GLAST Sensitivity to Point Sources of Dark Matter Annihilation

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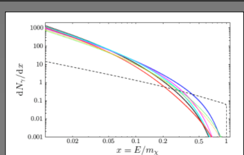
Abstract

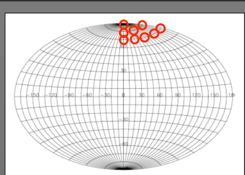
We study the prospects for detecting gamma-rays from point sources of Dark Matter annihilation with the space satellite GLAST. We simulate the instrument response to the gamma-ray spectrum arising from the annihilation of common Dark Matter candidates, and derive full-sky sensitivity maps for the detection} of point sources and for the identification of the Dark Matter (as opposed to astrophysical) origin of the gamma-ray emission. These maps represent a powerful tool to assess the detectability of point sources, i.e. sources with angular size smaller than the angular resolution of GLAST, ~ 0.1 degrees, in any DM scenario. As an example, we apply the obtained results to the so-called 'mini-spikes' scenario, where the annihilation signal originates from large Dark Matter overdensities around Intermediate Mass Black Holes. We find that if these objects exist in the Galaxy, not only GLAST should be able to detect them over a timescale as short as 2 months, but in many cases it should be possible to determine with good accuracy the mass of the annihilating Dark Matter particles, while null searches would place stringent constraints on this scenario.

GLAST Sensitivity Map

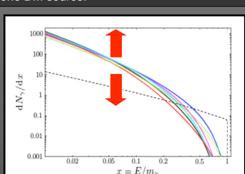
GLAST is expected to play a crucial role in indirect DM searches, thanks both to its ability to perform observations at energy scales comparable to the mass of common DM candidates and to its potential of making deep full-sky maps in gamma-rays, thanks to its large field-of-view.
Here, we study the prospects for detecting point sources of DM annihilation with GLAST, and assess the possibility to discriminate them from ordinary astrophysical sources. As a result of this analysis, we obtain full-sky sensitivity maps for the *detection* of sources above the diffuse background, as well as for the *identification* of DM annihilation sources.
To produce the sensitivity maps we go through the following steps:



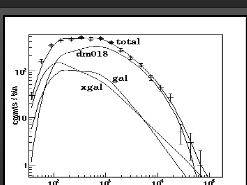
I) We specify a Dark Matter candidate, and estimate the relevant annihilation spectrum. In the figure above, the annihilation spectra relative to different leading annihilation channels are shown. Below, we show sensitivity estimates for annihilation to bb quarks.



II) We divided the sky into regions of about 10 degrees in radius, and in each region we placed one DM source.



III) We considered each source separately and let the flux intensity vary up and down

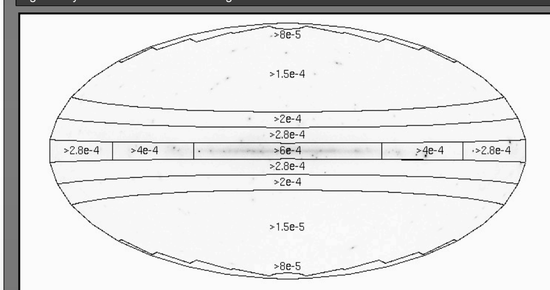


IV) We calculated the significance of the observed signal, given the local background counts, with a maximum likelihood analysis assuming Poisson statistics.

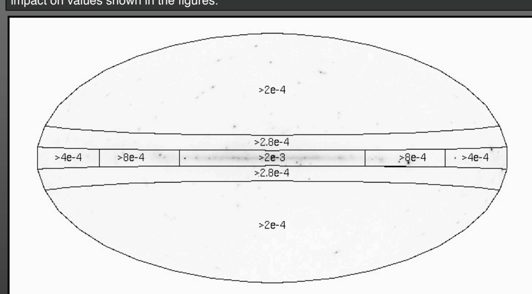
Sensitivity Maps

By estimating the minimum flux (above 100 MeV) required to discriminate the DM source from the background at a 5σ level on a grid of points uniformly distributed over the sky, we have obtained the first of the sensitivity maps shown below (where we adopted a DM particle mass m_χ = 150 GeV). The sensitivity appears to depend significantly on the Galactic longitude only along the Galactic disk, as expected. At high galactic latitudes a source as faint as $8x10^{-5}$ ph m^2 s^{-1} is resolved, while close to the galactic center a minimum flux of $6x10^{-4}$ ph m^2 s^{-1} is required.

