Special issue editorial - Plasma Interactions with Solar System Objects: Anticipating Rosetta, Maven and Mars Orbiter Mission

A.J. Coates[1,2], A. Wellbrock[1,2] and M.Yamauchi[3]

1. Mullard Space Science Laboratory, University College London, Holmbury St Mary, Dorking, Surrey RH5 6NT, UK

2. Centre for Planetary Science at UCL-Birkbeck, Gower St, London WC1E 6BT

3. Swedish Institute of Space Physics, PO Box 812, SE-98128 Kiruna, Sweden

Abstract

Within our solar system, the planets, moons, comets and asteroids all have plasma interactions. The interaction depends on the nature of the object, particularly the presence of an atmosphere and a magnetic field. Even the size of the object matters through the finite gyroradius effect and the scale height of cold ions of exospheric origin. It also depends on the upstream conditions, including position within the solar wind or the presence within a planetary magnetosphere. Soon after ESA's Rosetta reached comet Churyumov-Gerasimenko, NASA's Maven and ISRO's Mars Orbiter Mission (MOM) reached Mars, and ESA's Venus Express mission was completed, this issue explores our understanding of plasma interactions with comets, Mars, Venus, and moons in the solar system. We explore the processes which characterise the interactions, such as ion pickup and field draping, and their effects such as plasma escape. Papers are based on data from current and recent space missions, modelling and theory, as we explore our local part of the 'plasma universe'.

Introduction

The issue represents predictions for missions which have recently reached their targets. Some of the papers were presented at the 6th Alfven Conference on Plasma Interactions with Solar System Objects: Anticipating Rosetta, MAVEN and Mars Orbiter Mission, held at University College London on 7-11 July 2014 (see Figure 1). The conference included 65 oral (including 19 invited) papers and 19 poster presentations. The structure of the conference included sections on comets, Mars, Venus, moons, missions and comparisons between the interactions. The special issue was open to paper presenters and to the wider scientific community, and has resulted in the 12 papers included here.

Summary of papers

Comets:

Ion pickup is one essential element of a comet's interaction with the solar wind. As a comet nears the Sun, water and other molecules sublime away from the nucleus. These are eventually ionised and then are accelerated by the solar wind convective electric field, and they then gyrate around the field to form a ring distribution in velocity space. This is unstable and a shell distribution, and plasma waves, result. Several boundaries occur including a bow shock and a contact surface.

Matteini et al. (2015) use hybrid simulations to study the ion pickup process. Bispherical and non-gyrotropic distributions are studied, and the resulting waves serve as predictions for comet 67P (Churyumov-Gerasimenko, Rosetta's target). Gunell et al. (2015) use hybrid simulations but also include a charged dust population, and make predictions for the morphology, effectiveness and timing of dust acceleration at 67P. Nordheim et al. (2015) model the surface potential and electric field at the surface of 67P at 3.5 and 3 AU, finding positive potentials on the sunlit side and the possibility of substantial charging in the wake.

Venus:

Venus has a dense atmosphere and an ionosphere, but no magnetic field. The solar wind interaction region includes the ionopause, induced magnetosphere, draped magnetic field, a sheath region with thermalised and decelerated solar wind, and a bow shock.

Luhmann et al. (2015) re-examine PVO and Venus Express data and compare with MHD simulations to explore a previously discovered hemispheric bias in the magnetic field low in the wake region. They find that although some aspects of the results are consistent with a weak global magnetic field, this can be ruled out in preference for other effects, such as hemispheric asymmetries in the interaction or the possibility of external field diffusion through the planet.

Mars:

The Mars interaction with the solar wind is somewhat similar to Venus except that the ratio of the ion gyroradius to the obstacle size is larger, and Mars has crustal magnetic fields which distort the interaction to some extent. Atmospheric escape is a key issue over the 3.8 billion years since Mars lost its global magnetic field, studied over the last solar cycle by Mars Express and studies are beginning with the comprehensively-instrumented MAVEN mission.

Holmstrom et al. (2015) use a hybrid model to study the Mars-solar wind interaction on a large scale, finding a polar plume of ions and escape along the tail. The escape rate increases as the assumed production rate increases, and comparisons are made with a comet.

Yamauchi et al. (2015a) present Mars Express ASPERA-3 observations of the Martian foreshock. They find protons and, for the first time, oxygen ions upstream of the bow shock. They discuss how this may be an additional escape mechanism involving acceleration in the bow shock-sheath region.

