From HERMES Pathfinder to DAMA

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

Outline

- Motivations
- Two revolutions
  - Space 4.0
  - The multimessenger revolution
- The HERMES-Pathfinder/SpIRIT projects
- The need for a sensitive GRB all sky monitor during the 2020’ and 2030’

www.hermes-sp.eu

Motivation

- Prove that ***breakthrough science*** can be done with nano-sats, not only with large, complex, expensive missions. ***"Smaller"*** enables the"***faster, better, cheaper***"[1] mantra, but also ***expand usership,*** increasing competition ***and*** collaborations

- ***Join the multimessenger revolution*** by providing a first mini-constellation for GRB localizations

- Develop miniaturized payload technology for breakthrough science and demonstrate COTS applicability to challenging missions, contribute to Space 4.0 goals

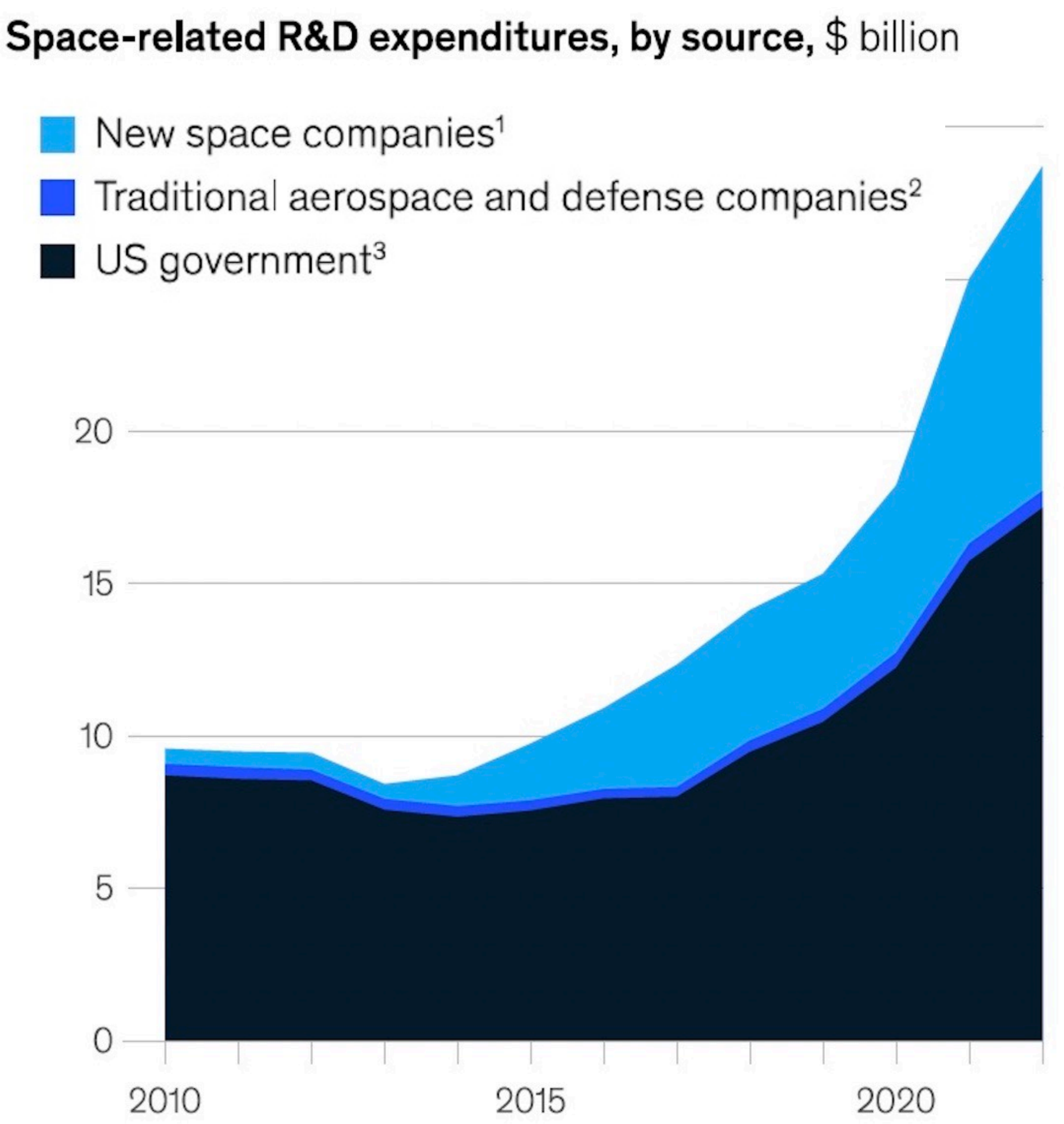
- Push and prepare for a high reliability, large constellation

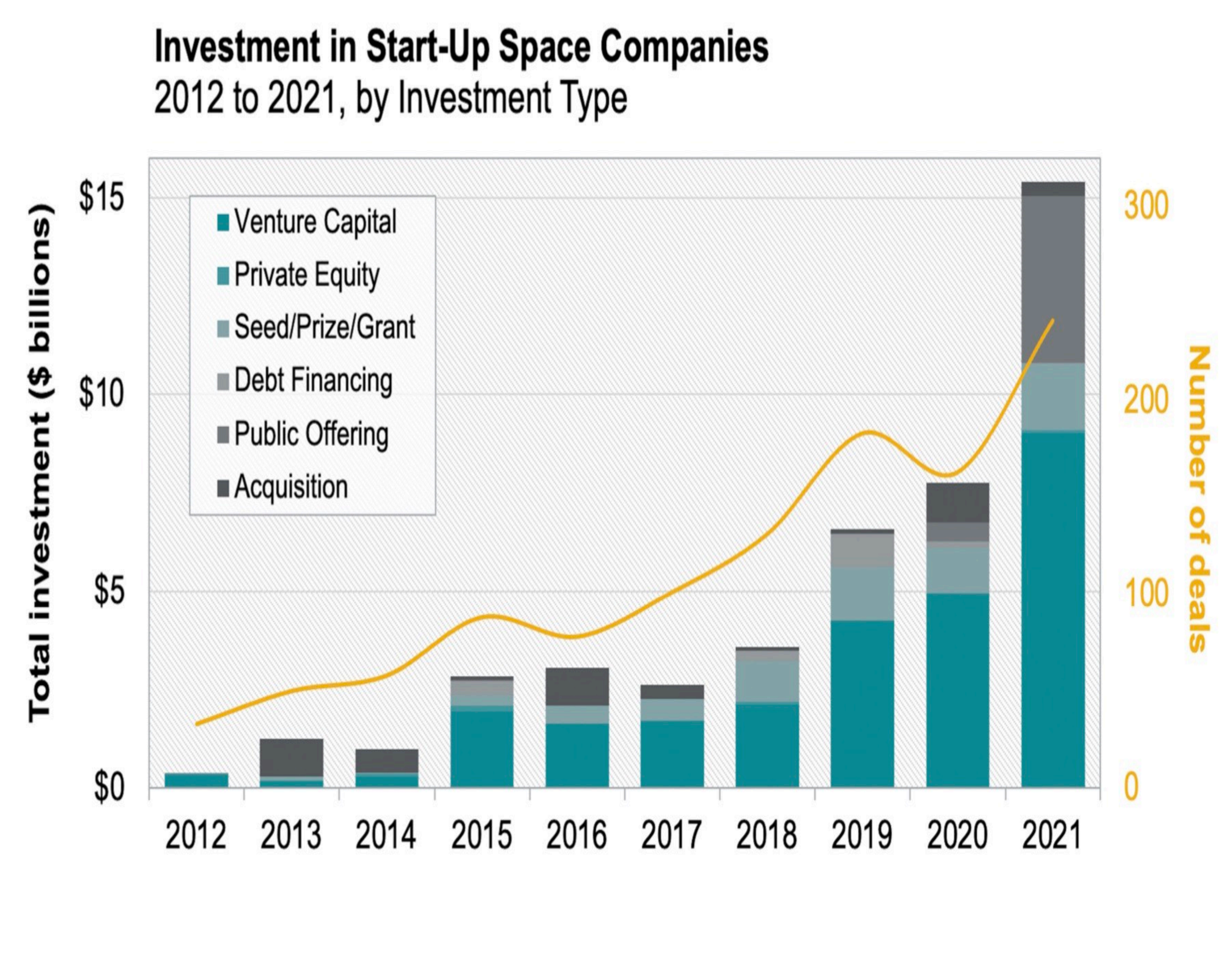
1 Dan Goldin 1992

Two revolutions: Space 4.0

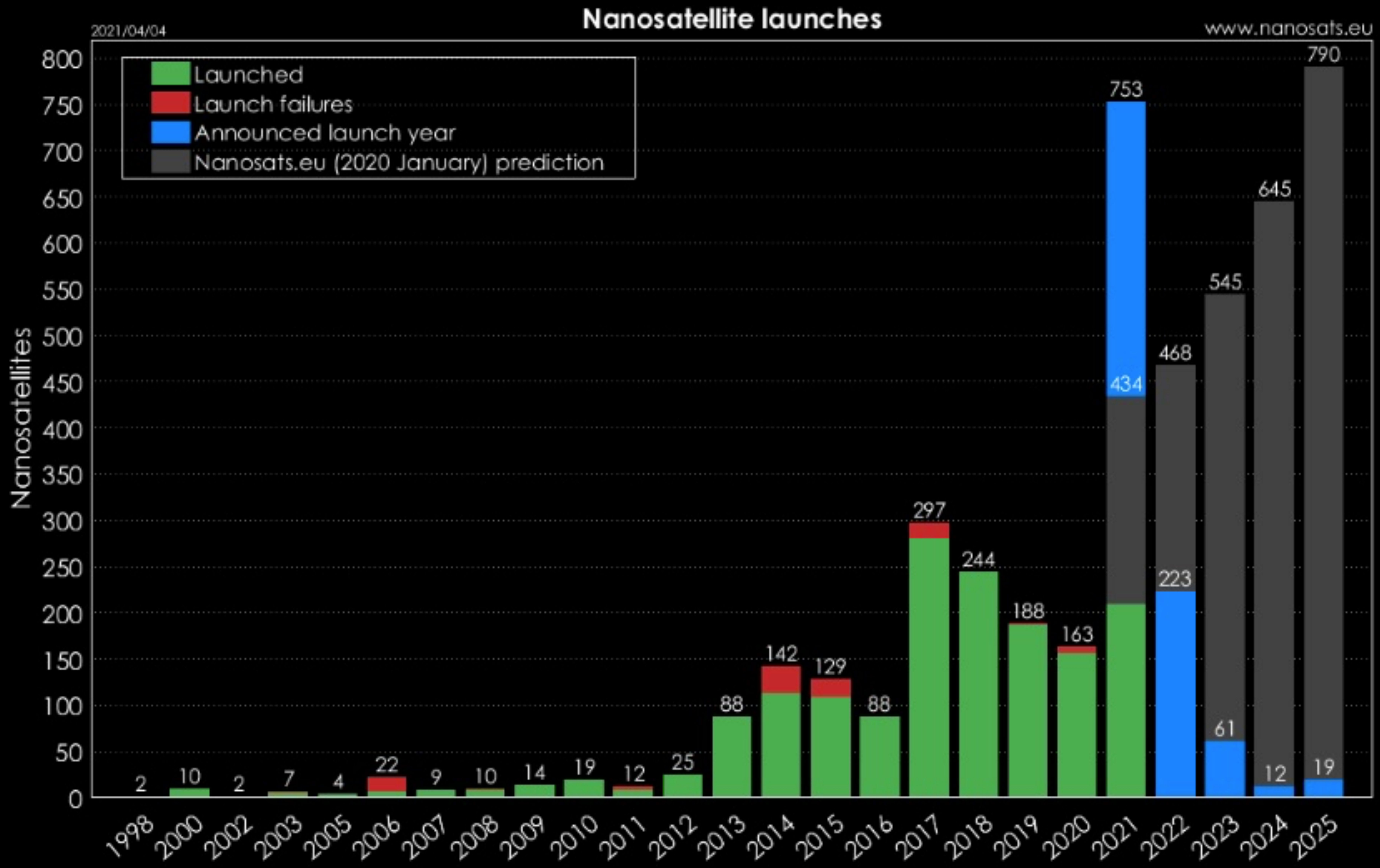
Two revolutions: Space 4.0

McKinsey 2022





Two revolutions: Space 4.0



The multi-messenger revolution

Phinney 2009

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Is NS-NS & BH-NS coalescence the engine of short GRBs?
Associations of GWEs and SGRBs will tell.

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Are GRBs powered by BH accretion or magnetars?
GW detections provide mass of final compact object.

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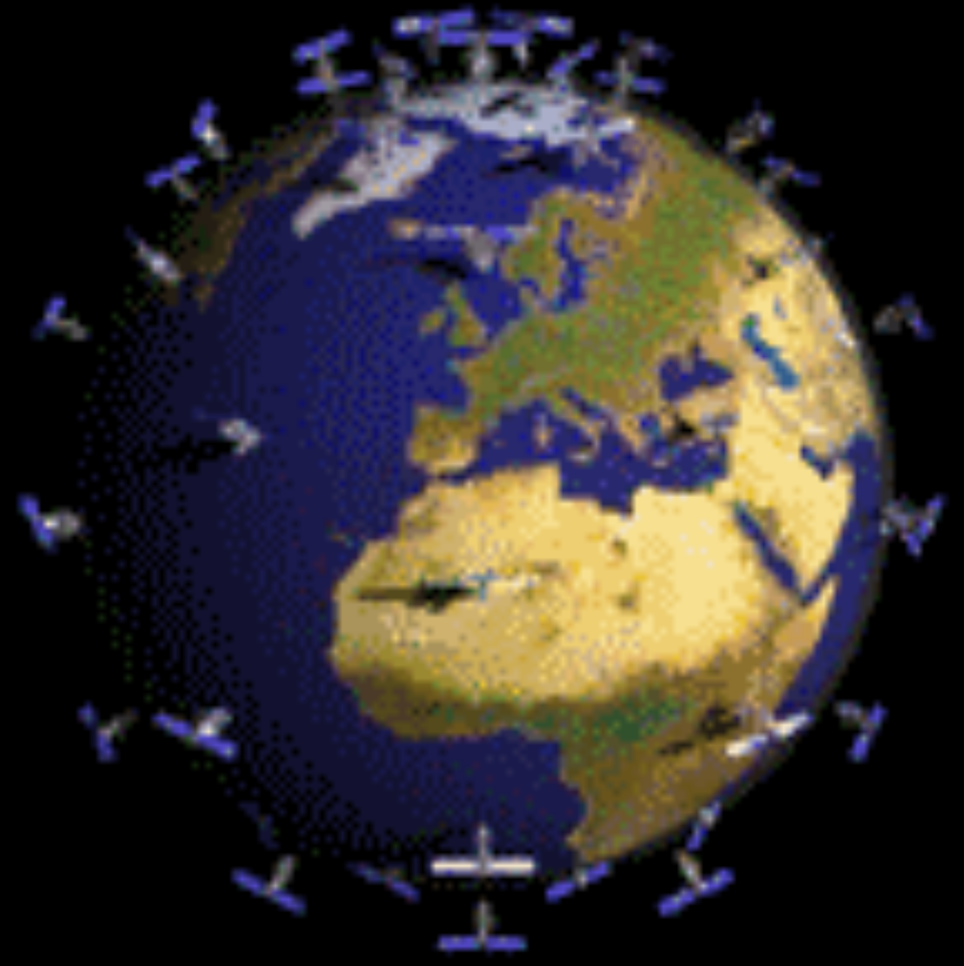

Is NS-NS & BH-NS coalescence the engine of short GRBs?
Associations of GWEs and SGRBs will tell.

Are GRBs powered by BH accretion or magnetars?
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Which are the GRB, outflows and afterglows opening angles?
GW detections provide system inclination.

The multi-messenger revolution

Phinney 2009

Which are the galaxy environments where coalescing NS-NS, BH-NS and BH-BH are found?
Identification of the GWE host galaxy will tell

The multi-messenger revolution

Phinney 2009

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Identification of the GWE host galaxy will tell

How some stars explode as SNe?
GW will provide core dynamics, EM will provide explosion type, nucleosynthesis, BH vs NS remnant

