Sky Watching in Gamma Rays: Searching the Universe for High Energy Processes

José Ferreira e Miguel Godinho

Laboratório de Instrumentação e Física Experimental de Partículas

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Supervisors:

Dr. Giovanni La Mura & Dr. Ruben Conceição

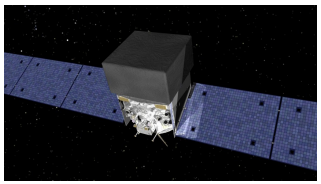
Gamma-Ray Astrophysics

- Gamma rays are high energy photons.
- They can arise from artificial or natural sources. Of the natural ones, they can come from Earth or from space.
- The gamma-rays coming from space are originated by high energy sources and the detected photons tend to vary between MeV and beyond TeV.
- In our case, we are going to study flares from blazars.
- A **Blazar** is active galactic nucleus with a relativistic jet directed very nearly towards an observer and **Flare** is defined as a sudden, rapid, and intense increase in brightness.

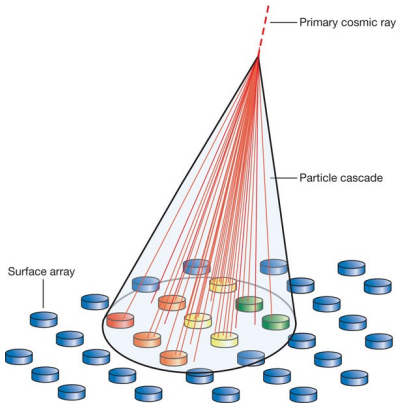
Gamma-Ray Detection

There are two ways to detect photons:

- Direct Form:
  - Compton Scattering;
  - Pair Production.

