Strongly magnetized accretion disks around black holes

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Types of Accretion disks

Geometrically:

Thin disk - Cold, close to sub-Eddington, optically thick

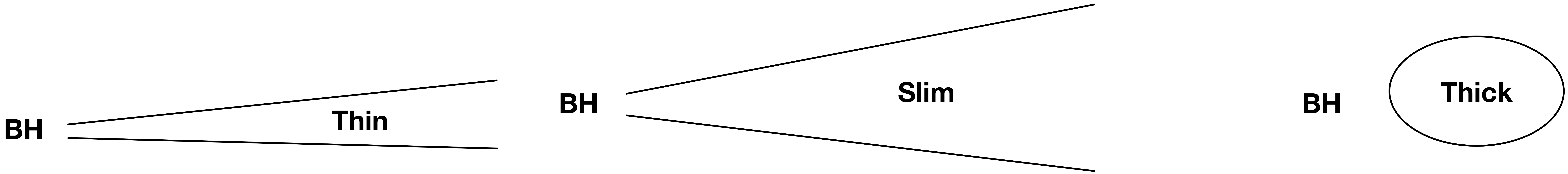
Shakura & Sunyaev 1973, Novikov & Thorne 1973, Lynden-Bell & Pringle 1974

Slim disk - Cold, Eddington or super-Eddington, optically thick, advection dominated

