The Isaac Newton Telescope

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 ING is operated jointly by the Science and Technology Facilities Council (STFC) of the UK, the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of the Netherlands and the Instituto de Astrofísica de Canarias (IAC) of Spain. The telescopes are located in the Spanish Observatorio del Roque de Los Muchachos on La Palma, Canary Islands, which is operated by the IAC.

The INT has a 2.54-metre primary mirror with a focal ratio of f/2.94. It uses a polar-disc/fork type of equatorial mount. Instruments can be mounted at the corrected f/3.29 Prime or f/15 Cassegrain foci. Total weight of the telescope is about 90 tonnes. Since its first operation on La Palma, the role of the telescope has been as a facility for wide-field imaging and intermediate to low dispersion spectroscopy, and the scientific impact of the telescope is as high as that of the best telescopes of its kind. Its student programme is also very remarkable.

The INT at Herstmonceux and at La Palma

Since the 40s, there had been talk of providing UK astronomers with a telescope large enough to allow them to compete on equal terms with their counterparts abroad, especially in the USA and Russia. It was eventually agreed that a 100-inch telescope would be constructed, funded jointly by the Treasury and the Admiralty. The telescope would be for the use of all UK astronomers and located at Herstmonceux (Sussex, UK), where the Royal Greenwich Observatory had been moved in the 1950s. In 1967, Her Majesty the Queen performed the opening ceremony for the new Isaac Newton Telescope (INT) at Herstmonceux.

But after a number of years it became clear that better astronomical weather conditions than the UK would benefit the astronomical use of the INT. A large telescope is used to look at the faintest, most distant objects and to glean as much information as possible about them. Hence it requires the very best observing conditions that can be obtained. Such conditions are found on La Palma, and therefore it was decided in the early 1970's to move the telescope to its current location on the Roque de Los Muchachos Observatory where it resumed operation in 1984. The re-installation of the telescope was also used to modernise its instrumentation and provide the telescope out with a new, high-quality primary mirror.

The INT was officially re-inaugurated on 29 June 1985, when the inauguration of the Canary Islands observatories took place in the presence of the monarchs and members of the Royal Families of five European countries, and the Presidents of another two. On 29 May 1984, the telescope welcomed its first scheduled astronomer at the new location on La Palma.

The born-again Isaac Newton Telescope at La Palma differs significantly in its mechanics, electronics and optics from the earlier incarnation at Herstmonceux. The change in latitude from 50 degrees 51 minutes 58 seconds to 28 degrees 45 minutes 43.4 seconds resulted in a large change of angle to the polar disc which stands almost on edge. A segment was removed from the disc in order to allow operation to a declination of -30 degrees. The primary mirror was replaced with a slightly larger one (from 98 inches to 100 inches) of considerably higher optical quality made of low-expansion material. The old prime-focus assembly, which required a caged observer, was replaced with one operated entirely by remote control. The telescope was housed in a new dome, the old one being left as a landmark for channel shipping. Finally, a new suite of instruments was set up.

Isaac Newton

Isaac Newton was born at Woolsthorpe, Lincolnshire, on 25 December 1642. Born into a farming family and first educated at Grantham, Isaac Newton was sent to Trinity College, Cambridge, where as an undergraduate, he came under the influence of Cartesian philosophy. When confined to his home at Woolsthorpe by the plague between 1665 and 1666 Newton carried through work in the analysis of the physical world which has profoundly influenced the whole of modern science.

On returning to Cambridge, Newton became a Fellow of Trinity College, and was then appointed to the Lucasian Chair of mathematics in succession to Isaac Barrow. In the 1670s lectures, demonstrations and theoretical investigations in optics occupied Newton, constructing in 1672 the reflecting telescope today named after him, but in the early years of the 1680s correspondence with Robert Hooke re-awakened his interest in dynamics. After Edmond Halley's visit to Cambridge to encourage him in this work, Newton laid the foundations of classical mechanics in the composition of his fundamental work Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy), which was presented to the Royal Society in 1686 and its subsequent publication being paid for by his close friend Edmund Halley.

