EQUAL-MASS BINARY NEAR-EARTH ASTEROIDS: (190166) 2005 UP156 AND 2017 YE5. Patrick A. Taylor[1], E. G. Rivera-Valentín[1], A. K. Virkki[2], B. D. Warner[3], J. Oey[4], F. C. F. Venditti[2], S. E. Marshall[2], L. F. Zambrano-Marin[2], M. Brozovic[5], S. P. Naidu[5], L. A. M. Benner[5], J. S. Jao[5], A. Bonsall[6], F. D. Ghigo[6], A. Aznar[7], P. Pravec[8], J. L. Margot[9], B. Aponte-Hernandez[1], S. S. Bhiravarasu[1], C. Rodriguez Sanchez-Vahamonde[10], R. McGlasson[11], B. Presler-Marshall[12], and J. D. Giorgini[5], [1]Lunar and Planetary Institute, Universities Space Research Association, 3600 Bay Area Blvd., Houston, TX 77058, USA (ptaylor@usra.edu), [2]Arecibo Observatory, University of Central Florida, [3]Center for Solar System Studies, MoreData!, Inc., [4]Blue Mountains Observatory, [5]Jet Propulsion Laboratory, California Institute of Technology, [6]Green Bank Observatory, [7]Observatorio Isaac Aznar, [8]Academy of Sciences of the Czech Republic, [9]University of California at Los Angeles, [10]University of Western Ontario, [11]Macalester College, [12]Agnes Scott College.

Introduction: To date, only four equal-mass binary asteroids have been discovered among the near-Earth population: (69230) Hermes, 1994 CJ1, (190166) 2005 UP156, and 2017 YE5, all of which have been characterized with radar and optical lightcurves. Equal-mass binaries are relatively rare, making up less than 1% of radar-observed near-Earth objects larger than 200 meters in diameter, compared to ~15% for binaries with more disparate sizes and ~15% for bilobate (peanut-shaped) asteroids. Here, we report on modeling of the most recently observed systems: (190166) 2005 UP156 and 2017 YE5.

Observations: Radar and optical lightcurve observations of binary asteroids are very complementary. Optical observations constrain the spin states of the components, the mutual-orbital period, and the size ratio, while radar observations precisely constrain the sizes, shapes, and scale of the mutual orbit. Whenever possible, radar and optical observations are combined to better understand the physical and dynamical characteristics of multiple-asteroid systems.

(190166) 2005 UP156. The binary nature of near-Earth asteroid 2005 UP156 was shown by distinctive mutual events in its optical lightcurves [1] from 2017 May 4 through June 12. The observed lightcurve period of 40.542 +/- 0.008 h agrees with the period determined in 2014 [2], though no mutual events were noted in 2014. An out-of-eclipse lightcurve amplitude of 0.5 mag suggests the components have significant elongations. Radar observations with the Arecibo planetary radar system (Figure 1) on 15 dates from 2017 June 2 to July 10, when 2005 UP156 was 0.13 to 0.19 au from Earth, unambiguously revealed the nearly equal-size components of the binary system.

2017 YE5. Radar observations with the Goldstone, Arecibo, and Green Bank radio telescopes between 2018 June 21 and 26 showed that 2017 YE5 is also two asteroids of similar size in mutual orbit about each other (Figure 2). The relatively close approach to Earth, only 0.04 au (16 lunar distances), helped make the radar images of 2017 YE5 the best yet of a nearly equal-mass binary system with echo power nearly two orders of magnitude greater than for the more-distant 2005 UP156 encounter. With resolution as fine as 7.5 meters per pixel, these radar images show ten times finer detail than radar images of any other equal-mass binary system.

Figure 1. Arecibo range-Doppler images of (190166) 2005 UP156 with 75-m resolution clearly show the two nearly equal-size components with elongated shapes and their long axes pointed toward each other.

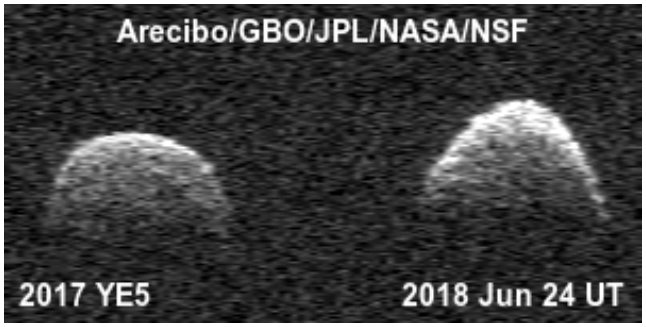

Figure 2. Arecibo-Green Bank range-Doppler image of 2017 YE5 with 7.5-meter resolution clearly shows two nearly equal-size components with somewhat different shapes.

Radar images from consecutive days are remarkably consistent, implying a 24-hour orbital period. Optical lightcurves are more complex, possibly hinting at an additional period in the system. Mutual events were not noted among the optical data until roughly one month after the radar observations.

Results: Modeling of the shapes, spin states, and mutual orbits of these systems is underway and a progress report will be presented.

(190166) 2005 UP156. Preliminary size estimates from radar images are 900 meters in the longest dimension for both components. Images at different orientations confirm their elongated shapes, as expected from the out-of-eclipse lightcurve variations, with the long axes aligned, i.e., face-locked synchronous rotation, and an orbital period commensurate with the optical lightcurve period. The elongations of the shapes suggest equatorial axis ratios of about 1.5 to 1 for both components making these objects possibly the most elongated near-Earth asteroids known to have a satellite. The semimajor axis of the mutual orbit is likely about 2.7 km, implying a density of ~1.6 g/cm^3.

2017 YE5. Both components in the 2017 YE5 system are approximately 900 m in diameter. The radar images suggest the components have somewhat different shapes and possibly also different radar-scattering properties. The system was initially viewed nearly along the mutual-orbit axis and spin axes of the components. A semimajor axis of the mutual orbit of about 1.8 km (four component radii) and a period of roughly 24 hours corresponds to a low density of less than 1 g/cm^3, implying significant macroporosity. Analysis of optical lightcurves, including possible mutual events, collected between 2018 June 24 and August 4 is ongoing and suggests there may be an additional period in the system due to non-principal-axis rotation or precession. Analysis of the radar images suggests the spin axes of the components may also be misaligned by a few degrees.

Conclusions: For both 2005 UP156 and 2017 YE5, the longest dimensions of the components appear to be about 900 meters; however, the similarities end there. The components of 2005 UP156 appear significantly elongated compared to the more spherical components of 2017 YE5. The mutual orbit of 2005 UP156 is much wider at more than 6 component radii compared to only 4 radii for 2017 YE5, in addition to a much longer mutual-orbit period. Despite small-number statistics, there appears to be significant variation in the properties of nearly equal-mass binary near-Earth asteroids. Additionally, the total angular momentum in these systems is 25 to 50% larger than "typical" binary systems with more disparate mass ratios, which must be accounted for in their mechanisms of formation and evolution.

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