NATIONAL SCIENCE CENTRE
POLAND

gamma rays from space (instruments)

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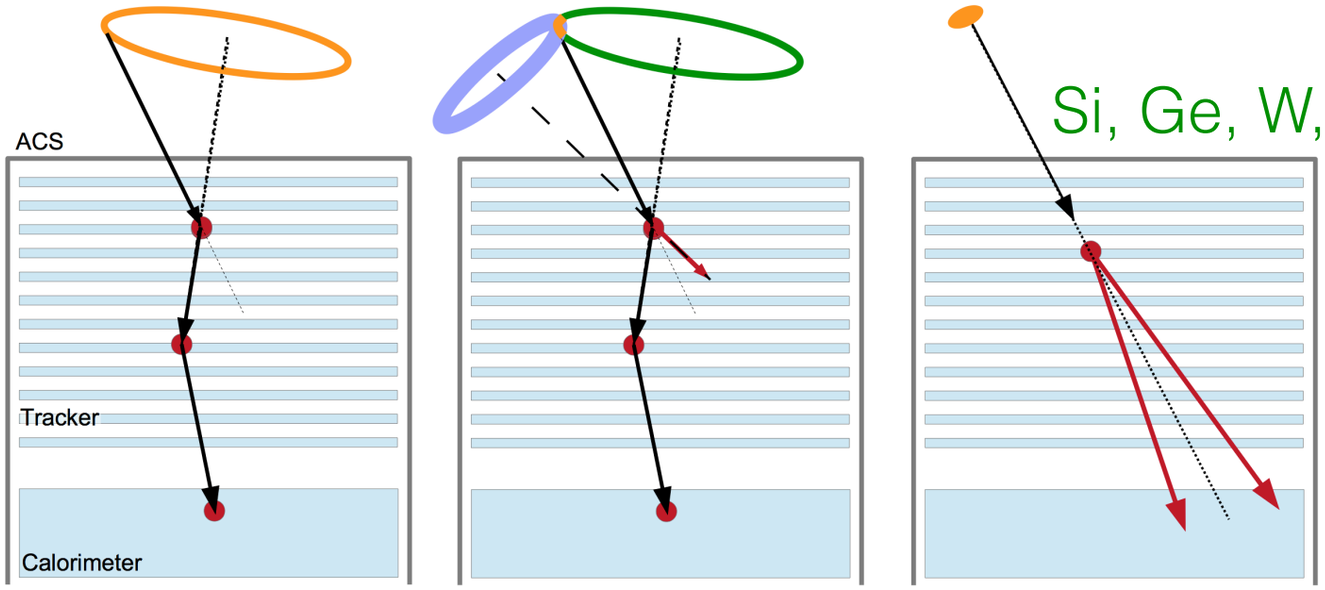
disclaimer: the presenter is not participating in any observational gamma-ray project

reflection limit ~ 80 keV (NuSTAR)

POLARIZATION!

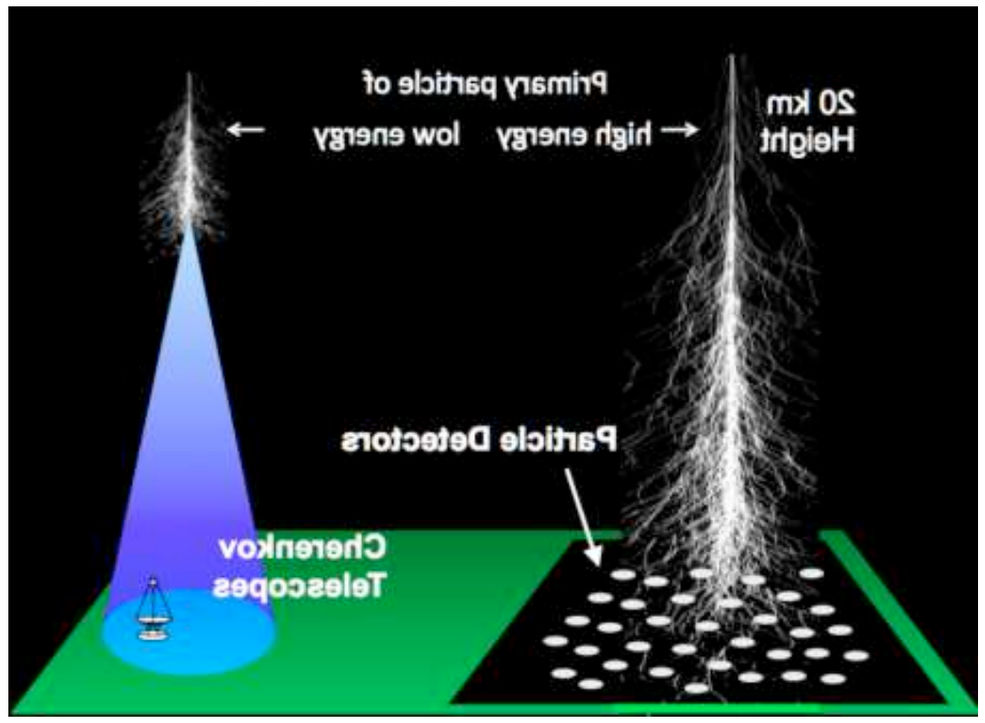
Compton scattering

pair conversion



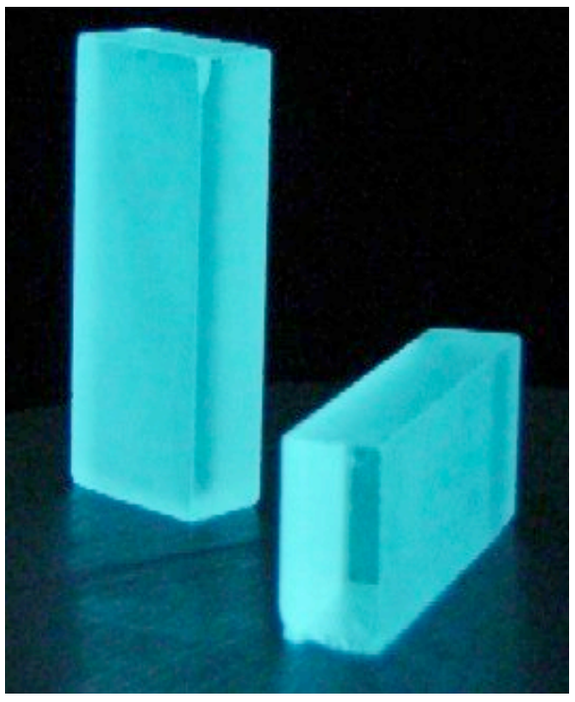
Si, Ge, W, Ta

atmospheric particle showers



ground-based

scintillation



NaI(Tl)
CsI(Tl)
BGO
…

photon
cosmic ray
discrimination

imaging
atmospheric
Cherenkov
telescopes
(IACT)

