SLODAR: Profiling Atmospheric Turbulence at the WHT

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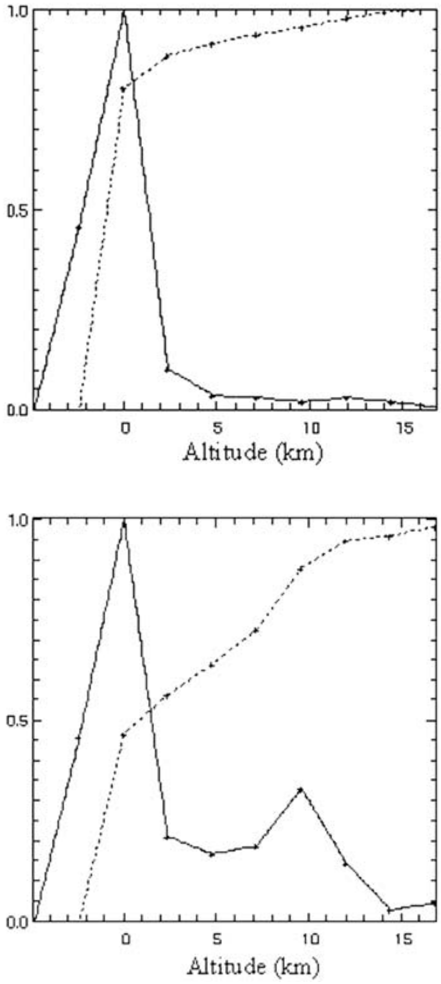

Figure 1. Normalised profiles of the strength of optical turbulence versus altitude for April 15 21:38 UT (top) and April 16 20:45 UT (bottom), 2003.

A new method for measuring the altitude and velocity of turbulent layers in the atmosphere —which cause the astronomical seeing and scintillation or 'twinkling' of the stars— has been demonstrated at the WHT. SLODAR (SLOpe Detection And Ranging) is a triangulation method, in which the turbulence profile is recovered from observations of bright binary stars using a Shack-Hartmann wavefront sensor.

In the past, astronomers have been concerned only with the overall effects of the turbulence, in terms of the resulting image spread or 'seeing angle' (FWHM for a point source) at the telescope focus. However with the advent of adaptive optical correction for astronomy, measurements of the changing atmospheric turbulence structure are of increasing importance.

The altitude distribution of the turbulence determines the corrected or 'isoplanatic' field of view for adaptive optics (AO). High altitude layers reduce the isoplanatic angle, since for these layers the wave-front aberrations measured in the direction of the AO guide star will not coincide perfectly with the aberrations at off-axis field-angles.

The velocities of the turbulent layers are also important, since these determine the rate of change of the seeing aberration at the telescope, and hence the temporal bandwidth of the AO control system required to achieve effective image correction.

SLODAR is a highly automated system which can provide real-time data for optimising and calibrating observations with AO. More details of the method and instrument can be found at the Durham astronomical instrumentation website: `http://aig-www.dur.ac.uk/ /fix/projects/slodar/res/wht.html`.

Figures 1 and 2 show SLODAR results for April 15th and 16th, both recorded in excellent seeing (0.45 arcsec), but with contrasting turbulence profiles. The conditions on April 15th were dominated by ground-level turbulence, whereas significant turbulence at higher altitudes was present on the 16th. Hence although the overall seeing was the same for the two nights the conditions for AO were different. The isoplanatic angle was very large on April 15th, but was reduced on the 16th by the presence of the high altitude turbulence.¤

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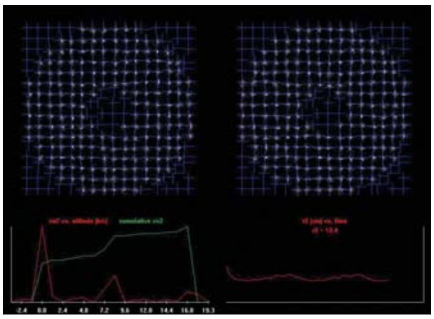

Figure 2. Snapshot of the WHT SLODAR system graphical user interface, showing the Shack-Hartmann spot patterns for a binary star, and real-time plots of the turbulence-altitude profile and the integrated turbulence strength versus time.

