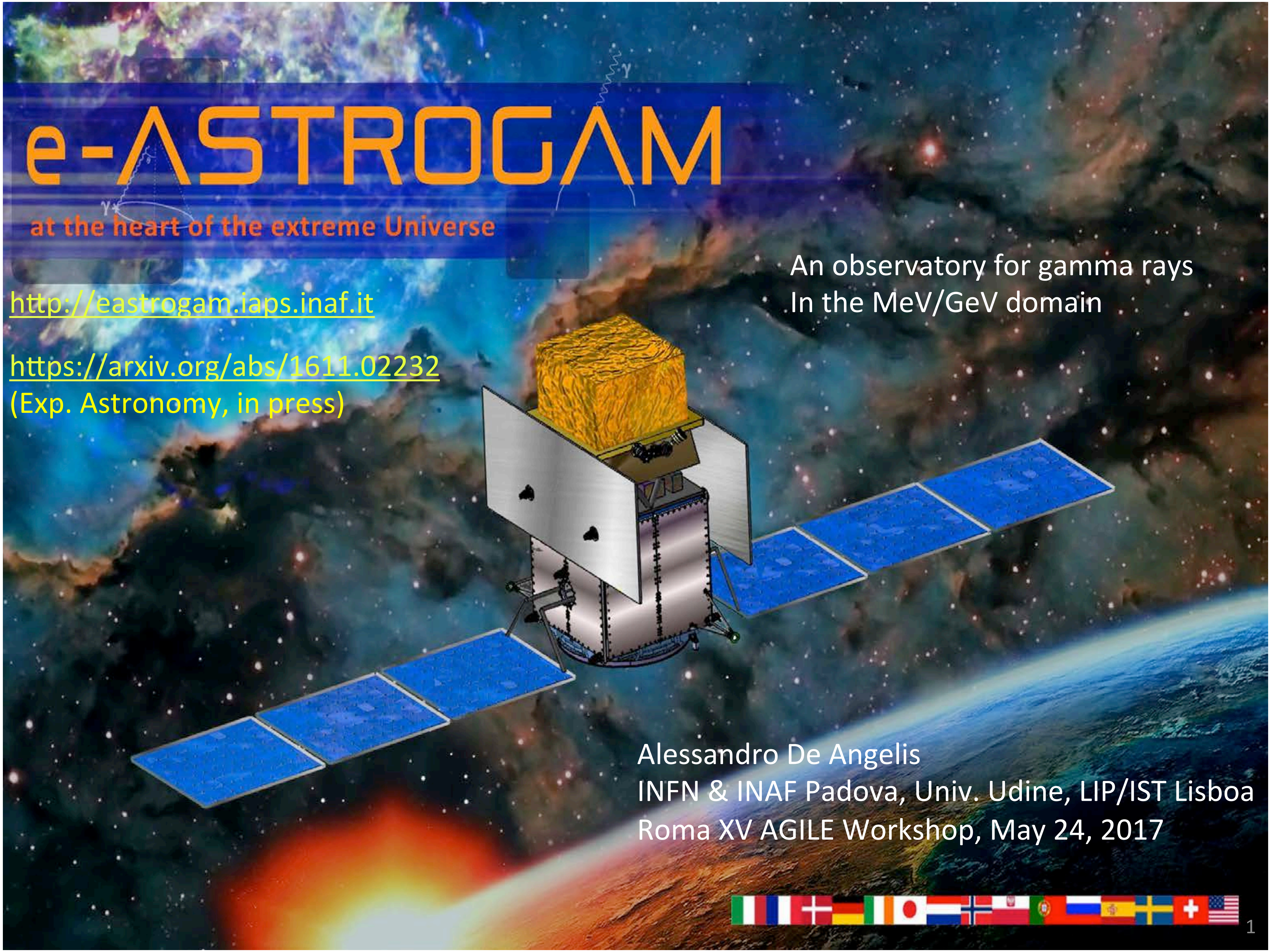
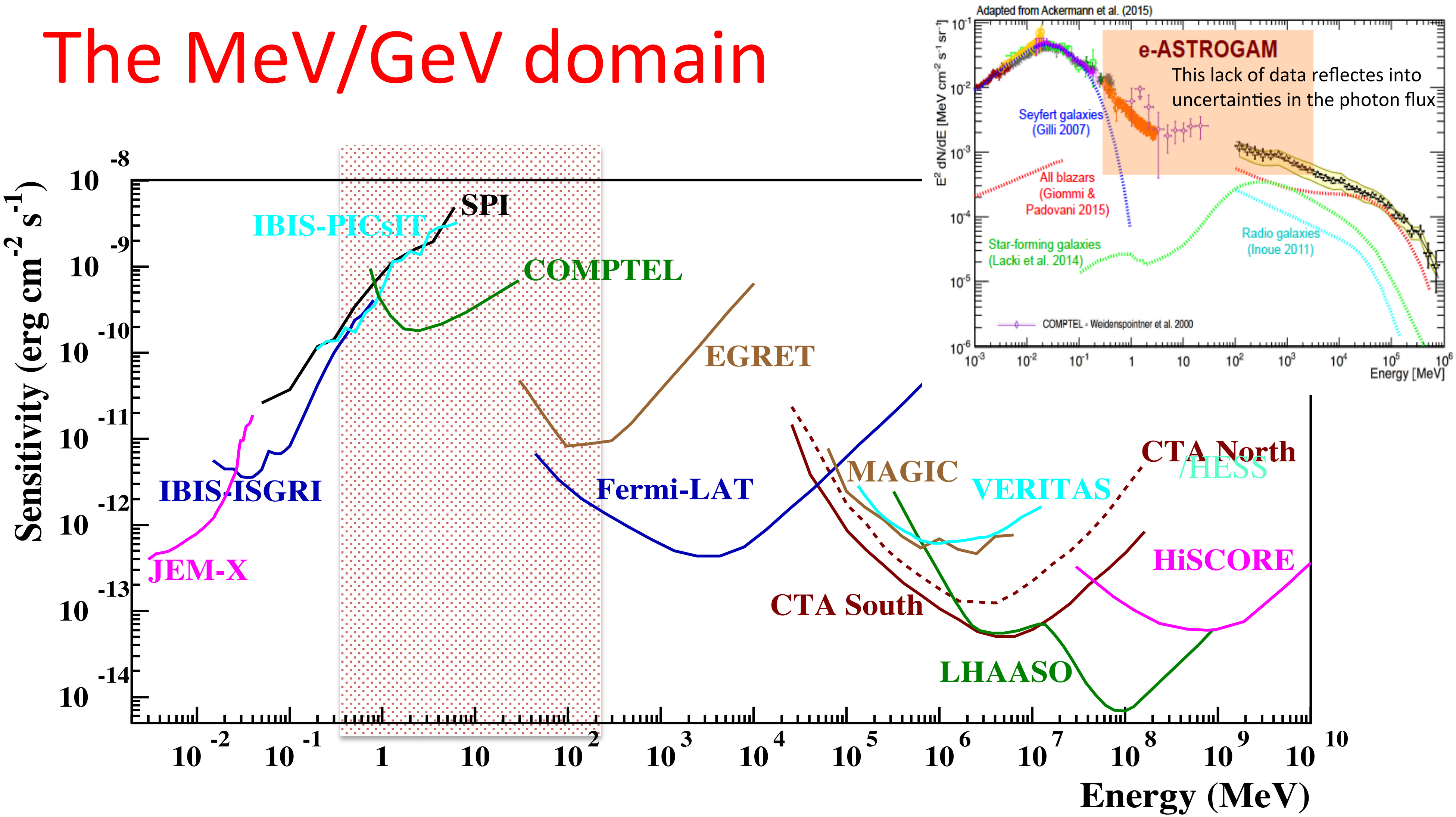

