# HERMES

## Pathfinder

fabrizio.fiore@inaf.it

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The project has received funding from the Accordo Attuativi ASI-INAF and ASI-POLIMI

# Outline

- Why i am here
- Today challenges & opportunities: two revolutions:
  - Multimessenger astrophysics
  - Space 4.0
- HERMES ***distributed*** instrument: a coming breakthrough
  - Concept
  - Programmatics and funds
  - Status of the project(s)
  - Outlook and criticalities

# Two revolutions

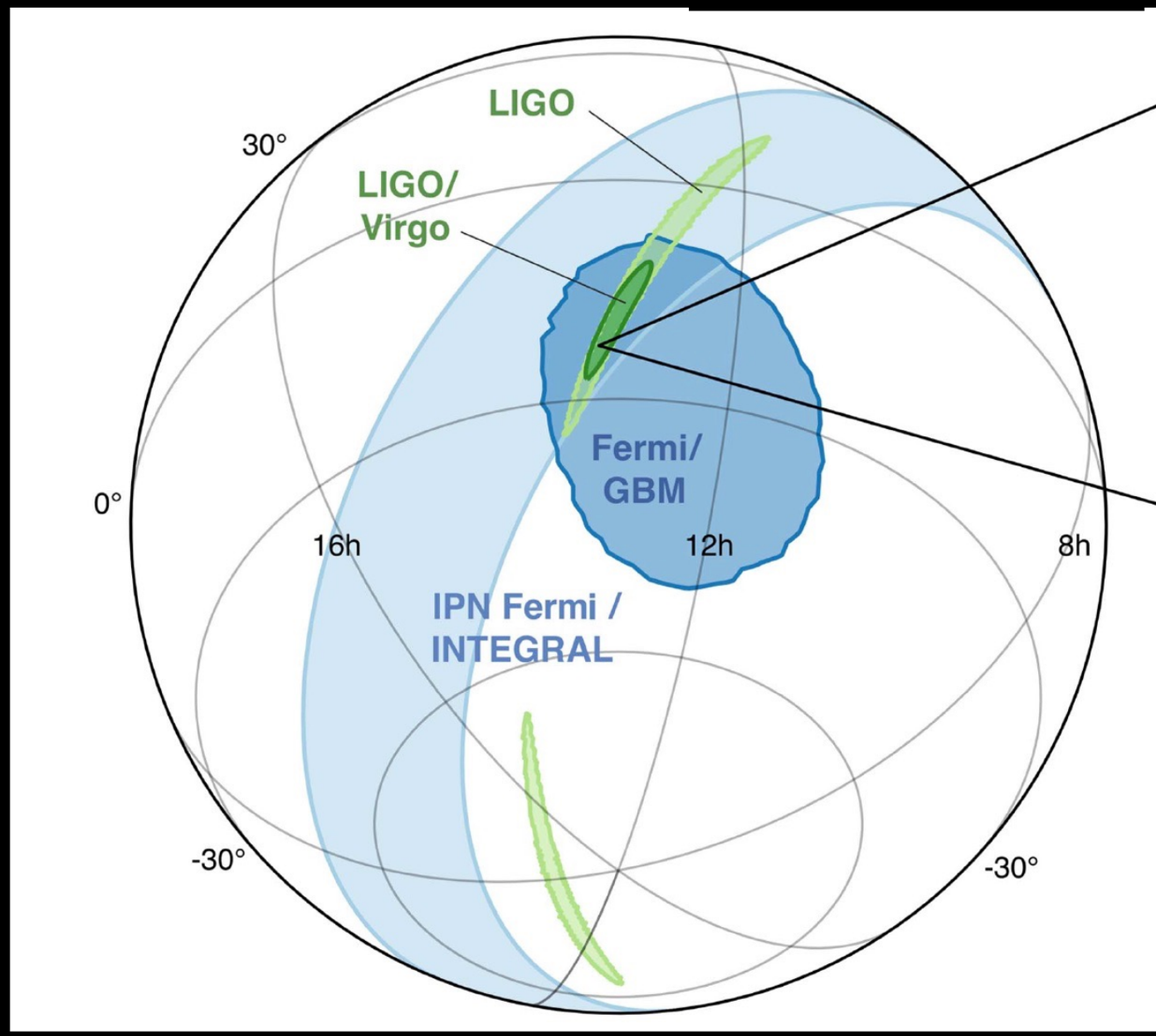
## Multimessenger astrophysics

## GW170817

Advanced Ligo/Virgo provide position with accuracy ~ tens deg

NS-NS and BH-NS coalescence:
100-200 Mpc horizon
GRB, cocoon, kilonova..

BH-BH coalescence:
>Gpc horizon
no expected EM counterpart
(even more exciting if one is found…)



# Two revolutions

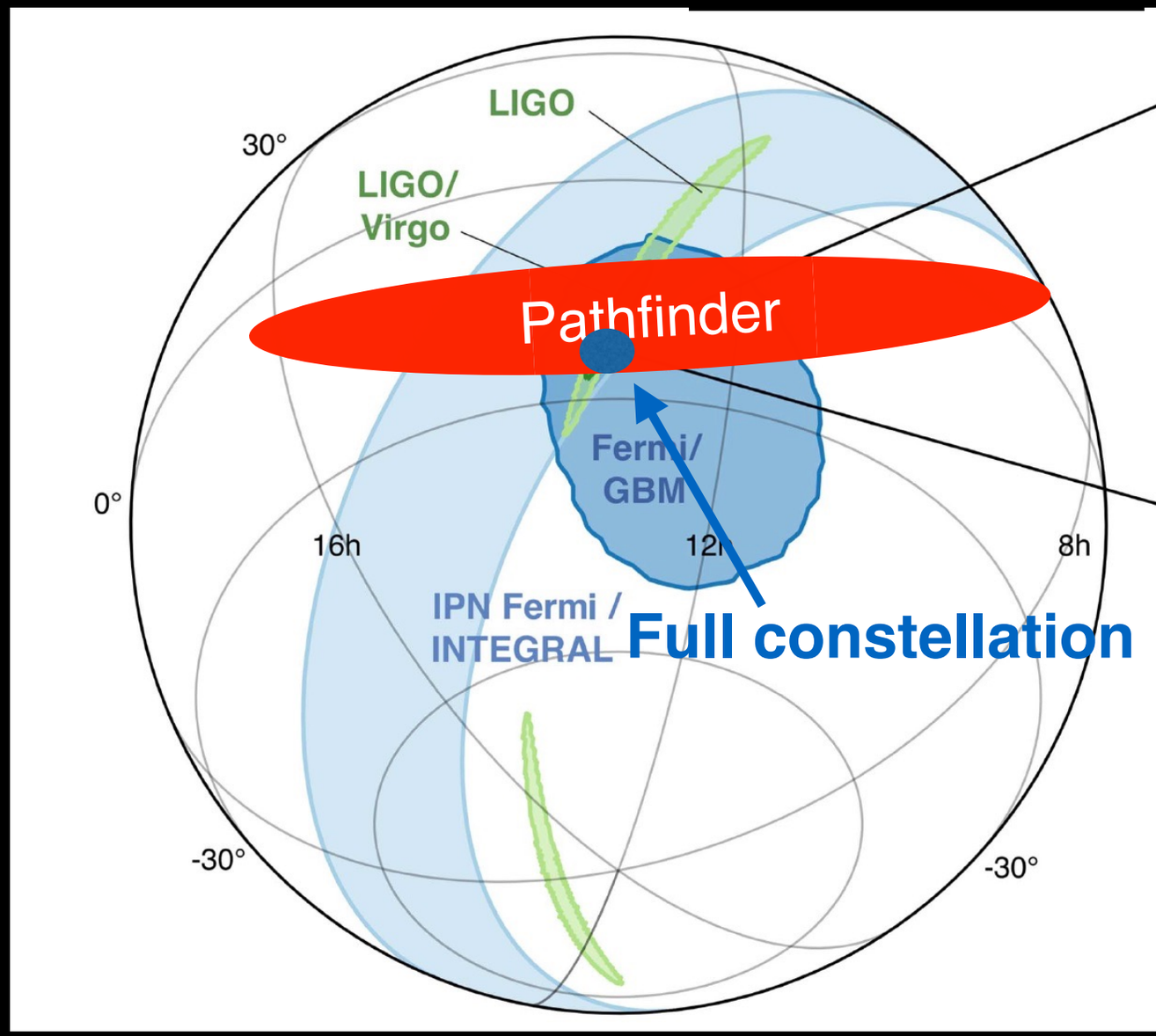
## Multimessenger astrophysics

## GW170817

Large volumes difficult to survey at optical λ.

Tens/hundreds/thousands optical transients.

Best strategy:
~ all sky prompt search for transients at high energies.
Negligible probability to find an uncorrelated HEA transient at the time of GWE



