Towards planetary population syntheses in MHD wind-driven discs

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UNIVERSITÄT BERN

THEORETICAL ASTROPHYSICS AND PLANETARY SCIENCE
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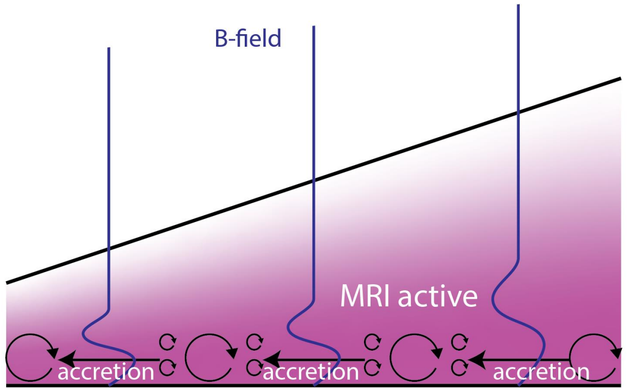
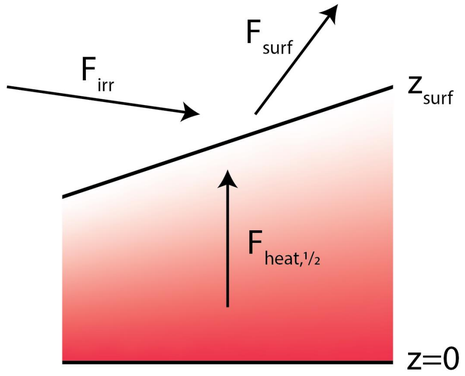
PlanetS

