Chapter 2

OPERATION, MAINTENANCE AND DEVELOPMENTS

TELESCOPE OPERATION

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

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

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

Day-to-day telescope operations support is carried out by a dedicated Operations Team, taking responsibility for upkeep of the telescopes and associated infrastructure. Efforts for day-time and night-time support activities concentrate on the WHT where many observing teams visit every year. On this telescope five common-user instruments are supported, one of which is the complex adaptive-optics suite. Also, several visiting instruments were supported at the WHT during the reporting period. The INT, in contrast, operates in a much simpler fashion and has only two facility instruments. On this telescope in 2006 the Intermediate Dispersion Spectrograph was refurbished and put back in operation in response to popular demand from the user community. The 1-m Jacobus Kapteyn Telescope no longer hosts science observations, but is now regularly being used for measuring the atmospheric turbulence profile above the observatory by the IAC. At night, a telescope operator is always present at the WHT to assist the scientists in taking the observations. ING's team of astronomers acts as the primary contact for visiting scientists and also provides introduction and training at the telescope. They also assist visitors in taking the observations and in carrying out observations in service for the community. Astronomy support on the INT is now competently taken care of by students.

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

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

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

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

In 2007 the WHT celebrated its 20th operational anniversary, and later that year the 1,000,000th CCD science exposure was obtained. During these two decades, the WHT has contributed data to some 1500 science papers published in refereed journals, and to many important discoveries.

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

INSTRUMENTATION

The GLAS Rayleigh laser beacon for Adaptive Optics

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

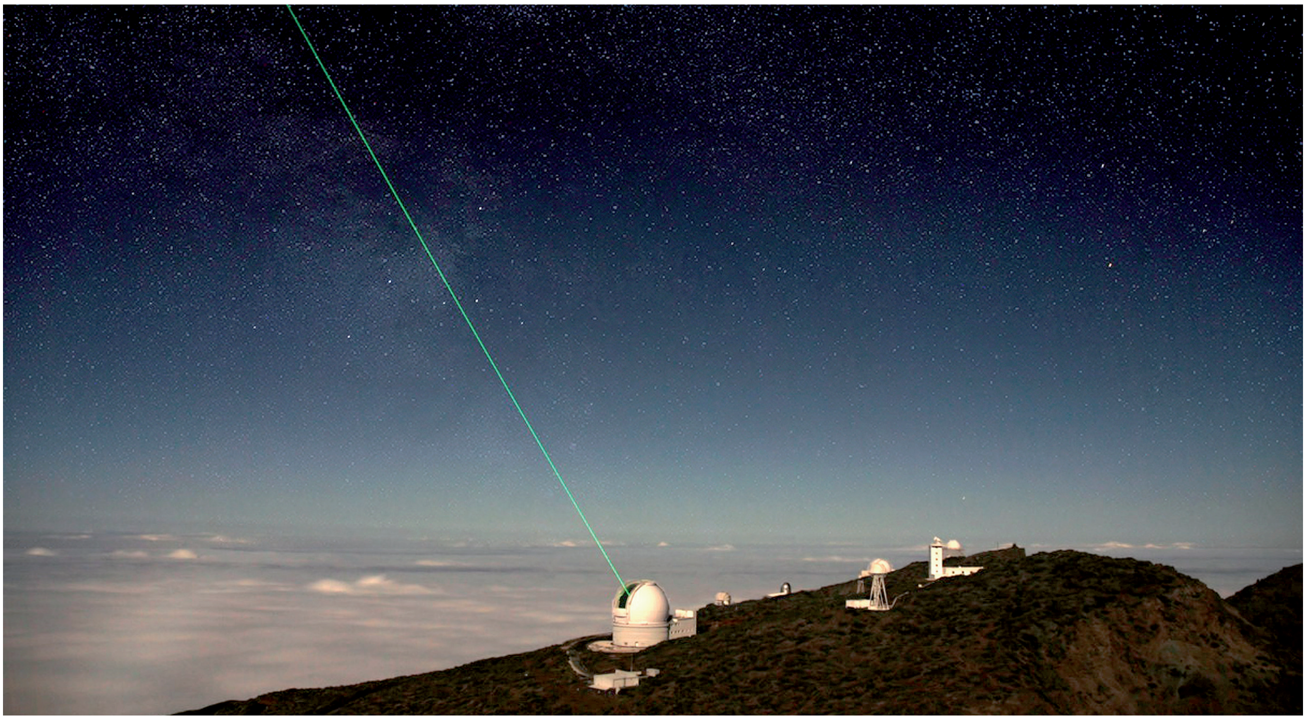

Figure 40. The GLAS laser beam emerging from the WHT.

