OASIS 3D Spectroscopy of P Cygni

Richard Parker[1,2], Samantha Rix[1] & Danny Lennon[1]

1) Isaac Newton Group, La Palma, Spain 2) University of Sheffield, UK

Abstract

We have obtained 3D spectra of the *Luminous* Blue Variable P Cygni and its surrounding nebula using the OASIS spectrograph on the WHT. The spatial resolution was optimised by exploiting the WHT's adaptive optics system NAOMI. Here we present an overview of OASIS, a description of the reduction process with the specialist software XOasis, and preliminary results from our study of P Cygni.

OASIS on the WHT

OASIS is an optical integral field spectrograph which uses a lenslet array to simultaneously obtain ~1100 spectra over a two dimensional field of view. 15 spectroscopic modes and 4 different fields of view are available (see Figures 1 and 2), giving the user the choice of 60 possible configurations.

OASIS can be used with or without AO correction from the NAOMI adaptive optics system. With good to median seeing conditions (i.e. 0.5" to 0.7" FWHM), and a bright guide star, NAOMI can typically improve the spatial resolution in the R band by a factor ~2.5. In the near future, OASIS will be available with the WHT's laser guide star system GLAS (see poster by Rutten et al.).

OASIS is available to the UK, Dutch and Spanish communities as a common user instrument and can be applied for through both the appropriate time allocation committee and the ING service programme. Observations are usually performed in service mode.

OASIS (Optically Adaptive System for Imaging Spectroscopy) was built by the Observatoire de Lyon for use at CFHT, and was transferred to the WHT in 2003.

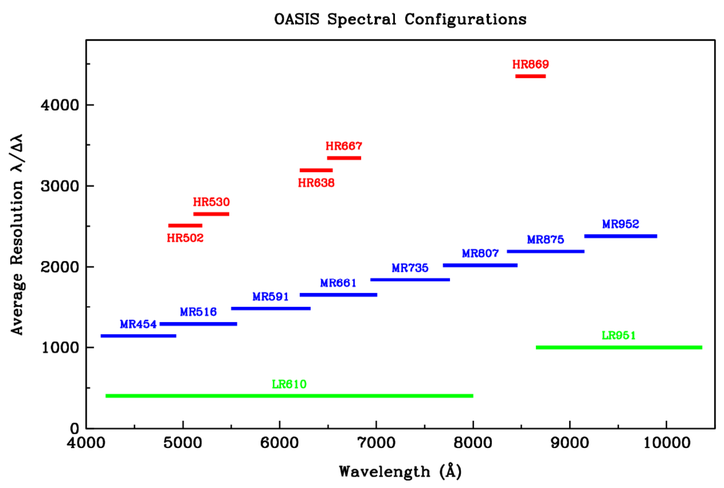


Figure 1: The wavelength coverage and spectral resolution of the 15 available spectroscopic configurations.

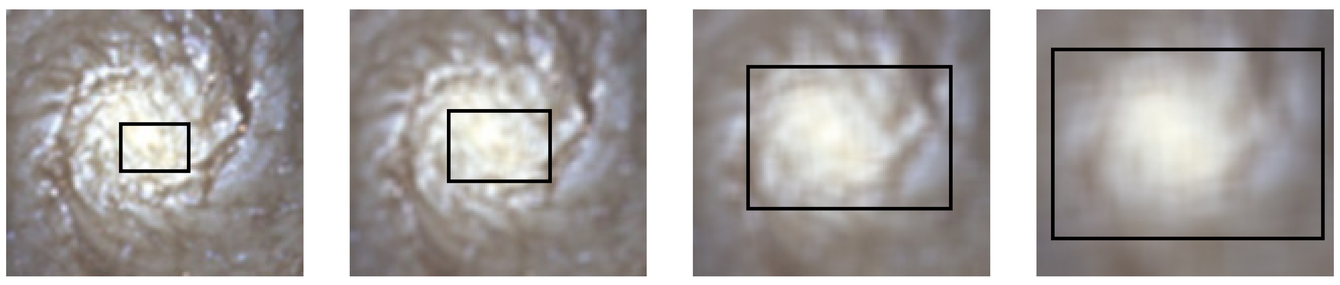


Figure 2: An illustration of the 4 different fields of view (FOVs) that are available with OASIS, and the corresponding spatial samplings. From left to right: (i) The 3.7" x 2.7" FOV (0.09" spatial sampling), (ii) 5.5" x 4.0" FOV (0.14" spatial sampling), (iii) 10.3" x 7.4" FOV (0.26" spatial sampling), and (iv) 16.7" x 12.0" FOV (0.42" spatial sampling). Note that the largest FOV is yet to be commissioned. (Figures adapted from ref [1].)

