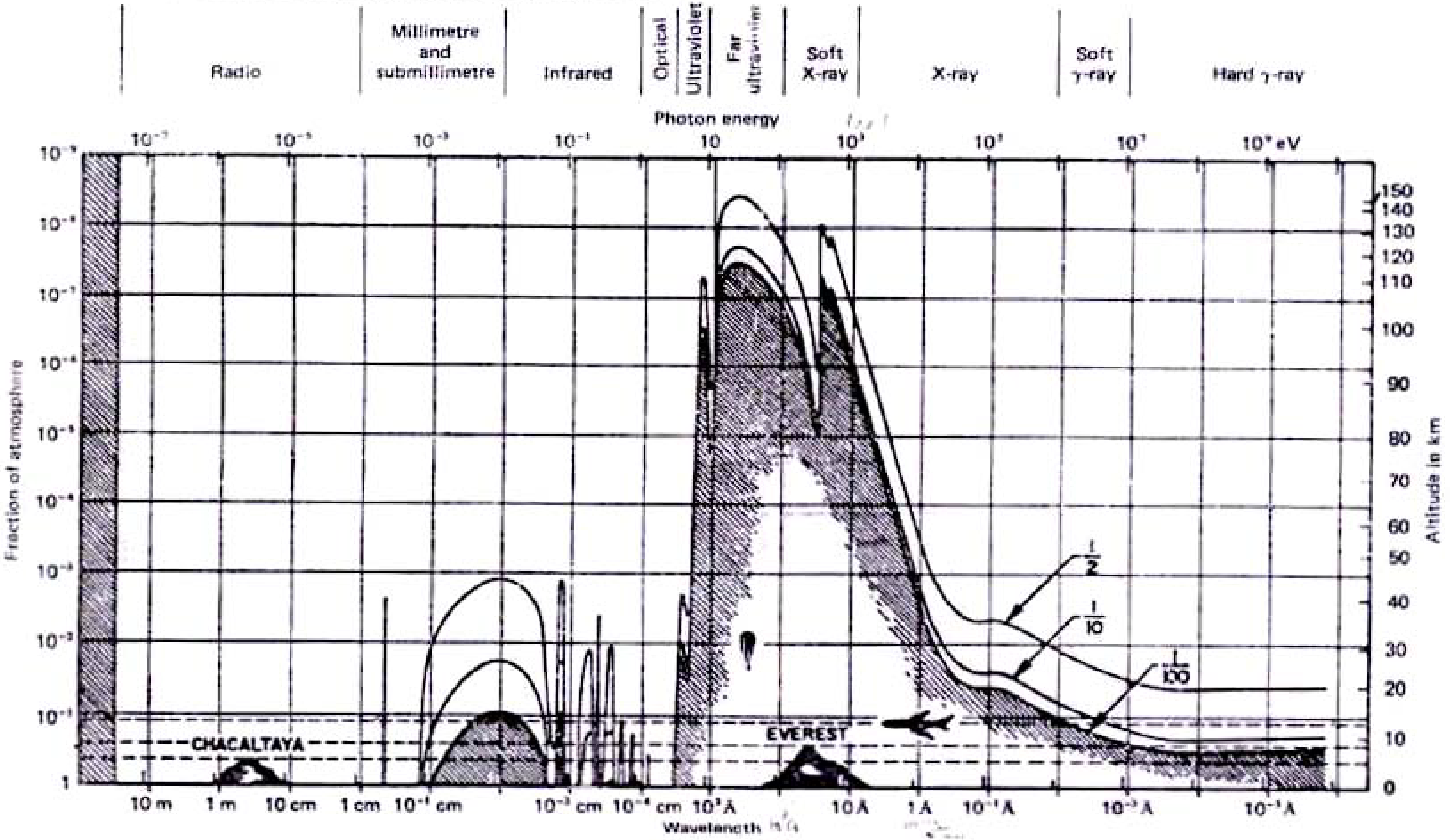
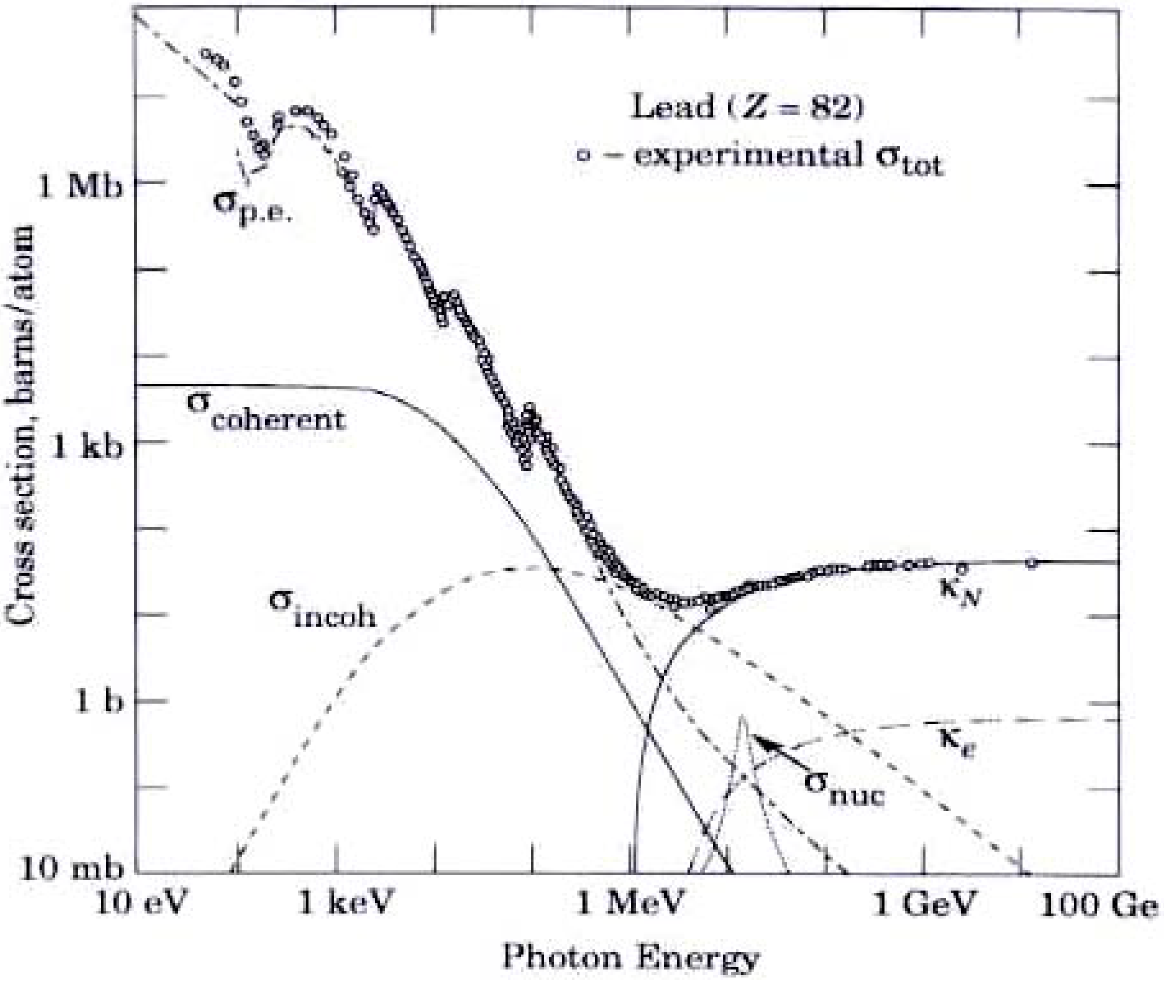
OUTLINE

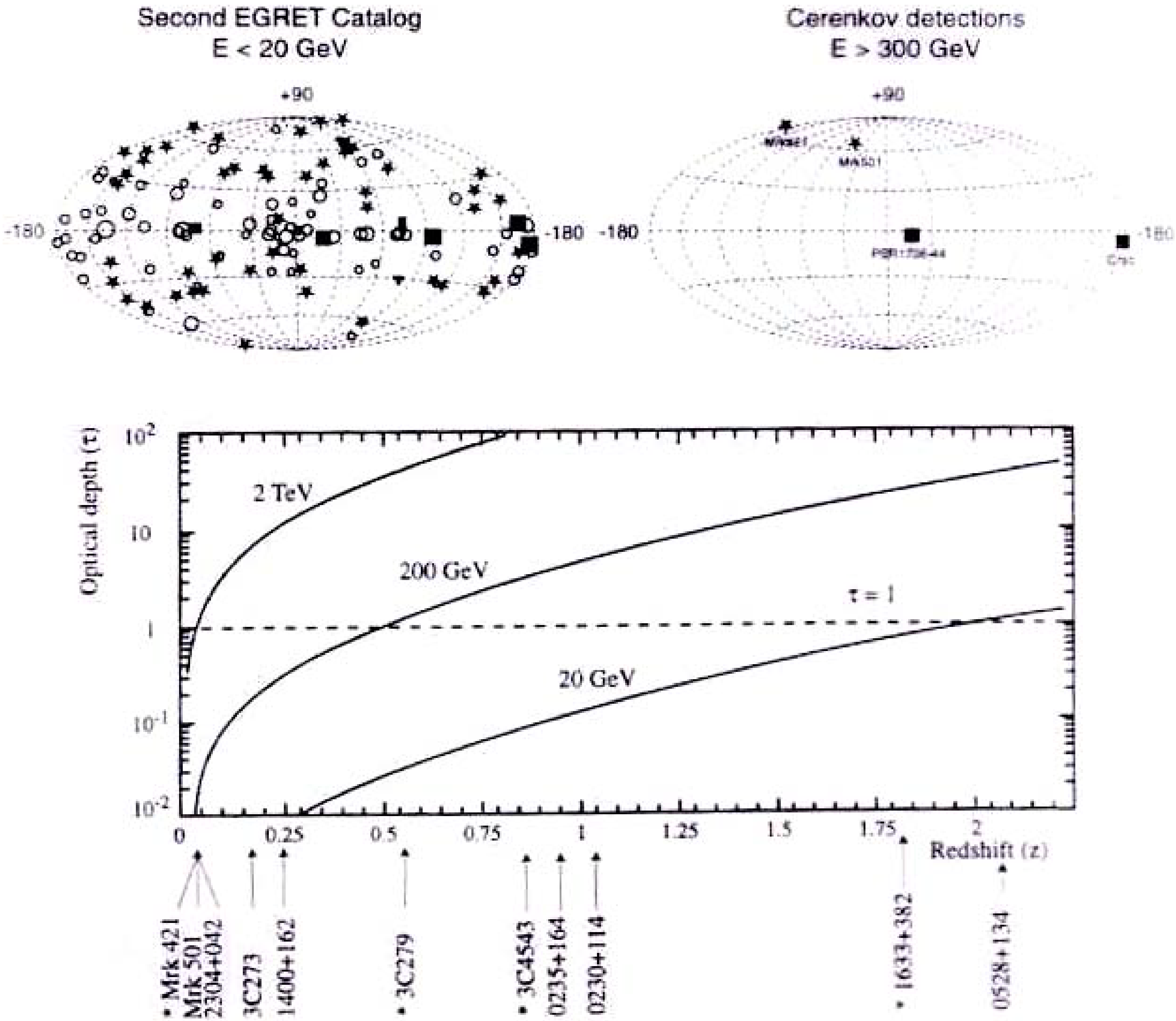
- Introduction
- Gamma Ray Missions and Detectors
- Low-Energy Gamma Rays
- High-Energy Gamma Rays
- Very High-Energy Gamma Rays
- Highlights
- Conclusions

Fig. 1.1 Attenuation of electromagnetic radiation in the atmosphere. Solid curves indicate the altitude (and corresponding pressure as a fraction of 1 atmosphere) at which the indicated fractional attenuation occurs for radiation of a given wavelength. Along the top of the diagram are the conventional designations of the different wavebands. (Adapted from Giacconi, Gursky & Van Speybroeck, 1968.)

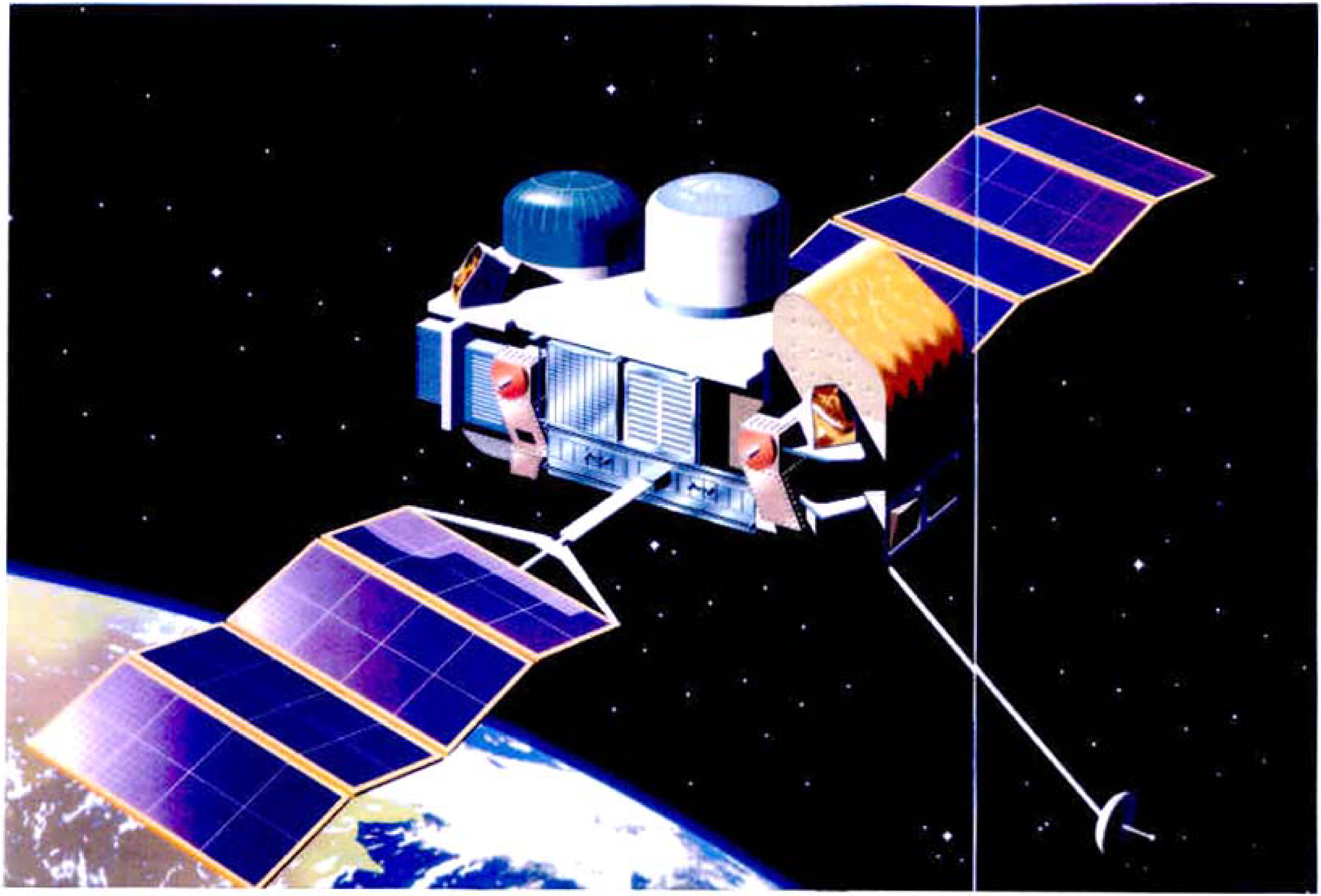


Photon Cross Section



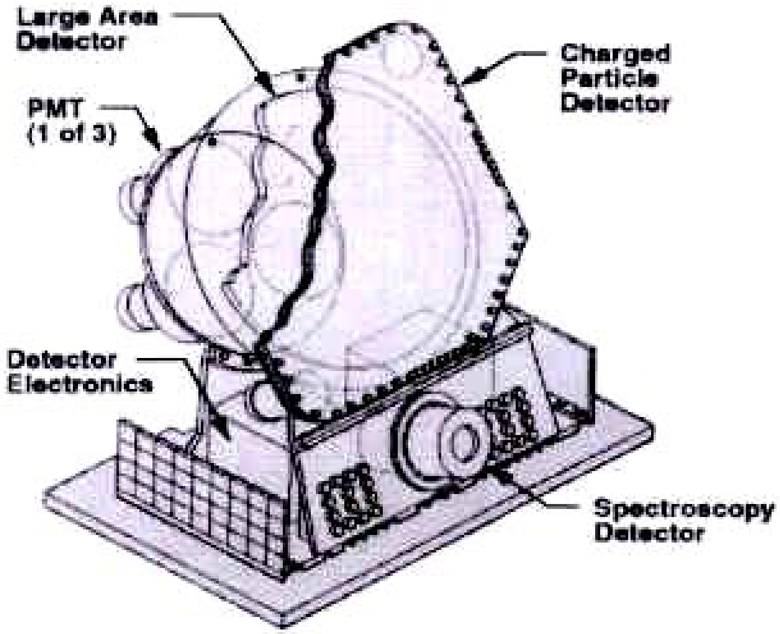


Second EGRET Catalog
E < 20 GeV
+90
-180
-180
Cerenkov detections
E > 300 GeV
+90
-180
-180
Optical depth (τ)
10^2
10
1
10^{-1}
10^{-2}
2 TeV
200 GeV
τ = 1
20 GeV
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
Redshift (z)
Mrk 421
Mrk 501
2304+042
3C273
1400+162
3C279
3C4543
0235+164
0230+114
1633+382
0528+134



Gamma-Ray Missions and Detectors

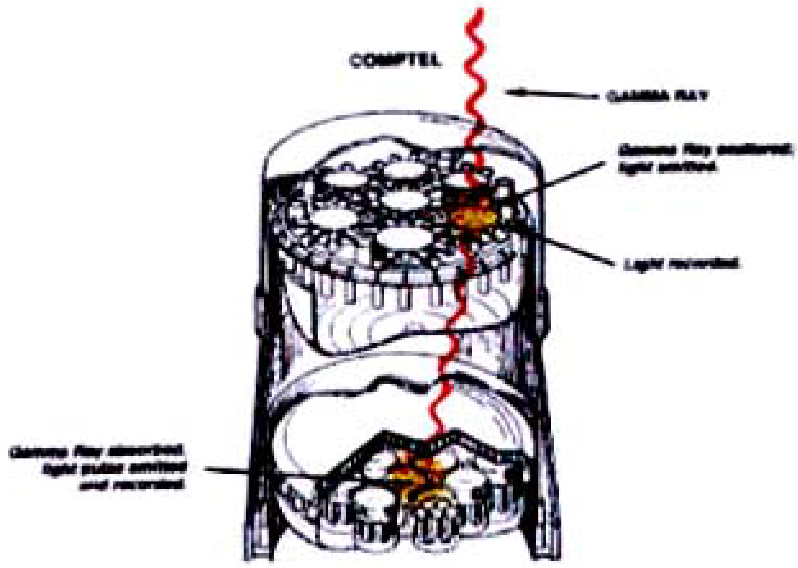
BATSE



- Burst And Transient Source Experiment
- NaI Scintillators
- Energy Band (20 keV - 1 MeV)
- Field of View: $\sim 4\pi$