Katz 1977, Begelman 1979, Begelman & Meier 1982, Abramowicz et al. 1988

Thick disk - Optically thin, advection dominated

Abramowicz, Jaroszynski, Sikora 1978, Narayan & Yi 1994

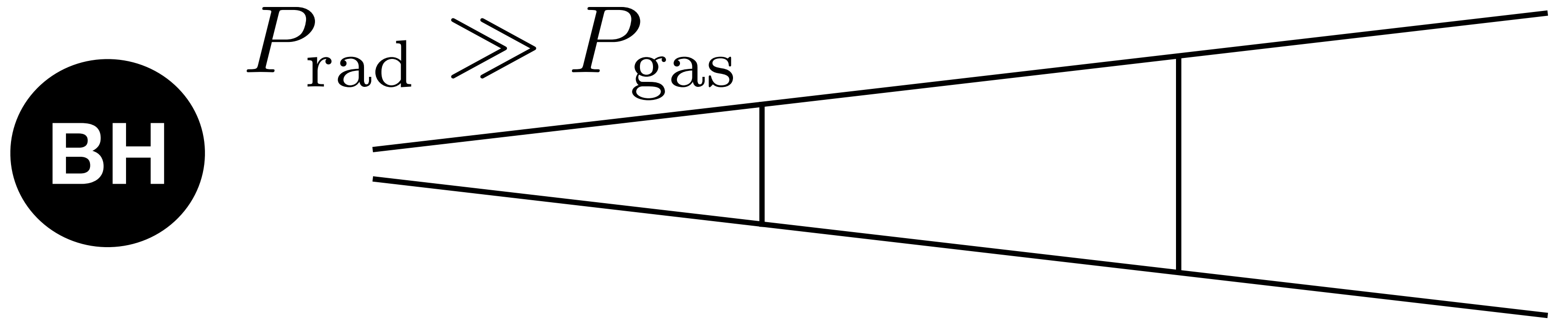


Geometrically thin disks

$$H/r \ll 1$$

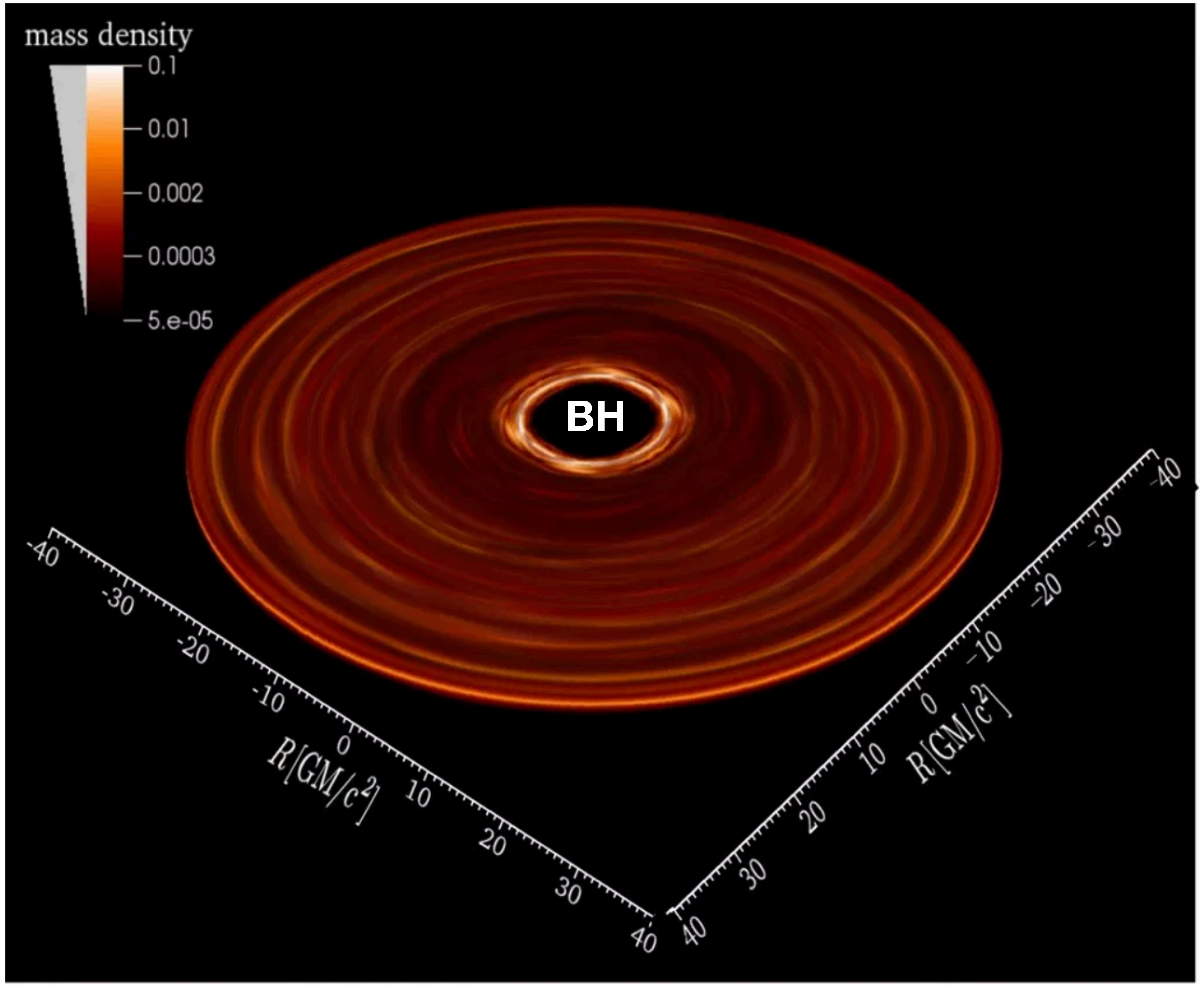
Radiatively efficient

$$P_{\mathrm{rad}} \gg P_{\mathrm{gas}}$$



$$\alpha = \frac{< T_{r\phi} >}{< P_{\mathrm{gas}} >}$$

Shakura & Sunyaev 1973



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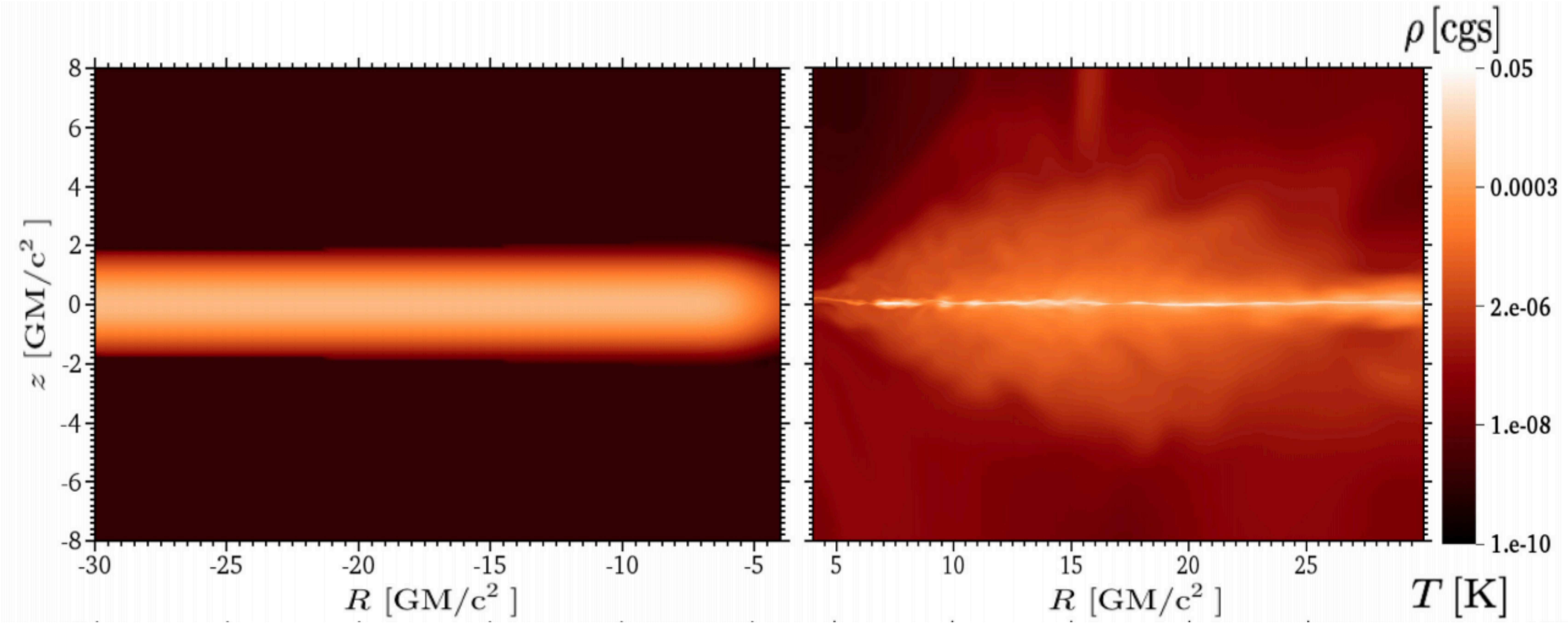
Instabilities

Hydrodynamical:

Thermal Instability

Viscous Instability



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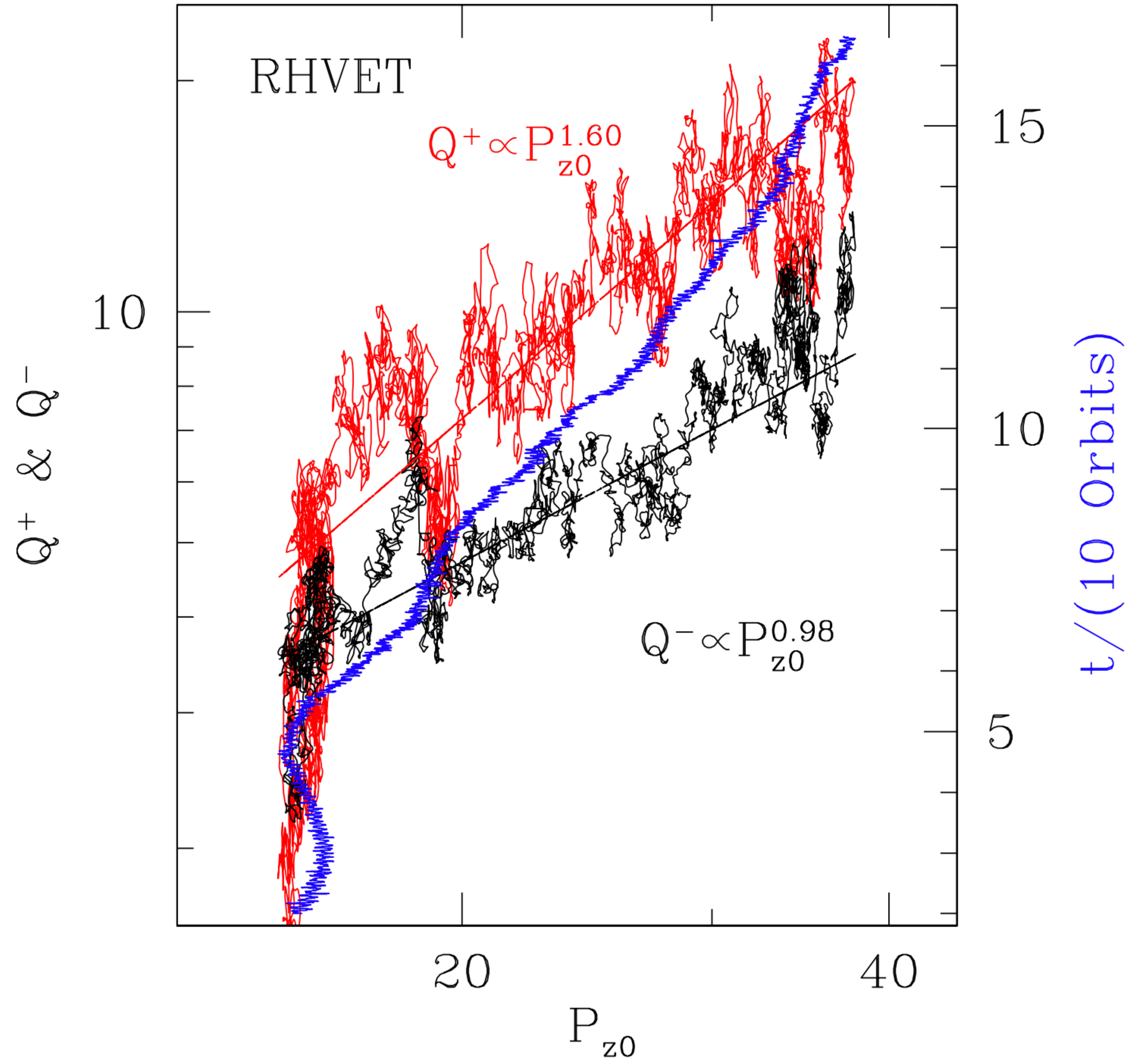
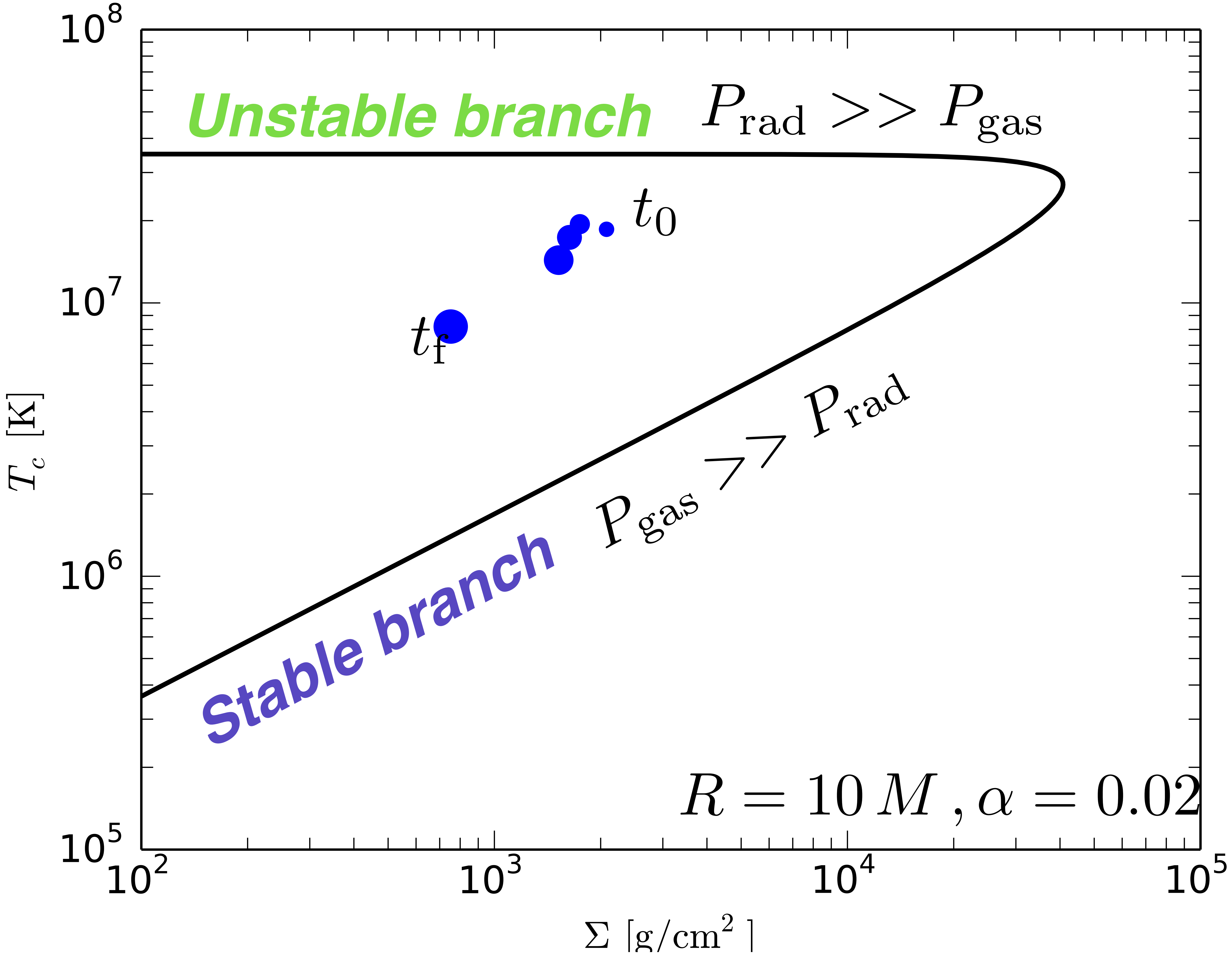
Local simulations



