PERGAMON

Planetary and Space Science 50 (2002) 257–260

Planetary and Space Science

www.elsevier.com/locate/planspasci

Radar observations of asteroid 7335 (1989 JA)

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Received 17 September 2001; received in revised form 17 December 2001; accepted 20 December 2001

Abstract

Radar observations of 1989 JA during its discovery apparition yielded dual-polarization echo spectra on two dates at Arecibo and three dates at Goldstone. The echoes indicate that this object has an effective diameter within a factor of two of 1 km, a rotation period less than half a day, and a surface that is fairly smooth at centimeter-to-meter scales. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Asteroids; Radar

1. Introduction

7335 (1989 JA) was discovered by E.F. Helin and colleagues (Green, 1989) at Palomar on May 1, 1989, and passed 0.088 AU from Earth five weeks later. 1989 JA was the 55th Apollo asteroid discovered and the first one discovered as much as a month before closest approach to Earth. We observed it during May 24–June 9, first at Arecibo (2380 MHz, 12.6 cm) and then at Goldstone (8510 MHz, 3.52 cm) (Table 1). 1989 JA was the first asteroid detected at both Arecibo and Goldstone during its discovery apparition.

Optical observations of this object are sparse. The only extant photometry apparently was recorded in the notes of the late W.Z. Wisniewski (published posthumously by Wisniewski et al., 1997) and consists of single magnitude estimates on each of the three nights: May 22, 27 and June 1, 1989. That paper also is the source of the only value in the peer-reviewed literature for 1989 JA's visual absolute magnitude, $H = 17.8 \pm 0.3$, calculated using a slope parameter, G (Bowell et al., 1989) equal to 0.23. Minor Planet Circular 28570, published on October 14, 1989, reported $H = 16.5$ and $G = 0.25$. The range of available values of H allows a range of effective diameters from at least as small as 0.8 km to at least as large as 3.2 km.

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2. Observations

All our observations (Table 1) used a circularly polarized, continuous wave (cw) transmission and reception in the same and opposite circular polarizations (SC and OC). Fig. 1 shows single-date weighted sums of echo spectra at the raw frequency resolution (0.488 Hz for Arecibo and 2.77 Hz for Goldstone) and the same spectra smoothed to maximize the signal-to-noise ratio (SNR). The horizontal scales of Fig. 1 are adjusted so each panel's width corresponds to a radial velocity spread of 3.8 m s^{-1}, so the bandwidths of Arecibo and Goldstone echoes can be compared easily.

Table 2 shows our estimates of radar cross section and circular polarization ratio, SC/OC. 1989 JA's SC/OC is lower than about 80% of the values estimated for near-Earth asteroids (mean ± r.m.s. dispersion $= 0.35 \pm 0.25$) but slightly larger than the average value for main-belt asteroids (mean± r.m.s. dispersion=0.14 ± 0.10). This indicates that 1989 JA's surface is relatively smooth at scales near our radar wavelengths. In other words, there probably are not very many centimeter-to-decimeter-sized rocks on the surface.

The strongest echoes were obtained on May 25/26 at Arecibo. Fig. 2 shows four consecutive, independent sums of five, five, five, and four OC spectra from that track. The cross section estimates for this four-block sequence are, chronologically, 0.062, 0.058, 0.093, and 0.11 km^2 (with relative uncertainties of about 15%), suggesting that the asteroid's projected area may have been higher during the last two

PII: S0032-0633(02)00002-8

Table 1
Observations of 7335 (1989 JA)

Date	Telescope	RA[a]	Dec[b]	RTT[c] (s)	Runs	UTC start–stop hh:mm–hh:mm
May 24	Arecibo	181°	9°	110	6	23:26–23:49
May 25–26	Arecibo	180°	9°	106	19	23:20–00:40
May 28	Goldstone	172°	4°	98	75	01:32–06:43
June 3	Goldstone	148°	−1°	88	29	21:15–22:58
June 9	Goldstone	125°	−23°	97	36	20:42–23:08

[a]RA: Right ascension.
[b]Dec: Declination.
[c]RTT: roundtrip time delay.