Yamauchi et al. (2015b) study pickup protons in the solar wind near Mars over 8 years, finding that the amount of pickup ions is related to the Sun-Mars distance. This indicates that the UV flux plays a major role in pickup ion production but other effects are important too, a topic for MAVEN.

Xu et al. (2015) study the production of photoelectrons in the Martian ionosphere using three different solar irradiance models. They find a factor ~2 variation in the modelled photoelectron fluxes.

Vaisberg (2015) reviews ion escape mechanisms at Mars, including pickup ions, tail escape and ionospheric escape. Simulations are also discussed, discrepancies between observations and simulations are identified, and suggestions are made for future research including MAVEN and MOM.

Fraenz et al. (2015) use ASPERA-3 and MARSIS data to estimate Martian escape rates. By including the previously underestimated cold ion component they find higher total escape rates ($2.8 \pm 0.4 \times 10^{25}$ s^{-1}) than previously reported, and in agreement with some modelling studies.

Alho et al. (2015) use a hybrid simulation to study the shielding effect of an early Mars magnetic field, starting at a reasonable assumed level and declining to today's induced magnetosphere. They find significant shielding is present on early Mars against solar energetic particles, caused by the solar wind interaction.

Moons:

Poppe et al. (2015) study the charging environment of airless bodies for a range of angles between the incident flow and the solar direction, relevant for the moons of Mars and some outer planet moons as well as Earth's Moon. They find some complex potential structures can exist near the surfaces.

Acknowledgments

We wish to thank the Scientific and Local Organising Committees for their help with the conference, and the referees for their help with the individual papers. We particularly thank the LOC for their hard work before, during and after the meeting. We thank the sponsors of the meeting for their generous support – ESA (including the Rosetta project), RAS, STFC, UKSA, Rosetta project and ADS (UK)

References

Matteini, L., S.J. Schwartz, and P. Hellinger, Cometary ion instabilities in the solar wind, PSS in press 2015

Gunell, H., I. Mann, C. S. Wedlund, E. Kallio, M. Alhod, H. Nilsson, J. De Keyser, F. Dhooghe, R. Maggiolo, Acceleration of ions and nano dust at a comet in the solar wind, PSS in press 2015

Nordheim, T., G. H. Jones, J. S. Halekas, E. Roussos, A. J. Coates, Surface charging and electrostatic dust acceleration at the nucleus of comet 67P during periods of low activity, PSS in press 2015

Luhmann, J.G. Y-J. Ma, M.N. Villarreal, H-Y. Wei, and T-L. Zhang, The Venus-Solar Wind Interaction: Is it Purely Ionospheric?, PSS in press 2015

Holmstrom, M., X.-D. Wang, Mars as a comet: Solar wind interaction on a large scale, PSS in press 2015

Yamauchi M., R. Lundin, R.A. Frahm, J.-A. Sauvaud, M. Holmström, and S. Barabash, Oxygen foreshock of Mars, PSS in press 2015a

Yamauchi M., T. Hara, R. Lundin, E. Dubinin, A. Fedorov, J.-A. Sauvaud, R.A. Frahm, R. Ramstad, Y. Futaana, M. Holmstrom, and S. Barabash, Seasonal Variation of Martian Pick-up Ions: Evidence of Breathing Exosphere, PSS in press 2015b

Xu, S., M.W. Liemohn, W.K. Peterson, J. Fontenla, P. Chamberlin, Comparison of Different Solar Irradiance Models for the Superthermal Electron Transport Model for Mars, PSS in press 2015

Vaisberg, O., Mars atmospheric losses induced by the solar wind: comparison of observations with models, PSS in press 2015

Fraenz, M., E. Dubinin, D. Andrews, S. Barabash, H. Nilsson, A. Fedorov, Cold Ion Escape from the Martian Ionosphere, PSS in press 2015

Alho, M., S. McKenna-Lawlor, E. Kallio, Paleo Mars Energetic Particle Precipitation, PSS in press 2015

Poppe, A.R., M. I. Zimmerman, J. S. Halekas, W. M. Farrell, The electrostatic plasma environment of a small airless body under non-aligned plasma flow and UV conditions, PSS in press 2015

Figure 1 - Attendees at the 6th Alfvén Conference, 10 July 2014