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# The Wave Driver of Relativistic Microbursts Through Ground Observations

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## Introduction

### Relativistic Microbursts:

- Precipitation of >1 MeV electrons.
- Short duration, <1 second.
- Occur in morning MLT region from $L = 3 - 8$.

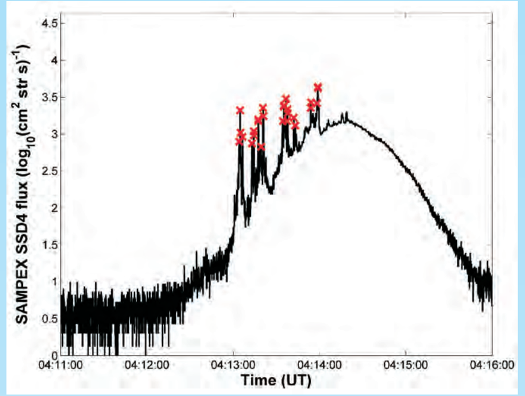

**Figure 1. Relativistic Microbursts detected (red) on 17 August 1999.**

### Importance:

- Microburst precipitation losses significant in the radiation belts, with a single storm precipitating the entire relativistic electron population [*Lorentzen et al.*, 2001].
- Microburst precipitation causes significant changes to the polar atmospheric chemistry and results in significant ozone loss [*Seppälä et al.*, 2018].

### Microburst Detection Algorithm:

$$\frac{(C-A)}{\sqrt{(1+A)}} > 10$$

Where $C$ is the SAMPEX HILT SSD4 counts and $A$ is the 500 ms running average of the counts.

### Possible Microburst Drivers:

- Whistler mode chorus waves [*Thorne et al.*, 2005].
- EMIC waves [*Omura and Zhao*, 2013].

### Microburst Event Definition:

Relativistic microbursts that occur within 4 minutes of each other are grouped into "clusters".

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## Case Study Conjunctions Between SAMPEX and Halley

### Case 1: Whistler Mode Chorus Wave

- 16 individual microbursts on 2 March 2005, beginning at 12:25:56 UT.
- Sunlight conditions at Halley.
- Increase in wave amplitude in the 1-4 kHz range of VELOX.
- Rounded shape identified as whistler mode chorus waves.
- There is no wave power the Bz component of Halley magnetometer.
- No EMIC wave activity present.

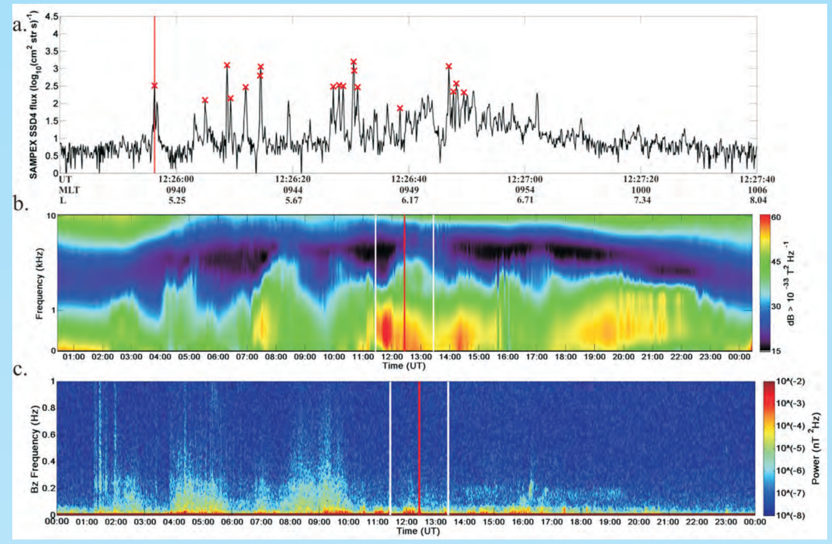

**Figure 2. Microburst event on 2 March 2005. (a) SAMPEX flux plot with microburst detections (red crosses). (b) Halley VELOX, red indicates the start of the microburst event, white indicates 1 hour from event onset. (c) Halley magnetometer, Bz component.**

