# Astrofisica Nucleare e Subnucleare

## Gamma ray Bursts – I

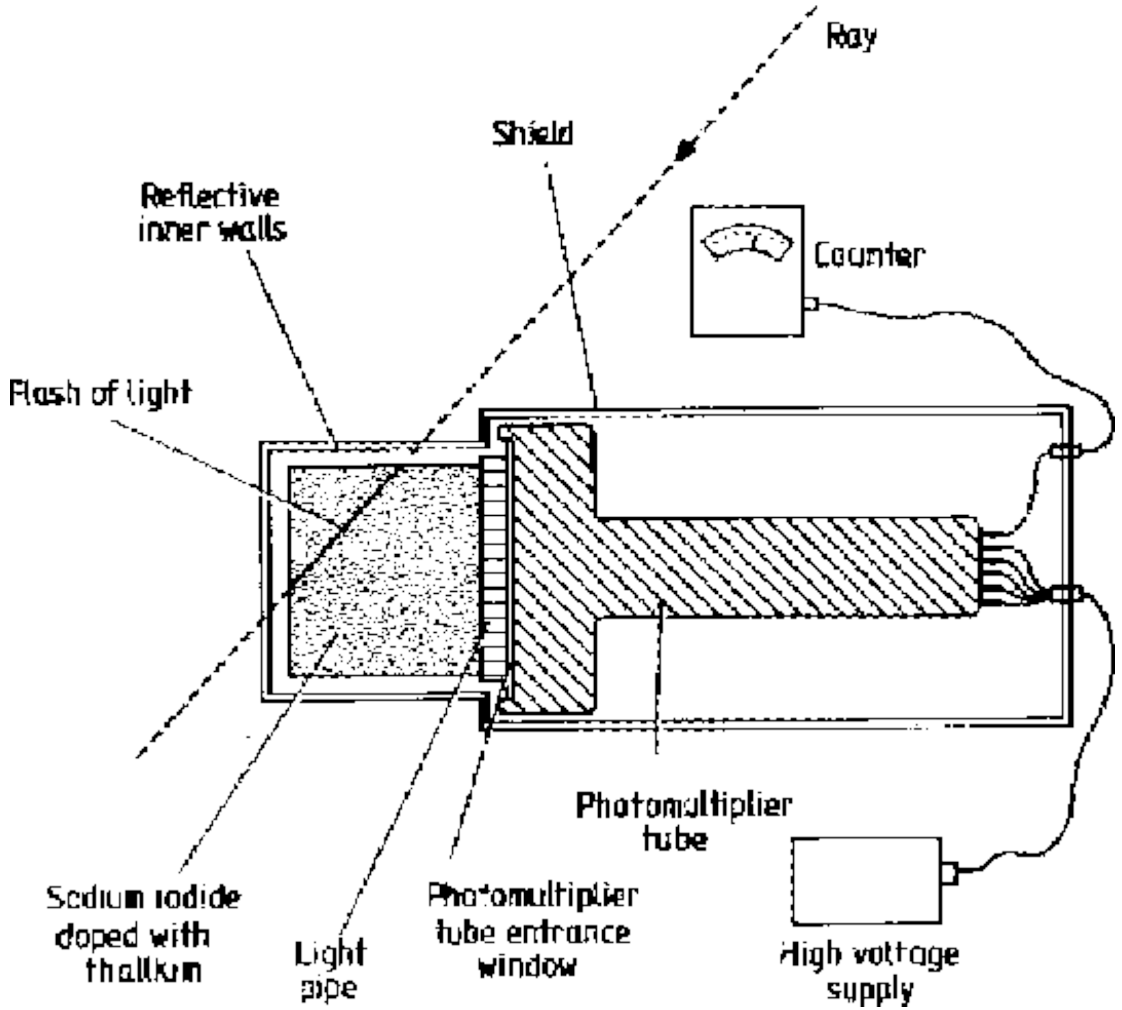
# Exercise #2

- Find the web sites of BATSE (?), Fermi/ GBM and Swift

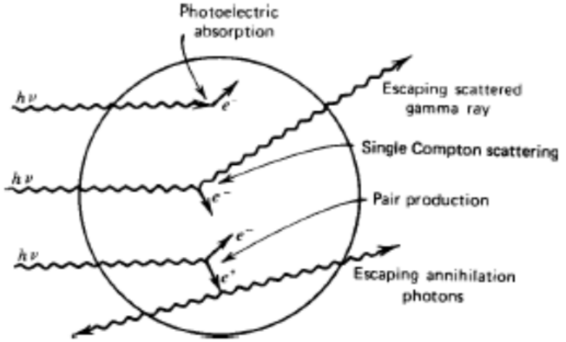
# Review on GRB

- Gamma-ray bursts and Population III stars (2016)
- Gamma-ray bursts at the High and Very High Energies (2015)
- Gamma-Ray Bursts as Sources of Strong Magnetic Fields (2015)
- Physics of Prompt GRB emission (2015)
- Short duration GRBs (2014)
- GRB in the Swift Era (2009)
- Theories of GRBs (2002)

# Scintillator Detectors

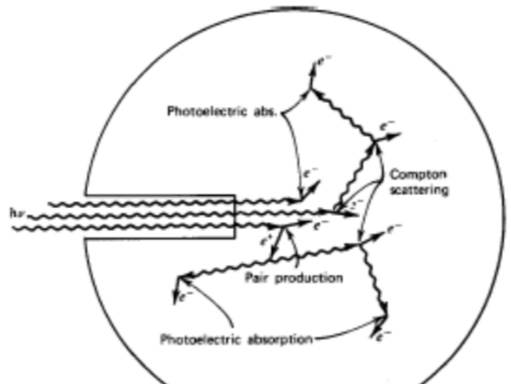


# Risposta del rivelatore - 1




Only single interactions take place

Figure 9: "Small" detector




Also secondary radiations interact within the detector active volume

Figure 10: "Large" detector

most of the “secondary products” remain in the detector

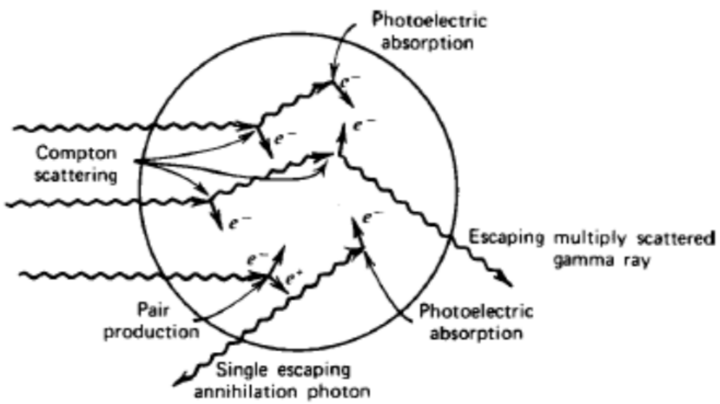



Figure 11: Intermediately sized detector

F. Knoll

# Risposta del rivelatore - 2

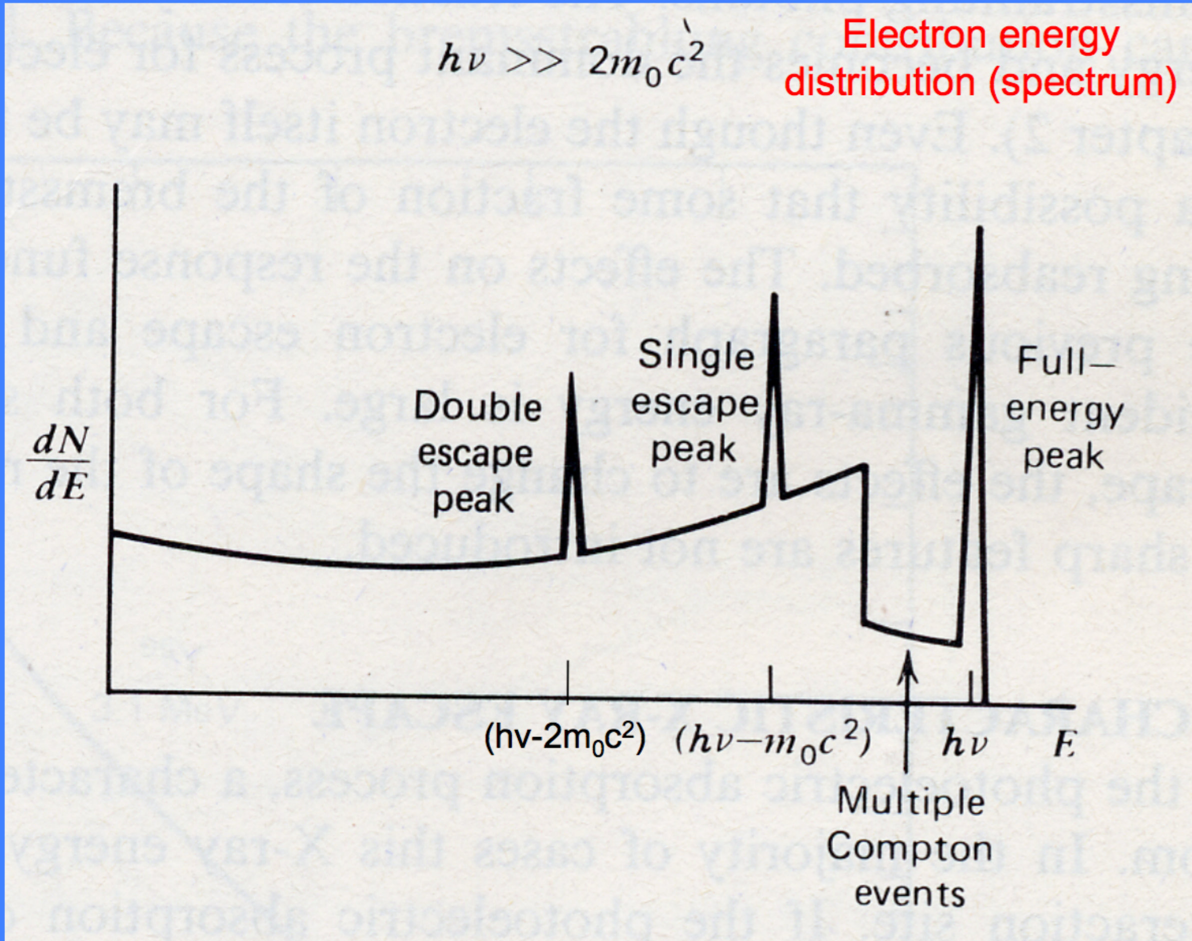


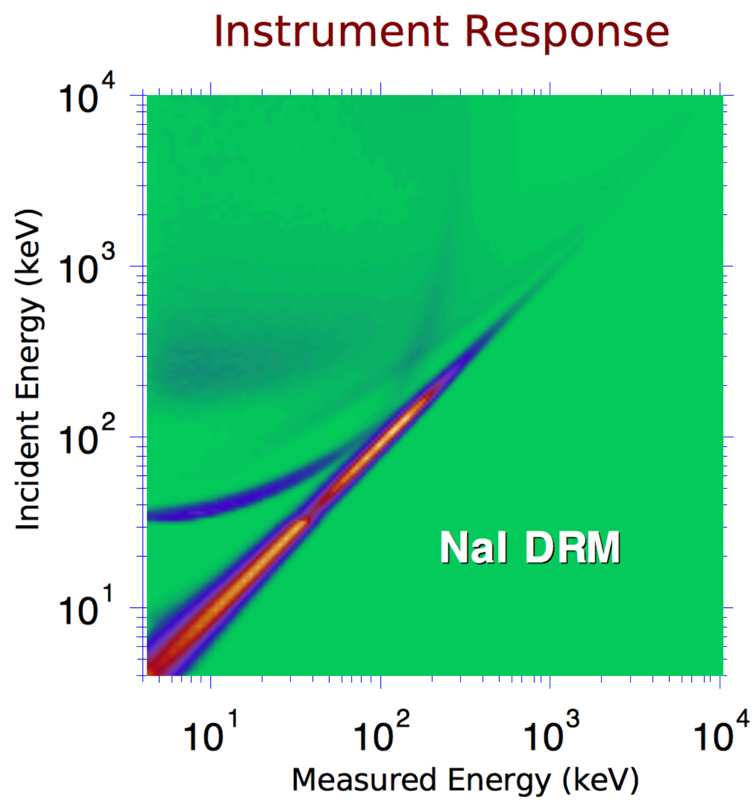

**Photo-peak (full-energy peak)**: all photoelectric events remain in the detector and produce an energy deposit at the energy of the incoming photon