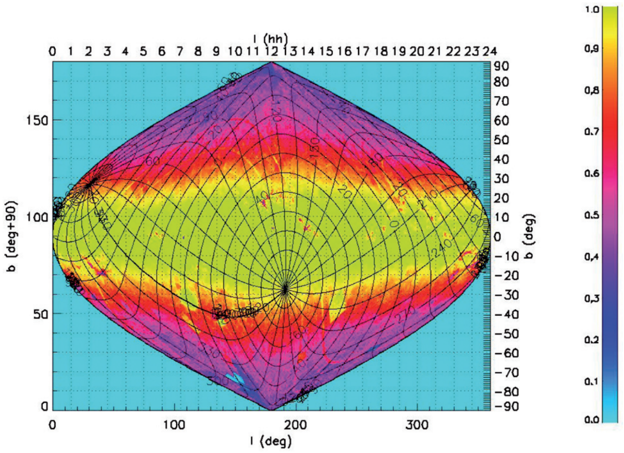

Figure 41. Sky coverage predictions based on achieving an R=17 limit for the tip-tilt natural guide star and a 2 arcmin patrol field. (courtesy Remko Stuik, Leiden).

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

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

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

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

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

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

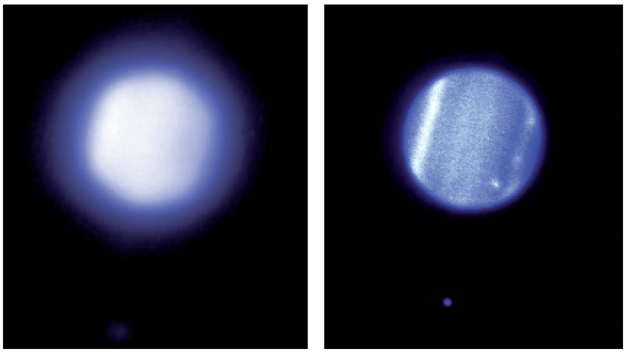

Figure 42. H-band images of Uranus with GLAS and adaptive optics correction off (left) and on (right). The faint object at the bottom is the moon Miranda.

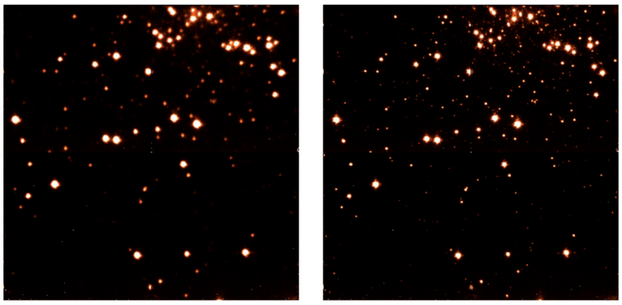

Figure 43. Uncorrected and laser-corrected images (left and right, respectively) of a region in the globular cluster M15. The increased sharpness and brightness of the stars in the right hand image demonstrate the clear enhancement in image quality.

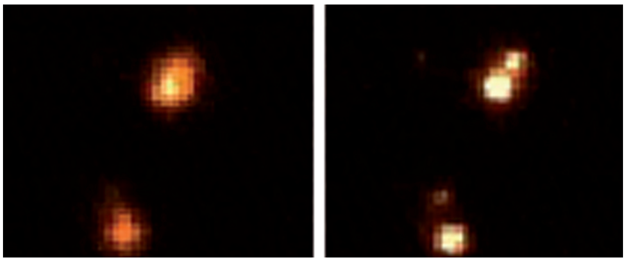

Figure 44. A zoom into one small section reveals how what appears to be two stars in the uncorrected image are actually four stars.

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

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

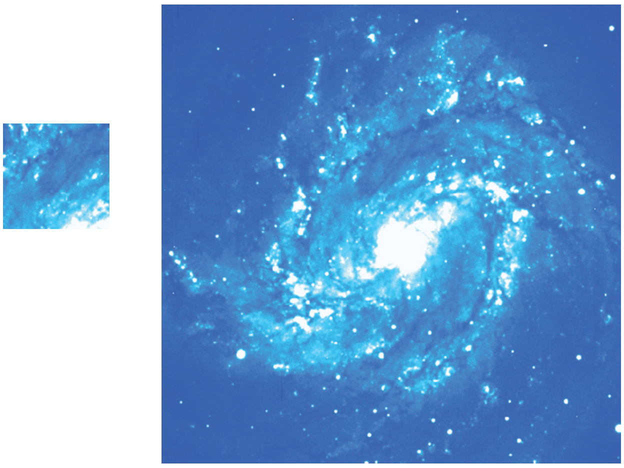

Figure 45. M81, as it would be imaged by cameras with fields 1.8 and 8 arcmin across (representing aux-port and ACAM).

