Towards Planetary Population Syntheses in MHD Wind-Driven Discs

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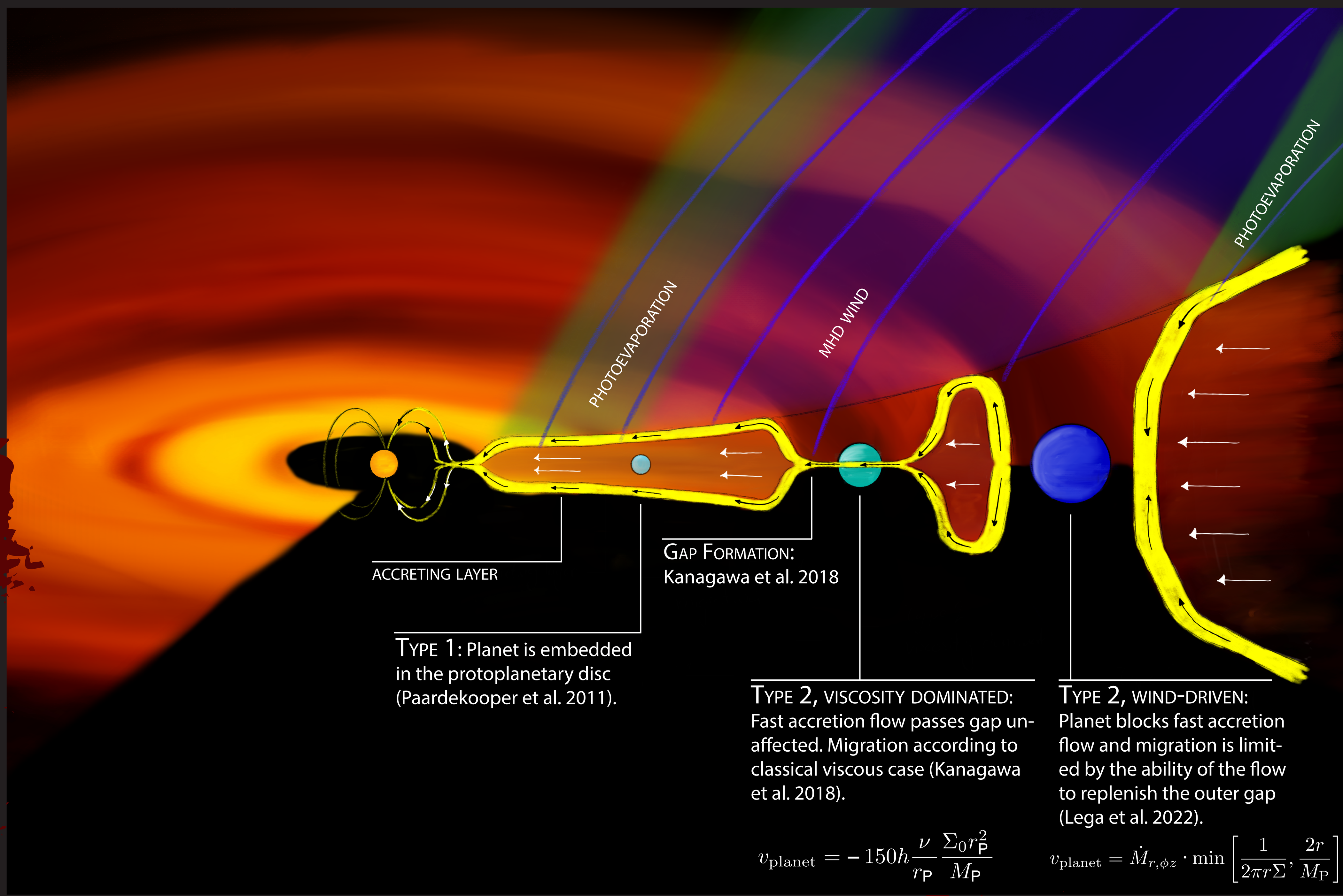
CONTEXT: MHD wind-driven disc evolution has gained popularity in recent years and has become a widely accepted alternative to the viscous model. We study planet migration in these wind-driven discs with the goal to move forward towards planet population syntheses in MHD wind-driven discs.



