EPSC Abstracts
Vol. 10, EPSC2015-15, 2015
European Planetary Science Congress 2015

Non-monotonic potentials near the sunlit side of the Moon

T.M.Burinskaya
Space Research Institute, Moscow, Russia (tburinsk@iki.rssi.ru)

Abstract

The day-side lunar surface is electrically charged due to the joint action of solar ultraviolet radiation and interactions with the plasma environment. Basic equations describing stable non-monotonic altitude profiles of the electric potential arising near the Moon's surface exposed to the solar radiation are obtained for various plasma environments that surround it: the solar wind and the terrestrial plasma sheet. It is found that for both cases the surface potential grows as the photoelectron density increases, but the minimum value of the non-monotonic potential profiles is practically independent of the photoelectron density, and is defined by the parameters of the surrounding plasma. When the lunar surface is irradiated by the solar wind both potentials possess the minimum values in the range of drift velocities typical of the slow solar wind under normal conditions. When the Moon is exposed to both solar radiation and the terrestrial plasma sheet, the surface potential and the minimum value of the non-monotonic profile depend strongly on the temperature of plasma sheet populations, particularly in the range where the ratio of the ion temperature to the electron temperature is less than three.

1. Introduction

On the sunlit side of the Moon the lunar surface is charged due to the joint action of solar ultraviolet radiation, resulting in the photoelectron emission and interactions with the ambient plasma. A number of papers have been done on the formation of electric fields near a surface emitting photoelectrons under the action of solar radiation. It was found that two types of potential distribution can take place: a monotonic distribution that constantly increases or decreases, and a non-monotonic distribution that decreases from the surface to a negative minimum and then tends to zero at infinity; and it was shown that the non-monotonic potential profile is energetically preferred to the monotonic solution, see [1] and references therein. The objective of this paper is to investigate how the key parameter of the non-monotonic potential distribution varies under different plasma conditions in a wide range of the photoelectron densities. Currently we have not the unambiguous data of the parameters and distributions of photoelectrons over the illuminated lunar surface. This problem is discussed in the paper [2], where it is shown that the quantum yield of lunar regolith is the main parameter determining the density, temperature, and distribution function of photoelectrons. At present, this parameter is determined with significant uncertainty analyzed in the above mentioned paper, and the direct measurements on the Moon's surface performed in the framework of future lunar missions are proposed as the best solution of this problem. Taking into account the incompleteness of our knowledge of photoelectron density near the lunar surface, we made calculations in a wide range of densities with a purpose to estimate its influence on the potential profile near the lunar surface. At first, we used the results of [3], examining the lunar regolith samples exposed to sunlight. It was shown that the current density of photoelectrons emitted from the lunar surface could be estimated as 4.5×10^{-6} A/m^2, and the energy distribution could be approximated by a Maxwellian distribution with temperature 1.47 eV. Therefore, the photoelectron density is ~ 1.38×10^{8} m^{-3}. Recently measurements performed on the Lunar Reconnaissance Orbiter have demonstrated the presence of hydrogen-containing regions on the Moon's surface. For these regions the photoemission capability can be higher in comparison with the pure regolith regions. In [2] the photoelectron density was calculated for regions covered with a hydrogen monolayer under assumption that the photoelectric work function is 4 eV. The obtained photoelectron density ~2×10^{14} m^{-3} is much greater than the density for regolith regions. So we have used this value as the highest limit for the photoelectron density. We carried out calculations as well for the photoelectron density ~2×10^{11} m^{-3} found in [2] using the semiempirical dependence of the quantum yield obtained on the experimental database for the work function on the order of 6 eV.

