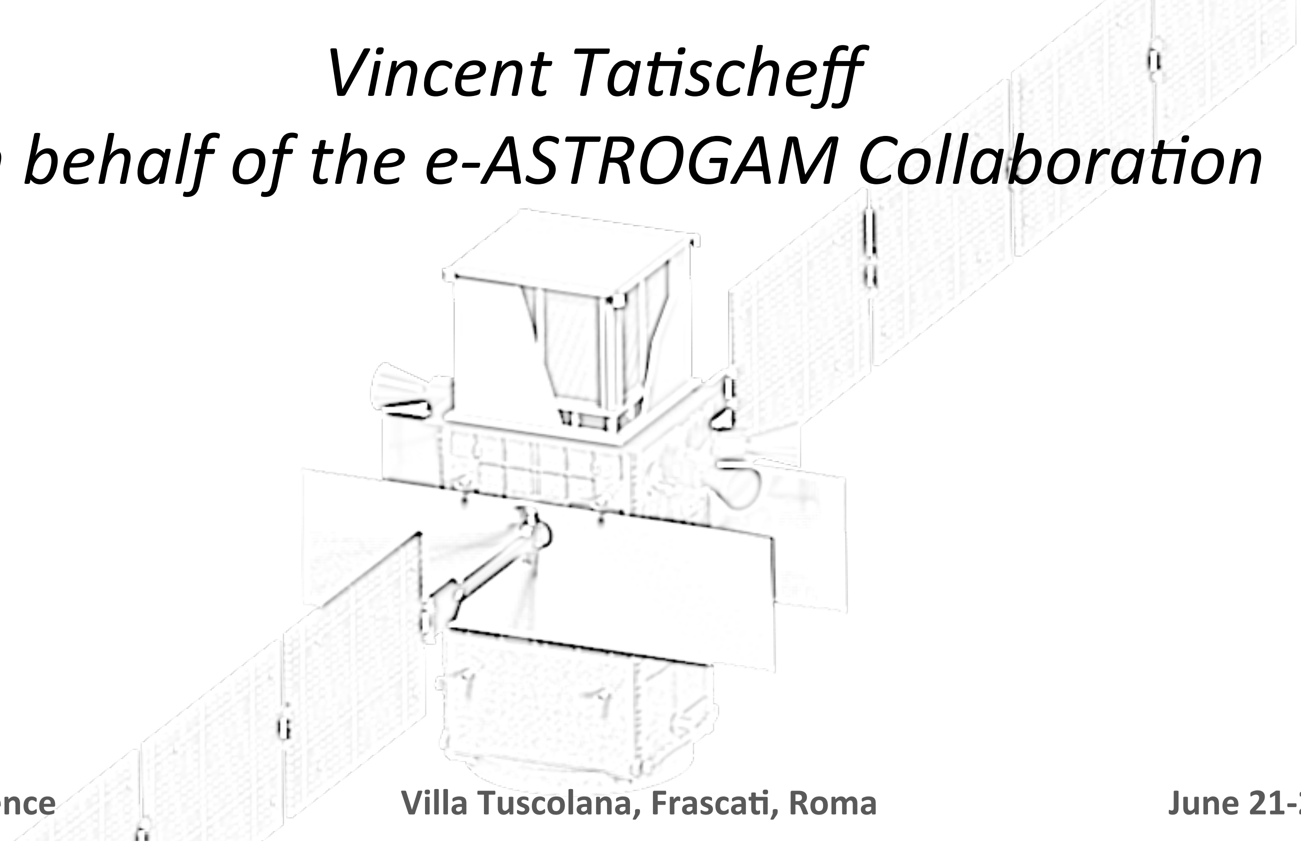
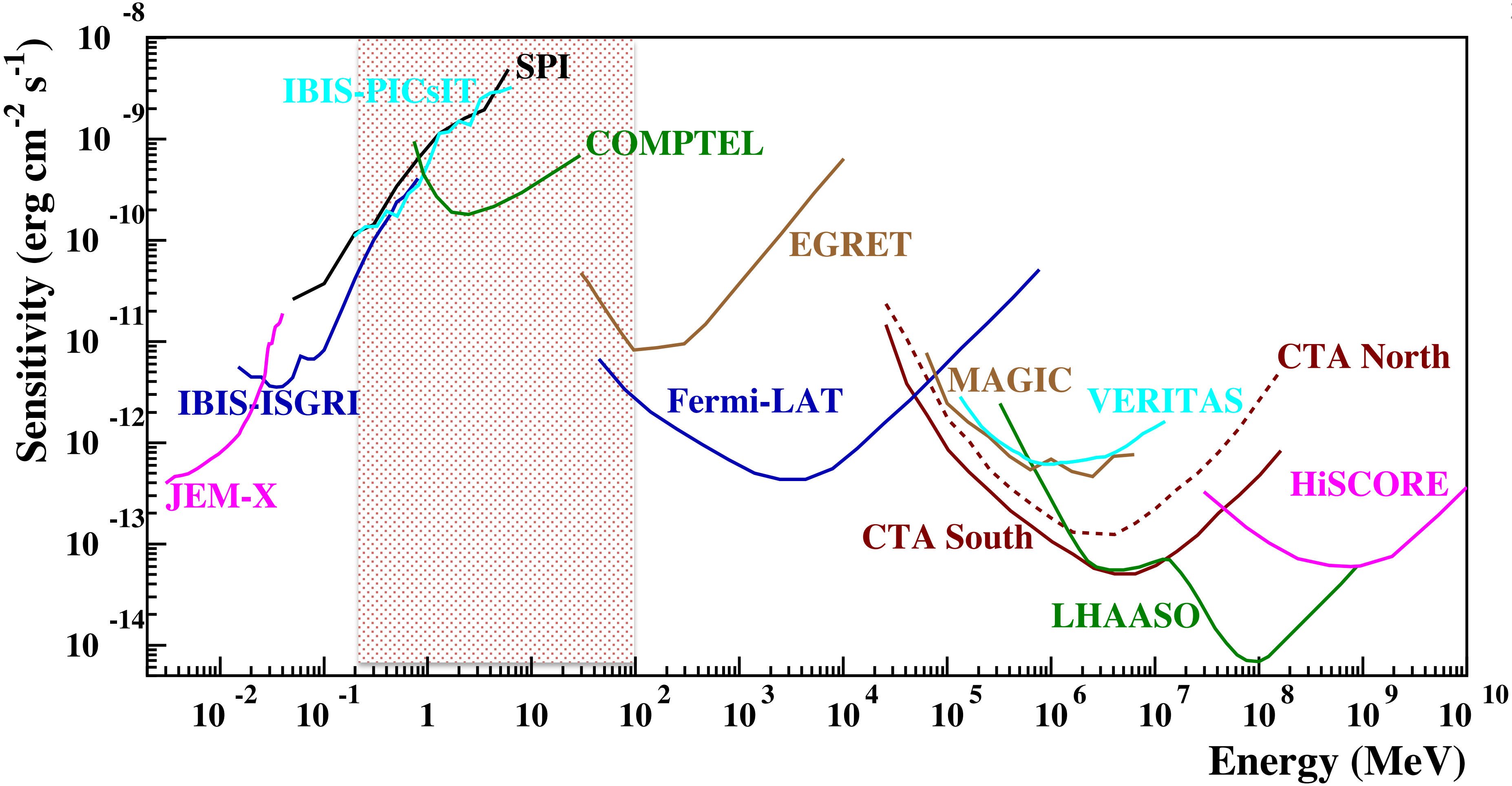
The e-ASTROGAM gamma-ray space mission

