The History of High-Energy Astrophysics

Gottfried Kanbach, MPE, Garching

"All truths are easy to understand once they are discovered; the point is to discover them."
Galileo Galilei (1564–1642)

1940-1960:	Roots:	Cosmic Rays, Nuclear & Particle Physics
1960-1980:	Foundations:	pioneering space experiments
1980-2000:	Breakthroughs:	multi-λ h.e. surveys, CGRO
2000-2020:	Maturity:	Fermi, Swift, Cerenkov telescopes

1940's – 1960: The Roots

The status of particle physics, cosmic ray (CR) research, and radio astronomy allowed questions like:

- where do the cosmic rays come from?
- what is the photon fraction in the CR beam?
- what powers the strong galactic radio emission?
- are there gamma-ray sources in the sky?
- what is the nature of gamma-ray sources?
- Is there antimatter around?

1940's – 1960: The Roots

The potential of cosmic gamma radiation from the interaction of energetic particles (cosmic rays) with matter, fields, and photons

Source processes:

Compton Scattering: Feenberg & Primakoff, Phys. Rev. 73, 449 (1948)

Meson production: Hayakawa, Prog. Theor. Phys., 8, 571 (1952)

Bremsstrahlung: Hutchinson, Phil. Mag., 43, 847 (1952)

Detection:

Photoeffect (<100 keV); Compton scattering (100kEV-30 MeV)

Pair creation (>20 MeV); e-m Showers+Cerenkov light (>20 GeV)

Estimates for cosmic gamma-ray sources

Morrison, Nuovo Cimento, 7, 858, 1958

→ Fluxes too high → optimistic observers were soon revising the estimates after balloon experiments failed to see the predicted intensities

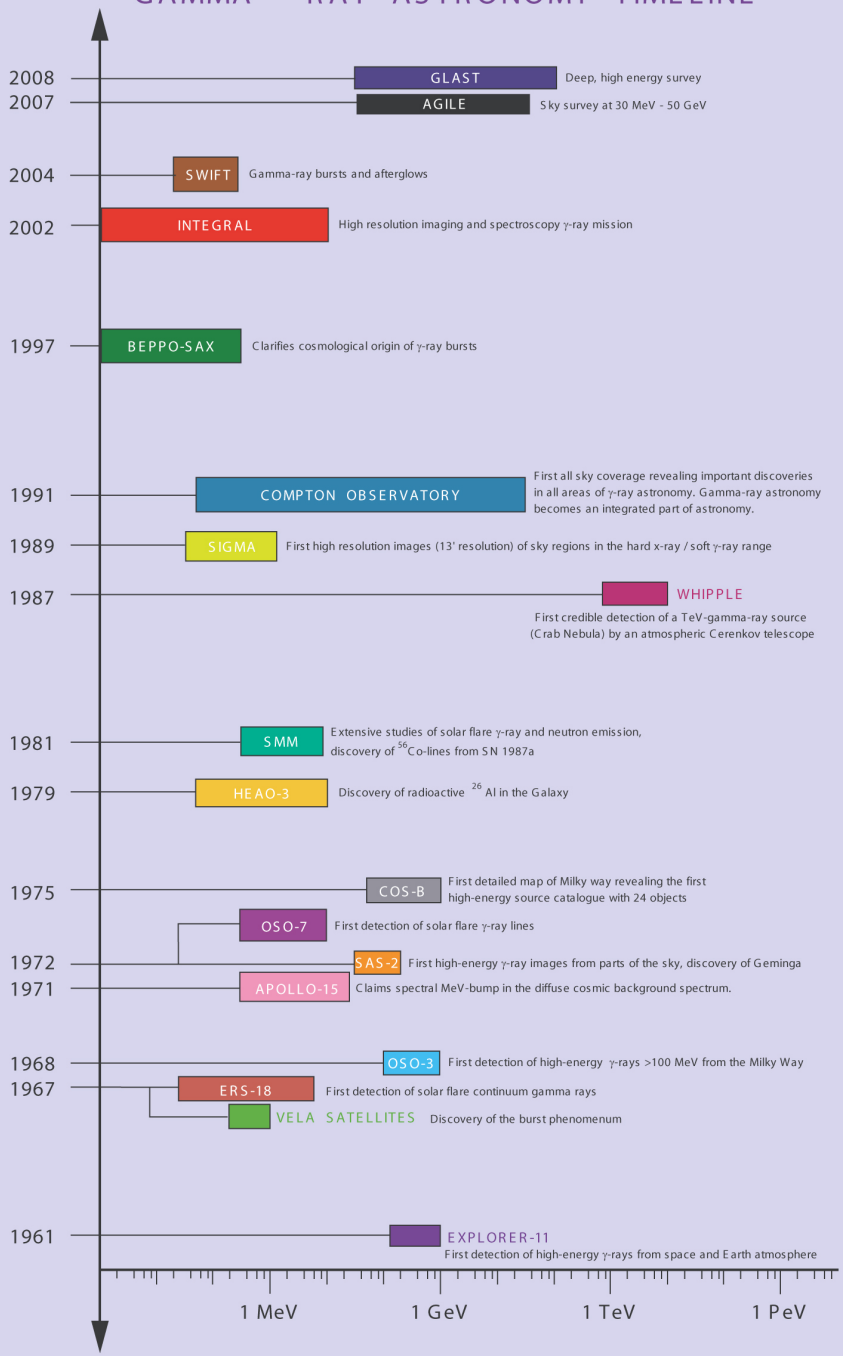
Source processes:
Compton Scattering: Feenberg & Primakoff, Phys. Rev. 73, 449 (1948)
Meson production: Hayakawa, Prog. Theor. Phys., 8, 571 (1952)
Bremsstrahlung: Hutchinson, Phil. Mag., 43, 847 (1952)

Estimates for cosmic gamma-ray sources
→ Morrison, Nuovo Cimento, 7, 858, 1958

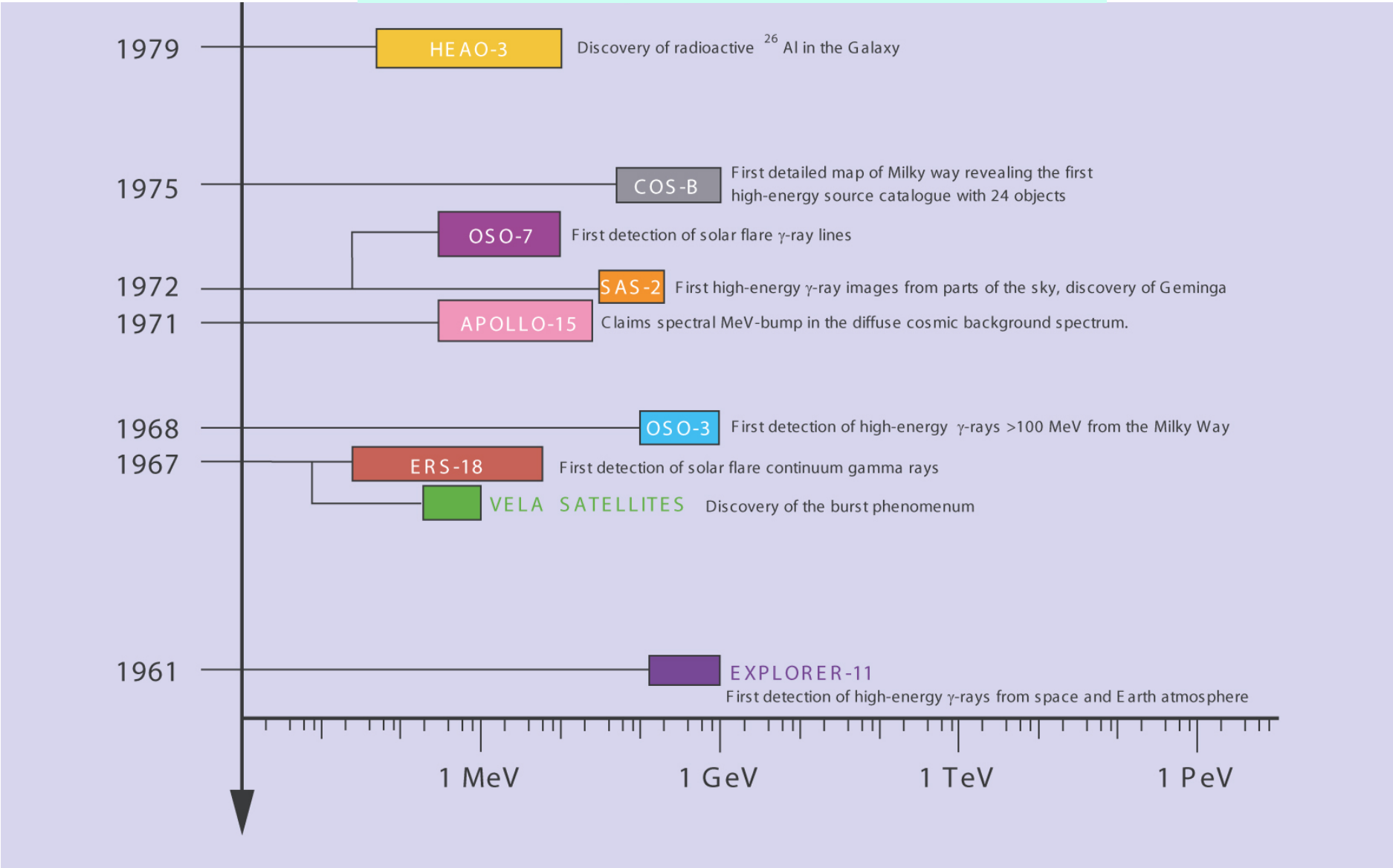
Pollack & Fazio write (Phys.Rev., 131, 2684, 1963):
…the most probable sources of gamma rays of energy
greater than 0.2 MeV are
(1) Decay of neutral π mesons produced in high-energy nuclear interactions
and produced in antiparticle annihilations;
(2) electron-positron annihilations;
(3) electron bremsstrahlung by collision;
(4) synchrotron radiation (magnetic bremsstrahlung);
(5) de-excitation of nuclei
(6) Compton scattering.

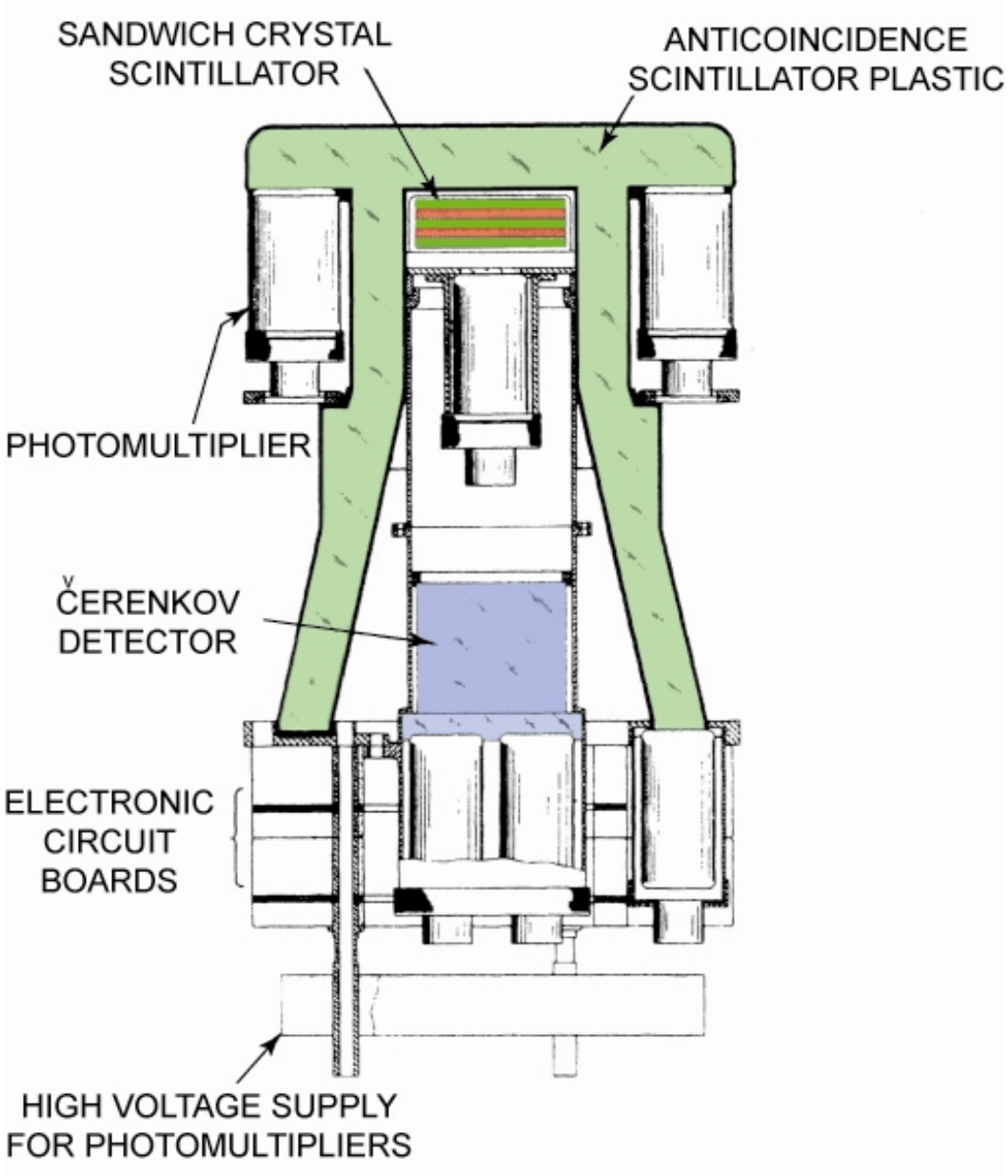
→ flux estimates initially too high
→ observers, failing to see the predicted intensities, were either frustrated or stubbornly developed better and larger instruments and learned how to suppress background

