2020 BX12: THE LAST BINARY ASTEROID DISCOVERED BY ARECIBO OBSERVATORY

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Introduction: We present initial results of the radar observations of Near-Earth asteroid 2020 BX12, which was found to be a binary system during the radar observations with the S-band planetary radar system (2380 MHz, 12.6 cm) at the Arecibo Observatory on 2020 Feb 04 and Feb 05. This Apollo-group object was discovered on 2020 Jan 27 by the Asteroid Terrestrial-impact Last Alert System (ATLAS) survey at Mauna Loa Observatory [1], seven days before its close approach, on 2020 Feb 03 (TDB). Its absolute magnitude of 20.8, its Earth minimum orbit intersection distance of 0.0021 au (less than 1 lunar distance), and its close approach of 0.0292 au (within 11.4 lunar distances) classified this object as a Potentially Hazardous asteroid (PHA). Its next close approach will occur on 2101 jan 31 at 0.045 au [1].

Methods: The S-band system transmits a circularly polarized wave, and receives both: the same-sense circular (SC) and opposite-sense circular polarization (OC) as transmitted. Radar observations usually start by a continuous-wave measurement to obtain the Doppler frequency spectrum of the echo. The measured Doppler spectrum bandwidth provides initial limits for rotation period and the object's apparent diameter. For targets with a relatively high signal-to-noise-ratio (SNR) we use phase modulation to produce delay-Doppler images, with range resolution as fine as 7.5 m per pixel in some cases. These images aid in the estimation of objects' diameter, rotation rate and provide an idea of the body's shape [2].

Continuous-Wave spectra: On the first day of observation (2020 Feb 04), the observations in continuous-wave spectra immediately revealed a secondary body, as a narrow echo superimposed on the broader echo of the primary component (Fig 1a). The primary's bandwidth was about 1.6 Hz and the secondary of 0.08 Hz (resolved at 0.04 Hz resolution); we see an offset from the expected zero frequency of about 10.8 Hz. On the second day of observation (Fig 1b), the primary bandwidth was about 1Hz and the secondary was roughly unresolved. The difference in the sizes of the components and their rotation rates is responsible for the bandwidth differences, along with the objects receding motion.

Delay-Doppler imaging: Follow up radar imaging at 0.05 us (7.5 m/px, 0.075 Hz/pixel Hz resolution) resolved the two components of the binary system unambiguously. The primary seems to be of about 160 ± 30 m in diameter with a spheroidal shape, based on its visible extent in this mode of observation. The secondary shape is unresolved, and roughly half the size of the primary.

Results: Preliminary results based on its visible extent in radar images and its observed echo bandwidth, place the estimated rotation period for the primary at 2.8 hr and less than 49 hr for the secondary. The maximum separation observed for the two bodies was roughly 360 m. If we assume the spin axis is aligned with the heliocentric orbit normal, the sub-radar latitude at observation would be at 30 to 40 deg. Radar images roughly 24 hr apart showed a mutual-orbital phase change by about 180 degrees; where the secondary is initially leading the primary to the secondary trailing the primary. This could support a tidally locked secondary and a mutual-orbit period of 45-50 hours, though a shorter orbital period of 15-16 hours has not been ruled out. We estimate an apparent spin rate between 13 and 29 deg/day.

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References: [1] https://ssd.jpl.nasa.gov/horizons/ [2] Black G. J. (2002) *Single-Dish Radio Astronomy: Techniques and Applications, 278,* 271-290.

