Dark Matter constraint from the Fermi-LAT diffuse data

on behalf of the Fermi-LAT collaboration
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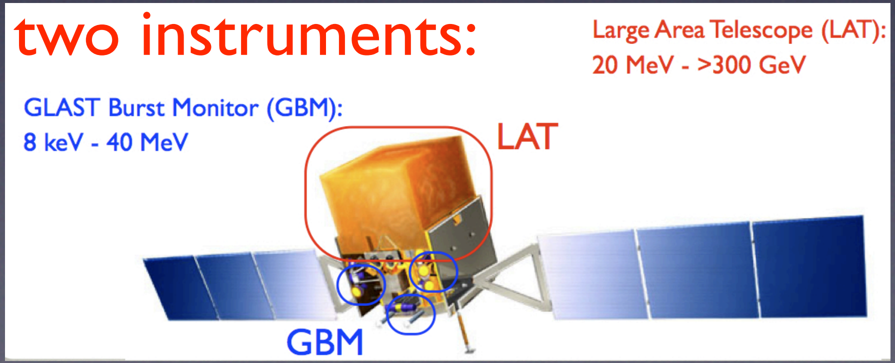
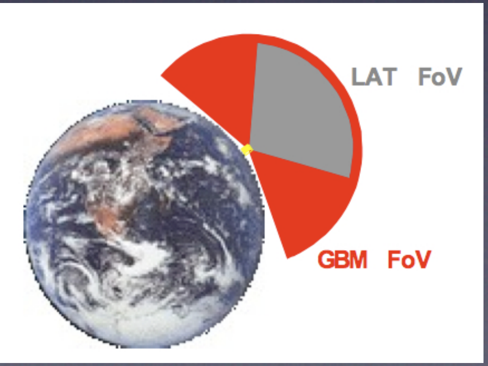
The instrument

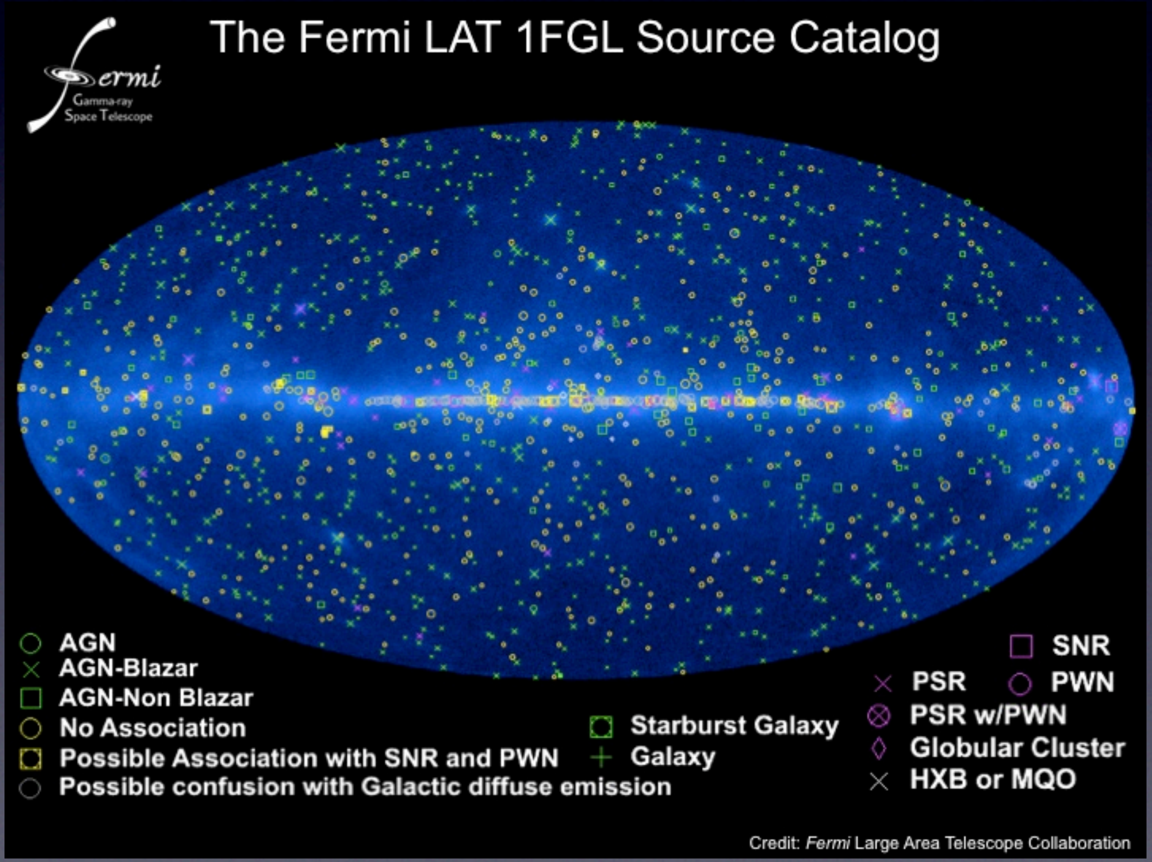
- Key features: Large field of view: 20% of the sky at any instant. In the survey mode exposes every part of the sky for ~30 min, every 3 hours.
- Energy range: 20 MeV to >300 GeV (LAT), includes previously unexplored energy band 10-100 GeV.
- angular resolution ~ 0.1 deg above 10 GeV
- Excellent charged particle discrimination (critical in separating gamma rays from the background cosmic rays).

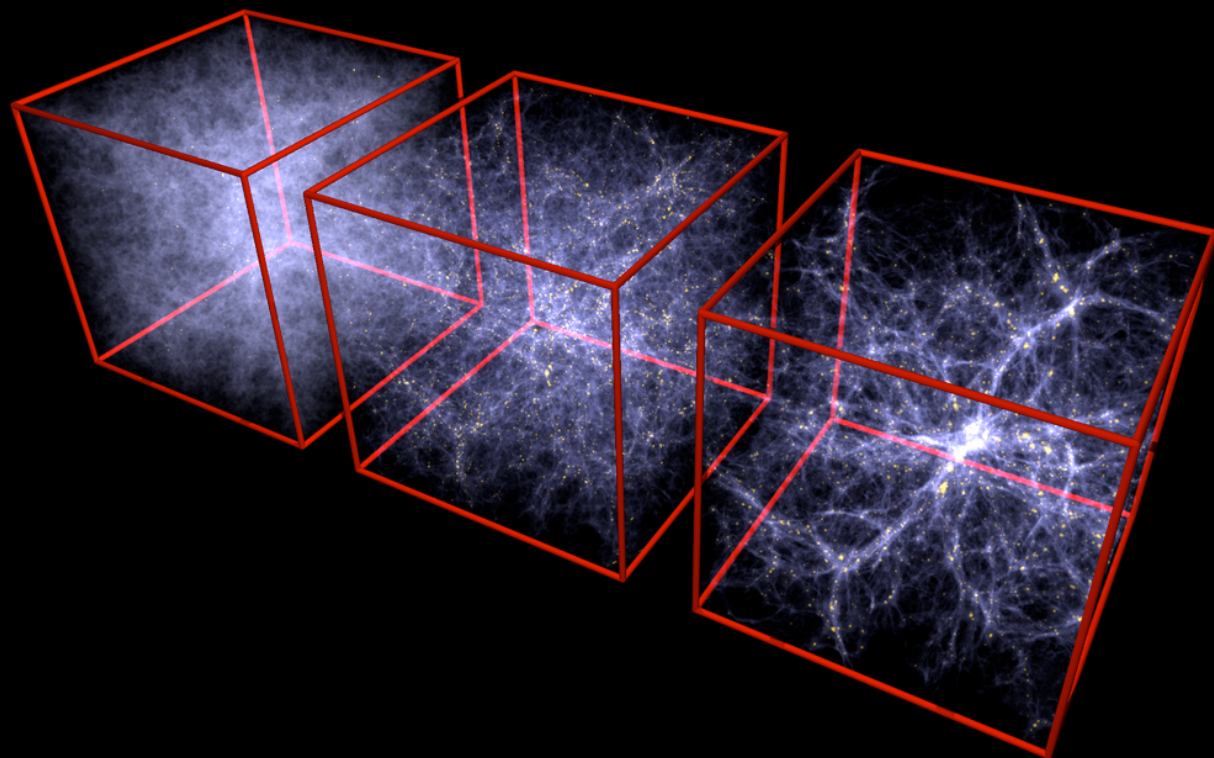




Science with Fermi

•AGNs (~700 (EGRET ~60))
•Pulsars (~50 in a first catalog)
+discovery of ~10 MSPs
•SNRs and PWN
•Gamma Ray Bursts
•Source populations and identification
•Diffuse emission
•Cosmic ray electrons
•Solar system (Sun flares, Moon,...)
+ Discovery/constraints:
 New source classes?
 Dark matter?
...

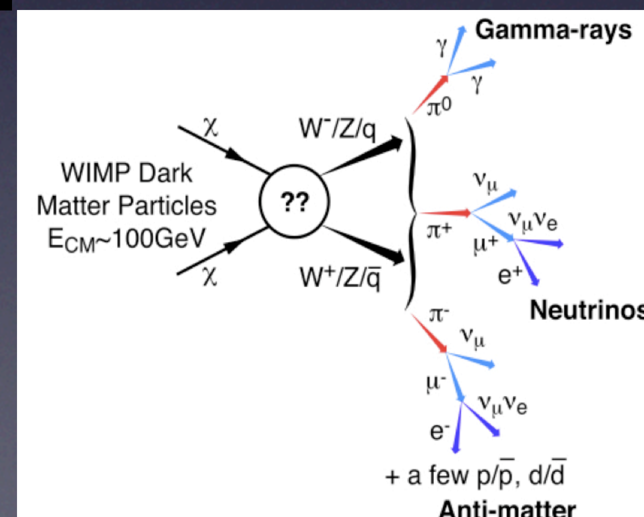




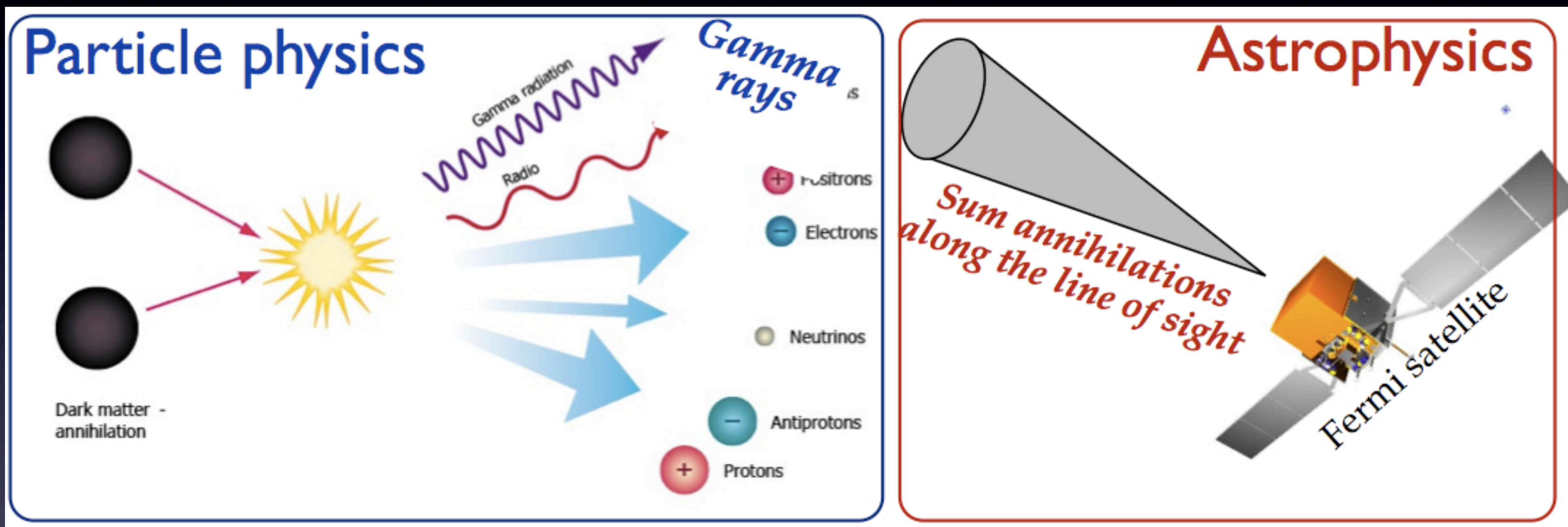
WIMP candidates: The annihilation rate comes purely from particle physics and automatically gives the right answer for the relic density!

In turn, we expect dark matter to annihilate to Standard Model particles, with cross sections which are within near reach of current experiments.

The gravitational effects of DM have been has been demonstrated from plethora of astrophysical and cosmological observations.



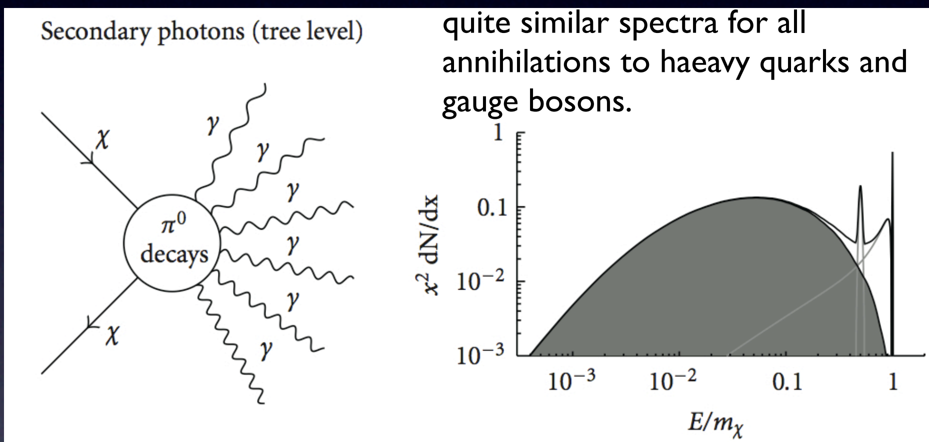
DM signal in gamma-rays



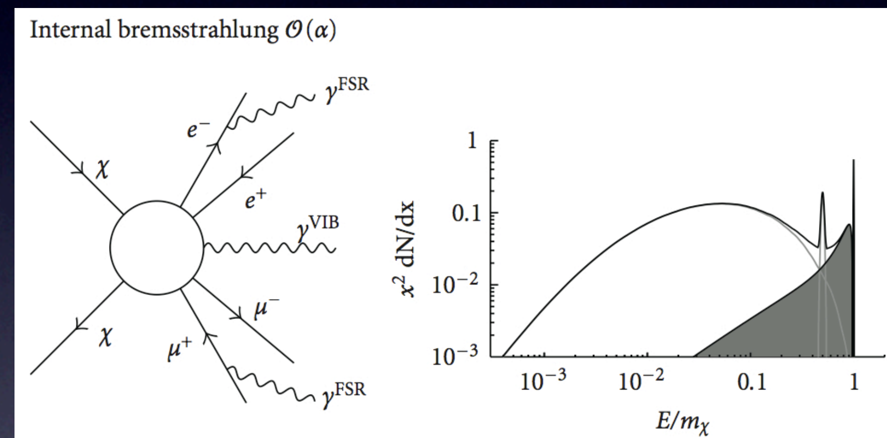
Advantages of gamma-rays: Not affected by propagation in the Galaxy. Can give clear signatures both in spectral shape and in spatial variation.

