

MeV Science Highlights from CGRO/COMPTEL

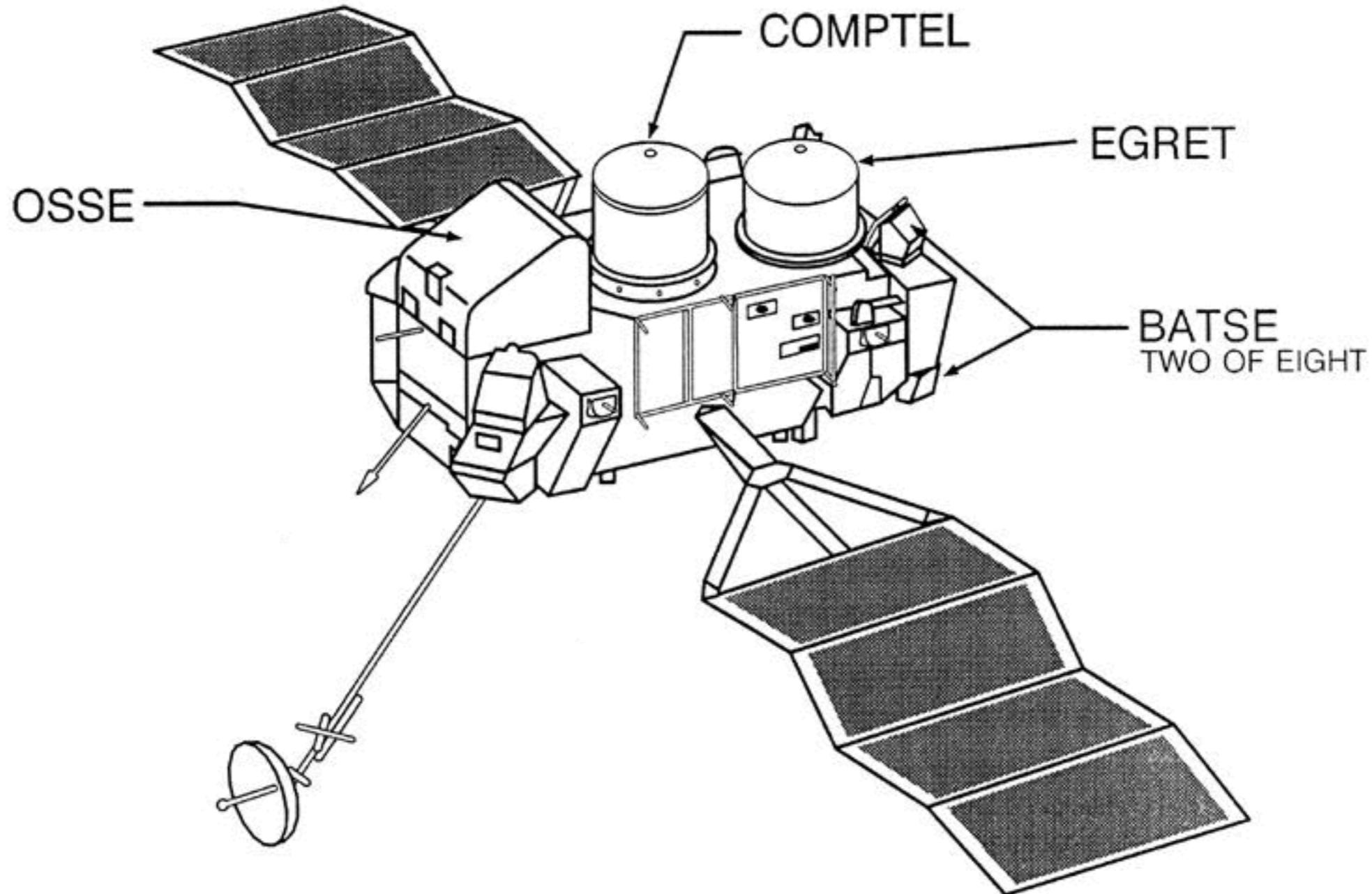


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Compton Gamma Ray Observatory

COMPTON OBSERVATORY INSTRUMENTS



CGRO Energy Coverage

The Instruments on CGRO Cover Six Orders of Magnitude in Photon Energy

 BATSE

 OSSE

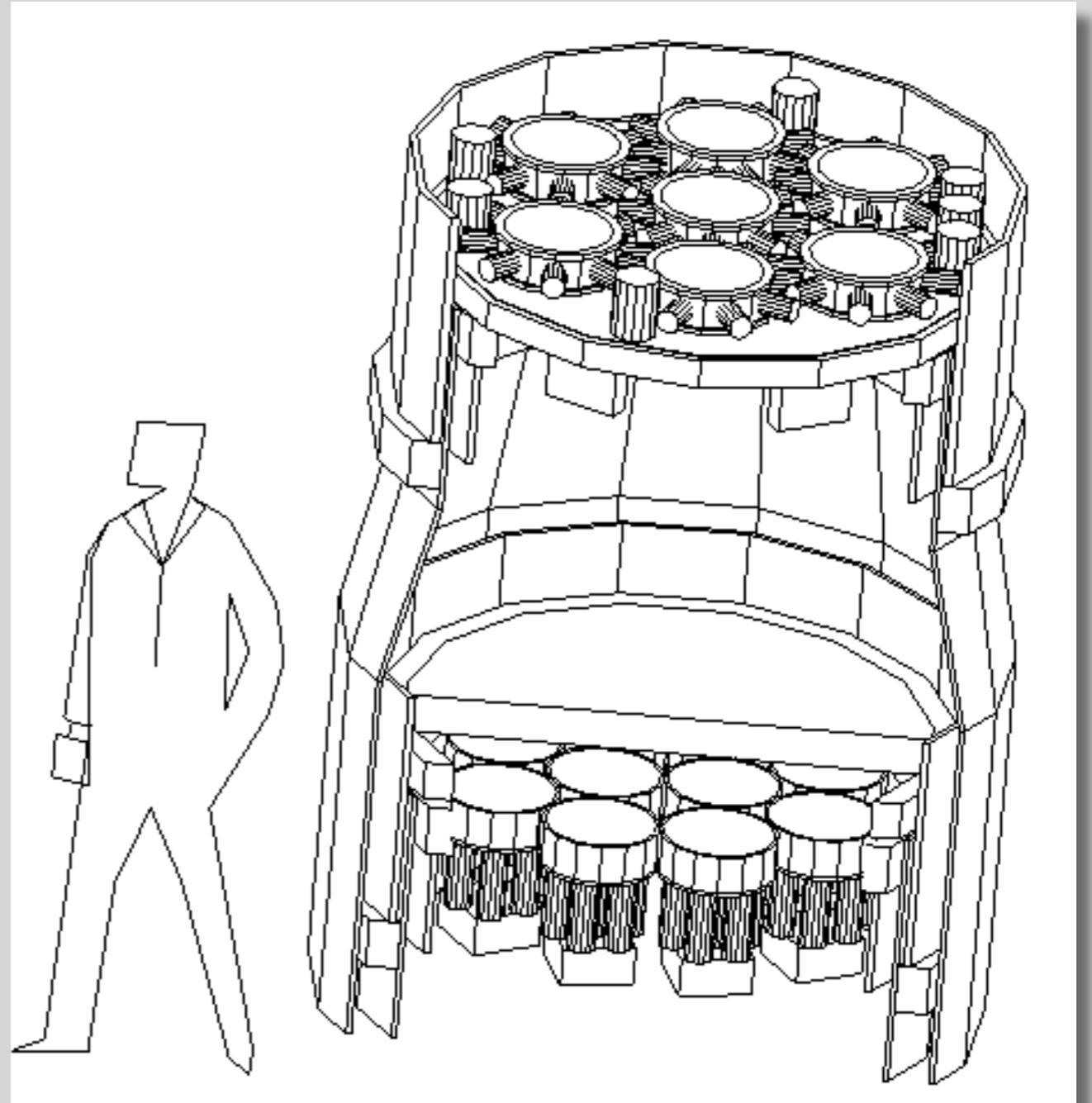
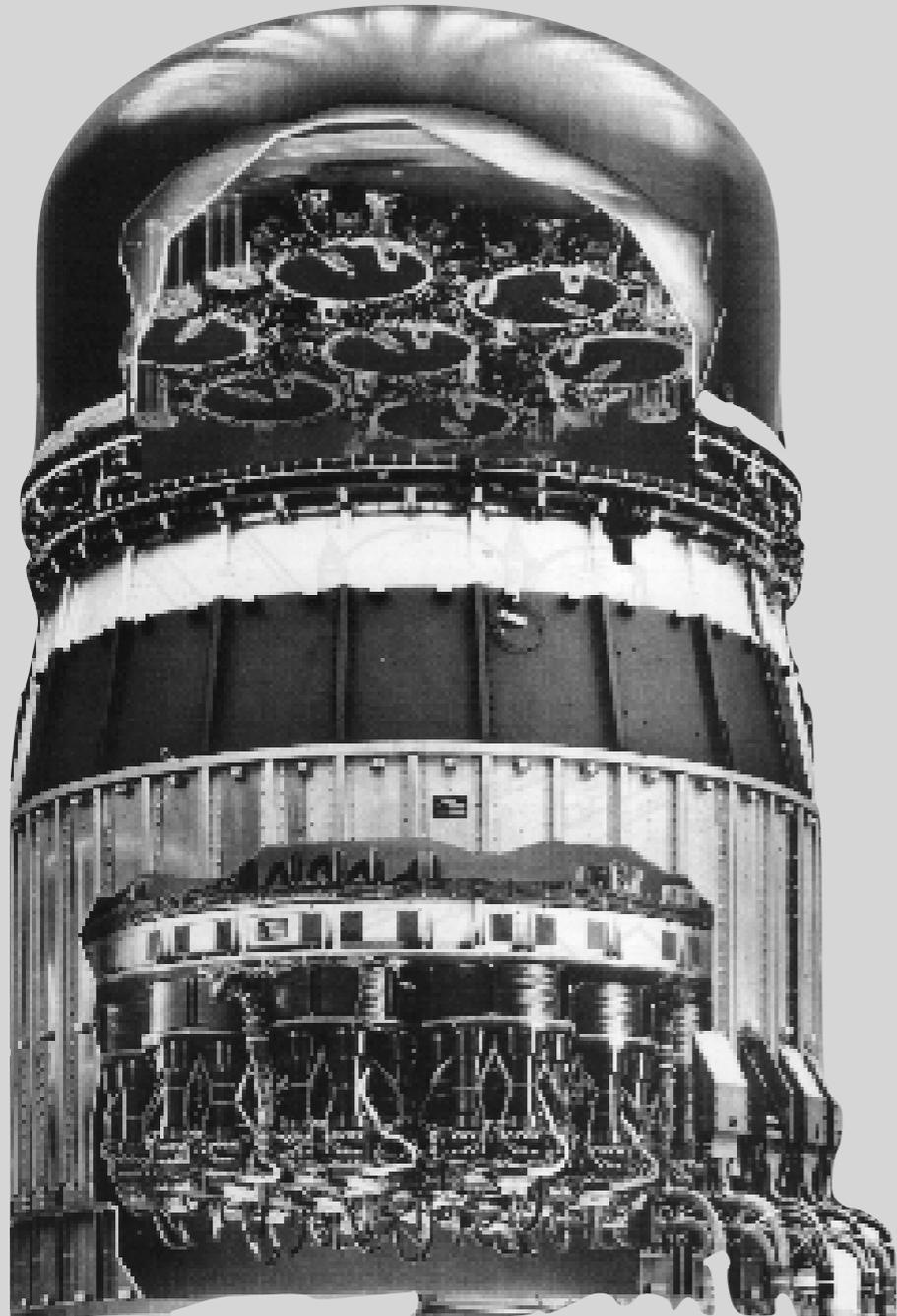
 COMPTEL

EGRET 

10 keV 100 keV 1 MeV 10 MeV 100 MeV 1 GeV 10 GeV 100 GeV

COMPton TELEscope

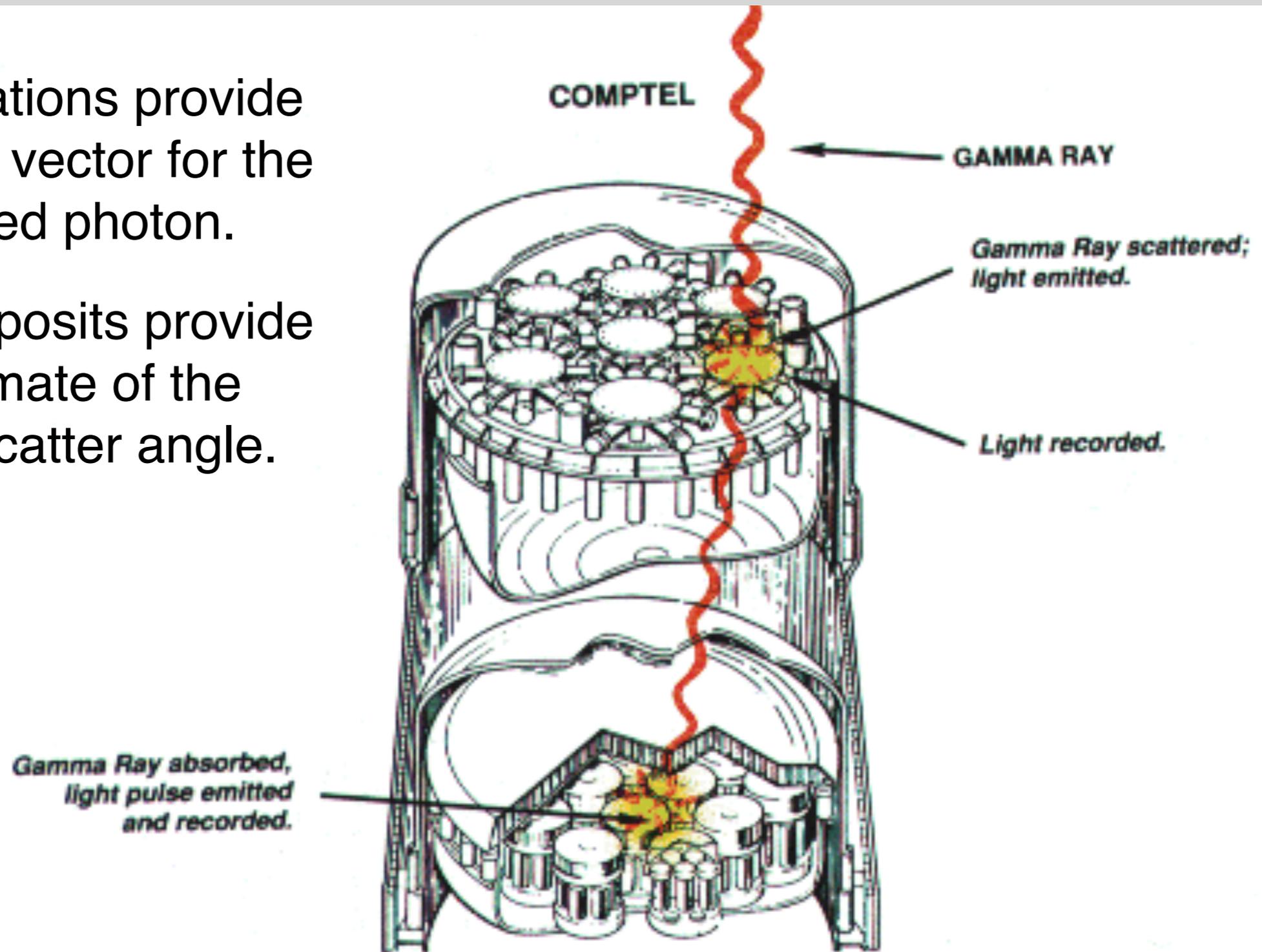
Compton telescope operating from 0.75 -30 MeV



COMPTEL Description

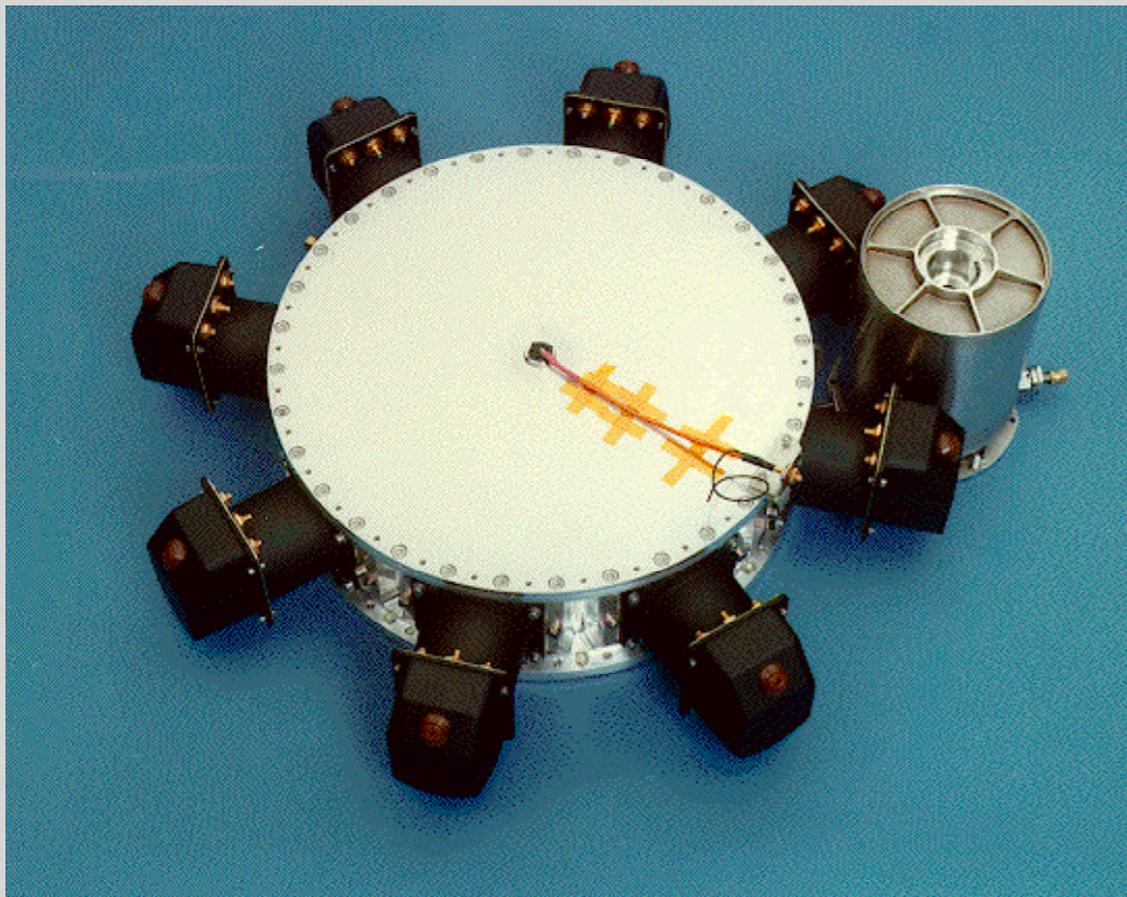
Event locations provide a direction vector for the scattered photon.

