# e-ASTROGAM

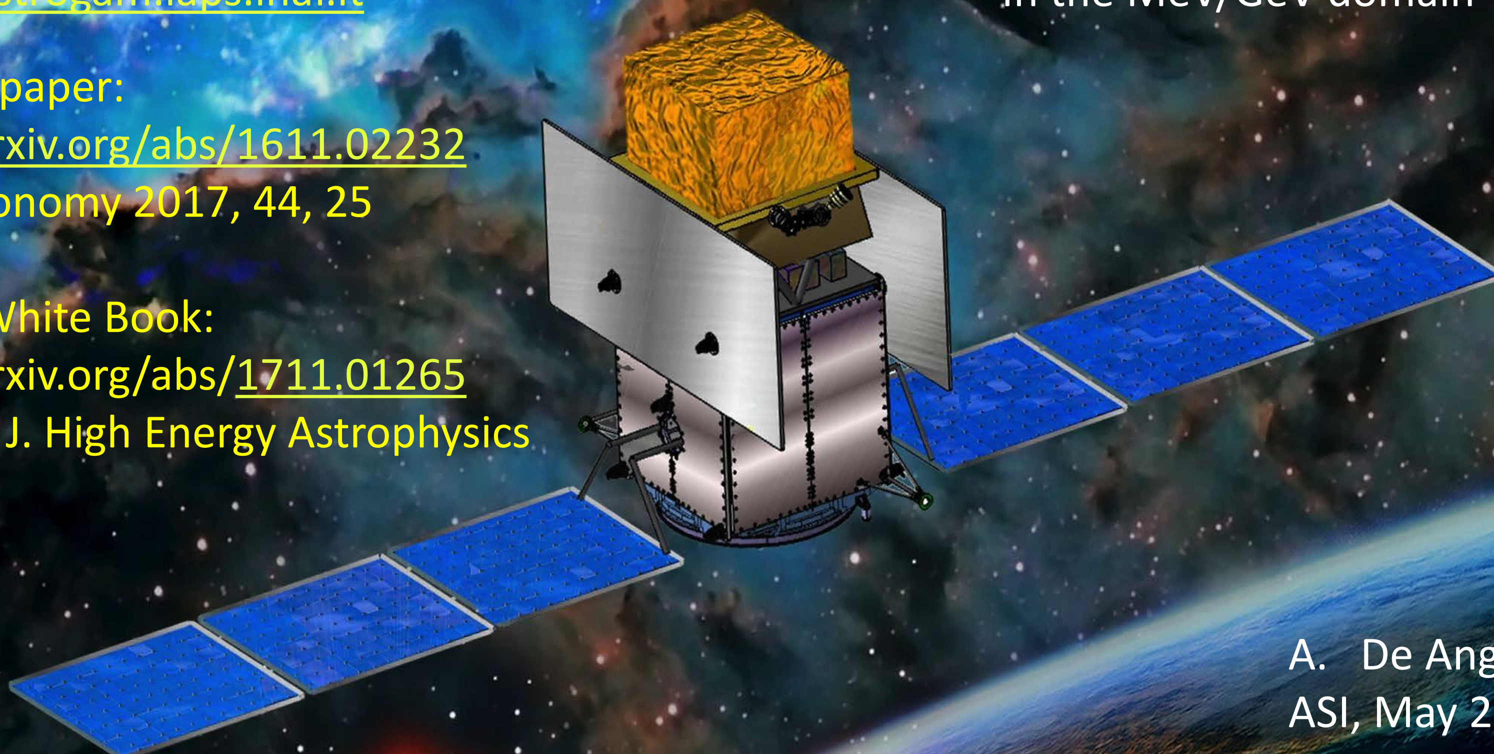
at the heart of the extreme Universe

An observatory for gamma rays
In the MeV/GeV domain

http://eastrogam.iaps.inaf.it

Detector paper:
https://arxiv.org/abs/1611.02232
Exp. Astronomy 2017, 44, 25

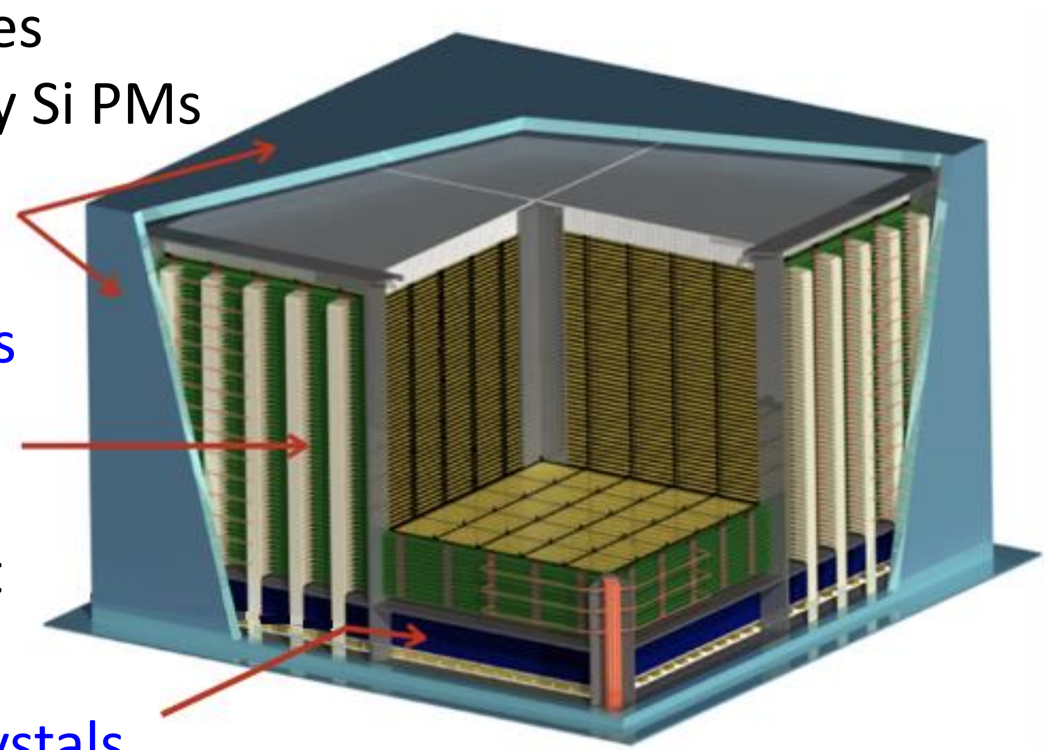
Science White Book:
https://arxiv.org/abs/1711.01265
Subm. To J. High Energy Astrophysics



A. De Angelis
ASI, May 2018

# e-ASTROGAM

**Anti-Coincidence System**
to veto charged particles
plastic scintillators readout by Si PMs
+ Time of Flight

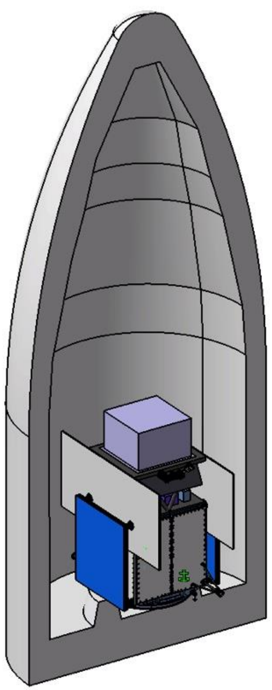


**Tracker** – DS Si strip detectors
for spectral resolution
& 3-D resolution
$1m^2$, 500 µm thick, 0.3 $X_o$ tot

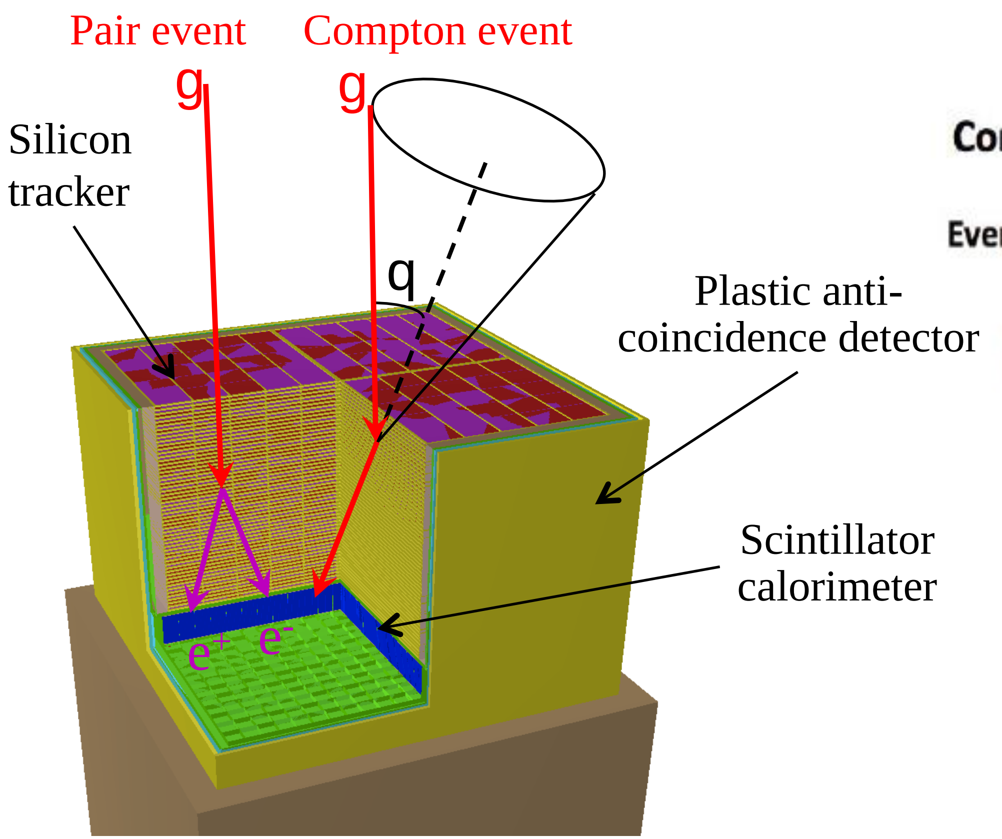
**Calorimeter** – CsI(Tl) crystals
readout by Si drift detectors for best ΔE/E,
8 cm (4.3 Xo)

