FERMI/GLAST and the Future of High Energy Gamma Ray Astronomy

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1 Introduction

The Fermi Gamma-ray Space Telescope is an observatory for the study of γ-ray emission from astrophysical sources. Fermi has two main instruments: (1) the Large Area Telescope (LAT), a γ-ray imager operating in the energy band between 30 MeV and 300GeV; (2) the Gamma Ray Burst Monitor (GBM), a detector covering the 8keV-20MeV energy range, devoted to the study of the Gamma Ray Bursts. Detailed descriptions of Fermi, which was previously known as GLAST, are in [1], [2] and [3].

Previous studies of the γ-ray sources in the LAT energy band were performed with the Energetic Gamma Ray Experiment Telescope (EGRET) onboard of the Compton Gamma Ray Oservatory between 1991 and 2000. EGRET detected 271 sources [4], an half of which unidentified, mainly because of the relatively large errors associated with the source location. The majority of the identified EGRET sources are pulsars (spinning neutron stars, with powerful magnetic field, capable to accelerated particles up to the high energy regime) or Flat Spectrum Radio Quasars and Blazars (active galactic nuclei, with relativistic jets of plasma). Furthermore diffuse galactic and extra-galactic γ-ray emission was detected with EGRET.

The LAT instrument has an effective area five times larger and a much better angular resolution, if compared with EGRET, then Fermi has a sensitivity 30 times better than its predecessor. Fermi scientific objectives span from the detailed study of pulsar, AGNs and diffuse emission, to the search for new classes of γ-ray emitters and the possible signals of new physics, such as from the dark matter (DM). The GBM adds the study of Gamma Ray Bursts, up to GeV energies, to the scientific objectives of the observatory [5].

An international collaboration was set up in order to build and operate Fermi. This collaboration is made of more than 300 members, both astrophysicists and particle physicists, coming from institutions of France, Italy, Japan, Spain, Sweden and

United States of America. Fermi was launched the 11th June of 2008, with a Delta II 7920H rocket, and it is foreseen to be operated for 10 years. In August the observatory was renamed in honour of Enrico Fermi.

2 The Large Area Telescope

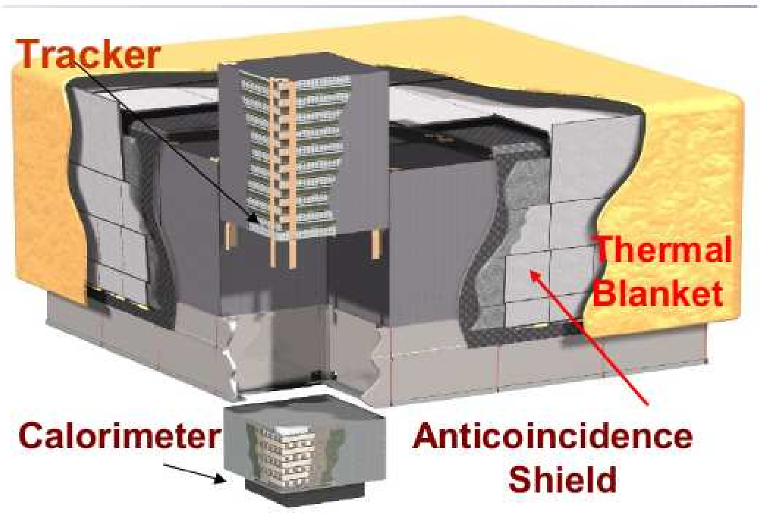

Figure 1: The LAT instrument and the sub-detectors.

LAT is a *pair conversion telescope*. With this type of instrument: (a) the γ rays interact with the instrument mainly by means of electron-positron pair production; (b) the electron and positron trajectories are tracked with precision; (c) the incoming direction of the parent gamma is reconstucted with the electron and positron trajectories; (d) the energy of electron and positron are measured with a calorimeter located at the bottom side of the tracker; (e) the telescope is shielded by an anti-coincidence detector, which covers the tracker and rejects the majority of the charged particles.

LAT is a modular instrument composed by 4×4 units dubbed *towers*, with total dimensions of $1733 \times 1733 \times 970$ mm. Each tower is composed by a tracker and a calorimeter section. The tracker is composed by 18 double planes of single-sided silicon-strip detectors (pitch = 0.288μm). The first 12 planes are interleaved with 0.035 X_0 of tungsten, while the next 4 with $0.18X_0$ and the last 2 without any converter layer. This pattern is used for optimizing both the gamma ray conversion and the tracking precision. The LAT trackers form a quite large silicon detector with a total surface of ≈ 80 m^2 and 8.8×10^5 readout channels.

Each of the 16 LAT calorimeters contains 96 CsI(Tl) cristals, with dimension of 326 × 27 × 20 mm, read by two PIN photodiodes. The dynamical range for each cristal is 20MeV - 70GeV. The total depth of the calorimeters is $8.5X_0$

The LAT anti-coincidence veto (ACD) is composed by 89 plastic scintillator tiles, with an overall efficiency of >0.9997 in response to the passage of charged particles. ACD surrounds the LAT towers. High Energy gamma rays can create secondary charged particles, which might interact with a monolithic veto and severely reduce the telescope sensitivity of a pair conversion telescope (*self-veto effect*). The ACD segmentation is reducing this effect.