2. Lunar surface in the terrestrial plasma sheet exposed to the solar radiation

We are looking for a steady state non-monotonic distribution of the electric potential along the normal to the lunar surface. The electric potential at the surface is equal to φ_0, an altitude profile of the potential has one minimum $\varphi_1<0$ and tends to zero at infinity. Because the thermal velocity of the solar wind ions is much less than the flow velocity of the solar wind, ions are assumed to be cold and moving with a drift velocity at infinity. The solar wind electrons have a Maxwellian velocity distribution shifted by the drift velocity. Photoelectrons emitted from the lunar surface can be approximated by a Maxwellian distribution. Plasma at infinity is assumed to be neutral with zero net current and zero electric field. We find the set of equations which numerical solutions allow us to construct the altitudes profiles of the electric field above the Moon's surface and the densities of photoelectrons and solar wind electrons as functions of the solar wind velocity and photoelectron density emitting from the surface [4]. Calculations have been performed in a wide range of the ratio of the solar wind velocity to the electron thermal velocity for different values of photoelectron densities. It is shown that, although the thermal velocity of electrons is well above the drift velocity, accounting for the latter in the electron velocity distribution substantially affects the value of the potential, particularly in the lunar regolith regions, where the surface potential halves, while the absolute value of the potential minimum doubles as compared to the calculations made when the electron flow velocity was disregarded. The results of our investigation have shown that the value of the potential minimum φ_1 is practically independent of the photoelectron density, and is defined by the parameters of the solar wind. For a given velocity of the solar wind the surface potential φ_0 grows as the photoelectron density increases. Both potentials possess the minimal values when the ratio of the solar wind velocity to the electron thermal velocity is on the order of 0.23 which corresponds to a slow solar wind for normal solar wind conditions.

3. Lunar surface in the terrestrial plasma sheet exposed to the solar radiation

Large negative potentials detected by the Lunar Prospector Electron Reflectometer (LPER) instrument, when the Moon was in the terrestrial plasma sheet exposed to the solar radiation, were analyzed extensively in [5] by comparison between a sample of measurements obtained onboard the Lunar Prospector and 1-D particle-in-cell simulations. It was found that LPER measurements are best explained by the presence of stable, non-monotonic potential above the lunar surface. However in [5] it was not taken into account that the ratio of ion to electron temperatures in the plasma sheet for distances more than 60 Earth's radius is on the order of 5.5. Taking into account that this parameter is still understood incompletely, we made calculations of key parameters φ_0 and φ_1 controlling the non-monotonic potential profile in a wide range of T_i/T_e ratios for different values of the photoelectron density under assumption that the plasma sheet ions and electrons have Maxwellian velocity distributions, each of them with its temperature. The numerical calculations of obtained equations have shown that a value of the potential minimum φ_1 is defined by the parameters of the terrestrial plasma sheet and does not depend on the photoelectron density [4]. The surface potential grows as the photoelectron density increases but remains negative in a range of parameters under consideration; however the surface charge remains positive and electric field is directed upward from the surface because there is a potential minimum. Both potentials are strongly governed by the temperature of the plasma sheet ions and electrons, and rise sharply in the range $T_i/T_e \leqslant 3$. Then both potentials continue to grow more gradually.

Acknowledgments

This work was partially supported by RFBR grant №15-02-05627.

References

[1] Poppe, A., and M. Horányi: Simulations of the photoelectron sheath and dust levitation on the lunar surface. J. Geophys. Res. 115, A08106, , 2010

[2] Popel, S. I., A. P. Golub, Yu. N. Izvekova, V.: On the distribution of photoelectrons over illuminated part of the Moon. JETP Letters, 99, 115-120, 2014.

[3] Feuerbacher, B., M. Anderegg, B. Fitton, L. D. Laude, R. F. Willis, and R. J. L. Grard: Photoemission from lunar surface fines and the lunar photoelectron sheath. Geochin. Cosmochim. Acta. Suppl. 3, 2655-2663, 1972.

[4] Burinskaya T. M.: Non-monotonic potentials above the day-side lunar surface exposed to the solar radiation, Planet. Space Sci., doi:10.1016/j.pss.2015.03.004, 2015.

[5] Poppe, A., J. S. Halekas, and M. Horányi: Negative potentials above the day-side lunar surface in the terrestrial plasma sheet: Evidence of non-monotonic potentials. Geophys. Res. Lett. 38, L02103, 2011.