HERMES

Nano-satellites for high energy astrophysics and fundamental physics research

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on behalf of the HERMES-TP and HERMES-SP collabotations

HORIZON 2020

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

POLITECNICO MILANO 1863

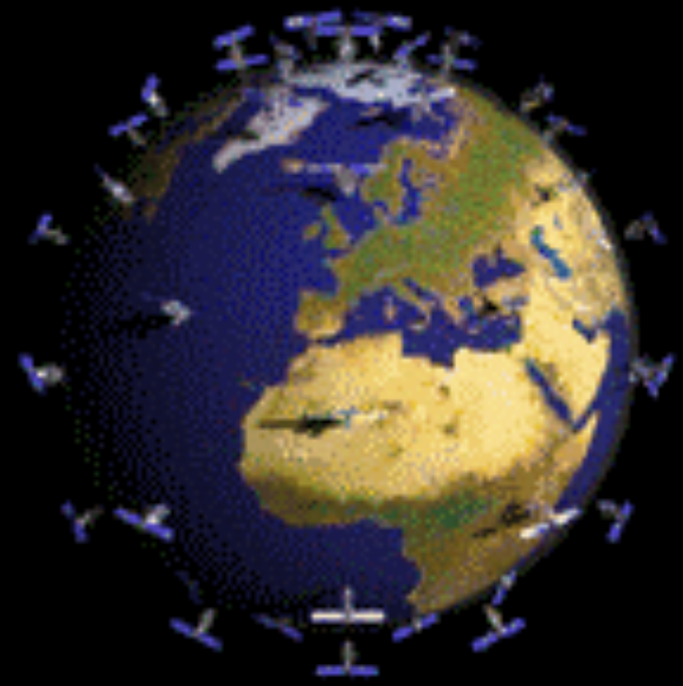
Agenzia Spaziale Italiana

Mission concept

Disruptive technologies: cheap, underperforming, but producing high impact. Distributed instrument, tens/hundreds of simple units

HERMES constellation of cubesat

2016: ASI funds for detector R&D
2018: MIUR funds for pathfinder (Progetti premiali 2015)
2018 H2020 Space-SCI-20 project
2019 ASI internal funds



Why HERMES now

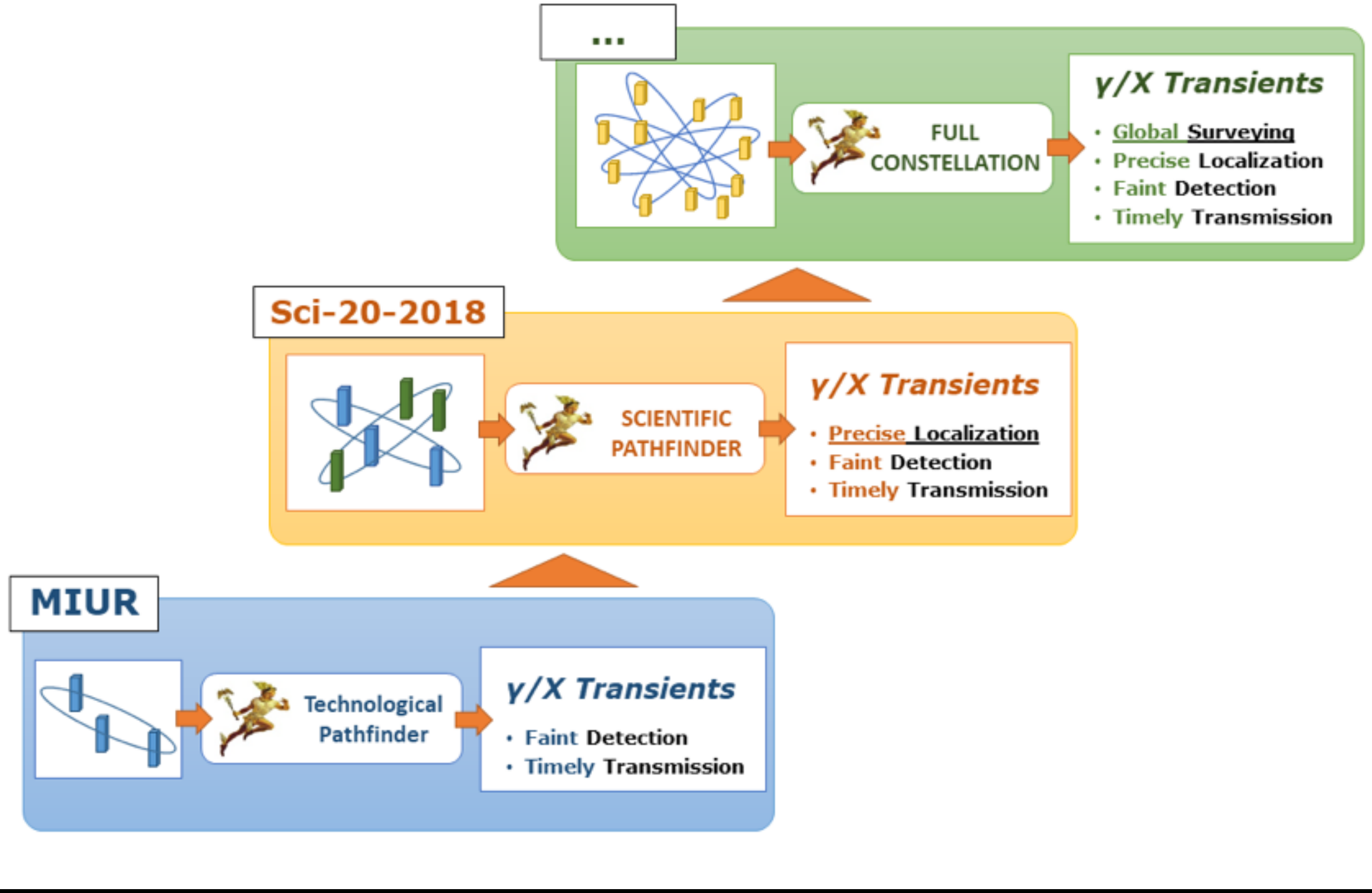
Breakthrough scientific case:

- EM of GWE

Modularity:

- Avoid single point failures, improve hardware
- Pathfinder

Why HERMES now



Why HERMES now

Breakthrough scientific case:

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Modularity:

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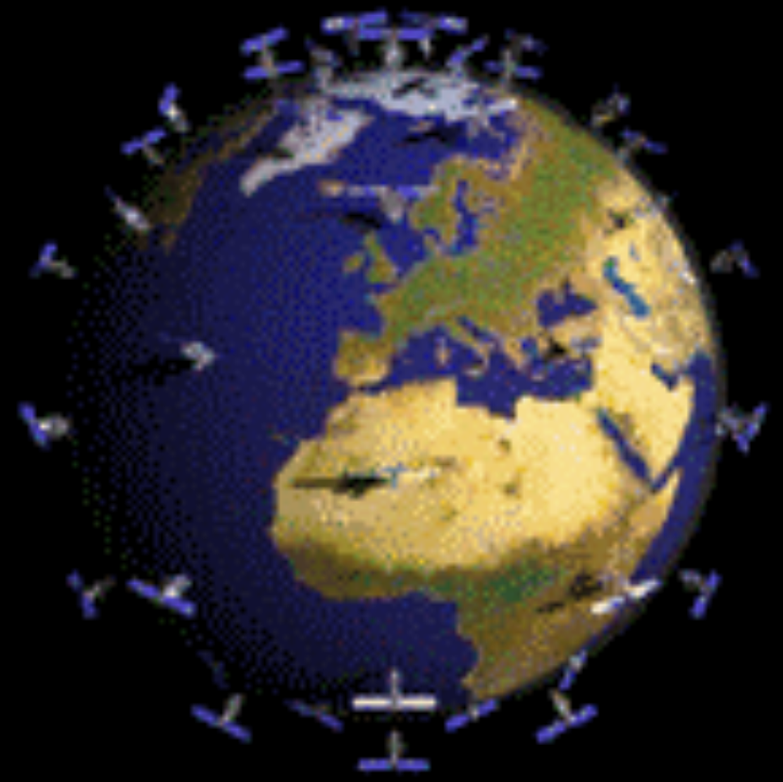
Open μsec - msec window:

