The Enigma of Hydrogen Emission in T Tauri Stars

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Summary

- CTTSs are known for their hydrogen emission lines, magnetospheric accretion and mass outflow[1].
- By comparing synthetic hydrogen profiles from the RT code TORUS[2] with observations of CTTSs, we aim to constrain and provide insight into the physics.
- Our initial parameter study indicates that the existing line broadening mechanisms are insufficient to account for the observed hydrogen emission.

Radiative Transfer Model

TORUS

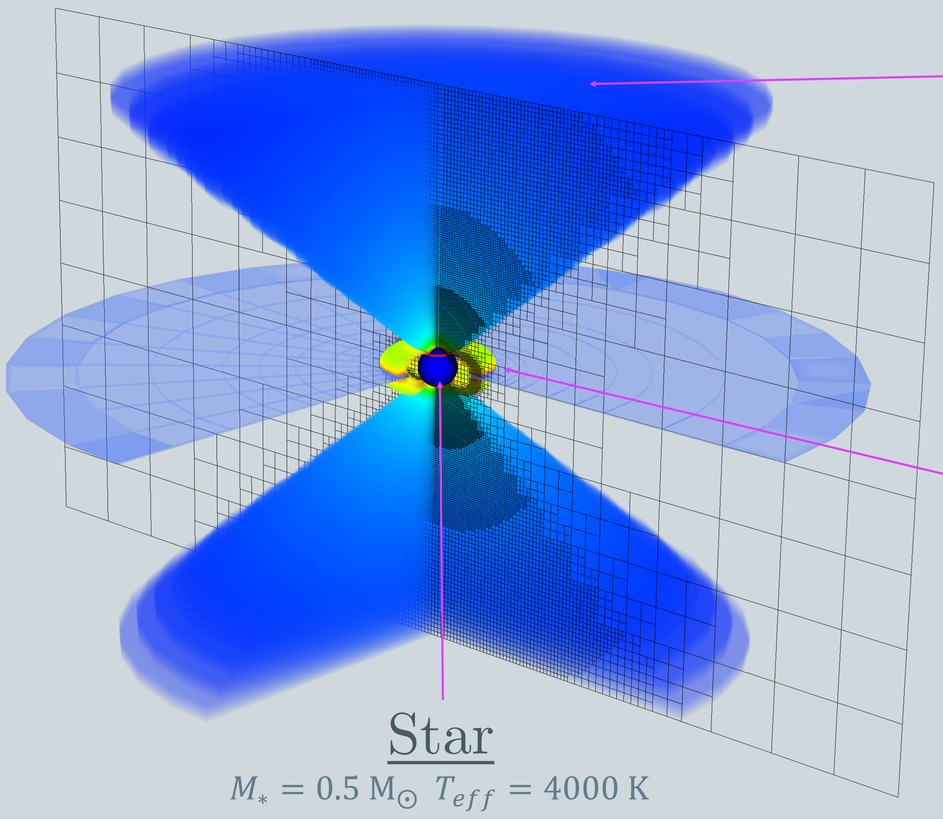
Input
Analytic model

Grid
2.5D with adaptive mesh refinement

Microphysics
Atomic statistical equilibrium calculated for non-LTE. Sobolev with exact integration and pressure broadening

