

AGN Multiwavelength Research Strategies: The Fermi Large Area Telescope Experience

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Synergies in the Exploration of the Extreme Universe Webinar

April 29, 2021

Outline

Background – AGN as multiwavelength sources

Data sharing – the LAT approach

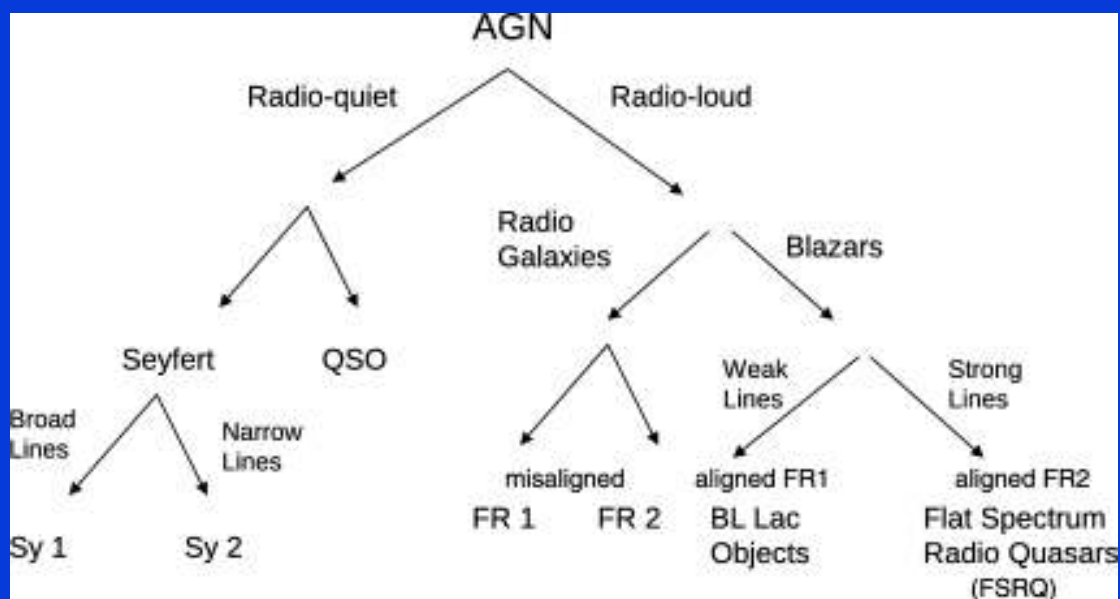
Monitoring programs

Pre-planned campaigns

Rapid response strategies

AGN vs. Gamma-ray AGN - reminders

An Active Galactic Nucleus (AGN) is a bright core of a galaxy, probably powered by a supermassive black hole. There is a whole “zoo” of AGN types. **~90% of AGN are radio quiet.**



Almost all gamma-ray AGN are in the radio-loud branch.

Gamma-ray AGN are the dominant source class at GeV energies and a major source class at TeV energies.

Why? Some gamma-ray AGN science questions

What powers the jets of supermassive black holes?

What causes the variability time scale to be so short during intense flaring periods?

Do shocks or turbulence in blazar jets accelerate the ultra-high energy cosmic rays, or do UHECRs have a different origin?

What acceleration and radiation physics explains the peak synchrotron and Compton frequencies of blazars of different types?

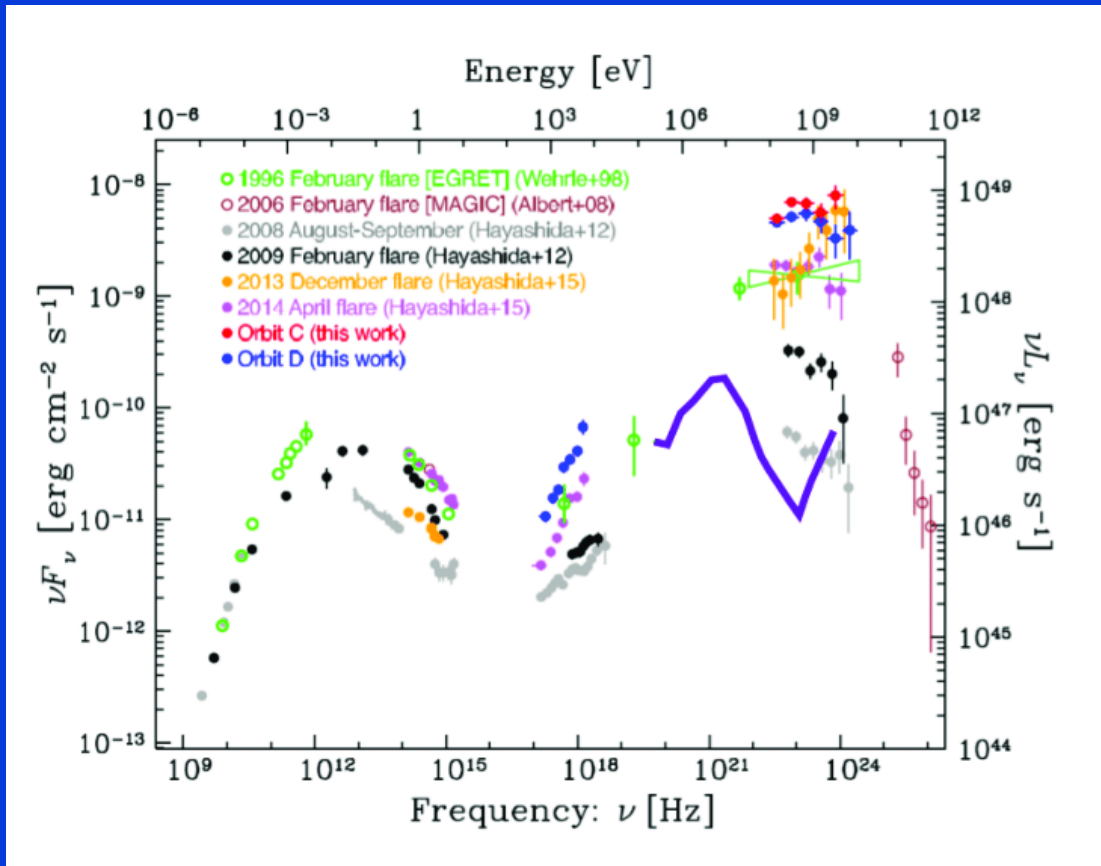
Are gamma-ray AGN a source of high-energy neutrinos?

What can gamma-ray AGN reveal about extragalactic background light and extragalactic magnetic fields?

How much can we limit the dark-matter cross section by modeling the gamma-ray background light?

Adapted from Dermer and Giebels (2016)

Multiwavelength nature of gamma-ray AGN



This Spectral Energy Distribution of 3C279 illustrates how gamma-ray AGN span the electromagnetic spectrum.

This importance was obvious even 25 years ago.

Multiwavelength nature of gamma-ray AGN

More than just detectability or variability, multiwavelength observations provide ESSENTIAL information to understand gamma-ray AGN.

Examples:

- **Distance – redshift**
- **Composition – spectroscopy**
- **Mass**
- **Precise imaging**
- **Velocities**
- **Polarization**
- **Magnetic fields**

Data Sharing – A Critical Fermi Starting Point

Once Upon a Time ...

Astrophysicists used to treat data and results sort of the way mythological dragons treated gold – we sat on them, polished them, squeezed every result out, and only shared by published papers.

There have been valid reasons for being “dragons”:

- Communication was difficult
- Multiwavelength resources were limited
- Gamma-ray data analysis was time-consuming
- Systematic uncertainties were hard to quantify

AND

We wanted a fair return for the time we invested building the instruments.

The term “multiwavelength” was almost unheard of before the emergence of the World Wide Web in the mid-1990s.

Before the GLAST Launch (pre-renaming to Fermi)