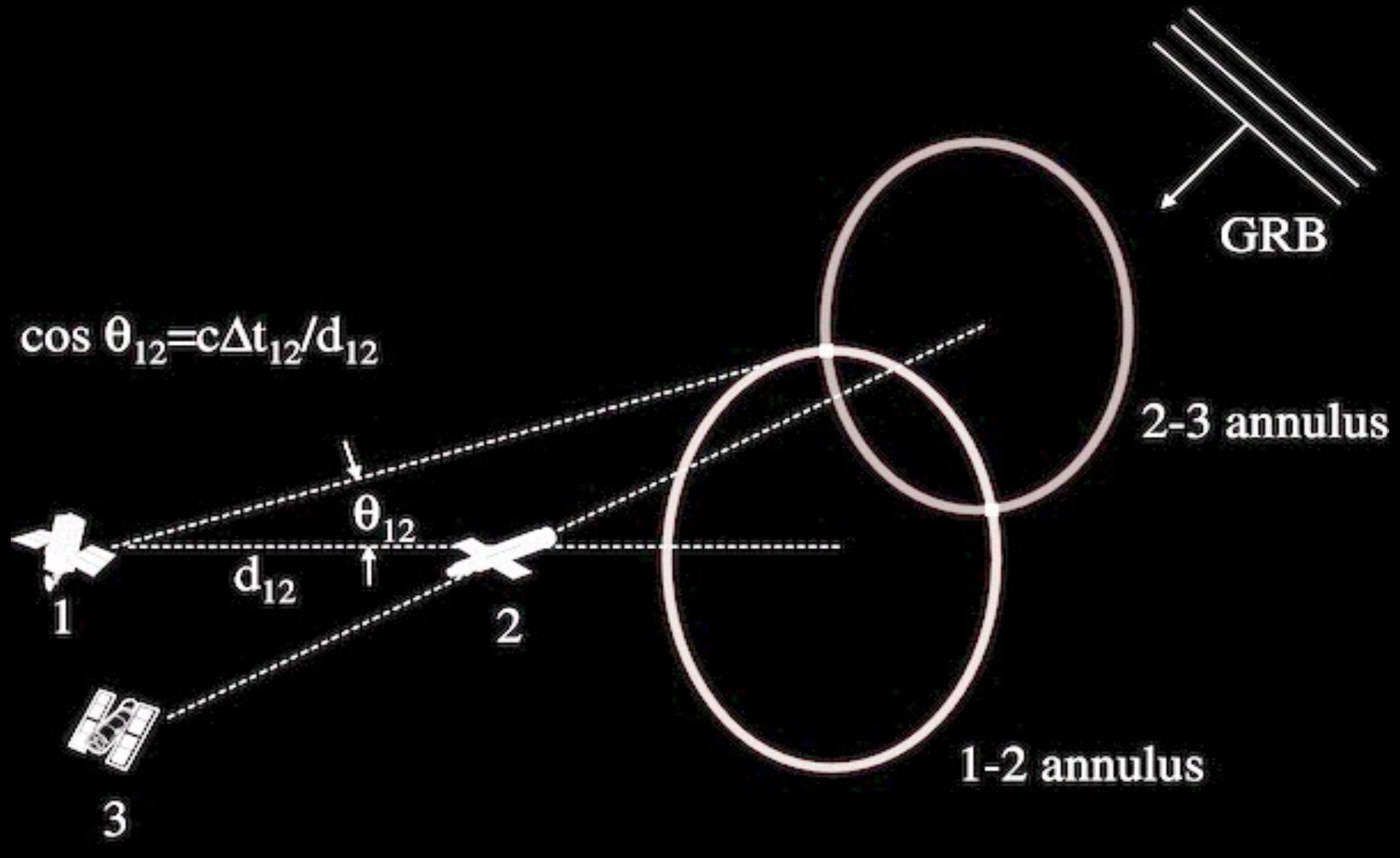
- Accurate positions
- QG tests



Limited cost and quick development

- COTS + in-house components
- Trend in cost reduction of manufacturing and launching QS

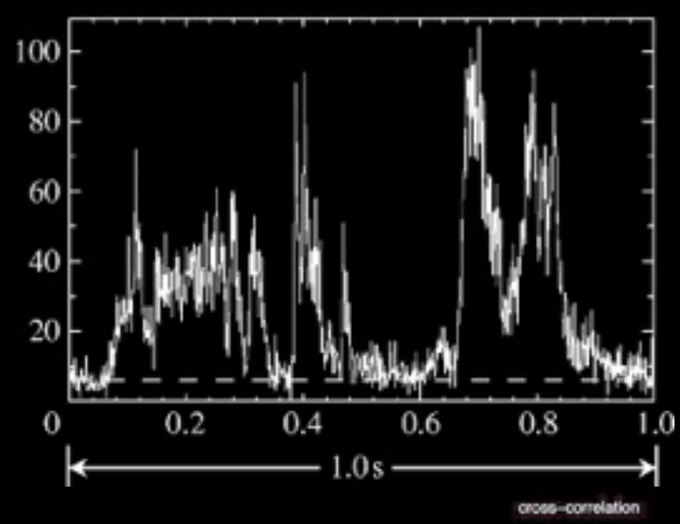
Experiment concept



Experiment concept

1. Measure GRB positions through delays between photons arrival times:

$$\sigma_{Pos} = (\sigma^2_{CCF} + \sigma_{sys}^2)^{0.5} \times c / \langle B \rangle / (N - 1 - 2)^{0.5}$$



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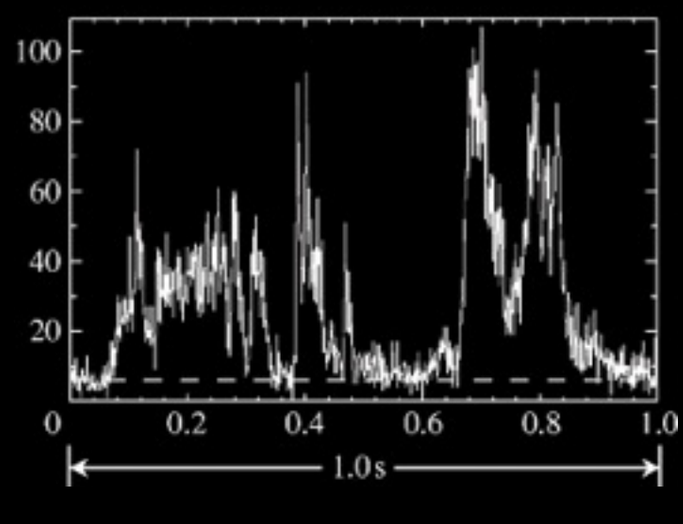

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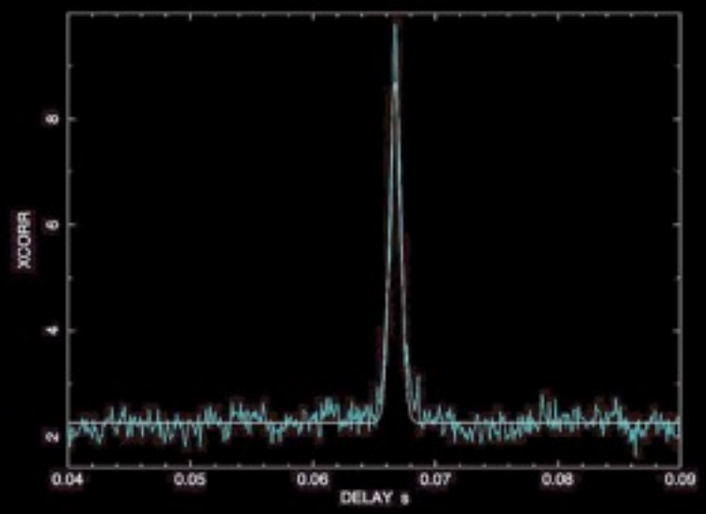
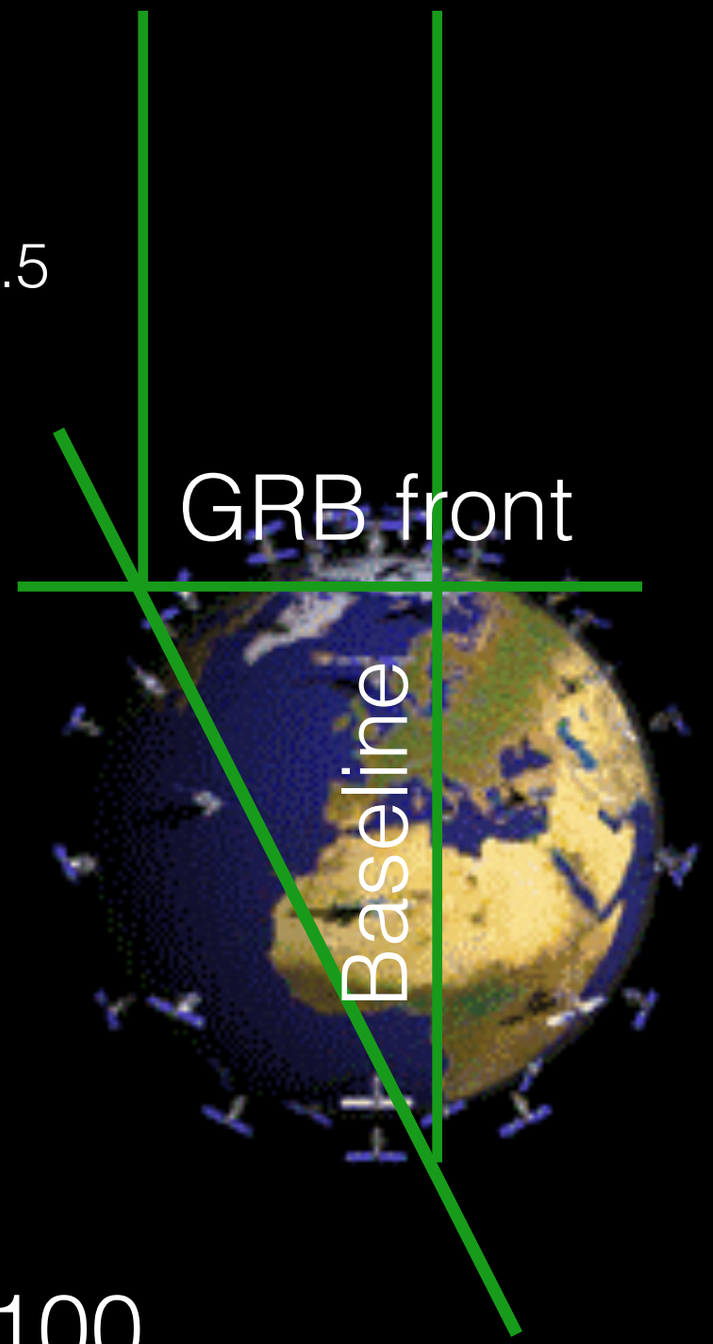


