JeTSeT

JET Simulations, Experiments and Theories

Two-component jet simulations:
Combining analytical disk & stellar outflow solutions

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PLUTO

MARIE CURIE ACTIONS

www.jetsets.org

Outline

- Motivation – Aims
- 1-component model results
- Setting up 2-component jet scenarios
- 2-component model results
- Conclusions

Motivation - Aims

Motivation – Aims

- <u>Observations</u> of CTTSs[1] suggest the presence of two genres of winds:

  Stellar and Disk outflows

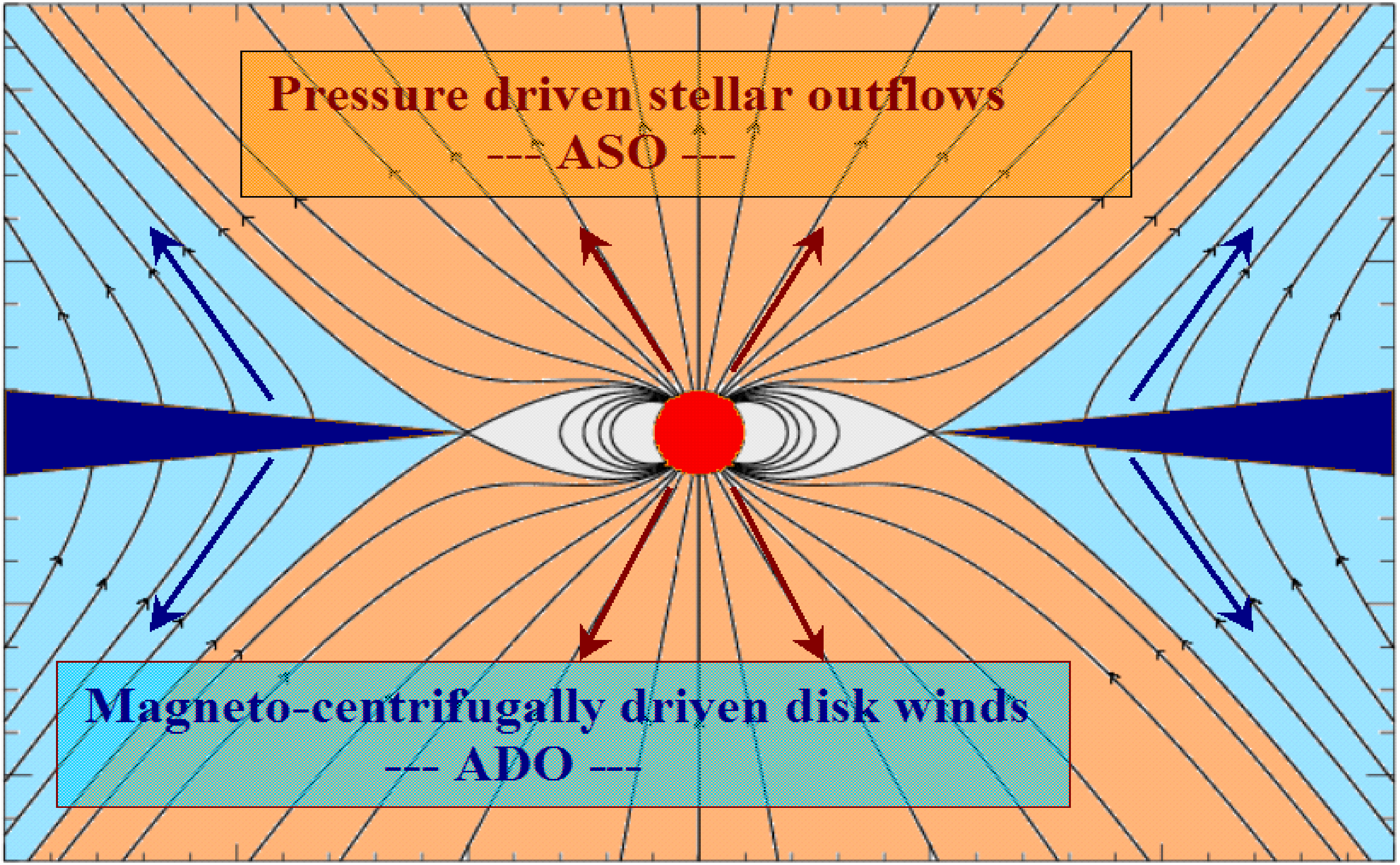
  with different dominance depending on the YSO

- <u>Theoretical arguments</u>[2] propose:

Extended warm **disk winds** (explain mass loss rates and collimation)
Pressure driven **stellar outflows** (probably spin down the star)
Sporadic **X-type winds** (related with jet variability?)

[1] Edwards et al. (2006), Kwan et al. (2007)
[2] Ferreira, Dougados & Cabrit (2006), Bogovalov & Tsinganos (2001)

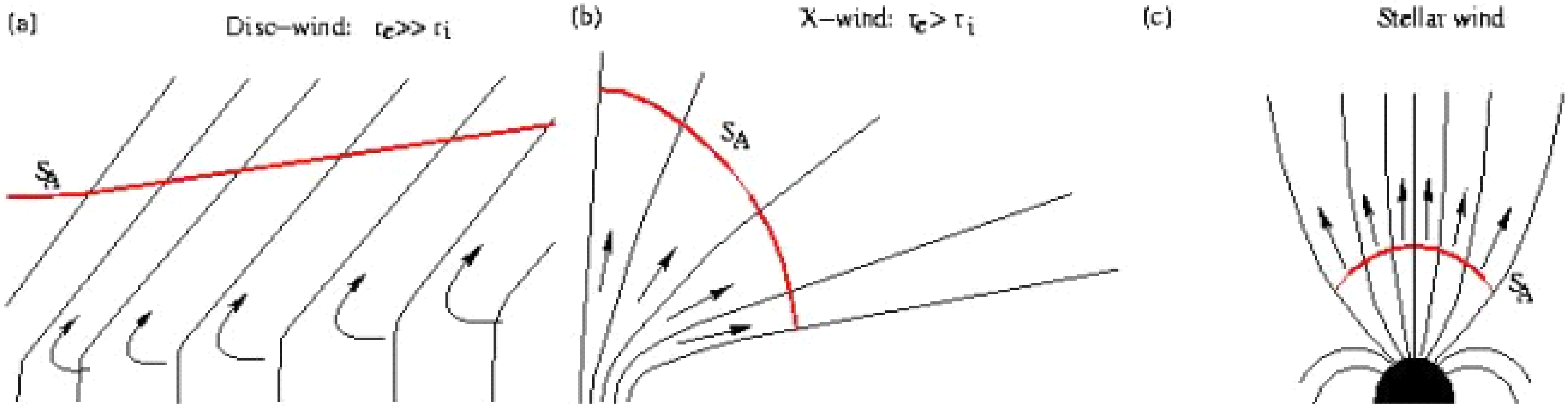
A qualitative picture



(* The magnetic field has a self-similar dependence)

