**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 during 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.

**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.

**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.

**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.

**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.

**References**

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