Indirect Search for Dark Matter from the center of the Milky Way with Fermi-Large Area Telescope

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Summary: the update of the data analysis for the indirect search of Dark Matter from the Center of the Galaxy.

Abstract

Dark Matter (DM) as weakly interacting massive particle could annihilate or decay and give rise to high energy gamma-rays. Then an indirect search for Dark Matter is possible by means of the Large Area Telescope on board the Fermi satellite. A relatively large signal is expected from the regions where the Dark Matter is expected to have the greatest density, such as the central region of the Milky Way. This region also hosts many high-energy gamma ray sources, of many different classes. Furthermore diffuse emission due to cosmic ray interaction with interstellar gas and radiation is detected from the same direction. A greatly improved understanding of the gamma ray emission from the Galactic Center region is going to be obtained with the Fermi LAT first-year data. The data along with refined modelling of the diffuse emission and a careful evaluation of the discrete sources will improve our ability to disentangle a potential dark matter signal from the astrophysical background and to place new limits on the mass and annihilation rate (or lifetime) of Dark Matter particles

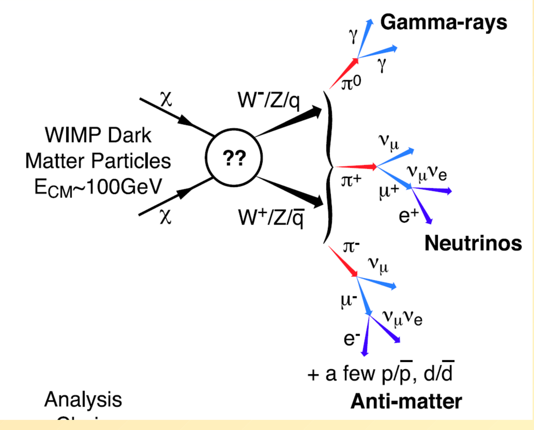
Dark Matter particles might produce gamma rays:
1) if the DM particles self-annihilate in pairs. This yields a continuum gamma ray emission with a cut-off at DM particle mass, produced by hadronization (or final state radiation) of the annihilation products. The direct production of two gammas as annihilation products is suppressed in many models (10^{-3}-10^{-4} of the continuum);
2) if pseudo-stable DM particles decay in gammas. In this case the gamma ray flux is proportional to the DM particle density. The DM decay constant is bound to be larger than 10^{26} sec and is model dependent.
The gamma ray flux from DM particle annihilation can be decomposed in a Particle physics factor and an Astrophysical one.

$$\phi_{WIMP}(E,\psi) = \frac{1}{2}\frac{<\sigma v>}{4\pi}\sum_f \frac{dN_f}{dE}B_f \int_{\mathrm{l.o.s}} dl(\psi)\frac{\rho(l)^2}{m^2_{WIMP}}$$

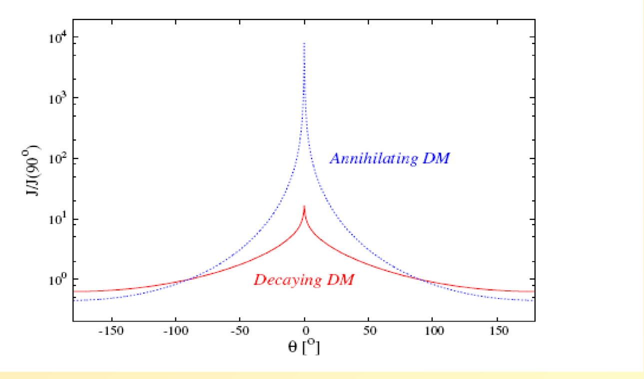
Gamma ray flux from annihilation

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma,\Omega) = \frac{\Gamma}{4\pi m_{\mathrm{DM}}}\frac{dN_\gamma}{dE_\gamma}\int_{\mathrm{los}} \rho_{\mathrm{DM}}(r,\Omega)dr$$