Analytical solutions

Image from Ferreira, Dougados & Cabrit (2006)



Analytical Disk Outflow	?	Analytical Stellar Ouflow
ADO		**ASO**

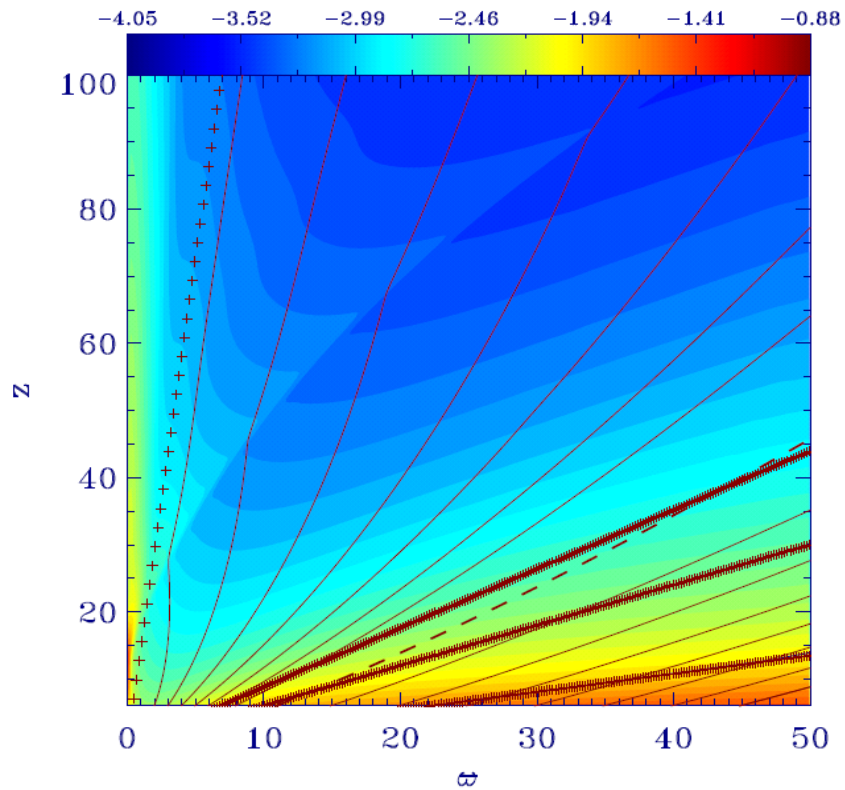
Our aim

- Take advantage of **both analytical & numerical approaches** of the jet phenomenon to study 2-component jets:

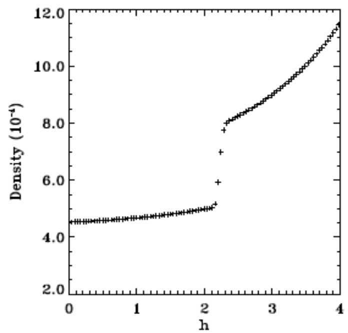
- Unify the 1-component analytical jets numerically and study stability, potential steady states, interaction etc.
- Parametrize the two-component jet models and investigate a variety of scenarios
- Introduce radiation cooling and try to compare the results with observational data (future work)

