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Fig1. Jupiter aurora

Characteristics of Jupiter's magnetospheric turbulence observed by Galileo

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Abstract

Using Galileo/MAG high- and low- time resolution data, we analyze turbulent feature of magnetic field observed in the Jovian magnetosphere. We obtained spectral break feature with wide-variable index and intermittent features. The spectral break frequency relates with local ion frequencies .

Introduction

Jupiter creates the rotation-dominant large magnetosphere due to the fast planetary rotation, the strong magnetic field, and the dominant plasma source from the volcanic moon, Io. Small-scale fluctuation of magnetic field observed in the magnetosphere show turbulent behavior [e.g., Glassmier et al., 1995]. They are considered to take a role in heating the expanding plasma from Io and the relationship with the electric potential drop which accelerates electrons to produce strong Jovian aurora [e.g., Saur et al., 2002; 2003]. In this study, we extend the previous analysis limited in low frequency range to higher frequencies of the turbulent spectra using high-time resolution data to clarify the turbulence feature under various background magnetic field strength.

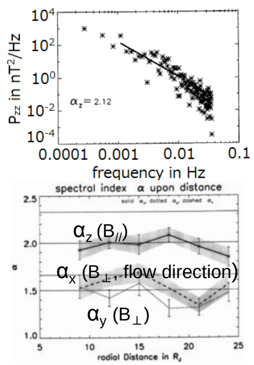

Fig.2 Spectral power of 1 hour interval (upper) and spectral index variation [Saur et al., 2002]

Observation and Data Analysis

Galileo observed Jovian magnetosphere from 1995 to 2003 (Fig. 3).

Dataset: taken from NASA Planetary Data System (PDS)

- -magnetometer MAG [Kivelson et al., 1992]
- -plasma spectrometer (PLS) [Frank et al., 1992] or empirical model [Bagenal and Delamere, 2011]

→ Ion characteristic frequencies

High time-resolution (**HR**) data :

- -moon flyby (not used)
- -magnetosphere: 10 events (above noise) Δt~0.33 sec. 35-280 min. interval

Low time-resolution (**LR**) data :
Δt=12, 24 sec.

MAG data 3 components **B**

→ 1-hour (5-min for HR) running average to have "average field" B_0 at each time

→ rotate **B** into parallel to B_0 "$B_{//}$" and perpendicular to B_0 "($B_{\perp 1}$, $B_{\perp 2}$)"

→ wavelet transfer W(*)

→ Parallel spectrum power: $W(B_{//})^2$
perpendicular power: $W(B_{\perp 1})^2+W(B_{\perp 2})^2$
total power: $W(B_{//})^2 + W(B_{\perp 1})^2+W(B_{\perp 2})^2$

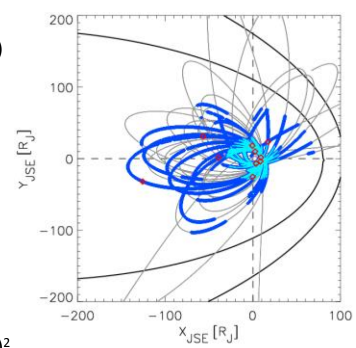

Fig.3 Galileo orbit with LR (blue) and HR (red) MAG data and PLS (light blue) momentum data.

Results

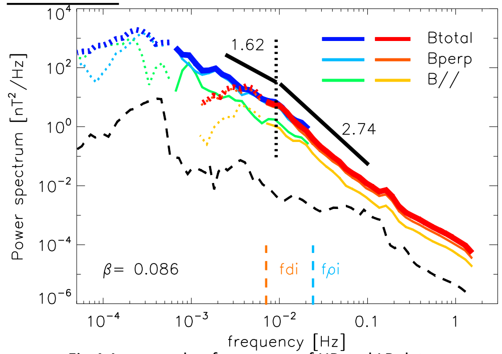

Fig.4 An example of spectrum of HR and LR data

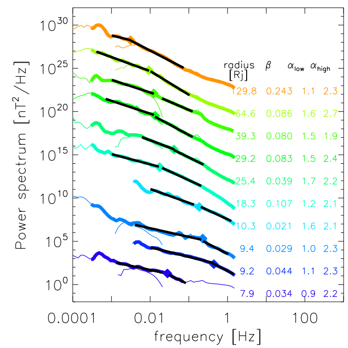

Fig.5 All spectrum with fitting slopes

Magnetic field spectrum over [3x10^{-4}, 1] Hz (Figs. 4-5)

-Spectral break is seen at 0.003-0.3 Hz in LR and/or HR range

-Spectral index is 0.9-1.7 (1.9-2.7) at lower (higher) frequency range

-$B_{//}$ ($B_\perp$) is dominant at lower (higher) frequency range

-Higher order statistics (moments >3 of the PDFs of the increments) show an intermittent feature (Fig. 6).