Amazing GRACE

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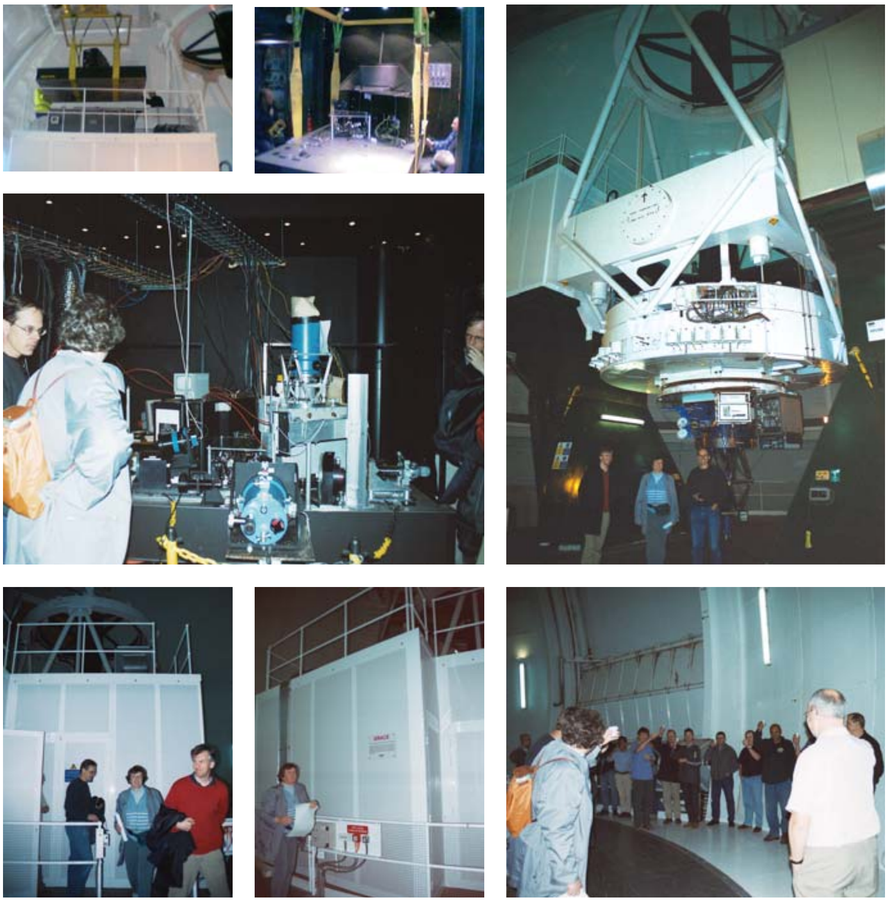
The profile of the William Herschel Telescope (WHT) has changed since the beginning of this year, with the addition of a new facility at one of the telescope's Nasmyth platforms. For many years the WHT has had the GHRIL building on the Nasmyth1 platform —now the ING has added GRACE to the opposite side of the telescope. GRACE (**GR**ound based **A**daptive optics **C**ontrolled **E**nvironment) is a dedicated structure designed to facilitate the routine use of adaptive optics (AO) at the WHT, using ING's AO instrument suite. The design of GRACE allows for the future use of laser guide stars.



Top left: NAOMI suspended from the crane (by the yellow straps) above GRACE, just before being lowered through the access hatch. Middle top: The Eagle has landed! The NAOMI bench complete with deformable mirror being lowered onto its kinematic mounts inside GRACE. Right top: Dr Ronald Stark, Dr Annejet Meijler and Dr René Rutten standing up in front of WHT. GRACE can be seen on the Nasmyth platform on the left, opposite to GHRIL. Middle left: Inside GRACE. Bottom left: Inaugurating committee leaving GRACE. Bottom middle: Dr Annejet Meijler uncovering the inauguration plate. Bottom right: Dedication to ING staff.