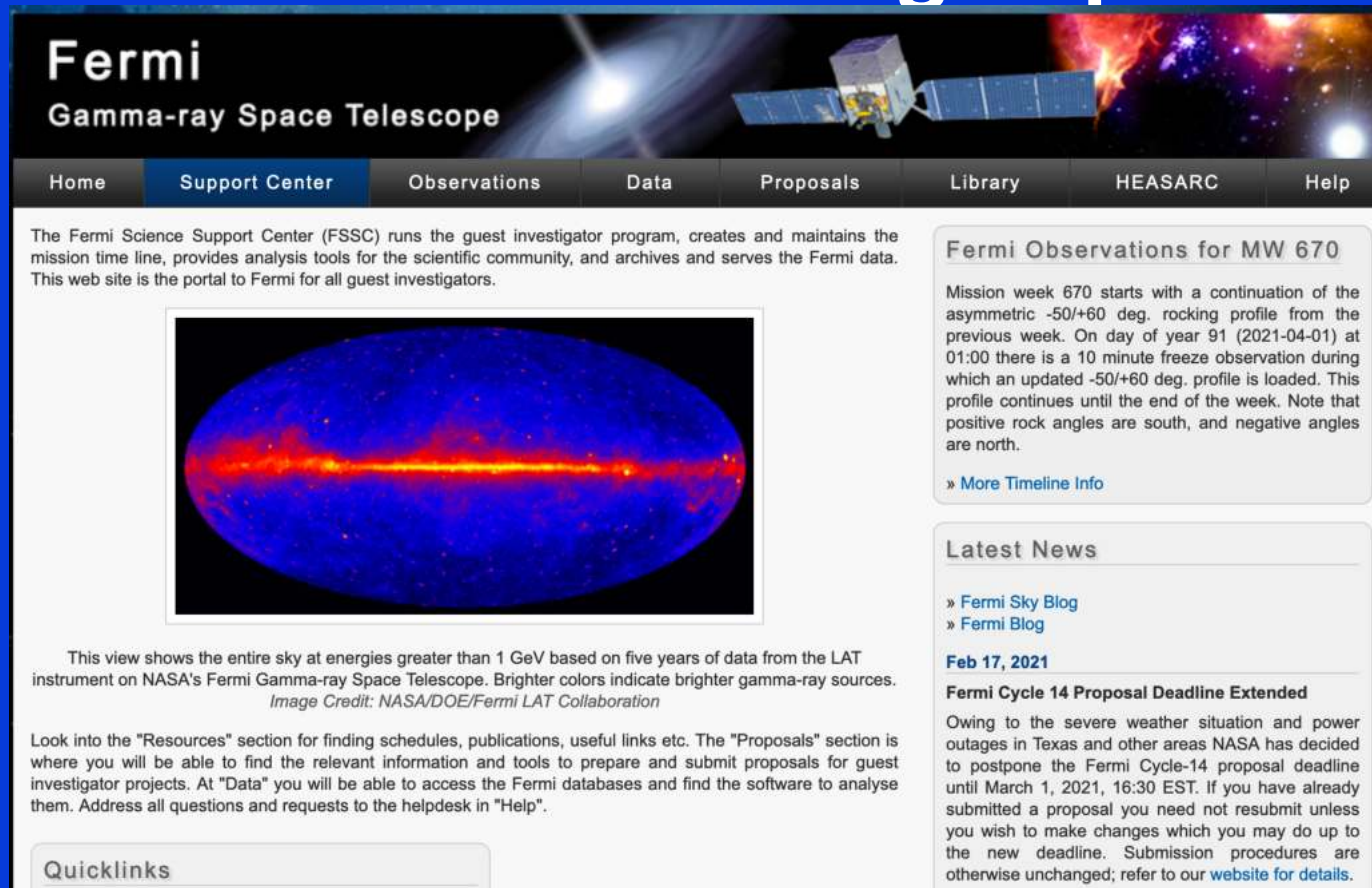
The Large Area Telescope (LAT) Collaboration included some “dragons” who were reluctant to share any data.

Collaboration members who had multiwavelength experience argued that the project would be a scientific disaster if we could not be fairly open with the gamma-ray data.

NASA Headquarters pressured the team into a compromise: data release would be limited in the first year after launch, to allow checkout and testing, but after that all gamma-ray data would become public immediately.

That critical decision to make data public has been the driver for the Fermi multiwavelength program.

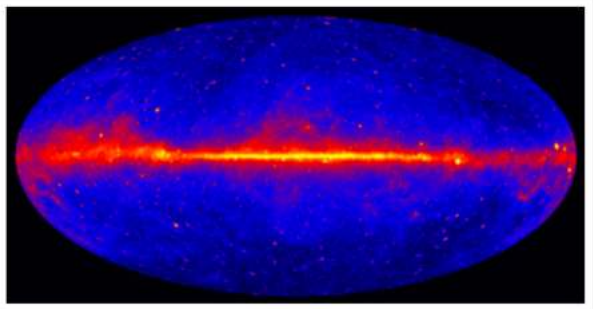
The Fermi Data-sharing Implementation



Fermi
Gamma-ray Space Telescope

Home Support Center Observations Data Proposals Library HEASARC Help

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 view shows the entire sky at energies greater than 1 GeV based on five years of data from the LAT instrument on NASA's Fermi Gamma-ray Space Telescope. Brighter colors indicate brighter gamma-ray sources.
Image Credit: NASA/DOE/Fermi LAT Collaboration

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".

Quicklinks

Fermi Observations for MW 670

Mission week 670 starts with a continuation of the asymmetric -50/+60 deg. rocking profile from the previous week. On day of year 91 (2021-04-01) at 01:00 there is a 10 minute freeze observation during which an updated -50/+60 deg. profile is loaded. This profile continues until the end of the week. Note that positive rock angles are south, and negative angles are north.

» More Timeline Info

Latest News

» Fermi Sky Blog
» Fermi Blog

Feb 17, 2021

Fermi Cycle 14 Proposal Deadline Extended

Owing to the severe weather situation and power outages in Texas and other areas NASA has decided to postpone the Fermi Cycle-14 proposal deadline until March 1, 2021, 16:30 EST. If you have already submitted a proposal you need not resubmit unless you wish to make changes which you may do up to the new deadline. Submission procedures are otherwise unchanged; refer to our [website](#) for details.

Includes:

Data/software distribution

Help desk

Guest Investigator program

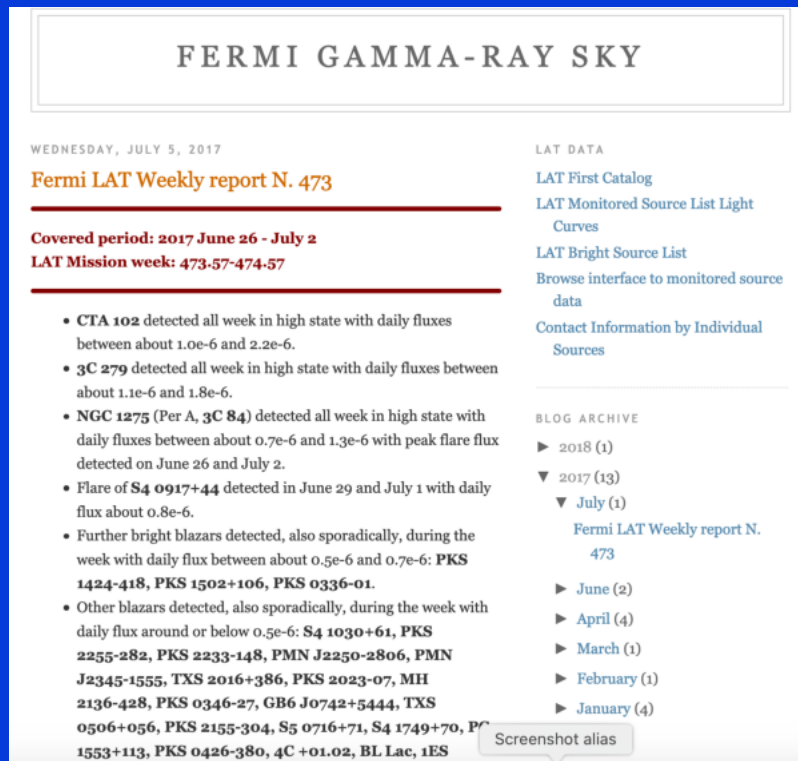
Users group - advisers

Press and outreach activities

The Fermi Science Support Center (FSSC) is the central element in sharing.

The Fermi Blogs

For a while, the Fermi Project shared information via blogs, including information about which sources were active.



The screenshot shows a web page titled "FERMI GAMMA-RAY SKY" dated Wednesday, July 5, 2017. The main heading is "Fermi LAT Weekly report N. 473". Below this, it states "Covered period: 2017 June 26 - July 2" and "LAT Mission week: 473-57-474-57". The main content is a bulleted list of astronomical observations, including detections of CTA 102, 3C 279, NGC 1275, and various blazars like PKS 1424-418 and PKS 1502+106. A sidebar on the right contains a "LAT DATA" section with links to catalogs and source lists, and a "BLOG ARCHIVE" section with a tree view for the years 2018 and 2017, where July 2017 is expanded to show the current report. A "Screenshot alias" tooltip is visible over the bottom of the page.

This information might have been useful for multiwavelength studies, but in practice almost no one read these blogs. We finally discontinued them.

Next Steps by the Fermi-LAT Collaboration

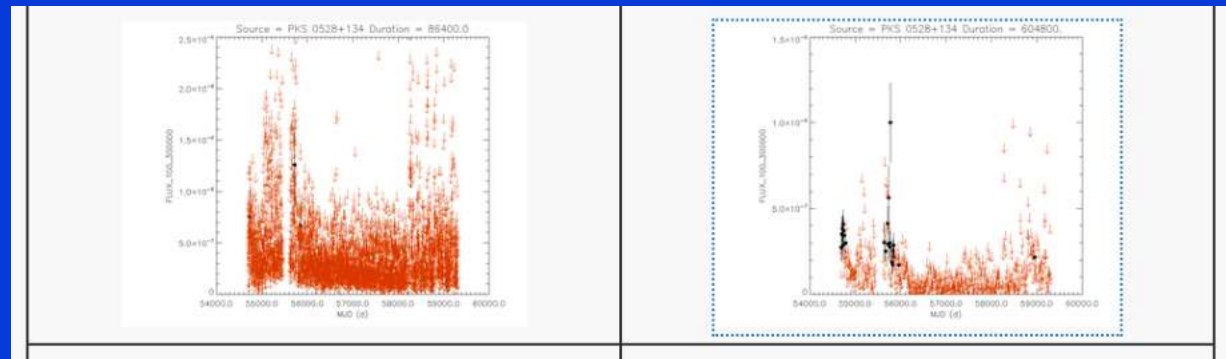
The basic agreement was to deliver the gamma-ray data, software that would allow anyone to analyze the data, and documentation.

