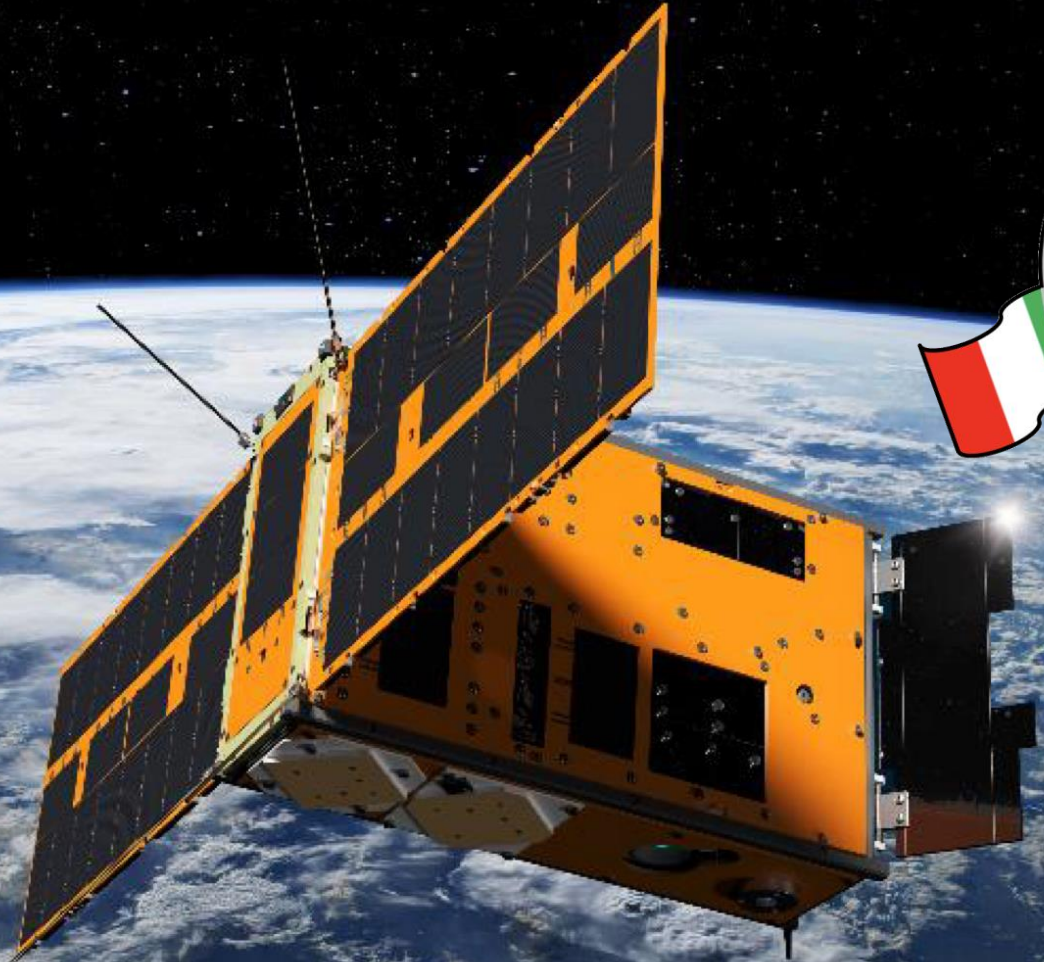
Nanosatellite constellations and astrophysical transients



Prof. Michele Trenti
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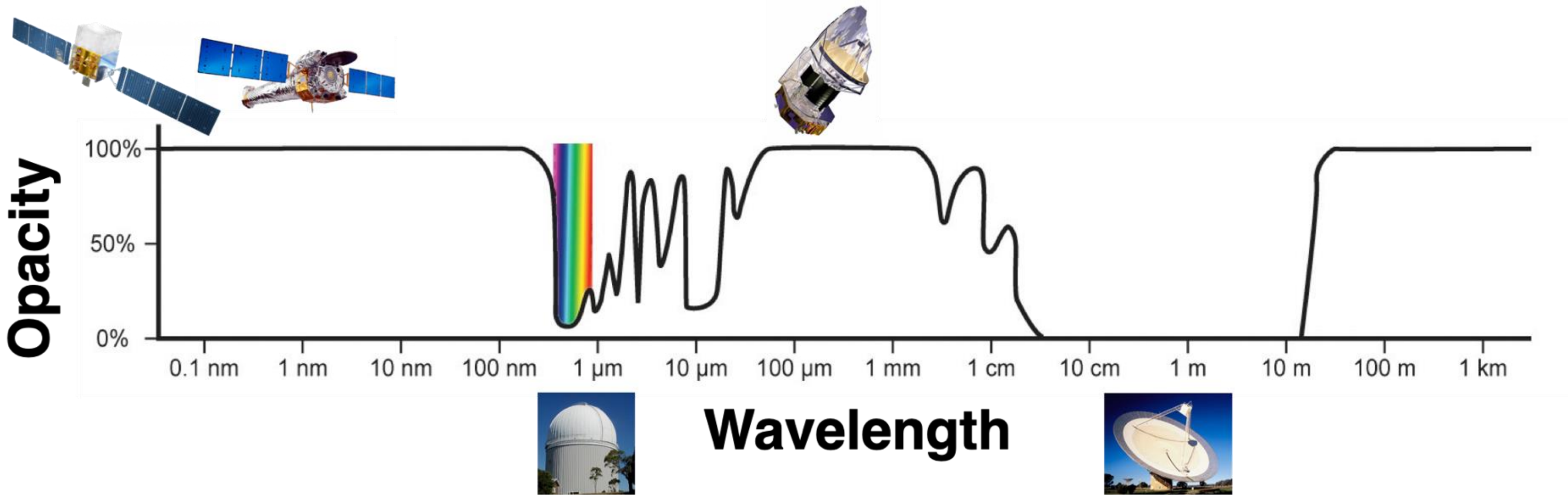
February 19, 2025

