Вісник Астрономічної школи | Astronomical School's Report

ISSN 1607–2855

Том 7 • № 2 • 2011 С. 185 – 189

UDC 523.3

Behavior of Na atoms in the lunar exosphere during activity of meteor showers

A.A. Berezhnoy[1], K.I. Churyumov[2], V.V. Shevchenko[1], A.A. Buchachenko[3], O.R. Baransky[2], T.K. Churyumova[2], V.V. Kleshchenok[2], E.A. Kozlova[1], V.O. Ponomarenko[2], A.V. Stolyarov[3], O.V. Tvorun[4]

[1]Sternberg Astronomical Institute, Moscow State University, Moscow, Russia

[2]Shevchenko National University, Kiev, Ukraine

[3]Department of Chemistry, Moscow State University, Moscow, Russia

[4]Vinnitsa State Technical University, Vinnitsa, Ukraine

The chemical composition of gas-phase species released to the lunar exosphere during meteoroid impacts has been analyzed. Majority of impact-produced metal-containing molecules are destroyed by the solar photons because typical photolysis lifetimes are shorter than ballistic flight times. Energies of metal atoms produced via photolysis of its monoxides are estimated. The column density of impact-produced Na atoms in the exosphere during activity of main meteor shower and quiet periods are estimated. In searching for impact-produced Na atoms in the lunar exosphere, it is better to perform spectral observations during activity of the main meteor showers at altitudes of about 1000–2000 km, lunar eclipses, and during passages of the Moon through the Earth's magnetosphere.

ПОВЕДІНКА АТОМІВ NA У МІСЯЧНІЙ ЕКЗОСФЕРИ ПІД ЧАС ДІЇ МЕТЕОРНИХ ПОТОКІВ, Бережний А.А., Чурюмов К.І., Баранський О.Р., Шевченко В.В., Бучаченко А.А., Чурюмова Т.К., Клещонок В.В., Козлова Е.А., Пономаренко В.О., Столяров А.В., Творун О.В. — Оцінено хімічний склад сполук, що доставляються в місячну атмосферу під час падінь метеороїдів. Більшість ударно-утворених металовмісних молекул руйнується сонячними фотонами, так як типові часи фотолізу коротше, ніж часи балістичного польоту. Оцінена енергія атомів металів, утворених при фотолізі їх оксидів, а також зміст ударно-утворених атомів Na під час дії метеорних потоків і в спокійний час. Для пошуку атомів натрію метеороїдного походження слід проводити спектральні спостереження під час дії основних метеорних потоків на висотах 1000–2000 км, місячних затемнень, а також під час проходження Місяцем земної магнітосфери.

ПОВЕДЕНИЕ АТОМОВ NA В ЛУННОЙ ЭКЗОСФЕРЕ ВО ВРЕМЯ ДЕЙСТВИЯ МЕТЕОРНЫХ ПОТОКОВ, Бережной А.А., Чурюмов К.И., Баранский А.Р., Шевченко В.В., Бучаченко А.А., Чурюмова Т.К., Клещенок В.В., Козлова Е.А., Пономаренко В.А., Столяров А.В., Творун О.В. — Оценен химический состав соединений, доставляемых в лунную атмосферу во время падений метеороидов. Большинство ударно-образуемых металлосодержащих молекул разрушается солнечными фотонами, так как типичные времена фотолиза короче, чем времена баллистического полета. Оценена энергия атомов металлов, образуемых при фотолизе их оксидов, а также содержание ударно-образуемых атомов Na во времена действия метеорных потоков и в спокойное время. Для поиска атомов натрия метеороидного происхождения следует проводить спектральные наблюдения во время действия основных метеорных потоков на высотах 1000–2000 км, лунных затмений, а также во времена прохождения Луной земной магнитосферы.

Ключевые слова: метеорные потоки; лунная поверхность; лунная экзосфера.

Key words: meteor showers; lunar surface; lunar exosphere.

1. INTRODUCTION

The species found in the lunar exosphere come mainly from the interactions of solar photons and solar wind with the lunar regolith. However, micrometeorite bombardment can also be an important contributor especially during main meteor showers and on the night side of the Moon. A bright Na spot of lunar origin in the anti-lunar direction was detected after maximum of very strong Leonid meteor showers in 1998, but was absent at other times [20]. Thus, meteoroid impacts lead to production of sodium atoms which are able to escape the lunar exosphere. However, subsequent observations of the Moon have not presented clear evidence of increasing of the temperature and the column density of lunar sodium during Geminid 1999 and Quadrantid 1999 meteor showers [1]. It is easy to explain because the activity of Leonid meteor shower in 1997 and 1998 was significantly higher than that of main annual meteor showers such as Geminids and Quadrantids.