Introduction

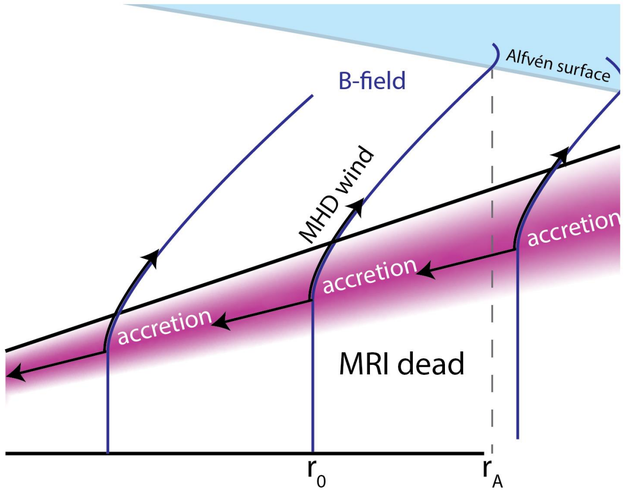
A new disc evolution scenario

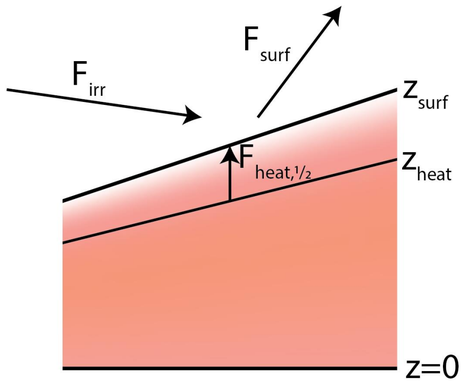
Viscous scenario





MHD wind-driven





low viscosity

low temperature

Introduction

A new disc evolution scenario

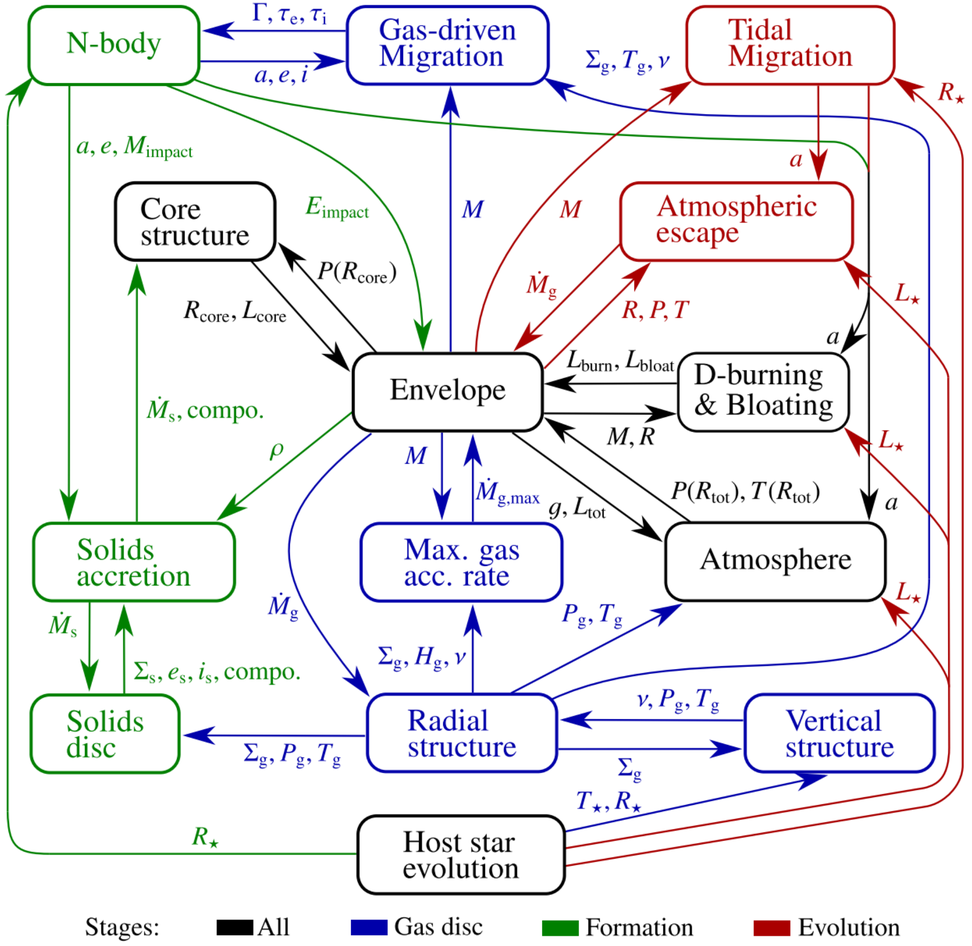


Figure from Emsenhuber et al. 2021a

Introduction

A new disc evolution scenario

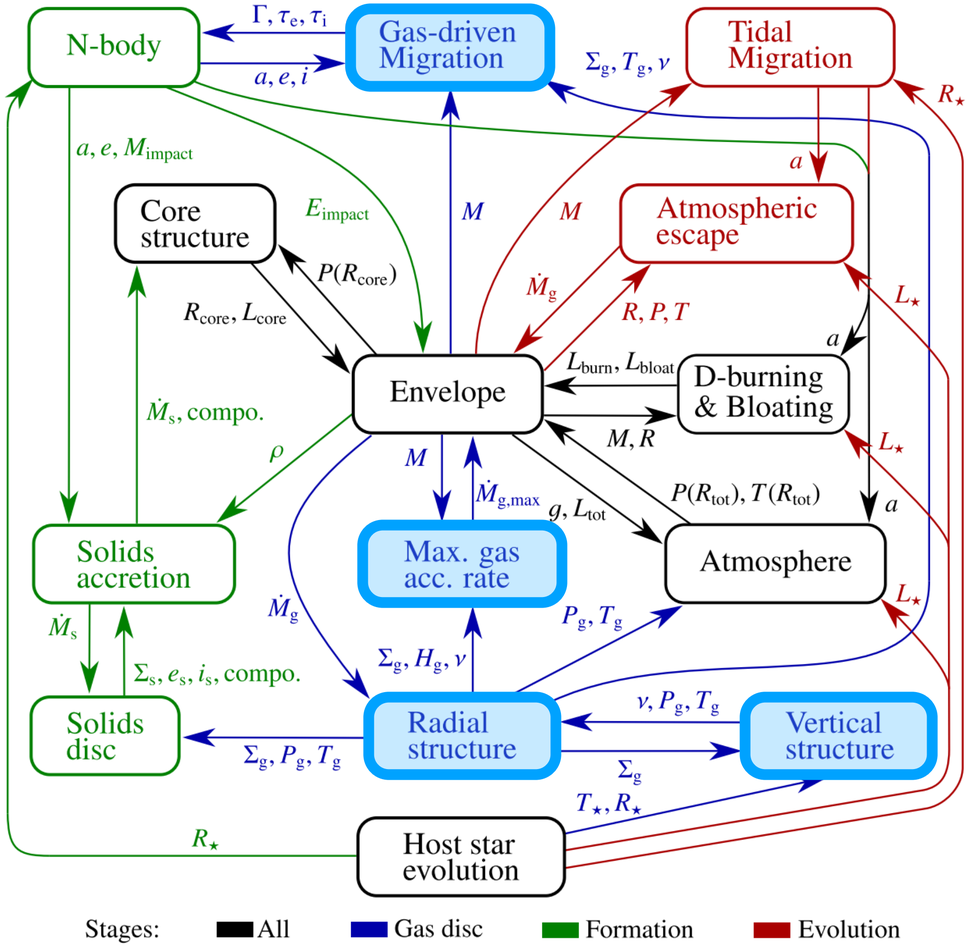
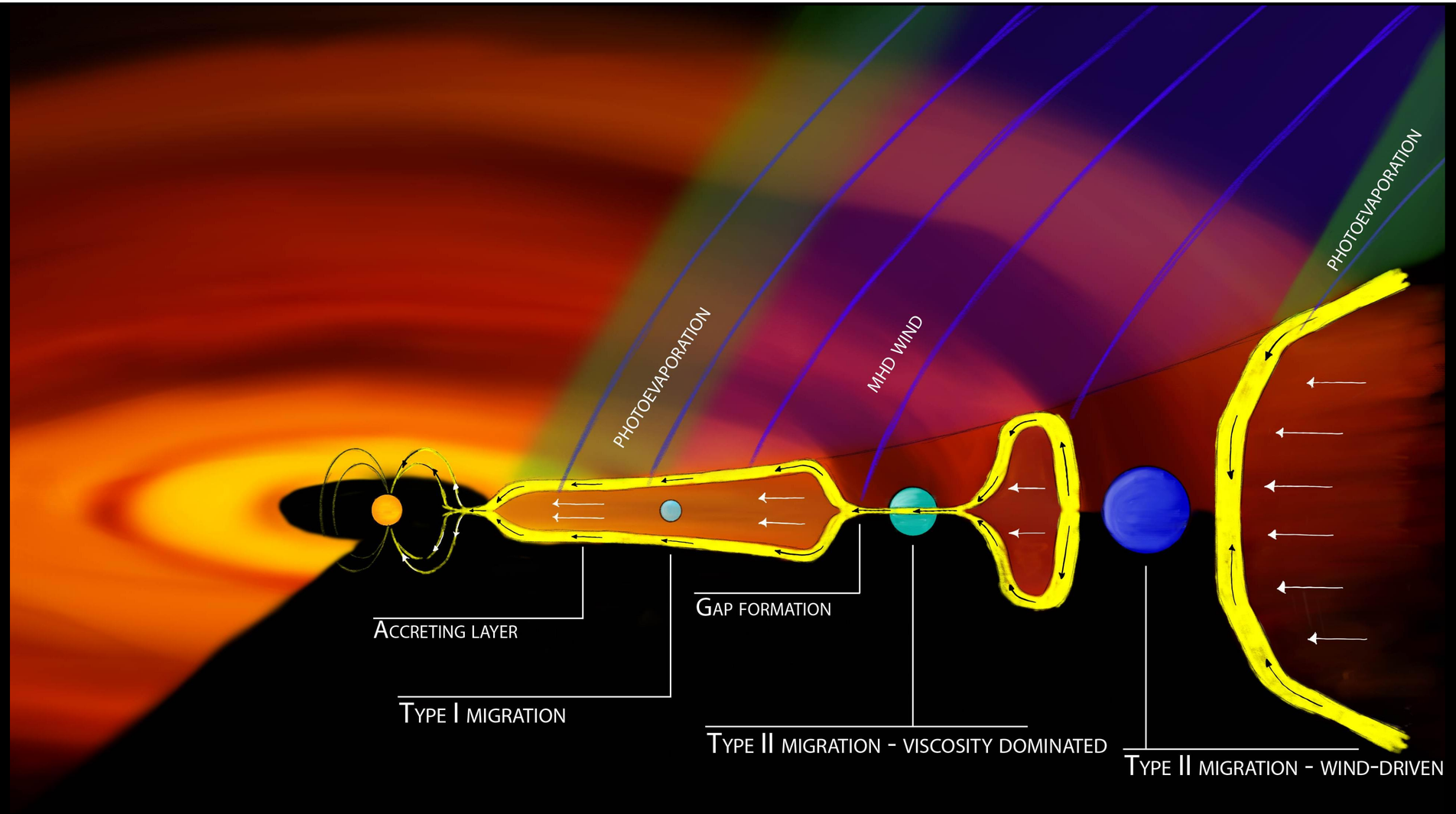


Figure from Emsenhuber et al. 2021a

Planetary migration in MHD wind-driven discs

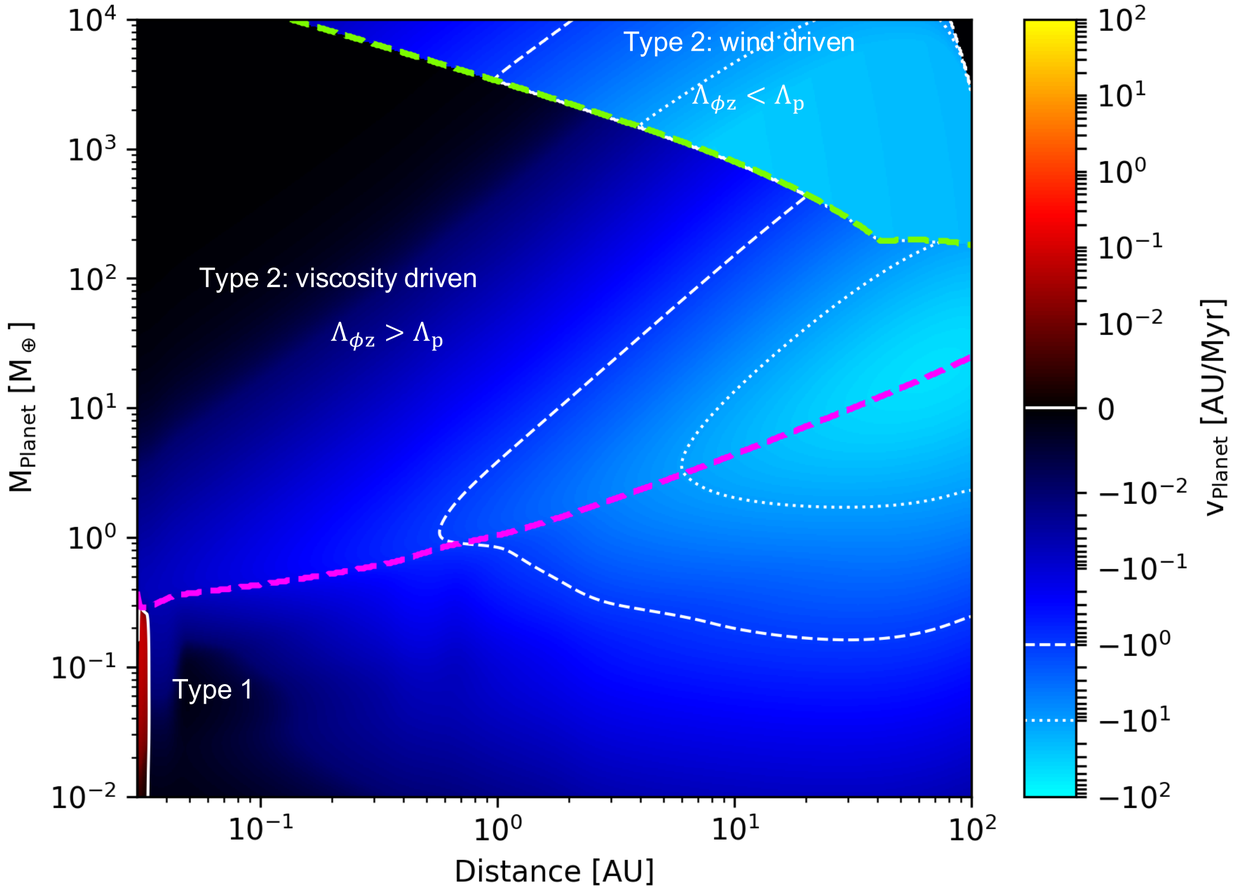
The big picture



Planetary migration in MHD wind-driven discs

Migration regimes

- **Type 2 - wind driven:** Planet blocks accretion flow and is pushed inwards. (Lega+2022, Nelson+2023)
- **Type 2 - viscosity driven:** Lindblad torque with reduced surface density. (Kanagawa+2018)
- **Gap opening:** Kanagawa+2018
- **Type 1:** Lindblad, Corotation- and dynamical corotation torque (Paardekooper+2011, Weder+2025)



