NewAstrogam Mission

The MeV to GeV Gamma-Ray Observatory

Proposal for the ESA M8 Mission Opportunity Call

Step-1 proposal deadline: 21 May 2025

Aldo Morselli

on behalf of the M8 MeV team

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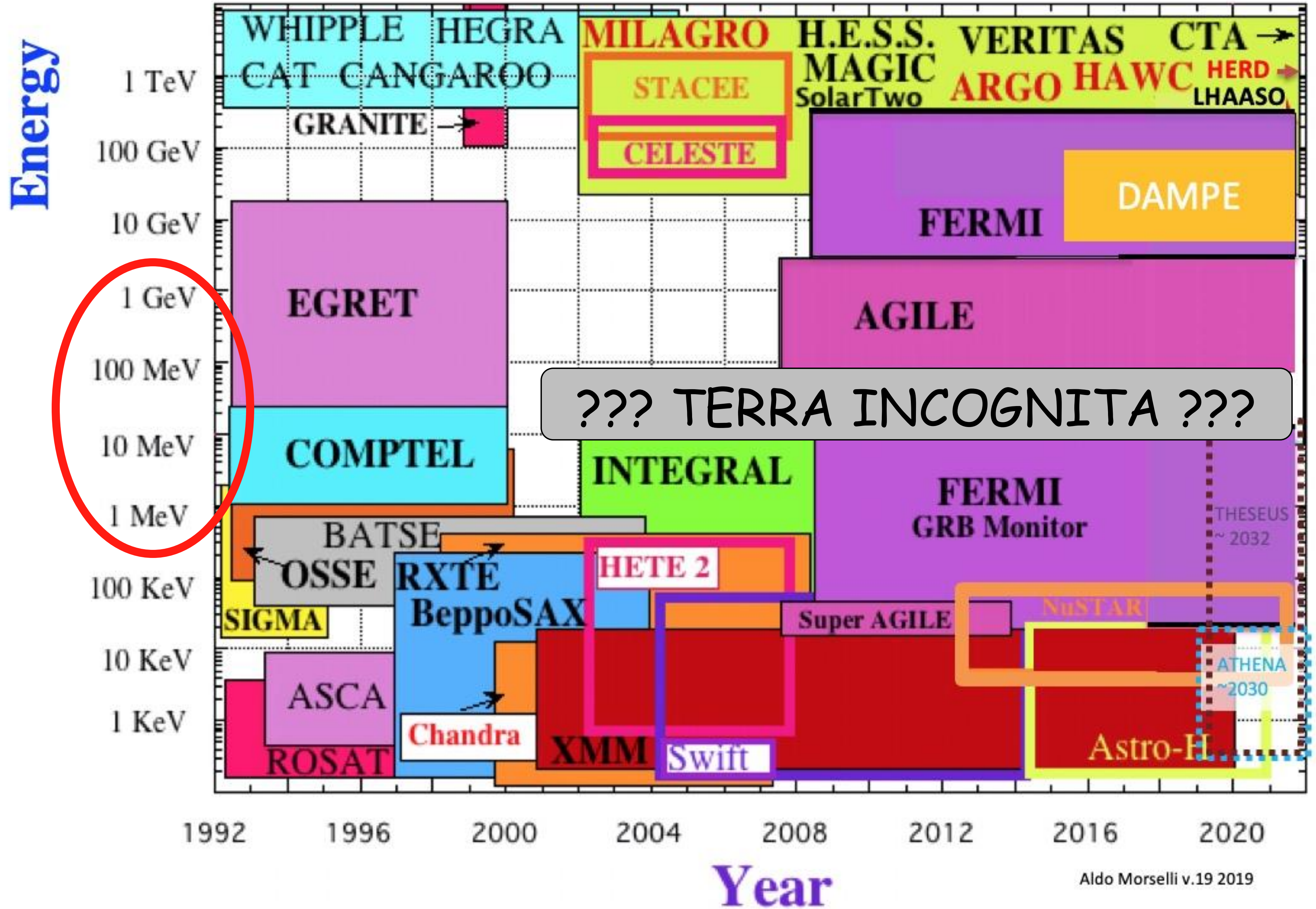
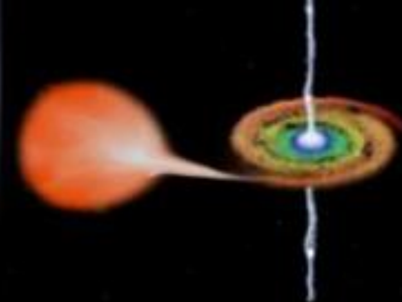
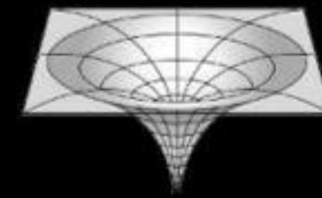
ADVANCES IN MODELING HIGH-ENERGY ASTROPHYSICAL SOURCES

Sexen Center for Astrophysics, 3 July 2025

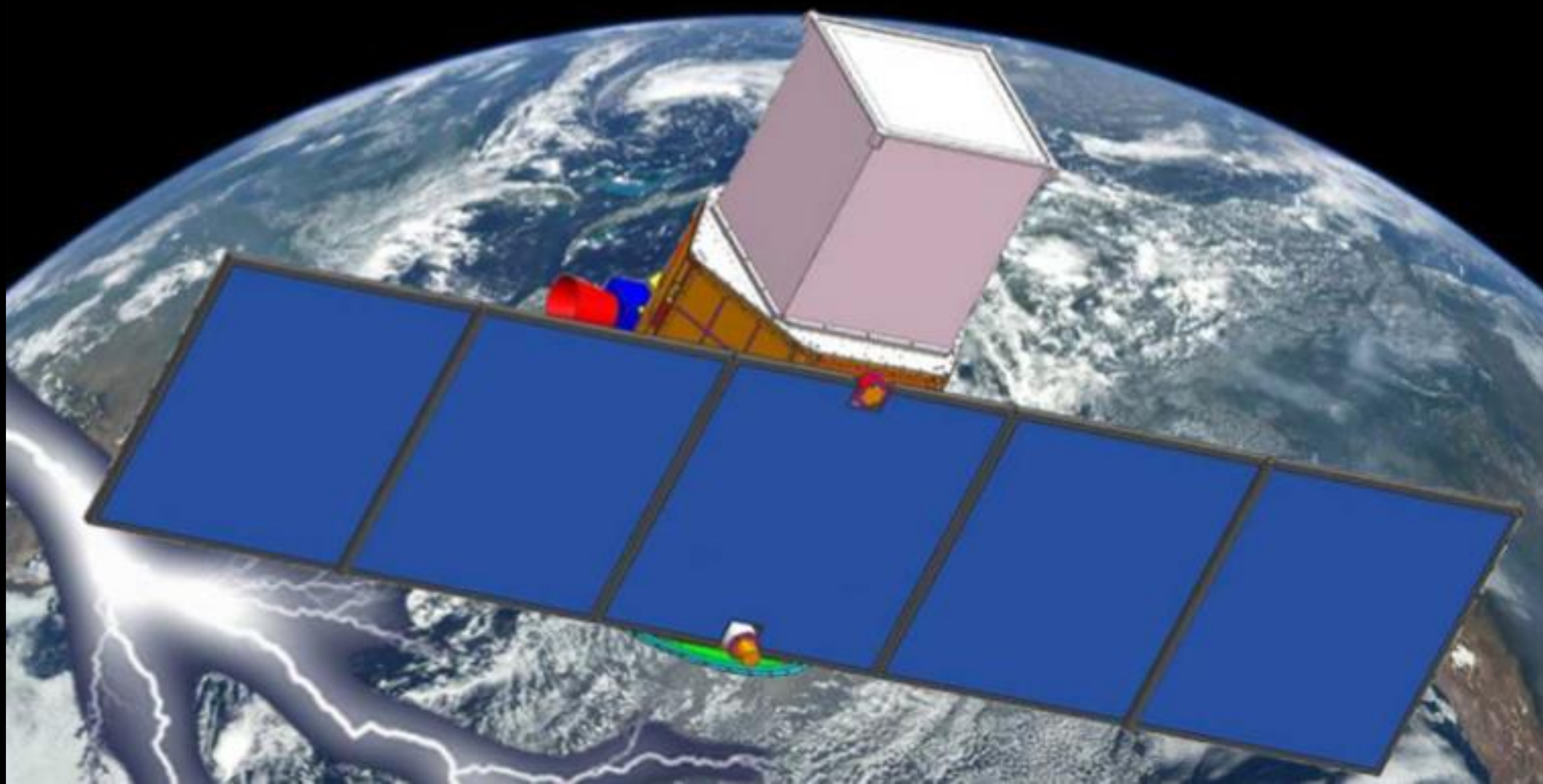


Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE HEGRA
CAT CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
CTA
ARGO
HAWC
HERD
LHAASO
DAMPE
FERMI
EGRET
AGILE
??? TERRA INCOGNITA ???
COMPTEL
INTEGRAL
FERMI
GRB Monitor
THESEUS
~ 2032
BATSE
OSSE
RXTE
HETE 2
SIGMA
BeppoSAX
Super AGILE
NuSTAR
ATHENA
~2030
ASCA
Chandra
XMM
Swift
Astro-H
ROSAT
1992
1996
2000
2004
2008
2012
2016
2020
Year
Aldo Morselli v.19 2019



