FROM THE HERMES FLEET TO THE FLIGHT OF THE ALBATROS: SURFING THE WAVES OF QUANTUM SPACE-TIME

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ON BEHALF OF THE ALBATROS AND THE HERMES COLLABORATIONS

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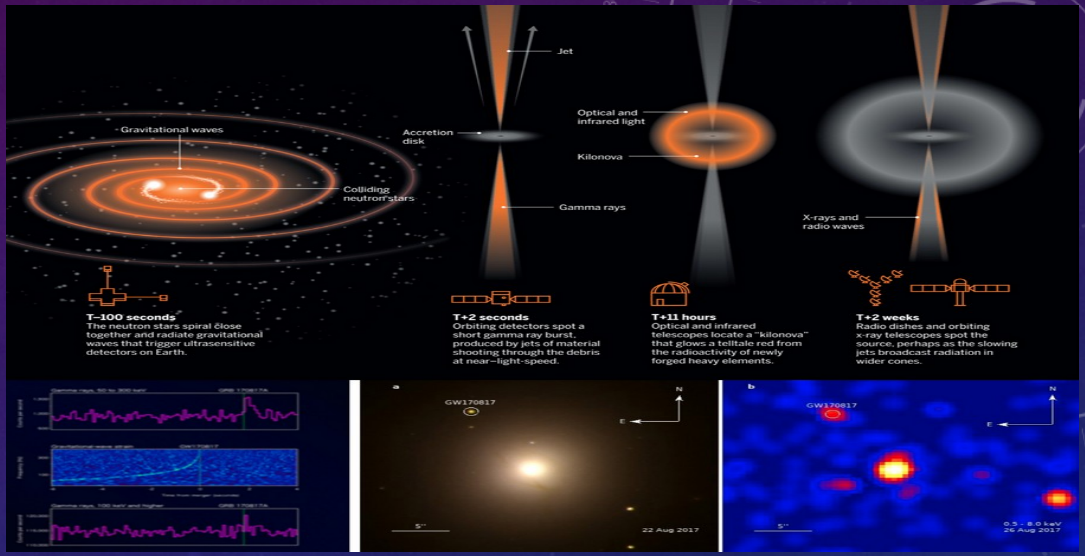
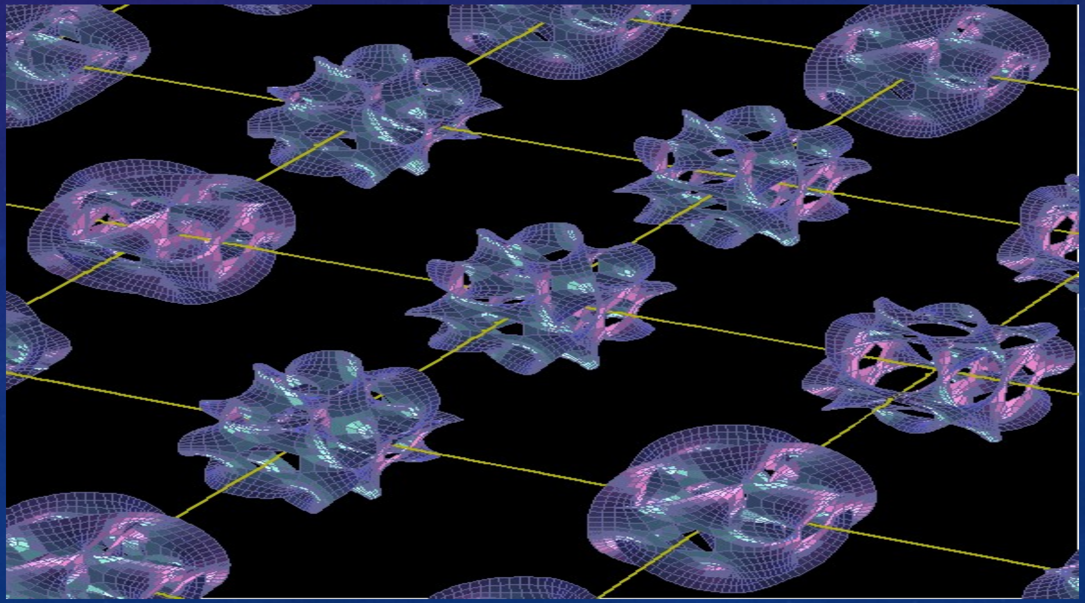
SCIENTIFIC CHALLENGES FOR THE NEXT DECADES

