

# More notes from the Workshop

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## Part 1 - Notes from the meeting

### Sparse notes from TOPIC 1 - BLAZAR VARIABILITY

Malaga 2016 MW conference [jets2016.iaa.es](http://jets2016.iaa.es)

One of the best example are Jorstad et al. with BL Lac, GASP large database of radio-optical flux data on BL Lac (other example NRAO 530/PKS 1730-13), emission lines blazar PKS 1510-08, 3C 454.3, 3C 279 (optical magnitude more bright after the ejection of a huge bright superluminal radio components)

Svetlana J.: 1. theoreticians have to pay attention to these behaviors. 2. what theoreticians want from MW campaigns/observations? 3. there are needs to justifications in maintain VLBI monitor for example.

Radio flux monitors: Metsahovi, OVRO, Effelsberg FGAMMA, some more global collaborations.

Alan M.: CTA 102, Coppi's talk in Krakow (UV flashes, emission lines, variability. ...).

What else do we need ? Alan M.'s inputs: MOJAVE 37 sources, we want more VLBI images, newly interesting blazars?, wavelength-dependent optical polarization, test turbulence and magnetic reconnection models, better X-ray, UV, IR coverage, more Swift data, Astrosat?, ground-based IR telescopes ?, monitor emission line profiles (central line part, orbital motion etc.), follow-up studies like Isler et al, Leon-Tavarez et al...

RoboPol new interesting facility, good weather implies many observations but observing time very busy for this telescope,

MW observations need a lot of man power!

No still broad and systematic variability analysis and statistical patterns studies in the bands, radio, X-ray etc... i.e. for complete sets and samples of AGN /blazars.

PDS affected by variable bin sizes among different sources. A lot of stochastic processes/noise going on, need to asset systematics,

Example: for 1 single source too what is the relation between the flare length and size with the energy band ? Timescale of variability in function of the energy band ? Any universal properties of flares ?

Stefan W.: cover some timescale for some objects, effort in systematic monitor, problem in correlate events (we correlate some timescales and we miss other scales).

Manpower problem to: 1.obtain data, 2.analyze them, 3.do analysis, 4.write paper, 5.then release data to the community.

Matt L.: sharing data problem. Chicago conference years ago. Problem to schedule the share of the data. Matt's web table regularly updated (trying to).

Dave T.: please send information to Matt L. (MW observations, sources, etc.). Also use and fill confluence LAT MW coordinating page. Text automatically generated would be nice.

Stefano C.: eRosita MoU with Fermi ? (unid. sources, blazar association, population studies, etc.). What we have learned from the observation (for the first time) of low gamma-ray states (for example in 3C 454.3, in PKS 1510-08, ...)? . GAIA mission (some strips of the sky scanned also 70 times i.e. multi-epoch data) and possible studies of the photocenter shift localization of the optical emission zone during gamma-ray flares (origin of gamma-ray emission and the blazar zone emission production). Only for bright optical blazars (mag < 17 ?) anyway.

### Sparse notes from TOPIC 2 - AGN DEMOGRAPHY

Matt L.talk: 1 SED (nu peak, synch/IC peaks, Compton dominance, SED dependence on optical class? jet kinetic power? other props?); 2 Luminosity functions (beamed vs unbeamed, dependence on optical class) ; 3 Nature of unidentified sources (how many are the blazars? can we predict their SEDs at low energies based on Fermi SEDs?); 4. fundamental properties of blazars ? which are the most useful classifications ? (SED peaks, luminosity, frequency, jet Lorentz factor/Doppler factor, BLR/no-BLR ?).

There are some biases. Several year to try to arrive at a sort of HR stellar diagram (mass/luminosity parameter that determines the position and fate of a star) for blazars (blazar sequence). But biases and too much parameters for blazar physics tat is not mono-parameter. Blazar classification system quite complicated.

Justin F.: we have a lot of population and luminosity functions in the radio, optical and now in Fermi (Ajello etc.). How we connect different luminosity functions extracted from the radio, from the X-ray from the gamma-ray ?

Benoit L.: BL Lac objects show some correlations in terms of blazar sequence-like (biased) schemes but not the FSRQs. FSRQ are almost all low-energy peaked so the lack of correlation even if there is very broad luminosity range the range of peak frequencies is narrow.

Small number of misaligned AGN (radiogalaxies) detected by the LAT. This is a problem for population studies.

