EPJ Web of Conferences **16**, 05004 (2011)
DOI: 10.1051/epjconf/20111605004

Planet formation with different gas depletion timescales: Comparing with observations

H. Liu, J.-L. Zhou[a] and S. Wang

Department of Astronomy, Nanjing University, Nanjing 210093, China

Abstract. This paper mainly focus on the influence of N-body interaction in the later stage of planets formation, especially the gas depleted timescale. We want to interpret the distribution of eccentricity comparing with observations.

1. INTRODUCTION

Ida & Lin (2004a, 2004b, 2005 and 2008) use the core accretion model to reproduce the distribution of a-M of planets successfully. Due to the core accretion model, some planets growth to gas giants fast, and the interaction between planets become important to influence their final configuration. The eccentricities of planets can also be excited by gravitation via resonance.

In this paper, we mainly focus on the eccentricities of planets, as well as the influences of different gas depletion timescale. In Section 2, we will describe the protoplanetary disk model and oue main results. Finally we will make conclusions and further discussions.

2. DISK MODEL AND RESULTS

Here we derive a modified minimum mass solar nebular (MMSN) according to Pringle 1981:

$$\Sigma_g = \frac{\dot{M}}{3\pi\alpha c_s h}\left[1 - \left(\frac{R_*}{a}\right)^{1/2}\right], \qquad (1)$$

and give a gas surface density profile as following:

$$\Sigma_g = \Sigma_0 f_g \left(\frac{a}{1\mathrm{AU}}\right)^{-1} \left(\frac{\alpha_{\mathrm{eff}}}{10^{-4}}\right)^{-1} \left(\frac{M_*}{M_\odot}\right)^{4/5} \exp\left(-\frac{t}{\tau_{disk}}\right), \qquad (2)$$

MRI effect (Kretke et al. 2009), caused by different degree of ionization of protoplanetary disk, is included in our model. Type I migration rate and damp of eccentricity given by Cresswell & Nelson (2006) are adopted, while type II migration is following Albert et al. (2005).

To understand the influence of gas depletion timescale, we use a uniform distribution of log τ_{disk} with a range of $5 \times 10^5 \sim 5 \times 10^6$ yr, which is indicated by Haisch et al. (2001). To highlight this influence, we fix some other parameters: the typical mass of a host star $M_* = 1M_\odot$; the gas enhancement factory $f_g = 1.\Sigma_0 = 280\,\mathrm{g/cm^{-2}}$ corresponding to the mean total gas disk mass of a Taurus-Auriga

[a]e-mail: zhoujl@nju.edu.cn

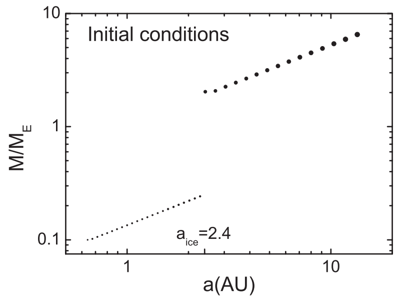

Figure 1. A sketch map of the initial conditions in our simulations, mars-size planets extend from 0.5 2.4 AU, while earth-size planets extend to 10 AU.

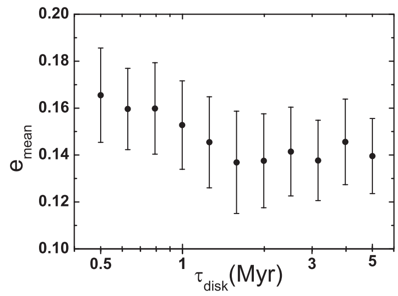

Figure 2. The influences of τ_{disk} for e_{mean}. e_{mean} is decreasing with τ_{disk} before $\tau_{disk} = 2$ Myr, then a slight increase. The error bars are the standard error of mean.

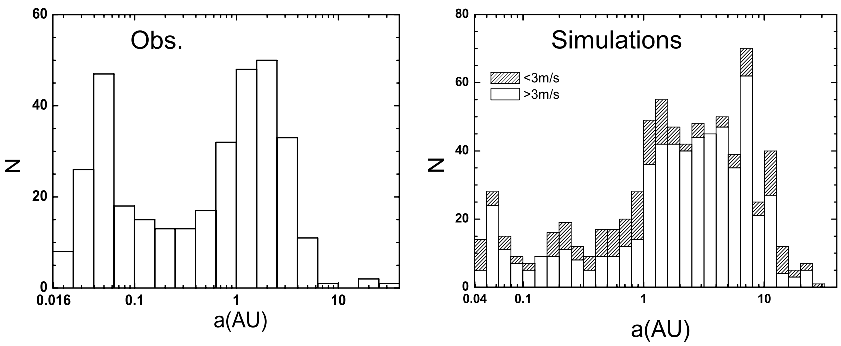

Figure 3. Comparing observations and our simulations in statics about the semi-majoy axis.

star formation region. The protoplanetary disk extend from 0.05 AU to 100 AU. The initial condition of planets are following Zhou et al. (2007) who considered the dynamical stability. as shown in Figure 1.

The main results are shown as following Figure 2 give the correlation between the mean ecc of planets in each system e_{mean} and τ_{disk}. Figure 3 comparing our results and observations in statistics.

The timescale τ_{disk} will influence the e_{mean} by two ways: (1) damp the eccentricity via tidal damp; (2) excite the eccentricity via scattering. The tidal damp is effective before gas depletion. After gas depletion, there is no way to damp the eccentricity, so smaller τ_{disk} lead to larger e_{mean}. In contrast, the planets experience a sufficient migration inward. The initial embryos will be compacted spatially and then scattered with large eccentricities. This effect will enhance e_{maen} at large τ_{disk}. As seen in Figure 2 e_{mean} is decreasing with τ_{disk} but there is a slight increase when $\tau_{disk} > 2$ Myr.

For the diagram of $a - N$, the same with observations, there is an accumulation at 0.05AU, the inner boundary of gas disk. A few small planets were scattered into 0.05 AU. Another accumulation appears near 0.2 AU, which isn't detected by observations. Due to the type I migration model we adopted in Section 2.1, i.e. the MRI effect, small planets may halt at a_{crit}, we can evaluate $a_{crit} \sim 0.2$ AU. Because type I migration only affects the small planets. Most planets locate from 1 AU to 8 AU while the observation indicates a range about 1∼5 AU. Most of them are massive, and experienced type II migration. Due to the braking phase, they can't migrate too close to the star, hence they halted out of 1 AU and located at different location because of their different masses and initial locations. Some small planets, about tens of Earth's mass, appear in this range. Most of these small planets were scattered from inner region.

3. CONCLUSIONS AND DISCUSSION

Our results show a correlation between the mean e and τ_{disk}. We also interpret observations and may guide the further observations. The accumulations around 0.2 AU are predicted in our simulations which can be verified in the future.

There are some uncertainties in our model. The migration rates as well as the boundary between type I and type II migrations are still debated. Different type I migration rate will influence the locations of planets directly. The uncertain initial conditions of embryos still affect our results.

References

Alibert et al. (2005a), A&A, 434, 343
Cresswell, P., & Nelson, R. P. (2006), A&A, 450, 833
Ida, S., & Lin, D.N.C. (2004a), ApJ, 604, 388
Kennedy, G. M. & Kenyon, S. J. (2008), ApJ, 673, 502