Probing the Wind of P Cygni with OASIS

We have obtained sixteen dithered 1 second observations of P Cygni with the MR735 spectral configuration (see Fig. 1) and the 0.26" spatial sampling (see Fig. 2). The data were reduced and mosaiced using the dedicated data reduction package XOasis (see panel to right). A sample spectrum is shown in Figure 3.

Our preliminary analysis indicates a source of [Ni II] λλ 7378, 7412 emission, almost centred on the star, with an intensity profile that is approximately Gaussian and of FWHM ~1" (see Fig. 4). For comparison, the stellar FWHM is 0.6".

The [Ni II] lines are formed by continuum fluorescence [ref. 2] and have previously been recorded in the spectrum of P Cygni's "inner nebula" (with an angular diameter of ~20") and its "outer arcs" (at 60" to 90") [ref. 3].

Our new high spatial resolution observations prove the existence of ejected material much closer to P Cygni.

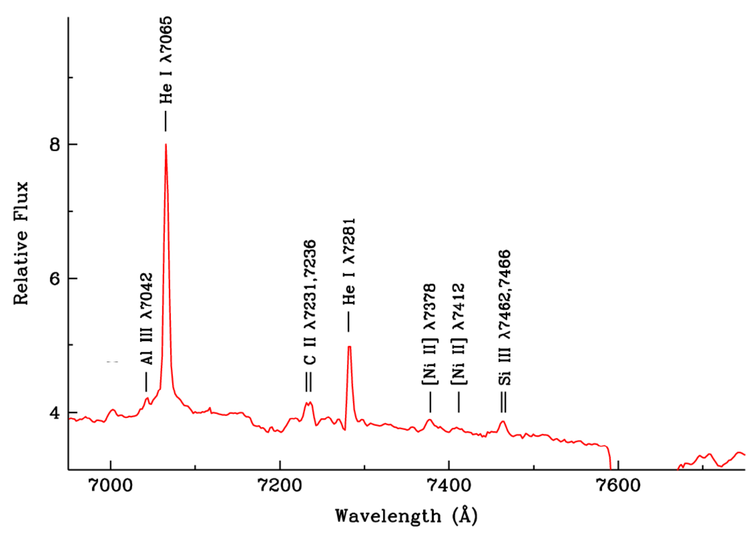


Figure 3: The spectrum of P Cygni, obtained using OASIS's MR735 spectral configuration. This particular spectrum corresponds to a single spatial element of the datacube, located at the centre of the stellar PSF.

