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Recent Results from the Fermi Gamma-ray Space Telescope

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The Fermi Gamma-ray Space Telescope, formerly named GLAST, is a mission in low-Earth orbit to observe gamma rays from the cosmos in the broad energy range from 20 MeV to >300 GeV, with supporting observations of gamma-ray bursts from 8 keV to 30 MeV. The telescope far surpasses previous generations in its ability to detect and localize faint gamma-ray sources, as well as its ability to see 20% of the sky at any instant and scan the entire sky on a timescale of a few hours. With its launch on 11 June 2008, Fermi opened a new and exciting window on a wide variety of exotic astrophysical objects and is enabling new research on such topics as the origin and circulation of cosmic rays and searches for hypothetical new phenomena such as annihilation of dark matter. In addition to introducing the mission and the instruments, we summarize the latest catalogs of sources, including active galaxies and pulsars, and we present some of the latest results on diffuse gamma-ray production, dark matter searches, and gamma-ray bursts.

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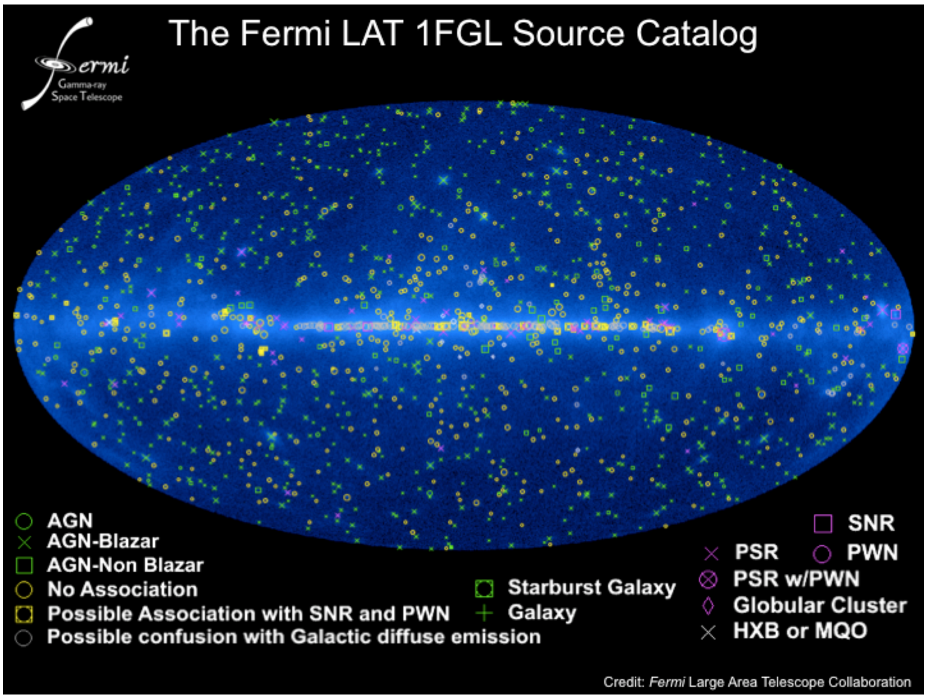

Figure 1. All-sky view of photons above 200 MeV, with catalog source locations.

1. Introduction

The Fermi observatory, launched into low Earth orbit on June 11, 2008, includes two instruments: the Gamma-ray Burst Monitor (GBM) [1], and the Large Area Telescope (LAT) [2]. The GBM detectors photons from 8 keV to 30 MeV with rough directionality for transient point sources, while the LAT is a pair-conversion telescope for photons from about 20 MeV to hundreds of GeV. The LAT is a 4×4 array of tracker/converter modules, based on tungsten foils interleaved with silicon-strip detectors, and calorimeter modules, based on CsI crystals read out by photodiodes. A system of anti-coincidence detectors, based on plastic scintillators read out by waveshifting fibers and photomultiplier tubes, surrounds the top and sides to reject background from charged cosmic rays.

The Fermi instruments have very large fields of view. The GBM sees the full unocculted sky, while the LAT sees more than 20% of the full 4π sr at any instant. Therefore, the normal operating mode is to scan the sky, rocked 50° from the zenith toward, on alternating orbits, the north and south orbital poles. This provides a fairly uniform exposure over the full sky in the course of a day or, especially, a year. Important for transients, it provides a view of any point in the sky every 180 minutes.

2. Source Catalogs

The Fermi-LAT collaboration has published a catalog of 1451 sources of greater than 4σ significance from the first 11 months of data [3]. The source locations are plotted in Figure 1, together with a list of their types. The largest class of sources is made up of 689 active galaxies, most of them roughly equally divided between flat-spectrum radio quasars and BL-LAC blazars [4]. There are also more than 56 pulsars detected with gamma-ray pulsation [5], both energetic young pulsars and the first set of high-confidence detections of millisecond gamma-ray pulsars [6]. Of the young pulsars, 24 were previously unknown pulsars discovered by the Fermi-LAT alone (of which 21 have no detectable radio emission) [7][8].

3. Gamma-Ray Bursts and Lorenz Invariance Violation

As of April 2010 at total of 427 Gamma-Ray Bursts (GRB) were observed by the Fermi-GBM, about half of which were also within the LAT field of view. Of those, only 16 were detected by the LAT with high energy emission, with photon energies up to 31 GeV. The highest energy photon, in GRB-090510, was used to set a conservative lower limit on a quantum gravity scale that could lead to Lorentz invariance violation of 1.2 times the Planck mass [9].

4. Electron Spectrum and Anisotropy

The Fermi-LAT measurement of the electron spectrum has been updated by a low-energy analysis from 7 to 20 GeV that matches well with the existing high-energy analysis, even though the two rely upon independent triggers [10]. The high-energy analysis was also repeated by selecting only tracks that pass through at least 12 radiation lengths of material (with an average of 16 radiation lengths). The results have lower statistical power but are consistent with the previously published spectrum [11], conclusively ruling out any sharp peak in the five to six hundred GeV region. Another recent study has set upper limits on the anisotropy in the cosmic-ray electron arrival directions [12].

5. Diffuse Emission and Dark Matter Searches

The first Fermi-LAT publication on the Galactic diffuse emission [13] conclusively ruled out the so-called GeV excess reported by EGRET [14], as well as any hope for an unexpectedly large contribution from dark-matter annihilation. Work is in progress to calculate robust upper limits on the annihilation cross section (versus WIMP mass) from dark matter in the Galactic halo. However, upper limits have been reported from observations of dwarf spheroidal galaxies [15] and galaxy clusters [16], none of which so far show significant gamma-ray emission (not counting emission from AGN in clusters). The dwarf-galaxy limits are probably the most robust, because stellar velocity-dispersion measurements have given us relatively clear measurements of the dark-matter content. At 100 GeV the best limits are about a factor of 4 higher than the $\sigma v \approx 3\times10^{-26}$ cm^3/s expected in models based on cosmological thermal WIMP production. A factor of 10 more data, a combined analysis of all dwarfs, and a larger selection of dwarfs from more complete surveys of the sky could bring the Fermi-LAT sensitivity into some of the most interesting regions of model space.

The Fermi-LAT collaboration has also published a measurement of the isotropic diffuse gamma-ray spectrum up to 100 GeV [17], believed to be mostly due to extragalactic sources. When conservatively interpreted in terms of dark matter annihilation, cross-section upper limits were calculated that are similar to those obtained from the dwarfs but are very sensitive to the assumed cosmological model for structure evolution [18].

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