e-ASTROGAM
at the heart of the extreme Universe
http://eastrogam.iaps.inaf.it
https://arxiv.org/abs/1611.02232
(Exp. Astronomy, in press)
An observatory for gamma rays
In the MeV/GeV domain
Alessandro De Angelis
INFN & INAF Padova, Univ. Udine, LIP/IST Lisboa
Roma XV AGILE Workshop, May 24, 2017

The MeV/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...)
- Binding energies of atomic nuclei fall in this range, which therefore is as important for HE astronomy as visible light is for phenomena related to atomic physics

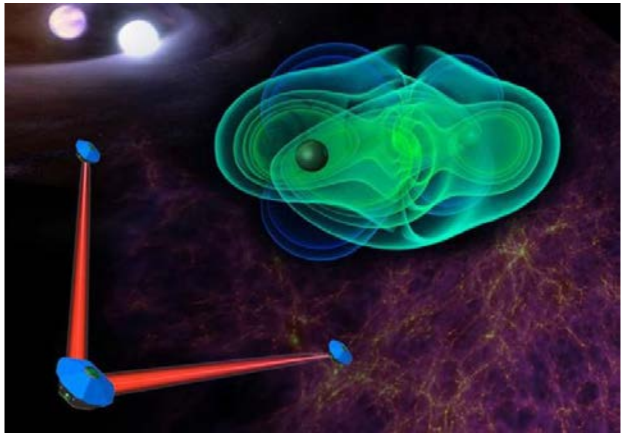
Core science motivation

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 CTA, SKA, eLISA, ν detectors...), with special focus on transient phenomena

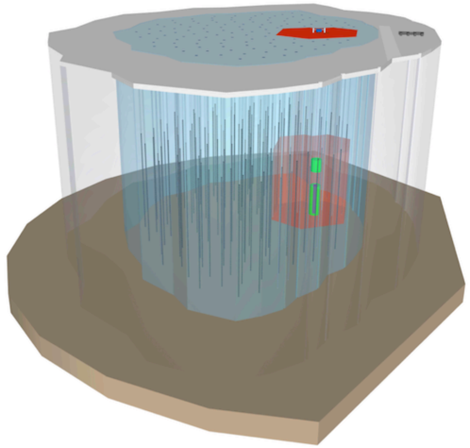
2. The origin of high-energy particles and impact on galaxy evolution, from cosmic rays to antimatter

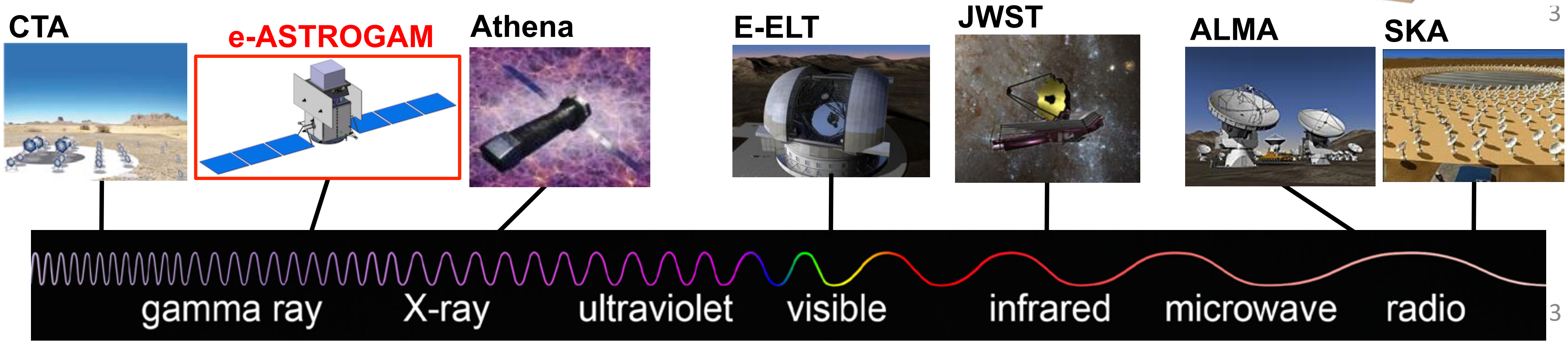
3. Nucleosynthesis and the chemical enrichment of our Galaxy

