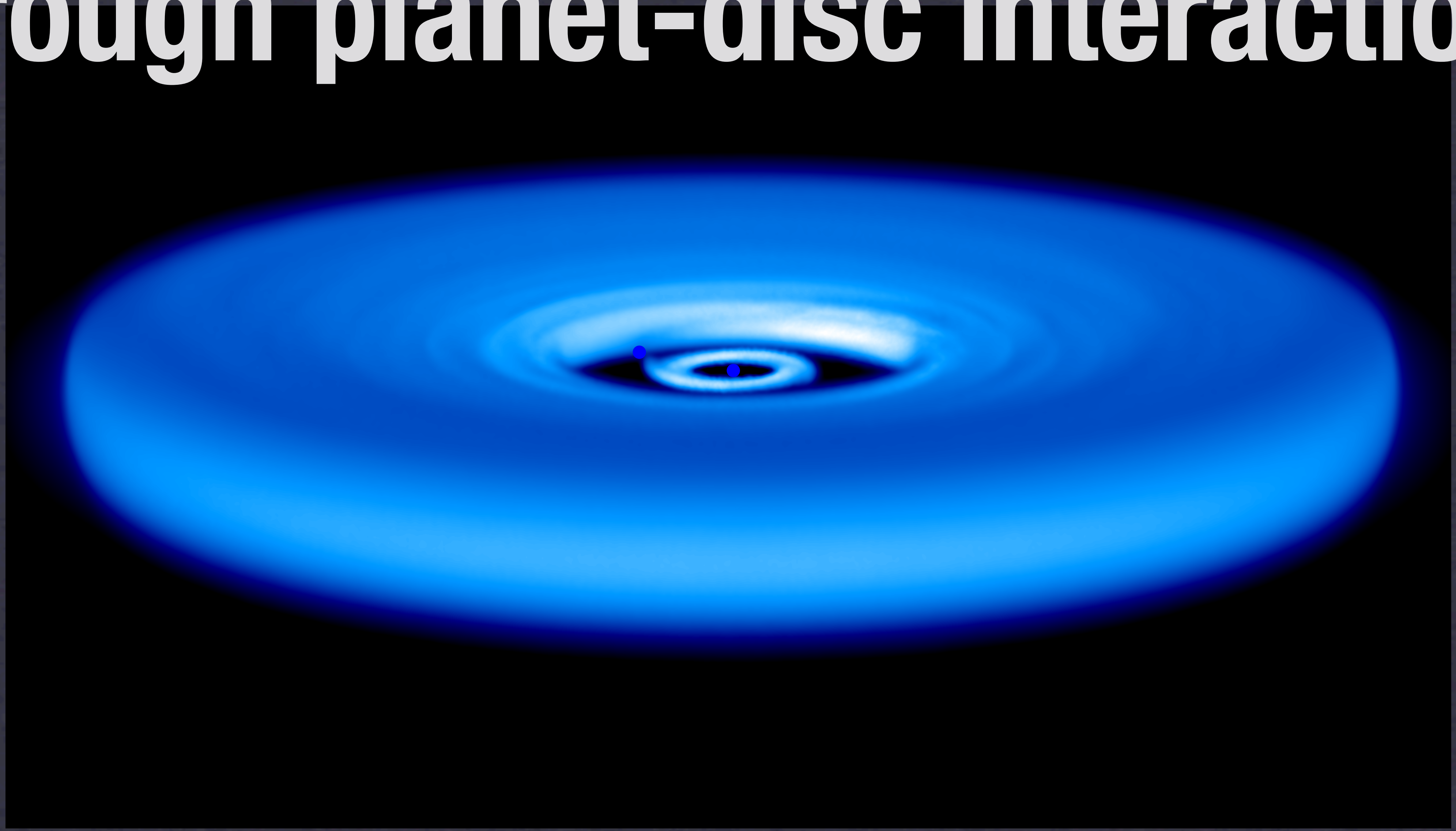
A limit on eccentricity growth through planet-disc interactions



