Design of the Microburst Detector (MBD) for the RADICALS mission: A novel miniaturized instrument to characterize electron microburst precipitation

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Presentation Overview

- Electron Microburst Precipitation
- The Microburst Detector on RADICALS
- Detector Concept and Design
- Electronics Design
- Testing and Current Status
- Summary and Conclusion

Fig: Exploded view of a CAD model of the Microburst Detector prototype

Electron Microburst Precipitation

- **Microbursts:** Bursty and short timescale (< 1 s) scattering of energetic (few keV to MeV) electrons from the Van Allen belts into the Earth's atmosphere
  - Microbursts are considered to be a major loss mechanism during geomagnetic storms. (E.g. O'Brien et al., GRL, 2014)
  - Thought to be a major driver of Magnetosphere-Ionosphere-Thermosphere coupling through creation of NOx/HOx (E.g. Seppälä et al, GRL, 2018)

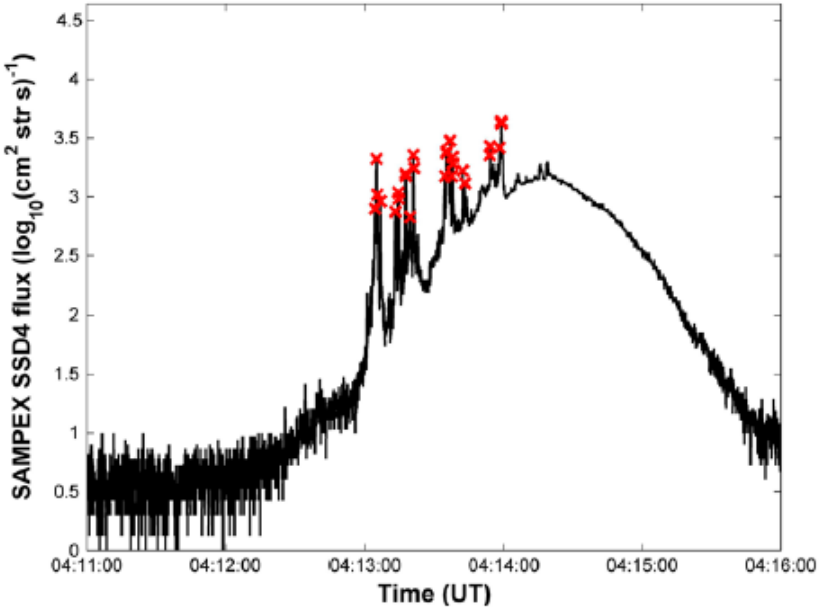


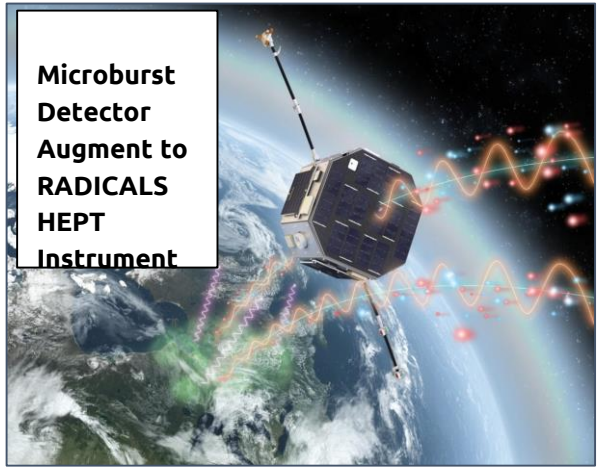
Fig: Example Microburst Event from SAMPEX measurements showing Electron Flux (>1 MeV) vs Time, red crosses indicate Microbursts

The Microburst Detector on RADICALS

Many open questions pertaining to Microbursts (E.g. Elliott et al., Front. Astron. Space Sci., 2014):

- What is the energy spectrum of electron microbursts?
- Do low-energy (100s keV) and relativistic (MeVs) microbursts occur simultaneously?
- What is the contribution of microbursts to the overall precipitation budget?
- What are the driving mechanisms for Microbursts of different energies (sub-relativistic and relativistic)?

