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

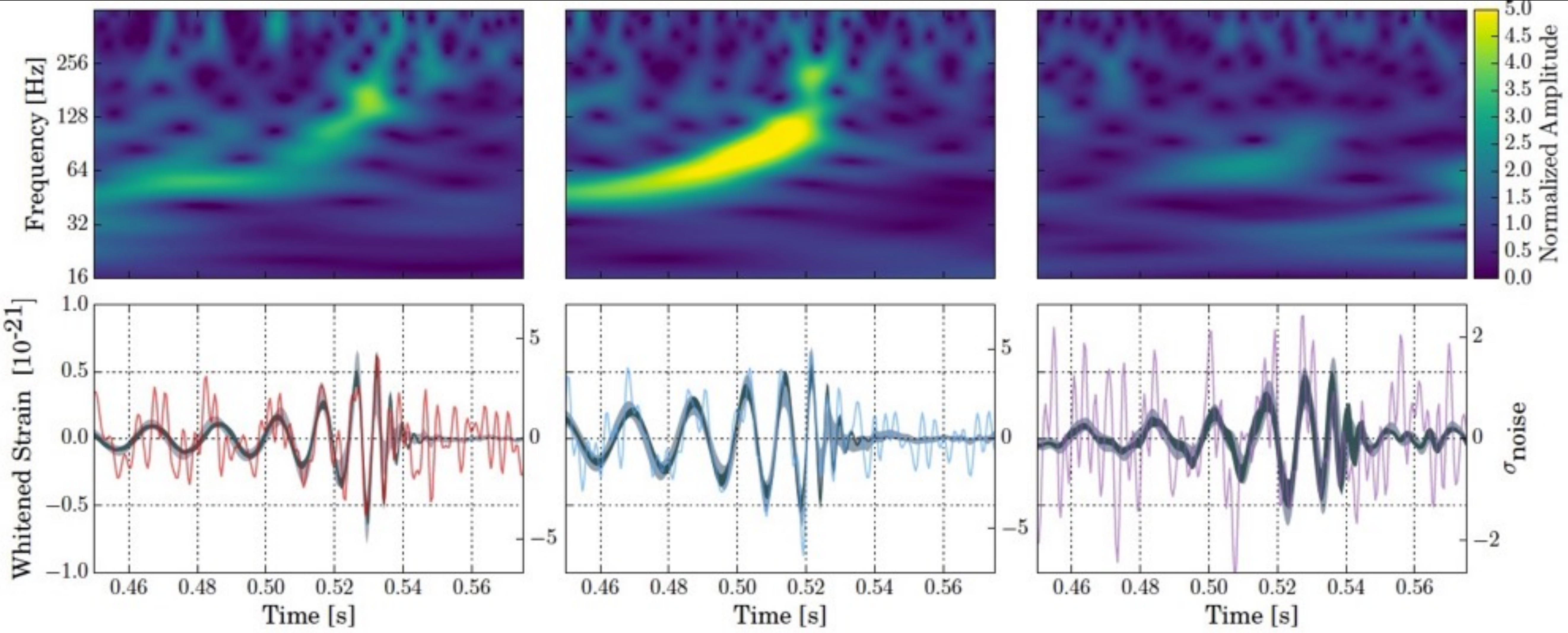
POLITECNICO MILANO 1863

Agenzia Spaziale Italiana

Two revolutions

Multimessenger astrophysics

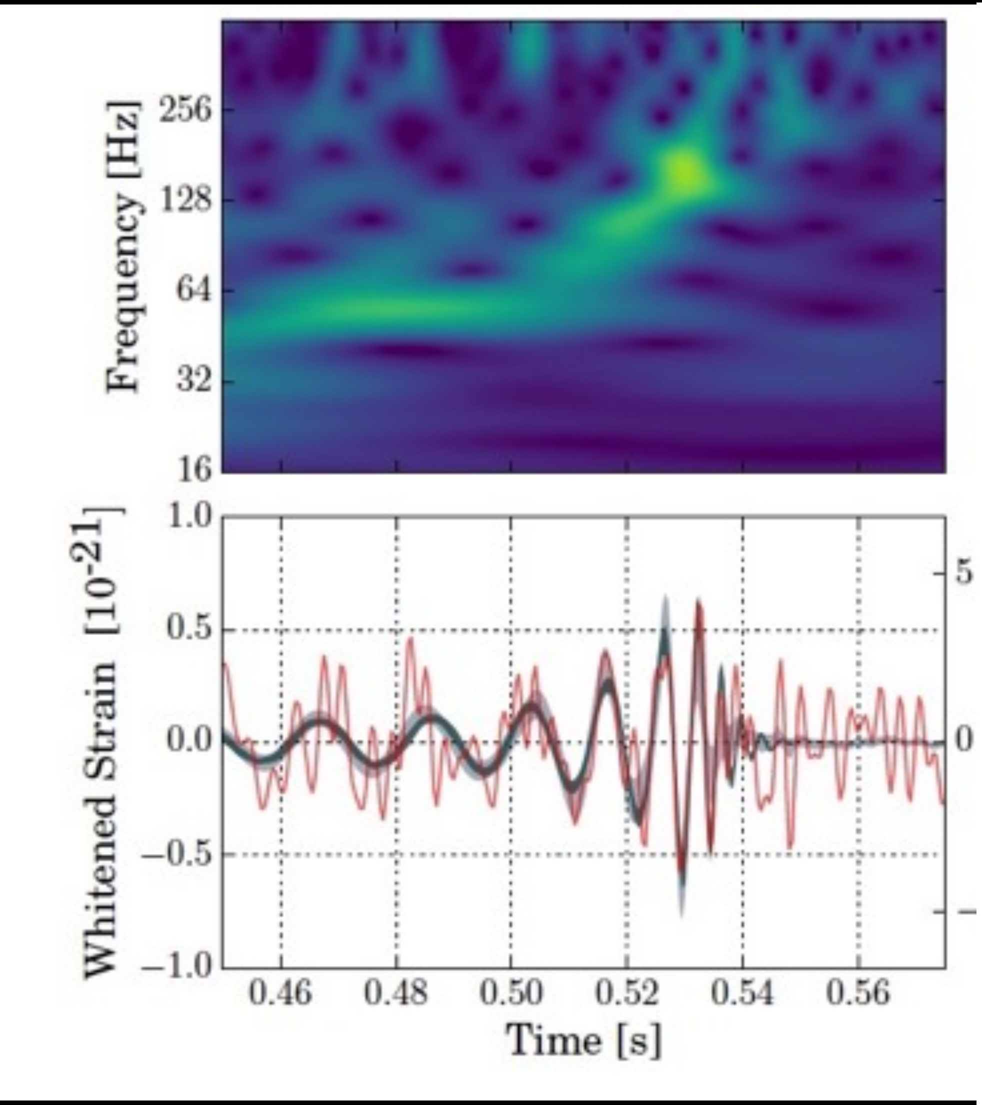
GW170814

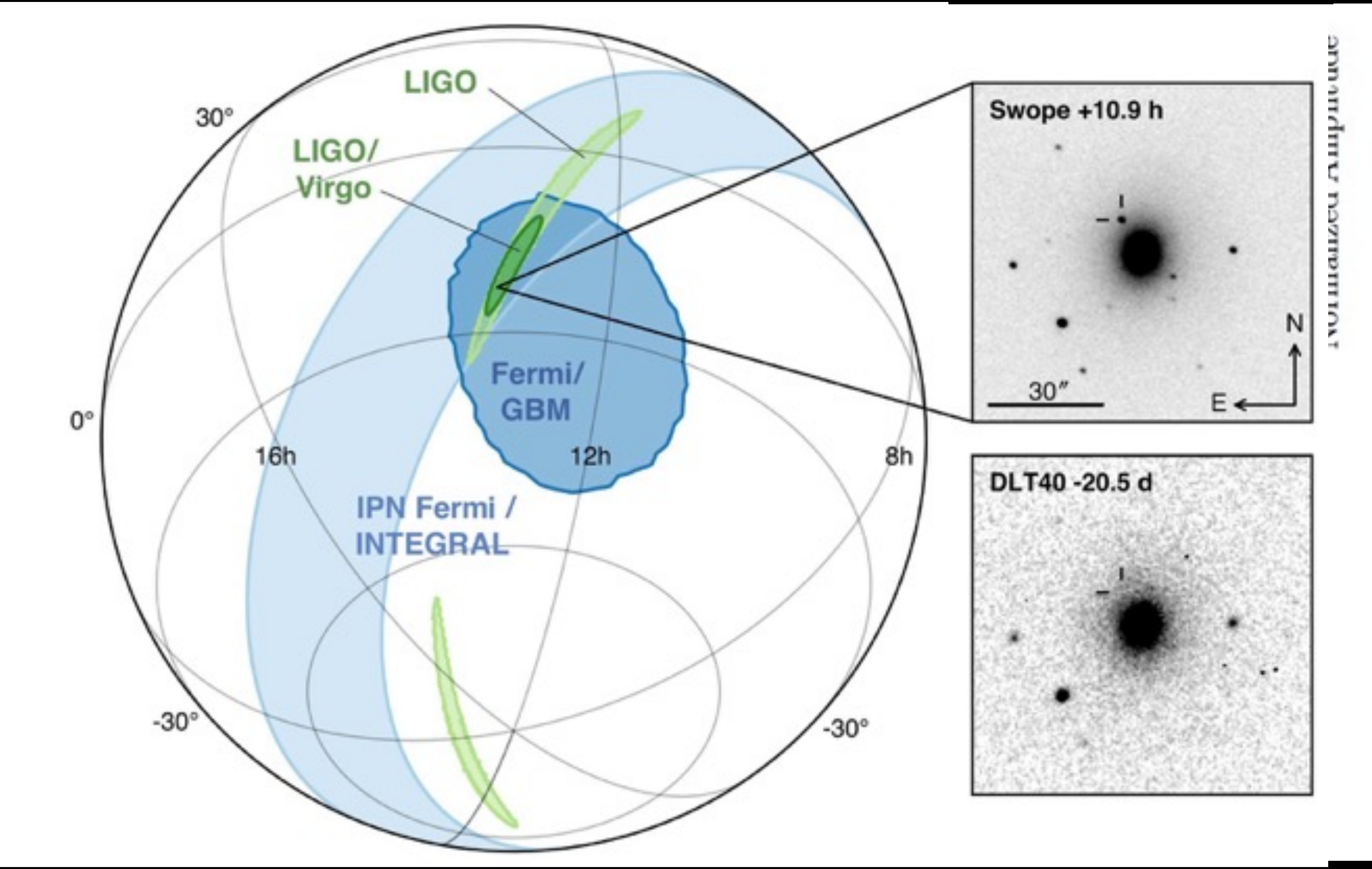


Two revolutions

Multimessenger astrophysics

GW170817





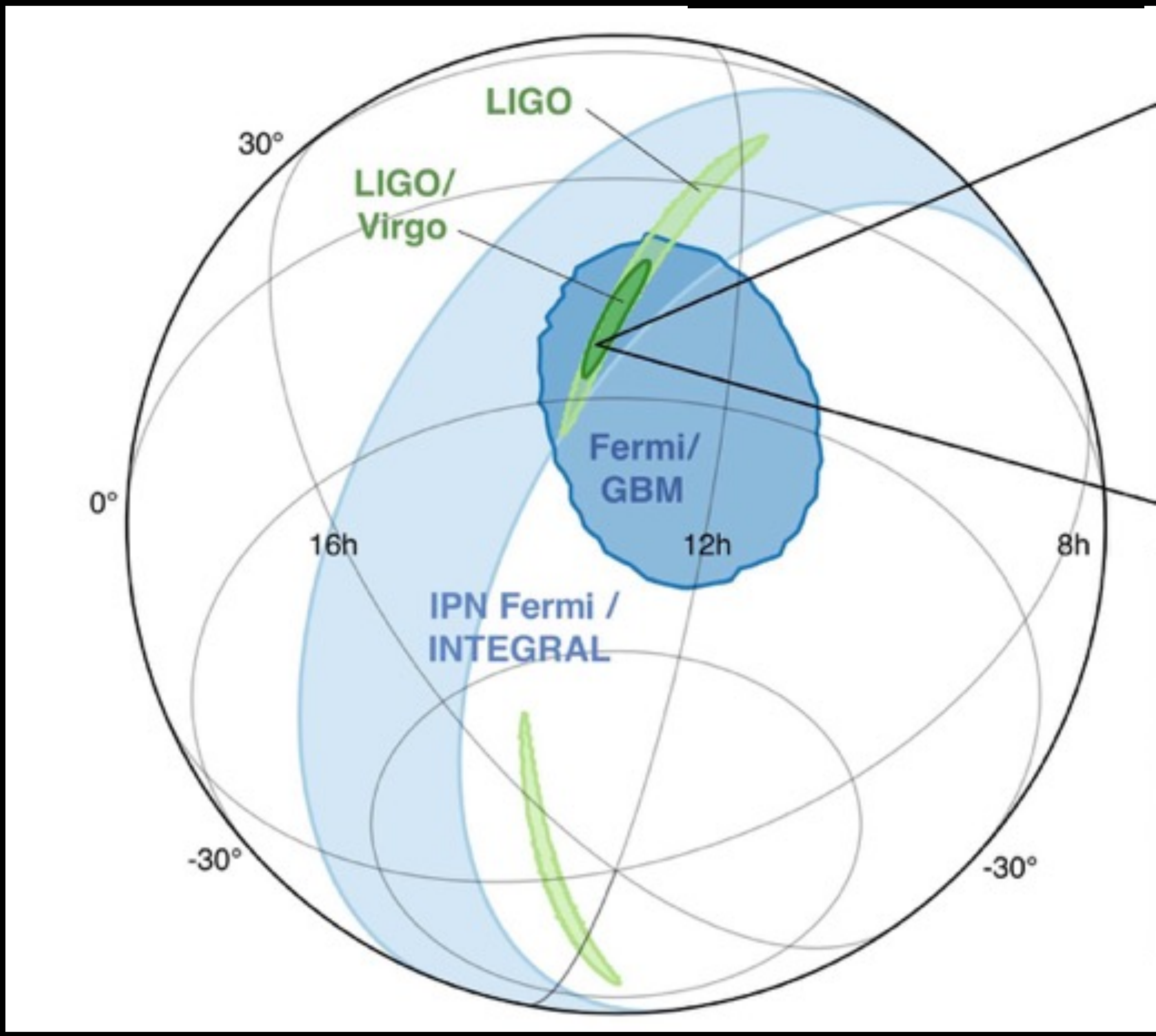
The multimessenger revolution

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…)