**Single-escape peak**: one annihilation photon leaves the detector without further interaction

**Double-escape peak**: both annihilation photons leave the detector (escape)

Case of intermediate-size detector (Knoll)

# Detector Response Matrix




The response of a detector, which signal depends of the energy of an incoming photon, distributes the photon of a certain energy over many pulse height channels according to the gain and energy resolution of the detector. Usually this resolution function is relative complicated and depends on the photon energy. Since the energy acceptance and resolution of a given detector is determined by its design it is convenient to table this function while the photon energy serves as a parameter. This procedure leads directly to a form of a matrix and gives the whole data set the name *detector response matrix*.

# GRB history

THE ASTROPHYSICAL JOURNAL, **182**:L85–L88, 1973 June 1


OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

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*Received 1973 March 16; revised 1973 April 2*

ABSTRACT

Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to ~30 s, and time-integrated flux densities from $\sim 10^{-5}$ ergs $cm^{-2}$ to $\sim 2 \times 10^{-4}$ ergs $cm^{-2}$ in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.

*Subject headings:* gamma rays — X-rays — variable stars

I. INTRODUCTION

On several occasions in the past we have searched the records of data from early *Vela* spacecraft for indications of gamma-ray fluxes near the times of appearance of supernovae. These searches proved uniformly fruitless. Specific predictions of gamma-ray emission during the initial stages of the development of supernovae have since been made by Colgate (1968). Also, more recent Vela spacecraft are equipped with much improved instrumentation. This encouraged a more general search, not restricted to specific time periods. The search covered data acquired with almost continuous coverage between 1969 July and 1972 July, yielding records of 16 gamma-ray bursts distributed throughout that period. Search criteria and some characteristics of the bursts are given below.

II. INSTRUMENTATION

The observations were made by detectors on the four *Vela* spacecraft, *Vela 5A, 5B, 6A,* and *6B,* which are arranged almost equally spaced in a circular orbit with a geocentric radius of $\sim 1.2 \times 10^5$ km.

On each spacecraft six 10 $cm^3$ CsI scintillation counters are so distributed as to achieve a nearly isotropic sensitivity. Individual detectors respond to energy depositions of 0.2–1.0 MeV for *Vela 5* spacecraft and 0.3–1.5 MeV for *Vela 6* spacecraft, with a detection efficiency ranging between 17 and 50 percent. The scintillators are shielded against direct penetration by electrons below ~0.75 MeV and protons below ~20 MeV. A high-*Z* shield attenuates photons with energy below that of the counting threshold. No active anticoincidence shielding is provided.

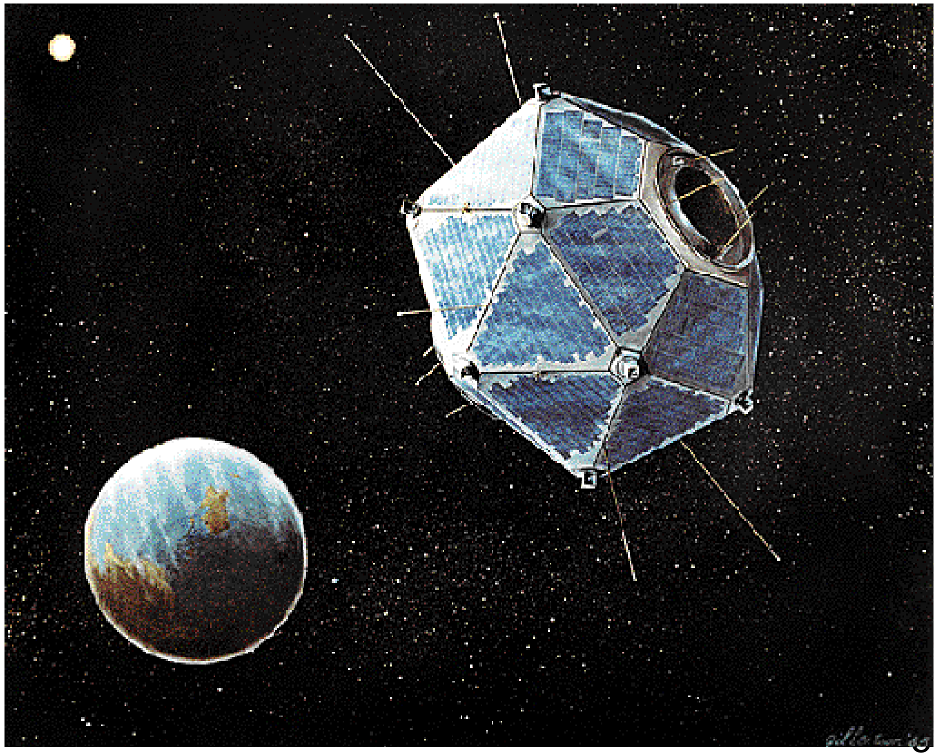
Normalized output pulses from the six detectors are summed into the counting and logics circuitry. Logical sensing of a rapid, statistically significant rise in count rate initiates the recording of discrete counts in a series of quasi-logarithmically increasing time intervals. This capability provides continuous coverage in time which, coupled with isotropic response, is unique in observatonal astronomy. A time measurement is also associated with each record.

The data accumulations include a background component due to cosmic particles and their secondary effects. The observed background rate, which is a function of the energy threshold, is ~150 counts per second for the *Vela 5* spacecraft and ~20 counts per second for the *Vela 6* spacecraft.

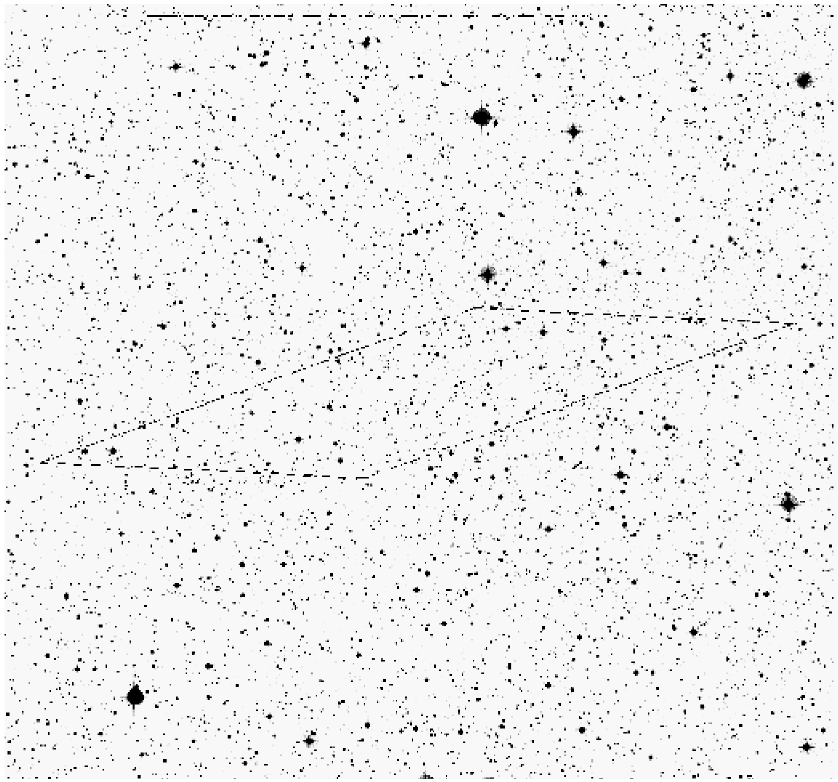
L85



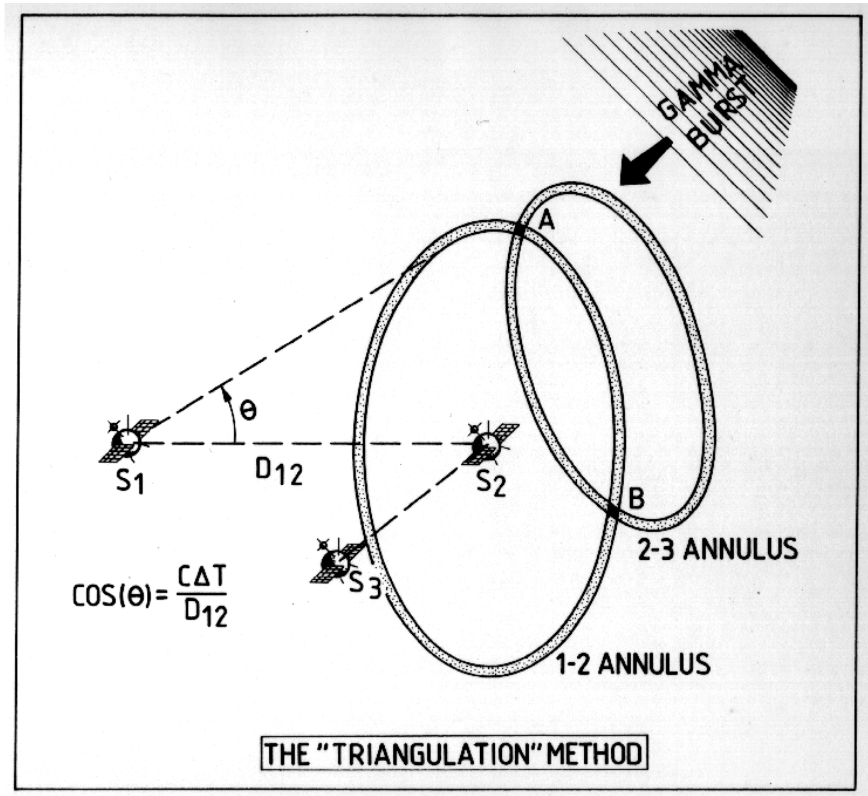
- Vela satellites discovery (1967 - 1973)



