GRB Localization Analysis

with Fermi Large Area Telescope

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Training program

Michela Negro is working with my group at Goddard to perform a study of the location accuracy of Fermi-LAT to gamma-ray bursts. Michela is using data from gamma-ray bursts detected by LAT, in addition to instrument simulations to evaluate the systematic uncertainty on the LAT-determined location for gamma-ray bursts. This work is extremely important, as an understanding of the total (statistical + systematic) location uncertainty is essential for optimizing follow up observations by other observatories. The goal of this work it to evaluate systematic uncertainties as a function of the position of the gamma-ray burst in the LAT field of view and of the energy. This will be the first detailed evaluation of LAT-localization systematics for gamma-ray bursts.

Julie McEnery

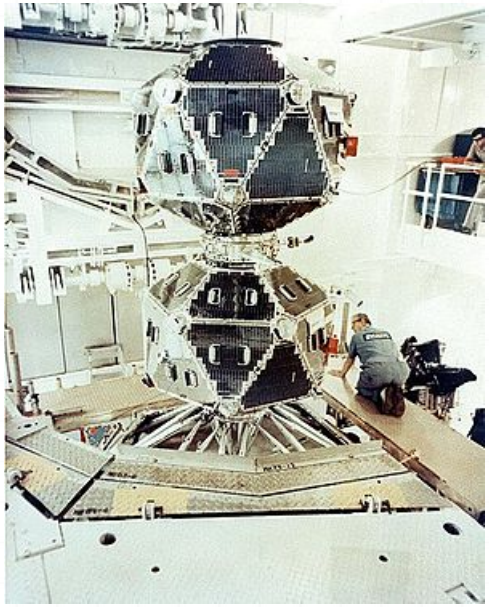
Gamma Ray Bursts

- Flashes of gamma rays + Extremely energetic explosions
(in a few seconds as much energy as the Sun in its life)

- Observed in distance galaxes
(billions of light years away from Earth)

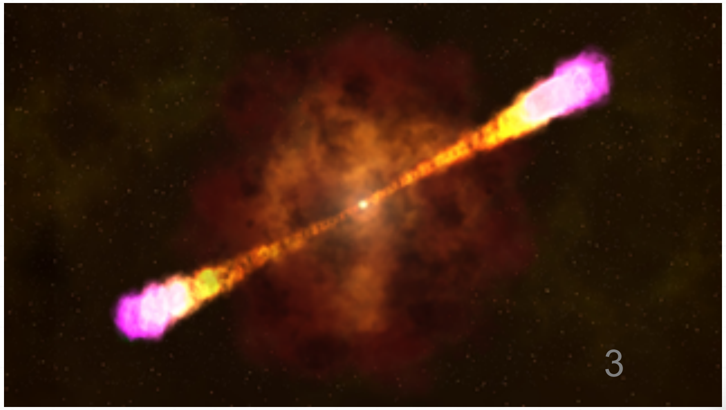
- Extremely rare
(a few per galaxy per million years)

- First detected in 1967 by Vela satellites



- In 1997
  - first detection of the afterglows (X-ray & optical)
  - Redshift measurements -> mesurements of the distance

- Nov 21 2013: detailed data about the strongest GRB
  -> 130427A (April 27, 2013)