Energy deposits provide an estimate of the photon scatter angle.

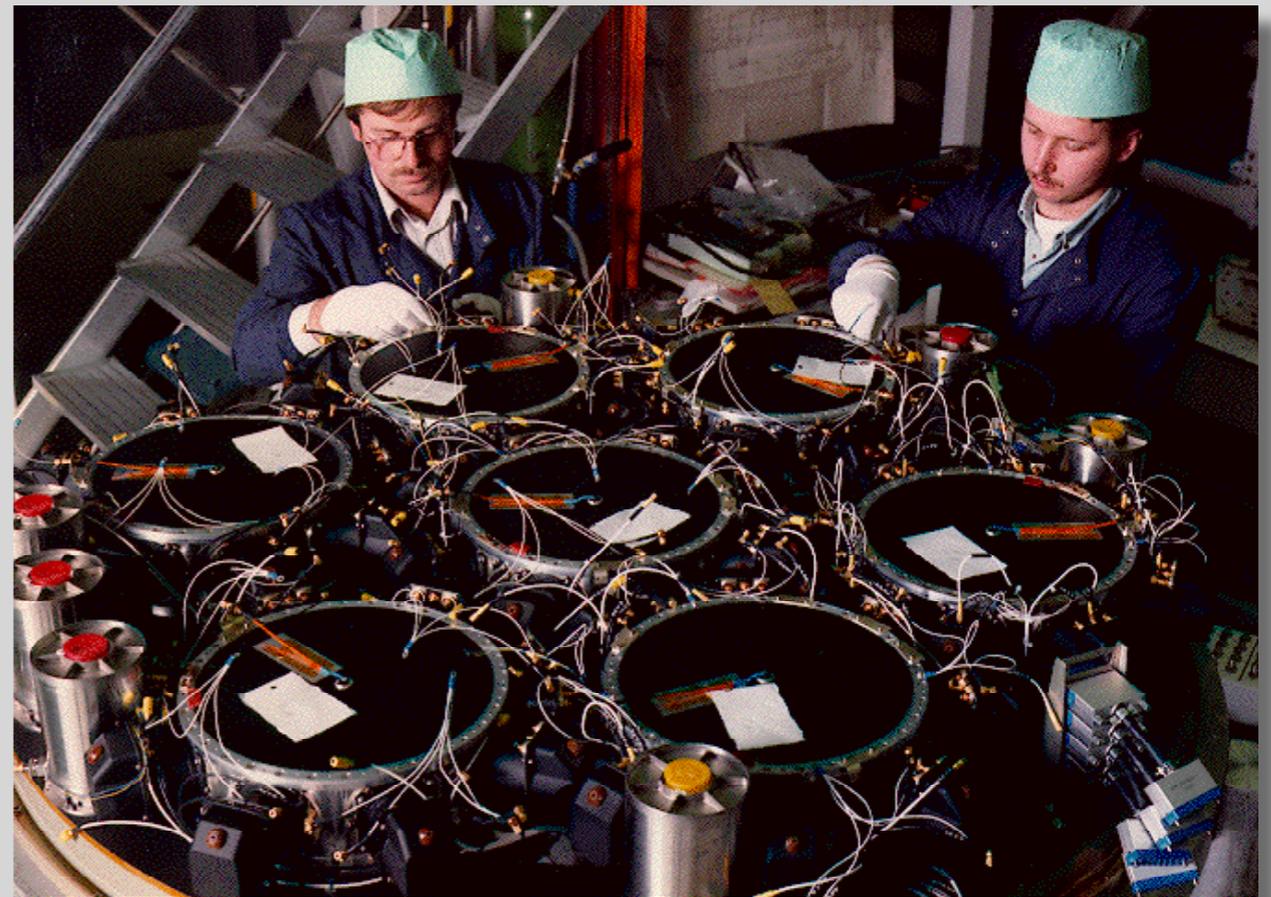


COMPTEL D1 Detectors

Each of the 7 D1 detectors consisted of a cylindrical volume of NE213A liquid scintillator, 28 cm in diameter by 8.5 cm deep. The interaction location of each event could be determined to about 1-2 cm.



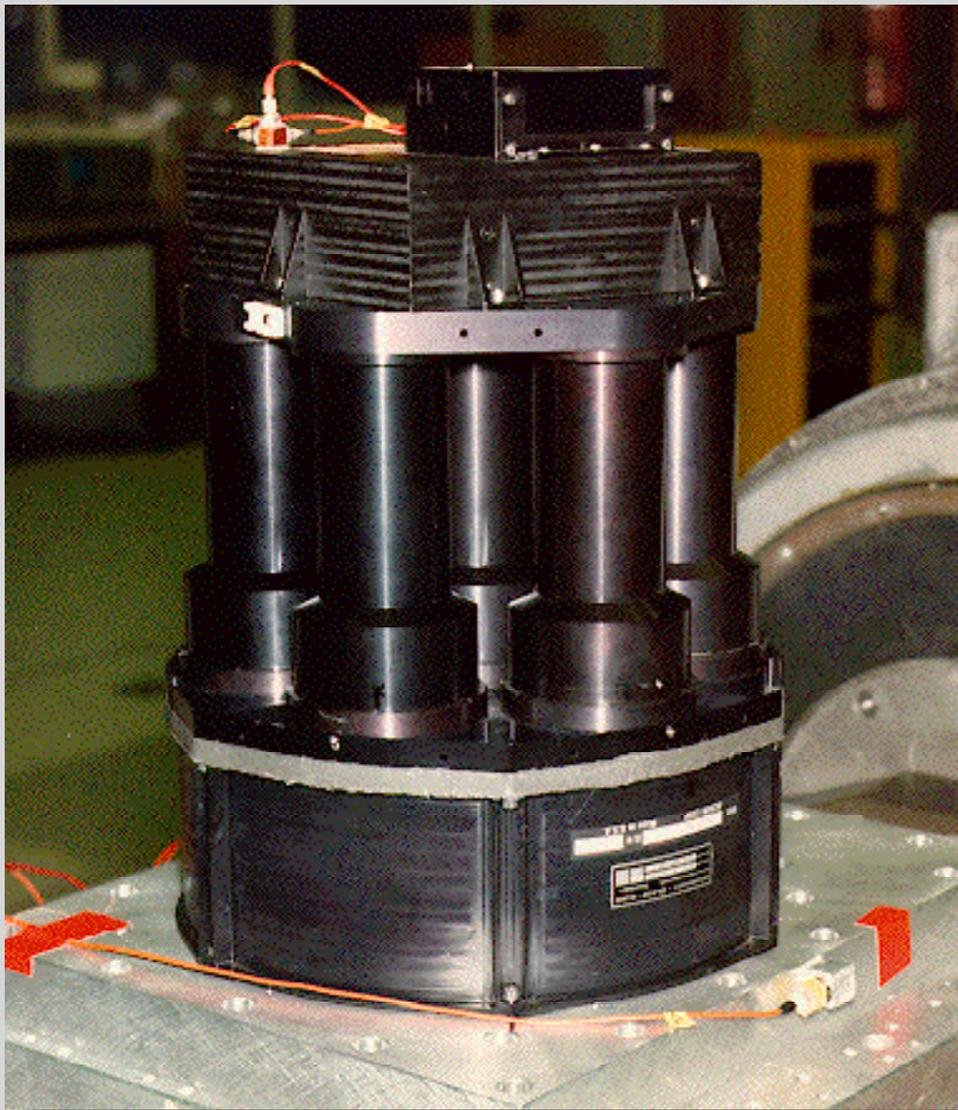
Individual D1 Cell



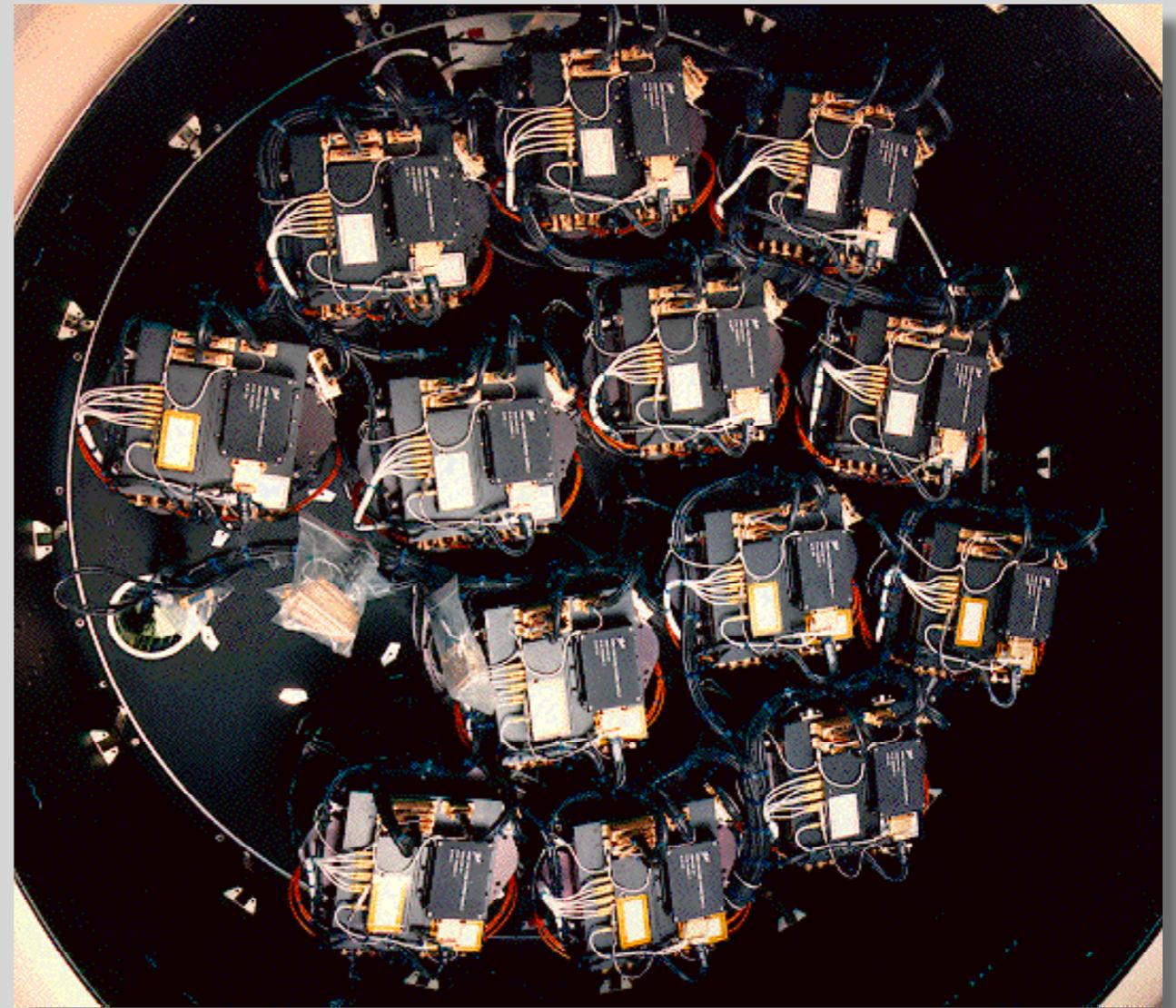
Complete Assembly of 7 D1 Cells

COMPTEL D2 Detectors

Each of the 14 D2 cells consisted of a cylindrical volume of NaI scintillator, 28 cm in diameter and 7.5 cm deep. Event interactions could be located with a spatial resolution of $\sim 1\text{-}2$ cm.