# GRB History



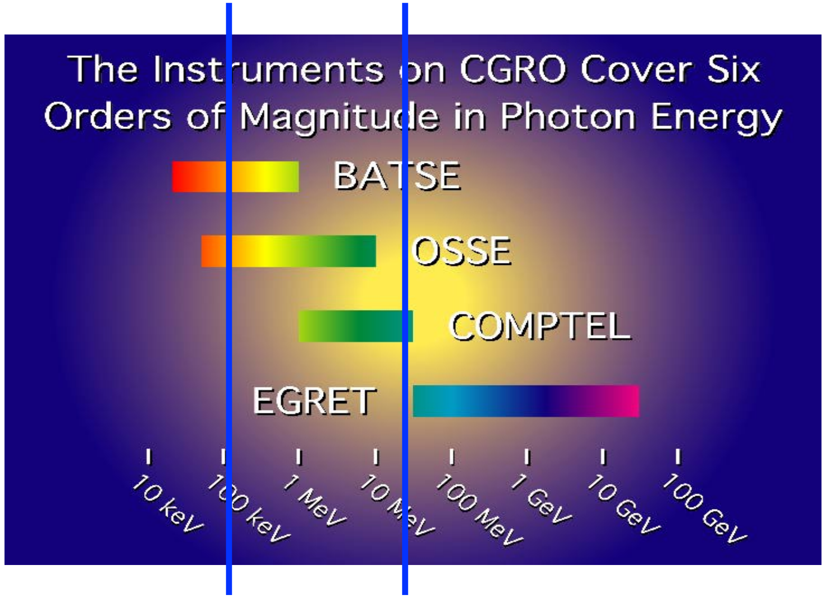
Interplanetary Network (IPN)



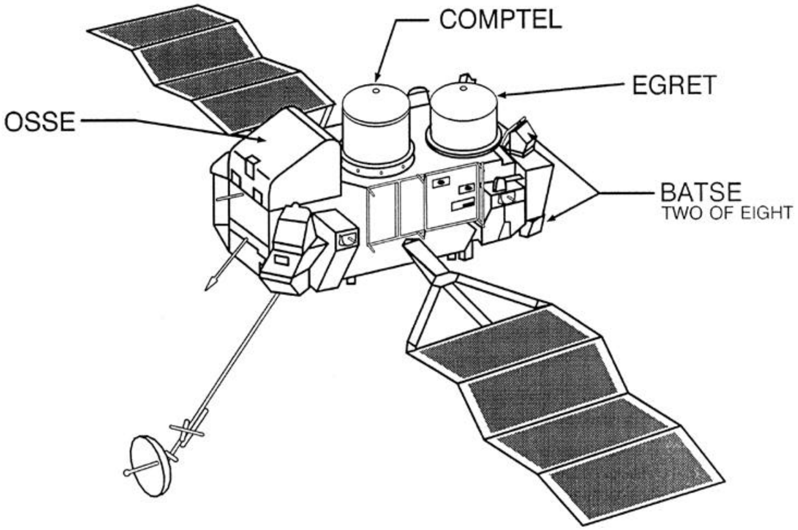

http://www.ssl.berkeley.edu/ipn3/

# The Compton Gamma Ray Observatory

http://cossc.gsfc.nasa.gov

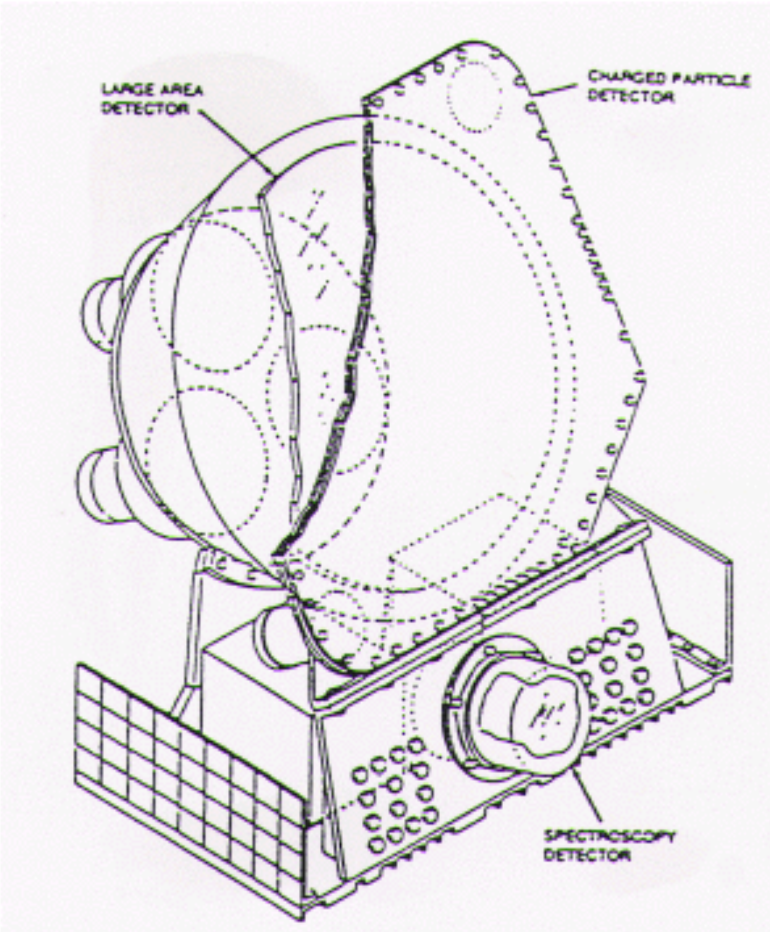



COMPTON OBSERVATORY INSTRUMENTS



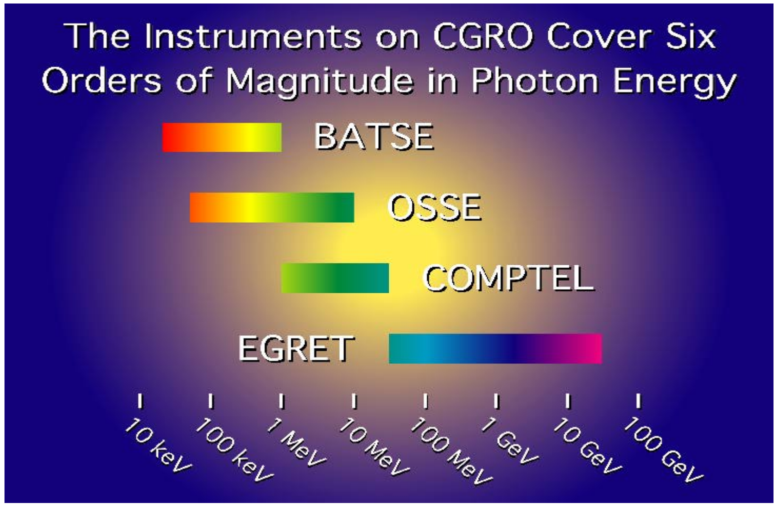

The Compton Gamma Ray Observatory (CGRO) is a sophisticated satellite observatory dedicated to observing the high-energy Universe. It is the second in NASA's program of orbiting "Great Observatories", following the Hubble Space Telescope.
While Hubble's instruments operate at visible and ultraviolet wavelengths, Compton carries a collection of four instruments which together can detect an unprecedented broad range of high-energy radiation called gamma rays. These instruments are the Burst And Transient Source Experiment (BATSE), the Oriented Scintillation Spectrometer Experiment (OSSE), the Imaging Compton Telescope (COMPTEL), and the Energetic Gamma Ray Experiment Telescope (EGRET).

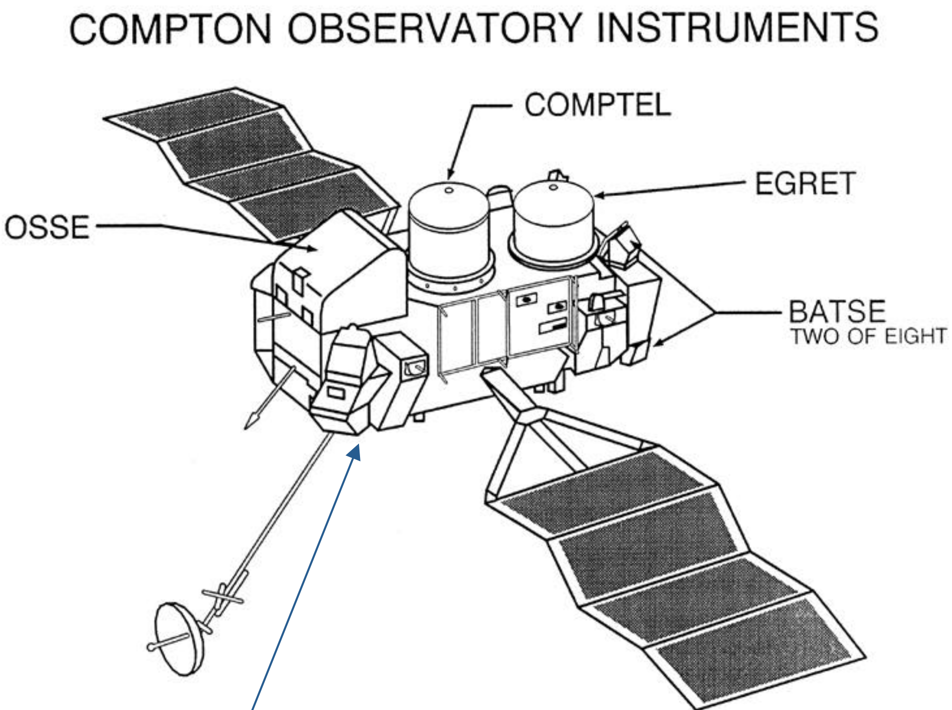
# The Compton Gamma Ray Observatory




BATSE
- 20 keV -10 MeV
- GRB, SGR, X-ray sources

# CGRO-BATSE (1991-2000)

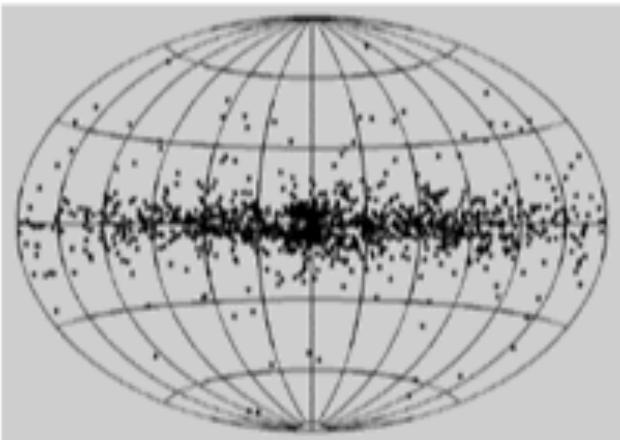


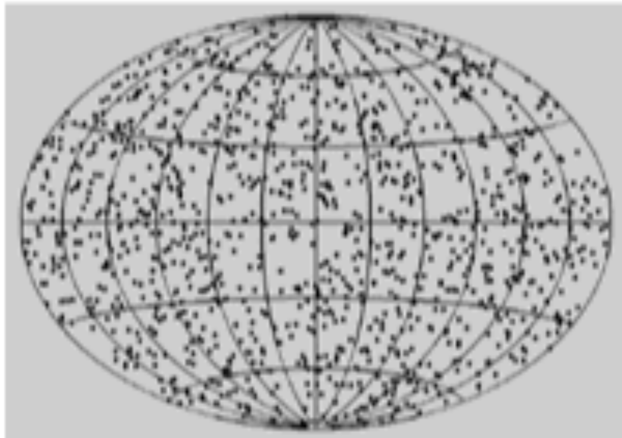

CGRO/BATSE (20 keV÷10 MeV)