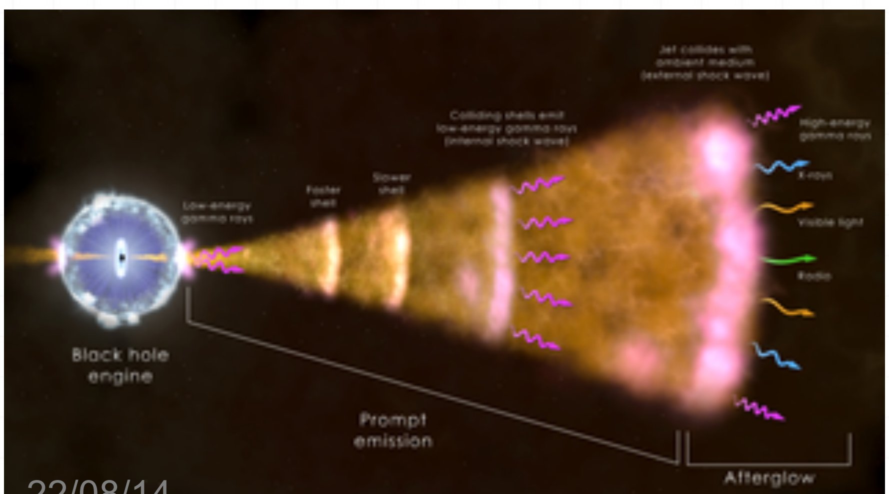


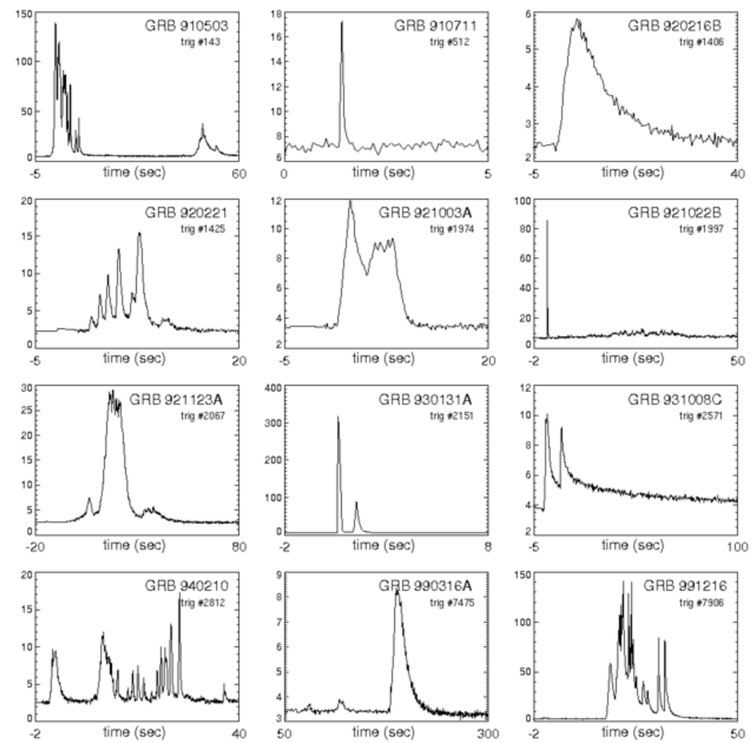
Forward and Reverse shock

- Initial burst of gamma-rays (a few seconds) -> Collimated (2-20 degrees) jets (99.95% of *c*)
  - Main Mechanism of gamma-ray production = Inverse Compton

- Emition at longer wavelengths (hours- days) = **Afterglow**
  - Energy not radiated = matter
  - Matter collides with the ISM -> relativistic **Foreward** shock wave
  - A second **Reverse** shock propagate back
  - electrons in the shock wave radiate as syncrotron emission (X-ray, radio, optic)

- Light curves:
  - To study the GRB emission mechanisms
  - different from a GRB to an other!