Gamma-Ray Missions and Detectors

COMPTEL



- COMPton TELescope
- Compton Effect
- Energy Band (1-30 MeV)
- Imaging Detector

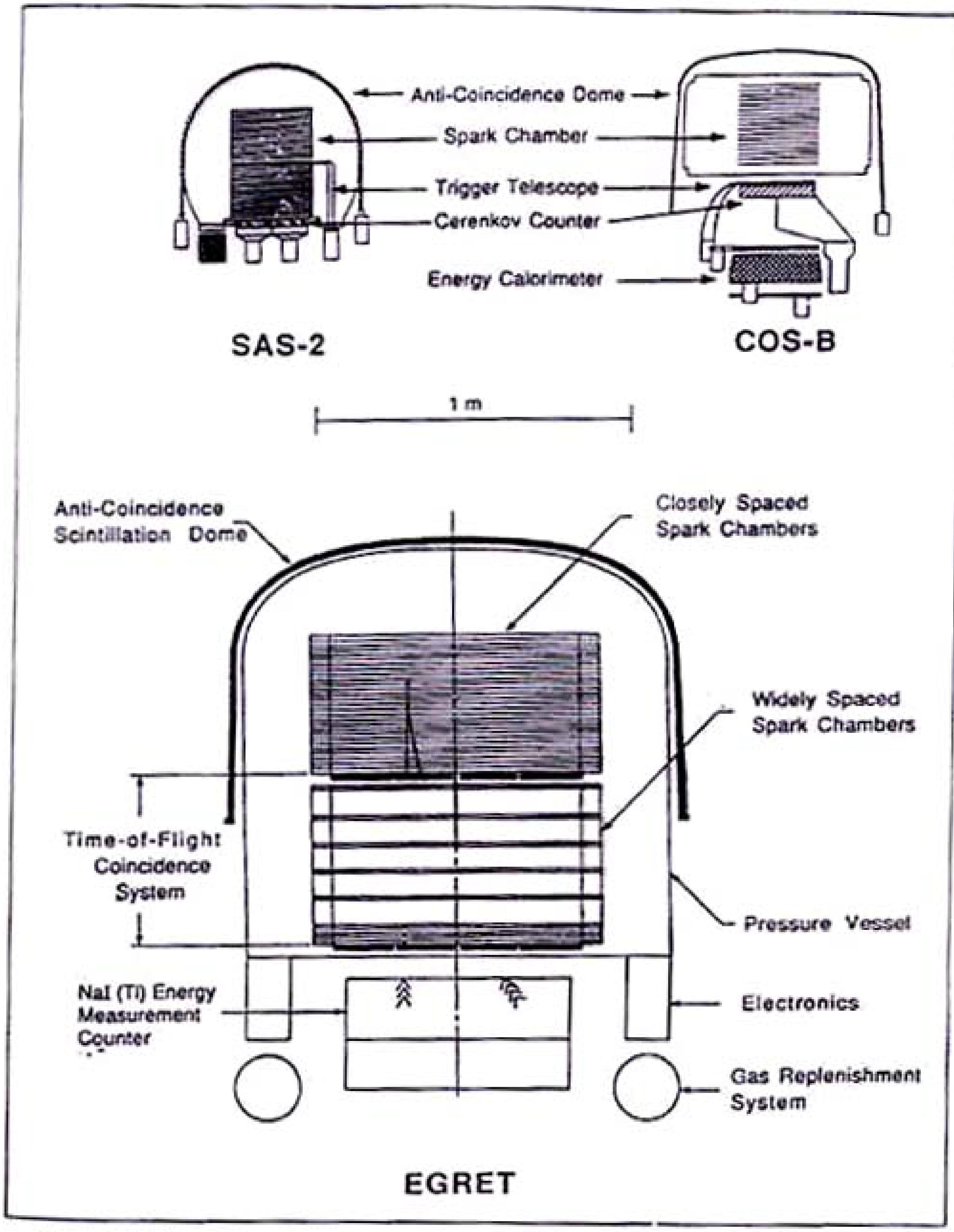


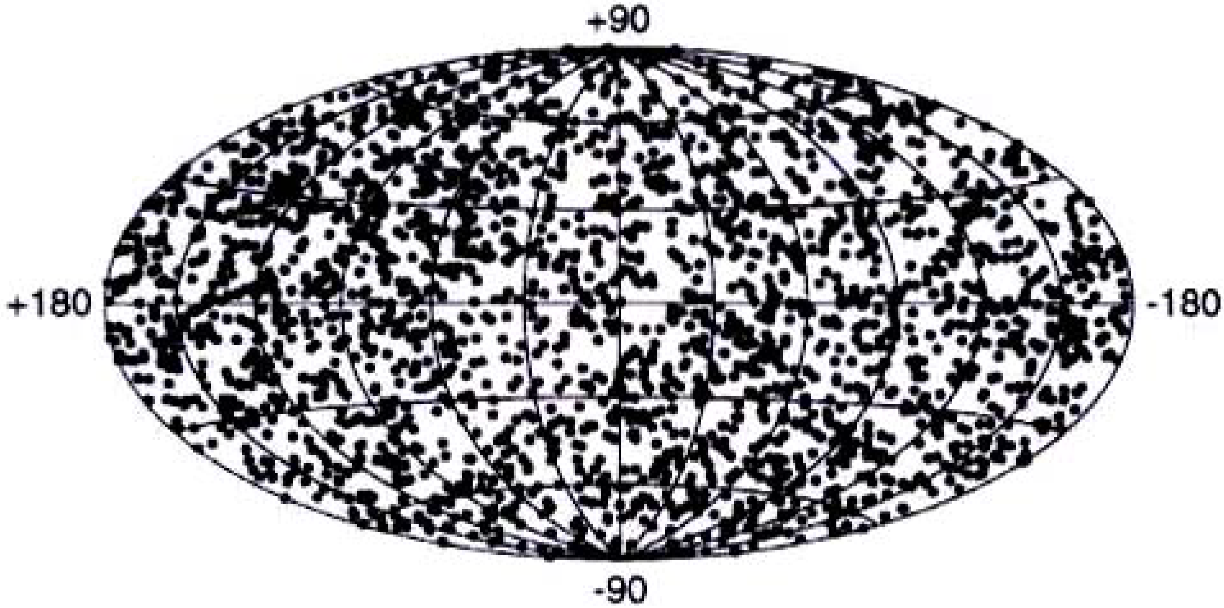
Fig.1: SAS-2, COS-B and EGRET schematic drawings (to scale).

- a detector to determine the energy of the secondary charged particles released by the incident photon. For EGRET this is a Total Absorption Shower Counter (TASC) made of NaI. Its

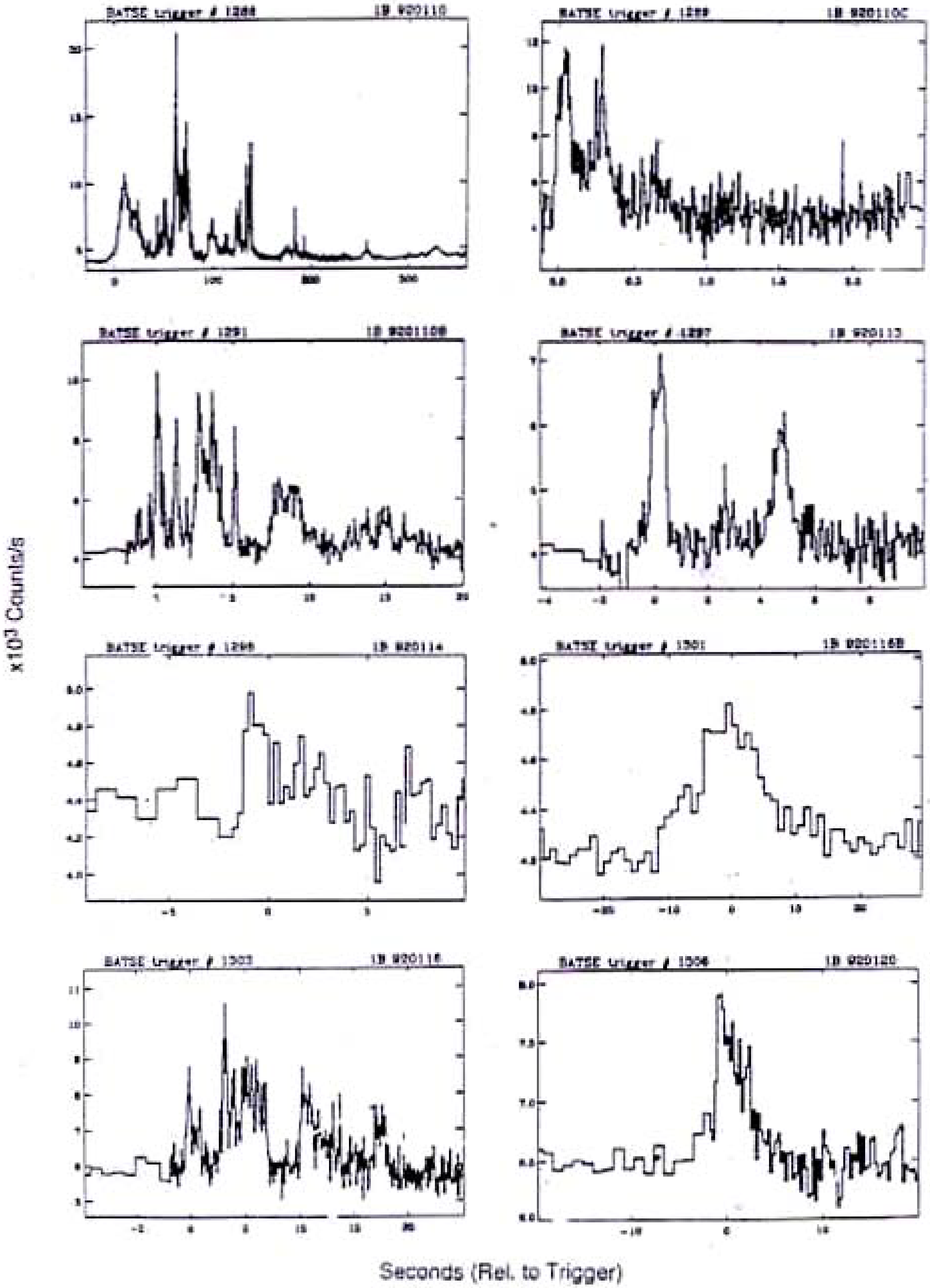
Low-Energy Gamma-Rays

Gamma Ray Bursts

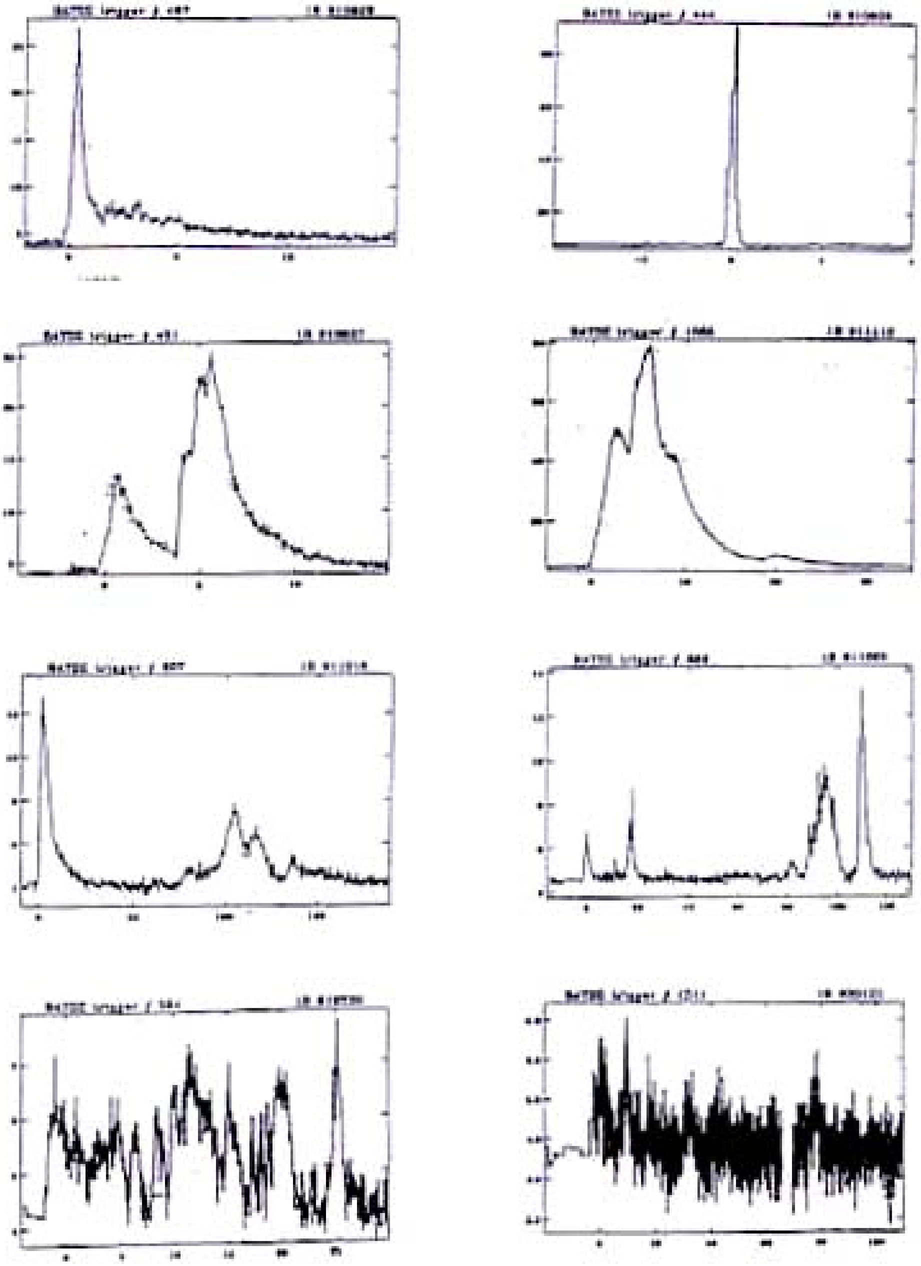
2300 BATSE Gamma-Ray Bursts

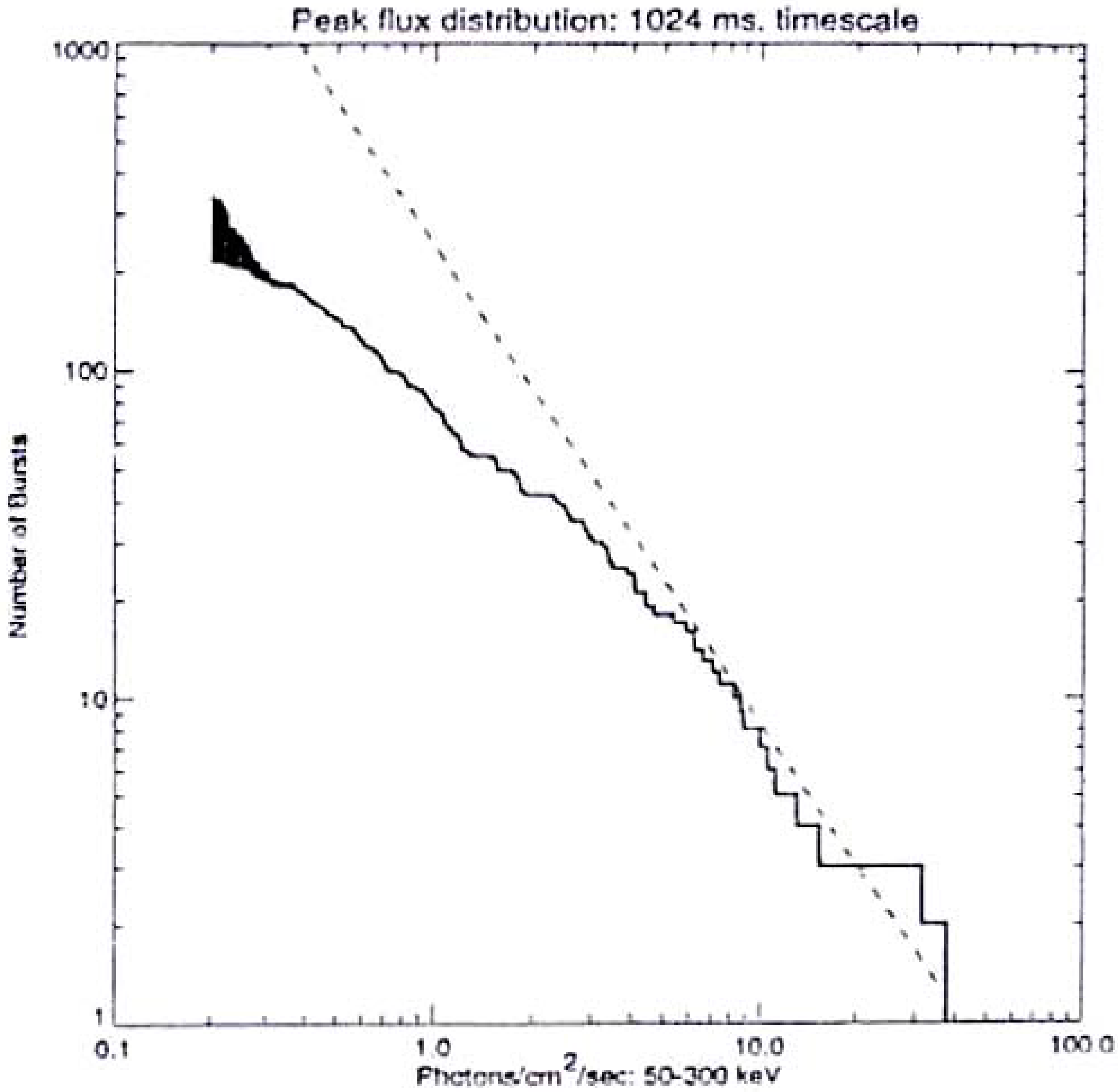


- Isotropic Angular Distribution of GRBs
- Light curves
- Non Thermal Spectra (20 keV - 10 MeV)

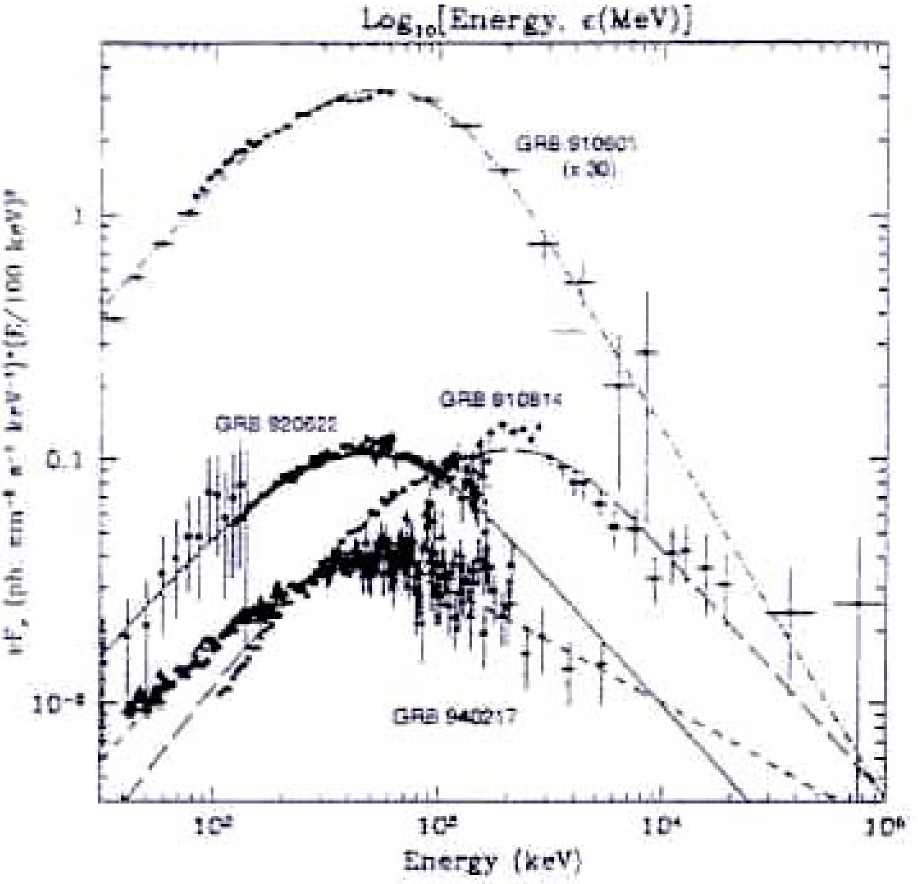


A sample page from the First BATSE Catalog of gamma-ray bursts, showing the extreme diversity of gamma ray burst time profiles and durations.





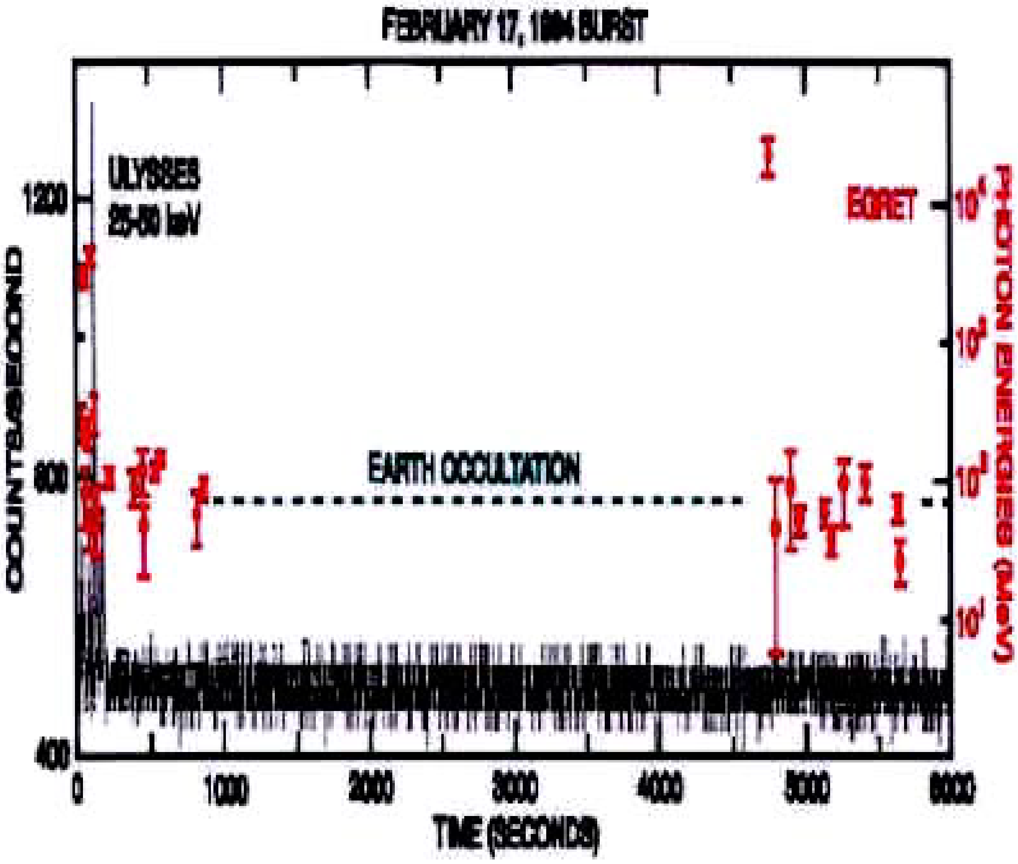
Peak flux distribution: 1024 ms. timescale
1000
100
10
1
Number of Bursts
0.1
1.0
10.0
100.0
Photons/cm2/sec: 50-300 keV



Log10[Energy, ε(MeV)]
GRB 910601
(x 30)
GRB 920622
GRB 910814
GRB 940217
1
0.1
10^2
10^3
10^4
10^5
Energy (keV)

High-Energy Gamma-Rays

GAMMA RAY BURSTS

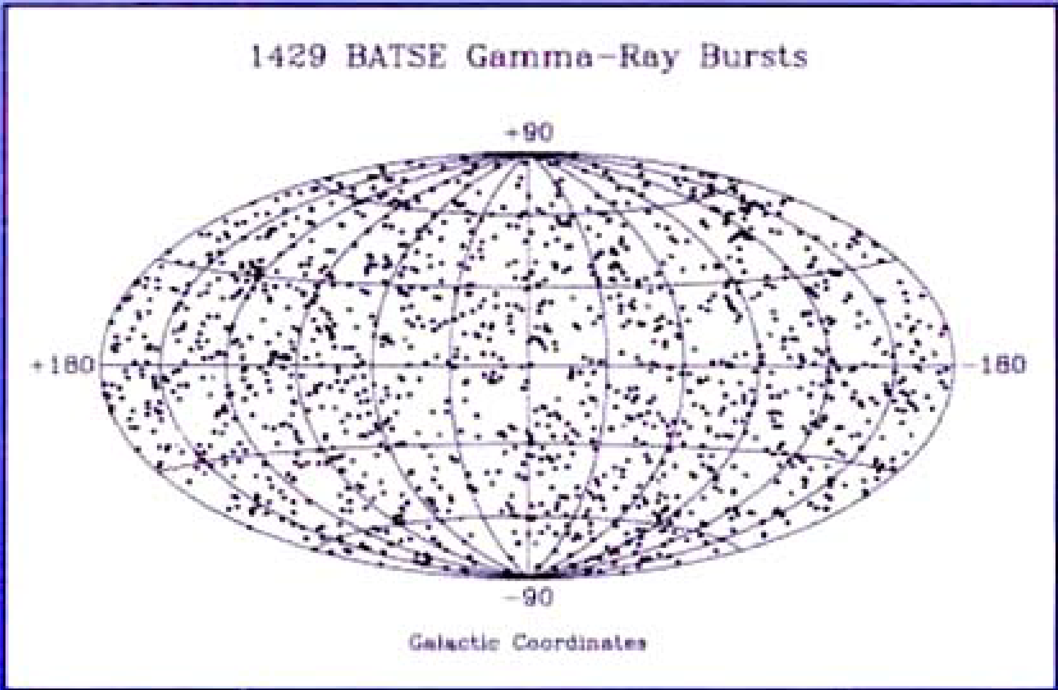


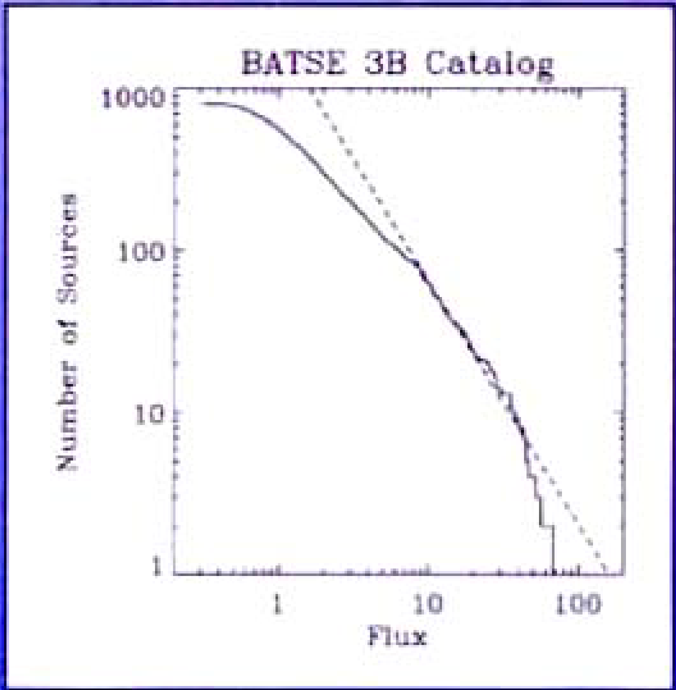
- High Energy Afterglow
- Prompt high energy emission?