Planetary migration in MHD wind-driven discs

The accretion layer thickness $\Sigma_{\rm active}$

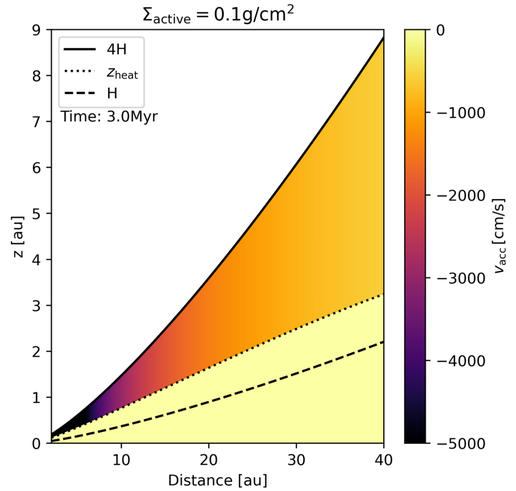
- Specific torque of the wind:

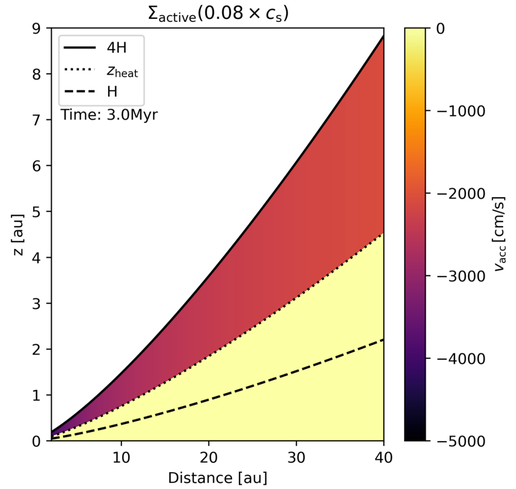
$$\Lambda_{\phi \rm z} = \frac{1}{2} r \Omega v_{\rm acc} = \frac{\Omega}{4\pi} \frac{\dot{M}_{\rm r,\phi z}}{\Sigma_{\rm active}} \quad \text{with} \quad v_{\rm acc} = \frac{\dot{M}_{\rm r,\phi z}}{2\pi r \Sigma_{\rm active}}$$

- Specific torque of the planet: $\Lambda_{\rm p}$

- Two approaches for $\Sigma_{\rm active}$:

  1. Constant layer: $\Sigma_{\rm active} = 0.1 {\rm g/cm^2}$
  2. Sonic accretion: $\Sigma_{\rm active}(0.08 \times c_{\rm s})$