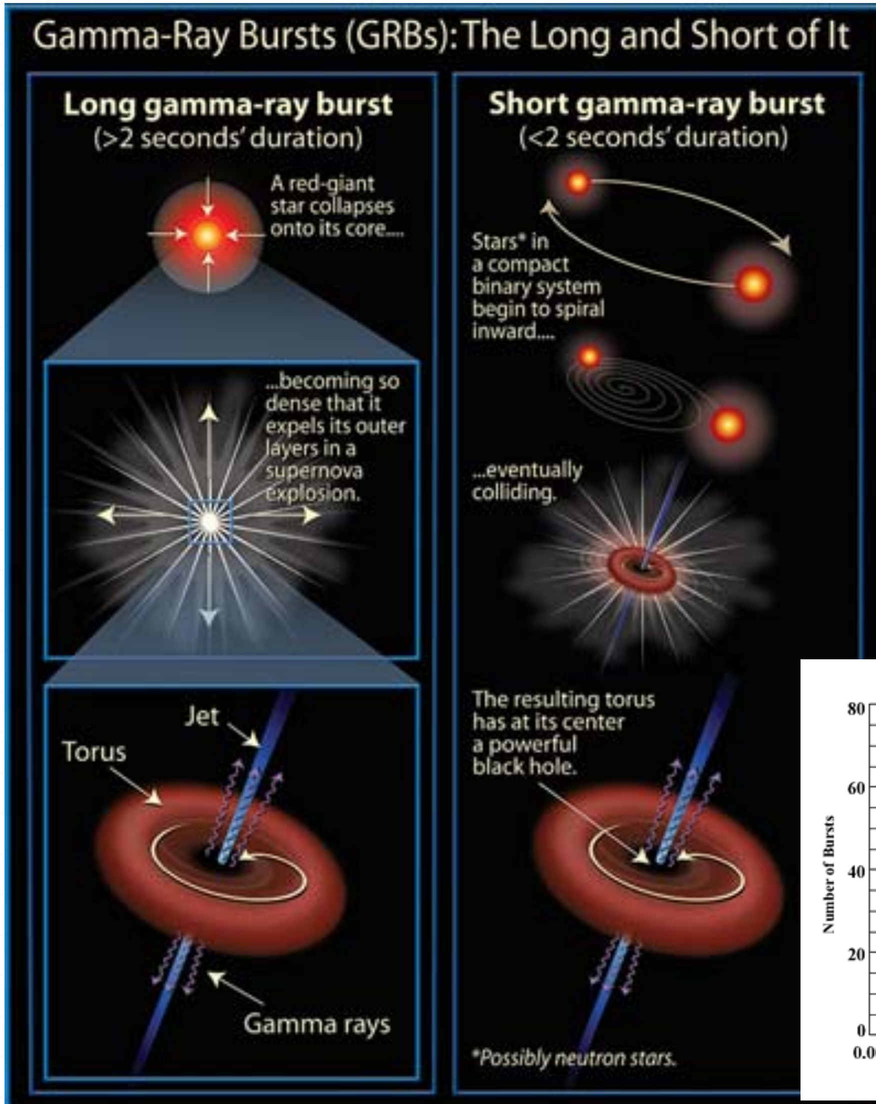


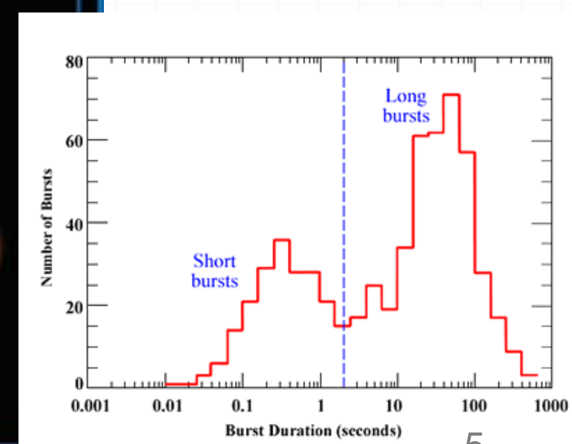
Light curves

Classification

Long GRBs

- more than 2 s
- 70% of GRBs
- region of star formation
- linked to a core-collapse supernova
- origin: death of massive stars

