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Planetesimal vs pebble accretion formation model

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Abstract

Using two separate models of planet formation we compare the outcomes of two different accretions of solids: planetesimals or pebbles. In order to do so we adopt some similar properties. The Hueso & Guillot 2005 disc model is used for both codes and the outcomes are compared. We also compare the accretion of gas onto the planet, which is similarly implemented in both models. And finally we use the same migration formulae in both cases. With this comparison we would like to show the impact of the accretion of solids.

1. Introduction

One of the main scenarios of planet formation is the core accretion model where a massive core forms first accreting solids, either planetesimals or pebbles, and then accretes a gaseous envelope. Our goal here is to compare the two scenarios of solid accretion, keeping all the other parameters the same. To proceed we consider two separate models, one using planetesimal accretion, the other pebble accretion, and implement the same disc model, gas accretion and migration.

2. Disc model and evolution

We use the disc model provided by Hueso & Guillot 2005 in the two models. It is a one-dimensional model that includes star irradiation as well as dissipation of viscous energy. It is based on an approach giving the central temperature (Nakamoto & Nagakawa 1994, Hueso & Guillot 2005):

$$T_m^4 = \frac{1}{2\sigma}\left(\frac{3\kappa_R}{8}\Sigma + \frac{1}{2\kappa_p\Sigma}\right)\dot{E}_\nu + T_{cloud}^4, \qquad (1)$$

where T_{cloud} is the molecular cloud temperature. The vertical structure of the disc can then be derived from Eq. 1. Once the properties of the disc are defined, its evolution follows the continuity equation (Lin & Papaloizou 1986):

$$\frac{\partial\Sigma}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left[3r^{1/2}\frac{\partial}{\partial r}(\nu\Sigma r^{1/2})\right]. \qquad (2)$$

Fig. 1 shows the comparison of temperature profile between the two disctinct codes, while Fig. 2 represents the surface density evolution.

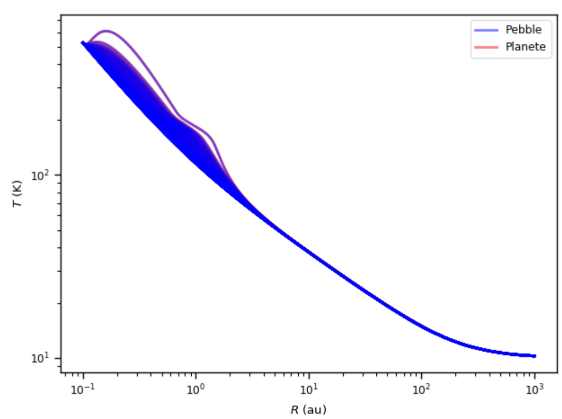

Figure 1: Comparison for two sperate models of the temperature profile of the disc.

3. Gas accretion model

The gas accretion is also computed similarly in both planetesimal and pebble model. The internal structure of the planetary envelope is considered :

$$\frac{\partial m}{\partial r} = 4\pi r^2\rho, \qquad (3)$$

$$\frac{\partial P}{\partial r} = -\frac{Gm}{r^2}\rho, \qquad (4)$$

and:

$$\frac{\partial T}{\partial r} = \frac{T}{P}\frac{dP}{dr}\nabla, \qquad (5)$$

which represent the mass conservation, the equation of hydro-equilibrium and energy transfer respectively

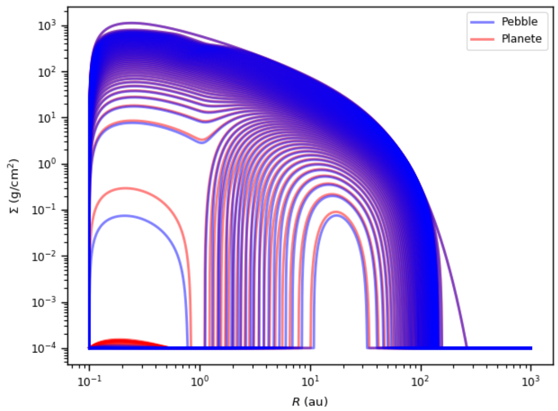

Figure 2: Comparison for two sperate models of the surface density profile of the disc.

(Alibert 2016). The mass of the envelope is then determined by iteration. Comparing the results between two iterations provides the gas accretion rate (Alibert et al. 2005). When the planet starts a phase of rapid gas accretion, the latter is limited by what is provided by the disc as Machida et al. 2010.

4. Migration

The migration of planets through the disc is again treated the same way in both models. We follow Paardekooper et al. 2011 for type I migration. If the planet is big enough to open a gap in the disc (following Crida et al. 2006), it starts to migrate with type II migration.

5. Planetesimal and pebble accretion model

The solid accretion is the only difference between the two models. Solids are either accreted in the forms of planetesimals or pebbles. In the planetesimal case we adopt the model described by Alibert et al. 2013 and Fortier et al. 2013. In the pebble case, we follow Brügger et al. 2018 but the accretion of pebbles is given by Johansen & Lambrechts 2017.

6. Conclusions and future outcomes

Using the same parameters we would like to show the impact of the accretion of solids. Focusing not only on one planet but on a whole population, our on-going project is to compare the outcomes of planetary populations with the two different accretions (Brügger et al. in prep). Therefore the mass distributions or the period distributions could be discussed and compared with observations.

Acknowledgements

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