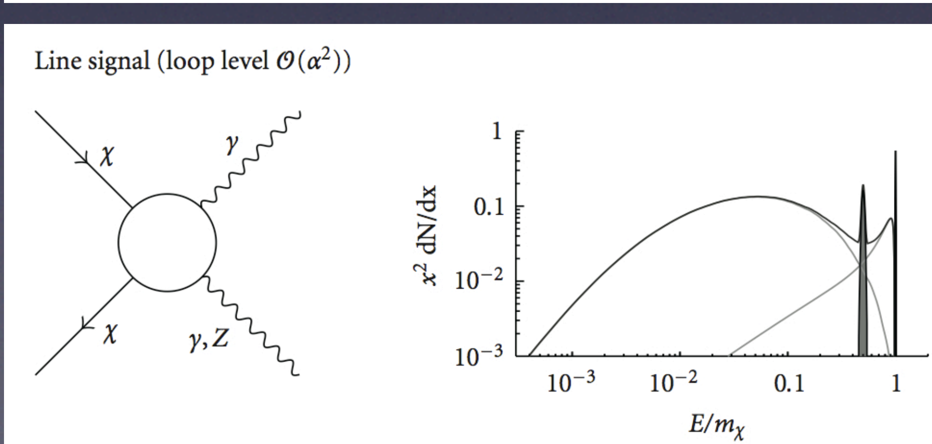
$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma,\theta,\phi) = \frac{1}{4\pi}\underbrace{\boxed{\frac{\langle\sigma v\rangle_{T_0}}{2\,M_\chi^2}\sum_f \frac{dN_\gamma^f}{dE_\gamma}B_f}}_{\text{Particle physics}}\cdot\underbrace{\boxed{\int_{\Delta\Omega(\theta,\phi)} d\Omega' \int_{l.o.s.} dl\;\rho_\chi^2(l)}}_{\text{Astrophysics}}$$

DM signal: spectral shape



quite similar spectra for all annihilations to haeavy quarks and gauge bosons.





Figures: Michael Kuhlen, Advances in Astronomy Volume 2010, Article ID 162083

+ electroweak corrections (arXiv:1009.0224 and arXiv:0911.0001), important for ~TeV DM.

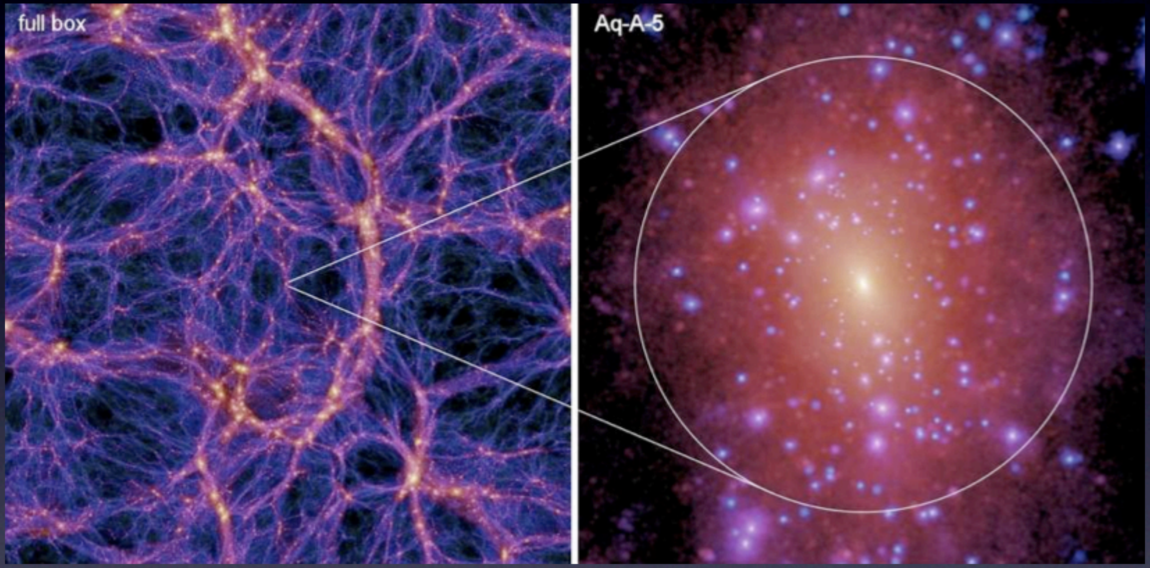
the annihilation spectra is known considerably well, however we are still learning...

DM signal: spectral shape

Or, through radiative losses in ambient backgrounds and fields.
Important if there is a significant branching ratio to leptons.

$$\chi\,\bar{\chi} \rightarrow \begin{cases} \boxed{e^+\,e^-} \\ l^+\,l^- \text{ or } \phi\,\phi \rightarrow \dots + \boxed{e^+\,e^-} \\ P\,\bar{P} \rightarrow \dots + \pi^\pm \rightarrow \dots + \boxed{e^\pm} \end{cases} \begin{matrix} \text{ambient} \\ \text{backgrounds} \\ \text{and fields} \end{matrix} \begin{cases} \text{Synchrotron} \\ \text{Inv. Compton} \\ \text{Bremstrahlung} \\ \text{Coulomb} \\ \text{Ionization} \end{cases} \begin{cases} \text{radio} \\ \text{IR} \\ \text{X-rays} \\ \Upsilon\text{s} \end{cases}$$

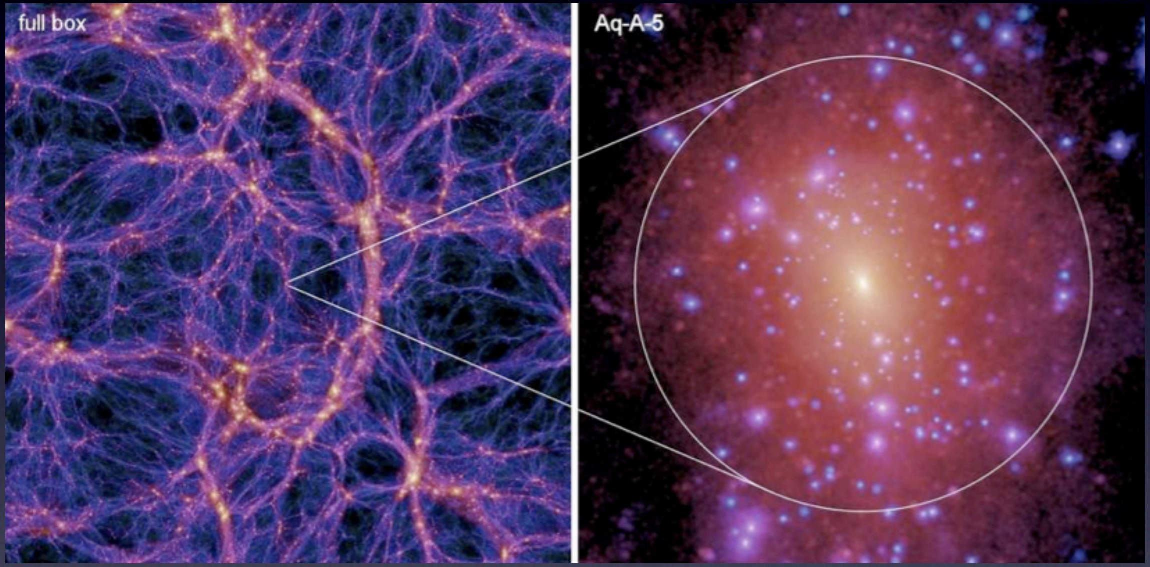
DM signal: morphology



Springel, V. et al, Mon.Not.Roy.Astron.Soc. 391:1685-1711,2008.

Obtained from N-body simulations which have impressive agreement with large scale structures. They find cuspy host halos (NFW or Einasto DM density profile) with numerous subhalos.

DM signal: morphology

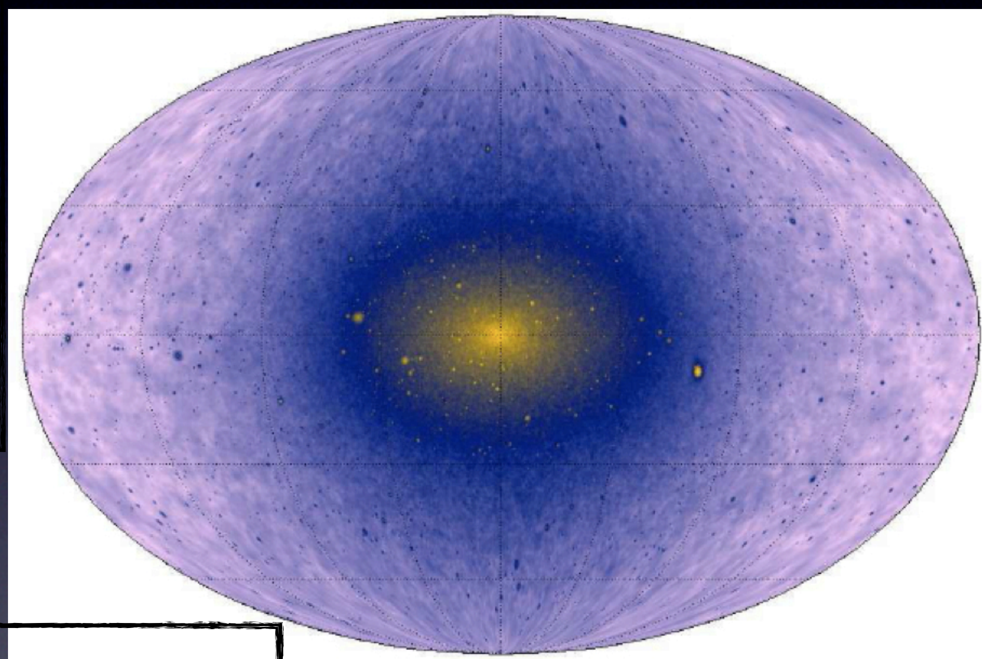


Springel, V. et al, Mon.Not.Roy.Astron.Soc. 391:1685-1711,2008.

However:
simulations typically do not include interaction with baryons;
Do not resolve the inner most region of the halo (<~100 pc);
They have also limited mass resolution to >~10^5 M_{sol} (sub) halos.
Related uncertainties in estimating the DM signal can be ~ order(s) of magnitude.

DM searches by the Fermi team

1. Galactic Center:
*brightest spot on the DM sky
*high astrophysical signal



Diemand, Kuhlen, Madau, APJ, astro-ph/0611370

5. Galaxy Clusters
6. Spectral Line search

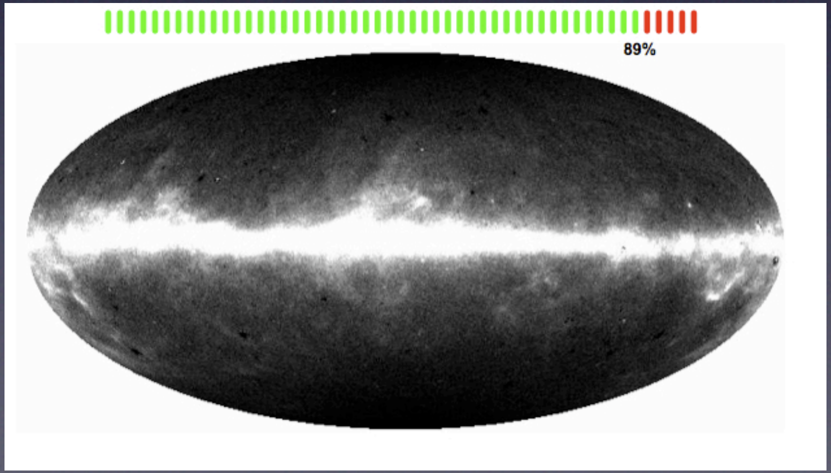
3. Dwarf Galaxies:
(largest Galactic subhalos)
*low backgrounds
*but low statistics, too.

4. search for Dark subhalos in a set of unassociated sources.

and *contribution of DM to the Galactic and extragalactic diffuse signal.*

Diffuse emission

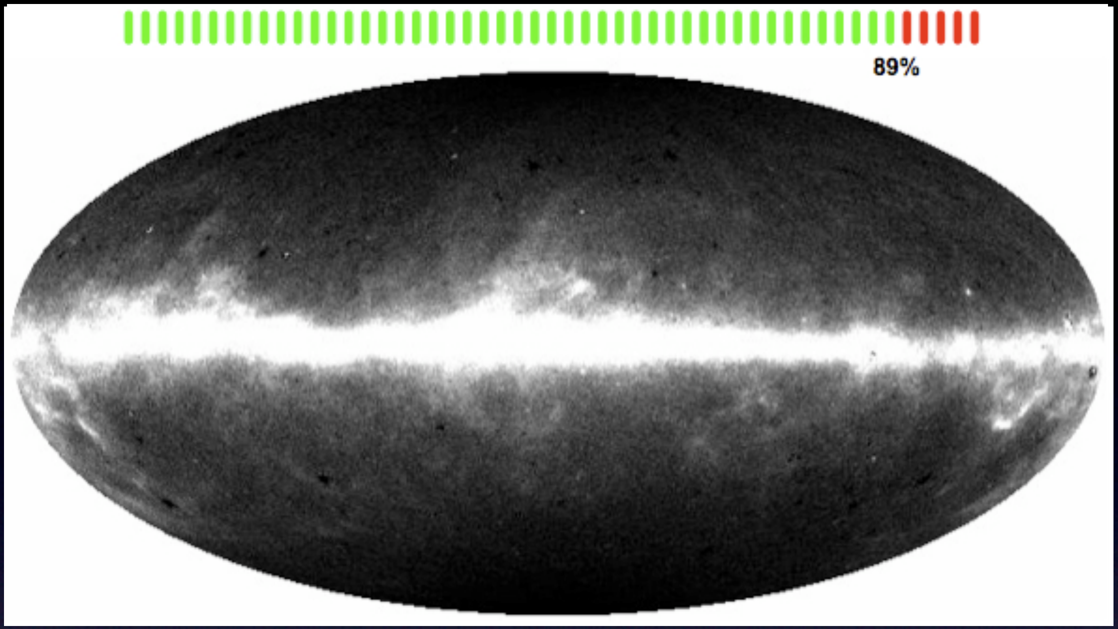
- Diffuse emission has good potential for DM searches -- contains information on the morphology as well as on the DM annihilation/decay spectral features.
- It has good statistics (~90% of LAT photons!), but it is background dominated.
- search strategies based on differences in expected morphology and spectral features of astrophysical vs dark matter signals.