eLISA – Gravitational waves



Km3Net/IceCube-Gen2 - ν





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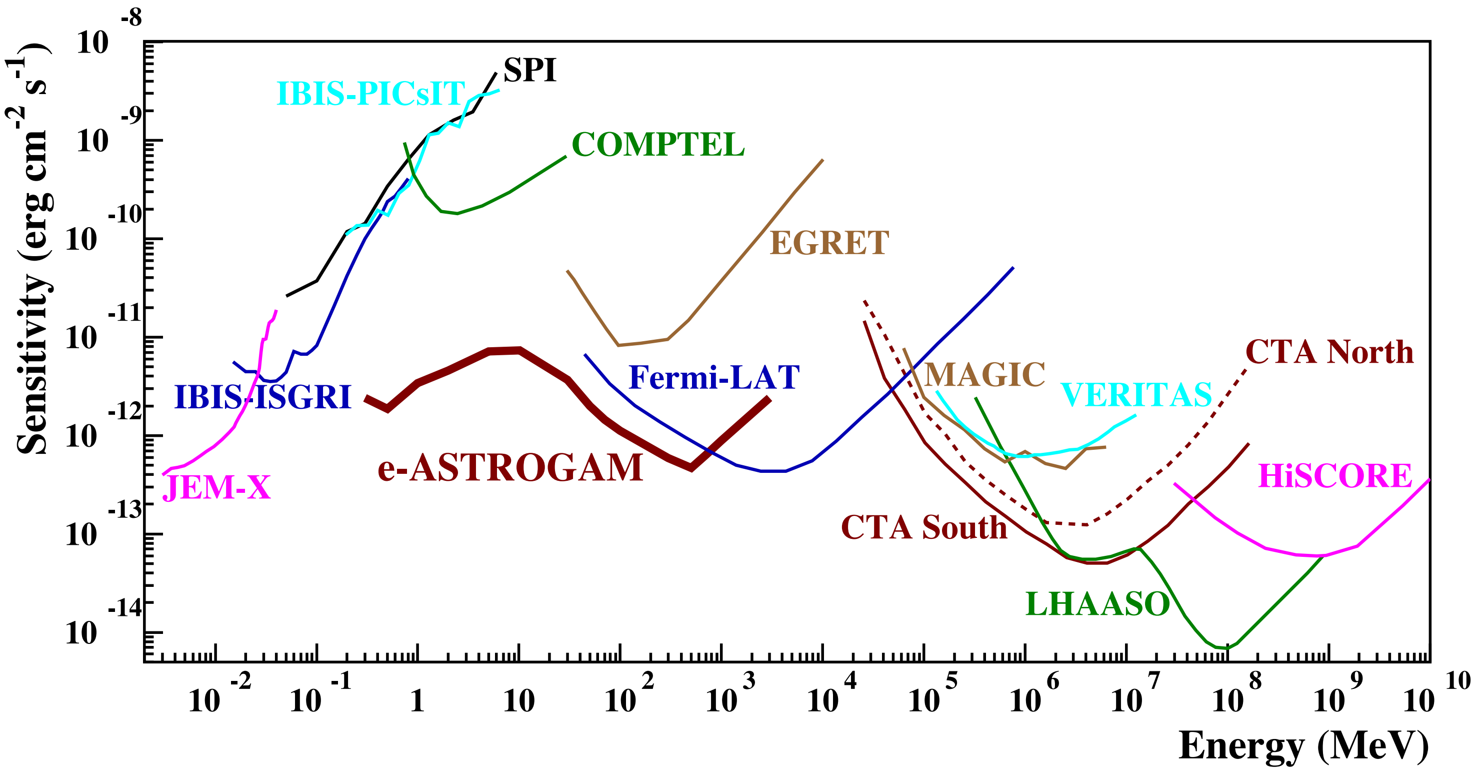
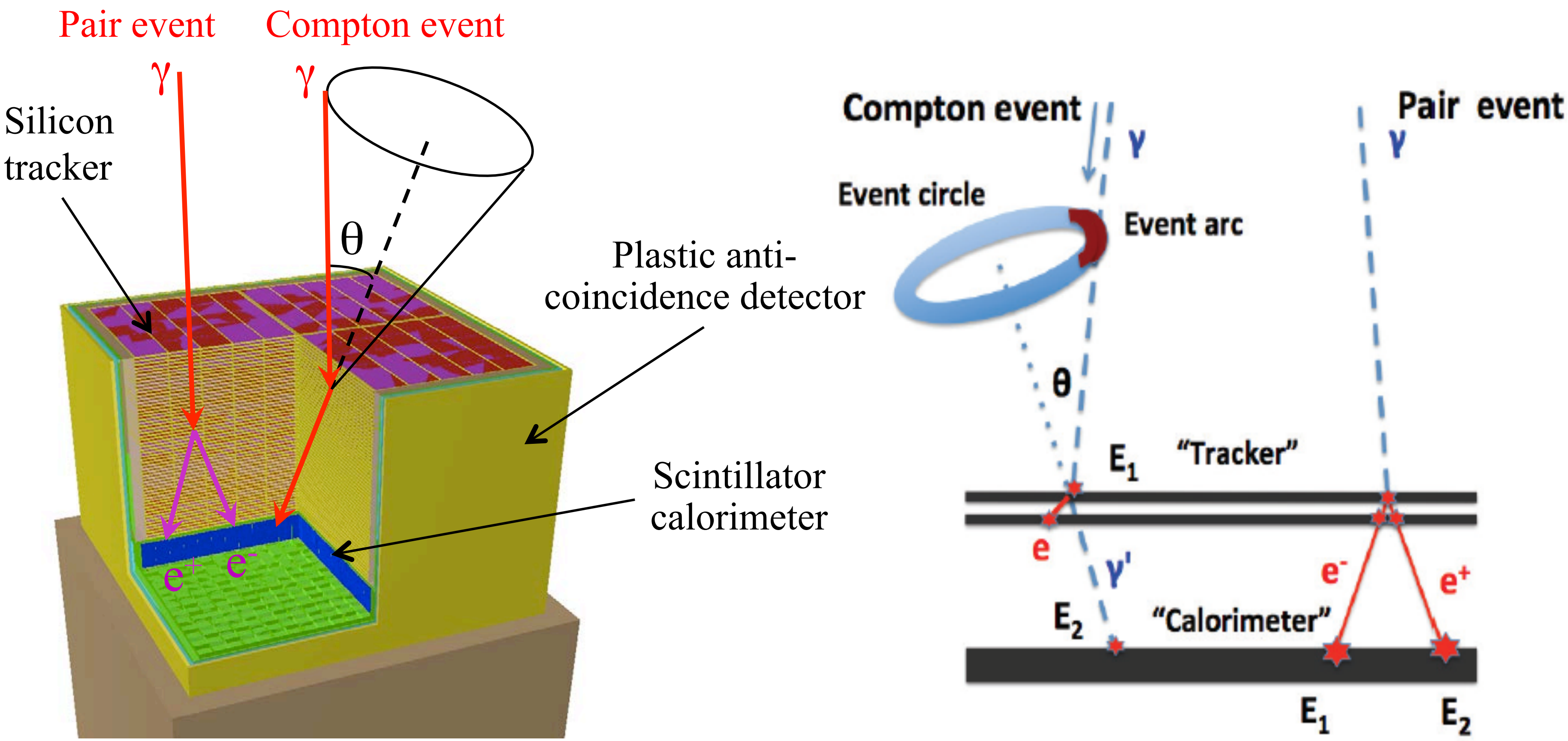
e-ASTROGAM scientific requirements

1. Achieve a sensitivity better than INTEGRAL/CGRO/COMPTEL by a factor of 20 - 50 – 100 in the range 0.2 – 30 MeV
2. Fully exploit gamma-ray polarization for both transient and steady sources
3. Improve significantly the angular resolution (to reach, e.g., ~ 10’ at 1 GeV)
4. Achieve a very large field of view (~ 2.5 sr) ⇒ efficient monitoring of the γ-ray sky
5. Enable sub-millisecond trigger and alert capability for transients



How to measure gamma rays in the MeV-GeV?



