

# Astrophysics on the edge: New Instrumental Developments at the ING

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**Abstract** Present and future key instruments at the Isaac Newton Group of Telescopes (ING) are introduced, and their corresponding latest scientific highlights are presented.

**GLAS** (Ground-layer Laser Adaptive optics System): The recently installed 515-nm laser, mounted on the WHT (William Herschel Telescope), produces a bright artificial star at a height of 15 km. This enables almost full-sky access to Adaptive Optics observations. Recent commissioning observations with the NAOMI+GLAS system showed that very significant improvement in image quality can be obtained, e.g. down to 0.16 arcsec in the  $H$  band.

**QUCAM2 and QUCAM3**: Two Low Light Level (L3) CCD cameras for fast or faint-object spectroscopy with the twin-armed ISIS spectrograph at the WHT. Their use opens a new window of high time-frequency observations, as well as access to fainter objects. They are powerful instruments for research on compact objects such as white dwarfs, neutron stars or black holes, stellar pulsations, and compact binaries.

**HARPS-NEF** (High-Accuracy Radial-velocity Planet Searcher of the New Earths Facility): An extremely stable, high-resolution ( $R \sim 120000$ ) spectrograph for the WHT which is being constructed for commissioning in 2009-2010. Its radial velocity stability of  $< 1 \text{ m s}^{-1}$  may in the future be even further improved by using a Fabry-Perot “laser-comb”, a wavelength calibration unit capable of achieving an accuracy of  $1 \text{ cm s}^{-1}$ . This instrument will effectively allow to search for earth-like exoplanets.

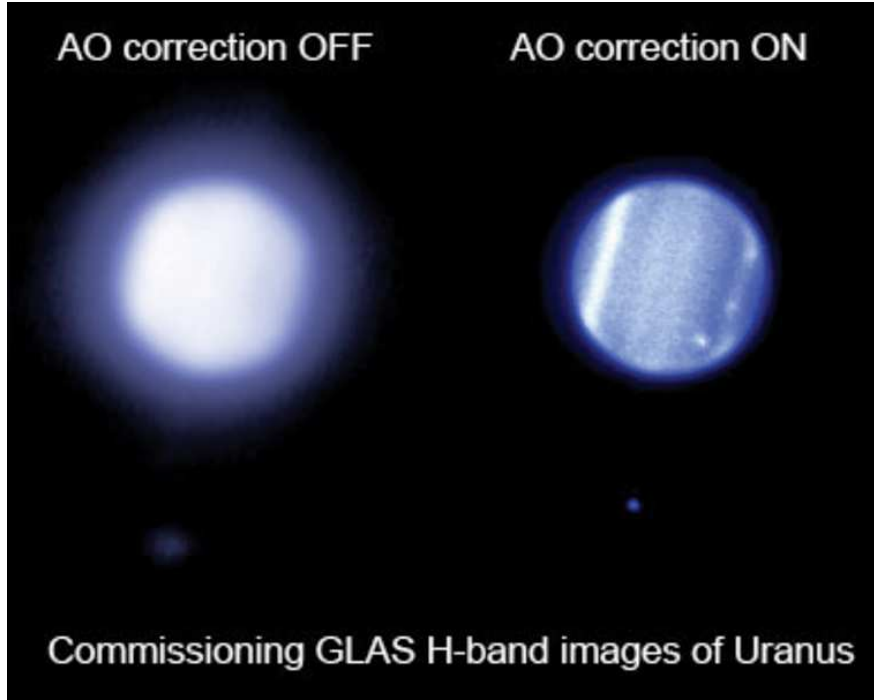
## 1 GLAS: On the edge of spatial resolution

The 20W-power GLAS (Ground-layer Laser Adaptive optics System) 515 nm LASER, mounted on the WHT, produces a star-like point at a height of 15 km.

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The Rayleigh back-scattered light from this bright artificial star is captured by a dedicated wavefront sensor where the signal is analyzed in order to correct for atmospheric turbulence at a rate of 300 Hz. This enables almost full-sky access to Adaptive Optics (AO) observations with the INGRID near-infrared imager or the OASIS optical integral-field spectrograph. Recent commissioning observations with GLAS showed that correction up to the diffraction limit of the telescope (0.16 arcsec in the  $H$  band) is achievable.

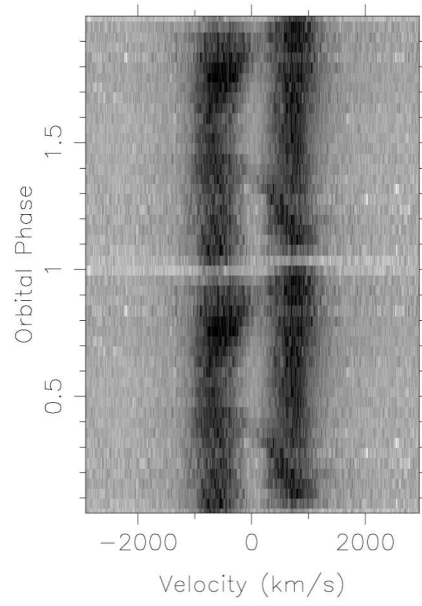


**Fig. 1** Comparison of  $H$ -band images of Uranus with GLAS and adaptive optics correction off (left) and on (right). The faint point at the bottom is the moon Miranda, which moved approximately 0.7 arcsec between the two images. Credit: Rene Rutten, Javier Méndez and the GLAS commissioning team.