In a similar way, we can also produce a sensitivity map for a reliable identification of the DM spectral cutoff. To do so, we compare for each observed spectrum the likelihood of a plain power law, with that of a DM-like spectrum, and check whether the latter hypothesis is favoured. The result of this analysis is shown in the second map below. Inside the galactic plane the minimum intensity required to pinpoint the high energy cutoff is far greater than the intensity required for a 5σ detection. This implies that there will be some sources that can correctly be identified as a DM signal only after observation times longer than the 2 months considered here.



GLAST sensitivity map for the *detection* of point sources of Dark Matter annihilations, i.e. full-sky map in galactic coordinates of the minimum flux above 100 MeV, in units of [ph m^{-2} s^{-1}], that is required for a 5σ detection of an annihilation spectrum, assuming a DM particle with mass m_χ =150 GeV annihilating into b quark pairs (note, however, that the map does not depend very sensitively on DM properties). The map is relative to a 2 months observation period; for longer observation times, fluxes scale approximately as $t_{obs}^{-1/2}$. For reference, we also show a simulated gamma ray sky. We neglected the possibility of spatial coincidence with non-DM point sources. A north-south asymmetry up to 20% in exposure, due to the GLAST orbit, would have negligible impact on values shown in the figures.

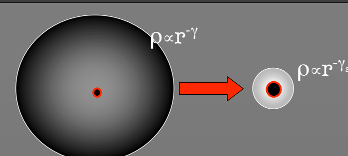


GLAST sensitivity map for the *identification* of point sources of Dark Matter annihilation, i.e. full-sky map in galactic coordinates of the minimum flux above 100 MeV, in units of [ph m^{-2} s^{-1}], necessary to discriminate the annihilation spectrum from an ordinary astrophysical source, assuming a DM particle with mass m_χ=150 GeV annihilating into bb quarks, after a 2 months observation period (see text for a further discussion). As in the first map, we also show a simulated gamma ray sky (see the caption above for further details).

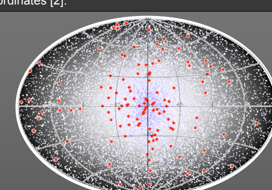
Application to Mini-Spikes

Black Holes can be braodly classified in 3 categories, based on their mass

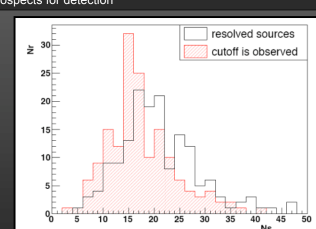
The (adiabatic) growth of a massive object, inevitably affects the surrounding distribution of matter. If the surrounding distribution of Dark Matter around is distributed initially as a power law of index γ, the final distribution will be a steeper power law of index γsp=9-2 γ/4- γ. Such a concentration of DM is called “spike”.



Although it is unlikely that a spike may survive around the Super-massive Black Hole at the Galactic center, they can evolve unperturbed around Intermediate Mass Black Holes (IMBHs), i.e. wandering BHs with mass comprised between a hundred and a million solar masses [3]. Below, a mock catalog of mini-spikes in Galactic coordinates [2].



Given the simulated coordinates and fluxes of mini-spikes, a simple comparison with the sensitivity maps presented above, allows a straightforward assessment of the prospects for detection



Number of relaizations Nr where a number of black holes Ns is observed (empty histogram) and identified as DM sources (red dashed). DM mass is m_χ=150 GeV

References: [1] This poster is based on astro-ph/-612387. See *ibid.* for a full set of references [2] Bertone, Phys.Rev.D73:103519,2006 [3] Bertone, Zentner and Silk, Phys.Rev.D72:103517,2005