# Multiple scattering of light by the surfaces of small Solar System objects

K. Muinonen[1,2], A. Penttilä[1], O. Wilkman[1], and G. Videen[3,4]

[1]Department of Physics, University of Helsinki, Finland
[2]Finnish Geodetic Institute, Masala, Finland
[3]Space Science Institute, Boulder, Colorado, U.S.A.
[4]Army Research Laboratory, Adelphi, Maryland, U.S.A.

Scattering of electromagnetic waves in a macroscopic particulate medium composed of microscopic particles constitutes an open computational problem in planetary astrophysics. This problem manifests itself in the absence of inverse methods to address fundamental astronomical observations of small Solar System objects. There are two ubiquitous phenomena observed at small solar phase angles (the Sun-Object-Observer angle) from, for example, asteroids and transneptunian objects. First, a nonlinear increase of brightness is observed toward the zero phase angle in the magnitude scale that is commonly called the opposition effect. Second, the scattered light is observed to be partially linearly polarized parallel to the Sun-Object-Observer plane that is commonly called the negative polarization surge.

The aforedescribed polarimetric and photometric observations of small Solar System objects are interpreted using a radiative-transfer coherent-backscattering model (RT-CB, Muinonen 2004) that makes use of a so-called phenomenological fundamental single scatterer (Muinonen and Videen 2012). For the validity of RT-CB, see Muinonen et al. (2012, 2013). The modeling allows us to constrain the single-scattering albedo, phase function, and polarization characteristics as well as the mean free path length between successive scatterings. With the help of laboratory experiments (Muñoz et al. and Peltoniemi et al., present meeting) and exact theoretical methods (e.g., Markkanen et al., present meeting), it further allows us to put constraints on the size, shape, and refractive index of the fundamental scatterers. We illustrate the application of RT-CB by interpreting the polarimetric and photometric observations of the C, M, S, and E-class asteroids.

**Acknowledgements:** The research has been partially funded by the ERC Advanced Grant No 320773 entitled ”Scattering and Absorption of Electromagnetic Waves in Particulate Media” (SAEMPL), by the Academy of Finland (contract 257966), NASA Outer Planets Research Program (contract NNX10AP93G), and NASA Lunar Advanced Science and Exploration Research Program (contract NNX11AB25G).

**References:** Muinonen, K. (2004). Coherent backscattering of light by complex random media of spherical scatterers: Numerical solution. *Waves in Random Media* **14**, 365; Muinonen, K., and Videen, G. (2012). A phenomenological single scatterer for studies of complex particulate media. *JQSRT* **113**, 2385; Muinonen, K., Mishchenko, M. I., Dlugach, J. M., Zubko, E., Penttilä, A., and Videen, G. (2012). Coherent backscattering numerically verified for a finite volume of spherical particles. *ApJ* **760**, 118; Muinonen, K., Penttilä, A., and Videen, G. (2014). Multiple scattering of light in particulate planetary media. In *Polarimetry of stars and planetary systems*, L. Kolokolova, A.-C. Levasseur-Regourd, J. Hough, Eds., in press.