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Highligths from the Fermi Large Area Telescope

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Abstract

The Fermi mission is operating in low Earth orbit since June 2008. Thanks to its large acceptance, the Large Area Telescope (LAT), the on-board pair-conversion telescope for high-energy electromagnetic radiation, has collected more than one billion photons from the whole sky above 20 MeV. The LAT also provided the largest high-energy cosmic-ray electron sample to date, with about 10k events above 1 TeV.

This unique database allows the study of thousands of gamma-ray sources of very different nature, from our own Galaxy to distant and active galactic nuclei, as well as addressing fundamental questions of particle astrophysics like the nature of dark matter and the origin of energetic gamma-ray bursts. In addition, cosmic-ray electrons provide a unique probe of the origin and propagation mechanisms of cosmic rays in local galactic environment.

Keywords:
Cosmic rays, γ-ray astrophysics, Dark matter, Source catalogs

1. Introduction

The Universe is basically transparent to γ radiation. Contrary to charged cosmic rays, which are deflected by magnetic fields and rapidly lose memory of their sources, γ-rays carry directional information, while being, compared to neutrinos or gravitational waves, way easier to detect.

1.1. The Fermi mission

The Fermi γ-ray Space Telescope is a NASA mission designed to survey the sky in the broad energy range from 20 MeV to more than 300 GeV, with the additional capability of studying transient phenomena at lower energies and of detecting charged species, notably leptons, from GeV to TeV energies.

The Fermi observatory carries two instruments on-board: the γ-ray Burst Monitor (GBM) [1] and the Large Area Telescope (LAT) [2]. The GBM, sensitive in the energy range between 8 keV and 40 MeV, observes the full unocculted sky with rough directional capabilities – at the level of one to a few degrees – for the study of transient sources, in particular Gamma Ray Bursts (GRBs). The LAT, exploiting state-of-the-art, high-energy physics detector techniques, is designed to detect γ-rays of energy greater than 20 MeV, where pair-conversion is the dominant interaction process.

Fermi was launched on June 11, 2008 and is since then orbiting at an altitude of 565 km with a 25.6 degree inclination. Science operation began on August 4, 2008 and is still ongoing. The large field of view of the telescope (2.5 sr) provides the ability to observe 20% of the sky at any time which, in the nominal scanning mode of operation, translates in a full sky survey every three hours.

1.2. The LAT instrument

The LAT is a 4×4 array of identical towers, each made by a tracker-converter and a calorimeter module. A segmented anti-coincidence detector (ACD) covers the tracker array, and a programmable trigger and data acquisition system completes the instrument.

Each tracker module features 16 tungsten layers, inducing the conversion of γ-rays into e^+/e^- pairs, and 18 x-y pairs of single-sided silicon strip detector planes, for

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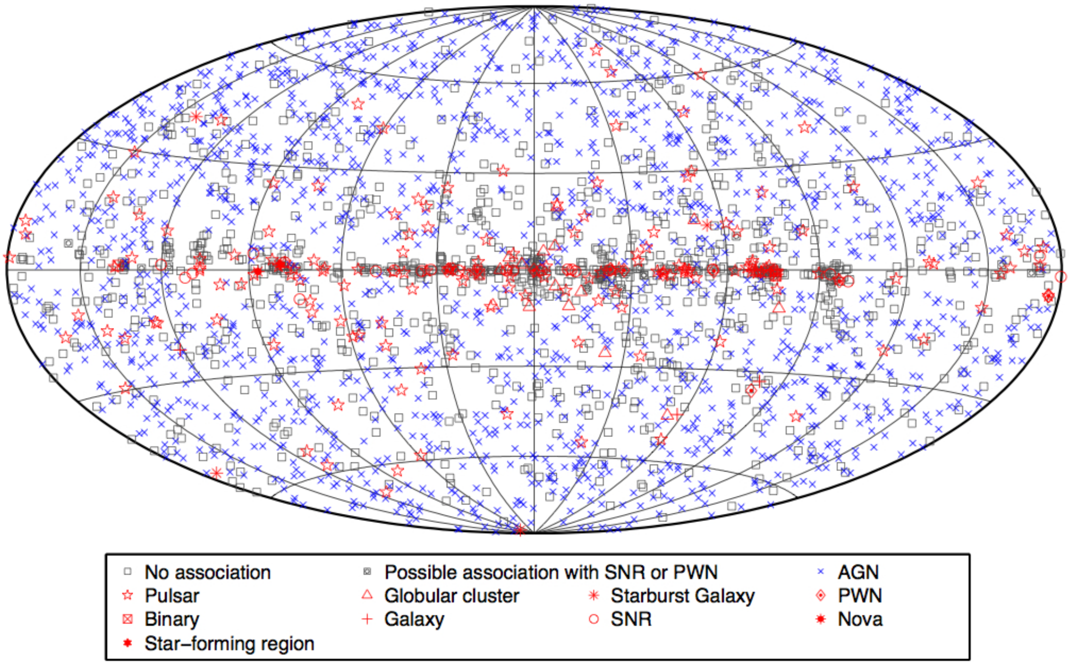

Figure 1: Map of γ-ray sources included in the Third Fermi-LAT Catalog (Aitoff projection in galactic coordinates).

a total of 1.5 radiation lengths of material on-axis. The silicon sensor technology allows precise tracking with no detector-induced dead time and no use of consumables, and the capability to self-trigger.

Each calorimeter module consists of 96 CsI(Tl) crystals, arranged in a hodoscopic configuration for a total depth of $\sim$ 8.6 radiation lengths on axis. The calorimeter provides an intrinsically three-dimensional image of the shower development, which is crucial for both the energy reconstruction, especially at high-energy where a significant part of the shower can leak out of the back of the instrument, and for background rejection.

The ACD, a set of plastic scintillators surrounding the tracker, serves as a veto against the overwhelming background due to charged cosmic rays. In order to limit the self-veto effect due to the backsplash of secondaries from high-energy particles hitting the calorimeter, it is segmented in 89 tiles providing spatial information that can be correlated with the signal from the tracker and the calorimeter. The overall power budget of the LAT is 650 W.

The normal trigger configuration is designed for the rejection of charged particles. However, all events with a raw deposit in the calorimeter greater than 20 GeV are registered. An on-board filter reduces the data rate to be downliked to Earth from about 10 kHz to 300–500 Hz.

2. The Fermi sky

The high-energy γ-ray sky is dominated by diffuse emission: more than 70% of the photons detected by the LAT are produced in the interstellar medium of our Galaxy by interactions of high-energy charged cosmic rays with matter and low-energy radiation fields. This component is highly anisotropic: the emission is peaked toward the galactic plane. However, the γ-ray sky is not really dark in any direction: an additional diffuse component with an almost isotropic distribution, therefore thought to be of extragalactic origin, accounts for another sizable fraction of the LAT photon sample. The rest consists of emission detected from a heterogeneous zoo of sources, galactic and extragalctic, including pulsars and their relativistic Wind Nebulae (PWN), Active Galactic Nuclei (AGN), globular clusters, shock-waves remaining from Supernova explosions (SNR), binary systems, as well as nearby solar-system bodies like the Sun and the Moon.

2.1. The starting point: source catalogs

Compared to what is known at longer wavelengths, a characteristic feature of the γ-ray sky is its rapid vari-