The End of Accretion: the Case of a Very Slowly Accreting T Tauri Star CVSO 1335

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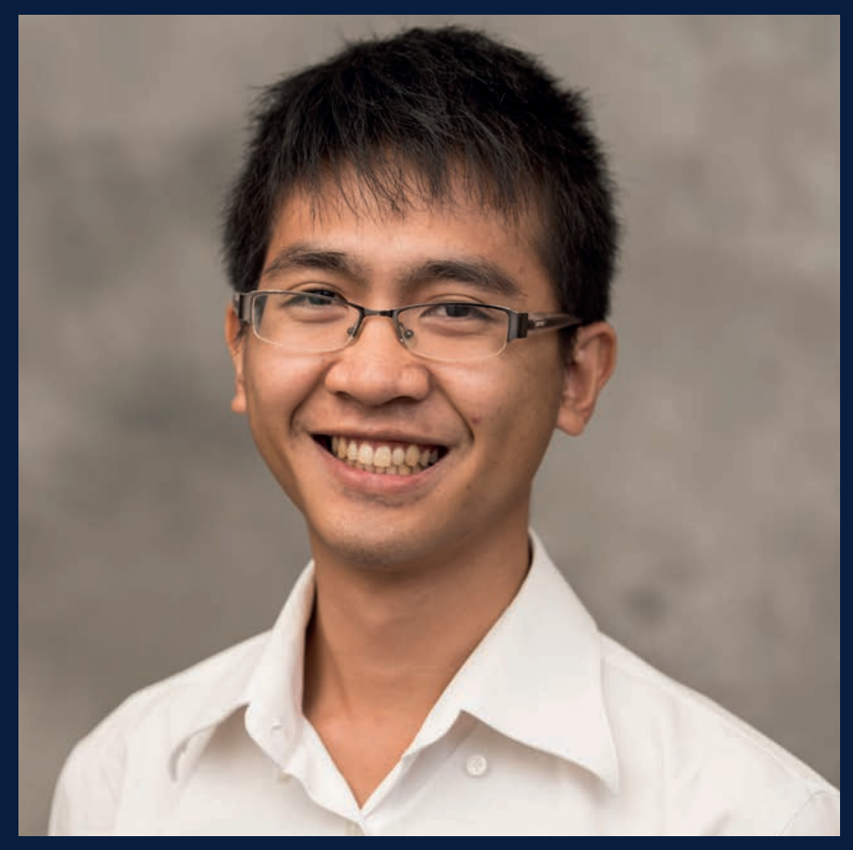
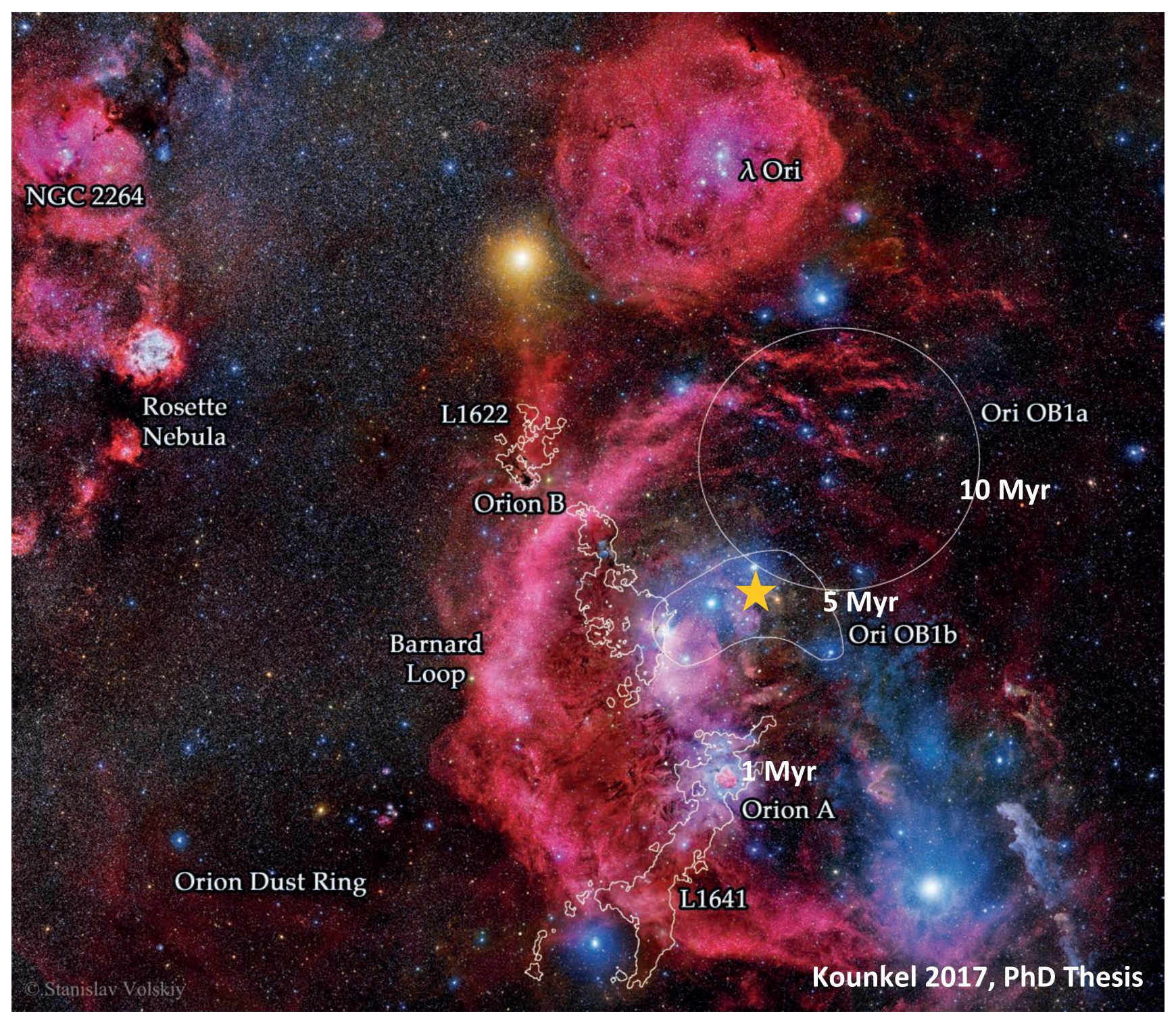