GW170817



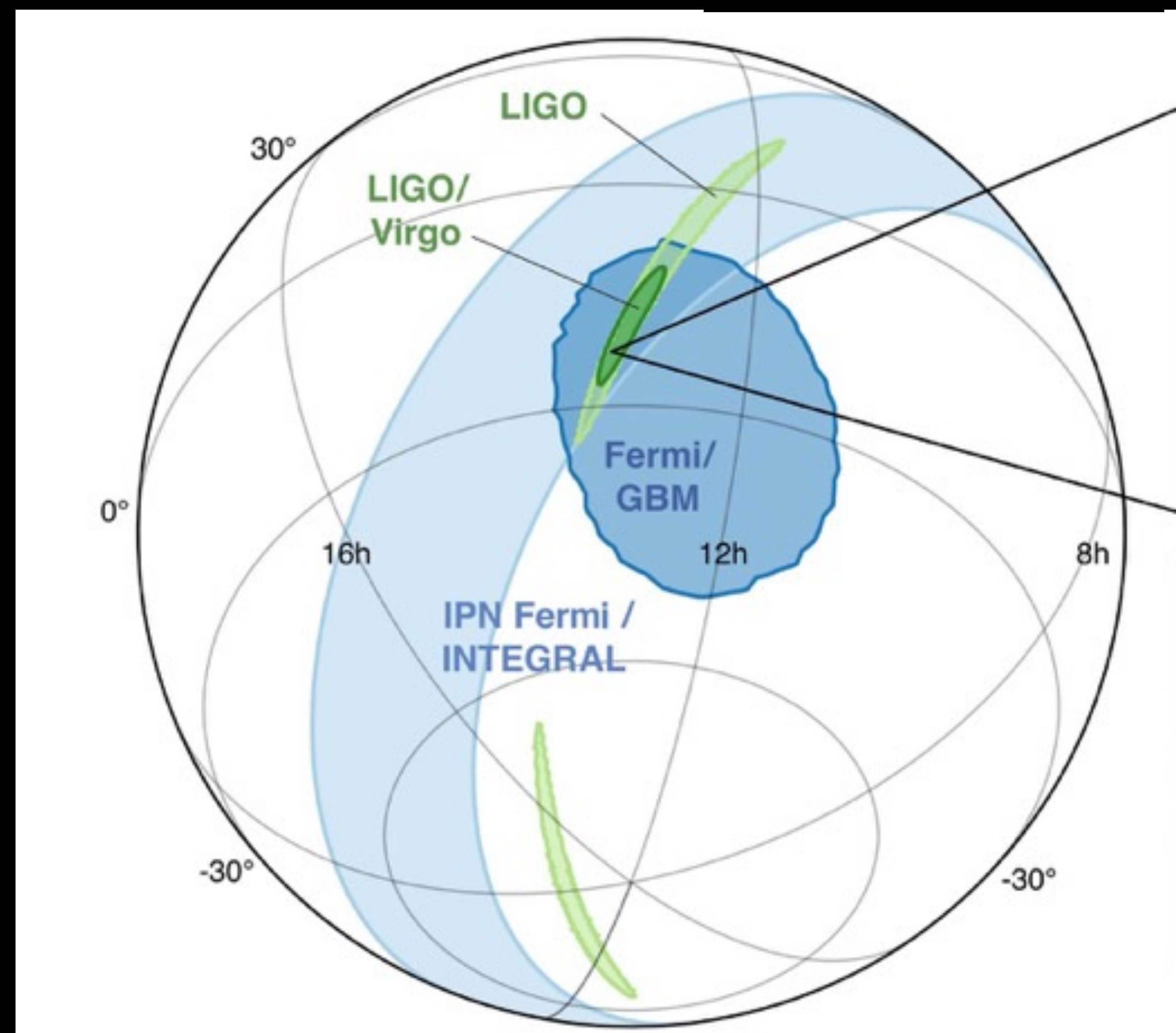
The multimessenger revolution

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

GW170817



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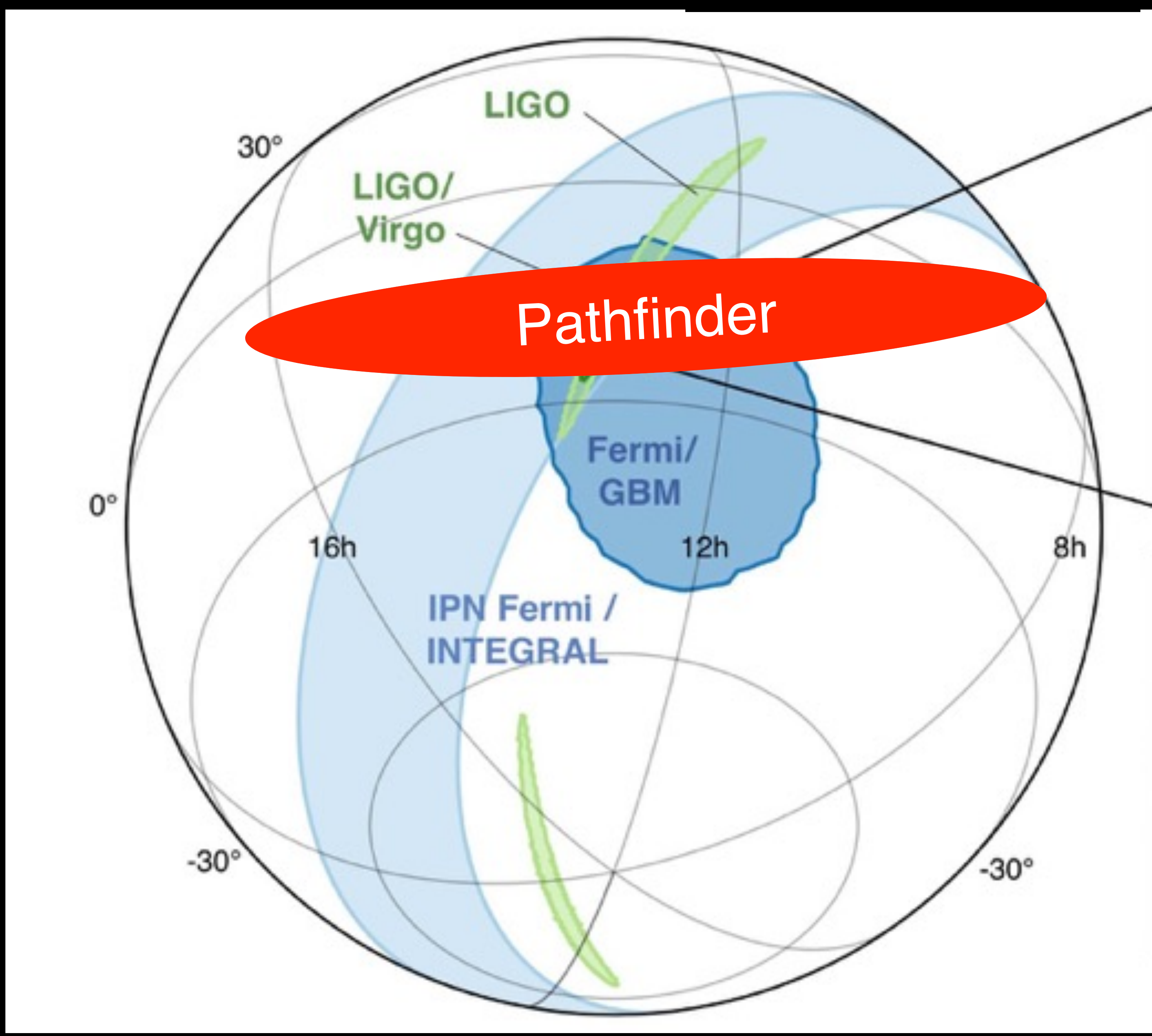

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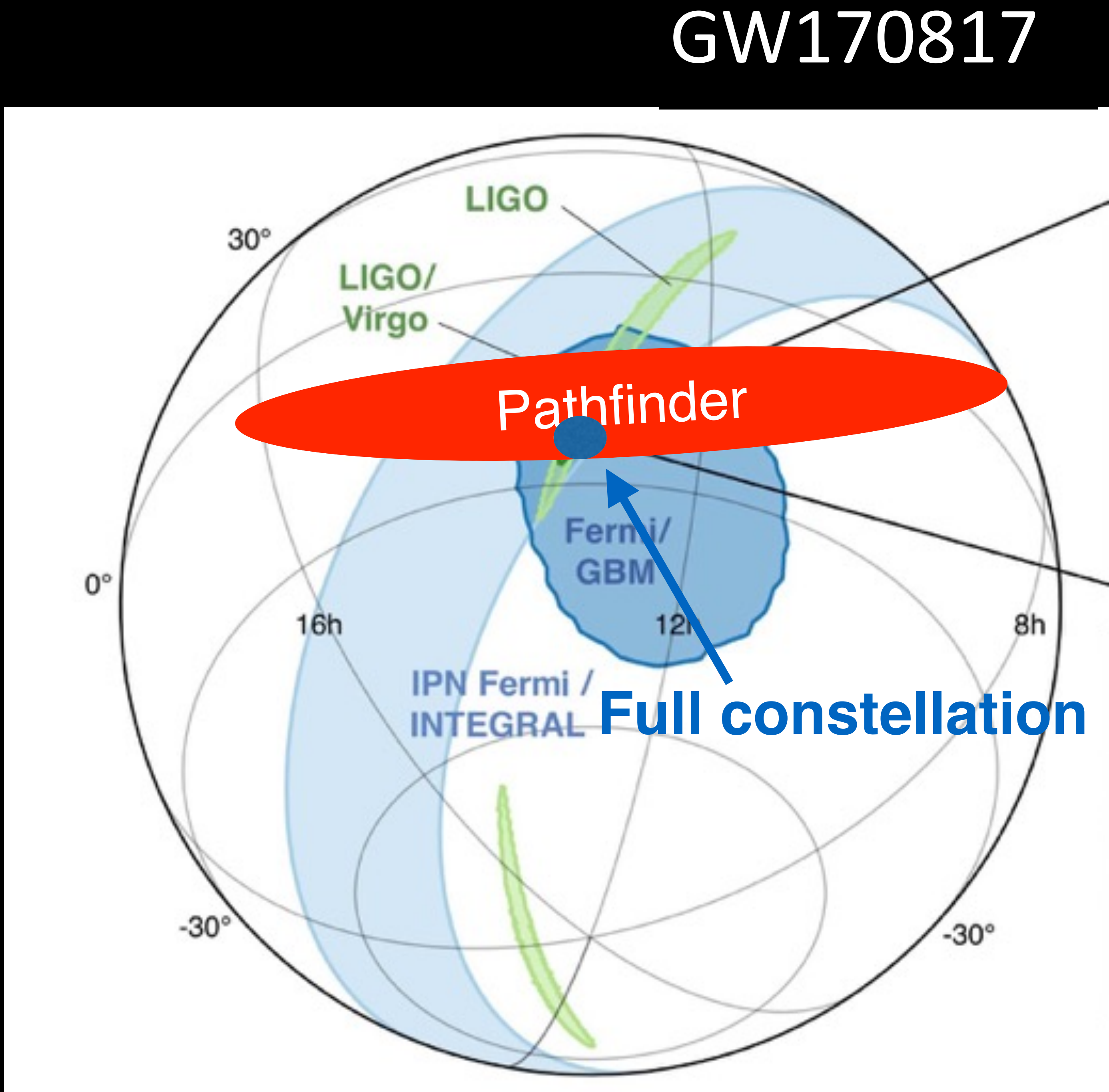