Exploring the Astrophysics of Extremes

The Gamma-Ray Burst Mystery

- Gamma-ray burst mystery may be most baffling problem in all of astrophysics
- High degree of isotropy of source distribution on sky and radially bounded extent suggest a cosmological origin
- *GLAST will see ~50 bursts per year, and will constrain their positions to within a few arc minutes, greatly facilitating real-time, ground-based searches for counterparts*

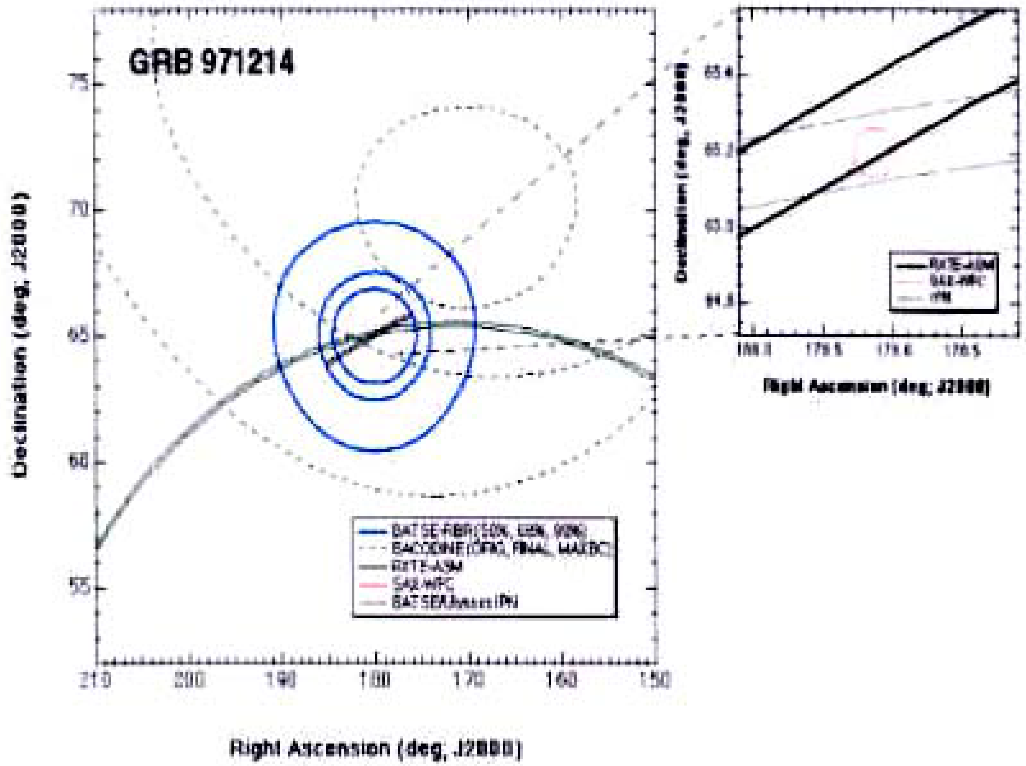




Highlights

GAMMA RAY BURSTS

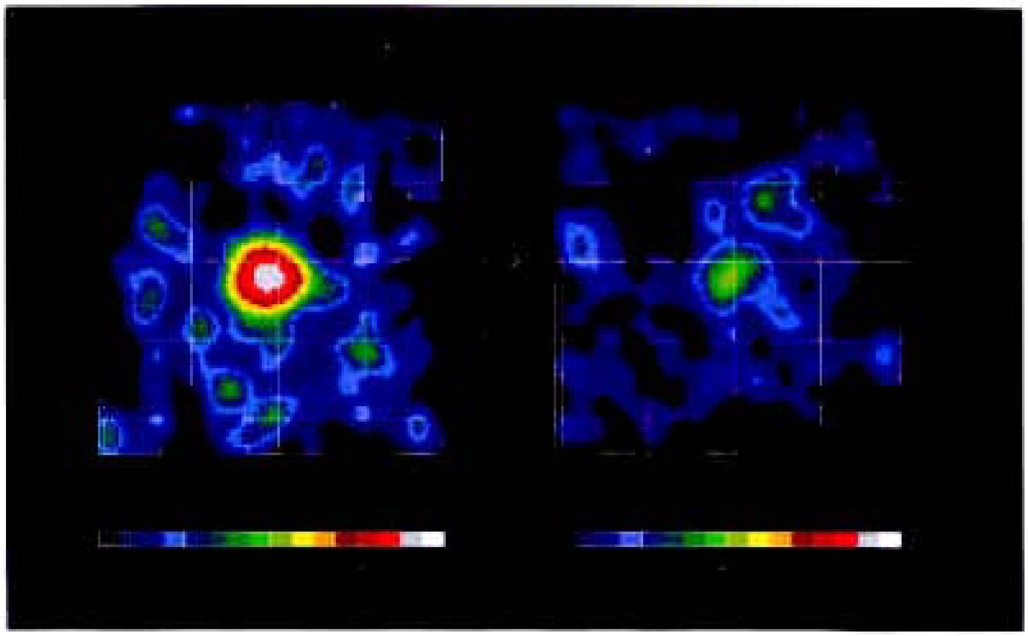
A Puzzle Being Resolved



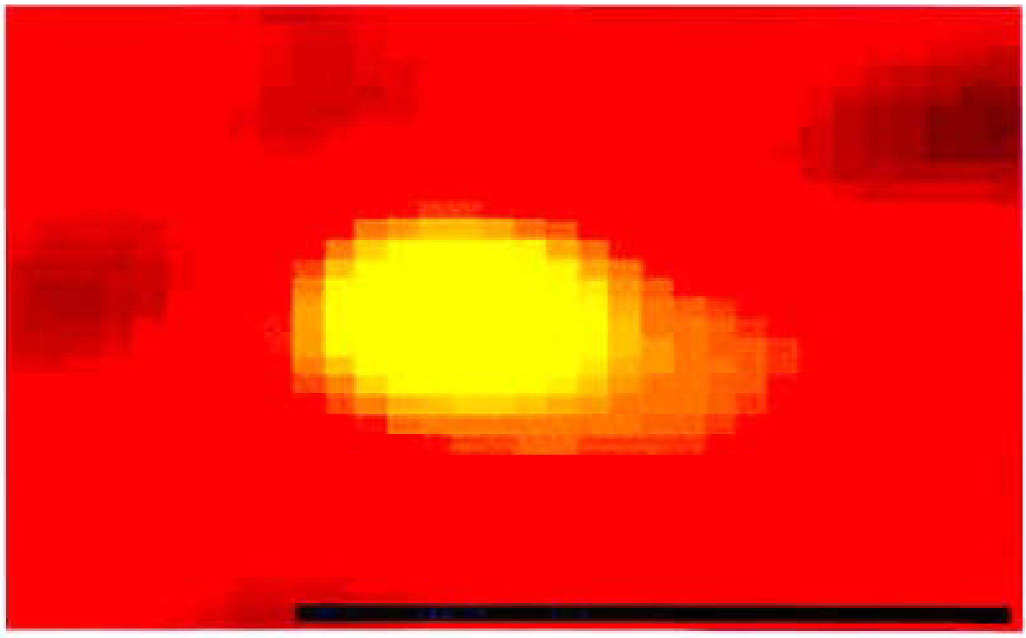
- BeppoSAX detection of X-ray afterglows of GRB
- Error Boxes $\sim 10''$
- Optical, Radio, X-ray Counterparts

Highlights

GRB 970228



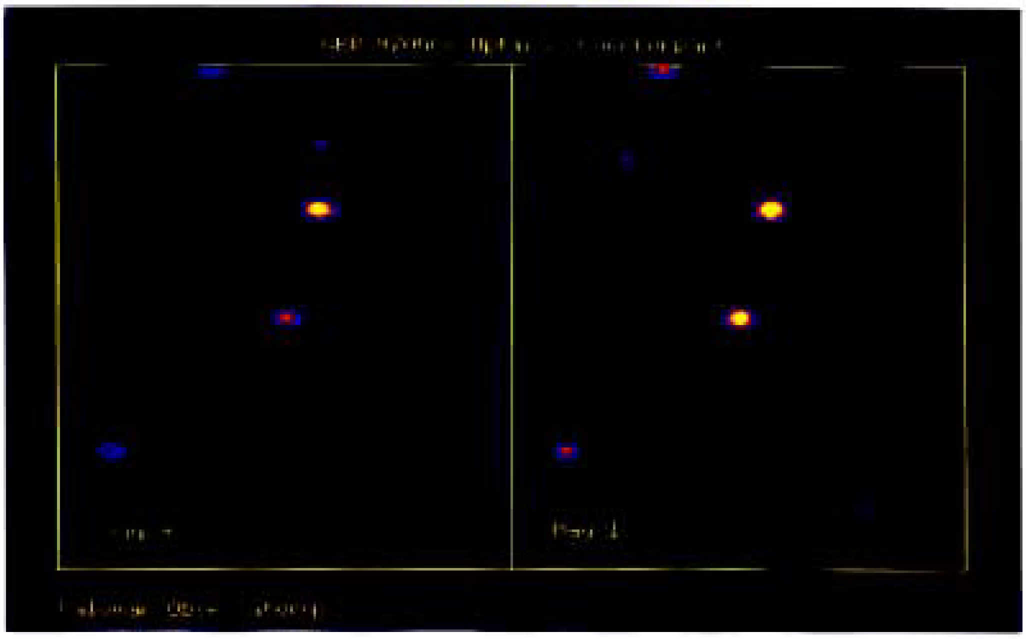
- SAX detection of X-ray afterglow



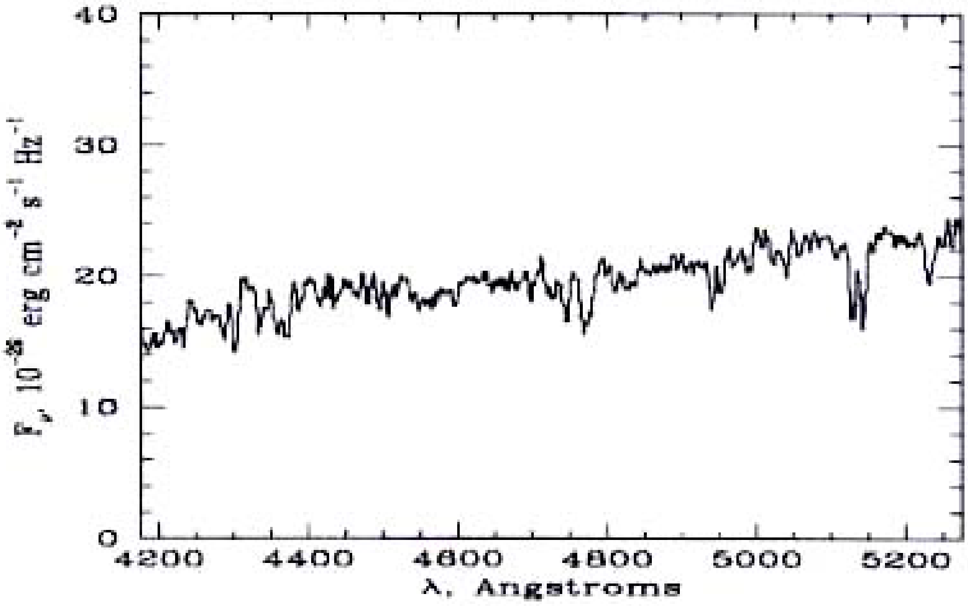
- HST detection of probable host galaxy

Highlights

GRB 970508



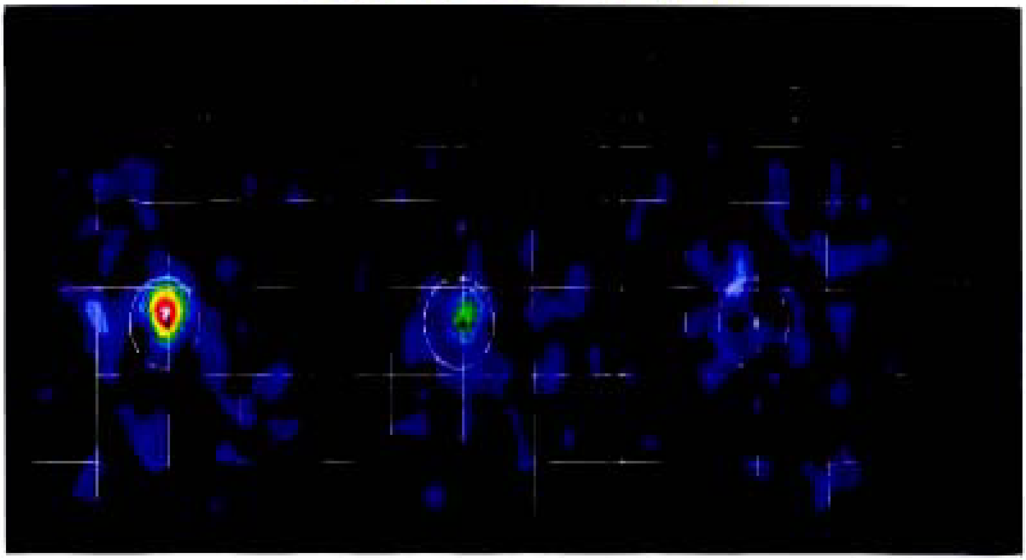
- Optical Transient (Palomar)