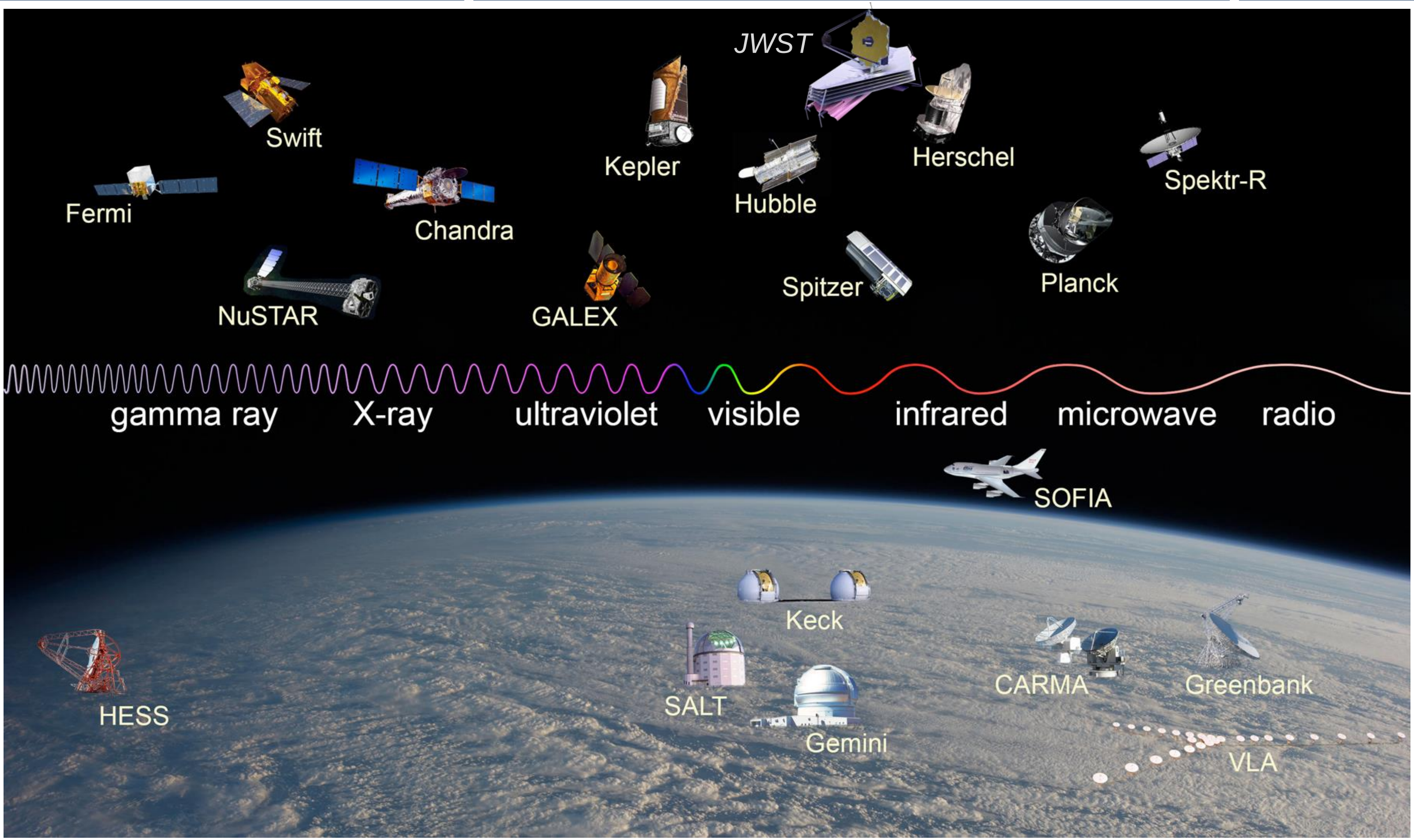
Why astronomy from space?