$\sigma_{CCF} \sim 10\mu s$

$\sigma_{Pos} \sim 10arcsec$

if $\langle B \rangle \sim 7000km$, $N \sim 100$

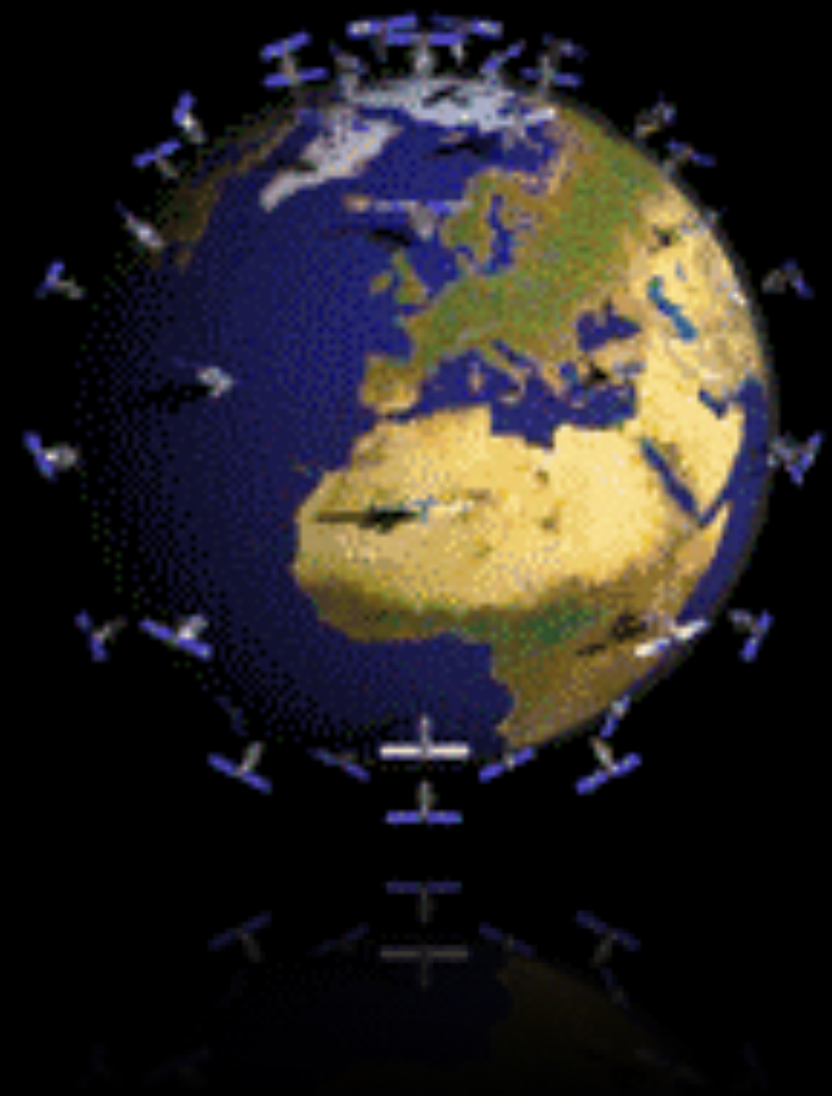


Experiment concept

2. Add the signal from different units

Total collecting area 50-100-cm^2 x 100-200 = 0.5-2 m^2

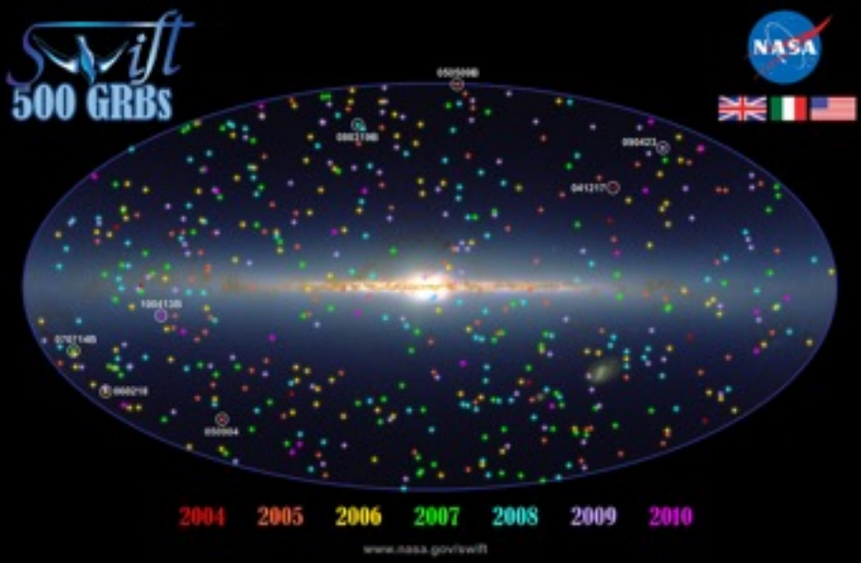
Transient fine (subμs-ms) temporal structure

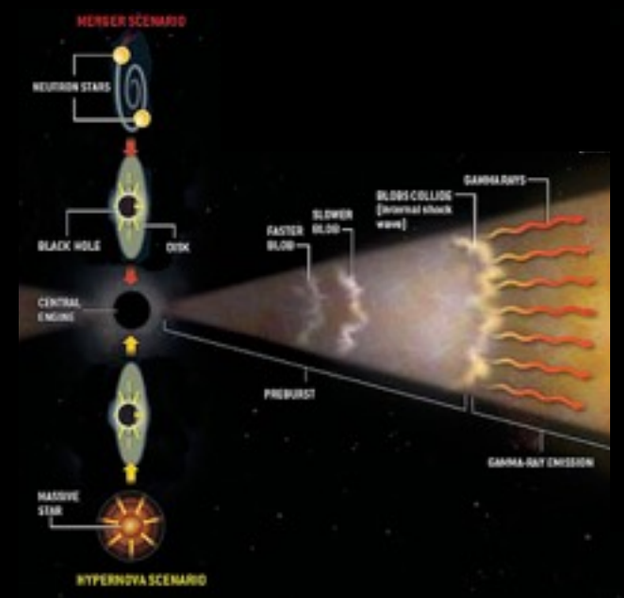


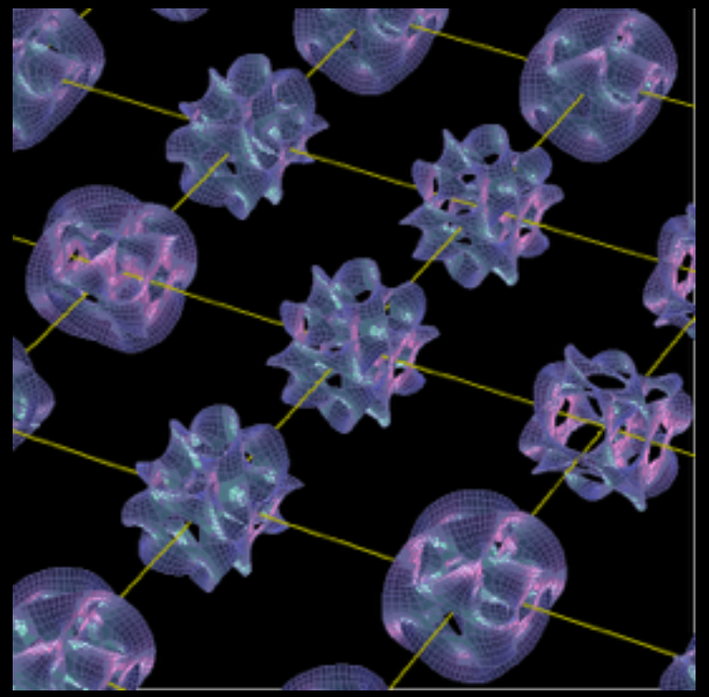
How to *promptly* localise a GRB *prompt* event?

How to construct a GRB engine?

Which is the ultimate granular structure of space-time?







Requirements

Scientific:

Arcmin-arcsec positions of ~a few dozen GRB/yr

Prompt(minute) localisation

sub-μs timing

$\Delta t/\Delta E$~3μs/100keV 30μs/1MeV—> $M_{QG} \sim M_{Planck}$

Requirements

System:

≈from a few to hundreds detectors

single collecting area ≥50cm^2

total collecting area ≥1m^2

Energy range 3-10 — 300-1000 keV

Temporal resolution a few hundred ns

Position reconstruction of each satellite < 30m

Absolute time reconstruction <100 ns

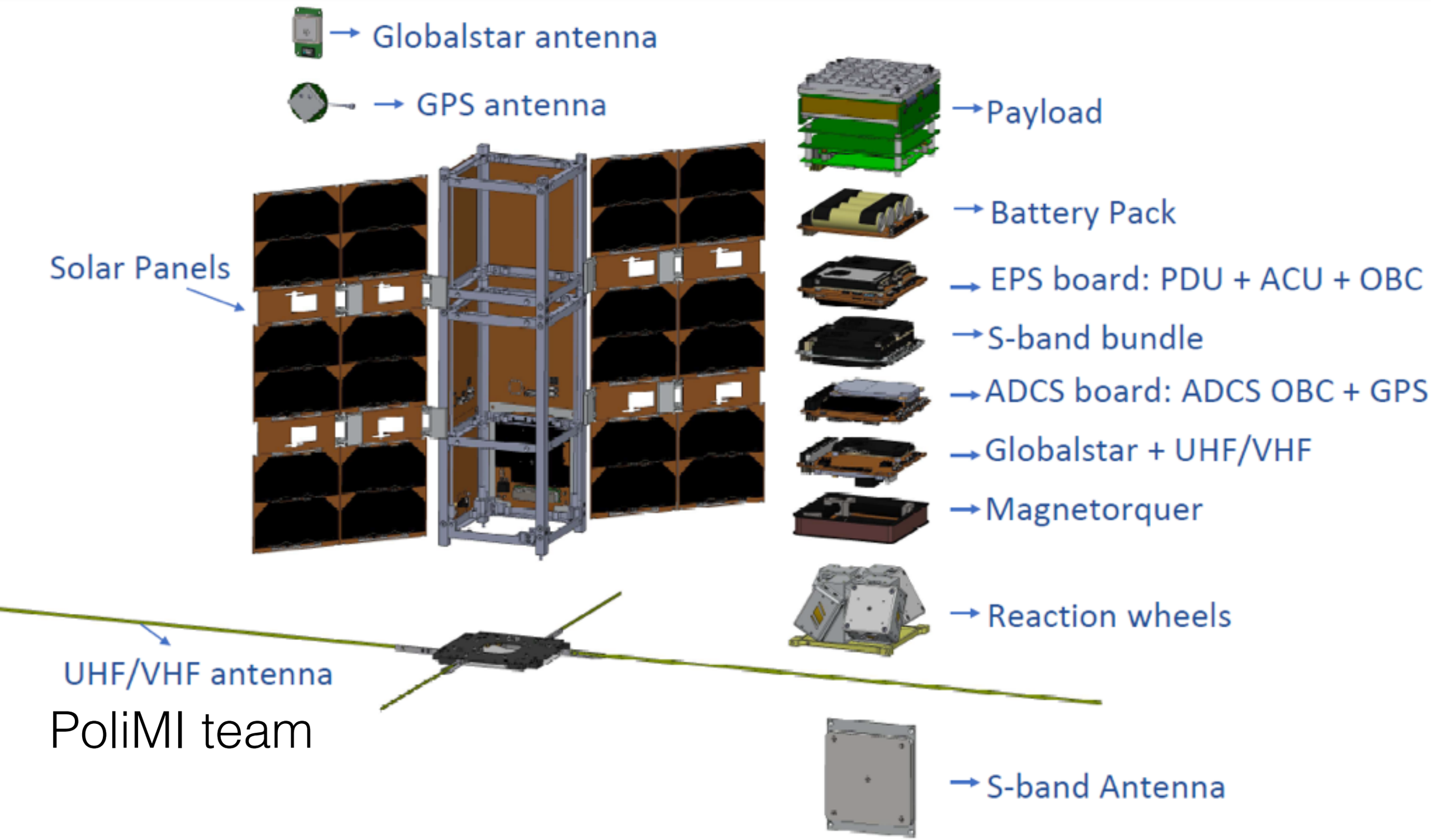
Download full burst info in minutes

Spacecraft

3U minimum, simplest basic configuration
50 cm^2 detector: Pathfinder

6U more performing configuration
~200cm^2 detector, more accurate GPS, more accurate AOCS: Full Constellation