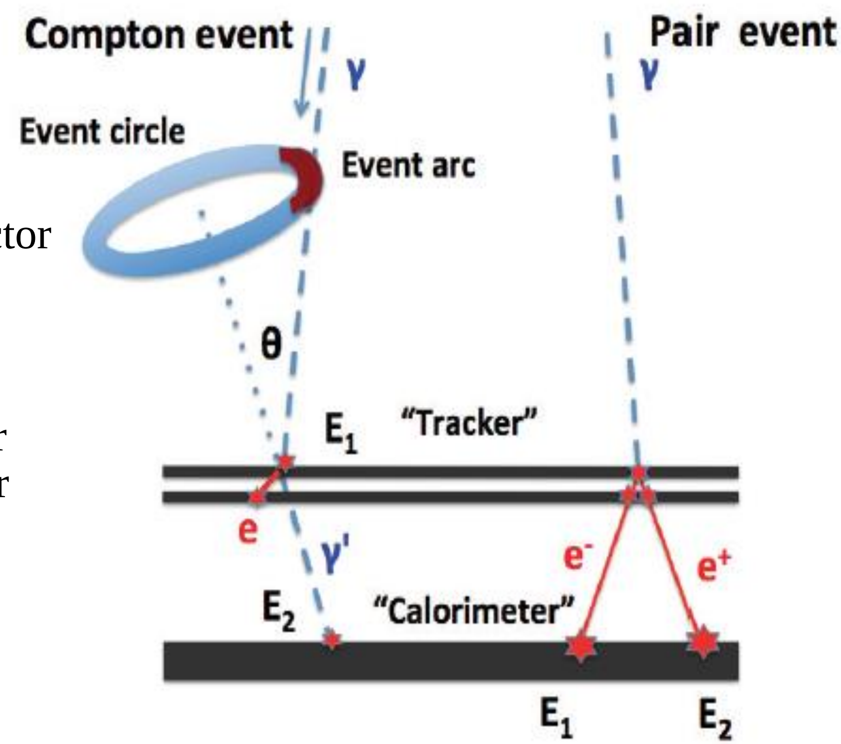
# e-ASTROGAM

- Large FoV, scanning & pointing modes
- Proven and robust technology
  - AGILE; Fermi
- Proven capability to separate signal from background
- No consumables



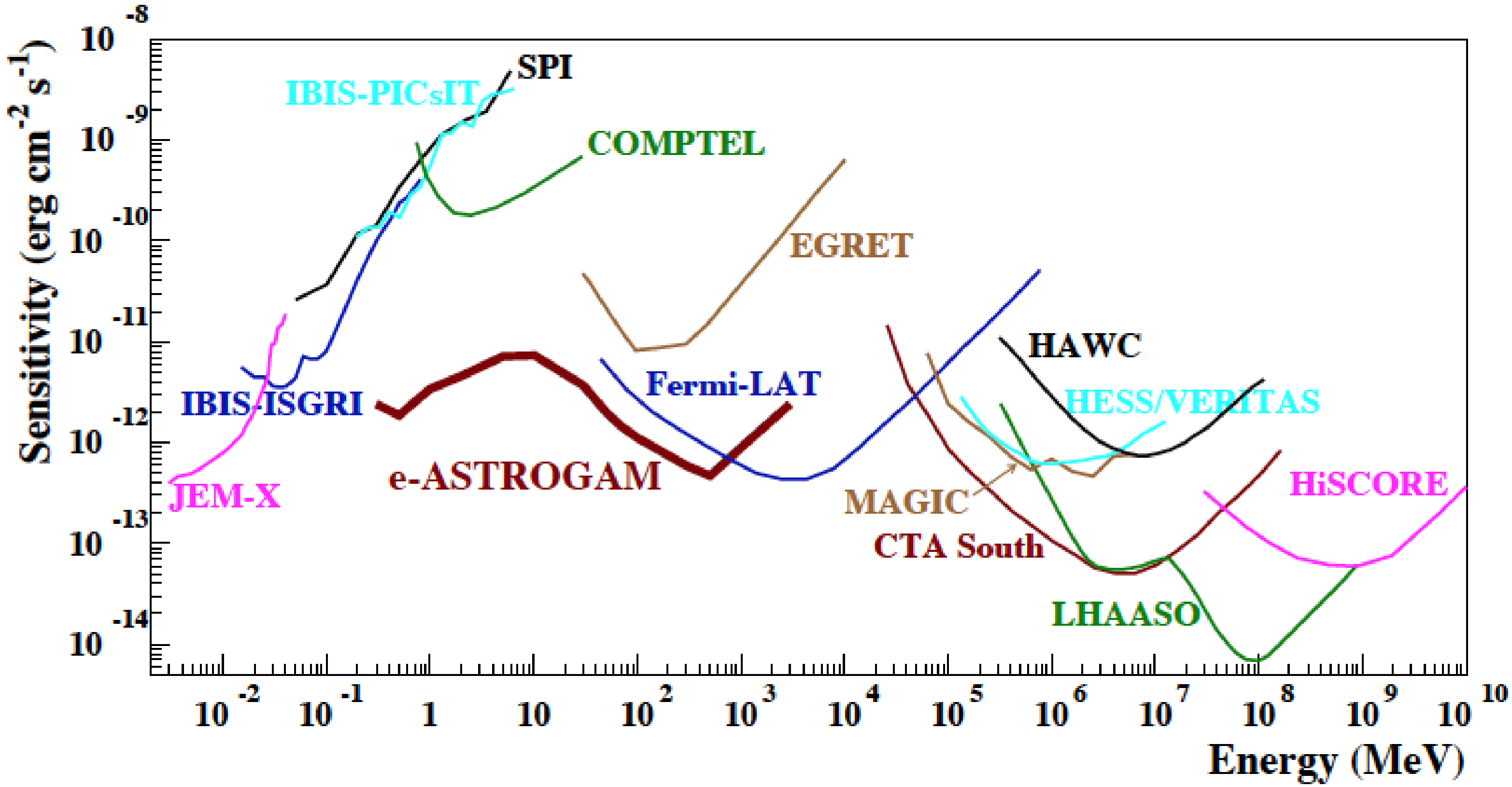
# How to measure gamma rays in the MeV-GeV?



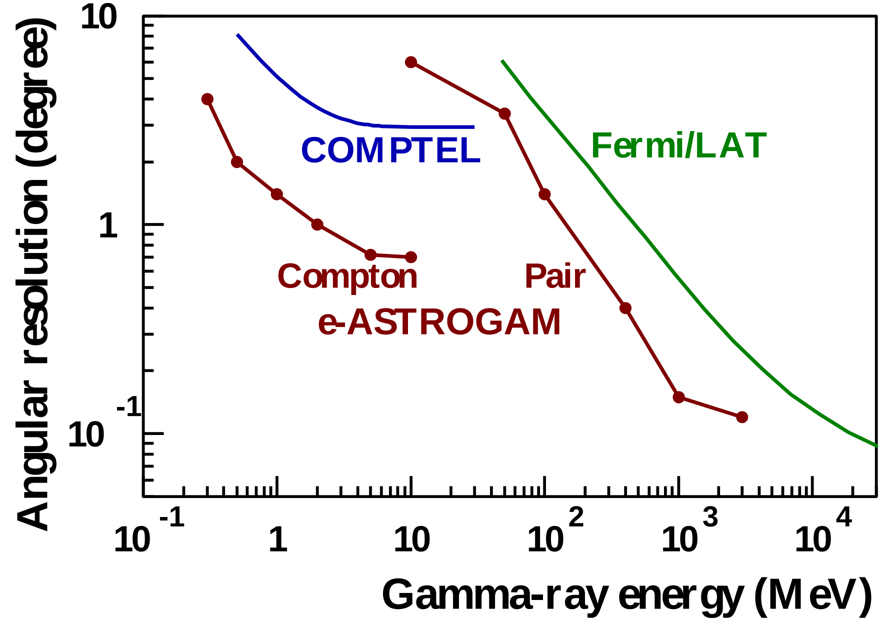
# e-ASTROGAM performance

1. Excellent sensitivity in the 1-50 MeV energy range
2. γ-ray polarization for both transient and steady sources
3. Unprecedented angular resolution (e.g., ~ 10' at 1 GeV)
4. Large field of view (~ 2.5 sr) ⇒ efficient monitoring of the γ-ray sky
5. Sub-millisecond trigger and alert capability for transients

