GLAST LAT Multiwavelength Studies: Involving the User Community

Notes from Report of the Ad Hoc Multiwavelength Observation Planning Group

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Outline

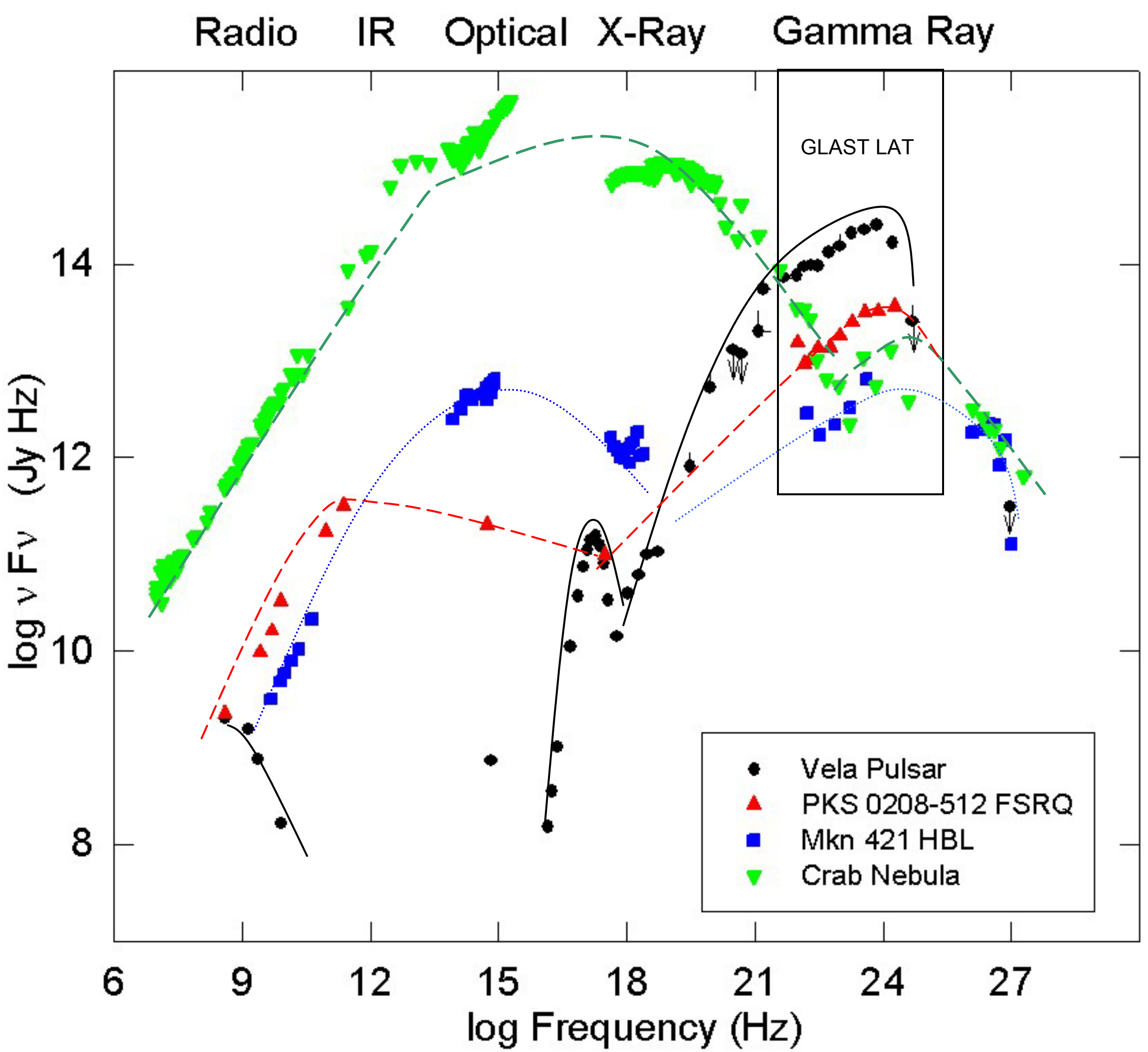
- MOTIVATION: Why gamma-ray sources should be multiwavelength (MW) objects
- IDENTIFICATION: Finding the blazars and pulsars.
- DISCOVERY: New science; counterpart searches.
- EXPLORING: MW blazar monitoring and campaigns.
  MW pulsar studies
- SUMMARY: What is needed and when

