The Science Case for a future gamma-ray missions in the 300 keV - 100 MeV domain

Peter von Ballmoos, IRAP Toulouse - RICAP 2016

The Science Case for a future gamma-ray missions in the 300 keV - 100 MeV domain

Galactic Radioactivities

^{26}Al, ^{60}Fe, ^{44}Ti, activation lines

e^-e^+ Annihilation Radiation

sensitive all sky spectro-imaging

Compact Sources

AGN, XRBs, μ-quasars, magnetars …

Gamma-ray bursts

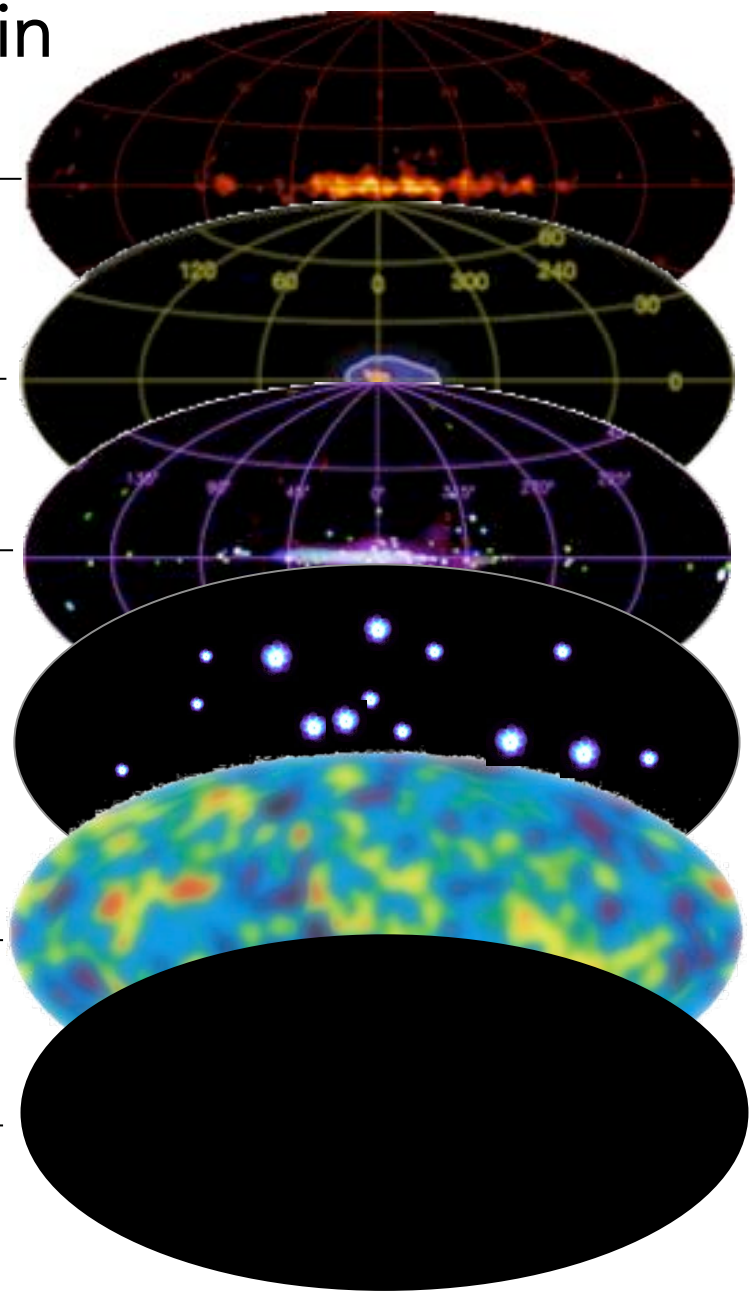
localization, spectroscopy, polarisation !