The multimessenger revolution

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

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

Best strategy:
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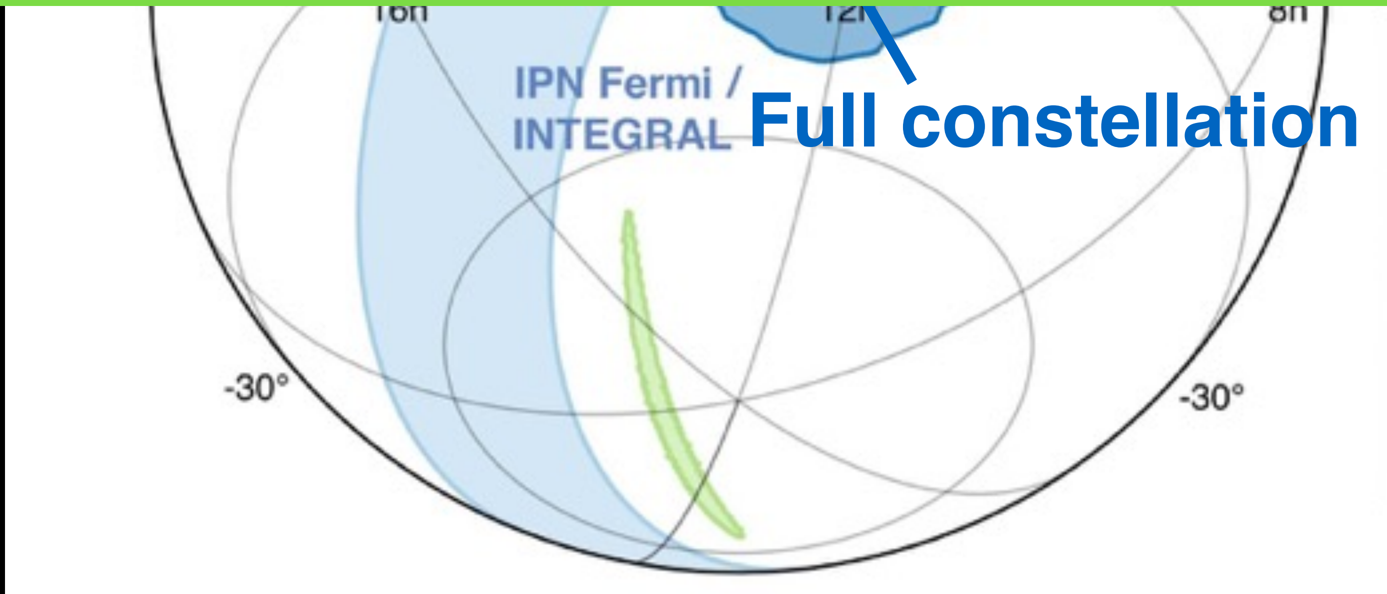
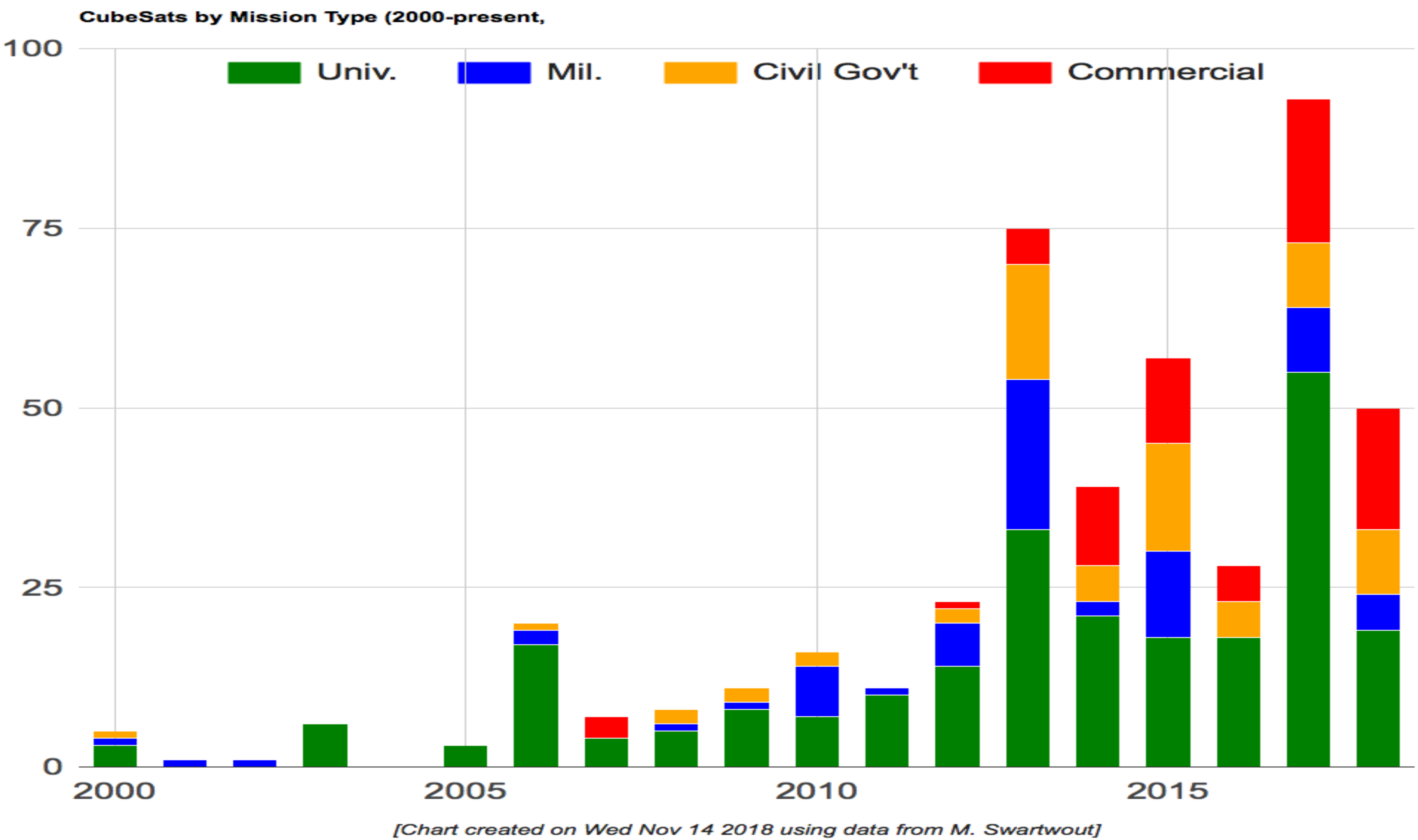
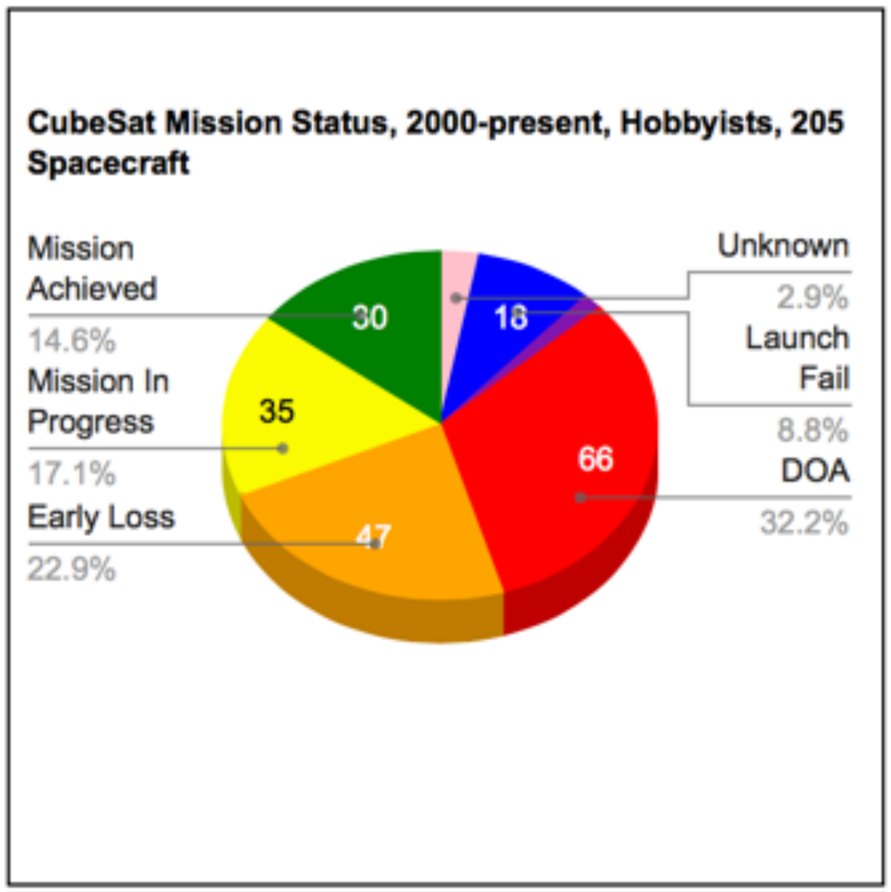


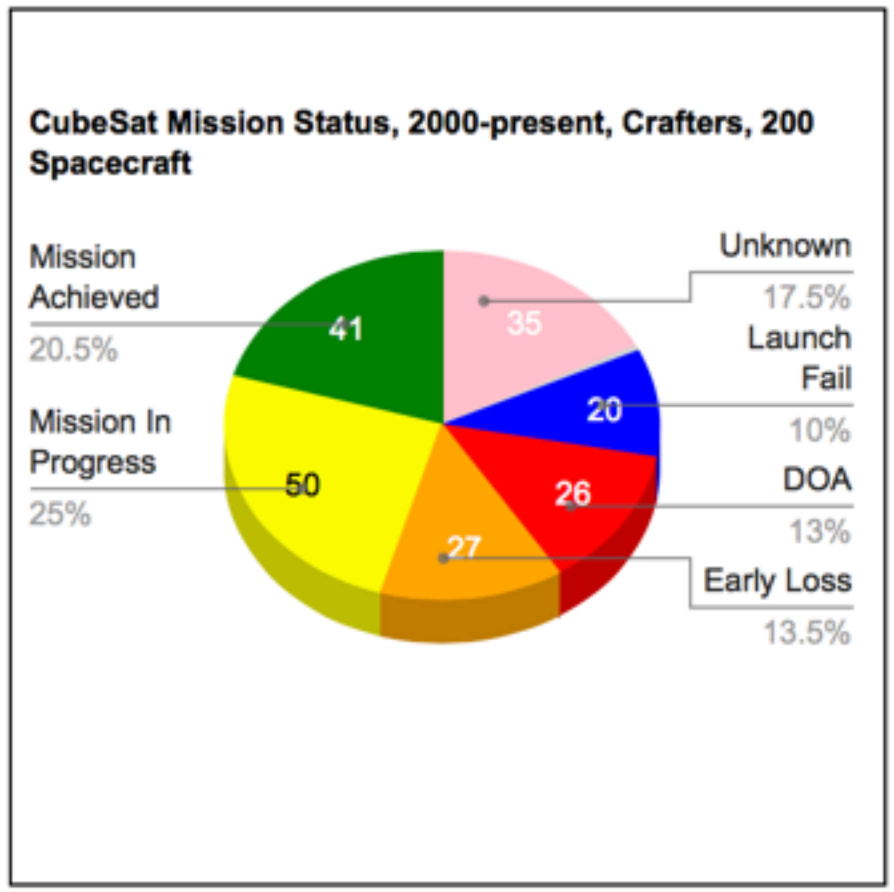
Space 4.0

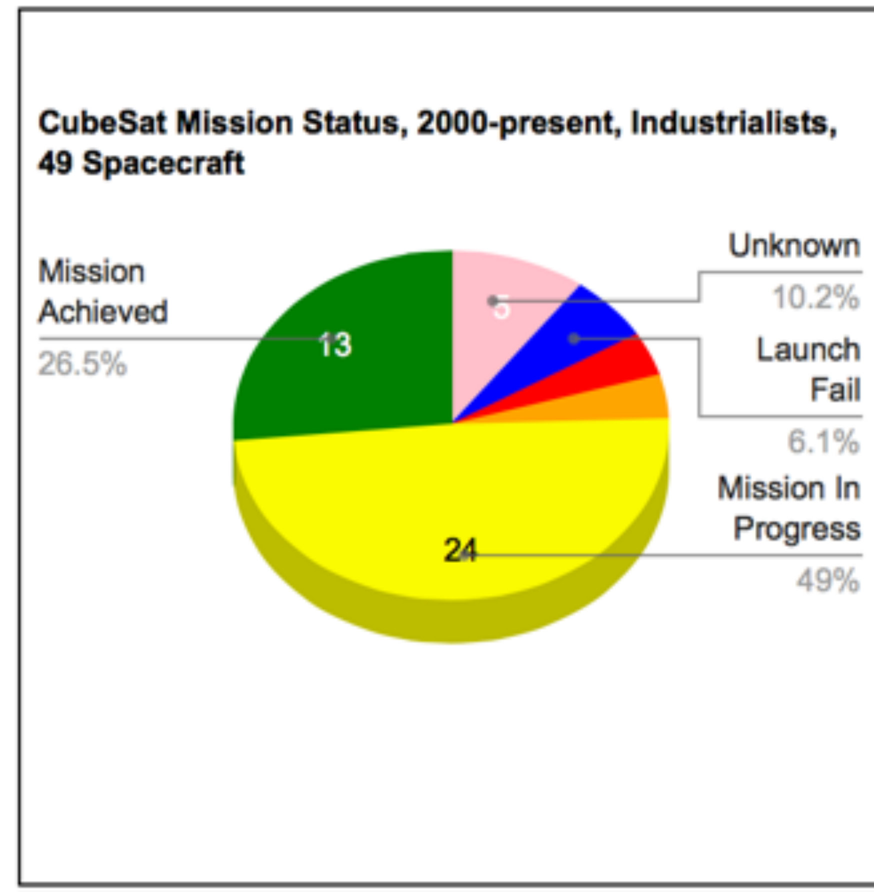


CubeSats by Mission Type (2000-present,
100
75
50
25
0
Univ.
Mil.
Civil Gov't
Commercial
2000
2005
2010
2015
[Chart created on Wed Nov 14 2018 using data from M. Swartwout]

Space 4.0







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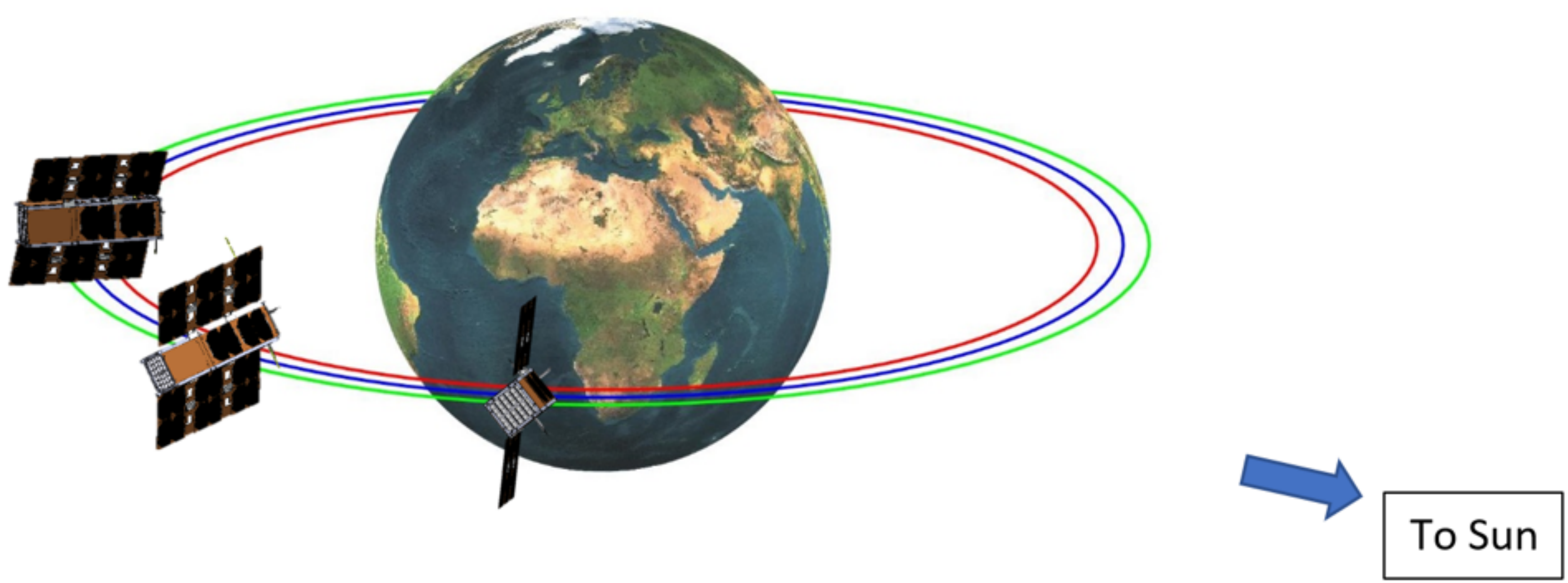
HERMES



