The Ca II lines as tracers of the magnetospheric accretion flows: the Chamaeleon I star-forming region

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Motivation

The broad emission lines characteristic of young stars are formed in accretion flows (Fig. 1). Modeling them has provided estimates of the mass accretion rate onto the star, as well as indication of the geometry of the flows and of the region of interaction with the disk (Muzerolle+ 1998,2001; Thanathibodee+ 2019,2020). However, the models rely on empirical temperature structures. Modeling lines arising from a variety of elements in different ionization stages can help constrain the temperature structure and the geometry, and provide better determinations of the accretion rates.

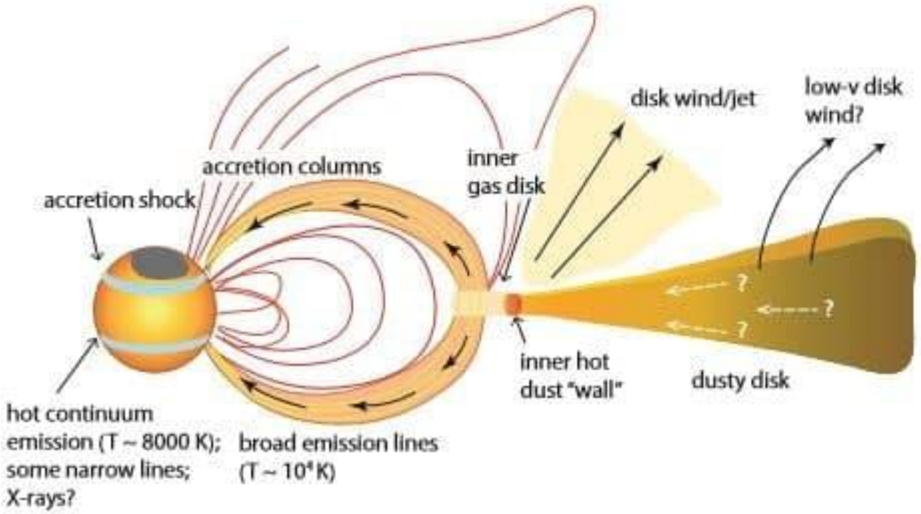

Figure 1: Schematic view of a young star accreting from a disk through the stellar magnetosphere

Goals

- Understanding the Ca II lines formation in young stars surrounded by disks.
- Assuming that the magnetospheric model is valid, refine it, in particular, constrain the temperature and geometry.

References

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Magnetospheric Model

Magnetospheric accretion assumes that the disk is truncated at a few stellar radii and material falls onto the star along the stellar magnetic field lines. We follow the method of Muzerolle et al. (2001) to calculate the Ca II H,K and IR Triplet lines for an extensive grid of models. The models parameters are:

- Log mass accretion rate ($\dot{M}$) between -10 and -7 $M_{\odot}$ yr^{-1}.
- Maximum temperature (*Tmax*) between 8000K and 11000K.
- Inclination between 15 and 75 degrees.
- Geometry specified by the inner (*Rmi*) and outer (*Rmo*) radii of the magnetic dipolar field lines on the disk in units of the stellar radius (Fig. 2).

CaII K models profiles are shown in Fig. 3 for a selection of parameters.

