The Role of Tholins on Solar System Bodies

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Solid bodies in the outer Solar System exhibit colors ranging from neutral to very red. Objects of low albedo (0.01-0.15) commonly show a red slope extending somewhat longer than 1 µm, while icy planetary satellites with much higher albedo (0.2 - 1.0) also have varying degrees of color, but the positive spectral reflectance gradient of these bodies is usually limited to the wavelength region 0.2-0.6 µm. Gradie and Veverka (1980) introduced the concept of *organic solids* to explain the red color of D-type asteroids, suggesting the presence of "…very opaque, very red, polymer-type organic compounds, which are structurally similar to aromatic-type kerogen".

Tholins, the refractory residues from the irradiation of gases and ices containing hydrocarbons, have color properties that make them reasonable candidates for comparison to the spectra of Solar System bodies (Cruikshank et al. 2005). Furthermore, they are produced in laboratory conditions that are reasonably analogous to the conditions of the exposure of atmospheric gases and surface ices in planetary settings in various natural environments. Several tholins have been prepared in the context of the photochemical aerosols in Titan's atmosphere (e.g., Khare et al. 1984; Coll et al. 1999, 2001; Ramíriz et al. 2002; Tran et al. 2003; Imanaka et al. 2004), and while they are optically (spectrally) similar to Titan's aerosol haze, they have until recently proven difficult to analyze and characterize fully from a chemical point of view. The recent work, for example by Tran et al. (2003), and Imanaka et al. (2004), has greatly improved the analysis and characterization of a class of tholins produced by cold plasma irradiation of gaseous mixtures of N_2 + CH_4 (9:1). Other recent analyses focusing on the reflectance of Titan's surface measured by Huygens *in situ* include Bernard et al. (2006), Quirico et al. (2008), and Carrasco et al. (2009).

The current status of applications of tholins to models of the colors of planetary surfaces, including Pluto, will be reviewed, together with alternative possibilities under investigation in the lab and computationally.

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June 30, 2011