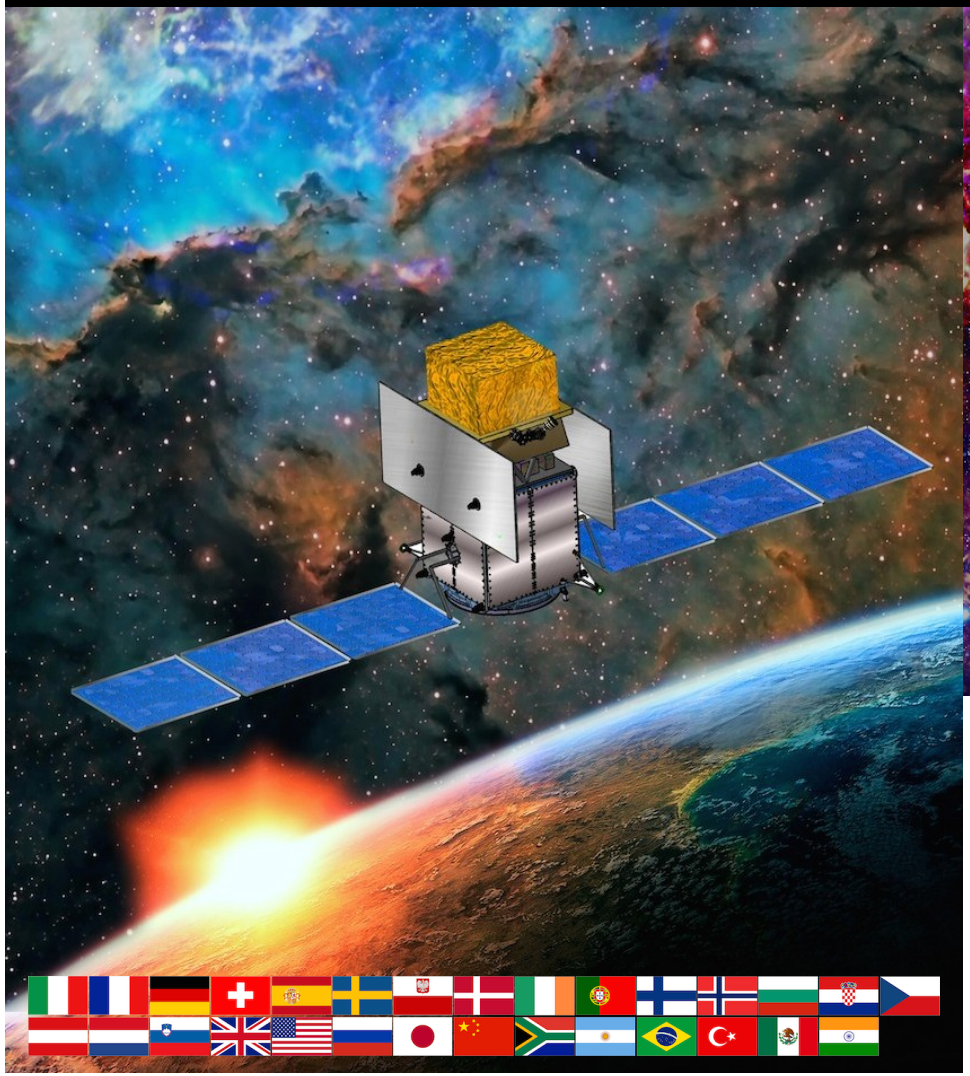
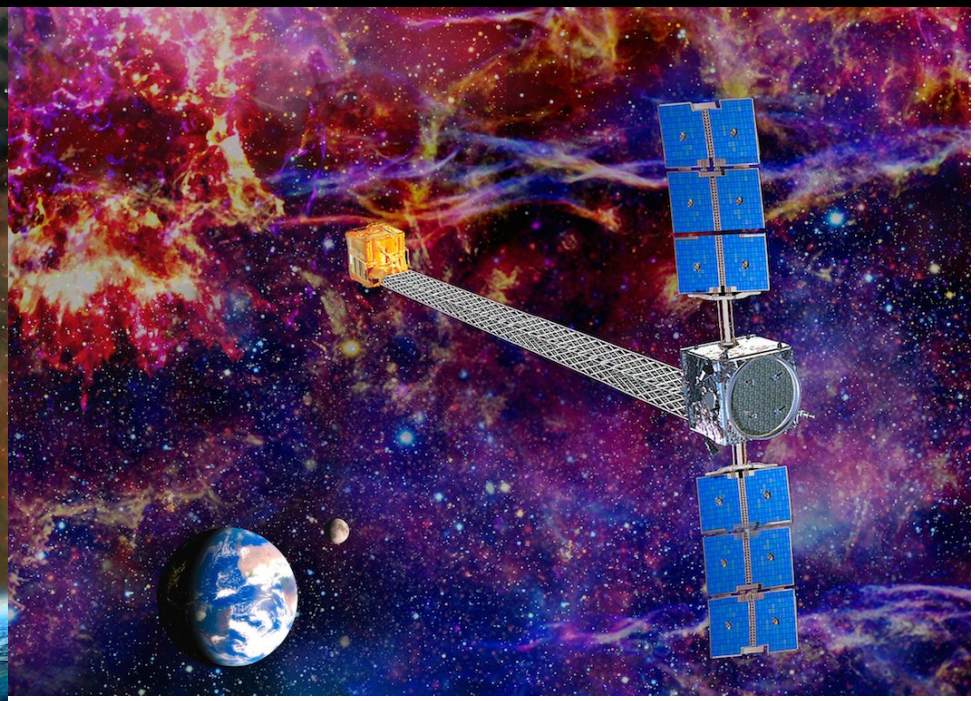
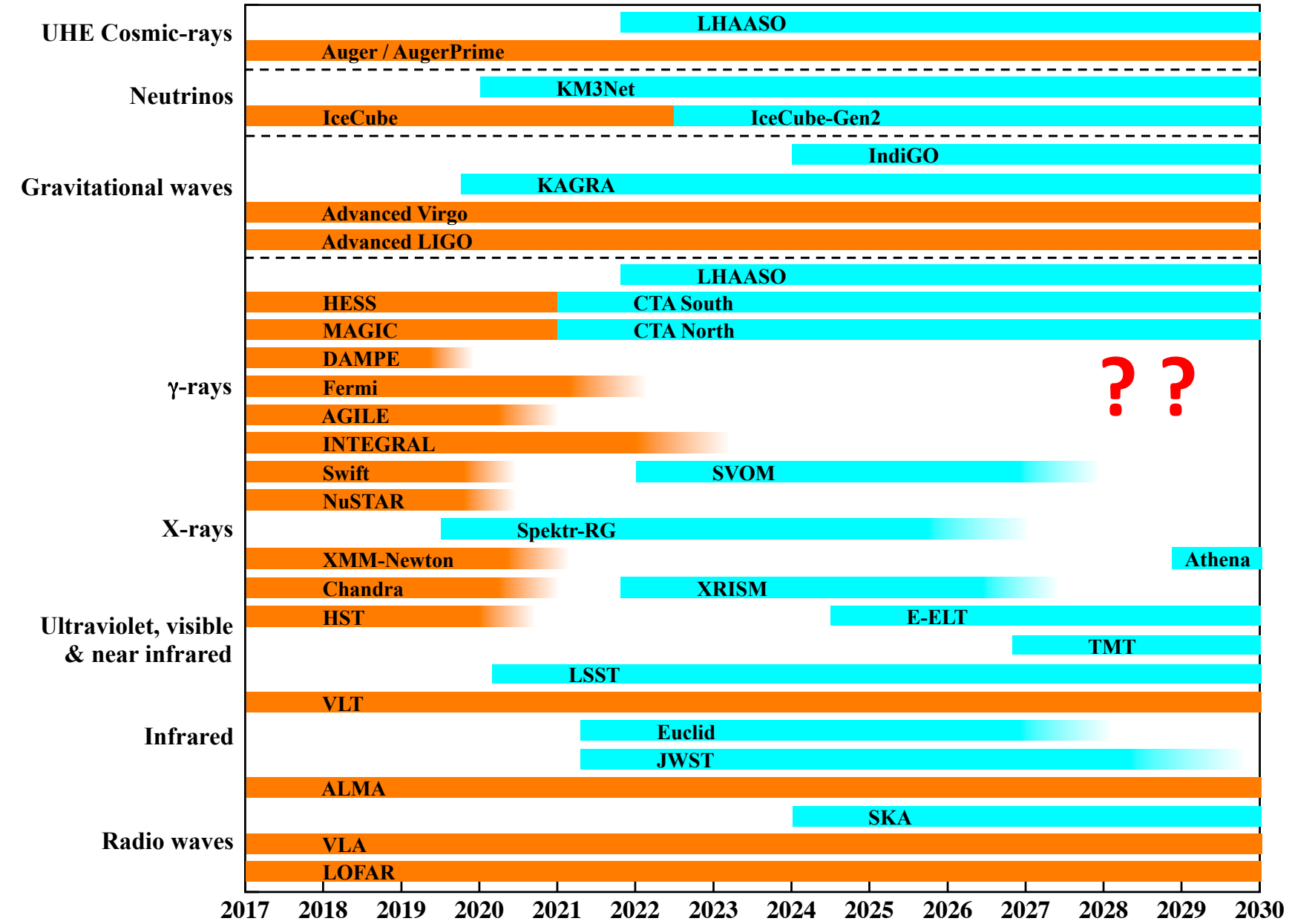
From e-ASTROGAM to an All-Sky Gamma-Ray Imager