LAT diffuse emission (point sources subtracted)

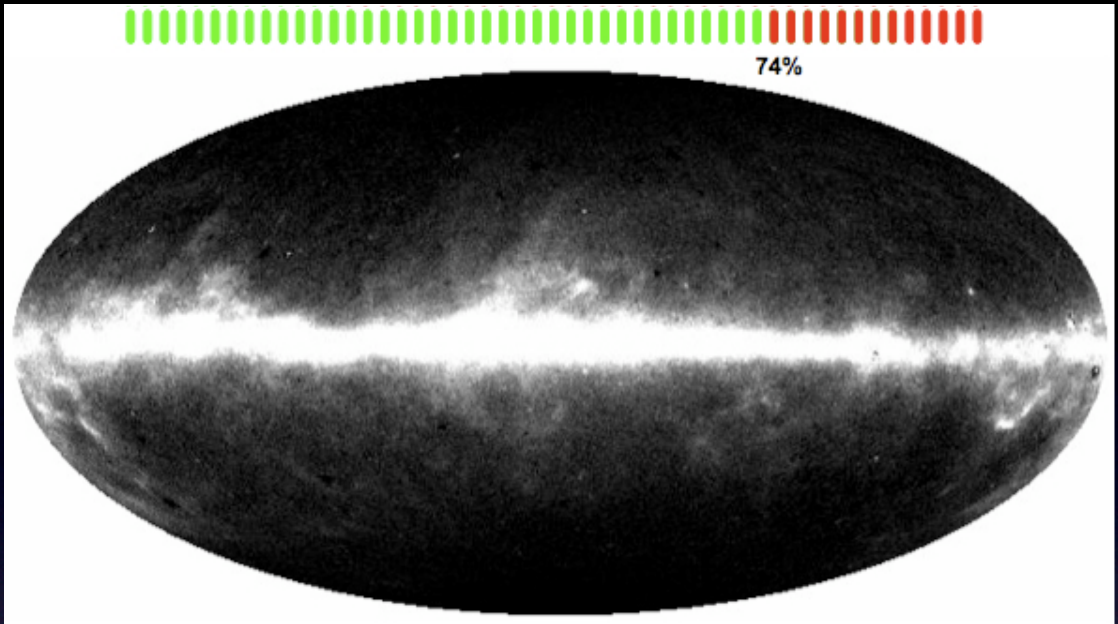
[J-M Casandjian, TeVPa2010]

Components of the diffuse emission:



[J-M Casandjian, TeVPa2010]

- Isotropic (extragalactic) component



[J-M Casandjian, TeVPa2010]

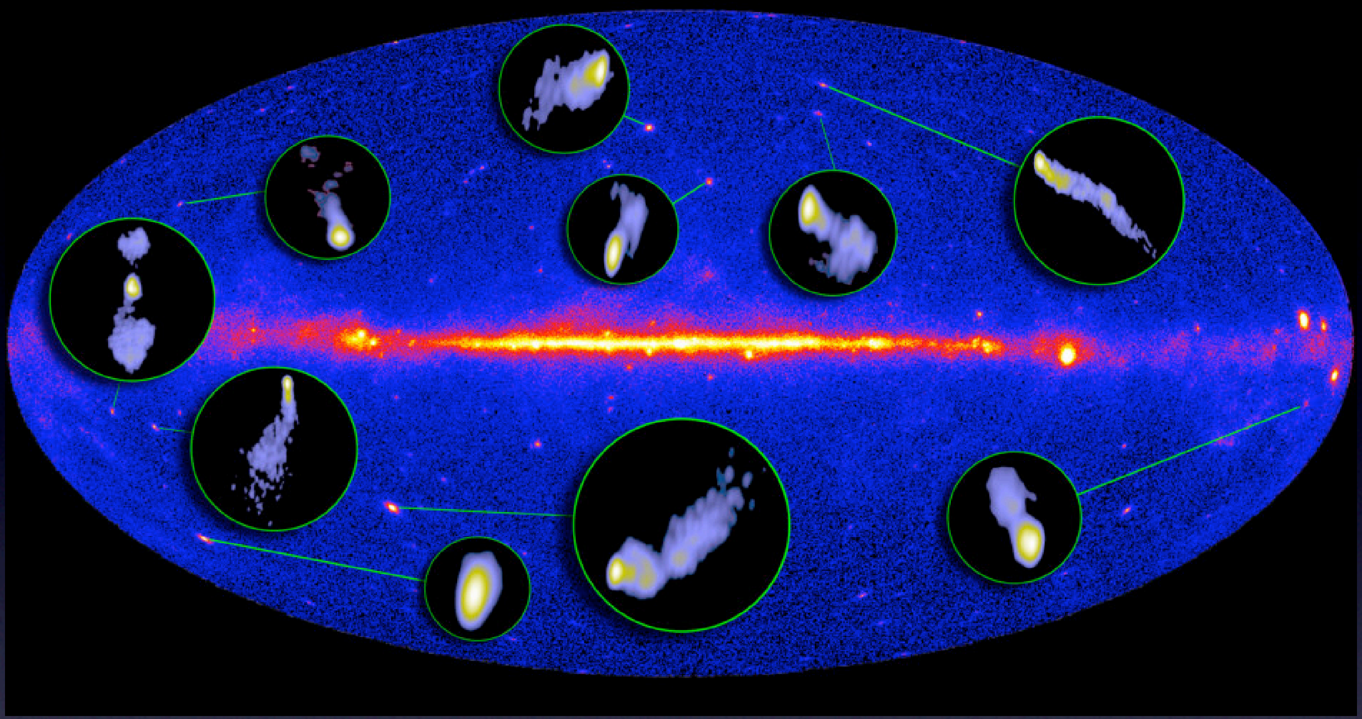
- Isotropic (extragalactic) component (15%)

Produced by *unresolved* energetic phenomena over cosmological scales:

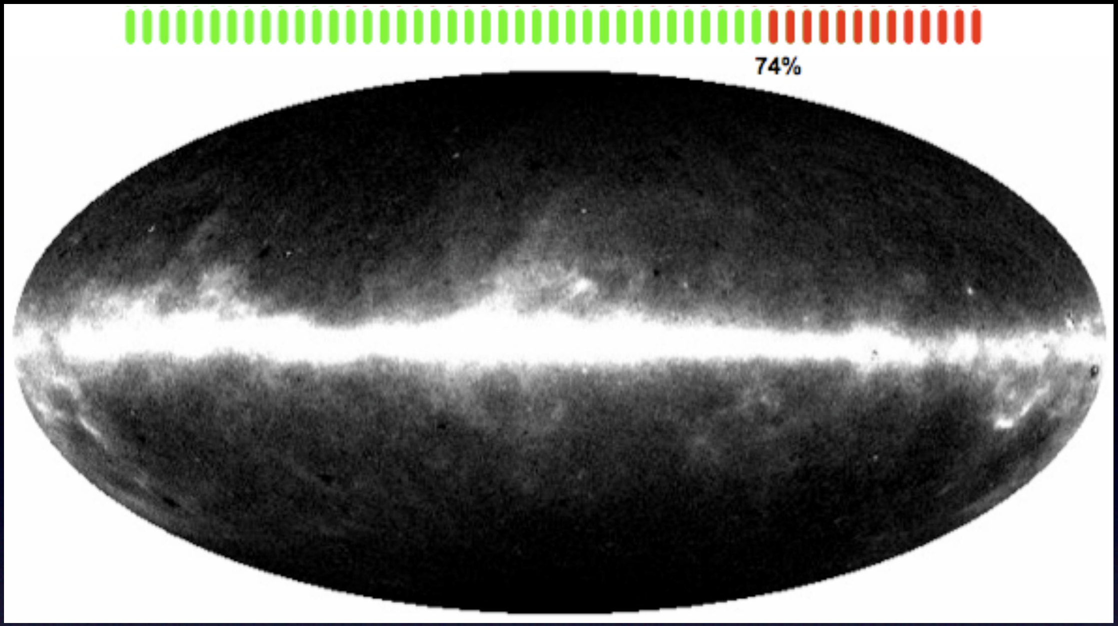
i) AGN

ii) star burst and star forming galaxies

iii) DM?

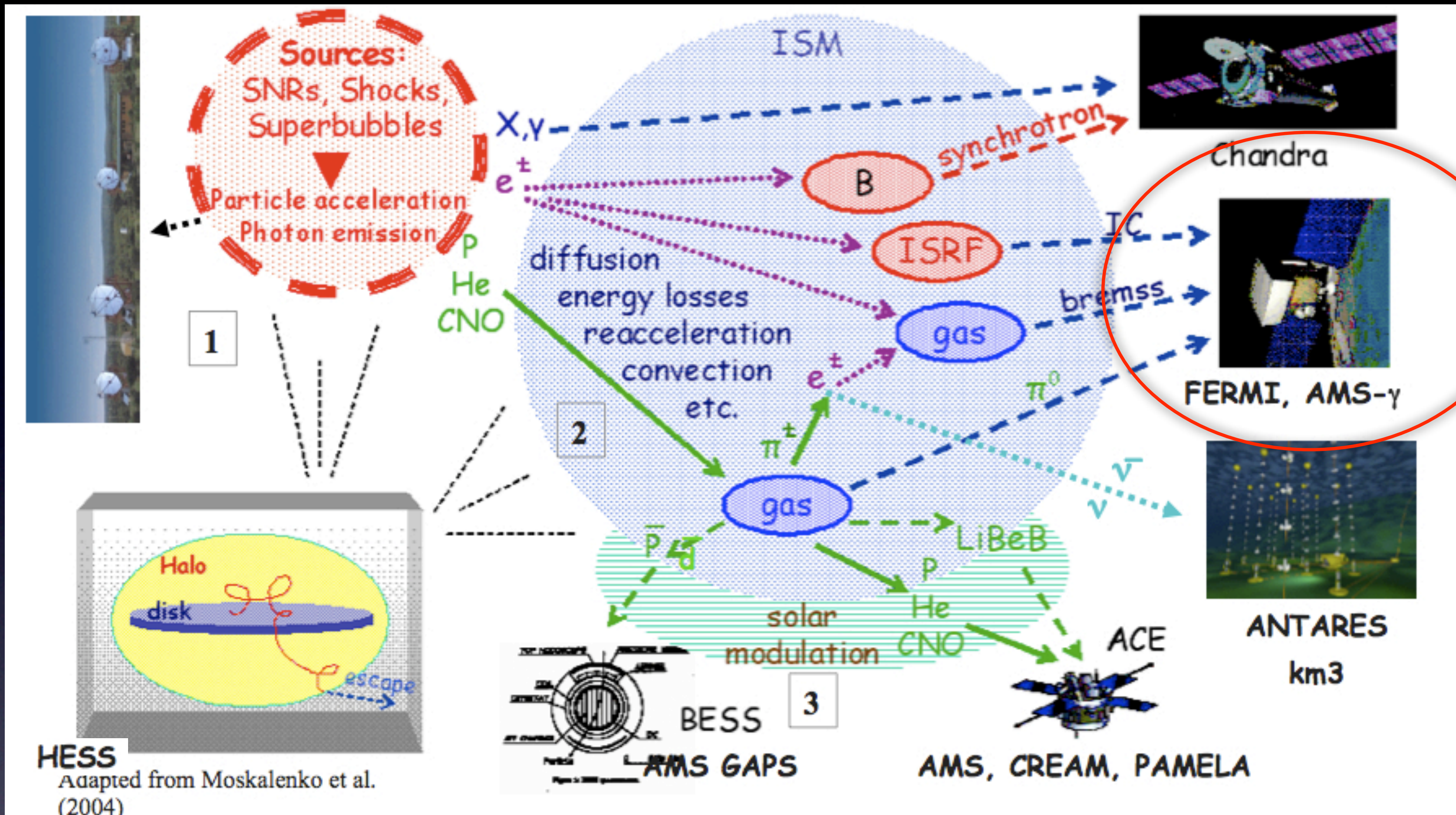


Selected Active Galactic Nuclei observed in radio by the VLBA (which has a million times better resolution than the Fermi-LAT) and gamma-rays by the Fermi-LAT.

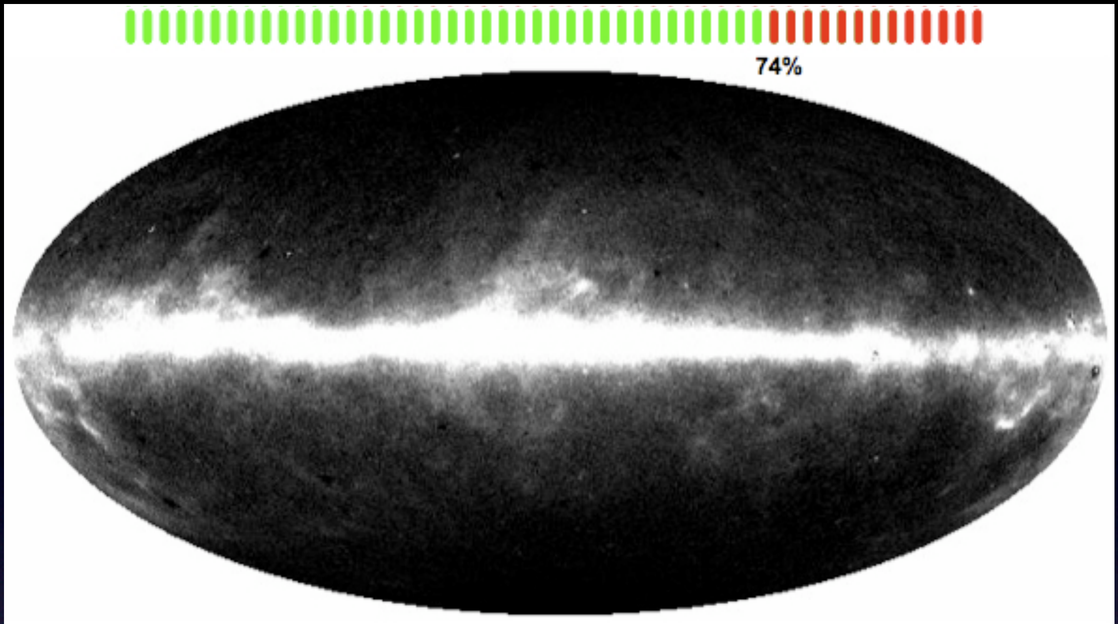


[J-M Casandjian, TeVPa2010]

- Isotropic (extragalactic) component (15%)
- Galactic diffuse component:



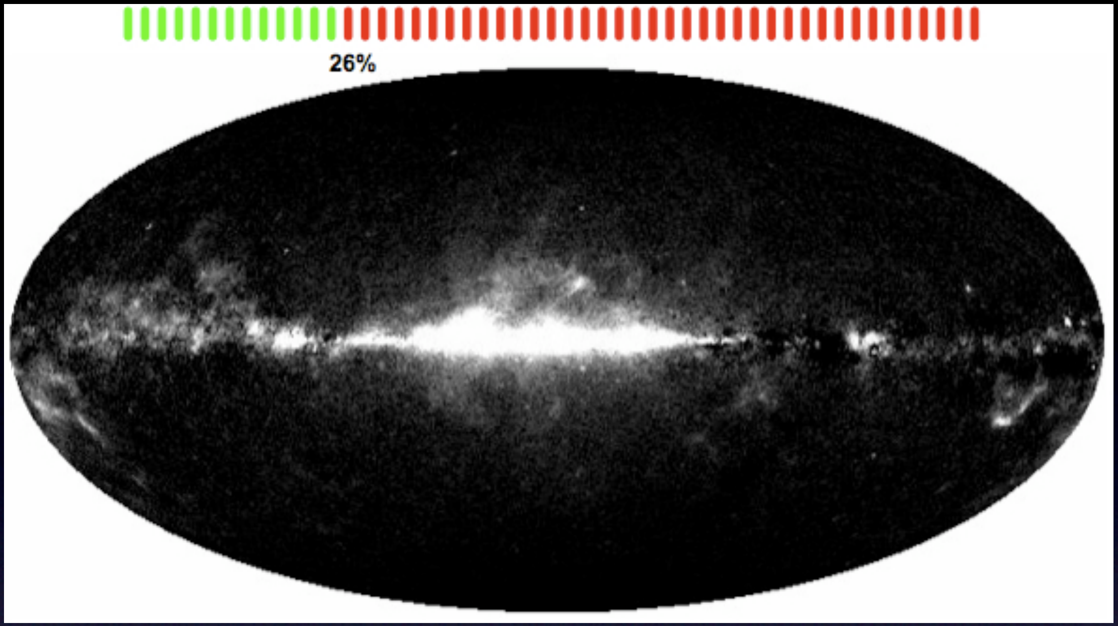
Galactic diffuse component: produced in interaction of cosmic rays with ambient medium and radiation fields.



