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GLAST Large Area Telescope Multiwavelength Planning

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Abstract Gamma-ray astrophysics depends in many ways on multiwavelength studies. The Gamma-ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT) Collaboration has started multiwavelength planning well before the scheduled 2007 launch of the observatory. Some of the high-priority multiwavelength needs include: (1) availability of contemporaneous radio and X-ray timing of pulsars; (2) expansion of blazar catalogs, including redshift measurements; (3) improved observations of molecular clouds, especially at high galactic latitudes; (4) simultaneous broad-spectrum blazar monitoring; (5) characterization of gamma-ray transients, including gamma ray bursts; (6) radio, optical, X-ray and TeV counterpart searches for reliable and effective sources identification and characterization. Several of these activities are needed to be in place before launch.

Keywords gamma rays · multiwavelength · observatories

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1 Introduction

Multiwavelength (MW) observations are important for the GLAST observatory [1]. Particular motivations for such studies with the LAT include:

- Source identification and population studies.
- Intensive exploration of the brightest and most variable sources that will allow deep study of the source physics.
- Rapid follow-up on transients (e.g. GRBs, blazar flares). The GLAST mission is designed to support rapid notification for follow-up.
- Understanding the high-energy diffuse emission of the Milky Way

The GLAST LAT Multiwavelength Coordination Group (GLAMCOG) has been formed to prioritize science-driven needs and develop an implementation plan for cooperative multiwavelength observations before and during the GLAST mission. This work is being coordinated with the GLAST Burst Monitor (GBM) and GLAST Project science teams. Some of the known multiwavelength needs are described here, along with the steps being taken to meet those needs. This work is preliminary and does not represent the full range of multiwavelength activities that will be investigated.

2 Science Goals Needing Multiwavelength Studies

Based on current knowledge of the gamma-ray sky, many GLAST LAT studies will require MW cooperation for the maximum scientific return. Four of these are described here. Table 1 summarizes the ways GLAST will use MW observations to address these issues.

2.1 Probing the Extragalactic Background Light (EBL) with Blazars

The EBL contains unique information about the epochs of formation and the evolution of galaxies and in what environments the stars of the universe formed. Direct EBL measurements, however, require accurate model-based subtraction of bright foregrounds (e.g., zodiacal light). An alternative approach is to extract the imprint of EBL absorption, as a function of redshift, from high-energy spectra of extragalactic sources. GeV Gamma rays seen by the LAT interact with the optical EBL. Blazars, a known gamma-ray source class, provide the source photons. This approach is only feasible on a statistical basis and therefore requires detailed broad-band spectral measurements and redshifts for a large sample of blazars, probably more than the known blazar population[2].

2.2 Modeling the Diffuse Gamma-Ray Emission from the Milky Way

The diffuse Galactic gamma-ray emission must be well characterized for analysis of LAT data, much more so than for EGRET, owing to the LAT's vastly better statistics and better angular resolution. The origin of this radiation is predominantly cosmic-ray interactions with interstellar gas and the interstellar radiation field. Information about these cosmic-ray targets can only come from multiwavelength observations and analysis (e.g. [3]). Some fundamental questions remain from EGRET, with results limited by knowledge of the diffuse emission; e.g.

- What is the nature of the source in the Galactic Center region?
- What is the origin(s) of the isotropic γ -ray background?
- Is there gamma-ray evidence for particle dark matter?

2.3 Identifying New Source Classes

About half the sources in the third EGRET catalog [4] remain unidentified, largely because the error boxes were too large for identifying a unique counterpart in deep searches at other wavelengths. Potential new source classes include starburst galaxies, radio galaxies, clusters of galaxies, pulsar wind nebulae, colliding winds of massive stars, and microquasars. The major increase in sensitivity and better angular resolution of GLAST LAT (especially at higher energies) will produce much smaller error boxes, sub-arcmin in many cases. Finding new source classes is an important part of the discovery potential of the LAT.

2.4 Investigating Physics of Extreme Conditions in Pulsars

Pulsars, rotating neutron stars, are sites of particle acceleration and interactions in extreme gravitational, electric, and magnetic fields. Multiwavelength pulsar studies have shown significant variety of pulsar properties as a function of wavelength[5]. A key to using gamma rays to help decipher these extreme processes is having accurate, absolute timing data for many pulsars. With the exception of a few X-ray pulsars, the radio band provides the timing information needed by observations across the spectrum. A sizeable radio timing program is beyond the scope of routine radio pulsar programs.

3 Planning for GLAST LAT Multiwavelength Studies

A variety of approaches for MW research will be used. Four of these are outlined here.

3.1 Coordinated Multiwavelength Campaigns

Particularly for time-variable emission phenomena as, e.g. in blazars, coordinated observations across the electromagnetic spectrum provide essential information about locations and processes of particle acceleration and interaction. Examples are campaigns by the Whole Earth Blazar Telescope (WEBT) [6]. The GLAST LAT team will be an active participant in such campaigns. Because LAT will serve as an all-sky monitor, it will be an important trigger for coordinated efforts. The GLAST Project is a co-sponsor of the Global Telescope Network (<http://gtm.sonoma.edu/public/>), an informal association of small telescopes supporting such observations.

