The "Early" History of Gamma-Ray Astronomy

1912: Discovery of "High Altitude Radiation" by Hess (Vienna) and Kohlhörster (Berlin) via ionisation rate measurements in air at different altitudes.

1920's: Millican introduces the name "cosmic rays".

The radiation is supposed to consist of γ-rays, which enter the atmosphere from outside and produce recoil-electrons in the atmosphere causing the measured ionisation.

1929: Bothe and Kohlhörster discover the corpuscular nature of the "high altitude radiation" by means of two Geiger-Müller counters in coincidence.

1940's to early 1950's:

Upper limits to fraction of γ-rays in primary cosmic radiation (balloon and rocket experiments).

1950's: Predictions about cosmic γ-radiation:

- 1952 Hayakawa (π^0-decay)
- 1952 Hutchinson (electron-bremsstrahlung)
- 1958 Morrison (celestial γ-ray sources)

Morrison's Predications in the Light of our Present Knowledge

Source	Expected Fluxes (photons cm^{-2} sec^{-1})	Actual Fluxes (photons cm^{-2} sec^{-1})
Solar flares: - 10 – 100 MeV - 2.223 MeV	0.1 to few 1 to 100	$\sim 10^{-2}$ few 10^{-1}
Crab Nebula: - radioactive γ-ray lines	$\sim 10^{-2}$	< few 10^{-5}
Radio Galaxies (M 87, Cyg A): - 10 – 100 MeV - 511 keV	 0.1 to 1 0.1 to 1	**(Cen A):** $\leq 10^{-5}$ $< 2.6 \cdot 10^{-5}$

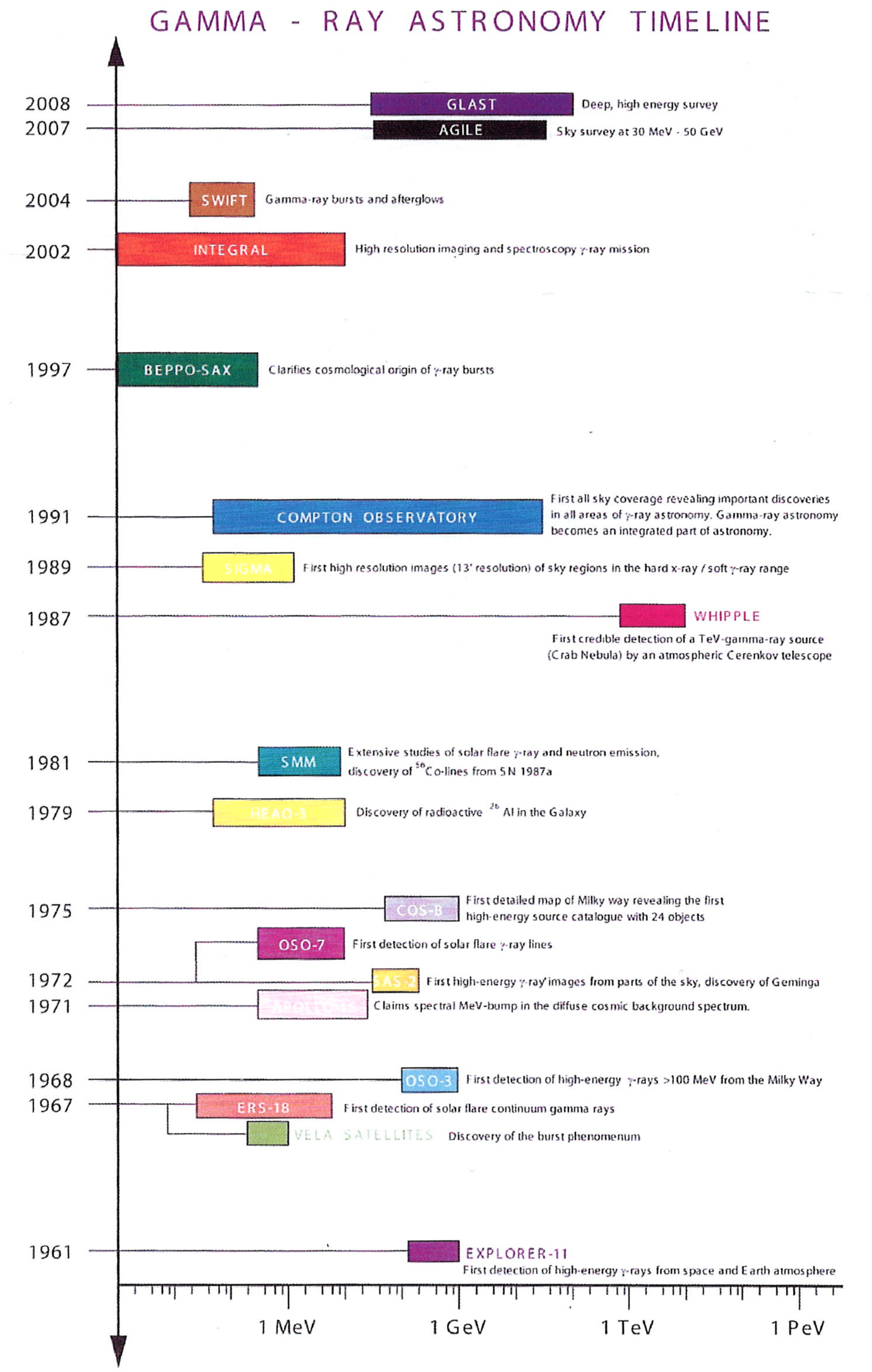
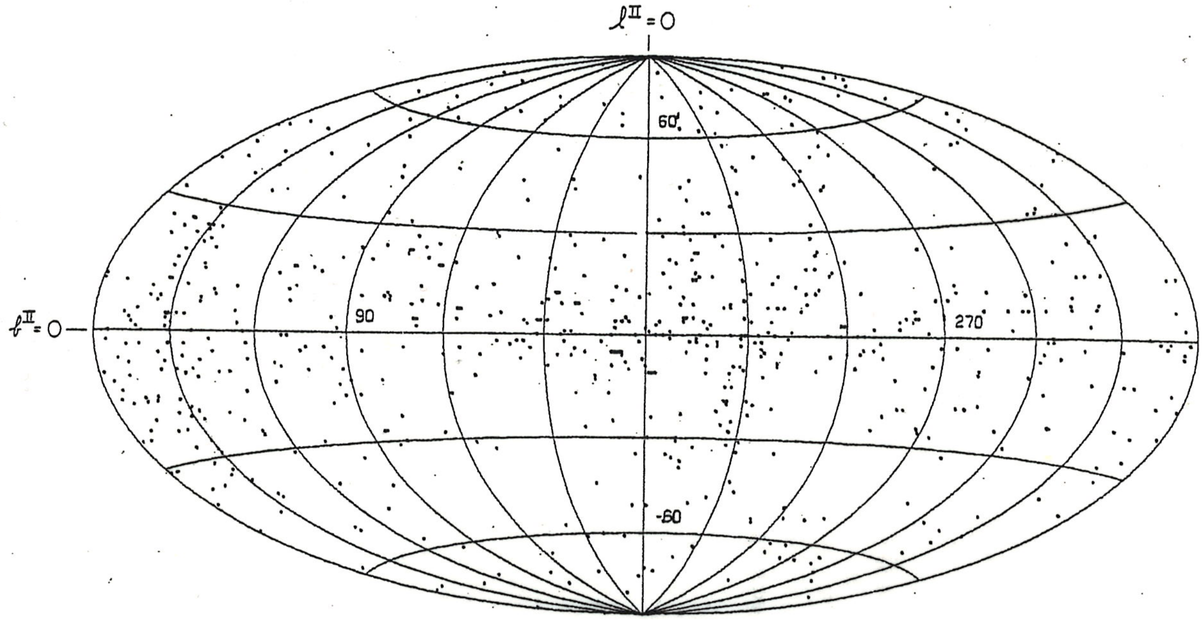
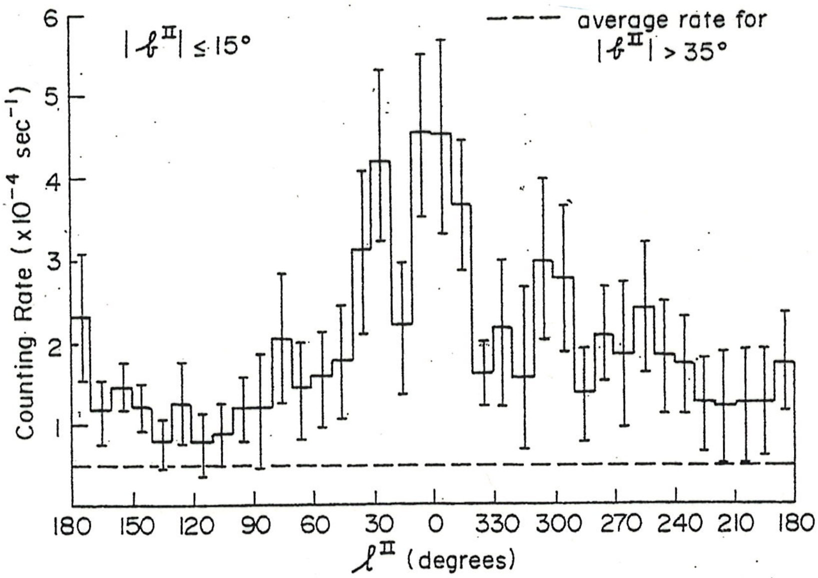


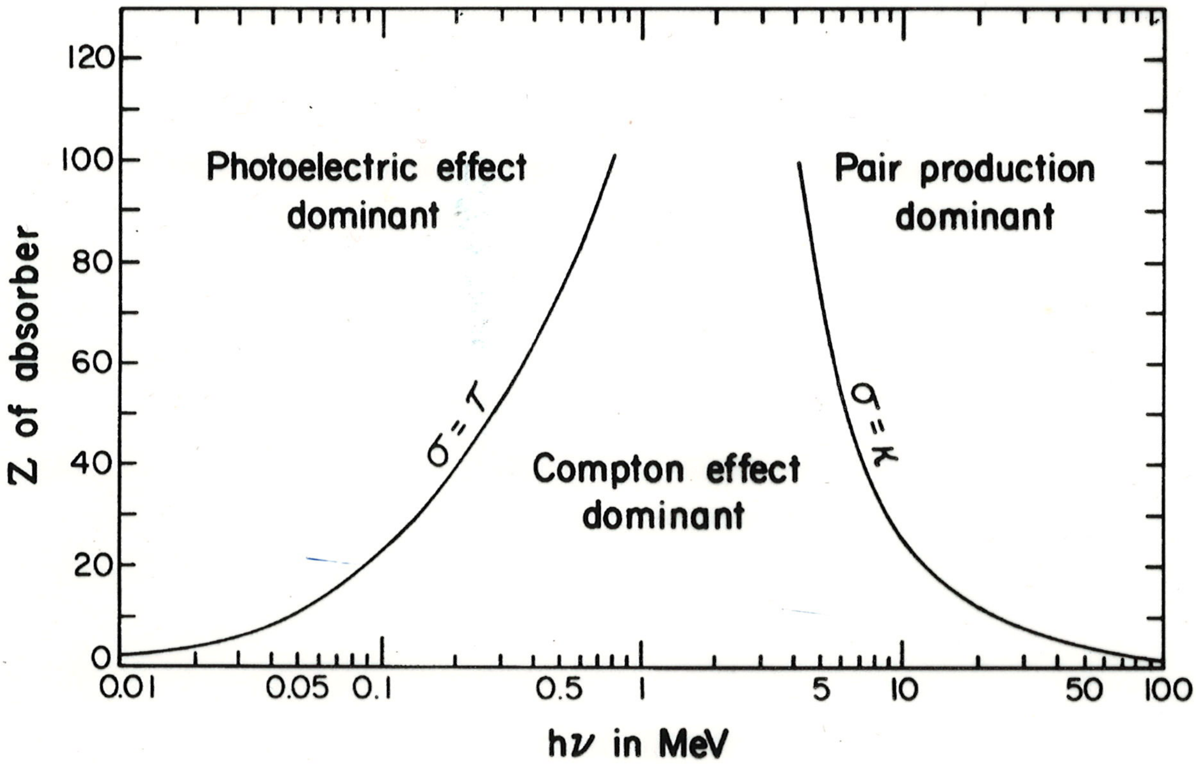
Figure 3.1: The history of observational γ-ray astronomy from the early 1960s until the launch of the *Fermi* Gamma-ray Space Telescope, formerly *GLAST*.