The challenge of the optical design was to deliver good image quality across the whole field of view, and at all optical wavelengths, without compromising the throughput. The final 7-lens design was agreed in late 2007, and most of the manufacturing took place in 2008. The detector will be a 2k×4k CCD with peak QE~0.9 and very low fringing. Commissioning is expected mid-2009.

The WHT as planet hunter: the HARPS-NEF instrument

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

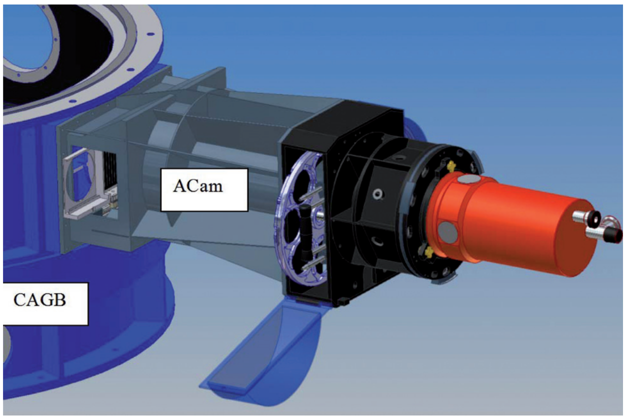

Figure 46. ACAM instrument design model shown mounted in the Cassegrain A&G box.

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

Instrument enhancements

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

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

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

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

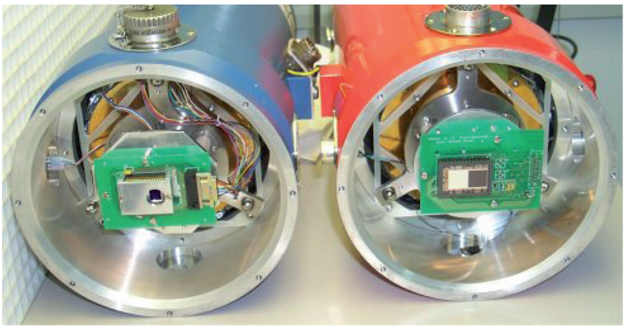

Figure 47. Two general-purpose L3CCD heads, with at the right the operational 1k x 1k pixel QUCAM CCD.

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

Visiting instruments

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

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

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

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

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

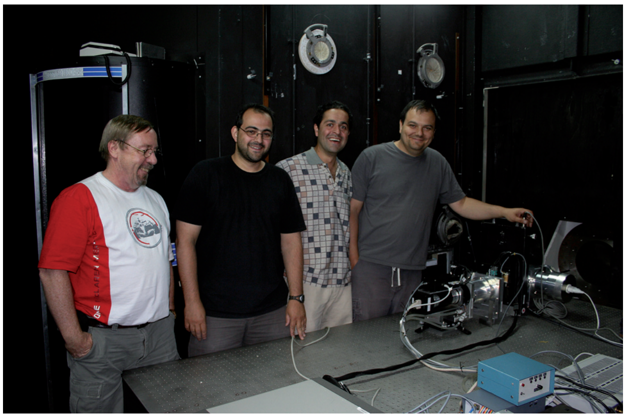

Figure 48. Some members of the GHaFaS first-light team. From left to right: C. Carignan, O. Hernández, K. Fathi, and J-L. Gach at the Nasmyth focus of the WHT.

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

INFRASTRUCTURE

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

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

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

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

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

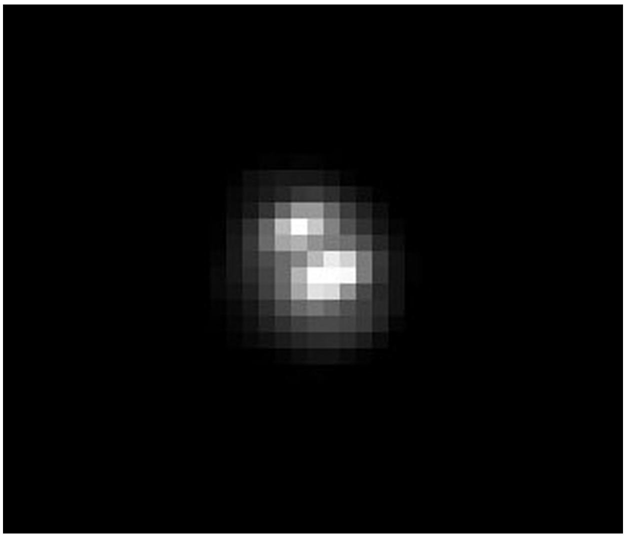

Figure 50. This R-band image shows the result of combining the best 5% of a series of 8000 images obtained for the binary star COU 292 (V=8.4 and 8.7 magnitudes respectively). Based on available orbital information an angular separation of 0.07 arcsec was expected. The binary was resolved and an angular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

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