# From Observations to Numerical Simulations of YSO jets with Magnetospheric Accretion and Dead Zone

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# Observations & Simulations with Accretion Funnel and Stellar Jet

Threshold Value

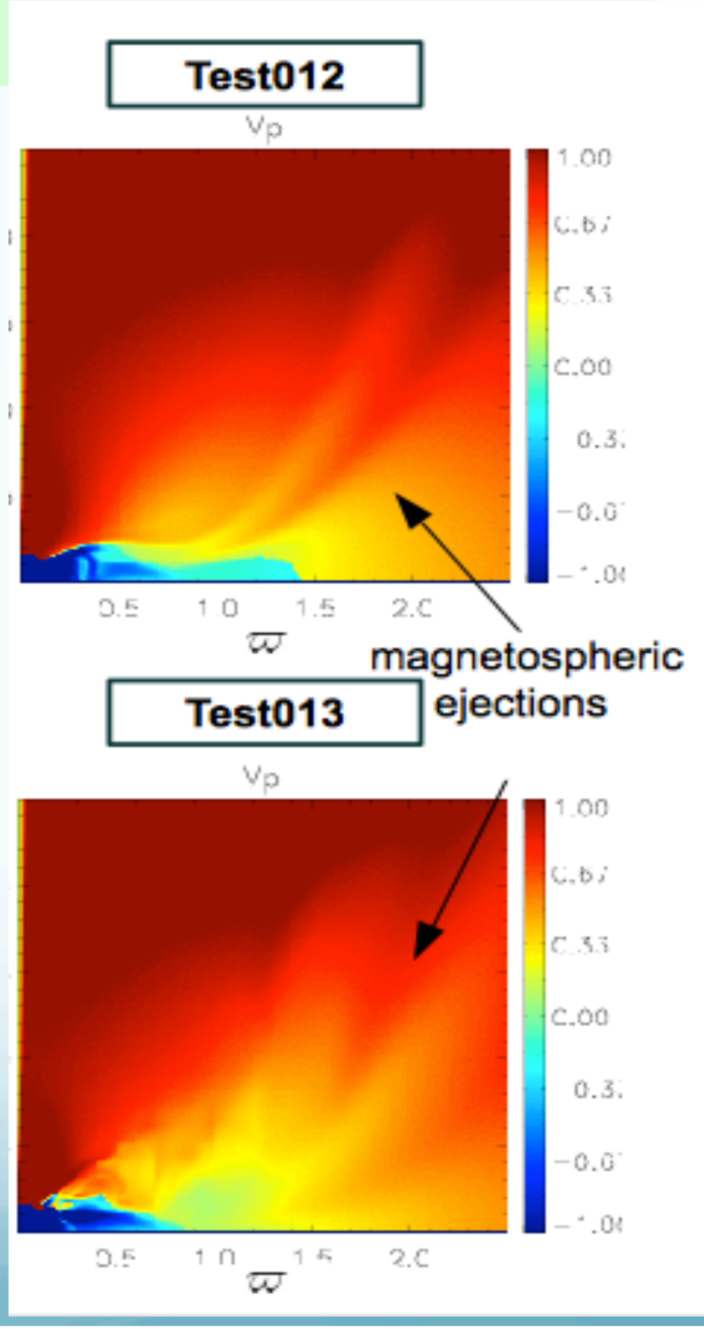
Alubuquerque et al. Submitted to A&A

Synthetic Map
→
New coll. L. Ibgui, R. Albuquerque MEETING in December

| Simulation | Multiplying factors | | $\dot{M}_{ejec} / \dot{M}_{acc}$ |
|---|---|---|---|
| | $V_r$ | ρ | |
| **Test010** | 1.0 | 1 | 0.79 |
| **Test011** | 1.5 | 1 | 0.46 |
| **Test012** | 1.5 | 5 | 0.15 |
| **Test013** | 2.0 | 10 | 0.04 |