Gamma ray flux from decay

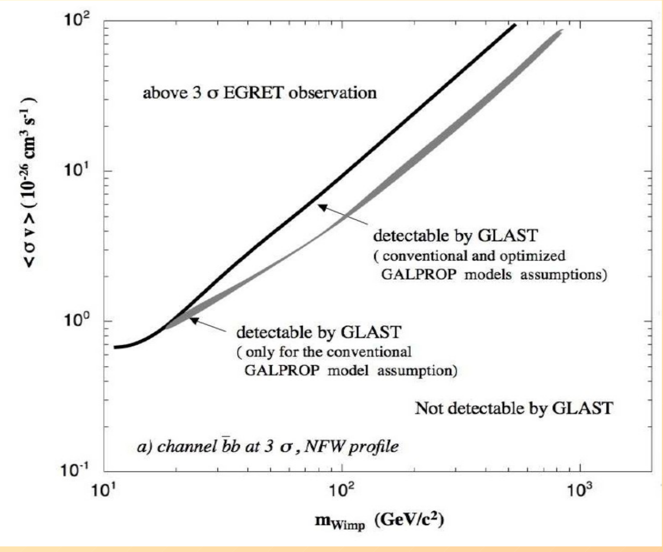


Gamma ray production scheme for DM annihilation

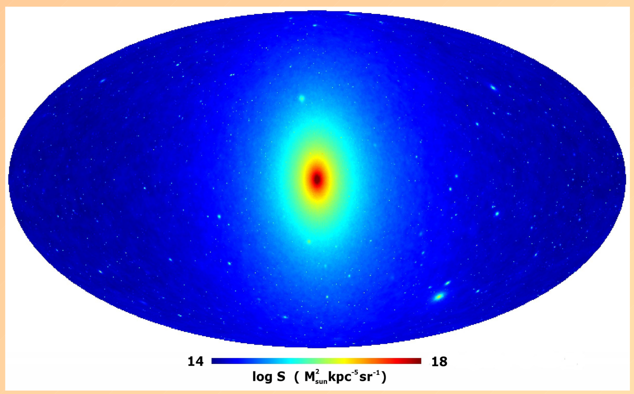


Comparison of expected gamma ray emission profile in the case of annihilating (proportional to the square of the density) and decaying (proportional to the density) Dark Matter particles.

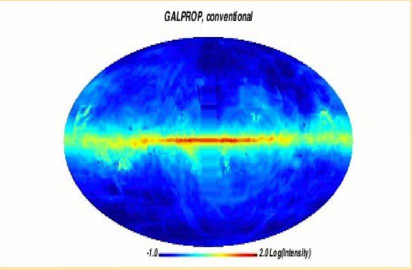
Bertone et al. JCAP 0711:003,2007



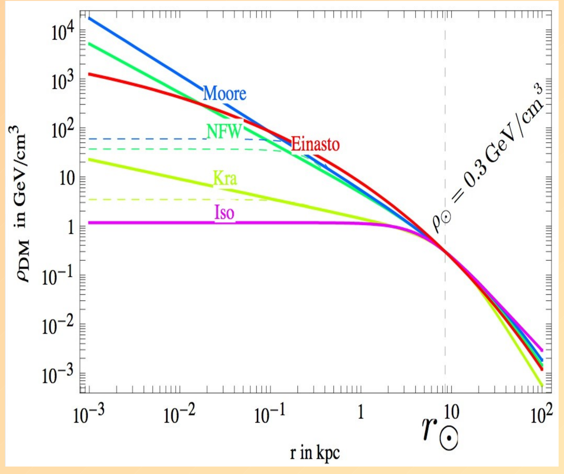
In a pre-launch publication (Baltz et al JCAP 2008, 7, 13) the foreseen constraints to the <σv> parameter, which can be obtained with observations of the Galactic Center, with the LAT, are reported. The plot shows the constraints in <σv> vs WIMP mass for an assumed pure b-b bar annihilation channel



A model of Galactic Diffuse background



Springel at al. NATURE 456, 44, simulated gamma emission from an annihilating DM halo



Comparison of DM density profile parametrization, obtained with fits of the N-body simulations

N-body simulations predict that Dark Matter is arranged in large structures called "halos". DM halos have a central density enhancement, from which a larger gamma ray emission is expected. Our Galaxy could be embedded in a DM halo with the central density enhancement co-located with the Galactic Center. Then the Galactic Center might be the brightest source of gamma rays coming from DM annihilation and it might be possible to detect such an emission. An indirect search for DM by means of gamma ray observations from the Galactic Center is then possible. The DM gamma ray emission is expected to be a function of the DM density profile, which is not experimentally known in the center of the Galaxy. Another problem comes from a major gamma ray background, which is generated both by discrete sources and diffuse emissions in the Galactic Center.

