



Fermi

Gamma-ray Space Telescope



The COSMAX project

Denis Dumora, Benoît Lott
CEN Bordeaux-Gradignan



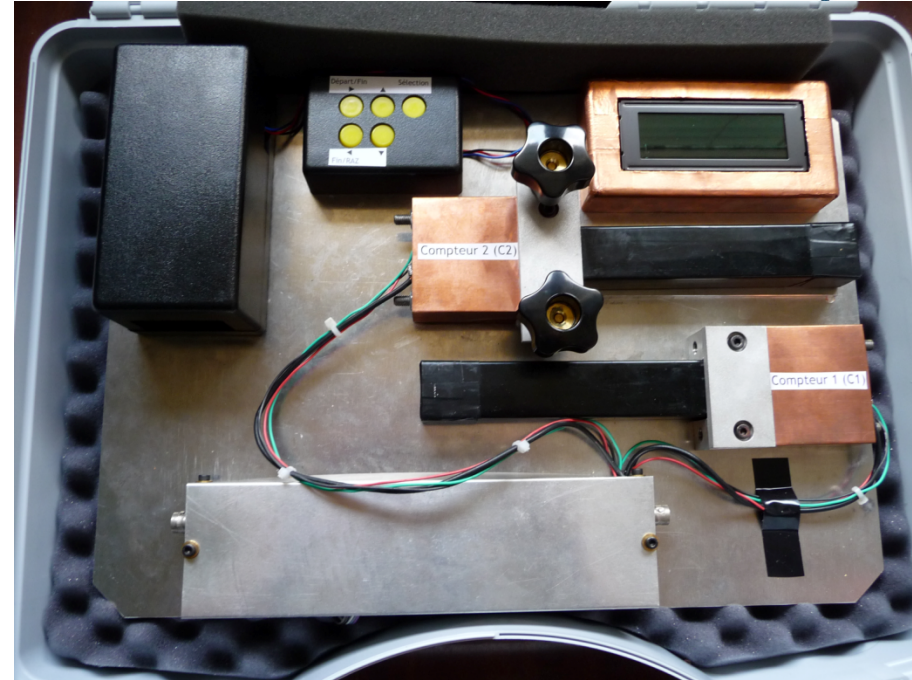
Educational kit usable by any high-school physics teacher without special training.

Allows the existence of cosmic rays to be demonstrated

- **Visualization of pulses with oscilloscopes** available in all french high-schools
- **Counting and datalogging** via an Arduino-based acquisition system on an SD microcard


Fitted with a GPS and altimeter sensor

- Advantages:**
- **Low cost 1200 euros:** recycling of prototype Fermi (aka GLAST) detectors +electronics
 - **Ease of use**
 - **Portability (powered by USB)**
 - **No background ($E_{\text{dep}} \sim 12 \text{ MeV}$ for muons)**



Press release on flaring 3C 454.3





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Past Missions


Future Missions

Launch Schedule

Mission Calendar

Fermi

Fermi Gamma-ray Space Telescope



Feature

Text Size + -

Fermi Sees Brightest-Ever Blazar Flare 12.08.09

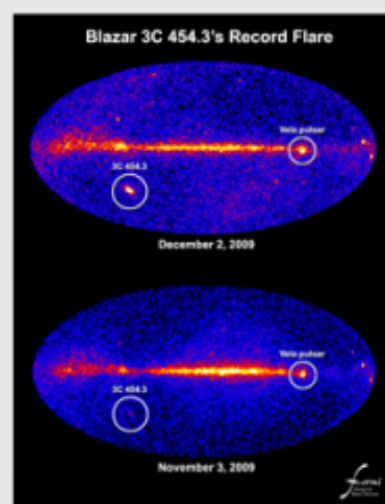
A galaxy located billions of light-years away is commanding the attention of NASA's Fermi Gamma-ray Space Telescope and astronomers around the globe. Thanks to a series of flares that began September 15, the galaxy is now the brightest source in the gamma-ray sky -- more than ten times brighter than it was in the summer.

Astronomers identify the object as 3C 454.3, an active galaxy located 7.2 billion light-years away in the constellation Pegasus. But even among active galaxies, it's exceptional.

"We're looking right down the barrel of a particle jet powered by the galaxy's supermassive black hole," said Gino Tosti at the National Institute of Nuclear Physics in Perugia, Italy. "Some change within that jet -- we don't know what -- is likely responsible for these flares."

Blazars, like many active galaxies, emit oppositely directed jets of particles traveling near the speed of light when matter falls toward their central supermassive black holes. What makes a blazar so bright in gamma rays is its orientation: One of the jets happens to be aimed straight at us.

