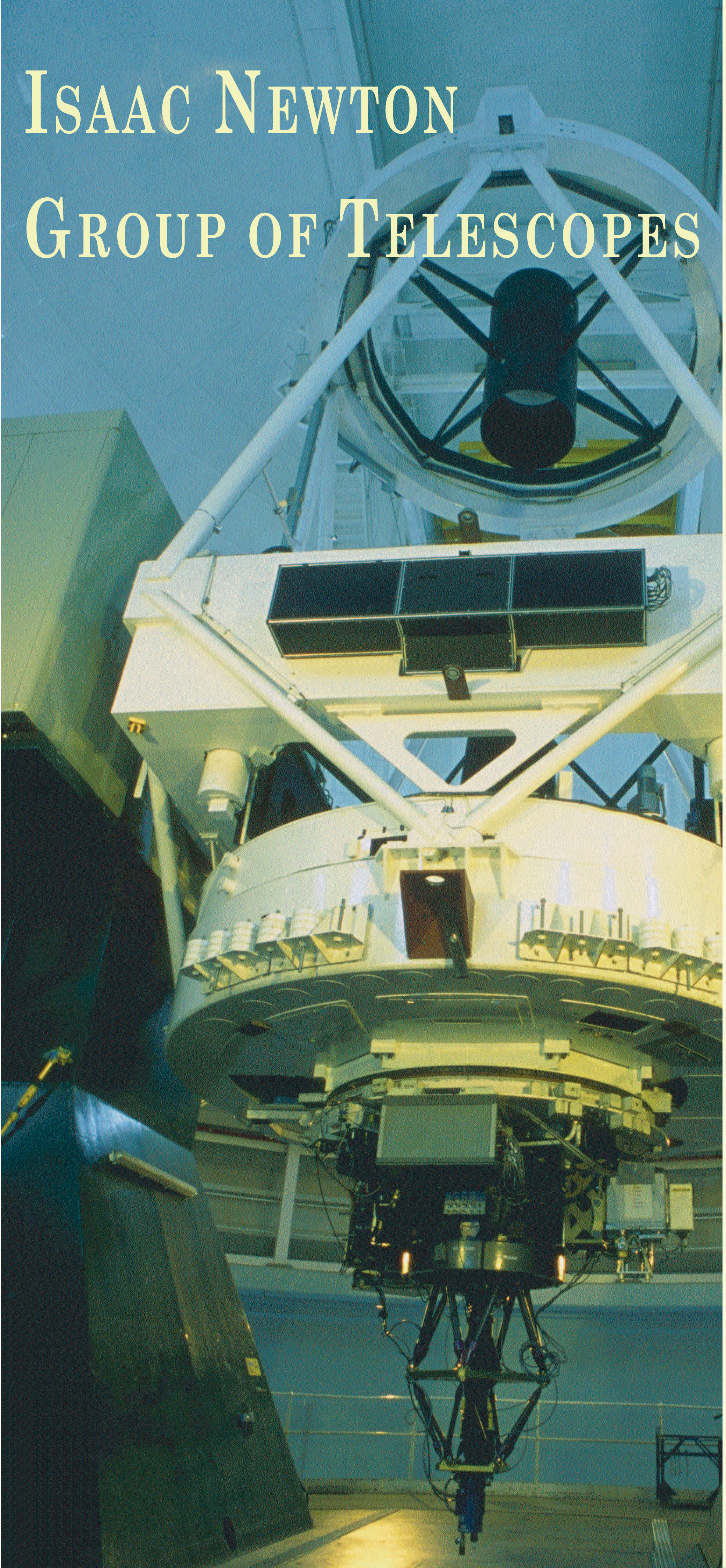
Isaac Newton Group of Telescopes



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1999

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Front Cover: William Herschel Telescope. The instrument on the Cassegrain focus is SAURON. Picture credit: Rainer Girnstein.

ISAAC NEWTON
GROUP OF TELESCOPES

Annual
Report

of the
PPARC-NWO
ING Board

PPARC NWO

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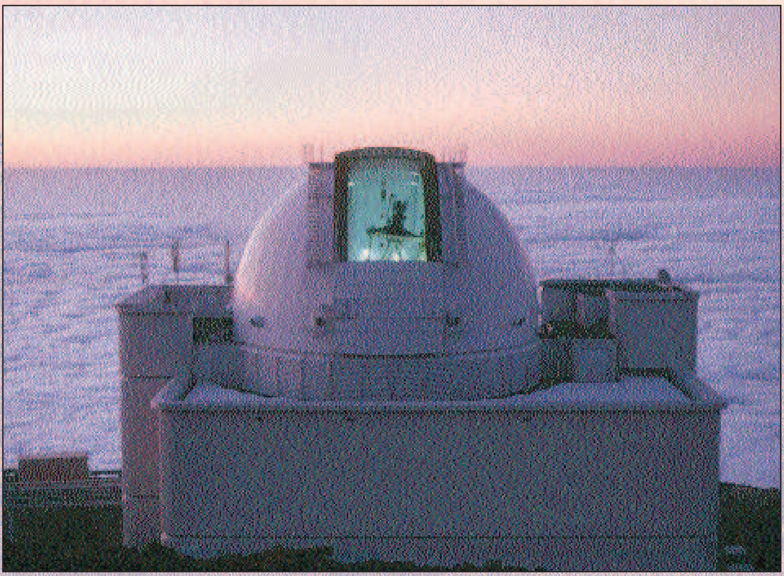
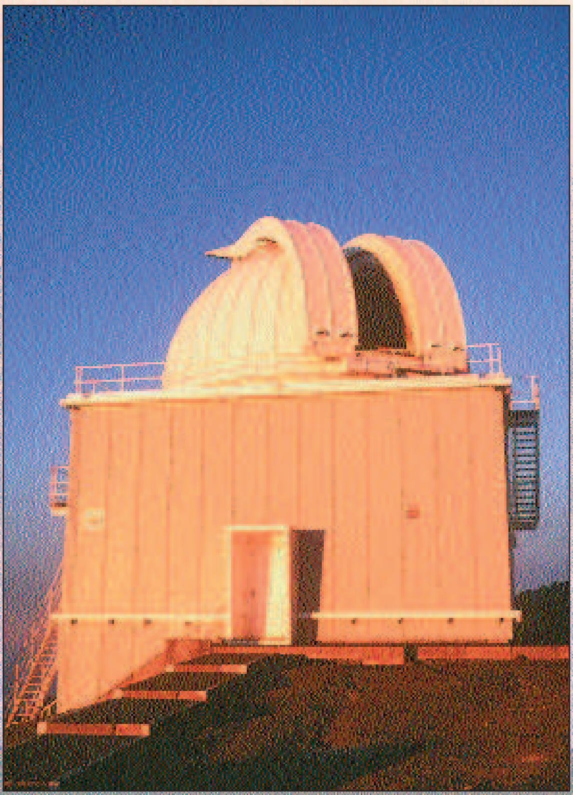
ISAAC NEWTON GROUP

William Herschel Telescope



Isaac Newton Telescope



Jacobus Kapteyn Telescope

OF TELESCOPES

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

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

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

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

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FOREWORD

Professor Tim de Zeeuw
Chairman of the
ING Board

It is a pleasure to follow in the footsteps of the previous Chairman, Carlos Frenk, and write the foreword to the 1999 Annual Report of the Isaac Newton Group of Telescopes, on behalf of the ING Board.

The past year has been another excellent one, scientifically and operationally for the ING, with high scientific output, low downtime, improved scientific atmosphere within the ING and excellent prospects for the immediate future.

ISIS and UES continue to be workhorses on the WHT. The WFC is in strong demand, and so is the infrared camera INGRID which was recently completed by ING staff. Unique private instruments, such as the ESTEC STJ-based camera, and the F/NL/UK wide-field integral-field spectrograph SAURON, produced their first scientific results. UES studies of extra-solar planets attracted world-wide press coverage. The INT produces high-quality wide-field survey data, and also the JKT is used effectively.

The ING has very recently started the commissioning of the natural guide star adaptive optics system NAOMI, which will exploit INGRID. The Board has agreed an exciting medium term development plan for the WHT which is supported by PPARC and by NWO. This includes funding for a coronagraph to work with NAOMI, design studies towards a multi-object spectrograph (MOSAIC) and adaptation of OASIS (an integral-field spectrograph currently on the CFHT) for use on the WHT with NAOMI. The new ING Newsletter is a very effective way of informing the astronomical community of all that goes on at the ING.

The ING is continuing to adapt to changing scientific and financial conditions and has, through the Director's good management, coped well with the changes imposed by the closure of the RGO and constraints placed upon the Joint ING Operations Budget. Maintaining scientific output has been possible through major improvements in the mode of working and model for operations and is assisted by specific investments in new computing networks for the facilities, and restructuring resources, allowing new and more efficient systems be put in place. The addition of postdoctoral fellows funded by PPARC has had a very positive effect on the scientific environment of the ING.

The astronomical landscape in Europe is changing rapidly, with the coming on line of the VLT, the prospect of UK membership in ESO and the start of the construction phase of the GranTeCan.

The Board encourages the on-going efforts to find ways in which the ING might collaborate with the GranTeCan project. These include the development of a joint sea level facility and the possibility of collaboration in instrumentation. The Board is convinced that the ING's present success and status is a good reflection on the energies and skills of the Director who has worked very hard to take the programme forward and to develop the strategies which are needed to ensure that the ING continues to provide key astronomical facilities for many years to come.

INTRODUCTION

Dr René Rutten
Director of ING

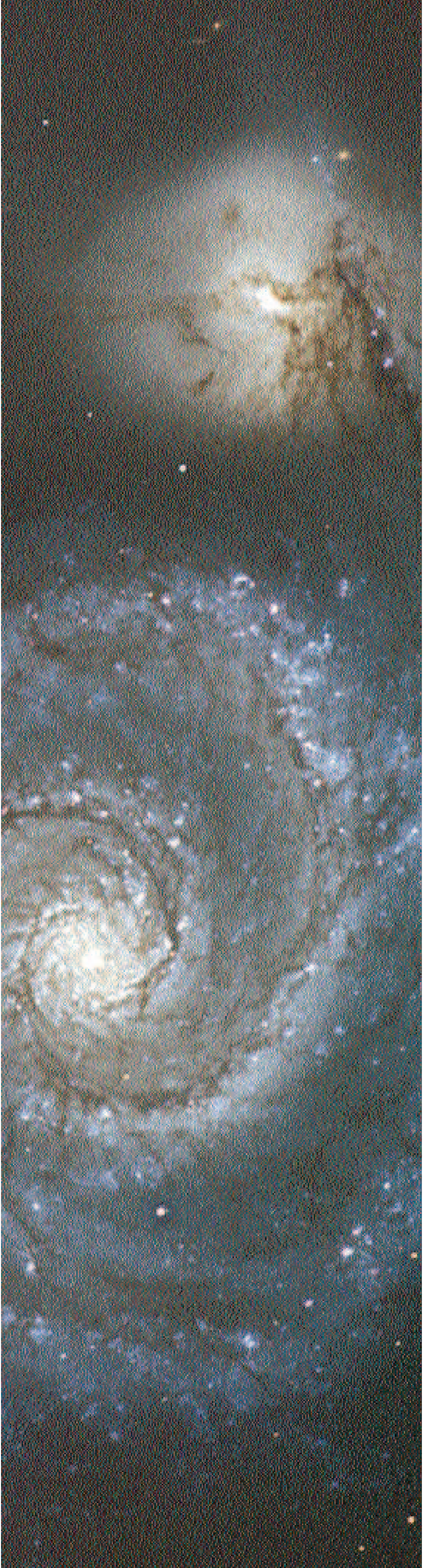
Discussions in ground-based optical astronomy now focus on telescopes that are even an order of magnitude larger than the current generation of 8-m class telescopes. In the midst of these exciting long-term prospects telescopes such as those of the Isaac Newton Group keep producing top quality data serving many astronomers. The large telescopes will, however, not leave ING unaffected, and therefore during this year ING started to focus on the medium and longer term future prospects for the observatory. Ideas and plans were extensively discussed during a special workshop held in Sheffield, where also the Instrumentation Working Group was re-established. In this report you can read about the first results of those discussions.

A historic highlight this year for the Roque de los Muchachos Observatory was the celebration of the 20th anniversary of the signing of the international agreements that led to the foundation of the observatory on La Palma. The event was celebrated on La Palma with an impressive exhibit and a number of public lectures organized by the Instituto de Astrofísica de Canarias. These initiatives brought the observatory once again to the attention of the general public of La Palma.

In looking back over the twenty years there have been plenty of scientific and technical accomplishments that have contributed to the success of the observatory. But even more important is looking ahead to what the future might bring. At ING there are many events to look forward to: just to mention a few, the new infra-red camera for the William Herschel Telescope; the adaptive optics system; and the further development of the ESTEC-built superconducting tunnel junction detector. For the observatory on La Palma as a whole, the 10-m GranTeCan project which broke ground in 1999, has represented an important milestone.

And the dreaded millennium rollover? Well, it just happened. The fact that it passed unnoticed from the operational point of view was no accident, but the result of over 18 months of careful preparation and testing.

The year 1999 has been highly productive in terms of the scientific output of the telescopes. At the same time many improvements have been introduced at the telescopes. All this has not happened automatically, but has been the fruit of concerted effort of all those working at ING and of the continued scientific exploitation of the facilities by many astronomers.



Chapter 1

Scientific Highlights

The following presents a selection of highlights, intended to be representative of the scientific quality and range of research being undertaken at the ING telescopes.

THE SEARCH FOR EXTRASOLAR VERY LOW-MASS OBJECTS

WHT+ISIS, +WHIRCAM, INT+WFC, +PFC

Stellar clusters and associations offer a unique opportunity to study substellar objects in a context of known age, distance, and metallicity; they are laboratories of key importance in understanding the evolution of brown dwarfs. Deep- and wide-imaging surveys to search for low-mass objects have continued on the ING telescopes. Such surveys can probe the cluster luminosity and mass functions down to the substellar limit, and beyond in the case of the nearest and youngest open clusters. In particular, the Pleiades, a star cluster which is an ideal hunting ground for substellar objects mainly due to its richness of members, young age, proximity and scarce interstellar absorption, have revealed a large population. Recently, about 45 brown dwarf candidates have been discovered.

The extension of these studies to other clusters, especially in the younger regions, is therefore very important for confirming and enlarging these results. With this intention a survey in the young stellar cluster around the young multiple star σ Orionis was carried out. The cool nature of eight candidates (spectral types M6–M8.5) was spectroscopically confirmed. One of the latest type candidates, S Ori 45 (M8.5), is one of the least massive objects known to date, with a best estimate of its mass at 0.020–0.025 solar masses.

Praesepe is a nearby and rich Galactic open cluster within the Hyades moving group. Though similar to the Hyades in terms of age, kinematics and chemical composition, Praesepe's larger distance and smaller angular extent make it an excellent target for wide-area CCD surveys. However, the brown dwarf population of Praesepe is sensitive to both the age and distance of the cluster. If the cluster is 500 Myr old, then a recent survey would have found 3 good candidates. But if the cluster is 1 Gyr old, then only one might be a brown dwarf.

A NEW LOCAL GROUP GALAXY: THE CETUS DWARF GALAXY

INT+WFC

The observational Universe is built mostly from galaxies. For obvious reasons, most of the known (detected and catalogued) galaxies are intrinsically the largest and brightest ones, those which can be seen from the greatest distance and are most easily studied. Dwarf galaxies, however, dominate numerically in any volume-limited sample, and were probably even more numerous in the cosmological past. Despite their unassuming appearance dwarf galaxies hold the key to many questions of galaxy formation, structure and evolution. They also provide important constraints on the distribution and nature of dark matter, and star formation in low density environments.

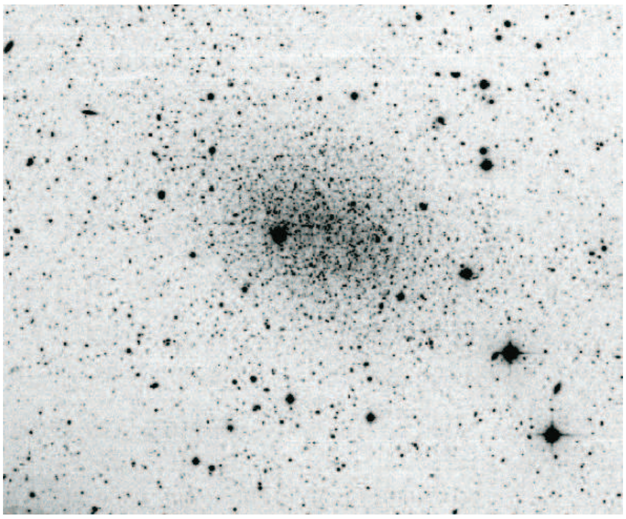
The need for more data in all these matters, together with the relatively few known dwarf galaxies, make a search for more of them very worthwhile. However, almost by definition dwarf galaxies are difficult to detect and observe.

Searches for dwarf galaxies have been carried out in nearby galaxy groups with good results. However, owing to their small intrinsic size, dwarfs in external groups are difficult to characterise morphologically, and it is only within and near the Local Group that the resolved stellar photometry necessary for construction of detailed star formation histories can be obtained. Thus it appears most promising to limit a search to the Local Group and its immediate environs.

To this end a visual examination of all 894 fields covered by the ESO-SRC and SERC equatorial surveys of the southern sky was performed. Objects resembling the Andromeda dwarf spheroidals and the Tucana dwarf, that is of very low surface brightness (VLSB), diffuse and large (1 to a few minutes of arc), were noted. Some of the more northerly candidates were followed up using the Wide Field Camera (WFC) on the Isaac Newton Telescope.

Candidates were initially examined by taking short exposures in the R band. With good seeing this enables stellar objects to R~23 to be detected. At this depth objects close to or within the Local Group should begin to resolve into stars, with the tip of the giant branch becoming readily visible. If a candidate appeared to resolve into stellar components, further broadband observations in V and I together with narrow-band Hα were obtained. The initial exposure of an uncataloged object in the constellation Cetus showed a diffuse swarm of faint stars. Further exposures were taken in order to characterise the new object.

The Cetus dwarf has a smooth, diffuse appearance and appears to be a dwarf spheroidal of type dE3.5. A color-magnitude diagram in V, V−I shows a clear giant branch but no sign of recent star formation. From the position of the tip of the giant branch, a reddening-corrected distance modulus of 24.45±0.15 and a



Combined V-band image of the Cetus dwarf with a total exposure of 1800s taken using the Wide Field Camera on the Isaac Newton Telescope. The obvious visible stars in the dwarf galaxy are all red giants. The area shown is approximately 11×11 arcmin corresponding to one-half of the central CCD of the four WFC CCDs.

metallicity of –1.9±0.2 is derived. With an implied heliocentric distance of 775±50 kpc, and a corresponding Local Group barycentric distance of 615 kpc, the Cetus dwarf lies well within the boundaries of the Local Group. Although the Cetus dwarf is unlikely to be directly associated with any other Local Group galaxy, it does lie in the general direction of the extension of the Local Group toward the Sculptor Group.

