l'Observatoire de Paris

PSL RESEARCH UNIVERSITY PARIS

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

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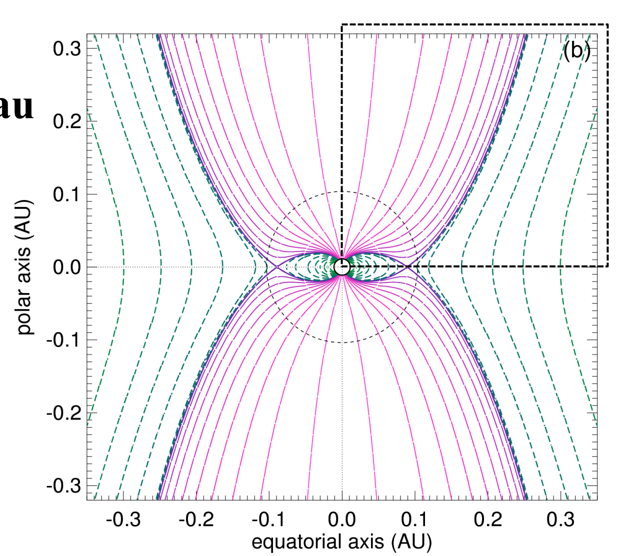
Numerical Simulations of jet & magnetospheric accretion and dead zones

Initial conditions

= analytical solution for RY Tau

Sauty et al. 2011



Boundary conditions

DEAD ZONE

1) solid body rotation, under dense

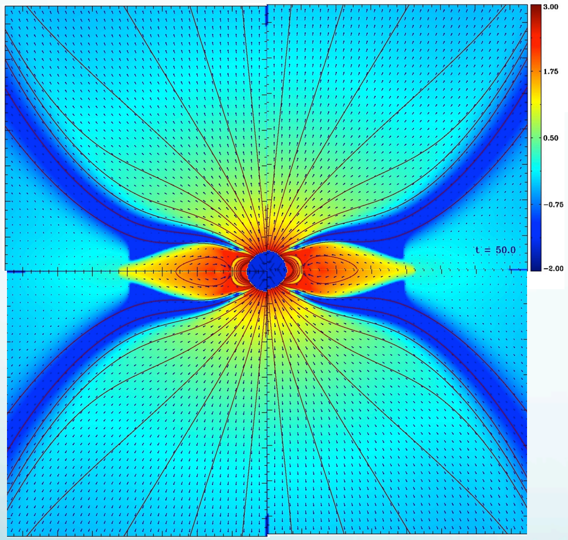
2) Low & Tsinganos 1989 enhanced density

ACCRETING MAGNETOSPHERE

reverse velocity in accretion zone

& Adapted heating (see after)

