Photophoresis: transporting hot minerals to comets.

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Crystalline silicates have been detected via remote sensing in a growing number of comets [1] [2] [3]. Moreover, high-temperature minerals such as fosterite (Mg_2SiO_4) and enstatite ($MgSiO_3$), along with grains resembling calcium-aluminium inclusions (CAIs), have been indentified in the samples returned from Comet 81P/Wild 2 by the Stardust mission [4]. All these minerals were formed at moderately to extremely high temperatures in the solar nebula (reaching 1400-1500 K for CAIs [5]).

Since comets are presumed to have formed in the cold outer part of the solar nebula, some processes of transport need to be invoked in order to explain the origin of the detected high-temperature minerals. Here, we describe a mechanism alternative to the diffusive transport or shock waves scenarios proposed in the literature [6] [7].

In some thermodynamic formulations of the solar nebula (when the existence of an inner gap is postulated), the disk becomes optically thin enough for particles to see the proto-Sun, but still has a reasonable gas content, enabling the photophoretic force to push dust grains outward. This provides a mechanism to transport high temperature material from the inner solar system to the regions in which the comets were forming. Eventually, the dust driven outward in this manner will reach a region where the gas pressure is so low that the combined outward forces of radiation pressure and photophoresis can only balance the inward effects of gas drag. Depending on the nebula model considered, this can lead to a 'pile-up' of dust between 5 and 23 AU. Such a process would result in an influx of hot minerals to the regions in which Edgeworth-Kuiper belt and Oort Cloud bodies were forming, which could result in a "dust-loading" of these bodies.

In this work, we use a time-dependent model of the solar nebula [8] to describe the outward transport of particles in the form of hot mineral aggregates with sizes ranging between 10^{-5} and 10^{-1} m to the outer regions via photophoresis [9] [10] [11]. These aggregates are presumed to be assembled from hot mineral individual grains ranging down to the submicron size. We consider these hot minerals to be formed from condensation in the hottest portion of the solar nebula, well inside 1 AU. From these assumptions, we show that, despite Rayleigh scattering adding a significant contribution to opacity in the nebula, photophoresis can be considered as an alternative transport mechanism to explain the presence of hot minerals in the formation regions of comets.

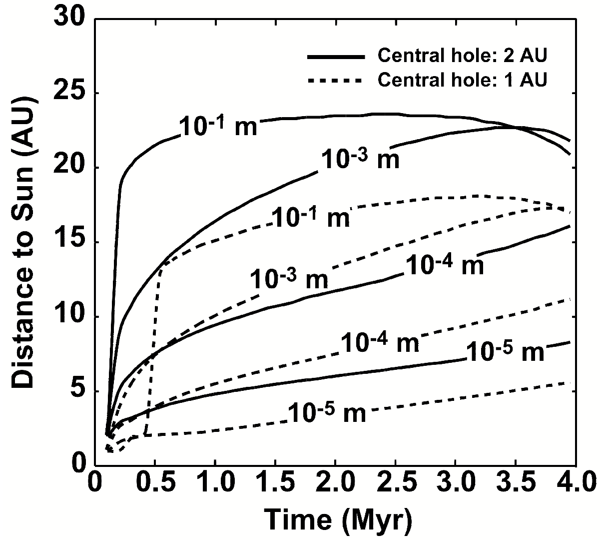

Figure 1: From bottom to top: position of particles of size 10^{-5} to 10^{-1} m, as a function of time and of the radius (AU) of the inner gap in the nebula. Positions of particles of size 10^{-2} to 10^{-1} m remain superposed with time.

References

[1] J. et al. Crovisier. *Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths*, 196:109–117, 2000.

[2] M. L. et al. Sitko. *Astrophys. J.*, 612:576–587, 2004.

[3] D. H. et al. Wooden. *Astrophys. J.*, 612:L77–L80, 2004.

[4] D. et al. Brownlee. *Science*, 314:1711–, 2006.

[5] R. H. et al. Jones. *Protostars and Planets IV*, pages 927–+, 2000.

[6] D. et al. Bockelée-Morvan. *A&A*, 384:1107–1118, 2002.

[7] D. E. Harker and S. J. Desch. *Astrophys. J.*, 565:L109–L112, 2002.

[8] Y. et al. Alibert. *Astrophys. J.*, 622:L145–L148, 2005.

[9] O. Krauss and G. Wurm. *Astrophys. J.*, 630:1088–1092, 2005.

[10] G. Wurm and O. Krauss. *Icarus*, 180:487–495, 2006.

[11] O. et al. Krauss. *A&A*, 462:977–987, 2007.