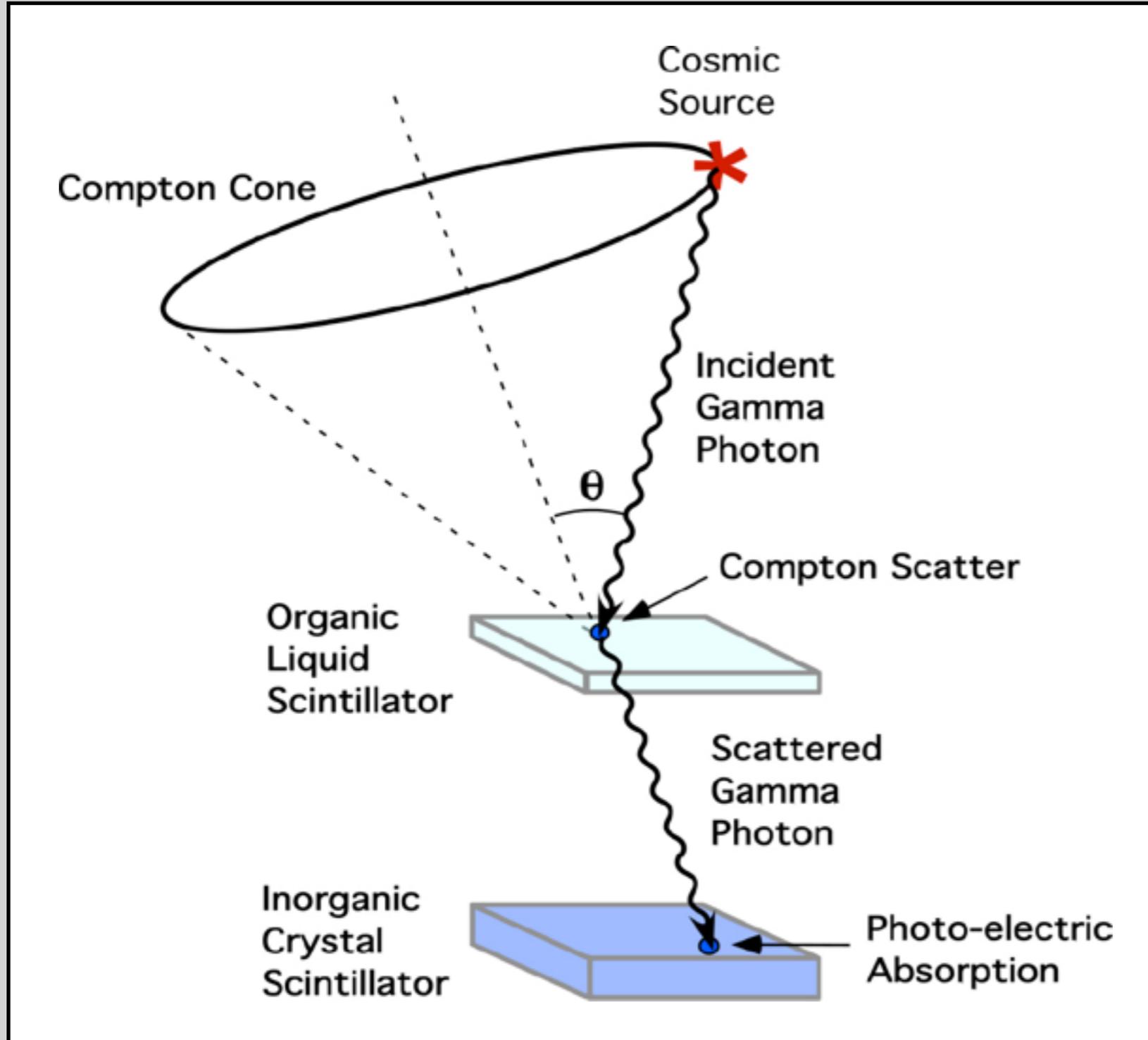


Individual D2 Cell



Nearly Complete Assembly of 14 D2 Cells

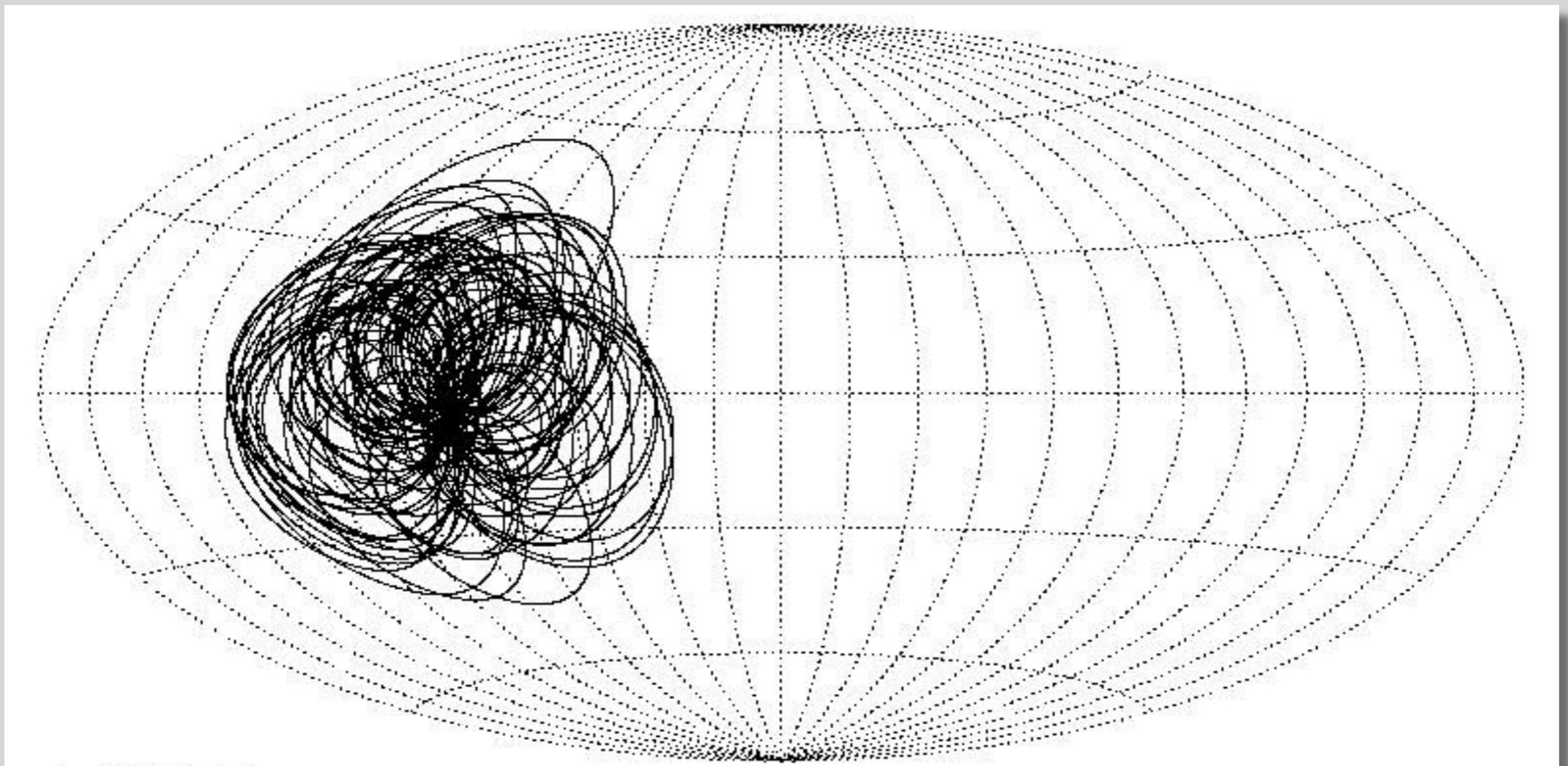
Compton Imaging



Without knowledge of the Compton scattered electron, the direction of the incident photon is determined to lie on an circle.

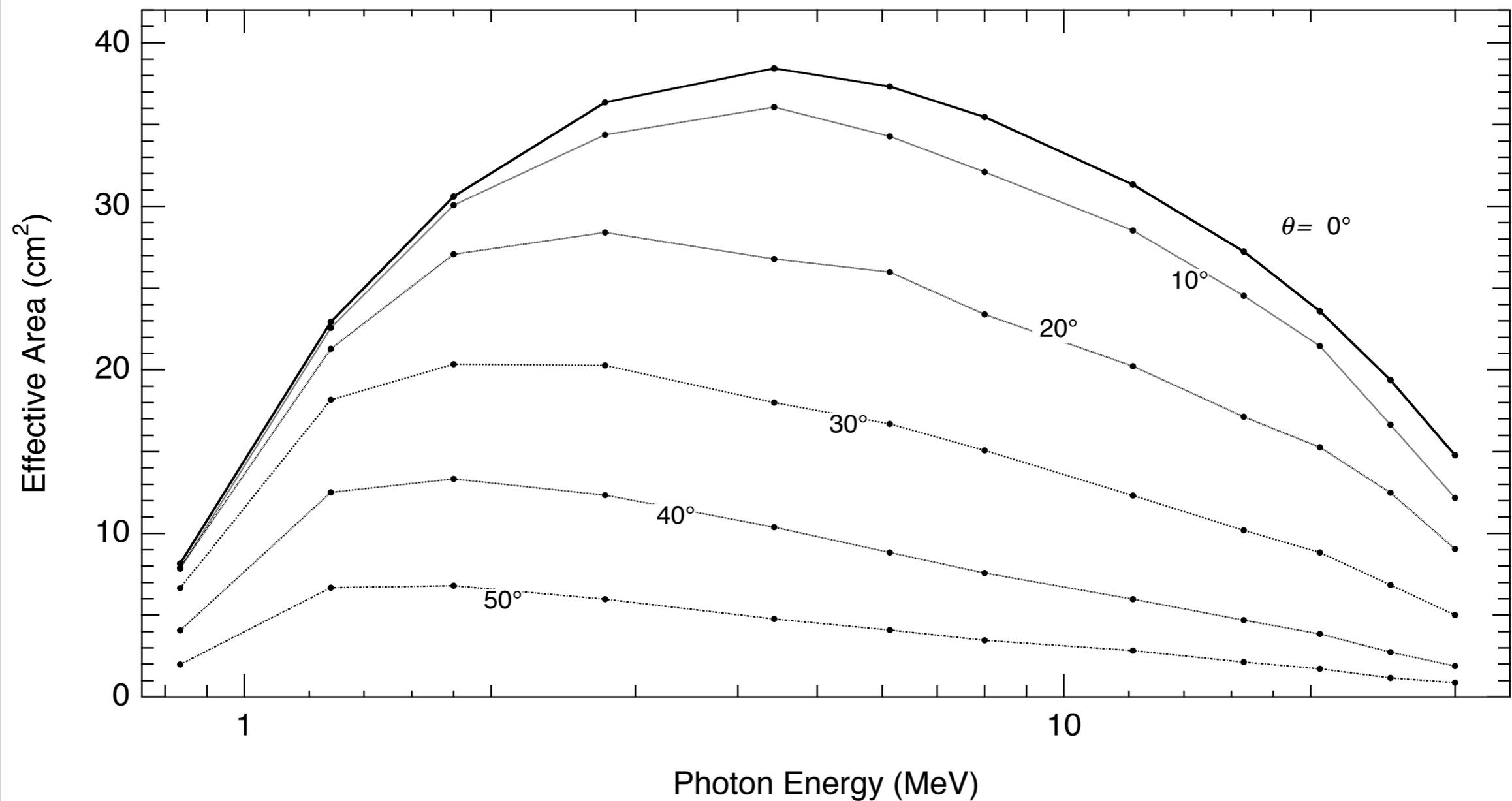
Event Circle Imaging

Summation of ~ 100 event circles from the gamma-ray burst of 3-May-1991.



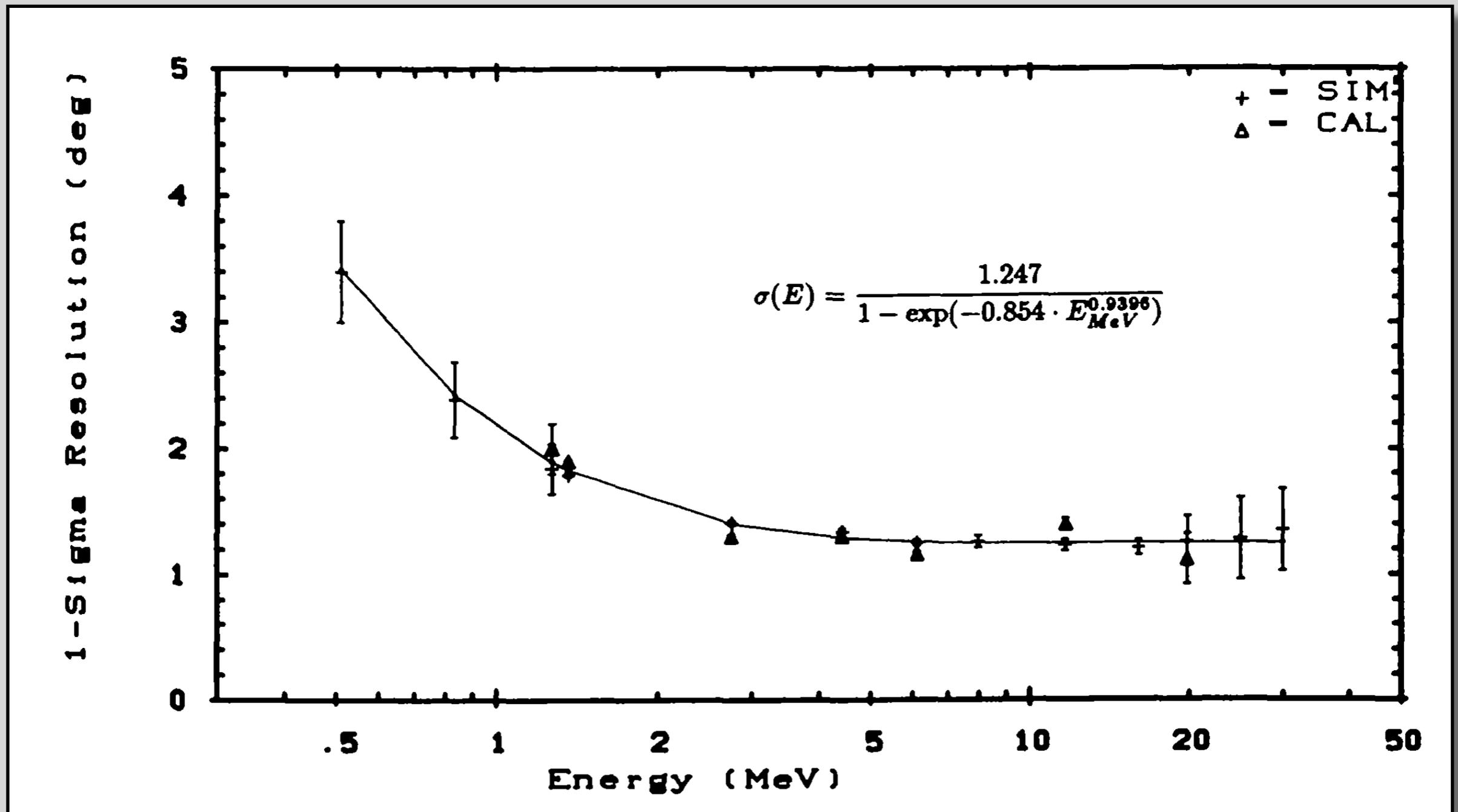
COMPTEL Effective Area

Effective area as a function of photon energy for various incidence angles.

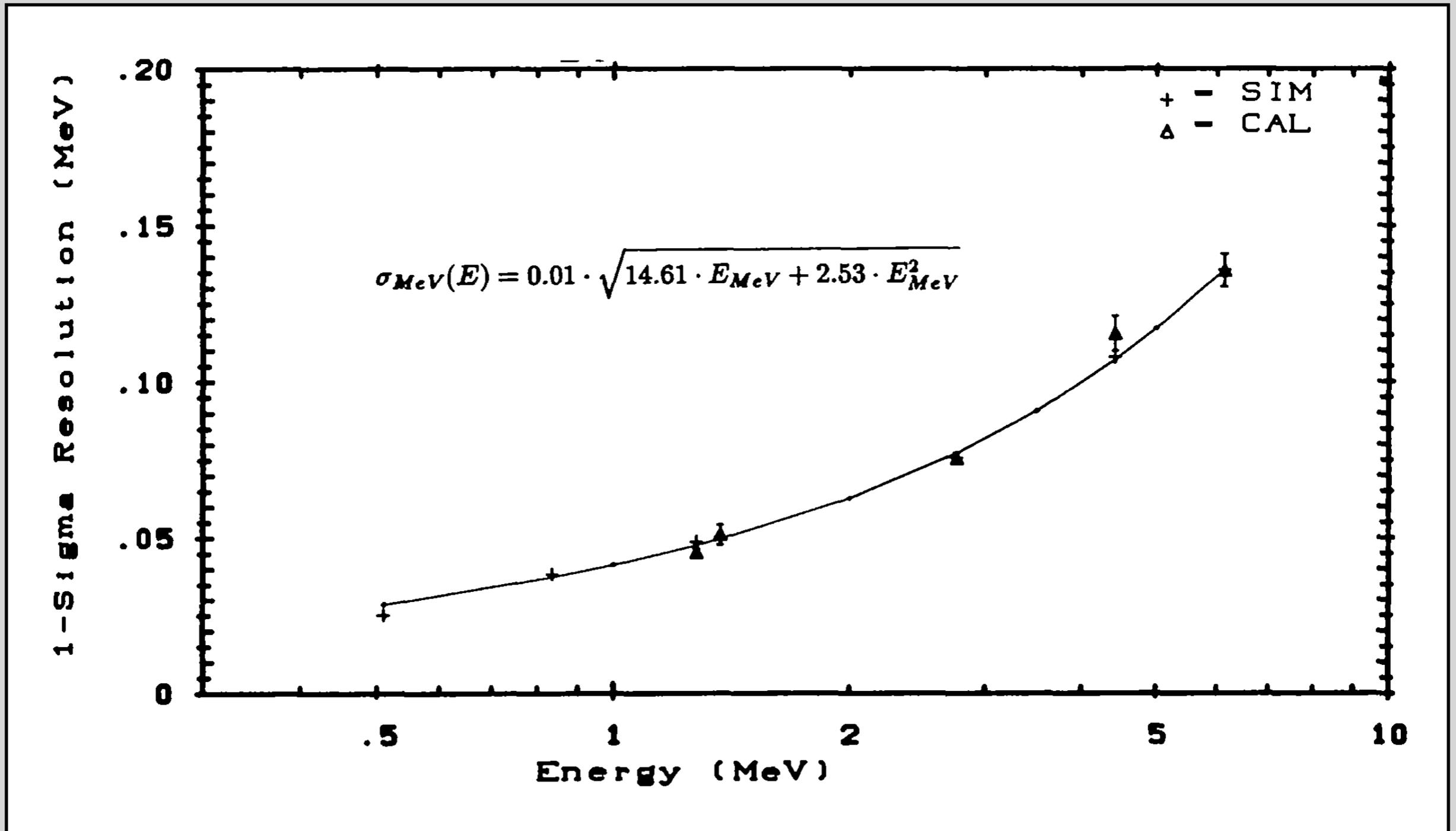


Angular Resolution

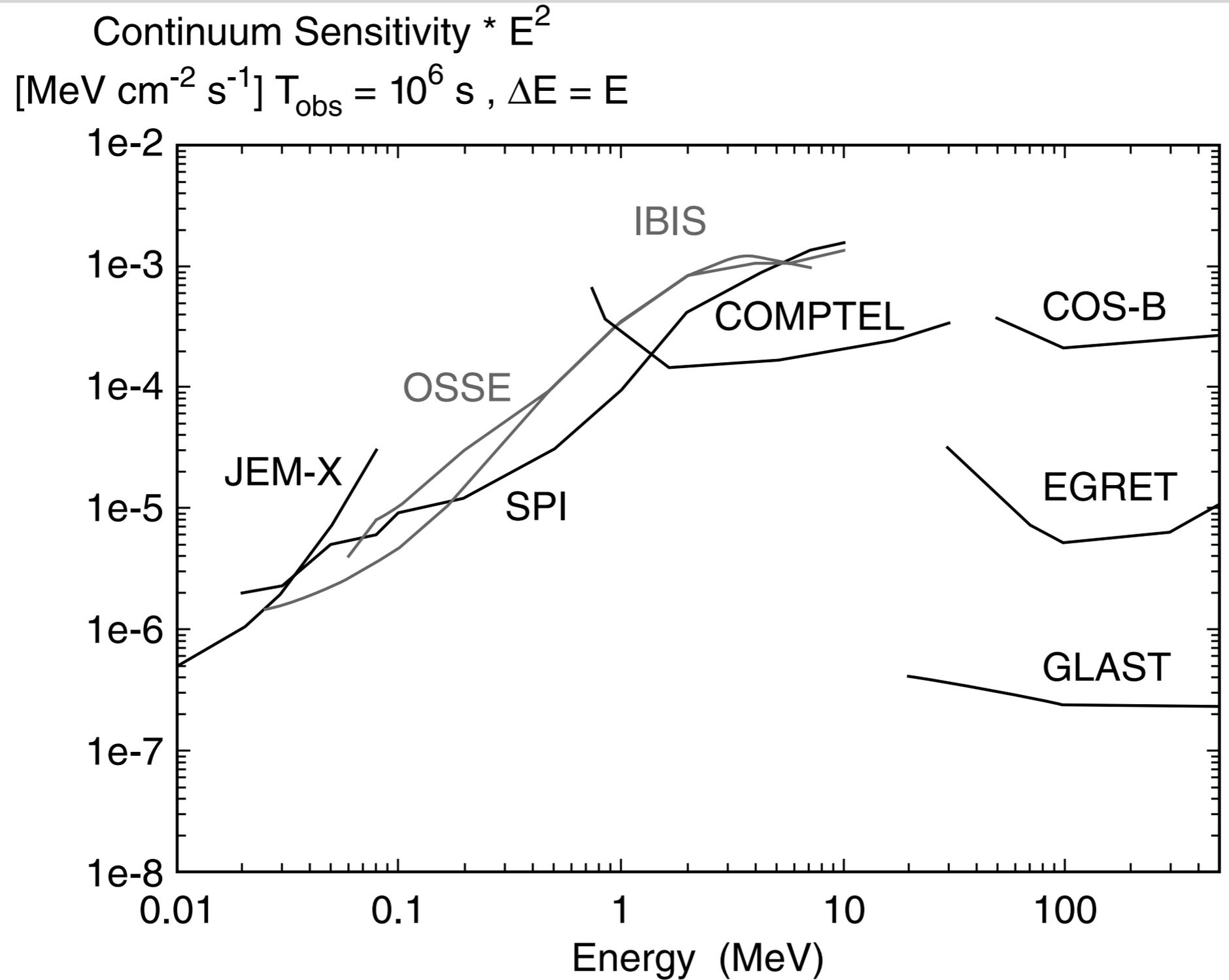
Angular resolution reached $\sim 1.5^\circ$ above 2 MeV.