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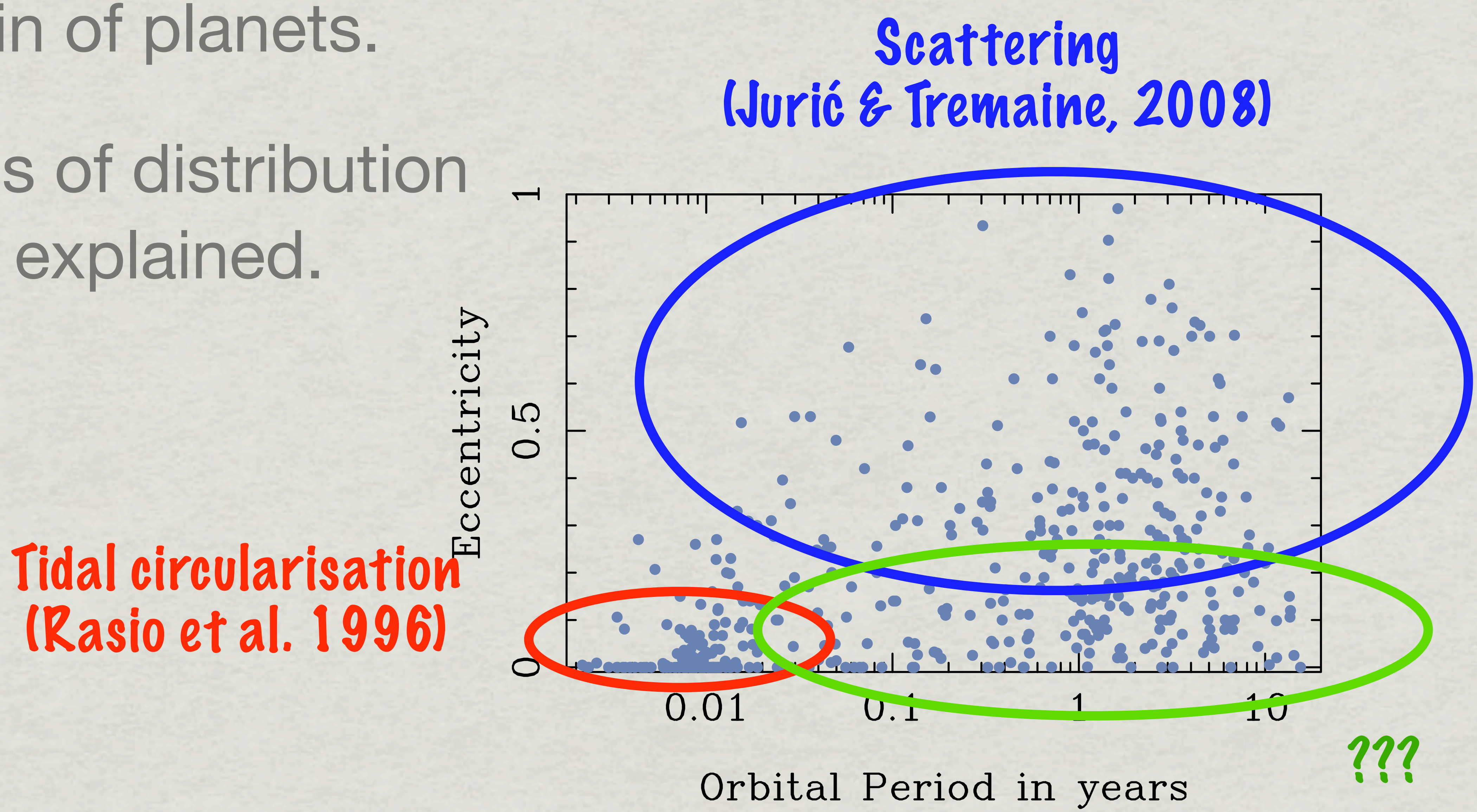
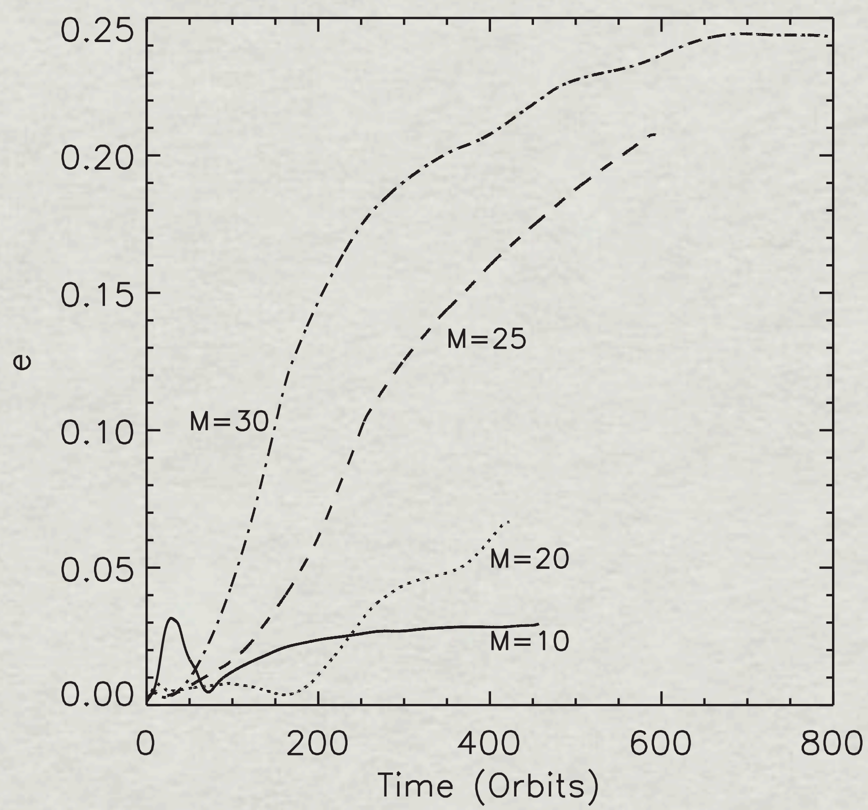
Motivation