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

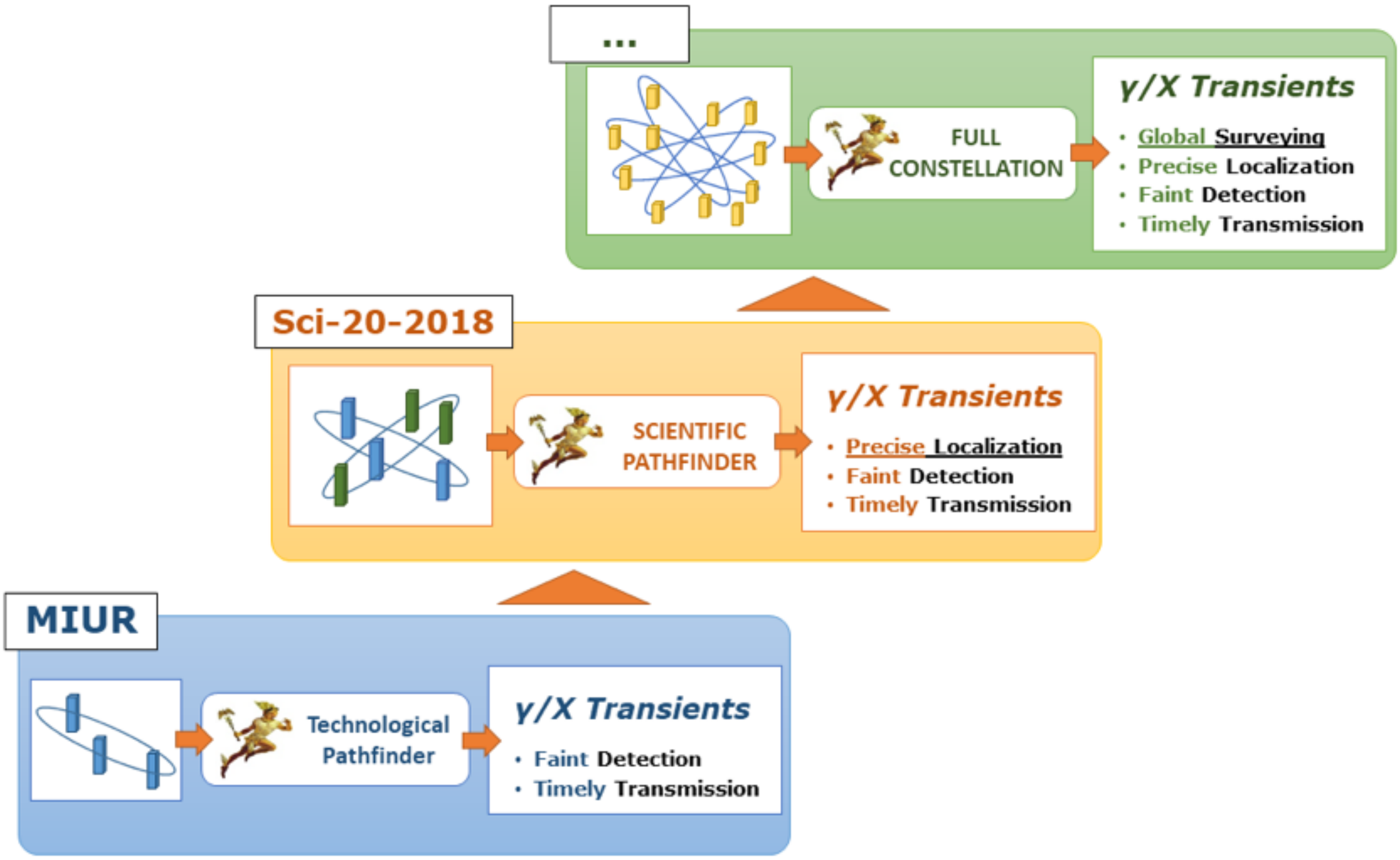
Breakthrough scientific case:

- EM of GWE

Modularity:

- Avoid single point failures, improve hardware
- Pathfinder

Why HERMES now



Why HERMES now

Breakthrough scientific case:

- EM of GWE

Modularity:

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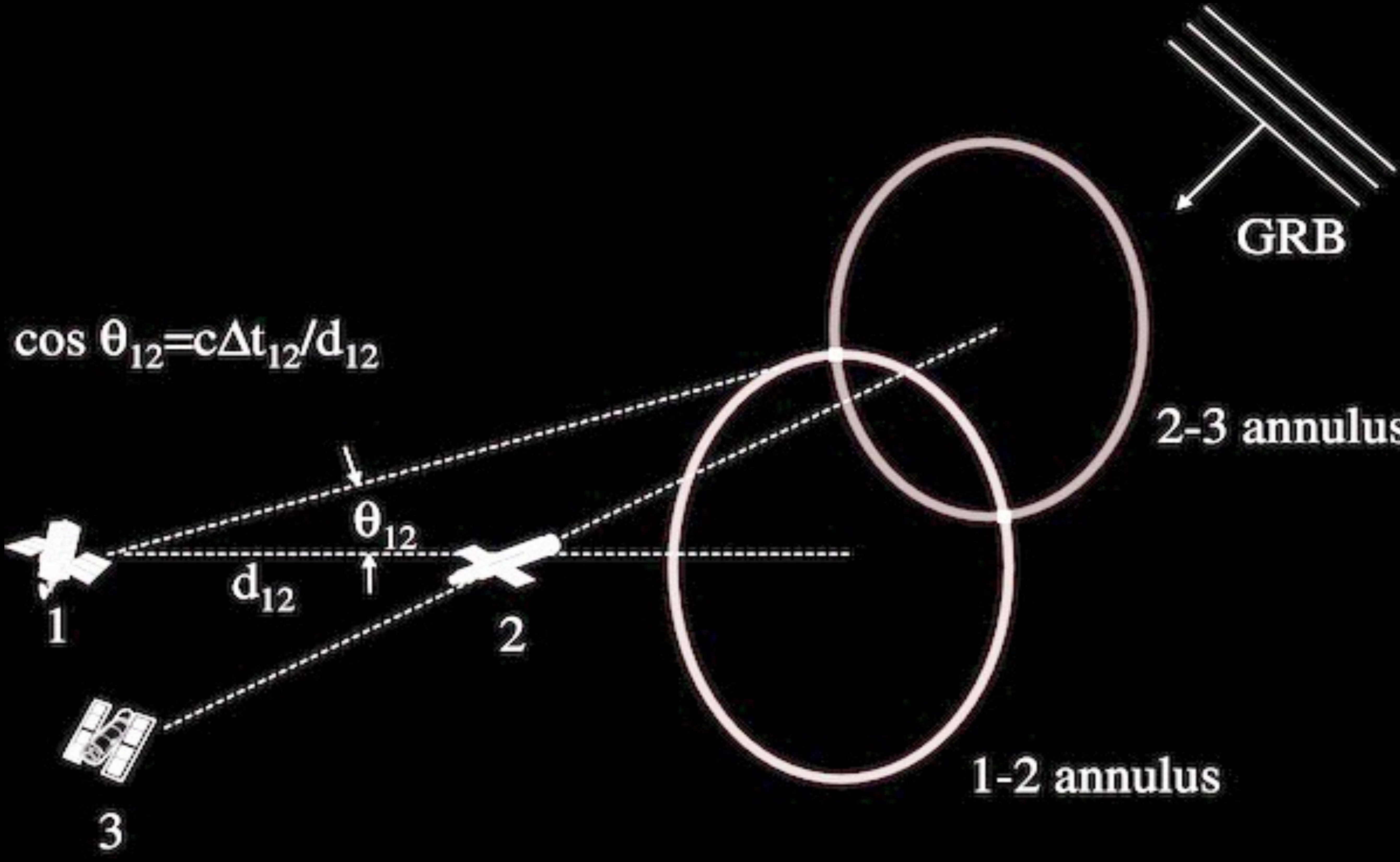
Open µsec - msec window:

- Accurate positions
- QG tests

Limited cost and quick development

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

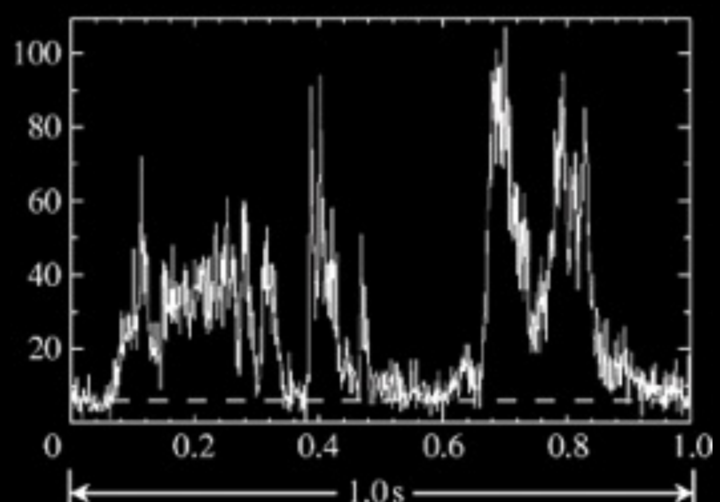
Experiment concept



Experiment concept

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

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



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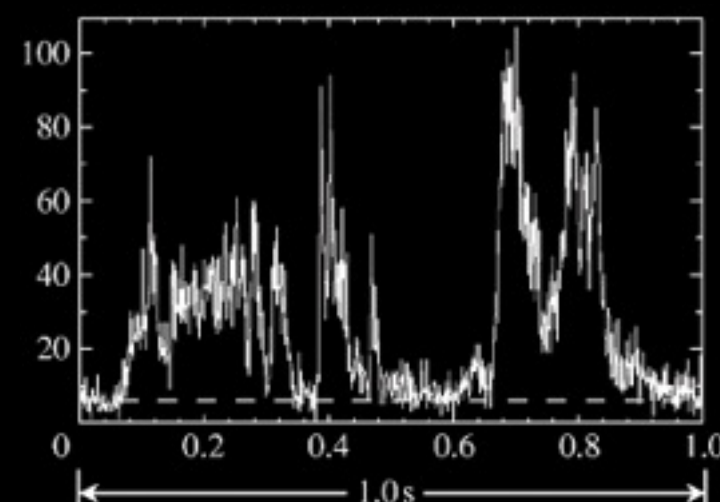

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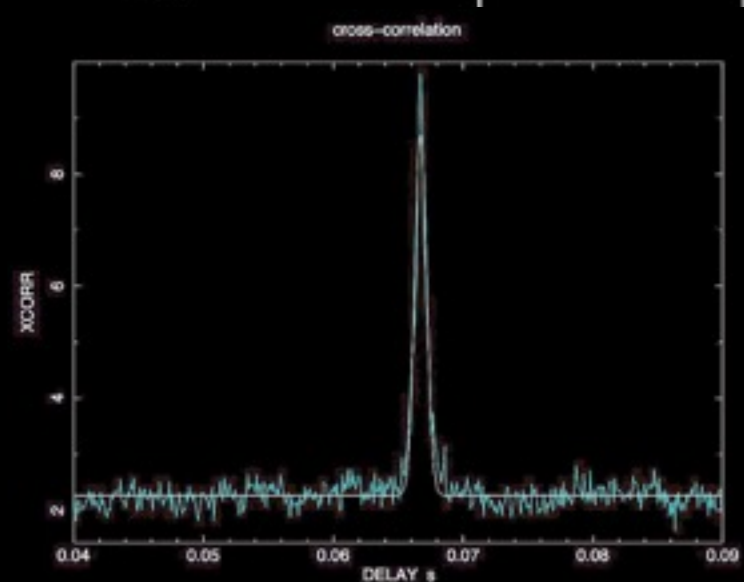
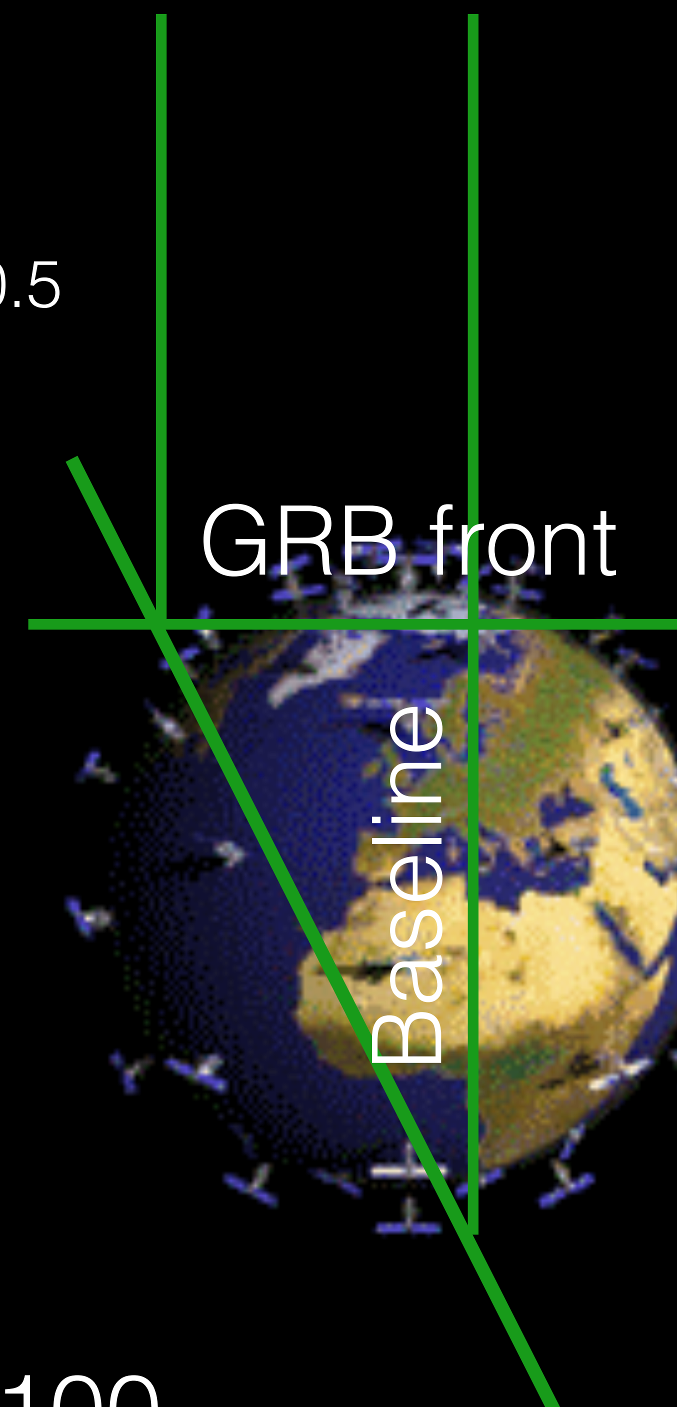