HIGH VELOCITY CLOUDS

WHT+UES

Scattered across the sky are hundreds of clouds of hydrogen gas, moving at such high velocities that they clearly stand out from the usual interstellar material in the Milky Way. These High-Velocity Clouds (HVCs) have remained enigmatic since their discovery in the 1960s. Their origins and role in Galactic evolution remain poorly understood, largely for lack of information on their distances.

The HVCs might result from gas blown from the Milky Way disk into the halo by supernovae, in which case they would enrich the Galaxy with heavy elements as they fall back onto the disk. Alternatively, they may consist of metal-poor gas —remnants of the era of galaxy formation, accreted by the Galaxy and reducing its metal abundance. Or they might be truly extragalactic objects in the Local Group of galaxies.

Distance estimates of HVCs have long been based on models or indirect arguments. The only direct method uses the presence or absence of interstellar absorption lines at the HVC's velocity in spectra of stars at different distances. The presence of absorption shows the HVC to lie in front of the star; absence places it beyond, provided that the expected absorption is well above the detection limit. So far distance measurements are lacking.

HVC complex A, also called chain A, was the first HVC discovered and has been studied in detail. It is a 30º-long filament, containing several well-aligned concentrations with velocities between –210 and –140 km/s. Spectra from the Hubble Space Telescope set a firm lower distance limit, $d>4\pm1$ kpc for chain A. Astronomers have now also measured an upper limit, $d<10$ kpc, for the upper end of chain A, using UES spectra of the the RR Lyrae star AD Ursae Majoris. This is the first time a firm distance bracket for a large high-velocity cloud is obtained.

According to this distance bracket, chain A is placed in the Milky Way halo (2.5 to 7 kiloparsecs above the Galactic plane), rather than at an extragalactic distance, and its mass is constrained to between 10^5 and 10^6 solar masses. The obtained distance bracket excludes models for its nature and origin requiring a distance of the order of 1 kpc or less, such as relationships to local molecular clouds, or collision of an intergalactic cloud with the Galactic disk. It also rules out chain A being a Galactic satellite at ~50 kpc distance, or a protogalactic gas cloud at ~500 kpc distance, or a member of the Local Group of galaxies, as proposed recently for HVCs in general.

The location of chain A in the Galactic halo still allows several models for its origin. For its height $2.5 < z < 7$ kpc to be consistent with a Galactic-fountain model, a sufficiently hot halo would be required. The small-scale structure observed in chain A would then be due to instabilities formed in the downward flow of cooling clouds. Alternatively, chain A may represent gas captured from intergalactic space. In that case, collision with an ionised halo extending high above the Galactic plane may have served to decelerate the gas to its present velocity, and to form the small-scale structure. In this accretion model, the question whether the origin of chain A lies in the Magellanic system (as debris from encounters between Milky Way and Magellanic Clouds), or far away in the Local Group (as remnant of Local Group formation), remains open: location in the Galactic halo does not preclude such a distant origin.

OPTICAL STJ OBSERVATIONS OF THE CRAB PULSAR

WHT+S-CAM

A totally new concept in optical detector instrumentation made its first appearance at the WHT. The Superconducting Tunnel Junction (STJ) Camera (S-Cam), designed and built by members of the Astrophysical Division of the European Space Agency, is a high-efficiency photon-counting system which provides position and arrival time of each detected photon, along with the photon energy.

A tunnel junction consists of two conductors separated by a tiny gap of insulating material or even a vacuum.

If the gap is thin enough, electrons can tunnel across anyway, and if the conductors are superconductors, the junction displays very useful quantum-mechanical properties and electrical non-linearities. An arriving photon breaks apart the pairs of electrons responsible for the superconducting state, which can then be collected. Each individual photon creates a large number of free electrons, in proportion to photon energy. Thus by measuring the charge released by each detected photon, these can be sorted in energy, or wavelength. The main advantages of STJs is that they operate at high speed at very low temperatures, dissipate very little power and are very small.

The first observations of an astronomical object using an STJ device took place at the William Herschel Telescope in February 1999. The Crab pulsar was observed using a 6×6 array of Tantalum STJs, covering an area of about 4×4 arcsec^2, cooled with the help of a bath of liquid helium to a temperature within a degree of absolute zero. This object, a neutron star spinning about 30 revolutions per second and one of the few pulsars that is known to emit optical pulses, was an ideal target for verifying the STJ camera's photon counting and timing capabilities. The astronomers recorded a light curve for the pulsar in two bands simultaneously over the wavelength range 310–610 nm, based on data acquired over a ten-minute interval, with an arrival-time accuracy of 5 μs. The light curve clearly shows the characteristic two beams of light which shine out, like a lighthouse, one weak and long and the other bright and short, in each revolution. The color didn't change through the pulses.

The astronomical impact of these results may have been modest, but it has presented a glimpse of what STJ technology holds in store for the future.

COSMIC FLOW OF GALAXIES ACROSS ONE BILLION LIGHT YEARS OF THE UNIVERSE

INT+IDS, JKT+CCD

According to the 'cosmological principle', the large-scale Universe should be smooth and well behaved. Distant galaxies ought to be evenly distributed in space, and their motions should correspond to a pure 'Hubble flow', a uniform expansion of space in all directions. In other words, the Universe, in some average sense, is homogeneous and isotropic. But galaxies have other "peculiar velocities", over and above the general cosmic expansion.

Although the cosmological principle is one of the central tenets of cosmological theory, it is obvious that the Universe is not exactly homogeneous and isotropic. Matter is not smoothly distributed, but organised into galaxies, galaxy clusters and even superclusters of galaxy clusters. This complex hierarchy of density fluctuations is, according to 'inflation theory', a result of the gravitational amplification of low-amplitude 'ripples' that were present in the very early Universe. But there should be a scale beyond which gravity has not had sufficient time to produce structures, and beyond which the Universe should therefore appear homogenous.

Besides generating spatial patterns, gravity also generates velocities. In a perfectly uniform Universe, everything moves away from everything else with a velocity that is proportional to the distance between. This is known as the Hubble law. But the presence of density fluctuations distorts this uniform Hubble flow by introducing peculiar motions.

All galaxies execute some kind of peculiar motion, as a consequence of the gravitational influence of the lumpy distribution of material around them. In the densest galaxy clusters —known as Abell clusters— where gravitational forces are very strong, galaxies move around with peculiar velocities of ~1,000 km/s generated by the deep potential well in which they reside. On scales larger than individual clusters, the concerted action of entire superclusters produces a calmer, more coherent flow towards regions of above-average density, and away from regions of below-average density. These 'streaming' motions contain clues to the size of the largest structures doing the pulling and thus furnish an important test of cosmological models.

In 1988, a study of streaming motions in a sample of elliptical galaxies revealed evidence for a systematic flow, simple modelling of which suggested that it could be explained by a hypothetical object about 60 Mpc away from the Milky Way, which became known as the 'Great Attractor'.

To map cluster motions, astronomers have to work out how much their velocity —easy to determine from redshift— departs from the velocity that the overall cosmic expansion would give to an object at that distance. That means determining their distance without relying on redshift, a much tougher requirement. The usual strategy is to find some observable feature of galaxies that is thought to indicate their actual brightness or size, then compare it with the brightness or size observed from Earth to get distances.

The Streaming Motions of Abell Clusters (SMAC) Collaboration looked at elliptical galaxies and determined their absolute size by measuring the mean surface brightness in the central part of the galaxy and how fast stars are darting around within it —indicated by the broadening of spectral lines. Then they compared these to similar known galaxies close to Earth. They applied the constructed distance indicator to about 700 galaxies in 56 rich clusters spanning a volume some 1.2 billion light years in diameter. Many telescopes were used in this survey, including the INT and the JKT.

The SMAC survey went far beyond the proposed location of the Great Attractor and they still see outward motion of galaxies beyond it. The reported bulk flow is of amplitude 630±200 km/s with respect to the cosmic microwave background. This flow is robust against the effects of individual clusters and data subsets, the choice of Galactic extinction maps, Malmquist bias, and stellar population effects. The direction of the SMAC flow is about 90º away from the flow found by other astronomers, but it is in good agreement with the gravity dipole predicted from the distribution of X-ray-luminous clusters.

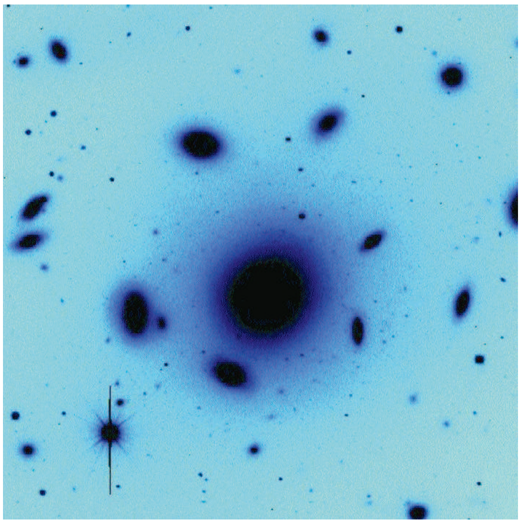


Image of the galaxy cluster Abell 1656 studied by the SMAC team with the Isaac Newton Group of Telescopes. The SMAC survey was based on measurements of 699 galaxies in 56 galaxy clusters like Abell 1656.

GAMMA RAY BURSTS: NEW LIGHT ON THE UNDERSTANDING OF THESE OBJECTS

WHT, INT, JKT

In 1999 the ING telescopes discovered and followed up more optical afterglows of Gamma-Ray Bursts (GRBs), like the extremely intense GRB 991208. Moreover, the observations carried out by the ING telescopes have been used to shed new light on the understanding of these objects. Below we extend on two interesting topics related to GRB research.

Gamma-ray Burst 990123

Gamma-ray bursts are believed to be the largest explosions in the Universe since the Big Bang. However, the origin of these bursts have remained a mystery since their discovery more than 30 years ago. The bursts occur almost daily and shine at least a billion times brighter than any other phenomenon in the Universe, including quasars. The bursts last anywhere from a few milliseconds to several minutes, then disappear forever. The bursts are followed by afterglows that are visible for a few hours or days at other wavelengths.

GRBs are thought to arise when an extremely relativistic outflow of particles from a massive explosion interacts with material surrounding the site of the explosion. Multi-wavelength observations, following their light-curves, are needed to understand the nature of the explosions.

The time scale of the decay since the gamma-ray explosion is detected is about 10 days: the brightness of the optical counterpart can decrease about fifteen magnitudes over this period. Therefore, a quick and accurate determination of the position of the optical counterpart and the follow-up photometry of the source is crucial, which requires a global observing campaign, involving many telescopes.

On 23 January 1999 one of the brightest GRBs ever seen was detected by the BATSE satellite. For the first time, observations at optical, infrared, sub-millimetre and radio wavelengths were obtained of an entire gamma-ray burst. In this effort the Jacobus Kapteyn Telescope was involved, contributing to the photometric light-curve at multiple wavelengths. These observations revealed that the optical and gamma-ray light curves are not the same. This was also the first time that the three different regions involved in the emission process were seen: the internal shocks causing the GRB, the reverse shock causing the pronounced optical flash, and the forward shock causing the afterglow.

If the blast radiated the same amount of energy in all directions as it did towards Earth, its energy would be equivalent to that of almost two neutron stars and irreconcilable with current theories of GRBs. However, the speed at which the radiation faded over the following two days suggests that material was ejected from the explosion in two cones, one of which pointed towards the Earth. This would make it easier to explain GRBs by conventional mechanisms such as the shock waves formed following the death of a massive star.

Links between supernovae and GRBs strengthen

The discovery of both an X-ray and optical afterglow to GRB 970228 by the William Herschel Telescope and the Isaac Newton Telescope revolutionised the study of gamma-ray bursters. The mean temporal and spectral properties of this afterglow appeared to be consistent with the relativistic fireball model. However, now that more data has been gathered on several GRBs, not all of them appear to fit the fireball model. One of them is GRB 970228.

Studies of this GRB, including observations from the WHT and INT, found evidence of extreme reddening of the afterglow with time, which is difficult to explain in the fireball model. Re-analysing the light-curves of the afterglow at different wavelengths suggested a link with a possible rare type of supernova explosions, which strengthens ideas that at least some type of GRBs are produced following the collapse of a massive star.

HR 8752, A HYPERGIANT NEAR THE BORDER OF INSTABILITY

WHT+UES

Hypergiants are supergiant stars with strongly developed large-scale atmospheric velocity fields, excessive mass loss, and extended circumstellar envelopes. They are rare objects, only 12 of them being known in our Galaxy. There are indications that yellow hypergiants are evolved stars, evolving from the red supergiant phase to the blue phase. However, stars with effective temperature near 9,000 K have density inversions, which may indicate instability. This has led to research on the ‘yellow evolutionary void’. Inside the void the atmospheres are moderately unstable. The process of approaching the void has not yet been studied and this is a field in which no observations have guided theory so far. A monitoring of stars approaching the void will help to understand the nature of the instabilities and the hydrodynamics of unstable atmospheres and finally to answer the most important question of whether or not these stars can pass the void.

It is believed that the Galactic hypergiant HR 8752 is presently bouncing against the yellow evolutionary void. From UES spectra astronomers reported for the first time the finding of spectroscopically recorded large changes of the effective temperature, from 5,000 K in 1969 to about 8,000 K in 1998, which cannot be ascribed to the regular variability of a supergiant atmosphere. This finding is based on a unique combination of high-resolution optical spectra that span a period of about 30 years. Thus, HR 8752 turns out to be the first cool supergiant that shows the effects of stellar evolution from a study of its 30 year old spectroscopic history.

Now that HR 8752 approaches the yellow evolutionary void three possibilities arise: 1) The star might return to the point when the effective temperature was 4,000−5,000 K; 2) It might explode as a supernova or, 3) It might occupy the void, which would mean that theory should change. Observations in the coming years will tell us the next evolutionary stage.

THE ORIGIN OF EARLY-TYPE STARS FOUND IN THE GALACTIC HALO

WHT+UES, +ISIS, JKT+CCD

Among the faint, blue stars that are observed at intermediate and high Galactic latitudes, there exists a small subset of objects that are spectroscopically indistinguishable from normal, young Population I B-type stars found in the Galactic disk. The majority of this subset are plausible ‘runaway’ stars, recently formed in the Galactic disk and subsequently ejected by some mechanism. However, in a few cases these apparently normal stars are found at large distances from the Galactic disk, and their evolutionary ages are too short for the objects to have attained their current Galactic locations.

There is no doubt that star formation at large distances from the Galactic plane is controversial. However, shock induced star formation between halo high velocity clouds has been postulated as the origin of the apparently young, distant B-type stars where formation *in situ* seems to be the only possible explanation for their existence.

From recent echelle spectroscopy of 21, apparently normal, high Galactic latitude, early-type stars of solar metallicity drawn from the Palomar-Green survey, astronomers concluded that distances, ages, and velocities are consistent with escape from the Galactic plane. In other words, all these objects are ‘runaway’ stars, formed in the Galactic disk and subsequently ejected, possibly by supernovae explosions or dynamical interactions. In particular high-resolution, high signal-to-noise ratio spectra of HD 100340 showed that this is a normal main-sequence B-type star, at a distance of 2.6 kpc above the Galactic plane. A kinematical analysis strongly suggests that HD 100340 formed in the Galactic disc, and was subsequently violently ejected towards the halo, as a result of the dynamical evolution of a stellar cluster.

EVIDENCE FOR A MASSIVE BLACK HOLE IN THE S0 GALAXY NGC 4342

WHT+ISIS

Several lines of evidence suggest that Active Galactic Nuclei (AGNs) are powered by accretion onto super-massive black holes. The much higher volume-number density of AGNs observed at redshift $z \sim 2$ than at $z \sim 0$ suggest that many quiescent (or ‘normal’) galaxies today must have gone through an active phase in the past, and therefore harbour a massive black hole as well. Such a black hole will significantly influence the dynamics of the galaxy within a certain distance, imposing conditions to the profile of the velocity dispersion of the stars surrounding this massive object. Taking into account these theoretical predictions a study was undertaken of the lenticular (type-S0) galaxy NGC 4342. This study involved a combination of HST and WHT imaging and spectroscopy. The data obtained from these observations were compared with theoretical models describing the dynamics and morphology of the galaxy. Spectra obtained with the WHT have revealed a very steep central rotation curve and a strong central increase in velocity dispersion. These data suggest a large central mass concentration. However, although the dynamical evidence for the presence of a massive dark object in NGC 4342 is compelling, it does not automatically imply evidence for a black hole. If it exists, the mass of the super-massive black hole must be approximately between 3 and 6×10^8 solar masses. Then NGC 4342 would have one of the highest ratios of black-hole mass to bulge mass.

DISCOVERY OF YOUNG STARS IN NGC 185, A DWARF ELLIPTICAL GALAXY

JKT+CCD

Since the early work of Baade elliptical galaxies were considered to be essentially old, coeval systems with ages comparable to those of Milky Way Population II globular clusters. In the light of recent data, however, there is evidence that the majority of the Local Group dwarf elliptical (dE) galaxies have undergone recent star formation activity.

The study of the stellar content of dE galaxies by means of their color-magnitude diagrams provides the most direct method of establishing whether they have had star formation episodes since the initial primeval event and even to locate in time, in a more precise way, that initial star formation event. The Local Group dE galaxies offer a unique opportunity to study their evolution in detail by this means.

NGC 185 is a dE companion of the Andromeda galaxy. The presence of a dozen of bright, blue stars and two conspicuous dust patches in the central area of NGC 185 was firstly noted by Baade in 1951. These “Population I” features indicated that NGC 185 did not fit the concept of dE galaxies as pure Population II systems. For this reason, NGC 185 was classified as a peculiar dE galaxy.

A recent study of NGC 185 shows that the luminous, blue stars discovered by Baade are in fact young stellar clusters at the distance of the galaxy. Furthermore, the recent analysis of the star formation history of NGC 185 using synthetic color-magnitude diagrams shows that the bulk of the stars were formed in an early epoch of its evolution. After that, star formation proceeded at a low rate until the recent past, the age of the most recent traces of star formation activity detected in the galaxy being some 100 Myr. These conclusions rule out the possibility of NGC 185 being an old galaxy formed by Population II stars only.

