OSUG
Observatoire des Sciences de l'Univers de Grenoble

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Accretion in dwarf novae

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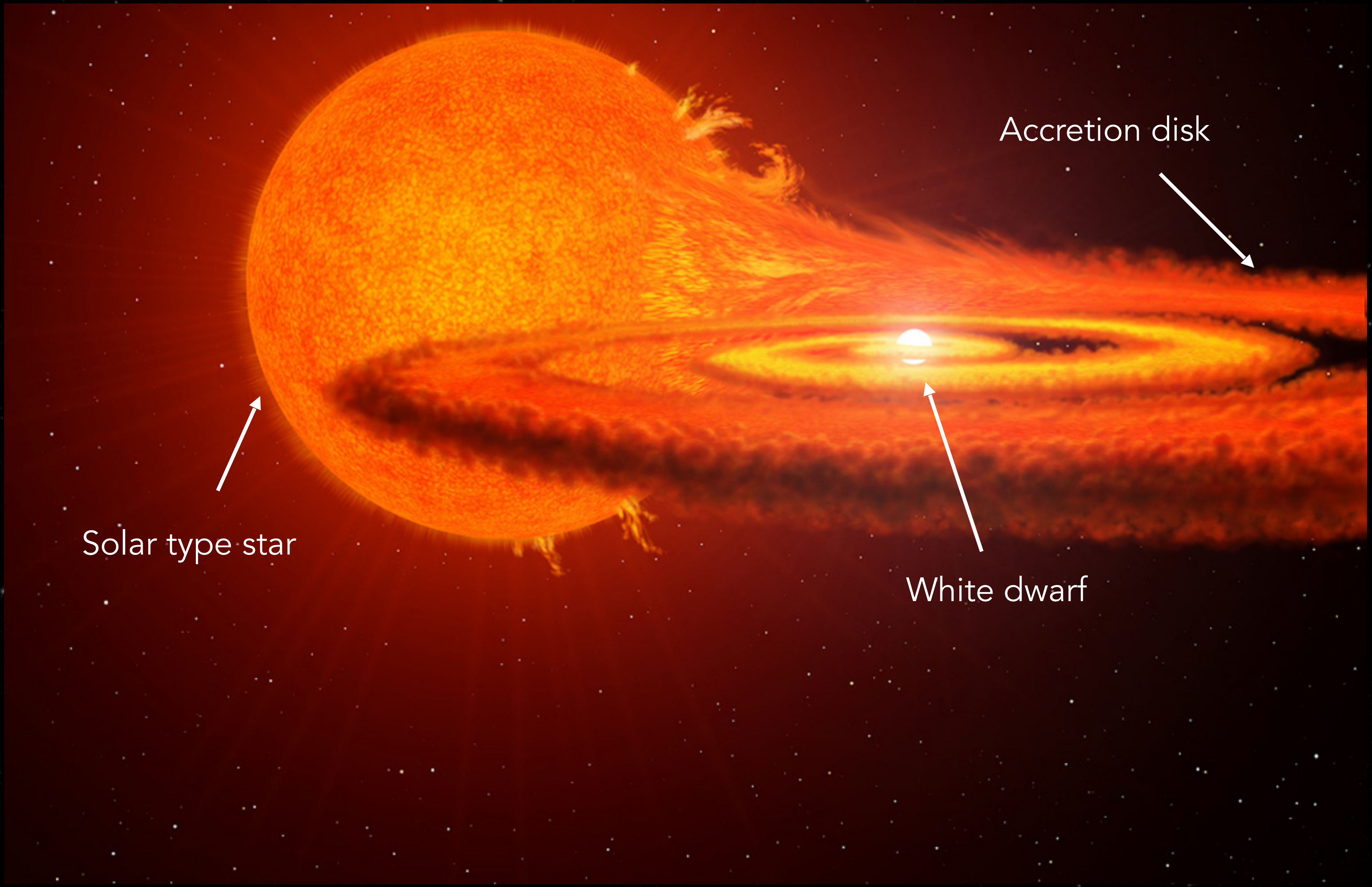
supervised by Guillaume Dubus and Geoffroy Lesur

Dautreppe, 4th of December 2018

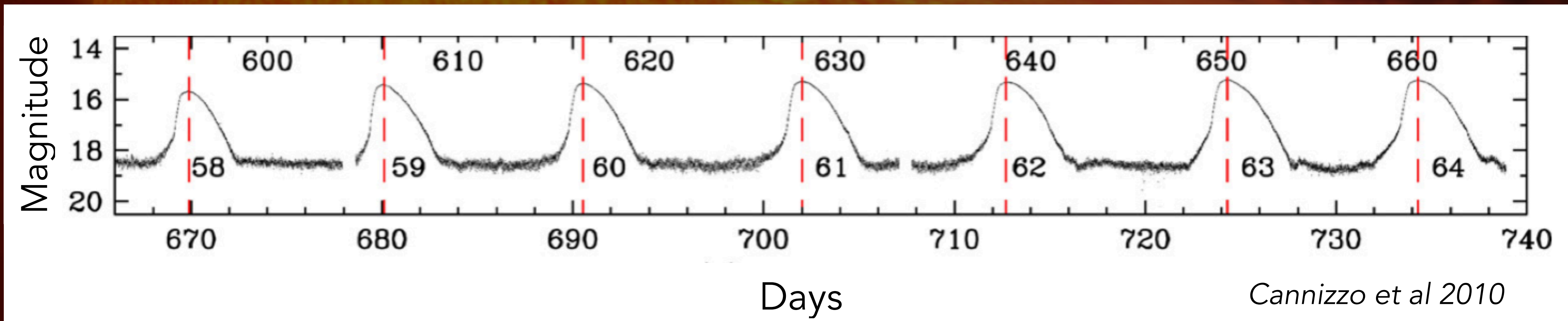
Dwarf novae



Dwarf novae are ideal to study accretion :

- emission in the visible, UV
- access to structure of the disk via eclipse mapping
- **high variability with time scales going from seconds to months**

Variability in dwarf novae (DNe)

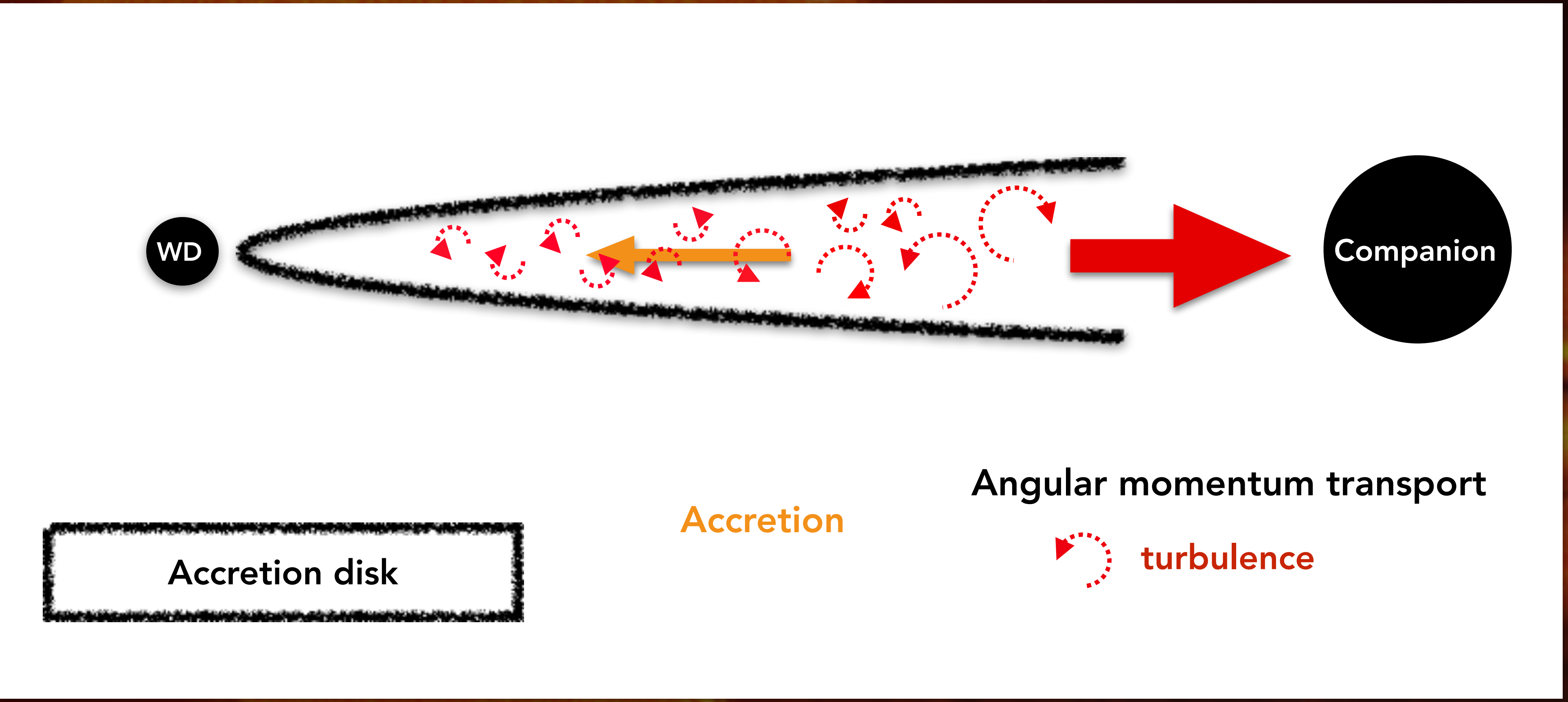


Cannizzo et al 2010

Luminosity coming from the accretion in the disk.