Gamma-ray Sources: Inherently Multiwavelength

In the MeV range and above, sources are non-thermal
$\Rightarrow$ produced by interactions of energetic particles

- Nature rarely produces monoenergetic particle beams. Broad range of particle energies leads to a broad range of photon energies.
  - Example: π^o production
- Charged particles rarely interact by only one process. Different processes radiate in different energy bands.
  - Example: synchrotron-Compton processes
- High-energy particles needed to produce gamma rays can radiate in lower-energy bands as they lose energy.
  - Example: gamma-ray burst afterglows

Multiwavelength Gamma-ray Sources



MW Approaches for LAT

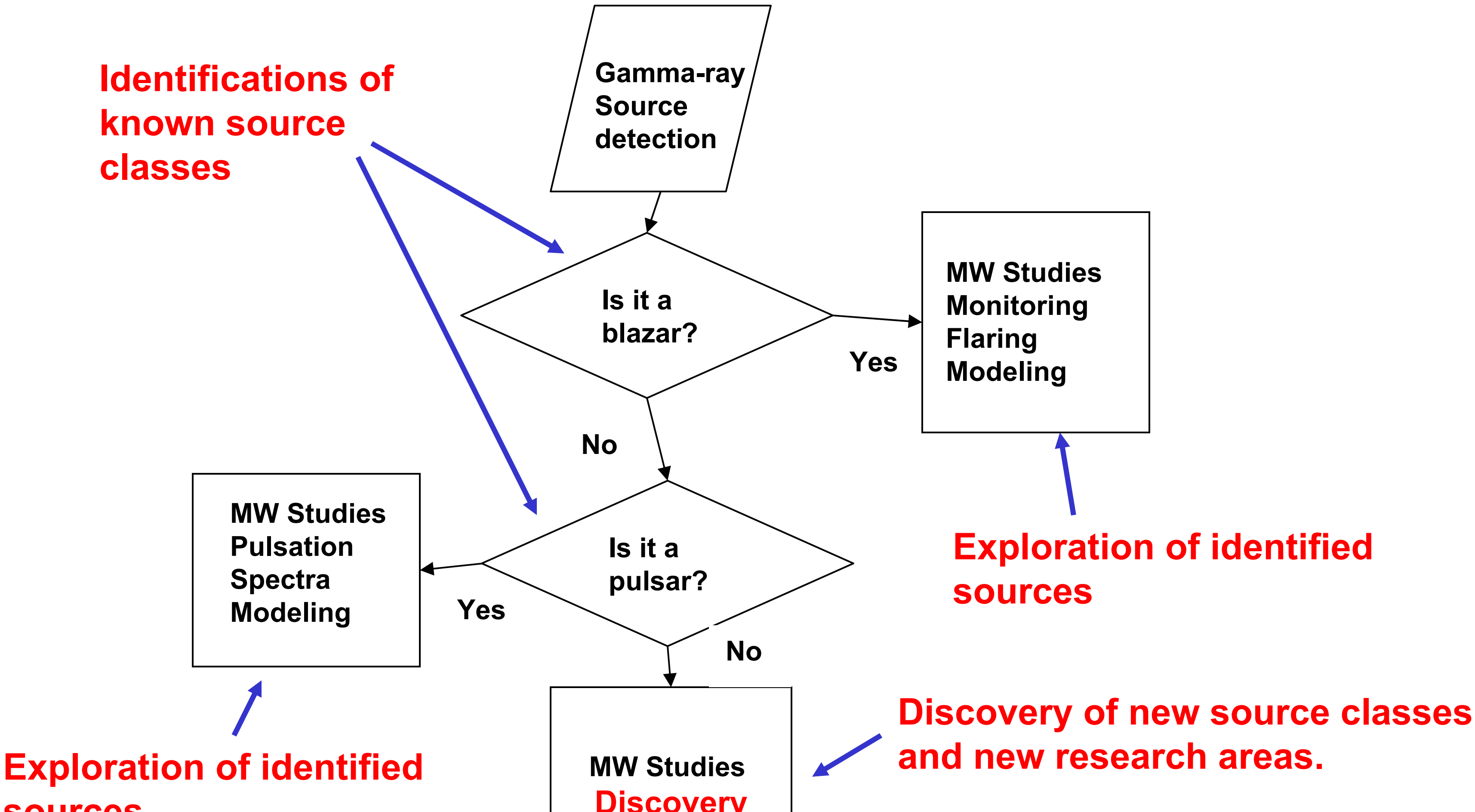
Source Class	Number seen by EGRET	Number anticipated with LAT
Blazars	80 definite 50 possible	>2000
Rotation-powered pulsars	6 definite 3 possible	100-500
Normal galaxies	2	4-5
Gamma-ray bursts	5	>500
Unidentified sources	170	?
Supernova remnants/plerions	1 likely ~5 possible	>10
Radio galaxies	1 likely 1 possible	?
X-ray binaries/microquasars	1 likely 2 possible	?
Starburst galaxies	0	~10
Clusters of galaxies	0	?