Difference in EGRET and Fermi LAT blazars (even if Fermi LAT has detected the brightest EGRET blazars).

Problem of the peak determination arise by the lack of mid/far-IR data. For IC peak we need hard-X and MeV data (lack again).

We might monitor the change of the IC Compton peak even in the most 5 famous blazars. Bright flares show small changes in LAT gamma-ray photon index! Studying these changes during flares with also MW data because there is always the problem we have not so much observations to monitor the synchrotron peak changes. We have not done it for much sources ( except maybe Mkn 421, Mkn 501, PKS 2155-304).

PKS 2155-304: surprises! Opposite behavior to that one expected. TeV correlates with optical. GeV LAT correlates with X-rays!

Archival SED data of low quality or anyway not simultaneous data. Problem and bias for the SED sequence paradigm.

We had some joint campaigns with the Fermi LAT and TeV Cherenkov telescopes, but we need the synchrotron monitor at the same time.

Question: how can more Fermi observation time contribute to the several open questions in blazar topic? (+ fraction of flaring sources, + better error circles, + better variability characterization, + better determination IC SED peak, + cases of flaring/non-flaring states comparisons, + long-term variations, + energy index vs IC peak variability, ...).

What are the key MW observations we need?

IR and sub-mm coverage, targeted coverage of Fermi error circles of unidentified sources; simultaneous coverage to look correlated variability in unidentified sources, more campaigns on the famous blazars (like PKS 2155-304?); multi-epoch spectroscopy (can we detect masquerading BL Lac?, how variable is the BLR emission? relation BLR emission line vs gamma-ray flux/hardness).

Several ATels on hard-GeV flares recently thanks to the new Pass 8 LAT data. More releases from the Flare Advocate service and quicklook sky watching.

Open questions: best ways to find TeV AGN in  $0.5 < z < 1$  ? We have the 2FHL catalog! Other thoughts?

Benoit L: More ways to associate sources ? Please propose potential new further schemes.

Determine the distribution and range of nu-synch-peak for all blazars down to some limiting flux nu-peak\*f-peak? How increase the number of known ISP BL Lacs? Broadband blazar surveys ? Create a way to release and publish and distribute the MW data where one is working ?

### **Sparse notes from TOPIC 3 - SED MODELING**

Alerts, emails etc. would be fine for flares and transients.

Discussion on how fast we can have alert from the LAT (possibly with still low case of false-positives!) . Efforts to go below 1 day (12 hours possible?). Anyway data are on the FSSC server asap they are available and users can run their own quicklook/prompt analysis (some cases Pacciani, other).

How we can distinguish leptonic models from hadronic models ? Hadronic processes require much power in the jet.

Blazar sequence again: Fossati 1998, Meyer 2011, etc.

Models: Alan M.'s mix of turbulence and reconnection. Model of decelerating jet. Models of spine/sheath emission regions.

Can SED modeling constraint the location of the emission region?

### **Sparse notes from TOPIC 4 - OBSERVING STRATEGY**

Stefan W. talk: Few sources very well OR many good as possibly ? Both? Smart cadence ? Coordination. If few, which one ?

Critical parameters (span luminosity range (z) ?, span Doppler factors ? Span thermal photon field ?, Span IC peaks ? Span gamma-min ?

Many may be sparse, how often ? What kind of data we want ? Be aware of biases.

How narrow band (e.g. MW photometry, MW polarimetry). Have we learned anything from color indexes in the optical regime? Have we learned something from multicolor polarimetry ? We do mix of things. Can we agree on must to do ? Flares any ? Specific sources ? Flux levels ?

Communication Matt Lister's page. Other forums ?

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## **Part 2 - Summary of the pre-workshop questionnaire**

(tentative summary) Participants: Smith, Ojha, Santander, Thompson, Saam, Su, Coppi, Shrader, Bangale, Dorner, Finke, Angelakis, Ciprini, Jorstad, Kar, Lott, Kong, Krauß, Mueller, Lister, Cameron, Marscher, Kargaltsev.

