Dark Matter implications of Fermi-LAT measurement of anisotropies in the gamma-ray diffuse background

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For the first time, the Fermi-LAT measured the angular power spectrum (APS) of anisotropies in the diffuse gamma-ray background at the GeV energies. The results (that will be presented at this Symposium) consist of the detection of angular power with a significance of a few σ. The data is found to be independent on the multipole (above l=154) and incompatible with a model with contributions from the point sources in the 1-year catalog, the Galactic diffuse background and the extragalactic isotropic emission. In this study we complement the model with a contribution from Dark Matter (DM) whose distribution is modeled exploiting the results of the most recent *N*-body simulations, considering both the contribution of extragalactic halos and subhalos (from Millennium-II) and of Galactic substructures (from Aquarius). With the use of the Fermi Science Tools, these simulations serve as templates to produce mock gamma-ray count maps for DM gamma-ray emission, both in the case of an annihilating and a decaying DM candidate. The APS will then be compared with the Fermi-LAT results to derive constraints on the DM particle physics properties. The possible systematics due to an imperfect model of the Galactic foreground will also be studied and taken into account properly.

The goal of the project is to derive constraints on the particle physics characteristics of a WIMP Dark Matter (DM) particle from the analysis of the angular anisotropies of the gamma-ray emission due to DM annihilation or decay, in comparison with the recent data provided by the Fermi-LAT telescope on the anisotropies of gamma-ray diffuse emission [1,2,3]. The first part of the project is devoted to the computation of realistic maps of gamma-ray emission from DM annihilation/decay. The DM distribution is tuned to the results of the most recent *N*-body simulations: Millennium-II for extragalactic DM structures and substructures, and Aquarius for the halo of the Milky Way and its hierarchy of substructures. Details on the computation of the DM template maps will be discussed in Sections I and II, and represent the subject of a first paper in preparation [4]. The angular power spectrum (APS) of anisotropies will then be computed from the template DM maps. The results will be compared to the APS obtained from the first 22 months of Fermi-LAT data: the detection of angular power above multipole l=154 can thus be used here to put constraints on the DM annihilation cross section or decay lifetime (Sec. III).

I. Extragalactic emission

Extragalactic DM distribution is modeled following the results of the Millennium-II *N*-body simulation [5]. Exact copies of the original simulation box (with a size of 100 Mpc/h) are used to fill concentric shells situated at increasing distances from the observer, in order to map a volume much larger than the original simulation box. The technique has already been used in Ref. [6] and each shell is randomly rotated in order to avoid unwanted repetition of the same structures along the line of sight. The contribution of DM halos and subhalos with a mass below the mass resolution of Millennium-II (M_{res}) is also considered. Main halos are Monte Carlo simulated down to a minimal mass M_{min} of $10^{-6}M_{\odot}$, assuming that their two-point correlation function remains the same as that of the smallest objects just above M_{res}. The contribution of their subhalos, on the contrary, will be analytically estimated following the results of Refs. [7,8] , once again driven from *N*-body simulations. In Fig. 1 you can see a map of gamma-ray emission from DM decay (left panel) or annihilation (right panel) if only objects above M_{res} are considered.

II. Galactic emission

For the case of Galactic DM we will refer to Aquarius [9]: apart from the smooth DM halo of the Milky Way and its resolved subhalos, the substructures content will be extended down to M_{min}, using a method consistent with that used for the extragalactic component. The extrapolation will be done by means of an hybrid method similar to the one used in Ref. [10], Monte Carlo simulating each DM subhalo until a certain maximal distance from the observer.