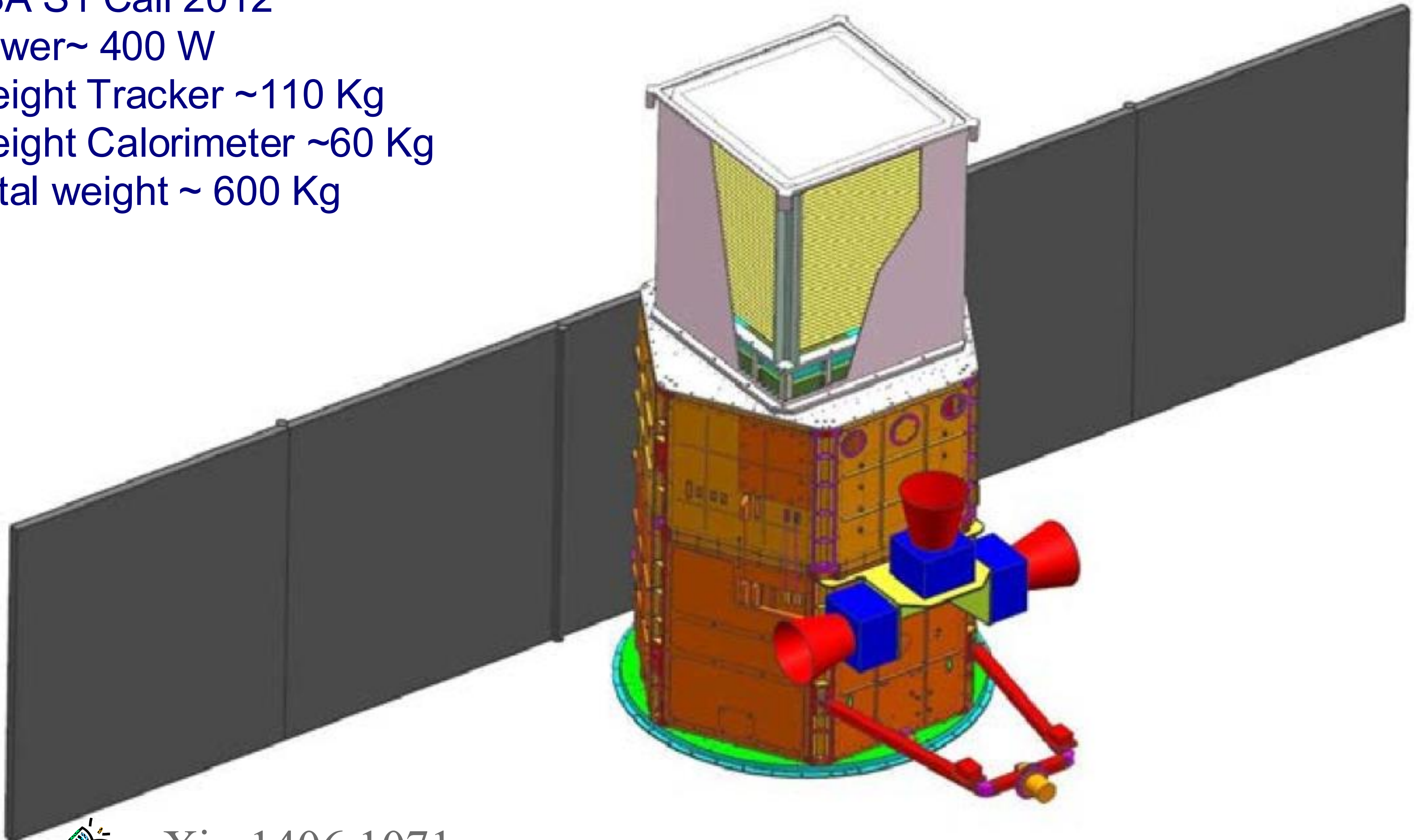



Gamma-Light



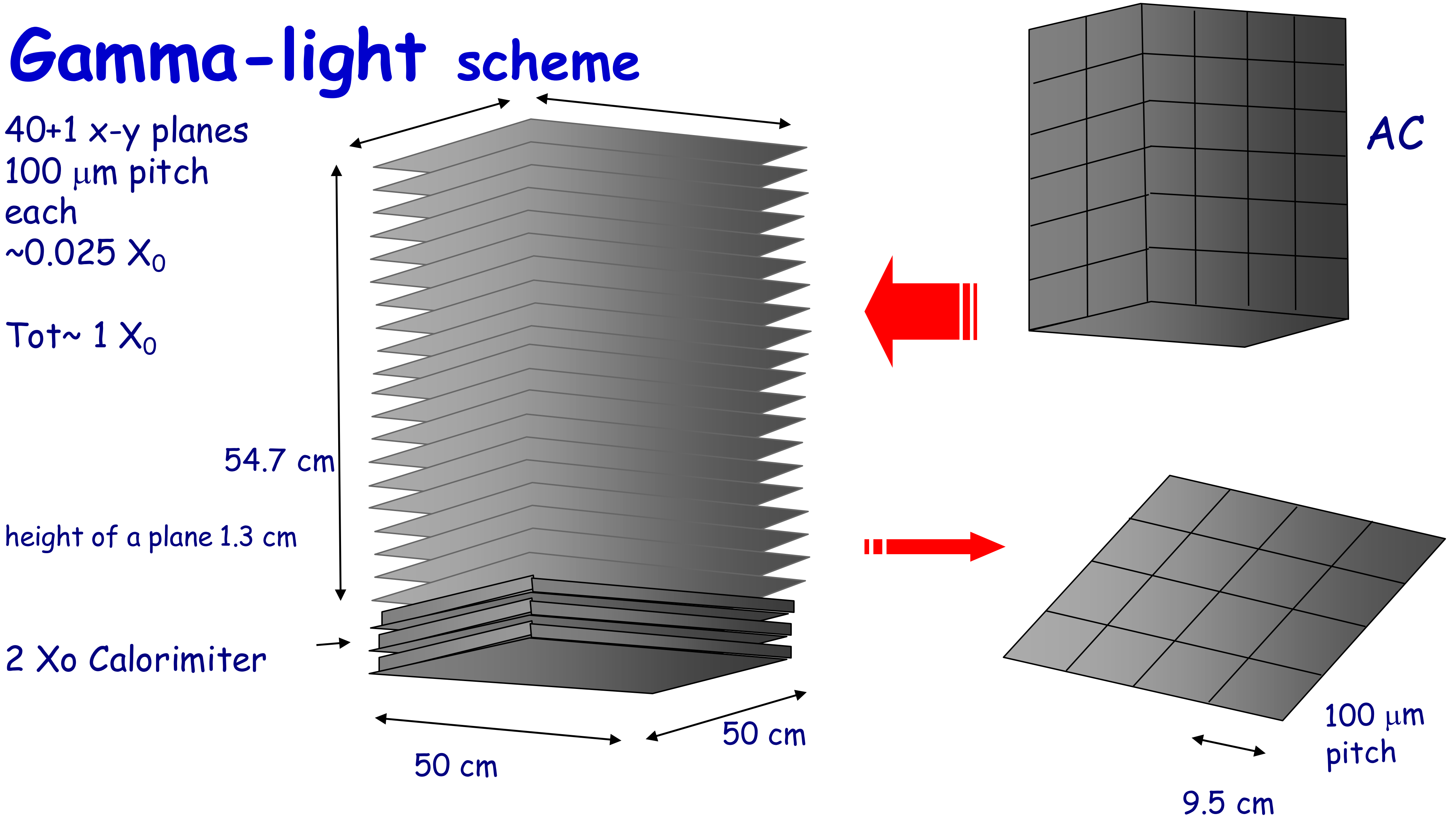
Gamma-light project

ESA S1 Call 2012
Power~ 400 W
Weight Tracker ~110 Kg
Weight Calorimeter ~60 Kg
Total weight ~ 600 Kg