# GRB history

Distribution of Gamma-Ray Bursts on the Sky



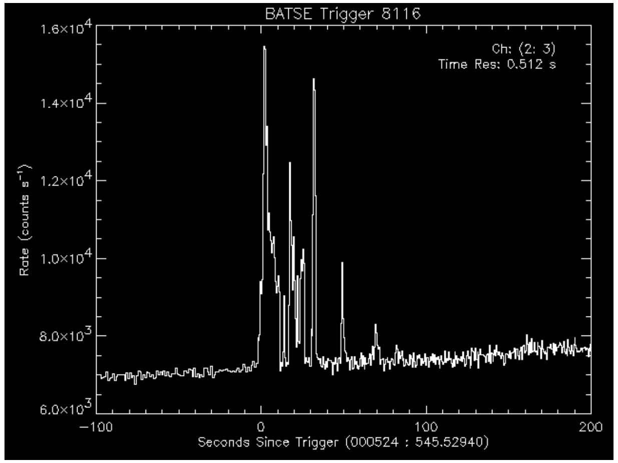
Expected



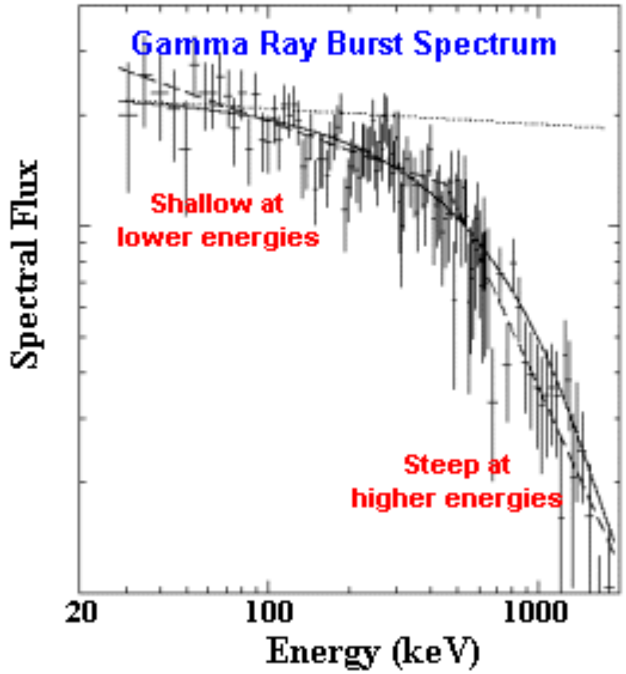
Observed

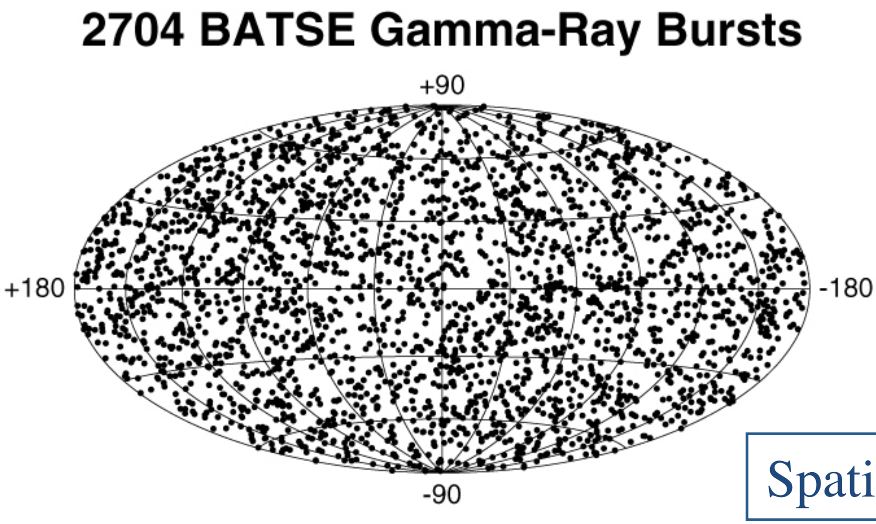
# Gamma-Ray Bursts

Temporal behaviour



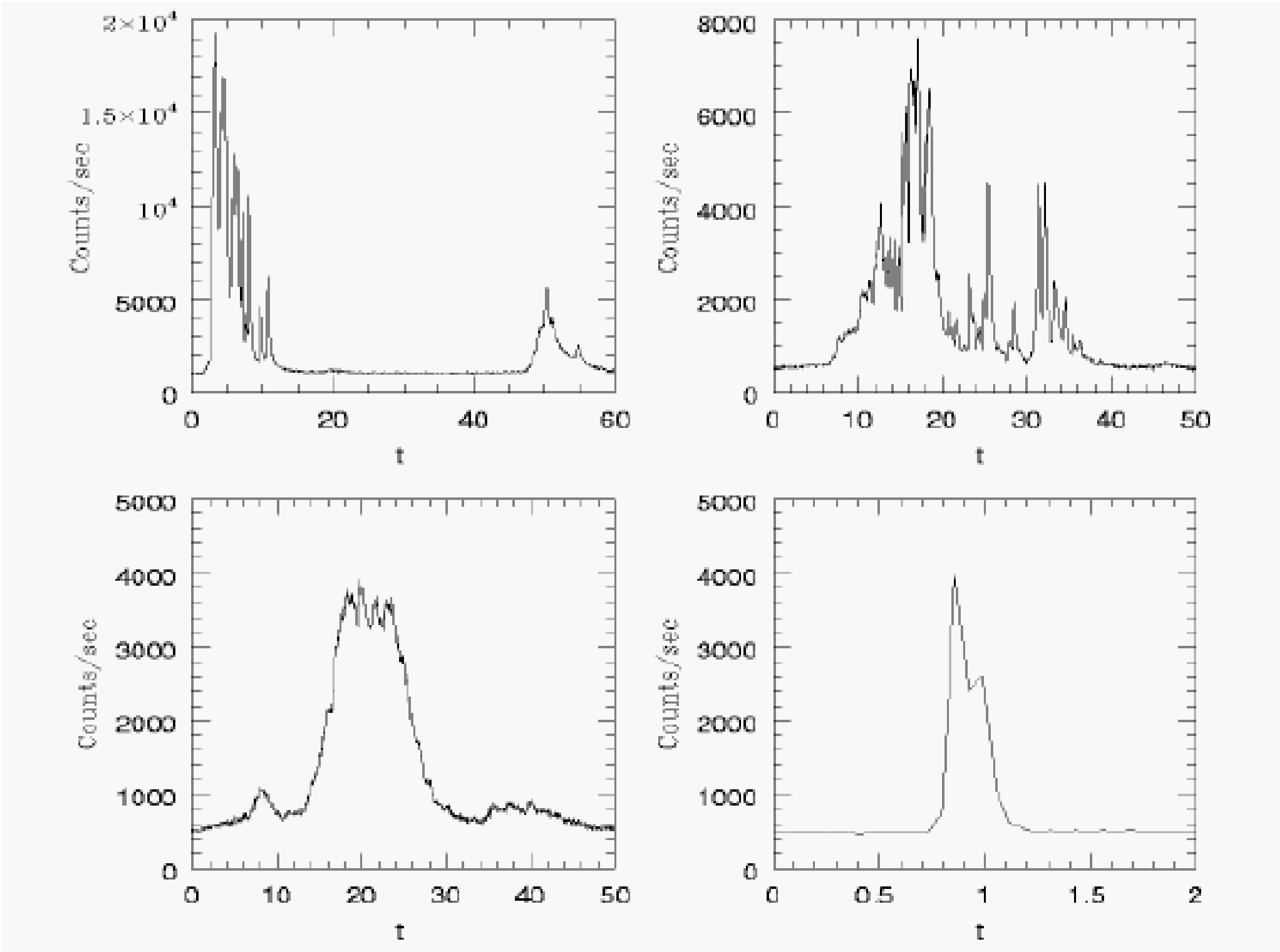

Spectral shape



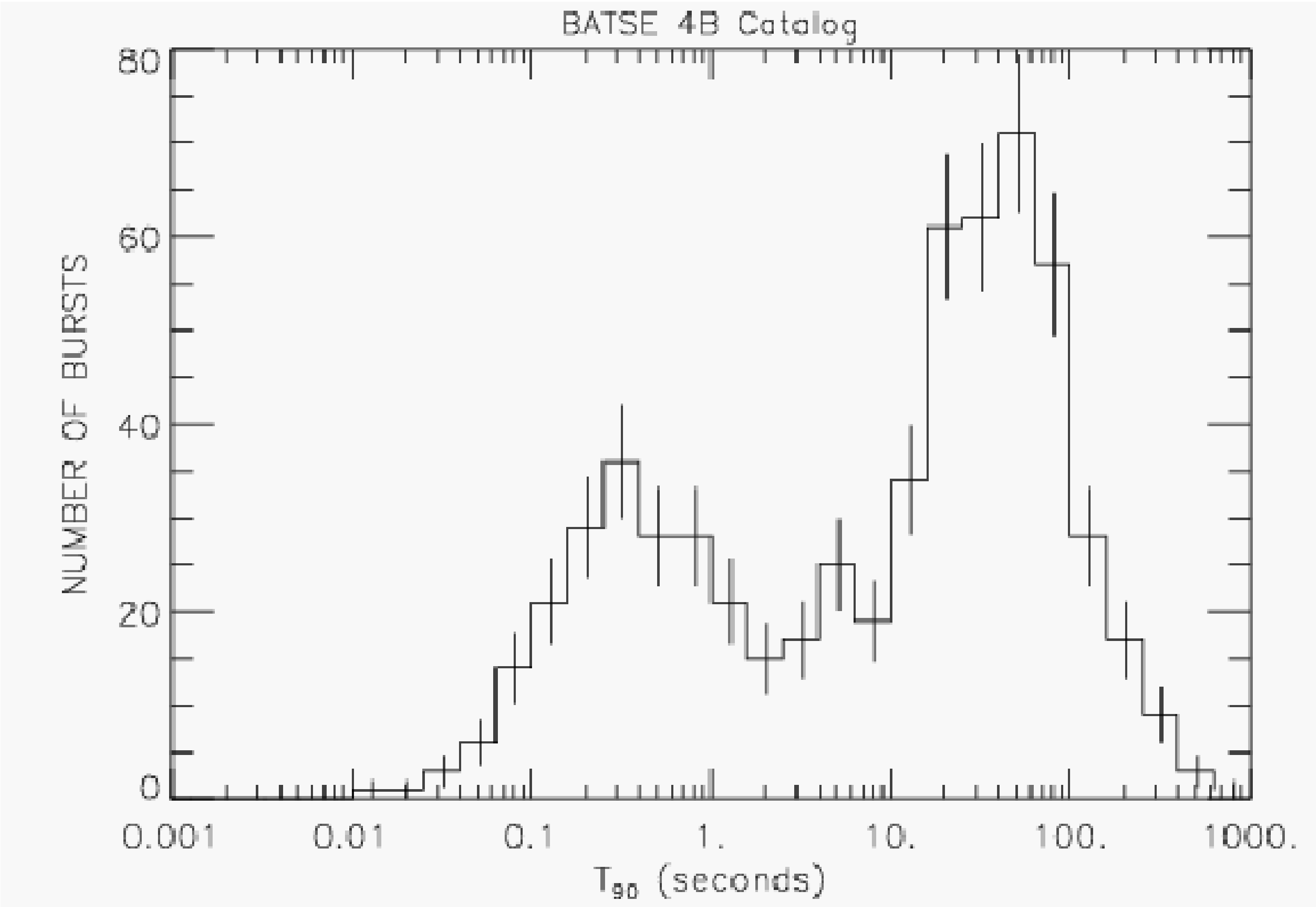




Spatial distribution

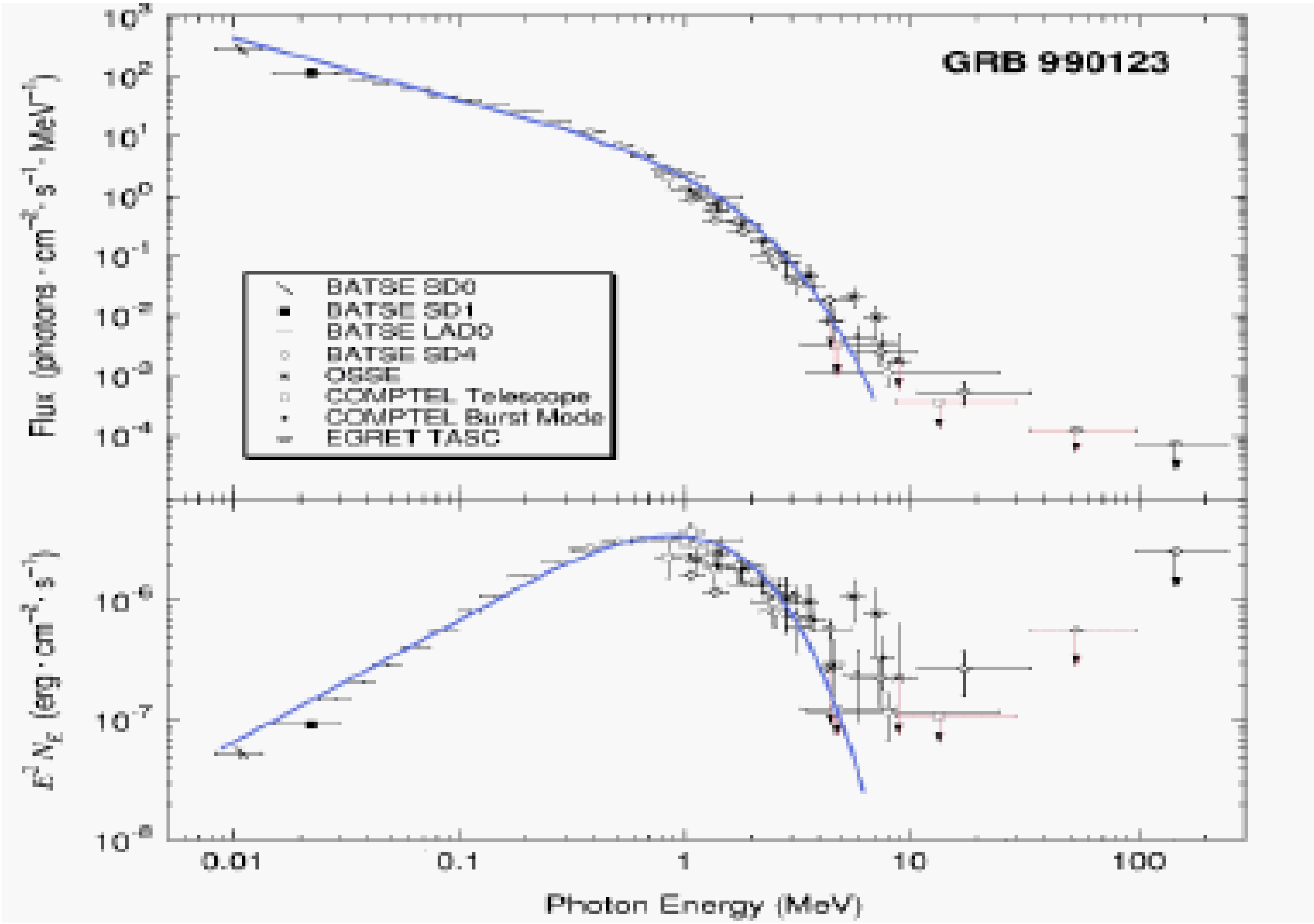
# BATSE (1991-2000)



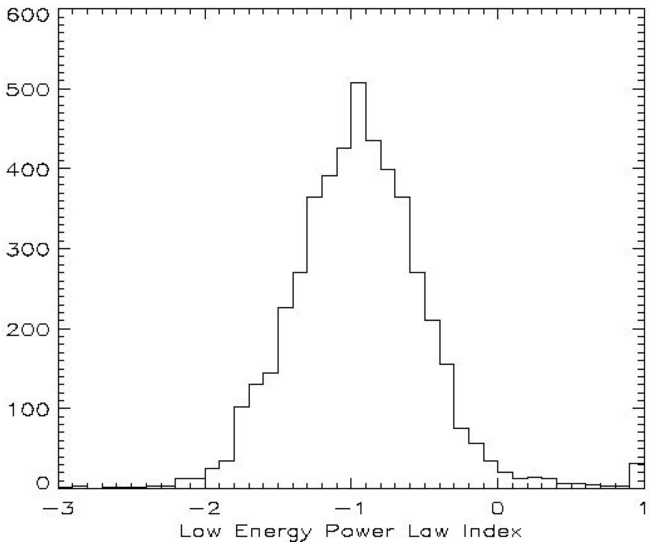