Need for new measurements



Proposed Measurement Goals

Parameter	Previous Measurement Made		Proposed Goal
Mission	FIREBIRDII [7]	SAMPEX [10]	RADICALS
Energy Range	0.2 to 1 MeV, $>$ 1 MeV	$>$ 1 MeV	0.2 to 4 MeV
Energy Res.	5 channels	N/A	$>$ 8 channels
Time Res.	18.75 ms	20 ms	10 ms
Field of View	180 (and 45) deg	60 deg	180 deg

Detector Concept

- Multi-Pixel Photon Counter (MPPC) / Silicon Photomultiplier (SiPM) based Scintillation detector
- Different Scintillators being considered:
  - CsI (Na)
  - CsI (Tl)
  - BGO
  - LYSO
  - LaBr (Hygroscopic)

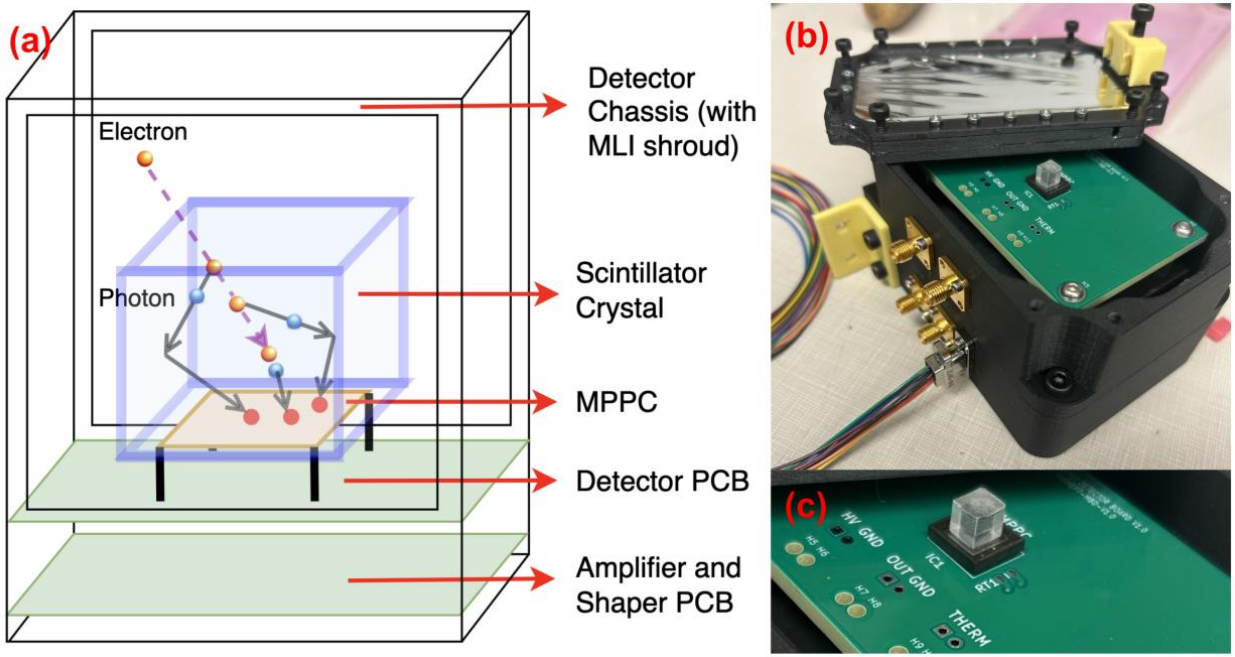
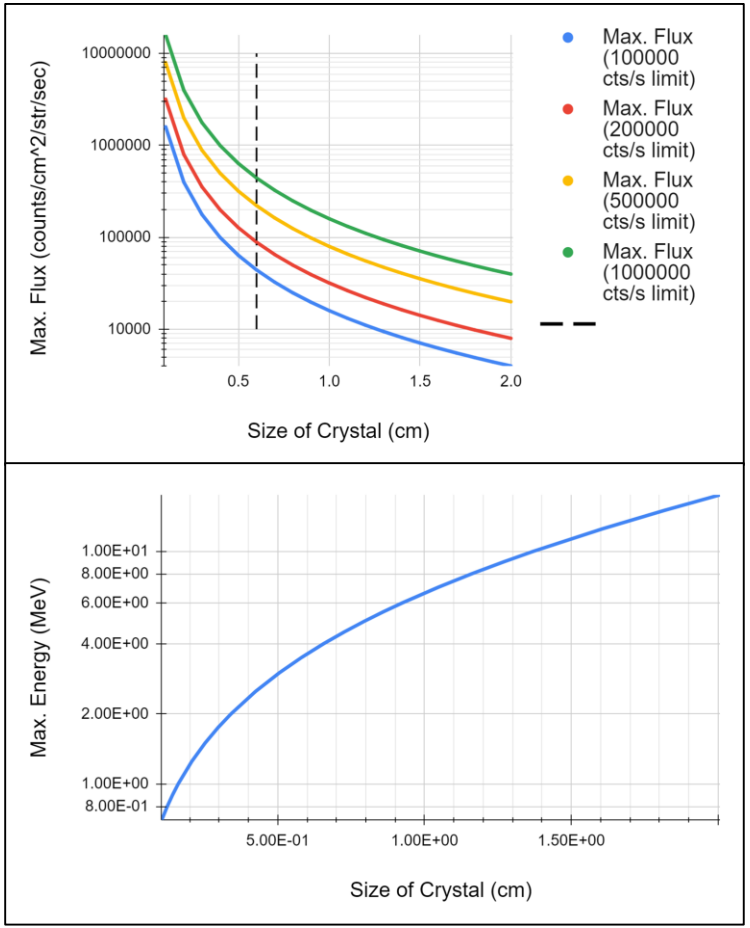