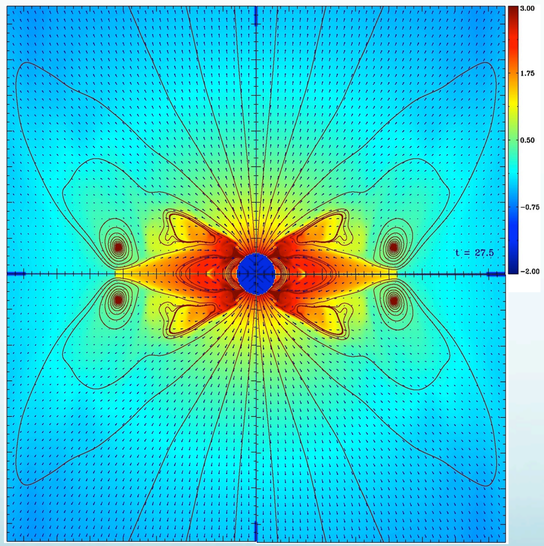
& Increased mass flux



Maccr/Mjet = 15

ρ acc=10 ρ jet V acc=-1.5 V jet

no CMEs/Xwind



Maccr/Mjet = 27

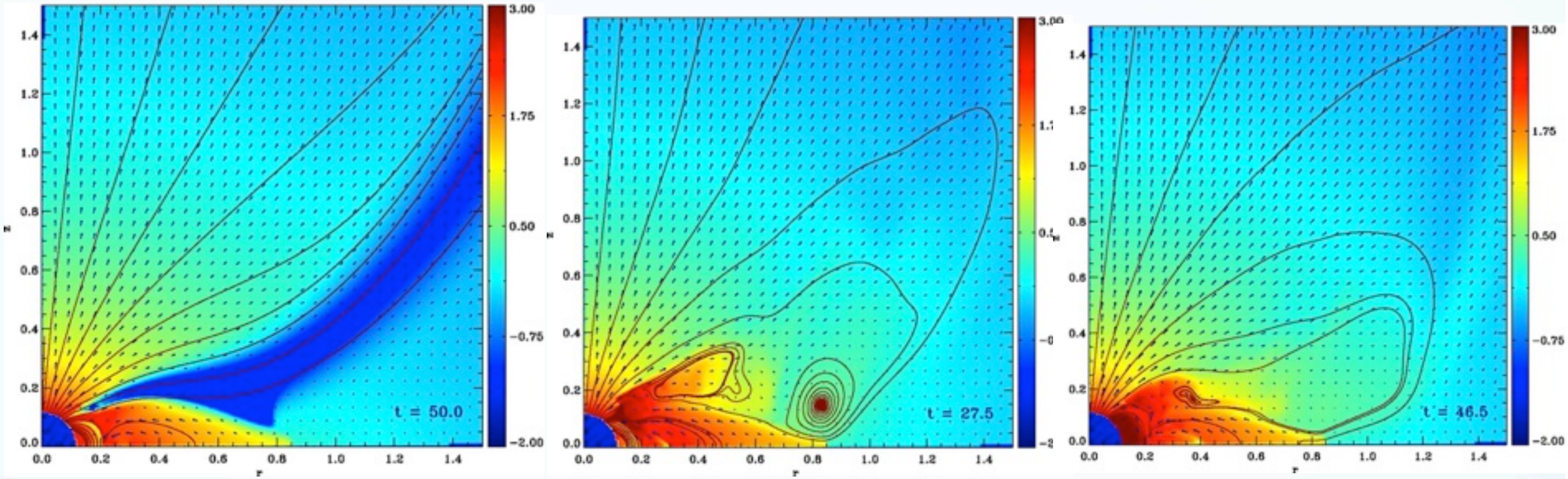
ρ acc=15 ρ jet V acc=-1.8 V jet

Strong CMEs/X-wind

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

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 →

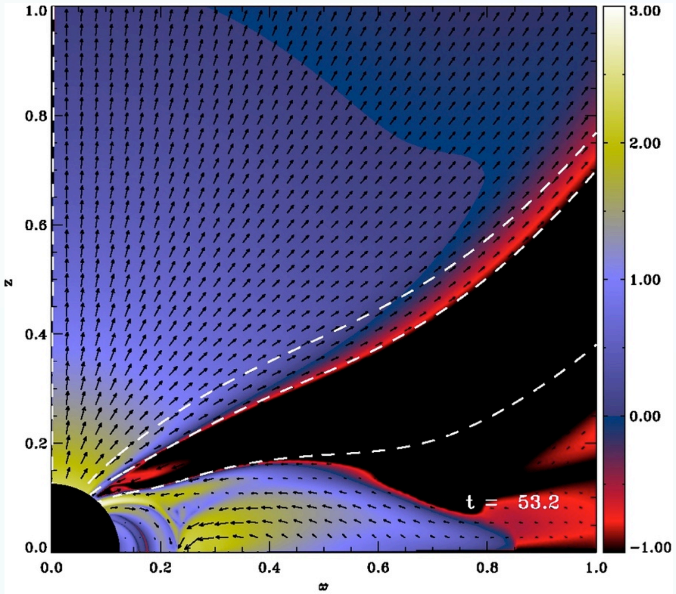
ρ acc=15 ρ jet

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...)