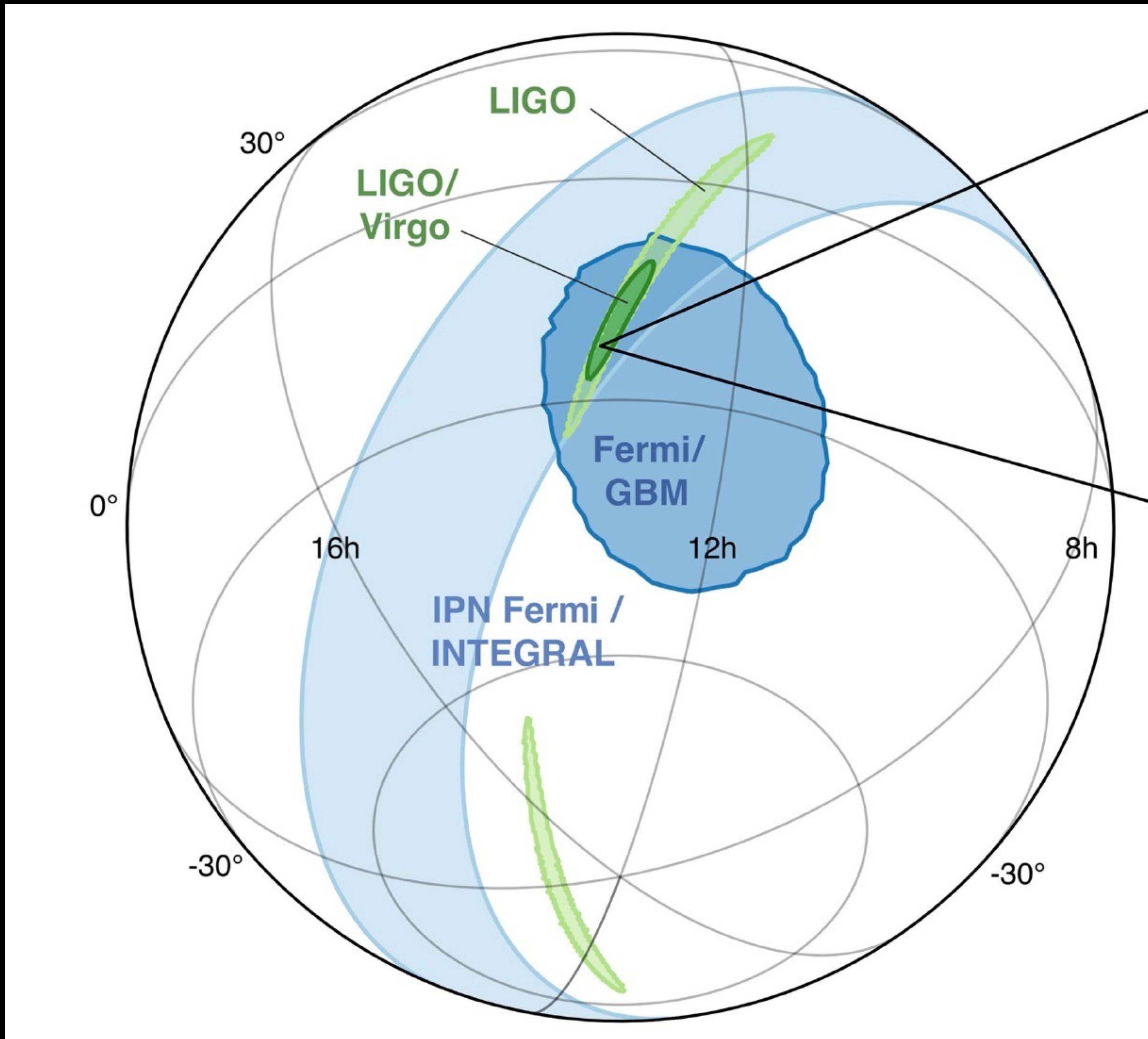
The multimessenger revolution

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

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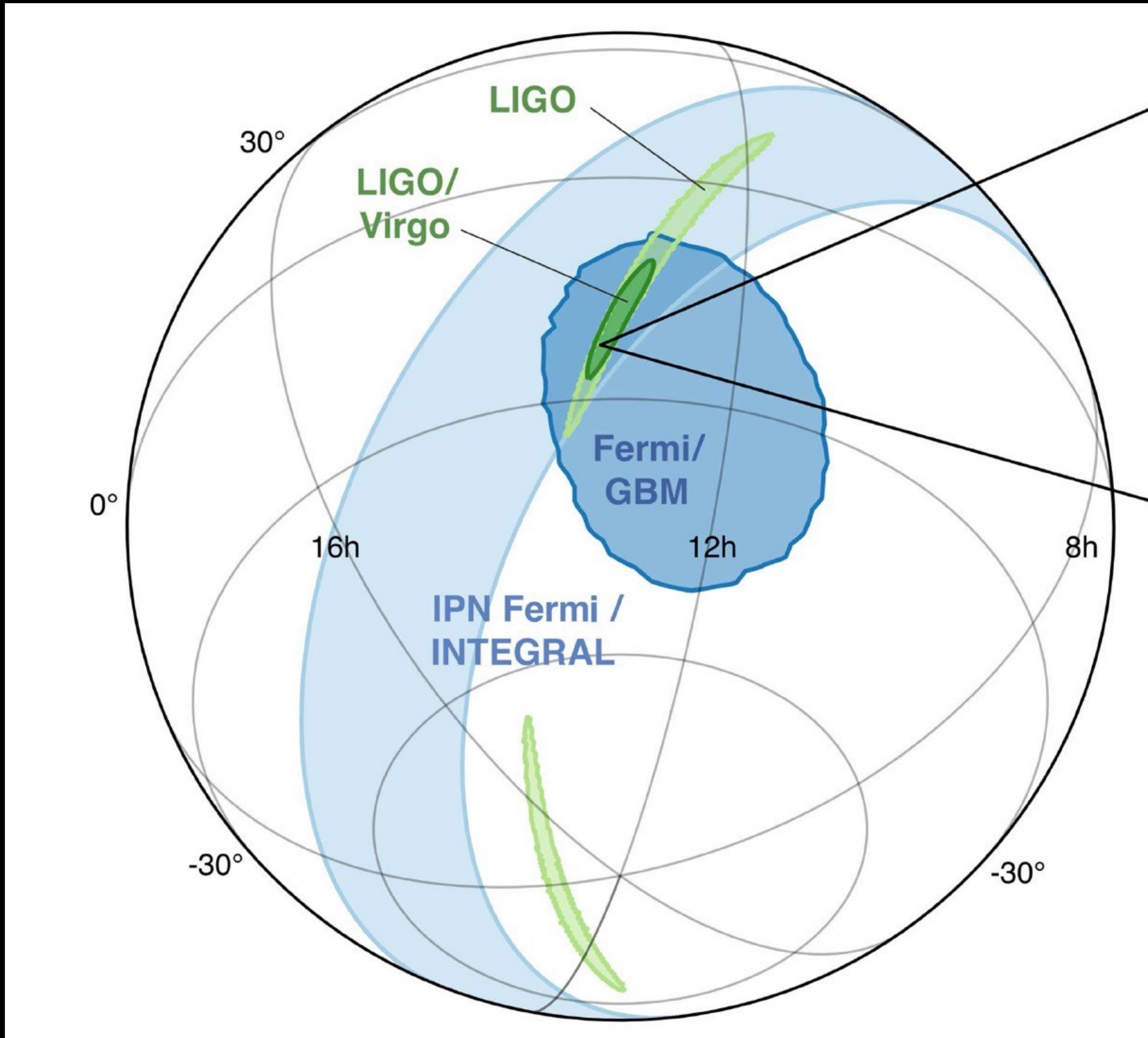

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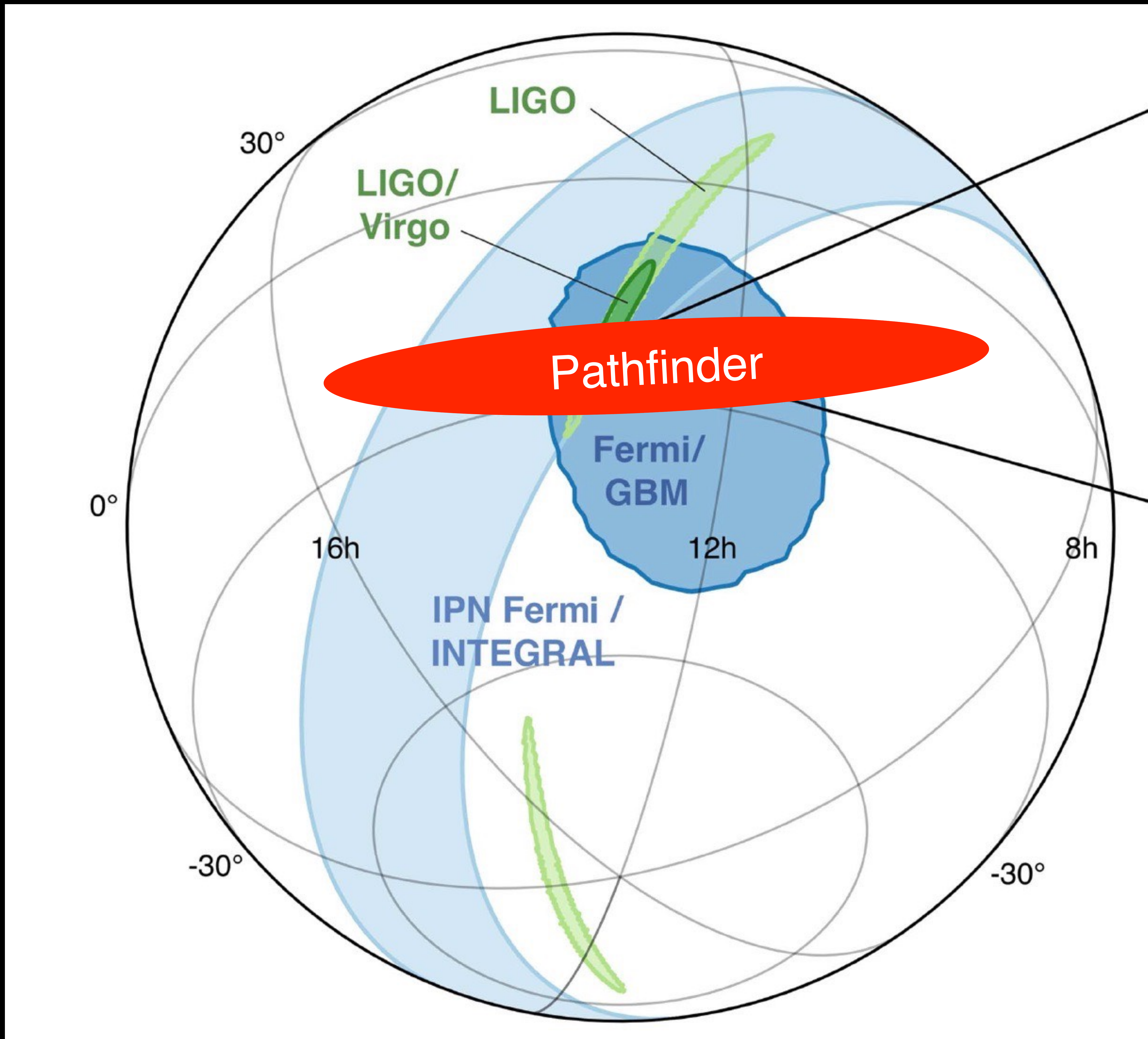

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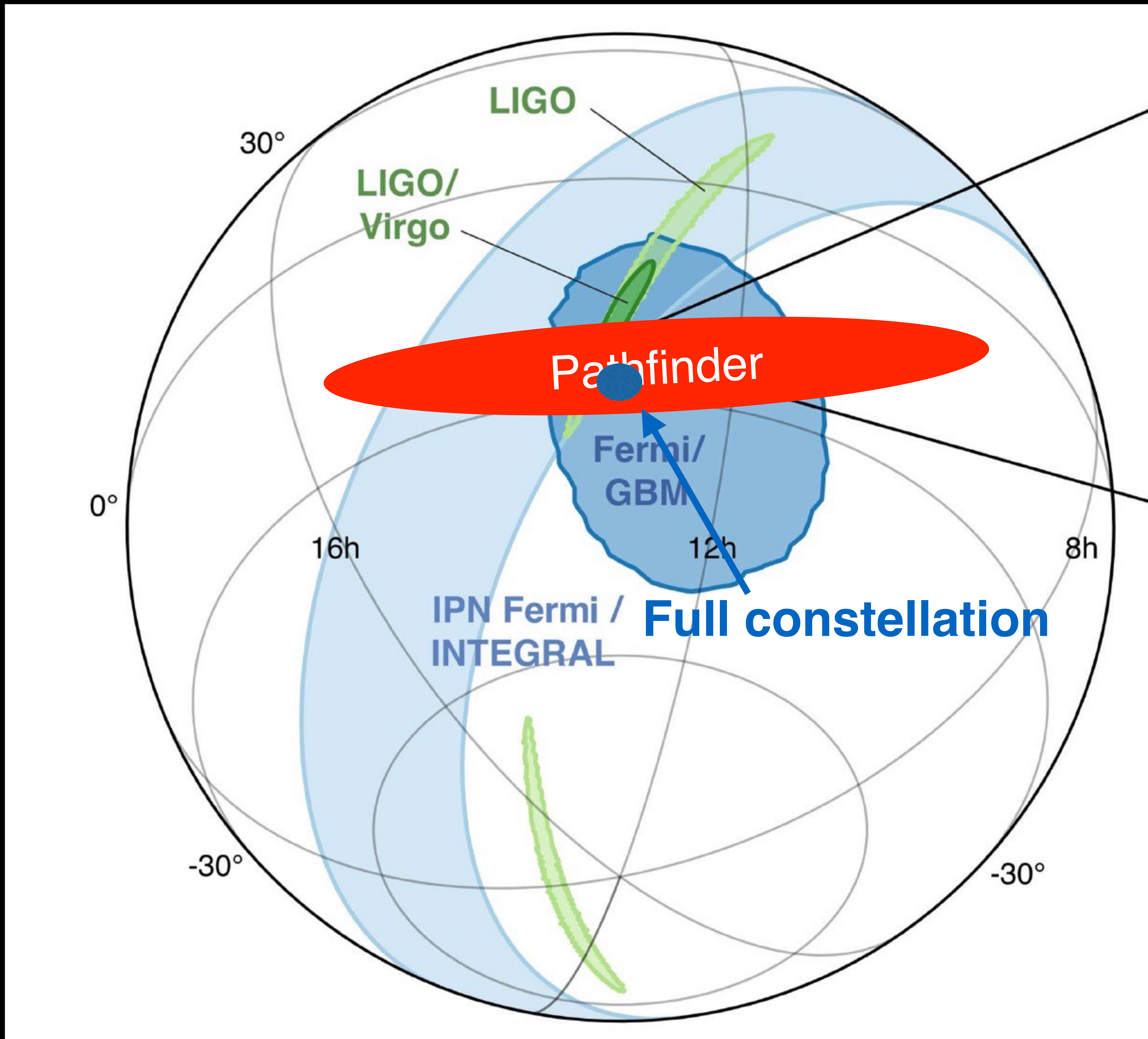
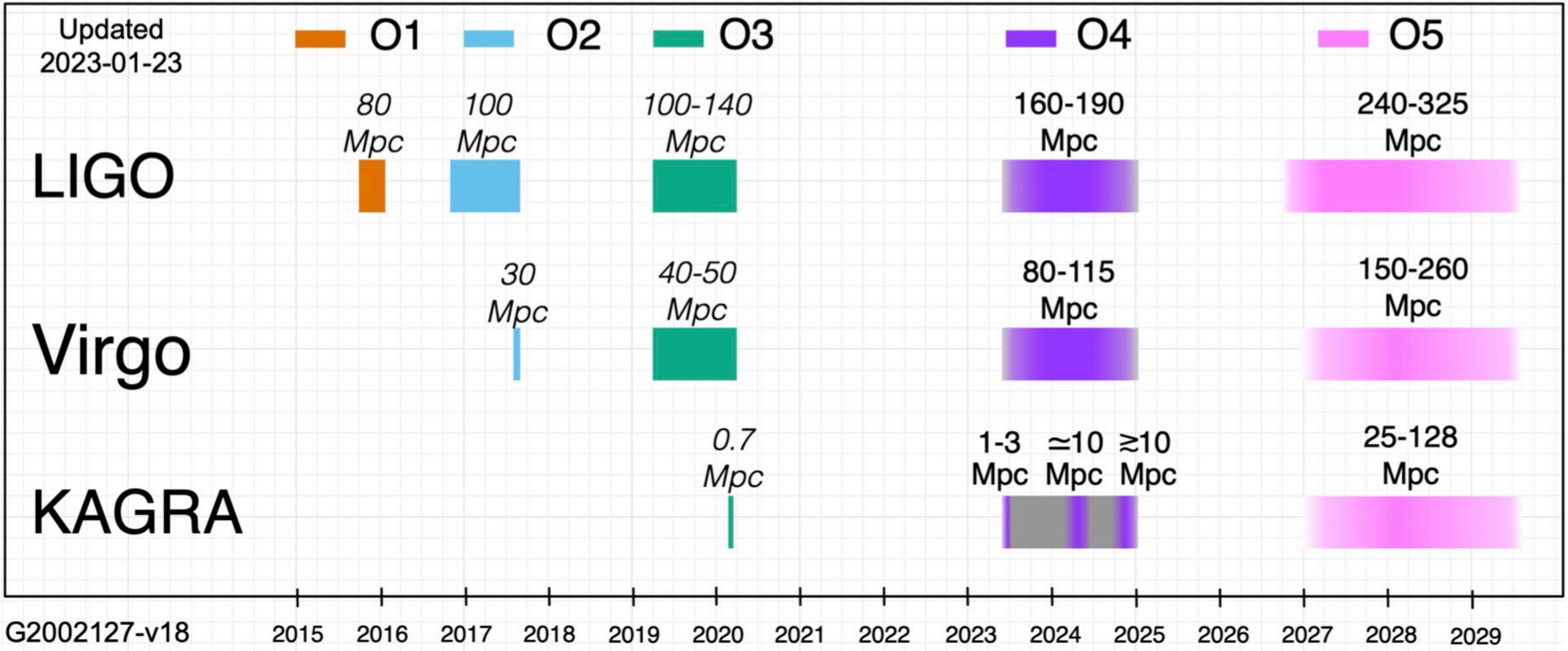


Why: GRBs and Compact binary coalescence



Why: GRBs and Compact binary coalescence

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

Loosing one event is a big science loss

A sensitive X-ray all-sky monitor during the 20':

DAMA: Distributed Architectures for Multimessenger Astrophysics

Requirements

All-sky monitor during the 2020’-2030’

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- prompt(<=minute) localisation
- sub-μs timing

Requirements

in orbit demonstrator: HERMES Pathfinder

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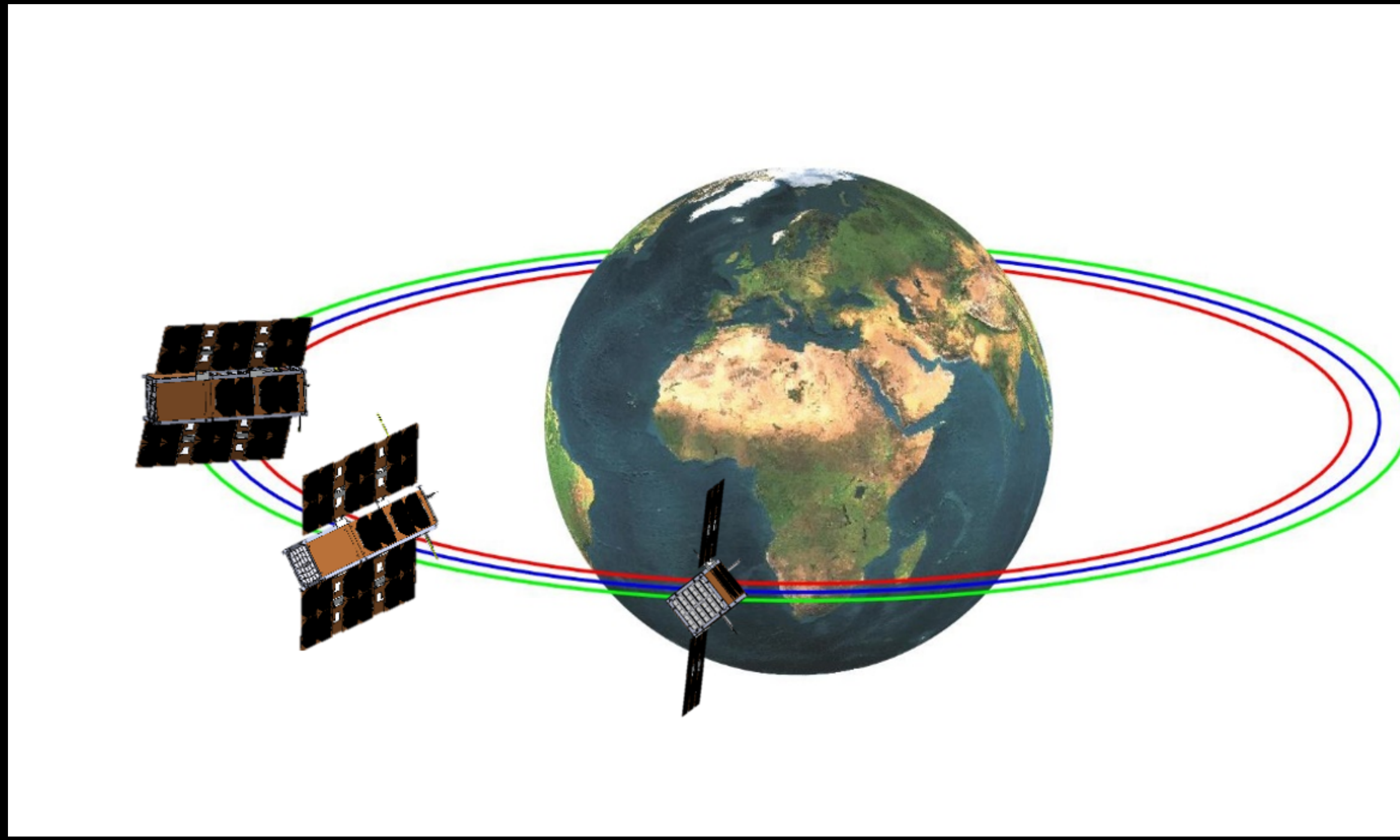
- Temporal resolution a few hundred ns
- Position reconstruction of each satellite < 30m
- Absolute time reconstruction <100 ns
- Download full burst info in minutes

