The Effect of Eccentricity on the Accretion Rate onto Newly Formed Planets in Protoplanetary Discs

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Abstract:

When planets form and evolve in protoplanetary discs, they accrete material from the disc. This material first flows onto a circumplanetary disc, before falling onto the planet. We investigate the significance of the protoplanet's orbital eccentricity on the variability of the accretion rates, and how this affects the planet's evolution.

Using the SPH code Phantom (Price et al., 2018), we simulate the evolution of a young planet in a protoplanetary disc. We vary the initial eccentricity of the planet and the initial disc mass. We then measure the accretion rate onto the circumplanetary disc and the planet itself.

We find that these accretion rates can vary by an order of magnitude throughout a single orbit of the planet. The average accretion rate for different initial conditions also show an order of magnitude difference.

Accretion rates which vary to this extent could influence the formation of satellites around the planet.

Protoplanetary Disc Simulations:

Simulations were based off the parameters of the HR8799 system, and the protoplanet HR8799 c (Goździewski and Migaszewski, 2020).

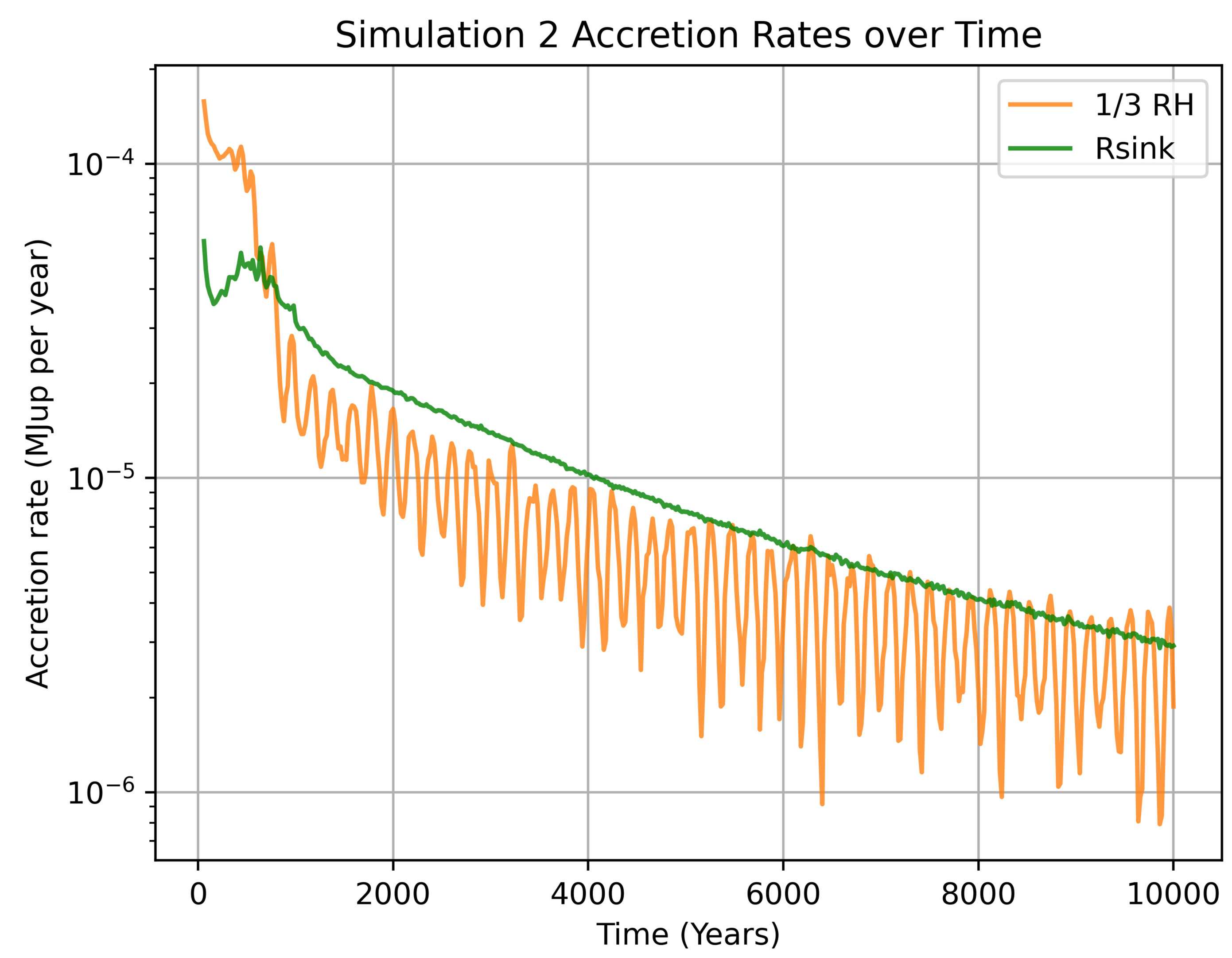
Parameters:
- Particle number – 2 million
- Star mass – 1.5 $M_\odot$
- Initial planet mass – 8 M_{Jup}
- Initial planet distance – 40 AU
- Inner disc radius – 2 AU
- Outer disc radius – 100 AU

