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Influence of B_y and B_z interplanetary magnetic field components on planetary magnetopause position and shape: qualitative analysis and comparison with modelling and observation results

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Abstract

Interplanetary magnetic field (IMF) B_y and B_z components influence on planetary magnetopause position and shape in two different ways: (i) presence of both components generally leads to increase of total pressure near the magnetosheath flow stagnation point and (ii) B_z part of IMF additionally leads to variation of the magnetopause shape. Both effects are qualitatively considered in the talk.

1. Introduction

It is generally valid that the solar wind ram pressure ρV^2 is the main factor contributing into the magnetopause stagnation pressure which can be approximated then as $\Pi \approx k\rho V^2$ with k being a function of solar wind specific heat ratio γ and sonic Mach number M_s :

$$k = \frac{1}{\gamma}\left(\frac{\gamma+1}{2}\right)^{(\gamma+1)/(\gamma-1)}\left(\gamma - \frac{\gamma-1}{2M_s^2}\right)^{1/(1-\gamma)} . \quad (1)$$

Complementary factors that are influencing on magnetopause position and shape are: (i) magnetic field line tension resulting in the clock angle dependency of the magnetopause terminator cross-section [1], (ii) magnetic field pressure leading to magnetopause movement towards the Earth when the IMF cone angle approaching $\pi/2$ [2], and (iii) IMF B_z component increasing magnetopause nose bluntness for southward B_z direction [3]. It was shown [4] that the contribution of the magnetic field line tension to the stagnation pressure is ~ $2\Delta/R$ times less than contribution of the magnetic pressure itself, where Δ is the magnetosheath thickness and R is the magnetic field lines curvature radius. Thus field line tension effects will be omitted in subsequent analysis.

2. Basic approach and relations

Empiric relations for the description of the total Π, thermal P_{th}, and magnetic field P_{mag} pressures at the magnetopause nose are based on results of 3-D MHD modelling [5] and analytic solutions in Lagrangian variables [6]:

$$\Pi = k\rho V^2 \cdot \left(1 + \left(\frac{\sqrt{6}\cdot Sin^2\vartheta_{bv}}{M_a^2}\right)^{2/3}\right), \quad (2)$$

$$P_{th} = k\rho V^2 \Big/ \left(1 + 25\sqrt{\frac{Sin^2\vartheta_{bv}}{M_a^2}}\left(2 - \sqrt{\frac{6}{M_s}}\right)\right), \quad (3)$$

$$P_{mag} = \Pi - P_{th} , \quad (4)$$

where M_a is Alvenic Mach number and ϑ_{bv} is the angle between solar wind and IMF directions. Figure 1 presents correspondence of relations (2 - 4) to results of 3-D MHD modelling [5].

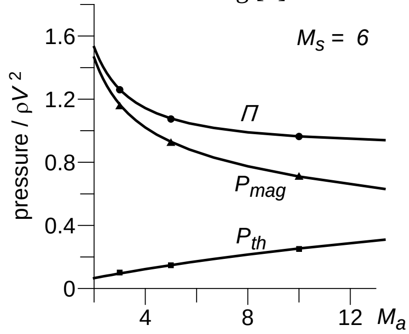

Figure 1. Comparison of 3-D MHD calculations with approximating relations (2 - 4).

The next important relation (5) of our approach comes from so called 'doubling factor' f_d that indicate how much the internal magnetosperic field is increased in the subsolar region due to

Chapman-Ferraro currents. With the use of ellipsoidal model by Tsyganenko [7] we approximated f_d by the following relation :

$$f_d = 2 + \exp\left(-\frac{5}{3}\left(\frac{R_0}{r_0} - 1\right)\right), \qquad (5)$$

where r_o and R_o are the planetocentric distance to the magnetopause nose and its curvature radius. Figure 2 presents correspondence of relation (5) to results of model [7].

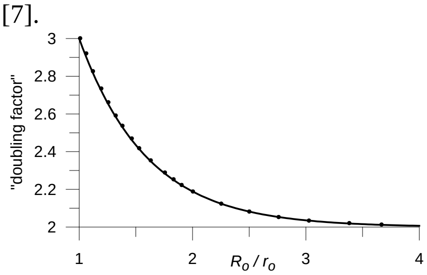

Figure 2. Comparison of Tsyganenko model [7] results (dots) with calculations by the expression (5).

Additional basic relation of the model (adjusted by comparison of resultant model with observations) describes the increase of the ratio R_o / r_o in (5) with increase of southward IMF B_z component that provides more blunt magnetosphere nose for the southward IMF.

3. Summary and Conclusions

Incorporation of theoretically background relations (2 - 5) into magnetopause model (e.g. in [1]) provides possibility to describe variation of the magnetopause position and shape for wide range of solar wind ram pressures and IMF B_y and B_z components.

Qualitatively, increase of either northward or southward IMF B_z component leads to the increase of total magnetosheath pressure at the stagnation point (see relation (2)) thus suggesting magnetopause motion to the planet. On the other hand, the dependence of the magnetopause shape R_o / r_o and 'doubling factor' (5) on IMF B_z component provides "blunted" magnetopause for southward IMF and "sharpened" magnetopause for northward IMF. Decreased 'doubling factor' (5) for southward IMF leads to "rapid" approach of "blunted" magnetopause to the Earth while increased f_d for northward IMF provides "stagnative" behavior of the "sharpened" magnetopause with increase of northward component of IMF, that qualitatively corresponds to magnetopause observations (see, e.g., [3]).

Acknowledgements

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