Blazar 3C 454.3's Record Flare



December 2, 2009

November 3, 2009

Unprecedented flares from the blazar 3C 454.3 in the constellation Pegasus now make it the brightest persistent

The COSMAX toolkit

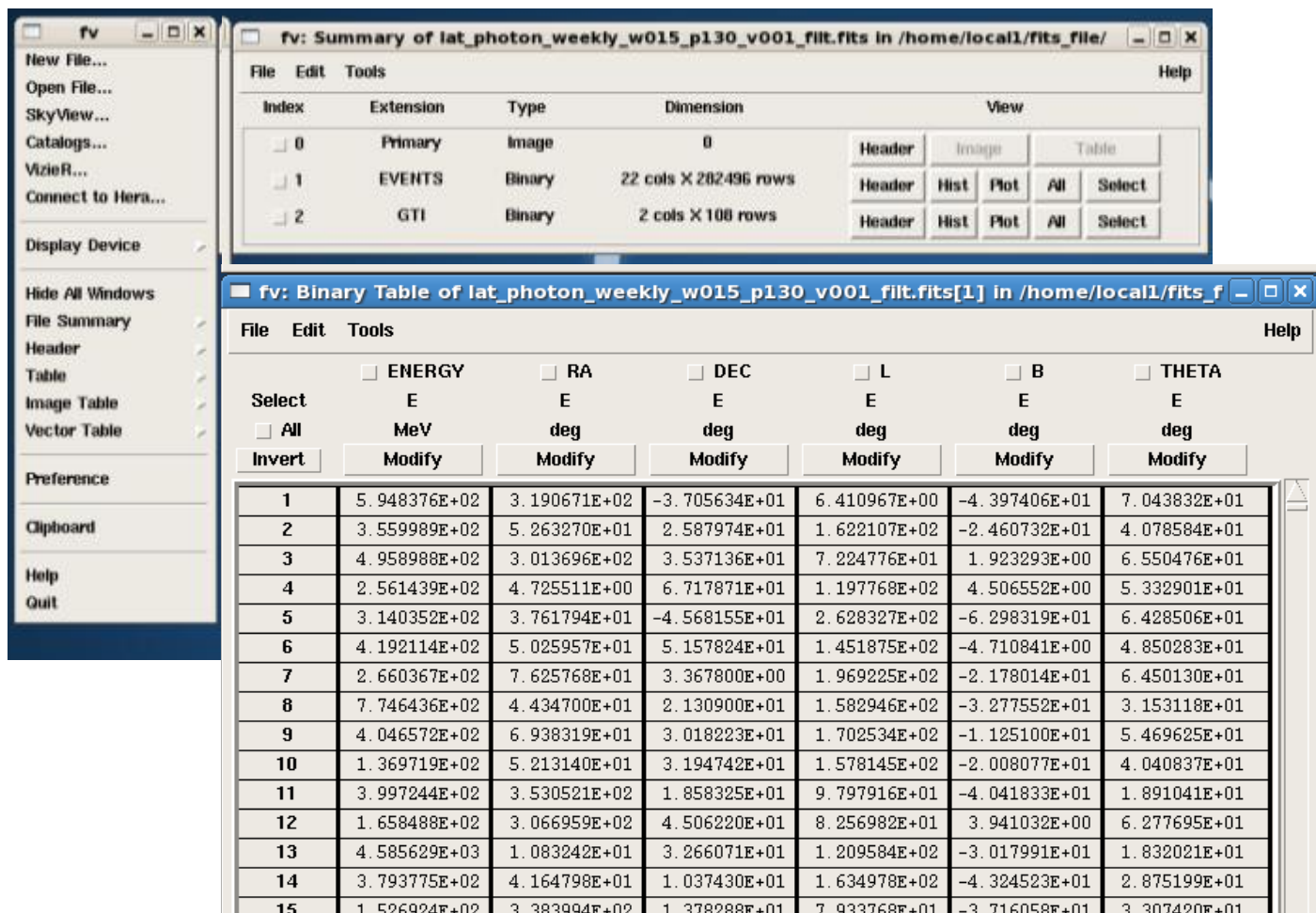


- **Building upon the unique properties of the LAT data**
- **Suite of python scripts allowing a simple exploration and manipulation of the LAT data by non-experts.**
- **Preinstalled on a VMWare virtual machine or available as a linux tarball**
- **Functionalities:**
 - data download
 - exploring the data with fv
 - creation of sky maps, animations, light curves, exposure maps...
 - display the Fermi blog
 - spectral fitting
- **Advertised to physics teachers, amateur astronomers and (mostly french) scientists in the field of high-energy astrophysics.**
- **Tutorial: ftp://www.cenbg.in2p3.fr/astropart/VM/cosmax_english.pdf**