Jiang et al. 2013

Global simulation



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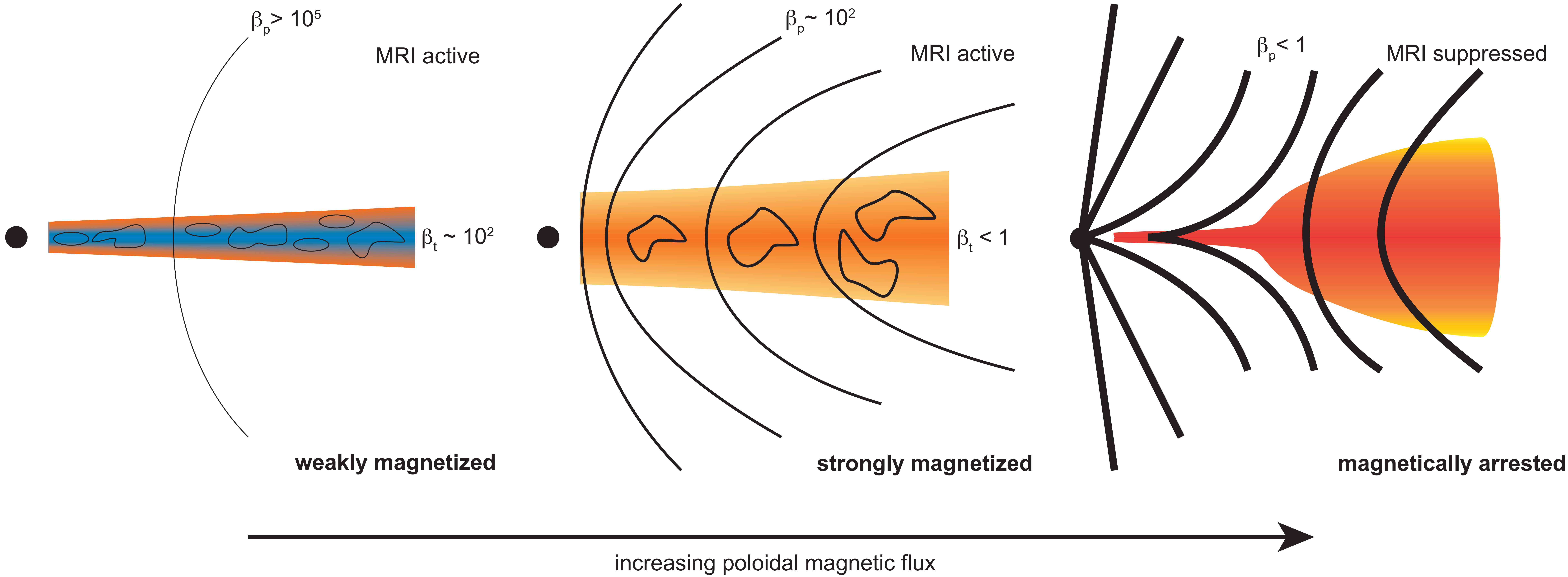
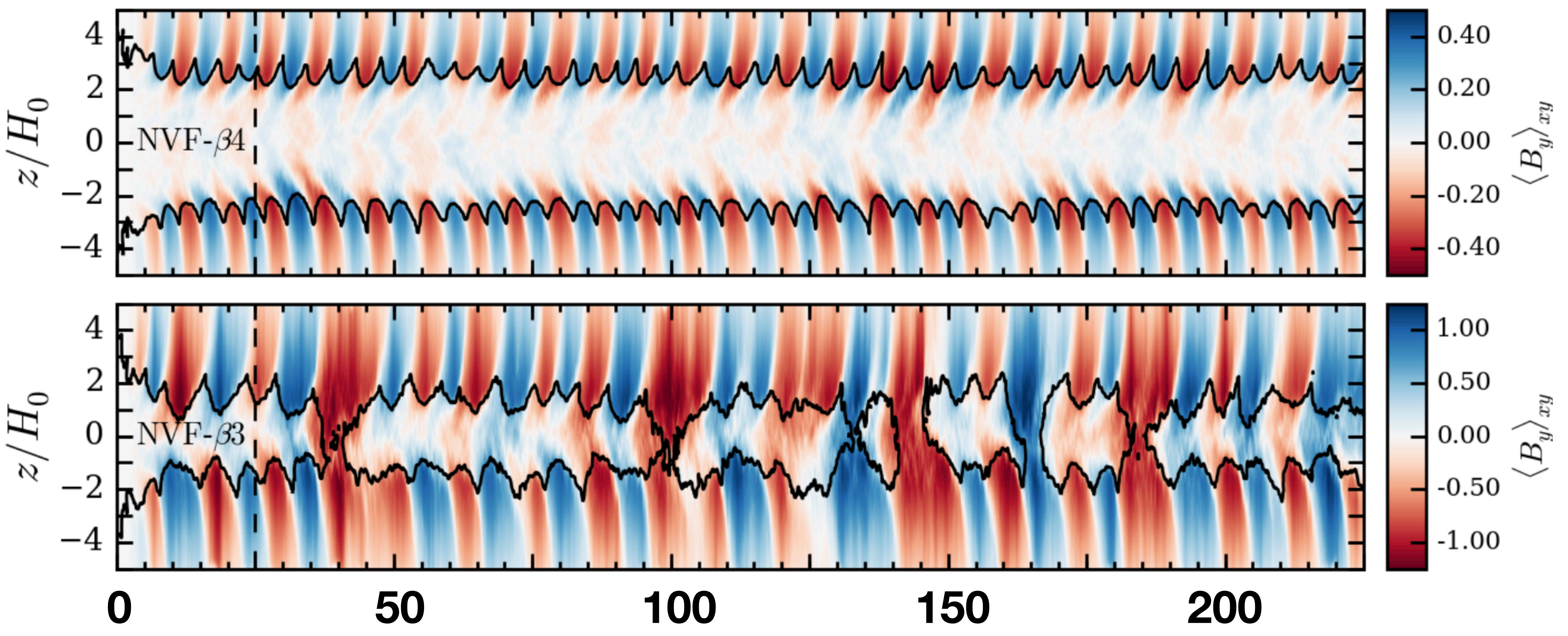
Open Questions

