

# Astrofisica Nucleare e Subnucleare

## UHECR

## ◎ Astonishing variety of TeV\* emitters

### ✦ Within the Milky Way

- ✦ Supernova remnants
- ✦ Bombarded molecular clouds
- ✦ Stellar binaries - colliding wind & X-ray
- ✦ Massive stellar clusters
- ✦ Pulsars and pulsar wind nebulae
- ✦ Supermassive black hole Sgr A\*

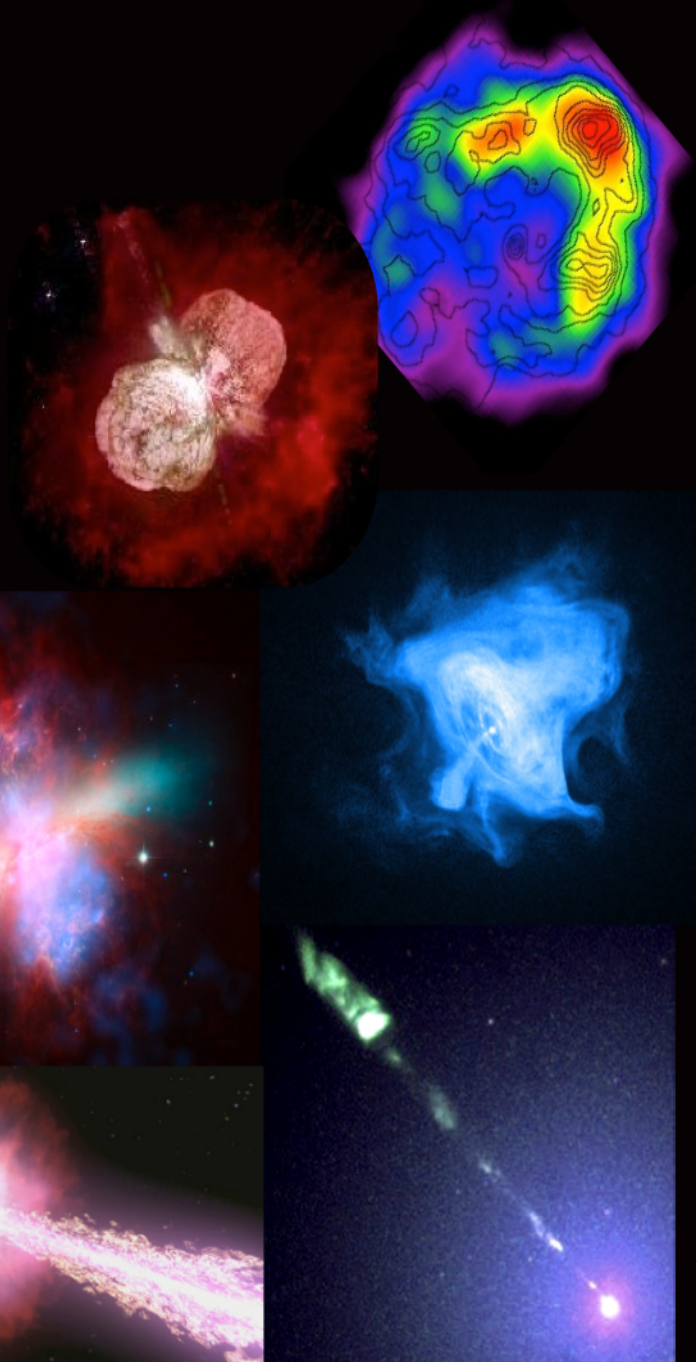
### ✦ Extragalactic

- ✦ Starburst galaxies
- ✦ MW satellites
- ✦ Radio galaxies
- ✦ Flat-spectrum radio quasars
- ✦ 'BL Lac' objects
- ✦ Gamma-ray bursts

## ◎ Acceleration to TeV energies is common, gamma-rays are an effective probe

- ✦ Strongly complementary to sync. measurements

\*0.05-50 TeV



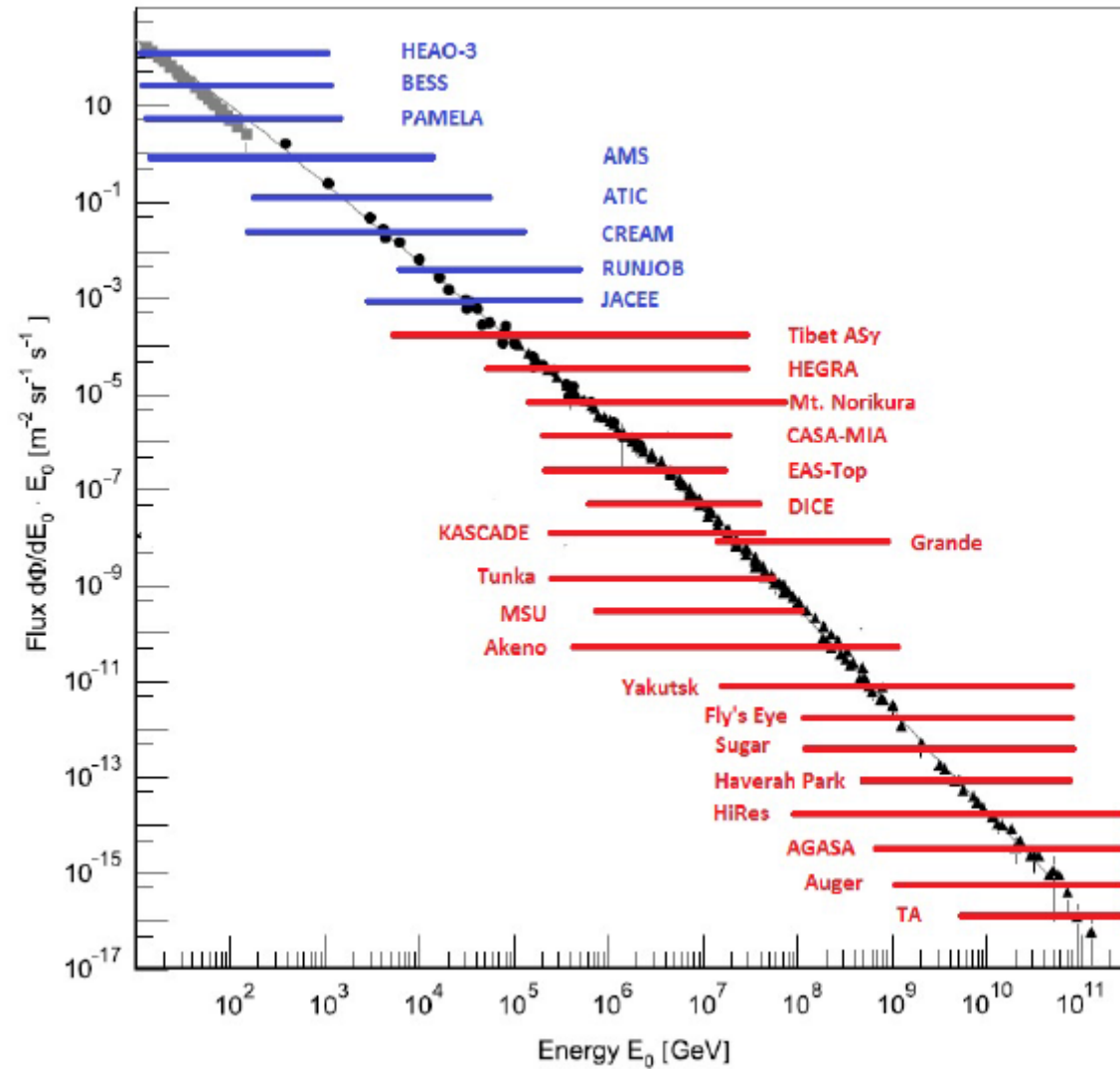
# Metodi di misura dei raggi cosmici

Misure dirette

$E < 10^{14}$  eV

Misure indirette,

$E > 10^{14}$  eV

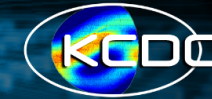


# KASCADE

KIT | IAP | HOME | Data Privacy | Impressum | admin | login



KASCADE Cosmic Ray Data Centre (KCDC) / Open  $\beta$



KCDC Homepage

KCDC Motivation

KCDC Regulations

▶ Information

▶ Announcements

FAQs

▶ User Account

▶ Data Shops

▶ Simulations

Spectra

Materials

▶ Publications

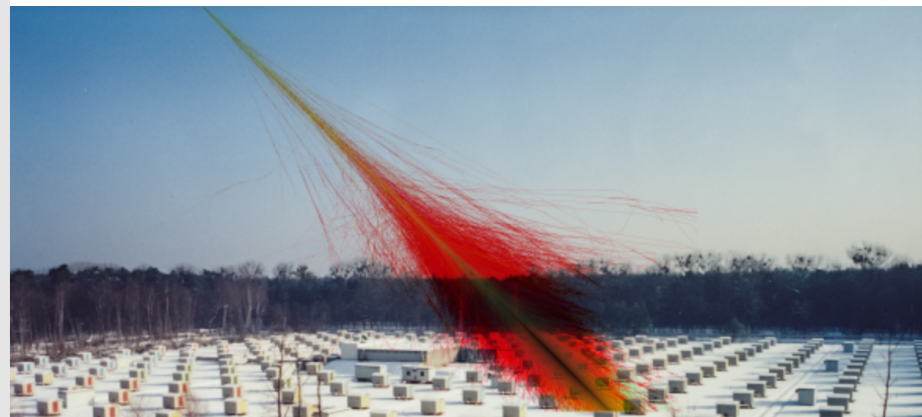
▶ Report a Bug

▶ Education/Lehre

KCDC Partners

## Welcome to kcdc

The aim of the project **KCDC** (**KASCADE Cosmic Ray Data Centre**) is the installation and establishment of a public data centre for high-energy astroparticle physics based on the data of the KASCADE experiment. KASCADE was a very successful large detector array which recorded data during more than 20 years on site of the KIT-Campus North, Karlsruhe, Germany (formerly Forschungszentrum, Karlsruhe) at 49,1°N, 8,4°E; 110m a.s.l. KASCADE collected within its lifetime more than 1.7 billion events of which some 433.000.000 survived all quality cuts and are made available here for public usage via three DataShops. The first, called 'KASCADE', was introduced in 2013 and has been continuously extended since then. It contains data from four KASCADE-Grande detectors, which were analysed separately and from the LOPES radio antennas. The second, called COMBINED, is based on a subsample of the KASCADE-Grande data, but was evaluated in a joint analysis of the KASCADE and GRANDE detector arrays. Newly added in 2021 was the MAKET-ANI DataShop, which contains data from the MAKET-ANI air shower experiment at Mount Aragats, Armenia.



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(IAP)  
KIT Campus North

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**DOI:**  
▶ [doi.org/10.17616/R3TS4P](https://doi.org/10.17616/R3TS4P)

Downloads  
▶ [KCDC Materials](#)

<https://kcdc.ipk.kit.edu/>

# CORSIKA Simulation

QGSJET/EGS4

proton

$E=10^{14}$  eV

iron nucleus

50 km

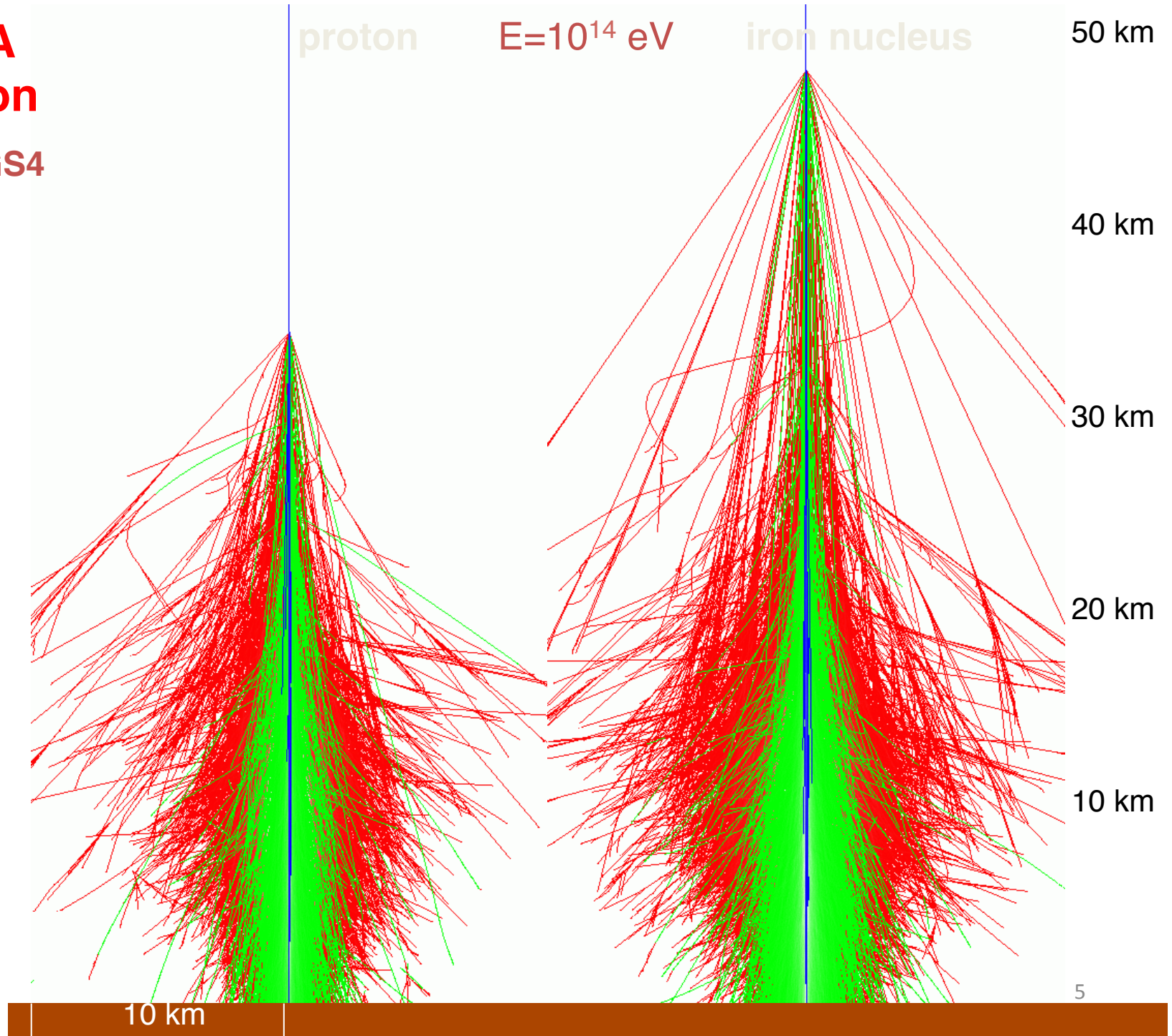
40 km

30 km

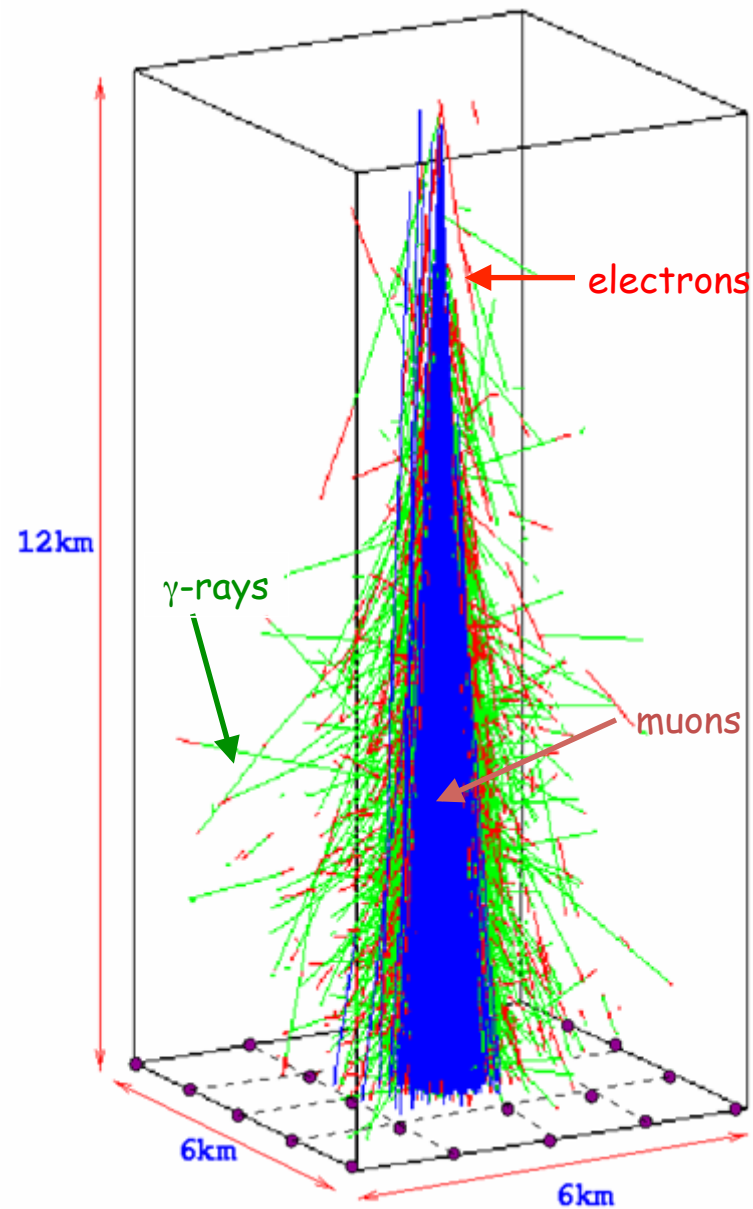
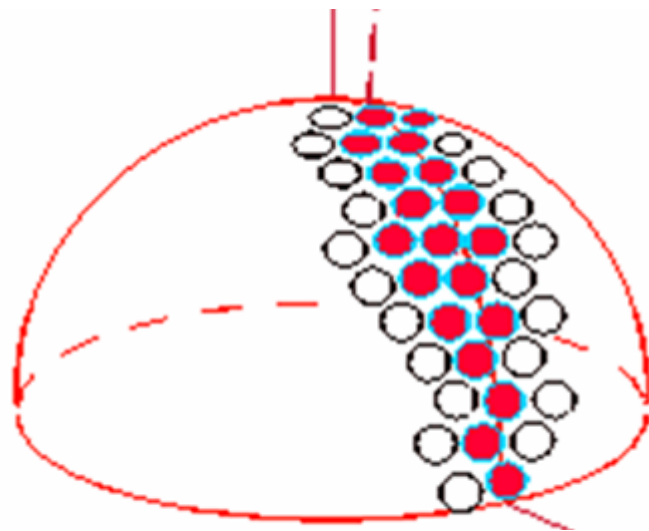
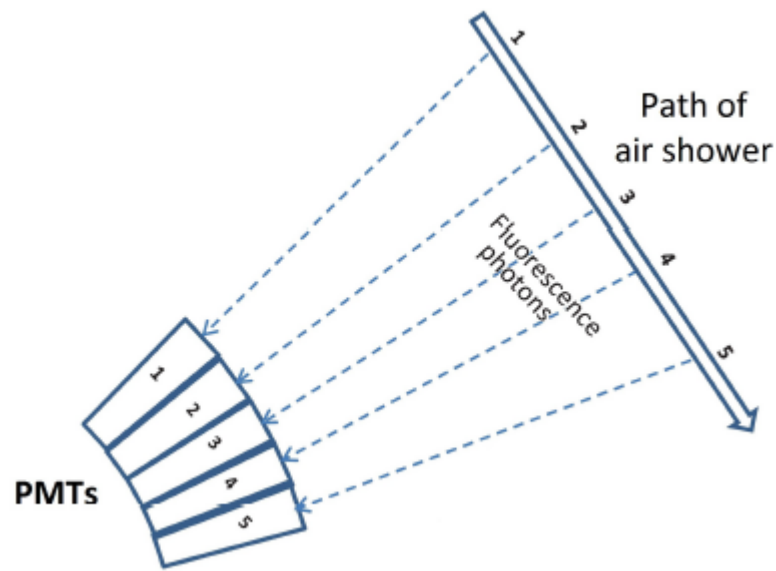
20 km

