Progress on the Search for Binary Asteroids

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We describe a program to detect binary asteroids by imaging and discuss some of the results. Since 1998, our group has been performing observations of (primarily) main-belt asteroids in search of companions. In that time, we have acquired data on over 500 asteroids, and have found a frequency of binaries near 2%. Similarities and differences in the characteristics of the systems give clues to the collisional environment and mechanisms of formation. Computation of the orbits allows a determination of the density of the primary asteroid.

After decades of speculation and unconfirmed reports of discovery, we have finally reached the point where asteroid satellites, although not common, have been detected within most dynamical populations of asteroids (NEAs, main-belt, Trojans, TNOs). The first satellite of an asteroid was discovered in 1993 from imaging data of Ida during the flyby of the Galileo spacecraft. In 1998, our group reported the first verifiable discovery of a satellite from Earth, when we found that Eugenia had a small moon. Since that time, more than a dozen additional main-belt binaries have been found, and among all populations 40 binaries are known.

Discovery and study of binary asteroids allows us to determine the bulk density for the primary asteroid, which in turn yields information on the composition and structure (e.g. bulk porosity). This is usually the only way we can get asteroid densities other than by expensive flyby or orbital spacecraft missions. The densities are of particular importance for some asteroid populations, such as the Trojans, because we may not even have meteorite samples to guide us on composition or microporosity. Binary asteroids also provide a real-life laboratory for studying the results of collisions. The binaries we see are almost certainly the result of collisions, a ubiquitous process in the past and present solar system. The populations of binaries we observe must be the result of steady-state collisional processes that create and destroy these systems. In some cases, e.g., among very young (few MY) dynamical families, we may have an opportunity to observe the results of binary production from catastrophic collisions before enough time has passed for destruction of the systems by subsequent collisions or dynamical instabilities. We have recently begun a combined ground-based and HST program that targets just such populations.

Most of the detections among main-belt and Trojan asteroids have come about as a result of the advancement of adaptive optics (AO) technology. Distortion of the wavefront caused by Earth's atmosphere is detected and corrected, in real time, at up to kHz rates, by AO techniques. When employed on large telescopes (4-10m-class, such as Keck, VLT, Gemini, and CFHT), diffraction-limited imaging can result, achieving angular resolutions as small as 0.04 arcsec.

One of the major results of our work is the discovery that most C-like asteroids have very low densities, typically of about 1.3 g/cc, but as low as about 1.0 g/cc. These seem to be distinctly different than the typical S-like density of about 2.5 g/cc. This may imply a substantial difference in the internal macroporosity of these objects, possibly between a rubble-pile structure and a fractured-in-place shard.

Most of the binaries are seen around larger C-like primaries. The satellites occur in orbits at about 10 primary radii, and are small relative to the primary. We believe these objects were formed by a mechanism of reaccretion of ejecta, in orbit, from a large impact, as described by Weidenschilling et al. (1989, Asteroids II) and further by Merline et al. (2002, Asteroids III). Interestingly, the two smallest main-belt asteroids known to be binary, are both S-type and show loosely-bound companions that are larger, relative to the primary, than those in the C-like systems. These are likely to be examples of systems formed as co-orbiting ejecta fragments from a catastrophic impact, also predicted by Weidenschilling et al. New models of both of these formation mechanisms are being made by Durda et al. (2003, LPSC).

Overall, we find that at least 3 mechanisms are likely to be required to explain the main-belt binaries alone. Yet other mechanisms are probably needed to explain binaries in other populations.