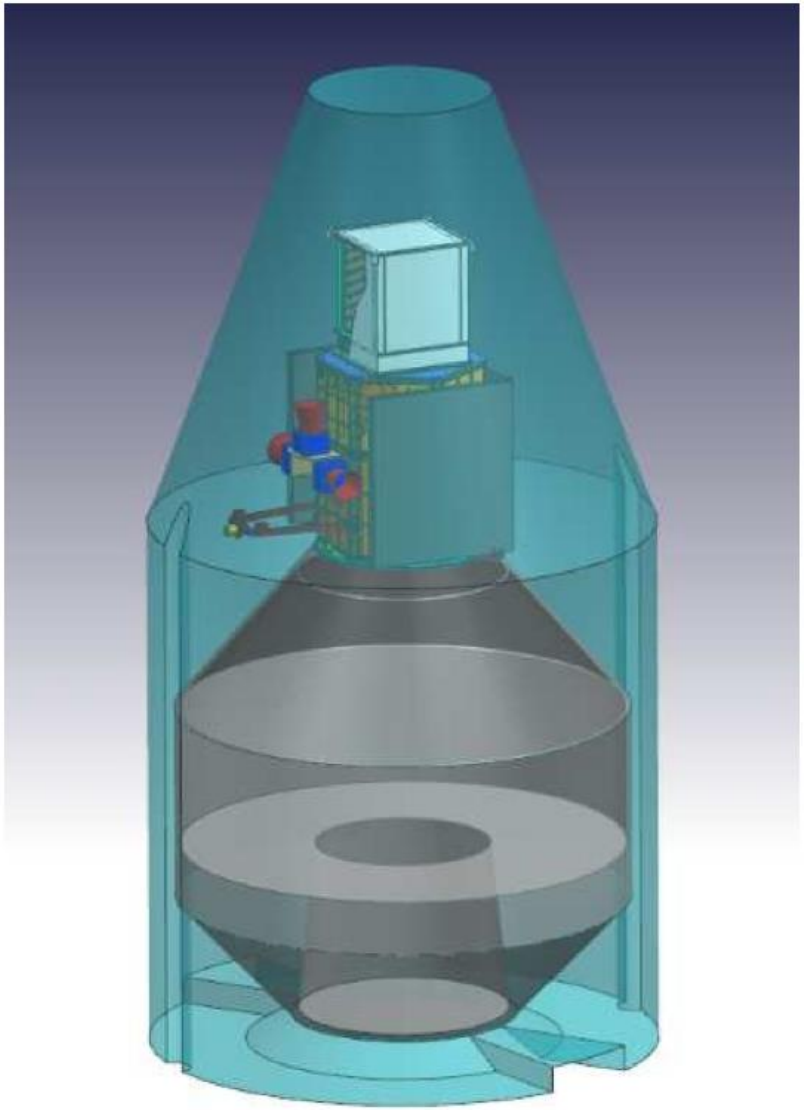
arXiv:1406.1071

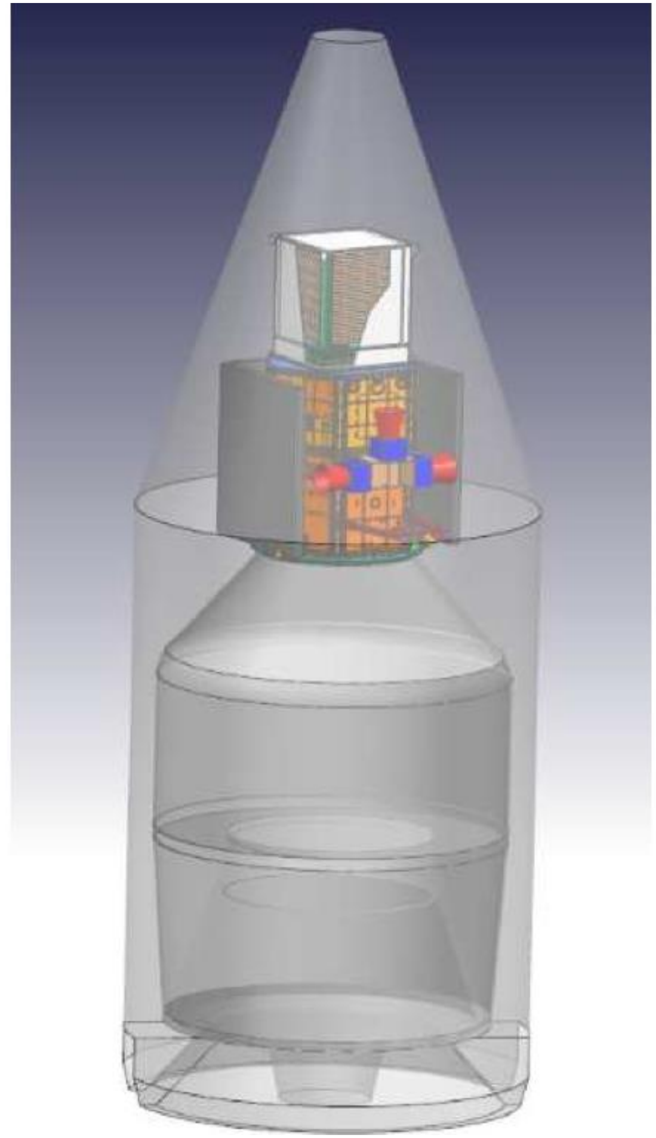
Gamma-light scheme



*Compton scattering **and** pair production telescope*

GAMMA-LIGHT satellite launch configurations for the PSLV and VEGA

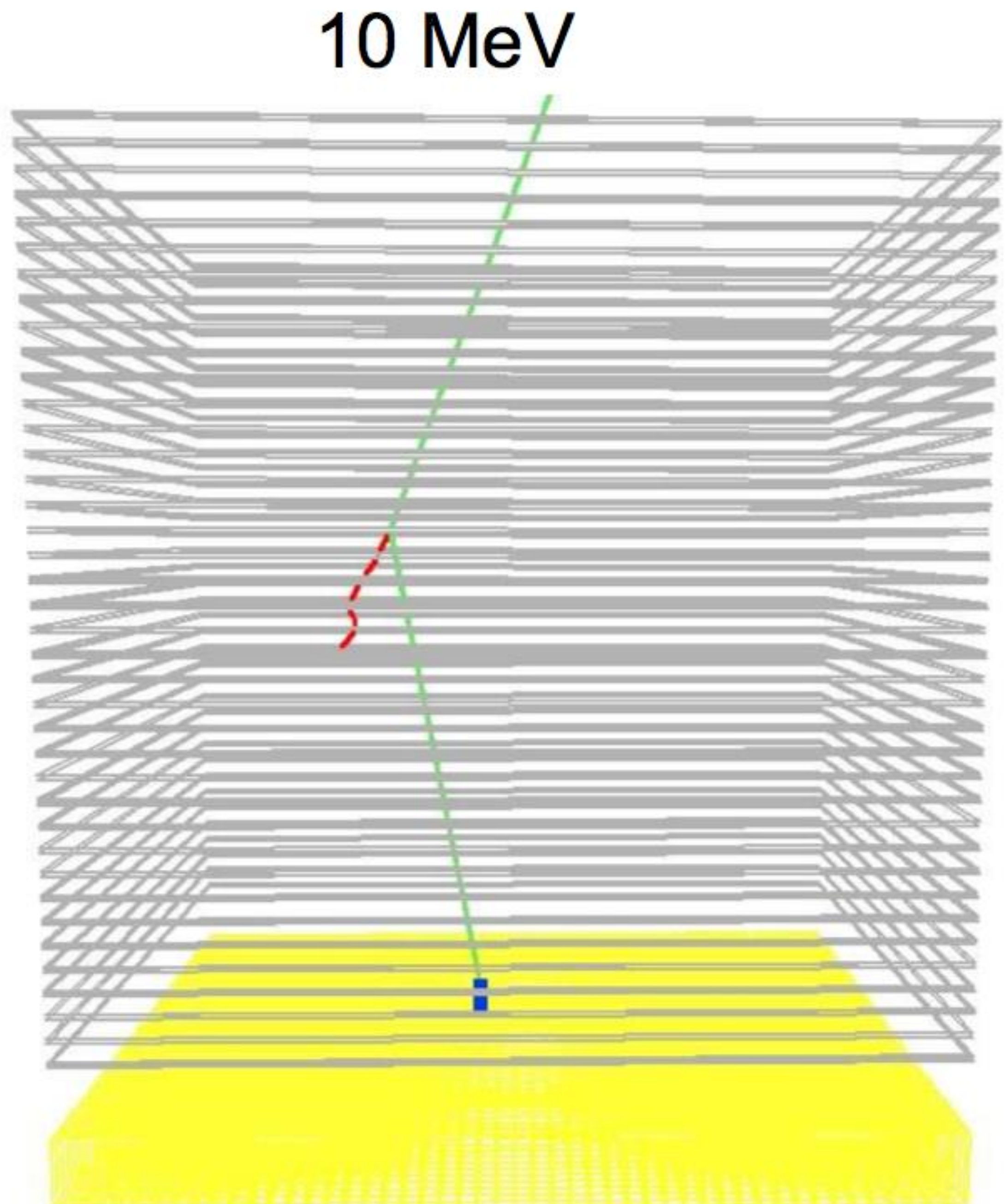




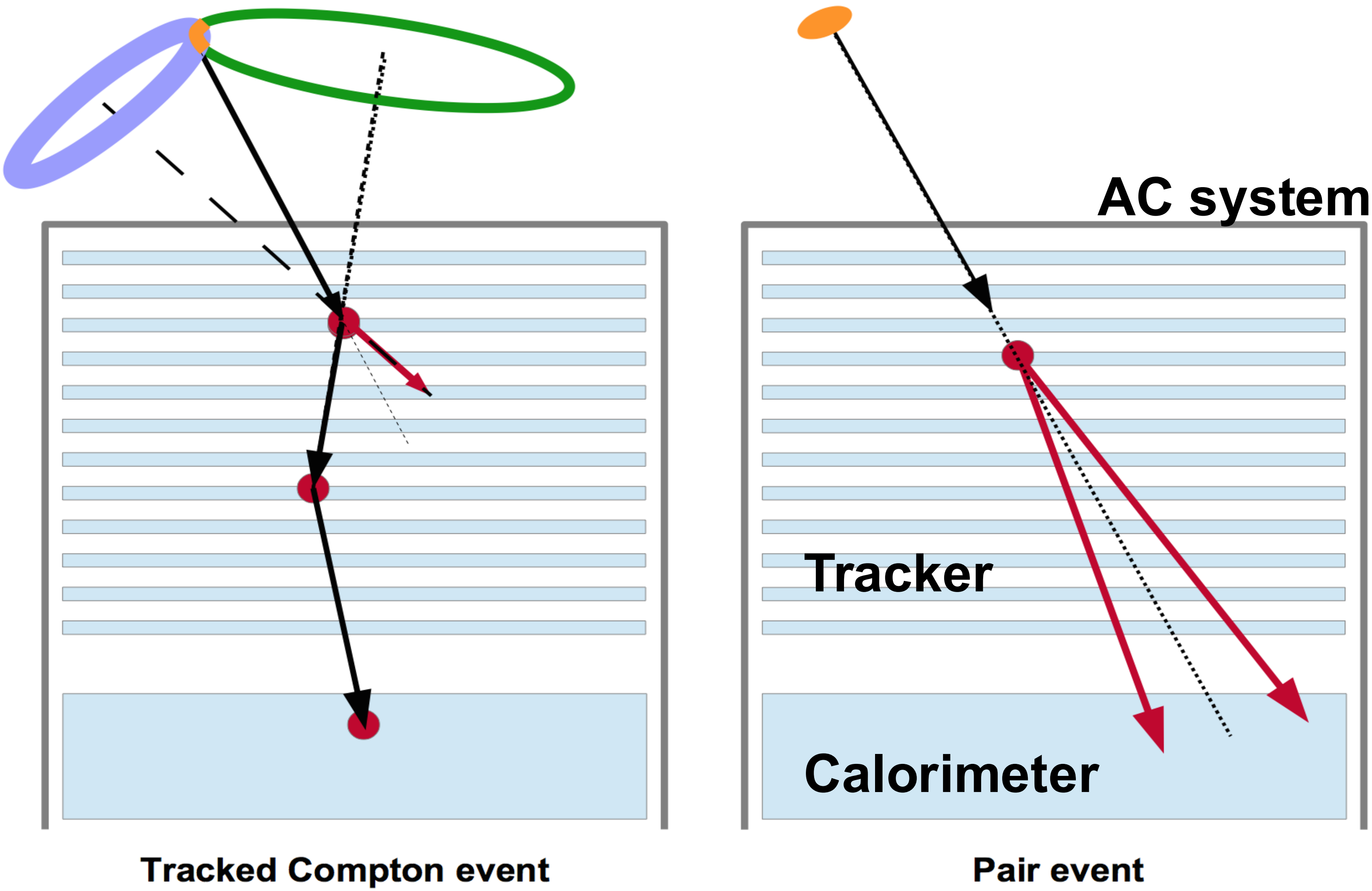
- a companion satellite similar to G-LIGHT can be accomodated.

G-LIGHT Simulation

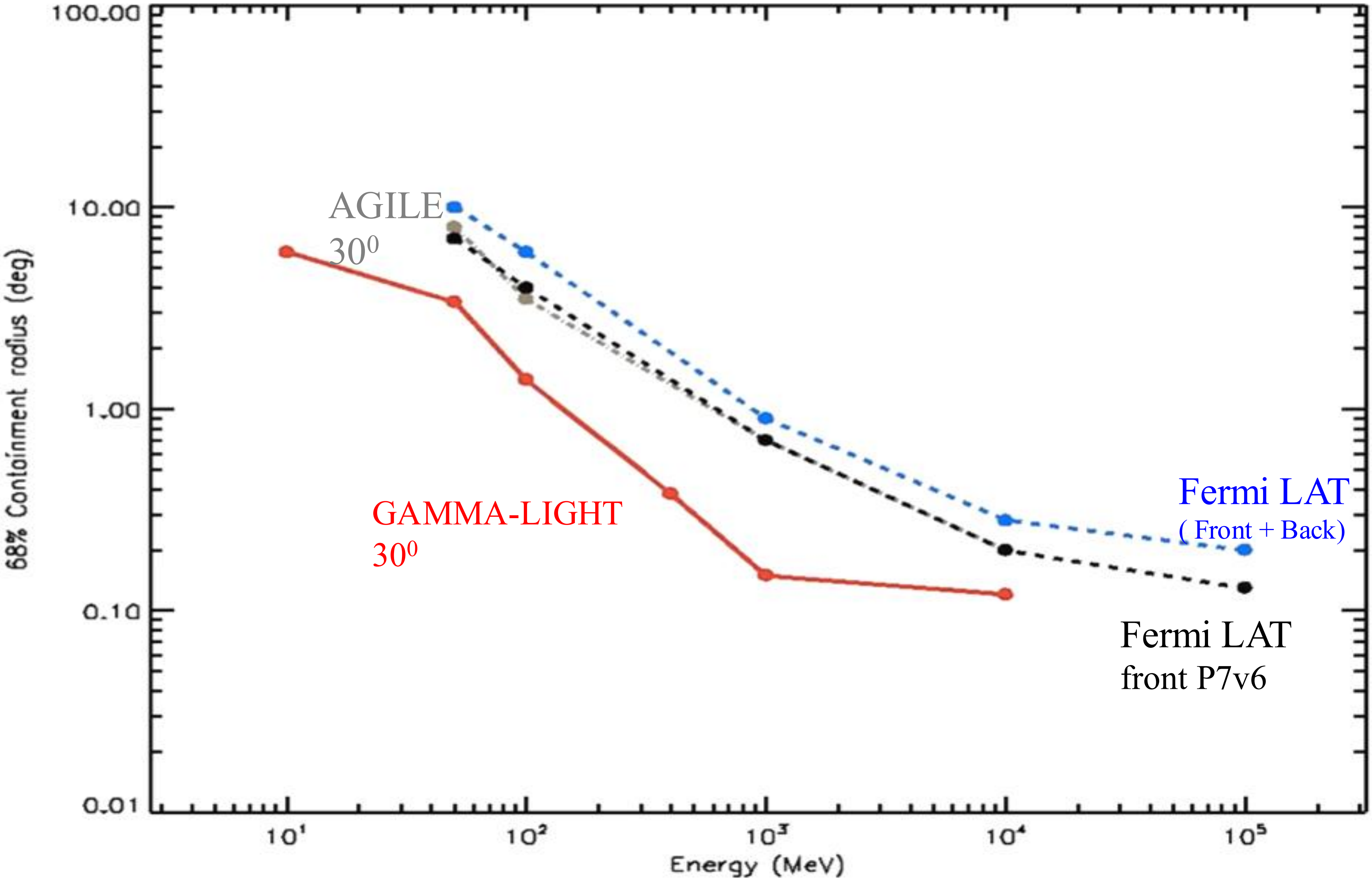
Compton interaction of a 10 MeV photon producing a low-energy single-track electron, and depositing energy in the Calorimeter for a 30^0 incidence



An instrument that combine two detection techniques



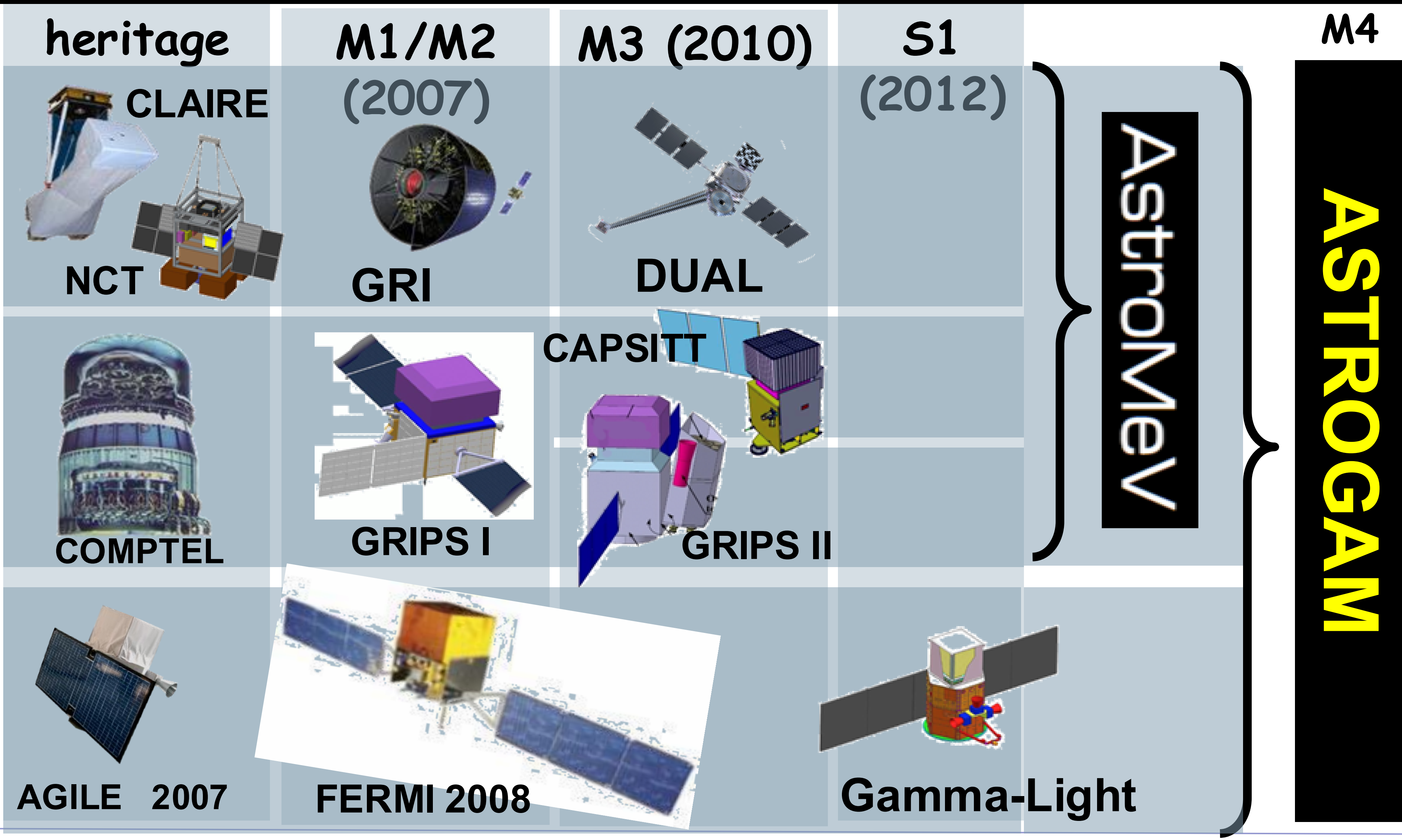
Gamma-Light Point Spread Function (angular resolution)