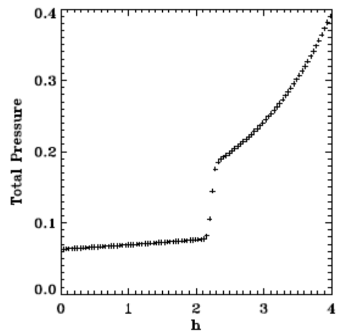
1-component jet results

1-comp. numerical jets - ADO

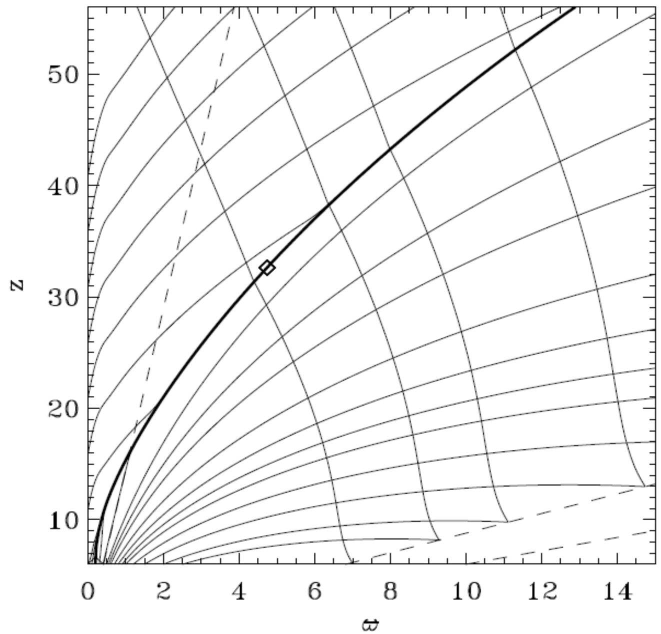


Density and pressure jumps

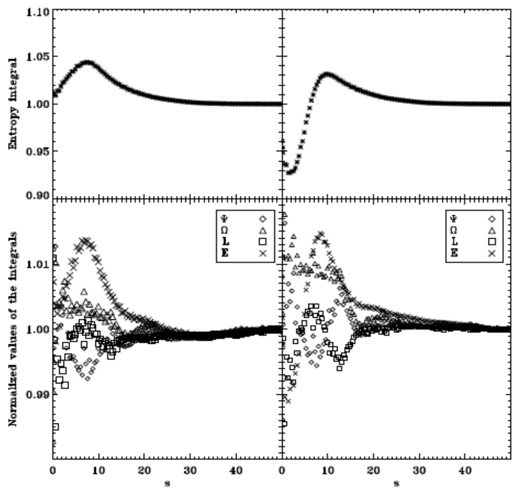




Density contours and magnetic fieldlines



Characteristics

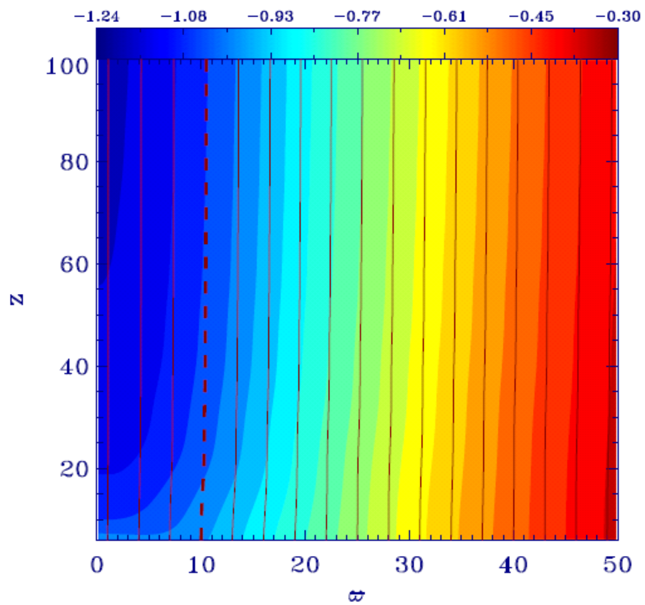


Integrals of motion deviate by only ~1%

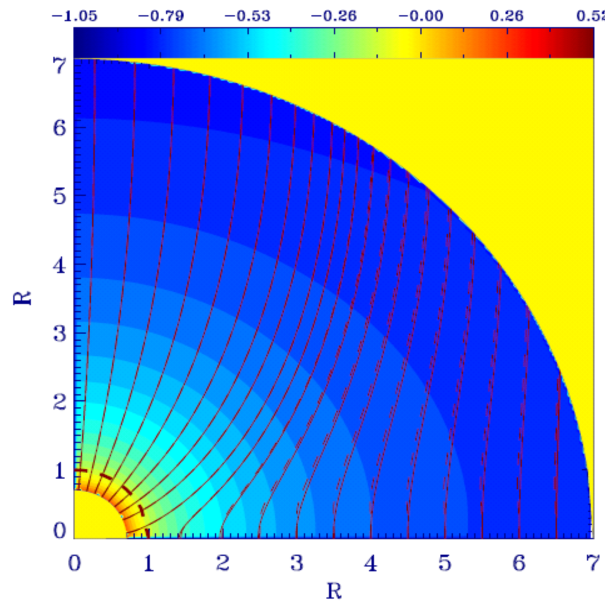
Matsakos, et al. (2008)

1-comp. numerical jets - ASO

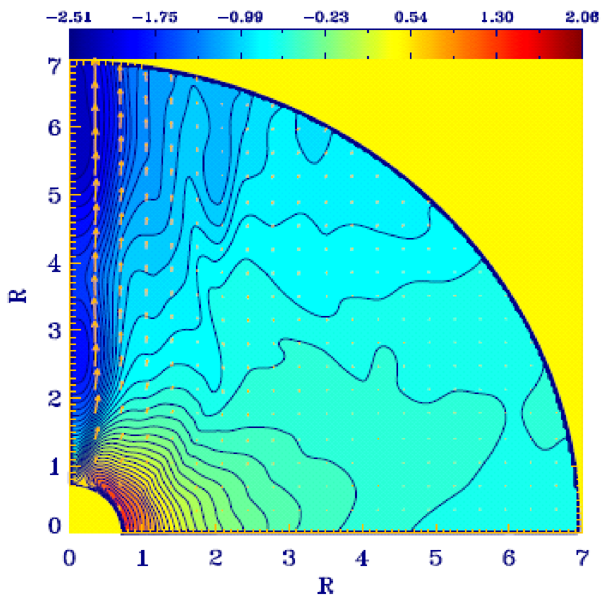
Super-alfvenic



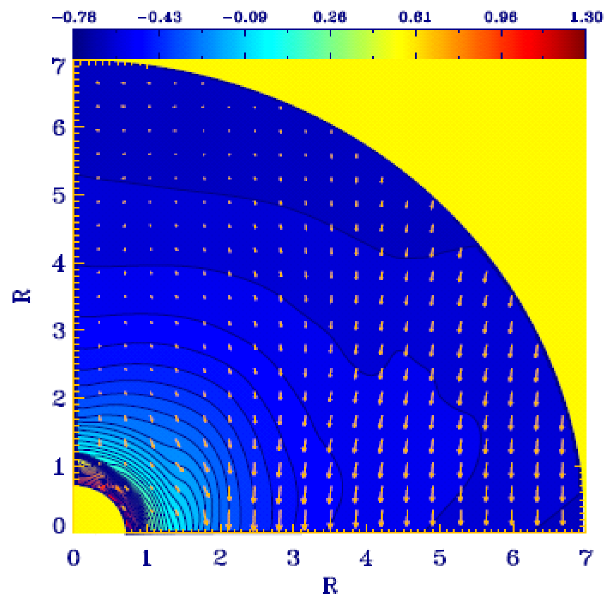
Trans-alfvenic



Poly-tropic trans-alfvenic



Adia-batic trans-alfvenic



Matsakos, et al. (2008)

Setting up 2-component jet scenarios

2-comp. jet parameters

- **Normalization provides the ratios of the characteristic:**
  - lengths (L) $\lambda_L = \frac{R_*}{\varpi_*}$
  - velocities (V) $\lambda_V = \frac{V_{S*}}{V_{D*}}$
  - magnetic fields (B) $\lambda_B = \frac{B_{S*}}{B_{D*}}$
- **Mixing provides:**
  - the location of the matching surface
  - the steepness of the transition region

Free parameters

- **Physical arguments (protostellar mass) and observations constraints (launching region)**
  fix 2 out of the 5 parameters

- **The free parameters are**
  - the contribution of each component in the total magnetic field (or density)
  - the footpoint of the matching fieldline
  - the steepness of the transition

- **Such numerical models allow the study of plethora of two-component jet scenarios depending on the evolutionary stage and intrinsic physical conditions**

