Unveiling YSO dynamics through observations and simulations

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Introduction

Young **S**tellar **O**bjects (YSO) are known by the complexity of the angular momentum extraction processes responsible for their deceleration. Some plausible explanations focus on the star-disk interaction, held by strong magnetic fields. Classical T Tauri Stars (CTTS) are the target YSO for this study. Besides being young solar-like stars, they are still accreting from their circumstellar disks and ejecting material in the shape of jets, winds and magnetospheric ejections, for instance.

Goal: Study of accretion and outflow dynamics through observations and magnetohydrodynamic (MHD) simulations.

Observations

We studied 35 CTTS échelle spectra taken at the Utrech Echelle Spectrograph (La Palma), in 7-9 November 1998, by A. Pedrosa.

Simulations

The ideal MHD simulations were performed with PLUTO code (Mignone at al., 2007), until a simulation time of *t = 100*. The magnetosphere of YSOs was simulated through the implementation of the analytical solution for RY Tau derived in Sauty et al. (2011).

Methods

1) Spectral analysis of stellar activity parameters:
- Hα 6563Å → Mass accretion rate
- [OI] 6300Å + [SII] 6731Å → Jet/Wind terminal velocity
- He I (5876Å + 6678Å) → Accretion velocity

2) Simulation of a stellar jet surrounded by an accreting magnetosphere by:
- Reversing the poloidal velocity inside the magnestophere;
- Adjusting mass accretion rates through the multiplying factors of density and velocity.

3) Comparison of stellar activity parameters of this work with the literature, namely for the mass loss/accretion rates:

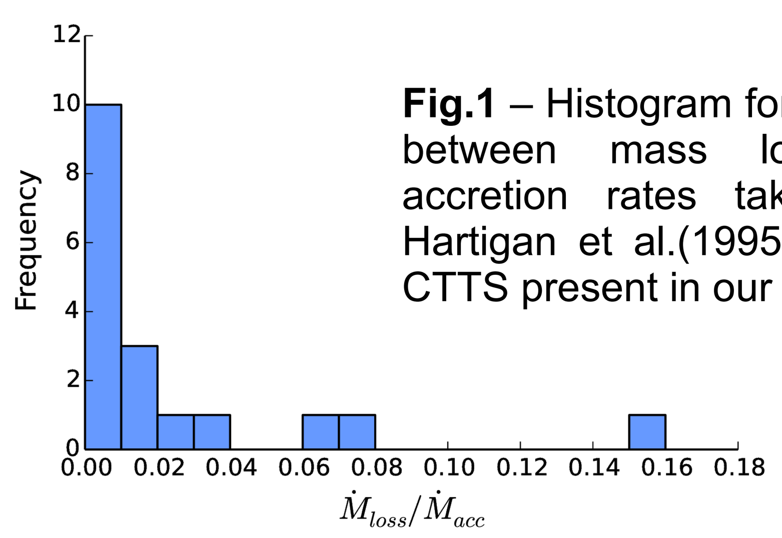


Fig.1 – Histogram for the ratio between mass loss and accretion rates taken from Hartigan et al.(1995), for the CTTS present in our sample.

