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

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

POLITECNICO MILANO 1863

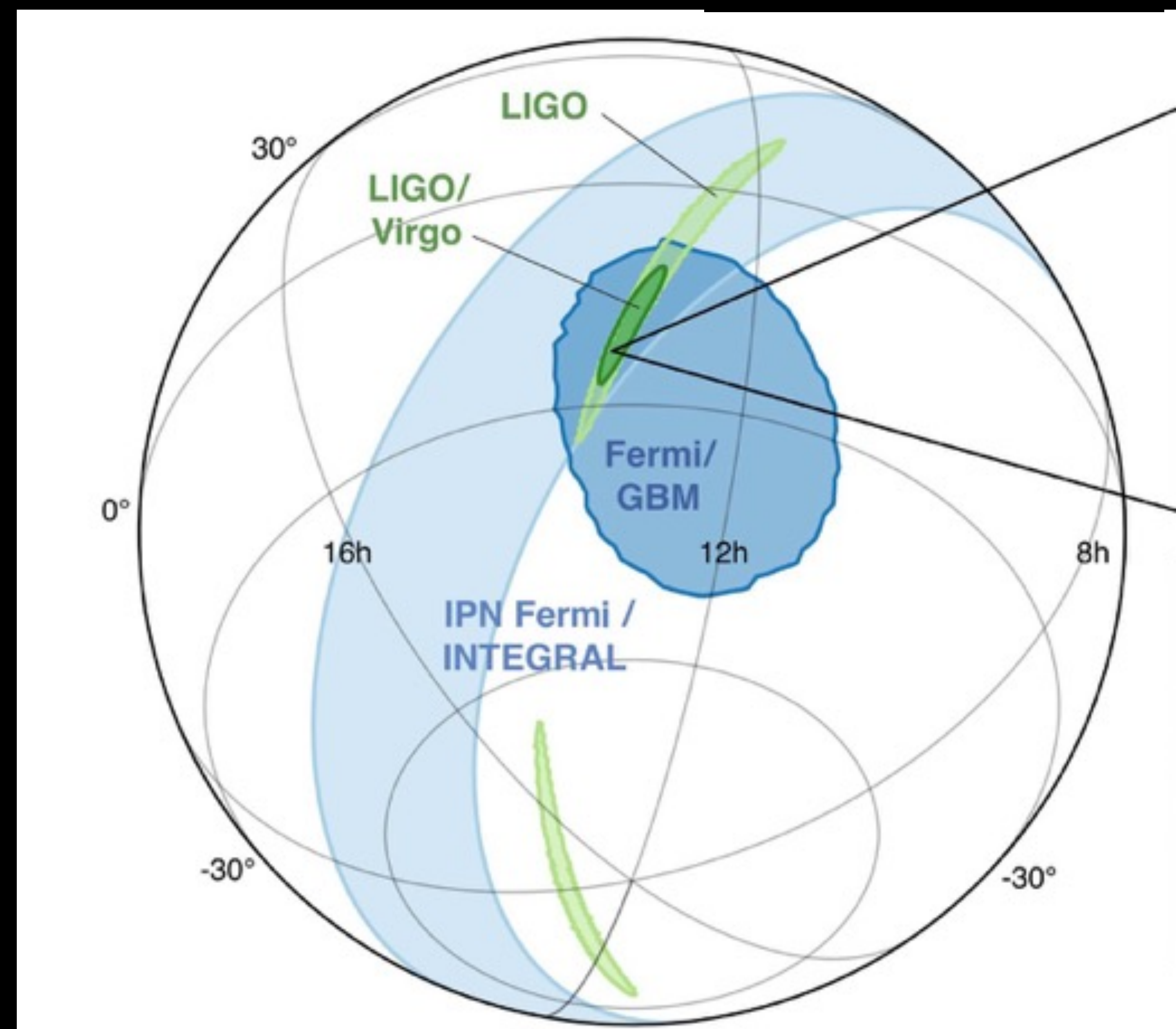
ASI
Agenzia Spaziale Italiana

Two revolutions

Multimessenger astrophysics

Advanced Ligo/Virgo provide position with accuracy ~ tens deg

GW170817



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

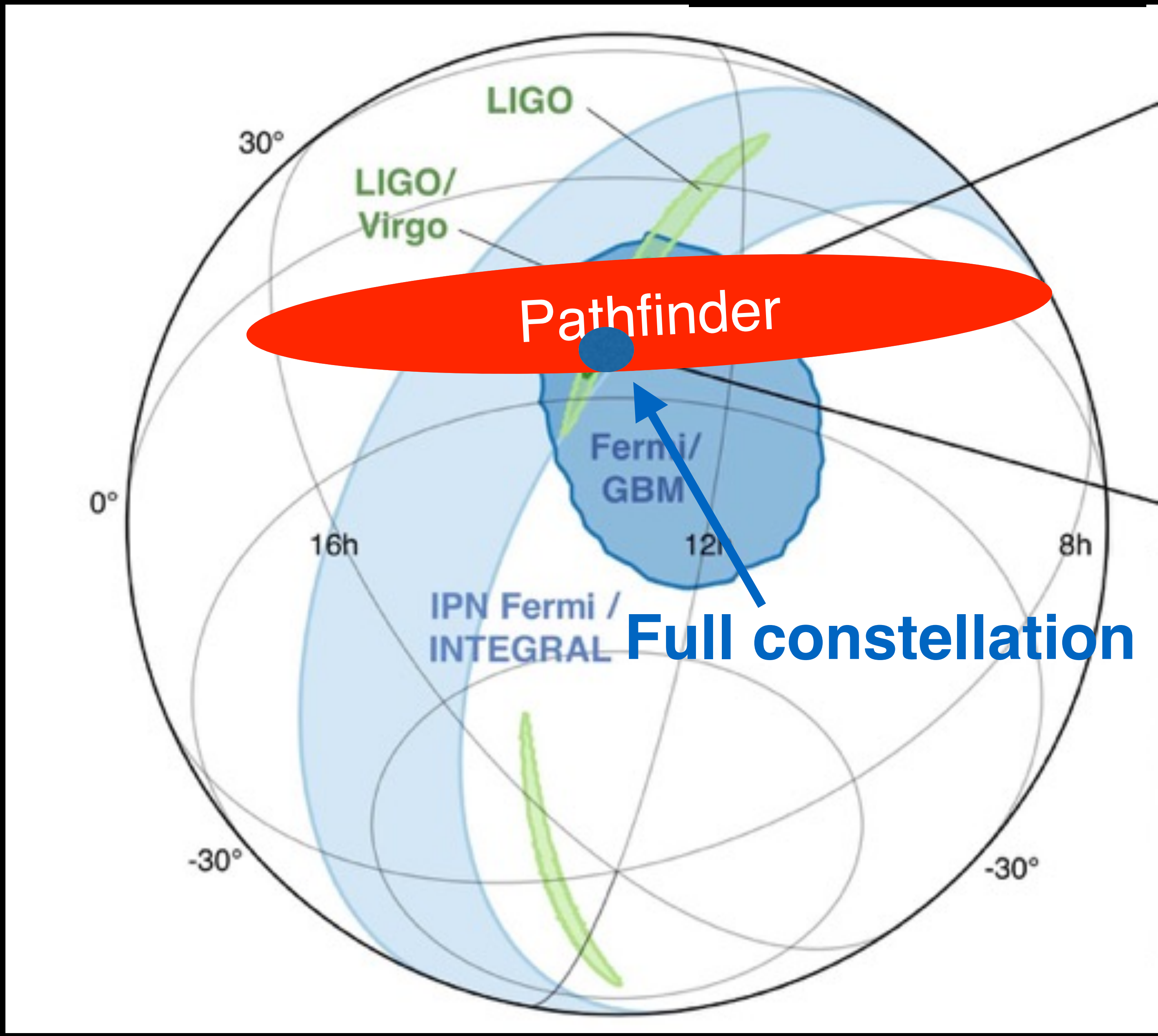
Large volumes difficult to survey at optical λ.

