Reflectance measurements from particulate surfaces

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Asteroids consists of, e.g., metals and rocky materials, and comets consist of, e.g., icy and rocky materials and dust. Their surfaces can be covered by small particles. To certain extent, these surfaces can resemble some natural or artificial surfaces on the Earth, such as snow layers, sand, gravels, or silt. By measuring the reflectance from such surfaces, one can gain better understanding on how to interpret astronomical observations of asteroids and comets. Even if not completely analogous, these samples and measurements provide a strict test bed for the scattering models applied to interpret observations of small Solar System bodies.

FIGIFIGO (Finnish Geodetic Institute's Field Gonio-spectro-polari- radiometer) can measure the bidirectional reflectance factor (BRF) of surface targets of a diameter of around 10 cm, in a selected angular range and resolution, in the spectral range of 400–2400 nm, at about 10-nm resolution, including linear polarisation (Stokes I, Q, and U, or reflection coefficient matrix elements R_{11}, R_{12}, and R_{13}). Using FIGIFIGO, over 500 samples have been measured over the past years, including over 100 snow samples and almost 100 samples resembling sand, silt, soil, dust, or gravel.

For planetary studies, especially interesting are dark volcanic ash and silt samples from Eyjafjallajökull and Grímsvönt eruptions. These have been measured loose and compressed, smooth and rough, purely and deposited on snow. Further single-scattering measurements using the Granada setup and measurements using the Univ. Helsinki integrating sphere complement the picture.

Generally, we have observed that the reflectance from volcanic materials behaves mostly as expected and modelled. BRF shows typical bowl shape with strong phase-angle dependence. Spectral features are smooth, with slight angular dependence. Polarisation depends strongly on the phase angle, weaker on other angles defining the scattering geometry, and smoothly on the wavelength. There are the typical small negative branch backwards and stronger positive polarisation in mid to forward angles, with maxima typically at 110–130° phase angles.

Polarization tells mostly about the composition of the particle, secondly on the wavelength scale structure. Wavelength dependence can add more information on the structures, though in most cases the signal is weak. Measurements must then be made at very high accuracy in very specific directions, otherwise the results are too incomparable and vague for interpretation. Even then, it can be difficult to recognize characteristic polarization features, since the natural noise adds so much uncertainty. Thus, when utilizing polarization as a source of information, additional complementary data are in general needed.

The reflectance spectrum is of course the most significant source of material information, and can be a strong identifier in some cases, e.g., easily separating snow, water, vegetation, and several minerals. However, the volcanic silt and ash, and certain other dark rocky materials, appear just featureless grey throughout the measured spectrum.

The phase-angle dependence is linked to grain properties (shape, size, composition). The bowl shape and especially the large zenith angle behavior is indicative of the surface roughness.

Most of the measurement data are available at https://webdisk.kotisivut.com/fgi/Reflectance_Library/ (password available upon request). This data set provides an excellent starting point for model validation, especially, if the grain properties can be further characterized, and if the backscattering gap could be reduced.

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