EPSC Abstracts
Vol. 7 EPSC2012-328 2012
European Planetary Science Congress 2012

Bursty reconnection at Saturn's magnetopause: magnetopause conditions and auroral signatures

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Abstract

Signatures of bursty reconnection have been identified in Saturn's auroral emissions. The magnetopause conditions under which these reconnection events occur are investigated. The magnetosphere is found to be strongly compressed in each case. We propose that the pile-up of magnetic field affects the conditions at the magnetopause, characterised by a reduction in the magnetosheath beta parameter, and causes bursts of reconnection and flux transport away from the dayside magnetopause.

1. Introduction

Saturn's magnetospheric dynamics are driven by both the planetary rotation and the interaction with the surrounding solar wind. The solar wind can transfer plasma and momentum to the magnetosphere via reconnection between the interplanetary magnetic field (IMF) and the planetary field at the magnetopause.

The occurrence and significance of reconnection at Saturn's magnetopause is currently a topic of significant debate [1, 2, 3]. Reconnection can occur both at low-latitudes, resulting in the opening of planetary field lines to the solar wind, which is expected to occur when the IMF is northward, or at high-latitudes between the IMF and the open lobe field regions, expected when the IMF is southward. A further influence on the occurrence of reconnection is expected to be the plasma conditions at the magnetopause, specifically that a high value of the plasma beta parameter in the magnetosheath could inhibit reconnection when the fields are not anti-parallel [2].

Recent analysis of auroral images has revealed emission features in the high-latitude noon sector of the ionosphere, which are interpreted as the signatures of transient reconnection events [4, 5]. An example of these features is presented in Figure 1. It is of great interest to examine under which solar wind / IMF conditions this type of bursty reconnection can occur at

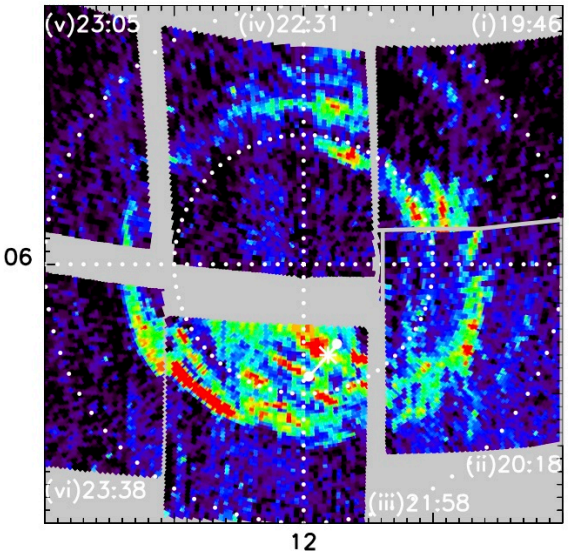

Figure 1: Signatures of transient reconnection observed in Saturn's H_3^+ aurora [5].

Saturn. To do this, the magnetopause crossings closest to the times of the reported images have been examined and are presented in the next section.

2. Magnetopause crossings

Three intervals were identified where a magnetopause crossing took place within three days of the auroral observations showing signatures of bursty reconnection. The plasma and field measurements made by Cassini during one of these intervals, interval C, is shown in Figure 2. From top to bottom the panels show: the magnetic field magnitude and components; the electron density and temperature obtained from ELS; the magnetic field pressure ('B'), the electron pressure ('e^-'), suprathermal particle pressure('S'), overall partial plasma pressure ('P') and the total pressure ('TOT'); and the partial beta parameter calculated

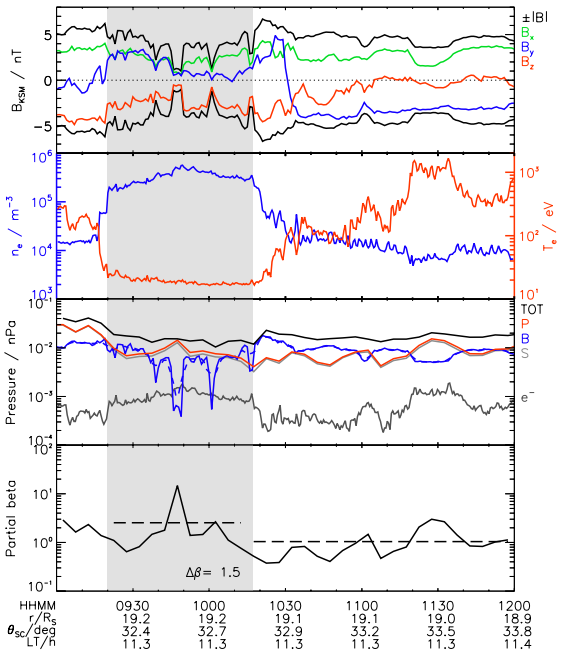

Figure 2: Magnetic field and plasma conditions at a magnetopause encounter (Event C in Table 1).

from these pressures. The grey shaded region indicates the excursion into the magnetosheath.

A model of Saturn's magnetopause was used to estimate the sub-solar stand-off distance of the magnetopause, R_{ss}, and the solar wind dynamic pressure, P [6]. These results, along with the partial beta and magnetosheath field measurements, are summarised in Table 1 for this and the other two intervals studied.

Table 1: Conditions at 3 magnetopause encounters.

Event	MP model	Partial β	Sheath field
A	$R_{ss} \sim 19$ R$_S$	$\beta_{sheath} \sim 3$	$\|B\| \sim 3$ nT
	$P \sim 0.05$ nPa	$\beta_{sphere} \sim 2$	$B_z < 0$
		$\Delta\beta \sim 1$	shear $\sim 50°$
B	R$_{ss} \sim 19$ R$_S$	$\beta_{sheath} \sim 16$	$\|B\| \sim 2$ nT
	$P \sim 0.04$ nPa	$\beta_{sphere} \sim 2$	$B_z < 0$
		$\Delta\beta \sim 14$	shear $\sim 115°$
C	R$_{ss} \sim 18$ R$_S$	$\beta_{sheath} \sim 2.5$	$\|B\| \sim 3$ nT
	$P \sim 0.07$ nPa	$\beta_{sphere} \sim 1$	$B_z < 0$
		$\Delta\beta \sim 1.5$	shear $\sim 50°$

The results from the magnetopause model show that all three encounters (A–C) took place when the magnetosphere was significantly compressed by high solar wind dynamic pressure. Supporting this, the magnetic field and partial plasma pressures just inside the magnetopause were in the upper ranges of those determined statistically by [6].

In intervals A and C, which occurred before the corresponding auroral signatures were observed, the partial β parameter was lower than typical values measured by [2]. We propose that under strong compression conditions, the magnetosheath field can 'pile-up' at the dayside magnetopause until the beta value becomes sufficiently reduced to encourage reconnection. In interval B, which occurred after its corresponding auroral observations, the estimate of partial β in the magentosheath was higher. This can be attributed to earlier reconnection events having transported some magnetic flux away, allowing beta to increase, in agreement with our proposed interpretation.

3. Summary and Conclusions

Cassini observations have revealed auroral signatures of transient reconnection at Saturn. The closest magnetopause crossings were investigated to discover under which conditions this type of reconnection can occur. The magnetosphere was strongly compressed in each case, and the partial beta parameter measured in the magnetosheath before the auroral observations was low. The IMF orientation and shear angle were variable during each interval and between intervals. We propose that the pile-up of magnetic field reduces the local plasma beta parameter and facilitates bursts of reconnection to transport the magnetic flux away from the dayside magnetosphere. Both the magnetic and plasma pressures, and the field orientation therefore affect the occurrence and location of reconnection.

References

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