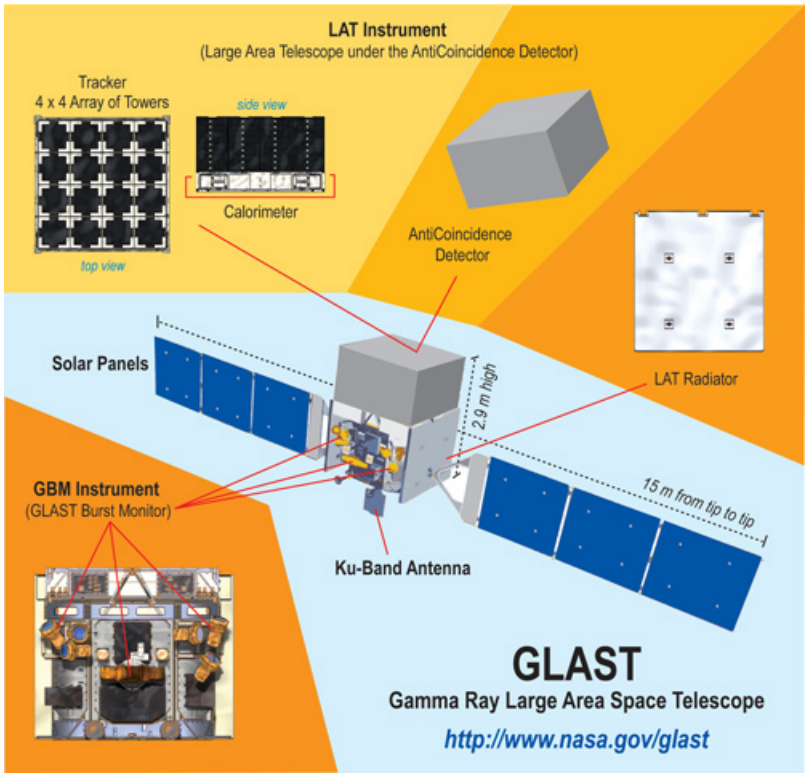


- Indirect Form:
  - Continuous atmospheric particle showers



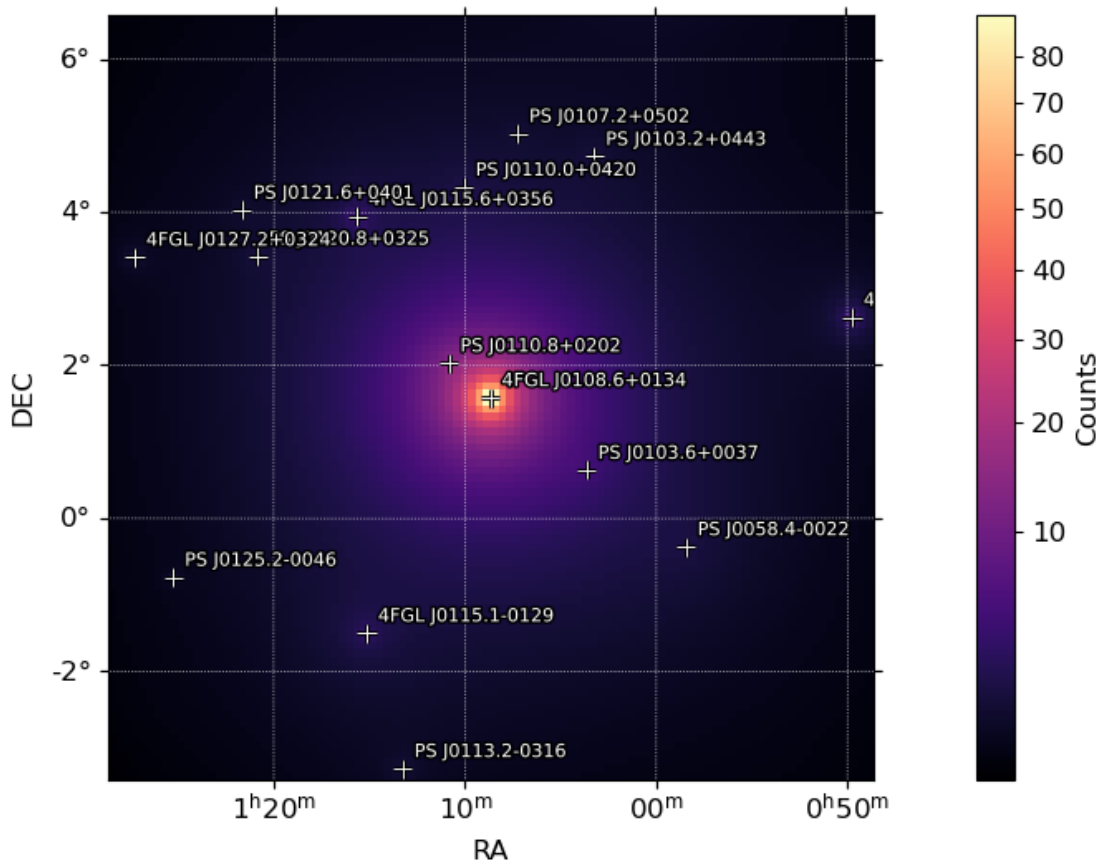
Fermi-LAT Satellite

- The Fermi satellite performs a continuous scanning of the sky orbiting the Earth trying to cover as much of the sky as possible.
- The purpose is to collect photon hit events, deducing their origin from incoming direction and spacecraft position information at any time in the mission and its energy.



Fermi-LAT Data

- The energy, the number of photons, the location, date and duration are part of the data collected by the satellite.
- Through the data collected we want to build the most likely model that allows us to interpret what the detector sees.



Data Analysis

- The Fermi-LAT mission already performs this analysis for some sources. We are going to work with a script that allows us to perform the same analysis, but in more general conditions, and we will compare the results.
- The analysis follows the following order:
  - Define a point in the skymap, draw a circle around that point and check the data or photons detected within that circle.
  - Then we count the photons, check where they came from and the probability that they were correctly reconstructed. With this information, the likely model is created.
  - Finally, check if there are corresponding sources.

