GRB detection at ground level using Water Cerenkov Tanks

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Outline

1. **Gamma Ray Bursts**
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   - BATSE
   - Beppo-SAX
   - SWIFT
2. **Water Cherenkov Tanks**
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   - WCD calibration
3. **The Large Aperture GRB observatory**
   - The Large Aperture GRB observatory
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4. **Conclusions**

Discovery of GRBs: Vela 5

GRBs - Vela 5

Discovered by accident in the 60's by US military satellites

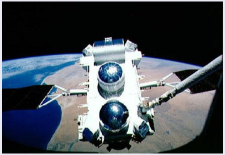
GRB

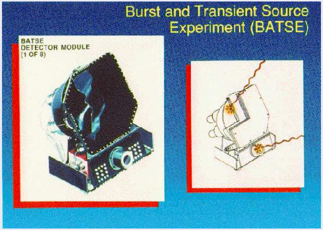
- $\Delta t \approx 0.01\text{s}$—100s
- E $>$ 100KeV

Enigma for 30 years

- Origin
- Distance
- Luminosity

BATSE: 1991 - 2000





Compton Gamma Ray Observatory

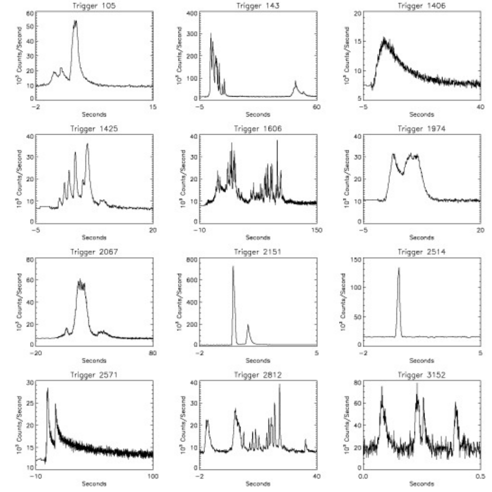
- OSSE 50KeV – 10MeV
- BATSE 20KeV – 20MeV
- COMPTEL 800KeV – 30MeV
- EGRET 20MeV – 30GeV

BATSE

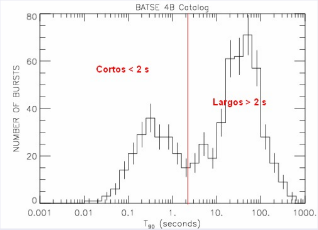
- Field of view: 4π sr
- Flux $> 0.1\ \gamma \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Angular resolution $> 4^{o}$

BATSE: 1991 - 2000

BATSE signals



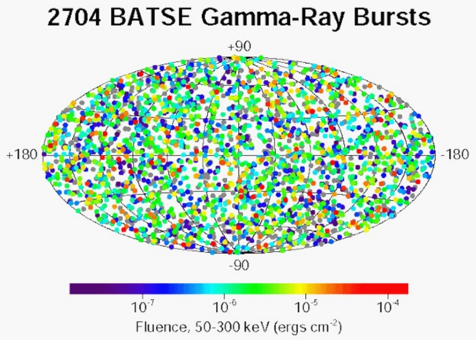
Duration



2 distinct populations

BATSE: 1991 - 2000

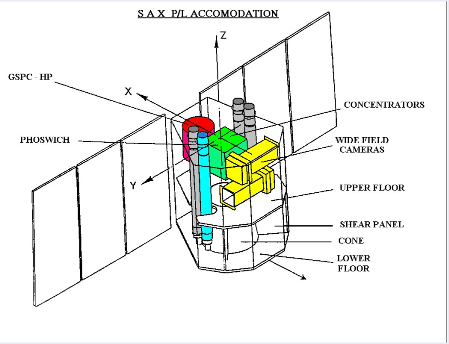
BATSE sky

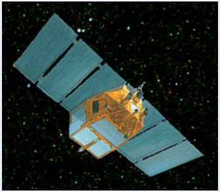


BATSE showed

- GRBs are isotropes
- GRBs are not homogeneous
- Need to measure distance to GRBs