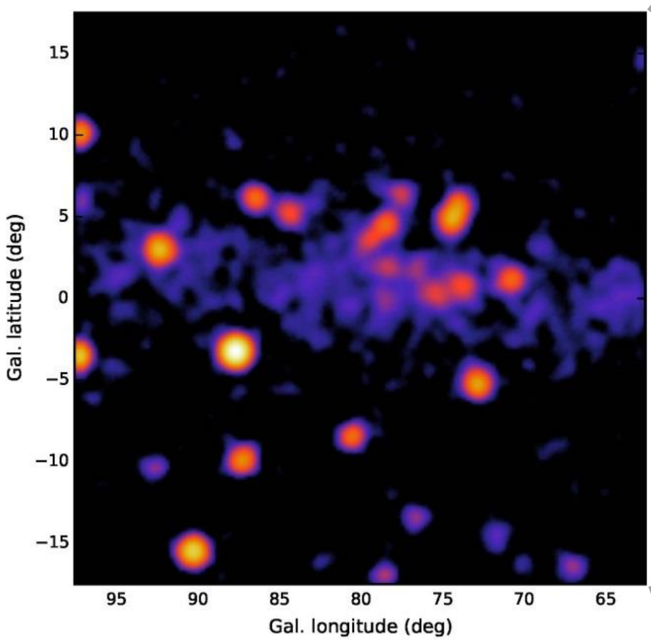


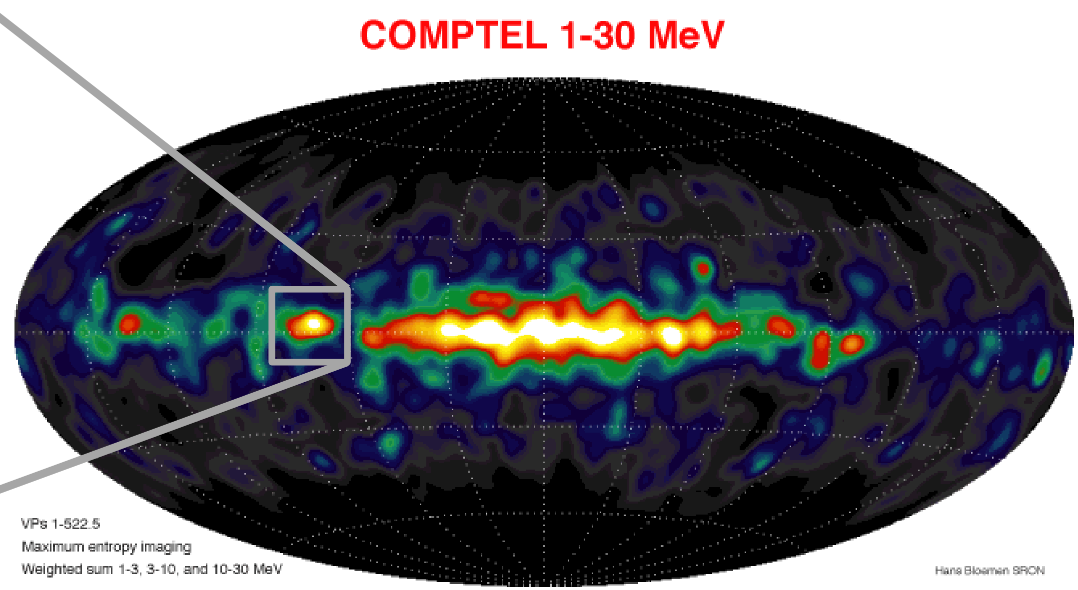
# Angular resolution

- Angular resolution improved close to the physical limits



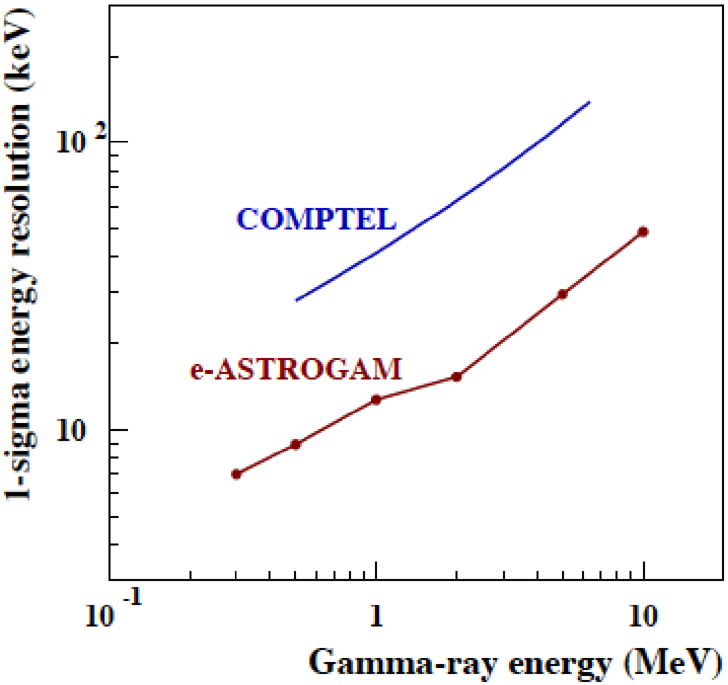

Cygnus region in the 1 - 3 MeV energy band with the e-ASTROGAM PSF (extrapolation of the 3FGL source spectra to low energies)



# Energy resolution

| | |
|---|---|
| ΔE/E (Gamma-ray imager) | 2.5% at 1 MeV<br>30% at 100 MeV |
| ΔE/E (Calorimeter burst) | < 25% FWHM at 0.3 MeV<br>< 10% FWHM at 1 MeV<br>< 5% FWHM at 10 MeV |



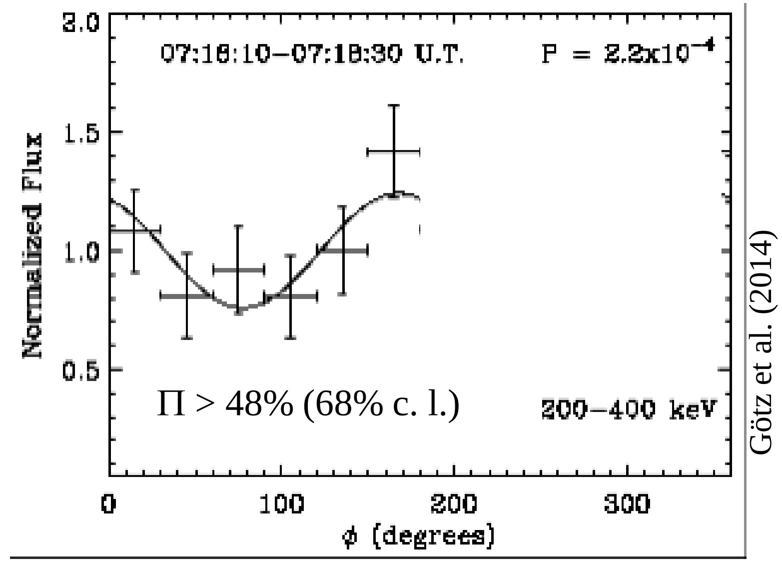
# Gamma-ray polarization

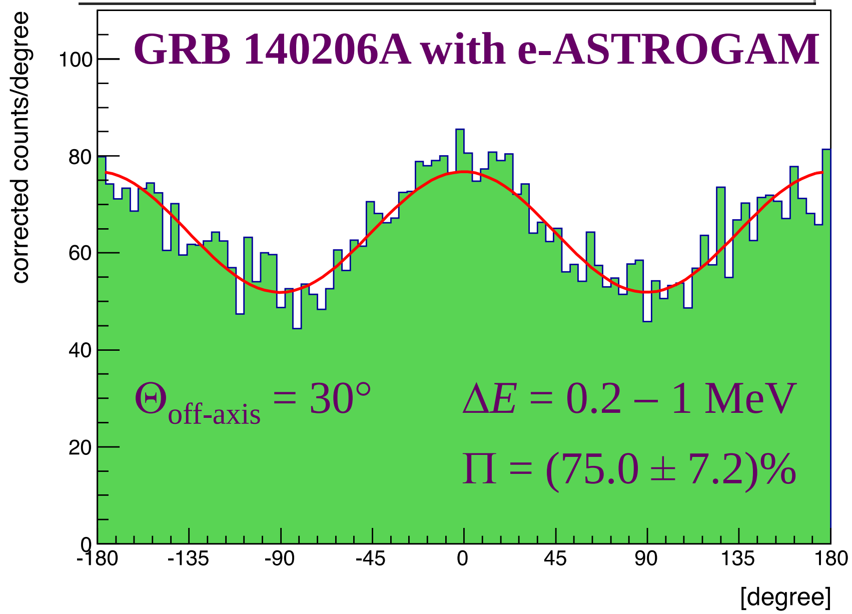
- $\gamma$-ray polarization in **objects emitting jets** (GRBs, Blazars, X-ray binaries) or with **strong magnetic field** (pulsars, magnetars) $\Rightarrow$ magnetization and content (hadrons, leptons, Poynting flux) of the outflows + radiation processes

