The effect of substructures on Dark Matter indirect detection with γ-rays

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in collaboration with

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Overview

What we "know"…

- Galactic satellites are predicted by N-body simulations
- If DM is a WIMP particle, the smaller halos should be Earth-mass halos
- About 10^{15} halos should populate the Milky Way, with $dN/dM \sim M^{-2}$
- Their spatial distribution should trace the mass of the MW
- Their inner density should not be affected by their history and should follow the NFW profile

Overview

What we "do not know"…

- Are there subhalos at all? None has seen them so far…
- Is DM a WIMP?
- Have all subhalos survived with invariate mass function till z=0?
- Which density profile for the MW?
- Which formulation for the concentration parameter of subhalos?
- Press&Schecter approach or "frozen" halos? Which density peak rareness?
- …

Overview

What we “would like”…

- Detecting subhalos: a multiwavelenght approach would be optimal.

- Extracting informations on both the nature and distribution of DM..

Project: assumptions

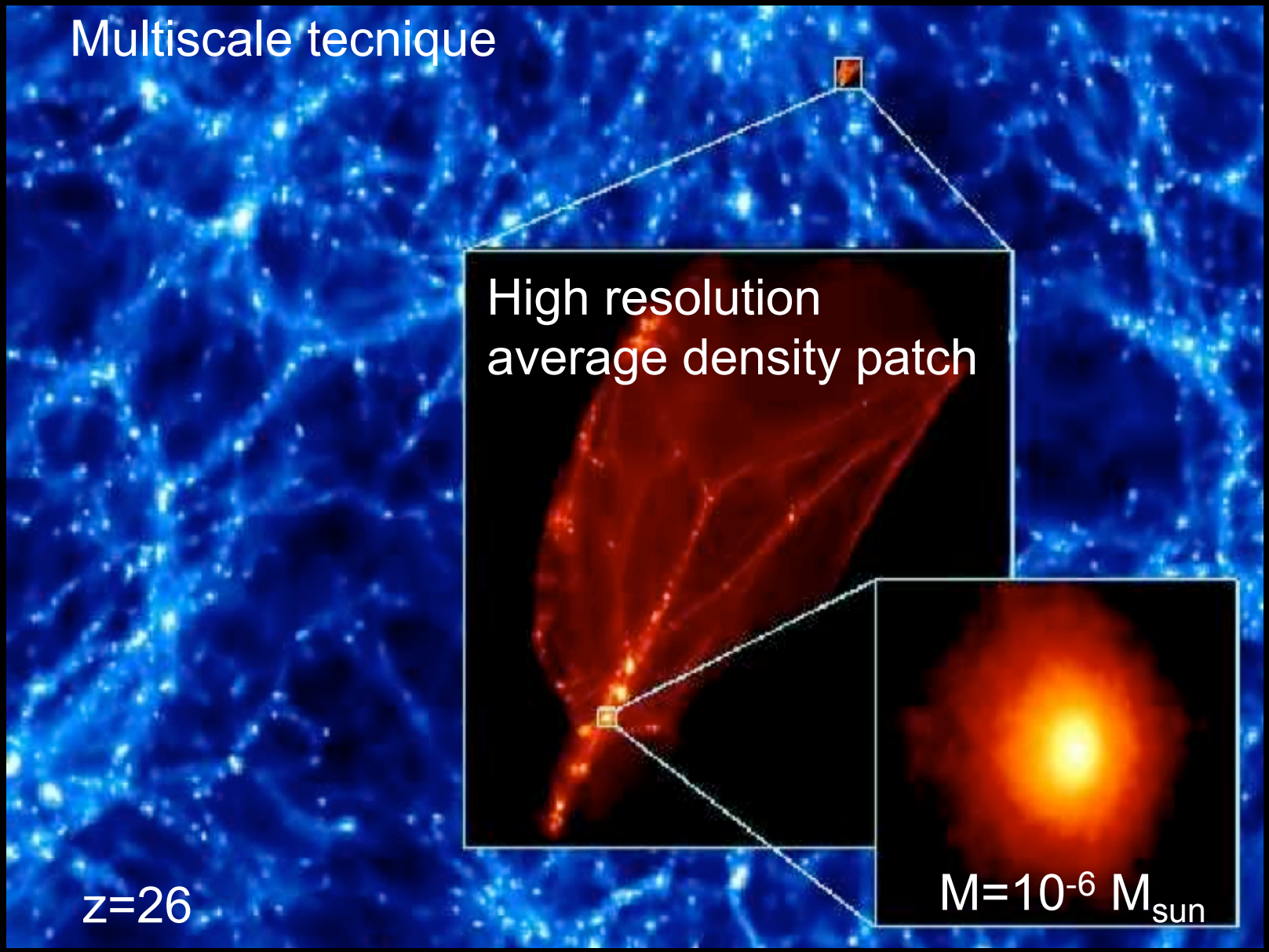
- Are there subhalos at all? None has seen them so far… assume YES

- Is DM a WIMP? assume YES

- Have all subhalos survived with invariate mass function till z=0? assume YES, without changing profile