10 km

$e/\gamma$   
 $\mu$   
h



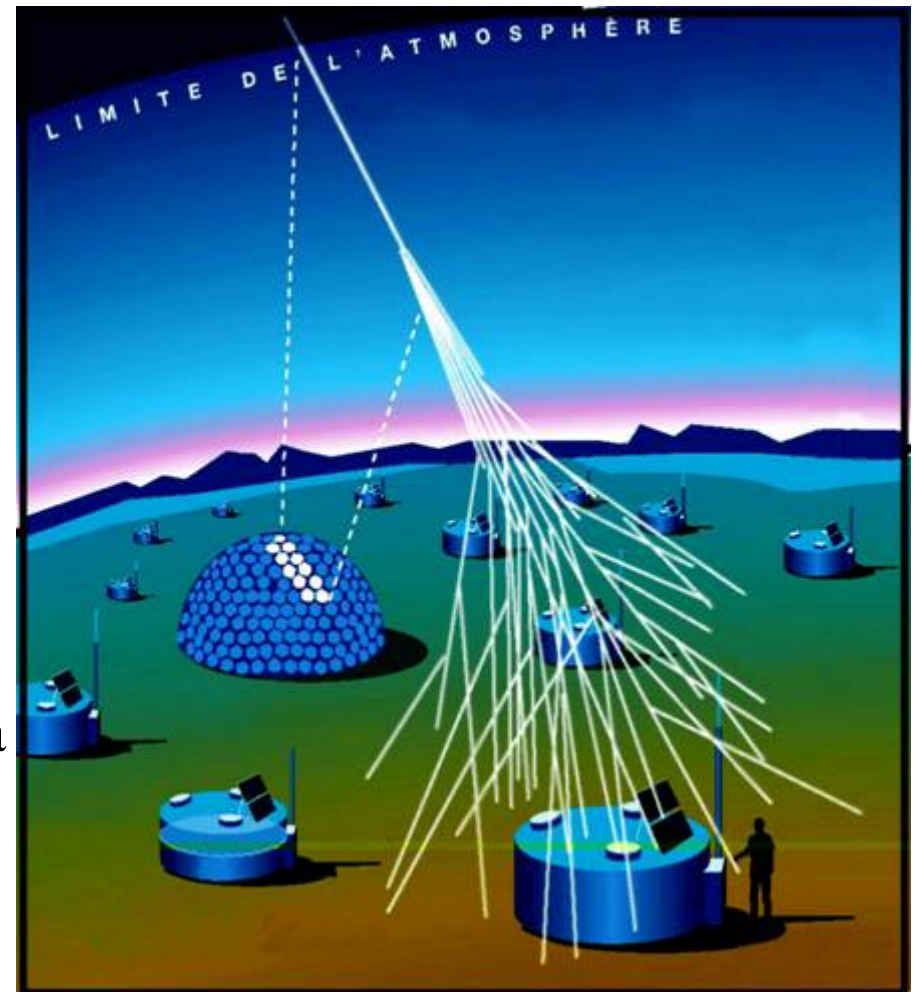
# Rivelatori di sciame di alta energia



# AUGER: Un rivelatore ibrido

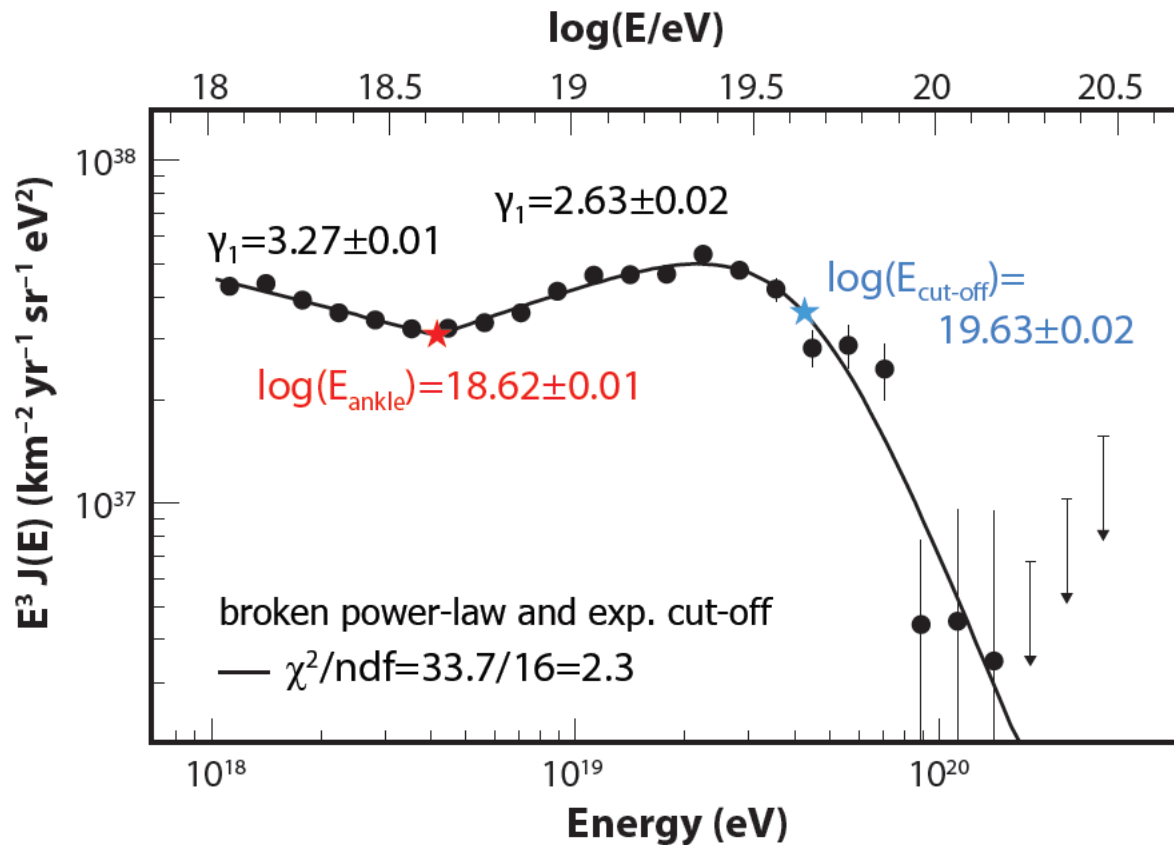
**Rivelatore di sciame:** 1600 taniche cilindriche (ciascuna di 10 m<sup>2</sup> ed alte 1.5 m) riempite di acqua, per rivelare gli sciame al suolo tramite la luce Cerenkov emessa dagli elettroni nell'acqua

- Il rivelatore di sciame misura la distribuzione laterale e temporale dello sciame
- Distanza tra taniche: 1.5 km
- Area di forma esagonale, di 60×60 km<sup>2</sup>
- Rivelatori di fluorescenza: 6 telescopi con ciascuno 4 “occhi” per determinare il profilo longitudinale dello sciame e l'altezza del suo massimo.



# AUGER Energy spectrum

## SD+Hybrid Combined Spectrum



#893:  
Salamida

#724:  
Dembinsky

**Exposure = 20905 km<sup>2</sup> sr yr** (60% increase over PLB 685 (2010) 239)

**Inclined showers add another 5300 km<sup>2</sup> sr yr (→ #724)**



# Auger

PIERRE  
AUGER  
OBSERVATORY

[Home](#) [News](#) [Observatory](#) [Collaboration](#) [Science](#) [Outreach](#) [Internal](#)

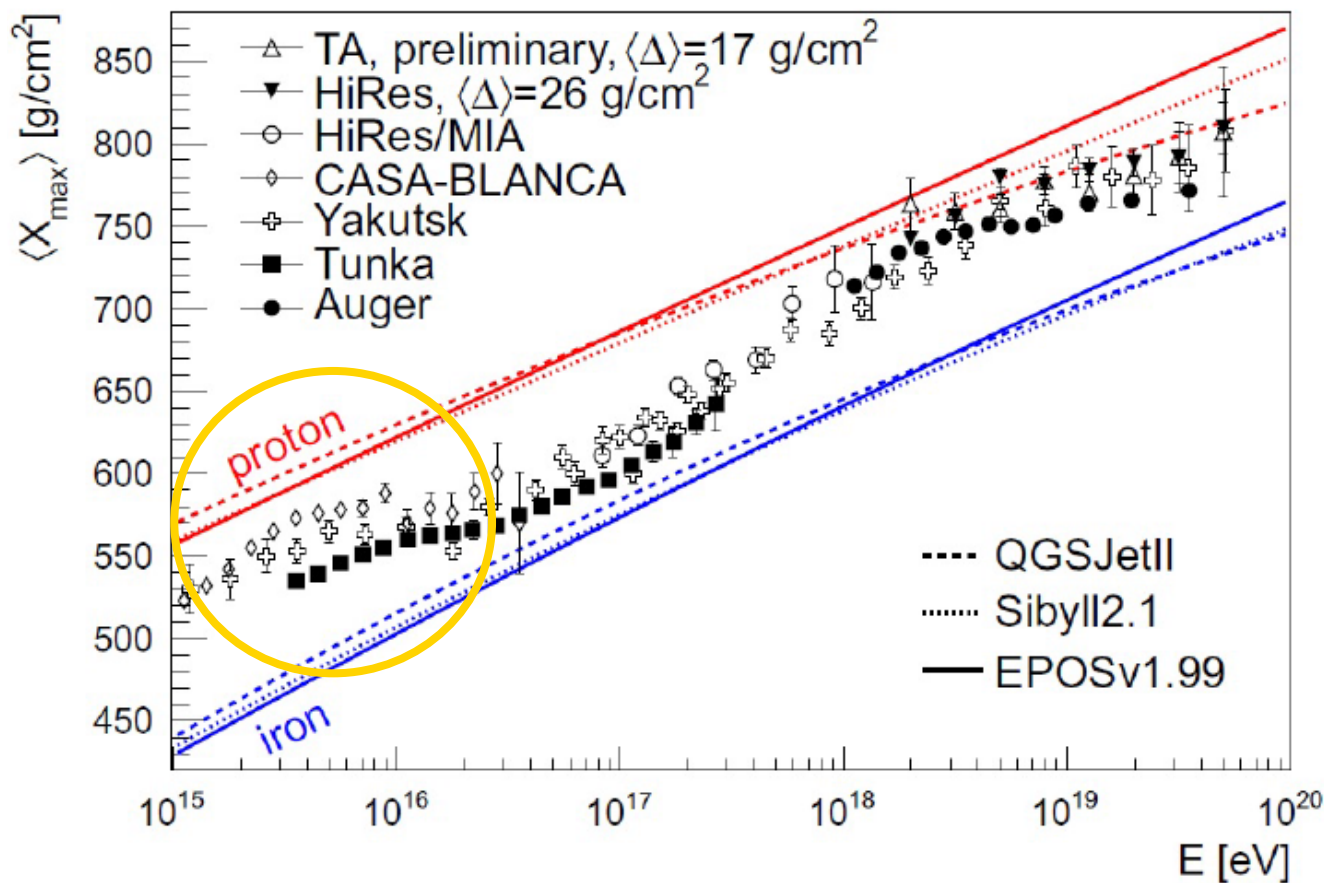


The Pierre Auger Collaboration wants to express all its closeness and solidarity to the people in Ukraine who are suffering the consequences of the war.

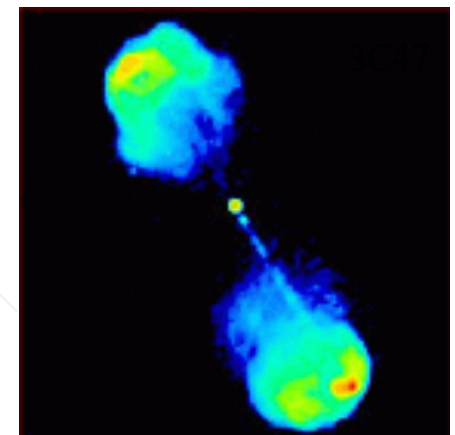
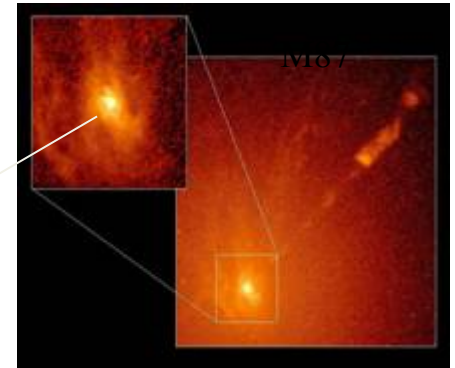
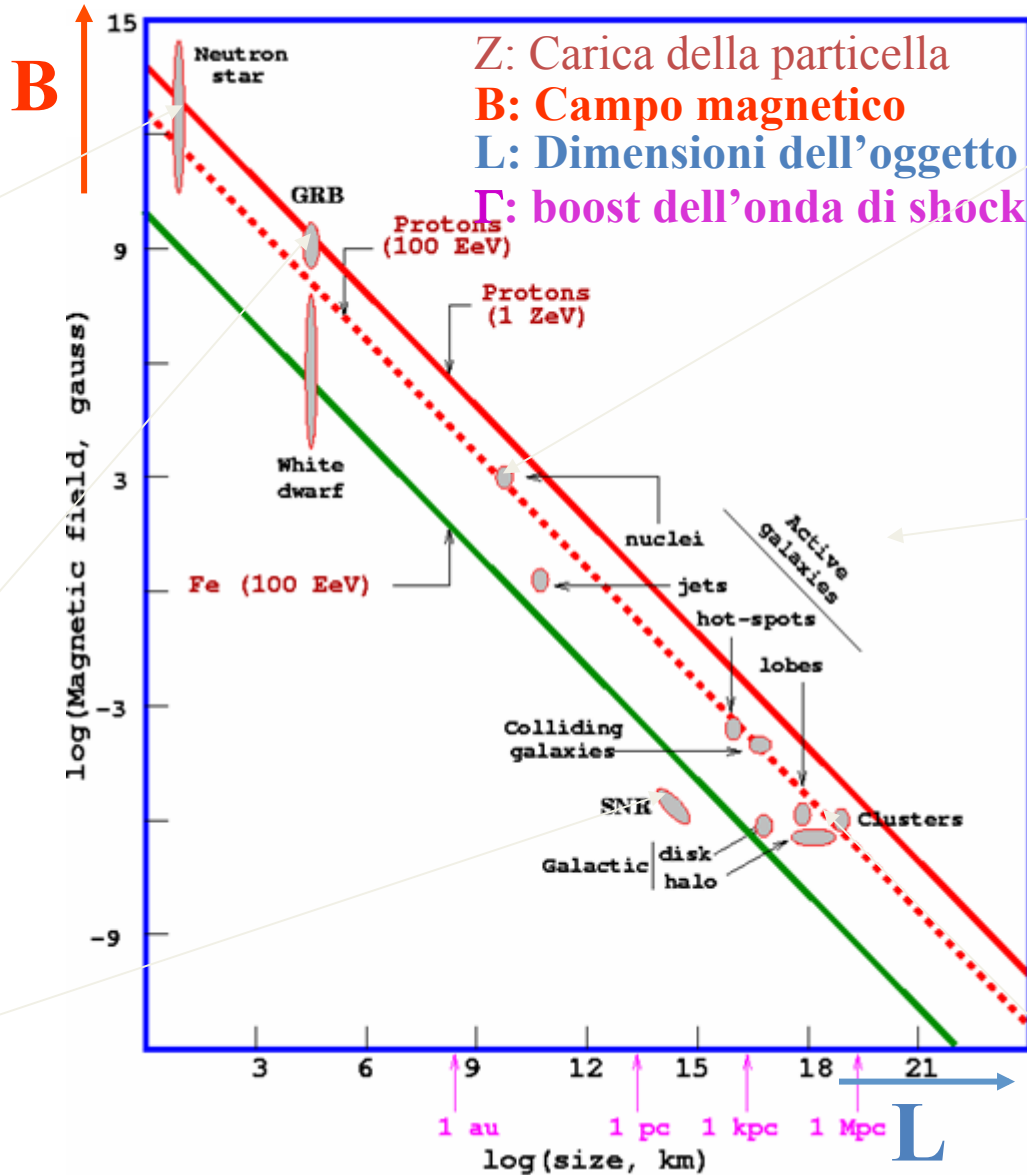
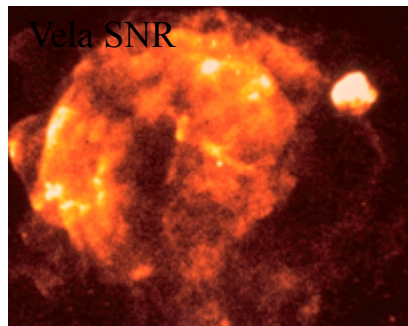
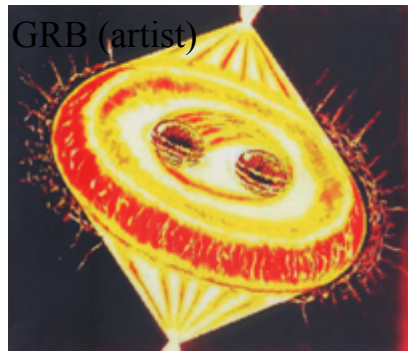
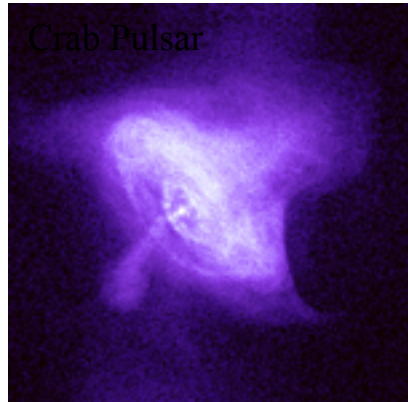
<https://www.auger.org/>

# Composizione chimica dei RC nella regione degli EAS

- Il modello del *leaky box* prevede un arricchimento di elementi pesanti nei RC sino al ginocchio.
- Gli EAS possono misurare  $\langle A \rangle$  con difficoltà.
- Le misure possono essere poi confrontate con *modelli estremi* (solo p o Fe) via MC



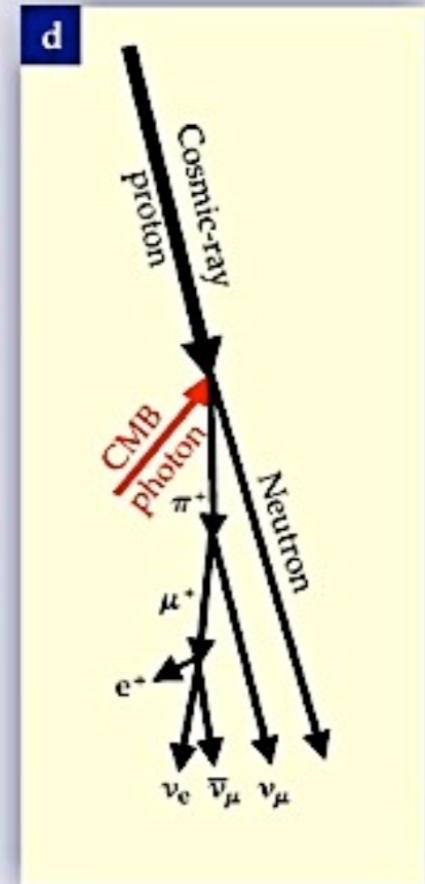
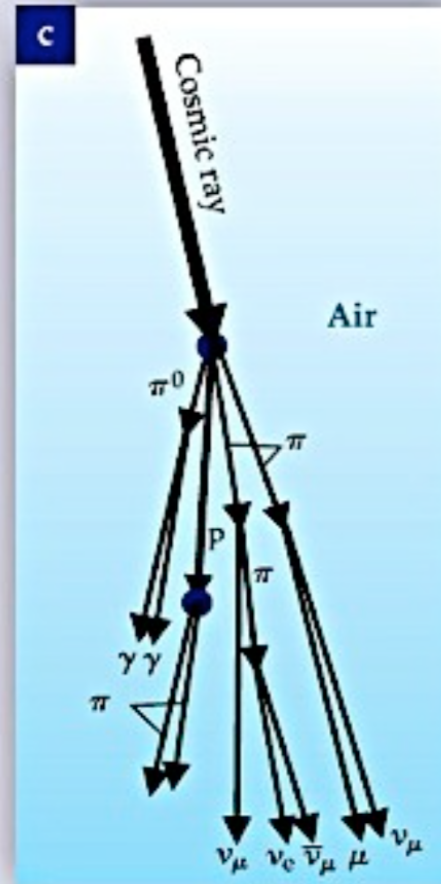
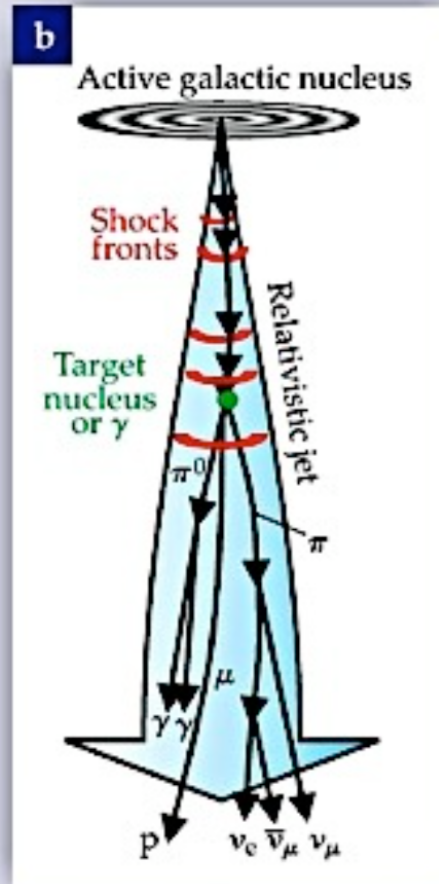
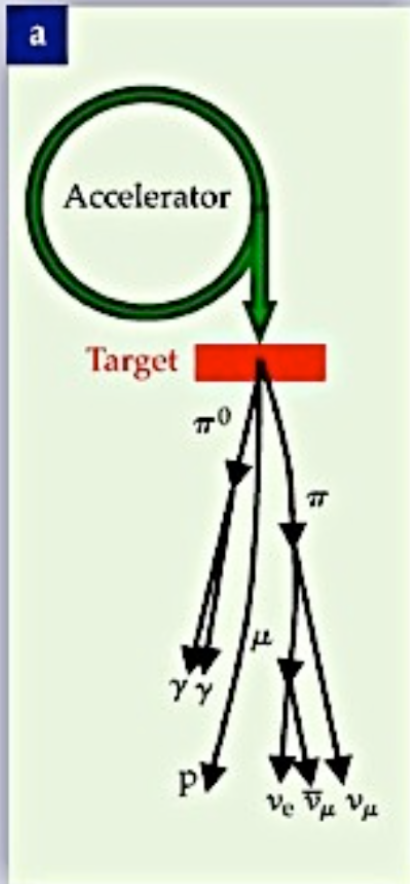
# Possibili macchine acceleratrici

