Scattering of light in planetary regoliths: theory, experiments, and applications

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Theoretical, numerical, and experimental methods are presented for scattering of light in macroscopic discrete random media of densely-packed microscopic particles. The theoretical and numerical methods constitute a framework of Radiative Transfer with Reciprocal Transactions (R^2T^2). The R^2T^2 framework entails Monte Carlo order-of-scattering tracing of interactions in the frequency space, assuming that the fundamental scatterers and absorbers are wavelength-scale volume elements composed of large numbers of randomly distributed particles. The discrete random media are fully packed with the volume elements. For spherical and nonspherical particles, the interactions within the volume elements are computed exactly using the Superposition *T*-Matrix Method (STMM) and the Volume Integral Equation Method, respectively. For both particle types, the interactions between different volume elements are computed exactly using the STMM. As the tracing takes place within the discrete random media, incoherent electromagnetic fields are utilized, that is, the coherent field of the volume elements is removed from the interactions. The experimental methods are based on acoustic levitation of the samples for non-contact, non-destructive scattering measurements. The levitation entails full ultrasonic control of the sample position and orientation, that is, six degrees of freedom. The light source is a laser-driven white-light source with a monochromator and polarizer. The detector is a mini-photomultiplier tube on a rotating wheel, equipped with polarizers. The R^2T^2 is validated using measurements for a mm-scale spherical sample of densely-packed spherical silica particles. After validation, the methods are applied to interpret astronomical observations for asteroid (4) Vesta and comet 67P/Churyumov–Gerasimenko visited by the NASA Dawn mission and the ESA Rosetta mission, respectively.

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