Last Stages of Accretion

Magnetospheric Accretion[1] is the accepted view of accretion in low-mass, pre-main sequence stars (T Tauri Stars; TTS). Under this paradigm, the stellar magnetic field truncates the inner region of the surrounding protoplanetary disk at a few stellar radii and material flows onto the star along the field lines. Although this main concept has been accepted, it is still unclear how accretion proceeds at a very low accretion rate, or how accretion stops. Here we report observations of a low accretor at a critical age of disk evolution and interpret them with self-consistent accretion shock and magnetospheric accretion models.

Target and Observations

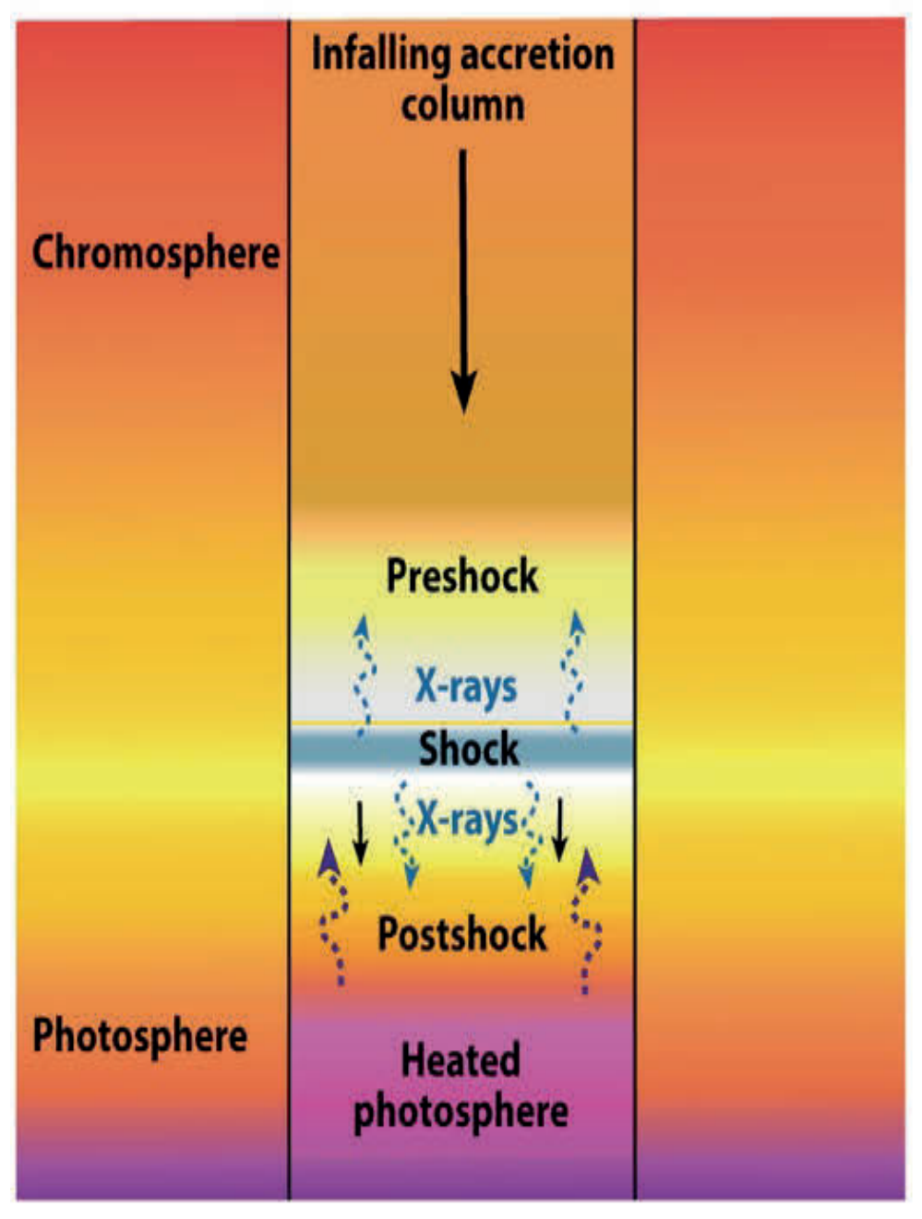


Kounkel 2017, PhD Thesis

CVSO 1335 is an accreting (Classical) TTS in the Orion OB1b sub-association[2], with an age of 5 Myr, the critical age at which more than 80% of stars in a population have stopped accreting[3]. The star is a K5 star with $M=0.87\ M_{\odot}$, $R=1.58\ R_{\odot}$, at d=375 pc.

The star was observed on 4 consecutive nights in November 2017. We used the MagE spectrograph on the Magellan Baade Telescope, obtaining **simultaneous** observations of the Balmer jump (accretion shock emission) and Hα (magnetospheric flow emission). The 1’’ slit was used for all epochs, giving a resolution of R~4100 (~ 75 km/s).