Data Analysis

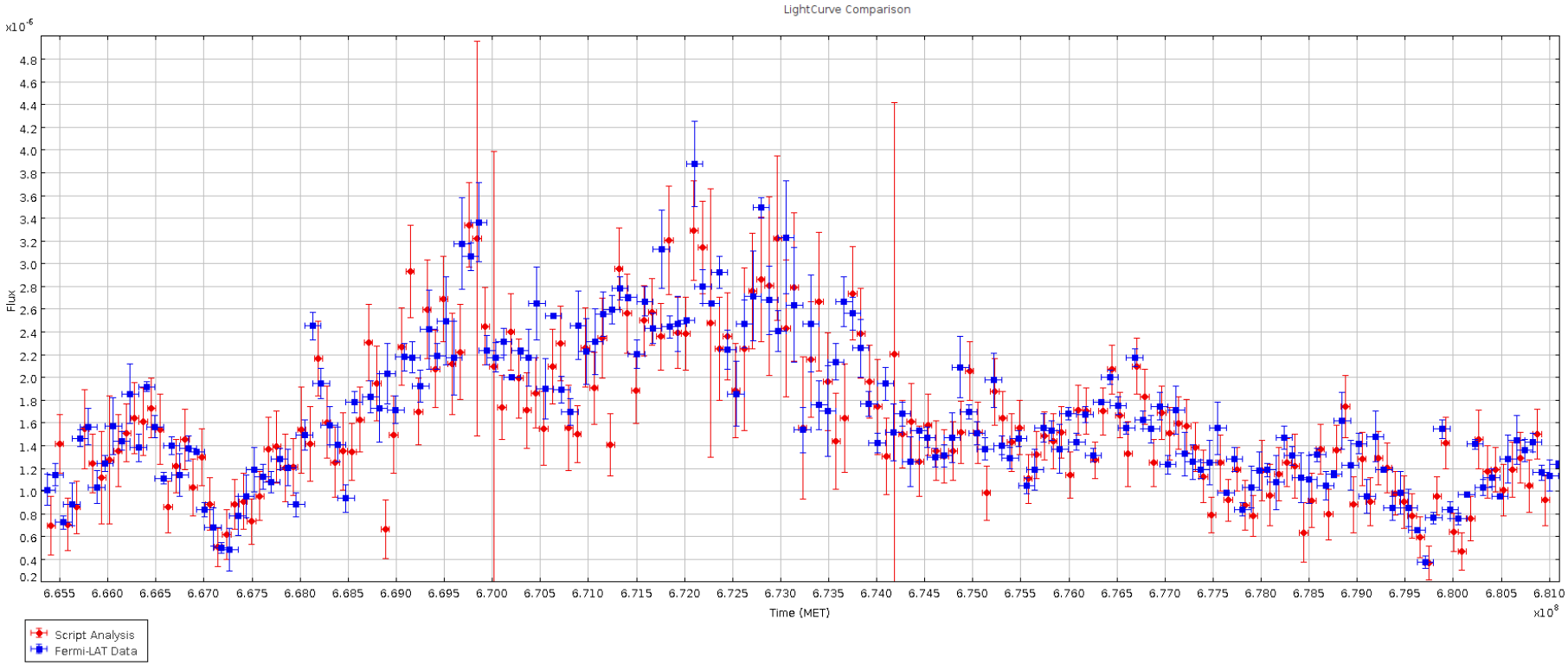
- The Likelihood for Fermi-LAT Data Analysis comes in two forms:
  - Binned Likelihood: $L = e^{-N_{\text{pred}}} \prod \frac{m_i^{n_i}}{n_i!}$
  - Unbinned Likelihood: $L = e^{-N_{\text{pred}}} \prod m_i$
- The confidence with which we detect a source is measured by the "Test Statistics" (TS):
  - $TS = 2 \ln \frac{L_{max,1}}{L_{max,0}}$

