

## Surface waves on Saturn's magnetopause

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### Abstract

Waves on the surface of a planetary magnetopause lead to the transport of energy into the magnetosphere, making them an important aspect of solar wind-magnetosphere coupling. In the case of Saturn's magnetosphere it has been proposed that the growth of the Kelvin-Helmholtz (K-H) instability produces greater wave activity on the dawn side of the magnetopause than on the dusk side. Here we test this hypothesis using data taken by the Cassini spacecraft during 520 magnetopause crossings. We determine the surface normal for 477 of the crossings and show that perturbations of the surface orientation are predominantly in the direction perpendicular to the local magnetospheric magnetic field, due to the stabilizing influence of magnetic tension forces. There are two most likely orientations with respect to the magnetospheric magnetic field, and 45% of the crossings were part of a clear oscillation of consecutive normals. The only local time asymmetry in the surface orientation is a greater level of normal perturbations at dusk than at dawn. These results suggest that surface waves on Saturn's magnetopause are ubiquitous, and the K-H instability is the most plausible driving mechanism. The waves generally propagate tailward, with a typical period, wavelength, speed, and amplitude of 4 hrs, 10 Saturn radii ( $R_S$ ),  $50 \text{ km s}^{-1}$ , and  $1 R_S$ , respectively. The lack of the hypothesized dawn-dusk asymmetry in wave activity means that we need to revise our understanding of the growth of the K-H instability at Saturn's magnetopause, which will have implications for the study of other planetary magnetospheres.

### 1. Introduction

Wave activity on a planetary magnetopause is one of the processes that produces energy transport from the

solar wind into a planetary magnetosphere. Our understanding of this phenomenon is based on spacecraft data taken at the boundary of Earth's magnetosphere, which is understandably the most observed planetary magnetopause. Substantial evidence for surface waves on Earth's magnetopause has been reported and the driving mechanisms responsible for these waves include solar wind pressure pulses [1,2], growth of the Kelvin-Helmholtz (K-H) instability [3,4], and magnetic reconnection [3]. Resolving the wave driving mechanism is often difficult, but is important because of the insight it provides into the solar wind-magnetosphere interaction.

One of the principal differences between the magnetospheres of Earth and Saturn is that plasma in Saturn's magnetosphere circulates in the sense of planetary rotation throughout the dayside magnetosphere, whereas at Earth such plasma motion is confined to the inner magnetosphere. This produces a much greater flow shear across the dawn magnetopause than across the dusk magnetopause, which is predicted to produce a generally K-H unstable dawn side and a generally K-H stable dusk side [5]. This plausible expectation should lead to greater wave activity at dawn than at dusk. Waves have been previously identified at dawn [6].

However, recent global simulations [7] suggest that this dawn-dusk asymmetry in wave activity may not exist.

### 2. Analysis

We analyse data taken by the Cassini spacecraft during 520 crossings of Saturn's magnetopause. We determine the orientation of the surface in each case by applying minimum variance analysis (MVA) to the magnetic field measurements made during the traversal of the magnetopause current layer.

The oscillation of consecutive normals is strong evidence for surface wave activity, and can also tell us the direction of surface wave propagation.

### 3. Figures

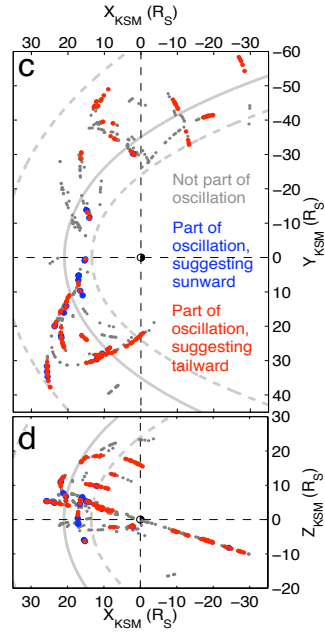


Figure 1: Positions of crossings of Saturn's magnetopause made by the Cassini spacecraft. Crossings with normals that are part of a set of oscillating consecutive normals are indicated, as well as the associated surface wave propagation direction

### 4. Summary

Strong perturbations of the orientation of Saturn's magnetopause can occur, which are primarily controlled by the orientation of the local magnetospheric magnetic field. We propose that surface waves are ubiquitous across Saturn's low-latitude, dayside magnetopause, and that the K-H instability is likely to be the dominant wave driving mechanism. These waves generally propagate tailward, and the typical period, wavelength, speed, and amplitude of the dominant wave type is 4 hours, 10  $R_S$ , 50  $\text{km s}^{-1}$ , and 1  $R_S$ , respectively.

We do not find any evidence for the predicted dawn-dusk asymmetry in either the level of boundary perturbations, or the level of surface wave activity. This result suggests we need to revise our understanding of the growth of the K-H instability at the boundary of Saturn's magnetosphere, which will have implications for other corotation-dominated magnetospheres.

### Acknowledgements

AM acknowledges useful discussions with S. W. H. Cowley. We acknowledge the support of the MAG and CAPS data processing/distribution staff, and L. K. Gilbert and G. R. Lewis for ELS data processing. We acknowledge the use of the list of Cassini magnetopause crossings compiled by H. J. McAndrews and S. J. Kanani. This work was supported by UK STFC through rolling grants to MSSL/UCL and Imperial College London.

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