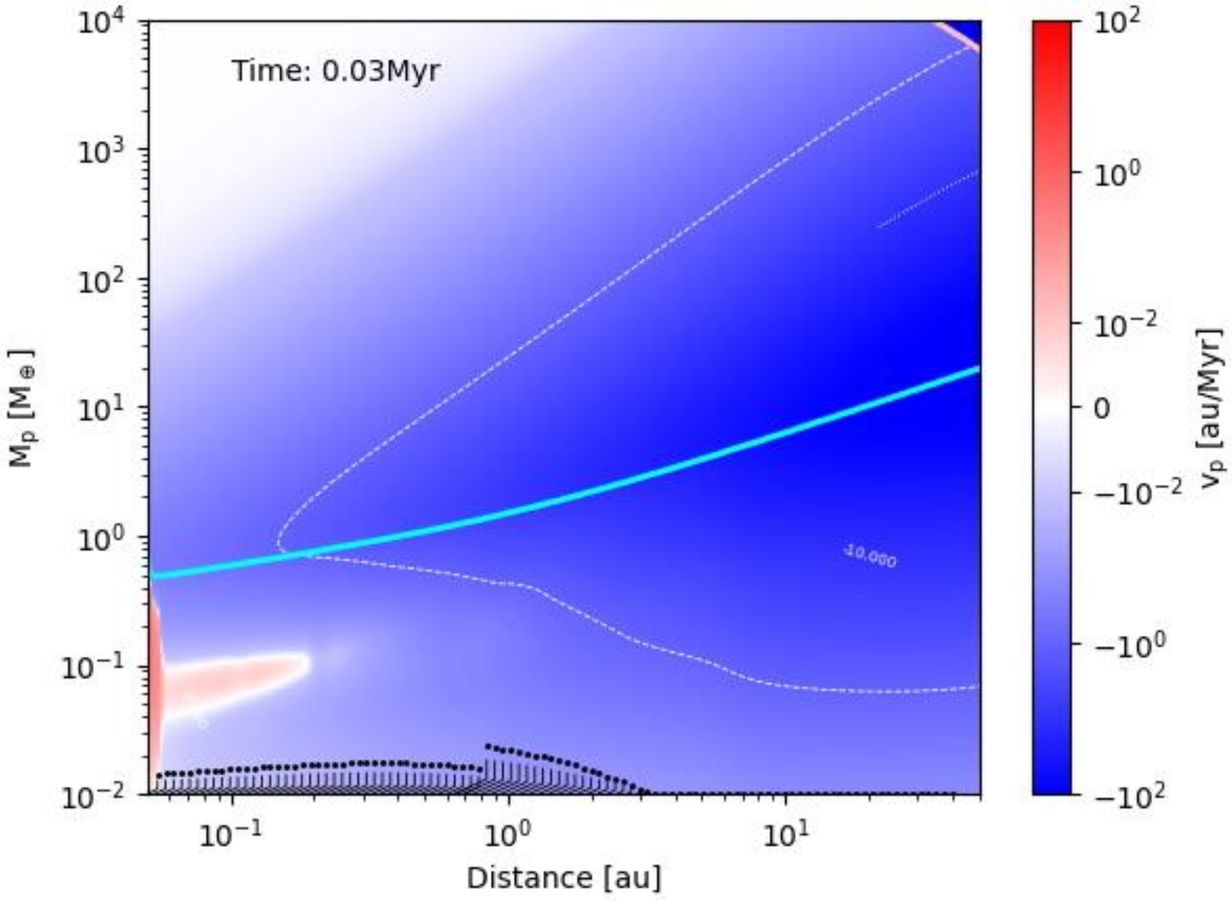




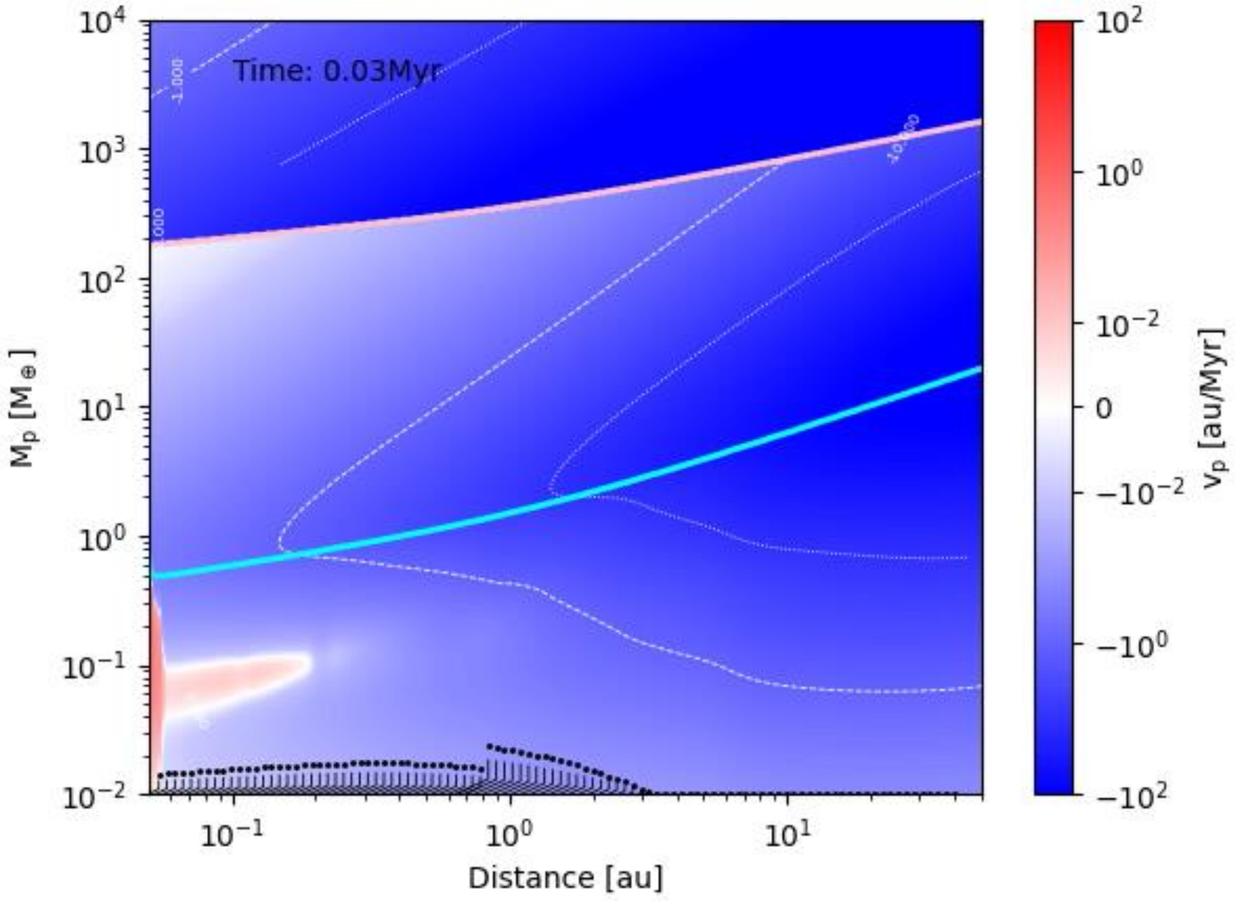
Population synthesis in MHD wind-driven discs

Single embryo simulations - the accretion layer thickness $\Sigma_{\rm active}$

$\Sigma_{\rm active} = 0.1 {\rm g/cm^2}$



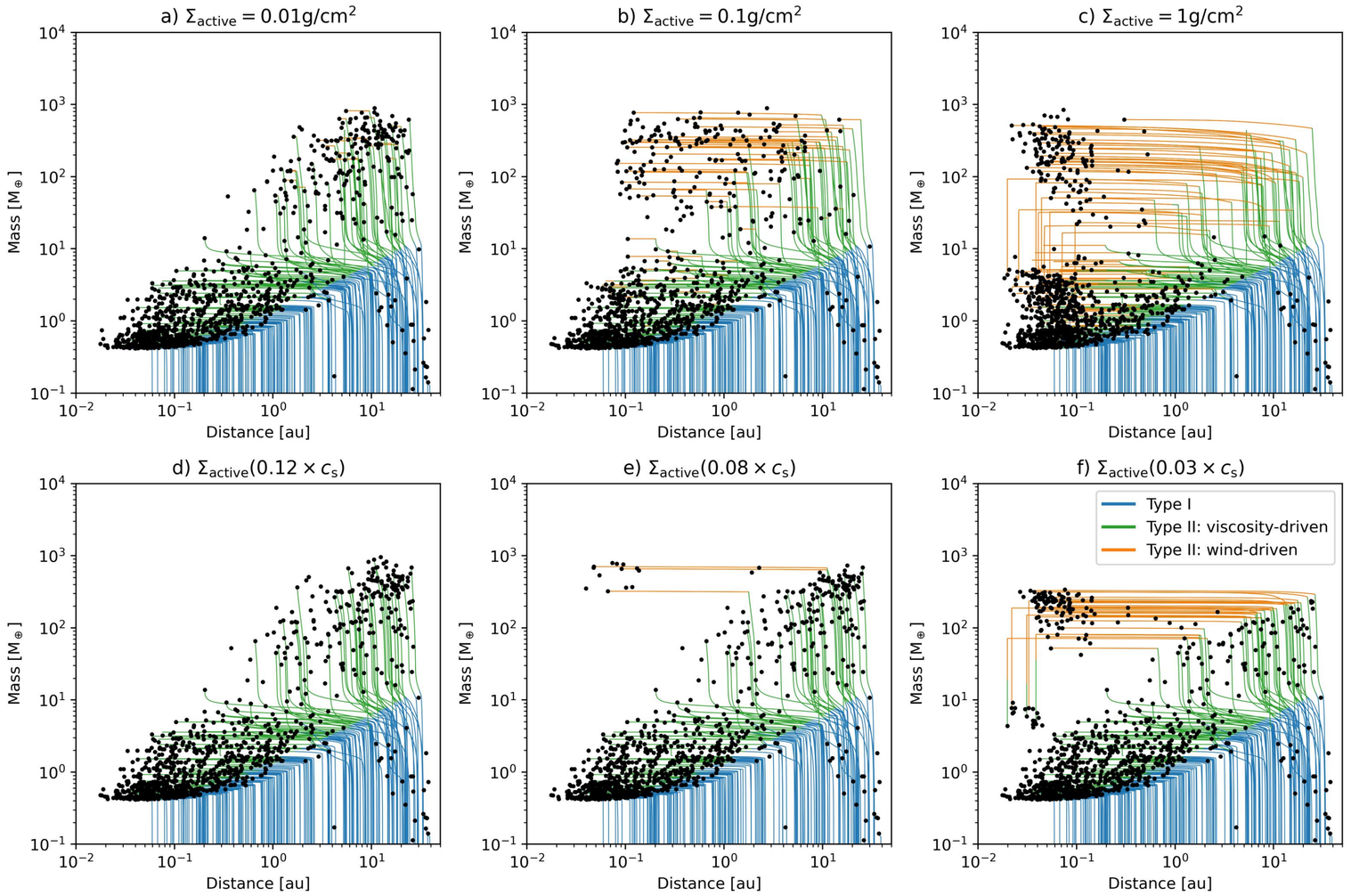
$\Sigma_{\rm active}(0.08 \times c_{\rm s})$