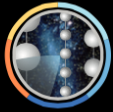


# Astrofisica Nucleare e Subnucleare

## Astrophysical Neutrinos

# Summary of neutrino production modes





# THE ICECUBE NEUTRINO OBSERVATORY

*Deployed in the deep glacial ice at the South Pole*

11

**5160** PMTs

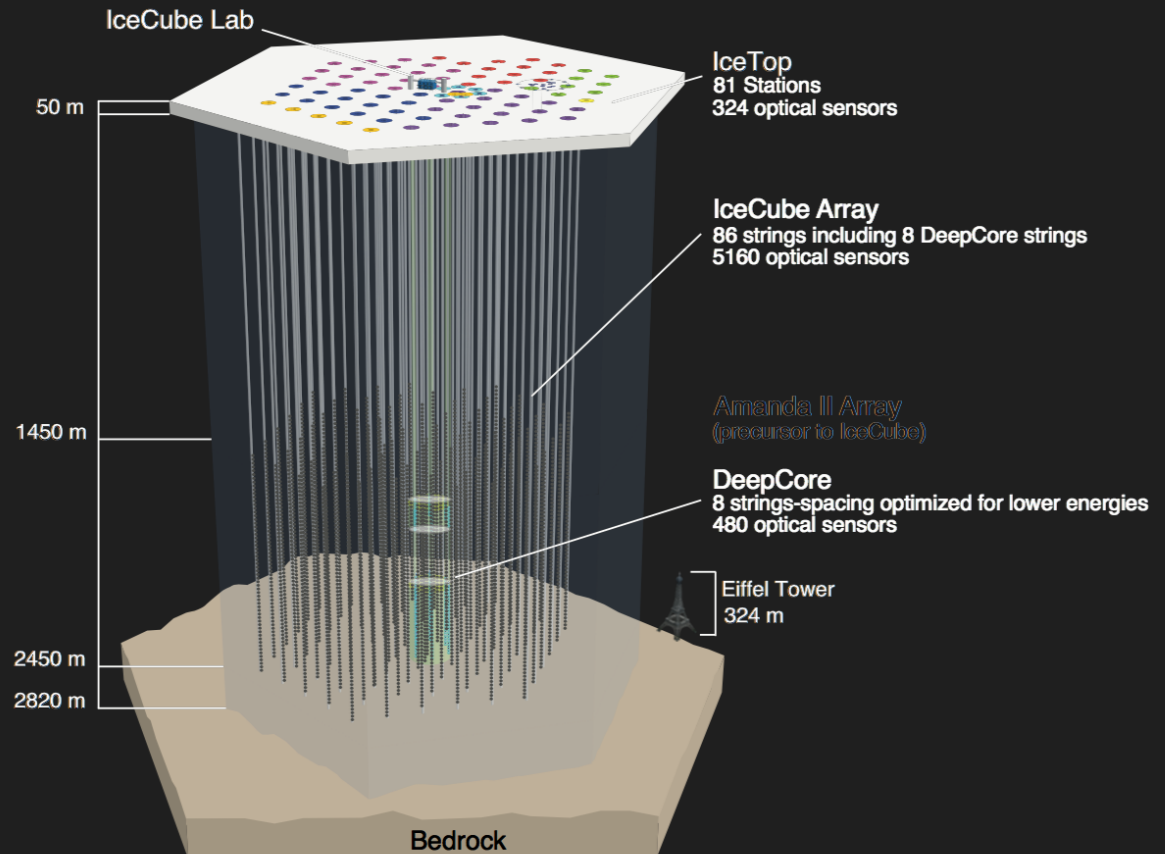
**1 km<sup>3</sup>** volume

**86** strings

**17 m** vertical spacing

**125 m** string spacing

Completed **2010**





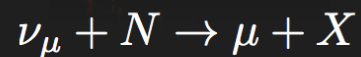
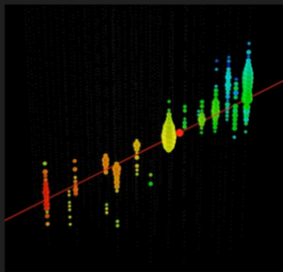
# NEUTRINO EVENT SIGNATURES

*Signatures of signal events*

12



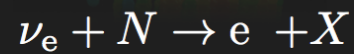
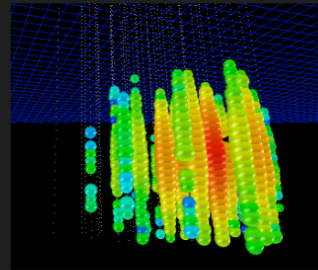
## CC Muon Neutrino



track (data)

factor of  $\approx 2$  energy resolution  
<  $1^{\circ}$  angular resolution at high energies

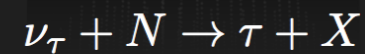
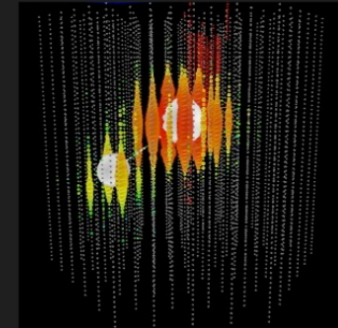
## Neutral Current / Electron Neutrino



cascade (data)

$\approx \pm 15\%$  deposited energy resolution  
 $\approx 10^{\circ}$  angular resolution (in IceCube)  
(at energies  $\approx 100$  TeV)

## CC Tau Neutrino



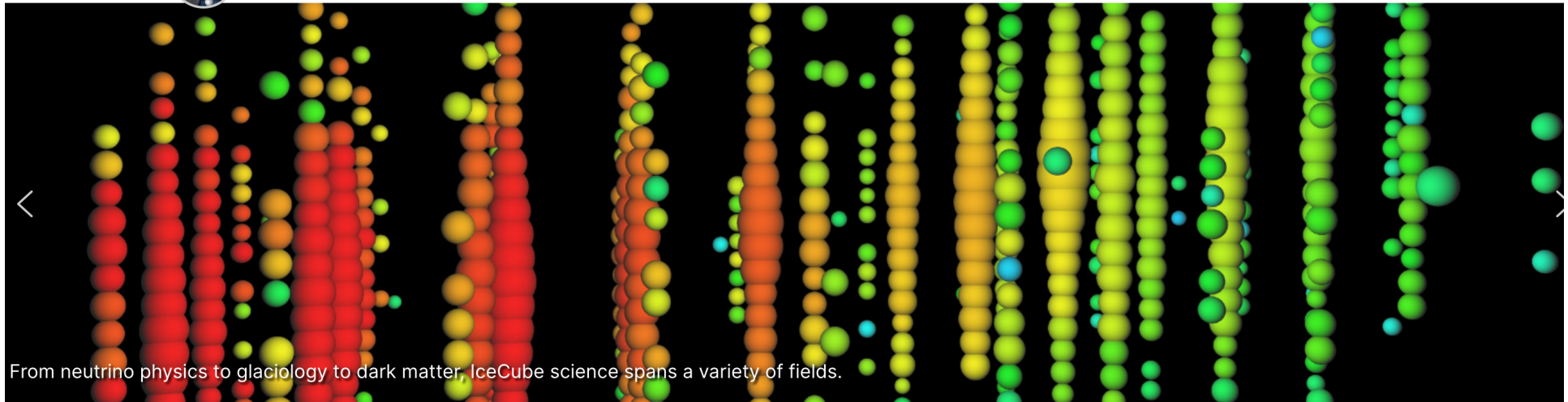
"double-bang" ( $\approx 10$  PeV) and other signatures (simulation)

(not observed yet:  $\tau$  decay length is 50 m/PeV)

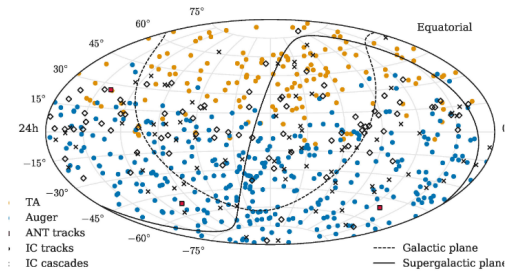
# Icecube



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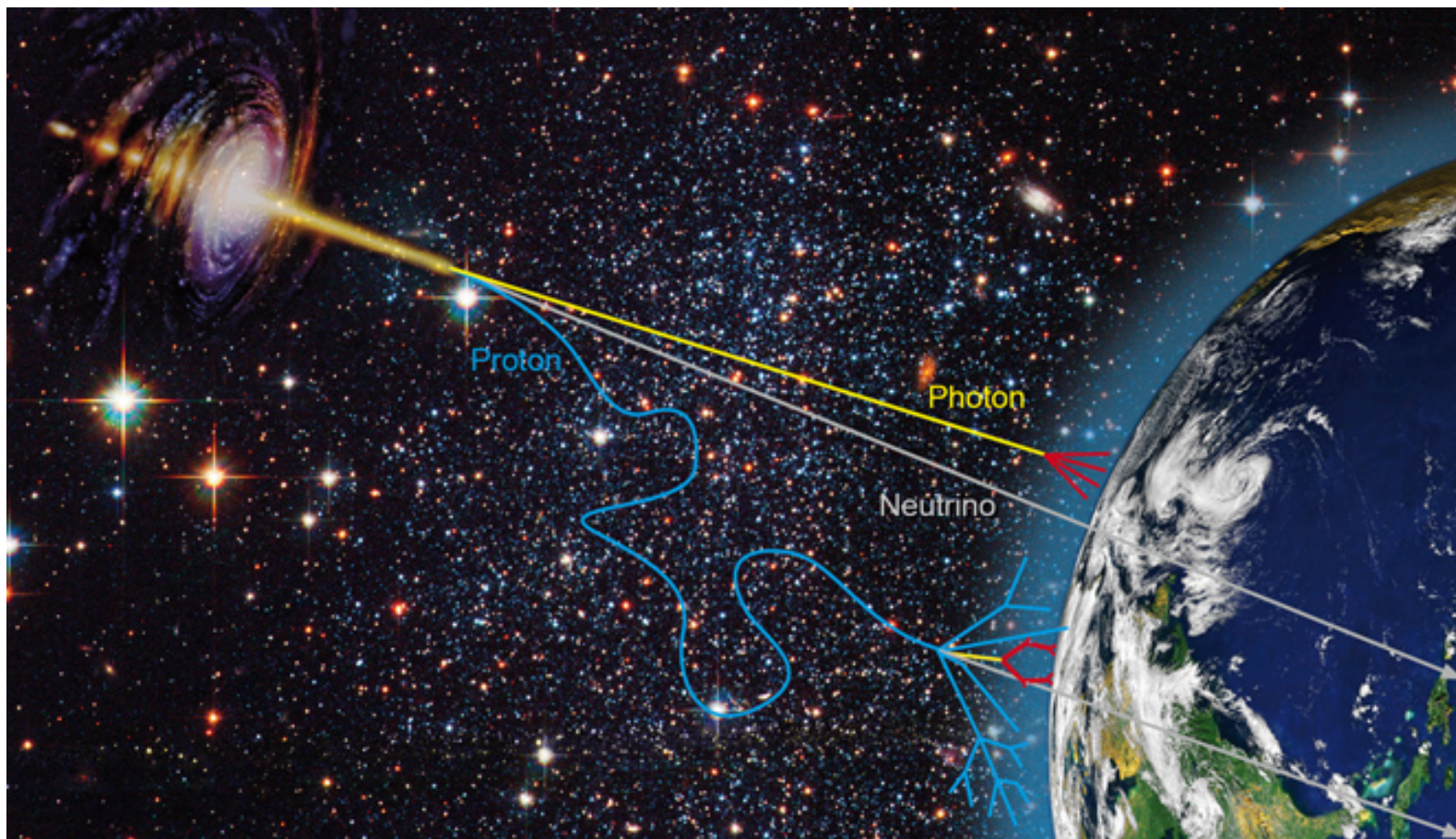
From neutrino physics to glaciology to dark matter, IceCube science spans a variety of fields.



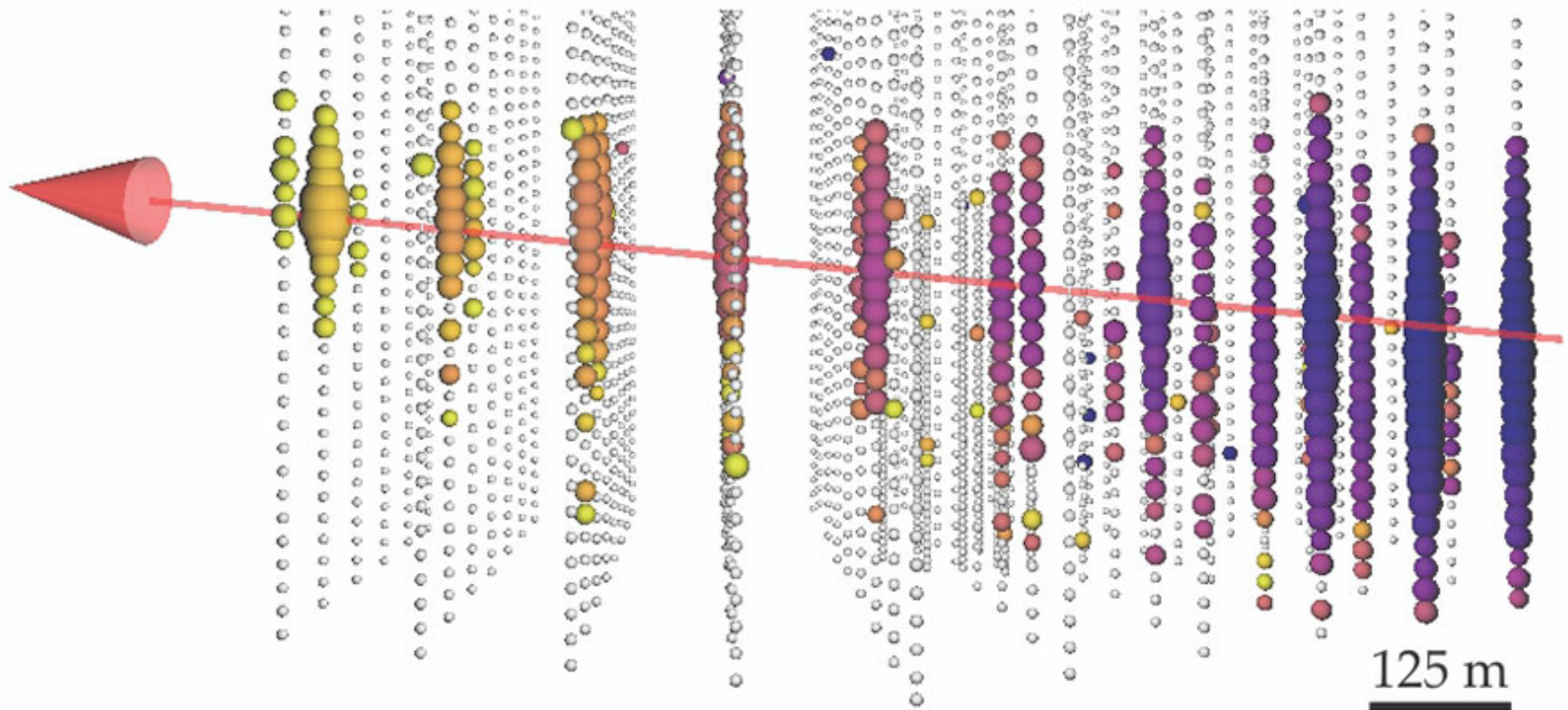
<https://icecube.wisc.edu/>



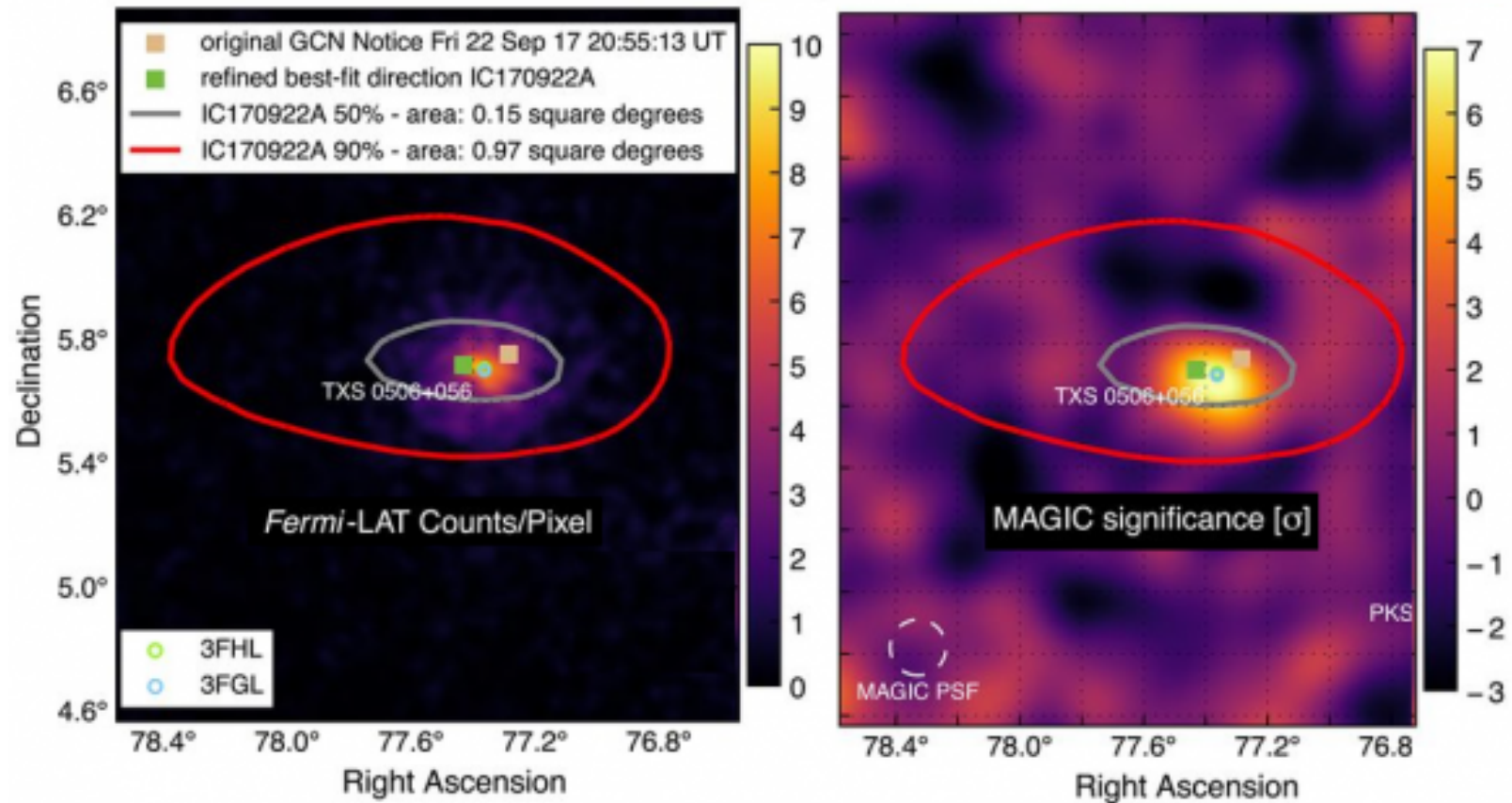
# Astrophysical Neutrinos



# “The” neutrino ...



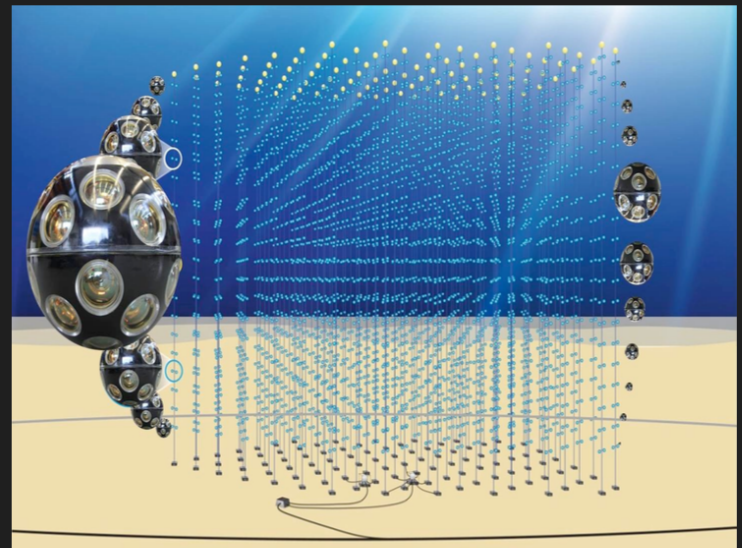
# TXS 0506+056



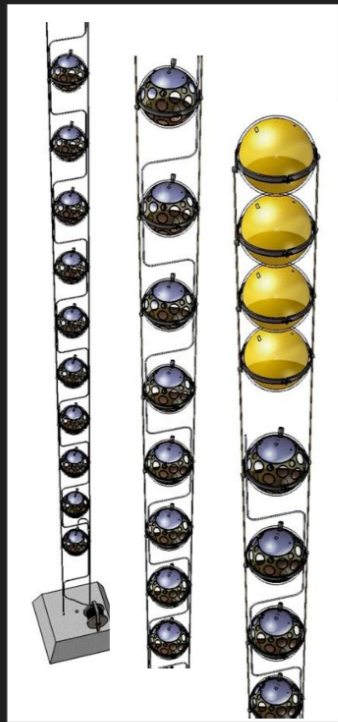


# THE KM3NET NEUTRINO TELESCOPE

*Multi-site installation in the Mediterranean Sea (France, Italy), instrumented in “building blocks”, started construction*