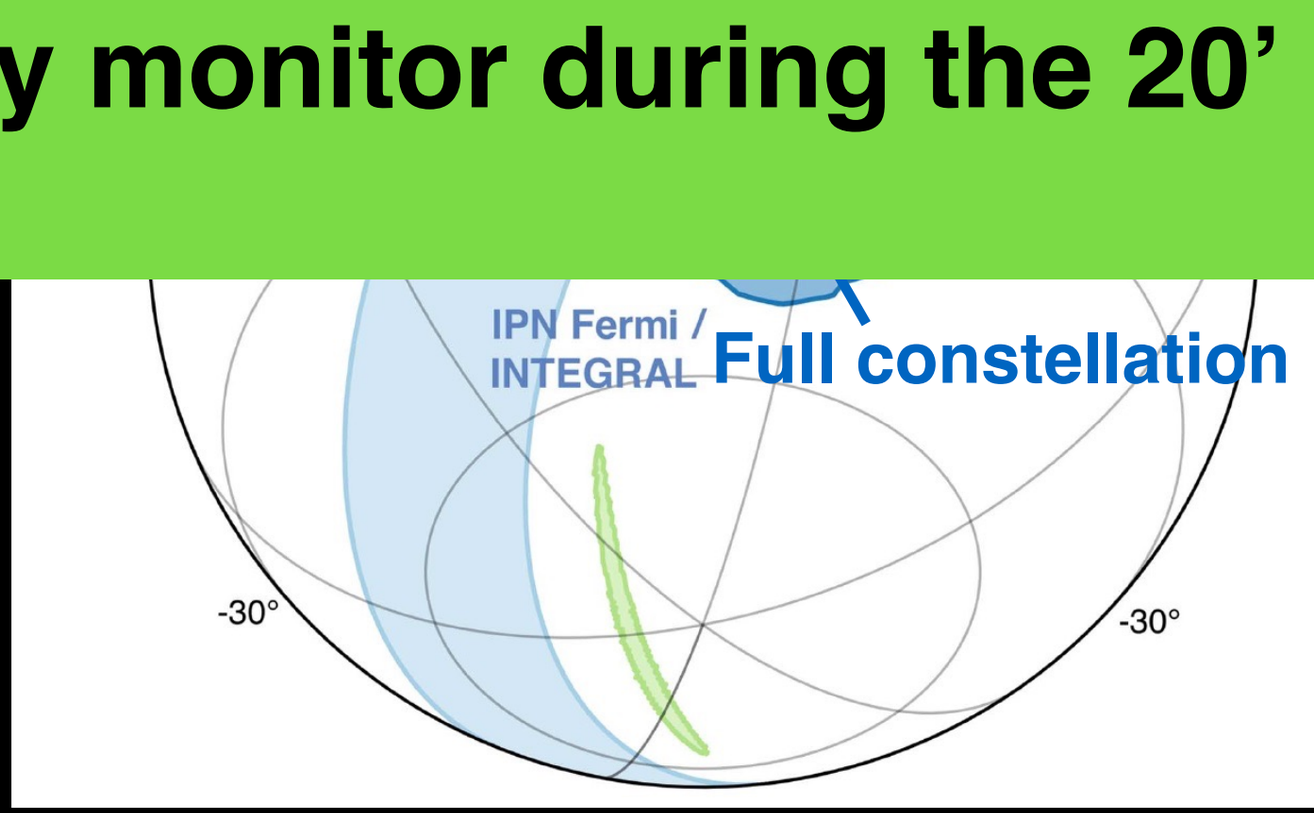
# Two revolutions

## Multimessenger astrophysics

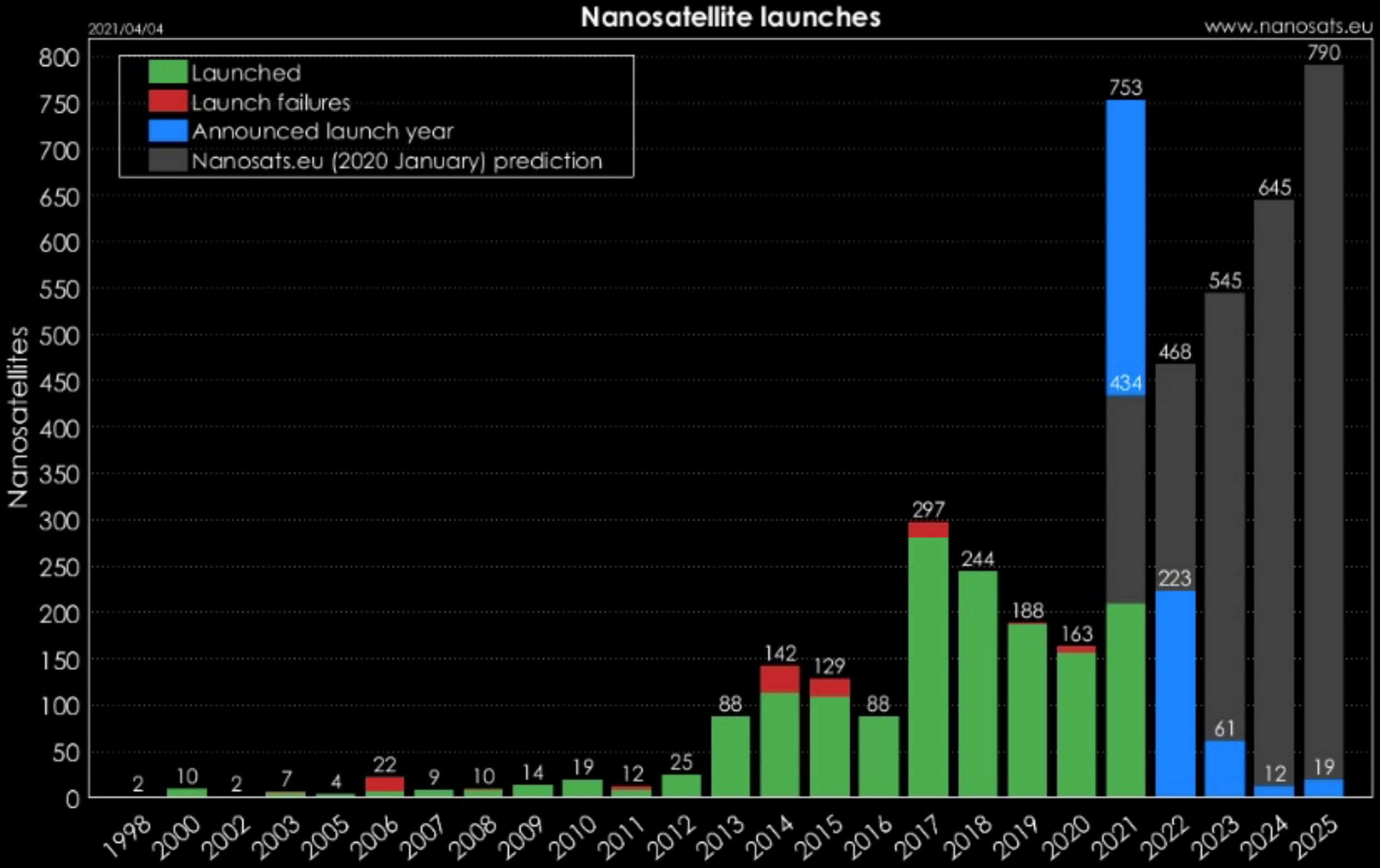
**Current facilities, Swift, INTEGRAL, FERMI, AGILE, are aging:**

**A sensitive X-ray all sky monitor during the 20’**

Best strategy:
~ all sky prompt search for transients at high energies.
Negligible probability to find an uncorrelated HEA transient at the time of GWE



# Space 4.0


Nanosatellite launches
2021/04/04
www.nanosats.eu
Launched
Launch failures
Announced launch year
Nanosats.eu (2020 January) prediction
Nanosatellites
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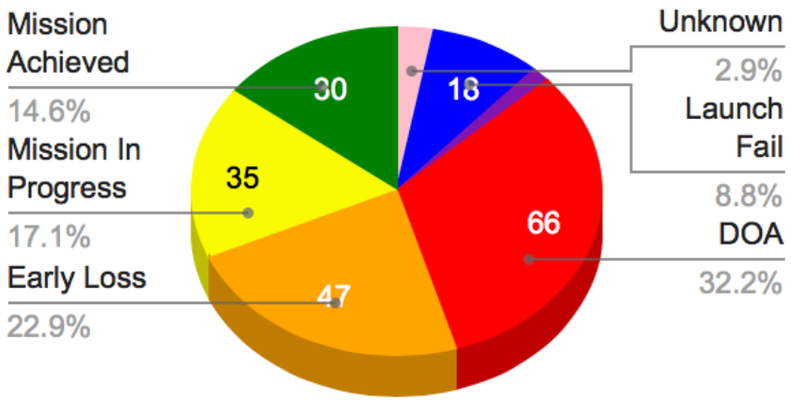
# Space 4.0

## Nanosatellite launches

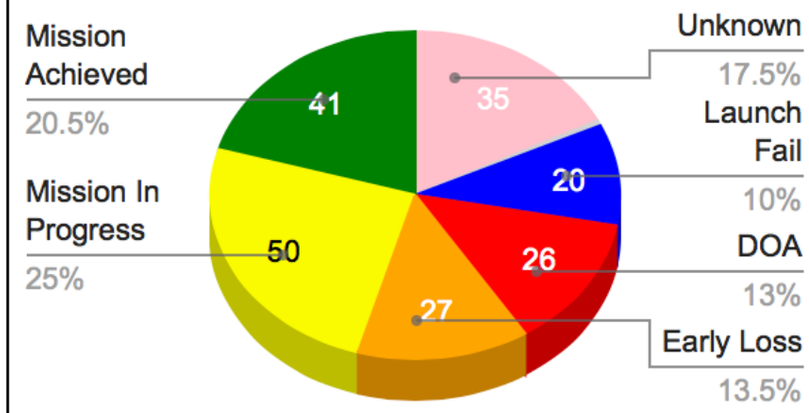
2021/04/04

www.nanosats.eu

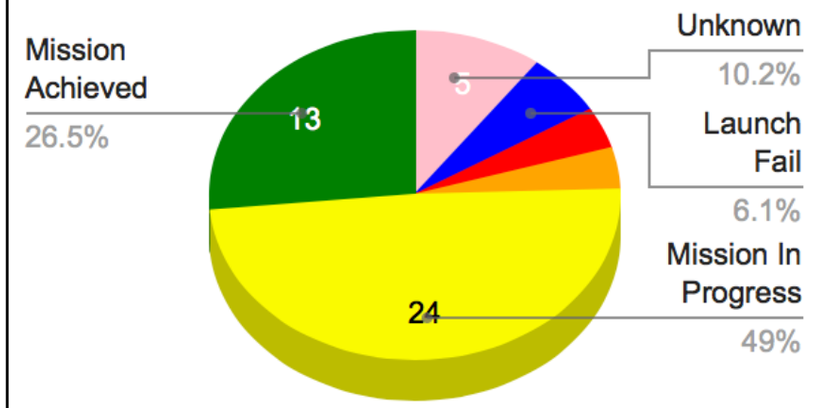
**CubeSat Mission Status, 2000-present, Hobbyists, 205 Spacecraft**



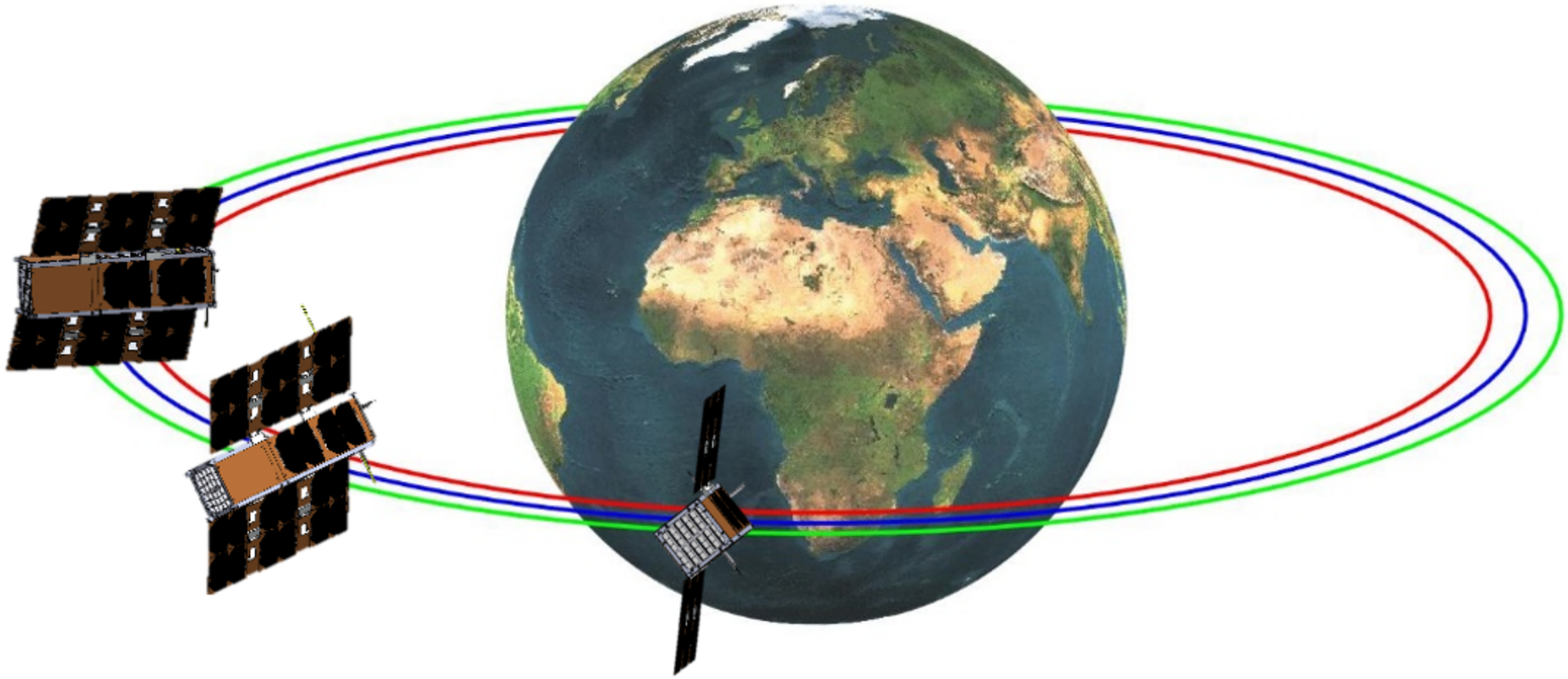

**CubeSat Mission Status, 2000-present, Crafters, 200 Spacecraft**




**CubeSat Mission Status, 2000-present, Industrialists, 49 Spacecraft**



# HERMES



# Mission concept

Disruptive technologies: cheap, underperforming, but producing high impact. ***Distributed instrument:*** tens/hundreds of simple units to form a sensitive ***all sky monitor***