Explore a weekly data file with the command `fv` (fits viewer)

➤ `fv fits_file/lat_photon_weekly_w074_p302_v001_filt.fits`



The screenshot shows the Fermi-LAT data viewer (fv) interface. The main window displays a summary of the data file `lat_photon_weekly_w015_p130_v001_filt.fits`. The summary table is as follows:

| Index | Extension | Type | Dimension | View |
|-------|-----------|--------|-----------------------|---------------------------------|
| 0 | Primary | Image | 0 | Header, Image, Table |
| 1 | EVENTS | Binary | 22 cols X 282496 rows | Header, Hist, Plot, All, Select |
| 2 | GTI | Binary | 2 cols X 100 rows | Header, Hist, Plot, All, Select |

The viewer also displays a binary table of photon events for the selected file. The table columns are ENERGY, RA, DEC, L, B, and THETA, all in degrees. The table contains 15 rows of data:

| Select | ENERGY E MeV | RA E deg | DEC E deg | L E deg | B E deg | THETA E deg |
|--------|--------------------|----------------|-----------------|---------------|---------------|-------------------|
| 1 | 5.948376E+02 | 3.190671E+02 | -3.705634E+01 | 6.410967E+00 | -4.397406E+01 | 7.043832E+01 |
| 2 | 3.559989E+02 | 5.263270E+01 | 2.587974E+01 | 1.622107E+02 | -2.460732E+01 | 4.078584E+01 |
| 3 | 4.958988E+02 | 3.013696E+02 | 3.537136E+01 | 7.224776E+01 | 1.923293E+00 | 6.550476E+01 |
| 4 | 2.561439E+02 | 4.725511E+00 | 6.717871E+01 | 1.197768E+02 | 4.506552E+00 | 5.332901E+01 |
| 5 | 3.140352E+02 | 3.761794E+01 | -4.568155E+01 | 2.628327E+02 | -6.298319E+01 | 6.428506E+01 |
| 6 | 4.192114E+02 | 5.025957E+01 | 5.157824E+01 | 1.451875E+02 | -4.710841E+00 | 4.850283E+01 |
| 7 | 2.660367E+02 | 7.625768E+01 | 3.367800E+00 | 1.969225E+02 | -2.178014E+01 | 6.450130E+01 |
| 8 | 7.746436E+02 | 4.434700E+01 | 2.130900E+01 | 1.582946E+02 | -3.277552E+01 | 3.153118E+01 |
| 9 | 4.046572E+02 | 6.938319E+01 | 3.018223E+01 | 1.702534E+02 | -1.125100E+01 | 5.469625E+01 |
| 10 | 1.369719E+02 | 5.213140E+01 | 3.194742E+01 | 1.578145E+02 | -2.008077E+01 | 4.040837E+01 |
| 11 | 3.997244E+02 | 3.530521E+02 | 1.858325E+01 | 9.797916E+01 | -4.041833E+01 | 1.891041E+01 |
| 12 | 1.658488E+02 | 3.066959E+02 | 4.506220E+01 | 8.256982E+01 | 3.941032E+00 | 6.277695E+01 |
| 13 | 4.585629E+03 | 1.083242E+01 | 3.266071E+01 | 1.209584E+02 | -3.017991E+01 | 1.832021E+01 |
| 14 | 3.793775E+02 | 4.164798E+01 | 1.037430E+01 | 1.634978E+02 | -4.324523E+01 | 2.875199E+01 |
| 15 | 1.526924E+02 | 3.383994E+02 | 1.378288E+01 | 7.933768E+01 | -3.716058E+01 | 3.307420E+01 |

Cosmax VMWare



SL5.7 - VMware Player (Non-commercial use only)

Player | Applications | Places | System | 4:29 PM

SAOImage ds9

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

File: counts_map_406_ait.fits

Object: []

Value: []