A sensitive wide-field observatory for the MeV / sub-GeV band

Vincent Tatischeff
On behalf of the e-ASTROGAM Collaboration

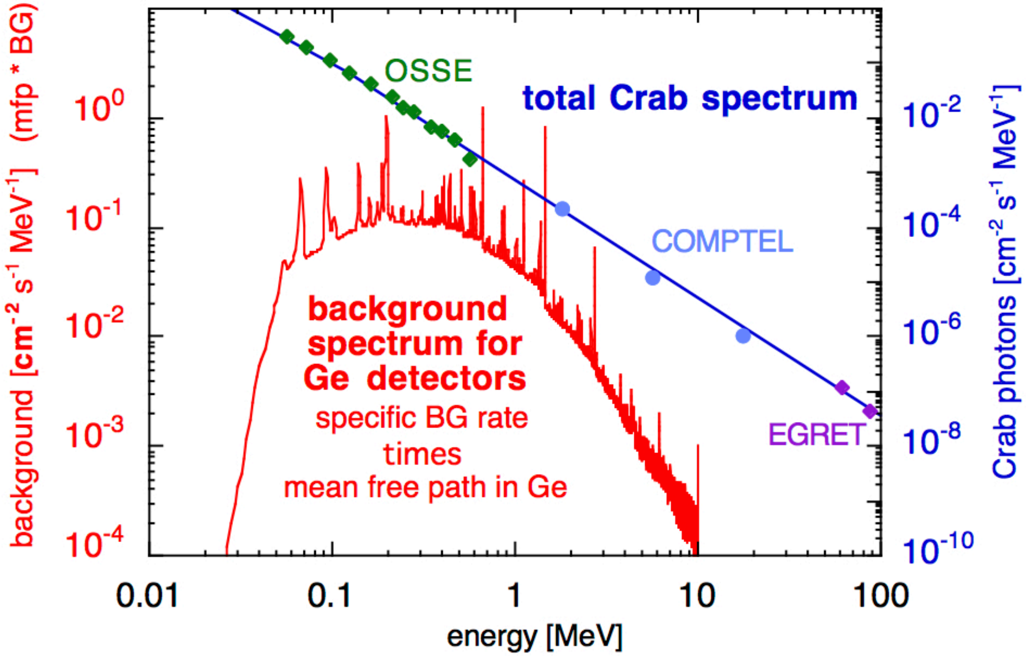


e-ASTROGAM The MeV/sub-GeV domain



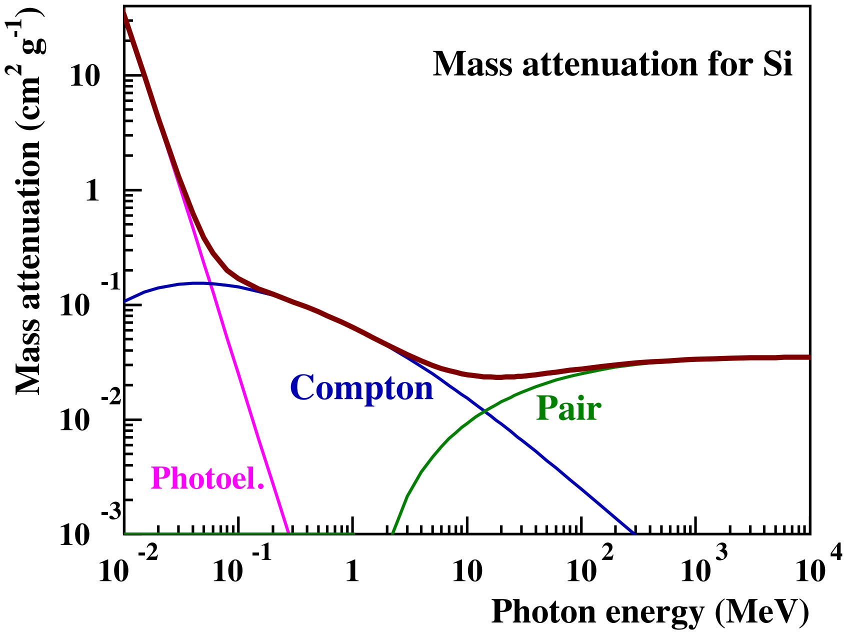
- Worst covered part of the electromagnetic spectrum (only a few tens of steady sources detected so far between 0.2 and 30 MeV)
- Many objects have their peak emissivity in this range (GRBs, blazars, pulsars...)

e-ASTROGAM Observational challenges



☺ The MeV range is the domain of nuclear γ-ray lines (radioactivity, nuclear collision, positron annihilation, neutron capture)

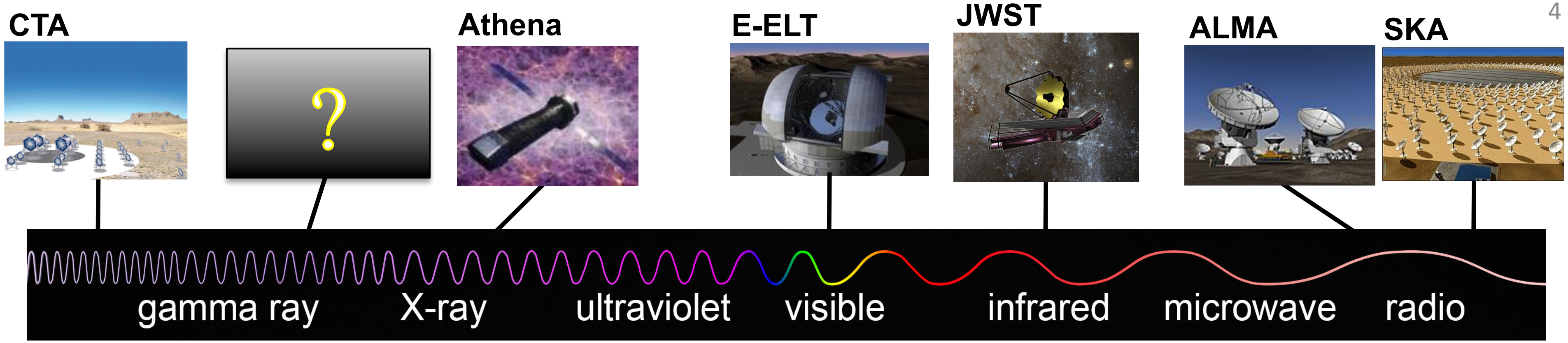
☹ Strong instrumental background from activation of space-irradiated materials



☹ Photon interaction probability reaches a minimum at ~ 10 MeV

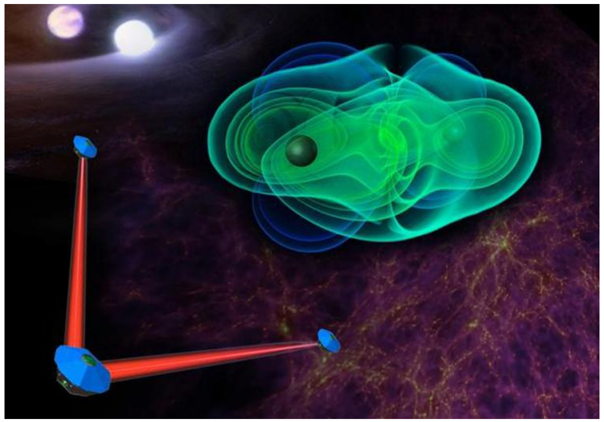
☹ Three competing processes of interaction, Compton scattering being dominant around 1 MeV
⇒ complicated event reconstruction

e-ASTROGAM γ-ray astronomy in context

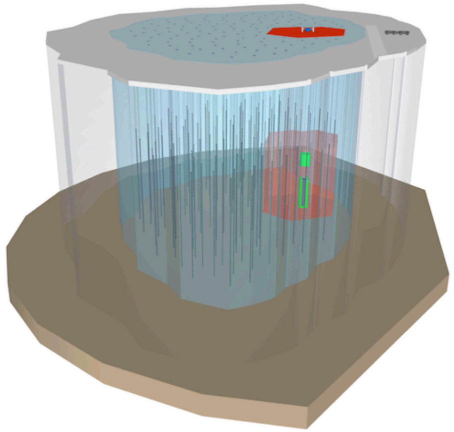


New Astronomies:
gravitational waves
neutrinos

eLISA – Gravitational waves



IceCube-Gen2 – Neutrinos



- Need for a sensitive, wide-field γ-ray space observatory operating at the same time as facilities like SKA and CTA, as well as eLISA and neutrino detectors, to get a coherent picture of the transient sky and the sources of gravitational waves and high-energy neutrinos