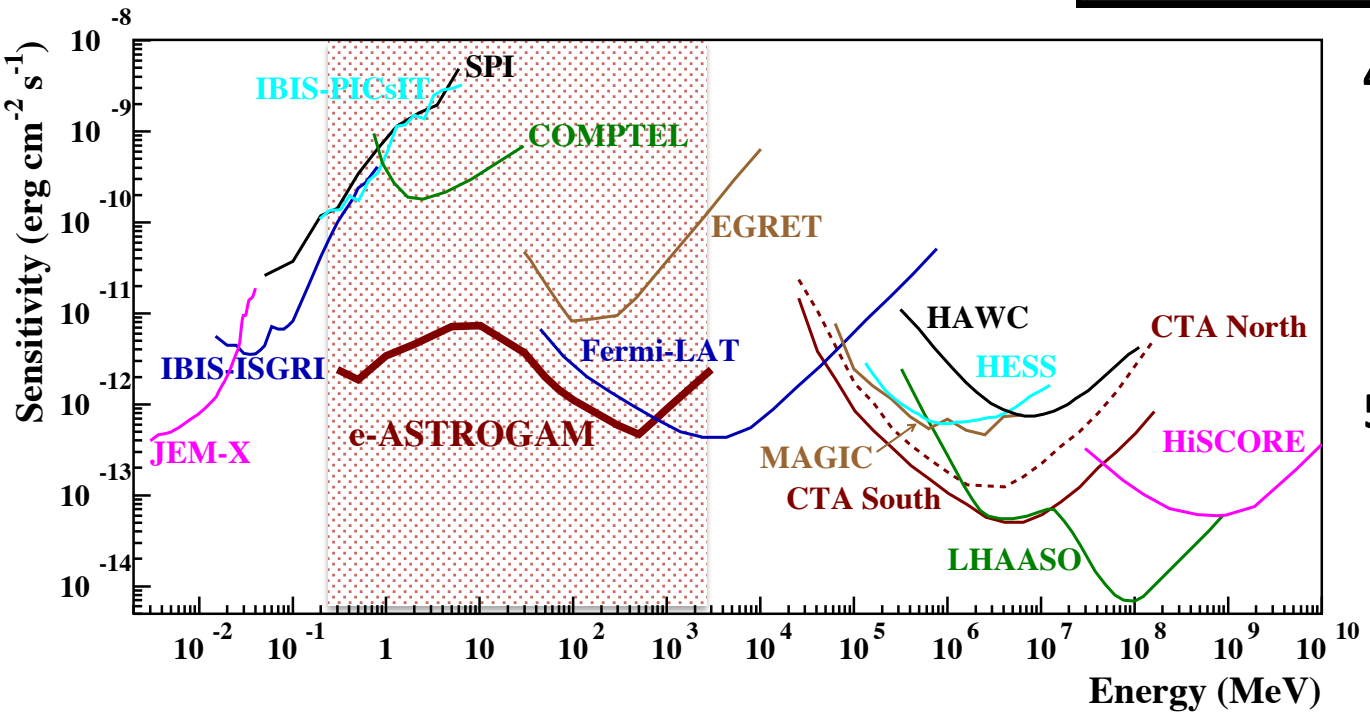
Vincent Tatischeff
(CSNSM Orsay, France)

Multi-wavelength/messenger context



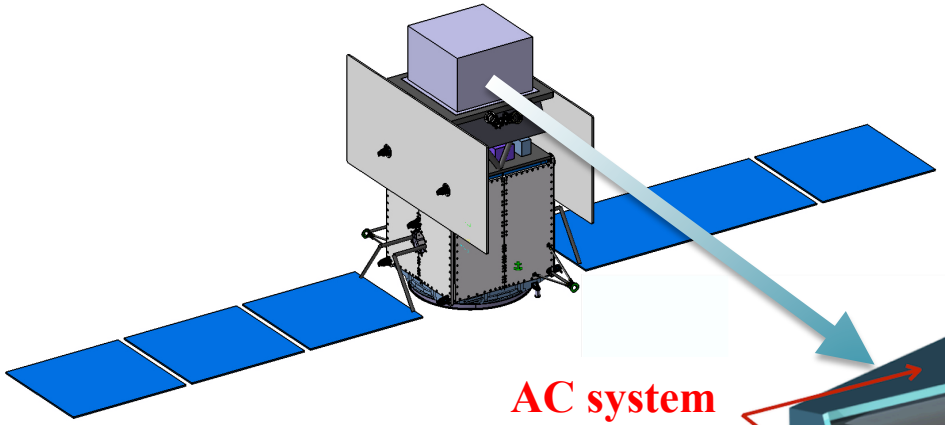
e-ASTROGAM design goals

1. **Sensitivity** = 20 to 100 times better than INTEGRAL and CGRO/COMPTEL in the range 0.2 - 30 MeV
2. **Gamma-ray polarization** for transient and steady sources
3. **Improved angular resolution** close to the physical limits (e.g., about 10' at 1 GeV)