- $\gamma$-ray polarization from **cosmological sources** (GRBs, Blazars) $\Rightarrow$ fundamental questions of physics related to Lorentz Invariance Violation (vacuum birefringence)

✓ e-ASTROGAM will measure the $\gamma$-ray polarization of **~ 200 GRBs per year** (promising candidates for highly $\gamma$-ray polarized sources)

*INTEGRAL*/IBIS – GRB 140206A ($z$ = 2.74)



# Core science motivation

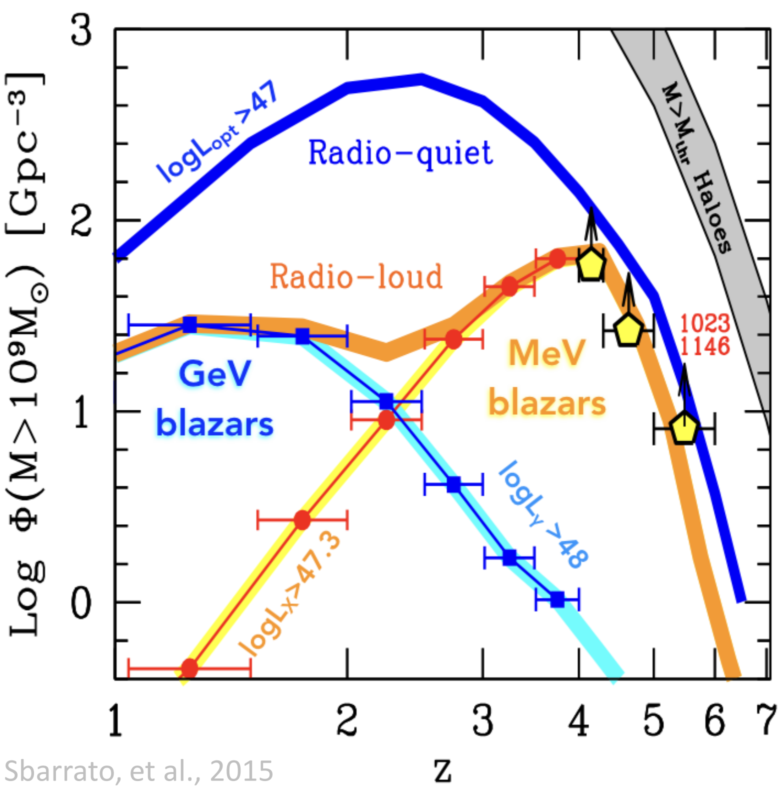
1. Processes at the heart of the extreme Universe (AGNs, GRBs, microquasars): prospects for the Astronomy of the 2030s
    - Multi-wavelength, multi-messenger coverage of the sky (with SKA, JWST, E-ELT, Athena, CTA, ⍰ and GW detectors...), w/ special focus on transient phenomena

2. The origin of high-energy particles and impact to galaxy evolution, from cosmic rays to antimatter

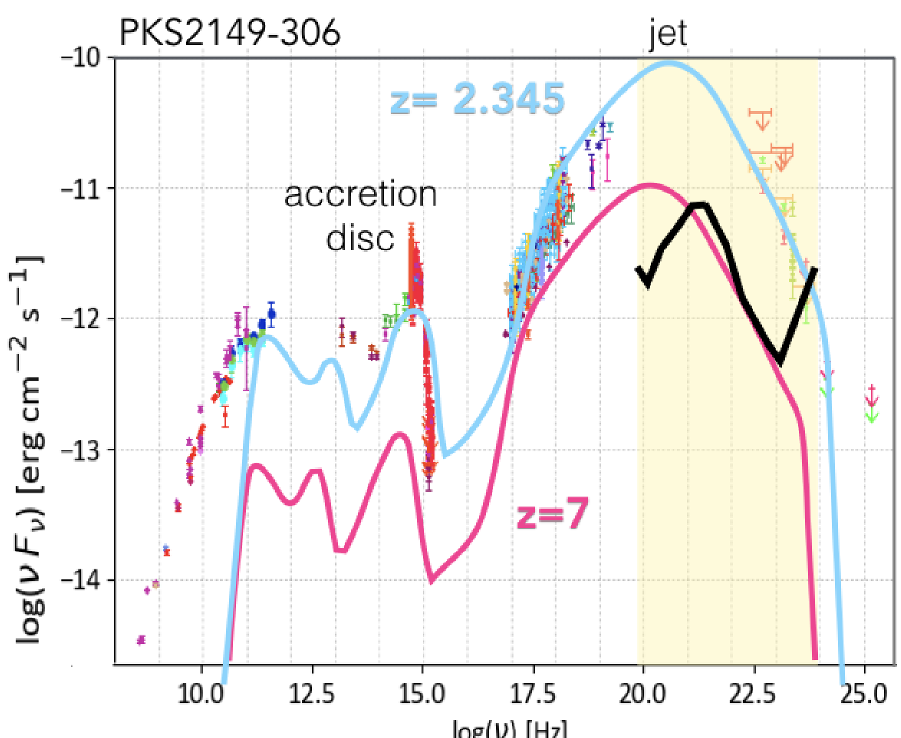
3. Nucleosynthesis and the chemical enrichment of our Galaxy

# Jets and acceleration from supermassive BHs at high z

- Why did the most luminous, jetted AGN form earlier? with mass > $10^9\ M_\odot$?
- Jet power vs. accretion power? ($L_X$ Athena, …)
- e-ASTROGAM: > 1000 detections with 60% below 100 MeV



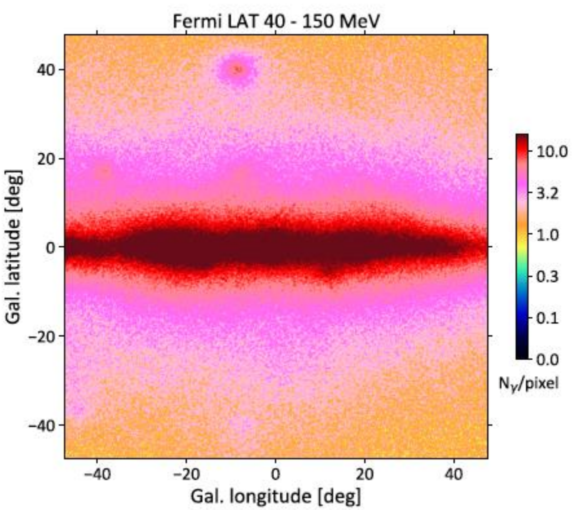

Sbarrato, et al., 2015

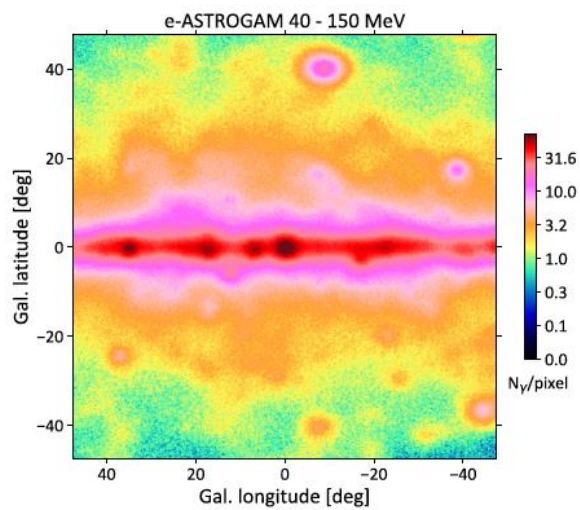


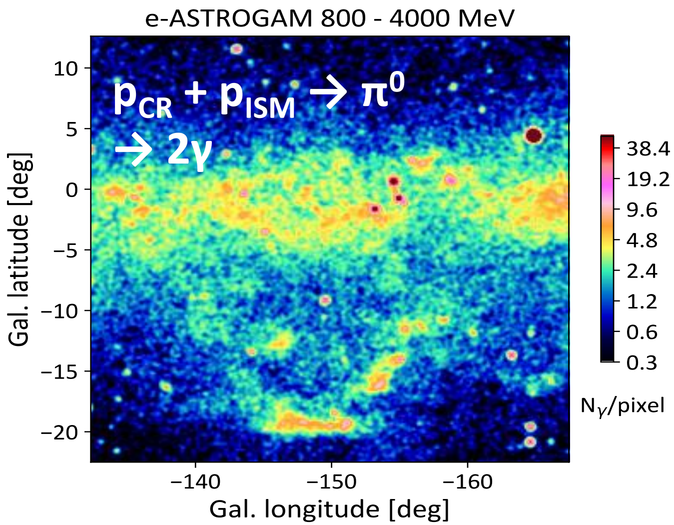

Sbarrato, et al., 2013

# Cosmic rays & the evolution of galaxies

- Understand the CRay feedback on star formation, ISM structures, galactic winds, & B-field growth
- Reveal the GeV (pressure) and sub-GeV (heat, ionization) CRays in the Galactic ISM, & diffusion properties in different environments
- A unique tracer of the number of nucleons in all phases of the ISM