GAMMA - RAY ASTRONOMY TIMELINE



Foundations: 1960-1980



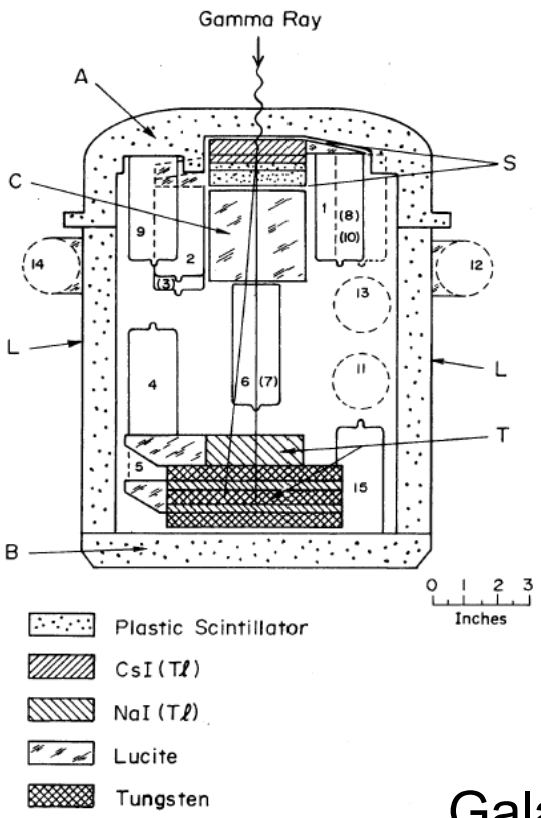


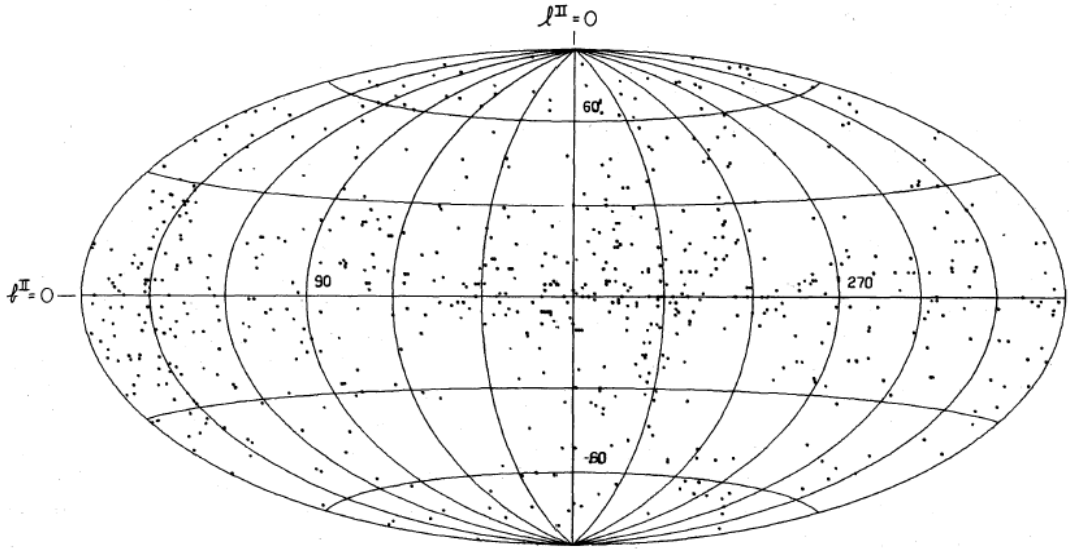
Gamma-ray detector on EXPLORER XI

Kraushaar & Clark, PRL, **8**, 106, 1962

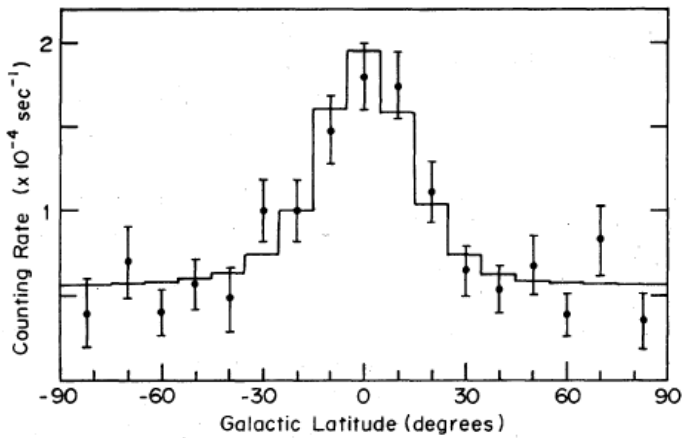
Detects first cosmic γ-rays above 100 MeV

OSO-3 (1967-69)
(Kraushaar et al., ApJ, 177, 341, 1972)

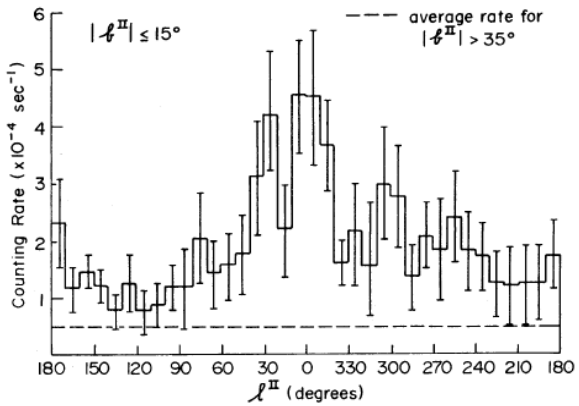




Galactic Map of 621 sky events (E>50MeV)



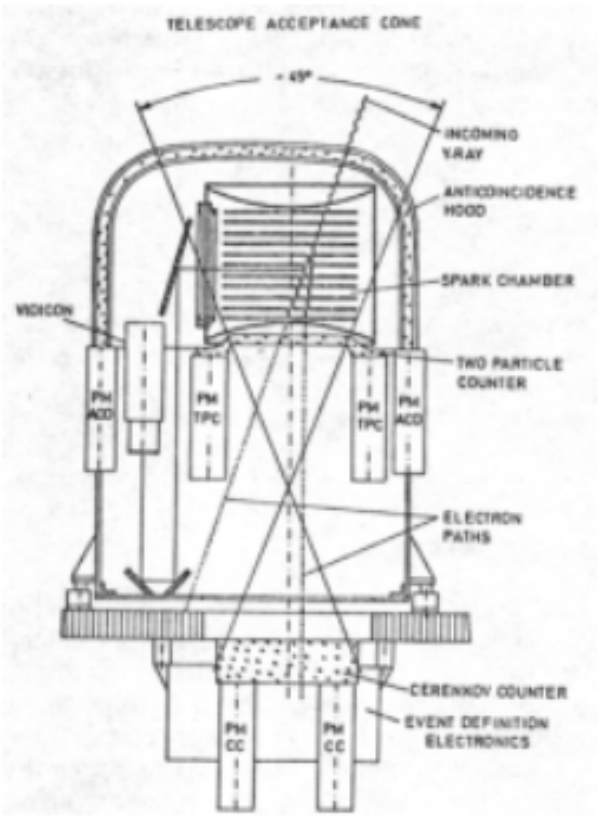
Latitude Distrib. inner Galaxy

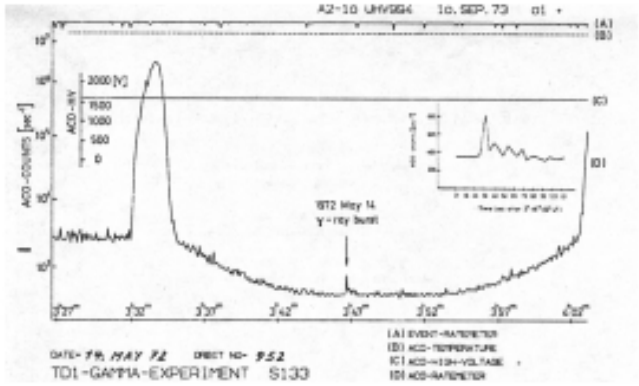


Longitude Distrib.

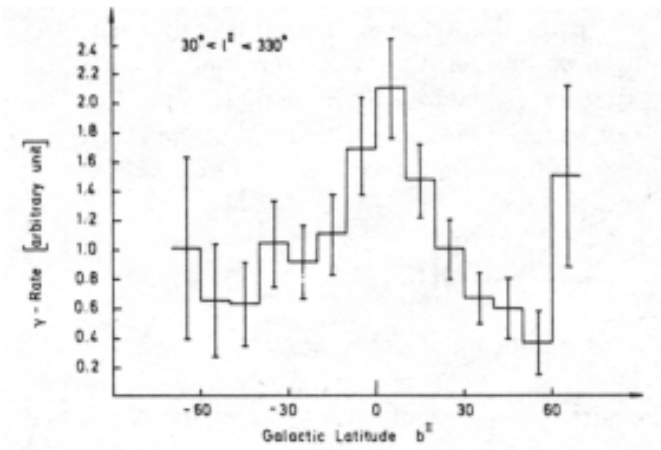
S-113 Experiment auf TD-1: Start 12.3.1972, Ende der Mission: Mai 1974

