Laboratory light scattering measurement of planetary regolith analogs.

Hao Zhang[1] and Han Zheng[2]

[1]*China University of Geosciences School of Earth Sciences, Wuhan, China.* [2]*Lee S.K. Honors College, China University of Geosciences, Wuhan, China.*

The surface regolith of airless bodies is produced by long-term space weathering processes and therefore retains valuable information about the evolutionary history and space environment of the body. Remote identification of surface materials relies heavily on our understanding of the light-scattering properties of densely packed small grains. In this study, we present recent measurement results that address this issue from several perspectives. We first introduce an asymmetry factor (ASF) to characterize the directional scattering properties of particulate surfaces. This metric is based on our extensive reflectance measurements of analog materials spanning a wide range of optical properties. While the concept of the asymmetry parameter is well established for individual particles as a measure of the degree to which light is scattered in the forward or backward direction, it becomes inadequate when particles are densely packed into a layer, such as a planetary regolith. In such cases, the scattering behavior of the surface is more complex, and there remains ongoing debate over whether these surfaces are predominantly backscattering or forward scattering. To address this, we define the asymmetry factor (ASF) as a means to quantify the directional scattering behavior of packed surfaces. We measured the spectral bidirectional reflectance distribution function (BRDF) of various analog materials and fitted the results using Zernike polynomials, producing analytical expressions that closely match the measured data with a maximum fitting error of 5%. This level of accuracy enables reliable parameterization of discrete BRDF data. From the analytical BRDF expressions, we define the asymmetry factor through integration over the viewing zenith angle, within the appropriate angular ranges. Notably, the zeroth-order coefficient of the Zernike polynomial corresponds to the directional-hemispherical reflectance (DHR), also known as the plane albedo. By introducing a Lambertian factor (LF) and defining a ratio of ASF over LF, we found that samples with different grain sizes and optical transparencies exhibit distinct trends in the ASF/LF ratio versus DHR relationship. Using the analytical BRDF models, we also generated disk-integrated spectra (DIS), simulating the reflectance of an asteroid surface covered by such particulate layers. Comparison between DIS and the BRDF of a flat surface reveals that they can differ significantly, especially in spectral slope. For samples exhibiting weak phase reddening effects, DIS spectra closely match their BRDF counterparts, suggesting that the reflectance is relatively insensitive to viewing geometry. In contrast, samples with strong phase reddening effects show pronounced differences between their DIS and BRDF spectra. These results provide a valuable foundation for interpreting planetary remote sensing data, particularly in bridging the gap between laboratory measurements and spacecraft observations.