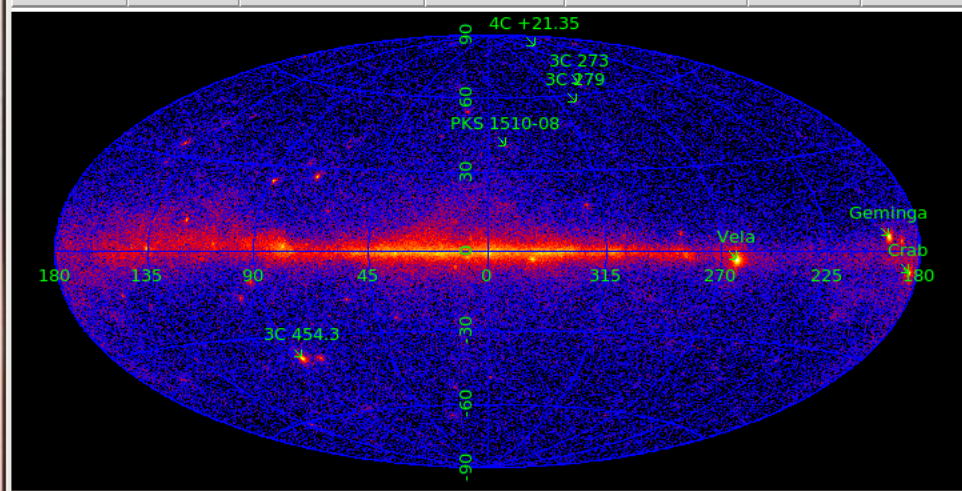
WCS: [] []

Physical: X [] Y []

Image: X [] Y []

Frame 1: x 1.000 0.000 °

| | | | | | | | | | | |
|------|------|------------|--------|------------|-------|-------|-------|--------|-----|------|
| file | edit | view | frame | bin | zoom | scale | color | region | wcs | help |
| open | save | save image | header | page setup | print | exit | | | | |



Terminal

```

os.system("ds9 -cmap b -scale log -zoom %s -grid yes -grid view axes tickmarks no -grid skyformat degrees -grid axes color blue -grid format1 d.0 -grid format2 d.0 -wcs galactic -colorbar no -file counts_maps/counts_map_%s_ait.fits -regions load %s" % (zoom,stweek,region))
<88>localhost:localhost.localdomain% create_map 406
option ait (default/default)
yes
gtbin evfile=fits_file/lat_photon_weekly_w406_p302_v001_filt.fits scfile=NONE outfile=counts_maps/counts_map_406_ait.fits algorithm=CMAP nxpix=720 nypix=360 bin sz=0.5 coordsys=GAL xref=0 yref=0 axisrot=0 proj=AIT
This is gtbin version ScienceTools-v10r0p5-fssc-20150518
gtbin: WARNING: No spacecraft file: EXPOSURE keyword will be set equal to ontimed.
Nombre de photons: 326431
<89>localhost:localhost.localdomain% create_map 406
option ait (default/default)
yes
gtbin evfile=fits_file/lat_photon_weekly_w406_p302_v001_filt.fits scfile=NONE outfile=counts_maps/counts_map_406_ait.fits algorithm=CMAP nxpix=720 nypix=360 bin sz=0.5 coordsys=GAL xref=0 yref=0 axisrot=0 proj=AIT
This is gtbin version ScienceTools-v10r0p5-fssc-20150518
gtbin: WARNING: No spacecraft file: EXPOSURE keyword will be set equal to ontimed.

```

Functionalities



- *fetch* (retrieve data from FSSC)

