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Does the magnetic field near Titan correspond to the induced magnetosphere

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Abstract

We show that the direction of the magnetic field tension in the Titan magnetic tail is not consisting with the induced magnetosphere produced by magnetic field lines draping.

1. Introduction

Induced magnetosphere arises when a magnetized plasma flow interacts with a non-magnetic body possessing ionosphere. Superposition of the external magnetic field and field produced by induced electric currents under the action of Lorentz electric field $\mathbf{E} = -\mathbf{v} \times \mathbf{B}$ results in a configuration which can be described be magnetic field lines draping around the obstacle [1]. A magnetic tail results from such a draping and two lobes of oppositely directed magnetic field lines are separated by the current sheet. Obviously, the orientation of such an induced magnetosphere depends on the direction of the magnetic field in the flow. If we consider the coordinate system with the unit vectors defined as

$$\begin{aligned} \mathbf{e}_x &= -\mathbf{v}_0 / v_0 \\ \mathbf{e}_y &= \mathbf{v}_0 \times \mathbf{B}_0 / \left| \mathbf{v}_0 \times \mathbf{B}_0 \right| \\ \mathbf{e}_z &= \mathbf{e}_x \times \mathbf{e}_y \end{aligned} \tag{1}$$

where $\mathbf{v}_0$ and $\mathbf{B}_0$ are flow velocity and magnetic field in the flow, respectively, then the simple criterion for ideal induced magnetosphere (field line draping) can be formulated as

$$\begin{aligned} B_x &> 0 \text{ for } z < 0 \\ B_x &< 0 \text{ for } z > 0 \end{aligned} \tag{2}$$

and $B_z > 0$ inside the magnetosphere. Moreover, the direction of projection of the magnetic field onto *YZ*-plane is close to the Z-axis. Such a configuration was observed for typical induced magnetosphere of Venus [2,3] and comet Halley [4]. Magnetic field perturbation discovered near Titan by Voyager-2 [5] does not satisfy these criteria. Strong rotation of the magnetic field around *X*-axis occurs in the Titan magnetic tail [6]. Systematic study of numerous Cassini flybys also does not show clear picture of the field line draping [7]. Good examples of draping were observed for the flybys with closest approach on the upstream ($x > 0$) side of Titan, and not in the tail. However, the criterion (2) may be obscured in the real induced magnetosphere by variations of corotation flow and upstream magnetic field directions. Therefore we perform another test for induced nature of the magnetic field in the Titan tail which is less subjected to flow variability.

2. Magnetic field tension in the Titan tail

Magnetic tension $(\mathbf{B}\nabla)\mathbf{B}$ is always directed downstream in the induced tail produced by field line draping. We estimate the value of the magnetic tension inside the Titan geometric shadow as $B_y \delta B_x / \delta y + B_y \delta B_x / \delta y$. This allows us to remove the magnetospheric changes due to upstream magnetic field variations. Figure 1 shows the direction of the tension force.

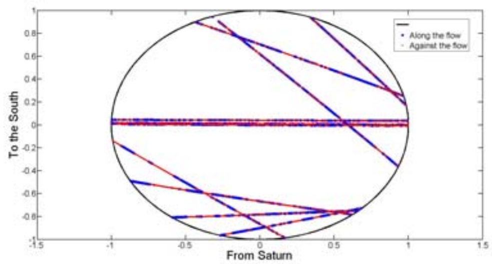

Figure 1: Direction of magnetic tension force in the Titan tail. (Blue dots along the flow, red dots against the flow, correspondingly).

Distribution of the tension direction is rather chaotical, but in average the magnetic tension is directed against the flow rather than downstream. Figure 2 shows the histogram of distribution of tension. Negative values correspond to the tension against the flow and contradict to draping nature of the Titan magnetic tail.

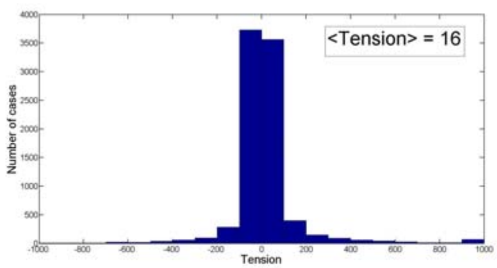

Figure 1: Direction of magnetic tension force in the Titan tail. (Blue dots along the flow, red dots against the flow, correspondingly).

3. Summary and Conclusions

We conclude that Cassini magnetic field measurements during Titan flybys do not correspond to the ideal picture of the induced magnetosphere. This demands to consider alternative or additional mechanisms responsible for the Titan interaction with Kronian plasma corotation flow. They may include intrinsic (crustal) magnetic field of Titan, significance of Hall effect in the process of interaction, influence of atmospheric neutral winds on the magnetospheric structure.

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