In the Principia were presented Newton's laws of motion, and the law of universal gravitation. The laws of motion are the foundation of modern dynamics, defining concepts such as force and acceleration, inertia, mass and weight. The universal law of gravitation described the attraction between any two masses. Newton showed how these fundamental physical laws could be used to predict the orbit of the moon around the earth, and the form of the planetary orbits previously observed by Johannes Kepler.

In 1703 he was elected President of the Royal Society and the next year published his Opticks, containing the first full exposition of his method of fluxions. He showed by passing light through prisms that it is made up of different colours. He investigated various optical effects, such as thin-film interference (Newton's rings). He was active in the debate over the corpuscular versus wave nature of light.

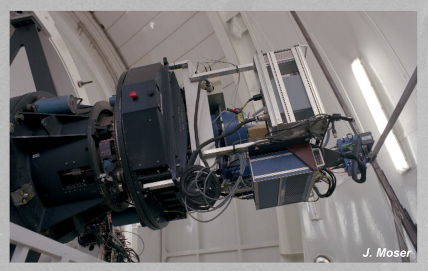
Newton's interests were wide-ranging, from alchemy and the transmutation of other metals into gold, to the authenticity of biblical texts. Newton was also a brilliant mathematician, developing the concepts of differential and integral calculus.

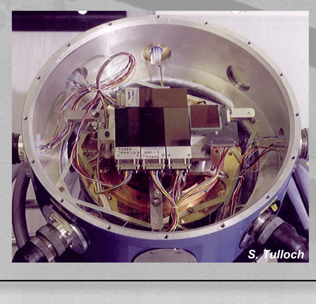
In later life Newton became less active as a scientist. He was elected member of parliament for the university in 1689. Subsequently he became Warden of the Royal Mint, becoming Master in 1699. He was knighted in 1705. He was elected President of the Royal Society in 1703, retaining that position until his death on 20 March 1727.

The Wide Field Camera

The Wide Field Camera (WFC) is an optical mosaic camera for use at the Prime focus of the INT.

The WFC consists of 4 thinned EEV 2k×4k CCDs. The CCDs have a pixel size of 13.5 microns corresponding to 0.33 arcsec/pixel. The edge to edge limit of the mosaic, neglecting the ~1 arcmin inter-chip spacing, is 34.2 arcmins. The cycle time for the whole mosaic is around 42 seconds. Both broadband and Stromgren filter sets are available, as well as a range of narrow-band filters, so the camera is ideal for wide field imaging surveys.