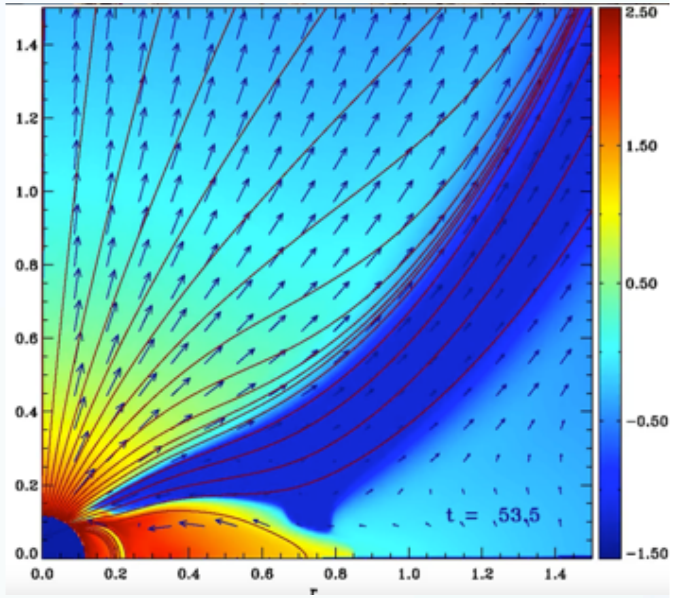


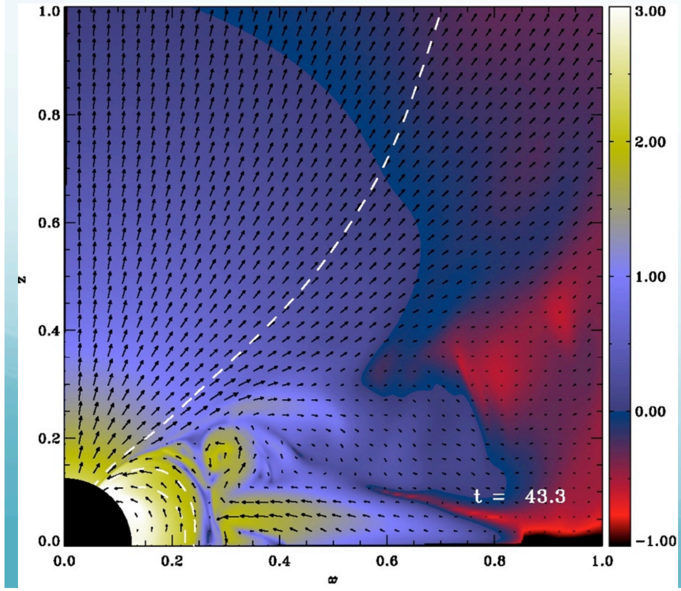
Maccr/Mjet = 12

ρ acc=8 ρ jet

V acc=-1.5 V jet

Dead Zone from the Analytical Solution



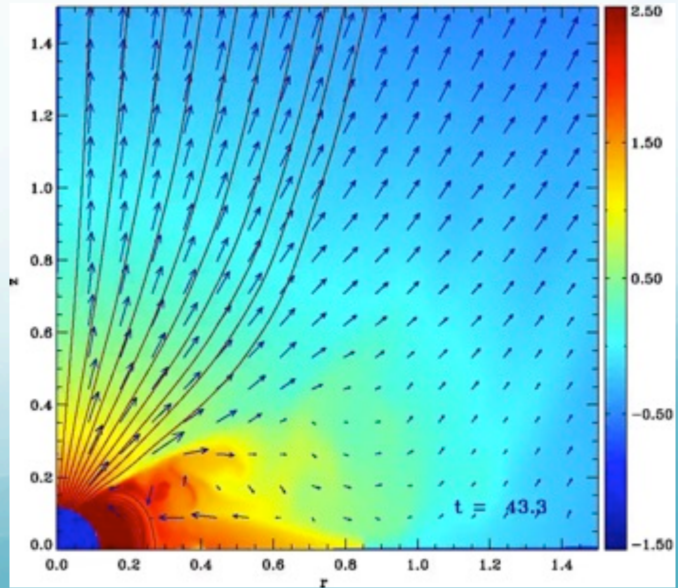


Maccr/Mjet = 12

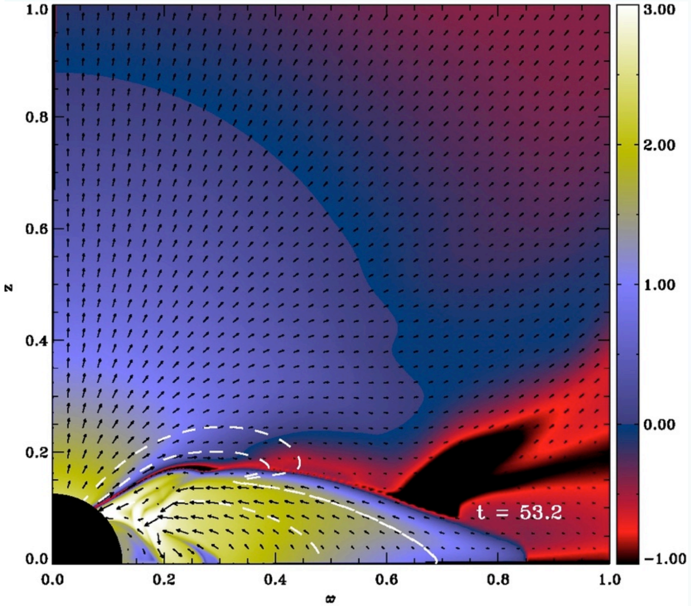
ρ acc=8 ρ jet

V acc=-1.5 V jet

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



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

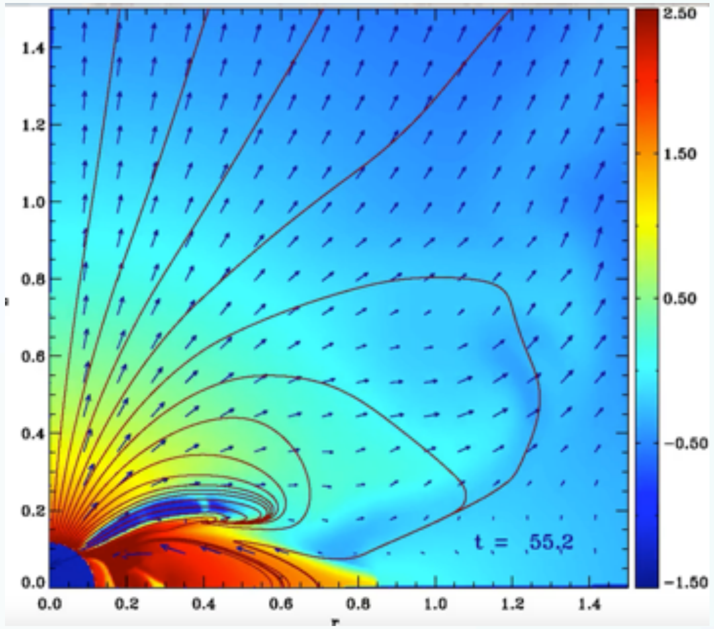


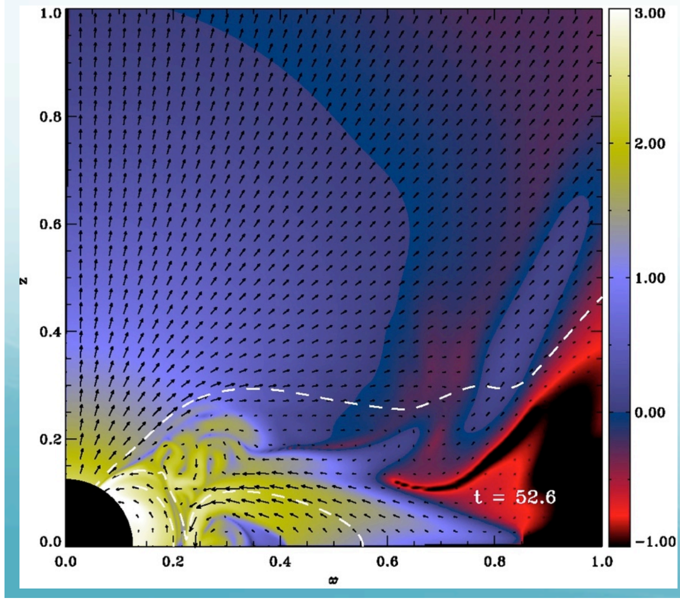
Maccr/Mjet = 27

ρ acc=15 ρ jet