Multi-Messenger Astronomy

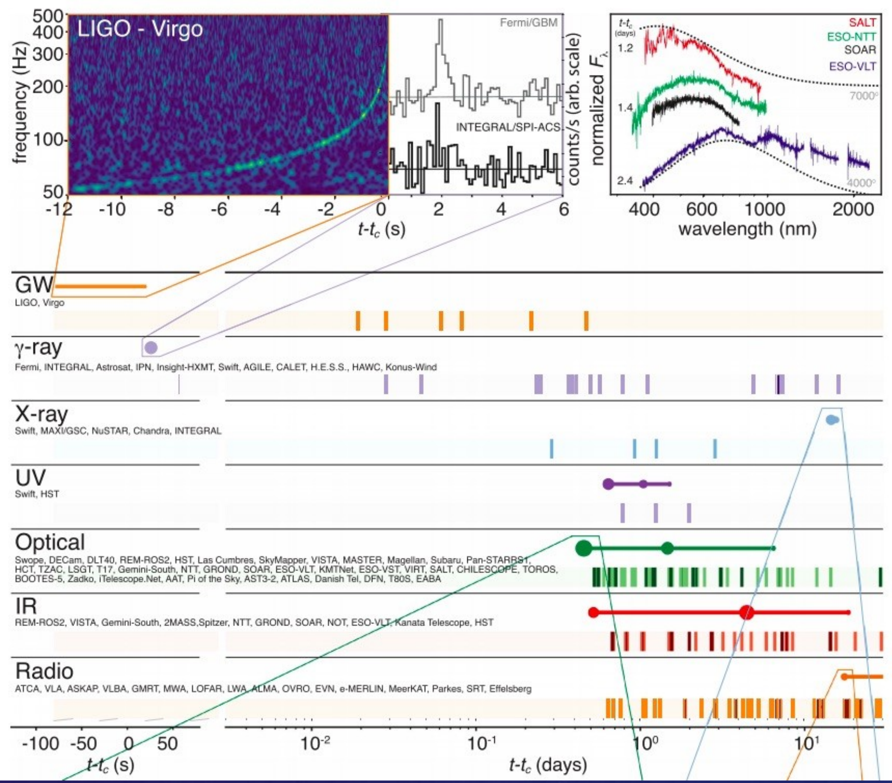


Testing Quantum Gravity

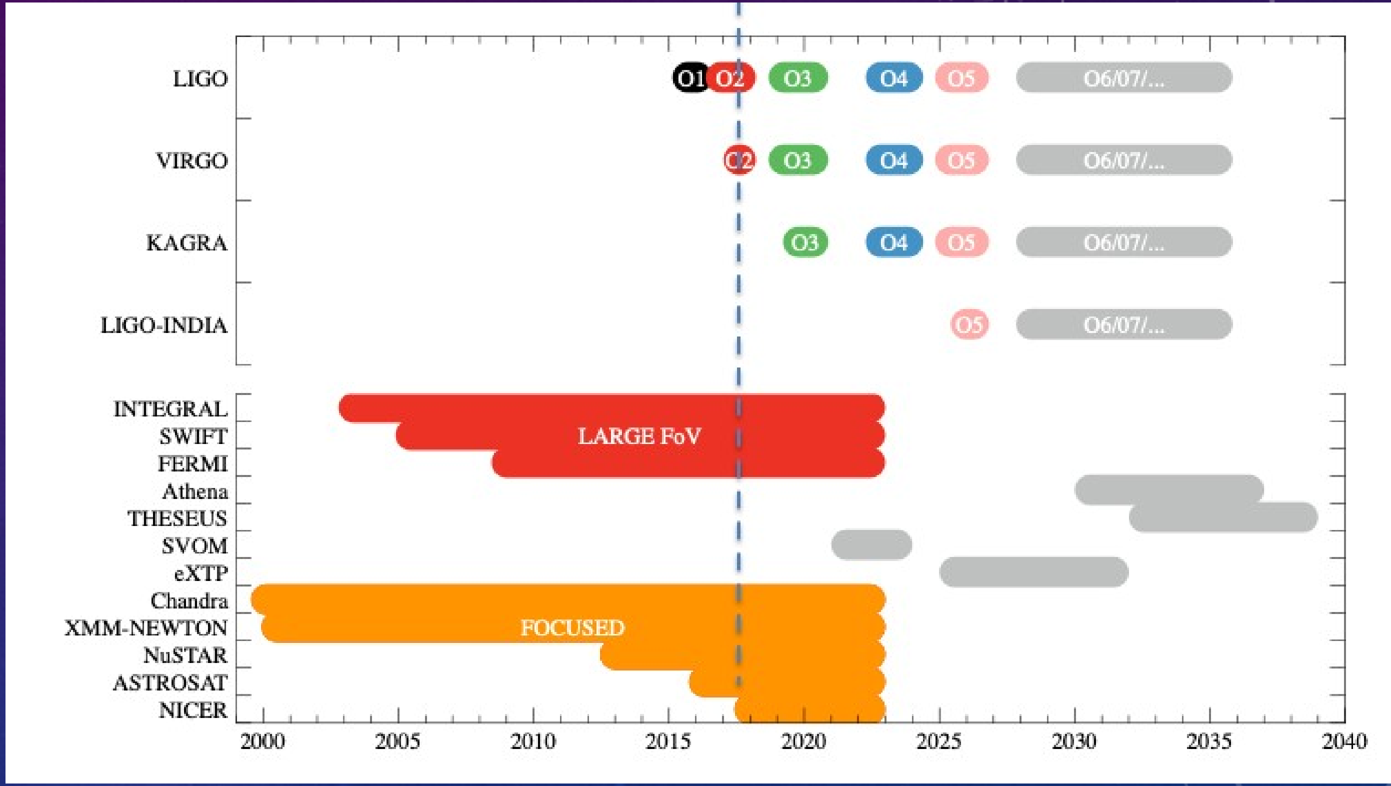


DEVELOPMENT OF MULTI-MESSENGER ASTRONOMY

GW/GRB 170817

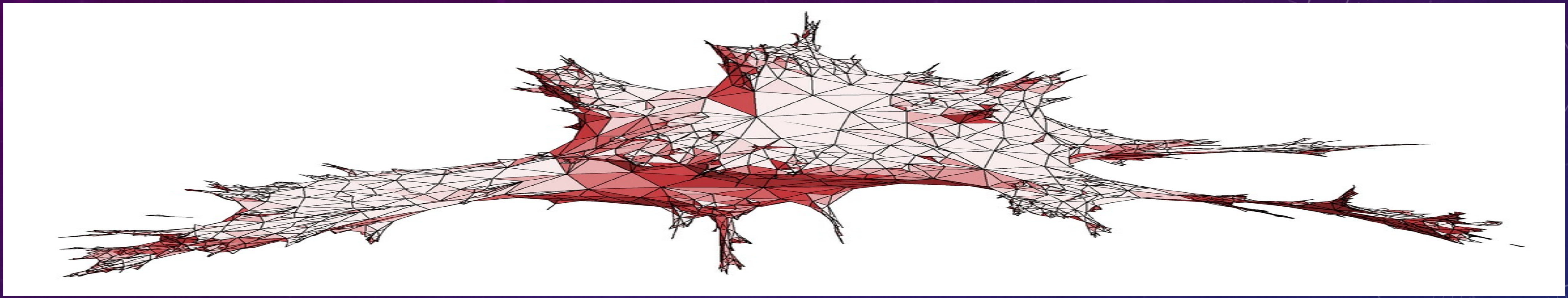


Multi-Messenger Astronomy Paradox



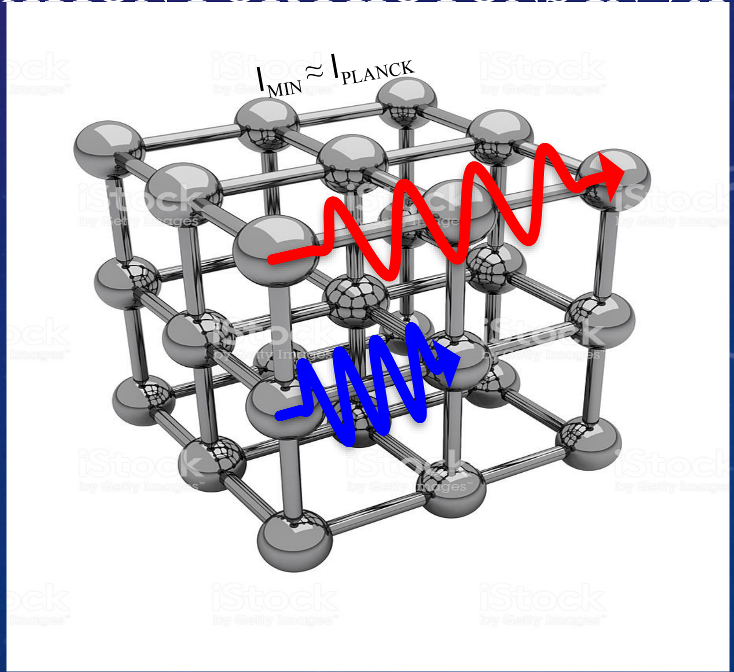
We need a high-energy All-sky Monitor with large area to allow Multi–Messenger Astronomy to develop from infancy to maturity!

QUANTUM GRAVITY EXPERIMENT



QUANTUM GRAVITY

MINIMAL LENGTH HYPOTHESIS, LIV AND DISPERSION RELATION FOR PHOTONS *IN VACUO*



Existence of a Minimal Length (String theories, etc.)

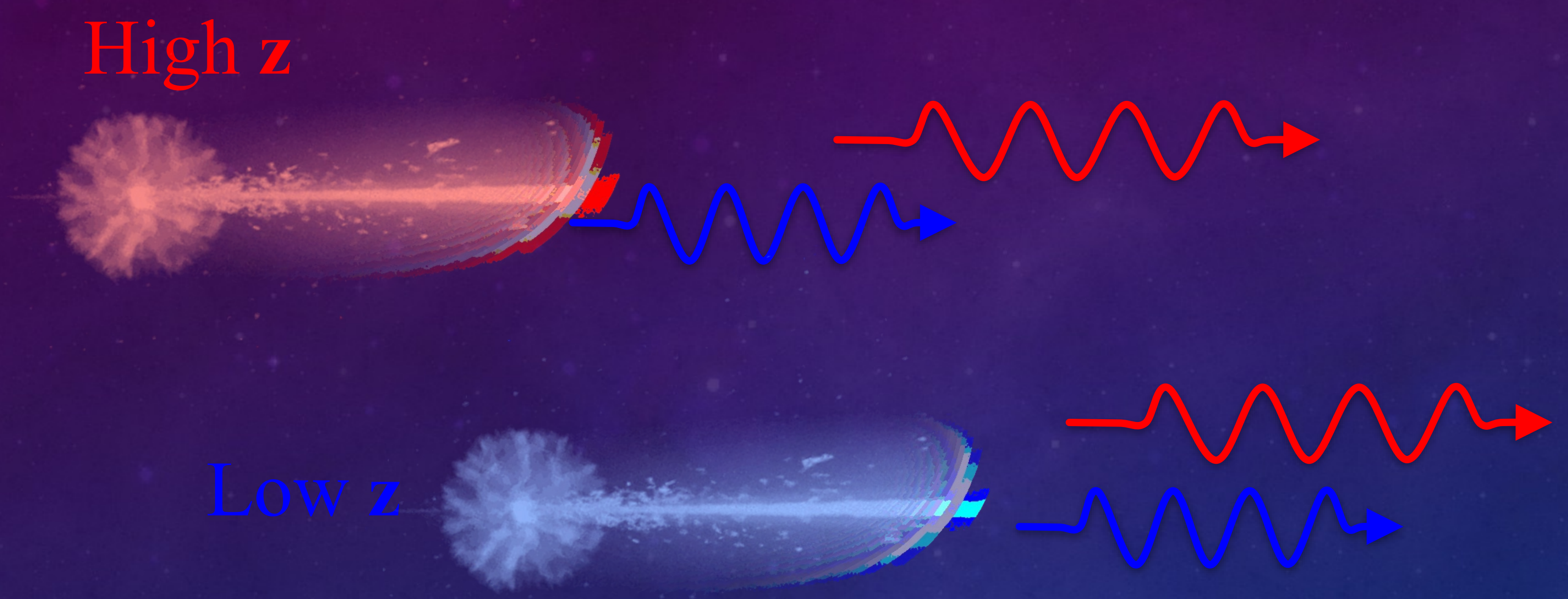
$$l_{MIN} \approx l_{PLANCK} = [Gh/(2\pi c^3)]^{1/2} = 1.6 \times 10^{-33}\ \text{cm}$$

implies:

i) Lorentz Invariance Violation (LIV): no further Lorentz contraction
ii) Space has the structure of a crystal lattice
iii) Existence of a dispersion law for photons *in vacuo*

QUANTUM GRAVITY EXPERIMENT

THE ENERGY AND REDSHIFT DELAY DEPENDENCE



Time lags caused by Quantum Gravity effects:

- $\propto |E_{phot}(\text{Band II}) - E_{phot}(\text{Band I})|$
- $\propto D_{TRAV}(z_{GRB})$

Time lags caused by prompt emission mechanism:

- complex dependence from E_{phot}(Band II) and E_{phot}(Band I)
- independent of $D_{TRAV}(z_{GRB})$

MONOLITHIC VS DISTRIBUTED HIGH ENERGY OBSERVATORIES

FERMI

AGILE

BeppoSAX

Pros:

- Reliability
- long heritage

Pros:

- modularity
- limited cost
- quicker development
- Low risk

Current nanosat and cubesat facts

Facts as of 2022 August 1

Nanosats launched: 2068

CubeSats launched: 1897

Interplanetary CubeSats: 4

Nanosats destroyed on launch: 108

Most nanosats on a rocket: 120

Countries with nanosats: 77

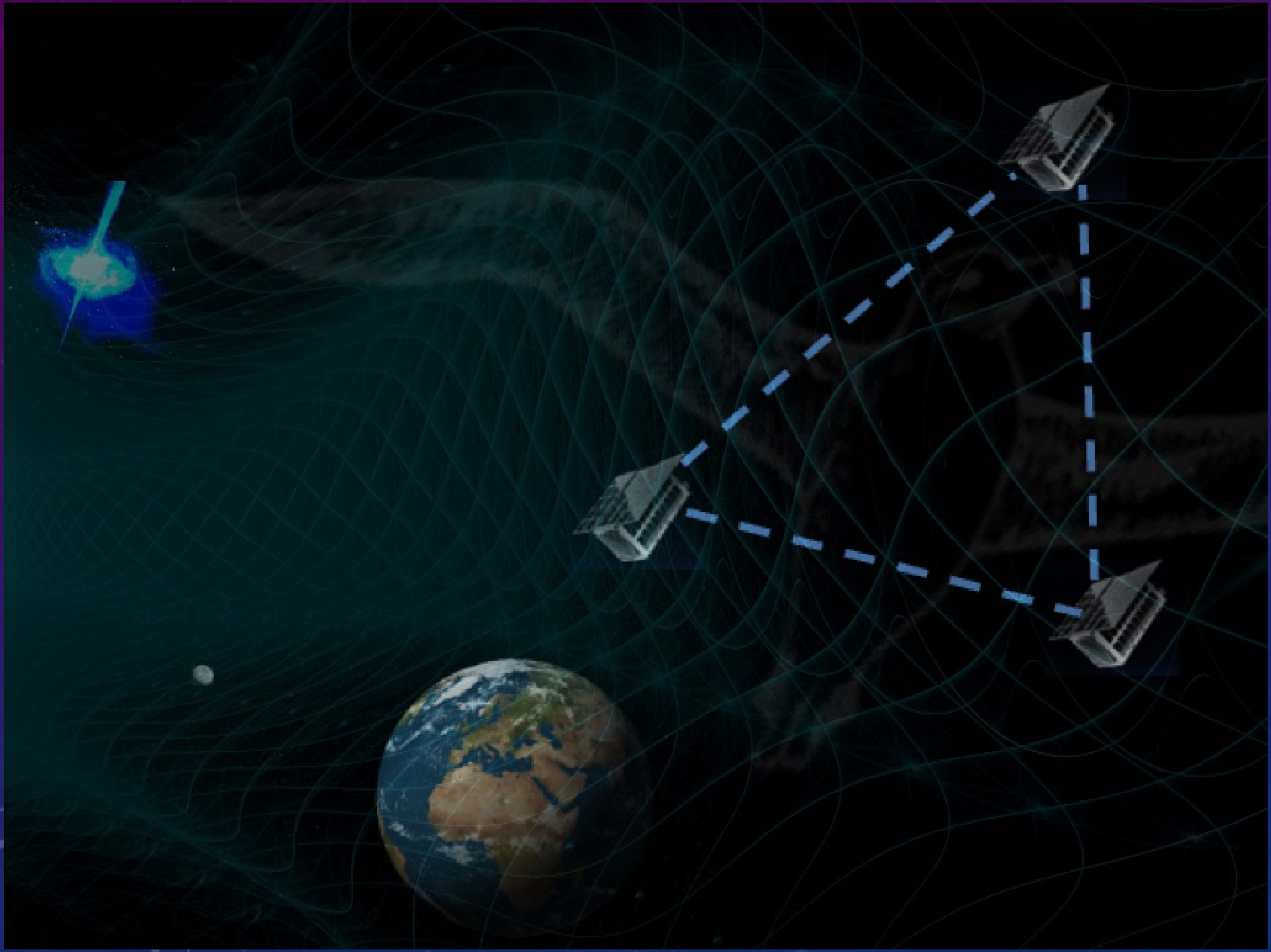
Companies in database: 575

Forecast: over 2080 nanosats to launch in 6 years

Credits: https://www.nanosats.eu/

THE ALBATROS MISSION

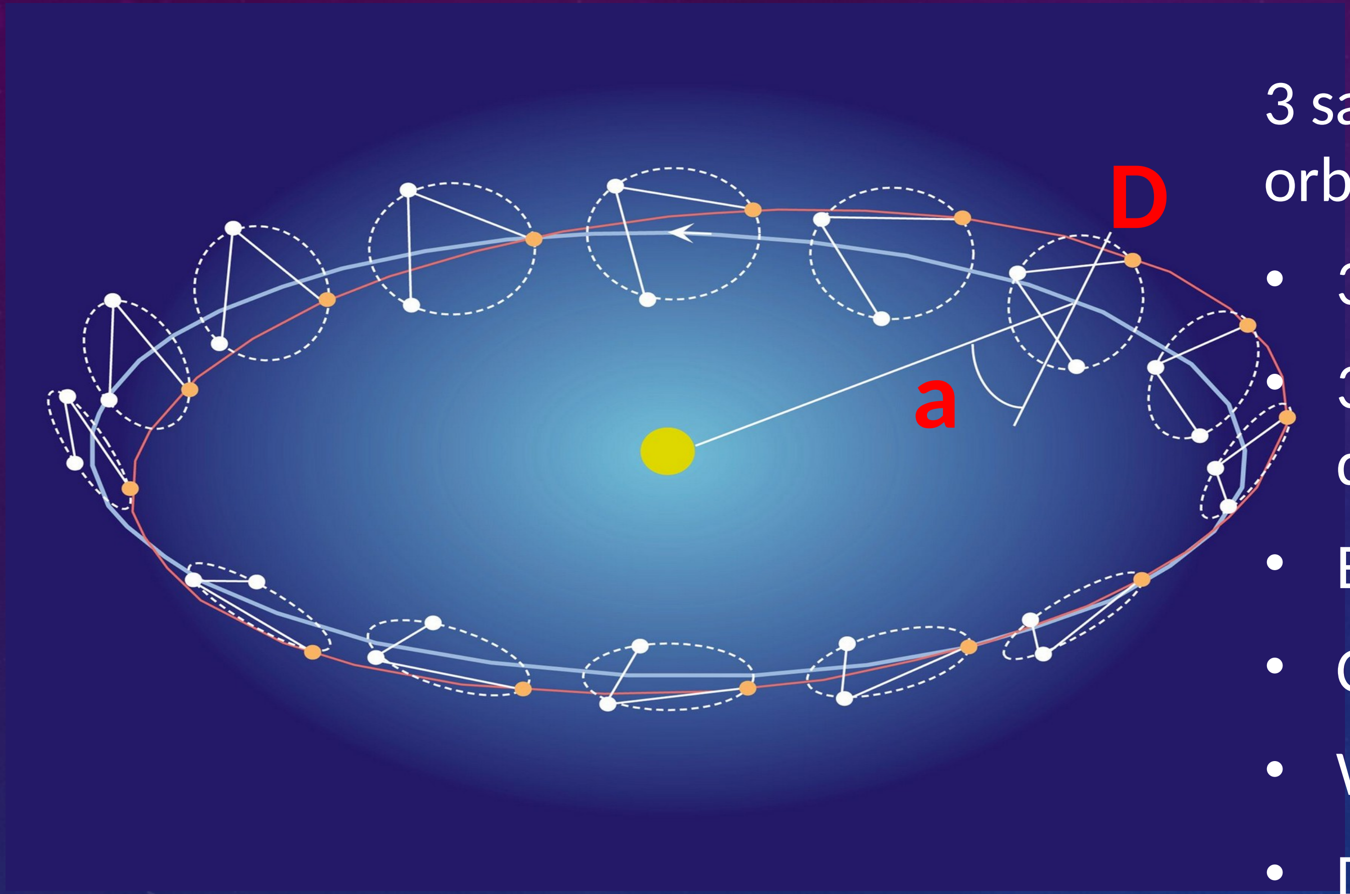
(Astonishingly Large Baseline Array Transient Reconnaissance Observatory from Space)