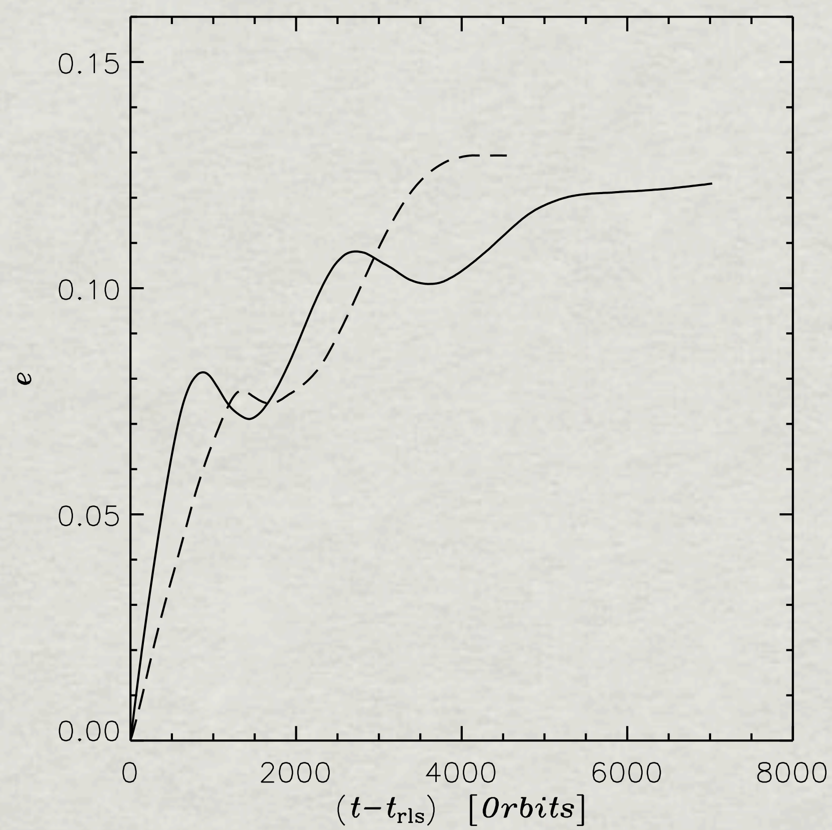
- Exoplanets observed with full range of eccentricities from 0 to ~1.
- Formation models agree on a circular disc as the origin of planets.
- Parts of distribution well explained.



Previous studies

- Bitsch & Kley (2010) looked at low mass eccentric planets in 3D discs - found *e* decay.
- Papaloizou et al. (2001) and D'Angelo et al. (2006) both explored planet mass.
- Both found eccentricity growth.