Spacecraft

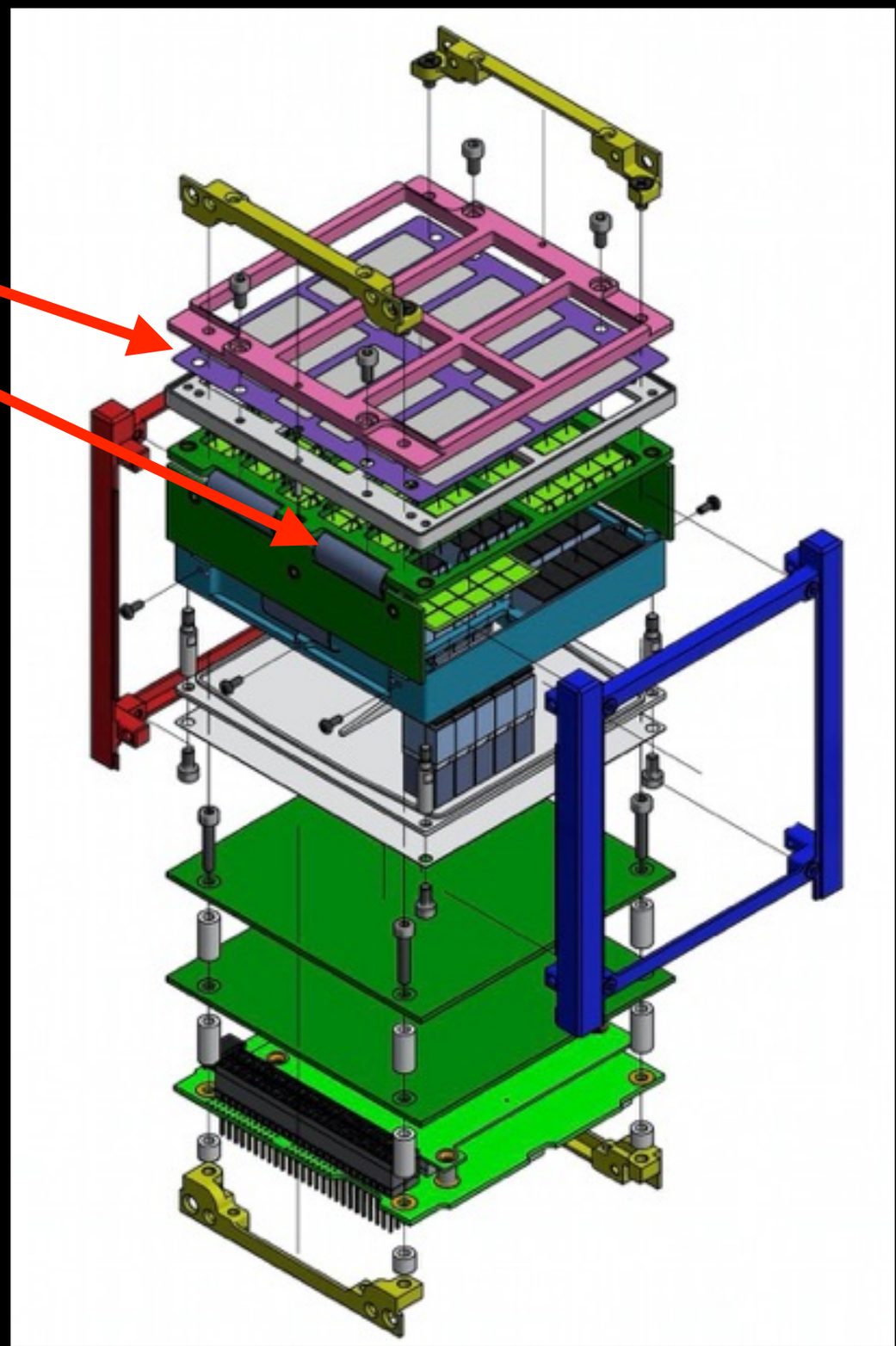


PoliMI team

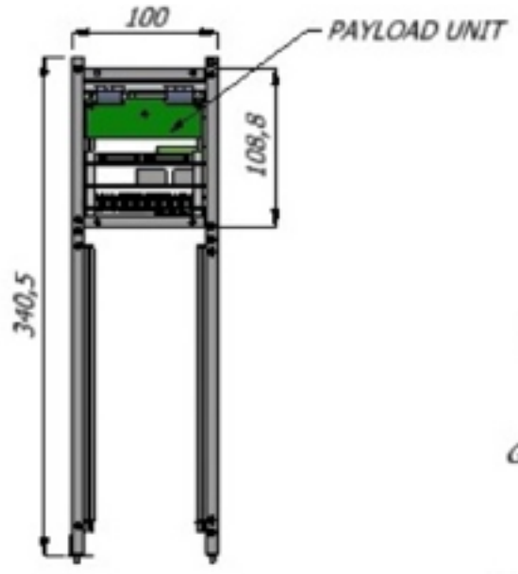
Payload concept

- Photo detector, SDD
  Scintillator crystal GAGG
- 5-300 keV (3-1000 keV)
- ≥50 cm^2 coll. area
- a few st FOV
- Temporal res. ≤300 nsec
- ~1.6kg

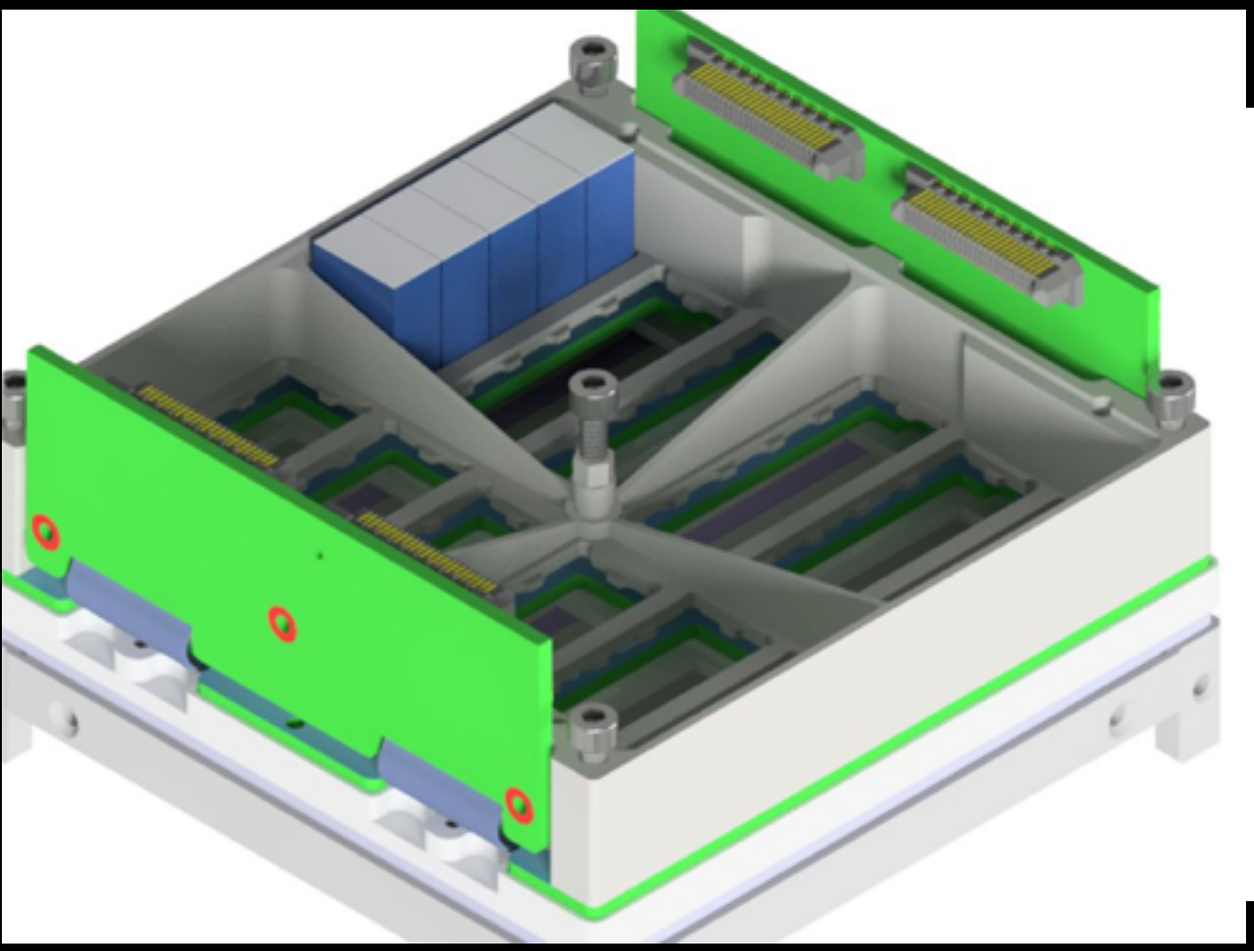
Fuschino+2018, 2020
Evangelista+2020
Campana+2020

