

Satellite observations of banded VLF emissions in conjunction with energy-banded ions during very large geomagnetic storms

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Abstract

Electromagnetic VLF emissions banded in frequency, coincident with warm energy-banded ions in the low latitude

Banded lon observations

Energy-banded ions are observed on the FAST satellite during every large geomagnetic storm. They are observed in downgoing, perpendicular, and occasionally upgoing components. The bands appear at the same energies in helium, hydrogen, and oxygen, suggesting typical time-of-flight dispersion could not generate these bands.

Banded waves observed on FAST



Waves are observed during large storms, coincident with banded ions, in the frequency range ~200-2000 Hz, appearing as discrete frequency bands separated by ~100-250 Hz. There appears to be a correlation with density enhancements, and the waves are evident in both parallel and perpendicular directions.





For all storms where banded ions are observed on FAST but there is no AC field data to confirm banded waves co-located with the ions, banded waves are observed on DEMETER. They last several orbits, are observed in both hemispheres in both electric and magnetic fields, and are strongly correlated with local density enhancements. Observed on 36 orbits during 14 separate storms from 2004-2006, they typically have frequency 100-1200 Hz (bands separated by 75-150 Hz), L-shell 1.2-2.6, MLT pre-midnight and pre-noon, and ILAT -50 to +50. The frequency spacing is always less than the proton cyclotron frequency of 300-600 Hz.

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Model distributions and simulated wave growth



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Model particle distributions are input into the WHAMP code (courtesy S. Schwartz and R. Denton, Dartmouth College) to investigate wave growth near the ion cyclotron frequency. Particle distributions include single and double proton energy rings, generating free energy in the ion distribution. This free energy gives rise to a band of wave growth just above the proton cyclotron frequency (fcp), with growth rates ~1-2 % of fcp. This is consistent with theoretical wave growth at harmonics of fcp due to ion bands, or rings in velocity space. Presence of oxygen or helium ion rings would create additional free energy for wave growth at other frequencies.

Conclusions and Future Work

Warm energy-banded ions are observed with the FAST satellite during every large geomagnetic storm. Frequency-banded waves are observed on FAST and DEMETER, concurrent with the ion bands. The waves are observed for several hours, in both hemispheres, in both electric and magnetic fields, with E-field both parallel and perpendicular to the ambient magnetic field. Theoretical mechanisms investigated for the generation of these waves involve free energy in the particle distribution due to the ion bands, and wave growth at harmonics of the proton cyclotron frequency. Simulations using the WHAMP code show wave growth in bands near fcp with single and double ion ring input particle distributions. Additional simulations including oxygen and helium ion rings will investigate growth at other frequencies. Future observations of these waves during large storms are needed to further explore heir nature.

Possible wave generation mechanisms