HERMES-PF & SpIRIT in a nutshel

- In orbit demonstration:
  1. Routinely detect GRB with miniaturized instrumentation
  2. Localize GRB using triangularization



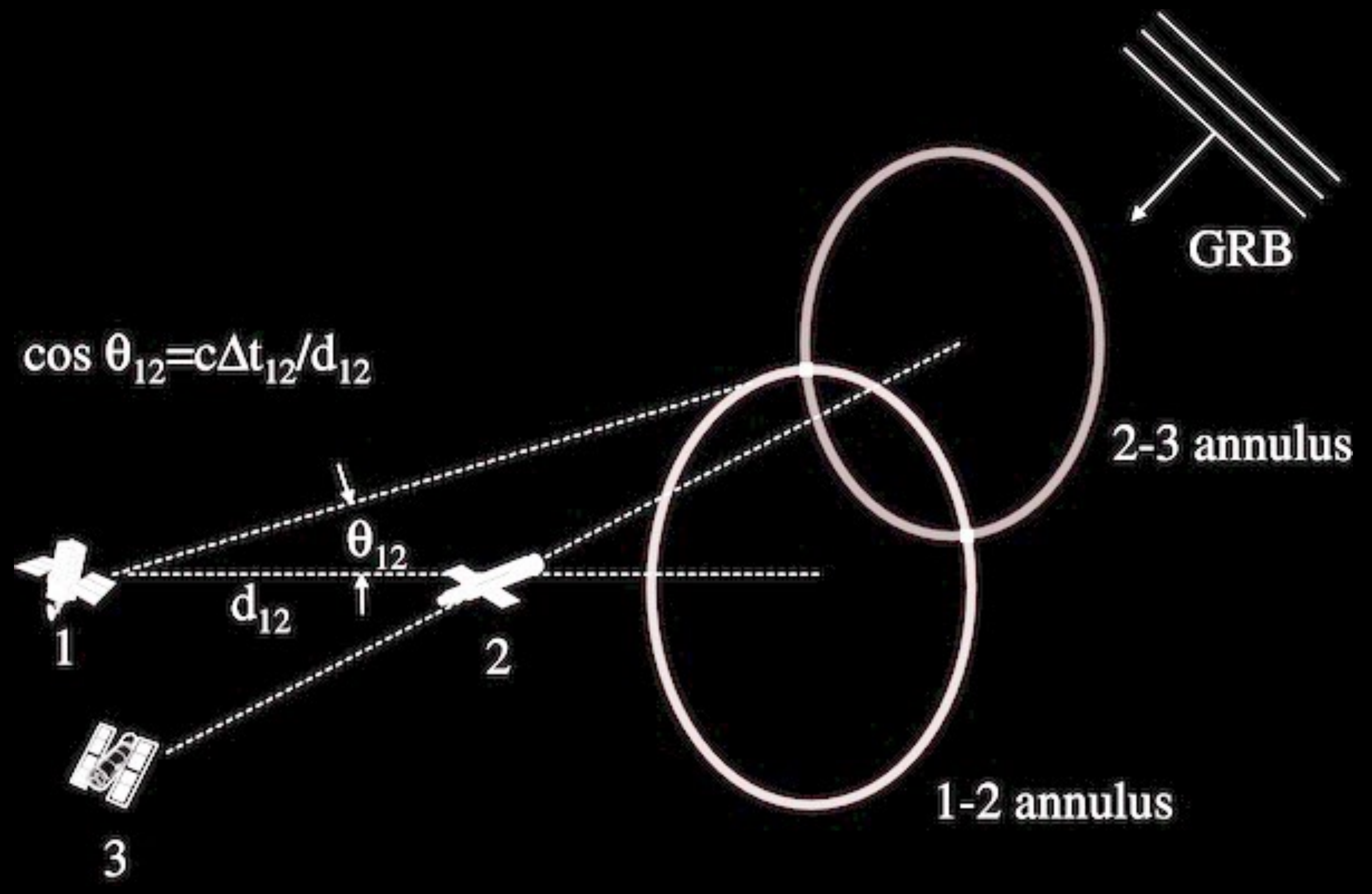
- HERMES Pathfinder: six 3U cubesat equipped with advanced X-ray/gamma/ray wide field detector. Nearly equatorial LEO.
- SpIRIT: 6U cubesat managed by University of Melbourne and funded by ASA. Host 1 HERMES-PF X-ray/gamma-ray payload + S-band system. SSO.

IPN legacy

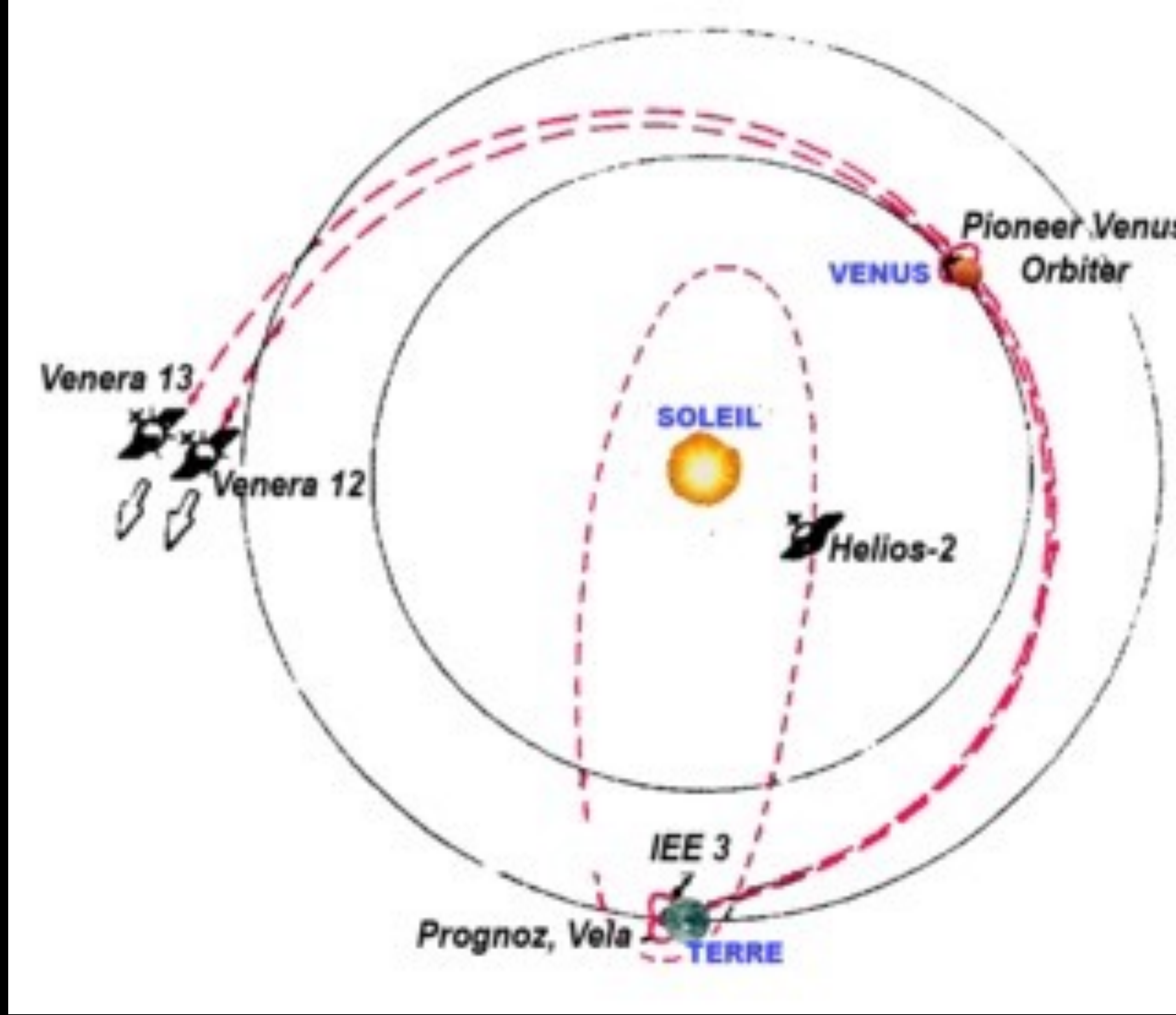
First IPN 1976
4-6 spacecrafts.
Baseline ~ 1 AU

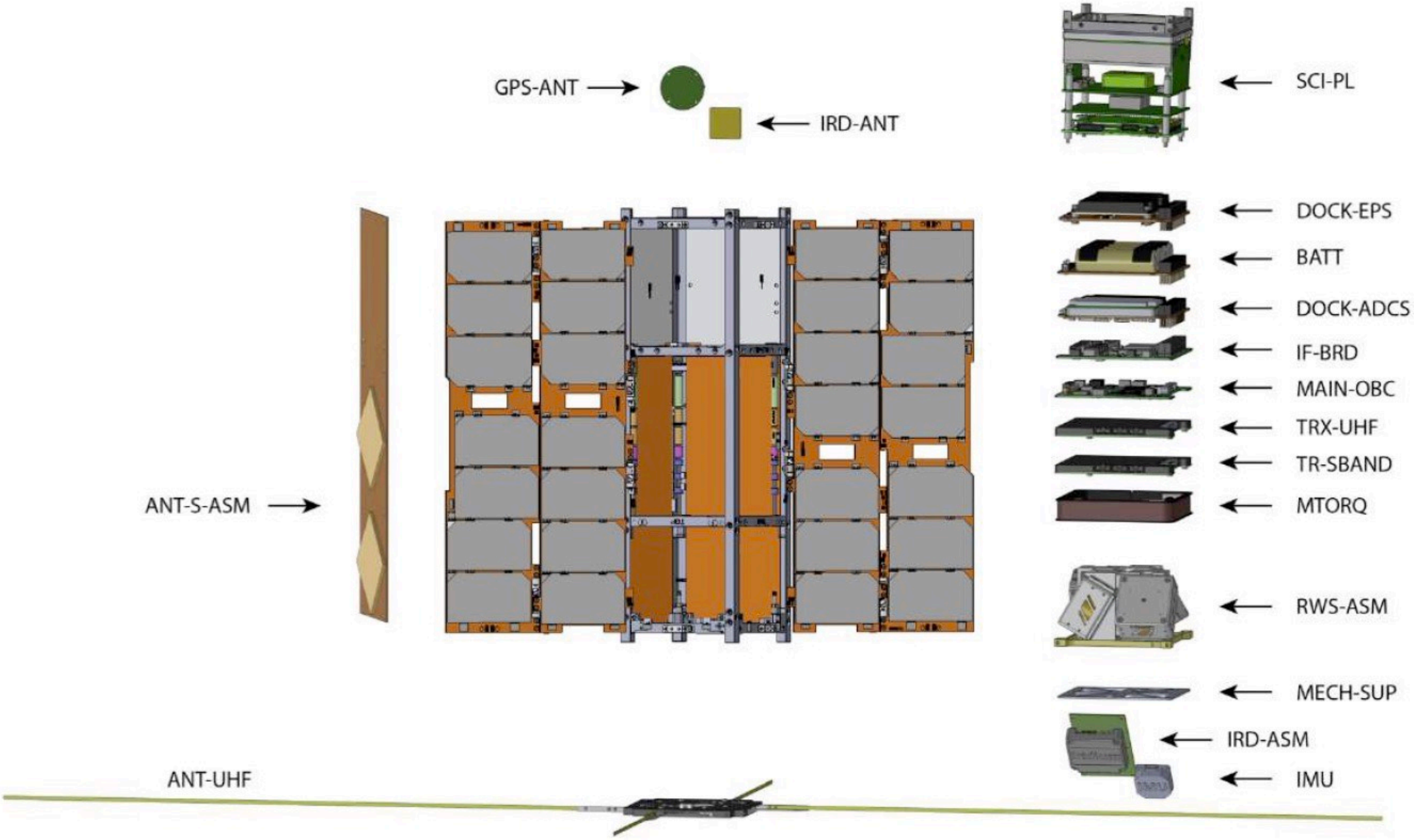
Second IPN ~1990
PVO, Ulysses, CGRO,
Wind

Third IPN 2000
~ 20 spacecrafts



Localisations: arcmin-deg
Main disadvantages: long data acquisition ~days,
large systematic errors




GPS-ANT
IRD-ANT
SCI-PL
DOCK-EPS
BATT
DOCK-ADCS
IF-BRD
MAIN-OBC
TRX-UHF
TR-SBAND
MTORQ
ANT-S-ASM
RWS-ASM
MECH-SUP
IRD-ASM
IMU
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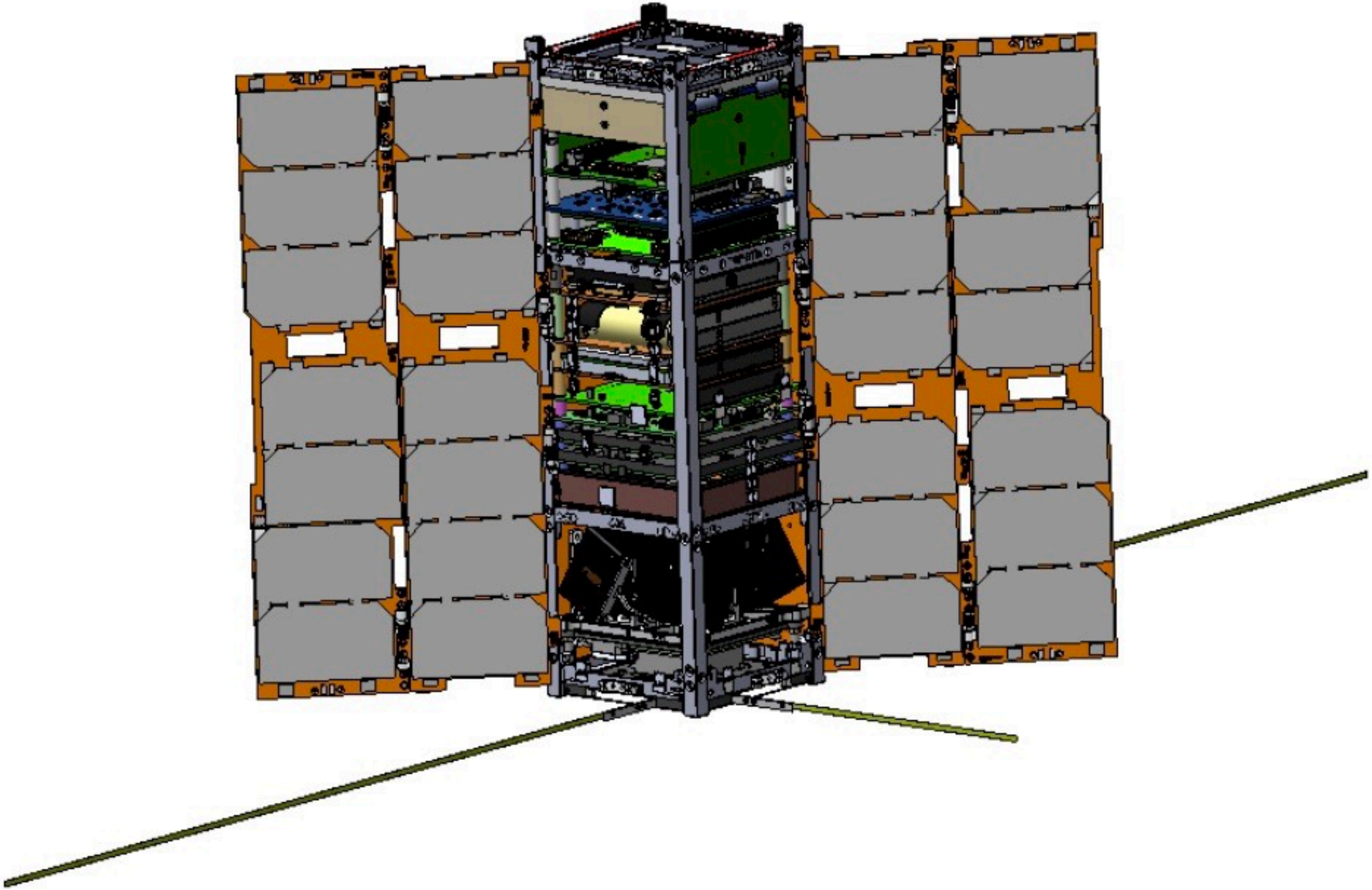
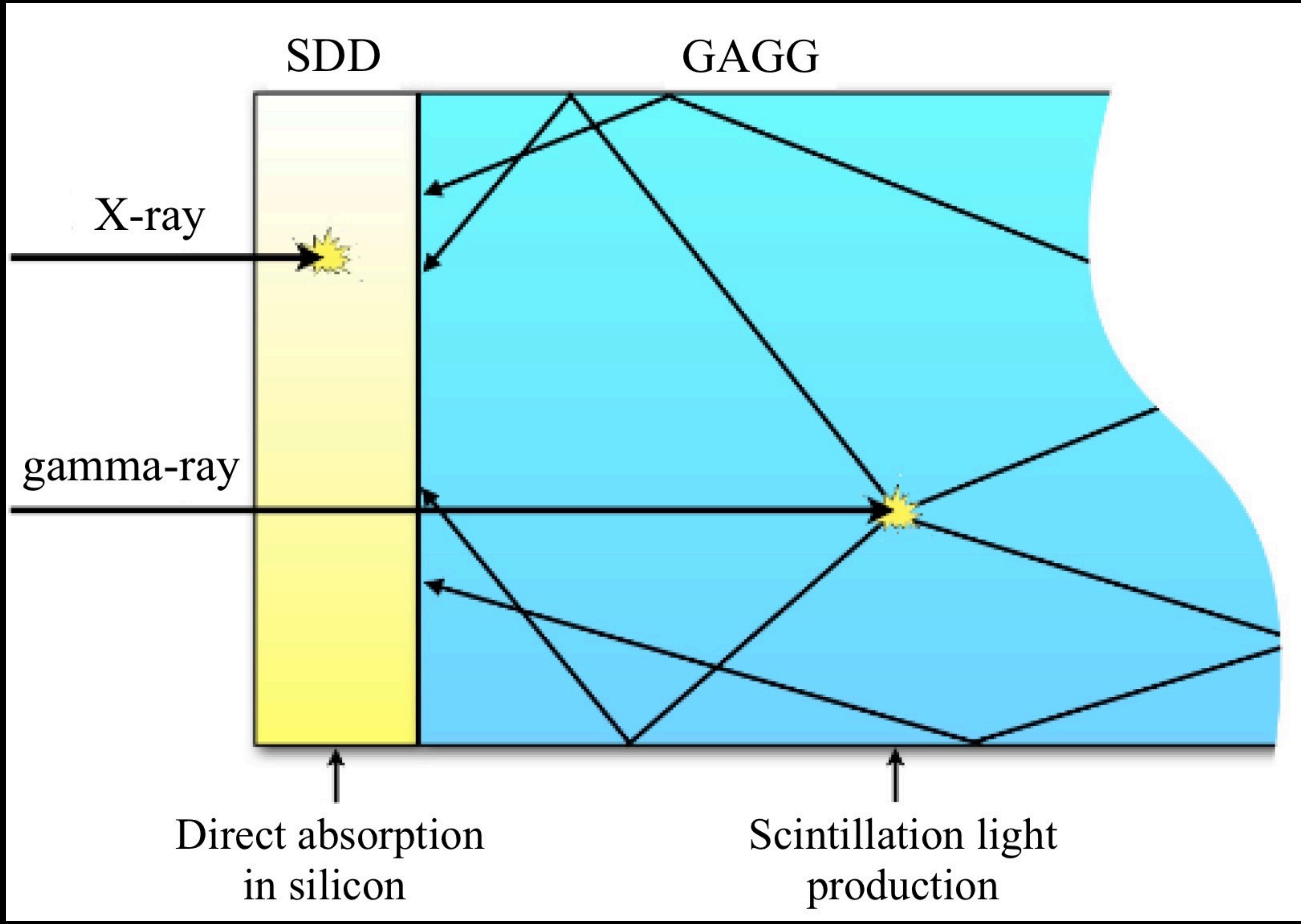


