Spectro-astrometry of Massive Young Stars

Jorge M. C. Grave[1,2] and M. S. Nanda Kumar[1]

[1]Centro de Astrofísica da Universidade do Porto
[2]Departamento de Matemática Aplicada da Faculdade de Ciências da Universidade do Porto

Abstract: We report a spectro-astrometric analysis of the near-infrared spectra of massive young stars, aiming to investigate the properties of their close environment. The study of emission lines such as Brγ and the CO 2-1 and CO 3-1 bandheads have revealed positional displacements with various shapes and magnitudes which imply the presence of large disks/envelopes of molecular gas and expanding shells of ionized material. In particular, the results obtained for the source 18006-2422nr766 provide large estimates (> 300AU) for the size of the CO emitting region suggesting that CO emission in massive young stellar objects is also arising from the inner regions of the dense envelopes.

Objectives - Understanding of close environment of massive young stellar objects (MYSOs) is a key step in unveiling the mechanisms by which these stars are formed. The relative larger distances at which they are generally situated have made observations of these structures very difficult. We have tested the technique of spectro-astrometry as a tool to analyze the inner regions of the environment of a massive young star due to its potential in revealing information at very small angular scales.

Data - We have analyzed VLT/ISAAC near IR spectra of 3 massive young stars obtained from the ESO Science Archive, namely 08576-4334nr292, 18006-2422nr766 and 16164-5046nr3636.

Spectro-astrometry – We obtained the position spectra (centroid of the PSF as a function of wavelength) for the emission lines of MgII, H_2, Brγ and CO bandheads. These are tracers of hot photospheres, shocked or fluorescent gas, ionized regions and dense disks/envelopes respectively.

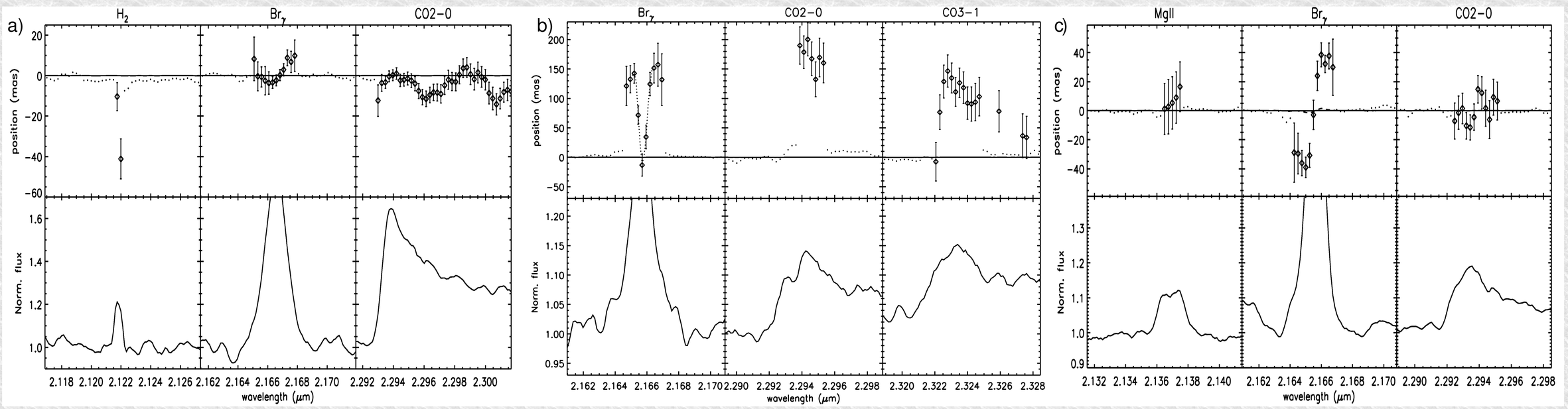

Fig.1- Position spectra (top rows) and normalized intensity spectra (bottom rows) for different lines found on the spectra of 08576-4334nr292 (a), 18006-2422nr766 (b) and 16164-5046nr3636 (c). The name of the line is represented on top of the respective position spectrum. The diamonds correspond to the position spectra of signals treated as lines and dots represent the position spectra of signals treated as continuum. The horizontal line marks the fitted continuum position. The dashed line on the Brγ position spectra plot of 16164-5046nr3636 shows the model of an artificial position spectra resulting from a distorted PSF[2].

16164-5046nr3636 – The Brγ line in fig.1c has a significant SA signal with the blue-shifted and red-shifted parts of the line profile displaced in opposite directions with respect to the continuum source. Comparing the measured Brγ position spectra with the distorted PSF spectra, we exclude the artifact scenario. Such a profile is most likely explained by an expanding shell around the central star due to an UCHII region or a wind.

08576-4334nr292 – No significant displacements were detected as can be seen in fig.1a.

Table 1- Details of the studied sources. Estimates for *M*, *i* and T_{ex} are from Bik & Thi (2004)

Name	R.A.(2000)	Dec.(2000)	*d* (*kpc*)	displacement (AU) Brγ	CO 2-0	CO 3-1	*M* ($M_\odot$)	*i* (°)	T_{ex} (*K*)
08576-4334nr292	08:59:21.58	-43:45:31.50	0.7	-	13±4	-	6	27	1660
16164-5046nr3636	16:20:11.31	-50:53:25.30	3.6	279±10	134±11	-	30	30	4480
18006-2422nr766	18:03:40.29	-24:22:39.60	1.9	247±23	311±32	210±39	11	60	1800

18006-2422nr766 – In fig.1b, all the lines show a displacement towards the same side of the continuum source. Local clumping, inclination towards the line of sight or the presence of an intense UV field can result in this asymmetric profile.

Origin of CO emission - The size scale of the CO emitting regions (~200-300 AU) for 18006-2422nr766 is comparable to the predicted sizes of inner disks from numerical simulations of MYSOs[4]. In the sources 18006-2422nr766 and 16164-5046nr3636, the CO bandhead profile is well described by keplerian disks of sizes ~3-4 AU[1]. Our results above indicate structures much larger than such disks, but much smaller than the observed toroids (~10^3 AU)[3]. CO emission may therefore be arising in large disks and/or inner regions of envelopes.

Binary scenario – The observed Brγ line intensities of the SA signal, if attributed to a binary companion, will require another MYSO. Such a scenario will contradict the observed total luminosities and produce a distorted PSF. Therefore, the binary scenario is not applicable to the sources studied here.

Future Work - Systematic observations of a large sample of MYSOs visible in the NIR, using instruments such as ISAAC and CRIRES at ESO VLT, can be very useful to understand the geometry of the structures in their close environment.

References: [1] Bik A., Thi, W. F., 2004, A&A, 455, 561; [2] Brannigan E. et al., 2006, MNRAS, 367, 315; [3] Beltrán M. T. et al., 2005, A&A, 435, 901; [4] Yorke H. W., Sonnhalter C., 2002, ApJ, 569, 846