SURFACE PROPERTIES OF SPACE FLIGHT ACCESSIBLE NEAR-EARTH OBJECTS. A. K. Virkki[1], P. A. Taylor[1], S. S. Bhiravarasu[1], E. S. Howell[2], C. Lejoly[2], M. C. Nolan[2], E. G. Rivera-Valentín[1,3], [1]Arecibo Observatory, Universities Space Research Association, HC-3 Box 53995, Arecibo, Puerto Rico (avirkki@naic.edu), [2]Lunar and Planetary Laboratory, University of Arizona, PO Box 210092, Tucson, AZ, USA, [3]Lunar and Planetary Institute, Universities Space Research Association, Houston, TX, USA.

Introduction: In 2018, two space missions to asteroids will be reaching their target objects: NASA's OSIRIS-REx mission to 101955 Bennu, and JAXA's Hayabusa 2 mission to 162173 Ryugu. In addition, several plans for sending space crafts to other objects exist, such as the Psyche mission to 16 Psyche, and DESTINY$^+$ to 3200 Phaethon. With increasing interest to space mining, we can expect to see a number of space missions to asteroids in the next few decades.

Near-Earth object Human space flight Accessible Targets Study (NHATS)-compliant asteroids [1] are the pool of objects from which crewed space missions, and the majority of robotic space missions to asteroids, will likely be selected in the future. The primary purpose of NHATS is to identify and characterize any known NEO that might be accessible for human beings in terms of orbital and physical properties. The criteria that an object must satisfy to in order to be NHATS-compliant are specific orbital properties related to the accessibility from the Earth's orbit, delta-v, and mission duration. However, the known physical properties of the target will also play a major role in the final selection of the target.

In this study, we discuss the physical properties of NHATS-compliant asteroids with a focus on what planetary radar observations can tell us of their surface properties.

The S-band (2.38 GHz, 12.6 cm, 1 MW power output) radar system on the 305-m William E. Gordon telescope in the Arecibo Observatory is the most powerful planetary radar system in the world [2]. Range-Doppler radar measurements can provide the distance to the target with a precision of ~10 m, the radial velocity down to ~1 mm/s, and set constraints on the spin state. The dual-polarization measurements provide implications of the near-surface chemical and structural composition. The radar images unambiguously reveal potential satellites, which can help to derive information on the mass, density, and internal structure of the bodies.

Arecibo Observatory planetary radar program has detected 131 NHATS-compliant asteroids in the interval of 1998 – 2017 (Fig. 1). The ultra-accurate orbit refinement and the ability for physical characterization are relevant for understanding NEO orbit distributions, sizes, and rotation rates, and also the surface environments that may pose a risk to crew, spacecraft, and operational assets.

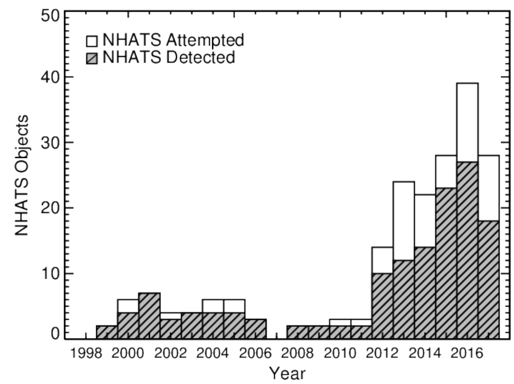

Figure 1. Radar observations of NHATS-compliant asteroids during 1998-2017.

Methods: Wavelength-scale particles backscatter electromagnetic radiation effectively, and cause polarization effects that are prominent only in this size scale. Consequently, decimeter-wavelength radar observations are the most powerful ground-based tool to investigate structural composition at size scales that are the most relevant to landing space probes. The penetration depth of the signal is typically a few wavelengths depending on the absorption properties of the material. This allows the radar signal to access structures covered by a moderately thick layer of fine-grained regolith.

In typical dual-polarization radar observations, the echo is received simultaneously in the same circular (SC) polarization and the opposite circular (OC) polarization as compared to the transmitted signal. If the surface is smooth and the effective near-surface is homogeneous at the wavelength scale, the echo is received fully in the OC polarization. Wavelength-scale surface roughness or boulders within the effective near-surface volume increase the fraction of echo power received in the SC polarization [3].

The radar cross section is descriptive of the received echo power normalized with the transmitted power, target distance and antenna gain. The radar reflectivity of the target can be described using the radar albedo, which normalizes radar cross section to projected area.

Analyzing the radar albedo in the OC and SC polarizations allows us to separate the radar signature of diffusely scattering wavelength-scale particles from the quasi-specular reflection by the fine-grained regolith covering the asteroid surface [4]. The correlation of the radar albedos in the two polarization senses (as shown in Fig. 2) is suggestive of the number, size and shape of wavelength-scale particles [4]. For example, a high SC radar albedo as compared to the OC radar albedo is a sign of a large number of sharp-edged cobbles. A low SC radar albedo, on the contrary, is a sign of a low abundance of centimeter-to-decimeter pebbles or cobbles. By extrapolating the radar albedos to correspond to a surface without wavelength-scale (or larger) particles, we can derive the near-surface density using the OC radar albedo.

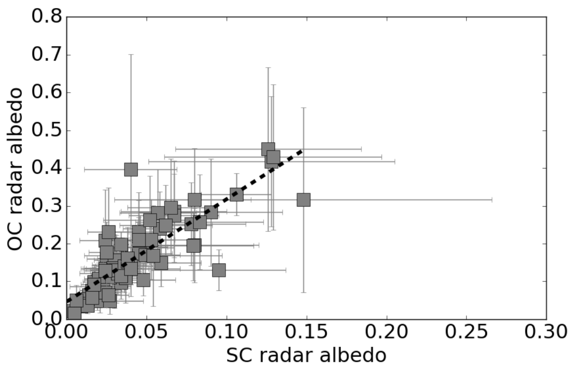

Figure 2. Correlation of the radar albedos in the opposite circular (OC) polarization to that in the same circular (SC) polarization is suggestive of the number, size, and shape of centimeter-to-decimeter-scale particles on the target surface. Each marker represents different S-complex near-Earth asteroid.

In addition to planetary radar, this method can have applications in remote-sensing of the Earth by satellites with radar instruments.

Summary: We present estimates of surface particle abundance and near-surface density for 131 NHATS-compliant asteroids detected by the Arecibo planetary radar program in the interval of 1998-2017, and discuss their suitability for landing space probes in terms of their other physical properties such as the size and rotation rate.

References:

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