MIMOSA Kollaboration: Universita di Milano; MPE (Monaco di Baviera); CEN, Saclay





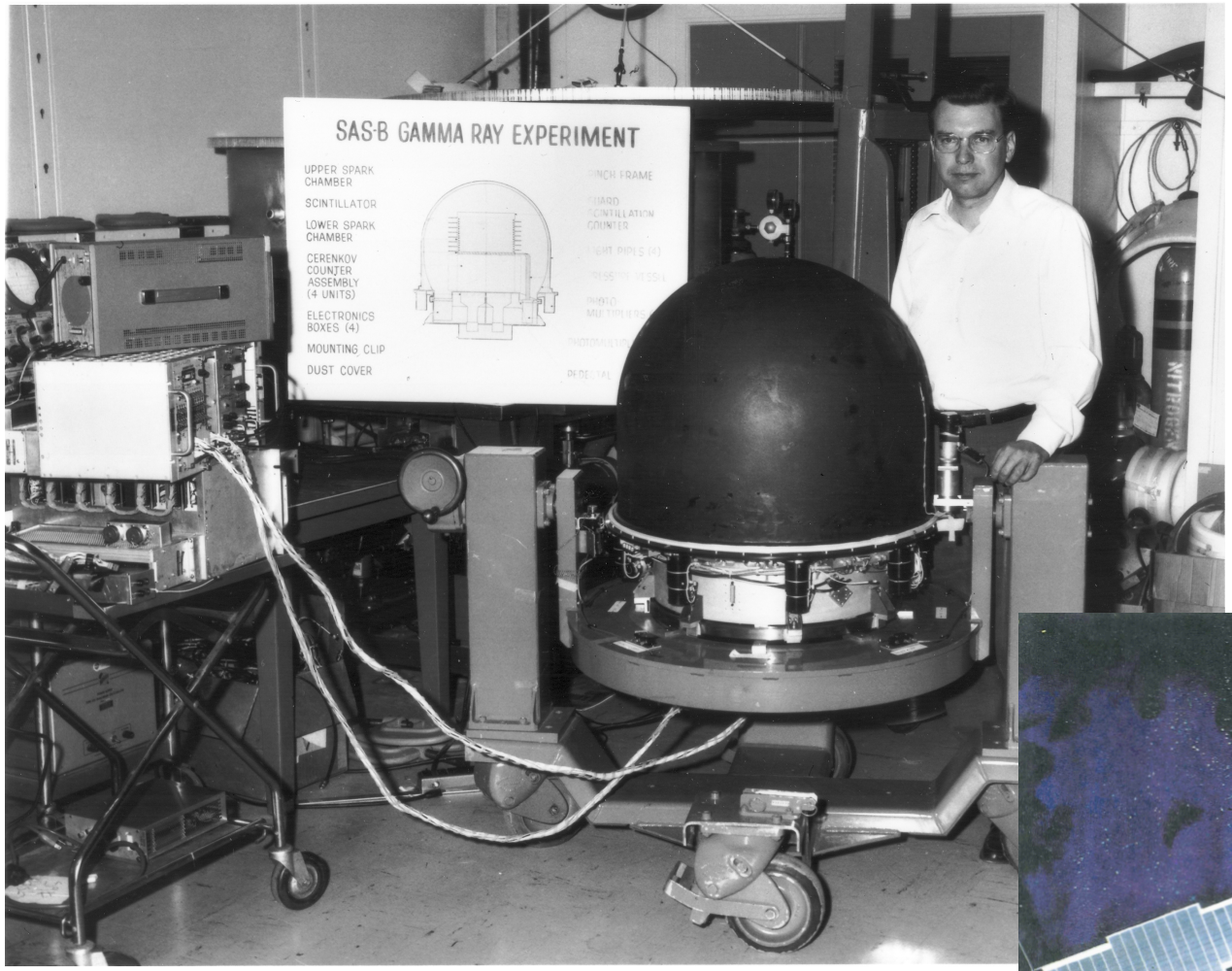
First European γ-ray burst GRB19720514!



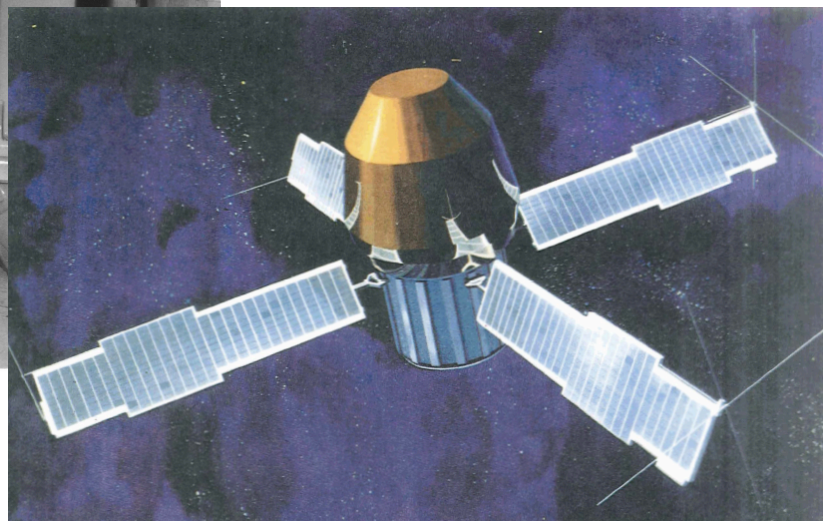
Confirmation Of galactic γ-ray emission

Fazit: orbital background in i= too high; Efficiency too small → few results

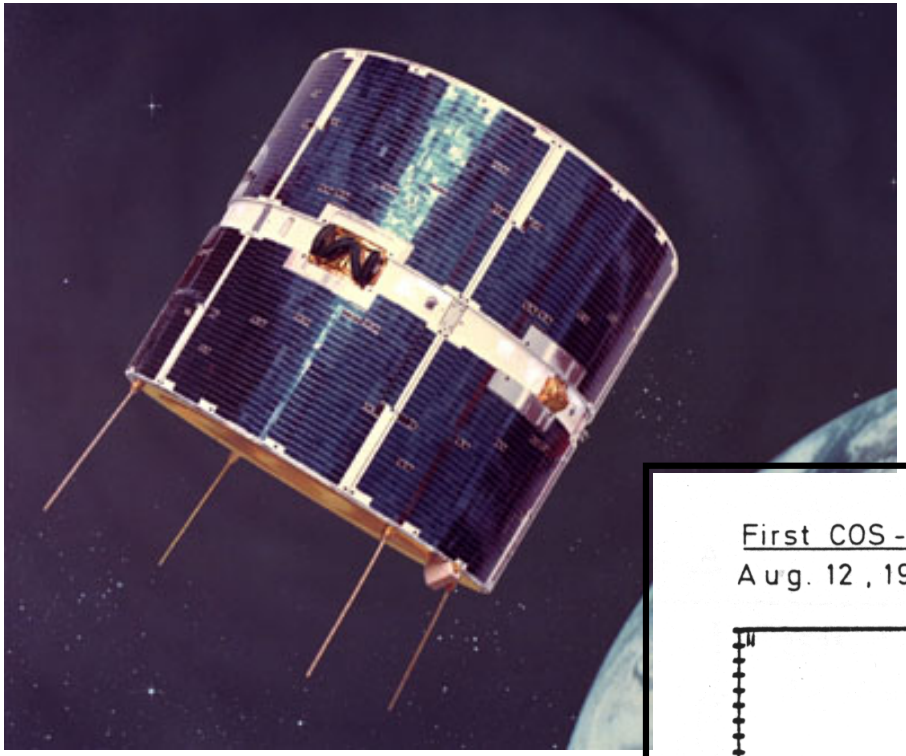
SAS-2 γ-ray experiment with Carl Fichtel (PI)

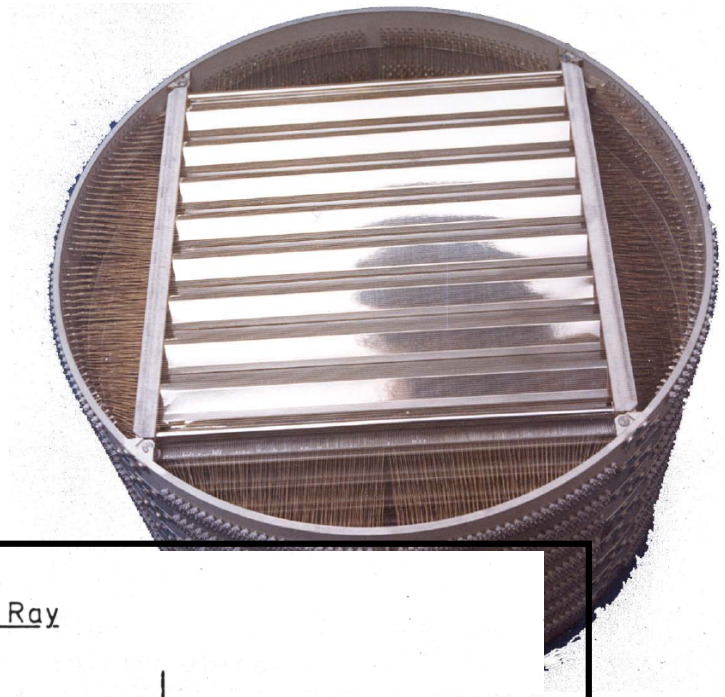


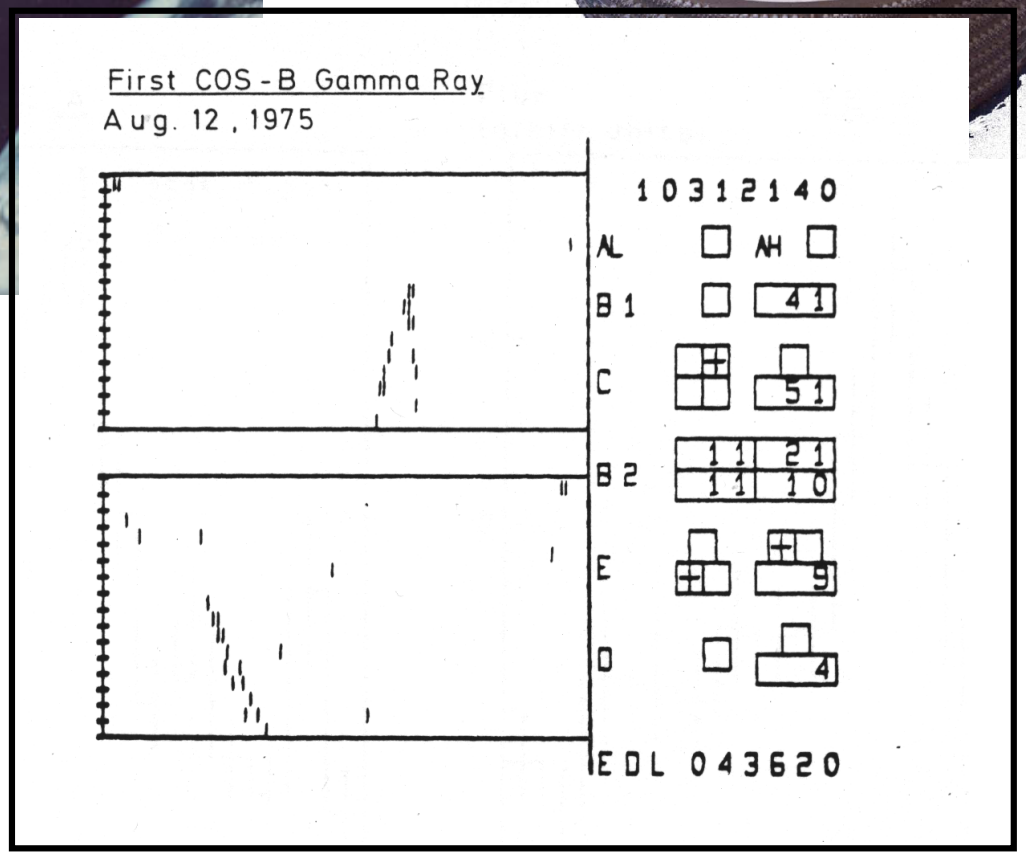
in space Nov 1972 - May 1973:
- survey of Galaxy;
- discovery of point sources and pulsars: Geminga, Crab, Vela
- extragalactic bkgnd



