ACCRETION PROPERTIES OF LOW MASS EMBEDDED PROTOSTARS.

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Mass accretion is the key process regulating how young stars build up their mass at early stages of their evolution. During the accretion phase low mass protostars are characterised by the presence of several structures in the circumstellar environment, such as the accretion disc, the magnetosphere accretion region, collimated jets and, in more embedded sources, the outer dusty envelope, that has not been dispersed yet. For these more embedded sources (the so-called Class I objects), the large extinction coupled with strong emission excess due to the circumstellar activity, make it difficult to disentangle the properties of the central star from those of the various active circumstellar regions, as is done for the more evolved and less extincted T Tauri stars (Class II sources) through observations at different wavelengths.

This is the main reason why the mass accretion rate of these Class I YSOs is still poorly constrained from an observational point of view, being in fact unknown, in particular, the real fraction of the source luminosity due to accretion only and the mass of the central protostellar object. Indeed, the general assumption so far applied is that most of the bolometric luminosity of Class I objects is due to accretion. Recently, however, the stellar properties of small samples of Class I stars have been derived on the basis of the weak photospheric lines detected in optical scattered light (White & Hillenbrand 2004) and in near-IR direct emission (Greene & Lada 2002; Nisini et al. 2005a; Doppmann et al. 2005). Such studies have shown that the characteristics of Class I objects vary significantly. In particular, the accretion luminosity may span from few percent up to 80% of the bolometric luminosity; these findings indicate that not all sources defined as Class I are actively accreting objects and suggest that the classification of young stellar objects based on the shape of their Spectral Energy Distribution (SED) needs probably to be revised.

On the other hand, indirect evidence of the ongoing accretion process in Class I sources is sometimes provided also by the presence of powerful collimated jet-like structures recognisable down to the source itself. According to the models (Königl & Pudritz 2000; Casse & Ferreira 2000), accretion and ejection are indeed intimately related through the presence of a magnetised accretion disc: the jets carry away the excess angular momentum, so that part of the disc material can move toward the star. The efficiency of this process is measured by the ratio between the mass ejection and mass accretion rates ($\dot{M}_{loss}/\dot{M}_{acc}$), and depends on the jet acceleration mechanism in place. Measurements of such an efficiency have been so far obtained only for classical T Tauri stars and values of $\dot{M}_{loss}/\dot{M}_{acc}$ in the range 1-10% has been found by different studies (e.g. Hartigan et al. 1995; Gullbring et al. 1998). Nevertheless, it is important to test accretion/ejection models in young sources at earlier stages of evolution, when accretion is believed to dominate the energetics of the system and thus the mechanism to extract angular momentum is expected to be more efficient.

In this framework, we have investigated a sample of Class I objects (selected for having a positive spectral index between 2 and 12 μm) using near-IR spectroscopic observations (VLT-ISAAC spectra in the H and K bands). The complete sample is composed of sources belonging to different star-forming regions; recent measurements on a group of objects in the ρ Oph cloud and on three sources showing collimated jets close to the source will be presented and compared to previous similar observations of a set of Class I objects in the R CrA star-forming region.

The measurements consist, for each source, of three medium resolution (R $\sim$ 9000) source spectra centered at 1.65, 2.14, 2.25 μm; in the investigated wavelength ranges lie important emission features tracing both the jet and the accretion region (e.g. H_2, [Fe II], HI, NaI, CO) as well as several absorption lines that can be used (if detected) as a diagnostic tool for spectral classification (Greene & Lada 2002; Nisini et al. 2005a). For objects with jets, the slit has been aligned along the known jet axis.

On the basis of the features detected in the spectra, we want to study the accretion properties of the sources, i.e. determine their accretion luminosity ($L_{\rm acc}$) and mass accretion rate and also discuss the connection of the $\dot{M}_{\rm acc}$ with other quantities such as the emission lines fluxes, the veiling from continuum excess emission and the mass loss rate $\dot{M}_{\rm loss}$, which can be estimated for sources of the sample displaying ejection activity close to the central star, thus getting information on the efficiency of the accretion/ejection process.

The spectra show typically the presence of several emission features: strong permitted lines (e.g. HI, NaI, CO) and tracers of outflow activity (H_2, [FeII]); two examples of the observed spectra are displayed in Fig 1. Such emission lines are believed to arise in the circumstallar gas (accretion flows, winds and disc) while the possible detection of absorption lines of the central star photosphere depends on the amount of veiling from continuum excess, related to the radiation emitted in the accretion shock. It is therefore evident that the analysis of these spectral features can provide information on the accretion process ongoing in the circumstellar region.

The accretion luminosity of the sources has been derived using the relationship found by Muzerolle et al. (1998) on the basis of observations of T Tauri stars, in which $L_{\rm acc}$ is directly related to the (extinction-corrected) HI Brγ flux, assuming therefore that this relation is still valid for the Class I sources of our sample. The analysis shows, in general, that in most cases the derived accretion luminosity accounts only for a small fraction of the bolometric luminosity of the sources. Accretion rates in the range 10^{-8}-10^{-7} $M_\odot$ yr^{-1} have been derived, similar to the average values found in T Tauri stars.