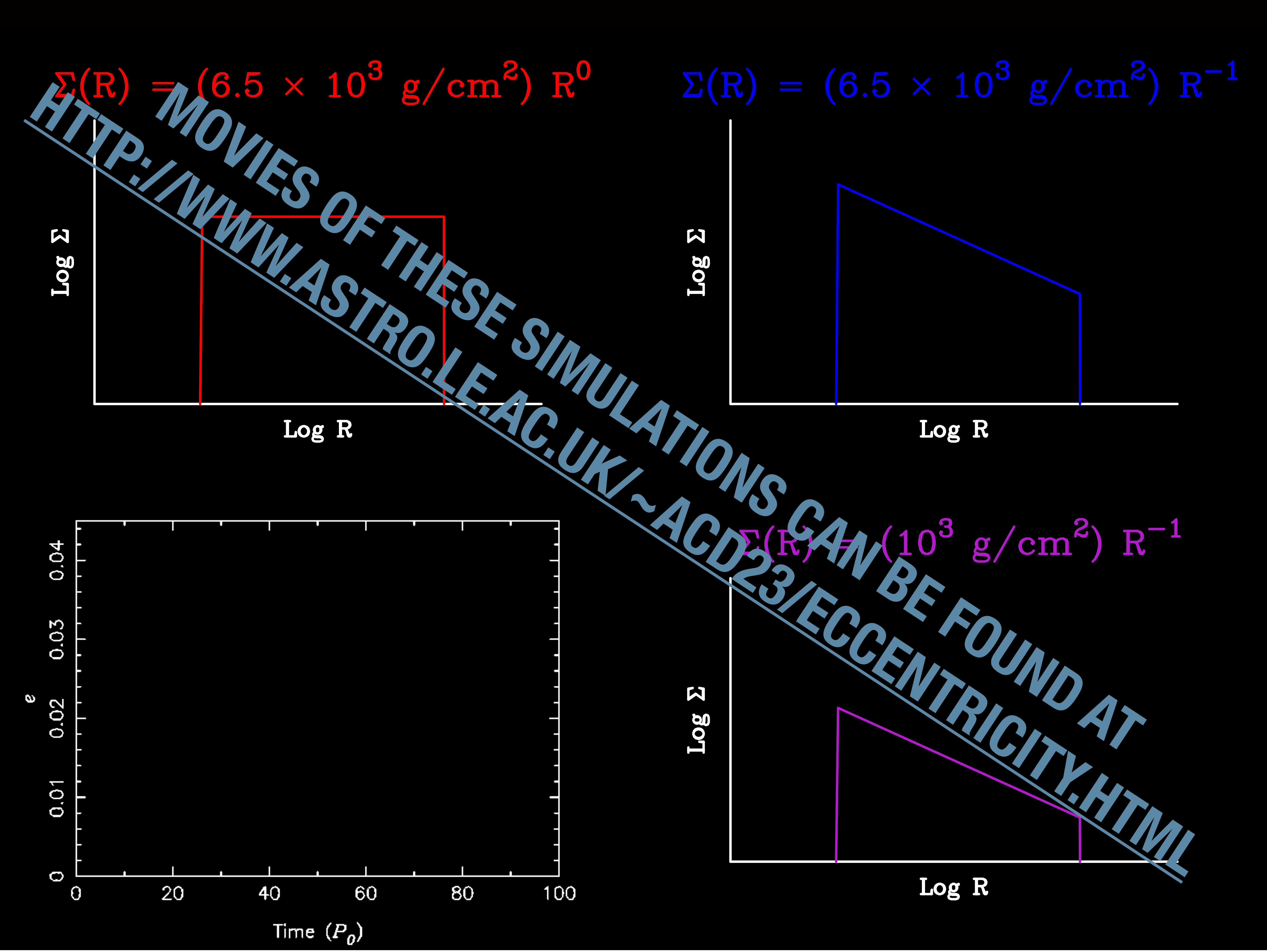




- But in 2D, grid hydro, high surface density discs.

Method

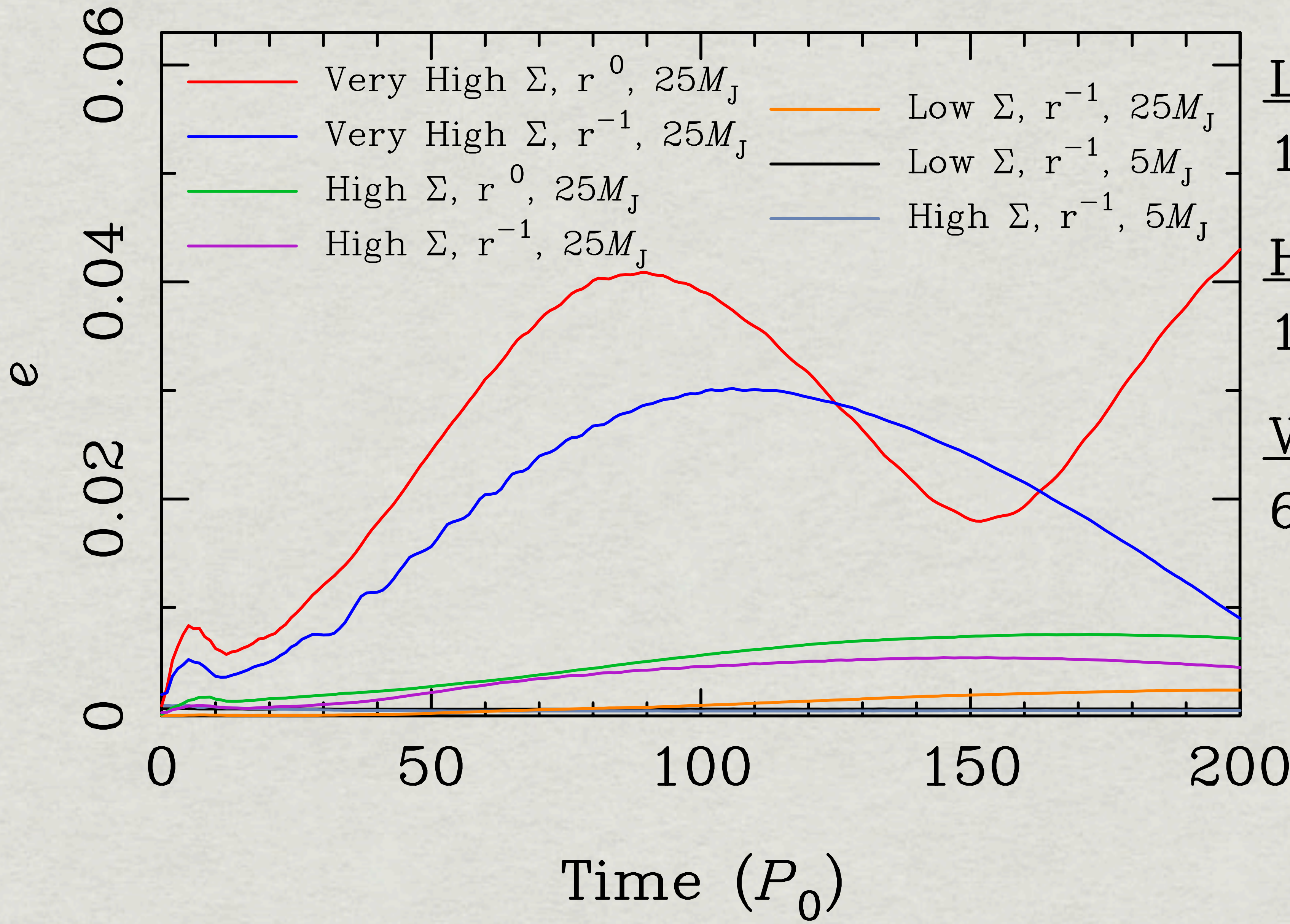
- High resolution (10^7 particle) 3D SPH simulations using GADGET-2.
- Directly calculates gravity for planet and star.
- Locally isothermal equation of state.
- High mass planet, varied surface density profiles.
- Explicit Navier-Stokes viscosity ($\alpha = 10^{-2}$).



