The Enigma of Hydrogen Emission from T Tauri Stars

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Summary

- We compare hydrogen emission from 29 T Tauri stars with a grid of 945 synthetic line profiles.
- Our synthetic line profiles match the observed Hα widths, intensities and profile morphologies.
- However, our study indicates that reproducing Hα, Paschen, and Brackett lines simultaneously is problematic. The synthetic infrared lines are too narrow and exhibit a higher than observed frequency of Inverse P-Cygni profiles.

Radiative Transfer Model – TORUS[1]

TORUS

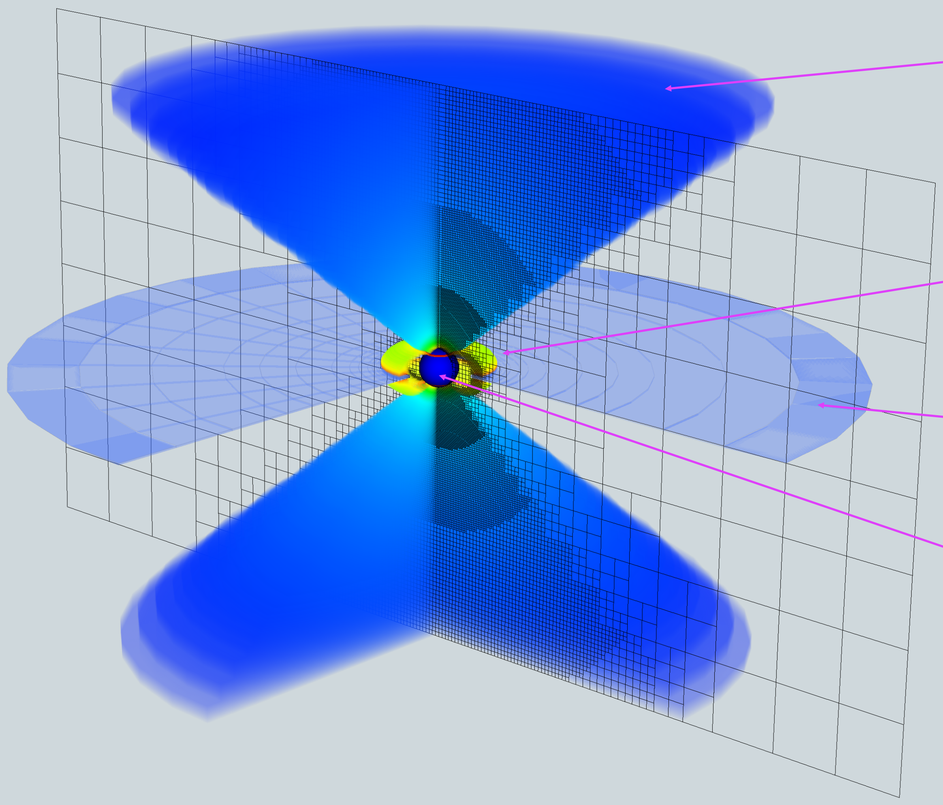
Input
Analytic model

Grid
2.5D with adaptive mesh refinement

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

Final RT
Co-moving frame ray-tracing

Output
Line Profile



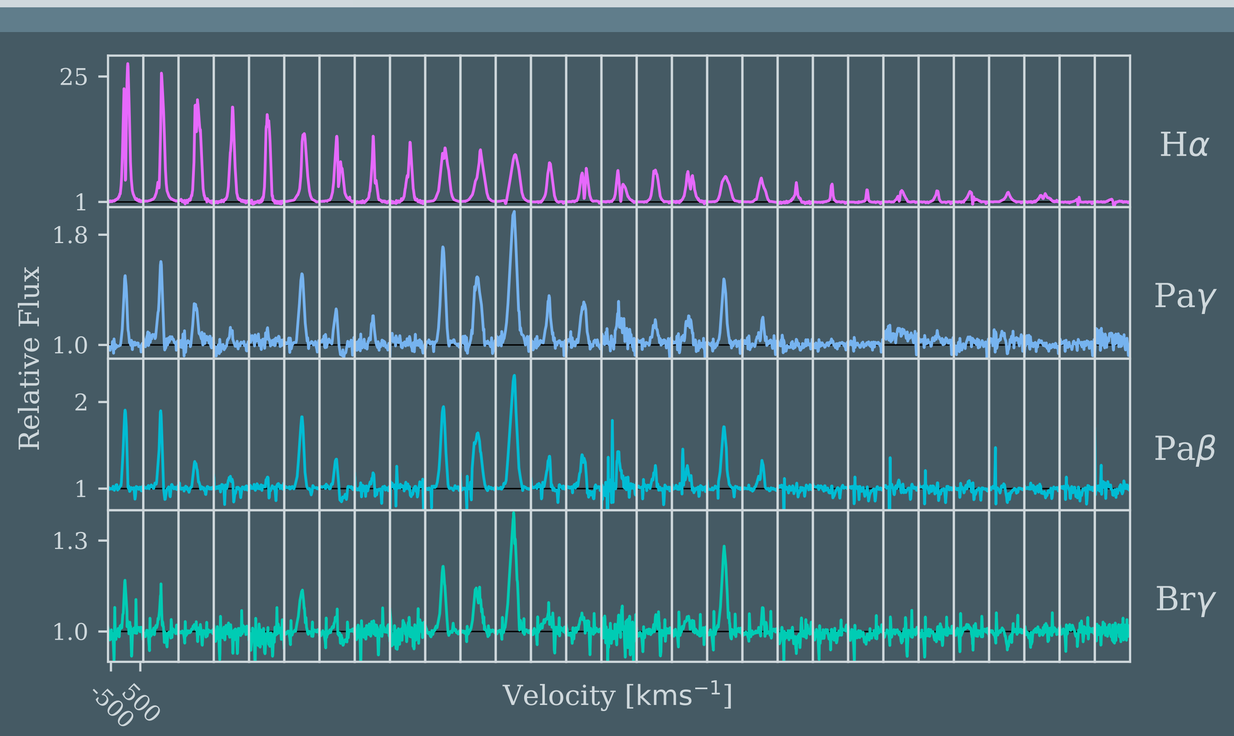
Stellar Wind
$\dot{M}_{sw} = 0.1, 0.01, 0.001\ \dot{\mathrm{M}}_{acc}$
$T_{sw} = 6000, 8000, 10000\ \mathrm{K}$
$v_{\infty} = 1.3\ v_{esc}\ \beta = 2.89$