- **Tracker** – Double sided Si strip detectors (DSSDs) for excellent spectral resolution and fine 3-D position resolution (1m^2, 500 μm thick, 0.3 Xo in total)
- **Calorimeter** – High-Z material for an efficient absorption of the scattered photon ⇒ CsI(Tl) scintillation crystals readout by Si drift detectors or photomultipliers for best energy resolution. 8 cm (4.3 Xo)
- **Anticoincidence detector** to veto charged-particle induced background ⇒ plastic scintillators readout by Si photomultipliers

Key instrument characteristics: a summary

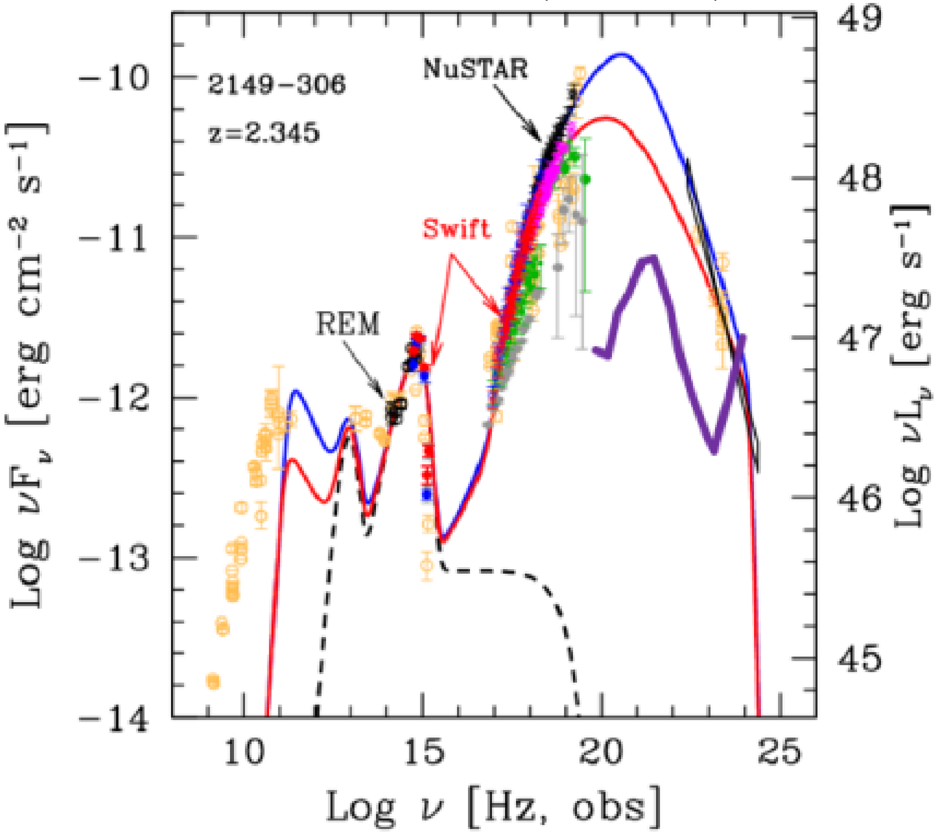
- Best PSF in MeV-GeV
  - Resolve sources
- Calorimetric measurements of MeV lines with high resolution:
  - Positron detection (511 keV line)
  - Measurements of isotopic contents, with highest sensitivity
  - Hadronic collisions of LECR with molecular clouds
- Capability of measuring polarization (marks Compton interactions at the sources and magnetic fields)
- SED resolution in the MeV/GeV range: allows to reconstruct the "pion bump", characteristic of the decay $\pi^o \rightarrow \gamma\gamma$ and thus an indicator of hadronic processes

e-ASTROGAM core science topic #1

At the heart of the extreme Universe

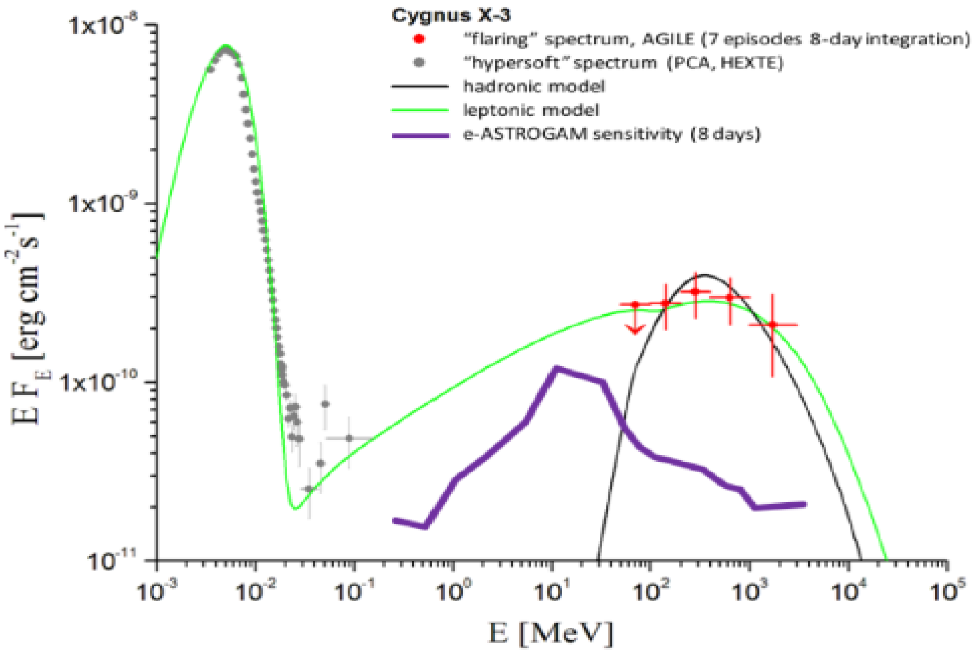
- *How does the accretion disk/jet transition occur around supermassive black holes in **AGN**?*
- *Are BL Lacs sources of **UHECRs** and high-energy **neutrinos**?*
- *Launch of ultra-relativistic jets in **GRBs**? Ejecta composition, radiation processes?*
- *Can short-duration GRBs be unequivocally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

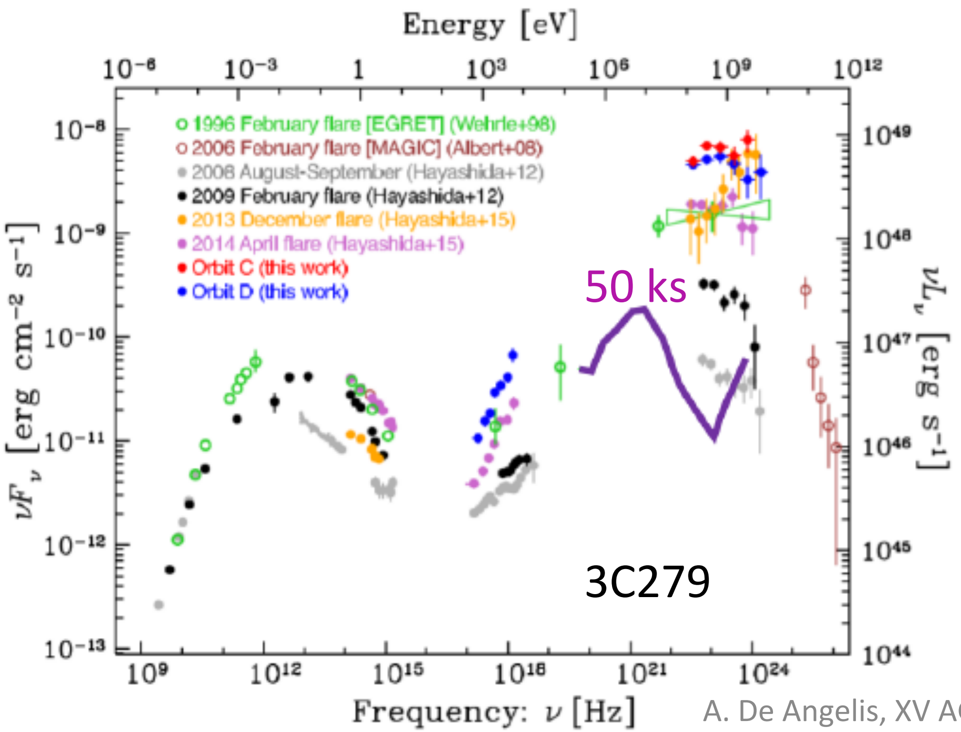
PKS 2149-306 (z = 2.345)