A.Morselli et al. , Nuclear Physics B Proc. Supp. 239–240 (2013) 193-198 [arXiv:1406.1071]

- 1-100 MeV unexplored domain for
  - Dark Matter searches
  - Galactic compact stars and nucleosynthesis
  - Cosmic rays
  - Relativistic jets, microquasars
  - Blazars
  - Gamma-Ray Bursts
  - Solar physics
- and…
  - Terrestrial Gamma-Ray Flashes

ASTROGAM a unified proposal from the entire gamma-ray community

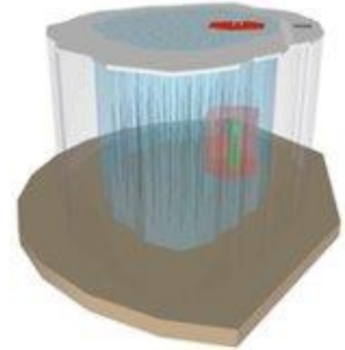



e-ASTROGAM
at the heart of the extreme Universe
M5 Call
An observatory for gamma rays
In the MeV/GeV domain
Detector paper: Exp. Astronomy 2017, 44, 25 arXiv:1611.02232
Science White Book: arXiv:1711.01265 (213 pages)

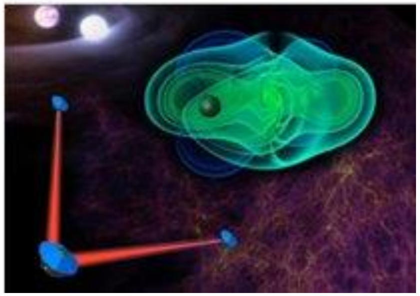
Science motivations

- Processes at the heart of the extreme Universe (AGNs, GRBs, microquasars): prospects for the Astronomy of the 2030s
- Multi-wavelength, multi-messenger coverage of the sky (with Ligo/Virgo, ET, CTA, SKA, eLISA, ...), with special focus on transient phenomena
- The origin of high-energy particles and impact on galaxy evolution, from cosmic rays to antimatter
- Nucleosynthesis and chemical enrichment of our Galaxy

Km3Net/IceCube-Gen2 - ν



eLISA – Gravitational waves



CTA

Athena

E-ELT

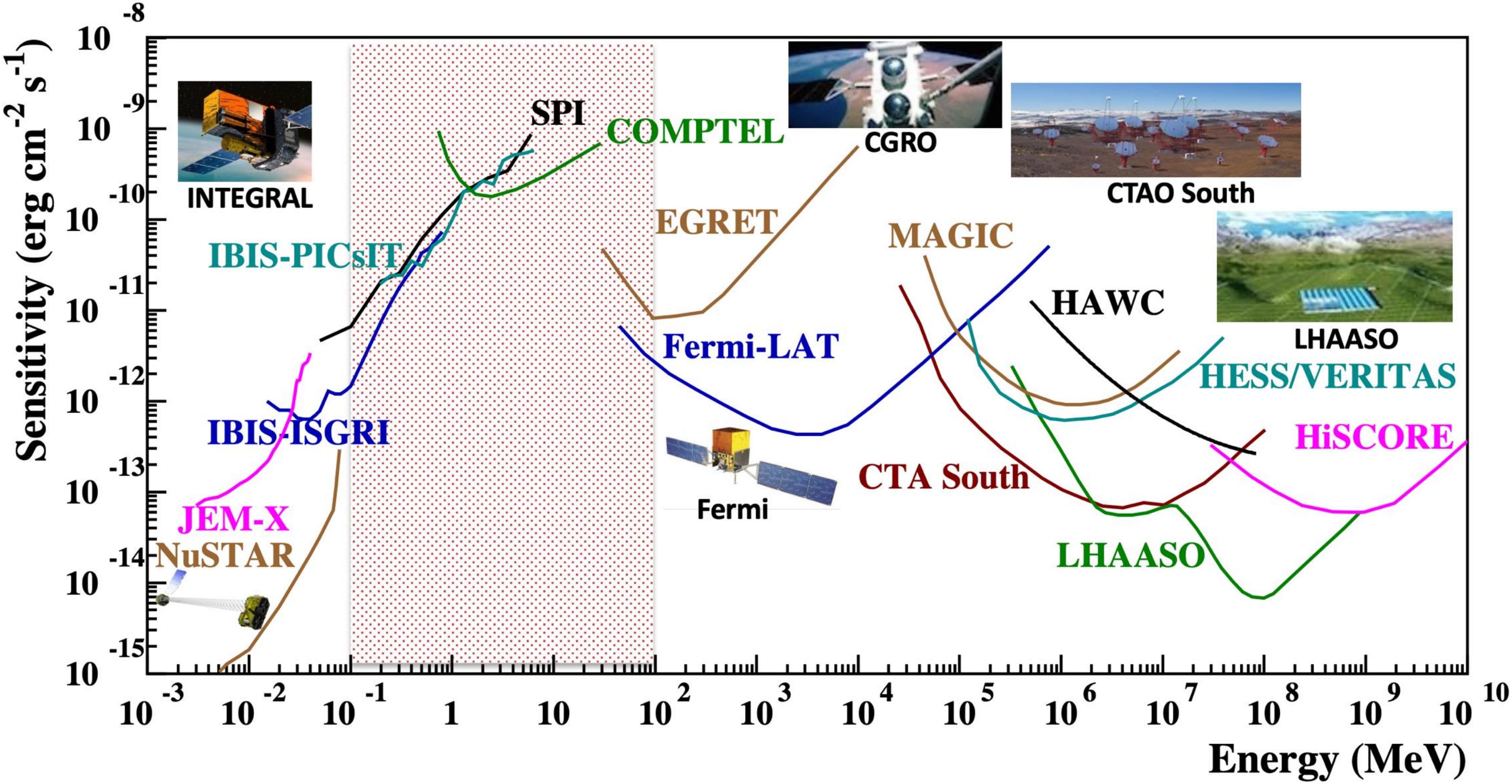
JWST

ALMA

SKA

13

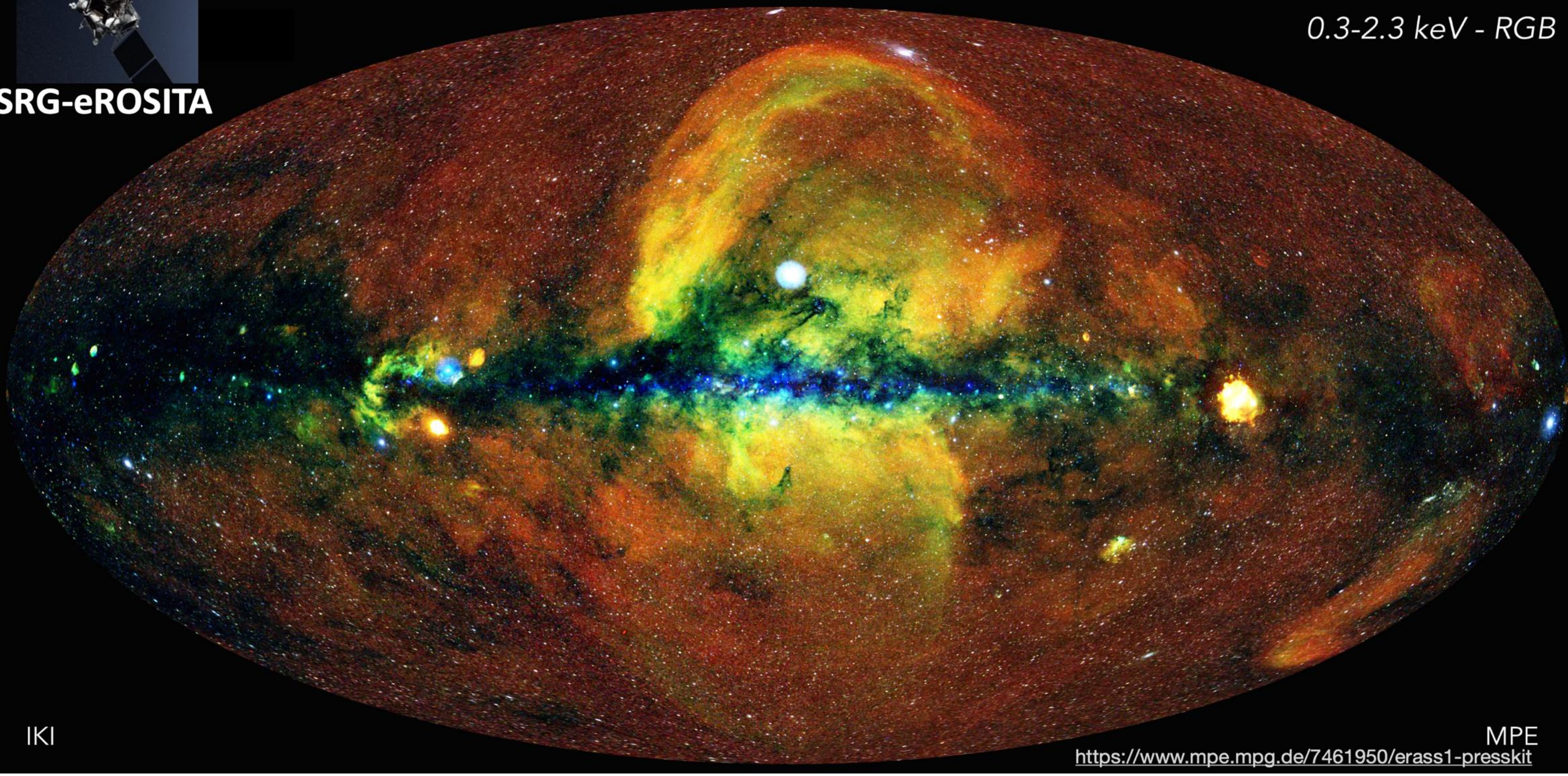
newASTROGAM The MeV / sub-GeV domain



Worst covered part of the electromagnetic spectrum (a few tens of steady sources detected so far between 1 and 30 MeV vs. 7000+ sources in *Fermi* LAT 4FGL-DR4)