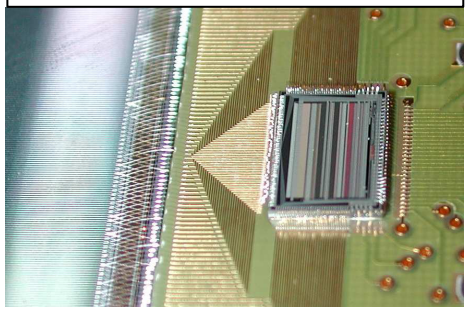


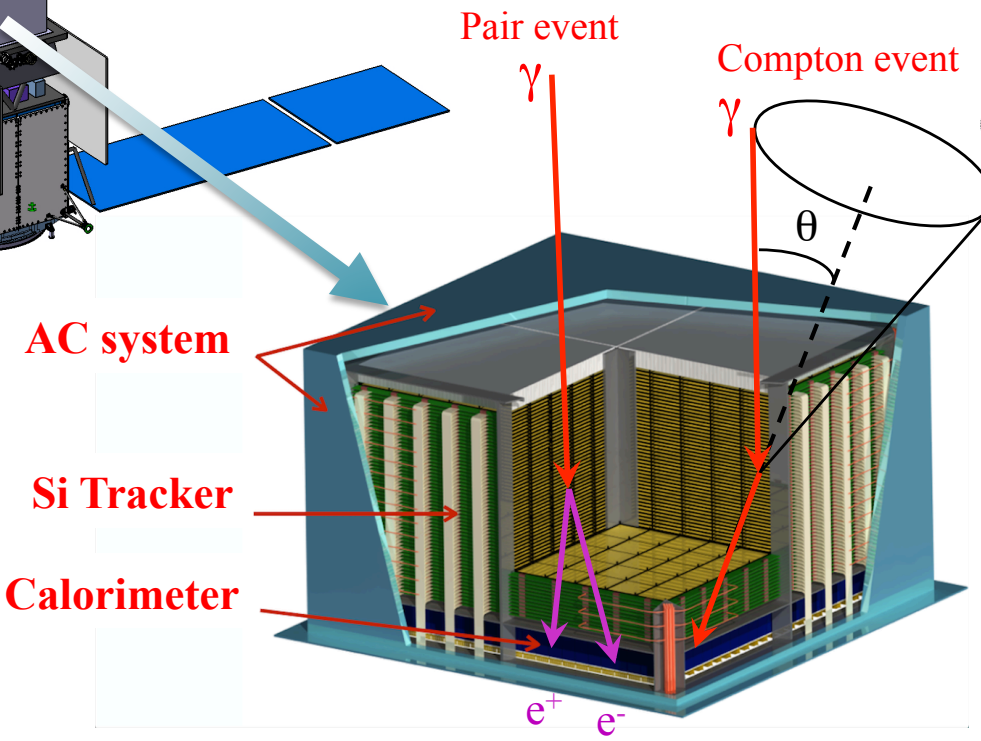
4. **Large field of view** (about 2.5 sr) for sky survey and time-domain monitoring of sources
5. **Sub-millisecond trigger** and **alert capability** for transients

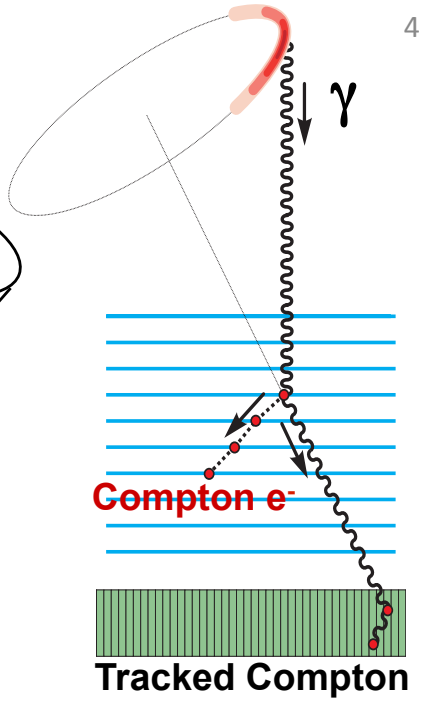
e-ASTROGAM design concept

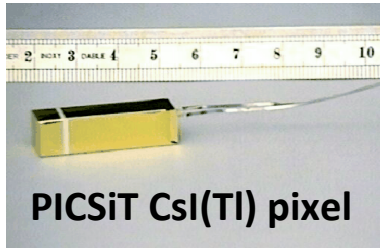


AGILE Si Tracker

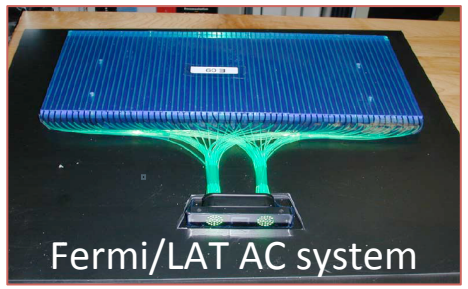






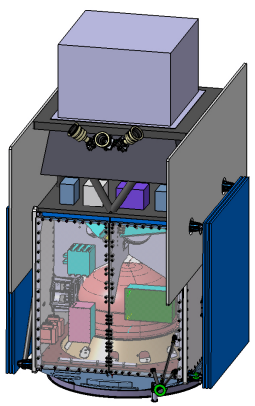


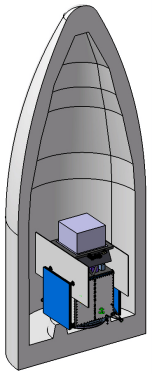
- **Si Tracker** – Double sided Si strip detectors (DSSDs) for excellent spectral resolution and fine 3-D position resolution
- **3D-imaging Calorimeter** – CsI(Tl) scintillation crystals readout by Si Drift Diodes for better energy resolution
- **Anticoincidence detector** to veto charged-particle induced background ⇒ plastic scintillators readout by SiPMs



e-ASTROGAM mission proposal

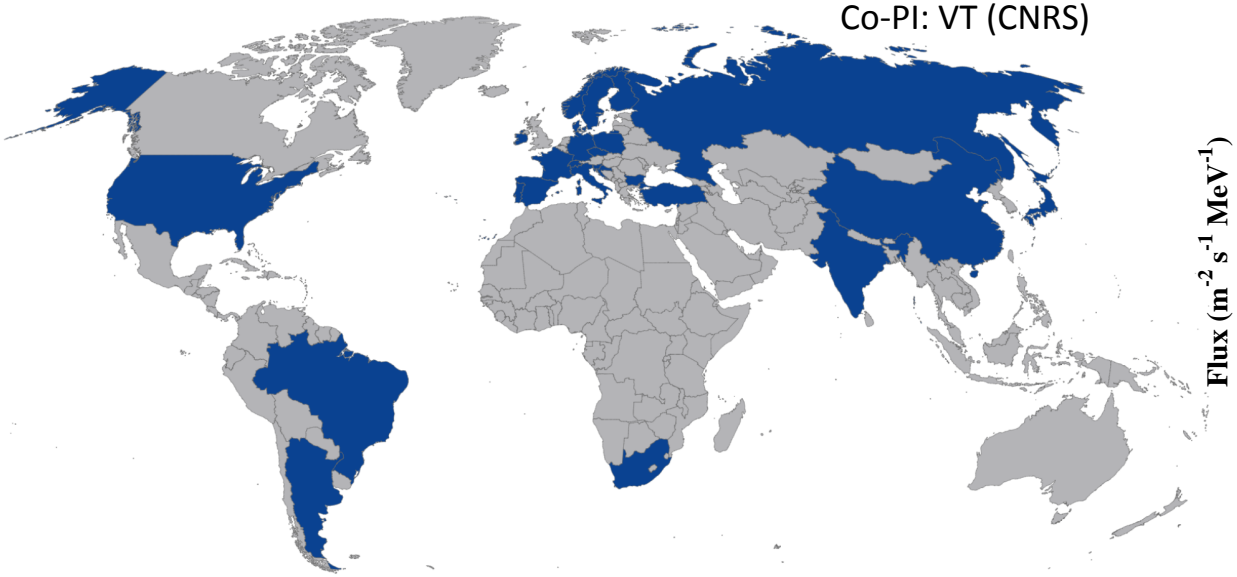
- **Satellite platform** – Thales Alenia Space PROTEUS 800 (SWOT) ⇒ spacecraft wet mass 2.7 tons
- **Low-Earth equatorial orbit** (inclination $i < 2.5°$, eccentricity $e < 0.01$, altitude 550 - 600 km) for optimal background environment
- **Science Collaboration** – more than 400 collaborators in 29 countries