The LAT team also agreed to provide some higher-level data products that would encourage multiwavelength studies:

Source catalog in machine-readable form for analysis and plotting

Pulsar timing information

Light curves (daily and weekly) for a selected set of about 20 sources, mostly AGN, based on the LAT team Automated Science Processing (ASP), which runs automatically once data are available.



PKS 0538+134, one of the original AGN in this Monitored Source List based on activity during the Compton era, has been largely quiet in the Fermi era.

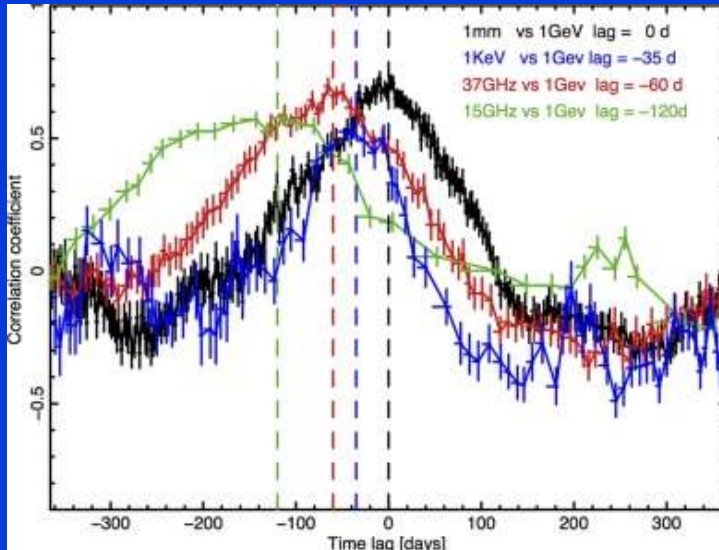
Fermi-LAT AGN Multiwavelength Strategy – Basic Idea

- We take advantage of the Fermi all-sky monitoring capability to offer useful information to the multiwavelength community. We recognize that even though the LAT data are public, most astrophysicists do not want to spend time learning how to do gamma-ray data analysis.
- By example and by direct communication, we promote the idea to other astrophysicists of making at least some data public in useful formats. This is nothing unique to Fermi; various other groups were already doing this.
- We encourage other scientists to work with us on multiwavelength/multimessenger projects. Not everyone will choose to do that. We accept that risk, but we make the offer in the interest of maximizing the scientific return from the Fermi-LAT data. We have set up Memoranda of Understanding with many groups to work on joint projects.

Three applications of these principles are monitoring, pre-planned campaigns, and rapid responses to events of interest.

Fermi-LAT AGN Multiwavelength Strategies – Monitoring Programs

Since AGN are highly variable, one goal is to compare variability patterns. Differences (or lack of those) shed light on where and how the radiation is produced.



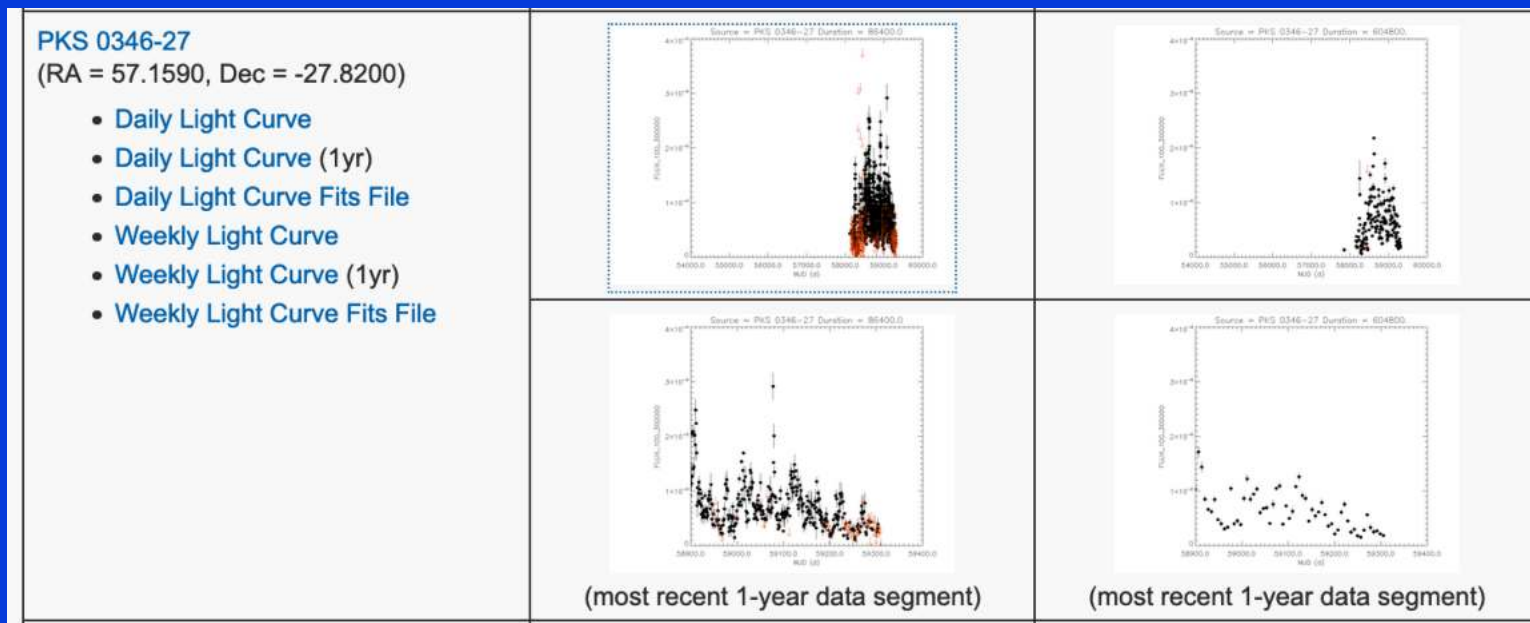
Discrete Cross Correlation Function for 3C454.3

Analysis tools like the Discrete Cross Correlation Function can extract the needed information – but only if simultaneous (or at least contemporaneous) data are available.

Monitoring of AGN without regard to the level of activity provides the data needed to carry out such analysis.

Fermi-LAT Quicklook – the Monitored Source List

Publication of these automated daily and weekly source fluxes has been expanded since the mission started (https://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/) :

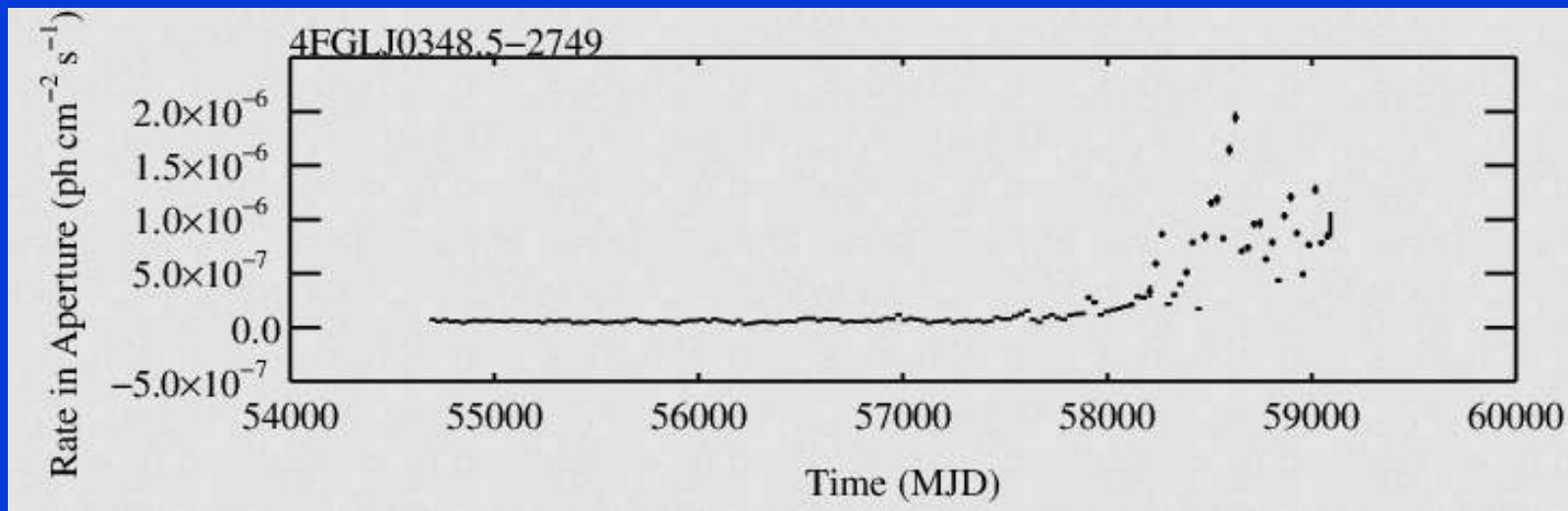


New sources are added when the LAT daily flux above 100 MeV reaches $1 \times 10^{-6} \text{ ph cm}^{-2} \text{ s}^{-1}$. Over 180 AGN are now part of this list. Example: PKS 0346-27 was only added in early 2018. It has remained fairly active since then. These light curves are updated daily.