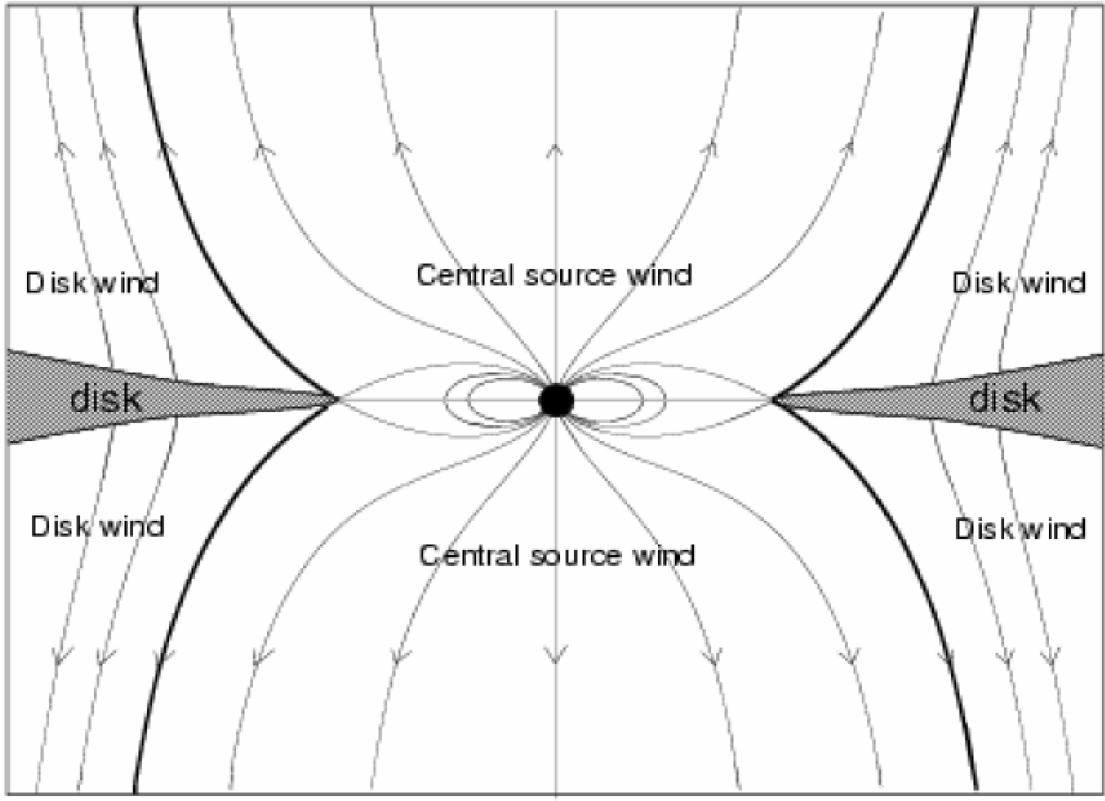
Mixing and time variability

- **Mixing function:**

$$U_{2comp} = w_D U_D + w_S U_S$$

$$w_S = \exp\left[-\left(\frac{A_{tr}}{qA_m}\right)^d\right]$$

$$w_D = 1 - w_S$$



- **Enforced time variability**

$$f_S(r,t) = 1.0 + 0.5\sin\left(\frac{2\pi t}{T_{var}}\right)\exp\left(-\frac{r^2}{r_m^2}\right)$$

Numerical Setup

- **We solve the time-dependent MHD eqution using PLUTO, (Mignone et al. 2007) a shock-capturing numerical code.**