### **A Number of MW Campaigns Have Been Performed. What has been missed?**

MeV  $\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$  Fermi data analysis in the 20(30) - 100 MeV range to see replication and further definition of spectral peak exhibited by EGRET. radio and optical polarisation could be emphasised  
IR and hard X-ray observations are missed in the majority of campaigns

Both in TeV but in GeV sources, there haven't sufficient strictly simultaneous observations on the SHORTEST variability timescales. In VHE emitters, this can mean timescales as short as 5 min. We've been looking into the brightest Fermi flares, where we have best statistics, and that means looking on half-hour timescales, ideally in pointed mode, -- and doing so continuously for the duration of the flares, e.g., several days. Such dedicated observations are painful for many observatories (e.g., SMARTS) and so haven't happened a lot. Such observations go right to the heart of the underlying acceleration mechanisms. So far (but this is not a robust statement), while there can be good correlations between gamma and optical and --day timescales, such correlations do NOT seem to exist on the short timescales. This is quite puzzling because in some models for FSRQ, the optical-NIR samples even higher energies than Fermi GeV. It could be that there are in fact short timescale correlations, but that optical fluctuation amplitude are much lower, e.g., at ~10% level seen in PKS 2155 due to dilution from some steadier source. This is fine, but besides invalidating most detailed SED fits in the literature, it means in one-zone language that the Compton dominance is much higher than one might expect (which can be a problem). If the optical flares were to be diluted on short timescales then one still has to explain why they don't seem to be diluted on ~day timescales. Anyways, what we're hoping for is when some big flare happens that Fermi can actually get good statistics on (like 3C454.3), then everyone will pound on it around the clock to nail what down what exactly is going on.

I leave it to the campaigns leaders to comment.

Rapid cadence (continuous) optical monitoring of blazars undergoing large gamma-ray outbursts, especially in optical polarization. This is a difficult problem given the relatively few number of groups involved in polarization monitoring. However, a key to understanding the region(s) giving rise to the flux outbursts is the magnetic field structure. Rapid cadence and high-quality polarization and flux measurements over extended periods of time during an outburst (requiring coordinated observation sites scattered across the globe) may help break some model degeneracies that are impossible to avoid with spotty coverage. e.g., it is important in source modeling to be able to properly assess if the changes observed in polarization position angle are in the same direction, or are more chaotic by reversing the sense of the PA rotation during an outburst. The behavior of the polarization PA is extremely important in determining the structure of the shocked regions within the jet and good temporal coverage is essential.

Stefano C: -- a) Long term high-energy data (rare in X-ray/gamma-ray energy bands except the Fermi LAT) vs low-energy data (radio/optical monitoring programs mainly) and cross correlation analysis are needed. For example at X rays only short-intensive campaigns or not-sufficient sensitivity long-term monitor (RXTE, BAT, MAXI) exists. e-ROSITA is coming (but data not public in the first years). This is not sufficient. -- b) An increased number of sources (AGN/Blazar and Galactic sources) monitored is needed at other wavelengths following the Fermi LAT monitor. -- c) Long-term temporal scales are important because they probe the large sizes and large dynamical scales/times of SMBH, discs and jets of AGN (galaxy-sized). -- d) Long-term temporal scales can be important because controversial/proposed periodicity scales for AGN radio-optical light curves ranges about 1 year to 25 years. -- e) Radio /optical polarization data still not sufficient. Important diagnostic for cross correlations with multifrequency and Fermi LAT data. -- f) Multi-messenger astro-particle physics still in the preliminary phase in these years (but a lot of high impact papers already with IceCube PeV neutrino data cross correlations with LAT gamma-ray data). Prolonged Fermi LAT mission in the next decade can allow to cross correlated with neutrino, gravitational-wave and PeV cosmic rays data collected by the incoming next facilities. No clear if multi-messenger astro-particle physics can develop in the future without the continuous all-sky survey and monitor of Fermi LAT. CTA will be not sufficient because it is mainly a pointing (not survey/monitor) facility with small FOV.

#### What sources and data should the community focus on?

1) as many sources as possible and as intense as possible 2) from radio to VHE

Wavelength gaps in AGN spectral coverage - difficulties in measuring synchrotron peak and inverse-Compton peak locations in  $\nu F_{\nu}$  vs  $\nu$  diagrams. As many as sources in as many wavebands as possible to avoid bias :) Problems include: getting the instrument time in all bands, for many instruments the data remains proprietary (e.g. optical)

Sources that are typically bright enough in gamma-rays for the LAT to make good-quality flux measurements over periods of <1 day to a few days should be emphasized. Over the first 7 years of Fermi's mission, most ground-based monitoring programs have tried to maximize their sample size given available observing resources. It may be time to collapse source samples to better follow rapid high-energy (GeV-TeV) developments. The above comments are directed largely at optical/IR programs. I believe that the radio monitoring programs now in place to support Fermi are fine as they currently stand given the observed variability properties of blazars. Facilities like the VLBA and OVRO are beautifully sampling the light curves and radio structure of a large number of blazars and these programs should continue for at least as long as Fermi is active. Possible targets to concentrate on are: 3C454.3, 3C279, BL Lac, PKS1222+216, PKS1510-08, B3 1633+382, Mrk421, and Mrk501 (mostly in conjunction with the TeV facilities).