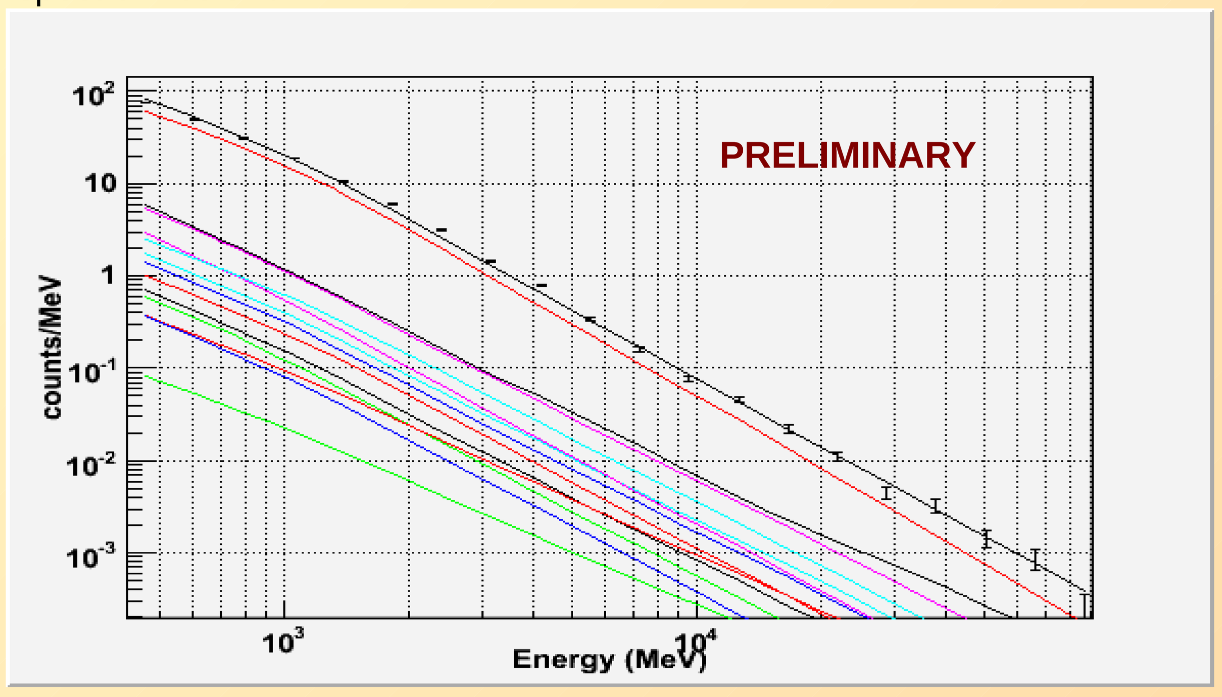
First results on the Galactic Center region are in the "Bright Source List" publication (2009, ApJS 183,46), where all the sources detected with the LAT above 10σ in 3 months are reported. The 0FGL J1746.0-29.00 is likely the source closest to the dynamical center of the of the Galaxy.

Source	l (°)	b (°)	θ_{95} (°)	Int.Flux(1<E<100GeV) $cm^{-2}s^{-1}$ 10^{-8}
0FGL J1732.8-3135	356.287	0.920	0.087	3.890±0.33
0FGL J1741.4-3046	357.959	-0.189	0.197	2.00±0.31
0FGL J1746.0-2900	359.988	-0.111	0.068	7.92±0.47