METHODS: We consider an MHD wind-driven disc with a low background viscosity (Suzuki et al. 2016) and photoevaporation. See Weder et al. 2023 for a full description.

$$\frac{\partial\Sigma}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left[\frac{3}{r\Omega}\frac{\partial}{\partial r}(r^2\Sigma\overline{\alpha_{r\phi}}c_s^2)\right] + \frac{1}{r}\frac{\partial}{\partial r}\left[\frac{2}{\Omega}r\overline{\alpha_{\phi z}}(\rho c_s^2)_{\text{mid}}\right] - \dot{\Sigma}_{\text{MDW}} - \dot{\Sigma}_{\text{PEW,int}} - \dot{\Sigma}_{\text{PEW,ext}}$$

By modelling planetary growth and migration, we obtain insights on planet migration in MHD wind-driven discs.

ACCRETION LAYER THICKNESS: Accretion velocity and accretion layer thickness are related through:

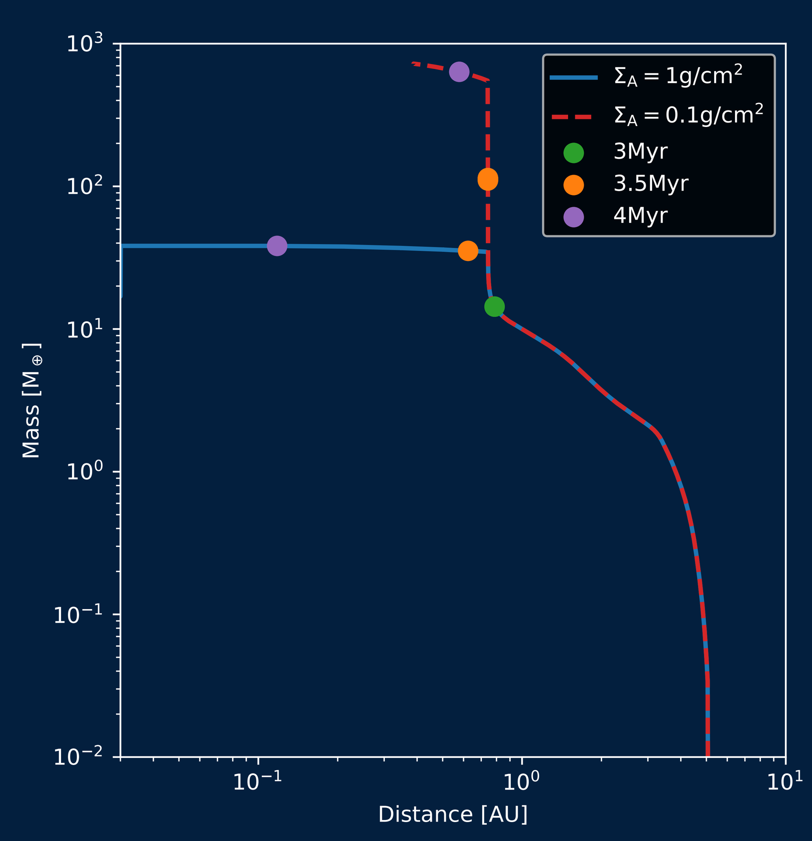
$$v_{\text{acc,A}} = \frac{\dot{M}_{r,\phi z}}{2\pi r\Sigma_A}$$

