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Fermi: Launched and Being Commissioned - Status and Prospects for Microquasars

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The Fermi Gamma-ray Space Telescope (Fermi) is a next generation high energy gamma-ray observatory launched in June 2008. The primary instrument is the Large Area Telescope (LAT), which will measure gamma-ray flux and spectra from 20 MeV to > 300 GeV and is a successor to the highly successful EGRET experiment on CGRO. The LAT has better angular resolution, greater effective area, wider field of view and broader energy coverage than any previous experiment in this energy range. An overview of the LAT instrument design and construction is presented which includes performance estimates with particular emphasis on how these apply to studies of microquasars. Early results on LS I +61 303 detection are presented.

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1. Introduction

Fermi is a next generation high-energy gamma-ray observatory designed for making observations of celestial gamma ray sources in the energy band extending from 20 MeV to more than 300 GeV. It follows in the footsteps of the Compton Gamma Ray Observatory EGRET experiment, which was operational between 1991-1999. The Fermi Mission, part of NASA's Office of Space and Science Strategic Plan, launched in June 2008 (Figure 1. The principal instrument of the Fermi mission is the Large Area Telescope (LAT) that is being developed jointly by NASA and the US Dept. of Energy (DOE) and is supported by an international collaboration of 26 institutions lead by Stanford University.

Figure 1: Fermi Launch from Pad 17b, Cape Canaveral on June 11, 2008.

The Fermi LAT is a high-energy pair conversion telescope that has been under development for over 10 years with support from NASA, DOE and international partners. It consists of a precision converter-tracker, CsI hodoscopic calorimeter, plastic scintillator anticoincidence system and a data acquisition system. The design is modular with a 4x4 array of identical tracker and calorimeter modules. The modules are approximately 38 x 38 cm. Figure 2 shows the LAT instrument concept.

The LAT science instrument consists of an Anti Coincidence Detector

(ACD), a silicon-strip detector Tracker (TKR), a hodoscopic CsI Calorimeter (CAL), and a Trigger and Data Flow system (T&DF). The principal purpose of the LAT is to measure the incidence direction, energy and time of cosmic gamma rays while rejecting background from charged cosmic rays and atmospheric albedo gamma rays and particles. The data, filtered by onboard software triggers, are streamed to the spacecraft for data storage and subsequent transmittal to ground-based analysis centers. The Tracker provides the principal trigger for the LAT, converts

