SPECTRAL PHOTOMETRIC PARAMETERS (UV,VIS,NIR) FOR 13 MATERIALS SIMILAR TO LUNAR AND ASTEROIDAL REGOLITHS. Oehler A., Dummel A., Hanowski N., Rebhan H., Neukum G., DLR, Institute for Planetary Exploration, 12489 Berlin, F.R.Germany

Introduction. Presented here are results of a large set of goniospectrophotometric measurements of regolith analog materials taken with the DLR-Goniospectrophotometer. For each of 13 different materials we took phase curves in 70 spectral channels [1,2,3]. The photometric model developed by Hapke [4,5] was fitted to each single phase curve (a second order Legendre polynomial was used for the phase function). Then the spectral Hapke parameters of all samples were analysed, leading to the following results: **1.** The opposition effect amplitude decreases approximately linearly with increasing single scattering albedo. **2.** The opposition effect amplitudes observed at low albedos are too high to be consistent with the theory of shadow hiding and (for one laboratory sample and for the lunar data) also too high to be consistent with a theory taking into account shadow hiding and coherent backscattering effects. **3.** The microstructure of the samples and not the single scattering albedo is the dominant factor influencing the distinct spectral forward/backward scattering properties of the individual samples. **4.** The increasing (g<90°) and decreasing (g>90°) redness of lunar soils with increasing phase angle can be simulated with the laboratory data set. **5.** The Hapke-parameters measured for the lunar surface lie within the parameter space covered by the laboratory samples.

Sample material. The samples analysed here are listed in Tab. 1. We have selected 13 materials relevant for the simulation of lunar and asteroidal surfaces. The grain sizes and porosities were selected to be analogous to the grain size of the upper lunar surface. SEM images were taken of each sample in order to analyse the particle microstructure. Structures range from individual particles with smooth surfaces to fluffy agglomerates, where it becomes difficult to determine what kind of structure makes up a single particle.

Results (example). Shown in Fig. 1 is for all samples and for all spectral channels the parameter b as a function of the single scattering albedo (SSA). This parameter scales the forward/backward scattering (negative/positive values) in the phase function of Hapke´s photometric model. It can be seen that in the range SSA<0.8, for an individual sample, backward scattering varies by a factor of 2 as a function of the SSA whereas it varies by a factor 4 among the samples. This shows that in the range SSA<0.8 sample structure and not absorption is the dominant factor influencing the backward/forward scattering process. Correlating the amplitude of the parameter b with the microstructure of the samples (compare Tab. 2 with Fig. 1) shows that backward scattering increases with decreasing particle size and increasing "fluffyness" of the particles. From the inspection of the SEM-images we suggest that agglomerate structures of a few microns are most effective for damping the forward scattered fraction of the radiation. In addition, Fig. 1 shows that the dependence between backward scattering and single scattering albedo is unique for each of the backward scattering samples (NI1, BA1, KO9, MU1). We suggest that this curve shape has the potential to be used for the remotely sensed analysis of the microstructural properties of planetary regoliths.

Discussion/Conclusions. The results of the study presented here are in good agreement with the scattering properties of lunar soils [6,7,8]. We detect the same deficiencies of the Hapke-model in describing the opposition effect and we can quantitatively reproduce most of the effects typically detected when analyzing data sets of the scattering properties of planetary surfaces. From this coincidence it can be concluded that the surface roughness term in Hapke´s photometric model [9] in fact allows detailed quantitative comparison of the scattering properties of samples with sizes differing in orders of magnitude (sample size in the laboratory is typically 1 cm^2, whereas sample size in remote sensing ranges from areas with diameters of kilometers up to whole planetary disks).

Outlook. Presently we are refining the DLR-goniospectrophotometer. In the near future the automated measurement of linear polarisation will be possible, the phase angle coverage will be improved, the spectral range will be extended to the range 250 nm - 2500 nm and it will be possible to take measurements outside the plane of incidence. Using this instrument we plan to build up a data base that can be used for testing photometric models, for constraining fits of photometric models to data sets with incomplete phase angle coverage, for providing support to photoclinometry and light curve inversion and to other methods using photometry as a step in the data reduction process.