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

Multimessenger astrophysics

GW170817



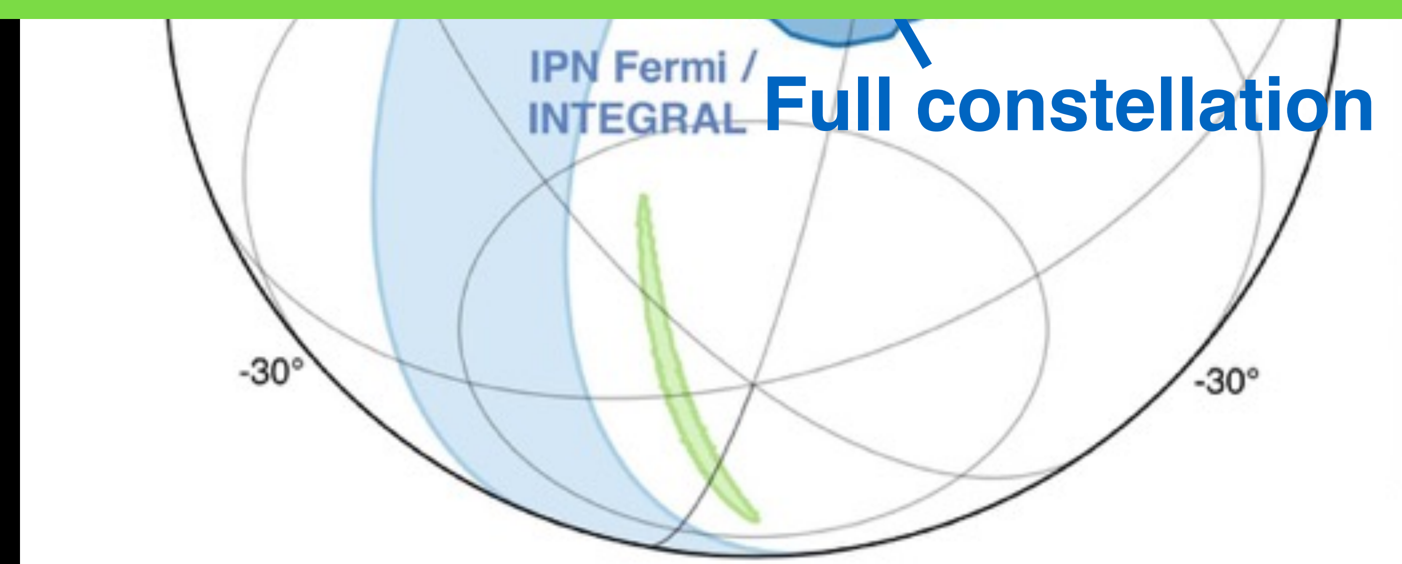
Two revolutions

Multimessenger astrophysics

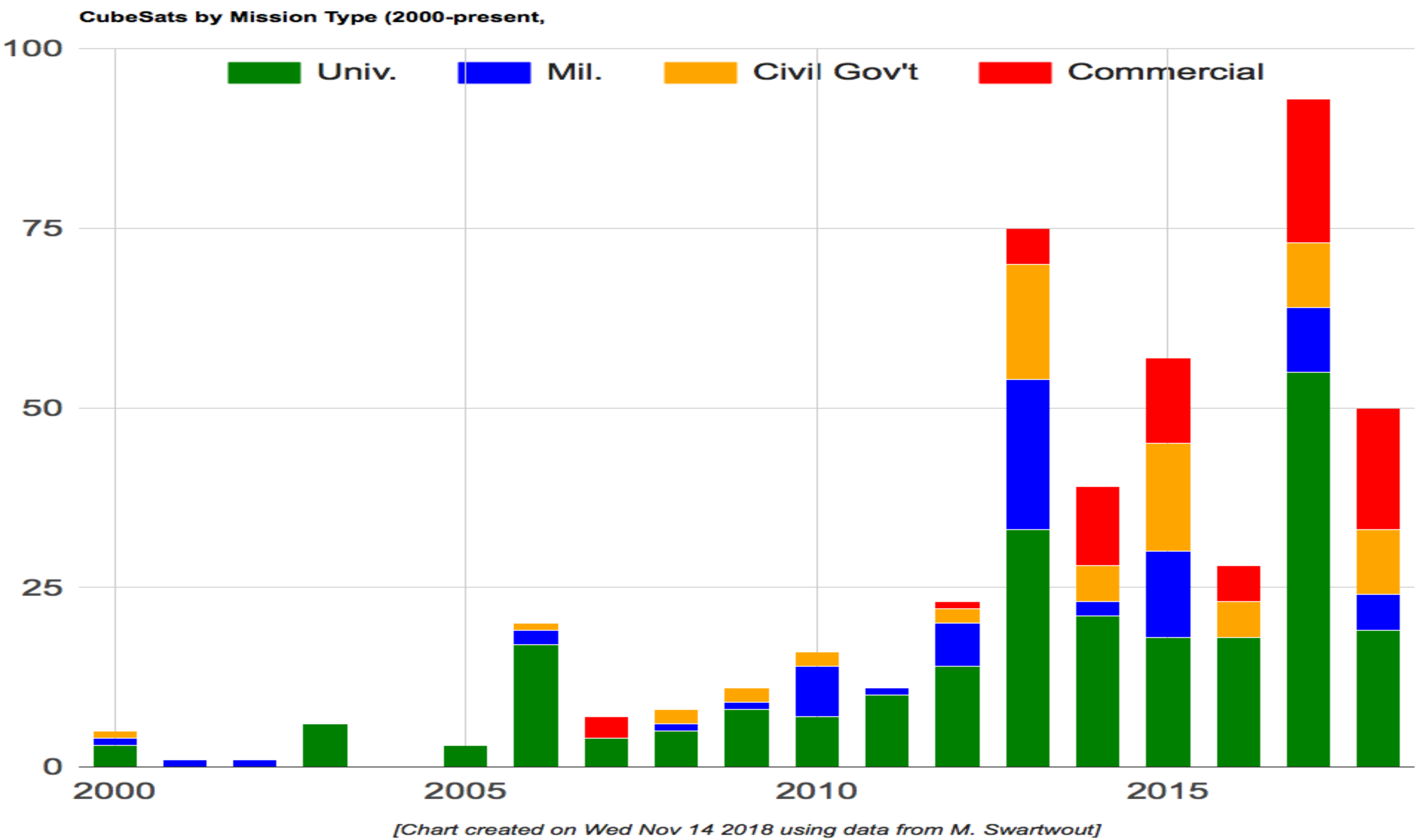
Current facilities, Swift, INTEGRAL, FERMI, AGILE, are aging:

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

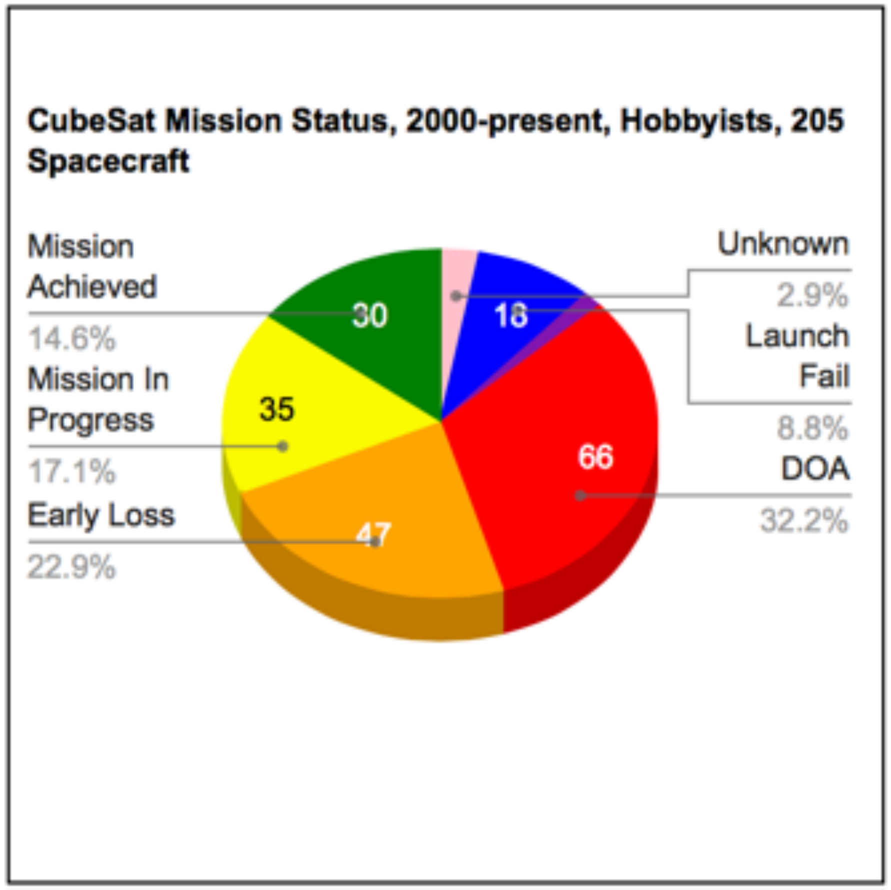
Best strategy:
~ all sky prompt search for transients at high energies. Negligible probability to find an uncorrelated HEA transient at the time of GWE