## HERMES constellation of cubesat

2016: ASI funds for detector R&D: **0.4MEUR**

2018: MIUR funds (Progetti premiali  2015), managed by ASI **~3 MEUR**

2018 H2020 Space-SCI-20 project:
**3.3 MEUR**

2019 ASI internal progetto premiale:
**1.9MEUR**

# Why HERMES now

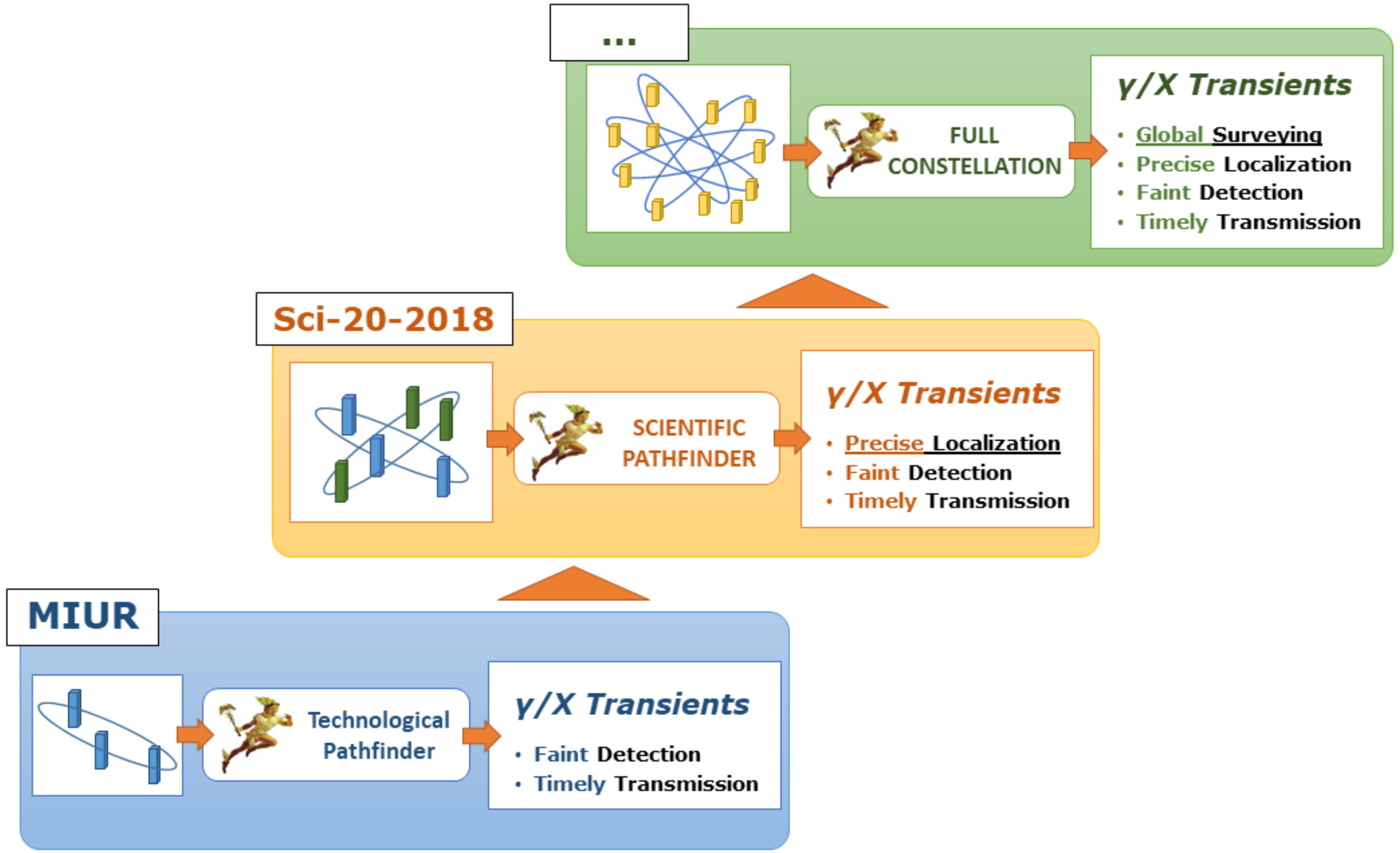
**Breakthrough scientific case:**

- EM of GWE

**Modularity:**

- Avoid single point failures, improve hardware
- Pathfinder

# Why HERMES now



# Why HERMES now

**Breakthrough scientific case:**

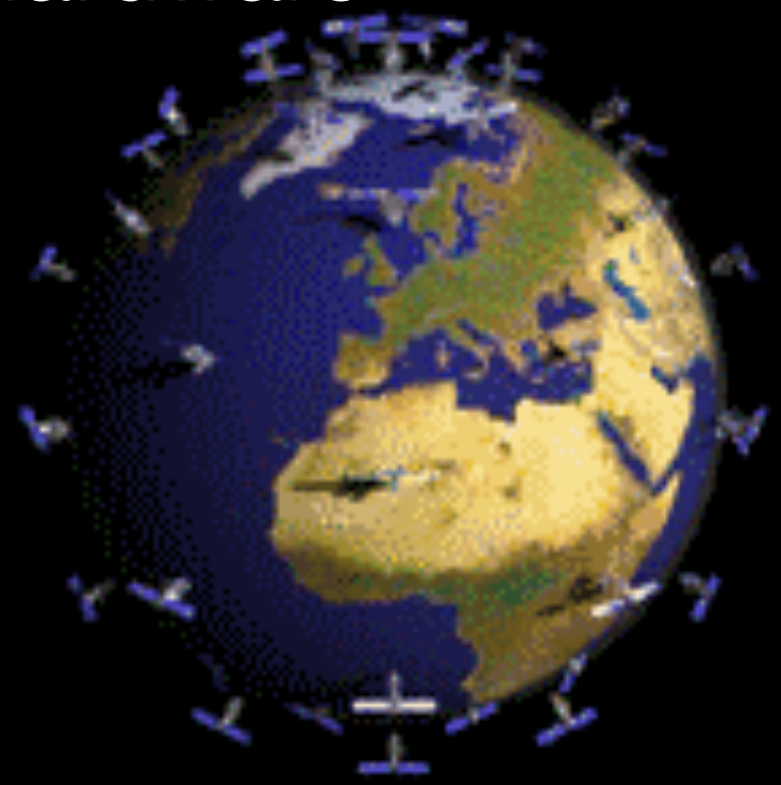
- EM of GWE

**Modularity:**

- Avoid single point failures, improve hardware
- Pathfinder

**Open µsec - msec window:**

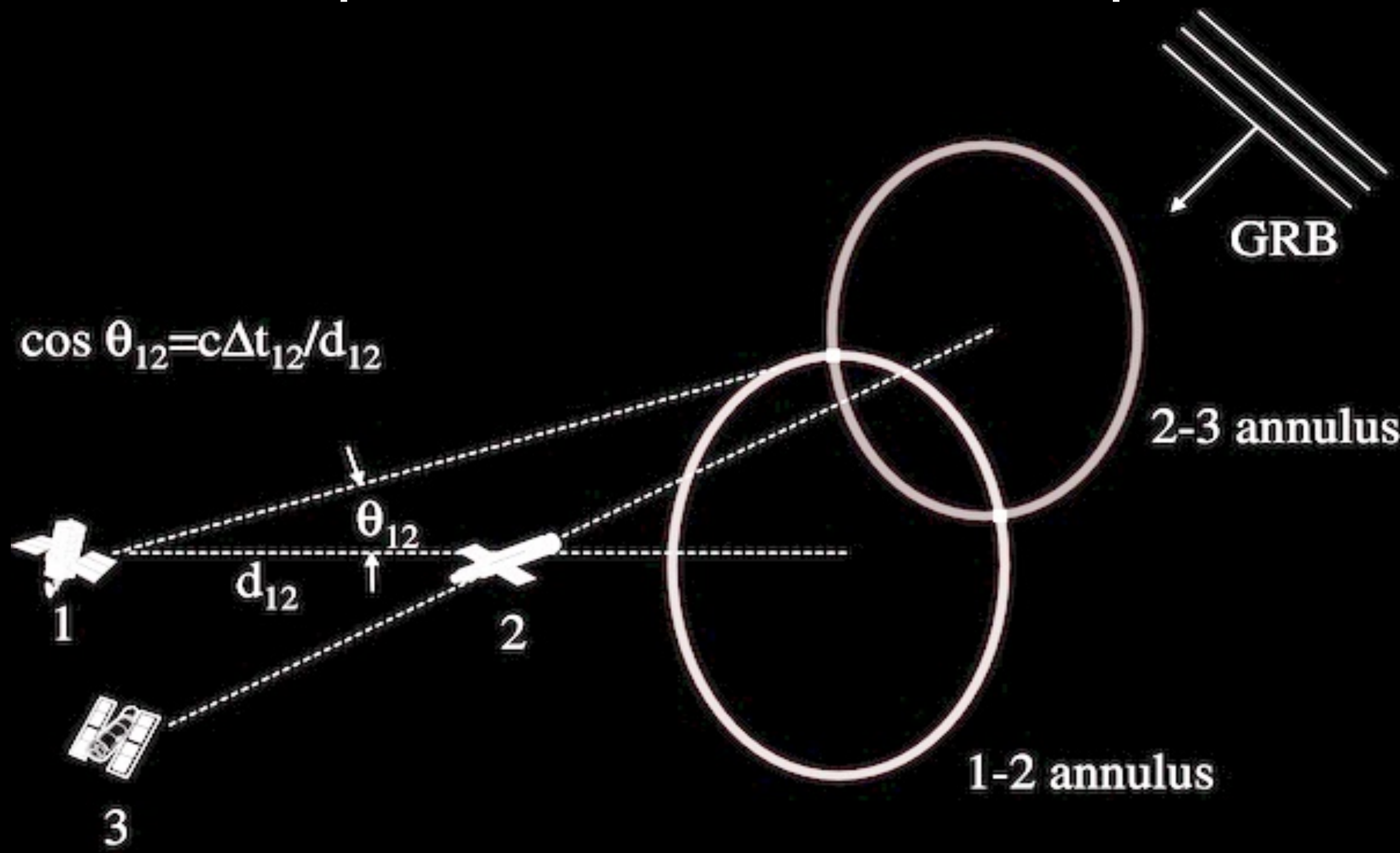
- Accurate positions
- QG tests



**Limited cost and quick development**

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