σ_{CCF}~10μs

σ_{Pos}~10arcsec

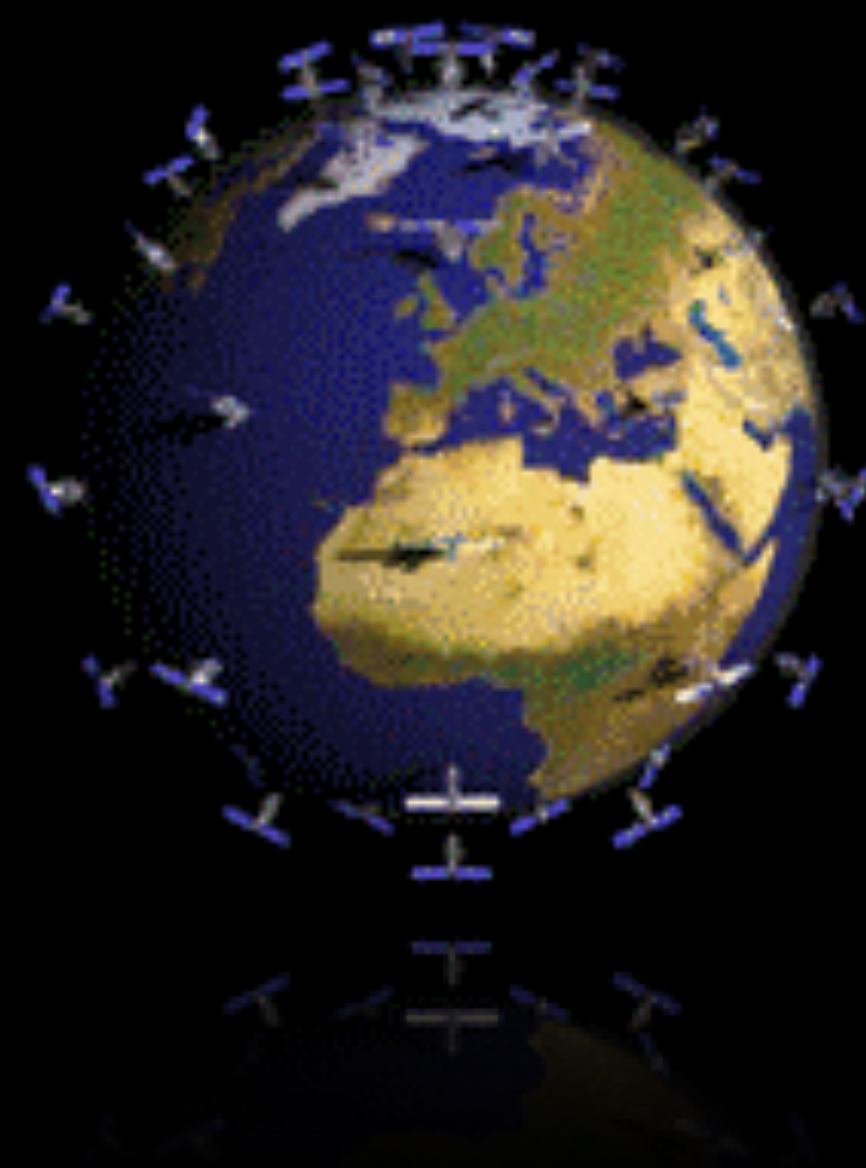
if <B>~7000km, N~100



Experiment concept

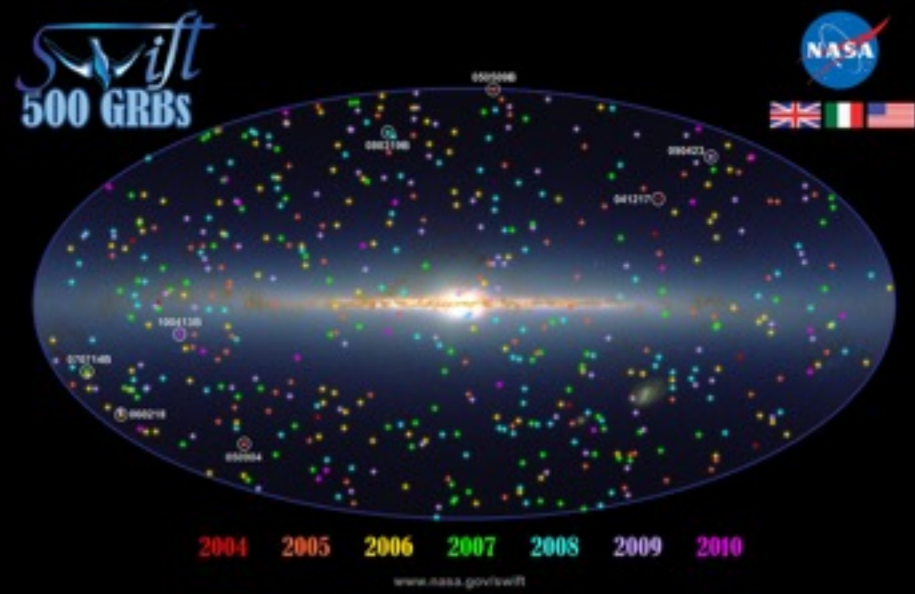
2. Add the signal from different units

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

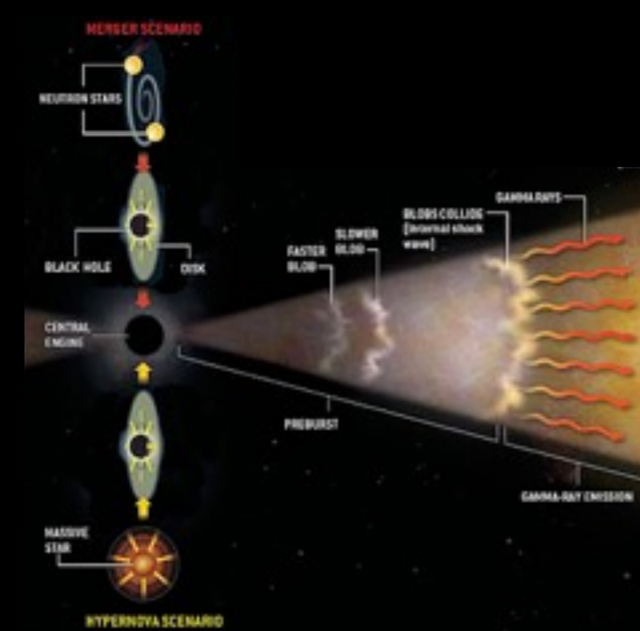


Transient fine (subμs-ms) temporal structure

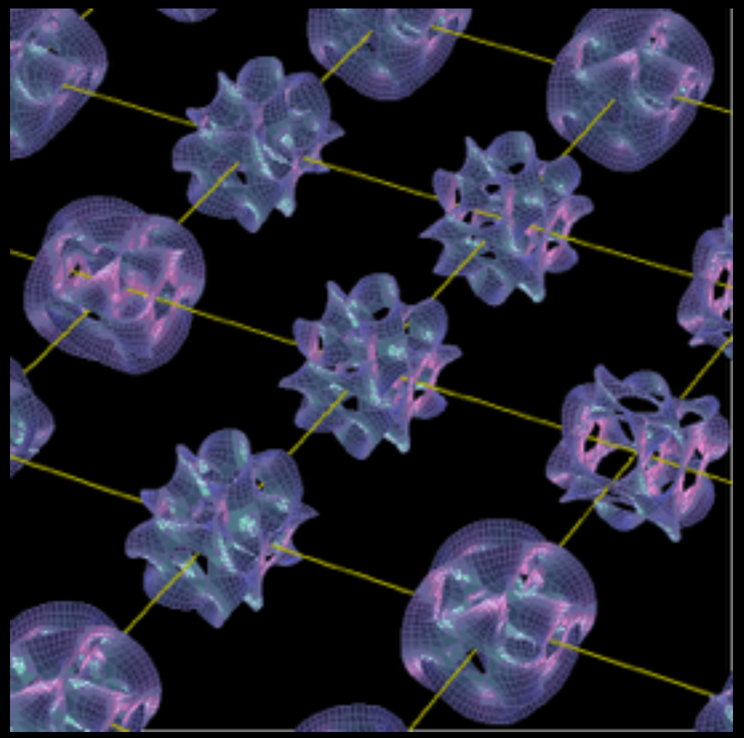
How to *promptly* localise a GRB *prompt* event?



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

$\Delta t/\Delta E \sim 3\mu s/100keV\ 30\mu s/1MeV \longrightarrow M_{QG} \sim M_{Planck}$