All-Sky Distribution of 621 Sky Events Detected by OSO-III between 1967 and 1968



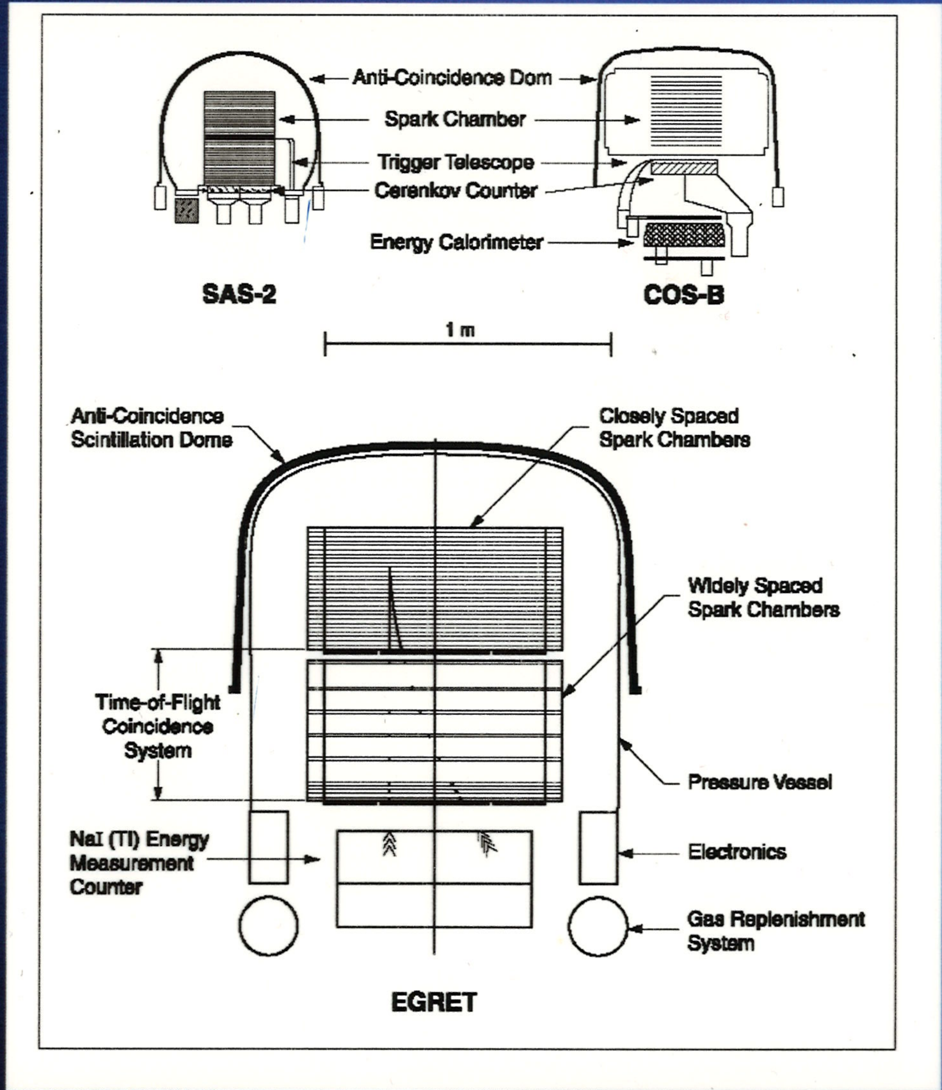


(4)

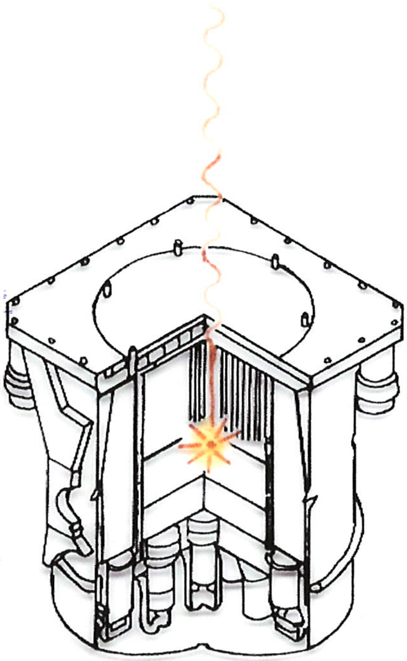


120
100
80
60
40
20
0
Z of absorber
Photoelectric effect dominant
Pair production dominant
Compton effect dominant
σ = τ
σ = κ
0.01
0.05
0.1
0.5
1
5
10
50
100
hν in MeV

Schematic Views of SAS-2, COS-B and EGRET



Methods of Low Energy Gammy-Ray Astronomy

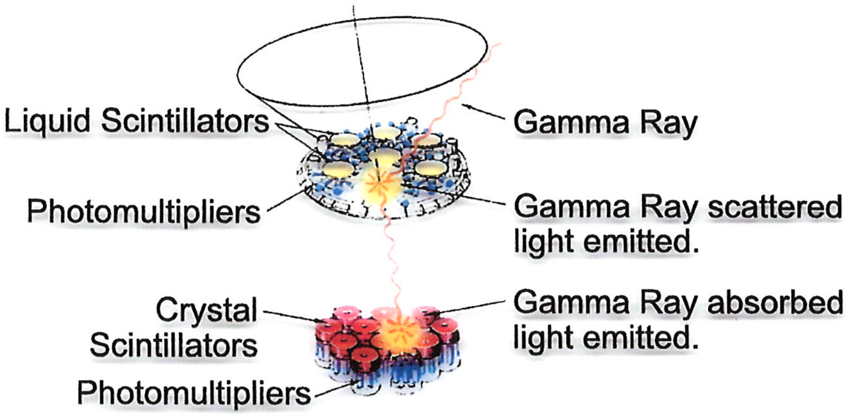


⇐ Shielding

(example OSSE)

Shadowing ⇒
(coded masks,
rotation collimators)

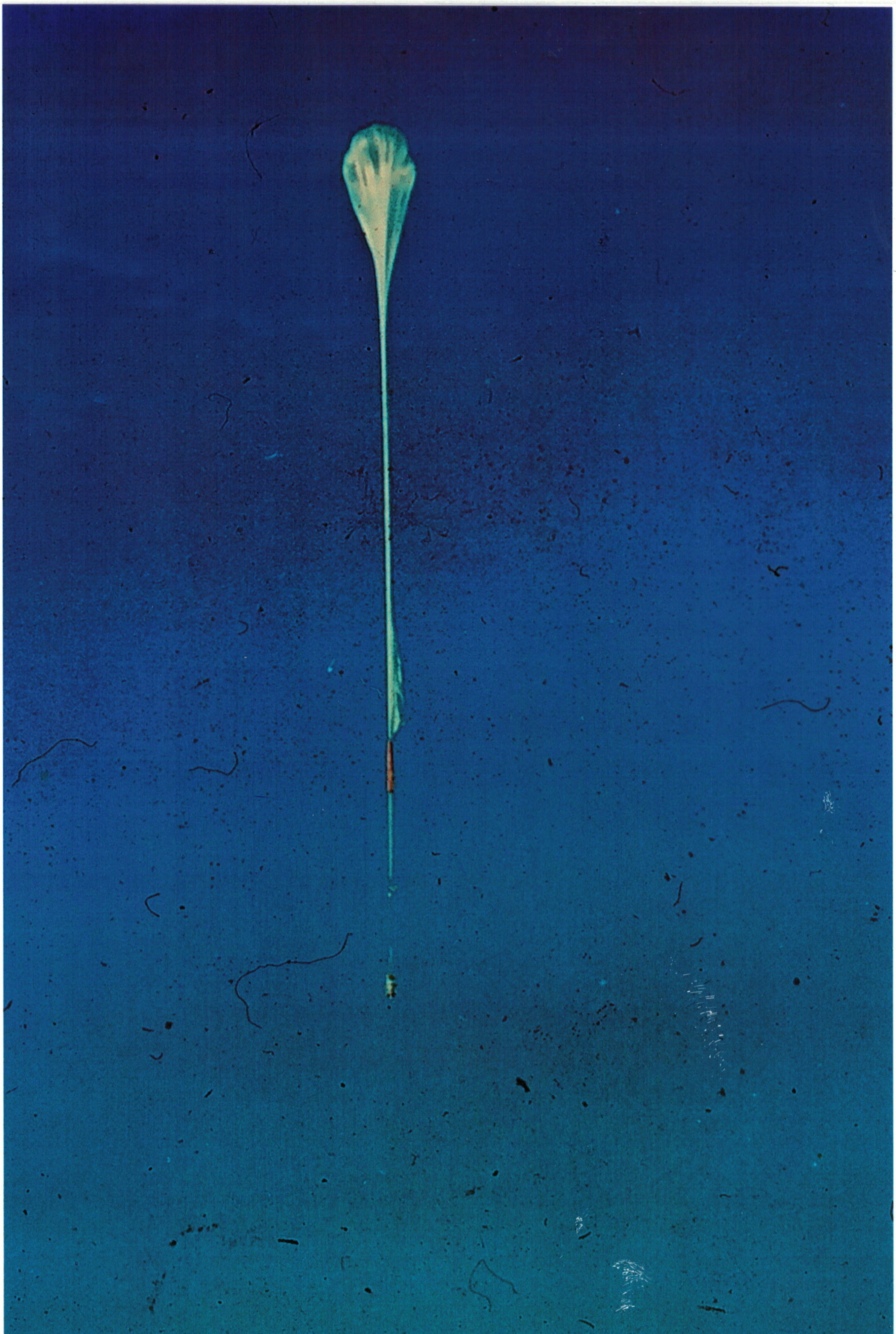
(examples: INTEGRAL
HESSI)

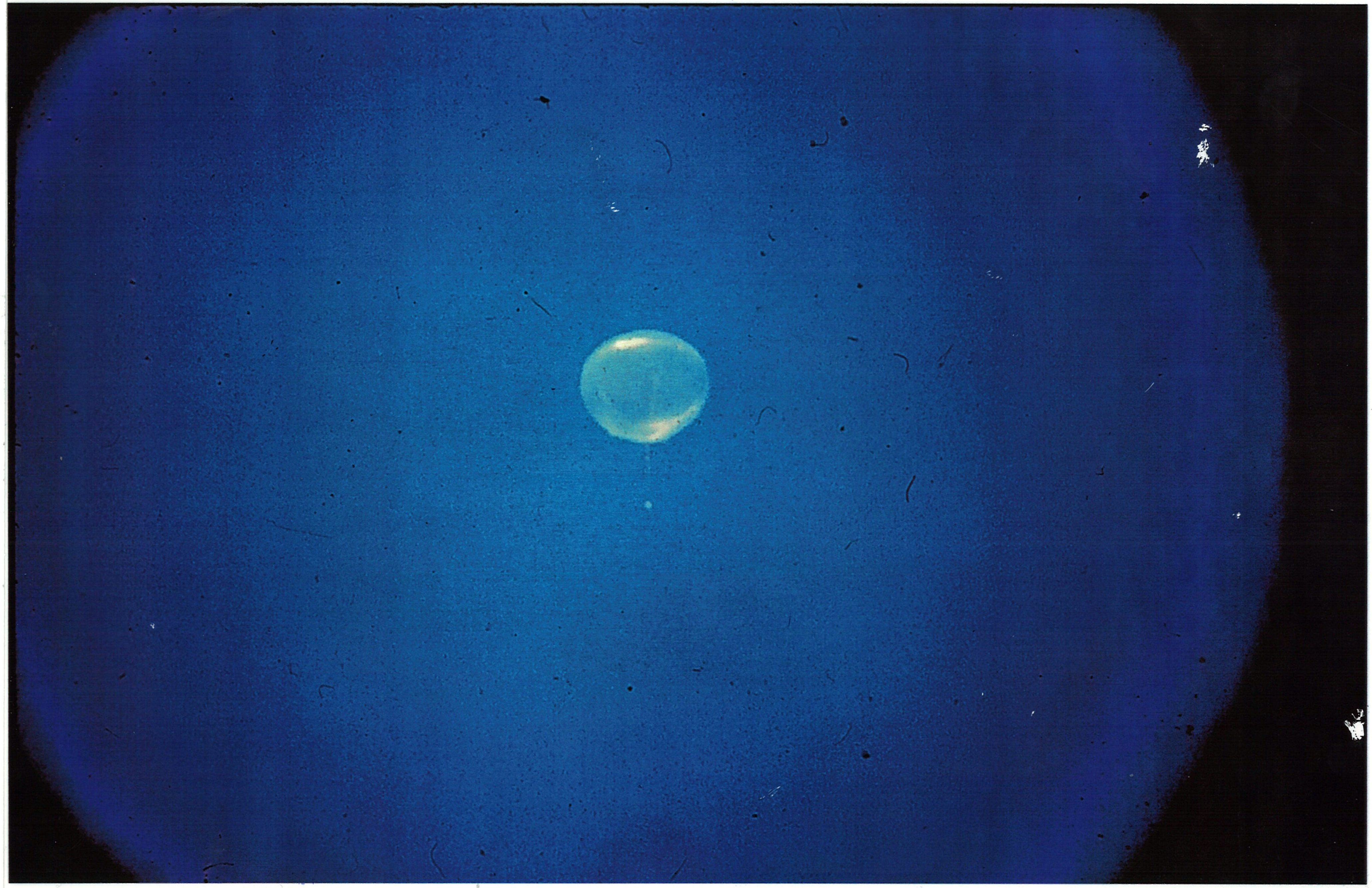


Compton telescopes

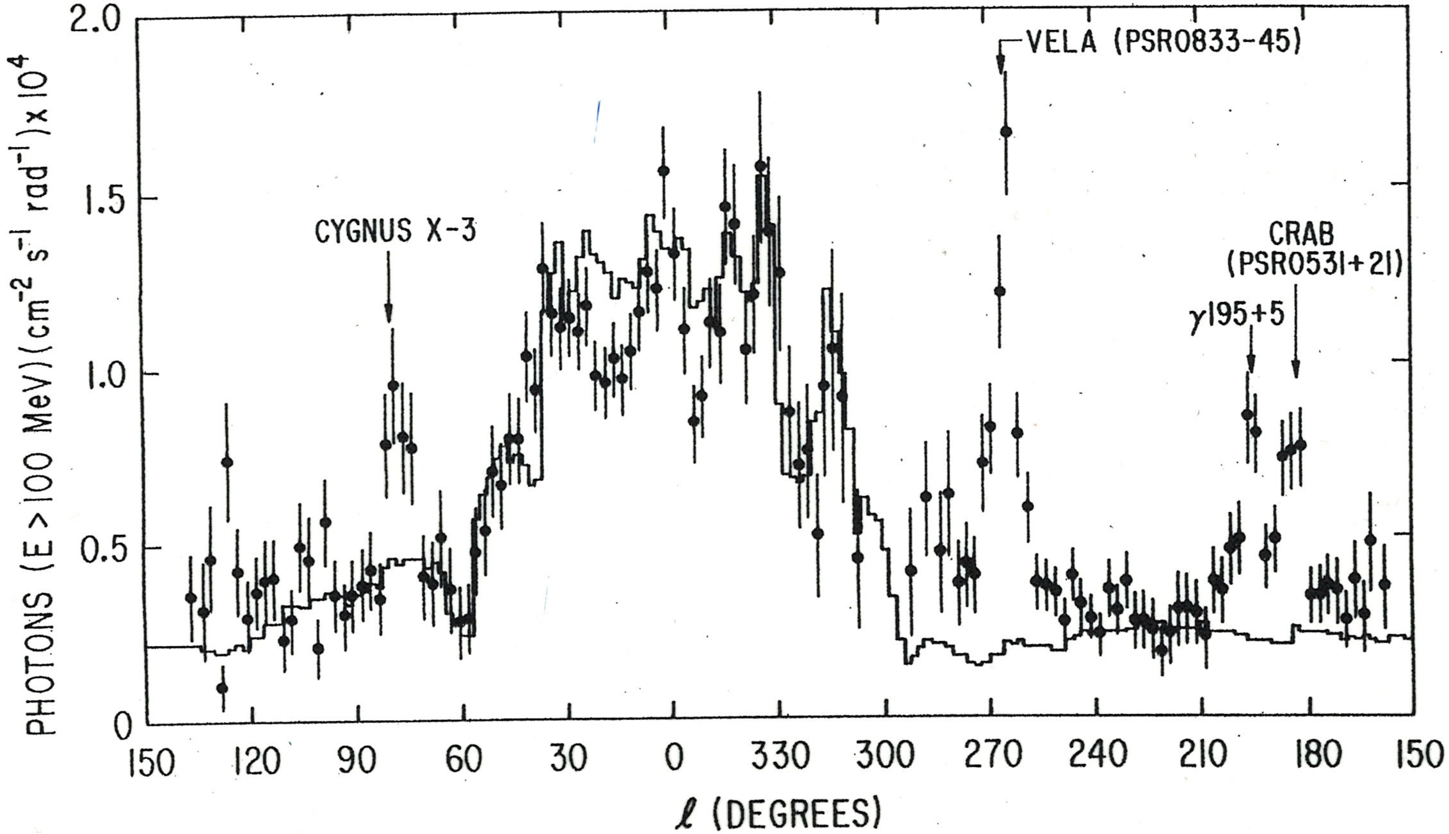
(example:
COMPTEL)