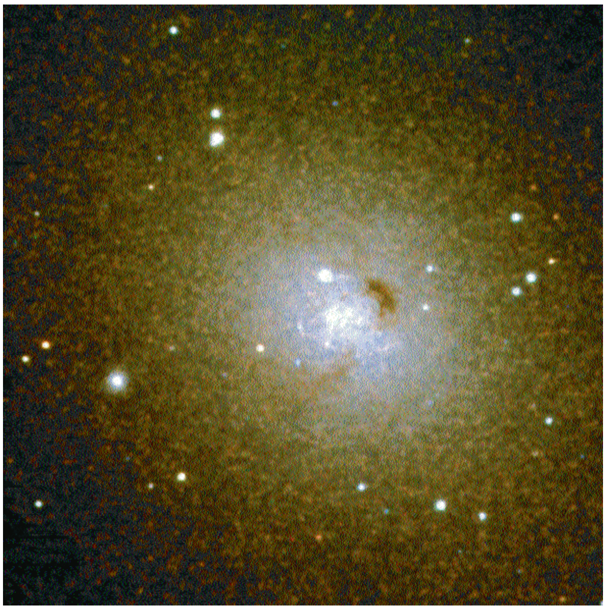


Image of the central region of NGC 185, obtained from a combination of B, V, and R images from the Jacobus Kapteyn Telescope.

CLOSING IN ON THE PRIMORDIAL POWER SPECTRUM OF MASS FLUCTUATIONS

WHT+ISIS

Modern cosmology is based on the hypothesis that structure in our Universe arose from the action of gravity on small initial density perturbations. The power spectrum of these initial fluctuations, P(k), is a fundamental discriminator between different cosmological theories, it offers a direct way to constrain any free parameters they might have, and it would also serve as a valuable baseline for the interpretation of cosmological phenomena.

One route to P(k) uses observations of microwave background anisotropies. However, estimates of the mass P(k) derived from such measurements depend on the assumed values of the cosmological parameters. Much effort has been spent on trying to infer P(k) from surveys of the galaxy distribution. Deriving an estimate of the primordial matter P(k) from galaxy measurements requires at the very least an understanding of how the present day distribution of galaxies is related to the primordial distribution of mass. Even with a theory of galaxy formation, the complexity of the processes involved makes it difficult to recover P(k) directly.

However, the Lyα forest seen in quasar spectra can be used to study mass fluctuations, but with two important differences. First, the framework of standard cosmology provides us with a well-motivated theory of Lyα formation. Second, the situation described by the theory is simple and leads to the prediction that an approximately local relationship holds between the absorbed flux in a quasar spectrum and the underlying matter density, a relationship that can be inverted to learn about matter clustering. In particular, P(k) itself can be recovered over a limited range of scales. The astronomers applied this procedure to a sample of 19 quasar spectra from a survey of damped Lyα systems carried out with the William Herschel Telescope.

The slope of the primordial power spectrum of mass fluctuations, P(k) at a mean redshift of $z=2.5$ is found to be $n=-2.25$. P(k) has never previously been measured at the scales of this work. The most significant theoretical implication of this result is that inflation and cold dark matter models, originally motivated by considerations of microwave background anisotropies at $z\sim1000$ and large-scale structure at $z\sim0$, predict a P(k) that is at least roughly consistent with this measurement.

OTHER SCIENTIFIC HIGHLIGHTS BRIEFLY

The Faint Star Variability Survey

The first phase of the planned five-year program to study faint objects, the so-called Faint Star Variability Survey, was completed. The astronomers recorded the brightness of celestial objects in several wavebands from blue to near-infrared, every 5–10 minutes throughout the night. The images are being analysed in order to search for faint red or blue objects as well as to record their variability. The survey results also provide detailed information on the nature and distribution of stars within the Milky Way galaxy, faint objects within our Solar System, galaxy clusters, quasars, and faint dwarf galaxy companions to our own Galaxy. This survey operates within the framework of the Isaac Newton Group's Wide Field Survey.

The Supernova Cosmology Project

The discovery of the accelerating expansion of the Universe by the Supernova Cosmology Project was already a scientific highlight in 1998 and named by the journal 'Science' as breakthrough of the year 1998. The paper with all the discovered type Ia supernova data was published in 1999 and it has become one of the most cited ING papers. In order to reduce the systematic errors in the measurements obtained by the Supernova Cosmology Project, the European Supernova Cosmology Consortium started a long-term project on the WHT, INT and JKT to discover and follow-up supernovae at intermediate redshifts.

The QDOT survey

The QDOT all-sky redshift survey is principally aimed at producing the first reliable quantification of the large-scale distribution of galaxies on scales greater than $10\,h^{-1}$Mpc. The QDOT survey results were made public in 1999. The catalogue consists of infrared properties and redshifts of an all-sky sample of 2387 IRAS galaxies brighter than the IRAS PSC 60 μm completeness limit ($S_{60}>0.6$ Jy), sparsely sampled at a rate of one-in-six. Astronomers used FOS-1 and FOS-2 spectrographs on the INT and WHT respectively.

Jets from quasar 4C 74.26

4C 74.26 is a double-lobed radio source associated with a V~15 quasar at a redshift of 0.104. The radio source is one of the largest known to be associated with a quasar. High signal-to-noise ratio spectropolarimetry using ISIS spectrograph of 4C 74.26 has revealed that in polarised light the Hα emission line is redshifted by about 2000 km/s. This is compelling evidence for scattering by a high-speed outflow. Arguments based on unified models and the one-sided nature of the radio jet suggest that the jet axis is inclined at an angle less than 45° to our line of sight. If the scattering outflow is co-axial with the jet, its velocity must be larger than 5000 km/s.

Imaging stellar surfaces

The availability of high-resolution imaging methods now allows the detailed scrutiny of the surfaces of the nearest cool evolved stars. The photospheric surfaces of five long-period variables were imaged in the optical/near-IR with a standard optical set-up at the Nasmyth focus of the WHT using a collimating lens, a pupil plane mask and magnification optics to convert the telescope into a multi-element interferometer. All of the sample stars exhibited strong departures from circular symmetry. The stellar surfaces were seen to change over time, with characteristic time-scales ranging from several months to a year.

Satellites of Saturn

Observations of the major satellites of Saturn have been continued to improve the orbital theories of the satellites in preparation for the NASA/ESA Cassini/Huygens mission which will reach Saturn in 2004. From 1,514 measurements made in 1995 and 1997 with the Jacobus Kapteyn Telescope, astronomers obtained observations of Tethys, Dione, Rhea and Titan with root-mean-square residuals of 0.08–0.10 arcsec.

Galaxy clusters

An extensive study of 10 distant rich clusters of galaxies made from observations collected since 1994 with the WHT and other telescopes was published in 1999. The data presented included positions, photometry, redshifts, spectral line strengths, and classifications for 657 galaxies in the fields of the 10 clusters. The catalogue is composed of 424 cluster members across the 10 clusters and 233 field galaxies. These data were used to study the formation of galaxies in these distant clusters.

Sakurai's object

The extraordinarily rapid evolution of the born-again giant star, also known as Sakurai's object following discovery in 1996, has been investigated thanks to observations carried out with the ING telescopes (WHT+ISIS, +UES, +Aux Port Camera, INT+IDS). The evolution can be traced both in a continued cooling of the stellar surface and dramatic changes in chemical composition on a timescale of merely a few months. The abundance alterations are the result of the mixing and nuclear reactions which have ensued due to the final He-shell flash which occurred during the descent along the white dwarf cooling track. Since Sakurai's object shows substantial abundance similarities with the R CrB stars and has recently undergone R CrB-like visual fading events, the "birth" of an R CrB star may have been witnessed for the first time ever. Sakurai's object thus lends strong support for the suggestion that at least some of the R CrB stars have been formed through a final He-shell flash in a post-AGB star. Optical imaging and long-slit spectroscopy of the planetary nebula surrounding Sakurai's object showed that this is a typical evolved planetary nebula. The observations are only consistent with white dwarf cooling tracks if the stellar mass lies between 0.5 and 0.8 solar masses.

Boxy bulges and bars

It has been suggested that the boxy and peanut-shaped bulges found in some edge-on galaxies are galactic bars viewed from the side. Using ISIS spectra, astronomers investigated this hypothesis by presenting emission-line spectra for a sample of 10 edge-on galaxies that display a variety of bulge morphologies. Generally, bulges classified as more boxy show the more complicated kinematics characteristic of edge-on bars, confirming the intimate relation between the two phenomena.

Jupiter's Great Red Spot

The Great Red Spot is the most prominent and long-lived feature on Jupiter. Despite the fact that it has been observed for more than 300 years, many unanswered questions on this oval region still remain. One of the most striking characteristics is its coloration. A different material and/or particle size distribution compared to its surroundings could explain this feature. From high-quality CCD observations acquired at the Nasmyth focus of the WHT astronomers concluded that the difference in colour between the Great Red Spot and its surroundings could be mainly due to different particle size, rather to a different composition, i.e. different refractive index.

T Tauri stars

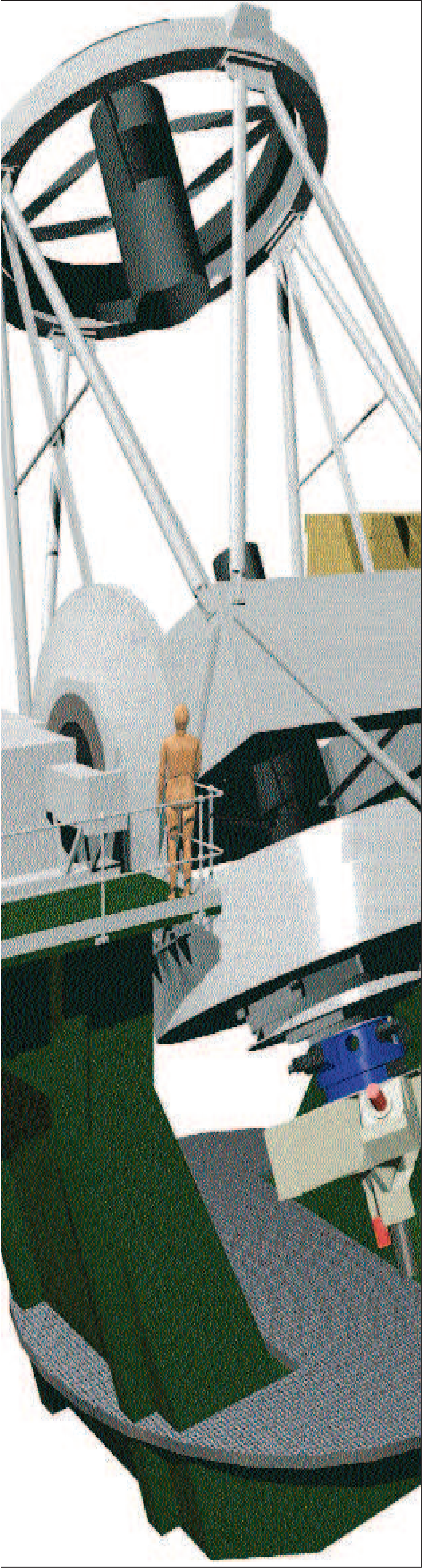
Several studies on T Tauri stars were carried out in 1999 using the ING telescopes (WHT+UES, INT+IDS). Hourly monitoring of several T Tauri stars allowed astronomers to discern a wide range of physical processes at work, such as the slow rotation of the stars, magnetic flaring activity, variable accretion and obscuration by circumstellar material. In particular, measurements of magnetic field strength derived from the differential change of the equivalent width of photospheric Fe I lines showed that ignoring magnetic fields in T Tauri stars could result in errors in effective temperature and underestimates of veiling.

Galaxy evolution

How early-type galaxies were formed and evolved is a key issue in extragalactic astronomy which remains controversial. The evolution of early-type galaxies in clusters seems to be well expressed by the so-called single-burst model, in which galaxies experience a starburst at the initial phase of their formation and then evolve passively without any subsequent star formation. However, it is fairly controversial whether the single-burst model holds for early-type galaxies in the field environment. From deep CCD imaging using the Multiple CCD (MCCD) camera on the WHT astronomers found that early-type galaxies in the field environment do not have the same evolutionary history as described by the single-burst model.

Lithium abundance in stars

According to the standard big bang nucleosynthesis model, lithium is one of the few elements synthesised in the first minutes of the Universe. In this scenario the primordial synthesis of lithium is very sensitive to the baryon/photon ratio, and the astronomical determination of its primordial abundance can constrain the baryonic contribution to the density of the Universe. Since the discovery of a rather uniform lithium abundance, the so-called lithium plateau, in the hotter halo dwarfs at about a value $\log n(\mathrm{Li})=2$, there has been a long debate on whether or not this abundance reflects the primordial one. In 1999 the research on this topic continued and several papers containing data from WHT+UES and INT+IDS were published showing new Li measurements from metal-poor stars.



Chapter 2

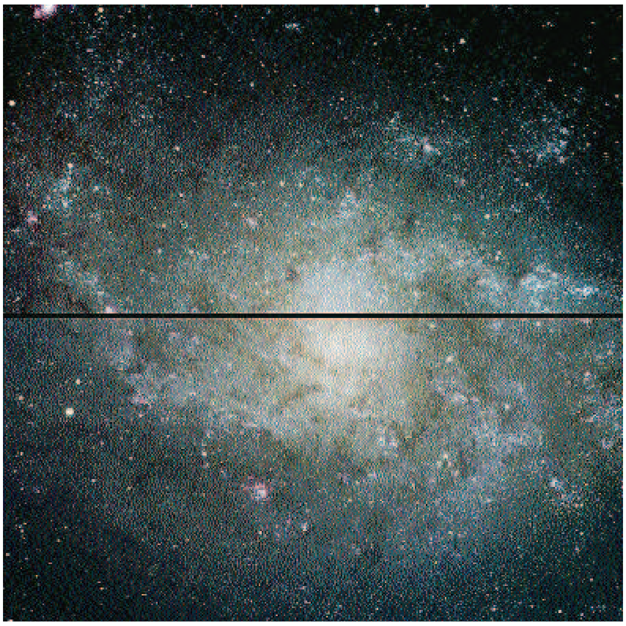
New Instrumentation and Enhancements

The ING telescopes continue to enjoy a high level of interest from instrument builders. Various developments are under way or have already been made to the telescopes during 1999, some of which are reported below.

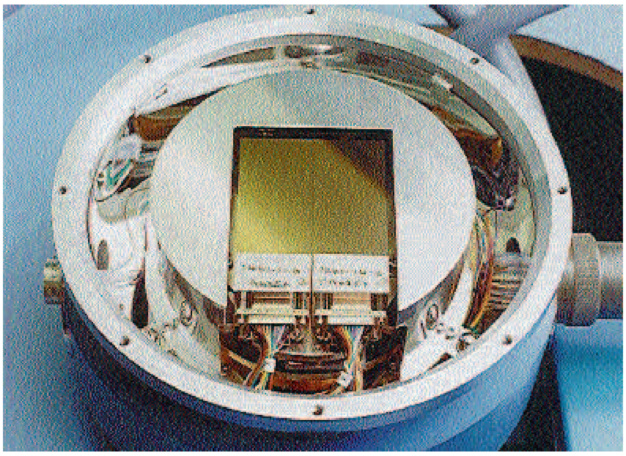
The twin CCD mosaic camera composed of two 2k×4k pixel EEV devices was commissioned in the WHT Prime Focus, replacing the single chip camera as the main imager. This was the first system on the WHT that was converted to the new data acquisition system based on an SDSU-2 controller. The new camera not only doubles the field-of-view compared to the previous single-chip camera, but in conjunction with speed gains from the new data acquisition system, imaging projects have become much more efficient. The substantial field of view of 16 by 16 arcmin together with the excellent response of the thinned EEV CCDs at short wavelengths makes it a highly competitive tool for deep imaging projects at short wavelengths.

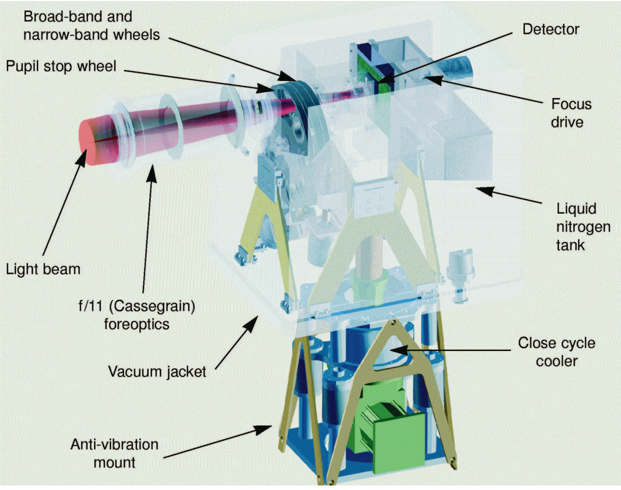
ING have formally joined a CCD development project led by the University of Hawaii for the procurement of high-QE, large format CCDs. These thick, deep-depletion CCDs are being developed by MIT Lincoln Laboratory. Although the currently operational CCDs have excellent quantum efficiency in the blue, they do suffer badly from fringing at long wavelengths. The detectors obtained through the consortium involvement are expected to show little fringing as well as very good quantum efficiency.

Development of the new infra-red camera for the WHT, INGRID, made important progress during 1999, although commissioning will be later than was originally anticipated.



From top to bottom, left to right: BVR image of M33 Galaxy, exposure time was 10s; The star-formation region M42, also known as the Orion nebula. Shown here is a 10s exposure true-colour image; Twin EEV CCD detector of the WHT Prime Focus camera. The new WHT prime focus camera contains two EEV 42-80 thinned CCDs butted along their long axes to provide a 4K x 4K pixel mosaic. Each pixel is 13.5μm square. A single detector comprises 2148 x 4128 pixels. The active area of the mosaic measures 55.8 x 55.35mm, with a 0.53mm gap between the chips.




Broad-band and narrow-band wheels
Pupil stop wheel
Detector
Focus drive
Liquid nitrogen tank
Light beam
f/11 (Cassegrain) foreoptics
Vacuum jacket
Close cycle cooler
Anti-vibration mount

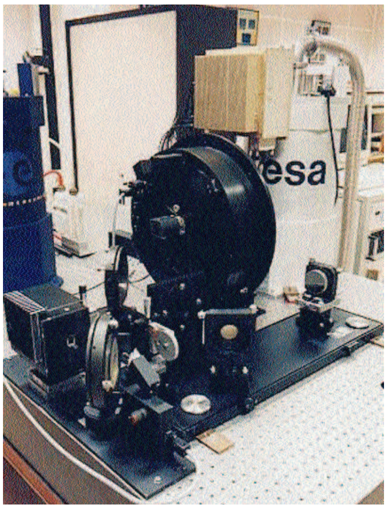
A 3-D transparent model of INGRID showing in red the light beam from the telescope focusing on the infrared detector.

This camera, which at its heart has a 1024×1024 pixel IR HgCdTe detector from Rockwell, will be used as a stand-alone IR imager in the Cassegrain focus, as well as the prime detector for the future adaptive optics system. For normal imaging the field-of-view will be over four minutes of arc. Delay in commissioning was mainly due to major rework that was required in various parts of the original design, in particular on the optics mounting arrangement to meet the very tight tolerances.