Σ(R) = (6.5 × 10^3 g/cm^2) R^0
Σ(R) = (6.5 × 10^3 g/cm^2) R^−1
Σ(R) = (10^3 g/cm^2) R^−1
Log Σ
Log R
e
0 0.01 0.02 0.03 0.04
0 20 40 60 80 100
Time (P_0)
MOVIES OF THESE SIMULATIONS CAN BE FOUND AT
HTTP://WWW.ASTRO.LE.AC.UK/~ACD23/ECCENTRICITY.HTML

Simulation results

- Run 7 models.



Low Σ

10^2 g/cm^2 @ 1 au

High Σ

10^3 g/cm^2 @ 1 au

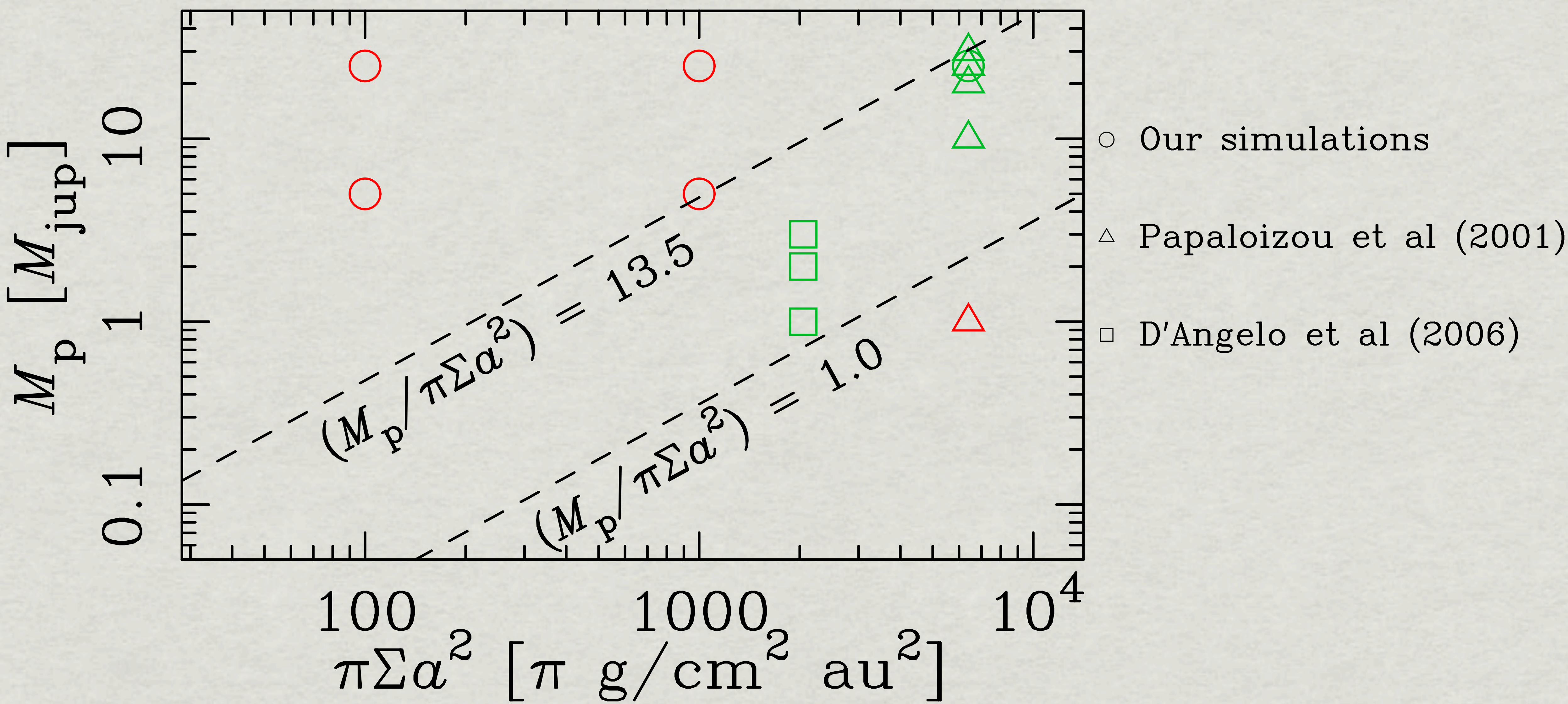
Very High Σ

6.5×10^3 g/cm^2 @ 1 au

- Eccentricity only grows for $\Sigma > 10^3$.