Space telescopes: Earth's atmosphere



- **Opacity:** Only limited windows with clear transmission
- **Blurring:** Time-variable refraction index from turbulence
- **Foreground:** Diffuse emission from molecule excitations

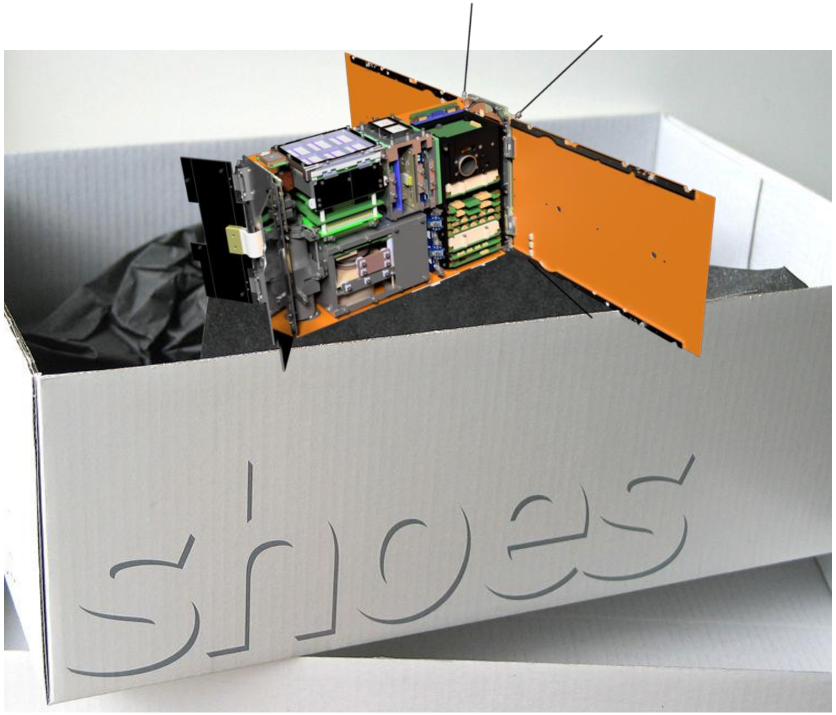
Space telescopes across EM spectrum



Credit: NASA

Emerging opportunities

Can meaningful scientific instrumentation fit in a shoe-box sized satellite?



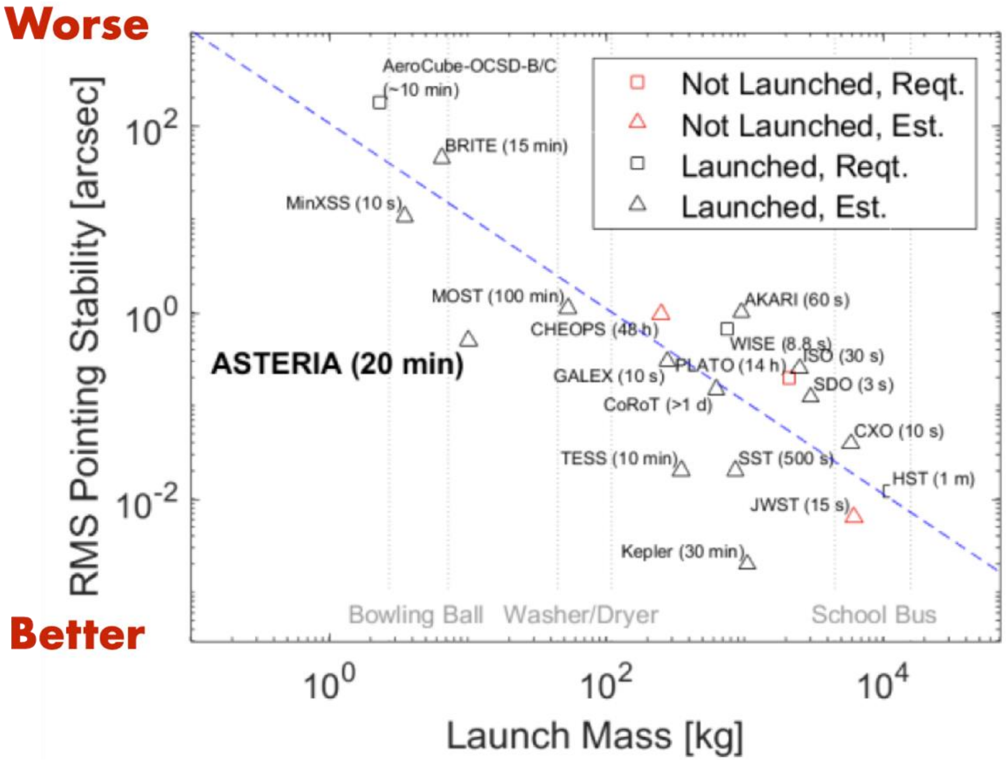
Astronomy nanosats challenges

- **Challenges**
  - Accurate attitude control
  - Data processing and retrieval
  - Thermal management