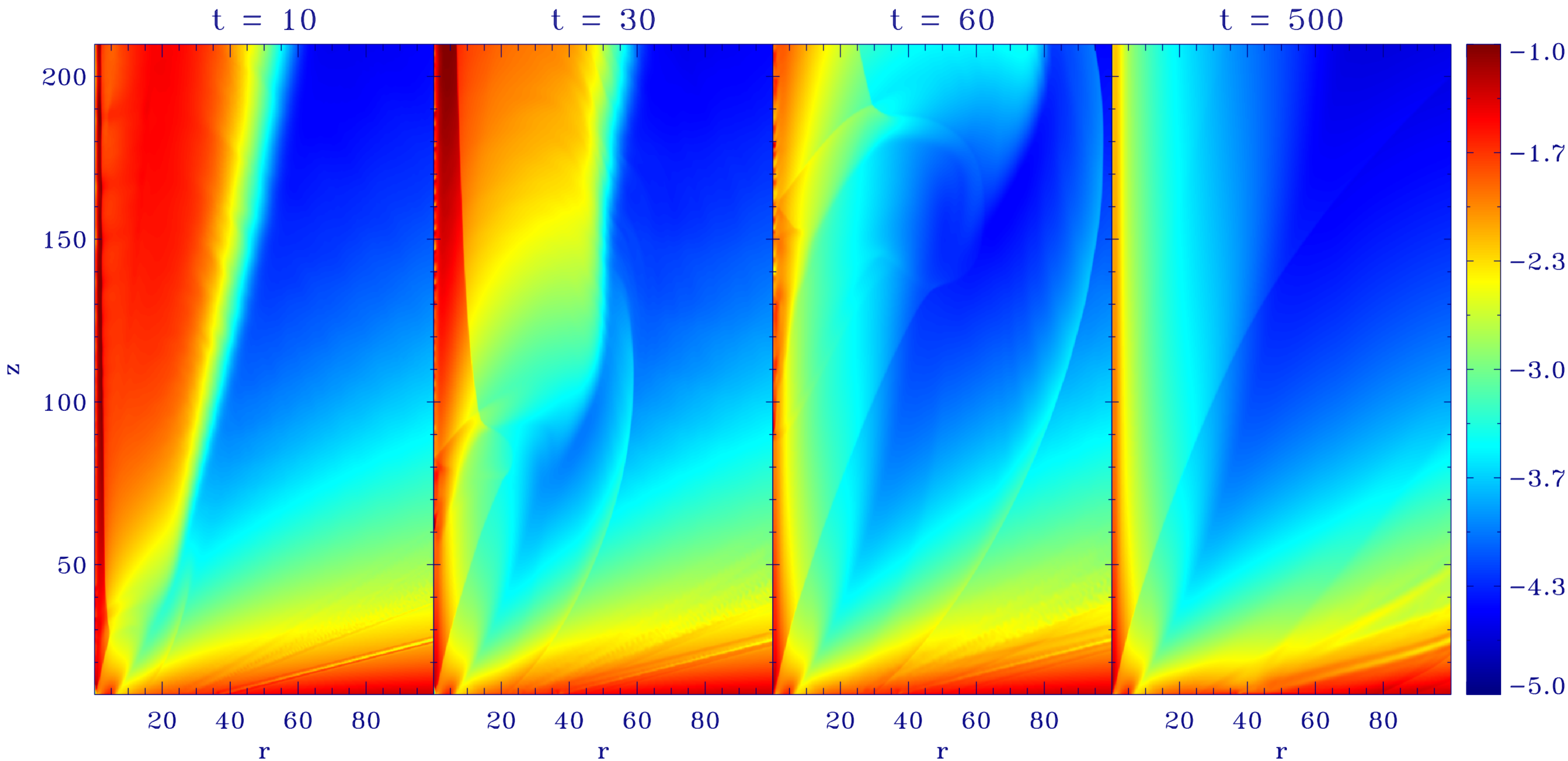
  http://plutocode.to.astro.it

Name	λ_B	q	d
1-q01	1.0	0.1	2.0
2-q02	1.0	0.2	2.0
3-q05	1.0	0.5	2.0
4-q01	2.0	0.1	2.0
5-q02	2.0	0.2	2.0
6-q05	2.0	0.5	2.0
7-B05	0.5	0.2	2.0
8-B5	5.0	0.2	2.0
9-B10	10.0	0.2	2.0
10-d1	2.0	0.2	1.0
11-d4	2.0	0.2	4.0

Name	T_{var}/T_K	Quantity	Variable wind
1-SD1	1.0	ρ	Stellar
2-SD10	10.0	ρ	Stellar
3-SD100	100.0	ρ	Stellar
4-SV1	1.0	V_z	Stellar
5-SV10	10.0	V_z	Stellar
6-SV100	100.0	V_z	Stellar
7-X1	1.0	both	X-type
8-X10	10.0	both	X-type
9-X100	100.0	both	X-type

2-component jet results

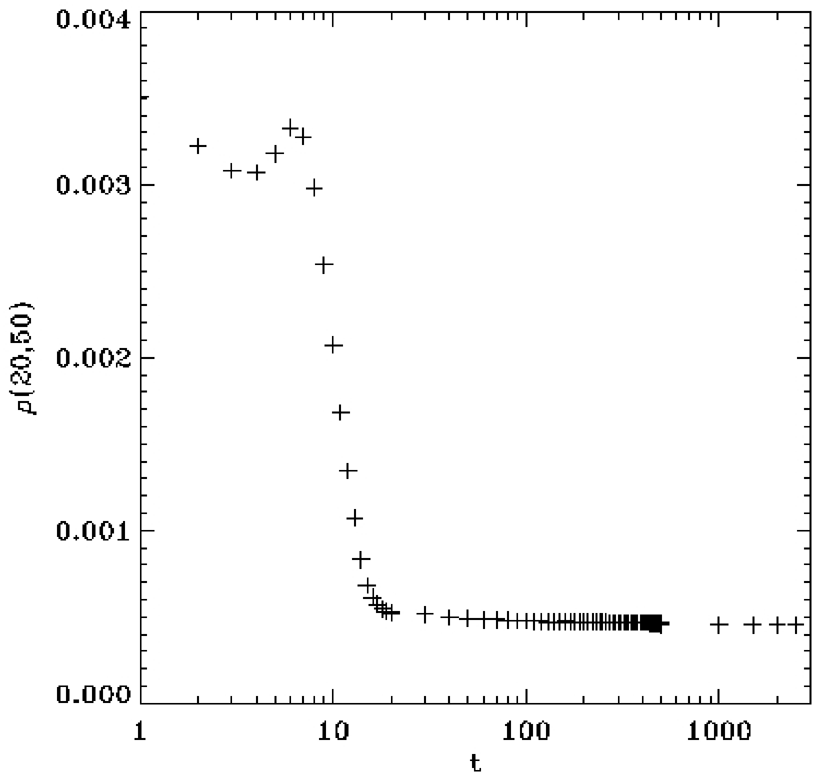
Time evolution



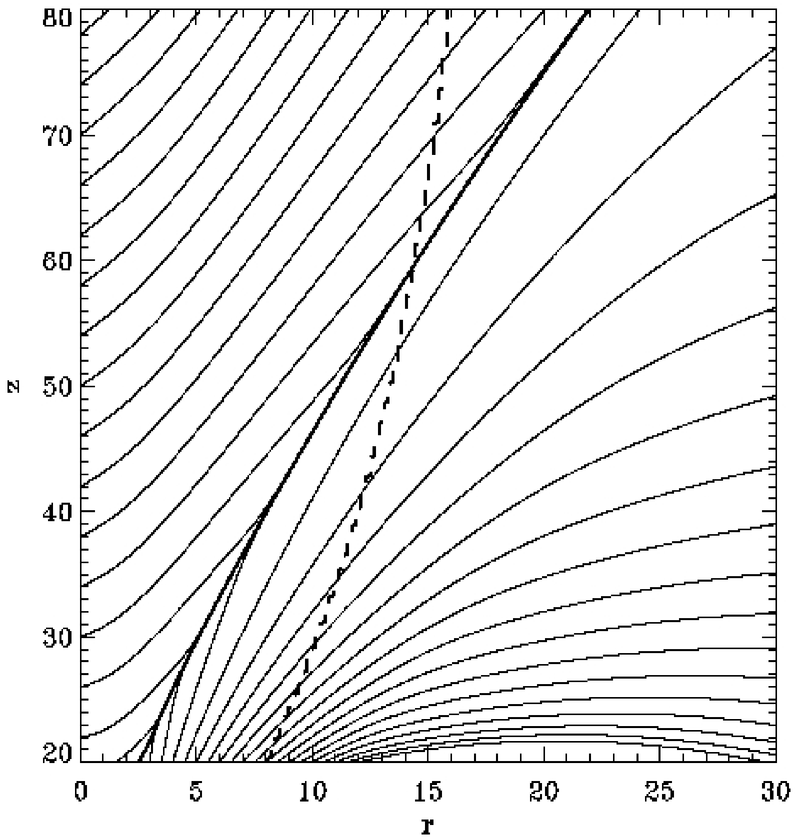
Time evolution (log(ρ)) of a typical 2-component model