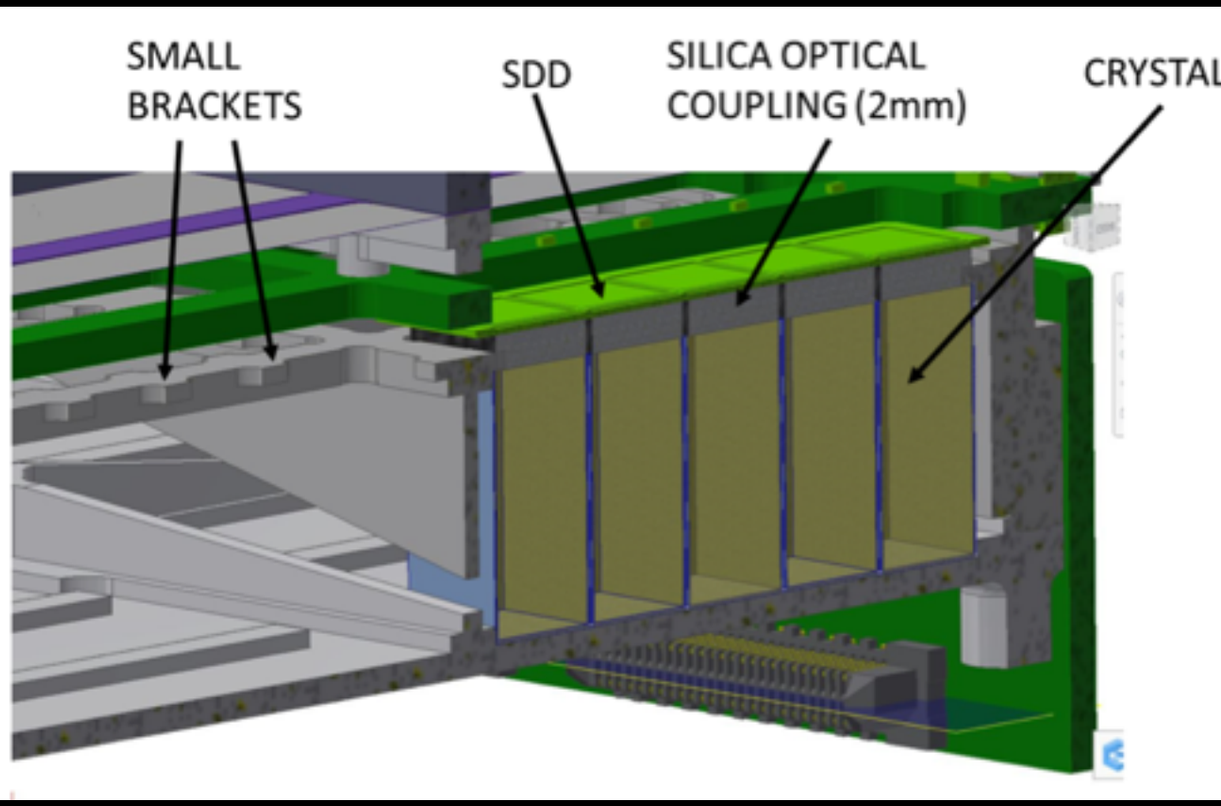


Payload design



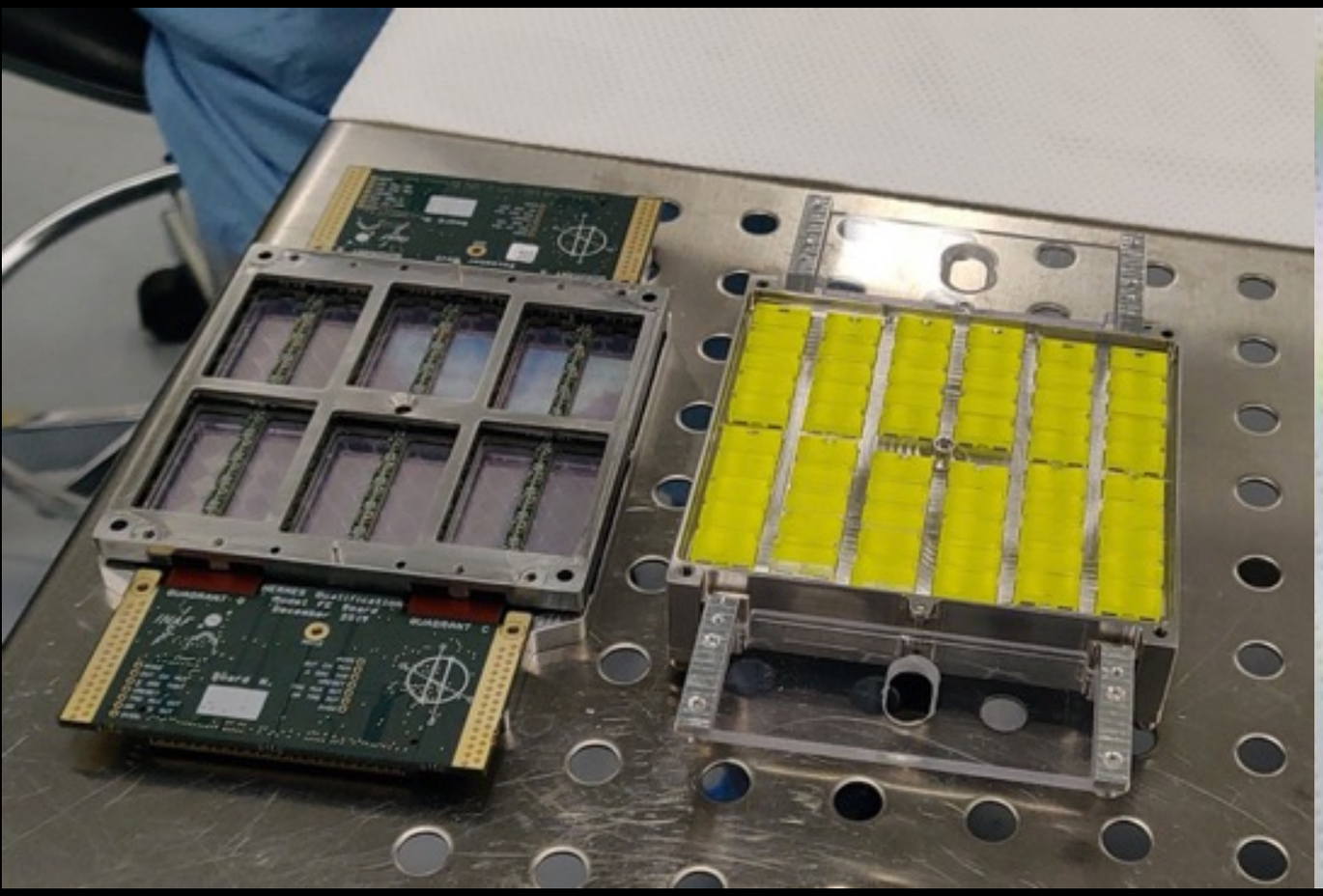
Detector design

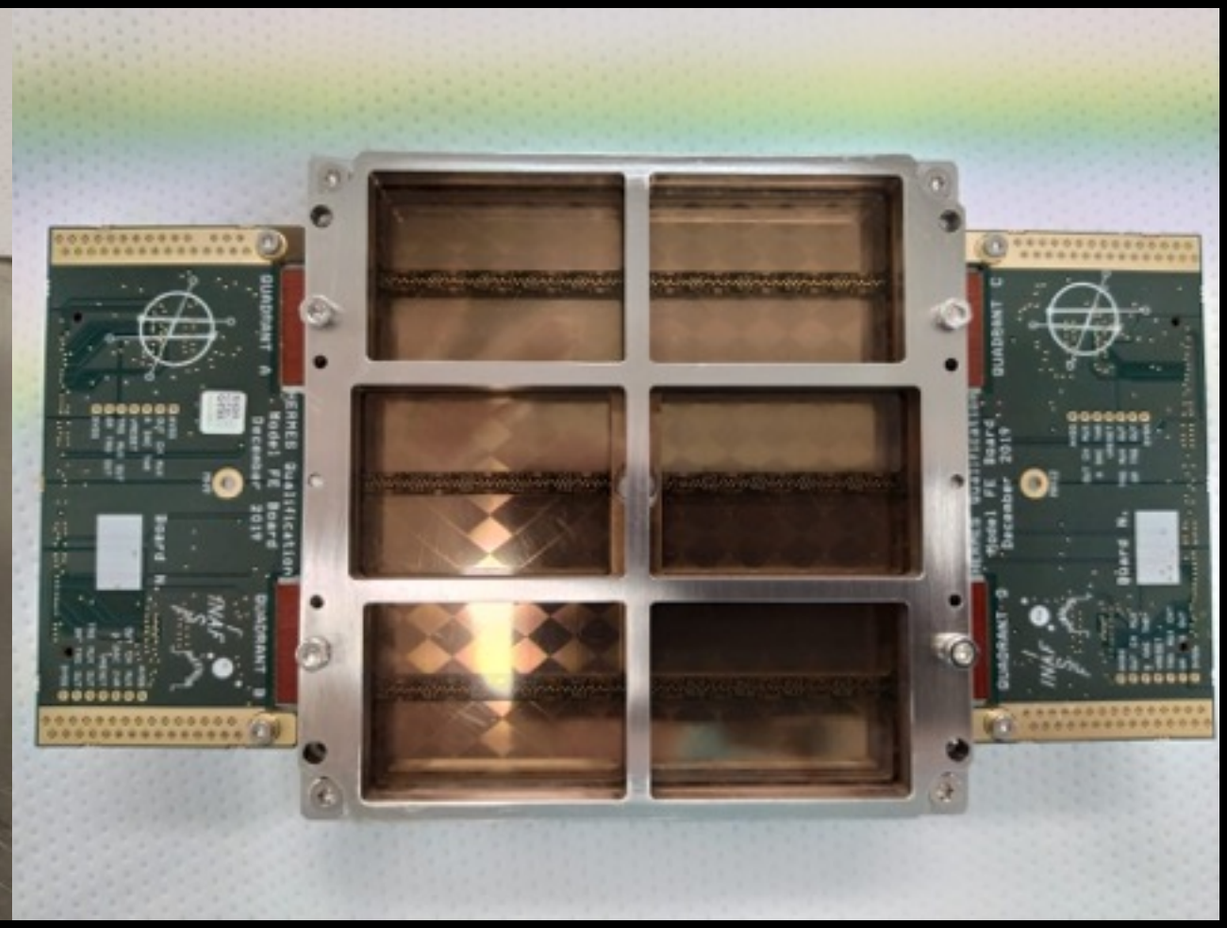


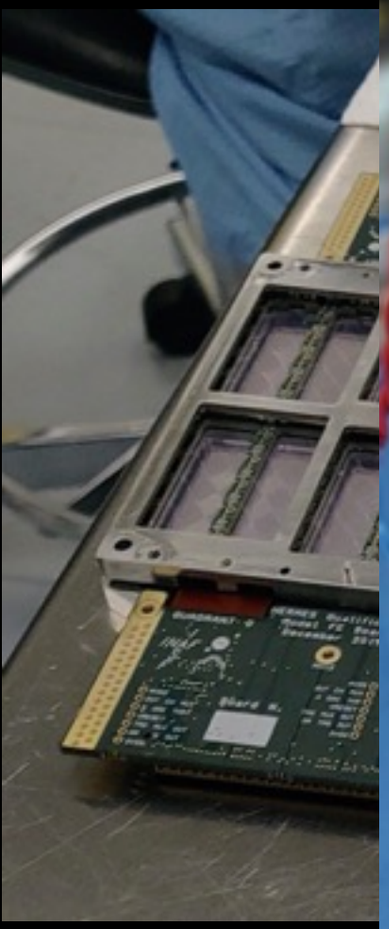


Stainless stell crystal box + tungsten layers on bottom and sides to reduce X-ray background