Blazars with repeated, bright gamma-ray outbursts to look for repeated patterns.

An in-depth study of sources transitioning from FRSQs to BLLacs or vice-versa could shed light on that dichotomy. How do these transitions manifest themselves in the gamma-ray band, in particular regarding the spectral shape? Similarly, monitoring sources with significant changes in the gamma-ray spectral index with time has a strong potential for a better understanding of what drives the SED shape.

Stefano C: -- a) Unassociated sources. Even if here there is a reasonable expectation for future association with AGN/blazars, pulsars and known sources there is the need for much more multi-frequency observations and data (radio-optical-X-rays) to associate these source. There is also a non-negligible chance to discover new GeV gamma-ray source classes here. The statistics and prolonged all-sky survey in the next years is able to better constrain source localization, that is an important goal toward the association/identification. -- b) Dwarf galaxies. For indirect DM signal search, also MW data are important. With additional 10 years (i.e. a 20-year mission) of Fermi mission, the all-sky LAT survey and the Pass 8 data might results in a factor 2-4 increase in sensitivity with respect to the current state after 7 years of mission. In parallel in the next 10 years the expected number of Dwarf galaxy targets discovered might double to 50-70, adding another 2-3 factor in cumulated statistics. The DM indirect signal limits/discovery space probed could benefit therefore of a factor 4-10 more in the next 10 years thanks to the Fermi LAT. -- c) Gravitationally lensed gamma-ray AGN/blazars (i.e. PKS 1830-211, S3 0218+35, GB 1310+48, etc.) -- d) Possible oscillating periodic/quasi-periodic/pseudo-periodic/binary AGN/blazars (i.e. PG 1553+113, OJ 287, PKS 2155-304, S5 0716+71, etc.). -- e) FSRQ, BL Lac objects, HMB, microquasars. -- f) MW observations of LAT unassociated sources and error circle fields. -- g) Possible idea to propose for the Swift-extended mission a dedicated and priority program and service for Fermi follow-up observations of flares, transient and sky fields of the unassociated LAT sources. Fermi-Swift synergy already demonstrated and Swift gained points in its evaluation also because is an optimal follow-up mission for Fermi LAT.

#### Data Have Revealed Features that Deserve Confirmation/Deeper Investigation. What are these features?

Some interesting features have been seen in 3C454.3: - occurrence of a plateau preceding the brightest flare; - repetition of flare timing patterns in different outbursts; - clustering of  $E > 10$  GeV photon arrival times at the falling edge of the flare. I don't think that indications for similar features in other sources have been systematically looked for.

Apparent associations of rotations of optical polarization rotations with gamma-ray flares

Systematic rotations in the optical polarization position angle and their possible connections to gamma-ray behavior.

Stefano C: -- a) Gravitationally lensed gamma-ray AGN/blazars. -- b) Possible oscillating periodic/quasi-periodic/pseudo-periodic/binary or AGN/blazars. -- c) Spectral features in gamma-ray blazars. -- d) Better constrain of the high energy SED component and temporal evolution useful for theoretical blazar emission modeling. -- e) Possible gamma-ray blazars with physics of complexity/intermittence/turbulence (disk-jet physics) features in lighth curves. -- f) DM indirect signal search in Dwarf galaxies. -- g) Are Globular Clusters of our Galaxy (i.e. roughly old mini-dwarf "galaxies") also useful for cumulated DM signal Fermi LAT searches ? -- h) Gamma-ray AGN/blazars as useful cosmic probes (EBL, EGB, etc.) and possible new-physics laboratories. -- i) Search for more Novae, cataclysmic stars, bursting stars in the past 7 years to be cross correlated with LAT data.

