Giant Planet Formation and Migration in Protoplanetary Disks Evolving under Viscous Accretion and Magnetically Driven Winds

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FIKUT NEXTGEN

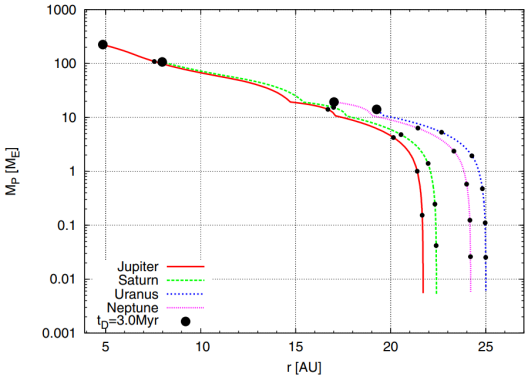
November 6, 2026

Motivation

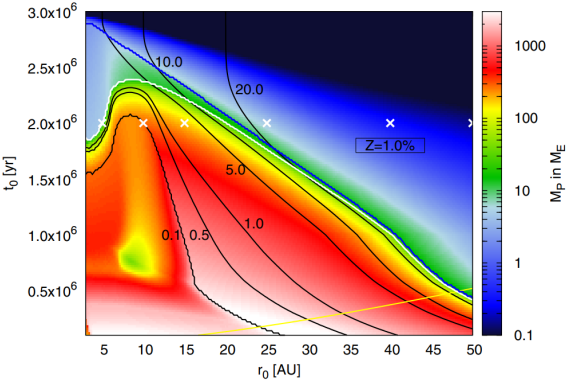
- In purely viscous protoplanetary disks, giant planets may undergo rapid inward migration, potentially preventing their survival on million-year timescales.
- Investigate whether magnetically driven disk winds can slow planetary migration and allow giant planets to remain on stable orbits over longer timescales.
- Examine how magnetically driven disk winds influence the migration rates, growth, and final masses of giant planets.

Previous studies

- Planet formation in a purely viscous disk are studied regularly.

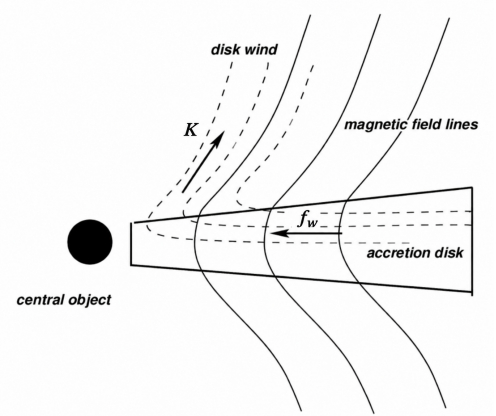


from Bitsch+ (2015)



from Bitsch+ (2015)

Viscous Evolution: Classical MRI and Disk Winds



from Sheikhnezami+ (2018)

- f_w: Fraction of accretion driven by magnetic torques.
- K: Parameter controlling mass loss through magnetically driven disk winds.

Four Disk Models

Disk model	f_w	K
Viscous	0	0
Fast wind	0.8	0
Slow wind	0.8	1
Laminar	0.99	1

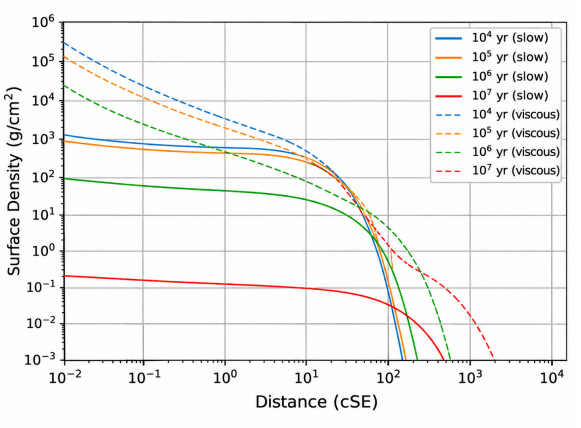
1D Numerical model: gas evolution

Chambers (2019): Analytical model for gas evolution

$$\Sigma = \frac{\Sigma_0}{A} p x^{-5/2} \left[\frac{1 + V^{-2} p x^{-9/2}}{1 + p x^{-5/2}} \right]^{1/4}$$

$$p = p_0 \left(1 + \frac{t}{\tau}\right)^n x^b \exp\left[\left(\frac{1}{s_0}\right)^{5/2} - \left(\frac{x}{s_0}\right)^{5/2} \left(1 + \frac{t}{\tau}\right)^{-1} \right]$$

$$x = \left(\frac{r}{r_0}\right)^{1/2}$$



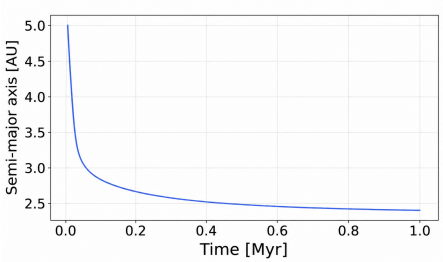
1D Numerical model: gap opening, migration