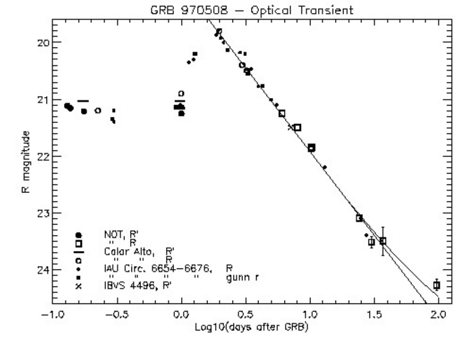
Beppo-SAX: 1996 - 2002





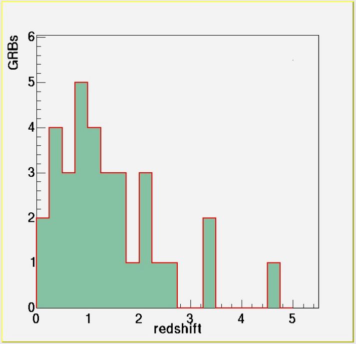
- GRB 40 – 700KeV monitor
- Various X-ray detectors
- Angular resolution: 50 “

GRB 970508



- Observation of absorption lines in the optical spectrum of the afterglow
- Redshift ≈ 0.84
- Cosmological origin

Redshifts



Luminosity

Typically $10^{51} - 10^{54}$ erg

Sun

4×10^{33} erg

Our galaxy

10^{44} erg

Redshifts

SWIFT (2004 -) allowed detection of short GRB afterglows, high redshifts...

Long GRBs

- happen in star formation zones
- likely to be core-colapse of massive stars
- connection with supernovas

Short GRBs

- dimmer but harder spectrum
- coalescence of a pair of objects?
- more data still needed

At higher energies?

EGRET

- detected 16 GRBs
- spectrum with a power law of about ≈ 2.2
- 3 GRBs with photons of $E_\gamma > 1$ GeV
- maximum energy 18 GeV

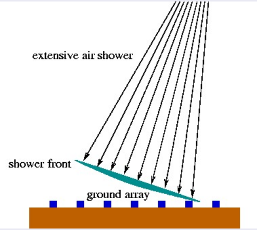
Observation at higher energies could help

GLAST (2007) should give the answer. Has it?

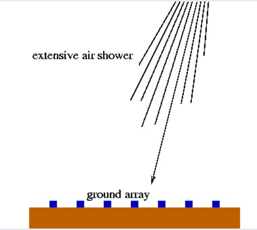
Single Particle Technique

A different use of a ground array

Normal mode (shower)



Single Particle Mode



with SPT there is no direction reconstruction

GRBs are detected as an excess of counts over background

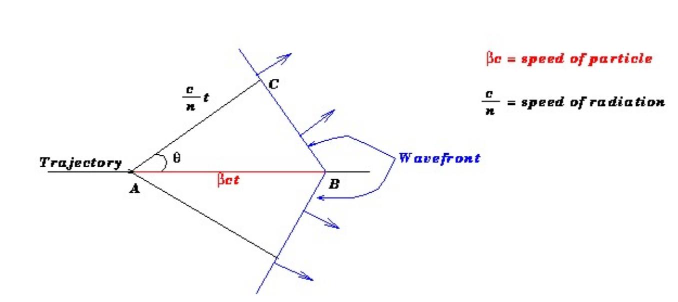
Water Cherenkov Detectors (WCD)

- Pure water
- Optical coating
- Phototube (PMT)

- Electrons
- Photons
- Muons

Cherenkov light

Particle crossing a medium at a speed higher than speed of light in that medium produce coherent Cherenkov light



Light mainly in the UV and blue

Water

Cherenkov photons propagate in Water and get absorved

The absortion length in water depends of λ. It varies from a few centimeters to tens of meters

Optical phenomena (e.g. scattering) may take place

Cherenkov photons will bounce many times before reaching the PMT

TMTyvek liner

Water enclosed in a light-tight bag

Tyvek is a highly reflective and diffusive material

- Allows light to reach PMT well after 100 ns (i.e. more than 10 reflections)
- Makes light in a tank uniform

PMT basics

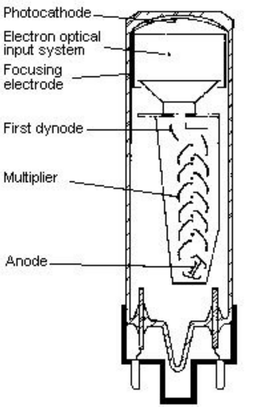


Fig. 8.1. Schematic diagram of a photomultiplier tube (from *Schonkeren* [9.1])

