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ACCRETION PROPERTIES OF CLASS 0 PROTOSTARS STUDIED WITH NEAR-INFRARED SPECTROSCOPY

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Abstract. Sun-like stars are thought to accrete most of their final mass during the protostellar phase, where the protostellar embryo is surrounded by an infalling dense envelope. The so-called Class 0 phase designates the youngest protostellar stage, where the accretion is the most vigorous. Because these objects are highly embedded, it is difficult to retrieve direct diagnostics from the accretion, whose observational imprint lie at small wavelengths, in the near-infrared and below. Therefore, little is known about the accretion mechanisms occurring in the Class 0 phase because of high extinction. However, in rare cases the blueshifted cavity created by the outflow is sufficiently close to pole-on to liberate enough near-infrared scattered light for us to probe the immediate surroundings of the central object. We present a new set of K-band spectra of 26 Class 0 protostars recently observed with Keck MOSFIRE. Br_γ, several H_2 and $\Delta\nu = 2$ CO lines are detected and analyzed. We detect Br_γ in several sources, which suggests a good fraction but not all of Class 0s may accrete via magnetospheric accretion. The H_2 lines are consistent with shock excitation indicating jets/outflows. Stella CO lines are seen in absorption in 6 sources suggesting recent vigorous accretion episodes. CO is seen in emission in 13 sources, tracing the heated inner accretion disk. We find that a significant higher fraction of Class 0 objects tend to exhibit CO in emission than in archival K-band spectra of later-evolved, Class I protostars. We also perform and discuss statistical tests comparing the near-IR line parameters of Class 0 and I objects. Our results suggest that the near-IR accretion properties of Class 0s tend to be different that of Class I objects. Upcoming JWST observations shall constrain further the accretion mechanisms of Class 0 protostars.

Keywords: ISM: jets and outflows - stars: formation - stars: protostars - accretion

1 New sample of K-band spectroscopy of low-mass Cass 0 protostars

Figure 1 presents the new observations of medium resolution (R $\sim$ 3300) NIR K-band spectroscopy for a sample of 26 Class 0 protostars in the Perseus, Serpens, and Orion molecular clouds. The H_2, Br_γ, and CO overtone emission bands features are detected toward $\sim$ 90, 65, and 50 % of the sample, respectively. [Fe II] lines, a common jet tracer, as well as Ca I and Na I emission lines, are also detected in several sources. The photosphere is detected in 6 sources, exhibiting CO, Na and Ca absorption features consistent with dwarf spectra, and indicative of low-veiling. We perform statistical comparisons with a sample of Class I K-band spectra taken from the literature.

Analysis of the Br_γ and CO overtone emission equivalent width and luminosity values shows that the accretion luminosity is on average higher in Class 0 systems, suggesting that Class 0s accrete more vigorously. The much higher detection rate of CO overtone in Class 0s (50 % against $\leq$15 % in Class Is) indicates that episodes of high accretion activity is more frequent in Class 0 systems. The H_2 excitation is similar between Class 0s and Is, pointing toward outflow/jet shock origin collisionally exciting H_2. However, the H_2 emission lines are much brighter in Class 0s, suggesting stronger shocks, *i.e.*larger shock velocity and pre-shock density. The Class 0 CO overtone emission is either consistent with redshifted emission or no shift. While the latter would suggest an inner disk origin, clear redshifted emission suggests that the dense and hot gas associated with the CO emitting regions can correspond to infalling material at $\sim$15-40 km s^{-1}. Br_γ emission lines usually attributed to the magnetospheric accretion column in T-Tauri systems exhibits clearly different velocity profiles

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between the two protostellar phases: while Class Is systems have blueshifted centroids and in a few sources a clear redshifted absorption, Class 0s exhibit symmetric Br_γ profiles with no velocity shifts. This could point toward an accretion mechanism of different nature in Class 0 systems.

This study reveals the NIR accretion properties of a statistically relevant sample of Class 0 protostellar systems. These objects exhibit systematic difference with the more evolved Class I objects: Class 0 accretion appears more vigorous and episodes of high accretion activity more frequent. Further modeling of the emission can reveal relevant further insights on the kinematics of the CO and Br_γL emission line regions. JWST diagnostics of the spatial location of these emissions and the extinction of these embedded regions will enable more quantitative analysis of the actual mass accretion rate of these systems.