Planet mass vs. surface density

- Combining results with previous studies yields:



Planet mass vs. surface density

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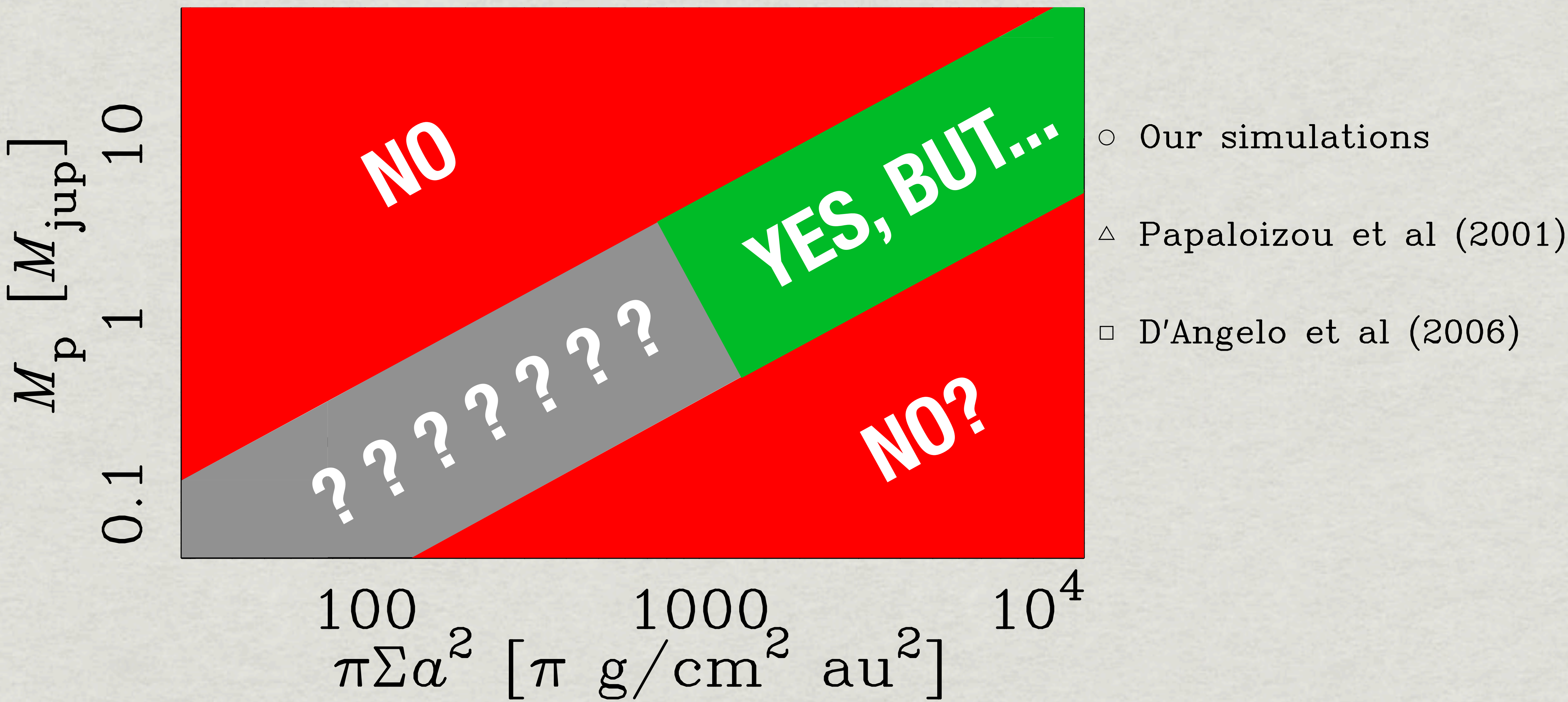
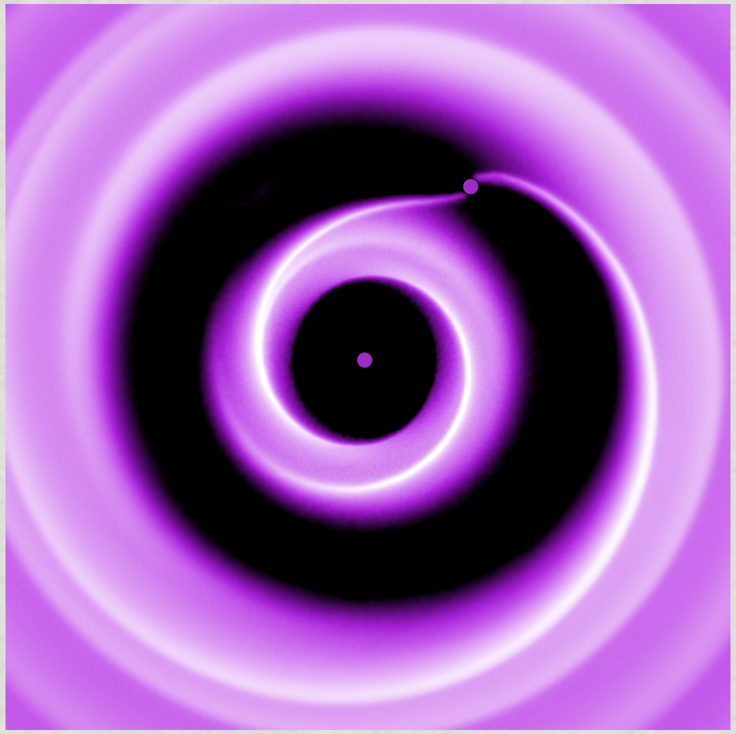