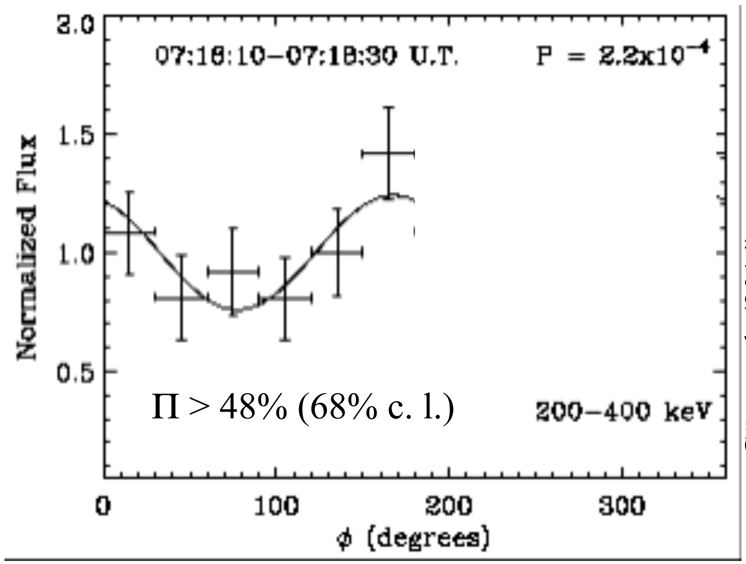
e-ASTROGAM Gamma-ray polarization

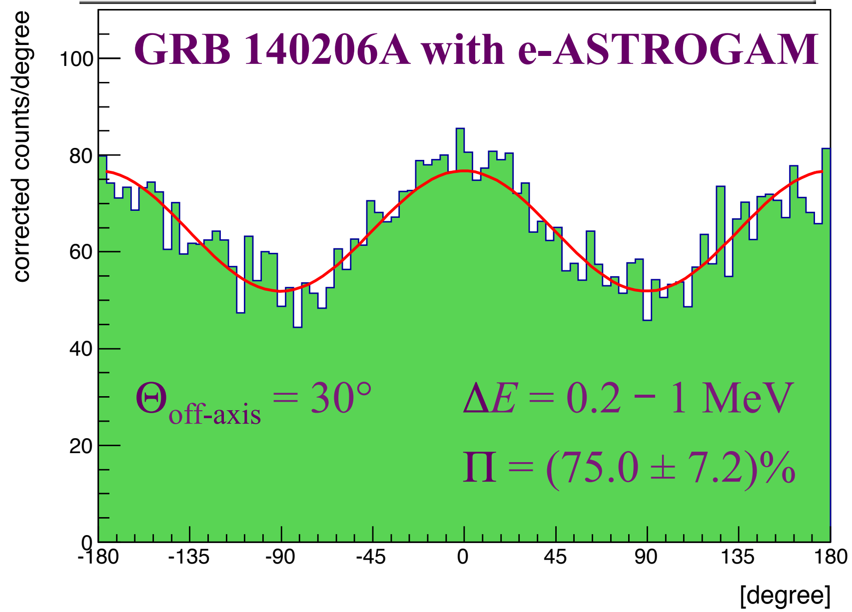
- γ-ray polarization in **objects emitting jets** (GRBs, Blazars, X-ray binaries) or with **strong magnetic field** (pulsars, magnetars) ⇒ magnetization and content (hadrons, leptons, Poynting flux) of the outflows + radiation processes

- γ-ray polarization from **cosmological sources** (GRBs, Blazars) ⇒ fundamental questions of physics related to Lorentz Invariance Violation (vacuum birefringence)

✓ e-ASTROGAM will measure the γ-ray polarization of ~ **100 GRBs per year** (promising candidates for highly γ-ray polarized sources)

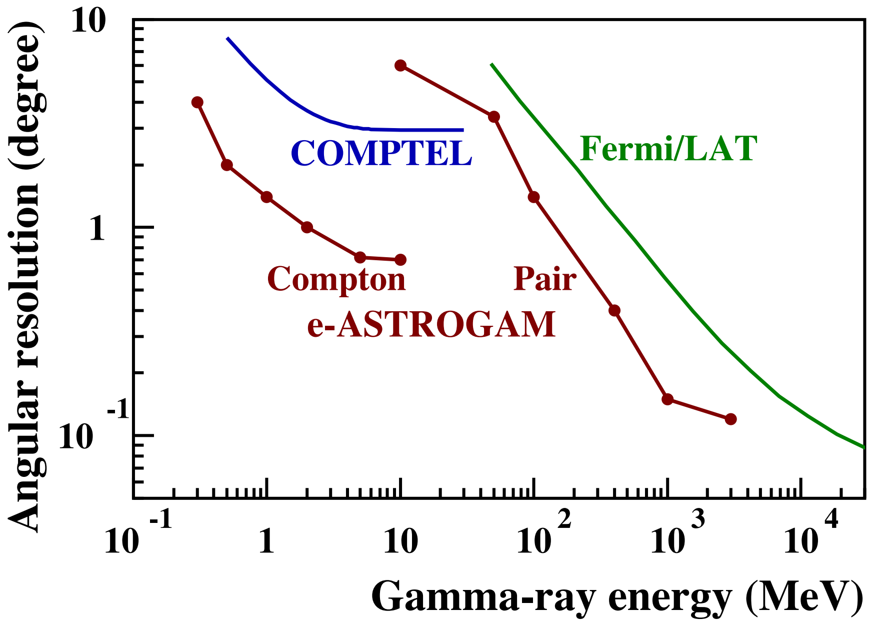
INTEGRAL/IBIS − GRB 140206A (z = 2.74)