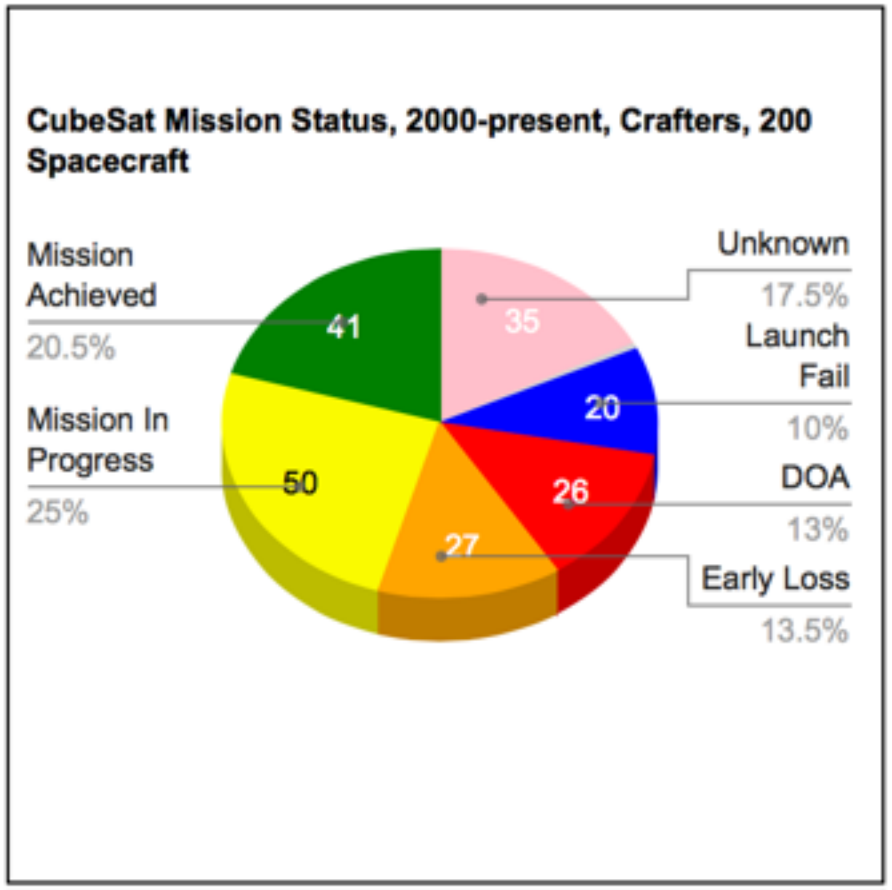


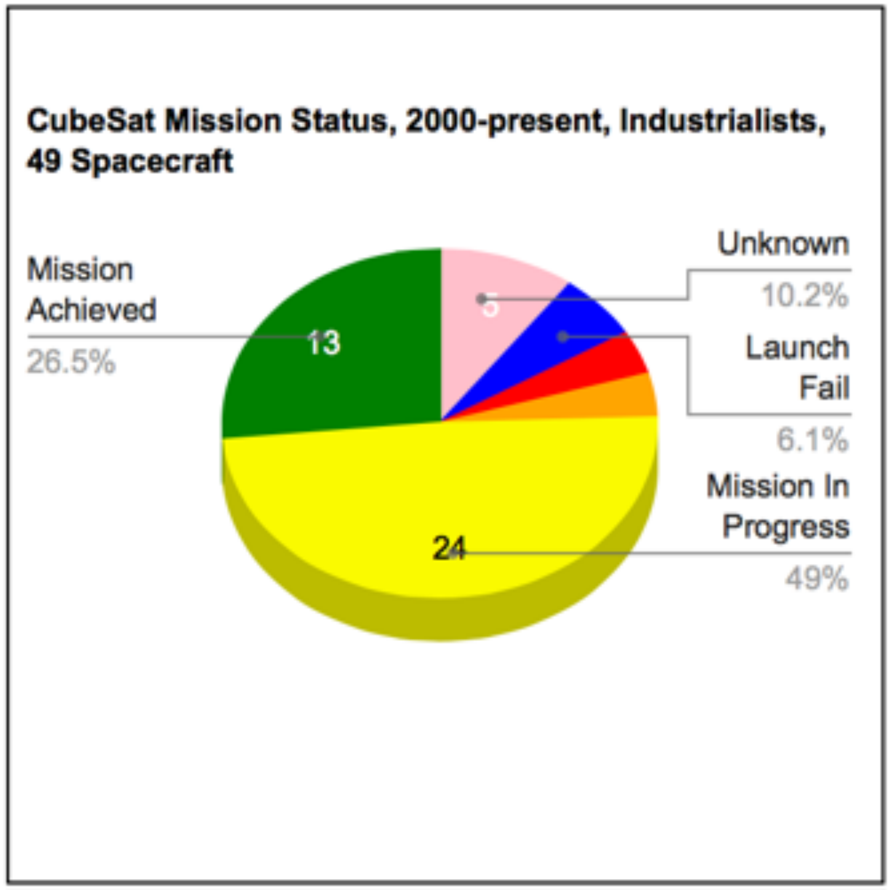
Space 4.0


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







[Chart created on Wed Nov 14 2018 using data from M. Swartwout]

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 (Progetti premiali 2015), managed by ASI
2018 H2020 Space-SCI-20 project
2019 ASI internal funds

Why HERMES now

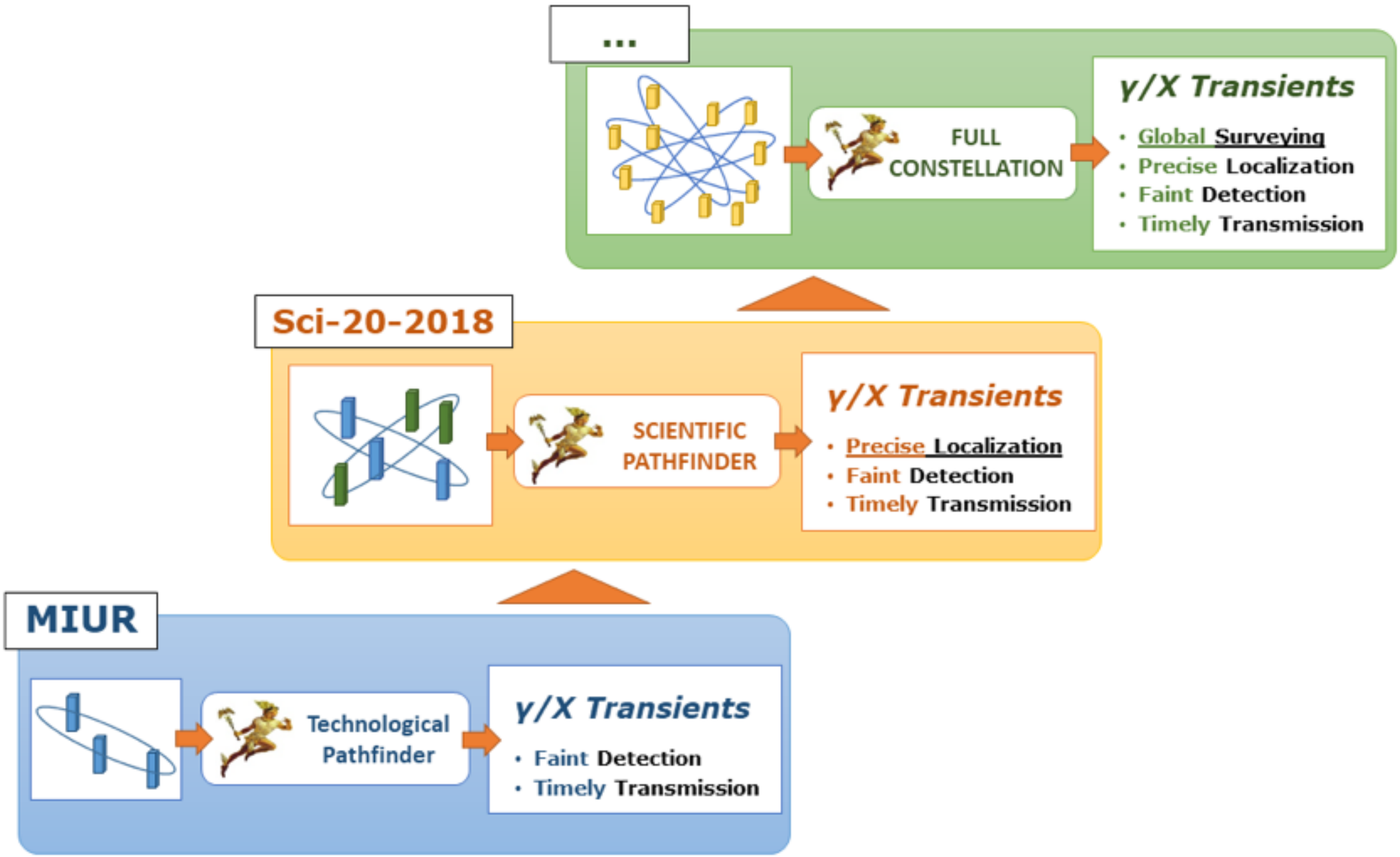
Breakthrough scientific case:

- EM of GWE

Modularity:

- Avoid single point failures, improve hardware
- Pathfinder

Why HERMES now



Why HERMES now

Breakthrough scientific case:

- EM of GWE

Modularity:

- Avoid single point failures, improve hardware
- Pathfinder

Open μsec - msec window:

- Accurate positions
- QG tests

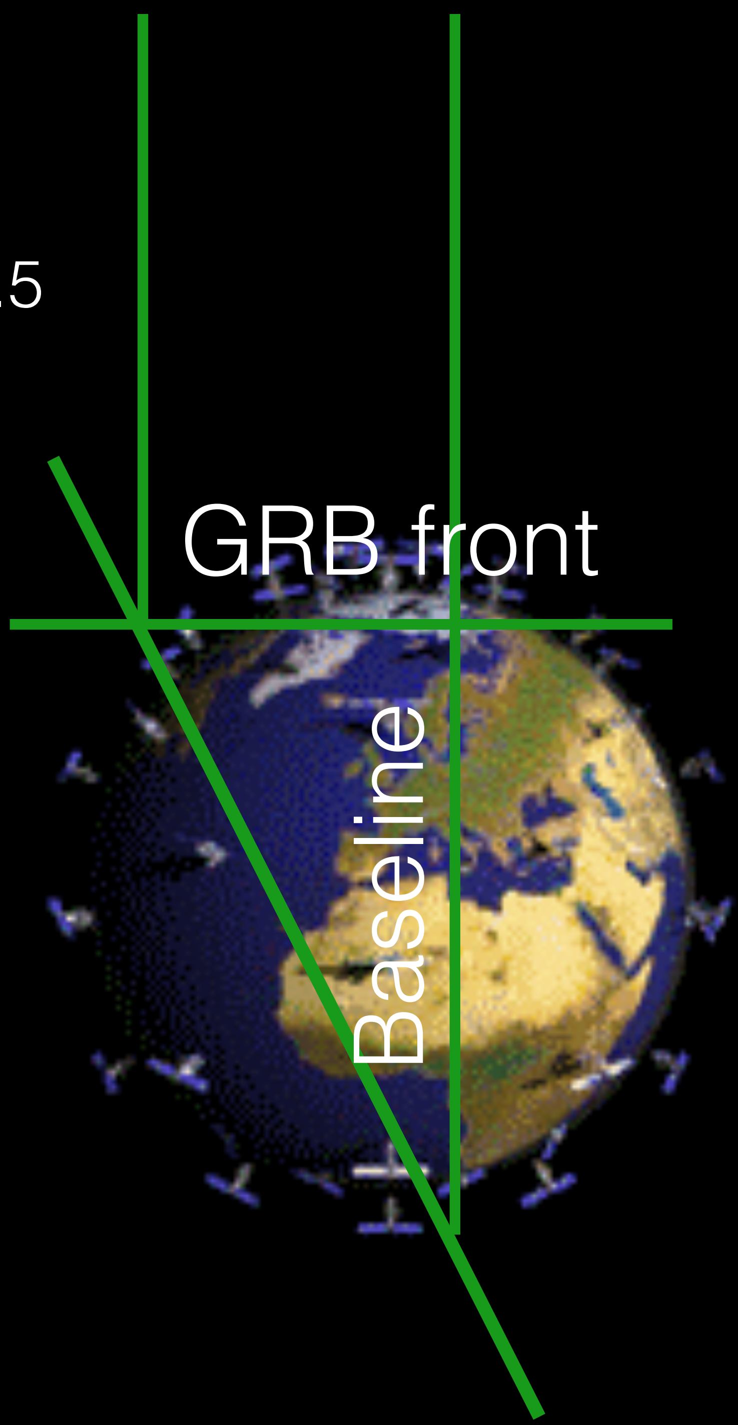
Limited cost and quick development

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

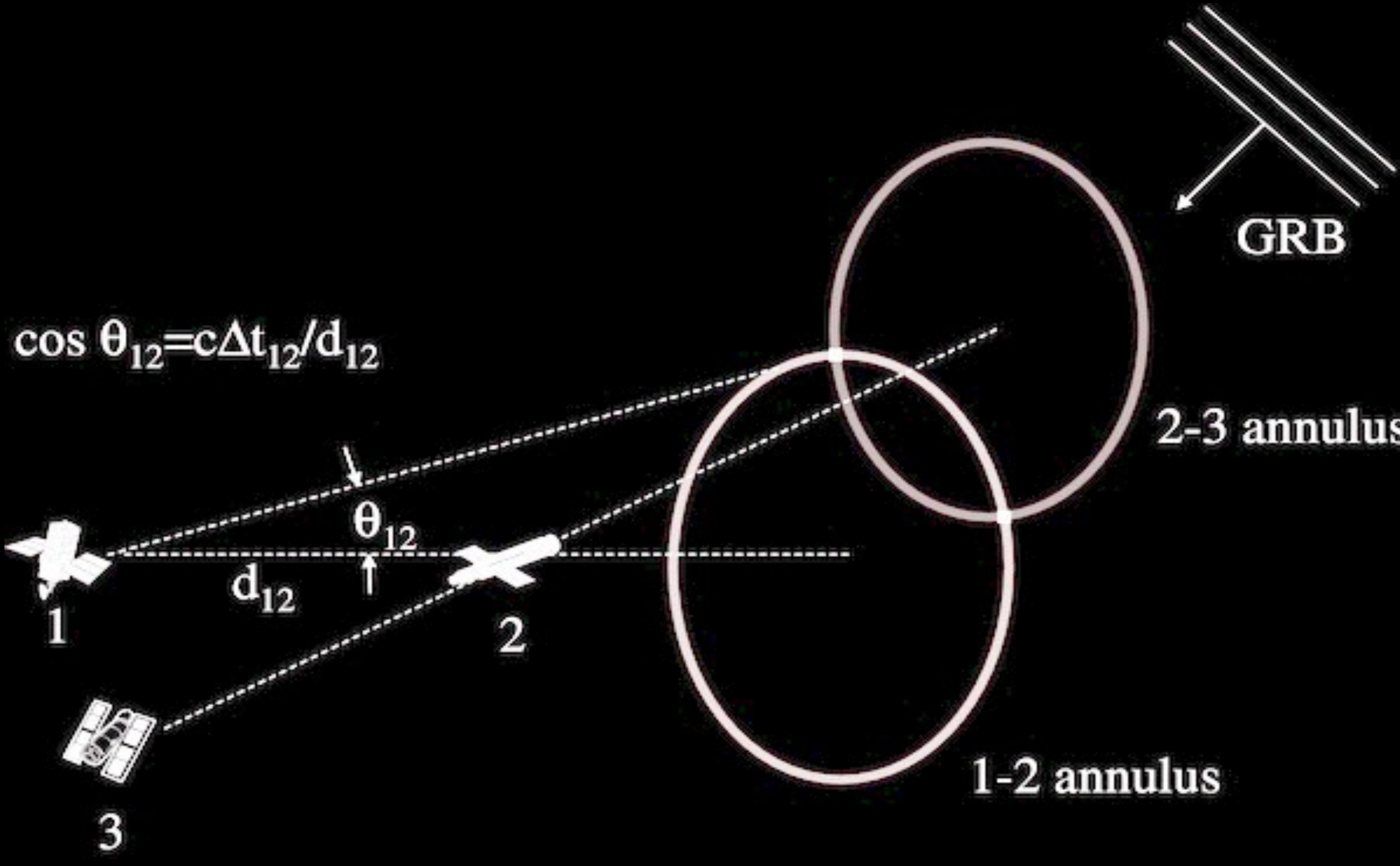
Experiment concept

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

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



Experiment concept



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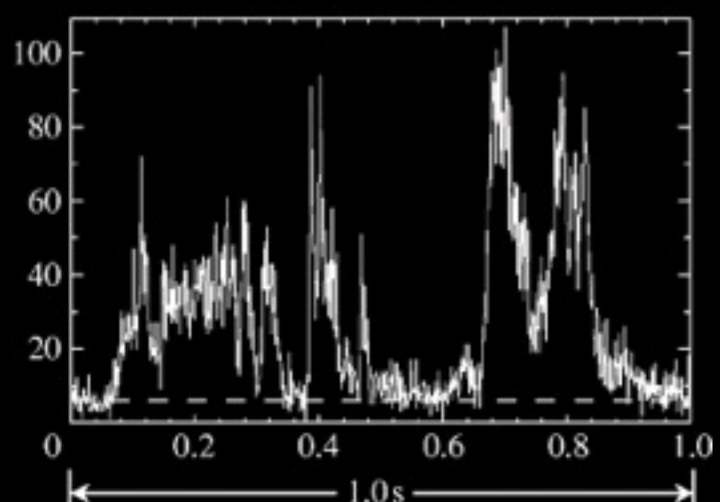

