PADRE MeDDEA

Steven Christe (NASA Goddard)

Measuring Directivity to Determine Electron Anisotropy (MeDDEA)

GSFC Team: Kyle Gregory, Dr. Eliad Peretz, Negeen Saghafi, Ryan Boggs, Augustyn Waczynski, Niharika Godbole, Pat Haas, Traci Rosnack
OMP Team: Thomas Baeyans, Marc-André Boucher
CEA Team: Olivier Limousin, Aline Meuris, Diana Renaud, Gwendoline Marc, Abel Vanel, Hugo Allaire
SwRI Team: Amir Caspi, Carlos Urdiales, Reynaldo Gonzales
SO Team: Muriel Stiefel, Laura Hayes, Daniel Ryan, Natasha Jeffrey, Säm Krucker

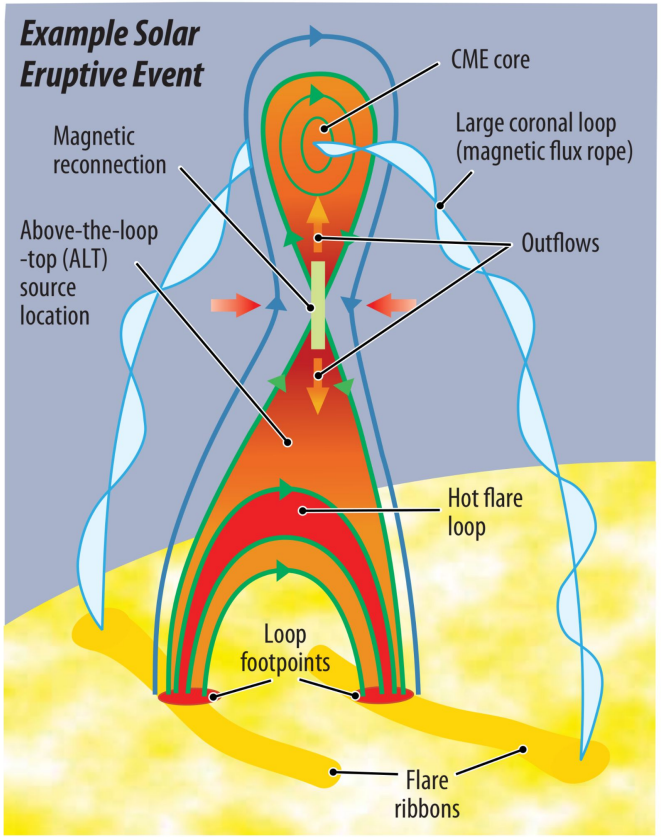
and PADRE Team!

Particle Acceleration in Solar flares

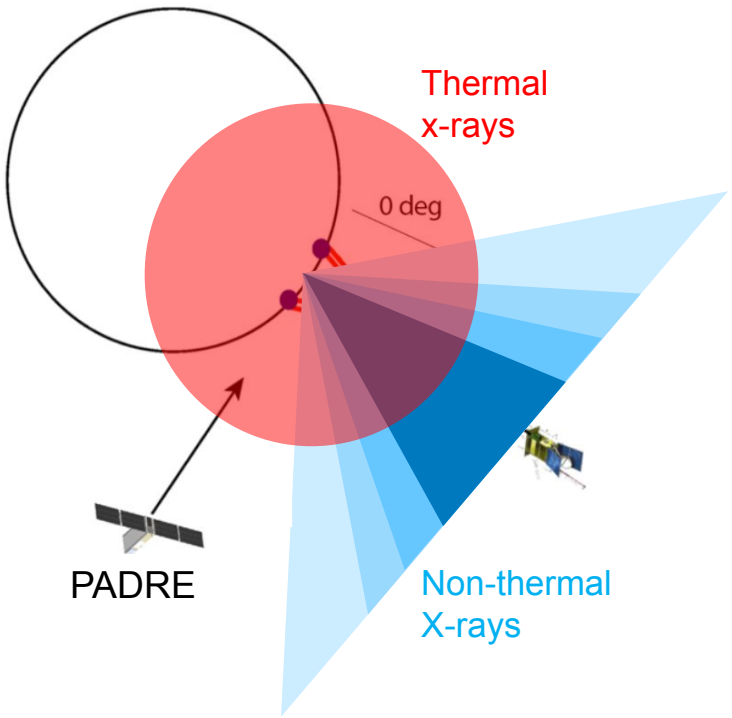
Solar flares are known to accelerate particle to high energies.

Some of these particles escape the Sun leading to intense and dangerous solar energetic particles (SEPs) that can damage satellites or endanger astronauts.

The physics of the acceleration is not yet understood limiting our ability to predict these dangerous events.



Measuring the X-ray directivity with PADRE and Solar Orbiter STIX



- MeDDEA makes energy-dependent measurements of X-ray flux from the Sun just like Solar Orbiter STIX
- Solar Orbiter provides opportunities to observe the same flares from a different angle than the Earth
- MeDDEA uses SO/STIX flight-spare detectors provided by CEA-Saclay.
- Comparing the two measurements, made using the same detectors in different locations will enable us to measure the X-ray directivity and constrain the acceleration mechanism of electrons.

What is PADRE?

