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A1_1 Does the solar wind have any significant effect on Jupiters Magnetosphere?

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Abstract

There are many forces that can contribute to a planet's plasma dynamics. This article will look into what influences Jupiter's plasma dynamics and whether the solar wind contributes significantly or if it could be neglected. The analysis concludes that the solar wind is significant, but not the dominant plasma dynamic in the case of Jupiter.

Introduction

Plasma flow within the magnetosphere of a planet usually depends on two main types of driving mechanism. One is due to the interaction that the plasma and the magnetic field have with the planet and its rotation. This is known as co-rotation. The other mechanism is due to the interaction with the solar wind, known as the Dungey cycle. Which driving mechanism is dominant depends on the magnetospheric conditions. However, the non-dominant mechanism may still have significant second order effects on the system. By calculating the contributions of both the mechanisms for Jupiter's unique magnetospheric conditions, it can be discussed whether the solar wind makes a significant contribution to Jupiter's plasma dynamics.

Analytical Method

Which of these two mechanisms is dominant can be estimated by finding the systems stagnation point. The stagnation point is the radial distance from the system centre, where the superposition of the two flows produces zero net velocity. This point is taken to be the boundary between the co-rotation dominated region and the Dungey cycle dominated region. Then if the planet's magnetopause lies within this boundary, its magnetosphere is thought to be co-rotation dominated, otherwise its magnetosphere is Dungey cycle dominated. The stagnation point can be estimated by combining the electric fields produced by both mechanisms [1]:

$$\frac{R_{SP}}{R_P} = \left(\frac{\omega_P B_{eq} R_P}{E_0} \right)^{1/2} \quad \textbf{(1)}$$

where $\boldsymbol{R_{SP}}$ is the distance of the stagnation point from the centre of the planet, $\boldsymbol{R_P}$ is the radius of the planet, ω_P is the angular momentum of the planet, $\boldsymbol{B_{eq}}$ is the strength of the magnetic field at the planets equatorial surface, and $\boldsymbol{E_0}$ is the magnitude of the dawn-dusk electric field in the equatorial plane associate with the Dungey cycle (assumed constant). For Jupiter these values are $\boldsymbol{R_P}$ ≈ 71000 km, $\omega_P \approx 1.8 \times 10^{-4}$ rads^{-1}, $\boldsymbol{B_{eq}}$ ≈ 425000nT, and $\boldsymbol{E_0} \approx 2\times10^{-4}$Vm [1].

Substituting these values into equation (1) gives a value for R_{sp} ≈ 390 R_p. The radius of Jupiters magnetosphere is approximately $\boldsymbol{R_M}$ ~ 100 $\boldsymbol{R_p}$ [2].

Figure 1 shows the stagnation point and the co-rotation/Dungey cycle boundary with respect to Earth's and Jupiter's magnetopause. From the figure it can be seen that Jupiter's magnetopause boundary lies within the stagnation point and thus the plasma flow must be co-rotation dominant.

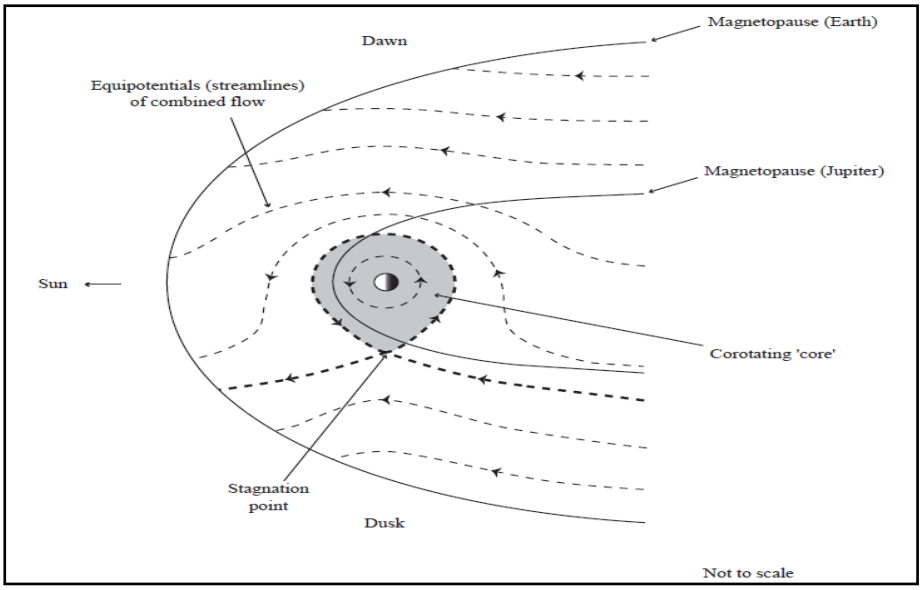

Figure 1: Sketch of Jupiter's magnetosphere indicating the position of the stagnation point, reproduced according to [1]

Discussion and implications

The calculations above clearly show that $R_M > R_{SP}$, hence co-rotation is the dominant mechanism, meaning that the Dungey cycle has only a minor role in influencing Jupiter's plasma dynamics. The question still remains whether it could be neglected altogether. Jupiters magnetosphere is a very complicated system compared with Earth's and is harder to measure; therefore it is still under debate whether the Dungey cycle has any effect on such a strong magnetic field, so far away from the sun.

However, even though Jupiter is co-rotation dominated, it doesn't mean that other sources have no effect on Jupiter's overall system. One big argument for the fact that the Dungey cycle does contribute is the existence of Jupiter's magnetotail. Jupiter's magnetosphere has an enormous tail extending past Saturn. With our current understanding, the solar wind is the only source capable of creating a magnetotail. Consequently it is more than likely the Dungey cycle is not insignificant. Furthermore Jupiter has many unexplained features like its unusually active auroras. These may also be explained by an additional source of plasma like the solar wind.

Conclusion

Considering all of the information presented here, it is reasonable to say that although the Dungey cycle is not the dominant mechanism in the plasma dynamics of Jupiter's magnetosphere, it is not negligible either. Without its contribution Jupiter would not exhibit many of its unique features, most obvious of which is its very long magnetotail. Although a lot is still not yet fully understood about Jupiter's complex system, it can be said that the Dungey cycle has some significance in dictating some of its behaviour.

If the Dungey cycle was mistakenly neglected from calculation concerning the magntospheric system, before knowing all the facts about Jupiter's complicated system, it could lead to wrong conclusions or gaps in knowledge. Maybe when more is known about Jupiter, with further research of the planet, it will be discovered that the only thing the solar wind does contribute, is in fact the shape of the magnetosphere and could in fact be neglected. But from the knowledge presented here it is unlikely that the solar wind has no contribution at all.

References

[1] Magnetosphere-Ionosphere Coupling Currents in Jupiter's Middle Magnetosphere – 2004 - J. D. Nichols – MPhys Thesis

[2] John S. Lewis *Physics and Chemistry of the Solar System* (Academic Press, 1997) p. 200