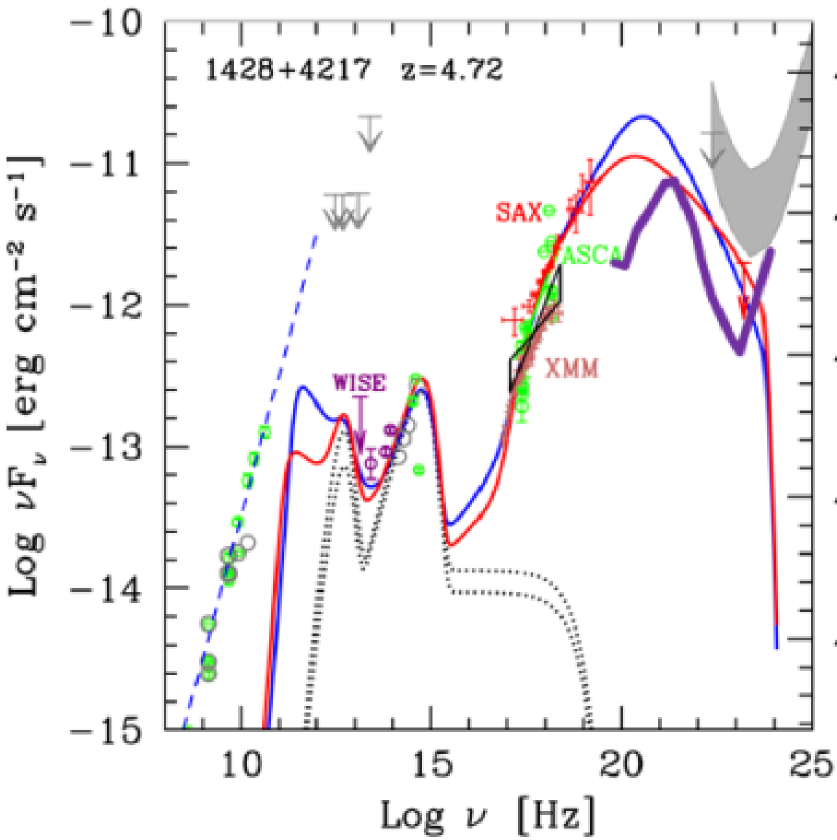


✓ With its wide **field of view**, unprecedented **sensitivity** over a large spectral band, and exceptional capacity for **polarimetry**, **e-ASTROGAM** will give access to a variety of extreme **transient** phenomena

Relativistic jets; flares
MeV blazars
Cosmology up to z ~ 4.5







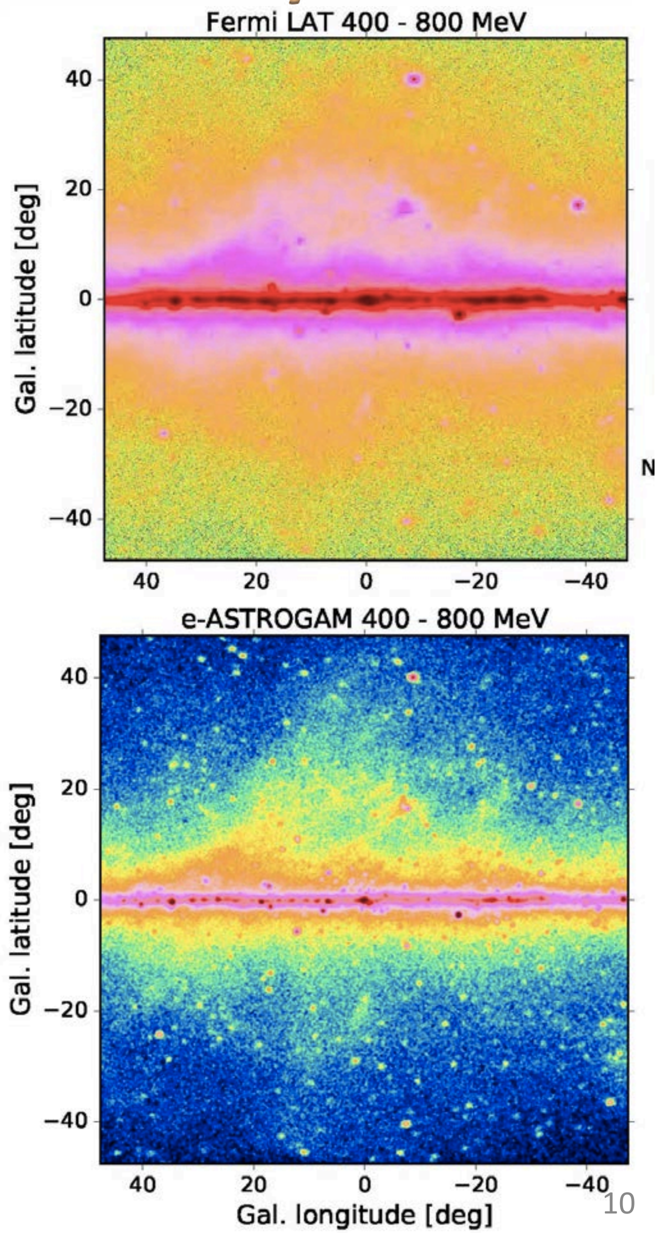
Gamma-ray bursts; the new Astronomy

- Threshold at 30 keV using the Calorimeter
- 200 GRB/year detected
  - Localized within 0.1-1 deg, and the information can be processed onboard
  - 42 GRBs/year with a detectable polarization fraction of 20%
- Possible detection of electromagnetic counterparts of impulsive GW events
  - MeV likely to be the threshold (Patricelli et al. 2016)
  - Possible associations GRB/GW
- MeV good target also for the counterparts of neutrino bursts

e-ASTROGAM core science topic #2

Origin and impact of high-energy particles on Galaxy evolution

- *What are the energy distributions and fluxes of CRs produced in supernova remnants and propagating in the interstellar medium?*
- *What is the role **of low-energy CRs**?*
- *What are the origins of the **Fermi Bubbles** and the **511 keV emission** from the Galaxy's bulge?*



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

Antimatter and Dark Matter

- Unique sensitivity to the 511-keV line
- Sensitivity to many classical positron sources: can constrain the contribution from nearby pulsars in the positron excess seen by PAMELA/AMS-02