V acc=-1.8 V jet

Dead Zone from the Analytical Solution



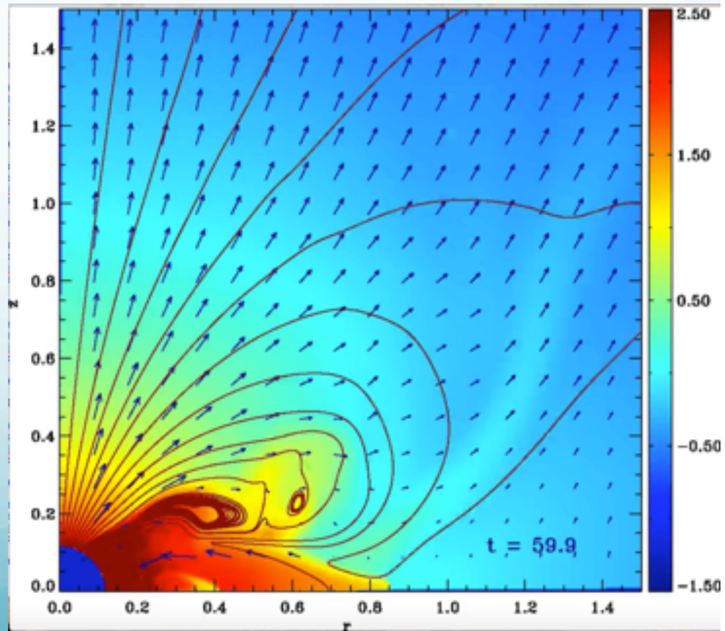


Maccr/Mjet = 27

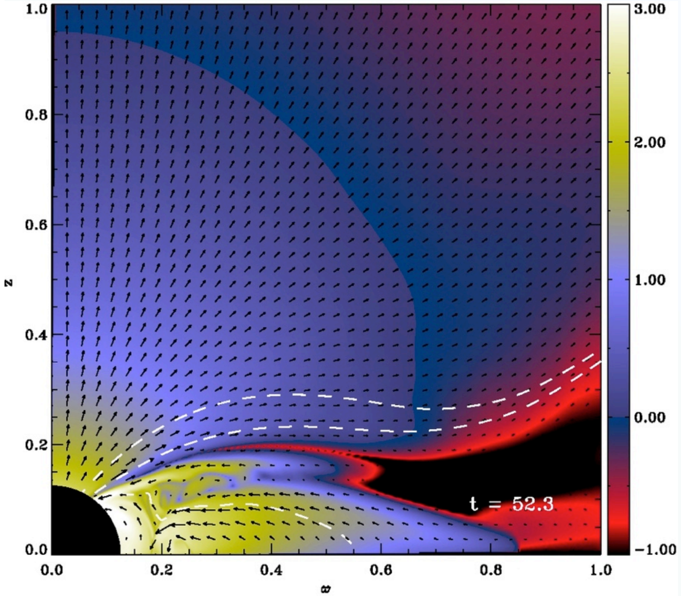
ρ acc=15 ρ jet

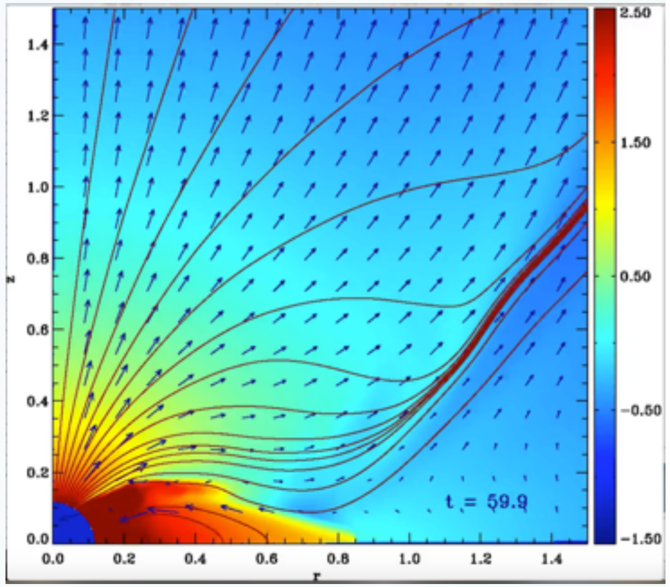
V acc=-1.8 V jet

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



Varying The Dead Zone



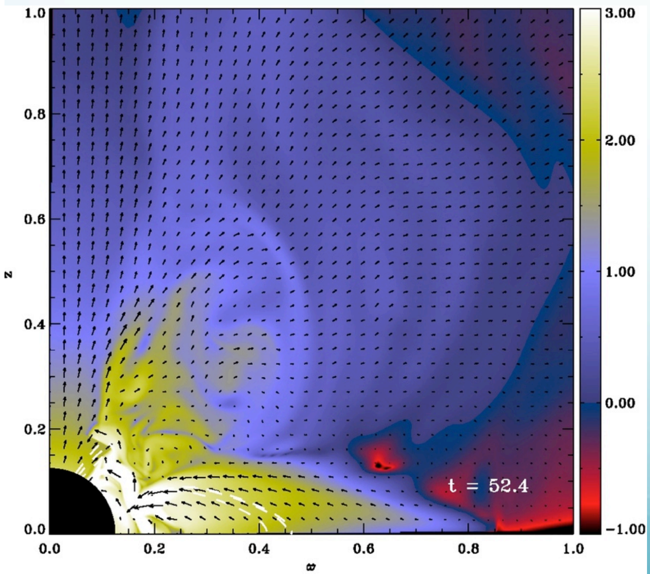


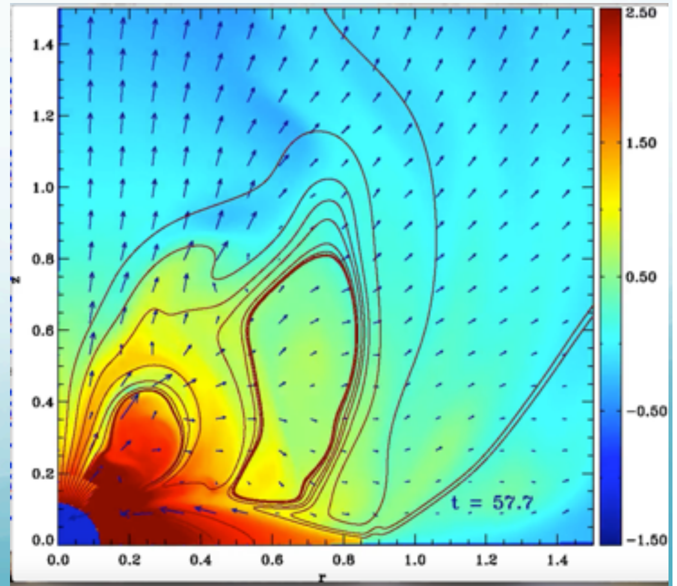
Maccr/Mjet = 18

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

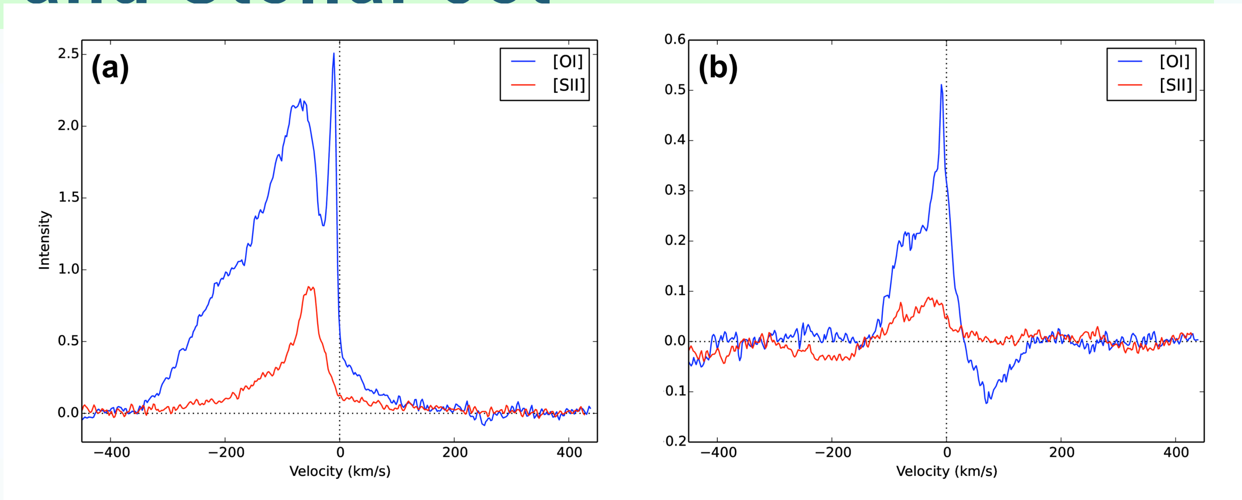
FUOR ?? Conical WIND