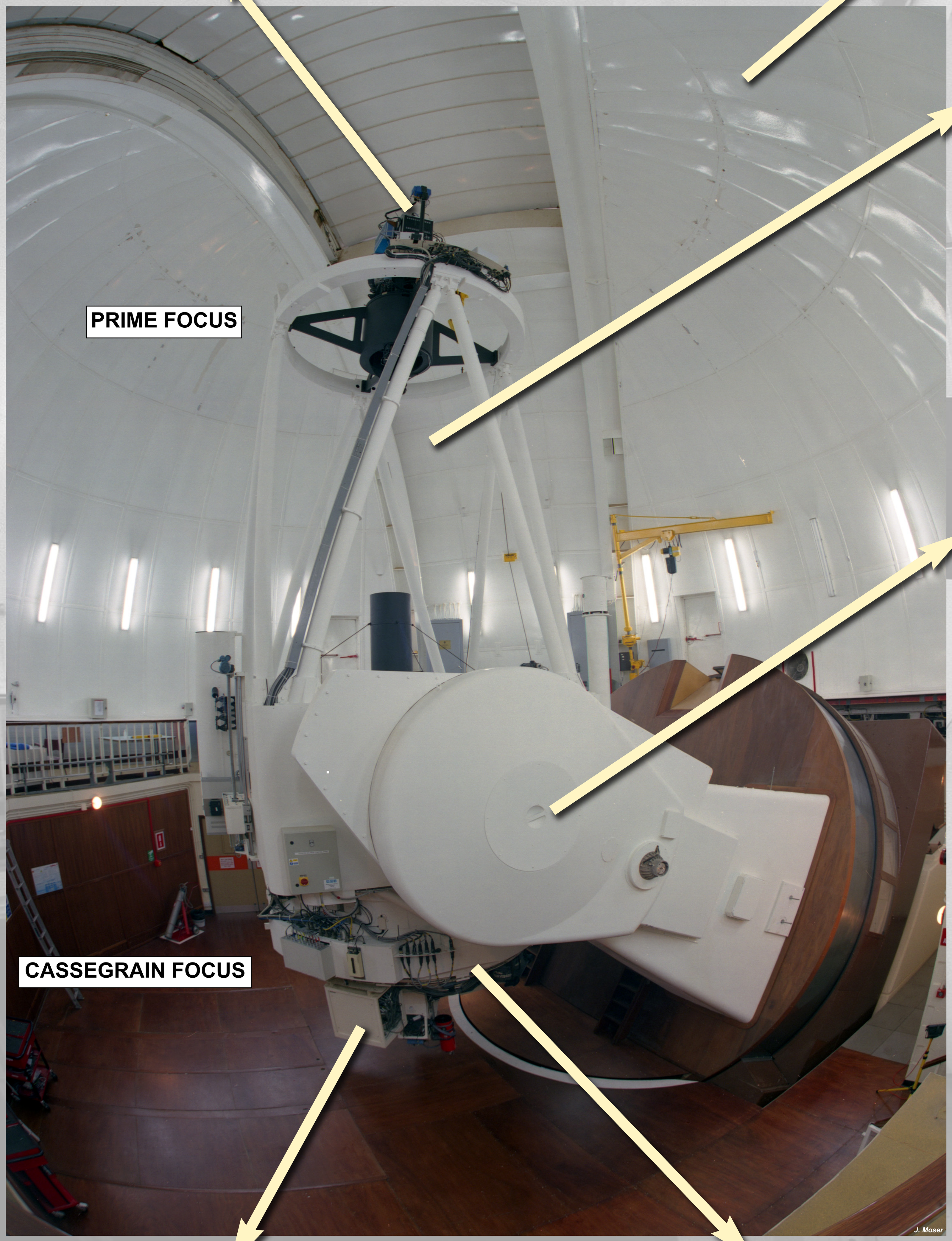




The Dome and the Building

The dome was built by the Canadian company Brittain Steel Ltd., Vancouver B. C., and the building by the Spanish company Huarte y Cia., Madrid. The dome is almost of spherical shape.

There are three floors, being the third the observing floor, including the control room, which stands 11.12 meters above the ground floor. The building is occupied by offices, workshops and stores.



The Optics

The optical system of the INT is a conventional Cassegrain with a paraboloidal primary mirror and a hyperboloidal secondary.

There are two focal stations, the f/3.29 Prime focus (with focal corrector) and the f/15 Cassegrain focus. Both Prime and Cassegrain foci are equipped with instrument rotators and autoguiders. The autoguiders continuously analyse the image of a guide star and provide small corrections to the telescope tracking.

A three-element corrector with a flat rear surface and increased back focal distance, is used at the Prime focus to give an unvignetted field of 40 arcmin at a scale of 24.68 arcsec/mm. The images are calculated to be smaller than 0.5 arcsec diameter everywhere over the unvignetted field for incident wavelengths in the range 3650 Å to 10,140 Å.

The two secondary mirrors give f/15 Cassegrain and f/50 Coudé foci (although the latter was never implemented). The scale at the Cassegrain focus is 5.41 arcsec/mm and the unvignetted field is 20 arcmin.