Two broad areas:

1. Identification for known source classes; discovery of new classes. "What are they?"
2. Exploration of identified sources. "What can we learn from them?"

Note: GRB needs are being studied by the GLAST Burst Committee.

MW Source Identification for LAT



"Eliminate all other factors, and the one which remains must be the truth." Sherlock Holmes

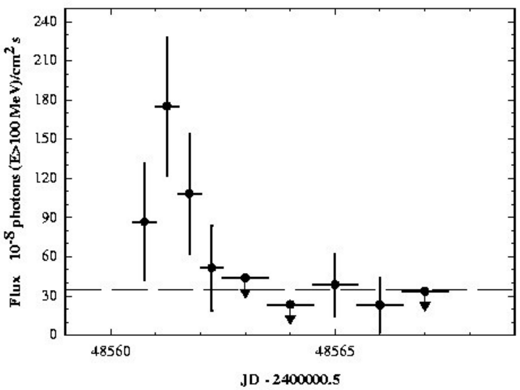
IDENTIFICATION

AND

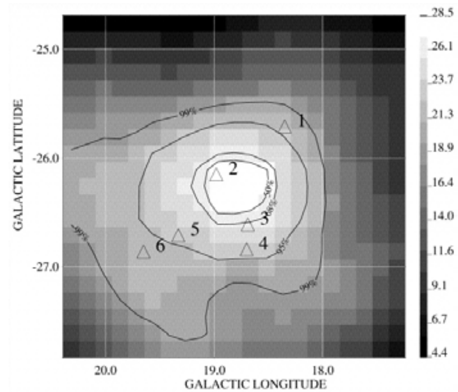
DISCOVERY

Blazar Identification Example: 3EG J2006-2321

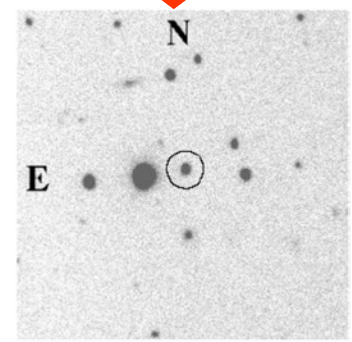
First Clue: Gamma-ray variability



Radio sources in the error box



One flat-spectrum radio source, 260 mJy at 5 GHz; one marginally-flat source, 49 mJy; other sources are much weaker



