

Cosmological dark matter annihilation with the Fermi-LAT

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Abstract. The Fermi Gamma-Ray Space Telescope has been in orbit since June 2008. It will map the high-energy gamma-ray universe with previous unprecedented accuracy. Amongst the many spectacular high-energy phenomena of the Universe, the Fermi-LAT, the biggest of the two experiments onboard the telescope, has the capability to look for traces of the elusive dark matter, a mayor component of the Universe with a so far unknown identity.

This work summarizes the Fermi-LAT collaborations effort to look for a WIMP dark matter component in the extra-galactic diffuse gamma-ray background (EGB). Such a signal originates from unresolved halos of dark matter, where WIMPs pair annihilate, resulting in high-energy gamma-rays. We present confidence intervals on WIMP masses and cross sections for certain configurations of dark matter halo properties and evolution.

Keywords: Dark Matter Cosmology Extra-galactic

I. INTRODUCTION

The constituents and exact properties of dark matter is still an unsolved mystery of the Universe. In the combined effort of the Fermi collaboration to search for indirect signals of dark matter we use a variety of methods and cover a range of regions where the signal is expected to be high

Among the regions of interest that we investigate are: the galactic center, where the density of dark matter is believed to be highest. The host halo of our galaxy, giving rise to a diffuse signal. Overdensities, or clumps, of dark matter where the signal is believed to be enhanced.

In this work we investigate the possible signal of a cosmological origin, originating from WIMPs annihilating in halos which are individually unresolved and thus contributing to an approximately isotropic diffuse emission.

Attempts to fit a cosmological WIMP to the EGB measured by EGRET [2], has been done by Elsaesser and Mannheim (2004) [3] where they find that a neutralino, as the lightest supersymmetric particle, with a mass $M_\chi \approx 500$ GeV is the best fit to the data. However, due to the the large uncertainties both in the data and in the background model, consisting of diffuse emission from a population of unresolved blazars, they do not claim a detection. (Also see [4] for another attempt to fit the EGB)

Using the Fermi-LAT [1] measured EGB (also presented at this conference) we present new limits on a

signal from cosmological WIMPs.

II. SIGNAL

The energy spectrum of photons originating from cosmological WIMPs is derived in the same way as by Ullio et al (2001) [5]. A similar, but more recent, calculations of the cosmological WIMP energy spectrum can be found in for instance [6]. The shape and normalization of the signal depends on the properties of the dark matter halos and their distribution as a function of redshift. These are primarily investigated through large N-body simulations of dark matter interacting gravitationally in an expanding universe. We use the same halo properties as in [7].

An example of an energy spectrum from a 100 GeV cosmological WIMP can be seen in figure 1. This example was calculated using a NFW halo profile and without the effect of substructures. Changing to a steeper profile or including moderate levels of substructures could boost the normalizations by almost two orders of magnitude.

At high energies the signal is strongly affected by the absorption of high-energy gamma-rays on the extra-galactic background light (EBL). Various studies of the EBL have been done (see for instance [8] or [9] and references therein). By observing high energy sources at different redshift the Fermi-LAT will provide information on the EBL and how it affects the absorption of high-energy gamma-rays. For this work we use the same parameterization of the optical depth as in [7].

A variety of different extensions of the Standard model of particle physics have been suggested that, through pair annihilation, could produce strong enough fluxes of gamma-rays to be observed by the Fermi Lat [7], such as Kaluza Klein, supersymmetric or Inert Higgs models. However, to a large extent these models are degenerate with respect to the gamma-ray spectrum and it would not be easy to distinguish between them. Therefore we adopt a generic particle physics model parameterized by the WIMP mass and pair annihilation cross section. These parameters should be at the electroweak scale in order to reproduce the observed relic abundance of dark matter. However, there are other particle physics models which are not WIMP-like, such as axions, where we do not expect to see any signal from pair annihilating into gamma-rays.

Following [7] we assume annihilation into $b\bar{b}$, that hadronizes into final states of photons, and a branching of 10^{-3} into the one loop process of a two photon final state, resulting in a monochromatic line. Since

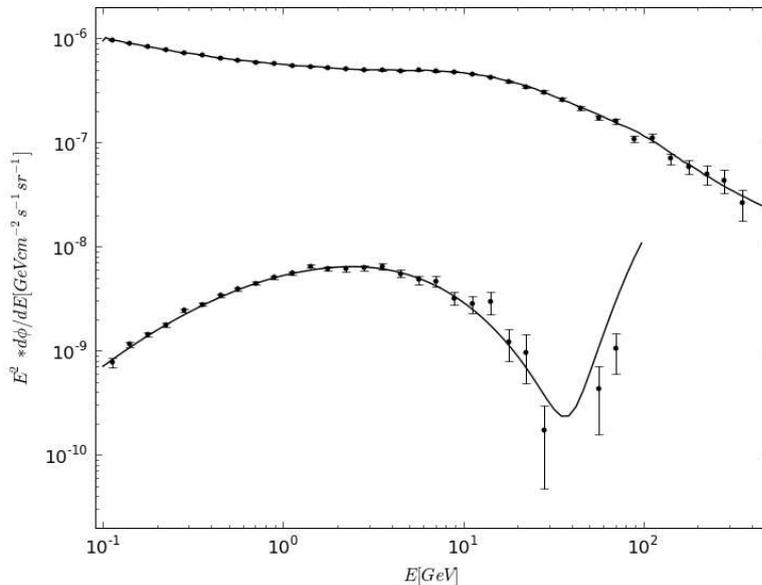


Fig. 1. The unresolved blazar model from [5] and an example of a generic cosmological WIMP with a 100 GeV mass, annihilating into bb with a cross section of $\sigma v = 3 \cdot 10^{-26} \text{ cm}^3 \text{ s}^{-1}$ and a branching of 10^{-3} into the two photon final state. The datapoints represents the deconvolved spectra from the equivalence of one year of exposure.

the annihilations take place during the evolution of the Universe the line is smeared over redshift resulting in a striking feature in the observed spectra at high energies.

III. BACKGROUND

The largest contribution to the EGB is believed to originate from unresolved point sources, the largest such from unresolved active galactic nuclei. But also other sources are believed to contribute such as ordinary galaxies, starbursting galaxies and merging clusters of galaxies. See [10] for an overview.

The gamma-ray properties of the individual populations of sources will be studied in much greater detail using the Fermi-LAT which will increase our understanding of their contribution to the EGB.

IV. ANALYSIS

To obtain the EGB spectrum from the photon count data, the response of the Fermi-LAT has to be deconvolved. This introduces systematic uncertainties in the determined spectrum and to be able to do a consistent comparison when applying our statistical analysis, we apply the same de-convolution method to the WIMP signal spectra.

The WIMP signal is calculated on a $n_{\text{side}} = 128$ Healpix [11] grid, with isotropic angular distribution, from which the counts are calculated by convolution of the Fermi PSF and the same exposure as used for the measurement of the EGB. Finally Poisson numbers are drawn to mimic statistical uncertainties. Dividing the obtained counts with the original WIMP flux yields an exposure map with the correct energy dependence. The

WIMP flux that is compared with data is then derived by dividing the count by that exposure.

As a cross check of the de-convolution method, in figure 1 we show an example of a spectrum originating from a 100 GeV generic cosmological WIMP together with what would be the de-convolved spectra from that source after the equivalents of one year of exposure. Also shown in figure 1 is the background originating from unresolved blazars derived in [5].

In our statistical method we will not introduce the statistical uncertainties in the signal but only the systematic errors introduced by the de-convolution method.

At the conference we will present confidence limits on the WIMP mass and cross section.

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