Plasma Wave Observations During Geomagnetic Storms with MMS

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○ Abstract

This project surveys data from NASA's Magnetospheric MultiScale mission (MMS) in the inner magnetosphere from September 2015 to April 2016, these dates were chosen due to the large number of geomagnetic storms. We also took advantage of high-resolution measurements and looked at higher frequency plasma waves observed at the vicinity of electron cyclotron frequencies. Surprisingly, over certain intervals of these events there is a clear modulation of high frequency chorus wave packets with low frequency ion cyclotron harmonic waves around the oxygen gyrofrequency. Though the mechanism for this modulation is yet to be investigated, these observations suggest a cross-frequency relationship between plasma processes happening at ion and electron scales which may be important for the magnetospheric dynamics. Additionally, we accidentally found ion cyclotron waves with unusual properties which have never been reported before.

○ Geomagnetic Conditions

The interval surveyed was selected due to the large number of geomagnetic storms. Storms were of interest because enhanced amounts of Oxygen are lost from the Earth's atmosphere to its magnetosphere during geomagnetic storms. Dates were chosen by investigating the DST index for September 2015-April 2016.

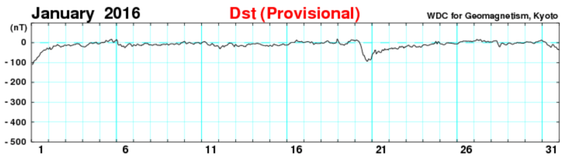


Figure 1. DST Index for January 2016.

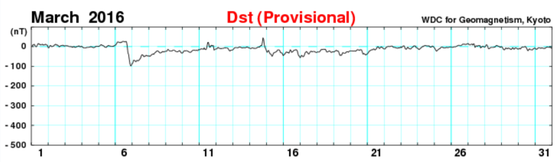


Figure 2. DST Index for March 2016.

○ References

Usanova, M.E., Ahmadi, N., Malaspina, D.M., Ergun, R.E., Trattner, K.J., Reece, Q., Leonard, T., Fuselier, S.A., Torbert, R.B., Russell, C.T., Burch, J.L. (2018). MMS Observations of Harmonic Electromagnetic Ion Cylotron Waves. *Geophysical Research Letters, 45, 8764-8772.* https://doi.org/10.1029/2018GL079006

Usanova, M. E., Malaspina, D. M., Jaynes, A. N., Bruder, R. J., Mann, I. R., Wygant, J. R., & Ergun, R. E. (2016). Van Allen Probes observations of oxygen cyclotron harmonic waves in the inner magnetosphere. Geophysical Research Letters, 43, 8827-8834 https://doi.org/10.1002/2016GL070233

○ Acknowledgments

We acknowledge SSCWeb, and Kyoto observatory for the use of their resources. MMS data is publicly available and can be accessed at https://lasp.colorado.edu/mms/sdc/public/. I also acknowledge Martin Snow, Willow Reed, and Claire Raftery for their continued support.

This research was supported by the National Science Foundation REU program, Award #1659878.

○ Wave Properties

Electromagnetic ion cyclotron waves at frequencies around the oxygen cyclotron frequency are visible in both the magnetic and electric fields. They can be seen with or without harmonics.