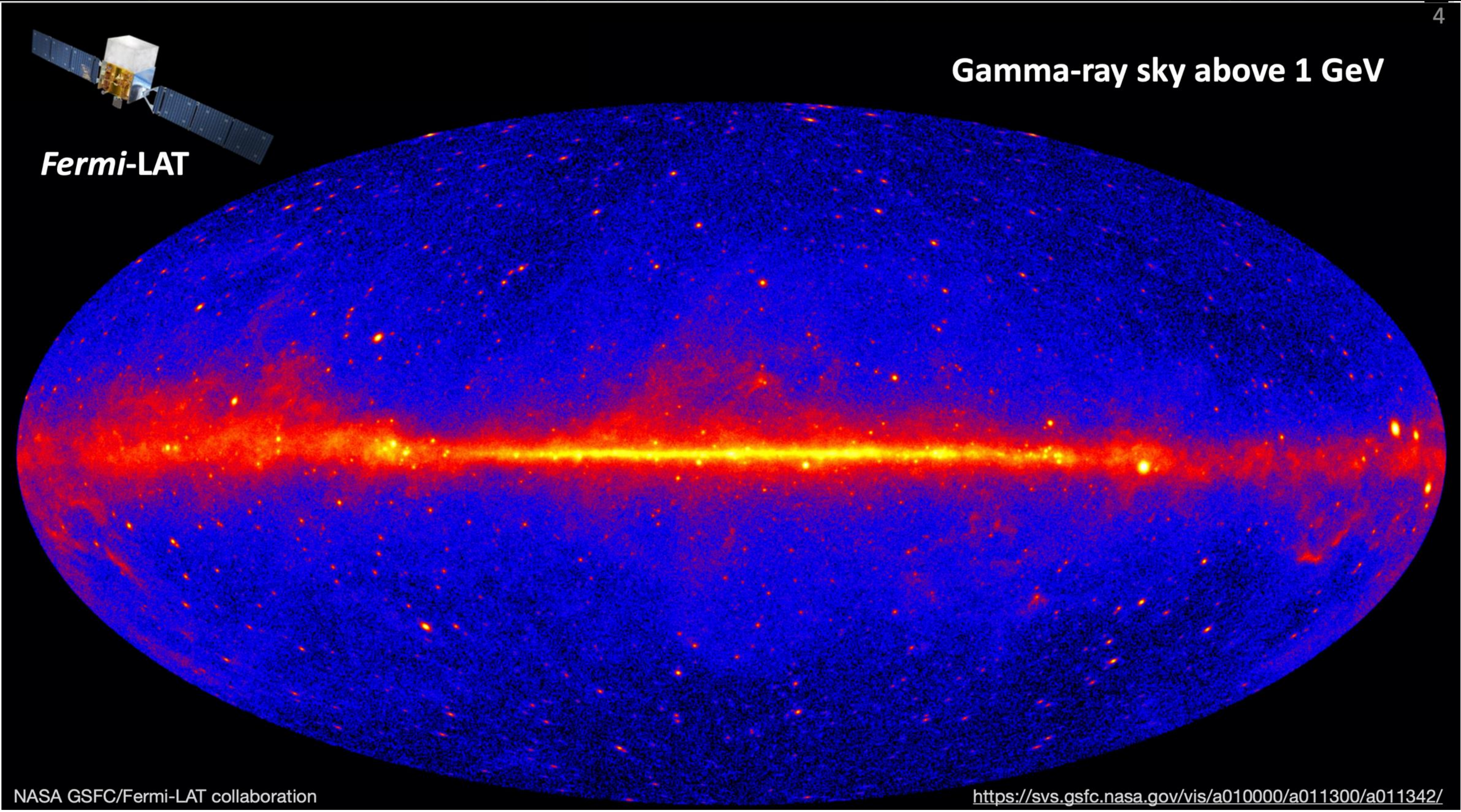
- Many objects have their **peak emissivity** in this range (GRBs, blazars, pulsars...)
- Domain of **nuclear spectroscopy**
- Crucial for **multi-messenger astronomy**

NewAstrogam X-ray sky in the keV range



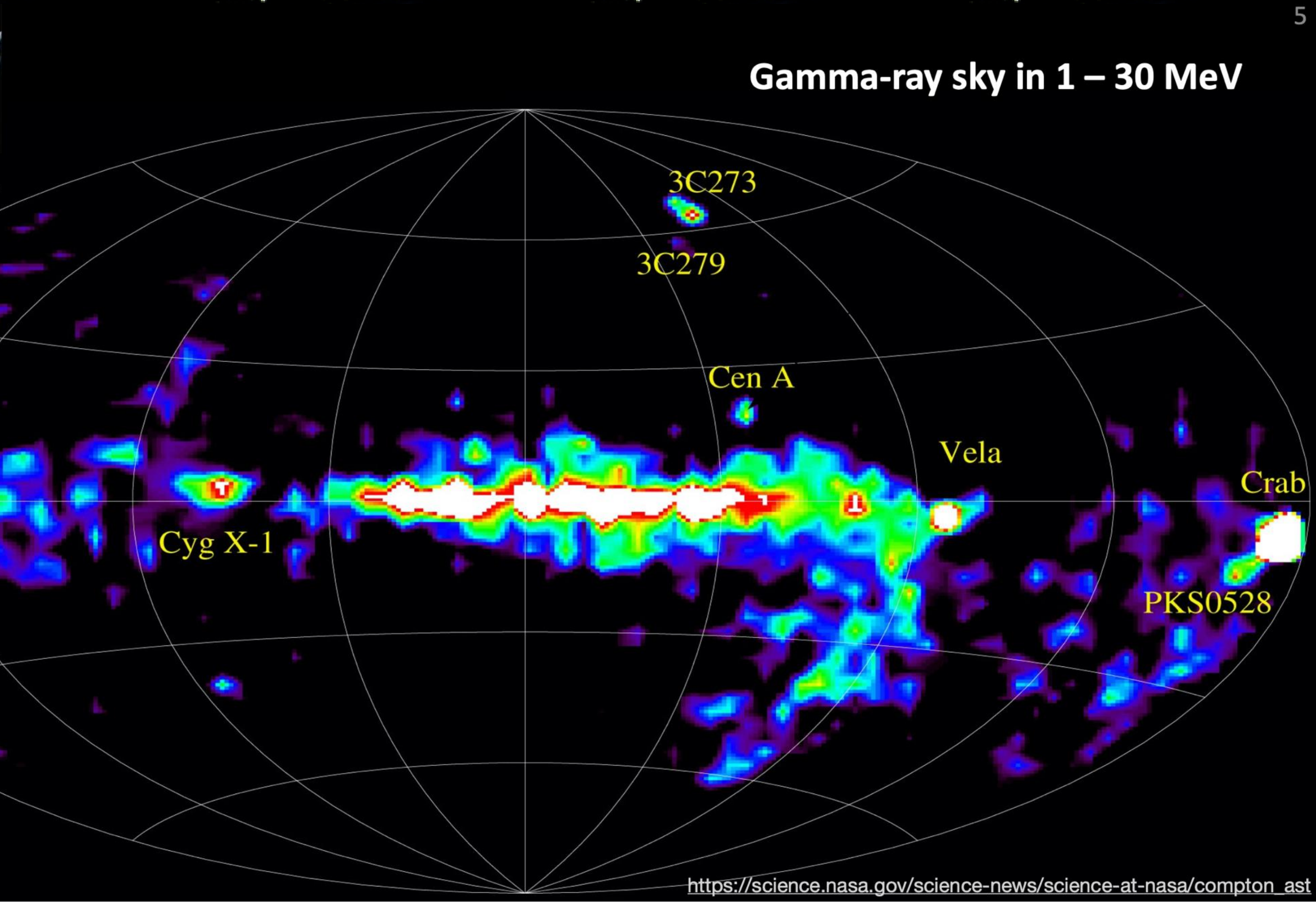
Already **930,000 X-ray sources** (0.3 – 2.3 keV) in the 1st *SRG*-eROSITA catalogue from the 1st 6 months (Merloni et al. 2024)

NewAstrogam Gamma-ray sky in the GeV range



7194 gamma-ray sources sources between 50 MeV and 1 TeV in the *Fermi*-LAT 14-yr catalogue (4FGL-DR4, Ballet et al. 2023)

NewAstrogam Gamma-ray sky in the GeV range

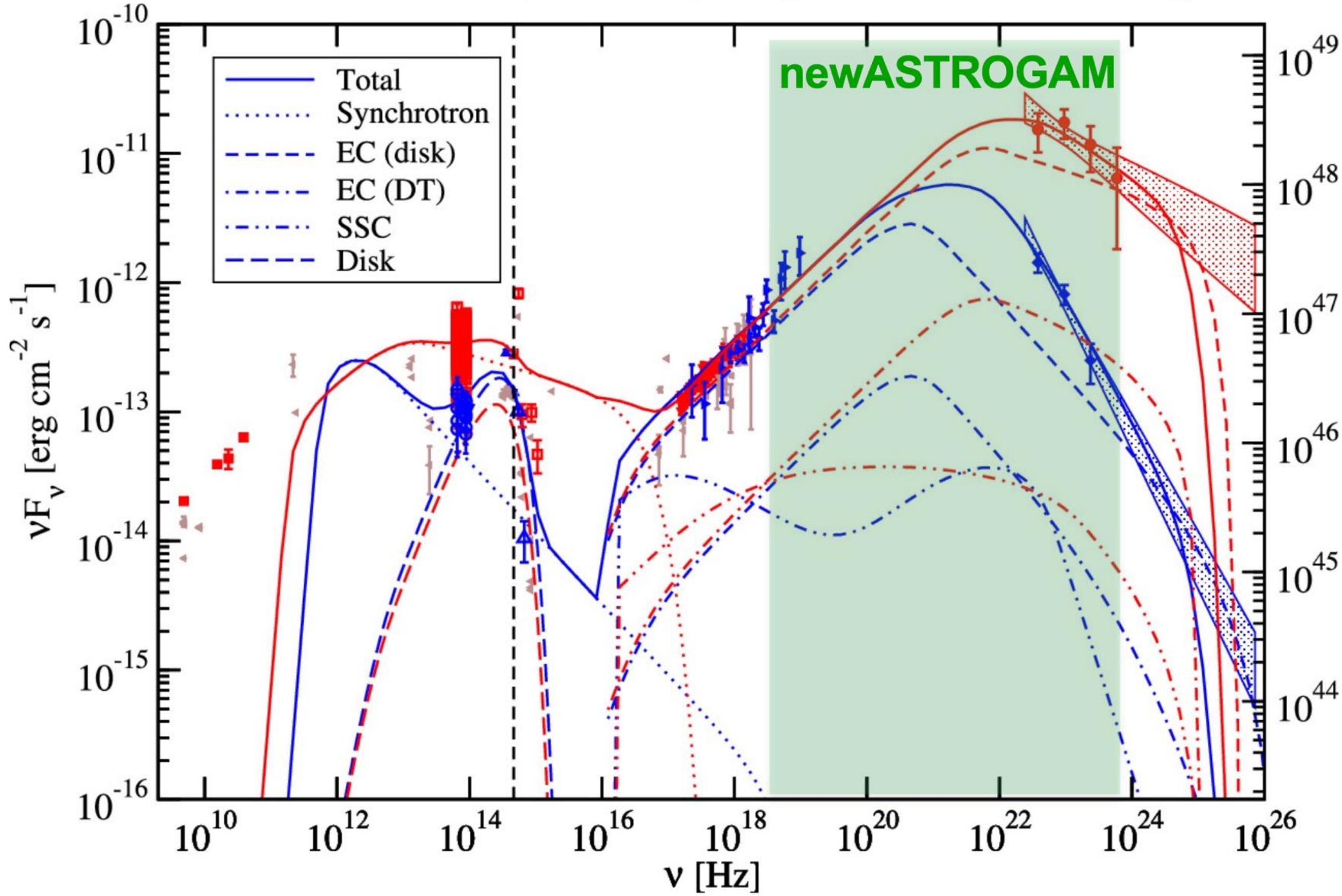


A few tens of known steady-state sources between 1 and 30 MeV (Schönfelder et al. 2000)

⇒ new field of discoveries!

NewAstrogam Extreme acceleration processes

Blazar TXS 1508+572 ($z = 4.31$) in quiescent and during flare



MeV to GeV gamma-ray coverage will be key for understanding the acceleration and radiation mechanisms in GRBs, (jet) AGN, microquasars, pulsars etc..