# BATSE (1991-2000)



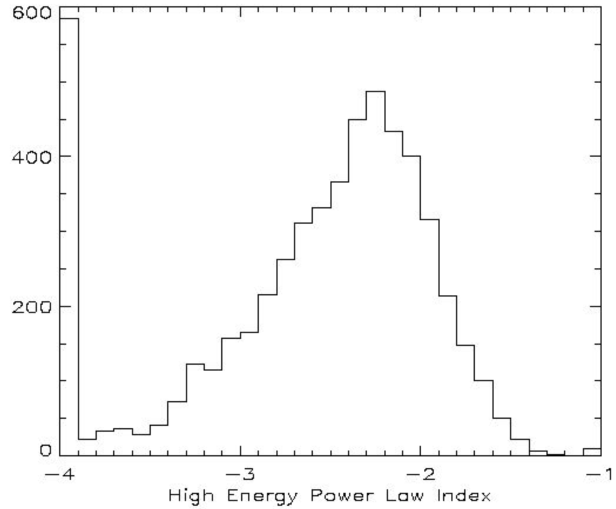
# BATSE (1991-2000)



# Spectral variability

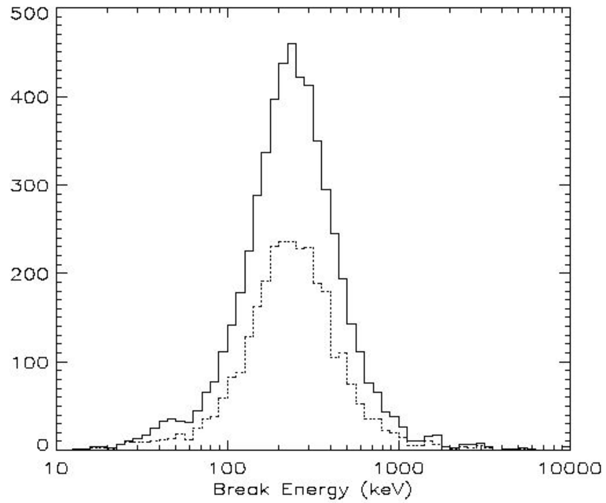



alpha




beta

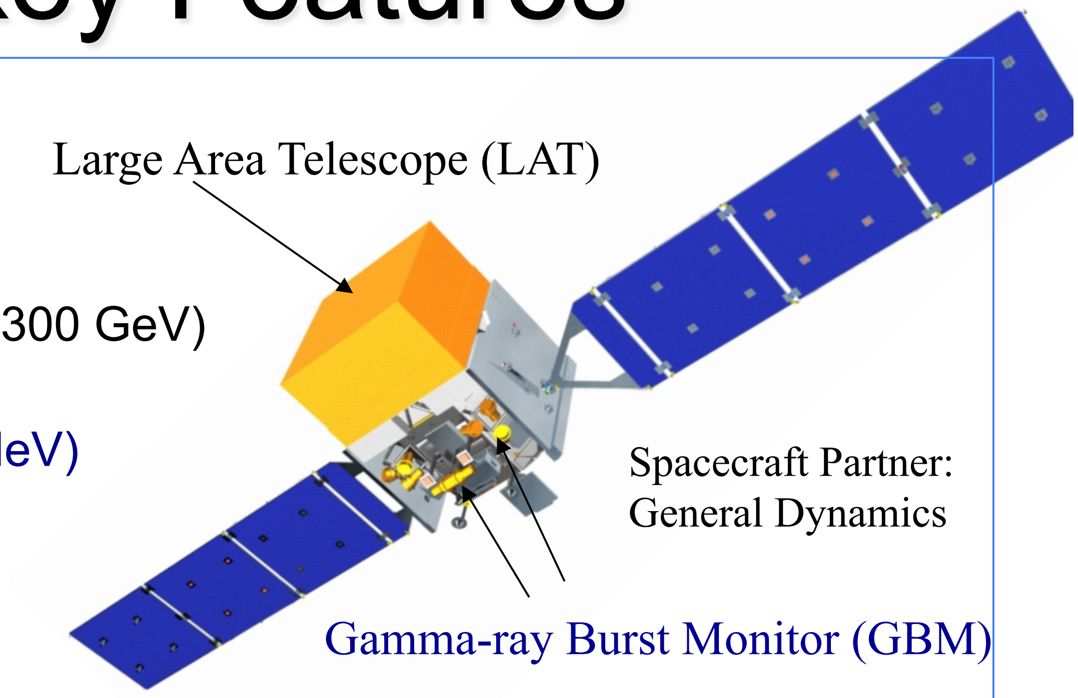
Epeak




Preece et al. (2000)

# Fermi Key Features

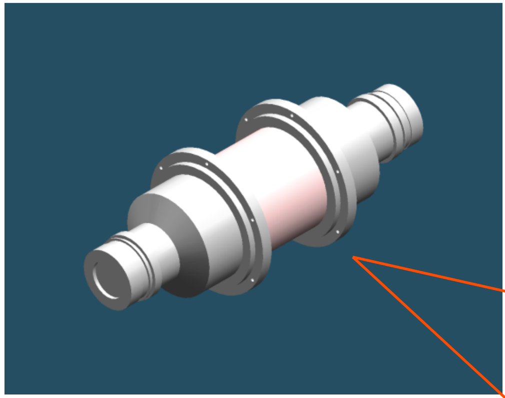
- Two instruments:
  - LAT:
    - high energy (20 MeV – >300 GeV)
  - GBM:
    - low energy (8 keV – 40 MeV)




- Huge field of view
  - LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.

