Radiative transfer in planetary regoliths: applications

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Computational light scattering methods applicable to many size scales are needed to solve the light scattering problems typical in planetary sciences. Especially, we are focused on the photometric, polarimetric, ans spectroscopic properties of atmosphereless, small Solar System bodies, i.e., asteroids, comets, dwarf planets, and moons. With these, the modeling starts from the nanometer-micrometer scale with the scattering properties of the dust grains on the surface of these objects (called regolith), or in the coma of comets. The size scale continue with optically large surface elements consisting of close-packed particulate random material all the way to the disk-integrated observations of a whole (one/ten/hundred) kilometer-sized objects.

Due to the large size scales needed, we also need to develop and use many different light scattering methods. The smallest scales will need explicit Maxwell equations solvers such as Mie, volume- or surface-integral methods. The next scales cannot be handled with exact Maxwell solvers, so we need to employ both physical/geometrical optics and radiative transfer (RT). We have developed Monte Carlo RT methods to handle close-packed random media[1,2,3].

In this talk, we will present some examples of how we apply and tie together these different methods into a multi-scale modeling approach that can predict spectral, photometric, and polarimetric properties of asteroids[4]. We will also introduce our laboratory measurement capabilities and how they link to the modeling[5].

[1] Muinonen K, Markkanen J, Väisänen T, Peltoniemi J, and Penttilä A (2018). Multiple Scattering of Light in Discrete Random Media Using Incoherent Interactions. Optics Letters 43(4), 683–686.

[2] Markkanen J, Väisänen T, Penttilä A, and Muinonen K (2018). Scattering and absorption in dense discrete random media of irregular particles. Optics Letters 43(12), 2925–2928.

[3] Väisänen T, Markkanen J, Penttilä A, and Muinonen K (2019). Radiative transfer with reciprocal transactions: Numerical method and its implementation. PLOS ONE 14(1), 1–24.

[4] Martikainen J, Penttilä A, Gritsevich M, Videen G, Muinonen K (2018). Absolute spectral modeling of asteroid (4) Vesta. MNRAS 483(2), 1952–1956.

[5] Penttilä A, Martikainen J, Gritsevich M, Muinonen K (2018). Laboratory spectroscopy of meteorite samples at UV-vis-NIR wavelengths: Analysis and discrimination by principal components analysis. JQSRT 206, 189–197.