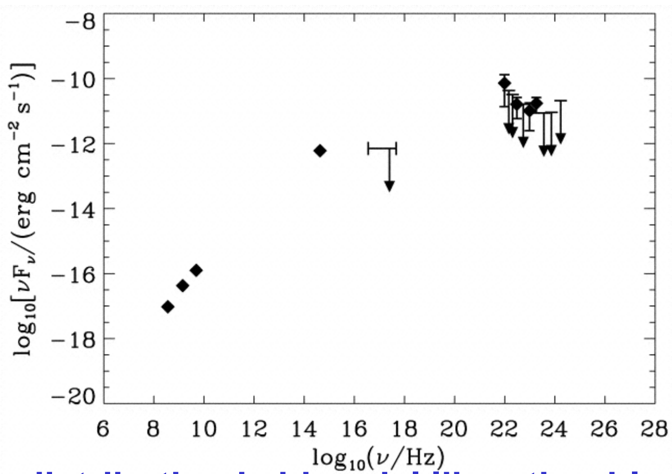
Optical observations:

The 49 mJy source is a normal galaxy;

The 260 mJy source has an optical counterpart with a redshift z=0.83

Variable optical polarization is seen.

Only an X-ray upper limit found.



Spectral energy distribution is bimodal like other blazars

Conclusion: a flat spectrum radio quasar (FSRQ)

Wallace et al.

Identifying Blazars

Problem: the exhaustive, one-at-a-time approach just described is impractical for the thousand or more blazars expected with LAT.

LAT needs an efficient blazar identification scheme, basically an expanded catalog of blazars. BEFORE LAUNCH.

Three examples of pilot projects to accomplish this goal:

1. **The Deep X-Ray Radio Blazar Survey (DXRBS) compares X-ray sources with flat-spectrum radio sources. Landt et al. X-ray selected blazars are not necessarily gamma-ray blazars.**
2. **Sowards-Emmerd, Romani, and Michelson have shown that compact, flat-spectrum radio sources are a good identifier of blazars. Their analysis has found a substantial number of new blazars in the EGRET source catalog.**
3. **The ASI (Italian Space Agency) Data Center Blazar Candidate sample uses cross-correlation between NVSS and ROSAT All Sky Survey (RASS) radio and X-ray surveys, plus optical magnitudes in the blazar range from the Guide Star Catalog 2 (GSC2), producing over 7400 candidates.**

MW Needs for Identifying Blazars

Strong correlation of blazars with flat-spectrum, compact radio sources.

In Northern Hemisphere, CLASS 8.4GHz + NVSS/FIRST

In Southern Hemisphere, need new observations. ATCA 20 GHz survey may help.

Recommendation: complete a Southern Hemisphere survey out to at least 8.4 GHz and down to at least 100 mJy, preferably to 30 mJy.

Optical identifications and redshift measurements are important to establish extragalactic origin and rule out unlikely candidates.

Recommendation: complete a program of optical identifications and redshift measurements for all known flat-spectrum radio sources brighter than 100 mJy at 8 GHz.

MW Needs for Identifying Gamma-ray Pulsars

Although some pulsars may be detectable in LAT data with blind searches, the deepest searches for pulsed emission will require timing information from other wavelengths, primarily radio.

Timing observations need to be contemporaneous, because young pulsars typically have significant timing noise.

Radio astronomers, coordinated by Steve Thorsett, are prepared to support LAT observations, but the number of pulsars to be monitored will have to be limited.

Recommendation: Use pulsar models to develop a prioritized list of radio pulsars to be monitored.

BEFORE LAUNCH AND DURING THE FULL MISSION

MW Needs for Discovery Space

If neither a blazar nor a radio pulsar identification is possible, then the challenge is one of discovery, covering a wide range of exciting possibilities.

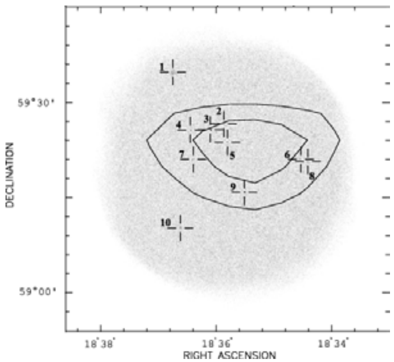
Although some specific source characteristics may motivate particular searches (e.g. non-variable, extended gamma-ray emission could be a molecular cloud, a supernova remnant, a galaxy, or a cluster of galaxies), we suggest that a generic approach is to work from X-rays downward in energy (as was done with Geminga, the classic example).