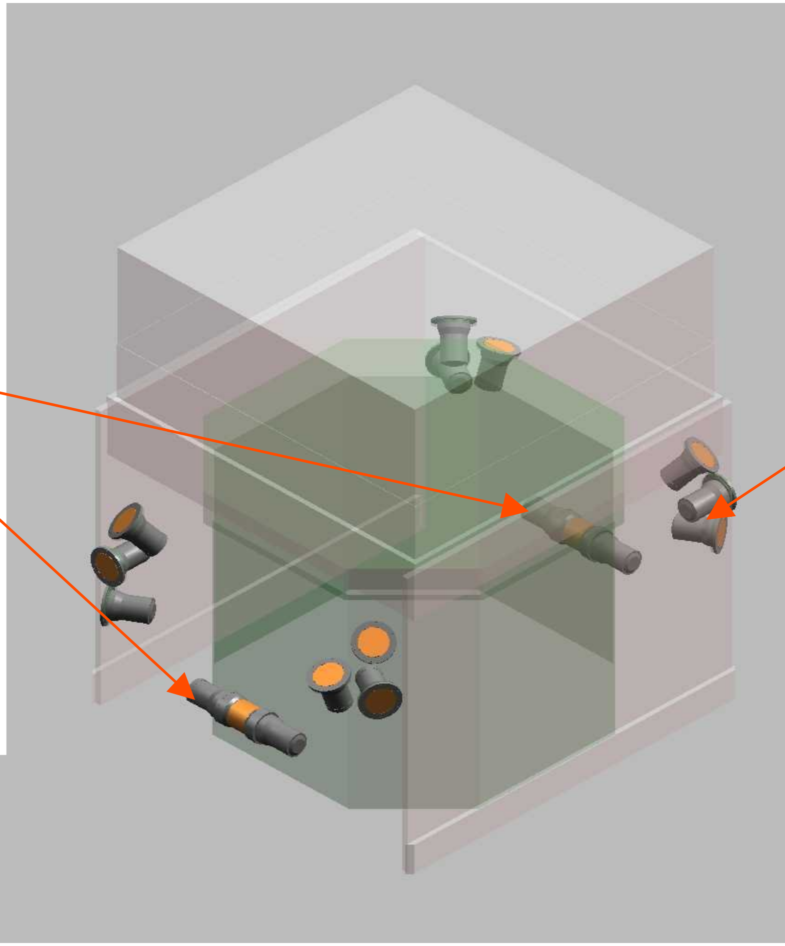
# GBM Detectors

## Bismuth Germanate (BGO) Scintillation Detector

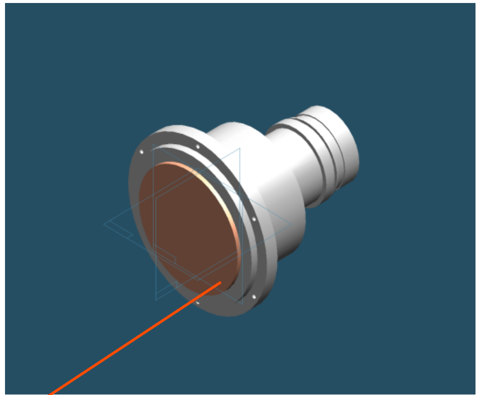


Major Purpose

- Provide high-energy spectral coverage (150 keV – 25 MeV) to overlap LAT range over a wide FoV



## (12) Sodium Iodide (NaI) Scintillation Detectors



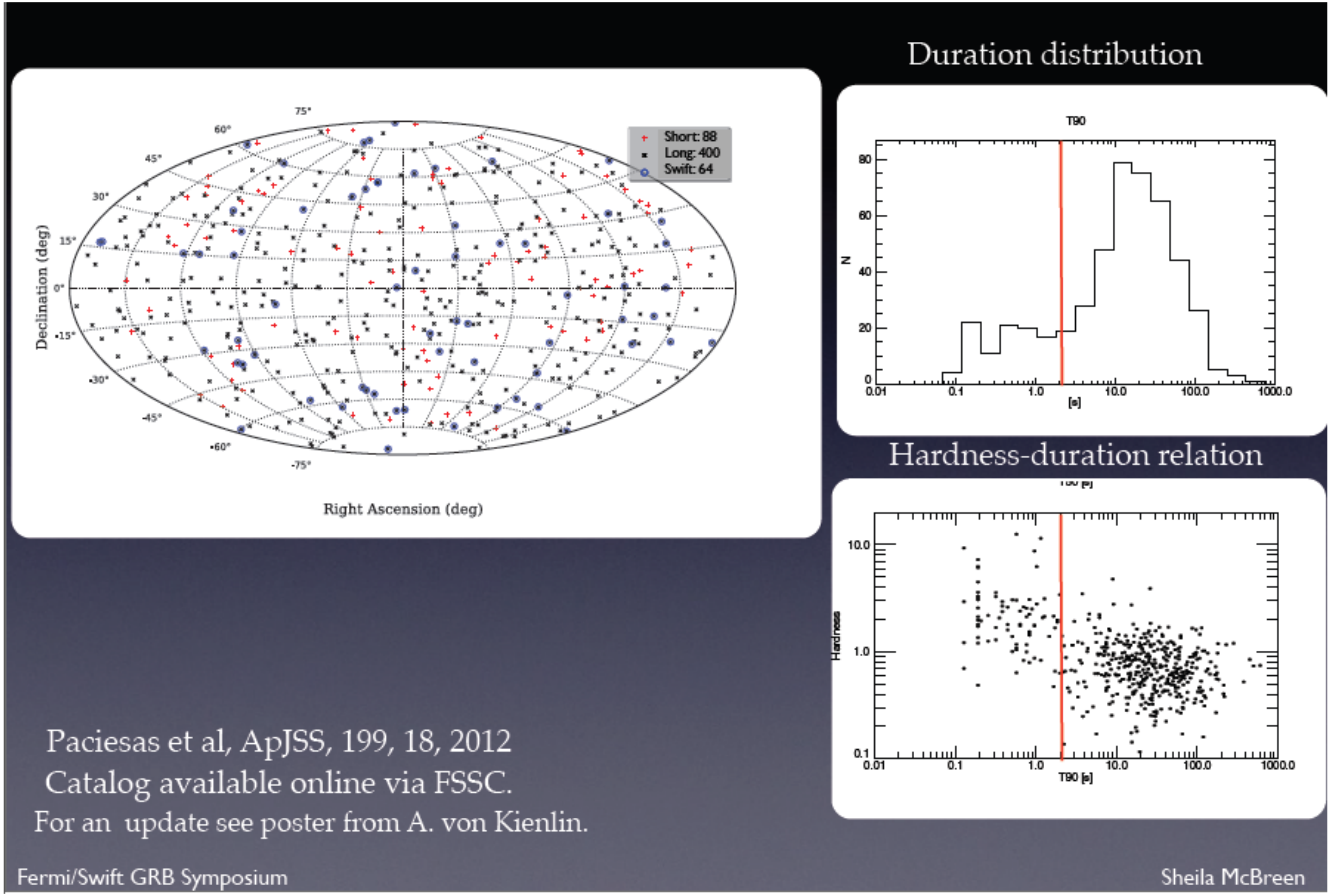
Major Purposes

- Provide low-energy spectral coverage in the typical GRB energy regime over a wide FoV (10 keV – 1 MeV)
- Provide rough burst locations over a wide FoV

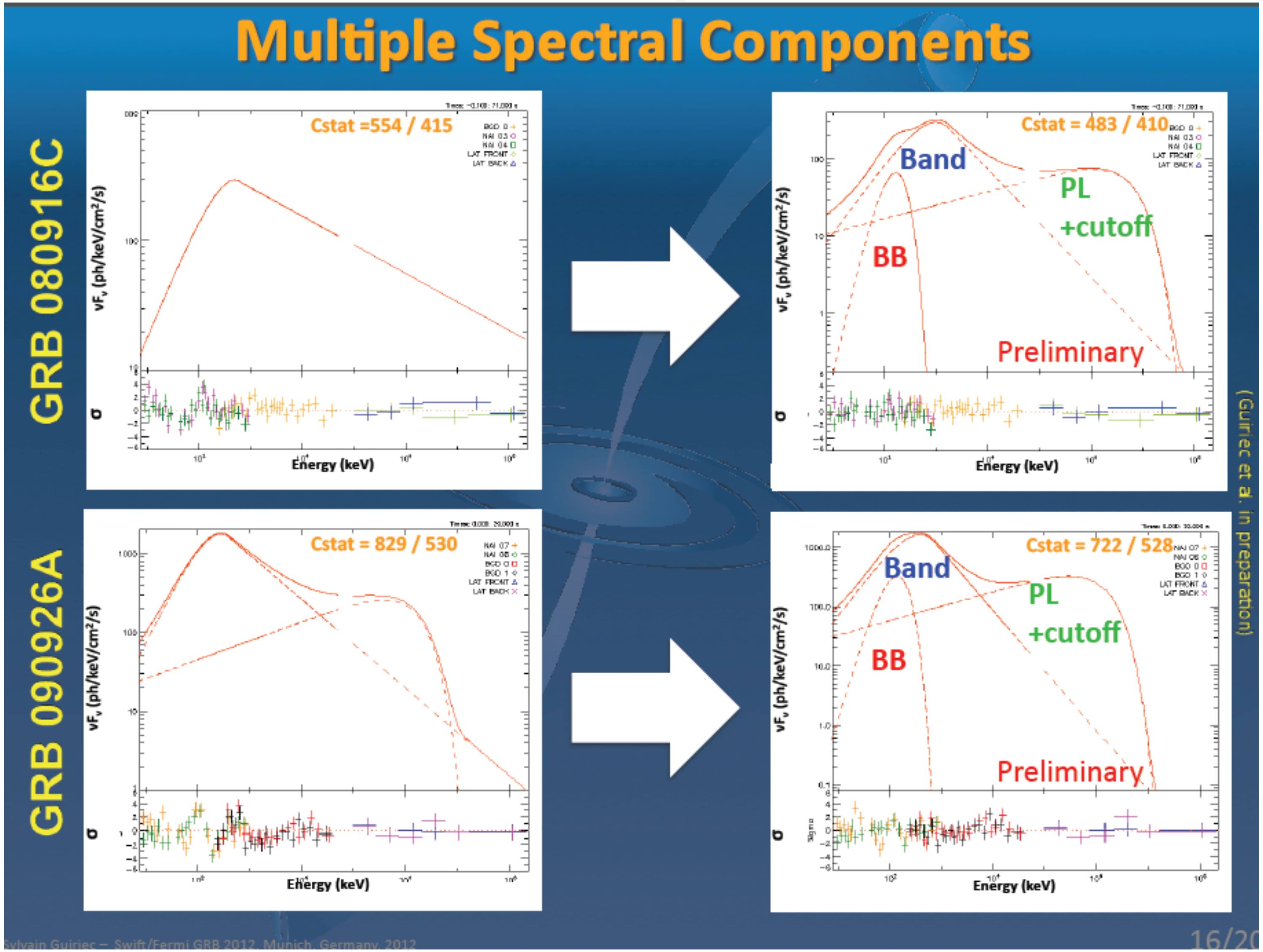
Provides spectra for GRB from 10 keV to 30 MeV.

Provides wide sky coverage (8 sr), enables autonomous repoints to allow for high energy afterglow observations with the LAT.