The WHT hosted the first on-sky trials of ESA's Super-conducting Tunnel Junction Camera, S-Cam, built by a team from ESTEC at Noordwijk, The Netherlands. The radically new technology deployed in this camera (breaking of Cooper pairs by incoming photons) permits measurement of both the energy and time of arrival of each photon striking the detector array. As the current incarnation of this technology an array of 6 by 6 pixel had been produced. The energy resolution at the moment reaches only about five, but future developments hold the promise of achieving a resolution of up to R~500. First science results of the pulsar in the center of the Crab nebula have been published.

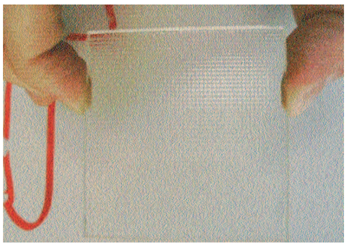
Another new instrument that came to the WHT was SAURON, an integral-field grism spectrograph built at Centre de Recherche Astronomique de Lyon, in collaboration with the Universities of Leiden and Durham. SAURON splits the telescope's Cassegrain focal plane into approximately 1500 elements, using a lenslet array. For each element of the focal plane a spectrum is produced, providing a huge multiplex advantage over classical spectrographs. This design principle has been successfully pioneered at the CFHT in instruments such as TIGER and OASIS. SAURON targets a number of specific scientific aims and is ideally suited to explore the dynamical parameter space occupied by elliptical galaxies and the bars and bulges of spirals galaxies.

Another integral field instrument that came to the WHT was TEIFU, the thousand-element integral-field fibre feed for the existing WYFFOS fibre spectrograph. This instrument, built in Durham uses a lenslet array to feed the fibres and thus achieves a very high filling factor. TEIFU can be used either as a stand-alone fibre feed, or in conjunction with the future adaptive optics system for the WHT to facilitate spectroscopic observations at very high spatial resolution.

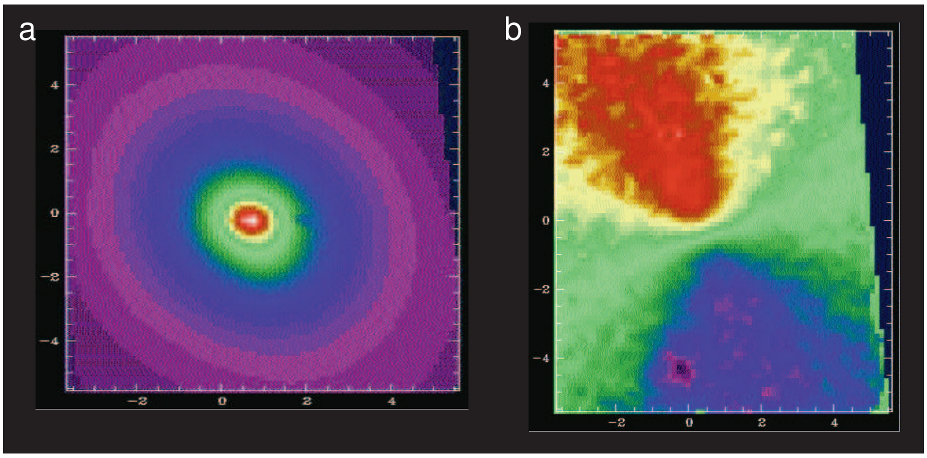


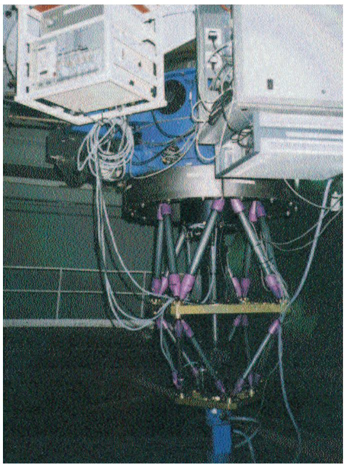
ESA's S-Cam set up at ESTEC.

An ING Workshop was held in Sheffield to discuss the future direction of the observatory instrumentation plans with the community of ING users. Many useful contributions inspired much discussion between the over 70 registered participants. In particular the role that 4-m class telescopes will play in the era of the much larger telescopes was a topic of discussion. There appeared to be a reasonable consensus that the strategy for the WHT would be to concentrate its development



From top to bottom, left to right: The SAURON lenslet array is made of fused silica, and consists of over 1600 square lenslets, each 1.35 mm on the side; SAURON measurements of M32. a) Reconstructed total intensity. b) Stellar mean velocity. The field of view is 9"×11", and the spatial sampling is 0.26"×0.26"; SAURON mounted on the Cassegrain port of the WHT.





on wide field multi-object spectroscopy and on exploiting high spatial resolution through adaptive optics.

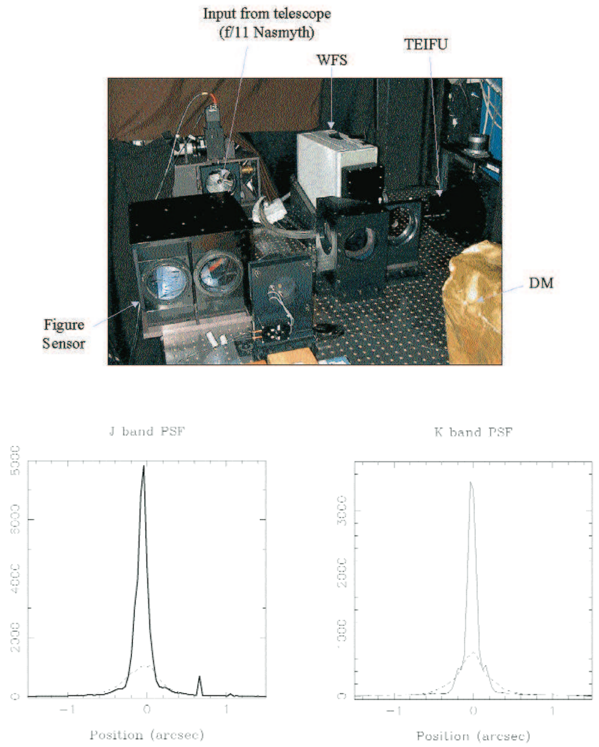
Following from this meeting an announcement of opportunity for new instrument ideas was sent out to the community. The ideas received all focussed on achieving high spatial resolution through adaptive optics. These proposals form the basis of future new instrument developments.

ADAPTIVE OPTICS AT THE WILLIAM HERSCHEL TELESCOPE

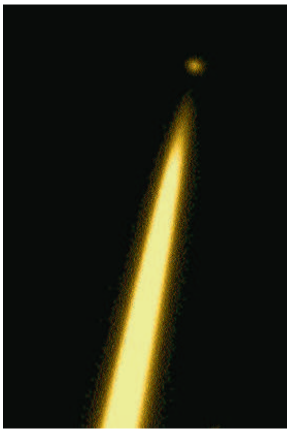
The Adaptive Optics (AO) programme for the WHT is a cornerstone development area at ING. Telescopes in the 4-m diameter range provide the ideal tools to exploit and develop AO techniques because, at this beam size, diffraction limited imaging at relatively short wavelengths and over moderately wide fields should be achievable. In this area 4-m class telescopes are likely to remain competitive next to the new generation of 8-m class telescopes.

During the summer important trial observations were carried out using ELECTRA whose adaptive-optics mirror will ultimately be at the heart of the WHT adaptive optics instrument, NAOMI. The tests were very encouraging and produced near diffraction-limited images in the J and K bands. Much experience was gained in optimising system performance, stability and calibration procedures.

The initial AO instrumentation will rely on natural guide stars to measure wavefront distortions. Optimal exploitation of AO would require the deployment of artificial guide stars produced by a laser beam since this would provide nearly full sky coverage. A sodium laser produces a fluorescent spot high in the Earth's atmosphere at an altitude of about 90 km, which is then used as an artificial star. A study was initiated to investigate whether the atmospheric conditions above La Palma are suitable for this technique and to look at the complexities of laser guide star deployment. This programme, led by Imperial College in London, resulted in first laser firing from a special purpose launch telescope in September. The very successful trials gave invaluable information and experience on both technical and atmospheric parameters. The brightness of the artificial star was measured, as well as the temporal variation and structure as function of height in the atmosphere. The full study will span about one year during which four laser runs will take place.



Top: Schematic layout of ELECTRA at GHRIL (WHT). Bottom: ELECTRA J-band and K-band images of a star before and after correction.



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

INFRASTRUCTURE ENHANCEMENTS

The most important infrastructure enhancement at ING during the reporting year has been the upgrade programme of the computing facilities and network. The network backbone requirements were audited and enhanced to allow for the much higher data rates that are now produced by the telescopes. New cables and fibres were laid, new computers installed, and RAID disk storage systems will be installed early in 2000. Following this, ING will also acquire a Digital Video Disk (DVD) tower with ancillary computer equipment and software to facilitate archiving of the large data volumes. These incremental upgrades to date have been carried out without loss of essential services to the observers. Although the project is not fully completed yet, its positive impact has been noticed by observers.

Repairs and major maintenance was carried out on the INT dome top shutter over the summer. Motors and drive system were replaced. Advantage of this stand-down period was also taken to replace pulleys and cables. All work was completed successfully within four days, with minimum loss of observing time.

ING's John Whelan library facilities were much extended thanks to the large number of books and journals received from the now closed Royal Greenwich Observatory. In order to accommodate this valuable addition the existing library space in the Santa Cruz de la Palma Sea Level Office was extended.

To carry out the work on the INT dome top shutter the largest crane on La Palma was hired to lift the half-tonne units.

Chapter 3

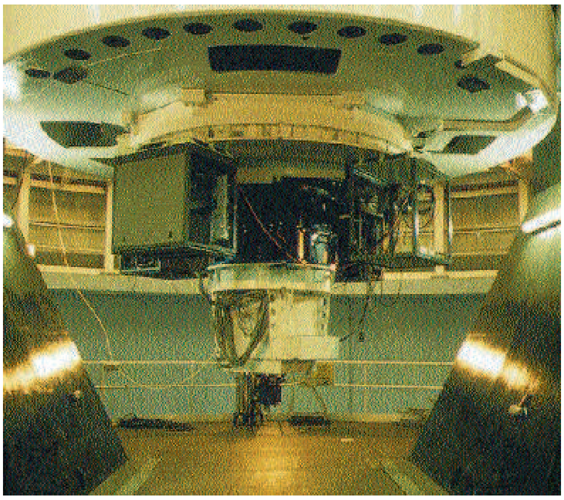
Telescope Operation and Maintenance

The year 2000 rollover had captivated many computer users across the globe in view of the potential havoc it might cause to IT systems. ING went through an extensive programme of making its systems Y2K ready, in which formal testing was a key element. Problem areas that were uncovered were corrected. As a precautionary measure and to avoid problems with visiting astronomers not being able to travel to La Palma, the telescopes were not operational on the night of December 31st. No major problems were experienced during the year change and operation resumed as normal on the first day of the New Year.

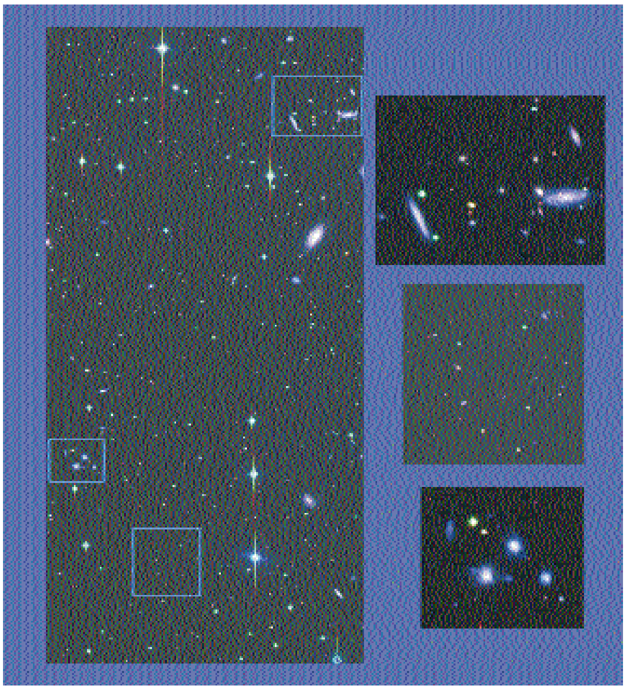
Some of the technical failures in 1999 were the result of recurrent, intermittent problems with specific subsystems. In particular the now-aging data acquisition system on the WHT suffered a period of poor performance. Although interim fixes to faults have been put in place, the ultimate solution is to replace the existing system with a modern Unix based acquisition system, a project that is now well under way.

The panoramic IR imager, CIRSI, was used extensively for observing runs on the INT and the WHT. This instrument, built by the Institute of Astronomy in Cambridge, is currently the largest format state-of-the-art IR camera in the world.

During the year it was decided to withdraw two instruments, the Low Dispersion Survey Spectrograph, LDSS, and the Fabry-Perot imaging spectrograph, TAURUS, as common-user instruments from the WHT instrumentation suite. Although both instrument offered excellent facility instruments for the community, their support required substantial observatory resources whilst the instruments were used only a relative small fraction of the time. Instead of decommissioning the instruments, university groups were invited to



The Fabry-Perot imaging spectrograph, TAURUS, was withdrawn as a common-user instrument from the WHT after 12 years of operation.



These images represent one of the fields observed in the Faint Star Variability Survey which is one of the INT Wide Field Survey programmes. Shown on the left is one of the 4 CCDs of the WFC.

adopt these instruments so that their capability was not automatically lost. Withdrawal of LDSS and TAURUS will free resources for commissioning and maintenance of new instruments.

The primary mirror's reflectivity on the three telescopes continues to be maintained by regular CO_2 snow cleaning and regular measures are made to monitor reflectivity and scattering. On-sky checks of the U-band throughput at the WHT showed little degradation over a period of 7 months, allaying fears that snow cleaning might be ineffective at short wavelengths. However, increased scattering over time is apparent, which could be improved by regularly washing the mirror. First tests with *in situ* mirror washing show very promising results.

Over the last year the INT was operated essentially as a two-instrument facility. Generally during bright time the Cassegrain Intermediate Dispersion Spectrograph was used, with a switch to the Wide Field Camera (WFC) during dark time. The observing system with the WFC was run largely without the presence of a telescope operator. As a result of various system-upgrades the complete observing system can now easily be operated efficiently and safely by a single person.

Important progress was made on the development of the new Data Acquisition System, UltraDAS, based around the SDSU-2 CCD controller technology. The new system was successfully deployed on the INT Wide Field Camera and on the WHT Prime Focus imager, with marked improvements in the detector readout time. Full implementation of the SDSU-2 controllers for all cameras and foci will take place during the next year.

THE INT WIDE FIELD SURVEY PROGRAMME

As a result of a special call for proposals in 1998 a substantial fraction of the observing time on the INT was devoted to imaging surveys with the Wide Field Camera in the prime focus. Since the start of the imaging survey observations very substantial progress has been made. Coverage passed the 100 square degrees mark in 1999. A data reduction pipeline came into routine use. It comprises flat fielding, fringe correction, astrometry, flux calibration, and object catalogue generation. Object catalogues are generated containing typically 1000 to 2000 objects per CCD frame, which equates to object densities of ~30,000 per square degree. Data products are being made available typically one month after the raw data are obtained.

The survey encompasses various scientific goals, one of which is the search for Type Ia supernovae to gauge expansion of the universe. Several new supernovae at intermediate redshift have already been found. Another survey project studies the variability of celestial objects of various kinds. To date over 1600 new variable objects have been discovered and light curves for some 100,000 objects have been generated. These are only two examples of the wealth of data generated by this survey. Also several square degrees of the Pleiades have been mapped in difference colours in a search for brown dwarfs.

The survey activities on the INT spawned further follow-up projects. Discussions were initiated to co-ordinate survey activities between telescopes in order to make optimal use of the data and look for options to extend the survey to other wavelength ranges and to spectroscopic surveys. A special workshop to address the progress and further exploitation of the survey data took place at the Institute of Astronomy in Cambridge in October.

Chapter 4

Telescope Performance 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 PPARC-NWO 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). On the other hand it is the responsibility of the Astrophysics Institute of the Canaries (IAC) to allocate the Spanish time via the Comité para la Asignación de Tiempos (CAT). The ratio of UK PATT : NL NFRA PC : SP CAT : ITP is nominally 60 : 15 : 20 : 5. This ratio is monitored and small differences in these proportions in any one year are corrected over a number of observing seasons.

The PPARC makes 27 nights per year of its share on the JKT available to the National Board of Science and Technology of Ireland (NBST) and the Dublin Institute for Advanced Studies (DIAS). In a similar way, the University of Porto (Portugal) has 28 nights of observing time on the JKT.

The aim of the ING service 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. For each telescope and instrument several nights per month are set aside especially for this purpose. During those nights, ING support astronomers perform observations for several service requests.

Allocation of time for semesters 99A and 99B

	WHT		INT		JKT	
	Nights	**%**	**Nights**	**%**	**Nights**	**%**
UK PATT*	163.5	44.8	119.0	32.6	192.0	52.6
NL NFRA PC	41.5	11.4	38.0	10.4	44.0	12.0
SP CAT	55.5	15.2	65.0	17.8	60.0	16.4
UK/NL WFS	–	–	79.5	21.8	–	–
ITP	15.0	4.1	16.0	4.4	13.0	3.6
Service/Discretionary**	58.0	15.9	37.5	10.3	33.0	9.1
Commissioning	30.5	8.3	7.0	1.9	18.0	4.9
Stand-down	1.0	0.3	3.0	0.8	5.0	1.4
Total	365.0	100.0	365.0	100.0	365.0	100.0

*Includes Irish and Portuguese time on the JKT.

** Service nights include UK, NL and SP service time.

Stand-down and discretionary nights are used for major maintenance activities, commissioning, minor enhancements, calibration and quality control tests, etc., and partly for astronomy, for example, as compensation for breakdowns or for observations of targets of opportunity. They are scheduled together with service nights for greater flexibility, but a careful record of service observations per nationality is kept.

The way the available observing time on the ING telescopes has been shared in semesters 99A and 99B is summarised in the table above.

USE OF INSTRUMENTATION

The table on the right shows for each telescope the number of nights in semesters 99A and 99B for which the different instruments were scheduled. Stand-down periods are excluded and commissioning nights are shown between parenthesis. The abbreviations are explained in Appendix J. The list of common-user instruments for the same period of time can be found in Appendix B.