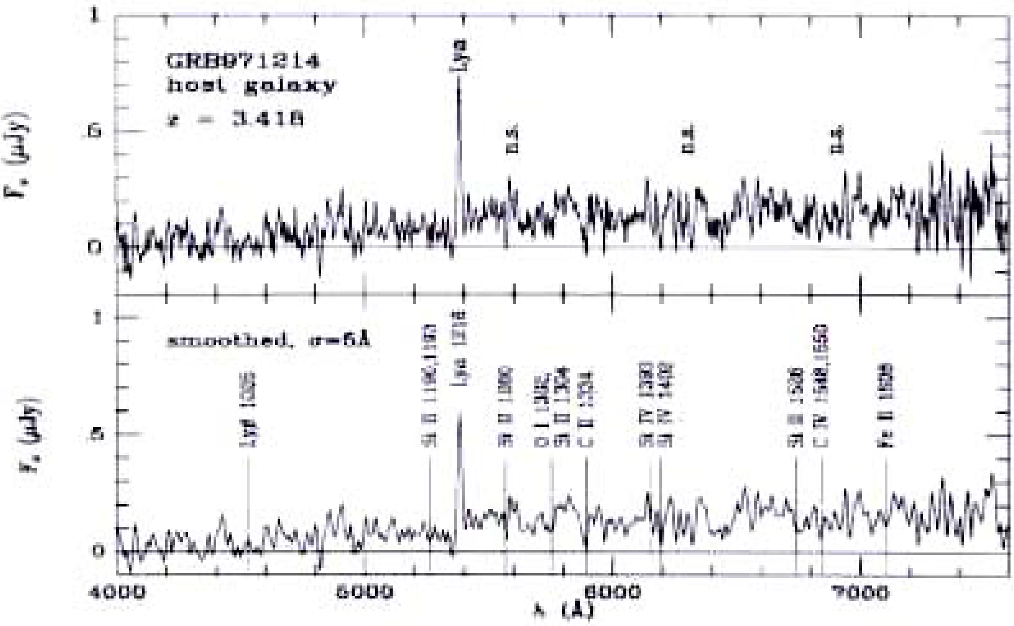
- Keck spectrum z=0.835

Highlights

GRB 971214



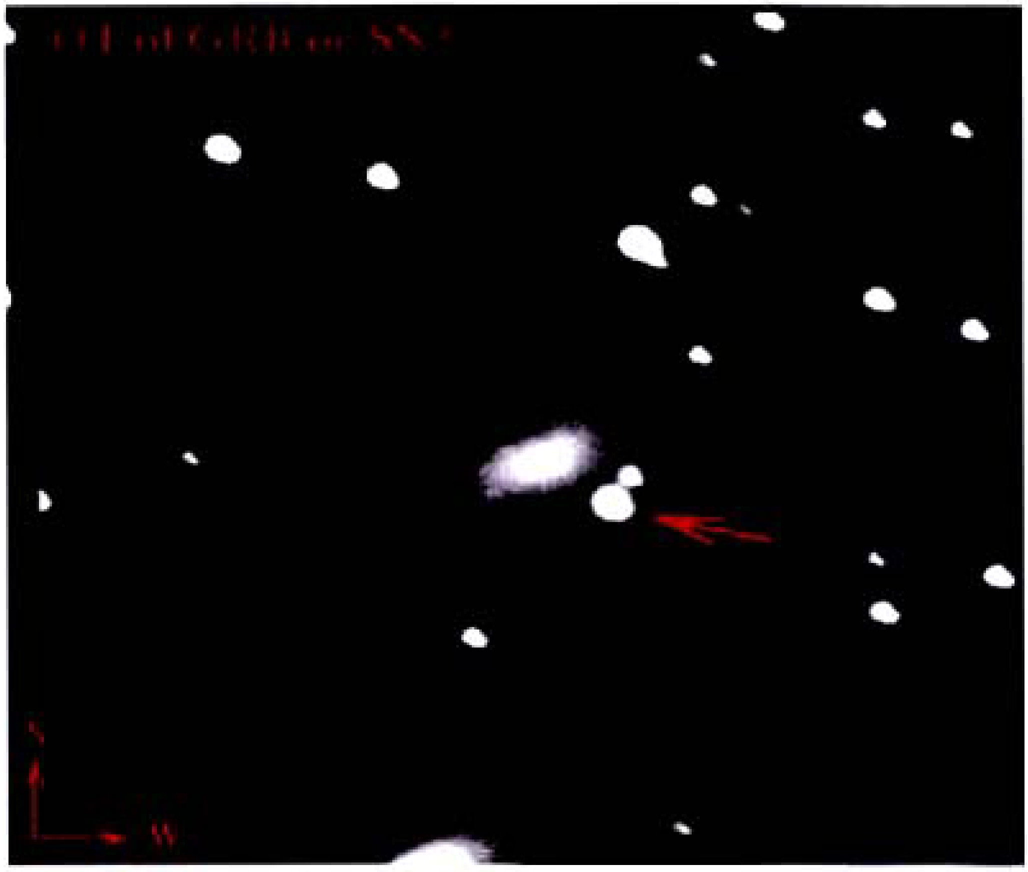
- SAX detection of X-ray afterglow



- Keck spectrum z=3.14

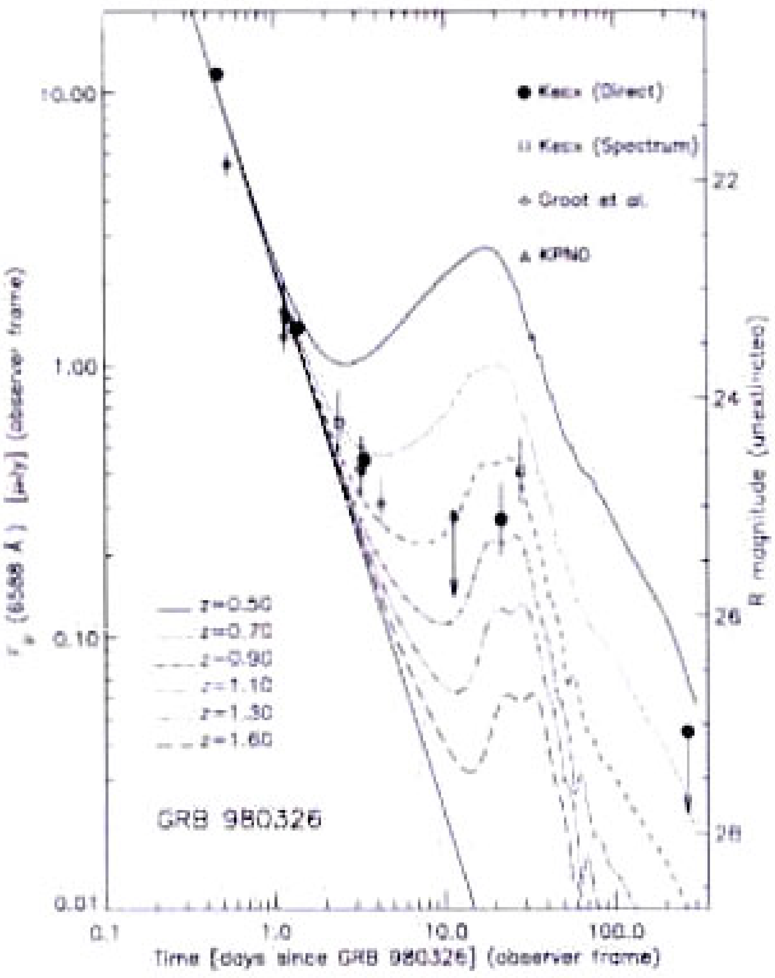
Highlights

GRB 980425



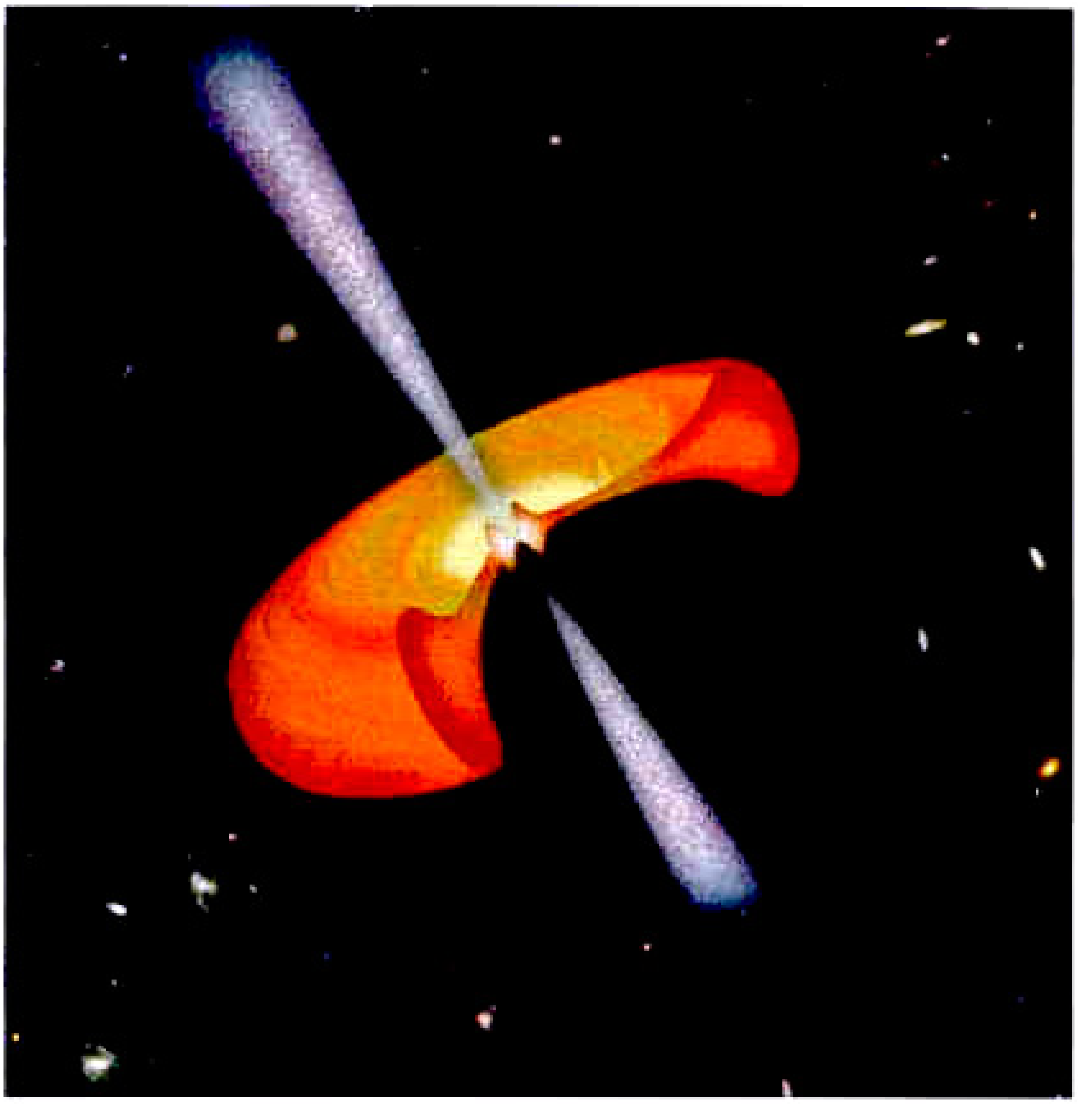
- Coincident Supernova?
- $z = 0.0085$

Highlights
GRB a distanza cosmologica



- GRB 980326
- Evidenza di connessioni GRB - SN a distanza cosmologica
- da Bloom et al. (1999)

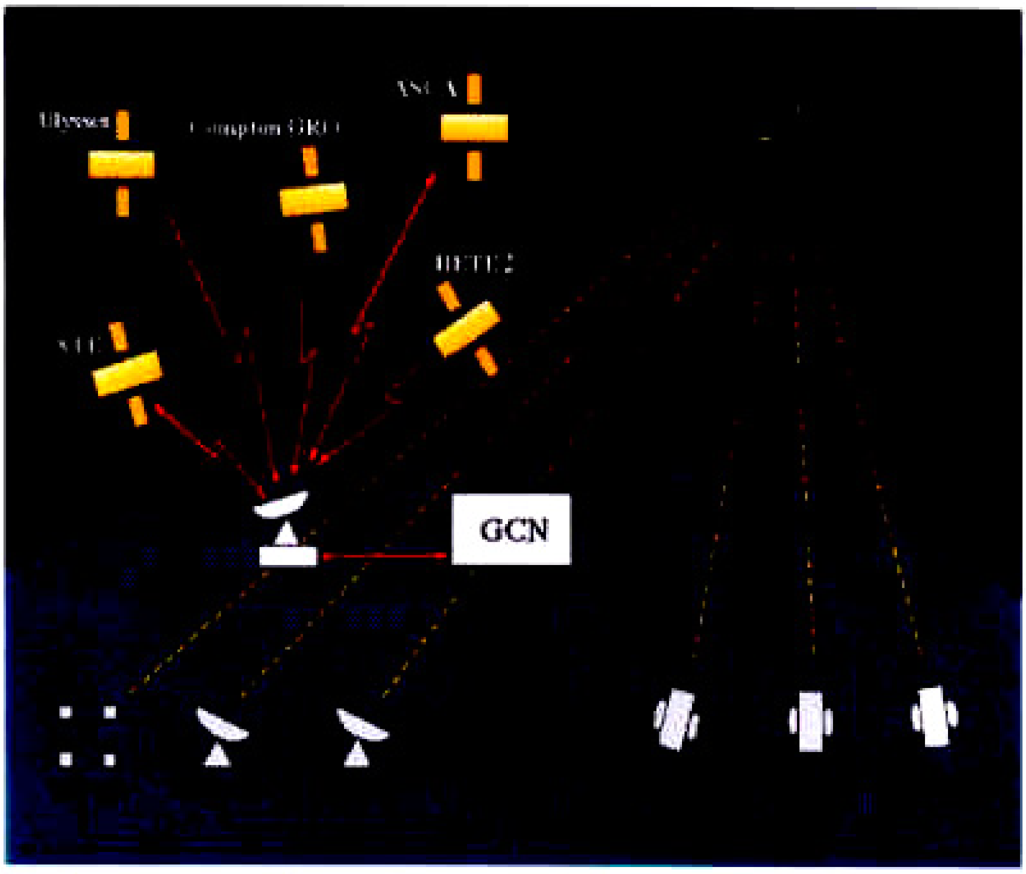
Highlights
Connessione GRB - SNe



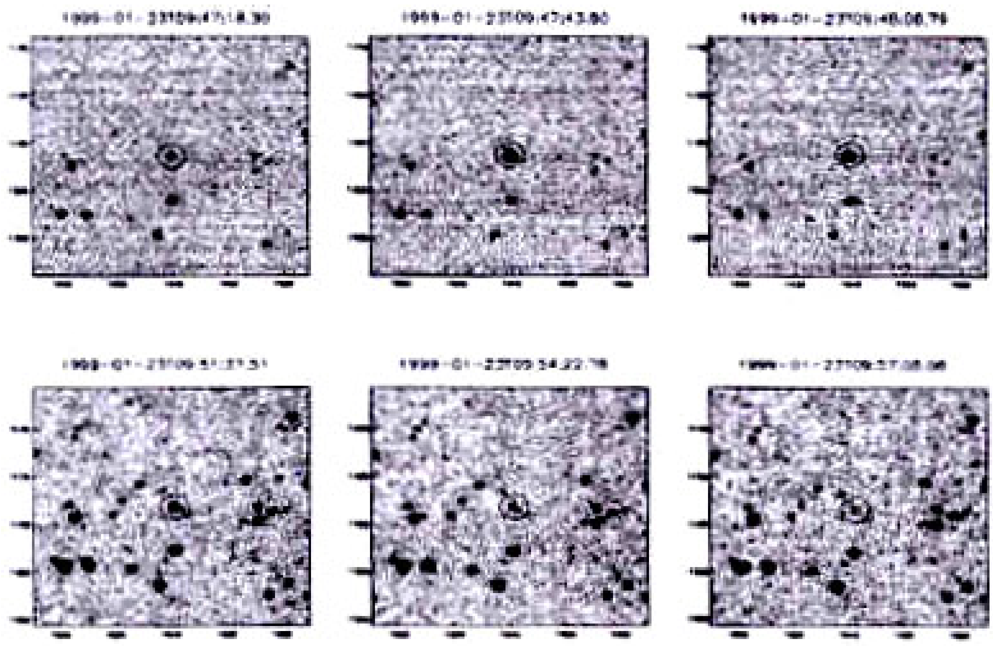
- Modello a *Hypernova*
- Collasso di stella massiva a BH
- Beaming dei GRBs

Highlights

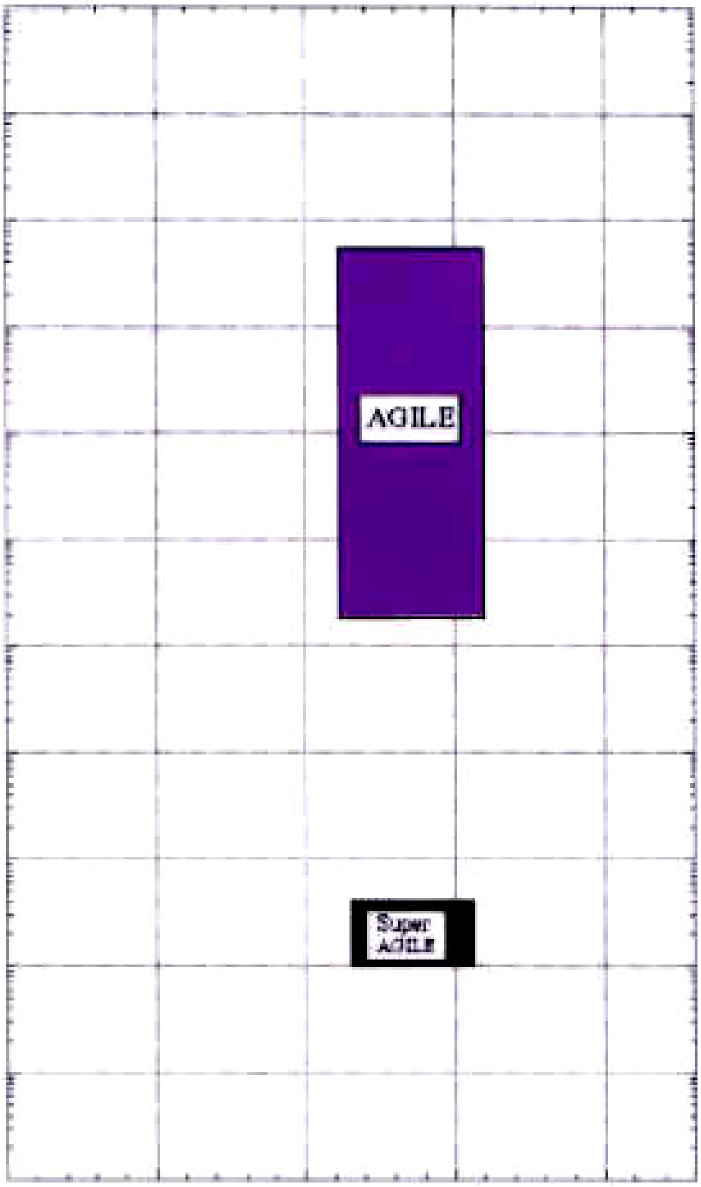
GRB 990123



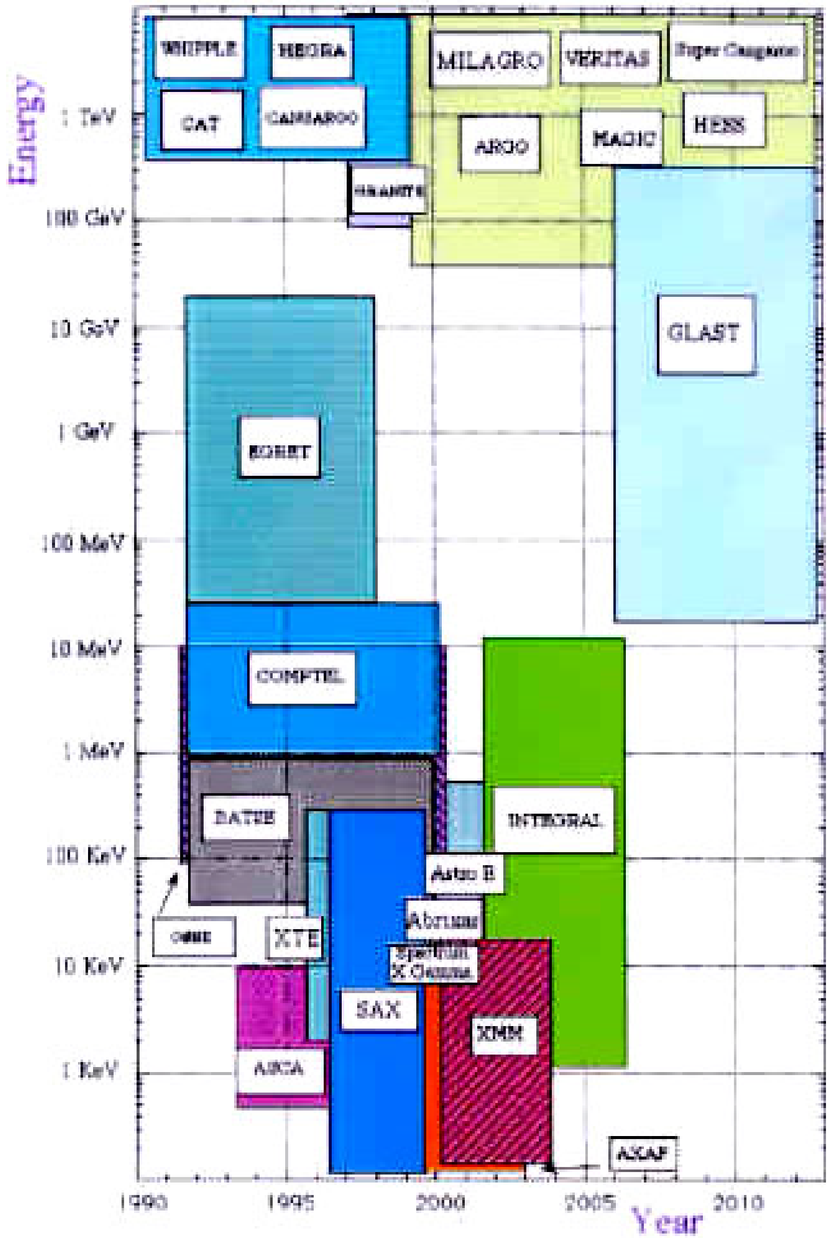
- Gamma Ray Bursts Coordinates Network (GCN)