**Accretion : Hα P Cygni Profile**
**-> Mass Accretion Rate**
**-> Max Accretion Speed**

**Jet : Forbidden Lines(SII, OI, ...)**
**-> Terminal Jet Velocity**
**-> Mass Loss Rate**



# Accretion Funnel and Stellar Jet

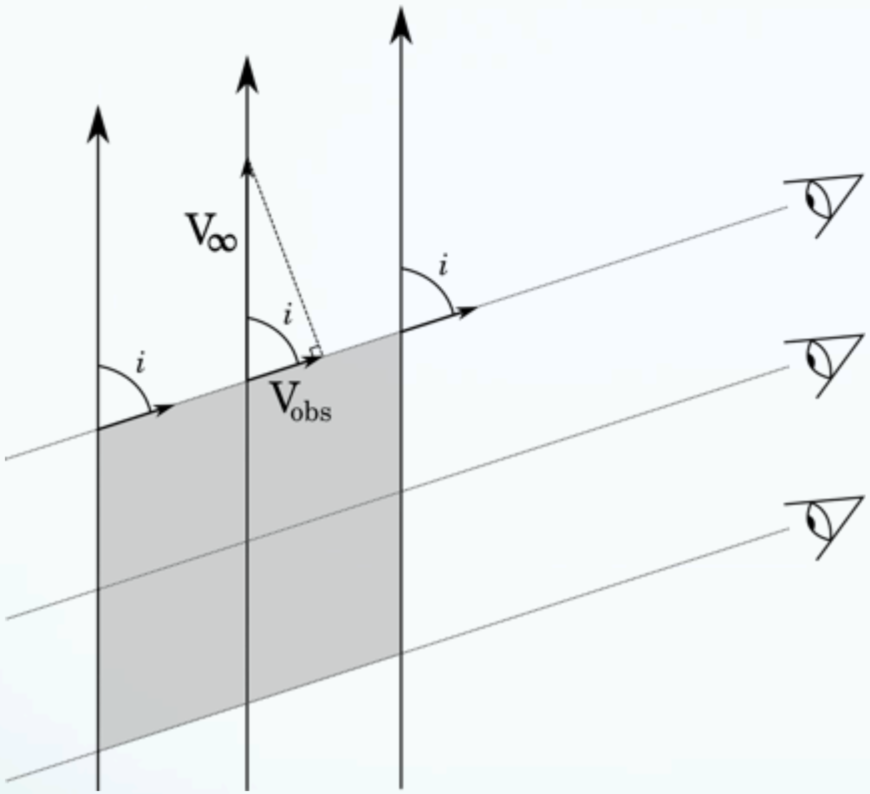



Fig. 7. Representation of the terminal velocity of the outflow faraway from the star, where the velocity should reach a constant value approximately, and the observed terminal velocity of the stellar jet pro- jected in the line of sight. The inclination angle is denoted by i.

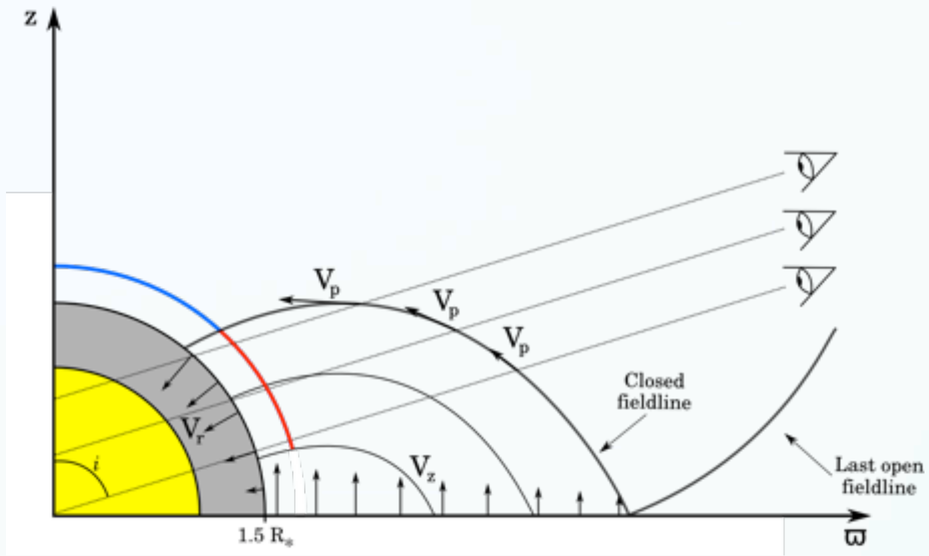



Fig. 6. Illustration of a star (yellow region) and respective magnetospheric region delimited by the closed magnetic fieldlines (black solid lines), in an initial stage of the MHD simulations. The PLUTO code simulations are conducted from 1.5 stellar radius (grey shaded region). The radial, vertical and poloidal velocity components are represented as well as the inclination angle (i) between the observer's line of sight and the star rotation axis. For this study, we choose the jet axis to be coincident with the stellar rotation axis. The mass flux determined for the jet and magnetospheric regions were computed along the blue and red lines, respectively. The last open magnetic fieldline defining the jet region and the closed fieldline delimiting the magnetospheric region are represented with the grey solid line.

# Accretion Funnel and Stellar Jet

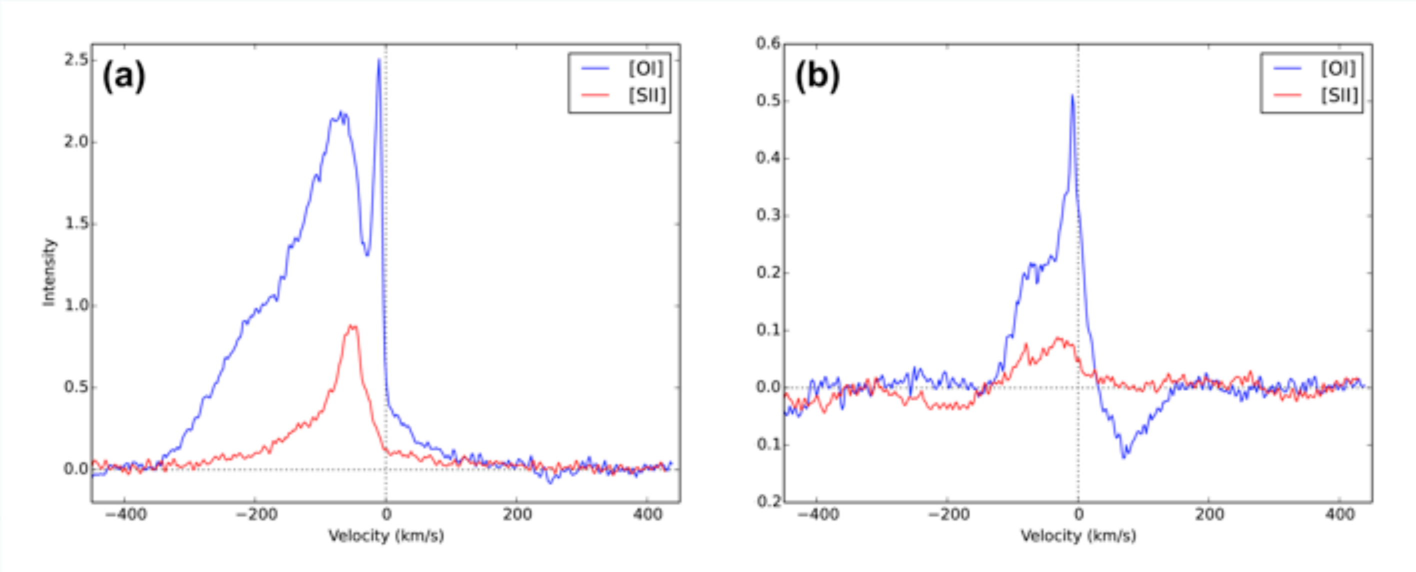



Fig. 1. Velocity plots for the forbidden lines of [O I] (blue line) and [S II] (red line) at 6300 and 6731Å, respectively, for (a) DG Tau and (b) RY Tau. The blue edge of the line emission that crosses the continuum gives an estimate of the terminal outflow velocities.