As in previous years, the ISIS spectrograph and polarimetre, and UES are the most popular WHT instruments. The improved large CCD detectors available in the WHT prime focus make imaging

Allocation of nights per instrument for semesters 99A and 99B

William Herschel Telescope

	Nights	%
ISIS	137.0 (1.5)	38.1
UES	70.4	19.3
AUTOFIB-2	28.0	7.7
INTEGRAL	24.0 (2.0)	7.1
PF	24.0 (2.0)	7.1
SAURON	14.0 (2.5)	4.5
ELECTRA	(14.0)	3.8
LDSS	13.0	3.6
TAURUS	8.0	2.2
STJ	(6.0)	1.7
CIRSI	4.0	1.1
ISIS POL	4.0	1.1
TRIFFID	4.0	1.1
AUX	3.1	0.9
TEIFU	(2.5)	0.7
Total	**333.5 (30.5)**	**100.0**

Isaac Newton Telescope

	Nights	%
WFC	199.0 (3.0)	55.8
IDS	131.0 (4.0)	37.3
MUSICOS	19.0	5.2
FOS	6.0	1.7
Total	**355.0 (7.0)**	**100.0**

Jacobus Kapteyn Telescope

	Nights	%
CCD Imager	342 (18)	100.0

projects very attractive. Both the AUTOFIB-2 and INTEGRAL fibre units are used in combination with the WYFFOS spectrograph located on the Nasmyth platform. When the telescope is in Nasmyth or Cassegrain configuration, imaging at the Auxiliary Port of the Acquisition and Guidance Unit at the Cassegrain focus is also possible. On the INT, dark time periods are almost exclusively used for CCD imaging with the Wide Field Camera. JKT is a single instrument telescope for CCD imaging.

TELESCOPE RELIABILITY

Over semesters 99A and 99B the telescopes performed well, with downtime figures due to technical problems averaging 4.1, 4.5, and 3.5 % on the William Herschel Telescope (WHT), the Isaac Newton Telescope (INT), and the Jacobus Kapteyn Telescope (JKT), respectively. Although technical downtime on the WHT in particular has been somewhat higher than in previous years, these figures meet the target value of a maximum of 5 percent technical downtime.

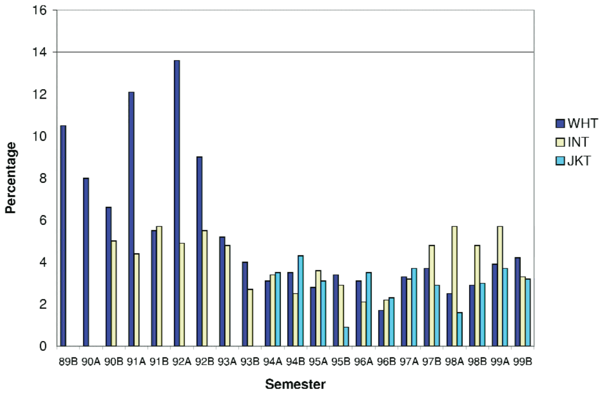
Weather downtime averaged 28.3, 24.0, and 26.6% on the WHT, INT and JKT respectively over the reporting period. These high figures are due to the exceptionally bad winter 1999–2000.

SCIENTIFIC PRODUCTIVITY

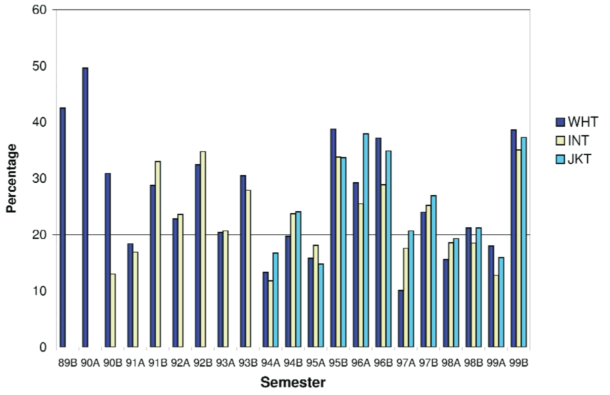
The scientific productivity over 1999 has again been very high with a total of 239 papers published in refereed astronomical journals: 115 for the WHT, 78 for the INT and the remaining 46 for the JKT. The scientific output of the WHT in particular places this telescope amongst the most productive ground-based facilities in the world. Also in terms of ground-breaking discoveries, as published in the journal *Nature*, the WHT is positioned as a top class facility. A full list of publications is presented in Appendix E.

A study was carried out to assess the scientific productivity of ground-based optical telescopes, comparing the ING telescopes to an international standard. As indicated by the figures above, the ING telescopes compare favourably in terms of number of papers, but do the papers represent important, high-impact discoveries? The index used in this study is the number of papers published in *Nature* between 1989 and 1998. The advantage of this measure is that it is

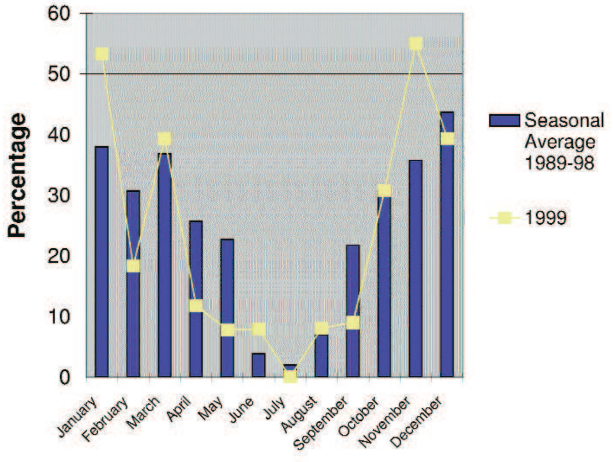
Technical down time per semester



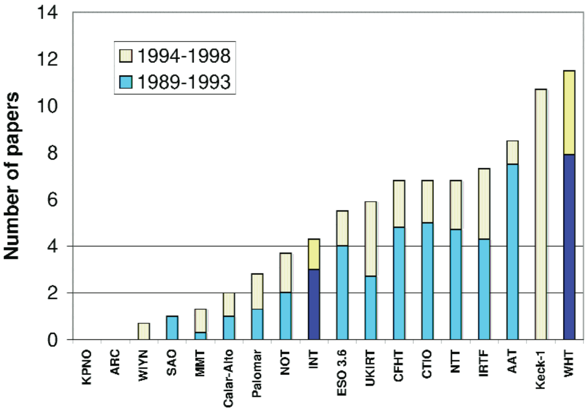
Weather down time per semester



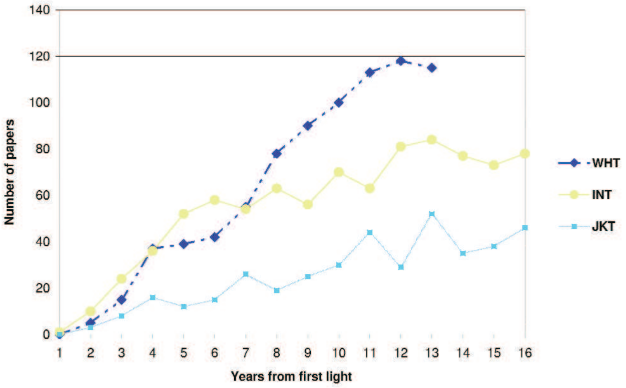
Monthly weather down time



relatively free from regional bias, and the time delay between discovery and publication is short. The accompanying graph shows the result over the past 10 years for the ING telescopes compared with large telescopes elsewhere that have been in operation for a number of years. The sample includes all telescopes with an aperture larger than 3.5-m, plus the Nordic Optical Telescope, and the INT. (Papers with contributions from more than one telescope are divided equally between those facilities). Clearly the WHT compares very favourably with other telescopes.


***Nature* papers from optical/IR ground based telescopes**

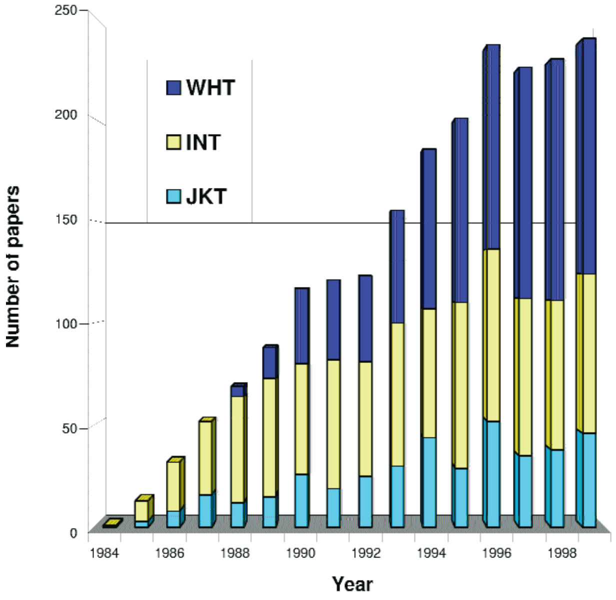
Number of publications per telescope since first light



Number of publications per year and telescope

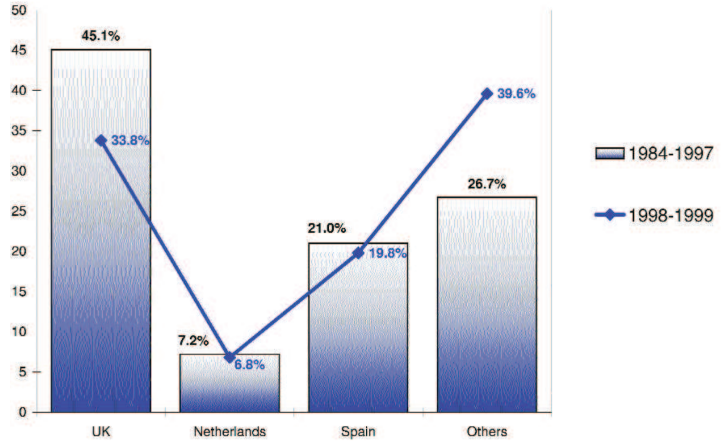
	WHT	INT	JKT	Total
1984	–	1	–	1
1985	–	10	3	13
1986	–	24	8	32
1987	–	36	16	52
1988	5	52	12	69
1989	15	58	15	88
1990	37	54	26	117
1991	39	63	19	121
1992	42	56	25	123
1993	55	70	30	155
1994	78	63	44	185
1995	90	81	29	200
1996	100	84	52	236
1997	113	77	35	225
1998	118	72	38	228
1999	115	78	46	239
Total	807	879	398	2,084

Total number of ING publications per year

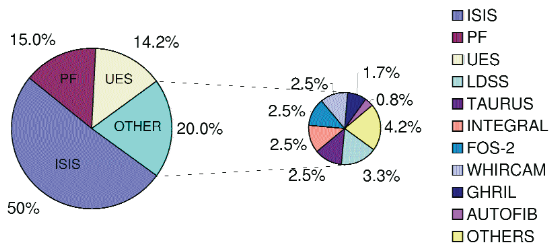


The charts below show the relative use of data in 1999 ING publications split by instrument used. The accompanying chart shows the authorship of all papers from 1984 to 1997 and for 1998-1999 only, split by nationality. The nationality of each author is attributed according to his or her address and equal weight is given to each author. It can be seen that the contribution from the rest of the world (others) has increased significantly as compared to the UK (only) contribution, which encourages us to believe that collaborative programmes are becoming increasingly important.

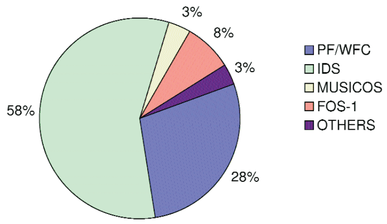
Paper authorship

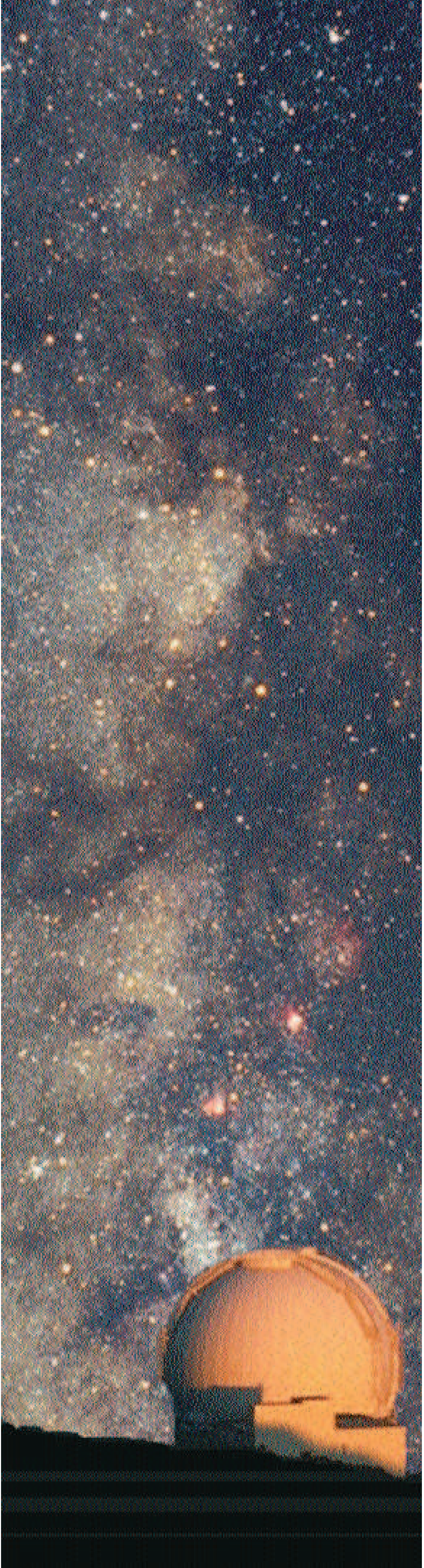


Use of instrument data in WHT papers



Use of instrument data in INT papers





Chapter 5

In-house Research and Development Activities

Activities at the ING naturally focus on the day-to-day operation of the telescopes. However, research and development activities are becoming more prominent. This section summarises these activities during 1999.

Research activities by ING astronomers covered a range of topics, many of which are linked to the activities of the telescopes. Key research areas of astronomy staff at ING included active galaxies, quasars, distant supernovae, planetary nebulae, evolution of early-type stars, and oscillations of massive stars. A compilation of the papers published in science journals during the year can be found in Appendix F.

Professor Philip Dufton ended his one year sabbatical leave from the Queen's University of Belfast in July. During his stay at the ING he worked closely with Danny Lennon and Steve Smartt on problems related to the chemical evolution of Local Group galaxies and massive star evolution.

Towards the end of this year, two new research fellows agreed to join the ING; Dr. Johan Knapen from the University of Hertfordshire and Dr. Romano Corradi from the IAC. Johan's current interests concern mainly the central regions of galaxies, particularly bars and circumnuclear star formation regions, while Romano's main lines of research are concerned with planetary nebulae and symbiotic stars.

Two long-term placement students, Jay Abbott and Andrew Humphrey from the University of Hertfordshire stayed at ING during the 1998/99 academic year. Both were involved in operation of the telescopes, in particular of the JKT, as well as in science projects such as polarimetry of active galaxies. Andrew was supervised by Chris Packham, while Jay Abbott, who worked on stellar oscillations, was supervised by John Telting.

During 1999 three students, Daniel Bramich, Edward Hawkins and Samantha Rix, worked at ING during the summer months, being engaged in various projects such as a study of the scientific productivity of the telescopes and quality control of Wide Field Survey data.

Engineering activities focussed strongly on the completion of the infra-red camera, INGRID, for which nearly all engineering work was carried out in-house at ING on La Palma. Work on INGRID included the design and manufacture of components, opto-mechanical assembly and alignment, cryogenics, motor controls, detector testing and integration, and instrument control software and data reduction tools.

Other key projects during this year were the development and first implementation at ING of SDSU-2 controllers for optical CCDs; the initiation of the design and construction of a thin fibre unit for the AUTOFIB robotic fibre positioner; a vast rebuild of the computing infrastructure involving a full re-cabling of the data network in all the buildings on site and the completion of the computer-based documentation system for mechanical drawings. Infrastructure improvements at ING's sea level facility, in particular the construction of a small detector laboratory and a (fibre) optics laboratory have been crucial in support of these development activities.

Chapter 6

Public Relations

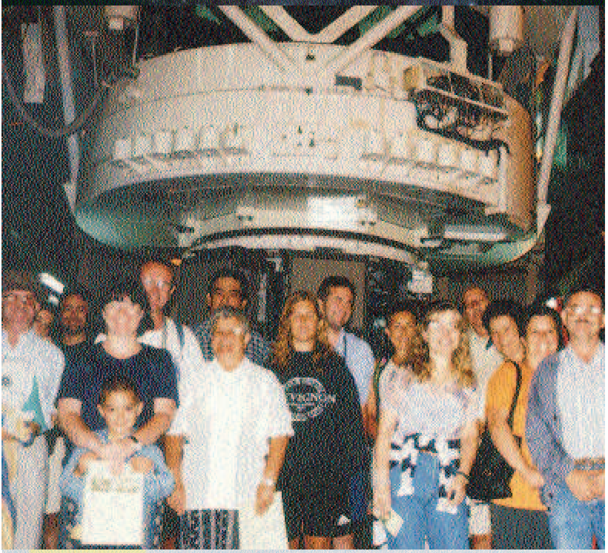
Various actions were taken as part of ING's outreach to the astronomical community and the general public. The first issue of the ING Newsletter was published, with the aim of improving our communication with the astronomical community. This Newsletter will appear twice per year, and will be made available primarily through the World Wide Web, and in hard copy to libraries in the United Kingdom, the Netherlands and Spain.

Furthermore, the [INGNEWS] e-mail exploder was started, which reaches hundreds of active ING users directly. The [INGNEWS] exploder has already proven invaluable for sending abroad urgent news from ING such as instrumentation announcements and notes on applying for observing time.

As during previous years, the public Open Days were organised on three days during the summer. A total of 3600 visitors were shown around during 111 guided tours to the ING telescopes. Also throughout the year many groups visited the WHT (see next page for detailed statistics).

The 4th International Site Managers Meeting was this year hosted by the ING on La Palma. Issues of interest common to observatories were discussed, ranging from transport arrangements at observatories to operational models and plant maintenance as well as many other topics. Attendance included representatives from observatories around the world.

ING collaborated with IAC in the preparation of the exhibit "20 Años de Astronomía en La Palma" (20 years of astronomy on La Palma) in order to commemorate the international agreements signed in 1979 which brought the Roque de Los Muchachos Observatory into existence.



THE ISAAC NEWTON GROUP OF TELESCOPES

NEWSLETTER

These images represent one of the fields observed in the Faint Star Variability Survey which is one of the Wide Field Survey programmes being carried out at the INT (see Nic Walton's article on page 3).