Payload concept

- 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+2020,2022, Campana+2020,2022

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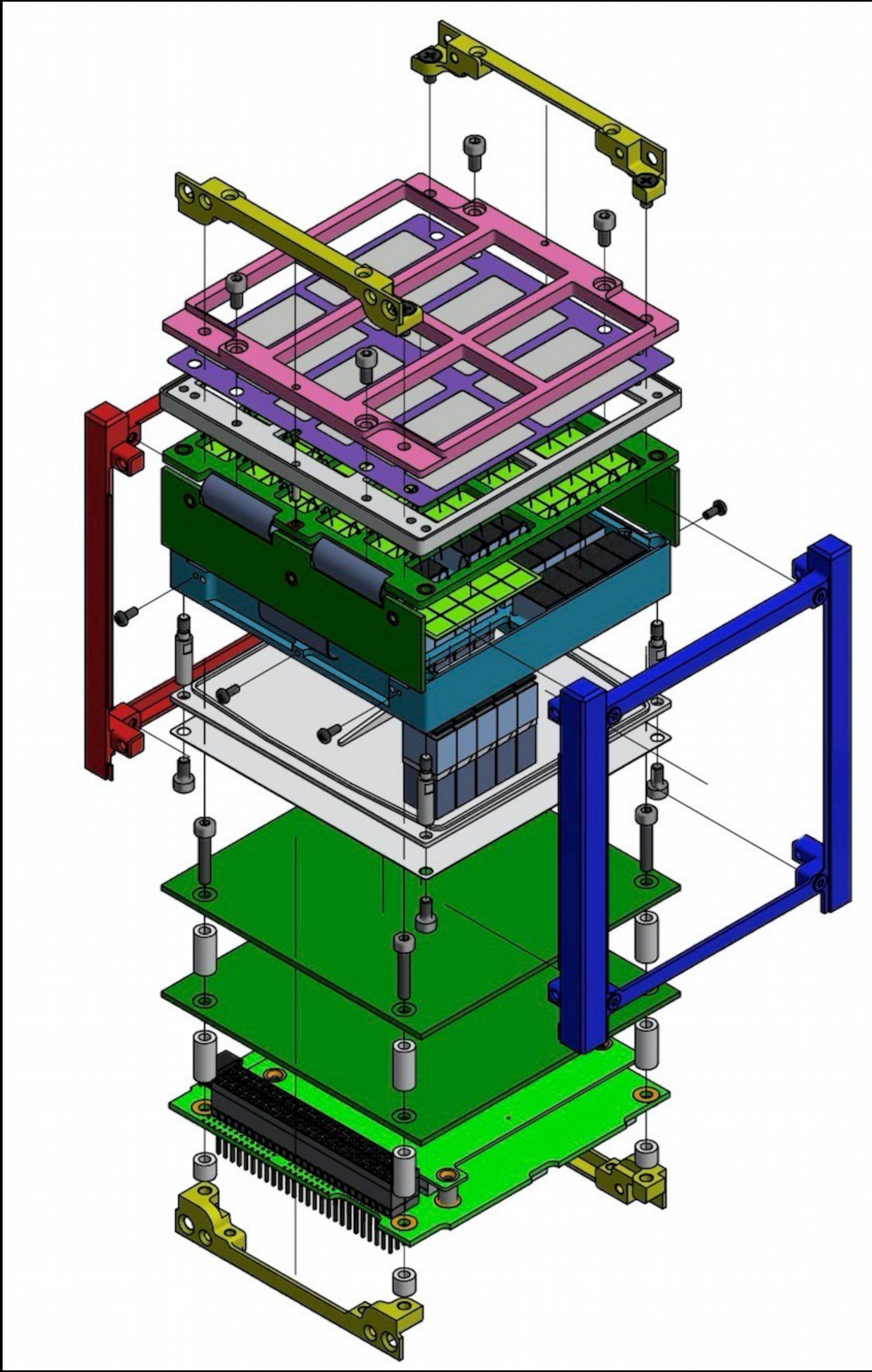

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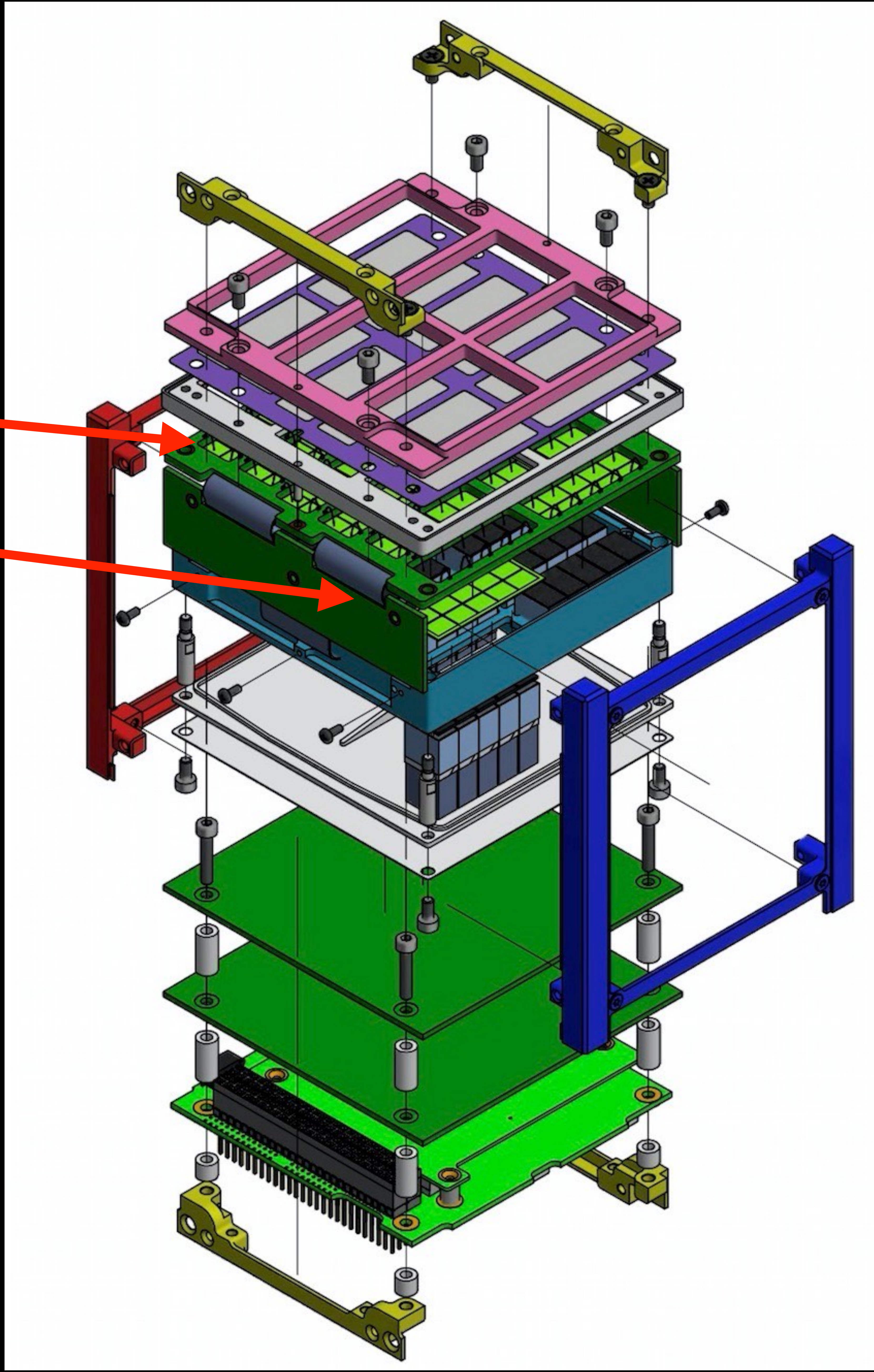
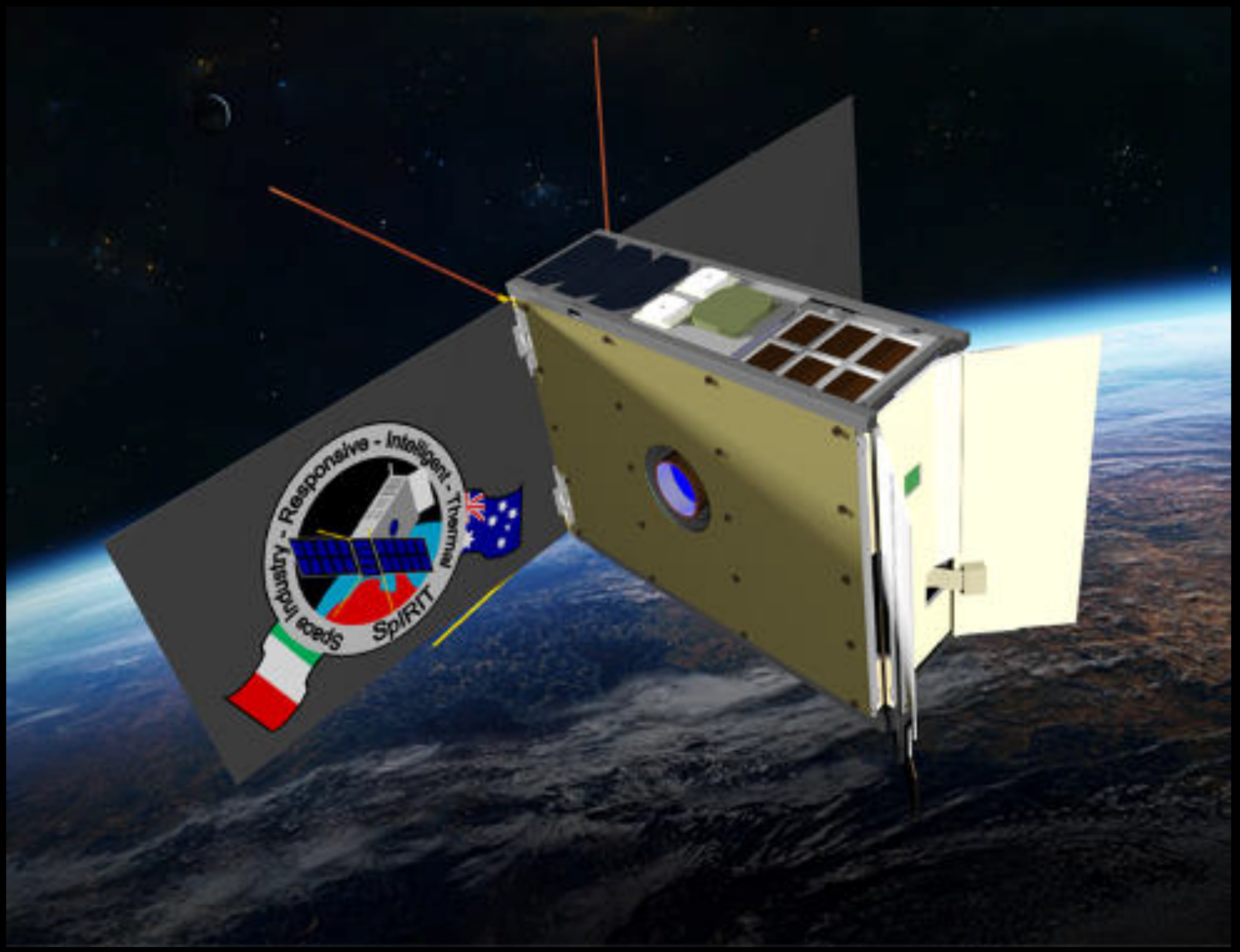
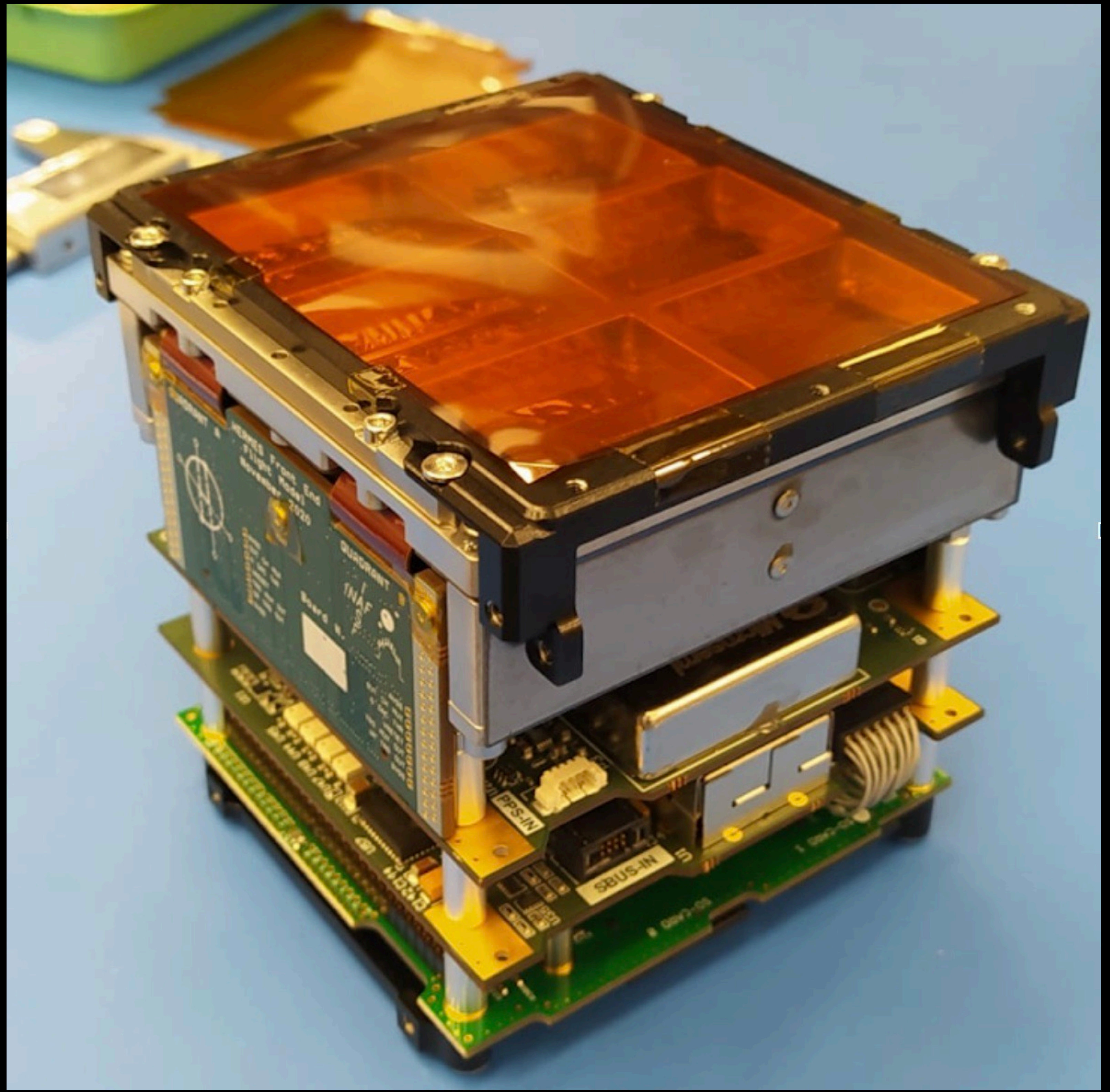


Fuschino+2018, 2020, Evangelista+2020,2022, Campana+2020,2022

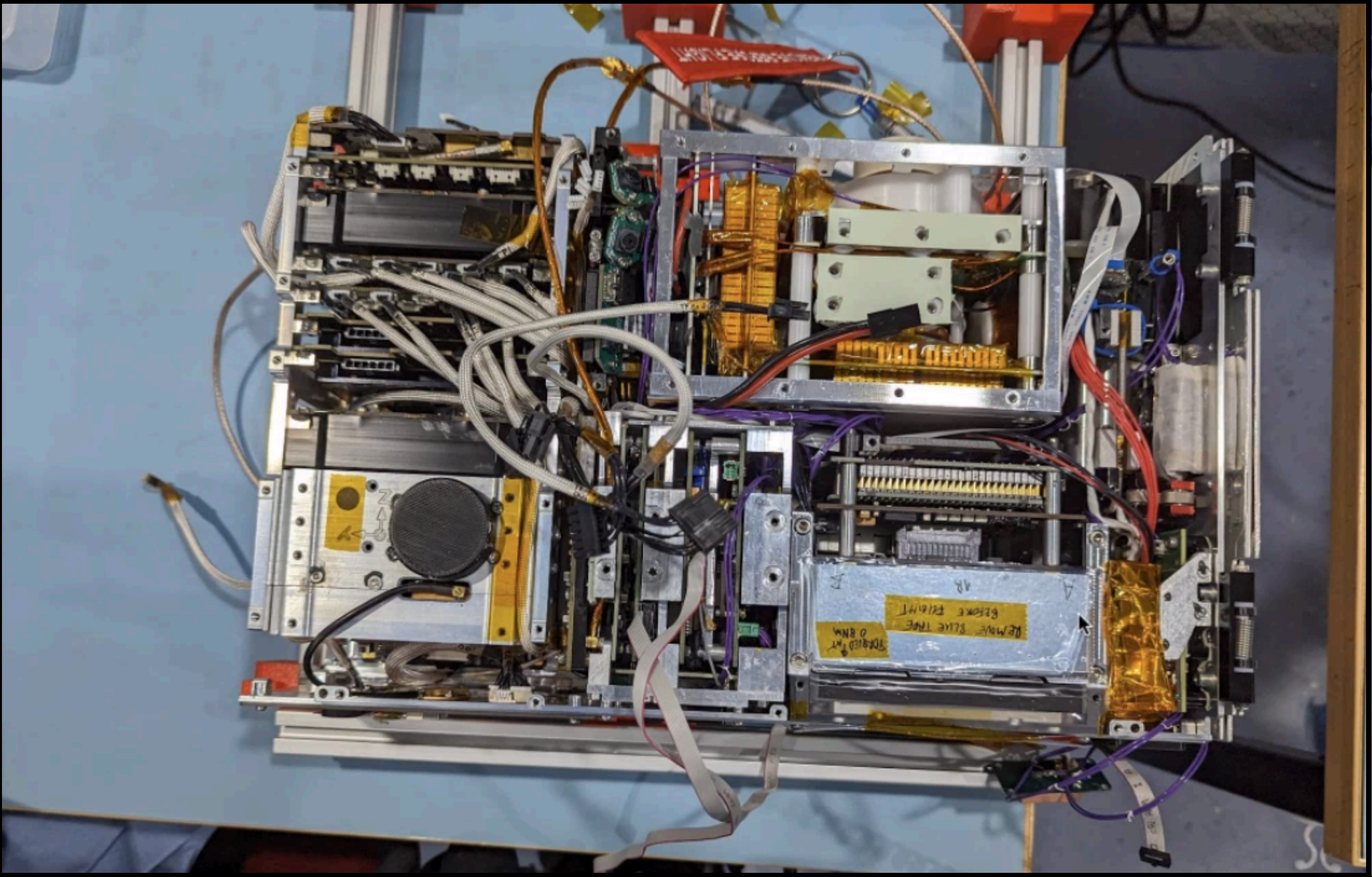
Where we are: SpIRIT

- SpIRIT paylod FM delivered to UoM on July 2022 after calibration and qualification (evironmental tests @ SERMS on June 2022).
- SpIRIT S-band system delivered to UoM Q2 2022
- Integration tests (mechanical, electrical, electronic) performed in July 2022
- P/L Integration into PMS completed May 2023
- PMS integrated into S/C July 2023
- TVAC & Vibe tests Aug 2023
- FRR 2023 Sept. 22, Ship to ISIS Sept 28th
- Launch Nov 2023