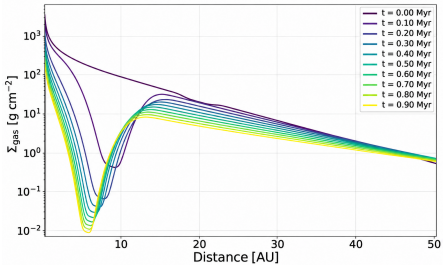
Kanagawa et al. (2018): Giant planet migration and gap profile

$$\tau_a = -\frac{1 + 0.04K}{\gamma_L + \gamma_C \exp(-K/K_t)}\tau_0$$

$$\Sigma_g(r) = \Sigma_{bg}(r)\, G(r)$$

$$G(r) = \frac{1}{1 + 0.04K} \qquad |r - a| < \Delta R_1$$





1D Numerical model: Gas accretion

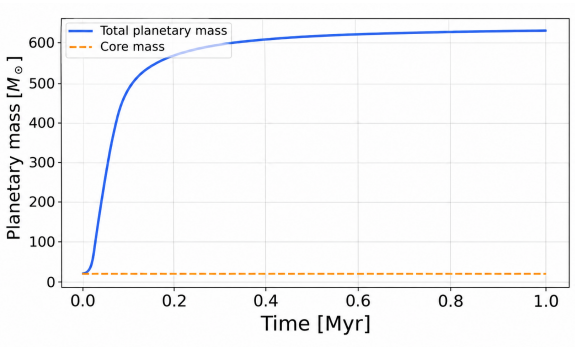
Guilera et al. (2019): Runaway gas accretion and its limitations

$$\frac{dM_g}{dt} = \min\left[\dot{M}_{\rm KH}, \dot{M}_{\rm disc}, \dot{M}_{\rm GP}\right]$$