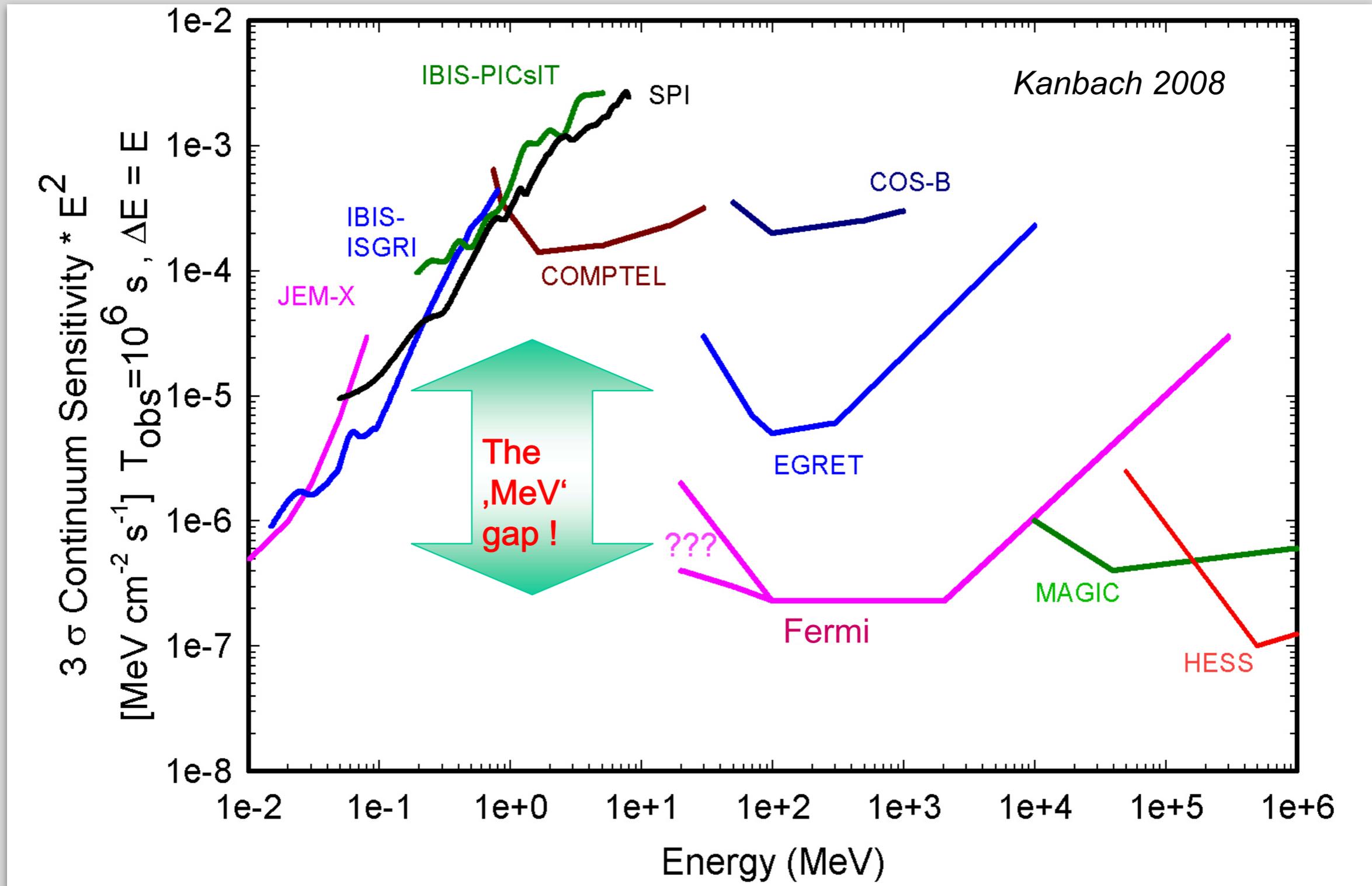
Energy Resolution



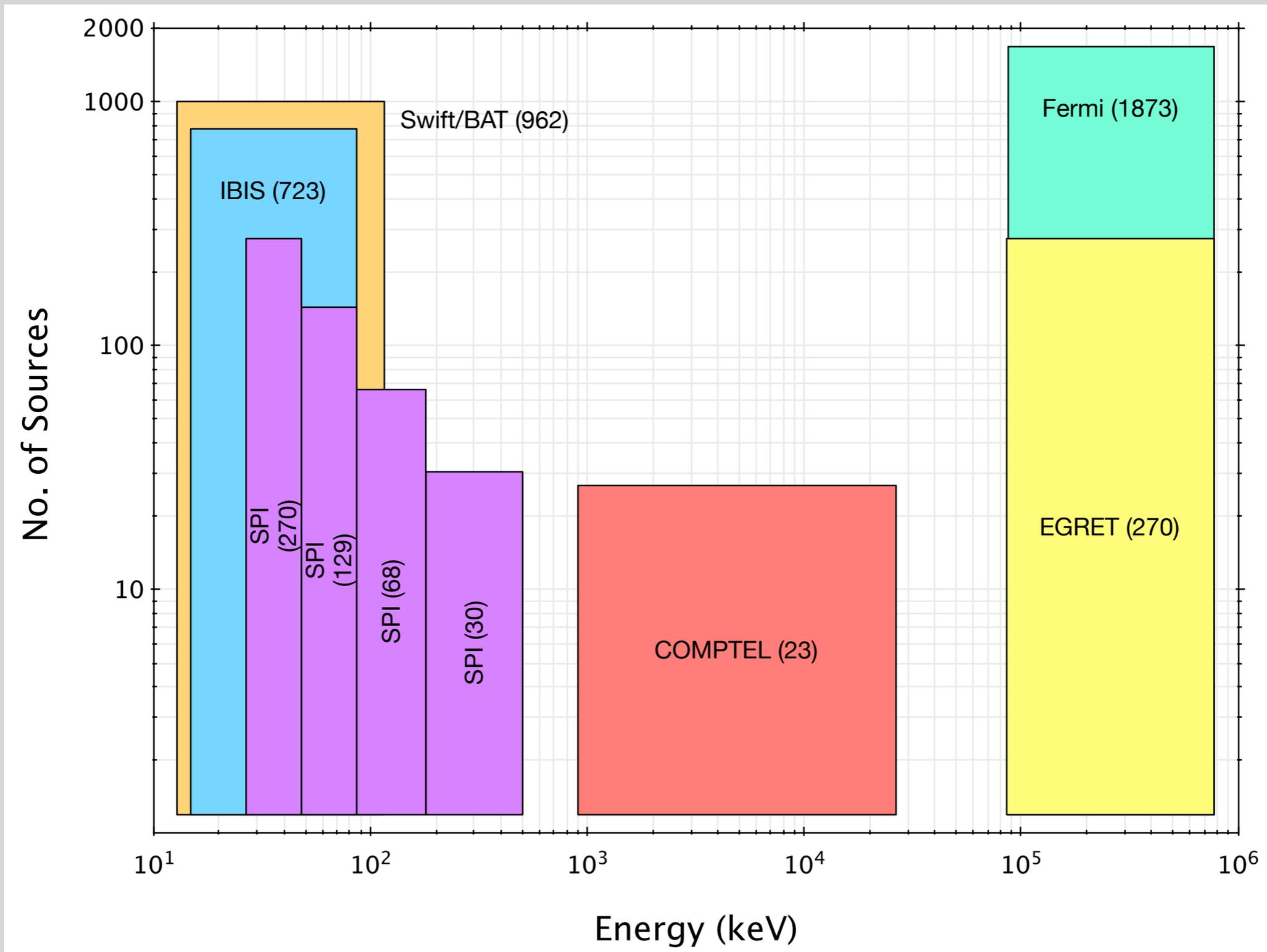
COMPTEL Sensitivity



The "MeV Gap"



Source Counts vs Energy



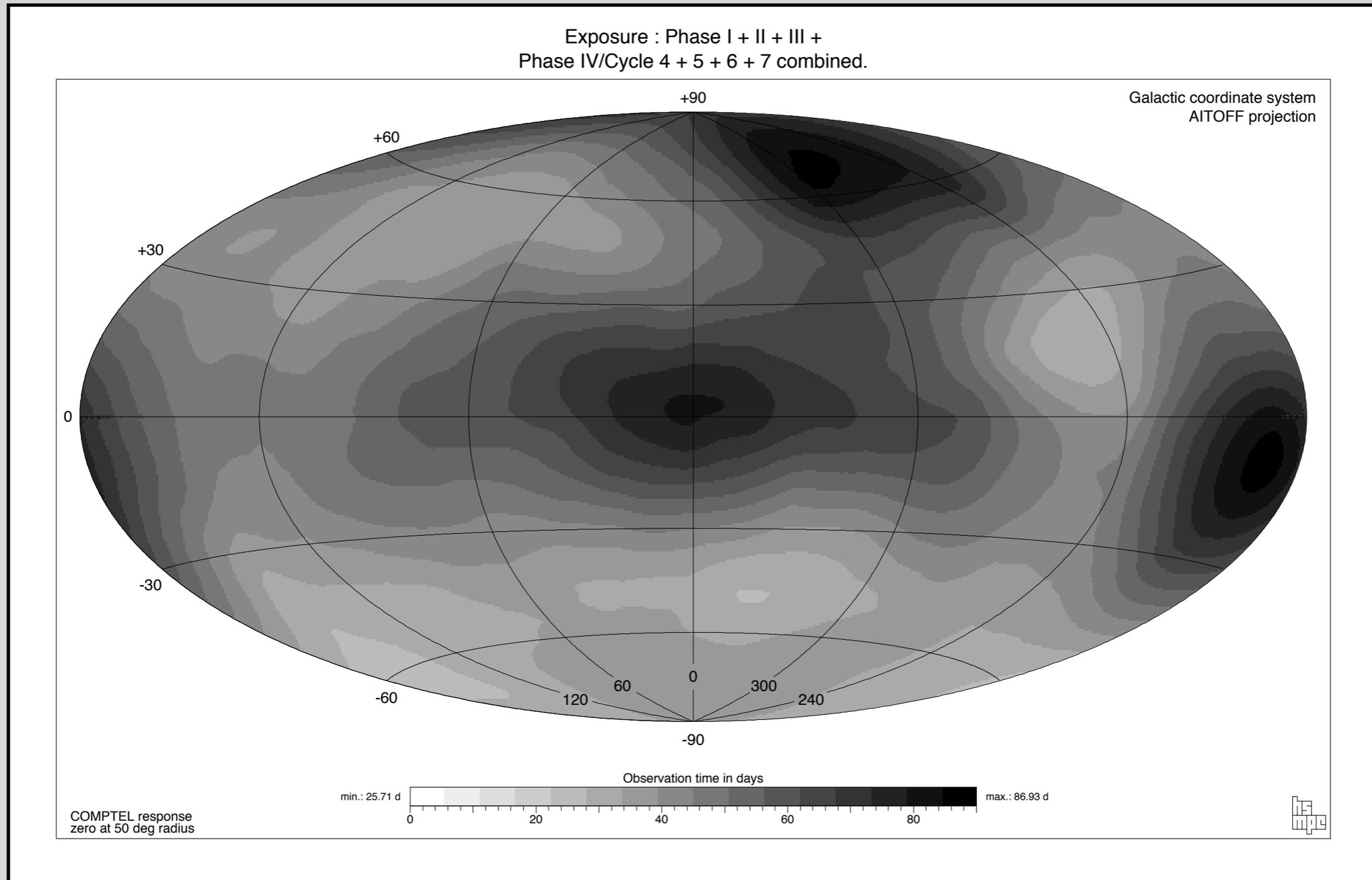
CGRO Mission

Launch on Space Shuttle Atlantis - April 5, 1991.
De-orbited on June 4, 2000.