steady state – shock fomation – small deviations from analytical models

Steady state & shock formation

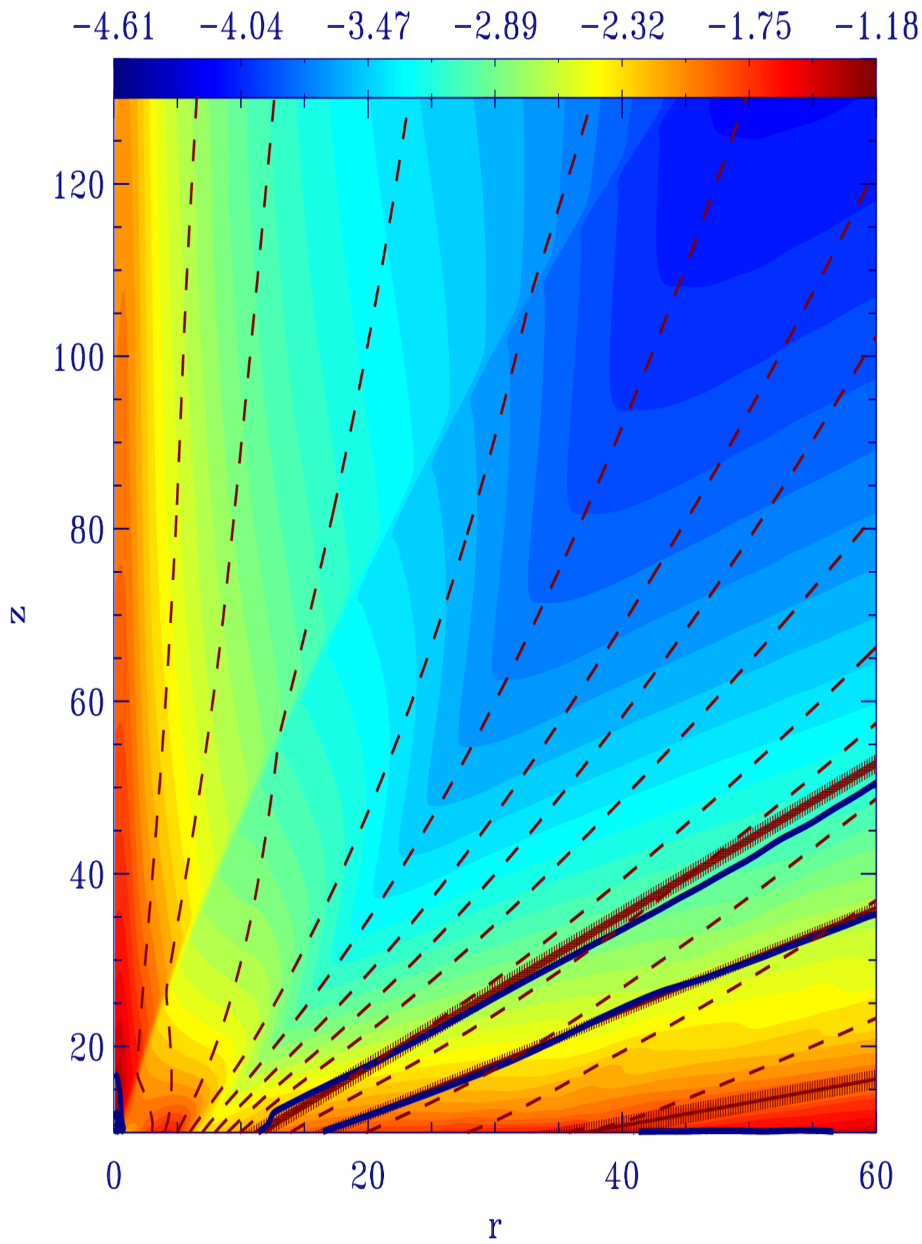


A well preserved steady state



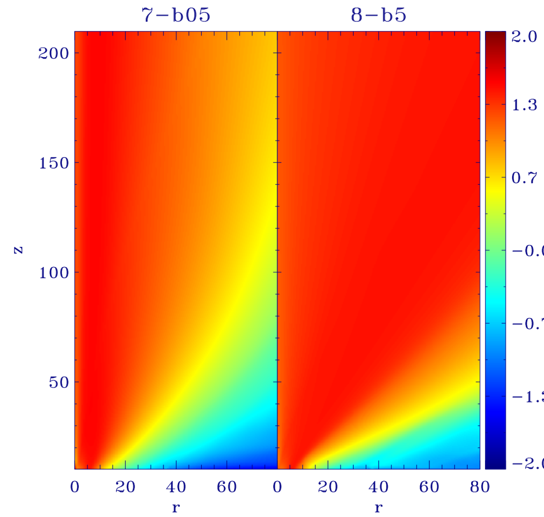
A shock is formed causally disconnecting the jet with its launching region