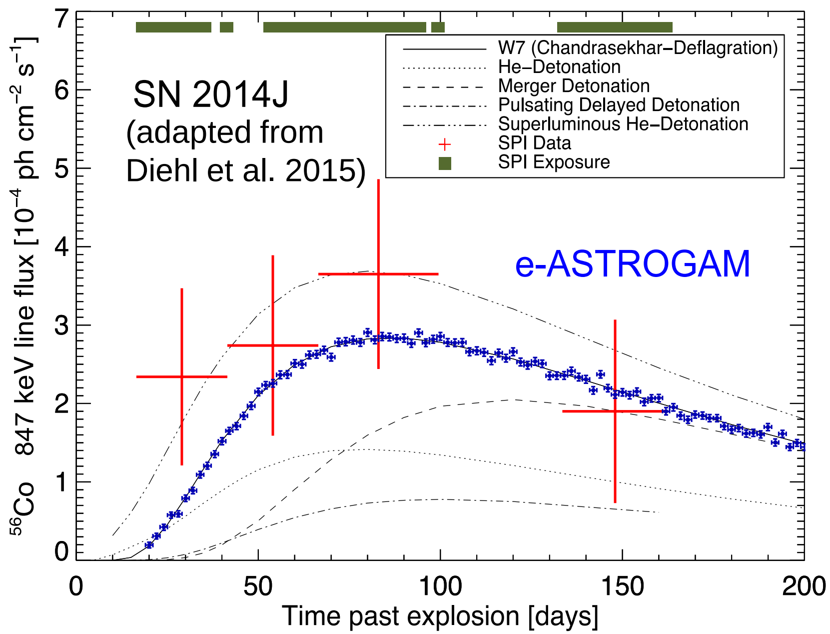



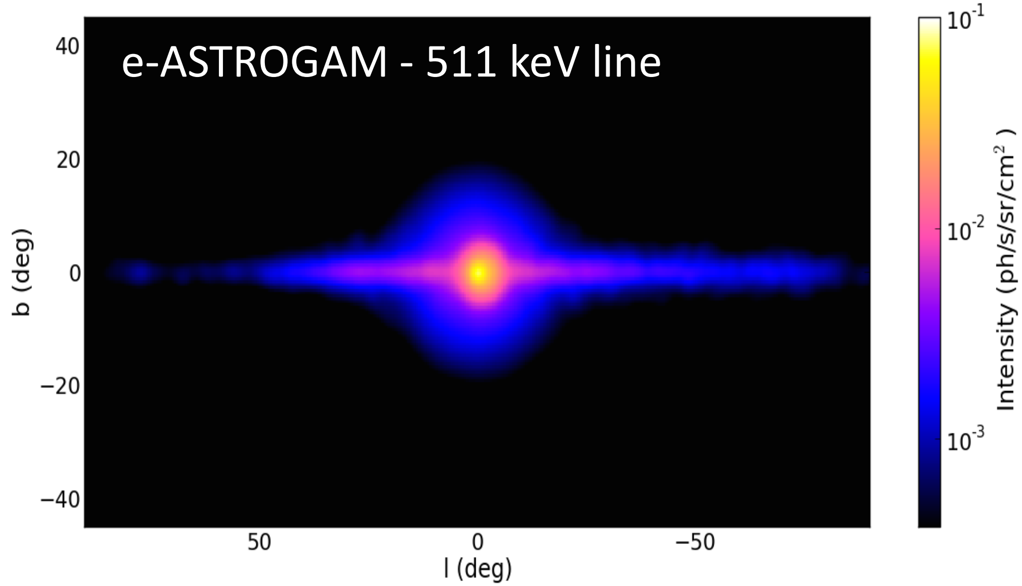



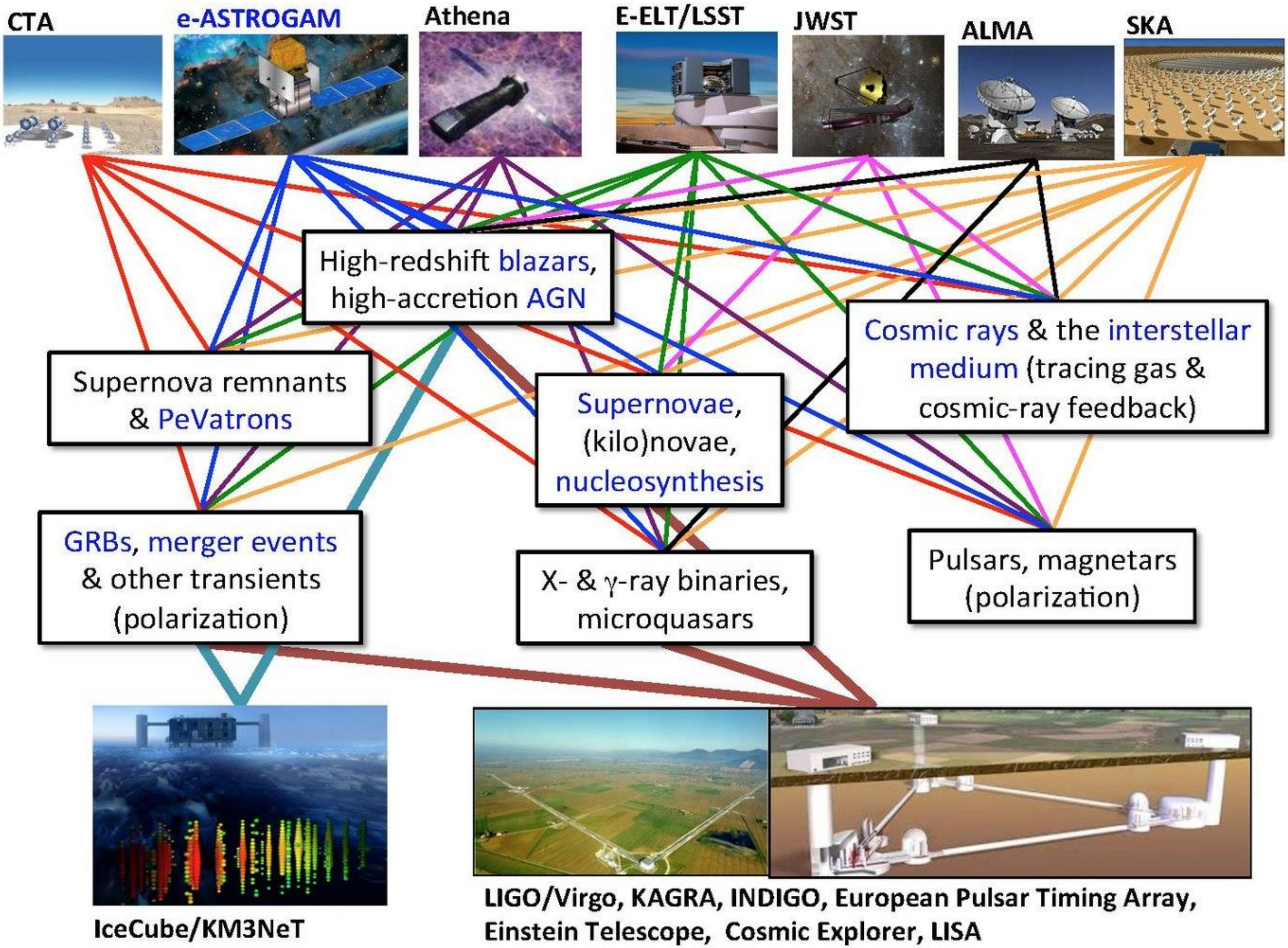
# Supernovae & cosmic evolution of matter

- Progenitor system(s) and explosion mechanism(s) of **Type Ia SNe**? **Standard candles** for precision cosmology?
- How are cosmic isotopes **created in stars and supernovae**, distributed in the ISM and recycled into new stars?
- What are the main sources of **positrons** in the Galaxy?

e-ASTROGAM:
- Mass and evolution of ejected $^{56}$Ni/$^{56}$Co in a dozen of SN Ia
- $^{44}$Ti radioactivity from all young Galactic SNRs & SN 1987A
- Deep survey of the $^{26}$Al, $^{60}$Fe and positron annihilation radiations



