# Accretion properties of the Chamaeleon II low-mass star-forming region


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## Introduction

The Chamaeleon II (Cha II) dark cloud, with a distance of 178±18 pc (Whittet et al. 1997) and an age of 4±2 Myr (Spezzi et al. 2008), is one of the three main clouds of the Chamaeleon Complex and covers ~2 deg$^2$ in the sky (see Luhman 2008 for a recent review). Cha II is one of the five clouds selected for the *Spitzer Space Telescope* Legacy Program "From Molecular Cores to Planet-forming Disks" (c2d; Evans et al. 2003) aimed to investigate the star formation activity in the cloud. Based on optical spectroscopy we are characterizing the Cha II star-forming region in terms of kinematics, elemental abundances, and mass accretion rates. Here, we present some preliminary results on accretion properties of the Cha II PMS stars derived through various diagnostics.

## Observations

**The sample** consists of 41 pre-main sequence (PMS) stars reported by Alcalá et al. (2008) and Spezzi et al. (2008), and selected on the base of their IR excess emission, Hα emission, X-ray emission, and lithium detection.

**Spectroscopic** observations were obtained in 2006-2007 with the ESO FLAMES spectrograph. The Cha II field was covered with 18 different observing pointings using the fiber links to GIRAFFE (R=8 600) and UVES (R=47 000) spectrographs. Both GIRAFFE and UVES spectra were used to derive spectral types, radial and rotational velocities, lithium abundance, and mass accretion. UVES spectra were also used to measure the abundance of some iron-peak and α- elements (Biazzo et al. 2011, in prep.).

## Accretion Diagnostics

We derive the **mass accretion rate** from several emission lines (Hα λ6563, Hβ λ4340, He I λ5876, He I λ6678, He I λ7065). We consider the magnetospheric accretion model, where the mass accretion rate $M_{acc}$ is related to the accretion luminosity $L_{acc}$ through the following relation (Hartmann 1998): $M_{acc}=L_{acc}R_*/GM_*(1-R_*/R_{in})$. In the case of the Cha II stars, we adopt inner-disk radii $R_{in}$ and stellar radii $R_*$ reported by Alcalá et al. (2008). Stellar masses $M_*$ are those measured by Spezzi et al. (2008). Then, $L_{acc}$ is derived from the observed line luminosity through empirical linear relations, such as those given by Herczeg & Hillenbrand (2008). In particular, we first use the relations between the observed line luminosity $L_{line}$ and the accretion luminosity $L_{acc}$ (see, e.g., Herczeg & Hillenbrand 2008). The line luminosity is given by $L_{line}=4\pi d^2 F_{line}$, where d is the distance to Cha II and $F_{line}$ is the absolute flux of the line, that we compute multiplying the line equivalent width (EW) by the continuum flux at the given line taken from NextGen Model Atmospheres (Hauschildt et al. 1999). Figure 1 shows the mass accretion rates of two lines (namely Hα and He I λ6678) versus stellar mass, where vertical bars refer to the different values obtained for observations at different epochs, e.g. they are related to the variability of the line intensity (see below).

**Line emission fluxes.** We use several different lines to determine $M_{acc}$ using the relation with $L_{acc}$ as described above. Figure 2 compares the Hα and He I λ6678 in terms of fluxes, luminosities, and mass accretion rates. The line fluxes in both lines are well correlated (*left panel*). When converted into line luminosities, the correlation is evident (*middle panel*), giving support to the goodness of the empirical relationships between $L_{line}$ and $L_{acc}$. The last panel, which compares the mass accretion rates as derived through these two diagnostics, shows how they are well correlated, thus justifying the use of both of them for estimating the accretion properties.

**Short time scale variability.** Young PMS stars are known to be variable, with most variations due to the combination of rotation and cool spots, or hot spots and accretion rate changes, or obscuration by circumstellar dust (see, e.g., Herbst et al. 1994, Schisano et al. 2009, Frasca et al. 2009, Sicilia-Aguilar et al. 2010). In Fig. 3 we show the Hα profile variations of four stars, which differ both in mass and mean mass accretion rate. On timescales of only two days, the $EW_{H\alpha}$ of these stars changes of 2-3 times and the variation of log $M_{acc}$ reaches 0.2-0.6 dex, i.e. factors of 1.6-4.0. We conclude that this $M_{acc}$ variability, even if large, cannot explain the $M_{acc}$ spread at a given mass. This means that **stellar parameters other than mass must also affect the accretion rate**.