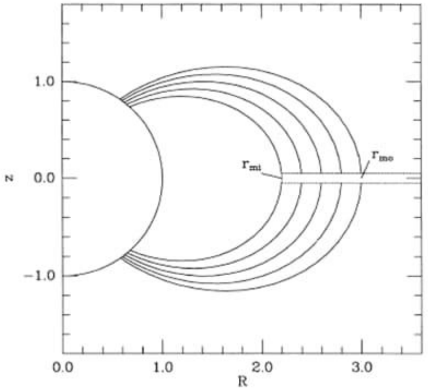

Figure 2: Geometry of the magnetosphere

ID	Rmi	Rmo
G01	2	2.5
G02	2	3
G03	3.5	4
G04	3.5	4.5
G05	5	5.5
G06	5	6

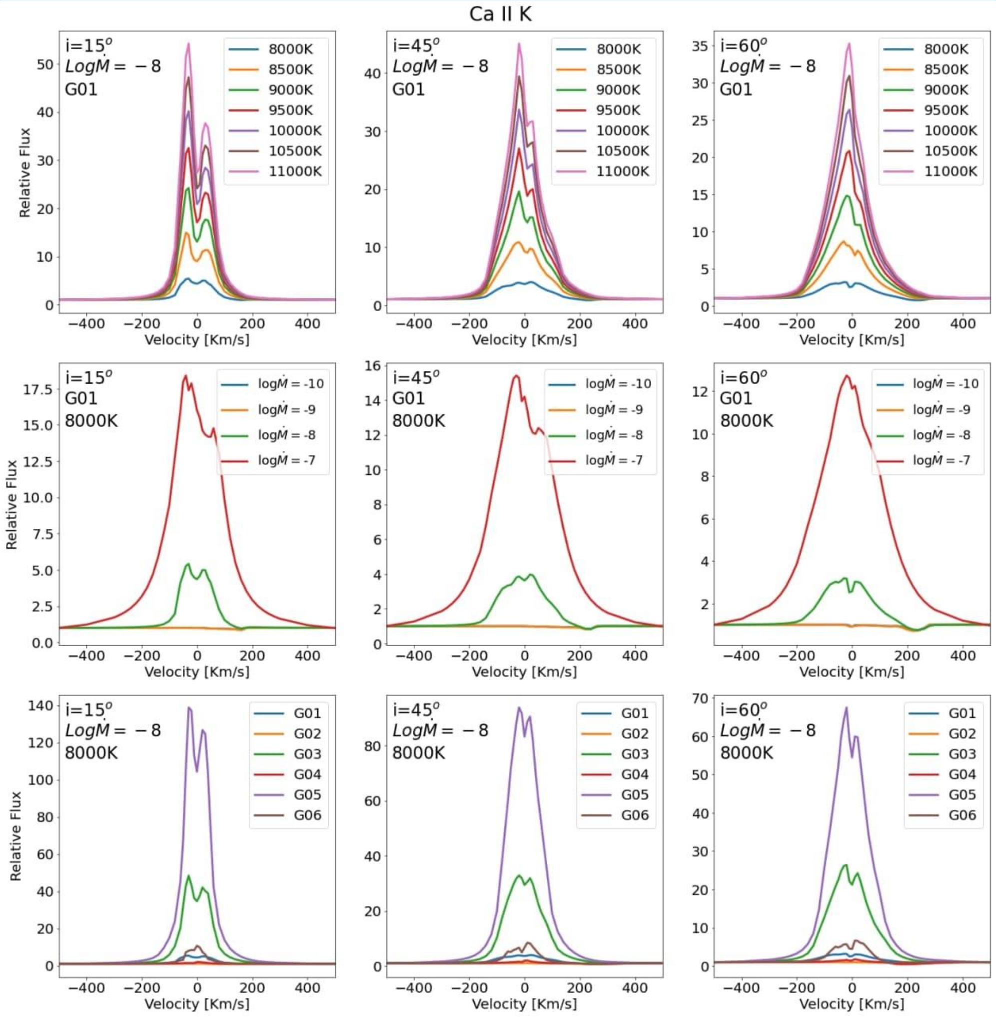

Figure 3: Models CaII K profiles for indicated parameters.

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Observations

We use X-shooter spectra of 21 CTTS stars from the Chamaeleon I region (Manara+ 2016, 2017 = M16, M17; examples in Fig. 4) to test the predictions of the magnetospheric accretion models for the characteristic Ca II lines: The H and K lines and the IR triplet.

We correct the spectra for reddening using the A_V values from M16, M17 and the standard extinction law (Cardelli+ 89). X-shooter values of heliocentric radial velocity are used to perform the heliocentric correction of the spectra. For the Ca II infrared triplet we subtract the photosphere for all stars. Instead, for the Ca II H and K lines we only subtract the photosphere for stars with $L_{acc}/L_* < 0.1$ (L_{acc} and L_* from M16, M17), since the contribution from the accretion shock is not dominant.