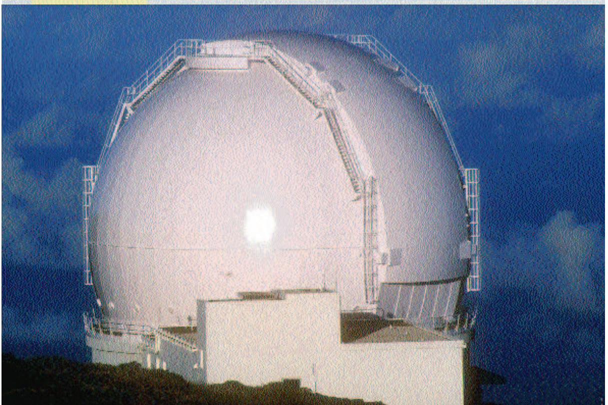
Message from the Director

Dear Reader,

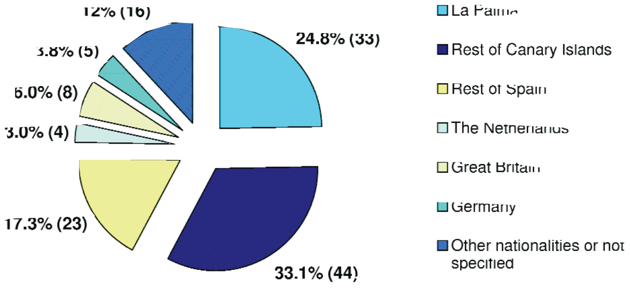
First there was the Gemini newsletter of the Royal Greenwich Observatory, then there was Spectrum, produced by the Royal Observatories.... But now there is ING's own magazine: the ING Newsletter !

The ING Newsletter is the third incarnation of the information bulletin for the Isaac Newton Group of Telescopes on La Palma. The changes in name over the years reflect the managerial changes that have passed the scene. The name of this newsletter may not be as poetic as the previous two incarnations, but at least it describes its purpose well.

The main purpose of the ING Newsletter is to keep users of the telescopes informed on the actual state of the facilities. It will report on telescope and instrument enhancements, on progress in improving the infrastructure, and to keep the community up to date with new instrument developments and policy issues. The ING Newsletter will also be a source of factual information that astronomers

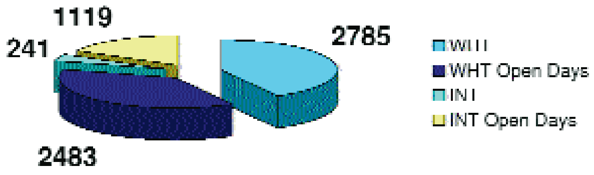


Origin of visits

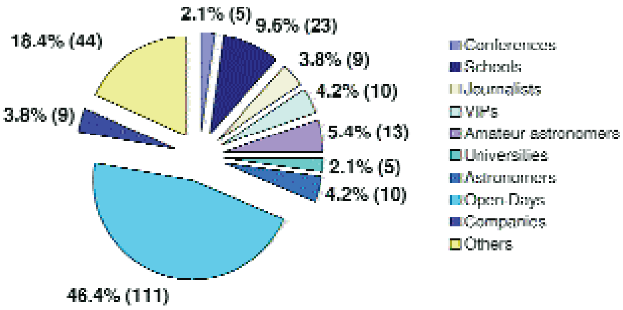


These plots show some statistics of the visits to the ING telescopes in 1999. Between parenthesis the total number of visits.

Visitors per telescope



Visits



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 three telescopes have complementary roles. The WHT, with its 4.2 m 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 2.54 m diameter primary mirror and is mostly used for wide-field imaging and spectroscopy. The JKT has a primary mirror of 1.0 m diameter. It is mainly used for observing relatively bright objects. Both the INT and the JKT were first operational in May 1984.

The Isaac Newton Group operates the telescopes on behalf of the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of the Netherlands.

The following table shows each telescope's location:

	Latitude	Longitude	Ground Floor Height
WHT	28° 45′ 38.3″ N	17° 52′ 53.9″ W	2,332 m
INT	28° 45′ 43.4″ N	17° 52′ 39.5″ W	2,336 m
JKT	28° 45′ 40.1″ N	17° 52′ 41.2″ W	2,364 m

The ING is located at the Observatorio del Roque de Los Muchachos (ORM), on the island of La Palma. The ORM, which is the principal European northern hemisphere observatory, is operated on behalf of Spain by the Instituto de Astrofísica de Canarias (IAC), as is the Teide Observatory on Tenerife. 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 Carlsberg Meridian Telescope, the 3.6m Italian Galileo National Telescope, the 2.5m Nordic Optical Telescope, the 60cm telescope of the Swedish Royal Academy of Sciences, the 50cm Swedish Solar Telescope, the 45cm Dutch Open Solar Telescope, and the German High Energy Gamma-Ray Array.

The observatory occupies an area of 1.89 square kilometres approximately 2,350m 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 Canary Archipiélago and the Canary Islands are an autonomous region of Spain.

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. The site is clear of cloud for 90 per cent of the time in the summer months.

The construction, operation, and development of the ING telescopes is the result of a collaboration between the United Kingdom and the Netherlands. The site is provided by Spain, and in return Spanish astronomers receive 20 per cent of the observing time on the telescopes. A further 75 per cent is shared by the United Kingdom and the Netherlands. On the JKT the international collaboration embraces astronomers from Ireland and the University of Porto (Portugal). The remaining 5 per cent is reserved for large scientific projects to promote international collaboration between institutions of the CCI member countries.

Many of the state-of-art telescope and instrument components are custom-built. New instruments are designed and built by technology groups 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 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 PPARC-NWO ING BOARD

The PPARC and the NWO have entered into collaborative agreements for the operation of and the sharing of observing time on the ING telescopes. The ING Board has been set up to oversee the operation of this agreement, to foster and develop collaboration between astronomers of the United Kingdom and the Netherlands 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.

TELESCOPE TIME AND DATA OWNERSHIP

Spain has at its disposal 20 per cent of the observing time on each of the three telescopes. It is the responsibility of the IAC to make this time available to Spanish institutions and others, via the Comité para la Asignación de Tiempos (CAT).

A further 5 per cent of the observing time is for international collaborative programmes 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.

The remaining 75 per cent of the time is distributed as follows. The PPARC and NWO share the time on all three telescopes with 80 per cent being allocated to PPARC and 20 per cent to NWO. The PPARC-NWO ING BOARD has delegated the task of time allocation to astronomers to the PPARC Panel for the Allocation of Telescope Time (PATT) and the NFRA Programme Committee (PC), which have set up procedures for achieving the 80 : 20 ratio whilst respecting the separate priorities of the United Kingdom and Dutch communities. The PPARC has made 27 nights per year of its share on the JKT available to the National Board of Science and Technology of Ireland (NBST) and the Dublin Institute for Advanced Studies (DIAS). The Irish Advisory Committee for La Palma set up by the two Irish Institutions has decided that JKT proposals by Irish astronomers should also be submitted to PATT. Irish astronomers are not however discouraged from applying for use of the other telescopes of the ING. In a similar way, the University of Porto (Portugal) has 28 nights of observing time on the JKT and access to the INT and WHT under open competition with other astronomers.

PATT includes representatives from the Republic of Ireland and Portugal. 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). The corresponding closing dates are the end of September and March respectively. Decisions on time allocations are made on the basis of scientific merit and technical feasibility of the proposed observations.

The PPARC-NWO ING Board and the CCI have decided that 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. 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 INT and JKT are equipped with a restricted set of instruments that match the capabilities of the telescopes whilst satisfying the requirements of a large percentage of users. The number of instrument changes on these telescopes is kept to a minimum in order to reduce costs and increase reliability. The design of the WHT allows much greater flexibility, since it is straightforward to switch between the Cassegrain and the two Nasmyth focal stations, and a much greater variety of instruments may be left on the telescope. A broad functional division between the WHT, INT and JKT is as follows:

WHT	Spectroscopy and spectropolarimetry over a wide range of resolving powers
	Multi-object spectroscopy
	Areal spectroscopy
	CCD imaging
	Infrared imaging
	High-resolution imaging and other projects in a laboratory environment
	Fabry-Perot imaging spectroscopy
INT	Intermediate- and low-dispersion spectroscopy
	CCD imaging
JKT	CCD imaging

The following table summarises the common-user instruments which were available during 1999.

Focus	Instrument	Detector
William Herschel Telescope		
Cassegrain	ISIS double spectrograph	Tektronix and EEV CCDs
	TAURUS Fabry-Perot imager	Tektronix and EEV CCDs
	Low Dispersion Survey Spectrograph (LDSS-2)	SITe CCD
	CCD imager (Acquisition and Guidance Unit Auxiliary Port)	Tektronix CCD
	TAURUS CCD imager (f/2 or f/4)	Tektronix and EEV CCDs
Nasmyth	Ground Based High Resolution Imaging Laboratory (GHRIL)	Tektronix and EEV CCDs
	Utrecht Echelle Spectrograph (UES)	SITe CCD
	INTEGRAL	Tektronix CCD (WYFFOS at GHRIL)
Prime	Prime Focus Camera	Tektronix and EEV CCDs
	Autofib Fibre Positioner (AUTOFIB-2)	Tektronix CCD (WYFFOS at GHRIL)
Isaac Newton Telescope		
Cassegrain	Intermediate Dispersion Spectrograph (IDS)	Tektronix and EEV CCDs
	Faint Object Spectrograph (FOS-1)	Loral CCD
Prime	Wide Field Camera	4 × EEV CCDs
Jacobus Kapteyn Telescope		
Cassegrain	CCD camera	Tektronix and SITe CCDs

Appendix C

Staff Organisation

During 1999 the staffing position at ING continued to be relatively stable, as reflected in the previous Annual Report. In fact the period saw an increase in UK staff on-island as tasks previously carried out at the RGO were transferred to La Palma. Some of these tasks were temporary, such as staff effort for specific enhancements projects, whilst others, such as the scheduling of telescope time, will be permanent additions. The 38.9 direct staff year funded for the financial year 1999/00 can therefore be considered as a temporary situation which will not be maintained into future years.

The level of UK based staff effort remained level at 7.4 direct staff during the year, although again, this is scheduled to decrease in the next financial year. The total approved staff effort for the Netherlands remained at 6.9 on-island and 1.0 in Cambridge.

For 1999, the telescope managers were: for the WHT, Dr C R Benn; for the INT, Dr N A Walton; for the JKT, Dr J H Telting.

The list of staff in post on La Palma during 1999 is as set out below.

MANAGEMENT

R G M Rutten, *Director*
R L Miles, *Personal Secretary*

ADMINISTRATION

M Acosta
E C Barreto
L I Edwins, *Head of Administration*
A Felipe (to 16/6/99)
I García
N L González (from 2/7/99)
S S Hunter
M Lorenzo
J Martínez
H J Watt

ASTRONOMY

M Azzaro
C R Benn
M Broxterman
R Corradi (from 1/11/99)
J N González
R Greimel (from 8/7/99)
D J Lennon, *Head of Astronomy*
C Martín
J Méndez
N O'Mahony (to 24/4/99)
C Packham
D L Pollacco (to 31/12/99)
J C Rey
V Reyes (from 24/4/99)
S Sánchez (from 16/5/99)
W J I Skillen (from 1/8/99)
S J Smartt (to 16/6/99)
P Sorensen
J H Telting
N A Walton

Support astronomers from the University of Porto:
Antonio Pedrosa (to 2/2/99)
Daniel Folha (to 30/11/99)

Students from University of Hertfordshire:
J Abbott (to 9/99)
A Humphrey (to 9/99)
D Batcheldor (from 9/99)
R Curran (from 9/99)

ENGINEERING

R G Talbot, *Head of Engineering*

Engineering Groups:

Computing Facilities

D-C Abrams
L Hernández
N R Johnson
G F Mitchell
P G Symonds
P v d Velde

Control Software

D Armstrong
R Bassom (from 13/3/99)
M Bec
C Bevil (from 1/3/99)
R Clark (from 27/4/99)
S M Crosby
M P Fisher (to 31/3/99)
F Gribbin
S G Rees

Electronics

C Benneker
T Gregory
A Guillén
C W M Jackman
K Kolle
S Magee (from 21/3/99)
R Martínez
E J Mills
P C Moore
R J Pit
A Ridings
S J Tulloch (from 1/5/99)
G Woodhouse

Mechanics

F Concepción
K M Dee
K Froggatt
P Jolley
P S Morrall
S Rodríguez
J C Pérez
M v d Hoeven
B v Venrooy
E Villani (to 15/2/99)

Site Services

C Alvarez
P Alvarez (from 15/2/99)
A K Chopping
J R Concepción
J M Díaz
D Gray
M V Hernández
C Ramón
M Simpson

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 semesters 99A and 99B. The principal applicant, his or her institute, 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.

ITP Programmes on the ING Telescopes

Browne (NRAL), *The CERES project: cosmology, luminosity functions and AGN unification.* ITP1/99
Ramella (Trieste), *Gravitational lensing: a cosmological and astrophysical tool.* ITP5/99

William Herschel Telescope

UK PATT

Almaini (Edinburgh), *Spectropolarimetry of narrow emission line galaxies - obscured AGN?* W/99A/17
Asif (ING), *Shocks and streaming motions in circumnuclear regions of barred Seyfert galaxies.* W/99A/77
Bailey (AAO), *Spectro-astrometric study of the narrow line region in Seyfert galaxies.* W/99A/2
Bailey (AAO), *Spectro-astrometry of Pre-Main-Sequence stars.* W/99B/4
Barbieri (Padova), *Na emission from the Moon's atmosphere during the Leonids meteor shower.* W/99B/78
Barnes (St Andrews), *Differential rotation patterns on α Persei dwarfs.* W/99B/15
Barstow (Leicester), *Metal abundances and temperatures scale of hot H-rich white dwarfs.* W/99A/23+99B/21
Bland-Hawthorn (AAO), *An H-alpha investigation of nearby spiral galaxies.* W/99A/28
Bowen (ROE), *The origin of extended gaseous halos around galaxies.* W/99A/47
Bowen (ROE), *Spectroscopy identification of galaxies responsible of high-ionization QSO absorption lines.* W/99B/19
Browne (NRAL), *Search for 6" to 15" separation gravitational multiple imaging in JVAS/CLASS.* W/99B/48
Cameron (St Andrews), *Are giant exoplanets cloudy?* W/99A/3
Carter (J Moores), *Kinematics of the Halo of M31.* W/99B/34
Charles (Oxford), *An optical/UV/X-ray study of luminous LMXB in a globular cluster.* W/99B/56
Crawford (Cambridge), *The composition of massive star formation in cooling flow galaxies.* W/99B/8
Davies (Durham), *Mapping galaxies along the Hubble sequence: the bulges of spiral and lenticular galaxies.* W/99A/54
Davies (Durham), *SAURON observations of galaxies along the Hubble sequence: Bulges of spirals and lenticulars.* W/99B/66
Dhillon (Sheffield), *The mass ratio of AC Cnc.* W/99B/51
Ellis (Cambridge), *A strategic optical-infrared weak lensing survey of high redshift clusters.* W/99A/56
Fabian (Cambridge), *Long term x-ray variability in a flux limited sample of QSOs.* W/99A/22
Ferguson (Cambridge), *Gas-phase chemical abundances in the extreme outer regions of disk galaxies.* W/99B/36

Fitzsimmons (Belfast), *The Exospheres and lonospheres of Io and Europa.* W/99B/60

Hynes (Brighton), *Pinning down spectral variability in V404 Cyg: advective flow or accretion disc?* W/99A/61

Jeffries (Keele), *Calibrating the metallicity dependence of the H-alpha emission clock.* W/99A/68

Jeffries (Keele), *Plumbing the depths of the substellar mass function.* W/99B/20

Jeffries (Keele), *Does Li I 6708Å line yield true photospheric lithium abundances in the Pleiades?* W/99B/29

Knapen (Hertsfordshire), *H-alpha survey of nuclear star-forming rings in spirals.* W/99B/50

Kodama (Cambridge), *The galaxy population of the 3C336 cluster.* W/99A/46

Laine (Herfordshire), *Stellar and gaseous kinematics in the bars of NGC 936 and NGC 7479.* W/99B/68

Liu (UCL), *High resolution spectroscopy of low-mettallicity blue compact dwarf galaxies and the primordial He abundances *** Backup.* W/99B/41

Lucey (Durham), *The fundamental properties of cluster early-type galaxies.* W/99A/63

Marsh (Southampton), *Stochastic variability in GP Com.* W/99A/48

Mathieu (Nottingham), *Kinematics of planetary nebulae in SBO galaxies: dark Halos and Bars.* W/99B/38

McHardy (Southampton), *Deep R-band imaging of a Very deep XMM survey field.* W/99B/73

McMahon (Cambridge), *The evolution of the neutral gas content of the high redshift universe.* W/98B/76

Merrifield (Southampton), *Dark halos and the kinematics of planetary nebulae in S0 galaxies.* W/99A/45

Merrifield (Nottingham), *What heats disk galaxies? *** Backup.* W/99B/58

O'Brien (Leicester), A long-term monitoring of Seyfert 1 galaxy broad emission-line profiles *** Long term. W/97A/35

Oudmaijer (London), *Are Hergib Ae/Be stars disk accretors?* W/99B/26

Péquignot (Paris), *He II Raman lines in planetary nebulae – unique probes of neutral atomic hydrogen.* W/99A/73

Pettini (RGO), *The large scale structure of galaxies at redshift z≃3.* W/98B/54

Pinfield (Belfast), *The are of Praesepe and the intial-final mass relation for white dwarfs.* W/99B/31

Rawlings (Oxford), *The cosmic evolution of radiosources using the TEXOX 1000-radiosource redshift survey *** Long-term.* W/99B/65

Refregier (Cambridge), *The detection and verification of cosmic shear arising from large scale structure.* W/99A/34

Robinson (Hertfordshire), *Scattering geometries in radio-loud quasars *** Backup.* W/99B/13

Shearer (Galway), *Simultaneous radio and high speed optical photometry of Geminga and Crab pulsars.* W/99B/25

Skidmore (Wyoming), *Rapid spectroscopy of the mysterious pulsations in the dwarf nova WZ Sge *** Backup.* W/99B/5

Sharples (Durham), *Dynamics of the outer halo of M87.* W/99A/24

Smartt (ING), *Wolf-Rayet content of the starburts galaxy IC10: an anomaly for stellar and galactic evolution?* W/99B/79

Smartt (ING), *A survey of massive, luminous blue supergiants in M31.* W/99B/80

Smith (London), *The dynamical mass of super star cluster F in M82: A proto-globular cluster?* W/99A/57

Smith (Durham), *Investigating the role of compact groups in early-type galaxies evolution.* W/99B/64

Steeghs (St Andrews), *Spiral density waves in quiescent disc.* W/99B/55

Storey (London), *Extending the diagnosis power of planetary nebulae through ultra-deep UV spectra of NGC 7027.* W/99A/66