The AO suite consists of the AO system NAOMI, the coronograph OSCA, near IR imager INGRID and the optical integral field spectrograph OASIS. The bench-mounted NAOMI system achieved first light in 2000 with INGRID as its science camera in GHRIL, but until the advent of GRACE, the NAOMI optical bench complete with delicate (and expensive!) optical and electronics components has had to be craned in and out of GHRIL every time there has been an instrument change. Quite apart from the risk involved, there has been a massive overhead for ING staff in disconnecting and removing everything, with an even more massive overhead in putting everything back, aligning it and getting it working — three weeks was allowed for this!

After the first NAOMI instrument change, it was realised that for routine operation moving NAOMI about was not sustainable. This was re-inforced with the signing of the agreement with the Centre de Recherche Astronomique de Lyon (CRAL) to bring OASIS to the WHT, which added a further large complex instrument to the equation.

Accordingly ING made the decision to create a dedicated facility on the Nasmyth 2 platform then used by the Utrecht Echelle Spectrograph (UES). A suitable building was designed taking into account the requirements of the AO suite. To provide sufficient space an extension to the Nasmyth platform was needed and this was also designed at this time. A local La Palma company, Grolei Servicios S. L., was successful in winning the contact to construct the building. Their proximity to ING allowed progress to be monitored, problems resolved and modifications to be made quickly resulting in an excellent building, fulfilling ING's requirements.

GRACE is not just a building, it offers all of the systems associated with providing the controlled environment necessary, especially cooling and filtering of the air, together with all of the services needed including electrical supplies, lighting and a computer network. While the building was being built, we continued to design and specify these systems.

Crucial to success is environmental control. The GRACE electronics room is maintained at a constant temperature by an air-handling unit mounted on the roof. For the optics room, the air is again maintained at a constant temperature for the stability of the instruments, additionally being finely filtered and introduced at low velocity through laminar flow units to minimise air currents. The heat from GRACE is removed (not dumped in the dome) through a water glycol circuit. The opportunity was taken to upgrade the cooling capacity to the whole of the WHT, in order to meet future needs including a laser guide star, by buying and installing a new external plant.

The first step was the removal of UES and the extension and modification of the platform ready for the building.

Installation of the completed building, which was dismantled for transportation, began late in 2002. A significant moment was reached on 18 March 2003 when the NAOMI adaptive optics system on its bench was lifted into its new and permanent home. This was followed quickly by its first light in GRACE using INGRID on 13 April at the beginning of a nine-night run. The second 'first light' event for GRACE followed soon after when, on the 11 July, OASIS went on sky with NAOMI on its first commissioning night.

A key concern was that GRACE would not change the telescope performance when replacing UES. During the construction phase several blocks (weighing a tonne each) were used to ensure that the removal of UES did not unbalance the telescope. These were progressively removed as GRACE was assembled. The opportunity was taken to brace the new platform extension to the telescope structure. Tests after GRACE installation was complete show this was effective in raising the natural frequency considerably, away from the telescope's azimuth locked rotor frequency, which was the required result.

During the time of restructuring for ING, the creation of GRACE is a major achievement, especially when set against the background of other project work not least adding the Universal Science Port to NAOMI to feed OASIS. Many, if not most ING staff have contributed to GRACE and in getting the AO suite installed and working. In the end —over the last months, then weeks— it's still hard to believe how much was done and how hard everyone worked.