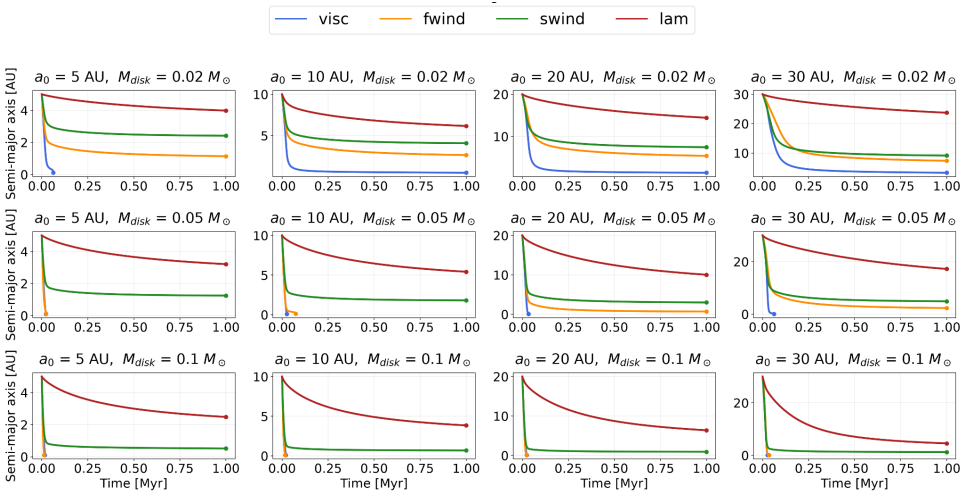
Initial core mass: 10 $M_\oplus$

Initial envelope mass: 10 $M_\oplus$

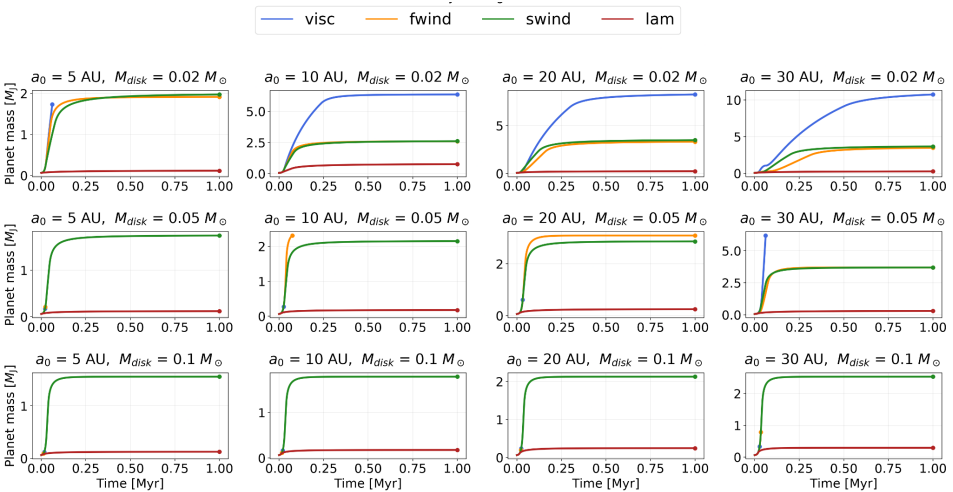
Initial planet mass: 20 $M_\oplus$



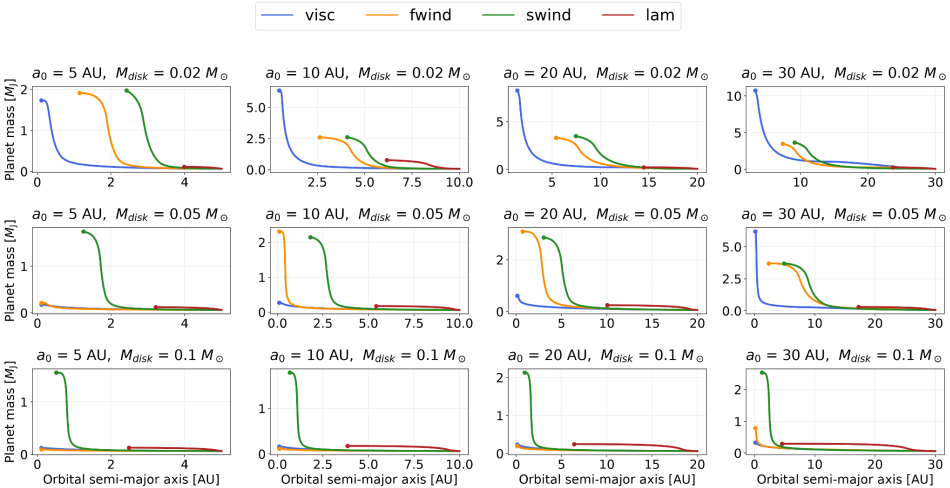
Results: Orbital migration



Results: Planetary mass growth

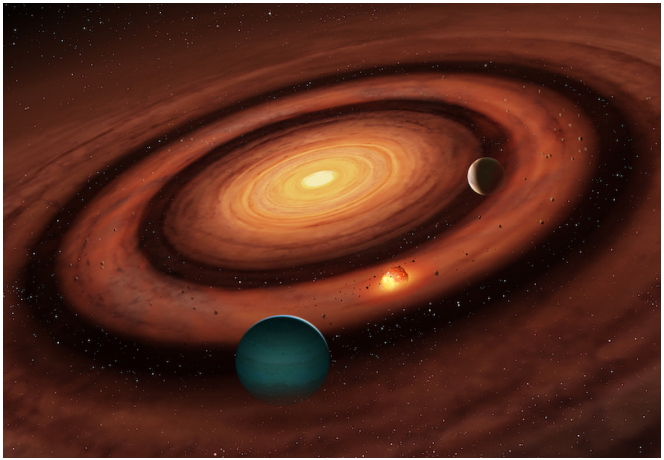


Results: mass vs orbit



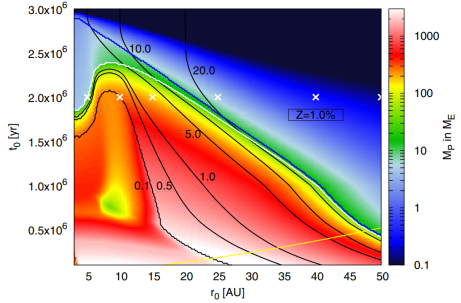
Conclusion

- Giant planets can form and survive in protoplanetary disks where gas accretion is dominantly driven by magnetically driven disk winds.

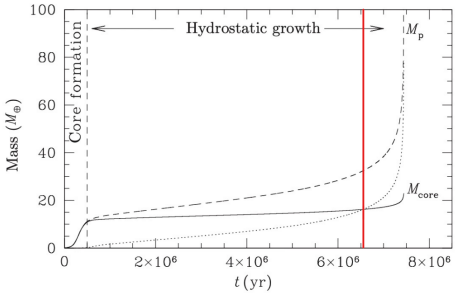


Future plans: generate "heat-maps"

- Investigate a larger paramter space, producing heat-maps. Implementing pebble accretion and low mass planets gas accretion.



