EPSC Abstracts
Vol. 12, EPSC2018-898, 2018
European Planetary Science Congress 2018

Survey of lion roar emissions observed in Saturn's magnetosheath by Cassini

David Píša (1), A. H. Sulaiman (2), O. Santolík (1,3), G. B. Hospodarsky (2), W. S. Kurth (2), D. A. Gurnett (2)
(1) Department of Space Physics, Institute of Atmospheric Physics CAS, Prague, Czechia (2) Department of Physics and Astronomy, University of Iowa, Iowa City, U.S. (3) Faculty of Mathematics and Physics, Charles University, Prague, Czechia

Abstract

Whistler-mode waves known as lion roars have been observed by many missions inside the terrestrial magnetosheath. Recently, we have reported the evidence of such emissions in Saturn's magnetosheath [1]. In this study, we present a survey of these intense waves observed inside Saturn's magnetosheath by the Cassini spacecraft between years 2004 and 2011. We have identified all available time intervals of the intense lion roar emissions in the low-band (up to 50 Hz) RPWS/WFR spectrogram. The emissions were observed across the day-side magnetosheath. The emissions were narrow-banded with a peak frequency up to the lower-band cutoff (∼30 Hz), well below the local electron cyclotron frequency (100–1000 Hz). Using the SVD method of the magnetic spectral matrices, we show that the waves are right hand circularly polarized and propagate at small wave normal angles (∼5 degrees) with respect to the ambient magnetic field.

1. Introduction

A magnetosheath is a transient region between the solar wind and planetary magnetosphere. Inside the terrestrial magnetosheath, electromagnetic emissions, also know as lion roars, are often observed at frequencies 100–1000 Hz (0.1–0.5 $\mathrm{f_{ce}}$, where $\mathrm{f_{ce}}$ is the local electron gyrofrequency). They are right-hand circularly polarized waves propagating at small wave normal angles ($< 15°$) to the ambient magnetic field (see in Fig. 1).

The solar wind conditions at Saturn result in a magnetosheath that has different properties compared to Earth [2]. The plasma pressure varies between 6 and 30 pPa, the plasma density between 0.05 and 0.25 $\mathrm{cm^{-3}}$, the plasma temperature between 210 and 370 eV, and plasma flow speed between 170 and 240 $\mathrm{km\,s^{-1}}$. In the dawn region of Saturn's magnetosphere the average direction of plasma flow projected onto the ecliptic plane and measured counterclockwise from the sunward direction has an angle in the range of 175–205 degrees. The magnitude of the magnetic field is typically 0.6–1.6 nT and results in a magnetic pressure of 0.2–1.1 pPa. The plasma β is in the range of 10–100.

2. Data

The waveform receiver (WFR), a part of the Radio and Plasma Wave Science (RPWS) instrument, collects simultaneous waveforms from up to five sensors in a frequency range of either 1–26 Hz (lower band) or 3 Hz–2.5 kHz (upper band). The waveforms are sampled at a frequency of 100 Hz with 12 bit resolution. The WFR snapshot with a length of 20.48 s is available every 24 s. During the analyzed time period the WFR receiver was measuring E_x and E_w signals from the electric antennas, and B_x, B_y, and B_z signals from the search coil instrument. An ambient magnetic field was obtained from the triaxial fluxgate magnetometer which is a part of the magnetometer (MAG) instrument. For the purpose of this study we used the list of time intervals inside the magnetosheath as identified in [2].

3. Summary and Conclusions

The lion roar emissions were observed across the day-side magnetosheath between magnetic local times from 0730 to 1600. The emissions were narrow-banded with a typical frequency at 0.16 $\mathrm{f_{ce}}$ (Fig. 2a). Using the singular value decomposition (SVD) method of the magnetic spectral matrices ([3], adapted for Cassini [4]), we show that the waves are right hand circularly polarized (Fig. 2b) and propagate at the typical wave normal angles of 5 degrees (Fig. 2c) with respect to the ambient magnetic field. Poynting flux directions (Fig. 2d) indicate that waves propagate parallel and anti-parallel to the ambient magnetic field lines.