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Tab. 1 Sample material. Increasing numbers of "+" signs indicate increasing relative intensities of the sample characteristics listed in the column header.

sample	*mineral*	*nominal grain size*	*porosity (measured sample)*	*compact particels >20 um*	*"fluffy" agglomerates <20 um*	*backward scattering*	*comment*
lunar surface [10]		70	52			++++	mean values
NI1	Nickel	<10	66		++++	++++	synthetic material
BA1	Basalte	<20	76		++	+++	Alkali-Basalte
KO9	Dunite + C	<20	85		++	++	0.1% C (by weight)
MU1	Murchison	<100	56	+	+	+	CM2 Chondrite
KE1	Kerogene	5-10	49	+			from Messel oil-schists
OL1	Olivine	<63	49	+			90% Forsterite, San Carlos, Arizona
OL2	Olivine	<90	44	+			
OL3	Olivine	90-120	46	+			
QU1	Quartz	300-500	38	+			naturally rounded grains
BR1	Bronzite	63-90	49	+			Kraubath-Austria
AU1	Augite	63-90	54	+			Risör-Norway
BY1	Bytownite	63-90	55	+			Crystal-Bay USA
AN1	Anorthite	<60	54	+			Ekersund/Norway

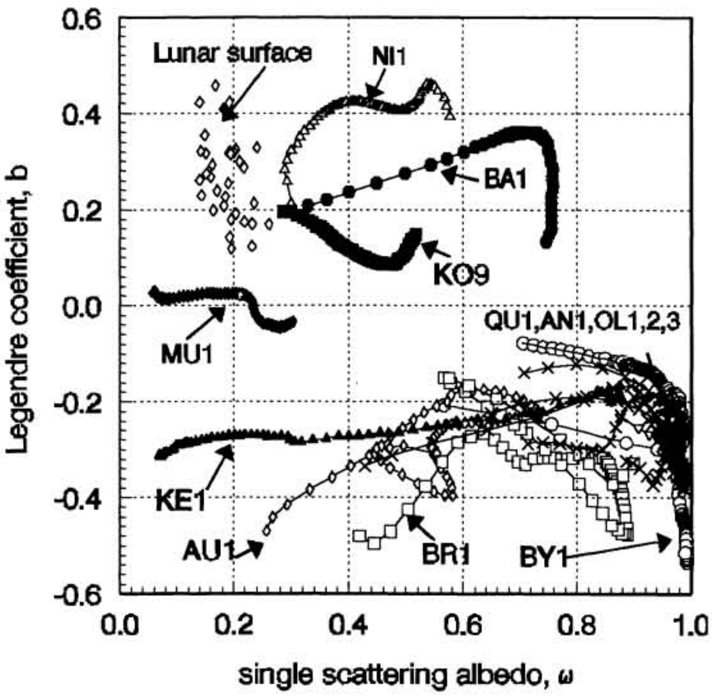

Fig. 1

The plot shows the spectral backward/forward scattering properties of the samples listed in Tab. 1 as a function of the single scattering albedo. Plotted on the vertical axis is the parameter *b* of the second order Legendre polynomial used in the Hapke model for modeling the single particle phase function. The value of this parameter is proportional to the degree of backward/forward scattering (positive/ negative values). Each curve in the plot shows the data points of the 70 spectral channels measured for each sample in the UV,VIS and NIR. The data points indicated with "Lunar surface" have been calculated from earth-based measured CCD-images which have been combined with data from the Galileo EM-1 encounter to obtain good phase angle coverage [7,8]. The data represent the scattering properties of 7 different spectral classes in the lunar Fra Mauro region. Due to the geological variability of the Fra Mauro region they represent a good mean over the scattering properties of the whole lunar surface.
See the abstract text for the interpretation of the data.

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