CENTER FOR
ERIC RESEARCH
BALLOON FACILITY





KNIFFEN AND FICHTEL



SAS-2 Longitude Distribution for Eγ > 100 MeV

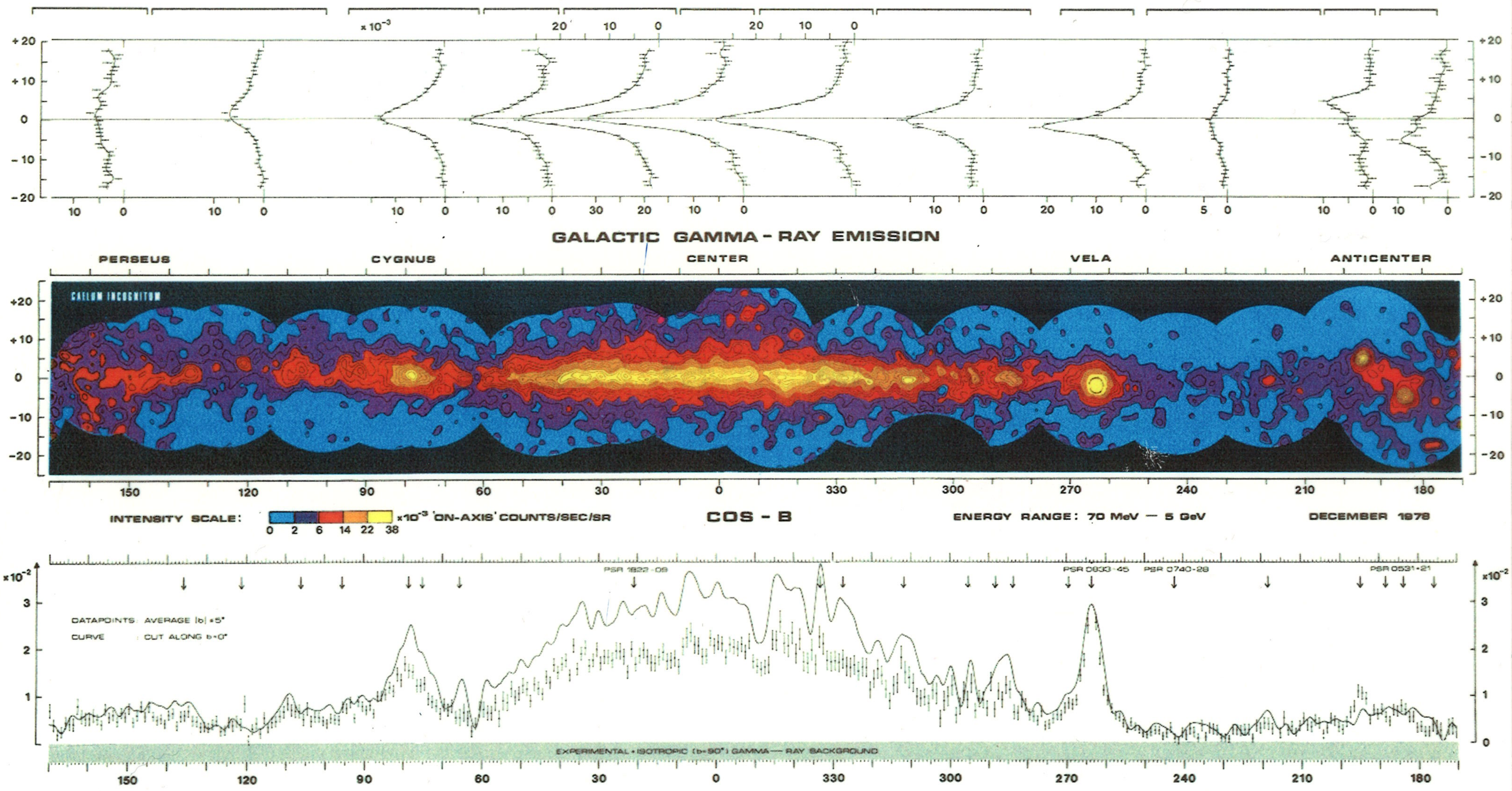
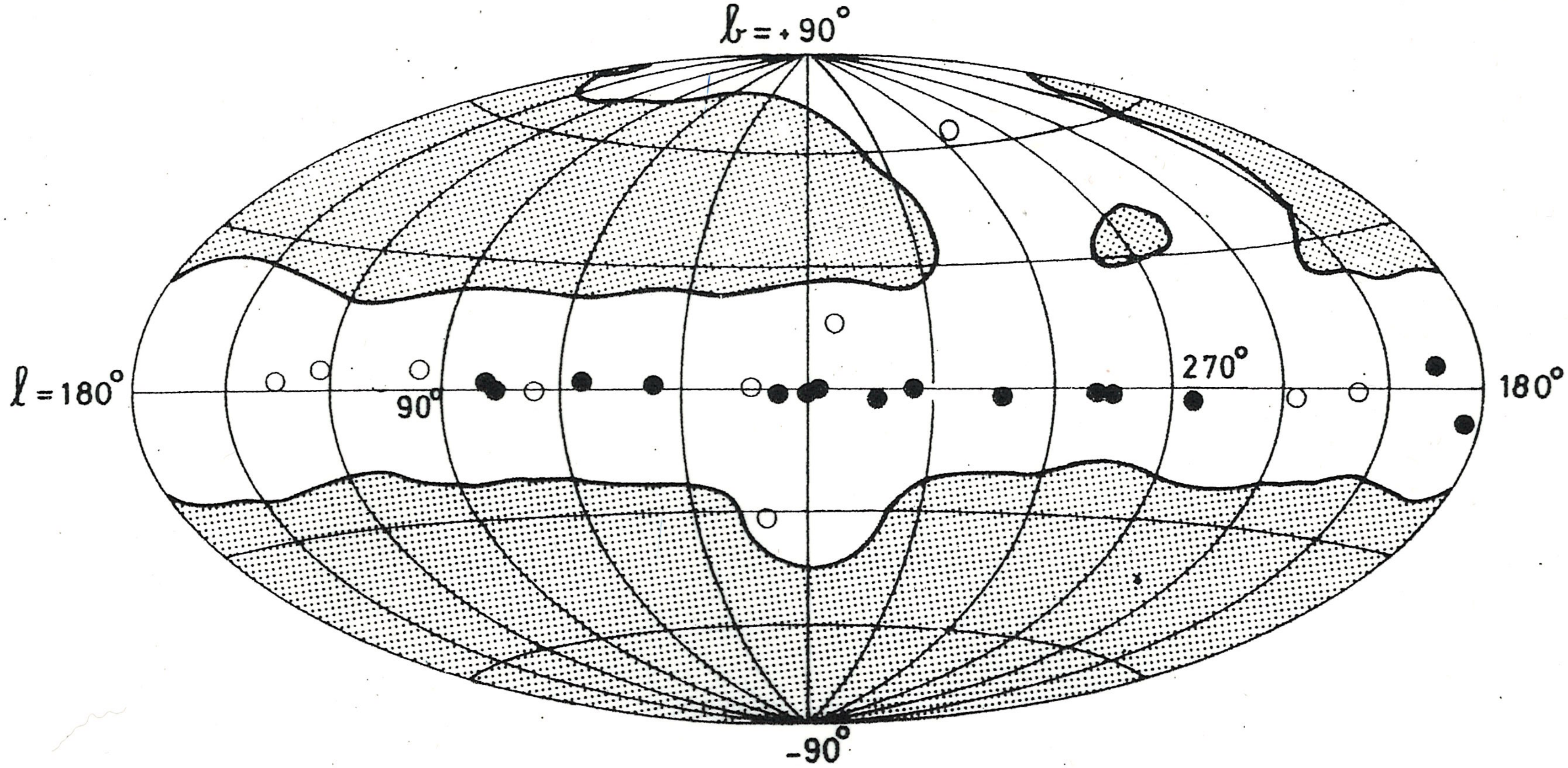
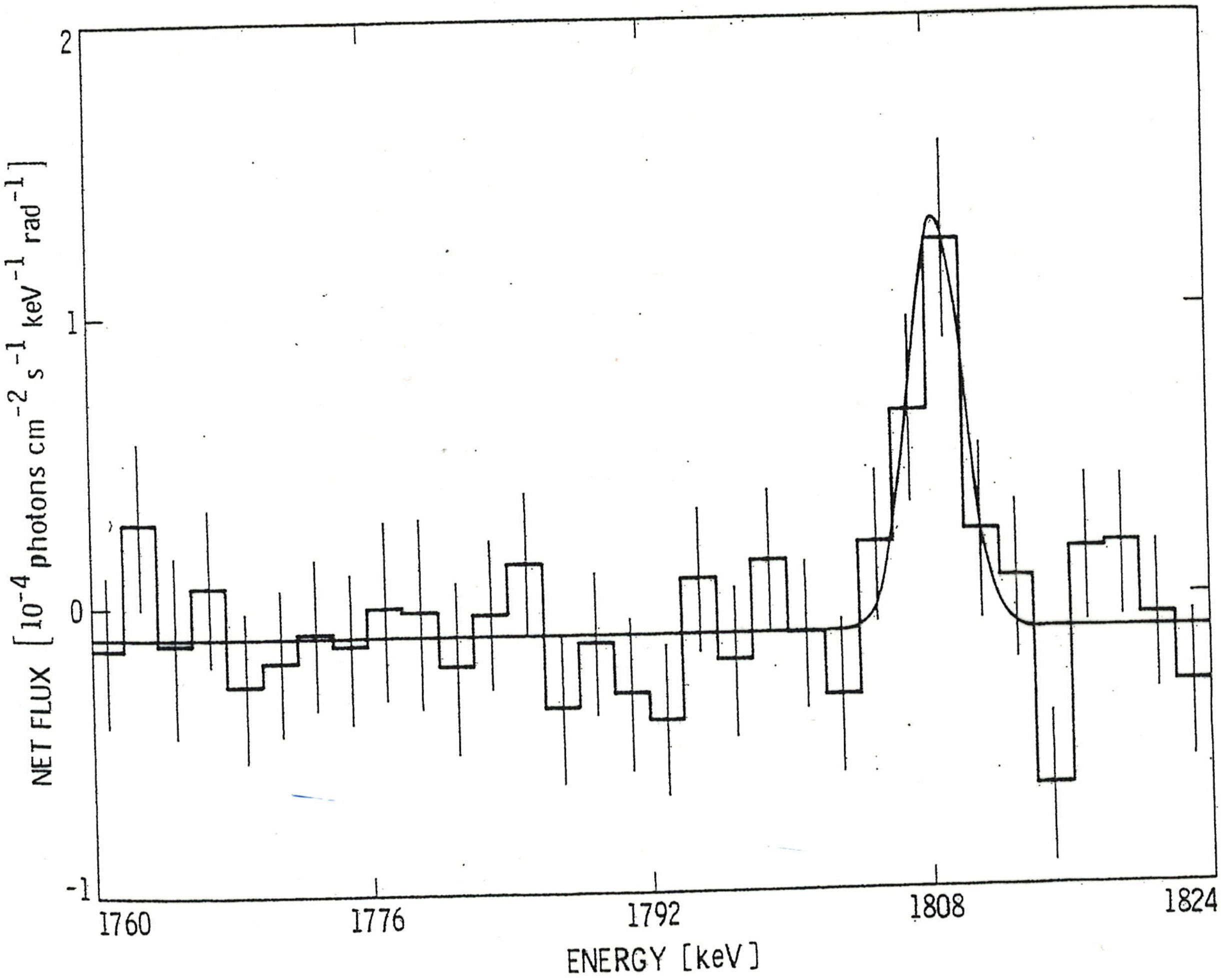


Abb. 63: Isointensitätskontourenkarte der Gammaemission der Milchstraße. Profile entlang galaktischer Länge bzw. Breite.