Results

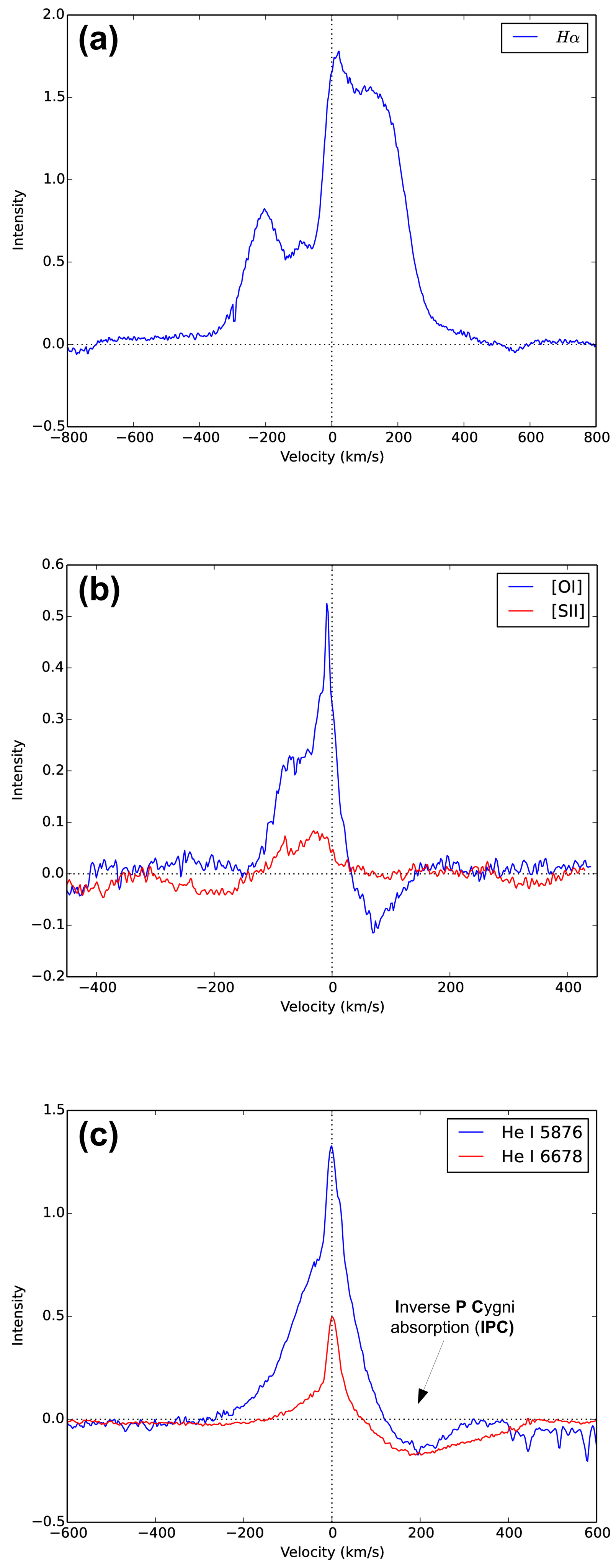


Fig.2 – Velocity plots for:
(a) Hα for RY Tau;
(b) [OI] and [SII] for RY Tau;
(c) He I at 5876Å and 6678Å for DG Tau.

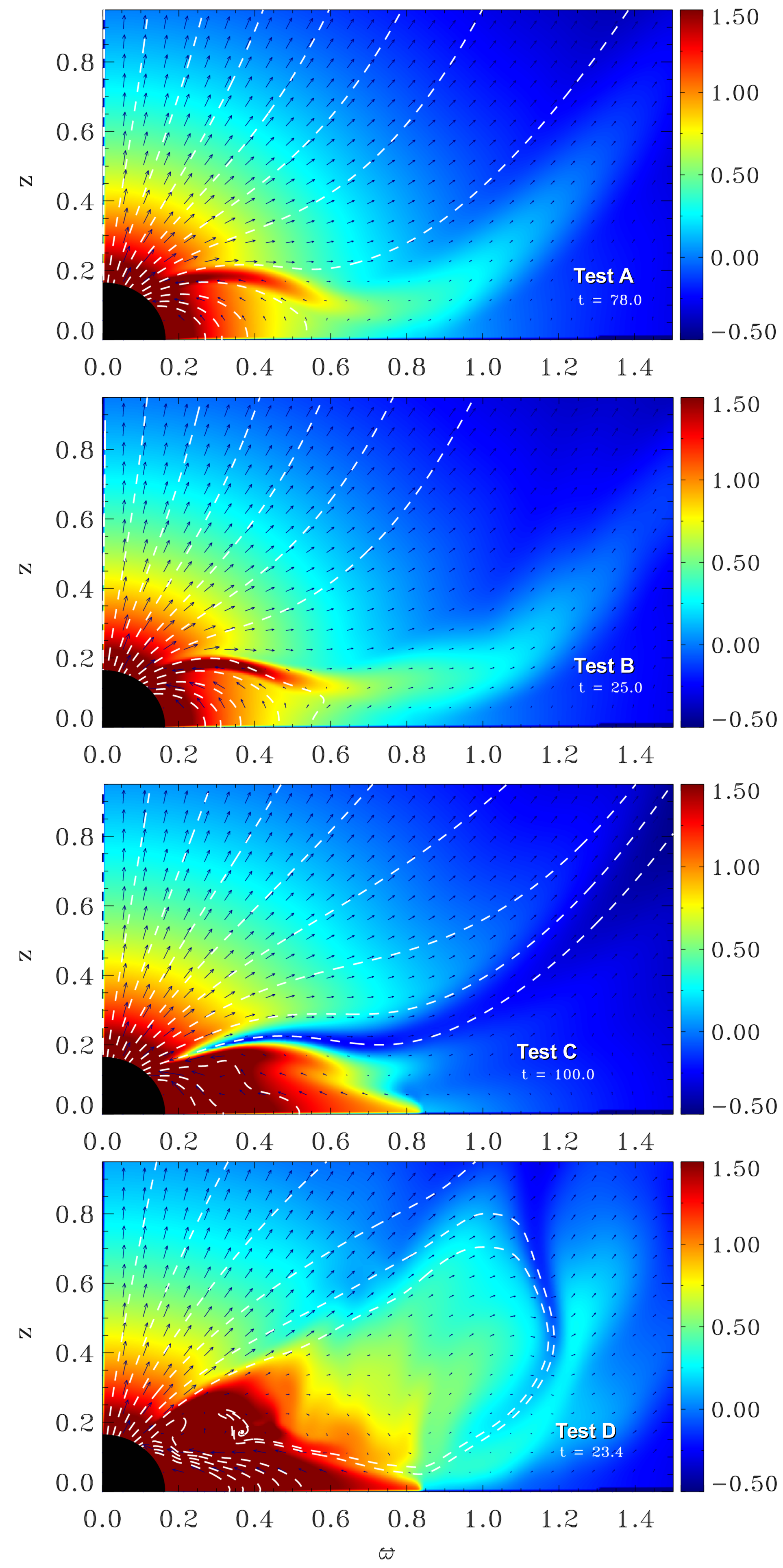
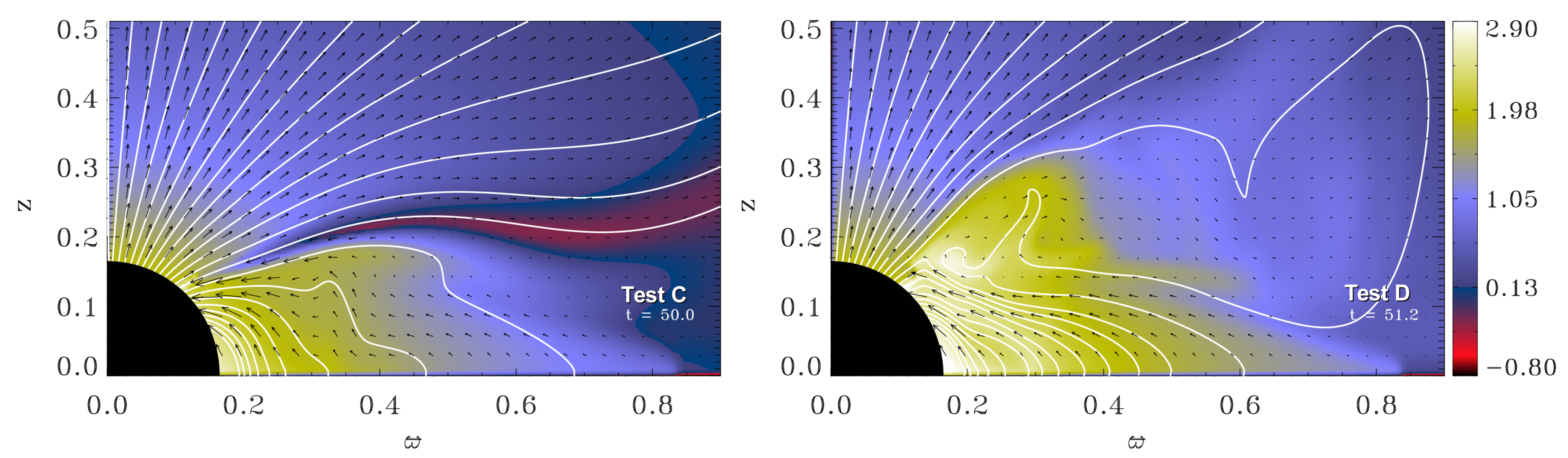