- *create_map* (create map with crv

- *fe*

- *cr*

- *cr*

- *cr*

- *fe*

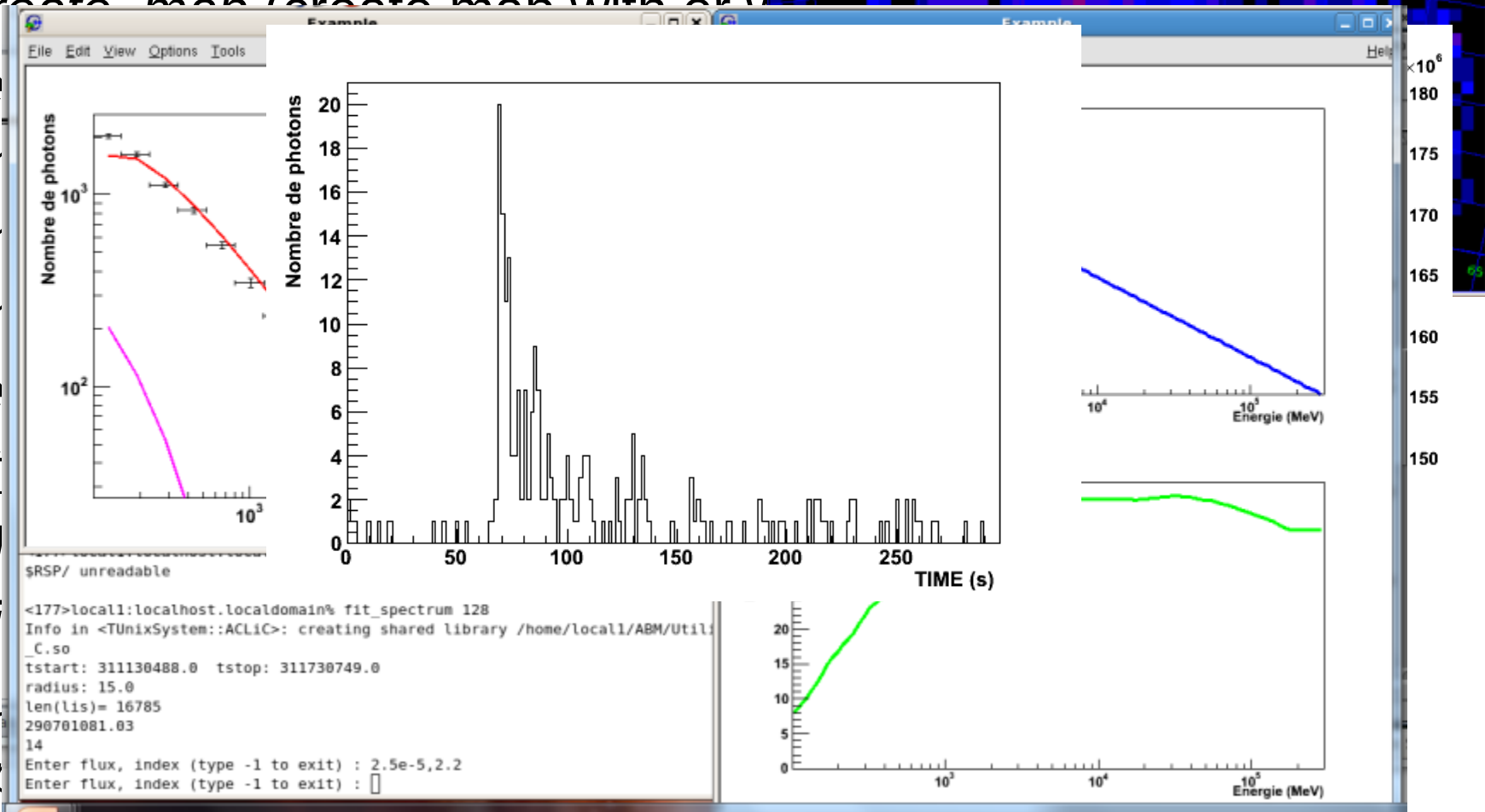
- *fit*

- *M*

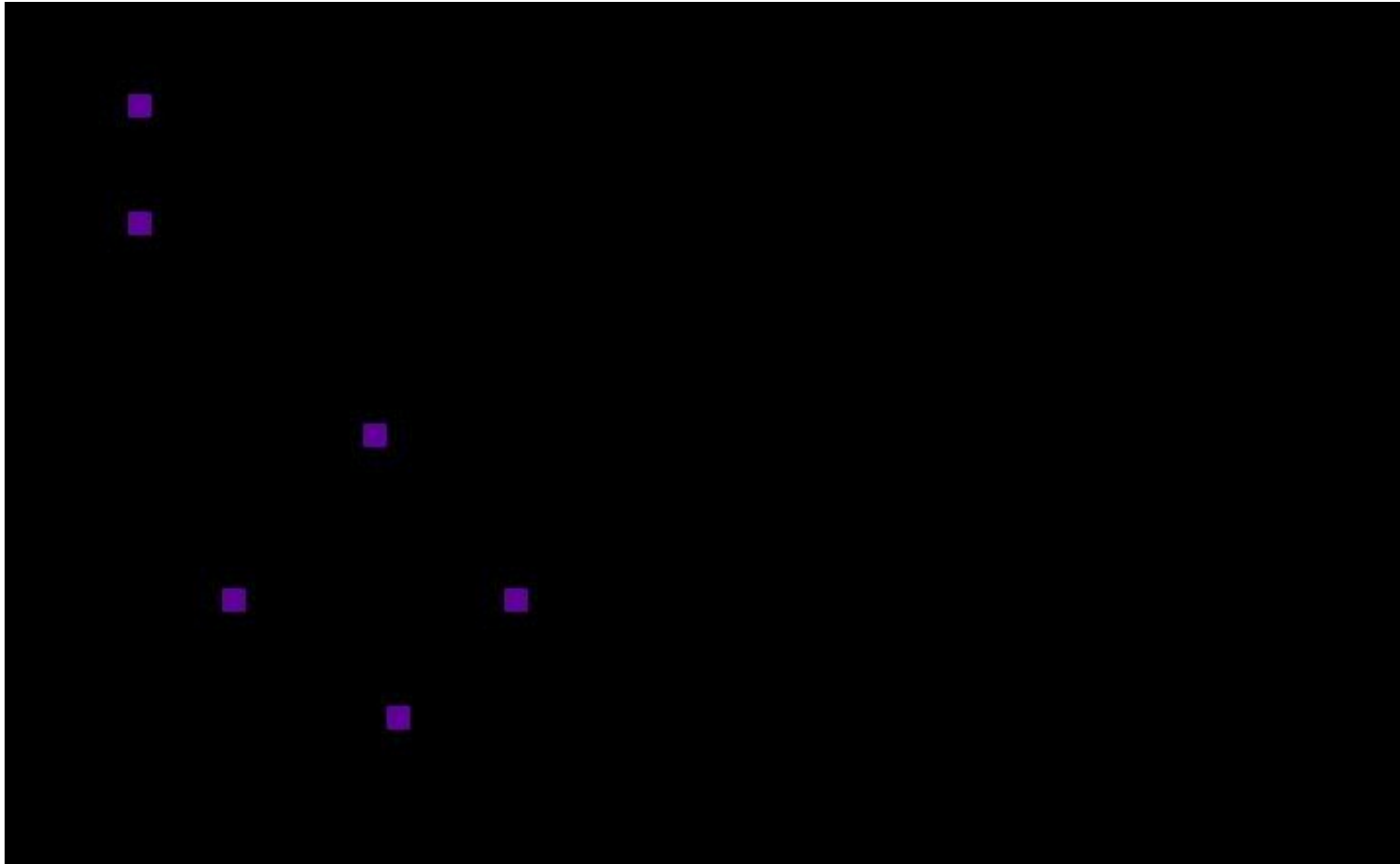
- *hi*

- *flu*

- *up*



GRB 080916C



The first Fermi masterclass

Nov. 19, 2015

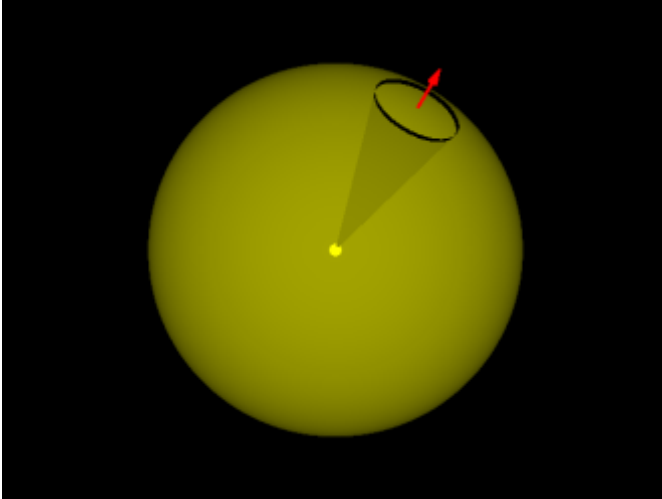


First masterclasses



- One-day event in 2015, 2016.
~70 students in France. Similar events in Italy.
- Theme: « **Black holes** » (as seen by the Fermi-LAT)
- Study of the bright flare of 3C454.3 in Nov. 2010 and GRB 080916C (maps, lightcurves, computation of luminosity or fluence), Some published results/figures were replicated.
- Very positive experience according to all parties
- Some interest by the media

Flux and luminosity



Flux $F_p = N / ST$

F_p = Flux (photons $\text{cm}^{-2} \text{s}^{-1}$)

N = Number of collected photons

S = Collecting area (cm^2)

T = Observing time (s)

Energy flux $F_E = F_p E$

F_E = Energy flux (W cm^{-2})

E = Mean photon energy (MeV)

1 MeV = $1.6 \cdot 10^{-13}$ J

Fluence $F = N E / S$

F = Fluence (J cm^{-2})

N = Number of collected photons

S = Collecting area (cm^2)

Luminosity $L = 4 \pi d^2 F_E$

L = Luminosity (W)