Previous theoretical studies of impact-produced atoms on the Moon (see, for example, [4]) assumed that impacts lead to delivery of alkali elements to the exosphere only in the form of atoms. However, chemical reactions in the impact-produced fireball can produce metal-containing molecules. This paper focus on the chemistry of meteoroid bombardment of the Moon and possibility of detection of impact-produced atoms.

Table 1. Main Na-containing species delivered during meteoroid bombardment to the lunar exosphere. Target-to-impactor mass ratio in the impact-induced cloud is 1 and 50 for low-speed and high-speed impacts, respectively.

Element	Low-speed impacts; Equilibrium condensation	Low-speed impacts; No condensation	High-speed impacts; Equilibrium condensation	High-speed impacts; No condensation
Na	Na, NaOH	Na, NaOH	Na, NaOH, NaO	Na, NaO

2. PHYSICS AND CHEMISTRY OF COLLISIONS BETWEEN METEOROIDS AND THE MOON

Typical velocities of sporadic meteoroids are in the 15 – 25 km/s range while main meteor showers collide with the Moon with 35 – 70 km/s speeds. After the impact, the Moon captures a part of the ejected material. Target-to-impactor mass ratio in the expanded hot cloud increases with increasing impact velocity and equals to 2, 11, and 50 for 15, 30, and 60 km/s impacts, respectively, according to [5]. Target-to-impactor mass ratio in the impact-induced hot cloud was assumed to be 6 and 50 for the cases of sporadic meteoroids and Perseid meteoroids, respectively. The Na content in troctolites, mare basalts, ferroan anorthosites, norites, KREEP basalts, and gabbronorites is equal to 0.09, 0.13, 0.14, 0.15, 0.32, 0.34, respectively [14]. The elemental compositions of the lunar regolith, sporadic meteoroids, and the Perseid meteoroids are assumed to be the same as composition of ferroan anorthosite's, CI chondrite's, and dust of comet Halley, respectively. The Na content in ferroan anorthosites and CI chondrites is equal to 0.5 and 0.14 wt%, respectively [14] while dust of comet Halley contains 0.44 wt% of Na [12]. Thus, the Na content in the impact-produced cloud is determined by the Na content in the lunar regolith, at least for the case of high-speed Perseid's impacts. Let us note that Na content in the fireball was assumed to be 0.36 wt% by [4], this value is 2.4 times higher than our estimation.

Thermodynamic calculations based on quenching theory were conducted in order to estimate the chemical composition of the fireball upon the adiabatic cooling to the point where chemical reactions effectively stopped. Specifically, it was assumed that chemical reactions stop when two quantities, the chemical and hydrodynamic time scales, became comparable. The initial fireball temperatures and pressures were set equal to $T_0 = 10\,000$ K and $P_0 = 1000$ bars, respectively. For a typical meteoroid size of about $10^{-4} - 10^{-5}$ m [4], the hydrodynamic time scale is about $10^{-7} - 10^{-8}$ s at the assumed average fireball expansion speed of about 3 km/s. Quenching of the main reactions in the fireball occurs at $T_q \sim 3000$ K and $P_q \sim 10$ bars [7].

Thermodynamic calculations of the fireball equilibrium chemical composition were performed for different target-to-impactor mass ratios, temperatures and pressures. Increasing of impact velocity leads to increasing of target-to-impactor mass ratio and decreasing of the content of volatile elements in the fireball because impactors are rich in volatiles while the Moon is almost dry. Condensation of dust grains can significantly change the elemental composition of gas phase of the impact-induced cloud; it leads to enrichment of volatile species in the gas phase. We performed thermodynamic calculations for two extreme cases: the equilibrium condensation and no condensation at all. The results of these calculations are summarized on Table 1.

3. PROPERTIES OF IMPACT-PRODUCED LUNAR EXOSPHERE

If all elements are delivered to the exosphere by the same effective mechanism, than we expect proportionality between atomic metal abundances in the lunar exosphere and elemental abundances in the regolith. Earth-based spectroscopic observations of the lunar atmosphere, however, do not indicate the presence of Si, Al, Mg, Ca, or Fe, which are major constituents of the regolith [6]. Therefore, the atoms of these refractory elements are not delivered to the exosphere by the same mechanisms valid for atoms of alkali elements such as Na and K. Low condensation temperatures of Na- and K-containing species favor remaining of these elements in the gas phase.