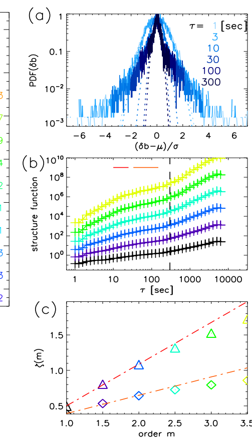

Fig.6 (a) PDF of δB ≡ B(t+τ)-B(t) for several τ shown by right hand. (b) structure functions as a function of τ, and (c) the index of the structure function.

The spectral break frequencies (Fig. 5) are well correlated with the Taylor-shifted characteristic scales, i.e., ion gyroradius and inertial length, of heavy ion with m=20 (Fig.7). Statistical survey of the spectral breaks using low-time resolution data suggests a moderate correlation with the local plasma beta (Fig.8).

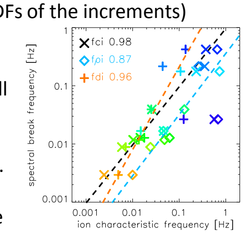

Fig.7 Ion characteristic and break frequencies from HR data.

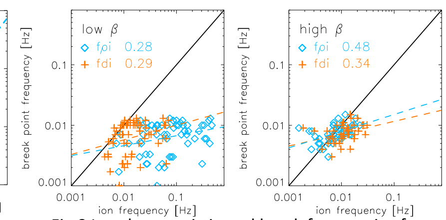

Fig.8 Ion characteristic and break frequencies from LR data for low (left) and high (right) β cases.

Discussion

1. Limitations of the used data and assumptions

i) MAG data providing [3x10^{-4}, 1 Hz] cf. Galileo/PWS search coil: 5.6 Hz – 75 kHz
10 events, 3.2 < |B| < 740 nT→0.0024 < fci (m_{av}=20) < 0.56 Hz, 89 Hz < fce < 20 kHz

ii) Ion parameters with m_{av}=20, due to O+ S+ components. fpi, fdi ∝ $(mi)^{-1/2}$ ~ 0.22% of proton.

iii) Plasma PLS data reflects low energy component. Comparing with EPD [e.g., Mauk et al., 2004], fpi ∝ $BV/(T_i)^{1/2}$, fdi ∝ $V(n_i)^{1/2}$ →larger (lower) estimation for fpi (fdi) a factor of 3-5 (0-20%)

iv) Plasma empirical model at current sheet for lack time of PLS-momentum data.
Comparison with observation and model, fpi, fdi, and β vary a factor of 2-3.

v) Taylor assumption: magnetospheric plasma corotates in wide region.
Using model and observed δB, this assumption valid achieving Vp < V_{alfven} at 20-100 Rj.

⇒These ambiguities affect dependence on fpi, fdi, while the positive trend seen in Fig.7 over 3 orders would be valid. → Confirmation for the former, future Juice or Cassini at Saturn.

2. Dependence of breakpoint frequency on ion characteristic scales
→Plasma cascade from lower to higher frequency scales, their behavior is shifted when they becomes either ion characteristic scales of gyro-radius or inertial length.

References

Bagenal and Delamere (2011), JGR, 116, A05209, doi:10.1029/2010JA016294.

Glassmeier (1995), Adv. Space Res., 16, 209.

Frank et al. (1992), Space Sci. Rev., 60, 283.

Kivelson and Khurana (2002), JGR, 107(A8), 1196, doi:10.1029/2001JA000249.

Mauk et al. (2004), JGR, 109, A09S12, doi:10.1029/2003JA010270.

Saur et al.(2002), Astron. Astrophys., 386, 699.

Saur et al.(2003), GRL, 30, 1260, doi:10.1029/2002GL015761, 5.