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Surface optical properties of geological materials: a new look at the regolith of the Moon, Mercury and asteroids

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With the exception of the lunar samples brought back to Earth, the only way to study the surface of a planet so far remains the use of remote-sensing techniques. Among them photometry can be used to determine the physical properties of surface particles (e.g., grain size, roughness…).

Laboratory measurements with the spectro-imaging instrument at the DTP laboratory (Toulouse, France) have been made to determine the photometric parameters of natural samples (e.g., basalts, pyroclastics and olivine grains). Each one has been sieved either into natural grain sizes or ground to get particles from 45 microns to 2 mm. Multiangular data spanning the phase range between 20 and 130° have been acquired and Hapke's photometric parameters b, c, theta and w have been determined by means of a dedicated genetic algorithm [Cord, Icarus, 2003].

The modelled phase functions match satisfactorily the observations, and the parameters show very different behaviours depending on the sample and grain size. For non glassy materials, such as fresh basalt or pyroclastics, surface roughness parameter theta ranges from 12° to 25° with an increase seemingly correlated with the grain size, while for glassy materials, such as olivine or Hawaiian basalt, this parameter is much lower (about 4 to 10°) and shows no increase with grain size. Phase parameters b and c estimates displayed on a double Henyey-Greenstein graph (c vs. b) [see McGuire & Hapke, Icarus, 1995] fall on the expected trend, with glassy materials becoming more and more forward-scattering when grain size increases. Non glassy samples display more variability when particle size increases, and generally show a more backward-scattering behaviour. These results show that a characterization of a surface state in terms of physical properties is possible from multiangular datasets using Hapke's photometric model. The combination of photometric results with spectroscopic analyses could thus lead to more thorough understanding of remotely observed surfaces, as these techniques give access to complementary information.

To date, few multiangular orbital datasets are available, with the additional difficulties that phase angles larger than 100° and less than 20° are more difficult to acquire than in laboratory experiments. In addition, high resolution topographic information is requested for this type of investigation. A study of multiangular imaging observations of the lunar crater Lavoisier recently made by the AMIE camera onboard the European spacecraft SMART-1 has been undertaken, with phase angles ranging from 26° to 83°. Despite this limited phase coverage, a first-order photometric survey has been carried out. Dark patches believed to be pyroclastic deposits [Gaddis, Icarus, 2003] show similar photometric behaviour (backward scattering, high surface roughness); another dark region within Lavoisier F crater appears to display an even higher surface roughness, associated with a less pronounced backward scattering. The fact that both the modelled phase curves match well the observation and the retrieved parameters are physically plausible, suggests that Hapke's model not only can be applied to laboratory data, but also to orbital imaging datasets. As more complete sets will be produced from ongoing or soon-to-come observations (e.g., Kaguya/Selene, Chandra'yaan, LRO for the Moon, Messenger, Bepi-Colombo for Mercury, Dawn for Vesta and Ceres, …), a more precise characterization of planetary surfaces should be achieved.