MIGRATION OF INTERPLANETARY DUST PARTICLES TO THE EARTH AND THE MOON

S. I. Ipatov, V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry of Russian Academy of Sciences, Kosygina st., 19, Moscow 119991, Russia. E-mail: siipatov@hotmail.com

Introduction: Probabilities of collisions of migrating dust particles produced by different small bodies with planets were studied, for example, in [1-4]. In [5] the simulated Doppler shifts of the solar Mg I Fraunhofer line scattered by asteroidal, cometary, and trans-Neptunian dust particles were compared with the shifts obtained by Wisconsin H-Alpha Mapper (WHAM) spectrometer. The comparison showed that cometary particles originating inside Jupiter's orbit and particles originating beyond Jupiter's orbit (including trans-Neptunian dust particles) can contribute to zodiacal dust about 1/3 each, with a possible deviation from 1/3 up to 0.1-0.2. The fraction of asteroidal dust was estimated to be ~0.3-0.5. Below I study probabilities of collisions of dust particles with the Earth and the Moon and also with their embryos.

Integration of motion of dust particles and calculations of probabilities of their collisions with celestial bodies: Migration of dust particles was studied with the use the BULSTO code from the integration package [6]. The gravitational influence of planets, the Poynting-Robertson drag, radiation pressure, and solar wind drag were taken into account. The influence of Mercury was omitted in most runs (exclusive for orbits close to that of Comet 2P/Encke). The ratio β between the radiation pressure force and the gravitational force varied from ≤0.0004 to 0.4. For silicates, such values of β correspond to particle diameters *d* between ≥1000 and 1 microns; *d* is proportional to 1/β.

The orbital evolution of ~20000 dust particles with initial orbits close to the orbits of different small bodies was studied during dynamical lifetimes of particles (until all particles reached 2000 AU from the Sun or collided with the Sun). Based on the orbital elements of particles during their dynamical lifetimes I calculated the probability of collisions of dust particles with the Earth (p_E), the Moon (p_M), the embryos of Earth and the Moon (p_{E01} and p_{M01}) which masses are smaller by a factor of 10 than masses of the Earth and the Moon, respectively. The algorithm of calculations of the probabilities was described in [7], and later it was improved in [8]. The probabilities at different values of β were calculated for particles launched from asteroids with numbers from 1 to 500 (runs marked as *ast*), discovered trans-Neptunian objects (*tno*), Comet 10P/Tempel 2 (10P, a≈3.1 AU, e≈0.53, i≈12°), Comet 39P/Oterma (39P, a≈7.25 AU, e≈0.25, i≈2°), Comet 2P/Encke at perihelion (2P*per*, a≈2.2 AU, e≈0.85, i≈12°), Comet 2P/Encke at aphelion (2P*aph*), Comet 2P/Encke in the middle between perihelion and aphelion (2P*m*), test long-period comets (*lp*) at eccentricity e=0.995 and perihelion distance q=0.9 AU, and test Halley-type comets (*ht*) at e=0.975 and q=0.5 AU (for *lp* and *ht* runs, initial inclinations i were from 0 to 180°, and particles were launched near perihelia).

Probabilities of collisions of migrating dust particles with the Earth, the Moon, and their embryos: For dust particles produced by asteroids and comets, p_E was found to have a maximum (~0.001-0.02) at 0.002≤β≤0.01, i.e., at d~100 microns (this value of d is in accordance with observational data). The maximum values of p_E for dust particles were usually (exclusive for Comet 2P/Encke) greater at least by an order of magnitude than the values for parental comets. For the same β, values of p_E/p_M, p_E/p_{E01} and p_M/p_{M01} typically were greater for greater p_E. For initial orbits with greater e, the ratio p_E/p_M is typically smaller. The maximum values of p_E and p_M, and the intervals of values of p_E/p_M, p_E/p_{E01} and p_M/p_{M01} are presented in the Table. For comparison, the square of the ratio of radii of the Earth and the Moon is 13.48, and the square of the ratio of radii of bodies differed in mass by a factor of 10 is 4.64.

	ast	*tno*	C39	C10	2P*per*	2P*aph*	2P*m*	*ht*	*lp*
max{p_E}	$1.7\cdot10^{-2}$	$1.5\cdot10^{-4}$	$1.1\cdot10^{-3}$	$1.6\cdot10^{-3}$	$2.0\cdot10^{-4}$	$1.9\cdot10^{-4}$	$1.6\cdot10^{-4}$	$1.6\cdot10^{-4}$	$9.3\cdot10^{-7}$
max{p_M}	$5.1\cdot10^{-4}$	$2.9\cdot10^{-6}$	$5.3\cdot10^{-5}$	$6.5\cdot10^{-5}$	$1.1\cdot10^{-5}$	$1.2\cdot10^{-5}$	$9.1\cdot10^{-6}$	$1.8\cdot10^{-6}$	$9.8\cdot10^{-8}$
β for max{p_E}	0.005	0.2	0.0001	0.01	0.002	0.002	0.004	0.001	0.001
p_E/p_M	16-33	16-52	16-32	16-30	15-23	9.5-14	17-19	10-18	9.5-14
p_E/p_{E01}	5.6-9.2	5.3-7.6	5.5-8.3	5.6-8.6	5.2-6.6	3.9-4.8	5.8-6.1	4.4-5.0	3.9-4.8
p_M/p_{M01}	3.5-5.4	4.6-8.0	4.2-5.2	4.2-4.8	4.2-5.3	4.6-4.9	4.4-4.7	4.5-4.7	4.2-4.6

The work was supported by the grant of Russian Science Foundation *N* 17-17-01279.

References: [1] Ipatov S. I. et al. (2004) *Annals of the New York Academy of Sciences* 1017: 66-80. http://arXiv.org/format/astro-ph/0308450. [2] Marov M. Ya. and Ipatov S. I. (2005) *Solar System Research* 39: 374-380. [3] Ipatov S. I. and Mather J. C. (2006) *Advances in Space Research* 37: 126-137, http://arXiv.org/format/astro-ph/0411004. [4] Ipatov S. I. (2010) *Proceedings of the International Astronomical Union, vol. 5, Symposium S263 "Icy bodies in the Solar System", Cambridge University Press*, pp. 41-44, http://arxiv.org/abs/0910.3017. [5] Ipatov S. I. et al. (2008) *Icarus* 194: 769-788. http://arXiv.org/format/astro-ph/0608141. [6] Levison H. F. and Duncan M. J. (1994) *Icarus* 108: 18-36. [7] Ipatov S. I. (1988) *Soviet Astronomy* 65: 1075-1085. [8] Ipatov S. I. and Mather J. C. (2003) *Earth, Moon, and Planets* 92: 89-98. http://arXiv.org/format/astro-ph/0305519.