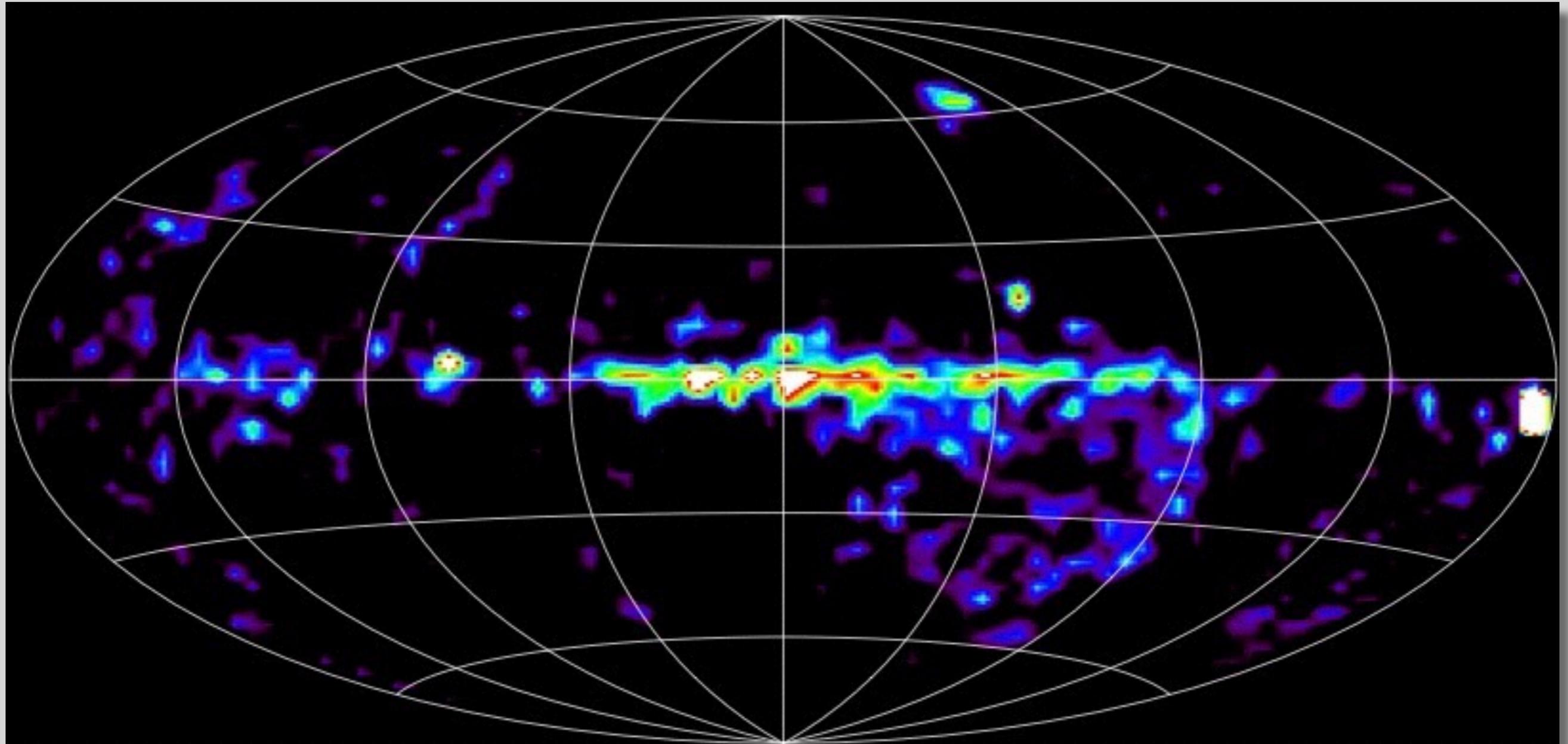
Sky Exposure

1991-1998



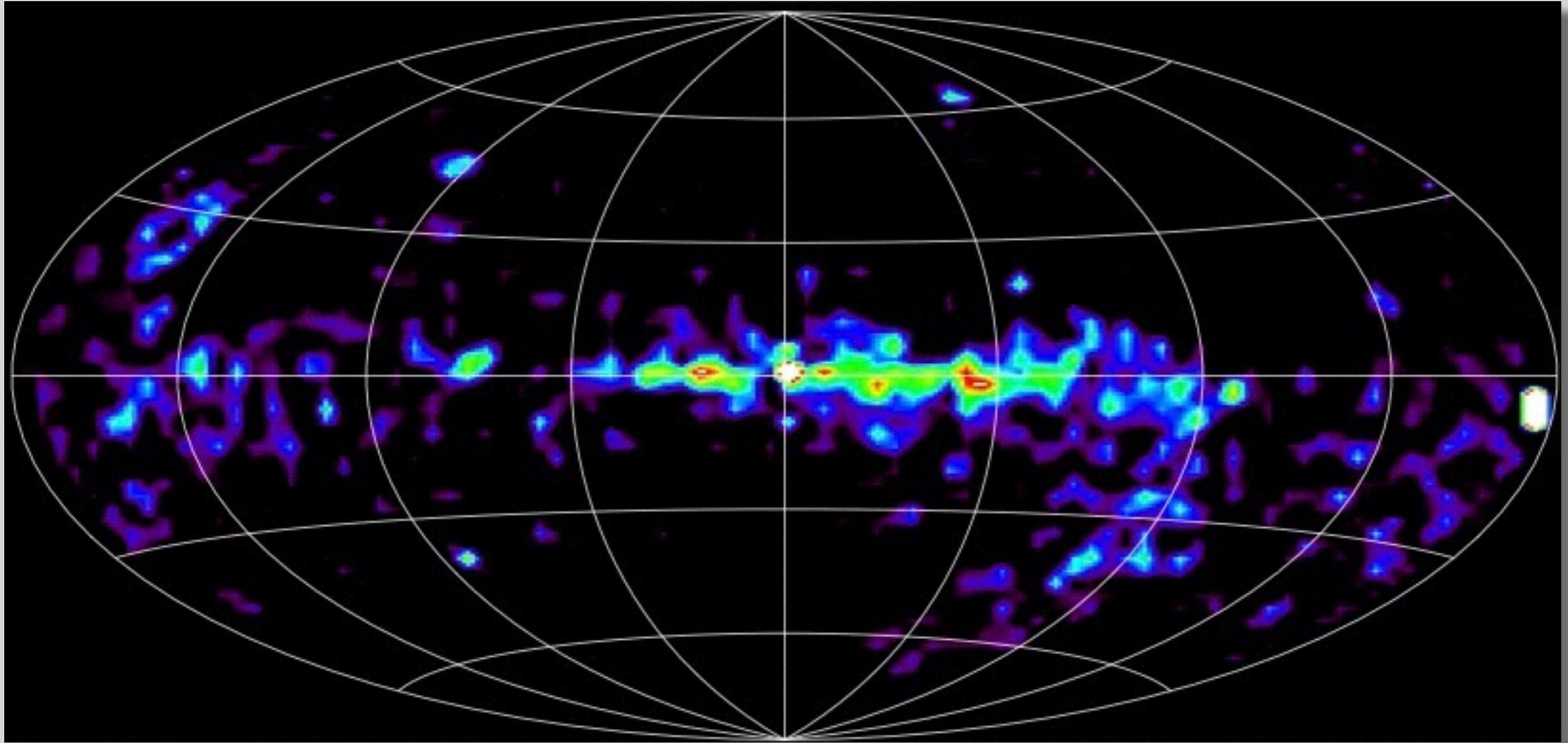
Schönfelder et al. 2000

All-Sky Map, 1-3 MeV



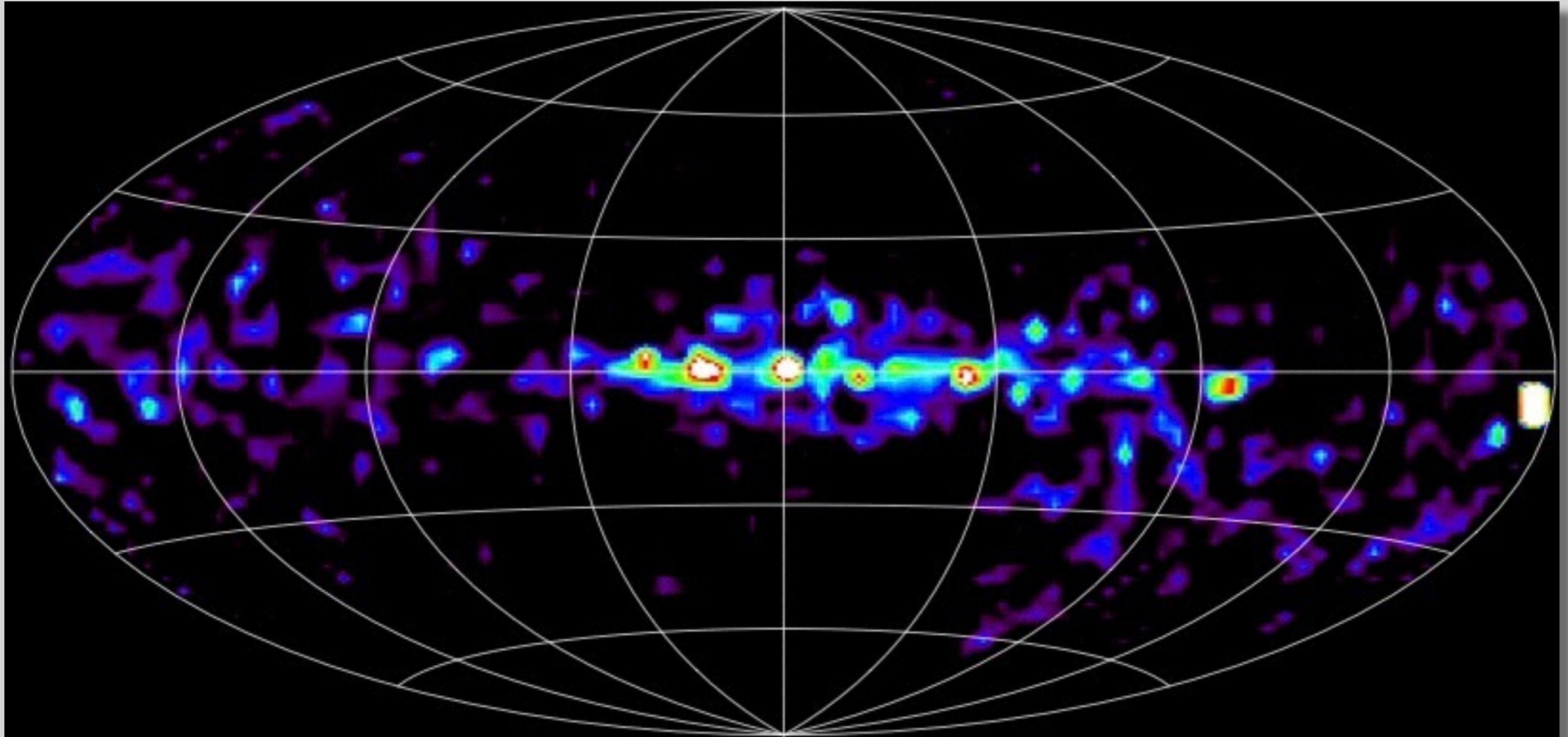
1991-1997

All-Sky Map, 3-10 MeV



1991-1997

All-Sky Map, 10-30 MeV



1991-1997

COMPTEL Point Sources

Schönfelder et al. 2000

Source Type	In Catalog	> 3 sigma	> 5 sigma
Pulsars	7	4	2
AGN	10	9	3
Galactic $b < 10^\circ$	5	5	3
$b > 10^\circ$	3	3	2
Line Sources	3	3	1
<i>TOTAL</i>	<i>28</i>	<i>24</i>	<i>13</i>

Pulsars

A total of seven pulsars were included in the COMPTEL source catalog (Schönfelder et al. 2000).

PSR B1951+32

Crab

Geminga

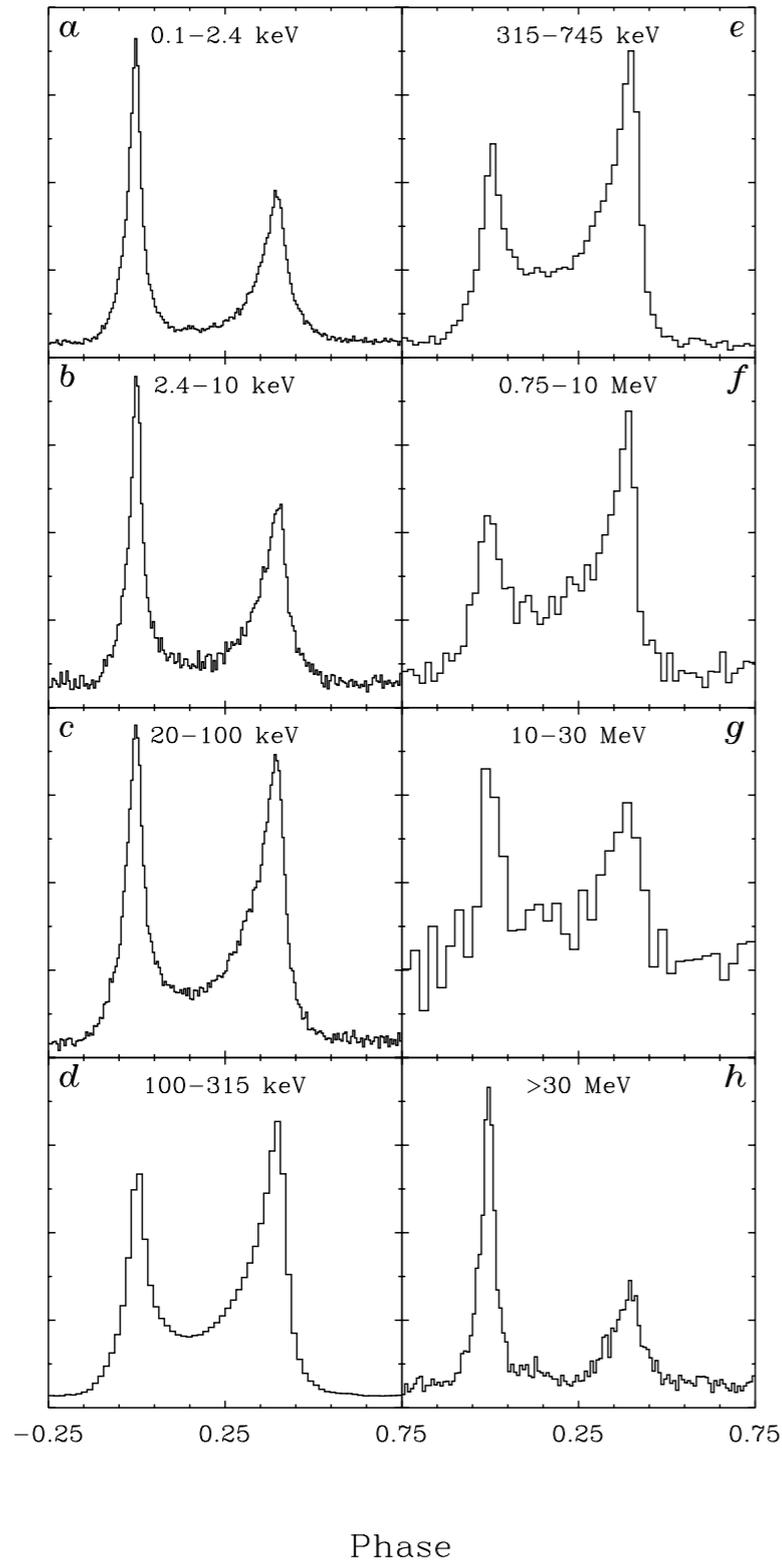
PSR B0656+14

Vela

PSR B1055-52

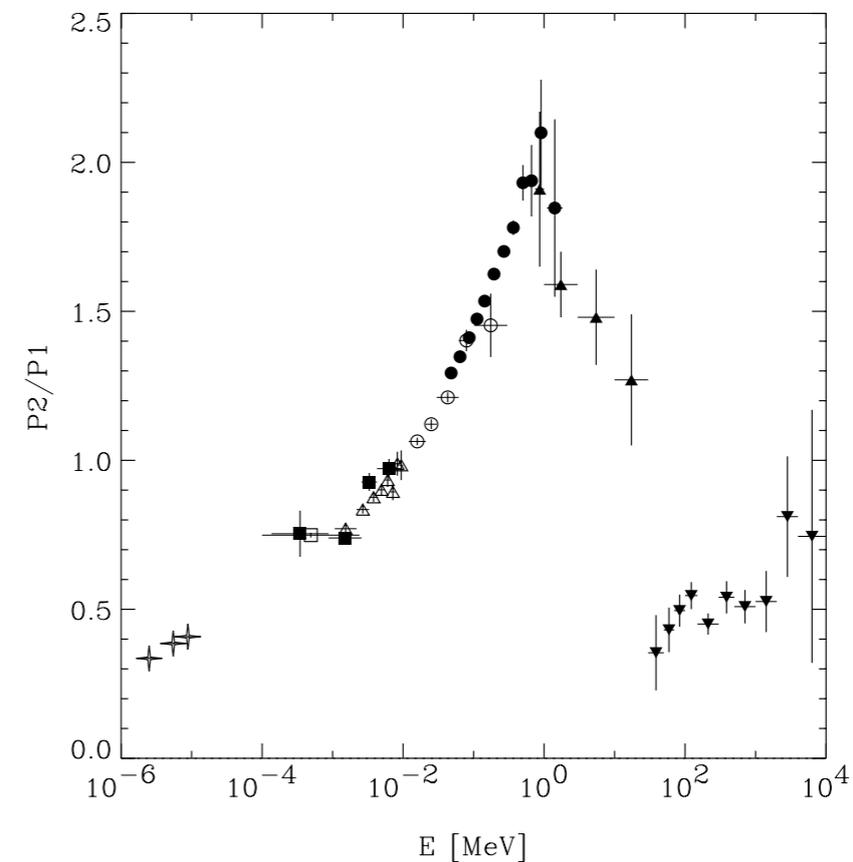
PSR B1509-58

Crab Pulsar Pulse Shape



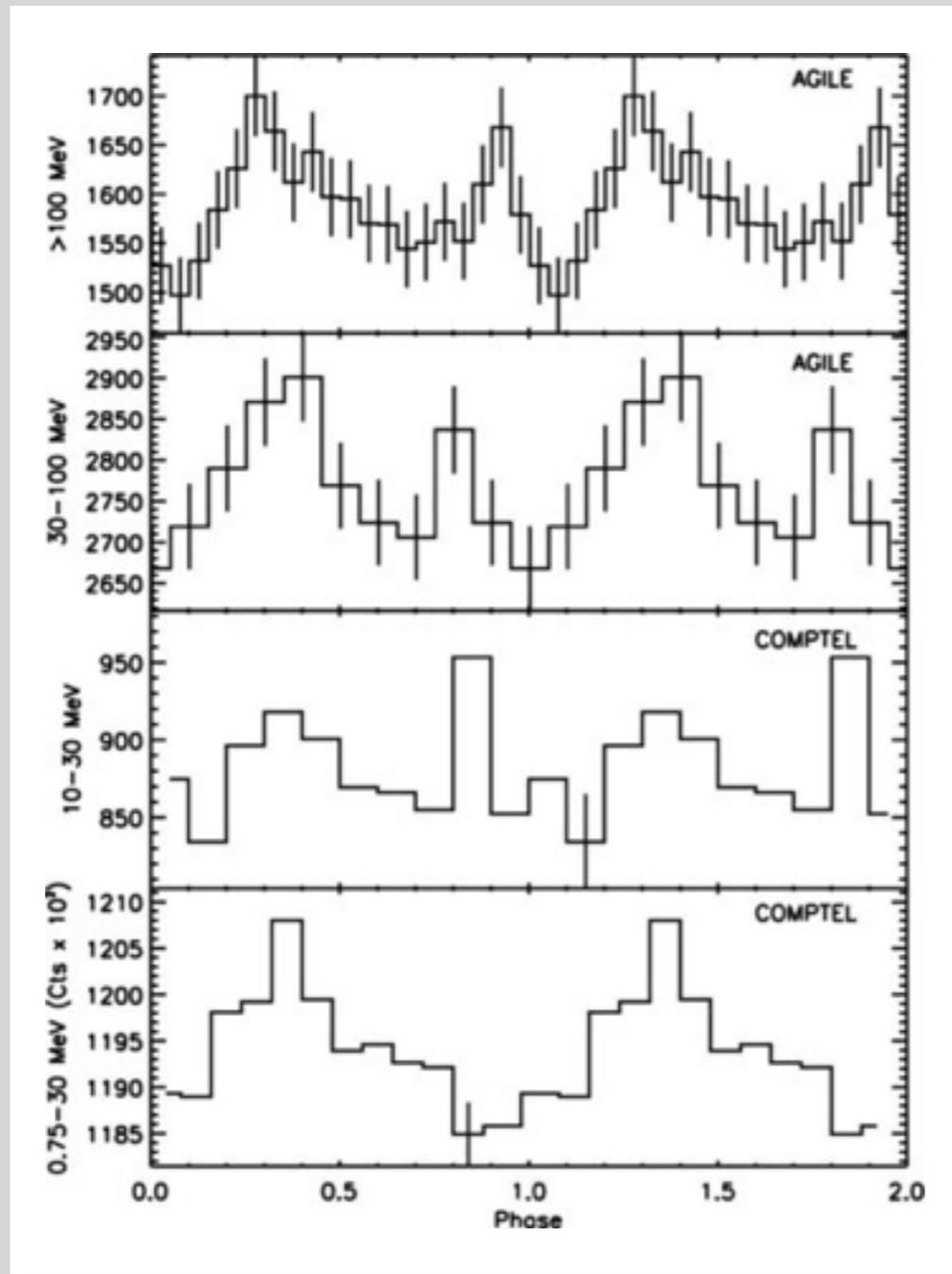
The pulse shape varies dramatically in the COMPTEL energy range, with a rapid change in the P2/P1 ratio.