[J-M Casandjian, TeVPa2010]

- Isotropic (extragalactic) component (15%)
- Galactic diffuse: *gas (π, bremss) & IC components*

i) atomic (HI) and ionized (HII) hydrogen ~50%

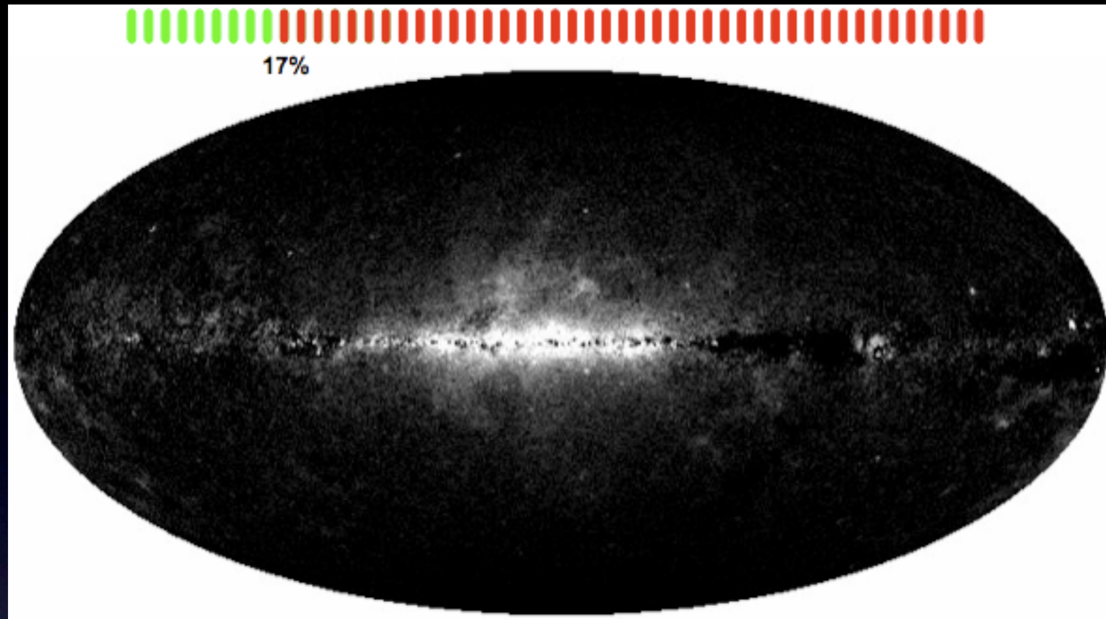


[J-M Casandjian, TeVPa2010]

- Isotropic (extragalactic) component ->15%
- Galactic diffuse: *gas (π, bremss) & IC components*

i) atomic (HI) and ionized (HII) hydrogen ~50%

ii) molecular hydrogen ~10%



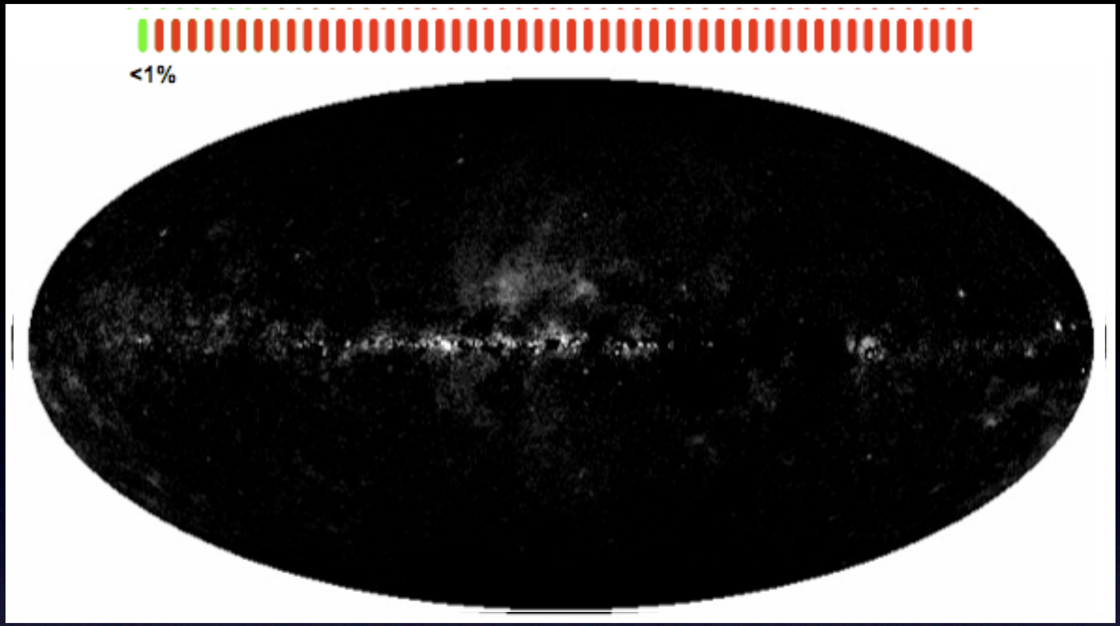
[J-M Casandjian, TeVPa2010]

- Isotropic (extragalactic) component ->15%
- Galactic diffuse: *gas (π, bremss) & IC components*

i) atomic (HI) and ionized (HII) hydrogen ~50%

ii) molecular hydrogen ~10%

iii) inverse compton ~10%



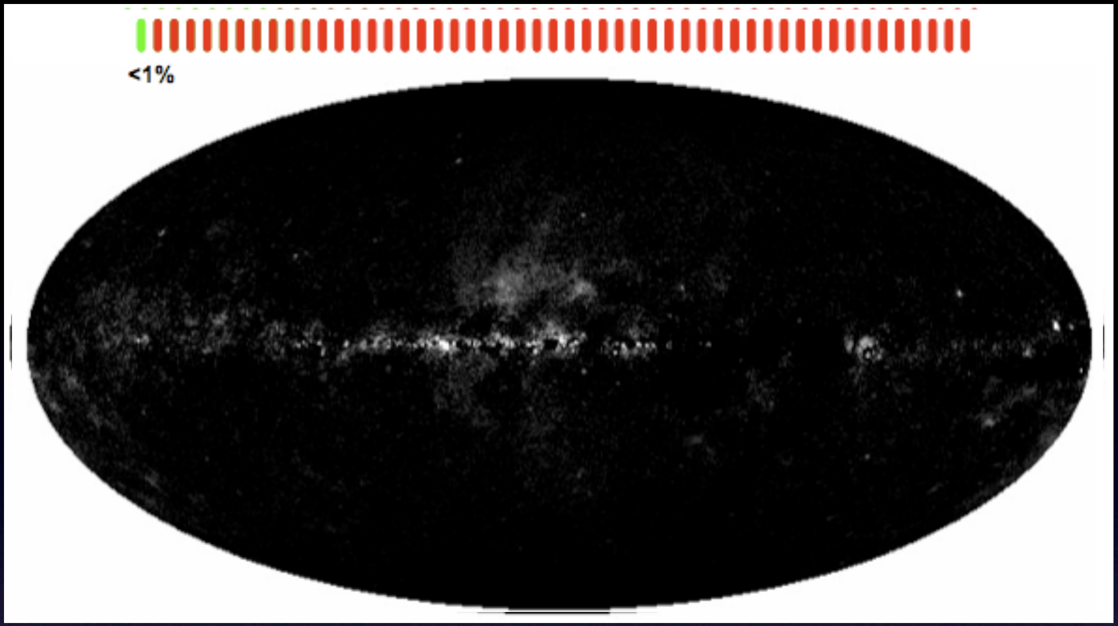
- Isotropic (extragalactic) component ->15%
- Galactic diffuse component (gas & IC) ->65%:

i) atomic (HI) and ionized (HII) hydrogen ~50%

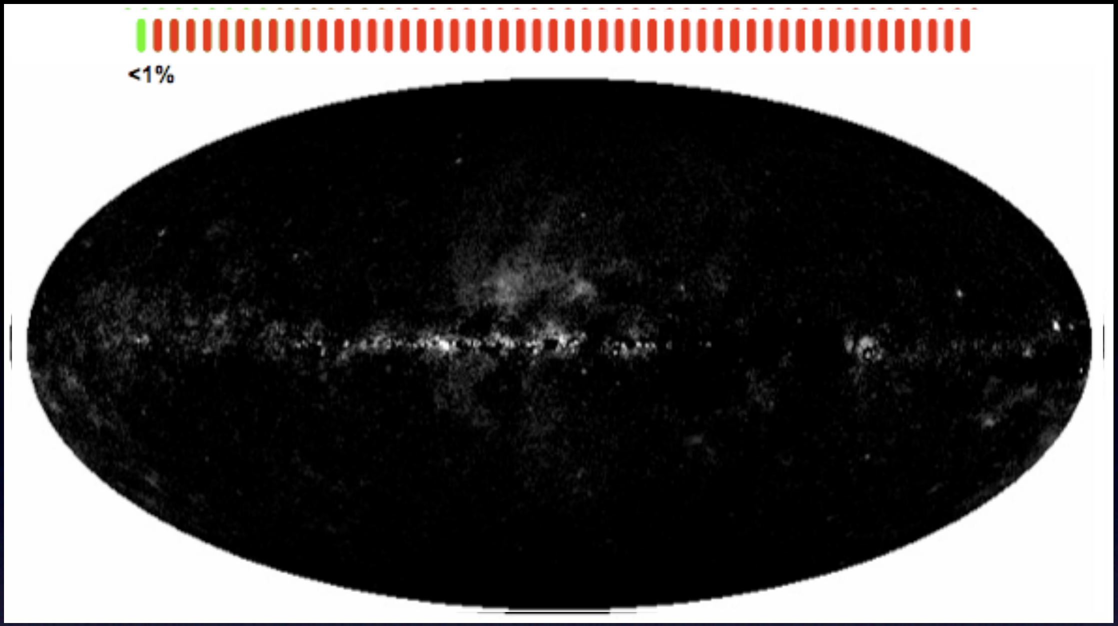
ii) molecular hydrogen ~10%

iii) inverse compton ~10%

iv) residuals <1 %; in part correlate with the dark gas



→The diffuse emission can be modeled with a linear combination of various templates (one of the main tools used in the analysis).

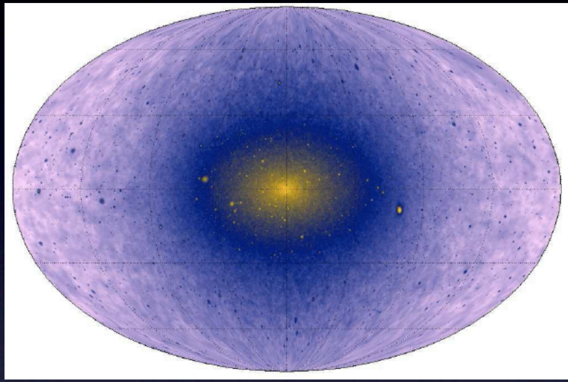


→The diffuse emission can be modeled with a linear combination of various templates (one of the main tools used in the analysis).
Gas templates:
• 21-cm Leiden-Argentine-Bonn survey of HI (Kalberla et al. 2005). The observed brightness temperature is converted to column density under the assumption of a uniform spin temperature *TS*.
•H II (ionized hydrogen) is added to this map, based on theoretical modeling(only 1% in density but important because it extends far from the plane ~2kpc).
•115 GHz Center for Astrophysics survey of CO (Dame et al. 2001). *X(CO)* factor to convert between CO and H2 column density is known to vary as a function of Galactocentric radius.
•Infrared surveys (IRAS, COBE) measure the emission from dust, which after correction for temperature variations can be converted to dust-reddening E(B-V), Schlegel et al. (1998).

‘Diffuse’ DM searches by the Fermi team

- analysis of the diffuse emission in terms of DM signal from the DM halo of our Galaxy.
- analysis of the diffuse Extragalactic (Isotropic) Signal to study DM annihilation at the cosmological scales, by using:
  - the *intensity and spectral shape* of the signal or
  - *angular anisotropies*.

Galactic Halo analysis

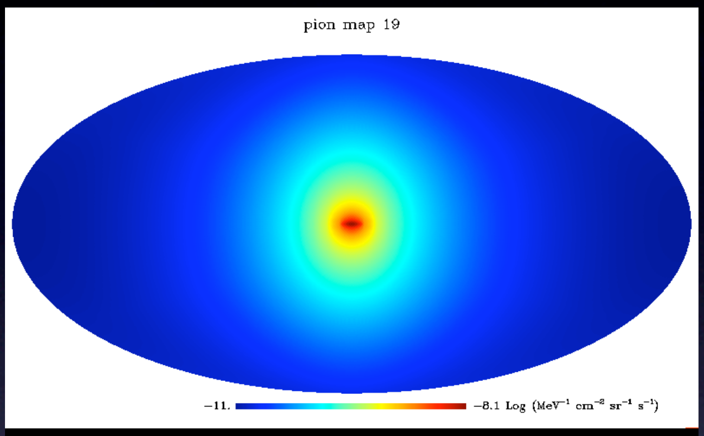


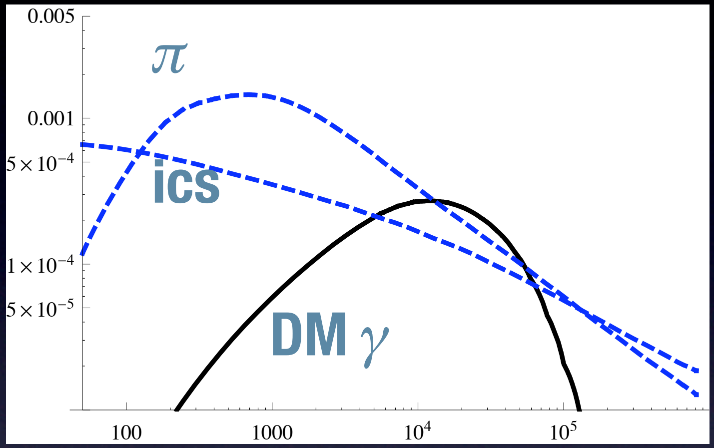
Signal from our galaxy:

- smooth halo: except in the inner most Galactic center region well understood
- subhalos -- model dependent. not taken into account here.

