Dynamics of Icy Grains in the Near-Nucleus Comae of Comets

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It has been suggested that icy grains play a role in the production of water in the comae of many comets (e.g., A'Hearn and Cowan 1980, Harris et al. 1997, Kawakita et al. 2004, McCarthy et al. 2007). First direct detection of individual icy grains in a cometary coma was carried out by the EPOXI mission during the comet 103P/Hartley 2 flyby (A'Hearn et al. 2011). This direct imaging of individual icy grains provides an opportunity to characterize the size and the spatial distributions of the icy grains (Kelley et al. 2011, Protopapa et al. 2011, Hermalyn et al. 2012).

Our coma dynamics code (Tricarico and Samarasinha 2011a,b) monitors the orbital dynamics of dust grains in the coma. The necessary modifications were made to this code in order to explore the orbital dynamics of icy grains in the near-nucleus comae of comets. At the meeting, we will present the results corresponding to icy grains of comet 103P/Hartley 2 based on the model runs and those will be compared with the observations made by EPOXI.

The dynamics code for dust grains incorporates effects due to solar gravity, nuclear gravity, radiation pressure, gas drag, the non-spherical nature of the nucleus, and the rotational state of the nucleus. When considering icy grains, two additional aspects need to be considered: (1) decrease in the icy grain size due to sublimation and how it will alter gas drag and the radiation pressure acceleration, and (2) any non-gravitational acceleration of the icy grain due to a net force caused by sublimation.

The lifetime of an icy grain, T_g, is given by $T_g \sim [\rho * r_g]/[Z*m]$ where ρ is the density of the icy grain, r_g is the grain radius, Z is the sublimation rate per unit area and m is the molecular weight of water. T_g is of the order of a few days for a 1 cm radius grain clearly indicating that the changes in the icy grain size is relevant for determining the gas drag and the radiation pressure effects.

If the sublimation occurs from the entire surface of the icy grain (i.e., assuming an isothermal icy grain), then the timescale for changes in the rotational state of the icy grain, T_r, is given by $T_r \sim [\rho * r_g^2]/[P*Z*m*V]$ where P is the rotational period of the grain and V is the velocity of the sublimating gas. For a 1 cm radius icy grain, T_r is of the order of 1/P seconds when P is expressed in seconds. If, T_r is unlikely to be greater than a few seconds, this suggests that the rotational state could vary over timescales of a few seconds or less and one can ignore the effects of sublimation forces on the orbital dynamics as the time-averaged net force due to sublimation in the initial frame is nearly zero. However, if the isothermal assumption is not exactly valid, there could be a net non-zero non-gravitational acceleration proportional to r_g^{-1} in the anti-sunward direction caused by preferentially sunward sublimation.

Therefore, the dynamical model to calculate the distribution of icy grains will include changes to the icy grain radius. The effects due to a non-zero yet small (e.g., comparable to radiation pressure) sublimation force on the orbital dynamics will also be explored.

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References:
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