Parameter study

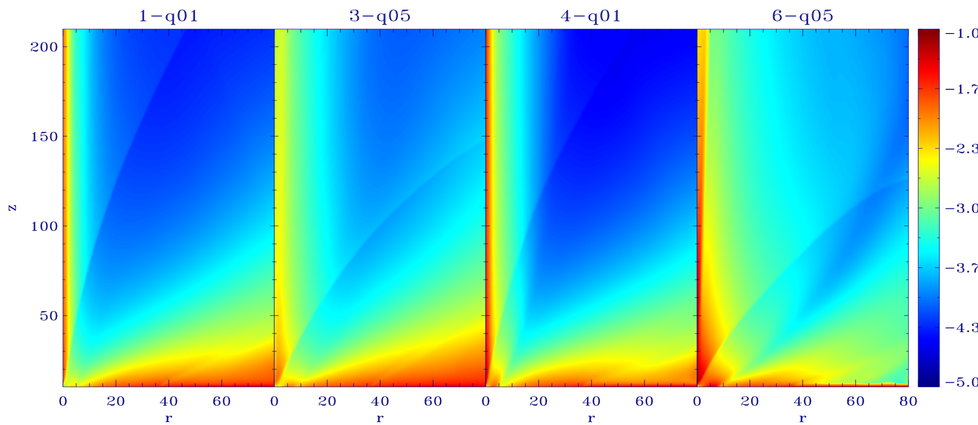


Numerical critical surfaces match pretty well & have an interesting shape

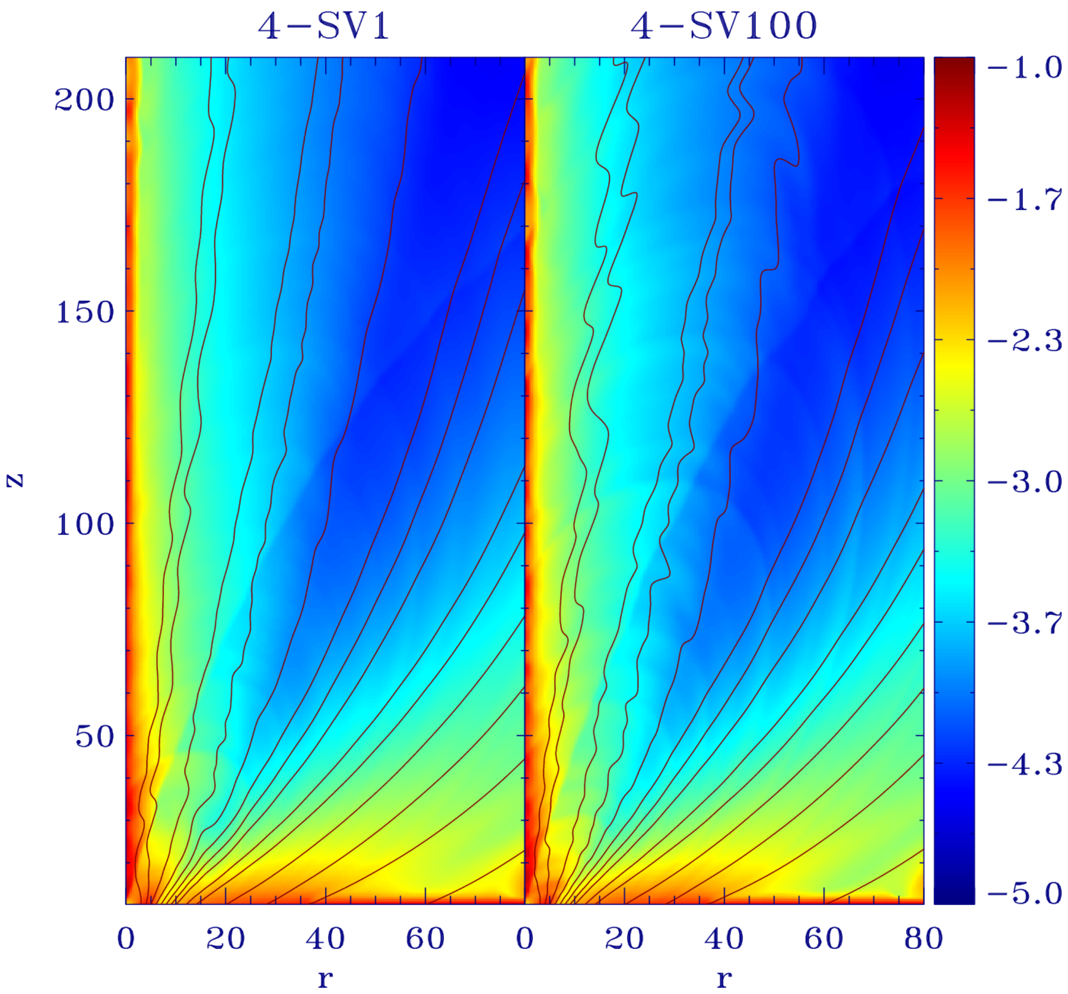
Dominance



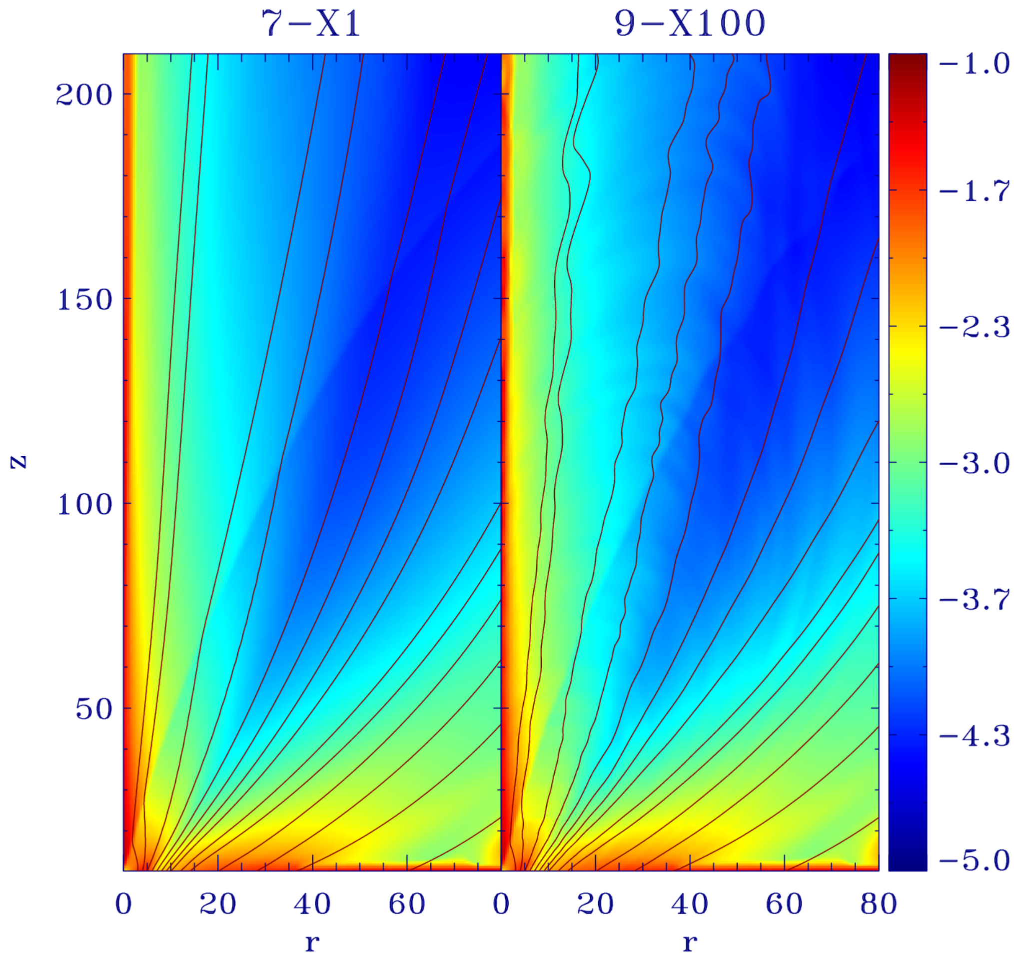
Location of matching surface



Enforced time variability



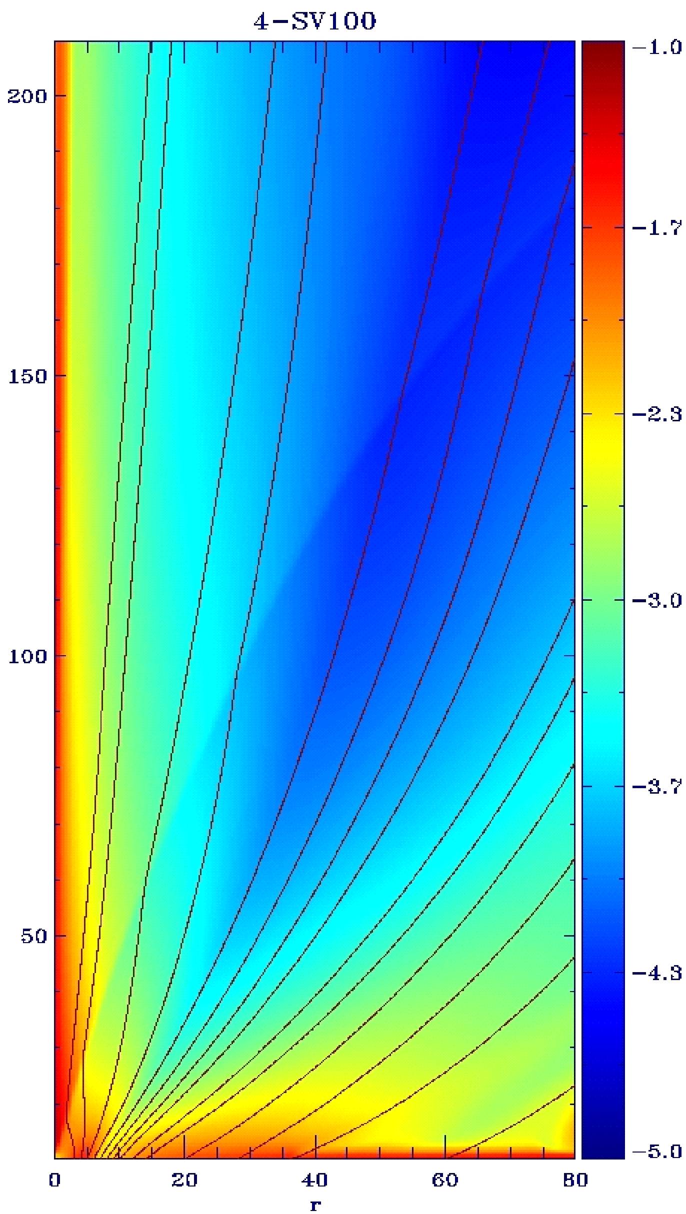
Time variable stellar wind

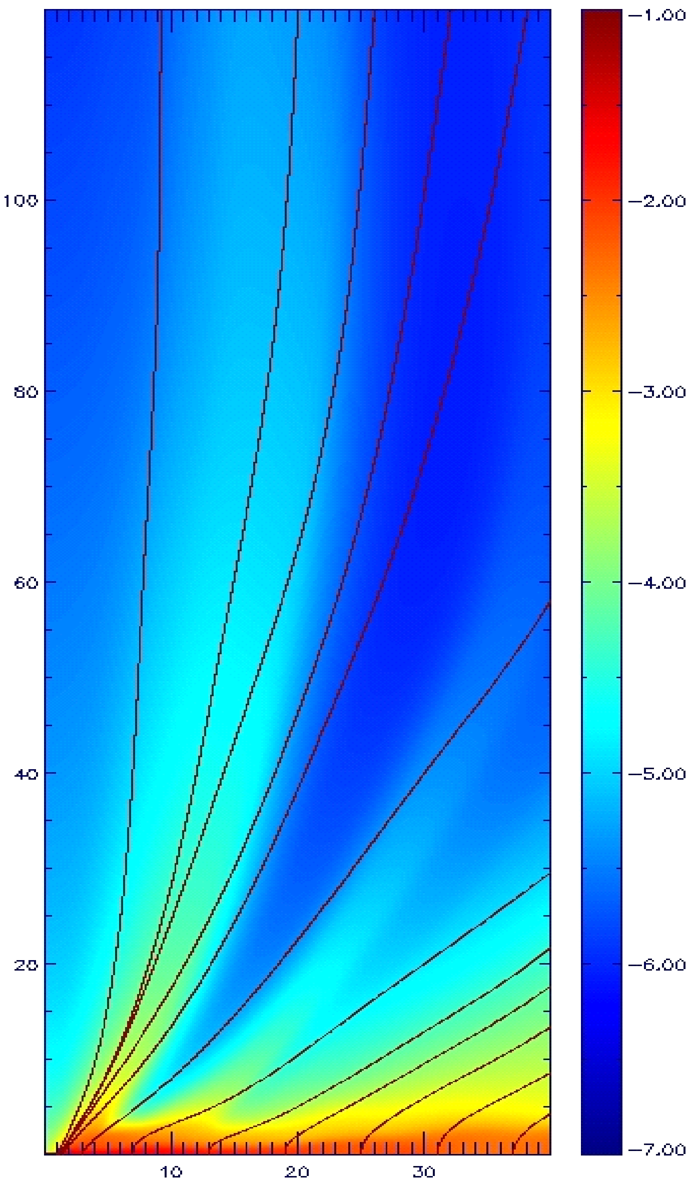


Time variable X-type wind

An interesting resemblance

2-component jet model





Tzeferacos et al. (to be submitted)

Conclusions

- A steady state is always reached, proving that the intrinsically different ADO & ASO can well co-exist in a stable structure even when time variability is enforced
- A shock forms disconnecting the launching region with the outflow
- The final outcome of the simulations stays close to the initial setup, hence retaining the validity of the analytical studies for each solution
- Freedom of choice of the parameters can explain several different cases of observed jets

Thank you

Btw, next time I will be in the LOB rather than the LOC!

LOB: Lying On the Beach

LOC: Lying On the Carpet (of the conference)

Ευχαριστώ πολύ

Thank you

Grazie