Radiative Transfer and Coherent Backscattering Using Mueller Matrix Decomposition

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Surfaces of airless Solar System objects, such as asteroids, are assumed to consist of regoliths, that is, loose layers of particles covering more solid material. The photometric and polarimetric phase curves of an asteroid describe, respectively, the dependences of the asteroid's disk-integrated brightness and degree of linear polarization on the solar phase angle, the angle between the Sun and the observer as seen from the object. On one hand, a number of different photometric phase curves can be derived from lightcurve observations, such as the sparse lightcurves from the ESA Gaia mission. On the other hand, polarimetric phase curves are rather insensitive to the shape and rotational characteristics of the asteroid.

Theoretical and numerical methods are presented for scattering and absorption of light in large discrete random media of densely-packed small particles. The methods are based on the frameworks of Radiative Transfer and Coherent Backscattering (RT-CB) and Radiative Transfer with Reciprocal Transactions (R^2T^2; e.g., [1-3]). In particular, for the purposes of inverse methods, we will describe RT-CB forward modeling based on ensemble-averaged 4×4 Mueller matrices. Decomposition of the ensemble-averaged matrices into pure Mueller matrices allows us to derive 2×2 Jones amplitude matrices. These amplitude matrices can be incorporated into the RT-CB methods for efficient computations that, on average, mimic the computations with true electromagnetic fields.

Scattering modeling will be offered for the photometric and polarimetric phase curves of airless objects. In particular, the modeling allows for the interpretation of both the photometric opposition effect and the negative degree of linear polarization near opposition that are ubiquitous phenomena observed for airless objects. The former phenomenon is a nonlinear increase of the object's disk-integrated brightness towards the opposition in the magnitude range, whereas the latter is a predominating linear polarization parallel to the scattering plane defined by the Sun, object, and the observer. A preliminary application of the models will be presented for a number of asteroids, the Moon, and Mercury.

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References

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