#### Which sources present these features?

3C 454.3, PKS 1830-211, S3 0218+35, GB 1310+48, PG 1553+113, OJ 287, PKS 2155-304, S5 0716+71, S5 0836+71, PKS 1510-089, 3C 279, CTA 102, 0954+658, NGC 1275, Cen A, AO 0235+164, 3C 273, M 87, OG 50, CTA 102, Ton 599, BL Lac, PKS 1424+240, 4C +21.35, 1ES 1959+650, NRAO 530, PKS 0537-286, and others

### What bands reveal these features?

Currently, only optical and radio since the measurement of polarization at high energies is not yet possible.

The gamma-ray band essentially, although KANATA in the optical band showed that a polarization swing is associated with the start of the plateau phase.

Usually optical, where the time coverage is often adequate to catch such events

-- radio/optical/gamma-rays

### A Number of Sources Have Exhibited Peculiar Behavior. What sources are these?

NGC 1275, Cen A, 3C 454.3, PKS 1510-08, 4C +21.35, PKS 1502+106, PKS 1830-211, S3 0218+35, PG 1553+113, OJ 287, PKS 2155-304, S5 0716+71, AO 0235+164, PKS 0735+178, S5 0836+71, S4 1150+49, PKS 1424-41, PKS 1424+240, 3C 279, 3C 273, M 87, OG 50, CTA 102, Ton 599, BL Lac, PKS 1424+240, radiogalaxies, starbursts galaxies (i.e. M 82 etc.), gamma-ray binaries, microquasars, 4C +21.35, M 31, PKS 0537-286, Mkn 421, Mkn 501, B2 1633+38, PKS 0454-234, 3C 66A, PMN J0948+0022, PKS 0521-365, W Com, PKS 2149-306, B2 0954+25A, PKS 2032+107, 1ES 1959+650, NRAO 530, NRAO 190, NRAO 676, 4C +50.11, PKS 0528+134, 3C 120, Mkn 180, CTA 26, 1ES 2322-409, PKS 0805-07, PKS 0235-618, PKS 0727-11, SBS 0846+513, OJ 248... and other.

The bizarre nature of 4C +55.17 has yet to be resolved.

PMNJ1603-4904 (radio-loud, gamma-ray loud possible CSO)

See above (sources with long-term photon-index drifts).

It is quite striking that a source like 3C454.3 shows a clear correlation between gamma-ray/optical/radio flux, but PKS1222+216 often shows "orphan" optical and gamma-ray outbursts.

### How does this shed light on an open issue?

We still have a ways to go in figuring out the locations of various outbursts in AGNs and what causes them.

The case outlined above concerning transitional objects is based on the observation that the gamma-ray spectral index distributions are quite distinct for different (sub)classes. An absence of change in photon index during a transition between classes would disfavor scenarios where the high-energy hump position is driven by parameters altered during the transition (broad-line strength or position of low-energy peak).

evolution of AGN, gamma-rays from young radio sources?

This blazar doesn't have a compact core, doesn't look beamed - why then is it a LAT source?

### What Has Not Been Done Yet? What correlations have we not studied?

Correlations of gamma-ray variations with degree of linear polarization and changes in the polarization - the number of optical polarization monitoring programs is now high enough to do this for a lot of objects. Previously, the time coverage was usually too poor in optical polarization.

Correlations involving polarization have generally not been studied in great depth yet. A lot of this is due to most researchers' unfamiliarity with this aspect of the multifrequency campaigns, and the fact that the relatively few investigators familiar with polarimetry are nearly overwhelmed just acquiring the needed data!

MW polarisation studies have not been exhausted.

While not exactly a multi-frequency program, I think it is important to expand the search for correlations with multi-messenger signals such as neutrinos, cosmic-rays, and even gravitational waves. The sources of the astrophysical neutrinos detected by IceCube remains unknown, and Fermi has unmatched field of view and uptime to search for hadronic gamma-rays in coincidence with neutrino events. Possible ToO observations could be triggered based on alerts from IceCube or other multi-messenger observatories to increase the sensitivity of these follow-ups. New detectors (such as the KM3Net neutrino telescopes) and upgrades of existing ones (such as IceCube-Gen2 or the Advanced LIGO GW detector) will provide more sensitive triggers in the coming years, and it would be beneficial to have Fermi participating in the search for correlations with these alerts.

More needs to be done on determining exactly how variable the low- and high-energy SED peak locations of AGN vary during flaring and non-flaring states, i.e., is synchrotron peak frequency a useful parameter for categorizing blazars?