PADRE is the Solar Polarization and Directivity X-Ray Experiment

12U CubeSat funded by the NASA

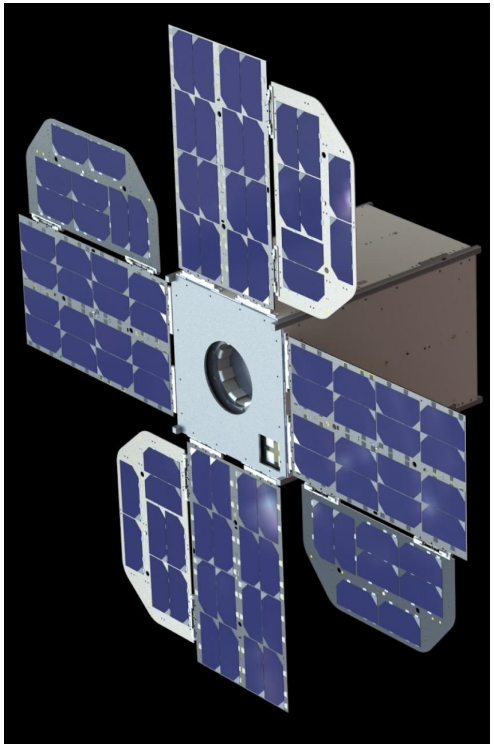
Led by UC Berkeley/Space Sciences Lab - Juan C. Martinez Oliveros (PI)

Science Goal: Investigate the dominant electron acceleration mechanisms in solar flares

Science Objective: Determine the degree of beaming (electron pitch angle anisotropy) of accelerated electrons in large solar flares

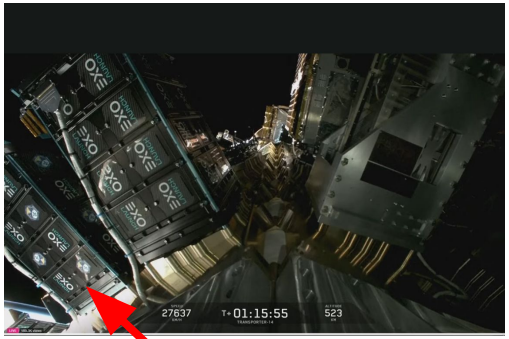
It achieves this single science objective with two instruments

- **Measuring Directivity to Determine Electron Anisotropy (MeDDEA)**
- Solar Hard X-ray Polarimeter (SHARP)



PADRE launched on 23-Jul-2025

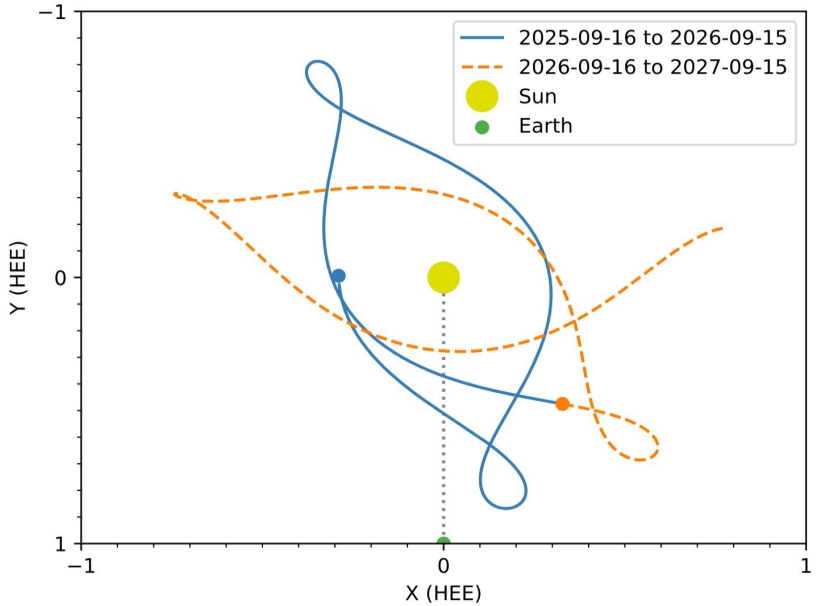
PADRE in launcher

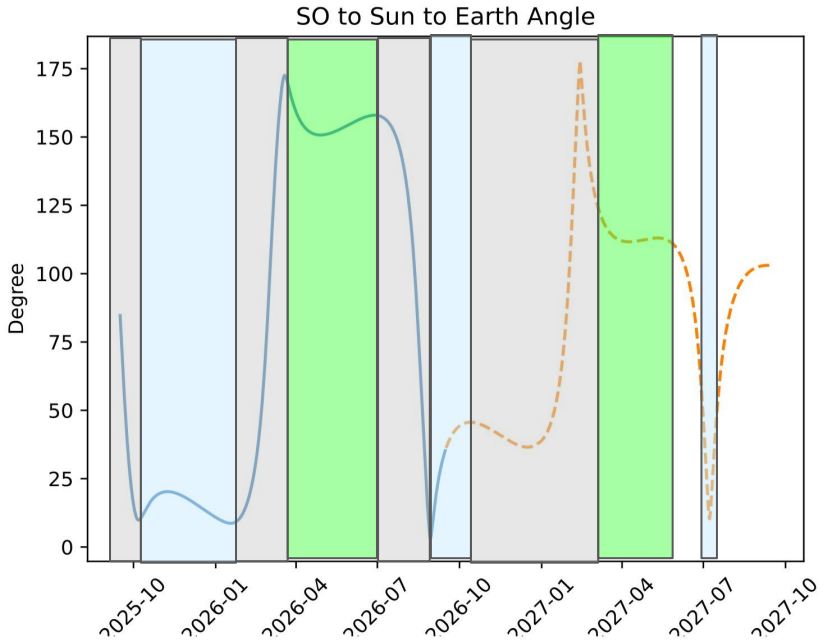


PADRE in space before deployment

NORAD ID: 64559
Perigee: 598.0 km
Apogee: 601.9 km
Inclination: 97.8 °
Period: 96.5 minutes
Semi major axis: 6970 km