extensive
air shower
(EAS)
detectors

MeV **GeV (HE)** **TeV (VHE)**

2020

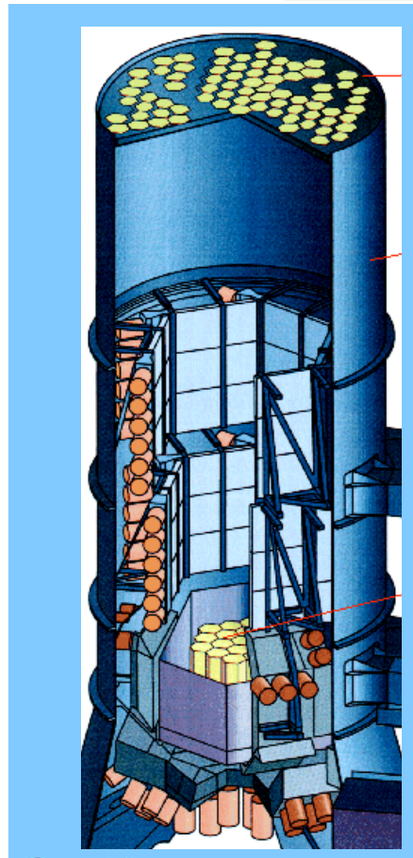
2010

2000

1990

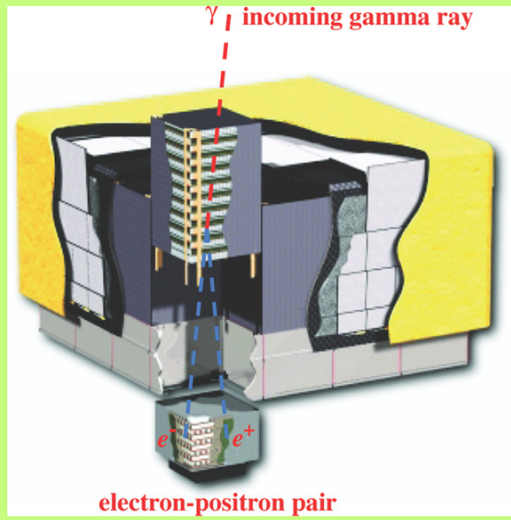
e-ASTROGAM

CTA



Swift
INTEGRAL

MeV
gap

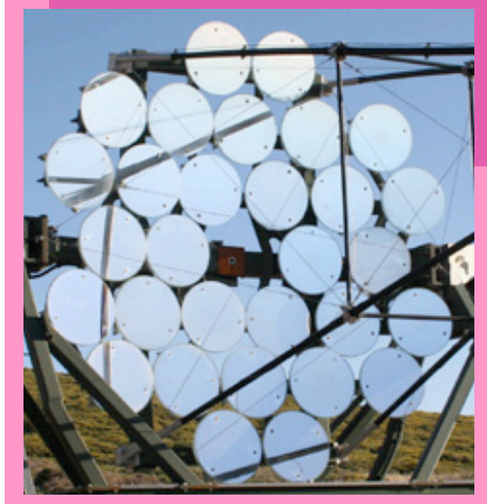


Fermi/LAT
AGILE

HAWC

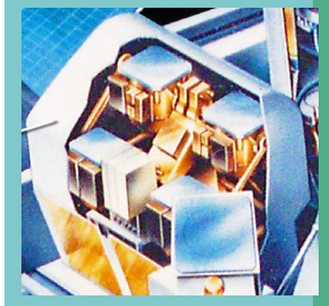
H.E.S.S.
MAGIC
VERITAS

MILAGRO

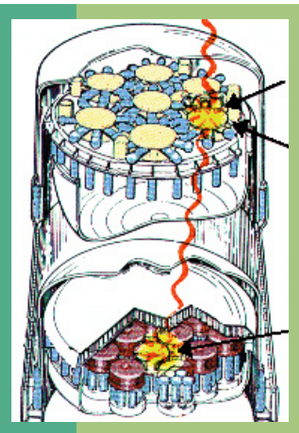


WHIPPLE
HEGRA

GeV gap



OSSE



COMPTEL

EGRET

MeV

GeV (HE)

TeV (VHE)

