ANALYSIS OF THE SOLAR PHASE CURVES OF THE GALILEAN SATELLITE CALLISTO

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Using long-term photoelectric observations by Shavlovskij and Lockwood *et al.* [7] for solar phase angles from 0 to 12 degree we have obtained Hapke's parameters w, g, h, B_0 of the solar phase functions for the leading and trailing hemispheres of the Jupiter's satellite Callisto. The curve, with parameters determined from the $\lambda\,0.54\,\mu$m ground-based observations in the small range of α, agrees well with the total solar phase functions for both hemispheres measured in the large interval of α (from 10 to 140 degree) during space probe missions.

During past decade many authors (Buratti [1, 2], Domingue *et al.* [3]) have used the photometric observations of the Galilean satellites for determination of such physical properties of the surface of the atmosphereless celestial bodies as porosity, roughness, regolith size distribution. Photometric modeling also describes such material properties as the average single scattering albedo and single scattering functions. Hapke's theory [4, 5, 6] is currently accepted for these purposes. Within the framework of this theory the parameters of the solar phase function are expressed in terms of the physical characteristics of the surface layer. At the same time the characteristics of the leading and trailing hemispheres of Callisto obtained by several authors (Buratti [2], Domingue *et al.* [3]) applying the Hapke's theory are not in agreement. It can be explained by the lack of observations near opposition, the heterogeneity of the data, and the formal procedure of separation of solar and orbital brightness variations.

From 1980 to 1985 years author obtained an extensive set of homogeneous high accurate photometric observations of the Galilean satellites in eleven spectral bands. The observations processed by Lockwood *et al.* [7] have been also used. It should be noted that many observations were carried out near opposition that allows to find reliable parameters of the solar phase functions for the leading and trailing hemispheres of Callisto in four spectral regions.

We introduced an approach to correct the orbital brightness variations. Within this approach it was assumed that surfaces of the leading and trailing hemispheres differ by their (w, g, B_0, h) parameters. We used [2] to estimate the values of the roughness parameters. The contribution of each hemisphere to the total light flux scattered by the surface is accepted to be proportional to the square of the projection of the hemisphere on the image plane. This contribution may be calculated using the Hapke's theory equations for the taken set of the parameters and α, θ values for time of observation. The fact that the geometric albedo value for each hemisphere is directly determined from the observations near α=0° simplifies the search for other parameters. The w, g, B_0, and h parameters were derived from the condition of the best accordance between the model and the observed reflectivity values. The derived values of parameters are presented in Table 1. The data presented in the lines 1–3 are obtained from the observational data by Shavlovskij, those in the lines 4, 5 from Lockwood's data, and finally the data in the line 6 are derived by combining the data in [7] and author's ones.

Analysis of the results in Table 1 shows that the surface of the leading side of Callisto, on the contrary to the surface of the trailing side, consists of particles with more strong backscattering and more porous state. The observational data and model curves at $\lambda = 0.54\,\mu$m are presented in Fig. 1 and Fig. 2. It can be seen in Fig. 3 that the curve with parameters derived from ground-based observations within a small range of α (< 12°) reproduces well the solar phase functions of both hemispheres obtained over a large range of α (up to 140°) during space probe missions [2]. This fact confirms the reality of the values of parameters derived by using the high quality ground-based observations.

Table 1: Hapke model parameters for Callisto

hemisphere	Hapke model parameters				λ
	B_0	h	w	g	μm
leading					
1	0.900	0.020	0.350	-0.225	0.346
2	0.925	0.025	0.400	-0.275	0.540
3	1.000	0.040	0.450	-0.200	0.792
4	0.950	0.030	0.337	-0.300	0.470
5	0.900	0.030	0.375	-0.300	0.550
6	0.925	0.025	0.400	-0.275	0.540
trailing					
1	0.800	0.055	0.450	-0.150	0.346
2	0.975	0.045	0.500	-0.175	0.540
3	0.800	0.045	0.600	-0.100	0.792
4	0.975	0.055	0.400	-0.225	0.470
5	0.900	0.045	0.450	-0.225	0.550
6	0.900	0.045	0.500	-0.175	0.540