Solar Orbiter STIX Orbit

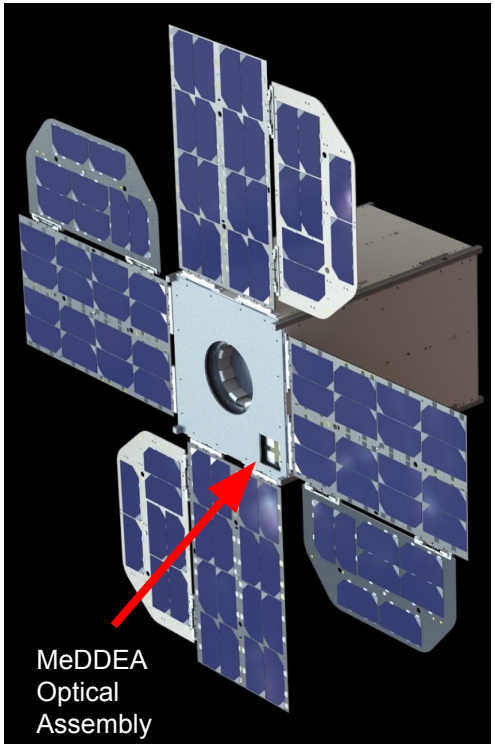


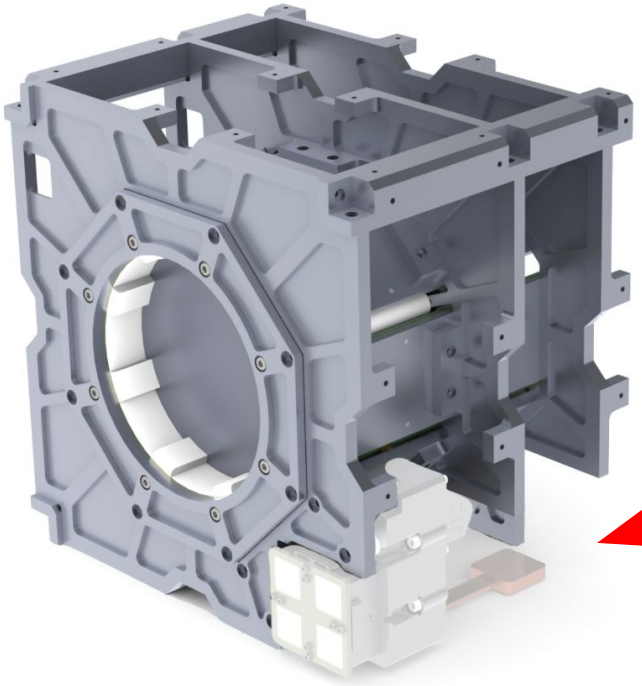


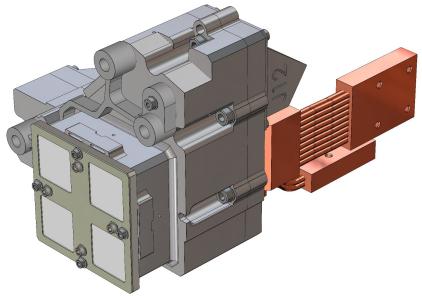
Blue - prime mission
orange - extended mission