KM3NeT “building block”



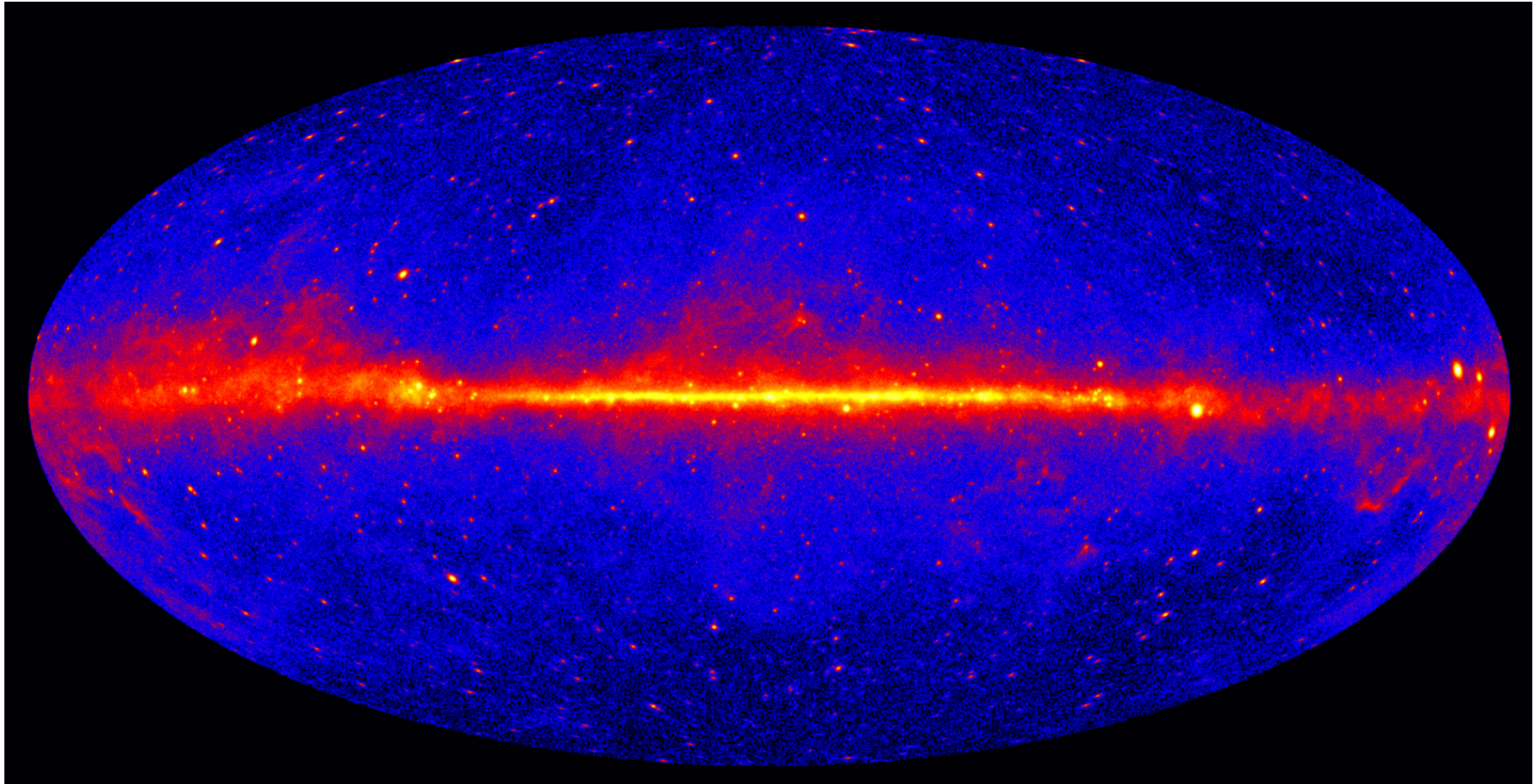
string with OMs



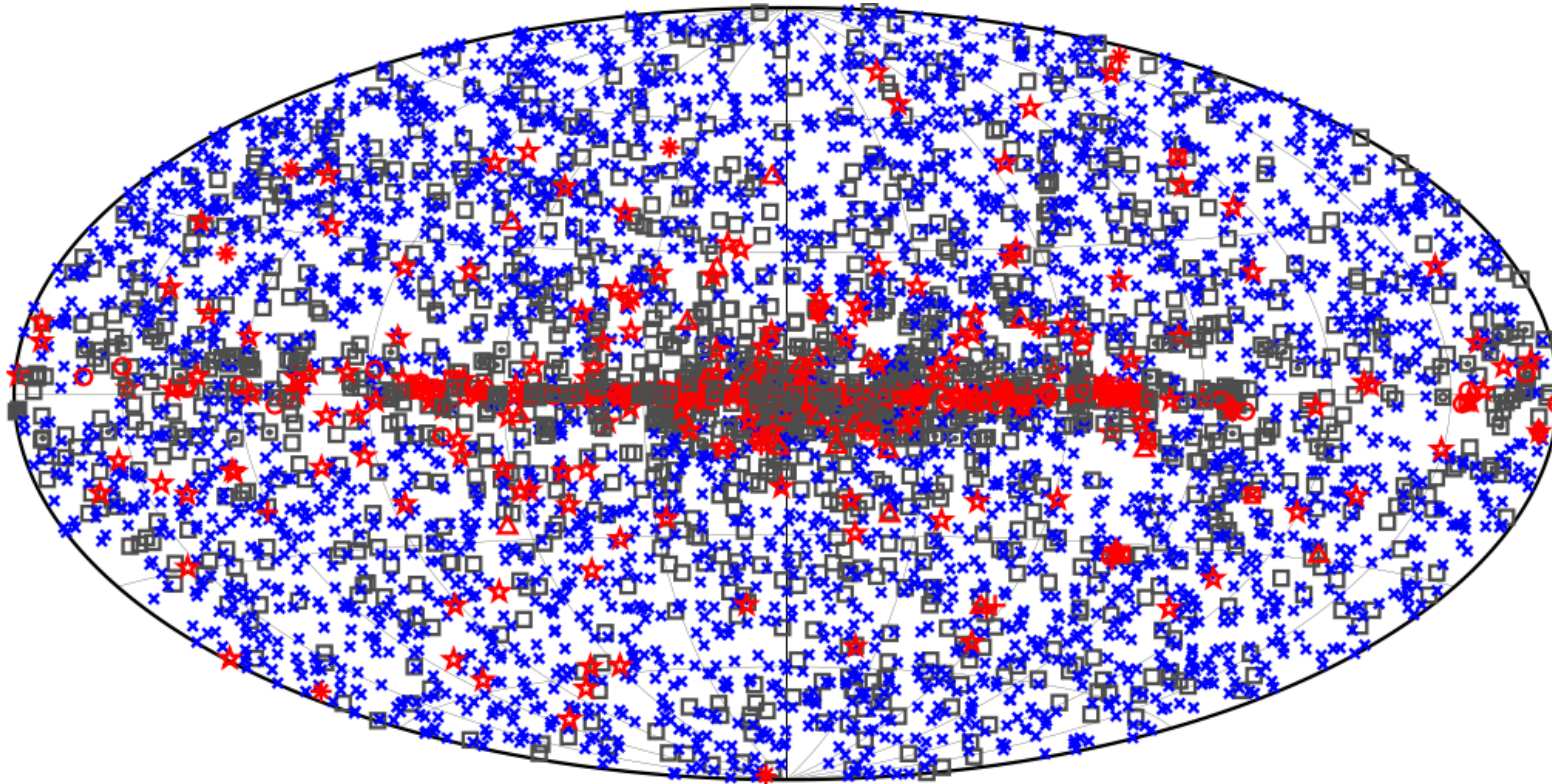
Multi-PMT digital optical module (“DOM”)

Fermi LAT

# The GeV sky



# 4FGL catalog

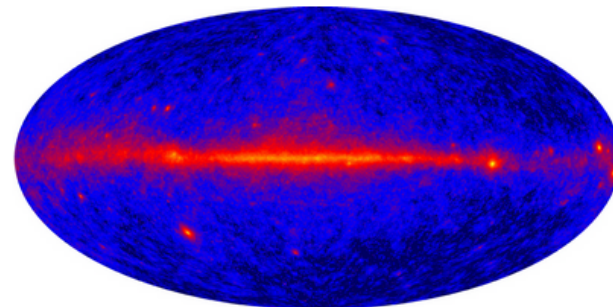


□ No association	■ Possible association with SNR or PWN	× AGN
★ Pulsar	△ Globular cluster	* Starburst Galaxy
▣ Binary	+ Galaxy	○ SNR
★ Star-forming region	□ Unclassified source	◆ PWN
		★ Nova

# Where to find data?

The screenshot shows the top section of the Fermi Science Support Center website. On the left is the NASA logo and the text "GODDARD SPACE FLIGHT CENTER". To the right are three links: "+ NASA Homepage", "+ GSFC Homepage", and "+ Fermi Homepage". Further right is a search box labeled "SEARCH Fermi:" with a "Search" button and a "+ GO" link below it. Below this is a banner image featuring the Fermi satellite and a colorful gamma-ray sky map. At the bottom of the banner is a navigation menu with the following items: HOME, OBSERVATIONS, DATA, PROPOSALS, LIBRARY, HEASARC, HELP, and SITE MAP.

The Fermi Science Support Center (FSSC) runs the guest investigator program, creates and maintains the mission time line, provides analysis tools for the scientific community, and archives and serves the Fermi data. This web site is the portal to Fermi for all guest investigators.



This all-sky view from Fermi reveals bright emission in the plane of the Milky Way (center), bright pulsars and super-massive black holes.

*Credit: NASA/DOE/International LAT Team*

Look into the "Resources" section for finding schedules, publications, useful links etc. The "Proposals" section is where you will be able to find the relevant information and tools to prepare and submit proposals for guest investigator projects. At "Data" you will be able to access the Fermi databases and find the software to analyse them. Address all questions and requests to the helpdesk in "Help".

## Quicklist

- [2011 Fermi Symposium](#)
- [Fermi Sky Blog](#)

<http://fermi.gsfc.nasa.gov/ssc/>

## News

**April 29, 2011**

### **Fermi Cycle 4: List of Approved Guest Investigations**

The phase-1 selection process for the Fermi Gamma-Ray Space Telescope Cycle-4 Guest Investigator Program has been completed. A total of 213 proposals were received in response to the cycle-4 NRA and 85 have been selected by NASA Headquarters on the basis of scientific peer-review evaluation completed in early April. A list of the titles and abstracts of the selected programs is available [here](#)

**Mar 30, 2011**

### **TOO for Cyg X-3**

A 500 ks TOO pointed mode observation for Cyg X-3 was requested and initiated on Friday, March 25th in response to an increase in gamma-ray activity from the source (ATel 3233). The TOO was terminated manually Monday, March 28th. Stay informed by subscribing to the Fermi-News mailing list.

+ [Sign up for Fermi-News](#)



# Fermi LAT Data Analysis Tutorial

# Tutorial

- Overview of the Fermi Large Area Telescope
  - LAT data
- **Fermi Science Tools**
  - General Introduction
- **Maximum Likelihood Overview**
  - Source modeling
- One study case:
  - **3c454.3: likelihood tutorial**
- **gtburst HE Analysis of GRBs**

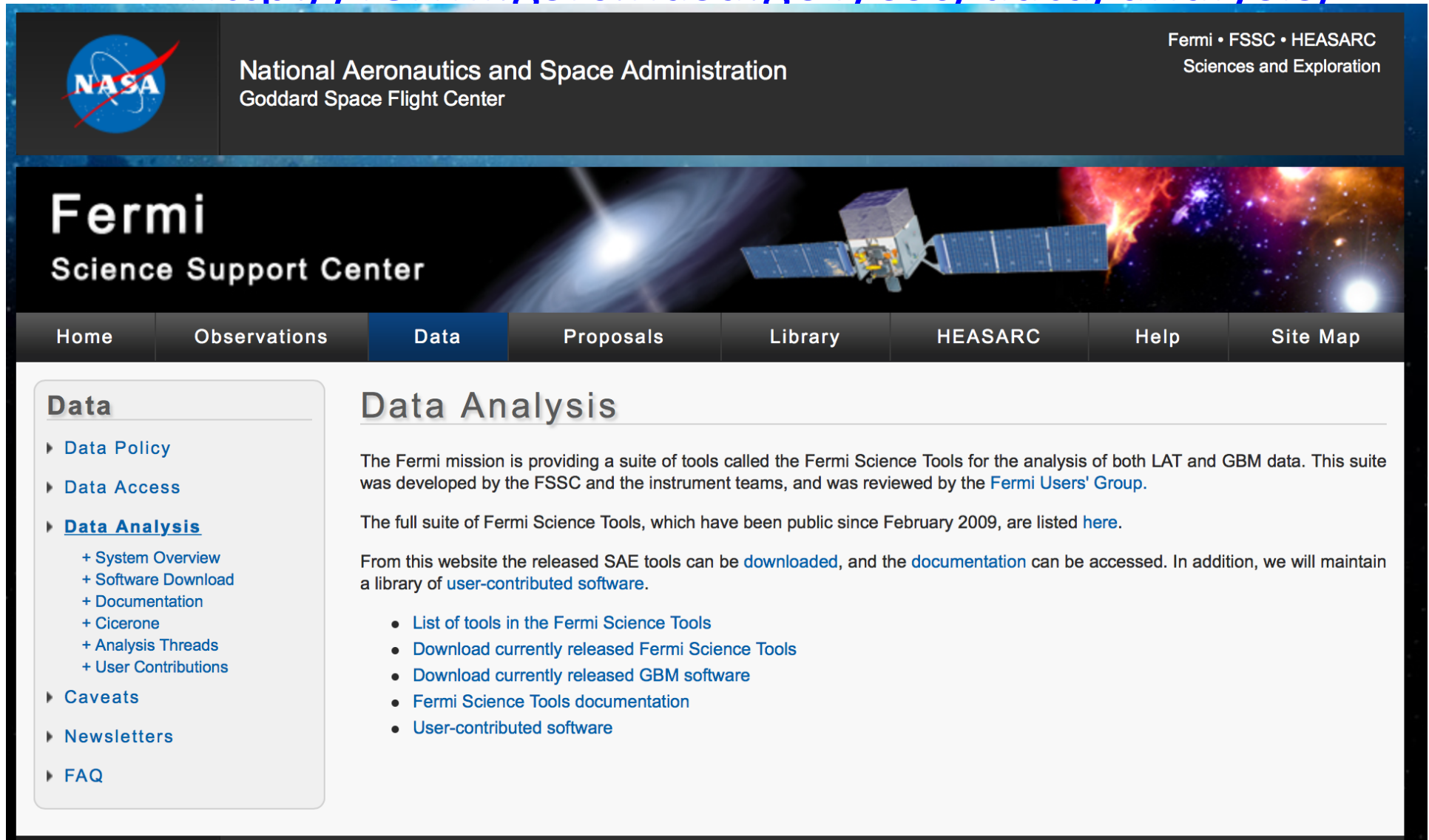
# What do you need for the analysis

- Data ...of course!
  - LAT detected events
  - Spacecraft related stuff
  - Extras (Backgrounds , catalog sources, timing.. )
- Fermi Science Tools
  - <http://fermi.gsfc.nasa.gov/ssc/data/analysis/software/>
- Other ancillary tools
  - ftools, HEASOFT, DS9 etc..
  - <http://heasarc.gsfc.nasa.gov/docs/software.html>
- Lots and lots of scripts!
  - Fermi tools are already scriptable
  - You can also use your favourite scripting language ... but ..
  - Science Tools can be imported as Python modules!

**LAT DATA ARE PUBLIC!!**

# How to access LAT Data

- <http://fermi.gsfc.nasa.gov/ssc/data/analysis/>



The screenshot shows the Fermi Science Support Center website. At the top left is the NASA logo. To its right, the text reads "National Aeronautics and Space Administration" and "Goddard Space Flight Center". In the top right corner, it says "Fermi • FSSC • HEASARC" and "Sciences and Exploration". Below this is a banner image of the Fermi satellite in space. A navigation menu is located below the banner, with "Data" highlighted. On the left side, there is a sidebar menu under the heading "Data" with items: "Data Policy", "Data Access", "Data Analysis" (expanded to show sub-items: "System Overview", "Software Download", "Documentation", "Cicerone", "Analysis Threads", "User Contributions"), "Caveats", "Newsletters", and "FAQ". The main content area is titled "Data Analysis" and contains the following text: "The Fermi mission is providing a suite of tools called the Fermi Science Tools for the analysis of both LAT and GBM data. This suite was developed by the FSSC and the instrument teams, and was reviewed by the [Fermi Users' Group](#)." "The full suite of Fermi Science Tools, which have been public since February 2009, are listed [here](#)." "From this website the released SAE tools can be [downloaded](#), and the [documentation](#) can be accessed. In addition, we will maintain a library of [user-contributed software](#)." Below this text is a bulleted list of links: "List of tools in the Fermi Science Tools", "Download currently released Fermi Science Tools", "Download currently released GBM software", "Fermi Science Tools documentation", and "User-contributed software".

# LAT Data

- LAT data products can be downloaded by the FSSC website
  - **LAT Data server** <http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi>
  - **Archive of weekly files**
  - <https://heasarc.gsfc.nasa.gov/FTP/fermi/data/lat/weekly/photon/>
- Two main data products (stored in FITS format)
  - **Events file (FT1)**
  - **i. e. “what the LAT sees”**
    - (photons, their energy, coordinates, time, event classes etc..)
  - **Spacecraft files (FT2)**
  - **i. e. “where the LAT is”**
    - (position, angles..)



# FT1: photons, photons...

Summary of L1307190816225D42602B76\_PH01.fits in D:/download/Sesto/cta1photon/

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	EVENTS	Binary	22 cols X 172002 rows	Header Hist Plot All Select
2	GTI	Binary	2 cols X 1623 rows	Header Hist Plot All Select

Binary Table of L1307190816225D42602B76\_PH01.fits[1] in D:/download/Sesto/cta1photon/

Select	ENERGY	RA	DEC	L	B	THETA
All	MeV	deg	deg	deg	deg	deg
Invert	Modify	Modify	Modify	Modify	Modify	Modify
1	2.336191E+003	3.356806E+002	8.163372E+001	1.175507E+002	2.036241E+001	4.115981E+001
2	2.887859E+002	3.380240E+002	8.752237E+001	1.213699E+002	2.508607E+001	4.264727E+001
3	1.225226E+003	3.883369E+002	8.072034E+001	1.204938E+002	1.812485E+001	3.609352E+001
4	4.534394E+003	3.088722E+002	8.240852E+001	1.154877E+002	2.360458E+001	4.293104E+001
5	4.019389E+002	3.552110E+002	8.628517E+001	1.216945E+002	2.305438E+001	7.299444E+001
6	2.392755E+002	3.180323E+002	8.210764E+001	1.158956E+002	2.241227E+001	7.694953E+001
7	1.264964E+002	3.255829E+002	8.287437E+001	1.172845E+002	2.218270E+001	7.469367E+001
8	1.547845E+002	3.234117E+002	8.472955E+001	1.185430E+002	2.363483E+001	7.346131E+001
9	1.454238E+002	3.474094E+002	8.746054E+001	1.217301E+002	2.493020E+001	5.535028E+001
10	3.449312E+002	3.310049E+002	8.453091E+001	1.189708E+002	2.299983E+001	5.160154E+001
11	5.811864E+002	3.575490E+002	7.964534E+001	1.200859E+002	1.711370E+001	2.737013E+001
12	2.344030E+002	3.502021E+002	8.416479E+001	1.205161E+002	2.172313E+001	3.792414E+001
13	5.823864E+002	3.126542E+002	8.261592E+001	1.158979E+002	2.328888E+001	5.608511E+001
14	1.448622E+003	3.584331E+002	8.189178E+001	1.207991E+002	1.926012E+001	4.726143E+001
15	3.600245E+002	3.483517E+002	8.227232E+001	1.195281E+002	2.005698E+001	3.439582E+001
16	1.747731E+003	3.294199E+002	8.365910E+001	1.182192E+002	2.244669E+001	3.296274E+001
17	1.688157E+002	3.483332E+002	8.084929E+001	1.189347E+002	1.874854E+001	3.663945E+001
18	3.378409E+002	3.136788E+002	8.375133E+001	1.170663E+002	2.380627E+001	5.706493E+001

Table Info of L13071908162...  
Total Columns: 22  
Total Rows: 172002  
Selected columns for display:  
 ENERGY  
 RA  
 DEC  
 L  
 B  
 THETA  
 PHI  
 ZENITH\_ANGLE  
 EARTH\_AZIMUTH\_ANGLE  
 TIME  
 EVENT\_ID  
 RUN\_ID  
 RECON\_VERSION  
 CALIB\_VERSION  
 EVENT\_CLASS  
 CONVERSION\_TYPE  
 LIVETIME  
 DIFRSP0  
 DIFRSP1  
 DIFRSP2  
 DIFRSP3  
 DIFRSP4

Events

Binary Table of L1307190816225D42602B76\_P...