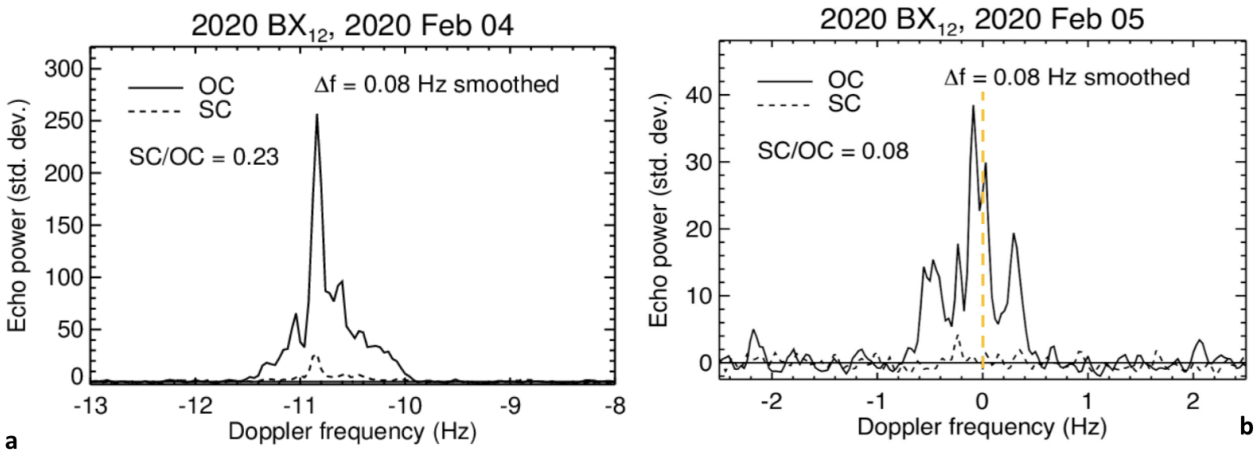

Fig 1: Continuous wave power spectra of 2020 BX12 during both nights of observation, with the Arecibo Observatory.

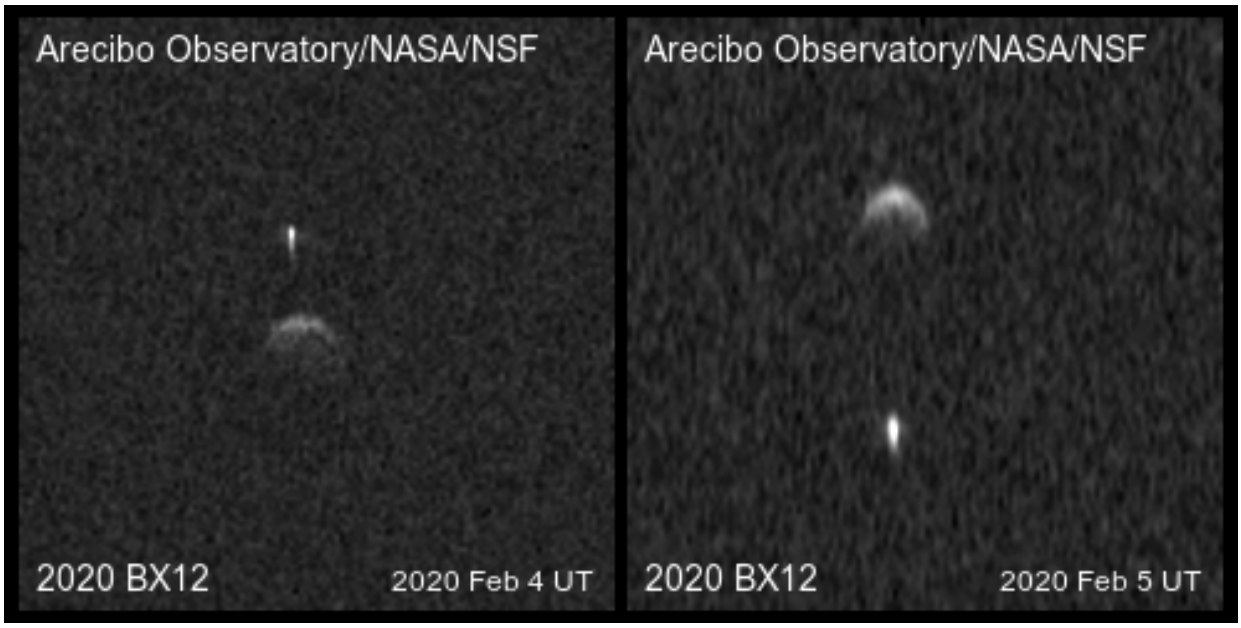

Fig. 2: Arecibo Observatory range-Doppler radar images of binary near-Earth asteroid 2020 BX12 with range resolution of 7.5 m/pixel (vertical axis) and Doppler frequency resolution of 0.075 Hz/pixel (~5 mm/s) horizontal axis. This image suggests the primary is 14 pixels deep at 7.5 m/pixel or 105 meters; the secondary is at least 9 pixels deep or 67.5 m but may be moving

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