Cross-calibration | Directivity | Occulted

MeDDEA Optical Assembly on the Observatory

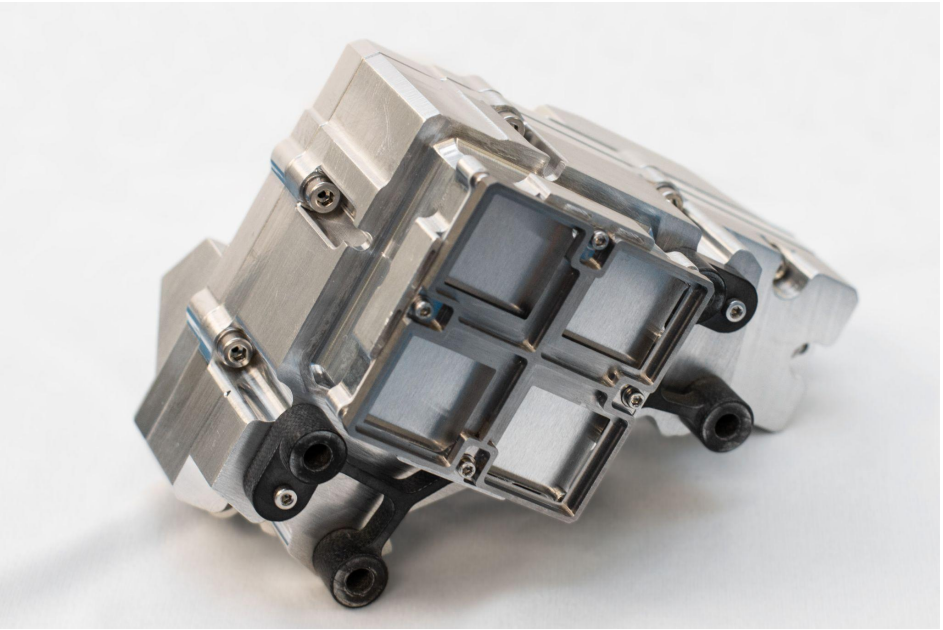


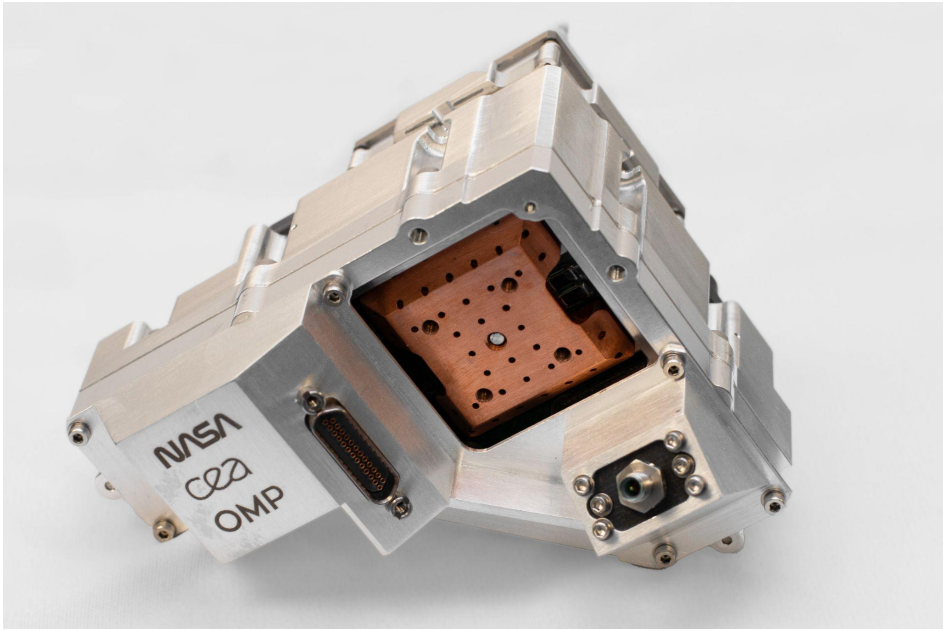




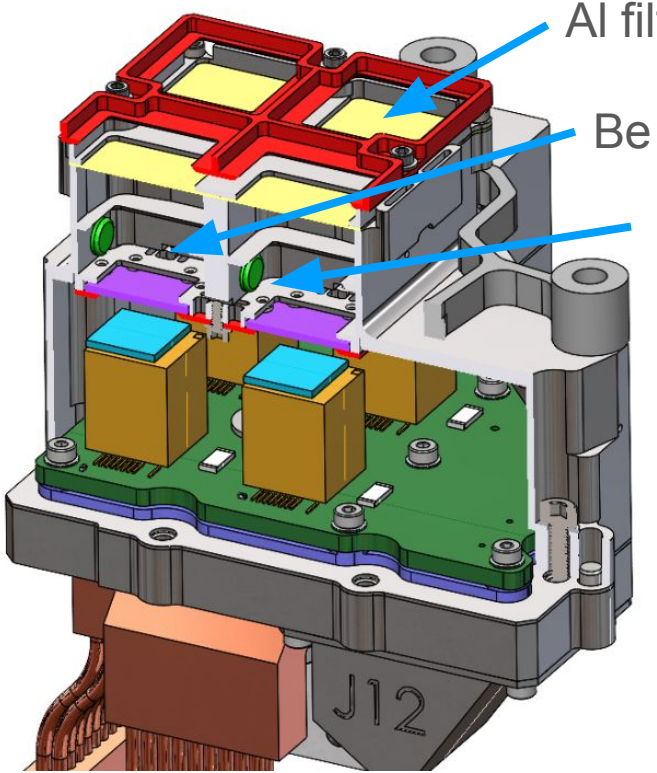
MeDDEA Optical Assembly

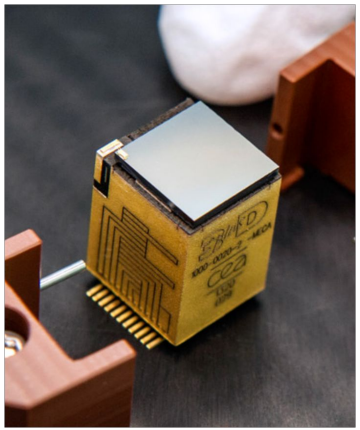
Optical Assembly Glamour Shots

