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Revisiting Cometary Bow Shock Positions

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Abstract

The Rosetta spacecraft will arrive at comet 67P/Churyumov-Gerasimenko in 2014 and will escort the comet along its journey around the Sun. The predicted outgassing rate of the comet and the solar wind properties next to its perihelion at 1.24 AU lead to the expectation that a cometary bow shock will form during the escort phase. Since the forecasts of the subsolar stand off distances differ, this study revisits selected models and presents hybrid simulations of the comet-solar wind interaction region performed with the A.I.K.E.F. code. In addition, an analytical model is presented that reproduces the bow shock distances observed in the hybrid simulations.

1. Motivation

The plasma instruments onboard Rosetta will perform measurements for the investigation of the interaction between the cometary exosphere and the solar wind. The important parameters of this interaction, e.g. the gas production rate of the comet and the solar wind parameters, will change during the escort phase of the mission, and, hence, also the positions of the boundaries in the interaction region will vary. As a consequence, the locations of the boundaries have to be known in advance in order to study their characteristics, their evolution and, based on that, the interaction of the whole comet exosphere with the solar wind. This paper will focus on one of the important boundaries, namely the bow shock.

The cometary bow shock has already been observed by several spacecraft mission to comets (c.f. [6]) and was predicted by [1]. For comet 67P/Churyumov-Gerasimenko several models predict the existence of a bow shock next to its perihelion. However, the predicted distances differ by a large extent for similar physical parameters. This is why this study revisits the different models and compares them.

2. Comparsion and Results

The study compares the 1D gasdynamical model by [1], the 1D magnetohydrodynamic model by [2], the 3D global MHD simulations by [3] and [4], and the latest state of the art hybrid plasma simulations with the A.I.K.E.F. code by [5]. Furthermore, the study performs series of hybrid simulations with changing gas production rates, magnetic field strengths, solar wind velocities, solar wind densities, and Parker angles. The bow shock positions in the magnetohydrodynamic models reveal a similar behavior, whereas the bow shock in the hybrid simulations shows significant variations to the magnetohydrodynamic models. This is why the ions in the hybrid plasma simulations are described as individual particles. Based on that, the model can describe kinetic effects of the ions such as gyration or the ring distribution of the picked-up ions in the phase space. These effects are important in the case of weak outgassing comets, e.g. 67P/Churyumov-Gerasimenko, because the size of the main interaction region is comparable to the gyroradii of the cometary ions. The reason for the differences in the positions of the bow shock in the hybrid model and the MHD models is the inertia of the new cometary ions, which are picked-up by the solar wind. This is why the mass loading of the flow is slower than the normal magnetohydrodynamic models and, therefore, the bow shock shifts towards the comet. An analytical model, which is based on the 1D magnetohydrodynamic model by [2] taking into consideration the inertia of the cometary ions, is able to reproduce the results of the hybrid simulations in an appropriate way.

This model allows the calculation of the subsolar position of the cometary bow shock during the escort phase of the Rosetta mission. This is shown in Figure (1) for the high activity case and the low activity case (ref. ESA Rosetta TN 5566) and for typical solar wind parameters (see [4]). The analytical model, which reproduces the results of the hybrid simulations, is valid as long as the bow shock distance is above $1000\ \mathrm{km}$, which is marked by the red line. In the hybrid simulations a Mach cone structure with a clear asymmetry can be observed when the stand off distance is below the red line. However, this study also shows that the bow shock distance changes significantly when the parameters of the solar wind slightly change. Hence, during a possible excursion of the spacecraft to the bow shock the bow shock might pass the spacecraft several times.

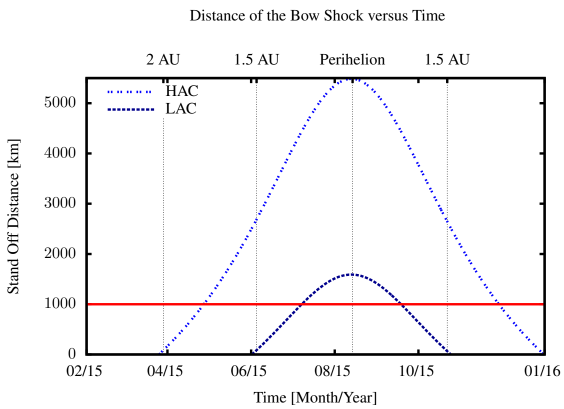

Figure 1: The subsolar stand off distances of the bow shock of comet 67P/Churyumov-Gerasimenko for the high and low activity case.

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References

[1] L. Biermann, B. Brosowski, and H. U. Schmidt. The interactions of the solar wind with a comet. *Solar Physics*, 1:254–284, March 1967. doi: 10.1007/BF00150860.

[2] K. R. Flammer and D. A. Mendis. A note on the mass-loaded MHD flow of the solar wind towards a cometary nucleus. *Astrophysics and Space Science*, 182:155–162, August 1991. doi: 10.1007/BF00646450.

[3] T. I. Gombosi, D. L. De Zeeuw, R. M. Häberli, and K. G. Powell. Three-dimensional multiscale MHD model of cometary plasma environments. *Journal of Geophysical Research*, 101:15233–15252, July 1996. doi: 10.1029/96JA01075.

[4] K. C. Hansen, 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, February 2007. doi: 10.1007/s11214-006-9142-6.

[5] J. Müller, S. Simon, U. Motschmann, J. Schüle, K.-H. Glassmeier, and G. J. Pringle. A.I.K.E.F.: Adaptive hybrid model for space plasma simulations. *Computer Physics Communications*, 182:946–966, April 2011. doi: 10.1016/j.cpc.2010.12.033.

[6] F. M. Neubauer, 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, May 1986. doi: 10.1038/321352a0.