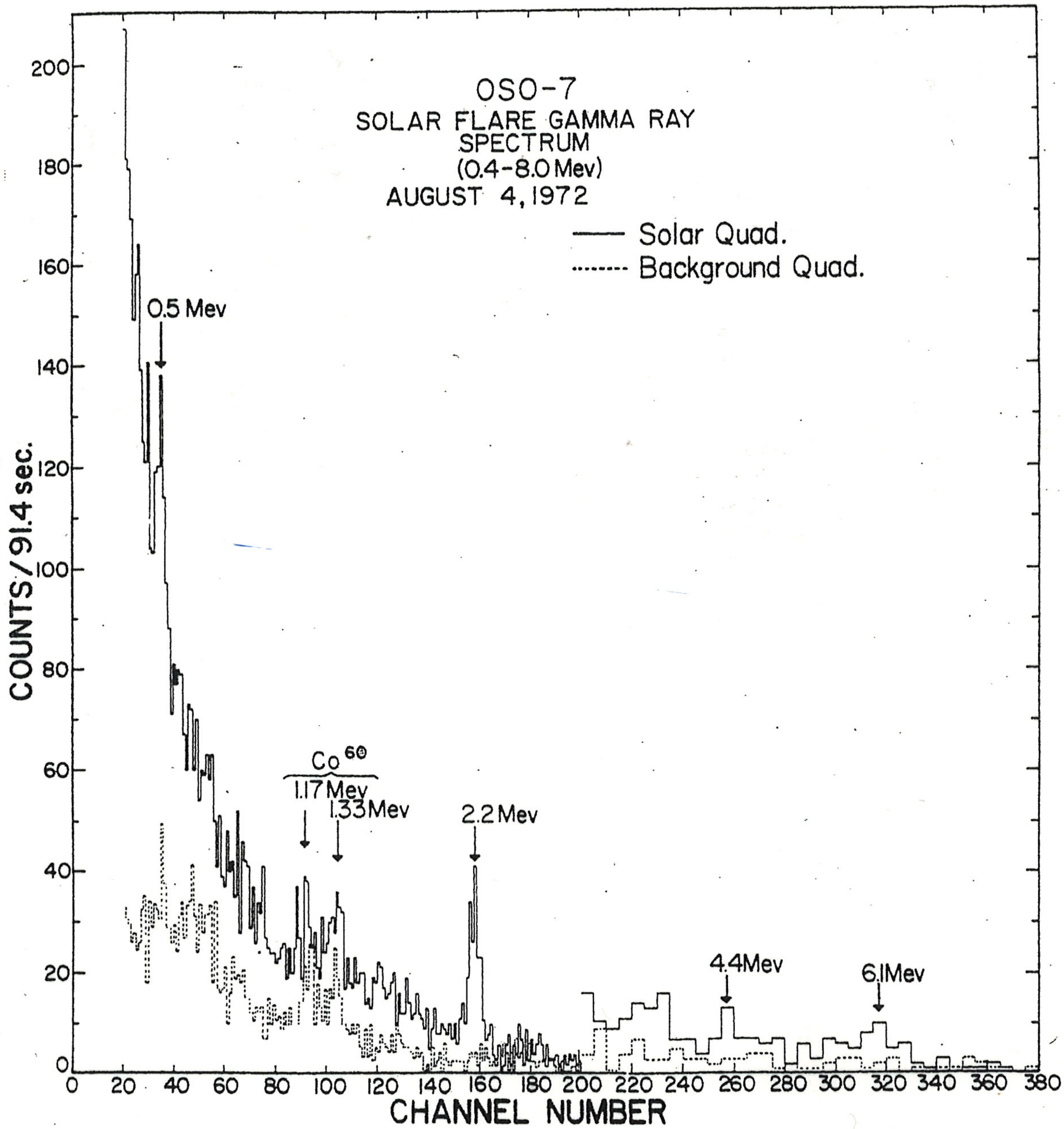
The Second COS-B Source Catalogue

(10)



Mahoney et al.: HEAO-3 Discovery of 1.809 MeV ^{26}Al Line

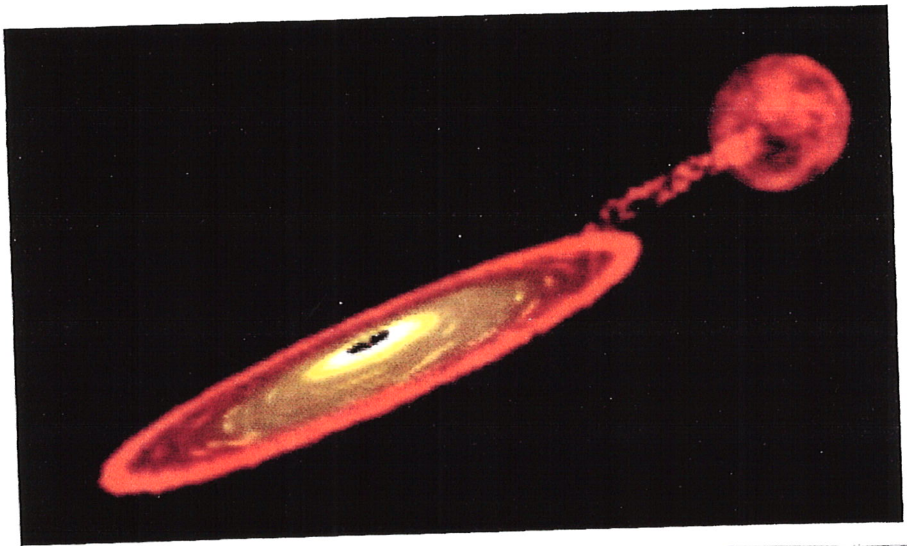
First Solar Flare Gamma Ray Line– and Continuum Detection from August 4, 1972 Flare by OSO-7



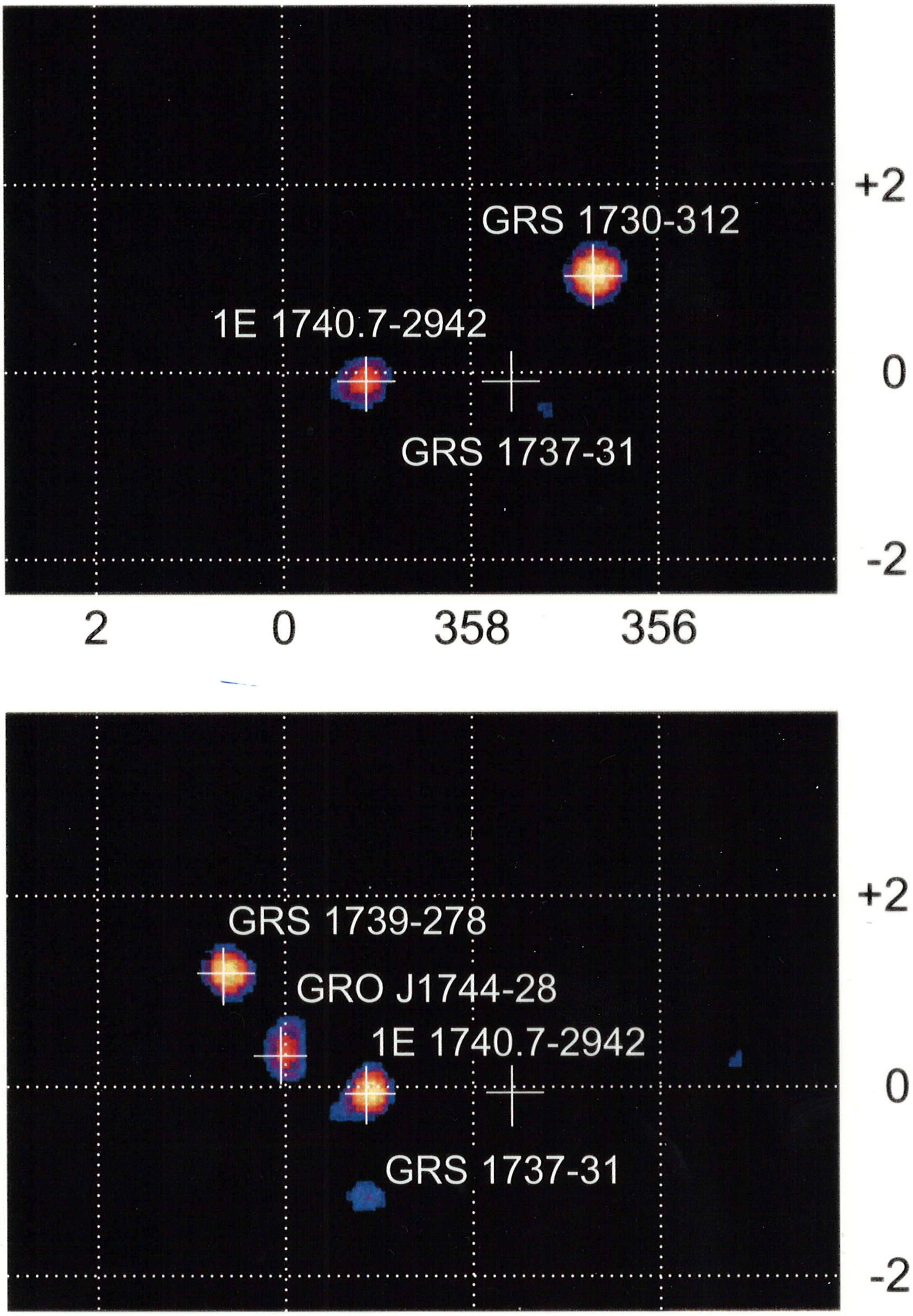
Mass Transfer in a Binary System from a Normal Star

Onto a Compact Object

(Computer Simmulation)



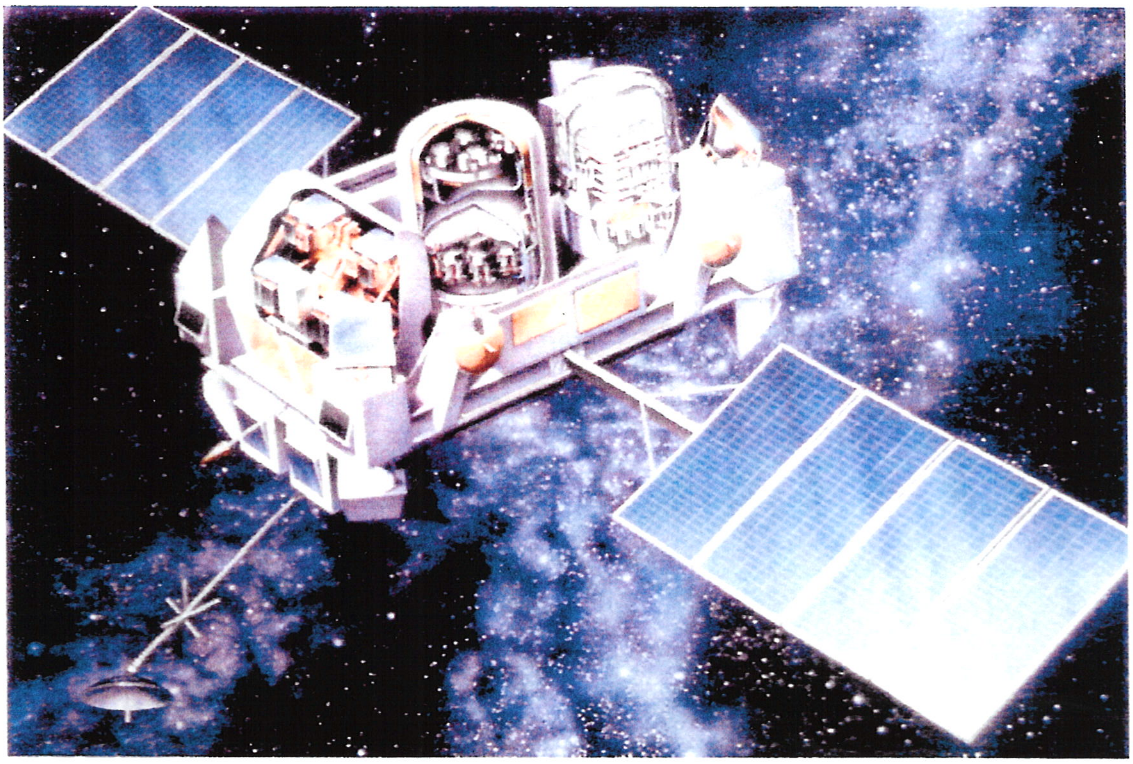
SIGMA Images of GC-Region
(40 - 150 keV)