Cosmic gamma background

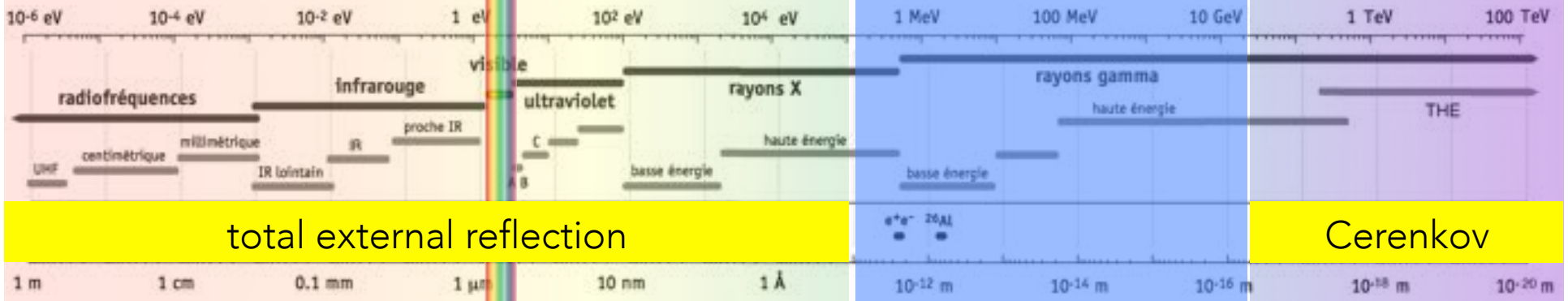
multipole analysis, search/constrain AM

Dark Matter Search

DM signatures, fundamental physics

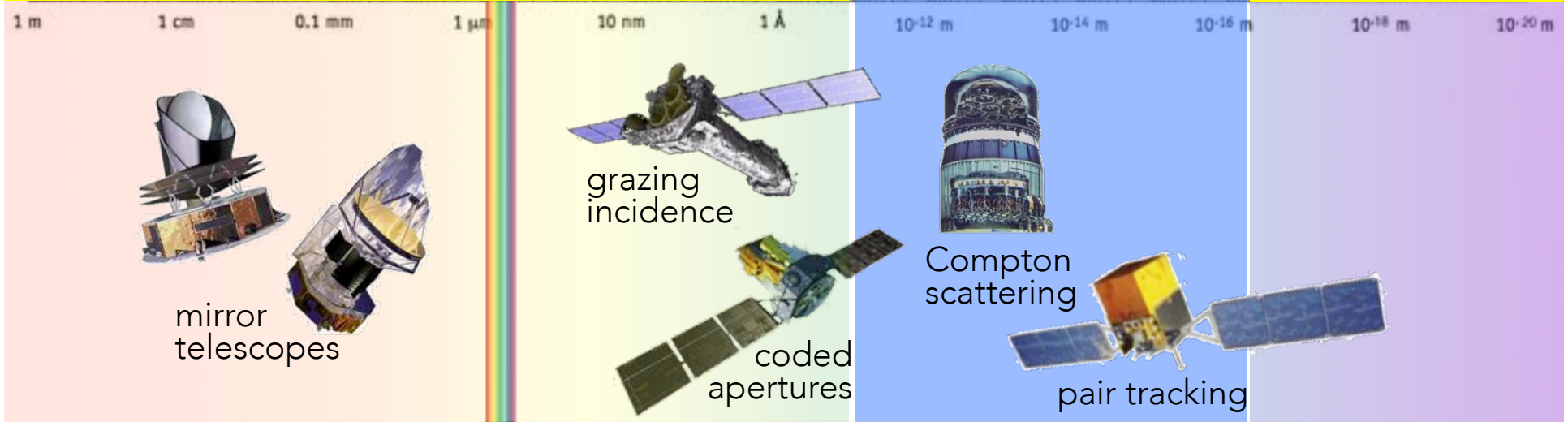


Experimental Astronomy and the MeV/GeV domain

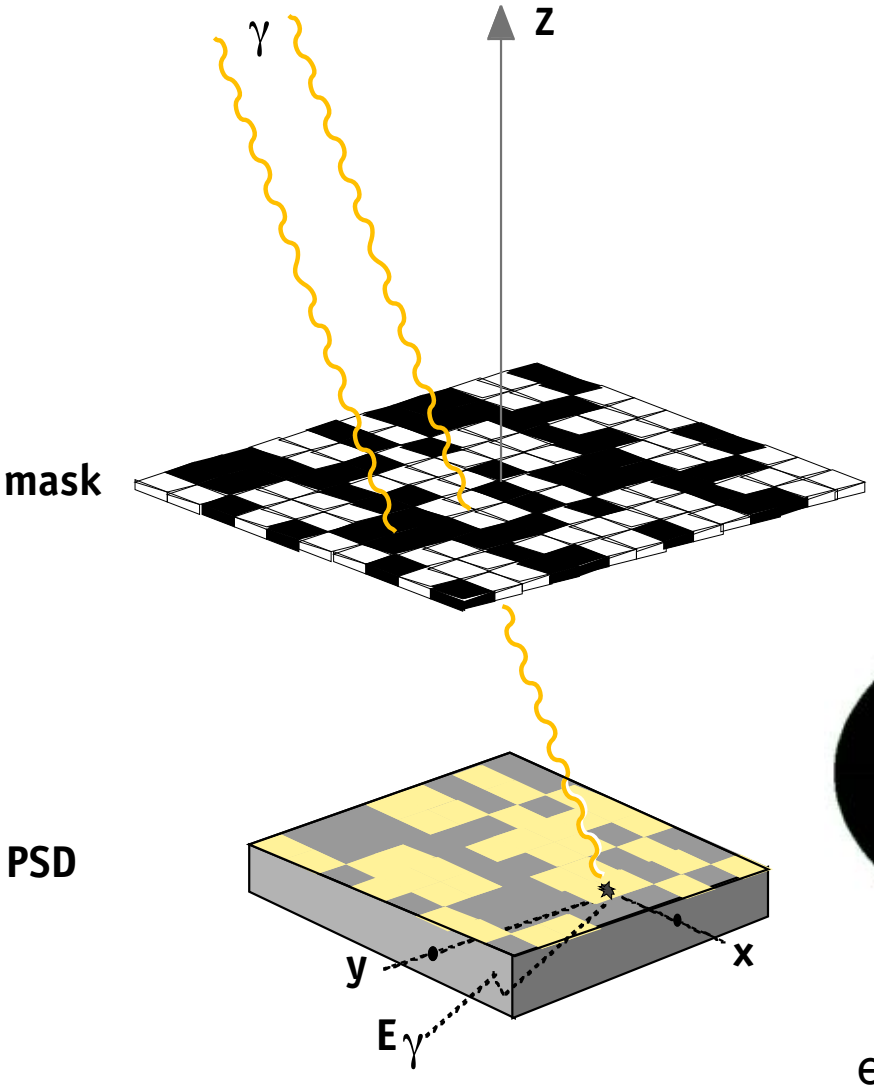


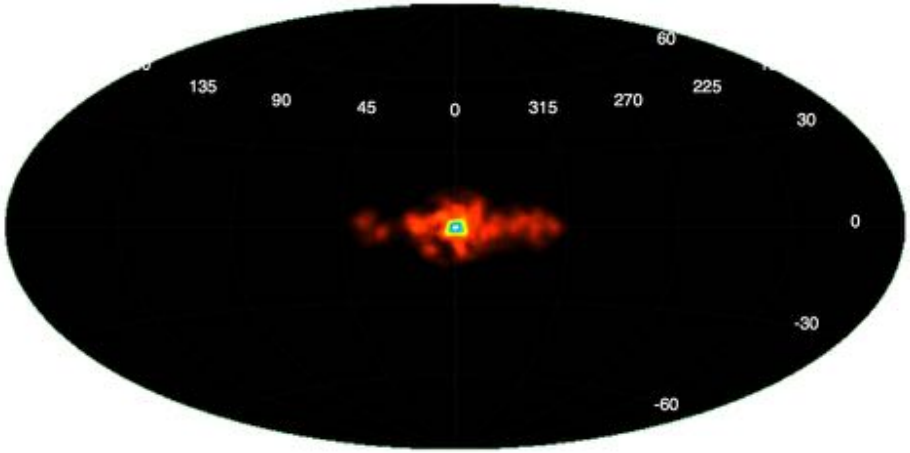
total external reflection

Cerenkov



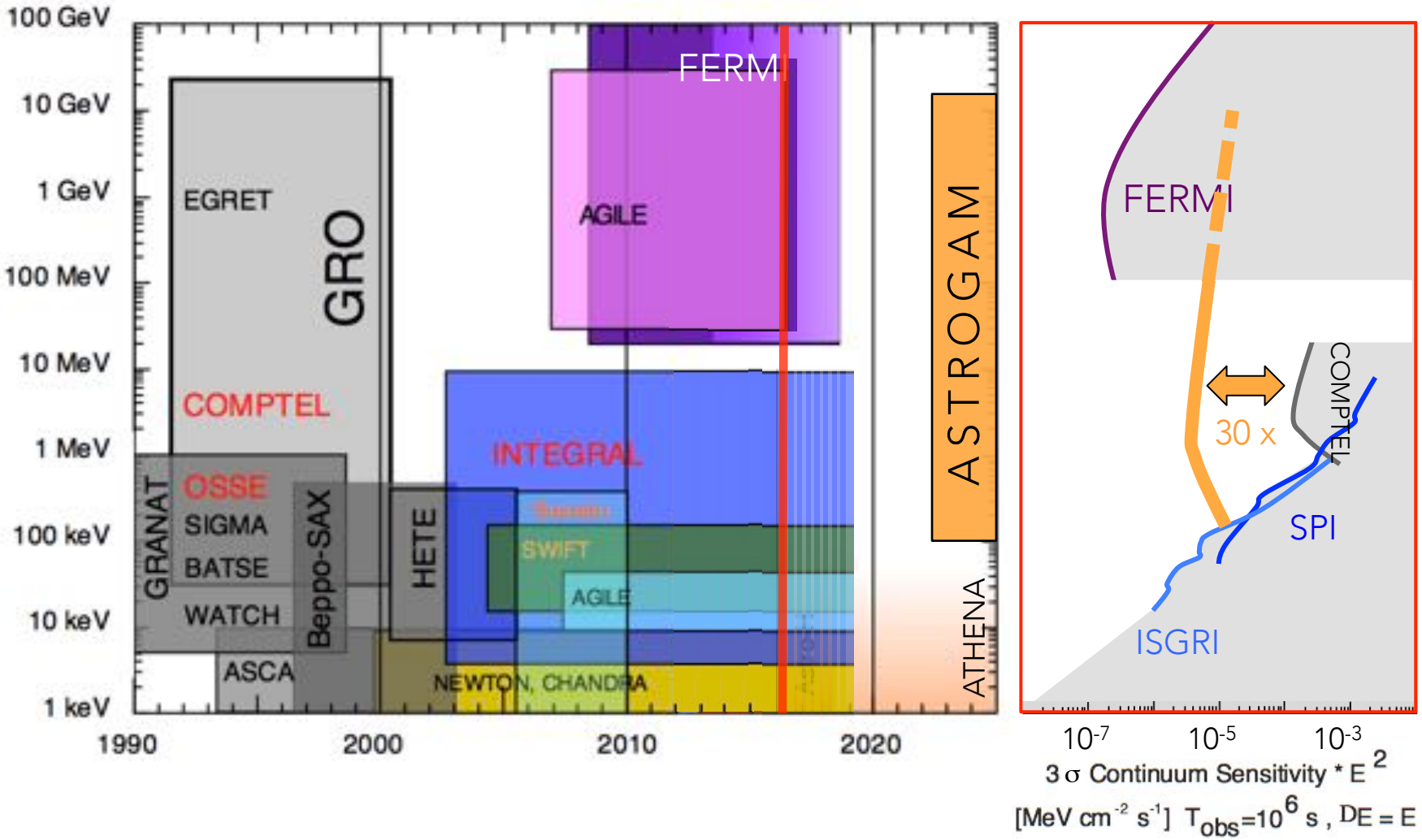
coded mask imaging





e+e- annihilation map

The roadmap of gamma-ray astronomy