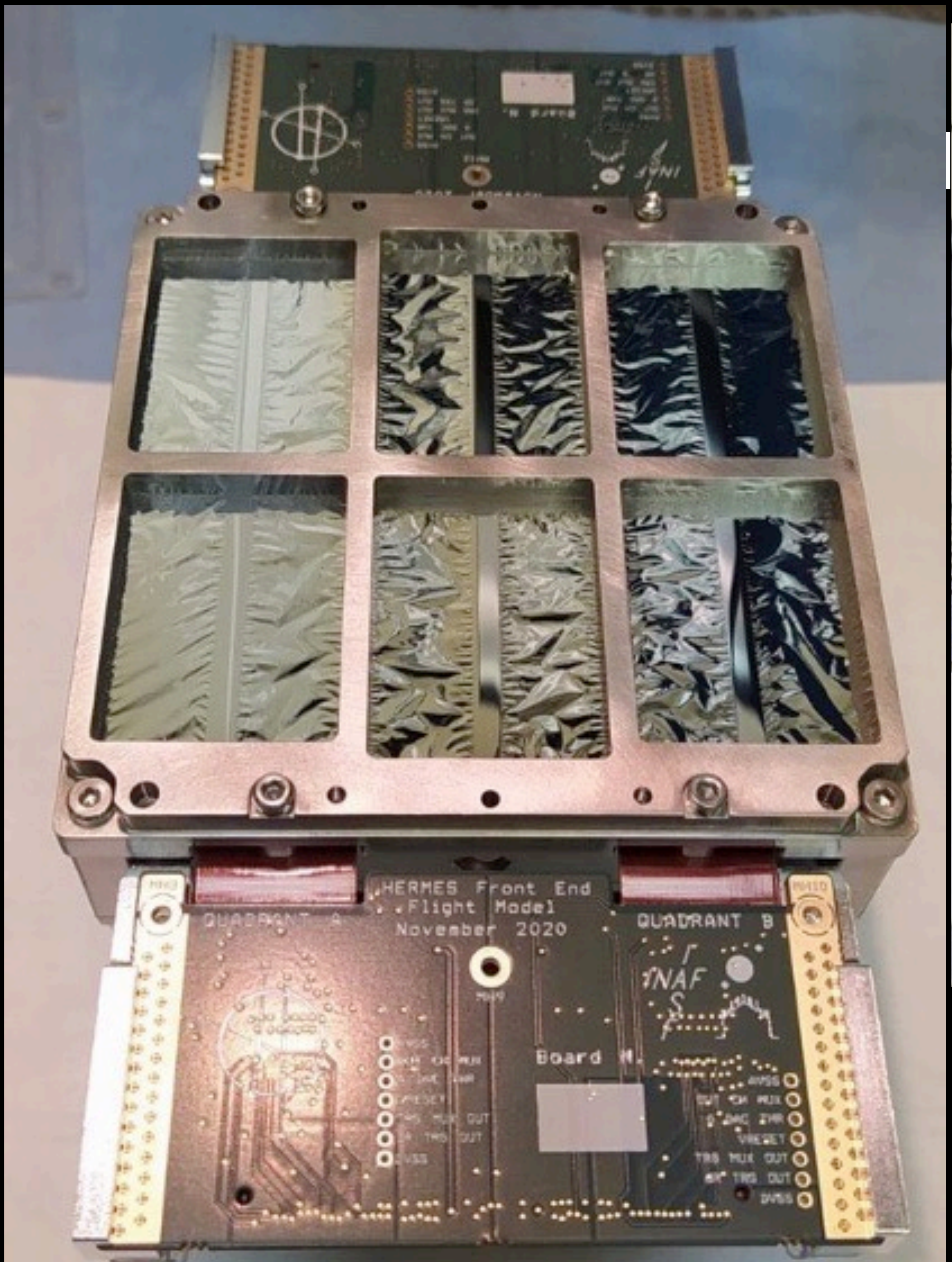


SpIRIT

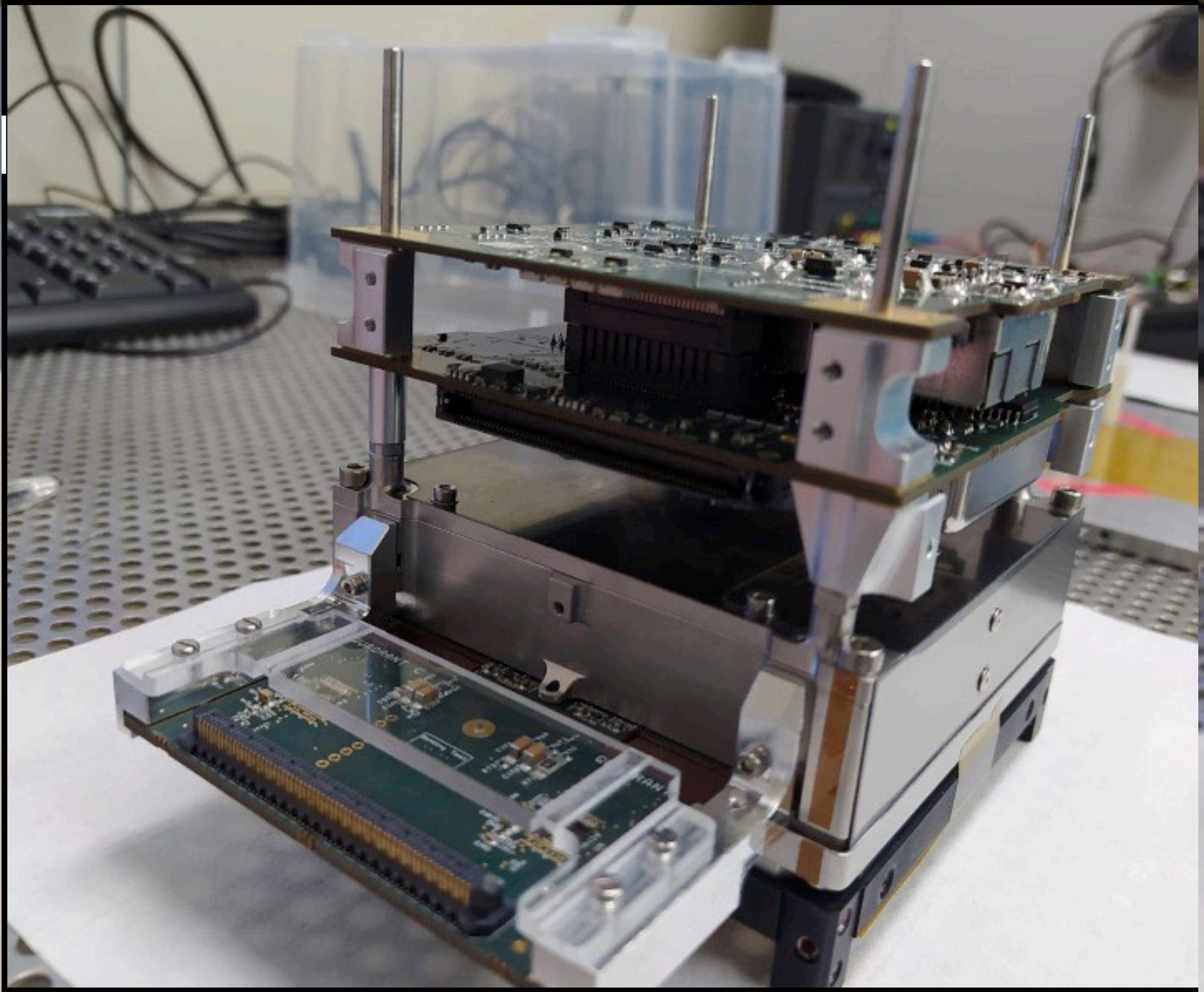


HERMES payload PFM

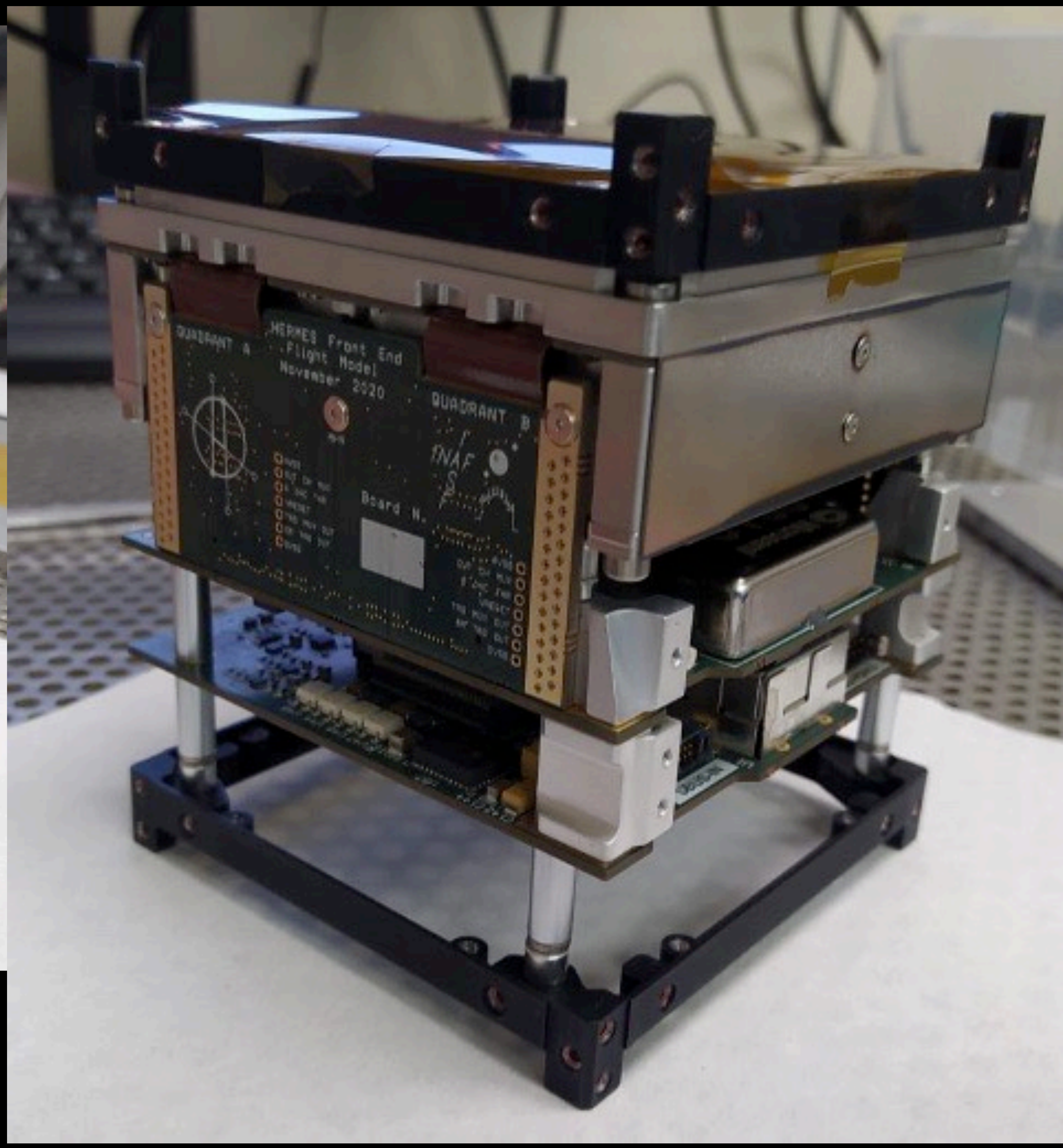
Detector system



+BEE+PSU

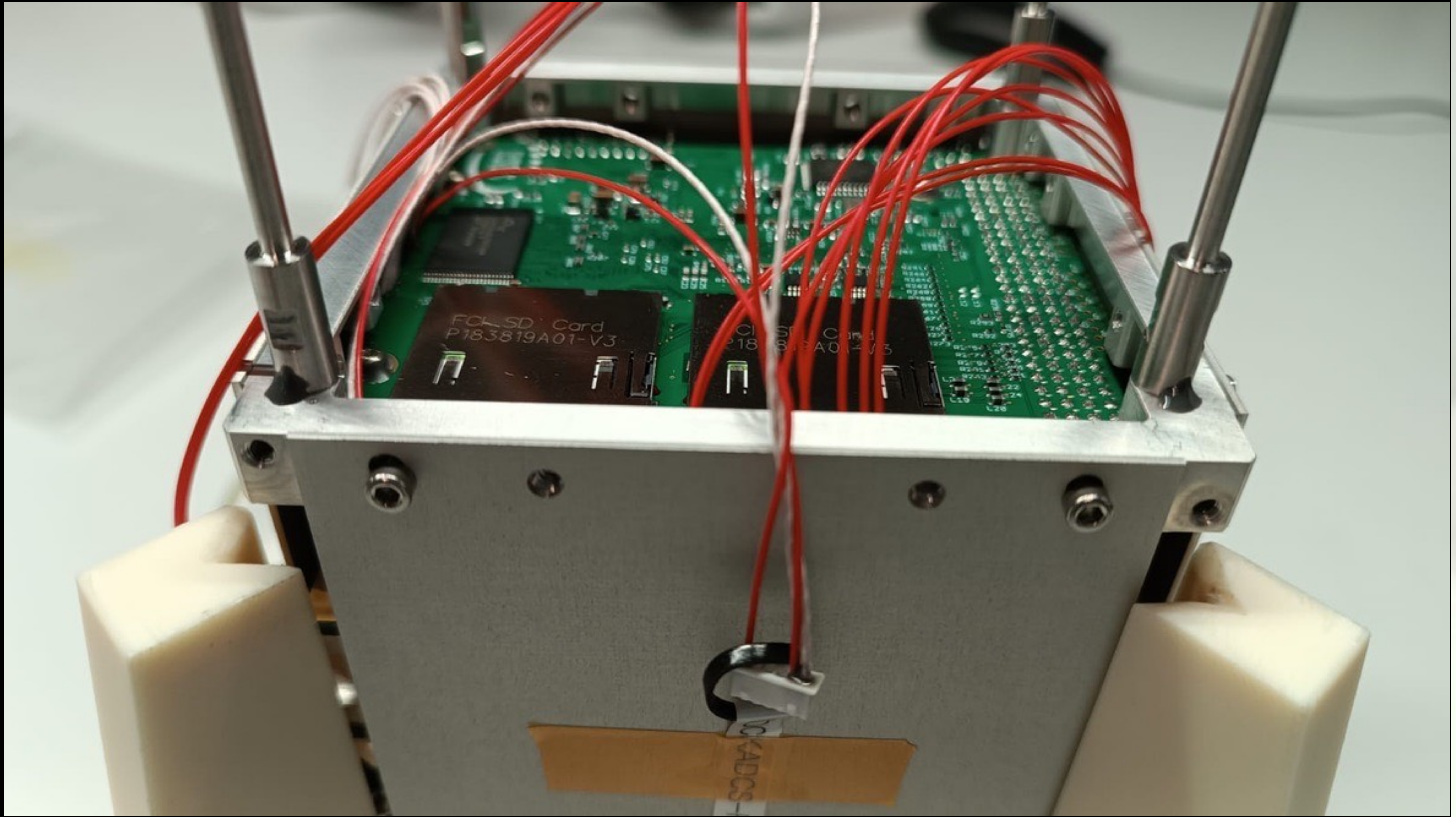


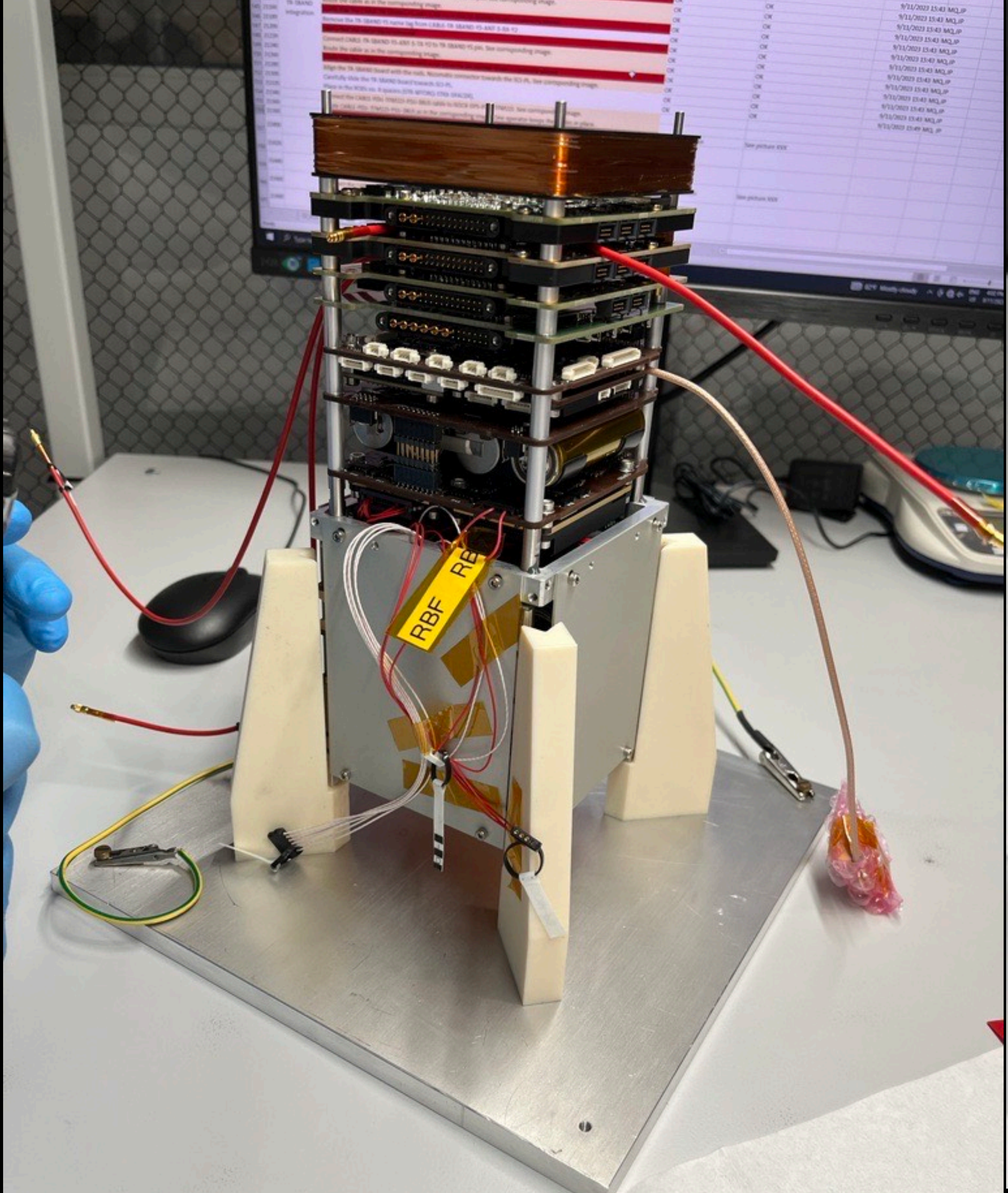
Side wings connected

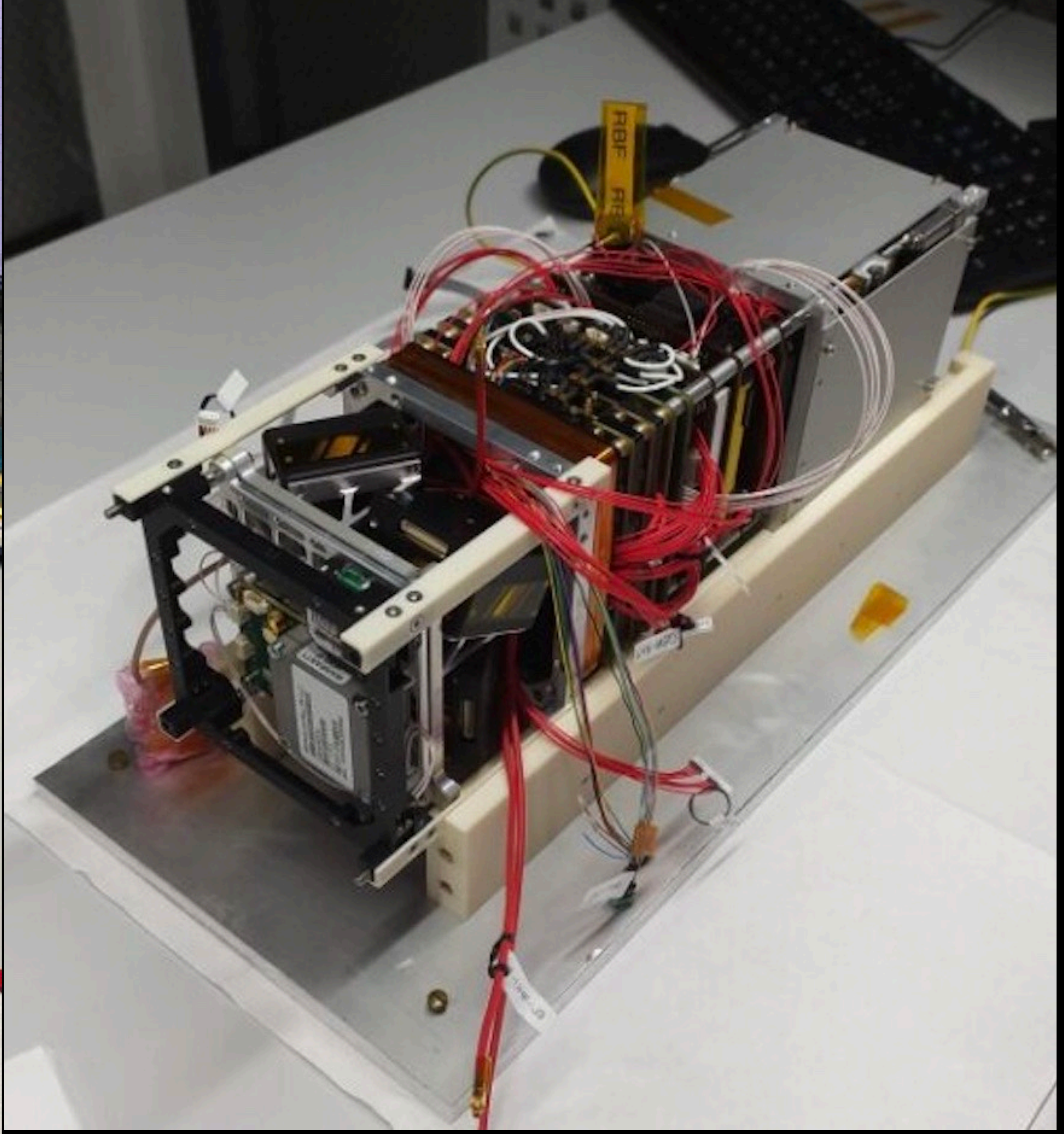



HERMES Pathfinder & SpIRIT
family picture
FM1-SpIRIT
PFM
FM2
FM3
FM4
FM5
FM6

PFM



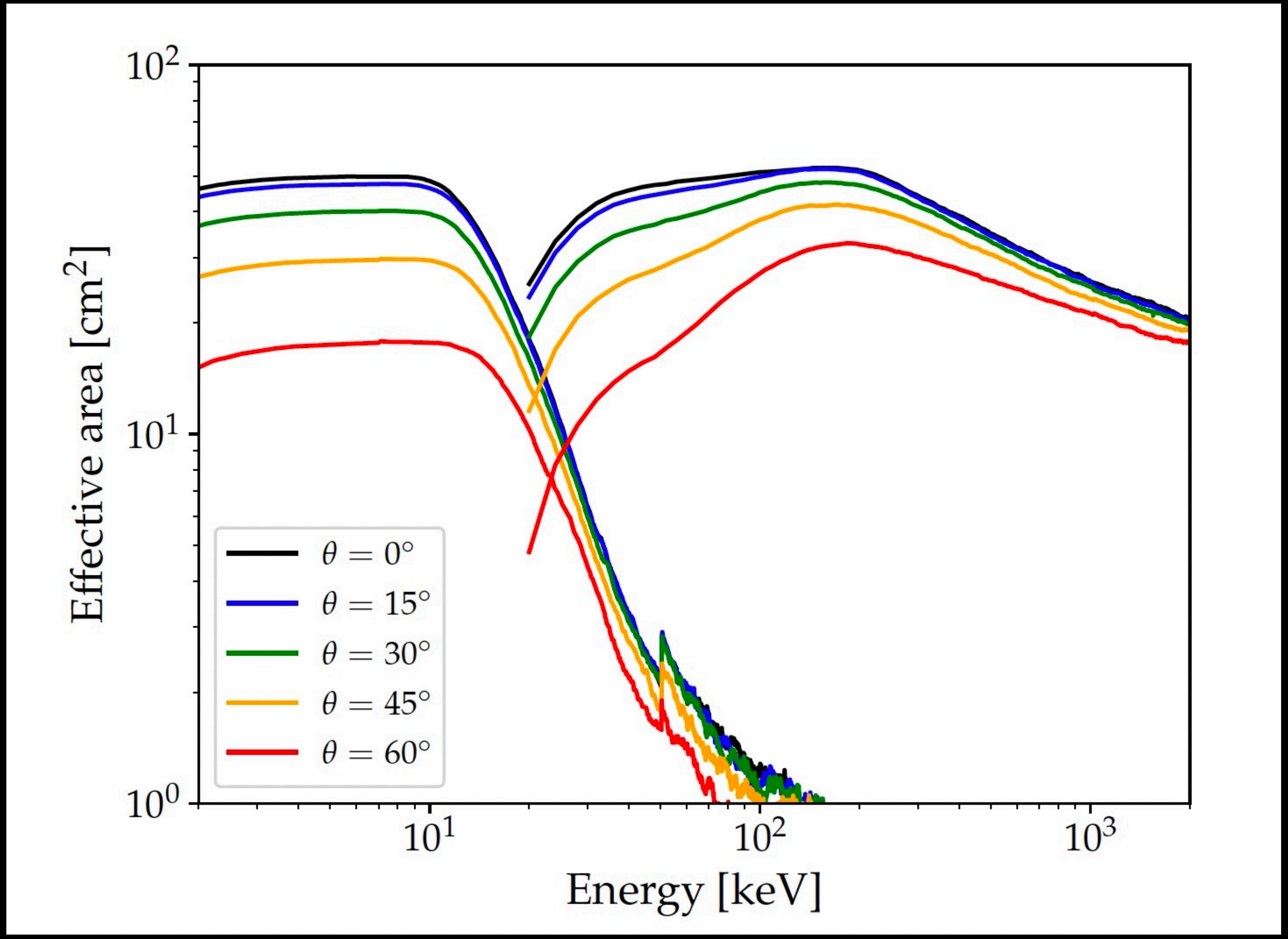

RBF

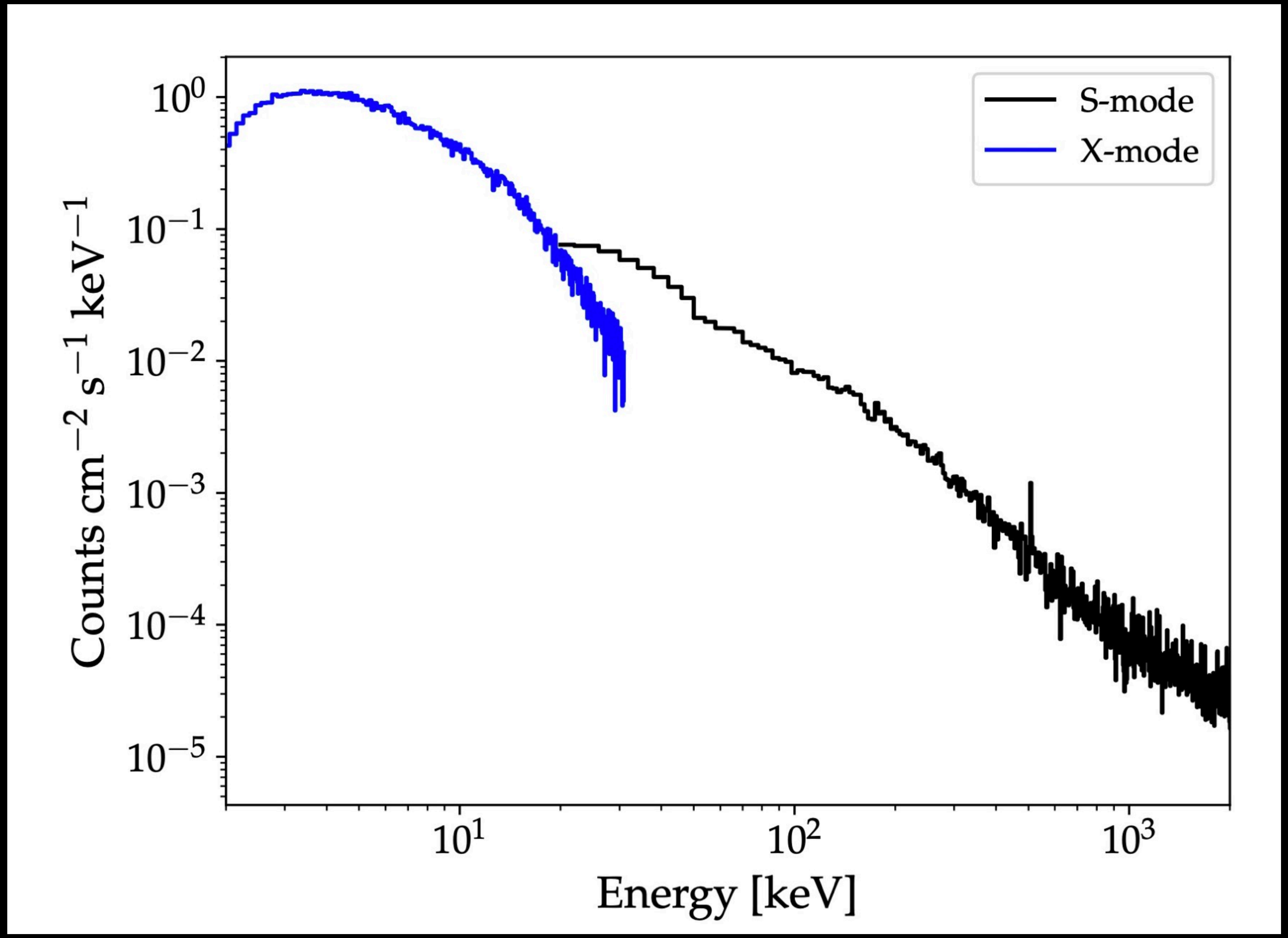

RBF

Where we are: HERMES Pathfinder program