COS-B: 1975-81





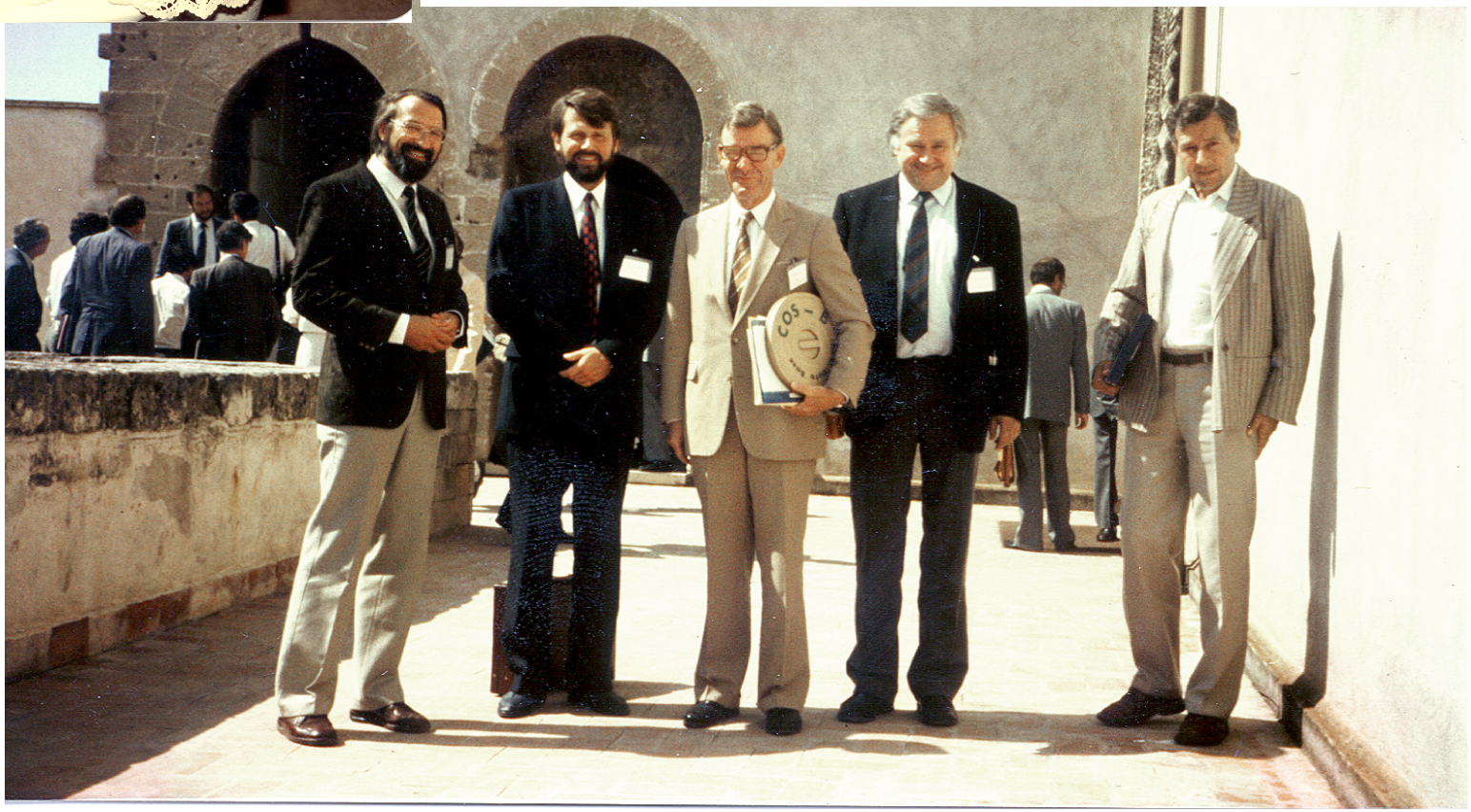


Single Experiment Satellite devoted to Gamma-Ray Astronomy:

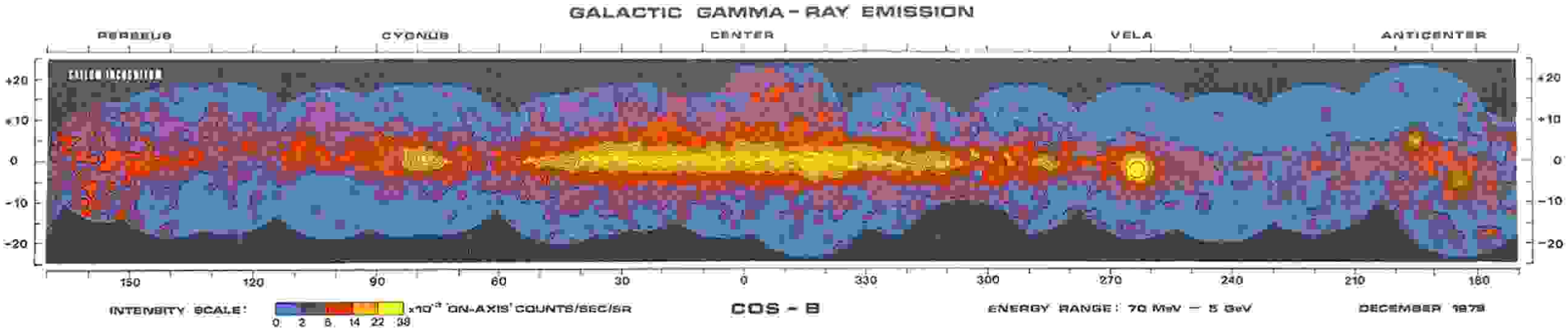
Collaboration:
Noordwijk (ESTEC), Leyden (Uni), Paris (Saclay), Garching (MPE), Milano, Palermo

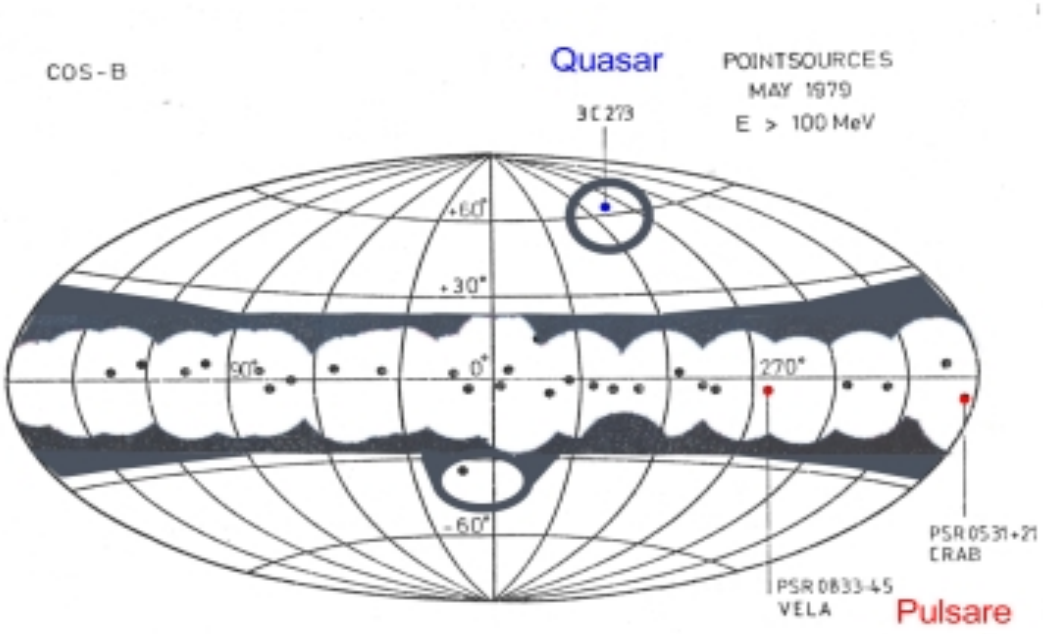
← COS-B 5 years in orbit

After 10 years,1985, Prof. Lüst (DG ESA) receives a tape with the final, processed COS-B data from Sommer, Voges, Pinkau, and Mayer-Hasselwander in Palermo

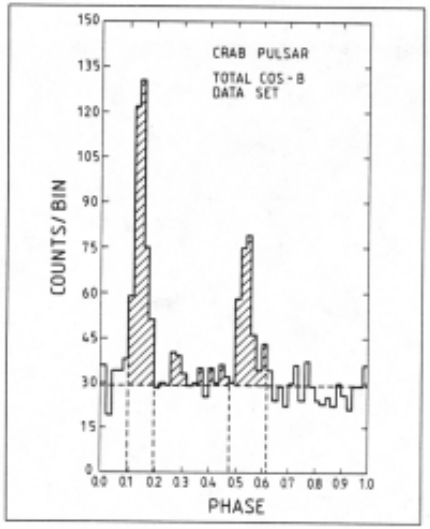


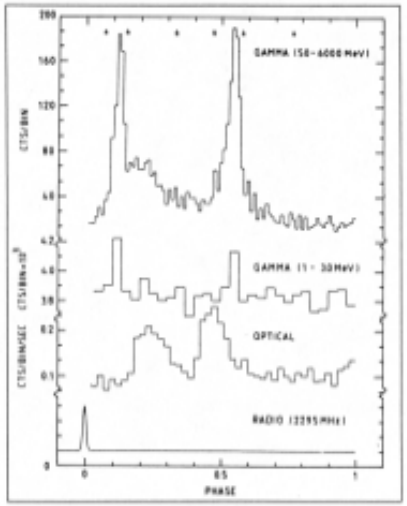
Most important results from COS-B: galactic survey, pointsources

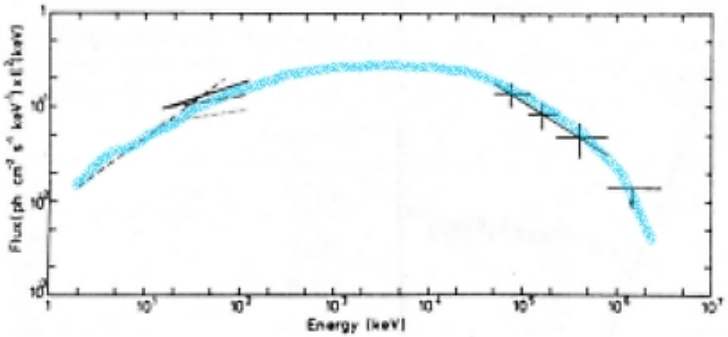


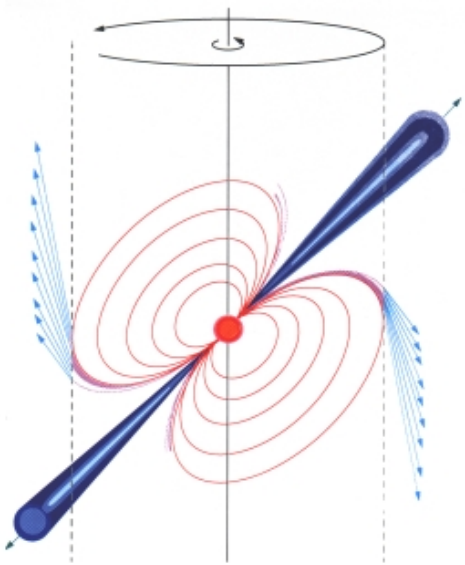


COS-B: pulsars and the first AGN (3C273)