Select	START	STOP
All	s	s
Invert	Modify	Modify
1	2.530705209249E+008	2.530762370846E+008
2	2.530762499232E+008	2.530819660843E+008
3	2.530819789232E+008	2.530846606084E+008
4	2.530855789267E+008	2.530904400805E+008
5	2.53091889232E+008	2.530963210855E+008
6	2.530979839214E+008	2.531022110850E+008
7	2.531040179214E+008	2.531081320847E+008
8	2.531100139199E+008	2.531143880845E+008
9	2.531159969215E+008	2.531205430862E+008
10	2.531219739250E+008	2.531266340844E+008
11	2.531279449252E+008	2.531327030917E+008
12	2.531337379250E+008	2.531387810841E+008
13	2.531390149267E+008	2.531449860918E+008
14	2.531449989233E+008	2.531507160943E+008
15	2.531507289250E+008	2.531564450855E+008
16	2.531564579233E+008	2.531621740877E+008
17	2.531621869233E+008	2.531679030844E+008

Good Time Intervals (GTIs)



# FT2: where is Fermi ?

fv: Summary of L1307190816225D42602876\_SC00.fits in D:/download/Sesto/cta1photon/

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	SC_DATA	Binary	29 cols X 886906 rows	Header Hist Plot All Select



fv: Binary Table of L1307190816225D42602876\_SC00.fits[1] in D:/download/Sesto/cta1photon/

Select	START	STOP	SC_POSITION	LAT_GEO	LON_GEO	RAD_GEO
All	D	D	3E	E	E	D
Invert	s	s	m	deg	deg	m
	Modify	Modify	Modify	Modify	Modify	Modify
1	2.395612776000E+008	2.395613076000E+008	Plot	6.592855E+000	1.288651E+002	5.504893679991E+005
2	2.395613076000E+008	2.395613376000E+008	Plot	7.383996E+000	1.304637E+002	5.501927909688E+005
3	2.395613376000E+008	2.395613676000E+008	Plot	8.168575E+000	1.320687E+002	5.499135114643E+005
4	2.395613676000E+008	2.395613976000E+008	Plot	8.945851E+000	1.336805E+002	5.496488803954E+005
5	2.395613976000E+008	2.395614276000E+008	Plot	9.715078E+000	1.352999E+002	5.494012096987E+005
6	2.395614276000E+008	2.395614576000E+008	Plot	1.047550E+001	1.369274E+002	5.491686522950E+005
7	2.395614576000E+008	2.395614876000E+008	Plot	1.122635E+001	1.385636E+002	5.489517414953E+005
8	2.395614876000E+008	2.395615176000E+008	Plot	1.196685E+001	1.402090E+002	5.487538278698E+005
9	2.395615176000E+008	2.395615476000E+008	Plot	1.269626E+001	1.418642E+002	5.485701226070E+005
10	2.395615476000E+008	2.395615776000E+008	Plot	1.341378E+001	1.435296E+002	5.483998366015E+005
11	2.395615776000E+008	2.395616076000E+008	Plot	1.411865E+001	1.452058E+002	5.482435574869E+005
12	2.395616076000E+008	2.395616376000E+008	Plot	1.481007E+001	1.468931E+002	5.481000357595E+005
13	2.395616376000E+008	2.395616676000E+008	Plot	1.548726E+001	1.485919E+002	5.479706011147E+005

fv: Table Info of L1307190816225D42602876\_SC00.fits[1] in D:/download/Sesto/cta1photon/

Total Columns: 29  
Total Rows : 886906

Selected columns for display

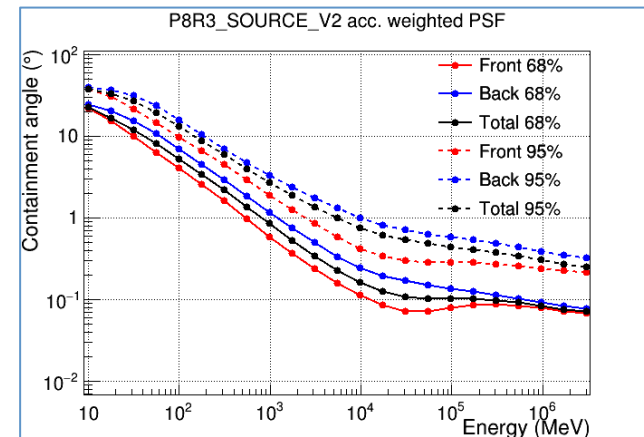
- START
- STOP
- SC\_POSITION
- LAT\_GEO
- LON\_GEO
- RAD\_GEO
- RA\_ZENITH
- DEC\_ZENITH
- B\_MCILWAIN
- L\_MCILWAIN
- GEOMAG\_LAT
- IN\_SAA
- RA\_SCZ
- DEC\_SCZ
- RA\_SCX
- DEC\_SCX
- RA\_NPOLE
- DEC\_NPOLE
- ROCK\_ANGLE
- LAT\_MODE
- LAT\_CONFIG
- DATA\_QUAL
- LIVETIME

Buttons: Display Table, Select All, Clear All, Cancel, Help

spacecraft Data

# Extras - IRFs

- LAT Instrument Response Functions (IRFs)
  - Point Spread Function (PSF)
  - Effective Area
  - Energy Resolution
- Highly dependent on energy and arrival direction of incident photon
- Fundamental for analysis!!



- [http://www.slac.stanford.edu/exp/glast/groups/canda/lat\\_Performance.htm](http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm)
- [https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone\\_LAT\\_IRFs/IRF\\_overview.html](https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_LAT_IRFs/IRF_overview.html)



# Extras

- Diffuse models (.txt & FITS files)
  - To correctly take into accounts the galactic and extagalactic backgrounds
  - <http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html>
- Source Catalogs (4FGL, 3FHL, PSRs, GRB, SNR ...)
- Region of Interest model definition (stored in XML files)
  - More on this later ...
- Choose the proper combination of
  - event classes based on the probability of being a photon and background level
    - TRANSIENT (for very short events)
    - SOURCE (suggested for source analysis)
    - CLEAN and ULTRACLEAN (lowest particle contamination – for diffuse sources analysis)
  - Event types based on conversion point or PSF or Energy reconstruction

# LAT background models

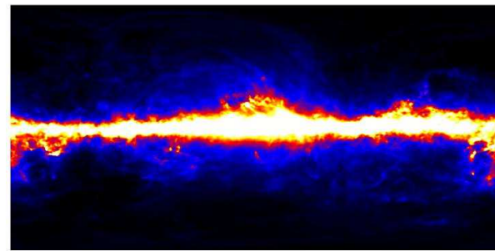


## Extras 2 : Diffuse Models

Galactic diffuse model	<a href="#">gll_iem_v02.fit</a>
Isotropic spectral template (all)	<a href="#">isotropic_iem_v02.txt</a>
Isotropic spectral template (front)	<a href="#">isotropic_iem_front_v02.txt</a>
Isotropic spectral template (back)	<a href="#">isotropic_iem_back_v02.txt</a>
Detailed description	<a href="#">Model Description</a>

Summary of gll\_iem\_v02.fit in /Users/ginotosti/TUTORIAL/

Index	Extension	Type	Dimension	View
<input type="checkbox"/> 0	Primary	Image	720 X 360 X 30	Header Image Table
<input type="checkbox"/> 1	ENERGIES	Binary	1 cols X 30 rows	Header Hist Plot All Select



39.3884	6.57144e-07	4.6946e-08
64.0414	4.09665e-07	5.72124e-09
104.125	1.72000e-07	8.35794e-10
169.296	6.60007e-08	2.15325e-10
275.257	2.24126e-08	7.58059e-11
447.539	7.21114e-09	2.95711e-11
727.651	2.20758e-09	1.16796e-11
1183.08	7.20365e-10	4.68072e-12
1923.57	2.35566e-10	1.93256e-12
3127.52	7.36933e-11	8.02165e-13
5085.02	2.75583e-11	3.52098e-13
8267.71	8.41675e-12	1.44008e-13
13442.4	2.61572e-12	6.04568e-14
21856	9.93124e-13	2.77996e-14
35535.5	4.07167e-13	1.32929e-14
57777	1.48419e-13	6.31664e-15
93939.4	6.49806e-14	3.22598e-15
152736	2.13205e-14	1.49108e-15
248332	6.498e-15	4.85176e-16
403761	2.1144e-15	2.60915e-16

<http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html>

# LAT background models

## LAT Background Models

Many analyses of LAT data require models of Galactic diffuse and isotropic emission. Detailed discussion of how the latest Galactic diffuse emission model (available from this Web page) has been developed, and important caveats on its use, is available [here](#). Please refer to the [binned](#) or [unbinned](#) likelihood analysis tutorials for some examples of how to incorporate these models into your own Fermi data analysis. Here is a list of IRFs and diffuse models to be used with the various data sets. We have provided the model files for you to download. However, the files for the most recent data release are included in the Fermitools installation (in the \$(FERMI\_DIR)/refdata/fermi/galdiffuse/ directory). As a result, it is unlikely that you will need to download each file separately.

For Pass 8, each event class and event type combination has a dedicated IRF and isotropic model. Only a subset are shown here, as examples.

Galactic interstellar emission model	Event Selection/ IRF Name	Isotropic spectral template
<a href="#">gll_iem_v07.fits</a> (see below for P8R3 usage notes)	Pass 8 Source (front+back, allPSF, allEDISP) P8R3_SOURCE_V3	<a href="#">iso_P8R3_SOURCE_V3_v1.txt</a>
	Pass 8 Source (front only) P8R3_SOURCE_V3::FRONT	<a href="#">iso_P8R3_SOURCE_V3_FRONT_v1.txt</a>
	Pass 8 Source (back only) P8R3_SOURCE_V3::BACK	<a href="#">iso_P8R3_SOURCE_V3_BACK_v1.txt</a>
	Pass 8 Clean (front+back, allPSF, allEDISP) P8R3_CLEAN_V3	<a href="#">iso_P8R3_CLEAN_V3_v1.txt</a>
	Pass 8 Clean (PSF0) P8R3_CLEAN_V3::PSF0	<a href="#">iso_P8R3_CLEAN_V3_PSF0_v1.txt</a>
	Pass 8 Clean (PSF1) P8R3_CLEAN_V3::PSF1	<a href="#">iso_P8R3_CLEAN_V3_PSF1_v1.txt</a>
	Pass 8 Clean (PSF2) P8R3_CLEAN_V3::PSF2	<a href="#">iso_P8R3_CLEAN_V3_PSF2_v1.txt</a>
	Pass 8 Clean (PSF3) P8R3_CLEAN_V3::PSF3	<a href="#">iso_P8R3_CLEAN_V3_PSF3_v1.txt</a>
	Pass 8 Ultraclean (front+back, allPSF, allEDISP) P8R3_ULTRACLEAN_V3	<a href="#">iso_P8R3_ULTRACLEAN_V3_v1.txt</a>

<https://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html>

**PASS8 DATA**

# Event classes

Standard Hierarchy for LAT Event Classes				
Event Class	evclass	Photon File	Extended File	Description
P8R3_TRANSIENT020	16		X	Transient event class with background rate equal to two times the A10 IGRB reference spectrum.
P8R3_TRANSIENT010	64		X	Transient event class with background rate equal to one times the A10 IGRB reference spectrum.
P8R3_SOURCE	128	X	X	This event class has a residual background rate that is comparable to P7REP_SOURCE. This is the recommended class for most analyses and provides good sensitivity for analysis of point sources and moderately extended sources.
P8R3_CLEAN	256	X	X	This class is identical to SOURCE below 3 GeV. Above 3 GeV it has a 1.3-2 times lower background rate than SOURCE and is slightly more sensitive to hard spectrum sources at high galactic latitudes.
P8R3_ULTRACLEAN	512	X	X	This class has a background rate very similar to ULTRACLEANVETO.
P8R3_ULTRACLEANVETO	1024	X	X	This is the cleanest Pass 8 event class. Its background rate is 15-20% lower than the background rate of SOURCE class below 10 GeV, and 50% lower at 200 GeV. This class is recommended to check for CR-induced systematics as well as for studies of diffuse emission that require low levels of CR contamination.
P8R3_SOURCEVETO	2048	X	X	This class has the same background rate than the SOURCE class background rate up to 10 GeV but, above 50 GeV, its background rate is the same as the ULTRACLEANVETO one while having 15% more acceptance.

# Event classes

Extended Hierarchy				
Event Class	evclass	Photon File	Extended File	Description
P8R3_TRANSIENT020E	8		X	Extended version of the P8R3_TRANSIENT020 event class with a less restrictive fiducial cut on projected track length through the Calorimeter.
P8R3_TRANSIENT010E	32		X	Extended version of the P8R3_TRANSIENT010 event class with a less restrictive fiducial cut on projected track length through the Calorimeter.
NON-ACD Hierarchy				
Event Class	evclass	Photon File	Extended File	Description
P8R3_TRANSIENT015S	65536		X	Transient event class designed for analysis of prompt solar flares in which pileup activity may be present. This class has a background rate equal to 1.5 times the A10 reference spectrum.

# Event types

Conversion Type Partition		
Event Type	evtype	Description
FRONT	1	Events converting in the Front-section of the Tracker. Equivalent to convtype=0.
BACK	2	Events converting in the Back-section of the Tracker. Equivalent to convtype=1.
PSF Type Partition		
Event Type	evtype	Description
PSF0	4	First (worst) quartile in the quality of the reconstructed direction.
PSF1	8	Second quartile in the quality of the reconstructed direction.
PSF2	16	Third quartile in the quality of the reconstructed direction.
PSF3	32	Fourth (best) quartile in the quality of the reconstructed direction.
EDISP Type Partition		
Event Type	evtype	Description
EDISP0	64	First (worst) quartile in the quality of the reconstructed energy.
EDISP1	128	Second quartile in the quality of the reconstructed energy.
EDISP2	256	Third quartile in the quality of the reconstructed energy.
EDISP3	512	Fourth (best) quartile in the quality of the reconstructed energy.

# Recommendations

## Event Selection Recommendations (P8R3)

Analysis Type	Minimum Energy (emin)	Maximum Energy (emax)	Max Zenith Angle (zmax)	Event Class (evclass)	IRF Name
Galactic Point Source Analysis	100 (MeV)	500000 (MeV)	90 (degrees)	128	P8R3_SOURCE_V2
Off-plane Point Source Analysis	100 (MeV)	500000 (MeV)	90 (degrees)	128	P8R3_SOURCE_V2
Burst and Transient Analysis (<200s)	100 (MeV)	500000 (MeV)	100 (degrees)	16	P8R3_TRANSIENT020_V2
Galactic Diffuse Analysis	100 (MeV)	500000 (MeV)	90 (degrees)	128	P8R3_SOURCE_V2
Extra-Galactic Diffuse Analysis	100 (MeV)	500000 (MeV)	90 (degrees)	1024	P8R3_ULTRACLEANVETO_V2 or P8R3_SOURCEVETO_V2 (when interested in E>1 GeV energy range)
Impulsive Solar Flare Analysis	100 (MeV)	500000 (MeV)	100 (degrees)	65536	P8R3_TRANSIENT015S_V2



# Recommendations

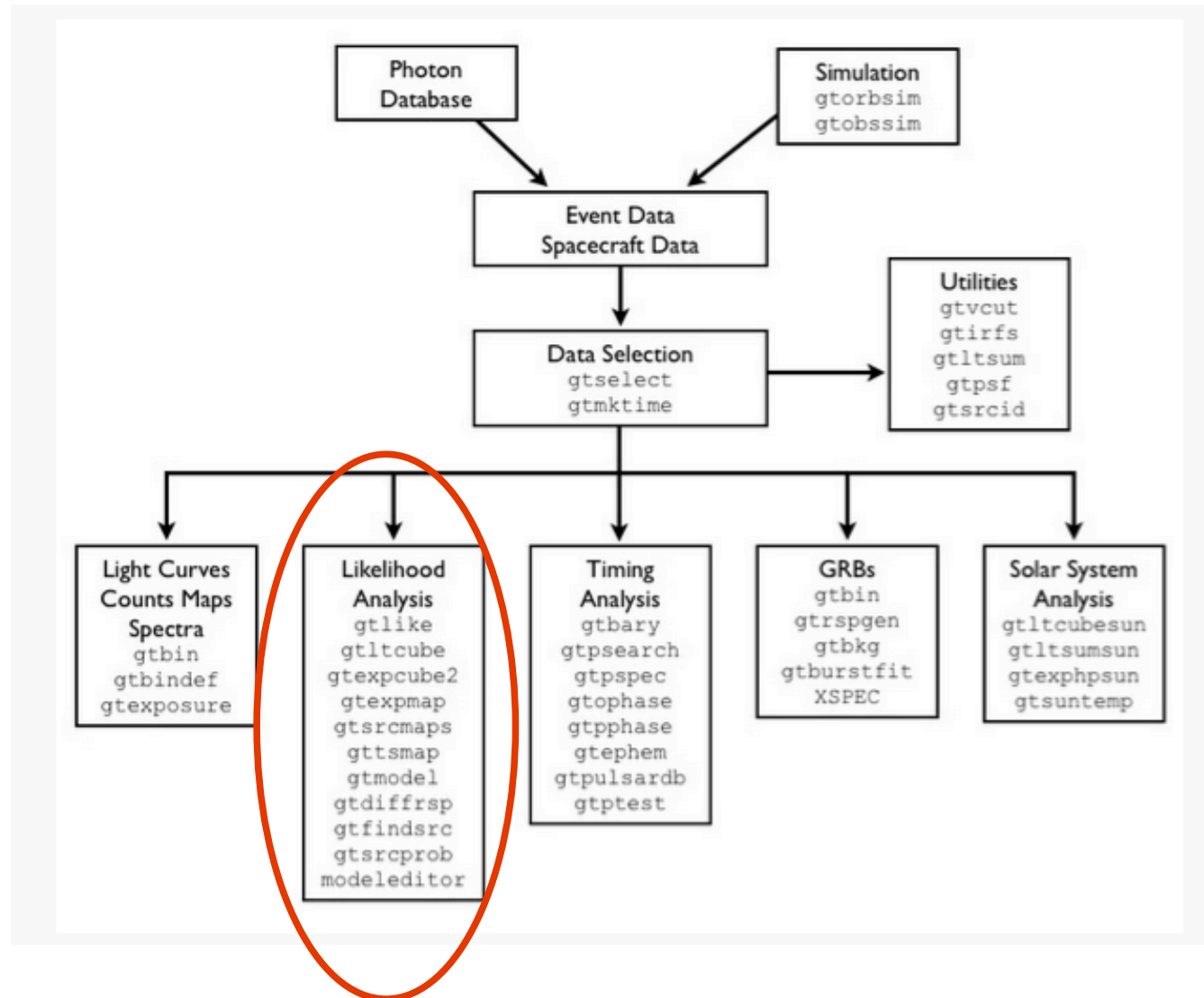
## Time Selection Recommendations

Analysis Type	ROI-Based Zenith Angle Cut (roicut)	Relational Filter Expression (filter)
Galactic Point Source Analysis	no	(DATA_QUAL>0)&&(LAT_CONFIG==1)
Off-plane Point Source Analysis	no	(DATA_QUAL>0)&&(LAT_CONFIG==1)
Burst and Transient Analysis	yes	(DATA_QUAL>0)&&(LAT_CONFIG==1)
Galactic Diffuse Analysis	no	(DATA_QUAL>0)&&(LAT_CONFIG==1)
Extra-Galactic Diffuse Analysis	no	(DATA_QUAL>0)&&(LAT_CONFIG==1)
Burst and Transient Analysis	yes	(DATA_QUAL>0  DATA_QUAL==-1)&&(LAT_CONFIG==1)

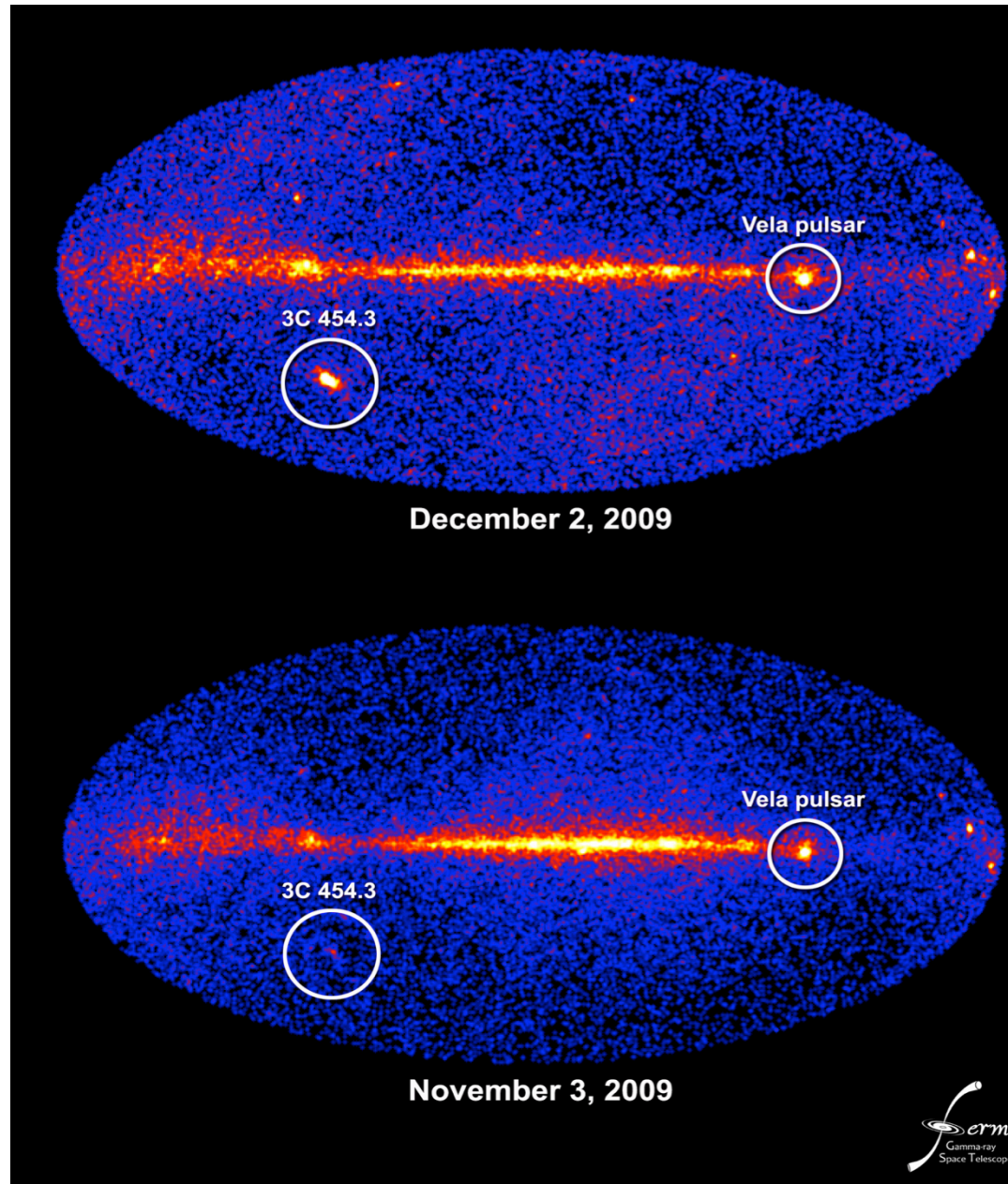
**IMPORTANT:** For analyses where an ROI-based zenith cut is NOT performed, an exposure correction must be made using the "zmax" option in the [gtlucube](#) tool.