- Launch contract awarded to D-Orbit. Lauch date Q4 2024.
- MOC deployment contract awarded to Altec.
- Ground Station implementations: two identical dedicated GS
  - Malindi managed by ASI
  - Katherine (NT, AU), managed by a consortium led by INAF and including Masaryk University, University of Tasmania, University of Melbourne and partly funded by AHEAD2020.

HERMES PF expected performances



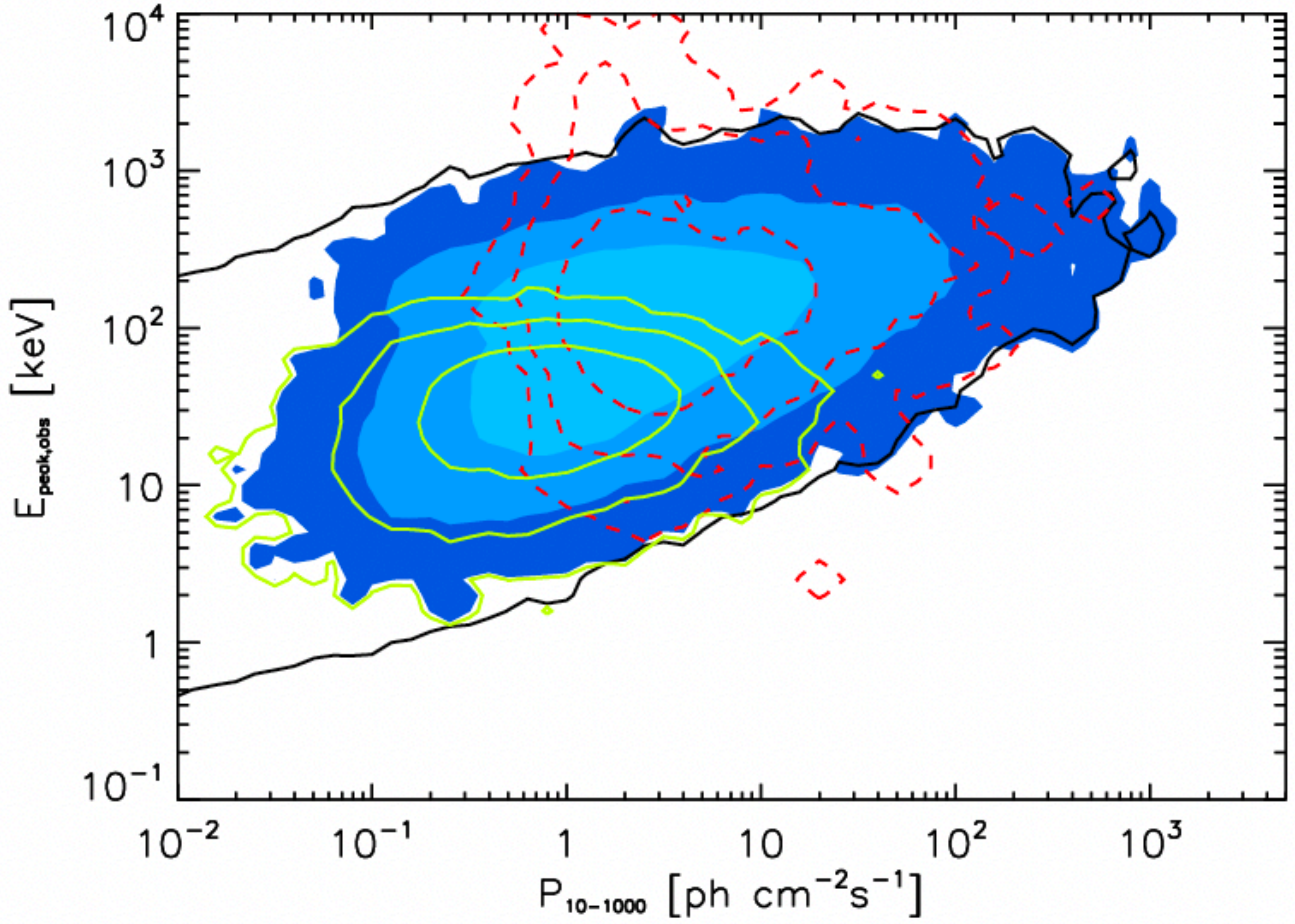


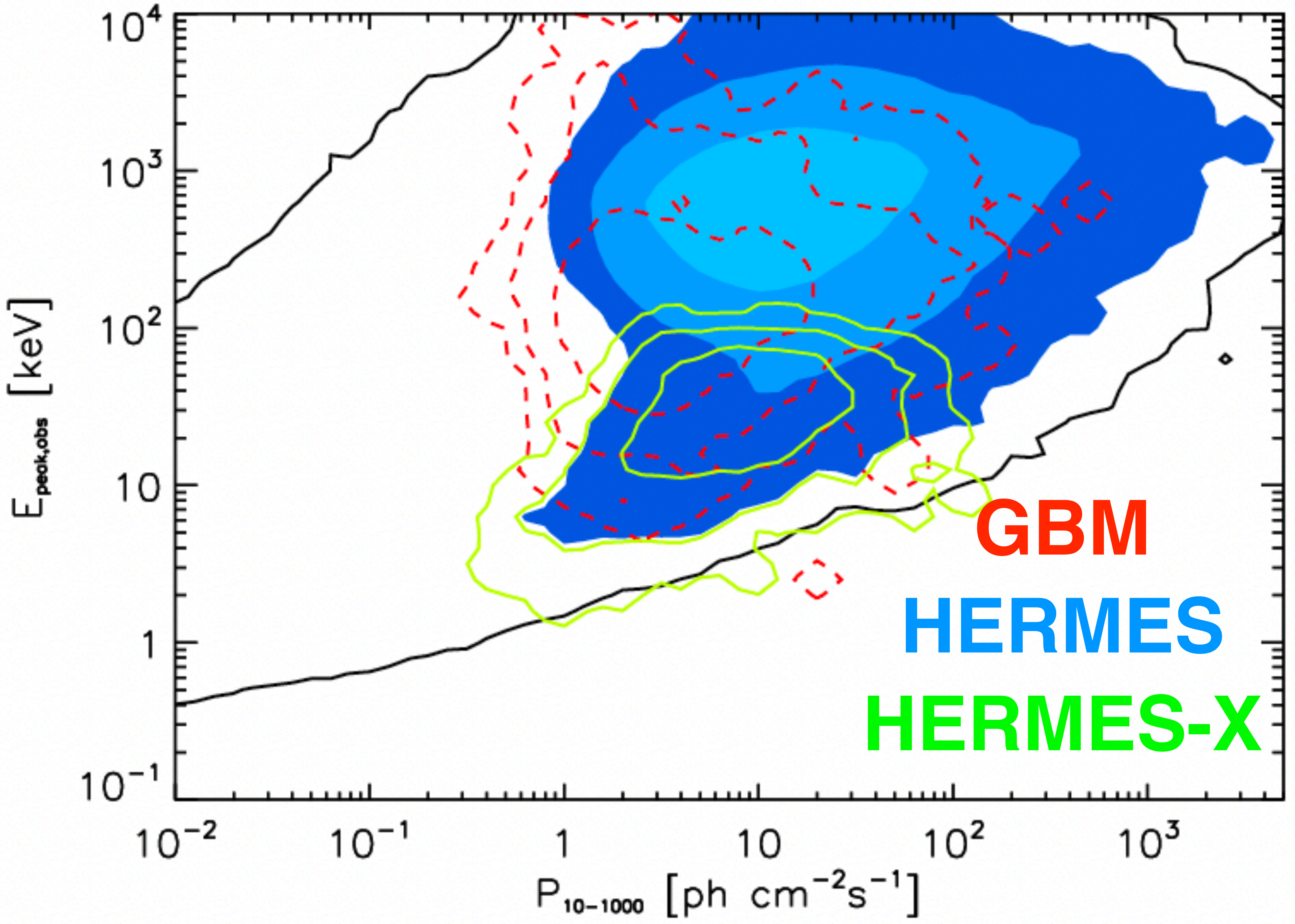
Background: 50-300 keV ~75cts/s; 100-500 keV~35cts/s; 3-20 keV 390counts/s

