Realistic estimation for the detectability of dark matter subhalos using Fermi-LAT catalogs



The aim is to **predict the detectability of Galactic dark** matter subhalos using Fermi-LAT source catalogs.

We generate Monte Carlo realizations of the dark matter subhalo population based on the results of a recent hydrodynamical simulation suite of Milky Way-sized galaxies¹.

We simulate the gamma-ray sky for both the setup of the 3FGL and 2FHL Fermi-LAT catalogs, including contribution from dark matter annihilation in subhalos.

We predict that the **number of dark matter subhalos** among the unassociated sources is very small.

The small (or even null) number of detectable DM SH candidates among the Fermi-LAT unassociated sources allows us to set upper limits on the dark matter annihilation cross section $\langle \sigma v \rangle$. We also find less than one extended subhalo in the Fermi-LAT 3FGL catalog. The figures show the **number of detectable subhalos vs the annihilation cross section** $\langle \sigma v \rangle$ for a fixed DM mass.

¹ F. Marinacci, R. Pakmor, and V. Springel, Mon. Not. Roy. Astron. Soc. 437 (2014), no. 2 1750–1775, [arXiv:1305.5360].

Francesca Calore, Valentina De Romeri, Mattia Di Mauro, Fiorenza Donato, Federico Marinacci Phys. Rev. D 96, 063009 [arXiv:1611.03503]





Modeling the DM distribution in the Galaxy and extracting the gamma-ray signal



Fermi-LAT.

For modeling the subhalo population in the Galaxy, we use the results of a suite of cosmological simulations of a Milky Way-size halo, namely the hydrodynamic (Hydro) run Aq-C-4¹ and the corresponding control **dark matter-only** (DMO) run.

The gamma-ray emissivity from dark matter annihilation in subhalos is determined by the internal spatial profile of the dark matter subhalos. The radial dark matter density profile of the subhalos is described by the **Einasto parametrization**. The scale radius is obtained directly from the output data of the simulation as $r_s = r_{max}/r_{max}$ 2.189. Given the subhalo mass, we compute the value of r_{max} from the polynomial best-fit shown in the *top figure* and we add a 3σ log-normal dispersion about the bestfit relation.

realization.

The *lower figure* shows the values of the **J-factor versus the subhalo mass** for the Hydro case. The color code indicates the distance of the subhalo from Earth (in kpc) - blue being the solutions for the closest subhalos and red those for the farthest ones.

¹ F. Marinacci, R. Pakmor, and V. Springel, Mon. Not. Roy. Astron. Soc. 437 (2014), no. 2 1750–1775, [arXiv:1305.5360].

We want to predict the detectability of Galactic dark matter subhalos by the

We generate about 800 (1200) subhalos in each Hydro (DMO) Monte Carlo

The results for the **Hydro and DMO** cases **are fully compatible**.











Properties of Fermi-LAT detectable subhalos

The subhalos that are detectable by the LAT are those with a flux above the Fermi-LAT sensitivity flux threshold (for a specific catalog setup) and which could be among the unassociated sources in the 3FGL and 2FHL catalogs.

We fix the dark matter mass to 100 GeV and the annihilation cross section to 3×10^{-26} cm³/s.

We obtain few detectable subhalos (depicted with black stars), with distances $d_{SH} \in [10, 300]$ kpc and masses $M_{SH} > 2 \times 10^7 \text{ M}_{\odot}$.

We find that the detectable dark and luminous subhalos may be more massive than 10⁷ Mo. The farther subhalos have to be extremely massive in order to be detectable. Such far and massive subhalos are also very likely to have a stellar counterpart and therefore to be detected in the optical wavelength as dwarf galaxies.

The detectable subhalos populate the lower part of the r_s distribution. Smaller values of r_s correspond to larger concentration parameters, and hence to larger DM signals emitted at fixed mass.









Source count distribution (LogN - LogF) of subhalos

The source count distribution as a function of the integrated flux F (LogN-LogF) is an important property of astrophysical source populations and it can also provide information about the faintest end of the flux distribution.

The figure shows the LogN-LogF of all simulated DM subhalos, with integrated flux above 0.1 GeV for the 3FGL catalog. We fixed the dark matter mass = 100 GeV, $\langle \sigma v \rangle$ = 10⁻²⁵ cm³/s and we considered annihilation into b-quark pairs. The cyan solid line represents the best-fit to the LogN-LogF of the **blazars** population in the 1FGL².

The LogN-LogF of dark matter subhalos shows a **sharp cutoff at high** fluxes, that corresponds to few very bright subhalos.

The numerous faint and undetectable subhalos populate the LogN -LogF at low fluxes.

Regardless of the choice of the integration energy threshold, the subhalos source count is strongly subdominant with respect to the observed flux distribution of AGN in both the 3FGL and 2FHL catalogs.