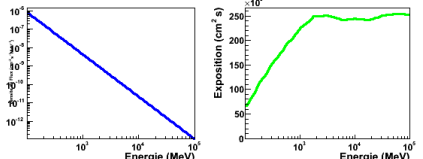
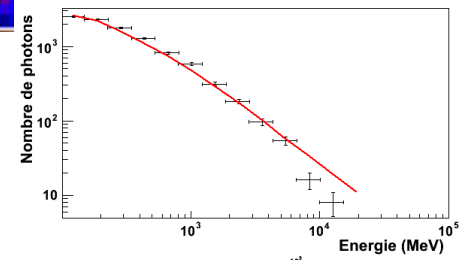
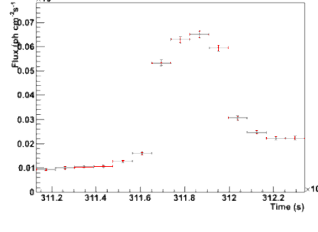
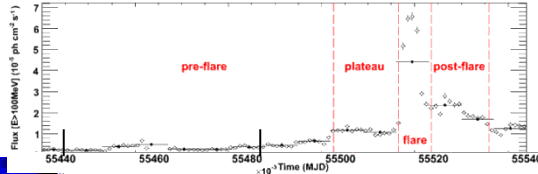
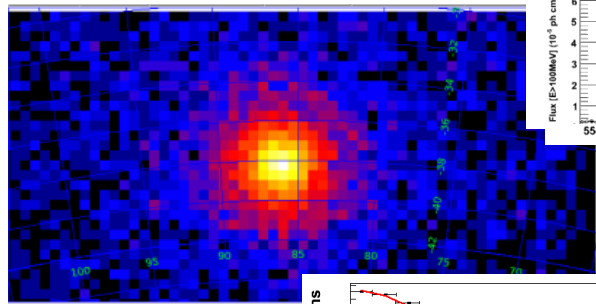
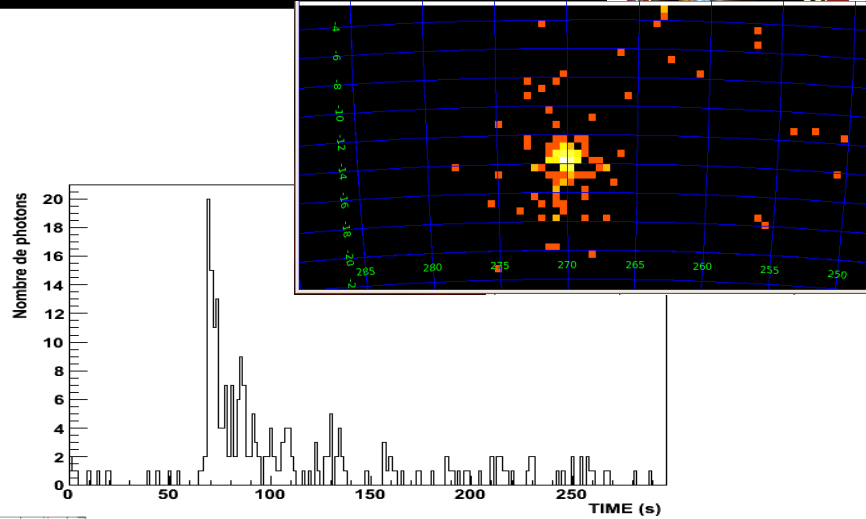
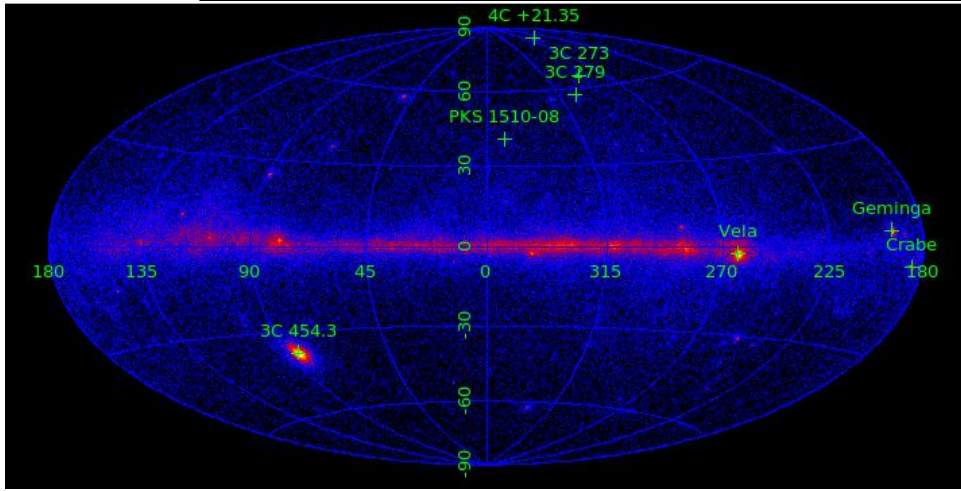
d = distance (cm)

Luminosity of the Sun: $4 \cdot 10^{26}$ W

Luminosity of the Milky Way: $5 \cdot 10^{36}$ W

- The number of photons emitted in a cone per second remains constant and thus is independent of the distance to the source.
- At a given distance, the area of a sphere intercepting the cone scales as the square of the distance.
- So the number of photons per square cm and second (= the flux) is inversely proportional to the distance squared ("inverse-square law").