Meteoroid bombardment is one of the main sources of the lunar exosphere. Lifetimes τ_{loss} of impact-produced Na atoms in the sun-lit exosphere are taken to be equal to its photoionization lifetimes at 300 K equal to $6.2 \cdot 10^4$ s [9]. This value is valid if there is no sticking of Na atoms to the surface after collisions with the surface. The mass flux of sporadic meteoroids is $3.3 \cdot 10^{-17}$ g cm^{-2}s^{-1} [21] and target-to-impactor mass ratio is 6 during such impacts. Using approach of [3] at assumption that metal-containing species remain in the gas phase, column density of Na atoms on the Moon produced by activity of sporadic meteoroids is estimated to be 10^9 cm^{-2}.

Let us note that typical column density of Na atoms in the lunar exosphere is $8 \cdot 10^8$ cm^{-2} [17]. According to observations during lunar passage through Earth's magnetosphere [18] the upper limit of column density of impact-induced Na atoms is $3 \cdot 10^8$ cm^{-2}. Thus, meteoroid bombardment is responsible for production of less than 40% of Na atoms in the lunar exosphere. Sticking of Na atoms on the surface can lead to decreasing of our estimation of column density of impact-produced Na atoms and better agreement between our estimation and observations.

4. PHOTOLYSIS OF IMPACT-PRODUCED MOLECULES

The photodissociation of NaOH and NaO may be responsible for the presence of hot Na atoms in the lunar atmosphere because NaOH and NaO molecules are abundant in the fireball and typical ballistic flight times at

3000 K are significantly larger than NaOH, NaO photolysis lifetimes equal to 11 and 42 s, respectively [19]. The velocity distribution of such photolysis-generated Na atoms is estimated from the solar flux [9] and NaOH, NaO photolysis cross sections versus wavelength at 300 K [19] using the energy and momentum conservation laws. Average excess kinetic energies of Na atoms produced through NaOH and NaO photolysis are 0.3 and 0.4 eV, respectively. The energy distribution of Na atoms can be described by Gaussian distribution with half maximum width of about 0.1 eV. The average velocity of such atoms is slightly lower than the escape velocity from the Moon, 2.38 km/s, and agrees well with observed velocity distribution of Na atoms in the outer exosphere during lunar eclipses [23].

More detailed information on the photolysis lifetimes and product distributions can be retrieved from the dynamical calculations. As a first step towards this goal, we performed high-level *ab initio* multireference study on the NaO molecule, for which reliable experimental data on the photolysis cross sections are available [19]. Left panel of the Figure 1 shows the lowest electronic states of the molecule, whereas right panel — the measured photolysis cross sections on the same energy scale. *Ab initio* results suggest that two maxima in the latter correspond to the states correlating to the first and second dissociation limits, respectively. The first maximum seems to be more important since it gives the products with high kinetic energies and stronger overlap with the solar spectrum at the Moon surface [9]. Figure 1 also indicates that the photolysis mechanism is rather complicated and can involve excitation of the unbound levels of the ground state, higher-lying repulsive states and predissociation of the bound states. Estimation of the relative populations of *X* and *A* states will constitute the second step in studying the photodissociation dynamics.

5. PARAMETERS OF THE LUNAR EXOSPHERE DURING MAIN METEOR SHOWERS

A bright Na spot of lunar origin in the anti-lunar direction was detected after maximum of Leonid 1998 meteor shower [20]. Maximal brightness of Na line was 90 R [20].

Let us check the influence of main meteor showers on the properties of lunar exosphere. Mass fluxes and mean velocities of Perseid, Geminid, and Quadrantid meteor showers on Earth are $2.8 \cdot 10^{-18}$, $2.4 \cdot 10^{-17}$, and $3.3 \cdot 10^{-17}$ g cm^{-2} s^{-1}, and 59, 34, and 41 km/s, respectively [8]. Using impactor-to-target mass ratio in the hot cloud [5], Na supply rate is estimated to be $3 \cdot 10^{3}$, 10^{4}, and $2 \cdot 10^{4}$ atoms cm^{-2} s^{-1} for Perseid, Geminid, and Quadrantid meteor showers, respectively. Quadrantids are responsible for almost the same column densities of impact-produced atoms as sporadic meteoroids, $3 \cdot 10^{4}$ atoms cm^{-2} s^{-1}. Thus, significant enrichment of the abundance of impact-produced sodium atoms in the lunar atmosphere can be observed during activity of main meteor showers.

