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ORBITAL MIGRATIONS IN PLANETESIMAL DISKS

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We have performed N-Body numerical simulations of the exchange of angular momentum between a massive planet and a 3D keplerian disk of planetesimals. Our interest is directed to the study of the orbital migrations of the planets, as well as to the validity of the classical analytical expressions of the lineal theory of density waves, as representative of the dynamical friction in disks 'dominated by the planet'.

We should seek for a time interval in which the net inward migration and the variation of the semi major axis are not strongly affected by relaxation or saturation of resonances. This time interval to measure the planetary migration rate, was determined in the way proposed by Wahde et al. (1996). The torque measured in numerical experiments yields inward migration in a minimum-mass solar disk ($\Sigma \sim 10$ g cm^2), with a characteristic drift time of $\sim$ a few 10^6 yr. The planets predate the disk, but the orbital decay rate is not sufficient to allow accretion in a time scale relevant to the giant planets formation (Pollack et al. 1996).

Goldreich & Tremaine (1979, 1980) have developed a theory for resonant torque driven by density waves, showing that in this particular case, this formulation is equivalent to the resonant dynamical friction in disks (Lynden-Bell & Kalnajs 1972).

We found reductions of the measured torque on the planet, with respect to the linear theory, by a factor of 0.38 for M_c ($10M_\oplus$), 0.04 for Saturn and 0.01 for Jupiter, due to the increase in the perturbation on the disk. The behavior of planets whose mass is larger than M_c is similar to the one of type II migrators in gaseous disks (Ward 1997). Our results suggest that, in a minimum mass solar planetesimals disk, type I migrations occur for masses smaller than M_c, whereas for this mass values it could be a transition zone between the two type of migrations. This is shown in Figure 1.

We cannot say anything respect to the final destiny of the planets. Due to the time span of the simulations, it fails to explain any switch-off of this mechanism of migration, which must be related to the involved time of relaxation, even though it must be orders of magnitude larger.

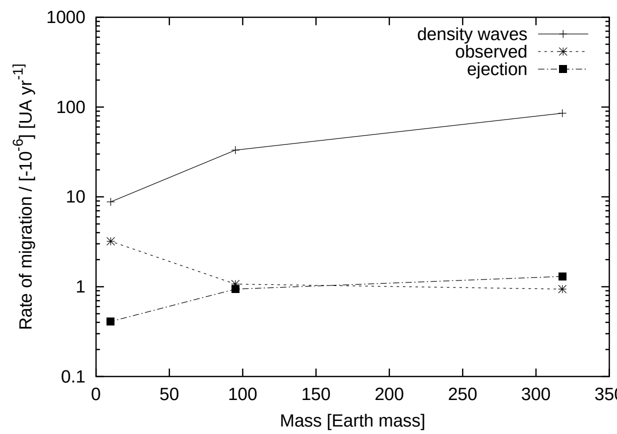

Fig. 1. Migration rate calculated by 2D density waves theory (solid line), the 'observed' in our simulations (dashed line) and the result from the ejection(dash-dotted lines).

Finally, for a complete comparison of migrators in planetesimals and gaseous disks, a more wide range of planetary masses should be simulated (the smaller ones), in particular, for the study of the transition stage between the two types of orbital evolution. We think, in accordance with Ida & Makino (1993), that at 5 UA this stage appears between $0.1M_\oplus$ and masses smaller than M_c.

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