(Shakura & Sunyaev 1973)

Historical framework : Turbulent/viscous accretion

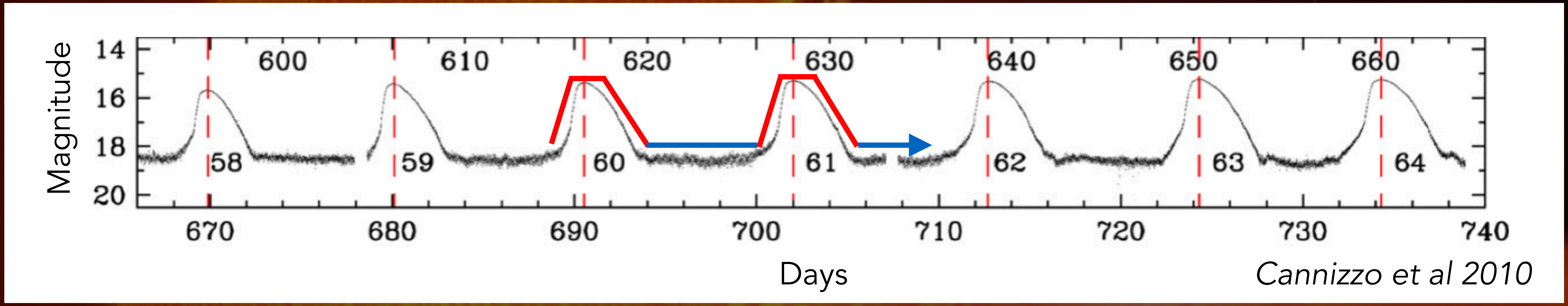


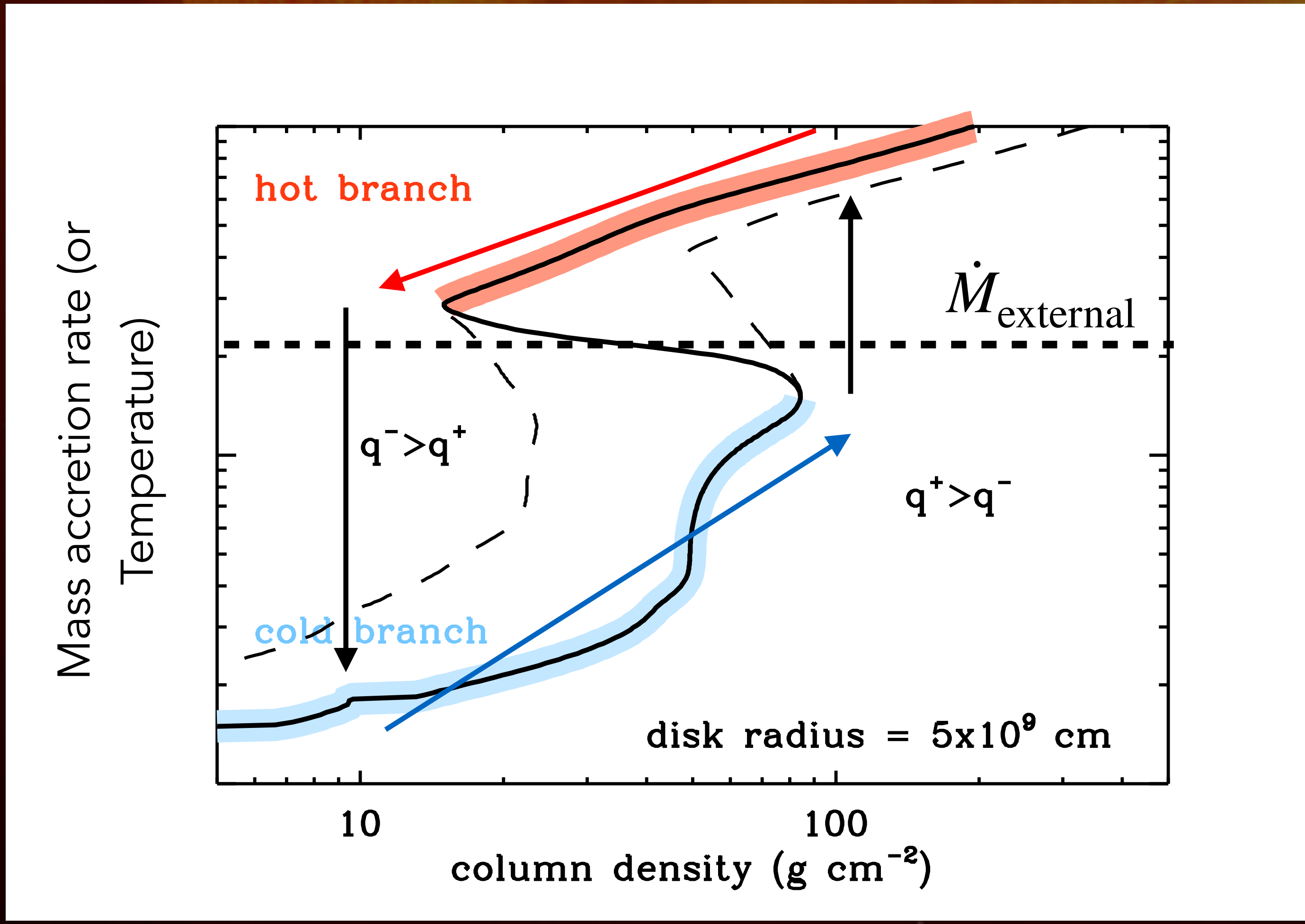
Turbulent transport modeled as a viscous transport
(Shakura & Sunyaev 1973)

$$\nu_{\mathrm{eff}} = \alpha c_s H$$

where turbulence is supposedly due to MRI.
(Balbus & Hawley 1991)

Disk instability model (DIM)





S-curve from the DIM

$$t_{\rm vis} = \frac{1}{\alpha\Omega}\left(\frac{R}{H}\right)^2 \qquad t_{\rm therm} = \frac{1}{\alpha\Omega}$$

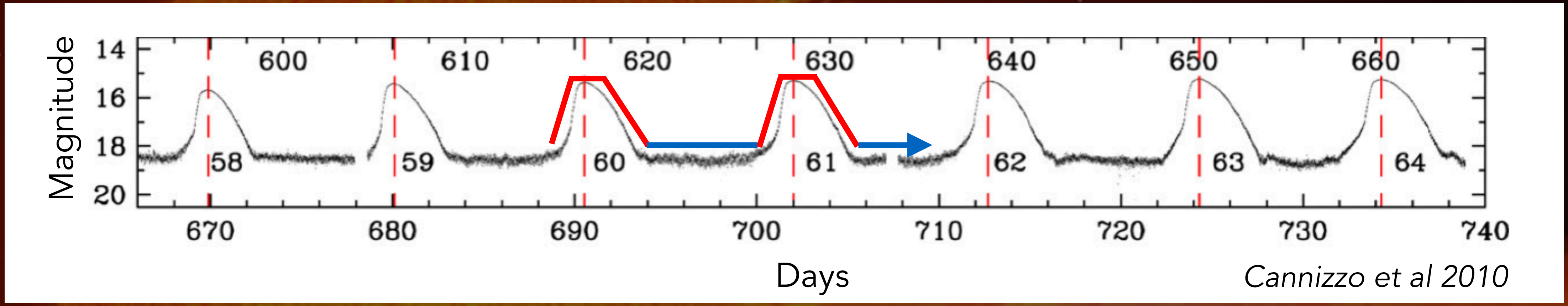
Eruptive state $\alpha \sim 0.1$

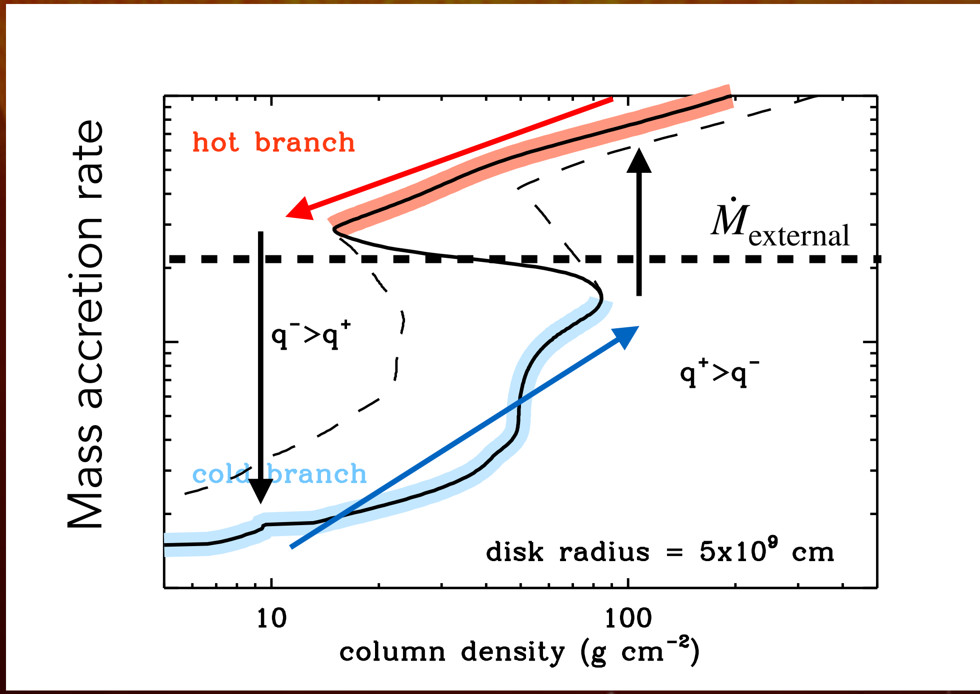
(Kotko & Lasota 2012)

Quiescent state $\alpha \sim 0.01$

(Cannizzo et al. 2012)

Disk instability model (DIM)





S-curve from the DIM

$$t_{\rm vis} = \frac{1}{\alpha\Omega}\left(\frac{R}{H}\right)^2 \qquad t_{\rm therm} = \frac{1}{\alpha\Omega}$$