Fermi-LAT Quicklook – Aperture Photometry Light Curves

These are 30-day light curves for all known Fermi-LAT sources, with energies above 100 MeV, based on 1 degree apertures (with no background subtraction).

(https://fermi.gsfc.nasa.gov/ssc/data/access/lat/10yr_catalog/ap_lcs.php) :

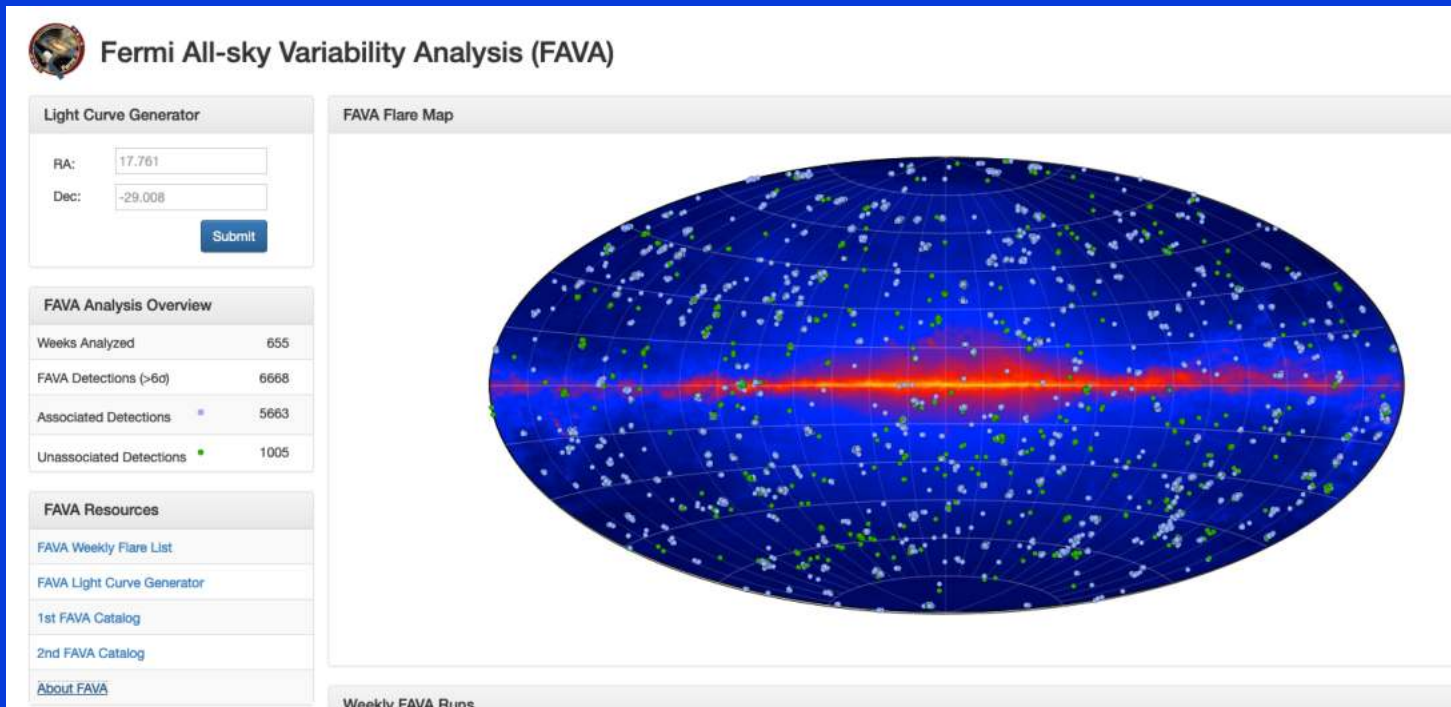


These light curves are updated weekly. The analysis also shows the power spectra of the light curves between 65 days and the length of the light curve. This is the 4FGL-DR2 source corresponding to PKS 0346-27, the same source shown on the previous slide.

Fermi All-sky Variability Analysis (FAVA)

FAVA is a photometric analysis of the LAT data on weekly intervals, in two energy ranges: 100-800 MeV and 800 MeV – 10 GeV

(<https://fermi.gsfc.nasa.gov/ssc/data/access/lat/FAVA/index.php>) :



A list of flares is produced every week.

The analysis is not limited to known sources.

Fermi All-sky Variability Analysis (FAVA) – light curves

Because FAVA is a photometric analysis of the LAT data, it can generate a weekly light curve for ANY point in the sky.



Fermi All-sky Variability Analysis (FAVA) - Light Curve Generator

Coordinate Input

RA:

Dec:

Light Curve Information

Coordinates

RA: 57.16°

Dec: -27.82°

Galactic l: 224.5263°

Galactic b: -50.9083°

Low Energy Analysis

Start Time: 239859818

End Time: 639027818

Maximum Variation: 40.00σ

Time of Max Variation: 579757418

Median Variation: 0.07

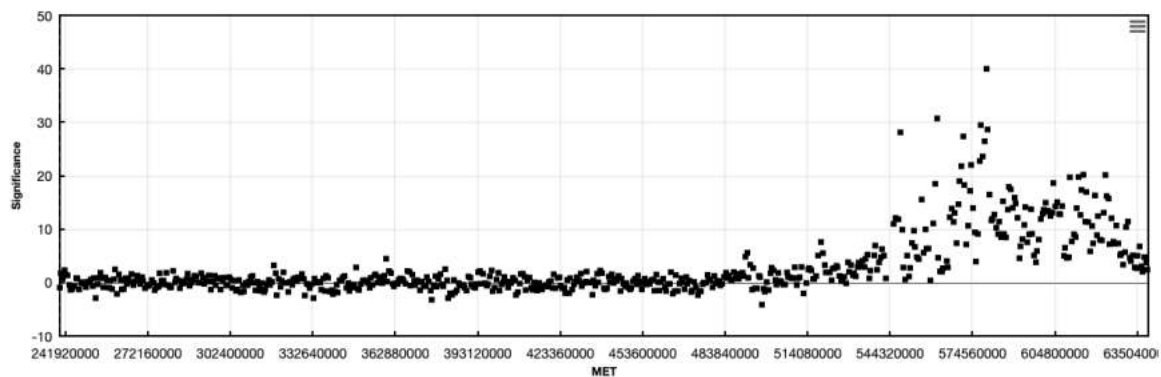
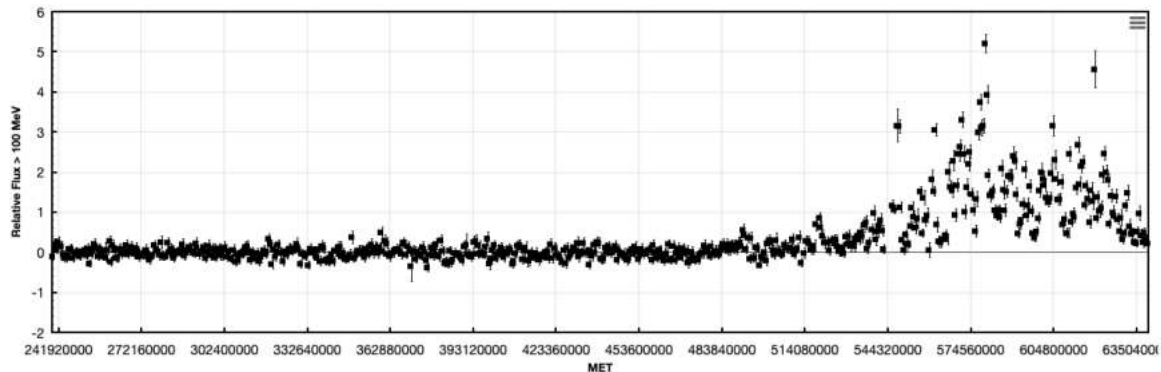
Standard Deviation: 0.74

High Energy Analysis

Start Time: 239859818

End Time: 639027818

Low Energy Light Curve (100 - 800 MeV)