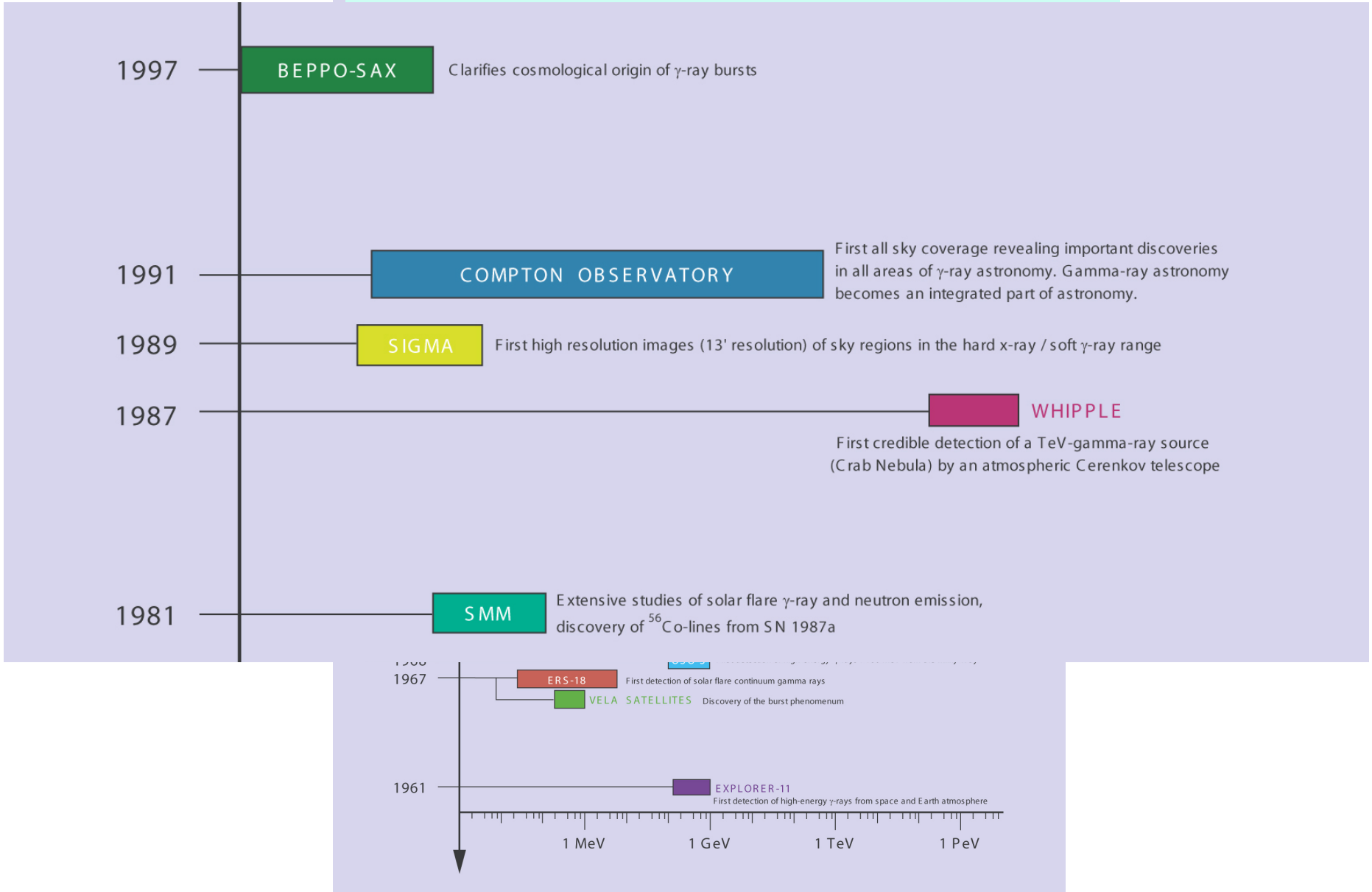






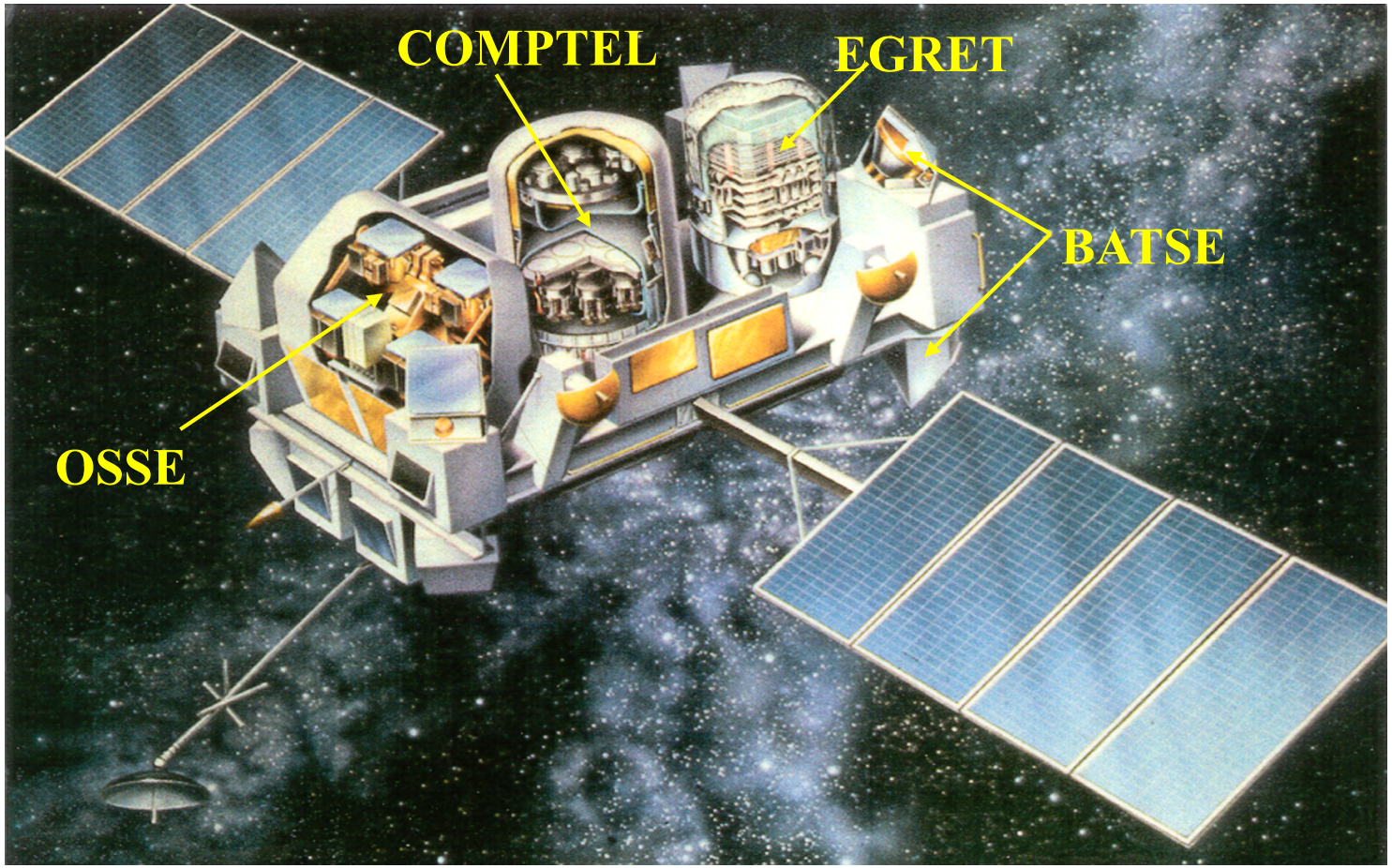


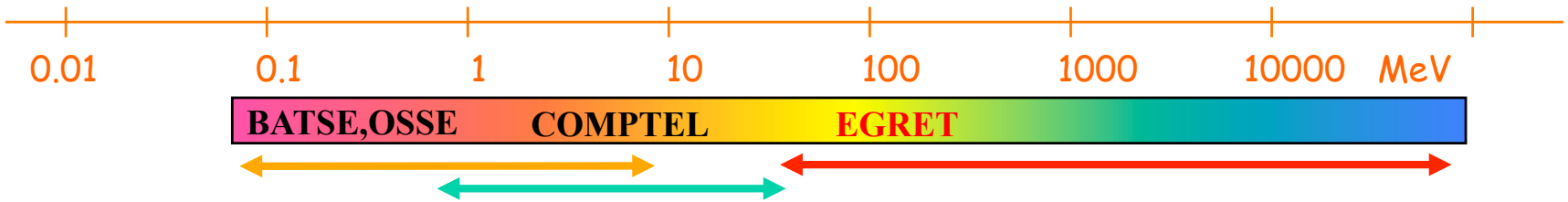
Breakthrough: 1980-2000



Launch of the Compton Gamma-Ray Observatory (CGRO) from STS-37 on April 5, 1991

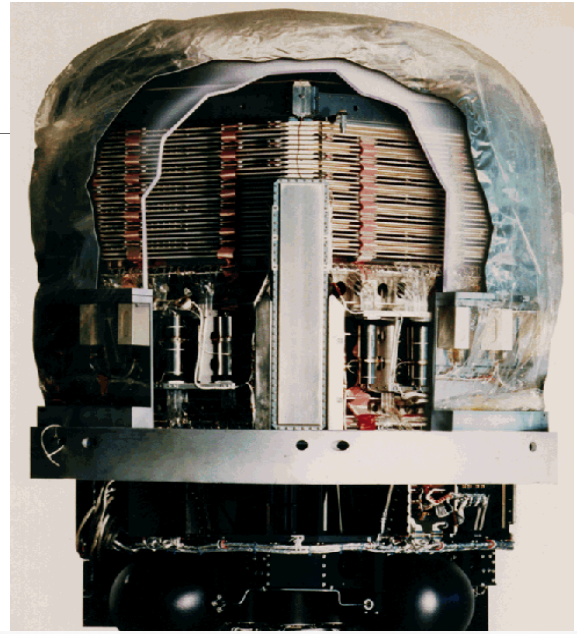
Compton Gamma-Ray Observatory (1991-2000)



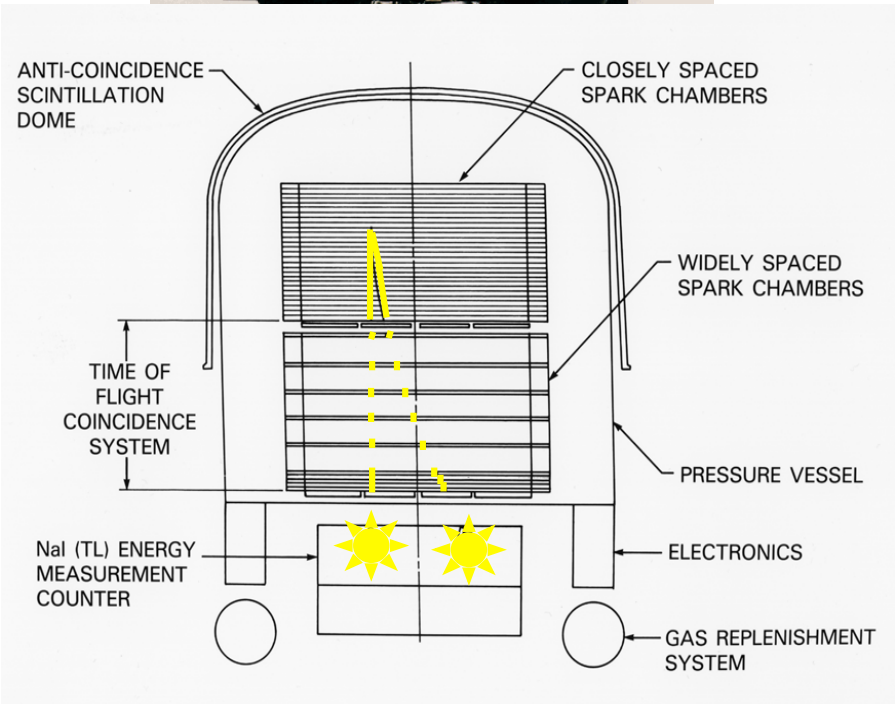


CGRO

EGRET



2.3 m



EGRET Properties:

Range: 20 MeV – 30 GeV

Eff. area (on axis):~ 1000 cm^2

Angular resolution:~ 5.8° $(E/100\ MeV)^{-0.5}$

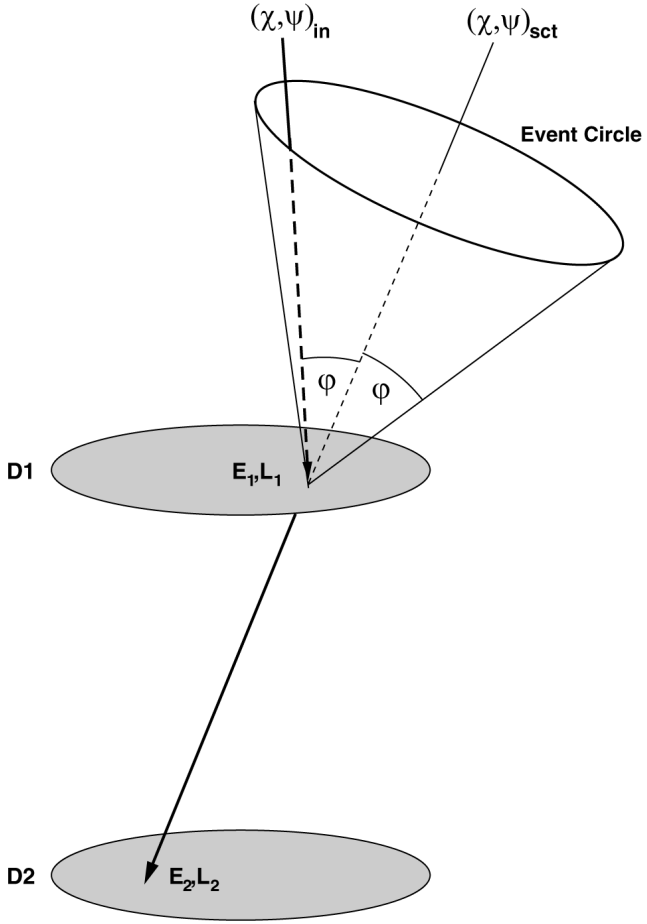
Position accuracy: ~ 5-10 arcmin

Field of view: ~0.6 sr (dia. 50°)