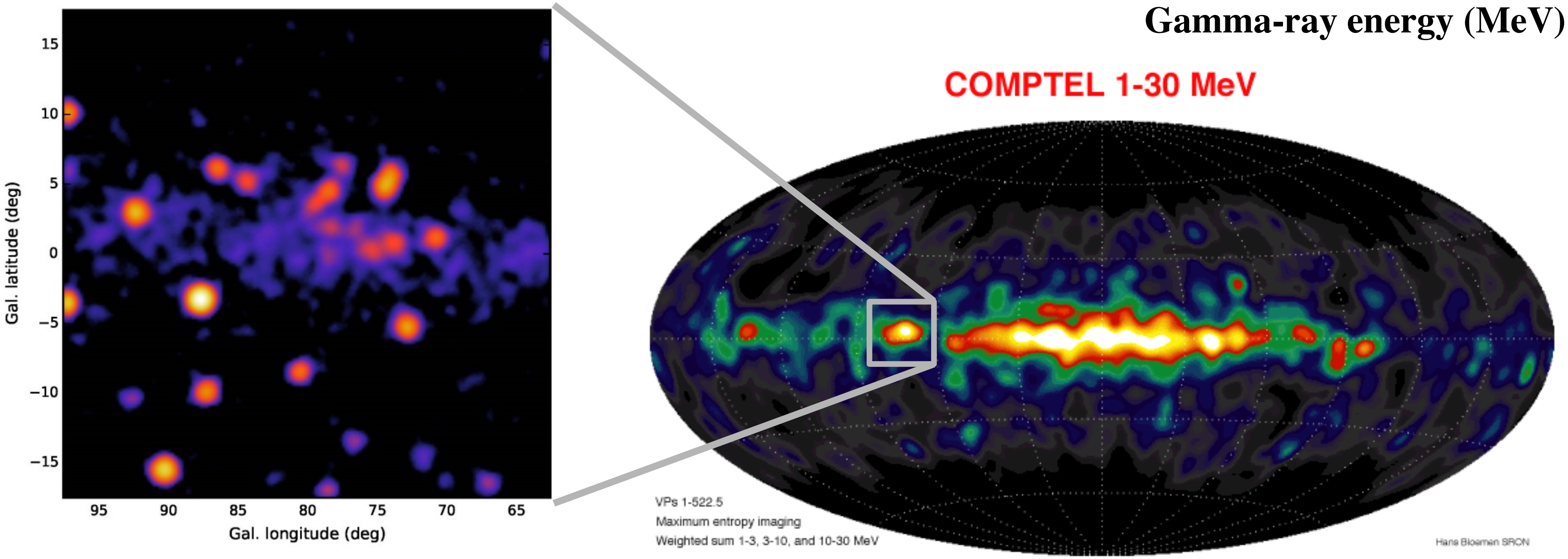


e-ASTROGAM Angular resolution

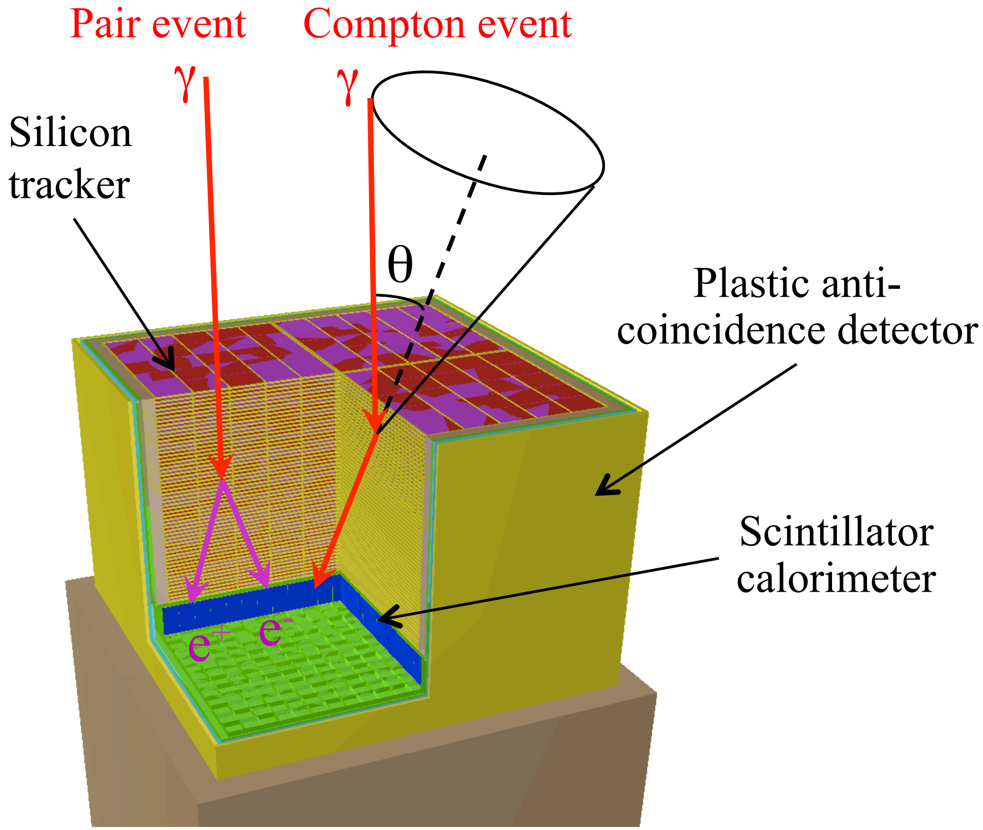
- Angular resolution needs to be improved close to the physical limits (Doppler broadening, nuclear recoil)

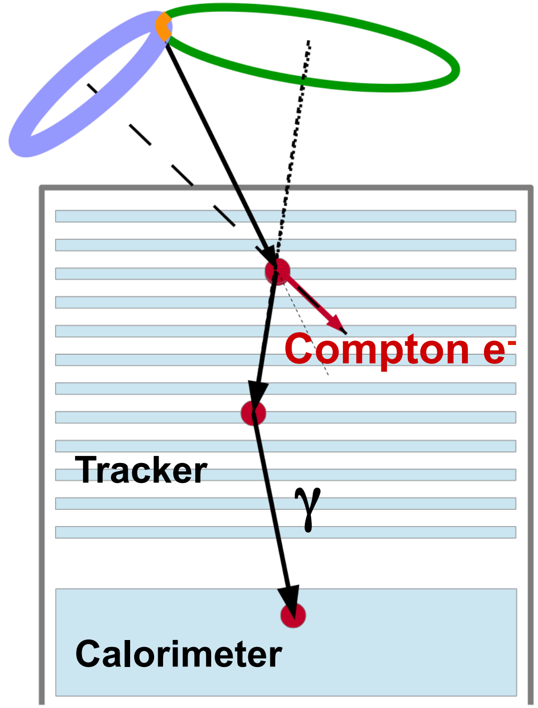


Cygnus region in the 1 - 3 MeV energy band with the e-ASTROGAM PSF (extrapolation of the 3FGL source spectra to low energies)