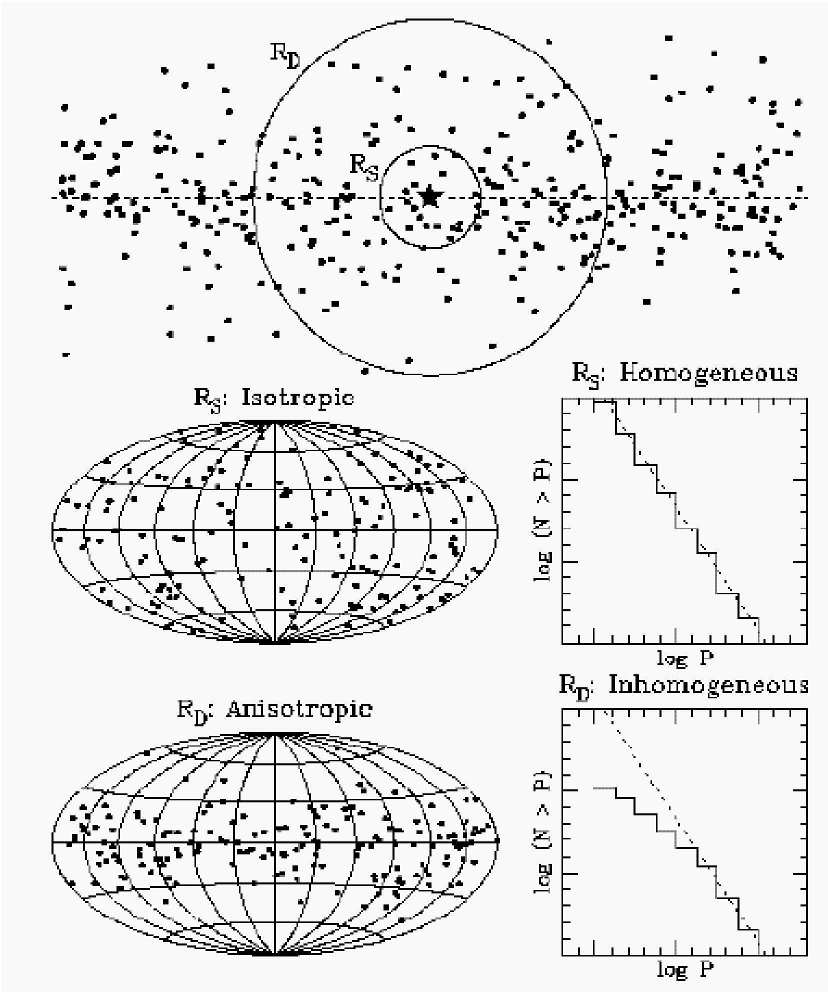
# Fermi GBM

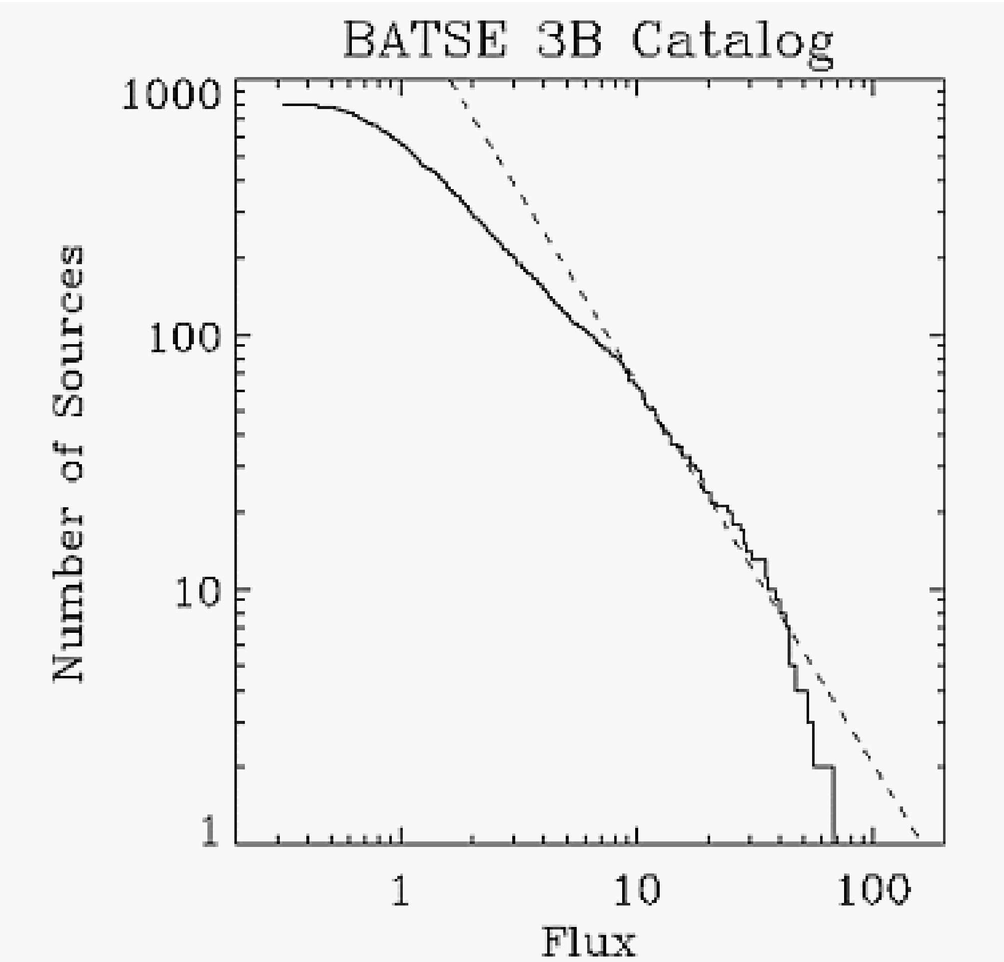

Duration distribution
Short: 88
Long: 400
Swift: 64
Declination (deg)
Right Ascension (deg)
T90
N
[s]
Hardness-duration relation
Hardness
T90 [s]
Paciesas et al, ApJSS, 199, 18, 2012
Catalog available online via FSSC.
For an update see poster from A. von Kienlin.
Fermi/Swift GRB Symposium
Sheila McBreen

# Fermi spectra

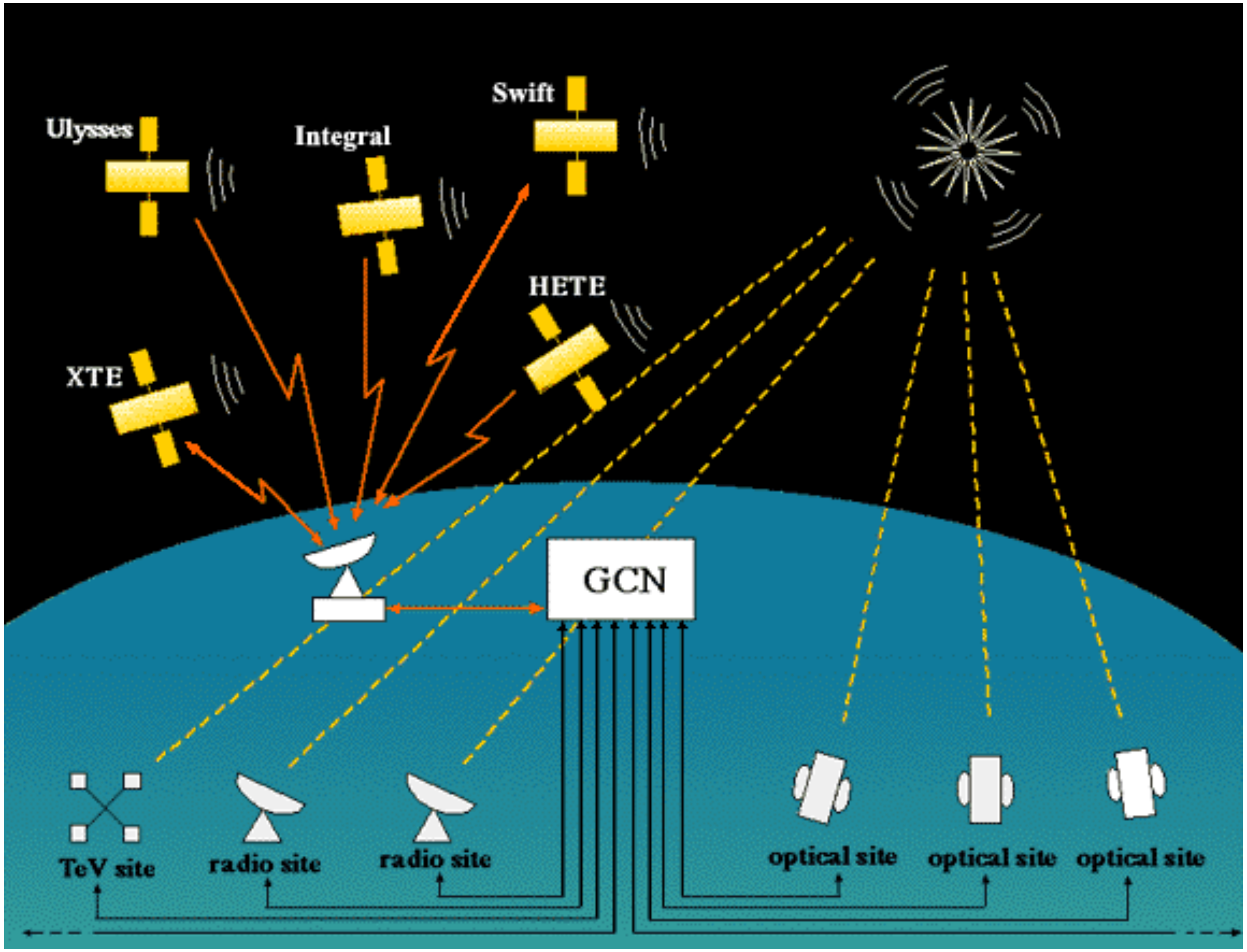


# BATSE (1991 - 2000)



# BATSE (1991-2000)



# GRB: where are they?

The great debate (1995)

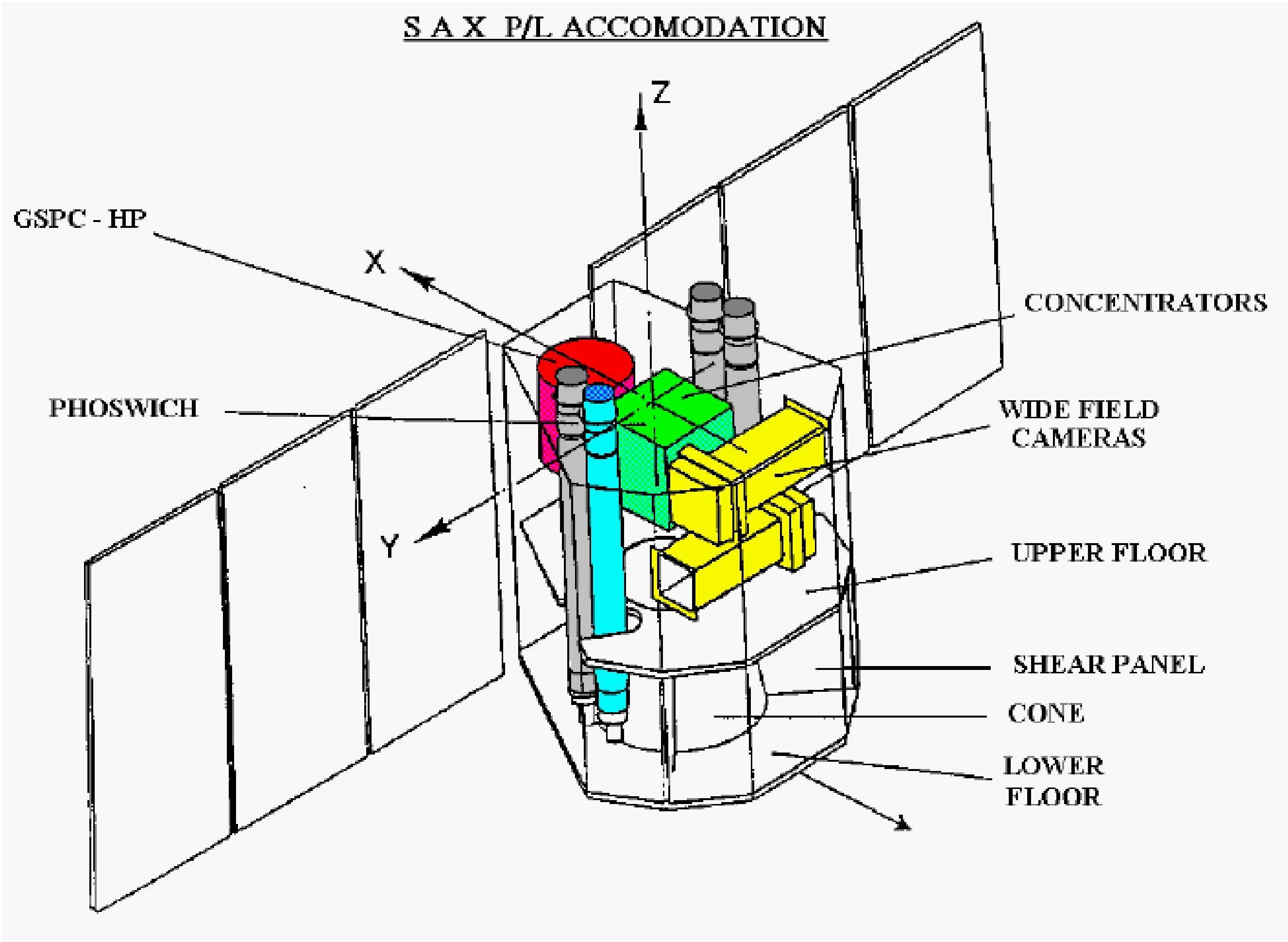
Flux: $10^{-7}$ erg $cm^{-2}$ $s^{-1}$
Distance: 1 Gpc
Energy: $10^{51}$ erg