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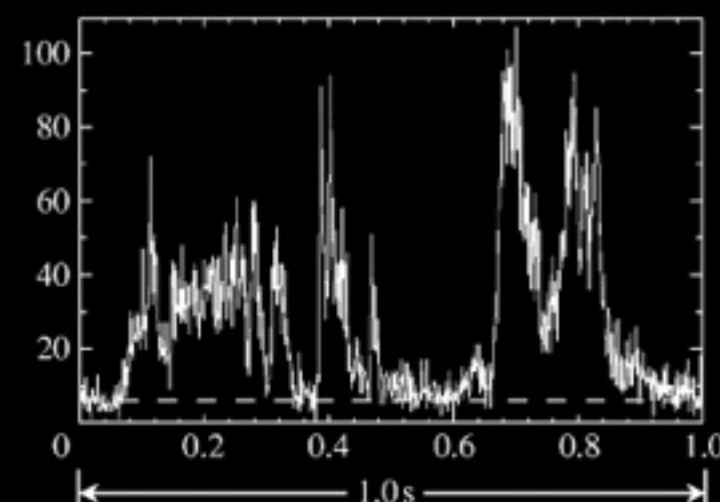

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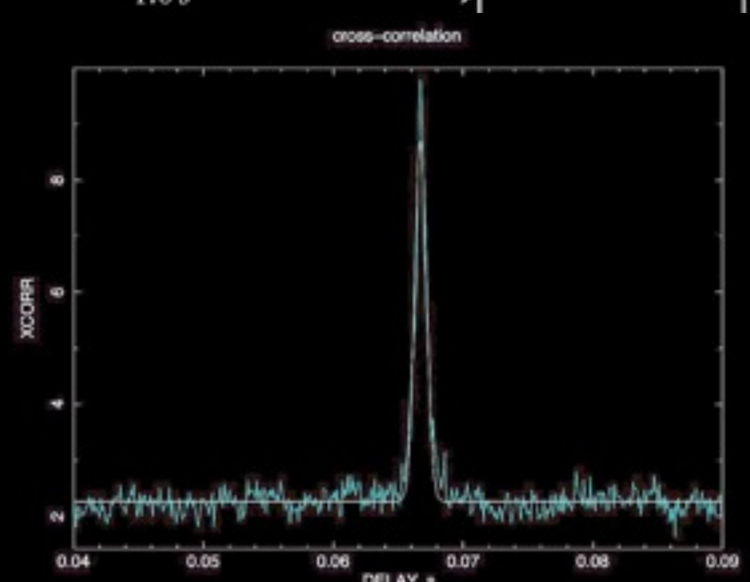
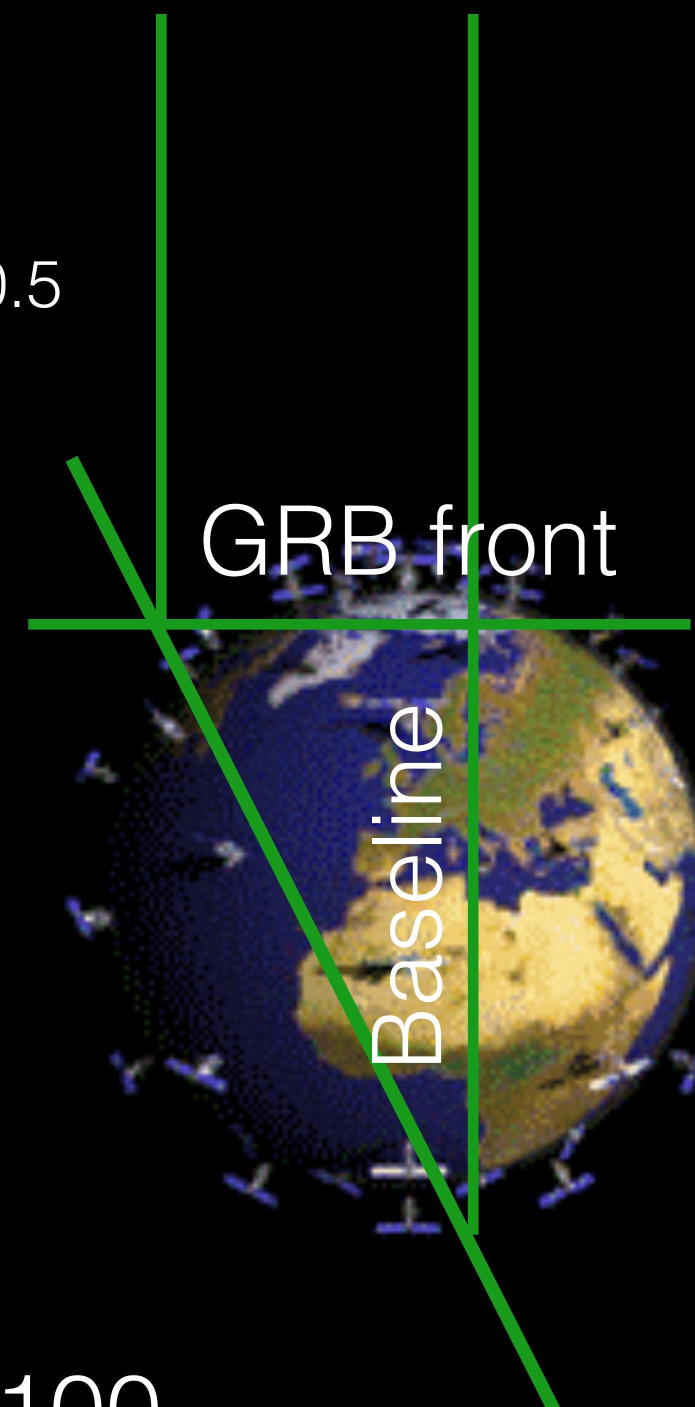


$\sigma_{CCF} \sim 10\mu s$

$\sigma_{Pos} \sim 10 arcsec$

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



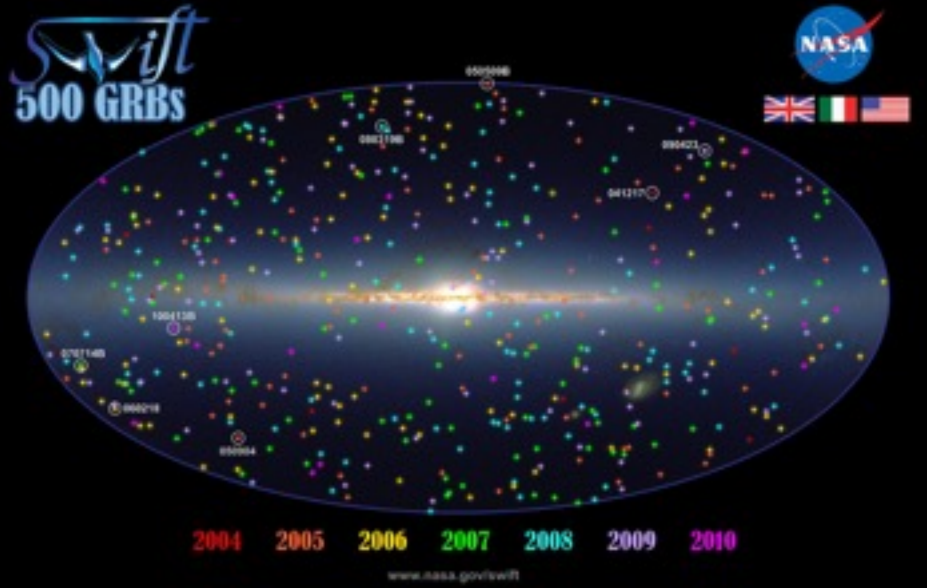
Experiment concept

2. Add the signal from different units

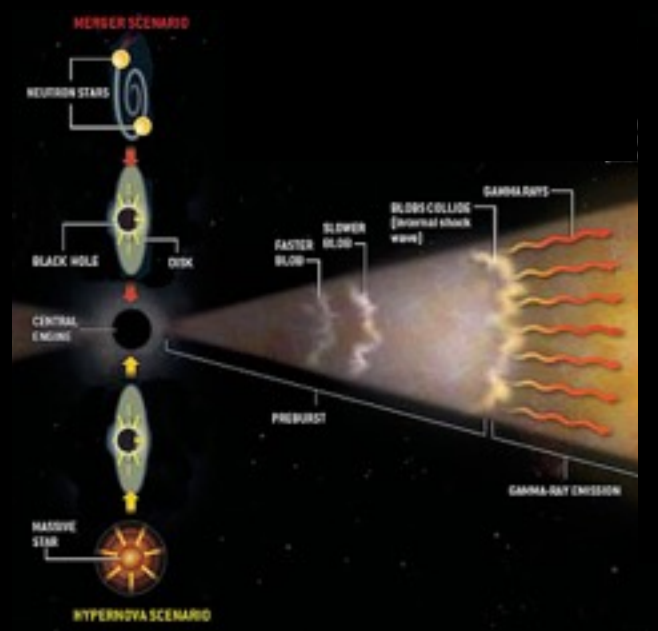
Total collecting area 50-100-cm^2 x 100-200 = 0.5-2 m^2