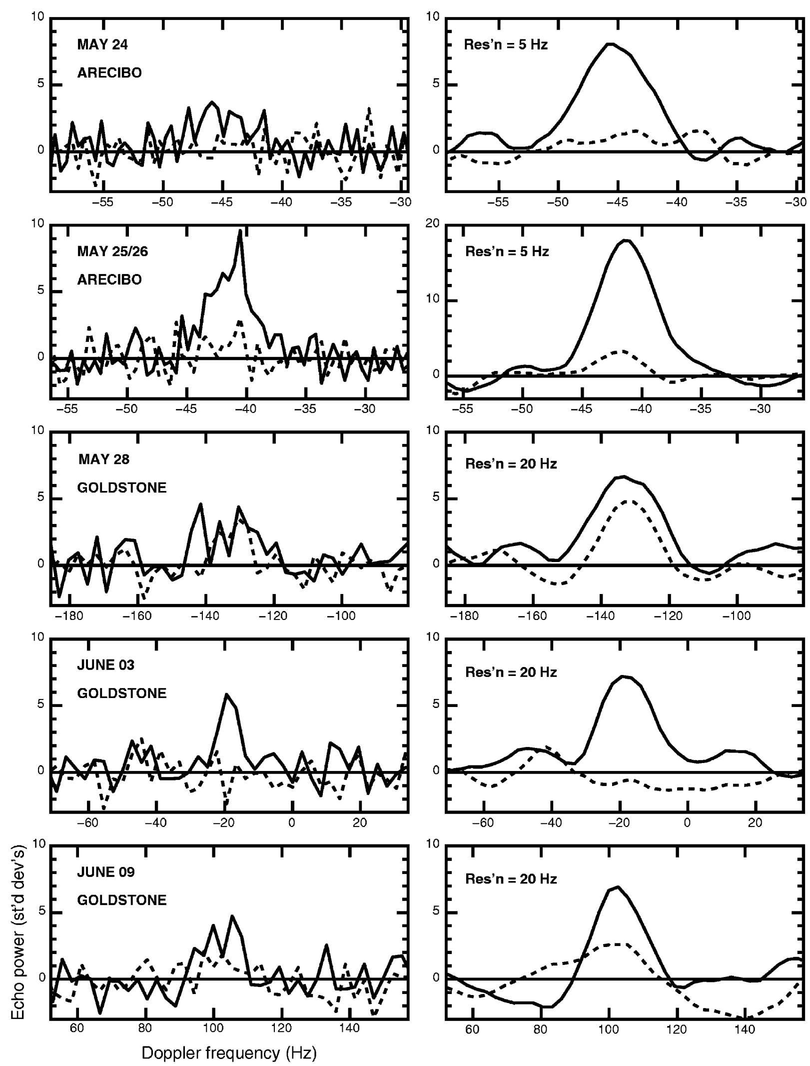

Fig. 1. Sums of echo spectra from each date, in the OC and SC polarizations (solid and dashed curves, respectively). The left column shows spectra at their raw resolution (0.488 Hz for Arecibo and 2.774 Hz for Goldstone). The right column shows the spectra smoothed to the indicated resolutions. The frequency axis labels are with respect to the predictions of the Doppler ephemeris used to take the data. The substantial offsets of the echoes from that ephemeris, which was based on optical observations available at the time, were used to calculate the astrometric results reported by Ostro et al. (1991), which in turn were used by Yeomans et al. (1992) to refine 1989 JA's orbital elements. However, in this figure, the spectra are centered on echo frequencies predicted by an orbit solution that incorporates the radar astrometry as well as optical astrometry obtained during 1989–1996.

Table 2
Radar cross section and polarization ratio[a]

	OC Radar Cross Section (km^2)	SC/OC Ratio
Arecibo	0.08 ± 0.02	0.14 ± 0.05
Goldstone	0.07 ± 0.02	0.24 ± 0.08
Expt. Average	0.07 ± 0.02	0.17 ± 0.04

[a]Cross section errors are dominated by systematic (calibration) uncertainties. The circular polarization ratio suffers just from statistical uncertainties, i.e., from propagation of system noise. All errors given are estimates of 68% confidence intervals.

