Disruption and Splitting of Cometary Nuclei

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Disruption and/or splitting events associated with cometary nuclei have been observed at an increasing rate in the past decade as the quality and quantity of cometary observations have increased. It is now recognized that splitting and disruption events may be a common process among comets and may be the principal physical loss mechanism for nuclei, far more so than outgassing and/or collisions with other solar system bodies. Disruption and splitting events fall into two categories: tidal and random. Tidal splittings are caused by passage of a nucleus through the Roche limit of the Sun or a planet. Classic examples are comet Ikeya-Seki (C/1965 S1) for the Sun and comet Shoemaker-Levy 9 (D/1993 F2) for Jupiter. The tidal forces break the nuclei into many pieces; these fragments may be the original, loosely bound cometesimals that came together to form the rubble-pile nuclei in the primordial solar nebula. Self-gravitation may then reassemble these fragments into multiple smaller nuclei, though not all fragments are incorporated in the new nuclei. Asphaug and Benz (Nature, 1994; Icarus, 1996) showed for comet Shoemaker-Levy 9 that this reassembly provides valuable clues to the bulk density of the cometesimals. Random disruption events occur, as the name implies, at random times in the comets' orbits and do not show any correlation with time of perihelion passage, perihelion distance, distance above or below the ecliptic, etc. Classic examples are comet 3D/Biela (1852 III) and comet LINEAR (C/1999 S4). Random disruption events range from small, short-lived fragments breaking off a main nucleus, to the creation of multiple returning comets, to total disruption and disappearance of the comet. The physical explanation for random disruption events is lacking. Weissman (A&A, 1980) showed that random disruption events were observed about 10% of the time for dynamically new long-period comets, ~4% of the time for returning long-period comets, and ~1% of the time for periodic comets (per orbit). The statistics suggest that the probability that a comet splits or disrupts involves some intrinsic physical property of the nucleus, whereby comets that are likely to split do so early in their dynamical evolution, and that comets resistant to random disruption survive far longer in both time and cumulative number of orbits. Disruption events are likely related to cometary outbursts but again, the specific physical mechanism(s) is unknown. Some suggested mechanisms are: 1) rotational spin-up due to outgassing torques; 2) sudden pressure release from pockets of volatile gases and ices (more volatile than water); and 3) the transition of cold amorphous ice into crystalline ice, which is an exothermic reaction. Impacts with solar system debris are likely too infrequent to provide a plausible explanation for disruption events. The current observational evidence and the suggested mechanisms will be discussed. This work was supported by the NASA Planetary Geology & Geophysics Program and was performed at the Jet Propulsion Laboratory/California Institute of Technology.