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Photophoresis and the rotation of dust particles in turbulent circumstellar gas disks

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Protoplanetary disks become optically thin to the central star's light, after the number of small dust particles has reduced due to the dust growth. A particle receives the starlight directly and the surface facing to the star becomes hotter than the opposite surface. If the disk gas still remains, then the gas molecules are adsorbed and ejected at the surface. The gas molecules ejected from the hotter surface have higher velocities than those from the colder surface. Consequently, the particles receive the photophoretic force and are pushed in the direction of the light.

If the particle rotates quickly, the light illuminates the whole surface homogeneously and the surface temperature becomes constant, resulting in suppression of photophoresis. The rotation timescale due to Brownian motion is not rapid enough. In this presentation, we consider the rotation due to the turbulent motion of the gas.

We assume the Kolmogorov scaling law for isotropic turbulence. The size and the velocity of the largest eddies are alpha^(1/2) times the disk thickness and the sound speed, respectively, and alpha=0.01. The rotation timescale of the particle is assumed to be same as the rotation timescale of the smallest eddies that the particle synchronizes. We compare the rotation timescale to the thermal relaxation timescale.

The thermal relaxation timescale is shorter than the rotation timescale. Consequently, the gas turbulent motion does not induce rotation of the dust particles rapid enough to suppress photophoresis.