Population synthesis in MHD wind-driven discs

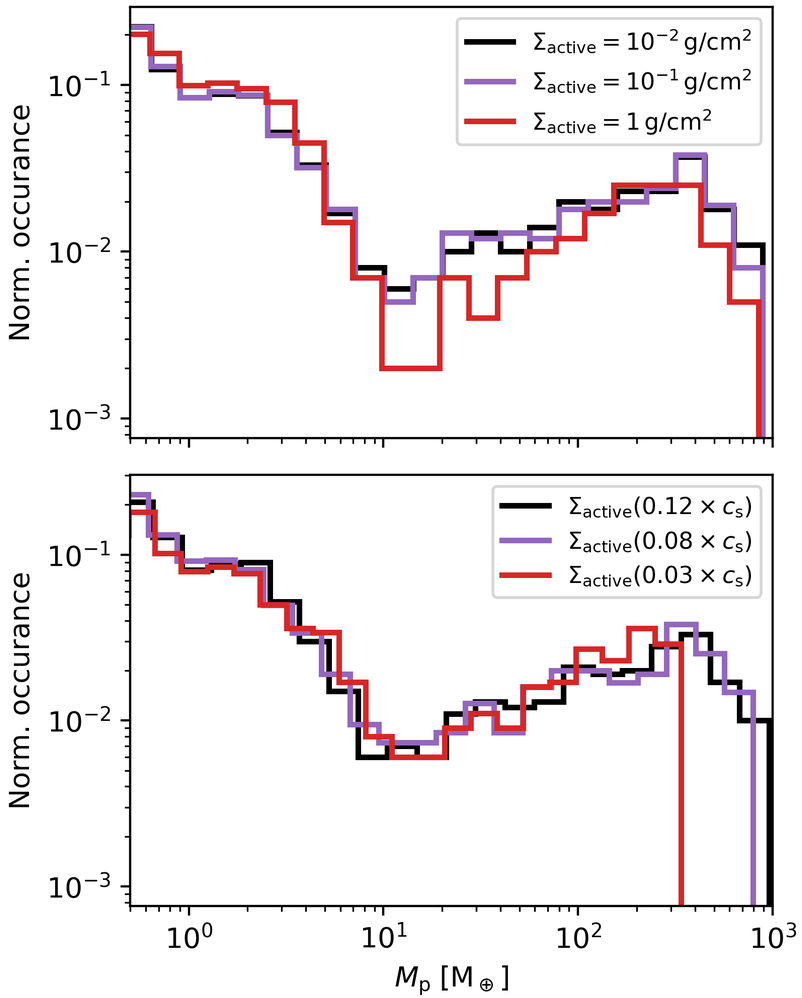
Influence of the accretion layer thickness Σ_{active}

- low $\Sigma_{\mathrm{active}} \rightarrow$ high $\Lambda_{\phi z}$
  no influence
- intermediate Σ_{active}
- high $\Sigma_{\mathrm{active}} \rightarrow$ low $\Lambda_{\phi z}$
  many close in giant planets



Population synthesis in MHD wind-driven discs

Planetary desert



- Planetary desert set by the pebble isolation mass$\sim 10 - 20 M_\oplus$
- Lower upper mass limit set by deep gap opening in low viscosity.

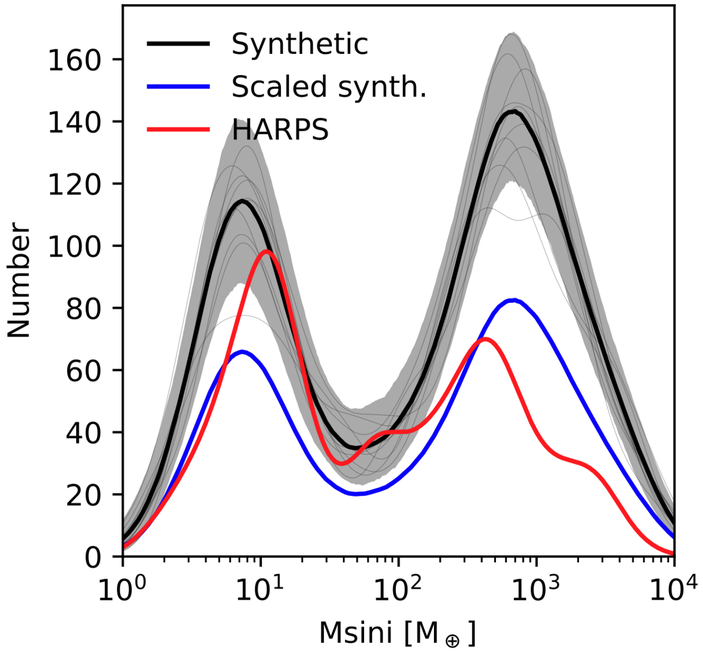


Figure from Emsenhuber et al. 2025

Take home messages

- Layered MHD wind-driven disc evolution **can reproduce observations on a basic level**.
- The **thickness of the active layer has a large impact** on the final location of giant planets.
- We see a **bifurcation in low viscosity discs** (close-in low-mass planets, far-out giant planets) → see also talk by Alex

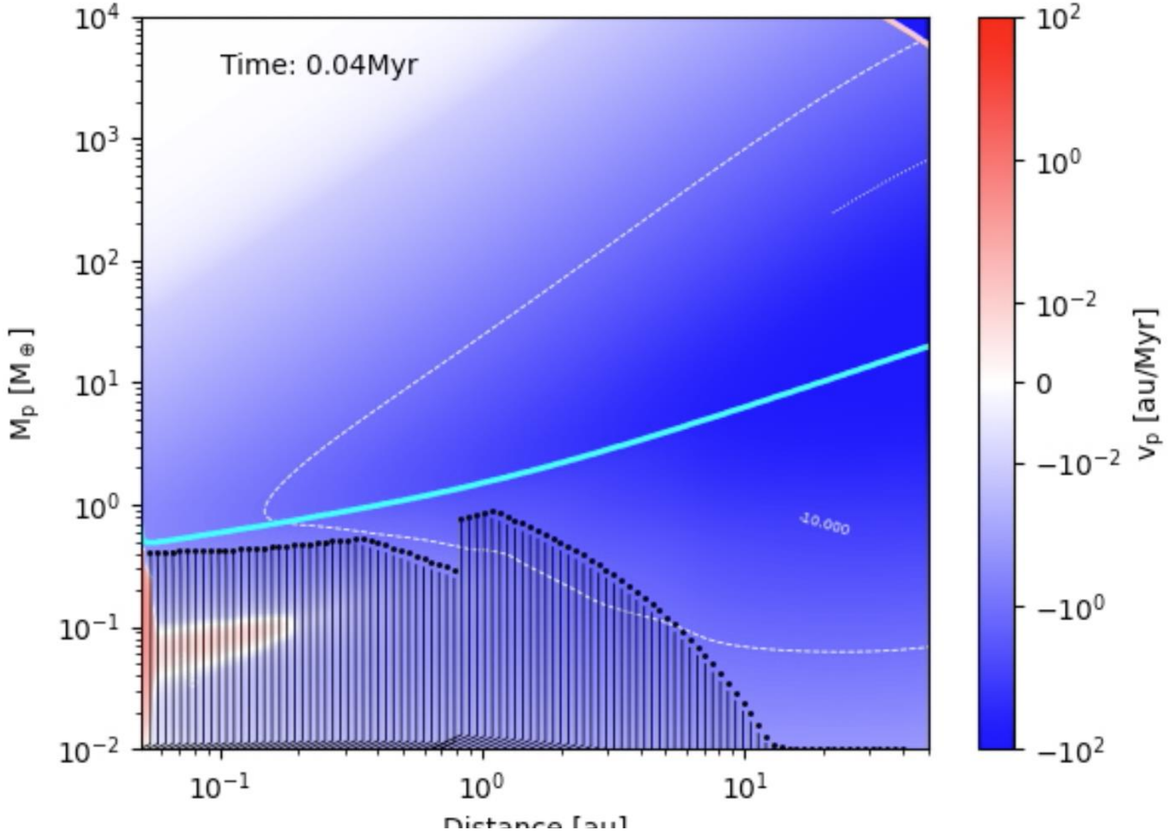
Open issues / questions

- Current **gap opening** prescription make it difficult to grow past $\gtrsim 10^3 \mathrm{M}_\oplus$, which is in contrast to observations.
- Who will be my **future employer**?
- **Who** is the winner of the Ping-Pong tournament?