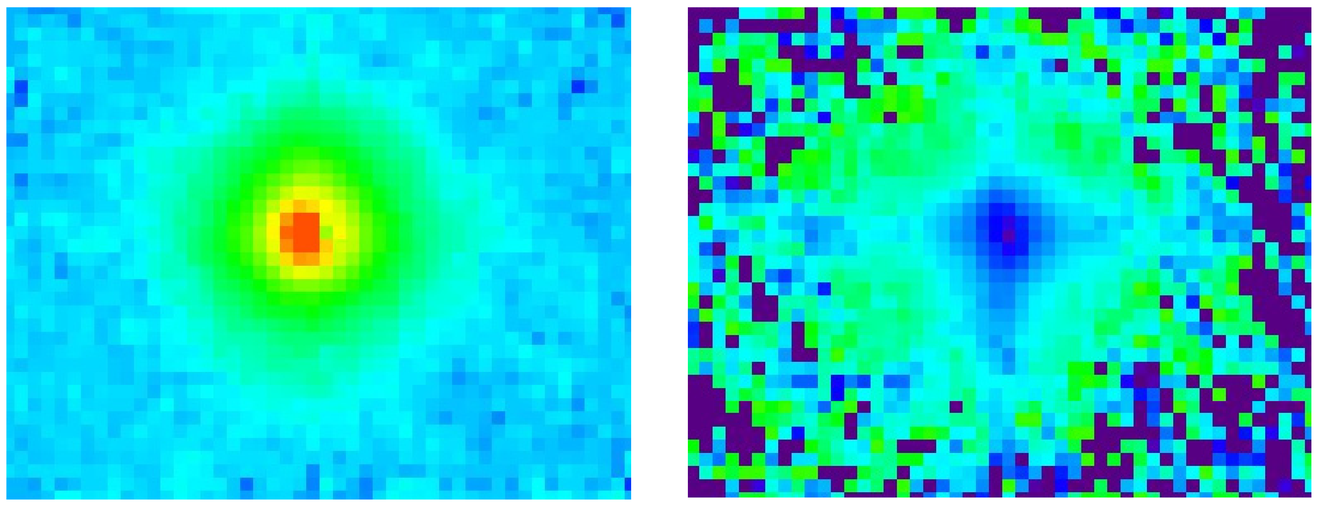
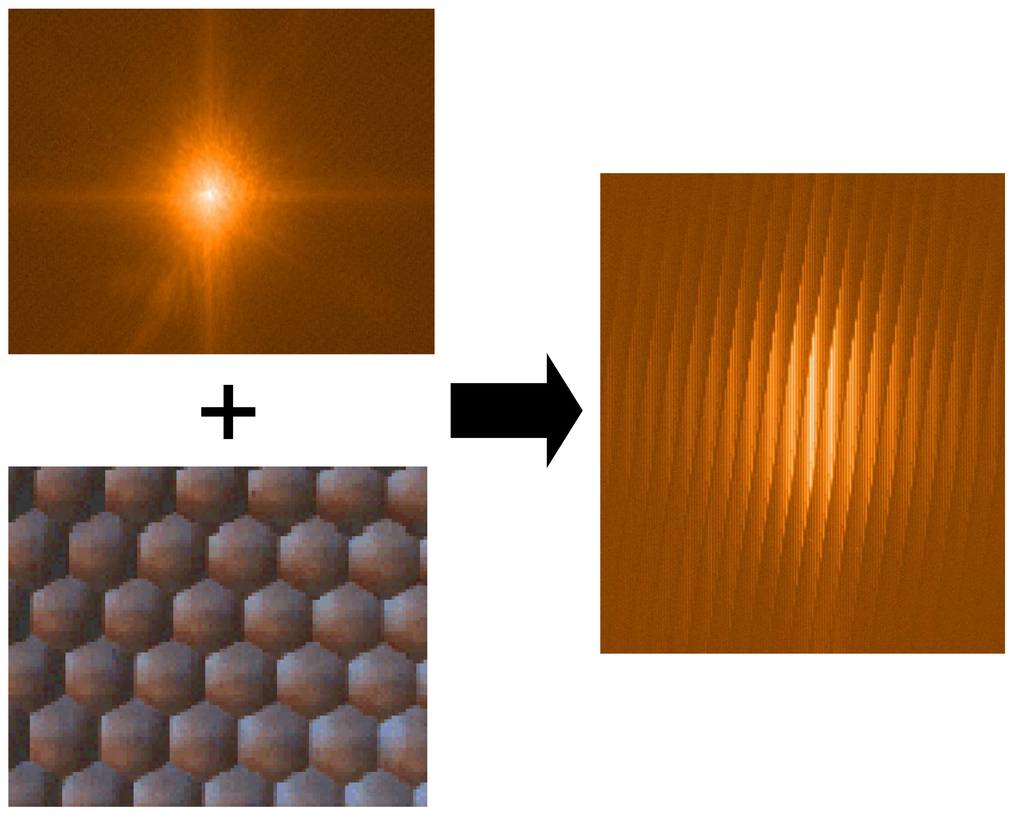


Figure 4: Reconstructed images showing (i) the strength of the [Ni II] λ7378 emission and (ii) the ratio of the [Ni II] λ7378 line to the stellar He I λ7281 line. The field of view of both images is 9.6" x 7.6". The second plot illustrates how the [Ni II] emission is distributed differently from the stellar light, confirming that it is being emitted from a different volume.

