

COMPARISON OF OBSERVED AND MODELLED METEOROID CRATER DISTRIBUTION ON PHOBOS

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ABSTRACT:

A database of 1037 periodical comets and about 30000 asteroids was analysed for identifying potential parent bodies of Martian meteoroids. The probability of impacts of asteroidal meteoroids with Phobos was estimated by Opik method [7]. Also our model of the cumulative particle flux for cometary meteoroids was used [5,6]. As a result, we may estimate the probability and velocity of asteroidal and cometary meteoroid encounters with Mars and its satellites. During the simulation shielding of meteoroids by Mars, and shift of the radiant due to the Phobos orbital motion were taken into account. Global Phobos Geodatabase [9] was used for comparison of observed and modeled global meteoroid crater distribution.

1. INTRODUCTION

This paper discusses the three main types of meteoroids: cometary stream meteoroids; sporadic meteoroids of cometary origin, and meteoroids of asteroidal origin.

Meteoroids are derived from comets and asteroids. Cometary meteoroids result from degradation of comets following their approaches to the Sun. They may be divided into two main types: meteoroids in streams and sporadic meteoroids. Streams are formed from long period ($T > 200$ years) comets (LPC) and Halley-type ($20 < T < 200$ years) comets (HTC), which are typically in rather stable orbits. Jupiter-family comets (JFC), are in rather unstable orbits and are thought to be the source of sporadic cometary meteoroids. Long periodic-, Halley-type-, and Jupiter-family comets that have close approach to Mars orbit can be potential parent bodies of Martian meteoroid streams and sporadic meteoroid. Asteroids that have close approaches to Mars orbit also can be potential parent bodies of Martian meteoroids.

The JPL's HORIZONS database of 1037 periodical comets and about 30000 asteroids [1] was analyzed to search for parent bodies of Martian meteoroids.

We found 64 long period-, 54 Jupiter-family- and 10 Halley type comets that orbits have approach to Mars orbit less than 0.15AU. Also we identified 6223 asteroids approaching the orbit of Mars within less than 0.1 AU. This paper presents results of numerical simulation of Phobos meteoroid bombardement from these three main sources.

2. STOCHASTIC MODELLING

2.1. Cometary meteoroids

The comet model was constructed earlier and described in detail in [5,6]. The time of activity of potential Martian meteoroid streams was obtained for each selected comet. The cumulative particle flux (ρ) was presented as function of distance (r) from the stream axis [5] $\rho(r) = a e^{-br}$, where a – is a parameter depending on the cumulative mass distribution, and b – is a depending on specific stream structure and describing the stream density. The stochastic modeling of meteoroid impacts on Phobos and global crater distributions was performed using a uniform random-event generator on a sphere [8].

Directions and velocities of possible impacts were calculated. The radiant is the result of the vector sum of the instantaneous velocity of Phobos and velocity of the meteoroid at the time of closest approach of the comet with the Mars orbit. The effect of meteoroid shielding by Mars and the different impact velocities on the leading or trailing Phobos hemispheres were taken into account.

The global impact distribution is presented by latitude and longitude in the Phobos centered Phobos-fixed coordinate system (Fig. 1).

The impact rate is reduced in the area around the prime meridian. This is an effect of meteoroid screening by Mars. In general, it is for up to 11% of particles that impact on the Phobos hemisphere oriented to Mars or about 5.5% of common meteoroid number. The leading hemisphere received 18% more impacts than the trailing hemisphere. Most cometary meteoroid impacts were with velocities from 30 km/s to 60 km/s.

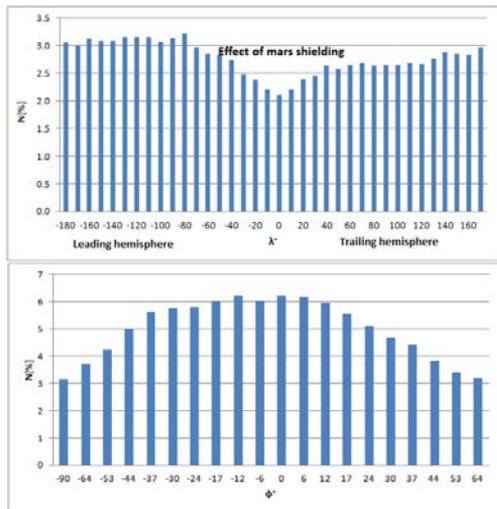


Figure 1. Stochastic model of impacts cometary meteoroids (streaming and sporadic) with Phobos. Distribution of impact is presented in Phobos-fixed frame by latitude and longitude

2.2. Asteroidal meteoroids

Asteroid impact probabilities were modeled by the Opik technique [7]. At the next step asteroid magnitudes were converted into diameters and masses. All asteroids with magnitude more than 18 suffer from significant observational bias. This was

corrected by extrapolating the Hartmann function [4]. We calculated Phobos-fixed coordinates of impacts for asteroidal meteoroids as in the cometary model above. Asteroidal meteoroid encounters are characterized by a much lower velocity than cometary ones, so we would expect a greater asymmetry between the leading and trailing hemispheres, which is confirmed by our simulations.