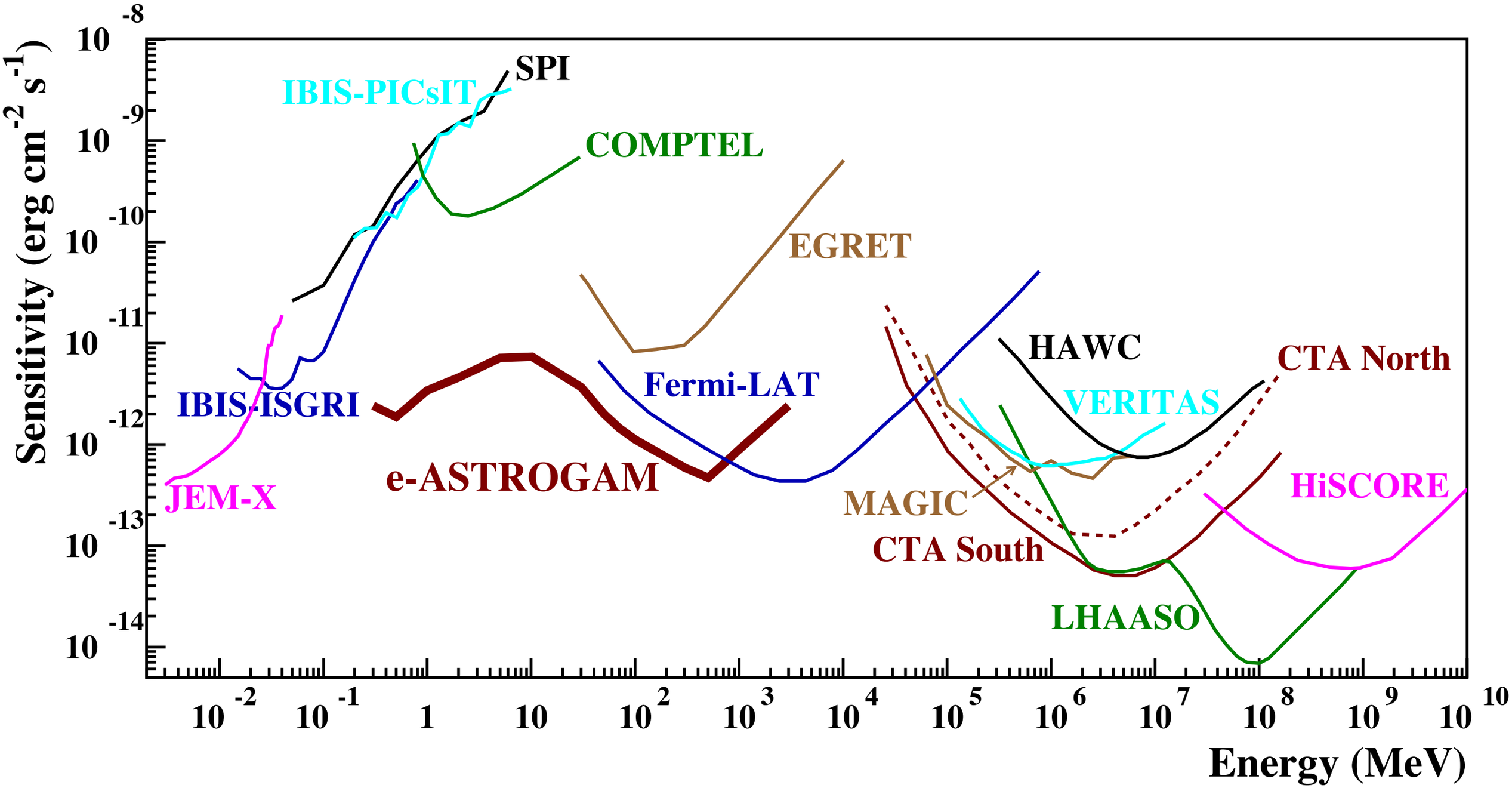


Figure 1: Point source continuum sensitivity of different X- and γ-ray instruments. The curves for INTEGRAL/JEM-X, IBIS (ISGRI and PICsIT), and SPI are for an observing time $T_{\rm obs} = 1$ Ms. The COMPTEL and EGRET sensitivities are given for the time accumulated during the duration of the CGRO mission ($T_{\rm obs} \sim 9$ years). The Fermi/LAT sensitivity is for a high Galactic latitude source over 10 years. For MAGIC, VERITAS, and CTA, the sensitivities are given for $T_{\rm obs} = 50$ hours. For HAWC $T_{\rm obs} = 5$ yr, for LHAASO $T_{\rm obs} = 1$ yr, and for HiSCORE $T_{\rm obs} = 1000$ h. The e-ASTROGAM sensitivity is for an effective exposure of 1 year for a source at high Galactic latitude.

e-ASTROGAM ESA/M5 proposal

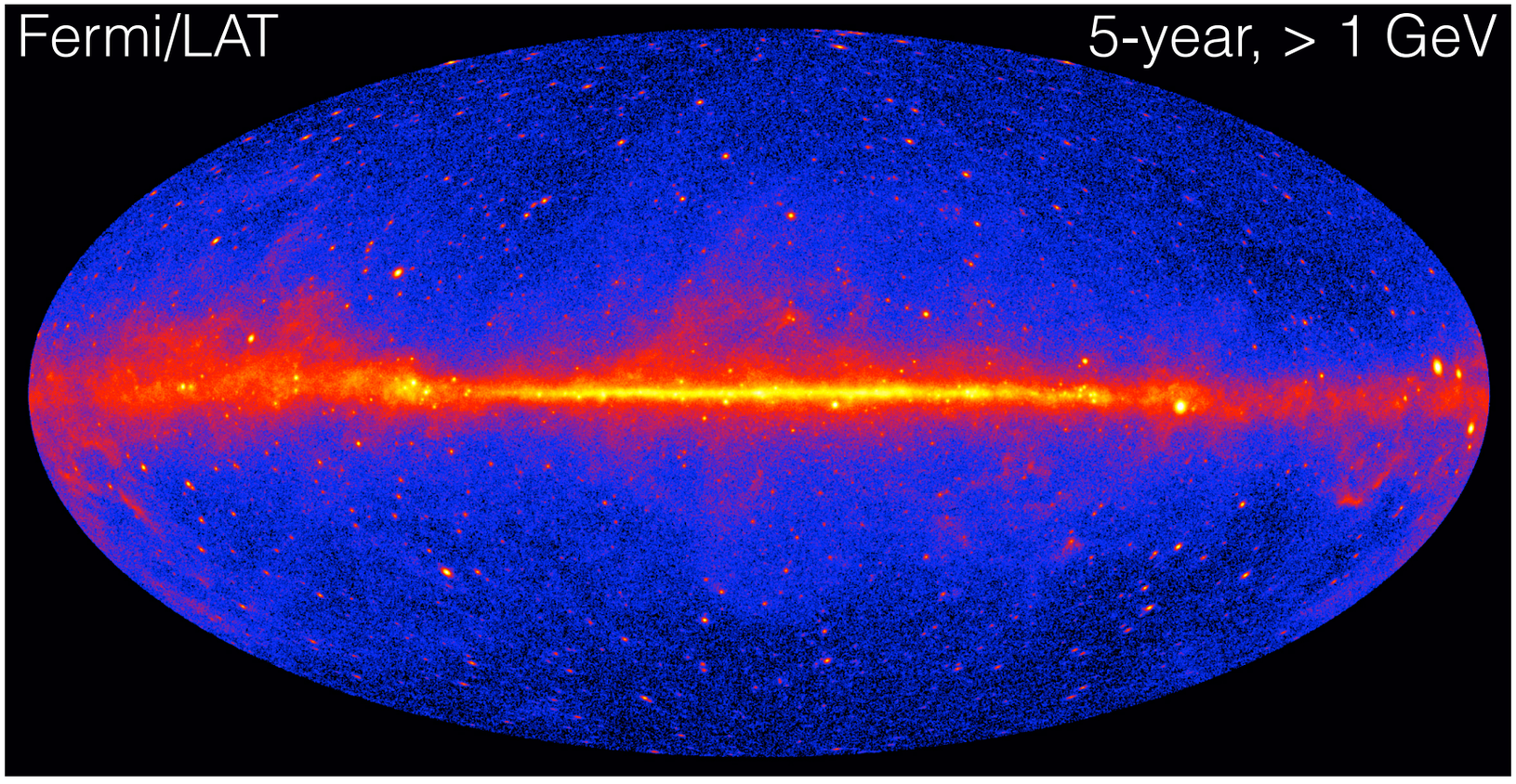
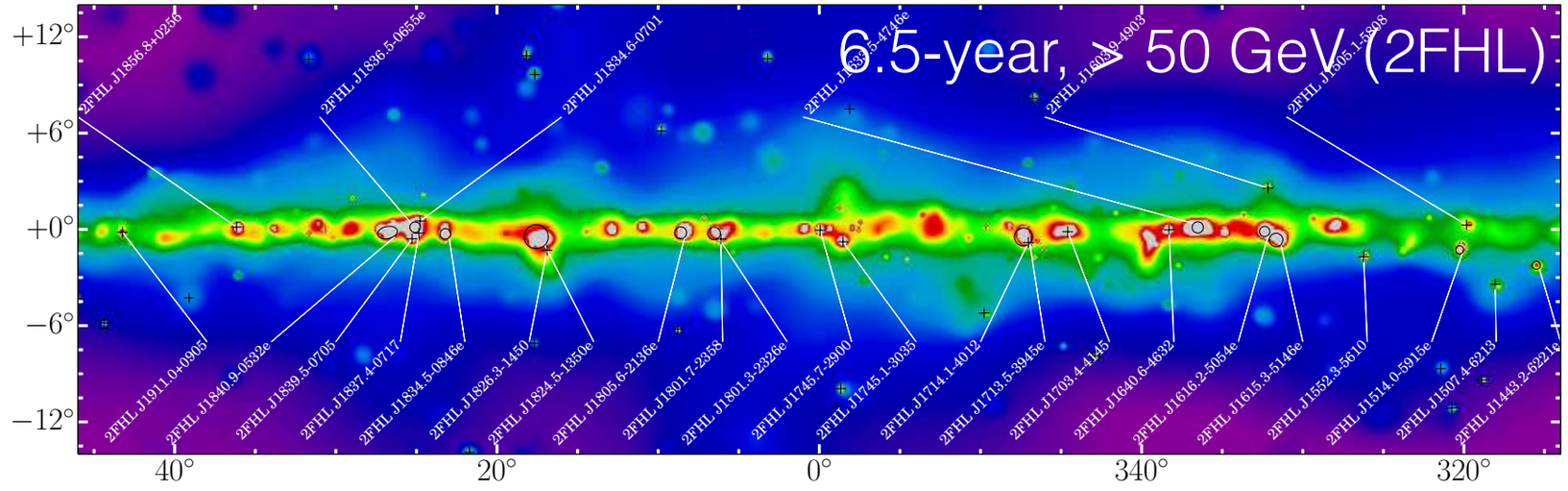
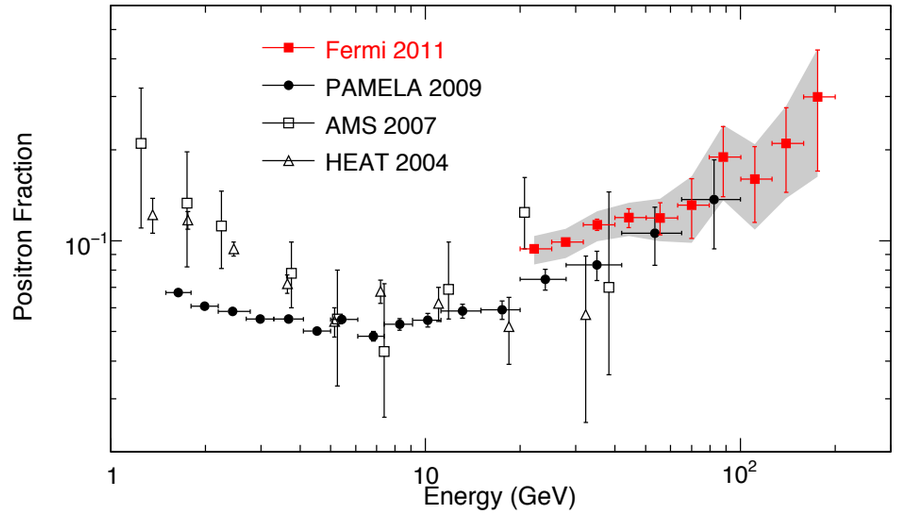
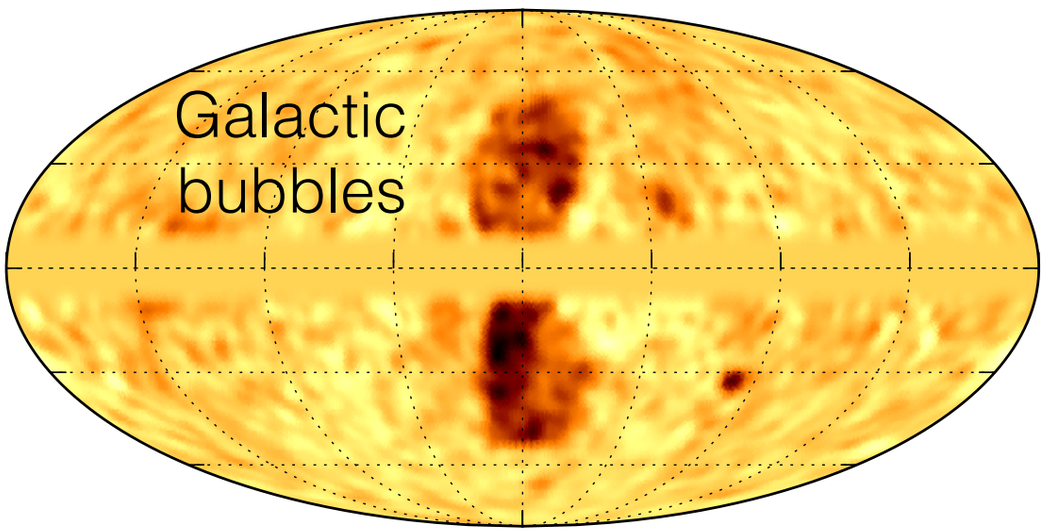