The energy of impact-produced Na atoms, about 0.3 eV, is higher than the average energy of majority of lunar alkali atoms, about 0.1 eV, desorbed from the regolith by solar photons. Impact-produced atoms will lose its energy during collisions with the lunar surface. For example, at the energy accommodation coefficient equal to 0.62 for sodium and 0.26 for potassium [10], the surface temperature of 600 K, and the initial temperature of Na atoms of 3000 K the temperature will be equal to 1500 and 950 K first and second collision of Na atoms with the surface. Relative abundance of impact-produced Na atoms increases with increasing altitude because typical height scales of such atoms, about 700 km, are higher than height scales of the majority of Na atoms.

6. OBSERVATIONS OF NA LUNAR EXOSPHERE AT 2-M TERSKOL TELESCOPE

Observations of Na resonance lines (5890 and 5896 Å) in the lunar exosphere at the 2-m Zeiss Terskol telescope (Kabardino-Balkaria, Russia) were performed during 2008–2011. The most successful observations

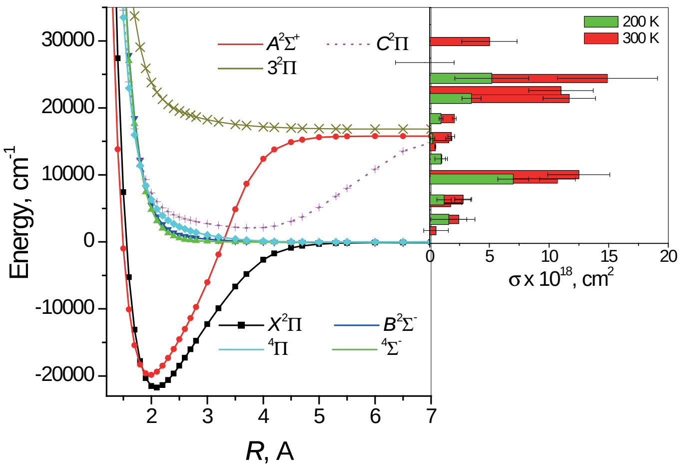

Fig. 1. Potential energy curves of the lowest electronic states of NaO molecule (left panel). Right panel shows the absolute photolysis cross sections as measured by [19] on the same energy scale

were performed on August 12, 2009 at 20–22 UT and August 13, 2009 at 20–22 UT during maximum of Perseid meteor shower. Six eshelle spectra at the distances of 50″, 150″, and 250″ from the lunar limb above the north pole of the Moon were obtained. Spectral resolution was equal to 15 000, the exposure time of each spectrum was equal to 1 800 s.

Spectra of the lunar atmosphere were obtained also in June 15–16 and 16–17, 2011, during and after the full lunar eclipse. Seven eshelle spectra were obtained while the exposure time was equal to 600 and 2 700 s. Noticeable glow of the intensity of Na lines of the lunar origin in the background of continuous solar spectrum was not found in June 2011. Probably, it can be explained by absence of active meteor showers bombarding the lunar regolith at the time of observations. Complete analysis of performed observations including estimation of column density of Na atoms in the lunar exosphere and rough estimation of temperature of Na atoms will be presented in the next paper.

7. POSSIBILITY OF DETECTION OF NA DEPOSITS AT THE POLES OF THE MOON DURING METEOR SHOWERS

During our observations in August 2009 we studied north pole of the Moon bombarded by Perseids' meteoroids. At the poles of the Moon the content of Na-rich KREEP basalts and gabbronorites is quite low [2]. Thus, average Na content in lunar rocks at the poles is almost the same as that at the equator. However, Na atoms released to the exosphere can move toward the poles because at the poles temperature is so low that Na atoms are stable against thermal evaporation. Enrichment of Na content at the polar regions of Mercury in comparison with equatorial regions is already detected by Messenger spacecraft [24]. Properties of Na exosphere and temperature regime of Mercury and the Moon are comparable. Thus, we expect that Na content is enriched at the poles of the Moon also. For this reason the content of polar ices may be high, even about 10 wt%. About 1.5 kg of Na atoms were released to the impact-produced plume above the south pole of the Moon after the LCROSS impact in the crater Cabeus [13], this amount corresponds to about 0.015 wt% of Na content in the polar caps at assumed mass of the plume of about 10 000 kg.