For sources displaying jet-like structures close to the central object (namely HH34 IRS, HH26 IRS and HH46 IRS) the mass loss rate has been determined using flux measurement of the [FeII] and H_2 emission lines along the jet (Nisini et al.

2005b). In such a way, it is possible to perform a comparison between the rates, deriving information on the efficiency of the accretion/ejection process. The inferred $\dot{M}_{\rm loss}/\dot{M}_{\rm acc}$ ratio spans in the range 0.05-0.2 for HH26 IRS and HH46 IRS and is larger than $\sim$0.7 for HH34 IRS, quantities to be compared to a value of around 0.1 expected from models. The wide range of ejection/accretion efficiency derived, together with the low L_{acc}/L_{bol} found, could be explained in the framework of time dependent accretion bursts lasting for time-spans shorter than the jet cooling time. We cannot however exclude the possibility that accretion luminosities derived from HI lines might underestimate the true L_{acc} value in embedded young stars. This could be the case if the ionization fraction in the HI emission region is lower than in classical T Tauri stars. Evidences in this sense are given by the low Brγ/NaI ratio observed in some sources, at variance with what is observed in other young embedded objects where an L_{acc}/L_{bol} $> 50\%$ have been estimated (Nisini et al. 2005a).

We note that in these objects the presence of permitted emission lines does not appear to be connected with the simultaneous presence of jet lines from the region closely surrounding the central source, indicating that no precise correlation exists between the presence of the jet and the accretion properties displayed by the objects.

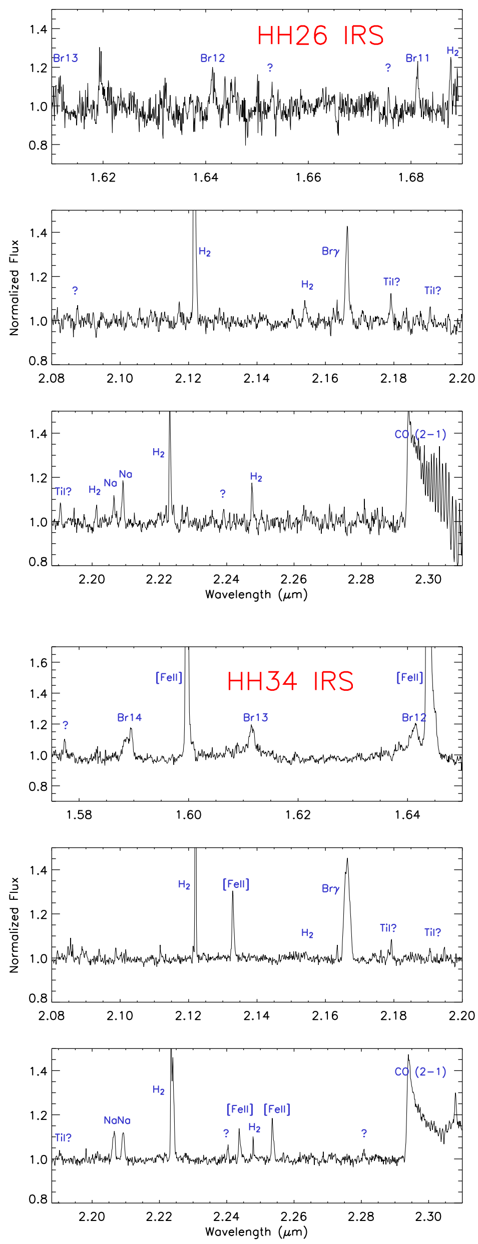

Fig. 1. Examples of observed NIR VLT-ISAAC spectra: HH26 and HH34 IRS (Antoniucci et al. 2007). The plots display an H band segment (top panels) and two contiguos spectral regions in the K band. Several emission features can be observed, related to the accretion and ejection processes ongoing in the young sources. The analysis of these features provides therefore information on the physical parameters of such processes, permitting to derive estimates of the mass accretion rate $\dot{M}_{\rm acc}$ and mass loss rate $\dot{M}_{\rm loss}$.

References

Antoniucci, S., Nisini, B., Giannini, T., & Lorenzetti, D. 2007, A&A, in preparation

Casse, F. & Ferreira, J. 2000, A&A, 353, 1115

Doppmann, G. W., Greene, T. P., Covey, K. R., & Lada, C. J. 2005, AJ, 130, 1145

Greene, T. P. & Lada, C. J. 2002, AJ, 124, 2185

Gullbring, E., Hartmann, L., Briceno, C., & Calvet, N. 1998, ApJ, 492, 323

Hartigan, P., Edwards, S., & Ghandour, L. 1995, ApJ, 452, 736

Königl, A. & Pudritz, R. E. 2000, Protostars and Planets IV, 759

Muzerolle, J., Hartmann, L., & Calvet, N. 1998, AJ, 116, 2965

Nisini, B., Antoniucci, S., Giannini, T., & Lorenzetti, D. 2005a, A&A, 429, 543

Nisini, B., Bacciotti, F., Giannini, T., et al. 2005b, A&A, 441, 159

White, R. J. & Hillenbrand, L. A. 2004, ApJ, 616, 998