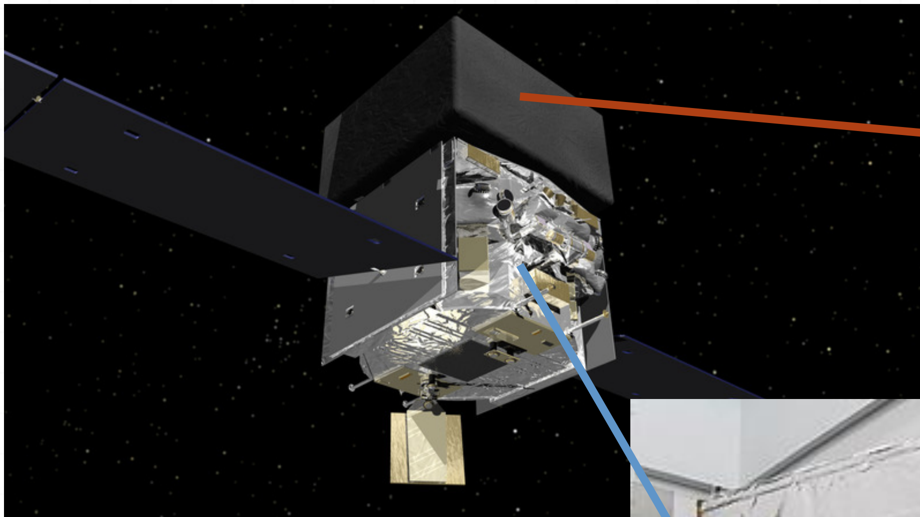


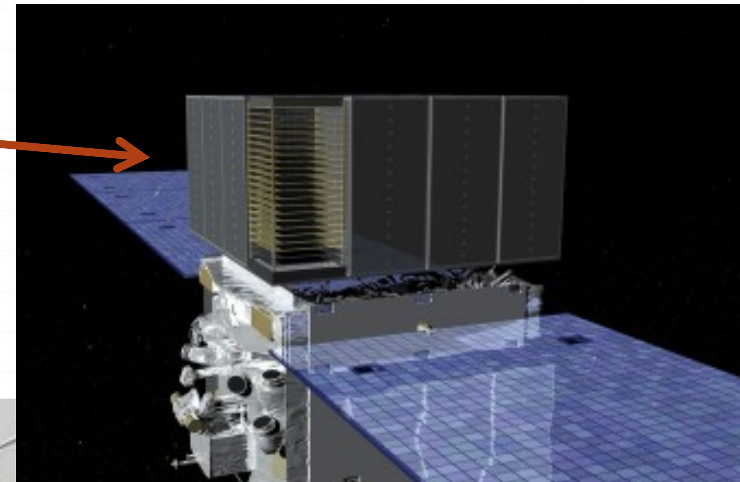


Short GRBs

- less than 2 s
- 30% of GRBs
- regions of no star formation
- linked to masive stars
- origin: NS+NS or NS+BH

Fermi LAT & GBM



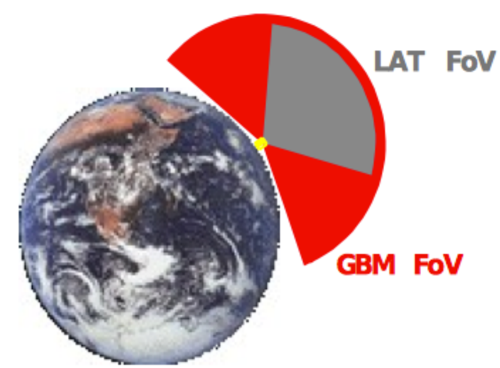


LAT
(Large Area Telescope)

Launch: June 11 2008, NASA

Orbit: - circular

- 565 km altitude
- 25.6° inclination



GBM
(Gamma-ray Burst Monitoring)

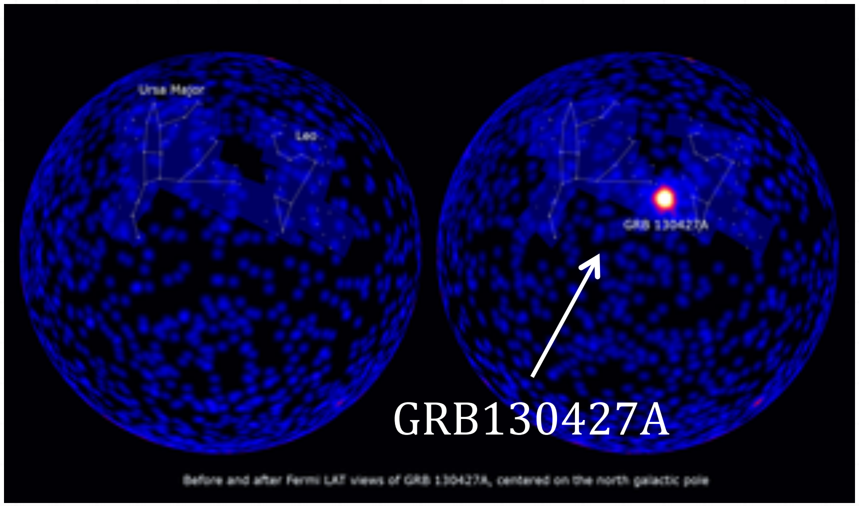
Localization Analysis

Using Fermi **Science Tools** for an unbinned likelihood analysis**:**

- Run **gtmktime** to select good time intervals (e.g. when the spacecraft is outside the SAA, has a livetime > 0, and is pointing at your area of interest)
- Run **gtselect** to further cut on energy and radius around some location on the sky
- Run **gtltcube** to create the livetime cube
- Run **gtexpmap** to generate the exposure map
- Make an xml model that includes all the sources in your region of interest plus the GRB
- Run **gtdiffrsp** to compute the diffuse response
- Perform a likelihood fit (**gtlike**)
- Generate a ts map (**gttsmap**)
- Extract the error radii from the ts map