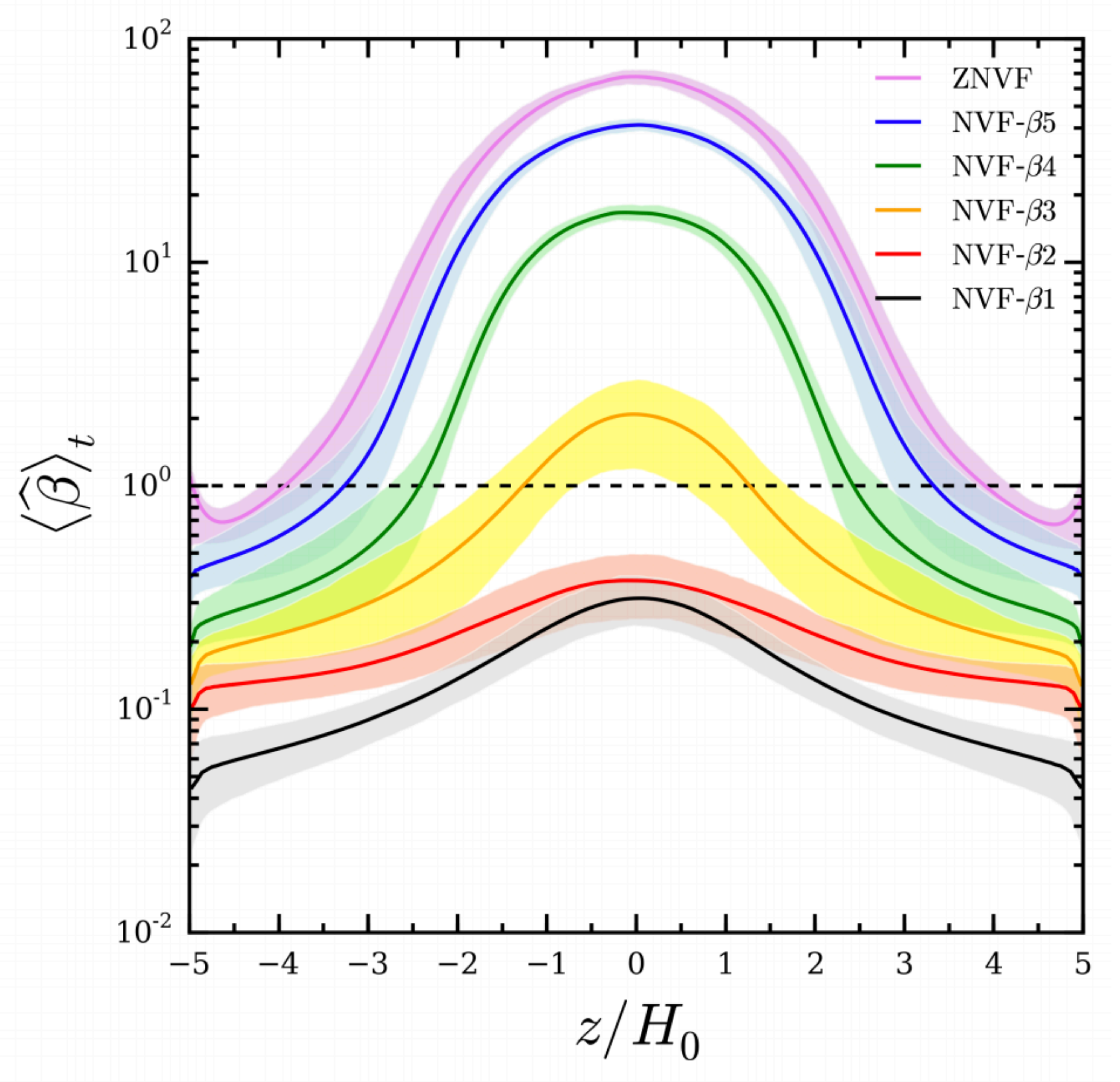
- Why do we find thermally unstable disks in simulations ? What can stabilize them ? Perhaps magnetic field (Sàdowski 2016)
- What are effects of net vertical magnetic field in global simulations?
- Can we learn something about AGN accretion ?