Note that gamma-ray source identification in general, but particular for sources near the Galactic Plane, is strongly dependent on development of a good model of the diffuse emission, a responsibility of the LAT team.

Recommendation: support detailed CO observations for specific directions needed to augment models of the diffuse emission.

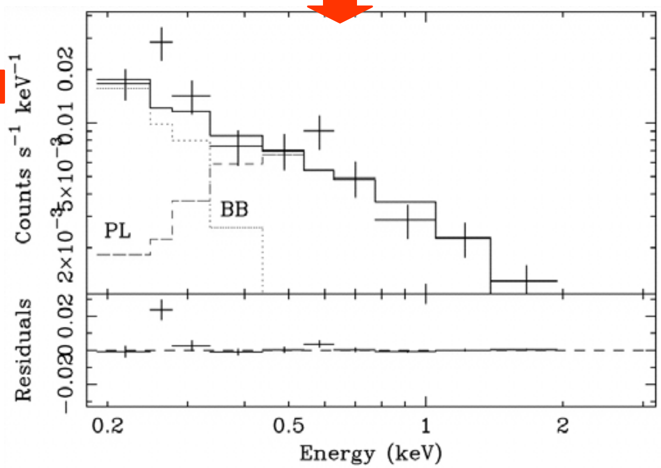
Nearby/High-Latitude Discovery Approach Example

Parallel effort by two groups, headed by Mirabal/Halpern and Reimer/Carramiñana – used the same approach and reached the same conclusion for 3EG J1835+5918



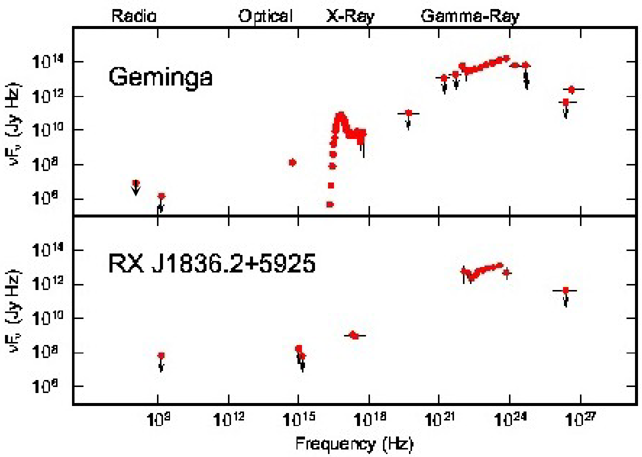
Start with deep ROSAT image (soft X-rays)

Take deep optical images to try to identify all the X-ray sources. Most turn out to be stars or QSOs, unlikely gamma-ray sources. One candidate has no obvious optical counterpart: RX J1836.2+5925.



Use Chandra to obtain X-ray spectrum of the candidate: two components, one thermal, one power law.

Use radio search to look for possible radio pulsar. None found.



Construct MW spectrum. It resembles that of Geminga, a spin-powered pulsar. No pulsations have yet been found for 3EG J1835+5918.

MW Needs for Discovery Space

Catalogs of existing objects, plus search tools such as NED and Simbad, provide tools for population studies, which are important but do not necessarily identify individual sources.

The most useful X-ray observations for discovering gamma-ray counterparts are likely to be those with good angular resolution and sensitivity above 2 keV, where absorption effects are minimized.

Recommendation: Plan campaigns with Chandra, XMM, Astro E2, and (if selected) NuSTAR for high-energy X-ray studies of unidentified gamma-ray source error boxes, supplemented by radio mapping.

