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.

Scattering (Jurić & Tremaine, 2008)

Tidal circularisation (Rasio et al. 1996)
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 (\(\alpha = 10^{-2}\)).
MOVIES OF THESE SIMULATIONS CAN BE FOUND AT HTTP://WWW.ASTRO.LE.AC.UK/~ACD23/ECCENTRICITY.HTML

\[ \Sigma(R) = (6.5 \times 10^3 \text{ g/cm}^2) R^{-1} \]
Simulation results

Run 7 models.

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

![Graph showing simulation results]

- Low $\Sigma$
  - $10^2 \text{ g/cm}^2$ @ 1 au

- High $\Sigma$
  - $10^3 \text{ g/cm}^2$ @ 1 au

- Very High $\Sigma$
  - $6.5 \times 10^3 \text{ g/cm}^2$ @ 1 au
Planet mass vs. surface density

* Combining results with previous studies yields:
Planet mass vs. surface density

Combining results with previous studies yields:

- Our simulations
- Papaloizou et al (2001)
- D'Angelo et al (2006)
Growth timescales

- Planets in gaps accrete:

- Growth timescale for giant planet in a $\Sigma \sim 10^{2-3} \text{ g/cm}^2$ disc (Lubow et al., 1999; D’Angelo et al., 2002):

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

- Similar to timescale for eccentricity growth for a Jupiter (D’Angelo et al., 2006).
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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 not an efficient process for growing planetary eccentricities: Some other mechanism!

Dunhill, Alexander & Armitage 2012 (submitted)