From OI line luminosity using Comeron et al 2003 we also get the Mass Loss rates

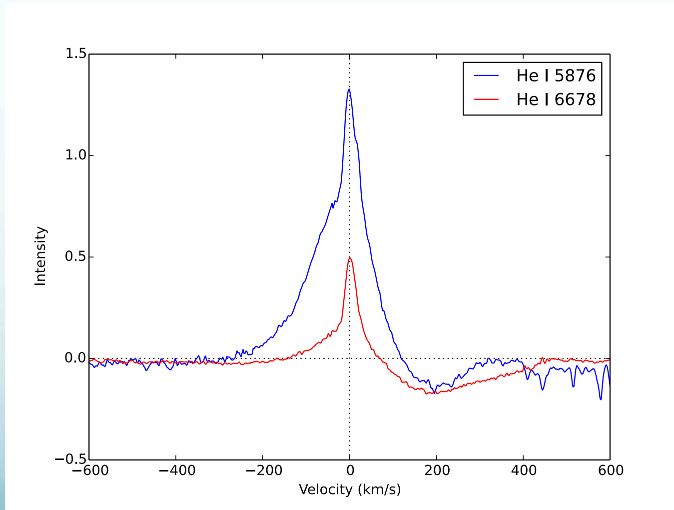



Fig. 2. Velocity plot for He I emission line at 5876Å (blue line) and 6678Å (red line) in DR Tau. The red edge of the inverse P Cygni absorption that crosses the continuum gives an estimate of the projected accretion velocities.

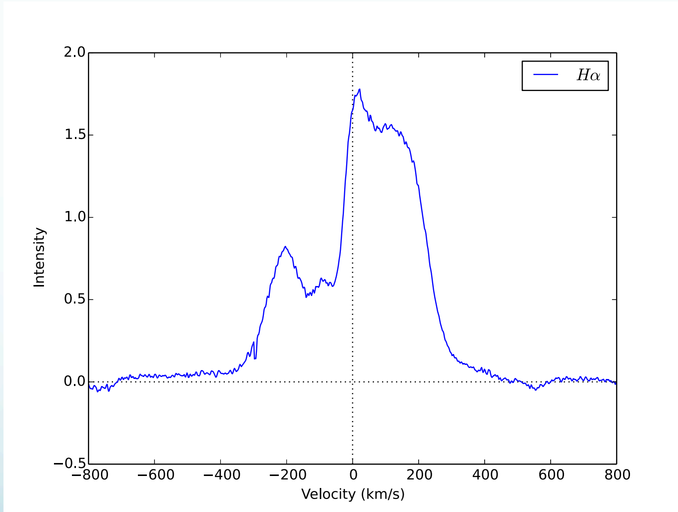



Fig. 3. RY Tau velocity plot for the Hα emission line. From the line profile using the empirical law of Alcala et al 2014) we determine the Accretion Rate

# Observations

35 Stars, Comparison our Observations / Litterature

| Object | $EW_{H\alpha}$ (Å) | $EW_{HeI}$ (Å) | $EW_{[OI]}$ (Å) | $V_{term}$ (km/s) | $r_{6200}$ | $R_0$ | $\log \dot{M}_{acc}^{H\alpha}$ ($M_\odot$/yr) | $\log \dot{M}_{acc}^{HeI}$ ($M_\odot$/yr) | $\log \dot{M}_{acc}^{lit}$ ($M_\odot$/yr) | $\log \dot{M}_{loss}$ ($M_\odot$/yr) | $\log \dot{M}_{loss}^{lit}$ ($M_\odot$/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | 13 | ... | [illegible] | [illegible] | [illegible] | ... | ... | ... | [illegible] | ... | ... |
| RW Aur | 61 | 1.41 | 1.9 | 299 | >2 | 8.64 | -7.2* | -7.1* | -6.47[c] | -6.7* | -7.6[b] |
| RY Tau | 12 | 0.05 | 0.7 | 143 | 0.21 | 9.83 | -7.6 | (-8.3) | -7.6[b] | -7.8 | -8.8 to -7.6[b] |

Table 2. The list of targets with their names is shown in the 1st column followed by corresponding data.

The equivalent widths measured in IRAF, whenever possible, for Hα 6563Å, He 5876Å and [O i] 6300Å emission lines are listed from the 2nd to the 4th columns.

The absolute values of the measured terminal velocities from the forbidden line of [O i] at 6300 Å are shown in the 5th column. The veiling values estimated in this work, near 6200Å, are shown as well as the derredened magnitudes taken from Hartigan et al.

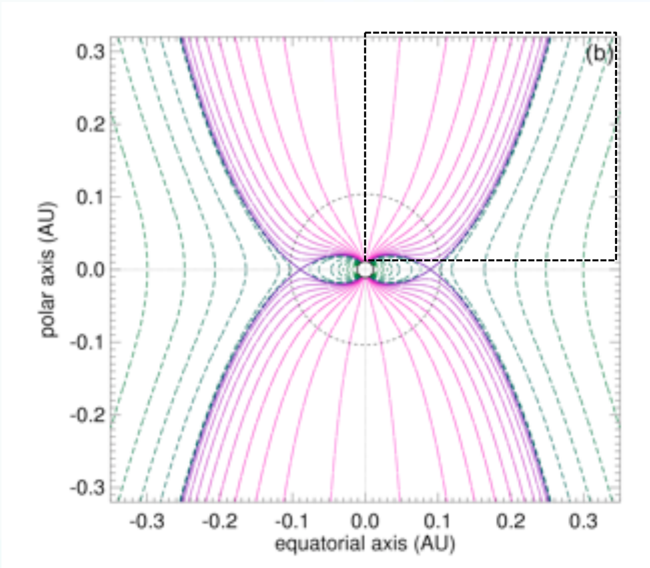
(1995) (6th and 7th column, respectively).