Eruptive state α ~ 0.1

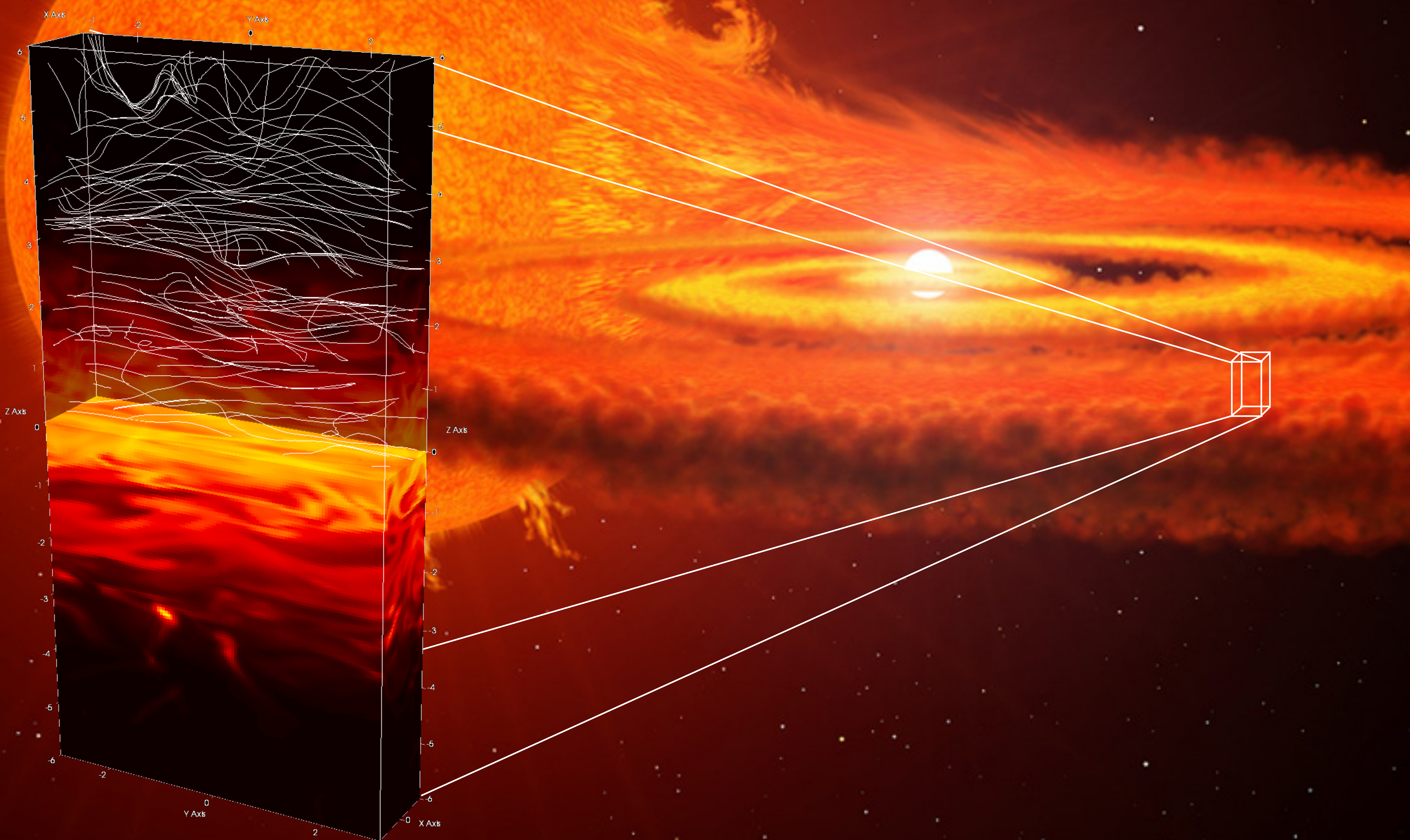
(Kotko & Lasota 2012)

Quiescent state α ~ 0.01

(Cannizzo et al. 2012)

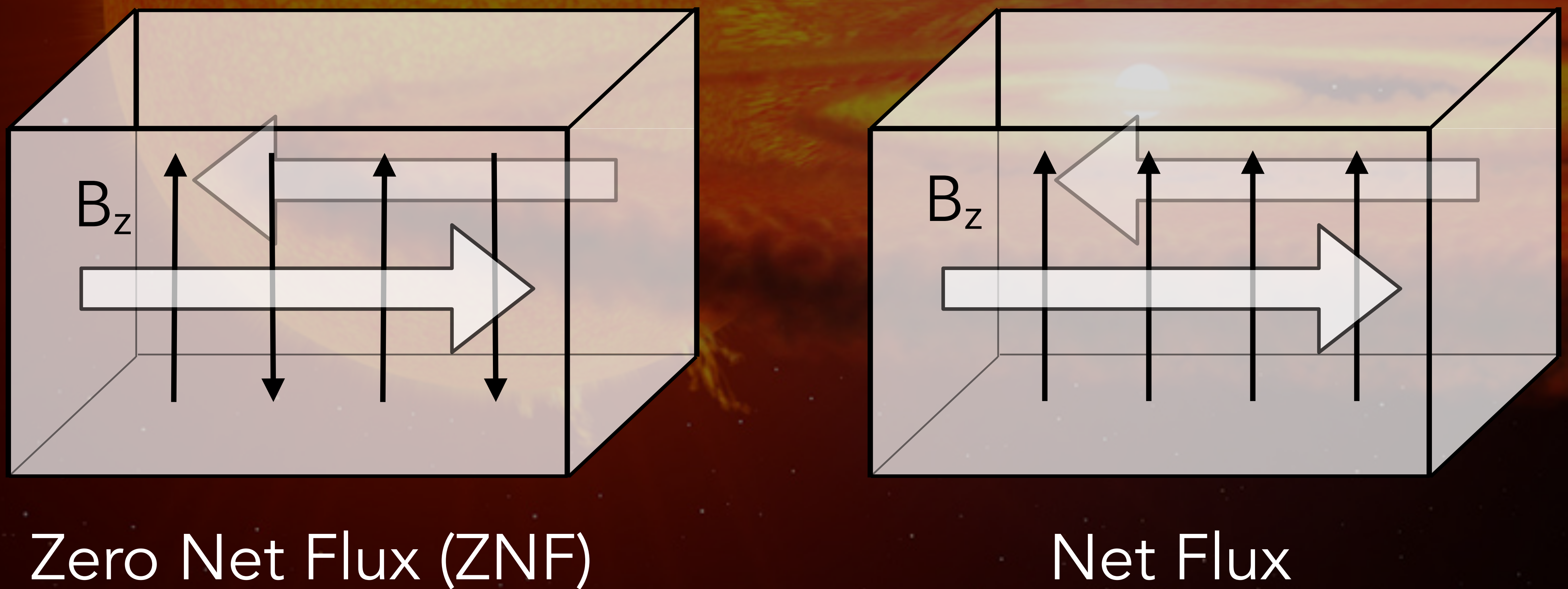
Can MRI give these values of α ?

Shearing box simulations



Compute α from the simulations !!

