EPSC Abstracts
Vol. 7 EPSC2012-92 2012
European Planetary Science Congress 2012

The heavy (Na^+) and light (He^+, H_2^+, H^+) pickup ion dynamics near the moon: 3D hybrid modeling

A.S. Lipatov (1), J.F. Cooper (2), E.C. Sittler Jr. (2) and R.E. Hartle (2)
(1) Goddard Planetary and Heliophysics Institute University of Maryland, Baltimore County/NASA GSFC, Maryland, USA,
(2) NASA GSFC, Greenbelt, Maryland, USA (alexander.lipatov-1@nasa.gov /Fax: 1-301-2861648)

Abstract

The hybrid kinetic model used here supports comprehensive simulation of the interaction between different spatial and energetic elements of the moon-solar wind-magnetosphere of the Earth system. This involves variable upstream magnetic field and solar wind plasma, including energetic ions, electrons, and neutral atoms. This capability is critical to improved interpretation of existing measurements for surface and atmospheric composition from previous missions and planning future missions. There is a set of MHD, kinetic, hybrid, drift kinetic, electrostatic and full kinetic modeling of the Lunar plasma environment that were performed in [1, 2, 3, 5, 6, 7, 8, 12, 13, 14]. However, observations show the existence of several species of the neutrals and pickup ions like Na, He etc., [4]. The solar wind parameters are chosen from ARTEMIS observations [14]. The hybrid kinetic model allows us to take into account the finite gyroradius effects of pickup ions and to estimate correctly the ions velocity distribution and the fluxes along the magnetic field. This is in opposition to the MHD simulation with Maxwellian velocity distributions for background and pickup ions. The effective ionization and charge exchange are included in all current models (see, e.g. [15]). We will also take into account collisions between ions and the surface of the moon and further sputtering of fragments from the surface of the moon. We will discuss the results of modeling, which includes separate species of pickup ions, (Na^+, He^+, H_2^+, H^+) and their combinations. Modeling shows the asymmetric Mach cone, Fig. 1, pickup ion tails, Figs. 1 and 2, and presents another type of lunar-solar wind interaction. Our simulation may be important for the study of the interaction between the solar wind and very weak comets, Mercury and Pluto (see, e.g. [8, 9, 10, 11]).

Acknowledgments

The work was supported by the Grant *Solar Wind Interaction with Lunar Exosphere and Surface* (PI - J.F. Cooper) from the NASA NRA: Lunar Advance Science and Exploration Research Program (NNH08ZDA001-LASER).

References

[1] Birch, P.C., and Chapman, S.C.: Detailed structure and dynamics in particle-in-cell simulations of the lunar wake, Physics of Plasmas, Vol. 8, 4551-4559, 2001.

[2] Catto, P.J.: A model for steady interaction of the solar wind with the Moon, Astrophys. Space Sci., Vol. 26(10), 47, 1974.

[3] Farrell, W.M., Kaiser, M.L., Steinberg, J.T., and Bale, S.D.: A simple simulation of a plasma void: Applications to Wind observations of the lunar wake, J. Geophys. Res., Vol. 103(A10), 23653, 1998.

[4] Hartle, R.E., and Killen, R.: Measuring pickup ions to characterize the surfaces and exospheres of planetary bodies: applications to the Moon, Geophys. Res. Lett., Vol. 33, L05201, 2006.

[5] Holmström, M., Fatemi, S., and Nilsson, H.: The interaction between the Moon and the solar wind, arXiv:1104.1440v1 [physics.space-ph] 7 Apr 2011

[6] Kallio, E.: Formation of the lunar wake in quasi-neutral hybrid model, Geophys. Rev. Lett., Vol. 32, L06107, 2005.

[7] Lipatov, A.S.: Three-dimensional structure of the plasma wake of the Moon, Cosmic Res. (Sov. J. Kosmich. Issled.), Vol. 14(1), 103, 1976.

[8] Lipatov, A.S.: The Hybrid Multiscale Simulation Technology. An Introduction with Application to Astrophysical and Laboratory Plasmas, Springer, Berlin, Heidelberg, New York, pp. 403, 2002.

