Asteroids, Comets, Meteors 1991, pp. 9-15
Lunar and Planetary Institute, Houston, 1992

PHOBOS AND DEIMOS ARE SOURCES OF METEOROIDS

V.V.Andreev, O.I.Belkovich

Engelhardt Astronomical Observatory, SU-422526, Kazan, USSR

ABSTRACT

Data of Pioneer 10 meteoroid penetration detectors were revised taking into account the orientation of detectors and the spacecraft velocity relative to the sporadic meteor flux . The meteor flux density increases as an exponent to the orbit of Mars for two times for the particles with masses greater than 10^{-6} g and six times for the particles with masses greater than 10^{-12} - 10^{-9} g then decreases after the orbit. Ejections of secondary meteoroid particles from surfaces of Phobos and Deimos are possible explanation of the increase the meteoroid flux.

INTRODUCTION

One source of our knowledge on distribution of meteor matter in the interplanetary space is data obtained in situ from space probes. Beyond of the Earth's orbit progress has been made by space probes Mariner 4 and Pioneer 10 experimental. It is a pity the number of registered events is scanty. In this case a correct interpretation of experimet results is very important.

INTERPRETATION OF EXPERIMENTAL RESULTS

The problem has been discussed in detail by many authors, for example, Humes et al, 1974. For the interpretation of observational data one must consider the orientation of the collecting area relative to flux of the sporadic meteoroids and equipment selectivity. The solution of the problem is simplified in the case of the isotropic sporadic flux density. But it is not the case since we have a very unisotropic distribution of the sporadic flux density over the celestial sphere (Andreev and Belkovich, 1987). The flux density $Q(V,\varepsilon,\psi)$ is determined as

$$Q \cdot P(V,\varepsilon,\psi) = Q\, P_{\varepsilon,\psi}(V)\, P(\varepsilon,\psi),$$

Q is the total flux density of meteoroids with masses greater than some value m coming from all celestial sphere, intersecting for unit time unit area normal to the velocity vector; $P(V,\varepsilon,\psi)$ is the three-dimensional distribution of a meteoriod velocity V and coordinates of meteor radiant ε, ψ; $P_{\varepsilon,\psi}(V)$ is the conditional distribution of velocities for a radiant direction ε, ψ and $P(\varepsilon,\psi)$ is the two-dimensional distribution of meteor radiants. The mathematical model of $Q(V,\varepsilon,\psi)$ in the vicinity of the Earth's orbit for sporadic meteoroids with masses greater than 10^{-6} g in heliocentric system of coordinates has been derived from radar meteor observations (Andreev and Belkovich, 1987).

A number of events (registrations) N in unit of time is

$$N = Q_o \Phi$$

where

$$\Phi = \int \int \int F(V_1,\varepsilon_1,\psi_1)\ P(V_1,\varepsilon_1,\psi_1)\ \sin \varepsilon_1 d\varepsilon_1 d\psi_1 dV_1,$$

$F(V_1, \varepsilon_1, \psi_1)$ is a selectivity function that takes into accout radiant coordinates relative to a collecting area and the physical conditions of registration. In the last equation the reference system V_1, ε_1, ψ_1 is related to the space probe. The transformation of the flux density from the heliocentric reference system to the space probe frame of reference is carried out by the next equation

$$Q(V_1,\varepsilon_1,\psi_1) = Q(V,\varepsilon,\psi)\ (V_1/V)^3\ (\mathrm{Sin}\ \varepsilon_1\ /\ \mathrm{Sin}\ \varepsilon)$$

(Andreev and Belkovich, 1987).

Two kinds of equipment were installed on board of Pioneer 10 for registration of meteoroids. The first was the meteoroid penetration detectors and the second was the asteroid/meteoroid detector (AMD) or Sisyphus. In the case of the penetration detectors the orientation of the collected area has very important role due to their small field-of-view. The line of vision was directed opposite to the Earth's direction during the whole mission and parallel to spacecraft spin axis. In contrast to this its field of view of the AMD experiment was much greater due to the rotation of the spacecraft and the optical subsystem was pointed at an angle of 45° relative to the spacecraft spin axis (Soberman et al, 1977).

RESULTS AND DISCUSSION

For the part of orbit of Pioneer 10 from 1 AU to 2 AU values of the function Φ have been calculated. The function F for penetration detectors has been taken on the base of results of Humes et al, 1974. For the Sisyphus experiment the collecting area has been taken into account. The variations of the function Φ versus heliocentric distance for the two experiments are shown in Fig. 1. As pointed out earlier the variations of the function are greater for the penetration experiment due to orientation of collecting area.