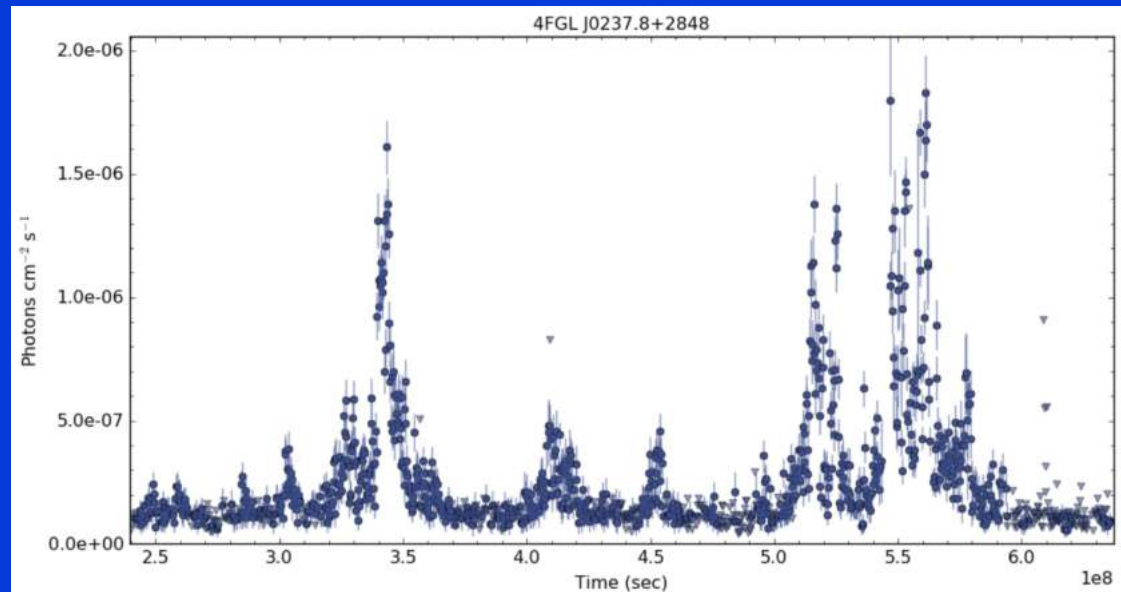
This is the light curve for one of the Monitored Sources, PKS 0346-27 (the same source shown in a previous slide).

Publication-quality Fermi-LAT Light Curves – Coming Soon

None of the previous methods produce light curves with a full maximum likelihood analysis including all backgrounds and nearby sources. These other methods are useful for qualitative inspection of variability trends, but not for quantitative analysis or publication. The LAT team, led by Daniel Kocevski, will soon be releasing a repository of publication-quality light curves for all 4FGL-DR2 variable sources (1525 of these), with time bins of 3 days, 1 week, and 1 month.

This is a sample 3-day light curve for 4C +28.07

The plan is to update these light curves regularly, making them useful for multiwavelength analysis.



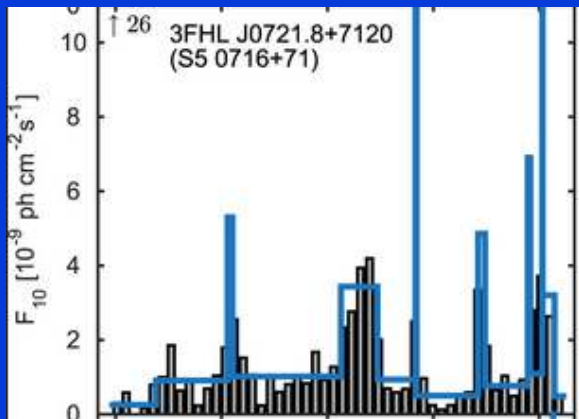
Monitoring time-resolved energy spectra?

The Fermi-LAT public monitoring data do not include any information about time-resolved energy spectra. Flux values are not particularly sensitive to the spectral shape. The Automated Science Processing does construct a power-law spectrum for each source (typically with large uncertainties), but we know that many LAT sources are not well represented by this functional form, so making those public would not be scientifically valid.

The basic issue is that on short time scales, the LAT data are usually limited by photon counting statistics.

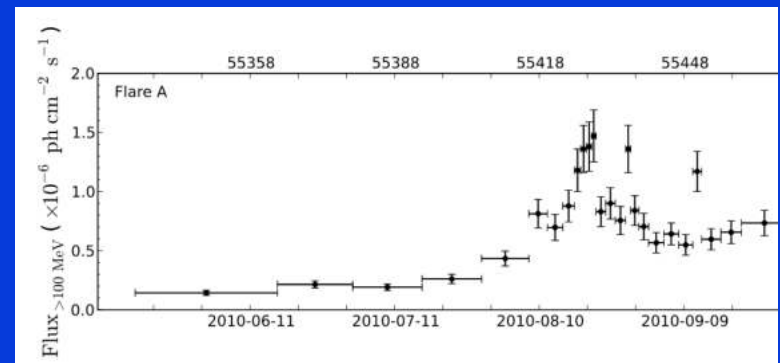
What about identifying gamma-ray time features?

Uncertainties due to limited counting statistics can challenge the separation of real variability from statistical fluctuations. The tendency has been to divide data sets “by eye.” There are quantitative ways to handle this issue:



Jeff Scargle developed the Bayesian Block method of identifying significant changes in data without relying on binning

<https://arxiv.org/abs/1207.5578>



A complementary approach is adaptive binning, developed by Benoit Lott and colleagues

<https://arxiv.org/pdf/1201.4851.pdf>

Fermi-LAT promotion of multiwavelength monitoring

A number of groups across the electromagnetic spectrum have already made monitoring data available for quite a few sources – Examples include OVRO, MOJAVE, Catalina Sky Survey, WEBT/GASP, Tuorla, SMARTS, Swift, Fermi. The Fermi Project and the Fermi-LAT team have been encouraging programs like this. Some of these have been supported by the Fermi Guest Investigator program. For sources that happen to be monitored, data are readily available when interesting events occur.

Links to many of these resources are publicly available at

<https://confluence.slac.stanford.edu/display/GLAMCOG/Fermi+LAT+Multiwavelength+Coordinating+Group>

OR

<https://fermi.gsfc.nasa.gov/ssc/observations/multi/programs.html>

One way the LAT team has encouraged cooperation is to make sure we reference ANY data source, even if the data are public.

Fermi-LAT promotion of multiwavelength monitoring

For blazars, one particularly useful link is the one by Matt Lister that lists which observatories are monitoring which blazars: <http://www.physics.purdue.edu/astro/MOJAVE/blazarlist.html>

This list is updated regularly. Here is a segment of that list, showing the most heavily monitored blazars:

J2000	B1950	Alias	RA (J2000)	Dec (J2000)	#	M J A V E R	O P E R	T A M M E	F - G A M M E	B E A M E R	E F F E L S E R	M A R O R O	O U A V O	M E T S A R O I A	M E D I C I N E Z	P O L A R I M M A A	A S L M A A	T U O L R A D	S T E W A C A I T A	P E R U G R R I S	S M A R T S B	S T P E R E K I N S	P E R I N S
J1256-0547	1253-055	3C 279	12 56 11.167	-05 47 21.525	28	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
J2253+1608	2251+158	3C 454.3	22 53 57.748	+16 08 53.561	28	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
J0238+1636	0235+164	AO 0235+164	02 38 38.930	+16 36 59.275	27	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
J0854+2006	0851+202	OJ 287	08 54 48.875	+20 06 30.641	27	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
J2202+4216	2200+420	BL Lac	22 02 43.291	+42 16 39.980	27	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
J1229+0203	1226+023	3C 273	12 29 06.700	+02 03 08.598	26	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
J1512-0905	1510-089	PKS 1510-089	15 12 50.533	-09 05 59.830	26	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
J0721+7120	0716+714	TXS 0716+714	07 21 53.448	+71 20 36.363	25	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
J1104+3812	1101+384	Mrk 421	11 04 27.314	+38 12 31.799	25	Y	Y		Y	Y	Y	Y	Y		Y		Y	Y	Y	Y		Y	Y
J1221+2813	1219+285	W Comae	12 21 31.691	+28 13 58.500	25	Y			Y		Y	Y	Y	Y	Y		Y	Y	Y	Y		Y	Y

Fermi-LAT AGN Multiwavelength Strategies – Planned Campaigns

Monitoring programs cover only a fraction of the known gamma-ray AGN, and different monitoring efforts cover different sources. An obvious alternative to relying on monitoring is to organize multiwavelength campaigns on specific sources of interest.

Organizing a multiwavelength campaign is a LOT of work, starting with deciding on a source and then finding the resources to make the observations. The LAT team tried a general organizing system:

VIP List of AGNs for Continued Study
Created by David J. Thompson, last modified on Dec 19, 2017

This Very Important Project (VIP) list is intended as part of the LAT legacy program. These are AGN of special interest. The concept is to have someone watch each one closely, encourage multi wavelength studies, and possibly even organize full multi wavelength campaigns. These are ones for which we will make a particular effort to cooperate with anyone doing studies.

Source Common Name	R.A.	Dec.	Class	Monitoring programs	Leaders	Notes/rationale
4C +01.02 (PKS B0106+013)	17.1804	1.579	FSRQ	several	Richard Britto (richardb777 at hotmail.fr)	

This top-down sort of planning did not turn out to be a very useful exercise.