Post-INTEGRAL/FERMI aera : a white spot on the astrophysics roadmap

Requirements for a future gamma-ray mission

$f_{3\sigma} < 5 \cdot 10^{-7}\ s^{-1} \cdot cm^{-2}$

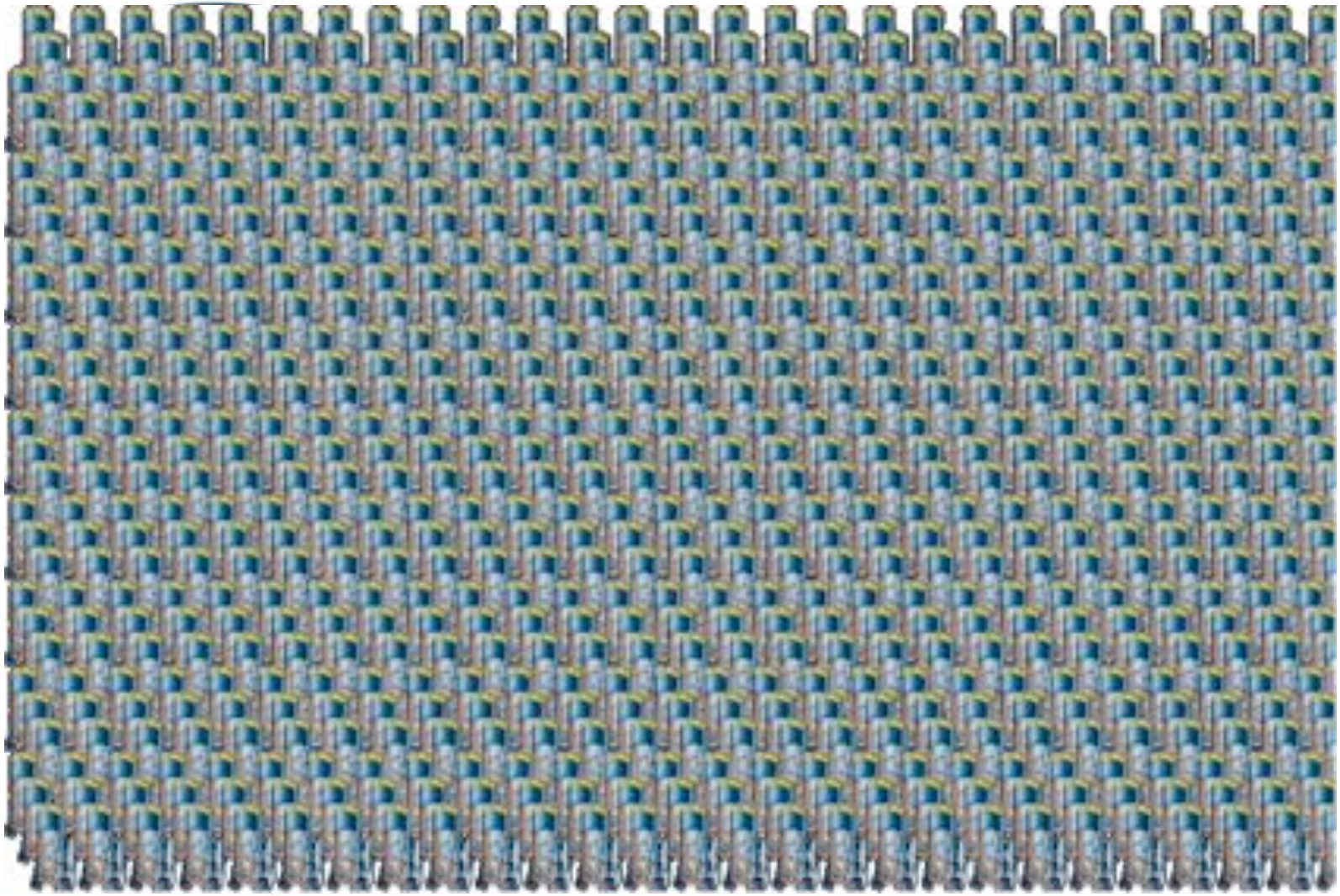
$$f_{3s} < 5 \cdot 10^{-7}\ s^{-1} \cdot cm^{-2}\ !$$

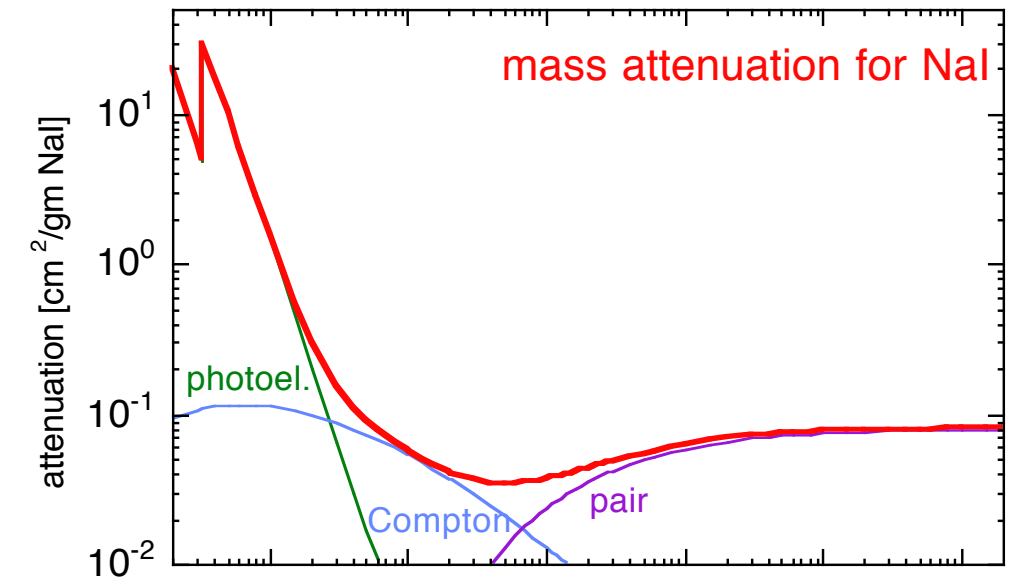
You must be kidding

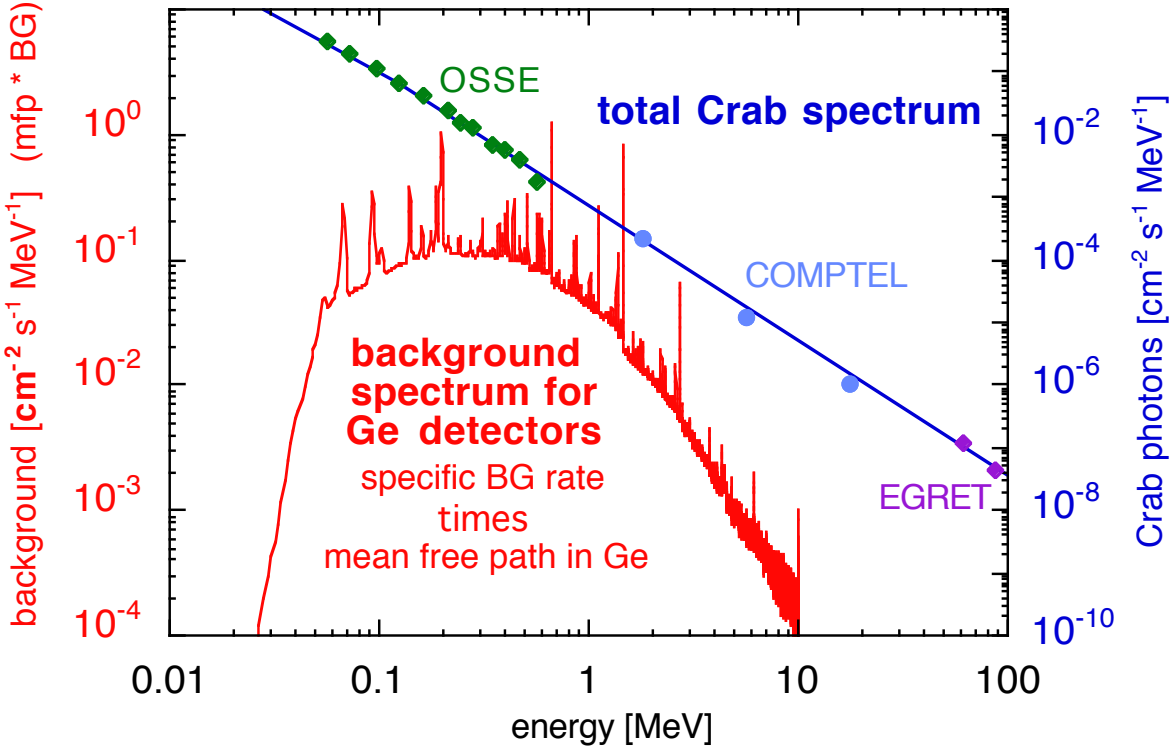
This means detecting one photon per cm^2 and month

with a BG of one CR particle per cm^2 and second
producing about one 511 keV BG event per cm^3 every minute in a Ge detector