The mass accretion rates determined through the Hα (log $\dot{M}_{HA}$) and He i (log $\dot{M}_{HeI}$) are listed in the 8th and 9th columns, respectively, and the corresponding values in the literature are also shown in the 10th column.

Finally, the mass loss rates determined from the forbidden line of [O i] (11th column) and the values available in the literature log $\dot{M}$ lit (12th column) are also listed.

**TABLE 2**

# Numerical Simulations of jet & magnetospheric accretion and dead zones




## Initial conditions

**Use of the analytical solution**

**for RY Tau**

Sauty et al. 2011

## Boundary conditions

**DEAD ZONE**

**1) zero Poloidal velocity, solid body rotation (star surface, equatorial plane)**

**OR**

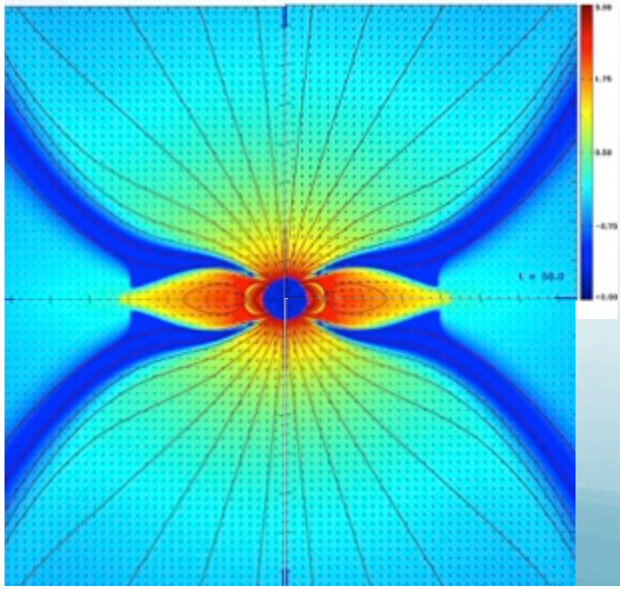
**2) Low & Tsinganos 1989 model with enhanced r and continuous B and P**