## 2 QUCAM2 and QUCAM3: On the edge of time resolution

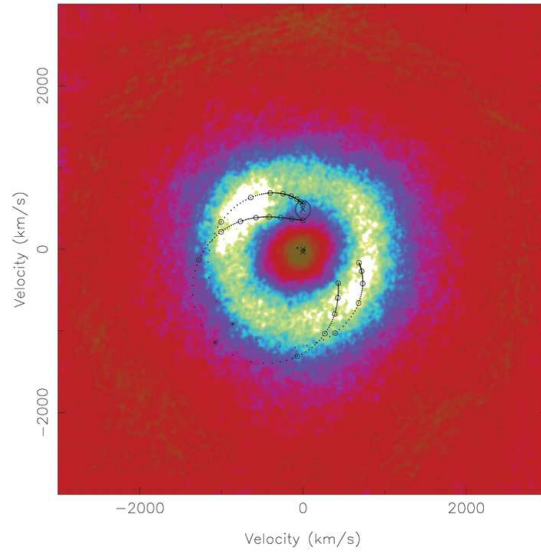
Two E2V electron-multiplying, low-light-level (L3) CCD cameras are available for use on ISIS red and blue arms to perform fast or faint-object spectroscopy. The L3 detectors are  $1\text{k} \times 1\text{k}$  pixel, 13 micron/pixel, full frame transfer devices, that can be used in two multiplying modes: slow or fast. In the fast mode the readout noise

**Fig. 2** Trailed spectra diagram of the  $H\alpha$  emission line of the eclipsing cataclysmic variable SDSS J1433+1011 with QUCAM2. The faintness of the system ( $V=18.6$ ) and its short orbital period (78.1 min) would have prevented its study with ISIS in the standard spectroscopic mode. The emission S-wave produced by the bright spot in the system is clearly detected and the eclipse at orbital phase 1 resolved.



(RON) is nearly zero. Exposure times shorter than one second are possible with almost no dead times (20 milliseconds per full transfer) as the system continuously exposes while reading the previous image. The detectors have very good cosmetic characteristics, and excellent quantum efficiency.

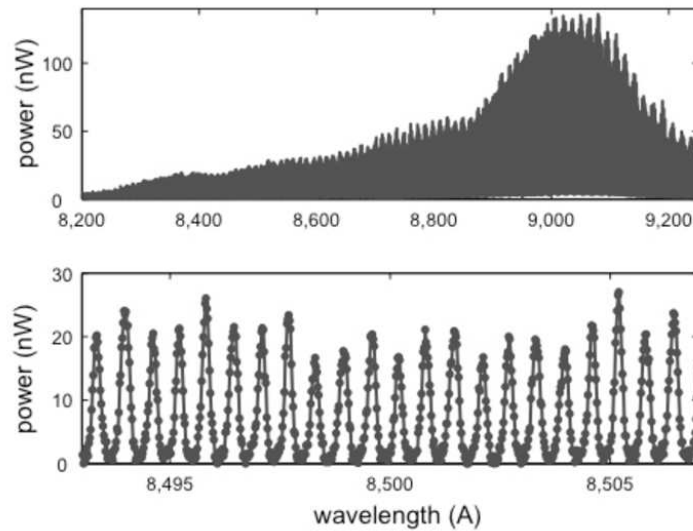
**Fig. 3** Doppler tomogram of the  $H\alpha$  emission line of the same system. The ring-like emission from the accretion disc and the location of the bright spot are apparent.



The QUCAMs are designed to explore the high time-frequency domain in spectroscopic mode, boosting the capabilities of the WHT in that range started by the ULTRACAM ultrafast imager. As examples, high time resolution, spectroscopic studies of compact binaries as cataclysmic variables (see Figs. 2 and 3), neutron stars and black hole binaries, as well as stellar pulsations, are now possible at the WHT. Spectroscopy of fainter objects is also achievable with these cameras.

### 3 HARPS-NEF: On the edge of dispersion resolution

Fruit of the collaboration between the Harvard College Observatory, the Smithsonian Astrophysical Observatory and the Observatoire de Genève institutions, the HARPS-NEF (High Accuracy Radial-velocity Planet Searcher of the New Earths Facility) high-resolution ( $R \sim 120000$ ) spectrograph is intended to be mounted on the WHT and commissioned in 2009-2010. Its extremely stable radial-velocity calibration accuracy of  $< 1 \text{ m s}^{-1}$  will in the future be improved to  $< 1 \text{ cm s}^{-1}$  with the installation of a Fabry-Perot laser “astro-comb” calibration unit, making HARPS-NEF ideal for finding earth-like exoplanets.



**Fig. 4** Example astro-comb output spectrum with 37-GHz line spacing. Extracted from *Li et al. 2008, Nature, 452, L610*

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