# Explore LAT data

# Overview of Fermi Science Tools



# Blazar one of ... 3c454.3's record flares!



# How to download data

- <http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/>

The screenshot shows the 'LAT Photon, Event, and Spacecraft Data Query' web interface. The navigation menu at the top includes Home, Observations, Data (selected), Proposals, Library, HEASARC, Help, and Site Map. The left sidebar contains a 'Data' section with links for Data Policy, Data Access (including LAT Data, LAT Catalog, LAT Data Queries, LAT Query Results, LAT Weekly Files, and GBM Data), Data Analysis, Caveats, Newsletters, and FAQ. The main content area features a search form with the following fields: Object name or coordinates (3c 454.3), Coordinate system (J2000), Search radius (degrees) (15), Observation dates (55166, 55173), Time system (MJD), Energy range (MeV), LAT data type (Photon), and Spacecraft data (checked). A red box highlights a note: 'NOTE: Additional selections must be applied to data downloaded from the data server prior to use in a data analysis. See recommended data selections and LAT caveats for more details.' Another red box highlights the 'Start Search' button. A red text annotation on the right side of the page reads 'The week of the giant outburst!!'.

→ Download both spacecraft and photon data ←  
Take note of the start and stop MET  
follow the link

▶ [Data Policy](#)

▶ [Data Access](#)

- + [LAT Data](#)
- + [LAT Catalog](#)
- + [LAT Data Queries](#)
- + [LAT Query Results](#)
- + [LAT Weekly Files](#)
- + [GBM Data](#)

▶ [Data Analysis](#)

▶ [Caveats](#)

▶ [Newsletters](#)

▶ [FAQ](#)

Your search criteria were:

Equatorial coordinates (degrees)	(343.491,16.1482)
Time range (MET)	(281318400,281923200)
Time range (Gregorian)	(2009-12-01 00:00:00,2009-12-08 00:00:00)
Energy range (MeV)	(100,300)
Search radius (degrees)	15

The state of your query is 2 (Query complete)

<u>Server</u>	<u>Position in Queue</u>	<u>Estimated Time Remaining (sec)</u>
Photon Server	Query complete	N/A
Spacecraft Server	Query complete	N/A

The filenames of the result files consist of the query ID string with an identifier appended to indicate which database the file came from. The identifiers are of the form: `_DDNN` where DD indicates the database and NN is the file number. The file number will generally be '00' unless the query resulted in a large data volume. In that case the data is broken up into multiple files. The values of the database field are:

- PH - Photon Database
- SC - Spacecraft Pointing, Livetime, and History Database
- EV - Extended Database

In the event that you do not see any files with the data type you requested listed below, you should try resubmitting your query as there may have been a problem.

<u>Filename</u>	<u>Number of Entries</u>	<u>Size (MB)</u>	<u>Status</u>
L14090420274034A4AC2B81_PH00.fits	3372	0.33	Available
L14090420274034A4AC2B81_SC00.fits	17120	2.52	Available

If you would like to download the files via wget, simply copy the following commands and paste them into a terminal window. The files will be downloaded to the current directory in the terminal window.

```
wget http://fermi.gsfc.nasa.gov/FTP/fermi/data/lat/queries/L14090420274034A4AC2B81_PH00.fits  
wget http://fermi.gsfc.nasa.gov/FTP/fermi/data/lat/queries/L14090420274034A4AC2B81_SC00.fits
```

# gtselect (select data)

- [/home/]\$ `gtselect evclass=128 evtype=3`
- Input FT1 file[photon.fits]
- Output FT1 file[filtered.fits]
- RA for new search center (degrees) (0:360) [343.494812]
- Dec for new search center (degrees) (-90:90) [16.1495]
- radius of new search region (degrees) (0:180) [10]
- start time (MET in s) (0:) [281318400]
- end time (MET in s) (0:) [281923200]
- lower energy limit (MeV) (0:) [100]
- upper energy limit (MeV) (0:) [500000]
- maximum zenith angle value (degrees) (0:180) [90]

Events with a high prob. to be gammas

Setting the max ZA, filter gammas from albedo events (gamma from the Earth that can be a significant source of background)

- > `gtselect evclass=128 evtype=3 infile=ph.fits outfile=filtered.fits \`
- `ra=343.49 dec=16.15 rad=15 tmin=281318400 tmax=281923200 \`
- `emin=100 emax=500000 zmax=90`
- Note: all analysis steps are scriptable via explicit assign parameters on command-line. Look at the manual for details.

# gtmktime (cut the bad time intervals)

- [/home/]\$ `gtmktime`
- Spacecraft data file[spacecraft.fits]
- Filter expression[(DATA\_QUAL>0)&&(LAT\_CONFIG==1)]
- Apply ROI-based zenith angle cut[no]
- Event data file[filtered.fits]
- Output event file name[filtered\_gti.fits]

Filter out events collected while passing in SAA and other low-quality events

Use ZA to filter only proper GTIs



# gtbin (Counts Map)

- [/home]\$ `gtbin`
- Type of output file (CCUBE|CMAP|LC|PHA1|PHA2|HEALPIX) [CMAP]
- Event data file name[filtered\_gti.fits]
- Output file name[cmap.fits]
- Spacecraft data file name[spacecraft.fits]
- Size of the X axis in pixels[120]
- Size of the Y axis in pixels[120]
- Image scale (in degrees/pixel)[0.25]
- Coordinate system (CEL - celestial, GAL -galactic) (CEL|GAL) [CEL]
- First coordinate of image center in degrees (RA or galactic l)[343.494812]
- Second coordinate of image center in degrees (DEC or galactic b) [16.1495]
- Rotation angle of image axis, in degrees[0]
- Projection method e.g. AIT|ARC|CAR|GLS|MER|NCP|SIN|STG|TAN:[AIT]

# Maximum Likelihood Overview

# Perform the fit: the likelihood

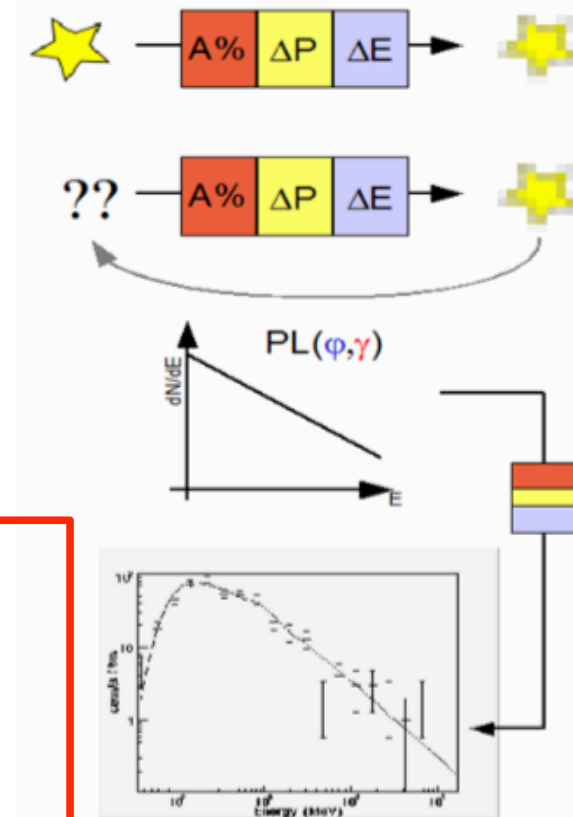
In high energy gamma rays it is never possible to really isolate a source because of limited statistics and strong and structured background.

Therefore statistical techniques have to be applied.

The most used method is the likelihood analysis based on the Poisson statistics.

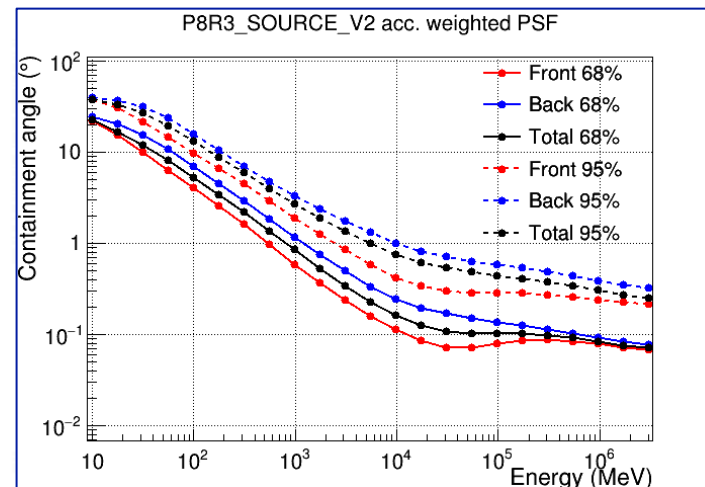
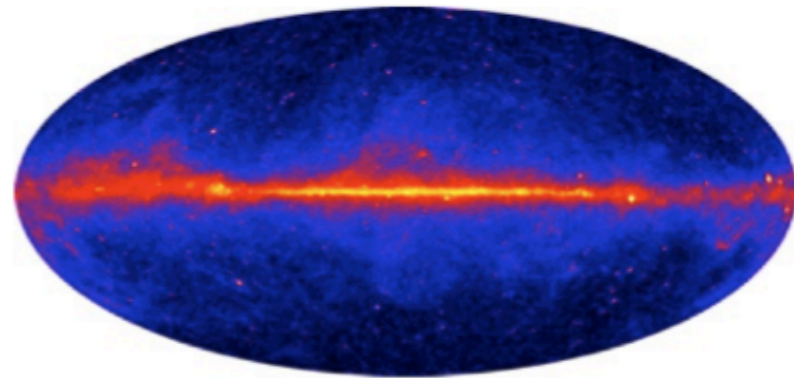
The method requires to assume a model for the signal detected by the telescope.

- Assume a **model**
- Model **convolved** with Instrument response Function (IRF)
- Maximizing likelihood find the best set of parameters that reproduce the observed spectrum



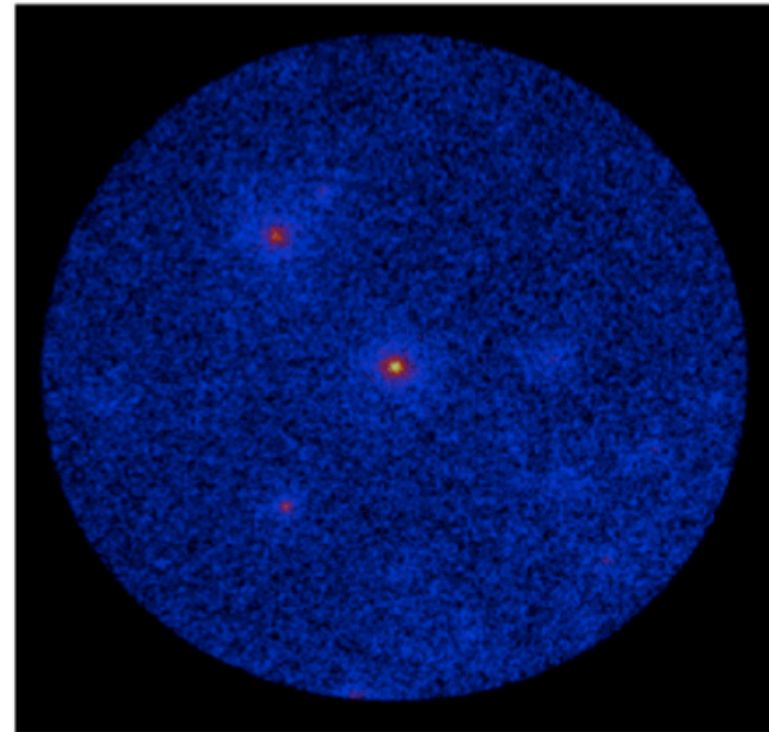
# Why Model Fitting?

- We use the Likelihood method because the LAT data are limited by statistics, a bright diffuse background and a broad PSF.
- The model construction defines the questions we want to ask which means:
  - It will not answer a question you are not asking (ie. unknown parameters).
- The Likelihood will not tell you if a fit is 'good'. If the model does not represent your data well, the results will also not represent reality well.



# The Challenge

- Gamma-ray data is a list of counts (photons) reconstructed in the detector.
- Qualitative exploration of the data suggests the presence of sources (spatial clustering).
- Quantitative analysis requires evaluating the significance of a 'model' of our region.

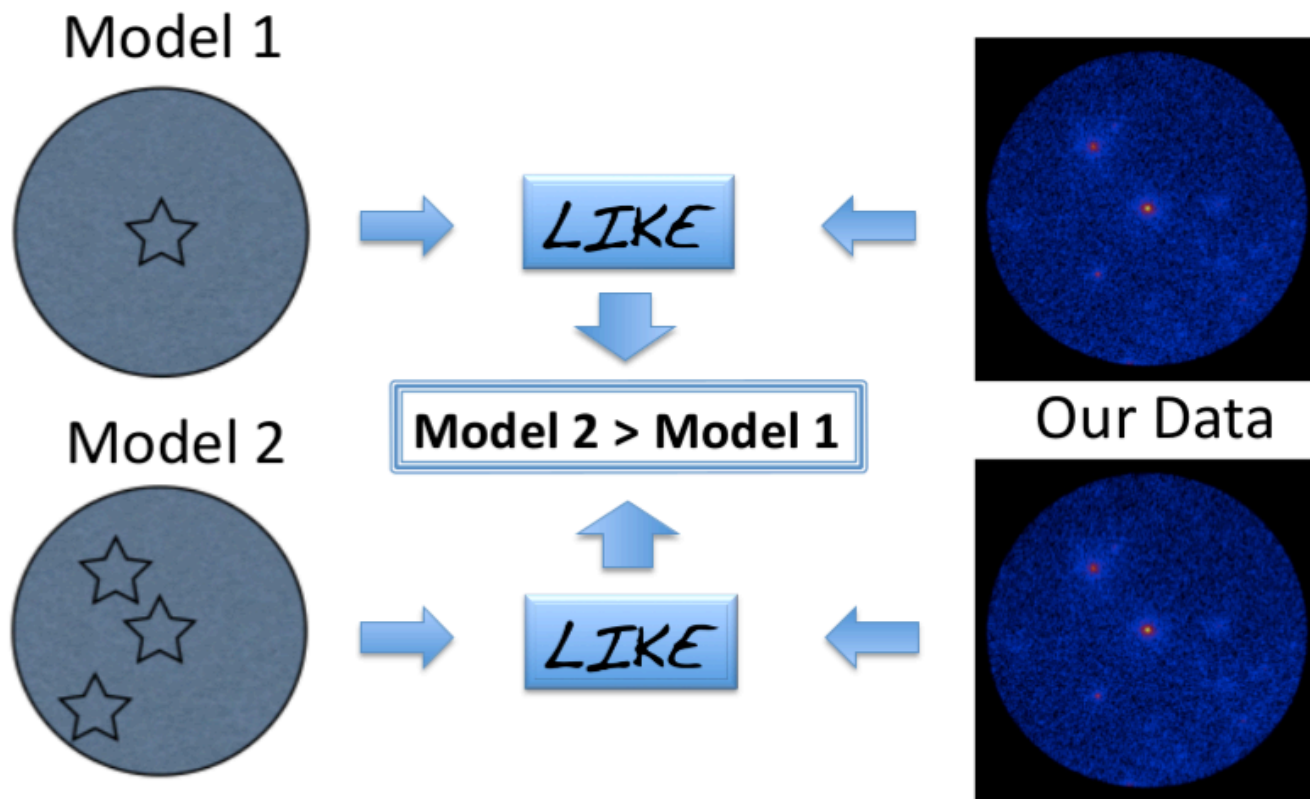


Count Map

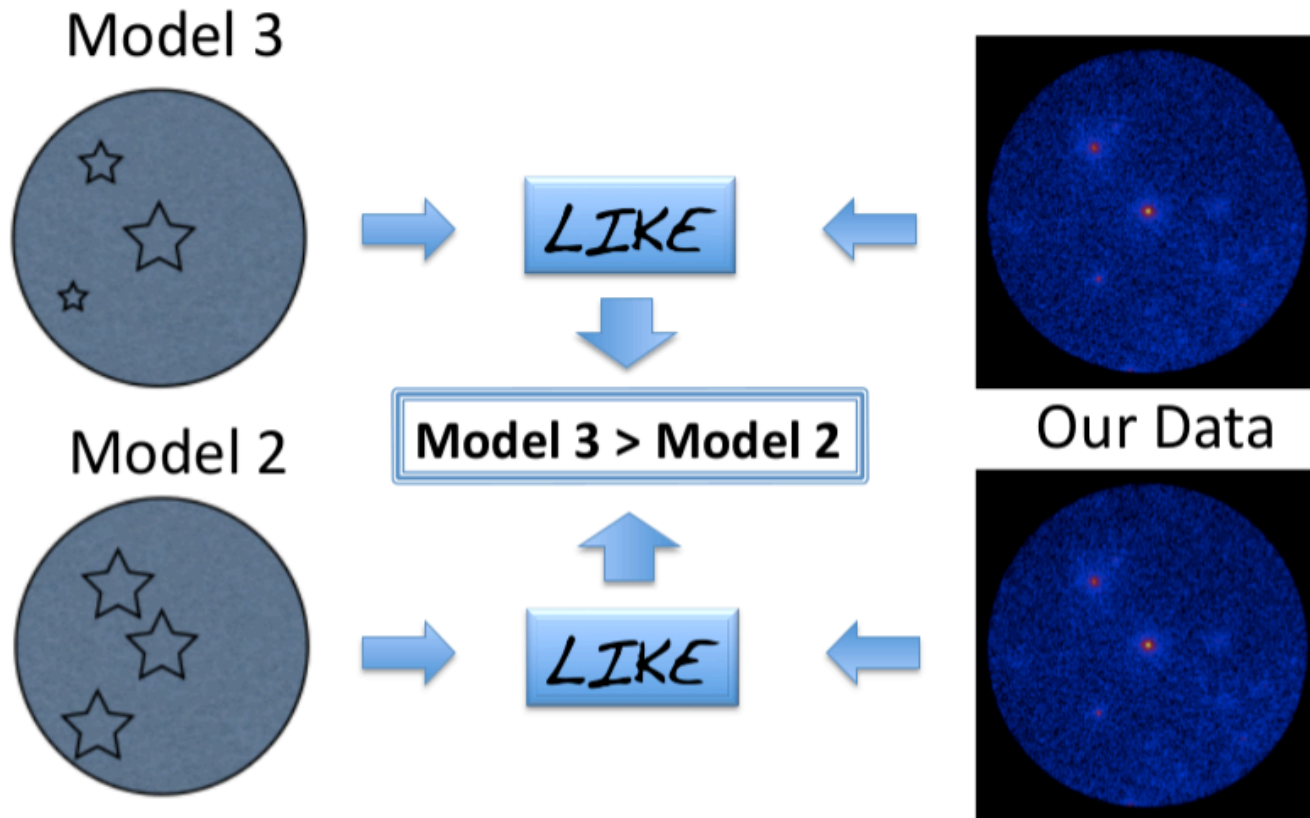
# The Procedure

- Basically the initial '**model**' is a guess of the various parameters of the sources in our region:
  - location
  - spectral shape
  - flux
  - etc.
- The guess can be easier if you have a starting point like the 2FGL (3FGL).
- We quantify (using the Likelihood Method) the statistical significance of the model and vary the parameters to determine the most likely parameter values.