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 < 300m

Absolute time reconstruction <100 ns

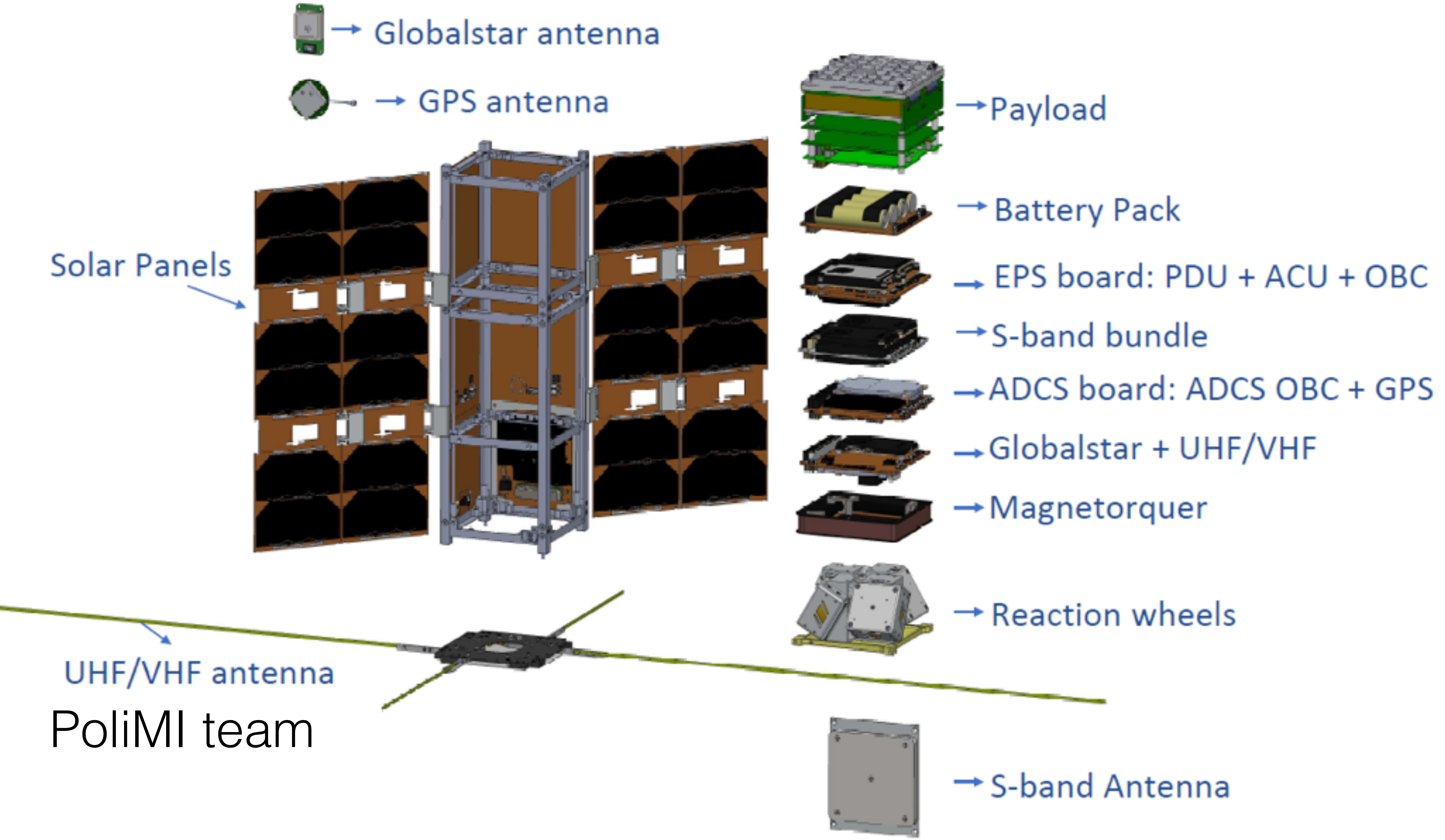
Download full burst info in minutes

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

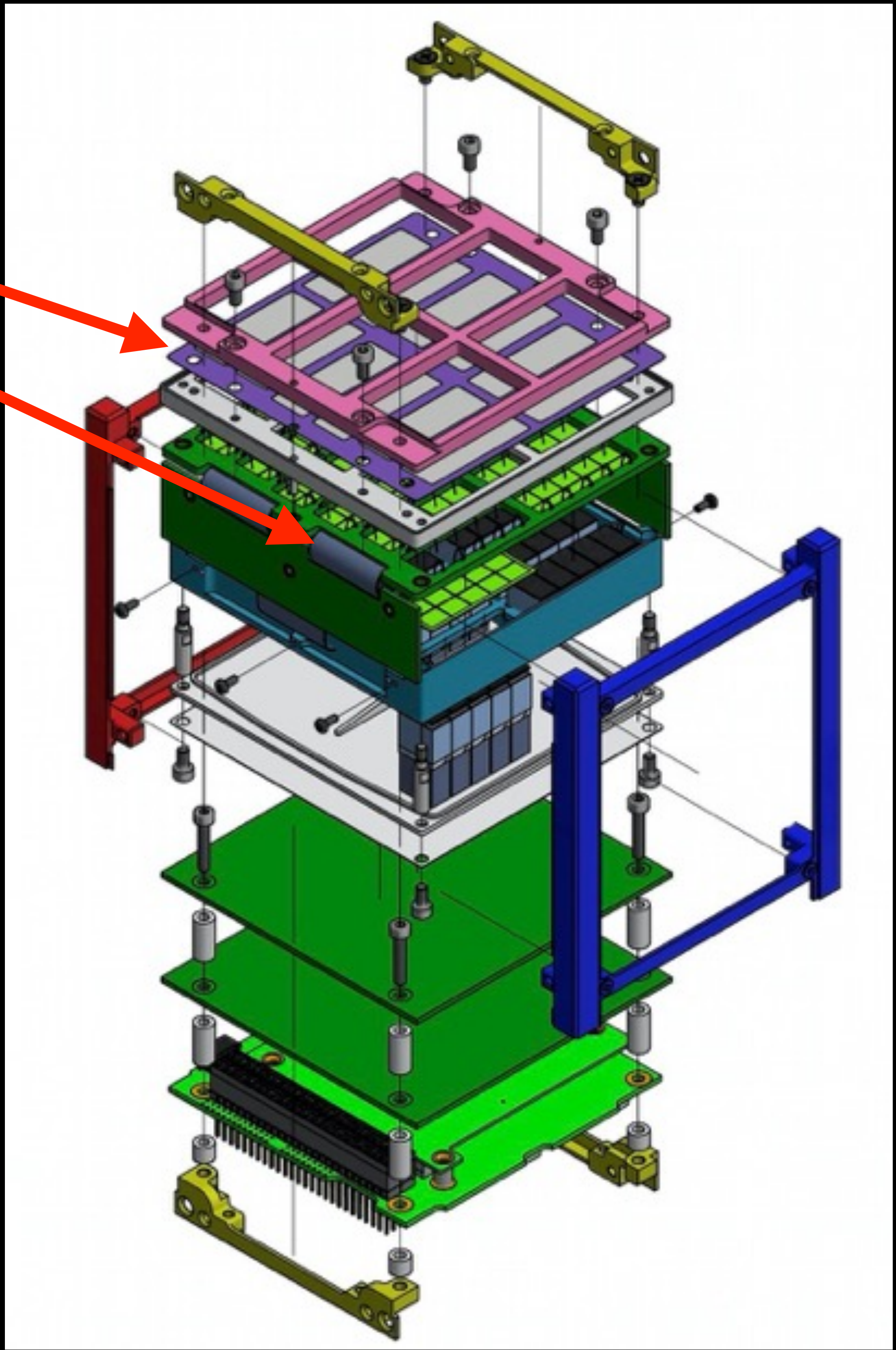


PoliMI team

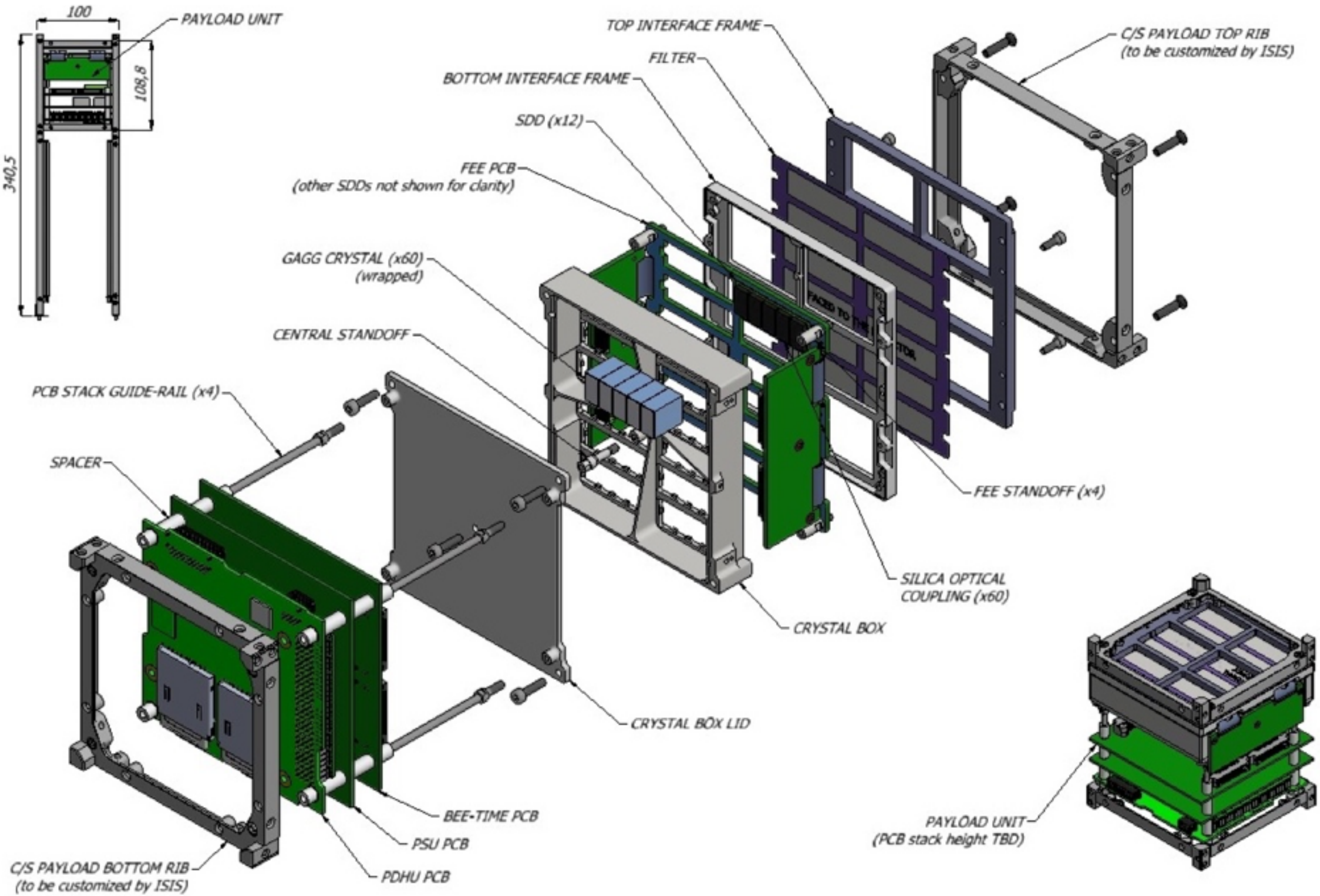
Payload concept

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

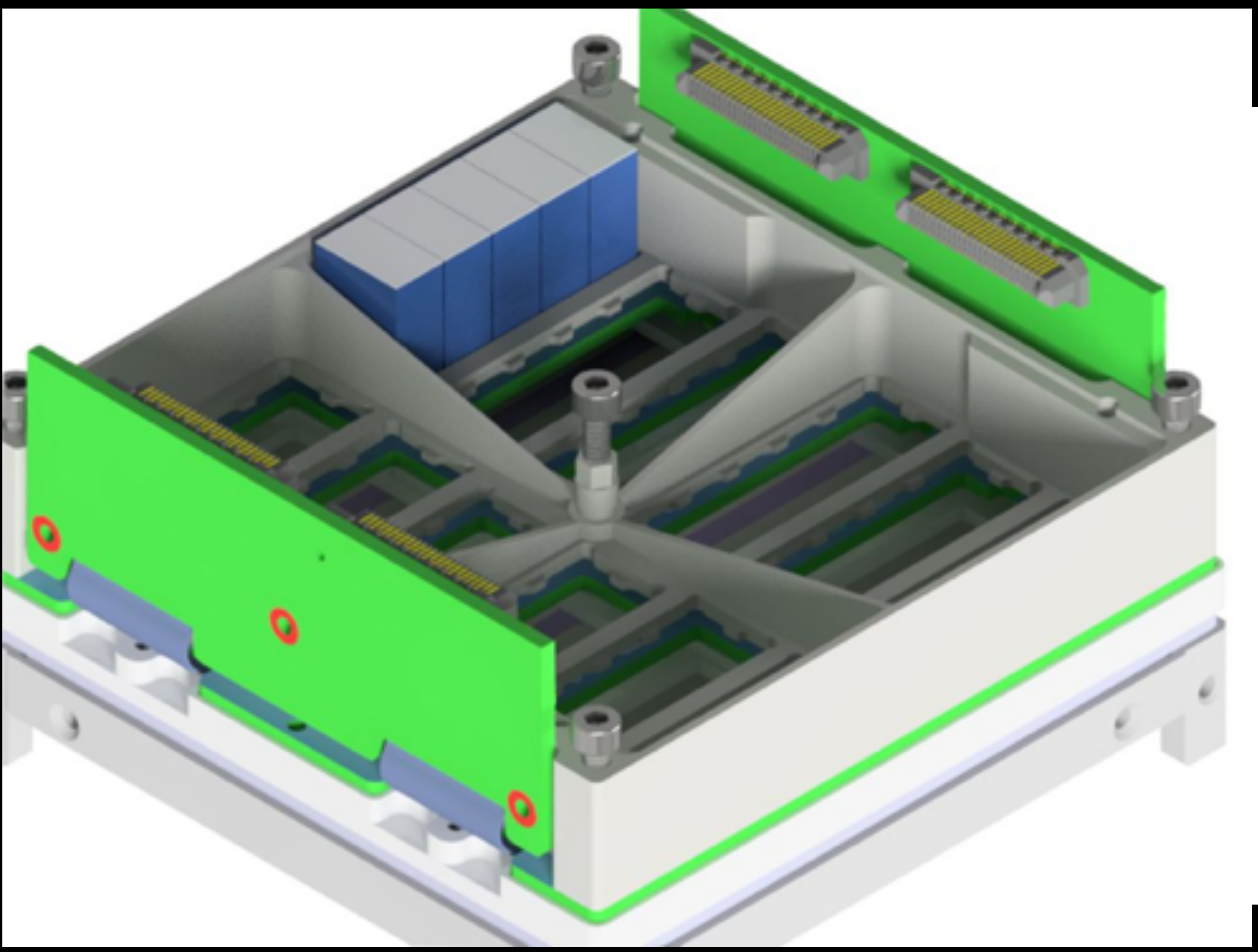
Fuschino+2018, 2020
Evangelista+2020
Campana+2020

