Radar characterization of asteroids and comets

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Radar observations are one of the few ground-based techniques that reveal shapes and surface details of asteroids and comets. Since 1998, over 400 asteroids and 15 comets have been detected by radar at either the Arecibo Observatory, the Goldstone Solar System Radar, or both. With resolution as fine as 7.5 m at Arecibo and 3.75 m at Goldstone for the highest signal-to-noise (SNR) observations, the images show a variety of shapes. Nearly 60 percent of near-Earth asteroids (NEAs) detected are of high-enough SNR or have enough time coverage to at least categorize the shape. At least 35 percent of the NEAs are spheroidal, including the 15 percent that are binary or multiple systems. These NEAs, with diameters less than a few kilometers, must have little or no internal strength, in order to have a spheroidal shape. Contact binary, or two-lobed objects, where the lobes are nearly the same size, may also be strengthless. NEA contact binaries may have formed by being spun up, but then failing to form a stable binary system. Few cometary nuclei have been imaged using radar, but several of those also seem to have a contact binary, or two-lobed structure. 103P/Hartley 2, and 8P/Tuttle both have nearly equal lobes joined by a narrow waist [1,2]. The very slow rotation rates of comet nuclei compared to most asteroids suggests that they may not share a common formation mechanism.

Radar measurements also give an instantaneous measure of the line-of-sight velocity of the asteroid limb, which is proportional to the rotation rate for an equatorial view. NEAs with $H > 21$ (diameter smaller than 150–300 m) frequently have rotation rates well beyond the spin limit for a strengthless body. However, not all small asteroids are rotating at very rapid rates. Lightcurve measurements become difficult for very small asteroids, which are not observable for long periods of time and have rapidly changing viewing geometries. Radar measurements of the rotation rates, while affected by projection effects, can give useful statistics and are not biased against very slow rotation rates. Comparison of lightcurve rotation rates [3] and those derived from radar measurements agree very well overall. We do see some slowly rotating asteroids with radar, but we do not seem to be missing a large population of these objects.

Both shape and spin rate give clues to internal structure, and, as we sample smaller sizes, we may be able to determine the size at which the transition occurs from strenghless rubble piles to those having components with internal strength. Compositional characterization has lagged behind discovery and orbital characterization, but has steadily increased nonetheless. Binary NEAs are seen in all taxonomic classes, and formation efficiency does not seem to depend strongly on composition. Other shapes and spin configurations also do not seem to be correlated with composition, although the statistics are not yet very large. The effort to characterize NEAs and comets using radar observations, in concert with observations at other wavelengths whenever possible, will be presented.

References: [1] Harmon et al. (2010) Icarus 207, 499–502. [2] Harmon et al. (2011) Ap.J., 734, L2. [3] Warner, B. D. (2009) Icarus 202, 134–146.