- **Enabling tech**

Astronomy demonstration in orbit

- **Asteria (6U, 2017, JPL/MIT): optical telescope**



Smith+ 2018

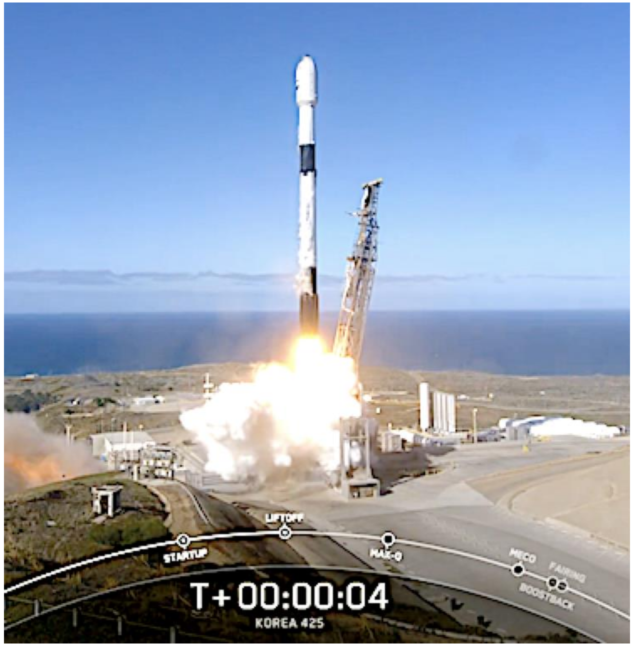
An Australian space telescope

SpIRIT: Mission aims

- First mission of the Australian Space Agency
- Australian-made spacecraft with gamma/x-ray instrument from Italian Space Agency
- Key goals:
  - Advance high-energy astrophysics
  - Grow Australian space industry capabilities
  - Demonstrate novel technology

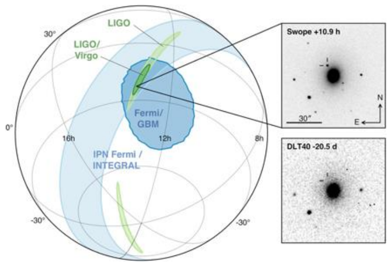
SpIRIT: At a glance

- Operational 6U - 11.8 kg
- 500km Polar orbit since 1/12/2023
- AU $10M+ budget
  (AU $6.7M from Australian Space Agency)
- International cooperation with Italy
- 4yr proposal to launch
- 2yr main mission



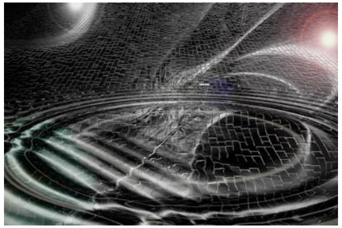
SpIRIT: Frontier science

- **The transient sky at high energies**
  - Gamma Ray Bursts localisation



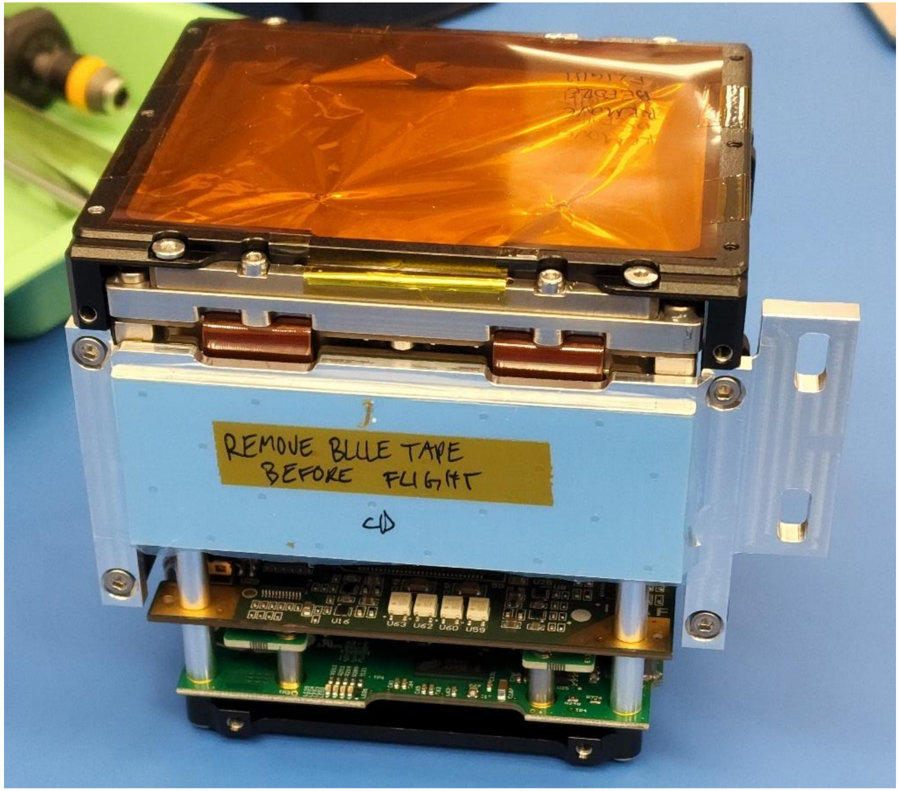
- **Gamma Ray Bursts inner engine**
  - Fast variability studies

- **Granular structure of space time**
  - Photon arrival time vs. energy (demo only)



Fiore et al. (2021)