- the goal: Give an estimate for the **Systematic error!**

Example of Localization Analysis: GRB130427A



Before and after Fermi LAT views of GRB 130427A, centered on the north galactic pole

Output of **gtlike**:
TS = 2 (loglike(M1) - loglike(M0))
M1 = model with GRB included
M2 = background model

Max TS: 1855.96789551

Related to the probability that the source is not part of the model
Great detection!!

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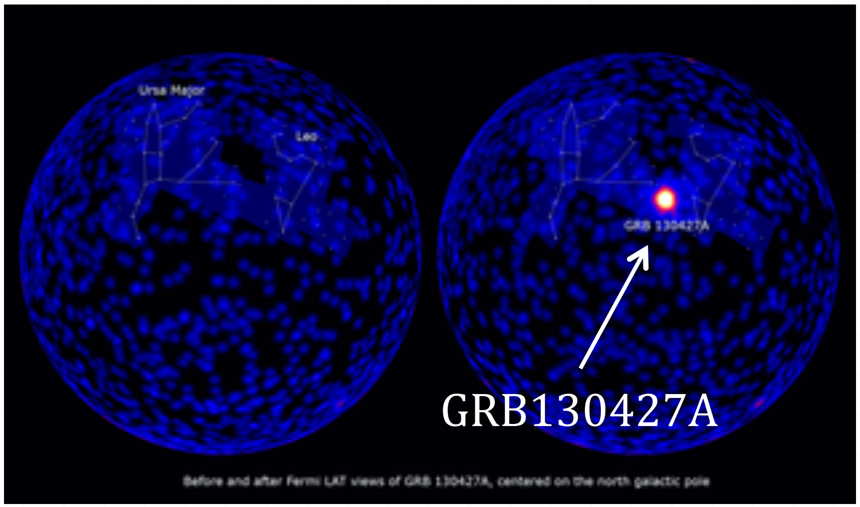
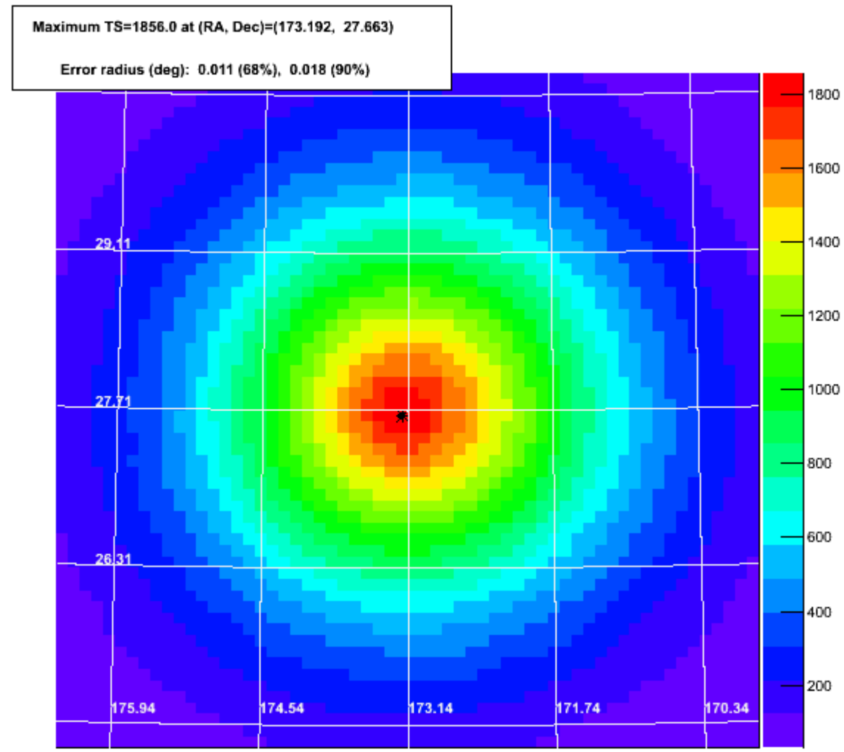