# A Graphical Example



# A Graphical Example

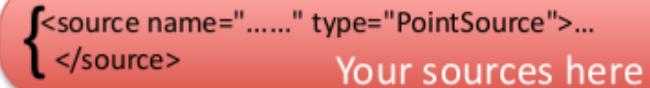




# Describing the Source Model: the XML model

- Typical source entry for an assumed powerlaw spectrum

- `<!-- Point Sources -->`



```
{<source name="....." type="PointSource">...  
</source>
```

Your sources here

- `<source name="3c454.3" type="PointSource">`

- `<spectrum type="PowerLaw2">`

- `<!-- Source is in ROI center -->`

- `<parameter error="0.00" free="1" max="1000" min="1e-06" name="Integral" scale="1e-04" value="1.000"/>`

- `<parameter error="0.00" free="1" max="0" min="-5" name="Index" scale="1" value="-2.000"/>`

- `<parameter free="0" max="3e6" min="20" name="LowerLimit" scale="1" value="100."/>`

- `<parameter free="0" max="3e6" min="20" name="UpperLimit" scale="1" value="300000."/>`

- `</spectrum>`

- `<spatialModel type="SkyDirFunction">`

- `<parameter free="0" max="360.0" min="-360.0" name="RA" scale="1.0" value="343.494812"/>`

- `<parameter free="0" max="90" min="-90" name="DEC" scale="1.0" value="16.149500"/>`

- `</spatialModel>`

- `</source>`

# XML model

- Test different models... power law \* HE exponential cut-off
- `<source name="3c454.3" type="PointSource">`
- `<spectrum type="PLSuperExpCutoff">`
- `<parameter free="1" max="1000" min="1e-05" name="Prefactor" scale="1e-07" value="1"/>`
- `<parameter free="1" max="0" min="-5" name="Index1" scale="1" value="-1.7"/>`
- `<parameter free="0" max="1000" min="50" name="Scale" scale="1" value="200"/>`
- `<parameter free="1" max="30000" min="500" name="Cutoff" scale="1" value="3000"/>`
- `<parameter free="0" max="5" min="0" name="Index2" scale="1" value="1"/>`
- `</spectrum>`
  
- Look here for source model definition and XML model definitions:
- [http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/xml\\_model\\_defs.html](http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/xml_model_defs.html)
- [http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source\\_models.html](http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source_models.html)
  
- Useful python script to load 4FGL sources that belongs to your ROI in your XML file model ( [make4FGLxml.py](#) )
- <http://fermi.gsfc.nasa.gov/ssc/data/analysis/user/>
-

# Describing the Source Model: the XML model

- Backgrounds

- `<!-- Diffuse Sources -->`
- `<source name="galactic_background" type="DiffuseSource">`
- `<spectrum type="PowerLaw">`
- `<parameter free="1" max="10" min="0" name="Prefactor" scale="1" value="1"/>`
- `<parameter free="0" max="1" min="-1" name="Index" scale="1.0" value="0"/>`
- `<parameter free="0" max="2e2" min="5e1" name="Scale" scale="1.0" value="1e2"/>`
- `</spectrum>`
- `<spatialModel file="gll_iem_v07.fits" type="MapCubeFunction">`
- `<parameter free="0" max="1e3" min="1e-3" name="Normalization" scale="1.0" value="1.0"/>`
- `</spatialModel>`
- `</source>`
- `<source name="extragalactic_background" type="DiffuseSource">`
- `<spectrum file="iso_P8R3_SOURCE_V3_v1.txt" type="FileFunction">`
- `<parameter free="1" max="10" min="1e-2" name="Normalization" scale="1" value="1"/>`
- `</spectrum>`
- `<spatialModel type="ConstantValue">`
- `<parameter free="0" max="10.0" min="0.0" name="Value" scale="1.0" value="1.0"/>`
- `</spatialModel>`
- `</source>`

# Likelihood 1st step: gtlcube

- [/home]\$ `gtlcube zmax=90`
- Event data file[filtered\_gti.fits]
- Spacecraft data file[sc.fits]
- Output file[lCube.fits]
- Step size in  $\cos(\theta)$  (0.:1.) [0.025]
- Pixel size (degrees)[1]
- .....

The “lifetime cube” must be re-calculated when a new time-interval or a new ZA is selected

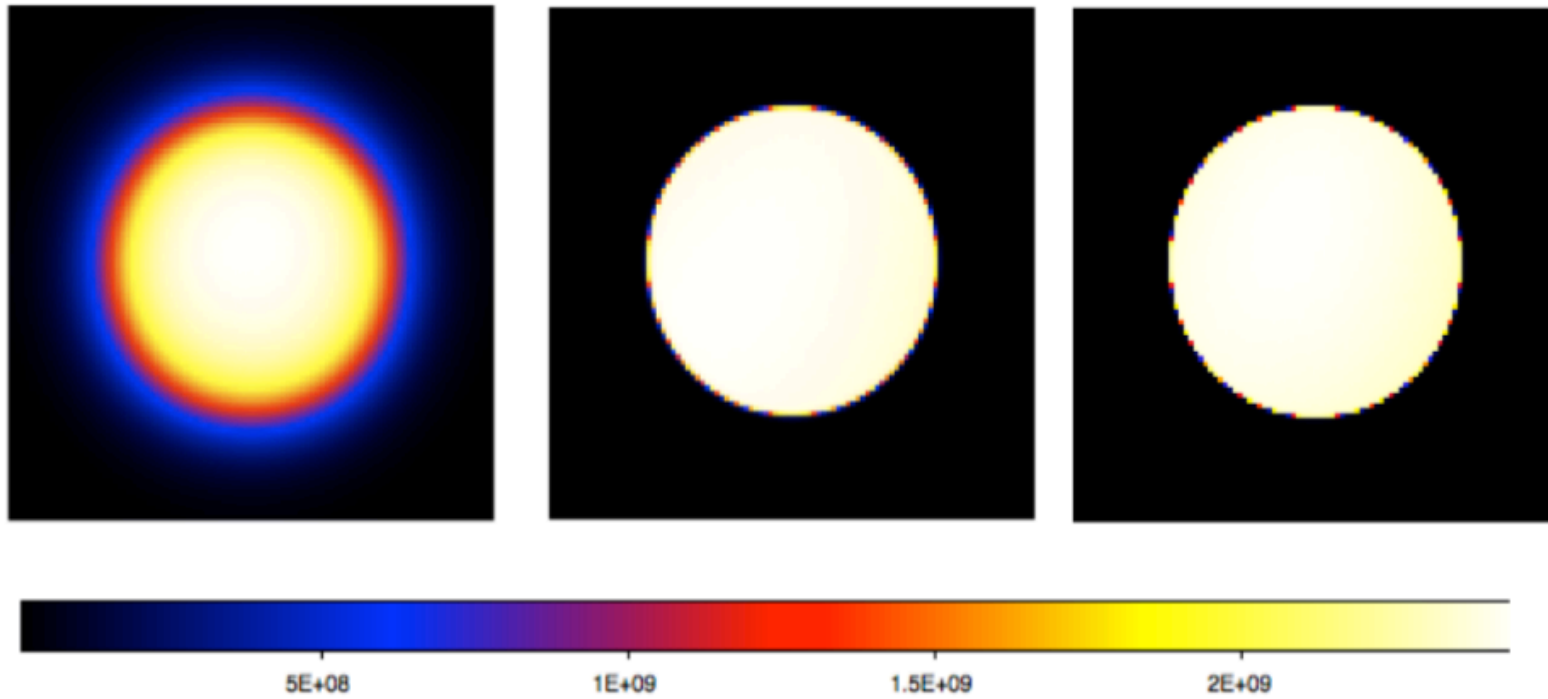
# Likelihood 2nd step: gtexpmap

- [/home/]\$ `gtexpmap`
- Event data file[filtered\_gti.fits]
- Spacecraft data file[sc.fits]
- Exposure hypercube file[ItCube.fits]
- output file name[expMap.fits]
- Response functions[CALDB]
- Radius of the source region (in degrees)[30]
- Number of longitude points (2:1000) [120]
- Number of latitude points (2:1000) [120]
- Number of energies (2:100) [20]
- Computing the ExposureMap using ItCube.fits
- ...

Add 15° to the ROI  
radius

# gtexpmap

Quick check with DS9: fields must be homogenous



# Likelihood 3rd step: the XML model

## 5. Create a source model XML file

The [gtlike](#) tool reads the source model from an XML file. The model file contains your best guess at the locations and spectral forms for the sources in your data. A source model can be created using the [model editor](#) tool, by using the user contributed tool [make3FGLxml.py](#) (available at the [user-contributed tools](#) page), or by editing the file directly within a text editor.

Here we cannot use the same source model that was used to analyze six months of data in the [Unbinned Likelihood](#) tutorial, as the 2-year data set contains many more significant sources and will not converge. Instead, we will use the 3FGL catalog to define our source model by running [make3FGLxml.py](#). To run the script, you will need to download the current [LAT catalog file](#) and place it in your working directory:

```
prompt> make3FGLxml.py gll_psc_v16.fit 3C279_binned_gti.fits -o 3C279_input_model.xml
-G $FERMI_DIR/refdata/fermi/galdiffuse/gll_iem_v06.fits -g gll_iem_v06
-I $FERMI_DIR/refdata/fermi/galdiffuse/iso_P8R2_SOURCE_V6_v06.txt
-i iso_P8R2_SOURCE_V6_v06 -s 120 -p TRUE -v TRUE
This is make3FGLxml version 01r0.
The default diffuse model files and names are for pass 8
and assume you have v10r00p05 of the Fermi Science Tools or higher.
Creating file and adding sources from 3FGL
Added 312 point sources, note that any extended sources in ROI were modeled as point sources
because psForce option was set to True
prompt>
```

Note that we are using a high level of significance so that we only fit the brightest sources and we have forced the extended sources to be modeled as point sources. This only affects the lobes of Centarus A which are just outside the FOV.

It is also necessary to specify the entire path to location of the diffuse model on your system. The resulting XML model contains 312 sources. Clearly, the simple 4-source model we used for the 6-month [Unbinned Likelihood](#) analysis would have been too simplistic.

This XML file uses the spectral model from the 3FGL catalog analysis for each source. (The catalog file is available at the [LAT 4-yr Catalog page](#).) However, that analysis used a subset of the available spectral models. A dedicated analysis of the region may indicate a different spectral model is preferred. For more details on the options available for your XML models, see:

- Descriptions of available [Spectral and Spatial Models](#)
- Examples of [XML Model Definitions for Likelihood](#)

# Likelihood 3<sup>rd</sup> step

- `python make4FGLxml.py gll_psc_v28.xml  
filtered_gti.fits -o 3C454.xml -r 5.0`



# Describing the Source Model: the XML model

- Backgrounds
- `<!-- Diffuse Sources -->`
- `<source name="galactic_background" type="DiffuseSource">`
- `<spectrum type="PowerLaw">`
- `<parameter free="1" max="10" min="0" name="Prefactor" scale="1" value="1"/>`
- `<parameter free="0" max="1" min="-1" name="Index" scale="1.0" value="0"/>`
- `<parameter free="0" max="2e2" min="5e1" name="Scale" scale="1.0" value="1e2"/>`
- `</spectrum>`
- `<spatialModel file="gll_iem_v07.fits" type="MapCubeFunction">`
- `<parameter free="0" max="1e3" min="1e-3" name="Normalization" scale="1.0" value="1.0"/>`
- `</spatialModel>`
- `</source>`
- `<source name="extragalactic_background" type="DiffuseSource">`
- `<spectrum file="iso_P8R3_SOURCE_V3_v1.txt" type="FileFunction">`
- `<parameter free="1" max="10" min="1e-2" name="Normalization" scale="1" value="1"/>`
- `</spectrum>`
- `<spatialModel type="ConstantValue">`
- `<parameter free="0" max="10.0" min="0.0" name="Value" scale="1.0" value="1.0"/>`
- `</spatialModel>`
- `</source>`

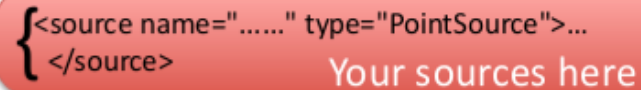
# Likelihood 3rd step: the XML model

- Backgrounds
- `<!-- Diffuse Sources -->`
- `<source name="galactic_background" type="DiffuseSource">`
- `<spectrum type="PowerLaw">`
- `<parameter free="1" max="10" min="0" name="Prefactor" scale="1" value="1"/>`
- `<parameter free="0" max="1" min="-1" name="Index" scale="1.0" value="0"/>`
- `<parameter free="0" max="2e2" min="5e1" name="Scale" scale="1.0" value="1e2"/>`
- `</spectrum>`
- `<spatialModel file="gll_iem_v06.fits" type="MapCubeFunction">`
- `<parameter free="0" max="1e3" min="1e-3" name="Normalization" scale="1.0" value="1.0"/>`
- `</spatialModel>`
- `</source>`
- `<source name="extragalactic_background" type="DiffuseSource">`
- `<spectrum file="iso_P8R2_SOURCE_V6_v06.txt" type="FileFunction">`
- `<parameter free="1" max="10" min="1e-2" name="Normalization" scale="1" value="1"/>`
- `</spectrum>`
- `<spatialModel type="ConstantValue">`
- `<parameter free="0" max="10.0" min="0.0" name="Value" scale="1.0" value="1.0"/>`
- `</spatialModel>`
- `</source>`

# XML model

- Typical source entry for an assumed powerlaw spectrum

- <!-- Point Sources -->



```
{<source name="....." type="PointSource">...  
</source>
```

Your sources here

- <source name="3c454.3" type="PointSource">

- <spectrum type="PowerLaw2">

- <!-- Source is in ROI center -->

- <parameter error="0.00" free="1" max="1000" min="1e-06" name="Integral" scale="1e-04" value="1.000"/>

- <parameter error="0.00" free="1" max="0" min="-5" name="Index" scale="1" value="-2.000"/>

- <parameter free="0" max="3e6" min="20" name="LowerLimit" scale="1" value="100."/>

- <parameter free="0" max="3e6" min="20" name="UpperLimit" scale="1" value="300000."/>

- </spectrum>

- <spatialModel type="SkyDirFunction">

- <parameter free="0" max="360.0" min="-360.0" name="RA" scale="1.0" value="343.494812"/>

- <parameter free="0" max="90" min="-90" name="DEC" scale="1.0" value="16.149500"/>

- </spatialModel>

- </source>

# XML model

- Test different models... power law \* HE exponential cut-off
- `<source name="3c454.3" type="PointSource">`
- `<spectrum type="PLSuperExpCutoff">`
- `<parameter free="1" max="1000" min="1e-05" name="Prefactor" scale="1e-07" value="1"/>`
- `<parameter free="1" max="0" min="-5" name="Index1" scale="1" value="-1.7"/>`
- `<parameter free="0" max="1000" min="50" name="Scale" scale="1" value="200"/>`
- `<parameter free="1" max="30000" min="500" name="Cutoff" scale="1" value="3000"/>`
- `<parameter free="0" max="5" min="0" name="Index2" scale="1" value="1"/>`
- `</spectrum>`
  
- Look here for source model definition and XML model definitions:
- [http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/xml\\_model\\_defs.html](http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/xml_model_defs.html)
- [http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source\\_models.html](http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source_models.html)
  
- Useful python script to load 2FGL sources that belongs to your ROI in your XML file model ( [make3FGLxml.py](#) )
- <http://fermi.gsfc.nasa.gov/ssc/data/analysis/user/>
-

# Diffuse response

- [/home/]\$gtdiffrsp
- Event data file[] filtered\_gti.fits
- Spacecraft data file[] sc.fits
- Source model file[] 3c454.3.xml
- Response functions to use[] CALDB

# Finally... gtlike performing the actual fit

- [/home/]\$ `gtlike` plot=no
- Statistic to use (BINNED|UNBINNED) [UNBINNED]
- Spacecraft file[sc.fits]
- Event file[filtered\_gti.fits]
- Unbinned exposure map[expMap.fits]
- Exposure hypercube file[lcCube.fits]
- Source model file[../xml\_models/\_3c454.3\_model\_ROI15.xml]
- Response functions to use[CALDB]
- Optimizer (DRMNFB|NEWMINUIT|MINUIT|DRMNGB|LBFGS) [DRMNFB]

Typically use DRMNGB/DRMNFB to find a rough estimate of the likelihood maxima  
and refine later on with **MINUIT** (or **NEWMINUIT**)

# Likelihood output

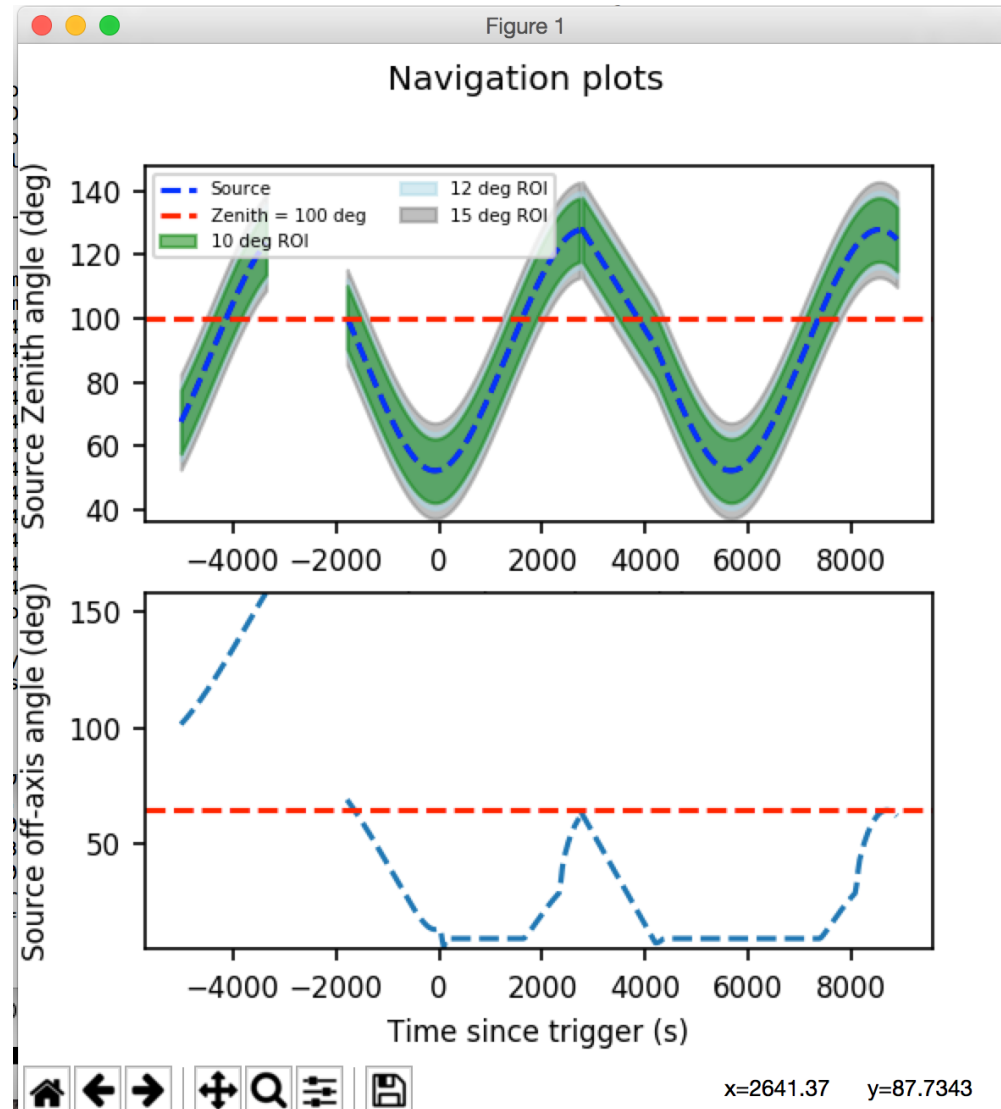
- {'3c454.3': {'Integral': '0.146106 +/- 0.00271733',
- 'Index': '-2.29973 +/- 0.017189',
- 'LowerLimit': '100',
- 'UpperLimit': '300000',
- 'Npred': '4171.85',
- 'ROI distance': '0',
- 'TS value': '17548.4',
- 'Flux': '1.46192e-05 +/- 2.7178e-07',
- ...
- extragalactic\_background: {'Normalization': '1.20197 +/- 0.23541',
- 'Npred': '643.953',
- 'Flux': '0.000170707 +/- 3.34331e-05',
- },
- 'galactic\_background': {'Prefactor': '0.739969 +/- 0.251827',
- 'Index': '0',
- 'Scale': '100',
- 'Npred': '357.929',
- 'Flux': '0.000215978 +/- 7.35023e-05',

gtlike creates two output files:  
1) results.dat: fit results  
2) counts\_spectra.fits: the counts in a proper energy binning