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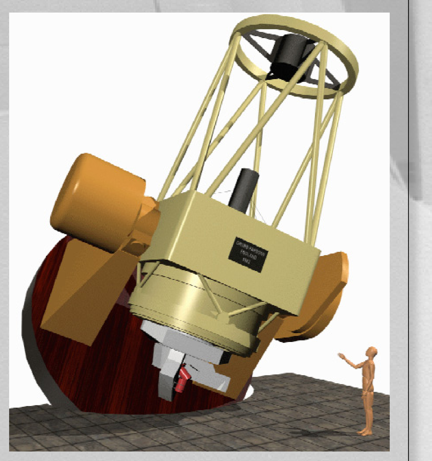


The telescope has a polar disc/fork type equatorial mounting supported by five axial and three radial hydrostatic oil bearing pads. The tube, a conventional open Serrurièr truss structure, supports the Prime-focus assembly or secondary mirror for Cassegrain and Coudé operation.

Declination coverage was improved when moved to La Palma by cutting a sector out of the polar disc, and by a redesign of the dome aperture (a proposal to remount the telescope on an altazimuth mount was found to have some attractive features, but was rejected because of extra costs). Drive limits are currently set at -30 degrees Declination, 70 degrees zenith distance and ±6h Hour Angle (operation below the pole is also possible).

DC servo motors with integral tachogenerators are used for the slow-motion drives on both arms. The RA axis is driven by a worm/worm-wheel assembly and the Declination axis by a recirculating ball screw and nut. Preload and quick motion drive are provided by a pair of motors driving through spur gearing.

The telescope's position is determined by Moiré fringe grating encoders mounted on each axis. There are three reading heads per axis. One bit corresponds to 0.3 arcsec in RA and 1 arcsec in Declination, although systematic errors are larger. When the telescope is being driven by the slow-motion motors, optical incremental encoders are used, with resolutions of 0.01875 and 0.01 arcsec in RA and Declination, respectively, mounted on the drive shafts.

The pointing model for the INT comprises the standard errors of an equatorially mounted telescope (offsets in Hour Angle and Declination, collimation error, misalignment of the polar axis and non-perpendicularity of axes), together with an empirical (Fourièr series and polynomial) model of flexure in the telescope structure and large-scale errors in the encoder readings. The r.m.s. errors in the absolute pointing of the INT are always less than 5 arcsec; values between 2.8 and 4.5 arcsec were obtained during the first tests at Prime and Cassegrain foci during 1985. Short-term tracking errors are less than 0.25 arcsec; longer-term drifts are removed by the autoguiders.

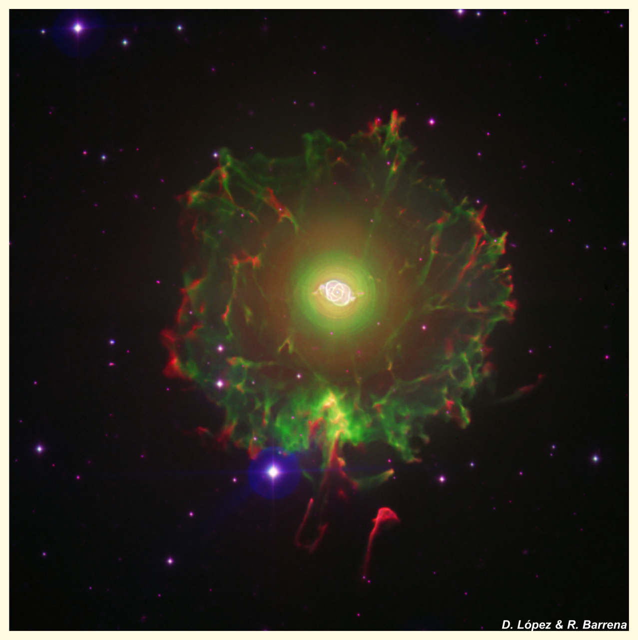
Telescope limits:

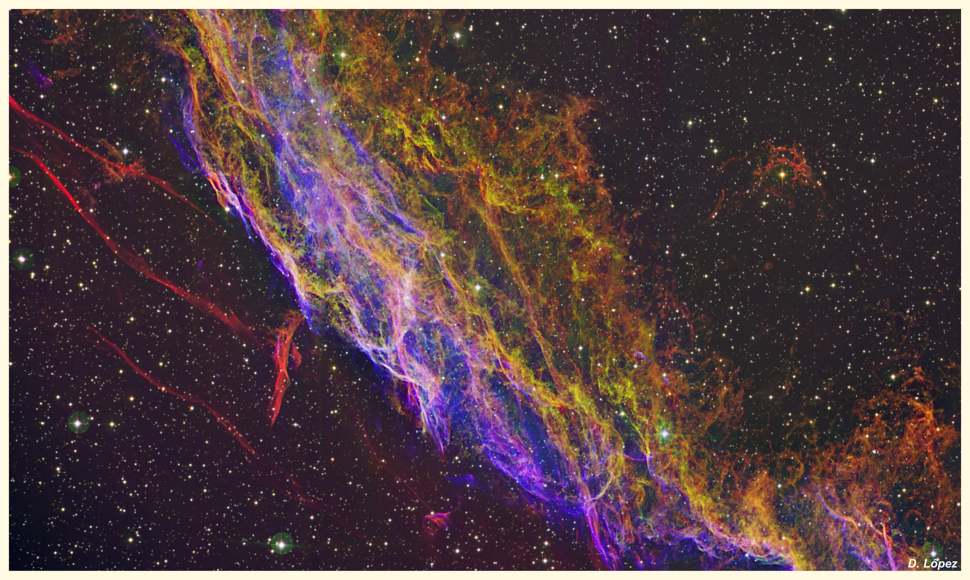
Zenith distance < 70°.
- 6 h < hour angle < + 6 h (above pole).
Declination > -30° 09' 30".
Operation below the pole is possible, but only gains a small extra area of sky; consider it in exceptional circumstances.
The lower windshield causes vignetting for zenith distances > 57° and is raised for such observations.

The optical telescope assembly weighs 51.4 tonnes, and including the mount, 85.4 tonnes.

CCD Wide Field Imaging

A CCD is an array of photosensitive elements, each of which generates photoelectrons and stores them as a small charge. When requested, the elements form a bucket brigade; each row of charges is passed from element to element down the columns and horizontally along the final row to be measured in turn and recorded digitally. One of the first ever uses of a CCD in observational astronomy took place at the INT in 1984. Since then CCDs have been extensively used and they are considered the standard detector nowadays. Below there are some examples of CCD wide field imaging using the Wide Field Camera on the INT.

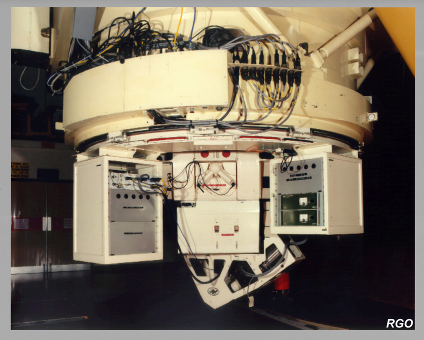




The Intermediate Dispersion Spectrograph

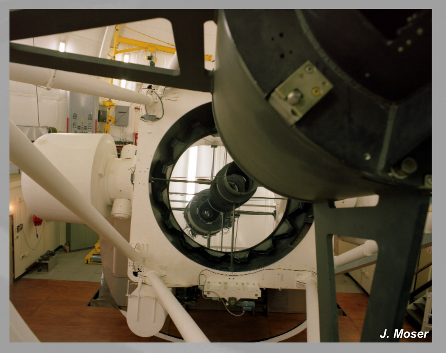
The Intermediate Dispersion Spectrograph (IDS) is a long-slit spectrograph which sits at the Cassegrain focal station of the 2.5m Isaac Newton Telescope and it is equipped with two cameras, called the 235mm and 500mm cameras according to their respective focal lengths.