TS map = ROI – background model



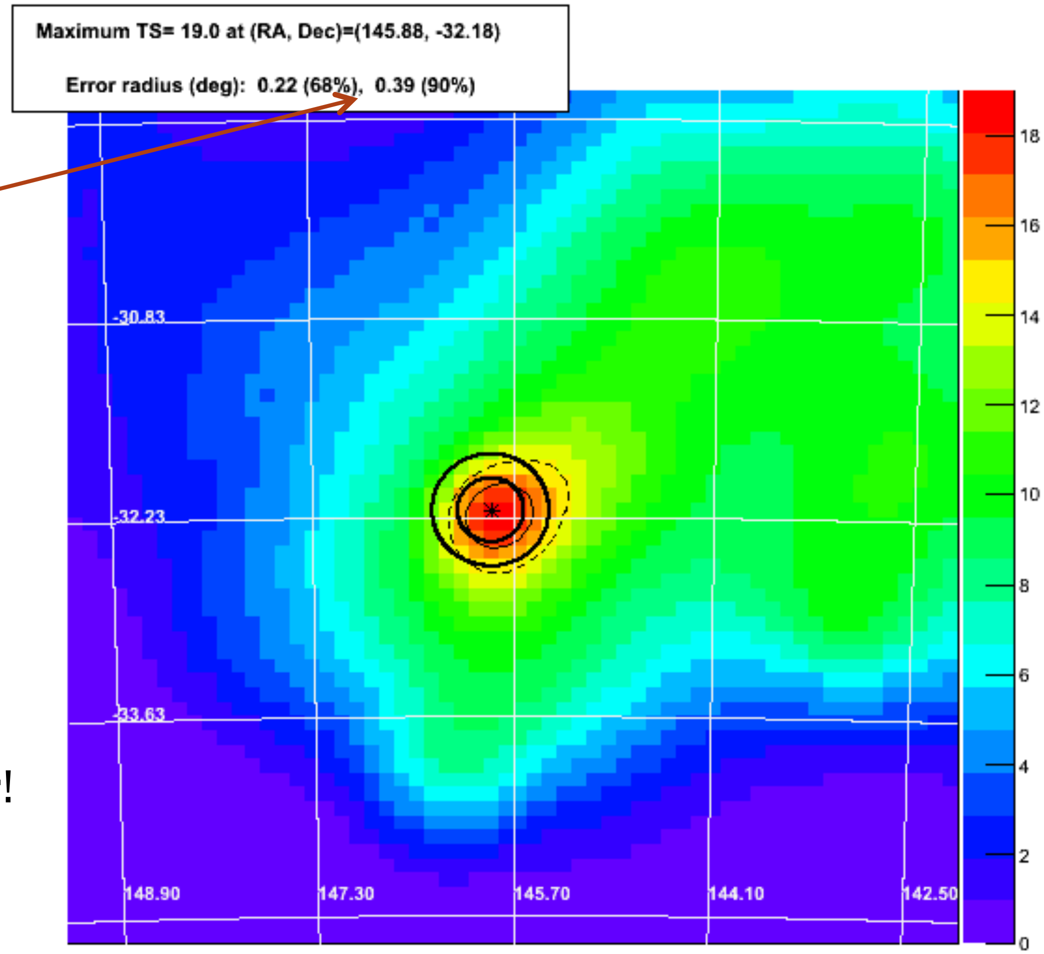
68 percent C.L. error: 0.011°
90 percent C.L. error: 0.018°
95 percent C.L. error: 0.024°
99 percent C.L. error: 0.041°

Well localized in this case!
But what about systematics?

Example 2: GRB140329295

Little TS value: not wll detected

Greater error radii
(dashed lines)



Now:
- only statistical error is well known for Fermi detections;

To Do List
- Search for a method to estimate the systematic error!
- Simulate GRBs at different θ and look at how systematics change.