Some highlights



fv: Summary of lat_photon_weekly_w015_p130_v001_fit.fits in /home/local/fits_file/

| File | Extension | Type | Dimension | View |
|------|-----------|--------|-----------------------|-----------------------------|
| 0 | Primary | Image | 0 | Header Image Table |
| 1 | EVENTS | Binary | 22 cols X 282496 rows | Header Hist Plot All Select |
| 2 | GTI | Binary | 2 cols X 100 rows | Header Hist Plot All Select |

fv

- New File...
- Open File...
- SkyView...
- Catalogs...
- Connect to Hera...
- Display Device
- Hide All Windows
- File Summary
- Header
- Table
- Image Table
- Vector Table
- Preference
- Clipboard
- Help
- Quit

fv: Binary Table of lat_photon_weekly_w015_p130_v001_fit.fits[1] in /home/local/fits_f...

| Select | ENERGY | RA | DEC | L | B | THETA |
|--------|--------------|--------------|---------------|--------------|---------------|--------------|
| All | E | E | E | E | E | E |
| Invert | Modify | Modify | Modify | Modify | Modify | Modify |
| 1 | 5.948376E+02 | 3.190671E+02 | -3.705634E+01 | 6.410967E+00 | -4.397406E+01 | 7.043832E+01 |
| 2 | 3.559989E+02 | 5.263270E+01 | 2.587974E+01 | 1.622107E+02 | -2.460732E+01 | 4.078584E+01 |
| 3 | 4.958988E+02 | 3.013696E+02 | 3.537136E+01 | 7.224776E+01 | 1.923293E+00 | 6.550476E+01 |
| 4 | 2.614391E+02 | 4.785511E+00 | 6.711871E+01 | 1.197768E+02 | 4.506552E+00 | 5.332901E+01 |
| 5 | 3.140352E+02 | 3.761794E+01 | -4.568155E+01 | 2.628327E+02 | -5.298319E+01 | 6.428506E+01 |
| 6 | 4.192114E+02 | 5.025957E+01 | 5.157824E+01 | 1.451875E+02 | -4.710841E+00 | 4.850283E+01 |
| 7 | 2.660367E+02 | 7.625768E+01 | 3.367800E+00 | 1.969225E+02 | -2.178014E+01 | 6.450130E+01 |
| 8 | 7.746436E+02 | 4.434700E+01 | 2.130900E+01 | 1.582946E+02 | -3.277552E+01 | 3.153118E+01 |
| 9 | 4.046572E+02 | 6.938319E+01 | 3.018223E+01 | 1.702534E+02 | -1.125100E+01 | 5.469625E+01 |
| 10 | 1.369719E+02 | 5.213140E+01 | 3.194742E+01 | 1.578145E+02 | -2.008077E+01 | 4.040837E+01 |
| 11 | 3.997244E+02 | 3.530521E+02 | 1.858325E+01 | 9.797916E+01 | -4.041833E+01 | 1.891041E+01 |
| 12 | 1.658488E+02 | 3.066959E+02 | 4.506220E+01 | 8.256982E+01 | 3.941032E+00 | 6.277695E+01 |
| 13 | 4.585629E+03 | 1.083242E+01 | 3.266071E+01 | 1.209584E+02 | -3.017991E+01 | 1.832021E+01 |
| 14 | 3.793775E+02 | 4.164798E+01 | 1.037430E+01 | 1.634978E+02 | -4.324533E+01 | 2.875199E+01 |
| 15 | 1.526924E+02 | 3.383994E+02 | 1.378988E+01 | 7.933768E+01 | -3.716058E+01 | 3.307420E+01 |
| 16 | 1.013430E+02 | 3.353424E+02 | 1.529149E+01 | 7.774402E+01 | -3.410194E+01 | 3.591610E+01 |
| 17 | 1.856876E+02 | 3.167148E+01 | 2.925471E+01 | 1.420531E+02 | -3.080777E+01 | 2.286978E+01 |
| 18 | 2.878818E+02 | 3.101717E+02 | 3.919566E+01 | 7.939149E+01 | -1.622287E+00 | 5.984022E+01 |
| 19 | 5.396586E+02 | 3.551581E+02 | 5.789342E+01 | 1.136128E+02 | -3.691428E+00 | 4.532473E+01 |
| 20 | 2.482490E+02 | 5.011462E+01 | 5.818341E+01 | 1.415458E+02 | 8.086598E+01 | 5.125824E+01 |

Conclusion



- **Interested in using cosmax?
Feedback, suggestions welcome.**
- **You may consider doing masterclasses with
some of your data.**