Accretion Shock Model



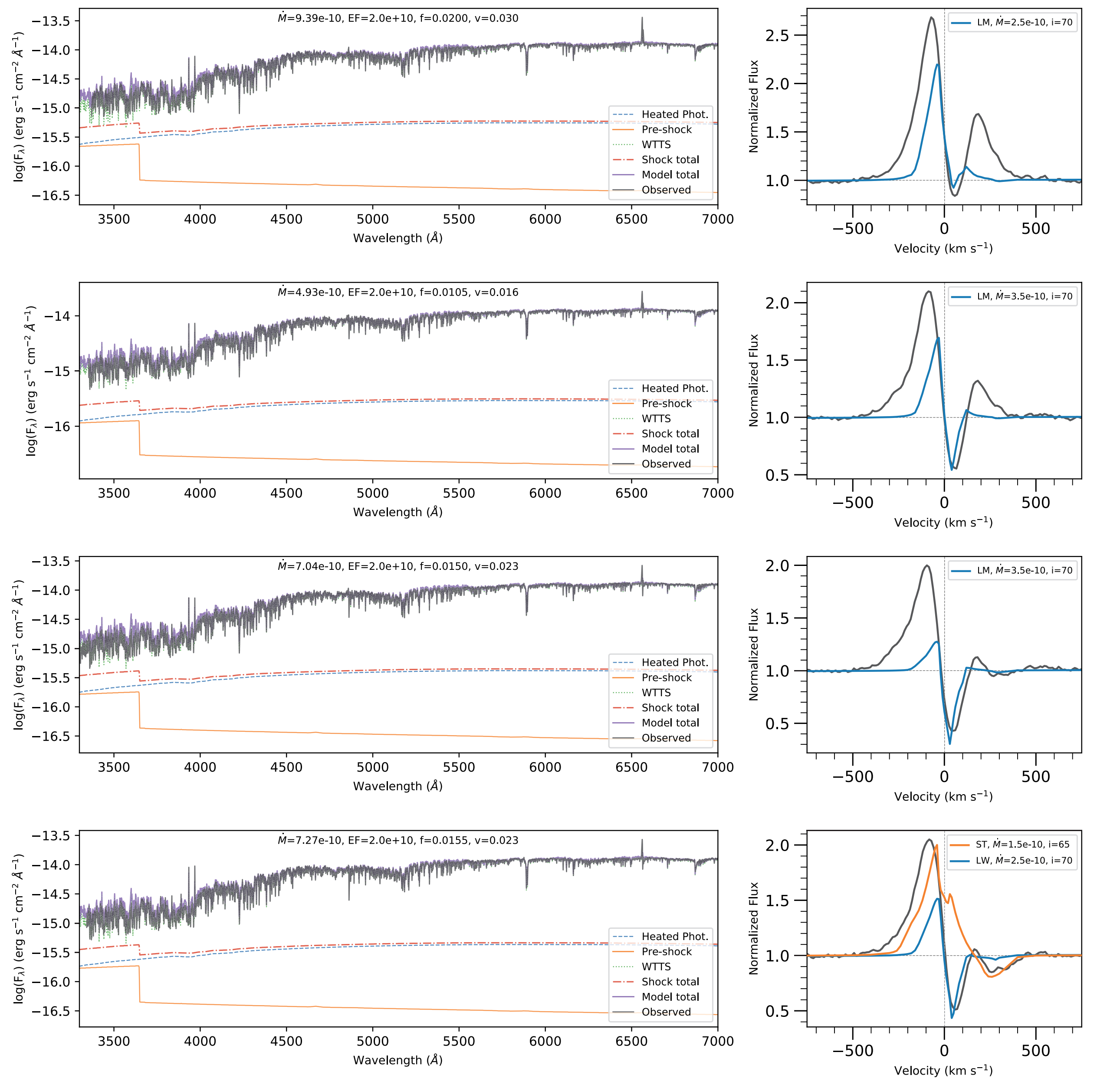
Hartmann+2016

We use an accretion shock model[4] to place an upper limit on the mass accretion rate. Since young stars have active chromospheres, we use a non-accreting TTS as a template of the star’s intrinsic emission[5]. The excess over the template is from the accretion column, specifically the pre-shock and the heated photosphere at the base of the column.