Simulation Number	Initial disc mass ($M_\odot$)	Initial planet eccentricity
1	0.001	0.05
2	0.001	0
3	0.005	0.05
4	0.005	0
5	0.01	0

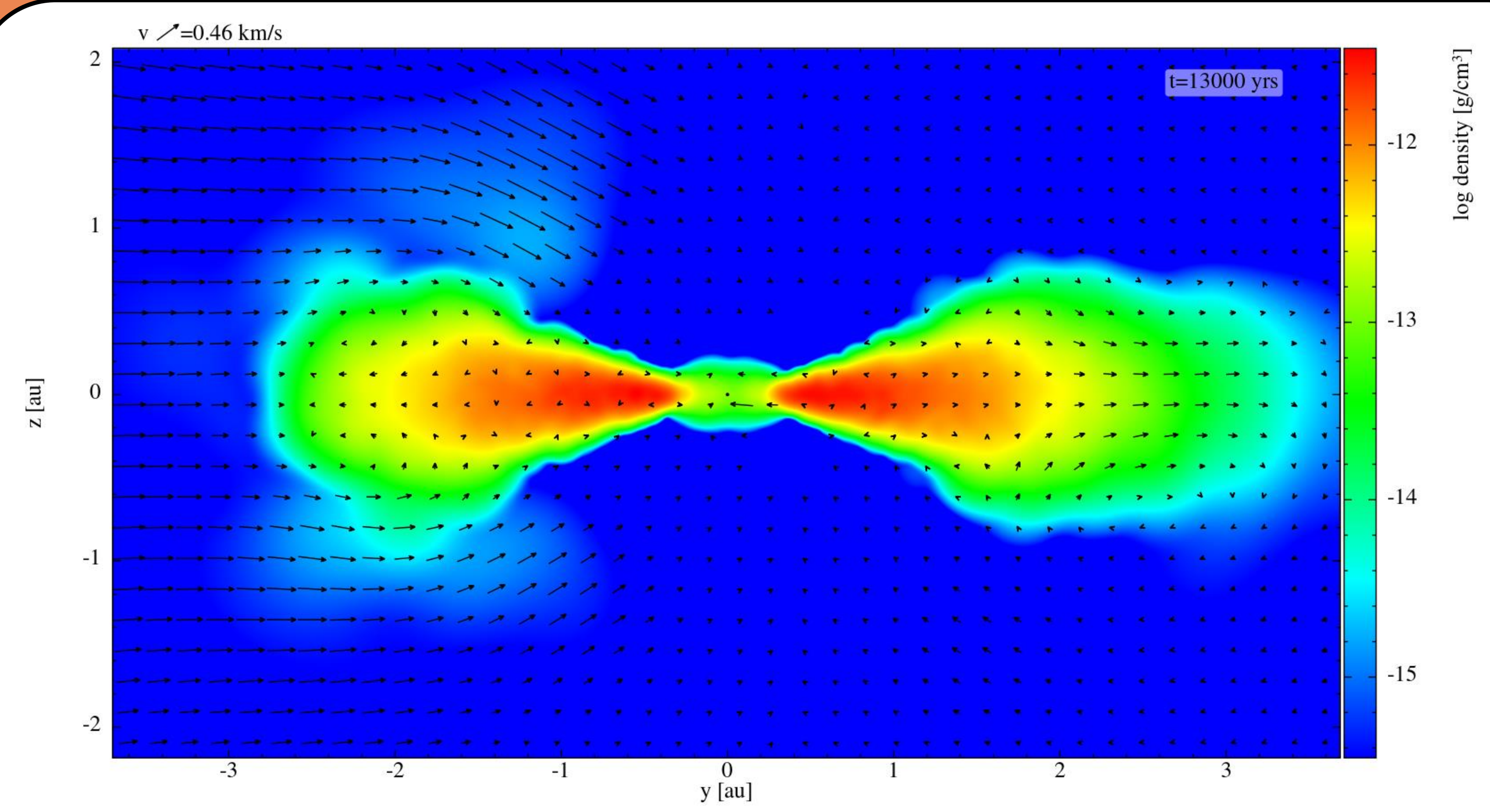
Circumplanetary Disc Radius:

An estimation of the radius of the circumplanetary disc (CPD) is needed to calculate the accretion rate.