### Case 2: EMIC Wave

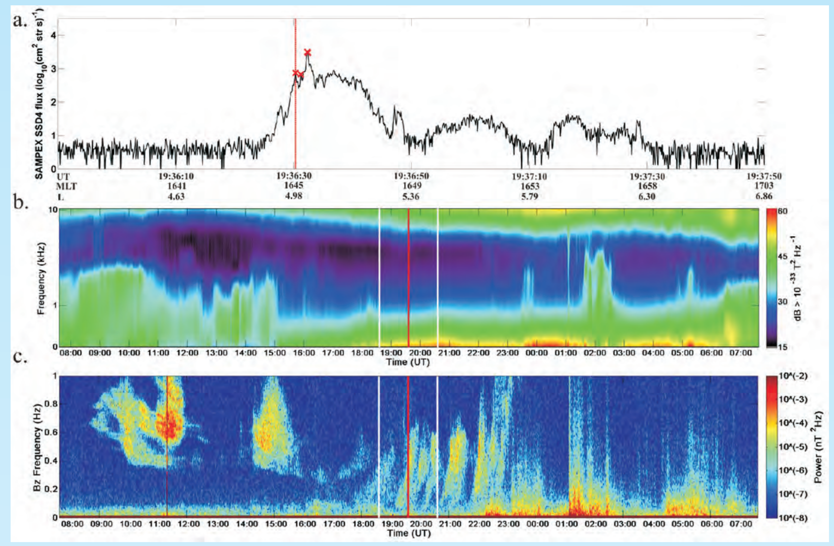

**Figure 3. As in Figure 2 but for the relativistic microburst event on 1 July 2005.**

- 3 individual microbursts on 1 July 2005, beginning at 19:36:30 UT.
- Night conditions at Halley.
- No increase in wave amplitude in the 1-4 kHz range of VELOX.
- No whistler mode chorus wave activity present.
- Bursts of wave power in the Bz component of the Halley magnetometer.
- Wave power is identified as Helium band IPDP EMIC waves.

### Case 3: Whistler Mode Chorus and EMIC Waves

- 4 individual microbursts on 19 May 2005, beginning at 12:14:58 UT.
- Partial sunlight conditions at Halley.
- Increase in wave amplitude in the 1-4 kHz range of VELOX.
- Rounded shape identifies whistler mode chorus wave activity.
- Bursts of wave power in Bz component of Halley magnetometer.
- Wave power is identified as Hydrogen band EMIC waves.