DURING EARLY PART OF MISSION IN PARTICULAR

EXPLORATION
OF
IDENTIFIED SOURCES

Pulsars and Blazars
as examples

MW Needs/Resources for Pulsar Exploration

In order to study phase relationships of pulses and to add data over long time intervals, we need absolute phase information. This requires continued timing of pulsars, along with occasional collection of Dispersion Measure (DM) information from radio measurements.

Recommendation: Work with radio pulsar astronomers to collect radio timing information regularly over the life of GLAST, for some set of pulsars. Obtaining DM information is a straightforward effort.

Deep radio, optical and X-ray exposures, with timing, will be needed in order to develop true MW information about pulsars, both young and millisecond.

Recommendation: Plan proposals for follow-on pulsar observations with X-ray, optical, and radio telescopes.

DURING THE MISSION

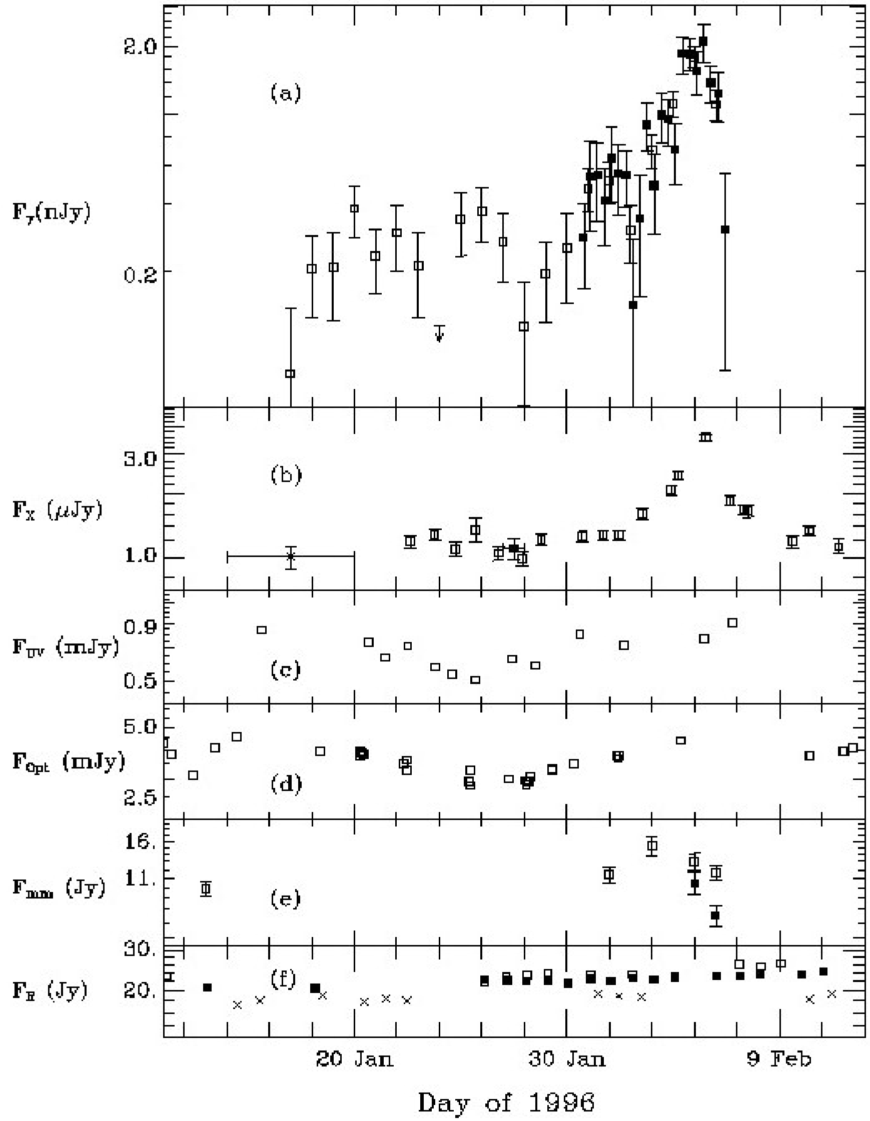
MW Needs for Blazar Exploration

Blazars are characterized by both short-term and long-term variability at essentially all wavelengths. The relationship between changes at different wavelengths is a powerful tool for studying the jets in these sources.