**ACCRETING MAGNETOSPHERE**

**reverse velocity in accretion zone**

**& Adapted heating (see after)**

**& Increased mass flux (multiply r and Vp)**

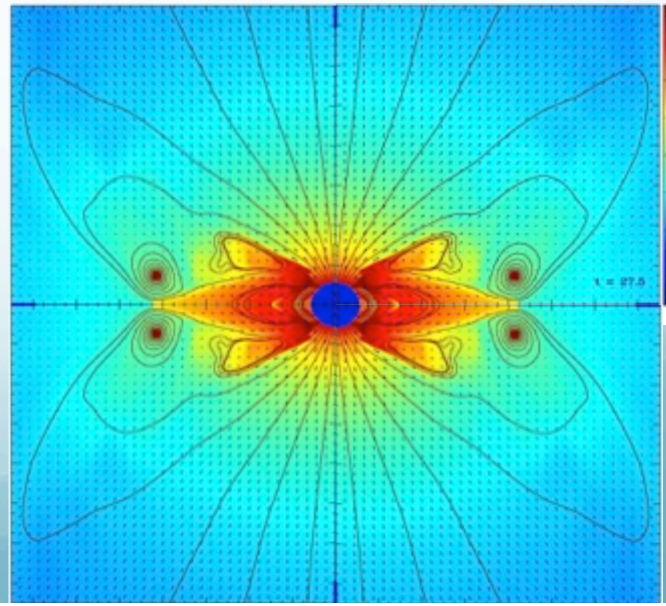


**Maccr/Mjet = 15**

r acc=10 r jet

V acc=-1.5 V jet

no CMEs/Xwind



**Maccr/Mjet = 27**

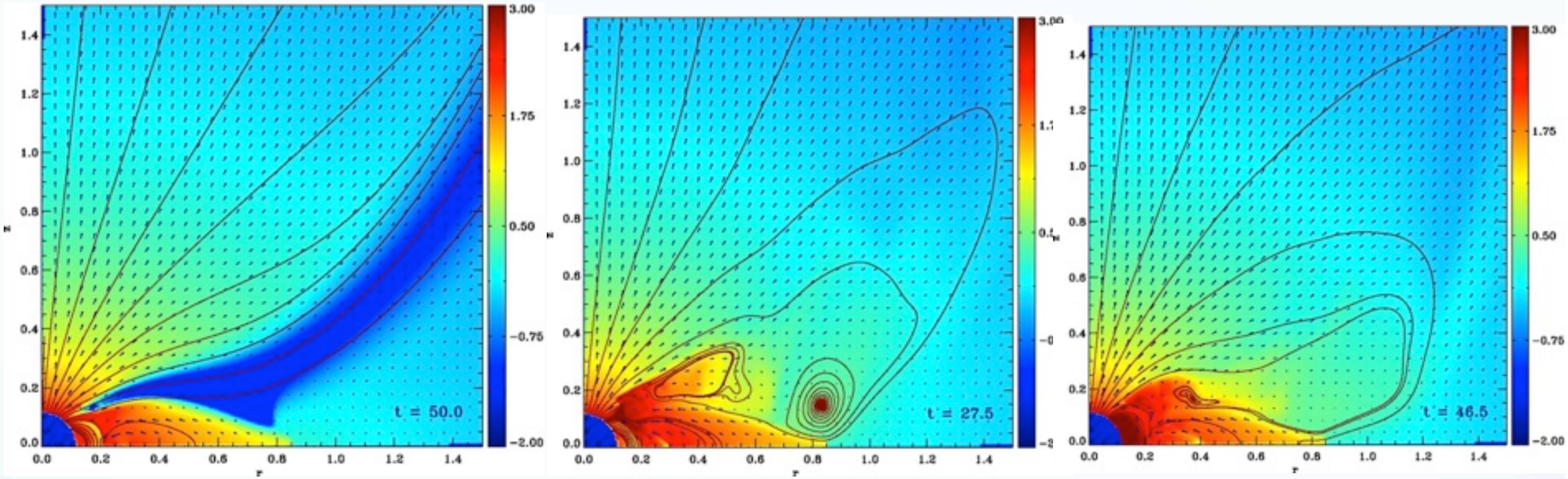
r acc=15 r jet

V acc=-1.8 V jet

Strong CMEs/X-wind

## Varying Accretion Rate (15x & 27 x Mass Loss Rate) (OCCIGEN, MesoPSL, etc...)

properties depending on the accretion rate & the strength of stellar wind




**Maccr/Mjet = 15**

Lower Accretion Rate →

ρ acc=10 ρ jet

V acc=-1.5 V jet

no CMEs/Xwind