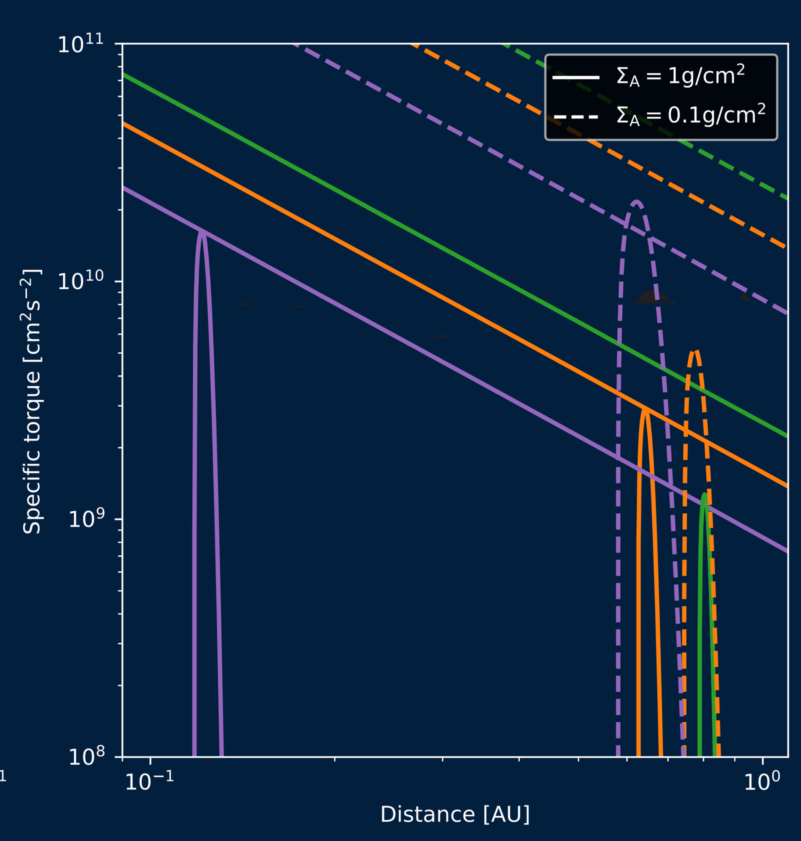
We adopt values of 1g/cm² and 0.1 g/cm² for the accretion layer thickness Σ_A. For accretion rates of several $10^{-9}M_{\text{sol}}$ per year, this corresponds to mostly subsonic accretion.

PLANETARY ACCRETION: Planetary growth is modelled by planetesimal- and gas accretion. Following findings from 3D hydrodynamical simulations by Nelson et al. (2023), gas accretion is reduced as the specific torque of the planet onto the accretion layer Λ exceeds the specific torque exerted by the magnetic field $\Gamma_{\varphi z}$.

$$\Lambda = \frac{1}{2}F(x,a,b)\Omega^2R^2q^2\left(\frac{R_p}{R_H}\right)^4 \qquad \Gamma_{\phi z} = \frac{1}{2}r\Omega v_{r,A} = \frac{1}{2}r\Omega\left(\frac{\dot{M}_{r,\phi z}}{2\pi r\Sigma_A}\right) = \Omega\frac{\dot{M}_{r,\phi z}}{4\pi\Sigma_A}$$

RESULTS: Below we show results for planetary growth and migration in a 5% solar mass disc around a solar mass star accreting at several $10^{-9}M_{\text{sol}}$ per year and with a lifetime of 4.7 Myrs. We chose the background viscosity $\alpha_{r\varphi}$ to be 10^{-4} and the disc wind torque $\alpha_{\varphi z}$ is $5\cdot10^{-4}$.





