X-shooter Science Verification Proposal

Title: Testing the accretion tracers in a Pre-Main Sequence star.

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Abstract:

Determining the mass accretion rate ($\dot{M}_{acc}$) of Pre Main Sequence (PMS) stars is a fundamental issue in order to understand their evolution. However, values of $\dot{M}_{acc}$ derived for a given object from simultaneous measurements of different spectroscopic accretion tracers could differ significantly. Testing the consistency of all the accretion probes has been difficult to date since PMS stars are variable accretors and the tracers span from the UV to the nIR, difficulting their simultaneous measurements. This proposal aims to compare different commonly used accretion tracers measuring them from three different epoch spectra of a Classical T Tauri (CTT) star. VLT/X-Shooter provides for the first time the opportunity of testing and comparing the values of $\dot{M}_{acc}$ derived from the UV-veiling, and their variations, with those obtained from simultaneous measurements of the Hα, CaII (8662 Å), Paβ and Brγ lines.

Scientific Case:

Quantifying the mass accretion rate of PMS stars is crucial for understanding the evolution of the gas content in their circumstellar disks.

Emission lines from the optical to the nIR are used as quantitative accretion tracers. The Brγ (2.2 μm), Paβ (1.3 μm) and CaII (8662 Å) luminosities, as well as the width at 10% peak intensity (W_{10}) of the Hα (6562 Å) line, are commonly used to estimate the accretion rates of CTT stars. Those correlate with the values of $\dot{M}_{acc}$ derived from the UV veiling resulting from the accretion shock (Calvet et al. 2004), or from the magnetospheric accretion modelling of the Hα line (Muzerolle et al. 2003, Natta et al. 2004). In this way, it has been established that log $L_{acc}/L_\odot$ = 0.9 $\times$ (log $L_{Br\gamma}/L_\odot$) + 4) - 0.7 (Calvet et al. 2004), log $L_{acc}/L_\odot$ = 1.36 $\times$ log $L_{Pa\beta}/L_\odot$ + 4.00, log $\dot{M}_{acc}$ = -12.89 + 9.7 $\times$ $10^{-3}W_{10}$(Hα) (Natta et al. 2004) and log $\dot{M}_{acc}$ = 0.93 $\times$ log F_{CaII} -15.03 (Mohanty et al. 2005) are useful correlations to derive accretion rates in PMS stars.

Although the mentioned accretion tracers are widely used, it is not proven that all of them really provide the same results when they are measured simultaneously. In fact, they could also probe different physical processes not related to accretion. Nguyen et al. (2009) recently found that the amplitudes of the $\dot{M}_{acc}$ variability, as derived from the Hα and CaII (8662 Å) tracers, do not correlate to each other in CTT stars. A similar result is suggested by Mendigutía et al. (2009) for the Hα and Brγ lines in the more massive Herbig Ae/Be objects. PMS stars are variable and the spectroscopic accretion tracers extend over a wide wavelenth range; therefore, testing the consistency of all of them has been almost impossible to date, since it would require simultaneous observations using observing modes covering different wavelength regions (UV-VIS and nIR spectroscopy and photometry). VLT/X-Shooter offers, for the first time, the possibility of obtaining simultaneous spectroscopic and spectrophotometric information in the whole 0.3–2.5 μm range.

We propose to use this unique capability of VLT/X-Shooter to test and compare the feasibility of the different accretion tracers. In order to achieve this goal we will probe the PMS object ISO-Oph 40 in the ρ Ophiuchi star forming region. This is a CTT star whose mass ($\sim$ 0.8 $M_\odot$, Wilking et al. 2005) is apropriate to apply the above mentioned correlations with the accretion tracers. This object is susceptible of showing veiling. Moreover,it is a strong accretor according to its Paβ luminosity (log $\dot{M}_{acc}$ $\sim$ -6.7, Natta et al. 2006) and its X-ray detection (Gagné et al. 2004), it has the CaII8662 and the Hα lines in emission (EW $\sim$ -4.4 Å, and FWHM $\sim$ 240 km s^{-1}, respectively. Wilking et al. 2005, which translates into $\dot{M}_{acc}$ > -10.6) and its visibility is optimum during the X-Shooter SV period.