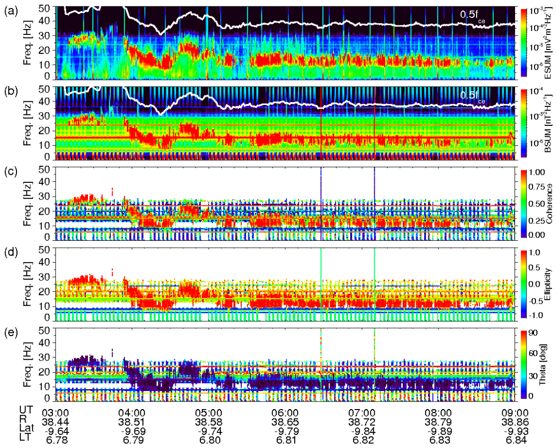

Figure 1: Cassini RPWS/WFR lower band data measured on 3 July 2005 as presented in [1]. (a and b) Sum of the power spectral densities of electric and magnetic field, respectively. The white line shows one half of the local electron gyrofrequency, f_{ce}. (c) Coherence in the polarization plane using the SVD method of the magnetic spectral matrices. (d) Ellipticity of the wave polarization combined with the sense of polarization, +1 for right-hand and -1 for the left-hand circularly polarized waves. (e) Polar angle of a wave vector, 0° for waves propagating parallel to the ambient magnetic field and 90° for transverse wave propagation.

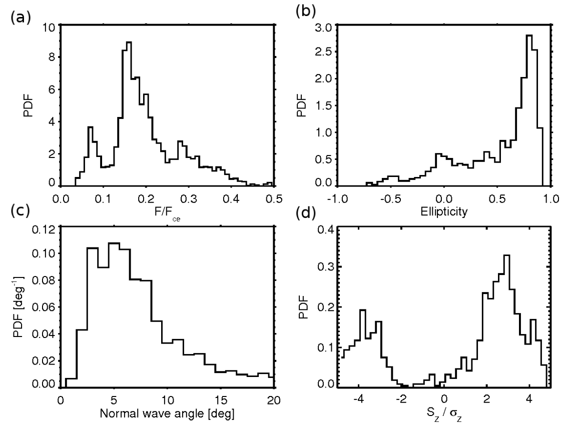

Figure 2: (a) Distribution of normalized frequencies for the most intense spectral peak of the sum of electric components. (b) Distribution of the ellipticity of wave polarization with the polarization sense. (c) Distribution of normal wave angles. (d) Distribution of the normalized Poynting flux component along the magnetic field with the level of confidence, positive values indicate parallel propagation and negative values antiparallel propagation.

We show the first long-term study of lion roar emissions outside the terrestrial environment. Our observations suggest that lion roars are a solar-system-wide phenomenon and capable of existing in a broad range of parameter space. This also includes 1 order of magnitude difference in frequencies. We anticipate our result to provide insight into such emissions in a vastly different parameter regime characterized by a higher plasma beta compared to Earth.

Acknowledgements

The authors are grateful to Nick Sergis for his list of Cassini's magnetosheath visits. The authors also thank the CASSINI/MAG team for their support and for access to magnetometer data. The work has been supported by NASA through contract 1415150 with the Jet Propulsion Laboratory, from grant 16-6050Y of the Grant Agency of Czech Republic, from the MSMT grant LTAUSA17070, and from the Praemium Academiae award.

References

[1] Píša, D., Sulaiman, A. H., Santolik, O., Hospodarsky, G. B., Kurth, W. S., & Gurnett, D. A. (2018). First observation of lion roar emission in Saturn's magnetosheath. Geophys. Res. Letters, 45. https://doi.org/10.1002/2017GL075919

[2] Sergis, N., Jackman, C. M., Masters, A., Krimigis, S. M., Thomsen, M. F., Hamilton, D. C., et al. (2013). Particle and magnetic field properties of the Saturnian magnetosheath: Presence and upstream escape of hot magnetospheric plasma. J. Geophys. Res. Space Physics, 118, 1620–1634. https://doi.org/10.1002/jgra.50164

[3] Santolík, O., Parrot, M., & Lefeuvre, F. (2003). Singular value decomposition methods for wave propagation analysis. Radio Science, 38, 1010. https://doi.org/10.1029/2000RS002523

[4] Santolík, O., Gurnett, D. A., Jones, G. H., et al. (2011). Intense plasma wave emissions associated with Saturn's moon Rhea, Geophys. Res. Letters, 38, L19204. https://doi.org/10.1029/2011GL049219