NewAstrogam Multimessenger Astronomy

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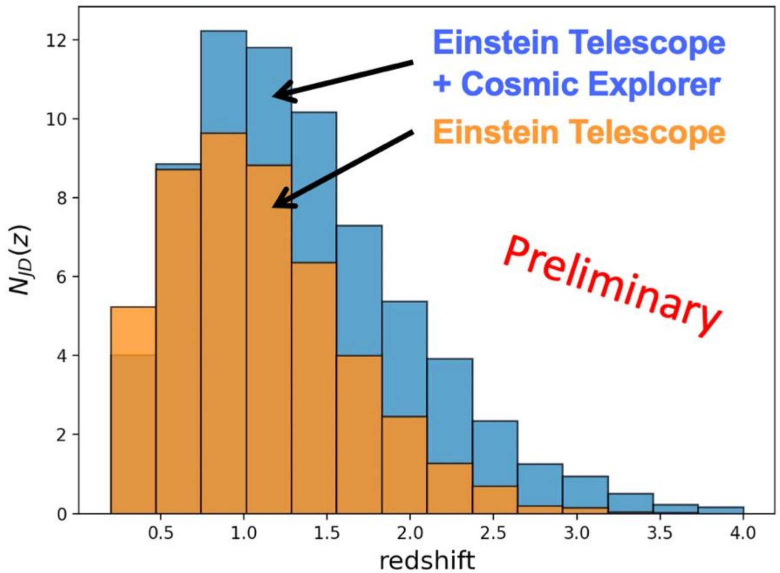
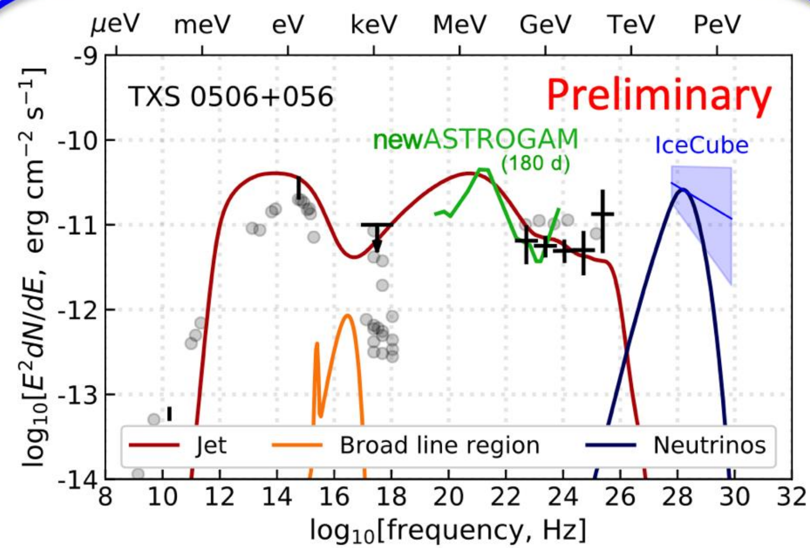
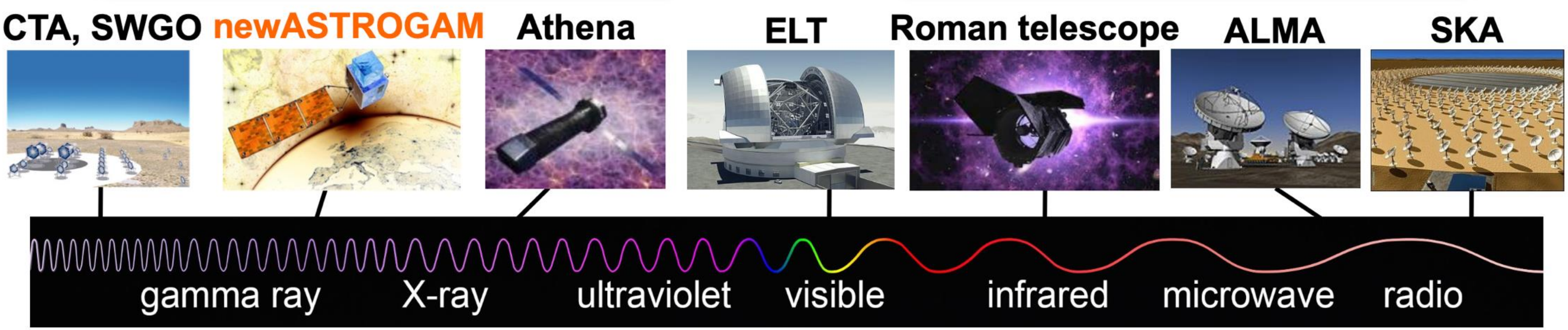
GW + γ-ray detections with newASTROGAM



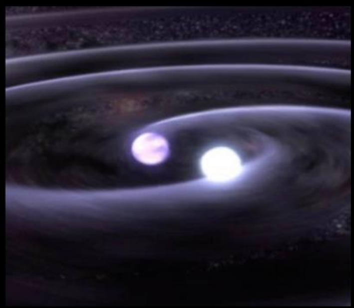
~70 **gravitational wave** (ET+CE) + short GRB events (like GW170817) per year



MeV γ-ray range is key to probing **high-energy neutrino sources** (accelerated hadrons) “hidden” at GeV-TeV γ-rays

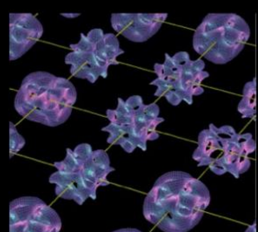


NewAstrogam Science topics

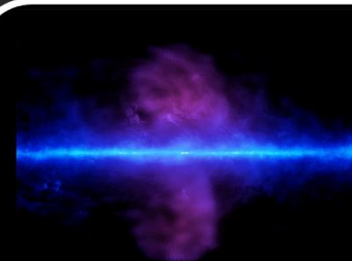


- GW170817-like astrophysics from joint **gravitational wave** & short GRB detections
- What are the sources of **very high-energy neutrinos** and ultra-high energy cosmic rays?
- How do **supermassive black holes** form, evolve and impact the **evolution of galaxies**?

- How are **cosmic elements synthesized** in stars and supernovae?
- How do **massive stars explode**?
- Can **thermonuclear supernovae** be used for **precision cosmology**?



- What is the nature of **dark matter**?
- What is the structure of space time in **quantum gravity**?



- What are the sources of galactic **cosmic rays**?
- How do cosmic rays impact **star formation** and **galaxy evolution**?

NewAstrogam M7 Proposal – ESA SSC assessment

Conclusions of the Senior Science Committee assessment of ASTROGAM M7:

... with improvements in detector technology it is now possible to design an imaging instrument with two orders of magnitude better sensitivity than previous missions. The fact that some significant science could be done by these earlier missions, even with their limited sensitivity, gives reassurance that ASTROGAM would deliver many new results.

The science case for Galactic astrophysics is strong and the potential to distinguish between gamma-ray emission driven by accelerated protons and that driven by accelerated electrons addresses a major ambiguity in many models for the observed GeV and TeV emission, for example, in supernova remnants. The science case for Extragalactic astrophysics is less convincing as it is based on optimistic assumptions about the underlying populations and processes, such as the relationship between MeV jet emission and other AGN properties. The mission would also have a relatively poor performance in localising burst sources, which detracts from its potential to contribute to multi-messenger studies.

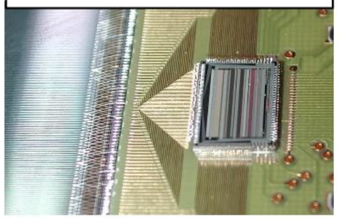
⇒ Improve the **science case for extragalactic astrophysics** (MeV blazars…)

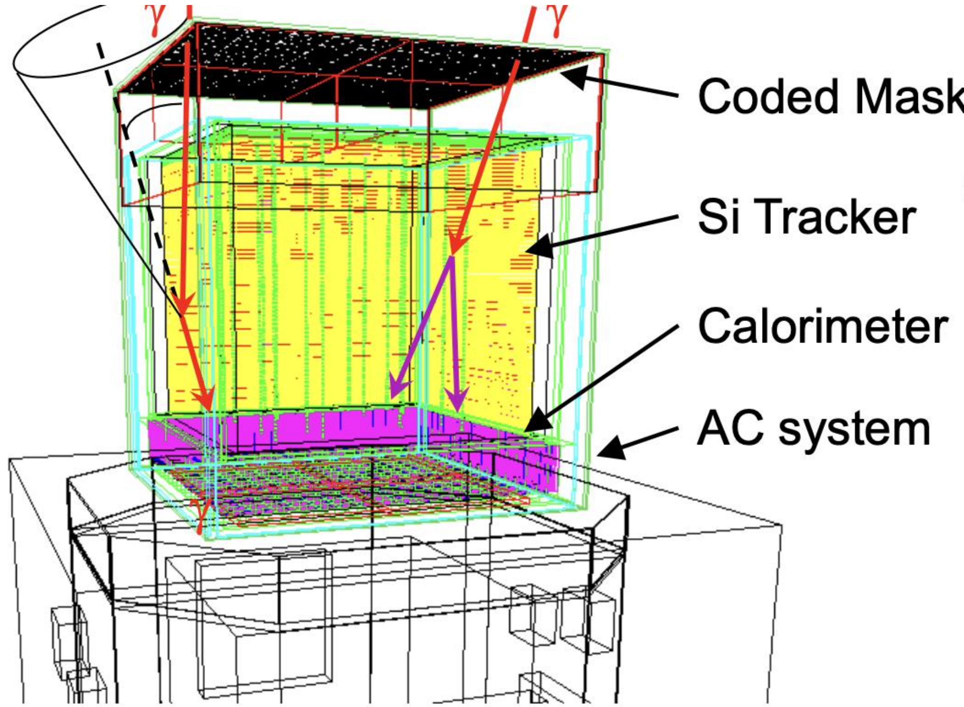
⇒ Improve **performance of source localisation**, in particular for multi-messenger astrophysics, with the **addition of a hard X-ray coded mask**

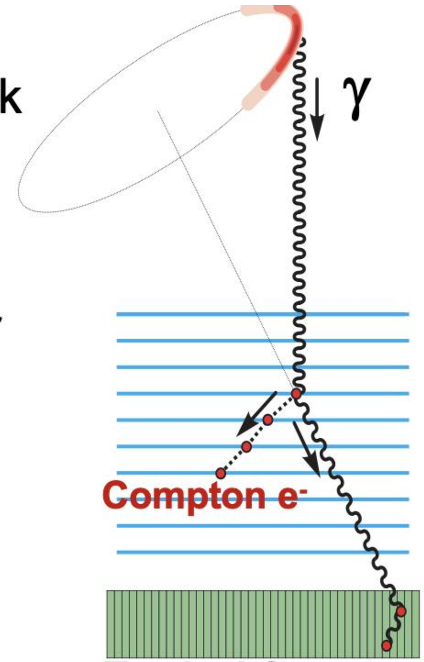
\+ **Reduce the science alert latency** using a satellite relay system such as the **European Data Relay System** (EDRS)

NewAstrogam M8 Design concept

AGILE Si Tracker



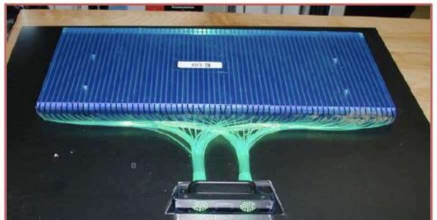




Tracked Compton

- **Si Tracker** – Double sided Si strip detectors (or CMOS Active Pixels) for excellent spectral resolution and fine 3-D position resolution
- **3D-imaging Calorimeter** – CsI(Tl) (or GAGG:Ce or $CeBr_3$) crystals readout by Si photo-detectors for efficient photon absorption
- **Anticoincidence detector** to veto charged-particle induced background ⇒ plastic scintillators readout by SiPMs
- **Light coded mask** build from a thin tungsten sheet for hard X-ray monitoring and arcminute localisation of transient sources

PICSiT CsI(Tl) pixel



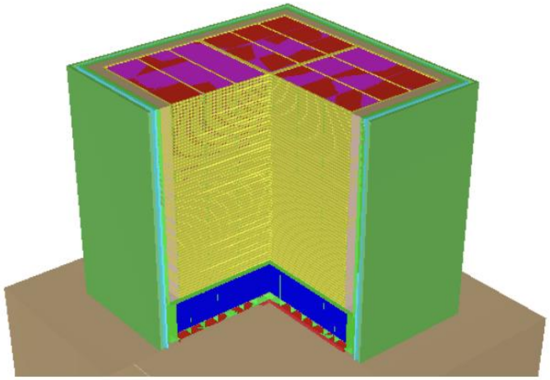
Fermi/LAT AC system

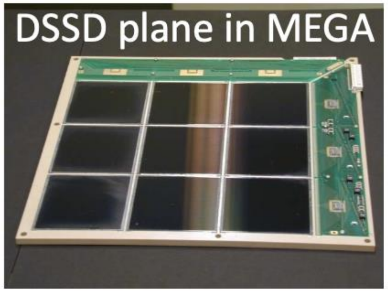
NewAstrogam M8 Silicon Tracker

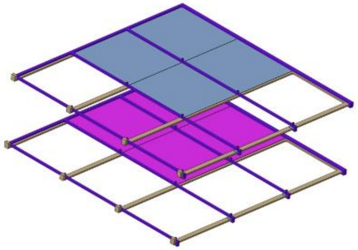
- 75 layers of 4 times 3×3 double sided Si strip detectors (in the baseline) = 2700 DSSDs
- Each DSSD has a total area of $9.5 \times 9.5\ cm^2$, a thickness of 500 μm, a strip width of 100 μm and pitch of 480 μm (192 strips per side), except for those in the first 3 layers whose pitch is 240 μm **for coded-mask imaging**
- The DSSDs are wire bonded strip to strip to form 3×3 2-D ladders