- Which density profile for the MW? assume NFW

FRAMEWORK: Diemand, Moore, Stadel 2005



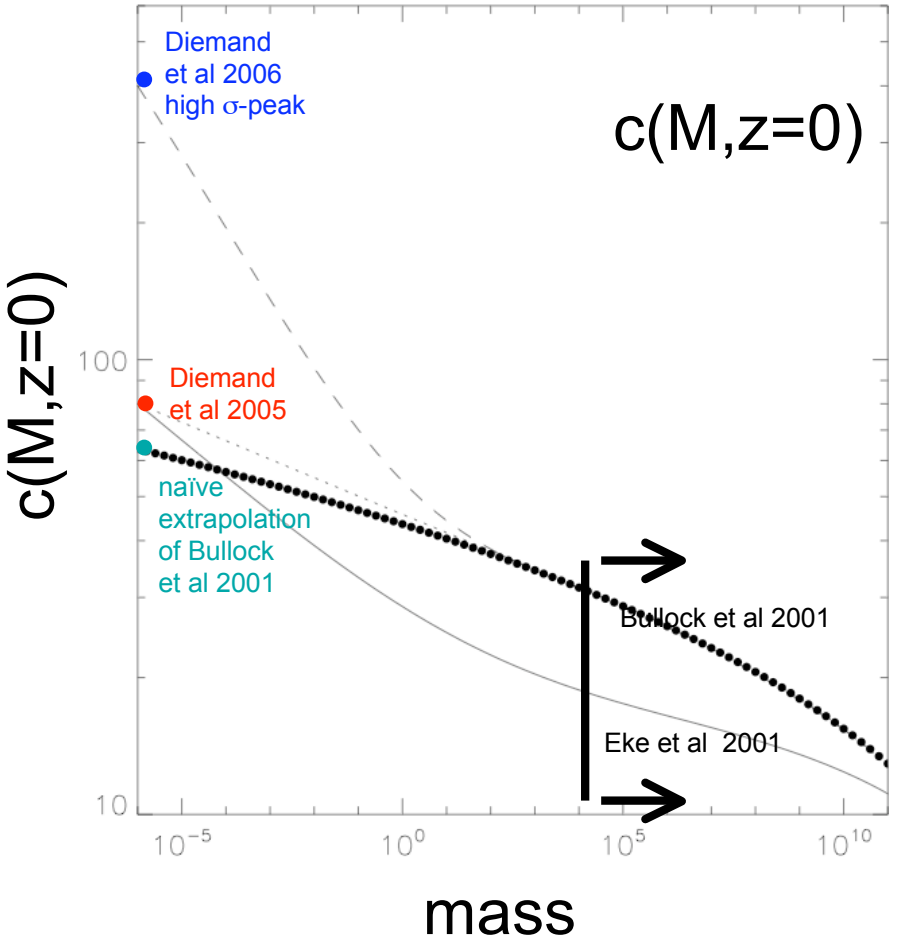
Project: exploring models

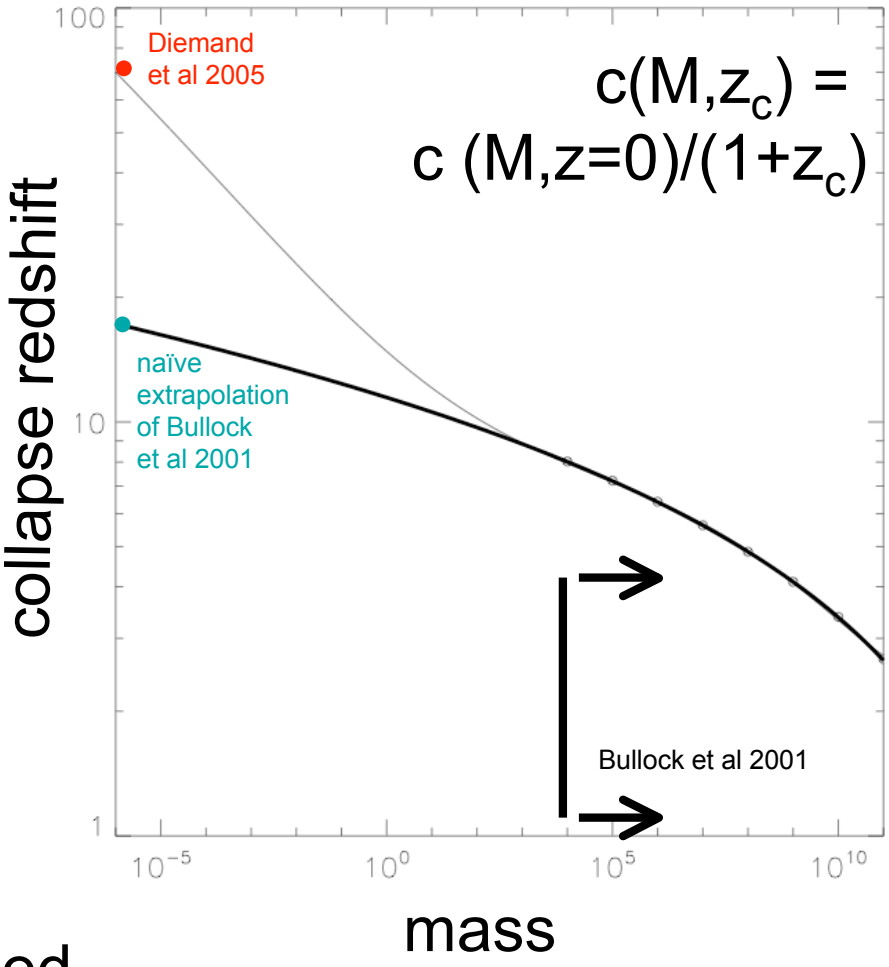
- Which formulation for the concentration parameter of subhalos? explore

- Press&Schecter approach or “frozen” halos? explore

- Which density peak rareness? assume 1σ peak for the moment (developments in C.Giocoli, LP, G.Tormen, in preparation. See Carlo Giocoli’s talk later in this session.)

Subhalo models

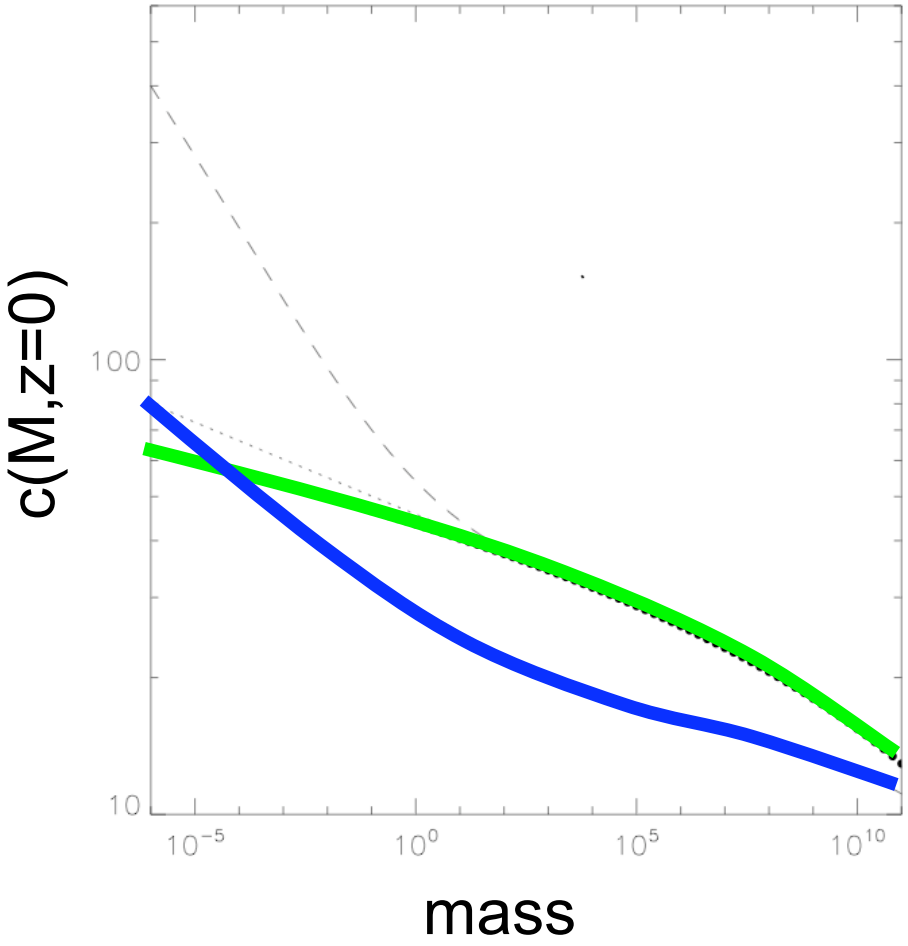


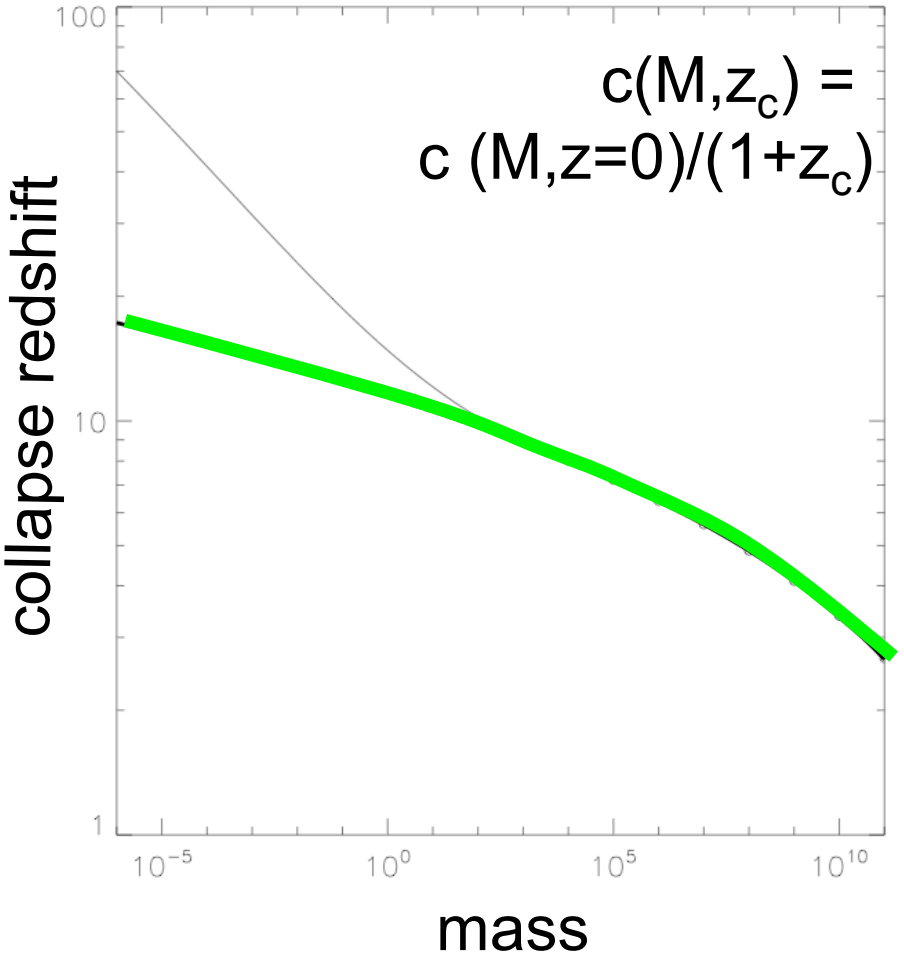


NB: these are average values!
a lognormal probability is assumed
everywhere in the analysis

L.Pieri, G. Bertone, E. Branchini, arXiv 0706.2101 [astro-ph]

Subhalo models: benchmarks





Model “1”: optimistic

Model “2”: pessimistic

L.Pieri, G. Bertone, E. Branchini, arXiv 0706.2101 [astro-ph]

Project

• Detecting subhalos: a multiwavelenght approach would be optimal.

✓ Use only γ-rays for the moment

• Calculate numerically the diffuse contribution of the entire population of subhalos, for the different models explored

• MC simulate the closer and more brilliant subhalos, for the different models explored

• Compute detectability of both diffuse and resolved halos with a GLAST-like satellite.