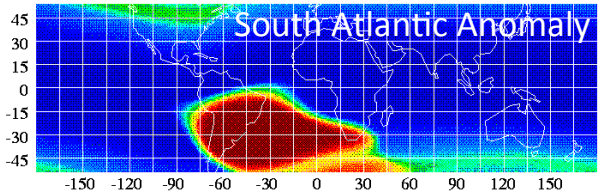


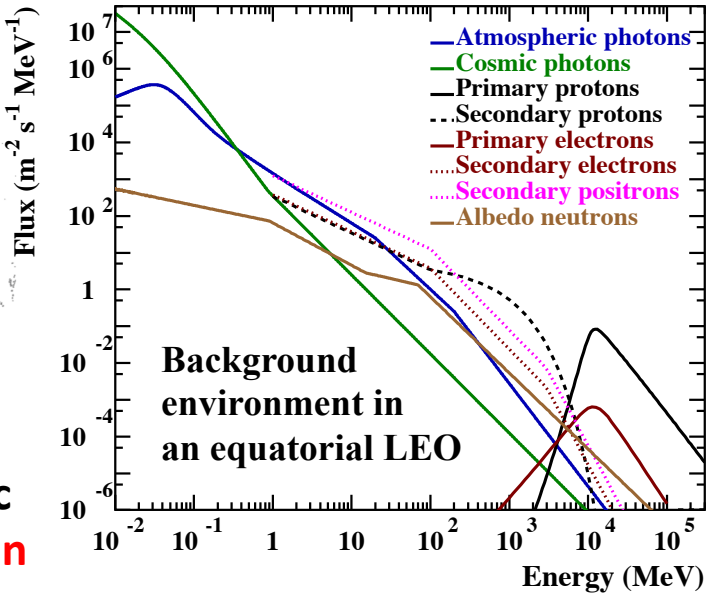


Ariane 6.2

PI: A. De Angelis (INFN)
Co-PI: VT (CNRS)

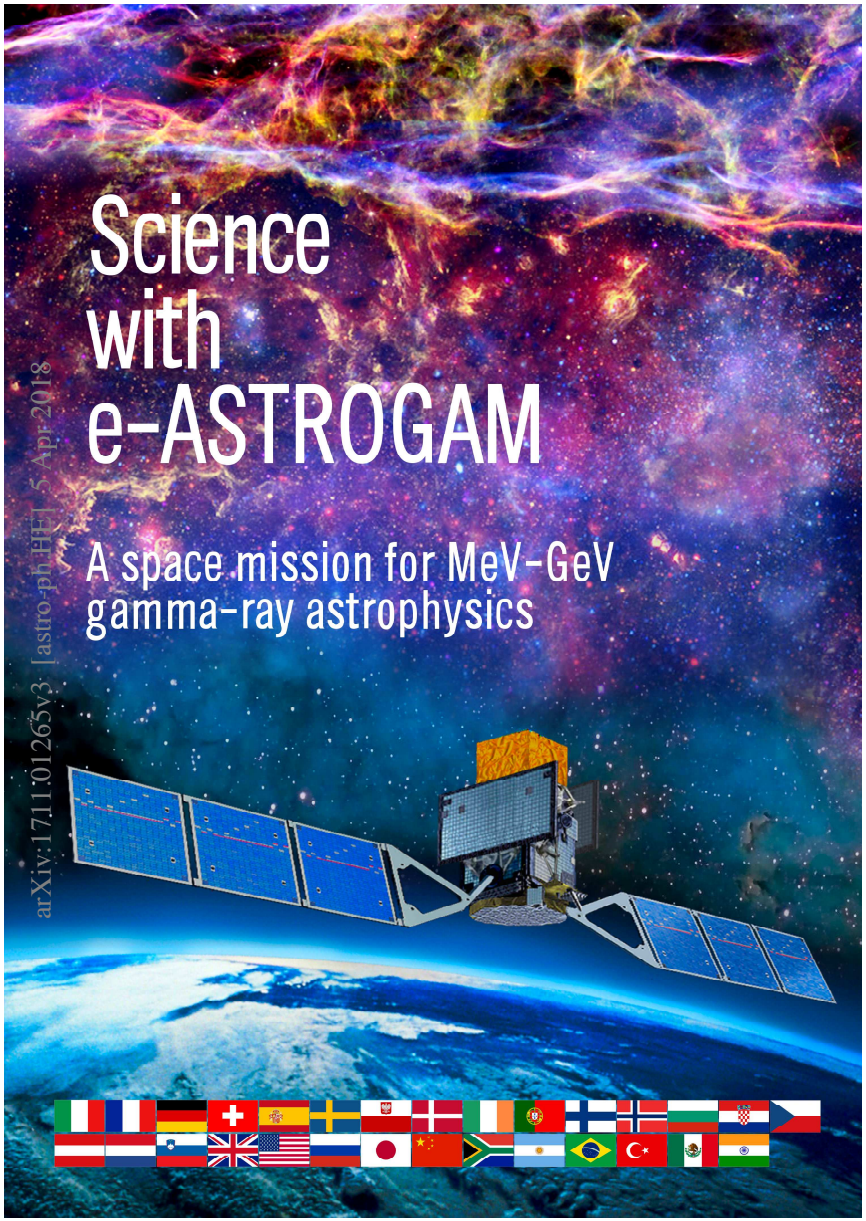






Favourably evaluated by ESA's Technical and Programmatic Evaluation Panel, but finally not selected for the M5 mission

Gamma-ray Space Science White Book



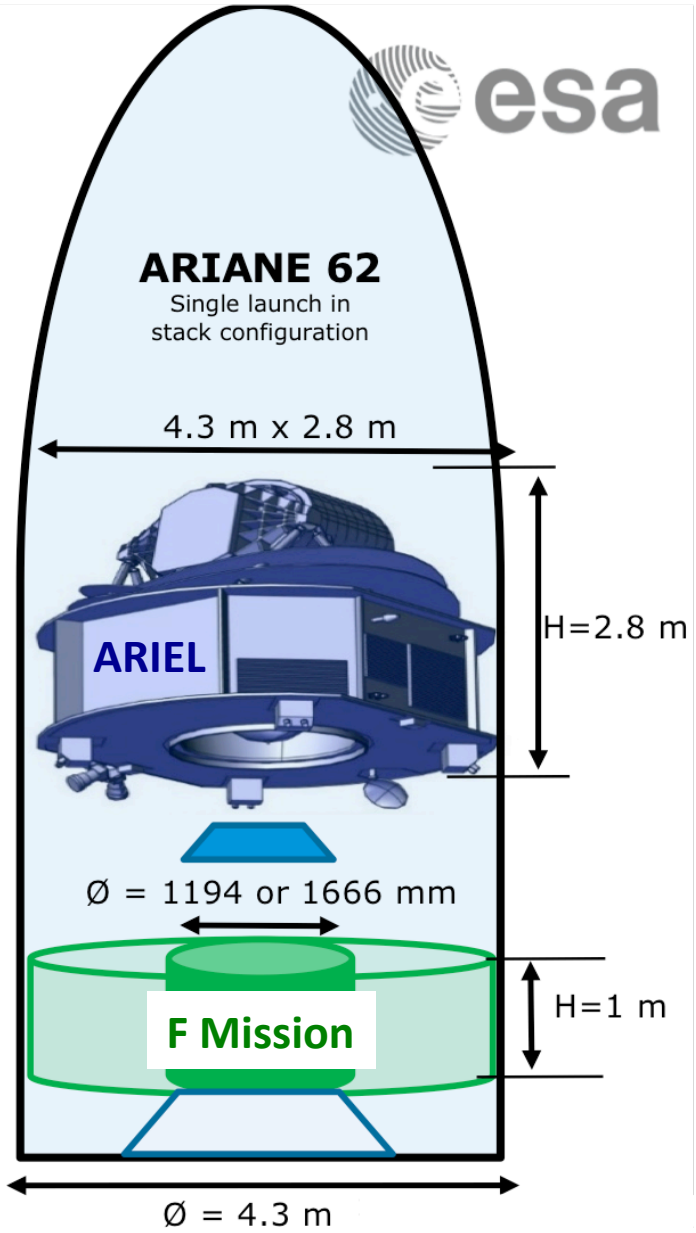
*251 authors, published in Journal of High Energy Astrophysics **19** (2018) 1*