Hardware






QUADRANT
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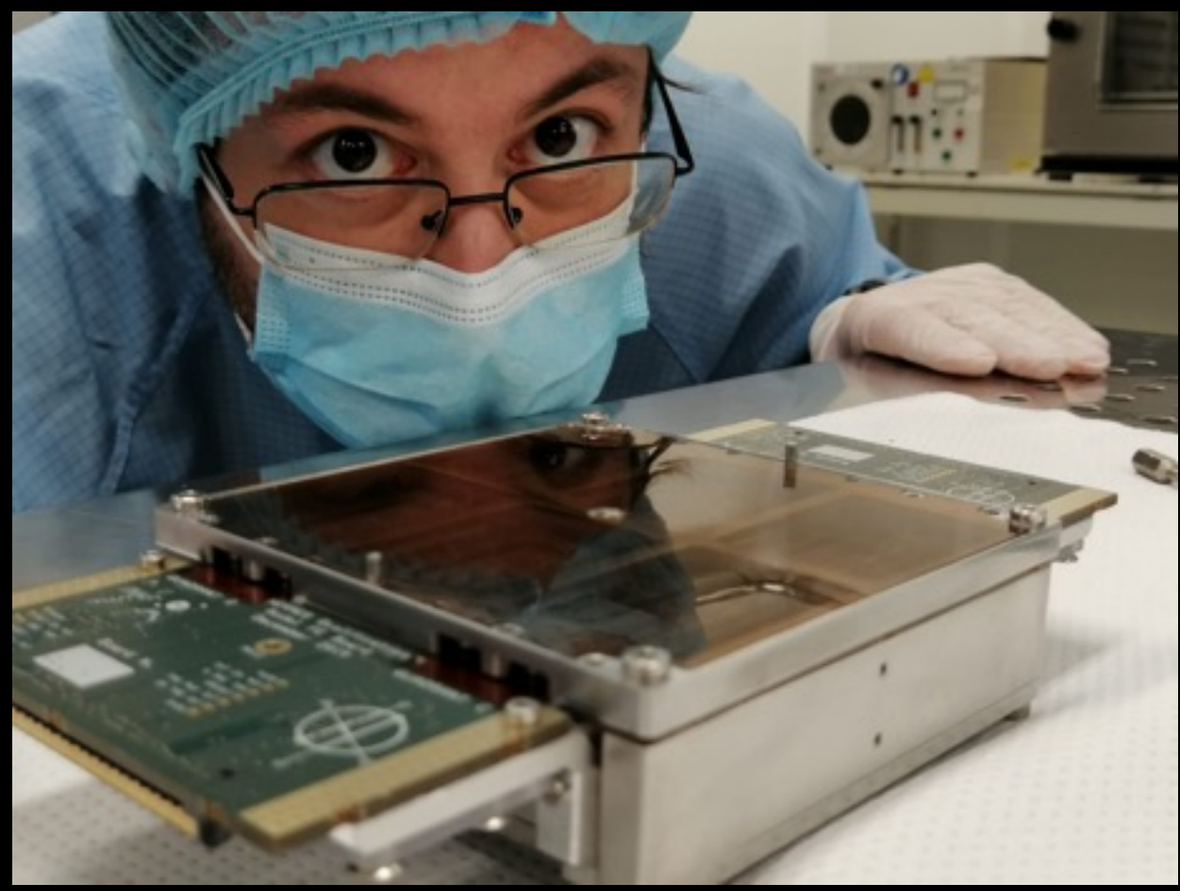
Payload DM

http://www.hermes-sp.eu/?p=5010

- Assembly, Integration procedure and test plan consolidation
- FEE PCB functional tests
- FEE PCB (preliminary) performances verification
- SDD + ASICs power consumption verification
- Absence of channel-to-channel electrical cross-talk
- Room-temperature performance as expected. Spectroscopic characterisation with ^{137}CS



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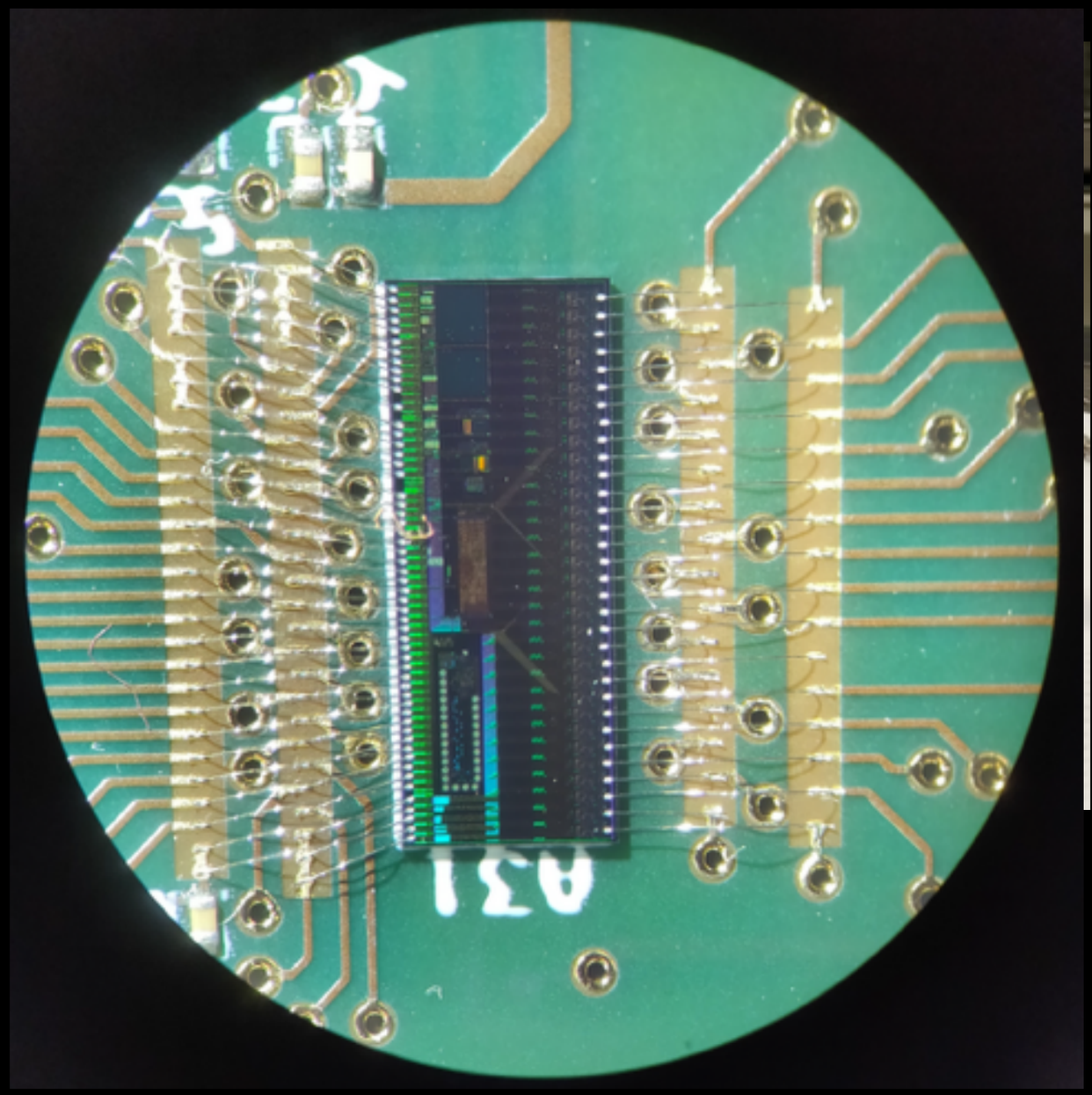

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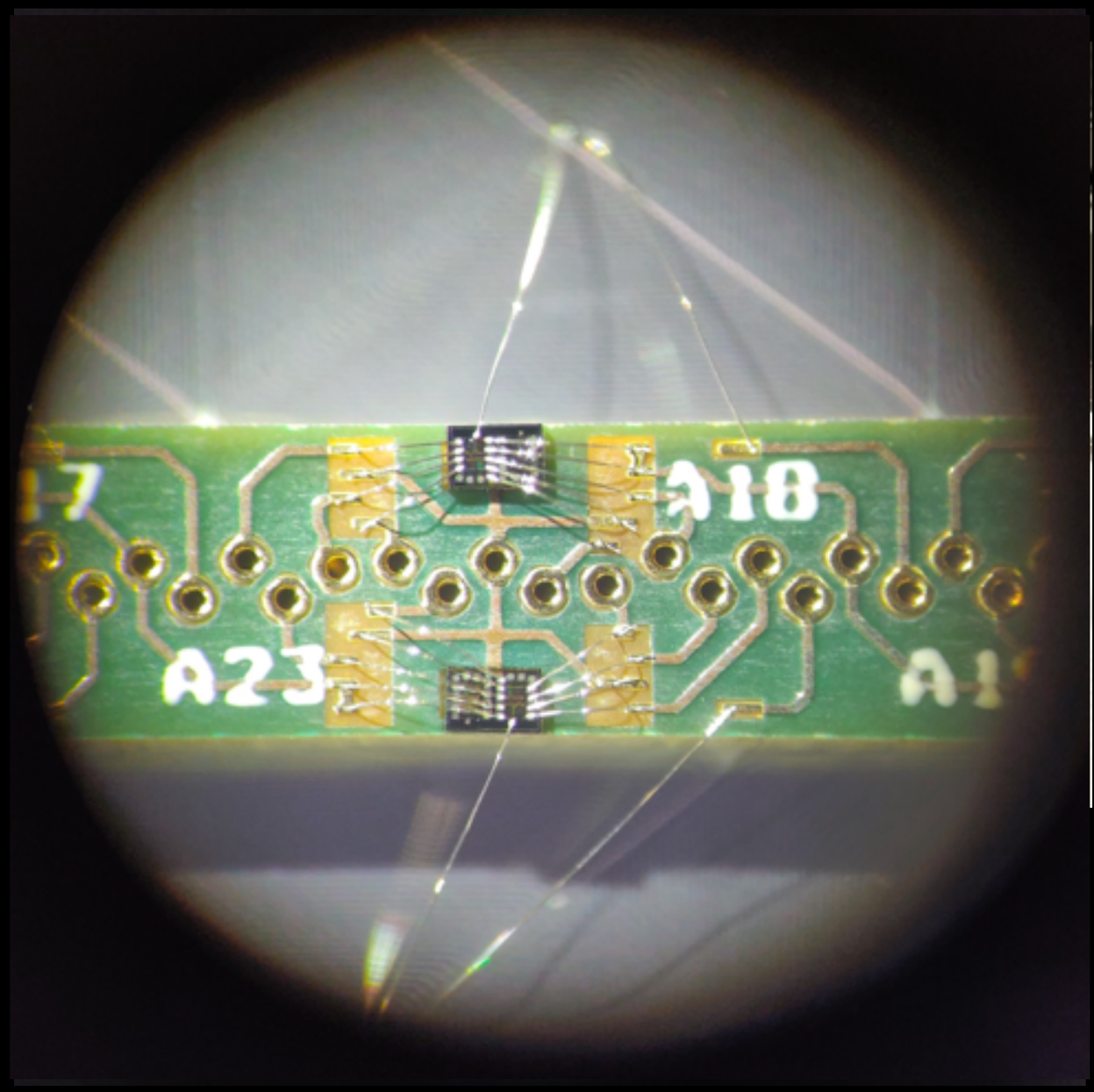