Starting from semester 2006B, IDS is offered with the whole set of gratings (16), but only with the 235mm camera and the EEV10 CCD detector. Possible grating combinations with this configuration allow dispersions of between 0.24 and 3.7 Å per pixel. The spatial scale along the slit is 0.4 arcsec per pixel. The full unvignetted slit length is 3.3 arcmin.



The Primary Mirror

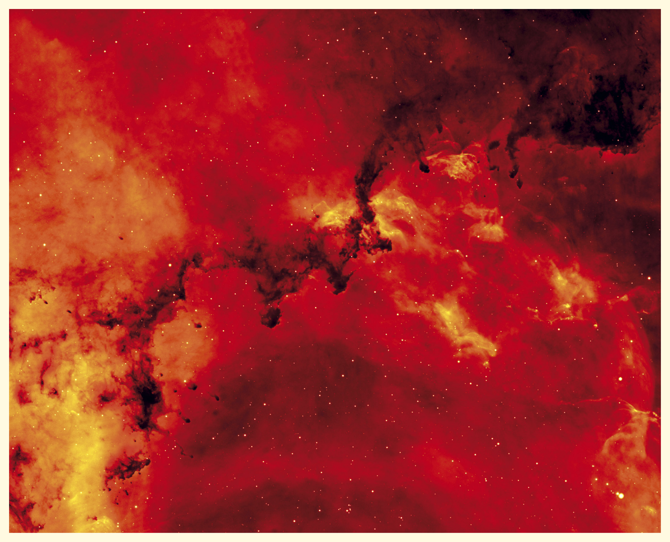
The primary mirror has a diameter of 2.54 m (the original 98-inch primary mirror was replaced by a 100-inch mirror when the INT was moved to La Palma) and a focal length of 7.5 m, giving a focal ratio of f/2.94 at the uncorrected primary focus. It weighs 4361 kg, it is made of Zerodur and it has a negligible coefficient of expansion ~10^{-7} K^{-1}. On axis, 80% of the light from a point image lies within a circle of 0.3 arcsec in diameter.

