# Radial migration of gap-opening planets in protoplanetary disks

*Kazuhiro Kanagawa[1,2], Hidekazu Tanaka[3], Ewa Szuszkiewicz[1]

1. University of Szczecin, 2. Research Center for the Early Universe, 3. Tohoku University

A large planet orbiting a star in a protoplanetary disk opens a density gap along its orbit due to the strong disk-planet interaction and migrates with the gap in the disk, which is referred to as type II migration. It is expected that in the ideal case, a gap-opening planet migrates at the viscous drift rate. However, recent hydrodynamic simulations have shown that, in general, the gap-opening planet is not locked to the viscous disk evolution. A new physical model is required to explain the migration speed of such a planet. For this reason, we re-examined the migration of a single planet in a protoplanetary disk, by carrying out the two-dimensional hydrodynamic simulations in a wide parameter range.

We have found that the torque exerted on the gap-opening planet is proportional to the surface density at the bottom of the gap. Hence its migration slows down as the gap becomes deeper and wider. Using the gap model developed in our previous studies, we have constructed an empirical formula of the migration speed of the gap-opening planets, which is consistent with the results obtained before in the hydrodynamic simulations performed by us and other researchers. Our model easily explains why the migration speed of the gap-opening planets can be faster than the viscous gas drift speed. Our model can also predict the planet mass at which the transition from type I to type II migrations occurs and provide a gap-opening criterion in terms of planetary migration.

Keywords: Disk-planet interaction, Protoplanetary disk, Type II migration

 