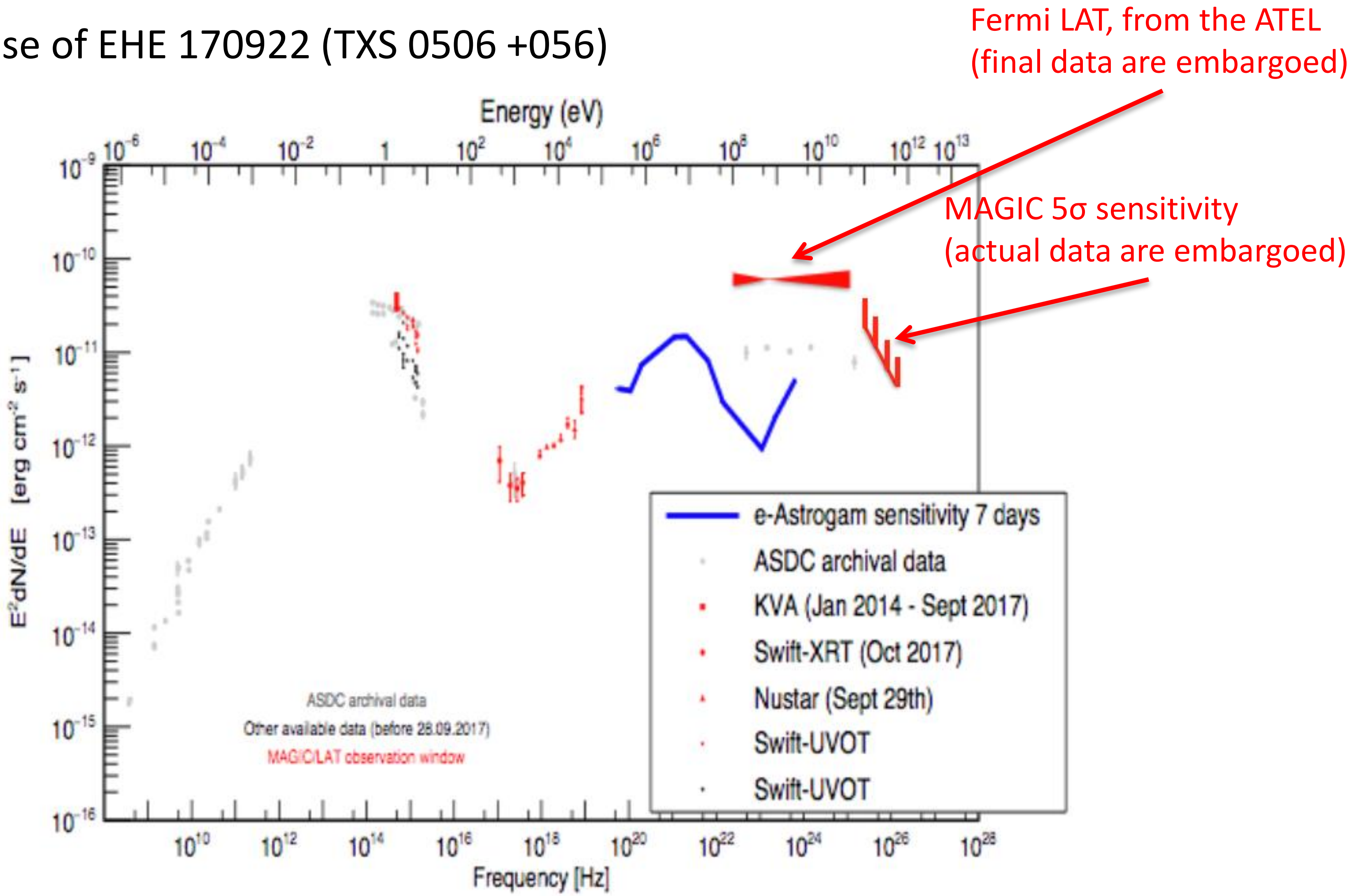





CTA
e-ASTROGAM
Athena
E-ELT/LSST
JWST
ALMA
SKA
High-redshift blazars, high-accretion AGN
Supernova remnants & PeVatrons
Cosmic rays & the interstellar medium (tracing gas & cosmic-ray feedback)
Supernovae, (kilo)novae, nucleosynthesis
GRBs, merger events & other transients (polarization)
X- & γ-ray binaries, microquasars
Pulsars, magnetars (polarization)
IceCube/KM3NeT
LIGO/Virgo, KAGRA, INDIGO, European Pulsar Timing Array, Einstein Telescope, Cosmic Explorer, LISA

# Multimessenger Astronomy: Neutrinos

- Are AGN sources of VHE neutrinos and thus of UHECR?
- The case of EHE 170922 (TXS 0506 +056)



# Multimessenger Astronomy: Gravitational Waves

- wide FoV, prompt detection, localization
- detection of (1.2 – 18) NS-NS mergers/year with GW after KAGRA + INDIGO

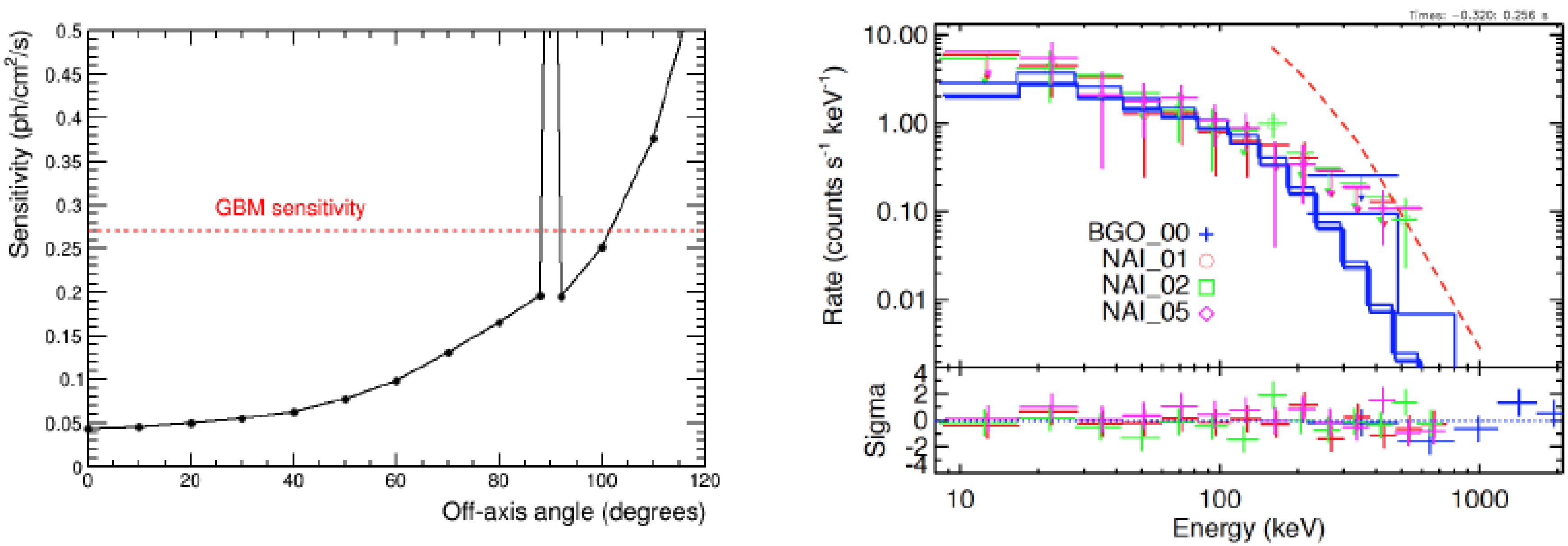
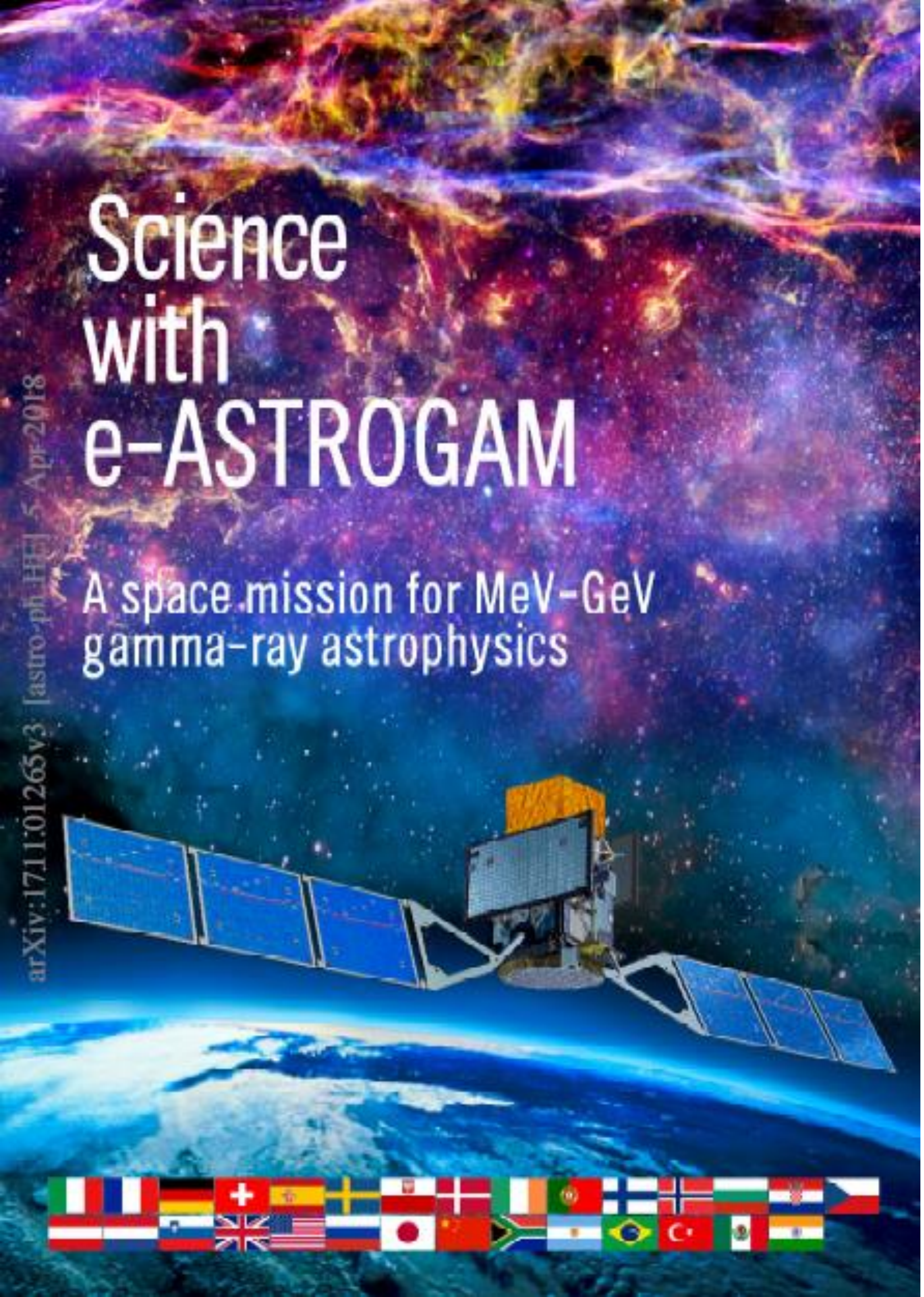