Fig: (a) Microburst Detector Concept: An incoming electron generates multiple photons in the scintillator, that are then counted by the MPPC. (b) A 3D printed prototype of the detector with the mylar cover removed. (c) Zoomed-in picture of the crystal and MPPC in the prototype (before the aluminium and parylene protective coating is added)

Detector Design

- Design Parameters
  - Scintillator Material
  - Scintillator Size
  - Reflector Coating (Aluminium + Parylene)
  - Optical Glue
  - Additional Light Tight Cover (Aluminized Mylar)
- Example Design Trade: Size of Scintillator Figure Top: Max. Measurable Flux vs Size of Crystal (d) assuming a geometric factor of 2π*d2 Figure Bottom: Max. measurable energy vs Size of Crystal, using CsI crystal



Electronics Design

- Modular Design with multiple PCBs:
  - Power Conditioning Board
  - Digital Processing Board
  - Detector Interface board
  - Amplifier and shaper Board

- On-board processing done by FPGA:
  - Peak finding
  - Histogram Generation
  - Packetization

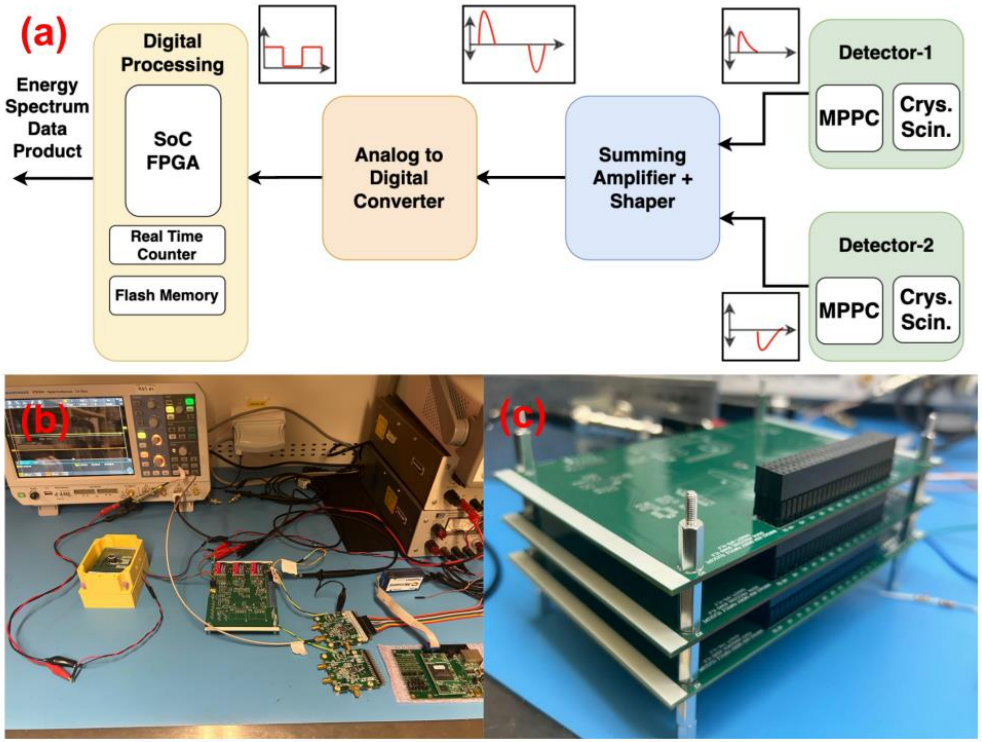


Fig: (a) Simplified functional block diagram of the detector electronics, that consists of summing amplifier and shaper, analog to digital converter, and digital processing FPGA. (b) FlatSat test setup of detector (c) Prototype electronics boards connected together