Properties:

- 3 satellites in heliocentric orbits
- 2x400 cm^2 detectors (~20 kg) per satellite pointing in opposite directions
- keV – MeV energy band
- Sub-microsecond time resolution
- 4 steradians FoV (whole sky)
- 1-2 GRB/day detection rate
- 75% expected success in GRB redshift determination with ground-based facilities follow-up

THE ALBATROS MISSION: CART-WHEEL ORBITS



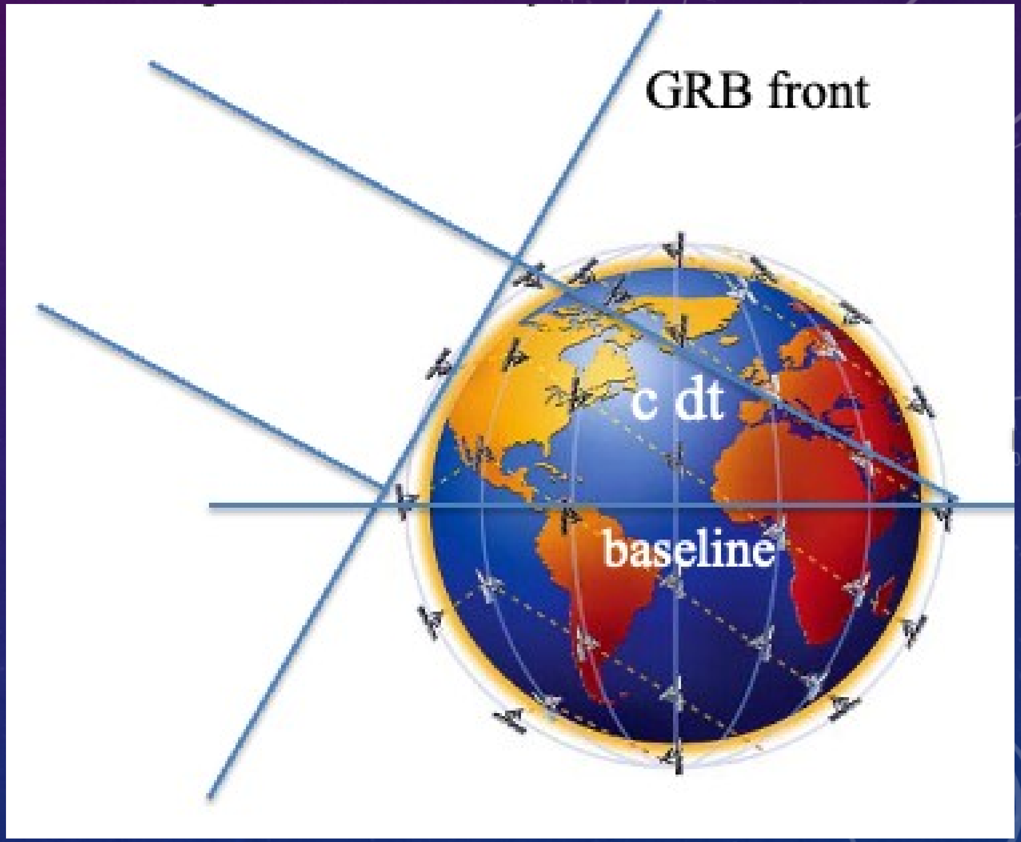
3 satellites in "Cart-wheel" orbits (e.g., LISA orbits):

- 3 heliocentric orbits with a=1AU
- 3 slightly different small inclinations (~0.5 degrees) w.r.t. to ecliptic plane
- Equatorial triangle of side: 2.5×10^6 km
- Contact to ground up to 23 hours per day
- Wet mass ~ 230 kg per satellite
- Dry mass ~ 165 kg per satellite

THE ALBATROS MISSION: LOCALIZATION CAPABILITIES

Determination of source position through Delays in Time of Arrival (ToA) of an impulsive event (variable signal) over 3 (or more) spatially separate detectors

Transient source in the sky defined by time of the event, position in the sky: T_0, α, δ (3 parameters, $N_{PAR} = 3$)

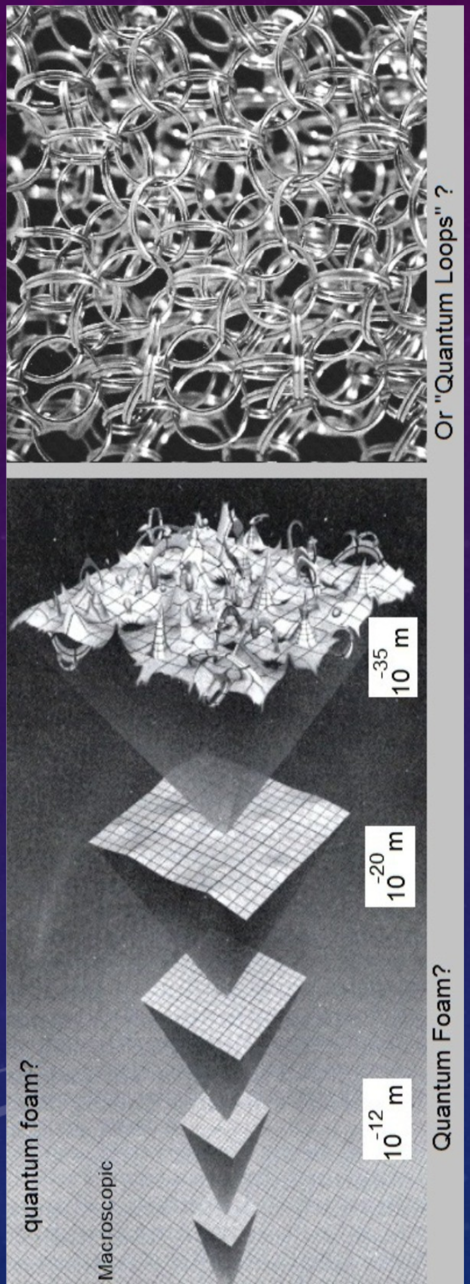


Statistical accuracy in determining α and δ with N_{SAT}:

$$\sigma_\alpha \approx \sigma_\delta = c\, \sigma_{ToA} / \langle \mathrm{baseline} \rangle \times (N_{SAT} - N_{PAR})^{-1/2}$$

$$\sigma_\alpha \approx \sigma_\delta \approx c\, \sigma_{ToA} / B \approx 24\ \mathrm{arcsec} \times (B / 2.5\times10^{6}\ \mathrm{km})^{-1} \times (\sigma_{ToA}/1\mathrm{ms})$$

THE ALBATROS MISSION: FIRST QUANTUM GRAVITY EXPERIMENT



SEARCH FOR A FIRST ORDER DISPERSION RELATION IN A SAMPLE OF GRBS OF KNOWN REDSHIFT (BURDERI *ET AL.* EXP. ASTR., 2021)

For a sample of **i = 1…N** GRBs of known redshift $\mathbf{z_i}$ at a given energy **E**, adopt:

$$\Delta t_i(E) = \tau(E) + \Delta t_{LIV}\,(z_i, E)$$

where **τ(E) = intrinsic spectral delay at E and**

$$\Delta t_{LIV}(z_i, E) \;=\; D_{TRAV}(z_i)/c\;\alpha(E)(E - E_0)/(m_{PLANCK}c^2) = \alpha(E) \times t_i$$

for a first order dispersion law.

$\alpha(E) \approx 1$ = delay constant at E and $D_{TRAV}(z_i)$ parametrises the GRB distance as function of redshift.

Now we plot $\mathbf{\Delta t_i}$ vs. $\mathbf{t_i}$ and fit with $\mathbf{\Delta t_i = \tau(E) + \alpha(E) \times t_i}$ to obtain **τ(E)** and **α(E).**

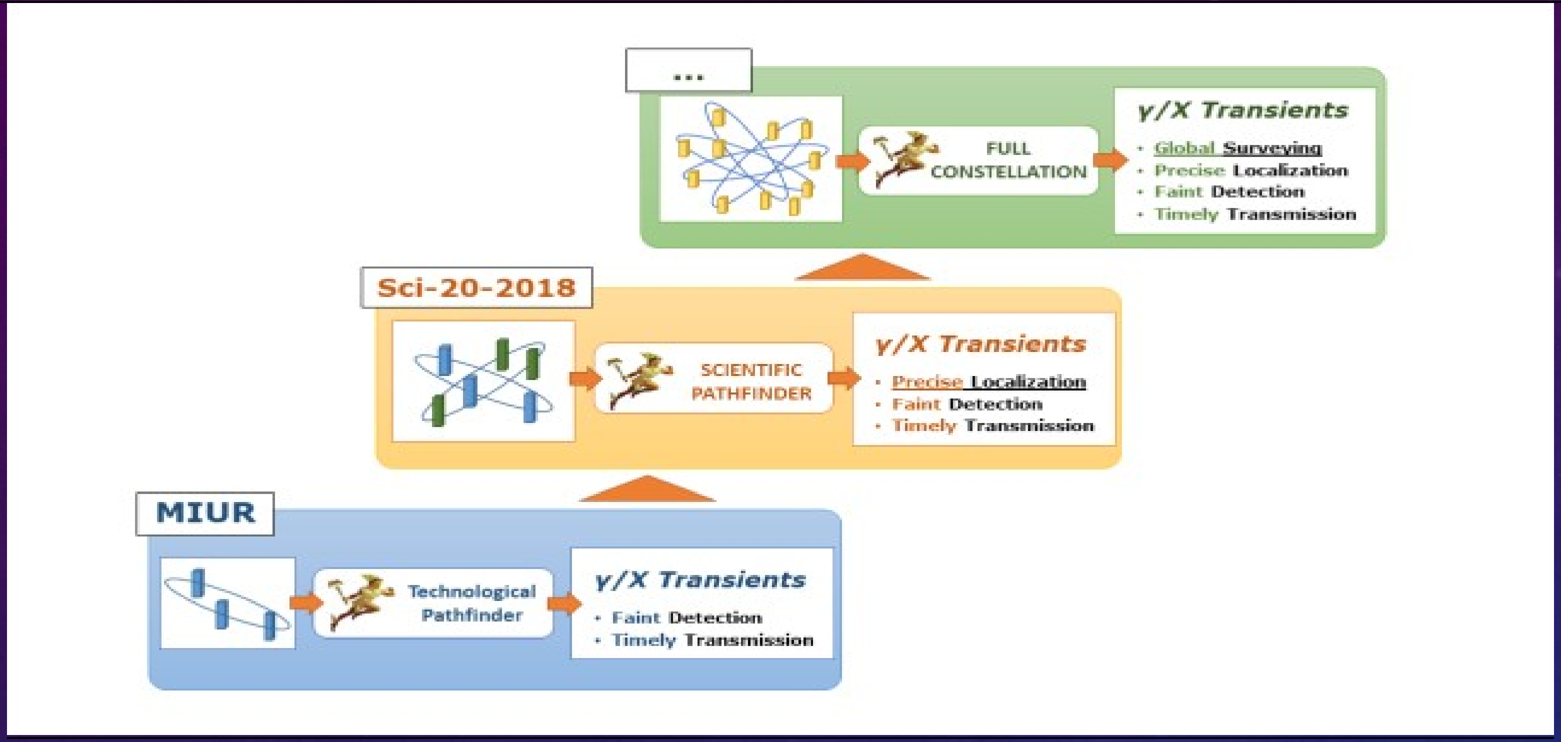
If a first order dispersion relation is present, α(E) = α for any energy E

Compute the average value of **α(E)** and its standard deviation: **α = <α(E)>** and $\mathbf{\sigma_\alpha}$, for all the energy considered. If $\mathbf{\sigma_\alpha \ll \alpha}$ the first order dispersion relation is found, otherwise an upper limit is $\mathbf{\alpha \leq \sigma_\alpha}$.