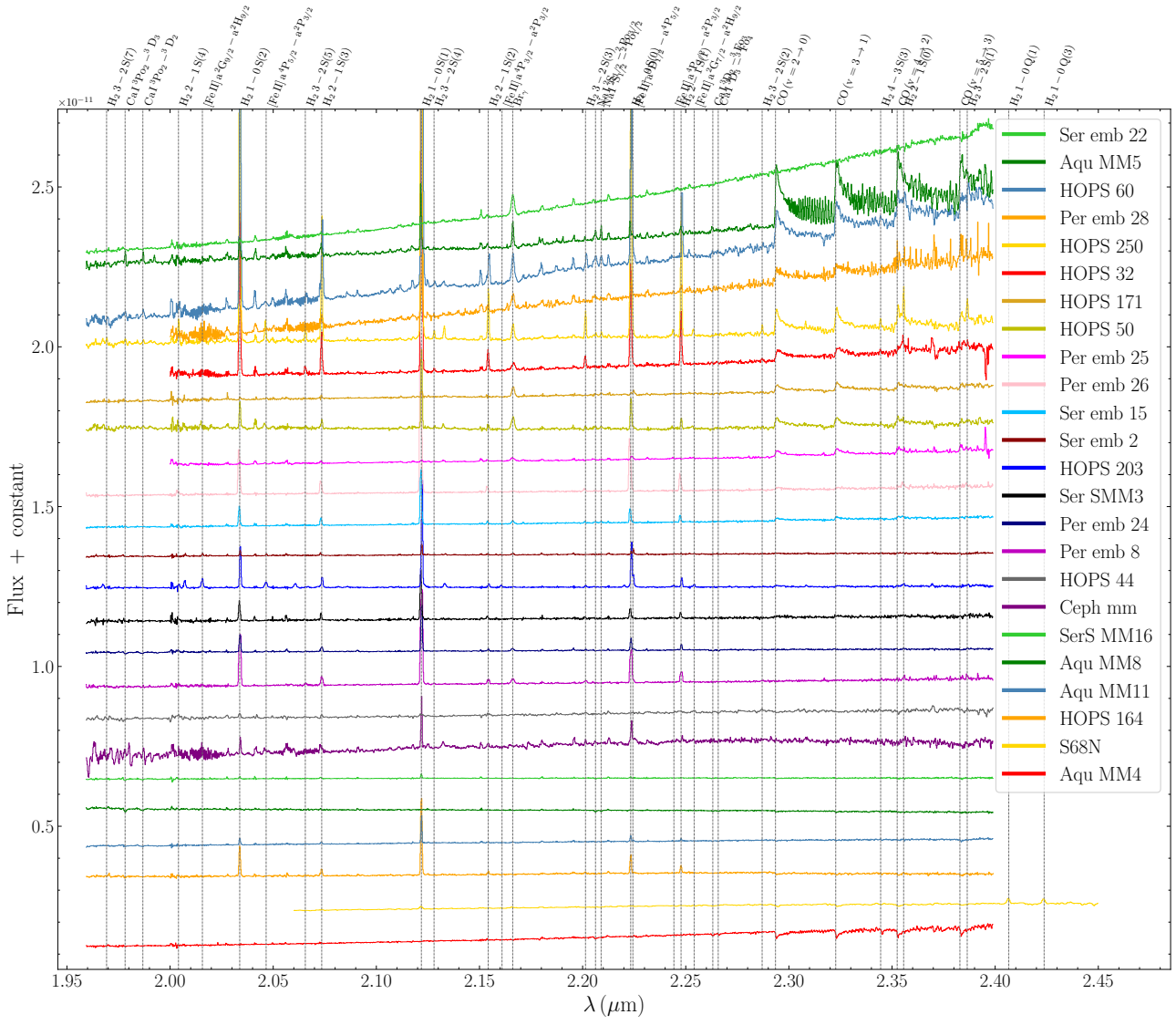

Fig. 1. Extracted 1D K band spectra of our sample of Class 0 protostars. We sorted the spectra such as the reddest spectra and the CO overtone emitting sources are at the top, while the sources exhibiting photospheric features are at the bottom. These spectra are not corrected for extinction. The grey vertical dashed line report all the detected lines in the sample. Per emb 21 and HOPS 87 are not shown here because no continuum has been detected in these sources. However, their spectra show bright emission lines for nearly all of the H2 lines outlined in this Figure.