CAN LUNAR OPPOSITION SPIKE MEASURED BY CLEMENTINE EXIST?

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The brightness opposition spike measured by Clementine is probably an artifact. The spike has too small width, 0.25°. It could not be observed because the light source (the Sun) has the angular diameter of 0.5°.

Among new results obtained by Clementine, the narrow brightness opposition spike seems to be most sensation[1], though spikes of such kind have discovered for bright asteroids and bright satellites of Jupiter and Saturn (e.g., see [2, 3]). The effect is believed to be set up due to interference of rays passed direct and time reversed trajectories in light-scattered particulate media. For the first time this interference has been considered as an origin of the opposition effect and the negative polarization of atmosphereless celestial bodies in [4]. Now this mechanism is usually called the effect of coherence enhancement or the effect of weak localization of photons [5]. It seems to be temptingly to explain the Clementine's spike (see points in Fig. 1 adopted from [1]) by the effect.

Before that, however, we should ask ourselves: can Clementine's spike be observed at all? Indeed, the width of the spike is less of 0.25°, while the width of the light source (the Sun) equals to 0.5°. Each point of the solar disk is an independent light source, which has its phase angle. Thus, even if the phase angle of the central point of the Sun's disk equals zero, the effective phase angle of this light source is not zero. This makes it practically impossible to observe any details of brightness phase curves, the widths of which are less than the angle radius of the Sun [6]. If the Moon has really narrow opposition spike, it should be smoothed due to integration of phase angles over the solar disk, and Clementine could not observe the effect. We decided to model this smoothing using the following empirical formula, which gives, as a rule, a good fit to experimental data:

$$F(a,b,c,\alpha) = a\exp(-\alpha/b) + (1-a)\exp(-\alpha/c),$$

where α is the phase angle (rad); a, b, and c are fitting constants. The finite angle size of the Sun. was taken into account by means of the obvious generalization

$$f(a,b,c,\alpha_0) = \frac{\int_0^{\pi}\left\{\int_0^{R} B(r)F(a,b,c,\alpha(\alpha_0,r,\varphi))r\mathrm{d}r\right\}\mathrm{d}\varphi}{\int_0^{\pi}\left\{\int_0^{R} B(r)F(a,b,c,\alpha(0,r,\varphi))r\mathrm{d}r\right\}\mathrm{d}\varphi}$$

where α_0 is the phase respecting the central point the Sun's disk, $B(r)$ is the brightness distribution over solar disk at $\lambda = 0.9$ μm [7], r and φ are the polar coordinates of an arbitrary point on the disk, R is the visible angular radius of the Sun. If we assume that $R = 0.25°$, the best fitting curve presented by dashed line in Fig. 1 reveals a feature, which does not resemble experimental data at small phase angles: this line is convex. There is no way to avoid this feature and there is no way to obtain a concave line, if we believe, of course, that $R = 0.25°$.

Thus, the opposition spike found by Clementine [1] should be interpreted in a different way, e.g., as a result of spatial variations of surface albedo, which must spring up as the spacecraft moved along the lunar surface measuring the phase curve.

To suppress these variations we try to smooth Clementine's data (points) and renormalize them at $\alpha = 0$. The scale of smoothing was chosen equal to typical size of the variations (see details at $\alpha = 0.5°$ and $\alpha = 0.8°$ in figure), the symmetry of phase curve being taken into the account. The result of this smoothing shows more weak opposition spike and closes to the model fit.

Non zero angular size of light sources and receivers must certainly be taken into account in laboratory measurements as that have been carried out by Hapke [8].

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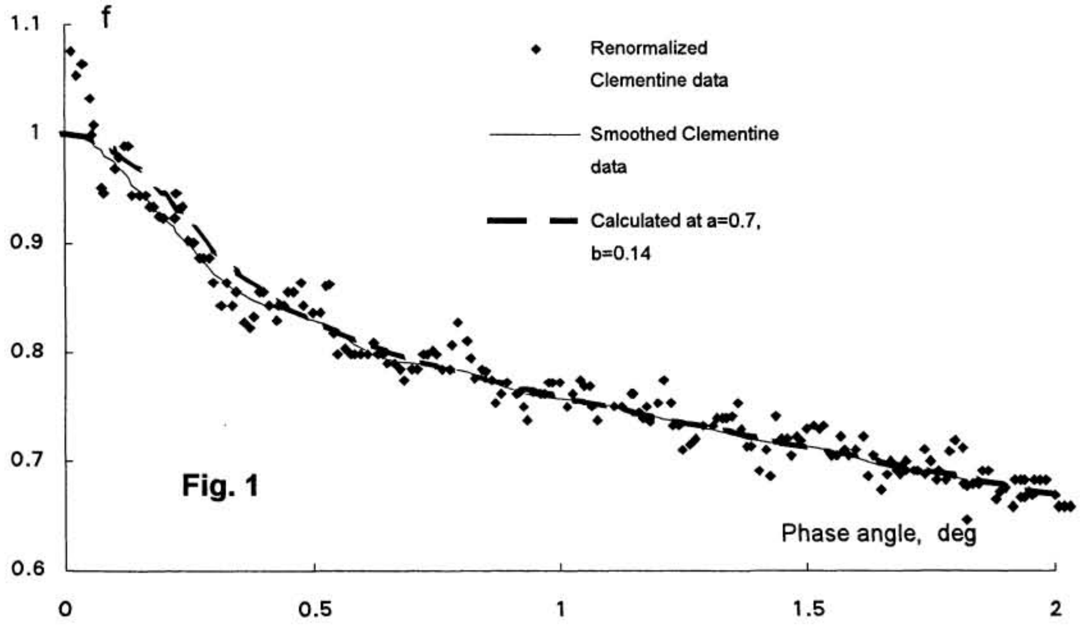

Fig. 1