Distance: 100 kpc
Energy: $10^{43}$ erg

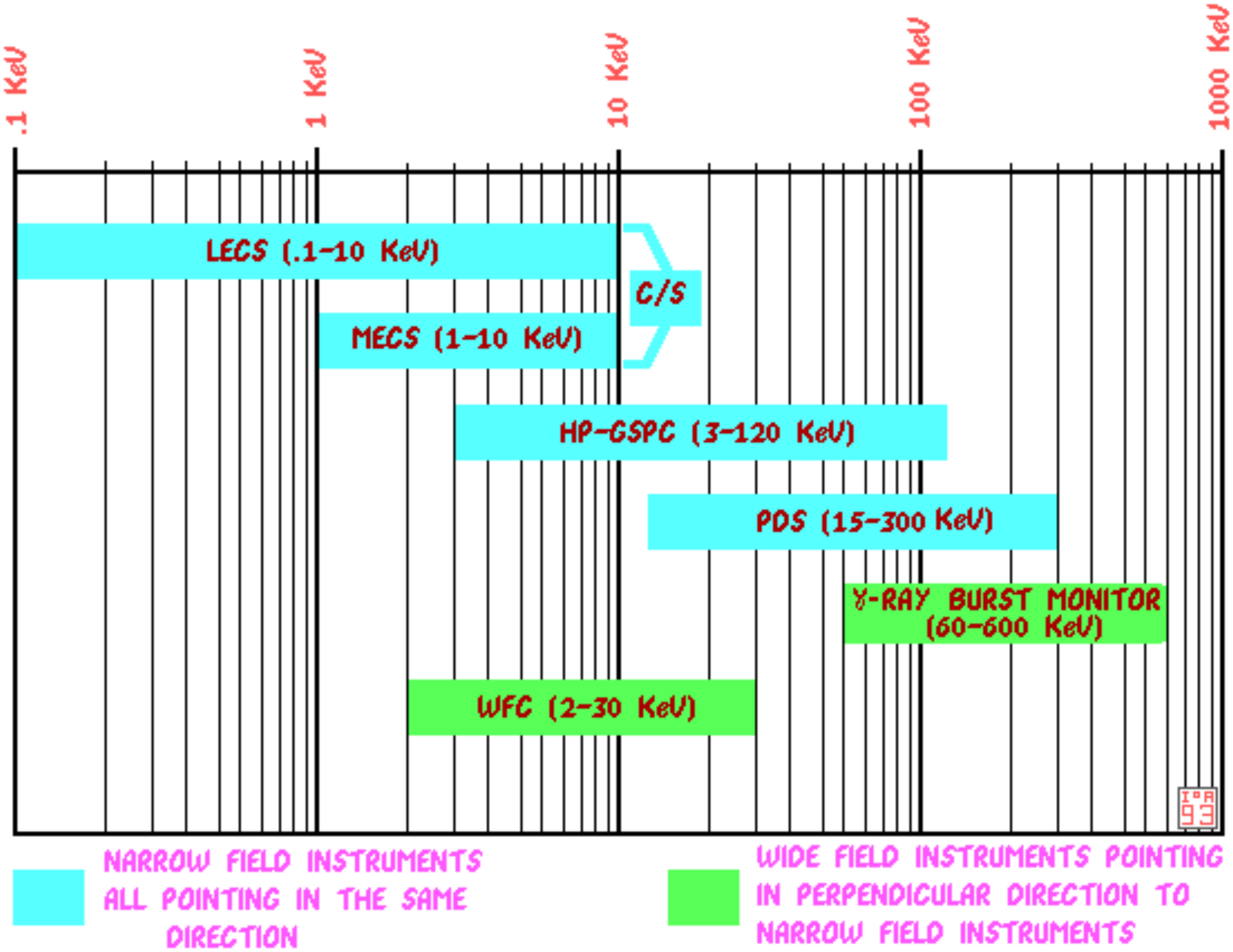
Cosmological - Galactic?

Need a new type of observation!

# BeppoSAX (1995 - 2002 )

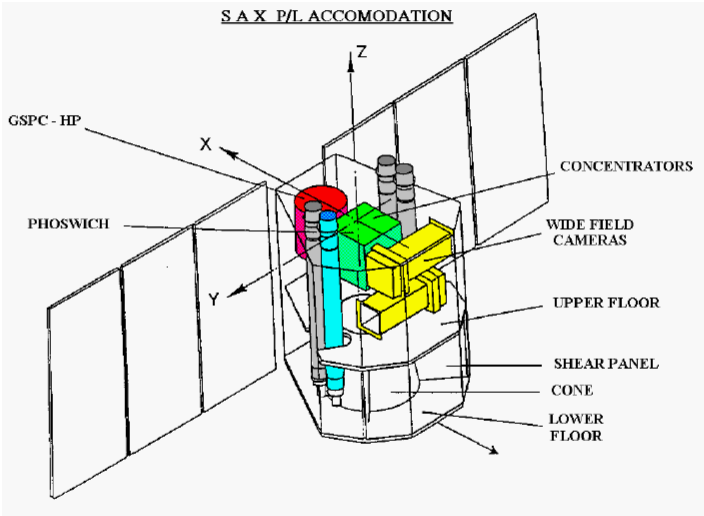


# BeppoSAX

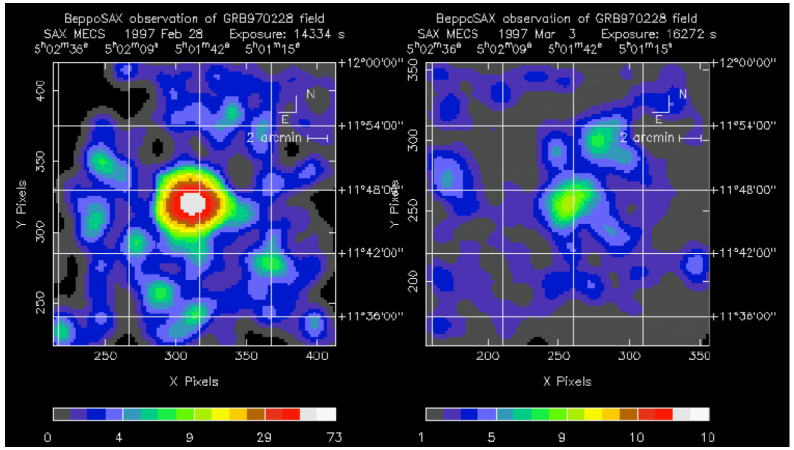


.1 KeV
1 KeV
10 KeV
100 KeV
1000 KeV
LECS (.1-10 KeV)
C/S
MECS (1-10 KeV)
HP-GSPC (3-120 KeV)
PDS (15-300 KeV)
γ-RAY BURST MONITOR (60-600 KeV)
WFC (2-30 KeV)
NARROW FIELD INSTRUMENTS ALL POINTING IN THE SAME DIRECTION
WIDE FIELD INSTRUMENTS POINTING IN PERPENDICULAR DIRECTION TO NARROW FIELD INSTRUMENTS

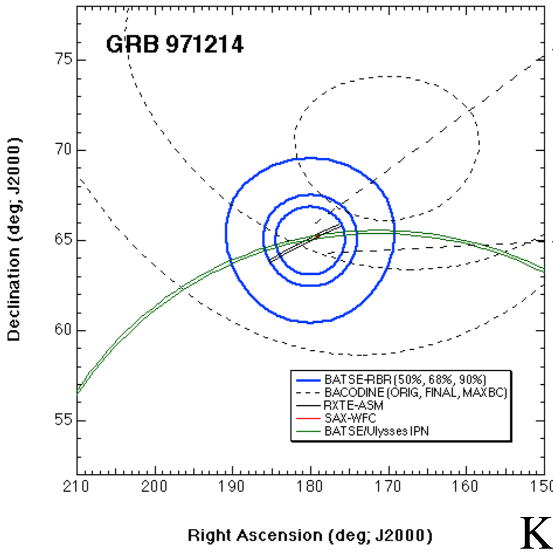
# BeppoSAX and the Afterglows

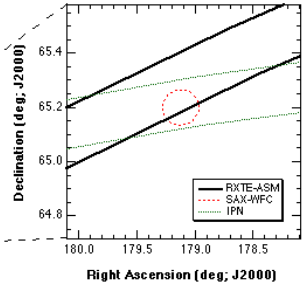



- Good Angular resolution (< arcmin)
- Observation of the X-Afterglow

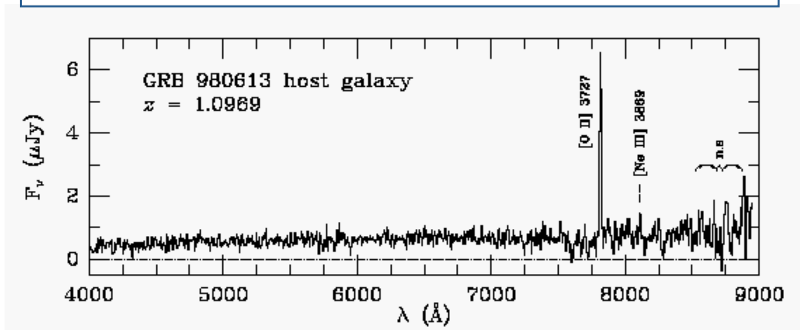



Costa et al. (1997)




- Optical Afterglow (HST, Keck)
- Direct observation of the host galaxies
- Distance determination




Kippen et al. (1998)

Djorgoski et al. (2000)