Testing magnetospheric accretion models for low mass young stars: Hydrogen lines in Lupus

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Goals

We aim to determine the validity of the magnetospheric accretion models to hydrogen emission lines, so that we can restraint the physical and geometrical parameters of the magnetospheres and calculate the accretion rate more accurately

Observations

We have used the de-reddened Xshooter spectra of 37 accreting T-Tauri (CTTS) from the Lupus star-forming region (Alcalá et al. 2014,2017=A14,A17) to test the predictions of the magnetospheric models and test consistency between Balmer, Paschen and Brackett lines. Figure 1 shows normalized line profiles of H-α, Pa-β and Br-γ for two stars in Lupus

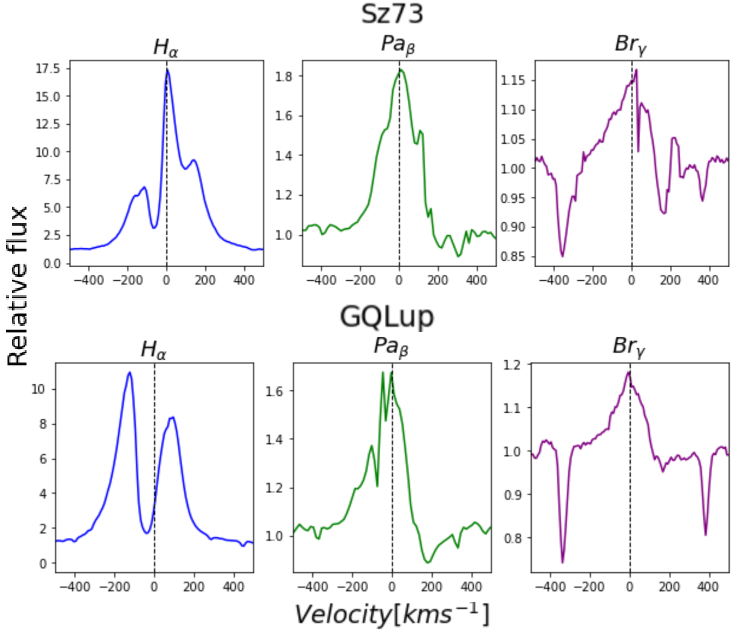

Figure 1. H-α, Pa-β and Br-γ emission lines in two K7 stars. The corresponding accretion rates are logMacc= -8.26 (top) and -7.67 (bottom). The photosphere has not been subtracted

Models

We use the magnetospheric models of Muzerolle et al. (2001). The magnetic field has a dipolar geometry (Fig. 2) and truncates the disk at radius R_{in} . Matter from R_{in} to R_{out} free-falls onto the star with a mass rate $\dot{M}_{acc}$.The temperature of the flow is described by the parameter $T_{\max}$. We solve a 20-level H atom to calculate populations at each point in the flow. The mean intensity at each transition is calculated with the extended Sobolev approximation (Muzerolle et al. 2001)

We calculate an extended grid of Balmer, Paschen and Brackett line profiles for a K7 star and following parameters:

- $log\dot{M}_{acc}$ = -7,-8,-9 and -10. Corresponding to labels M04, M03, M02 and M01
- $T_{\max}$ = 8000K, 8500K, 9000K, 9500K, 10000K, 10500K and 11000K
- Inclination = 15°, 30°,45°,60 and 75°
- Geometries shown in Table 1. Characterized by the location and size of the magnetosphere, according to the inner and outer radii of the flows

Table 1. Inner and outer radii for the magnetosphere model

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	5.6

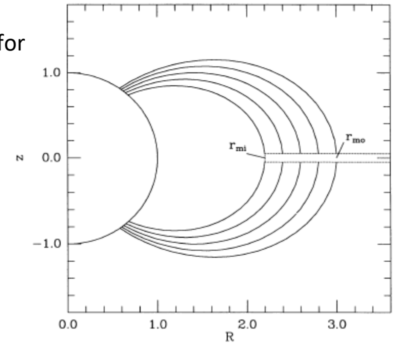

Figure 2. Geometry of the magnetosphere

The dependence of the line profiles (illustrated by Pa-β) to the parameters is shown in Figure 3