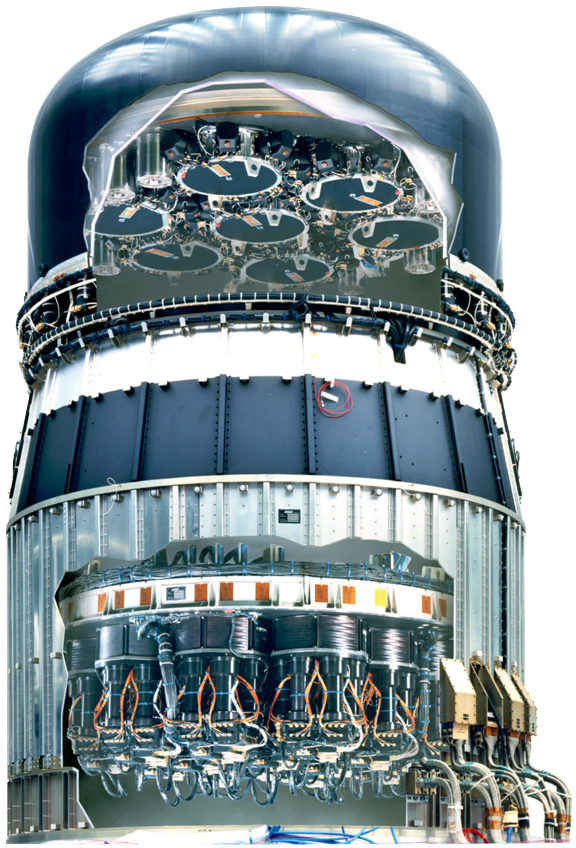
Energy resolution: ~ 20%

Sensitivity (>100 MeV): ~ 5 10^{-8} $cm^{-2}s^{-1}$

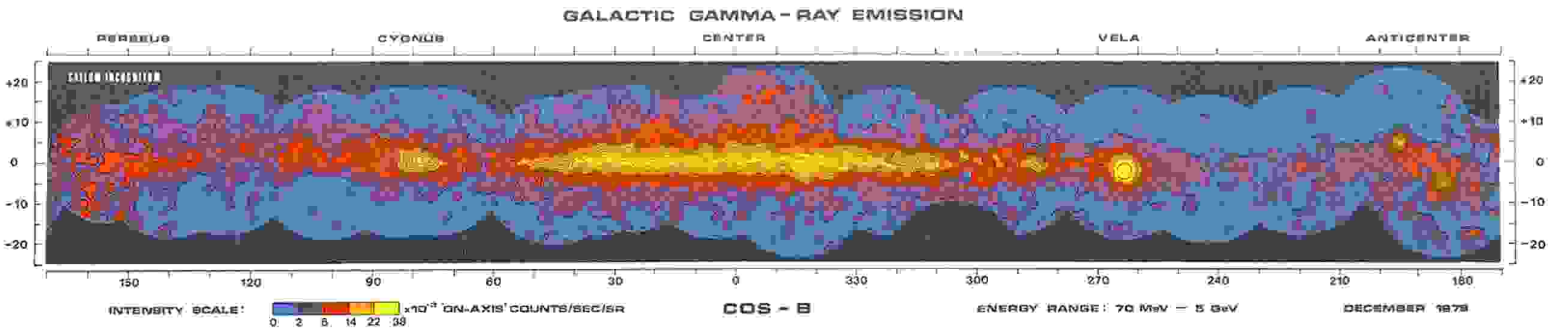
Compton Telescope



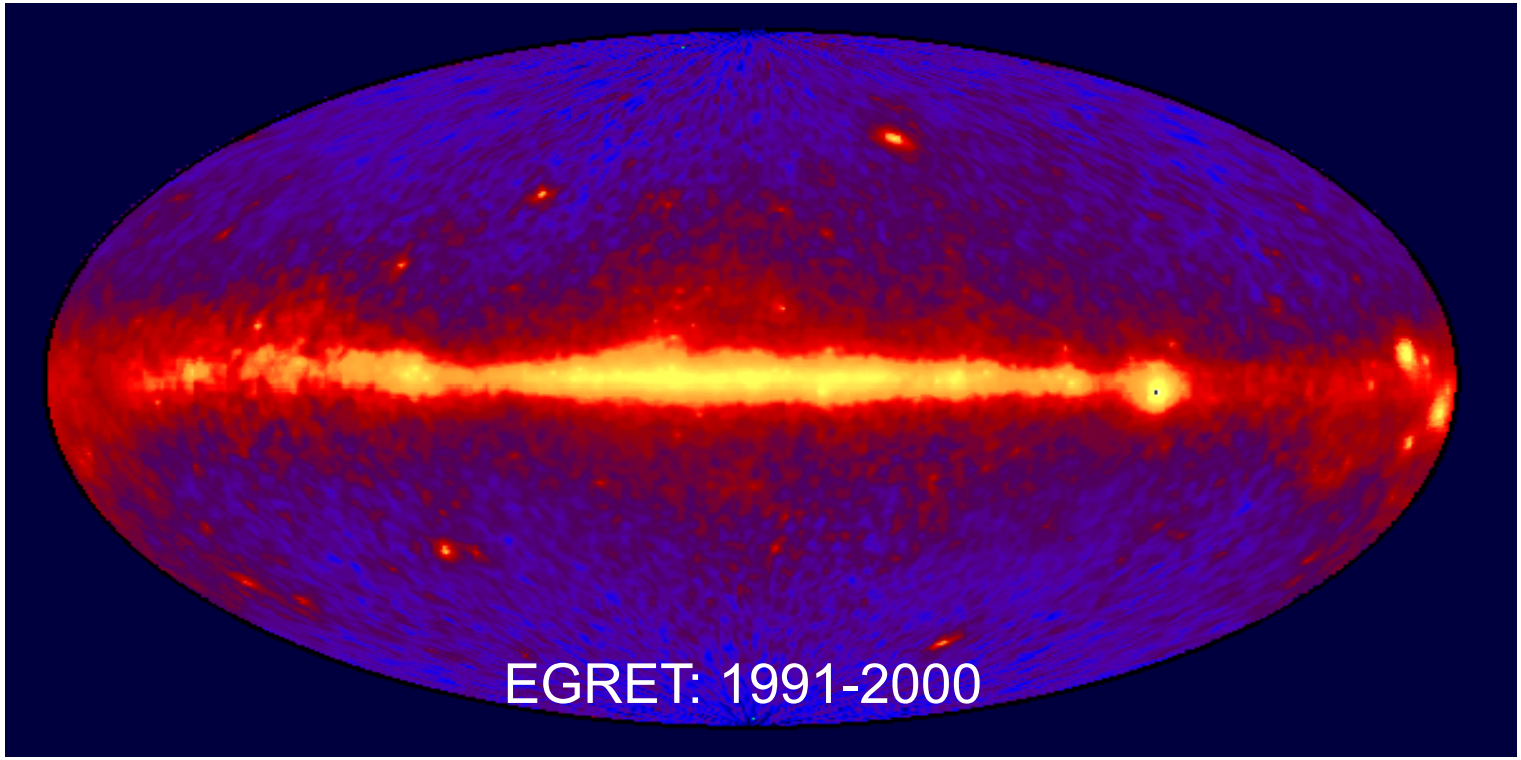
$$\cos\varphi = 1 - m_0 c^2 \left(\frac{1}{\varepsilon_1 + \Delta} - \frac{1}{\varepsilon_0 + \Delta} \right)$$



