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Evolution of the magnetic field at comet 67P/Churyumov-Gerasimenko

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Abstract

The magnetic field at a comet is significantly influenced by the solar wind on one side and the outgassing rate on the other. There are no simple radial models for the magnetic field, neither at a comet with low outgassing rates ($\sim 10^{25}\,\mathrm{s}^{-1}$) where ion gyroradius effects are non-negligable, nor at high outgassing rates ($\sim 10^{27}\,\mathrm{s}^{-1}$) where plasma boundaries form. However, the long duration of the ESA Rosetta mission has made it possible to track the evolution of the magnetic field while comet 67P/Churyumov-Gerasimenko approaches the Sun. Herein we present a simple model that seems to fit the data quite well, depending on input parameters. The study also includes the influence of the comet's gas production rate and the solar wind conditions, which both have complex effects on the magnetic field, but are clearly recognizable. The evolution of the magnetic field direction related to draping is more complex than previously suggested. Classical draping only exists at the comet for high outgassing rates, for lower rates, the magnetic field roughly follows the Parker angle. It is shown that the interaction of the solar wind with the comet can be roughly devided into three main classes.

1. Introduction

The Rosetta spacecraft was the first to explore the plasma environment at a comet for an entire perihelion passage, thus observing the growth and diminishment of the environment. As the comet approaches the Sun, the insolation leads to outgassing of mostly water of the nucleus and ionization of a significant part of these neutrals. Theser ions need to be incorporated in the incoming solar wind which leads to the formation of different plasma regions depending on the ion number density. These regions include (but are not limited to) the diamagnetic cavity, the bow shock the solar wind cavity and possibly an ion collisionopause [3, 4, 2, 5]. All of these regions have different magnetic field signatures that change with the outgassing rate. The long term development of the magnetic field is studied using different techniques.

2. The magnetic field at comets

The pile-up of the magnetic field in the vicinity of the comet was predicted and then observed by multiple spacecraft [1, 6]. This behaviour was also observed at comet 67P and it is shown that the magnetic field pile-up may be calculated using an MHD model. However to correctly account for the high variability of the magnetic field measured by Rosetta, the solar wind input parameters need to be based on real solar wind observations. Investigations of the global structure of the plasma environment are complicated by the fact that the spacecraft is constantly changing position and therefore the model is also used to disentangle the effect of this from the solar wind influence.

It is also found that the variance of the magnetic field significantly increases with the outgassing rate, meaning that the magnetic field strength and variance are largest shortly after the perihelion passage.

As the comet nucleus rotates, the outgassing profile changes due to the different active regions on the surface. This should then also be reflected in the different magnetic field strength corresponding to the ion density variations. However, the magnetic field is not as sensitive to the neutral density changes as the ion density and therefore, on short time scales, there is no observable correlation between the comet's rotation and the magnetic field. However for very long periods of time the statistics are significantly improved and the cometary rotation may be linked to enhancements in different frequency bands of the magnetic field.

As the pile-up is significantly dependent on the incoming solar wind dynamic pressure, the magnetic

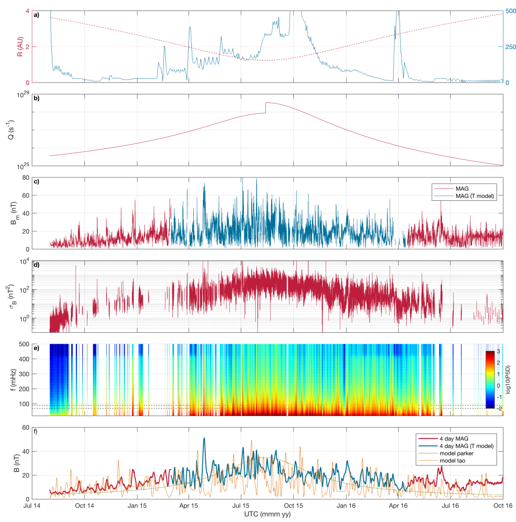

Figure 1: An overview of the data examined in the publication. The panels show a) Rosetta's distance to the comet (blue) and the comet's distance to the Sun (red), b) the outgassing rate, c) the magnetic field magnitude using two different offset models, d) the magnetic field variance, e) magnetic field spectral density and f) the magnetic field compared to a model.

field strength may also be related to the rotation period of the Sun, as this in turn correlates with the appearance of high speed solar wind time intervals.

On short-scales, the expected draping of the magnetic field is only observable close to the nucleus, further away transient effects dominate the plasma environment. But when examining longer intervals it becomes apparent that the draping structure is observable for high ($> 10^{27}\,\mathrm{s}^{-1}$) gas production rates. In general the structure of the plasma environment significantly changes when the gas production rate increases, leading to the categorization of the interaction regimes into three groups: the weak, the intermediate and high activity case.

3. Summary and Conclusions

Here we show that the long duration of the Rosetta mission not only may be used to observe the evolution of the plasma environment, but it also affords the opportunity to use increased statistics to find tenuous connections between magnetic field and other parameters.

We find that the pile-up at the comet can (on timescales of more than a month) be described by a simple MHD model, although short-time variations are not covered well by this model. Classical draping is found only for high gas production rates, for lower rates, the magnetic field on average follows the solar wind parker angle. We also show that the cometary rotation period as well as the Sun rotation period influence the magnetic field strength in the comet's plasma environment.

Acknowledgements

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