The relative variations the flux density in the heliocentric frame of reference versus heliocentric distances are shown in Fig. 2. The flux density is normalized so that it is equal to 1 at the Earth's orbit. Data for the experiment carried out at the space probe Mariner IV are also shown without correction on observational bias because of the absence of information about the orbit and equipment of the probe. This correction is negligible in the case of the random orientation of the collecting area. Both sets of the data show similar exponential increase of meteor flux density to the Mars orbit. The exponential decay of the flux density one can see after the maxima. The slight difference of the maxima position may be attributed to experimental uncertainties. The function of the relative flux density variation R between the Earth's and Mars orbits for the meteoroid masses 10^{-12} - 10^{-9} g is

$$R = \exp [a (r-1)]$$

where a is equal to 4.3 for this meteoroid masses.

Interpretation of Sisyphus experiment results have been made in the assumtion of similarity of the function R for meteoroid with masses greater than 10^{-6} g at heliocentric distances 1.0 - 1.4 AU. We have assumed also that R = 0.96 for the heliocentric distances 1.4 - 2.0 AU. The function R fits best of all to the experimental data for a equal to 1.8.

Table 1. Observed (N_{obs}) and calculated (N_{cal}) number of registrations of AMD experiments

r_1 - r_2	N_{obs}	N_{cal}
1.04 - 1.2	32	31.9
1.2 - 1.4	32	32.0
1.4 - 1.6	15	15.7
1.6 - 1.8	15	15.1
1.8 - 2.0	15	15.1

N_{cal} is taken proportional to

$$\int_{r_1}^{r_2} \exp [a (r-1)] \, dt$$

where t is the time of flight of the spaceprobe.

The value of a becames greater if the maximum of the R function corresponds to the distance from the Sun less than 1.4.

CONCLUSION

Thus the correct interpretation of the Pioneer 10 and Mariner IV data on the sporadic meteoroid flux density at the heliocentric distances 1.0 - 2.0 AU lead us to the conclusion that the flux maximum corresponds to the vicinity of the martian orbit. But the escape velocity from the planet surface is greater than one for the satellites of Mars. Phobos and Deimos are most possible sourses of meteoroids.

REFERENCES

Andreev V.V. and Belkovich O.I. (1987) Models of sporadic meteor body distributions. Handbook for MAP, 25, 298-304.

Humes D.H., Alvarez J.M., O'Neal R.L., and Kinard W.H. (1974) The interplanetary and near-Jupiter meteoroidal envinronments. J. Geophys. Res., 79, 3677-3684.

Soberman R.K., Neste S.L., and Lichtenfeld K. (1977) Results of the asteroid - meteoroid particle experiment on Pioneer 11. Space Res., 17, 559-564.

Captions for Figures

Fig. 1. Variations of the Φ functions vs heliocentric distances.

Fig. 2. Relative flux density at the heliolcentric distances from 1.0 to 2.0 AU. Dashed line is the flux density for the AMD experiment.

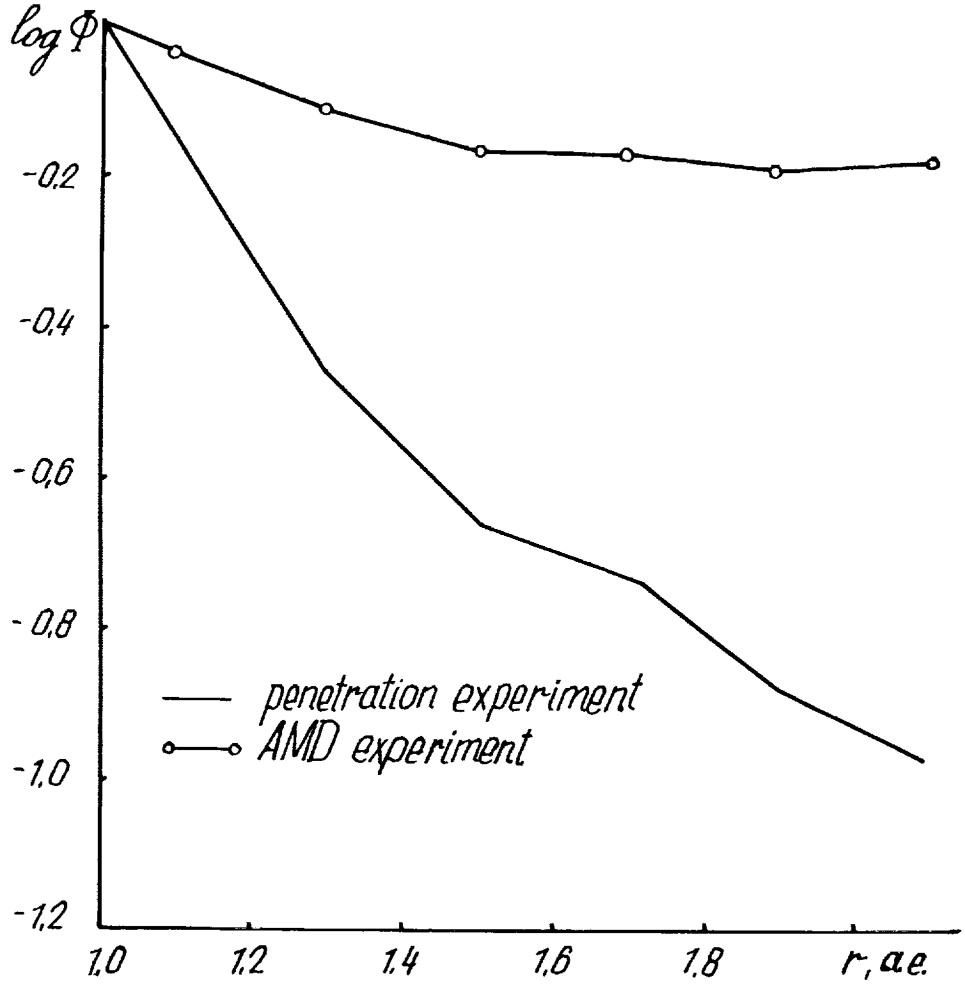
log Φ
-0,2
-0,4
-0,6
-0,8
-1,0
-1,2
1,0
1,2
1,4
1,6
1,8
r, a.e.
penetration experiment
AMD experiment