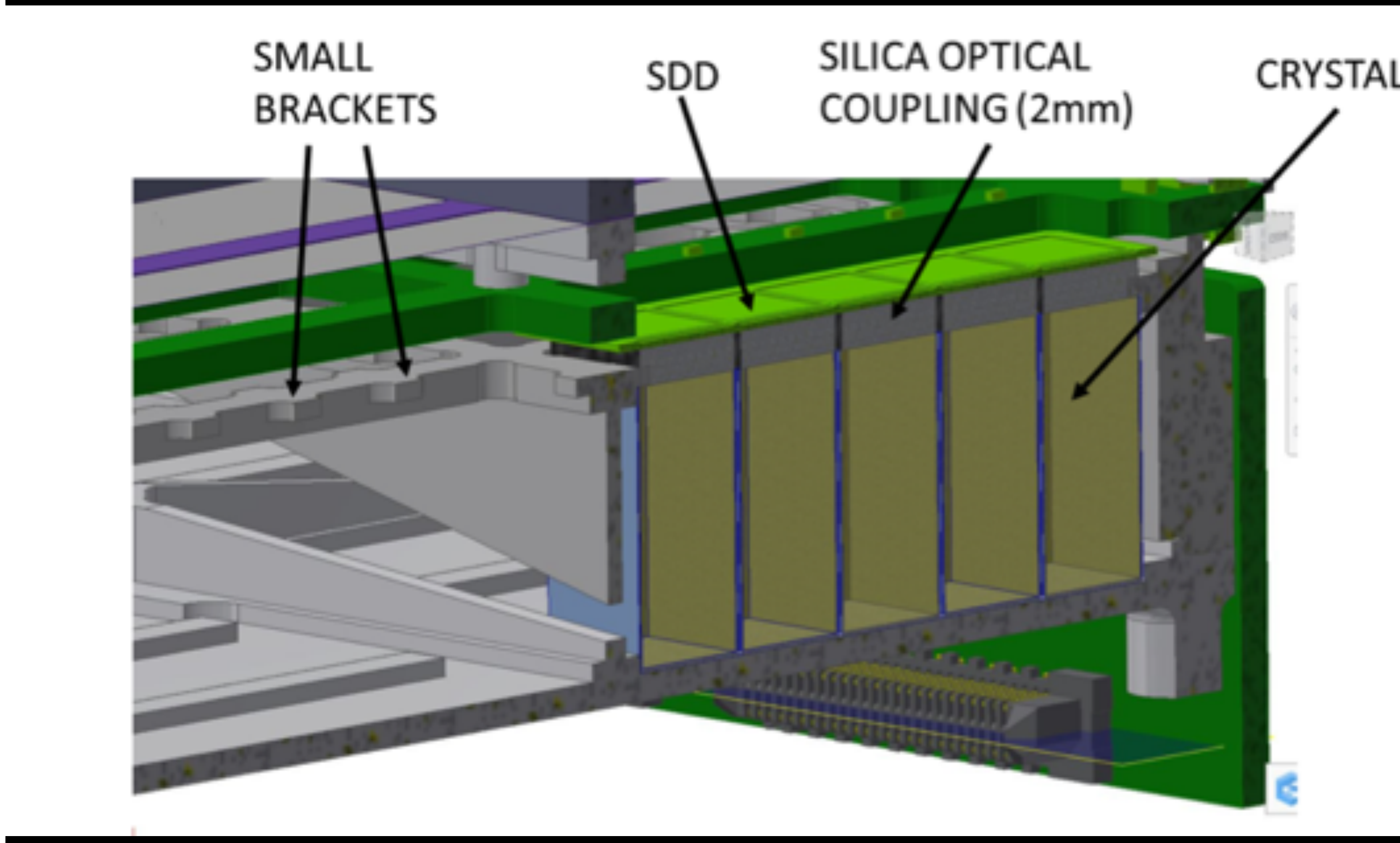


Payload design



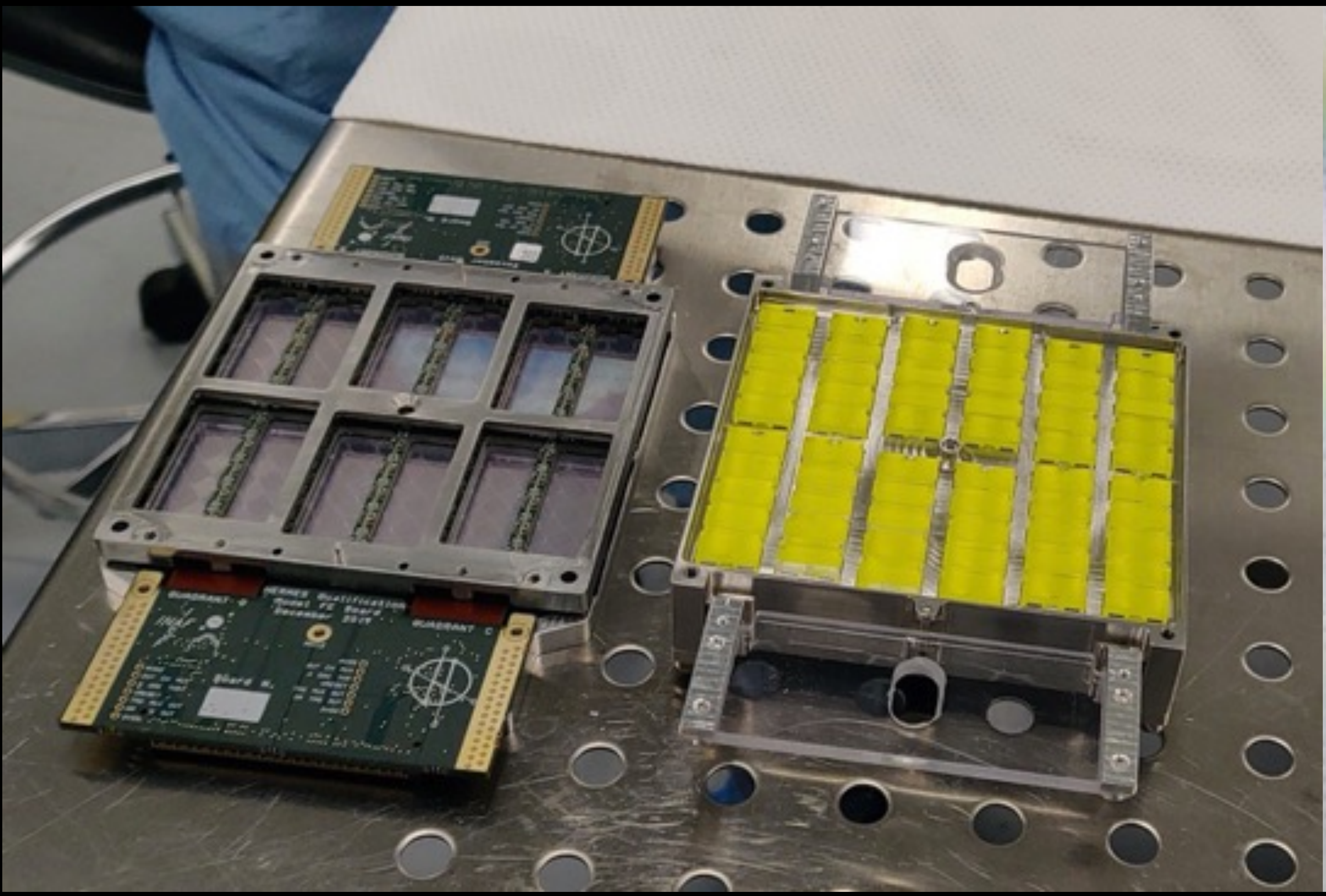
Detector design

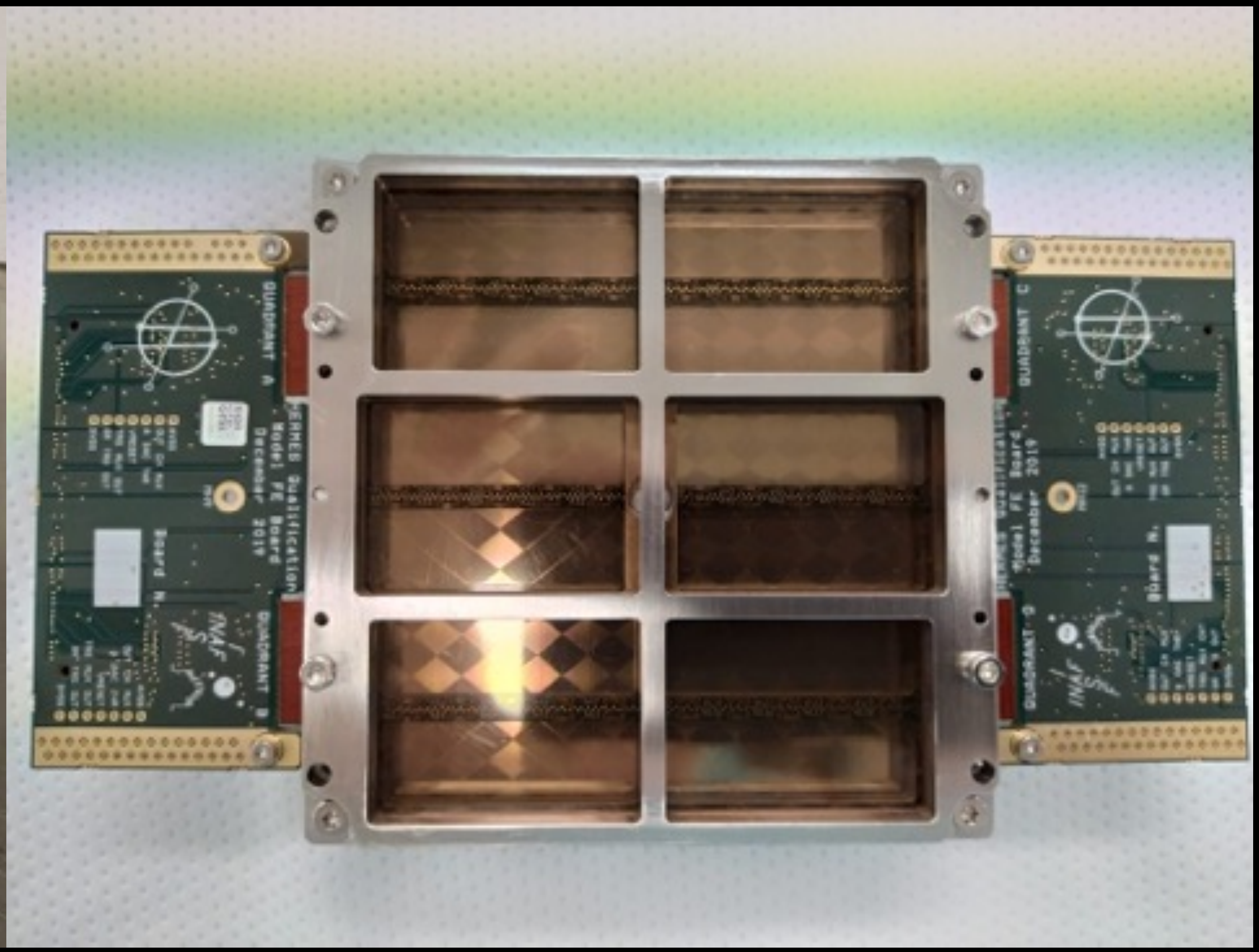




Stainless stell crystal box + tungsten layers on bottom and sides to reduce X-ray background

Hardware

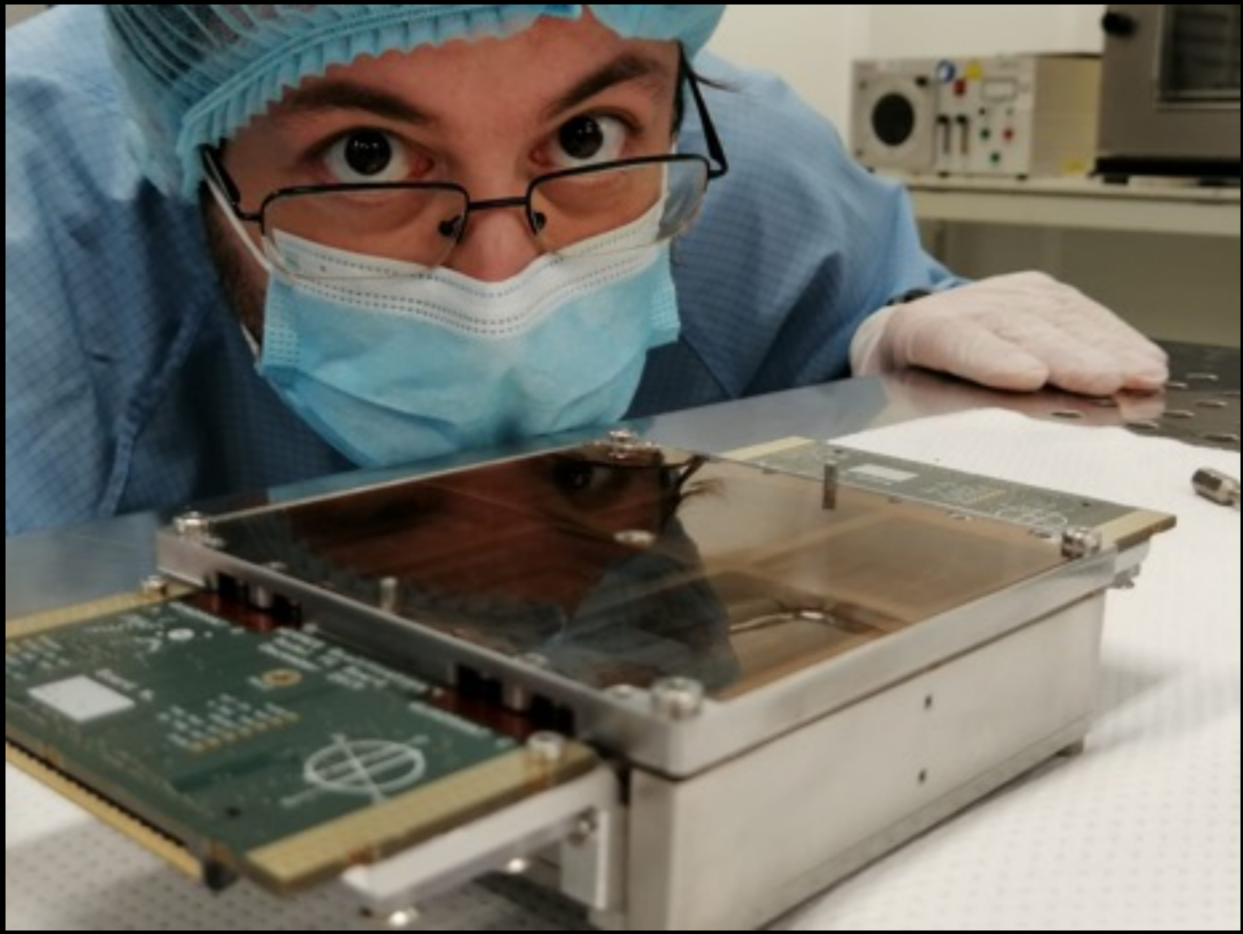



QUADRANT A
HERMES Qualification
Model FE Board
December 2019
QUADRANT B
QUADRANT C

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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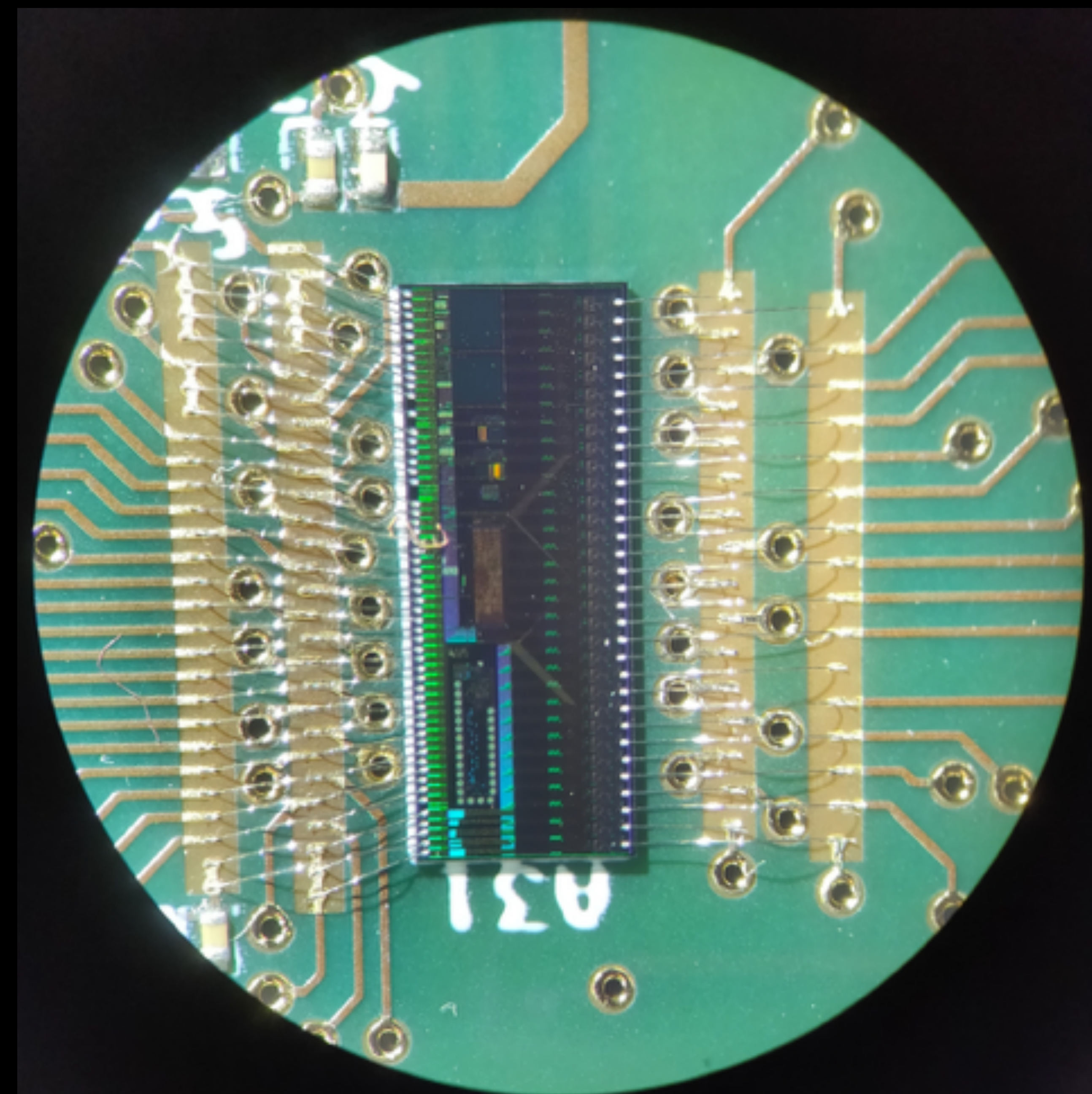

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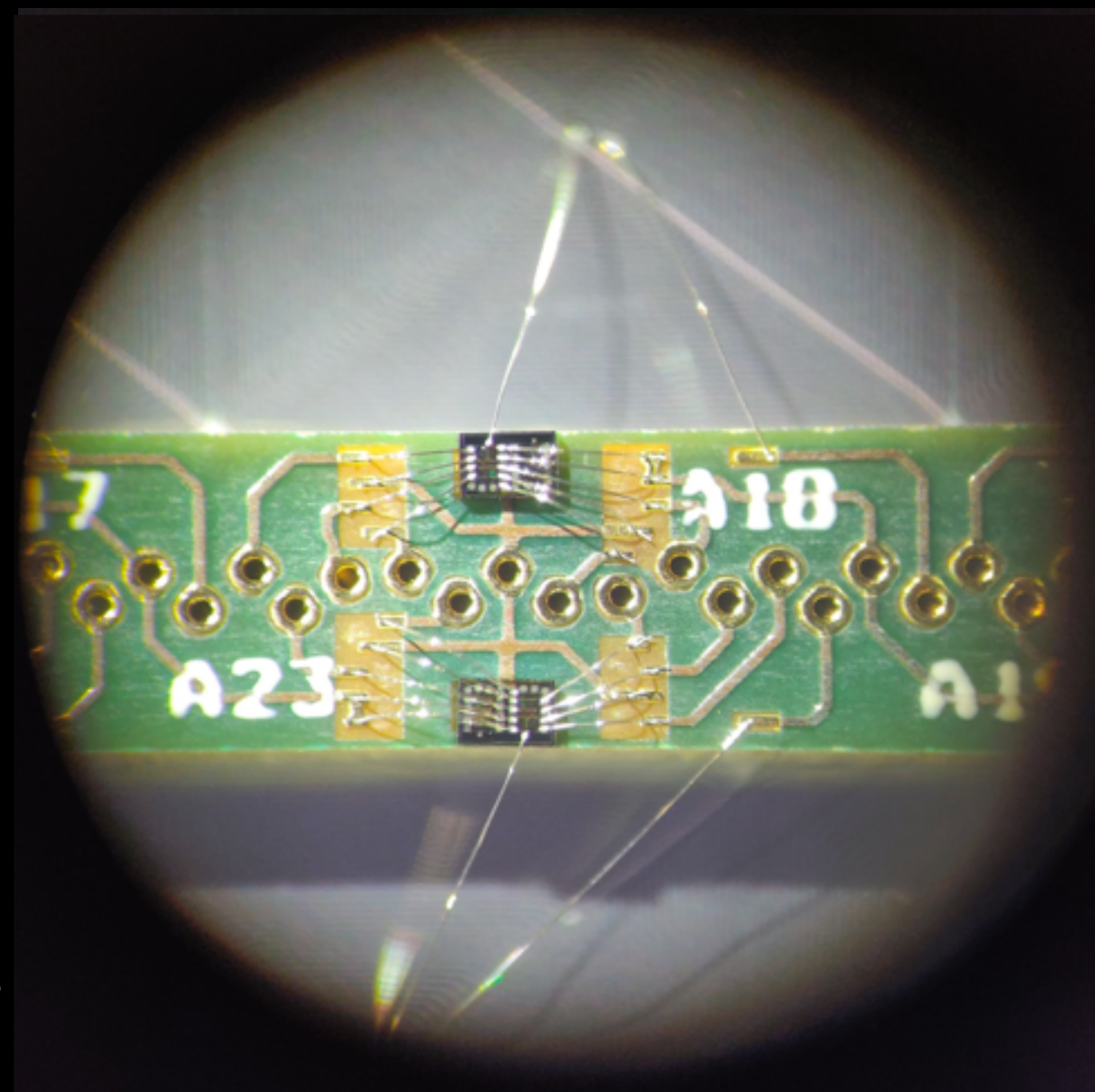
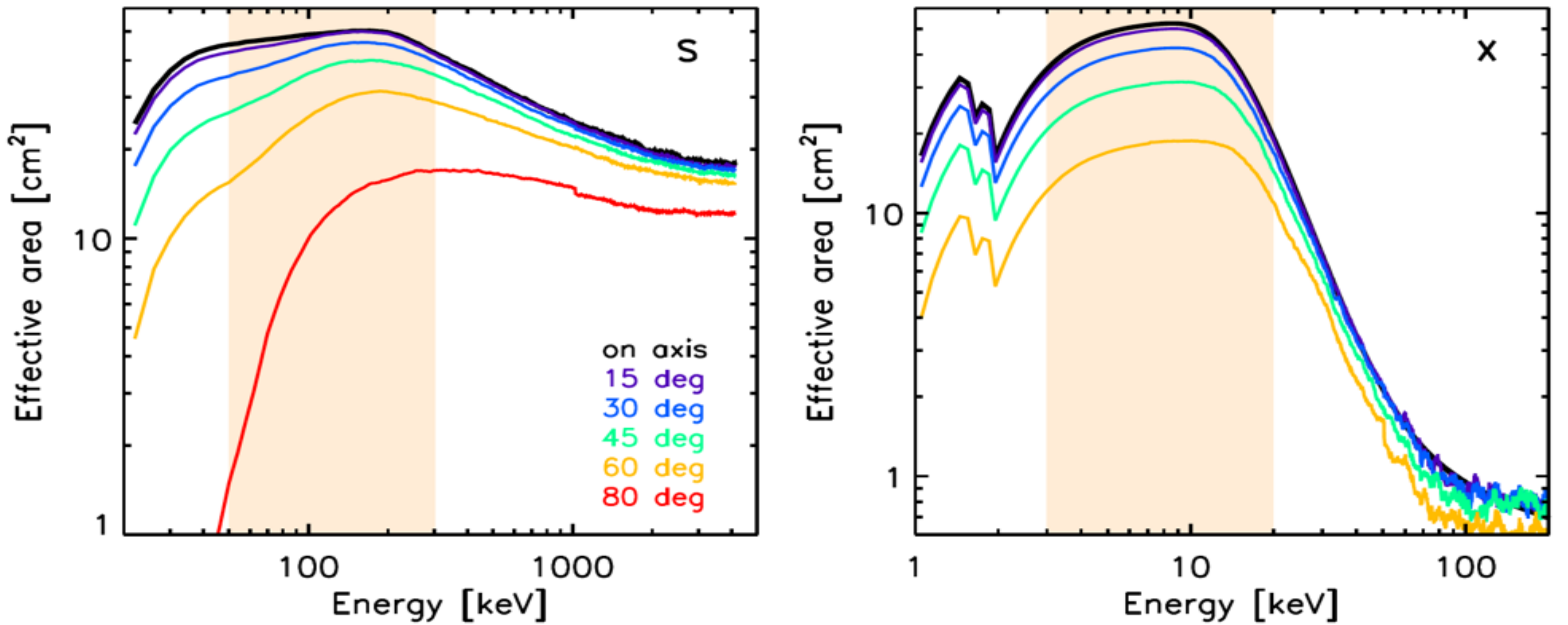