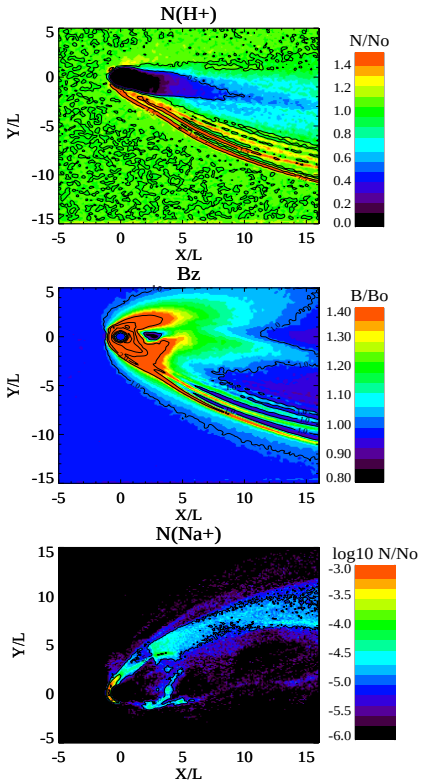

Figure 1: Solar wind and pickup ion (Na^+) density and B_z profiles. $U_0 = 305\,\mathrm{km/s}$; $N_{sw} = 3\,\mathrm{cm}^{-3}$

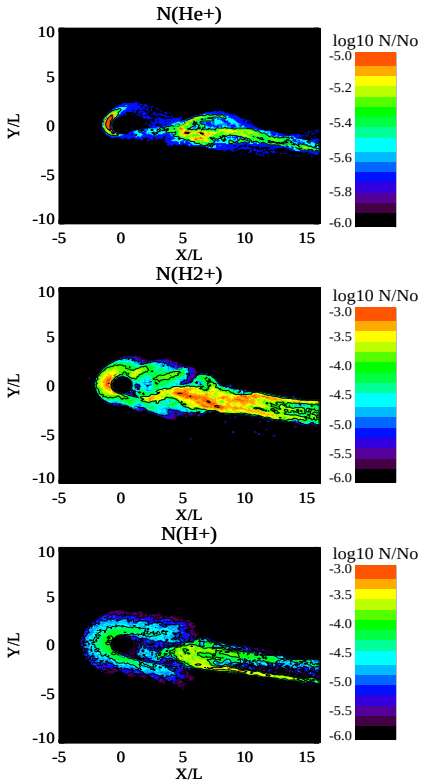

Figure 2: Pickup ion ($He+$, H_2^+, H^+) density profiles. $M_A = 5.17$; $B_0 = 5.2\,\mathrm{nT}$

[9] Lipatov, A.S., Motschmann, U., Bagdonat, T.: 3-D hybrid simulations of the interaction of the solar wind with a weak comet, Planet. Space Sci., Vol. 50, 403-411, 2002.

[10] Lipatov, A.S., Sauer, K., and Baumgärtel, K.: 2.5D hybrid code simulation of the solar wind interaction with weak comets and related objects, Adv. Space Res., Vol. 20(2), 289-282, 1997.

[11] Sauer, K., Lipatov, A.S., Baumgärtel, K., and Dubinin, E.: Solar Wind-Pluto Interaction Revised, Adv. Space Res., Vol. 20(2), 295, 1997.

[12] Travnichek, P., Hellinger, P., Schriver, D., Bale, S.D.: Structure of the lunar wake: Two-dimensional global hybrid simulations, Geophys. Res. Lett., Vol. 32, L06102, 2005.

[13] Whang, Y.C.: Field and plasma in the Lunar wake, Phys. Rev., Vol. 186(1), 143, 1969.

[14] Wiehle, S., Plaschke, F., Motschmann, et al.: First Lunar Wake Passage of ARTEMIS: Discrimination of Wake Effects and Solar Wind Fluctuations by 3D Hybrid Simulations, Planet. Space Sci., Vol. 59(8), 661-671, 2011.

[15] Gruntman, M.: H_2^+ pickup ions in the solar wind: Outgassing of interplanetary dust, J. Geophys. Res., 101(A7), 15555-15568, 1996.