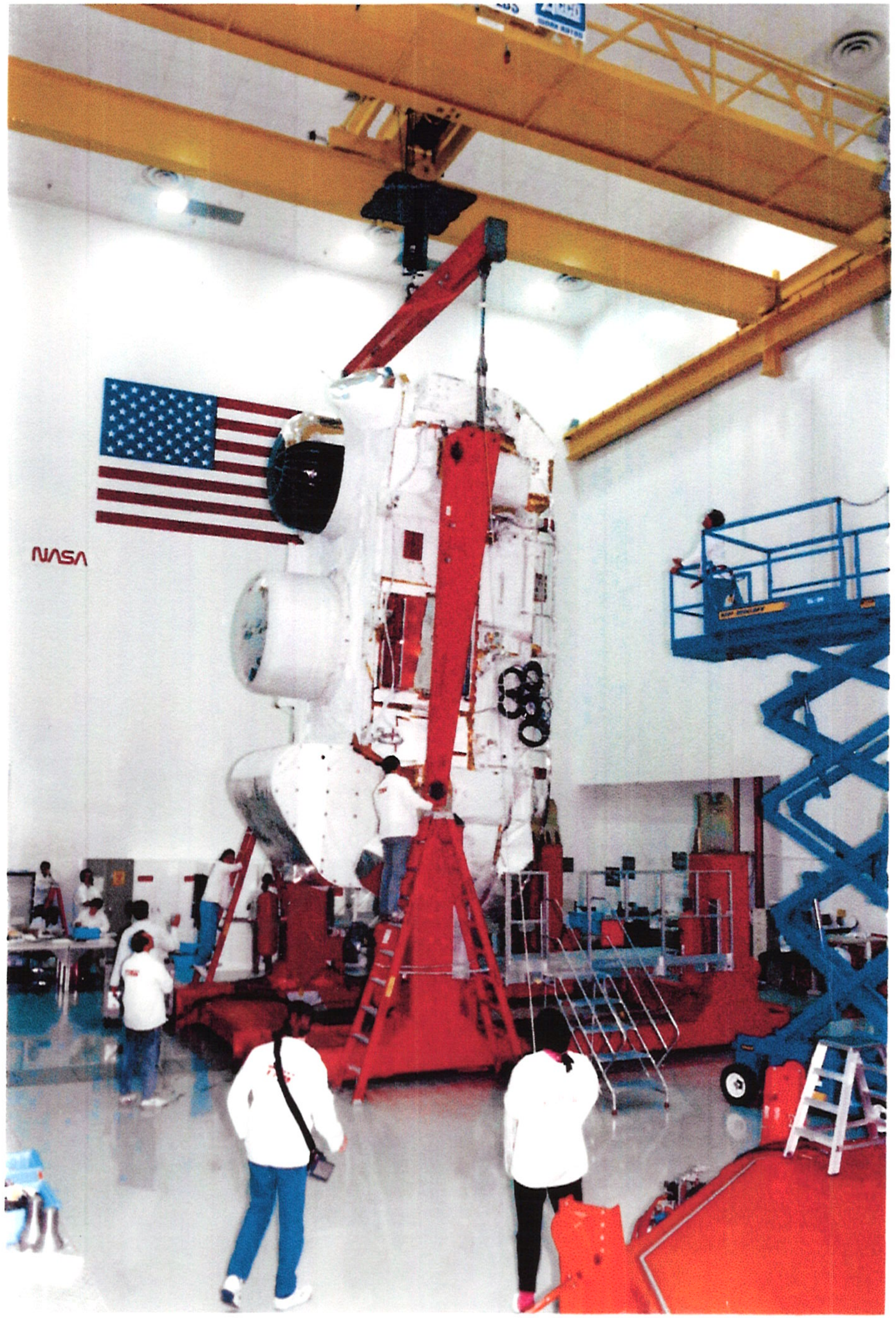


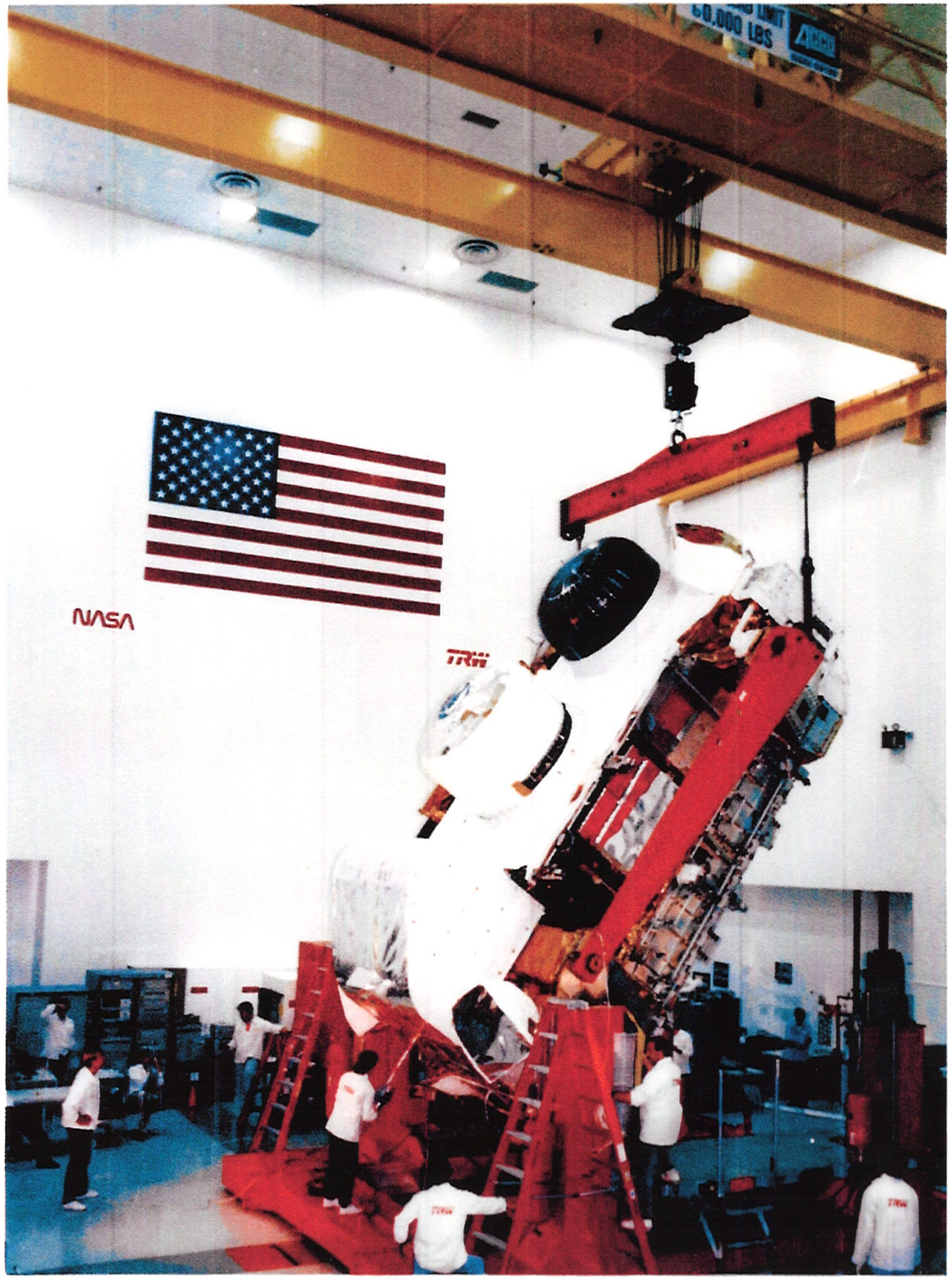
The Gamma-Ray Observatory

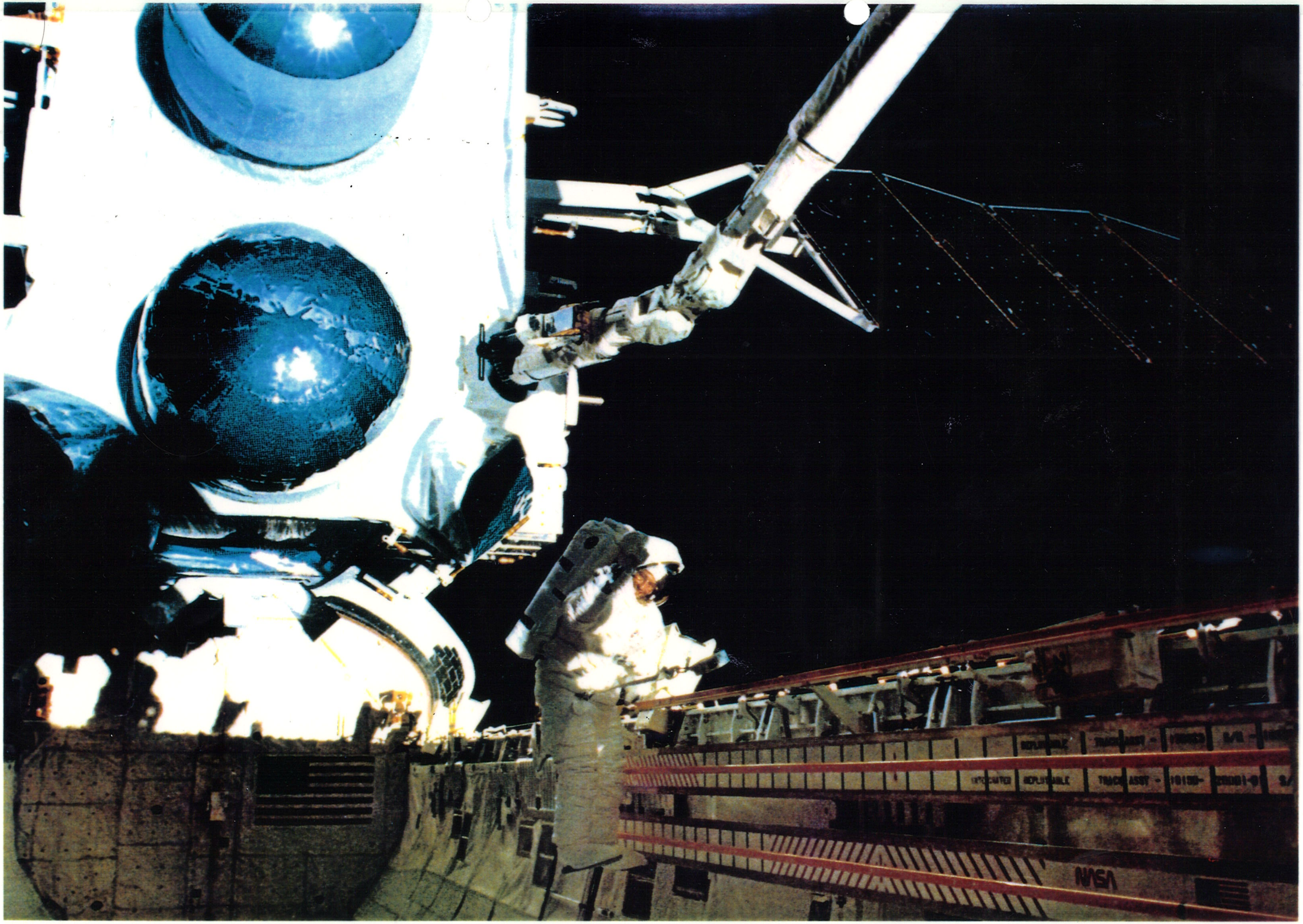
(100 keV to 30 GeV)

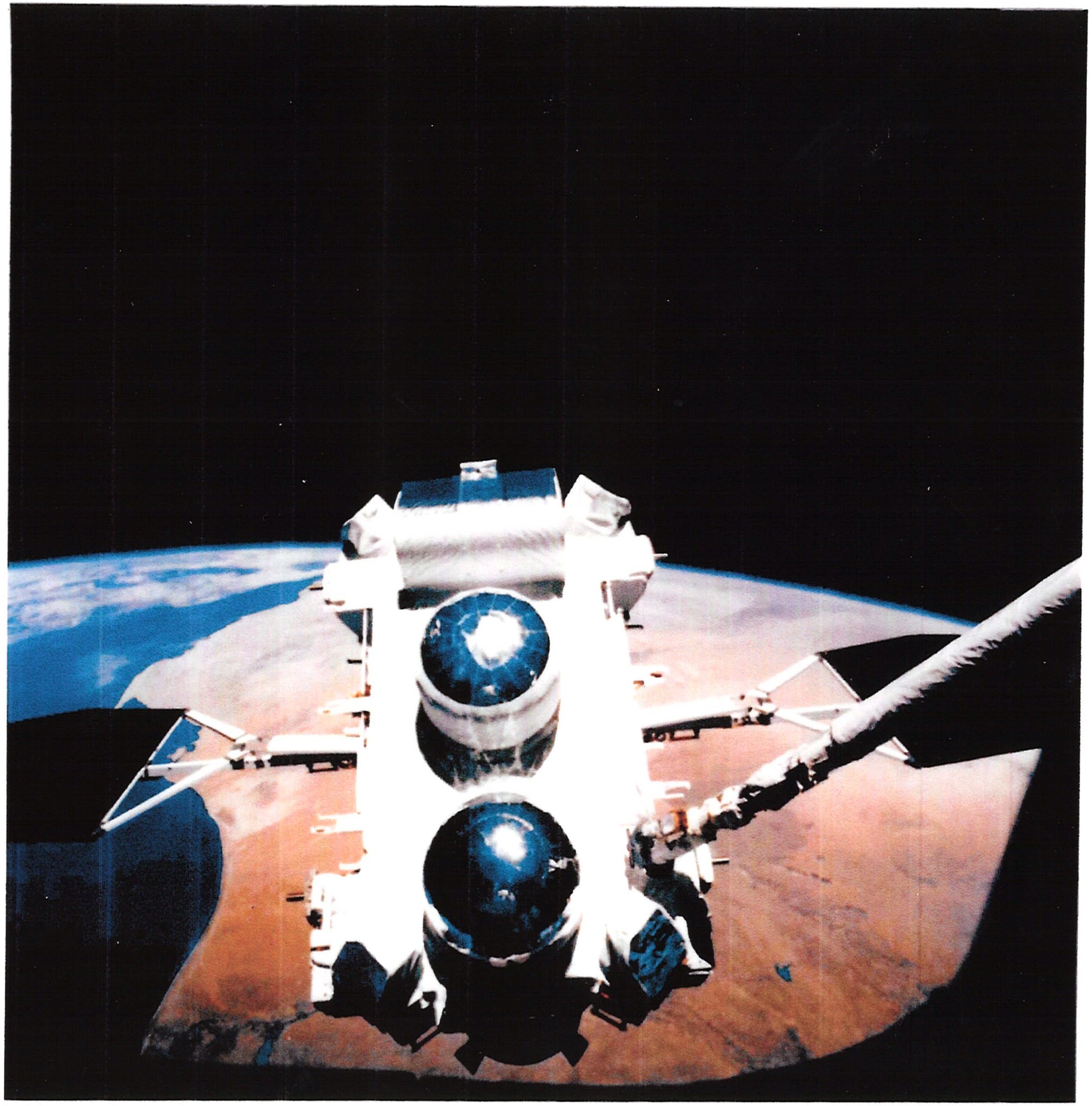
OSSE	COMPTEL	EGRET	BATSE (8)
100 keV to 10 MeV 3.8° × 11.4°	1 to 30 MeV 1° to 4° within 64° FWHM	20 MeV to 30 GeV 0.4° to 2° within 45° FWHM	20 keV to 30 MeV