Two general aspects to exploration of blazar variability:

1. **Monitoring to know what the long-term behavior is and to identify short-term flares.**
2. **Campaigns for intensive study, particular during flares.**

DURING THE MISSION



3C279

Wehrle et al.

Gamma rays

X-rays

UV

Optical

IR

Radio

MW Resources for Blazar Monitoring

- LAT itself will be an excellent monitor for blazar activity, particularly in scanning mode.
- There are a number of existing blazar monitoring programs at other wavelengths.
- Recommendation: We should be sure to collaborate with existing programs.

Measurement	Facility	Possible Contact (bold – contact made)
Radio monitoring	Metsahovi	**Terasranta**
Radio monitoring	Michigan	**Aller**
Radio monitoring	VLA/VLBA	Kellerman
Optical monitoring	ESO	**S. Wagner**
Optical monitoring	WYBT	Villata
Optical monitoring	GTN	**Cominsky**
Optical monitoring	Perugia	Tosti
Optical monitoring	Crimea	
X-ray monitoring	RXTE	Marscher
X-ray monitoring	Swift	**Gehrels**
TeV monitoring	VERITAS	**Ong**
TeV monitoring	Magic	**Merck**
TeV monitoring	HESS	
TeV monitoring	CANGAROO	Mori

MW Resources for Blazar Campaigns

Planned MW campaigns require substantial effort to organize but can produce broader coverage.

Target of Opportunity campaigns are easier to manage, but the coverage is less likely to be complete.

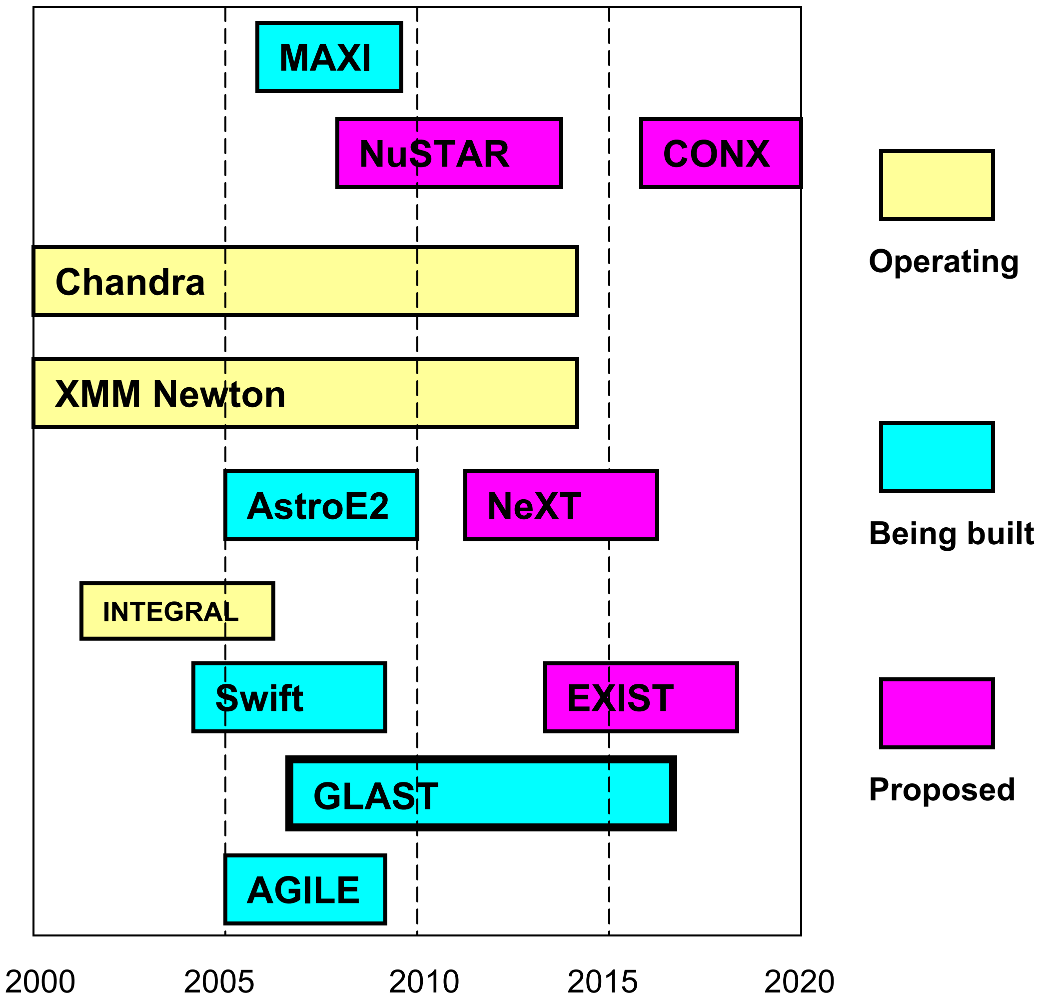
Recommendation: We should collaborate in both types of MW blazar campaigns and work to obtain 24 hr. coverage around the world for ground-based telescopes.