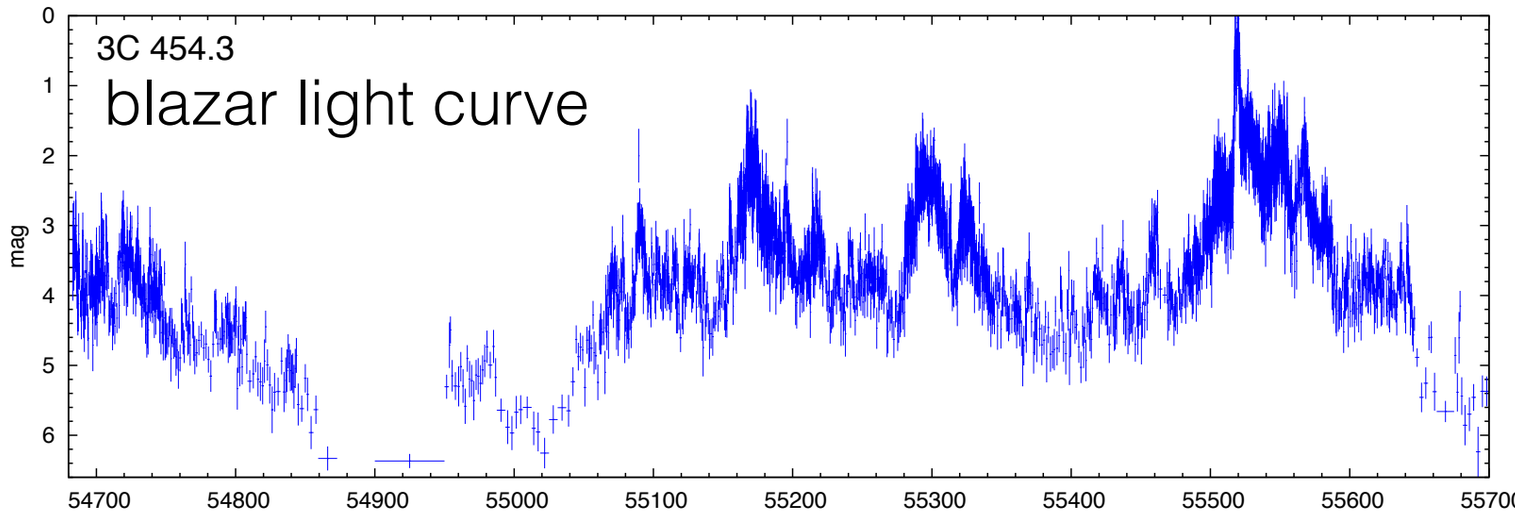
Table 6. LAT 3FGL Source Classes

Description	Identified		Associated	
	Designator	Number	Designator	Number
Pulsar, identified by pulsations	PSR	137	···	···
Pulsar, no pulsations seen in LAT yet	···	···	psr	29
Pulsar wind nebula	PWN	9	pwn	2
Supernova remnant	SNR	12	snr	11
Supernova remnant / Pulsar wind nebula	···	···	spp	51
Globular cluster	GLC	0	glc	15
High-mass binary	HMB	3	hmb	0
Binary	BIN	1	bin	0
Nova	NOV	1	nov	0
Star-forming region	SFR	1	sfr	0
Compact Steep Spectrum Quasar	CSS	0	css	1
BL Lac type of blazar	BLL	18	bll	642
FSRQ type of blazar	FSRQ	38	fsrq	447
Non-blazar active galaxy	AGN	0	agn	3
Radio galaxy	RDG	3	rdg	13
Seyfert galaxy	SEY	0	sey	1
Active galaxy of uncertain type	AGU	5	agu	578
Normal galaxy (or part)	GAL	2	gal	6
Starburst galaxy	SBG	0	sbg	4
Narrow line Seyfert 1	NLSY1	2	nlsy1	3
Soft spectrum radio quasar	SSRQ	0	ssrq	3
Total	···	232	···	1809
Unassociated	···	···	···	992









