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Radar observations of near-Earth Asteroids using the Quasar VLBI Network Telescopes

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Abstract

We report results of intercontinental bistatic radar observations of near-Earth Asteroids 2011 UW158, 2003 YT1, 2014 JO25 and 2003 BD44 which have been carried out using the Goldstone and Quasar VLBI Network Telescopes for three years. Analysis of observations allowed us to estimate the size and spin period, which agrees with the photometric observations as well as obtain some information about asteroid's shape and near-surface roughness.

1. Introduction

Today, radar astronomy is one of the most effective techniques for determining the physical properties of near-Earth asteroids (NEAs). The size, shape, spin period and surface properties of NEAs can be obtained using radar observations. Since 2015 intercontinental radar observations are regularly carried out at the Institute of Applied Astronomy of the Russian Academy of Sciences in cooperation with the Goldstone Observatory using 70 m antenna (DSS-14) to transmit and 32 m radio telescopes (RT-32) of Quasar VLBI network in Svetloe, Zelenchukskaya and Badary observatories to receive the echoes [1]. Such type of radar observations called bistatic, where the transmitter and receiver are located on different antennas.

2. Observations

Usually the DSS-14 radar transmits a circularly polarized continuous wave (CW) signal at 8560 MHz (3.5 cm). We use two sets of separate channels at the RT-32 telescopes to receive echoes in the same (SC) and opposite (OC) circular polarizations as that of the transmitted wave. The received echo is sampled by R1002M Data Acquisition System and recorded by Mark5B [2]. Taking into account the Doppler frequency as a function of time we apply the Fourier transform to the echo time series. As a result we obtain CW echo power spectra for selected time intervals with the required frequency resolution. At the Fig. 1 you may see the example of such echo power spectra of 2001 UW158 near-Earth Asteroid. Echo power is plotted in standard deviations versus Doppler frequency relative to the estimated frequency of echoes from the asteroid's center of mass. Solid and dashed lines denote echo power in the OC and SC polarizations. Circular polarization of the signal is reversed after reflection from the plane surface and the maximum power of the reflected signal is expected in the OC polarization, though some of the signal, due to secondary reflections, is received with the same polarization. The ratio of SC to OC is a measure of near-surface wavelength-scale roughness [3].

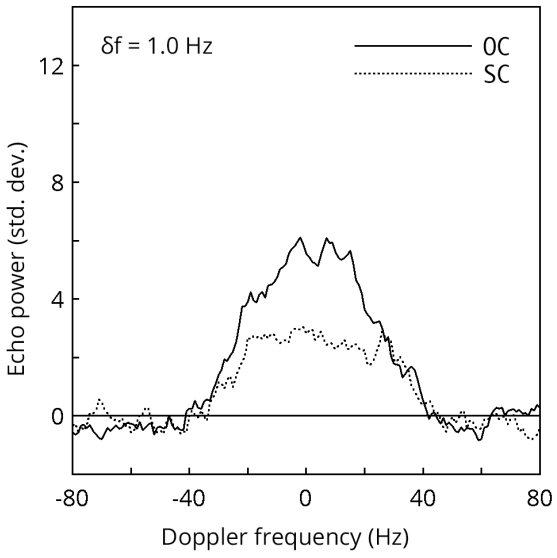

Figure 1: Opposite- and same-circularization continuous wave echo power spectra of 2011 UW158 obtained at Zelenchukskaya observatory.

3. Shape

The power spectrum bandwidth as function of time can be used for obtain the spin period in case of long observation series. Taking the geometric relation between echo power spectrum and the shape of rotating asteroid [4] into account, we estimate the hull of asteroids polar silhouette. Knowing the obtained spin period and assuming that the spectrum bandwidth is a continuous vector function of rotation phase we use least squares to fit an 3-harmonic Fourier series to the data vector. The result is a two-dimensional convex hull which is a projection of the asteroid onto its equatorial plane. To convert Hz to meters we assume that the asteroid-centered declination of the radar is equal to zero. Obtained convex hull of 2011 UW158 polar silhouette is shown in Fig. 2. The solid profile represents the joint solution and the dotted profiles correspond to the observatories individually. The Earth is toward the bottom of the Fig. 2. The figure shows that the body has an elongated shape with dimensions varies from 350 to 520 meters, which is consistent with the radar observations of the Arecibo, Green Bank and Goldstone observatories [5].

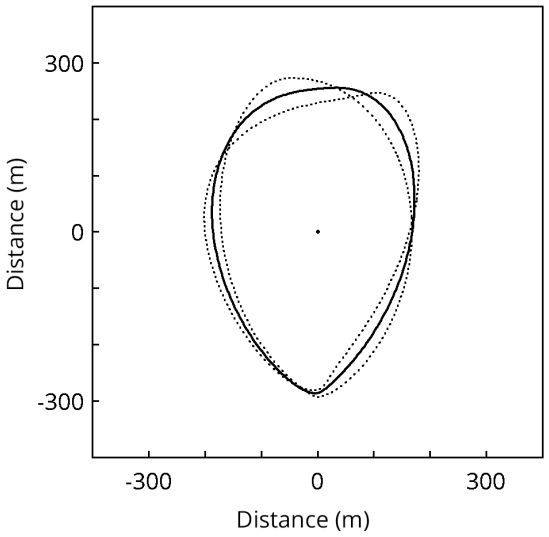

Figure 2: Convex hull of 2011 UW158 polar silhouette.

4. Summary

The radar echoes of signals transmitted from the 70 m antenna of the Goldstone Observatory were successfully detected. Obtained results confirm the possibility and effectiveness of the bistatic radar observations of near-Earth Asteroids using 32 m radio telescopes of Quasar VLBI network as receiving part of a bistatic configuration. It was shown that receiving and processing of the continuous wave echo allows to estimate the value of the Doppler frequency with sufficient accuracy which can be used to obtain the spin period and size of Near-Earth Object. Following this positive experience we plan to continue bistatic radar experiments for obtaining continuous wave spectra and range-Doppler images in the near future. This work was supported by the Russian Scientific Foundation grant No 16-12-00071.

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