Requirements for a future gamma-ray mission



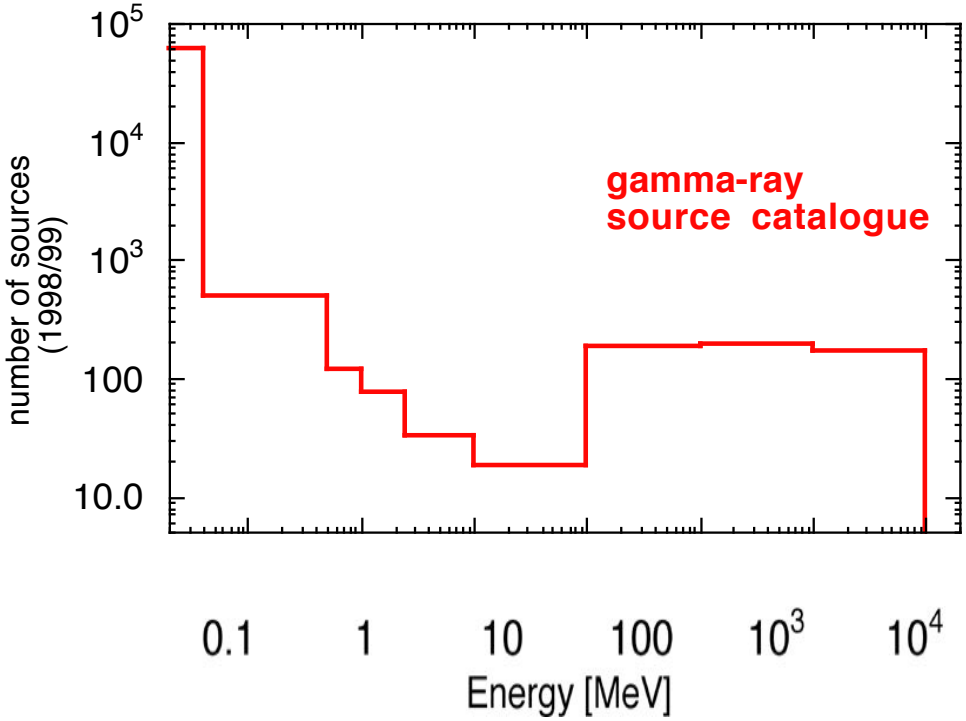




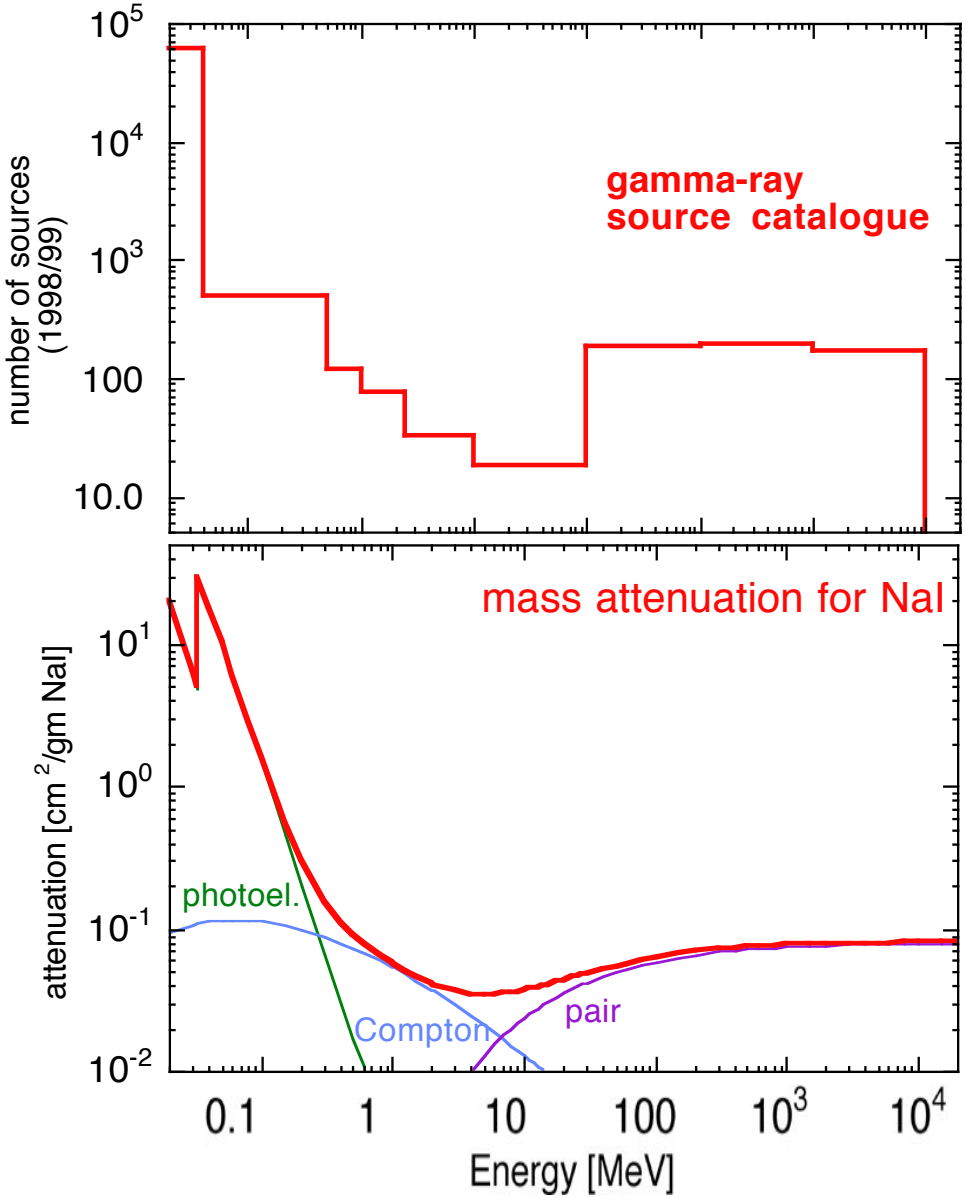
The "impossible" MeV range :

- three energy-loss processes plus coherent interactions ...
- minimum cross section
- "rich" background !