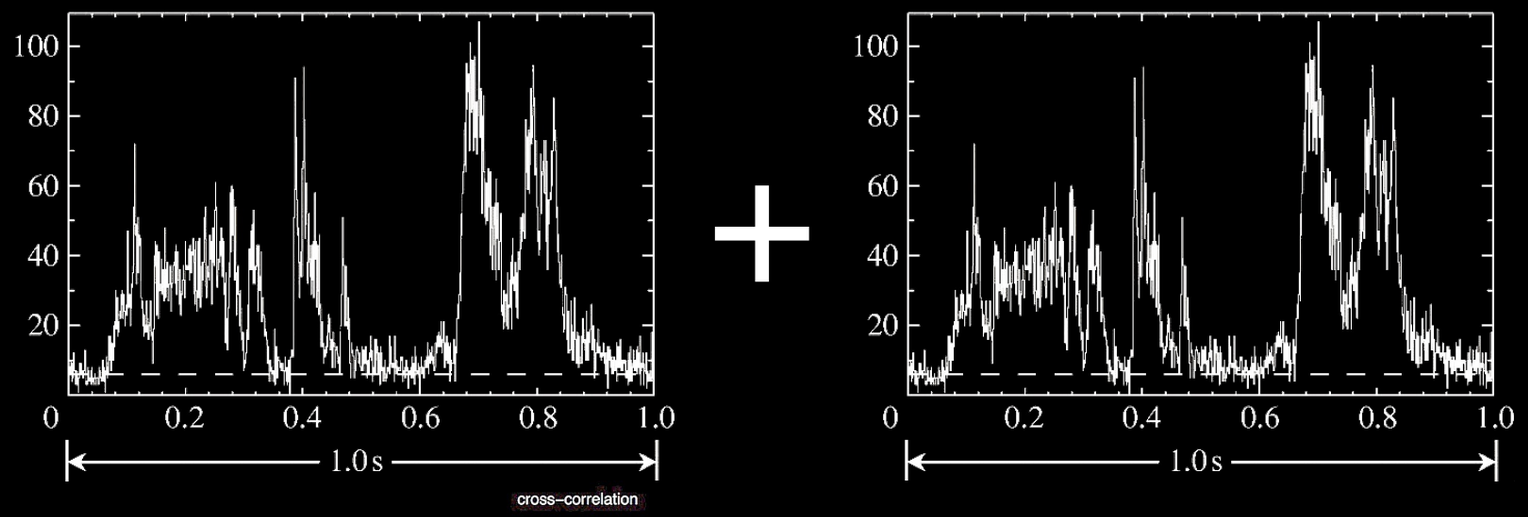
# Experiment concept

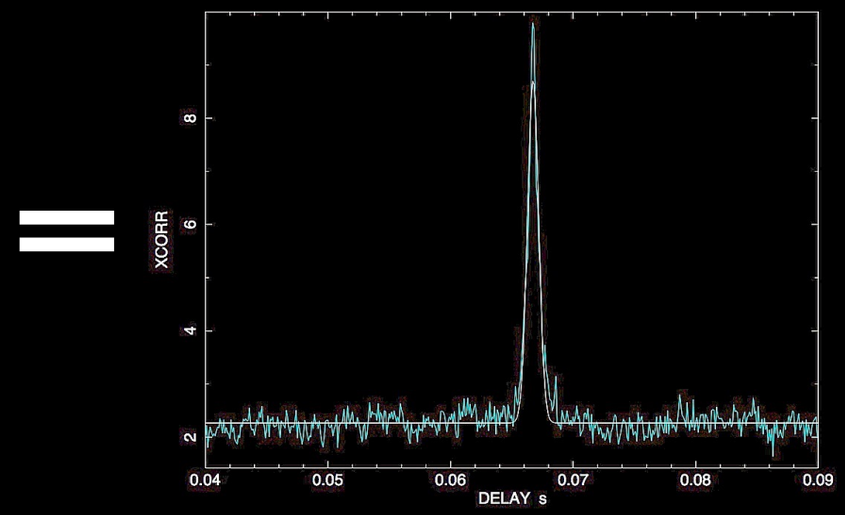


# Experiment concept

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

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

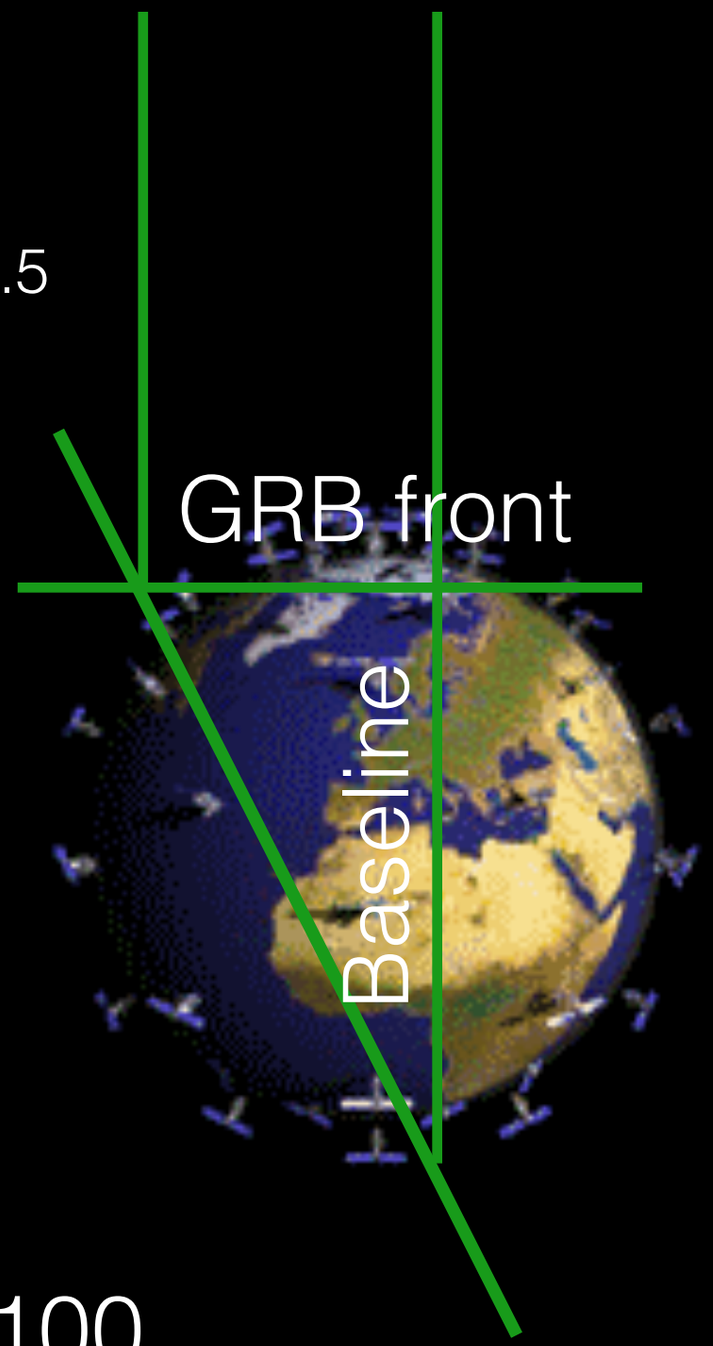



$\sigma_{CCF} \sim 10\mu s$

$\sigma_{Pos} \sim 10 arcsec$

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



# Experiment concept

2. Add the signal from different units

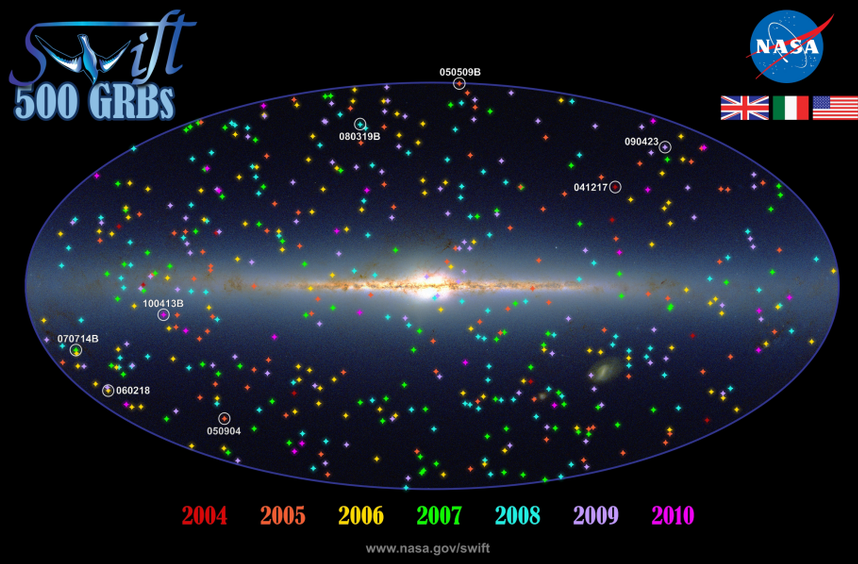
Total collecting area 50-100-$cm^2$ x 100-200 = 0.5-2 $m^2$

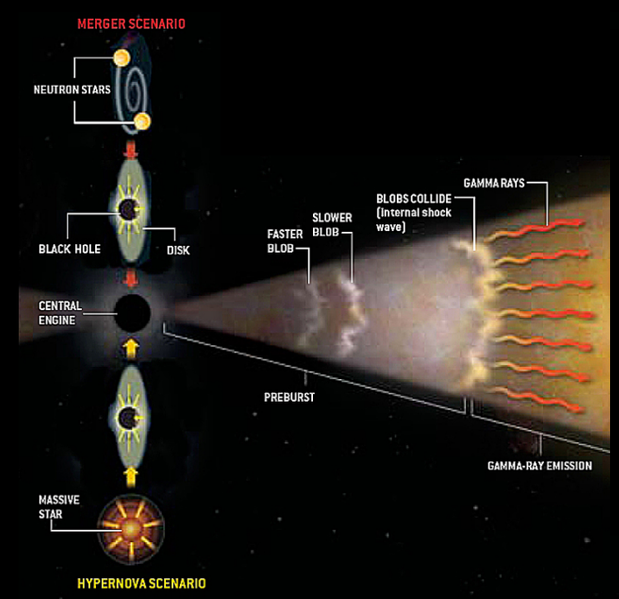
Transient fine (subμs-ms) temporal structure

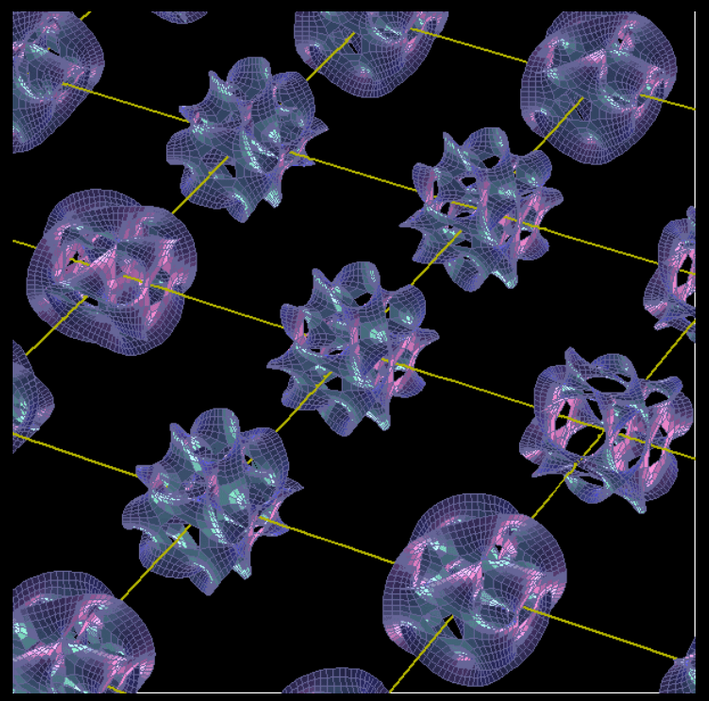
How to *promptly* localise a GRB *prompt* event?

How to construct a GRB engine?

Which is the ultimate granular structure of space-time?