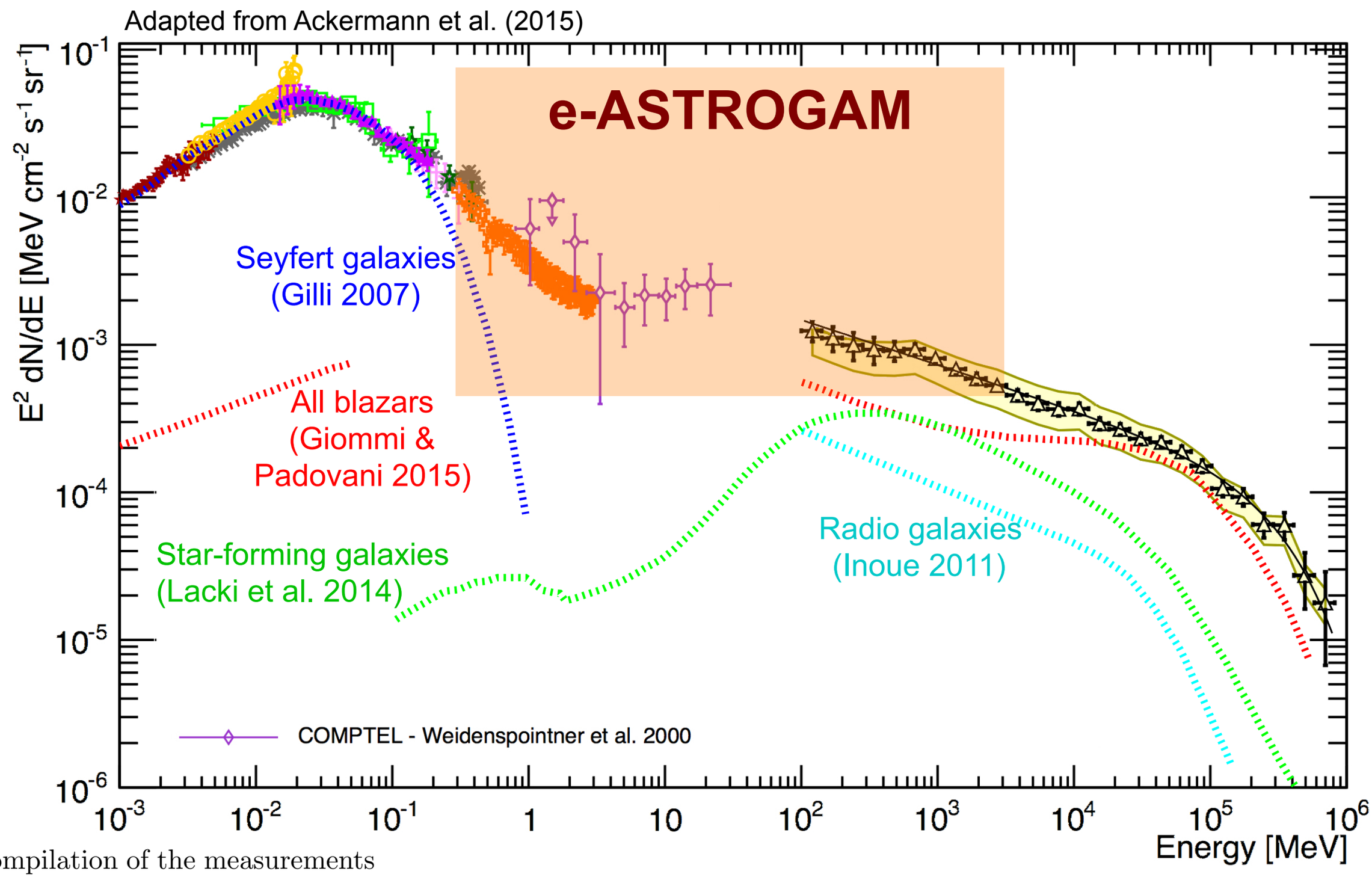
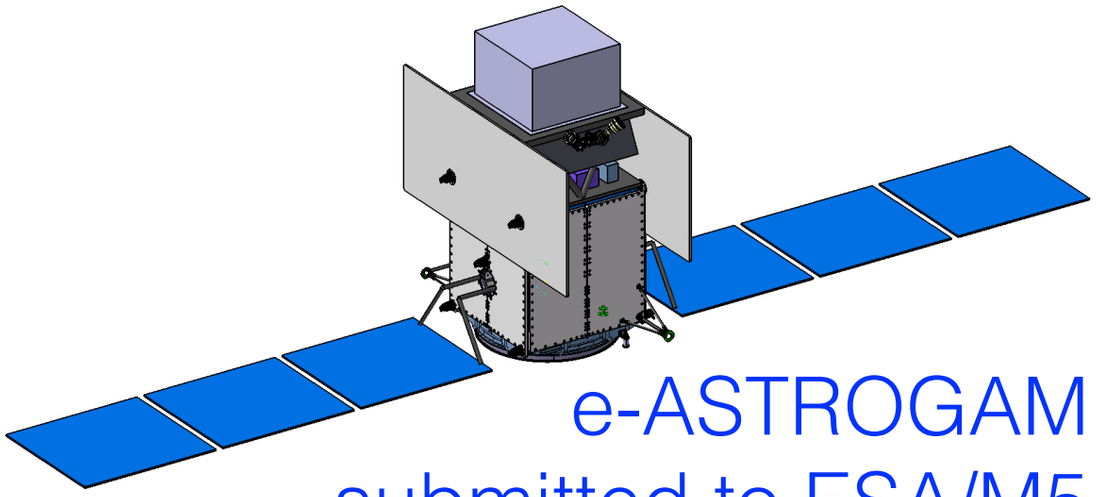
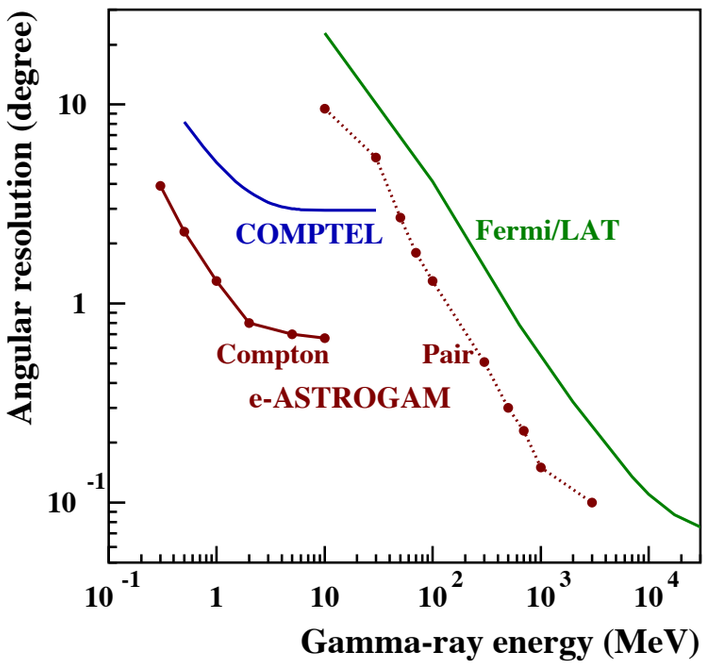
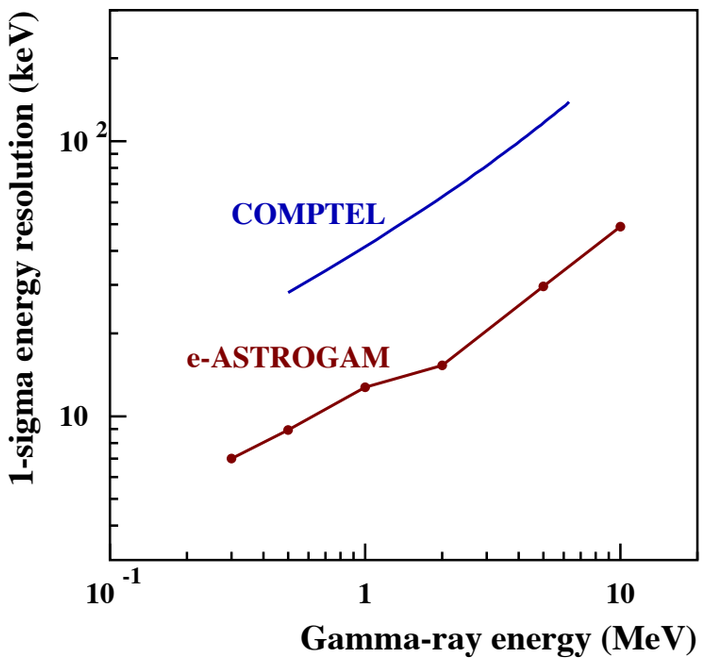