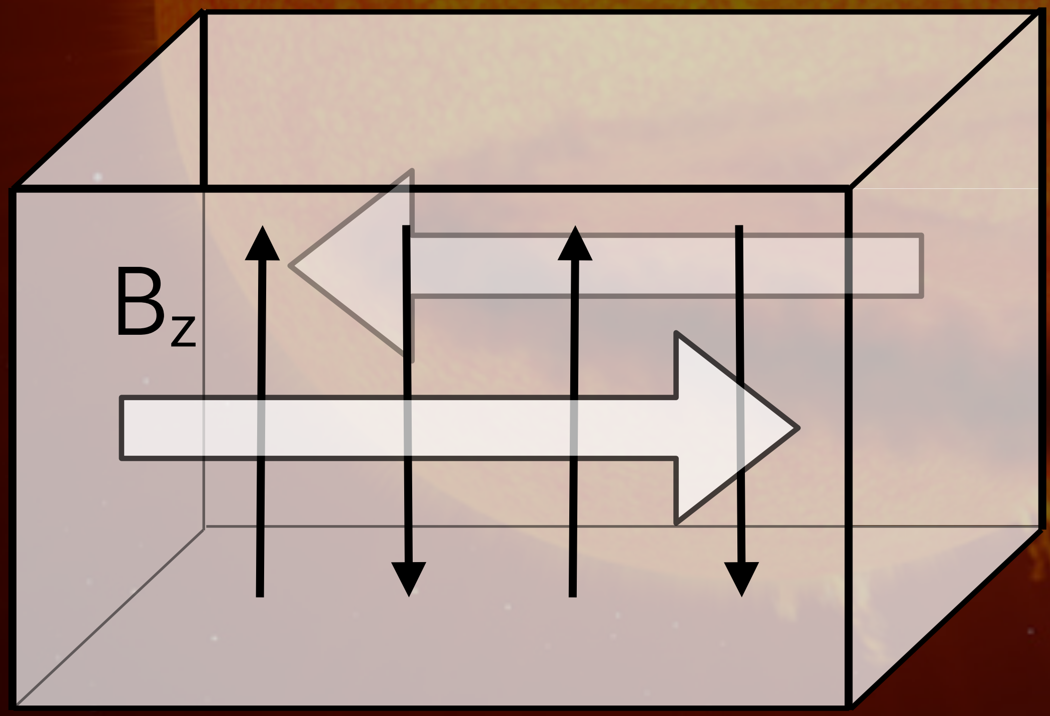
Magnetic configuration



Magnetic configuration

α does not depend on Bz

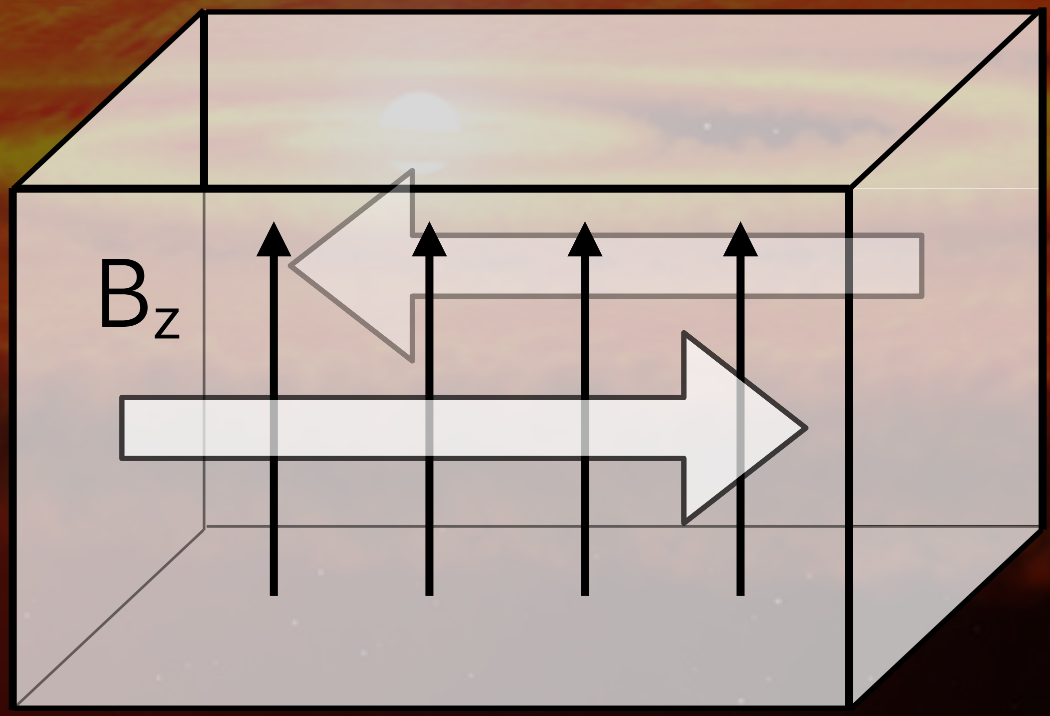
(*Hawley et al. 1996,Simon et al. 2012*)



Zero Net Flux (ZNF)

α depends on B_z

(*Hawley et al. 1995*)



Net Flux

Overview

1) Zero Net Flux simulations

2) Net Flux simulations

3) Disk-wind model

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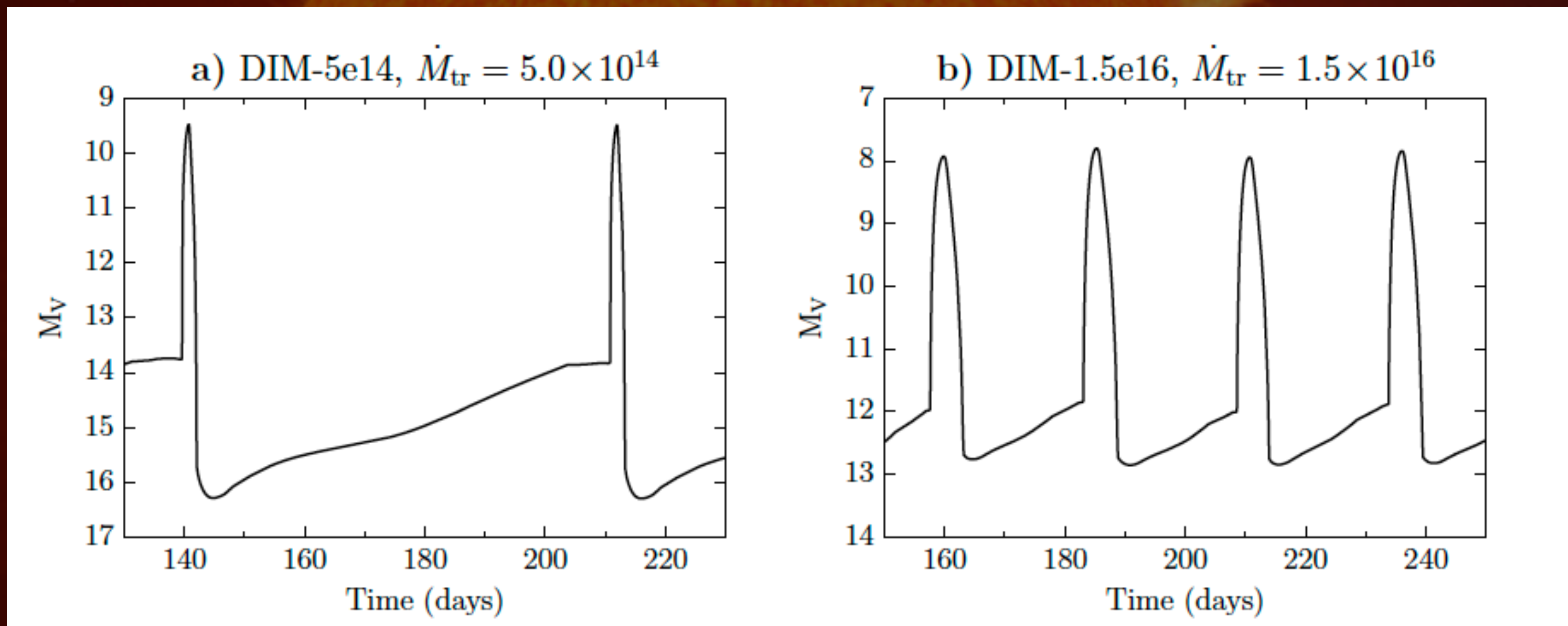
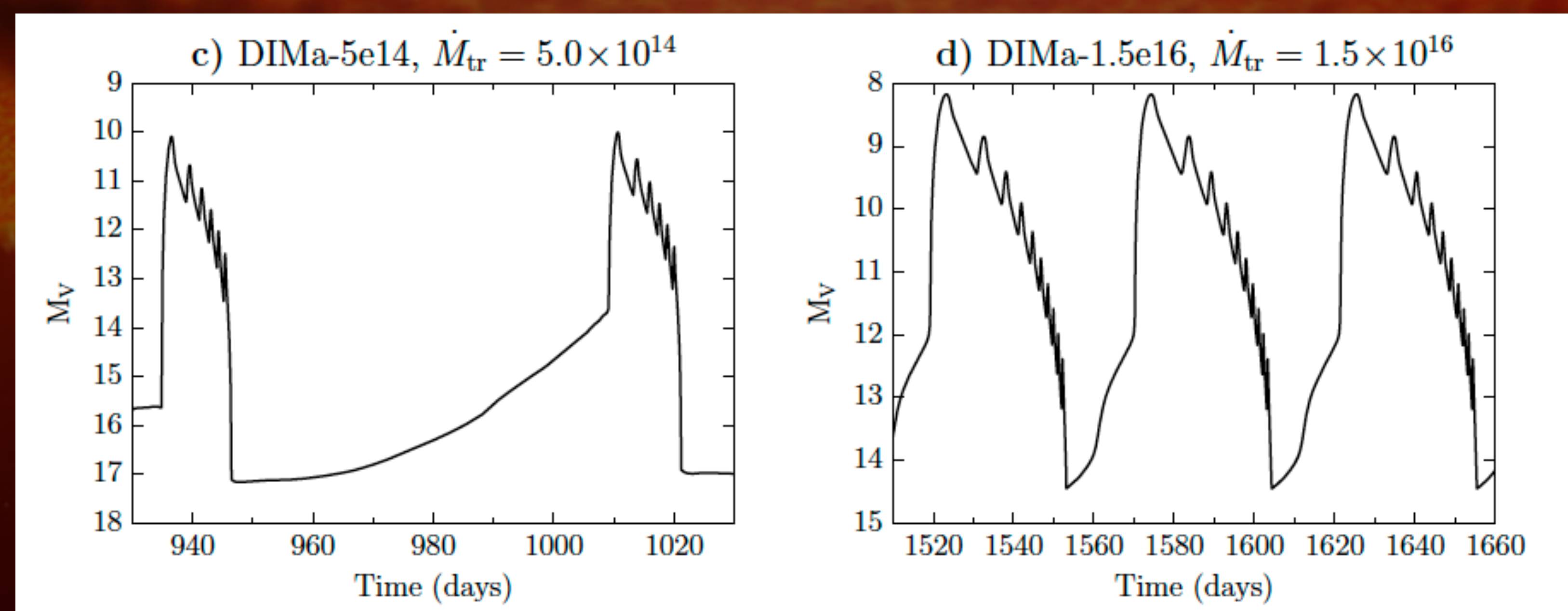
Light curves from Zero Net Flux simulations