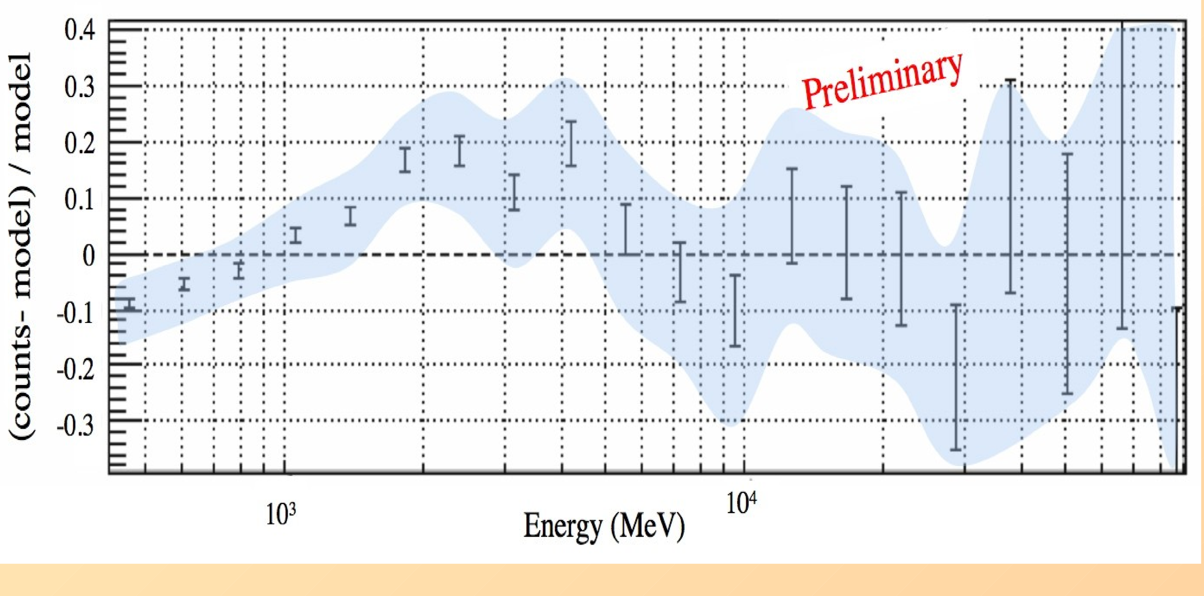
Sources in the "Bright Source List", which are close to the Galactic Center

A previous preliminary analysis was performed on data taken during 8 months. A 1°X1° region was considered. Data with energy between 200MeV and 40GeV and the diffuse class have been selected. A sub-optimal analysis, based on the spectral information only was performed. It was possible to put an upper limit of 2.43±0.02 10^{-7} $cm^{-2}s^{-1}$ (95% confidence level, above 100MeV) to the integral gamma ray flux from a DM annihilation source, which was assumed to have a Navarro-Frenk-White density profile. If a DM particle mass of 50GeV is considered then an upper limit of 39.8 10^{-26} cm^3s^{-1} to the <σv> parameter is obtained

Any attempt to disentangle a potential dark matter signal from the galactic center region requires deep understanding of the conventional astrophysics background. A preliminary analysis of the Fermi/LAT observations of the Galactic Center is reported. The analysis is performed with data collected during the first 11 months of operation. A 7°x7° region centered on the Galactic Center was analyzed with binned likelihood analysis (gtlike). The data were selected to have energy above 400MeV, to be of diffuse class (high quality data), to have converted in the front part of the tracker, and to satisfy other quality requirements. The P6_v3 Instrument Response Function was used. In order to model the observed data a Galactic Diffuse emission model (gll_iem_54_87Xexph7S.fit) , based on the GALPROP code and Extragalactic Diffuse emission model have been used to fit the data plus the model of 11 sources in the Fermi 1 year catalog (to be published) contained in the region of interest . Only the total GALPROP model is varied, not the components. The bulk of the gamma ray emission from this region is explained by means of the above described components, but a residual emission is left.The systematic uncertainty of the effective area of the LAT is ~10% at 100 MeV, decreasing to 5% at 560 MeV and increasing to 20% at 10 GeV. This uncertainty propagates to the model predictions and should be considered in interpreting the residual spectrum below.'



Spectra from the likelihood analysis of the Fermi/LAT data:
-red is the Galactic diffuse emission; - the black component is the isotropic extragalactic;
-other components are the sources detected and the extragalactic background .



Residuals (($counts_{experim}$- model)/model) of the above likelihood analysis. The blue area shows the systematic errors on the effective area.

CONCLUSIONS

- Any attempt to disentangle a potential dark matter signal from the galactic center region requires deep understanding of the conventional astrophysics background.
- The bulk of the gamma ray emission from the GC region is explained with the detected sources and the Galactic Diffuse emission model, but ...
- ... a residual gamma ray emission is left, not accounted for by the above models;
- The Galactic diffuse model is currently reanalyzed to attempt to correctly account for this excess emission".