1. **The extreme extragalactic universe:** AGN, GRBs, link to new messengers; **15 papers**
2. **Cosmic-ray interactions:** cosmic-ray origin, Fermi bubbles, CR impact on ISM; **7 papers**
3. **Fundamental physics:** dark matter searches, Axion, primordial black holes, baryon asymmetry; **15 papers**
4. **Explosive nucleosynthesis and chemical evolution of the Galaxy:** supernovae, novae, diffuse radioactivities, 511 keV; **5 papers**
5. **Physics of compact objects:** pulsars, magnetars, pulsar wind nebulae, X- and gamma-ray binaries; **9 papers**
6. **Solar and Earth Science:** Terrestrial gamma-ray flashes, solar flares, Moon; **5 papers**
7. **Miscellanea:** unidentified gamma-ray sources, gamma-SETI etc..; **5 papers**

Wide interest from the scientific community

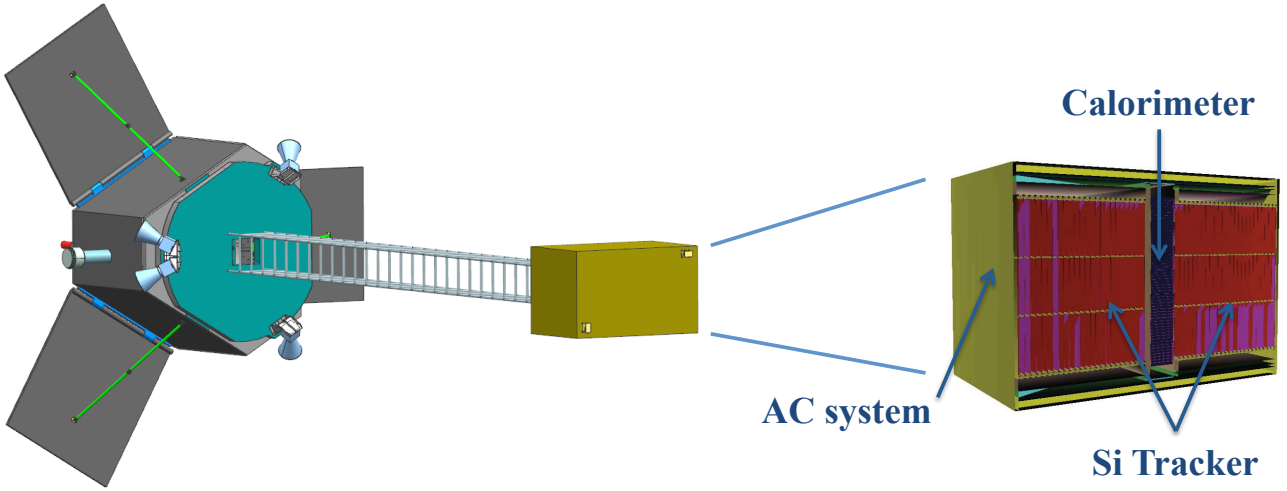
ESA Call for a Fast (F) Mission

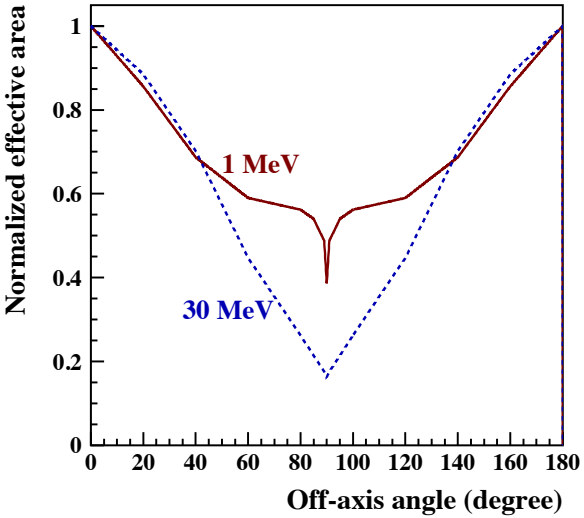
- Call in July 2018 for a **"Fast" Mission of modest size** to be launched in 2028 with the ARIEL M4 Mission to an **L2 orbit**
- F-spacecraft wet mass < 850 – 900 kg (depends on Ariane 62 performance)
- **Payload mass < 80 kg** (?); fast and reliable payload development in 3 – 3.5 years; **TRL 6** required by mission selection (Q1 2020)
- Launch in a stacked configuration with the F-spacecraft structure used for holding ARIEL ⇒ **highly non-standard platform**
- L2 orbit (1.5 million km from Earth):
  - ☹ **High cosmic-ray background**
  - ☺ **No occultation by Earth**



