stars: binaries, mergers or bizarre?	A. Ahmad	Armagh Observatory
7 Apr	SuperWASP: The Super Wide Angle Search for Planets	D. Pollacco	Queen's University of Belfast
15 Apr	Basaltic Asteroids	R. Duffard	Observatorio Nazional de Rio, Brasil
21 Apr	Observing Galaxy Haloes	A. Romanowsky	University of Nottingham
2 Jul	SALT: 6 months to go!	P. Charles	University of Southampton
7 Jul	Planetary transits and stellar variability	S. Aigrain	IoA, Cambridge
30 Jul	What's the role of environment on galaxies?	P. Focardi	Dipartimento di Astronomia, Università di Bologna
10 Aug	Gamma Ray Bursts in the SWIFT Era	A. Antonelli	INAF-Osservatorio Astronomico di RomaItaly
22 Nov	Physical Studies of Minor Bodies	S. Fornasier	Astronomy Dep. of Padova University
1 Dec	Hot Stellar Populations in Galactic Globular Clusters: The population(s) puzzle goes deeper	S. Cassisi	Osservatorio Astronomico di Collurania in Teramo
2005			
18 Feb	The SOAR telescope is nigh !	H. Schwarz	CTIO/NOAO/AURA
17 Mar	Population of variable stars in the dwarf irregular galaxy NGC6822	L. Baldacci	Osservatorio Astronomico di Bologna
5 May	Asteroid Families: A new analysis	T. Mothe Diniz	Paris Observatory, Meudon
20 Jun	The AstroGrid Virtual Observatory System: Release 1.0	N. Walton	IoA, Cambridge & Astrogrid Consortium
8 July	Is Scintillation the key to an improved ICRF?	R. Ojha	Australia Telescope National Facility, CSIRO
26 Aug	OB associations in the era of planet formation	T. Naylor	School of Physics, University of Exeter
7 Sep	Extreme clumping in the winds of Luminous Blue Variables	B. Davies	Dept. of Physics & Astronomy, Univ. of Leeds
23 Sep	Old open clusters as tracers of galactic chemical evolution	A. Bragaglia	INAF-Osservatorio Astronomico di Bologna
13 Oct	Remote observations with the NOT at the Nordic- Baltic summer school in August 2005	J.-E. Solheim	Institute of Theoretical Astrophysics, Oslo
24 Oct	Features and performance of the Copenhagen generation 3 array-controller	P. Nørregaard	Copenhagen University Observatory
14 Nov	New developments in CCD technology	S. Tulloch	ING

Appendix H

FINANCIAL STATEMENT

Financial year 2004/05 saw a continuation in the reduction of the UK's contribution to ING operations as planned for under PPARC's restructuring plan for ground based facilities. This was a result of the UK's membership of the European Southern Observatory (ESO) and the consequent need to make savings in other parts of the UK's ground based programme. Nevertheless, the overall financial position for the observatory was healthy and enabled not only a full operational programme to be carried out but also an interesting programme of enhancement and development projects. However, it should be noted that, as part of the restructuring plan, the 1.0m Jacobus Kapten Telescope (JKT) had been withdrawn from service in semester 2003B. The approved funding for ING's Joint Programme during financial year 2004/05 provided a requisitions budget of €3317k, including receipts for repayment services provided to other observatories at the Roque de Los Muchachos Observatory (ORM). As a result of careful financial management, the observatory managed to hold back approximately €600k. This money was "banked" with PPARC to be called forward in the future to help offset the significant budgetary reductions planned from 2005 onwards. The resulting allocations and associated expenditure are set out below under the main budget headings (staff costs associated with the international posts at ING are excluded).

