X-shooter Science Verification Proposal

Shooting the massive post-Red Supergiants, IRC +10420 and HD 179821

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Abstract:

Few stars appear to evolve on timescales that they can be followed by astronomers. With this proposal we plan to observe the massive post-red supergiants IRC +10420 and HD 179821, objects that have evolved significantly over the past 30 years. IRC +10420 has been shown to have increased its temperature by 2000K, while HD 179821 appears to be evolving to the blue now. Both objects display a variable emission line spectrum, betraying recent changes in the circumstellar material. We propose to obtain the first simultaneous blue-optical-near-infrared spectra of these objects. The primary aim is to study the temperature evolution, while the data finally allow us to analyse the emission line spectra from the optical to the near-infrared simultaneously. The objects are relatively bright, and the half-an-hour observations will result in good SNR spectra, yet stretch the X-Shooter spectrograph as both stars are very red. Indeed, IRC +10420 is an extremely red object with B=14 ranging to K=3.5.

Scientific Case:

Post-Red Supergiants are yellow hypergiants found in the evolutionary phase between the Red Supergiants and the Wolf-Rayet or Luminous Blue Variable stars. It is here that the shaping of the circumstellar material takes place and as SN-progenitors, these objects can provide crucial information on the geometry of SNe and Gamma-Ray Bursts. Many yellow hypergiants are known (e.g. Lobel et al. 2003, ApJ 583 923) but IRC+10420 and HD 179821 are the only ones with an infrared excess due to cool dust, and as such are the *only* objects known to be in this short evolutionary phase (e.g. Kastner & Weintraub 1995, ApJ 452, 883, Oudmaijer et al. 2008 arXiv:0801.2315). Hence, these two objects provide a unique opportunity to study the late stages of evolution of massive stars.

In Patel et al. (2008, MNRAS 385, 967) we reviewed the photometric history of both objects, and found that both objects show evidence of evolution towards the blue in the HR diagram, consistent with evolutionary computations. For IRC +10420 this had been spectroscopically confirmed (Oudmaijer 1998, A&AS 129, 541 discussed the change in spectral type from F8I to A-type). Currently, the photometry seems to indicate a slowing down of the temperature increase, but this needs spectroscopic confirmation. For HD 179821 the temperature increase is limited to 1 or 2 subtypes (Patel et al.). Importantly however, few spectral classification-grade spectra have been discussed in the literature. Therefore, to investigate the temperature evolution, we need new spectroscopy to underpin the photometry in both cases.

IRC +10420 has a particularly rich emission line spectrum (e.g. Humphreys et al. 2002 AJ 124, 1026). The emission lines in the optical and near-infrared could never be properly compared as the data were inevitably taken non-simultaneously. This is particularly important when investigating the nature of the hydrogen recombination line emission. To interpret the AMBER interferometry of IRC +10420 around Brγ, its NIR emission had to be compared to Hα (de Wit et al. 2008, A&A 480, 149). However, with non-simultaneous data, it is impossible to draw final conclusions.

The *JHK*-band spectra of both objects have hardly been discussed in the literature, yet, the on-going uncertainty on the non-symmetry of the inner regions of their circumstellar material (e.g. Davies et al. 2007 ApJ 671, 2059) needs the crucial information provided by the CO first overtone emission at 2.3 μm tracing hot dense, disky material. HD 179821 has variable CO emission (Oudmaijer et al. 1995, A&A 299, 69), but a high resolution study has been lacking. X-Shooter data will allow us to study the kinematics of the CO emitting region and assess whether it is formed in a small circumstellar disk or not.

Calibration strategy:

An early type standard star for the correction of telluric absorption lines should be observed close to the targets. As both objects are close on the sky, the sequence could be target - standard - target. If this is not done automatically during the SV phase, I can provide a target list.

Targets and number of visibility measurements

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
IRC+10420	19 26 48	+11 21 16	B=14, V=11,K=3.5	slit	
HD179821	19 13 58	+00 07 32	B=9.6,V=8, K=4.7	slit	

Time Justification:

Apart from the blue spectral arm for IRC +10420, both objects are bright enough for narrow slits and this a high spectral resolution of ∼10,000. A

Ideally, a SNR of more than 100 is required to provide good measurements of even faint features. With the exception of the bluest wavelengths in IRC +10420 this is easily achieved with X-Shooter:

IRC +10420 (B=14.5, V=11, K=3.5): For slit widths of 1.0, 0.4, 0.4 arcsec respectively, a 3000K Black Body (to mimick the redness of the object) and a typical seeing of 1arcsec, the ETC indicates exposure times of 1200s are needed for B=15 to result in a SNR larger than 50 at the Balmer cut-off at 3650 Å. This sets the total on-target time.

At all other wavelengths the signal to noise ratios comfortably exceed 100-200. In the blue the exposure times need to be split over shorter exposures of order 300s to prevent saturation at the redder wavelength. Splitting the 1200s exposure into 4 separate exposures will allow us to do the ABBA sequence required for the NIR observations. In the optical arm maximum individual exposure times of order 60s are required.

In the near-infrared exposures have to be limited to 0.5s or 1s. The observations need to be split into one ABBA sequence (4 observations, one per sky position) to eliminate the background emission in the NIR images. 1 exposure per target position would be enough. Given the overheads involved, as many exposures within the 300 s per sky position will be done.

The overheads will then be 570s (target acquisition) + 4×48s (slowest (VIS) readout per sky position) + 4×15s (offsets) gives 822sec. So, 2000s are required for IRC +10420.

HD 179821 (B=9.6, V=8, K=4.7). For 1arcsec seeing, 0.5, 0.4, 0.4 arcsec slits and a 6000K Black Bosy, we find that a total 150s exposure time will result in SNR much larger than 100 at all wavelengths. Just like IRC +10420, the exposure time needs to be split in individual exposures to prevent saturation. Including the overhead of 822s, we arrive at 972 ∼ 1000s for this object. Giving a total of 3000s.

In addition, a telluric standard star needs to be observed. This can be interspersed with the targets as they are close together, and just like the bright HD 179821, around 1000s is needed, giving a grand total of 4000s, a little over an hour of observing time for this SV proposal.