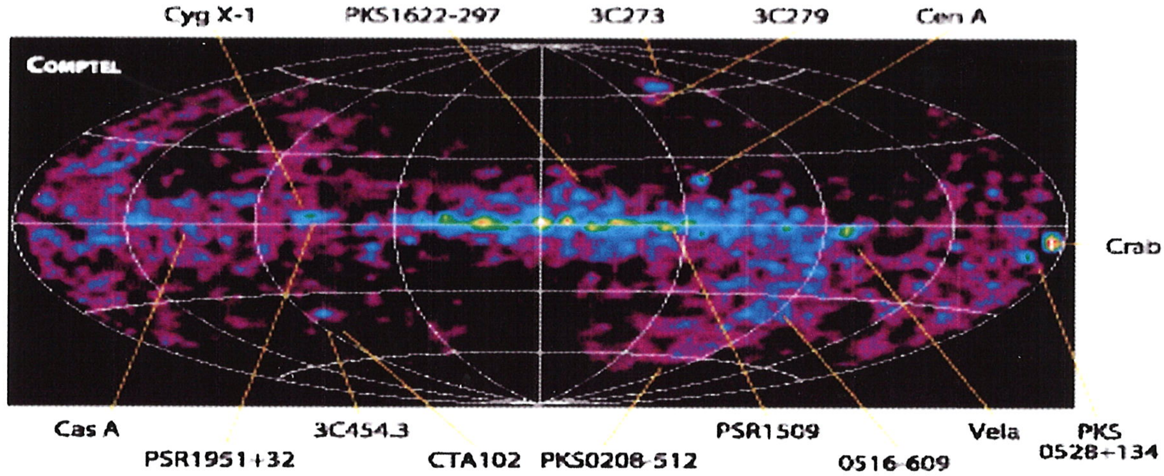

NASA


60,000 LBS
NASA
TRW

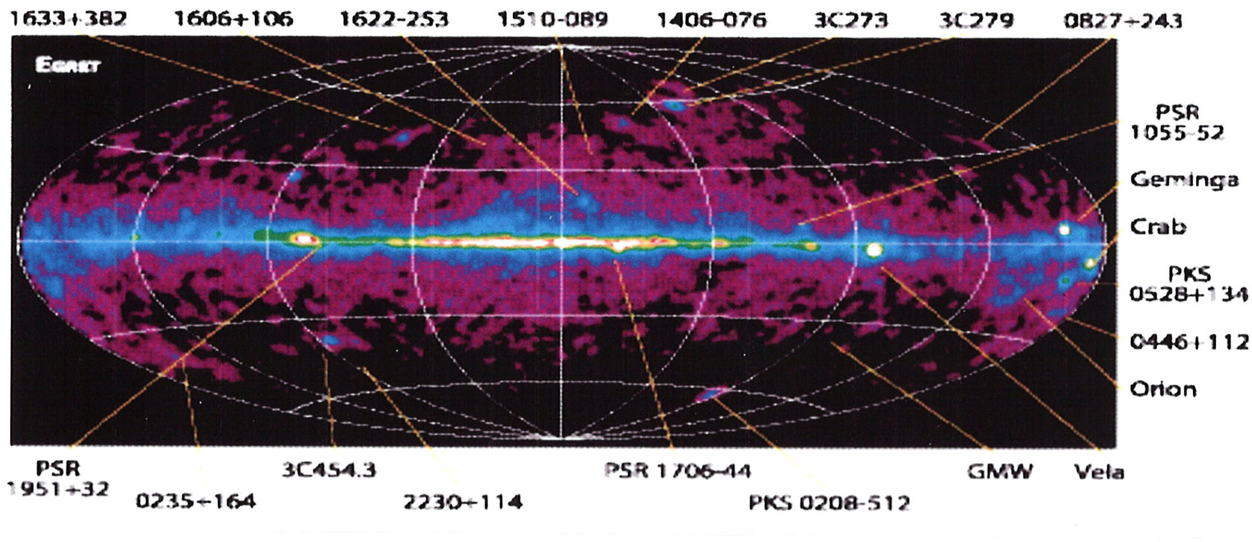

NASA



COMPTEL 1-30 MeV Phases 1- 6

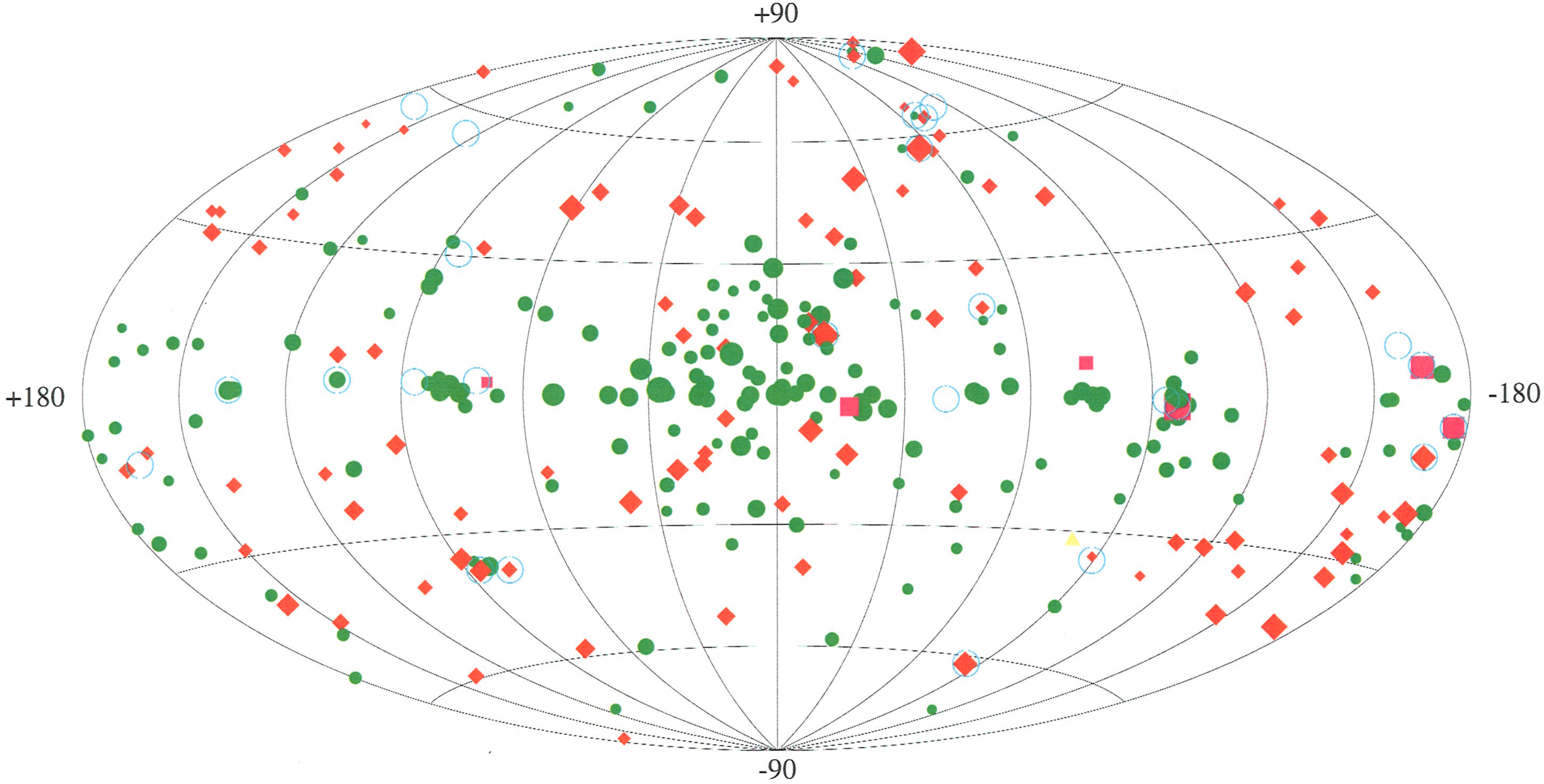


EGRET > 100 MeV



COMPTEL and EGRET Gamma-Quellen

MeV < E < GeV



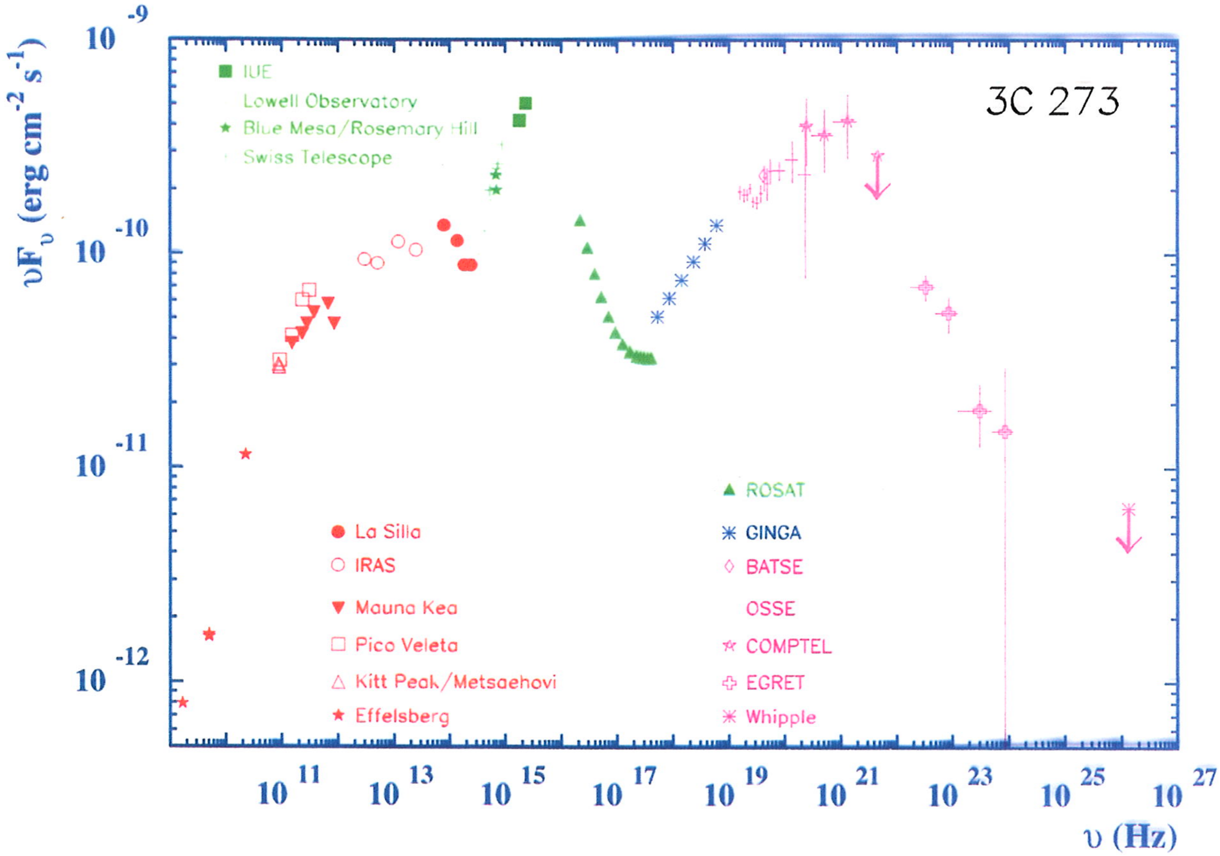
EGRET AGN

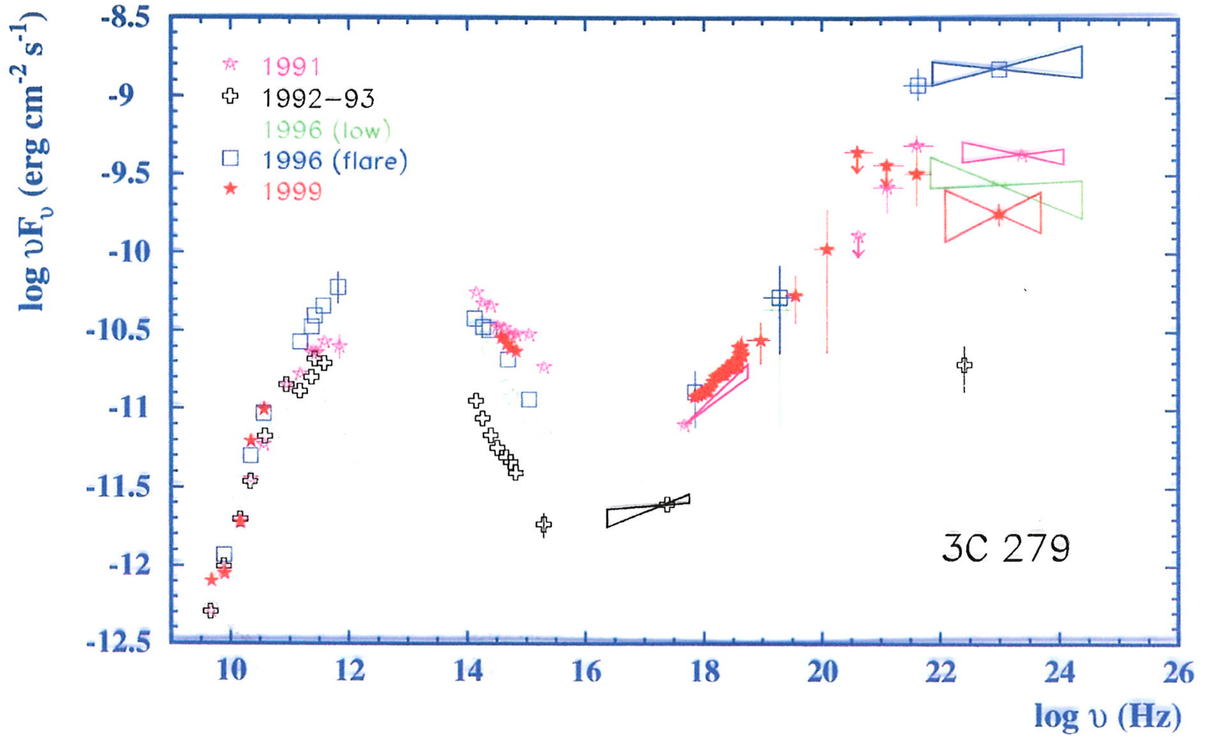
EGRET Pulsare

EGRET LMC

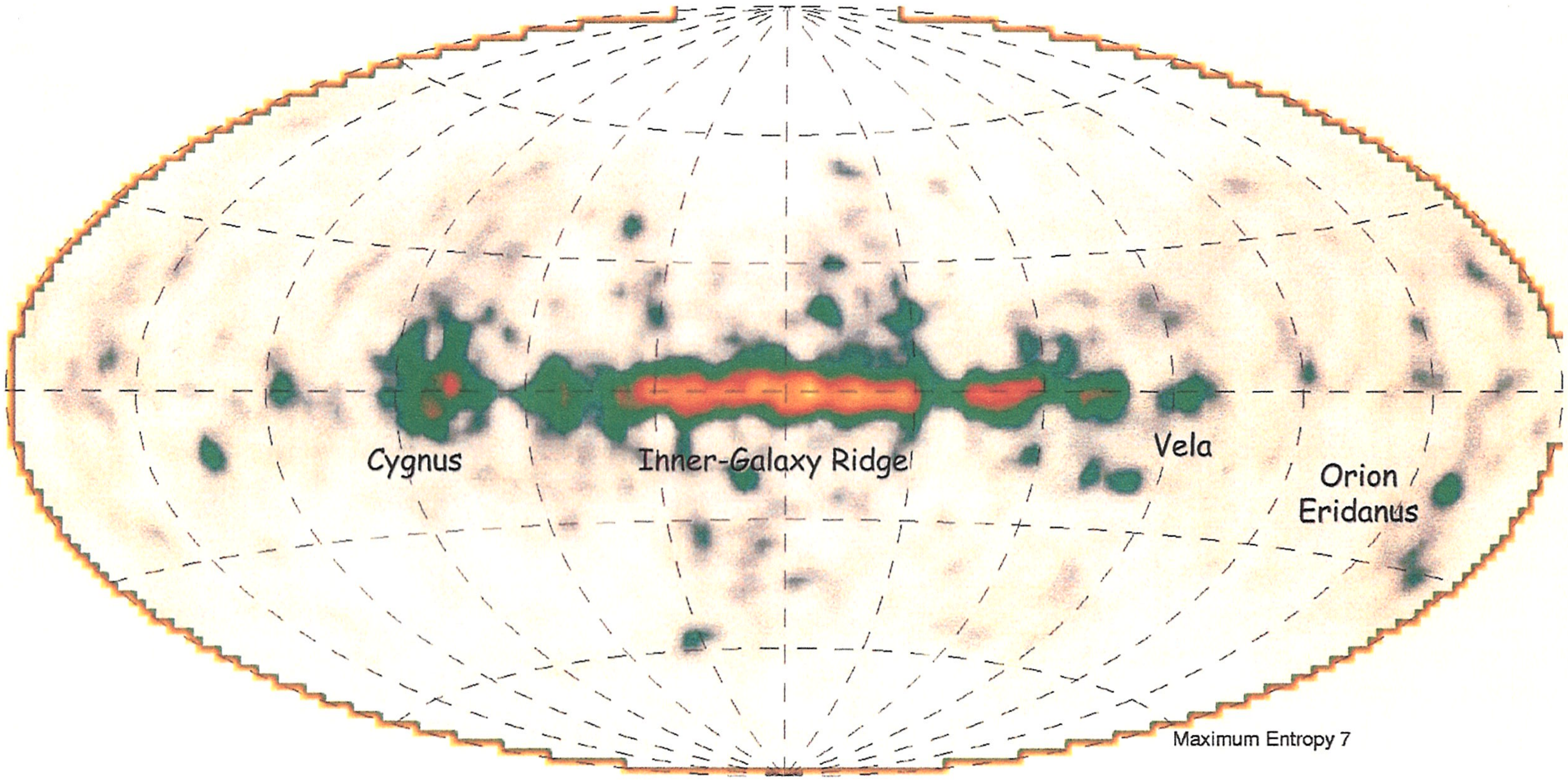
EGRET unidentifizierte Quellen

COMPTEL Quellen (750 keV - 30 MeV)


3C 273
νF_υ (erg cm^-2 s^-1)
10^-9
10^-10
10^-11
10^-12
IUE
Lowell Observatory
Blue Mesa/Rosemary Hill
Swiss Telescope
La Silla
IRAS
Mauna Kea
Pico Veleta
Kitt Peak/Metsaehovi
Effelsberg
ROSAT
GINGA
BATSE
OSSE
COMPTEL
EGRET
Whipple
10^11
10^13
10^15
10^17
10^19
10^21
10^23
10^25
10^27
υ (Hz)

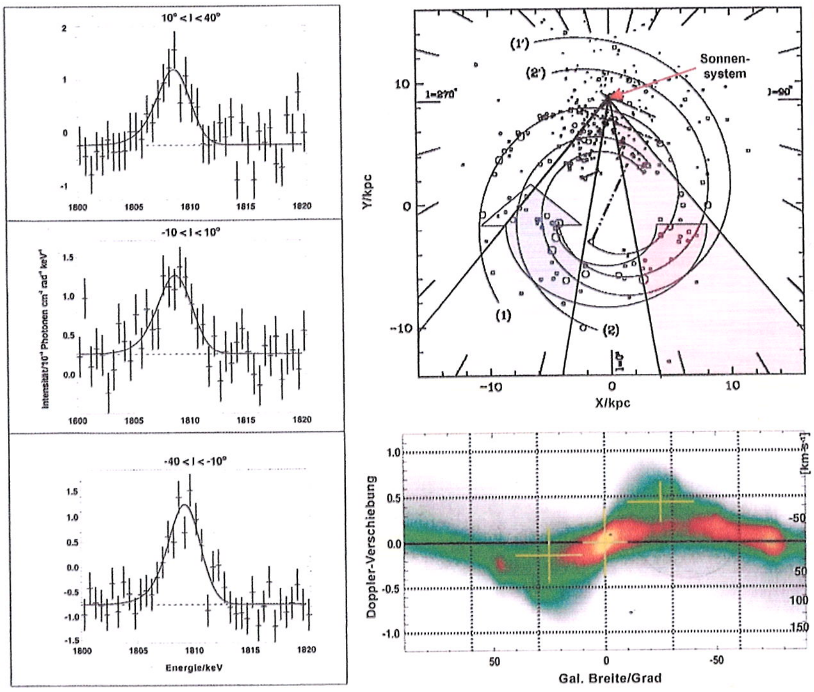

3C 279
log νF_υ (erg cm^-2 s^-1)
-8.5
-9
-9.5
-10
-10.5
-11
-11.5
-12
-12.5
1991
1992–93
1996 (low)
1996 (flare)
1999
10
12
14
16
18
20
22
24
26
log υ (Hz)

COMPTEL All-Sky Image at 1.8 MeV:
^{26}Al Nucleosynthesis in the Galaxy



Complete CGRO Mission
(Plüschke et al. 2001)

ABB. 5 | DOPPLER-VERSCHIEBUNG DER ^{26}AL-LINIE

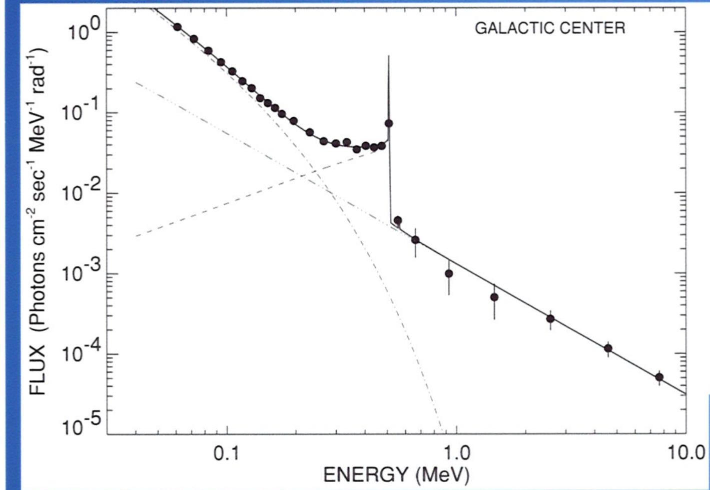


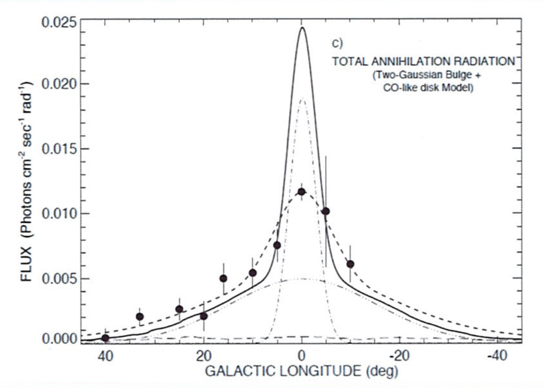
Spektrallinie des ^{26}Al-Zerfalls, entlang unterschiedlicher Sichtlinien in unserer Galaxis (drei fächerförmige Bereiche wie im Bild rechts oben gezeigt). Die großräumige Rotation der Milchstraßenebene (breiter Pfeil rechts oben) führt zu Relativbewegungen von etwa 100 km s^{-1} zwischen dem ^{26}Al im interstellaren Gas und dem