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

Campana et al. 2020

Performances





Long

Short

Ghirlanda, Nava, FF 2023

Localization performances

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

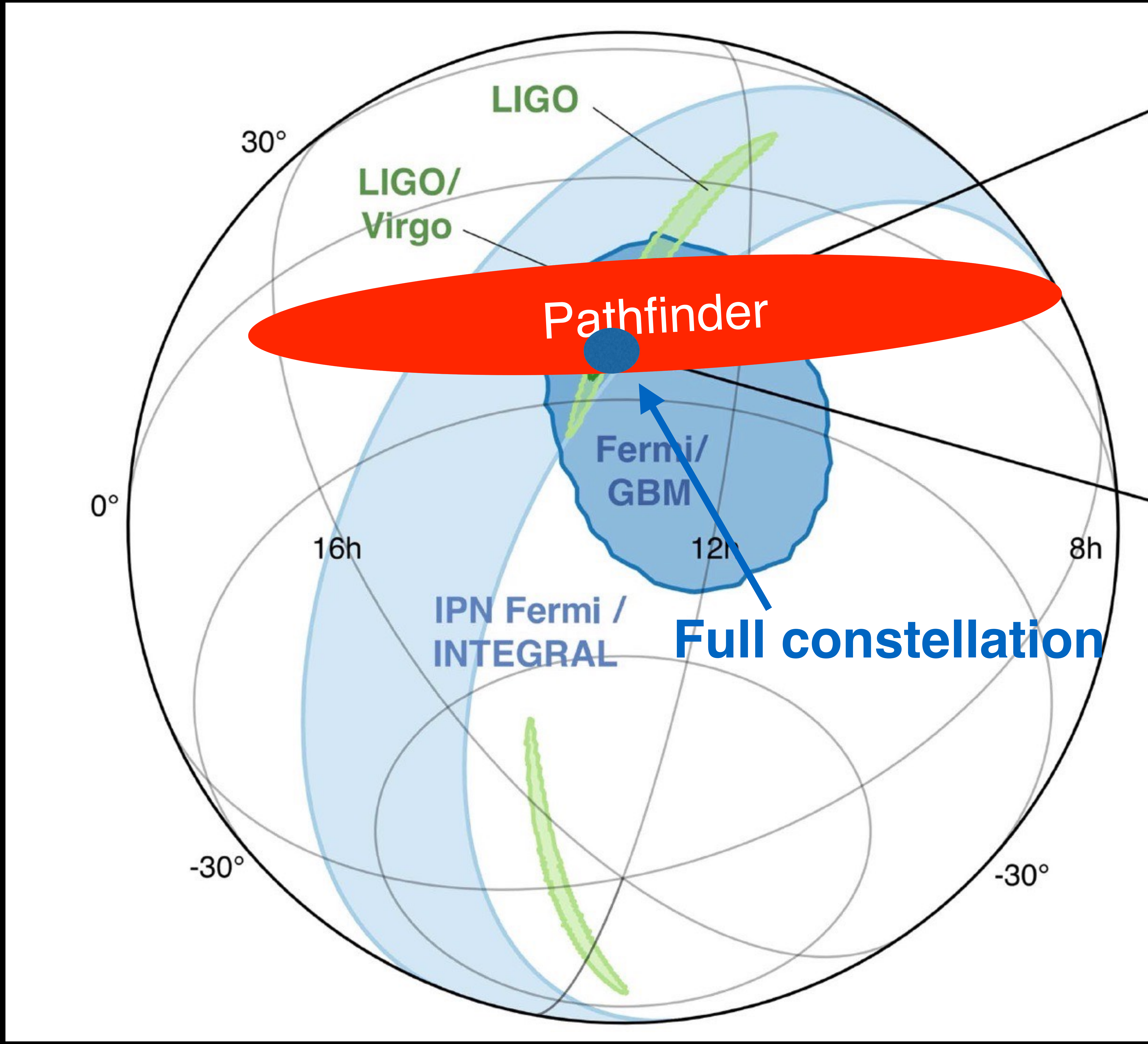
<B>~7000km

N(pathfinder)~6-8, active simultaneously 3-4

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

Goal for a real observatory (more units, longer baseline)

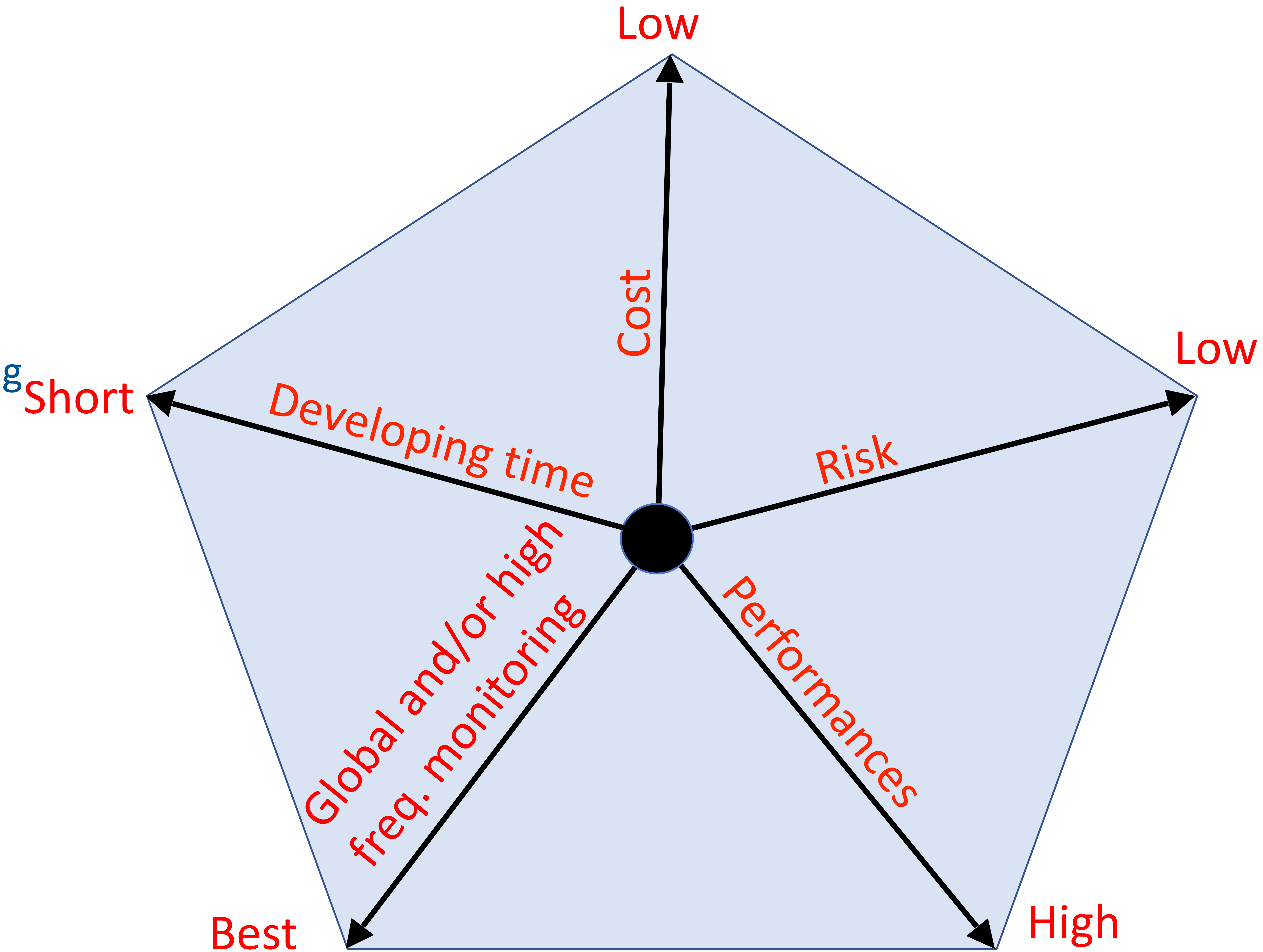
$\sigma_{Pos(FC)}$ ~ 15 arcmin **if** $\boldsymbol{\sigma_{CCF}, \sigma_{sys}}$**~1ms**



From HERMES Pathfinder
to an all-sky all-time monitor: DAMA

Trade-offs

- Development time
- Cost
- Risk
- Performances
- Global and/or high frequency monitoring



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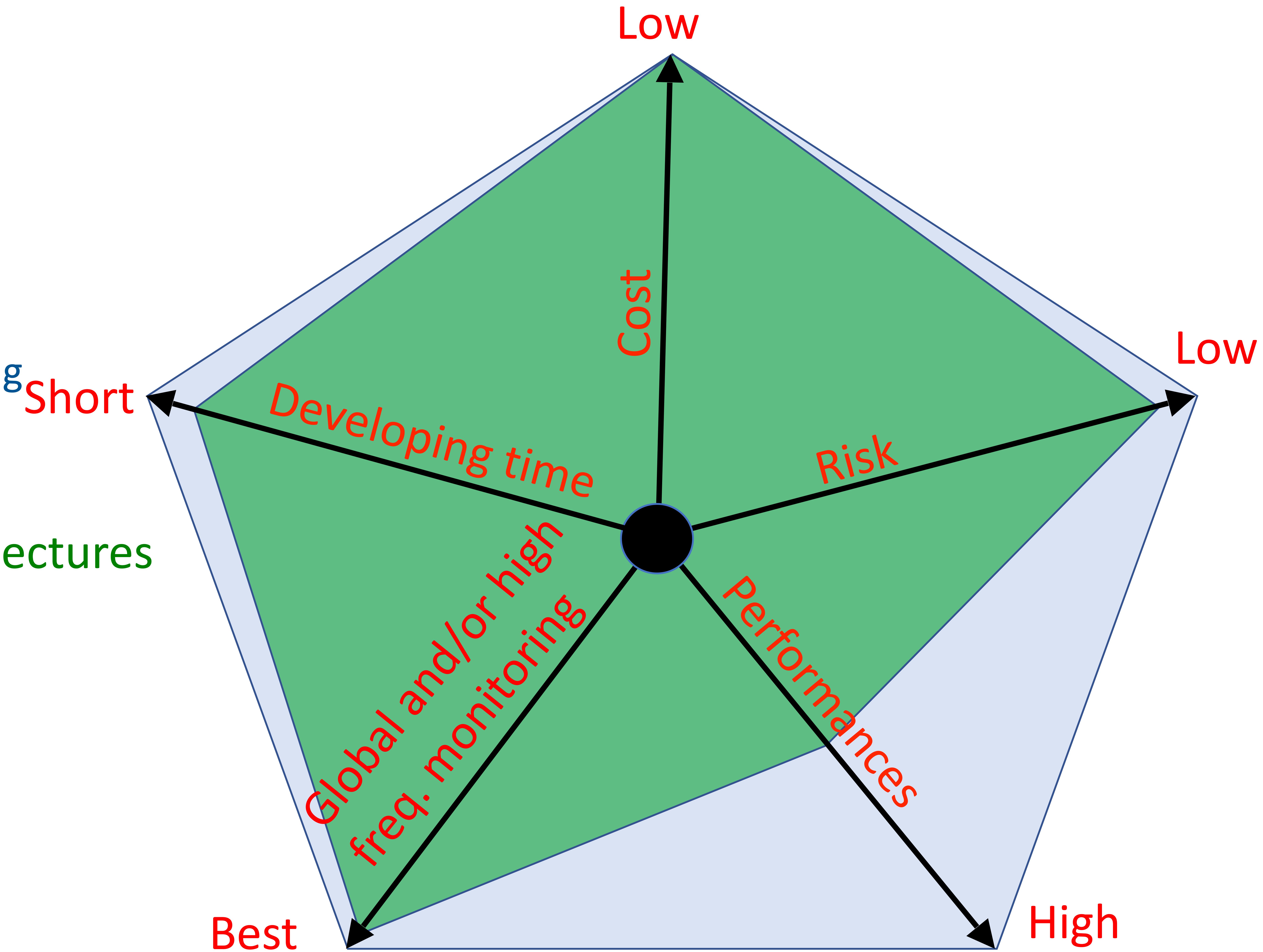

Distributed architectures of nanosatellites

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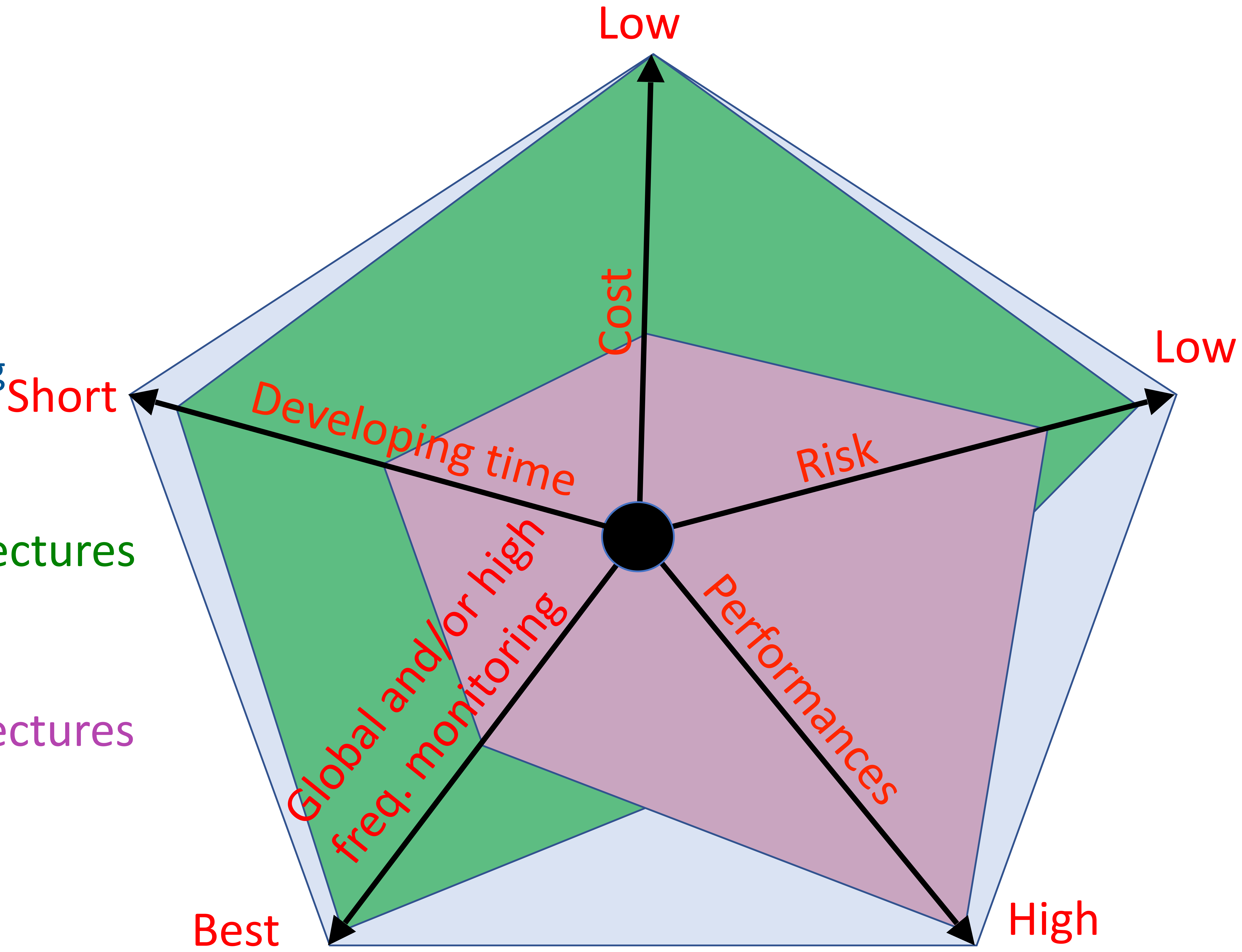
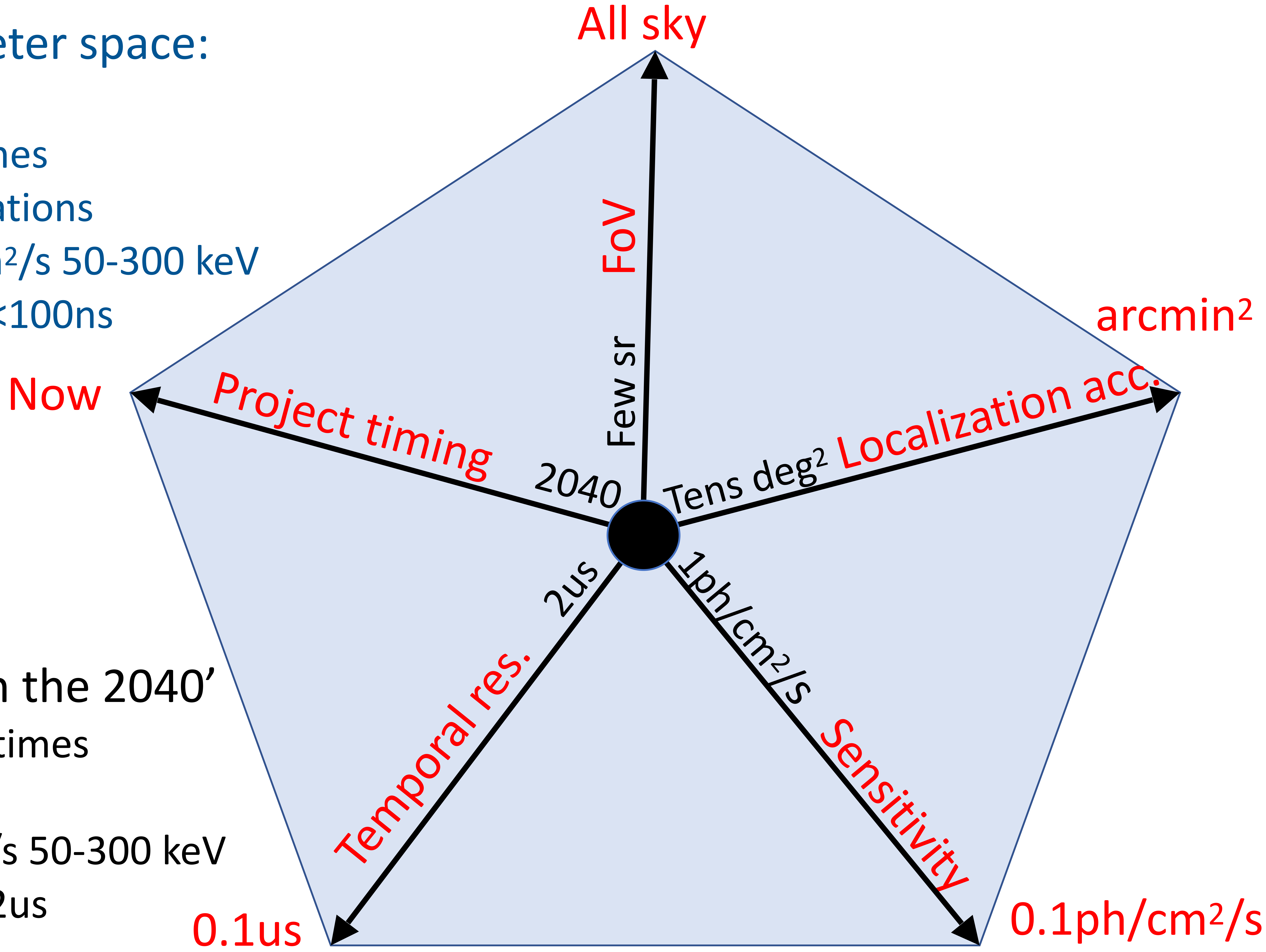
Distributed architectures of nanosatellites