SpIRIT: Main instrument



HERMES: High Energy Rapid Modular Ensemble of Satellites

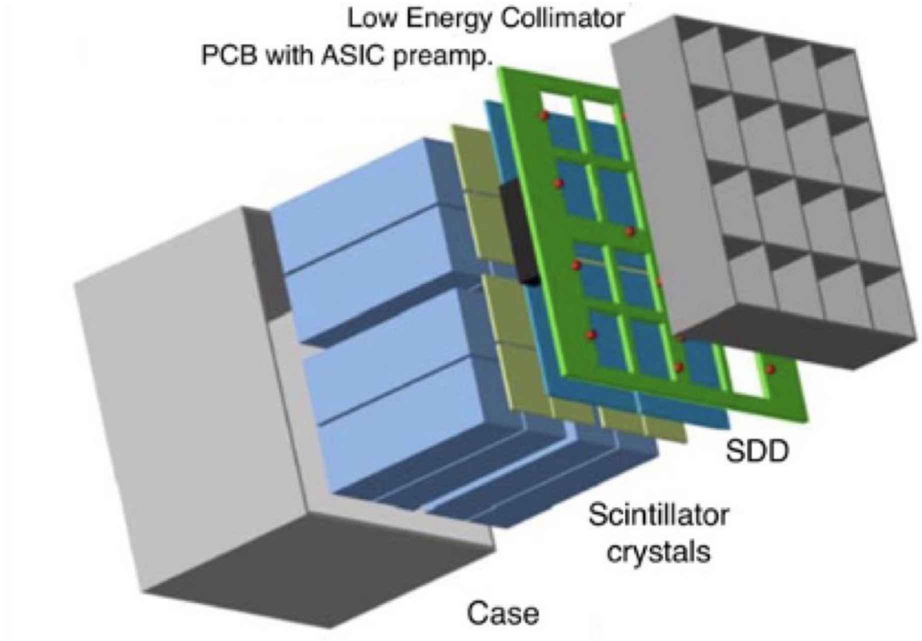
Agenzia Spaziale Italiana

All-sky X/gamma-ray transient monitor

First flight of the instrument on SpIRIT

6 other instruments on 3U CubeSats currently on launchpad (Transporter 13)

SpIRIT: Main instrument



3keV - 2 MeV

Exquisite time resolution (<400ns)

Sensitivity ~1 photon/s/cm^2

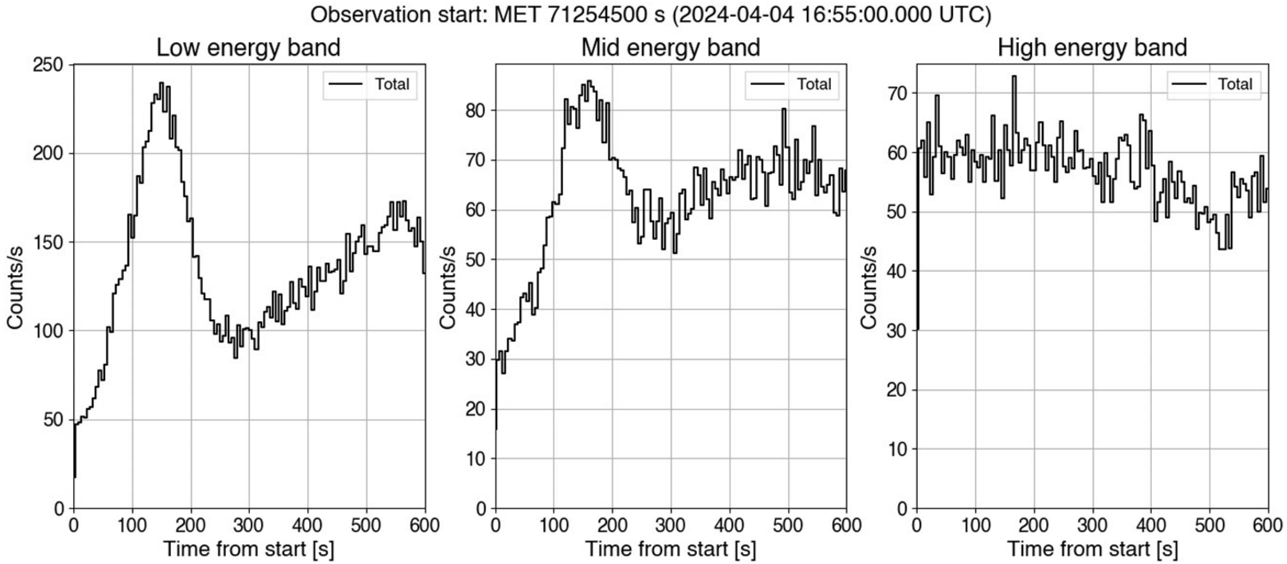
Similar performance to Fermi Gamma Burst Monitor