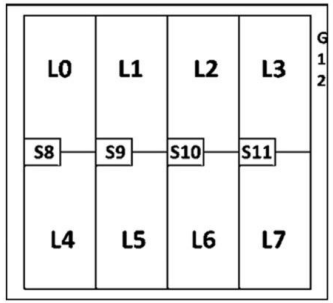




Optical Assembly



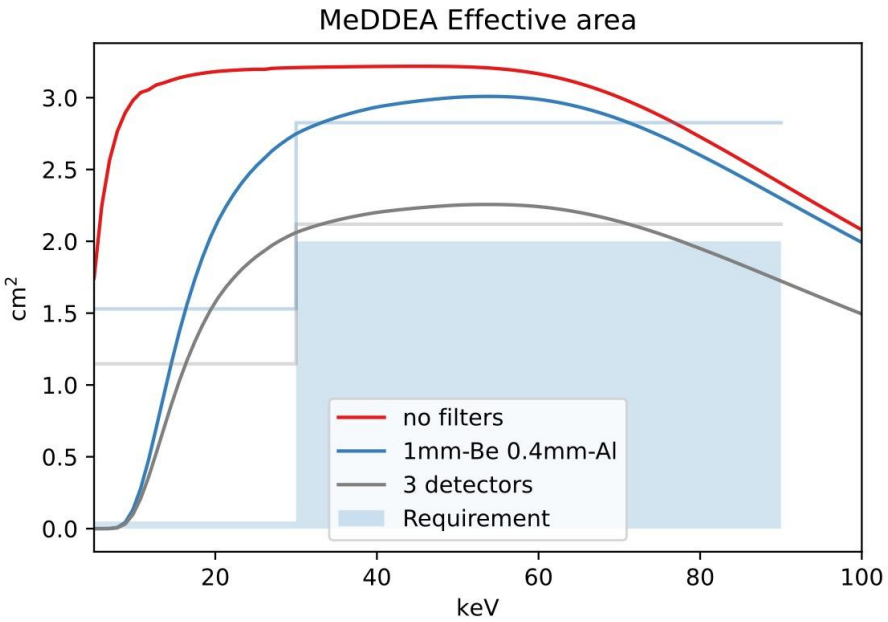




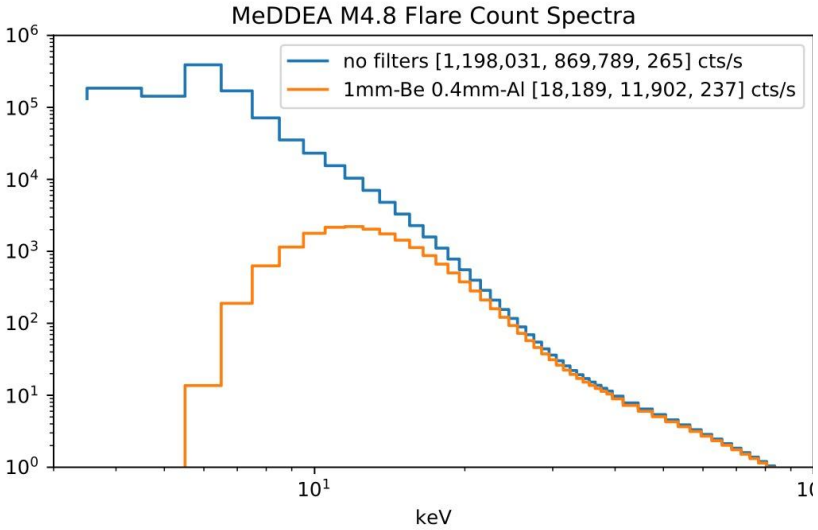
Caliste-SO Detectors

- Provided by CEA-Saclay
- Flight spares from Solar Orbiter STIX
- Rad-hard detectors and ASIC
- Triggered detector system, front-end custom ASIC (IDeF-X)

