X-shooter Science Verification Proposal

V458 Vul - a classical nova inside a planetary nebula

Investigators	Institute	EMAIL
Roger Wesson	University College London	rwesson@star.ucl.ac.uk
Paul Groot	Radboud University Nijmegen	pgroot@astro.ru.nl
Mike Barlow	University College London	mjb@star.ucl.ac.uk
Janet Drew	University of Hertfordshire	j.drew@herts.ac.uk
Jeremy Walsh	ESO	jwalsh@eso.org

Abstract:

V458 Vul was a classical nova which erupted in August 2007. Serendipitous pre-explosion images revealed the presence of a wasp-waisted nebula surrounding the nova progenitor, and spectroscopic follow-up showed that this was a planetary nebula. Subsequent images have shown dramatic changes in the nebula as the nova flash passes through it. The occurrence of a nova inside a planetary nebula is extremely rare and somewhat difficult to account for. Observations with the X-shooter IFU will permit a detailed kinematic and chemical study of the nebula and may shed important light on the common envelope phase of close binary evolution, and the role of close binaries in the formation of planetary nebulae.

Scientific Case:

Classical novae occur when mass transfer onto a white dwarf in a close binary system triggers runaway thermonuclear burning of hydrogen on the white dwarf's surface. Massive WDs in some nova systems may eventually produce Type Ia supernovae (Hillebrandt & Niemeyer 2000). Planetary nebulae (PNe) are formed when thermal pulsations in low to intermediate mass stars cause the ejection of the stellar envelope during the asymptotic giant branch (AGB) phase (Iben & Renzini 1983). It has been proposed that PNe are predominantly produced by close binary systems, during their common envelope stage of evolution (Moe & De Marco 2006). In this picture, some novae should occur inside PNe. V458 Vul, which erupted in August 2007, was later found to be an example of this phenomenon, only the second known after GK Per (Nova Perseii 1901). V458 Vul lies at a distance of 13kpc, and the combined mass of the two stars is likely to exceed $1.4M_{\odot}$ (Wesson et al. 2008). The two stars could potentially merge within a few million years.

The existence of a PN around V458 Vul is a boon for studies of both planetary nebulae and classical novae. It is likely to have been formed through common envelope ejection, and thus a detailed study of it can shed light on this aspect of close binary evolution. In addition, the current ongoing flash ionisation allows tight constraints to be placed on the distribution of circumstellar material, and the distance to the nebula - a unique opportunity in modern astronomy. A good understanding of the chemical composition and kinematics of V458 Vul's nebula is vital to understanding how this system arose, and whether or not a common envelope ejection is the dominant formation mechanism for planetary nebulae.

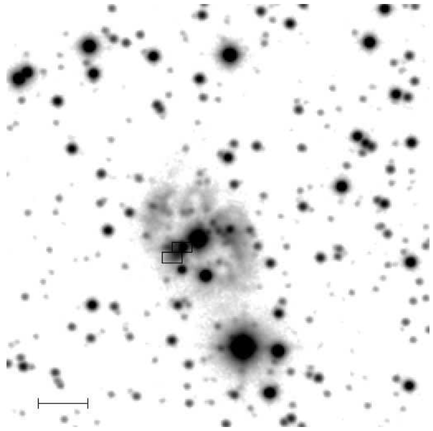

Figure 1: The nebula surrounding V458 Vul. The two boxes show the proposed IFU positions. The scale bar at the bottom left is 10 arcsec long

The high-resolution spatially-resolved spectra covering a very large wavelength range that X-shooter permits would be ideal for studying V458 Vul and its nebula. The nebula measures about 25x15 arcsec (Figure 1). With two pointings of the 4x1.8" X-shooter IFU (indicated on the Figure), we can observe the prominent knot 4.5" to the SE of the central star and some material beyond the knot which is likely to have been flash ionized. Spectra from the UVB and VIS arms would yield the Balmer jump and Balmer lines, permitting mapping of the temperature, density and extinction; a number of standard collisionally-excited line temperature and density diagnostics; and lines of helium and heavier elements to permit abundance determinations. The NIR arm would further give the hydrogen Paschen and Brackett series, and would also allow us to determine whether molecular hydrogen is present, giving further constraints on the mass of the PN progenitor. We may also detect an infrared excess from flash-heated dust.

Targets and observing mode

Target	**RA**	**DEC**	**V** mag	**Mode** (slit/IFU)	**Remarks**
V458 Vul	19 54 24.3	+20 52 47	>3e-16 erg/cm^2/s/"^{2*}	IFU	* Hα surface brightness

Time Justification:

Before the eruption of its central star, the nebula surrounding V458 Vul had an Hα surface brightness of about 3e-16 erg/cm^2/s/arcsec^2. Following its flash ionization it is a factor of several brighter. Using the X-shoooter exposure time calculator we find that an 1800s exposure would give a signal to noise ratio of 50-100 per spectral bin in the UBV and VIS arms (the NIR arm is not covered by the template spectra available to the ETC). This would allow us to accurately measure the fainter diagnostic lines such as [O III] 4363, [N II] 5754, [S III] 6312 and [Ar III] 5192. We request two pointings, with an exposure time of 1800s on each, split into two exposures to allow cosmic ray rejection. Including all overheads, this gives a total time request of 76 minutes.