Cobble Distribution on Surface of Near-Earth Asteroids using Radar Observations .

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Introduction

Boulders (meter-scale particles) usually appear in radar image as brightness anomalies or speckles, ubiquitously distributed on the surface of asteroids or small rocky bodies in the inner solar system, and they are indicative that there are also cobbles (decimeter-scale particles). Their spatial and size distribution gives us indications of the geological evolution and the outcome of the collision event history [1]. The abundance of cobbles can be suggestive of whether the asteroid is monolithic or a rubble pile [2].

Our goal is to use the most up-to-date theoretical methodology of radar scattering, to study the near-surface densities, chemical compositions, and roughness of asteroids from the diffuse components of the opposite circular (OC) polarization and same circular (SC) polarization.

Methods

We use radar observations by the Arecibo Observatory Planetary Radar Program to study decimeter-scale particle ("cobble") distribution on the Near-Earth Asteroid (NEA) surfaces. In a typical radar observation at Arecibo Observatory, radar system transmits a powerful circularly polarized signal using a frequency of 2380 MHz (wavelength of 12.6 cm) and receives the echo in the SC and the OC polarization. The intensity and the polarization are suggestive of the physical properties of the target's near-surface.

The integrated echo power is described using the radar cross-section, which is 4π times the backscattered power per steradian divided by the power incident in a unit area [3]. If the radar cross section is divided by the projected area of the target, the radar albedo is obtained. The analysis of the radar albedos gives us hints of the cobble shape and size distribution as well as the effective near-surface bulk density of the underlying layer of sub-centimeter-scale particles [4].

The penetration depth of the signal is typically a few wavelengths depending on the absorption of the material. If the surface is smooth and the effective near-surface is homogeneous in the wavelength-scale the echo is received fully in the OC polarization. The increase of the echo power received in the SC polarization has been attributed to the presence of cobbles or wavelength-scale surface roughness in the near-surface [5, 6]. The radar reflectivity (radar albedo) in the SC and OC polarizations are suggestive of the surface structure: a larger number of wavelength-scale cobbles increases both SC radar albedo ($\hat{\sigma}_{SC}$) and OC radar albedo ($\hat{\sigma}_{OC}$) [6].

The reflection from a layer of fine-grained regolith and diffuse scattering and refractions between the wavelength-scale particles compose the OC polarized part of the echo (also referred to the quasi-specular and diffuse components).

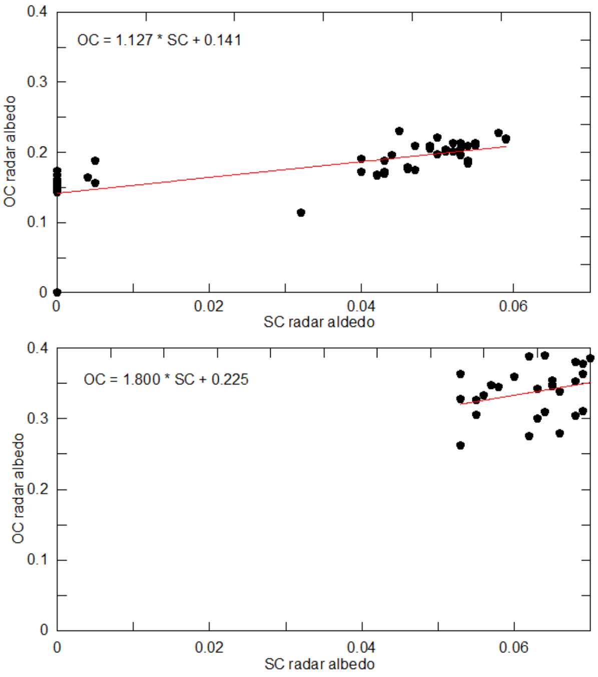

Figure 1: The diffuse parts of the OC and SC polarization echoes are correlated for the 1998 CS_1 (top panel) and 1992 UY_4 (bottom panel) asteroids. The intercept point in the $\hat{\sigma}_{OC}$-axis depends on the electric permittivity or density of the fine-grained regolith layer. The gradient of the line depends on the size, shape and electric permittivity of the wavelength-scale particles.

To determine those parameters we utilize the information that the diffuse components of the OC and SC parts are correlated (Fig. 1). The trend is a linear regression applied to the obtained values of $\hat{\sigma}_{SC}$ and $\hat{\sigma}_{OC}$ in order to separate the diffuse-scattering part of the quasi-specular part of $\hat{\sigma}_{\mathrm{OC}}$. Thus we are able to evaluate the surface roughness of a specific target compared to other similar objects.

Sources of errors for the method are caused by the size (projected area) estimation of the target, which is essential to calculate the radar albedos. We will examine the variation of circular polarization ratio (μ_{C}), which is the SC radar cross-section divided by the OC radar cross-section, as a function of the rotational phase, to investigate if the change in radar albedos are real or due to the variation of the projected area.

Summary and Conclusions

We study the effect of physical properties of eleven NEAs using the state-of-the-art methodology [6, 4] to interpret the physical properties using the diffuse parts of the OC and SC polarized echoes. We selected the targets based on the visibility of the speckles in the radar images, which imply an abundance of boulders and cobbles. We study whether the abundance of boulders and cobbles is detectable in the dual-polarization radar data, and whether it changes as a function of the rotational phase, as seen for the asteroid 2006 AM_4 [7]. The radar reflectivity increases as a function of the number density of the diffusive surface scatterers or the surface roughness (to both $\hat{\sigma}_{\mathrm{SC}}$ and $\hat{\sigma}_{\mathrm{OC}}$).For asteroids with long periods, such as 1992 UY_4 with a period of 12.90 h, a clear correlation is difficult to show. Nevertheless, the low variation of albedos values indicates that there is not a significant amount of variation in the near-surface area that the data covers.

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