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THE ROLE OF RADAR ASTRONOMY IN ASSESSING AND MITIGATING THE ASTEROID IMPACT HAZARD

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ABSTRACT

Radar instruments play a critical role in studies of Near-Earth Asteroids (NEAs) on two distinct levels: trajectory prediction and physical characterization.

Because of superb (~10^{-8}) fractional uncertainties in round-trip delay and Doppler measurements, which are orthogonal to plane-of-sky optical astrometry, radar measurements can decrease orbital parameter uncertainties by factors of 10^3-10^5 and increase the interval over which an object's Earth close approaches can be reliably known at the three-sigma level of confidence by factors of 5-10 (Ostro and Giorgini 2004). The addition of radar data is particularly valuable for single-apparition objects and for objects that have been observed with an optical arc shorter than 10-20 years. The radar benefits can be secured for about 10-25 percent of NEAs within five years of their detection (NASA 2007).

For most NEAs observed on two or more apparitions, the primary source of uncertainty in trajectory prediction is usually the object-specific (and normally unmeasured) Yarkovsky effect. This has been demonstrated for the ~1.2 km diameter object (29075) 1950 DA (Giorgini et al 2002, Busch et al 2007) and the ~270 m diameter object (99942) Apophis (Giorgini et al 2008, Farnocchia et al 2013). Our study of Yarkovsky influences on near-Earth objects show that radar ranges on at least two apparitions improve the precision of the semi-major axis drift rate determinations on average by an order of magnitude compared to optical-only determinations (Nugent et al 2012). Therefore, radar data not only improve trajectory predictions but also improve the knowledge of uncertainties affecting the predictions, which allows for a better quantification of the risk associated with NEAs.

Physical characterization of objects posing a significant risk will be paramount in any mitigation effort. For instance, knowledge of multiplicity will be required. Because 1 in 6 NEAs larger than 200 m is a binary (Margot et al 2002, Pravec et al 2006), it will be essential to conduct radar observations to assess binarity. Optical observations of mutual events can reveal binarity in some geometries, but radar observations can detect satellites even if they do not produce detectable mutual events. Radar observations have uncovered the majority of known binary NEAs and all the known triple NEAs. Effective mitigation efforts would also rely on adequate knowledge of the spin, shape, mass, density, and porosity of the potential impactor. Radar observations provide the most realistic ground-based prospects of securing estimates of all of these quantities. The combination of radar observations with observations at other wavelengths will provide the best possible ground-based characterization and will inform decisions about mitigation approaches.

Efforts in our research group include detailed physical characterization of NEAs, orbit computations for binaries and triples, astrometric measurements, Yarkovsky drift determinations, training of radar observers, development of data-taking hardware and software, development of data-reduction software, improvements to shape modeling software, and development of a publicly-available database for archival of asteroid radar results (http://radarastronomy.org).

References:

Busch et al, Physical modeling of near-Earth Asteroid (29075) 1950 DA, Icarus 190, 2007.

Farnocchia et al, Yarkovsky-driven impact risk analysis for asteroid (99942) Apophis, submitted (http://arxiv.org/abs/1301.1607).

Giorgini et al, Asteroid 1950 DA's Encounter with Earth in 2880: Physical Limits of Collision Probability Prediction, Science 296, 2002.

Giorgini et al, Predicting the Earth encounters of (99942) Apophis, Icarus 193, 2008.

Margot et al, Binary Asteroids in the Near-Earth Object Population, Science 296, 2002.

NASA, Near-Earth Object Survey and Deflection Analysis of Alternatives, Report to Congress, 2007.

Nugent el al, Detection of Semi-Major Axis Drifts in 54 Near-Earth Asteroids: New Measurements of the Yarkovsky Effect. Astronomical Journal 144, 2012.

Ostro and Giorgini, in Mitigation of Hazardous Impacts due to Comets and Asteroids, CUP, 2004.

Pravec et al, Photometric survey of binary near-Earth asteroids, Icarus 181, 2006.