- Vacuum-tight glass envelope
- Photon knock on photocathode and electron release (photoelectric effect)
- Each dinode is a multiplication stage
- Last step is anode, for a cleared signal

Response to particles

Electrons (and positrons)

- Typical energy: few 10 MeV
- $\approx$ 10% of secondaries

Simple calorimeter, signal proportional to energy

Photons

- Typical energy: few MeV
- $\approx$ 90% of secondaries

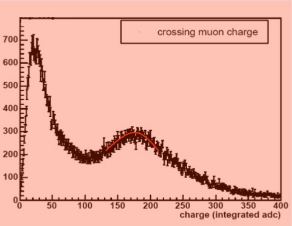
1.2m is deep enough to produce pair creation. Then the $e - e+$ pair produces Cherenkov light

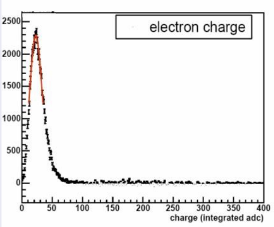
Muons

- Typical energy: $1 - 50$ GeV
- $\approx$ 1% of secondaries

Usually to energetic to be stoped inside a WCD. Leaves a signal proportional to the track length.

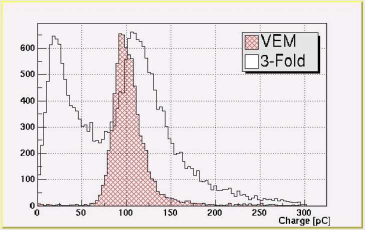
Charge histograms





Muon hump to VEM

VEM: Vertical Equivalent Muon
The average charge deposited by a vertical and central muon



VEM - hump shift due to muon track distribution and photostatistics

Muon decay rate proportional to water volume of the WCD. Signal is two consecutive peaks with a time diference of $\approx 2.2\mu s$.

LAGO

LAGO

Large Aperture GRB Observatory

Idea

Detect high energy GRB at ground level

Who?

- Argentina
- Bolivia
- Mexico
- Peru
- Venezuela

How?

Using WCD:

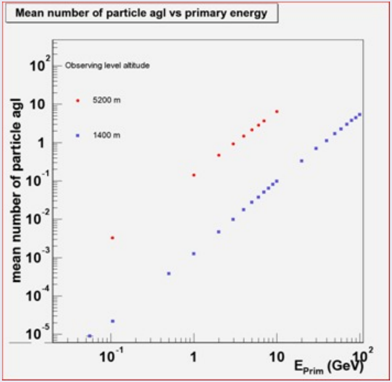
- Easy to calibrate
- Able to "see" photons

Where?

High altitude mountain sites (> 4000m)

Why go high?

Particles in altitude



At 5200m

- 100 times more signal
- 8 times more noise
- $S/\sqrt{N} \approx 35 \approx \sqrt{1600}$

1 detector at 5200 $\approx$ 1600 Auger detectors at 1400m

LAGO sites

Various Sites

- Sierra Negra, Mexico
- Monte Pico Espejo, Venezuela
- Chacaltaya, Bolivia
- Auger South, Argentina

Detection in coincidence Bolivia - Argentina

Pictures

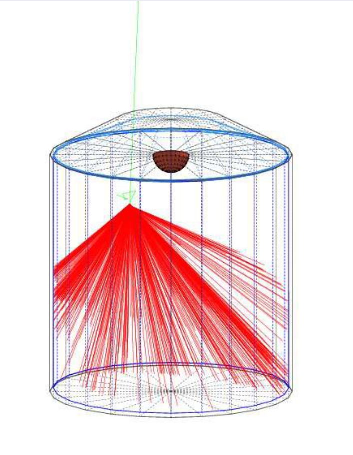
Prototype detectors

Prototype detectors for Chacaltaya

- Old prototype equipment from Auger:
  - Electronics
  - PMTs
- Commercial water tanks:
  - 1 PMT per tank
  - 6 tanks per electronic
- Software rewritten:
  - Data Acquisition
  - Detector simulations (I was involved ;-)

Low cost

Prototype detectors



- GRBs are no longer the mistery the used to be. Still, more information at higher energies is needed.
- WCD are very efficient detectors to study GRBs from the ground
- Auger is quite competitive with ground based experiments
- A low-cost efficient experiement can be done using WCD at high altitudes

gracias