Since all the errors are of statistical origin, the accuracy of the method depend on the number of photons detected.

1 GRB observed by a large area detector (100 m^2) ⟷ 1000 GRBs observed by a smaller area detector (1000 cm^2)

FROM HERMES TO ALBATROS



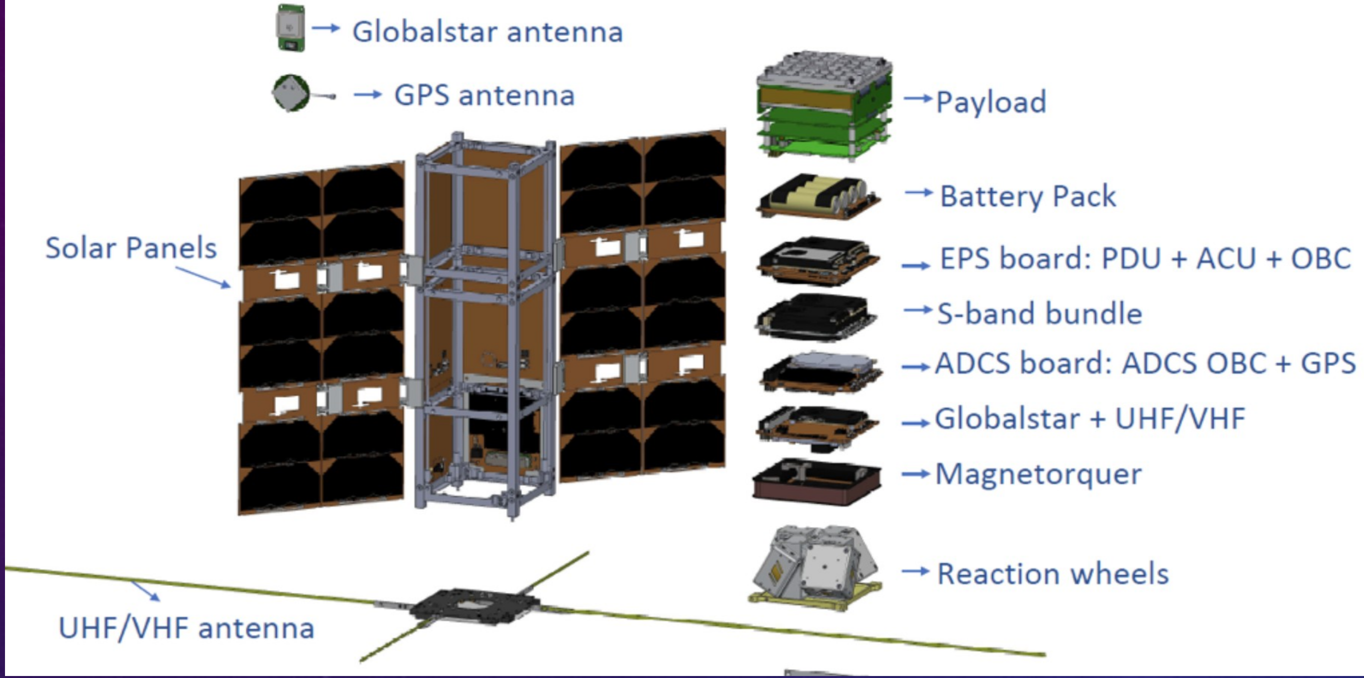
High Energy Rapid Modular Ensemble of Satellites

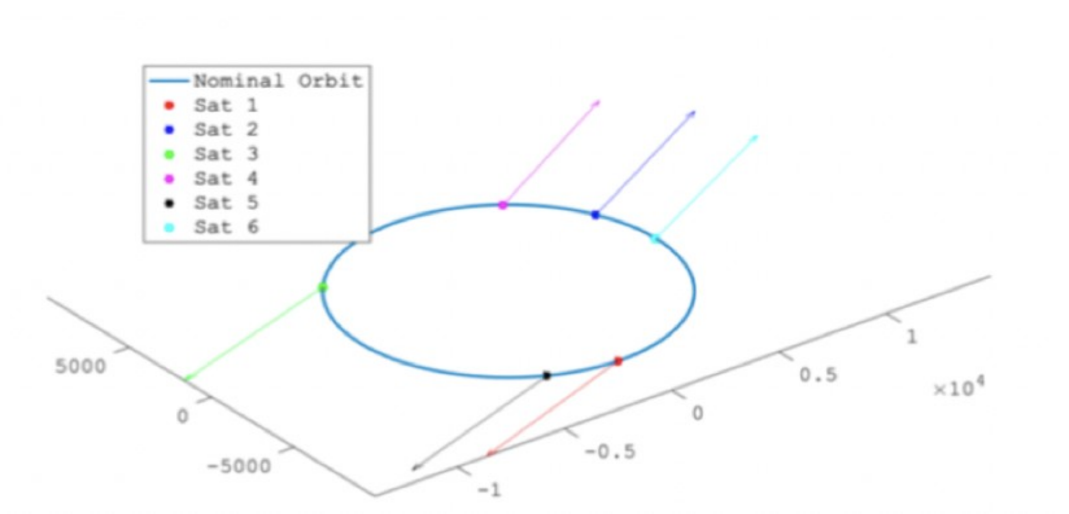
6 x 3U CubeSats
in LEO (500-550 km)
to be launch in Q1 2024(?)
+
SpIRIT payload (Q1 2023)