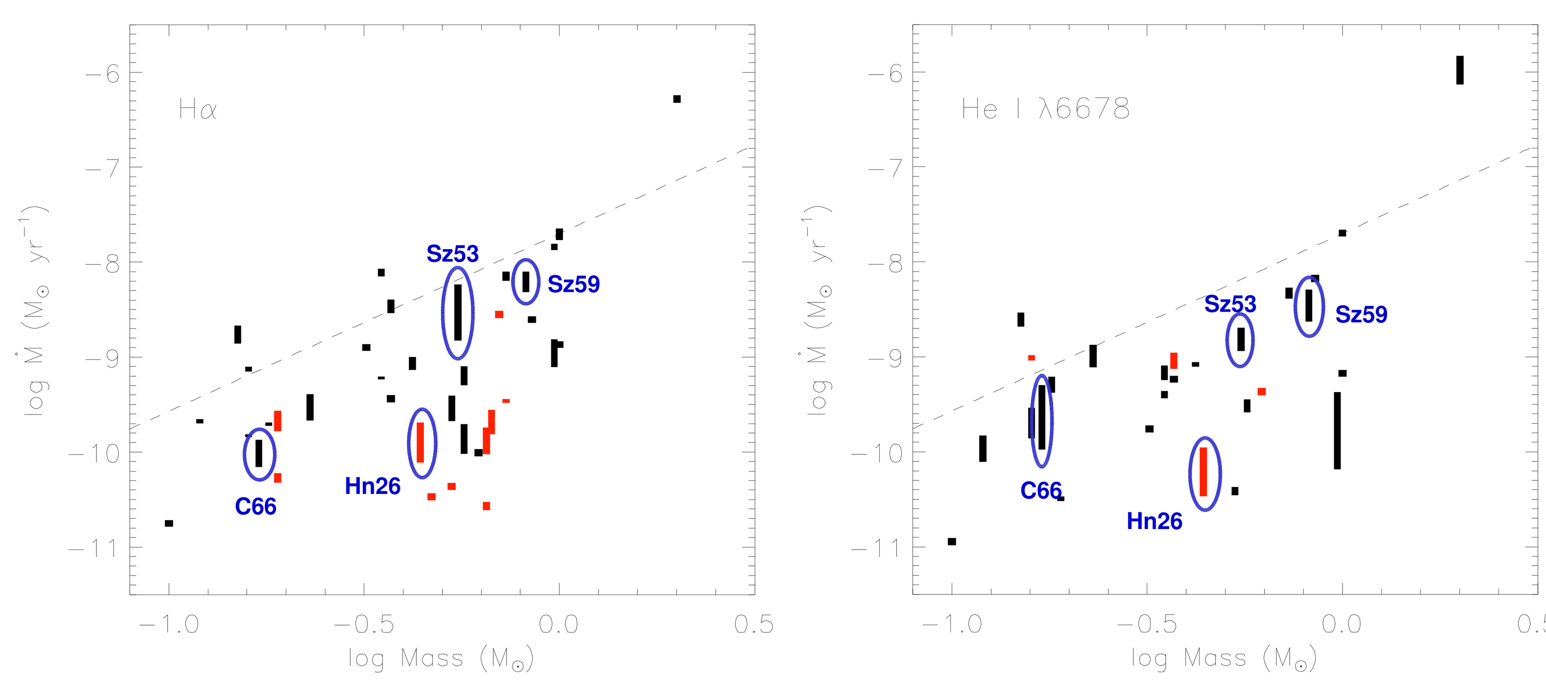


Fig. 1 – Examples of mass accretion rate versus stellar mass for Cha II PMS stars: $M_{acc}$ measured from the Hα (*left panel*) and from He I λ6678 lines (*right panel*). Stars are roughly divided into high Hα emitters ($EW_{H\alpha}$>10 Å; black) and low Hα emitters ($EW_{H\alpha}$<10 Å; red). The dashed line represents the relation obtained by Herczeg & Hillenbrand (2008). The four stars whose line profiles are plotted in Fig. 3 are marked.