• Extracting informations on both the nature and distribution of DM..

✓ Can we already constrain some models through EGRET observations ?

Indirect detection of γ-rays

$$\Phi_\gamma = \Phi_{\text{particle physics}} \times \Phi_{\text{cosmology}}$$

- distribution of DM along the l.o.s.
MW + SMOOTH + CLUMPY
- geometry of the experiment

$$\Phi_{PP} = \frac{1}{4\pi} \frac{\sigma_{ann} v}{2m_\chi^2} \int_{E_0}^{m_\chi} \sum_f \frac{dN_f^\gamma}{dE_\gamma} BR_f$$

$$\Phi_{COSMO} = \int_{\Delta\Omega,\lambda} \frac{\rho^2(r(\Delta\Omega,\lambda))}{\lambda^2} dV$$

Indirect detection of γ-rays

$$\Phi_\gamma = \Phi_{\text{particle physics}} \times \Phi_{\text{cosmology}}$$

↓

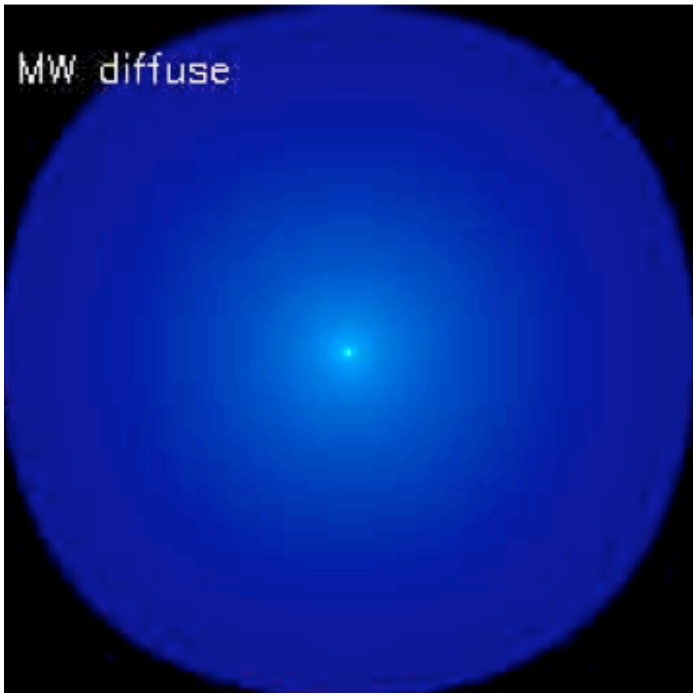
- distribution of DM along the l.o.s.

MW + SMOOTH + CLUMPY

- geometry of the experiment

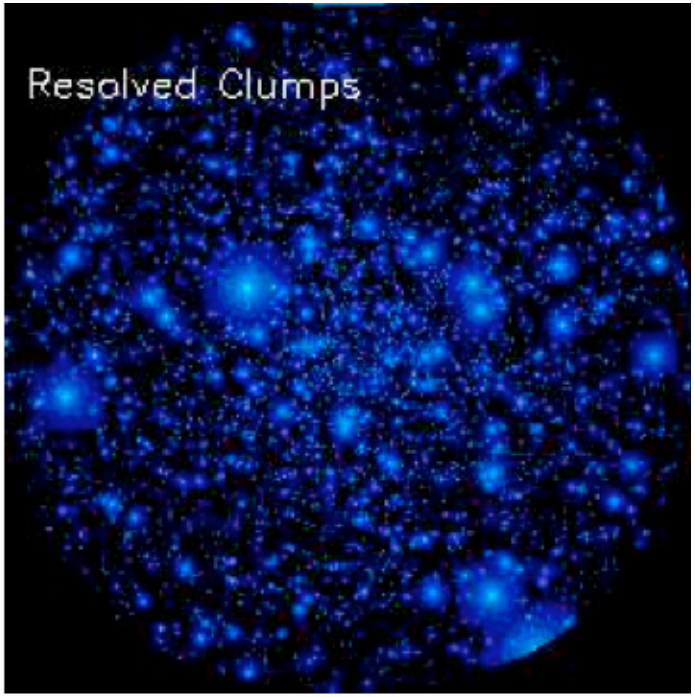
$$\Phi_{COSMO}(\psi,\Delta\Omega) = \int_M dM \int_c dc \iint_{\Delta\Omega} d\vartheta d\varphi \int_{l.o.s} d\lambda \Big[\rho_{sh}(M,R(R_{sun},\lambda,\psi,\vartheta,\varphi)) \cdot P(c) \cdot \Phi^{halo}_{COSMO}(M,c,r(\lambda,\lambda',\psi,\vartheta',\varphi')) \cdot J(x,y,z;\lambda,\vartheta,\varphi)\Big]$$

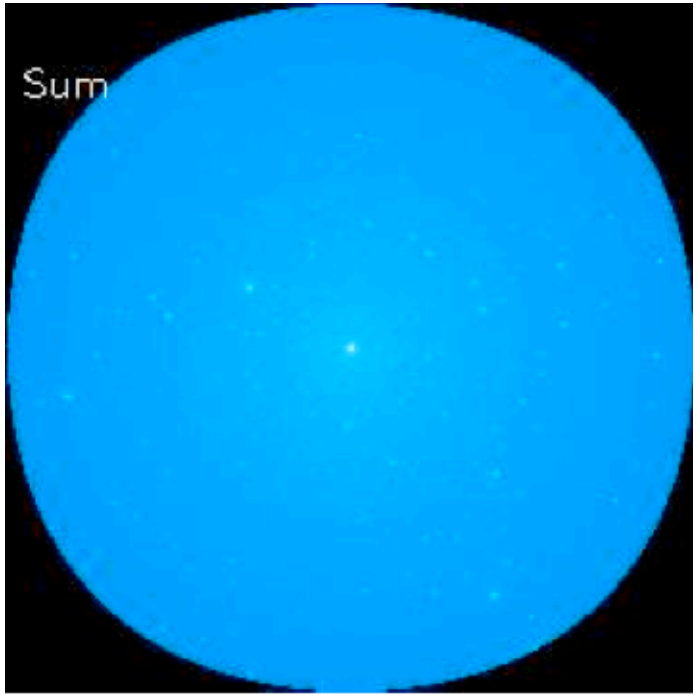
$$\Phi^{halo}_{COSMO}(M,c,r) = \iint_{\Delta\Omega} d\vartheta' d\varphi' \int_{l.o.s} d\lambda' \left[\frac{\rho^2_{DM}\left(M,c,r(\lambda,\lambda',\psi,\theta',\varphi')\right)}{\lambda^2} J(x,y,z;\lambda',\vartheta',\varphi')\right]$$

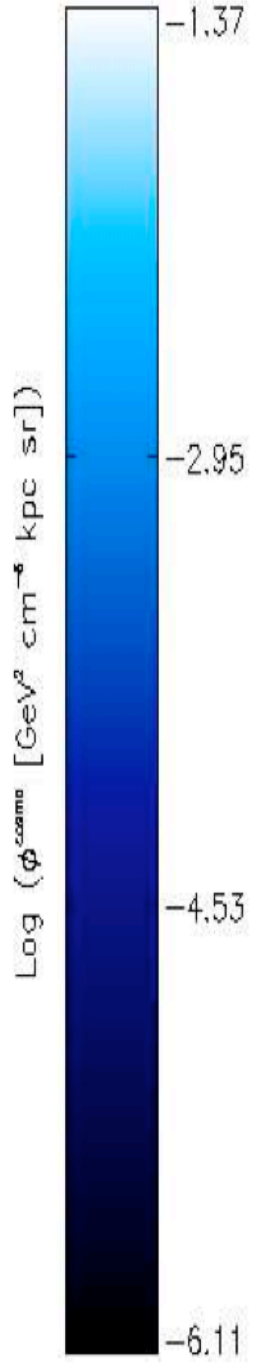


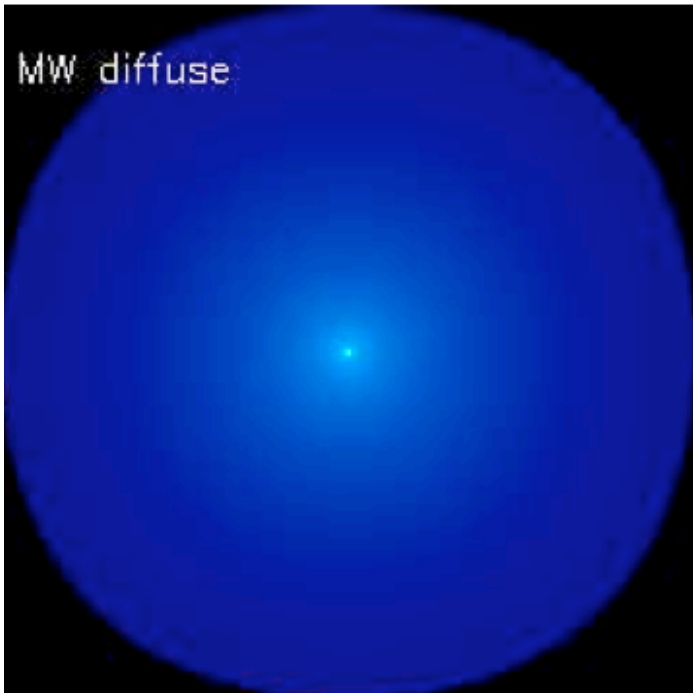
Contribution to $\Phi_{cosmology}$

Model “1”



