COMMENTS ON COMET SHAPES AND AGGREGATION PROCESSES

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An important question for a comet mission is whether comet nuclei preserve information clarifying aggregation processes of planetary matter. Planets are too big to do so, and many (most) asteroids in the main asteroid belt have probably undergone enough metamorphism and/or collisional evolution to alter original aggregate textures resulting from low-velocity accretion processes, either on a micro- or macro-scale.

A common unexamined paradigm is that comets were thrown into the "deep freeze" of the Oort cloud during planet growth, and thus preserve "primitive" properties that can be found in no other solar system bodies. This common view may turn out to be naive. Comets could not be ejected until giant planets had grown, and the growth processes pumped up approach velocities of planetesimals. The whole accretion environment was one of collision, and by the time comet nuclei were ejected, they may have undergone collisional evolution, both in the original low- velocity accretion regime and in a later higher-velocity regime, perhaps inducing some fragmentation. Thus, while comets undoubtedly had less total collisional evolution than belt asteroids, the total collisional and velocity history is an unresolved problem.

The granularity of texture, at micro- to macro-scales, is an important indicator of this history, and can be studied by spacecraft. We anticipate that the aggregation phase occurred at very low relative velocities. The initial texture of the comet nuclei aggregates may have been on of fluff-balls of ice/soil crystals and grains at a micro scale. Sufficiently high resolution view might reveal whether such texture is present.

Another unexamined paradigm is that planetesimals grew out of innumerable small grains -- rather like building a 10-km body out of sand grains or peas. This has led to an almost unconscious supposition that primordial planetesimals (primitive comet nuclei?) were relatively spheroidal, and that the irregular shapes found among asteroids are due to fragmentation events, which produce splinter-like fragments. According to that view, unaltered primitive comet material may consist of innumerable small, highly-compacted grains (< meter-scale), but no larger sub-units (> km-scale), and unfragmented asteroids would be relatively spheroidal.

That view is being challenged by unexpected new observational evidence. Hartmann et al. (1987, 1988) and French (1987) have found that Trojan asteroids, as a group, display a higher fraction of highly-elongated objects than the belt. More recently evidence has accumulated that comet nuclei, as a group, also display highly-elongated shapes at macro-scale. This evidence comes from the several comets whose nuclear lightcurves or shapes have be well studies. Figure 1 shows this evidence.

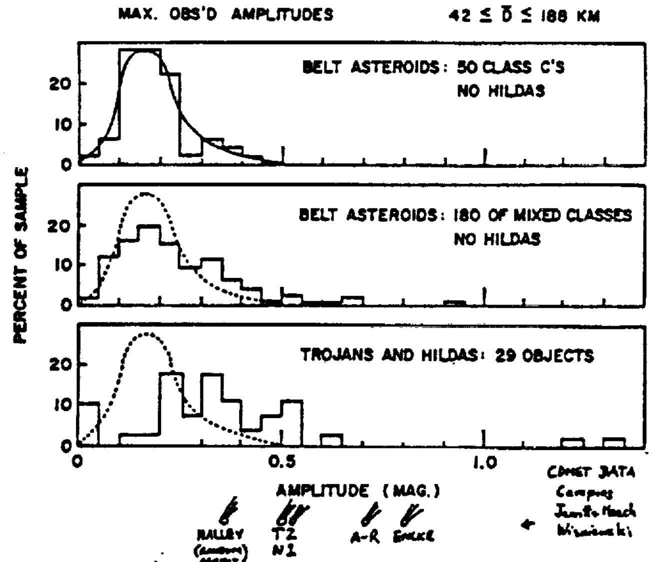

Figure 1. Histograms of frequency distribution of amplitudes of samples of main-belt asteroids (top and middle) and Trojan asteroids (bottom). Bell curve repeats a rough fit to the top distribution, for reference. Trojans have a tail of highly irregular shapes. At bottom are data for several comets, indicating that they, too, have irregular shapes.

Intriguingly, Trojans and comet nuclei share other properties. Both groups have extremely low albedos and reddish-to neutral-black colors typical of asteroids of spectral class D, P, and C. Both groups may have had relatively low collision frequencies.

An important problem to resolve with spacecraft imaging is whether these elongated shapes are primordial, or due to evolution of the objects. Two hypotheses that might be tested by a combination of global-scale and close-up imaging from various directions are:

(1) The irregular shapes are primordial and related to the fact that these bodies have had lower collision frequencies than belt asteroids. This could arise if the planetesimal population produced moderate size bodies (such as km-scale Goldreich-Ward planetesimals), which then "fell together," accreting at such low velocities that they produced "compound asteroids" in which original lumpy shapes have been preserved. Donn has shown growth of such irregular shaped bodies in a theoretical modelling program. In this case, imaging might show residual shapes of the initial, aggregated, bodies, stuck together like snowballs in a snowman, with possible smoothing by subsequent collisions.

(2) The irregular shapes may be due to volatile loss. This seems possible since they appear in volatile-rich bodies, and not so frequently in main-belt asteroids. Colwell and Jakosky (1987, Icarus) have described increase in topographic extremes due to sublimation and insolation considerations. Comets might evolve toward more elongated shapes. This could explain observed spontaneous splitting as an end result. Spacecraft observation of jetting and fissure evolution might clarify this process.