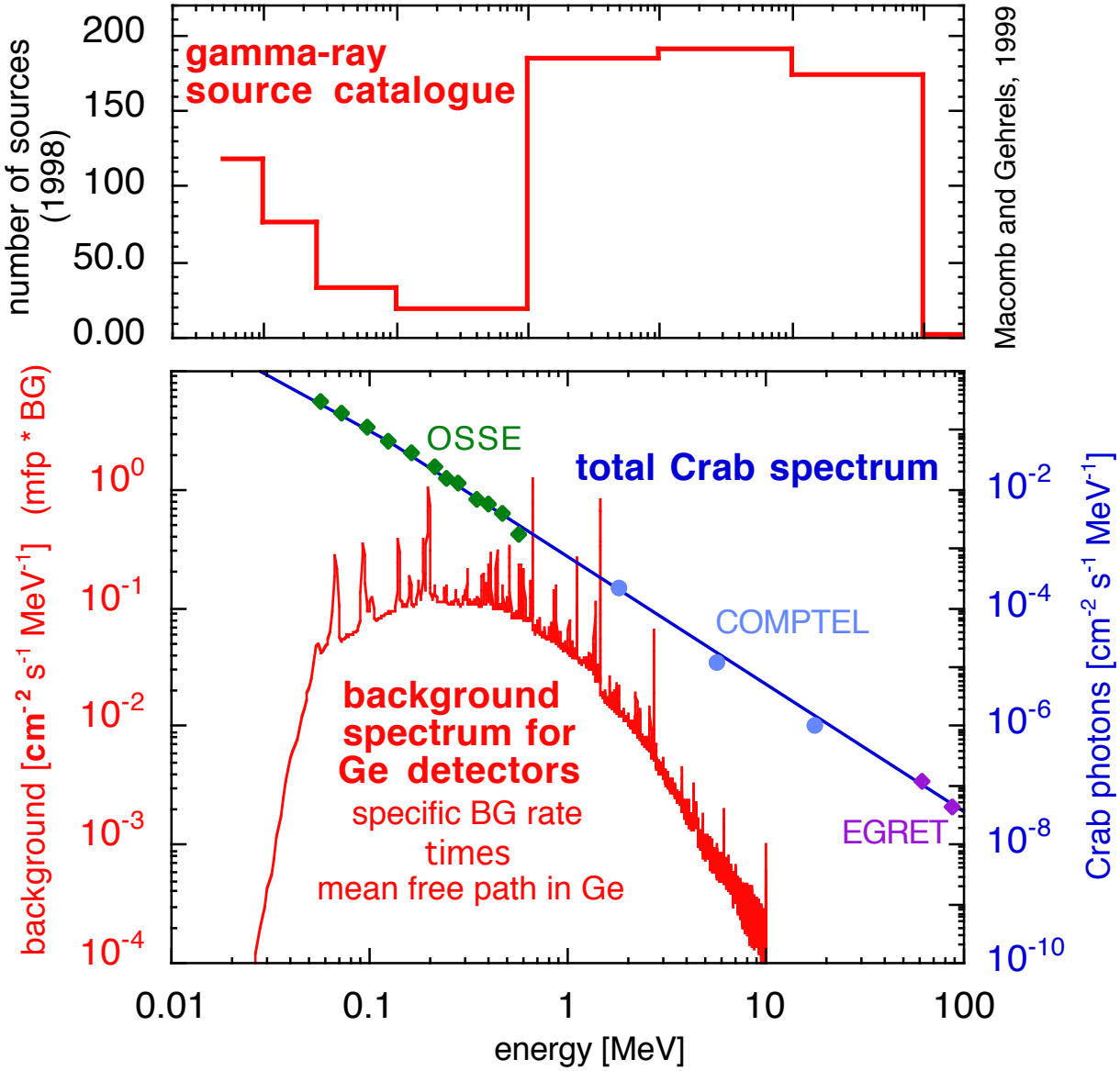
Gamma-ray source statistics



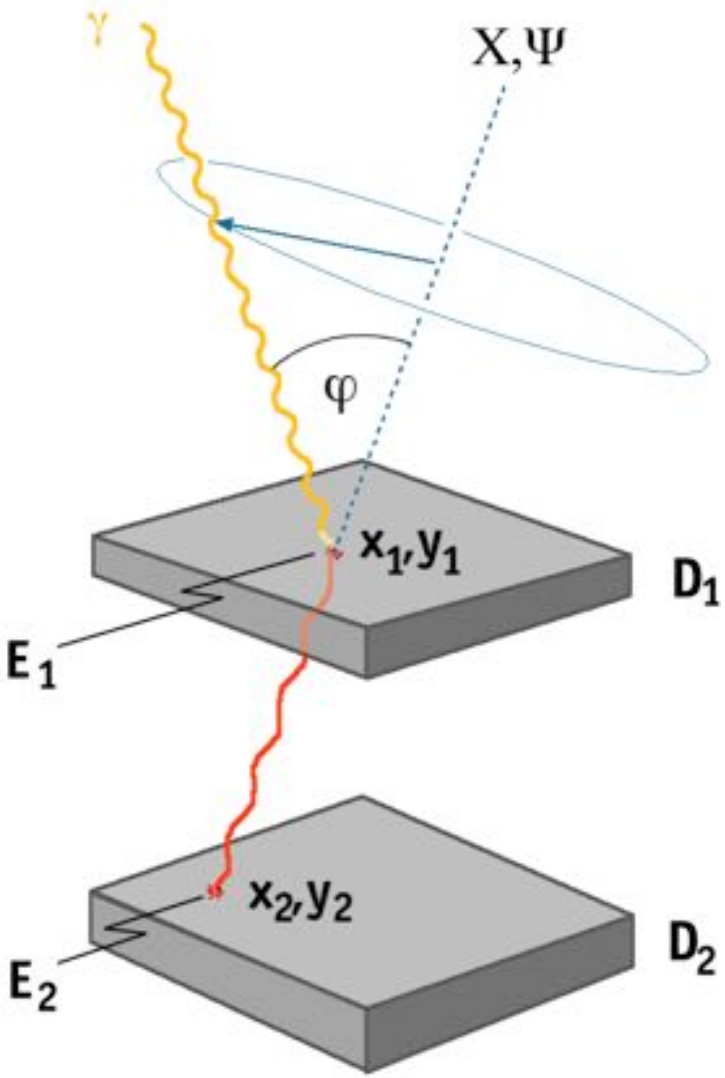
Gamma-ray source statistics



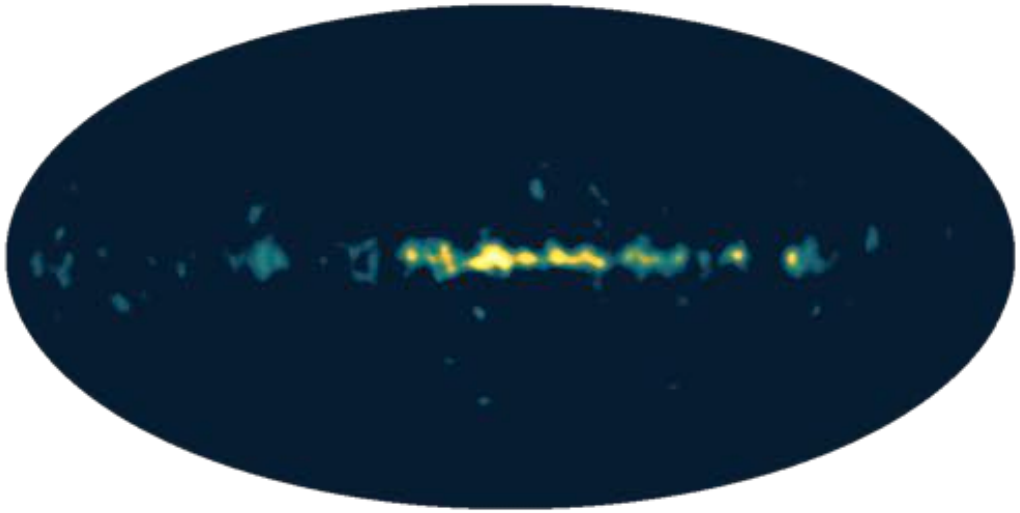
Gamma-ray source statistics



Compton Telescopes

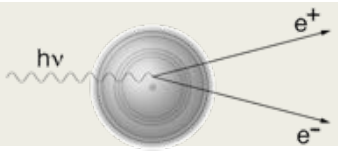


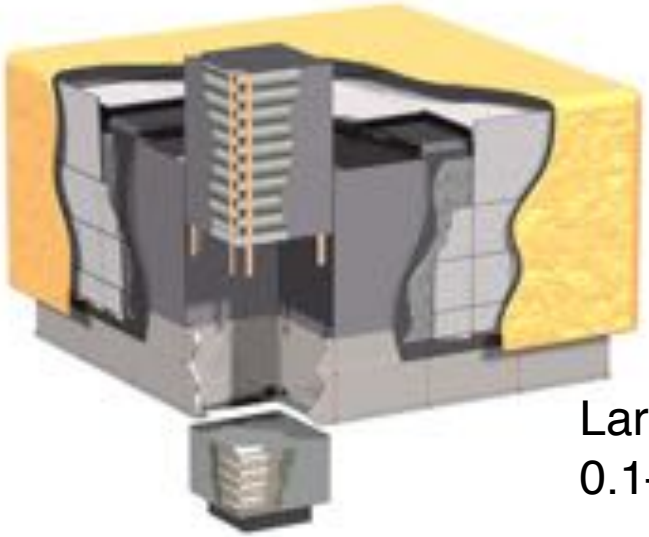
GRO/ COMPTEL



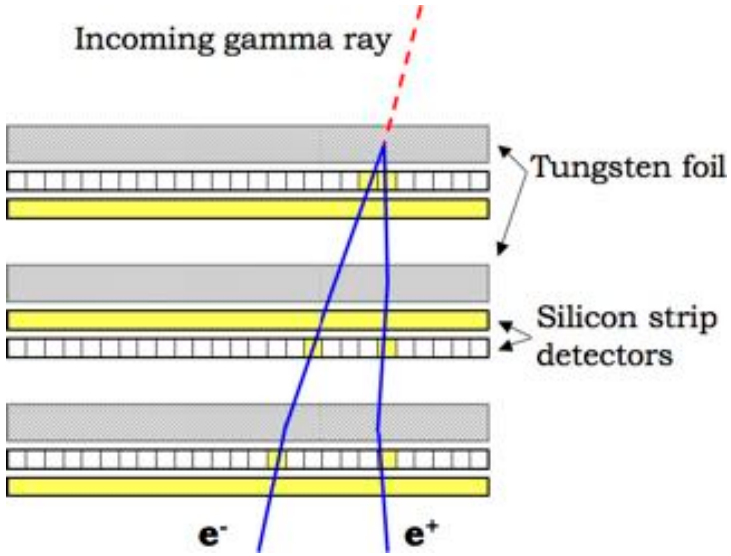
first ^{26}Al all-sky map

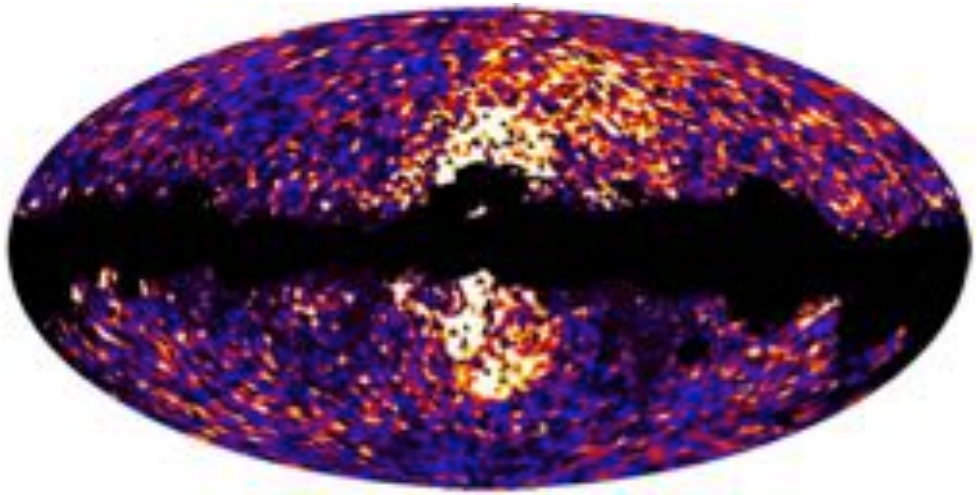
pair-conversion telescope





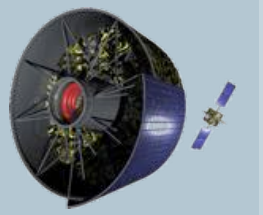
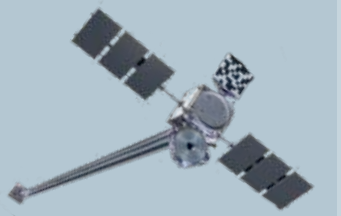
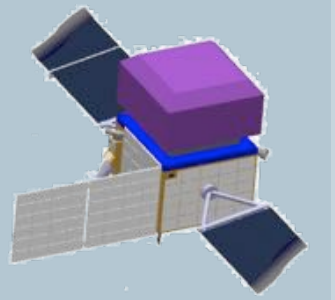
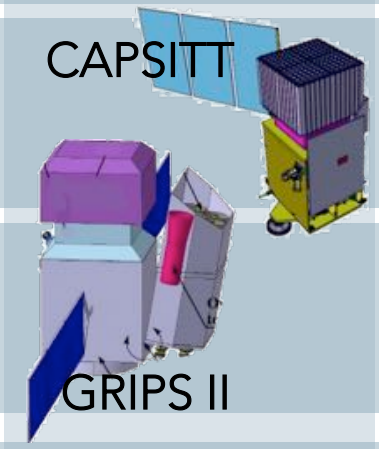
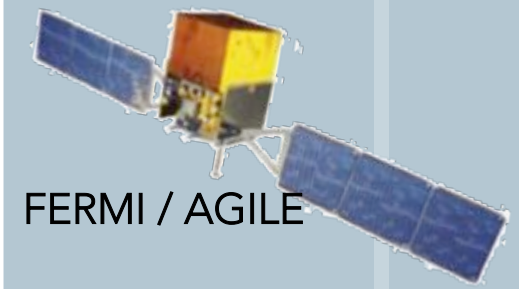
