A novel sub-grid model for super-Eddington accretion of spinning black holes in galaxy-scale simulations

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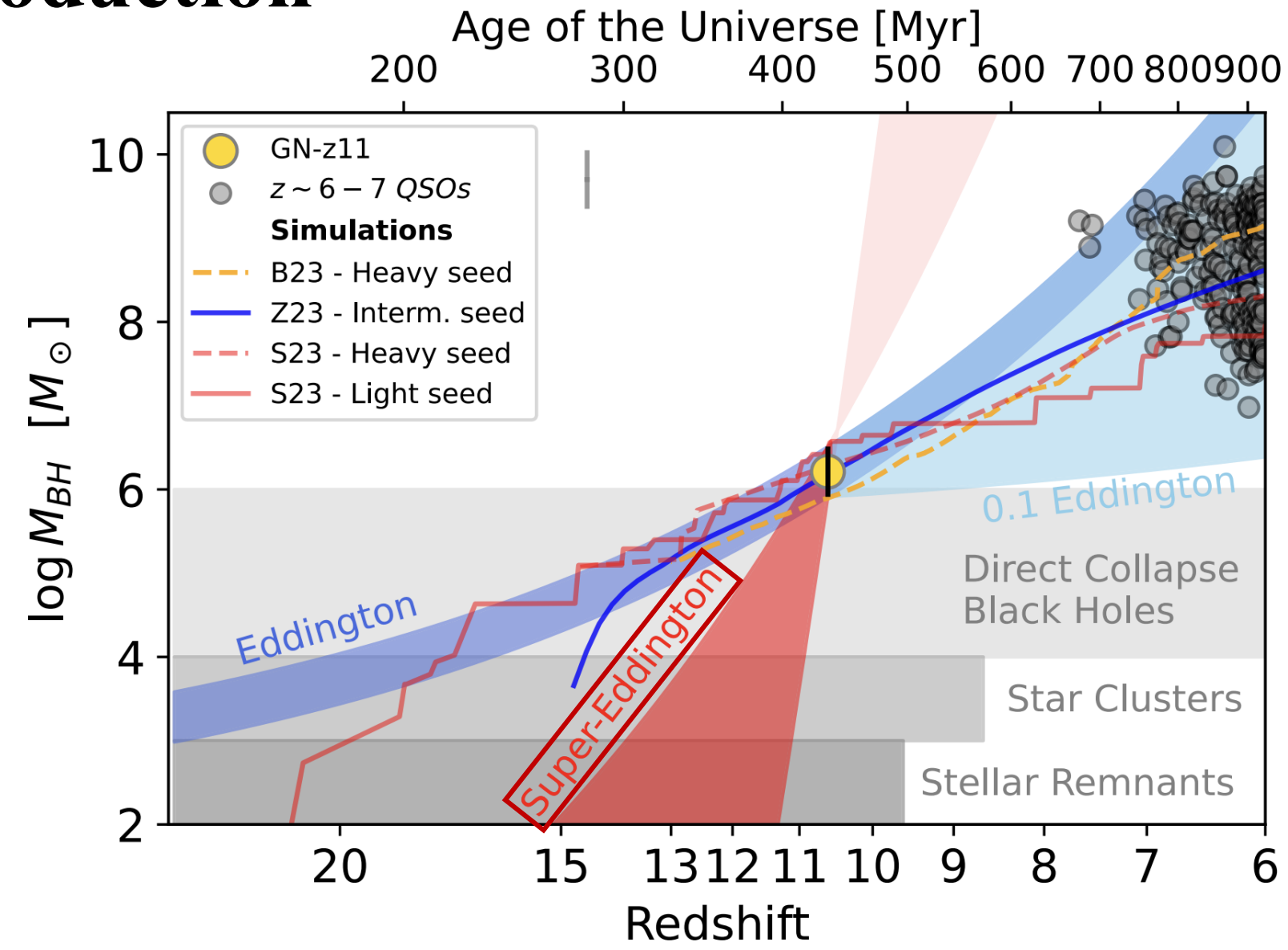
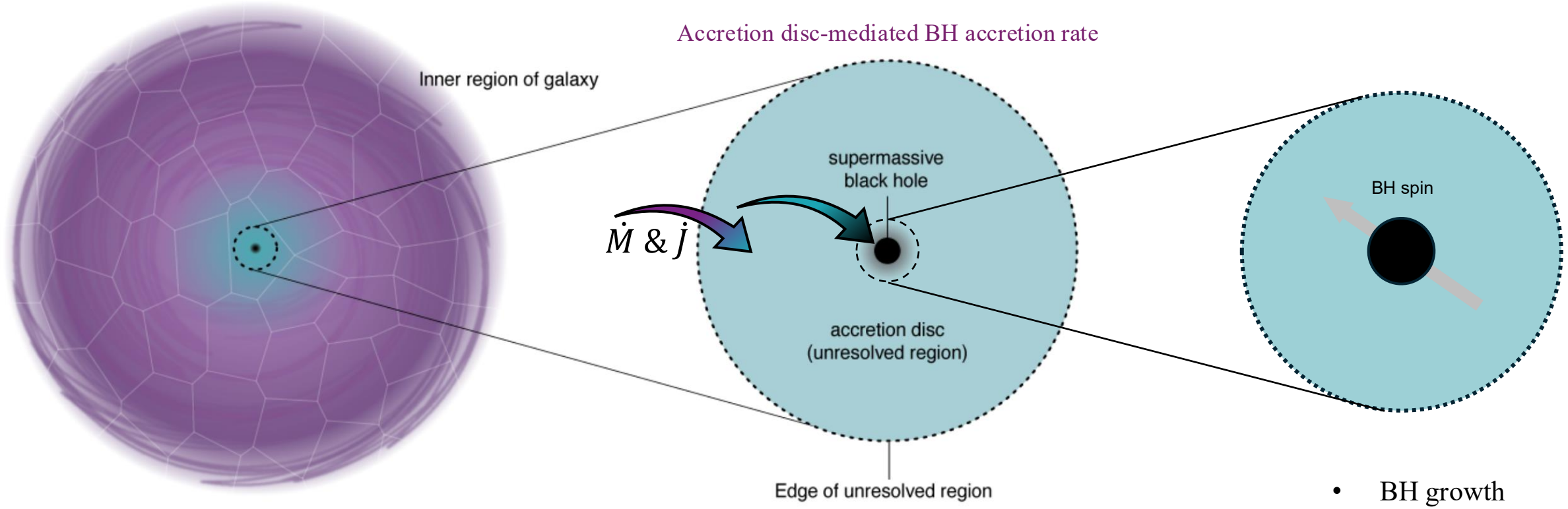
Introduction