Evaporation rate of Na atoms in the polar regions of the Moon is determined by the temperature regime of these regions. Species are stable on the surface against thermal evaporation if the evaporation rate is less than 10^{-7} cm/year or if the vapor pressure is less than 10^{-16} bar [22]. The vapor pressure of sodium versus temperature was adopted from [15]. Surface temperature depends on the latitude and relief. If we assume that the surface of the Moon is smooth then Na deposits are stable at latitudes between 83.6 and 90 degrees and unstable at lower latitudes at temperatures higher than 255 K. It corresponds to area of Na cold traps of about 10^5 km^2.

However, the surface of the Moon is not smooth. To calculate the lighting conditions and temperature of the lunar surface, we used data from altimeter LOLA [16], working on board the LRO spacecraft. The data were taken with step of 0.25° for latitude and with step of 1° for longitude. The investigated part of the lunar surface was divided into areas and for each area we have determined on the basis of altimeter data the height, the slope angle and the orientation of the area with respect to other areas. To investigate the illumination regime for each area we determined the azimuths and the angular heights of all the surrounding areas in order to get the real picture of horizon. The area of regions at the north pole of the Moon, where Na atoms can exist at the surface during geological periods of time, more than 10^9 years, was estimated to be similar as that estimated without taking into account influence of the lunar relief. For example, the area of stability of Na deposits between 85 and 90 degrees is estimated as 50 300 km^2.

At assumed temperature of Na atoms in the lunar exosphere equal to 1500 and 3000 K the effective area of regions, where Na column density was formed during our observations in August 2009, is estimated as $3\cdot10^6$ and $7\cdot10^6$ km^2, respectively. Assuming Na content in Na cold traps equal to 10 wt%, we obtain that at 1500 and 3000 K average Na content in the studied regions is equal to 0.47 and 0.28 wt%, respectively, this value is higher than the average value of Na content in the polar lunar rocks estimated as 0.14 wt%. Thus, it would be possible to estimate upper limit of Na abundance in cold traps from our observations of Na emission above the north pole of the Moon during Perseid meteor shower in the range of about 5 – 20 wt%.

Let us assume that activity of Perseid shower on the Moon was the same as that on Earth at the same time because during these observations the angle between Perseid's radiant and the Moon on the sky was about 90 degrees while 60 km/s Perseid meteoroids cross the distance between Earth and the Moon for 100 minutes. According to [11] the activity of Perseid shower on Earth was equal to 120 and 30 in units of ZHR on August 12, 20 UT and August 13, 20 UT, respectively. Thus, we expect enrichment of the content of impact-produced Na atoms in the lunar exosphere on August 12. Let us note that the activity of Perseid shower was equal to 150, 200, 120, and 90 at 16, 18, 20, and 22 UT on August 12, 2009, respectively. Quick variability of Perseid's activity during our two-hour observations of August 12 leads to different production rates of Na impact-produced atoms during obtaining of our 30-minute-long spectra. Thus, it would be impossible to estimate the temperature of impact-produced atoms from our spectra with high accuracy because the content of Na atoms significantly changes during the time of observations.

8. CONCLUSIONS

Based on quenching theory, the chemical composition of gas-phase species released to the lunar exosphere during meteoroid impacts has been estimated. The column densities of Na atoms in the exosphere during activity of main meteor shower are estimated. In searching for impact-produced Na atoms in the lunar exosphere, it is better to make spectral observations during activity of the main meteor showers at altitudes of about 1000 – 2000 km, during lunar eclipses and passages of the Moon through the Earth's magnetosphere. Very high-resolution optical spectral observations would be also highly desirable for detection of non-Maxwellian velocity distribution of Na atoms produced by NaOH and NaO photolysis. Analysis of observations of Na atoms in the lunar exosphere during Perseid meteor shower could lead to estimation of the upper limit of Na content in the cold traps at the lunar north pole and time of maximum of Perseid shower on the Moon.

Acknowledgments. This research was supported by RFBR grant 11-02-90440-Ukr_f_a and DFFD grant F40_2-087.