FIGURE 1.

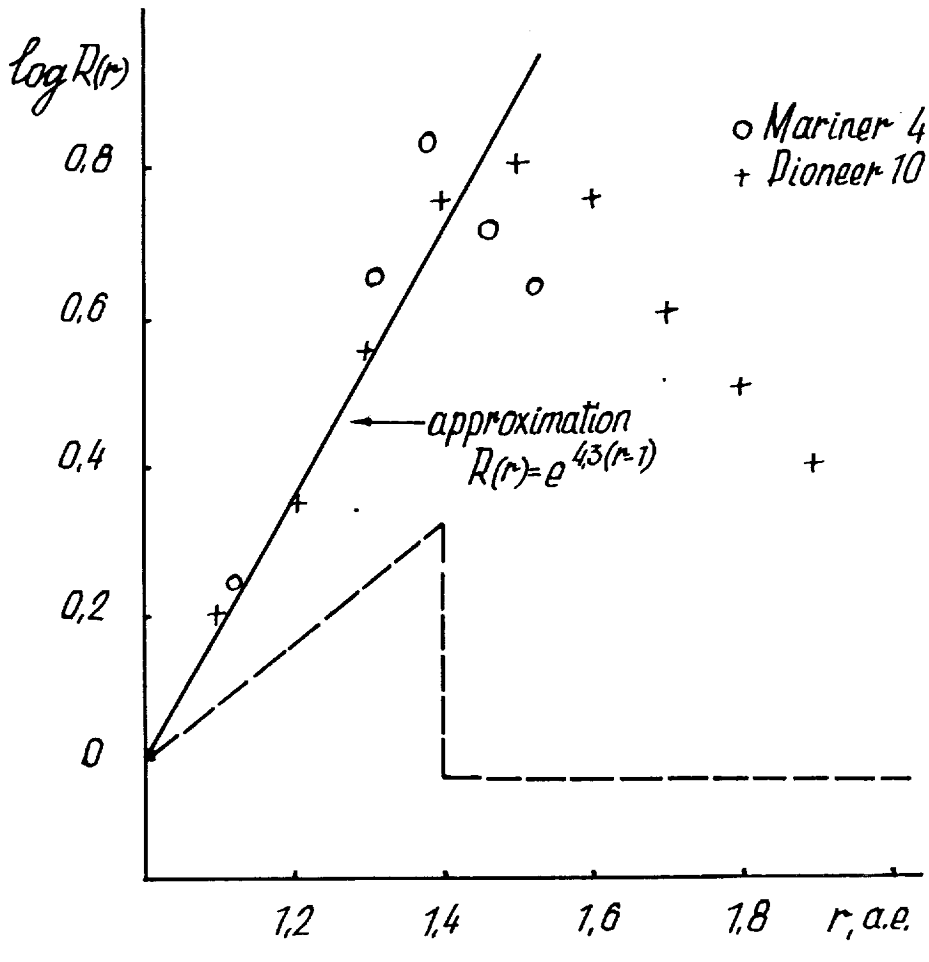
log R(r)
0,8
0,6
0,4
0,2
0
1,2
1,4
1,6
1,8
r, a.e.
o Mariner 4
+ Pioneer 10
approximation
R(r)=e^{4,3(r-1)}

FIGURE 2.