Measurement	Facility	Possible Contact (bold – contact made)
Radio	**Metsahovi**	**Terasranta**
Radio	**VLA**	
Radio	**VLBI**	Wehrle
Radio	**Green Bank**	
Radio	**Parkes**	
Radio	**Michigan**	**Aller**
Radio	**VLBA**	Kellerman
Sub-mm	**SEST**	Tornikovski
IR	**Spitzer**	
Optical	**ESO/ENIGMA**	**S. Wagner**
Optical	**WEBT**	Villata
Optical	**GTN**	**Cominsky**
Optical	**Perugia**	Tosti
Optical	**Crimea**	
X-ray	**Chandra**	
X-ray	**XMM**	
X-ray	**RXTE**	Marscher
X-ray	**Swift**	**Gehrels**
X-ray	**Astro E2**	**Takahashi**
X-ray	**NuSTAR**	**Harrison**
TeV	**VERITAS**	**Ong**
TeV	**Magic**	**Merck**
TeV	**HESS**	
TeV	**CANGAROO**	Mori

SOME ISSUES

In reviewing resources, we note two possible “choke points” in planning:

1. Far-IR (satellite) observations (the peak of some FSRQ synchrotron components) are only possible with Spitzer Space Telescope (SIRTF), but it is heavily oversubscribed and will lose cooling early in the GLAST mission.
2. The amount of X-ray telescope time needed for both identification and exploration is substantial, probably more than will be readily available through the few X-ray telescopes that will be operating in the GLAST era.



Some High-Energy Telescopes 2000-2020

Web Page with Information about GLAST for Mutiwavelength Observers

Multiwavelength Observations

- Gamma-ray Multiwavelength Mailing List Archive

  Please contact Dave Thompson or J.D. Myers to be added to the mailing list.

- **Science Requirements Document**
- **Large Area Telescope (LAT) Properties**
- **GLAST Burst Monitor (GBM) Properties**
- **Planning, Operations, and Data Policies (from the NASA Announcement of Opportunity)**
- **Operations Concept Document**
- Project Data Management Plan (in preparation)
- **GLAST Science Support Center**
- **GLAST Telescope Network**

Multiwavelength Contacts: Dave Thompson, Steve Thorsett (Pulsars)

http://glast.gsfc.nasa.gov/science/multi/

SUMMARY

- GLAST science will be maximized by MW studies carried out cooperatively between the instrument teams and the user community.

- BEFORE LAUNCH – expand the catalog of known blazars; start radio timing program for pulsars
- EARLY IN THE MISSION – carry out radio and X-ray observations, in particular, to help identify gamma-ray sources.
- THROUGHOUT THE MISSION – collaborate in monitoring and coordinated MW campaigns for flaring sources, regular timing for pulsars