(Kuiper et al. 2001)



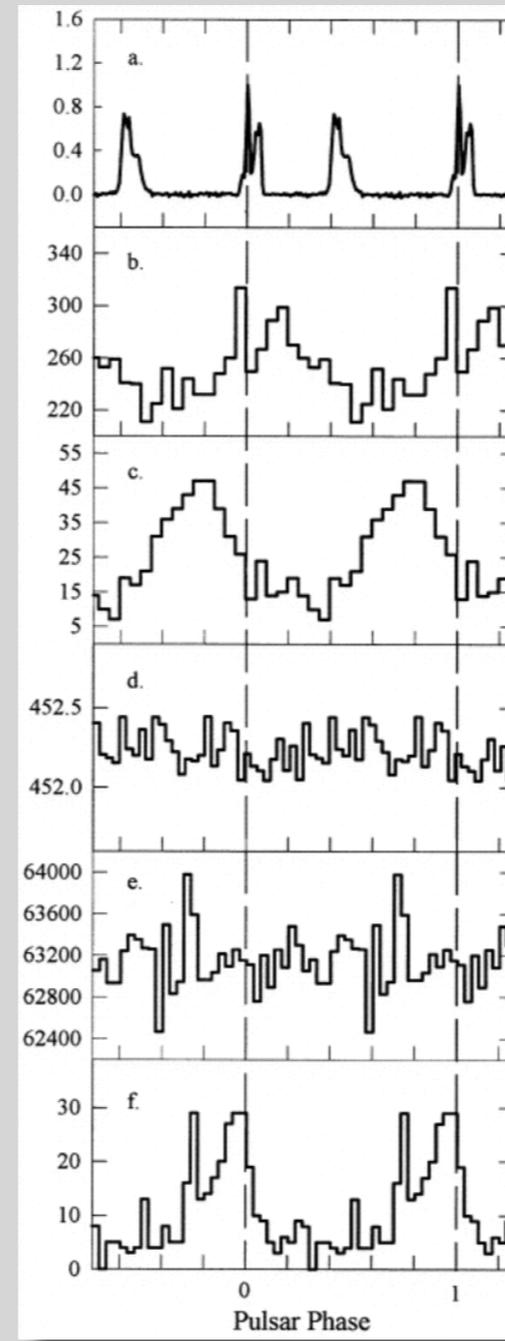
Pulse Shape Changes

PSR B1509-58



Pilia et al. 2010

PSR B1055-52



Radio 1520 MHz

ROSAT <0.5 keV

ROSAT >0.5 keV

OSSE 48-184 keV

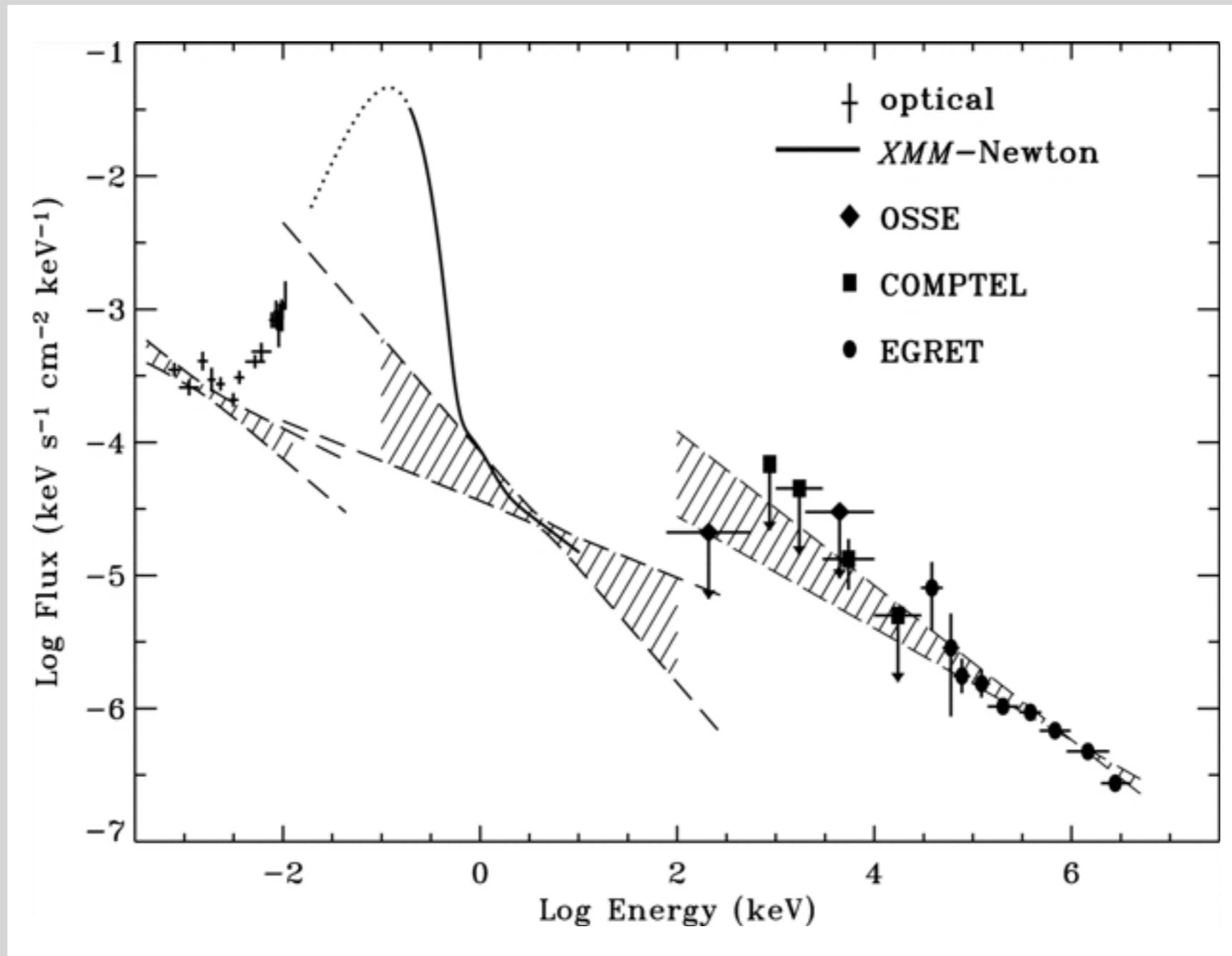
COMPTEL 0.75-30 MeV

EGRET >240 MeV

Thompson et al. 1999

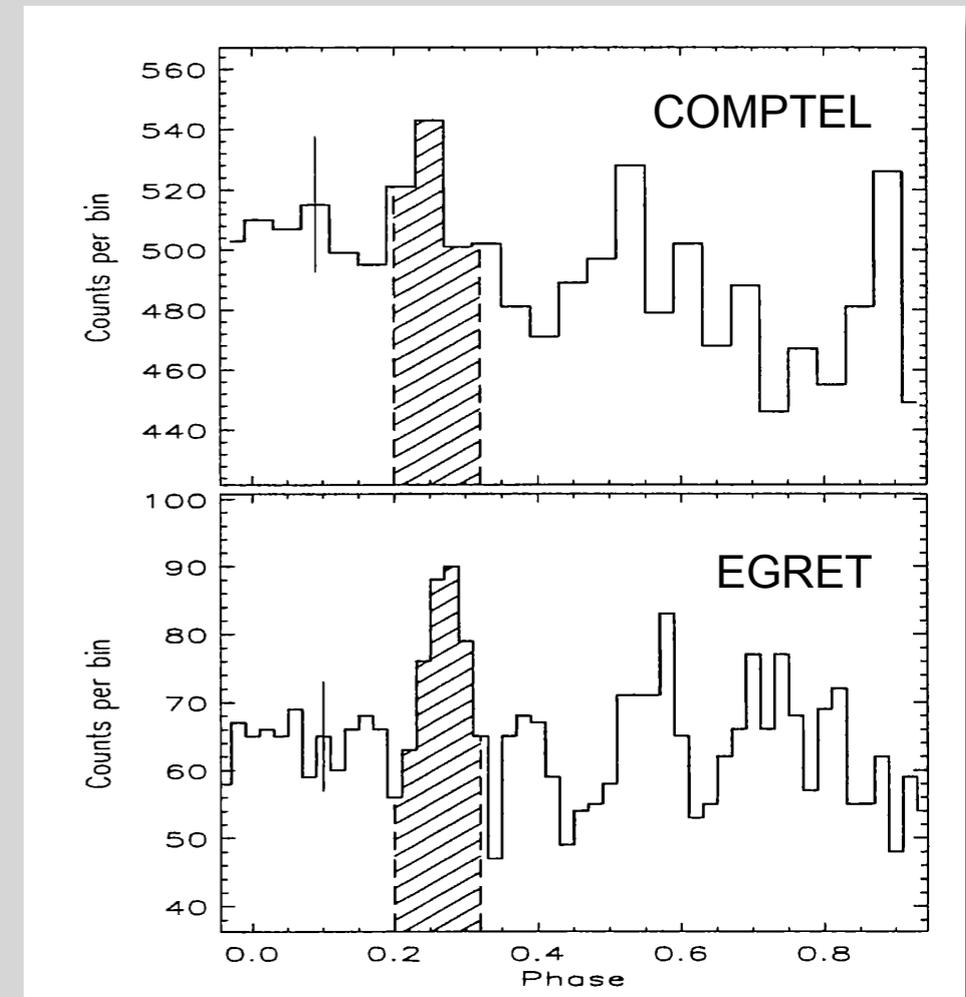
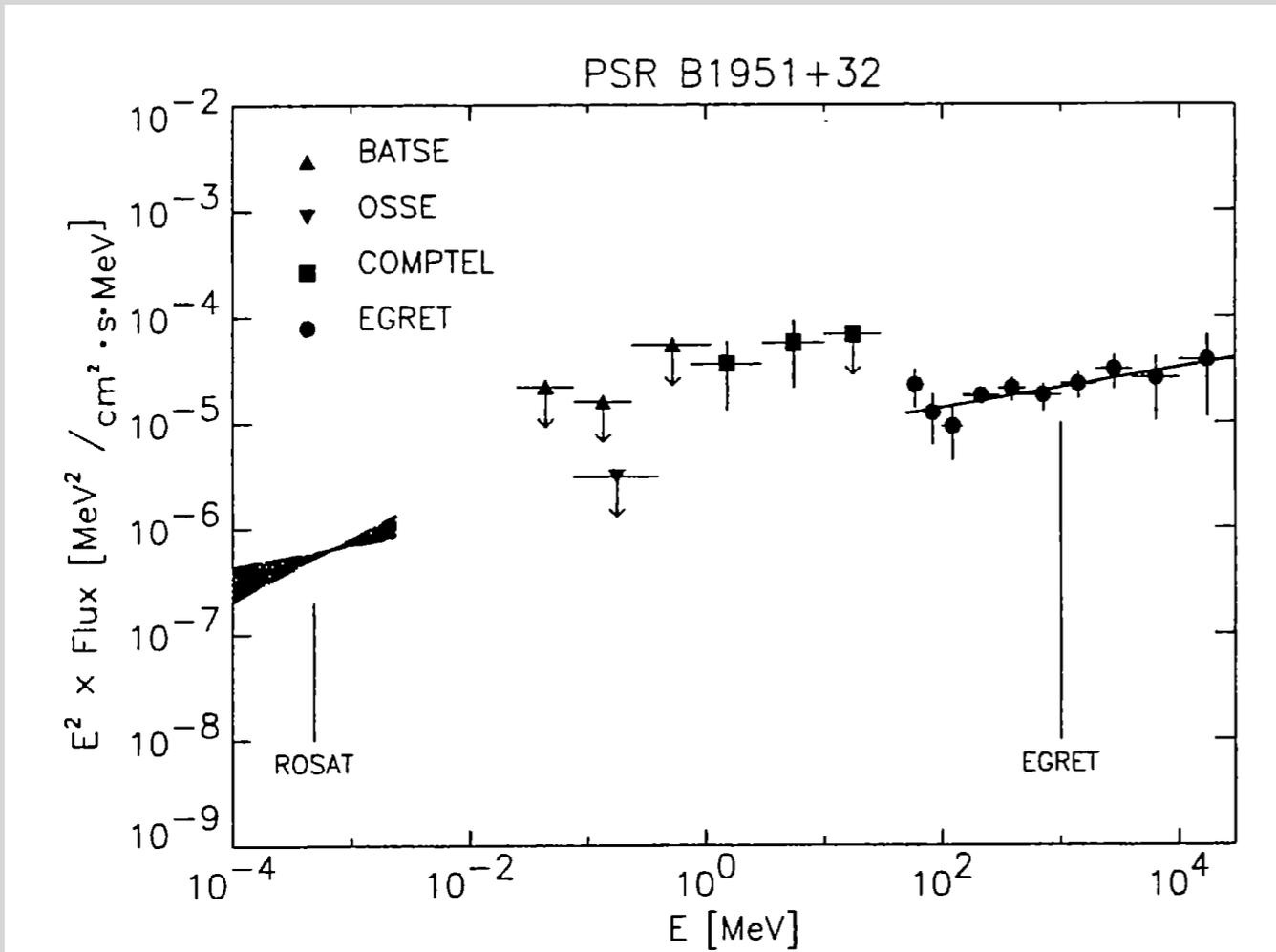
Geminga

The spectrum changes dramatically in the COMPTEL energy range, but how?



PSR B1951+32

(Hermsen et al. 1997)



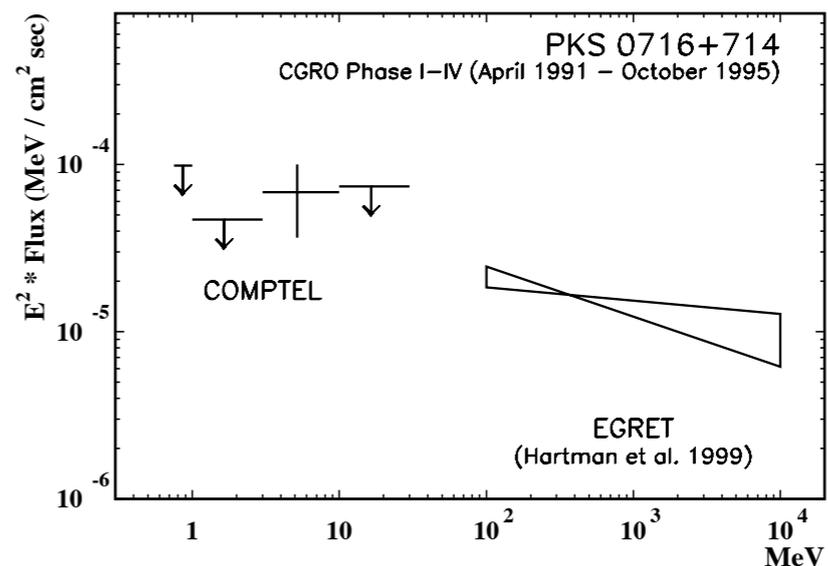
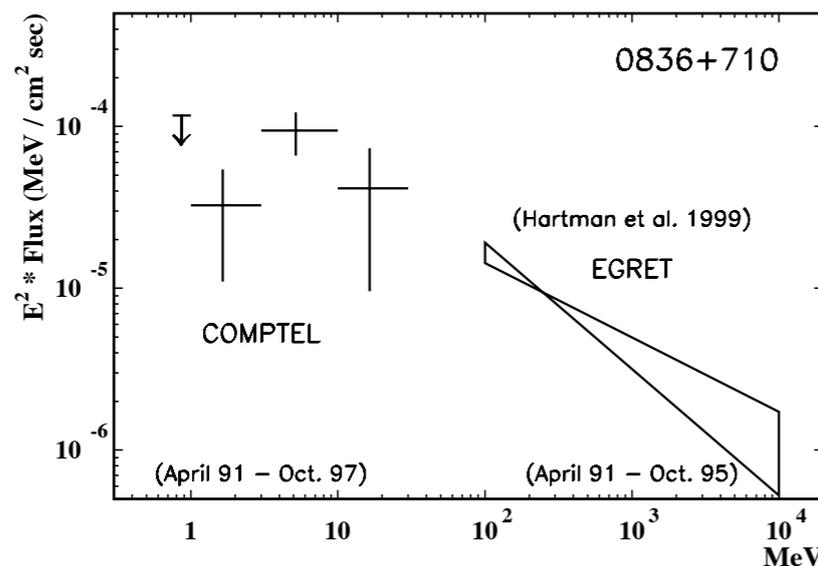
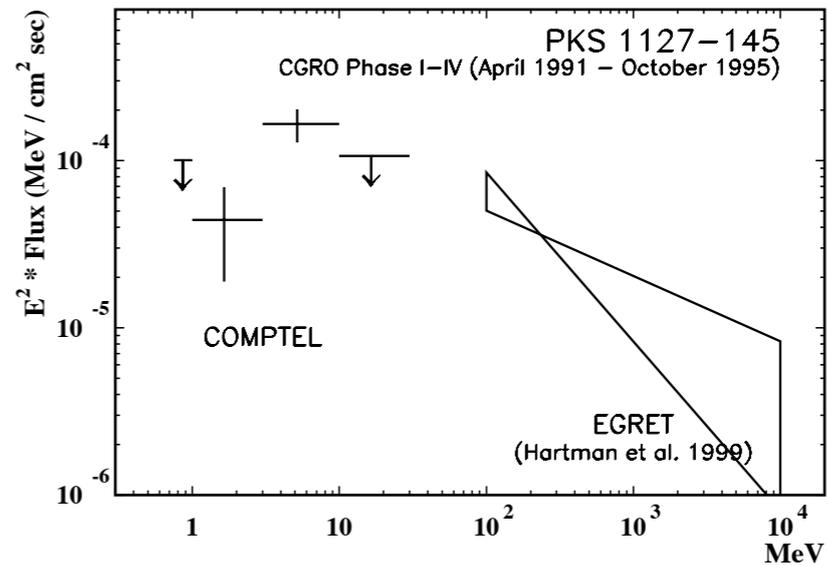
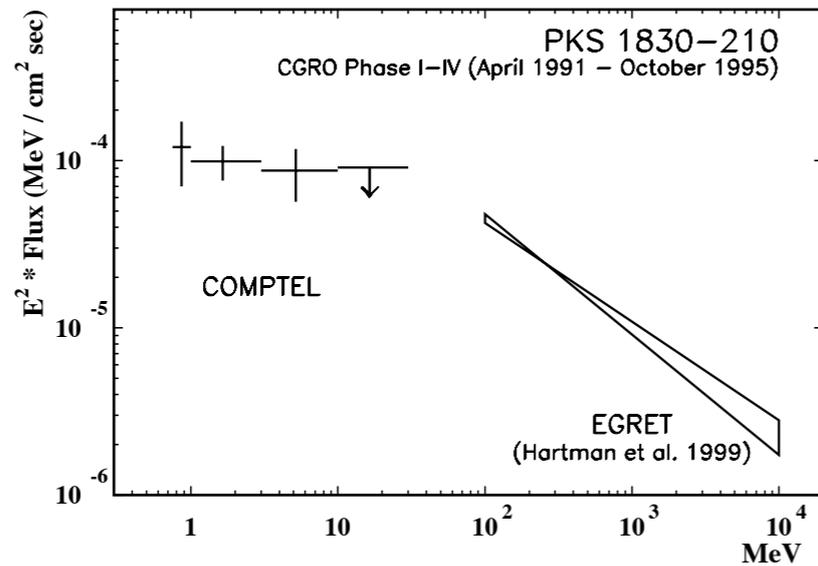
AGN Detections

Collmar (2006)

Source	Redshift	AGN Type	Significance
Cen A	0.0007	radio galaxy	high
Mkn 421	0.031	BL Lac object	low
3C 273	0.158	quasar	high
PKS 1222+216	0.435	quasar	medium
3C 279	0.538	quasar	high
PKS 1622-297	0.815	quasar	high
3C 454.3	0.859	quasar	high
PKS 0208-512	1.003	quasar	high
CTA 102	1.037	quasar	low
GRO J0516-609	1.09	quasar	medium
PKS 1127-145	1.187	quasar	medium
PKS 0528+134	2.06	quasar	high
PKS 0716+714	?	BL Lac object	low
0836+710	2.17	quasar	medium
PKS 1830-210	2.06	quasar	medium

MeV Blazars

Many AGN detections, when compared with higher energy data, appear to peak in the COMPTEL energy band.