e-ASTROGAM Measurement principle



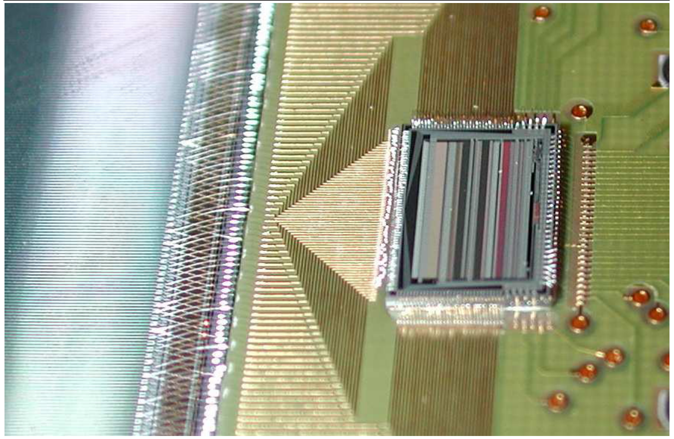


Tracked Compton event

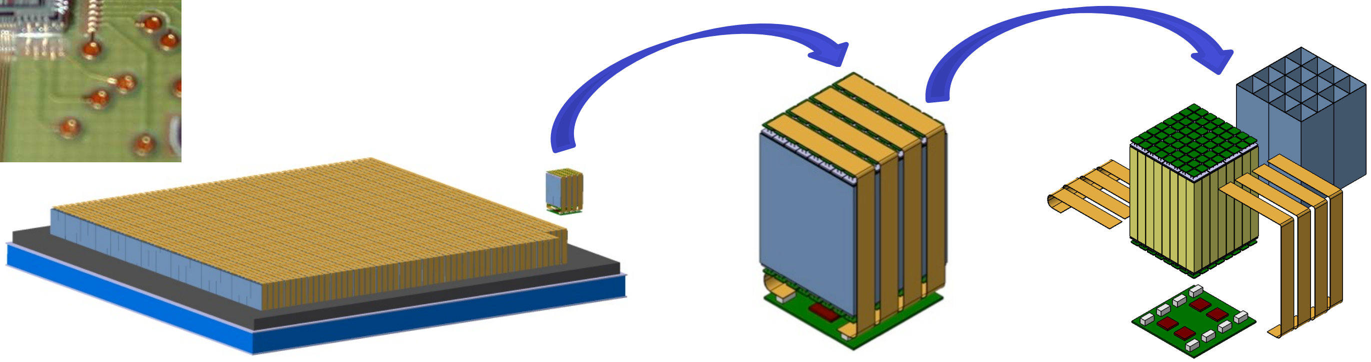
- **Tracker** – Double sided Si strip detectors (DSSDs) for excellent spectral resolution and fine 3-D position resolution
- **Calorimeter** – High-Z material for an efficient absorption of the scattered photon ⇒ CsI(Tl) scintillation crystals readout by Si Drift Diodes for better energy resolution
- **Anticoincidence detector** to veto charged-particle induced background ⇒ plastic scintillators readout by Si photomultipliers

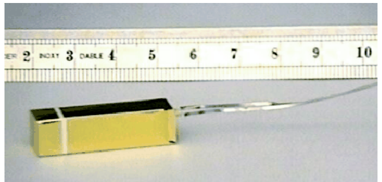
Payload

Detail of the detector-ASIC bonding in the AGILE Si Tracker



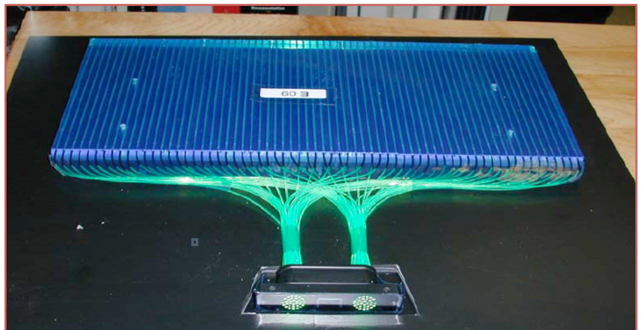
- **Tracker**: 56 layers of 4 times 5×5 DSSDs (5 600 in total) of 500 μm thickness and 240 μm pitch
- DSSDs bonded strip to strip to form 5×5 ladders
- Light and stiff mechanical structure
- Ultra low-noise front end electronics





PICSiT CsI(Tl) pixel

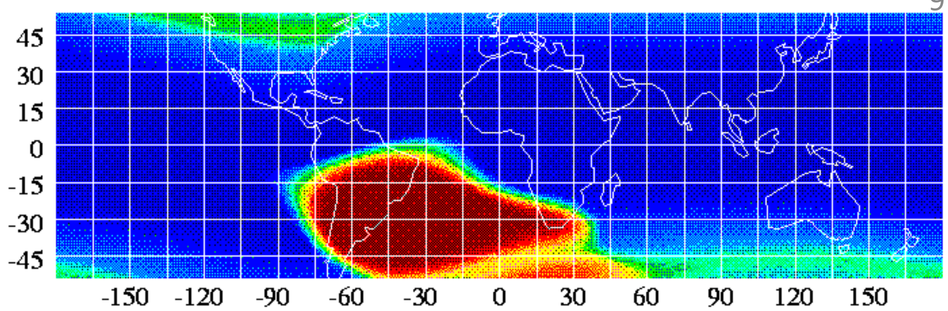
- **Calorimeter**: 33 856 CsI(Tl) bars coupled at both ends to low-noise Silicon Drift Detectors
- **ACD**: segmented plastic scintillators coupled to SiPM by optical fibers
- **Heritage**: AGILE, Fermi/LAT, AMS-02, INTEGRAL, LHC/ALICE…

