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GROUND-BASED RADAR OBSERVATIONS OF POTENTIALLY HAZARDOUS ASTEROIDS

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ABSTRACT

Ground-based radar is a powerful technique for post-discovery dynamical and physical characterization of near-Earth asteroids (NEAs) and spacecraft mission support. The most active radar facilities in the world are the 305-m William E. Gordon telescope at the Arecibo Observatory in Puerto Rico and the 70-m DSS-14 telescope at Goldstone in California (USA), which have averaged 87 NEA detections per year since 2012. While the fixed Arecibo reflector is more sensitive due to its sheer size, Goldstone is more maneuverable and capable of finer range and frequency resolution, making the facilities complementary.

Radar observations are critical for identifying objects that may present a hazard to Earth. The ultraprecise astrometric measurements of line-of-sight distance and velocity, of order tens of meters and millimeters per second, respectively, are

orthogonal to optical plane-of-sky astrometry, reduce orbital-element uncertainties by orders of magnitude, and routinely prevent newly discovered objects from being lost. Over multiple apparitions, radar astrometry greatly aids elucidation of the subtle Yarkovsky orbital drift of asteroids, the largest source of uncertainty for long-term trajectory prediction, and can yield mass estimates. Radar can also provide detailed physical characterizations of asteroids in terms of size, shape, spin, and surface properties (reflectivity, polarization, geologic features and sometimes composition and density) as signal strength allows. In fact, radar-imaging campaigns with resolution as fine as 7.5 meters with Arecibo and 3.75 meters with Goldstone are roughly equivalent in their science content to space flyby missions, but cost orders of magnitude less. Such campaigns have proven invaluable for rendezvous mission planning (*e.g.*, OSIRIS-REx) and will benefit any future impact mitigation efforts. Furthermore, radar is very efficient at unambiguously identifying multiple-asteroid systems that make up ~15% of the NEA population larger than 150 m in diameter, which provides insight into the bulk densities and implied porosities and internal structures of asteroids.

Here, we will specifically look at radar characterization of potentially hazardous asteroids (PHAs). To date, 311 PHAs have been detected with ground-based radar systems; nearly half of all radar-detected asteroids (664) are PHAs. In fact, PHAs, in addition to human accessible targets (see abstract by A.K. Virkki *et al.*), are actively prioritized for radar characterization. We will summarize radar observations of the PHA population and highlight recent observations from Arecibo and Goldstone.

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