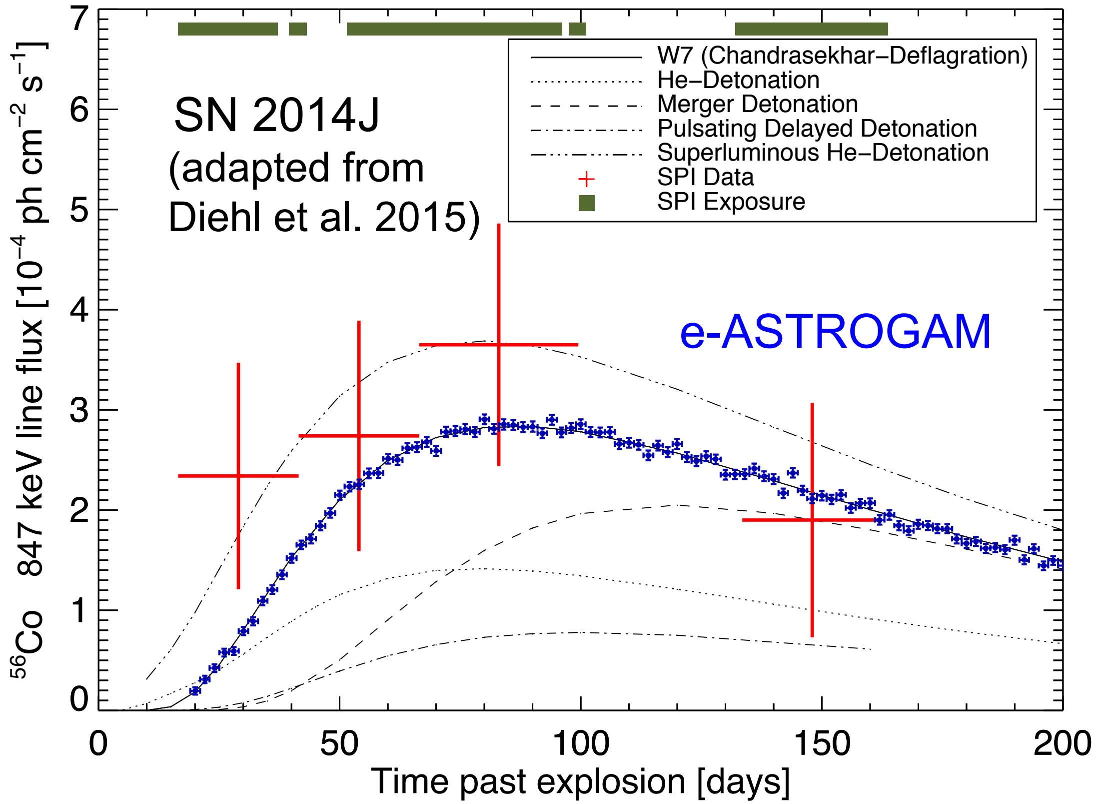
- The MeV region is the missing ingredient to determine the photon background from the Inner Galaxy: clarify if there is a photon excess (which might be due to DM, new particles)
- The MeV region is where the bulk of photons from WIMPs below 100 GeV is expected
- In some models, MeV dark matter
  – Plus Axions, ALPs:
    - Sensitivity to photons emitted by SNe (Meyer et al. 2016)
    - Sensitivity to photon/ALP oscillations (Roncadelli et al. 2011; Hooper et al. 2009)

e-ASTROGAM core science topic #3

Supernovae, nucleosynthesis, and Galactic chemical evolution

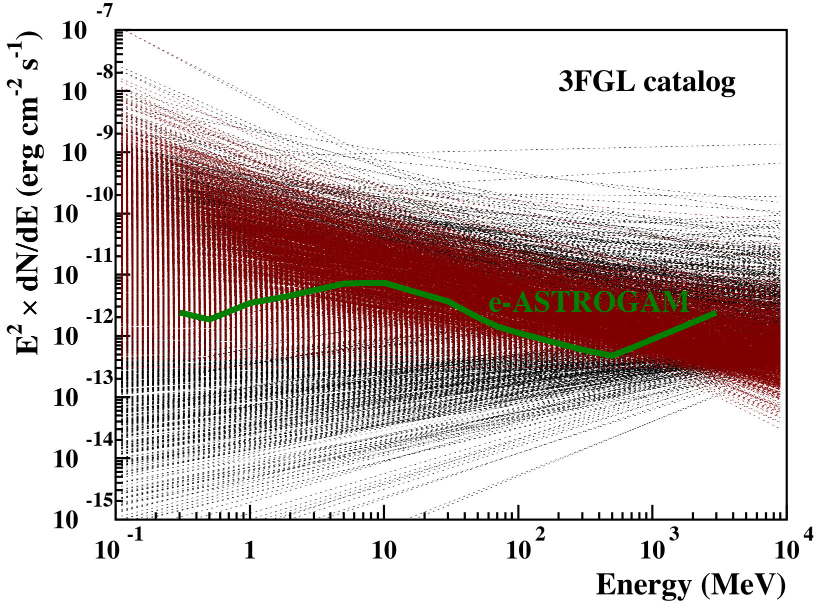
- *How do thermonuclear and core-collapse SNe explode? How are cosmic isotopes created in stars and distributed in the interstellar medium?*

✓ 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...)



e-ASTROGAM discovery space

- Over 2/3 of the 3033 sources from the 3[rd] *Fermi* LAT Catalog (3FGL) 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 about 1100 (candidate) blazars and more than **720 unassociated sources**
- Most of these sources will be detected by **e-ASTROGAM**