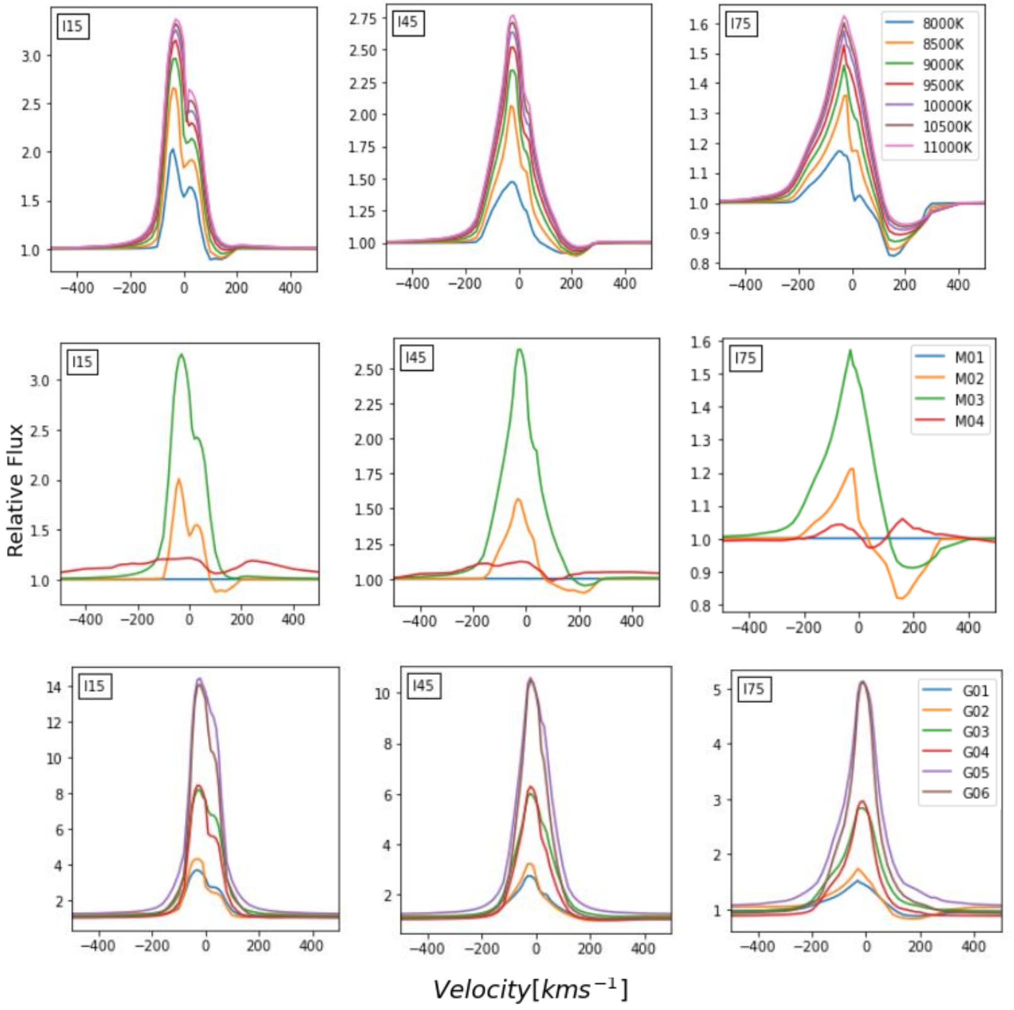

Figure 3. Emission line models for Pa-β. Each column is for an inclination. First row has $log\dot{M}_{acc}$ =-9 and G01. Second row has $T_{\max}$ =10000K and G01. Third row has $T_{\max}$ =10000K and $log\dot{M}_{acc}$ =-9