Figure 3: Compilation of the measurements of the total extragalactic gamma-ray intensity between 1 keV and 820 GeV [12], with different components from current models; the contribution from MeV blazars is largely unknown. The semi-transparent band indicates the energy region in which e-ASTROGAM will dramatically improve on present knowledge.



e-ASTROGAM
submitted to ESA/M5





Parameter	Value
Energy bands:	0.3 MeV – 3 GeV (Gamma-ray imager: Tracker + Calorimeter) 30 keV – 200 MeV (Calorimeter burst search)
Gamma-ray imager FOV (at 100 MeV)	≥ 2.5 sr
Gamma-ray imager Continuum flux sensitivity at 3σ confidence level	< 2×10^{-5} MeV cm^{-2} s^{-1} at 1 MeV ($T_{obs} = 10^6$ s effective observation time) < 5×10^{-5} MeV cm^{-2} s^{-1} at 10 MeV ($T_{obs} = 10^6$ s, high-latitude source) < 3×10^{-6} MeV cm^{-2} s^{-1} at 500 MeV ($T_{obs} = 10^6$ s, high-latitude source)
Gamma-ray imager Line flux sensitivity at 3σ confidence level	< 5×10^{-6} ph cm^{-2} s^{-1} for the 511 keV line ($T_{obs} = 10^6$ s effective obs. time) < 5×10^{-6} ph cm^{-2} s^{-1} for the 847 keV SN Ia line ($T_{obs} = 10^6$ s) < 3×10^{-6} ph cm^{-2} s^{-1} for the 4.44 MeV line from LECRs ($T_{obs} = 10^6$ s)
Gamma-ray imager angular resolution	≤ 1.5° at 1 MeV (FWHM of the angular resolution measure) ≤ 1.5° at 100 MeV (68% containment radius) ≤ 0.2° at 1 GeV (68% containment radius)
AC particle background rejection efficiency	> 99.99 %
Polarization sensitivity	MDP < 20% (99% c.l.) for a 10 mCrab source (0.3-2 MeV, T_{obs} = 1 yr) Detection of a polarization fract. ≥ 20% in more than 20 GRBs per year
ΔE/E (Gamma-ray imager)	2.5% at 1 MeV 30% at 100 MeV
ΔE/E (Calorimeter burst)	< 25% FWHM at 0.3 MeV < 10% FWHM at 1 MeV < 5% FWHM at 10 MeV
Time tagging accuracy	2 microseconds (at 3 sigma)
Impulsive event acquisition logic (Calorimeter burst)	sub-millisecond trigger and photon-by-photon acquisition capability
Orbit	Low Earth Orbit, equatorial with inclination i < 2.5°, eccentricity e < 0.01, altitude: 550-600 km
Average scientific telemetry	> 1.4 Mbit/s (after data compression)
Satellite attitude reconstruction	1' (at 3 sigma)
Satellite pointing modes	1. pointing mode (1 or 2 pointings per orbit); 2. survey zenith pointing mode.
Target of Opportunity observations	within 6 – 12 hours from alert (goal of 3 – 6 hours)
Mission duration	3 years + provision for a 2+ year extension

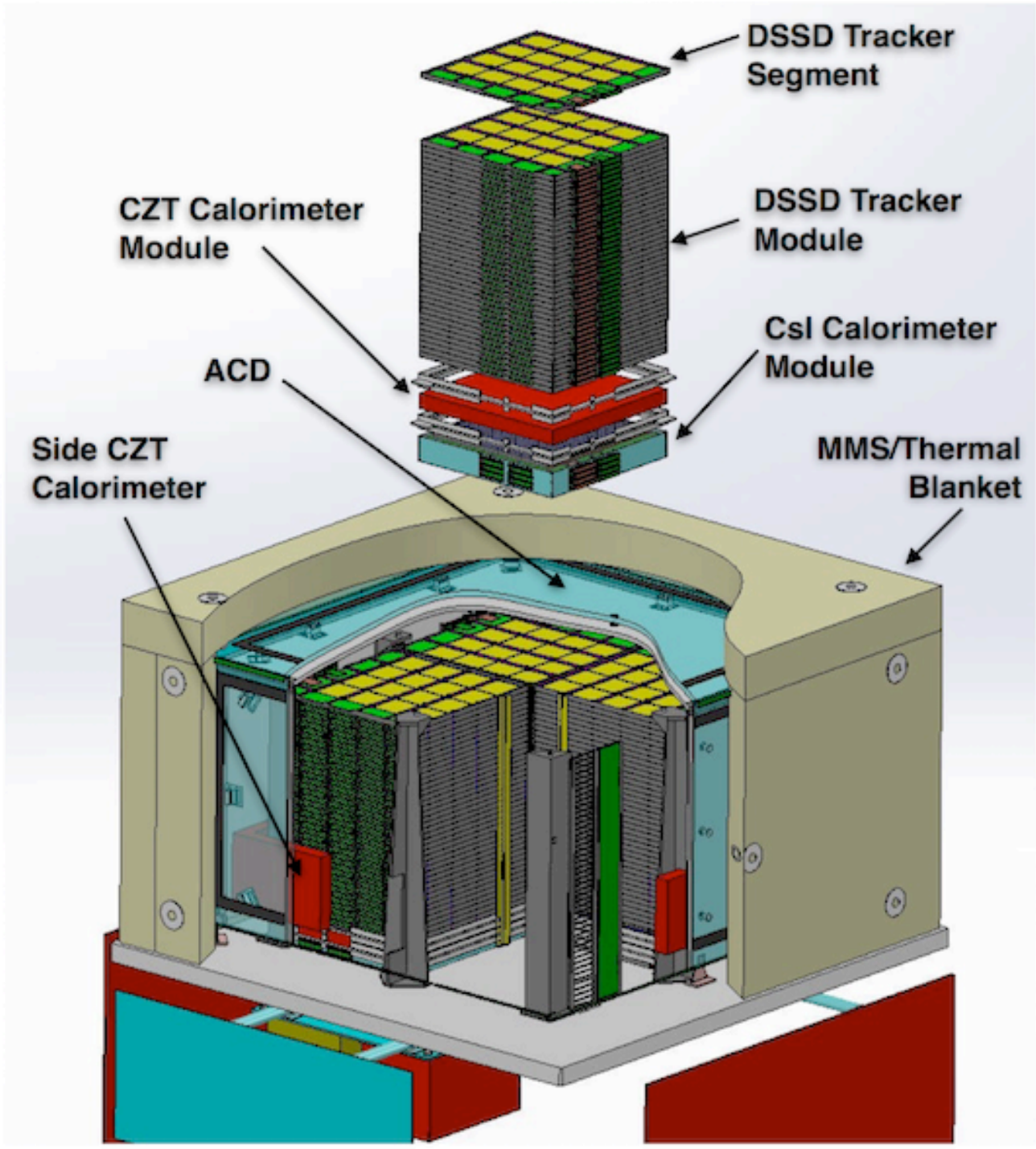
Polish participation: W. Nowosielski, P. Orleański, M. Ostrowski, Ł. Stawarz, A. Zdziarski, K. Ziętara