Accretion Funnel and Stellar Jet

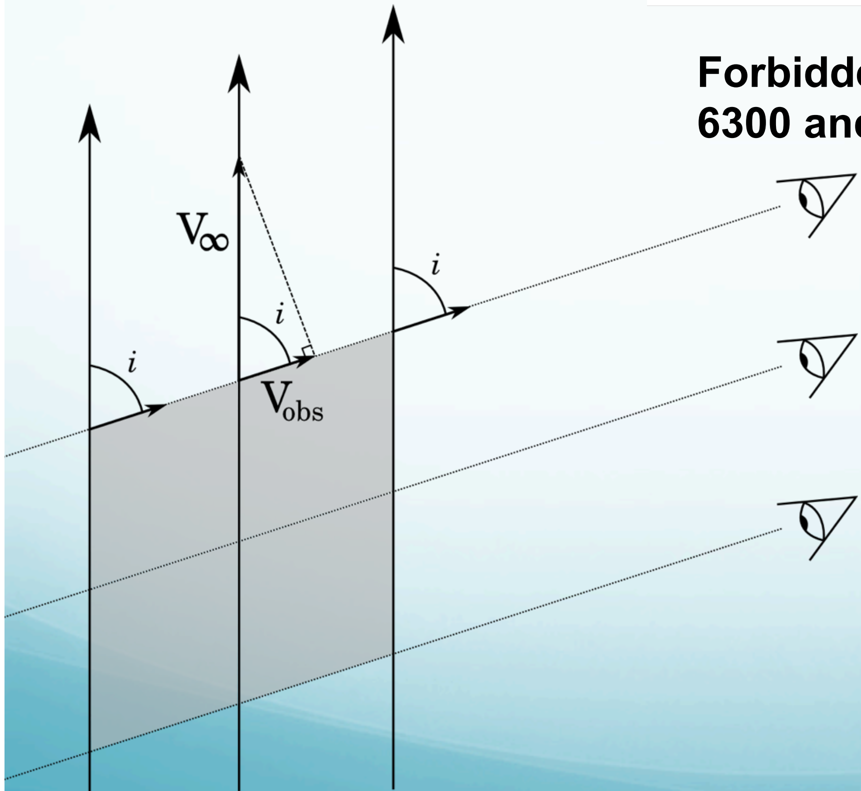
Observations in the Jet

35 stars analyzed

Comparison with literature



Forbidden lines of [O I] (blue line) and [S II] (red line) at 6300 and 6731Å (a) DG Tau and (b) RY Tau..

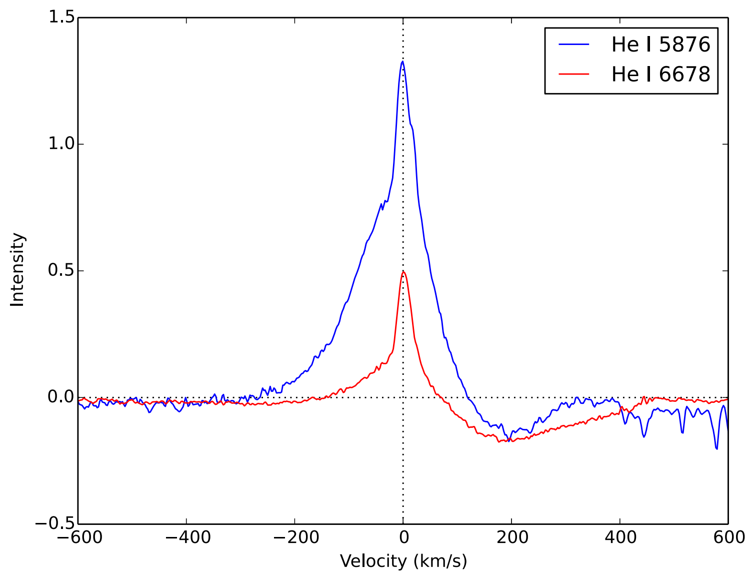


The blue edge of the line emission that crosses the continuum gives an estimate of the terminal outflow velocities

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

Perspective: compare simulations/obs
- Emission map using SNEQ in PLUTO