HERMES: First observations

First light achieved

Background noise consistent with pre-flight estimates

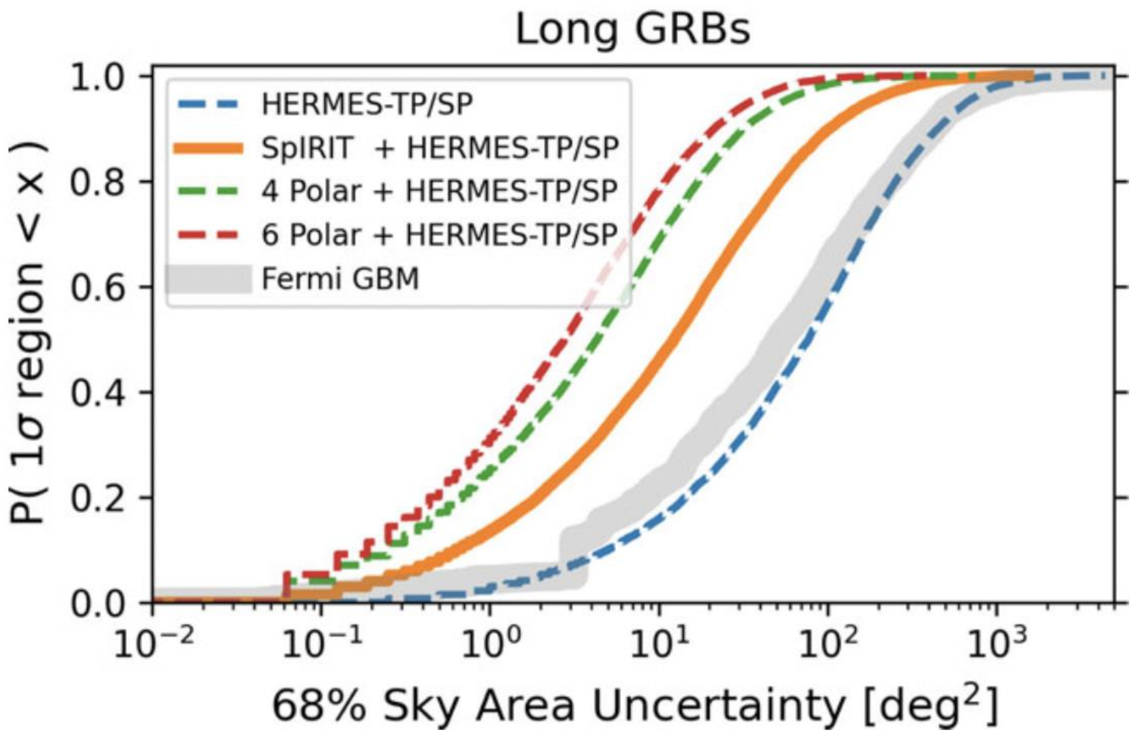
Testing & calibration ongoing



Trenti et al. (2024)

SpIRIT+HERMES TP/SP localization

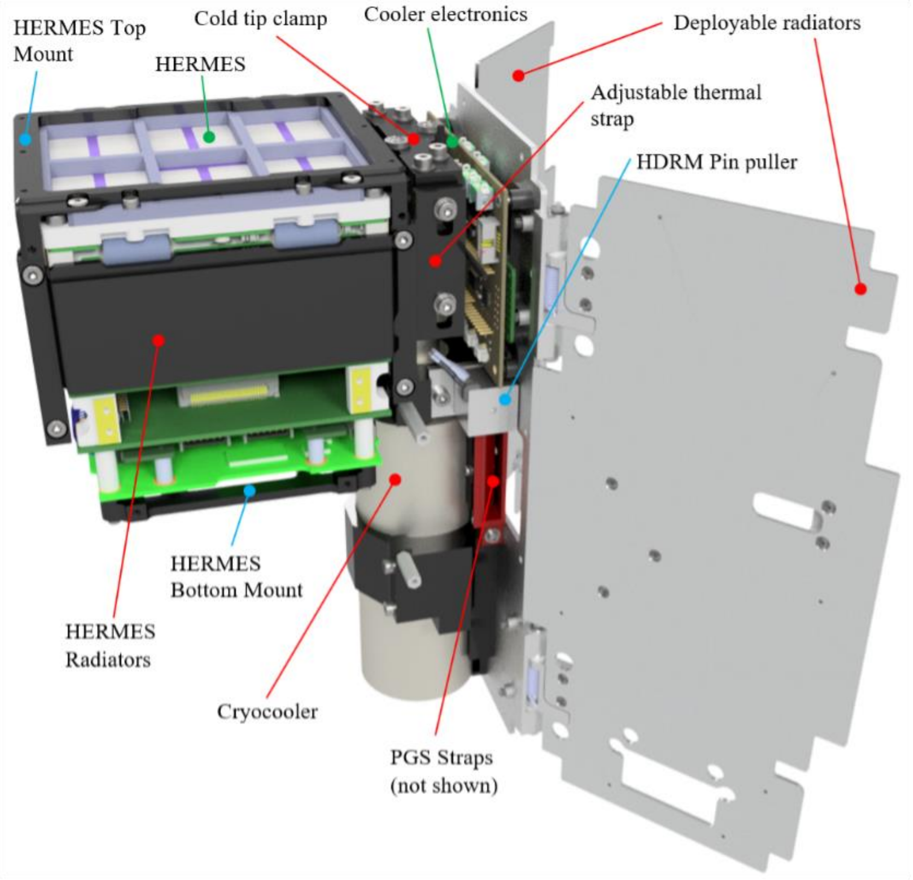
Long GRB localization at least comparable to Fermi GBM



Thomas, Trenti et al. (2023)