Growth timescales

- Planets in gaps accrete:



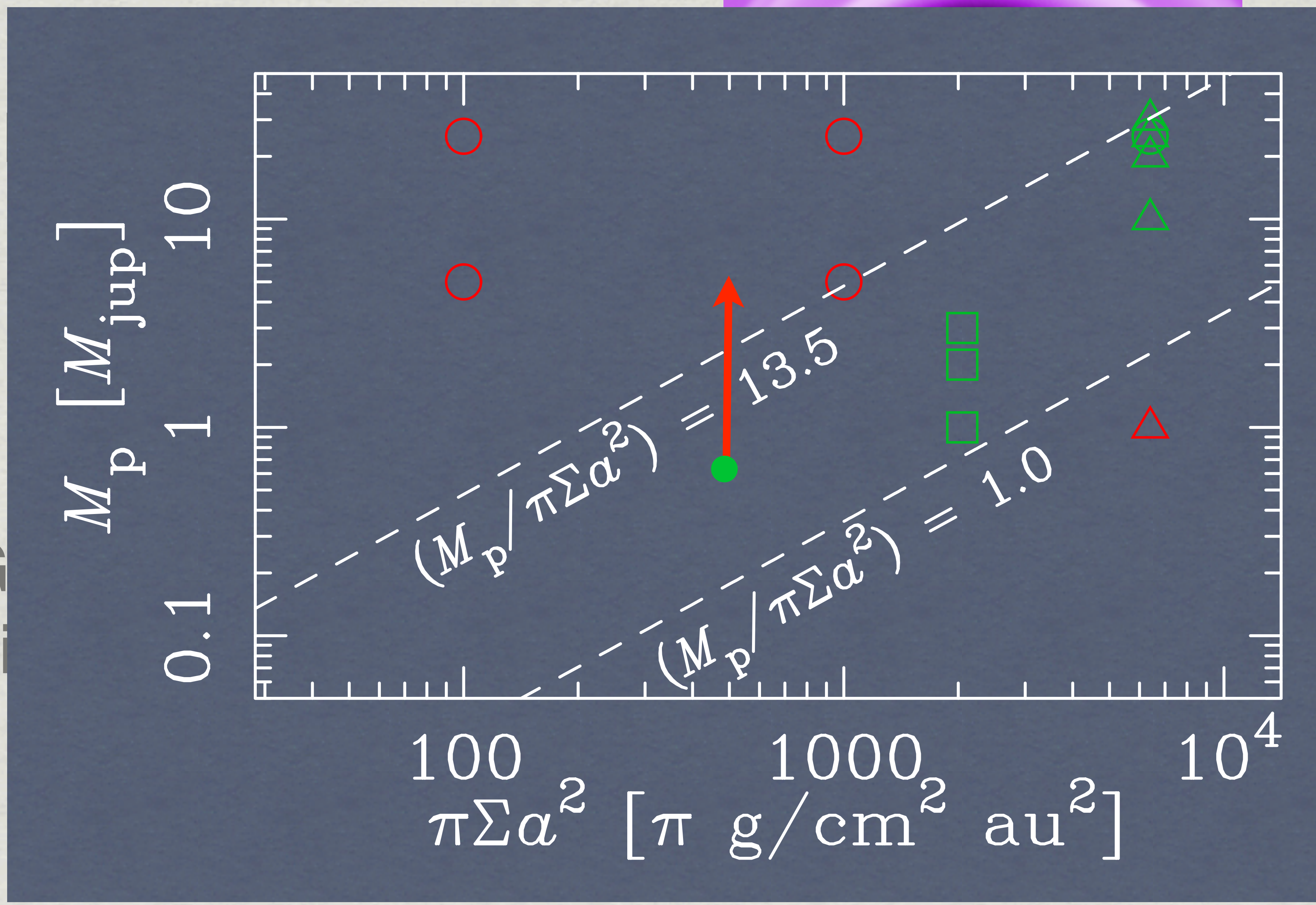
- Growth timescale for giant planet in a Σ~10^{2-3} g/cm^2 disc (Lubow et al., 1999; D' Angelo et al., 2002):

$$\tau_{accrete} \lesssim 10^{4-5}\, t_{dyn}$$

- Similar to timescale for eccentricity growth for a Jupiter (D'Angelo et al., 2006).