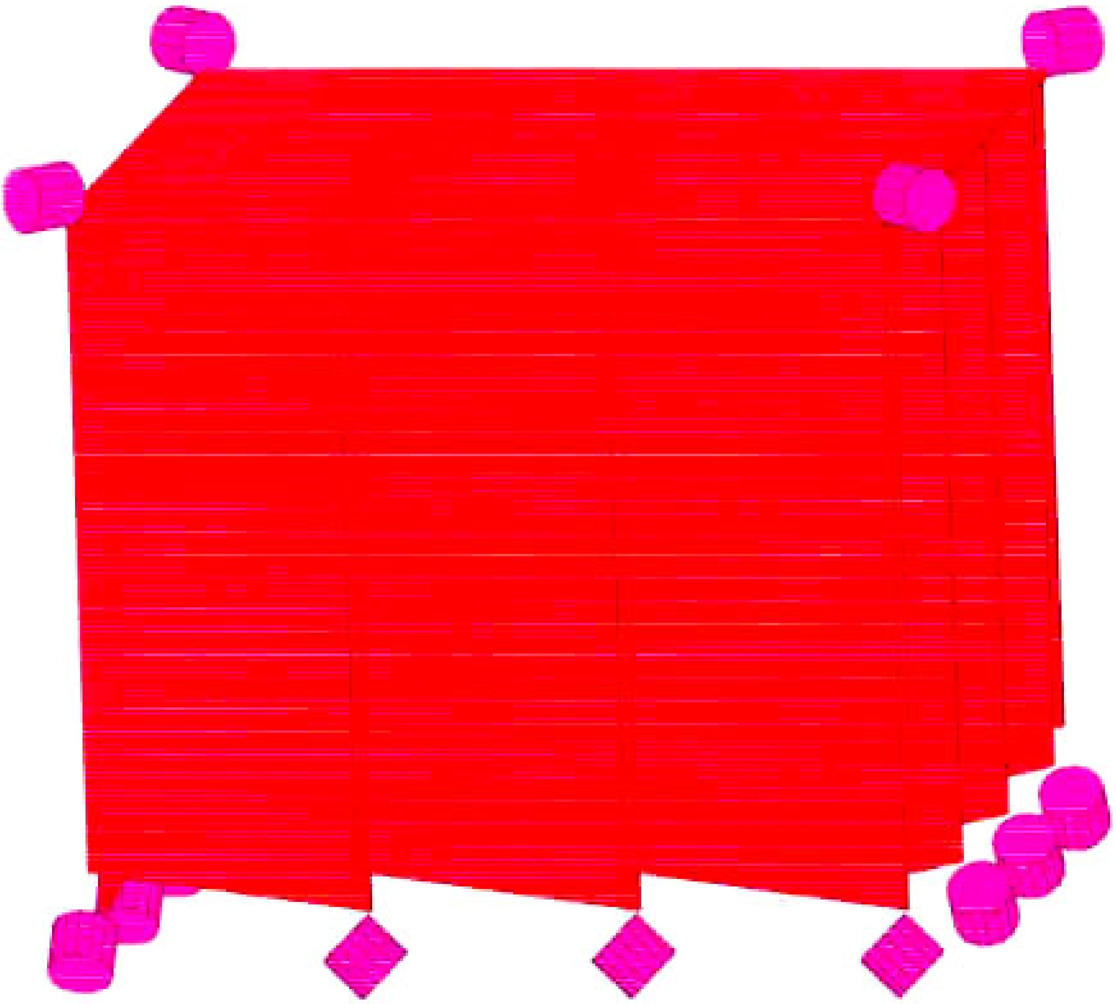


- ROTSE detection
- m_V=9.0
- z=1.6

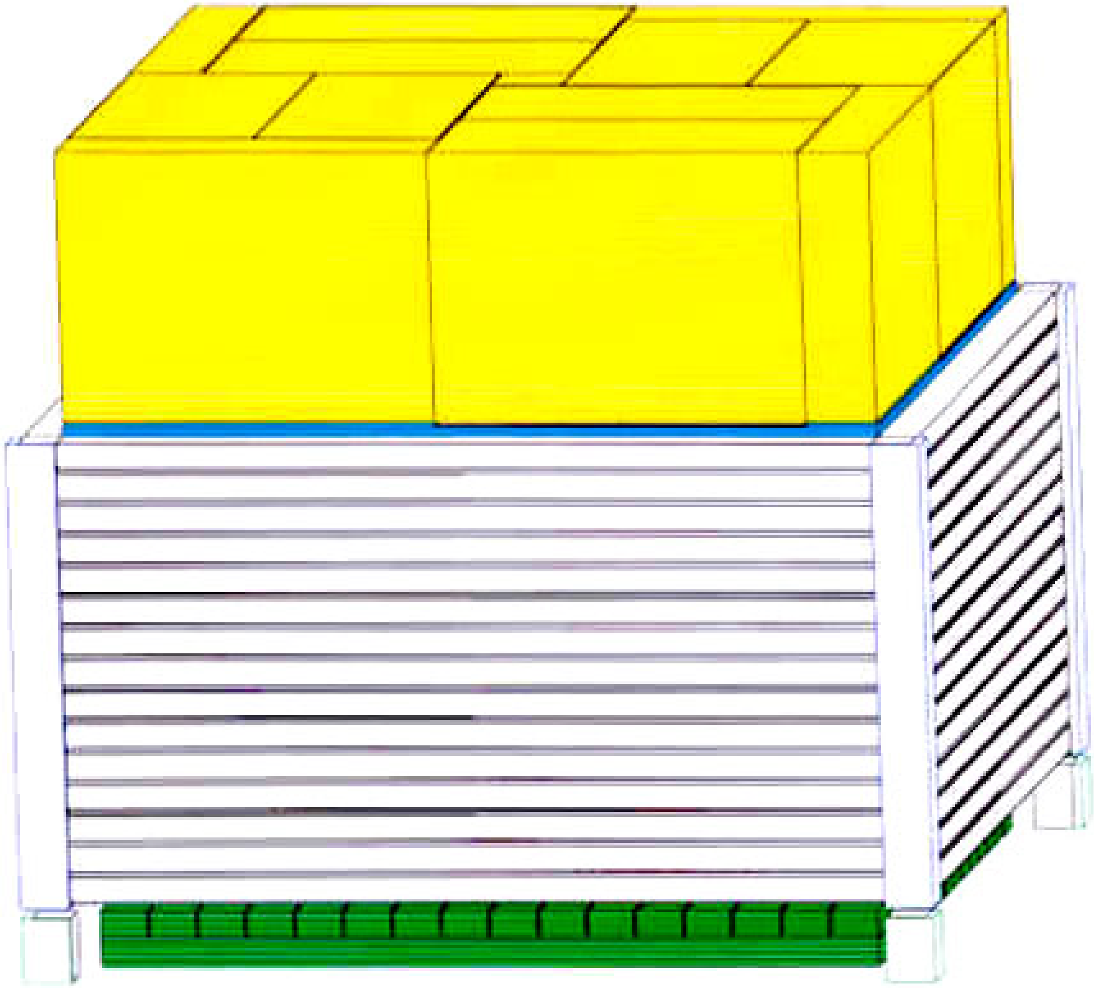

AGILE
Super AGILE

γ Astrophysics with AGILE



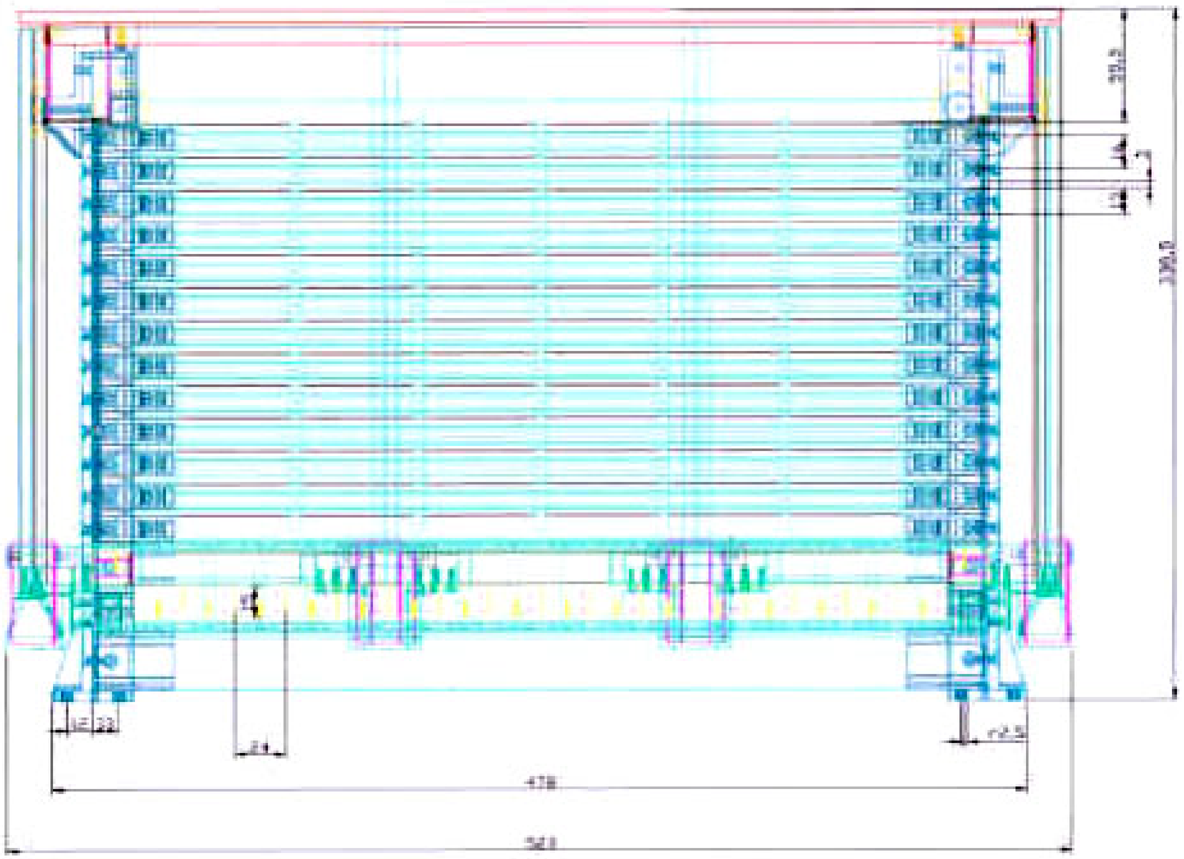


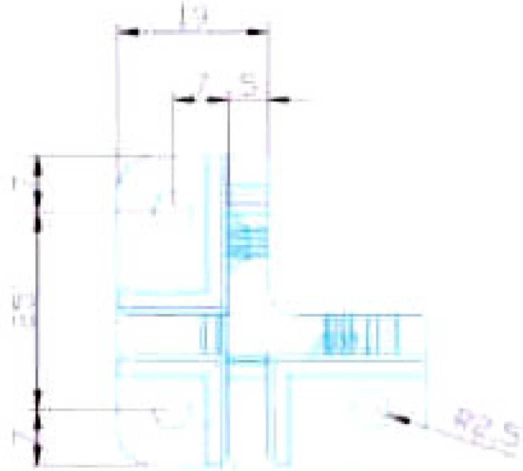
F.Longo, G.Fedel
INFN Trieste

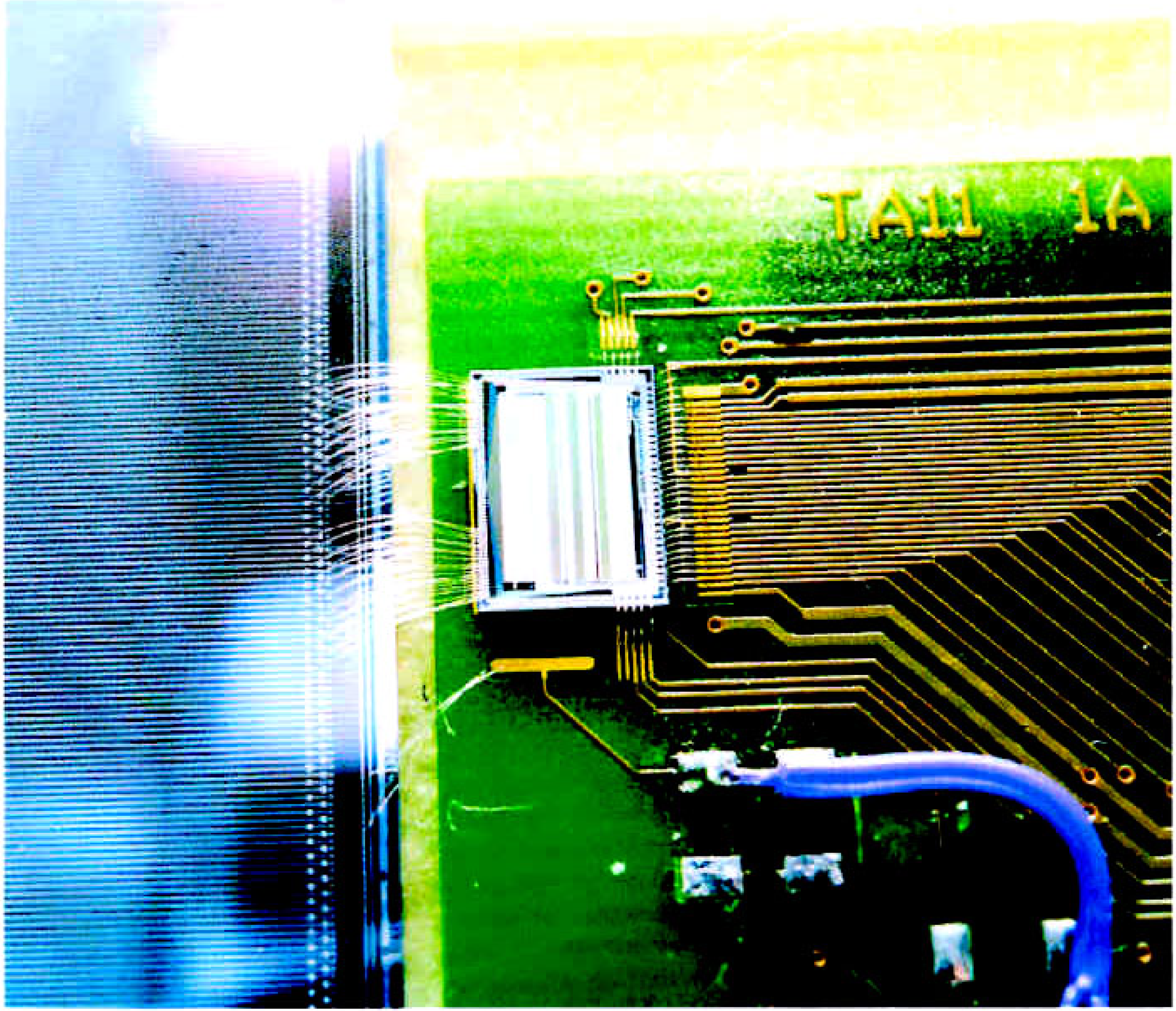


F.Longo, G.Fedel
INFN Trieste

GENERAL DIMENSIONS






TA11 1A

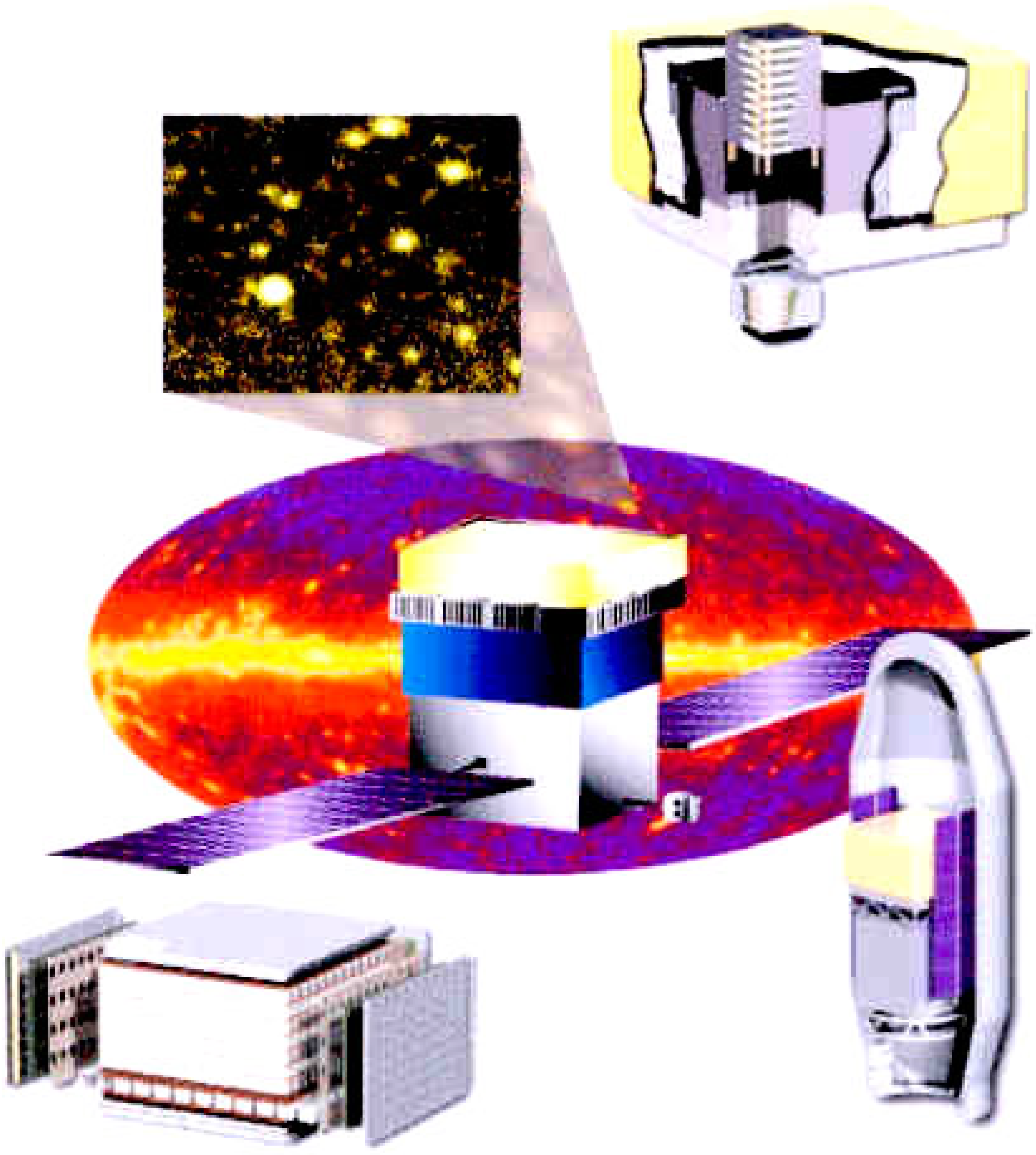
Response to AO 99-OSS-03

GLAST LARGE AREA TELESCOPE

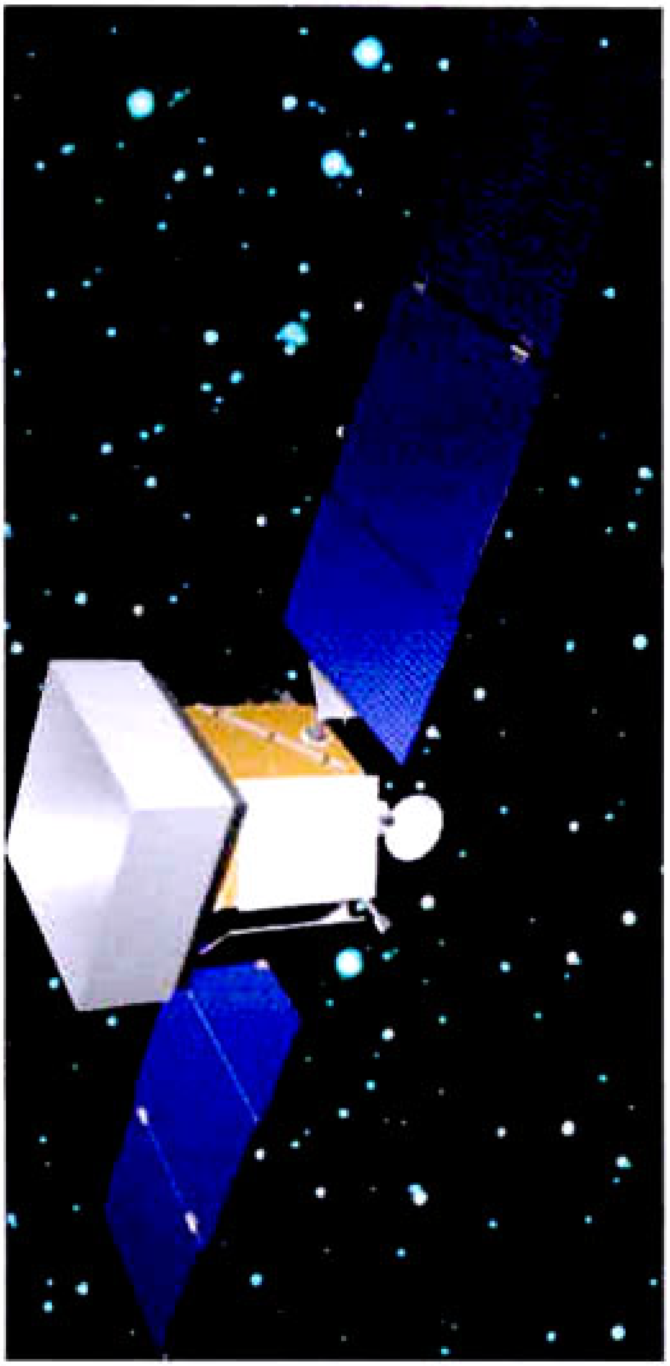
Flight Investigation:

An Astro-Particle Physics Partnership Exploring the High-Energy Universe

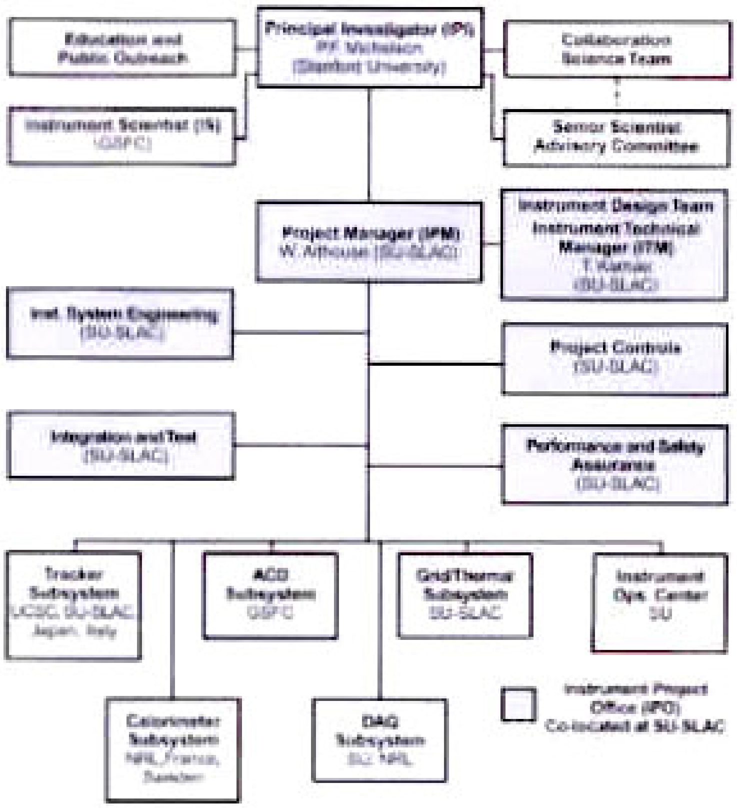
Volume 2: Cost and Management Plan



November 1999
Stanford University



The GLAST LAT Collaboration brings to the GLAST mission more than 7 years of focused LAT technology development. The team is a partnership of individuals and organizations with broad experience in experimental high-energy particle physics and space science instrumentation. This partnership is reflected in the support for the GLAST LAT team from the U.S. Department of Energy and foreign funding agencies.



Instrument Team Projects

- Conduct All-Sky Survey
- Provide Transient LAT Catalog and Alerts
- Perform in-depth analysis of selected sources

Organizations with Hardware Involvement

Stanford University: SLAC & HEPL

Goddard Space Flight Center

Naval Research Laboratory

University of California, Santa Cruz

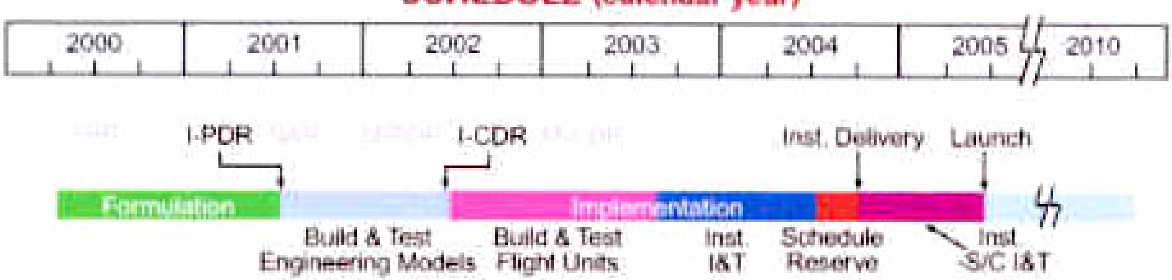
Hiroshima University, University of Tokyo, ISAS, & ICRR, Japan

INFN & ASI, Italy

Laboratorie du Commissariat a l'Energie Atomique & IN2P3, France

Royal Institute of Technology, Stockholm, Sweden

SCHEDULE (calendar year)



Science Investigation Cost:

	Cost to NASA	Total Cost
Formulation:	$7.0M	$33.6M
Implementation:	$51.9M	$107.0M
Operation:	$7.0M	$41.3M
TOTAL:	**$65.9M**	**$181.9M**

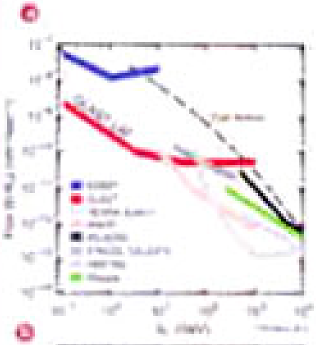
*All costs in FY99$, including reserves

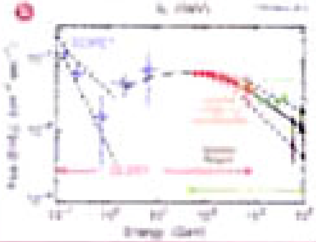
GLAST

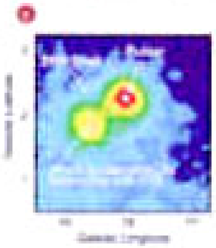
	EGRET	GLAST
Range Energetico	20 MeV - 30 GeV	20 MeV - 300 GeV
Risoluzione Energetica	10%	10 %
Area efficace	1500 cm^2	8000 cm^2
Campo di vista	0.5 sr	$>$ 3 sr
Risoluzione Angolare	5.8 ° @ 100 MeV	$\sim$ 3 ° @ 100 MeV
		$\sim$ 0.2 ° @ 10 GeV
Tempo Morto	100 ms	$<$ 20 μs
Sensibilità	$\sim 10^{-7}$ cm^{-2} s^{-1}	$\sim 2 \cdot 10^{-9}$ cm^{-2} s^{-1}
Localizzazione	5 – 30 '	30" – 5'

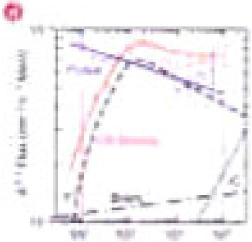
GLAST LAT/*Foldout A*
Science

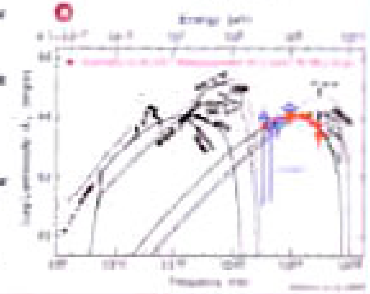
1. Particle Acceleration in AGN Jets, Pulsars, & SNRs





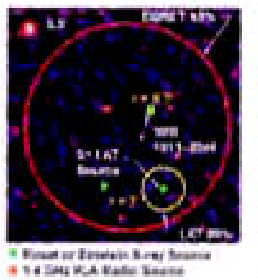






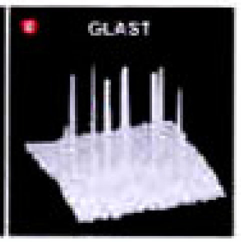
(a) Sensitivities of γ-ray experiments operating and accepted.
(b) LAT provides measurement of Crab unpulsed flux from below 100 MeV to ~1 TeV.
(c) & (d) Simulations showing SNR γ-Cygni spatially and spectrally resolved.
(e) LAT will measure diffuse quiescent emission and spectral transitions to flaring states. Example: LAT should detect low state emission from Mrk 501.