MeDDEA Effective Area

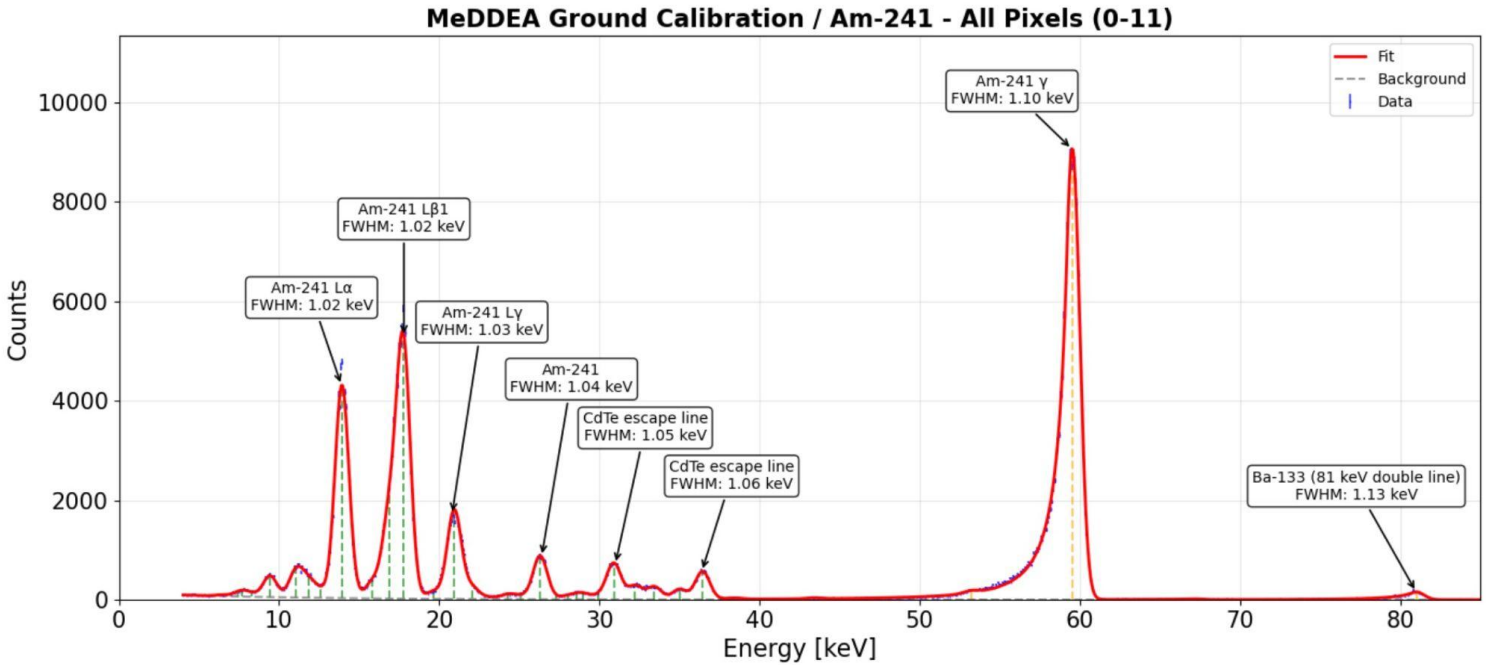


~½ STIX effective area
32 detectors vs 4 detectors



Why the thick filter?!