Fermi-LAT AGN Multiwavelength Strategies – Planned Campaigns

The LAT Collaboration experience is that multiwavelength campaigns are largely driven by **individual scientists who have a vested interest in particular sources**. Often this happens because they have access to observing facilities that can provide critical information, because they have some prior experience with these sources, and because these sources have some interesting properties.

An example is work on 4C +01.02, which was listed on the previous slide. This group has time on the South African Large Telescope (SALT), which can do polarimetry. The blazar is a fairly distant one, with $z = 2.1$. It has shown significant gamma-ray variability in the past (<https://www.astronomerstelegam.org/?read=8319>).



Fermi-LAT AGN Multiwavelength Strategies – Planned Campaigns

Table 1: List of participating instruments in the campaign on Mrk 421 during 2010 March.

Instrument/Observatory	Energy range covered
MAGIC	0.08–5.0 TeV
VERITAS	0.2–5.0 TeV
Whipple 10-m	0.4–2.0 TeV
<i>Fermi</i> -LAT	0.1–400 GeV
<i>Swift</i> -BAT	14–195 keV
<i>RXTE</i> -PCA	3–32 keV
<i>Swift</i> -XRT	0.3–10 keV
<i>RXTE</i> -ASM	2–10 keV
<i>MAXI</i>	2–10 keV
<i>Swift</i> -UVOT	UVW1, UVM2, UVW2
Abastumani [†]	R band
Lulin [†]	R band
Roque de los Muchachos (KVA) [†]	R band
St. Petersburg [†]	R band polarization
Sabadell [†]	R band
Goddard Robotic Telescope (GRT)	R band
The Remote Observatory for Variable Object Research (ROVOR)	B, R, V bands
New Mexico Skies (NMS)	R, V bands
Bradford Robotic Telescope (BRT)	B, R, V bands
Perkins	R band polarization
Steward	R band polarization
Crimean	R band polarization
Submillimeter Array (SMA)	225 GHz
Metsähovi Radio Observatory [†]	37 GHz
University of Michigan Radio Astronomy Observatory (UMRAO) [†]	8.0, 14.5 GHz
Owens Valley Radio Observatory (OVRO)	15 GHz

The most extensive multiwavelength campaigns involving gamma rays have been those on Mrk 421 and Mrk 501. This listing of participants in one of those gives an idea of how much effort is involved. Congratulations to David Paneque and other participants for their work on these.

Fermi Observatory Support for Planned Campaigns

The screenshot shows a web browser window with a navigation bar at the top containing links for Home, Support Center, Observations (highlighted), Data, Proposals, Library, HEASARC, and Help. On the left side, there is a sidebar menu under the heading 'Observations' with the following items: Observatory Status, Observing Timeline, Observation Types, Multiwavelength Observations (with sub-links: + Obs Reporting Form, + Obs Report Listing, + Support Programs), Targets-of-Opportunity, and Alternate Observing Strategies. The main content area is titled 'Multiwavelength Observations Reporting' and contains the following text: 'Please provide information on your observations that are relevant to Fermi. The Fermi mission will use these data in planning the Fermi timeline; for example, a requested Target-of-Opportunity observation may be modified or rejected because of an on-going multiwavelength campaign. At the end of the form you can indicate whether information about these observations is proprietary, and should be restricted to the Fermi Project Scientist and deputies. Non-proprietary information reported through this webform can be seen [here](#). All items are required.'

The form includes the following input fields and options:

- Name:
- E-mail:
- Telephone:
- Hide personal info? Yes No
- Object:
- Source Coordinates:
- Observation Start Date: (Format: YYYY-MM-DD)
- Observation Stop Date: (Format: YYYY-MM-DD)
- Wavelength Band:
- Details: (max 800 characters)

The Science Support Center provides information about the observatory in support of multiwavelength campaigns, including a form for observers to tell the project about planned campaigns. That alerts the operations team not to schedule calibrations that would conflict.

Fermi-LAT AGN Multiwavelength Strategies – Planned Campaigns

Contact Information for Individual Sources

Created by David J. Thompson, last modified by C. C. Teddy Cheung on Oct 15, 2020

Please note: **This is a public page (for multifrequency purposes).**

List of Contacts for Individual Sources

LAT Monitored Source List Light Curves are available for most of these sources

FSSC Aperture photometry lightcurves for 2FGL sources

FSSC Aperture photometry lightcurves for 3FGL sources

Fermi-LAT Weekly Sky blog and Daily Sky blog (interrupted).

For reference, see all Astronomer's Telegrams from the Fermi-LAT collaboration and the interactive list of sources in Fermi LAT ATels.

Extragalactic sources

Extragalactic sources from ATels, in order of (the First) ATel number, starting with earliest

Source Name(s)	Friend(s) of the Source	ATEL number(s)
3C 454.3	Greg Madejski (madejski at stanford.edu), Benoit Lott (lott at cenbg.in2p3.fr), formerly also Gino Tosti (tosti at pg.infn.it)	1628, 2200, 2328, 2534, 3041 (Erratum: 3064), 6236, 9190
PKS 1502+106 (OR 103)	Stefano Ciprini (stefano.ciprini at asdc.asi.it)	1650, 1905, 7592 , 7801

<https://confluence.slac.stanford.edu/display/GLAMCOG/Contact+Information+for+Individual+Sources>

Is a list of LAT team members who would be contact persons for multiwavelength campaigns on particular sources. These are AGN that have been bright enough to have warranted a LAT Astronomer's Telegram.

Fermi-LAT AGN Multiwavelength Strategies – Rapid Responses

Particularly for an instrument like the Fermi LAT, which views the entire sky regularly, alerting the multiwavelength community to interesting activity in the gamma-ray sky is critical to making best use of our data. We use a variety of ways to report AGN activity.

```
////////////////////////////////////
TITLE:          GCN/FERMI NOTICE
NOTICE_DATE:    Wed 15 Mar 17 15:21:35 UT
NOTICE_TYPE:    Fermi-LAT Monitor
SOURCE_OBJ:     3C279_86400.png
REF_NUM:        1489591295
RA:             194.047d {+12h 56m 11s} (J2000),
               194.270d {+12h 57m 05s} (current),
               193.400d {+12h 53m 36s} (1950)
DEC:            -5.789d {-05d 47' 19"} (J2000),
               -5.882d {-05d 52' 53"} (current),
               -5.518d {-05d 31' 05"} (1950)
CURR_FLUX:      2.90e-06 +- 1.30e-07 [ph/cm2/sec]
BASE_FLUX:      1.10e-06 +- 1.39e-07 [ph/cm2/sec]
SIGNIFICANCE:   9.19 [sigma]
TIME_SCALE:     0 {0=1day, 1=1week}
ENERGY_BAND:    0.1 - 300.0 [GeV]
OUTBURST_DATE:  17826 TJD; 73 DOY; 17/03/14 (yy/mm/dd)
OUTBURST_TIME:  43200.00 SOD {12:00:00.00} UT
SOLN_STATUS:    0x0
LC_URL:         http://fermi.gsfc.nasa.gov/FTP/glast/data/lat/catalogs/asp/current/lightcurves/3C279_86400.png
SUN_POSTN:      355.63d {+23h 42m 30s} -1.89d {-01d 53' 35"}
SUN_DIST:       159.82 [deg] Sun_angle= 10.8 [hr] (West of Sun)
MOON_POSTN:     209.53d {+13h 58m 08s} -7.33d {-07d 20' 01"}
MOON_DIST:      15.23 [deg]
MOON_ILLUM:     91 [%]
GAL_COORDS:     305.11, 57.06 [deg] galactic lon,lat of the burst (or transient)
ECL_COORDS:     195.17, 0.20 [deg] ecliptic lon,lat of the burst (or transient)
COMMENTS:       Fermi-LAT Monitor flare alert.
COMMENTS:       This Notice was ground-generated -- not flight-generated.
COMMENTS:
```

https://gcn.gsfc.nasa.gov/fermi_lat_mon_trans.html

GCN Notices

Gamma-ray Coordinates Network (GCN) Notices for Fermi-LAT AGN flares are generated automatically by software running on the Automated Science Processing data stream, based on an increase in the daily flux compared to two weeks' previous flux values.

Rapid Responses – the Fermi-LAT Flare Advocate Program

Flare Advocates are volunteer members of the LAT Collaboration who take one-week shifts, running a set of analysis scripts (written primarily by Denis Bastieri and Sara Buson) on the LAT data daily. The resulting report about all bright sources seen on 6-hour or daily time scales is then sent to the full team of Flare Advocates.

Fermi-LAT detection of gamma-ray flaring activity from the BL Lac GB6 J1058+2817

ATel #14491; *R. Angioni (SSDC/INFN) on behalf of the Fermi Large Area Telescope Collaboration*
on 29 Mar 2021; 17:56 UT
Credentia Certification: Roberto Angioni (r.angioni90@gmail.com)

Subjects: Gamma Ray, >GeV, Request for Observations, AGN, Blazar

Referred to by ATel #: [14496](#), [14506](#), [14511](#)

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The Large Area Telescope (LAT), one of the two instruments on the Fermi Gamma-ray Space Telescope, has observed gamma-ray flaring activity from a source positionally consistent with the BL Lac GB6 J1058+2817, also known as 4FGL J1058.6+2817 (The Fermi-LAT collaboration 2020, ApJS, 247, 33), with coordinates R.A. = 164.624562 deg, Decl. = 28.296170 deg (J2000; Petrov & Taylor 2011 AJ, 142, 89), and a tentative redshift $z=0.4793$ (Massaro et al. 2014 AJ, 148, 66).