Financial year 2004/2005

Budget centre	Allocation €k	Expenditure €k
Operations		
Administration and management	112.1	90.5
Astronomy support	71.1	67.0
Conferences	5.0	0.8
Engineering support	388.0	340.2
Local staff	1154.0	1157.0
ORM operations	613.5	659.7
Sea-level infrastructure and services	225.0	192.2
Students	21.0	16.2
SUBTOTAL	2589.8	2524.5
Enhancements and developments	358.0	157.9
TOTAL	2947.5	2682.4

Financial year 2005/06 saw the final phase of the planned reduction of the UK's contribution to ING's budget. As a result, the funds approved by the international partners through the ING Board totalled €2149.5k. The observatory therefore requested the first portion, €365k, of the "banked" funds be carried forward. This addition, plus funds received from the EU and repayment services mean that the total cash budget available increased to €2769.5k. In addition, during the year, it became clear that there would be sizable underspend against UK staff costs and €350k were therefore transferred from this budget to requisitions.This was distributed between the various activities as set out below. Due to delays in the delivery of goods and equipment, the year closed with approximately €140k unspent, although this sum had been fully committed. Details of the expenditure between the various activities is also set out in the table below.

Financial year 2005/2006

Budget centre	Allocation €k	Expenditure €k
Operations		
Administration and management	88.8	82.7
Astronomy support	40.0	41.0
Conferences	15.0	17.0
Engineering support	359.0	331.0
Local staff	1333.8	1344.0
ORM operations	647.3	743.4
Sea-level infrastructure and services	190.8	226.3
Students	21.7	19.9
SUBTOTAL	2696.5	2805.3
Enhancements and developments	404.8	158.4
TOTAL	3101.3	2963.7

Appendix I

COMMITTEE MEMBERSHIP

Name	Responsibility	Institution
ING BOARD		
Prof T van der Hulst (from 10.2005)	Chairperson	University of Groningen
Prof J Drew (to 10.2005)	Chairperson	Imperial College London
Dr P Crowther (from10.2004)		University of Sheffield
Dr G Dalton		University of Oxford
Dr R García López		IAC
Prof J Hough (from 10.2005)		University of Hertfordshire
Prof T Marsh (to 10.2004)		University of Warwick
Dr R Stark		NWO
Dr C Vincent		PPARC
Ms D Telfer	Secretary	PPARC
DIRECTOR'S ADVISORY COMMITTEE		
Dr M McCaughrean	Chairperson	University of Exeter
Dr M Balcells		IAC
Dr P A James		Liverpool John Moores University
Dr N Tanvir		University of Hertfordshire
Dr E Tolstoy		University of Groningen
ING TIME ALLOCATION GROUPS		
UK Panel for the Allocation of Telescope Time (PATT)		
Dr R D Jeffries (from09.2004)	Chairperson	University of Keele
Prof C Tadhunter (to 08.2004)	Chairperson	University of Sheffield
ING TAG		
Dr D Pollacco (from semester 2005B)	Chairperson	Queen's University of Belfast
Dr R Oudmayer (to semester 2005B)	Chairperson	University of Leeds
Dr O Almainy (to semester 2005B)		University of Nottingham
Dr J Baker (to semester 2005B)		University of Oxford
Dr M Jarvis (from semester 2005B)		University of Oxford
Dr C Knigge (from semester 2005B)		University of Southampton
Dr P Maxted (to semester 2005A)		University of Keele
Dr M Page (from semester 2005B)		University College London
Dr A Sansom (from semester 2004A)		University of Central Lancashire
Dr S Smartt (to semester 2004B)		University of Cambridge
Dr P Wheatley (from semester 2005A)		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
SP Comité de Asignación de Tiempos (CAT)		
Dr J A Belmonte (from 01.2004)	Chairperson	IAC
Dr E Mediavilla (to 12.2003)	Chairperson	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 Roque de Los Muchachos Observatory: Tel: +34 922 405 500 (residence's reception); +34 922 405 559 (WHT control room); +34 922 405 640 (INT control room); +34 922 405 585 (JKT control room).