# gtburst overview



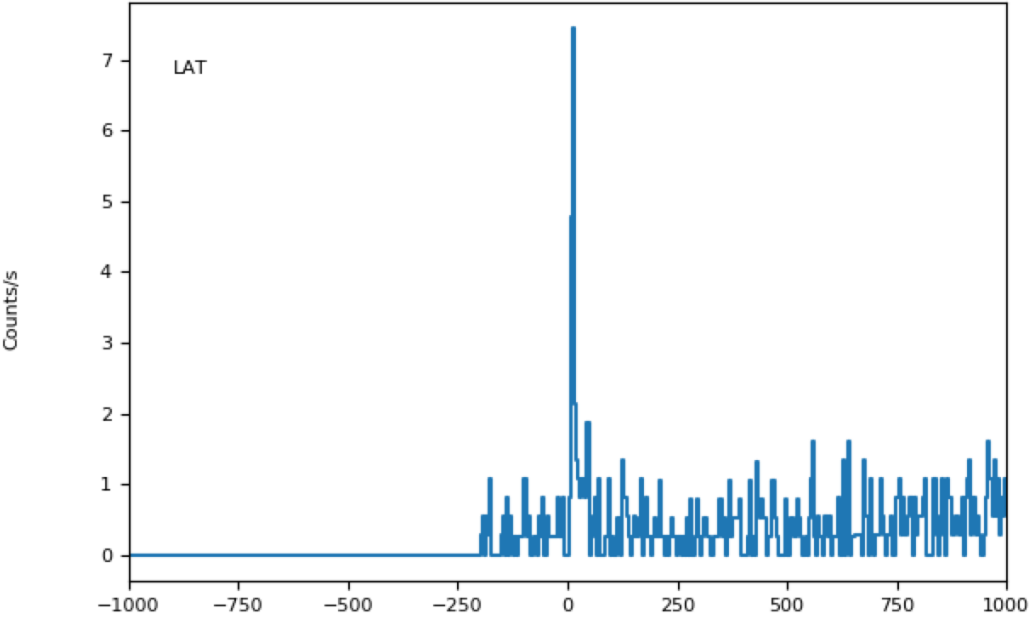
# Check the “Navigation” plot



# Likelihood with gtburst

Fermi bursts analysis GUI

Trigger name	bn160905471
R.A. (J2000)	162.245
Dec. (J2000)	-50.801
Trigger date (MET)	494767139.912




Counts/s


LAT

Counts/s

Detectors to display in the LC:  
 LAT (16 deg)

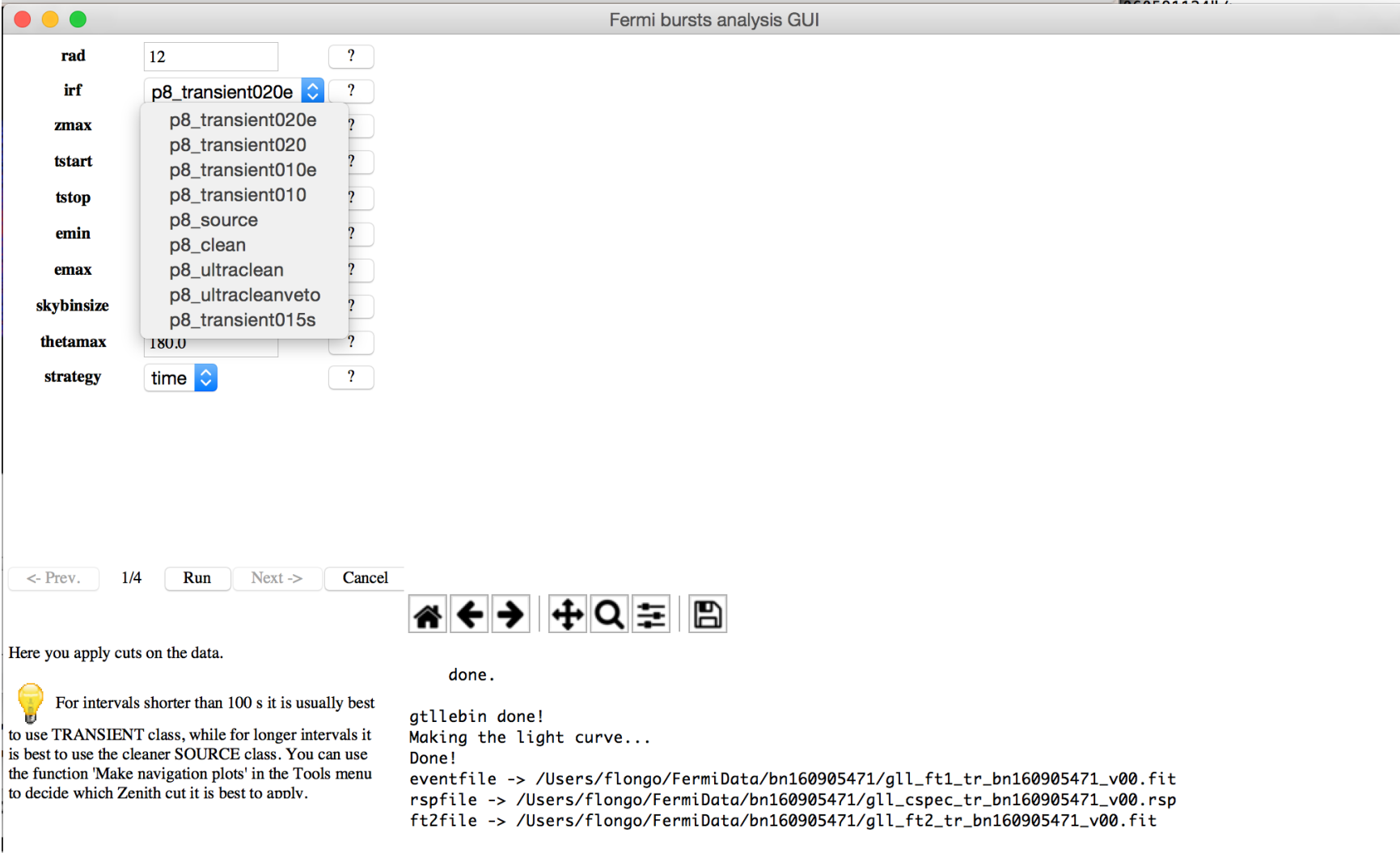
Loaded datasets: LAT

 You can zoom/pan the light curve using the toolbar at the bottom of the figure. For help on the use of the toolbar, see [http://matplotlib.org/users/navigation\\_toolbar.html](http://matplotlib.org/users/navigation_toolbar.html)



```
done.  
  
* Updating keywords in the headers of the CSPEC file...  
  
done.  
  
gtllebin done!  
Making the light curve...  
Done!
```

# Select event class



Fermi bursts analysis GUI

rad 12 ?

irf p8\_transient020e ?

zmax p8\_transient020e ?

tstart p8\_transient020 ?

tstop p8\_transient010e ?

emin p8\_transient010 ?

emax p8\_source ?

skybinsize p8\_clean ?

thetamax p8\_ultraclean ?

strategy p8\_ultracleanveto ?

time p8\_transient015s ?

180.0 ?


<- Prev. 1/4 Run Next -> Cancel

Home Left Right Zoom Search Filter Save

Here you apply cuts on the data.

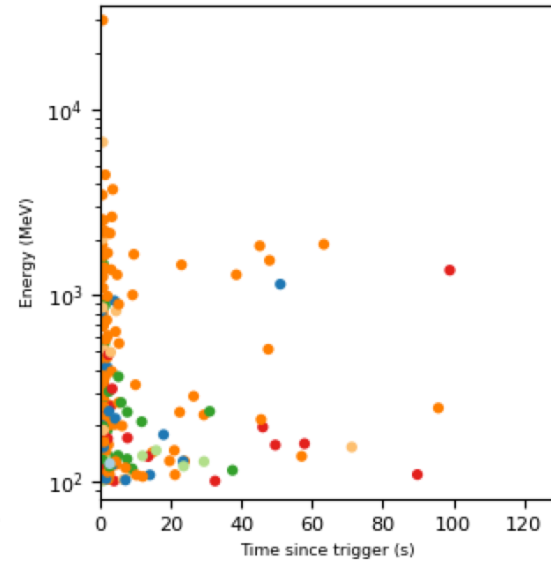
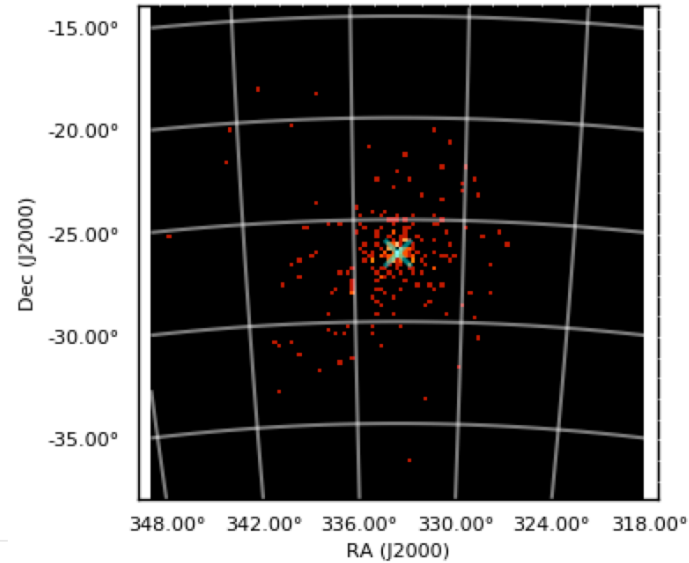
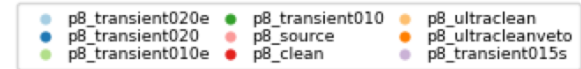
done.

gtllebin done!  
Making the light curve...  
Done!  
eventfile -> /Users/flongo/FermiData/bn160905471/gll\_ft1\_tr\_bn160905471\_v00.fit  
rspfile -> /Users/flongo/FermiData/bn160905471/gll\_cspectr\_bn160905471\_v00.rsp  
ft2file -> /Users/flongo/FermiData/bn160905471/gll\_ft2\_tr\_bn160905471\_v00.fit

 For intervals shorter than 100 s it is usually best to use TRANSIENT class, while for longer intervals it is best to use the cleaner SOURCE class. You can use the function 'Make navigation plots' in the Tools menu to decide which Zenith cut it is best to apply.

# See count map and list of photons

rad  ?  
 irf  ?  
 zmax  ?  
 tstart  ?  
 tstop  ?  
 emin  ?  
 emax  ?  
 skybinsize  ?  
 thetamax  ?  
 strategy  ?



1/4



Here you apply cuts on the data.



For intervals shorter than 100 s it is usually best

to use TRANSIENT class, while for longer intervals it is best to use the cleaner SOURCE class. You can use the function 'Make navigation plots' in the Tools menu to decide which Zenith cut it is best to apply.

Class p8_transient010 only:	47
Class p8_source only:	0
Class p8_clean only:	32
Class p8_ultraclean only:	19
Class p8_ultracleanveto only:	123
Class p8_transient015s only:	0

=====


# Create XML model

particle_model	isotr template	?
galactic_model	template	?
source_model	powerlaw2	?
fgl_mode	fast	?

<- Prev. 2/4 Run Next -> Cancel



You have to choose which model include in the likelihood analysis. See [http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source\\_models.html](http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source_models.html) for the list of available spectral model for the source\_model parameter.

 Use 'PowerLaw2' for normal GRB analysis.

Cutting the template around the ROI:

```
Keeping diffuse source 3FGL J0852.7-4631e (19.39 deg away) using template /Users/flongo/FermiTools/miniconda2/envs/fermi/share/fermitools/data/pyBurstAnalysisGUI/templates/VelaJr.fits...
Kept 1 point sources from the FGL catalog
```

=====

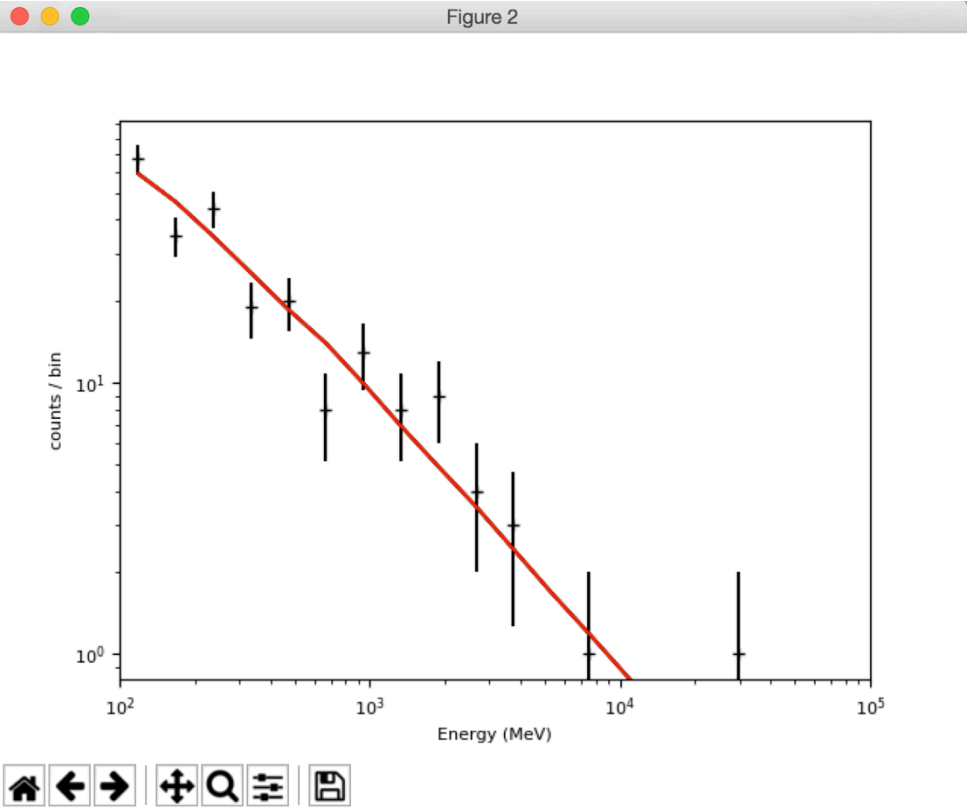
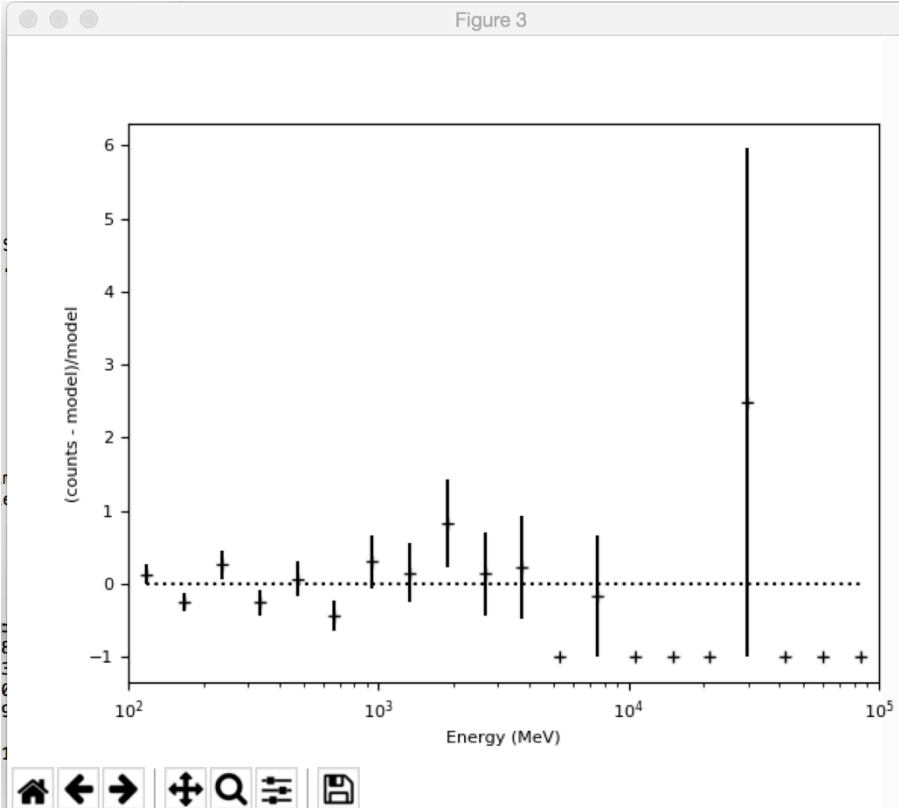
# Select the parameters of the model

Fermi bursts analysis GUI

Double click on a parameter to change it.

Source Name	Name	Value	Error	Min	Max	Scale	Free	Source Type	Feature	Feature Type	Fe
bn090510016	Integral	0.01		1e-05	1000.0	0.00	1	PointSource	spectrum	PowerLaw2	
bn090510016	Index	-2		-6.0	0.01	1.0	1	PointSource	spectrum	PowerLaw2	
bn090510016	LowerLimit	100		20.0	200000.	1.0	0	PointSource	spectrum	PowerLaw2	
bn090510016	UpperLimit	1e+0		20.0	500000	1.0	0	PointSource	spectrum	PowerLaw2	
bn090510016	RA	333.		-360.	360.0	1.0	0	PointSource	spatialMod	SkyDirFunction	
bn090510016	DEC	-26.0		-90.0	90.0	1.0	0	PointSource	spatialMod	SkyDirFunction	
IsotropicTemplat	Normalizatio	1		0.1	10.0	1	1	DiffuseSourc	spectrum	FileFunction	[../iso_P8R2_TRA
IsotropicTemplat	Value	1		0.0	10.0	1.0	0	DiffuseSourc	spatialMod	ConstantValue	
GalacticTemplat	Value	1		0.7	1.3	1.0	1	DiffuseSourc	spectrum	ConstantValue	
GalacticTemplat	Normalizatio	1		0.001	1000.0	1.0	0	DiffuseSourc	spatialMod	MapCubeFunctio	[../gll_iem_v06_ct

# Fit plots



# Fit results

Likelihood results					
Source name	Par. Name	Value	Error	Units	TS
GalacticTemplate					0
	Value	1	0.15	-	
	Energy flux	2.1e-07	3.14e-08	erg/cm2/s	
	Photon flux	0.000443	6.63e-05	ph./cm2/s	
IsotropicTemplate					1
	Normalization	0.426	1.32	-	
	Energy flux	4.75e-08	1.47e-07	erg/cm2/s	
	Photon flux	0.000134	0.000413	ph./cm2/s	
bn090510016					2056
	Integral	0.000363	2.31e-05	ph./cm2/s	
	Index	-2.03	0.0628	-	
	LowerLimit	100	n.a. (fixed)	MeV	
	UpperLimit	1e+05	n.a. (fixed)	MeV	
	Energy flux	1.33e-07	8.44e-09	erg/cm2/s	
	Photon flux	0.00033	2.2e-05	ph./cm2/s	

\*\*\* All fluxes and upper limits have been computed in the 100.0 - 1000.0 energy range.  
 \*\*\* Upper limits (if any) are computed assuming a photon index of -2.0, with the 95.0 % c.l.  
 Log(likelihood) = 769.199818608

New localization from gtfndsrc:

(R.A., Dec) = (333.567, -26.625)  
 68 % containment radius = 0.028  
 90 % containment radius = 0.040  
 Distance from initial position = 0.039

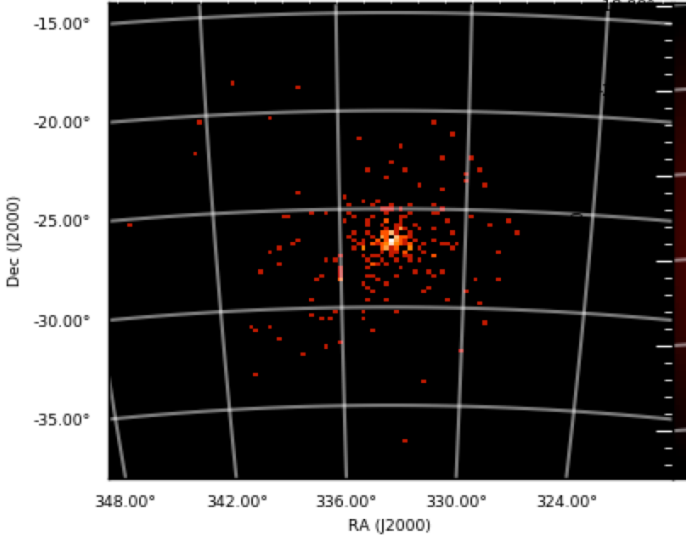
Results of the last likelihood analysis. Select 'close' from the file menu to close this window.



# Fit results

Fermi bursts analysis GUI

tmin	20	?
optimizeposition	yes	?
showmodelimage	yes	?
spectralfiles	yes	?
liketype	unbinned	?
clul	0.95	?
femin	100	?
femax	1000	?




<- Prev. 4/4 Run Finish! Cancel

Home Left Right Pan Zoom Fit Save

90 % containment radius = 0.040  
Distance from initial position = 0.039

NOTE: this new localization WILL NOT be used by default. If you judge it is a better localization than the one you started with, update the coordinates yourself and re-run the likelihood

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 The likelihood analysis should take between 5 and 10 minutes to complete.