Maiolino et al. 2024

Sub-grid model

10 orders of magnitude in spatial scale

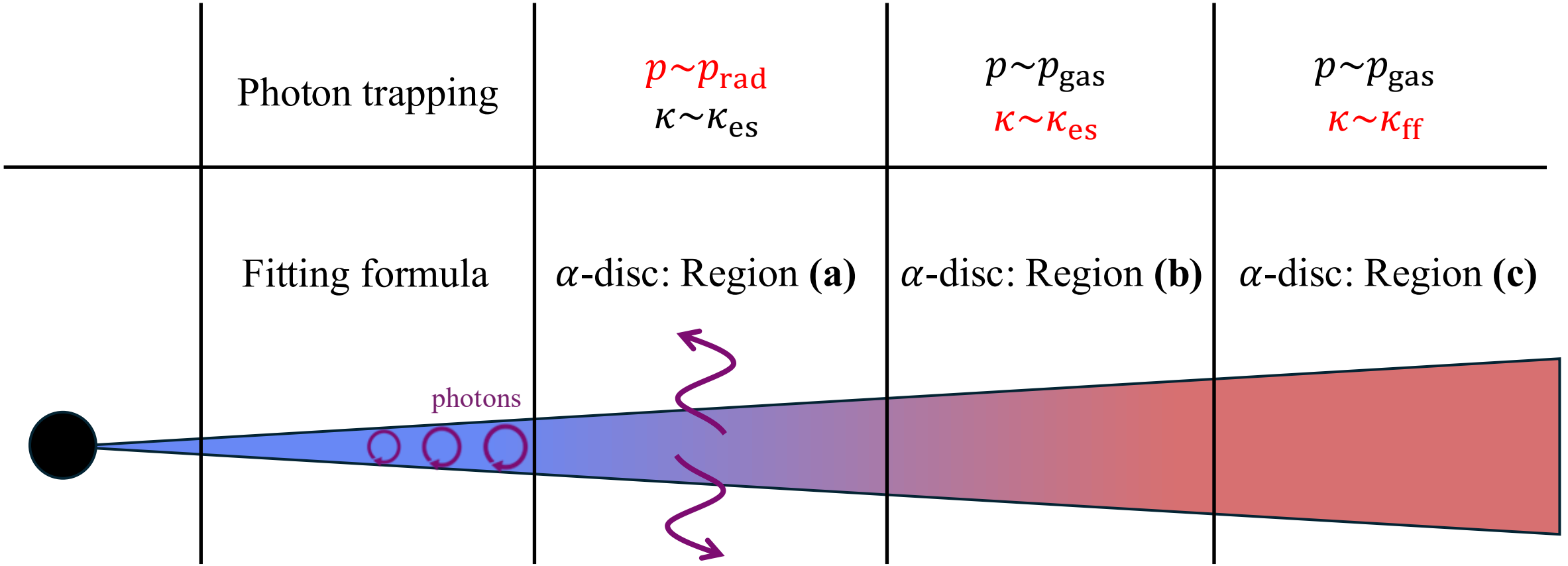


Koudmani et al. 2023

BH spin influences:

- BH growth
- Feedback
- Jets

Accretion disc structure

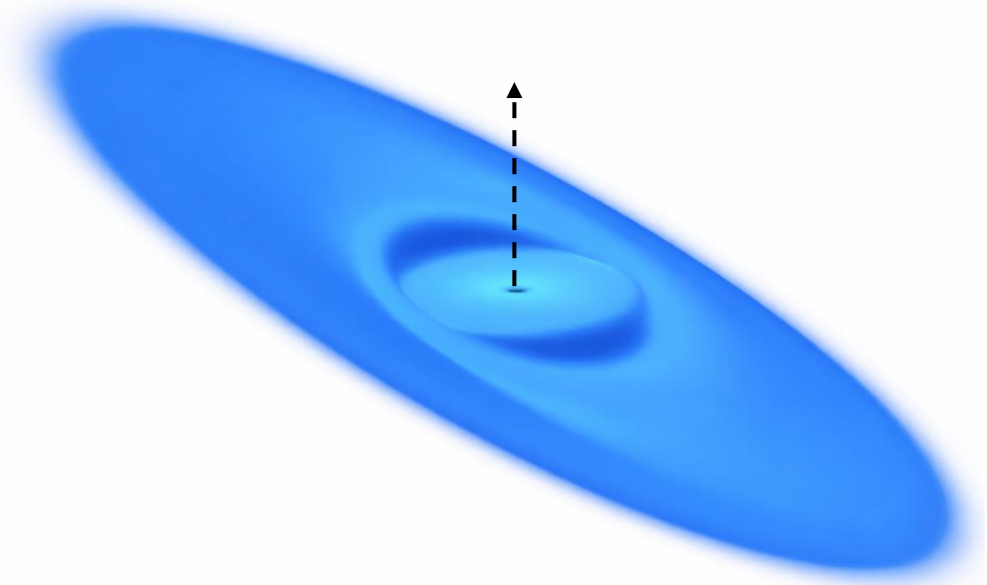
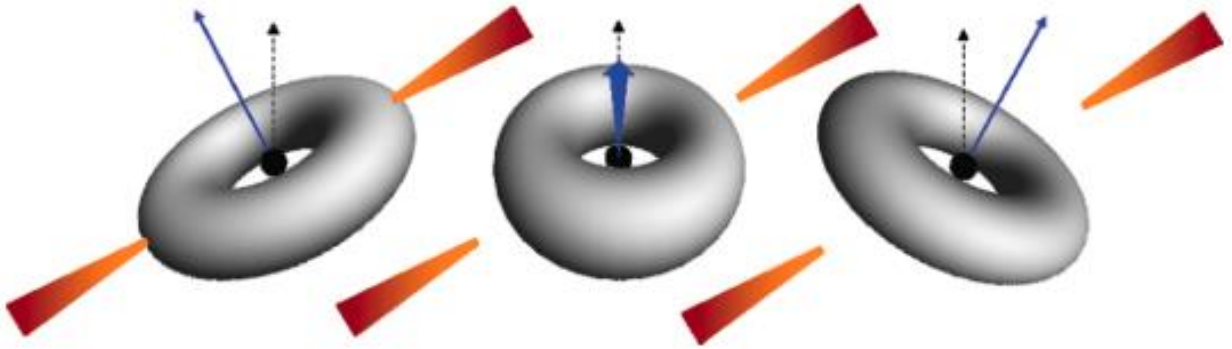


RHD simulations
(Kitaki et al. 2018)

Analytic solution (Kato et al. 2008; Shakura & Sunyaev 1973)