	Name	Telephone (+34 922)	E-mail (@ing.iac.es)
Director	René Rutten	425 420	rgmr
Head of Administration	Les Edwins	425 418	lie
Head of Astronomy	Danny Lennon	425 440	djl
Head of Engineering	Gordon Talbot	425 419	rgt
Head of Operations	Kevin Dee	405 565	kmd
Head of Computing	Don Carlos Abrams	425 450	don
Head of Telescope & Instrument Engineering	Diego Cano	425 446	dcano
Public Relations	Javier Méndez	425 464	jma
Telescope Scheduling	Ian Skillen	425 439	wji
Service Programme	Pierre Leisy	425 441	service
WHT Manager	Chris Benn	425 432	crb
INT Manager	Romano Corradi	425 461	rcorradi
Personnel	Chelo Barreto	425 417	chelo
Health and Safety	Jürg Rey	405 632	juerg
Freight	Juan Martínez	425 414	juan

Note: For updated ING contact information please visit `http://www.ing.iac.es/About-ING/`.

Particle Physics and Astronomy Research Council (PPARC). Polaris House; North Star Avenue; Swindon SN2 1SZ; United Kingdom; Tel: +44 (0)1793 442 000; Fax: +44 (0)1793 442 002; URL: `http://www.pparc.ac.uk/`.

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/`.

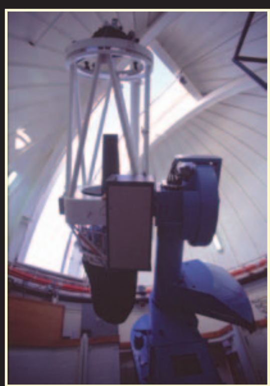
Enquiries about the operation of the Roque de Los Muchachos Observatory can be made to the Instituto de Astrofísica de Canarias (IAC), see address above. Enquiries about observing time on the ING telescopes allocated by the Panel for the Allocation of Telescope Time (PATT) should be made to the executive secretary, PATT, at the PPARC 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

AAO	Anglo-Australian Observatory
ASP Conf Ser	Astronomical Society of the Pacific Conference Series
Astron Astrophys	Astronomy and Astrophysics Journal
Astron Astrophys Suppl	Astronomy and Astrophysics Journal Supplement Series
Astron J	Astronomical Journal
Astron Soc Pac Conf Ser	Astronomical Society of the Pacific Conference Series
Astrophys J	Astrophysical Journal
Astrophys J Suppl	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
DAS	Data Acquisition System
DIAS	Dublin Institute for Advanced Studies
DIMM	Differential Image Motion Monitor
ELECTRA	Enhanced Light Efficiency Cophasing Telescope Resolution Actuator
ESA	European Space Agency
ESTEC	European Space Technology Centre
Fib	AUTOFIB fibre positioner
FOS	Faint Object Spectrograph
FWHM	Full Width Half Maximum
GHRIL	Ground Based High Resolution Imaging Laboratory
GLAS	Ground-layer Laser Adaptive optics System
GRACE	GRound based Adaptive optics Controlled Environment
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	Low Dispersion Survey Spectrograph
LIRIS	Long-Slit Intermediate-Resolution Infrared Spectrograph

LJMU	Liverpool John Moores University
MARTINI	Multi-Aperture Real Time Image Normalisation Instrument
MCCD	Mosaic CCD camera or National Astronomical Observatory of Japan camera
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
OAT	Observatorio Astronomico de Trieste
ORM	Observatorio del Roque de Los Muchachos (Roque de los Muchachos Observatory)
OSCA	OSCA Coronograph
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
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
SAURON	Spectrographic Areal Unit for Research on Optical Nebulae
S-Cam	Super-conducting Tunnel Junction Camera
Space Sci Rev	Space Science Reviews
SPIE	Society of Photo-Optical Instrumentation Engineers
STScI	Space Telescope Science Institute
TAC	Time Allocation Committee
TAG	Time Allocation Group
TAURUS	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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