Magnetospheric Accretion Model

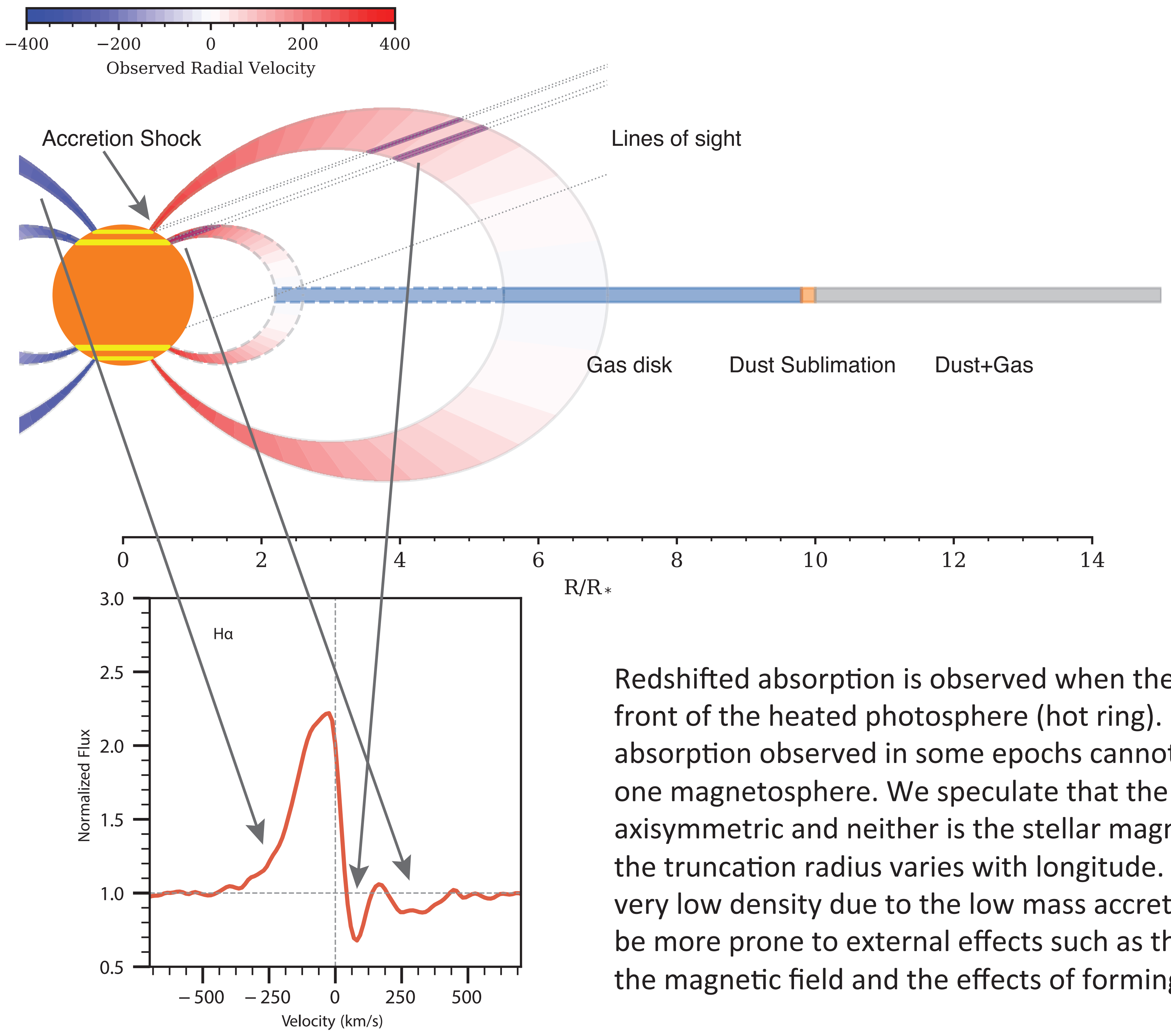
To estimate the geometry of the accretion flows, we modeled the line profile of Hα using a magnetospheric accretion model[6,7]. The model assumes a coaxial axisymmetric magnetosphere. The density is calculated by assuming steady flow, and the temperature goes as $T \propto 1/(n_H^2 r^3)$. The model uses the extended Sobolev approximation with a 16-level H atom. The flux is calculated using the ray-by-ray method.