From Telescope to Datacube

The target P Cygni (*top left*) is imaged onto the 1100 hexagonal lenslets of OASIS (*bottom left*). The light is then dispersed with either a grism or prism, before being imaged onto the MITLL3 CCD. The format of the resulting spectra is shown (*below right*) for P Cygni; each small vertical strip corresponds to a single spectrum.



Given the complex format of OASIS data, a dedicated data reduction package *XOasis* has been developed, and is freely available to the astronomical community. XOasis can be operated with either a user-friendly GUI (see Fig. 5), or with a command line interface (thereby enabling the reduction process to be scripted).

The first reduction step is to process the CCD frames. Next an extraction mask is made (from various calibration frames) and used to extract the 1100 spectra on each individual exposure into a single datacube (*x, y, λ*). The spectra in each datacube are then wavelength calibrated, flat-fielded, cosmic ray rejected, sky subtracted and flux calibrated. Finally multiple exposures of a target are mosaiced (or simply coadded) to produce a single datacube.

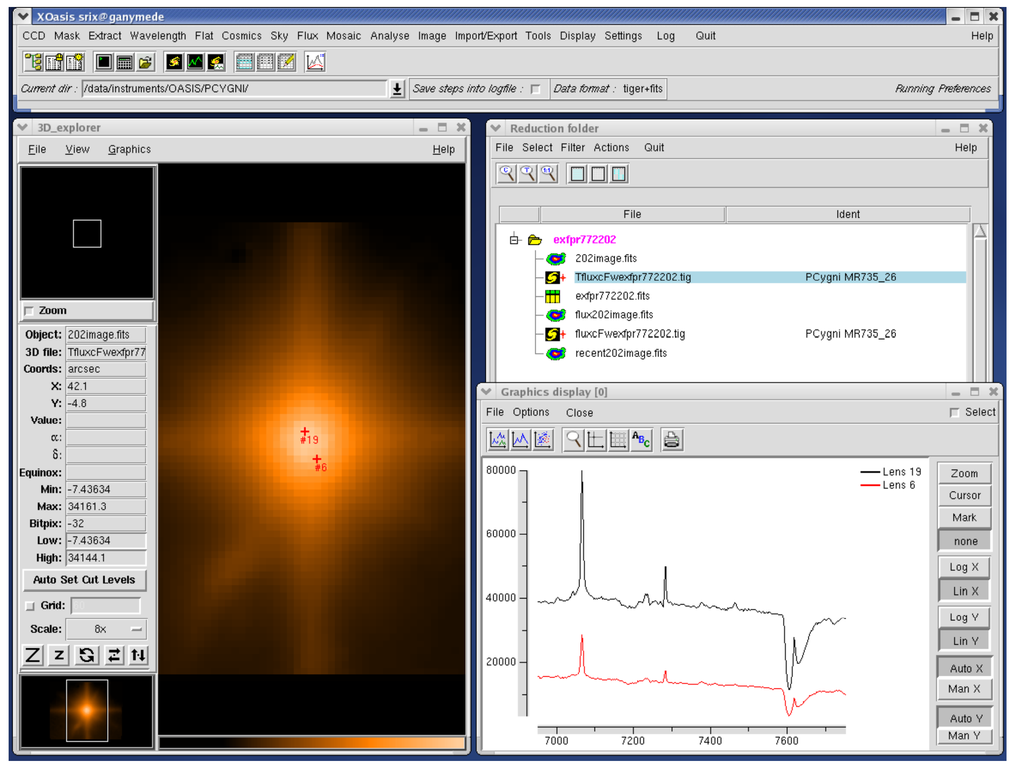


Figure 5: The XOasis GUI. The main GUI window (*top*) leads step-by-step through the reduction process, while the reduction folder (*centre right*) helps the user to keep track of the different files. XOasis also features a range of analysis and display tools. For example, it is possible to reconstruct an image of the target (by 'collapsing' the datacube in wavelength space), then display it using XOasis's integrated datacube explorer (*left*). By clicking on different positions in the field of view, one can interactively display the associated spectra (*bottom right*).

References

[1] Mendez, J. 2006, private communication

[2] Lucy, L. B. 1995, A&A, 294, 555, *Fluorescent excitation of [Ni II] lines in the spectra of gaseous nebulae*

[3] Barlow, M. J. et al. 1994, MNRAS, 268, L29, *The shock-excited P Cygni nebula*