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A Kronian current sheet/magnetodisk model to study Titan's induced magnetosphere

C. Bertucci (1), N. Achilleos (2) and M.K. Dougherty (3)
(1) Institute for Astronomy and Space Physics, Buenos Aires, Argentina (cbertucci@iafe.uba.ar, +54 11 47868114), (2) Atmospheric Physics Laboratory, University College London, United Kingdom (nicholas.achilleos@ucl.ac.uk), (3) Space and Atmospheric Physics Group, Imperial College London, United Kingdom (m.dougherty@imperial.ac.uk)

Abstract

In this work, we analyze and interpret magnetic field observations by Cassini during the T15 Titan flyby based on background magnetic field estimates provided by a new empirical model of Saturn's field in the outer magnetosphere. This new model combines previously developed axis symmetrical stress-balance model of Saturn's magnetodisk [1] and a dynamic, empirical model of the magnetodisk's current sheet shape [2] to mimic Cassini magnetometer measurements around Titan. The model is quite efficient in providing a reliable estimate of the Kronian magnetic field where Titan sits in. The best fit model outputs are next used to interpret Cassini MAG data inside Titan's induced magnetosphere using a coordinate system based on the upstream magnetic field and plasma flow velocity. In this new coordinate system, MAG data reveals an induced magnetotail whose magnetic structure is consistent with the draping of the modeled background magnetic field. As the background magnetic field varies in time during we compare results using time varying or static mean field coordinates. Finally, we discuss the implications of the use of this model for other Titan flybys and for theoretical studies involving time varying upstream conditions.

1. Summary

The plasma interaction between Titan and its environment is an exceptional example of that of a weakly magnetized object with a wind of plasma. Titan orbits parent planet Saturn at 20.3 R_S (1 R_S = 60280 km) distance, what places it on average within the Kronian co-rotating magnetosphere.

Photo ionization and particle impact contribute to the development of a highly conducting ionosphere and the occurrence of massloading of the external plasma flow by the moon's exospheric particles as they become ionized in this manner. The presence of ionospheric obstacle and the addition of mass via massloading generate a deceleration of the eternal flow around the obstacle and the formation of an induced magnetosphere similar to those at Venus, Mars and active comets.

The geometry of an induced magnetosphere is largely controlled by the orientation of the upstream magnetic field **B** and flow velocity vectors **v**. These two vectors define a coordinate system where the induced magnetosphere is simply described, and where **v** and **B** are measured just upstream from the interaction region. In work [3], authors introduced this 'draping' (DRAP) coordinate system for Titan based on an estimate of a single value of B from time averages during intervals both before and after the interaction region. The resulting flyby-based DRAP coordinate system was shown to be more efficient than the static Titan Ionospheric Interaction System (TIIS) in organizing the magnetoplasma regions in the tail. This coordinate system was successfully used in flybys TA, TB, T3 [3], and T9. In most of these flybys, the absence of plasma measurements led to the assumptions that either the upstream velocity vector was purely azimuthal (co-rotation), or perpendicular to the upstream field.

In addition to this 'static' draping coordinate system based on a single estimate of B, a 'dynamic' draping coordinate system was also defined for cases where the inbound and outbound B averages differed significantly [3]. In those cases, the background magnetic field within the interaction region would vary linearly between the inbound and outbound averages leading to a series of instantaneous coordinate systems.

Since the arrival of the Cassini spacecraft to the Saturnian system, much has been learned about the plasma properties of its outer magnetosphere. In particular, Cassini measurements revealed the presence of a dynamic magnetodisk where magnetospheric rotating fields and particles populating its central current sheet are in stress balance [1] which leads to a stable equilibrium.

In the outer magnetosphere, and in particular, on the dayside sector, the averaged shape and location of the magnetodisk is also controlled by the solar wind pressure and the Kronian season leading to a more or less pronounced 'bowl' shape [2]. In addition, oscillations in thickness and displacement of the disk's current sheet with respect to the geographic equator have been found to take place depending on the phase of the kilometric radiation emission (SKR) from each of the two hemispheres [2]. Three factors seem to influence the location of Saturn's magnetodisk:

- Season

- North/South SKR Phase

- Solar wind pressure

These changes in the location and shape of Saturn's magnetodisk in the lapses of time of the order of up to a few hours poses limitations to the steady-state description of Titan's interaction as these variations are perceived as spatial and temporal changes in the upstream conditions at Titan's location. In particular, changes are observed in all the components of the magnetic field.

In this work, we analyze and interpret magnetic field observations by Cassini during the T15 Titan flyby based on background magnetic field estimates provided by this new empirical model of Saturn's field

The best fit model outputs are used to interpret Cassini MAG data inside Titan's induced magnetosphere using static and dynamic DRAP coordinate systems. In the DRAP coordinate system, MAG data reveals an induced magnetotail whose magnetic structure is consistent with the draping of the modeled background magnetic field.

Next, we compare static and dynamic DRAP coordinates. Finally, we discuss the implications of the use of this model for other Titan flybys and for theoretical studies involving time varying upstream conditions.

2. Figures

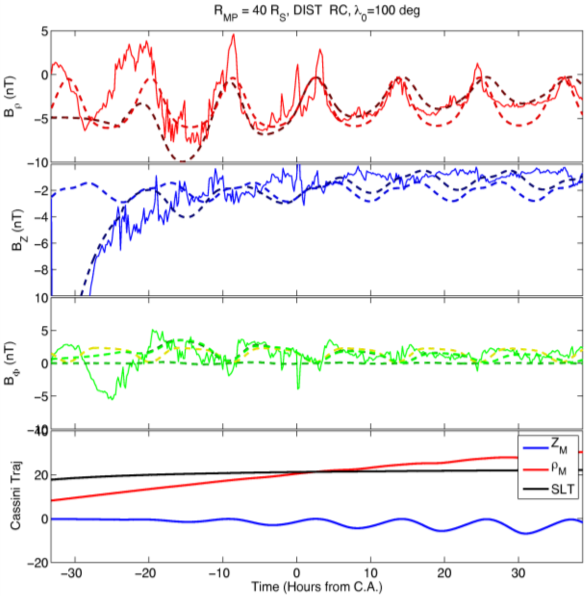

Figure: Top three panels, from top: radial, north/south, and azimuthal component of the magnetic field. Solid lines represent Cassini MAG measurements, dark red, dark blue and green dash lines describe model results in the Cassini frame. Red, blue and yellow dash lines describe model results in the Titan-centred frame. Bottom panel shows the spacecraft location with respect to the centre of the current sheet model. Time is measured from CA for the T15 flyby.

References

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