Fig.3 – Density plots for Tests A, B, C and D. The black region defines the star. The white dashed lines represent the magnetic field lines. The arrows correspond to the velocity vectors. One unit in both axis corresponds to 0.1 AU. 1 stellar rotation ↔ t = 8.1

Simulation	Multiplying factors V_r	Multiplying factors ρ	$\dot{M}_{ejec}$ $(M_\odot/yr)$	$\dot{M}_{acc}$ $(M_\odot/yr)$	$\frac{\dot{M}_{ejec}}{\dot{M}_{acc}}$
Test A	−1.0	1	$10^{-8.58}$	$10^{-8.44}$	0.71
Test B	−1.5	1	$10^{-8.61}$	$10^{-8.26}$	0.45
Test C	−1.5	5	$10^{-8.59}$	$10^{-7.68}$	0.12
Test D	−2.0	10	$10^{-8.58}$	$10^{-7.29}$	0.05

Table 1 – Multiplying factors for radial velocity (V_r) and density (ρ) used in each simulation. Mass fluxes for ejection and accretion are shown as well as the corresponding ejection/accretion ratios.

Fig.4 – Zoom-in density plots for Tests C and D, with a different colorbar and scale. The white solid lines represent the magnetic field lines and the remaining elements are the same as in Fig.3 .



Conclusions

- The **observations** returned terminal velocities between -350 and -120 km/s (e.g. Hartigan et al.,1995, 2004) and accretion velocities from 200 to 500 km/s (e.g. Hartmann, 2009). The mass accretion rates, derived with the empirical relation of Natta et al. (2004), are within the typical values for CTTS: 10^{-9} to 10^{-7} M_{sun}/yr (e.g. Basri and Bertout, 1989; Hartigan et al., 1995; Gullbring et al., 1998).
- The **simulations** confirm that accretion is dominant over ejection and Test D results are closer to the observational values of RY Tau. Accretion and outflow mechanisms seem to achieve a quasi-steady configuration for Test C.
- Observational data will help us to constrain future simulations with an accretion disk.

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