HERMES performances

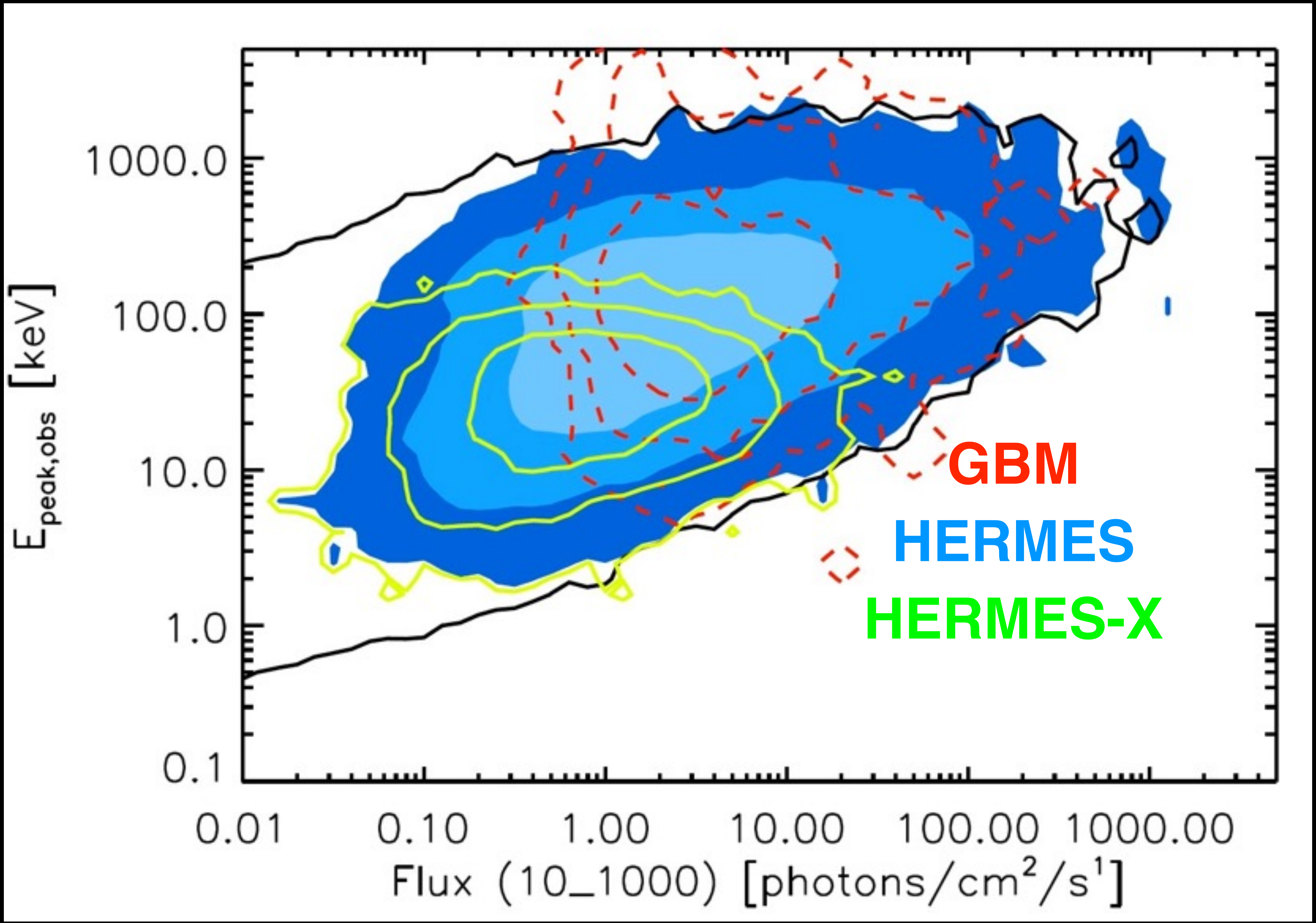


Background: 50-300 keV =75counts/s; 3-20 keV 390counts/s

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

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

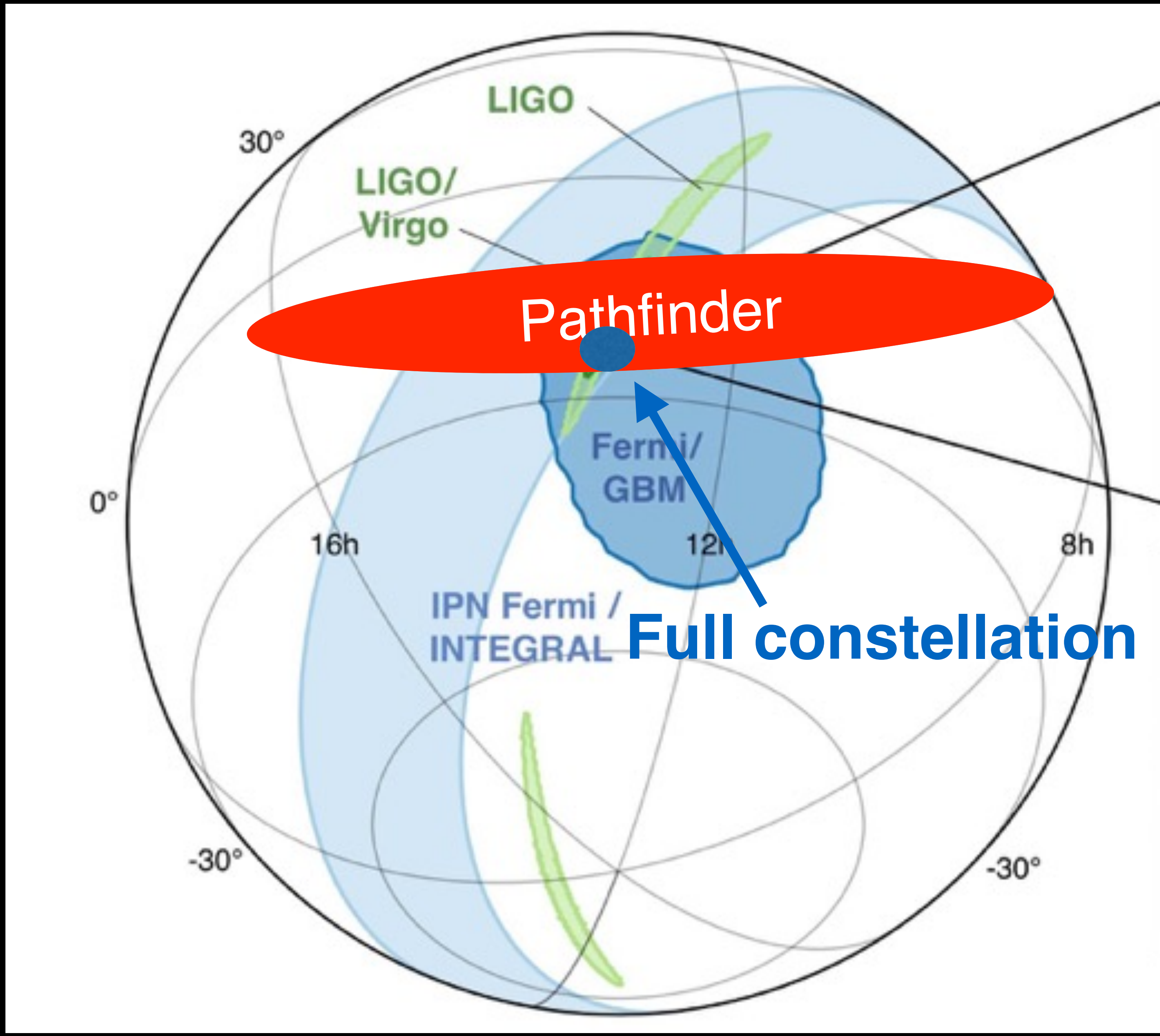
<B>~7000km

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

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

N(Full constellation) ~100, active 50

$\sigma_{Pos(FC)}$ ~ 15 arcmin if σ_{CCF},σ_{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:

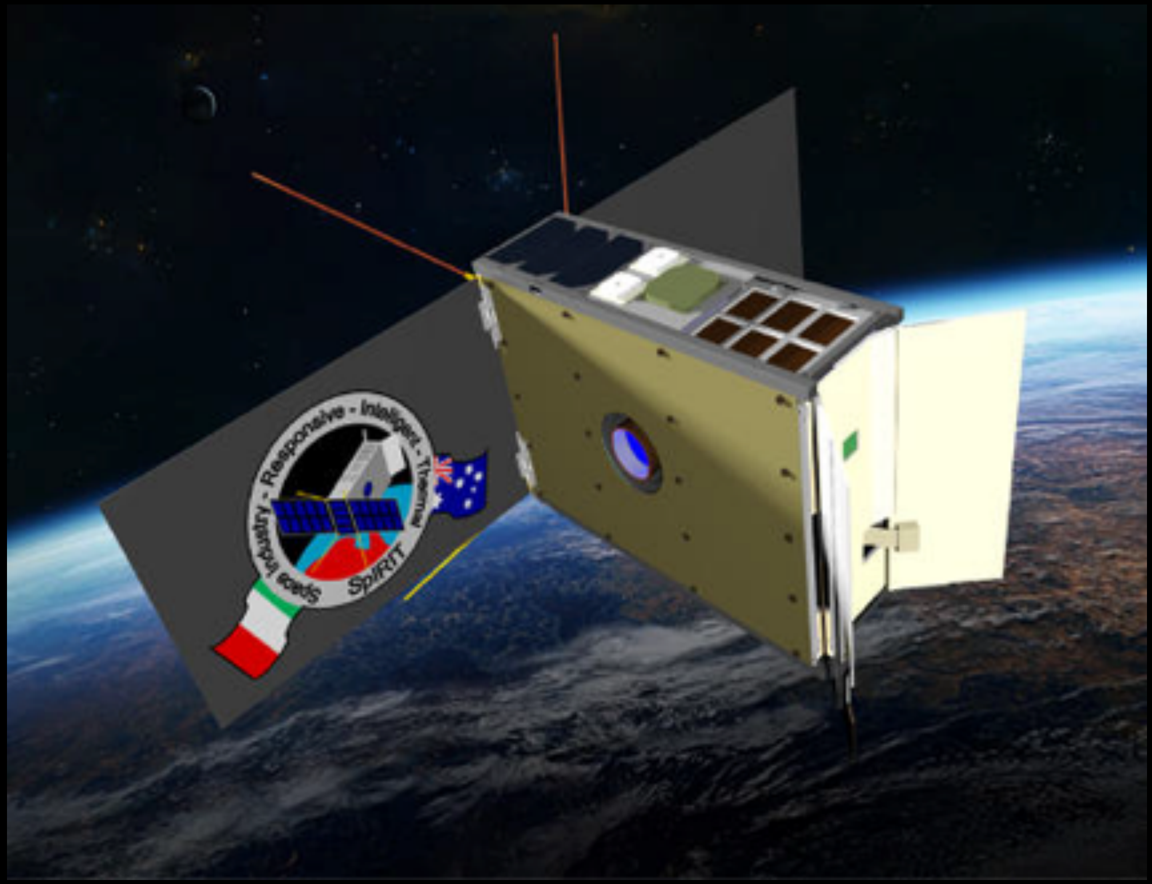
1. Detect GRBs with simple payload hosted by a 3U CubeSat
2. Study statistical and systematic errors in the CCF determination
3. **First GRB localization experiment with ≥3 CubeSat**

- 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



Farther Future

- From Pathfinder to full constellation
- From LEO to HEO, Moon, Mars

↓

- sub-arcsec positions
- 1-2 m^2 collecting area

Thanks!