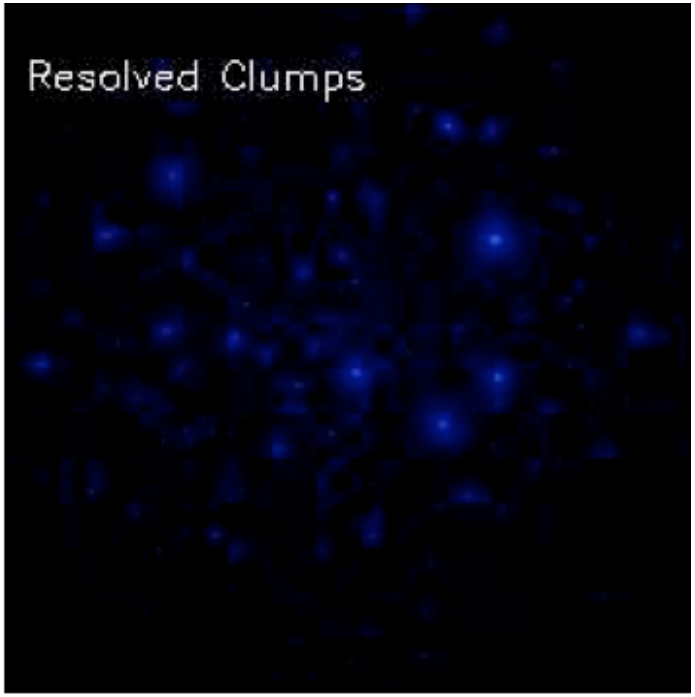


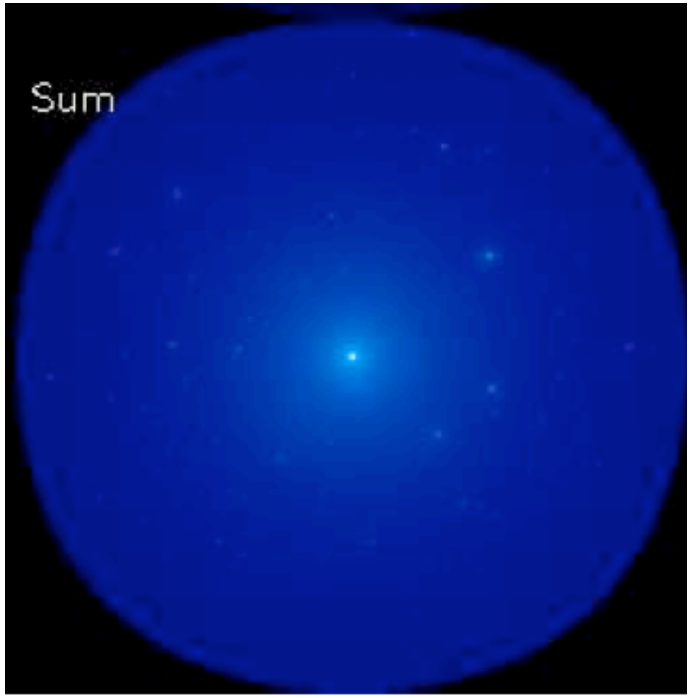


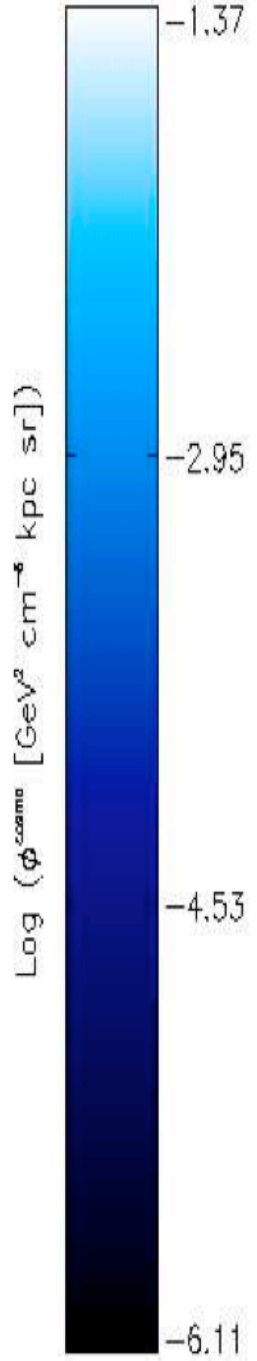


Contribution to $\Phi_{cosmology}$

Model “2”

