Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS21-27 Room:304 Time:May 21 09:45-10:00

Numerical simulations and analytical evaluations of type I migration in disks heated by the stellar irradiation

Naohiko Maeshima[1*], Sei-ichiro WATANABE[1]

[1]Division of Earth and Planetary Sciences, Graduate School of Science, Nagoya University

Planets are formed in protoplanetary disks and migrate radially by gravitational interaction with the disk gas. The type I migration was problematic because planets rapidly fall into the central stars in the isothermal disks. However, recent studies revealed that in the adiabatic disks planets can migrate outward in the region where the entropy gradient is negative (Paardekooper & Mellema 2006; Baruteau & Masset 2008; Paardekooper & Papaloizou 2008). There is a study calculating type I migration in the non-isothermal disks (Lyra et al. 2010), but they does not considered the stellar irradiation as the mechanism of the disk heating.

We studied the type I migration in the non-isothermal accretion disks heated by the central star using numerical calculation. As mechanisms of the disk heating, we considered both the viscous heating and the stellar irradiation. We find that 'equilibrium radii', where the torque exerting on a planet becomes zero, moves inward in the disk with the timescale of disk evolution, and planets move with the equilibrium radii until gas densities decrease so low that the planets stop migration. One of the equilibrium radii exists on the region where main heating mechanism changes from viscous heating to stellar irradiation and that the terminal position of a comoving planet with mass of 10 M_E is about 1AU. The terminal position is less sensitive to parameters such as turbulent viscosity, mass flux of photoevaporation, and mass of the central star. On the other hand, the planets migrating from the relatively inner disk arrive at the vicinity of the central star (disk inner edge). If core instabilities occur on the planets, hot jupiters are formed. We also obtain analytical expression of equilibrium radii and terminal positions of migrating planets, which coincides well with the results of our numerical simulations.

We compare our results with the distribution of the semimajor axes of observed exoplanets. Especially many giant planets ($>100M_E$) have been observed in the regions inside 0.1AU and outside 1AU, and the number ratio of planets is about 3:5. A relatively small number of exoplanets are observed between the two regions. Such a bimodal distribution of semimajor axes of exoplanets can be explained by the results of our simulation. We will discuss the ratio of the number of planets in the two regions quantitatively.

References

Baruteau, C., & Masset, F. 2008, ApJ, 672, 1054.
Lyra, W., Paardekooper, S.-J., & Mac Low, M.-M. 2010, ApJ, 715, L68.
Paardekooper, S.-J., & Mellema, G. 2006, A&A, 459, L17.
Paardekooper, S.-J., & Papaloizou, J. C. B. 2008, A&A, 485, 877.

Keywords: type I migration, protoplanetary disk, exoplanet