Final RT
Co-moving frame ray-tracing

Output
Line spectrum



Stellar wind

$v_r(r) = v_\infty(1-\frac{R_*}{r})^\beta$

$v_\infty = 1.3\ v_{esc}\ \beta = 2.89$

$\dot{M}_{sw} = 0.1, 0.01\dot{\mathrm{M}}_{acc}$

$T_{sw} = 6000, 8000, 10000\ \mathrm{K}$

Accretion funnel

$\dot{M}_{acc} = 10^{-7}, 10^{-8}, 10^{-9}\ \dot{\mathrm{M}}_\odot$

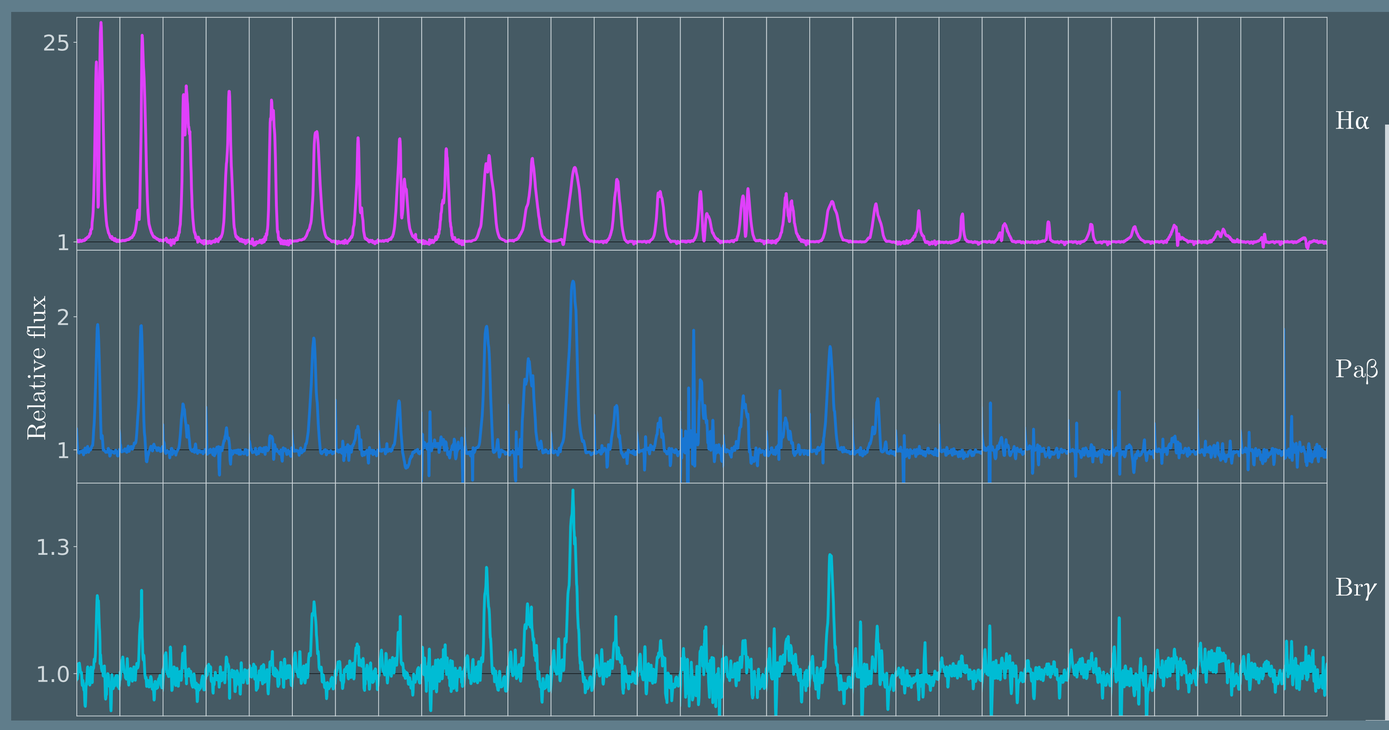
$T_{acc} = 6500, 7500, 8500, 9500\ \mathrm{K}$