Figure 2.1.2: Left: $6\,\sigma$ sensitivity of e-ASTROGAM to an average GRB on a 1 second timescale in the 0.2–2 MeV band. The sharp loss of sensitivity at 90° incidence is due to gamma-rays crossing the tracker parallel to the silicon detectors. The red line gives the equivalent trigger sensitivity of *Fermi* GBM, adapted from [49]. Right: the flux from the hard component of GRB170817A as recorded from *Fermi* GBM (solid blue line), and a conservative extrapolation (20x) to an on-axis flux (dashed red line).

# Wide interest for e-ASTROGAM

>400 collaborators from institutions in 24 countries; White Book published (>200 pages)




A. De Angelis*,[1,2,3,4] V. Tatischeff*,[5] I. A. Grenier*,[6] J. McEnery*,[7] M. Mallamaci*,[1] M. Tavani,[8,9,10]
U. Oberlack,[11] L. Hanlon,[12] R. Walter,[13] A. Argan,[14] P. Von Ballmoos,[15] A. Bulgarelli,[16] A. Bykov,[17] M. Hernanz,[18]
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R. Rando,[1,34] M. Razzano,[35,36] A. Aboudan,[34,2] M. Ackermann,[37] A. Addazi,[38] M. Ajello,[26] C. Albertus,[39]
J. M. Álvarez,[40] G. Ambrosi,[41] S. Antón,[42,43] L. A. Antonelli,[44] A. Babic,[45] B. Baibussinov,[1] M. Balbo,[13]
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A. Coleiro,[75,76] W. Collmar,[77] P. Coppi,[78] R. Curado da Silva,[79] S. Cutini,[44,41] F. D'Ammando,[80]
B. De Lotto,[81] D. de Martino,[82] A. De Rosa,[8] M. Del Santo,[83] L. Delgado,[18] R. Diehl,[77] S. Dietrich,[84]
A. D. Dolgov,[85,86] A. Dominguez,[49] D. Dominis Prester,[87] I. Donnarumma,[8] D. Dorner,[88] M. Doro,[1,34]
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G. Vankova-Kirilova,[59] C. Venter,[58] F. Verrecchia,[44,91] P. Vincent,[146] X. Wang,[147] C. Weniger,[50] X. Wu,[13]
G. Zaharijaš,[148] L. Zampieri,[2] S. Zane,[149] S. Zimmer,[150,13] A. Zoglauer,[151] and the e-ASTROGAM collaboration

White Book published in arXiv
Wide interest from the scientific community

# Impact of e-ASTROGAM

Wide field observatory in the new MeV energy band opens up a large discovery space

The MeV band is crucial for GW and multi-messenger astrophysics

Breakthrough polarimetric sensitivity achievable for the first time

MeV astronomy is for nuclear processes what optical astronomy is for atomic transitions

Payload innovative in many respects, but the technology is ready & reliable

BACKUP

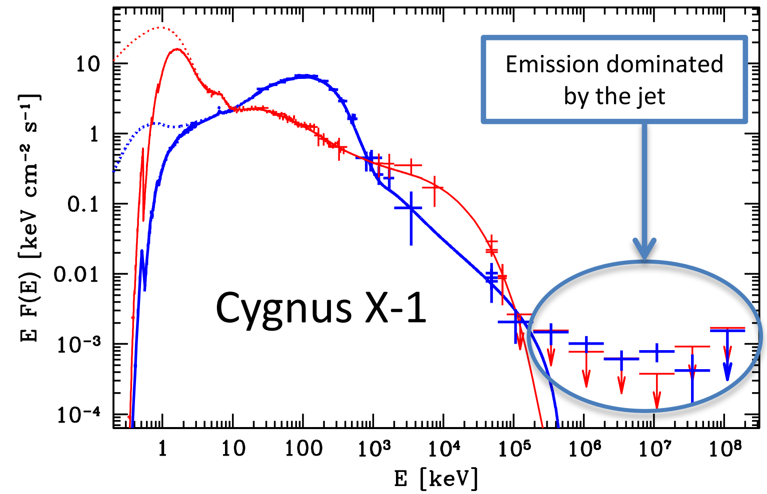
# Compact Object Physics

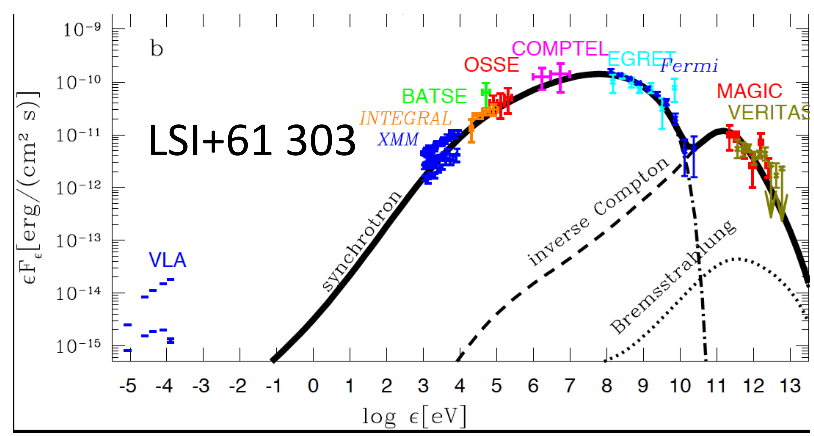
**Microquasars and Galactic X-ray sources: how can we contribute ?**

- Characterizing the physics behind the MeV-GeV emission when accretion and jets are present (e.g., distinguishing between accretion and jet emission) (Top figure: Cygnus X-1, hard-state and soft state)

- Discerning between accreting (microquasars) and non-acreting sources (pulsar gamma-ray binaries) by their crutially different spectral features in the MeV-GeV range (compare top figure with bottom figure, LSI+61303)