**Maccr/Mjet = 27**

Higher Accretion, 2 Dead Zones →

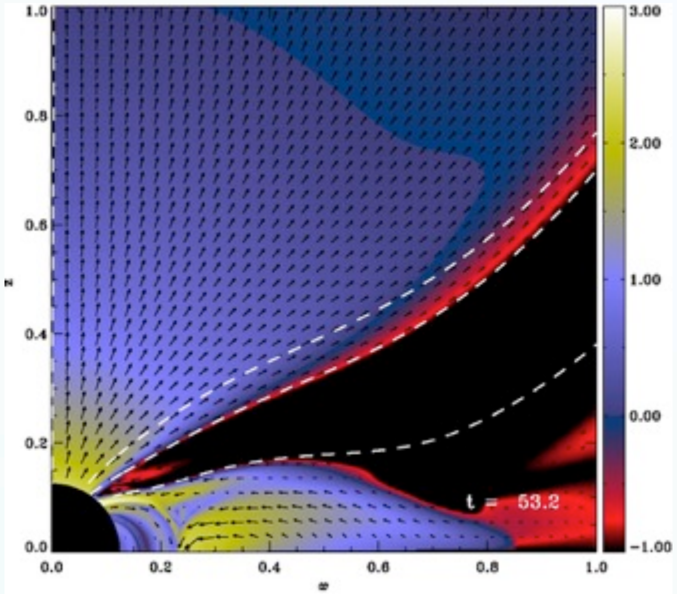
ρ acc=15 ρ jet

V acc=-1.8 V jet

*Strong?* CMEs/X-wind

**Isocontours of Log(ρ) solid lines: $B_P$ Magnetic Field Lines arrows: Velocity field**

# Varying The Dead Zone (OCCIGEN, MesoPSL, etc...)

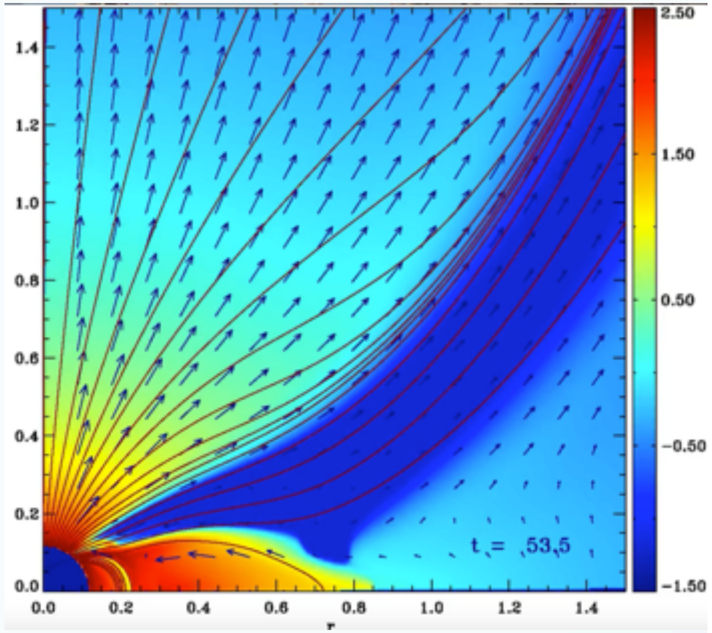


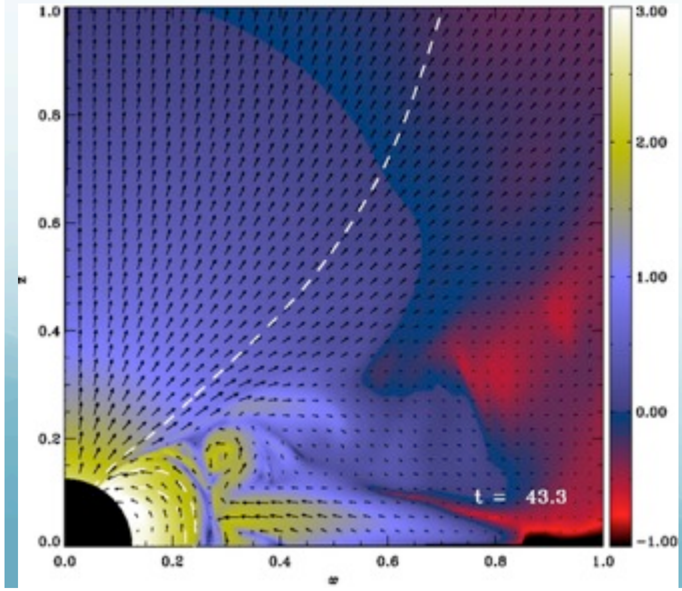

**Maccr/Mjet = 12**

ρ acc=8 ρ jet

V acc=-1.5 V jet

Dead Zone from the Analytical Solution



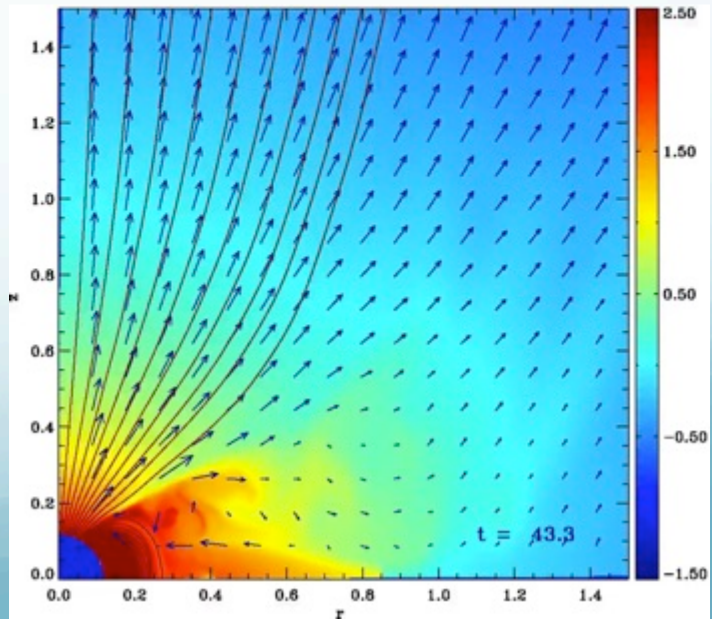




**Maccr/Mjet = 12**

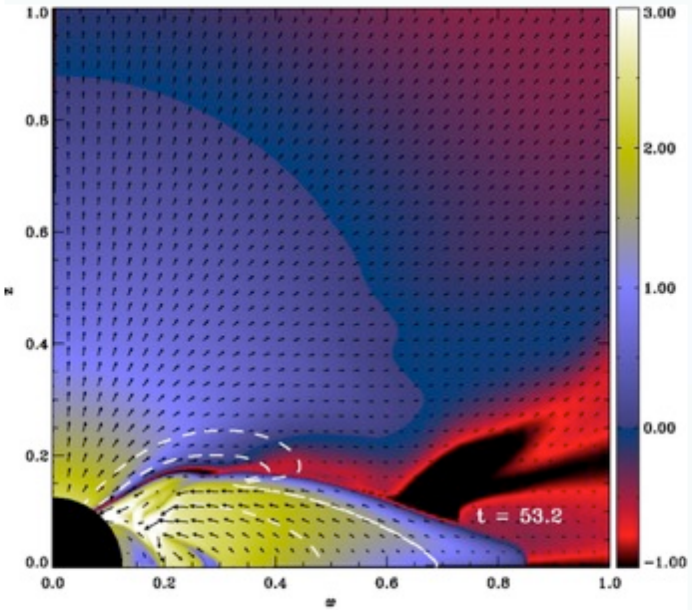
ρ acc=8 ρ jet

V acc=-1.5 V jet

Over dense dead zone with Pressure Eq. (Low & Tsinganos)