Star

$M_* = 0.5\ \mathrm{M}_\odot\ \ T_{eff} = 4000\ \mathrm{K}$

$R_* = 2\ \mathrm{R}_\odot$

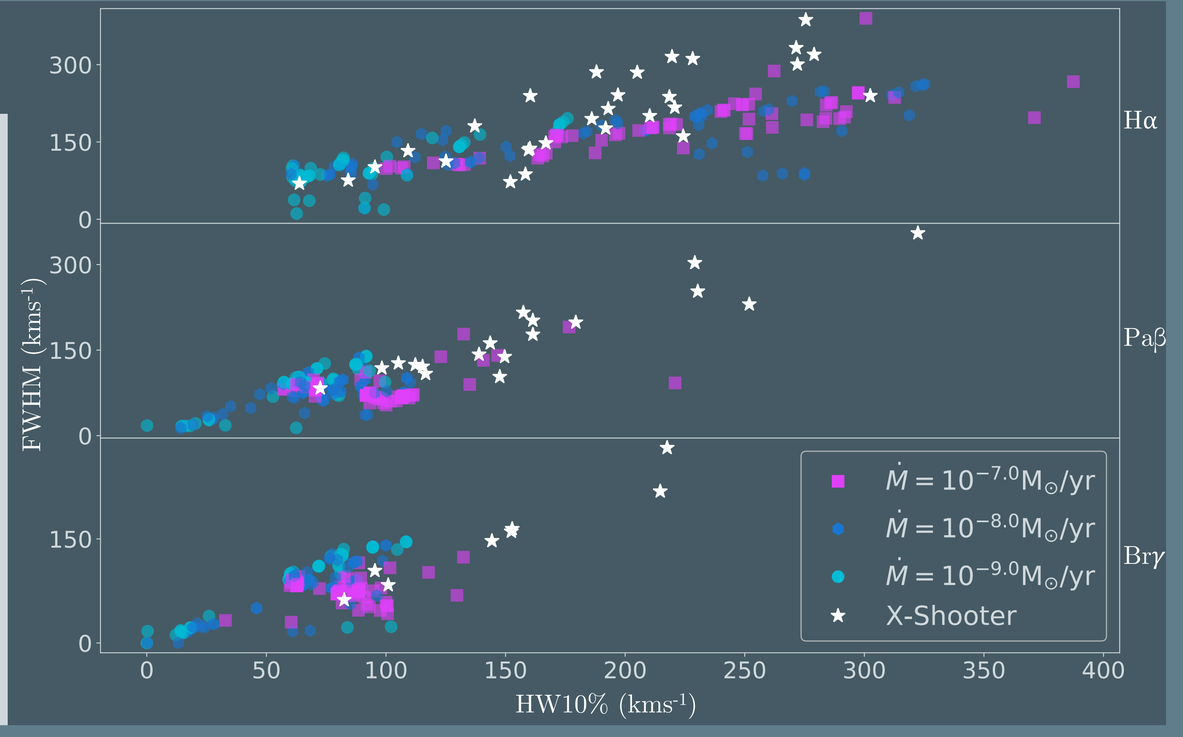
Observations



- Figure shows line profiles for 29 T Tauri stars (columns) from the ESO Archive,[3] selected to have an $\Delta\dot{M}_{acc}\sim10^4$. The stars are ordered by Hα peak intensity.
- High resolution: $R\sim1100$ (infrared) and $R\sim1800$ (optical) spectra from VLT's X-Shooter, observed in Jan 2010.
- Near simultaneous observations of Hα (top), Paβ (middle), and Brγ (bottom). The x-axis is velocity with a range of 600 to −600 kms^{-1}.
- A strong correlation of shape and intensity is seen between the infrared lines, but not between Hα and the infrared observations.

Comparison

- The figure shows the FWHM vs. half width at 10% maxima (HW10%). The synthetic observations are clipped so that the Hα data points lie near the observed parameter space.
- Synthetic and observed Hα lines show a good accord between the measured parameters of Reipurth classification,[4] W_λ, FWHM, and HW10%.
- Synthetic lines for Paβ and Brγ are found to be too narrow and Stark broadening is unable to account for the difference. This suggests another form of broadening needs to be invoked.
- Inverse P-Cygni profiles are commonly predicted by the simulations for Paβ and Brγ yet this is not reflected in the observations.[5]



This research has made use of the services of the ESO Science Archive Facility.

1. Folha, D. F. M. & Emerson, J. P. *Near infrared hydrogen lines as diagnostic of accretion and winds in T Tauri stars.* A&A 365, 90–109 (2001)
2. Harries, T. J., Haworth, T. J., Acreman, D., Ali, A. & Douglas, T. *The TORUS radiation transfer code.* Astronomy and Computing 27, 63–95 (2019)
3. Based on observations collected under ESO programme 084.C-1095(A)
4. Reipurth, B., Pedrosa, A. & Lago, M. T. V. T. Hα emission in pre-main sequence stars. I. an atlas of line profiles. Astronomy and Astrophysics Supplement 120, 229–256 (1996).
5. Folha, D. F. M. & Emerson, J. P, (2001)