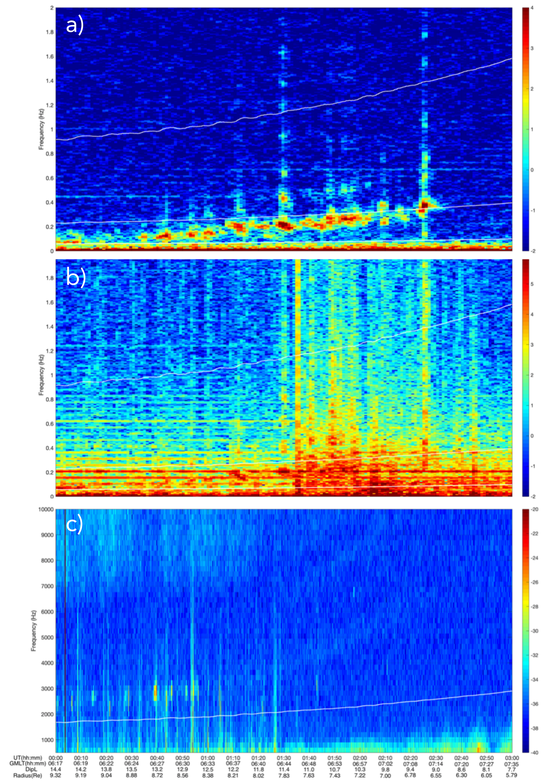


Figure 3. FFT spectrograms for March 26, 2019 from 0:00-3:00 UT. a) the low-frequency Bx_{GSE} magnetic field component, (b) the low-frequency Ex_{GSE} electric field component, (c) the high-frequency omni-directional electric field.The white curves in panels (a) and (b) show the local H^+, He^+, and O^+ ion gyrofrequencies. The white curve in panel (c) show the local electron gyrofrequency.

○ Low- and High-Frequency Waves

Surprisingly, we found that there are certain intervals in which the ion waves modulate at the same frequency as the chorus wave packets. This suggests a cross-frequency relationship between plasma waves happening at ion and electron frequency scales.

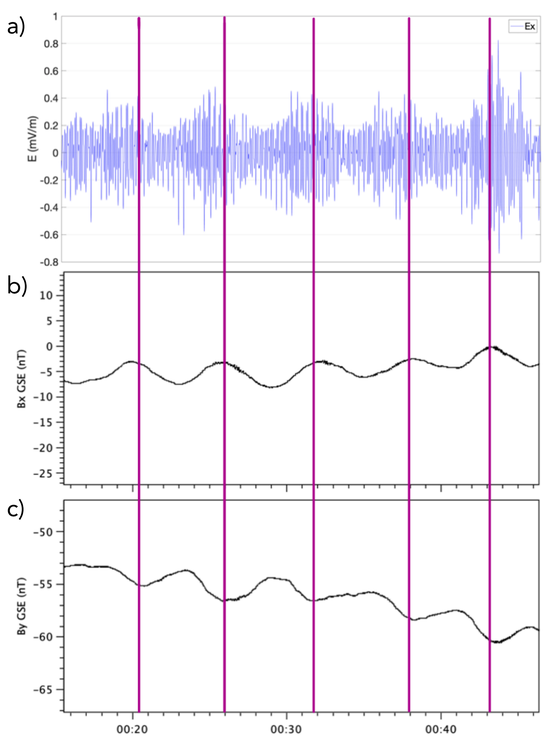


Figure 4. (a) E_x component of Electric Field, (b) B_x component of magnetic field , and (c) B_y of magnetic field on March 26, 2016 from 00:16-00:46.

○ Satellite Location and Trajectory

Satellite location was obtained using NASA's satellites situation center system and services. We looked at plots of the satellite's trajectory. Additionally, we obtained a list of the satellite's geomagnetic local time, the L-shell value, as well as the radius from the Earth.

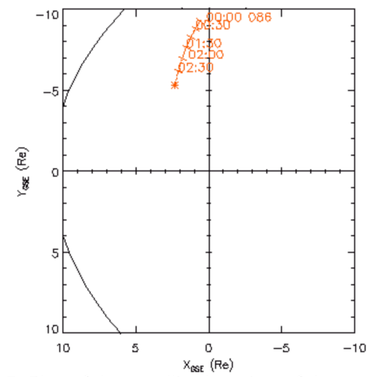


Figure 5. Plot of the satellite location of the event in figure 3 on March 26, 2016 from 0:00-3:00 UT.

Figure 6 shows that electromagnetic ion cyclotron waves occurring in the frequency band of the oxygen gyrofrequency are preferential to the dayside. Figure 7 shows that cross frequency events are also preferential to the dayside of the magnetosphere and could be a result of processes occurring there.

