Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD)

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Overview

- Overall premise
- Mission concept
- Mission science
- FIREBIRD observations
- Three scientific questions FIREBIRD will answer
Overall premise

• This is a science mission
  – Short term: order of months (think of as an extended sounding rocket)
  – Data amount set by science we are going after

• Students will be intimately involved and educated in the process of accomplishing a science mission
  – It will not be enough to teach students, the mission needs to go forward to the best of our ability in the time allotted

• This is a simple experiment to be done in a really short timeline ~3 years, funding to end of mission

• Exciting and challenging mission, big bang for the buck
  – Good chance of success
Mission concept

- Fly two 1.5kg (1.5u) cubesat spacecraft to assess the spatial scale and spatial temporal ambiguity of magnetospheric microbursts
  1) What is the spatial scale size of an individual burst?
  2) What is the energy dependence of an individual burst?
  3) How much total electron loss do bursts produce globally?
Mission concept

• Fly two 1.5kg (1.5u) cubesat spacecraft to assess the spatial scale and spatial temporal ambiguity of magnetospheric microbursts
  1) What is the spatial scale size of an individual burst?
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  3) How much total electron loss do bursts produce globally?

• Current and planned measurements alone cannot answer these questions, it takes low altitude multi-point measurements
  – Time is right for these questions to be answered with RBSP et al coming down the pipe rapidly
Microbursts

- Microbursts are short (~100ms) bursts of precipitation
- Initial work started in the 1960s from balloon measurements
- Studied sporadically since then (e.g. Aerospace and others)
- Primary form of electron loss on the dayside?
Effects

- Microbursts capable of losing large numbers of electrons
- Possible to empty pre-storm electron belt in a day [O’Brien, 2003]
- Need to understand temporal/spatial structure
- Recovery is on the timescale of a day
- Microbursts continue into recovery phase
- Part of balance between acceleration and loss
SAMPEX observations

> 1 MeV electrons

*Figure 3.* A plot of microbursts which occurred during two consecutive orbits on Day 254, 1992.
Freja observations

• Similar events are common in the Freja dataset
• Frequency/intensity associated with geomagnetic activity

Courtesy Jim Clemmons
FIREBIRD observations

• Two identical 10x10x15cm cubesats
• Passive magnetic attitude control
• Large GF omni solid state detector – one per s/c
• Uncontrolled separation over the 120 day prime mission to allow sampling across many spatial scales
  – About 3 cm/s separation
FIREBIRD

BU sensor module (1/2U)
Spence/Larsen/Students
w/ Aerospace Expertise
Blake

MSU spacecraft (1U)
Klumpar/Springer/Students
1) What is the spatial scale size of an individual burst?
   - Better insight into causes
   - Better insight into total radiation belt loss due to microbursts
Microburst region size scale

- Microbursts are in discrete “packets”
- FIREBIRD will help resolve spatio/temporal ambiguity and determine the size of the microburst region as the spacecraft drift apart
Chorus and microburst decorrelation length

(a) Cluster 4

From Santolik et al., 2004, Figs 4(b) and 6(b)

(c) Microbursts

After Lorentzen, 2001, Plate 3(b)  Seconds after 12 Sep 1996 03:33
2) What is the energy dependence of an individual burst?

- Better insight into causes
- Better insight into total radiation belt loss due to microbursts
- What resonance conditions are occurring?
Microburst energy coherence

- At MeV energies there is a high level of energy coherence
Microburst energy coherence

Zoom in
Microburst energy coherence

>150 keV SAMPEX/HILT PCRE

>1 Mev SAMPEX/HILT SSD

After Blake et al., 1996, Fig 10
UT sec, 4 Oct 1992
Microburst energy coherence

>150 keV SAMPEX/HILT PCRE

>1 MeV SAMPEX/HILT SSD

but there is coherence between 170-360 keV

Figure 2 The top panel shows an example of the lack of one-to-one correspondence between microbursts observed in the >150 keV (PCRE) channel and in the >1 MeV (SSD) channels on SAMPEX/HILT. The bottom panels show strong microburst correlation across the ~170-~360 keV range from STSAT-1.
Microburst energy coherence

Somewhere between 150 keV and 1 MeV energy coherence is broken…

but there is coherence between 170-360 keV

Figure 2: The top panel shows an example of the lack of one-to-one correspondence between microbursts observed in the >150 keV (PCRE) channel and in the >1 MeV (SSD) channels on SAMPEX/HILT. The bottom panels show strong microburst correlation across the ~170--360 keV range from STSAT-1.
Microburst energy coherence

- The FIREBIRD instrument provides enough counts for a high time resolution measurement with reasonable statistics
  - ~350 cm$^2$ sr
  - Measurements between 5-100 ms programmable depending on final TM, ground stations, and current separation

- 3 on-orbit programmable integral energy channels between >200 keV and >800+ keV
  - Find the decorrelation “length” in the energy spectra
3) How much total electron loss do bursts produce globally?

- How important are microbursts in the system as a whole?
- Better insight into total radiation belt loss due to microbursts
Electrons lost in microbursts

  - Calculate total number lost by integrating over time and space (with some basic assumptions)
- FIREBIRD contribution: by bringing in objectives 1 and 2 along with concurrent measurements, probability models, etc this can be further addressed
Summary

• In summary we are excited about this science
• We feel this is one of the viable options for cubesats in space weather
• It will certainly be exciting to see what science cubesats are built, flown, and what science is done