# Varying The Dead Zone (OCCIGEN, MesoPSL, etc...)

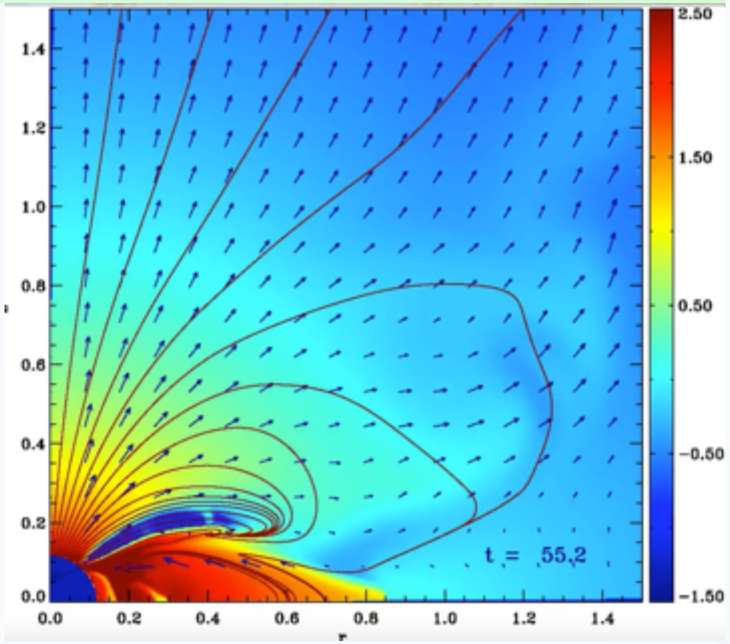


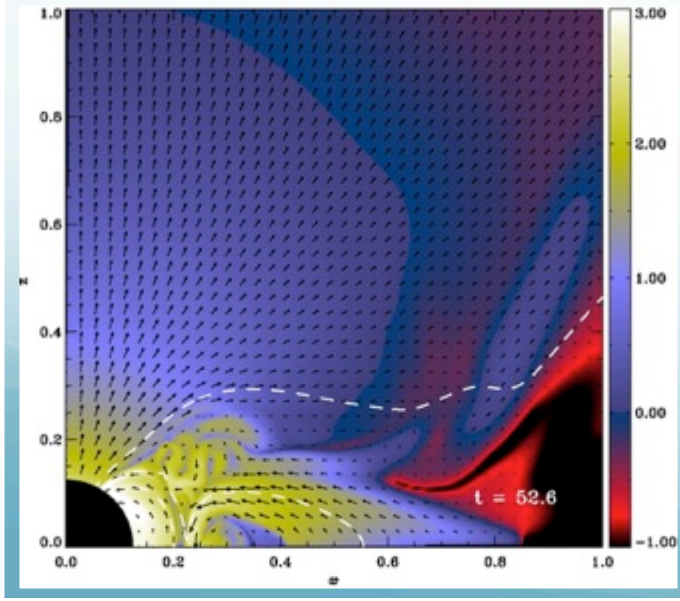

**Maccr/Mjet = 27**

ρ acc=15 ρ jet

V acc=-1.8 V jet

Dead Zone from the Analytical Solution



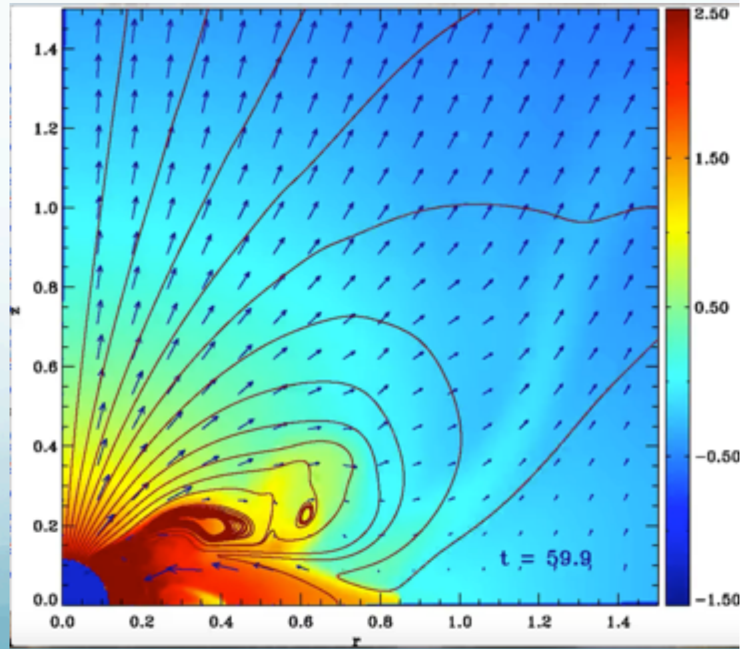




**Maccr/Mjet = 27**

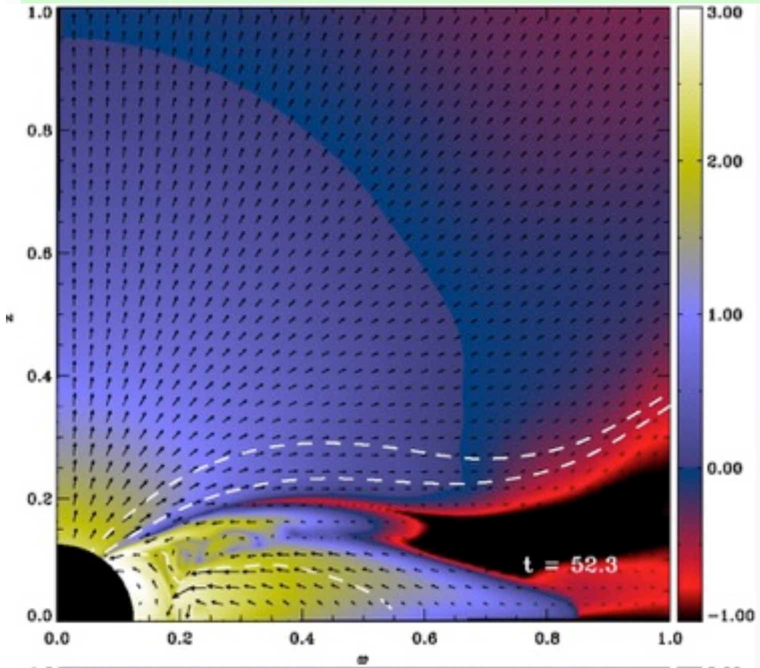
ρ acc=15 ρ jet

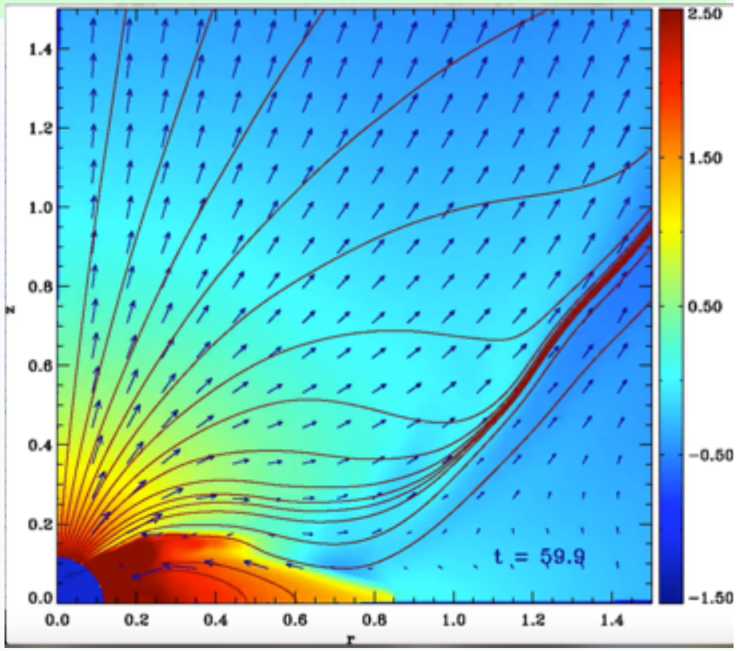
V acc=-1.8 V jet

Over dense dead zone with Pressure Equil. (Low & Tsinganos)