Transient fine (subμs-ms) temporal structure

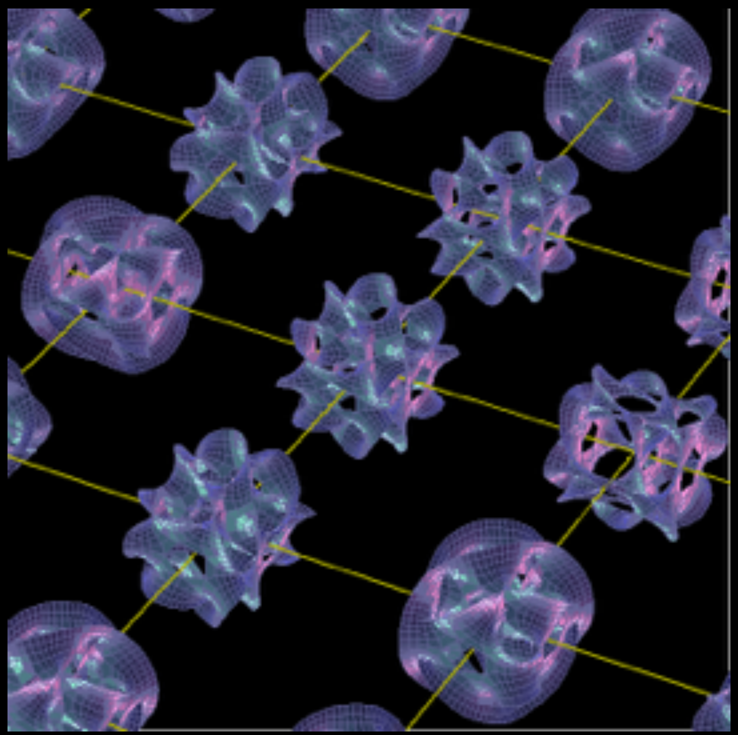
How to *promptly* localise a GRB *prompt* event? (see K. Hurley talk)



How to construct a GRB engine?



Which is the ultimate granular structure of space-time? (See G. Amelino-Camelia talk)



Requirements

Scientific:

Arcmin 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:

$\approx$from a few to hundreds detectors

single collecting area $\geq$50cm^2

total collecting area $\geq$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