Coleman et al. 2016



Using
α~0.1 for eruptive state
α~0.01 for quiescent state

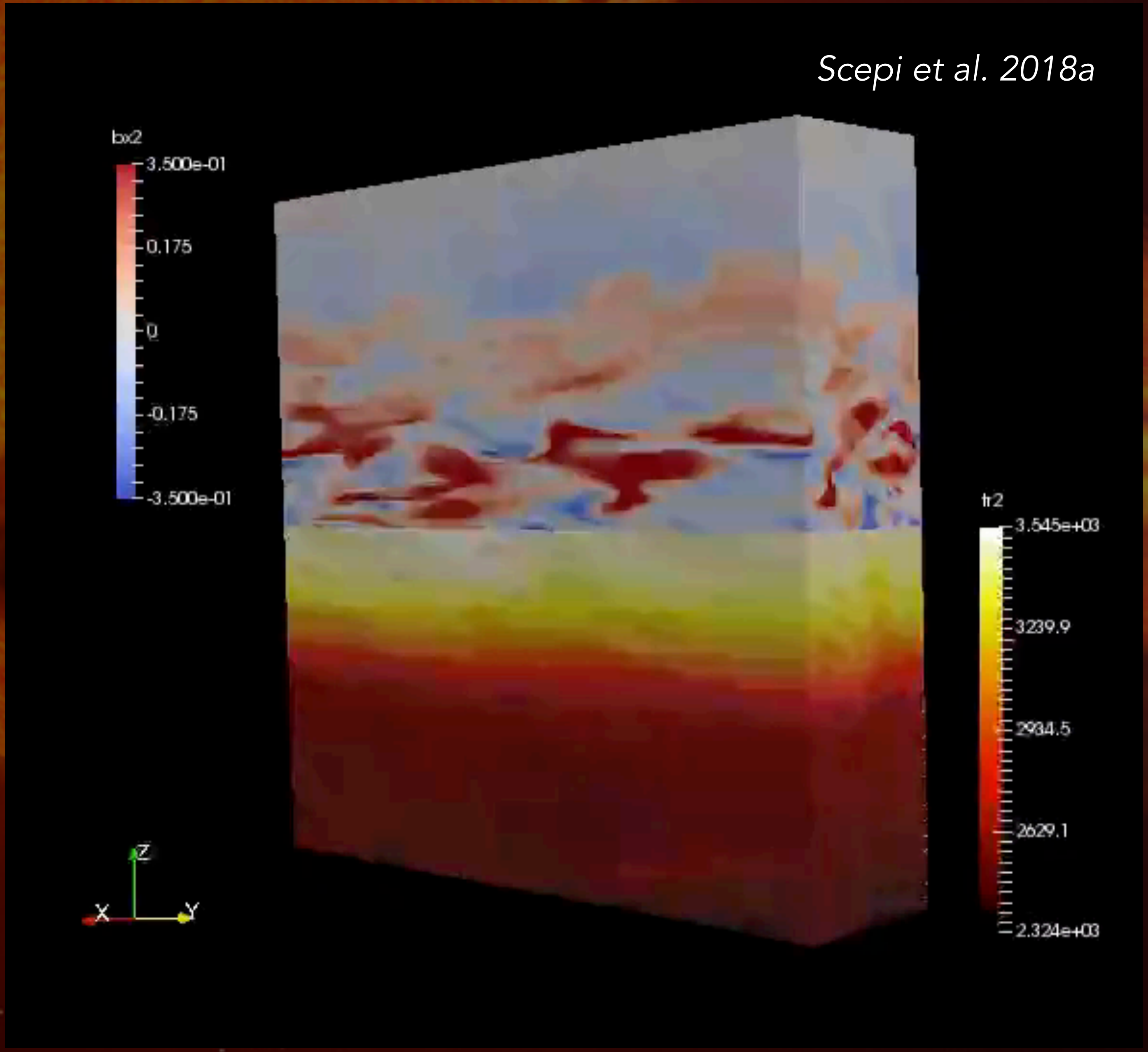
Coleman et al. 2016



Using α from simulations
(Hirose et al. 2014, Scepi et al. 2018a)

Do not match observational light curves !

Resistive cold branch



When we include resistivity MRI is quenched in the quiescent state *(as predicted by Gammie & Menou 1998)***.**

Yet, there is observational evidence that DNe in quiescence accrete *(Mukai et al 2017).*

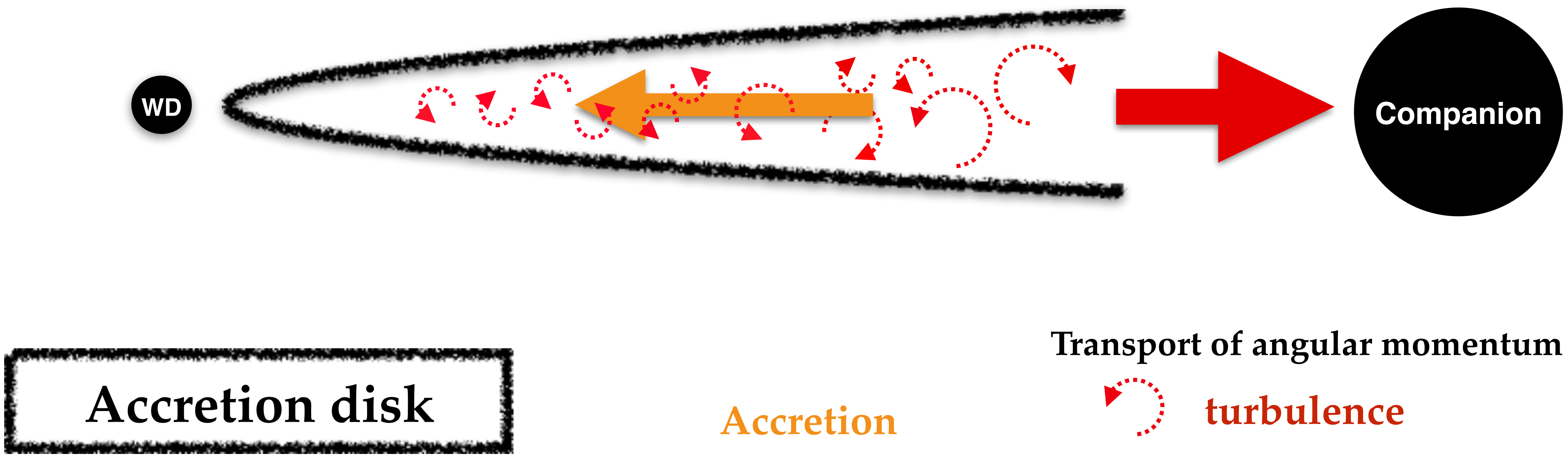
Overview

1) Zero Net Flux simulations

2) Net Flux simulations

3) Disk-wind model

Net flux simulations

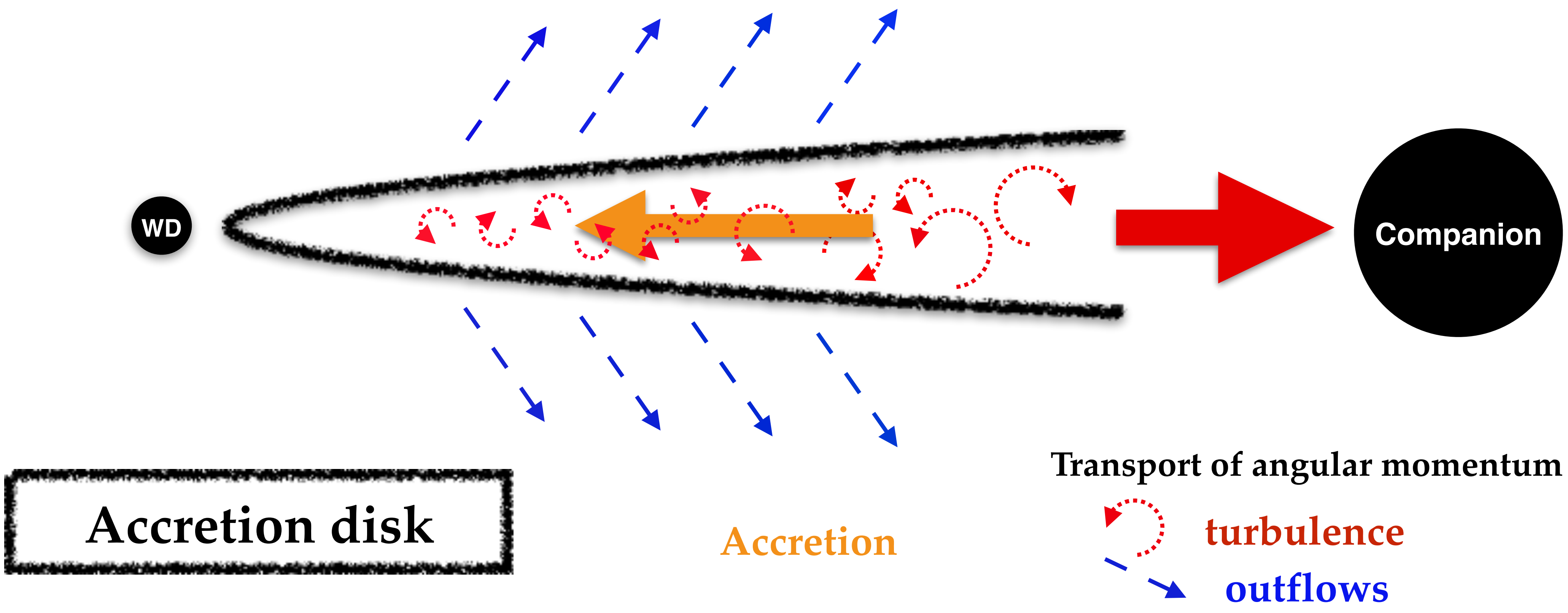


$$\Sigma \langle u_R \rangle_\rho = - \frac{1}{(R^2\Omega)'} \left(\frac{1}{R} \partial_R (\Sigma R^2 W_{R\phi}) \right)$$

$$\dot{M} = \dot{M}_{R\phi}$$

Mass accretion rate due
to turbulent transport.