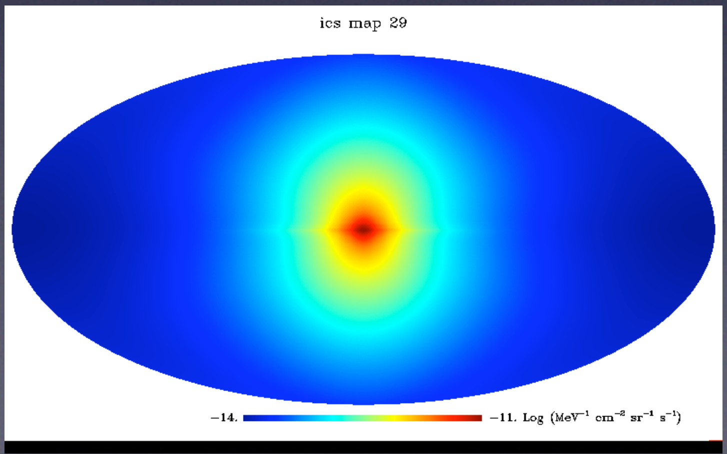
DM maps and energy spectra considered:

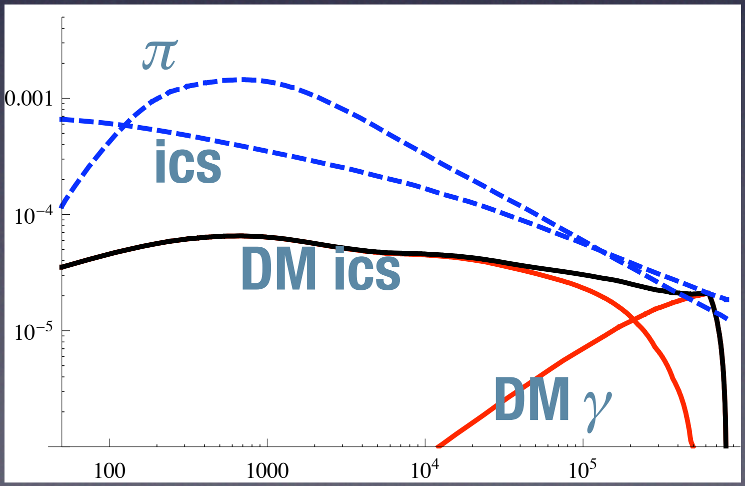
- photons directly produced in DM annihilations (through hadronization and pion decay, 'b-bbar' case)



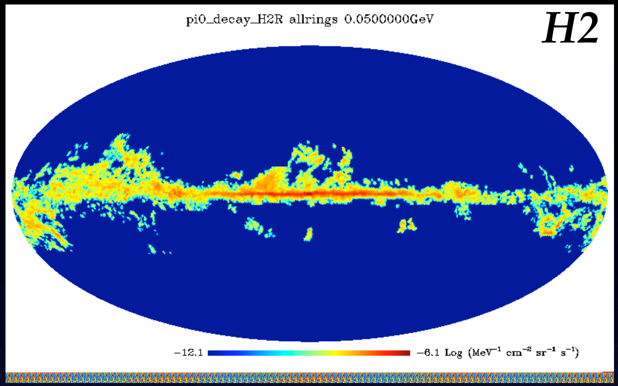


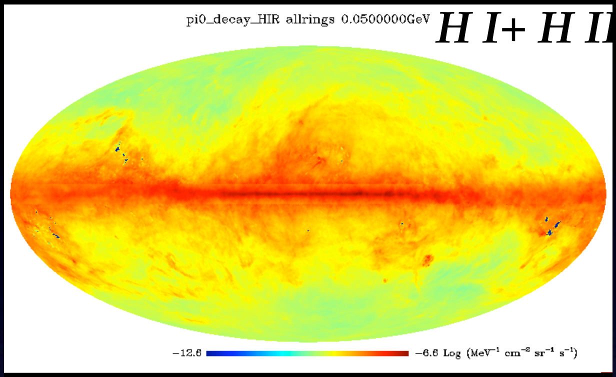
- photons produced directly (FSR) + through radiative processes (IC scattering); propagation parameters play role also for DM maps ('μ' case)

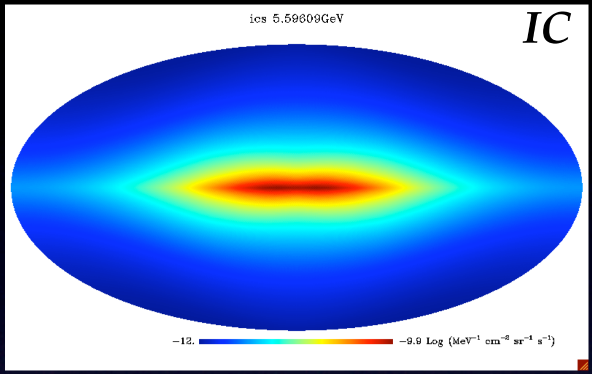


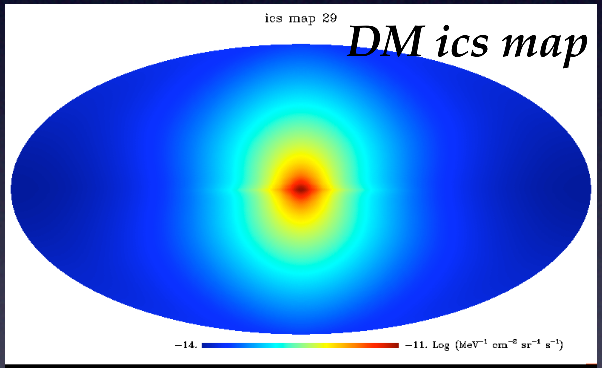


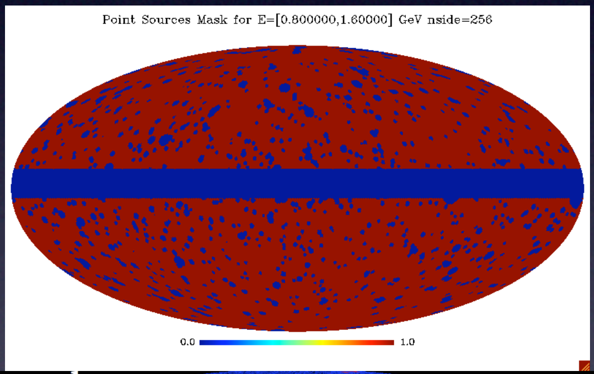
→*Main idea:* The diffuse emission can be modeled with a linear combination of various templates. We add a DM template, and perform a full sky spatial and energy fit to the 2 year Fermi data.

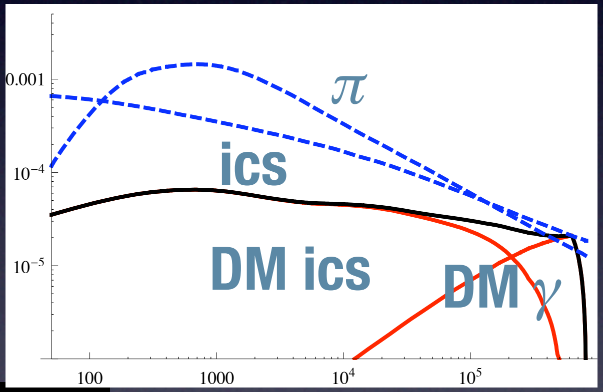


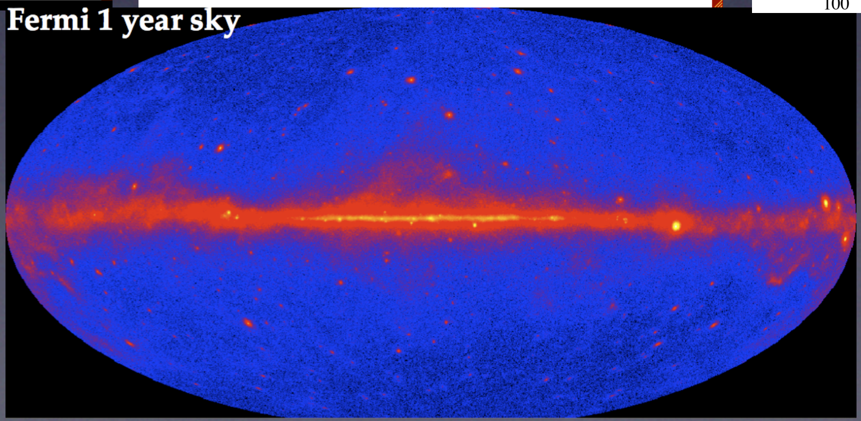












Galactic Astrophysical signal (background)

- this search relies heavily on modeling of the cosmic ray propagation.
- astrophysical signal which correlates with the used templates (HI, H2, IC, ...) are calculated with the GALPROP code.

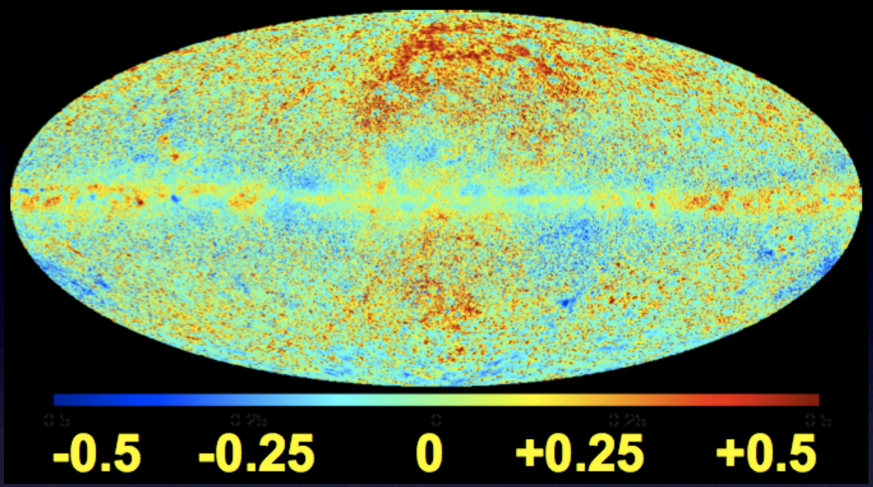
Main ingrediets of GALPROP modeling:

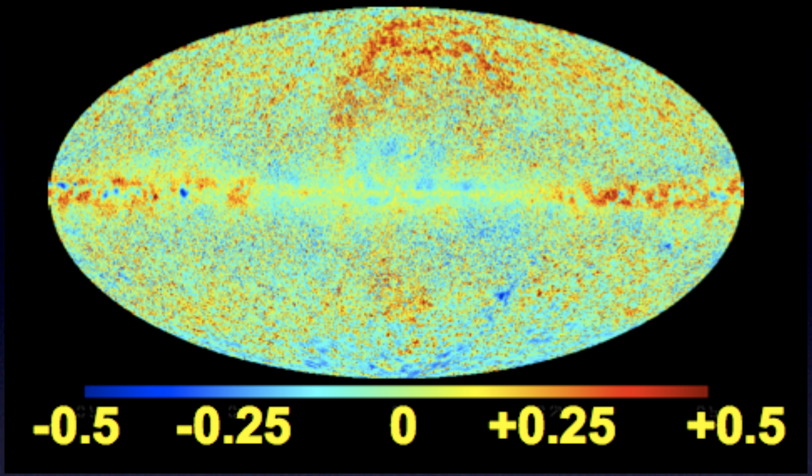
•cosmic ray source distribution, as obtained by direct observation of SNR or their tracers (i.e. pulsars)

•cosmic ray spectra: p, He, e+-, including secondaries, and Fermi-measured electrons

•measurement of secondary/primary (B/C), for propagation parameters

•halo height = 4-10 kpc (from radioactive cosmic ray nuclei).



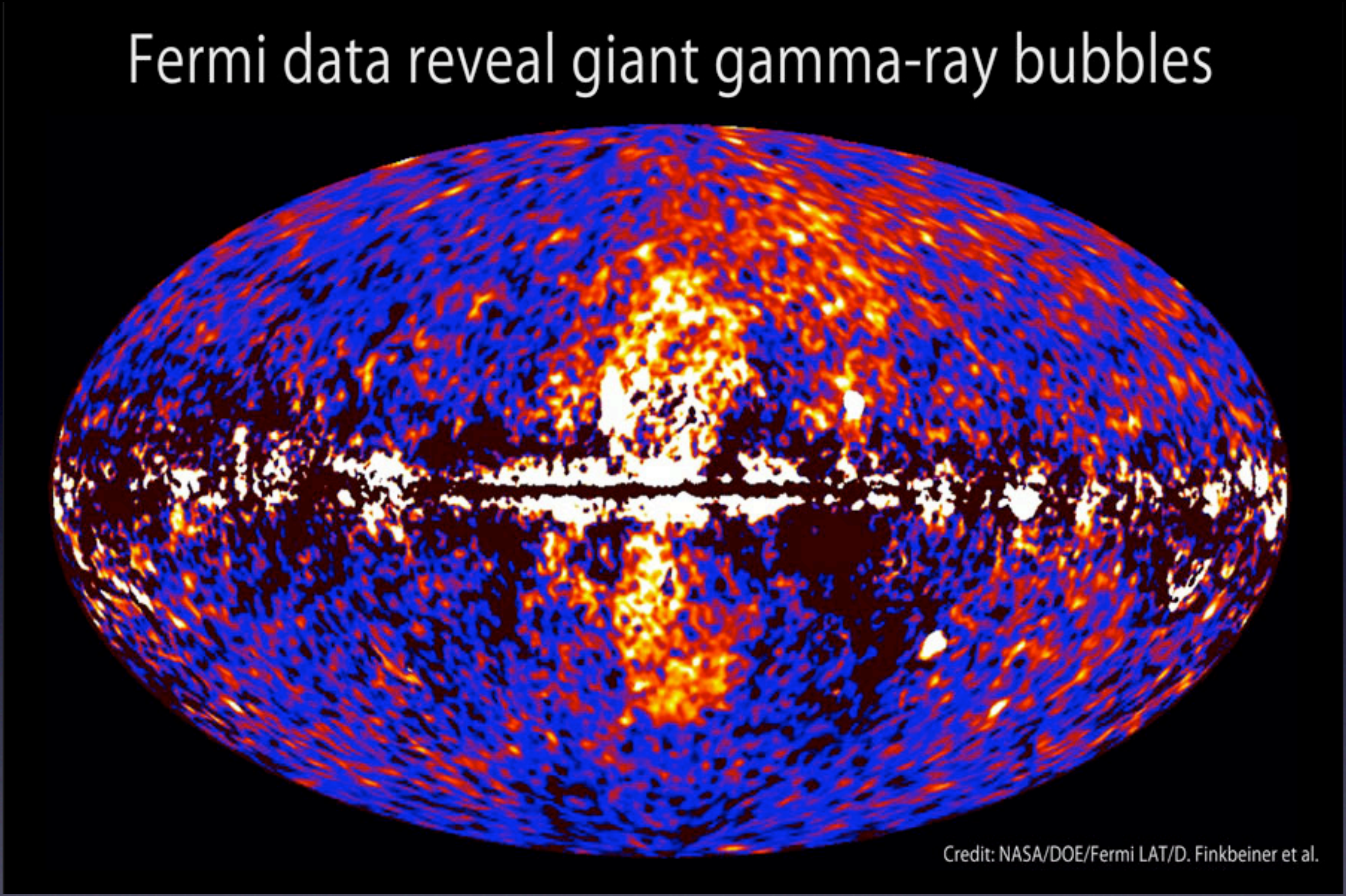


Based on this initial assumptions, a set of 'best' models is found through fitting of the template maps to the data.