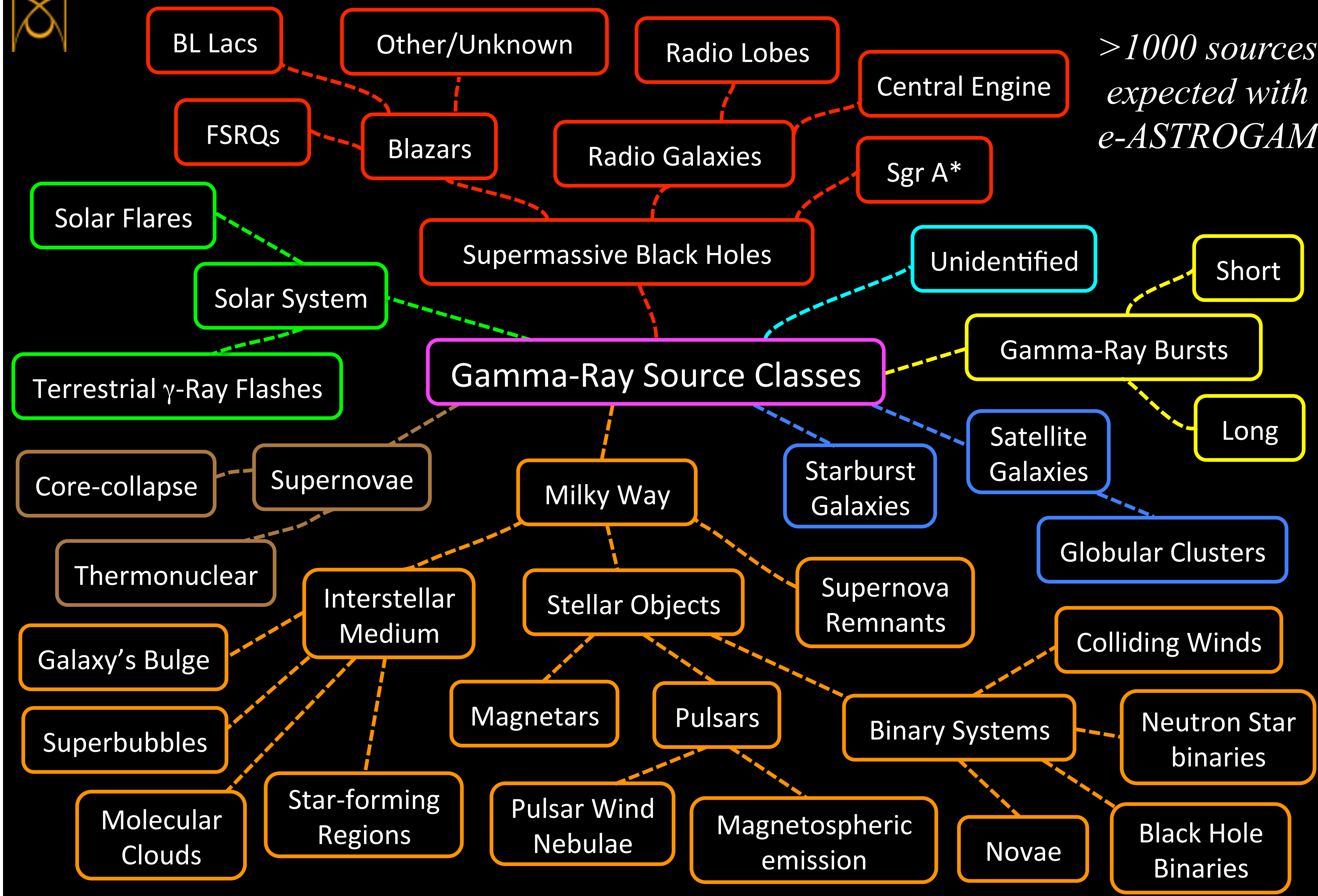
⇒ large discovery space for new sources and source classes

Type	3 yr	New sources
Total	3000 – 4000	∼1800 (including GRBs)
Galactic	∼ 1000	∼400
MeV blazars	∼ 350	∼ 350
GeV blazars	1000 – 1500	∼ 350
Other AGN (<10 MeV)	70 – 100	35 – 50
Supernovae	10 – 15	10 – 15
Novae	4 – 6	4 – 6
GRBs	∼600	∼600

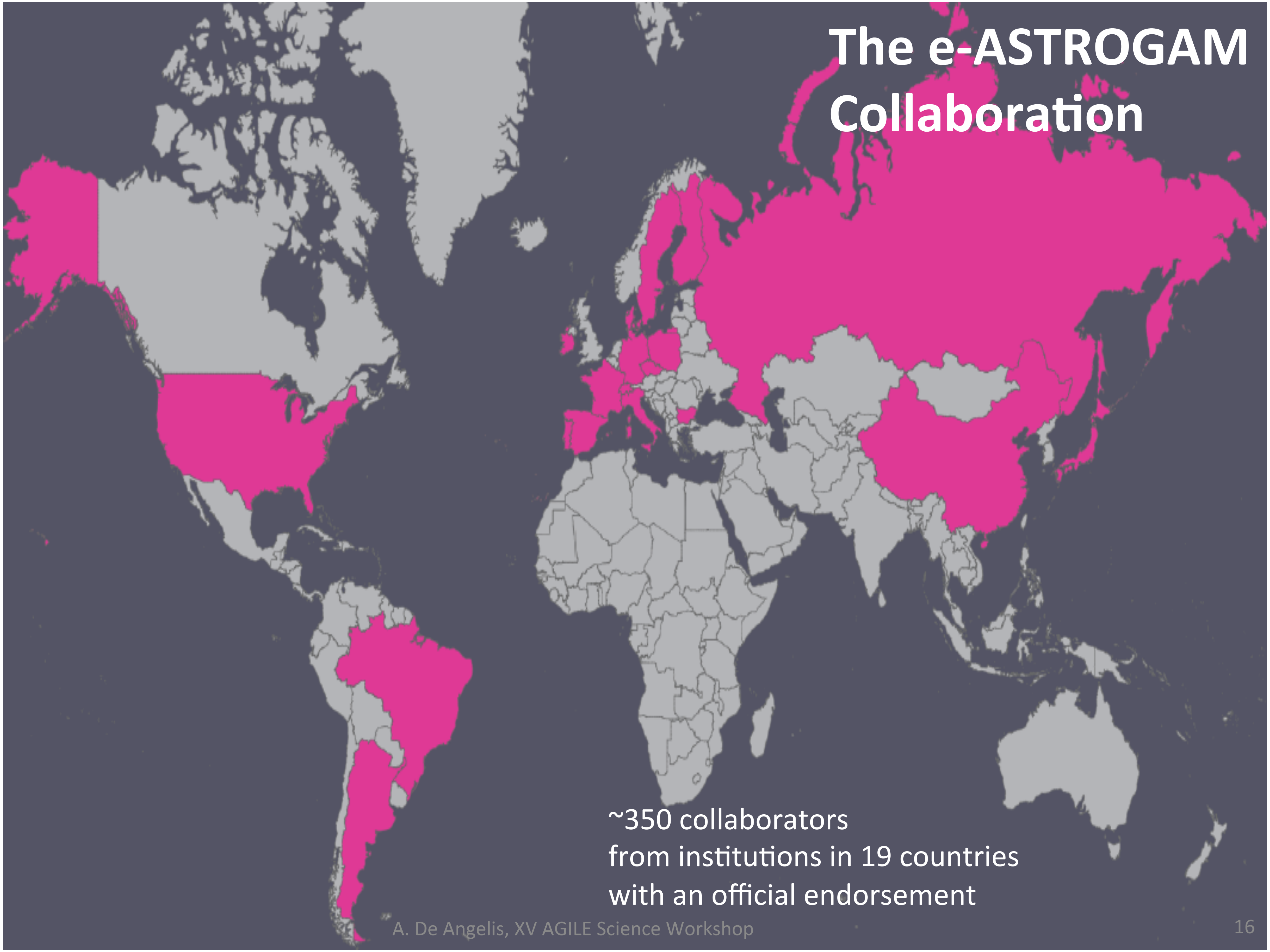
e-ASTROGAM Observatory science

- Diffuse Galactic gamma-ray background
- Pulsars and millisecond pulsars both isolated and in binaries, whose (pulsed or unpulsed) emission will be observable in a spectral range rich in information to discriminate between different particle acceleration models
- PWNe, for which e-ASTROGAM will obtain crucial data on particle acceleration and propagation
- Magnetars
- Galactic compact binaries, including NS and BHs whose spectral transitions and outbursts will be monitored
- Interstellar shocks
- Propagation over cosmological distances (LIV, ALPs, …)
- Novae
- Solar flares and terrestrial gamma-ray flashes

