Geophysical Research Abstracts
Vol. 14, EGU2012-12260, 2012
EGU General Assembly 2012
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Theoretical interpretation of light scattered by the surfaces of atmosphereless Solar-System bodies

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Two ubiquitous light-scattering phenomena are observed near opposition for atmosphereless solar-system objects covered with regoliths: negative linear polarization and nonlinear surge of brightness (opposition effect). The phenomena are confined to Sun-object-observer angles (phase angles) of less than 30 and 10 degrees, respectively. The coherent-backscattering and shadowing mechanisms have been introduced to explain the phenomena sometimes showing up at extremely small phase angles. Coherent backscattering has been shown to contribute to both brightness and polarization, whereas shadowing has been shown to contribute to the opposition effect only.

We have uncovered a single-scattering interference mechanism, a so-called interference dial, that can explain the considerable widths of the observed negative polarization branches and that can simultaneously contribute to the increase of brightness. The mechanism is related to the internal electric fields of wavelength-scale scatterers. First, a longitudinal internal-field component parallel to the wave vector of the incident wave results in negative polarization at intermediate phase angles with decreasing contribution towards the backward and forward-scattering directions. Second, interference among transverse internal-field components parallel to the incident electric field vector gives rise to negative polarization near backward-scattering directions, in resemblance to the multiple-scattering mechanism of coherent backscattering. The mechanism has been verified for both spherical and nonspherical single scatterers with wavelength-scale sizes.

We present multiple-scattering modeling for atmosphereless solar-system objects using the coherent-backscattering radiative-transfer method.. In the novel modeling, the fundamental scatterers in a regolith volume element are modeled using size distributions of spherical scatterers. Using a photometric model accounting for both coherent backscattering and shadowing due to the porous medium with fractional-Brownian-motion roughness, we derive constraints for the physical properties of the lunar surface.