The 'best fit' models describe the data well at the large scale, but leave residuals across the sky.

In order to properly set DM limits one would like to marginalize over these uncertainties (the full range of 'best' astrophysical models).

Astronomy picture of a day



Explanation: As the data from the Earth-orbiting Fermi satellite began acuminating over the past two years, however, a large and unusual feature toward our Galaxy's center became increasingly evident. The two bubbles are visible together as the red and white spotted oval surrounding the center of the above all sky image, released yesterday. Assuming the bubbles emanate from our Galaxy's center, the scale of the bubbles is huge, rivaling the entire Galaxy in size, and spanning about 50,000 light years from top to bottom. Earlier indications of the bubbles has been found on existing all sky maps in the radio, microwave, and X-ray. The cause of the bubbles is presently unknown, but will likely be researched for years to come.

DM limits - profile likelihood approach

[B. Anderson, IDM2010]

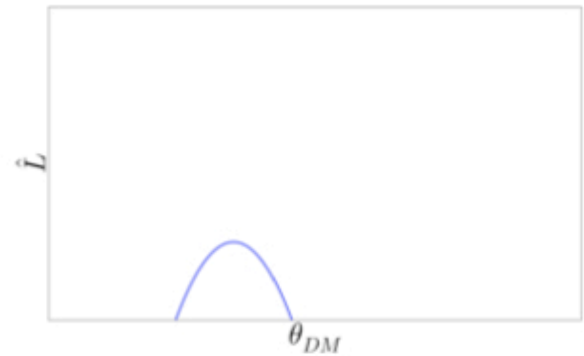
In Principle

Scanning the DM normalization, we smoothly transition between background models.

Step 1

For each GALPROP model, maximize $\hat{L}$ w.r.t. linear parameters, $\vec{\alpha}$, for each value of θ_{DM} (Flux Normalization).

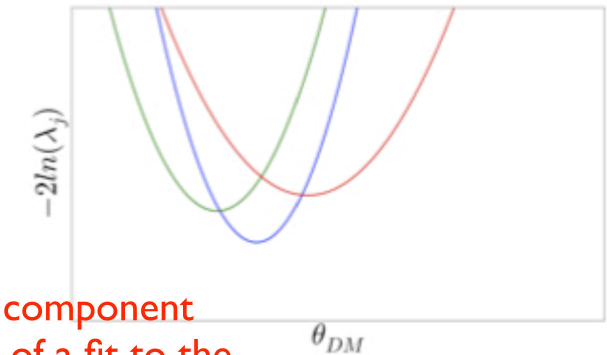
$\hat{L}_j(\theta_{DM}) = \prod_i P_{ij}(n_i; \vec{\alpha}_{max}, \theta_{DM})$



Step 2

Construct a test statistic for each diffuse model (different colors) using the best overall Likelihood and the CR fit probability.

$$\lambda_j(\theta_{DM}) = \frac{P_j^{CR}\hat{L}_j(\theta_{DM})}{(P_j^{CR}\hat{L}_j)_{best}}$$



for each galprop model and a normalization of DM component construct the test statistics based on the likelihood of a fit to the gamma and cosmic ray data.

DM limits - profile likelihood approach

[B. Anderson, IDM2010]

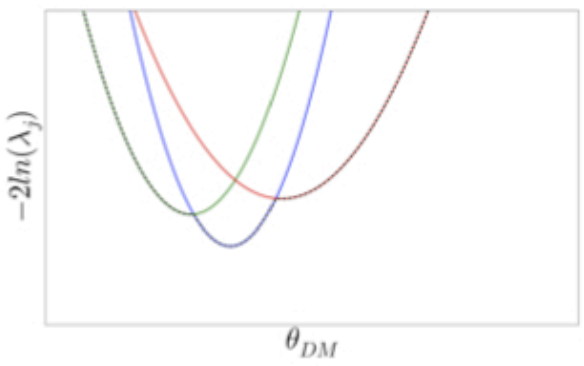
In Principle

Scanning the DM normalization, we smoothly transition between background models.

Step 3

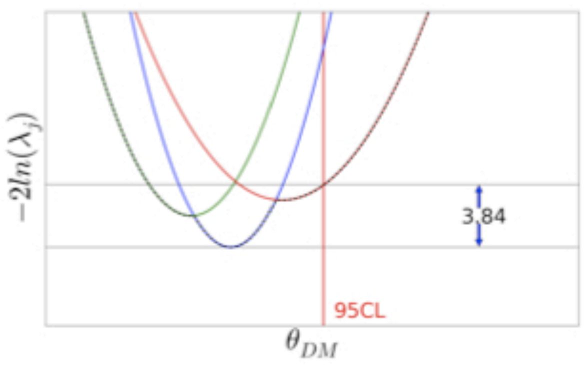
The profile likelihood is the curve that follows the minimum of all GALPROP models.

$$T_{chi^2}(\theta_{DM}) = -2ln\lambda_{jmax}(\theta_{DM})$$



Step 4

Since $T_{chi^2}(\theta_{DM})$ behaves as a χ^2 with one d.o.f., we set the 95% confidence upper limit to where the profile likelihood rises by 3.84 above the absolute minimum.

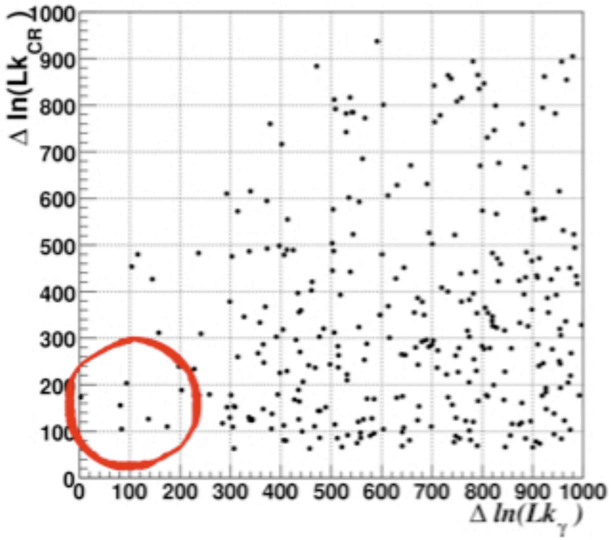


DM limits - profile likelihood approach

[B. Anderson, IDM2010]

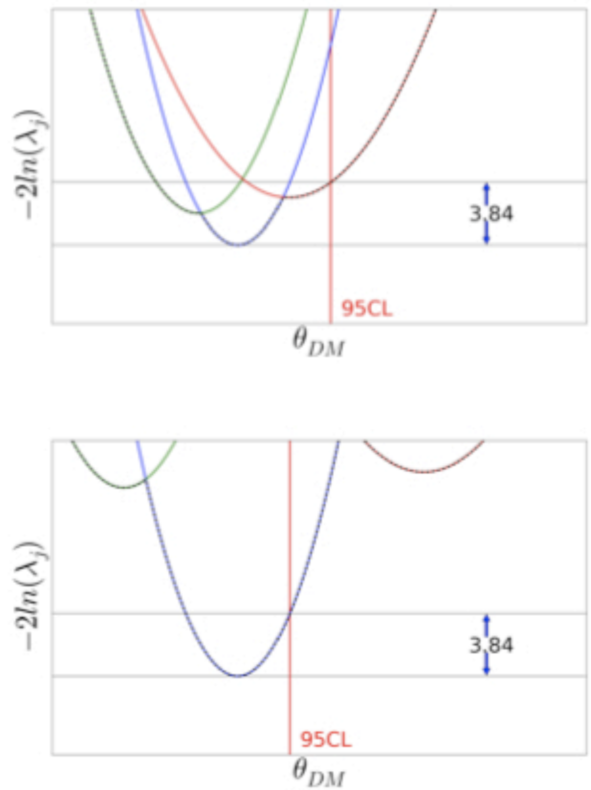
In Practice

Sparse sampling means our limits all still come from a single model.



Sparse Sampling

Including χ^2 from the CR data in the Likelihood makes it difficult (naively sampling) to populate the region that satisfies both CR and gamma rays. This important region is currently dominated by a couple of models.



work in progress

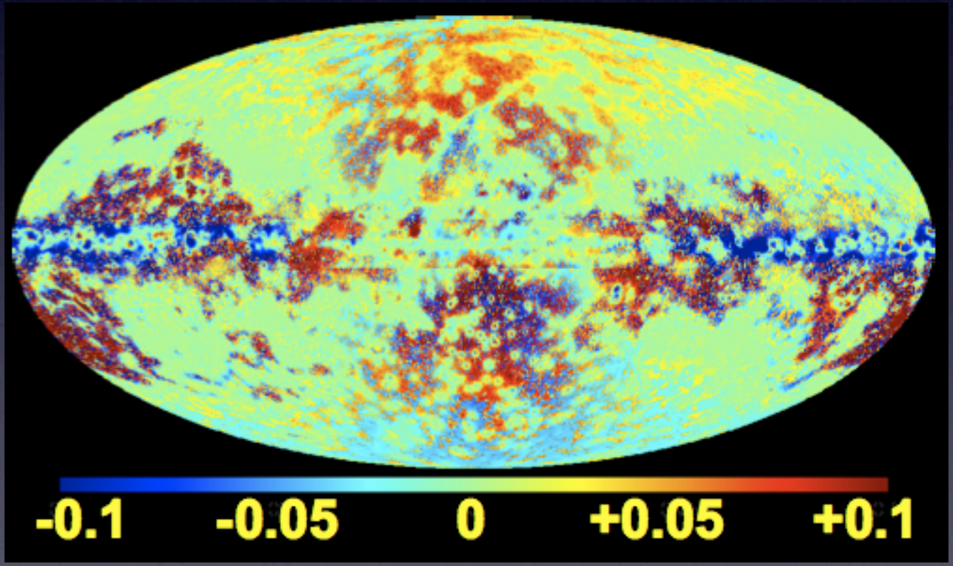
DM limits - current limits

Among all astrophysical models obtained as described we choose the one expected to give most conservative DM constraints.

The two most critical parameters in this respect are distributions of CR sources and diffusive halo size.

DM limits - current limits

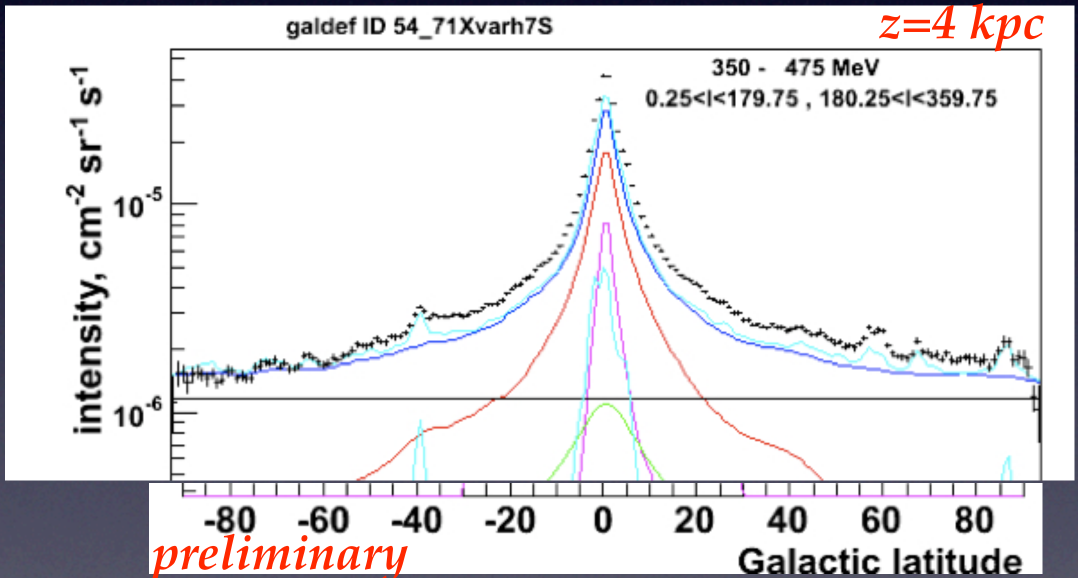
Distributions of CR sources: chosen distribution is based on the observation of 46 SNR, (observational bias) has low gradient in the inner Galaxy and it underpredicts data there → it gives one of the most conservative DM limits.



Negative pixels represent a better fit with SNR model, while positive pixels are better fit using pulsars as tracers of CR sources.

