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Estimating the solar wind pressure at comet 67P from Rosetta magnetic field measurements

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Abstract

The solar wind pressure is an important parameter of planetary space weather, which plays a crucial role in the interaction of the solar wind with the planetary plasma environment. Unfortunately, it is not always possible to measure its value at every locations where it would be useful or needed. Spacecraft observing the internal dynamics of a planetary magnetosphere, for example, would benefit greatly from solar wind pressure data, but as the solar wind does not penetrate to their locations, direct measurements are impossible. It is well known that the maximum of the magnetic field in the pile-up region of a magnetosphere is proportional to the square root of the solar wind pressure. Recent investigation of Rosetta data revealed that the maximum of the magnetic field in the pile-up region can be approximated by magnetic field measurements performed in the inner regions of the cometary magnetosphere close to the boundary of the diamagnetic cavity. This relationship holds for several months spanning from June 2015 to January 2016. Here we investigate the possibility to use this relationship to determine a solar wind pressure proxy for this time interval using magnetic field data measured by the Rosetta Magnetometer. This pressure proxy would be useful not only for other Rosetta related studies, but could also serve as a new independent input database for space weather propagation to other locations in the Solar System.

1. Introduction

Solar wind pressure (together with a few internal properties) determines the shape and size of a magnetosphere. It influences most of the magnetospheric boundaries and currents, and many other magnetospheric phenomena. Thus most magnetospheric investigations would benefit from knowing the solar wind pressure. Spacecraft deep inside a magnetosphere or spacecraft without proper instruments however cannot measure it directly. Solar wind monitoring spacecraft are sometimes millions of kilometers away, in which case researchers have to rely on data propagated to their region of interest by solar wind propagation tools. In this paper we describe a method, which can be used to derive an in situ solar wind pressure proxy based on Rosetta magnetic field measurements for the location of comet 67P, for such times when Rosetta was deep inside the cometary magnetosphere.

2. Method

It is well-known that the magnetic pressure of the compressed magnetic field in a cometary induced magnetosphere balances the pressure of the incoming solar wind. Thus the maximum of the magnetic field magnitude in the pile-up region (B_0) closely follows the square root of the solar wind pressure. When the solar wind pressure increases for example, the induced magnetosphere is compressed until the growing magnetic pressure of the compressed field is once again able to withstand the pressure of the solar wind.

Thus $B_0^2/2\mu_0$ would be a good proxy for the solar wind pressure, provided that one can actually measure its value. However, to measure this maximum a spacecraft should always be there, where the field is most compressed, which is a very specific and swiftly changing spatial position inside the magnetosphere. Instead of such direct measurements, we have to rely on some known relationships, which connect B_0 with $B(r)$, the field amplitude actually measured at the position *(r)* of the spacecraft. Since the magnetosphere is a very complex and dynamic environment, it is not always possible to find such a relationship, especially a relationship accurate enough to be useful as a basis of a pressure proxy.

Recent investigations [5] revealed that there is a region deep inside the cometary magnetosphere, where a single process seem to dominate the dynamics of the field magnitude. This raises the hope that we can determine a $B_0(r,B(r))$ relationship there, accurate enough for our purpose. This region is the vicinity of the diamagnetic cavity [2,3,4]. Here the neutral drag model [1] dominates the physical processes, and the model is able to predict not only the size (r_{cs}) of the cavity, but the field magnitude as well, as a function of B_0 and r. This $B(B_0,r)$ relationship can be inverted, to get the desired B_0 values from the measurements. The resulting magnetic field based pressure proxy is far better in predicting the size of the diamagnetic cavity, for example, than the pressure values propagated from other spacecraft by solar wind propagation tools. We test the accuracy of this pressure proxy on other phenomena observed in the plasma environment of comet 67P, which are also expected to be sensitive to the variation of the solar wind pressure.

Figure 1 shows the magnetic field based pressure proxy for the time interval between June 2015 and January 2016, in which Rosetta was close enough to the diamagnetic cavity that one can use the solution of the neutral drag model to estimate B_0. The results are compared to the predictions of the mSWiM solar wind propagation tool [6]. The two curves are very similar, they agree as well as the accuracy of the Earth based prediction allows.

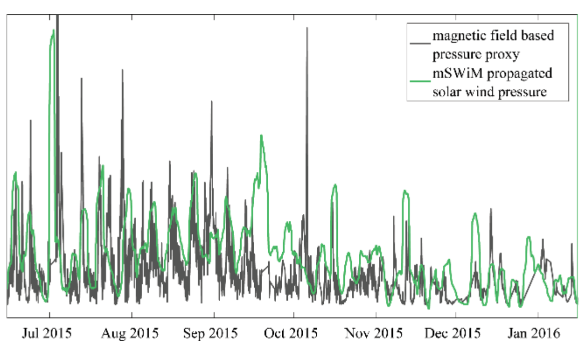

Figure 1: Pressure proxy derived from magnetic field measurements of the Rosetta Magnetometer (black); solar wind pressure propagated from Earth based spacecraft by the mSWiM propagation tool (green).

3. Summary and Conclusions

Magnetic field measurements performed near the diamagnetic cavity of comet 67P/Churyumov-Gerasimenko can be used to estimate the maximum of the magnetic field magnitude in the magnetic pile-up region, which in turn is a measure of the solar wind pressure acting on the outside of the cometary magnetosphere. Thus from the magnetic field measured deep inside the magnetosphere we can deduce the pressure of the solar wind around the comet. The pressure proxy derived by this method can be used in investigations of other solar wind pressure sensitive plasma phenomena of comet 67P. It also makes the Rosetta Magnetometer a solar wind pressure monitor, the data of which can be used as input for space weather predictions propagated to other locations in the Solar System.

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