The LAT instrument has a large field of view of 2.4sr and an effective area of ≈ 8000cm^2 for normal incedence at 1GeV. Furthermore the silicon detectors provide high angular resolution (0.15, 0.9 and 3.5 ° of single photon angular resolution, respectively at 10, 1 and 0.1 GeV). These factors allows one to get a sensitivity in order of $1.6 \times 10^{-9}\text{ph/cm}^2\text{s}$ in two years above 100MeV. Further improvements in respect of the past gamma ray missions are the energy resolution of 10-20 % and the timing accuracy of <10 μs

3 The Indirect Search for Dark Matter with Fermi

The estimated Universe energy content [6] is : 4% of baryonic *ordinary* matter, 23% of *Dark Matter* (DM) and 73% of *Dark Energy.* There are several evidences of the DM existence (see [7],[8],[9],[10],[11],[12]). Non-gravitational DM couplings are studied with: (1) the direct search for DM scattering on ordinary matter; (2) the indirect study of DM annihilation via the secondary products, both charged and neutral (e^+, $\overline{p}$, $\overline{d}$, ν, γ rays and lower frequency electro-magnetic radiation). For weakly interacting massive particles (WIMPs) of Maiorana the heavy fermions pairs, such as $b\bar{b}$,$t\bar{t}$, $\tau^+\tau^-$, are favoured as annihilation products [13]. The annihilation in two γ rays is loop-suppressed, with a braching ratio of 10^{-3}-10^{-4}, but γ-ray emission is expected after the decay of heavy fermions.

Then γ-ray observations can be used for the indirect search for annihilating Dark Matter [14]. Many possible observation strategies are currently carried out by the Fermi Dark Matter Working group (see Tab. 1). One of these is the targeting of regions where high DM density is foreseen, such as the Galactic Center or the Spheroidal Dwarf Galaxies.

For example the annihilating DM γ-ray flux, from the Galactic Center (GC) can be expressed as: $\Phi_{DM} = \sum b_i \frac{dN_{\gamma,i}}{dE_\gamma} \frac{\sigma v}{8\pi m_X^2} \int_{los} \rho^2(l)dl$ where σv is the DM annihilation cross section times the relative particles velocities, m_X = DM particle mass, ρ(r) = DM density as a function GC distance, the integral is performed along the line-of-sight, $\frac{dN_\gamma}{dE_\gamma}$ = annihilation γ-ray yield and b_i the braching ratio. DM forms halos with central density enhancements and the Milky Way is embedded in

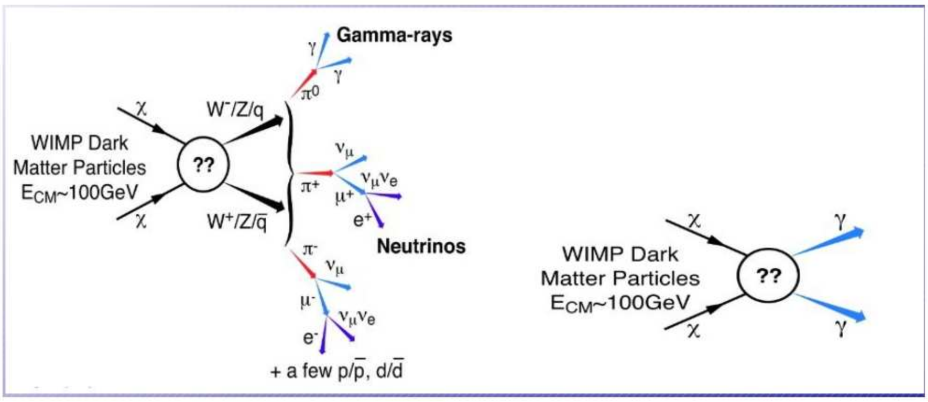

Figure 2: A cartoon on the possible WIMPs annihilation channels, from [14]

one of such structures. The galactic density profile is commonly parametrized as $\rho(r) = \frac{\rho_0}{(r/R)^{\gamma}\ (1+(r/R)^{\alpha})^{(\beta-\gamma)/\alpha}}$ with R $\approx$ 20 kpc as scale radius, ρ_0 fixed such as the DM density= 0.3 GeV/cm^3 in the Sun region. The other three parameters are defining the profile type: Navarro-Frenk-White (NFW, [15]) has α=1, β=3, γ=1; Moore profile [16] has α=1.5 β=3, γ=1.5.

The density profile is essential for the DM indirect study in the γ-ray channel as:(1) the γ-ray flux goes as ρ^2 and can be above or below the detection threshold as function of the profile type; (2) some density profiles might be detected as extended sources. The spatial information and the peculiar energy spectrum, expected by a DM source, will be fundamental in the GC region, where bright γ-ray sources are located. LAT is the most sensitive instrument in the 30MeV-300GeV band, and is well suited for the indirect DM investigations.

4 Summary

Fermi was successfully launched the 11th June of 2008, and is now taking data in the nominal regime. Early results have already been published, such as the discovery of a pulsar in CTA 1 [17], more than 12 alerts for flaring AGNs and for the detection of GRB 080916C above 1 GeV [18]. Furthermore the most sensitive indirect search for annihilating DM, in the H.E. γ-ray band is ongoing with the Fermi data. First constraints to the DM theories are expected within 1 year from the launch.

Target	Advantages	Challenges
Galactic Center	good statistics	source confusion galactic diffuse background
Galactic Halo	very good statistics	galactic diffuse background
Galaxy Satellites	low background good source identification	low statistics
Spectral Lines	no astrophysical uncertainties good source identification	low statistics
Extragalactic	very good statistics	galactic diffuse background

Table 1: Main targets for the search for annihilating DM with Fermi [14]

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