NEAR-EARTH ASTEROIDS:
A RADAR LINK BETWEEN COMPOSITION AND SURFACE ROUGHNESS

A 28-year radar survey of 214 near-Earth asteroids (NEAs, 65% of which are potentially hazardous) has revealed a striking correlation of echo polarization ratio, which is a measure of centimeter-to-several-decimeter surface roughness, with visible-infrared spectroscopic class, which is determined by mineralogy. This strong relation between composition and macroscopic structure has implications for ideas about NEA meteorite associations and collisional histories, and can provide key information for the design of sample-return techniques.

Meteorites are samples of small, Earth-orbit-crossing asteroids, which in turn are primarily derived from the main asteroid belt. Asteroid classification schemes based on optical (visible-to-near-infrared) spectroscopy now include some 26 spectral classes, in most cases tentatively associated with meteorite types. A dependence of the abundance of different spectral classes on heliocentric distance probably reflects the influence of temperature on the identity of condensates from the primitive solar nebula. However, there remains great uncertainty in the relationships between meteorite types and asteroid classes. The rare exceptions involve asteroids visited by rendezvous spacecraft: the ~15-km-diameter NEA 433 Eros and the several-hundred-meter-long NEA 25143 Itokawa are both mineralogically akin to ordinary chondrites, the most common type of meteorites that fall to Earth. Similarly, there is only limited information about the physical characteristics of NEA surfaces, which are the outcome of complex collisional histories and reflect the mechanical properties of objects' mineral assemblages.

A radar echo's circular polarization ratio, CPR, measures the wavelength-scale roughness of the target's surface. It can range from zero for a perfectly smooth surface to between one and two for echoes involving multiple scattering, subsurface reflections, or a great deal of wavelength-scale structure like rocks on or close to the surface.

Therefore, the CPR is a measure of the near-surface structural complexity near the scale of the radar wavelength, which for asteroids is 3.5 to 13 cm. Mercury, Venus, and the Moon have CPRs of about 0.1, and Mars has a ratio of about 0.3, although for each object, there are local variations.

The radar survey reported in a paper to be published in the planetary science journal Icarus finds that NEAs have CPRs ranging from 0.0 to 1.5, corresponding to surfaces that are smoother than the Moon's to surfaces rougher than any seen in close-up spacecraft pictures of any object in the solar system. The radar sample has a mean CPR of 0.34 and a median CPR of 0.26, indicating that most NEAs are at least as rough as Mars. Eros and Itokawa have ratios near the sample mean, and hence have roughnesses representative of the "typical" NEA.

More than half of the objects in the radar sample have been classified by optical observations. Most are C or S, which include carbonaceous and ordinary chondrite analogues as well as stony-iron analogues. The C and S NEAs have CPRs from ~0.1 to ~0.5.

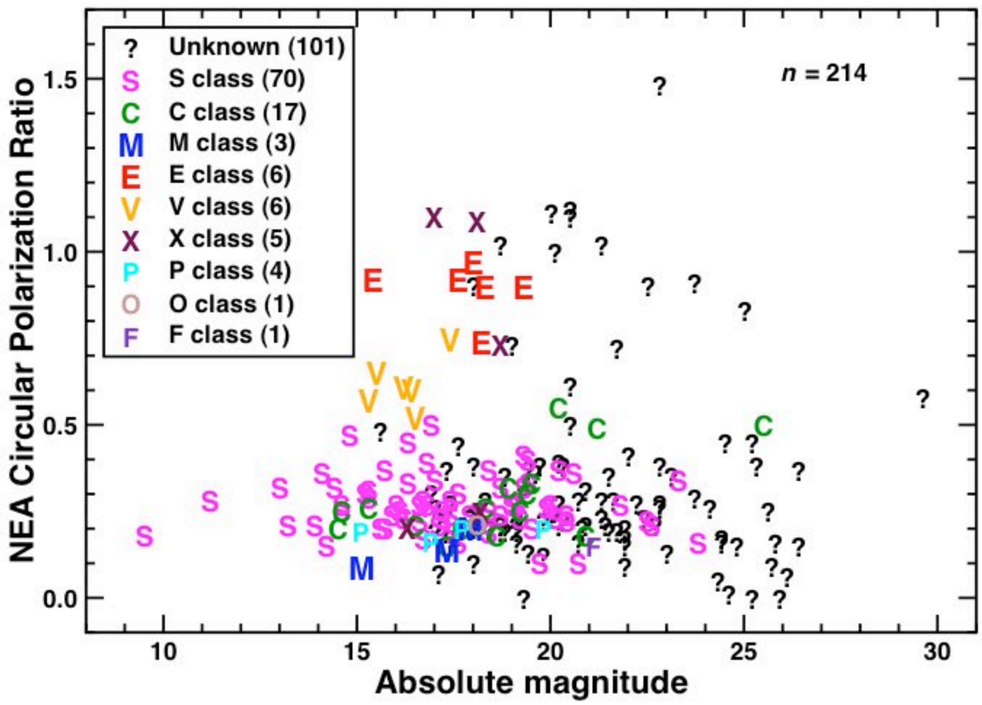

Fig. 1. The distribution of NEA CPR versus absolute magnitude, for which larger values mean decreasing visual brightness. (Five magnitudes corresponds to a factor of 100 in brightness.) Spectral classes are indicated with different letters and colors.

The highest ratios are measured for groups associated with achondritic igneous rocky meteorites: the E class, whose parent body may be 3103 Eger, and the V class, derived from the mainbelt asteroid 4 Vesta, the 2011 rendezvous target of NASA's Dawn Mission.

"The strong correlation between a radar measure of macroscopic structure and an optically determined indicator of composition for NEAs is striking," said Dr. Lance Benner of JPL, who led the team of astronomers reporting these results. The correlation probably is due to the intrinsic mechanical properties and hence the response to meteorite bombardment of different mineralogical assemblages, but it also also may reflect very different formation ages and collisional histories of objects in different compositional classes. However, Benner noted that "whatever the cause of the correlation, our work establishes that a radar measurement of CPR indicates what compositional class or classes are likely for the NEA, and optical determination of class gives us a range of likely CPRs and hence constrains the NEA's roughness. Both kinds of information determine the tractability of sampling techniques and would also bear on strategies for deflecting a threatening NEA."

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