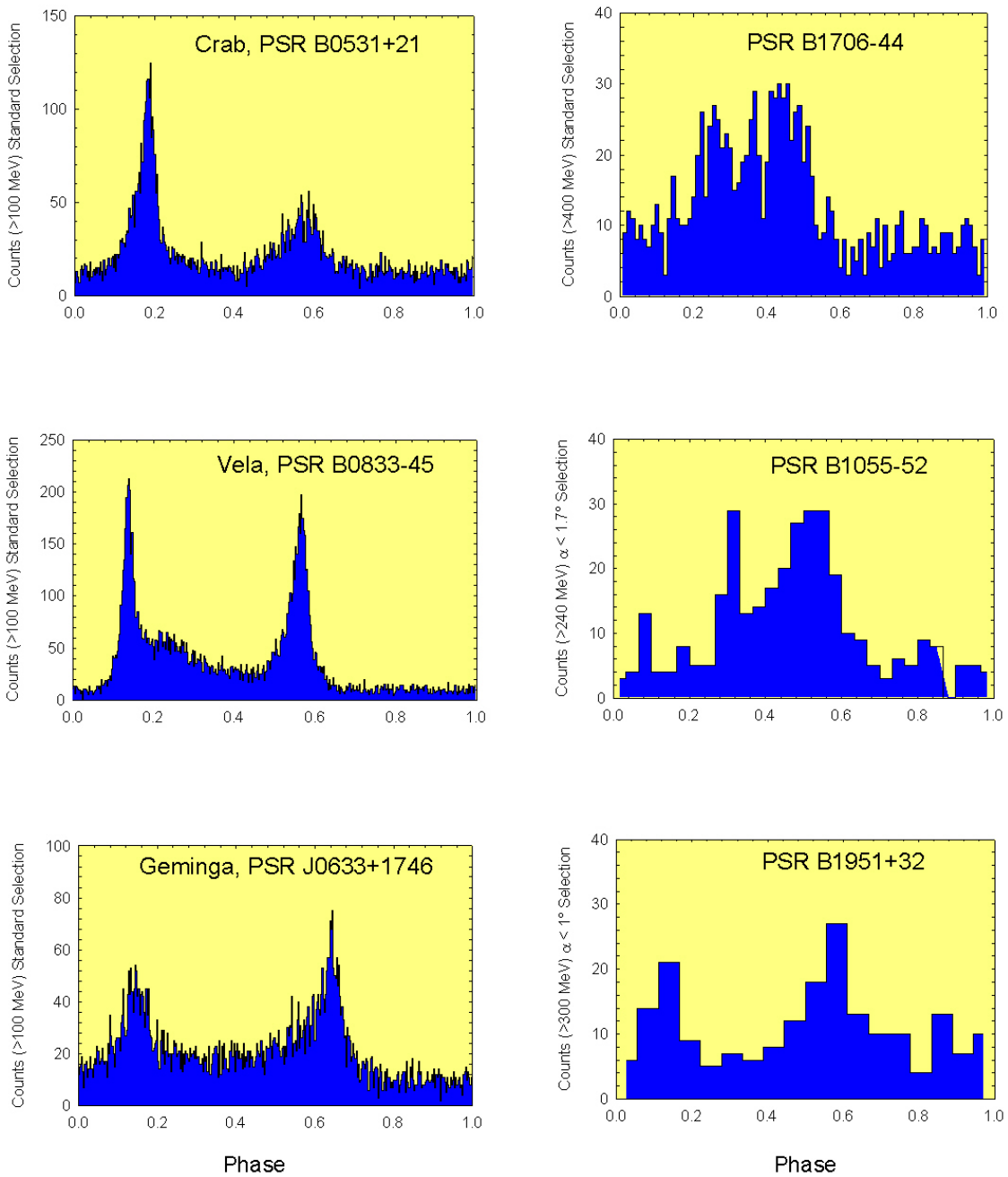
Imaging with Pair Telescopes >100 MeV



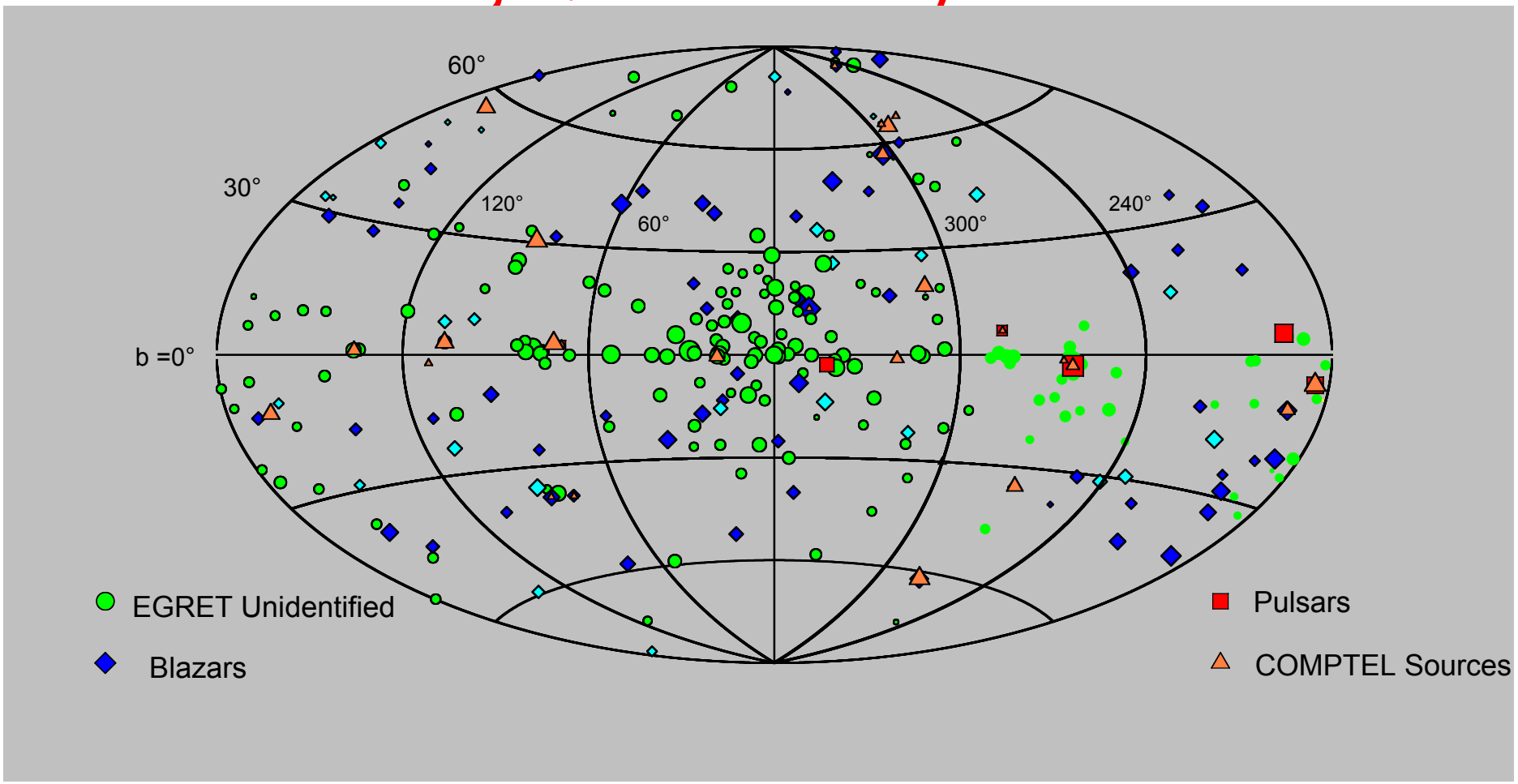
COS-B: 1975-82



High-Energy Pulsar Lightcurves (EGRET)



Catalog of Gamma-Ray-Sources



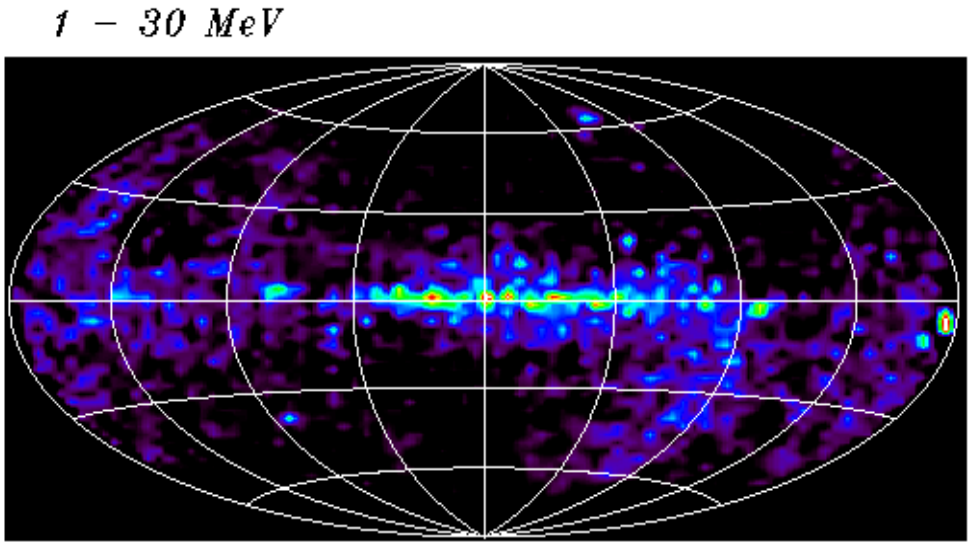
<u>3. EGRET Catalog:</u>
(3EG)
Hartman et al, 1999
ApJS, 123, 79

271 Sources
80-90 AGN
6-8 PSR
~170 Unid..

<u>1. COMPTEL Catalog:</u>
Schönfelder et al., 2000
A&AS, 143, 145

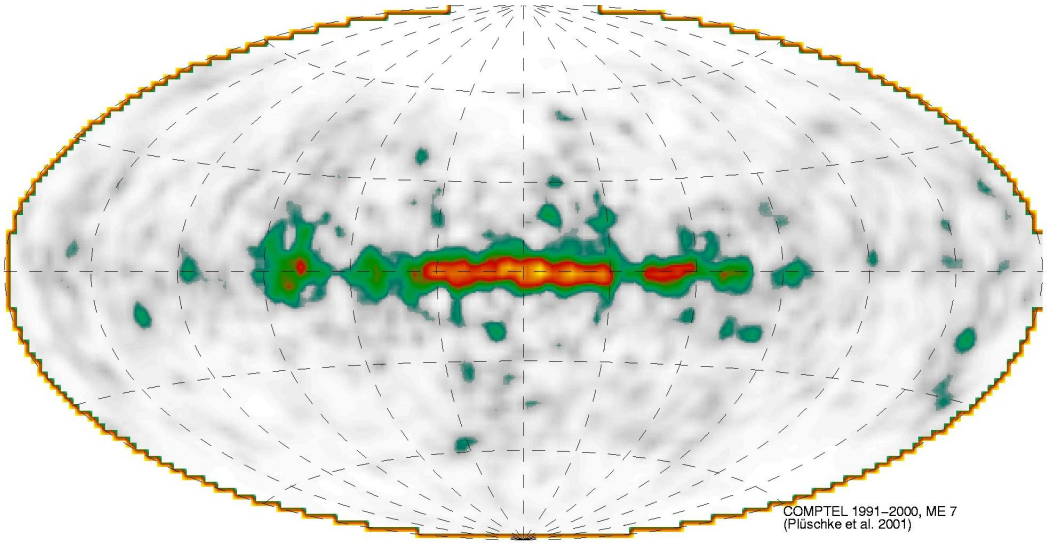
32 constant Srces.
39 transient
11 AGN
3 PSR
4 EGRET Unid.

Imaging with COMPTEL



COMPTEL: 1991-2000

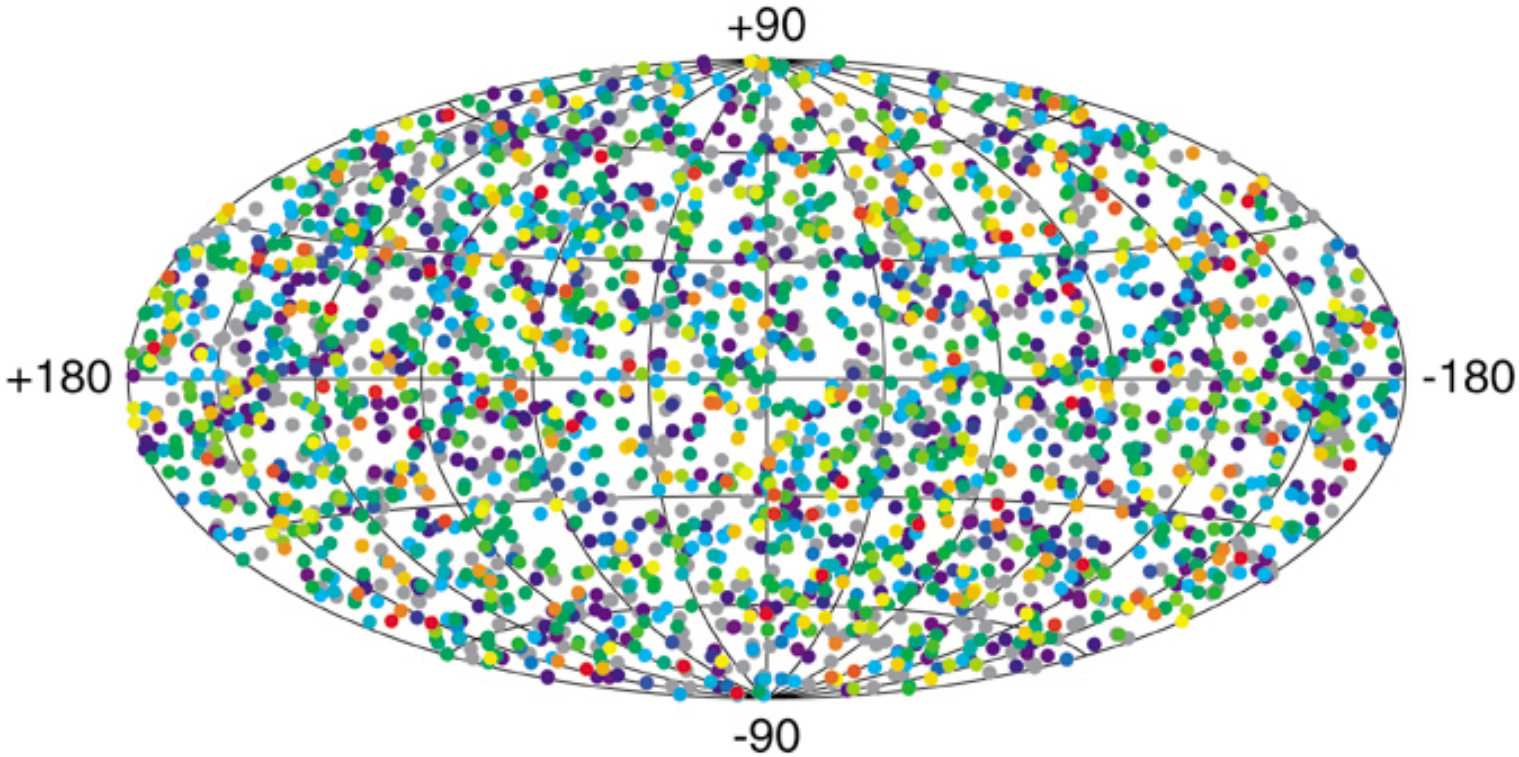
Continuum 1-30 MeV



γ-ray line survey

^{26}Al (1.809 MeV)