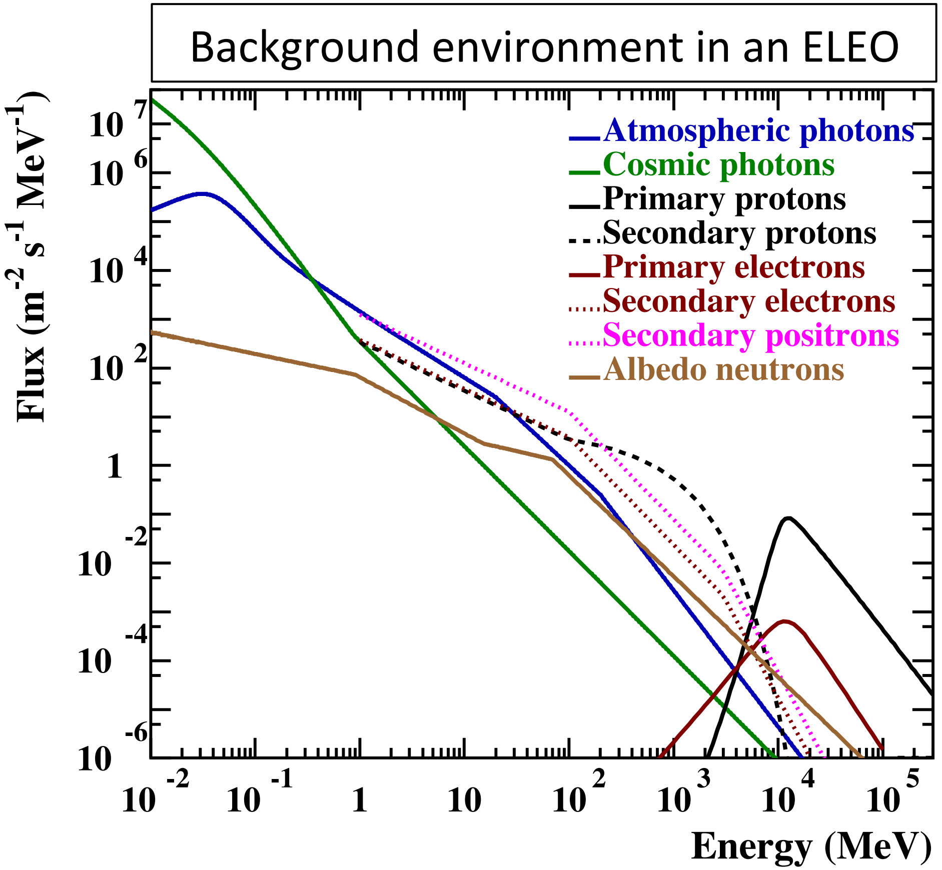


Fermi/LAT AC system

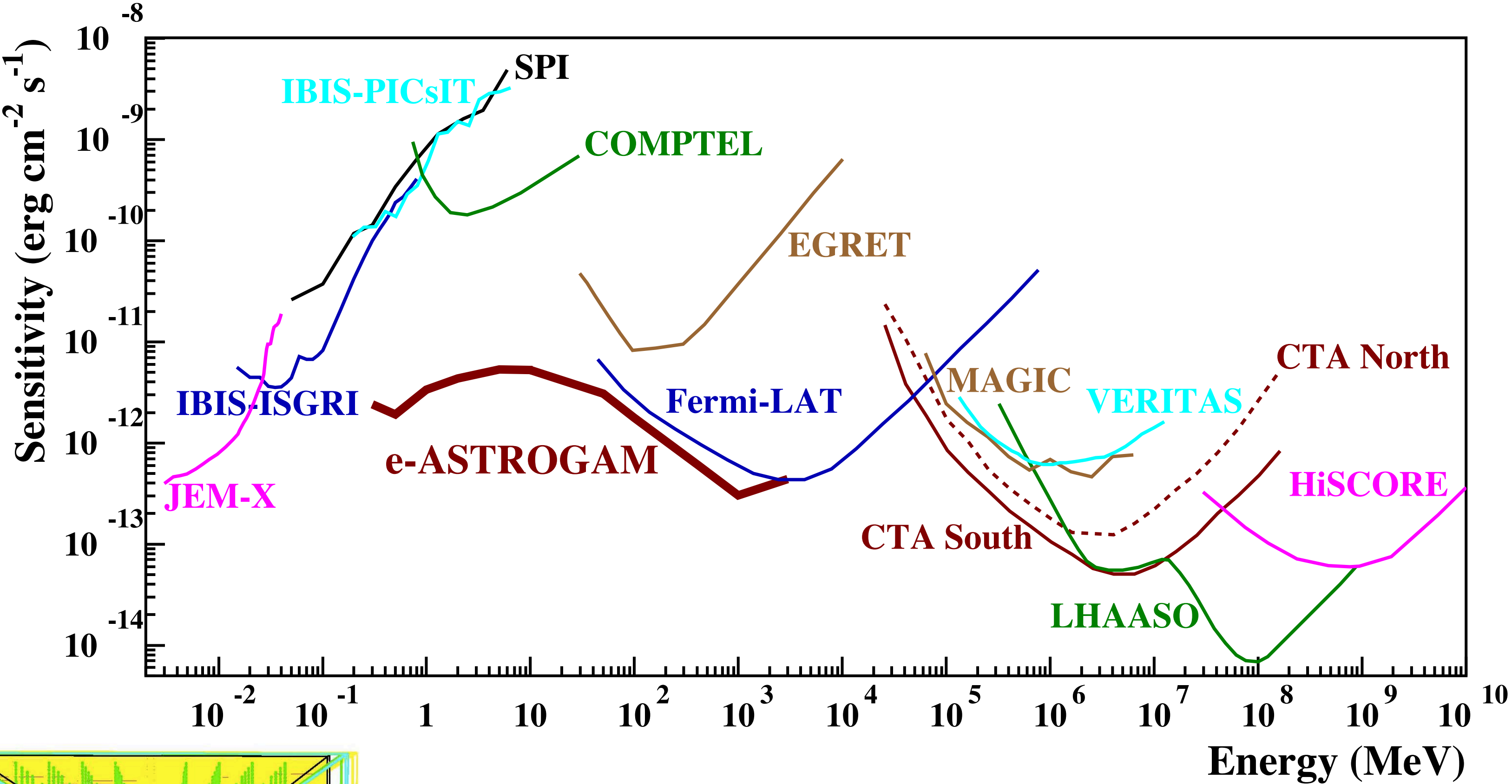
Mission profile

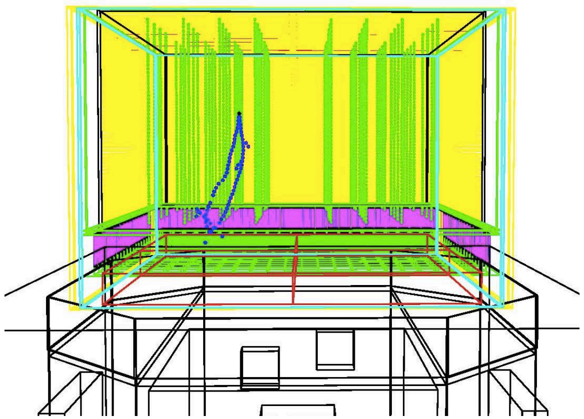
- **Orbit** – Equatorial (inclination *i* < 2.5°, eccentricity *e* < 0.01) low-Earth orbit (altitude in the range 550 - 600 km)
- **Launcher** – Ariane 6.2
- **Satellite communication** – ESA ground station at Kourou + ASI Malindi station (Kenya)
- **Data transmission** – via X-band (available downlink of 10 Mbps)
- **Observation modes** – (i) zenith-pointing sky-scanning mode, (ii) nearly inertial pointing, and (iii) fast repointing to avoid the Earth in the field of view
- **In-orbit operation** – 3 years duration + provisions for a 2+ year extension





e-ASTROGAM Performance assessment





- e-ASTROGAM performance evaluated with **MEGAlib** (Zoglauer et al. 2006) and **Bogemms** (Bulgarelli et al. 2012) – both tools based on Geant4 – and a detailed numerical mass model of the gamma-ray instrument

1. Jet astrophysics: a unique link to new astronomies (gravitational waves, neutrinos, ultra-high energy cosmic rays)

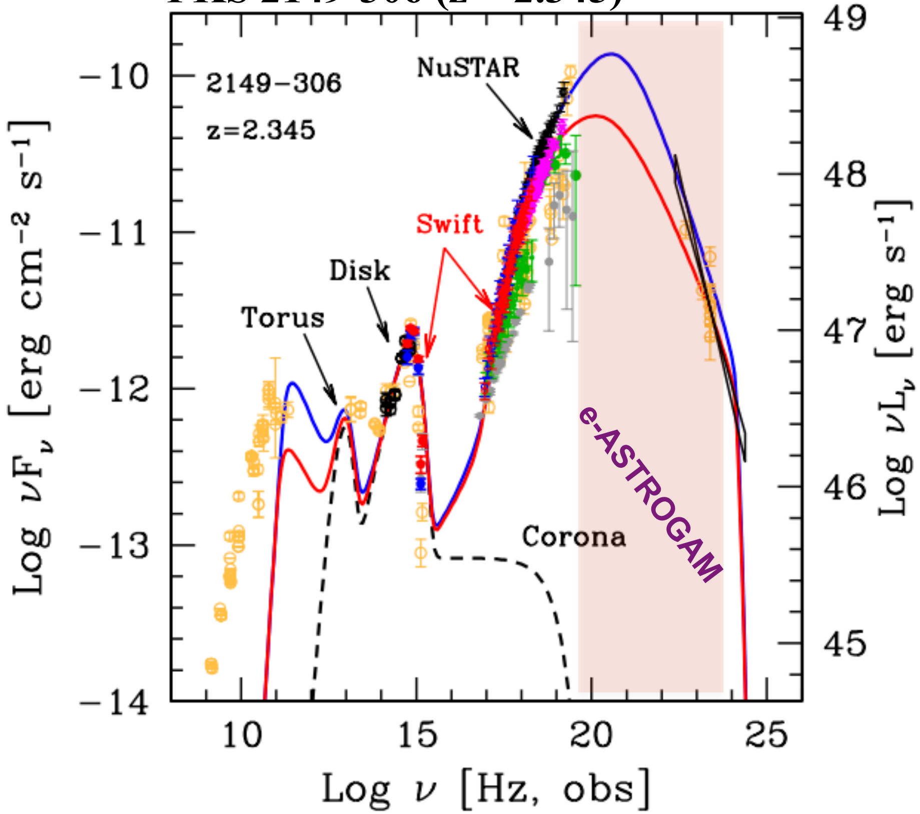
2. The high-energy mysteries of the Galactic center region

3. Supernovae, nucleosynthesis and Galactic chemical evolution

Jet astrophysics in the era of new astronomies

- *Launch of ultra-relativistic jets in* ***GRBs****? Ejecta composition, energy dissipation site, radiation processes?*
- *Can short-duration GRBs be unequivocally associated to* ***gravitational wave*** *signals?*
- *How does the accretion disk/jet transition occur around supermassive black holes in* ***AGN****?*
- *Are BL Lac blazars sources of* ***UHECRs*** *and high-energy* ***neutrinos****?*

PKS 2149-306 (z = 2.345)

