EPSC Abstracts
Vol. 6, EPSC-DPS2011-260, 2011
EPSC-DPS Joint Meeting 2011

Kelvin-Helmholtz instabilities at the magnetic cavity boundary of comet 67P/Churyumov-Gerasimenko

M. Rubin, M. R. Combi, L. K. S. Daldorff, T. I. Gombosi, K. C. Hansen, and V. M. Tenishev
Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, 2455 Hayward Street, Ann Arbor, MI 48109, USA (rubinmar@umich.edu)

Abstract

On March 14, 1986 the European Space Agency's Giotto spacecraft flew-by comet 1P/Halley. One of the main results of the mission was the discovery of the magnetic field-free cavity. The Giotto magnetometer observed a drastic decrease of the magnetic field strength along its trajectory at roughly 4500 km from the nucleus [6]. The magnetic cavity boundary (i.e. contact surface, ionopause) separates the magnetized from the unmagnetized cometary plasma [3]. This boundary is the consequence of a tight interplay between the out-flowing neutral gas and the plasma through ion-neutral friction preventing the magnetized cometary plasma from entering the cavity region. The boundary is located where this outward pointed ion-neutral drag force equals the magnetic pressure gradient force (jxB force) as discussed by [2].

Our global model of the comet – solar wind interaction [7], originally developed by [4] for comet 1P/Halley, has been used to simulate the involved ion neutral chemistry for an in depth comparison with the measurements obtained by Giotto's Ion Mass Spectrometer [1]. The Block Adaptive Tree Solar-wind Roe-type Upwind Scheme (BATSRUS) solves the governing equations of magnetohydrodynamics [8] accounting for photoionization, recombination, and ion-neutral frictional drag in an adaptive unstructured Cartesian mesh. Such an approach allows resolving the various features of the comet involving very different length scales.

Here we focus on the plasma environment of comet 67P/Churyumov-Gerasimenko the target of the European Space Agency's Rosetta mission. After the rendezvous with the comet the Rosetta spacecraft will accompany 67P/Churyumov-Gerasimenko from almost 3.5 AU all the way to perihelion at 1.3 AU. [5] presented model predictions for the comet's plasma environment in the whole range of heliocentric distances relevant for Rosetta using our magnetohydrodynamics model BATSRUS. In their work the neutral gas production rate was approximated as spherically symmetric. Here we are also interested in the effect of asymmetric neutral gas distributions. Asymmetric neutral gas production rates will affect the ion-neutral drag force that is balanced by the magnetic pressure gradient force at the location of the cavity boundary. In particular at larger heliocentric distances, where the strength of the interplanetary magnetic field and the magnetic pressure gradient force decrease, the distribution of active regions over the comet's surface influences the shape of the magnetic cavity. This is especially interesting as the geometry of the cavity influences the topology of the plasma streamlines crossing the shock. The jump-conditions can be derived from integrating the magnetohydrodynamics equations across the shock and are called Rankine-Hugoniot equations for MHD. The tail-ward plasma flow can be significantly altered and then concentrated in the plane perpendicular to the Interplanetary Magnetic Field (IMF). This effect might be observable by the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) and the Rosetta Plasma Consortium (RPC) instrument packages at specific locations around the comet. We will also show that, depending on the asymmetry of the neutral gas distribution and the strength of the magnetic field, the plasma flow around the cavity boundary can even become unstable due to the formation of Kelvin-Helmholtz instabilities.

Acknowledgements

This work has been supported by JPL subcontract 1266313 under NASA grant NMO710889, NASA Planetary Atmospheres program grant NNX09AB59G, and grant AST-0707283 from the NSF Planetary Astronomy program. We thank the comet modeling team from the International Space Science Institute (ISSI) for the fruitful discussions.

References

[1] Balsiger, H., K. Altwegg, F. Bühler, J. Geiss, A. G.

Ghielmetti, B. E. Goldstein, R. Goldstein, W. T. Huntress, W.-H. Ip, A. J. Lazarus, A. Meier, M. Neugebauer, U. Rettenmund, H. Rosenbauer, R. Schwenn, R. D. Sharp, E. G. Shelly, E. Ungstrup, and D. T. Young, Ion composition and dynamics at comet Halley, *Nature*, *321*, 330–334, 1986

[2] Cravens, T. E., Ion energetics in the inner coma of Comet Halley, *Geophys. Res. Lett., 14*, 983–986, 1987

[3] Cravens, T. E., Cometary plasma boundaries, *Advances in Space Research*, *9*, 293–304, 1989

[4] Gombosi, T. I., D. L. De Zeeuw, R. M. Häberli, and K. G. Powell, Three-dimensional multiscale MHD model of cometary plasma environments, *J. Geophys. Res.*, *101*, 15,233–15, 252, 1996

[5] Hansen, K. C., T. Bagdonat, U. Motschmann, C. Alexander, M. R. Combi, T. E. Cravens, T. I. Gombosi, Y.-D. Jia, and I. P. Robertson, The Plasma Environment of Comet 67P/Churyumov-Gerasimenko Throughout the Rosetta Main Mission, *Space Science Reviews*, *128*, 133–166, 2007

[6] Neubauer, F. M., K. H. Glassmeier, M. Pohl, J. Raeder, M. H. Acuna, L. F. Burlaga, N. F. Ness, G. Musmann, F. Mariani, M. K. Wallis, E. Ungstrup, and H. U. Schmidt, First results from the Giotto magnetometer experiment at comet Halley, *Nature*, *321*, 352–355, 1986

[7] Rubin, M., K. C. Hansen, T. I. Gombosi, M. R. Combi, K. Altwegg, and H. Balsiger, Ion composition and chemistry in the coma of Comet 1P/Halley: A comparison between Giotto's Ion Mass Spectrometer and our ion-chemical network, *Icarus*, *199*, 505–519, 2009

[8] Tóth, G., I. V. Sokolov, T. I. Gombosi, D. R. Chesney, C. R. Clauer, D. L. De Zeeuw, K. C. Hansen, K. J. Kane, W. B.Manchester, R. C. Oehmke, K.G. Powell, A. J. Ridley, I. I. Roussev, Q. F. Stout, O. Volberg, R. A. Wolf, S. Sazykin, A. Chan, B. Yu, and J. Kóta, Space Weather Modeling Framework: A new tool for the space science community, *J. Geophys. Res. (Space Physics)*, *110*, 12, 226–+, 2005