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# The Potentially Hazardous Binary and Triple Near-Earth Asteroids Observed with the Arecibo Planetary Radar System

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## ABSTRACT

Potentially hazardous asteroids (PHAs) are near-Earth objects (NEOs) that are larger than 140 meters and that can come closer to Earth than 0.05 au (~20 Lunar Distances). The population of binary and triple near-Earth asteroids (NEAs) observed with the Arecibo's S-band planetary radar system (2.38 GHz, 12.6 cm) includes 58 objects, 42 of them are classified as potentially hazardous asteroids. It is estimated that binary and triple asteroid systems represent at least 15% of the near-Earth asteroid (NEA) population larger than about 200 meters. Radar can help to discover or confirm asteroid satellites, and delay-Doppler images provide a unique way to characterize multiple asteroid systems, allowing us to extract information about the physical and dynamical properties of the system. The binary PHA observed with Arecibo's radar with the lowest minimum orbit intersection distance (MOID), which is minimum separation between the osculating ellipses, was 2020 BX12, observed on February 4th and 5th, 2020, with a MOID of 0.0024 au (see Zambrano-Marin et al. abstract); followed by 164121 (2003 YT1) and 143649 (2003 QQ47), with a MOID of 0.0026 au and 0.0038 au, respectively. Three out of four triple near-Earth asteroid systems observed at Arecibo are classified as PHAs: 3122 Florence, 136617 (1994CC), and 348400 (2005JF21). In addition, also three out of four equal mass binary systems observed at Arecibo are PHAs: 69230 Hermes, 1994CJ1, and 2017 YE5. The NEA system with the lowest upcoming close approach to Earth is 164121 (2003 YT1), passing at a distance of 0.01133 au (4.4 Lunar Distances) on April 29th 2073. The system with the next known approach within 0.05 au is 488453 (1994 XD), which will fly by Earth at a distance of 0.02 au (~8 Lunar Distances) on June 12th 2023. Radar detection of an asteroid satellite in radar images can provide information such as the separation distance between two components and mutual orbital period, and also makes it possible to estimate the mass of the system and density. This information is valuable to support our understanding of asteroid formation and evolution, as well as planning for small bodies space missions. An example of mission to a binary asteroid system supported by Arecibo radar observations is NASA's Double

Asteroid Redirection Test (DART) to the 65803 Didymos system, the first planetary defense test mission. We will present the population of potentially hazardous binary and triple NEAs observed with the Arecibo's planetary radar system during nearly 60 decades of operations.

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