THE "BLACK DROP" PHENOMENON AND REDUCTION OF THE MERCURY TRANSITS OBSERVATIONS

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Mercury transits are important for the investigation of long-term variations in the Earth rotation. They have been observed for more than 300 years. The basic array of this set is the visual observation of contacts (as a rule the second and third ones). The detection of the instant corresponding to the geometrical contact of the solar and Mercury limbs is a difficult task, since during 10^s to 60^s, the set of phases is observed transforming continuously from one to another. One of the encumbering factors, is the so-called "black drop" phenomenon, i.e., the dark cross-bar formed between the limbs (Struve, 1882; Kuhl, 1929; Wittman, 1974; Morrison et al., 1975). The influence of this factor could be negleted if the observations were distributed uniformly with regard to contacts, observers and observational conditions. In fact, it is far from that and the necessity of reduction corrections arises.

In forming the photometric profile of the border of some object, the following factors have an influence:

1) THE LIMB DARKENING (for the Sun).

2) IMAGE BLURRING including the atmospheric turbulence; the diffraction can be represented by two-dimensional isotropic Gaussian distribution in which the parameter σ depend on the amplitude of blurring.

3) The excitement of the elements of retina is not proportional to the illumination, but to its linear combination with the so-called CONTRAST FUNCTION, which takes into consideration nonlinear variations of illumination upon the retina.

The process of the formation of bar was investigated by numerical simulation (Sveshnikov et al., 1995). It was found that the main factor of the drop formation is image blurring. In good seeing ($\sigma \simeq 0.5''$), the black drop phenomenon is absent. For $\sigma \simeq 1.5 - 2''$ (mean or bad seeing), it is

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distinctly observed. Increasing the parameter σ up to these values, the filament, i.e. ,a dark narrow strip having the width about 1/3 of Mercury radius, appears for a distance between limbs from $\sigma/2$ to σ. Then, the filament is transformed into a drop (dark wide bar having a width of about Mercury radius R). In addition to that, the irradiation diminishes the apparent Mercury radius and the apparent moment of contact with the drop does not coincide with that of geometrical contact. For $\sigma \simeq R$, the observation of contacts is unrealizable practically. The half-sum of the moment of apparent contact with black drop and that of the drop breaking equals, approximately, the moment of the geometrical contact. The presence of contrast leads to the variation of apparent density of drop and the appearance of fictitious contacts.

The displacement of moment of apparent contact caused by the drop effect can be estimated by:

$$\Delta T^s \simeq \frac{d}{V\sqrt{1-(c_m/R_s)^2}},$$

where d is the distance between the geometrical limbs in the moment of apparent contact with the drop, in arcsec (d is determined by simulation; its mean value is $\simeq 1.4''$); V is the velocity of Mercury along its apparent trajectory (V equals 1/10 or 1/15 $''$/s for November and May transits); c_m is the minimal distance between centers; R_s is the solar radius.

The preliminary comparison of the obtained numerical values of the corrections for reduction of observations to moments of geometrical contacts have shown a good agreement with the real observations for the transits of 1878(II), 1878(III), 1907(III), 1914 (II), 1914 (III), 1953 (II), 1953(III), 1957 (II). In some cases, a significant diminution of the error of averaged moment of contact was recorded (about in 2 times). It should be noted that the photographic method of multiple observations of the position of planet across the solar surface excludes the errors connected with black drop, but, in the other hand, includes errors due to scale factor and oscillation of refraction. At present, at ITA RAS, the archive of Mercury transit observations is being revised. The above method of reduction permits to decrease the error in the calculation of contact's normal points.

References

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