-> O. Tesileanu

Accretion Funnel and Stellar Jet



He I emission line at 5876Å (blue line) and 6678Å (red line)
DR Tau.

The red edge of the inverse P Cygni absorption that crosses the continuum gives an estimate of the projected accretion velocities.

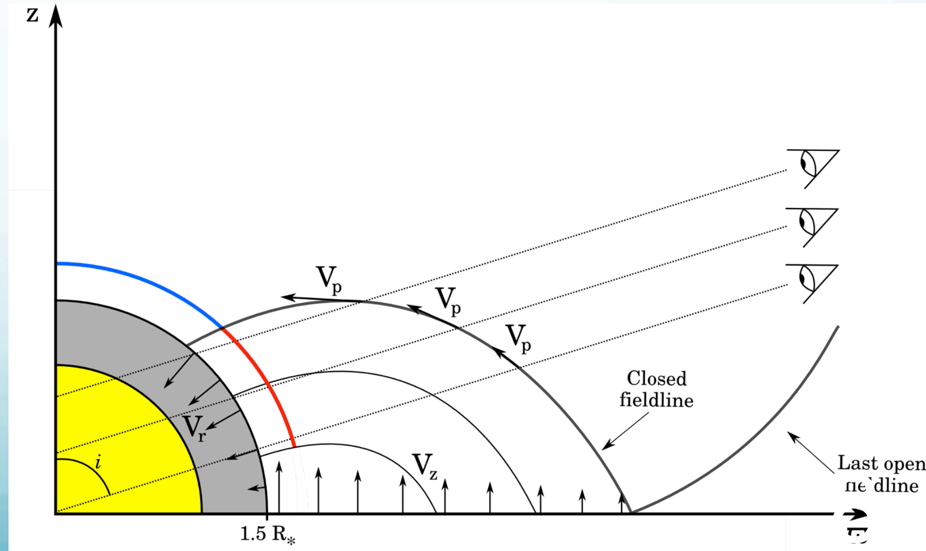
& Mass Accretion Rate

Observations of accretion zone

35 stars analyzed

Comparison with literature

Perspective: compare simulations/obs
- Line Emission
1D radiative transfer with -> I. Hubeny, C. Stehlé
3D IRIS -> L. Ibgui