Ground Calibration

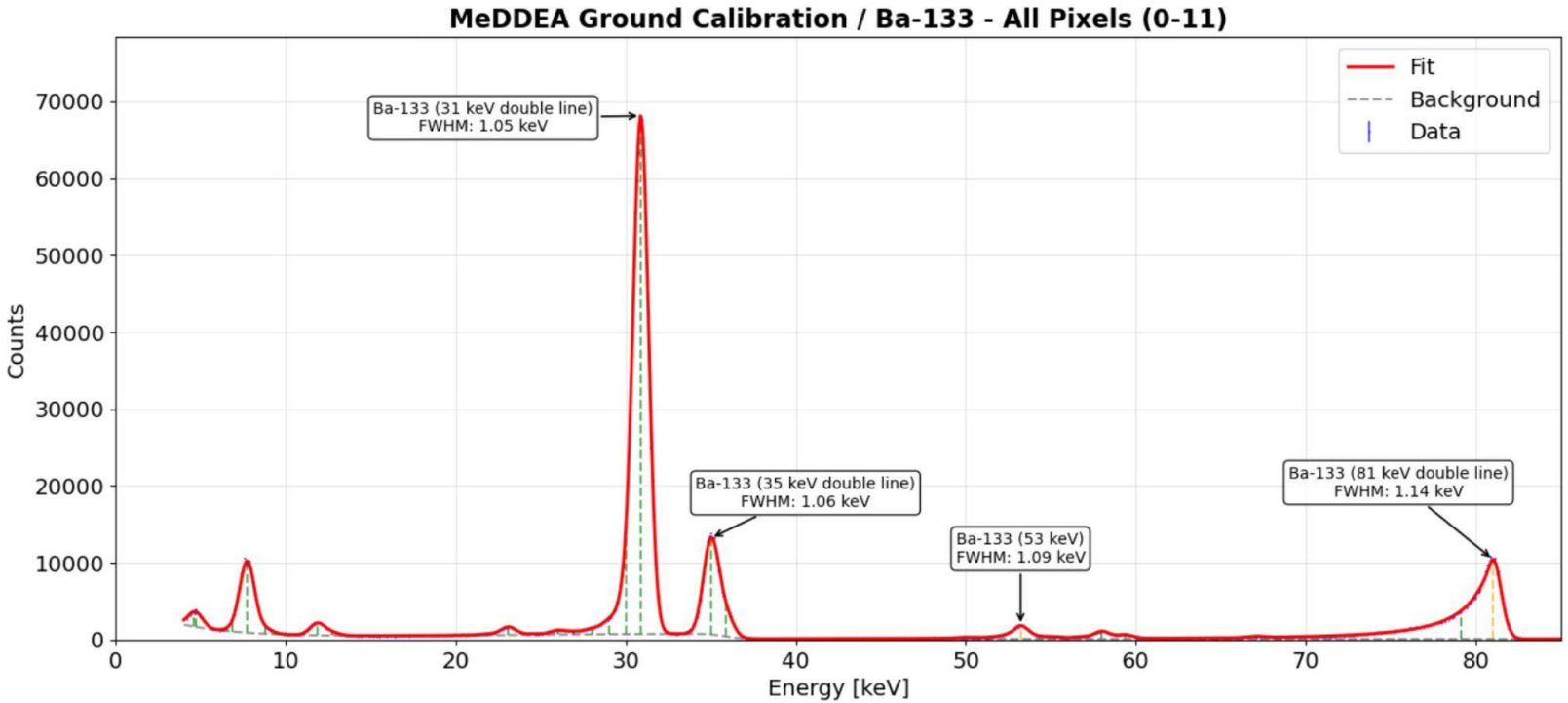


FWHM ~ 1 keV

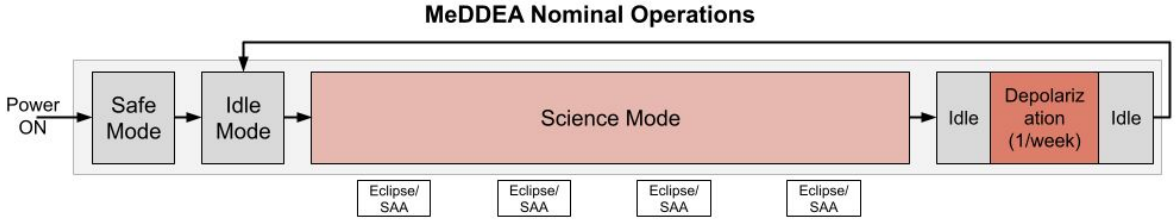
Low energy threshold ~3 keV

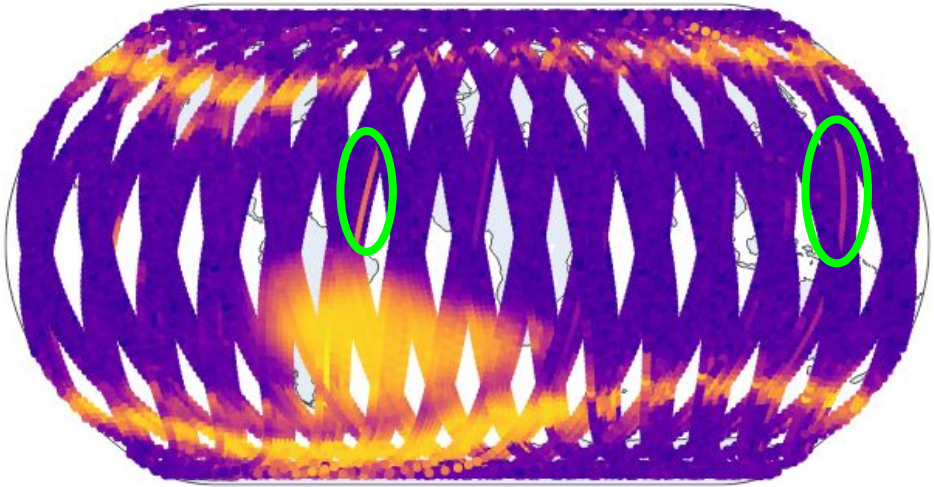
Flight calibration is comparable

Calibration Spectrum



MeDDEA is “always” operating





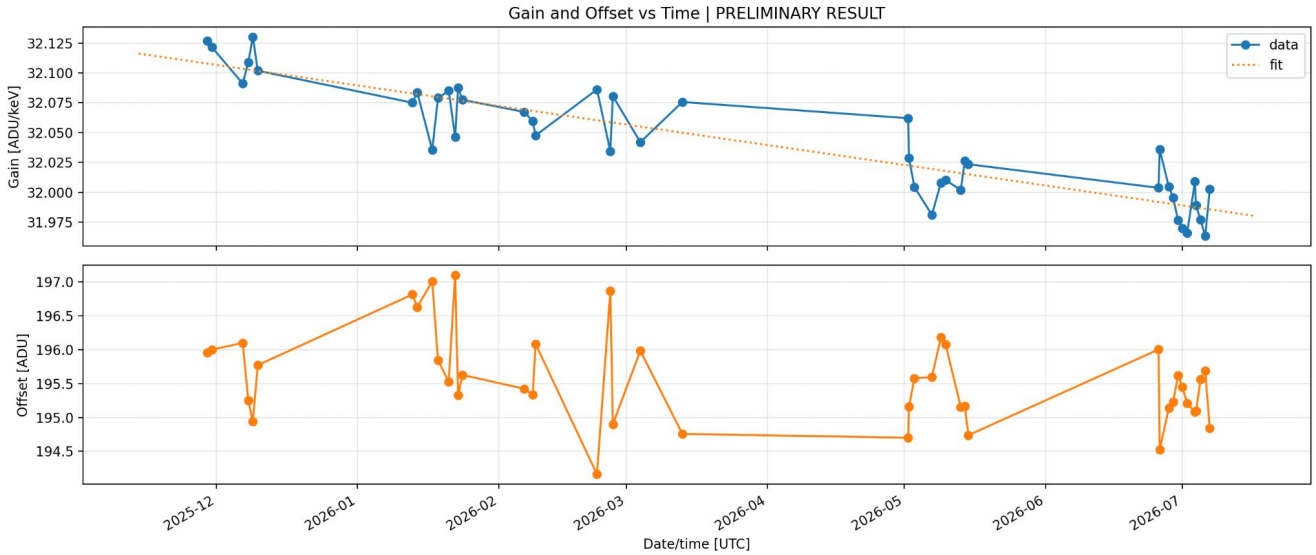
Take data throughout the orbit. In eclipse, measuring our calibration source.

Data also taken during SAA and belt crossing.

Potential monitor of space radiation in Low-Earth Orbit affecting spacecraft

Flares circled in green.

Performance Stability



- Preliminary look at detector gain/offset throughout the first year
- Very small changes seen and a slight trend over time.

Science Data Products

Detectors measure individual trigger events (photons) in each detector (time, pixel, energy). From this data, two products are generated.