# Requirements

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

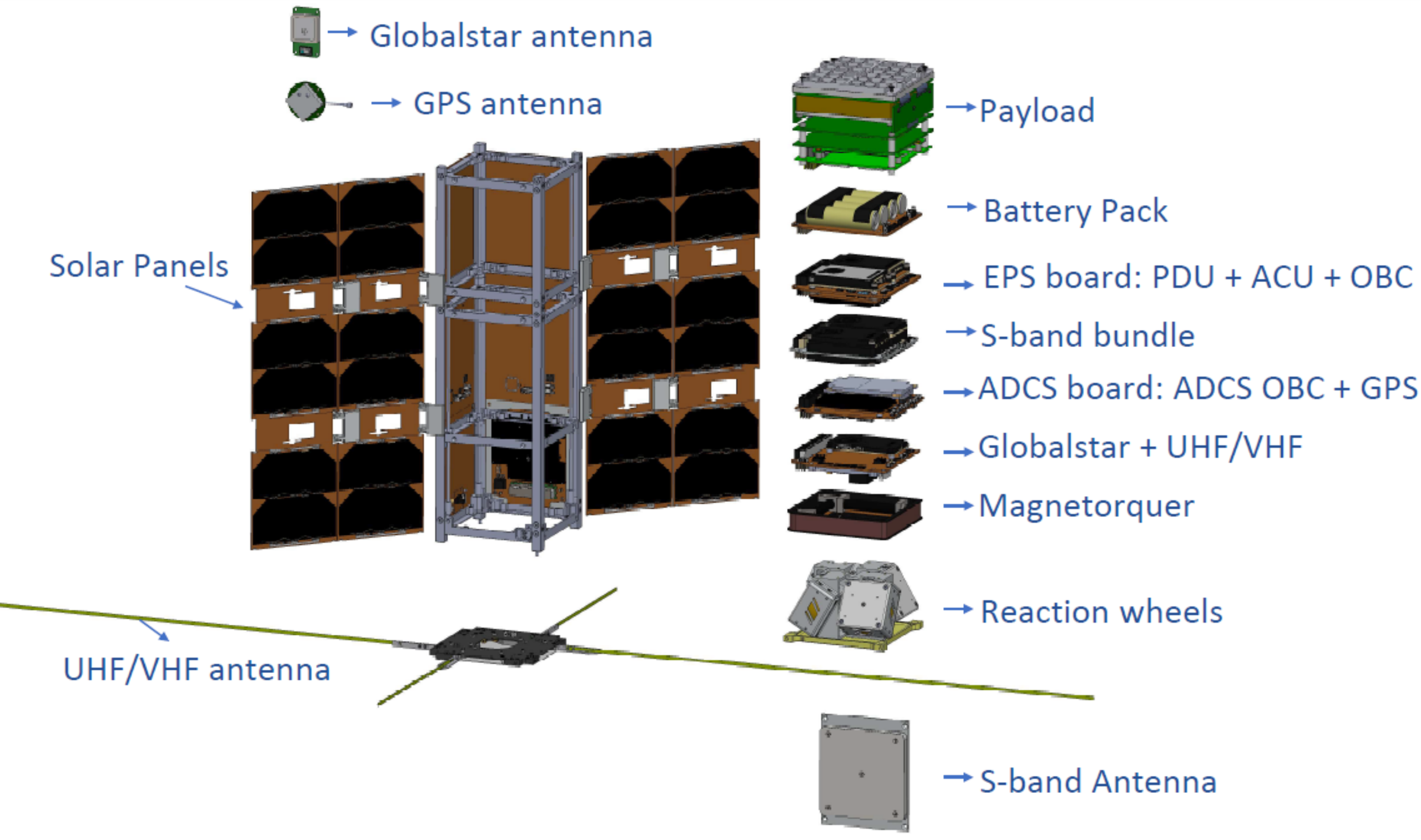
Download full burst info in minutes

# Spacecraft

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

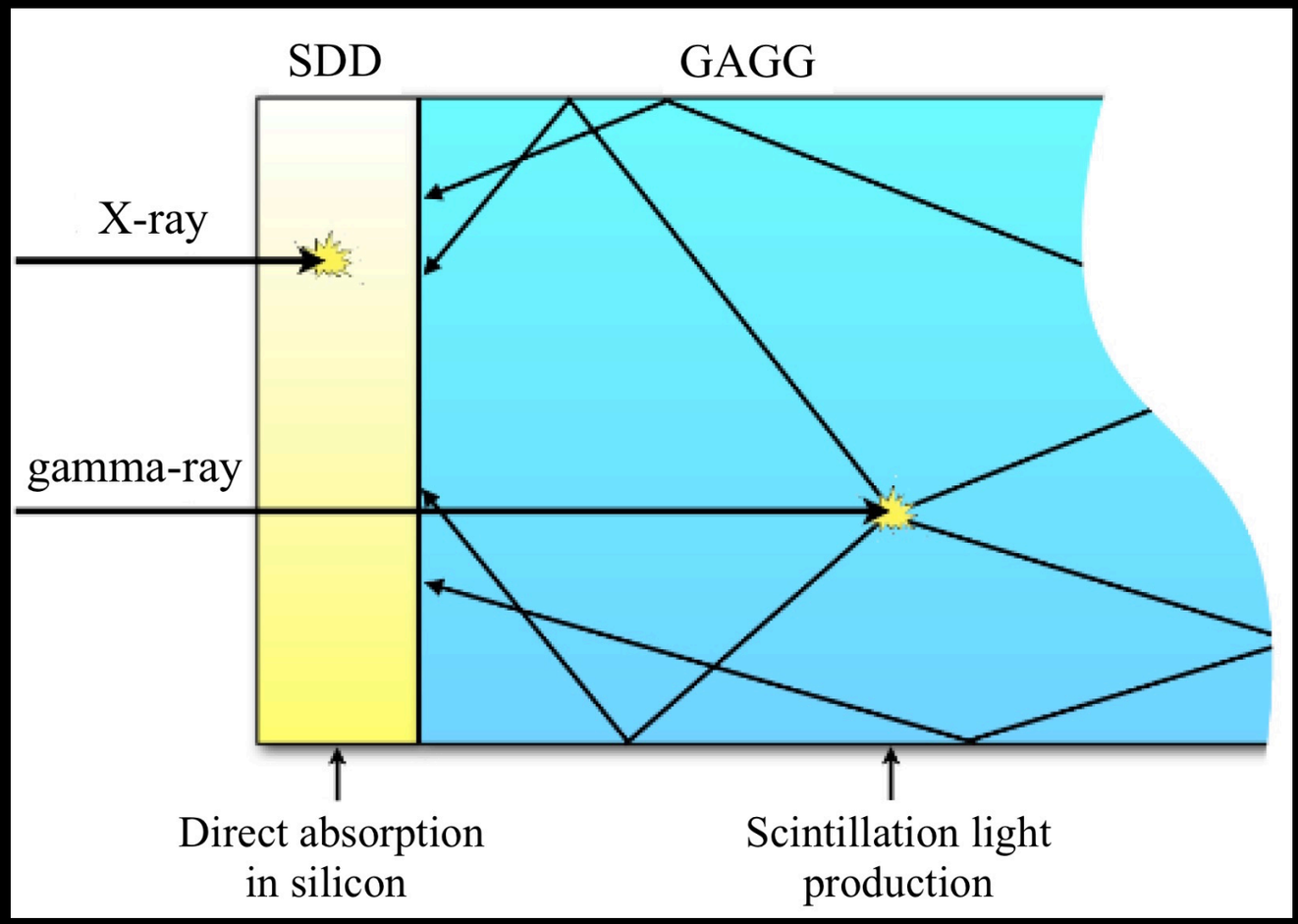
6U more performing configuration
~200$cm^2$ detector, more accurate GPS, more accurate AOCS: Full Constellation

# Spacecraft


Globalstar antenna
GPS antenna
Payload
Solar Panels
Battery Pack
EPS board: PDU + ACU + OBC
S-band bundle
ADCS board: ADCS OBC + GPS
Globalstar + UHF/VHF
Magnetorquer
Reaction wheels
UHF/VHF antenna
S-band Antenna

