ON THE PHOTOPHORETIC FORCE EXERTED ON MM- AND SUB-MM-SIZED PARTICLES.

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Introduction: Photophoresis is one of the two major forces caused by directed illumination acting on a solid particle suspended in rarefied, effectively infinite gas (radiation pressure being the other). Caused by interaction of the gas with the heated particle surface, photophoresis results in momentum transfer between gas and particle.

Photophoresis on realistically shaped particles and perfect spheres has previously been investigated in pressure ranges where the mean free path of the gas exceeds the size of the suspended particle [1]. Two new, unprecedentedly accurate, approximations for longitudinal photophoresis are introduced. One is temperature-based, while the other relies on the macroscopic parameters light flux, radius and thermal conductivity, as well as thermal radiation. For homogeneous, realistic particles, an almost perfect match of the directional mean photophoretic force with the force acting on a sphere with the same volume is found (all remaining parameters kept constant). To describe the force exerted on inhomogeneous particles, an effective thermal conductivity is introduced [1], [3]. Both variables enable description of the average photophoretic strength on realistic particles by the same means originally derived for spheres. Drop tower experiments were performed to test our models [2]. Rotation, collisions and reorientation all reduce the photophoretic strength. In particular, rotation can lead to particle trajectories diverging from the direction of light. A numerical model of rotating spheres can explain this behavior. However, rotation in protoplanetary disks is quickly damped and thus not relevant.

Application: Photophoresis can drive transport and sorting of chondrules. One region where it might occur is the inner edge of the disk. A size-sorting mechanism is inferred from differing average sizes of chondrules in different meteorite classes [4]. Photophoretic metal-silicate fractionation in the solar nebula has also been proposed [5]. These ideas both suggest more local transport. We find that thermal radiation arising from temperature fluctuations within a disk can drive local photophoresis. This leads to local particle concentration and sorting due to size and composition, as well as higher collision velocities that could assist coagulation and ultimately planetesimal formation.

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