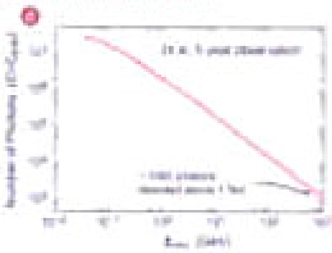
2. Resolving the γ-ray Sky: Unidentified Sources & Diffuse Emission



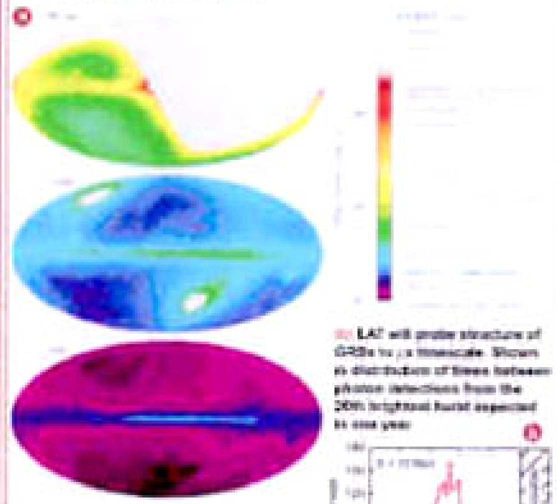
• Rosat or Einstein X-ray Source
• 1.4 GHz VLA Radio Source

(a) LAT 95% confidence radii localizations of a 5σ source in the one-year sky survey and of the EGRET source 3EG 1911-2000.
(b) & (c) Comparison of EGRET and LAT simulated observations of the Cygnus region E>1 GeV (10°×10°).
(d) Expected number of isotropic extragalactic photons detected by LAT after 5 years.
(e) LAT will map the cosmic-ray distribution in other galaxies. Shown is a simulated observation of M31 with the optical image for scale.



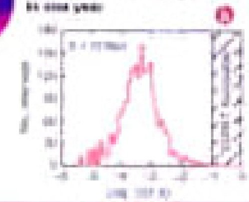


3. High Energy Behavior of γ-ray Bursts & Transients

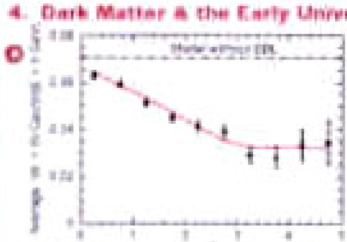


(a) In scanning mode LAT will achieve after one day a sensitivity sufficient to detect (5σ) the weakest EGRET sources.

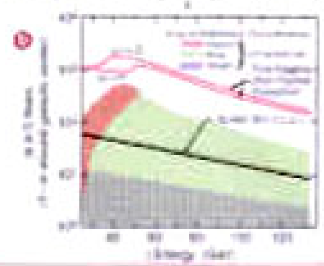
(b) LAT will probe structure of GRBs to μs timescale. Shown is distribution of times between photon detections from the 20th brightest burst expected in one year.



4. Dark Matter & the Early Universe



(a) LAT probes optical-UV Extragalactic Background Light by measurement of high-energy spectral roll-offs of AGN. Shown is simulation of ratio of integrated flux above 10 GeV to that above 1 GeV as function of redshift for EBL absorption model of Stecker et al. 1996.



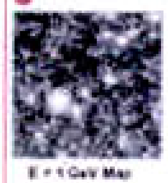
(b) LAT monoenergetic γ "line" sensitivity (95 % CL/UL) vs E. Colored areas are a range of MSSMs within a restricted parameter space from standard assumptions and thermal relic abundance calculations. Red lines are rates assuming a non-thermal origin with Higgsino accounting for the bulk of the Galactic

Key Features of the Instrument Enable an Exciting Science Program:

- Peak Effective Area: 12,900 cm²
- Precision Point Spread Function (0.15° for E > 10 GeV with a large and distinguishable subset of events with 0.074°)
- Excellent Background Rejection: 2.5 x 10⁵:1
- Good Energy Resolution for all Photons
- Discovery Reach Extends to TeV Energies

5. Extensive LAT Catalog

Sources from Simulated One Year All-sky Survey



E > 1 GeV Map

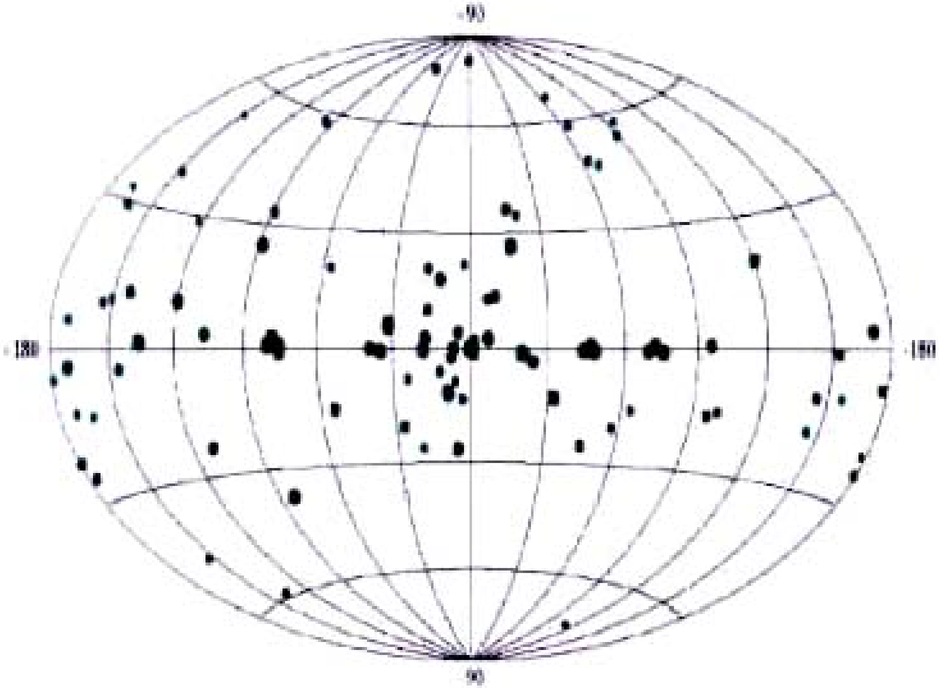
• AGN • Galactic Halo
• 3EG Catalog • Galactic Plane

Results of one year all-sky survey (Total 9000 sources)

Simulated LAT One Year All-sky map (E > 100 MeV)

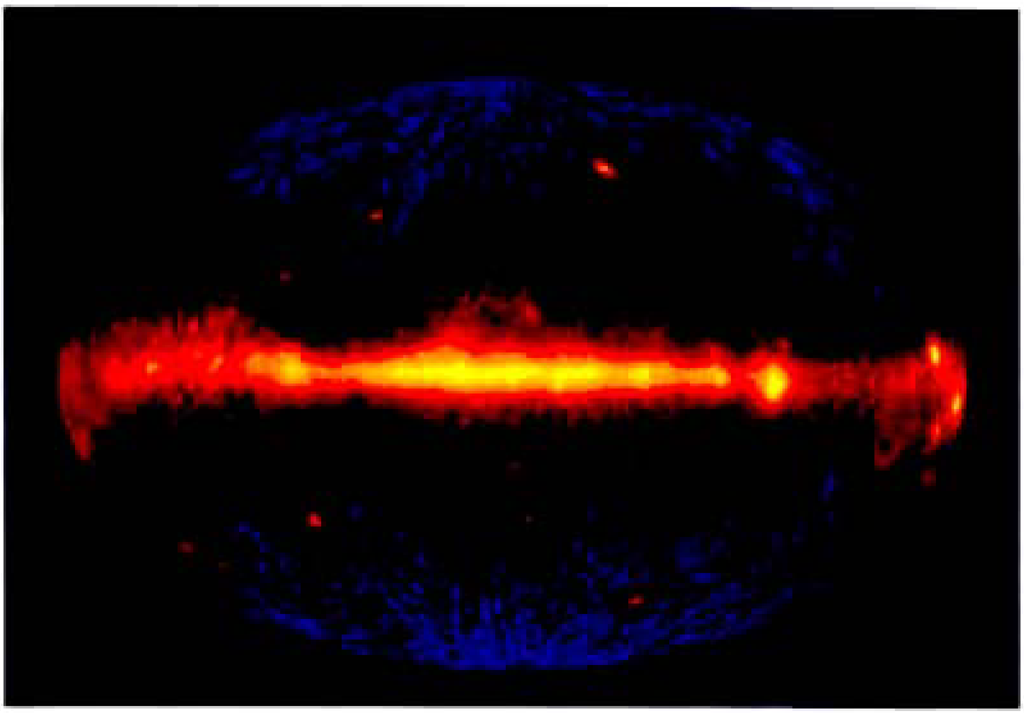
High-Energy Gamma-Rays
UNIDENTIFIED SOURCES

Unidentified EGRET Sources, E > 100 MeV



- Mistery of unidentified sources
- New Physics?

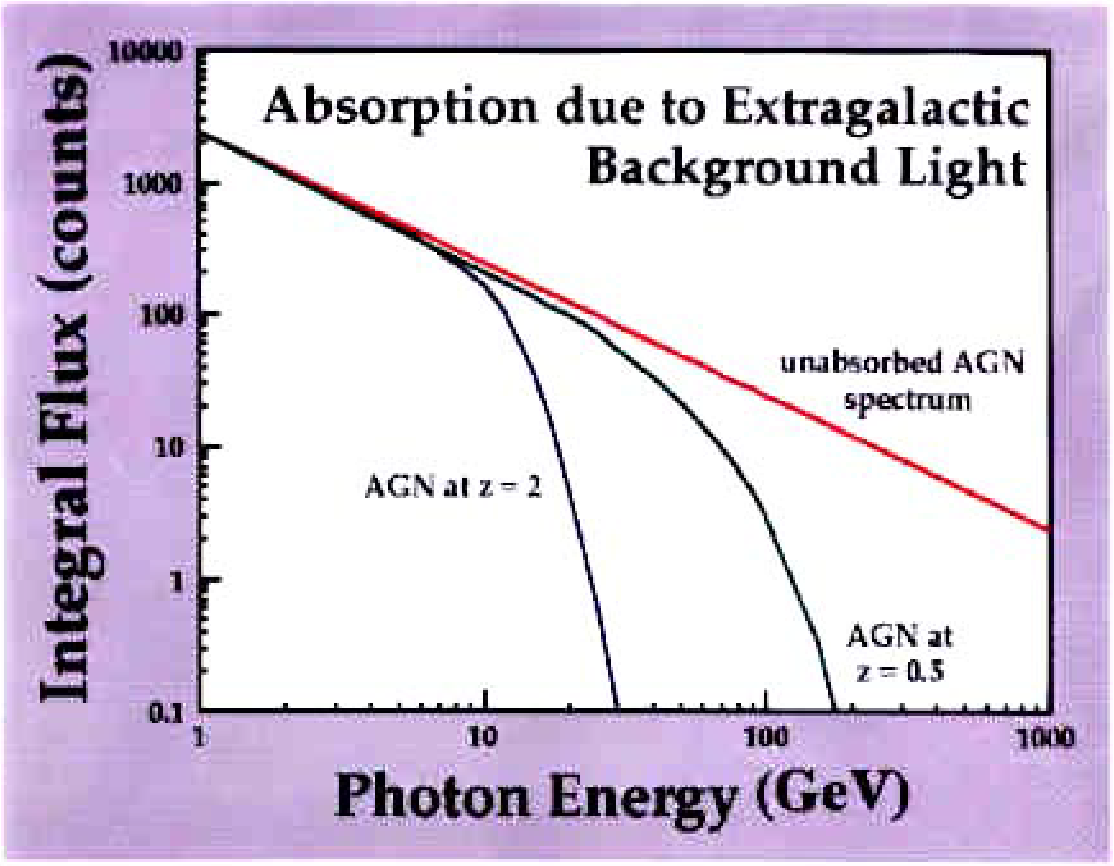
High-Energy Gamma-Rays
DIFFUSE BACKGROUND



- Origin and distribution of Galactic Cosmic Rays
- Extragalactic Gamma-Ray Background?

Cosmology

GLAST measurements of the spectral cutoffs of high-redshift (up to z = 4) active galactic nuclei (AGN) in the 10 GeV to ~100 GeV range will probe the extragalactic background light (EBL) produced by galaxies undergoing starbursts during the epoch of galaxy formation. The absorption of high-energy gamma rays occurs over cosmological distances via interactions with the near-ultraviolet, optical and near-infrared photons that make up the EBL. Determination of the EBL can provide unique information on the formation of galaxies at early epochs, and will test models for structure formation in the Universe, such as those in which a neutrino mass of 5 to 10 eV plays an important role.



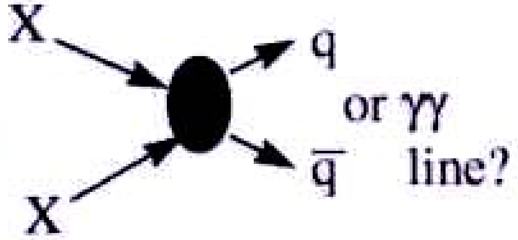
High-energy gamma rays emitted by distant AGN can interact with EBL photons before they have a chance to reach us. Shown above is how an unabsorbed AGN spectrum would appear if observed at redshifts of z = 0.5 and 2 for a particular EBL model. GLAST observations of the high-energy spectra for a large sample of AGN at various redshifts will map out the EBL.

If the cosmic gamma-ray bursts come from sources at cosmological distances, then, as mentioned on page 6, GLAST measurements of the spectra of bursts at various redshifts will also further the study of cosmic chemical evolution, assuming that host galaxies can be identified from which to measure redshifts.

WIMP annihilations

Good particle physics candidate for galactic halo dark matter is the LSP in R-parity conserving SUSY

If true, there may well be observable halo annihilations



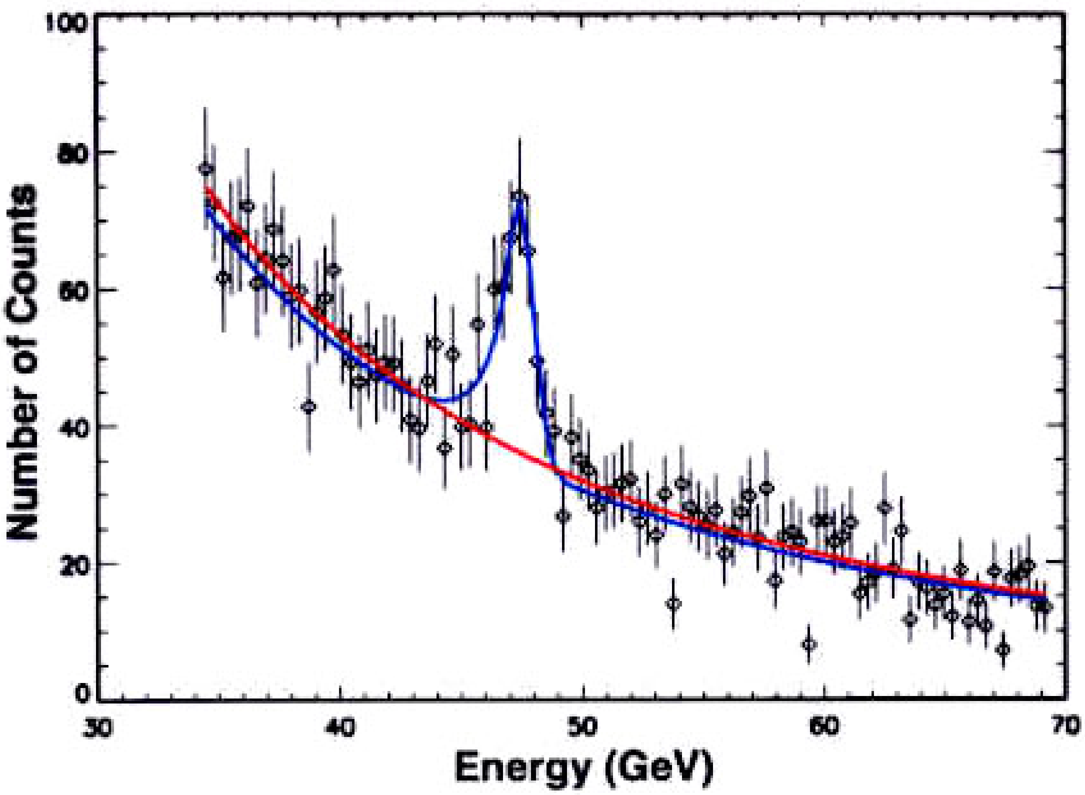
Example: X is $\tilde{\chi}^0$ from SUSY.

annihilations to jets, producing an extra component of multi-GeV γ flux that follows halo density (not isotropic) peaking at ~ 0.1 M χ^0 or lines at M χ^0

recent review: see Jungman, Kamionkowski, & Greist, Phys. Rep. [Ellis, Flores, Freese, Ritz, Seckel, Silk (1988)]

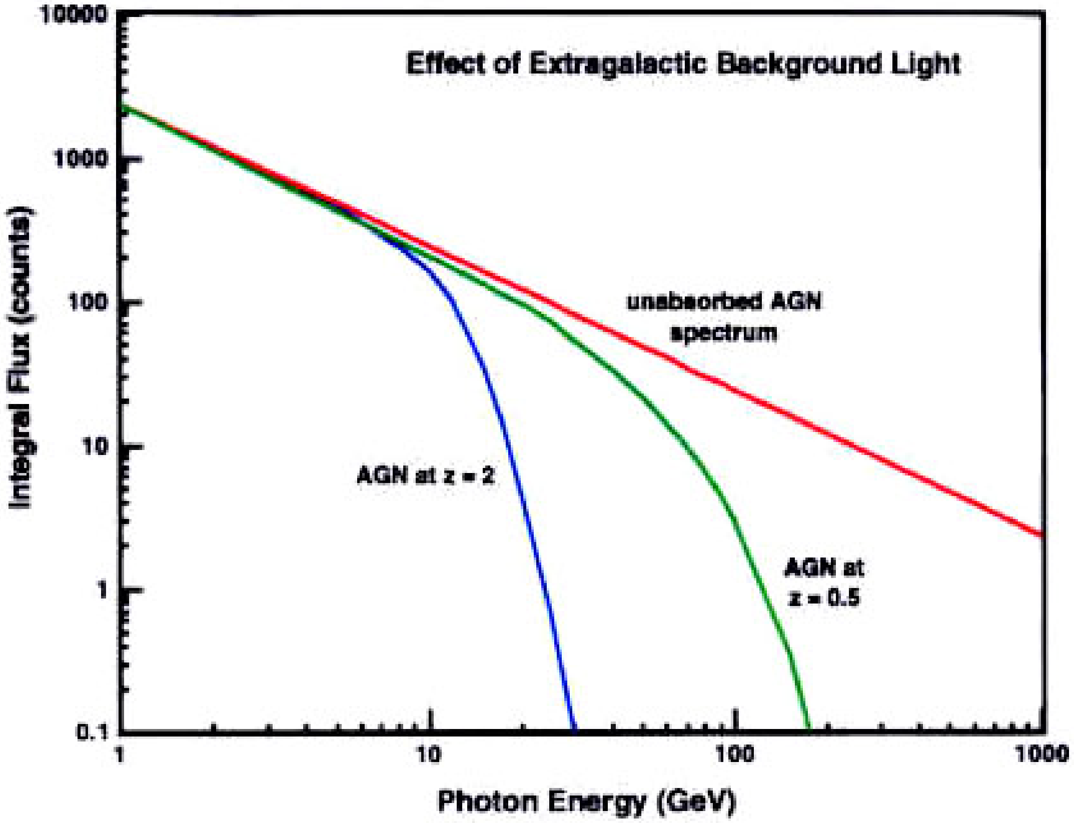
Although calculation for γ-rays is less uncertain than for other signals (multi-GeV antiprotons, positrons) a null result will not likely constrain parameter space.
If SUSY uncovered at accelerators, GLAST may be able to determine its cosmological significance quickly.