Correlation between BLR/blue bump luminosity and gamma-ray spectral index on a large sample.

Stefano C: -- a) long-term multifrequency correlations in a sufficient populated sample of objects and variety of sources -- b) radio/optical polarization vs multifrequency and gamma-ray correlation (there is large room to improve, still too few polarization data) -- c) radio structure -- gamma-ray correlations (there is room to improve in number of sources and temporal sampling of VLBI structures) -- d) VLBI detailed observations of HE-peaked BL Lac objects (very interesting ADAF,MDAF,turbulent regimes and complex structures, I know they are low/milliJy flux so difficult to observe). -- e) multimessenger: still in preliminary phase (only first tentative PeV IceCube neutrino vs gamma-ray correlations). Fermi needs to be a 20-year timescale mission to meet more multifrequency opportunities (more cosmic neutrino statistics experiments and the incoming gravitational wave detectors). -- f) waiting for a serendipity Galactic SN (or nearby Galaxy, like M31) SN explosion (30 Dor etc.). -- g) Sun occultations of 3C 279. -- h) Axions in blazars/AGN -- i) AGN halos -- j) Preliminary idea to propose for the Swift-extended mission a dedicated and priority program and service for Fermi mission in covering with observations all the sky fields of the unassociated LAT source error regions.

### What sources have we not focused on?

Multiwavelength surveys in Fermi error circle regions for unassociated sources need to be pursued more heavily - the radio-gamma correlations for AGN indicate, for example, very weak radio fluxes for some of these - can perhaps use existing statistical knowledge of AGN SEDs to predict fluxes in other wavebands as well.

As long as supporting observations are being gathered for the small number of blazars that generally are detected by the LAT in a day or so, nothing is being overlooked during the mission from the standpoint of the multifrequency campaigns.

faint sources (very difficult though)

Many bright sources have not been subjects of dedicated paper.

Stefano C: -- a) there is the need to cover the galactic plane possibly with catalog-pipeline detection chain, searching for galactic variable sources, transients on short timescales (like 3-month, 1-month, 1-week, 1-day, 3 or 6 hours). -- b) rapid alerts based on 3h intervals and a fast ASP-like data processing task

### How will long-term studies answer an open issue?

The strength (or lack) of correlation between long term variations of observables in different bands provides strong constraints on the nature of the parameters governing the properties of a source class.

long term radio monitoring -> changes in morphology, how related to quiet/flaring periods; long term multiwavelength studies -> better correlations between several bands

long-term studies provide an unbiased and consistent picture and are especially important for variable sources to understand the underlying physics. The wealth of behavior shown by blazars in near-term studies argues that a long-term, consistent, and systematic approach is required if real progress is to be made in uncovering the fundamental processes involved in these sources. Seeing similar behavior over several activity cycles in these sources is the only way robust models can take shape. A great example of analyzing a healthy chunk of long-term multifrequency monitoring data and uncovering repeated behavior that argues for the same feature, or series of features, within the jet causing the observed outbursts is given by Jorstad et al. (2013), ApJ, 773, 147.

Stefano C:-- a) Long term regular monitor possible only with Fermi LAT. A 20-year Fermi mission timescale would be a unique opportunity (unique regular and all-sky monitor from space and unique probe of high-energies, > optical band). -- b) Long-term temporal scales are important because they probe the large sizes and large dynamical scales/times of SMBH, discs and jets of AGN (galaxy-sized). General relativity effects acting on galaxy-sized systems. Numerical general relativity models is a growing field. -- c) Long-term temporal scales can be important because controversial/proposed periodicity scales for AGN radio-optical light curves ranges about 1 year to 25 years.

## General Questions

### How has the LAT changed the way you look at your data?

I have focused on gamma-ray data analysis.

The continuous light curves provided by Fermi are unattainable at the other wavelength regimes. It is crucially important for correlation studies for there to be at least one such wavelength region.

Yes. I see little reason to spend much effort in following sources if Fermi/LAT is unable to detect them within a few days. I also feel that if the decade of multifrequency studies anchored by LAT/Fermi leads to little progress on the matter of relativistic jets and/or accretion, I see little hope for campaigns organized after Fermi that will have no high-energy component. This, of course, assumes that some bright researcher doesn't come up with an idea that can be tested without needing something as powerful as Fermi in orbit.