1. *Barbieri C., Benn C.R., Cremonese G., et al.* Meteor showers on the lunar atmosphere // Earth, Moon, and Planets. — 2001. — **85–86**. — P. 479–486.
2. *Berezhnoy A.A., Hasebe N., Kobayashi M., et al.* A three end-member model for petrologic analysis of lunar prospector gamma-ray spectrometer data // Planet. Space Sci. — 2005. — **53**, Is. 11. — P. 1097–1108.
3. *Berezhnoy A.A.* Meteoroid bombardment as a source of the lunar exosphere // Advances in Space Research. — 2010. — **45**, Is. 1. — P. 70–76.
4. *Bruno M., Cremonese G., Marchi S.* Neutral sodium atoms release from the surfaces of the Moon and Mercury induced by meteoroid impacts // Planet. Space Sci. — 2007. — **55**. — P. 1494–1501.
5. *Cintala M.* Impact-induced thermal effects in the lunar and Mercurian regoliths // J. Geophys. Res. — 1992. — **97**. — P. 947–973.
6. *Flynn B.C., Stern S.A.* A spectroscopic survey of metallic species abundances in the lunar atmosphere // Icarus. — 1996. — **124**. — P. 530–536.
7. *Herzog G.F., Moynier F., Albarède F., et al.* Isotopic and elemental abundances of copper and zinc in lunar samples, Zagami, Pelé's hairs, and a terrestrial basalt // Geochimica Cosmochimica Acta. — 2009. — **73**, Is. 19. — P. 5884–5904.
8. *Hughes D., McBride N.* The mass of meteoroid streams // Mon. Not. Roy. Astron. Soc. — 1989. — **240**. — P. 73–79.
9. *Huebner W.F., Keady J.J., Lyon S.P.* Solar photo rates for planetary atmospheres and atmospheric pollutants // Astrophys. Space Sci. — 1992. — **195**. — P. 1–289, P. 291–294.
10. *Hunten D.M., Morgan T.M., Shemansky D.E.* The Mercury atmosphere // in: Vilas F., Chapman C., Matthews M., (Eds.) Mercury (A89-43751 19-91). — 1988. — Tucson, AZ. — University of Arizona Press, P. 562–612.
11. IMO. — 2009. — "Perseids 2009: visual data quicklook". — http://www.imo.net/live/perseids2009
12. *Jessberger E., Christoforidis A., Kissel J.* Aspects of the major element composition of Halley's dust // Nature. — 1988. — **332**. — P. 691–695.
13. *Killen R.M., Potter A.E., Hurley D.M., et al.* Observations of the lunar impact plume from the LCROSS event // Geophys. Res. Lett. — 2010. — **37**. — CiteID L23201.
14. *Lodders K., Fegley B.* The Planetary Scientist Companion // Oxford University Press. — 1998. — New York.
15. *Makansi M.M., Muendel C.H., Selke W.A.* Determination of vapor pressure of sodium // J. Physical Chemistry — 1955. — **59**. — P. 40–42.
16. PDS. — 2011. — http://ode.rsl.wustl.edu/moon/
17. *Potter A.E., Morgan T.H.* Discovery of sodium and potassium vapor in the atmosphere of the Moon // Science. — 1988. — **241**. — P. 675–680.
18. *Sarantos M., Killen R.M., Sharma A.S., et al.* Influence of plasma ions on source rates for the lunar exosphere during passage through the Earth's magnetosphere // Geophys. Res. Lett. — 2008. — **35**, Is. 4. — CiteID L04105.
19. *Self D.E., Plane J.M.C.* Absolute photolysis cross-sections for $NaHCO_3$, NaOH, NaO, NaO_2 and NaO_3: implications for sodium chemistry in the upper mesosphere // Physical Chemistry, Chemical Physics. — 2002. — **4**. — P. 16–23.
20. *Smith S.M., Wilson J.K., Baumgardner J., et al.* Discovery of the distant lunar sodium tail and its enhancement following the Leonid meteor shower of 1998 // Geophys. Res. Lett. — 1999. — **26**. — P. 1649–1652.
21. *Vanzani V., Marzari F., Dotto E.* Micrometeoroid impacts on the lunar surface // Lunar Planetary Science Conference. — 1997. — **28** — P. 481–482.
22. *Vasavada A.R., Paige D.A., Wood S.E.* Near-Surface Temperatures on Mercury and the Moon and the Stability of Polar Ice Deposits // Icarus. — 1999. — **141**. — P. 179–193.
23. *Wilson J.K., Baumgardner J., Mendillo M.J.* The outer limits of the lunar sodium exosphere // Geophys. Res. Lett. — 2003. — **30**. — P.1649. — doi:10.1029/2003GL017443.
24. *Zurbuchen T.H., Raines J.M., Slavin J.A., et al.* MESSENGER observations of the spatial distribution of planetary ions near Mercury // Science. — 2011. — **333**. — P. 1862–1865.

Received 24.10.2011