Thermal Management System

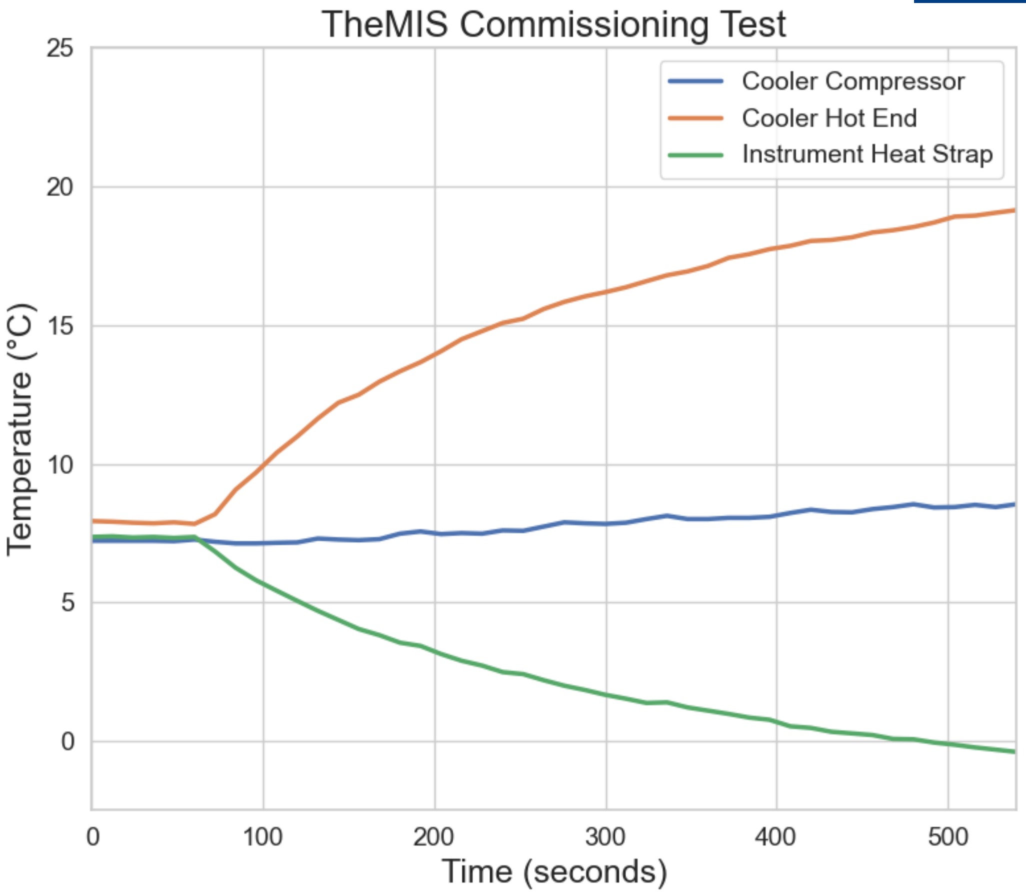
- System designed for cryogenic cooling of IR sensors, tech demo on SpIRIT
- Stirling cycle cooler (Thales LSF9997)
- In-house control electronics
- Deployable radiators
- Pyrolytic graphite thermal straps



Ortiz del Castillo et al. (2024)

TheMIS: technological innovation

- Among first high-performance active cooling systems on CubeSats
- System operating nominally
- High interest for technology improvement and commercialisation



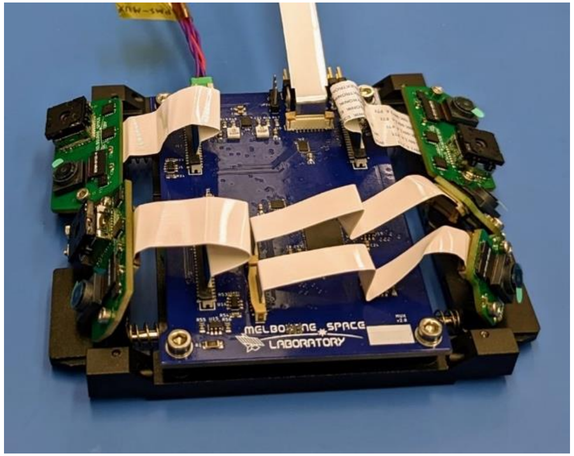
Ortiz del Castillo et al. (2024)

Loris – Imaging and AI Payload

NVIDIA Jetson Nano GPU with Python environment (edge computing)

6 visible light cameras
(Sony IMX219, 200m/pixel)