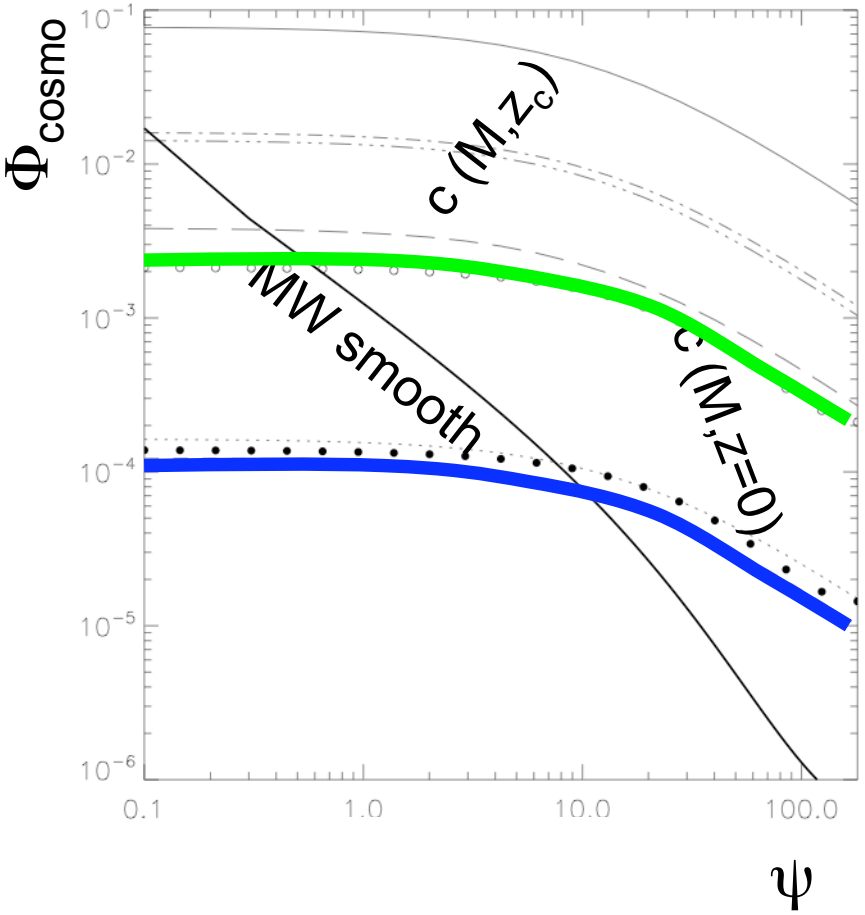




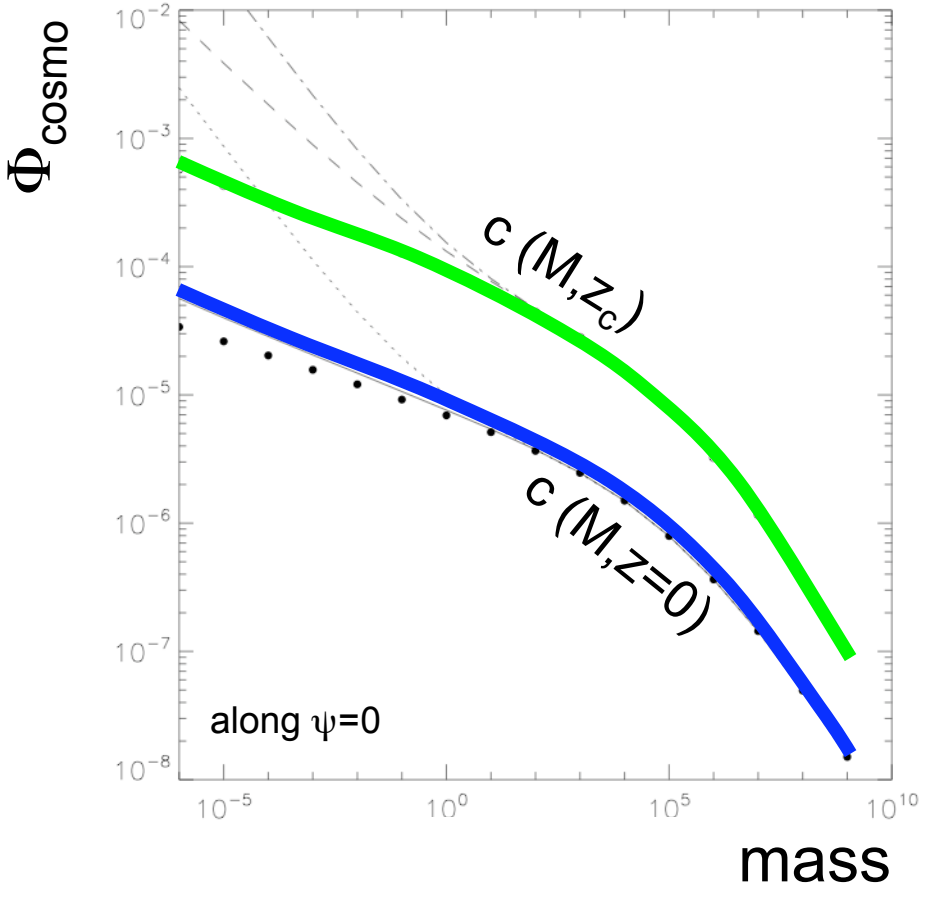


Results on subhalo models, smooth contribution the MILKY WAY case

Smooth Φ_{cosmo} VS ψ

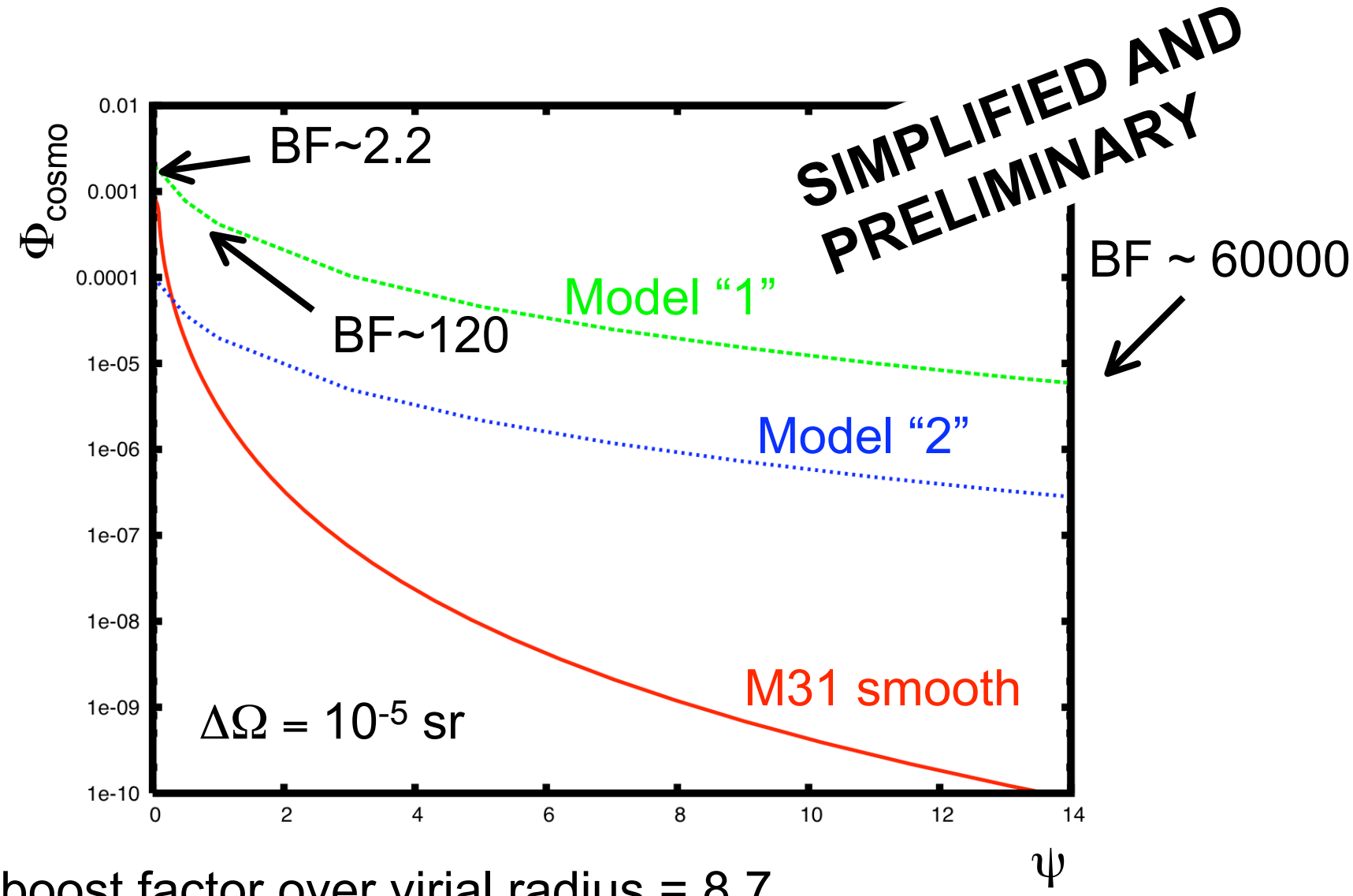


Smooth Φ_{cosmo} VS mass



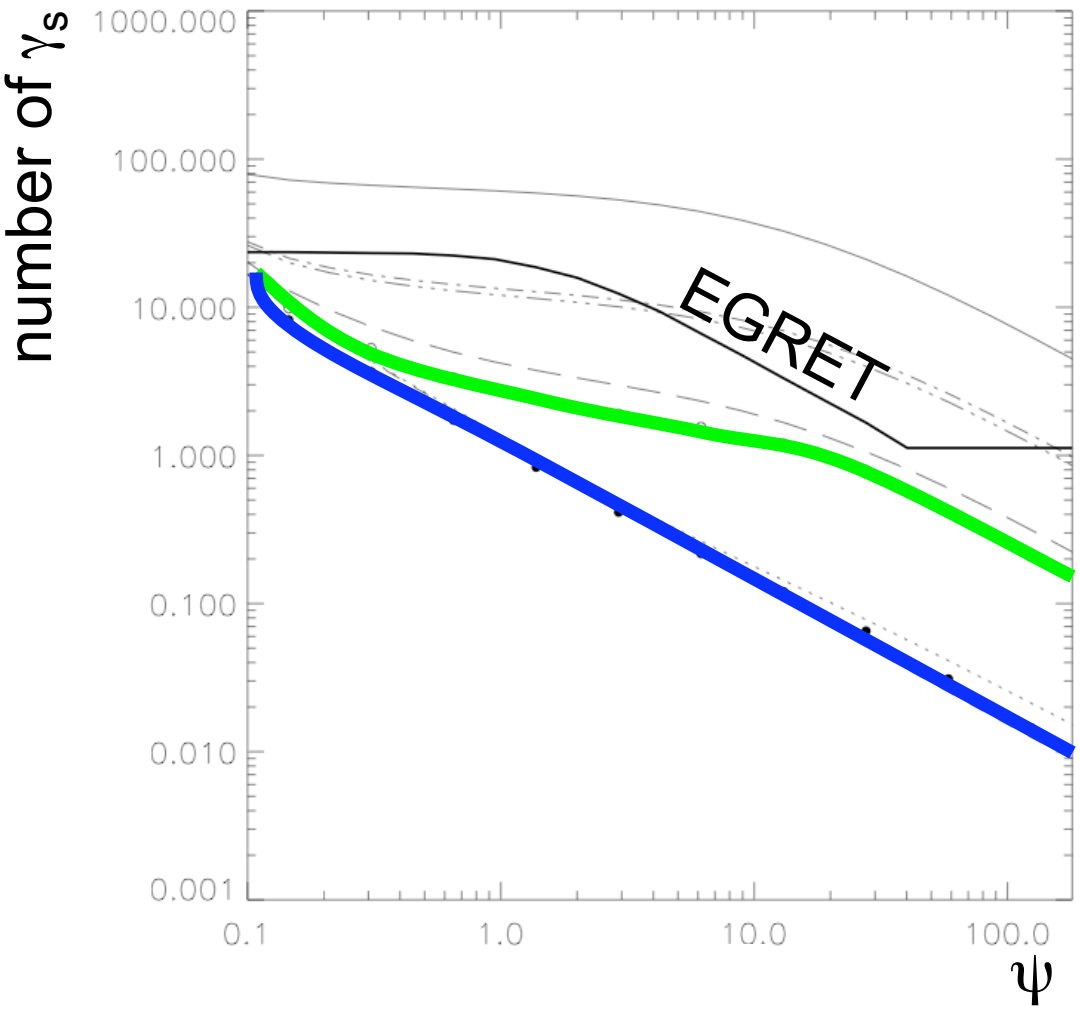
L.Pieri, G. Bertone, E. Branchini, arXiv 0706.2101 [astro-ph]