Testing and Current Status

- Prototype being developed for sounding rocket test flight in-advance of the RADICALS mission (PEPPER-X)
- Electronics Tests:
  - FlatSat testing of Electronics Boards in progress
  - End-to-end testing with sine wave source
- Detector Tests:
  - Thermal tests of the Glue
  - Strength Tests of the Glue
  - Radioisotope calibration using Ba-133 source

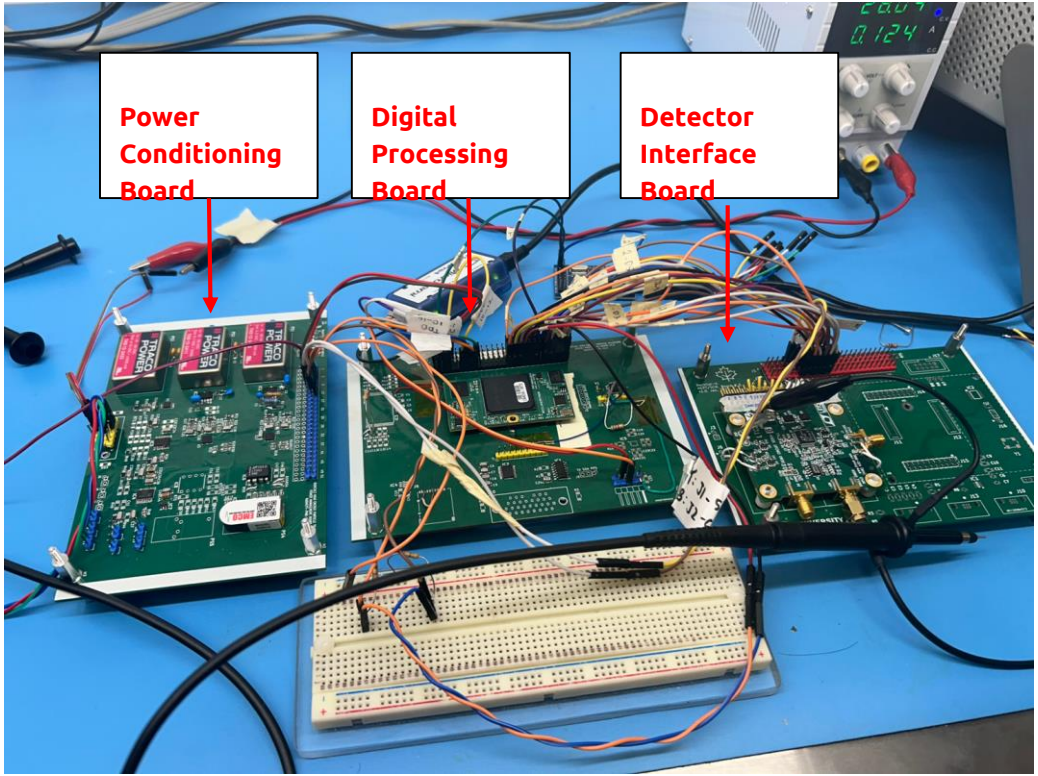


Fig: “FlatSat” testing of detector electronics boards

Summary and Conclusion

- The Microburst detector on RADICALS aims to make the high temporal and spectral resolution measurements of high energy electron microburst precipitation, extending the in-situ measurement database for further scientific analysis

- The detector is a novel miniaturized scintillator based detector. Previous small satellite missions have flown scintillation detectors for Gamma Ray and X-ray spectroscopy, we aim to extended this methodology for the detection of electro microbursts

- A prototype is being developed for a test flight as part of the Payload for Energetic Particle Precipitation Education and Research (PEPPER-X), which is slated to launch on the NASA RockSat-X sounding rocket mission from the NASA Wallops Flight Facility in August 2024

- A successful launch on the sounding rocket platform would raise the Technology Readiness Level (TRL) of the detector and electronics, in advance of the RADICALS mission

Thank You

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Key References:

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