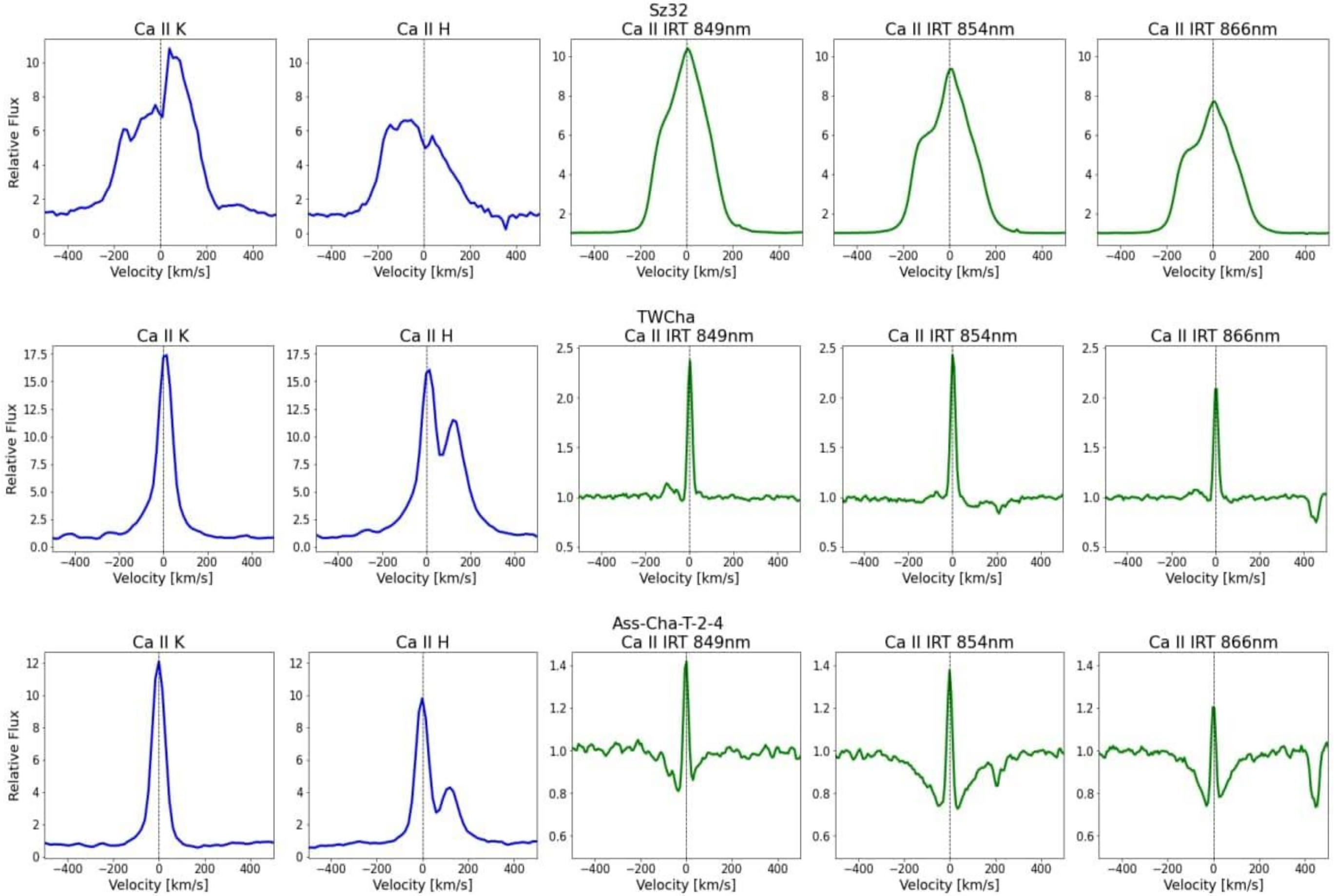

Figure 4: CaII H & K and CaII infrared triplet profiles of three K7 stars with different Log $\dot{M}$. From top to bottom Log $\dot{M}$ = -7.08, -8.86, -9.41 $M_\odot$ yr^{-1}.

