RADAR OBSERVATIONS OF ASTEROIDS: PROGRESS AND PERSPECTIVES

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Radar is a uniquely powerful source of information about asteroid physical properties and orbits. Measurements of the distribution of echo power in time delay (range) and Doppler frequency (radial velocity) constitute two-dimensional images that can provide spatial resolution as fine as a decameter if the echoes are strong enough. With adequate orientational coverage, such images can be used to construct geologically detailed three-dimensional models, to define the rotation state precisely, and to constrain the object's internal density distribution. The size of radar wavelengths (3.5 cm to 13 cm) and the observer's control of transmitted and received polarizations makes radar sensitive to surface bulk density and macroscopic structure. Since delay-Doppler measurements are orthogonal to optical angle measurements and typically have a fractional precision between 10^-5 and 10^-9, they are invaluable for refining orbits and prediction ephemerides: a single radar detection secures the orbit well enough to prevent "loss" of newly discovered asteroids, shrinking the instantaneous positional uncertainty by orders of magnitude with respect to an optical-only orbit.

The years since the publication of Asteroids II have seen critical developments in technical aspects of asteroid radar, including telescope upgrades and increases in sensitivity and versatility, the evolution and optimization of observational techniques, and the invention of analysis methods that optimize extraction of information from radar images. [Concurrently, the number of persons engaged in asteroid radar astronomy has increased dramatically. The core of people responsible for this field's recent progress includes (alphabetically) Lance Benner, Jon Giorgini, Scott Hudson, Christopher Magri, Jean-Luc Margot, and Michael Nolan.

Radar signatures have been measured for more than 120 asteroids (including 76 near-Earth objects) whose The size and spin-period distributions span four orders of magnitude. C and S mainbelt asteroids have radar albedos (and hence surface bulk densities) that are similar to each other but higher than those of BGFP asteroids. The very large radar albedos of 1986DA, Kleopatra, and Psyche suggest metallic compositions. The accuracy of constraints on the shape of Eros derived from relatively weak echo spectra gives us confidence in physical modeling from much stronger data sets. Images of Toutatis, 1999 JM8, and Mithra reveal geologically complex objects in slow, non-principal-axis spin states. 1998 ML14, 1999 RQ36, 7822 (1991 CS) and Ra-Shalom are unelongated; 1982TA has a triangular pole-on shape; and Castalia, Mithra, and Bacchus are bifurcated and may be contact binaries. Golevka is the most angular object imaged so far, with significant exposure of regolith-free rock. 1998 KY26, with the lowest rendezvous delta-V of any asteroid with a well known orbit, apparently is a carbonaceous chondritic, rapidly rotating, ~30-meter spheroid. Kleopatra is a dogbone-shaped, metallic object nearly the size of Sicily; its surface and perhaps most of its interior is unconsolidated rubble. The near-unity polarization ratios of Adonis, Eger, and 1992QN indicate extreme near-surface roughness at cm-to-m scales, and the km-sized object 3908 Nyx is extremely rough at cm-to-100-m scales. The potentially hazardous asteroids 2000 DP107 and 2000 UG11 are binary systems.