We used one third of the protoplanet's Hill radius for this (Ayliffe and Bate, 2009).

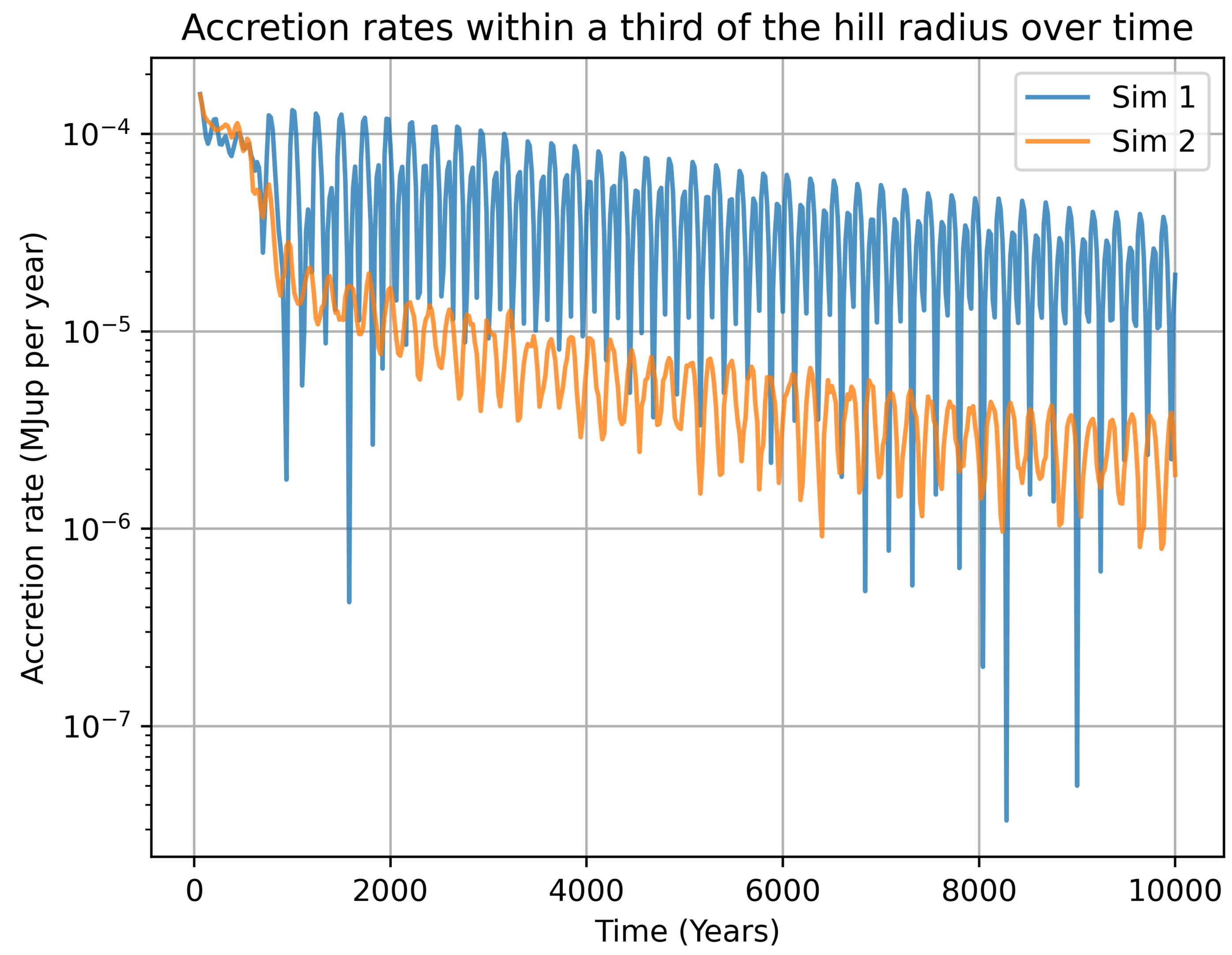


The accretion rate onto the planet (green) and the CPD (orange) for the 10000 years since the insertion of the planet into the disc, for simulation 2.