Stefano C:-- a) with the LAT now we look at multifrequency astrophysics -- b) with the LAT now we look at multimessenger astroparticle physics -- c) with the LAT now we look at time domain astronomy -- d) with the LAT now we look at survey astronomy -- e) with the LAT now we look at source association and identification -- f) with the LAT now we look at a particle-physics like large and international Collaboration, also related to a laboratory like SLAC. -- g) with the LAT now we profit at particle-physics and astrophysics synergy, and union of two prior separated communities -- h) wide science topic menu (from sun to extragalactic and cosmic background), from classical star evolution/pulsar astronomy to dark matter, etc. interesting more than a single science topic and community.

### Is there anything else you would like to share?

Investigators should not be shy about making their data public as fast as possible during the "Fermi Era." Many papers have not used the full array of multifrequency data available, largely because proprietary data has not been forthcoming. AGNs, especially blazars, are an extremely complex and difficult problem in astrophysics, so forget about "solving" the big issues with your own data exclusively. Pooling all of the data gives theorists and modelers the best possible chance of understanding the many interconnections (and lack of connections) observed between wavebands. Observers should work hard to get their data in a readily accessible form as quickly as possible. Fermi has given the research community an incredible opportunity in cracking the puzzle of accretion and outflow associated with super-massive black holes. It would be disturbing not to maximize the support for this mission at as many wavelengths as possible. Of course, like any science program, the complexities may turn out to be just too great, but if we can't make headway during Fermi's mission, what would be the point of continuing long-standing, proprietary blazar monitoring programs after this mission ends. My apologies for not being able to attend this extremely important workshop and the equally important Fermi Symposium. These events unfortunately coincide with an observing run to support Fermi. The Steward Observatory blazar monitoring program stands ready to carefully consider and adopt changes in observing strategy and/or data products made available in response to any recommendations adopted at this workshop. One last point is that I would like to see us develop a central site where all data at all bands obtained during the Fermi mission can be accessed to go along with the final Fermi data archive. Is there any interest within the multifrequency community and at NASA in hosting such a central data repository? It would be a static archive and only contain data obtained while Fermi was observing.

Hi, The Fermi Guest Investigator Program offers joint observation time on a variety of observatories from radio to TeV through arrangements with NRAO, Arecibo, NOAO, INTEGRAL and VERITAS. The observing time available through these opportunities has generally been undersubscribed, in some cases extremely so. In particular, the bulk of the Fermi community may not even be aware of two of these that were just recently implemented, Arecibo and INTEGRAL, judging from the dearth of requests in Cycle 7 and 8. We strongly encourage you, whether you reside in the US or abroad, to consider proposals for observation programs making use of these resources. Refer to the FSSC web pages for additional details. -- Chris.

Stefano C:-- a) Possible idea for a Memorandum of Understanding with e-ROSITA ? This will be a sensitive all-sky high-energy instrument simultaneous to Fermi LAT for joint high-energy X-ray-gamma-ray survey astronomy. -- b) Fermi with additional more 10 years of prolonged mission can be of interest from particle physics side: increase statistics and limits/detection of DM and new-physics signals + multimessenger astroparticle physics with cross correlations among the next neutrino, gravitational wave and ultra-high energy cosmic ray data coming in the next decade. Without Fermi the multi-messenger science cannot develop and grow well. Remarks for the physics community side. -- c) Without Fermi the science possible with CTA cannot develop and grow well. Remarks for the physics community side.

## Other Questions

Extra-Note: Why Time Domain topic is continuing to be hot for Fermi (in comparison to Swift).

Stefano C: I do not think Swift can do better in principle in all the fields and all the timescales of time domain astronomy when compared to Fermi. Two, *very qualitative* (and 2 cents opinion) possible 2 reasons here. 1) Fermi is providing data comparable with other sciences in terms of regular, no gapped, temporal sampling (bright sources only, yes, but these are not so few), so this LAT timeseries HE astrophysics has the same rank and pride of other continuous temporal-monitor/signal-analysis sciences (like climatology, geology, medicine, laboratory experiments, etc.). On the other hand Swift can only monitor limited temporal ranges, following a source in pointing mode for hours/days or performing repeated visits in pointing mode, every some hours/days/weeks. But what happens in the gaps between the recurrent visits of a source of interest ? For example, I do not understand well strong claims (like periodicity from commonly irregularly-variable sources like blazars) that are based only on gapped optical light curves, or based only on selected pieces of timeseries data. 2) Fermi is a real all-sky survey mission (i.e. all-sky time domain monitor) despite the photon count statistics. Also here Swift is behind, I think, because it cannot watch the entire X-ray sky. Also non-short-term timescales works better for the LAT, because of the long mission baseline and continuous monitor, and because of the accumulated photon count statistics in mid-/long-time bins. Well, the march of time and the ageing of the mission for Fermi works in the direction of more time-domain science possible (more statistics, more significance, smaller errors, more timescales...).