GLAST e la Cosmologia

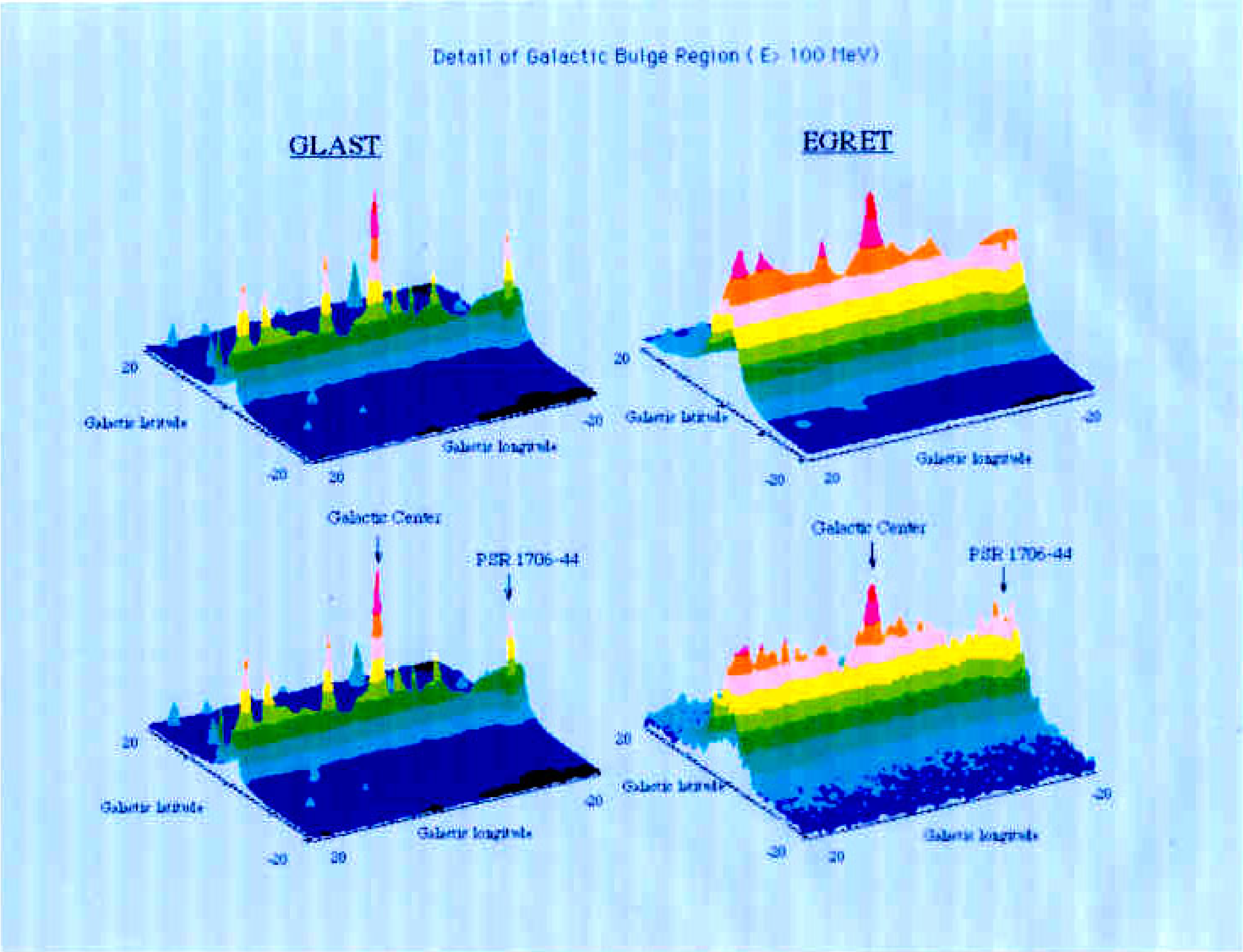


- Osservazione di linee gamma da annichilazione di materia oscura non barionica

GLAST e la Cosmologia



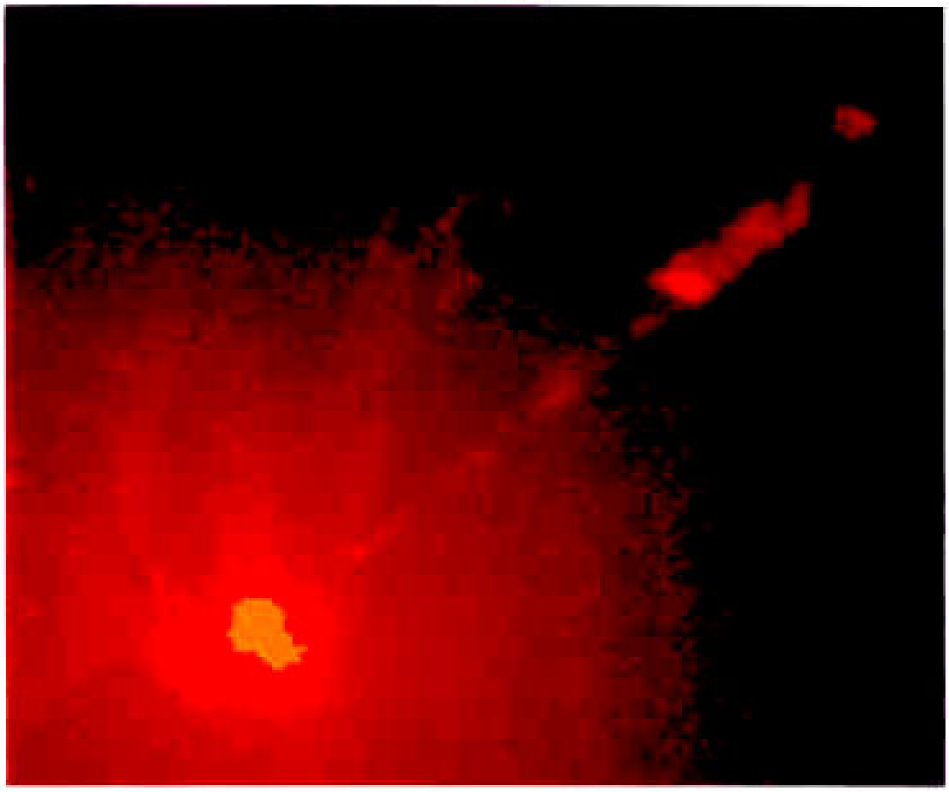
- Studio della EBL in funzione di z attraverso l'analisi dei cutoff spettrali degli AGN
- EBL prodotta dalle *Starburst Galaxies*



Detail of Galactic Bulge Region (E> 100 MeV)
GLAST
EGRET
20
Galactic latitude
-20
Galactic longitude
-20
20
Galactic Center
PSR 1706-44

High-Energy Gamma-Rays

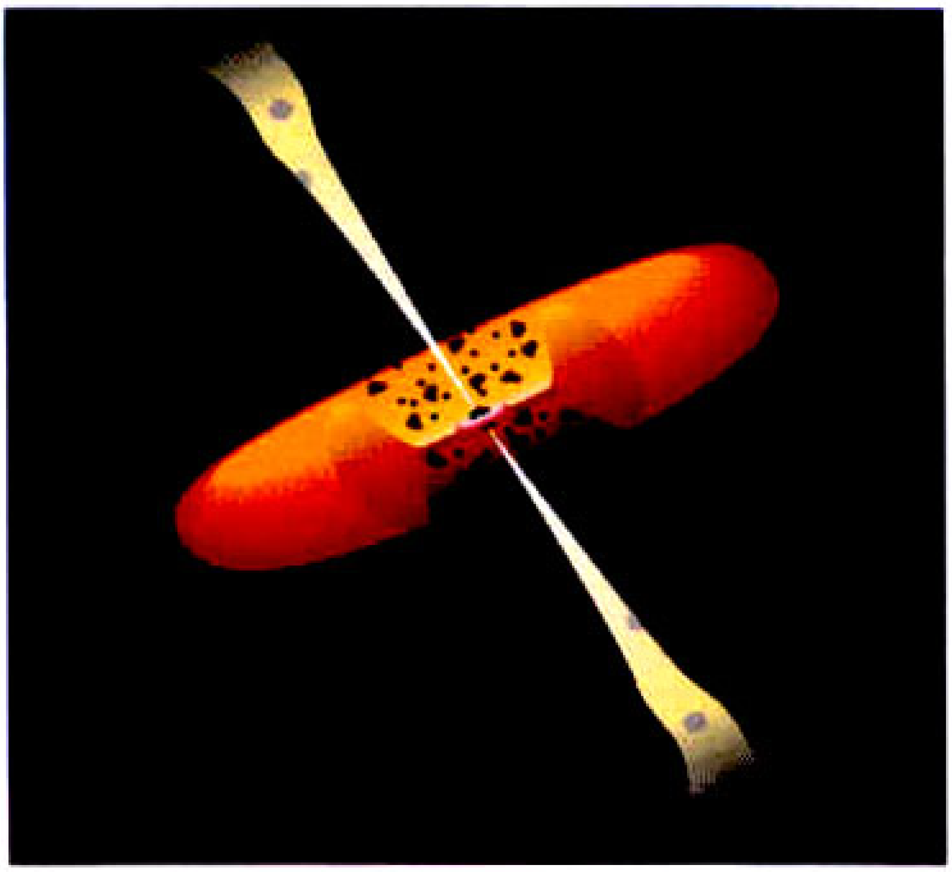
AGN



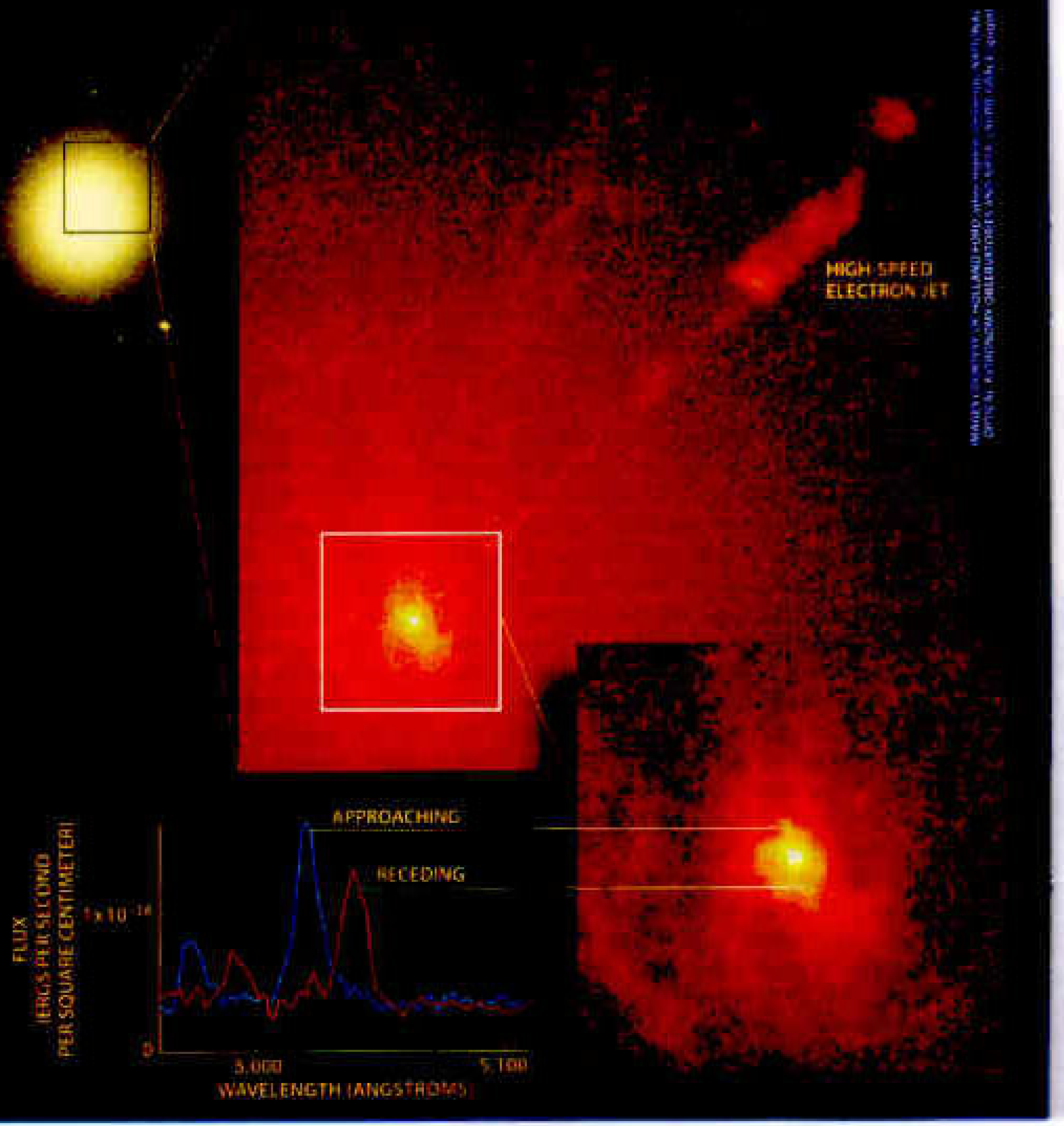
- EGRET Observations of 70 high variable AGN (Blazars)
- What is broad-band emission mechanism in AGNs?
- What are the physical processes in AGN jets?

High-Energy Gamma-Rays

AGN



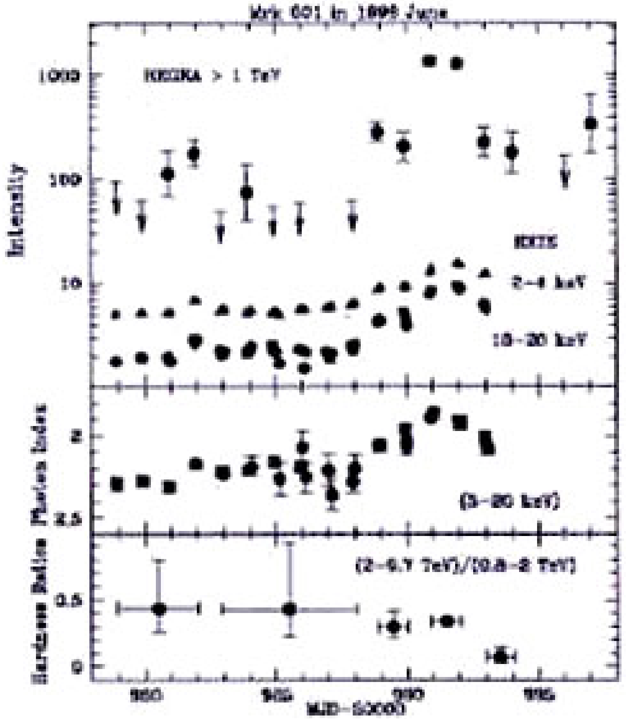
- Vast amount of energy from a very compact central volume
- Accretion onto Supermassive Black Holes (10^6- 10^{10} $M_\odot$)

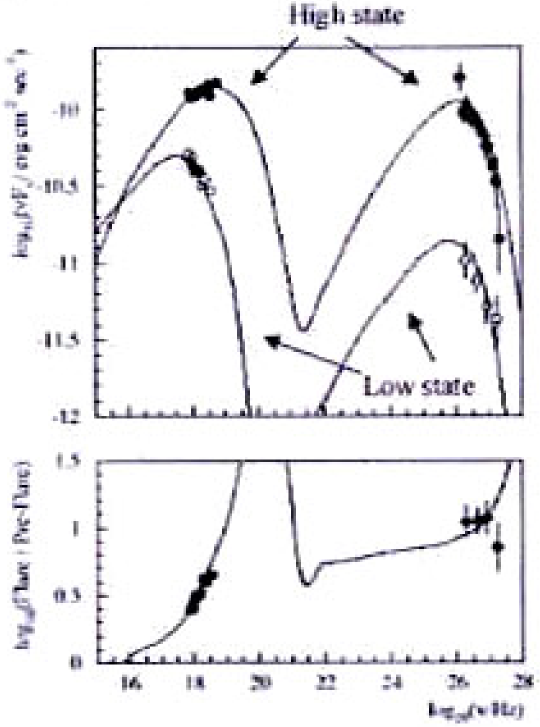


The Remains of a Quasar?

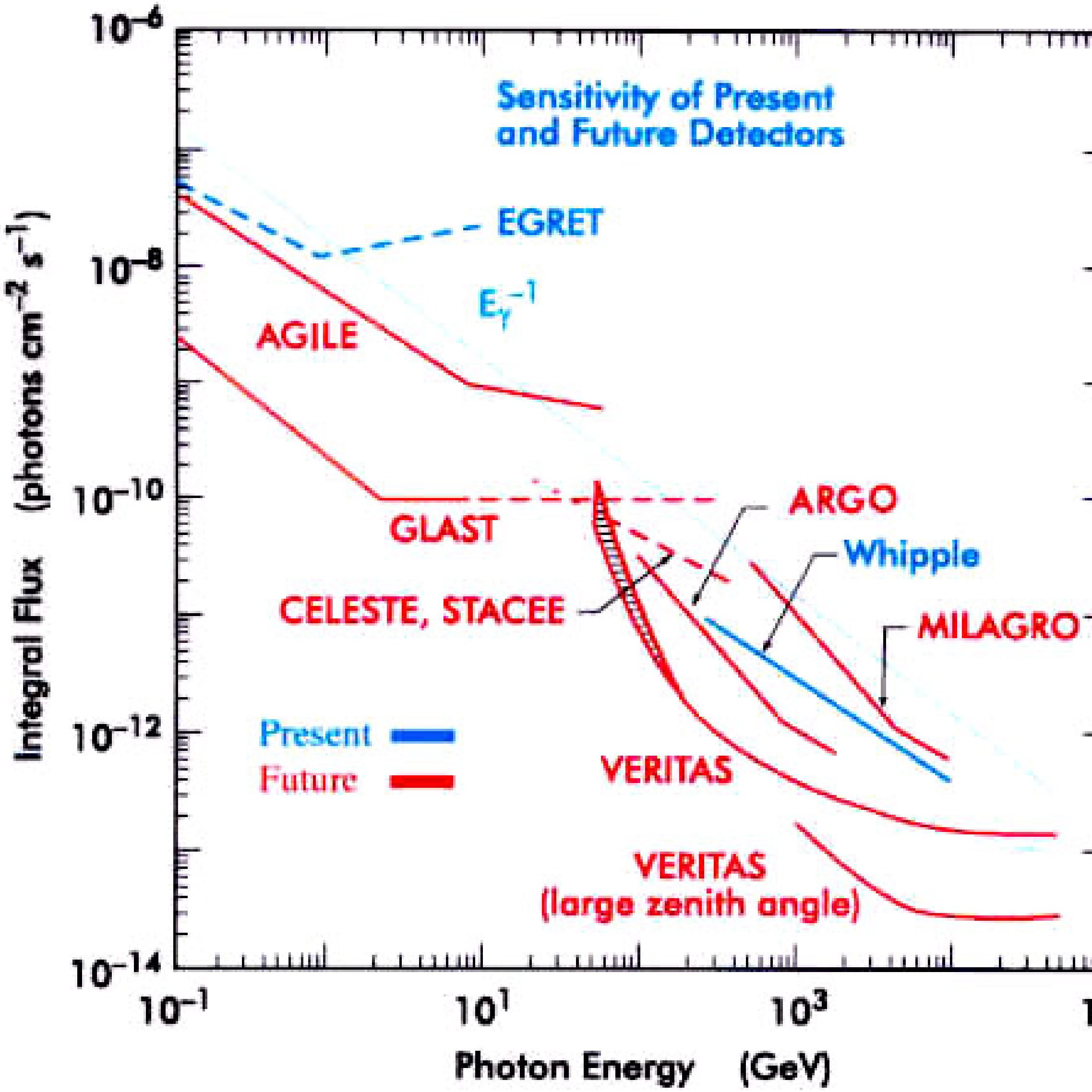
The active nucleus of M87, a giant elliptical galaxy in the Virgo cluster (*above*), may once have been a quasar. Astronomers trained the Hubble Space Telescope's Faint Object Spectrograph at the core of M87, which emits a jet of high-speed electrons. Because the light from one side of the nucleus was blueshifted and the light from the other side was redshifted (*right*), astronomers concluded that a disk of hot gas was spinning around the center of the galaxy at 550 kilometers per second (1.2 million miles per hour). The high velocity indicated the presence of a massive black hole, which may have powered a quasar billions of years ago. —*M.D.*

Multiwavelenght observation of Mrk 501 in June 98





R. Sambruna et al., RXTE and Hegra, astro-ph 0002215



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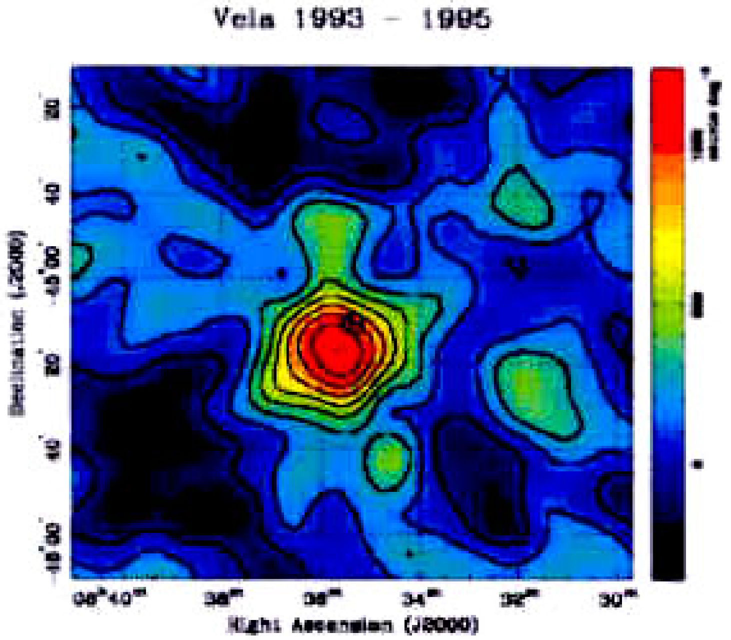
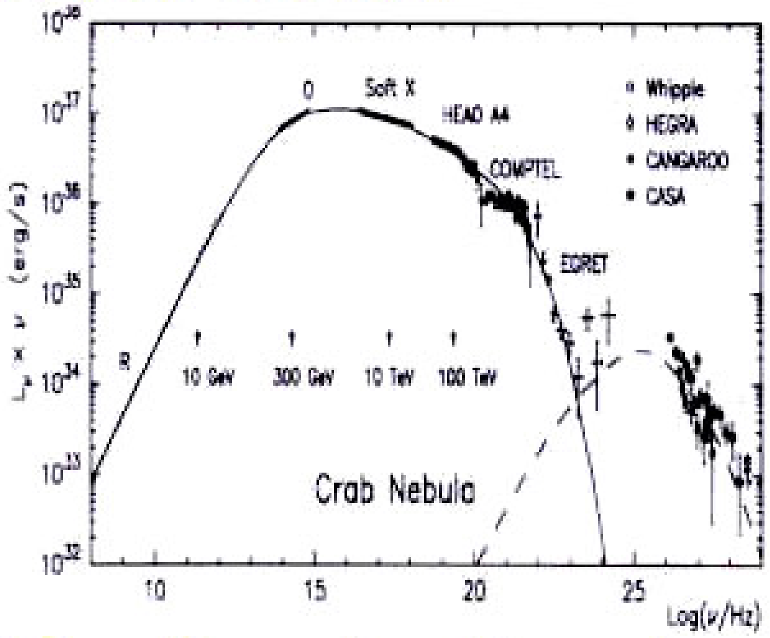
Very High-Energy Gamma-Rays

