Dust Circulation in Protoplanetary Disks: Effect of Photophoresis

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The radial distribution of dust particles in the protoplanetary disks is important for planetesimal formation. The radial distribution of dust particles is determined by the radial drift of particles, which is induced by the interaction between the gas and the dust. There are the two main mechanisms for the radial drift of dust particles; the radiation pressure, which leads to the outward drift, and the gas drag, which leads to the inward drift. We showed a process of dust circulation in protoplanetary disks using the disk model with the puffed-up inner rim, which has the shadowed region behind (Dullemond et al. 2001). Then, we found that the abundance of dust particles is enhanced in the inner shadowed region of the disk due to dust circulation.

Recently, Krauss and Wurm (2005), Wurm and Krauss (2006) suggested that the dust can move outward in the radial direction due to photophoresis. The photophoresis is based on the interaction between the particle with a radiation-induced non-uniform temperature distribution over its surface and the surrounding gas. Usually, the particle side facing the central star is heated by radiation to a higher temperature than the opposite, dark side. When the gas molecule sticks to the surface, they will leave faster on the hotter side of the particle than on the cooler side. And a net momentum is transferred from the gas molecular to the particle. As a result, the dust particle drifts outward in the radial direction. Depending on the gas pressure, photophoresis can be stronger than the radiation pressure and gas drag at the optically thin region of the disk. Therefore, photophoresis may be effectively influence the motion of dust particles at the inner rim of the disks, where the gas pressure is high and the disk is optically thin. At the inner rim, the size and the density of particles change due to the evaporation and re-condensation.

In this presentation, we will show the results of numerical simulations of dust circulation, taking the effect of photophoresis into account.