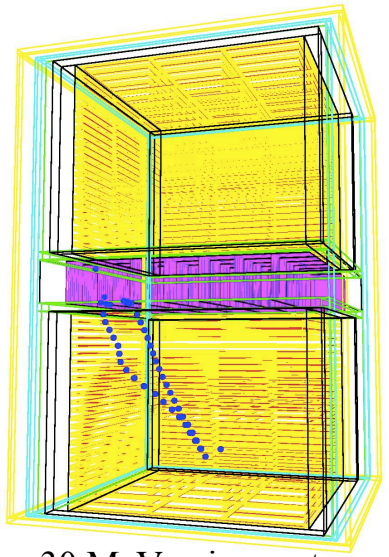
All-Sky-ASTROGAM

The MeV Gamma-Ray Companion to Multimessenger Astronomy





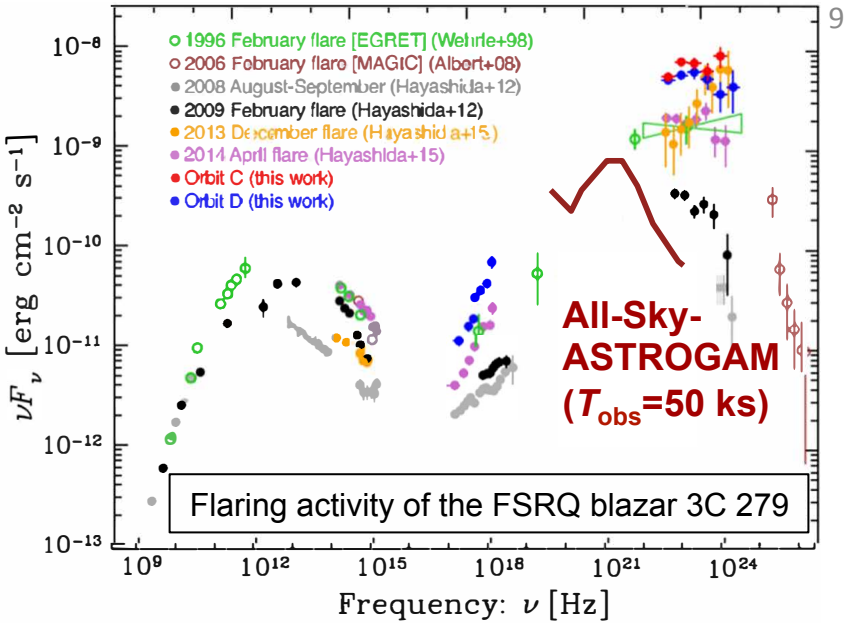
- **All-Sky Gamma-ray Monitor** (0.1 MeV - 500 MeV) with **good localisation** capabilities (e.g. 30 arcmin at 300 MeV) and **excellent sensitivity to polarisation** in the MeV domain
- Gamma-ray Imager (80 kg) attached to a **deployable boom**
  ⇒ **continuous coverage of almost the whole sky**
  ⇒ **reduction of the instrument background** (L2 orbit)
- **High-TRL payload** (Tracker, Calorimeter and Anticoincidence system based on e-ASTROGAM technology)

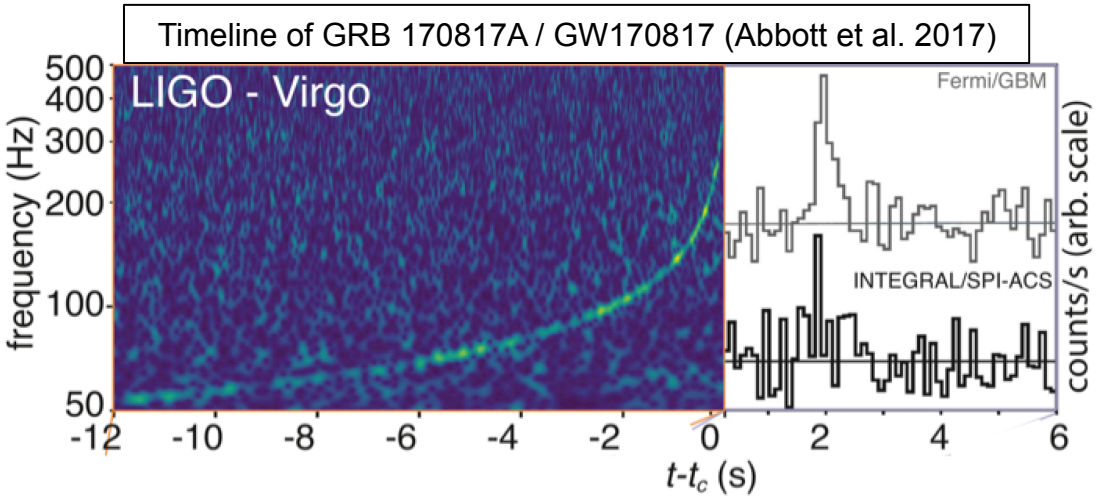


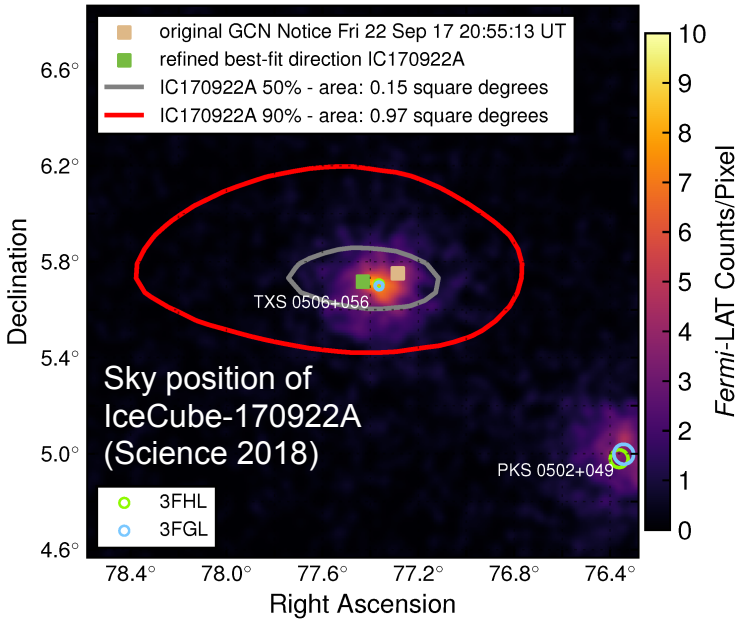
30 MeV pair event

Monitoring the gamma-ray Universe

- **Bright & intermediate flux transients (GRBs, AGN, X-ray binaries, novae, Crab flares...) at different timescales (seconds to weeks)** – crucial to identify the acceleration & radiation processes
- **Electromagnetic counterparts to gravitational wave events** – expected 0.2–6 NS-NS mergers per year with GW detection
- **Identification of high-energy neutrinos sources** (e.g. blazar TXS 0506+056)