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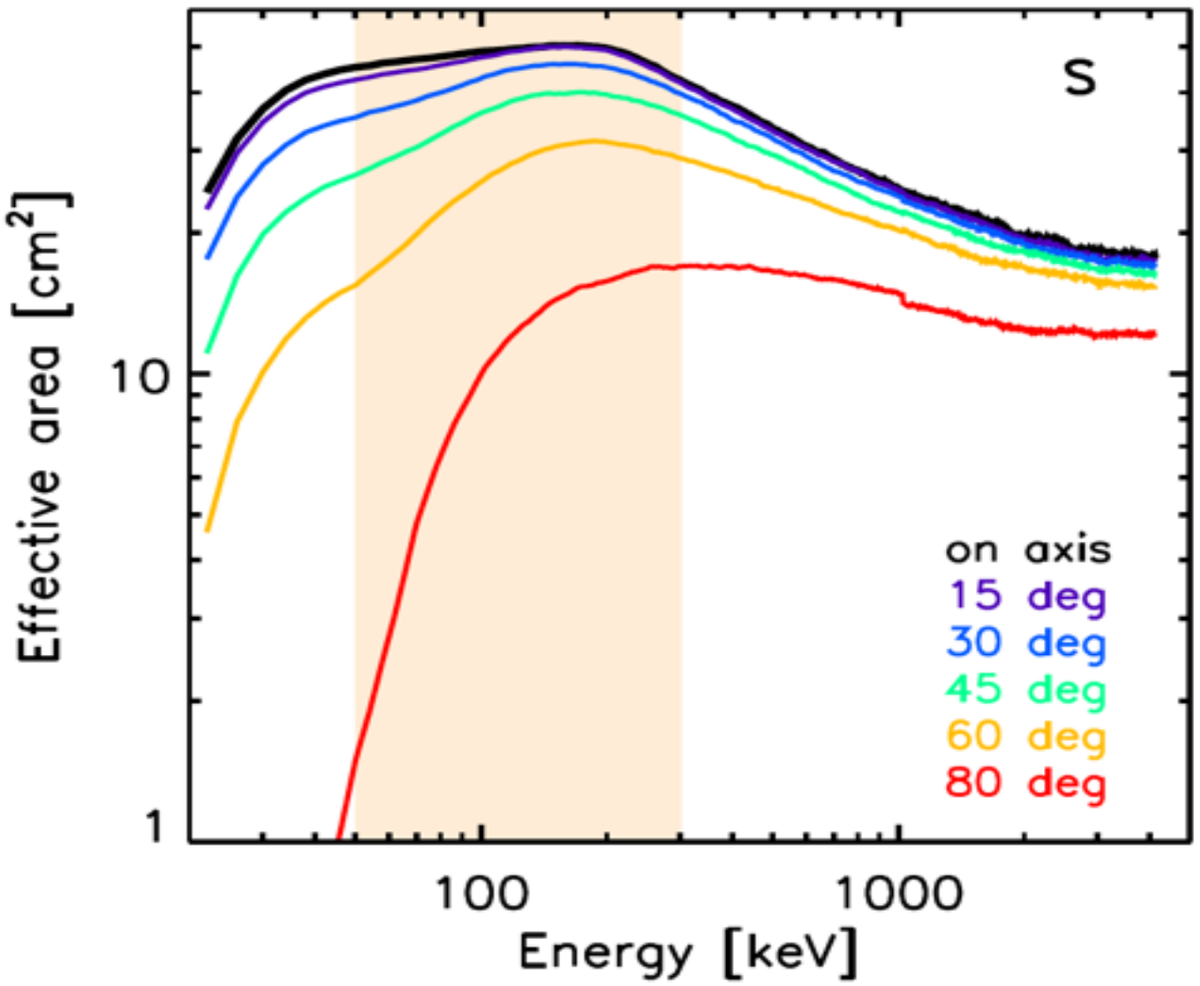
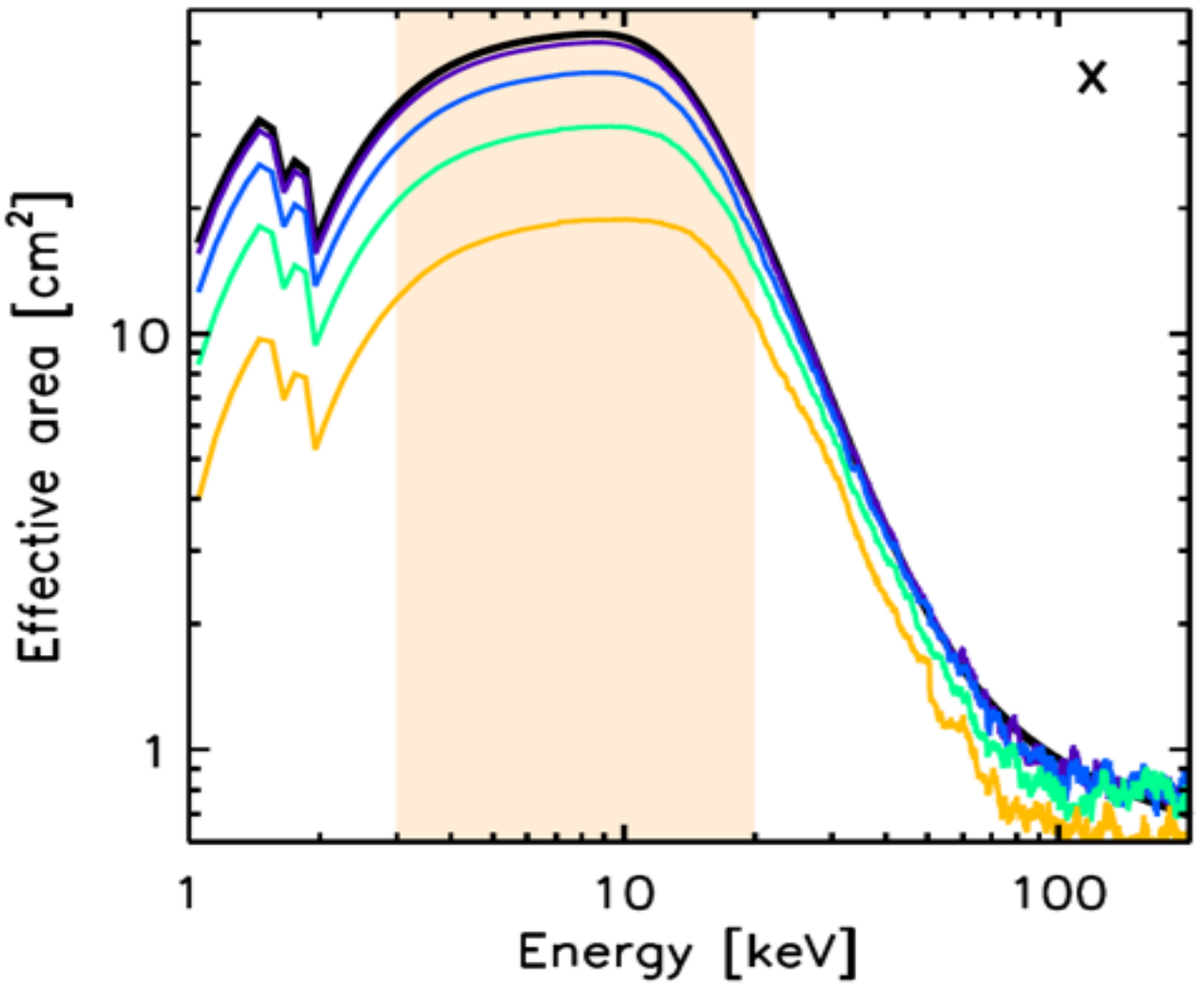
HERMES performances