Sketch: Phil Armitage

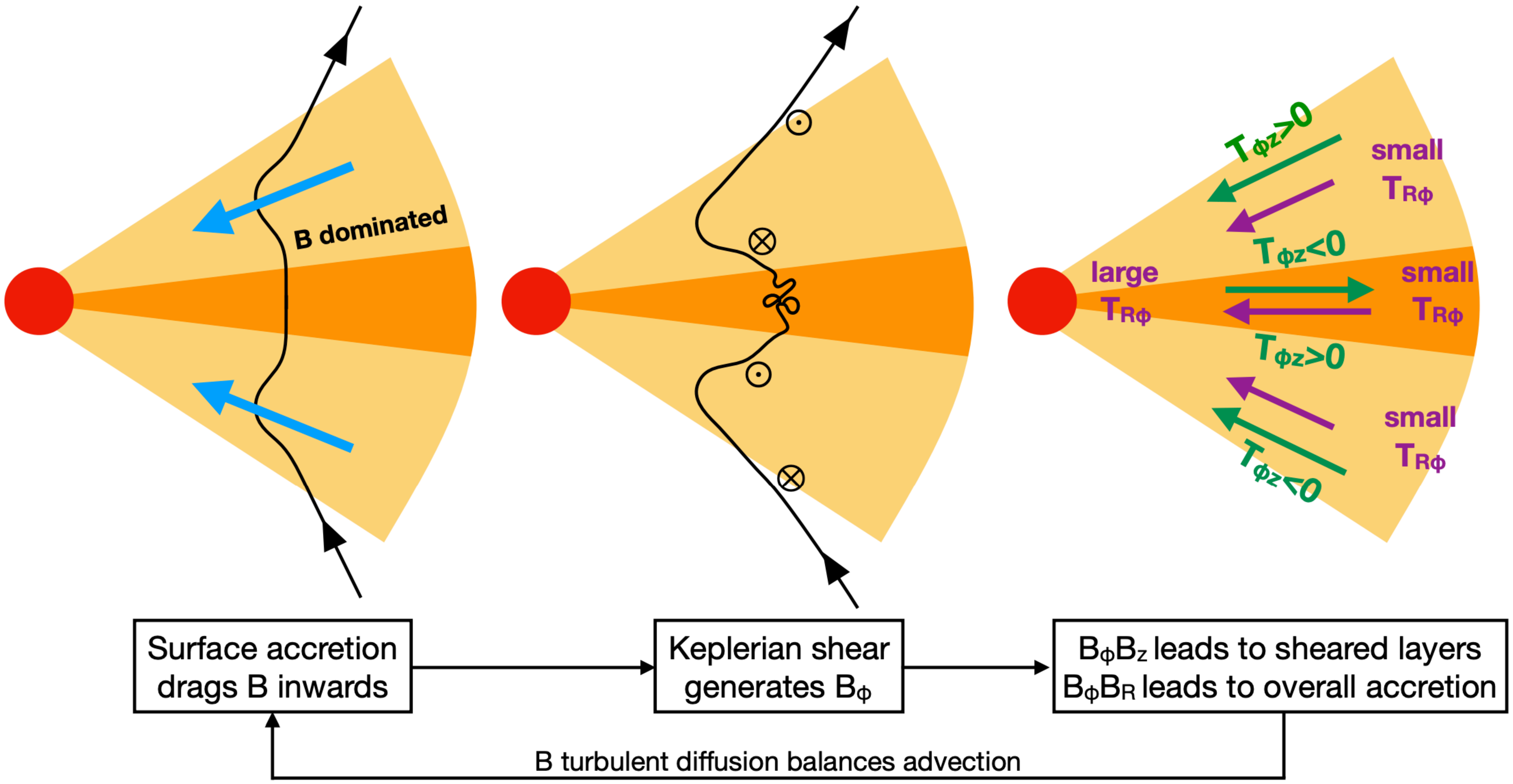
Local simulations





Salvesen et al. 2016

Global simulations



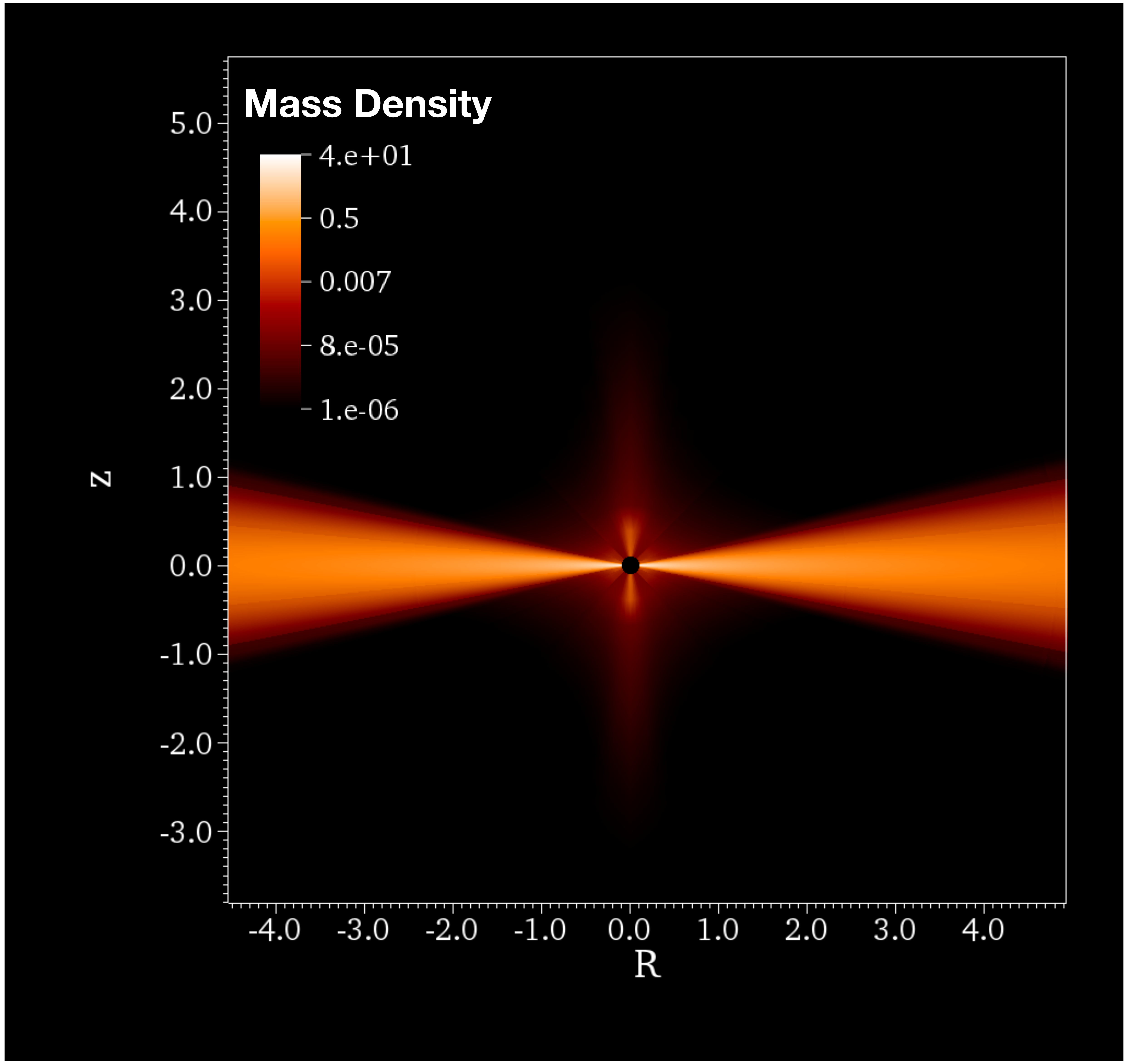
Zhu & Stone 2018

Initial setup

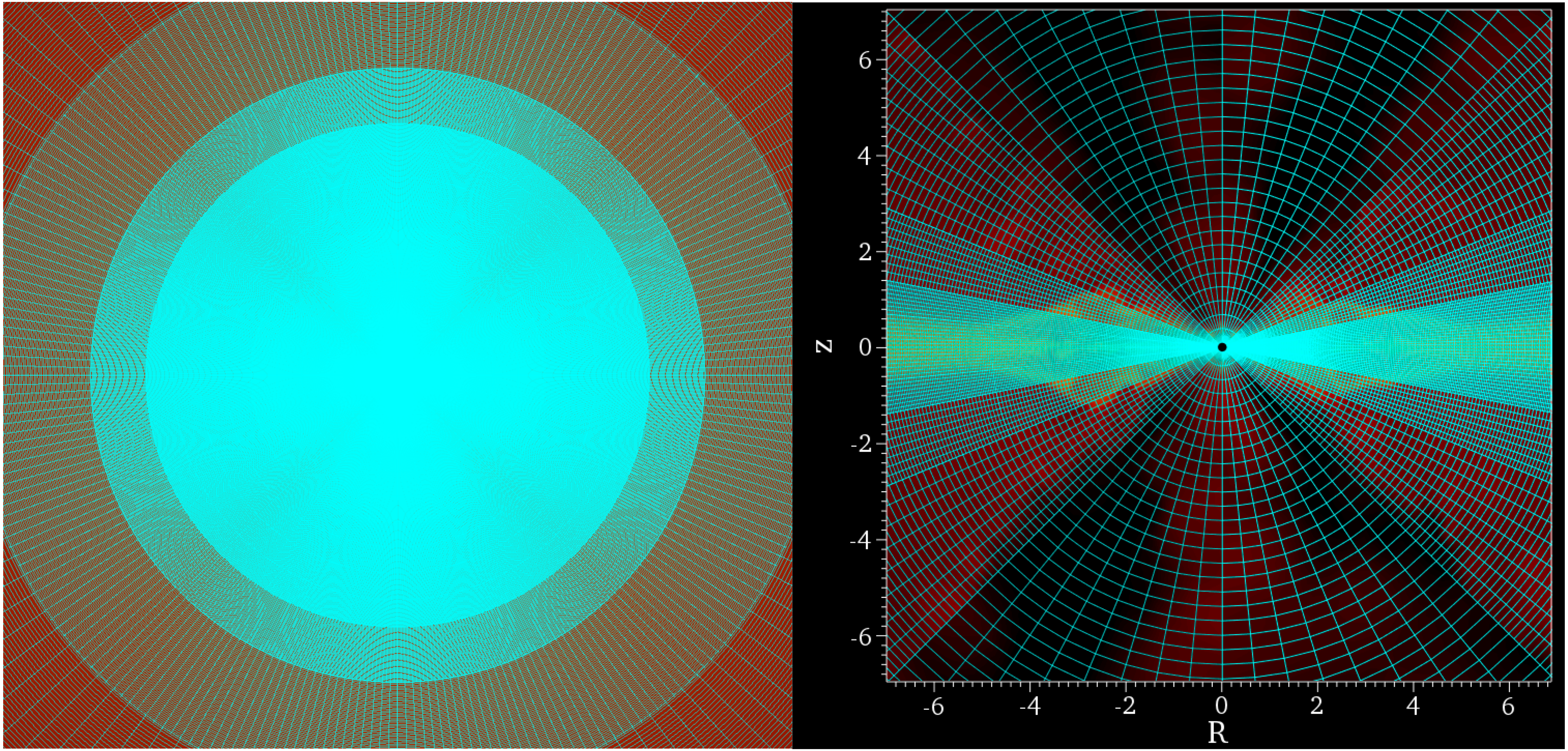
$$\rho_0(R, z=0) = \rho_0(R_0, z=0)\left(\frac{R}{R_0}\right)^q$$

$$\rho(R,z) = \rho(R, z=0) exp\left[\frac{GM}{c_s^2}\left(\frac{1}{\sqrt{R^2+z^2}} - \frac{1}{R}\right)\right]$$

$$v_\phi(R,z) = v_K\left[(p+q)\left(\frac{c_s}{v_{\phi,k}}\right)^2 + 1 + q - \frac{qR}{\sqrt{R^2+z^2}}\right]^{1/2}$$