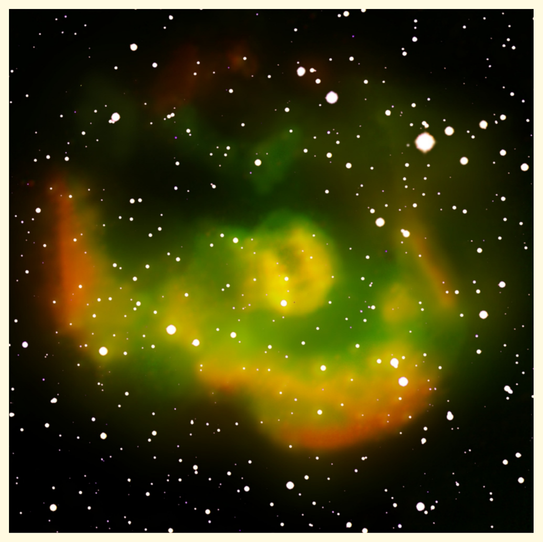


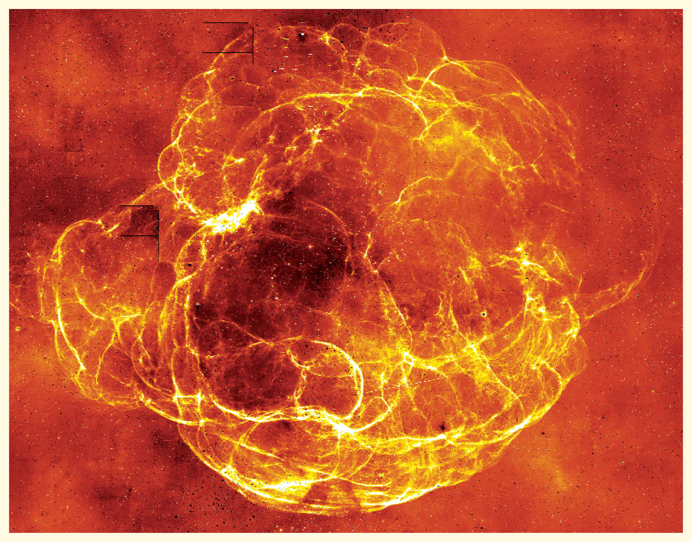
Scientific Highlights

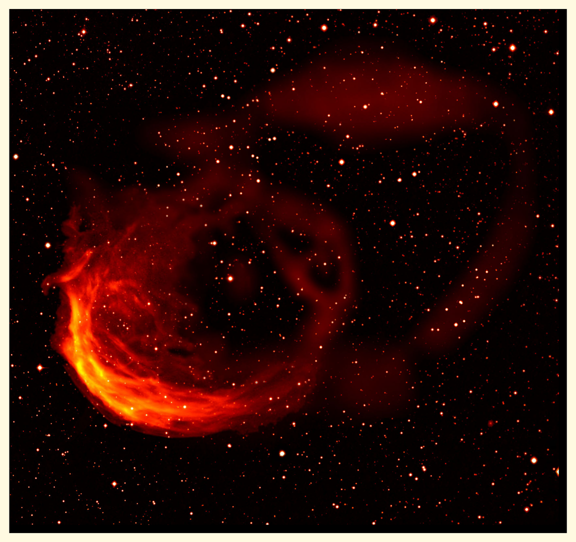
The quantity and quality of the research carried out at the Isaac Newton Telescope make it one of the best telescopes of its size in the world. Some of the scientific highlights include the discovery of the unequivocal evidence for a stellar-size black hole in the Galaxy. The X-ray transient source GS2023+338 was discovered in outburst in 1989 and was identified with the previously known recurrent nova V404 Cygni. The only certain way of identifying the primary star of the binary system as a black hole was to study the radial velocity of the less massive secondary star and measure the mass function. In order to get a good coverage of the radial velocity curve of V404 Cyg, several spectra were obtained using the INT in 1992. From the mass function of the system, it was possible to set lower limits to the mass of the primary star. The astronomers obtained a measurement of 6.26 solar masses, which substantially exceeds the 3 solar masses maximum allowed mass of a neutron star. So they concluded that the compact object had to be a black hole, the first-ever stellar-size black hole detected in our Galaxy.

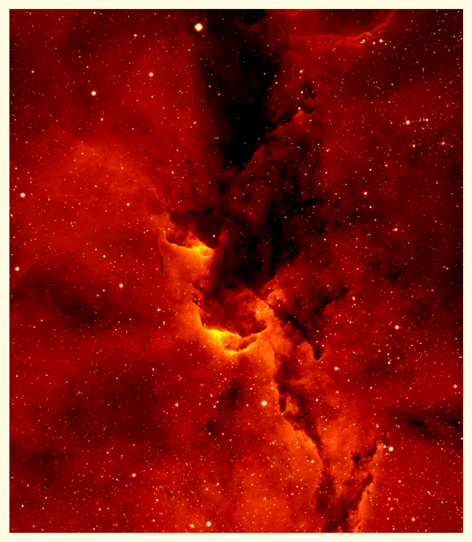
The Wide Field Camera (WFC), since its first commissioning in 1998, has produced many scientific highlights, including the first ever detection of a dark galaxy (a galaxy made of dark matter), the discovery of new dwarf galaxies in the Local Group, the observation of the disruption of the nucleus of comet C/1999 S4 (LINEAR), the discovery of a giant stream of stars in the halo of Andromeda galaxy, or a giant ring of stars surrounding the main plane of the Milky Way. Imaging surveys of the sky are crucial for the future research on very large telescopes and the WFC has produced huge amounts of data which astronomers access through online archives of products ready for research. The images shown to the right are a good example of this. They were made using data from the hydrogen-alpha survey of the northern Galactic plane IPHAS.











Javier Méndez (ING), September 2010.