# Payload concept

- Photo detector, SDD
  Scintillator crystal GAGG

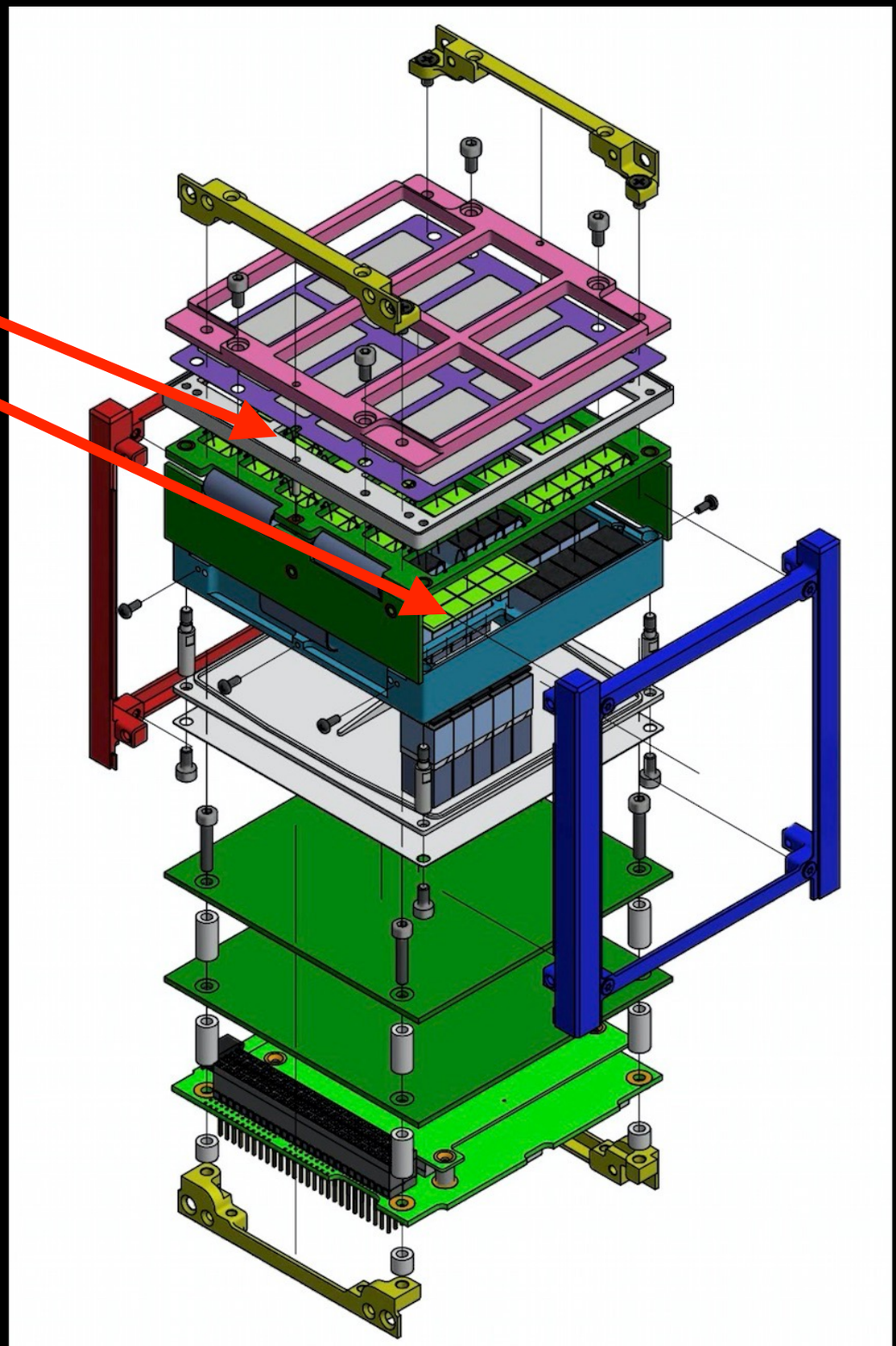



Fuschino+2018, 2020
Evangelista+2020
Campana+2020

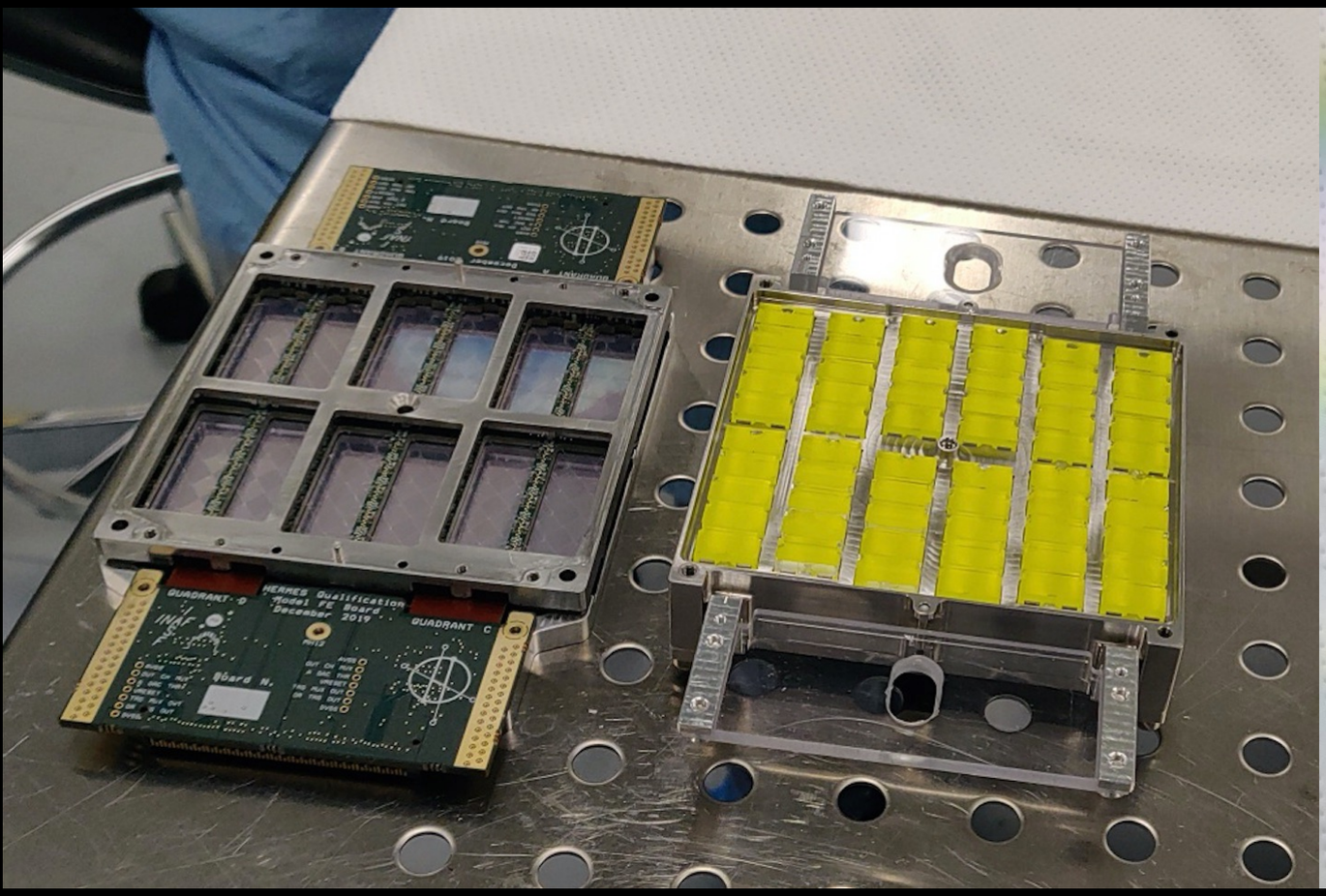
# Payload concept

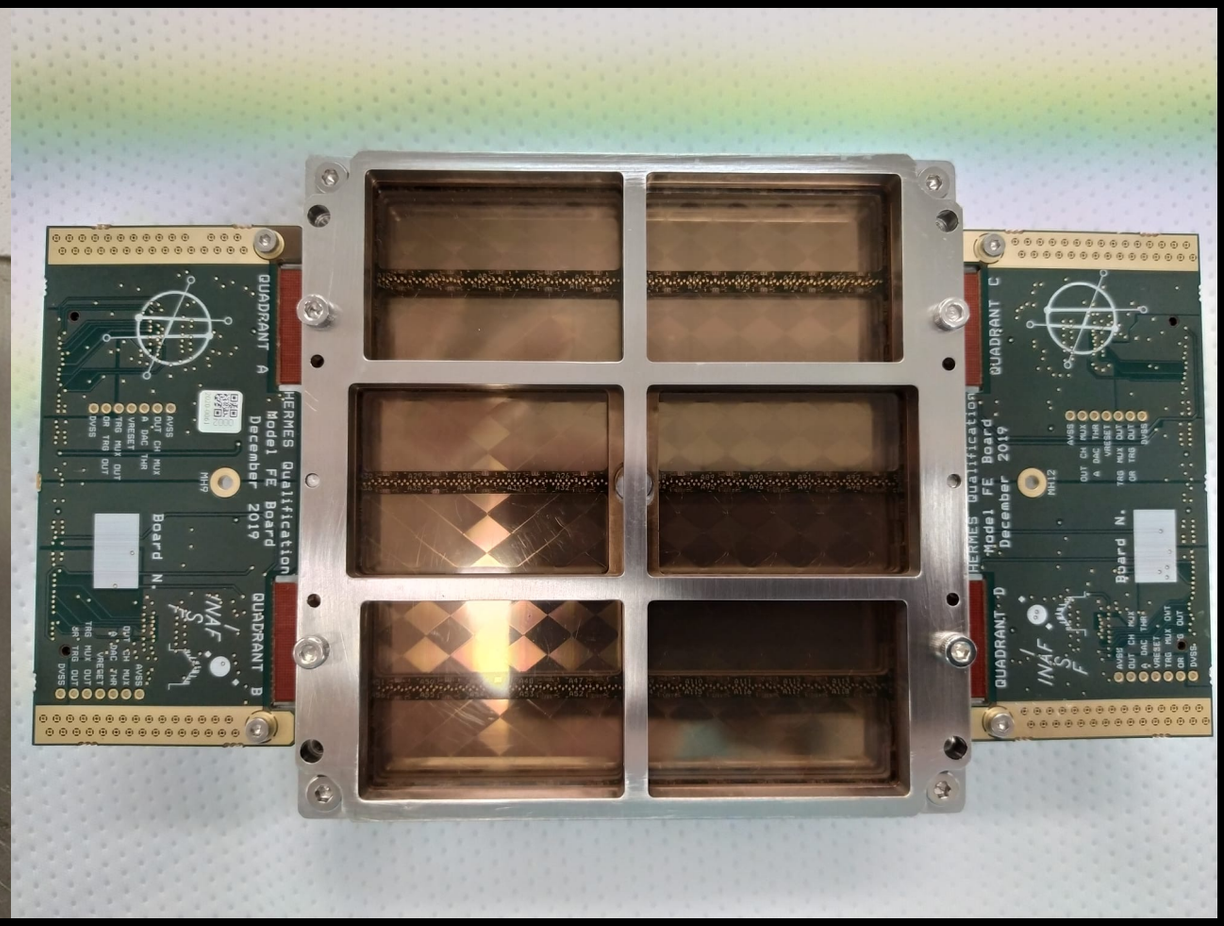
- Photo detector, SDD
  Scintillator crystal GAGG
- 5-300 keV (3-1000 keV)
- ≥50 $cm^2$ coll. area
- a few st FOV
- Temporal res. ≤300 nsec
- ~1.6kg

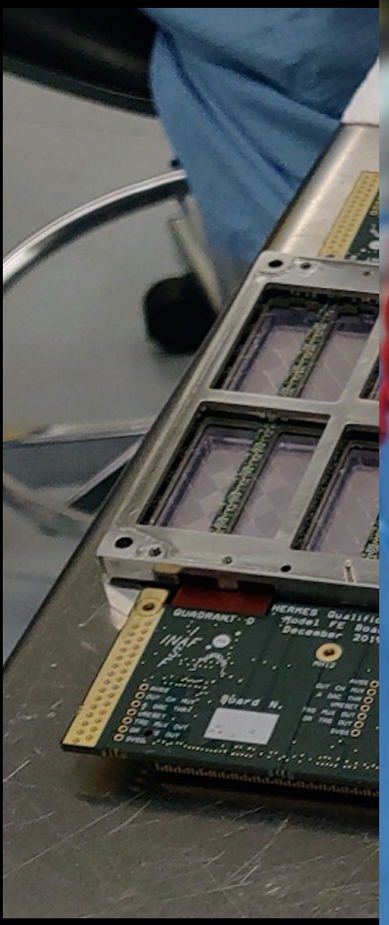
Fuschino+2018, 2020
Evangelista+2020
Campana+2020



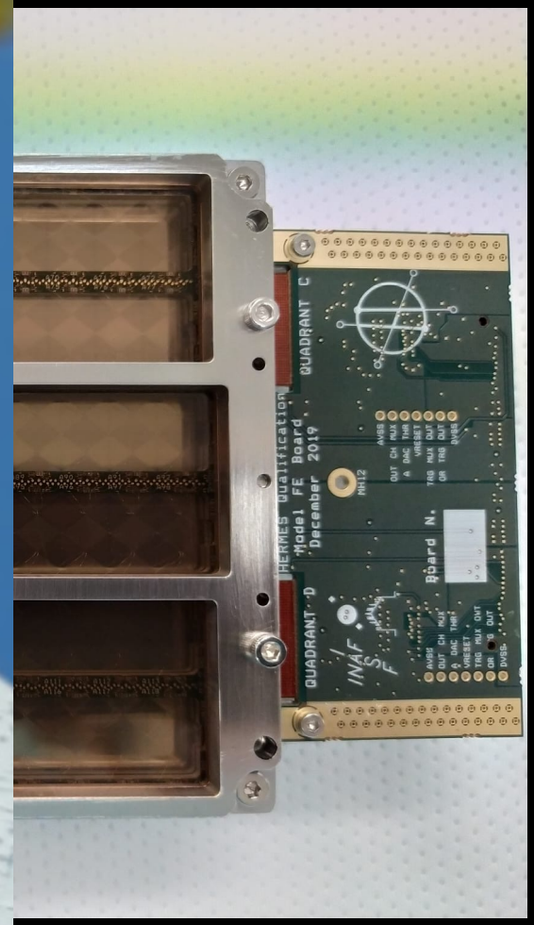
# Hardware


HERMES Qualification
Model FE Board
December 2019
QUADRANT D
QUADRANT C
Board N.


QUADRANT A
QUADRANT B
QUADRANT C
QUADRANT D
HERMES Qualification
Model FE Board
December 2019
Board N.


QUADRANT D
INAF


HERMES Qualification
Model FE Board
December 2019
QUADRANT C
INAF
Board N.
HERMES
SP


HERMES Qualification
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INAF
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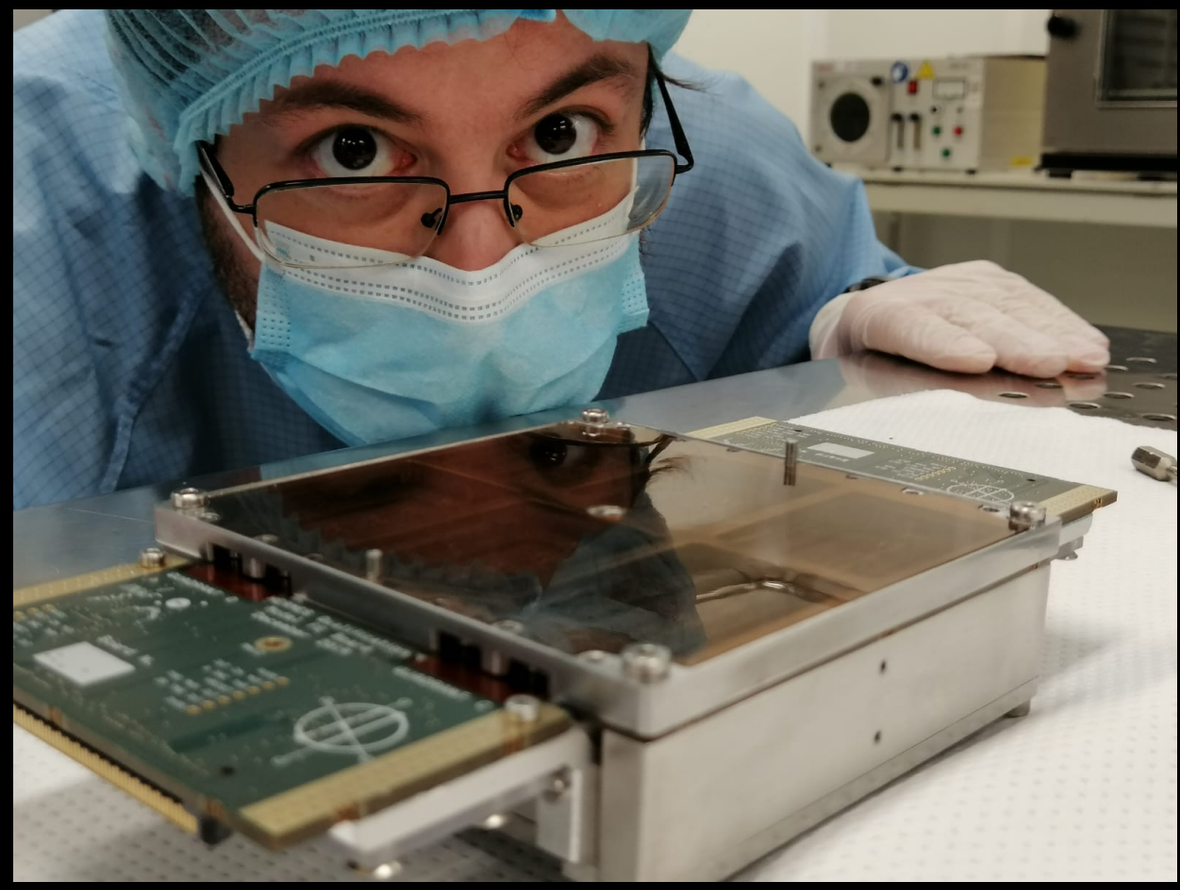
# Payload DM

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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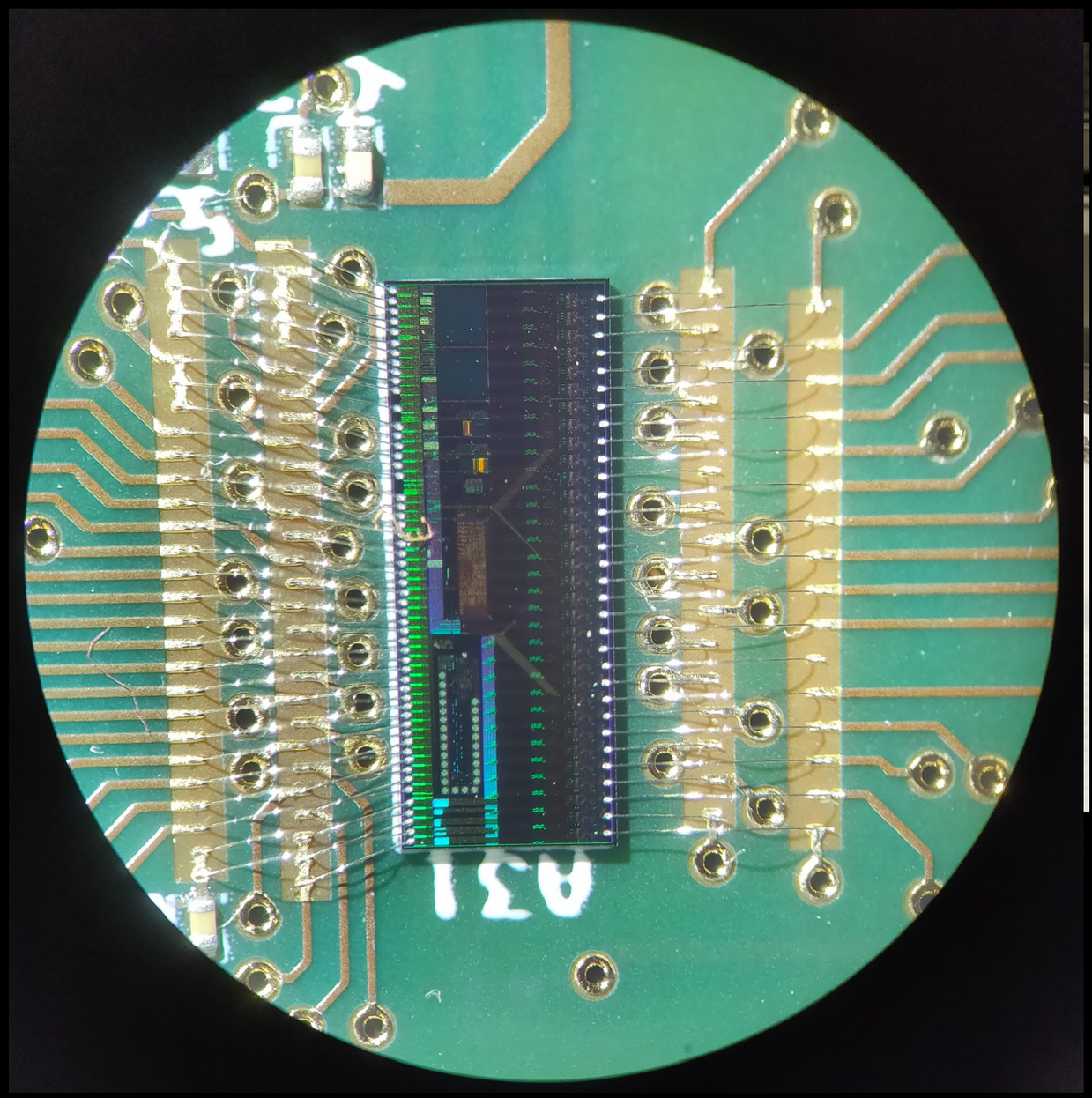