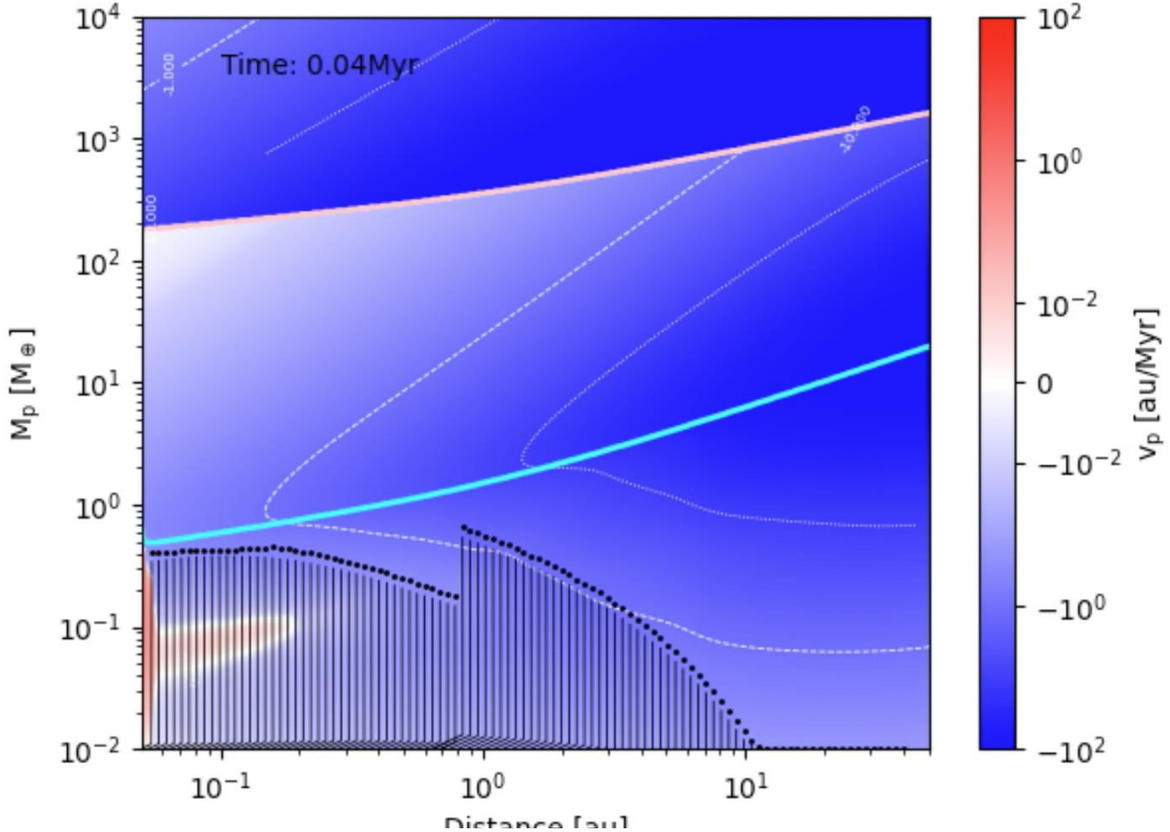
Planetary migration in MHD wind-driven discs

The accretion layer thickness $\Sigma_{\rm active}$

$\Sigma_{\rm active} = 0.1\ {\rm g/cm^2}$



$\Sigma_{\rm active}(0.08 \times c_{\rm s})$



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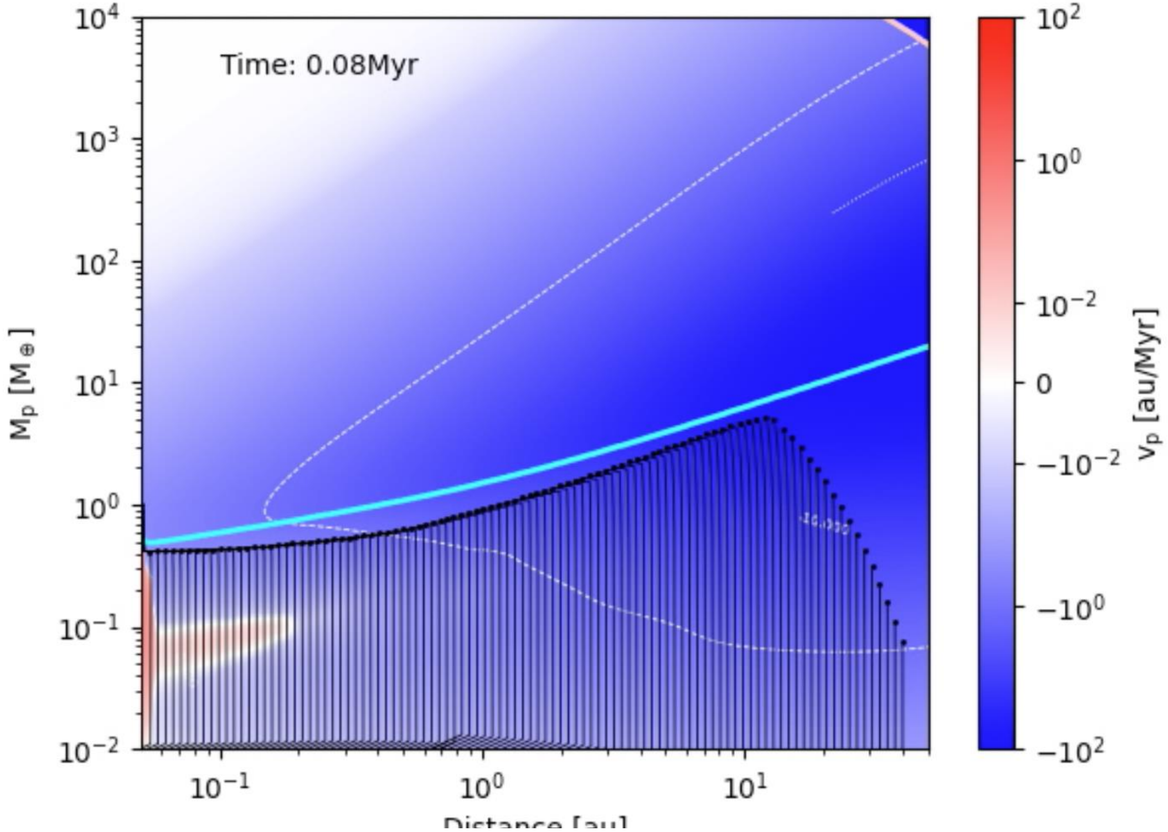

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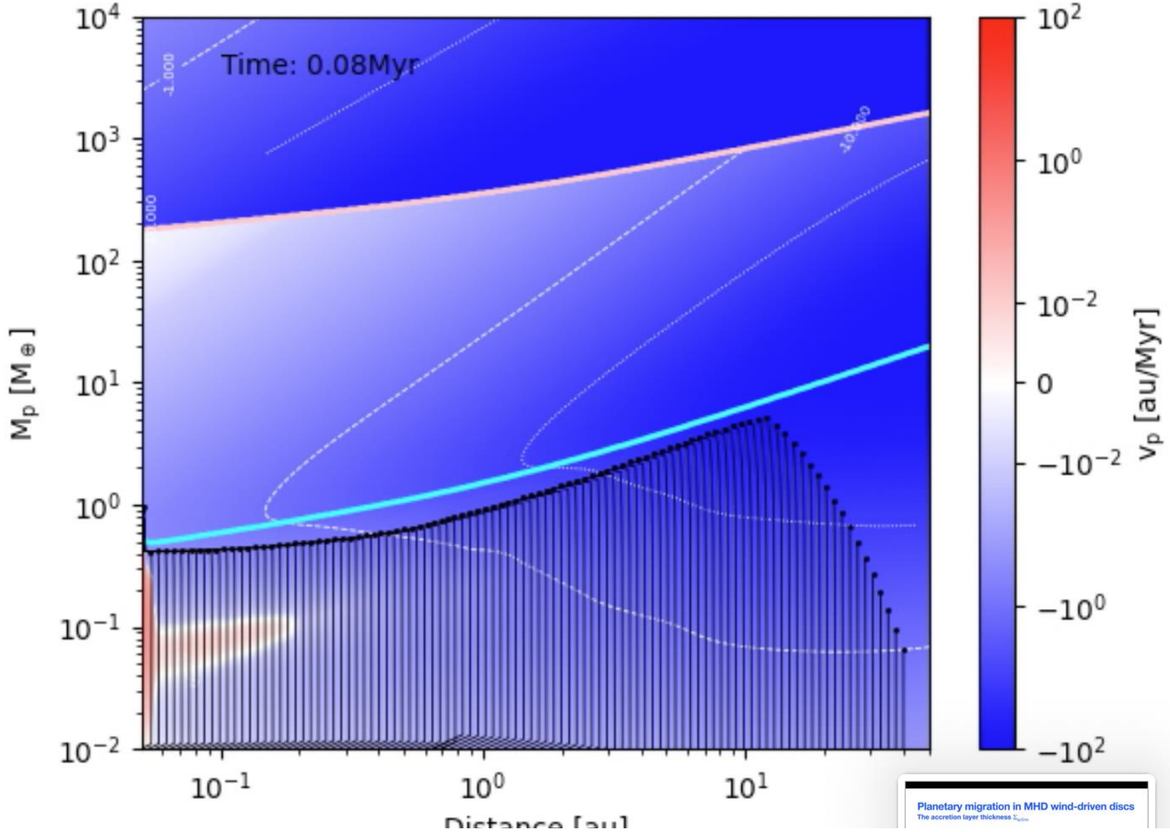