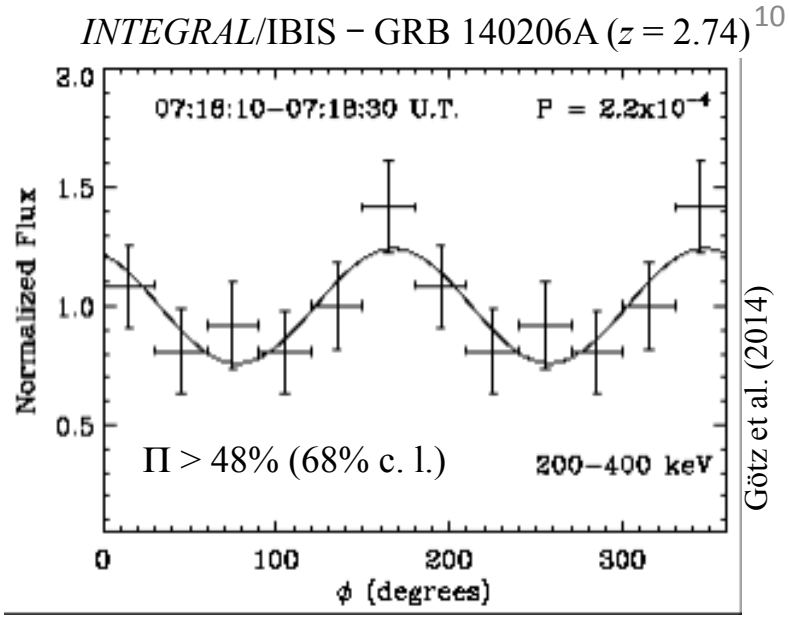


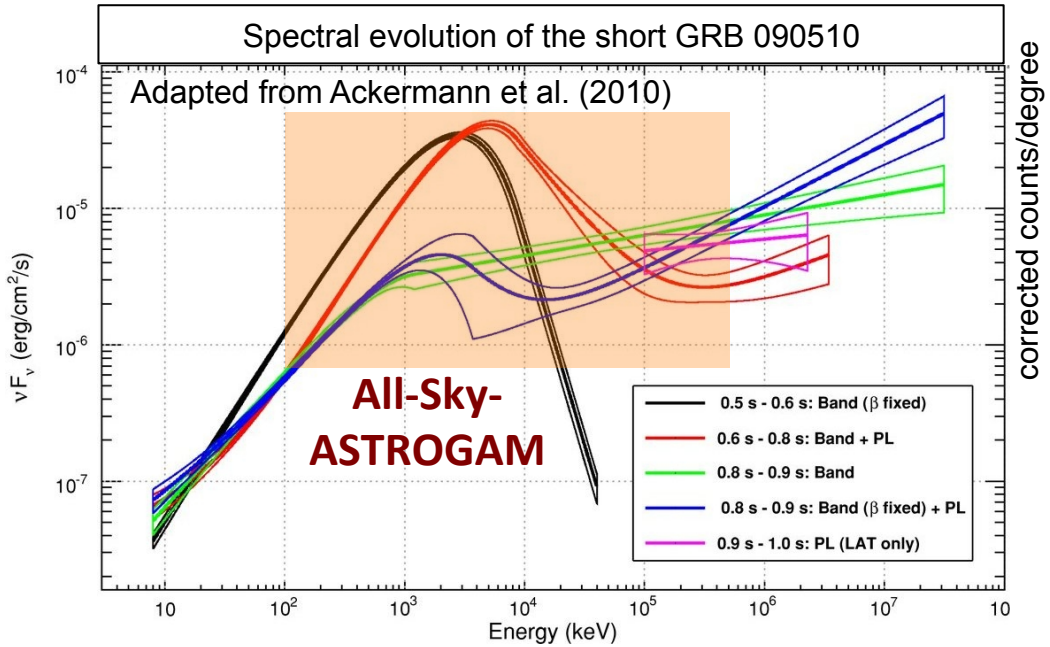


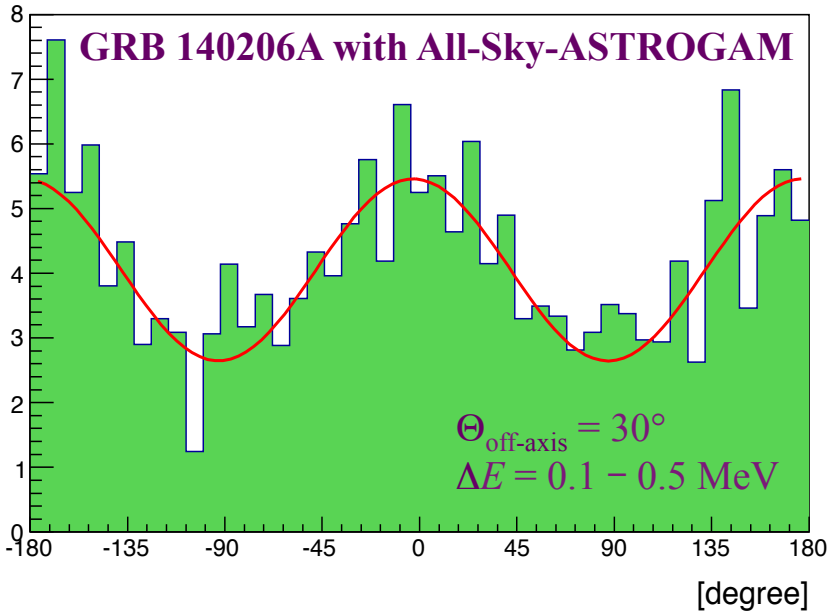


New views of gamma-ray bursts

- **Unprecedented gamma-ray polarimetry**
  ⇒ **GRB jet physical properties** (B-field), energy dissipation sites, radiation mechanisms...
  ⇒ Test of **Lorentz Invariance Violation**
- **Broad-band spectroscopy** with a single instrument
- **Expected detection rate**: ~ 100 GRBs per year