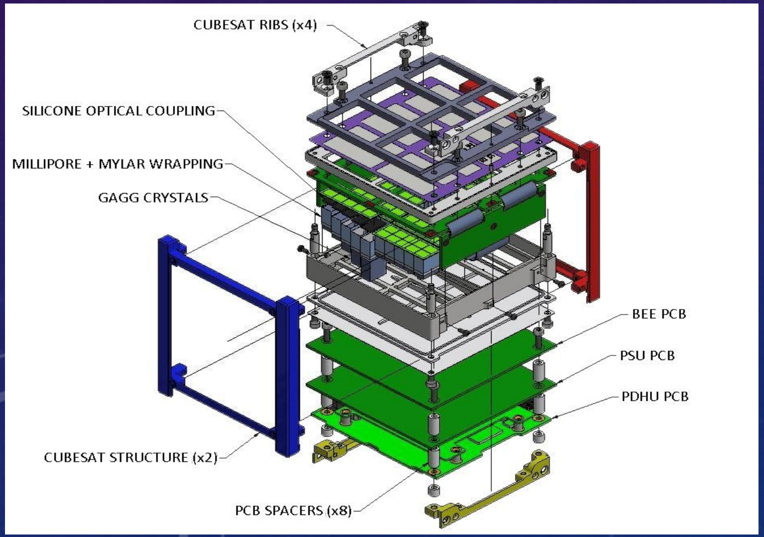
Funding status at 2022, April

ASI (Italian Space Agency) – 23/12/2016:	**€ 450,000**
MIUR (Italian Ministry of University and Research) + ASI 2018/19 :	**€ 3,450,000**
EU Horizon 2020 – Call: H2020-SPACE-2018-2020 – 17/07/2018:	**€ 3,300,000**
ASI (Italian Space Agency) – internal funding 2022 (MOC + operations)	**€ 1,700,000**
Total Funding (at 04/2022):	**€ 8,880,000**
Launch allocated funds	

FROM HERMES TO ALBATROS







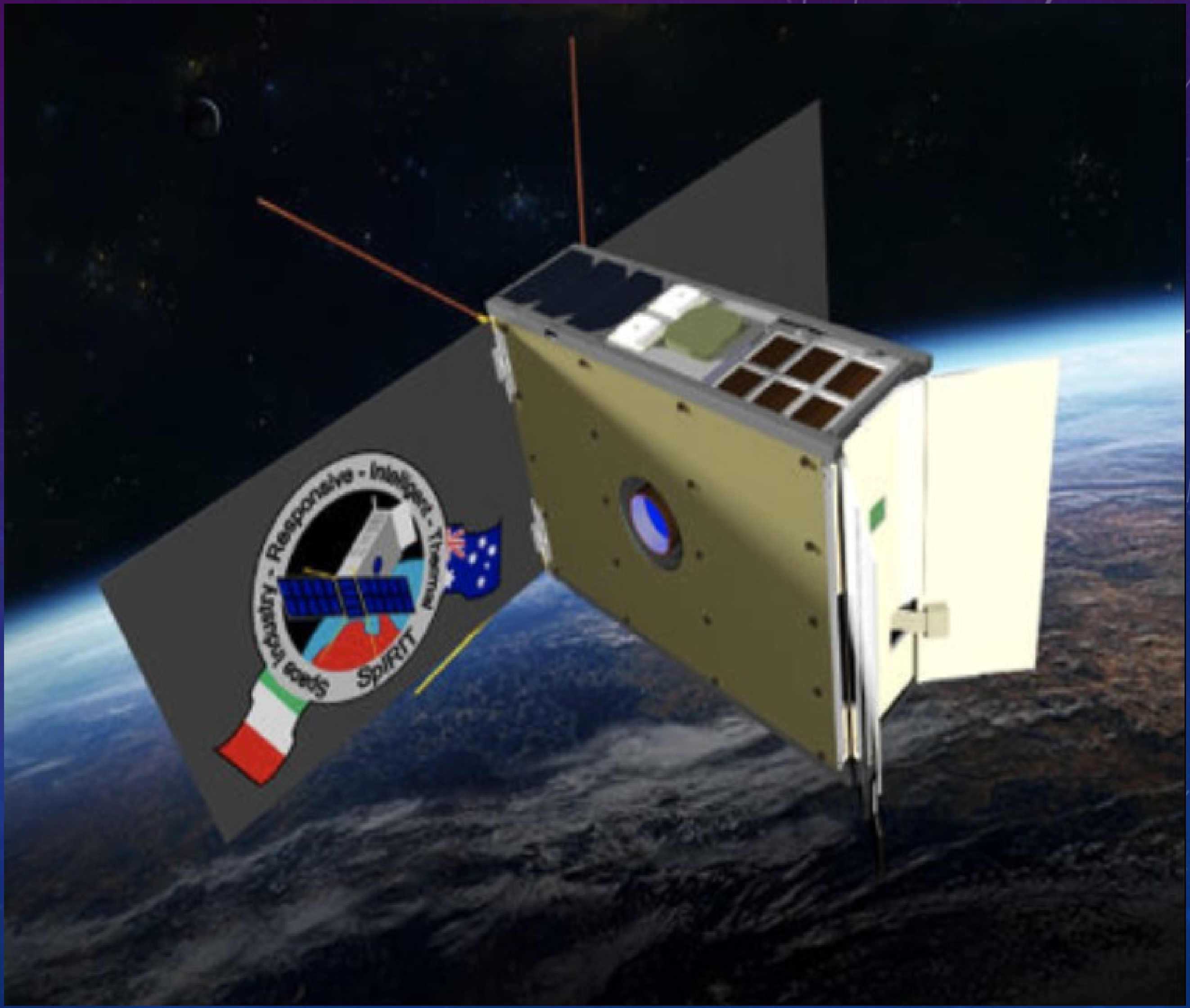
SDD + GAGG

Scintillator Crystal size:	0.7×1.2×1.5 cm
Crystal type:	60 GAGG crystals
Photo detector:	120 SDD (1x0.5 cm)
Energy range:	3 keV ÷ ≥ 0.5 Mev
Energy resolution:	~ 10% at 30 keV
Effective area:	~ 56 cm^2
FOV:	~ 3 steradians (FWHM)
Temporal resolution:	~ 0.5 µs
Mass:	~1.5 kg
Volume	< 10×10×12.5 cm
TRL	**6 (9 in 1 year)**

SPIRIT

(Space Industry – Responsive – Intelligent – Thermal Nano-satellite)

Australian Space Agency
+
University of Melbourne



- 6U Spacecraft
- HERMES payload
- 3 innovative products to qualify in space
- Lunch: Q1 2023
- Sun-Synchronous Orbit

The Hermes Project

Thanks for the attention!

Please join the HERMES Science Team:

https://www.hermes-sp.eu/?page_id=3643#ScienceTeam