Monolithic architectures



Ideal mission parameter space:

- Now
- All-sky monitor all times
- A few arcmin² localizations
- Sensitivity <0.1ph/cm²/s 50-300 keV
- Temporal resolution <100ns



Origin: Fermi/GBM in the 2040'

- ~1/3 of the sky at all times
- Tens deg² localization
- Sensitivity ~1ph/cm²/s 50-300 keV
- Temporal resolution 2us

Ideal mission parameter space:

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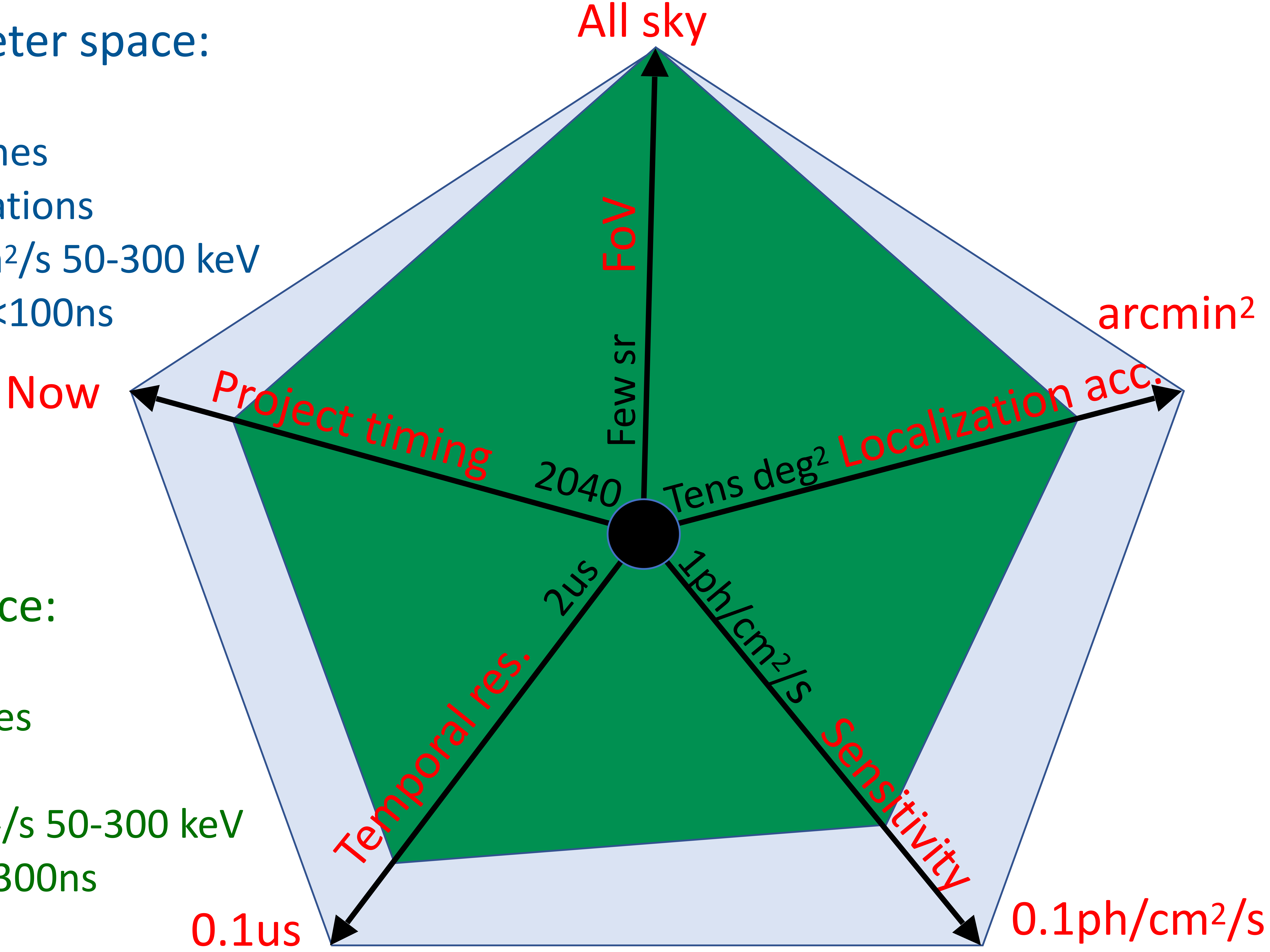


DAMA parameter space:

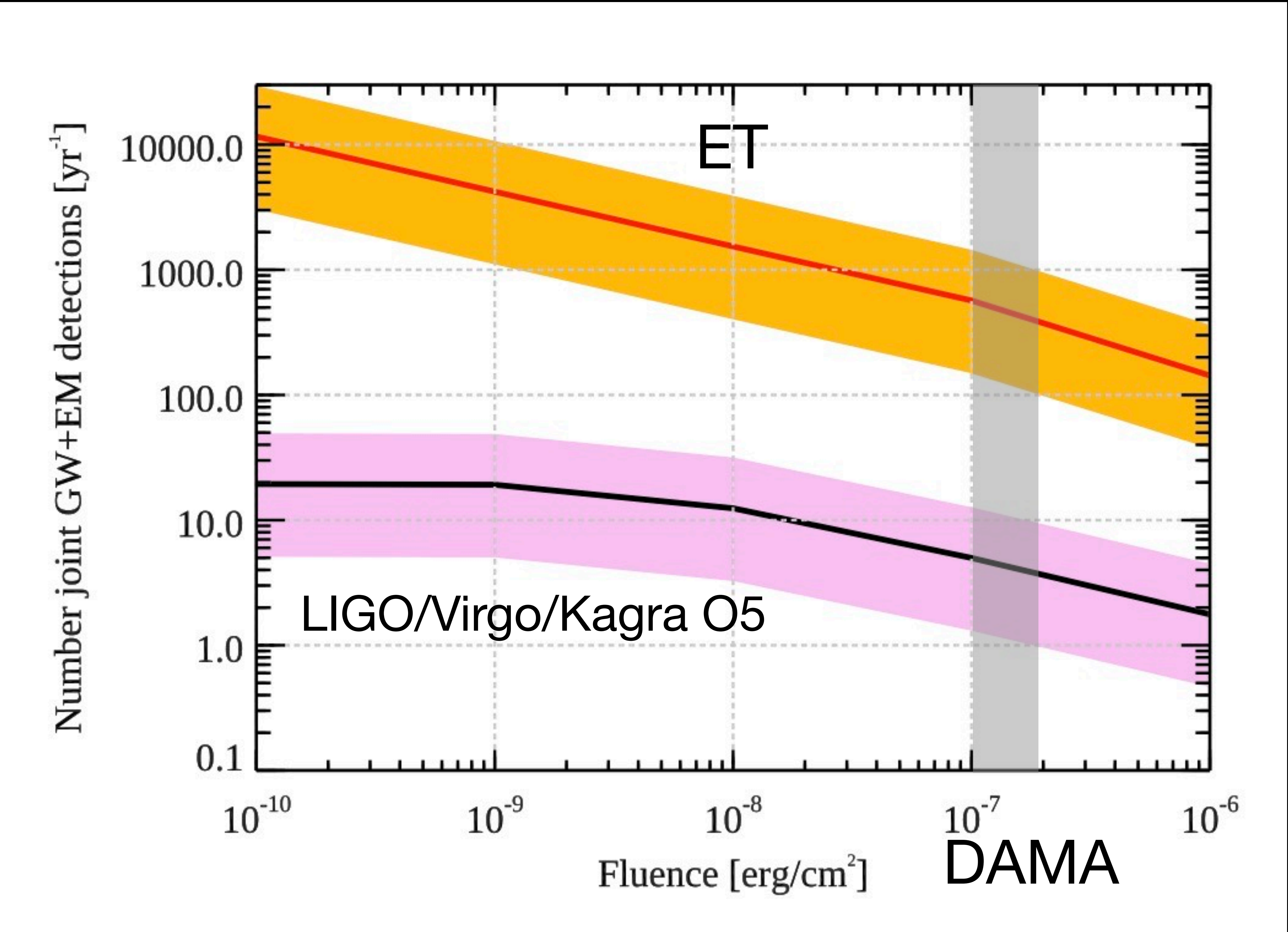
- 2027-2028
- All-sky monitor all times
- <deg^2 localization
- Sensitivity <0.3ph/cm^2/s 50-300 keV
- Temporal resolution <300ns

Main science goal: HEA all-sky, all-time monitor

LIGO/Virgo O5 >2028, ET>2035

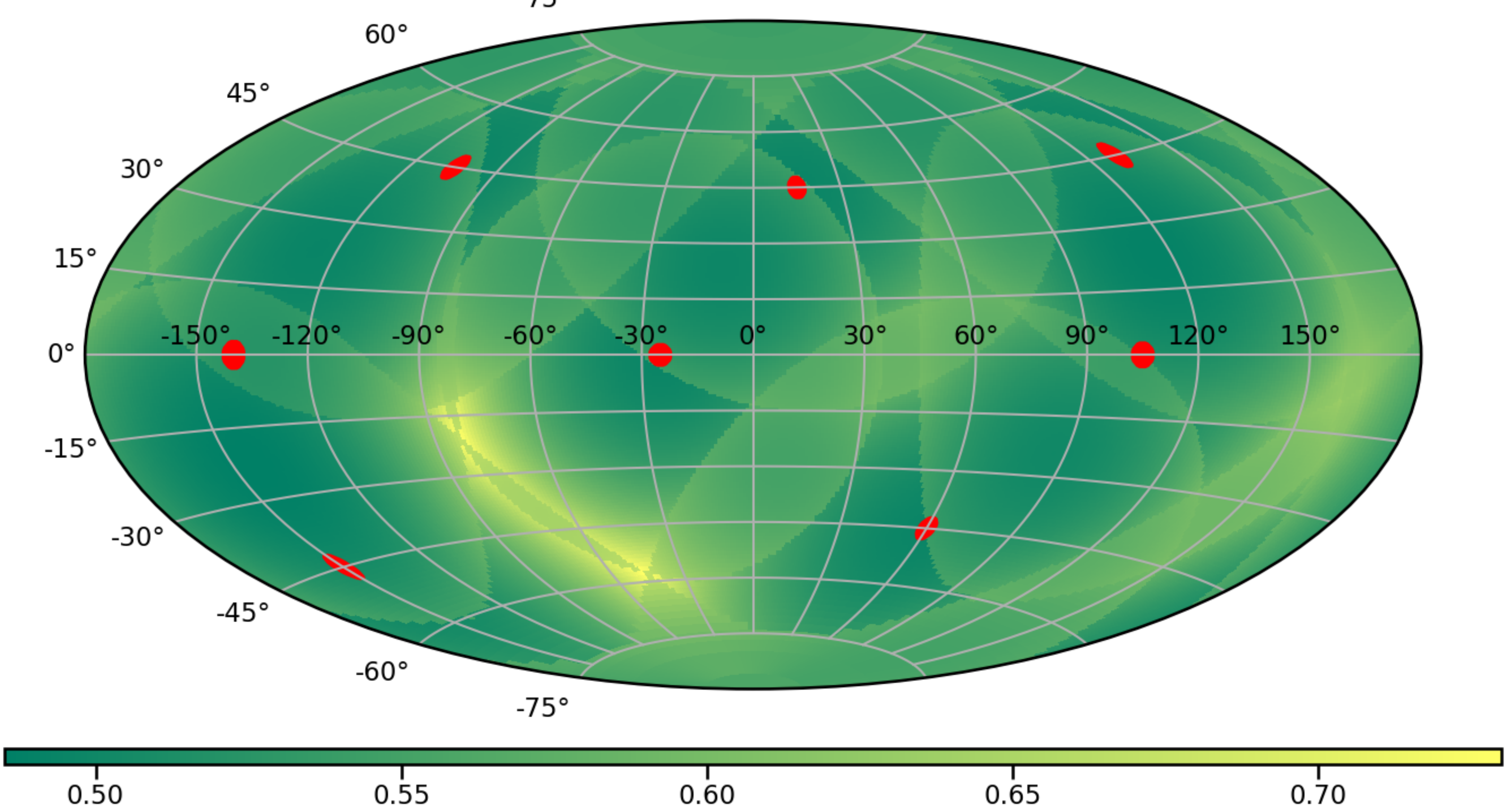
- LIGO/Virgo/Kagra: small improvement with P/L sensitivity. Jet seen offaxis
- ET: big improvement with P/L sensitivity. Jet seen on axis
- ET: large fraction with detection 5-10min before GRB. Repointing possible
- Large uncertainty on absolute value, many assumptions, to be verified in O5?
- No big advantage in buindilng large P/L
- $F \sim 10^{-7}$ erg/cm^2 few events/yr O5 and >30-40 events/yr ET

Ghirlanda, Nava, FF et al. 2023



Next steps

- Toward a sensitive all sky monitor during the 20’ using HERMES-PF, Camelot-PF and GALI technologies:
- First phase: **crash program to deploy in LEO 8-9 units (6-12U) in four years** to provide a first all-sky monitor for Ligo/Virgo O5 events
- Second phase: deploy additional 6-10 units (6-12U) after ~2 years to boost monitoring and localization capabilities during Ligo/Virgo O5 - O6… ET!
- Third phase: deploy a few units in HEO or Moon orbits to boost localization capabilities


75°
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°
0.50
0.55
0.60
0.65
0.70

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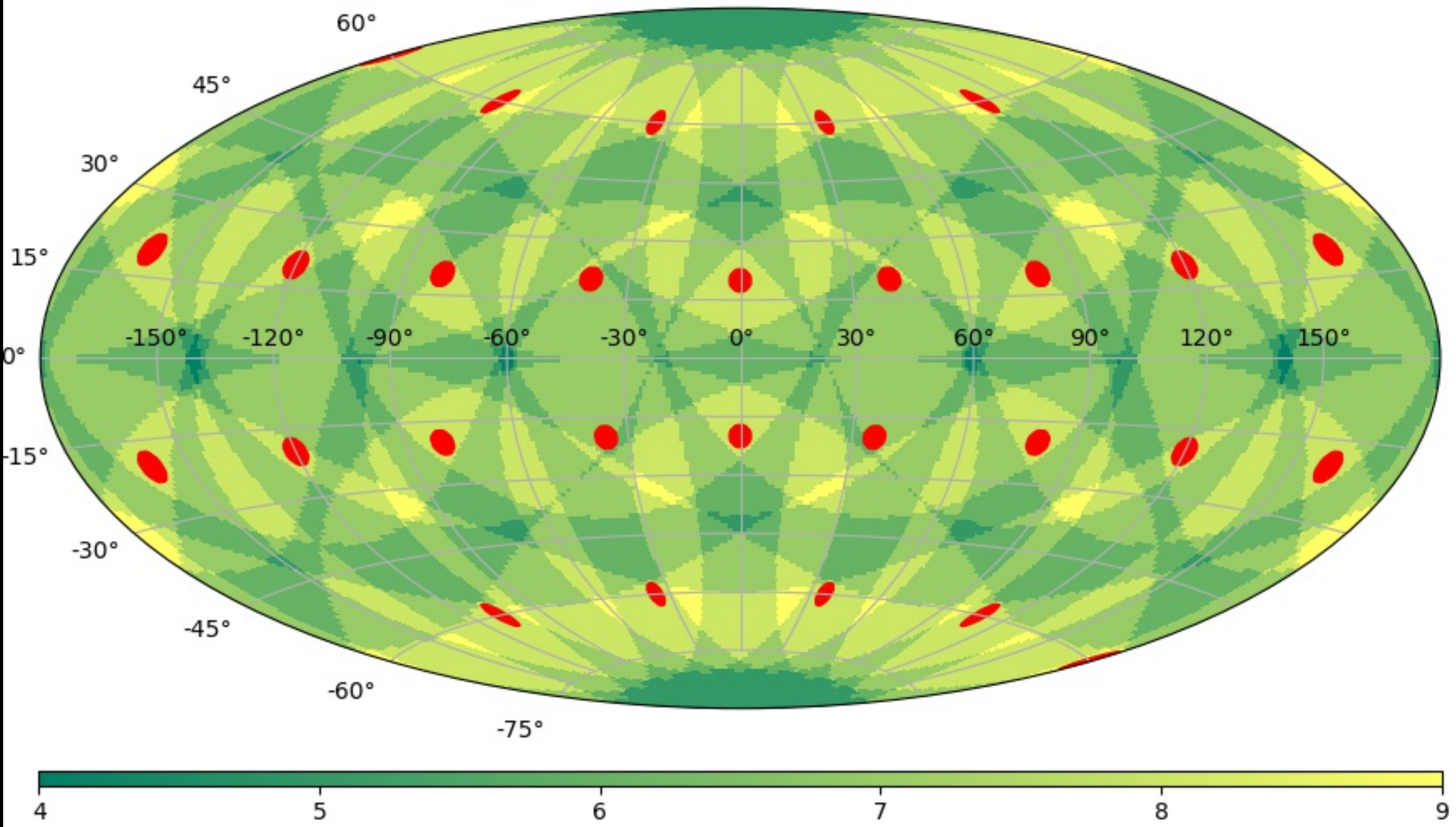

60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°
4
5
6
7
8
9

Next steps

- Toward a sensitive all sky monitor during the 20’ using HERMES-PF, Camelot-PF and GALI technologies:
- First phase: **crash program to deploy in LEO 8-9 units (6-12U) in four years** to provide a first all-sky monitor for Ligo/Virgo O5 events
- Second phase: deploy additional 6-10 units (6-12U) after ~2 years to boost monitoring and localization capabilities during Ligo/Virgo O5 - O6… ET!
- Third phase: deploy a few units in HEO or Moon orbits to boost localization capabilities

Thanks!