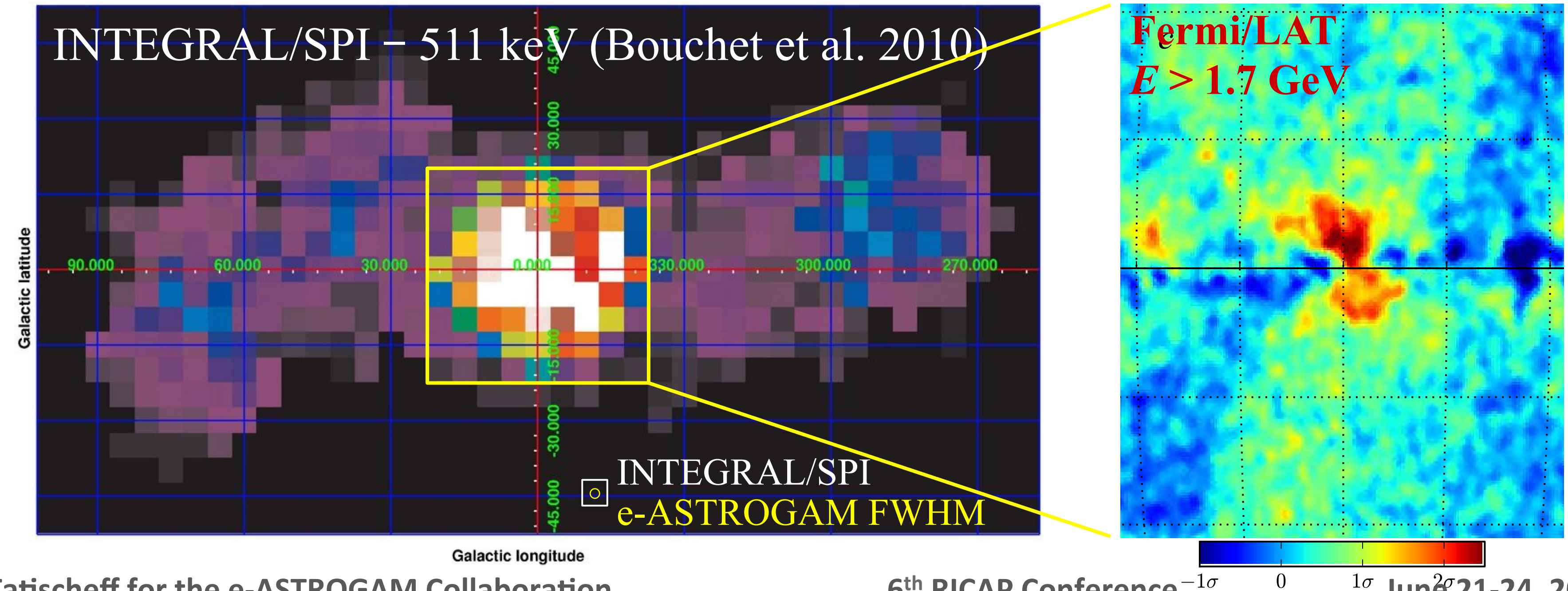


✓ With its wide **field of view**, unprecedented **sensitivity** over a large spectral band, and exceptional capacity for **polarimetry**, **e-ASTROGAM** will give access to a variety of extreme **transient** phenomena

The high-energy mysteries at the Galactic Center

- *Origin of the **Fermi Bubbles** and of the **511 keV emission** from the Galaxy's bulge? Are these linked to a past activity of the central **supermassive black hole**? What is causing the **GeV excess** emission from the center region?*

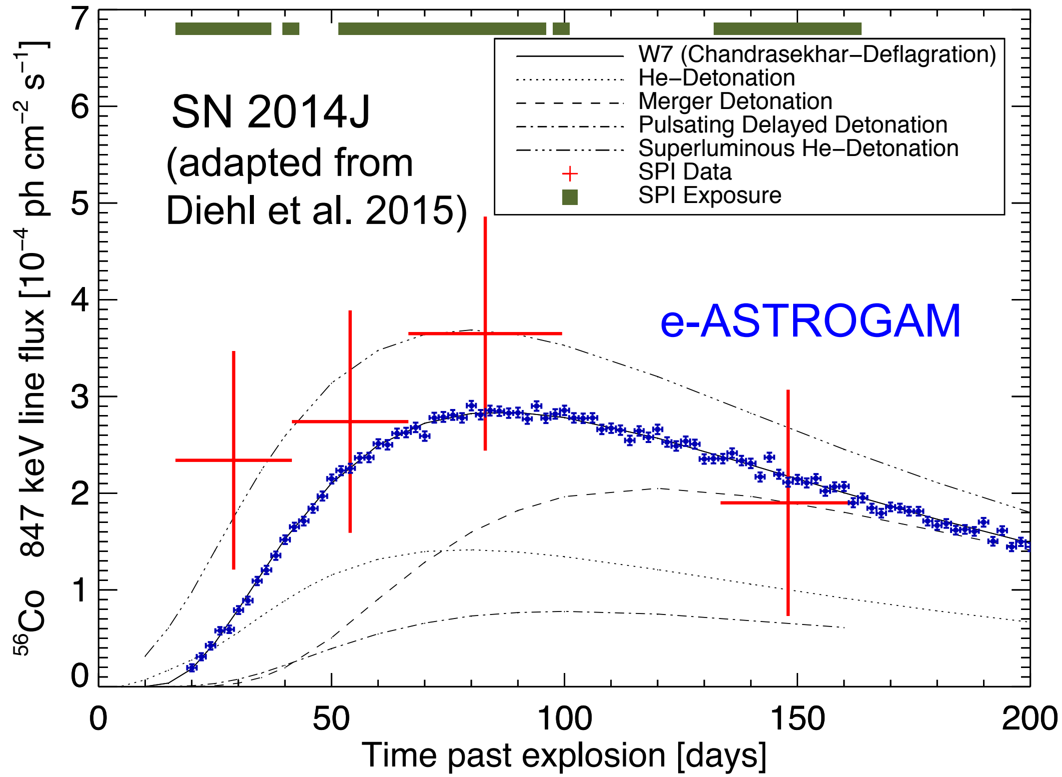
✓ With a **sensitivity** and an **angular resolution** in the MeV – GeV range significantly improved over previous missions, **e-ASTROGAM** will enable a detailed **spectro-imaging** of the various high-energy components