>1000 sources expected with e-ASTROGAM



The e-ASTROGAM Collaboration



~350 collaborators
from institutions in 19 countries
with an official endorsement

The e-ASTROGAM Collaboration (at the proposal time)

Principal investigator: Alessandro De Angelis, INFN/INAF Padova, U. Udine, Italy; LIP/IST, Portugal
Co-I: Vincent Tatischeff – CSNSM (CNRS/IN2P3) Paris, France; Univ. Paris Sud

INFN, INAF, U. Padova, U. & Polit. Bari, U. Roma Tor Vergata, U. Siena, U. Udine, U. Trieste

CSNSM, APC, CEA/Irfu, IPNO, LLR, CENBG, LUPM, IRAP

U. Mainz, KIT/IPE, U. Tübingen, U. Erlangen, RWTH Aachen, U. Potsdam, U. Würzburg, MPE

DPNC UniGe, ISDC, Univ. Geneva, PSI

ICE (CSIC-IEEC), IMB-CNM (CSIC), IFAE-BIST, Univ. Barcelona, CLPU & Univ. Salamanca

KTH and Univ. Stockholm

Czech Technical Univ., Prague; University of Coimbra, LIP and IST Lisboa; Univ.Sofia

DTU Copenhagen

Univ. College Dublin, Dublin City Univ.

Space Research Center of PAS Warsaw

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

Ioffe Institute, St. Petersburg

University of Tokyo

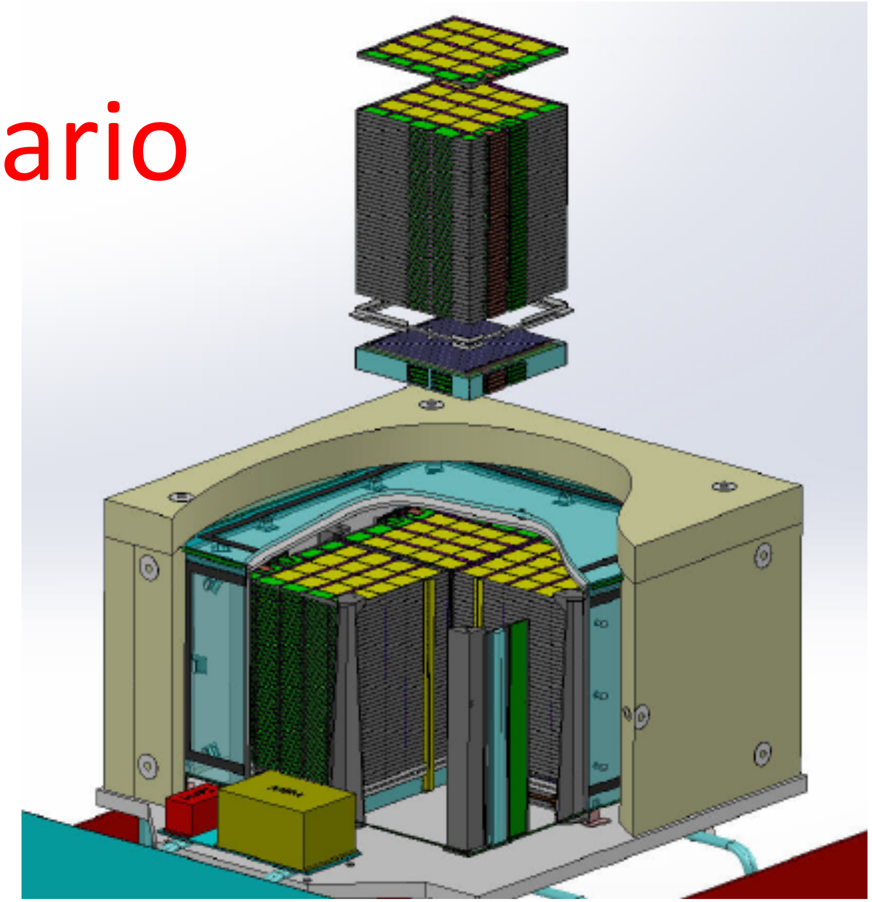
CBPF Rio de Janeiro

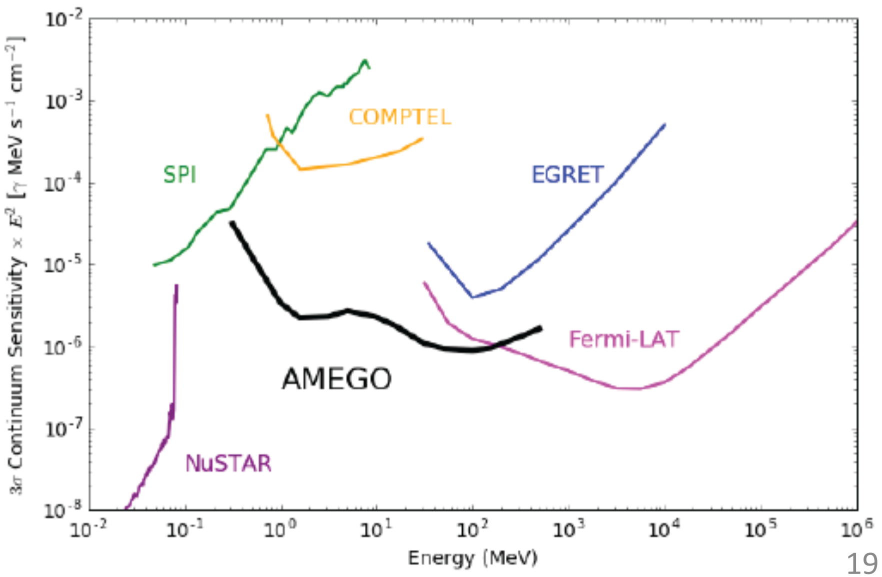
Endorsements from national agencies/ delegations to ESA

- ASI (Italy)
- CNES (France)
- DLR (Germany)
- (Switzerland)
- Swedish National Space Board (Sweden)
- National Space Agency/DTU (Denmark)
- Spanish Research Agency (Spain)
- Polish Space Agency
- FCT (Portugal)
- NASA (US)

The international scenario

- The All-sky Medium Energy Gamma-ray Observatory AMEGO, a similar project from NASA, started evaluation in Dec 2016
- PI is Julie McEnery, NASA GSFC (the old Fermi team); several e-ASTROGAM collaborators are co-I
- If approved, launch in 2028





First e-ASTROGAM Science Workshop

- Padova, Feb 28 - Mar 2, 2017
- Contributed talks & posters on multimessenger astrophysics
- A volume has been produced – google lulu workshop e-astrogam ebook
- Set up a team for a white book (with AMEGO)

Summary

The almost unexplored MeV/GeV gamma-ray band is one of the richest energy domains of astrophysics

e-ASTROGAM can fill the gap and be an essential observatory to study the extreme transient sky in the era of astronomy's new messengers and of multiwavelength science (AGILE)

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

A white book is in progress: participate!