Outflows



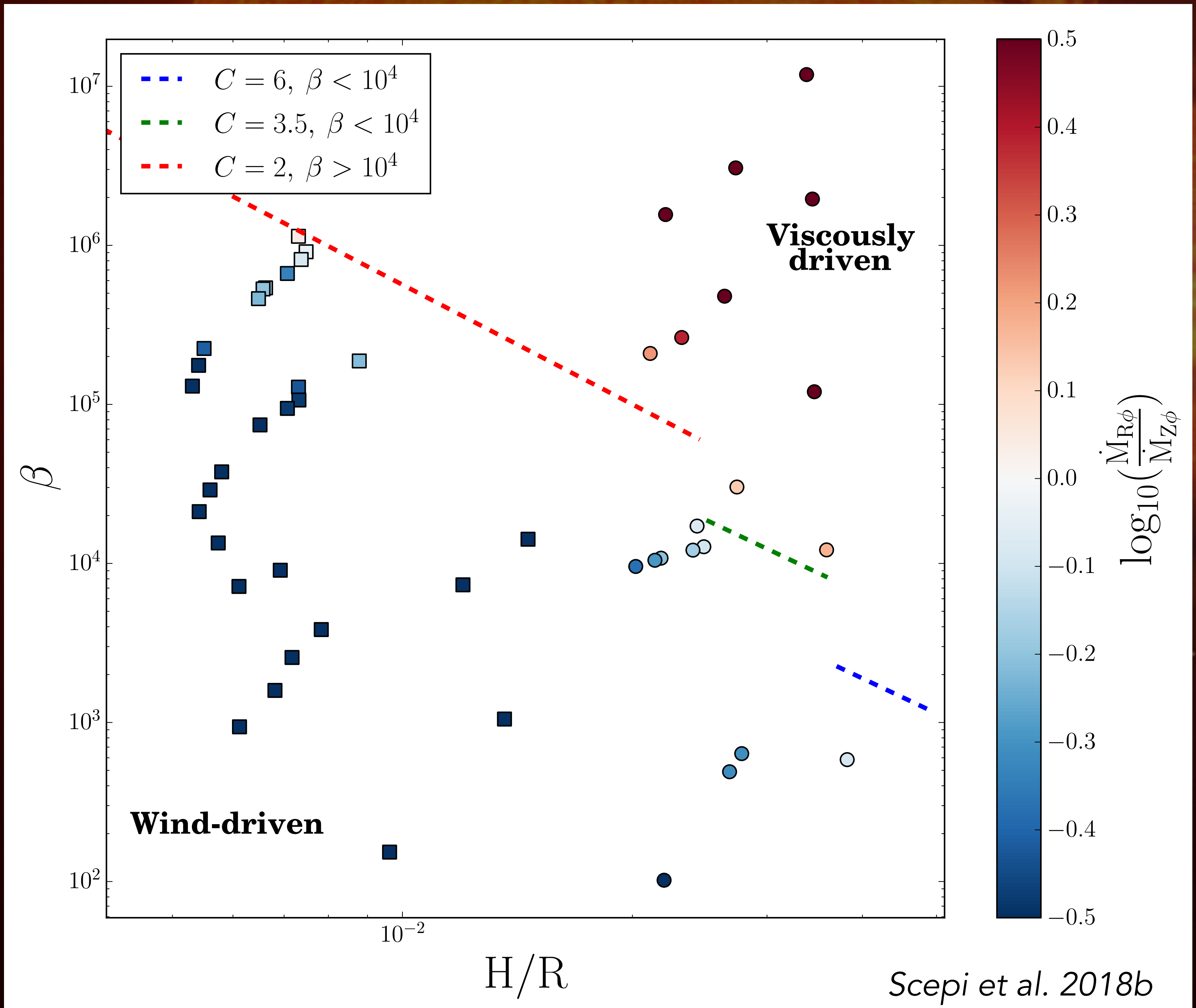
$$\Sigma \left\langle u_R \right\rangle_\rho = -\frac{1}{(R^2\Omega)'} \left(\frac{1}{R}\partial_R(\Sigma R^2 W_{R\phi}) + [\Sigma R W_{z\phi}]^{\mathrm{up}}_{\mathrm{down}} \right)$$

$$\dot{M} = \dot{M}_{R\phi} + \dot{M}_{z\phi}$$

Mass accretion rate due to turbulent transport.

Mass accretion rate due to wind-driven transport.

Turbulent VS wind-driven accretion



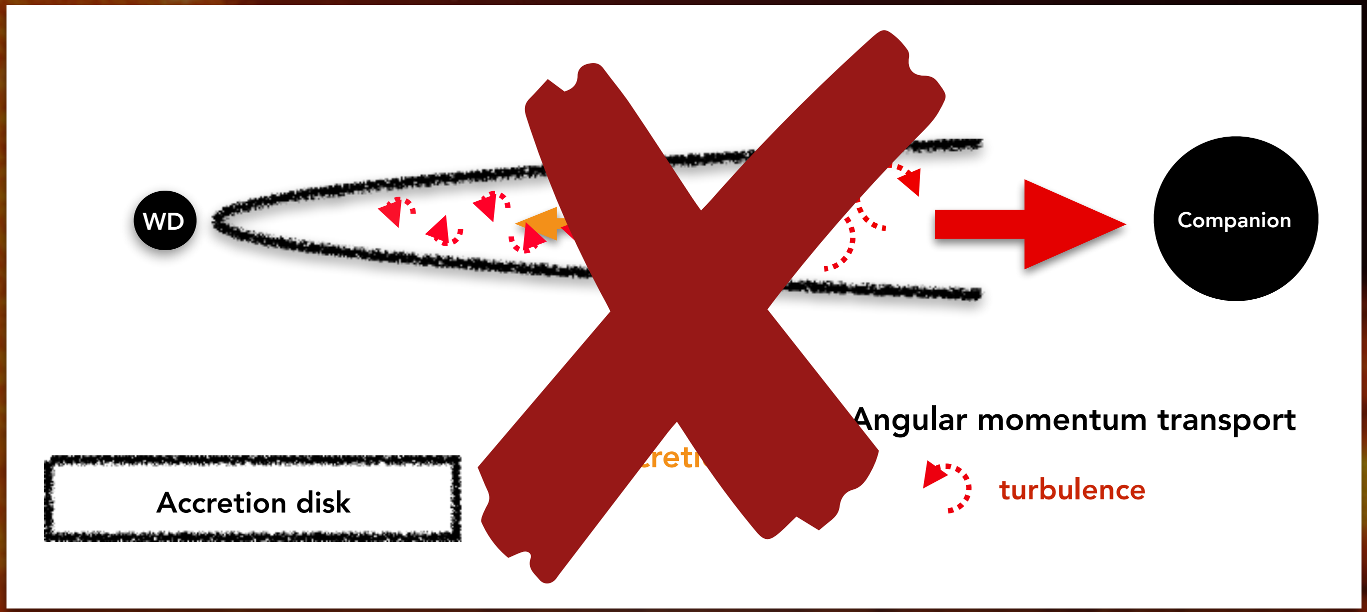
Scepi et al. 2018b

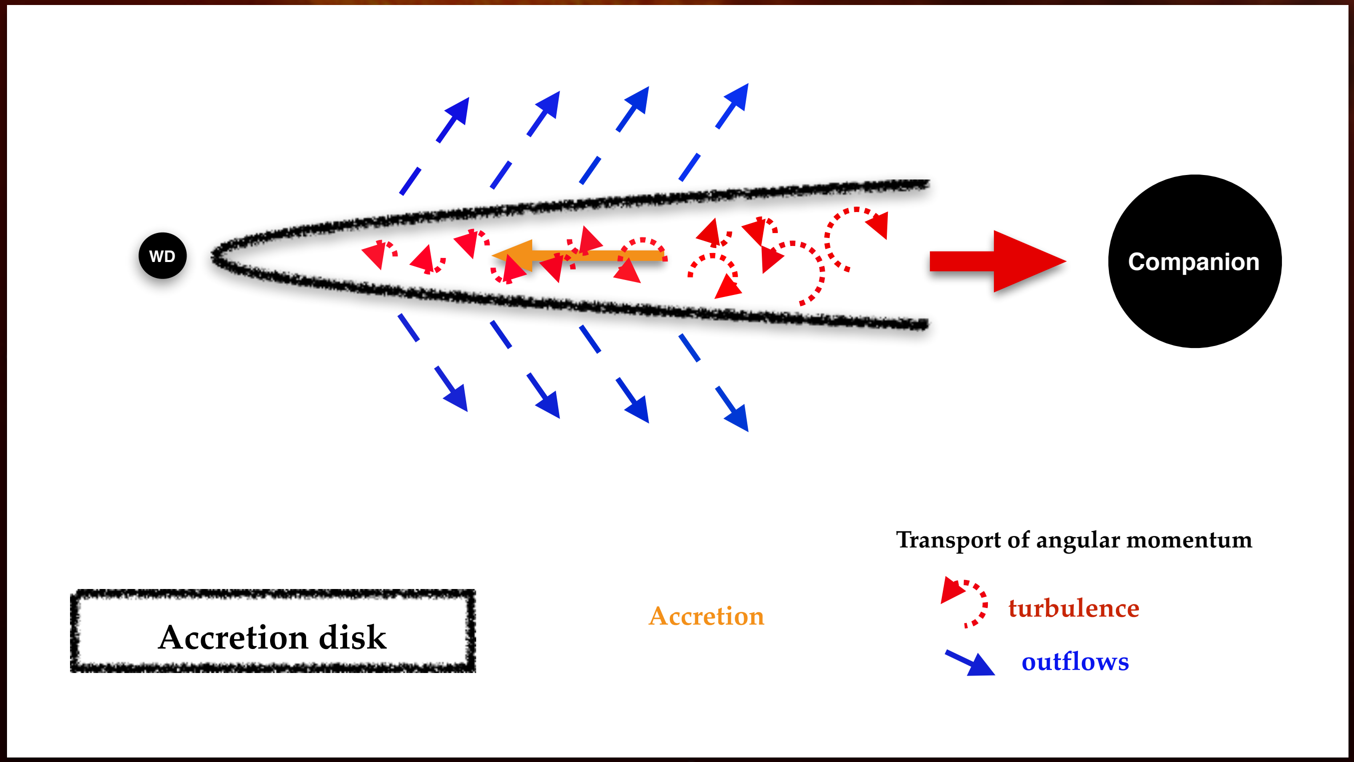
Eruptive state dominated by viscous accretion

Quiescent state dominated by the wind-driven accretion

A new framework

Disk with a wind will not behave as an α-disk.





Need to review observational constraints with a disk-wind model.