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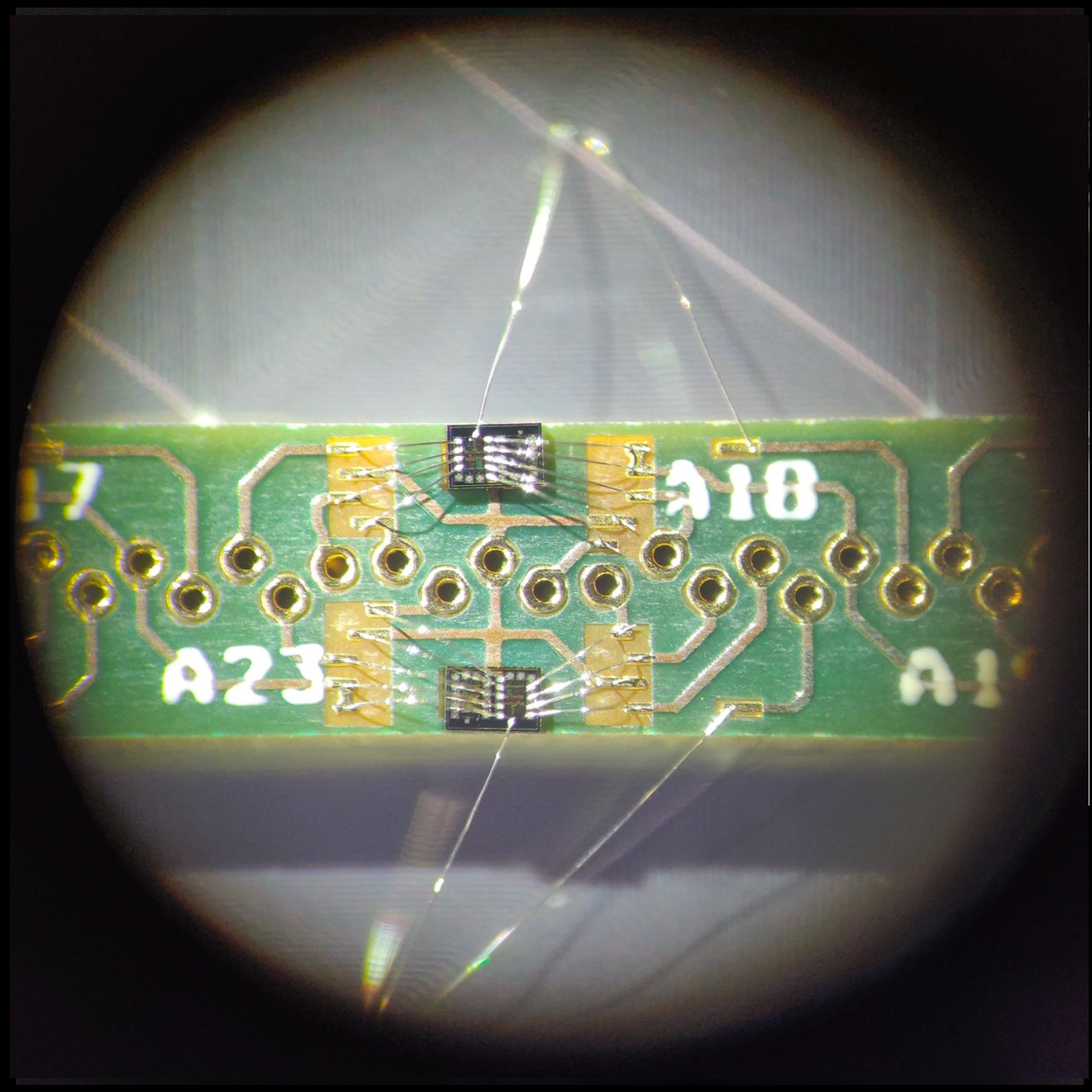

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http:

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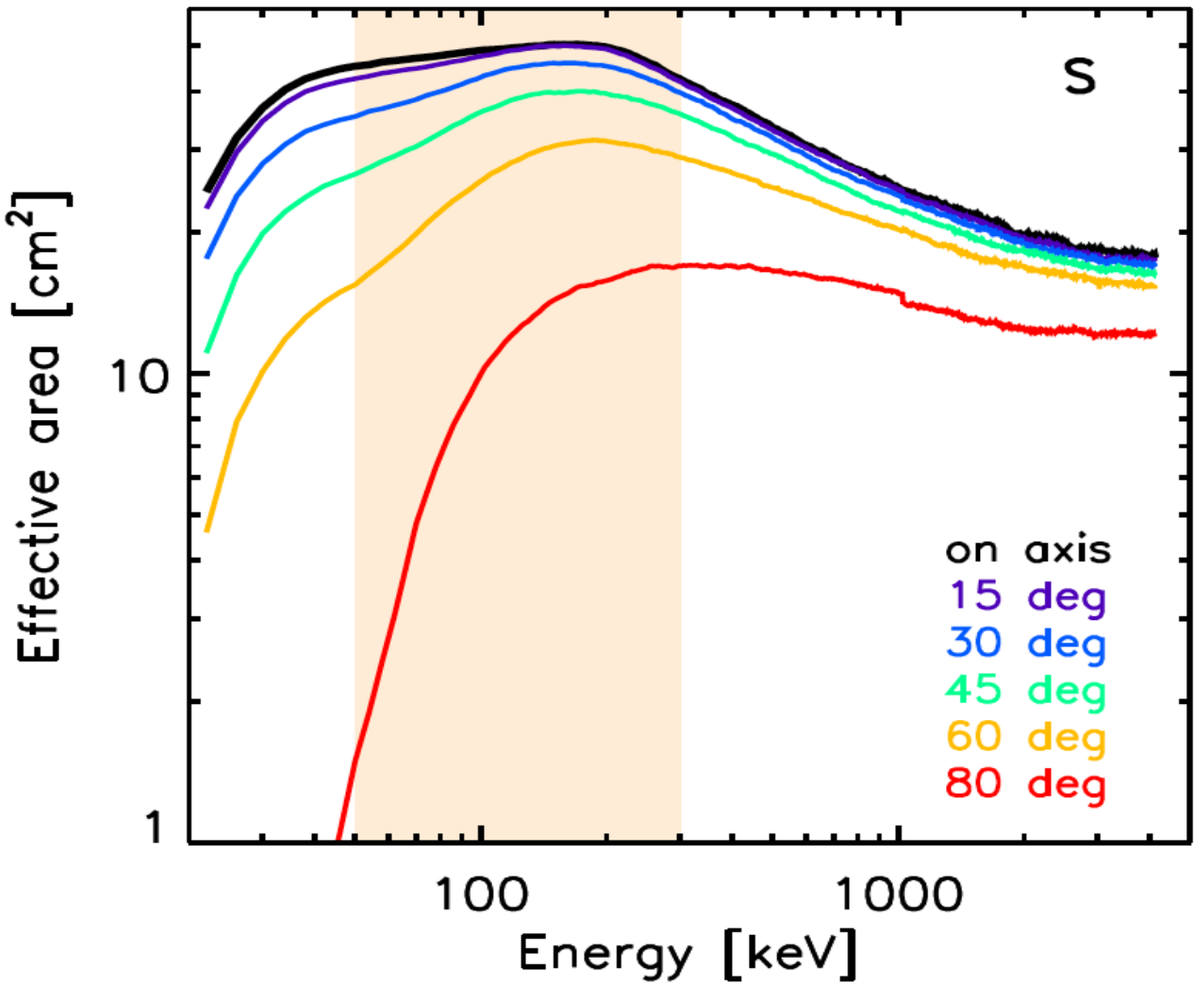
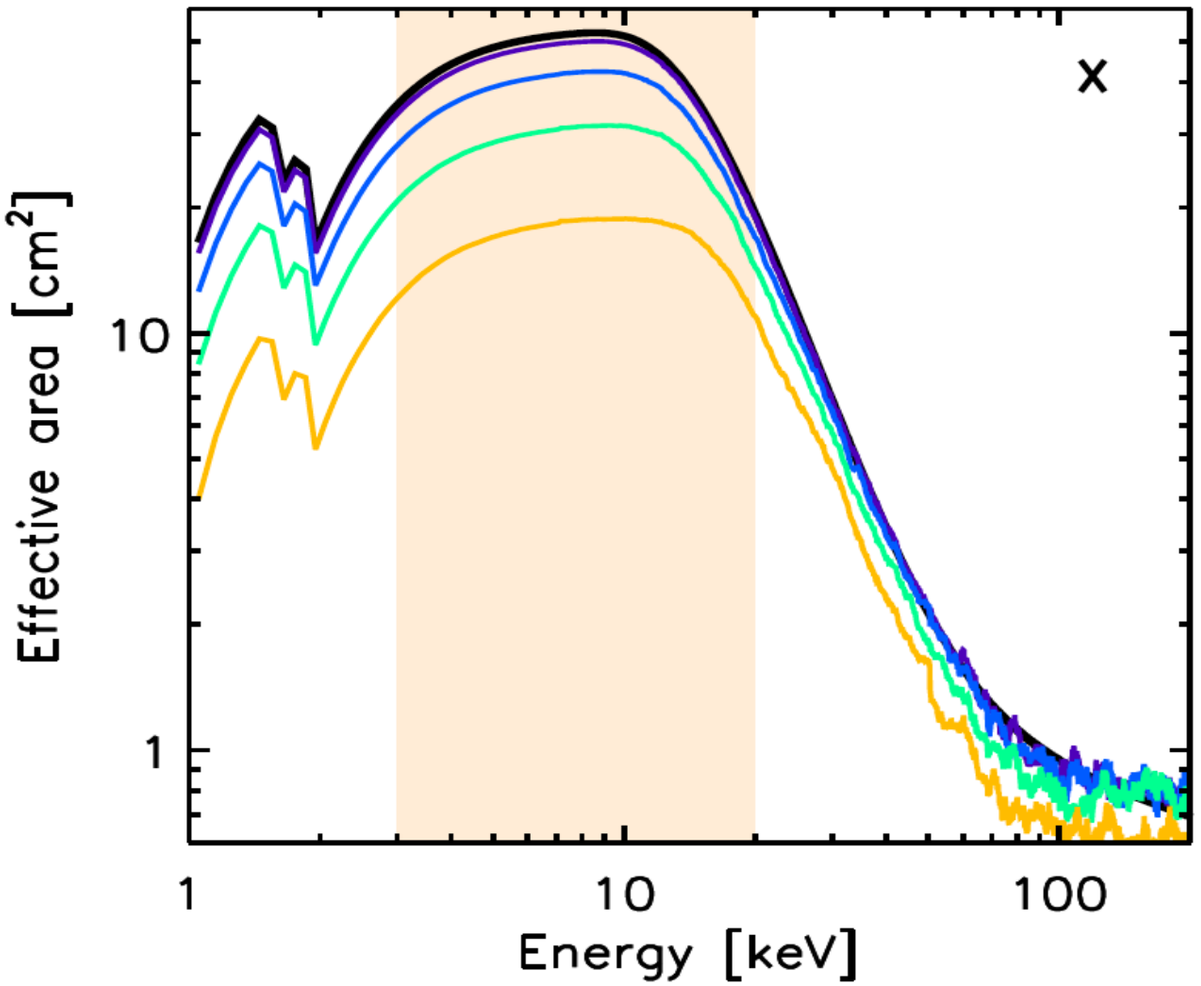
# HERMES performances