# Varying The Dead Zone



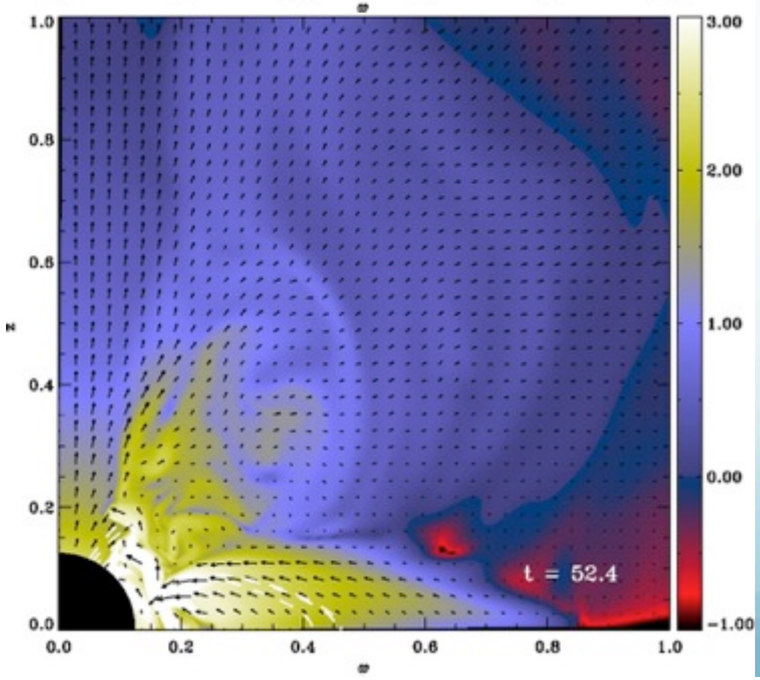



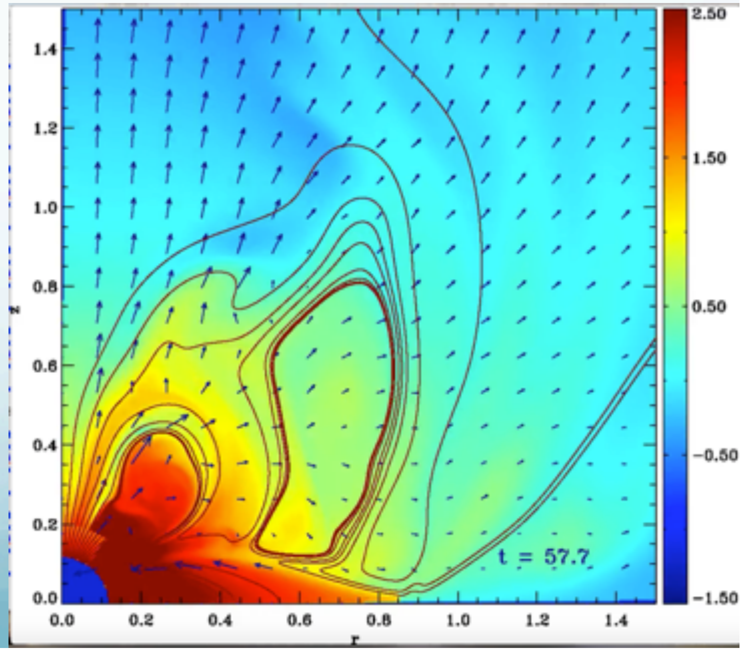

**Maccr/Mjet = 18**

ρ acc=12 ρ jet

V acc=-1.5 V jet

Over dense dead zone with Pressure Eq. (Low & Tsinganos)




**Maccr/Mjet = 40**

ρ acc=22 ρ jet

V acc=-1.8 V jet

FUOR ?? Conical WIND

# Conclusions

**Self-similar analytical solutions as initial conditions in PLUTO simulations**

⇒ **Consistent models of launching zone for jets with static magnetosphere, « dead zone » and an accretion funnel**

⇒ **Magnetospheric accretion, stellar and disk outflows in steady state after few tens of stellar rotations and are stable or quasi periodic**

⇒ **2 TYPES OF DEAD ZONES**

⇒ **NEED TO DETERMINE THE MASS FLUX of the X winds !!!!**

**Variation of velocity and density for initial conditions in accretion zone, variation of the construction of the dead zone**

⇒ **Accretion and ejection rates in agreement with observations**

⇒ **Transition from No X wind to episodic magnetospheric ejection**

⇒ ***QUANTITATIVELY DEPENDS ON THE CONSTRUCTION OF THE DEAD ZONE***

*1 Paper Submitted to A&A*

# Conclusions

**Synthetic Map : coll. between R. Albuquerque & L. Ibgui**
**Meeting in december 4, 5**

**This year:**

**- 6 months in France, PhD R. Albuquerque**

**- 2 participants to the meeting  Francesco's Legacy/ Star Formation in Space and Time 2017**

**- Invited to the 1 day conf in honour of T. Lago, T. Lago Amongst Friends**

**+ extension for a visit of coll. to CAUP (Oct.)**

**- (1 week visit to Athens  3 persons in July)**

**- visit of K. Tsinganos (invited OP, Nov)**

**- Visits to Athens ( 3 persons) in December (AFE)**

**Next year:**

**- invitation of J. Lima (sabbatical, 2 months OP, P7)**

**- K. Tsinganos 15 days invitation P7.**

**- Meeting in honour of K. Tsinganos on Jets and Accretion (PNPS, CIAS, AFE?),**