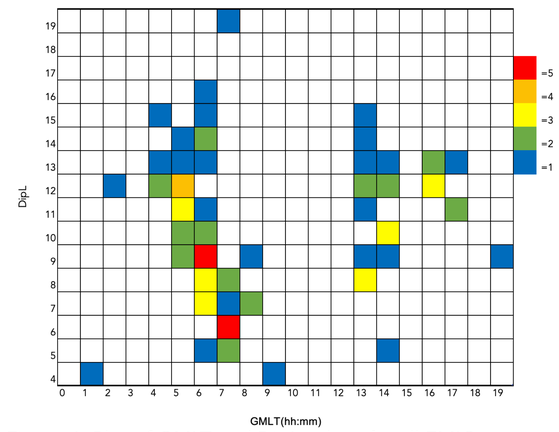


Figure 6. Plot of GMLT and DipL values for all EMIC waves occurring at the oxygen gyrofrequency.

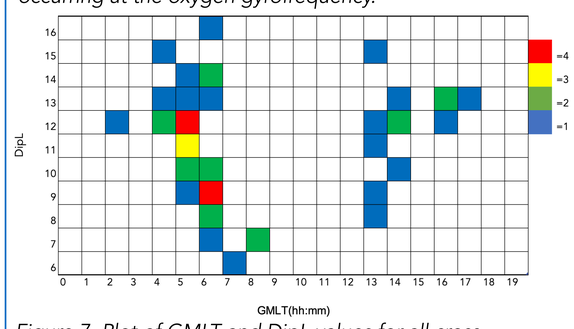


Figure 7. Plot of GMLT and DipL values for all cross frequency events.

○ Harmonics and High-Frequency Waves

- Events around the oxygen cyclotron frequency with harmonics
  - 19 out of 32 events, or 59.4% of events, are associated with higher frequency events around the electron cyclotron frequency
- Events around the oxygen cyclotron frequency without
  - 27 out of 49 events, or 55.1% of events, are associated with higher frequency events around the electron cyclotron frequency

○ Summary

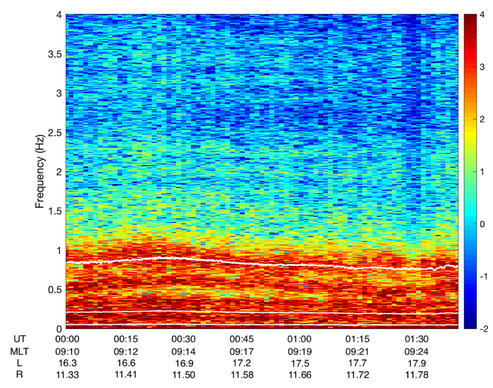
1. We surveyed low frequency MMS data from September 2015-April 2016 for electromagnetic ion cyclotron waves in the oxygen frequency band.
2. Using the DST index, it can be seen that these events occur in the recovery phase of geomagnetic storms.
3. We also surveyed high frequency electric field data for electromagnetic ion cyclotron waves in the electron frequency band.
4. We found that low frequency ion events modulate at the same frequency as chorus wave packets, suggesting a cross-frequency relationship.
5. These events appear to be preferential to the dayside of the magnetosphere.

○ Future Work

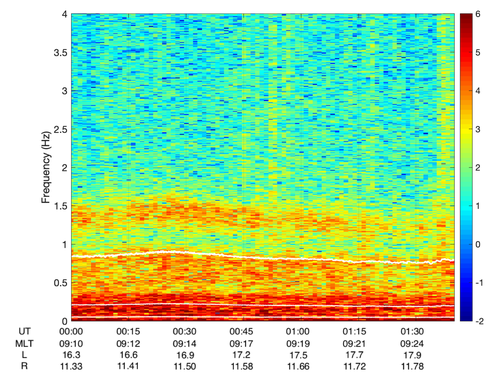
We plan on continuing to survey data through 2016 and 2017.We also plan to look at the solar wind dynamic pressure and other conditions. Additionally, we plan on continuing to look for more unstructured waves occurring at ion cyclotron frequencies.

○ HISS Waves

We accidentally discovered ion cyclotron waves with an unstructured appearance, typically seen at higher electron gyrofrequencies. We found three events: December 21, 2015, January 1, 2016, and January 20, 2016. All of these events occurred right before or during strong magnetic storms. The waves were seen both in the electric and magnetic field. We are unsure of the processes behind these waves as they have not been observed before.



FFT spectrogram for January 1, 2016 of the $B_{x,GSE}$ magnetic field component.



FFT spectrogram for January 1, 2016 of the $E_{x,GSE}$ electric field component.