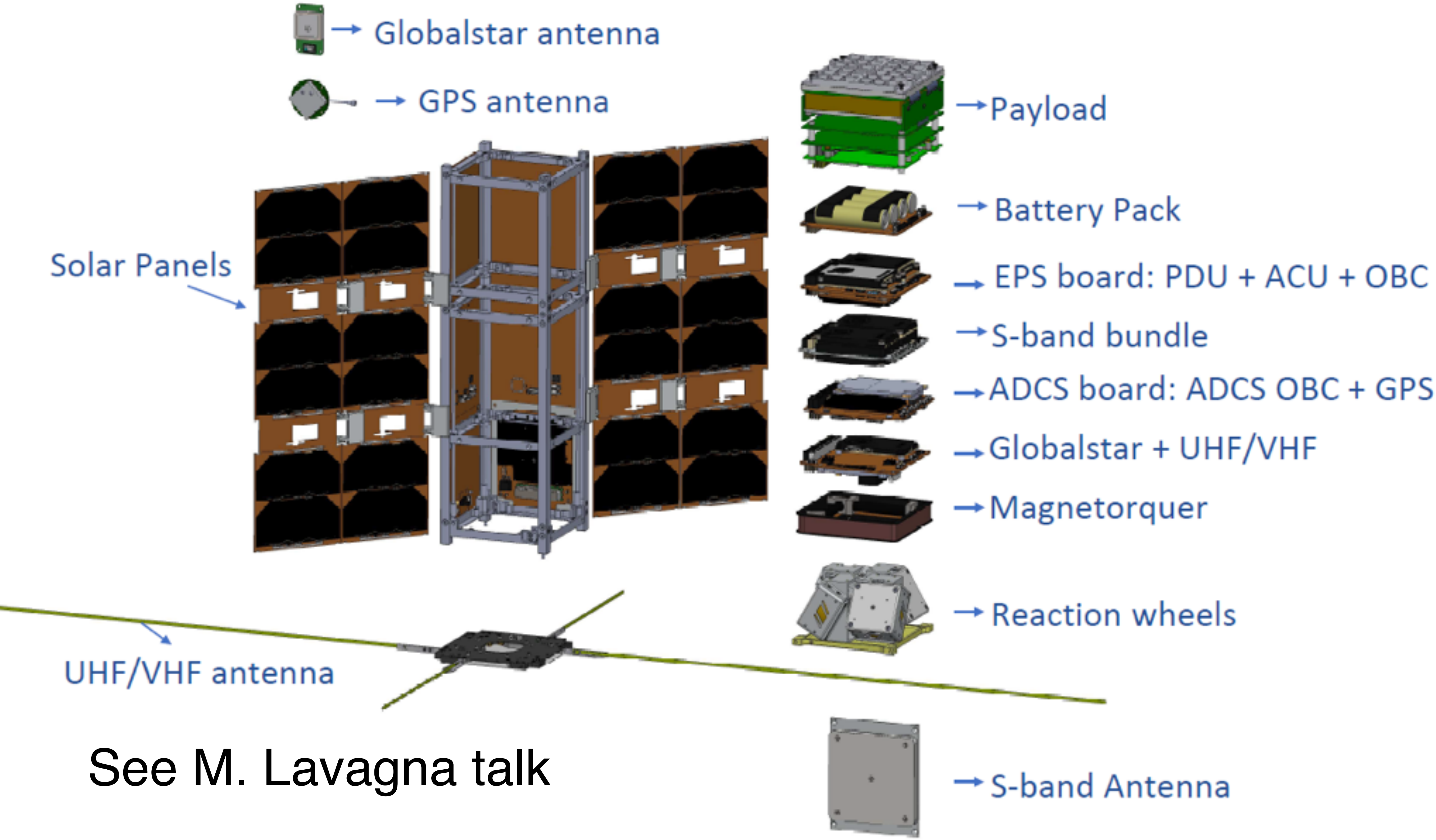
Download full burst info in minutes

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

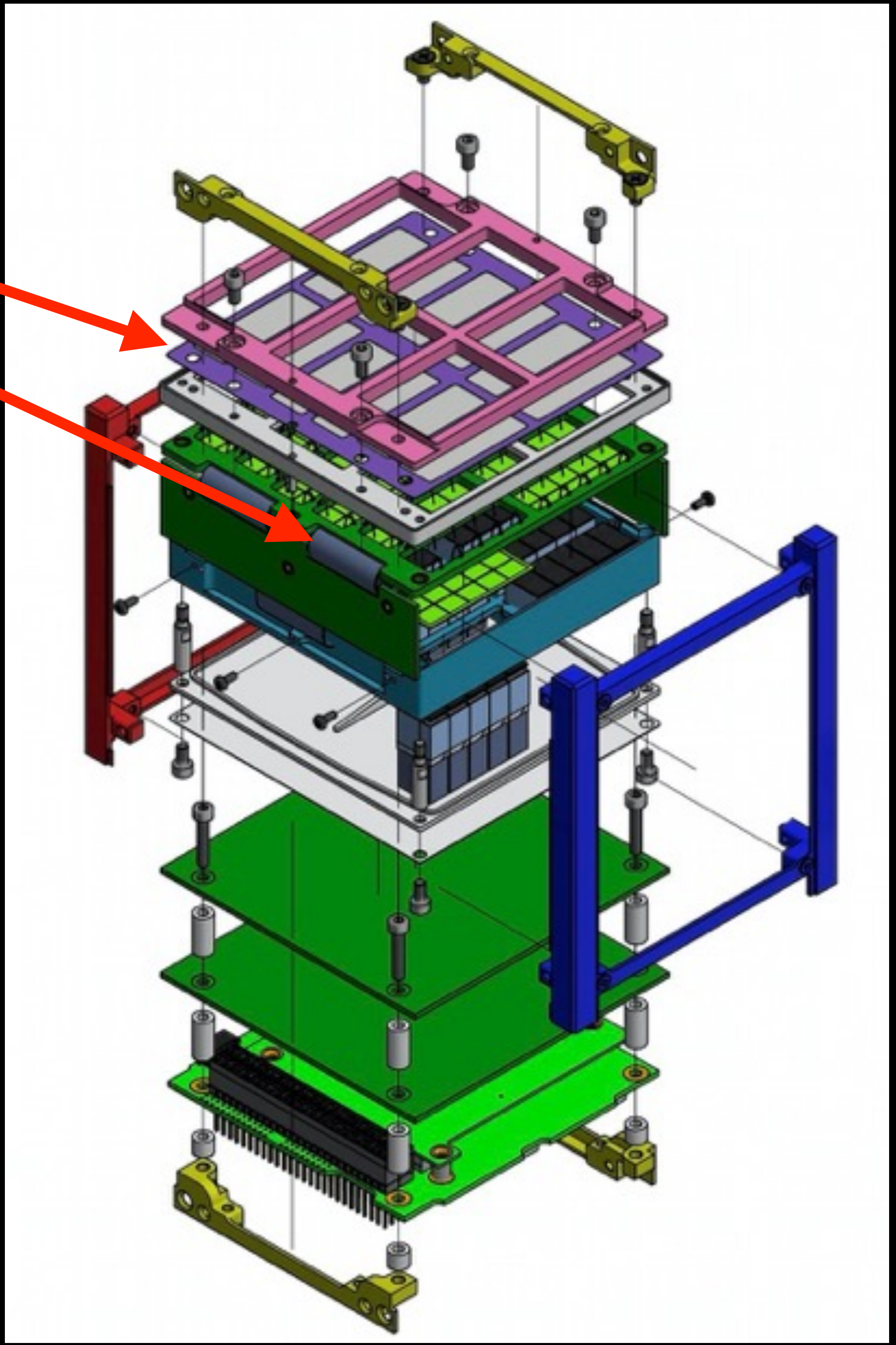


See M. Lavagna talk

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

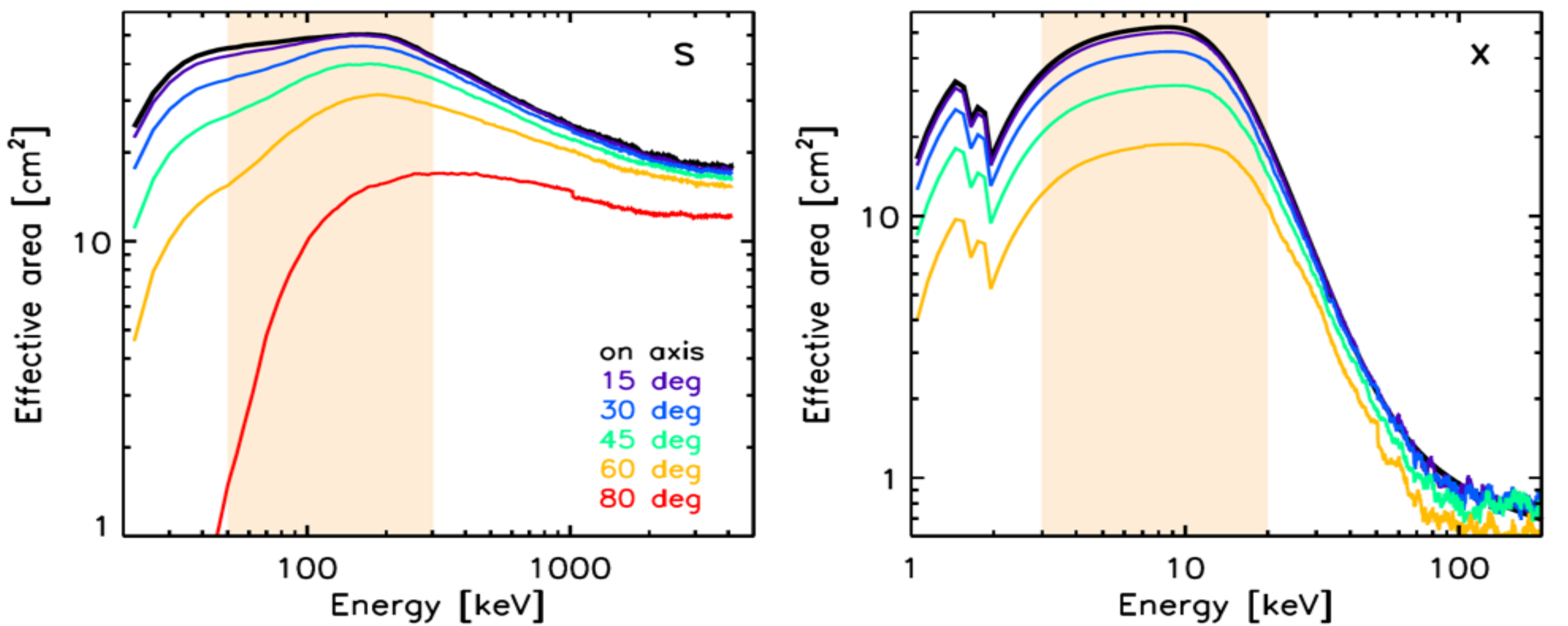
Fuschino+2018, 2020
Evangelista+2020
Campana+2020