We aim at obtaining intermediate-high resolution (R $\sim$ 9000 – 17000) UV–optical–nIR spectroscopic and spectrophotometric measurements of the CTT star ISO-Oph 40 using VLT/X-Shooter. We will derive the accretion rate from the UV-veiling. This will be compared with those obtained from the empirical calibrations between the accretion rate and the Brγ, Paβ, CaII (8662 Å) and Hα lines. Magnetospheric accretion fitting of this line will also be performed. The amplitude of the accretion rate variations derived from the different tracers can be compared to each other using multi-epoch observations. Three is the minimum number of spectra necessary to derive linear correlations, if any, between the different tracers. In this way, we propose to obtain three-epoch X-Shooter spectra of the selected target to test whether and to what extent the different accretion tracers correlate to each other and provide the correct values for $\dot{M}_{acc}$ and its variations.

This can be considered as a first-order approach to the scientific problem, that could be revisited in the future by submitting similar proposals using more stars and/or extended time-scale coverage. In any case, should the proposal be accepted, it will show the potential of X-Shooter to unveil hot topics as that described above.

References:

Calvet et al. 2004, AJ, 128, 1294
Gagné et al. 2004, ApJ, 613, 393
Mendigutía et al. 2009, A&A, "Optical spectroscopic variability of HAeBe stars". in prep.
Mohanty et al. 2005, ApJ, 626, 498
Mora et al. 2001, A&A, 378, 116
Muzerolle et al. 2003, ApJ, 592, 266
Natta et al. 2004, A&A, 424, 603
Natta et al. 2006, A&A, 452, 245
Nguyen et al. 2009, arxiv:0902.4235v1
Wilking et al. 2005, AJ, 130, 1733

Calibration strategy:

We need to derive absolute fluxes, therefore spectrophotometric observations are needed (see below). We assume the telluric and spectrophotometric standards absorbed by the X-Shooter calibration plan. Reduction procedures will be done using the pipelines provided by ESO.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**Mode** (slit/IFU)	**Remarks**
ISO-Oph 40	16 26 24.09	-24 16 13.3	14.40	slit	photometric conditions required

Time Justification:

As mentioned above, we propose to observe the target star three times during the SV runs. We request two of these observations to be separated $\sim$ 10 nigths to sample the timescale where variations in the accretion rate are typically higher (Nguyen et al. 2009). We also request the time interval between the first and the second observation to be different to that between the second and the third. This will allow to sample different timescales and to avoid possible periodicity from hot spot effects (the projected rotational velocity of the star will be derived by fitting and broadening a synthetic spectrum to the photospheric lines shown in the X-Shooter spectra, as in Mora et al. 2001). Each observing run consists of two different, complementary and consecutive observations of the target star: spectroscopic and spectrophotometric. The highest available resolutions will be used in each arm for the spectroscopic observations in order to detect, resolve and characterize the emission line accretion tracers. Low-resolution spectrophotometry will transform the spectroscopic equivalent widths into line fluxes, fixing the stellar continuum, which is typically variable in PMS stars. For the spectroscopic observations, the slit widths proposed are 0.5"/0.4"/0.4" for the UV/VIS/nIR arms, respectively. According to the X-Shooter manual this means resolutions of 9100/17400/11300, enough to study the spectroscopic accretion tracers (see the references above). An ABBA sequence is required. Assuming a seeing and airmass conditions of 1.2" and 1.6, the integration time needed per position is 2000 s, splitted into 8/4/4 exposures for the UV/VIS/nIR arms. This generates a SNR $\geq$ 100 in each arm. For the low resolution spectrophotometric observation, the widest slit of 5" will be used for each arm. Using the same conditions and requirements as in the spectroscopic observation, the ETC predicts a total exposure time of 1000 s per position. Overheads have been estimated from the X-Shooter manual. Using the slow 1×1 binning and fast 2×2 binning reading modes 10870 s and 4146 s are required for the spectroscopic and the spectrophotometric observations, respectively. Therefore 4.2 h is needed for each observing run. A total of 12.6 h is needed if the object is observed in three different nights during the SV runs.