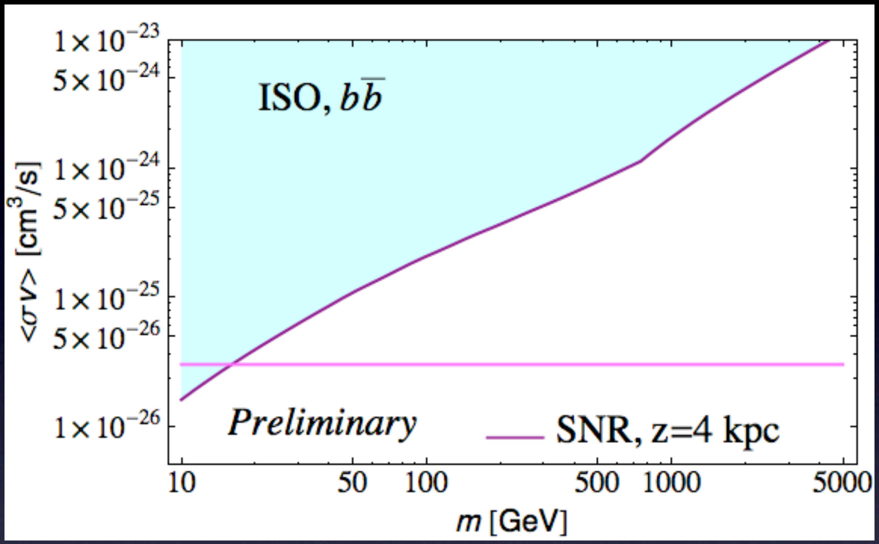
DM limits - current limits

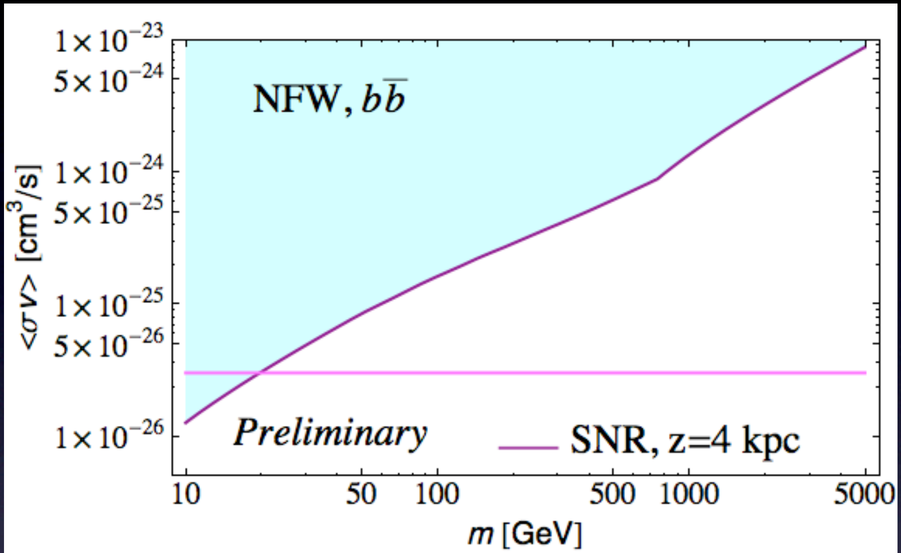
A larger halo gives a broader latitude distribution. Small halo size under predicts data in terms of the latitude profiles, making the DM limits weaker in that case.



We consider a model with CR source distribution as determined by the direct observation of SNR and smaller halo size z=4 kpc, (with other parameters optimized to the CRE and Fermi data) to set the DM limits.

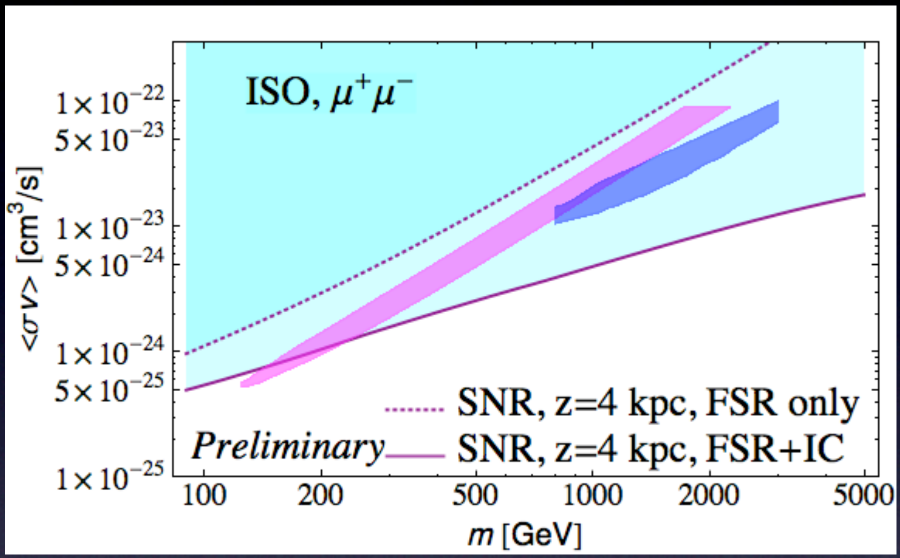
DM limits - current limits

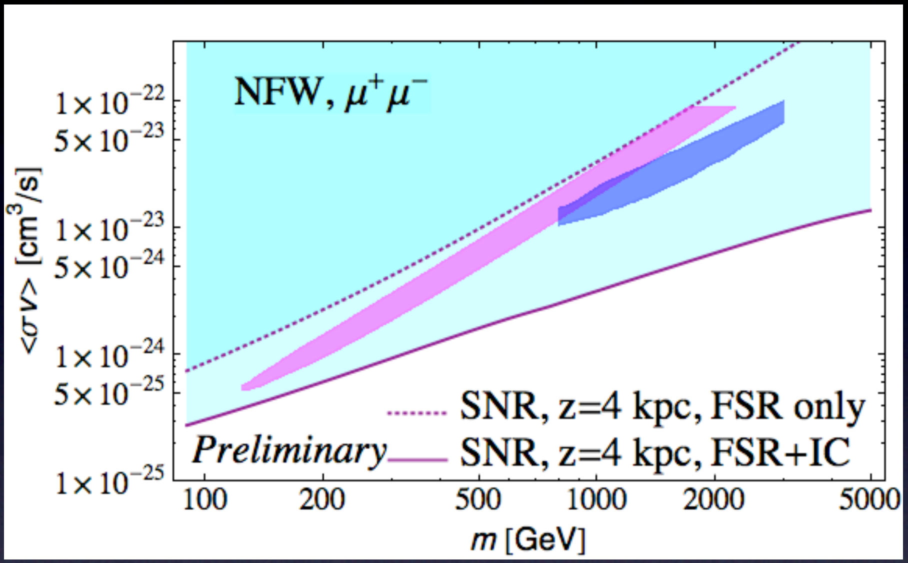




- as expected, limits do not depend much on the DM profile assumed (given mostly by a sky region 10<|b|<20 deg).
- good constraining potential of this approach, freeze-out value reached for low masses. Limits are expected to improve significantly with a better understanding of the astrophysical model (most critically in the region of the inner Galaxy).

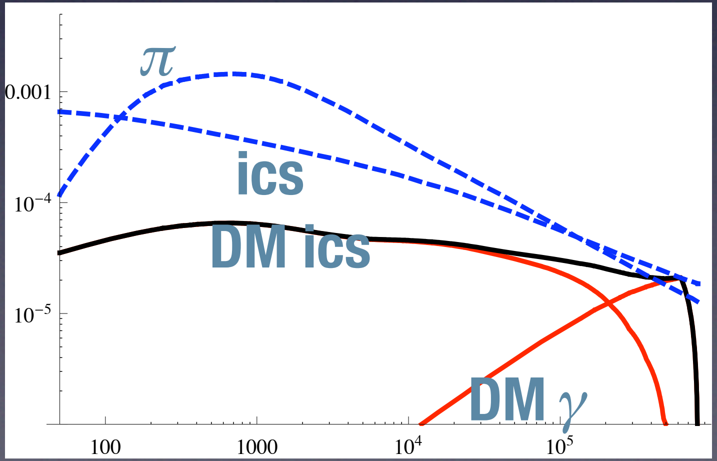
DM limits - current limits





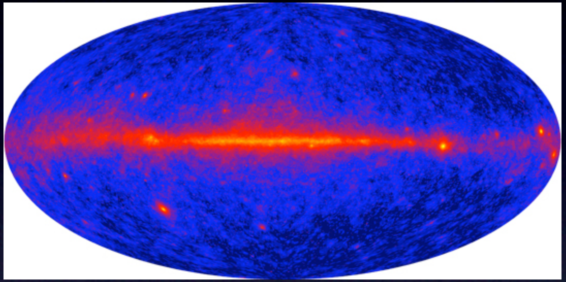
PAMELA (pink) and Fermi (Blue) regions are excluded when full DM spectrum (FSR+IC) is considered.

Note: FSR-only limits are weak since the data only up to 100 GeV has been used (will improve when/if <~300 GeV data set is used).



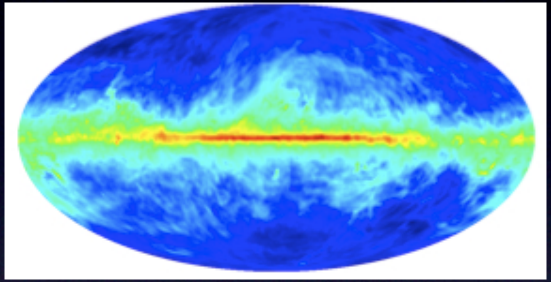
Extra Galactic diffuse signal - DM limits from the *intensity and spectral shape* of the signal

- Extra Galactic diffuse signal inferred the isotropic gamma-ray emission by multicomponent fit to Fermi-LAT gamma-ray data.



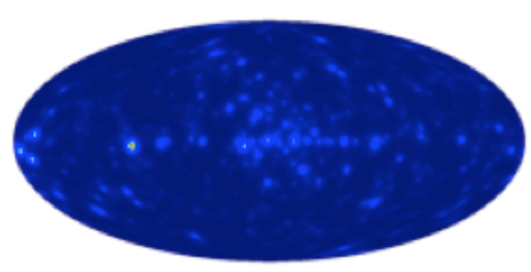
full sky data

-



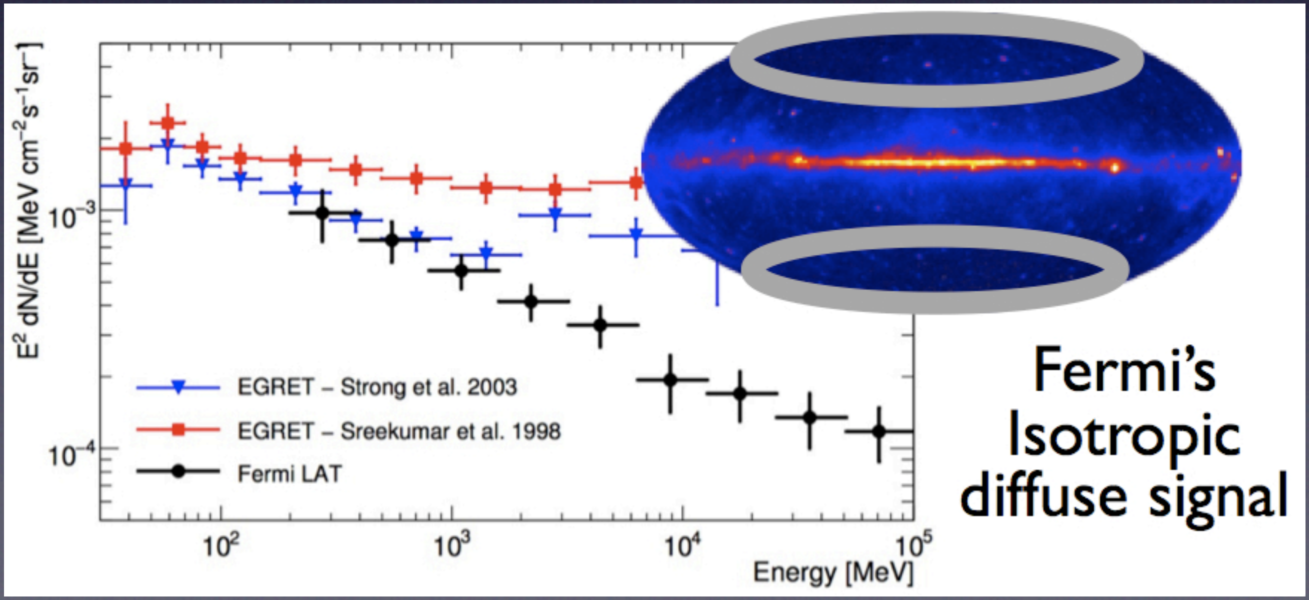
galactic diffuse emission

-



point sources

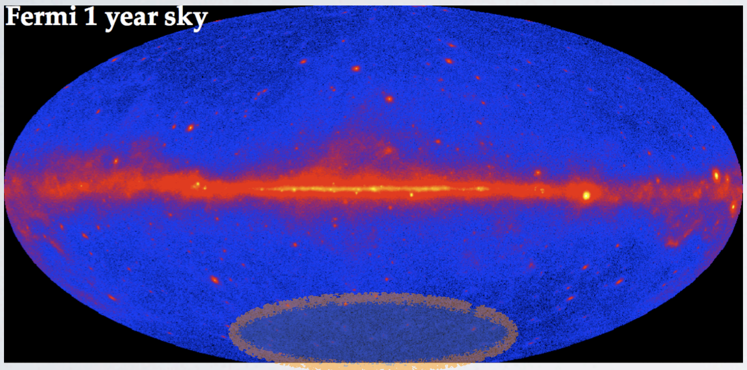
NB: the features of the inferred isotropic signal depend on the modeling of the galactic diffuse emission. Estimates of error~20%.

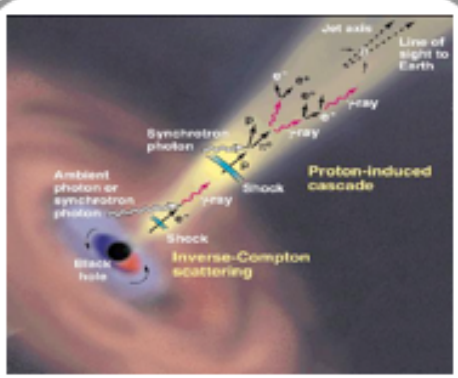


Isotropic diffuse signal

Fermi-LAT collaboration, JCAP 1004:014,2010.

What makes the GeV extragalactic signal?

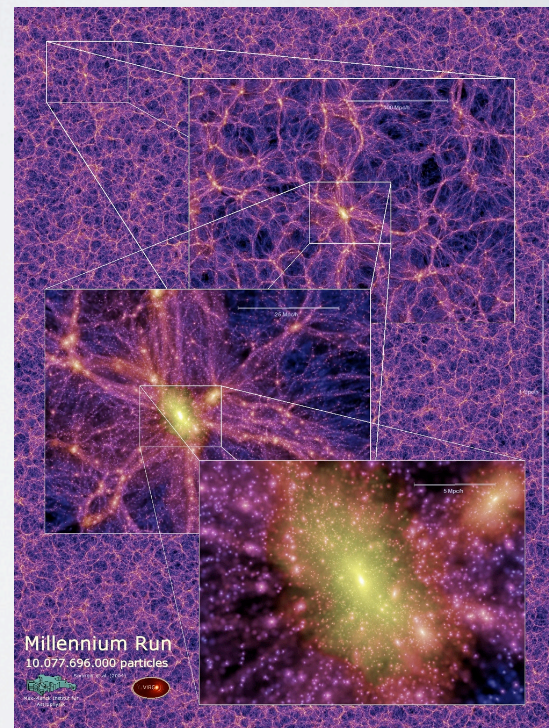




Credit: J. Buckley 1998 (Science), illustration: K. Sutliff

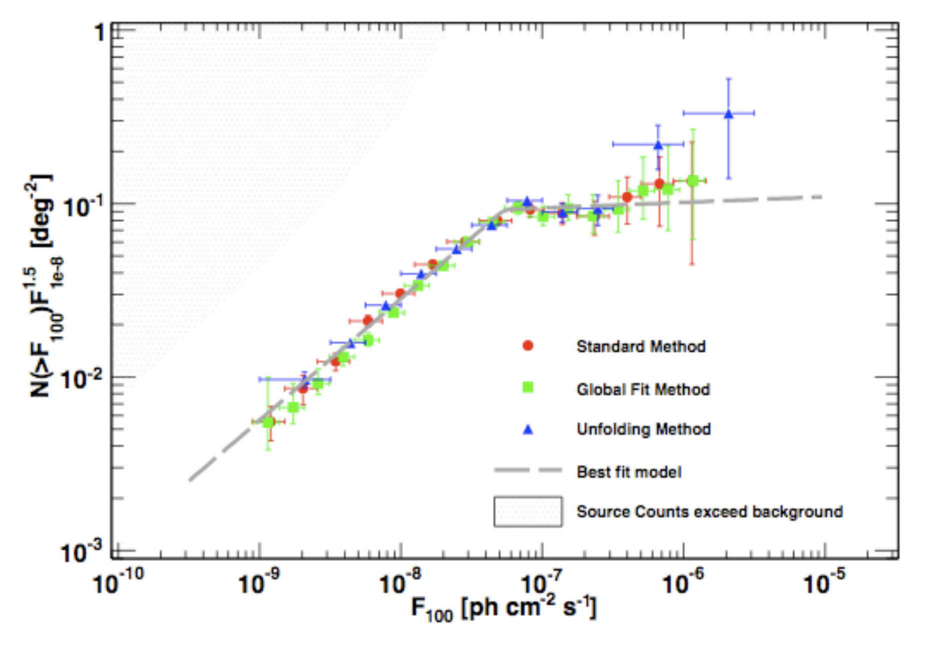
Guaranteed contribution: ***unresolved extragalactic sources***: blazars, star forming and star burst galaxies,...

