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Basic mechanism of planetary migration by the interaction with planetesimals

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Solar system has experienced planetary migration in its formation stage. Especially, Neptune has an evidence of outward migration in

the 3:2 mean motion resonance in the Kuiper belt objects. In the point of view of planetary formation theory, outer ice giant planet needs

planetary migration to shortening its growth time. Several simulations about planetary migration has done, and some results indicate that planet can migrate outward when disk has enough mass, but there are few works to understand the basic mechanism. To understand the basic mechanism, we simulated planetary migration using pseudo N-body calculation in several mass disks. In these calculations, we consider only one Neptune mass planet and

planetesimals which distributions are according to Hayashi model. In such system, the frequency of encounter with inner planetesimals is larger than which with outer one. As a result, planet loses its angular momentum and migrates inward. If there are enough mass around planet, planet experiences forced migration which can migrate continuously. Oppositely, if there aren't enough mass disk, migration velocity of planet gradually becomes small. That kind of migration are called damped migration. In our calculation, the threshold disk mass between forced and damped migration exists around 3 times of minimum mass model. To describe the basic mechanism of planetary migration, we focus attention on the mass flux that step over the planet. These planetsimals transport angular momentum as well as mass. If there are large mass flux, migration velocity of planet become large. Next, we focus attention on the individual planetesimal which consist of step over mass flux. Planetesimal which enter close encounter region experiences several strong scattering and increase its semi-major axis. After planet passed, such planetesimal gains larger angular momentum than other planetesimals. If migration velocity of planet is large, planetesimal stays short time in close encounter region and its semi-major axis becomes small, and vice versa. On the other hand, if the stay time of planetesimal becomes long, mass flux decreases. When

migration velocity is too small, the effect of decreasing mass flux overcomes the increasing specific angular momentum. This is the basic

mechanism of damped migration. In the case of forced migration, mass flux and specific angular momentum are well balanced. We will show model equation of migration that include these effects.