Overview

1) Zero Net Flux simulations

2) Net Flux simulations

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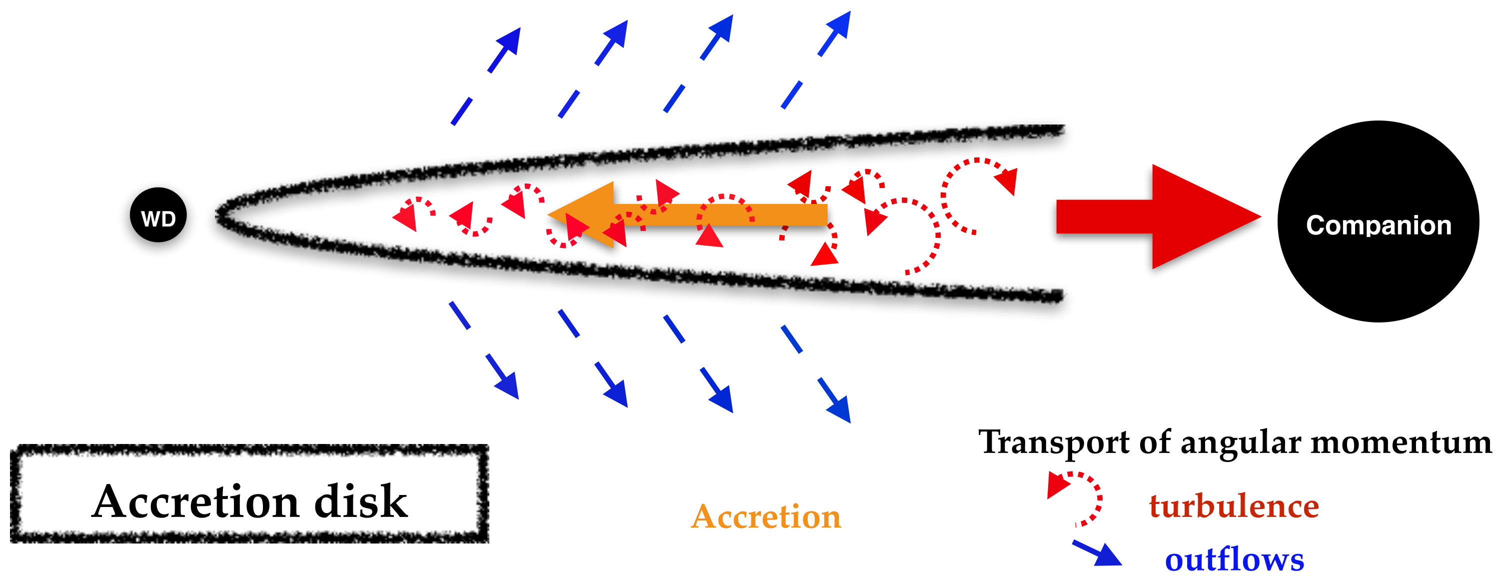
A new disk-wind instability model



$$\partial_t\Sigma - \frac{2}{R_0}\partial_{R_0}\left(R_0^{1/2}\partial_{R_0}\left(\frac{\Sigma}{\Omega_0}R_0^{1/2}\alpha\left\langle c_s^2\right\rangle_\rho\right) + \frac{2q}{\beta}\left\langle P_{\text{thermal mid}}\right\rangle\frac{R_0}{\Omega_0}\right) = 0$$

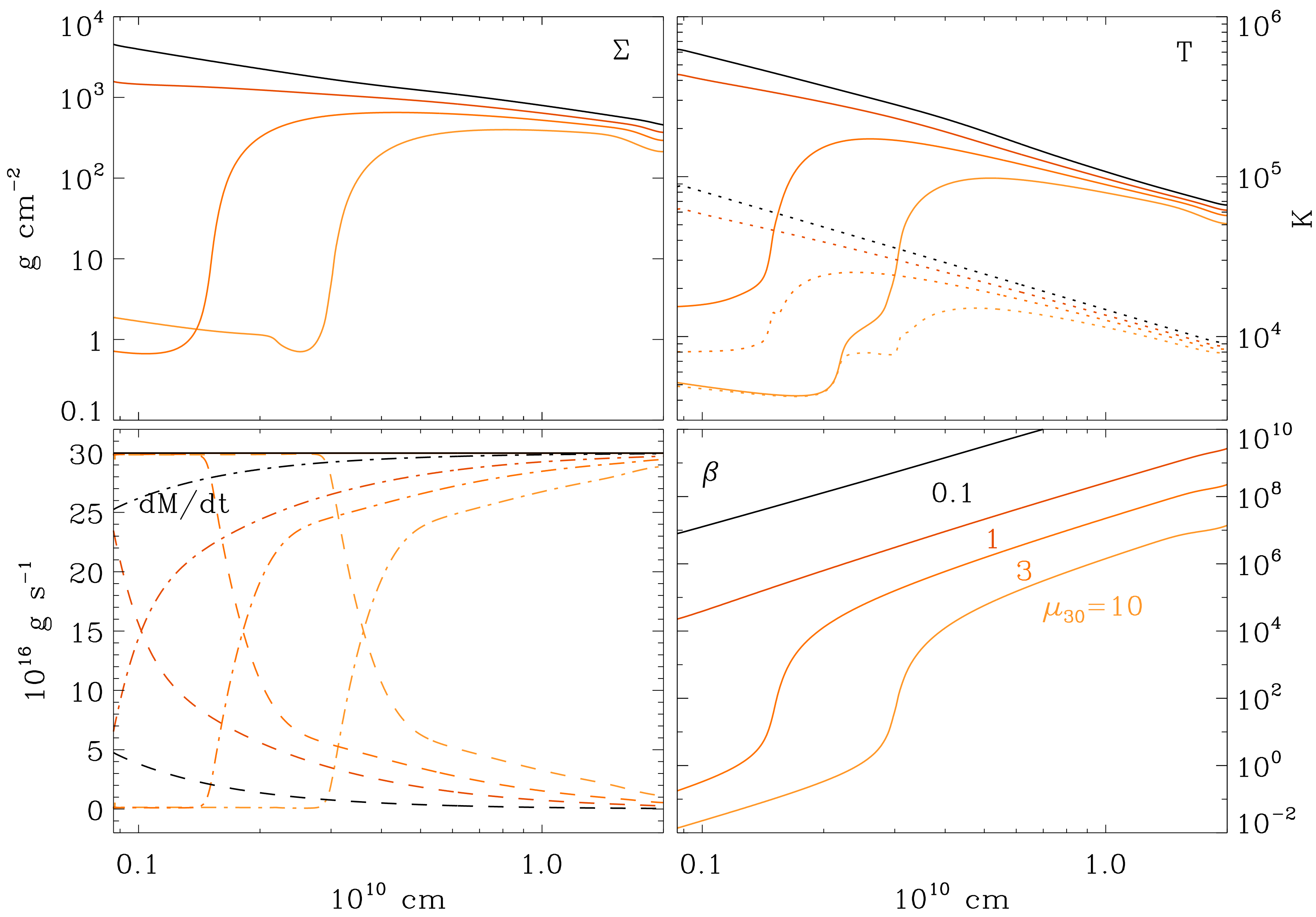
We used prescriptions on

$$\alpha(\beta),\ q(\beta)$$

from our simulations to construct a new DIM.
We used **a fixed magnetic field configuration.**

B dipolar

Stable case



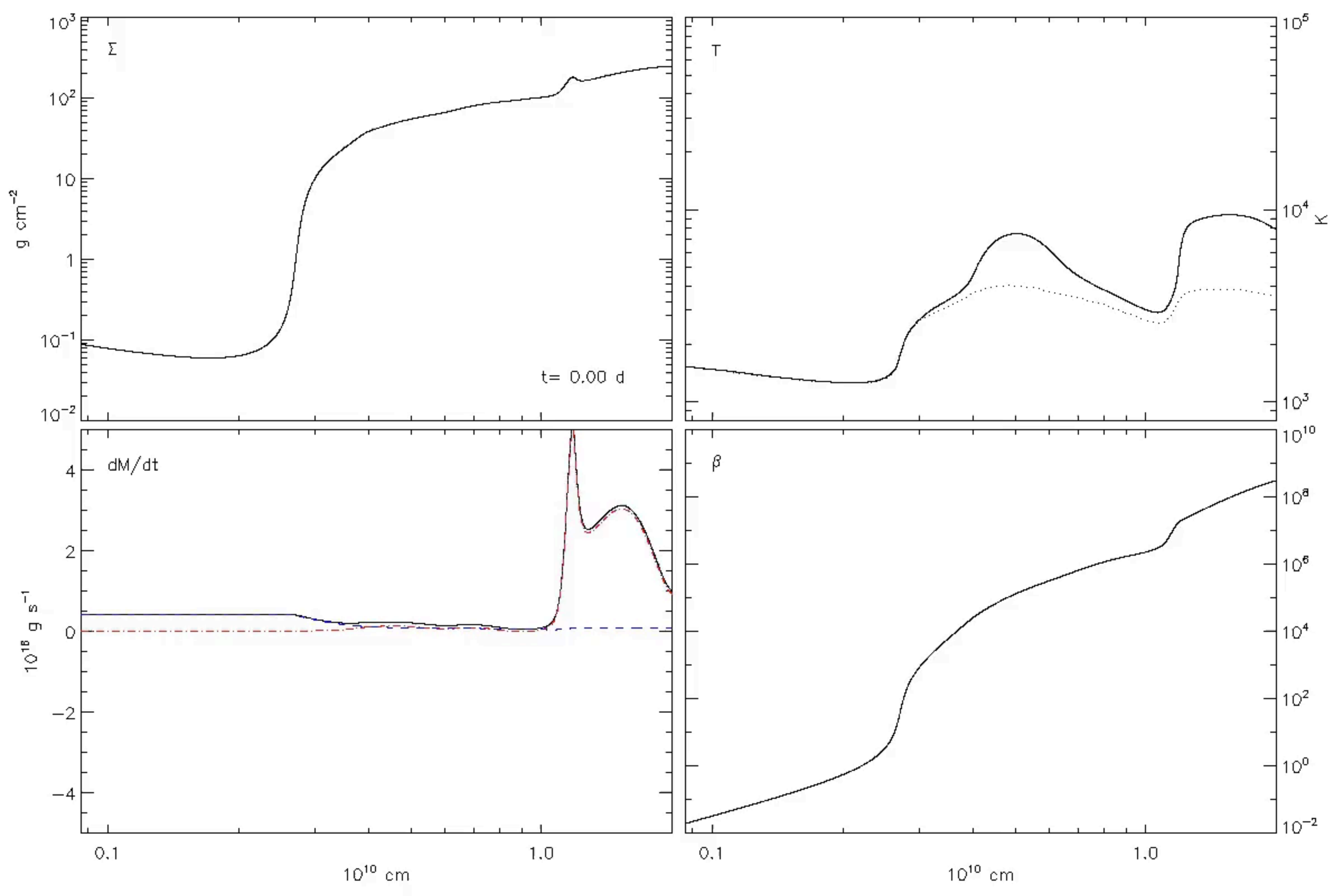
Scepi et al. 2018c in prep

$$\dot{M}_{\rm external} = 3 \times 10^{17}\ {\rm g\ s^{-1}},\ R_{\rm out} = 2 \times 10^{10}\ {\rm cm}$$