Dr Annejet Meijler, the Director of the Council of Physical Sciences of the NWO, formally inaugurated GRACE on May 2nd, 2003. ING staff take pride in having a world class environment for AO which was, in the words of the plaque unveiled, 'conceived, designed and built' by them.¤

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OASIS at the WHT

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The optical integral-field spectrograph OASIS, formerly at the CFHT, has moved permanently to the WHT. It is now installed at one of the science ports of NAOMI, the WHT's adaptive-optics system. OASIS was successfully commissioned on-sky with NAOMI in July 2003, and it is offered to the community on a shared-risks basis in semester 2004A.

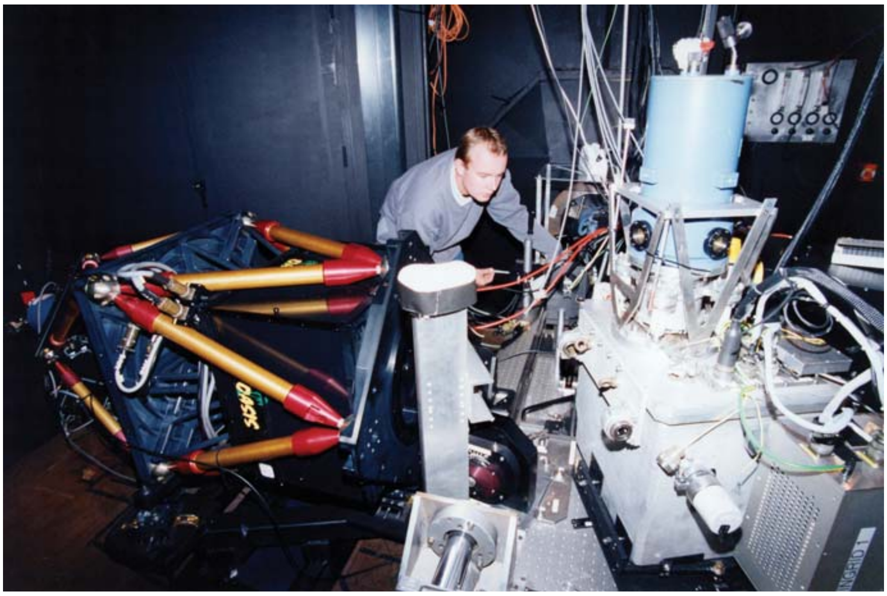

Figure 1. OASIS (left) joins NAOMI in the WHT's new AO-dedicated, temperature-controlled Nasmyth enclosure, GRACE. The IR camera INGRID is visible in the foreground on the right.

OASIS offers a range of spatial and spectral resolutions. An area of sky between 3 and 16 arcsec in diameter (4 enlarger options) can be imaged onto the array of 1100 lenslets in the focal plane. Six grisms provide spectral resolutions in the range $1000<\Re<4000$. The 1100 resulting spectra are imaged onto a deep-depletion MIT/LL CCD, with dispersion 1 to 4 Å/pixel (15 µ pixels). The CCD has high QE (0.9 at 0.75 microns) and low readout noise (2.3 electrons rms in slow mode). The fringing level is low, ~3% at 0.8 µ, and ~10% peak-to-peak at 1 µ. A version of CFHT's XOASIS data reduction package is available at ING for reduction of OASIS data. OASIS can also be used in imaging mode (primarily for target acquisition), with a field diameter of 38 arcsec. Further information about OASIS can be found on the web page: `http://www.ing.iac.es/Astronomy//instruments/oasis/index.html`.

OASIS can be used with or without AO correction. NAOMI typically delivers a reduction in FWHM of a few tenths of an arcsec at wavelengths 0.6–1.0 µ. The best corrected seeing achieved during the July 2003 OASIS commissioning was 0.3 arcsec. Guide stars must currently be brighter than V~13. The guide object may also be a galaxy nucleus, if sufficiently compact. Some correction is achieved even when the science target lies several 10s of arcsec from the guide star. Performance and throughput are expected to be at least as good as achieved at CFHT. Information about NAOMI can be found on the web page: `http://www.ing.iac.es/Astronomy//instruments/naomi/index.html`. ¤

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Figure 2. OASIS logo for joint operation with NAOMI.