EXPERIMENTAL DETERMINATION OF THE HAPKE SHADOWING FUNCTION PARAMETER FOR PLANETARY REGOLITH SURFACE ANALOGS. A. M. Cord, P. C. Pinet, Y. Daydou and S. Chevrel, UMR 5562 / OMP/GRGS/CNRS, 14 av. E. Belin, Toulouse, 31400 France, Aurelien.Cord@cnes.fr.

Introduction: The physics of the process that controls the interaction of light with planetary regolith surfaces is complex and only partially understood. In the past years, a number of semi-empirical models have been developed for analyzing the bidirectional reflectance data of particulate surfaces based on the scattering and absorption properties of minerals and rocks (e.g. [1], [2], [3], [4]). In particular, using the radiative transfer equation describing the scattering of light from soils, Hapke [1] developed an approximate analytical solution, which is widely used for studying reflectance data from planetary surfaces (e.g. [5], [6], [7]). This model is generally difficult to handle because it requires the knowledge of six physical parameters, linked with multiple scattering, phase function, opposition effect, and roughness. This work presents a method for a determination of the global set of parameters involved in Hapke's model for planetary surface analogs when considering a set of angular conditions representative of the usual range from spaceborne observation in planetary exploration. We focus on the physical meaning of the shadowing function parameter (θ).

Experiment description: We have selected for this study three different types of material representing good planetary surface analogs. They are crushed to give samples with a range of grain sizes less than 3 mm and are sorted into four classes G1 to G4 using sieves (less than 75 µm, from 75 to 250 µm, from 250 to 500 µm and from 0.5 to 2 mm) (fig. 1).

A new laboratory wide-field multispectral imaging facility [8] is used to obtain multispectral images of a 20x20 cm target taking varied incidence and emergence angles. 18 narrow band interferential filters are used for measurements in the spectral range 0.4 µm to 1.05 µm, with a 200 micron per pixel spatial sampling of the target. The range of geometries of observation investigated is presented in table I. Though restricted to the principal plane, this angular domain is quite useful for carrying out laboratory experiments [9], simulating the observational situations most frequently encountered in planetary exploration by spaceborne optical instruments. We extract, from the multispectral images, the spectrum of each sample, averaging within a given macroscopic cell (3 cm) the measured values for each wavelength (fig. 1).

Method: Considering the large volume of data (12 samples with 10 spectra each constituted by 18 discrete wavelength each), the present approach is founded on a genetic algorithm [10]: the whole set of Hapke parameters is treated simultaneously without any a priori assumptions. This limits the risk of meeting a local extreme and improves the stability and repeatability of the determination. Moreover, it requires less computational time than a Monte Carlo routine.

Results and Conclusion: First, parameter values for various grain sizes and material compositions of planetary regolith surface analogs are derived for Hapke's equation wich may be useful in future reflectance spectroscopy data interpretations. The results, coherent with the literature, validate all the steps in our methodology, including experimental measurements, the derivation of photometric quantities by means of Hapke's model and the genetic algorithm adapted to the problem (fig. 2).

Second, the θ determination for the investigated material (table II) is found to range between 5° and 30°. The values of θ are positively correlated with grain sizes and agree the planetary object whole-disk and disk-resolved photometric determinations [11].

In the millimeter range of grain size, the «rocky» aspect of the surface dominates the textural topography variation inside the pixels. The use of the Hapke's formalism handles the photometric behavior of the surface but on the basis of this new type of experimental data on natural surfaces [12]. We are in agreement with [13, 14] that the meaning of the mean topographic slope angle (θ) is an integral of the mesoscale and microscale roughness properties in the submillimetric-centimetric range. These findings strengthen the case that this parameter depends on both the grain size and the material. They also highlight the need for an improved theoretical model for describing the real case of natural regolithic surfaces, including regolith powders.

References: [1] Hapke B. (1993), Cam. Univ. Press, [2] Johnson P. et al. (1992), *JGR, 97*, E2, 2649-57, [3] Hiroi T. and Pieters C. (1994), *JGR*, *99*, E5, 10867-79, [4] Shkuratov Y. et al. (1999), *Icarus*, *137*, 235-246, [5] Johnson P. (1983), *JGR*, *88,* 3557-61, [6] Helfenstein P. and Veverka J. (1987), *Icarus*, *72*, 342-357, [7] Cheng A.and Domingue D. (2000), *JGR*, *105*, E4, 9477-82, [8] Pinet P. et al. (2001), LPSC XXXII, Abstract #1552, [9] Kamei A.and Nakamura A. (2002), *Icarus, 156*, 551-561, [10] Goldberg, D. (1989). *Genetic Algorithms in Search,* Addison-Wesley, [11] McEwen A. (1991), *Icarus*, *92*, 298-311, [12] Cord A. et al., *Icarus*, under revision, [13] Shepard M. and Campbell B. (1998), *Icarus, 134*, 279-291, [14] Helfenstein P. and Shepard M. (1999), *Icarus*, *141*, 107-131

Table I: Angular configurations of bidirectional reflectance measurements.

Incidence Angle (i)	20	30	40	0	30	50	20	30	40	50
Emergence Angle (e)	0	50	65	30	0	20	-35	-45	-55	-65
Phase Angle (φ)	20	20	25	30	30	30	55	75	95	115

Table II: Values of the shadowing function parameter (θ) with an uncertainty on the determination of about +/- 1°.

θ	G1	G2	G3	G4
Palagonite	14.4	20.4	21.9	24.9
Tephra	14.2	19.2	23.6	28.7
Basalt	5.8	13.5	16.2	20.7

Figure 1: Target composed of three materialsfor the different classes of grain size.

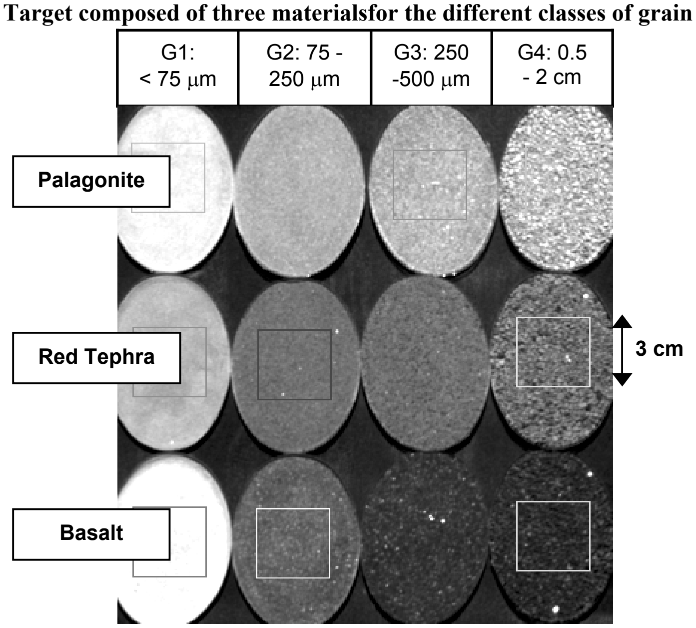

Figure 2: Measured and modeled spectra of the Tephra G3 sample, for the 10 configurations.