Results on subhalo models, smooth contribution the Andromeda case



Total boost factor over virial radius = 8.7

Results on subhalo models, number of expected photons



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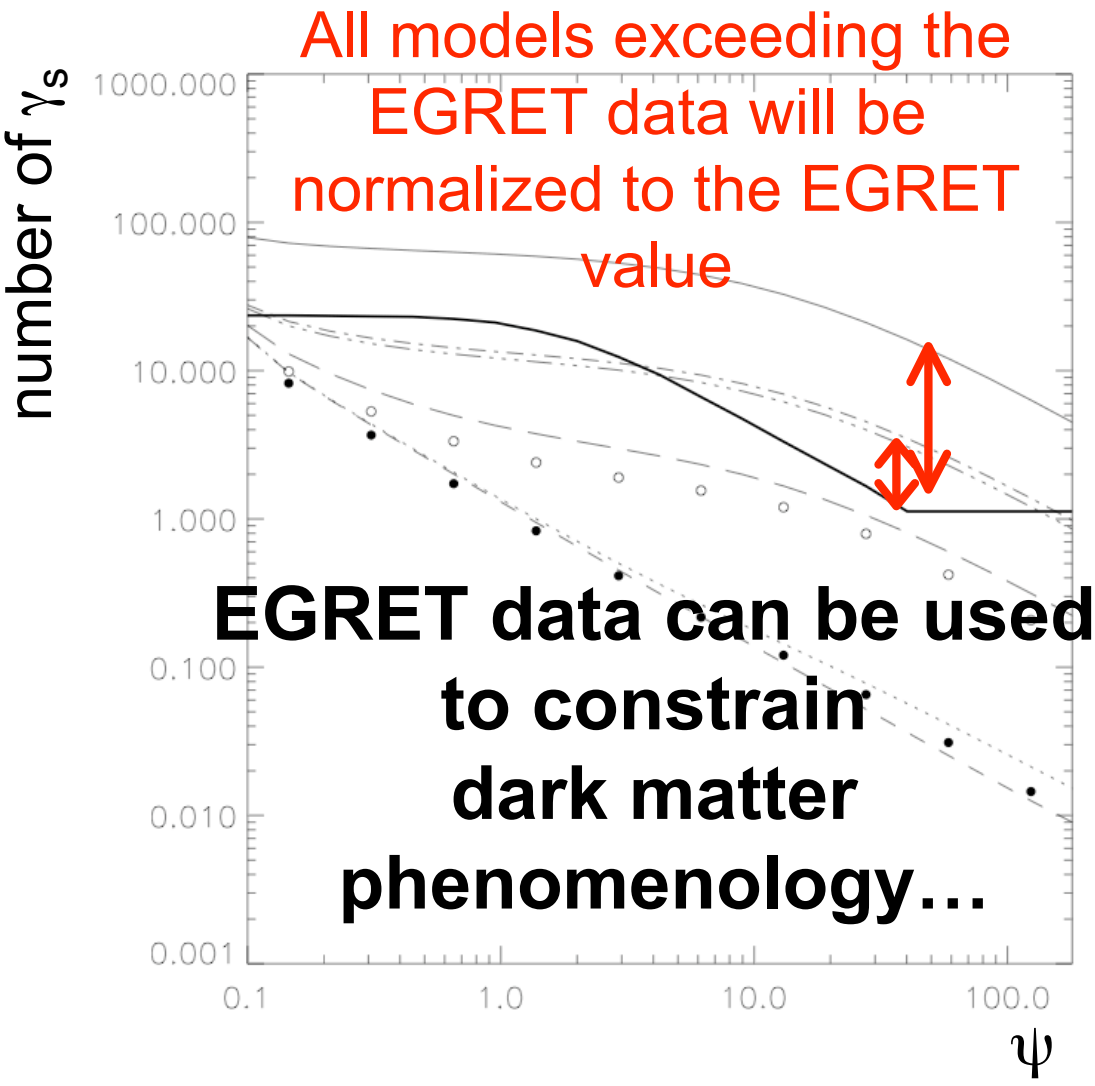
Results on subhalo models, constraints from EGRET data