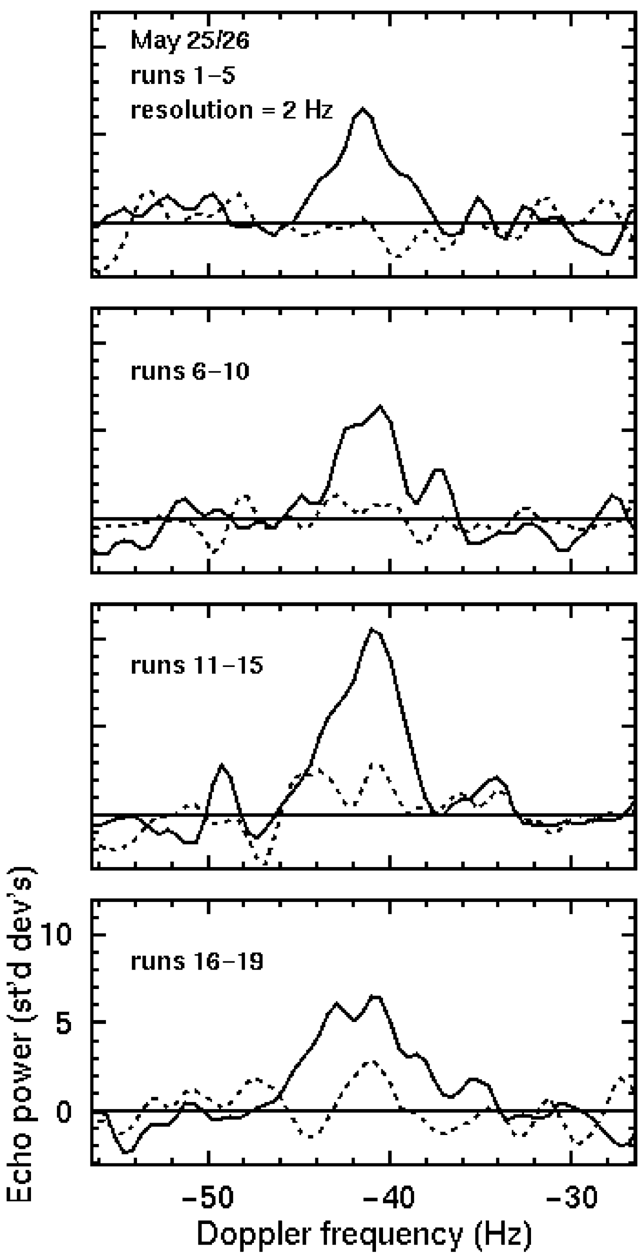

Fig. 2. Several-run sums of Arecibo echo spectra from May 25–26. The axis labels on the bottom panel apply to all the panels. See Fig. 1 second row and caption.

blocks than during the first two blocks. The SNRs of the spectra are too low for us to be able to see whether or not the echo bandwidth is changing during the sequence.

In Fig. 1, day-to-day variations in spectral shape are suggested, but not at a very high significance level. Any variations that are real would be attributable to differences in each date's sampling of rotational orientations and/or in the subradar latitude; the object's sky position changed by more than 60° over the course of our experiment.

A conservative lower bound on the maximum echo bandwidth is 5 Hz at the Arecibo transmitter frequency, thereby providing the joint constraint

$$D_{\max} \cos\delta > 0.18\,P \tag{1}$$

or

$$P < 5.5 D_{\max} \tag{2}$$

on the apparent rotation period P (h), the subradar latitude δ, and the asteroid's maximum pole-on breadth $D_{\max}$ (km). Unless the object is optically much darker than typical C-class asteroids, it is no more than several kilometers in its typical dimension. Thus our lower bound on bandwidth indicates that P is less than one day.

Nonmetallic asteroids observed to date have OC radar albedos between 0.05 and 0.25. If 1989 JA's albedo is assumed to lie in this range, then its effective diameter is between 1.3 and 0.6 km, and even if it is elongated by a factor of two, $D_{\max}$ is unlikely to be more than about 2 km, so P is likely to be less than half a day.

3. Conclusion

All the available information about 1989 JA is consistent with an effective diameter within a factor of two of 1 km, a rotation period less than half a day, and a surface that is fairly smooth at centimeter-to-meter scales. The next opportunity for radar observations of this object is in May–June 2022, when it traverses the Arecibo and Goldstone declination windows prior to a 0.027-AU close approach at declination −45°. Single-date SNRs of at least 1000 are expected at each radar telescope, adequate for decameter resolution imaging and shape reconstruction. The 2022 apparition will be the closest approach since 1454 and until after 3000.

Acknowledgements

We thank the technical staffs of the Arecibo Observatory and the Goldstone Solar System Radar for help with the observations. Part of this research was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration (NASA). Work at the CfA was supported in part by a grant from NASA. P.R. Mahapatra and L.A.M. Benner acknowledge support as Research Associates of the

National Research Council. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a cooperative agreement with the National Science Foundation and with support from NASA.

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