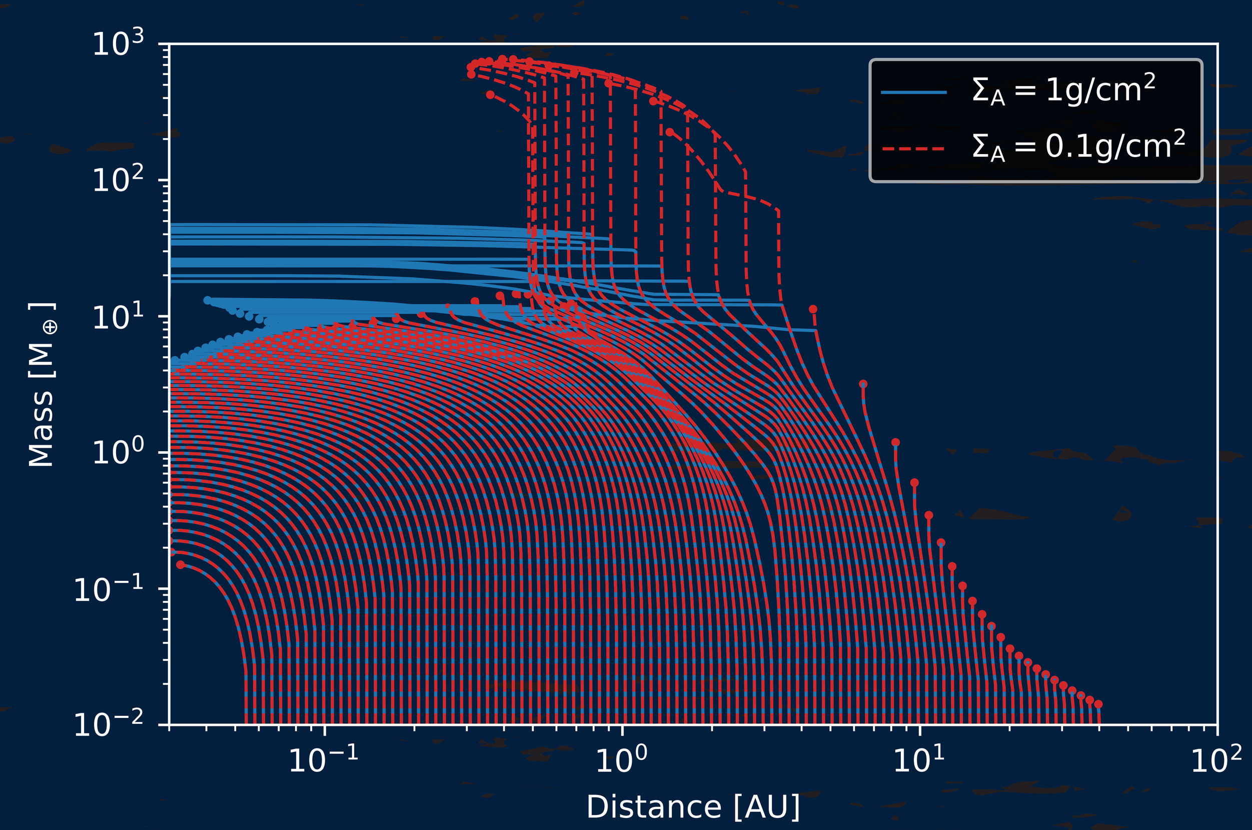
PLANET FORMATION: Comparison of planet formation tracks for accretion layer thickness of 1g/cm² and 0.1g/cm². Specific torques exerted by the magnetic field and the planet's torque onto the accreting layer are shown at 3, 3.5 and 4 Myrs.

- Planet is in the process of goint into runaway accretion. The planet does not yet block the fast accretion flow.
- While for Σ_A=1g/cm² the planet remains in runaway growth, for Σ_A=0.1g/cm² the planet enters the fast wind-driven migration and gas accretion is suppressed.
- Finally, the giant planet also enters the wind-driven migration regime.

SINGLE EMBRYO POPULATIONS: 100 simulations with 1 embryo each and varying initial location.

- Low background viscosity leads to type 1 inward migration only.
- Shortly after going into runaway migration and entering the type 2 migration regime, the planets enter the wind-driven migration regime and migrate far in.
- Type 2 migration is slow in low viscosity and planets grow to high masses after which they eventually enter the fast wind-driven migration.

This shows the importance of moving forward in understanding planet formation in MHD wind-driven discs on a populational level.



Swiss National Science Foundation

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ACKNOWLEDGEMENTS: This work has been carried out within the framework of the National Centre of Competence in Research PlanetS supported by the Swiss National Science Foundation (SNSF) under grants 51NF40_182901 and 51NF40_205606. The authors acknowledge the financial support of the SNSF. J.W. and C.M. acknowledge the support from the SNSF under grant 200021_204847 "PlanetsInTime".

REFERENCES:
Kanagawa, K.D., Tanaka, H., Szuszkiewicz, E., 2018, ApJ., 861:140
Lega, E., Morbidelli, A., Nelson, R.P., et al. 2022, A&A, 658, A32
Nelson, R. P., Lega, E., & Morbidelli, A. 2023, A&A, 670, A113
Paardekooper, S.-J., Baruteau, C., & Kley, W. 2011, MNRAS, 410, 293
Suzuki, T. K., Ogihara, M., Morbidelli, A., Crida, A., & Guillot, T. 2016, A&A, 596, A74
Weder J., Mordasini C., Emsenhuber A., 2023, A&A, 674, A165