Tanvir (Cambridge), *The hidden structure of the Virgo cluster – dynamics of the intracluster stars.* W/99A/78

Tanvir (Cambridge), *Rapid imaging of GRB error boxes and spectoscopy of GRB-related optical/IR transients *** Override.* W/99B/3

Terlevich (Durham), *The triggering mechanism for the Butcher Oemler Effect.* W/99A/38

Walton (ING), *Lamda-Omega: The intermediate redshift type Ia SN connection.* W/99A/58

Ward (Leicester), *Completing the ROSAT soft x-ray sample of AGN.* W/99A/25

Wood (Keele), *Surface compositional anomalies in Close Binaries *** Backup.* W/99B/62

NL NFRA PC

Best (Leiden), *Evolution of z~1 6C galaxies: discerning the role of the radio source.* W/99A/N10

de Zeeuw (Leiden), *SAURON observations of galaxies along the Hubble sequence: giant elliptical and lenticulars.* W/99A/N8+99B/N4

Doyle (Armagh), *Determination of the atmospheric structure of dwarf M stars using multiline fitting.* W/99A/9

Ehrenfreund (Leiden), *Diffuse interstellar bands and large molecules in single clouds and reddened targets.* W/99A/N5

Ehrenfreund (Leiden), *Environment of diffuse interstellar bands in Perseus OB2 and Cepheus.* W/99B/N7

Gerssen (Groningen), *Patterns speeds of Bars.* W/99B/N8

Groot (Amsterdam), *Spectroscopy of variable sources detected in the INT/WFC faint sky variable survey.* W/99B/N12

Higdon (Groningen), *A Taurus study of starburst nuclear rings.* W/99A/N4

Higdon (Groningen), *Metal abundances in extragalactic Tails and Bridges.* W/99B/N9

Kuijken (Groningen), *A strategic optical-infrared weak lensing survey of high redshift clusters.* W/99A/N14

Luu (Leiden), *Spectroscopy of outer Jovian satellites.* W/99B/N2
Luu (Leiden), *Rotational Kuiper Belt Objects.* W/99B/N3
Miley (Leiden), *A search for forming clusters at* $z>2.5$*.* W/99A/N9
Neeser (Groningen), *Damped Lyman-α survey of a* $z>2$ *, homogeneous, radio-selected quasar sample.* W/99A/N7
Swaters (Groningen), *Stellar velocity dispersion measurements of late dwarf galaxies.* W/99B/N6
v d Berg (Utrecht), *Spectroscopy of peculiar X-ray stars in the open clusters NGC752 and NGC6490.* W/99B/N5
Vreeswijk (Amsterdam), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients.* W/99B/1
van Woerden (Groningen), *Distance and metallicity of HVC complexes M and C.* W/99A/N12

SP CAT

Acosta-Pulido (VILSPA), *Kinematics of the highly ionised gas in the circumnuclear region of the Seyfert NGC 4388 galaxy.* W/99A/C31
Aretxaga (MPIA), *Compact SN remnant spectro-photometric follow-up.* W/99A/C12
Aretxaga (INAOE), *Spectro-photometric tracking of compact remnants of supernovae.* W/99B/C34
Benítez (Berkeley), *A new method for cluster mass reconstruction.* W/99B/C36
Campos (IMAFF), *13h 12m +42 deg: a cluster of galaxies at* $z=2.56$*?* W/99A/C17
Casares (IAC), *The magnetic field in the accretion disc of Sco X-1.* W/99A/C42
Centurión (IAC/OAT), *Deuterium abundance in high redshift QSO absorption systems.* W/99B/C22
Díaz (UAM), *Determination of the electronic temperature in H-II high-metallicity regions.* W/99B/C25
Fernández-S (NS Wales), *The definitive primordial D/H measurement: Phase I: Object selection.* W/99B/C23
Ferreras (IFCA), *Spectrophotometric analysis of blue spheroids in medium redshift clusters.* W/99A/C15
Gallego (Madrid), *Measuring the H-alpha star formation rate density and the SFR function of the universe at* $z\sim0.2$ *and* $z\sim0.4$*.* W/99A/C23
González (IAA), *The starburst-AGN connection in Seyfert 2 galaxies.* W/99A/C8
Gorgas (UCM), *Stellar populations in elliptical galaxies.* W/99A/C32
Israelian (IAC), *Searching for the evidence of supernova events in the low mass X-ray binary systems Her X-1 and Cyg X-2.* W/99B/C7
Mas (LAEFF-INTA), *WR stars acting as starburst tracers in Seyfert 2 galaxies.* W/99A/C35
Mediavilla (IAC), *2D Spectroscopy in gravitational lens systems.* W/99B/C26
Muñoz (IAC), *Spectroscopic study into the birth of dwarf galaxies around mergers.* W/99B/C9
Pérez (IAA), *Stellar dinamic and circumnuclear structure in isolated active galaxies.* W/99B/C21
Pérez (IAC), *Kinematical study of the merger NGC1144.* W/99B/C24
Rebolo (IAC), *Oxygen abundances in extremely metal-poor stars and the first nucleosynthesis events in the Galaxy.* W/99B/C8
Rozas (IAC), *Physical diagnosis of complete stellar populations in spiral galaxy HII regions.* W/99A/C41
Serra (IAC), *Limits to Omega_o and Lambda_o using stadistic analysis of radio-sources.* W/99B/C20
Solano (LAEFF-INTA), *Multiobject spectroscopy of the globular cluster M15.* W/99B/C12
Vazdekis (Cambridge), *The origin of the color-magnitude diagram.* W/99A/C29

Isaac Newton Telescope

UK PATT

Benn (ING), *Extinction of background radio galaxies by foreground spirals.* I/99A/17
Bode (LJMU), *Large scale nebulae associated with previous evolutionay phases of interacting binaries.* I/99B/11
Dhillon (Sheffield), *The masses of cataclysmic variables *** Long-term.* I/99B/20
Fitzsimmons (QUB), *The composition of Kuiper Belt comets.* I/99B/19
Hambly (ROE), *The faintest white dwarfs, optical identification of MACHOS.* I/99A/19
Hewett (Cambridge), *Probing the dark halo of M31 with pixel microlensing.* I/99B/30
Horne (St Andrews), *A hunt for hot jupiters (and Neptunes?) in open clusters.* I/99A/33
Jeffery (Armagh), *The dimensions of binary sdB stars.* I/99A/38
Jeffries (Keele), *Plumbing the depths of substellar mass function.* I/99B/21
Jones (Birmingham), *Galaxy evolution in X-ray selected clusters.* I/99A/10
Keenan (QUB), *The origin of runaway B-type stars in the Galactic halo.* I/99B/3
Keenan (QUB), *Determination of empirical evolutionary tracks for OB-type stars.* I/99A/2
Maxted (Southampton), *White dwarf binaries *** Long-term.* I/99A/39

McLure (Edinburgh), *Hβ emission-line determination of the black-hole masses in radio-quiet and radio-loud AGN *** Long-term.* I/99B/7

McHardy (Southampton), *Deep U and B-band imaging of a very deep XMM survey field.* I/99B/28

M-Rueda (Southampton), *Spectroscopy of dwarf novae in outburst *** Long-term.* I/99B/18

Naylor (Keele), *Do strong magnetic fields exist on secondary star surfaces in cataclysmic variables?* I/99A/35

Naylor (Keele), *A new method of determining component masses in CVs.* I/99B/22

Olling (USA), *Determining the stellar mass distribution of galaxies with extended HI rotation curves.* I/99A/22

Pollacco (ING), *Sakurai's Object: A real time evolution in a stellar thermal pulse *** Long-term.* I/99A/13

Ray (Dublin), *Proper motions of large scale Herbig-Haro flows from young stars.* I/99B/32

Sutherland (Oxford), *Mapping microlensing in M31.* I/99B/33

Tanvir (Cambridge), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients *** Override.* I/99A/16+99B/1

Tanvir (Cambridge), *Survey of halo and outer disc of M31.* I/99B/29

Wilkinson (NRAL), *Constraints on the frequency of cluster lensing: spectrocopy of lens search targets.* I/99B/13

Wood (Keele), *Is magnetic activity suppresed in rapidly rotating M-dwarfs in close binaries?* I/99B/12

NL NFRA PC

Foing (ESA), *Surface structures and flares on active stars observed by AXAF.* I/99A+B/N2

Le Poole (Leiden), *Assessing the quality of the GSC-II photographic photometry at the faint magnitude limit.* I/99B/N3

Sackett (Kapteyn), *The MEGA survey: mapping microlensing in M31.* I/99B/N4

Stempels (Uppsala), *High resolution spectroscopy of T Tauri stars.* I/99A/N3

Stempels (Uppsala), *Spectroscopy of Hydrogen Balmer lines.* I/99B/N5

Tschager (Leiden), *The optical hosts of young radio sources - redshifts (2).* I/99A+B/N1

van Dokkum (Leiden), *A large photometric survey of the Coma cluster.* I/99A/N4

UK/NL WFS Programmes

Dalton (Oxford), *A Deep UBVRI Imaging Survey with the WFC.* WFS16

McMahon (Cambridge), *The INT Wide Angle Survey.* WFS09

Paradijs (Amsterdam), *Faint Sky Variability Survey .* WFS10

SP CAT

Aparicio (IAC), *Old Halos in Dwarf Galaxies.* I/99B/C6

Beckman (IAC), *Stellar populations along the bars of barred galaxies.* I/99A/C16

Corral (IAC), *OB stars physical parameters and the wind-luminosity.* I/99A/C8

Díaz (Madrid), *Abundances in HII galaxies.* I/99A/C18

Esteban (IAC), *Interacting and merging phenomena in H-II galaxies.* I/99B/C4

F-Figueroa (UCM), *Simultaneous behaviour of several activity indicators in active binary stars.* I/99B/C2

Gallego (UCM), *Evolution of the Star Formation Rate density of the Universe at intermediate redshift.* I/99B/C9

García (IAC), *Optical counterparts and lithium abundances of ROSAT-discovered candidates in α Per, Orion and Taurus.* I/99B/C3

García Dabó (UCM), *Physical properties of low-luminosity galaxies with stellar formation.* I/99A/C20

Gómez (IAC), *Spectra of type IIn-Seyfert-1 supernovae in the nebular phase: interaction with the circumstellar medium.* W/99B/C14

Gómez-Flechoso (Switzerland), *Interplay between environment and elliptical galaxies in dense environments.* I/99A/C2

González (IAC), *Doppler tomography of the cataclysmic variable WX Arietis.* I/99B/C8

González (IAC), *Orbital resolution spectroscopy of SW Sex candidate systems.* I/99A/C17

González Serrano (Santander), *Redshifts of bright galaxies from the Westerbork radio survey.* I/99A/C9

Hammersley (IAC), *A deep multi-wavelength survey of the Galactic Plane.* I/99A/C14

Martínez-Delgado (IAC), *Testing the dark matter content in Ursa Minor dwarf galaxy.* I/99A/C19

Ribas (Barcelona), *Measurement of the distance to M31 from eclipsing binaries.* I/99B/C1

R-Lapuente (Barcelona), *High redshift supernovae: towards the determination of Omega matter and Omega Lambda and the high-z supernova rate.* I/99A/C4+99B/C5

Serra (IAC), *Limits to Omega_o and Lambda_o using statistic analysis of radio-sources.* W/99B/C20

Vílchez (IAC), *Study of the stellar formation rate in a sample of Virgo dwarf galaxies.* I/99A/C1

Jacobus Kapteyn Telescope

UK PATT

Bell (Durham), *Probing massive star formation in low surface brightness galaxies.* J/99A/3
C-Brown (QUB), *Search for evidence of outgassing in Kuiper Belt objects *** Long-term.* J/99B/5
Dhillon (Sheffield), *The masses of cataclysmic variables *** Long-term.* J/99B/13
Fitzsimmons (QUB), *Distant sublimation in short-period comets.* J/99A/7
Fitzsimmons (QUB), *The composition and origin of Near-Earth Asteroids.* J/99B/17
Hughes (Cambridge), *The spatial structure and distance of the Virgo cluster.* J/99A/6
Hynes (Brighton), *Pinning down spectral variability in V404 Cyg: Advective flow or accretion disc?* J/99A/12
James (St Andrews), *Black holes and nuclear activity in interacting galaxies.* J/99A/1
James (St Andrews), *Rotation period determinations in the intermediate-aged open cluster NGC 1039 (M34).* J/99B/6
Jeffery (Armagh), *Photometry of stellar remnants.* J/99A/18
Johnson (Cambridge), *Narrow band imaging of nearby galaxies. II.* J/99A/4
Knapen (Hertfordshire), *Arm vs. interarm star formation processes in spiral galaxies *** Long-term.* J/99A/9+99B/14
Marsh (Southampton), *Stochastic variability of GP Com.* J/99A/13
Roche (Sussex), *Optical identification of x-ray transients *** Long-term and Override.* J/99A/8
Rolfe (OU), *Red and blue photometry of PX And.* J/99B/15
Rolleston (QUB), *The determination of faint Strömgren standard stars for CCD photometric studies *** Long-term.* J/98B/17
Seigar (Ghent), *Optical properties of the disk of spiral galaxies.* J/99B/11
Smith (Cork), *A search for optical variability in radio intermediate quasars.* J/99A/14
Smith (Cork), *Characterising the properties of the newly discovered Intermediate BL Lac objects.* J/99B/12
Steele (LJMU), *Constraining low mass star models using the Praesepe open cluster.* J/99A/17
Steele (LJMU), *Low mass star evolution from ~100 to ~1000 Myr.* J/99B/7
Tanvir (Cambridge), *Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients *** Override.* J/99A/5+99B/1
Walton (ING), *Photometric follow-up of intermediate redshift type Ia SN *** Long term.* J/99A/11
Warren (IC), *Remote halo blue horizontal branch stars and the mass of the Milky Way *** Long-term.* J/99B/3
Williams (QMW), *Astrometry and photometry of the satellites of Saturn.* J/99B/2

NL NFRA PC

Barthel (Groningen), *Completion of multi-color search for very high redshift QSO candidates.* J/99B/N3
Groot (Amsterdam), *A comparative study of disk and halo cataclysmic variables.* J/99A/N3
Le Poole (Leiden), *Photometric Calibrations for the second generation Guide Star Catalog (GSC-II).* J/99A/N1+99B/N2
Tschager (Leiden), *The optical hosts of young radio sources - optical identification (3).* J/99A/N2+99B/N1

SP CAT

de Diego (IAUNAM), *Spectral characterisation of microvariability in quasars.* J/99A/C5+99B/C2
Delfosse (IAC), *Accurate optical and infrared photometry of field very low mass stars and brown dwarfs.* J/99B/C15
Iglesias (IAC), A *study of H-alpha emission in compact group elliptical and lenticular galaxies.* J/99A/C1
Kemp (IAC), *CCD surface photometry of faint features of galaxies in the Virgo cluster.* J/99A/C4
Kemp (IAC), *The structure and colours of the envelopes of cD galaxies.* J/99B/C3
García (IAC), *CCD multi-colour imaging of galaxy cluster candidates.* J/99A/C3
Oscoz (IAC), *Fast fluctuations in the gravitational lens Q0957+561.* J/99B/C1
Zamorano (UCM), *Color gradient in starburst galaxies.* J/99A/C2

Appendix E

ING Bibliography

Below is the list of research papers published in 1999 that resulted from observations carried out at the telescopes of the Isaac Newton Group. Only papers appearing in refereed journals have been included, although many other publications have appeared elsewhere, notably in workshop and conference proceedings.

WILLIAM HERSCHEL TELESCOPE

1. C Abia, Y Pavlenko, P de Laverny, “The formation of lithium lines in the atmospheres of super Li-rich AGB stars”, *Astron Astrophys*, **351**, 273.

2. V L Afanasiev, O K Sil'chenko, “Global structure and kinematics of the spiral galaxy NGC 2841”, *Astron J,* **117**, 1725.

3. A Alonso-Herrer, M J Ward, A Aragón-Salamanca, J Zamorano, “Multifrequency observations of the interacting galaxy NGC 4922 (UCM 1259+234)”, *MNRAS,* **302**, 561.

4. P Andreani, A Franceschini, G Granato, “Dust emission from quasars and quasar host galaxies”, *MNRAS*, **306**, 161.

5. S Arribas, E Mediavilla, C Del Burgo, B García-Lorenzo, “Two-dimensional spectroscopy in the circumnuclear region of the Seyfert 1 ring galaxy NGC 985”, *Astrophys J,* **511**, 680.

6. S Arribas, E Mediavilla, B García-Lorenzo, C del Burgo, J J Fuensalida, “Differential atmospheric refraction in integral-field spectroscopy: Effects and correction”, *Astron Astrophys Suppl,* **136**, 189.

7. M Asplund, D L Lambert, T Kipper, D Pollacco, M D Shetrone, “The rapid evolution of the born-again giant Sakurai’s object”, *Astron Astrophys,* **343**, 507.

8. S Balman, H B Ögelman, “The first resolved and detected classical nova shell in X-rays: The shell of nova Persei 1901”, *Astrophys J,* **518**, L111.

9. P N Best, H J A Röttgeri, M D Lehnert, “A 98 per cent spectroscopically complete sample of the most powerful equator radio sources at 408MHz”, *MNRAS*, **310**, 223.

10. A W Blain, A Jameson, I Smail, M S Longair, J P Kneib, R J Ivison, “Dust-obscured star formation and AGN fuelling in hierarchical models of galaxy evolution”, *MNRAS*, **309**, 715.

11. V J S Béjar, M R Zapatero Osorio, R Rebolo, “A search for very low mass stars and brown dwarfs in the young σ Orionis cluster”, *Astrophys J,* **521**, 671.

12. M Bryce, G Mellema, “The kinematics of the planetary nebula BD+30°3639”, *MNRAS,* **309**, 731.

13. A C Cameron, K Horne, A Penny, D James, “Probable detection of starlight reflected from the giant planet orbiting τ Boötis”, *Nature,* **402**, 751.

14. A Campos, A Yahil, R A Windhorst, E A Richards, S Pascarelle, C Impey, C Petry, “A cluster of filament of galaxies at redshift =2.5?”, *Astrophys J,* **511**, L1.

15. F J Castander, D Q Lamb, “A photometric investigation of the GRB 970228 afterglow and the associated nebulosity”, *Astrophys J,* **523**, 593.

16. A J Castro-Tirado, J Gorosabel, “Optical observations of GRB afterglows: GRB 970508 and GRB 980326 revisited”, *Astron Astrophys Suppl,* **138**, 449.

17. M S Catalán, A D Schwope, R C Smith, “Mapping the secondary star in QQ Vulpeculae”, *MNRAS,* **310**, 123.

18. L Colina, S Arribas, “The starburst-AGN connection in the active galaxies: the massive nuclear star-forming disk in NGC 4303”, *Astrophys J,* **514**, 637.