Other Galactic Sources

Galactic Sources at $|b| < 10^\circ$

GRO J1823-12

Cyg X-1

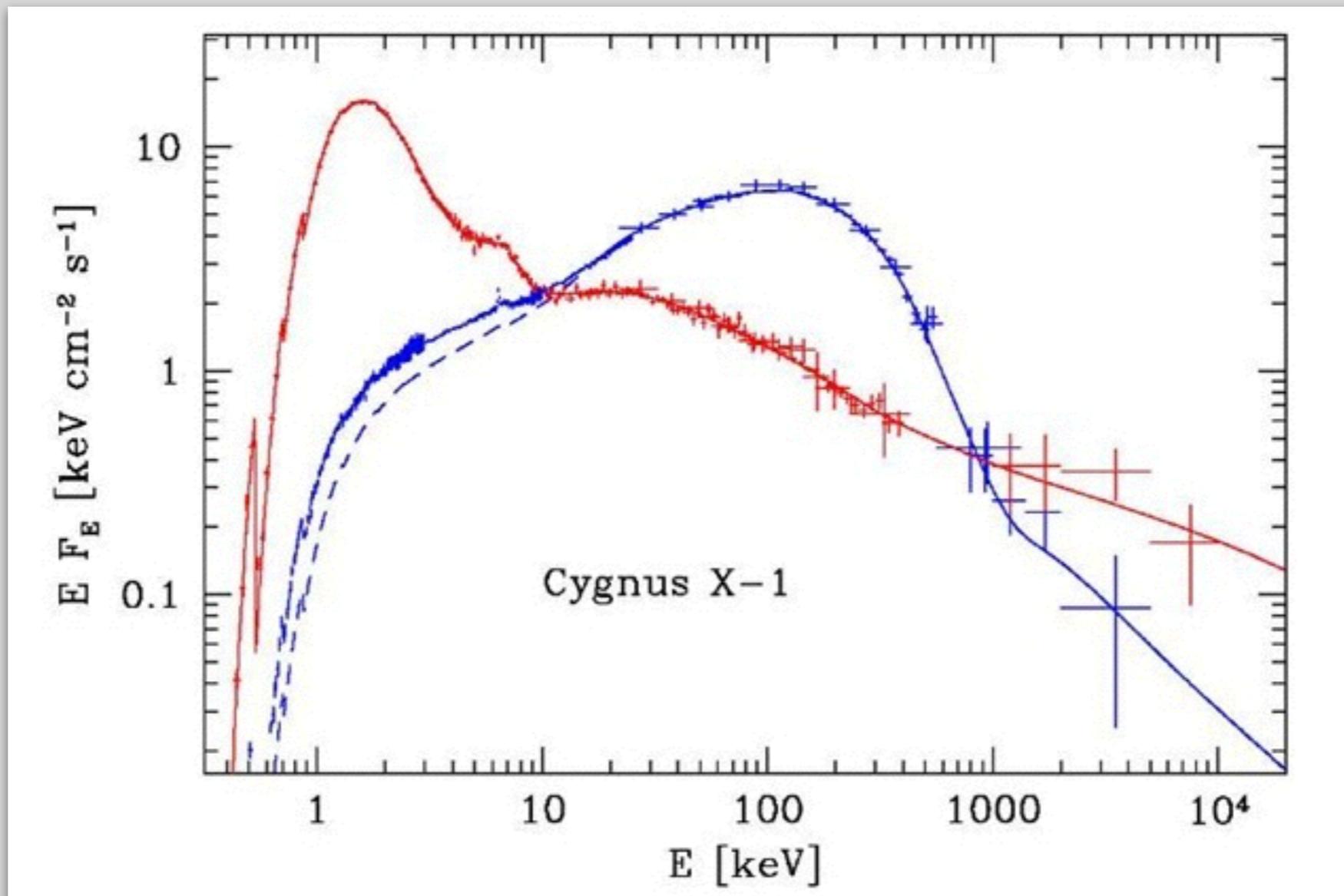
GRO J1227+61

GT 0236+610 (LSI +61 303)

GRO J0422+32

Cygnus X-1

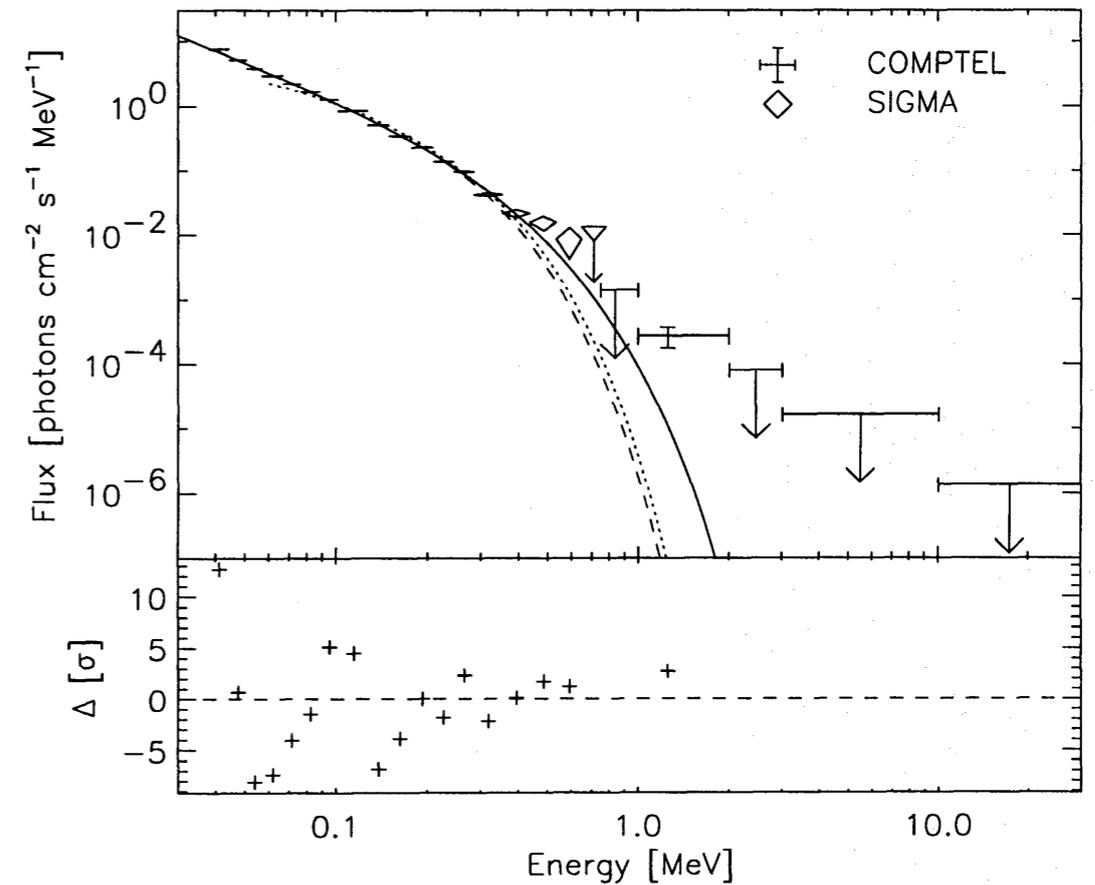
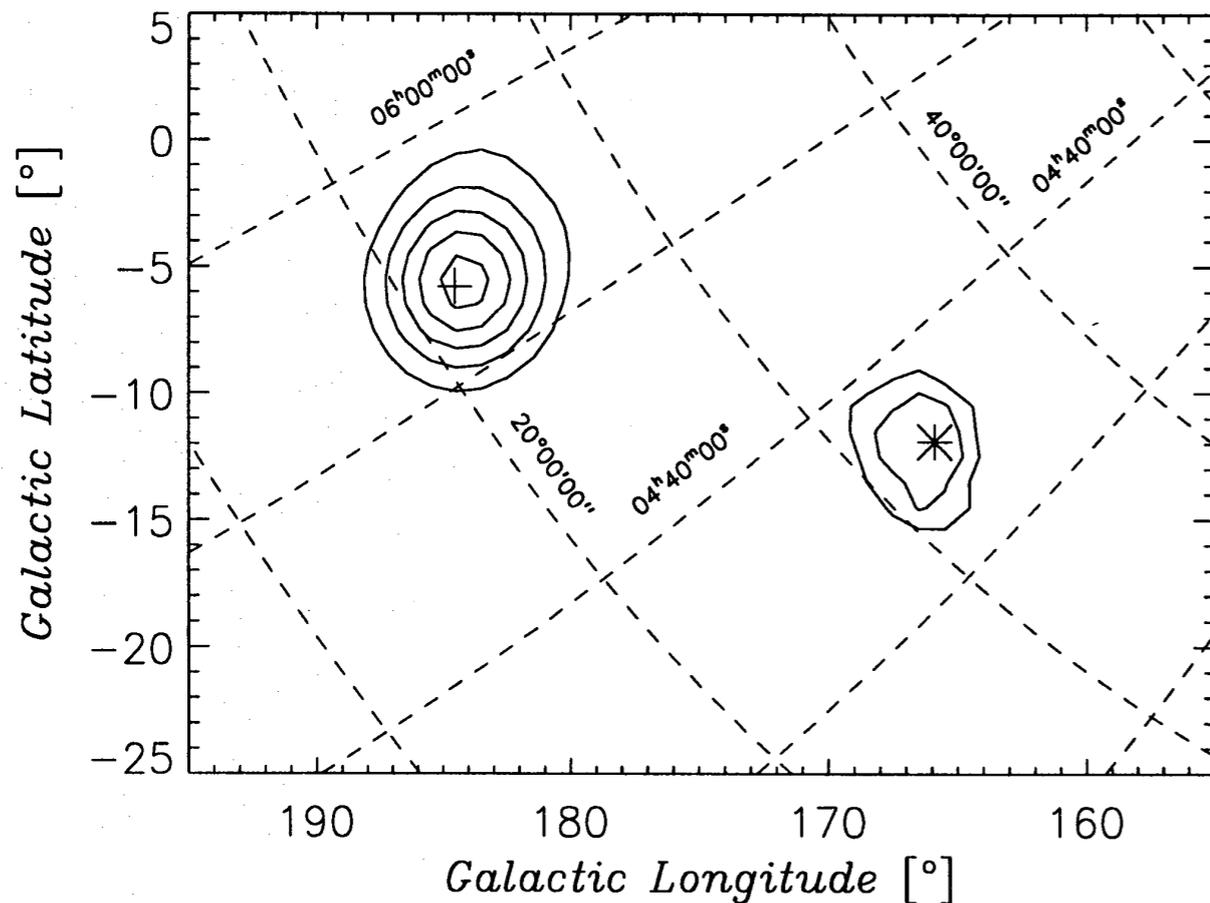
COMPTEL showed that there was a distinct non-thermal component to the spectrum that extended well above 1 MeV.



(McConnell et al. 2002)

GRO J0422+32

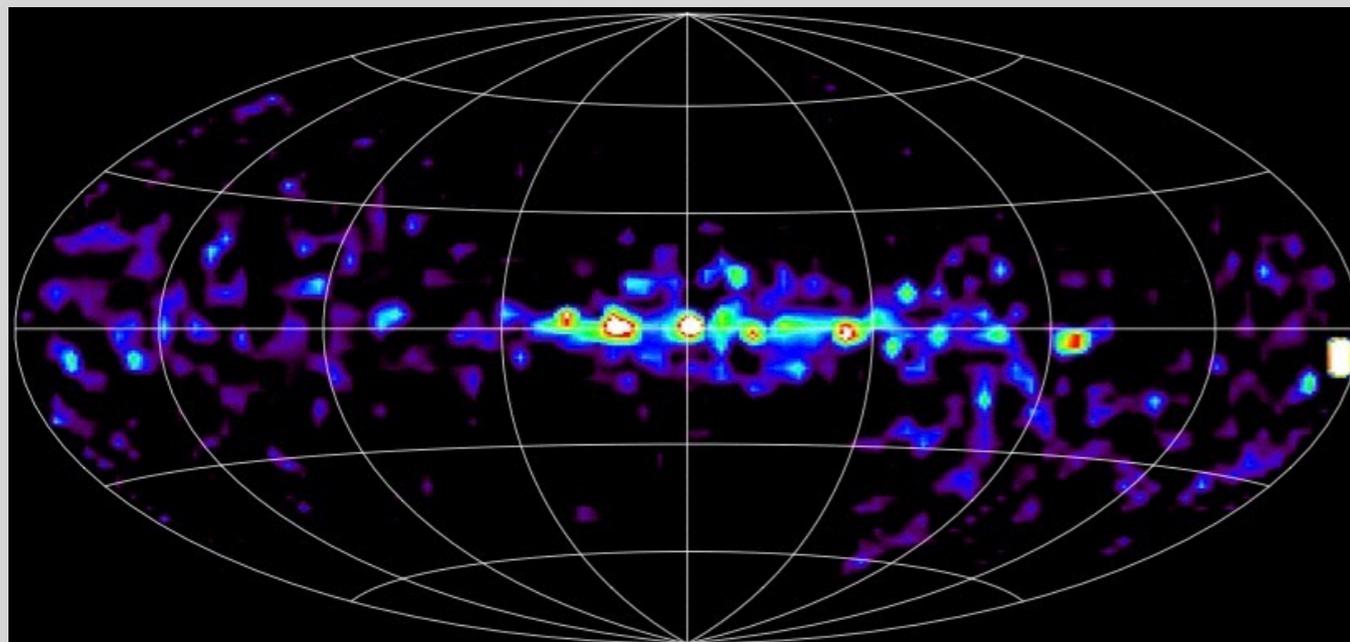
Nova Persei 1992 was briefly detected at 1-2 MeV, suggesting a non-thermal spectrum similar to that of Cyg X-1.



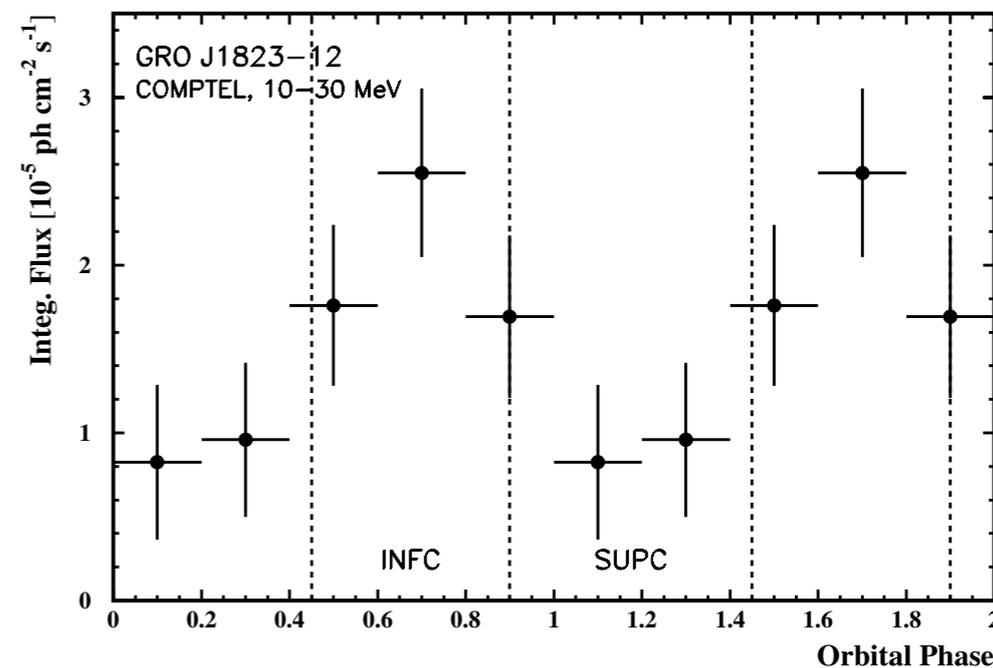
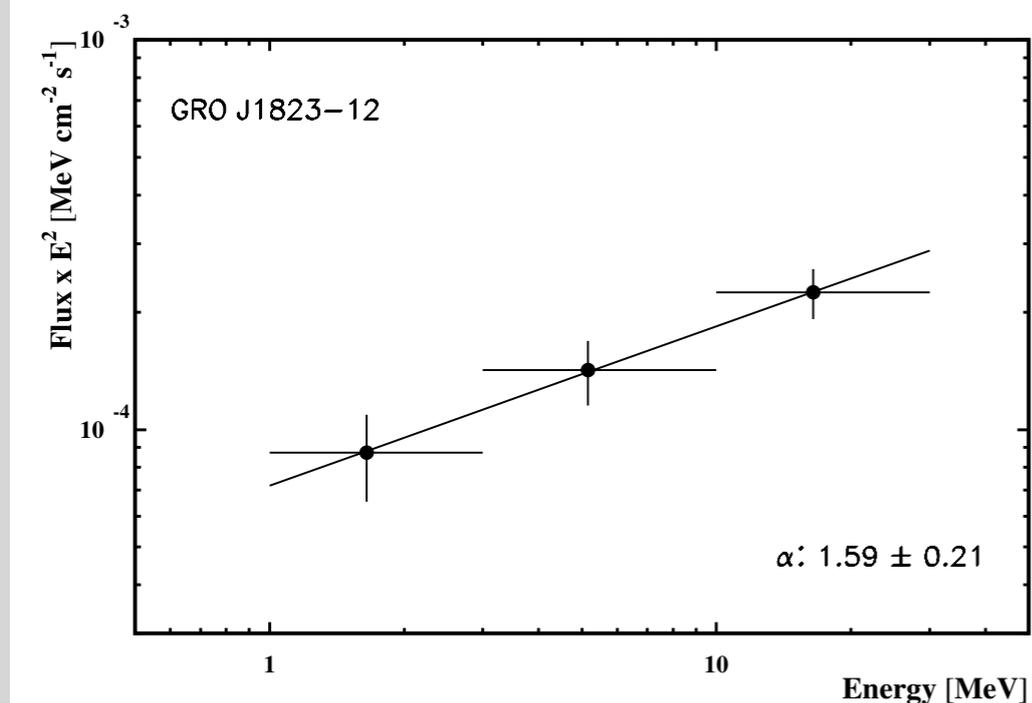
(van Dijk et al. 1997)