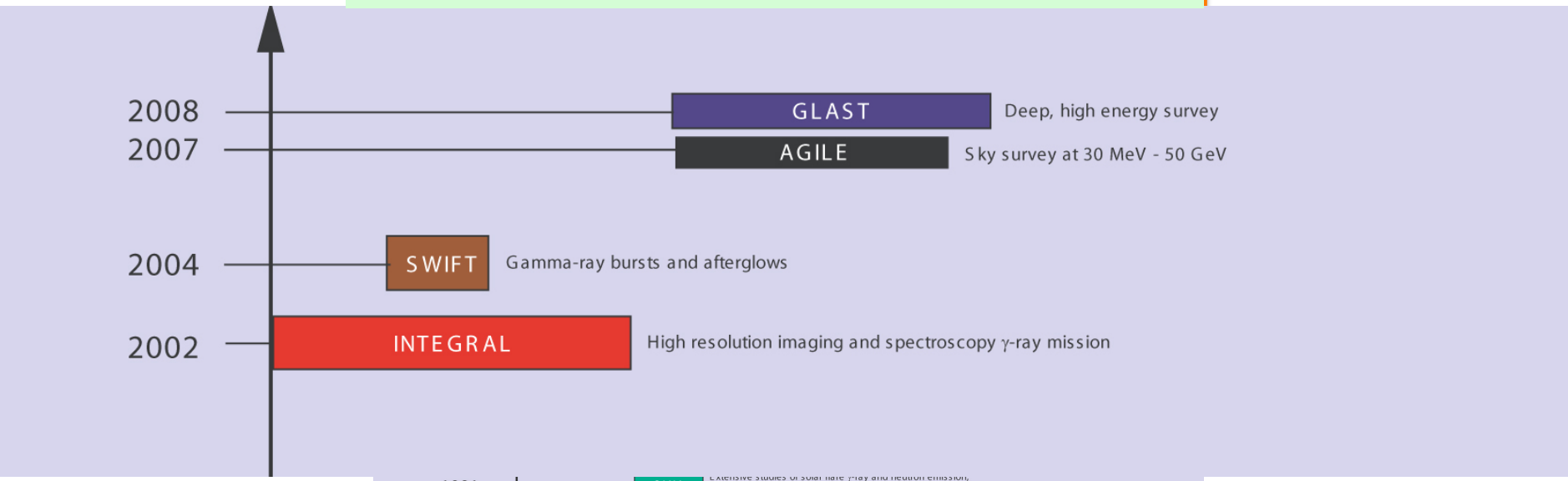
BATSE Catalogue of 2704 Gamma-Ray Bursts

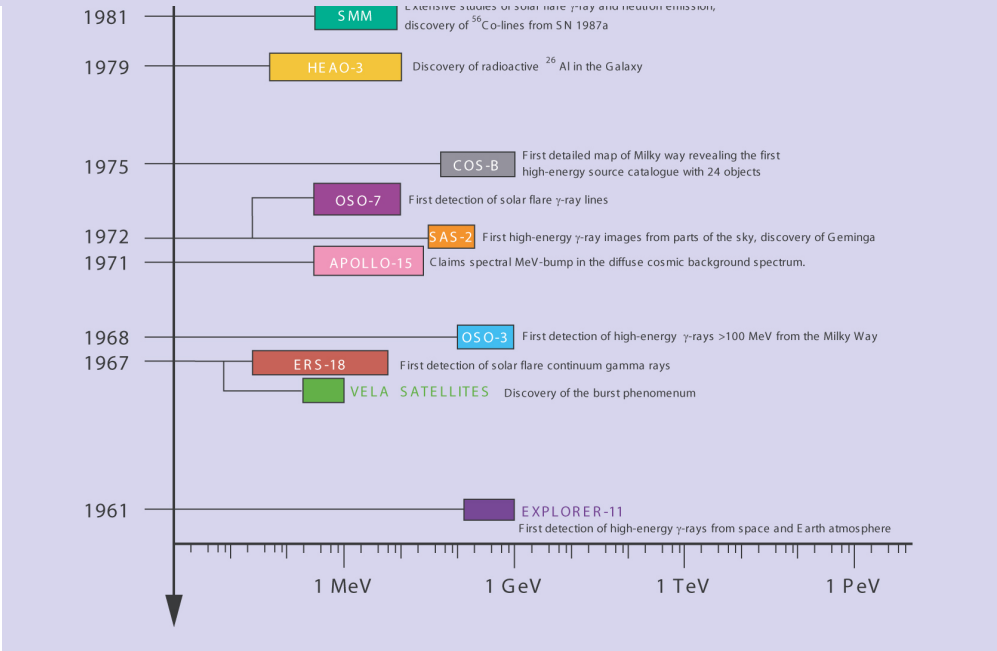


Gamma Ray Bursts are distributed isotropically. For many GRBs an X-ray or optical afterglow was detected and their red-shifts were measured. Most are around z ~1 but the farthest is now known at z=6.5.

GRBs are therefore the most luminous localized sources in the Universe!

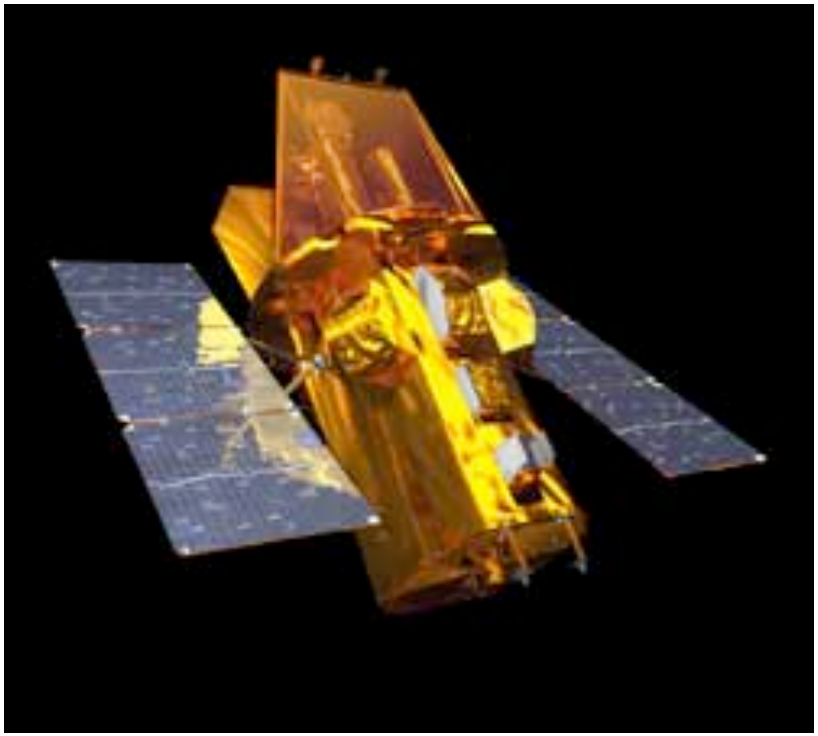
2000-2020 Maturity





TeV arrays: E>100 GeV

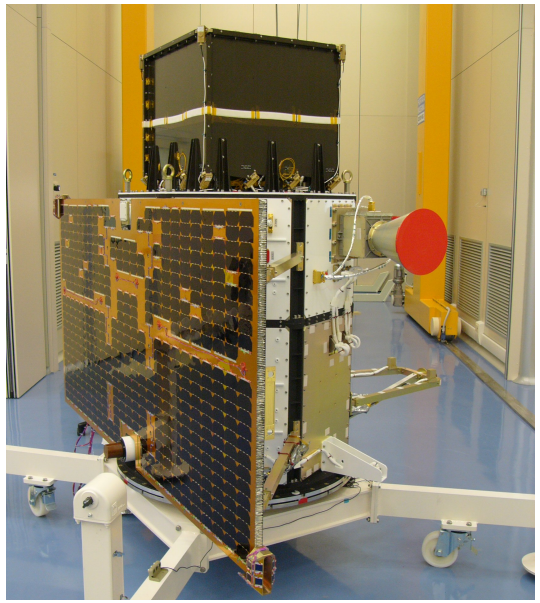
Swift:
GRB mission since Nov. 2004
BAT: large area GRB monitor
XRT: imaging X-ray telescope
OMC: opt. monitor



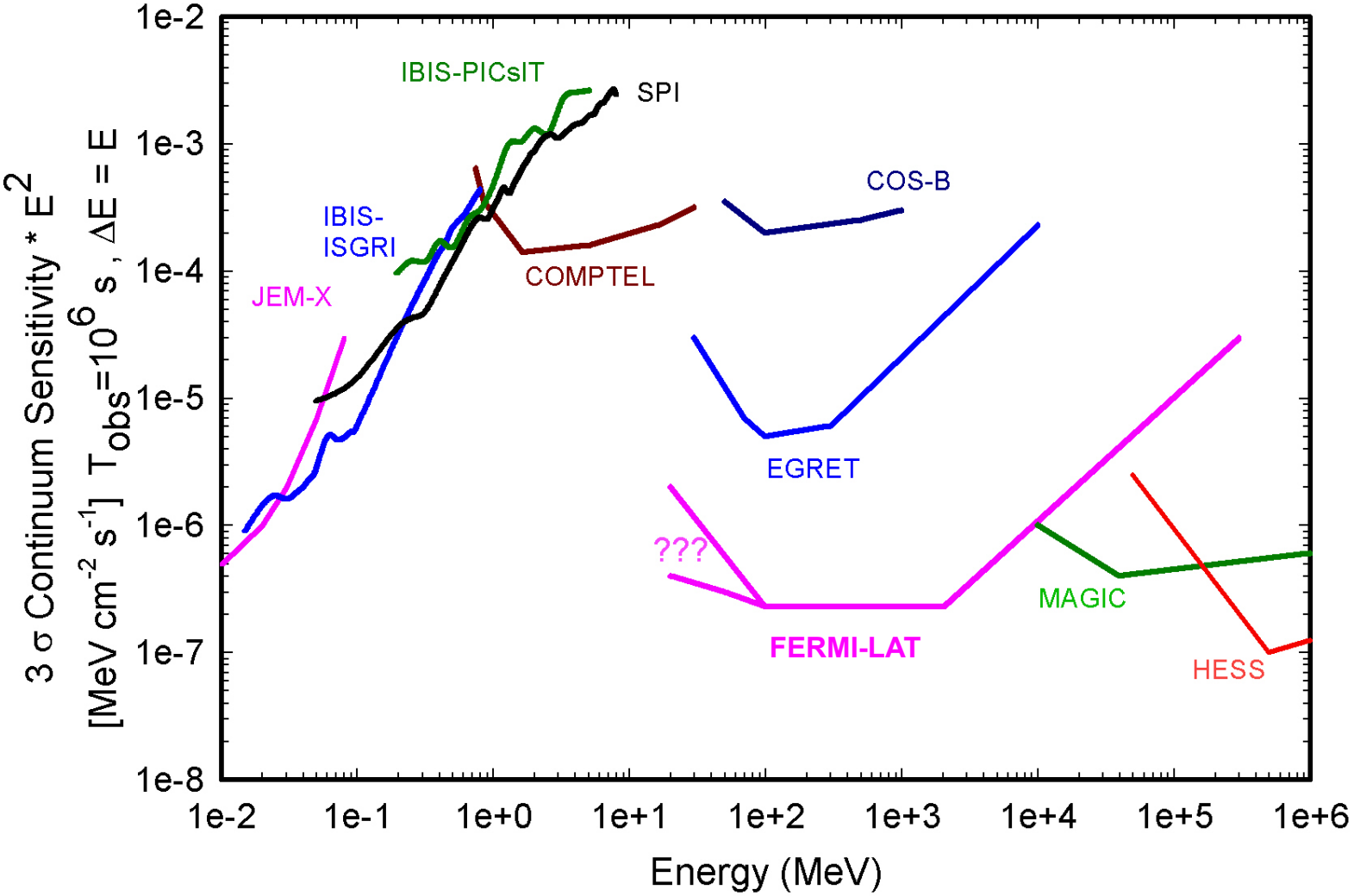
INTEGRAL: launch Oct 2002
IBIS: 15 keV-10 MeV, Imager
SPI: 20 keV- 8 MeV, Spectrom.
JEM-X, OMC

Fermi:
in Orbit since June 2008
Instruments: LAT
GBM

AGILE: in space
since April, 2007



Sensitivity of multi-wavelength High-Energy Astronomy: Status in 2010



...the presentations for the current high-energy facilities follows now in the program

Thank You for your attention