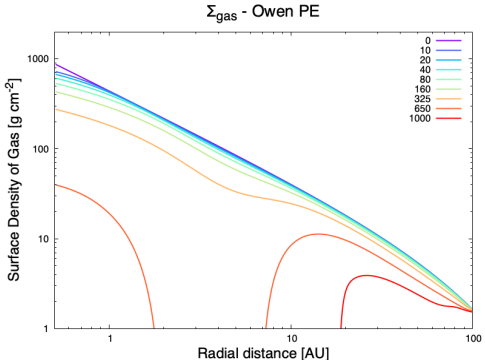
Bitsch+ (2015)



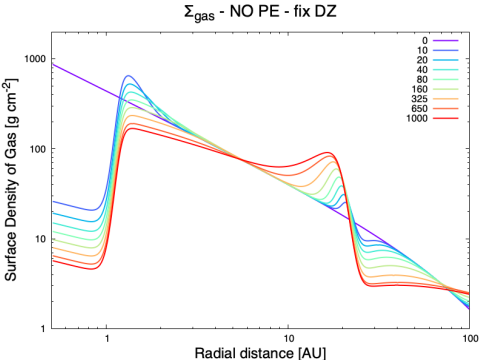
Pollack+ (1996)

Future plans: include photoevaporation and dead zone

- Furthermore, extend the model to incorporate photoevaporation and dead-zone physics.



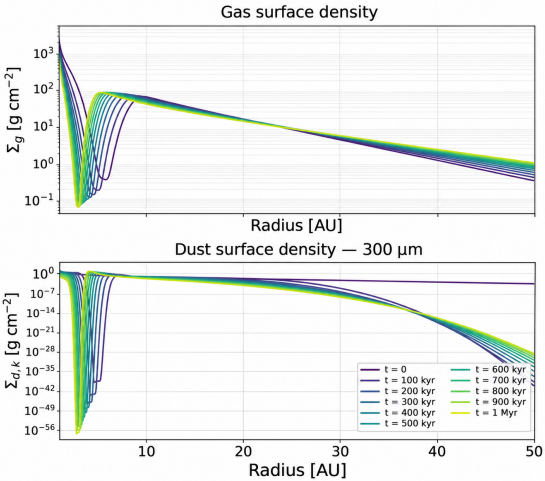
Anna Császár current research

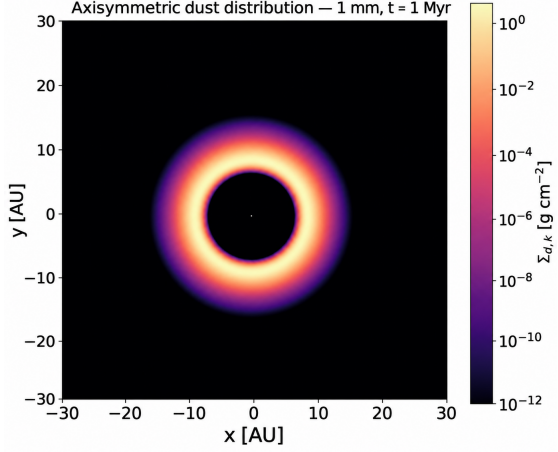


Anna Császár current research

Future plans: generate synthetic images

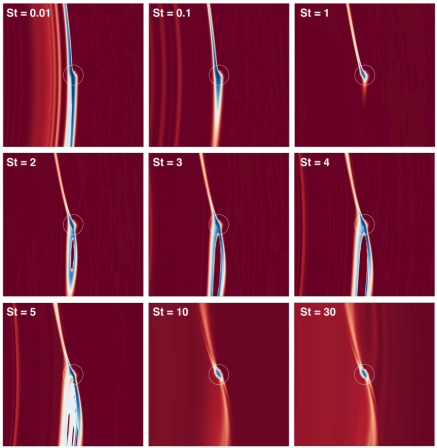
- Adding dust evolution and creating artificial ALMA pictures.

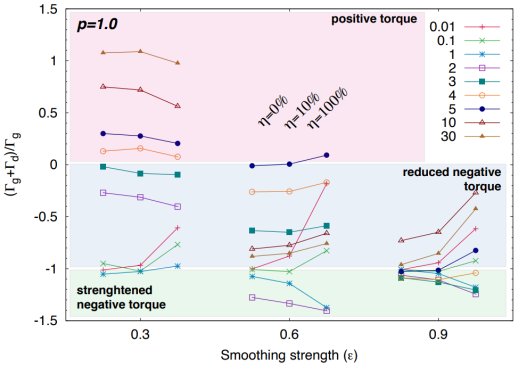




Far, far away... Future plans

- A more accurate description of early planetary evolution and migration requires a 2D model.





Regály (2020)

Thank you for your attention!

Q&A