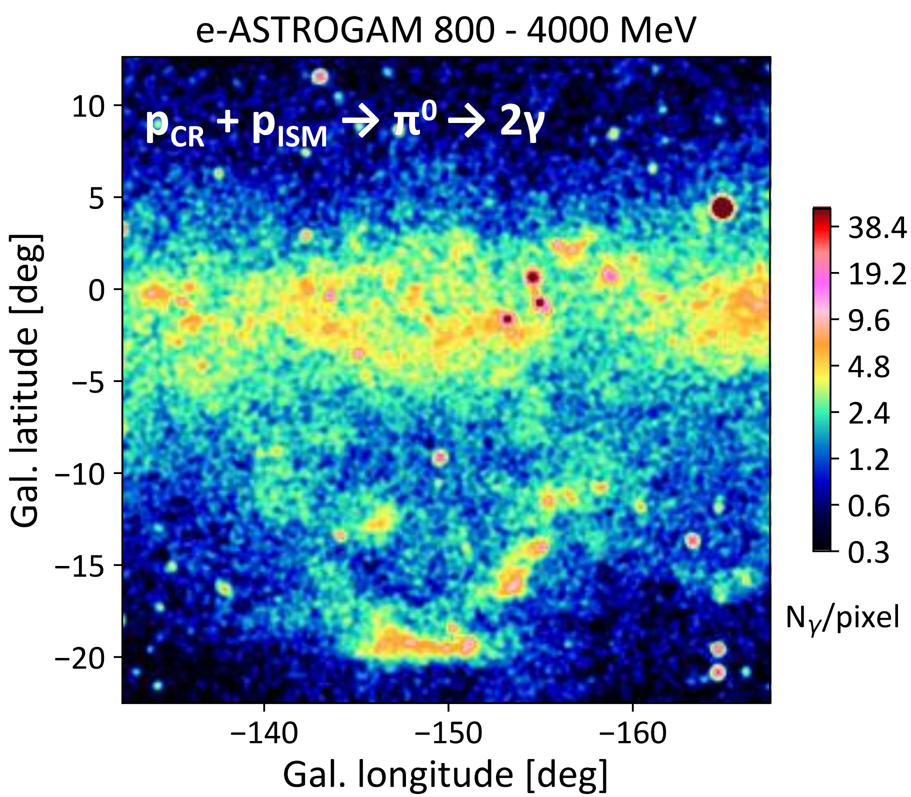
- e-ASTROGAM can discover new gamma-ray binaries, as they are bright at ~ 10 MeV and the sensitivity will be ~100 times better. Peaking at the MeV range (see bottom figure), will allow e- ASTROGAM to unveil the source dominant non-thermal physics.

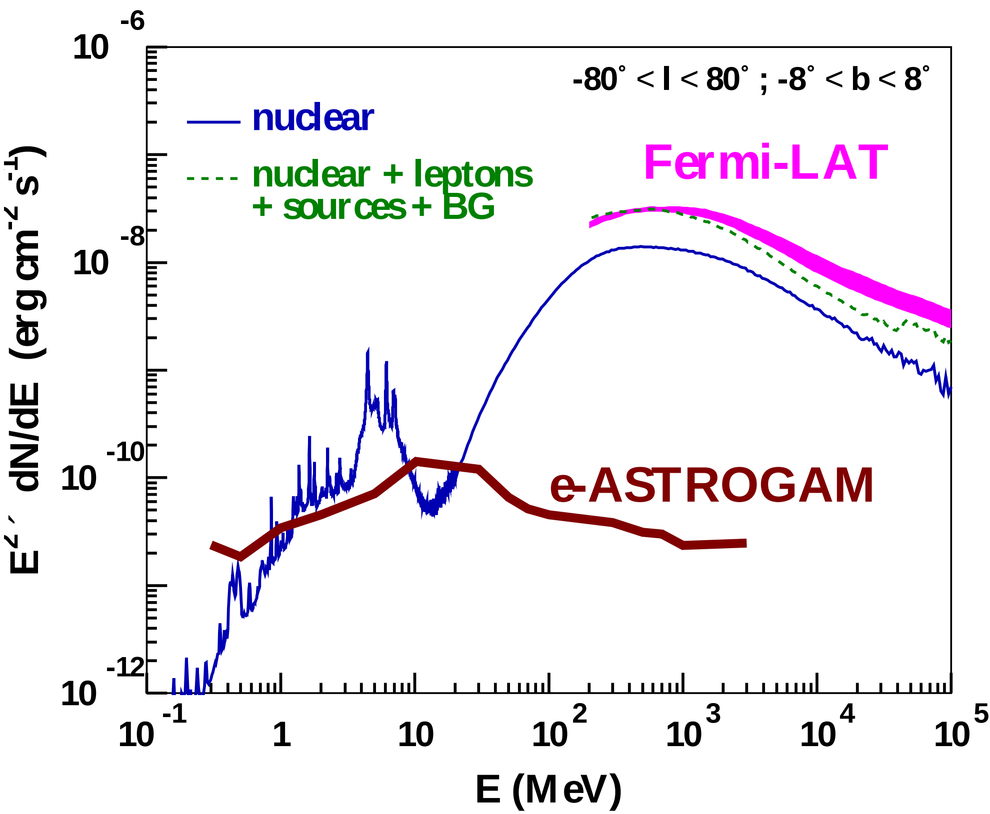


# Cosmic rays & the evolution of galaxies

- Understand the CRay feedback on star formation, ISM structures, galactic winds, & B-field growth
- Reveal the GeV (pressure) and sub-GeV (heat, ionization) CRays in the Galactic ISM, & diffusion properties in different environments
- Gauge non-linear gas tracers (dust properties per gas nucleon & CO-to-$H_2$ ratio) in different environments using CRays



# Summary: e-ASTROGAM

Will reveal the hardly explored and rich MeV sky and the GeV sky, detecting thousands of sources, from NS to BHs, from CRs in gas clouds to SNRs in an energy range never fully explored before, with polarimetric measurements

Uncover the largest part of non-thermal particles and their impact on their environment (jets, cosmic-ray feedback)

Detect & localize γ-ray transients for Athena & CTA, and in the era of astronomy's new messengers, GW and neutrinos in particular

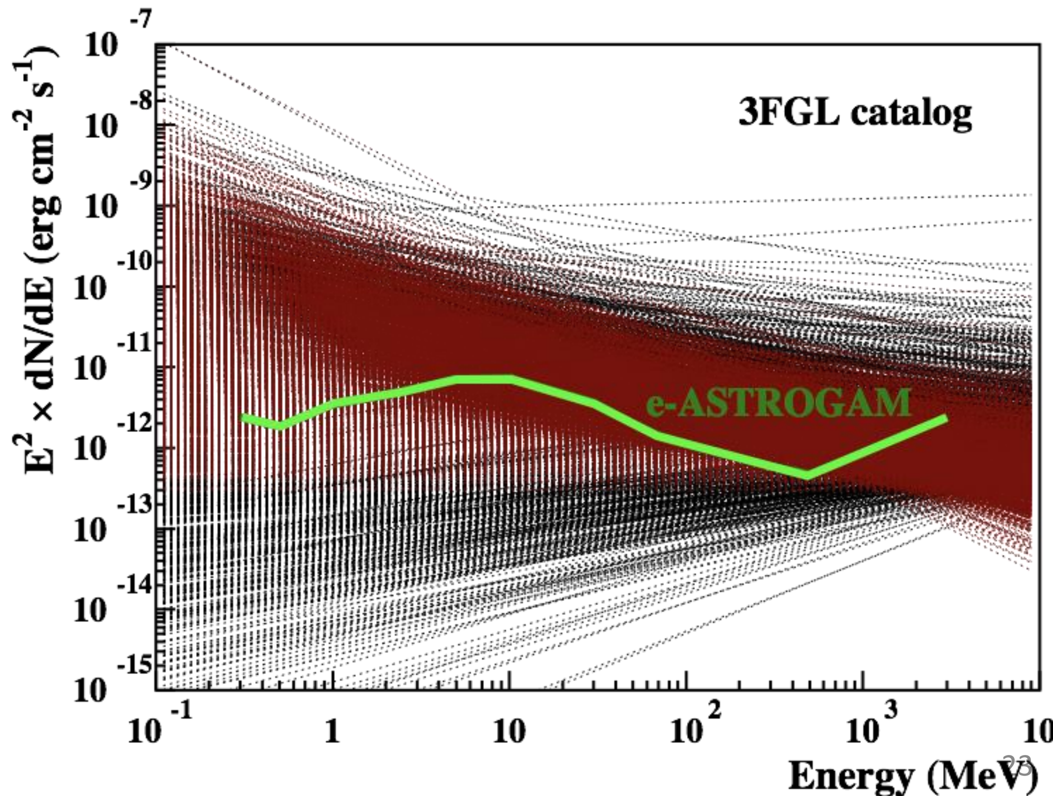
The e-ASTROGAM payload is innovative in many respects, but the technology is ready & reliable

Can be the only observatory in space exploring the crucial MeV-GeV region, and will be an important piece contributing to the European leadership in science & technology in a strategic field.

# And more Observatory data

Thousands of sources will be detected, from NS to BHs, from CRs in gas clouds to SNRs in an energy range never fully explored before, with a vital link to simultaneous GeV emission on board, and all the rest with the "global Observatory" putting together all other facilities for which Europe is going to be the main player.

- Extrapolated from 4FGL in 1 effective year:
    - > 1100 (candidate) blazars
    - 170 pulsars
    - 700 unidentified sources
- + resolved SNRs (Athena)
- + 180 long GRB + 60 short GRB/year
- + 4-6 novae, + 10-15 supernovae
- + new MeV sources & hard X-ray sources. New MeV source classes?



# A unique Observatory in synergy with the astrophysics of the 2030s

1. 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 SKA, JWST, E-ELT, Athena, CTA, ⍰ and GW detectors...), with special focus on transient phenomena

2. The origin of high-energy particles and impact on galaxy evolution, from cosmic rays to antimatter

3. Nucleosynthesis and the chemical enrichment of our Galaxy


Einstein Telescope,
Cosmic Explorer, LISA?