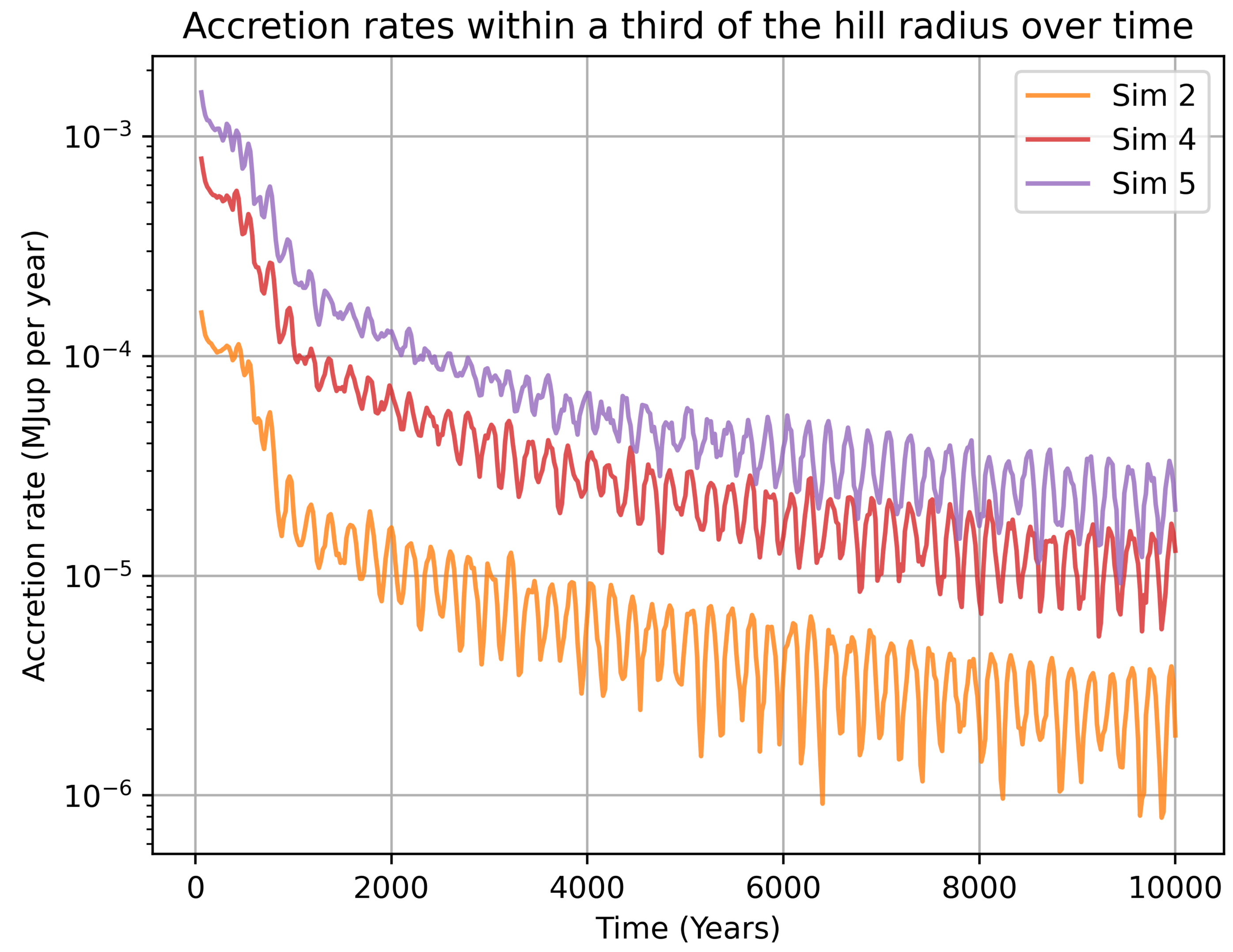


A cross-section density plot of the CPD at the end of simulation 1, with velocity vectors overlayed.

CPD Accretion Rate Comparisons:



The accretion rates onto the CPD for simulations 1 and 2. These simulations have identical parameters other than the initial planet eccentricity.



The accretion rates for simulations 2, 4, and 5, showing how the initial mass of the disc effects accretion onto the CPD.

Conclusion:

By comparing the accretion rate values for the circumplanetary disc radius between simulations, we found that:
- A higher initial eccentricity results in a much greater average accretion rate after 1000 years.
- Increasing the disc mass uniformly increases the accretion rate.

References:

Price, D.J. et al., Publications of the Astronomical Society of Australia, 35, p. e031. (2018)
Goździewski, K. and Migaszewski, C., Astrophysical Journal Letters, 902, 2. (2020)
Ayliffe, B. and Bate, M., Monthly Notices of the Royal Astronomical Society, 397, p. 657-665. (2009)