Payload design

See Y. Evangelista talk

HERMES performances

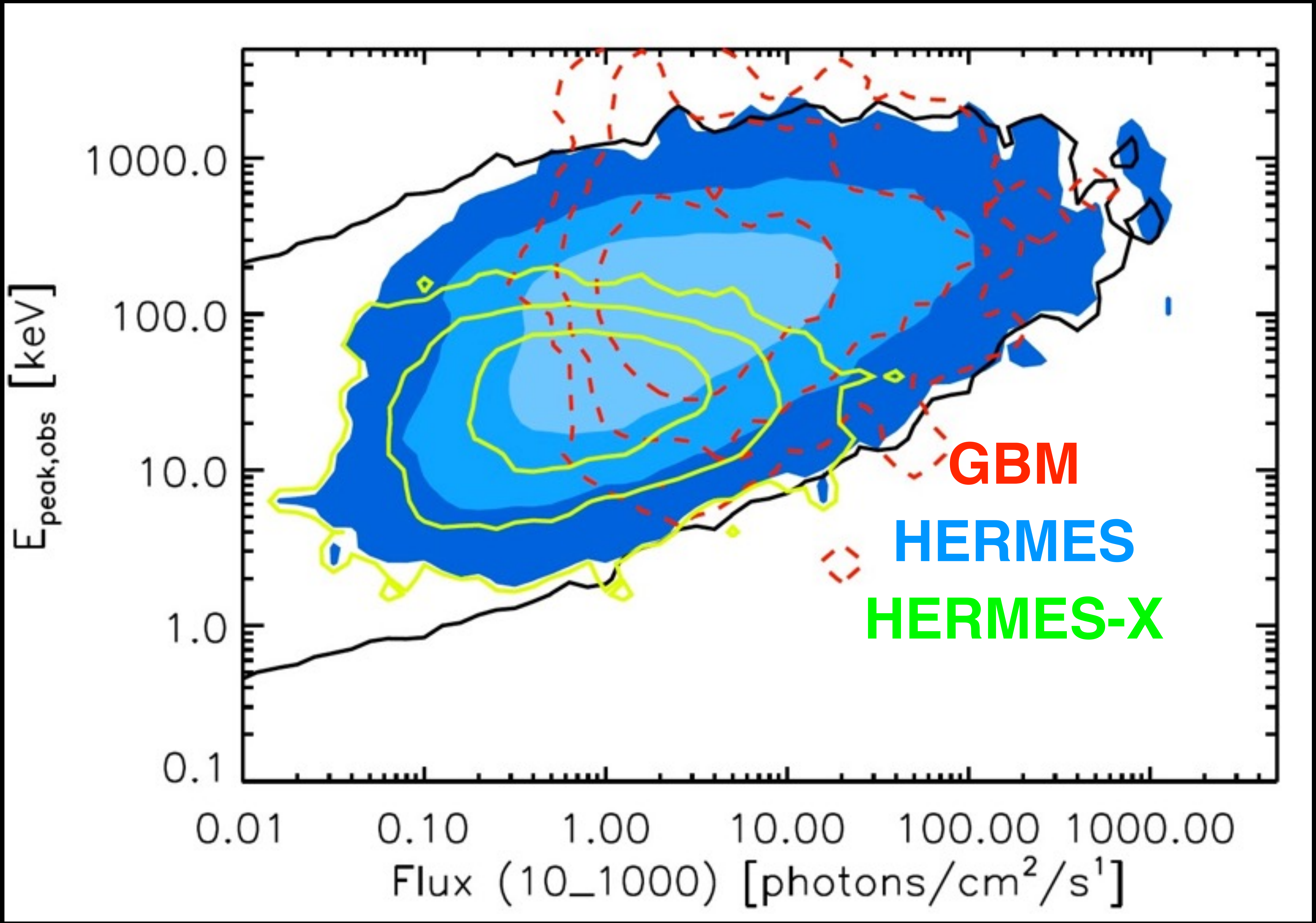


Background: 50-300 keV =75counts/s; 3-20 keV 390counts/s

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

HERMES performances

See G. Ghirlanda talk



HERMES performances

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

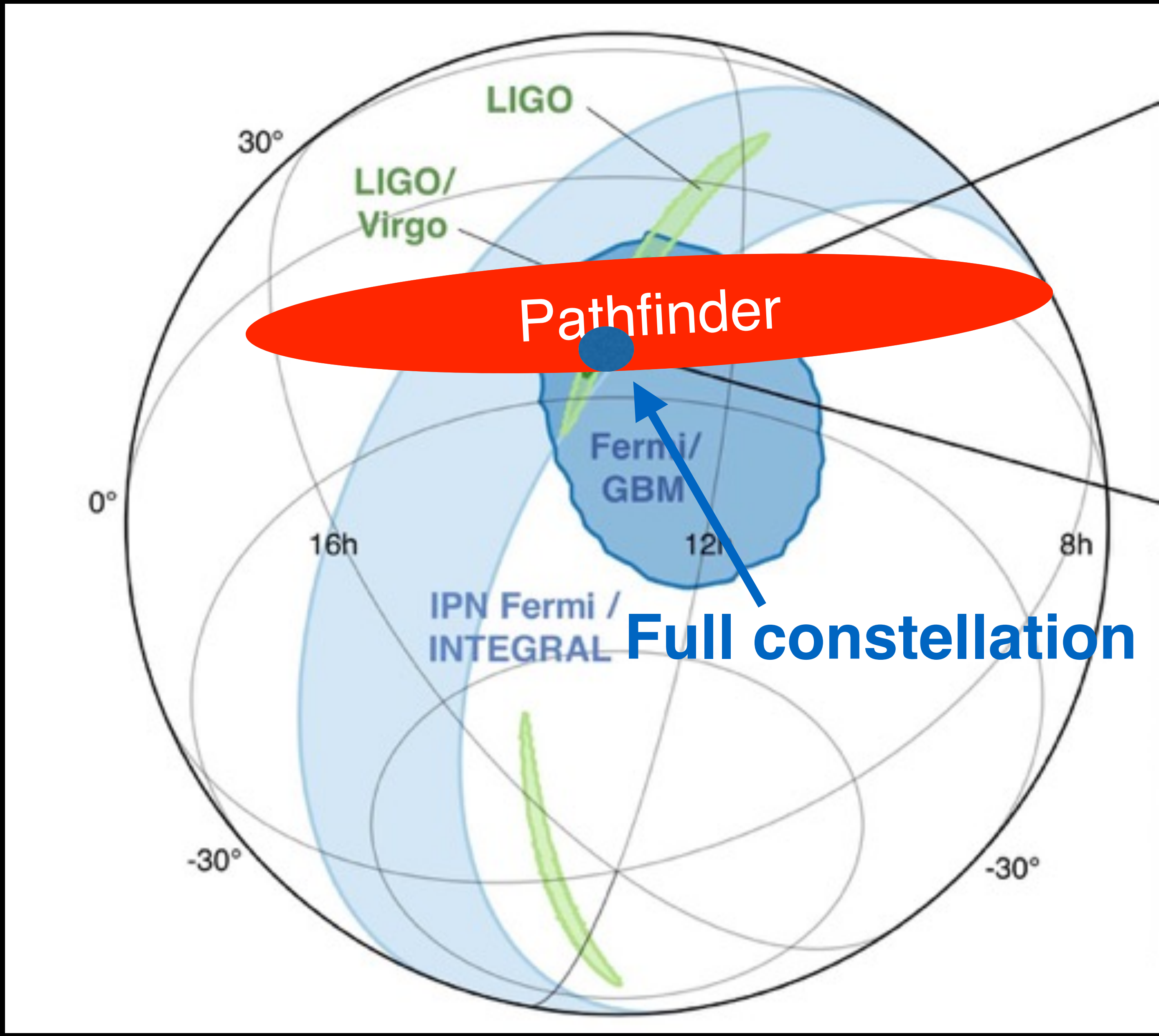
<B>~7000km

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:

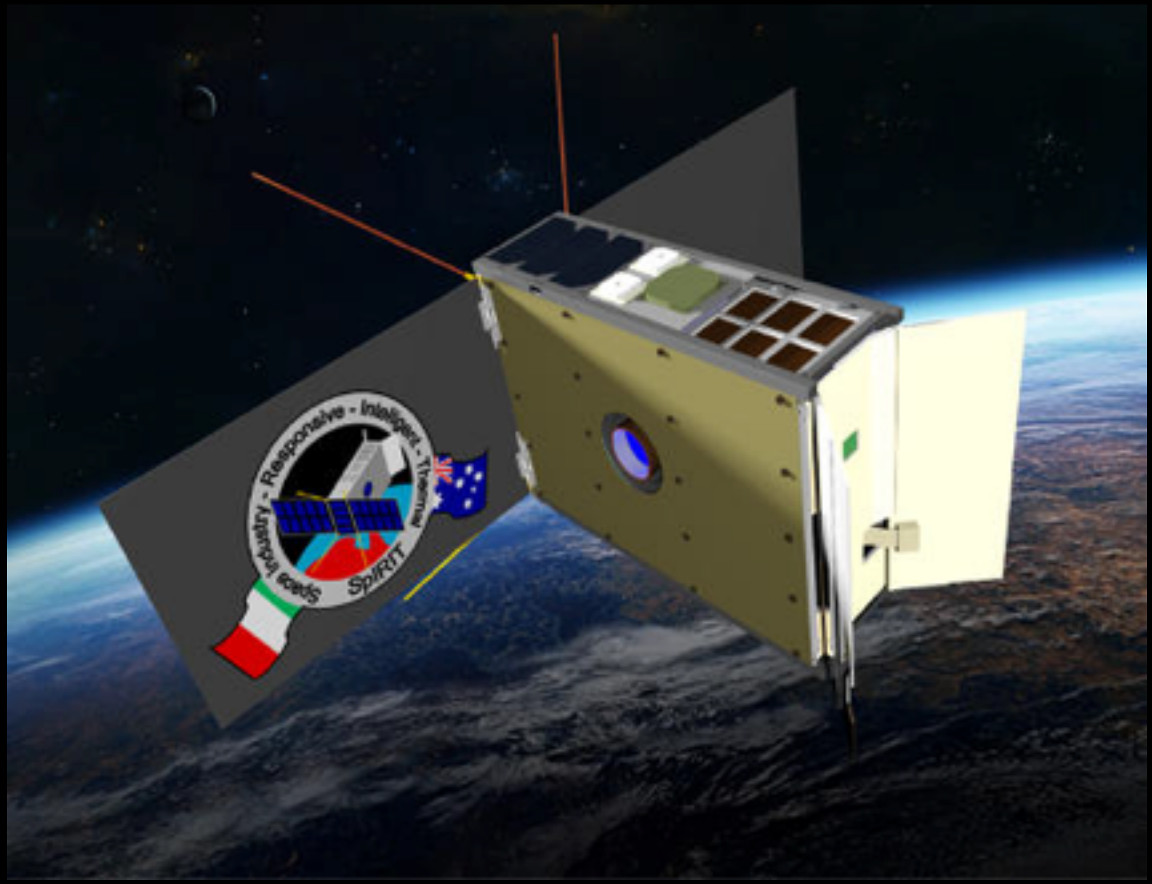
1. Detect GRBs with simple payload hosted by a 3U CubeSat
2. Study statistical and systematic errors in the CCF determination
3. **First GRB localization experiment with ≥3 CubeSat**

- 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



Thanks!