International Radar Observations of Near-Earth Asteroids on Radio Telescopes of the Quasar VLBI Network

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Abstract. The first radar observations of a near-Earth asteroid (NEA) with 32-meter radio telescopes (RT-32) of the Russian VLBI Network Quasar were carried out in July 2015 in collaboration with the Jet Propulsion Laboratory of the California Institute of Technology and the Goldstone Observatory. The object of study was the potentially hazardous asteroid 2011 UW158 during its close approach to the Earth. Since then, 8 more NEAs have been detected with the RT-32 radio telescopes. During processing and analysis of radar observations, the size, shape and spin states of these asteroids were estimated. The obtained radar scattering properties clarified the spectral classes and near-surface roughness.

Keywords: minor planets, asteroids: general; techniques: radar astronomy

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1 Introduction

Radar astronomy is one of the most precise methods to obtain information about the dynamic and physical properties of near-Earth asteroids (NEAs). The size, shape, spin period and surface properties of NEAs can be obtained using radar observations. Such observations suggest a transmitting and receiving antenna systems, a highly sensitive equipment for detecting echo signals and a software for observations scheduling and data processing. The Institute of Applied Astronomy of the Russian Academy of Sciences regularly participates in international radar observations of NEAs. The sources of radio signals are the 70-meter antenna of the Goldstone Deep Space Communications Complex (USA) and the 305-meter radio telescope located at the Arecibo Observatory (Puerto Rico),

equipped with powerful transmitters. Detection of signals reflected from asteroids is performed with 32-meter radio telescopes (RT-32) of the Russian VLBI Network Quasar (Marshalov et al. 2018).

2 Radar Observations of 1998 OR2

Here we report on our recent radar observations of near-Earth Asteroid 1998 OR2 during its close approach to the Earth in April 2020 using RT-32 in Svetloe observatory in cooperation with Arecibo observatory. Arecibo radar transmitted a monochromatic continuous wave (CW) with a carrier frequency of 2380 MHz (12.6 cm) and with a modulated carrier in left circular polarization (LCP). RT-32 antenna recorded the echoes simultaneously in the same (SC) and opposite (OC) senses of circular polarizations as the transmission. We applied the Fourier transform to the echo time series to obtain the CW echo power spectra and cross-correlating it with a replica of the transmitted code to obtain range-Doppler image of 1998 OR2. Range-Doppler image of 1998 OR2 obtained on April 20 is shown in Fig. 1 (left). Range (distance from the observer) increases down at 150 m per pixel and Doppler frequency increases to the right at 1 Hz per pixel. The image have been scaled to the same spatial range. In Fig. 1 (right) you may see the CW echo power spectra of 1998 OR2 with 0.2 Hz frequency resolution obtained at Svetloe observatory on April 22, 2020. Echo power is plotted in standard deviations of the noise versus Doppler frequency. Zero frequency in the figures corresponds to the frequency calculated for the asteroid's center of mass. Solid and dashed lines denote echo power in the OC and SC polarizations respectively.

Range-Doppler images are used to resolve the asteroid in two dimensions, whereas CW echo power spectra to measure the total power of the echo and its frequency extent. From the obtained spectra, we estimated the Doppler broadening or the spectra bandwidth of 6 Hz. Then taking into account the rotation period of 4.1 h we revealed the asteroid's equatorial breadth of 900 m. By integrating the OC and SC spectra we obtained the radar cross sections. Radar albedo is equal to radar cross section divided by geometric cross section and indicates the radar reflectivity of the surface compared to a perfect metal sphere. We obtained the OC radar albedo of 0.11 suggests S-class NEA (Margi et al. 2007). The ratio of the integrated SC and OC signal is a measure of near-surface wavelength-scale roughness. We estimated the circular polarization ratio of 0.39, indicates that the near-surface of 1998 OR2 at decimeter scales is morphologically rougher than those of most radar-detected NEA's (Benner et al. 2008).

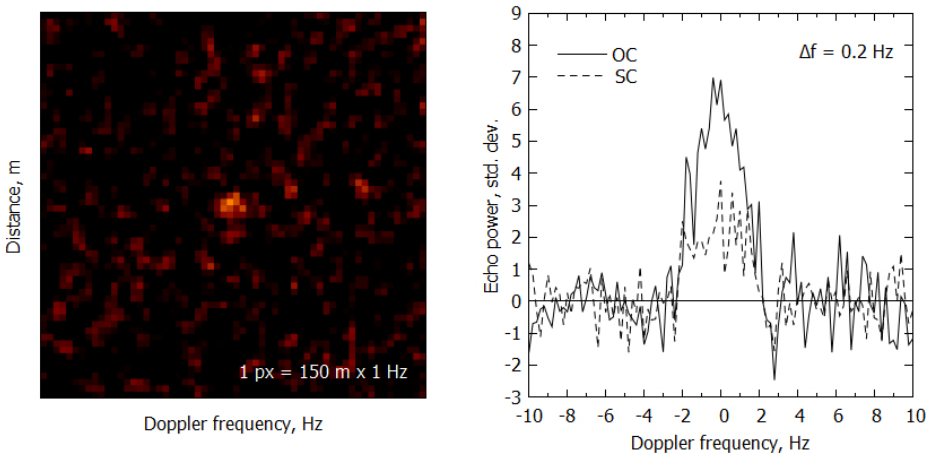

Fig. 1. Range-Doppler radar image and continuous wave echo power spectra of 1998 OR2 obtained at Svetloe observatory on April 20 and 22, 2020.

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