RADAR OBSERVATIONS AND CHARACTERIZATION OF BINARY NEAR-EARTH ASTEROID (35107) 1991 VH, A FLYBY TARGET FOR THE PROPOSED JANUS MISSION. Shantanu P. Naidu[1], Jean-Luc Margot[2], Lance A. M. Benner[1], Patrick A. Taylor[3], Michael C. Nolan[4], Chris Magri[5], Marina Brozovic[1], Michael W. Busch[6], Jon D. Giorgini[1], Daniel J. Scheeres[7]. [1]Jet Propulsion Laboratory, California Institute of Technology. [2]University of California, Los Angeles. [3]Lunar and Planetary Institute, Universities Space Research Association. [4]University of Arizona, Tucson. [5]University of Maine, Farmington. [6]SETI Institute, Mountain View. [7]University of Colorado, Boulder.

Abstract: Binary Near-Earth asteroid (35107) 1991 VH is one of the targets of the proposed Janus spacecraft mission, which will fly by two binary asteroids in order to study their formation and the evolutionary implications for small rubble-pile asteroids. 1991 VH was discovered on Nov. 9, 1991 at the Siding Spring Observatory (McNaught et al. 1991). Pravec et al. (1997) found that 1991 VH is a binary system through observations of mutual events (eclipses/occultations) in its lightcurves. The asteroid made a close approach to Earth in August 2008 at a distance of 0.045 au, which provided an excellent opportunity to observe it using Earth-based radar. We obtained an extensive set of radar images and echo power spectra between Jul. 29 and Aug. 12 with Arecibo (2380 MHz, 13 cm) and Goldstone (8560 MHz, 3.5 cm). The images have range resolutions as fine as 15 m that spatially resolve both components in the system. Arecibo images (Figure 1) show that the primary is roughly spheroidal with a visible range extent of 650 m. The images contain clear signatures of an equatorial ridge with longitudinal variations in its appearance. A concavity ~100 meters in extent is present along the ridge. A radar-bright linear feature that casts a radar shadow down-range is visible in some of the images, and occurs at mid- to high-latitudes.

A preliminary fit to images of the primary reveals a top-shaped object with a volume equivalent spherical diameter of roughly 1.2 km that is similar in shape to the (66391) 1999 KW4 primary (Ostro et al. 2006). The mutual orbit determined from the radar data has an orbital period of ~32 hours, a semimajor axis of 3.26 km, an eccentricity of 0.05, and a system mass of 1.5 x10^{12} kg. The orbital parameters are consistent with those estimated by Pravec et al. (2006). Heliocentric orbital fits yield a primary to secondary mass ratio of ~12 and a primary density of about 1500 kg/m^3. The range extents of the secondary echoes vary from less than 100 m to more than 200 m, and the bandwidths vary by about a factor of two, strongly implying that the secondary is highly elongated. Attempts to model the shape of the secondary using a single spin vector have so far yielded poor fits, hinting that the secondary might be spinning in an irregular manner as suggested by numerical simulations by Naidu & Margot (2015).

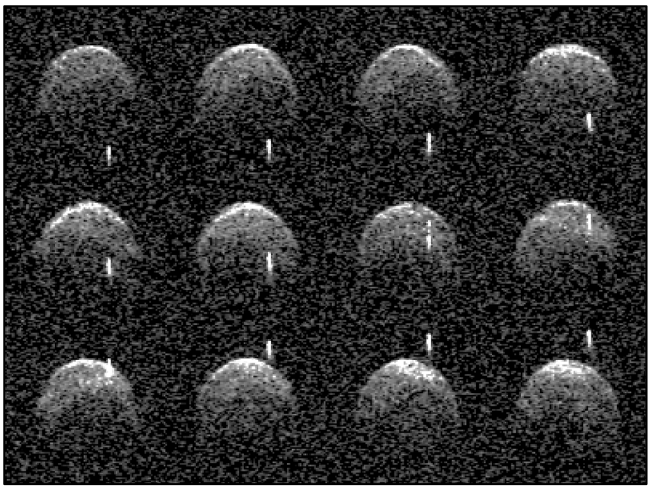

Figure 1. Arecibo delay-Doppler images of 1991 VH obtained on Aug. 7, 2008. Image resolution is 15 m x 0.3 Hz. Each image averages ~13 degrees of primary rotation and ~1 degree of the binary orbit. Images were taken over a span of about 1.6 hours when the asteroid was at a distance of about 0.05 au.

References: [1] McNaught, R. H. et al. (1991). IAUC 5390. [2] Pravec, P. et al. (1997). IAUC 6607. [3] Ostro et al. (2006). Science 314, 1276-1280. [4] Pravec et al. (2006). Icarus 181, 63-93. [5] Naidu, S. P. & Margot, J. L. (2015). AJ 149, 11.