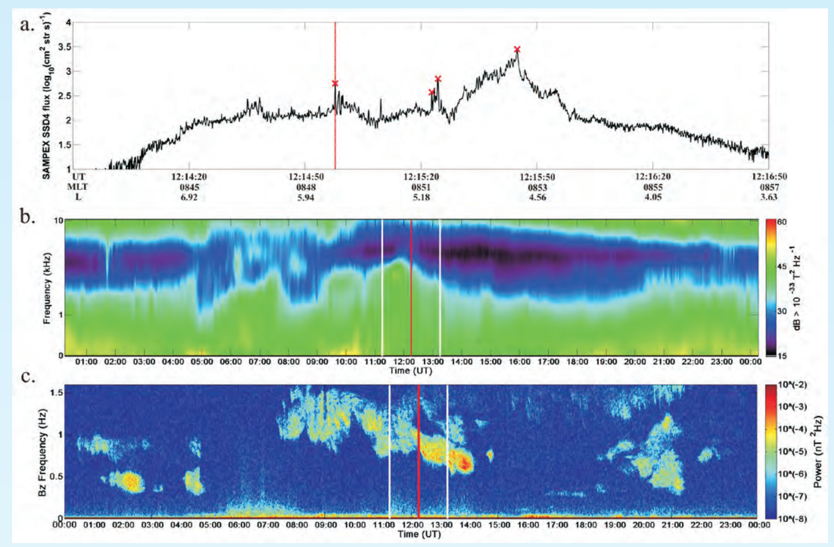

**Figure 4. As in Figure 2 but for the relativistic microburst event on 19 May 2005.**

## Superposed Epoch Anaylsis of Halley Wave Activity

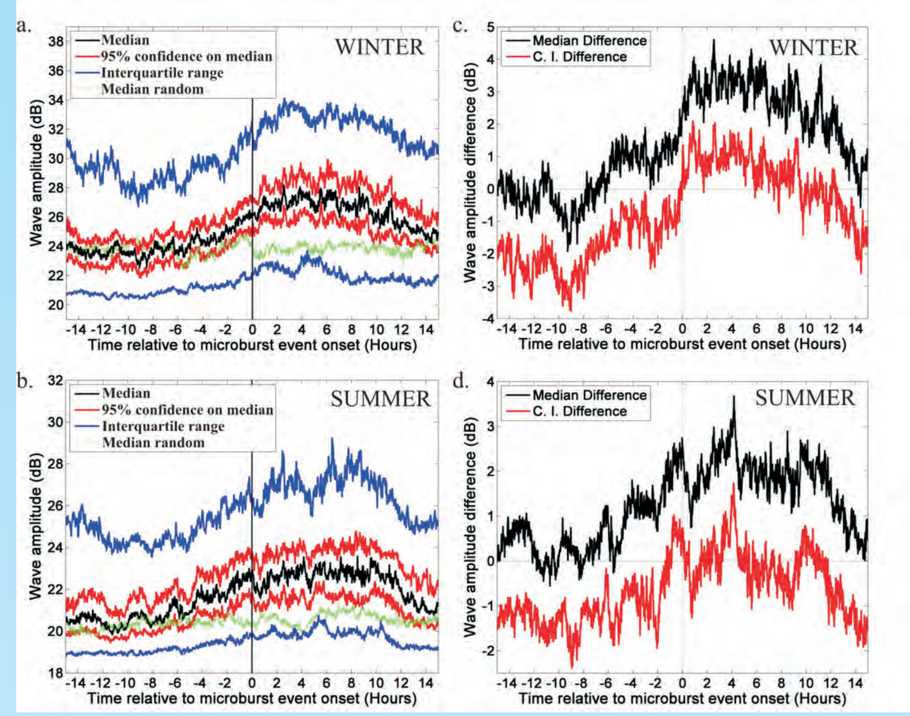


**Figure 5. Superposed epoch study of VLF amplitude in VELOX and its statistical significance.**

### Whistler Mode Chorus Wave Activity

- Superposed 1 min average wave amplitude in 2 kHz channel of VELOX.
- Ionospheric attenuation differences between Summer and Winter.
- 242 relativistic microburst events during Halley Winter.
- 170 relativistic microburst events during Halley Summer.
- Statistically significant increase in 2 kHz wave amplitude associated with relativistic microburst events.