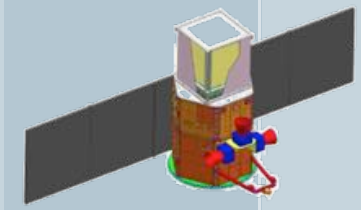
LAT
Large Area Telescope
0.1– 300 GeV





2-5 GeV, Dobler, ApJL 760, 2012

e- ASTROGAM - where we come from

heritage	M1/M2 (2007)	M3 (2011)	S1 (2012)	M4
CLAIRE  NCT	 GRI	 DUAL		AstroMeV & Gamma-Light
 COMPTEL	 GRIPS I	CAPSITT  GRIPS II		
 FERMI / AGILE			 Gamma-Light	

The Science Case for a future gamma-ray missions in the 300 keV - 100 MeV domain

Galactic Radioactivities

^{26}Al, ^{60}Fe, ^{44}Ti, activation lines

e^-e^+ Annihilation Radiation

sensitive all sky spectro-imaging

Compact Sources

AGN, XRBs, μ-quasars, magnetars …

Gamma-ray bursts

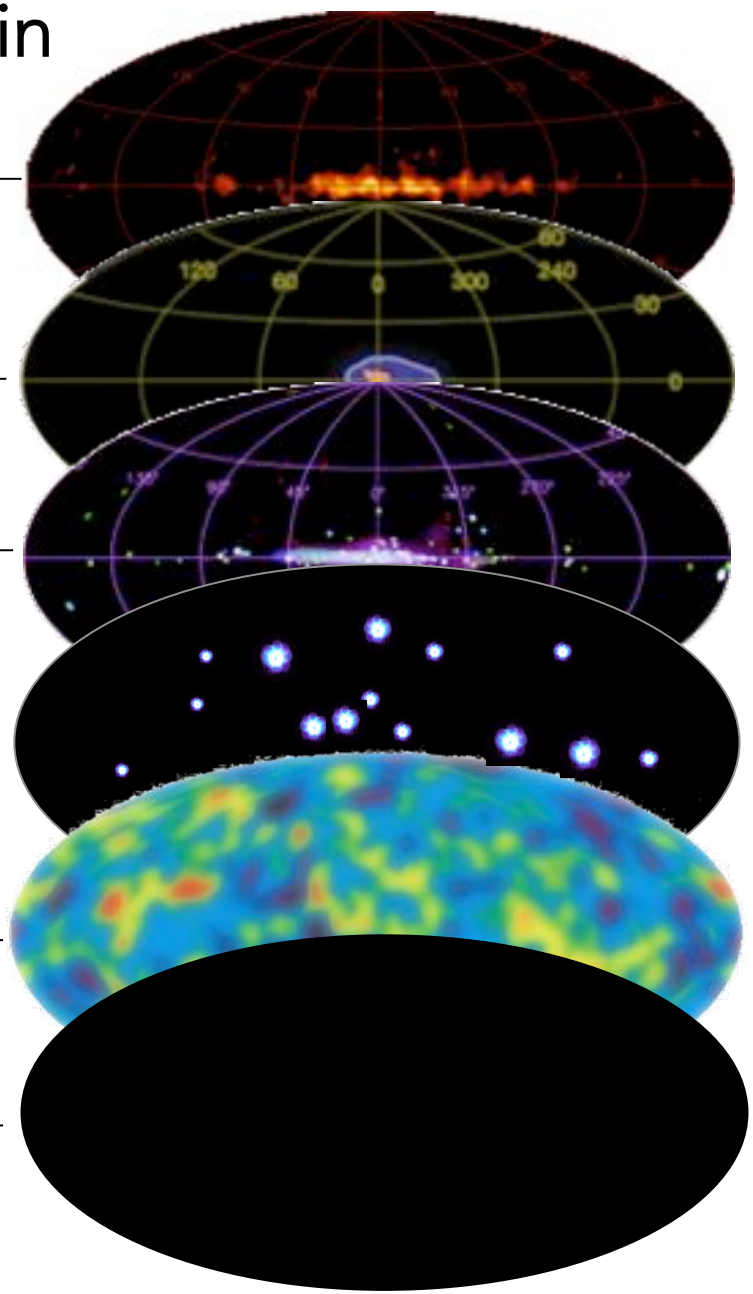
localization, spectroscopy, polarisation !