Accretion Funnel
$\dot{M}_{acc} = 10^{-7}, 10^{-8}, 10^{-9}\ M_{\odot}\mathrm{yr}^{-1}$
$T_{acc} = 6500, 7500, 8500, 9500\ \mathrm{K}$

Disk
Geometrically thin, optically thick

Star
$M_{*} = 0.5\ \mathrm{M}_{\odot}$
$T_{eff} = 4000\ \mathrm{K}$
$R_{*} = 2\ \mathrm{R}_{\odot}$

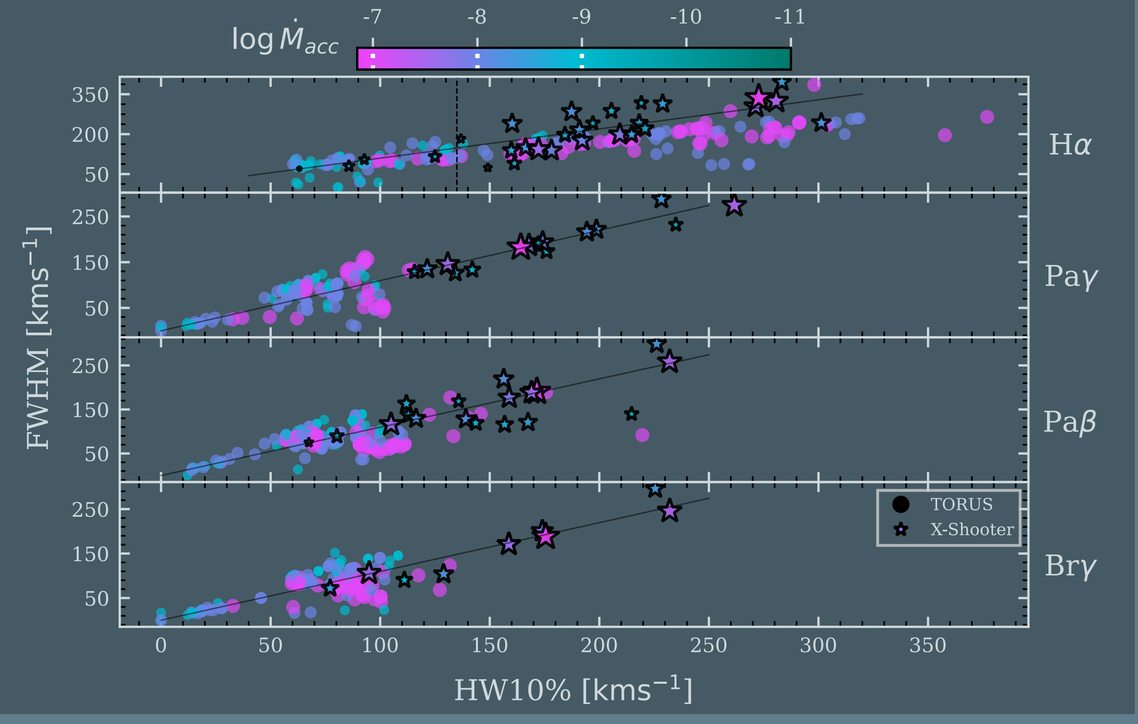
Observations



- Figure shows spectra of 29 T Tauri stars (columns) from the ESO Archive[2]. Stars are ordered by Hα intensity.
- Medium resolution (R~11600 − 18400) spectra from VLT's X-Shooter, observed in Jan 2010.
- Near simultaneous observations of **Hα** (6562 Å), **Paγ** (10938 Å), **Paβ** (12818 Å), and **Brγ** (21655 Å).
- A correlation of structure and intensity is seen between the infrared lines but this correlation is not reflected in Hα.

Comparison

- Figure shows the FWHM vs. half width at 10% maxima (HW10%). Models are clipped so that Hα matches the observed HW10% range.
- Synthetic Hα lines recreate the observed range of widths and distribution of Reipurth types[3].
- The same models produce Paγ, Paβ, and Brγ lines approximately 70 − 100 kms^{-1} too narrow.
- Over 80% of the synthetic Paγ, Paβ, and Brγ lines exhibit Inverse P-Cygni profiles.



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1. Harries, T. J., Haworth, T. J., Acreman, D., Ali, A. & Douglas, T. *The TORUS radiation transfer code.* Astronomy and Computing 27, 63–95 (2019)
2. Based on observations collected under ESO programme 084.C-1095(A)
3. Reipurth, B., Pedrosa, A. & Lago, M. T. V. T. *Ha emission in pre-main sequence stars. I. an atlas of line profiles.* Astronomy and Astrophysics Supplement 120, 229–256 (1996).