X-shooter Science Verification Proposal

Title: Probing the magnetospheric accretion in magnetic Herbig Ae stars

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Abstract:

It is generally accepted that star formation occurs via accretion. A number of Herbig Ae stars and classical T Tauri stars are surrounded by active accretion disks and, probably, most of the excess emission seen at various wavelength regions can be attributed to the interaction of the disk with a magnetically active star. This interaction is generally referred to as magnetospheric accretion. Longitudinal magnetic fields of different strength, from a few tens to a few hundreds of Gauss, have been detected in a dozen of Herbig stars. However, mass-accretion rates have been measured for only a few magnetic Herbig Ae stars. We propose to use X-shooter to compare the accretion properties of strongly and weakly magnetic Herbig Ae stars using Brγ, Paγ, Paβ, He I 10830, the Ca II near infrared triplet and Ca II doublet H and K, low number Balmer lines including Hα, the Na I D lines, and a number of metal emission lines (O I, Fe II, Ti II, etc.). The proposed observations are important to understand the role of magnetic fields in the dynamics of the accretion process in Herbig Ae stars.

Scientific Case:

Recent magnetospheric accretion models for Herbig Ae stars and classical T Tauri stars assume a dipolar magnetic field geometry and accreting gas from a circumstellar disk falling ballistically along the field lines to the stellar surface. Vink et al. (2002, MNRAS 337, 356) presented their results of Hα spectropolarimetric observations of a sample of 23 Herbig Ae/Be stars, pointing out the possibility of the existence of a physical transition region in the H-R diagram from magnetospheric accretion, similar to that of cTTS, at spectral type A to disk accretion at spectral type B. Also the recent results of low resolution linear spectropolarimetric observations of Herbig stars in Hα, Hβ, and Hγ by Mottram et al. (2007, MNRAS 377, 1363) support the presence of magnetospheric accretion in Herbig Ae stars.The main difference between the scenarios for Herbig Ae and Be stars is that in Herbig Ae stars the stellar magnetic field truncates the accretion disk at a few stellar radii and gas accretes along magnetic channels from the protoplanetary disk to the star, while in Herbig Be stars the accretion flow is not disrupted by the field.

As magnetic fields are believed to play a crucial role in controlling accretion onto, and winds from, Herbig Ae stars, there were several attempts to measure magnetic fields in these stars (e.g., Hubrig et al. 2004, A&A 428, 1; 2006, A&A 446, 1089; 2007, A&A 463, 1039; 2009, A&A in press; Wade et al. 2005, A&A 442, 31; Catala et al. 2007, A&A 462, 293). Longitudinal magnetic fields of the order of a few tens to a few hundreds of Gauss have been detected in a dozen of Herbig Ae stars: HD 31648, HD 97048, HD 101412, HD 135344B, HD 139614, HD 144432, HD 144668, HD 150193, HD 176380, HD 190073, BF Ori, and V380 Ori.

However, mass-accretion rates have been measured for only a few magnetic Herbig Ae stars. The values of $\dot{M}_{\rm acc}$ were derived by Garcia Lopez et al. (2006, A&A 459, 837) from the measured luminosity of the Brγ emission line, using the correlation between L(Brγ) and the accretion luminosity $L_{\rm acc}$, established by Muzerolle et al. (1999, AJ 116, 2965) and Calvet et al. (2004, ApJ 128, 1294). The correlation which was used is empirical and makes no assumptions on the origin of Brγ. An important result found recently by Kraus et al. (2008, A&A 489, 1157) is that the Brγ line can trace both mass infall and outflow, implying that Brγ is probably only an indirect tracer of the mass-accretion rate.

Using the huge wavelength coverage achievable with X-shooter in one shot, we will be able to derive the mass accretion rate of each object from the luminosity of the Brγ line and compare the results with accretion properties obtained from other hydrogen recombination lines Paγ and Paβ, the He I 10830 line, the low number Balmer lines including Hα, the Na I D lines, the Ca II near-infrared triplet and the Ca II doublet H and K lines, and a number of metal emission lines (O I, Fe II, Ti II, etc.). Some of these lines (such as He I 10830), are diagnostics for both, magnetospheric funnel flows and outflows and will provide important information on star-disk interaction regions. The forbidden lines [N II], [S II], and [O I] will be used to study T_e and n_e in outflows or in a jet. The atmospheric parameters necessary to produce the synthetic stellar photospheric spectrum are in part available from our own work or will be taken from other literature sources. Since Herbig stars are highly variable on different time scales the availability of the whole wavelength spectral regions obtained with X-shooter in one shot is indispensable to study different spectral lines as accretion/outflow tracers simultaneously. The proposed observations are important to understand the role of magnetic fields in the processes playing role in the star-disk interaction region.

Calibration strategy:

For the blue and red arms of X-shooter, apart from usual calibration frames, we would need the observations of a spectrophotometric standard star with a wide slit to estimate the slit losses. For observations in the near infrared we will need, in addition to usual calibration frames, the observations of a telluric star (hot star) observed at a similar airmass and of a NIR spectrophotometric standard star with a wide slit. At large zenith distances the slit should be placed at the parallactic angle.

Targets and number of visibility measurements

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
HD 101412	11 39 44	-60 10 28	9.0	slit	First priority
HD 139614	15 40 46	-42 29 54	8.3	slit	First priority
HD 144668	16 08 34	-39 06 18	7.0	slit	First priority
HD 150193	16 40 18	-23 53 45	8.9	slit	First priority
VV Ser	18 28 48	00 08 39	11.6	slit	First priority
HD 176386	19 01 39	-36 53 26	7.3	slit	First priority
HD 190073	20 03 03	05 44 17	7.8	slit	First priority

Time Justification:

The time necessary to observe seven Herbig Ae stars with X-shooter was estimated using the X-shooter exposure time calculator. To observe a star of 11.6 magnitude in mediocre conditions (seeing of $1.4''$) in the UVB arm with the $0.5''$ slit and with the RED arm with the $0.4''$ slit with the readout mode low,1x1,fast we would need an exposure time of $\approx$15 min to reach a S/N of $\sim$300–350. For the NIR arm, for a star of the same magnitude, we would like to obtain one nodding cycle with the slit $0.4''$ and exposure time of 20 min. Taking into account overheads, to observe all seven magnetic Herbig Ae stars we would need 1h 30min of telescope time.