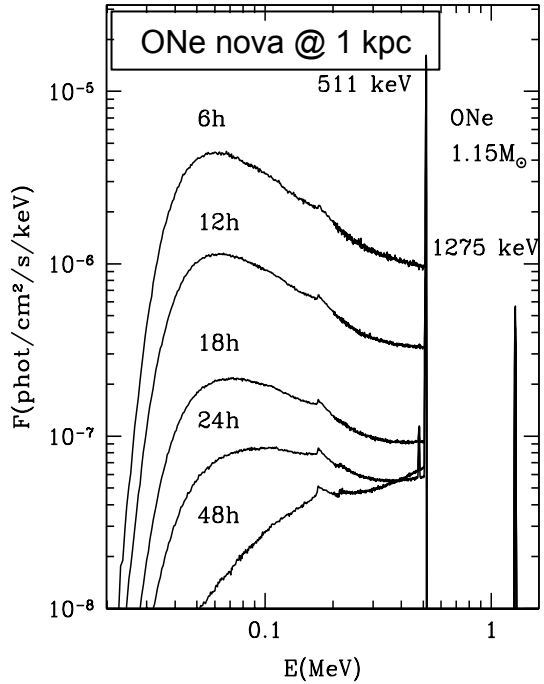


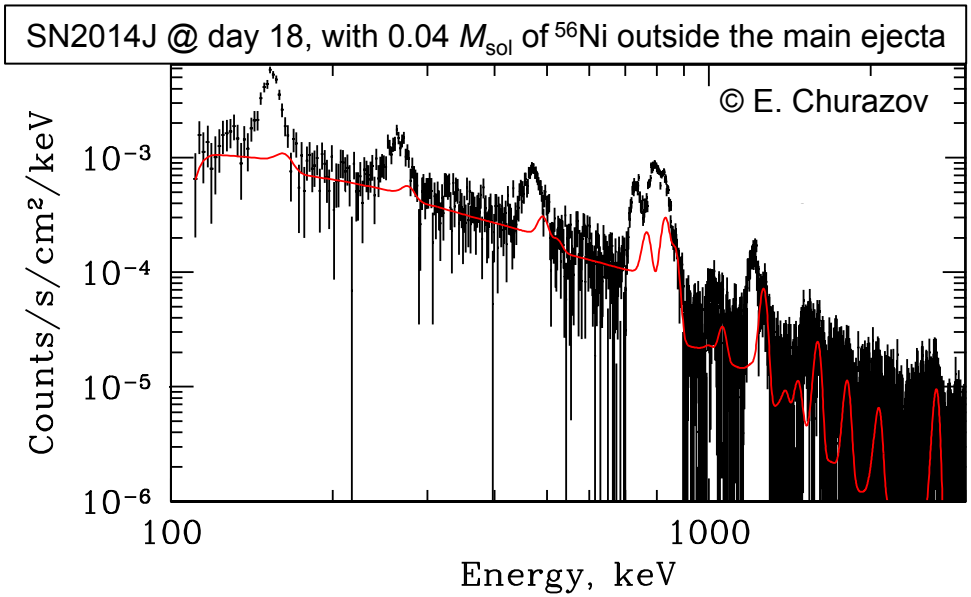


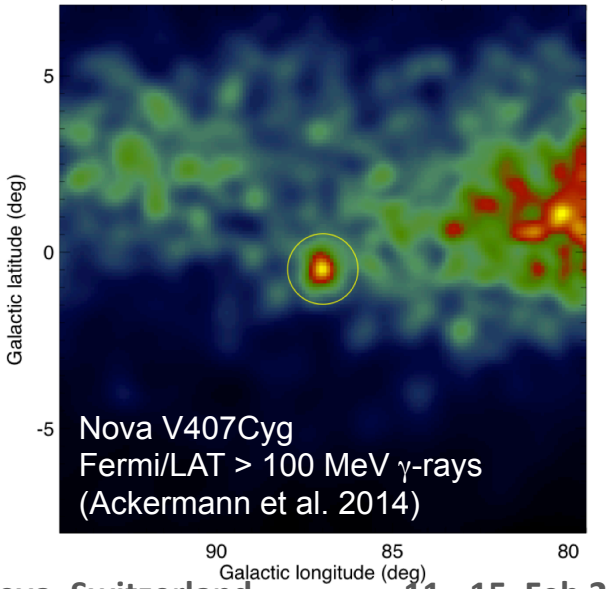


Explosive nucleosynthesis

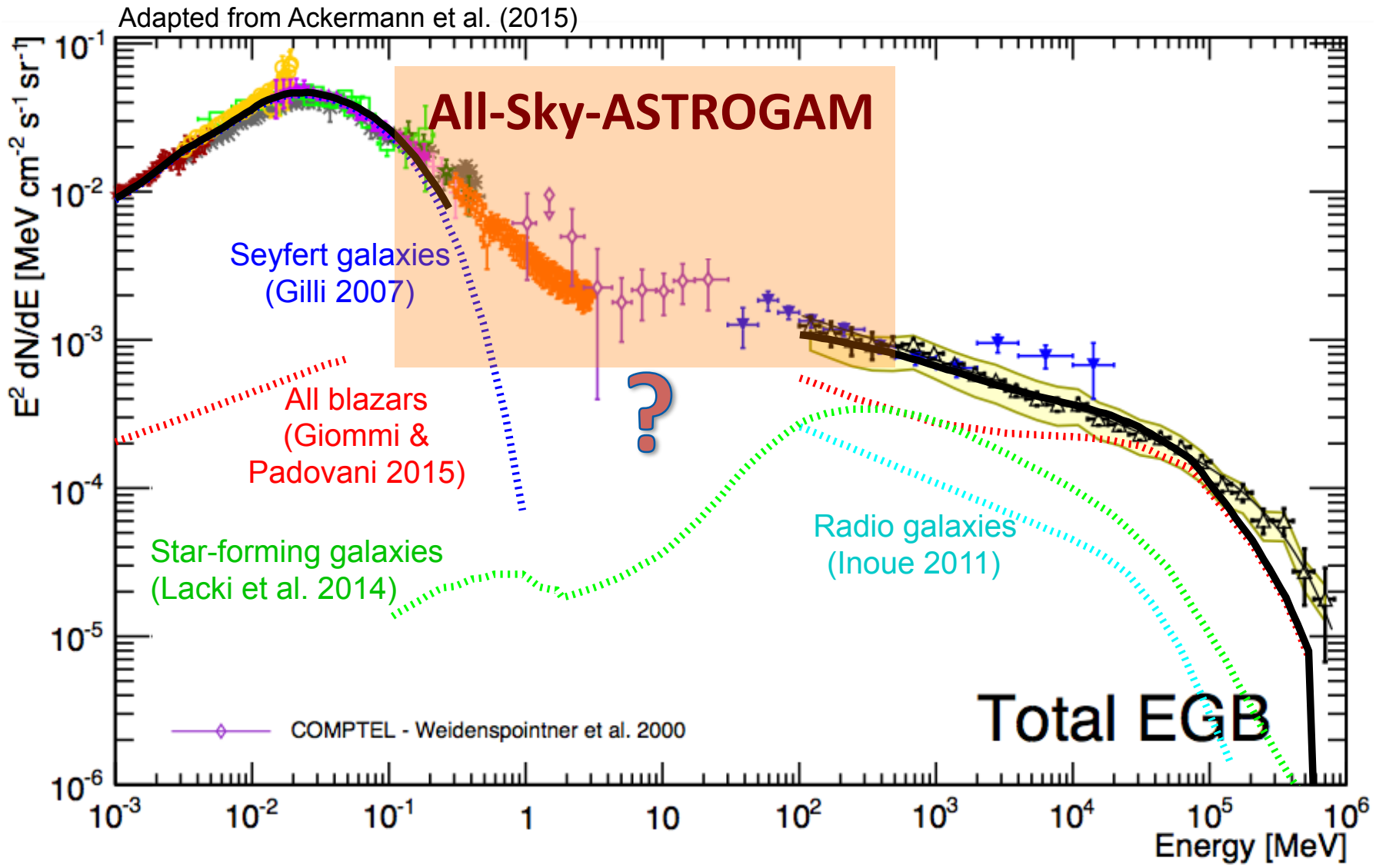
- **Thermonuclear SNe** – Detection of the **early γ-ray emission before the maximum optical light** is fundamental to understand the **nature of the progenitor** (standard candles for cosmology)
- **Novae** – Sky monitoring is essential to detect (i) **the early e^+-e^- annihilation emission** (before optical max) and (ii) the onset of **particle acceleration in shocks**
- **Core-collapse SNe** – Determination of the **ejected mass of ^{56}Ni** is crucial to understand the explosion mechanism







Extragalactic γ-ray background



- Origin of the EGB in the 1 - 100 MeV range? Constraint on dark matter contribution

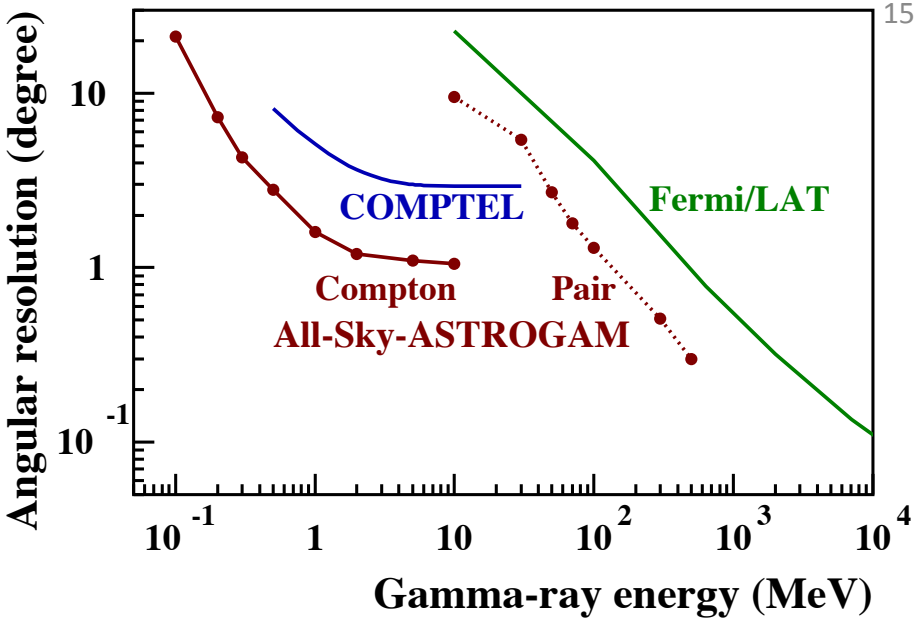
Conclusions

- **In the era of multi-wavelength and multi-messenger astronomy, crucial need for a MeV / sub-GeV γ-ray space imaging monitor**
- **All-Sky-ASTROGAM proposed for ESA's Fast mission and selected for phase 2 (with five other proposals)**
- **Selection for a study phase expected in summer 2019**
- **All-Sky-ASTROGAM is innovative in many respects, but the technology is ready and reliable**

Extra slides

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 All-Sky-ASTROGAM PSF (extrapolation of the 3FGL source spectra to low energies)