B dipolar

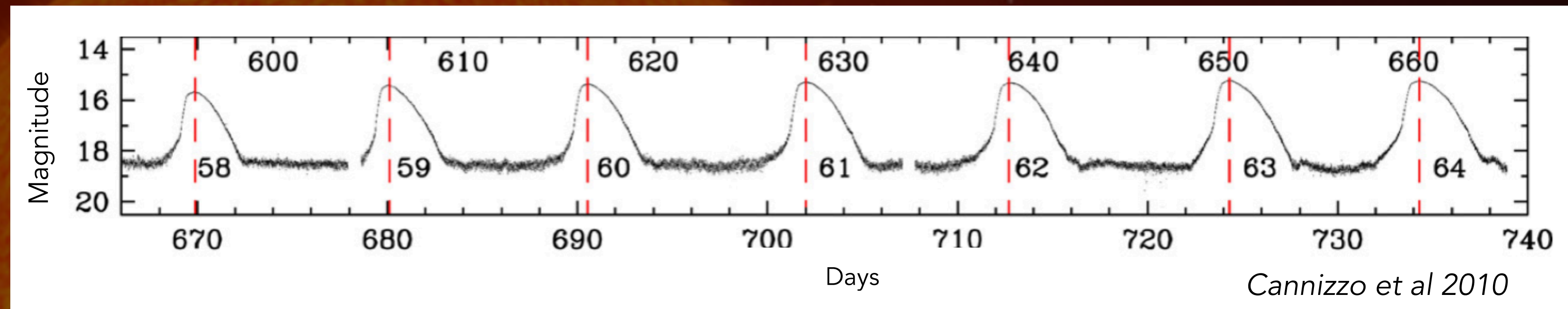
Unstable case

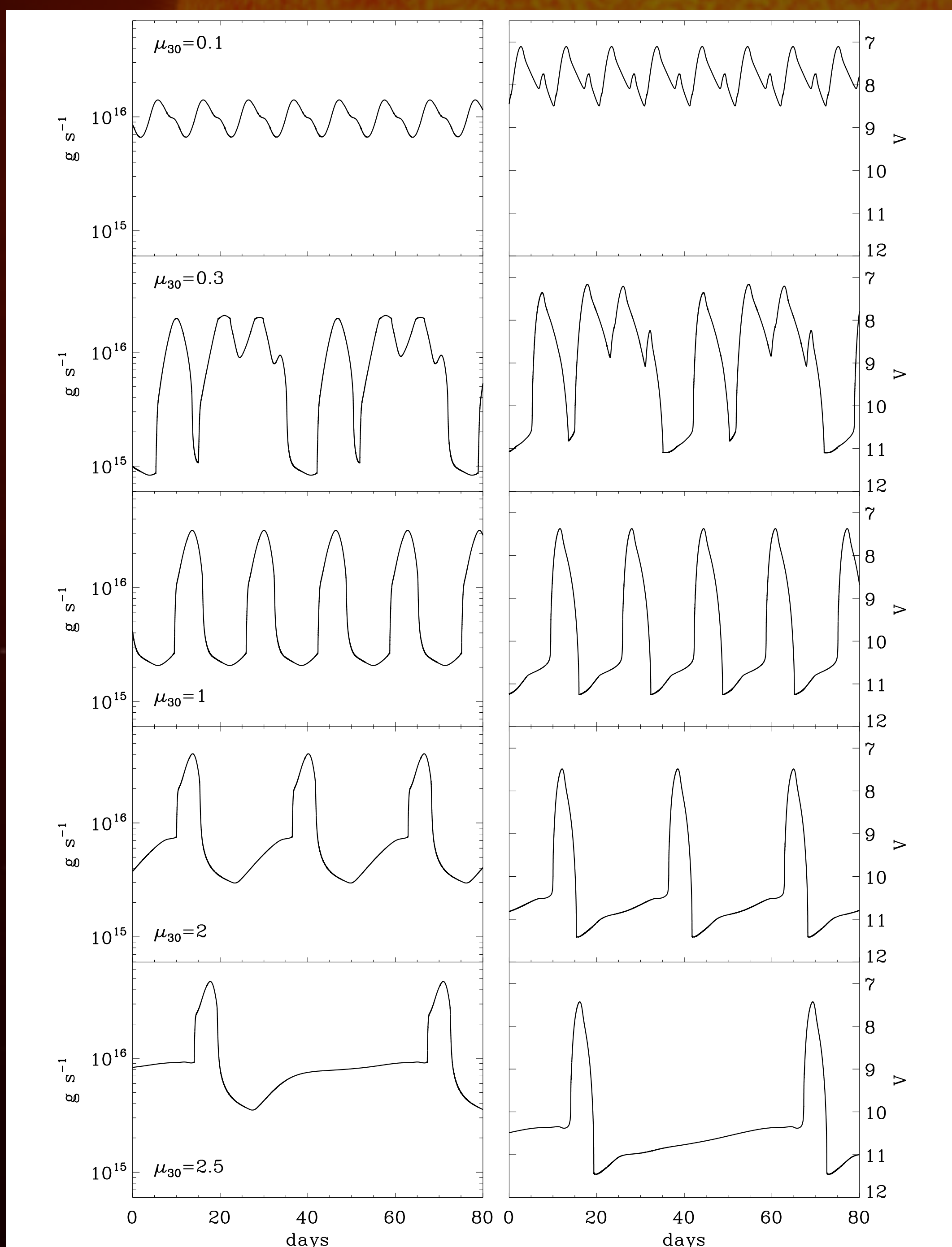
Scepi et al. 2018c in prep



$$\dot{M}_{\rm external} = 1 \times 10^{16}\ {\rm g\ s^{-1}},\ R_{\rm out} = 2 \times 10^{10}\ {\rm cm}$$

Observations vs Model





Scepi et al. 2018c in prep

For a dipolar moment of ~10^{30} G cm^3, light curves are very similar to that of DNe!

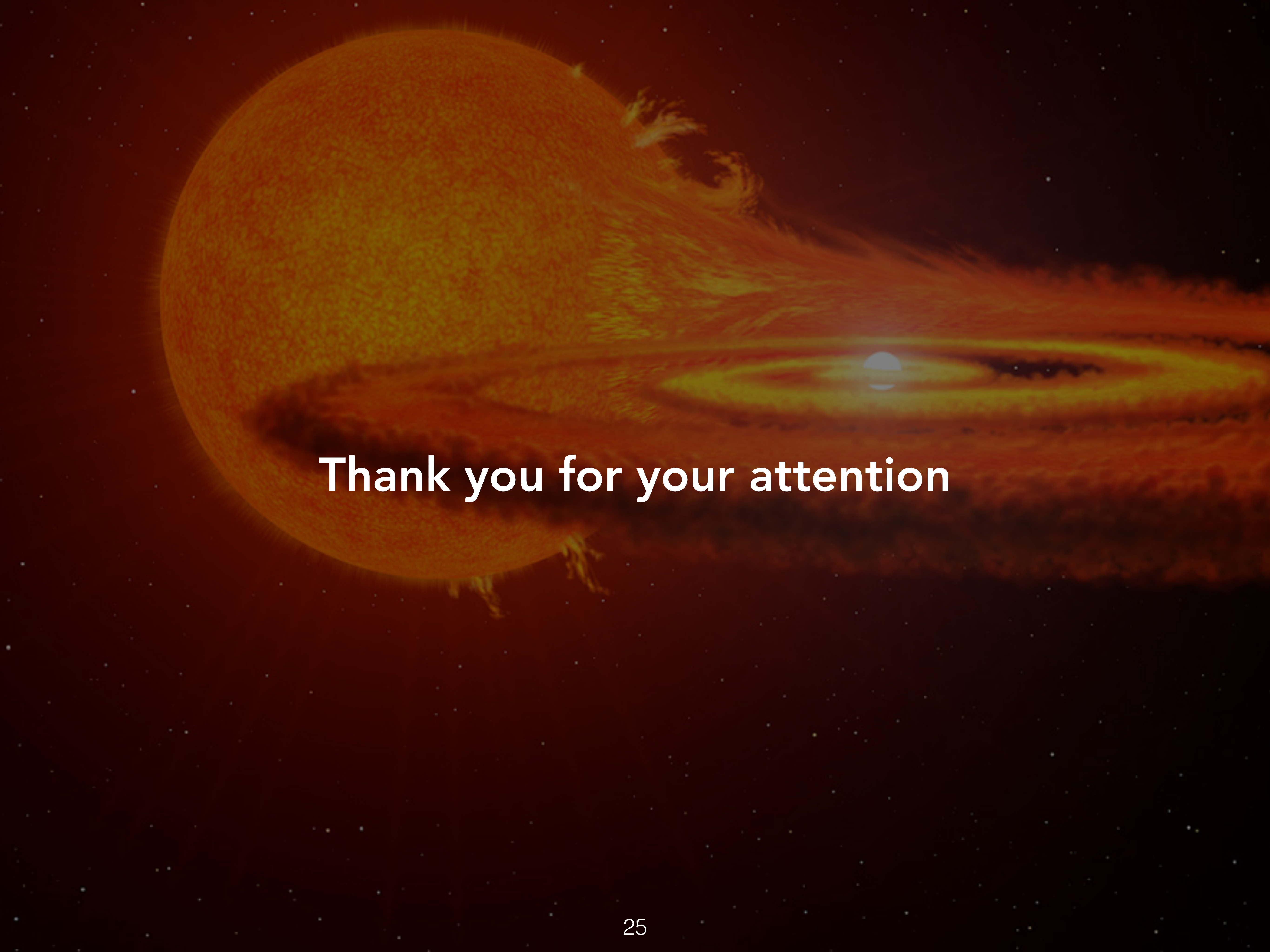
However, we used a fixed magnetic field. We need to compute the **evolution of the magnetic field**.

Conclusions

- Turbulent MRI transport alone cannot explain the behavior of DNe

- Net Flux simulations show that outflows transport angular momentum very efficiently in the quiescent state

- Taking into account turbulent and wind-driven transport, we can reproduce light-curves of DNe



Thank you for your attention