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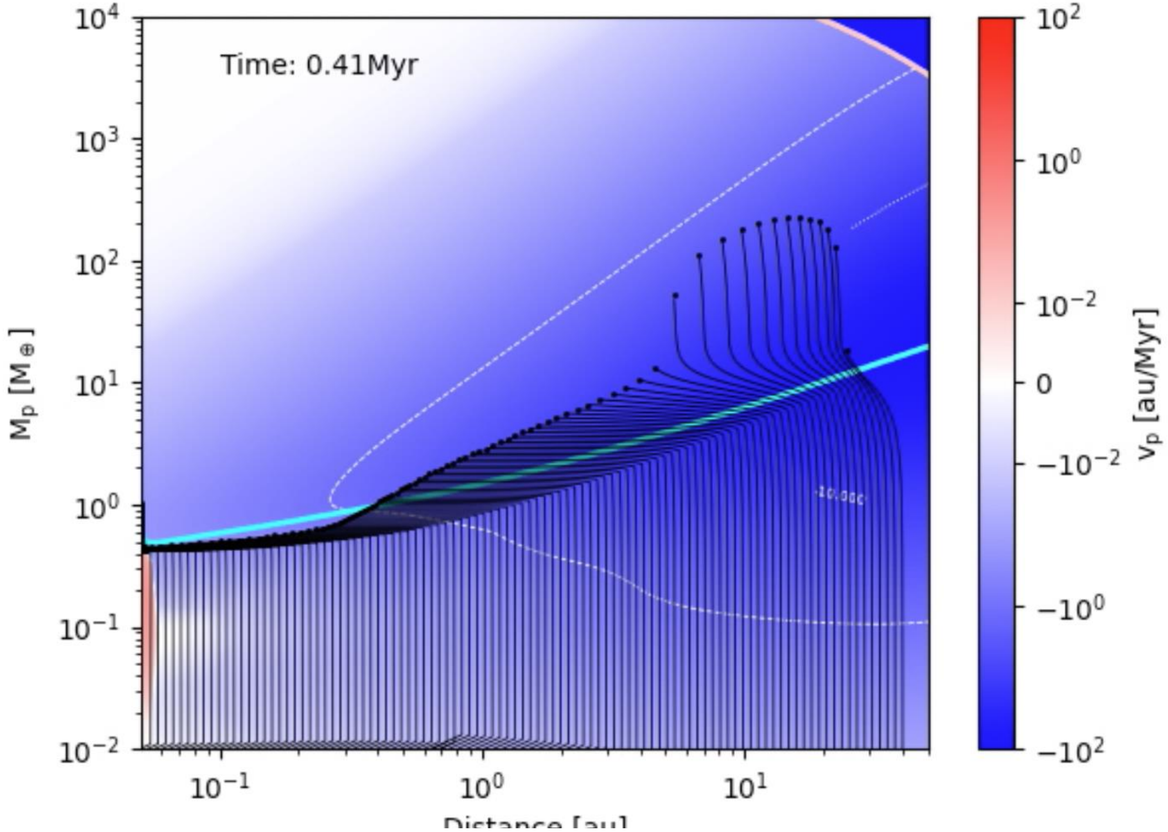

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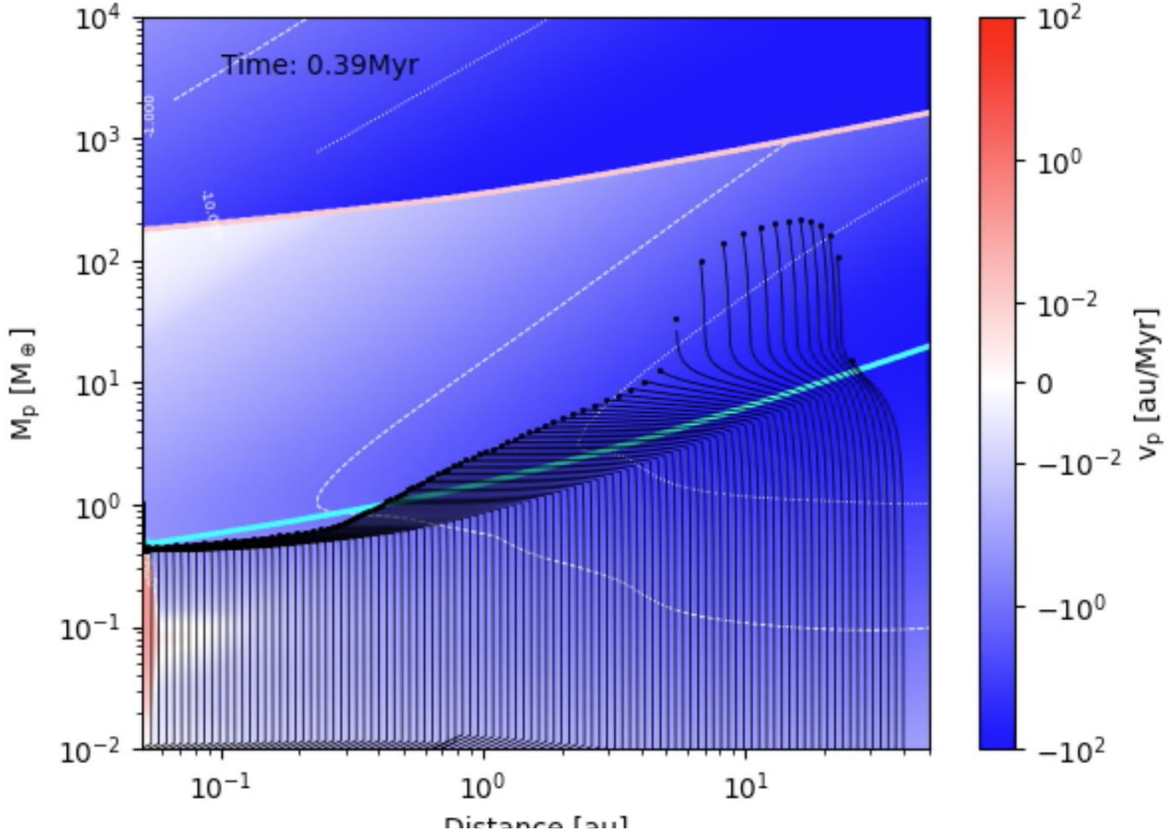

