The impact-rotational mechanism and origin of the grooves on Phobos and other small asteroids

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We present a new impact-rotational mechanism that explains the origin of grooves on Phobos. Its essence is that the boulders can move through the regolith and create the grooves, while their kinetic energy is supplied from the impact rotation of Phobos.

The geometric shape of Phobos approximately described by a triaxial ellipsoid with semi-axes

$$a_1 = 13.09 km, a_2 = 11.72 km, a_3 = 9.48\,km \qquad (1)$$

(the average radius $R = 11.3\,km$). On surface of Phobos there is a deep (reaching $100\,m$) layer of regolith. The regolith on Phobos is rougher than on the Moon. The grooves on Phobos relatively narrow of the width $100-200\,m$ with slanting edges and have several kilometers in length. Their depth is relatively small $10-30\,m.$ The length of some grooves sometimes reaches $20\,km.$ On Phobos there are three systems of grooves. Each family of grooves is of a different age. Grooves in each family are strictly parallel each other. The first system, in the accepted classification is «A» system, is the oldest, the grooves belonging to it go from the Stikney crater and are located in the meridional planes passing through the greatest axis of Phobos.

With all the richness of bright ideas, the previous hypotheses of forming the grooves on Phobos didn't solve a problem of so-called energy paradox. Essence of this paradox consists in the following: to create the groove of middle length, a boulder must have such velocity that exceeds the escape velocity from Phobos. The impact-rotational mechanism solves this energy paradox.

1. The main question: is it possible to use the forces

$$\boldsymbol{F} = \left[\boldsymbol{x}\frac{d\boldsymbol{\omega}}{dt}\right] + \frac{1}{2}\frac{\partial}{\partial \boldsymbol{x}}[\boldsymbol{\omega}\,\boldsymbol{x}]^2 + 2[\boldsymbol{\upsilon}\,\boldsymbol{\omega}]. \qquad (2)$$

which arise from additional rotation of Phobos with the angular velocity $\boldsymbol{\omega}$.

2. The condition of movement of a boulder would be written as inequality

$$\frac{r}{R} > \frac{1}{2\eta}\frac{\upsilon_0^2}{R^2\left(\dot{\omega} + \omega^2\right)}, \qquad (3)$$

where parameter $\eta \approx 28.4$, υ_0 – some characteristic velocity (the one is less than the shock wave velocity in the regolith), at which takes place the rupture of the soil. The inequality (3) superimposes restriction from below on radius of a boulder and foretells that only the large blocks shall slide on a surface, while the sand and crushed stone will remain on a place. It is shown that the impact forces set in motion only large enough boulders radius of that not less than $r_{\min} \approx 50\ m$.

3. Using the energy balance and the conservation law of angular momentum, the quadratic equation

$$\kappa^2 - \frac{2}{5}\kappa + \frac{4}{5}\frac{K}{MV^2\cos^2 i} = 0. \qquad (4)$$

for the ratio $\kappa = \dfrac{m}{M}$ of the impactor mass to the mass of the target is obtained. Here $K \approx 6.5 \cdot 10^{25} erg$ is the energy of formation of the crater Stikney. An conclusion ensues from it, that the Phobos's rotational energy E_{rot} is inversely proportional kinetic energy of the impactor.

4. The probable reason of absence of grooves in the region Laputa. **T**he height of the area to Phobos is very significant and, according to the map a height equal to $h \approx 800\ m.$ That the block could be gone on a quarter this height, they must have the average speedsuch height, it has to possess speed not less, than

$$\upsilon = \sqrt{2gh} \approx 1.5 \frac{м}{сек} \qquad (5)$$

5. Two options of formation of the crater Stickney are considered: for impactor's velocity $V = 5\,(7)\ km \cdot s^{-1}$ and angle of impact 45^0 we found $\kappa \approx 9.8\,(5) \cdot 10^{-5}$, $E_{rot} \approx 1.59\,(0.811) \cdot 10^{22} erg,$ and the rotational velocity of Phobos $\upsilon_{rot} \approx 86(62)\ cm \cdot s^{-1}$. Half of this energy is sufficient to form on Phobos $N \approx 500\,(300)$ grooves of the medium length $L \sim 10\ km.$ The average velocity and the time of movement of the blocks on Phobos are equal $\upsilon \approx 1.5\ m \cdot s^{-1}$ and $T \approx 2$ hours.