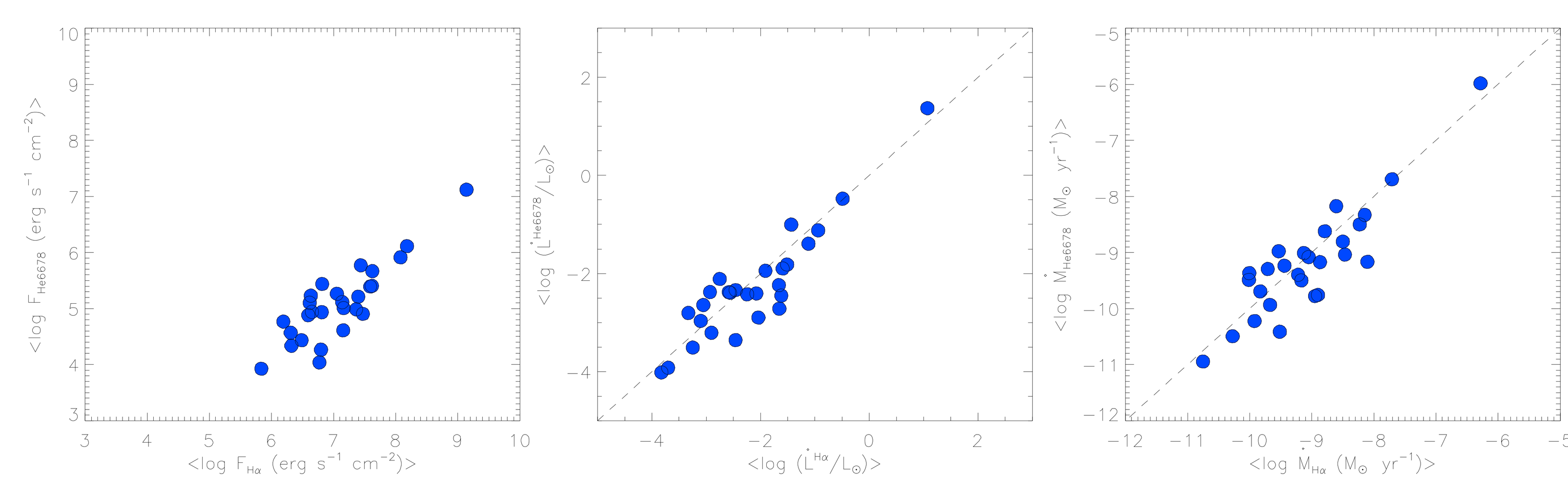

Fig. 2 – Examples of correlations between fluxes, accretion luminosity, and mass accretion rate derived using the Hα and He I λ6678 emission lines as diagnostics.

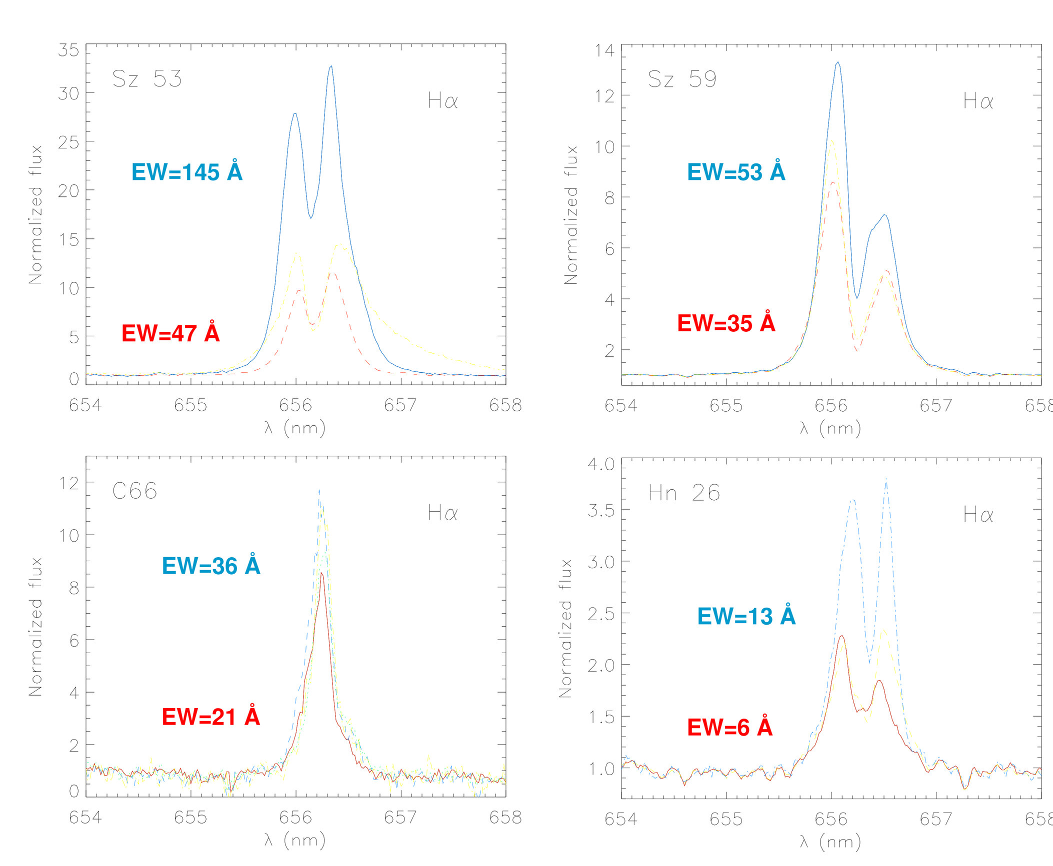


Fig. 3 – Hα profile variations of four stars. The fluxes are normalized to the continuum. Each star was observed 3-4 times during two days (see different line colors and styles). The variations in line intensity, profile, and equivalent width are evident.

## Future Work and Perspectives

Which parameters can play an important role in the mass accretion rate of PMS stars?

- Spectral type?
- Age?
- Metallicity?
- Other?

Important issues deserving further study:

- distinction between chromospheric and accretion origin at low accretion rate levels
- fine tuning of stellar physical parameters, by using more accurate distance determinations. The GAIA mission and the large X-Shooter surveys of star-forming regions in the near future will provide us with data sets representing benchmarks for investigations of low-mass stars, stellar atmospheres, and evolutionary models of PMS evolution (Alcalá et al. 2011).

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