Preliminary analysis indicates that this source was in an elevated gamma-ray emission state on 28 March 2021, with a daily averaged gamma-ray flux ($E>100\text{MeV}$) of $(3.3\pm 1.1) \times 10^{-7}$ photons $\text{cm}^{-2} \text{s}^{-1}$ (statistical uncertainty only). This corresponds to a flux increase of a factor of 45 relative to the average flux reported in the second data release of the fourth Fermi-LAT catalog (4FGL-DR2; Ballet et al., arXiv:2005.11208). This is the highest LAT daily flux ever observed for this source. The corresponding photon index is 1.8 ± 0.2 , and is significantly smaller than the 4FGL-DR2 value of 2.23 ± 0.07 . This hard-spectrum state was accompanied by the detection of two $E>10$ GeV photons with a probability $>99\%$ of having been emitted by the target source. The highest-energy photon was observed on the same day at 21:53:15.827 UTC, with an energy of ~ 14 GeV.

Because Fermi normally operates in an all-sky scanning mode, regular gamma-ray monitoring of this source will continue. We encourage multifrequency observations of this source. For this source






Flare Advocates prepare Astronomer's Telegrams for flaring sources. The Flare Advocate typically becomes the “friend of the source” who would follow up on any multiwavelength campaign.



Rapid Responses – the Fermi-LAT Flare Advocate Program

The Flare Advocate reports include approximate spectra and lists of gamma rays with energies above 10 GeV whose arrival directions are consistent with locations of known sources. If a spectrum is hard enough or if there are enough gamma rays from a source of possible interest, we can send an e-mail to the TeV facilities with whom the LAT team has Memoranda of Understanding (MOUs). Here is a sample of a recent message.

From: Dave Thompson  ↩ Reply ↩ Reply All → Forward 🗳 Archive 🗑 Junk 🗑 Delete More

Subject: **BL Lac high-energy events from Fermi LAT** 3/23/21, 10:27

To: Michelle Hui , Rene Ong <rene@astro.UCLA.EDU> , Massimo Persic <persic@oats.inaf.it> , S.Wagner@LSW.uni-heidelberg.de , Peter F. Michelson <peterm@stanford.edu>  **27 more**

Cc: Roberto Angioni , sara.buson@gmail.com 

TeV Colleagues,

BL Lac continues to show impressive activity. Roberto Angioni, the current Fermi-LAT Flare advocate reports this information about high-energy events (including two above 100 GeV) and the flux above 100 MeV:

	0.6'	638109901	339.13
	1.4'	638086702	258.36
	1.5'	638110001	25.71
2FHL J2202.7+4216 blL BL Lacertae	2.5'	638086034	12.95
	2.8'	638086110	12.40
	4.2'	638098919	34.30
	5.5'	638131875	11.91
	6.8'	638075714	23.53

Extragalactic Science

- BL Lacertae (TS=826) flux = $(2.3 \pm 0.2) \times 10^{-6}$, detected also in 18614 @TS=334, 18615 @TS=244, 18616 @TS=101, 18613 @TS=84

Rapid Responses – the gammamw mailing list

Another method of distributing information is the gammamw mailing list. This is a moderated mailing list limited to any persons interested in gamma-ray multiwavelength studies. Messages are archived. <https://lists.nasa.gov/mailman/listinfo/gammamw>

Multiwavelength Colleagues,

Information that might be of interest. You may receive a second copy.
My apologies if you do.

Gammamw mailing list

Dave Thompson

----- Forwarded Message -----

Subject: FGAMMA legacy program and polarisation conference
Date: Tue, 14 Mar 2017 09:03:36 +0100
From: Emmanouil Angelakis <eangelakis@mpifr-bonn.mpg.de>
To: David J. Thompson <David.J.Thompson@nasa.gov>
CC: Emmanouil Angelakis <eangelakis@mpifr-bonn.mpg.de>

I am writing to kindly inform you of the "F-GAMMA legacy dataset? which is available at or new page

<http://www3.mpifr-bonn.mpg.de/div/vlbi/fgamma/fgamma.html>

This mailing list seemed like a good idea, but it has not been extensively used.

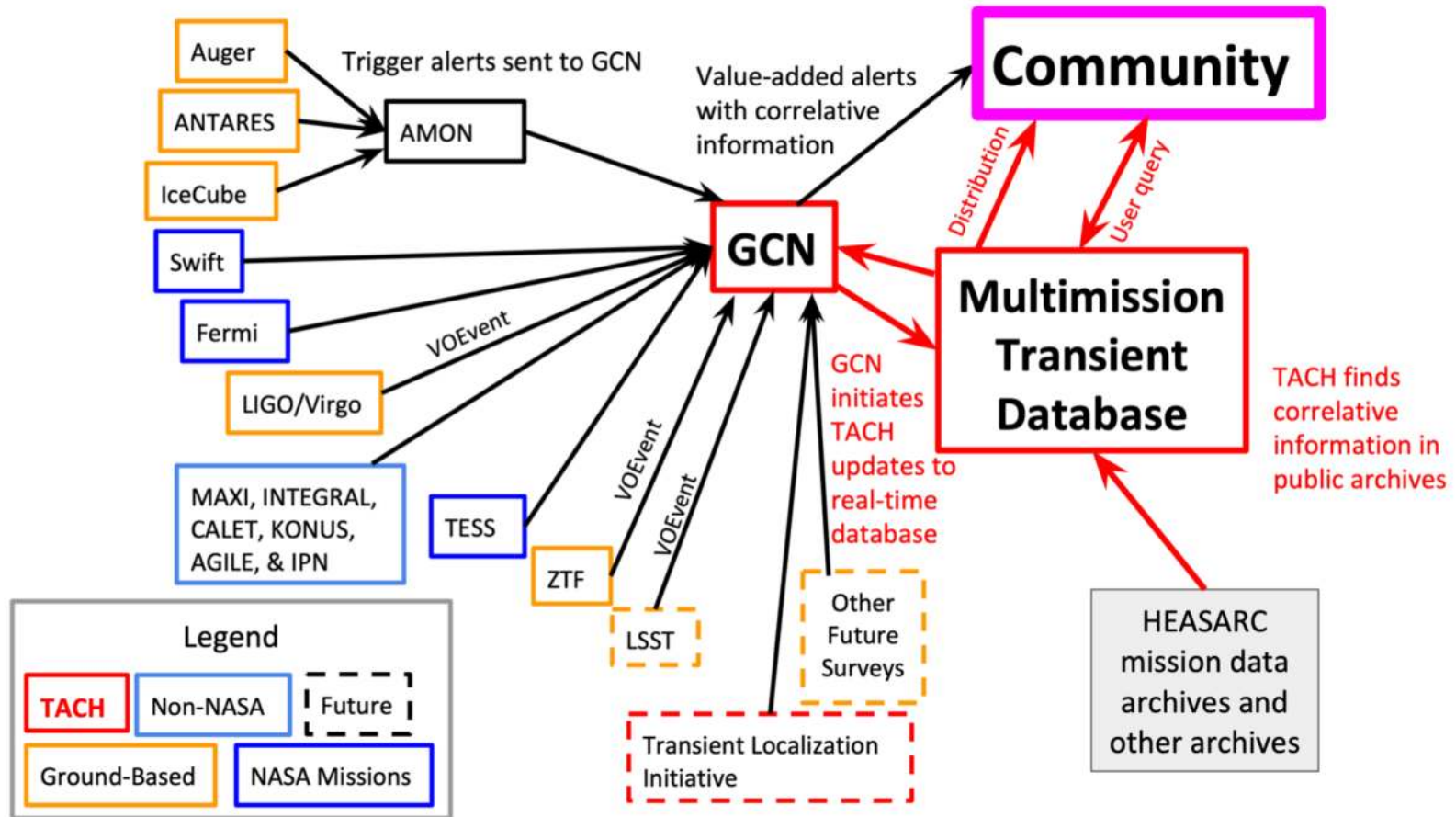
Rapid Responses – the future

With the emergence of observatories like the Zwicky Transient Facility and the Vera Rubin Observatory (LSST), which can generate vast numbers of transient notices, new systems of data sharing have become essential. Brokers are needed to manage the data streams (see <https://www.lsst.org/scientists/alert-brokers> for information) and distribute information. Merging those with existing systems is a challenge.

Although we often think of transients as primarily dealing with gamma-ray bursts, we know that GCN is already being used to distribute information about AGN flares and neutrino alerts. Two data management systems that are under development are outlined on the following slides, courtesy of Judy Racusin.