III. Comparison with Fermi-LAT data

The Fermi-LAT measured for the first time the APS of anisotropies in the data gathered during the first 22 months of operation. 4 energy bins have been considered from 1 to 50 GeV [1]. Angular power has been found above the photon noise in the first three energy bins (from 1 GeV to 10 GeV) and for multipoles above l=154. The signal is found to be constant in multipole and not compatible with a source model made of *i)* the point sources in the 1 year catalog, *ii)* either one of two Galactic foreground models and *iii)* isotropic background from residual emission and particle contamination (`isotropic_iem_v02.txt`). A mask is applied covering the point sources and the region within $|b|<30°$ to reduce the effect of the Galactic foreground and of the anisotropies of the point sources. The signal can be see in the upper panel of Fig.2 and the comparison with the source model is reported in the lower panel of Fig.2 (taken from Ref.[1]). The signal appears to be compatible with that expected from a population of unresolved gamma-ray emitters. In the present work we use this measurement to derive constraints on the nature of the DM particle: the template DM maps described in Secs. I and II will be included in the source model, the simulation of the DM events and their analysis will be performed with the Fermi Science Tools, exploiting the most recent instrument response functions. Moreover the possible systematic effects of the Galactic foreground will be studied. Different DM particle physics models will be considered in order to draw exclusion plots. Following the estimates in Refs. [11,12], for the case of an annihilating DM candidate with a mass around 100 GeV, the exclusion line can reach the thermal value of the annihilation cross section.

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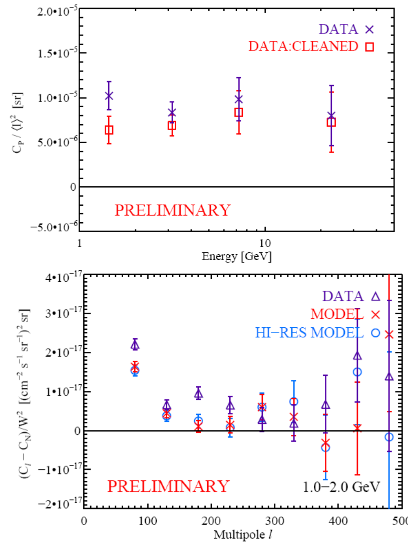

Figure 2: (upper panel) APS measured by the Fermi-LAT from the first 22-months of data as a function of the energy. The average APS in the multipole range between l=104 and 504 is reported. (botton panel) Comparison of the APS from the data and the contribution with two source models differing for the modelization of the Galactic foreground. Taken from Ref.[1].

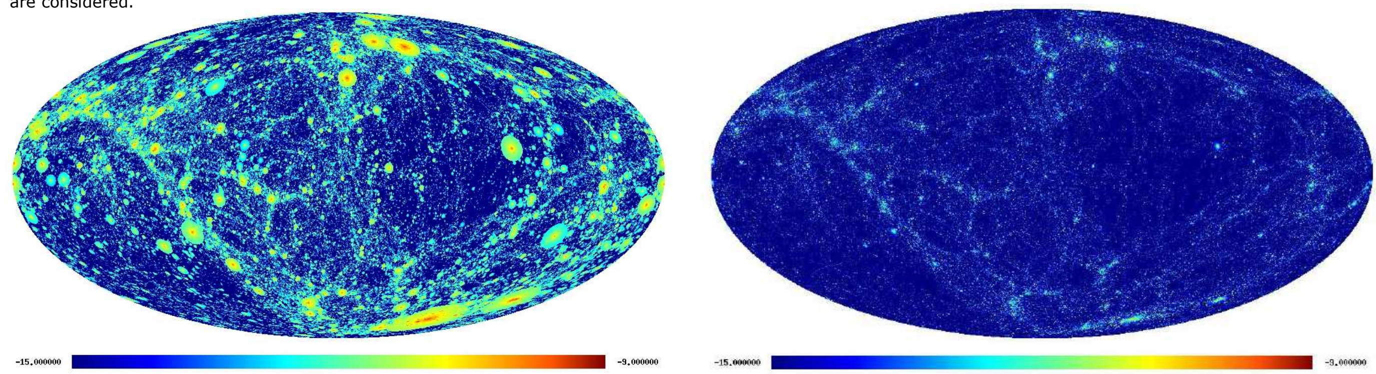

Figure 1: Gamma-ray emission in $cm^{-2}\ s^{-1}$ from a decaying DM particle with a mass of 2 TeV and a decay lifetime of 3×10^{27} s (left panel) and an annihilating DM particle with a mass of 200 GeV and $(\sigma v)=3\times10^{-26}cm^3s^{-1}$ (right panel). The emission is at 10 GeV. Only halos and subhalos in the first snapshot (z=0) of the Millennium-II *N*-body simulation are considered.