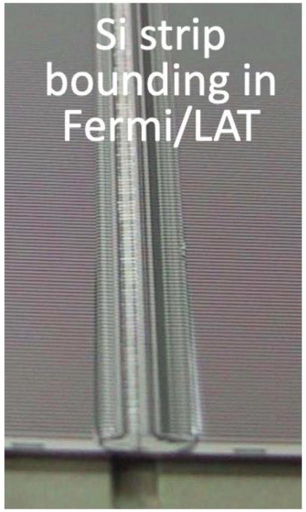
⇒ 359 424 electronic channels

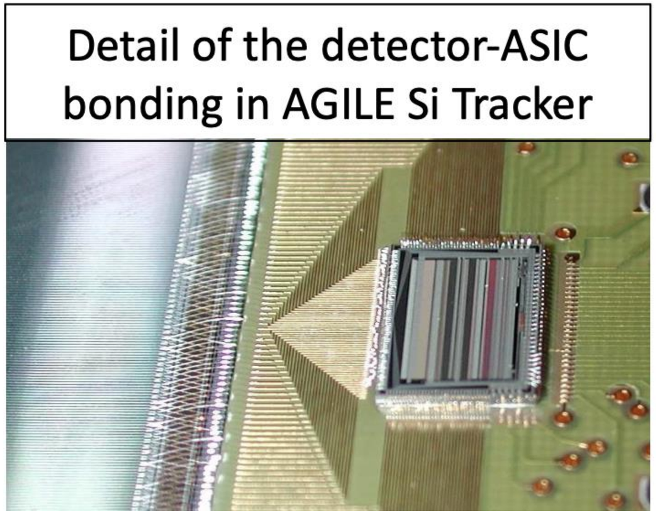
- FEE: ultra low-noise, space-qualified (Solar Orbiter / STIX) ASIC IDeF-X HDBD (baseline) (Baudin et al. 2021)
- Tracker power budget = 372 W (with maturity margin)





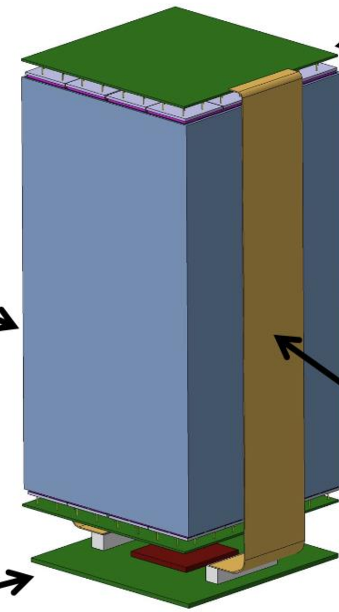


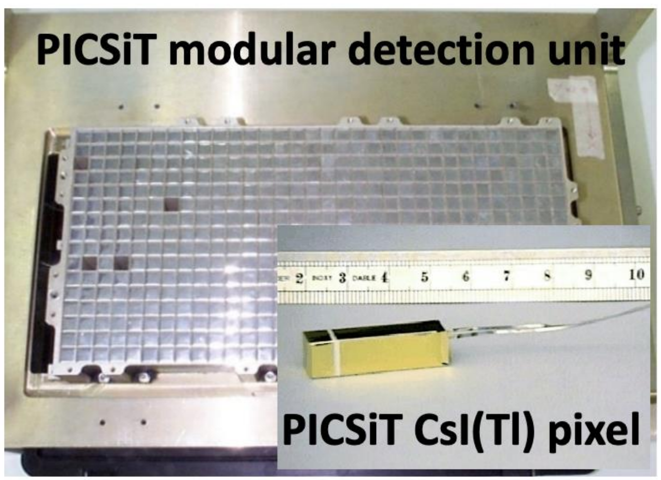


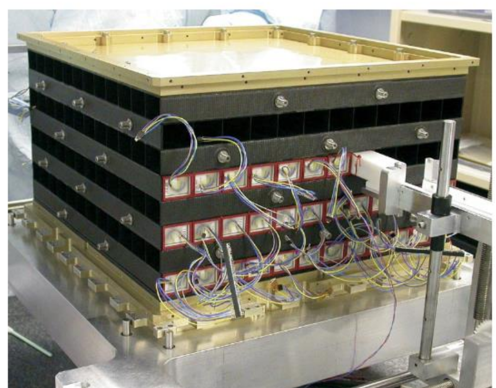


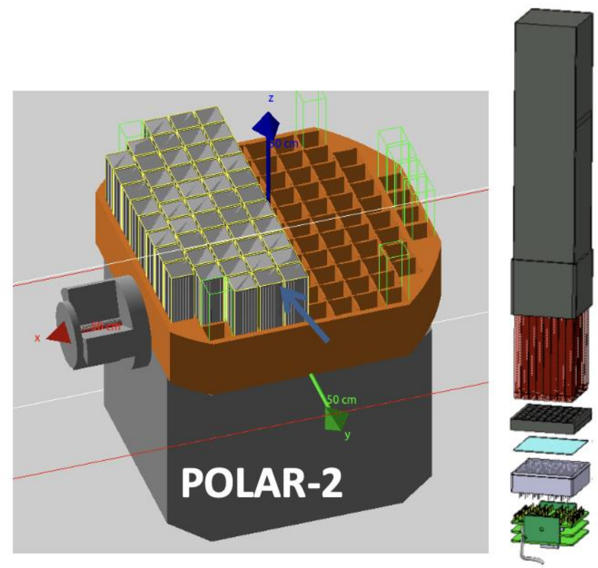
NewAstrogam M8 Calorimeter

- Pixelated detector made of 4096 CsI(Tl) (or GAGG:Ce or $CeBr_3$) scintillator bars of 8 cm length and 10×10 mm^2 cross section, glued at both ends to Silicon Drift Detectors (SDDs) or **SiPM**
- Calorimeter made of 256 (16×16) elementary modules of 16 crystals
- **Heritage**: *INTEGRAL*-PICsIT, *AGILE*, *Fermi*-LAT, POLAR-2, LHC-ALICE



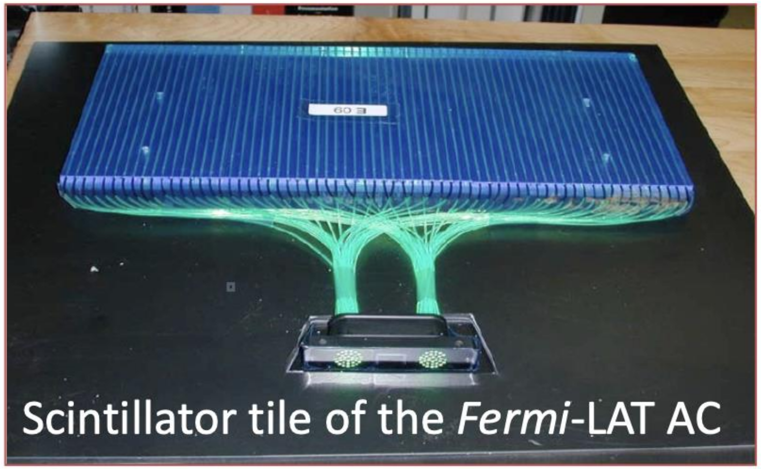



Fermi/LAT calorimeter

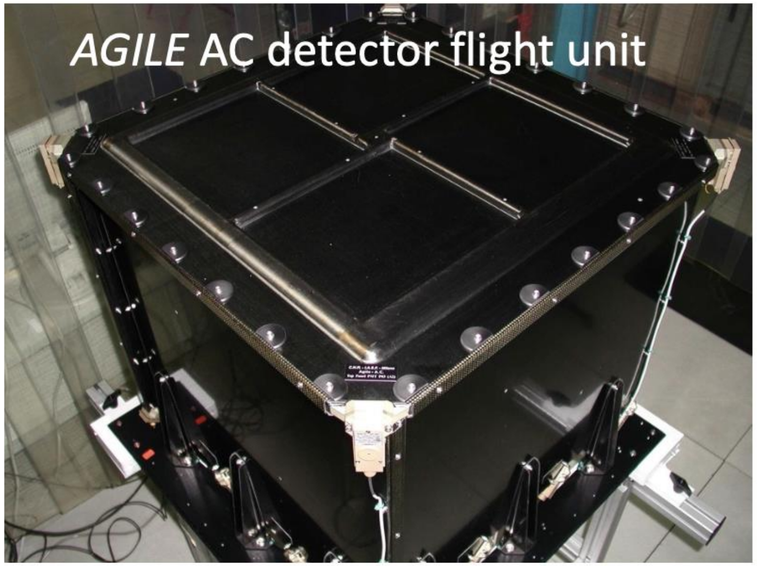


NewAstrogam M8 Anticoincidence system

- Requirement: charge particle detection inefficiency **< 10^{-4}**, a standard value (see, e.g., Moiseev et al. 2007)


Scintillator tile of the *Fermi*-LAT AC

- System formed by large panels of plastic scintillators covering 5 faces of the instrument, with a **thickness ≥ 6 mm** to detect enough scintillation light
- Wavelength shifting optical fibers buried in trenches convey the scintillation light to Si photomultipliers (e.g. the J-Series SiPMs of the ON Semiconductor company)
- The SiPM signals can be readout by the space-qualified SIPHRA ASICs from Ideas©
- **Heritage**: *Fermi*-LAT, *AGILE*

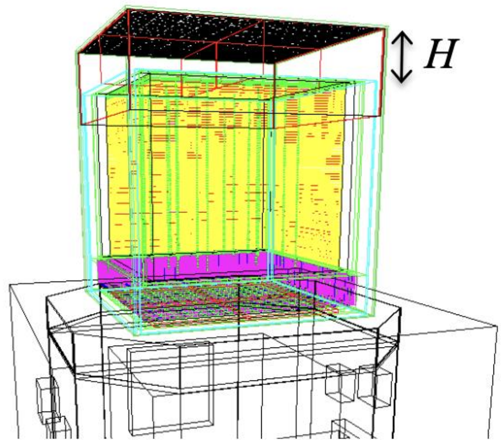

AGILE AC detector flight unit

NewAstrogam M8 X-ray coded mask

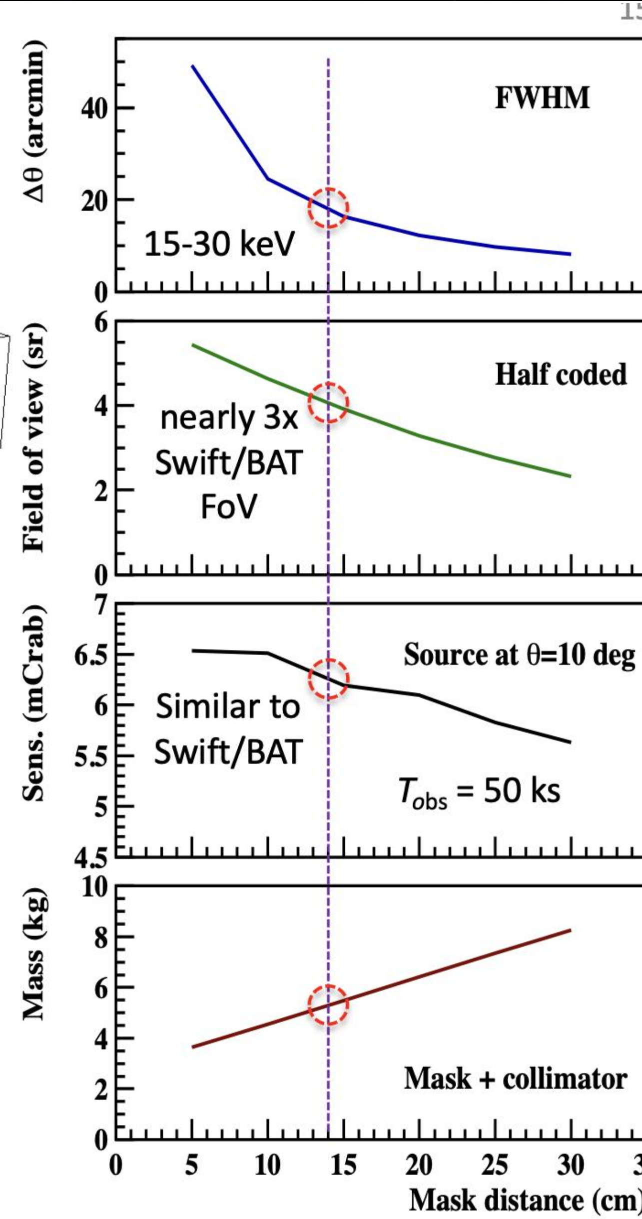
- Coded-mask imaging – resolution:

$$\Delta\vartheta\ (\mathrm{FWHM}) \sim \tan^{-1}\frac{\sqrt{d^2+m^2}}{H}$$

with $d = 240\ \mu\mathrm{m}$ (DSSD pitch in the 1st 3 layers of the Tracker), mask element size $m = 672\ \mu\mathrm{m}$ (= 2.8 x DSSD pitch)
$\Rightarrow$ Mask distance ***H* = 14 cm**