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 (under dense / over dense)**

⇒ **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***

Comparison Observations / Simulations
=> ACCRETION ZONE LTE Optically thick - Line Emission
1D radiative transfer -> I. Hubeny, C. Stehlé
3D IRIS -> L. Ibguii

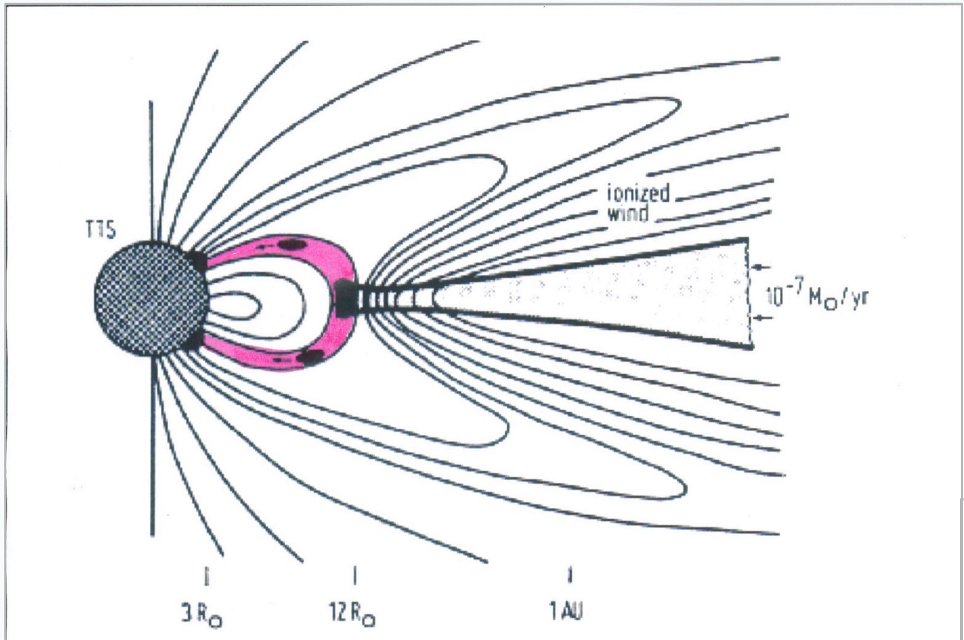
-=> JET NLTE Optically Thin
Emission map using SNEQ in PLUTO -> O. Tesileanu

Modeling the accretion on Young Stars : recent results and perspectives

L. de Sá, C. Stehlé, J. P. Chièze, I. Hubeny ,
T. Lanz, S. Colombo, L. Ibgui, S. Orlando

LERMA, Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, Paris
CEA/DSM/IRFU/SAp-AIM, CEA Saclay, CNRS, Gif-sur-Yvette
Steward Observatory, University of Arizona, Tucson
Observatoire de la Côte d'Azur, Nice
INAF-Osservatorio Astronomico di Palermo, Palermo

Colloque de Prospective du PNPS,
Montpellier, 26-28 Mars 2018



From Camenzind

3 major ingredients for stellar accretion (and ejection)

- **The disk**
- The magnetic field
- **The star**

Accretion

- is channelled along funnel streams along magnetic field lines
- can be stimulated by instabilities in the disk; such instabilities can be stimulated by flares in the disk

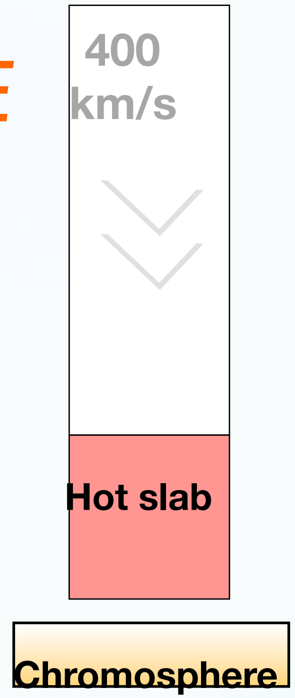
Accretion

- Is a major ingredient in transport of angular momentum and mass.