SNR



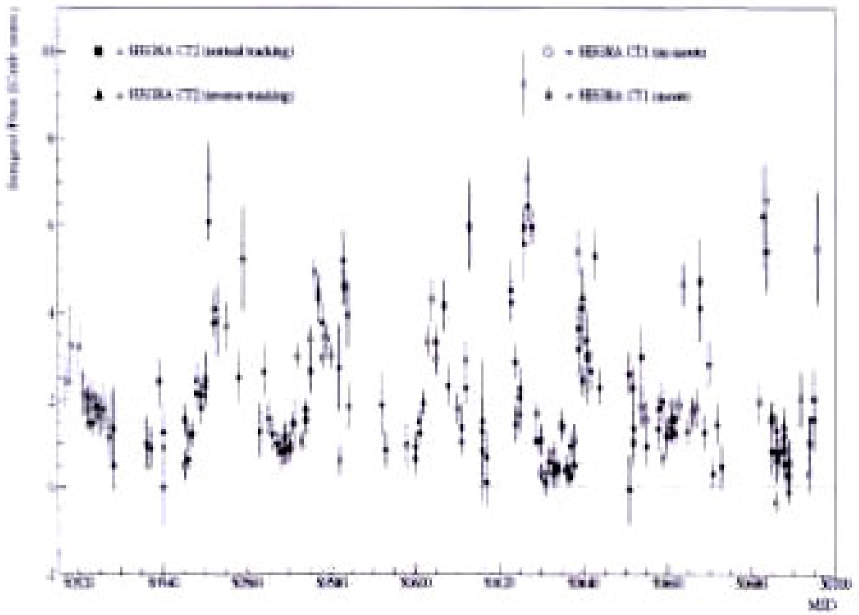
- Vela Pulsar detection



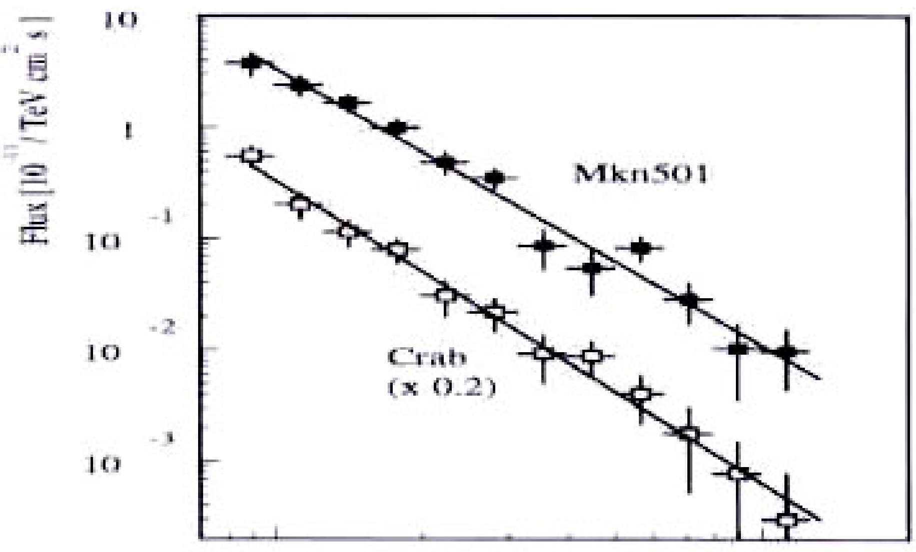
- CRAB multiwavelenght spectrum

Very High-Energy Gamma-Rays

Markarian 501



- Light Curve (1997)



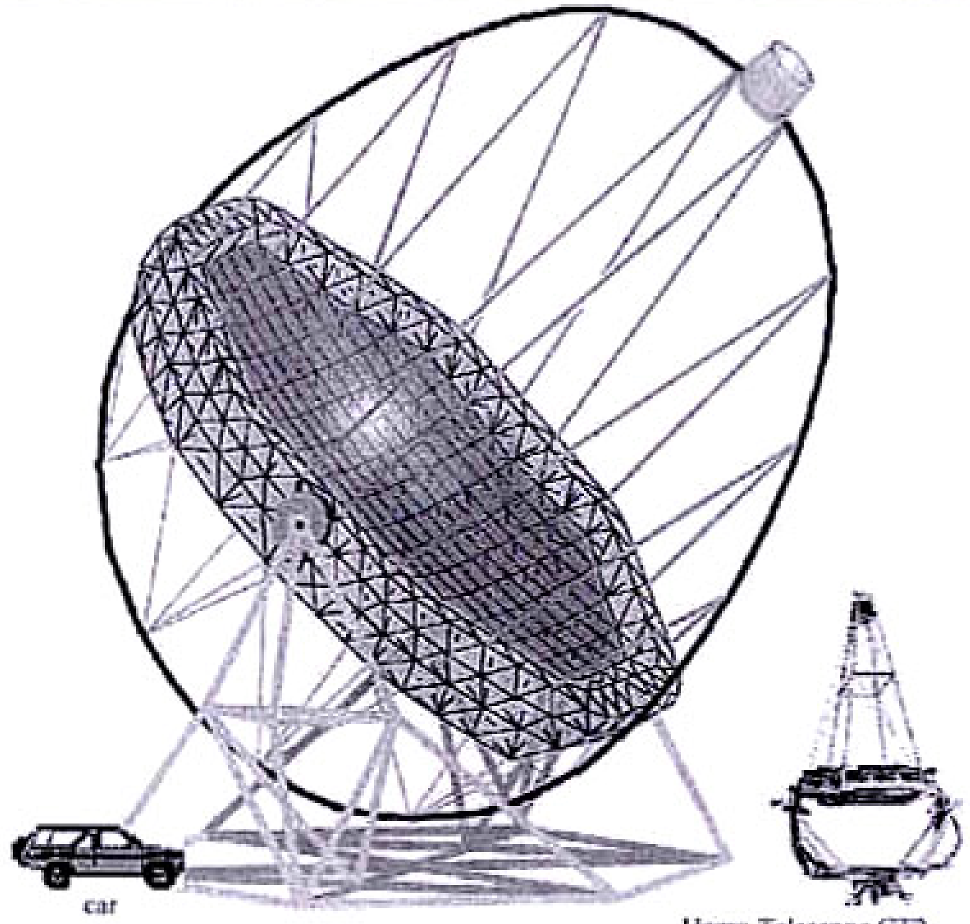
- Spectrum

High-Energy Gamma-Ray Detectors

- Ground Based Gamma-Ray Detectors
- Cherenkov Detectors
- Air Shower Detectors
- Energy Band ($\geq$ 500 GeV)

MAGIC

220 m² mirror area
E =10 GeV - 300 GeV
Location: La Palma
(Canary Islands)
Scheduled June 2001



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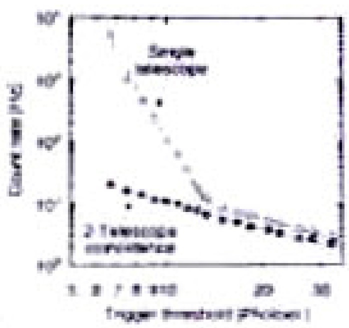
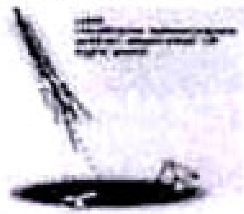
HESS Phase 2

four 110m^2 telescopes
Field of view 5 deg
Detection capability at E > 40 GeV
Spettroscopy at E > 100 GeV
Location: Namibia
Scheduled 2002

(artistic composition)
(not yet real !)

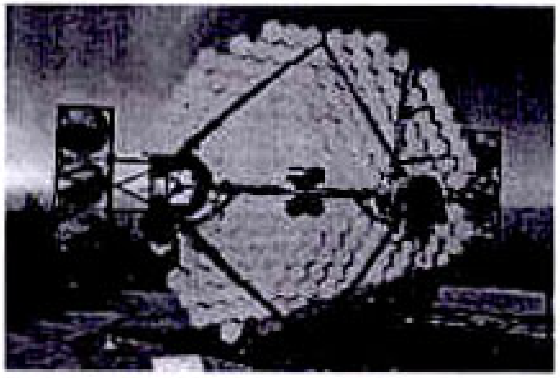
Night-sky background light





Veritas

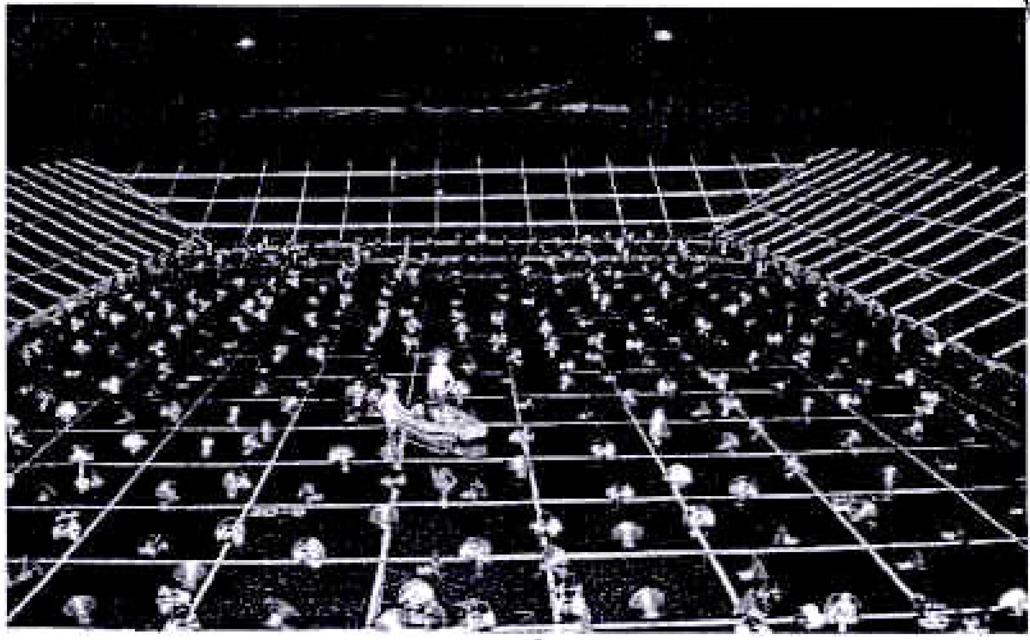
7 Whipple like 10 m^2 telescopes
E = 50 GeV -50TeV
Location: southern Arizona
Scheduled 2005



Whipple

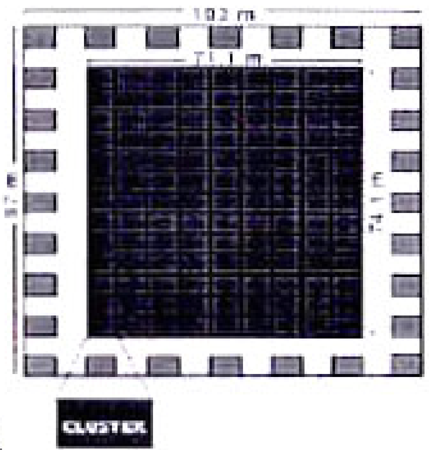
MILAGRO

Area 5000 m^2
Field of view ~ 1 sr
E = 250 GeV - 50 TeV
Location: New Mexico 2600m alt.
Started June '99



ARGO

Area 5.200 m^2 (full coverage)
(10.000 m^2 with guard ring)
Field of view ~ 1 sr
E = 50 GeV - 50 TeV
Location: Tibet 4300m alt.
Scheduled 2002 (final conf.)



17400 Pads 56 by 60 cm^2 each of Resistive Plate Chamber (RPC).
Each pad subdivided in pick-up strips 6 cm wide for the space pattern inside the pad.
The CLUSTER is made of 12 RPCs Pads.

"Solar Farm" Cerenkov gamma ray telescope concept

CELESTE

Location: Thémis , France

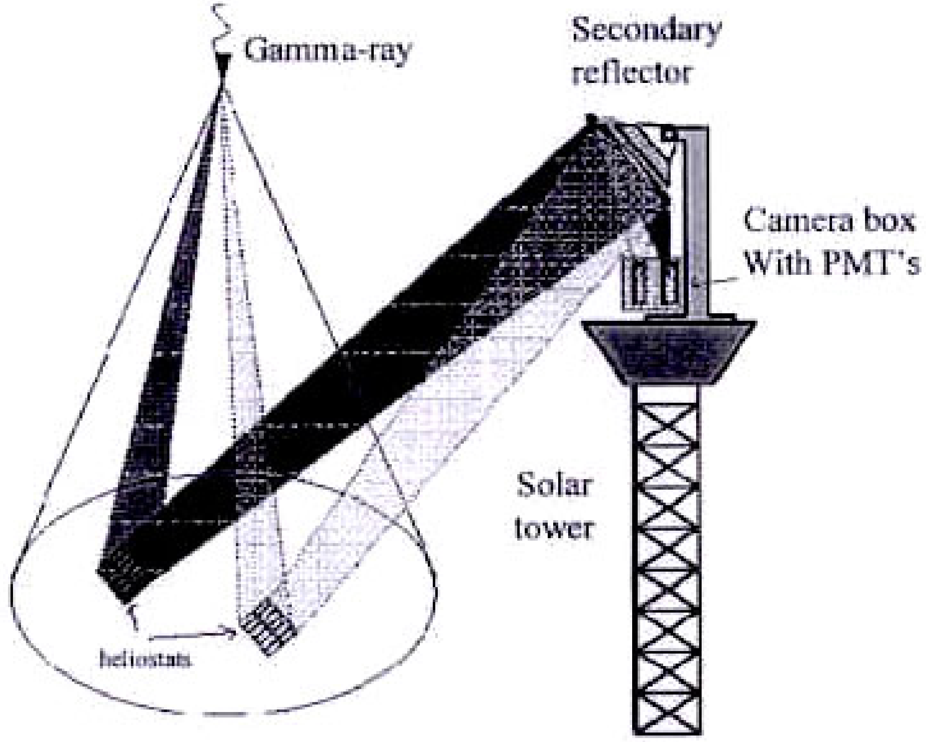
STACEE

Location: Albuquerque

~40 m^2 mirror area

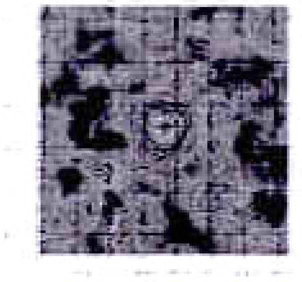
E =20 GeV - 200 GeV

Schedule: in test

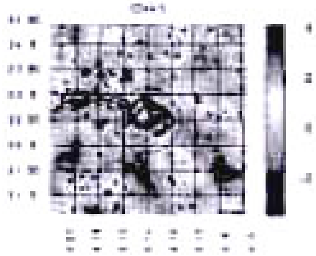


Whipple

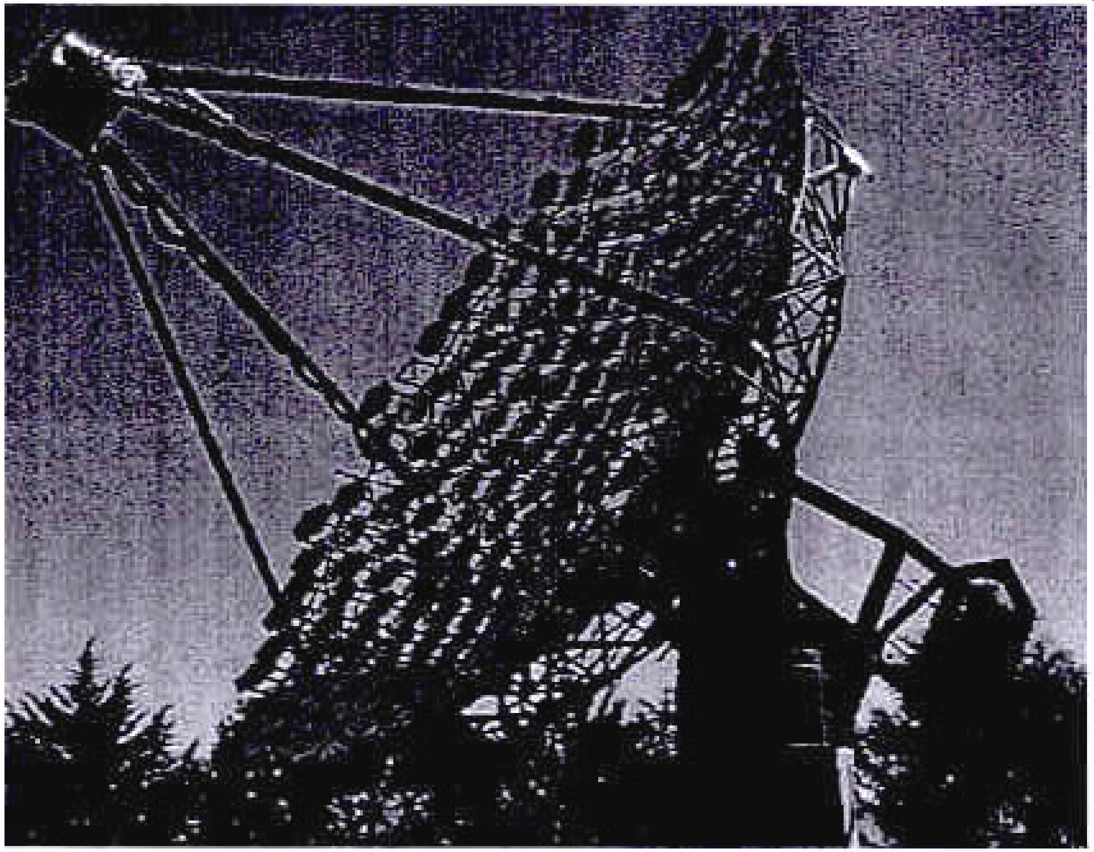
10 m^2 telescopes
E = >350 GeV
Location: Mt Hopkins
in operation



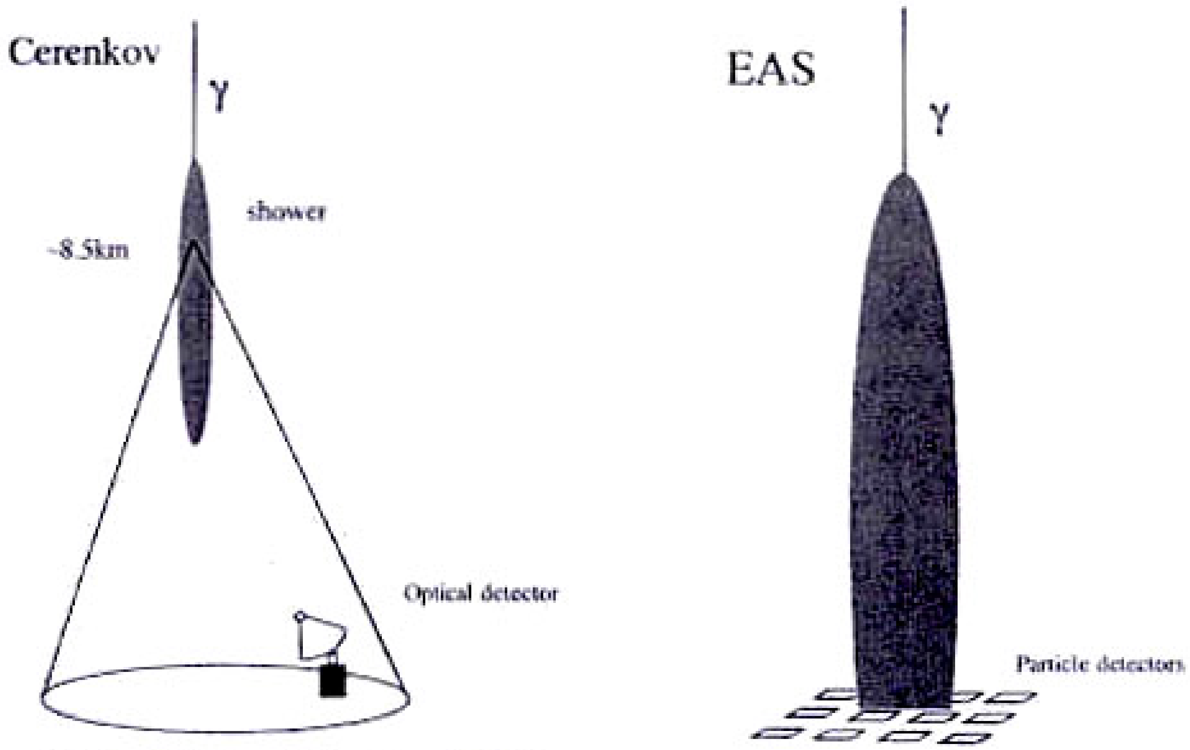
MHK501



Supernova remnants



Cerenkov and Extensive air shower (EAS) gamma ray telescope concepts



~ 40,000 m^2 , but no anticoincidence shield !

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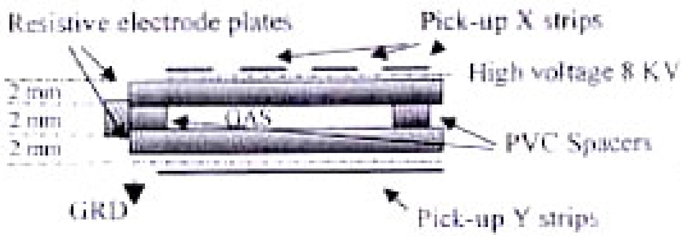
ARGO

Test Carpet in Tibet



The detector structure

Longitudinal development of the electron component of photon initiated shower
(with electron threshold energy of 5 MeV and fluctuations superimposed)