3 Long-wave IR sensors
(FLIR Lepton 3.5)



Central Australia from SpIRIT/Loris - 17th May 2024

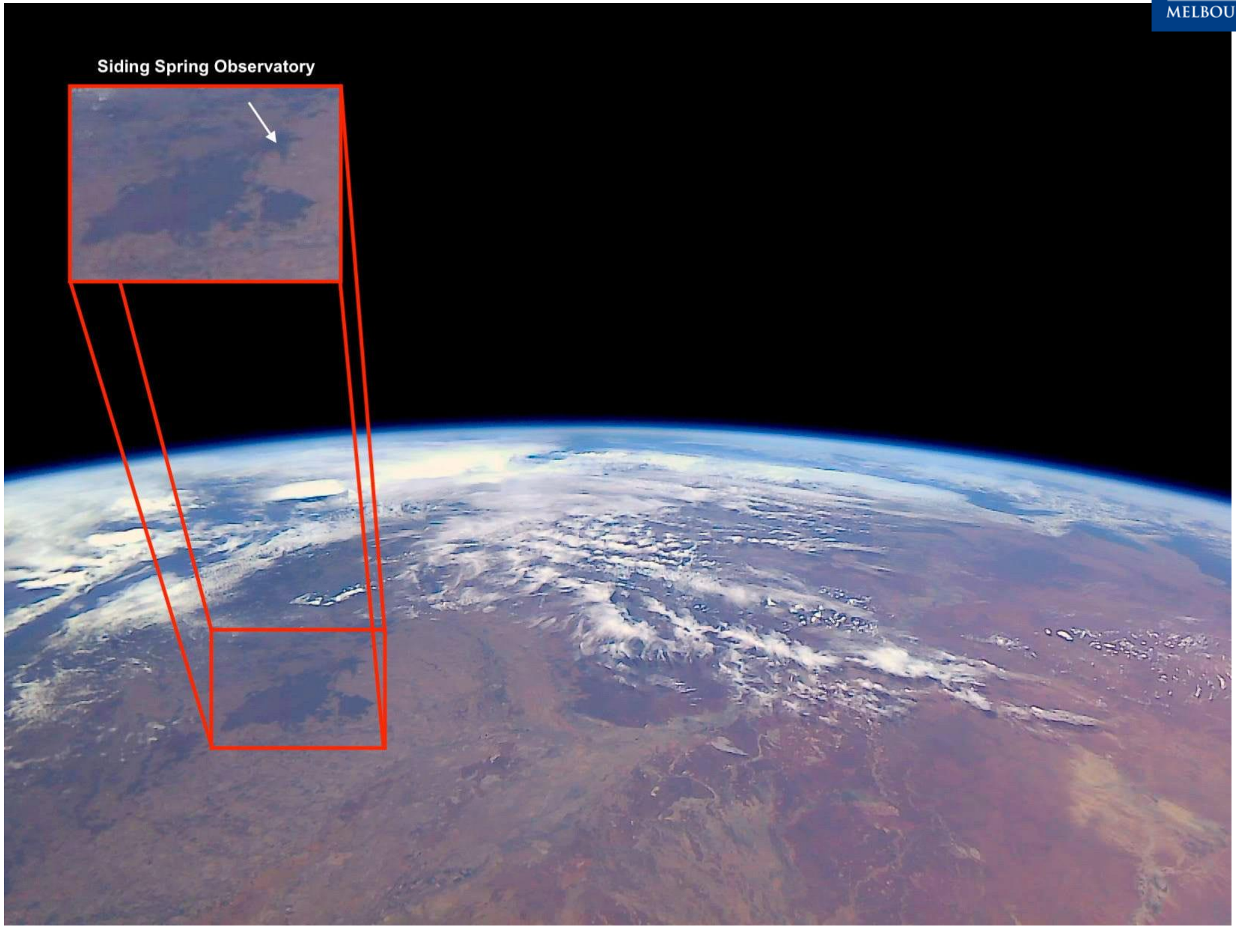
Public engagement

Images are key tools to raise public awareness of the importance of remote sensing from space

“Shooting for the Moon” - August 2024

Public engagement

Images are key tools to raise public awareness of the importance of remote sensing from space



“Telescope to telescope:- February 2025

Lessons learned from SpIRIT

- Define requirements clearly & avoid scope creep
- Establish priorities for descoping
- Ensure availability of EM (or FM-like) hardware
- Establish dedicated Project Manager role
- Have personnel backup roles
- Day-in-life rehearsals crucial for efficient commissioning
- Tech demo (TRL9) *much* easier than science operations

Future opportunities

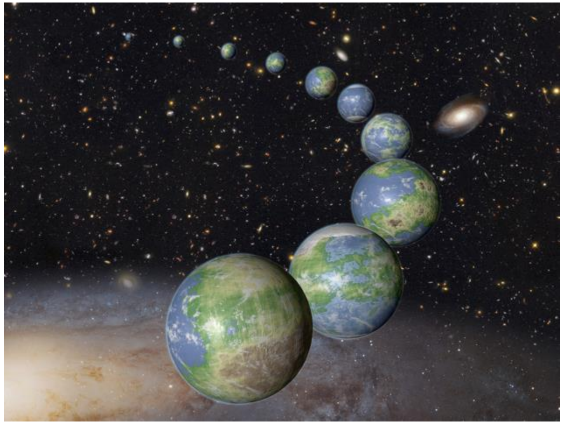
- Infrared space telescope (SkyHopper)
- Distributed aperture remote sensing (interferometry, segmented multi-satellite mirrors)

SkyHopper concept

- 30kg nanosatellite (e.g., 16U)
- 15cm IR (0.8-1.7 micron) imaging telescope
- Opportunity to collaborate with Italy (funded phase A)

Science case

- **Are we alone?**
  The search for other Earths



- **Where are we coming from?**
  First stars and galaxies from GRBs

Small mission budgets: OoM numbers

- Volume (payload): 1-10U
- Power (orbit average): 5-50W
- Edge computing: ~10-100 TOPS
- Memory: 4-40GB
- Downlink: 100MB-1GB/day

Space missions: reflections

- Access to space is affordable (SpIRIT launch ~3% budget)
- Constellation (“mass production”) is cost-effective
- Science mission with professional team (non-student) still $5M+ and 3yr+ development time
- Space is unforgiving environment
- Experienced team is critical for success

SpIRIT: Summary and outlook

- Rapid and efficient development cycle (4yrs)
- 14 months in orbit and continuing
- Major mission objectives achieved (12 publications)
- Constructive collaboration experience with Italy
- Ongoing learning experience
- Catalyst for future projects

Reference: https://arxiv.org/abs/2407.14034