Formulation of planetary migration in planetesimal disk

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Abstract: 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 shorten 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 planetesimal disk. 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. 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. We also 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. The amount of angular momentum which planetesimal obtains is in inverse proportion to migration velocity of planet. If migration velocity is large, planetesimal stays short time in close encounter region and its semi-major axis after encounter becomes small, and vice versa. On the other hand, if the stay time of planetesimal becomes long, mass flux decreases. Migration velocity of planet is decided by the balance of these two effect. We show new formulation of planetary migration velocity including this mechanism.