Modeling Accretion Shock and Magnetosphere



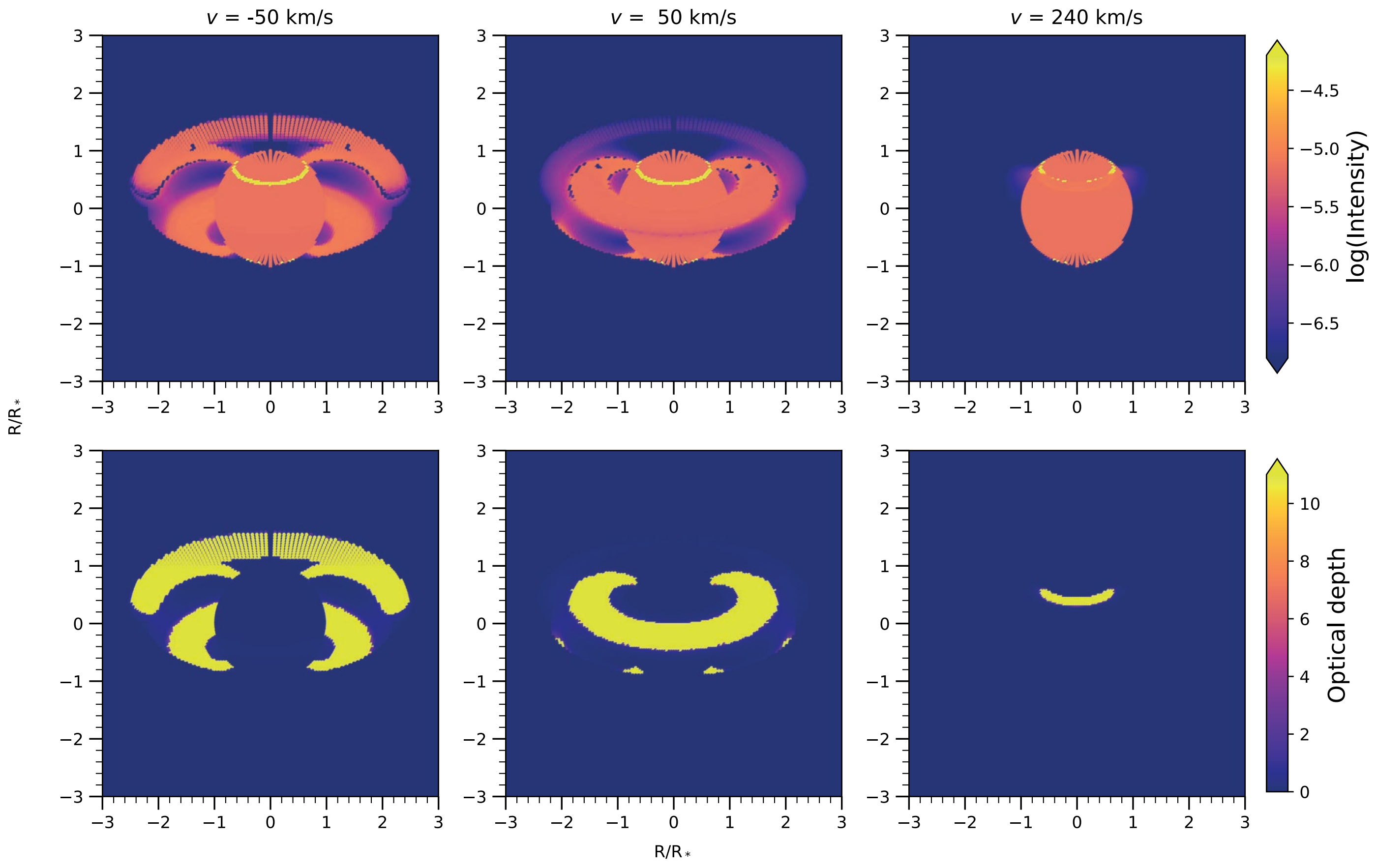
For each epoch, we modeled the Balmer jump using the accretion shock model with a non-accreting TTS and the shock with parameters shown in the figure (left). The corresponding Hα profile is shown on the right. We see large variability in the red wing of the line, especially in the redshifted absorption at high velocity. We modeled the profiles using the magnetospheric accretion model with parameters consistent with the shock model.

Geometry of the Magnetospheric Accretion Model



Redshifted absorption is observed when the material is in front of the heated photosphere (hot ring). Double redshifted absorption observed in some epochs cannot be modeled with one magnetosphere. We speculate that the disk is not axisymmetric and neither is the stellar magnetic field, so that the truncation radius varies with longitude. The disk has a very low density due to the low mass accretion rate, and may be more prone to external effects such as the asymmetry of the magnetic field and the effects of forming planets.

Where does the emission come from?



The top row shows intensity maps at different velocities along the Hα line profile. The bottom row shows maps of optical depth at the same velocity. The continuum comes from the star and the ring; line emission comes from the accretion flow. Redshifted absorption occurs when high optical depth material is occulting the ring.

Conclusions

- The accretion rate of CVSO 1335 may vary slightly (< 3x) on a daily timescale, as evidenced by the upper limit from the shock models and the variability of Hα profiles.
- Redshifted absorption at low velocity requires a large and thin magnetosphere, whereas absorption at high velocity requires a smaller magnetosphere.
- Observations of high and low velocity redshifted absorptions suggest a complex accretion geometry that may be more conspicuous at lower mass accretion rate.
- Larger changes in the high velocity component suggests higher variability in the “inner” magnetospheric flow.

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References

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