## Part 3 - Other sparse extra-notes from previous years

Main goals of time-series (variability) analysis:

- (1) identifying nature and gain physical understanding of the phenomenon/object producing the observed time series;
- (2) forecasting (predicting future behavior and future values of the time series quantity).

What we can learn from short timescales ( $<1$  day) of variability that can be observed by the LAT for very bright flares.

Search for breaks in the PDS (relation with physics, SMBH mass like for X-rays in Seyferts?).

Can the LAT allow systematic multiwavelength variability studies measuring the PDS-SED-plane (i.e. timescale-energy plane)?

Broad-band MW studies: cross-correlation and time lags. MW SED modeling. Gamma-ray-synchrotron amplitude ratio studies, orphan flares, physics of the gamma-ray emission in AGN, identification of newly discovered gamma-ray sources, spectral index hysteresis, etc.

PHYSICS OF GAMMA-RAY EMITTING AGN (includes mainly blazars and radio galaxies)

-- C.1 WHAT is the structure (ingredients/content) of the jet in blazars and radio galaxies?

-- C.2 HOW are the X-/gamma-ray flares produced in blazars and radio galaxies?

-- C.3 WHERE are the X-rays/gamma-rays produced ?

AGN studies with Fermi LAT: some pre-launch science goals:

- (1): Does the "blazar sequence" scheme hold for a large sample of objects?
  - (2): Are SSC models in trouble for the HBL-type blazars?
  - (3): Are single-zone synchrotron + Compton models applicable?
  - (4): Are synchrotron and Compton components produced co-spatially?
  - (5): What is the content of the innermost part of the relativistic jet?
  - (6): Total charged particle content / kinetic energy of the blazar jets as compared to the radiative output
  - (7): are gamma-ray flares related to dissipation of magnetic energy?
  - (8): Do blazars and radio galaxies accelerate ultra-high energy cosmic rays?
  - (9): Tests of the Compton-scattered CMBR interpretation of extended X-ray (Chandra) jets
  - (10): Energization Sites and Bulk Relativistic Speeds of Blazar Jets
  - (11): Constraints/hints on matter composition of gamma-ray emitting jet region
- Variability analysis of LAT and MW data is required in most of these topics.

Problem of faint sources: real variable source or background fluctuations?

High degree (up to 30%) and variability of the optical polarization (OP) is one of the defining properties of blazars (especially the classical BL Lac objects and high-pol. quasars HPQ). This means that OP observations might be an important element in confirmation of new blazar candidates.

Results from the LAT paper on blazars (106 sources) gamma-ray variability studies (first 11 month data):

LAT gamma-ray blazars are displaying 2 "flavors" of variability:

- 1) constant baseline with sporadic flaring activity showing also intermittence (flatter PDS, red noise);
- 2) a few sources showing strong activity with complex and structured time profiles characterized by the long-memory, steeper PDS slopes (random walk processes).

Dave T.:

Fermi Gamma-ray Space Telescope characteristics and experience from 7 years in orbit.

Methods for simultaneous studies: 1. Wide-field telescopes 2. Monitoring programs 3. Dedicated multiwavelength campaigns 4. Good luck

Methods for near-simultaneous/follow-up studies: Rapid sharing of information

The Fermi wide-field instruments are an approximation to "all the sky, all the time," which would be needed across the electromagnetic spectrum to catch everything of interest. Probably not practical. LOFAR, MAXI, HAWC, Swift-BAT are examples of other wide-field instruments, along with multimessenger facilities like IceCube, Antares, and Advanced LIGO/Virgo. This is a developing field.

Monitoring programs are being carried out for classes of objects known to show variability or transient behavior. For Fermi, blazars and pulsars are classes of interest that are monitored (at least for a subset) at many wavelengths. Example monitoring programs include MOJAVE, OVRO (radio), Tuorla, SMARTS (optical), Swift (X-rays).

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