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Physical Characterization of Binary Asteroid 65803 Didymos and Radar Detection of its Satellite Deflection from the DART Mission Impact in 2022

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ABSTRACT

Binary near-Earth asteroid 65803 Didymos is the target of the proposed Double Asteroid Redirection Test (DART) space mission. The mission consists of a spacecraft that will impact the asteroid's satellite and the effect would be measured by space and ground-based observers.

We observed the binary system using the planetary radars at Arecibo and Goldstone in November 2003. Delay-Doppler radar imaging of the binary system provided range resolutions of up to 15 m/pixel, which placed hundreds of pixels on the

primary. We used the radar data to estimate a shape and spin state for the primary, the secondary size and spin, the mutual orbit parameters, and the radar scattering properties of the binary system. We included lightcurves obtained by Pravec et al. (2006) in the shape model estimation. The primary has a volume equivalent diameter of 780 meters and dynamically equivalent equal volume ellipsoid dimensions along the x, y, and z principal axes of 783 m, 797 m, and 761 m respectively (uncertainties are 3% along the x and y axes, and 5% along the z axis). The extents along the three principal axes are 826 m, 814 m, and 786 m, respectively. The radar data does not provide complete rotational coverage of the secondary but shows visible extents between 75 m and 90 m, implying a diameter of roughly 150 - 180 m. The bandwidth of the secondary in the images indicates a spin period between 9 and 12 hours, which suggests that the secondary spin is synchronized with the mutual orbit period of 11.9 hours. We fit a mutual orbit to the system using the delay and Doppler separations between the binary components and obtained mutual orbit parameters that are consistent with those obtained by Scheirich & Pravec (2009) and Fang & Margot (2012). We obtain a semimajor axis of 1188 ± 33 m, an eccentricity of < 0.045, and an orbital period of 11.93 ± 0.01 hours. The mutual orbit implies a system mass of (5.37 ± 0.44) x 10^{11} kg and a bulk density of 2100 km m^{-3}.

The next time Didymos will be detectable by radar is at Goldstone beginning on September 25, 2022, about 10 days before the proposed DART impact. Arecibo radar observations will be possible after impact starting on October. 24. It is possible that Goldstone will observe Didymos at the moment of impact and/or within a few hours afterward. The close approach distance in 2022 will be 1.5 times larger than in 2003, so the radar signal-to-noise ratios (SNRs) will be six times weaker. Nevertheless, we anticipate SNRs strong enough to obtain radar images with resolutions of 75 m/pixel at Goldstone and 30 m/pixel at Arecibo, which will be sufficient to detect the secondary and spatially resolve the primary. The predicted 7-minute change in the mutual orbit period caused by the DART impact should be detectable by observing the secondary at Goldstone and Arecibo within ~3 weeks of impact.

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