Automated FIREBIRD Microburst Detection Using Wavelets in the 200 keV to >1 MeV Range

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Abstract

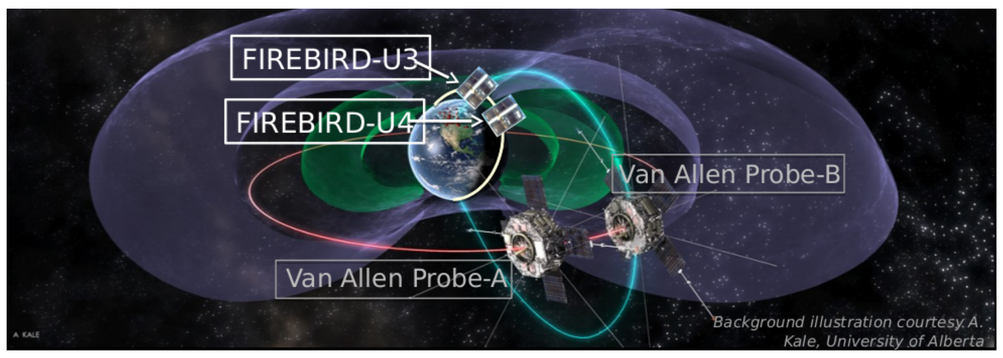
The FIREBIRD-II (Focused Intensity Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics) mission is presently exploring the consequences of complex interactions deep in the Earth's radiation belts that result in significant loss of stably trapped energetic electrons. The primary signatures that FIREBIRD observes from 500 km altitude in low earth orbit are sporadic and sudden bursts of Van Allen Belt electrons precipitating into the upper atmosphere. While such electron microbursts have directly been observed by previous satellites, and the Bremsstrahlung X-rays they produce have been observed by high altitude balloons, their spatio-temporal morphology and the electron energy distributions within individual events has not been well characterized. We present the work done to decouple the spatial and temporal components of microbursts using wavelets to automatically detect microbursts in the FIREBIRD-II data.

Science Objectives

What is the spatial scale size of an individual microburst?
Identically instrumented 1.5 U CubeSats, in a high inclination leader-follower configuration deployed together. The first data was taken when their separation was less than 11 km.

What is the energy dependence of an individual burst?
Each unit contains two solid state detectors, each with six energy channels. These channels resolve microburts on energy scales from 200 keV to > 1 MeV with resolution as good as 12 ms.

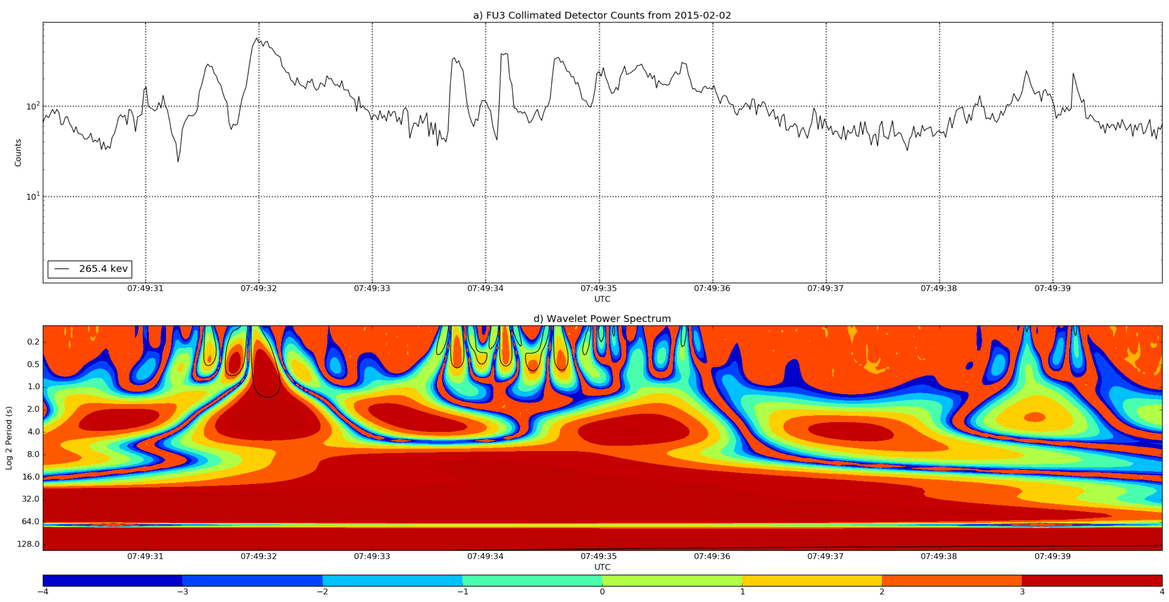
How much total electron loss do bursts produce globally?
Coordination with NASA's Van Allen Probes Mission, BARREL, and AC-6.