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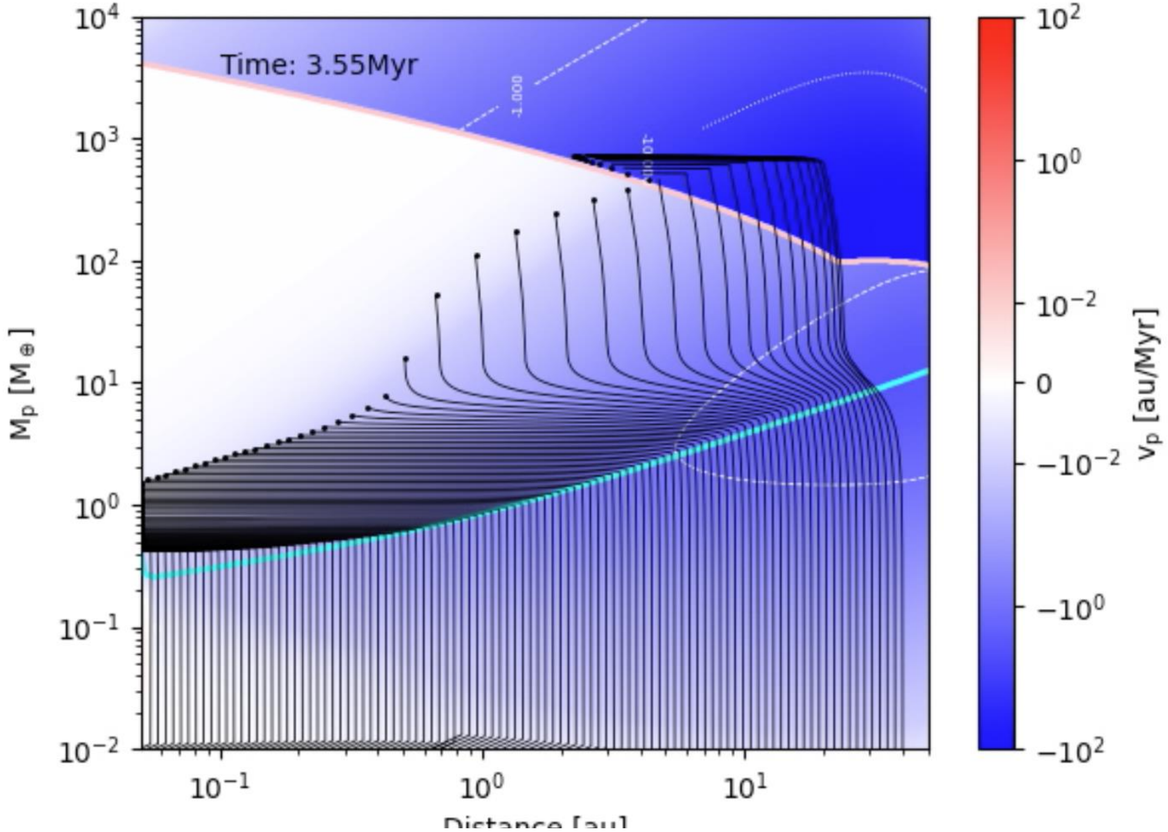

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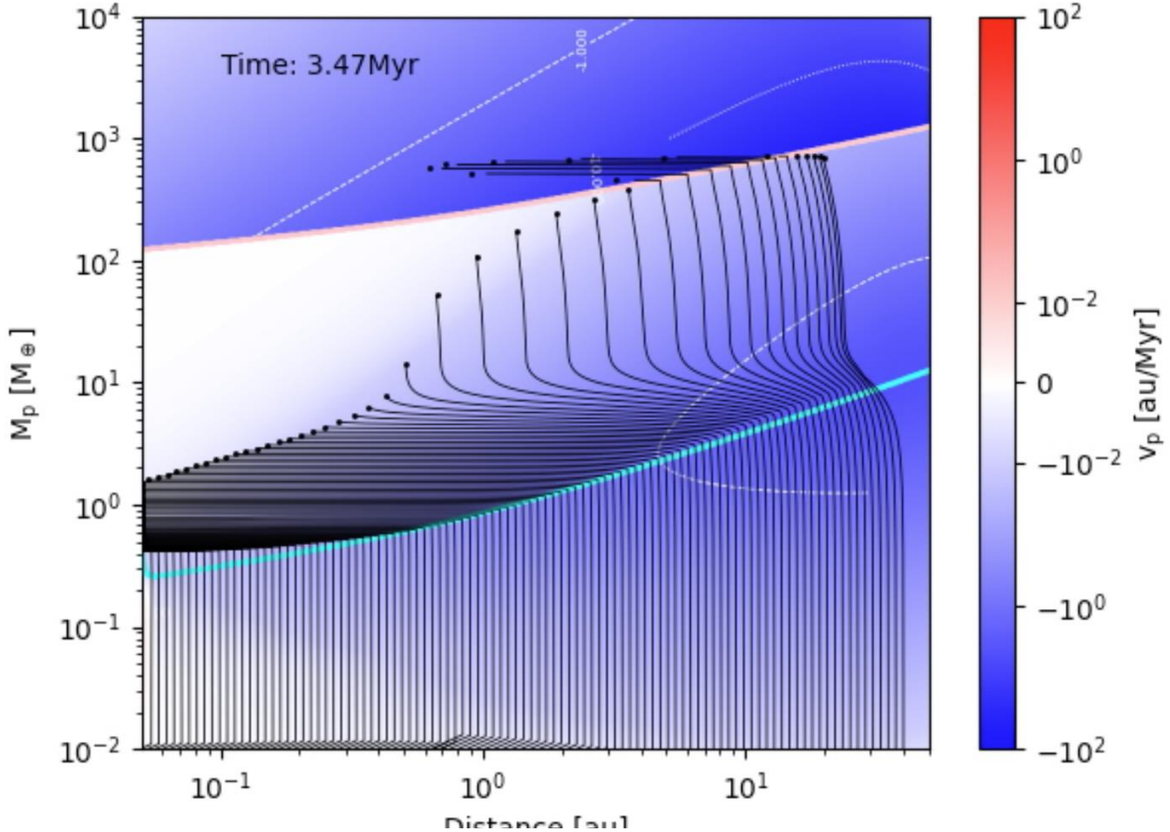

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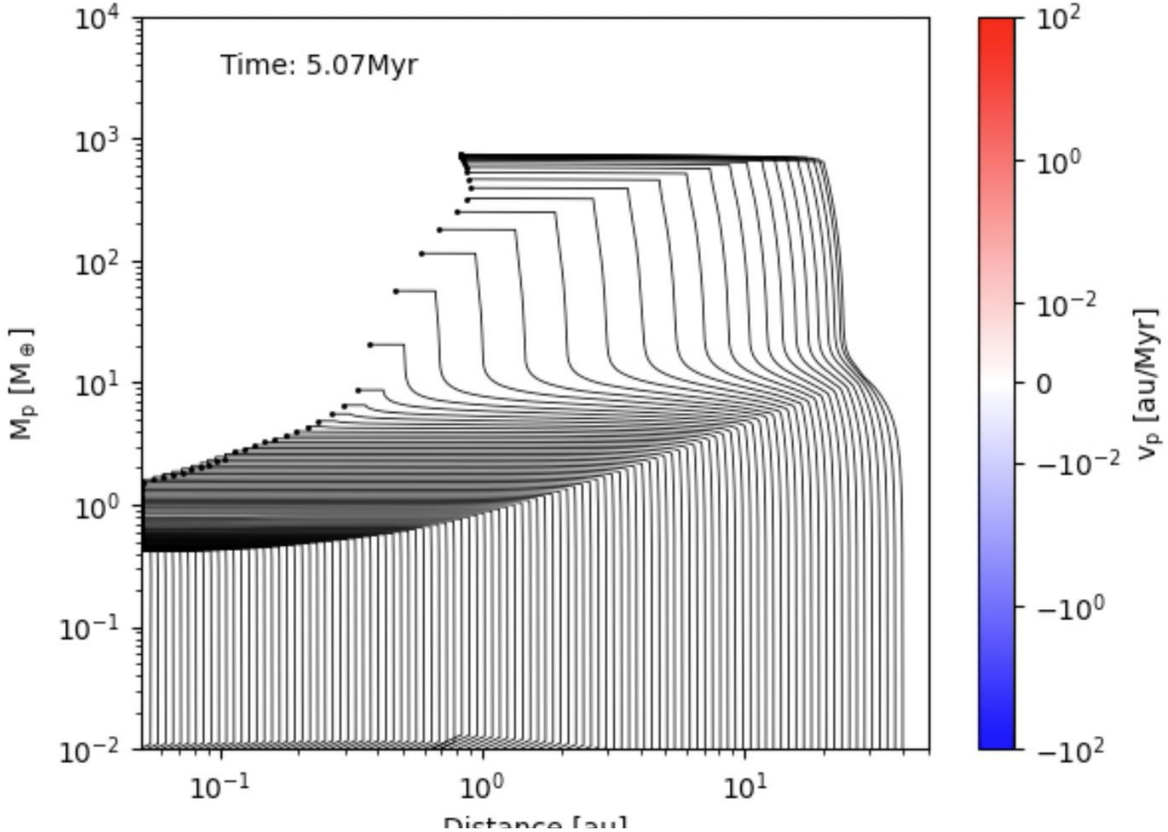

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