Cosmic gamma background

multipole analysis, search/constrain AM

Dark Matter Search

DM signatures, fundamental physics



Gamma-Ray science topics evaluated by AHEAD/WP9

(H2020 program : Integrated Activities in the High Energy Astrophysics Domain)

- GRB (grav. collapse, accelerators, early Universe, testing Lorentz invariance)
- Type Ia Supernovae (physics of SN, as standard candle)
- Galactic Radioactivities
- Low energy cosmic-rays, Origin CRs, acceleration in Galaxy, shock acc. (->DM)
- Origin of positrons (->DM)
- Dark Matter signatures
- High-z AGNs
- Origin of the “Fermi Bubbles”
- Galactic Centre Physics (central BH, interaction with surrounding medium)
- Galactic compact obj / binaries : jets, the disk/jet transition, testing Lorentz inv
- Extragalactic compact obj : jets, the disk/jet transition, testing Lorentz inv.
- Pulsars physics (high B fields, testing Lorentz invariance …)
- MeV extragalactic background / Baryon asymmetry at cosmological distances
- Core-Collapse Supernovae
- Novae
- Solar flare physics
- Terrestrial Gamma-Ray Flashes

Gamma-Ray science topics evaluated by AHEAD/WP9

(H2020 program : Integrated Activities in the High Energy Astrophysics Domain)

The gamma-ray work package of AHEAD (H2020) selected two top priorities :

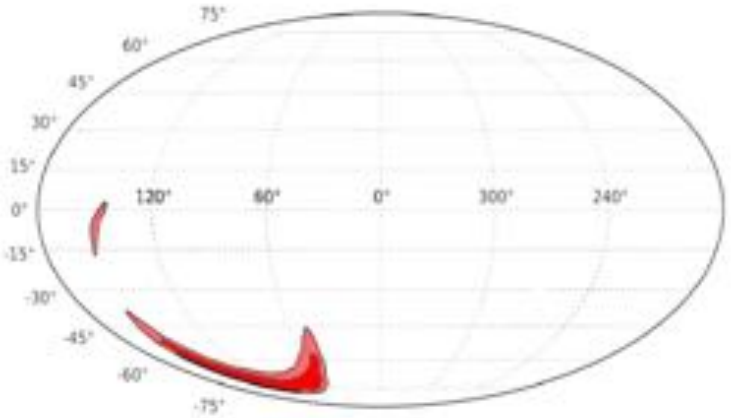
- *Gamma-Ray Bursts*
- *Nuclear Sciences* (inc. Stellar Explosions, LE Cosmic-Rays, Positrons,)

The *Legacy Science* topics are

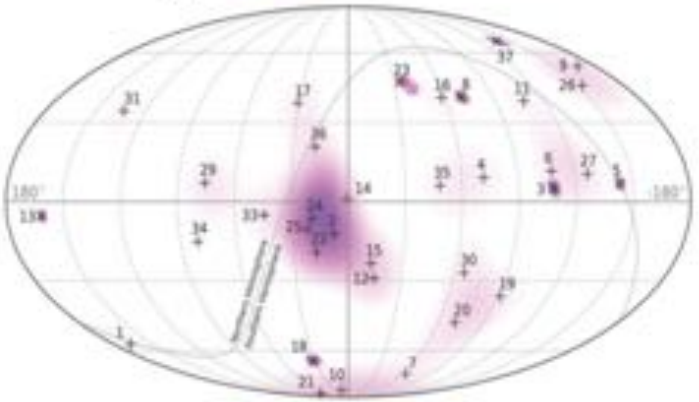
- Pulsars physics (high B fields, testing Lorentz invariance …)
- Extragalactic compact obj : jets, the disk/jet transition, testing Lorentz inv.
- Galactic compact obj / binaries : jets, the disk/jet transition, testing Lorentz - Dark Matter signatures
- Galactic Centre Physics (central BH, interaction with surrounding medium)
- High-z AGNs
- Origin of the "Fermi Bubbles"
- MeV extragalactic background / Baryon asymmetry at cosmological dist.
- Solar flare physics
- Terrestrial Gamma-Ray Flashes

It has to be noted that the SAG did not (officially) know about the detection GW's at the time this decision was taken …

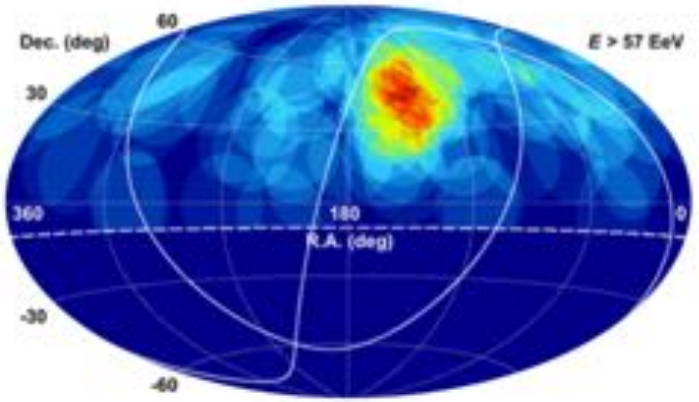
Three new Astronomies !



Gravitational Waves
Localization map for GW150914 detected by the *LIGO collaboration*, (galactic coordinates), Abbott et al. 2016



Neutrinos
Arrival directions of 37 neutrinos observed in 3-years by the IceCube detector (galactic coordinates), Aartsen et al. 2014



Ultra-High Energy Cosmic Rays
Arrival directions of 72 cosmic-ray events with energy E > 57 EeV observed as measured by the Telescope Array Experiment (equatorial coordinates), Abbasi et al. 2014

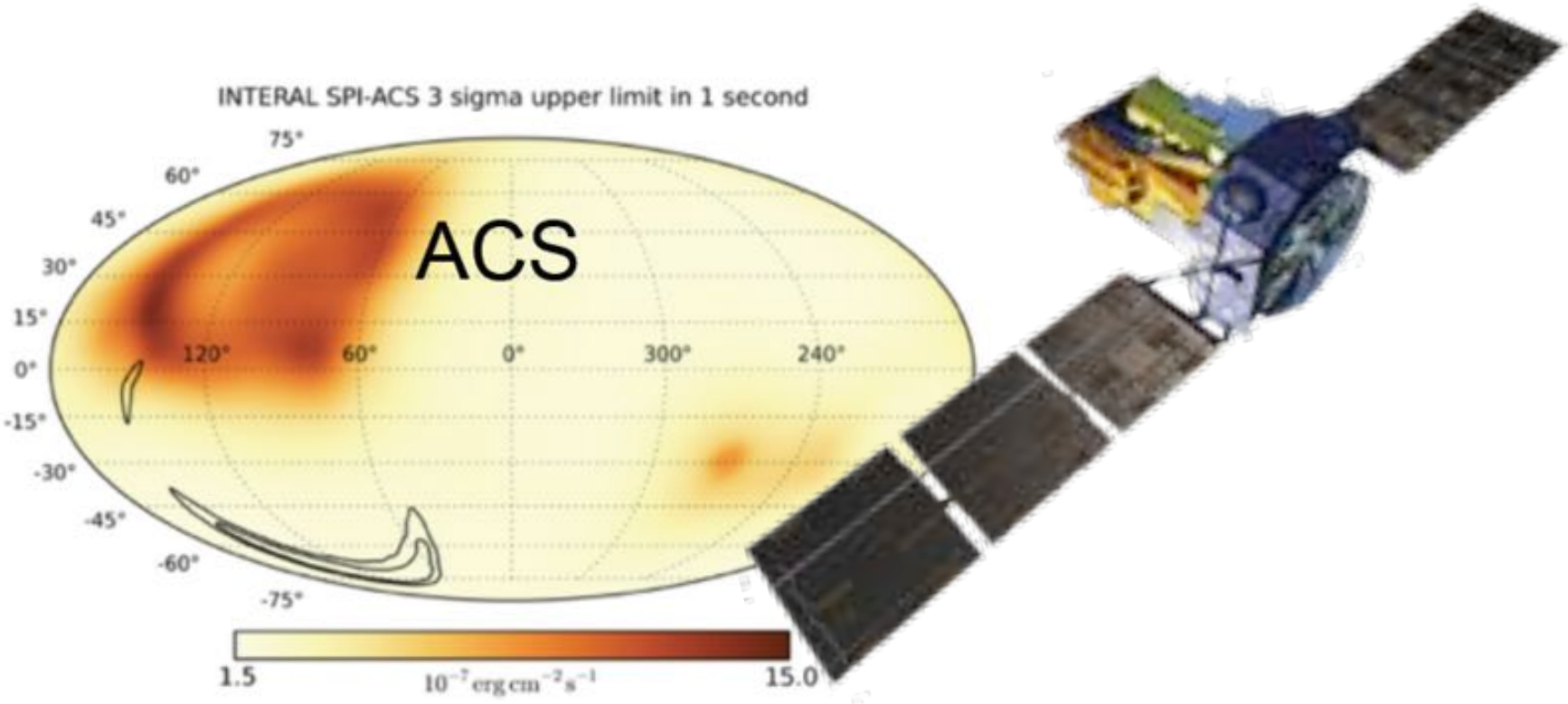
Gamma-Rays are the link to the New Astronomies

Our access to astrophysical information is boosted by three new Astronomies : Gravitational Waves, Neutrinos (and Ultra-High Energy Cosmic Rays)
are about to open new phase space – not only in Astronomy, but also in fundamental physics.