Data Analysis

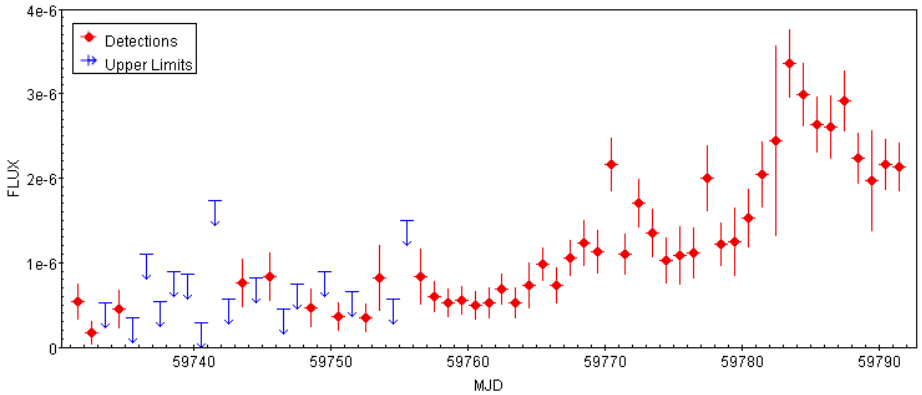
- What our script does differently is
  - Make a bigger circle.
  - The Fermi-LAT is restricted to a grid of sources that they find interesting while we can work with any source.
  - We do the full model, in the sense that we let all sources to vary, whereas Fermi-LAT tests only for target variations.

Flare 4C +01.02

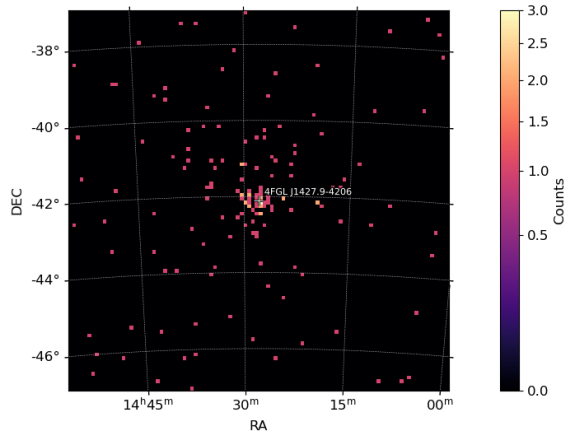
- It's a very bright flare from a source dominating the region.



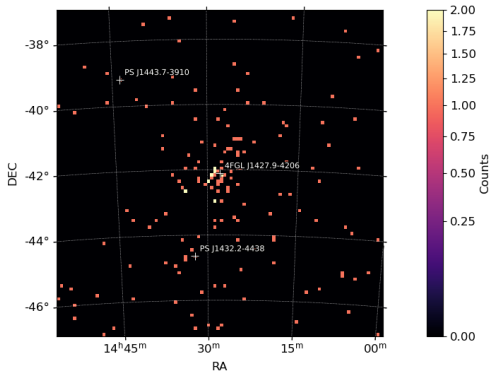
Blazar PKS B1424-418



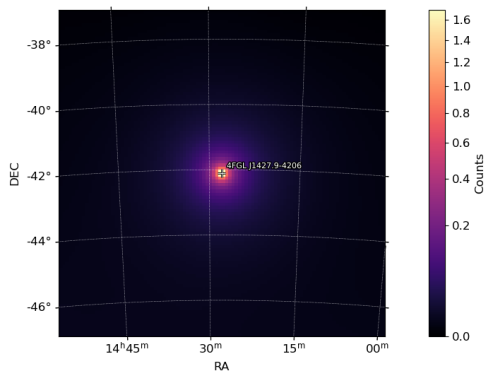
(a) Lightcurve from June 2022 to August 2022



(b) Photon Detection on day 52 (22/07/2022)



(c) Photon Detection on day 51 (21/07/2022)



(d) Model for photon detection on day 52

We hope you liked and thanks for coming!

THE END!!