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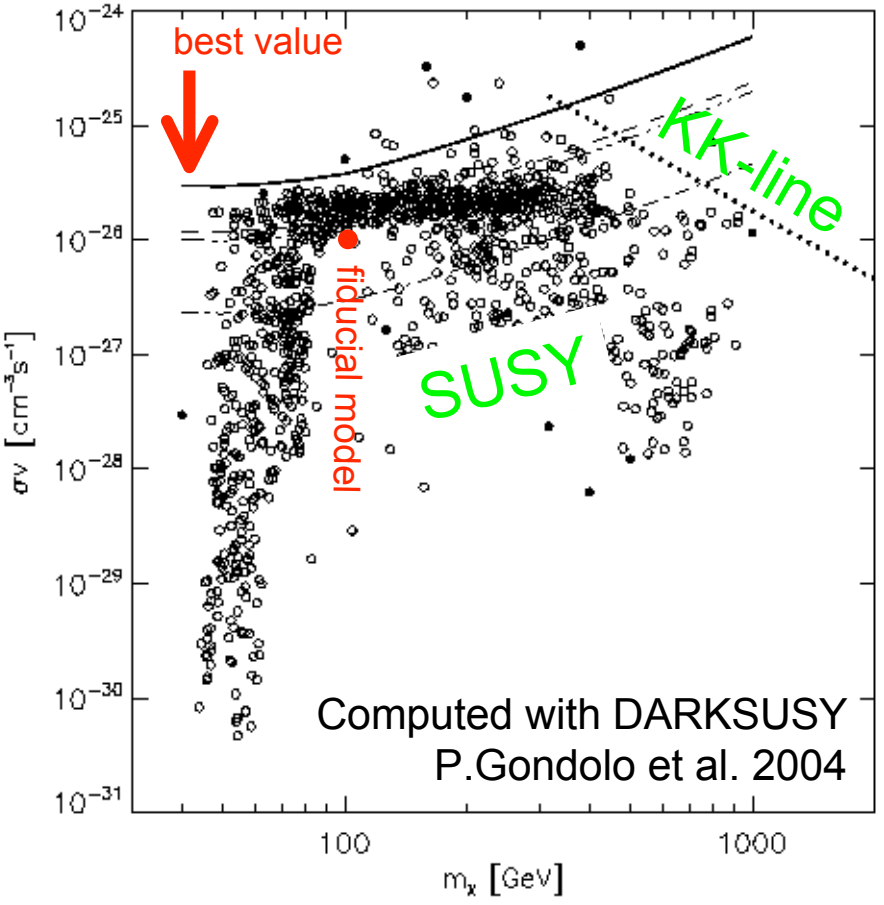
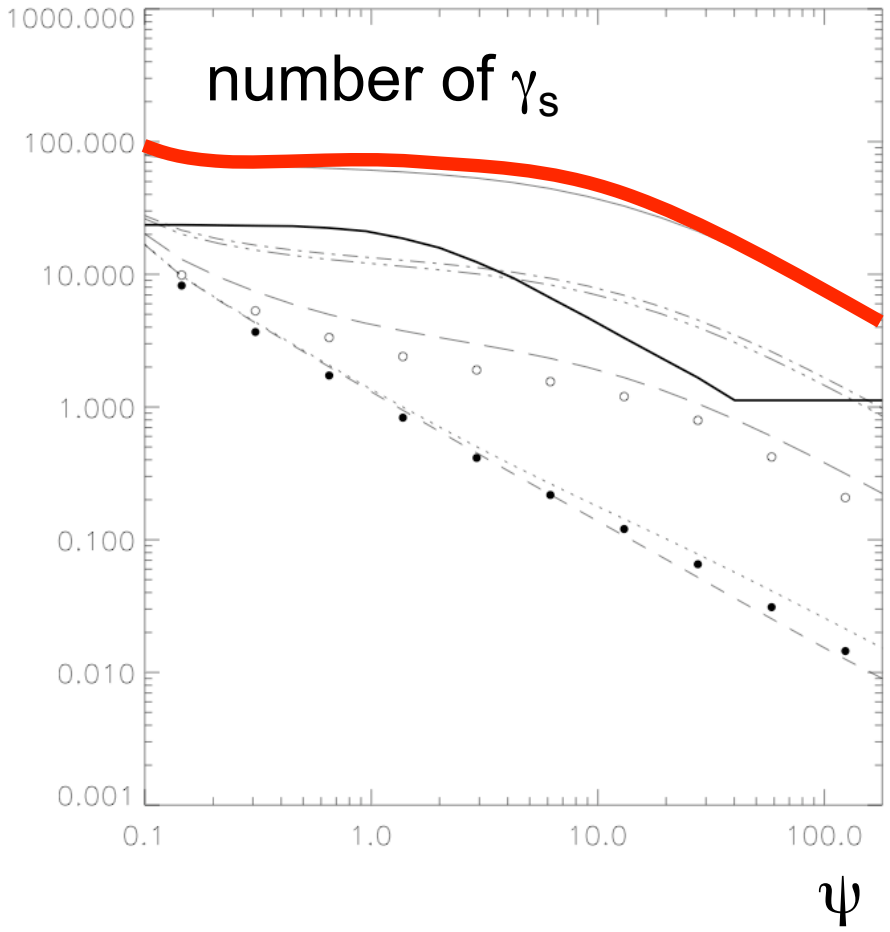
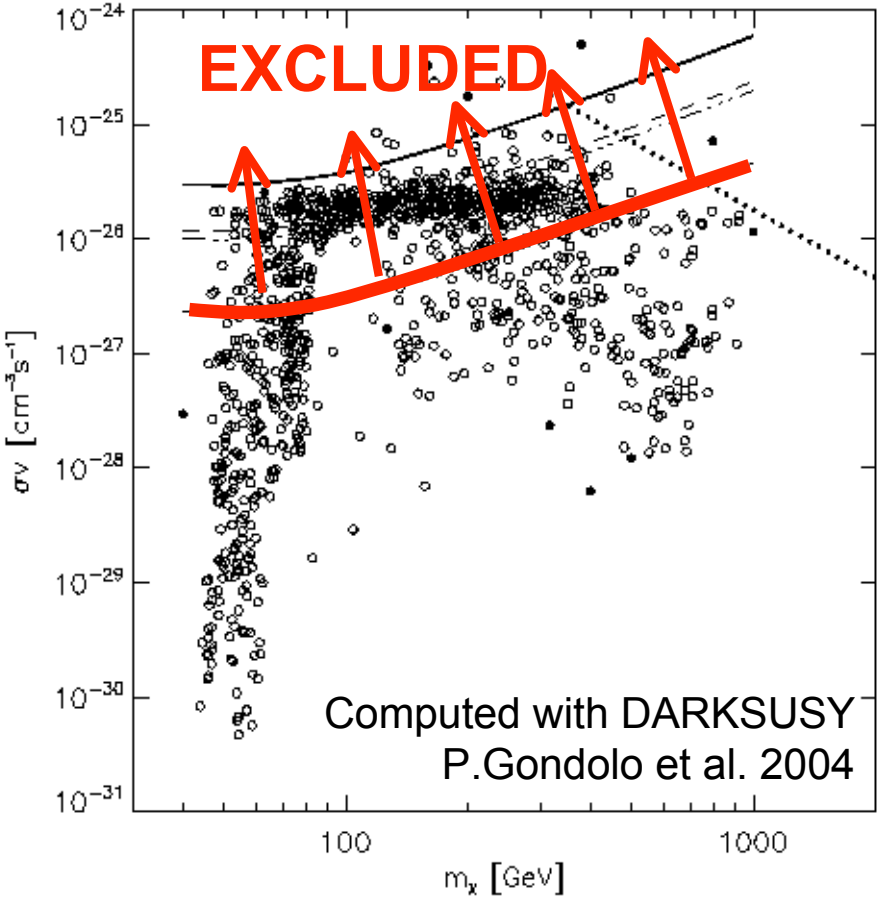


Constraints from EGRET





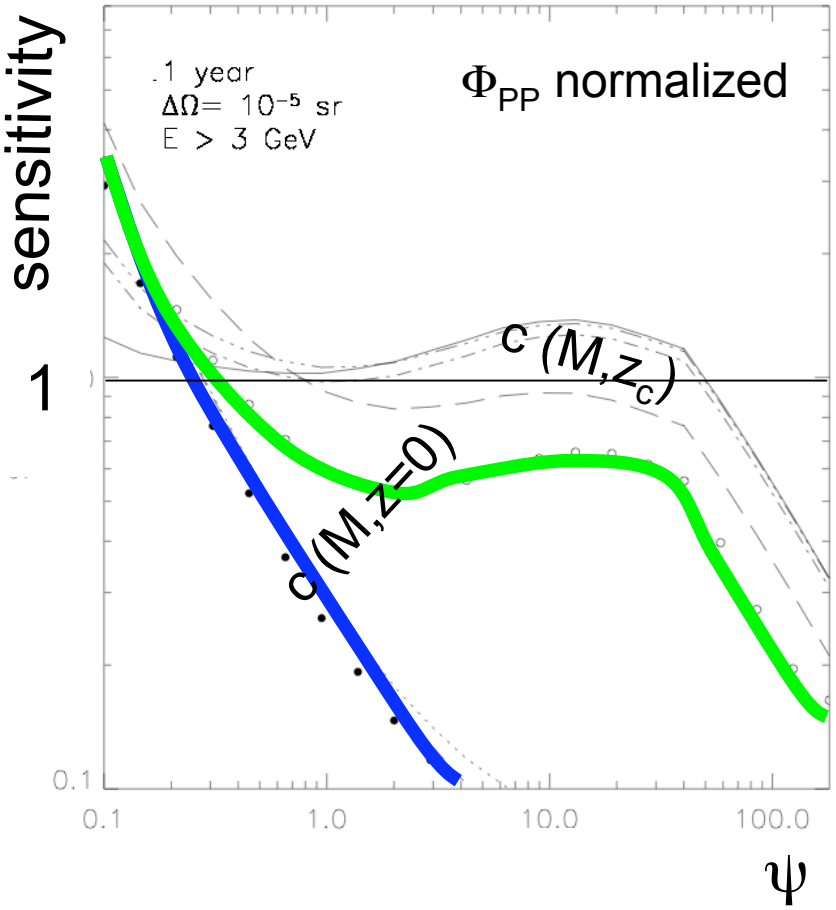
Φ_{cosmo} does not change, Φ_{PP} is normalized, resulting in an exclusion plot

L.Pieri, G. Bertone, E. Branchini, arXiv 0706.2101 [astro-ph]

Experimental sensitivity for a GLAST-like observatory

Charged background free
$A_{eff} = 10^4 cm^2$ always on-axis , independent on energy and incidence angle
Angular resolution 0.1°
$\varepsilon_\gamma = 100\ \%$, $\varepsilon_{\Delta\Omega} = 1$