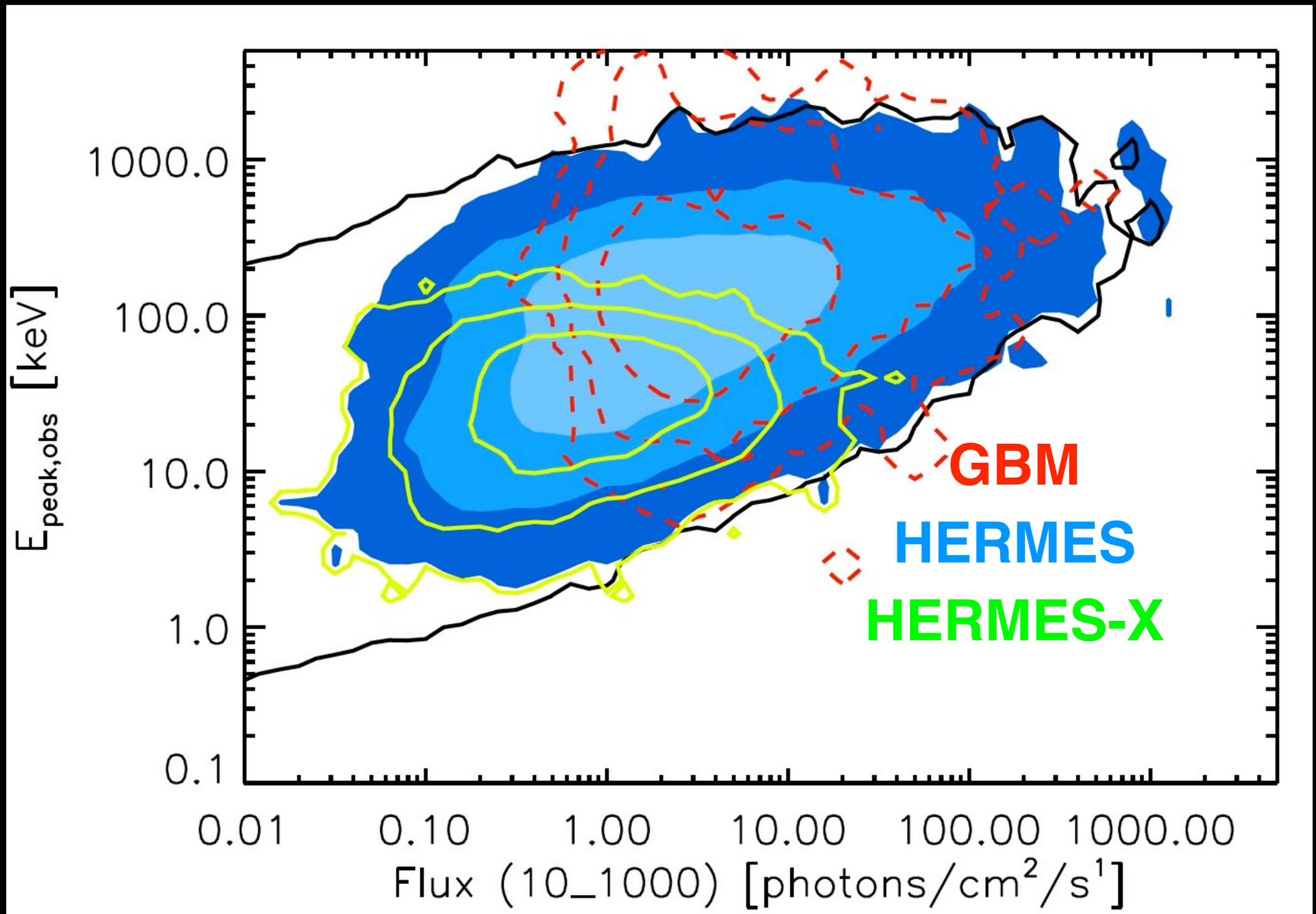




Background: 50-300 keV =75counts/s; 3-20 keV 390counts/s

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

# HERMES performances

## Ghirlanda & Nava



# HERMES performances

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

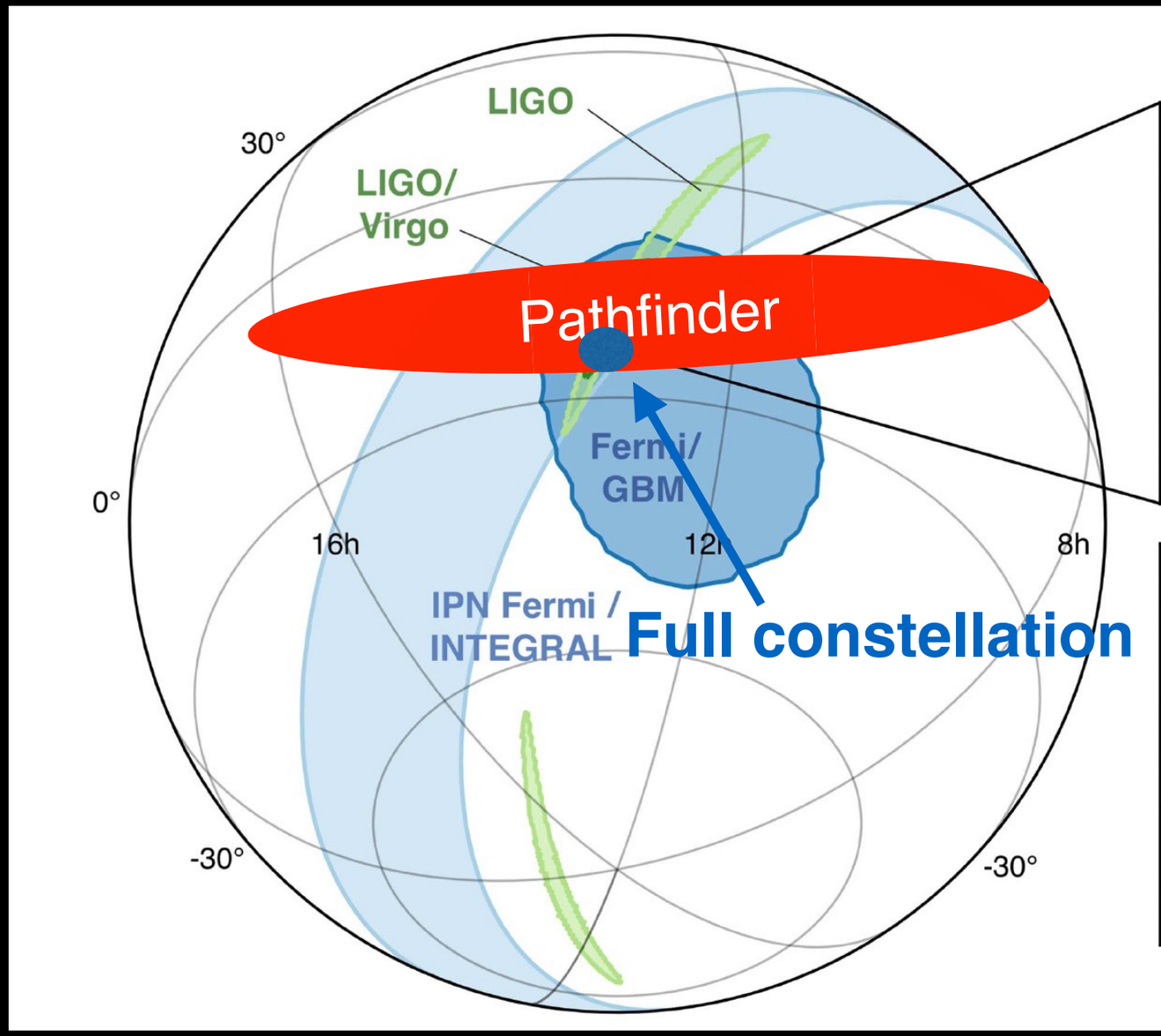
<B>~7000km

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

$\sigma_{Pos}$~ 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)
- Institute of High Energy Physics, Chinese Academy of Science

# Programmatics

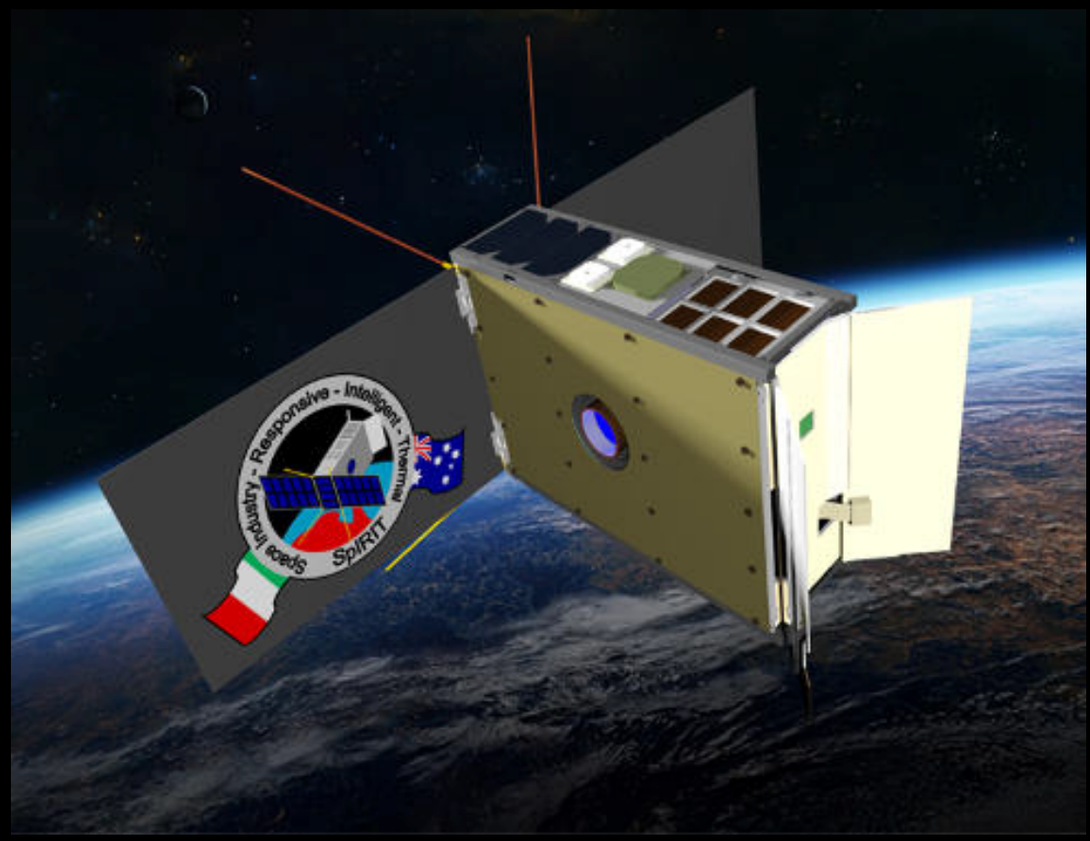
- Progetto Premiale 2015: **HERMES-Techonogic Pathfinder**
- H2020 SPACE-SCI-20: **HERMES-Scientific Pathfinder**
- Main objectives:

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  Q1 2022—> PFM1
- AR Q3 2022 —> FM2+FM3+FM4+FM5+FM6
- Launch 2022-2023, 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



# Outlook

- Toward the full constellation
  - mass production, assembly/test lines
  - Increase the baseline: outside LEO, toward the Moon
- Planetary HERMES, Moon, Mars (TASTE), Asteroids
- Exploit HERMES heritage to build a network of capacities in the field of **distributed instruments and nano-satellites** and transfer it to the territory
  - complete missions/experiments
  - complement of larger satellites
  - test of payloads/systems to be flown on larger satellites

# Criticalities

- Covid-19 sanitary emergency
- ASI reorganizazion
- Still missing:
  - Contract for MOC deployment and operations
  - Contract for the launch

Stay tuned!