Static mesh refinement

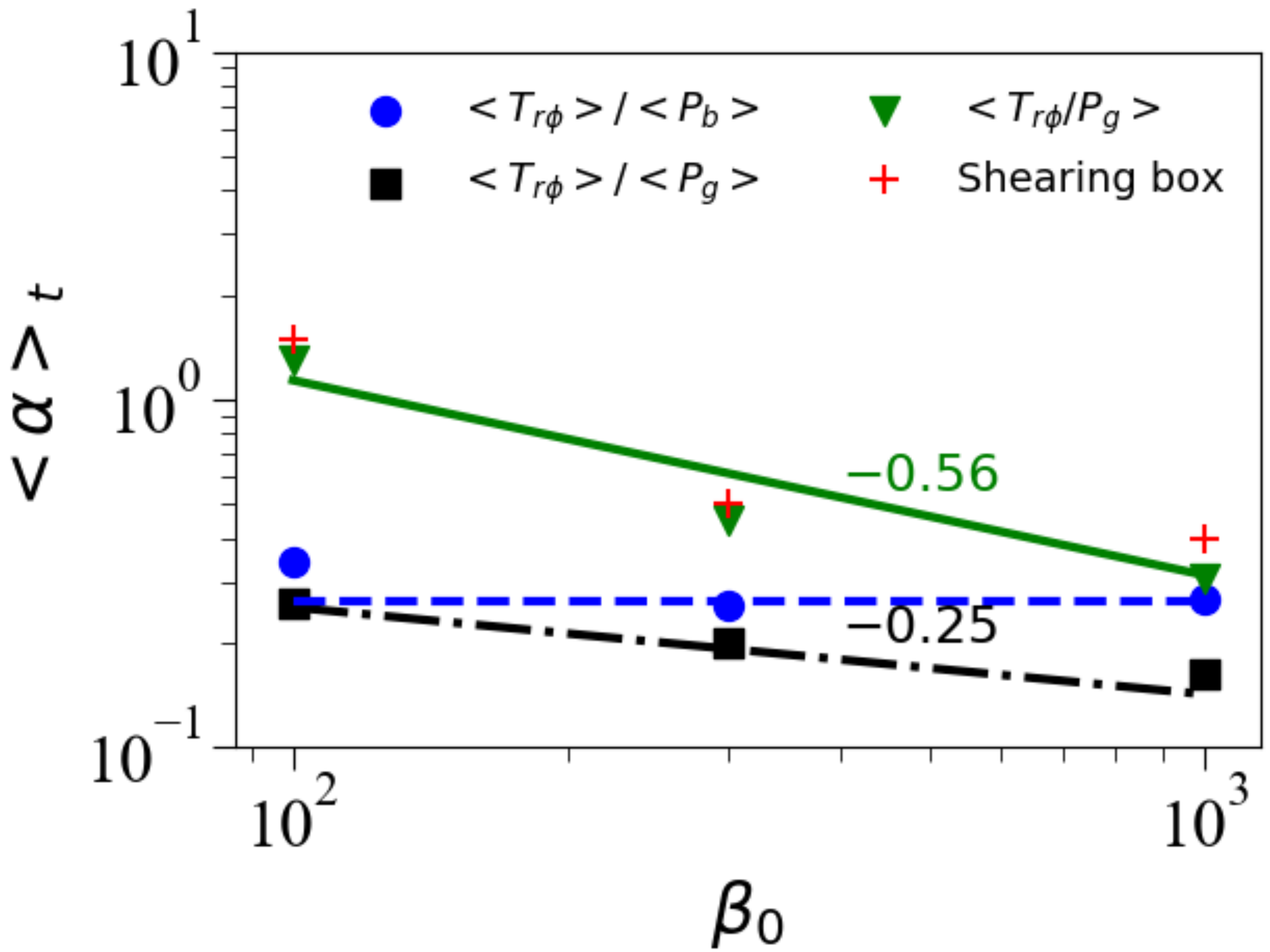


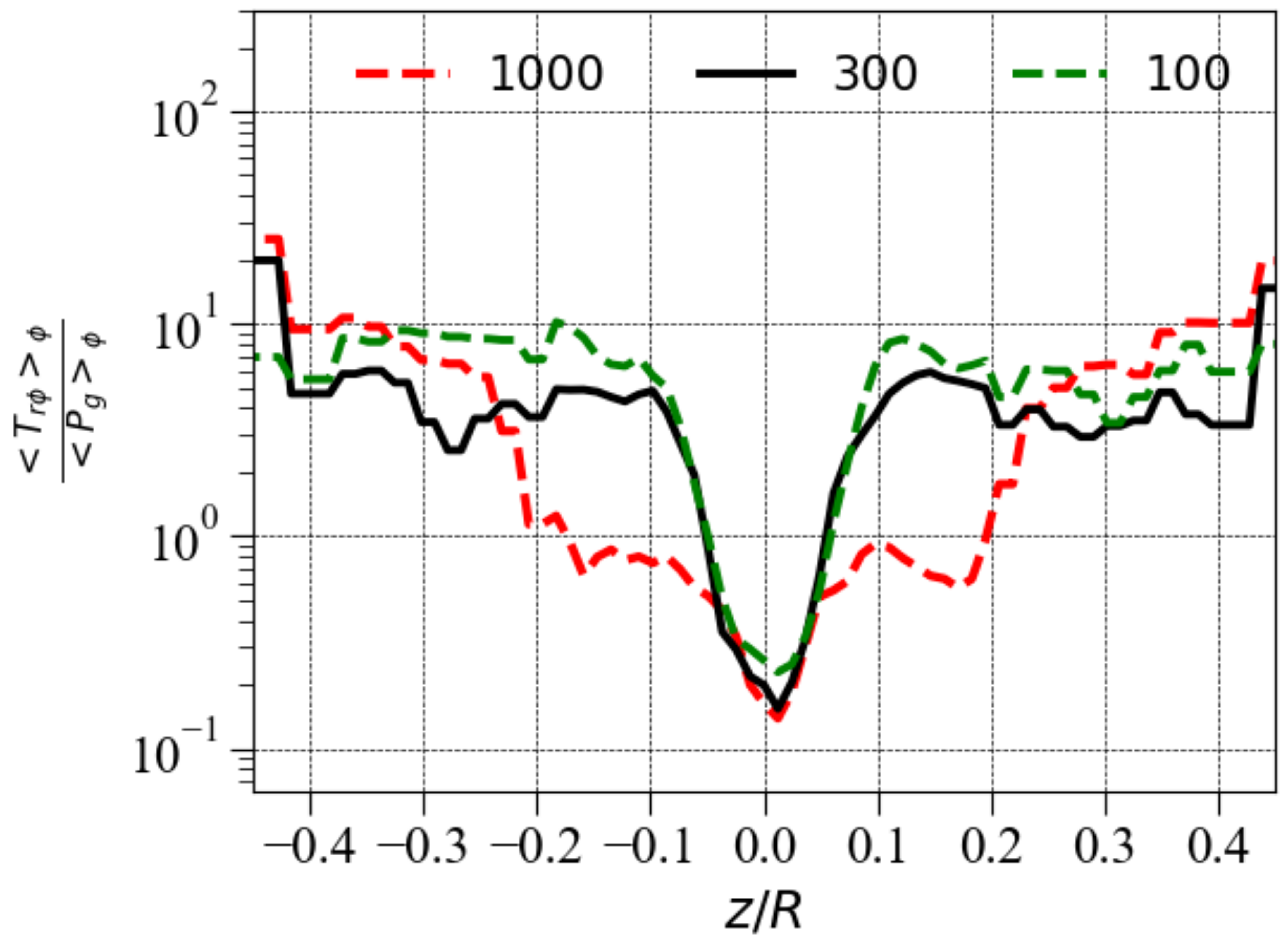
Magnetically elevated disks

$\beta_i = 100$ $\beta_i = 300$ $\beta_i = 1000$

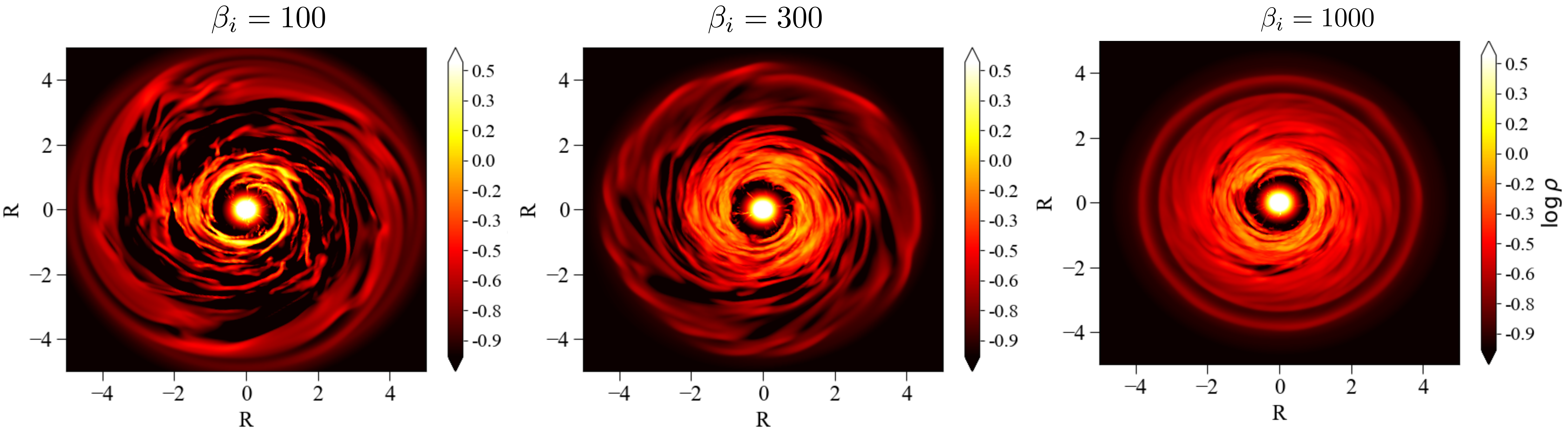
Elevated Accretion

Turbulent viscosity





Spiral structures



Spiral structures

Conclusions

- Accretion disks get elevated and inflow occurs in higher altitudes
- Qualitative agreement with local shearing box simulations
- Logarithmic spiral structures
- Future work: include radiative transfer

Thank you