Sonnensystem. Dies äußert sich in Doppler-Verschiebungen der Linien (linke Spalte). Die gesamte Doppler-Verschiebung in Abhängigkeit von der galaktischen Längenkoordinate (rechts unten) lässt sich gut mit einem Rotationsmodell der Milchstraße beschreiben (farbig dargestellt).

Table 1

Decay Chain	Mean Life (Yrs)	Emission (MeV)	Origin	Observed from
$^{7}Be \rightarrow {}^{7}Li$	0.145	e-capt, 0.478	Novae	
$^{56}Ni \rightarrow {}^{56}Co \rightarrow {}^{56}Fe$	0.31	e^+,0.847, 1.238	Supernova	SN 1987 a SN 1991T ?
$^{57}Ni \rightarrow {}^{57}Co \rightarrow {}^{57}Fe$	1.1	0.014, 0.122	Supernova	SN 1987 a
$^{22}Na \rightarrow {}^{22}Ne$	3.8	e^+, 1.275	Novae, WR-stars	NCas 1995(?) Gal. Bulge (?)
$^{44}Ti \rightarrow {}^{44}Sc \rightarrow {}^{44}Ca$	90.0	e^+, 0.068, 0.078, 1.156	Supernova	Cas A RX0852-4622 ?
$^{60}Fe \rightarrow {}^{60}Co \rightarrow {}^{60}Ni$	$2.2 \cdot 10^{6}$	0.059,1.173, 1.332	Supernova	Inner Galaxy
$^{26}Al \rightarrow {}^{26}Mg$	$1.1 \cdot 10^{6}$	e^+, 1.809	Supernova, WR-stars	Gal. Plane,RX 0852-4622 (?)

Mapping the Galactic Plane Positrons



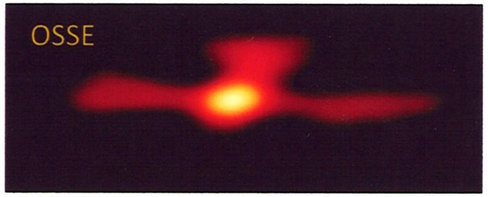


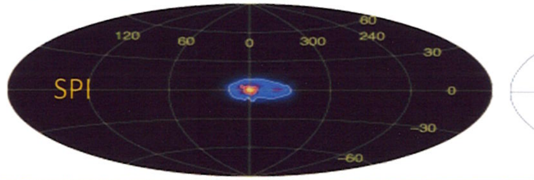
Positronium fraction 0.93 ± 0.04

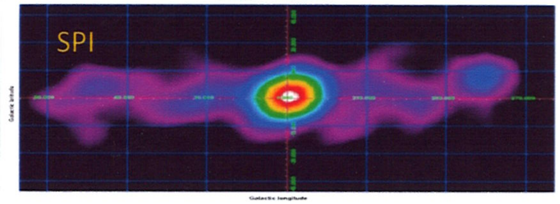
Longitude Distribution

~ 6° gaussian bulge + CO disk model (solid lines – intrinsic model, dashed lines – convolved w/ OSSE)

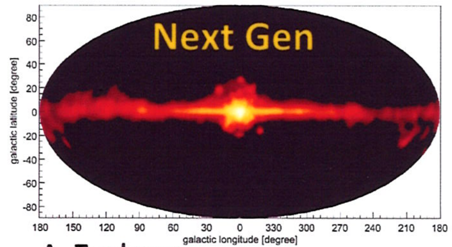
Kinzer et al. ApJ, 2001



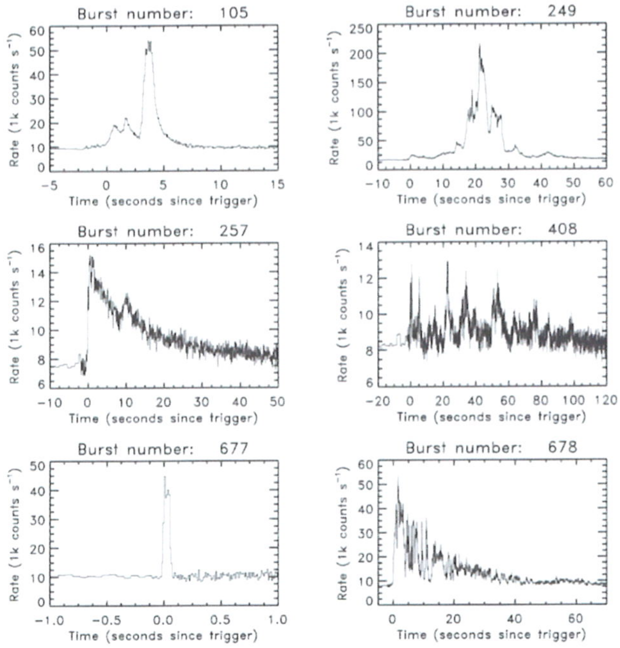




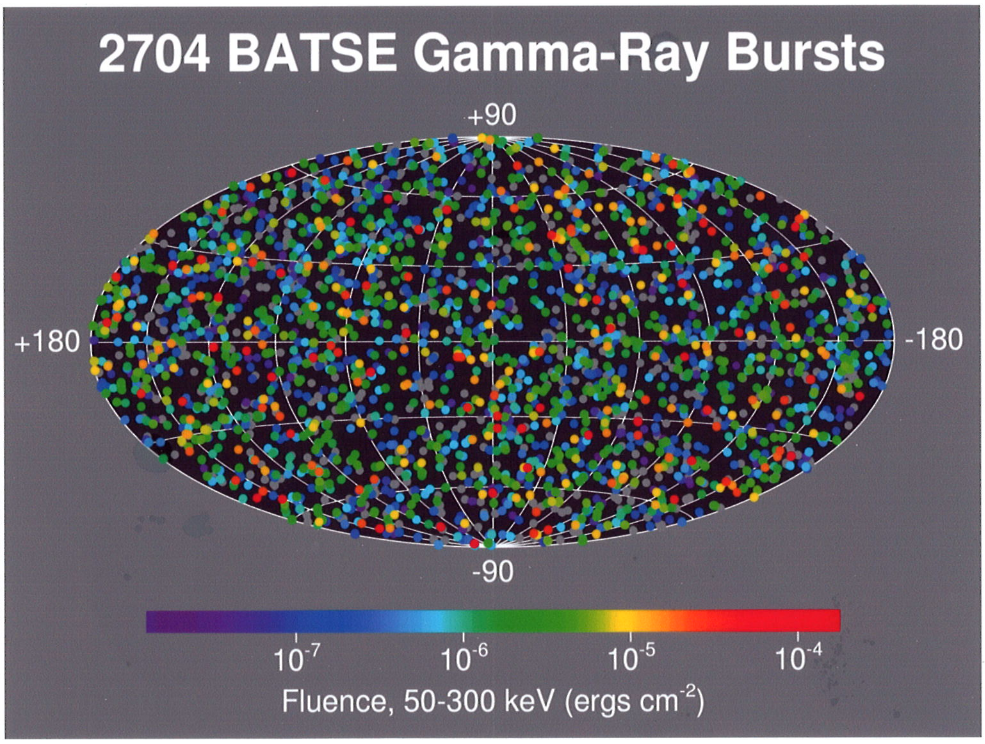
All-sky image in the 511 keV line after 5 years