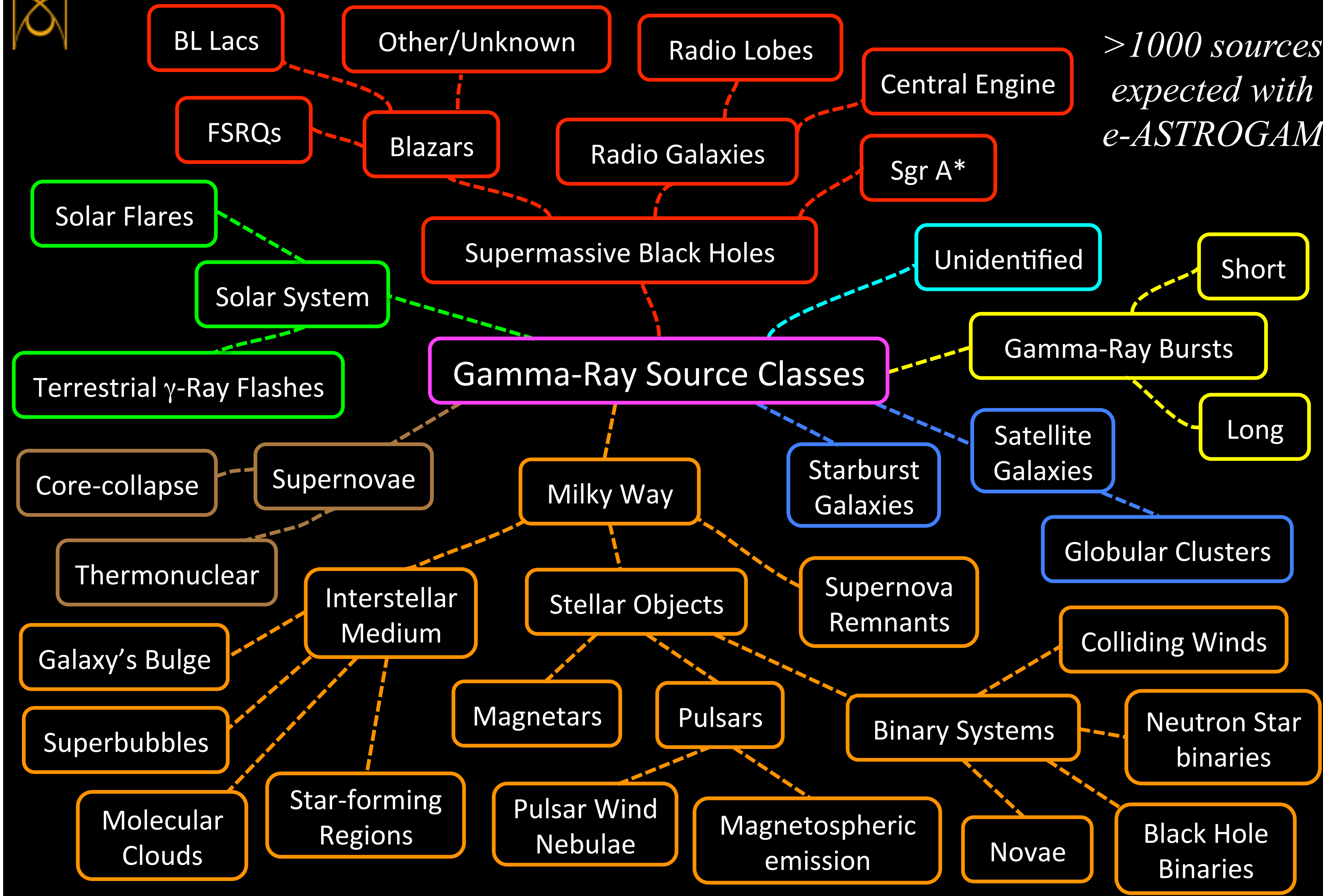
Supernovae, nucleosynthesis, and Galactic chemical evolution

- *How do thermonuclear and core-collapse SNe explode? How are cosmic isotopes created in stars and distributed in the interstellar medium?*

✓ With a remarkable improvement in **γ-ray line sensitivity** over previous missions, **e-ASTROGAM** should allow us to finally understand the progenitor system(s) and explosion mechanism(s) of **Type Ia SNe** (^{56}Ni, ^{56}Co), the dynamics of **core collapse** in massive star explosions (^{56}Co, ^{57}Co), and the history of **recent SNe** in the Milky Way (^{44}Ti, ^{60}Fe...)

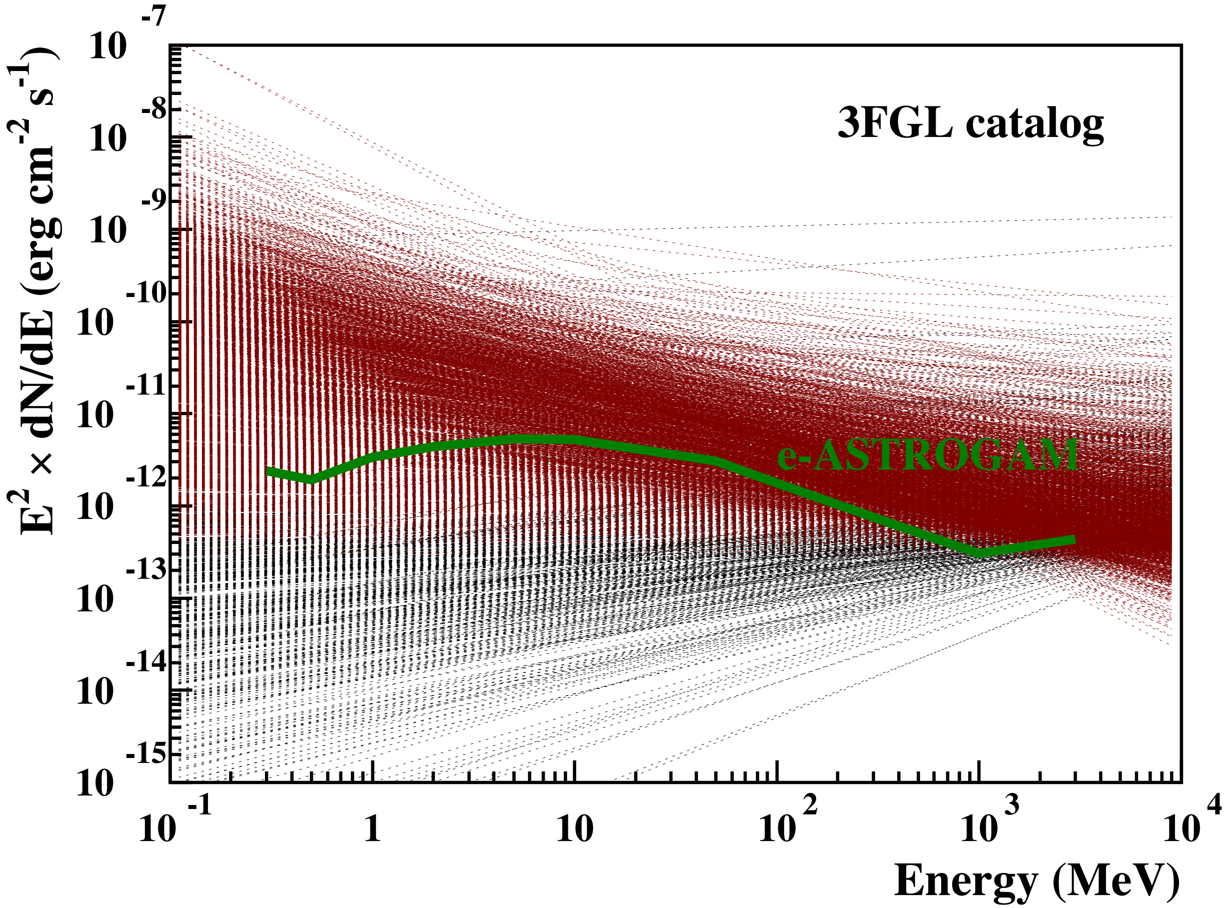


>1000 sources expected with e-ASTROGAM



Discovery space

- Over 3/4 of the sources from the 3rd *Fermi* LAT Catalog (3FGL), 2415 sources over 3033, have power-law spectra (E_γ > 100 MeV) steeper than E_γ^{-2}, implying that their peak energy output is below 100 MeV



- These includes more than 1200 (candidate) blazars (mostly FSRQ), about 150 pulsars, and nearly **900 unassociated sources**
- Most of these sources will be detected by **e-ASTROGAM** ⇒ large discovery space for new sources and source classes

e-ASTROGAM Collaboration

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University College Dublin, DIAS

DTU

University of Geneva

Jagiellonian University, CBK, NCAC

NASA GSFC, NRL, Clemson Univ., Washington Univ., Yale Univ., UC Berkeley

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University of Tokyo

Conclusions

- **The MeV / sub-GeV gamma-ray band is potentially one of the richest energy domain of astronomy**
- **e-ASTROGAM will be an essential observatory to study the extreme transient sky at the era of astronomy's new messengers**
- **The e-ASTROGAM payload is innovative in many respects, but the technology is ready**