3.2 Wider and Deeper Surveys for Molecular Gas

Despite extensive surveys, our knowledge of the matter and radiation fields in the Milky way remains incomplete. Two important sets of observations are needed in order to upgrade the model of the diffuse gamma-ray emission in the Galaxy:

- Extend CO surveys uniformly to high latitudes - CO is a tracer of the important molecular hydrogen component of clouds. Cosmic rays interacting with small molecular clouds will be interpreted as unidentified sources unless the matter content of the clouds is modeled properly [7]. Such identified clouds would clearly limit dark matter studies.
- $C^{18}O$ observations - This optically thin tracer of molecular hydrogen must be measured in special directions (e.g. the Galactic Center and spiral arm tangents) to

assess whether velocity crowding is affecting calculations of molecular column density, and for carefully pinning down the diffuse emission.

3.3 Sample Strategies for Identifying Gamma-Ray Sources

Even with the improved error boxes to be provided by LAT compared to EGRET, gamma-ray source identification will often involve more than simple positional association. We note three approaches that can be used to assist in this identification process:

- The “Top → Down” approach will search LAT error boxes for X-ray counterparts with nonthermal, hard spectra, then use the X-ray position to find corresponding optical and radio sources. An example of this method is the identification of 3EG J1835+5918 with the X-ray source RX J1836.2+5925 as a likely isolated neutron star [8],[9]. A challenge will be proposing for enough X-ray telescope time to identify the large number of new sources expected with LAT.
- The “Bottom → Up” approach will search LAT error boxes for radio counterparts with flat spectra, then follow up with redshift and polarization measurements in the optical to identify potential blazars. An example of this method was the identification of 3EG J2006–2321 as a likely blazar [10]. The VLBA Imaging and Polarization Survey (VIPS) program is one program studying candidate blazars at present (<http://www.phys.unm.edu/~gbtaylor/VIPS/>).
- Correlated variability between gamma-rays and radio, IR, optical, and/or X-rays will provide one of the most distinctive signatures for source identification. Pan-STARRS is one optical facility, well-matched to the LAT for correlated studies (<http://pan-starrs.ifa.hawaii.edu/public/>).

3.4 Pulsar Timing and Searches

Pulsar timing programs at facilities such as Arecibo, Parkes, Jodrell Bank, Nançay, and Green Bank are being planned in cooperation with Steve Thorsett, a GLAST Interdisciplinary Scientist. After launch, unidentified LAT sources will provide targets for deep radio pulsar searches. Similar searches will be needed using X-ray telescopes.

information. To be added to the Gamma-Ray multiwavelength information mailing list, please contact Dave Thompson (djt@egret.gsfc.nasa.gov). The GLAST Guest Investigator program will have opportunities for developmental and correlative observations.

See <http://glast.gsfc.nasa.gov/ssc/proposals/> for further information.

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4 Summary

The GLAST Large Area Telescope science will be optimized by coordinated multiwavelength observations and analysis. GLAST welcomes cooperative efforts from observers at all wavelengths.

See <http://glast.gsfc.nasa.gov/science/multi/> for further

Table 1 Summary of Some Multiwavelength Needs and Planning

Science Objective	What GLAST Provides	Multiwavelength Requirements	Multiwavelength Planning Activities
Differential measurement (vs Z) of extragalactic background light to $Z \sim 5.5$	Measurement of blazar spectra in band where cutoffs are expected from $\gamma + \gamma_{\text{EBL}} \rightarrow e^+ + e^-$	Broadband contemporaneous/ simultaneous spectral measurements (radio, optical, X-ray, TeV) of blazar spectra, particularly around the synchrotron peak	Cooperate with and expand existing multiwavelength blazar and GRB campaigns (e.g. WEBT, ENIGMA, GTN, Swift) to have the broadest possible coverage during the mission
Resolve origin of particle acceleration and emission mechanisms in systems with relativistic jets, supermassive black holes	All-sky monitoring coverage of blazar flares and Gamma Ray Bursts (GRB)	Radio and optical surveys of flat-spectrum radio sources to extend blazar catalogs, including redshift measurements	Participate with and encourage programs to expand blazar catalogs and measure redshifts for flat-spectrum radio sources
Reliable model of Milky Way diffuse emission required for accurate source localization and to facilitate search for dark matter	Mapping of cosmic ray interactions with all forms of interstellar matter	Extend CO surveys to high galactic latitude; Survey special directions (eg. spiral arms, Galactic Center) with optically thin tracer (e.g. $C^{18}O$)	Promote needed CO and other tracer observations; Work with observers to reduce data and incorporate into a model of the diffuse gamma-ray emission
Search out and understand new classes of gamma-ray sources	Large number of source detections; Relatively uniform sky coverage; Good positions, energy spectra, time histories	Counterpart searches at all other wavelengths, and in the Multi-Messenger observation channels; Population studies; Correlated variability; Contemporary, complete astronomical catalogs Multi-Messenger modeling	Identify facilities and plan proposal strategies for obtaining observing time needed to identify gamma-ray sources at other wavelengths; Cooperate with existing and planned monitoring surveys; Prepare for use of the many available astronomical catalogs and observation facilities
Understand particle acceleration and emission mechanisms in extreme environments of rotating neutron stars	Spectra and light curves resulting from primary interactions of the most energetic particles	Contemporaneous radio and X-ray pulsar timing observations	Select pulsar candidates for radio timing; Work with radio and X-ray astronomers to monitor timing of selected pulsars; Plan proposals for radio and X-ray pulsar searches