19. L Colina, S Arribas, K D Borne, “INTEGRAL field spectroscopy of markarian 273: Mapping high-velocity gas flow and an off-nucleus seyfert 2 nebula”, *Astrophys J,* **527**, L13.

20. P S Conti, I D Howarth, “1-m spectroscopy of normal OB stars”, *MNRAS,* **302**, 145.

21. C S Crawford, S W Allen, H Ebeling, A C Edge, A C Fabian, “The ROSAT Brightest Cluster Sample - III Optical spectra of the central cluster galaxies”, *MNRAS,* **306**, 857.

22. N Cretton, F C van den Bosch, “Evidence for a massive black hole in the S0 galaxy NGC 4342”, *Astrophys J,* 514, 704.

23. R A C Croft, D H Weinberg, M Pettini, L Hernsquist, N Katz, “The power spectrum of the mass fluctuations measured from the Lyα forest at redshift z=2.5”, *Astrophys J,* **520**, 1.

24. P A Crowther, L J Smith, “NaSt1: a Wolf-Rayet star cloacked by an Car-like nebula ?”, *MNRAS,* **308**, 82.

25. E W Cuether, H Lehmann, J P Emerson, J Staude, “Measurements of magnetic field strength on T Tauri stars”, *Astron Astrophys,* **341**, 768.

26. A Dressler, I Smail, B M Poggianti, H Butcher, W J Couch, R S Ellis, A Oemler Jr, “A spectroscopic catalog of 10 distant clusters of galaxies”, *Astrophys J Suppl,* **122**, 51.

27. M T Eibe, P B Byrne, R D Jeffries, A G Gunn, “Evidence for large-scale, global mass inflow and flaring on the late-type fast rotator BD+224409”, *Astron Astrophys,* **341**, 527.

28. R Edelson, S Vaughan, R Warwick, E Puchnarewicz, I George, “The ROSAT wide field camera extragalactic survey”, *MNRAS,* **307**, 91.

29. T J Galama, R A M J Wijers, P M Vreeswijk, P J Groot, J Van Paradijs, C Kouveliotou, C Robinson, M Bremer, R G Strom, N Tanvir, “Physical parameters of GRB 970508 from its afterglow synchrotron emission”, *Astron Astrophys Suppl,* **138**, 451.

30. J S Gallagher, L J Smith, “Stellar populations and ages of M82 super star clusters”, *MNRAS,* **304**, 540.

31. B García-Lorenzo, E Mediavilla, S Arribas, “Spectroscopic atlas of the central 24"×20" of the seyfert 2 galaxy NGC 1068”, *Astrophys J,* **518**, 190.

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Appendix F

ING Staff Research Publications

The following list includes research papers published by ING staff in refereed and unrefereed publications in 1999. It is organised by subjects and sorted in alphabetical order. ING authors appear in bold and italic.

THE SOLAR SYSTEM

E S Barker, C Allende Prieto, T L Farnham, D B Goldstein, R S Nerem, J V Austin, J Y Shim, A B Storrs, S A Stern, A B Binder, T Bida, T Morgan, S M Larson, A L Sprague, D M Hunten, R E Hill, R W H Kozlowski, B Ludwig, S Rubinson, J Baumgardner, M Mendillo, J Wilson, J Wroten, S Verani, ***C R Benn***, R J García López, E Gates, D L Talent, A Alday, A Pozar, D Witte, B Africano, B Villanneva, R Anderson, P Kervin, G S Rossano, R W Walker, S Hoss, C M Anderson, W Offutt, “Results of observational campaigns carried out during the impact of Lunar Prospector into a permanently shadowed crater near the South Pole of the Moon”, *Bull Am Astron Soc*, **31**, 1583.

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STARS

M Asplund, D L Lambert, T Kipper, ***D Pollacco***, M D Shetrone, “The rapid evolution of the born-again giant Sakurai’s object”, *Astron Astrophys*, **343**, 507.

C Catala, J F Donati, T Bohm, J Landstreet, H F Henrichs, Y Unruh, J Hao, A Collier Cameron, C M Johns-Krull, L Kaper, T Simon, B H Foing, H Cao, P Ehrenfreund, A P Hatzes, L Huang, J A de Jong, E J Kennelly, E T Kulve, C L Mulliss, J E Neff, J M Oliveira, C Schrijvers, H C Stempels, ***J H Telting***, ***N Walton***, D Yang, “Short-term spectroscopic variability in the pre-main sequence Herbig AE star AB Aurigae during the MUSICOS 96 campaign”, *Astron Astrophys*, **345**, 884.

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N C Hambly, ***S J Smartt***, S T Hodgkin, R F Jameson, S N Kemp, W R J Rolleston, I A Steele, “On the parallax of WD 0346++246: a halo white dwarf candidate”, *MNRAS*, **309**, 33.

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THE GALAXY

P L Dufton, ***S J Smartt***, N C Hambly, "A UKST survey of blue objects towards the galactic centre – a search for early-type stars", *Astron Astrophys Suppl*, **139**, 231.

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R Carballo, J I González-Serrano, ***C R Benn***, S F Sánchez, M Vigotti, "The shape of the blue/UV continuum of B3 VLA radio quasars", *MNRAS*, **306**, 137.

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T J Galama, M S Briggs, R A M Wijers, P M Vreeswijk, E Rol, D Band, J van Paradijs, C Kouveliotou, R D Preece, M Bremer, I A Smith, R P J Tilanus, A G de Bruyn, R G Strom, G Pooley, A J Castro-Tirado, N Tanvir, C Robinson, K Hurley, J Heise, ***J Telting***, ***R G M Rutten***, ***C Packham***, R Swaters, J K Davies, A Fassia, S F Green, M J Foster, R Sagar, A K Pandey, Nilakshi, R K S Yadav, E O Ofek, E Leibowitz, P Ibbetson, J Rhoads, E Falco, C Petry, C Impey, T R Geballe, D Bhattacharya, "The effect of magnetic fields on gamma-ray bursts inferred from multi-wavelength observations of the burst of 23 January 1999", *Nature*, **398**, 394.

D Hardin, ***N A Walton***, R S Ellis, M Irwin, R G McMahon, I Hook, P Ruíz-Lapuente, ***J Méndez***, A Visco, P Astier, C Balland, G Blanc, A Blanchard, S Fabbro, F Hammer, A Letessier-Selvon, J M Levy, M Mouchet, R Pain, J Rich, K Shahmaneche, R Taillet, "Supernovae 1999cj and 1999ck in Anonymous Galaxies", *IAU Circ*, **7182**.

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OBSERVATIONAL COSMOLOGY

S Perlmutter, G Aldering, G Goldhaber, R A Knop, P Nugent, P G Castro, S Deustua, S Fabbro, A Goobar, D E Droom, I M Hook, A G Kim, M Y Kim, J C Lee, N J Nunes, R Pain, C R Pennypacker, R Quimby, C Lidman, R S Ellis, M Irwin, R G McMahon, P Ruíz-Lapuente, ***N Walton***, B Schaefer, B J Boyle, A V Filippenko, T Matheson, A S Fruchter, N Panagia, H J M Newberg, W J Couch, “Measurements of Omega and Lambda from 42 High-Redshift Supernovae”, *Astrophys J*, **517**, 565.

SKY SURVEYS

J R Lewis, P S Bunclark, ***N A Walton***, “A Broadband Wide-Field Survey on the Isaac Newton Telescope”, in “Astronomical Data Analysis Software and Systems VIII”, edited by D M Mehringer, R L Plante, and D A Roberts, *Astron Soc Pac Conf Ser*, **172**, 179.

N A Walton, M Irwin, R McMahon, J R Lewis, “The Isaac Newton Group’s Wide Field Survey. Status of the survey and associated data pipeline”, *ING Newsl*, **1**, 3.

SITE CHARACTERIZATION

R W Wilson, ***N O’Mahony***, ***C Packham***, ***M Azzaro***, “The seeing at the William Herschel”, *MNRAS*, **309**, 379.

INSTRUMENTATION

C Packham, “INGRID: a new near-IR camera for the WHT”, *ING Newsl*, **1**, 12.

P Moore, N Rando, “Super Cool Technology”, *ING Newsl*, **1**, 13.

R Rutten, “Instrumentation Plans for the ING Telescopes”, *ING Newsl*, **1**, 19.

Appendix G

Financial Statement

At it's June 1999 meeting the ING Board confirmed the level of funding the agencies were prepared to make available for the financial year 1999/2000. This was £597k and 298,265kptas. At the agreed exchange rate this totalled £1,860.4k. Additional funds were added to the ING's joint budgets, however, through a carry forward from previous financial year of £201k for enhancements and a carry forward on operations of £128.3k. NWO also made a one-off contribution of £48.7k for the purchase of a DVD tower. Thus the total revenue for the year finally totalled £2,238.4k.

One aspect of the budget which is now becoming an increasing problem relates to the approved funding for locally engaged staff. The ING Board approved funding for 23.5 staff years of effort, 6.5 staff years below the current complement. As a consequence, funds had to be moved from the UK staff costs line to provide the required level of funding for joint operations. Details of the allocations and financial outurn are set out below.

UK/NL Joint Operations and Enhancement Programme

Allocations and Expenditure for Financial Year 1999/2000

	Allocation			Expenditure			Exp–Alloc
Budget centre	**K£**	**Kptas**	**Total K£**	**K£**	**Kptas**	**Total K£**	**K£**
Administration group	2.25	2,538	13.0	5.0	2,738	16.6	3.6
Astronomy support	9.0	2,597	20.0	8.7	4,006	25.7	5.7
Common services	—	1,180	5.0	—	10,915	46.2	41.2
Computing facilities	45.5	6,492	73.0	40.4	9,094	78.9	5.9
Conference fees	10.0	—	10.0	12.1	922	16.0	6.0
Electrical works	55.0	5,430	78.0	54.7	7,553	86.7	8.7
Electronics maintenance	22.0	4,250	40.0	16.1	7,099	46.2	6.2
INT clipcentre (power cabinet)	25.0	—	25.0	20.0	11	20.0	-5.0
INT dome shutter repairs	28.0	—	28.0	27.6	241	28.6	0.6
Library extension	17.6	—	17.6	15.5	579	17.9	0.3
Library/Public relations	35.8	992	40.0	23.9	3,849	40.2	0.2
Local staff costs	—	179,428	759.3	12.0	180,838	778.0	18.7
Mechanical engineering	24.0	4,958	45.0	27.6	6,320	54.4	9.4
ORM maintenance	—	5,902	25.0	—	4,081	17.3	-7.7
ORM utilities	—	31,872	135.0	1.5	34,976	149.7	14.7
ORM/SLB datalink	—	4,958	21.0	—	4,278	18.1	-2.9
Residencia costs	—	18,888	80.0	—	18,901	80.1	0.1
Royal Society talk	—	—	—	2.4	—	2.4	2.4
Safety	17.5	1,771	25.0	18.6	2,858	30.7	5.7
Sea-level base	—	33,053	140.0	1.8	34,743	148.9	8.9
Software	13.6	2,691	25.0	16.4	3,614	31.7	6.7
Strategic critical spares	26.0	—	26.0	15.5	1,345	21.2	-4.8
Transport fleet recurrent	—	4,014	17.0	—	4,939	20.9	3.9
Transport fleet maintenance	—	5,902	25.0	1.2	7,787	34.2	9.2
Transport fleet replacement	—	9,916	42.0	—	7,391	31.3	-10.7
UK/NL shared management costs	5.4	4,347	23.8	6.5	7,458	38.1	14.3
Enhancement programme	443.0	—	443.0	377.0	—	377.0	-66.0
Total	**779.65**	**331,179**	**2,181.7**	**704.5**	**366,536**	**2,257.0**	**75.3**

Appendix H

Committee Membership

During 1999 the membership of the ING Board and associated bodies was as follows:

ING BOARD

Professor C S Frenk – **Chairman** (until 30.6.99)	*University of Durham*
Professor P T de Zeeuw – **Chairman**	*University of Leiden*
Dr A Collier-Cameron – **Vice Chairman**	*University of St Andrews*
Dr W H W M Boland	*Nederlandse Organisatie voor Wetenschappelijk Onderzoek*
Professor J Drew (from 1.9.99)	*Imperial College London*
Professor M Merrifield (from 1.4.99)	*University of Nottingham*
Prof M Rowan-Robinson (until 1.3.99)	*Imperial College London*
Dr P G Murdin	*Particle Physics and Astronomy Research Council*
Dr A Mampaso Recio (from 20.4.99)	*Instituto de Astrofísica de Canarias*
Dr C Vincent – **Secretary**	*Particle Physics and Astronomy Research Council*

INSTRUMENTATION WORKING GROUP

Dr R G McMahon – **Chairman**	*University of Cambridge*
Dr G B Dalton	*University of Oxford*
Dr K H Kuijken	*University of Groningen*
Dr S Arribas	*Instituto de Astrofísica de Canarias*
Dr S F Green	*University of Kent*
Dr V S Dhillon	*University of Sheffield*
Dr N A Walton – **Technical Secretary**	*Isaac Newton Group of Telescopes*

ING TIME ALLOCATION GROUPS

UK Panel for the Allocation of Telescope Time (PATT)

Professor F P Keenan – **PATT Chairman**	*Queen's University Belfast*

WHT TAG

Dr R D Jeffries – **Chairman**	*University of Keele*
Dr C Tadhunter (until 31.8.99)	*University of Sheffield*
Dr A Aragón-Salamanca (until 31.8.99)	*University of Cambridge*
Dr C A Haswell	*Open University*
Dr N Jackson	*Jodrell Bank*
Dr N Hambly	*Royal Observatory Edinburgh*
Dr T Marsh (until 31.8.99)	*University of Southampton*
Dr R G Bower	*University of Durham*
Dr J H Knapen	*University of Hertfordshire*
Dr I Skillen – **Technical Secretary**	*Isaac Newton Group of Telescopes*

INT/JKT TAG

Dr A Fitzsimmons – **Chairman**	*Queen's University of Belfast*
Dr S P Driver	*University of St Andrews*
Dr C S Crawford (until 31.8.99)	*University of Cambridge*
Dr S T Hodgkin	*University of Cambridge*
Dr P A James (from 1.9.98)	*Liverpool John Moores University*
Dr M T Lago	*University of Porto*
Dr P Callanan	*University College Cork*
Dr I Skillen – **Technical Secretary**	*Isaac Newton Group of Telescopes*

NL NFRA Programme Committee (PC)

Dr T van der Hulst – **Chairman**	*University of Groningen*

SP Comité de Asignación de Tiempos (CAT)

Dr E Mediavilla – **Chairman**	*Instituto de Astrofísica de Canarias*

Appendix I

Addresses and Contacts

Isaac Newton Group of Telescopes (ING)

Apartado de correos 321
E-38700 Santa Cruz de La Palma
Canary Islands
SPAIN
E-mail: <username>@ing.iac.es
URL: http://www.ing.iac.es/
http://www.ast.cam.ac.uk/ING/ (UK mirror)

Sea-level Base:

Edificio Mayantigo
c/ Alvarez de Abreu, 68, piso 2
E-38700 Santa Cruz de La Palma
Canary Islands
SPAIN
Open from 08:30 to 17:00 Monday to Thursday and from 08:30 to 16:30 on Friday, closed for lunch from 13:00 to 14:00.
Tel: +34 922 425400
Fax: +34 922 425401

Mountain Top:

Reception is on the first floor of the INT building.
Open from 09:00 to 16:00 Monday to Thursday and from 09:00 to 15:30 on Friday, closed for lunch from 12:30 to 13:30.
Tel: +34 922 405655 (Reception)
559 (WHT control room)
640 (INT control room)
585 (JKT control room)
Fax: +34 922 405646 (Reception)

Director:

Dr René G M Rutten
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Fax: +34 922 425408
E-mail: rgmr@ing.iac.es, miles@ing.iac.es (*secretary*)

Particle Physics and Astronomy Research Council (PPARC)

Polaris House
North Star Avenue
Swindon
SN2 1SZ
UNITED KINGDOM
Tel: +44 (0)1793 442000
Fax: +44 (0)1793 442002
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 3440640
Fax: +31 (0)70 3850971
URL: http://www.nwo.nl/

Enquiries about the operation of the Roque de Los Muchachos Observatory can be made to: Instituto de Astrofísica de Canarias (IAC); c/ Vía Láctea s/n; E-38200 La Laguna; Canary Islands; SPAIN; Tel: +34 922 605200; Fax: +34 922 605210; URL: http://www.iac.es/

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 Prof. Dr. F. H. Briggs, at the Kapteyn Astronomical Institute in Groningen (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*, *Comité Científico Internacional* (CCI), at the IAC address given above.

CONTACTS AT ING

	Name	**Telephone (+34 922)**	**E-mail (@ing.iac.es)**
Head of Administration	*Les Edwins*	425418	lie
Head of Astronomy	*Danny Lennon*	425441	djl
Head of Engineering	*Gordon Talbot*	425419	rgt
Site Receptionist	*Mavi Hernández*	405655	mavi
Public Relations	*Javier Méndez*	425464	jma
Telescope Scheduling	*Ian Skillen*	425439	wji
Service Programme	*Ian Skillen*	425439	wji
WHT Manager	*Chris Benn*	425432	crb
INT Manager	*Thomas Augusteijn*	425433	tau
JKT Manager	*Thomas Augusteijn*	425433	tau
Instrumentation Scientist	*Nic Walton*	425440	naw
Instrumentation Technical Contact	Tom Gregory	425444	tgregory
Personnel	*Lucy Lawler*	425415	lal
Health and Safety	*Alan Chopping*	405633	akc
Freight	*Juan Martínez*	425414	juan

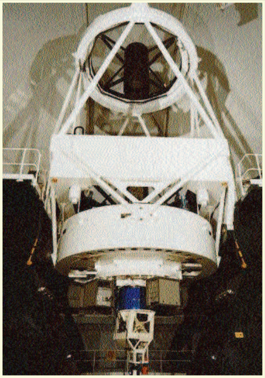
Appendix J

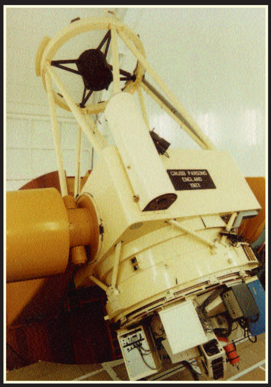
Acronyms and Abbreviations

AAO	Anglo-Australian Observatory
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
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
FOS	Faint Object Spectrograph
FWHM	Full Width Half Maximum
GHRIL	Ground Based High Resolution Imaging Laboratory
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, Mexico
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, Optica 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
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)
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
Planet Space Sci	Planetary and Space Science Journal
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
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
TAG	Time Allocation Group
TAURUS	TAURUS Fabry-Perot spectrograph or imager
TCS	Telescope Control System
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
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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