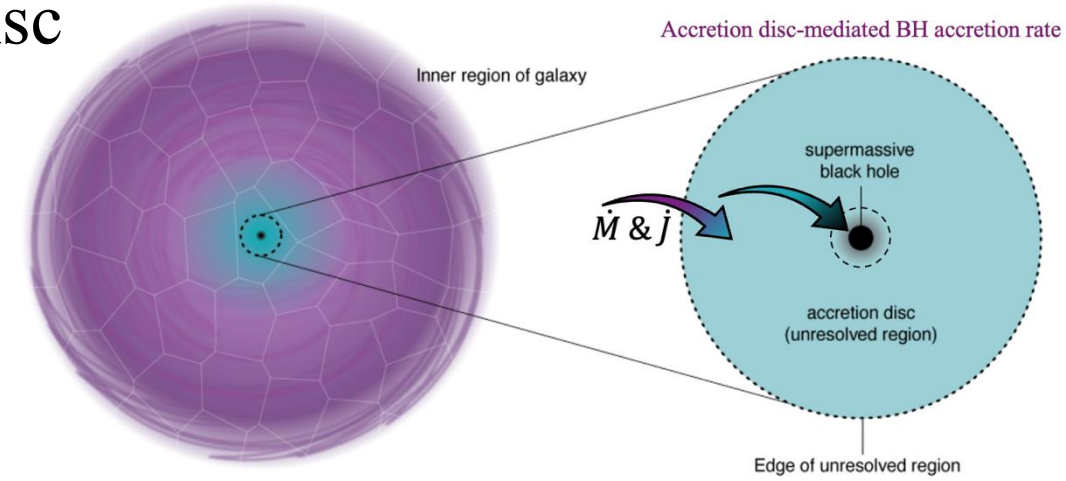
BH spin evolution (Lense-Thirring effect)

$\hat{f}_{\mathrm{Edd},16} \sim 1$

Low accretion rate	High accretion rate
	
Nealon et al. 2015	Ingrams et al. 2009

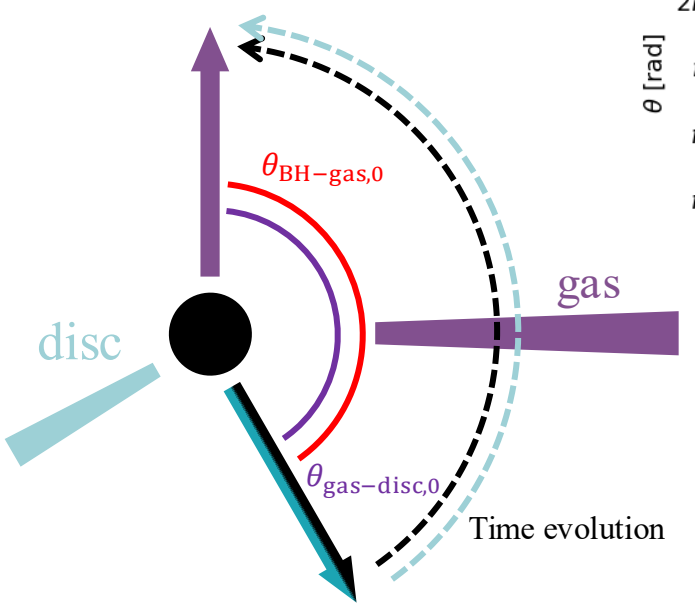
Simulation with GIZMO

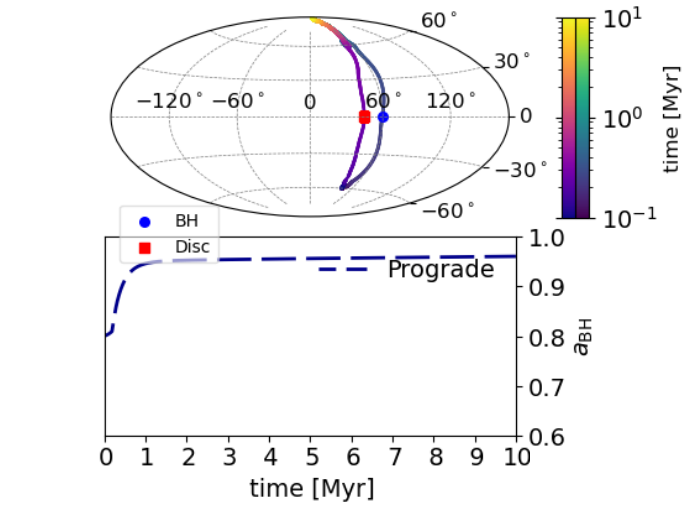
- Single BH particle (sub-resolution **BH + accretion disc** system)
  - Surrounded by a stellar spherical structure and a dense gaseous circumnuclear disc
- **No feedback**
- Self-gravity limit: $M_{\rm disc} \leq M_{\rm sg}$ and $J_{\rm disc} \leq J_{\rm sg}$
- Inflow from resolved gas onto accretion disc
  - $\dot{M}_{\rm in}$: Bondi accretion rates
  - $\dot{J}_{\rm in}$: Assume gas circularises at $R_{\rm circ}$