A sophisticated model of the accretion shock with AstroLabE

ASTROLABE 1D

- *High spatial resolution* with ALE (Arbitrary Lagrangian Eulerian) grid
- *Sophisticated treatment* of radiation transfer using M1 formalism (to treat the part of the system which is not transparent to radiation)
- No magnetic field (interior of the column)

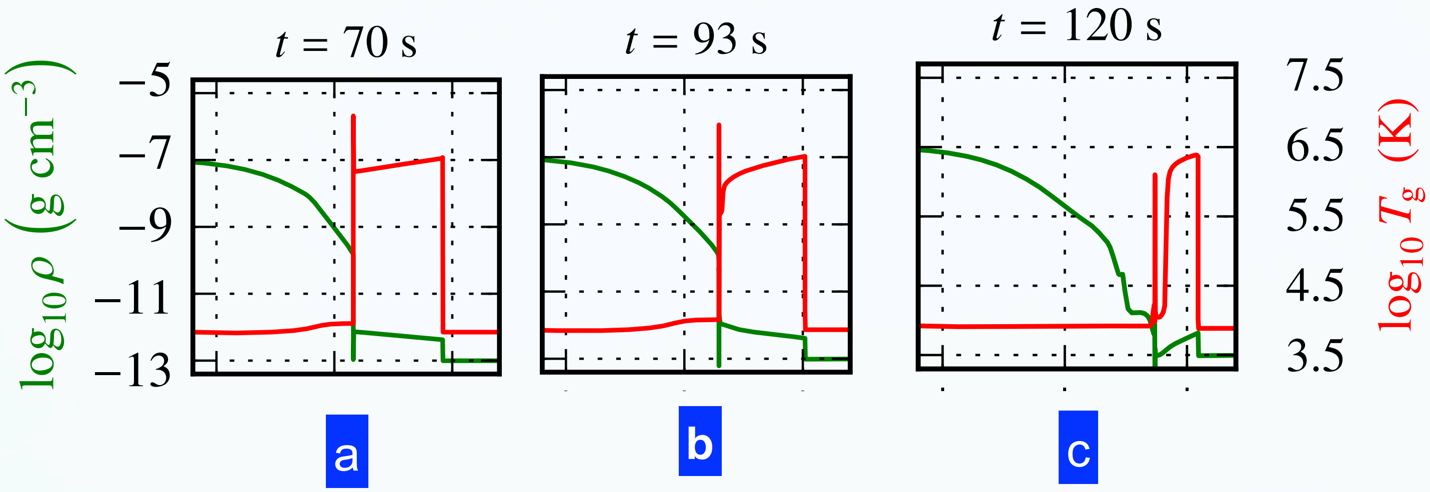


3 GOALS :

1) Use a realistic description of the chromosphere (not optically thin)
2) Heating and feedback of the chromosphere treated consistently
3) Compute the emerging spectrum

de Sá et al. to be submitted, Sacco et al. 2008

Quasi Periodic Oscillations



a accretion shock and development of the reverse shock

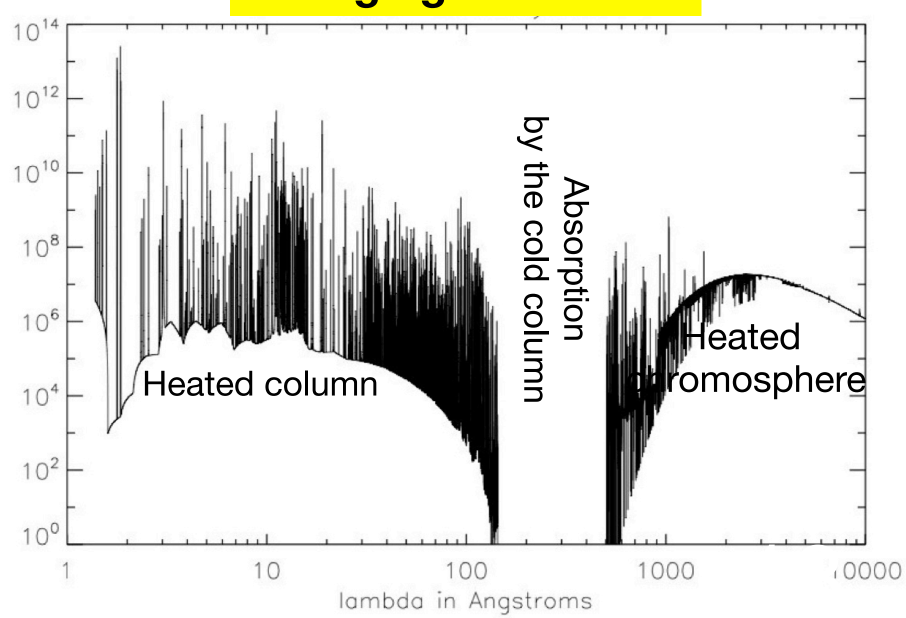
b start of the cooling in the post shock

c start of the collapse

Heating and expansion of the chromosphere at the contact discontinuity between the chromosphere and the heated column

Period 150 s, H_{max} = 8.5 10^6 m

Emerging flux at 70 s



perspectives

1D RHD non-LTE (PLUTO, Mignone et al. 2007,12; Kolb et al. 2013, opacities from R. Rodriguez)	in progress	**PhD project of S. Colombo**
2D RMHD non-LTE (PLUTO)	to start shortly	
3D MHD inclined stream (PLUTO)	in progress	
comparison with observations post-processing (IRIS, Ibgui et al. 2013)	planned for 2019	

Publications
Matsakos et al. 2013
Orlando et al. 2013
Costa et al. 2016
Bonito et al. 2014
Ibgui et al 2013