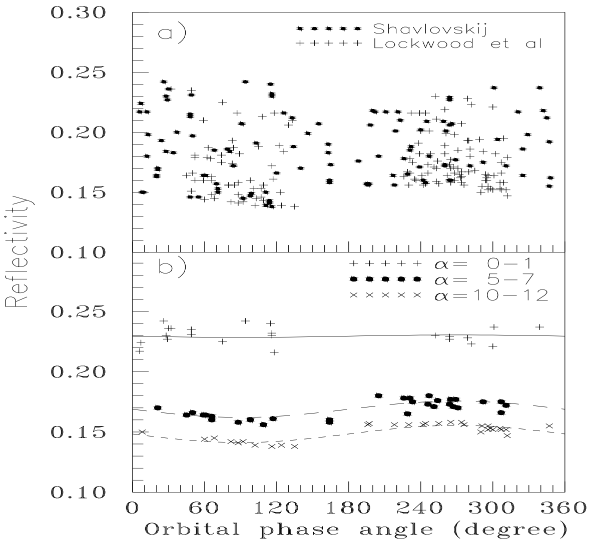

Figure 2: The reflectivity of Callisto at 5400 Å as a function of orbital phase angle. a) Total set of observational data. b) Observational data for a several fixed ranges of the solar phase angle and corresponding model predictions

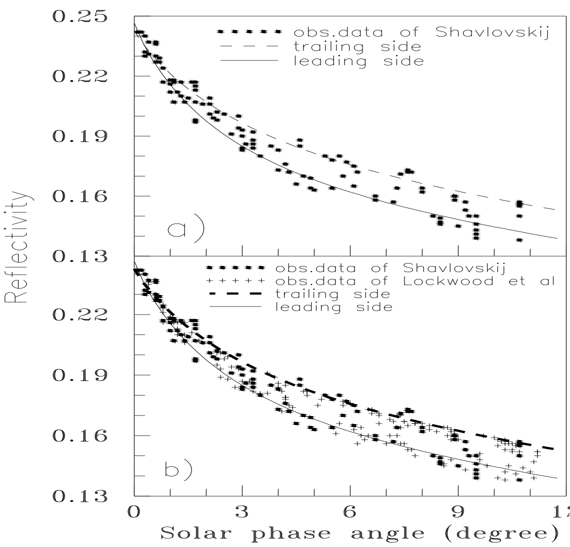

Figure 1: a) The observed reflectivity (points) of Callisto at 5400 Å as a function of solar phase angle. The model predictions are shown by the solid (leading side) and dashed (trailing side) lines. b) The same as in a) but for more extensive observational data set

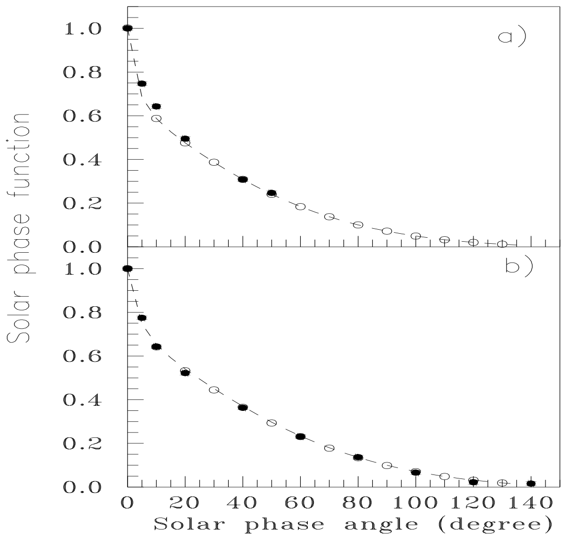

Figure 3: The solar phase function versus solar phase angle for leading (a) and trailing (b) hemispheres of Callisto at 5400 Å. Predictions of two models are shown by the dashed lines. Their parameters are derived by using the observational data by Shavlovskij, the parameters of the model presented by the open circles are based on Shavlovskij & Lockwood data. The Voyager data (filled circles) are shown for comparison

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