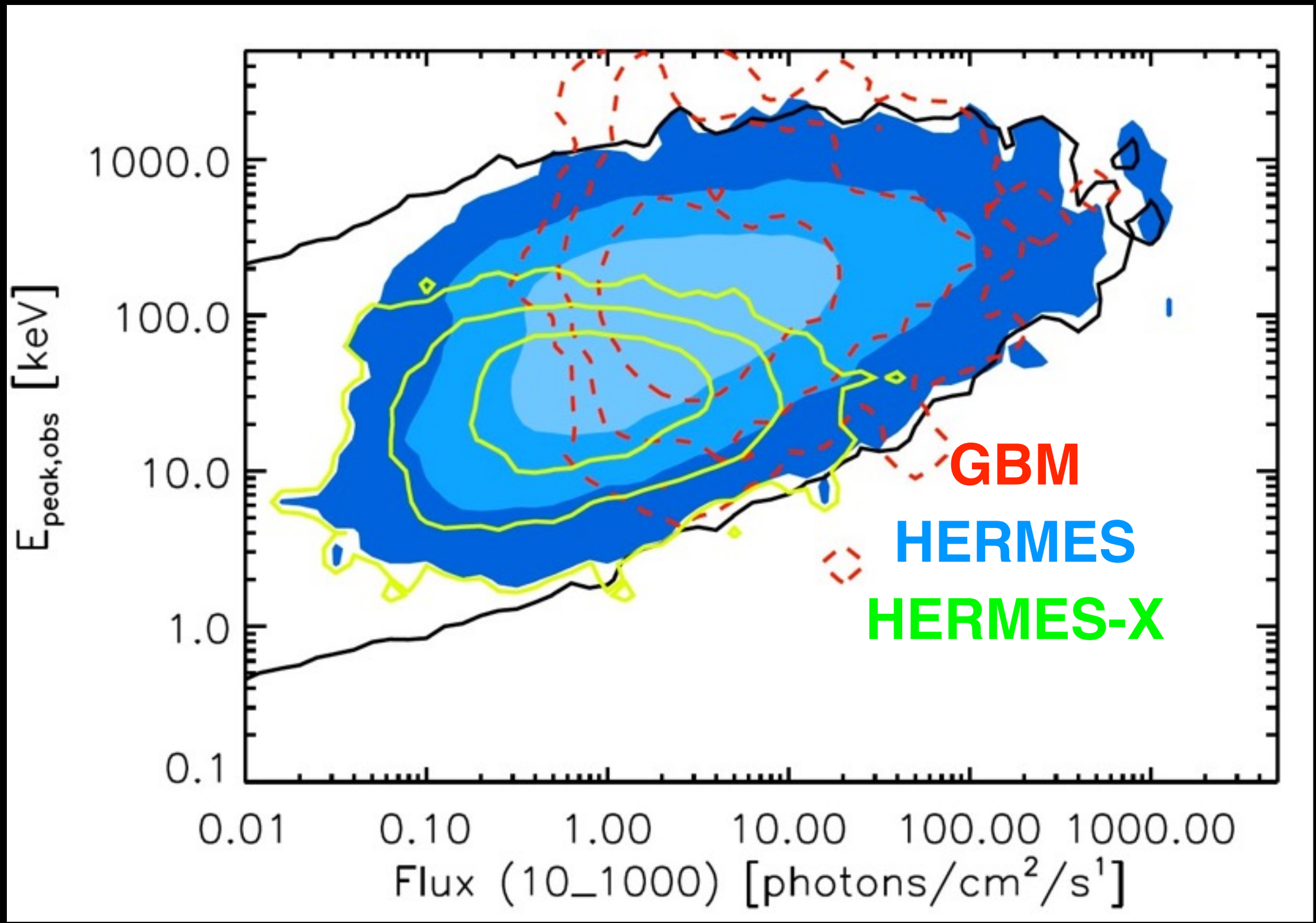


Background: 50-300 keV =75counts/s; 3-20 keV 390counts/s

HERMES vs. GBM: half collecting area but ~1/3 lower background and soft energy band

HERMES performances

Using Ghirlanda/Nava Mock GRB catalog



HERMES performances

$$\sigma_{Pos} = 2.4°[(\sigma_{CCF}^2 + \sigma_{sys}^2)/(N-3)]^{0.5}$$

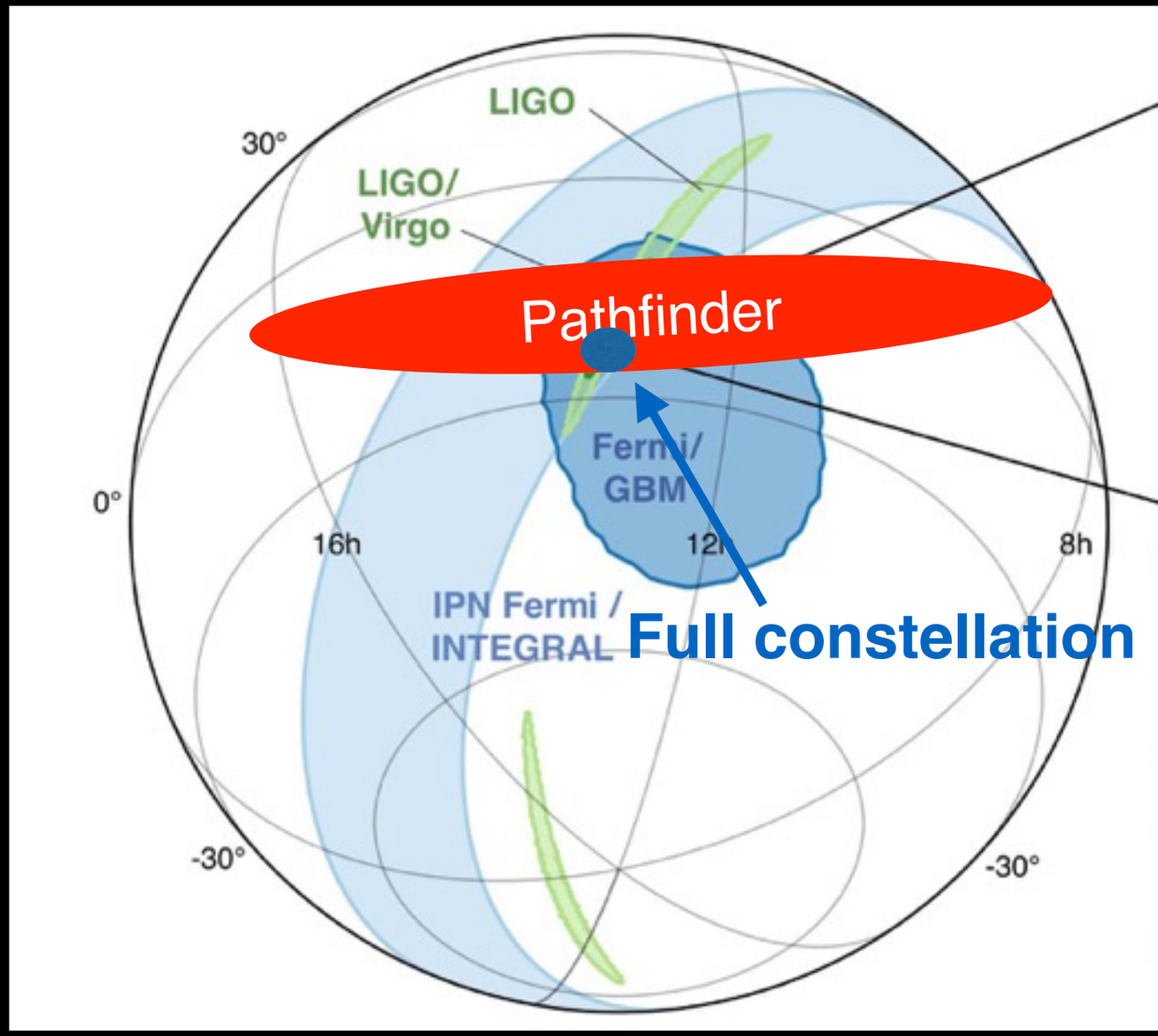
<B>~7000km

N(pathfinder)~6-8, active simultaneously 4-6

σ_{Pos}~ 2.4 deg if $\sigma_{CCF,}\sigma_{sys}$~1ms

N(Full constellation) ~100, active 50

$\sigma_{Pos(FC)}$ ~ 15 arcmin if $\sigma_{CCF,}\sigma_{sys}$~1ms



HERMES Institutes

- INAF, ASI, PoliMi, UniCagliari, UniPalermo, UniUdine, UniTrieste, UniPavia, UniFedericoII, UniFerrara, FBK, FPM
- University of Tubingen (Germany)
- University of Eotvos Budapest, C3S (Hungary)
- University of Nova Gorica, Skylabs, AALTA (Slovenia)
- Deimos (Spain)

Programmatics

Progetto Premiale 2015: **HERMES-Techonogic Pathfinder**

H2020 SPACE-SCI-20: **HERMES-Scientific Pathfinder**

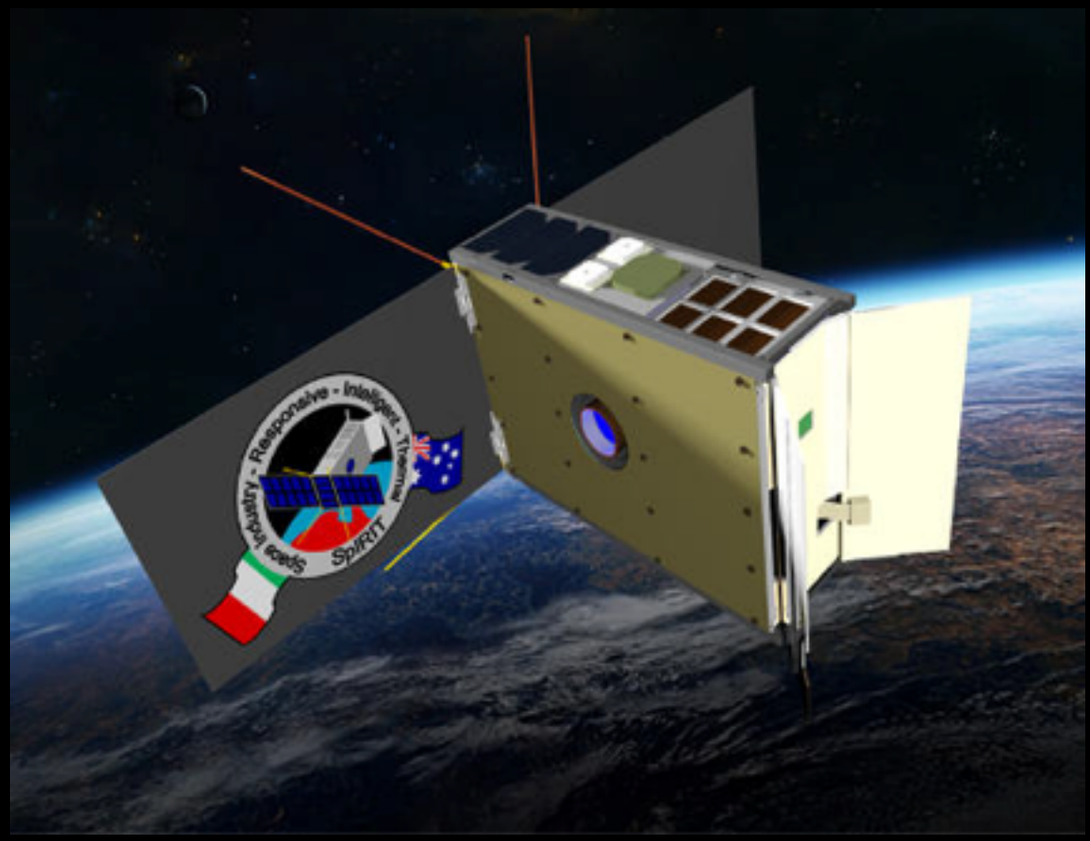
Main objectives:

1. Detect GRBs with simple payload hosted by a 3U CubeSat
2. Study statistical and systematic errors in the CCF determination
3. **First GRB localization experiment with ≥3 CubeSat**

- KO May 2018, Nov. 2018
- PDR February-March 2019, DeltaPDR November 2019
- CDR Q3 2020
- QR Q2 2021—> PFM1
- AR Q4 2021 —> FM2+FM3+FM4+FM5+FM6
- Launch 2022, ASI provided

Next Step

- ✦ Addition of a seventh unit: SpIRIT!
  - Australian Space Agency, University of Melbourne
  - 6U hosting 1 HERMES payload
  - Launch: Q3 2022
  - SSO



Thanks!