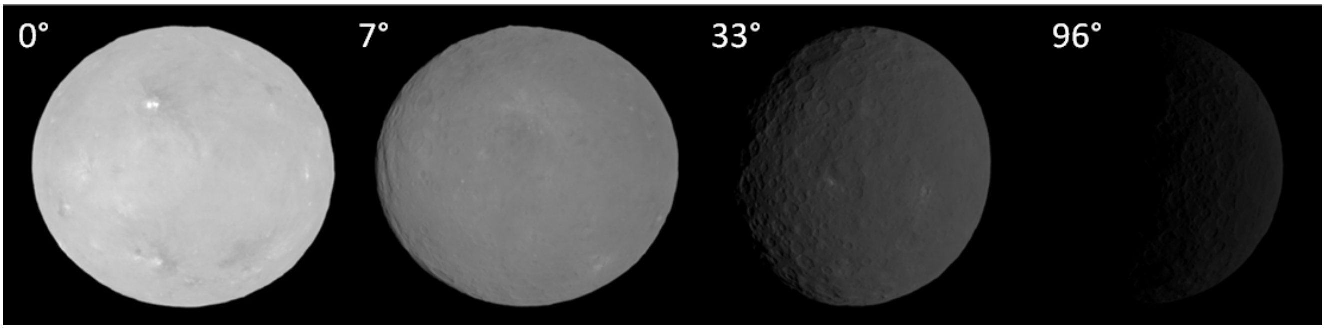
The Ceres opposition effect observed by the Dawn framing camera

*Stefan Ewoud Schroeder[1], Jian-Yang Li[2], Marc D. Rayman[3], Steven P. Joy[4], Carol A. Polanskey[3], Uri Carsenty[1], Julie C. Castillo-Rogez[3], Ralf Jaumann[1], Andrea Longobardo[6], Lucy A. McFadden[5], Stefano Mottola[1], Mark V. Sykes[2], Christopher T. Russell[4], Carol A. Raymond[3]

1. DLR, 2. PSI, 3. JPL, 4. UCLA, 5. GSFC, 6. INAF

The reflectance of planetary regoliths can increase dramatically towards zero solar phase angle, a phenomenon known as the opposition effect (OE). The OE is usually observed by Earth-based telescopes, and resolved observations by spacecraft are still rare. Zero phase images of asteroids are often acquired on approach during a flyby, as for 2867 Steins and 21 Lutetia. Sometimes, the small mass of the asteroid allows the spacecraft to slowly hover into the opposition geometry, as for 25143 Itokawa. In April 2017, the framing cameras on-board the NASA Dawn spacecraft observed the OE on dwarf planet / asteroid 1 Ceres. Dawn reached the opposition geometry through an ingenious scheme of orbital navigation to avoid eclipse half an orbit earlier or later [1]. The lowest phase angle at which Ceres had thus far been observed by ground-based telescopes was 1.1° [2]. Two physical processes that are thought to be the dominant contributors to the OE brightness surge are shadow hiding and coherent backscatter. Shadow hiding (SH) refers to the shadows cast by regolith particles and larger objects. Near phase angle zero, when the Sun is directly behind the observer, shadows are hidden, increasing the reflectance of the surface [3]. Coherent backscatter (CB) is a form of constructive interference of light at very small phase angles, the physics of which is well understood [4]. One prediction of CB theory is the wavelength dependence of the OE angular width [5]. Given its reliance on multiple scattering, it is likely that CB is experienced by bright E-type asteroids, but not by the darkest C-type asteroids. Whether CB is important for asteroids of intermediate albedo is not clear. Modeling suggests that CB contributes substantially to the OE of lunar maria [6], which are almost as dark as the surface of Ceres. The occurrence of SH on a surface like that of Ceres is self-evident, but in practice it proves difficult to unambiguously demonstrate CB from remote sensing data. When both photometric and polarimetric observations are available, the latter may be inferred and modeled, although quantitative interpretations of the observations in terms of sizes of particles, their refractive index, and packing density remain challenging [7]. Dawn, however, only acquired photometric observations of Ceres. Our analysis of the Ceres OE observations uncovers a correlation between normal albedo and OE angular width, but we find no wavelength dependence for the latter. While our results are inconclusive, they provide a piece to the puzzle that is the OE of planetary surfaces.
[1] Rayman, M. (2017) 68th International Astronautical Congress, Adelaide, Australia, IAC–17.A3.4A.2x39024. [2] Tedesco, E. F. et al. (1983) *Icarus* **54**, 23–29. [3] Hapke, B. (1986) *Icarus* **67**, 264–280. [4] Tishkovets, V. P. & Mishchenko, M. I. (2009) *JQSRT* **110**, 139–145. [5] Mishchenko, M. I. (1992) *Ap&SS* **194**, 327–333. [6] Muinonen, K. et al. (2011) *A&A* **531**, A150. [7] Petrova, E. V., Tishkovets, V. P. (2011) *Solar System Research* **45**, 304–322.

Keywords: Ceres, Regolith, Radiative transfer


0°
7°
33°
96°