MW + subhalo smooth



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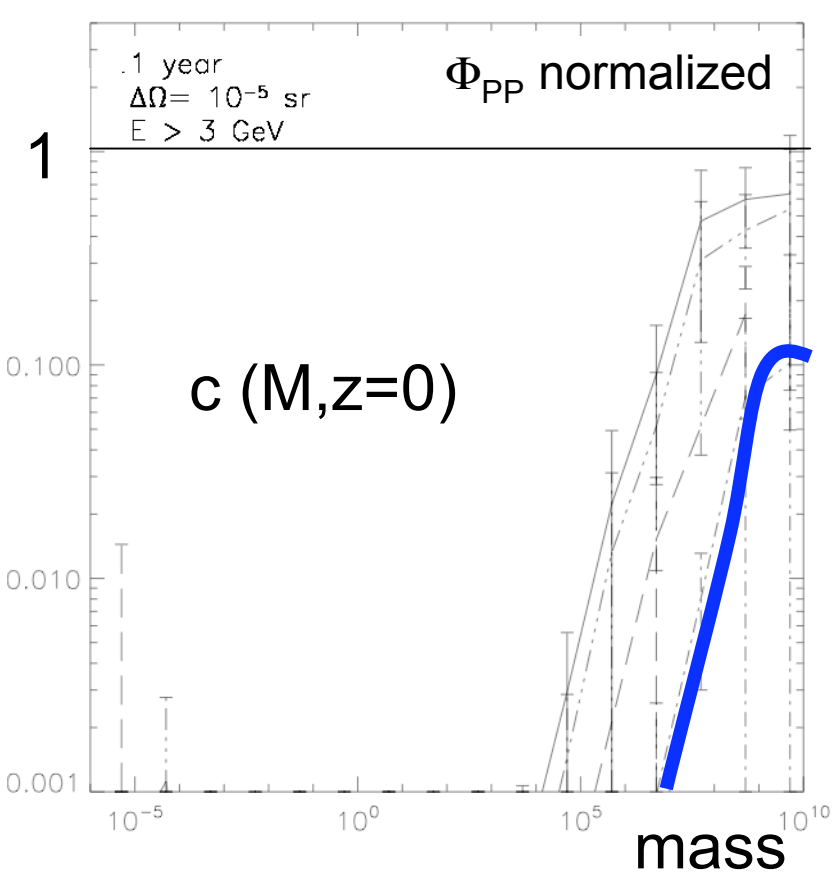
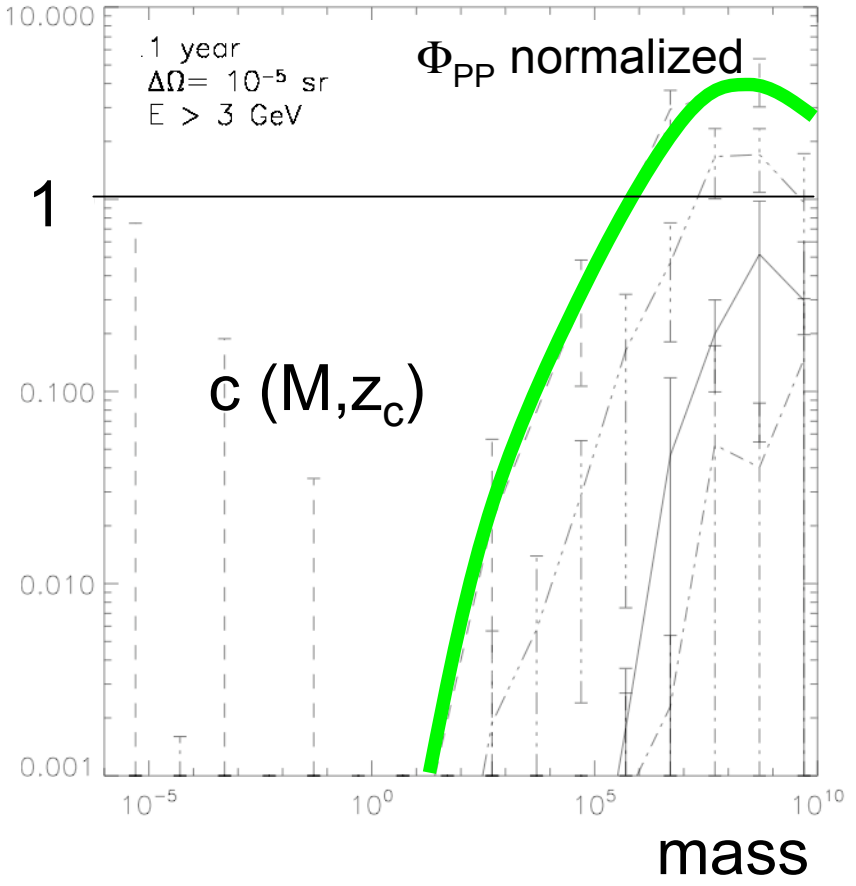
Experimental sensitivity for a GLAST-like observatory

Resolved halos

Number of halos detectable at 5σ in 2.4 sr toward the GC

The total number in the MW is about 2.5-3 times this value





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Experimental sensitivity for a GLAST-like observatory

Resolved halos

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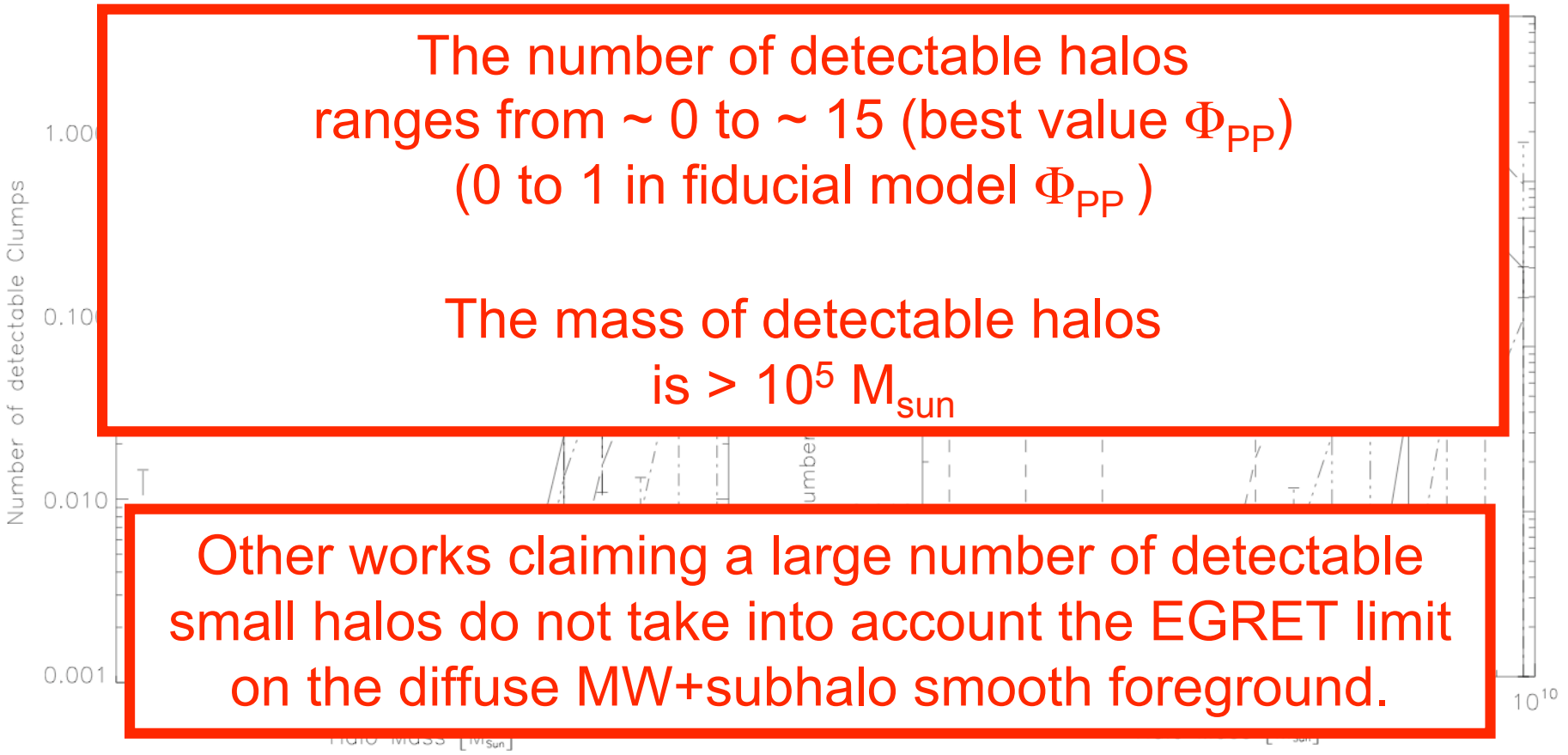
The total number in the MW is about 2.5-3 times this value

The number of detectable halos
ranges from ~ 0 to ~ 15 (best value Φ_{PP})
(0 to 1 in fiducial model Φ_{PP})

The mass of detectable halos
is > 10^5 M_{sun}



Other works claiming a large number of detectable small halos do not take into account the EGRET limit on the diffuse MW+subhalo smooth foreground.

L.Pieri, G. Bertone, E. Branchini, arXiv 0706.2101 [astro-ph]

Conclusions

We filled the MW with a population of ~10^{16} subhalos,
assuming different models for the concentration of subhalos

The overall smooth γ-ray foreground provided by such a population of subhalos has been derived and compared with EGRET data on extragalactic γ-ray background. Models exceeding the EGRET data were normalized.

Demistifying the effect of substructures for γ-rays indirect detection:

The GC could be detected, independenly on the existence of subhalos, but the astrophysical background is poorly known. The subhalo smooth foreground is not going to be detected with high sensitivity

Only a few subhalos, if any (depending on the model), could be observed with a GLAST-like observatory.
In any case they would be massive subhalos ($M > 10^5 M_{sun}$)
and no proper motion could be observed.