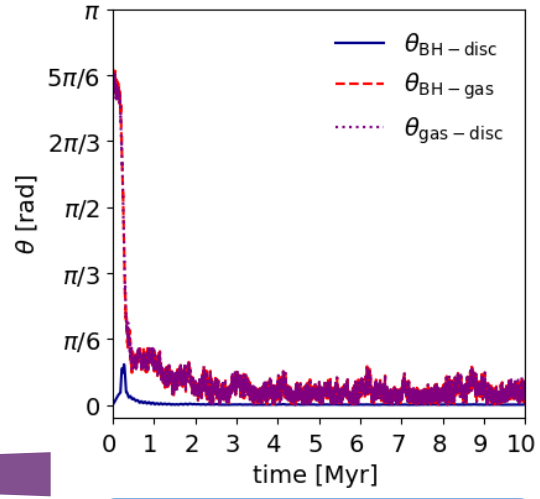


Results

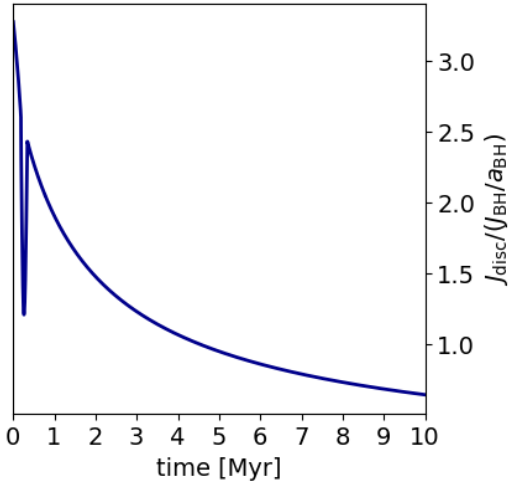
BH-disc alignment IC



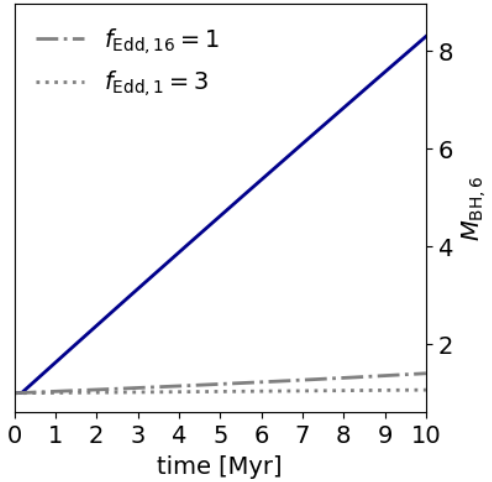




Misaligned gas inflow



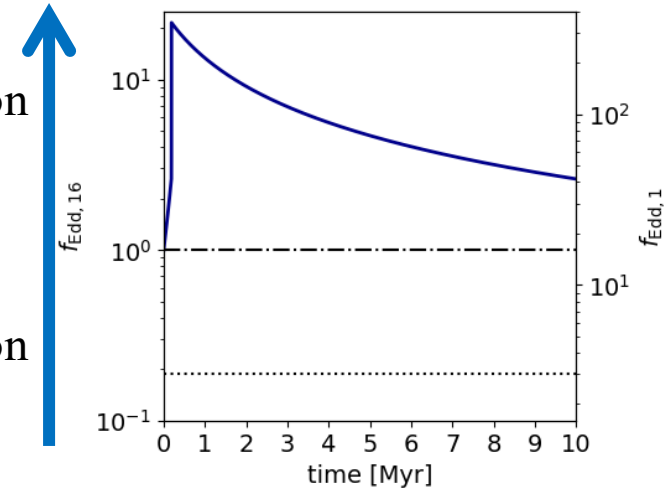
Angular momentum cancellation



Super-Eddington growth

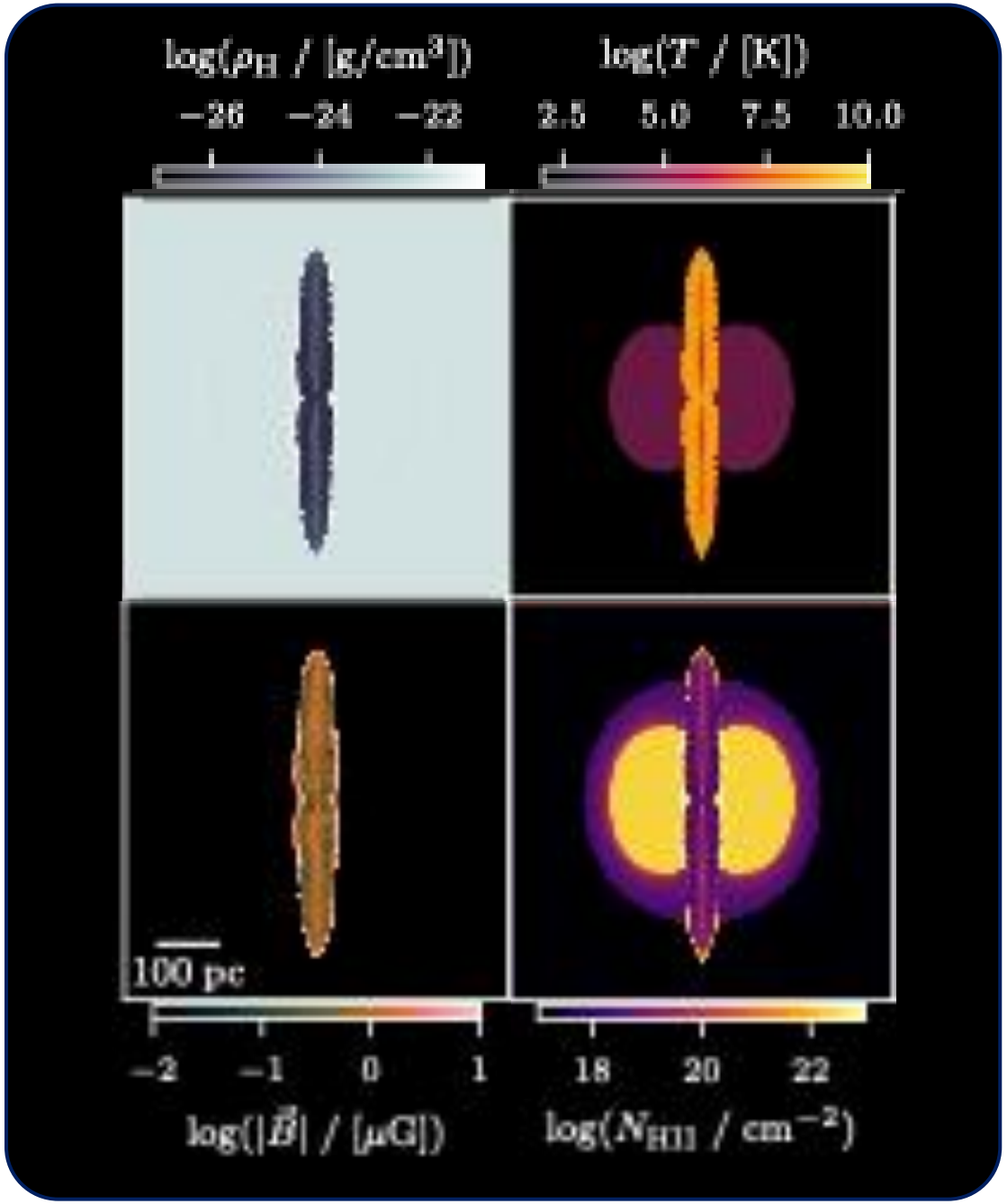
Super-Eddington

Sub-Eddington



Future work

Simulations with mini-RAMSES including the DRAGON feedback model (Choustikov et al. in prep.)



Conclusions

- Sub-grid model for SMBH evolution that allows **super-Eddington accretion** with self-consistent evolution of BH mass and spin.
  - Accretion disc structure: Photon trapping region + α-disc
  - Lense-Thirring torque
- Need efficient **removal of disc angular momentum** to reach super-Eddington
  - Most efficient through misaligned gas inflow
- New inflows of gas with **varying angular momentum direction** might trigger episodic super-Eddington accretion
  - More common in **early Universe**. Might explain the rapid growth of BH.

See Kao et al., 2026, MNRAS, 546, 33 (arXiv:2504.19281)

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Thank you