

session J6 Radar/Radio Studies in the Solar System

Radar Investigations of Asteroids

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Resolution of an asteroid's echoes in Doppler frequency and/or time delay provides 1-D or 2-D images, and hence direct measurements of the asteroid's size and shape even though its angular extent is tiny compared to that of the radar beam. Because of the macroscopic wavelengths employed, radar is sensitive to near-surface porosity, metal abundance, and structural scales larger than a few centimeters. Apart from physical characterization, radar is invaluable for refining orbits and prediction ephemerides, because delay-Doppler measurements are orthogonal to optical angle measurements and typically have a fractional precision between 10^{-5} and 10^{-8} .

During 1980-1992, echoes from 37 mainbelt asteroids (MBAs) and 31 near-Earth asteroids (NEAs) have provided new information about these objects' physical and dynamical properties. Many of the most interesting results of this research involve the observations of NEAs, of which about 200 have been discovered, all within the past century and most during the past five years. The current NEA population is thought to contain some 1000 kilometer-sized objects and some 100,000 objects at least as large as a city block. Such small bodies are very difficult to study with groundbased optical telescopes, but radar observations can provide high-resolution images of NEAs if the echoes are strong enough.

For example, 1989 Arecibo radar observations of 4769 Castalia revealed it to consist of two half-mile-diameter lobes that appear to be in contact. More recently, during the closest approach to Earth of any known asteroid or comet between 1992 and 2003, Goldstone observations of 4179 Toutatis revealed it, too, to be a contact binary, but with the lobes in a size ratio of $2/3$. For each of these bodies, it seems likely that the lobes once were separate and that they collided gently to produce the current contact-binary shape. Castalia and Toutatis, the first known examples of solid double objects in astronomy, are also the first several-kilometer-sized bodies in the solar system of which images have been made. The Toutatis and Castalia results, and hints of bifurcations in objects yielding weaker radar echoes, suggest an abundance of "double" asteroids among the Earth-crossing population. The Toutatis images place thousands of pixels on the object, providing fractional spatial resolution comparable to that of the images of 951 Gaspra returned from the Galileo spacecraft in 1991, inversion of all the (Goldstone and Arecibo) data can yield a model of Toutatis that is accurate to 100 m or better.

Radar has established itself as the most powerful groundbased technique for the physical characterization of asteroids. Upgrades underway at Arecibo and Goldstone will dramatically expand the range of those instruments and will optimize their imaging and astrometric capabilities.