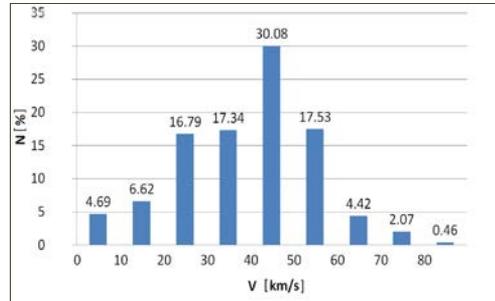


Figure 2. Distribution of impacts of cometary meteoroids (streaming and sporadic) by Phobos-centric velocity

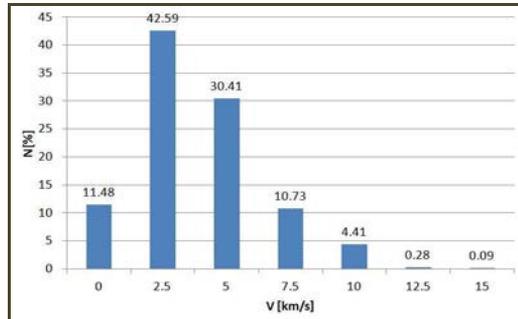


Figure 3. Distribution of impacts of asteroidal meteoroids by Phobos-centric velocity

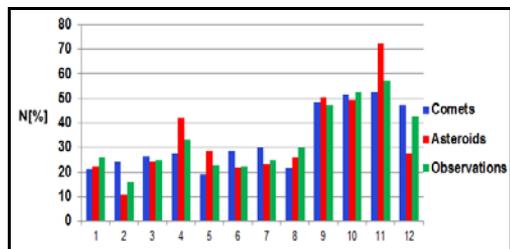


Figure 4. Statistics of modelled and observed meteoroid craters

Table 1. Statistics of modelled and observed meteoroid impact craters on Phobos

Location on Phobos	Long Period Comets	Jupiter-Family Comets	All Comets	Asteroids	Observations
	N[%]	N[%]	N[%]	N[%]	N[%]
Sub-Mars ($-45^\circ < \lambda < 45^\circ$)	23.2±1.3	21.6±1.3	21.4±1.3	23.0±1.3	26.0
Trailing ($45^\circ < \lambda < 135^\circ$)	24.1±1.3	23.1±1.4	24.2±1.4	15.2±0.9	15.9
Anti-Mars ($135^\circ < \lambda < 225^\circ$)	25.8±1.4	26.4±1.4	26.6±1.4	23.7±1.4	24.9
Leading ($225^\circ < \lambda < 315^\circ$)	26.9±1.4	28.8±1.5	27.8±1.5	38.0±1.8	33.3
North Polar ($\varphi > 30^\circ$)	24.2±1.3	13.8±1.2	19.5±1.2	33.3±1.5	22.6
North Equatorial ($0^\circ < \varphi < 30^\circ$)	22.9±1.3	23.6±1.3	28.9±1.5	28.8±1.5	22.4
South Equatorial ($-30^\circ < \varphi < 0^\circ$)	26.3±1.4	34.4±1.5	29.9±1.5	18.5±1.3	24.9
South Polar ($\varphi < -30^\circ$)	26.6±1.4	28.2±1.5	21.7±1.3	19.4±1.3	30.0
Northern Hemisphere	50.8±2.0	42.0±1.8	48.4±1.9	52.7±2.0	47.3
Southern Hemisphere	49.2±2.0	58.0±2.2	51.6±1.9	47.3±2.0	52.7
Western Hemisphere	52.0±2.1	54.1±2.1	52.7±2.0	64.9±2.4	57.3
Eastern Hemisphere	48.0±1.9	45.9±1.9	47.3±1.9	35.1±1.5	42.7

3. SUMMARY AND CONCLUSIONS

The results of stochastic modelling of meteoroid encounters are presented. Impact rates of meteoroids on the surface of Phobos were calculated. Velocities of particles that impact onto Phobos leading and trailing hemispheres different by up to ± 2 km/s. Average effect of the meteoroid screening by Mars for sub-Mars hemisphere is about 11% for cometary and 2% for asteroidal meteoroids. Simulated crater distribution is well correlated with observations. Our model may be useful to assess outcomes of seismic experiments on Mars, Phobos, and Deimos and to identify possible risks for spacecraft collisions with meteoroids near the Mars.

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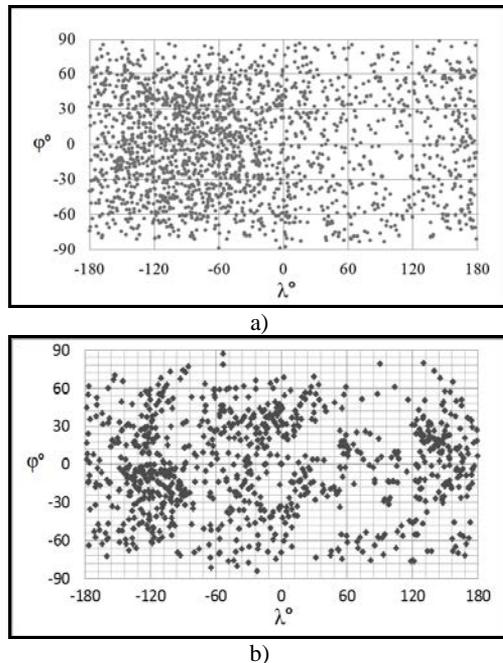


Figure 5. Craters distributions: a) simulated data; b) observations based on Phobos crater catalogue