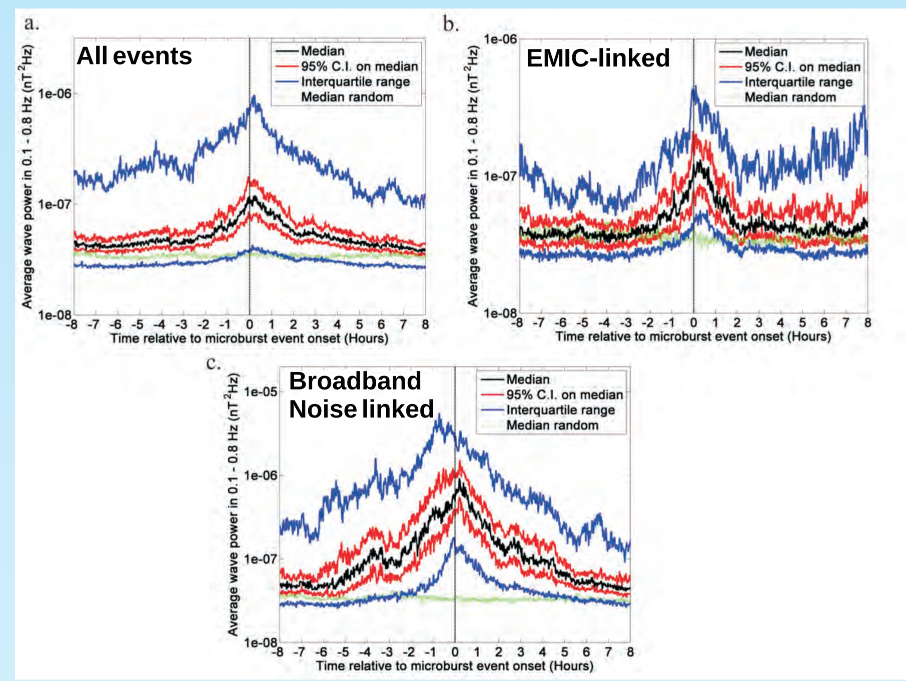


**Figure 6. Superposed epoch study of mean wave power in the 0.1-0.8 Hz frequency range of the Halley magnetometer.**

### EMIC Wave Activity

- Superposed mean wave power in 0.1-0.8 Hz frequency range of magnetometer.
- Usable data for 295 relativistic microburst events.
- 75 EMIC linked relativistic microbursts.
- 127 relativistic microbursts linked to broadband noise.
- EMIC linked microbursts, broadband noise linked microbursts and remaining microburst events all show an increase in the mean wave power around the time of relativistic microbursts.

- Clear upper and lower limit in mean wave power for EMIC-linked events.
- Increase in mean wave power for all microburst events more similar to broadband noise linked events.
- Random events have no change in mean wave power.

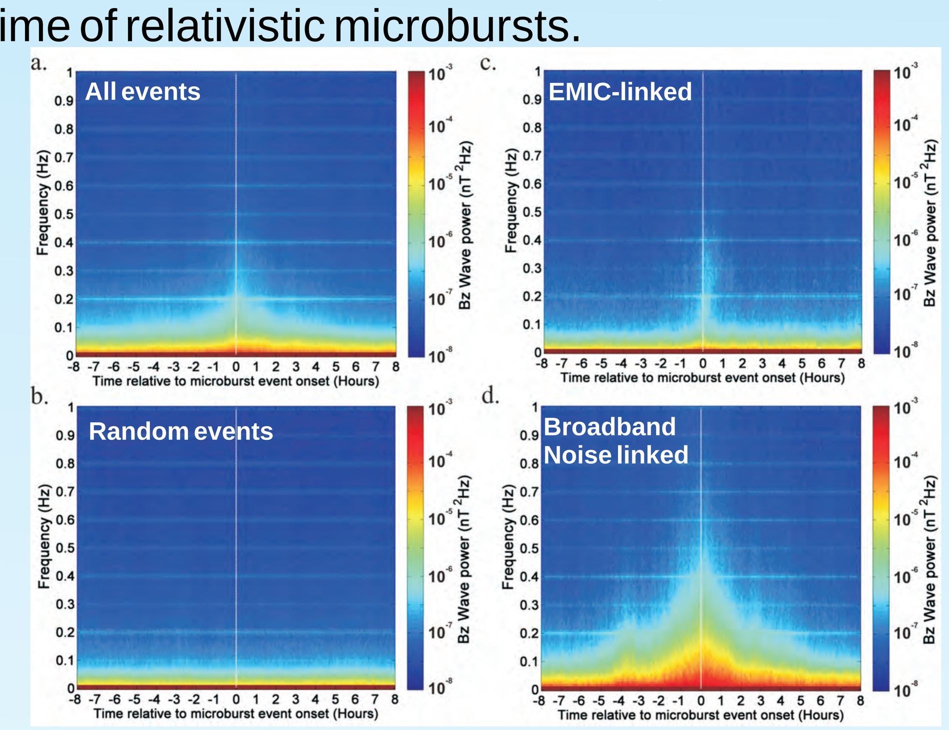


**Figure 7. Superposed epoch study of mean wave power in each frequency band of the Halley magnetometer.**

## Conclusions From Case Studies

- *** First evidence of EMIC waves associated with relativistic microbursts.**
- *** Case studies suggest that either whistler mode chorus waves or EMIC waves can drive the scattering resulting in relativistic microbursts.**
- *** Potential for EMIC waves to act as secondary driver of relativistic microbursts.**

## Conclusions From Statistical Analysis

- *** Increase in VLF wave amplitude, likely result of whistler mode chorus waves, associated with relativistic microbursts.**
- *** Burst of ULF wave power associated with microburst events dominated by broadband noise (not EMIC waves) which is not expected to scatter electrons.**
- *** Whistler mode chorus waves suggested primary driver of relativistic microbursts.**

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