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Field line resonance in the Hermean magnetosphere: structure and implications for plasma distribution

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Abstract

A full statistical survey of Hermean field line resonance (FLR) events is presented using the entire MESSENGER magnetometer dataset. A total of 566 FLRs were observed, each characterized by a peak in the transverse wave power with a reversal in the polarization handedness as MESSENGER traversed the resonant region. The fundamental frequencies of ULF waves observed in the dayside magnetosphere were used to provide estimates of the equatorial plasma mass density in the range of 1–650 amu cm^{-3} which is predicted to vary approximately with $R^{-7.5}$. The offset of the Hermean dipole into the northern hemisphere is found to cause significant asymmetries in the standing wave structure. The fundamental toroidal mode is also predicted to oscillate with a notably lower frequency than the fundamental poloidal mode, contrary to the relative toroidal and poloidal frequencies modeled for Earth's magnetosphere.

1. Introduction

Field line resonances (FLRs) have provided a unique way of probing the closed field line region of the terrestrial magnetosphere, using both space and ground based instrumentation. At Earth, toroidally polarized ULF waves, which oscillate azimuthally, are approximately shear Alfvén waves, the frequencies of which are determined by the distribution of plasma mass density along the field line. In this study we surveyed the MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) dataset for FLRs, then employed magnetoseismology techniques, originally developed for studying Earth's magnetosphere, to characterize the Hermean plasma.

Previous studies have shown that Hermean ULF waves with frequencies similar to the local H^+ and He^+ gyrofrequencies (∼1 Hz) [1] are common throughout the magnetosphere. Because these frequencies are so close to the local ion gyrofrequencies, it has been argued that magnetohydrodynamic ULF waves like those commonly observed at Earth might not exist at Mercury [2, 3]. Instead, FLRs could emerge as ion-ion-hybrid (IIH) resonances [4, 5].

A more recent study which examined wave activity throughout the Hermean magnetosphere found that transverse ULF wave power at frequencies within the MHD range (much lower than the local ion gyrofrequencies) was common throughout the closed field line region of the magnetosphere [6]. The work presented here uses MESSENGER's magnetometer data to detect transverse MHD wave activity and identify the existence of Earth-like FLRs. The FLRs are then used to make predictions about the plasma mass densities present in the Hermean magnetosphere.

2. Data Analysis

The toroidal (B_t), poloidal (B_p) and compressional ($B_{||}$) components of the magnetic field were Fourier analyzed using a 120s sliding window to create a time series of wave power and polarization throughout MESSENGER's mission. FLRs were found by searching for peaks in transverse wave power accompanied by reversals in polarization handedness. The observed wave frequencies were used as a starting point for predicting plasma mass densities; a Runge-Kutta routine was used to model the wave harmonic structure of the resonances along the KT17 model field [7], where the plasma mass density was varied in order to fit the observed frequency.

3. Results

Figure 1 shows an example of the poloidal (a) and toroidal (b) harmonic structure predicted for a FLR observed at ∼10:30 MLT. The equatorial plasma mass density is predicted to be ∼106 amu cm^{-3} using the observed fundamental toroidal wave frequency of 25 mHz. The predicted wave structures are all highly asymmetric about the magnetic equator, due to the offset of Mercury's dipole into the northern hemisphere. The predicted poloidal mode frequencies are much higher than the toroidal frequencies, contrary to the case in the terrestrial magnetosphere, as a result of the different background field geometries at the two planets.

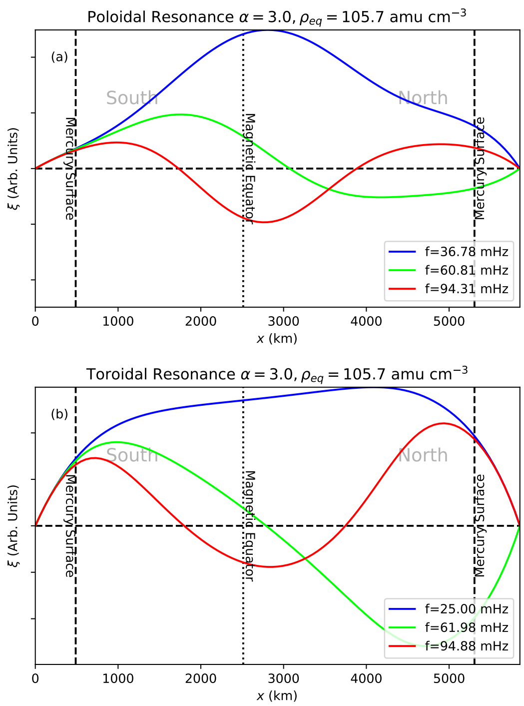

Figure 1: Poloidal (a) and toroidal (b) harmonic wave structure of the first three harmonics of a FLR event.

A total of 566 resonances were found and used to predict the plasma mass density at the magnetic equatorial plane. The majority of these resonances were detected in the dayside magnetosphere, with frequencies typically in the range of 15–50 mHz, most of which exhibited toroidal polarization. The average plasma mass density is presented in figure 2, where the highest densities (> 500 amu cm^{-3}) were inferred closest to the planet.

Acknowledgements

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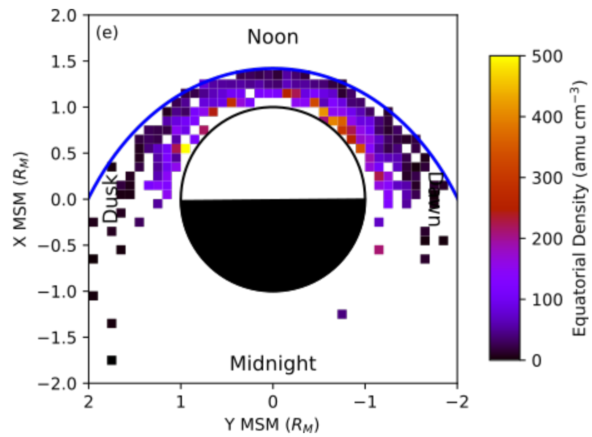

Figure 2: Plasma mass density mapped to the magnetic equatorial plane.

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