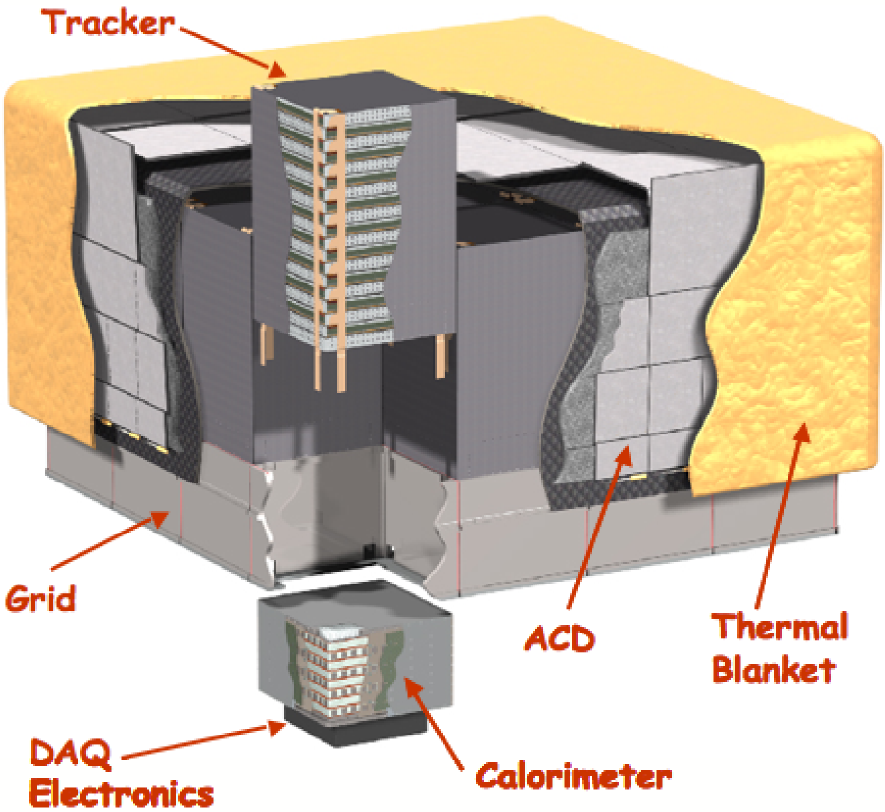

Figure 2: Large Area Telescope. Composed of 16 modules containing Tracker and Calorimeter elements, all surrounded by a scintillator anti-coincidence shield.

the gamma rays into electron-positron pairs, and measures the direction of the incident gamma ray from the charged-particle tracks. The first 12 layers of converter are about 3% X_0, while the next 4 layers (back) are about 18%. This was done to optimize efficiency for photons interacting near the calorimeter. The tracker is crucial in the first levels of background rejection for providing track information to extrapolate cosmic-ray tracks to the ACD scintillator tiles, and it is important for further levels of background analysis due to its capability to provide highly detailed track patterns in each event.

In normal operations the LAT will continually scan the sky, obtaining essentially complete sky coverage every 3 hours (two orbits). This uniformity of sky coverage together with the large effective area and good angular resolution should permit many advances in the study of microquasars in the GeV range. The performance properties of the LAT are summarized in Table 1. The most current LAT performance specifications are kept online[1].

2. Early Gamma Ray Binary Observations

Pre-launch simulations[5], and existing observations, suggested that the binaries sky would be a quiet place in gamma rays, with but two known steady sources (LS 1 +61 303 and LS5039) and suggestions of one short flare[8] in Cyg-X1. Furthermore, LS5039 was expected to be a difficult nut

Table 1: LAT Energy and Angular Resolution

Energy Resolution	≈10% (≈5% off axis)
PSF (68%) at 100 MeV	3.5^0 front; 5^0 total
PSF (68%) at 10 GeV	0.1^0
Field of View	2.4 sr
Point Source Sensitivity (> 100 MeV)	$3\text{x}10^{-9}$ cm^{-2} s^{-1}

to crack due to the busy neighbourhood; simulations indicated it would take months of observation to start separating it from the background.

LS I +61 303 and LS5039 have been observed in GeV gamma rays by EGRET and TeV gamma rays, by HESS[3] and MAGIC[4]. LS 5039 is near the galactic center and has two other nearby sources as well as a significant galactic diffuse background. On the other hand, LS I +61 303 is more isolated and in a lower diffuse background. In addition, their orbital periods differ by almost an order of magnitude.

Early Fermi LAT observations are bearing out these predictions; LS I +61 303 is easily seen above the diffuse background with no nearby point source neighbours and LS5039 is indeed difficult to extract from the first month's survey data.

Indications are that LS I +61 303 and LS5039 are, in fact, pulsars - see the contributions from Dubus[6] and Torres[7] at this meeting for details.

2.1 Detection of LS I +61 303

A counts map for some 23 days of survey mode data taking is shown in Figure 3, confirming it to be isolated and in a low background region.The location is found to be within 0.017 degree of the nominal location of the source.

We are still working out the systematics of our energy spectra, but do find a power law spectral index in rough agreement with EGRET's value of -2.19.

MAGIC has reported a large asymmetry[9] in orbital phase measurement, essentially setting an upper limit on observation for the first half of the phase. With our early collection of data, about 700 gammas above 100 MeV per week, we can separate out the orbit into two halves and see no difference in those halves in spectral index or flux to within about 8%.

2.2 Other Sources

In short, no other xrb's show up in our early searches, except for LS5039 which needs much more data to separate cleanly from the background.

An automated procedure is being put in place to watch some 70 known x-ray binary locations, looking for outburst activity.