Space Research Center of PAS, Warsaw	Poland	PDHU, PSU design, manufacturing, testing and integration with S/S and instrument.	P.Orleański, W.Nowosielski

AMEGO
submitted to NASA/Probe

- similar design to e-ASTROGAM
- compared to Fermi/LAT: finer tracker, no tungsten GeV -> 10 MeV

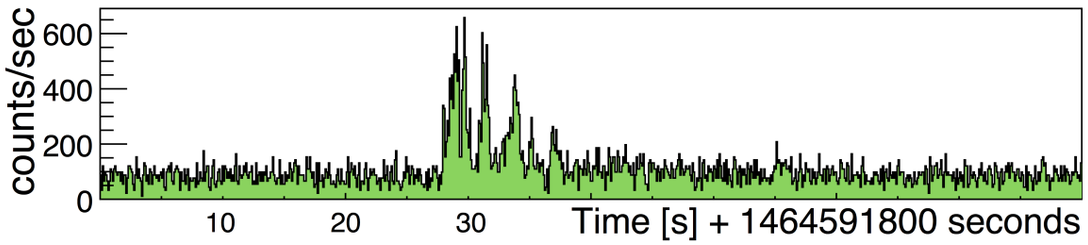
Energy range	0.2 MeV – >10 GeV
Angular Resolution	3º (1 MeV), 10º (10 MeV),
Energy Resolution	<1% below 2 MeV; 1-5% at 2-100 MeV; ~10% at 1 GeV
Field-of-View	2.5 sr
Sensitivity (MeV s^{-1} cm^{-2})	$4x10^{-6}$ (1 MeV); $4.8x10^{-6}$ (10 MeV); $1x10^{-6}$(100 MeV)

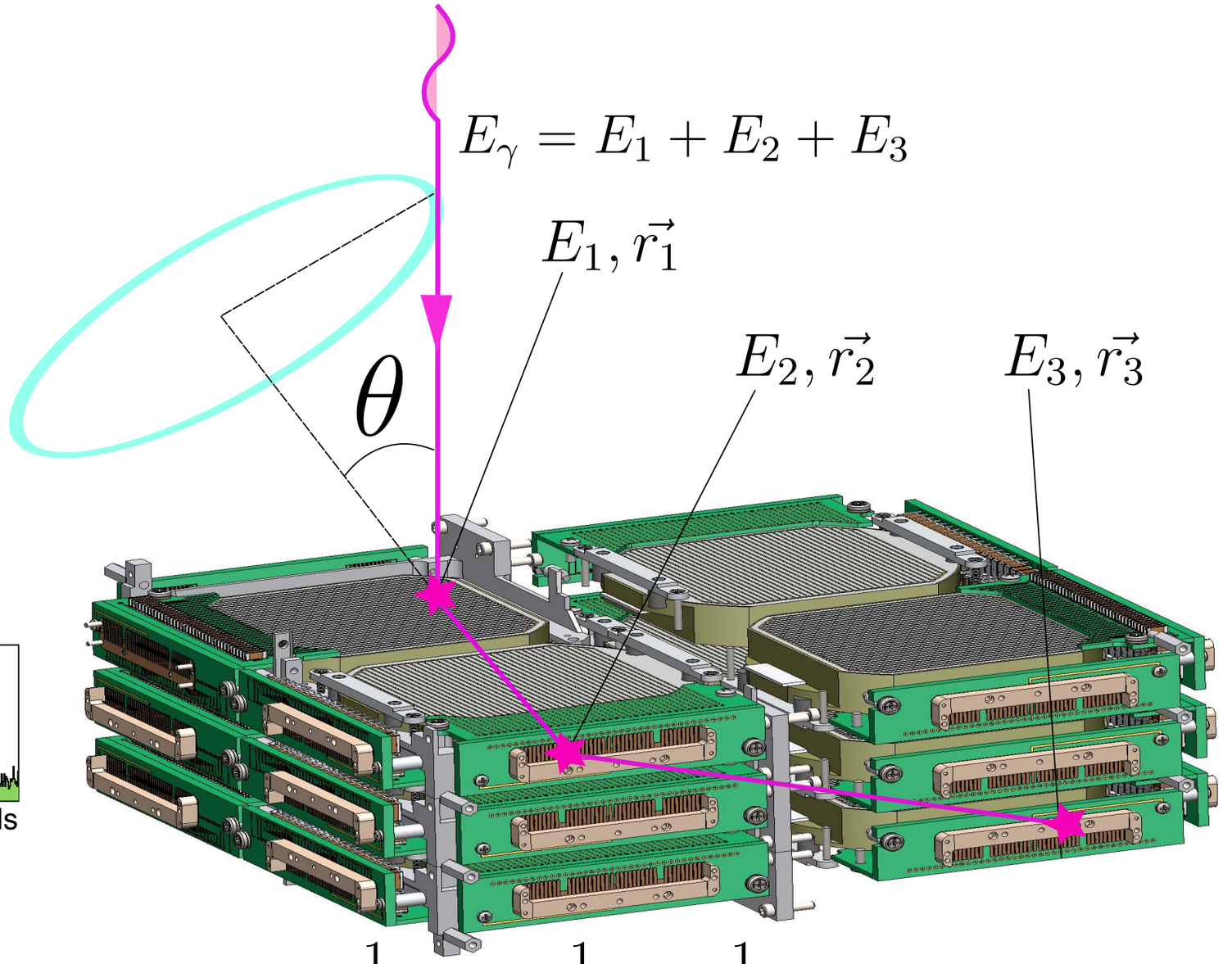


COSI
balloon experiment

- detector: Ge
  (0.2 - 5 MeV)