- Design based on **SuperAGILE** (Feroci et al. 2007)
  - **Mask**: **120 µm tungsten sheet**
  - **Carbon fibre support**: 0.5 mm thick plate below the mask + 0.5 mm thick cross-shaped support
  - **Collimator**: 2 mm thick carbon fibre walls covered with 120 µm thick W sheets for **shielding the diffuse Cosmic X-ray Background**
  - **Total mass:** Tungsten (mask and collimator): 2.3 kg, carbon fibre supports (mask and collimator): 3.0 kg



NewAstrogam M8 X-ray coded mask

Coded-mask mode

3D shadowgram

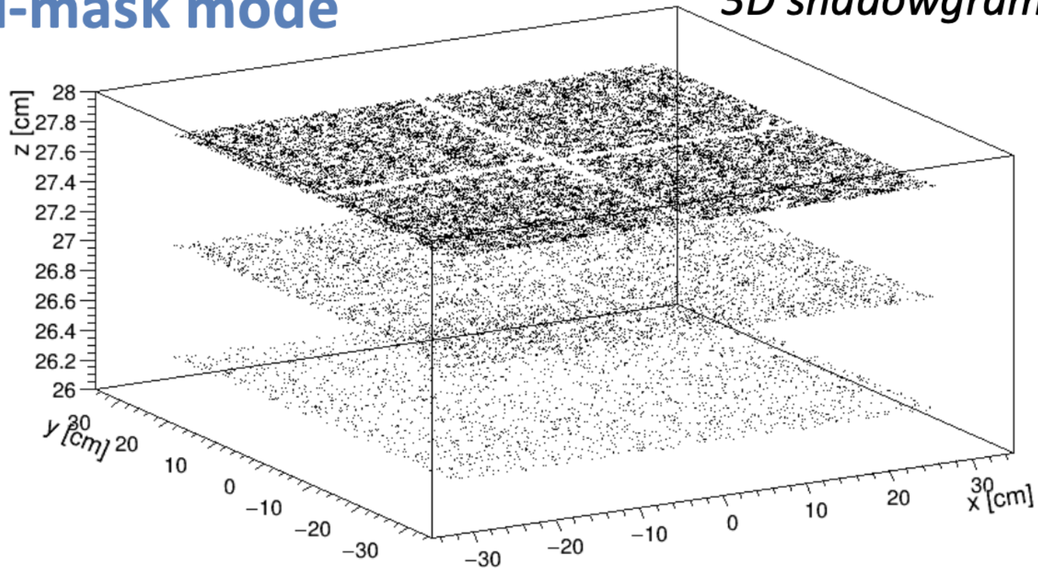
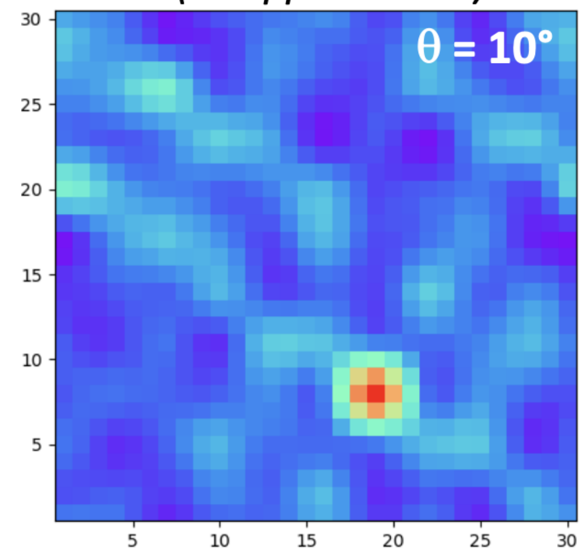
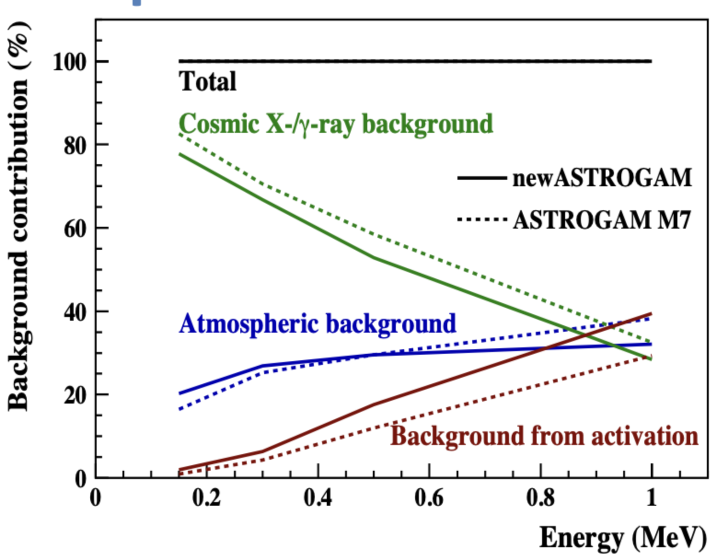
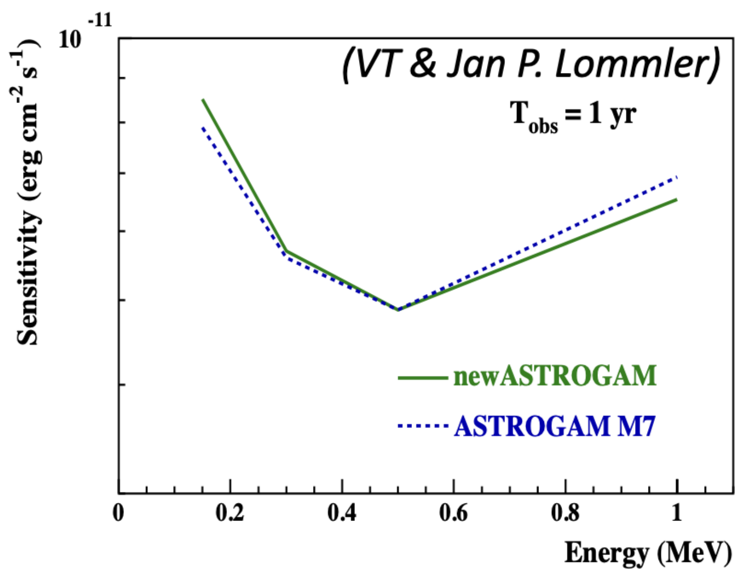


Image reconstruction (Philippe Laurent)



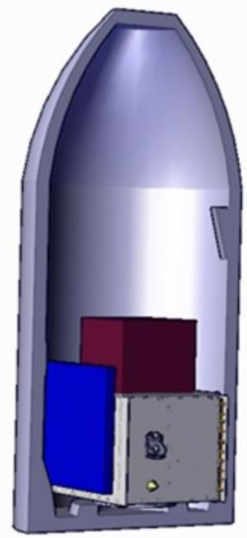
Compton mode

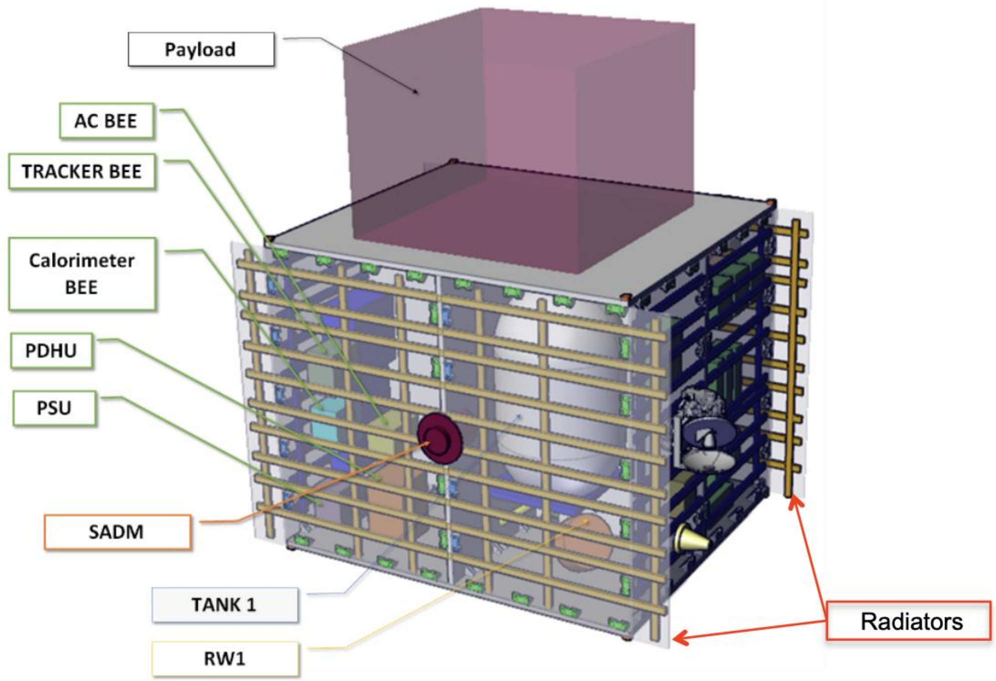


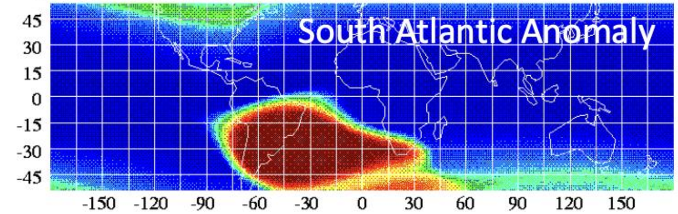


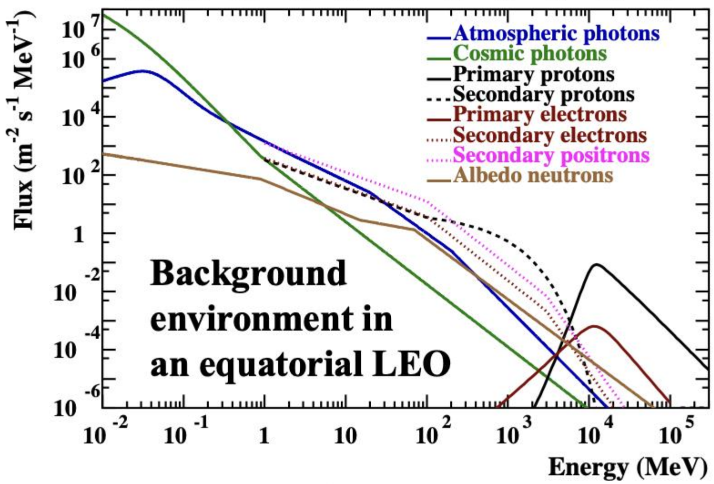
Reduction of sensitivity in the Compton mode caused by the coded mask (activation) compensated by the **increase in the mass of the instrument** (larger Si Tracker & Calorimeter), 529 kg vs. 441 kg for M7

- **Satellite platform** – **Thales Alenia Space** Multi-Mission Platform product line (MILA; baseline)
- **Launcher** – Vega-C (satellite dry mass with all margins: 1460 kg)
- **Low-Earth equatorial orbit** (inclination *i* < 2.5°, eccentricity *e* < 0.01, altitude 550 - 600 km) for optimal background environment
- **All-sky scanning mode** – maximises sky coverage over a day + nearly inertial pointing for ToO observations
- **In-orbit operation** – 3 years (provisions for 5+ years)









NewAstrogam M8 Conclusions

○ Thanks to its **unprecedented sensitivity**, **broad spectral coverage** over more than 5 orders of magnitude and ground-breaking capability for measuring **gamma-ray polarisation**, **newASTROGAM** has the potential for **many foundational discoveries**

○ The addition of a **light coded mask** on top of the gamma-ray instrument will provide hard X-ray localisation capability essential for **multi-wavelength follow-up observations** and **multi-messenger astronomy**

○ Alerts for new transient sources will be transmitted to the ground together with the source position within a minute after trigger using a **satellite relay system** such as EDRS ⇒ breakthrough mission for **time-domain astronomy**

Summary

- The whole astroparticle-multimessenger community is expecting a mission after Fermi

- The energy band just below Fermi energy is not explored since Comptel
- We hope that everybody will help in any possible way to have that mission approved