Results

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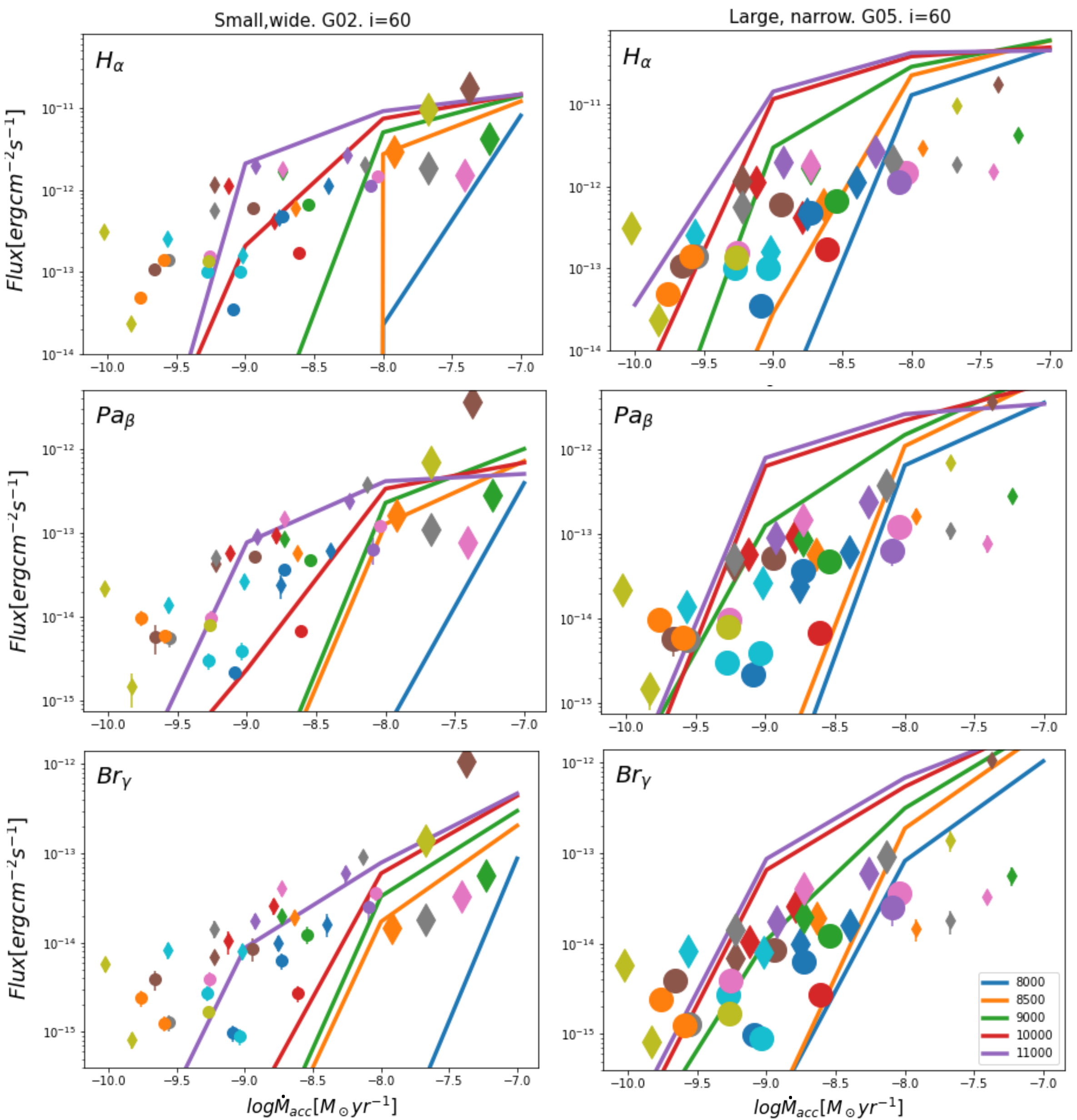

Figure 4. Reddening corrected fluxes of H-α (upper), Pa-β (middle) and Br-γ (lower) compared to model predictions. Fluxes and mass accretion rates from A14,A17. Models are shown for a range of $T_{\max}$ (see inset) and two geometries: Small, wide (G02,left) and large, narrow (G05,right). We represent stars with type M2 to K6 with diamonds and the rest with circles.

Results and conclusions

Figure 4 compares model predictions with observations. For simplicity, we only show models for i=60, and 5 temperatures. We show reddening corrected fluxes for H-α,Pa-β and Br-γ vs. $log\dot{M}_{acc}$ from A14,17.

Note that line fluxes and $\dot{M}_{acc}$ have been measured simultaneously, so they are not affected by variability and they have been corrected with the same A_v

We find:

- Stars with high accretion rates ($log\dot{M}_{acc} \gtrsim$ -8) are better described by cool and small magnetospheres (left column of Fig.4)
- Stars with low accretion rates agree with hotter and larger magnetospheres (right column of Fig.4)

These results agree with expectations for the thermal distribution of magnetospheres (Muzerolle et al. 2011) and for the truncation radius (Hartmann et al. 2016). The agreement between predictions for different lines supports the magnetospheric model

References

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