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Arecibo Radar Characterization of 138971 (2001 CB21), a Flyby Target for the DART Spacecraft

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138971 (2001 CB21), hereafter CB21, is a potentially hazardous Apollo asteroid that makes frequent close approaches to both Venus and Earth. CB21 was recently selected as the target for a flyby in 2022 March by the proposed DART spacecraft, while DART is en route to the asteroid 65803 Didymos.

On 2006 October 2, CB21 was 0.048 au from Earth and we observed it using the Arecibo Observatory planetary radar. We obtained 9 transmit-receive cycles ("runs") of continuous-wave (CW) radar echo spectra and 75 runs of delay-Doppler radar imaging with a range resolution of 75 m/pixel.

CB21's radar echo bandwidth was 3.3 ± 0.6 Hz (Fig. 1). The radar echoes had a range extent of 4 pixels or 300 m (Fig. 2). This does not allow detailed shape modeling or identification of surface features. We estimate CB21's average diameter as twice the range extent, D = 600 ± 150 m, under the assumption of a relatively spheroidal shape. This is consistent with a diameter estimate from the ExploreNEOs thermal radiometry survey, D = (580 +100 -80) m (Mueller et al. 2011).

Two candidate rotation periods for CB21 have been reported from optical lightcurve observations: P = 3.302 hours and P = 4.953 hours (Galad 2005). The radar echo bandwidth places a lower bound on CB21's maximum equatorial dimension of D_{eq} > 390 ± 80 m for P = 3.302 hours and D_{eq} > 590 ± 120 m for P = 4.953 hours. The radar echo bandwidth is maximized for a given diameter when a target is viewed from the equator. For both candidate rotation periods the echo bandwidth and visible range extent together indicate that Arecibo was not viewing CB21 from high subradar latitude.

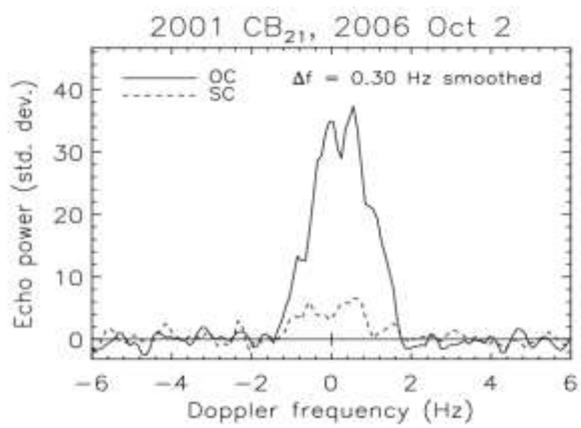

Fig. 1. Arecibo CW radar echo spectrum of 2001 CB21 from 2006 October 2, integrated over 20:04:05 to 20:17:41 UT, processed to provide a frequency resolution 0.3 Hz. "OC" is the opposite sense circular polarization as transmitted; "SC" is the same-sense circular polarization as transmitted. Echo power is given in standard deviations of the noise background.

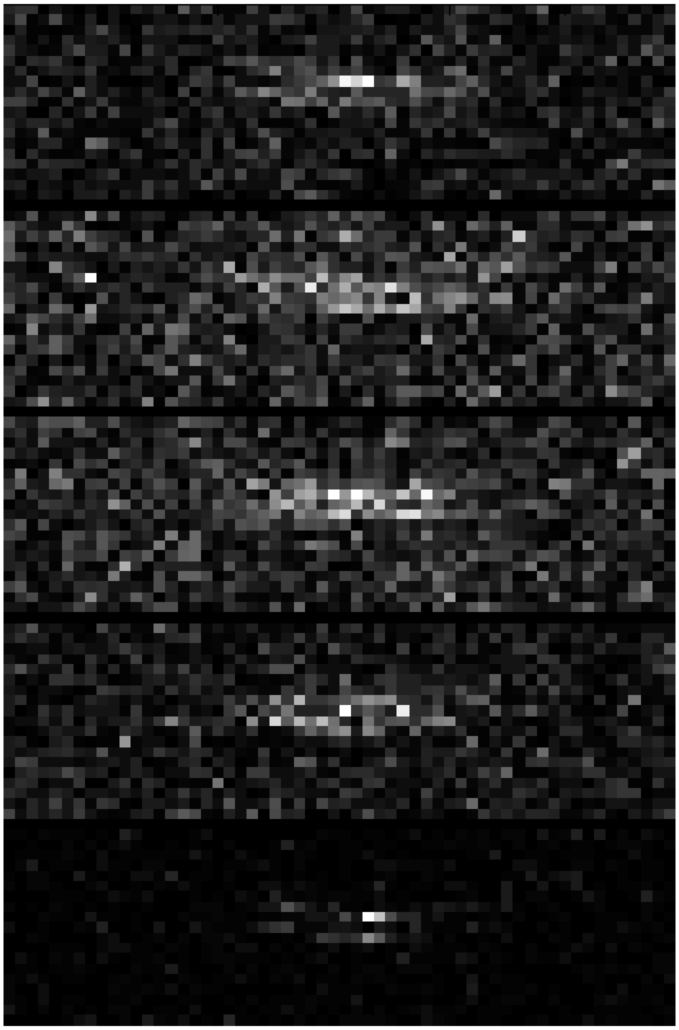

Fig. 2. Collage of Arecibo delay-Doppler radar images of 2001 CB21 from 2006 October 2, covering 20:30:16 to 22:29:20 UT. Within the collage, time increases from top to bottom. Each image is an integrated sum of 15 runs. Within each image, Doppler shift increases from left to right at 0.125 Hz/pixel and round-trip time delay of the radar signal increases from top to bottom at 0.5 µs/pixel - equivalent to 75 m range resolution. Rotation smearing within these images is substantial and surface features are not visible.

There was no significant variation in radar echo bandwidth or delay extent over 2 hours of radar imaging, corresponding to either 60% or 40% of a rotational period. Accordingly, CB21 is at most modestly elongated (elongation < 1.3).

CB21's spectral class is unknown. Its circular polarization ratio, SC/OC = 0.20 ± 0.02, is consistent with a wide range of potential surface compositions but not with the E or V spectral classes (Benner et al. 2008).

No satellites appear in the CB21 Arecibo radar data, to a detection threshold of SNR = 6. We set an upper size limit of 75 m on any undetected satellites, assuming a minimum satellite rotation period of 2 hours and a satellite radar albedo equal to that of CB21.

Radar observations of CB21 will next be possible in 2022 February – March, using both Arecibo and Goldstone. Radar image resolution will be as fine as 15 m when the asteroid is 0.033 au from Earth on 2022 March 4, due to the combination of a closer approach distance and much higher expected transmitter power. The current best-fit to CB21's trajectory has 3-sigma position uncertainty of ±500 km in 2022 March. Covariance simulations show that additional radar astrometry during 2022 February can decrease this uncertainty to ±12 km prior to DART's flyby and significantly reduce risk to the spacecraft.

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