- Raw event data (photon lists), stored and ~~**downlinked on demand**~~ **downloaded automatically**
  - Time, 12.8 us steps
  - All pixels
  - Energy bins ~0.02 keV steps
  - ~~Flare product~~
- Histogram/spectrum product (generated on board), ~~**"always" available**~~ **deprecated!**
  - Time, 10 s integration
  - 24/48 (selectable) pixels
  - Energy bins ~0.2 keV steps
  - Summary product (no decimation applied)

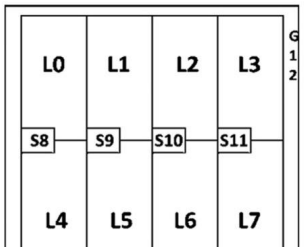
Changes in operations occurred ~6/26/2026

MeDDEA Detector Configurations

There are 3 detector configurations which control the detector thresholds

- **High Sensitivity**
  - Lowest thresholds set. Primarily for calibration or quiet solar activity. All thresholds set to ~2.9 keV. Primary mode
- **Default**
  - 5 keV threshold for small pixels, 15 keV threshold for large pixels. ~~Primary~~ mode during active flaring times. Primarily for M class flares
- **Large Flares (>=X Class flares)**
  - 5 keV threshold for small pixels. Most large pixels are turned off. Primary mode for extreme solar activity. **Never used.**

Changes in operations occurred ~6/26/2026



PADRE/MeDDEA Operations

Goddard
SPACE FLIGHT CENTER

56	466h	11	81	91
Flares Observed	**Science Data**	**Months In Orbit**	**Days**	**Days**
41 C-class • 15 M-class	MeDDEA downloaded	Launch: June 23, 2025	SHARP powered on	MeDDEA powered on

✓ **Minimum Mission Achieved** — Launched after maximum of SC25
• Decay Phase Ongoing • Big Flares Expected • First spinning sun-pointing CubeSat (1 rpm)

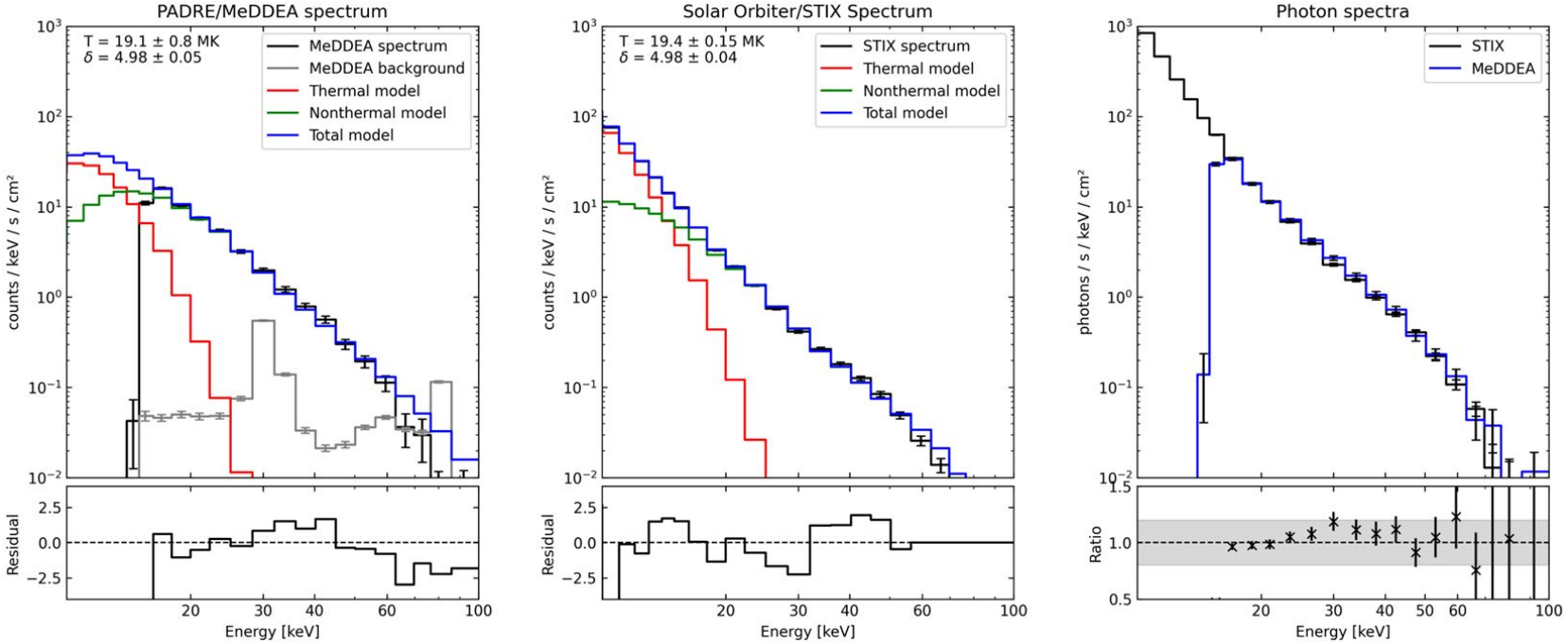
MeDDEA was powered on 24% of the time, and observed 14% of the time.

Observed ~41 C, ~15 M, 1X so far…

Operating a cubesat is difficult…we are improving!

M1.6 2025-Nov-29 00:02:00

Cross-calibration between STIX and MeDDEA - 17-jan-2026 (M2 flare)



Work is ongoing but spectra can already be compared. **More about this in the next talk by M. Stiefel**

Data Availability

- Data is made publicly available as soon as it is downlinked.
- Data is publicly available now (raw, L0, L1) along with code to process the data.
  Level 2 (calibrated data) to be released soon.
- MeDDEA data is available online from NASA SDAC:
  https://umbra.nascom.nasa.gov/padre/padre-meddea
- Python package to analyze MeDDEA data
  https:github.com/PADRESat/padre_meddea
- MeDDEA Flare list
- Contact me steven.christe@nasa.gov

Data Dashboard

GitHub Repository