- cryogenic (-200 C)



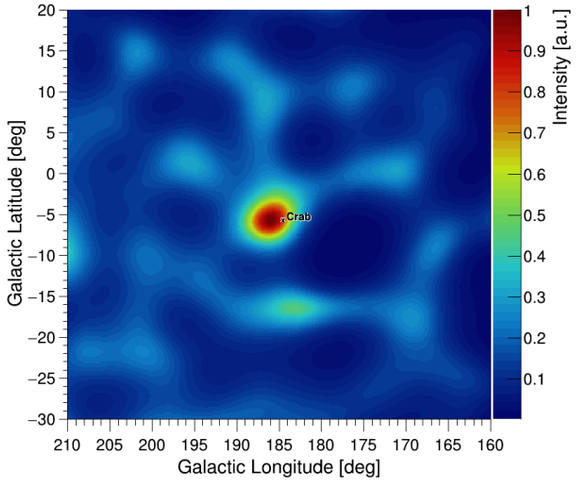


$$\frac{1}{E_\gamma - E_1} - \frac{1}{E_\gamma} = \frac{1}{mc^2}(1 - cos\theta)$$

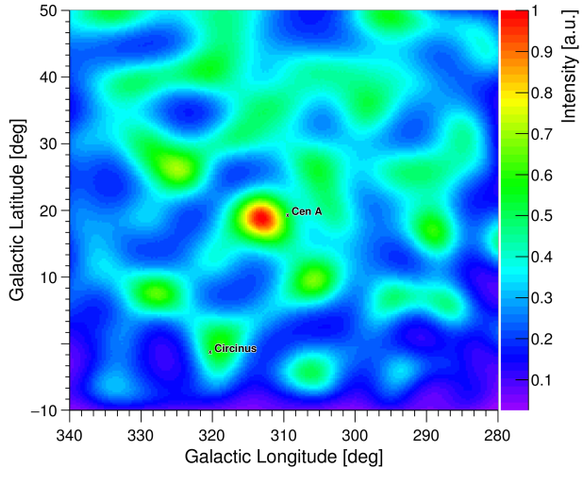
- energy resolution
  0.3% (0.66 MeV)

- angular resolution
  6 deg (0.66 MeV)

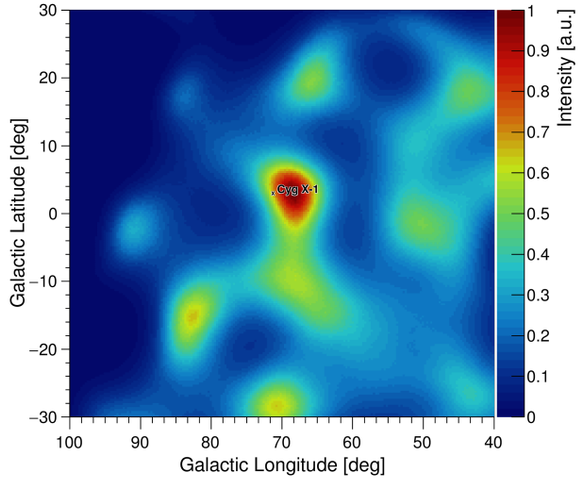
- first successful
  flight in 2016



(a) Crab Nebula



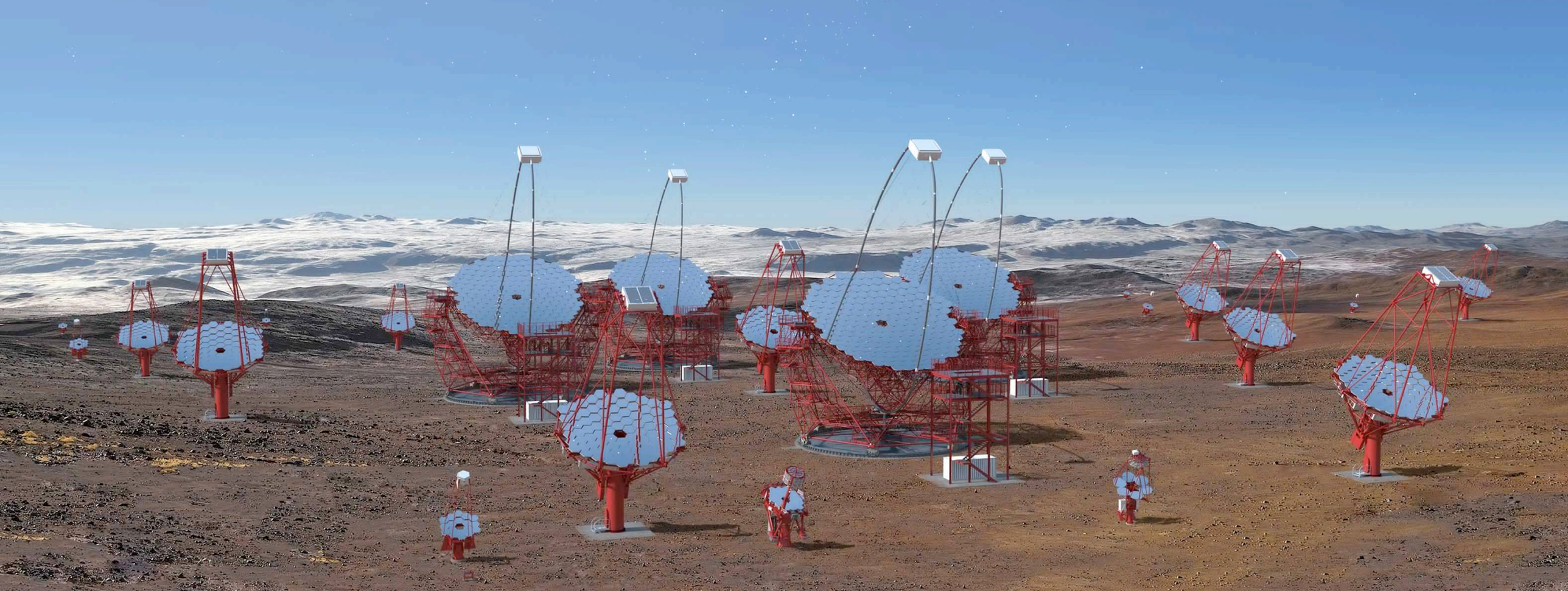
(b) Centaurus A



(c) Cygnus X-1

Cherenkov Telescope Array

- ~100 IACTs of three sizes: L, M, S (20 GeV - 100 TeV)
- 2 sites selected: Chile, La Palma
  observations planned to begin around 2022
- worldwide collaboration (combines H.E.S.S., MAGIC, VERITAS)
  Polish participation: SST-1M prototype and much more



summary

- three main gamma-ray bands:
  MeV, GeV (HE), TeV (VHE)

- different detection principles
  different detector designs

- space-based (MeV - TeV) - trackers, calorimeters
  ground-based (10s GeV - PeV) - air showers

- major gap in 1 - 30 MeV band: e-ASTROGAM

- polarimetry is possible in MeV band

- *significant* Polish participation: INTEGRAL, H.E.S.S., MAGIC, CTA, e-ASTROGAM

thank you!