Growth timescales

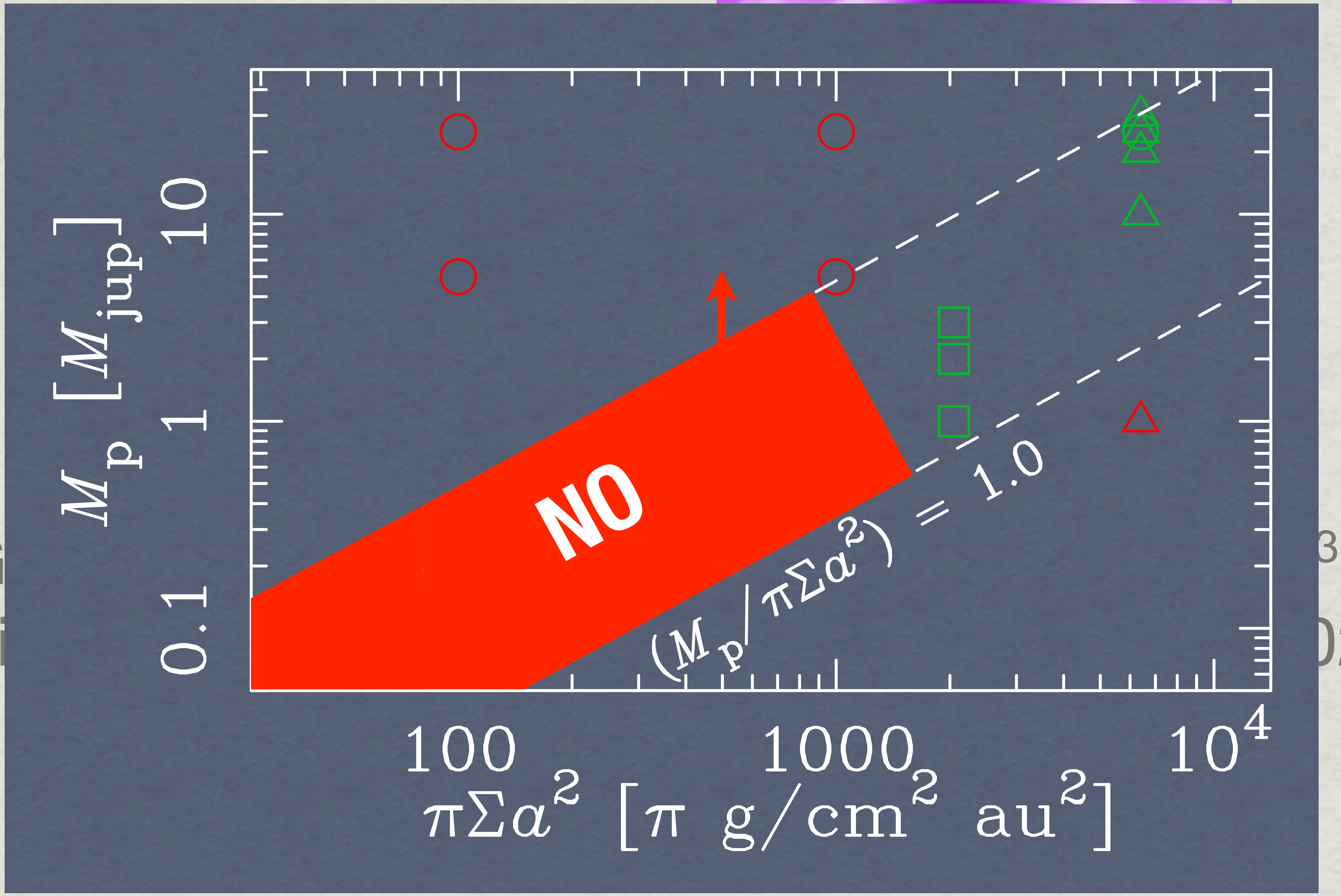
- P



- G ... ^{3} g/cm^2
  di ... 02):

- Similar to timescale for eccentricity growth for a Jupiter (D'Angelo et al., 2006).

Growth timescales



- P
- G ... ^{3} g/cm^2 di ... 02):
- Similar to timescale for eccentricity growth for a Jupiter (D'Angelo et al., 2006).

Conclusions

- No *e* growth for canonical disc parameters.
- For high mass planets, need high surface density in disc to grow eccentricity.
- For low mass planets, $\tau_{accrete} \sim \tau_{ecc}$, so quickly move outside region of allowed eccentricity growth.

We conclude that this is <u>not</u>
an efficient process for growing
planetary eccentricities:
Some other mechanism!

Dunhill, Alexander & Armitage 2012 (submitted)