GRO J1823-12

Zhang and Collmar (2006)

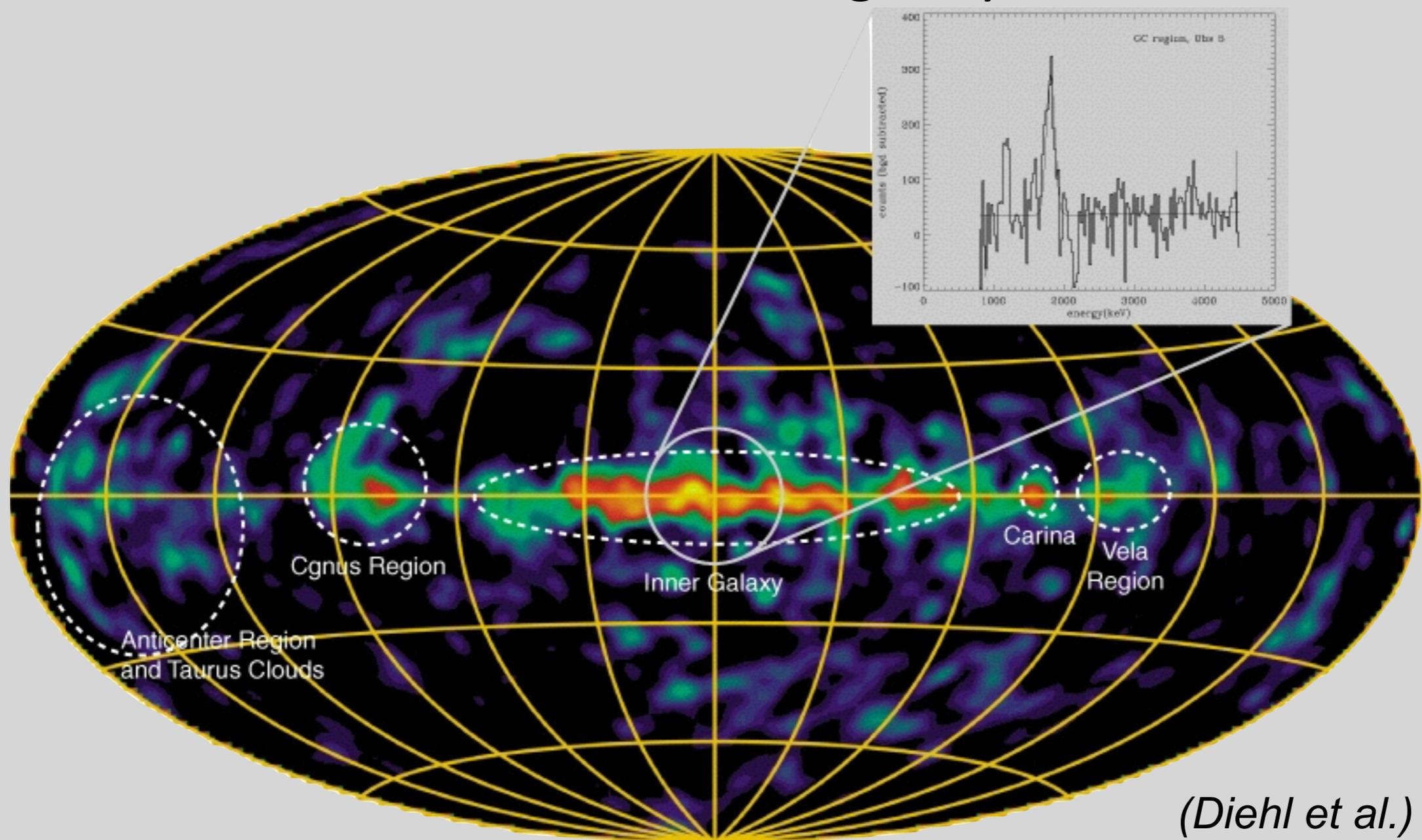


A very significant source lying in the Galactic Plane at $l = 18^\circ$. May be associated with LS 5039, a TeV XRB.



Galactic Diffuse Line Emission

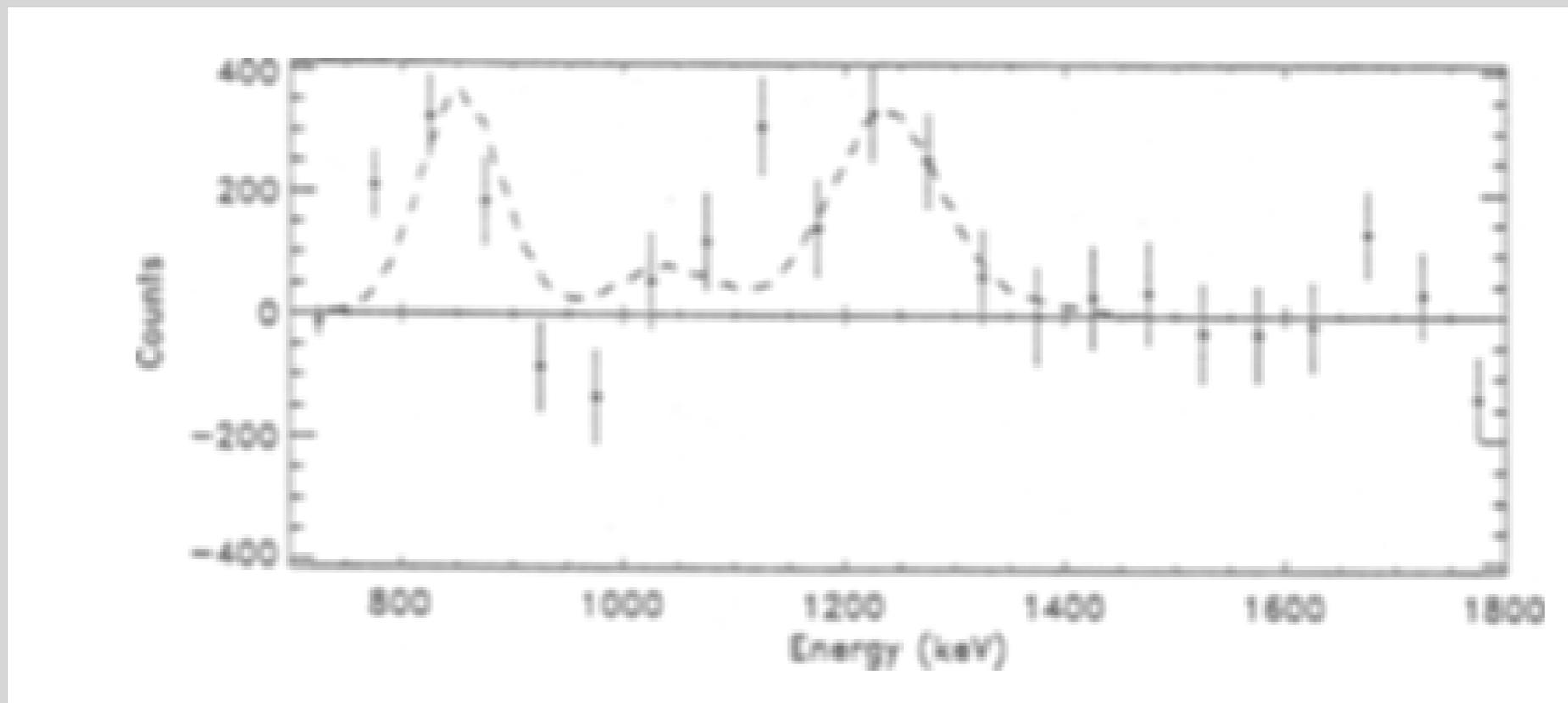
The emission of ^{26}Al as it decays into ^{26}Mg with a half-life of 700,000 years traces regions of recent star formation in the galaxy.



(Diehl et al.)

SN 1991T

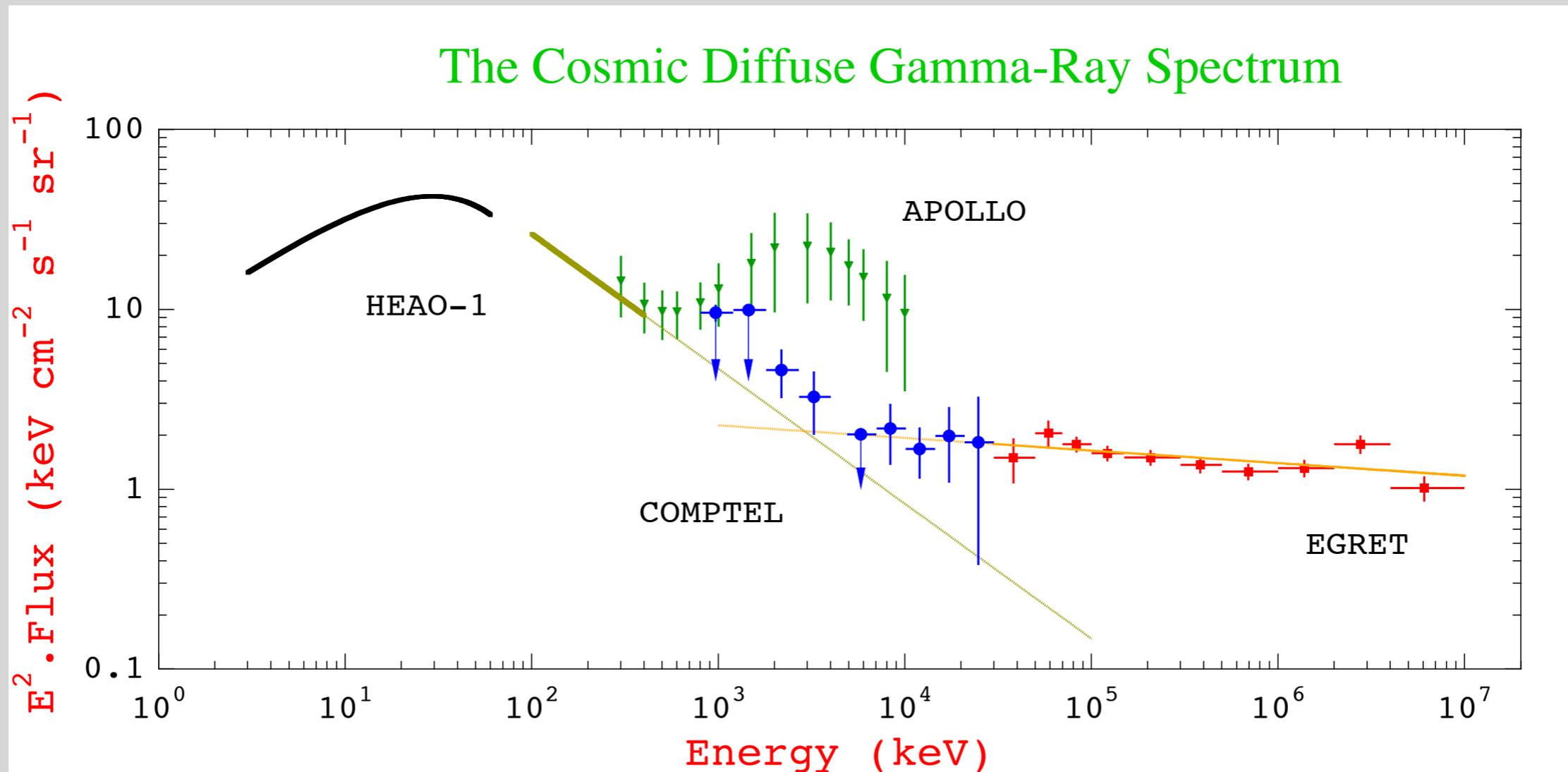
Evidence for ^{56}Co emission at 847 keV and 1238 keV.
(Recently seen also by INTEGRAL in SN 2014J.)



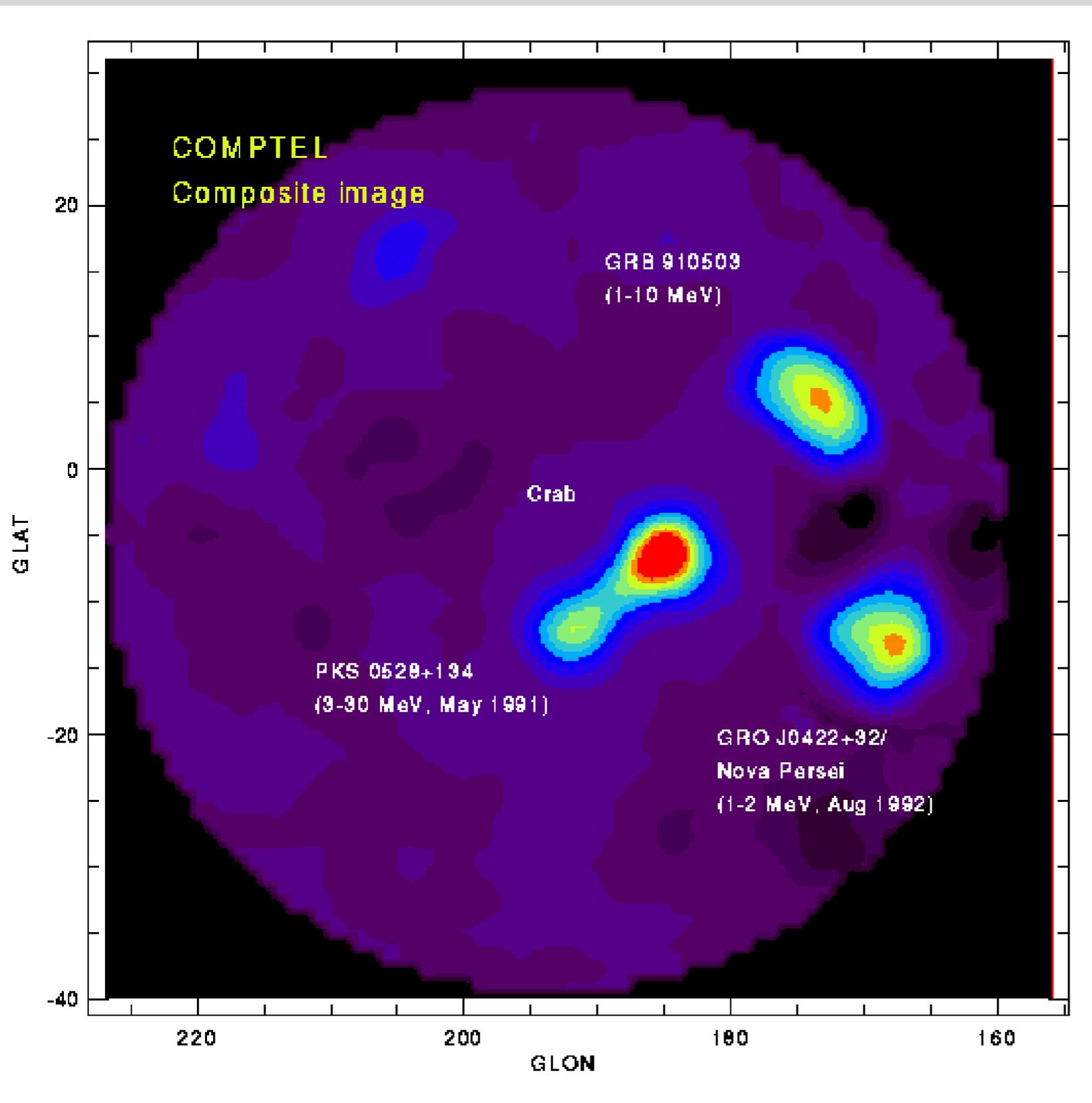
(Morris et al. 1997)

Cosmic Diffuse Emission

COMPTEL was capable of providing a reliable measurement of the Cosmic Diffuse Emission and disproving the existence of the “MeV Bump” that had been observed by Apollo 15 and others.



The Galactic Anticenter Region



A composite of the galactic anticenter region showing COMPTEL imaging results for several different types of sources.

Lessons Learned

There is a lot happening at these energies,
much of which we have barely explored.

COMPTEL just touched the surface.

We need more sensitivity to fill the MeV gap.