One of the most important observational challenges of our time is to establish the link between discoveries of the new Astronomies and the electromagnetic Universe.

As of today, INTEGRAL has established the most stringent upper limit on electromagnetic energy radiated during a gravitational wave event

GW150914 : $E\gamma/Egw < 10^{-6}$ (Savchenko et al. 2016).



see talk by P. Ubertini on Thursday (Integral follow up of the GW event)

Gamma-Rays as the link to the New Astronomies

Our access to astrophysical information is boosted by three new Astronomies : Gravitational Waves, Neutrinos and Ultra-High Energy Cosmic Rays
are about to open new phase space – not only in Astronomy, but also in fundamental physics.

One of the most important observational challenges of our time is to establish the link between discoveries of the new Astronomies and the electromagnetic Universe.

=> main goal for any future gamma-ray mission !


S.E. Boggs, UCB (PI), LBNL, Berkeley
IRAP Toulouse NTHU & NCU, Taiwan
COSI
Compton Spectrometer and Imager

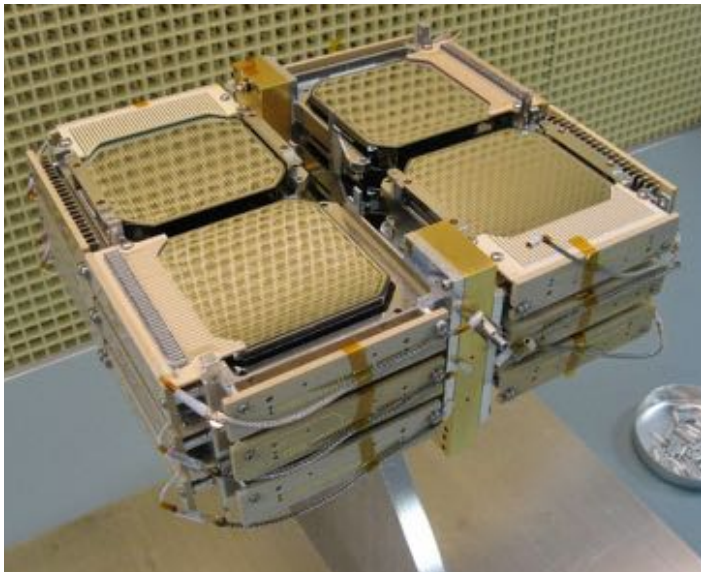
Overview: Instrument & Campaigns

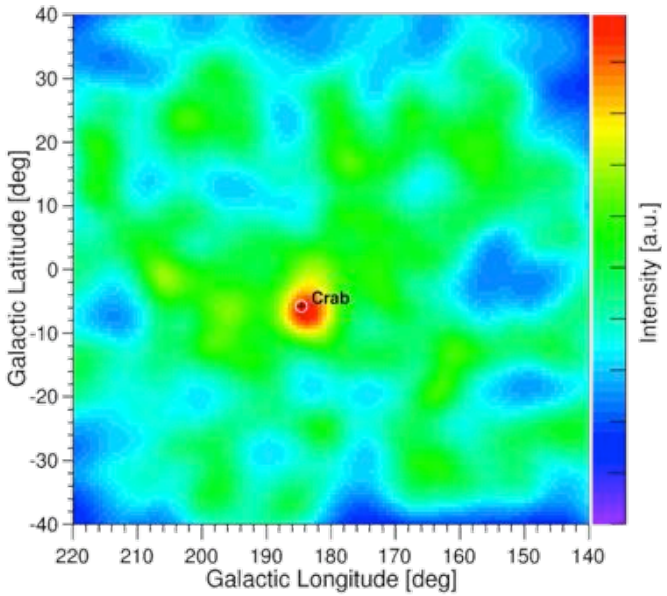
Instrument:

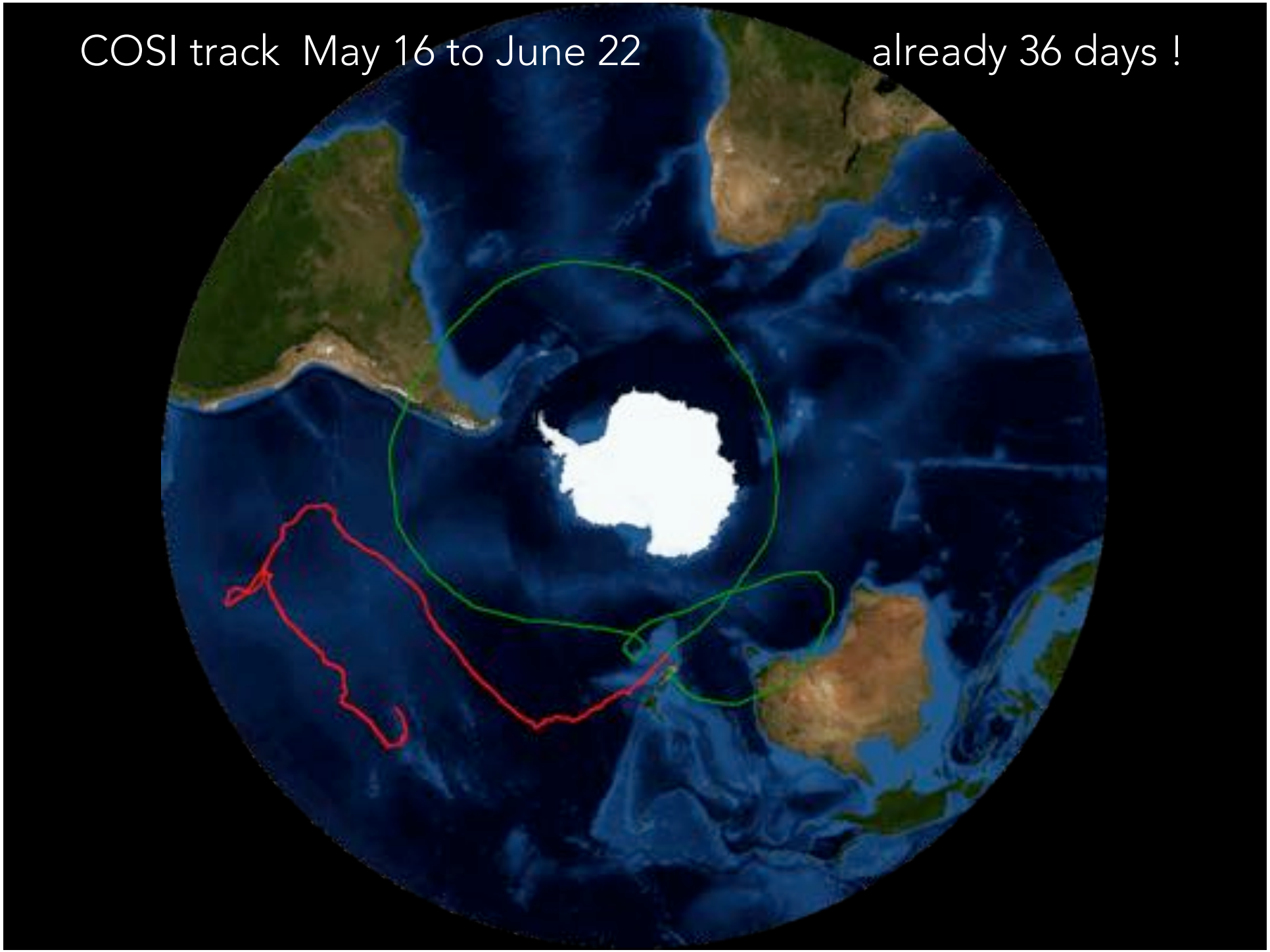
- Balloon-borne Compton telescope
- Energy range: 0.2 – several MeV
- 12 high-purity Ge double-sided strip detectors , 2 mm strip pitch
- Energy resolution: 1.5-3.0 keV FWHM
- Depth resolution: ~0.5 mm FWHM
- Angular resolution: up to ~4° FWHM
- Large field-of-view: almost 1/4 of sky

Balloon campaigns:

- NCT: 2 GeD prototype flew from Ft. Sumner, NM on June 1st, 2005
- NCT: 10 GeD instrument flew from Ft. Sumner, NM on May 17th, 2009
- NCT: Failed launch from Alice Springs, Australia on April 29th, 2010
- COSI: 2014 Antarctica campaign
- COSI: 2016 campaign …






COSI track May 16 to June 22
already 36 days !