3. Timeline

Following its tremendously successful two month commissioning period, Fermi is now engaged in its long term strategy of sky survey observation. The LAT collaboration is already releasing daily light curves for 23 sources, including LS I +61 303. We plan on releasing a high

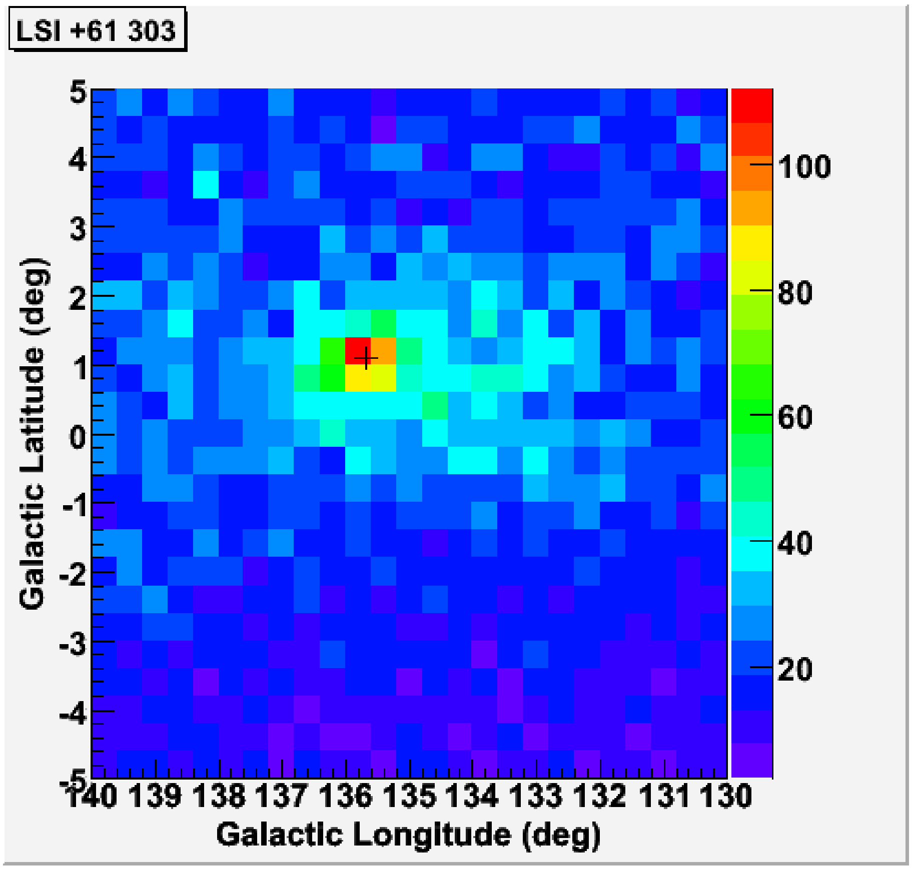

Figure 3: l vs b counts map with E>100 MeV for a 10^0 region around LS I +61 303. The cross denotes the nominal location of the source. The PSF at 1 GeV is about 0.5 degree. There are no other point sources observable.

confidence source list after six months and again at one year. At this lattter time, all LAT data becomes public immediately.

4. Conclusions

Fermi successfully launched in June 2008 and is starting to provide the promised unique view of the gamma ray sky over the 0.1-300 GeV energy range. The large field of view and survey mode of the LAT allow us to monitor all the microquasar candidates on a continuous basis. Commissioning was very smooth, with no major problems to overcome. Our long term sky survey is just underway.

For isolated sources, we will have no difficulty measuring the spectral and orbital period properties for sources with fluxes like those of LS I +61 303 ($\approx 10^{-7}-10^{-6}$ ph $s^{-1}cm^{-2}$) with a few months of survey data. For sources living in confused regions of the sky, like LS 5039, we will need to integrate longer (> 1 year) and make harder energy cuts to bring the signal out above background. The all-sky survey mode of Fermi makes it ideal to spot flaring sources.

5. Acknowledgments

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