An artists rendition of the FIREBIRD and RBSP missions with the Van Allen Belts shown.

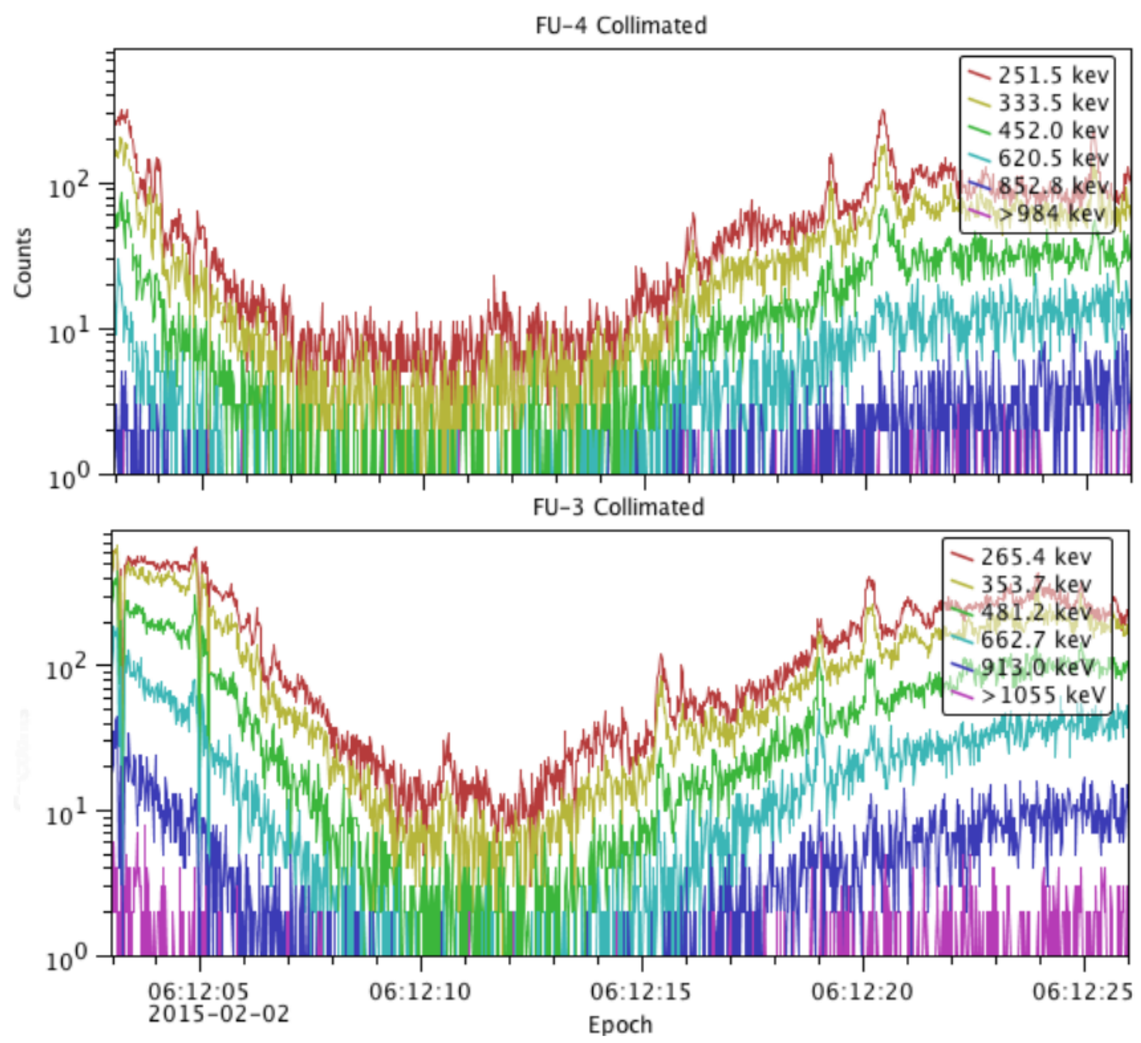
Approach

To convolve a second derivative of the Gaussian (DOG m=2) wavelet with the time series data to decompose the data into time-frequency wavelet space. Then use filtering in the wavelet domain to isolate microbursts. In the near future, the detected microbursts will be fitted to a Gaussian, from which the width and intensity parameters will be extracted.

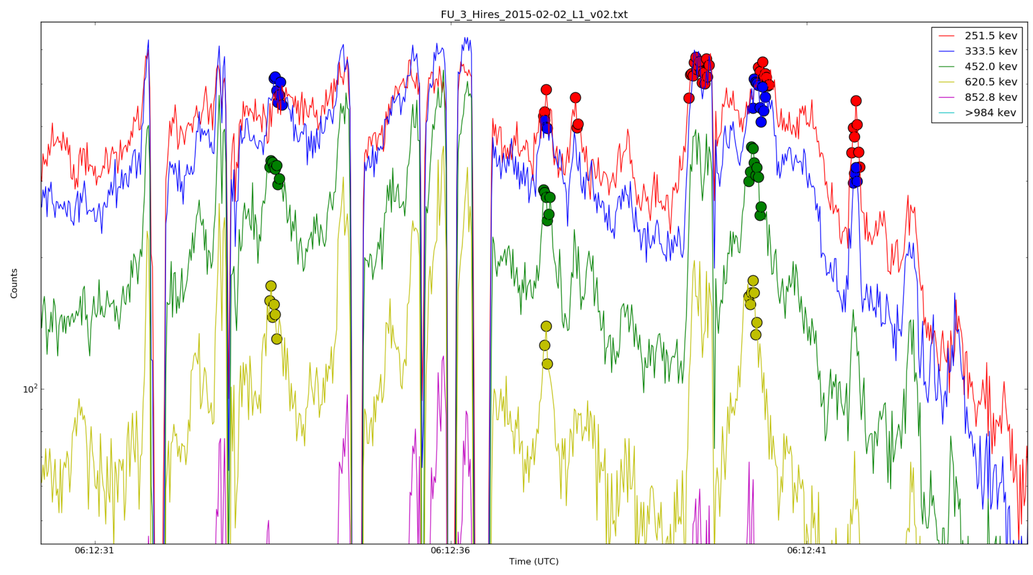


Top plot: An example of high resolution count data. Bottom Plot: Wavelet power spectrum from the above data. Statistically significant wavelet power from microbursts is enclosed by black contours in the high frequency region.

Results



Visual inspection of microbursts on Feb 2^{nd}, 2015 reveal two simultaneous bursts around 6:12:20 while both units were separated by 11 km. The automated wavelet-based microburst detection program will create a catalogue of these events from which microburst spatial and temporal properties can be decoupled [Alex Crew, 2016 JGR].



Microbursts detector applied to the six collimated energy channels on FU3. The detector has built in tests to avoid triggering on data gaps and dropouts.

Conclusion

FIREBIRD-II mission achieved full mission success. The CubeSats continue to nominally operate in the 8th data campaign. The two currently downlinked data products are continuous 6 second context data from the 250 keV and > 1 MeV channels, and 50 ms high resolution data from all channels. Data analysis work is ongoing, and the wavelet-based microburst detector will enable statistical studies to be done.

Acknowledgments

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The Team