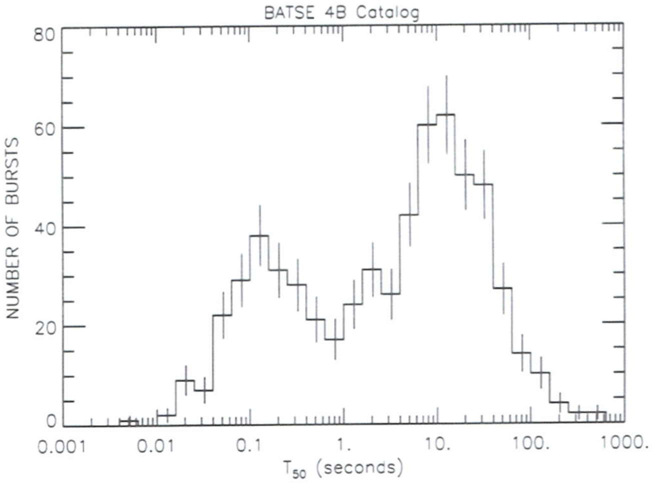
A. Zoglauer

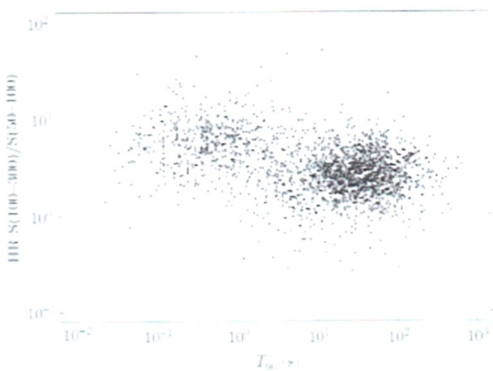


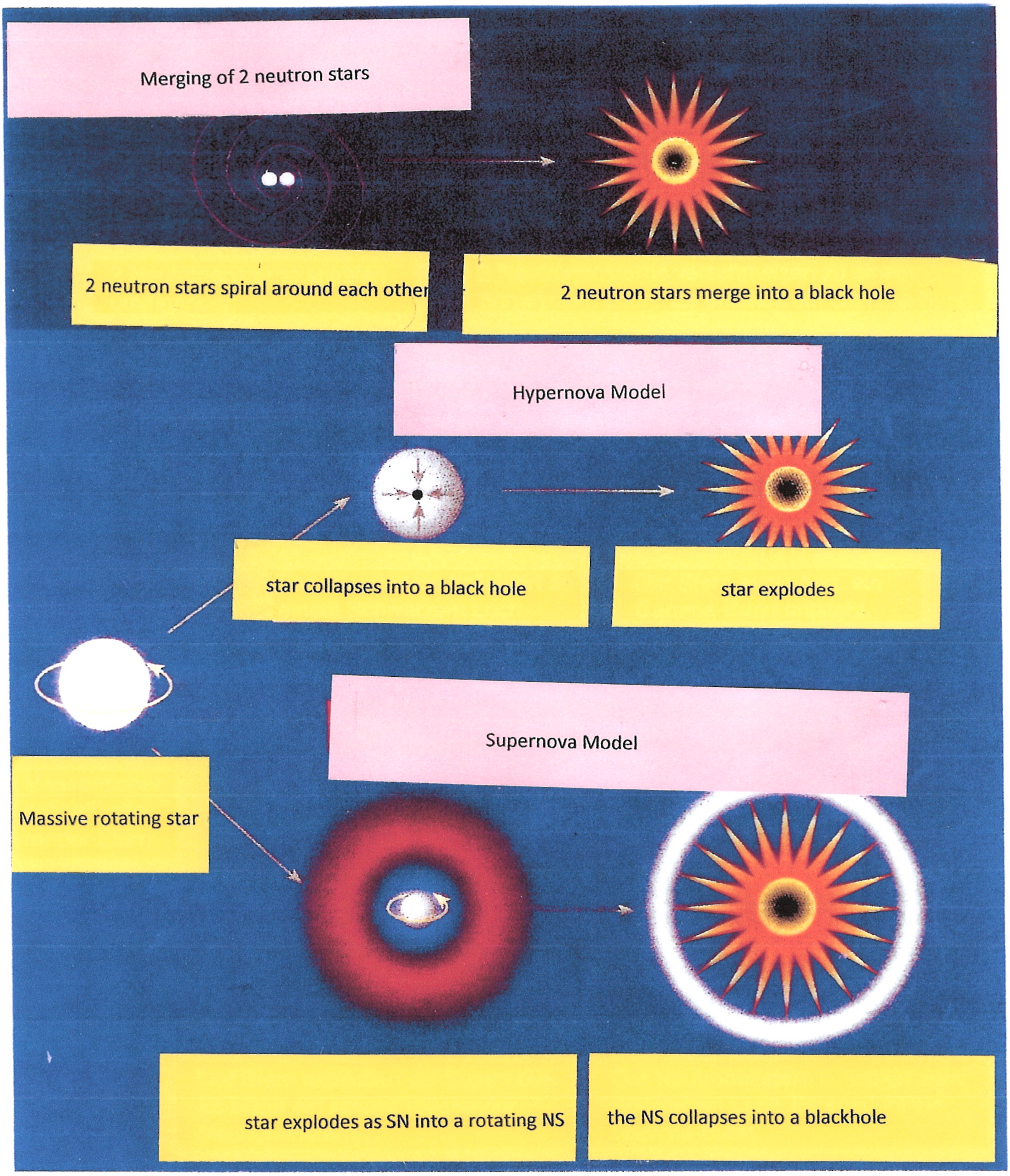
Burst number: 105
Burst number: 249
Burst number: 257
Burst number: 408
Burst number: 677
Burst number: 678
Rate (1k counts s⁻¹)
Time (seconds since trigger)


2704 BATSE Gamma-Ray Bursts
+90
+180
-180
-90
10-7
10-6
10-5
10-4
Fluence, 50-300 keV (ergs cm-2)

Duration Distribution

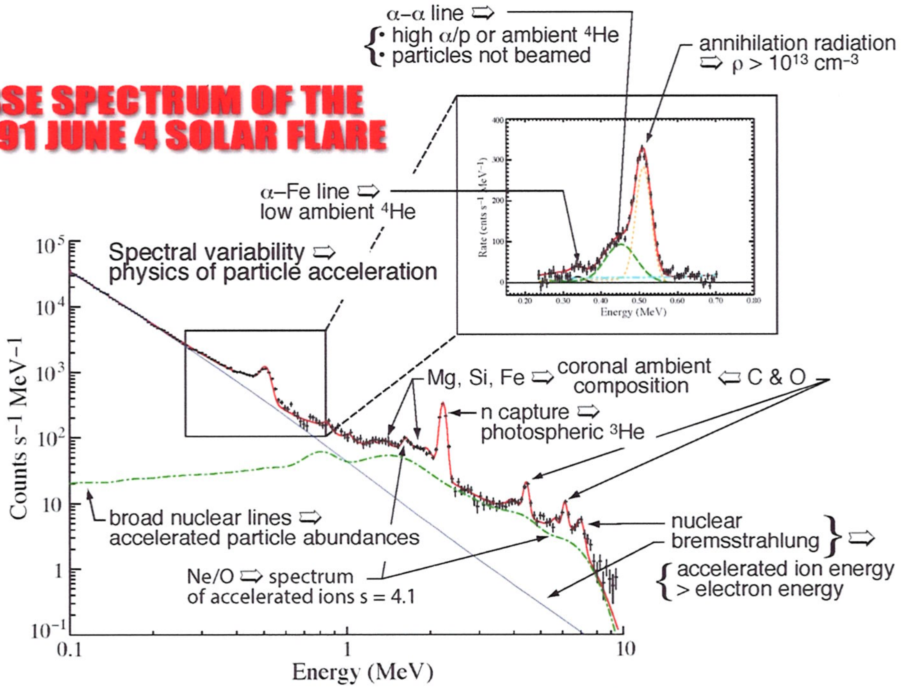





Merging of 2 neutron stars
2 neutron stars spiral around each other
2 neutron stars merge into a black hole
Hypernova Model
star collapses into a black hole
star explodes
Massive rotating star
Supernova Model
star explodes as SN into a rotating NS
the NS collapses into a blackhole

Start of Science Operations

OSSE SPECTRUM OF THE 1991 JUNE 4 SOLAR FLARE



Murphy, Share, et al., ApJ, 1997

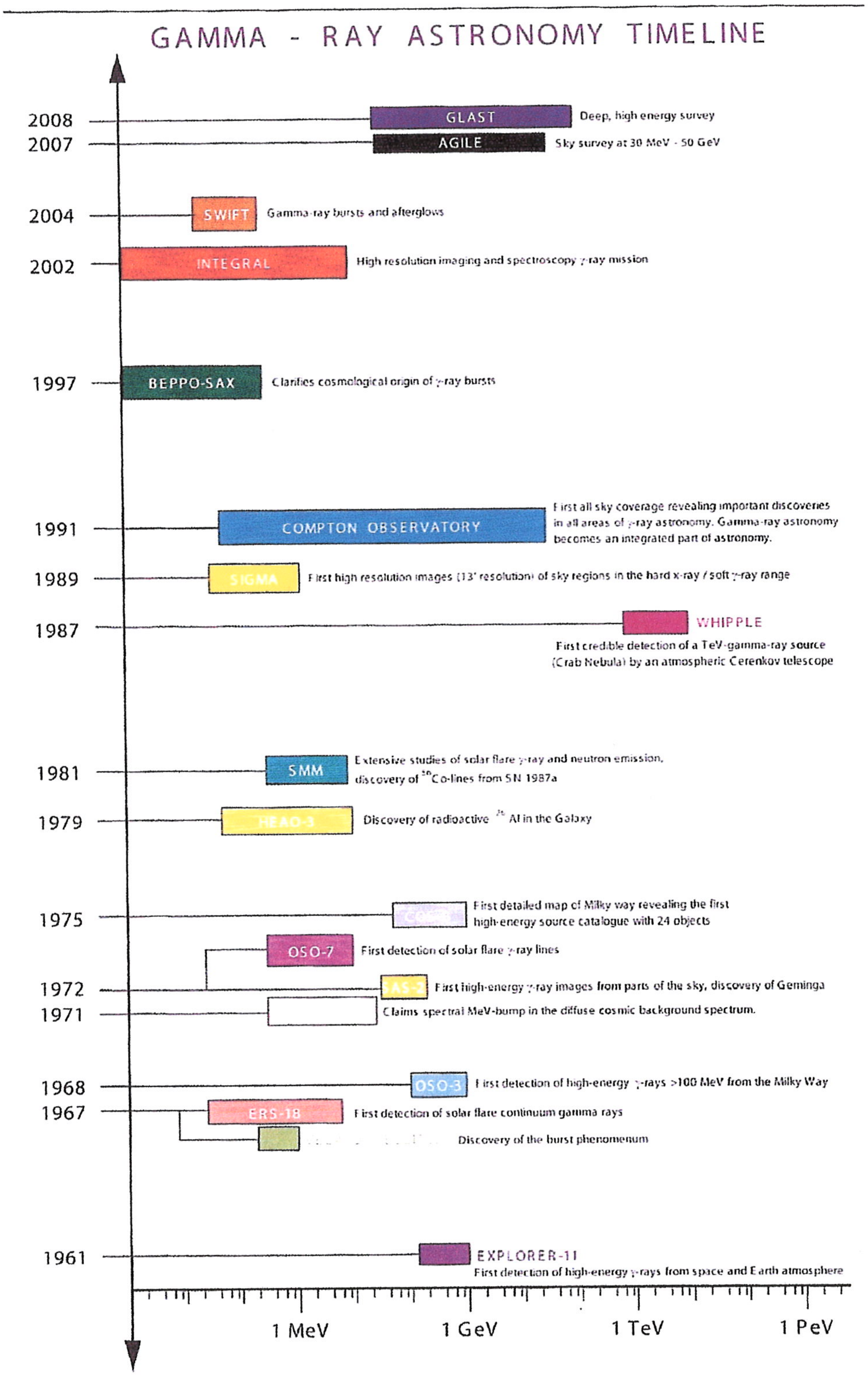


Figure 3.1: The history of observational γ-ray astronomy from the early 1960s until the launch of the *Fermi* Gamma-ray Space Telescope, formerly *GLAST*.