Time-domain Astronomy Coordination Hub (TACH)

TACH Interfaces



SCiMMA: Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics

- Developing cyberinfrastructure for the astronomy community
- Includes:
 - Infrastructure for astronomy alerts, influenced by Kafka usage by large ground-based optical surveys (ZTF, VRO)
 - Common IAM platform using federated identities (InCommon, CILogon), universities and other institutions act as IdPs
 - Alerts and IAM are not yet integrated, but may be in the future
- National Science Foundation funded project



The TACH and SCiMMA groups are working to develop compatibility.

How the Pieces Fit Together – An Example

The story started with the GCN Circular shown below, announcing a high-energy neutrino event seen by the IceCube observatory.

```
////////////////////////////////////  
TITLE:   GCN CIRCULAR  
NUMBER:  21916  
SUBJECT: IceCube-170922A - IceCube observation of a high-energy neutrino candidate event  
DATE:    17/09/23 01:09:26 GMT  
FROM:    Erik Blaufuss at U. Maryland/IceCube <blaufuss@icecube.umd.edu>
```

Claudio Kopper (University of Alberta) and Erik Blaufuss (University of Maryland) report on behalf of the IceCube Collaboration (<http://icecube.wisc.edu/>).

On 22 Sep, 2017 IceCube detected a track-like, very-high-energy event with a high probability of being of astrophysical origin. The event was identified by the Extremely High Energy (EHE) track event selection. The IceCube detector was in a normal operating state. EHE events typically have a neutrino interaction vertex that is outside the detector, produce a muon that traverses the detector volume, and have a high light level (a proxy for energy).

After the initial automated alert (https://gcn.gsfc.nasa.gov/notices_amon/50579430_130033.amon), more sophisticated reconstruction algorithms have been applied offline, with the direction refined to:

```
Date: 22 Sep, 2017  
Time: 20:54:30.43 UTC  
RA: 77.43 deg (-0.80 deg/+1.30 deg 90% PSF containment) J2000  
Dec: 5.72 deg (-0.40 deg/+0.70 deg 90% PSF containment) J2000
```

How the Pieces Fit Together – An Example

A few days later, I was in Amsterdam attending a meeting about transients, when we received this message from Yasuyuki Tanaka:

On 9/27/17 5:10 PM, Yasuyuki Tanaka wrote:

Dear Dave, FA people,

We (Kanata team) followed-up the IceCube-170922 error circle. We found that QSO 0509 is showing brightening in optical/IR. The source is also listed in 3FGL as 3FGL J0509.4+0541.

Interestingly, we found that QSO 0506 is also showing brightening in GeV band and indeed picked up by FAVA in recent months. Please see attached file (FAVA light curve).

The situation looks quite similar to the Kadler's paper.

Should we submit an ATel and mention the GeV brightening of QSO 0509?

In addition, it may be better to inform TeV people about this brightening and request long exposure, given that LAT spectrum is relatively hard (PL index of 2.0).

Elements

Catalog

FAVA

Atel

E-mail

How the Pieces Fit Together – An Example

The next steps: The Flare Advocates worked on the ATel, I sent an e-mail to the TeV community, and I talked to people at the meeting.

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Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.

ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration on 28 Sep 2017; 10:10 UT*
Credential Certification: David J. Thompson (David.J.Thompson@nasa.gov)

Subjects: Gamma Ray, Neutrinos, AGN

Referred to by ATel #: 10792, 10794, 10799, 10801, 10817, 10830, 10831, 10833, 10838, 10840, 10844, 10845, 10861, 10890, 10942, 11419, 11430, 11489, 12260

[Tweet](#)

We searched for Fermi-LAT sources inside the extremely high-energy (EHE) IceCube-170922A neutrino event error region (<https://gcn.gsfc.nasa.gov/gcn3/21916.gcn3>, see also ATels 10773, 10787) with all-sky survey data from the Large Area Telescope (LAT), on board the Fermi Gamma-ray Space Telescope. We found that one Fermi-LAT source, TXS 0506+056 (3FGL J0509.4+0541 and also included in the 3FHL catalog, Ajello et al., arXiv:1702.00664, as 3FHL J0509.4+0542), is located inside the IceCube error region. The FAVA (Fermi All-sky Variability Analysis) light curve at energies above 800 MeV shows a flaring state recently (<https://fermi.gsfc.nasa.gov/ssc/data/access/lat/FAVA/SourceReport.php?week=477&flare=27>). Indeed, the LAT 0.1--300 GeV flux during 2018 September 15 to 27 was $(3.6 \pm 0.5)E^{-7}$ photons $\text{cm}^{-2} \text{s}^{-1}$ (errors are statistical only), increased by a factor of ~ 6 compared to the 3FGL flux, with nearly the same power-law index of 2.0 ± 0.1 . We strongly encourage multiwavelength observations of this source. We also encourage optical spectroscopy for this source, because the redshift is still unknown. According to NED, the R-band magnitude is reported as 15.1 (Healey et al. 2008, ApJS 175, 97). Radio observations show that this blazar has had increasing flux during the past year: http://www.astro.caltech.edu/ovroblazars/data.php?page=data_query, <http://www.physics.purdue.edu/astro/MOJAVE/sourcepages/0506+056.shtml>.

Related

- 12274 Search for neutrinos from TXS 0506+056 with the ANTARES neutrino telescope
- 12267 IceCube search for neutrinos from TXS 0506+056 between November 28, 2018 and December 4, 2018
- 12260 MAGIC detects enhanced flux of VHE gamma rays from TXS 0506+056
- 11850 MASTER: IceCube 171106A follow up observations
- 11489 Optical and near-infrared polarimetric observations of the IceCube-170922A counterpart candidate TXS 0506+056
- 11430 Optical polarimetry of TXS 0506+056 (possible counterpart of IceCube-170922A)
- 11419 Fermi-LAT detection of enhanced gamma-ray activity and hard spectrum of TXS 0506+056, located inside the IceCube-170922A error region
- 10942 IceCube-171106A: Swift observations
- 10890 Subaru/FOCAS Optical Spectroscopy for a possible IceCube-170922A counterpart TXS 0506+056
- 10861 VLA Radio Observations of the blazar TXS 0506+056 associated with the IceCube-170922A neutrino event
- 10845 Joint Swift XRT and NuSTAR Observations of TXS 0506+056
- 10844 Kanata optical imaging and polarimetric follow-ups for possible IceCube counterpart TXS 0506+056
- 10840 VLTX-Shooter spectrum of the blazar TXS 0506+056 (located inside the IceCube-170922A error box)

By this time, we already knew that this blazar had brightened in the optical and radio bands as well as in the Fermi-LAT energy range.

How the Pieces Fit Together – An Example

Encouraged by Anna Franckowiak, I contacted the IceCube Collaboration to suggest a joint paper (Fermi-LAT does have an MOU with Ice Cube).

On 9/30/17 6:56 PM, Anna Franckowiak wrote:

Hi everyone,

I think it could be beneficial to bring the Fermi-LAT and IceCube team together for this. This way we could get the IceCube sensitivities *and* gamma-ray flare probability right. We'll have the IceCube collaboration meeting in Berlin next week. Let me know if you think that's a good idea - I'd be happy to support it at the meeting next week.

Best,
Anna

Dear Darren, Dawn, and Erik,

Anna Franckowiak, who is a member of both the Fermi LAT and IceCube collaborations, has suggested that the recent finding of a flaring gamma-ray blazar in the error region of a high-energy IceCube event might be an opportunity for the two teams to collaborate. On behalf of the LAT team (with Peter Michelson, the LAT PI, copied), I would invite the IceCube team to consider such an effort. Alternatively, if the IceCube team prefers to work separately, we could consider sharing information to coordinate our efforts.

I wish you success at your meeting this week,

Dave Thompson, Fermi LAT Multiwavelength/Multimessenger Coordinator

Meanwhile, the MAGIC team was making TeV observations and obtained a detection of this blazar.

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First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; *Razmik Mirzoyan for the MAGIC Collaboration*
on 4 Oct 2017; 17:17 UT

Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942, 12260

[Tweet](#)

After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794, #10799, #10801, GCN: #21941, #21930, #21924, #21923, #21917, #21916. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) E. Bernardini (elisa.bernardini@desy.de), K.Satalecka (konstancja.satalecka@desy.de). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatorio Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

How the Pieces Fit Together – An Example

The outcome was a multimessenger paper in *Science*, a U.S. National Science Foundation press conference, and extensive press coverage.

RESEARCH ARTICLE

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A

The IceCube Collaboration, *Fermi*-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S., INTEGRAL...

[+ See all authors and affiliations](#)

Science: 13 Jul 2018:
Vol. 361, Issue 6398, eaat1378
DOI: 10.1126/science.aat1378



Science

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13 July 2018

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Considering that this was essentially a 3 sigma result, its impact was significant primarily because all these groups cooperated.

Summary

The Fermi Large Area Telescope AGN multiwavelength experience has been focused on public sharing of information that could assist any type of multiwavelength/multimessenger research.

This information has included a variety of AGN monitoring information, links to resources at other wavelengths, and rapid sharing of AGN activity.

Although not all the LAT methods have been successful and there is always room for improvement, multiwavelength AGN research seems to have been successful in the Fermi era.

The Fermi-LAT Collaboration looks forward to continued cooperative efforts in the CTA era.