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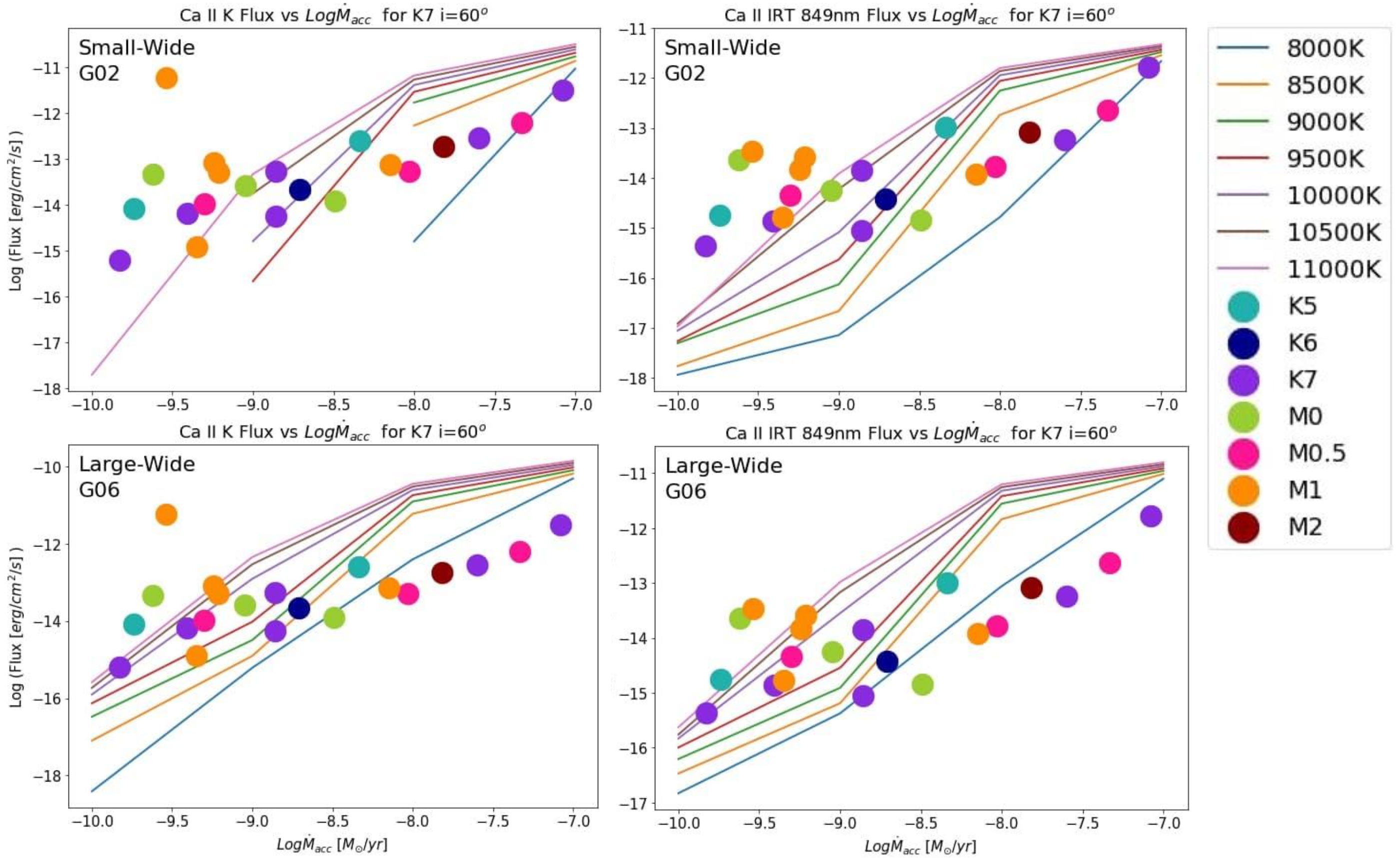

Figure 5: Reddening corrected lines fluxes vs mass accretion rate, taken from M16, M17. Lines correspond to models with different *Tmax* and the indicated geometry. Models are shown for i = 60°, but a change in inclination only produces a small change in the temperature of the best fit.

Results

Comparison between observations and models is shown in Figure 5. We find:

- CTTS with highest mass accretion rates ($\dot{M}$) tend to have the lowest *Tmax*, as expected from increasing cooling (Muzerolle+ 2001).
- High accretors tend to have small and wide magnetospheres, while low accretors have wide magnetospheres, as expected from the balance between magnetic and disk gas pressure (Hartmann+ 2016).
- We find agreement between models predictions inferred from different lines. We are currently developing an statistical method encompassing all lines to obtain best fits for each star and confirm our preliminary conclusions.

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