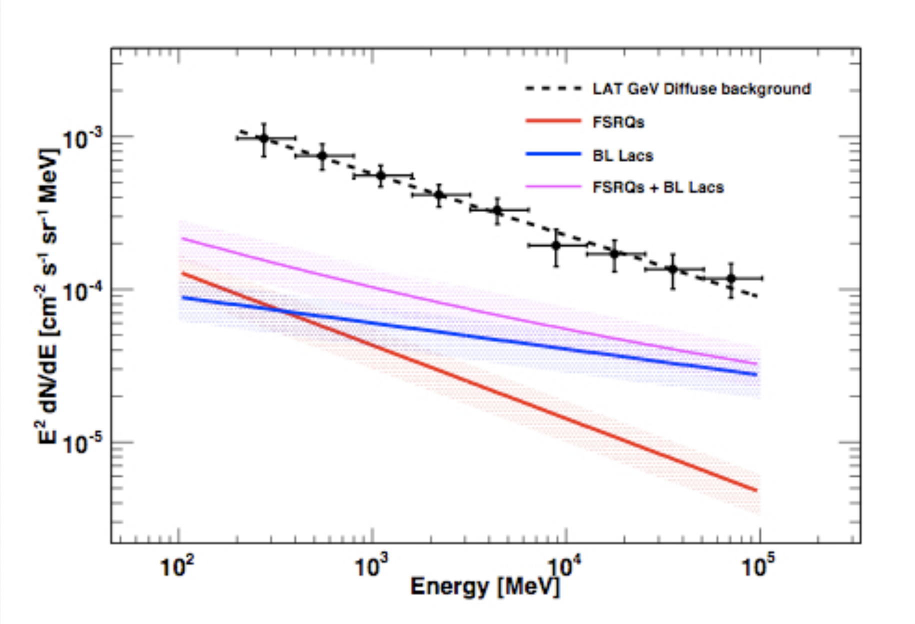
Dark matter annihilation in all halos at all red-shifts should contribute, too.



Intensity and Spectra of astrophysical contribution

AGNs, based on Fermi observation of ~700 AGNs, and a break in their luminosity function, -> **maximally 30% of the extragalactic signal.**





Fermi-LAT collaboration, arxiv:1003.0895

Cosmological signal of DM

DM forms structures (halos) in gravitational collapse, within which DM self-annihilation signal is greatly enhanced (ρ^2).

$$\frac{d\phi_\gamma}{dE_0} = \frac{\sigma v}{8\pi}\frac{c}{H_0}\frac{\bar{\rho}_0^2}{M_\chi^2}\int dz\,(1+z)^3\frac{\Delta^2(z)}{h(z)}\frac{dN_\gamma(E_0\,(1+z))}{dE}e^{-\tau(z,E_0)}$$

Ullio, P. et al.,2002.

Δ^2: *describes clustering properties of DM: number of halos of a given mass, at a given red-shift and the inner structure of halos (through their concentration) -- N body simulations. Depends sensitively on the resolution of N-body simulations.*
τ: *attenuation of photons due to pair production on Extragalactic Background Light (from UV to far-IR)*
dN/dE: DM annihilation spectrum at emission.

Cosmological signal of DM

$$\frac{d\phi_\gamma}{dE_0} = \frac{\sigma v}{8\pi}\frac{c}{H_0}\frac{\bar{\rho}_0^2}{M_\chi^2}\int dz\,(1+z)^3\frac{\Delta^2(z)}{h(z)}\frac{dN_\gamma(E_0\,(1+z))}{dE}e^{-\tau(z,E_0)}$$

Ullio, P. et al.,2002.

Information in OVERALL NORMALIZATION and SPECTRAL SHAPE.

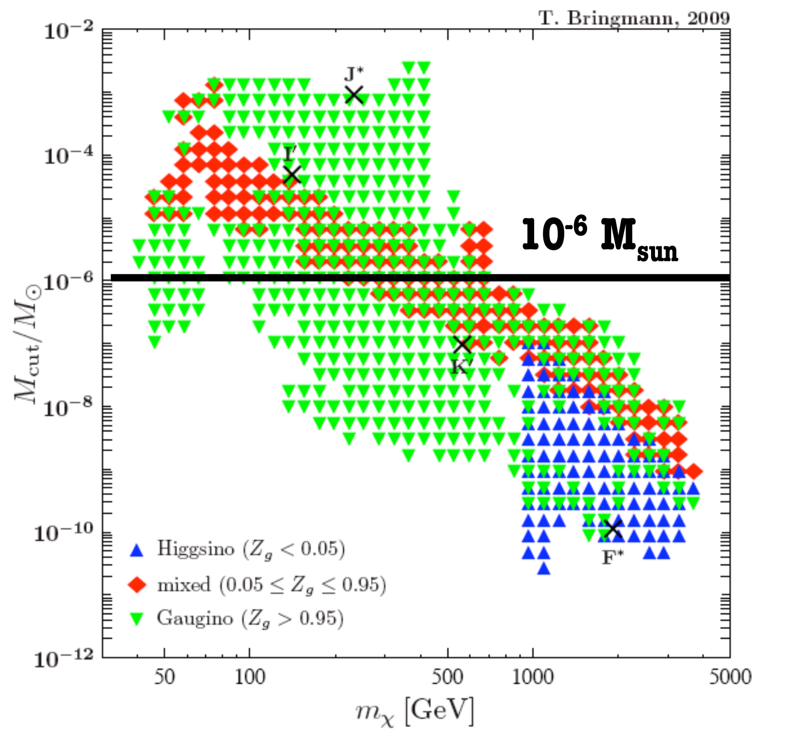
⋆*Overall normalization is degenerate, most notably between the DM annihilation rate and* Δ^2.

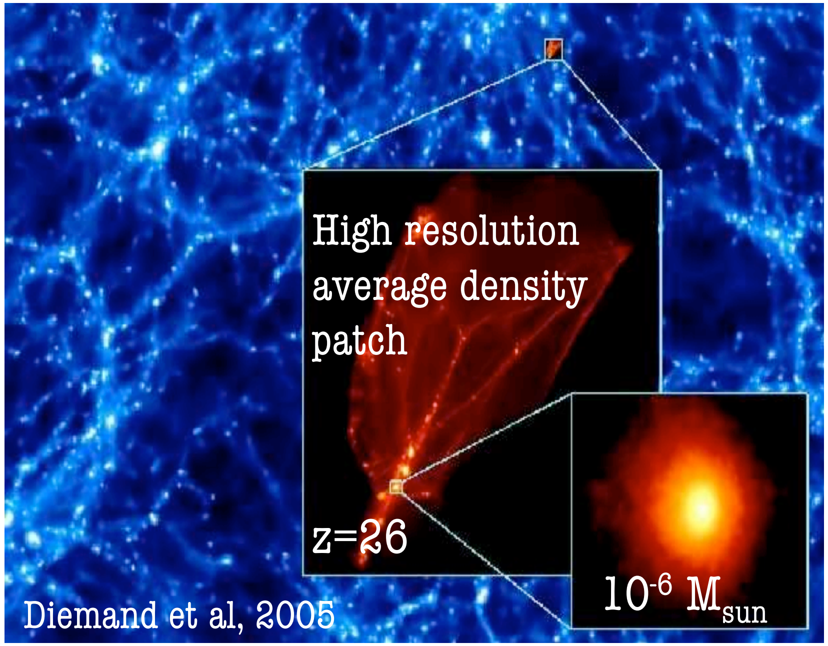
Δ^2: ***depends sensitively on the mass resolution of N-body simulations! - Introduces large uncertainties in limits one could place on*** $\langle \sigma v \rangle$

Normalization

⋆*The dominant contribution to* Δ^2 *comes from the smallest, most concentrated halos, which are unresolved in simulations - sensitive to the resolution limitations! (>$10^5 M_{sol}$, while theoretical lowest mass scale <$10^{-3} M_{sol}$).*

Typical M_{min} for a WIMP = 10^{-6} M_{sun}





Existence confirmed in a small high resolution patch of the universe, nested within a hierarchy of larger and lower resolution grids of particles - uncertainty in how measured properties at z=26 propagate to z=0.

$$\frac{d\phi_\gamma}{dE_0} = \frac{c}{H_0}\frac{\bar{\rho}_0^2}{8\pi}\int dz \boxed{(1+z)^3\frac{\Delta^2(z)}{h(z)}} \frac{\langle\sigma v\rangle}{m_{DM}^2}\frac{dN_\gamma(E_0(1+z))}{dE}e^{-\tau(z,E_0)}$$

★ STRUCTURE ENHANCEMENT $\Delta^2(z)$

Two approaches to determine Δ^2:

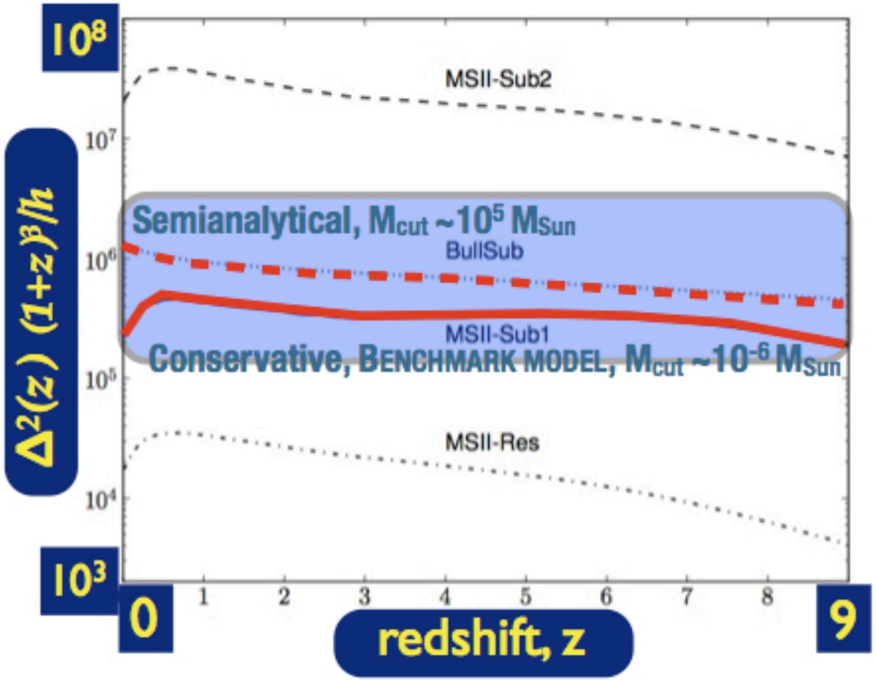
★ ***Semi-analytic approach:* halo mass function normalization from a Virgo simulation AND a *mass-concentration toy-model* by Blumenthal et al.**

[Ullio et al. 2002]

★ ***Results from Millennium Simulation II:* mass resolution $10^8\ M_{Sun}$, simple *power law extrapolations* of the luminosity vs halo mass - conservative/ optimistic choices.**

[Zavala et al., 2009]

Fermi-LAT collaboration, JCAP 1004:014,2010



Cosmological Dark Matter Signal

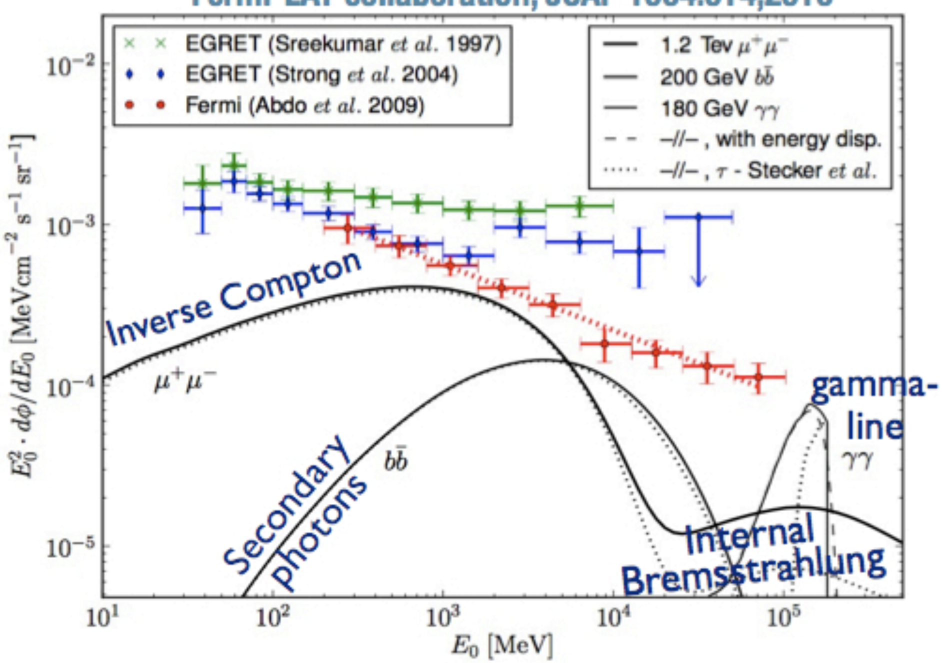
DM forms structures by gravitational collapse, and in those over-dense regions the DM self-annihilation signal is greatly enhanced (ρ^2).

$$\frac{d\phi_\gamma}{dE_0} = \frac{c}{H_0}\frac{\bar{\rho}_0^2}{8\pi}\int dz \boxed{(1+z)^3\frac{\Delta^2(z)}{h(z)}} \boxed{\frac{\langle\sigma v\rangle}{m_{DM}^2}\frac{dN_\gamma(E_0(1+z))}{dE}} \boxed{e^{-\tau(z,E_0)}}$$

★ *GAMMA-RAY SPECTRUM*

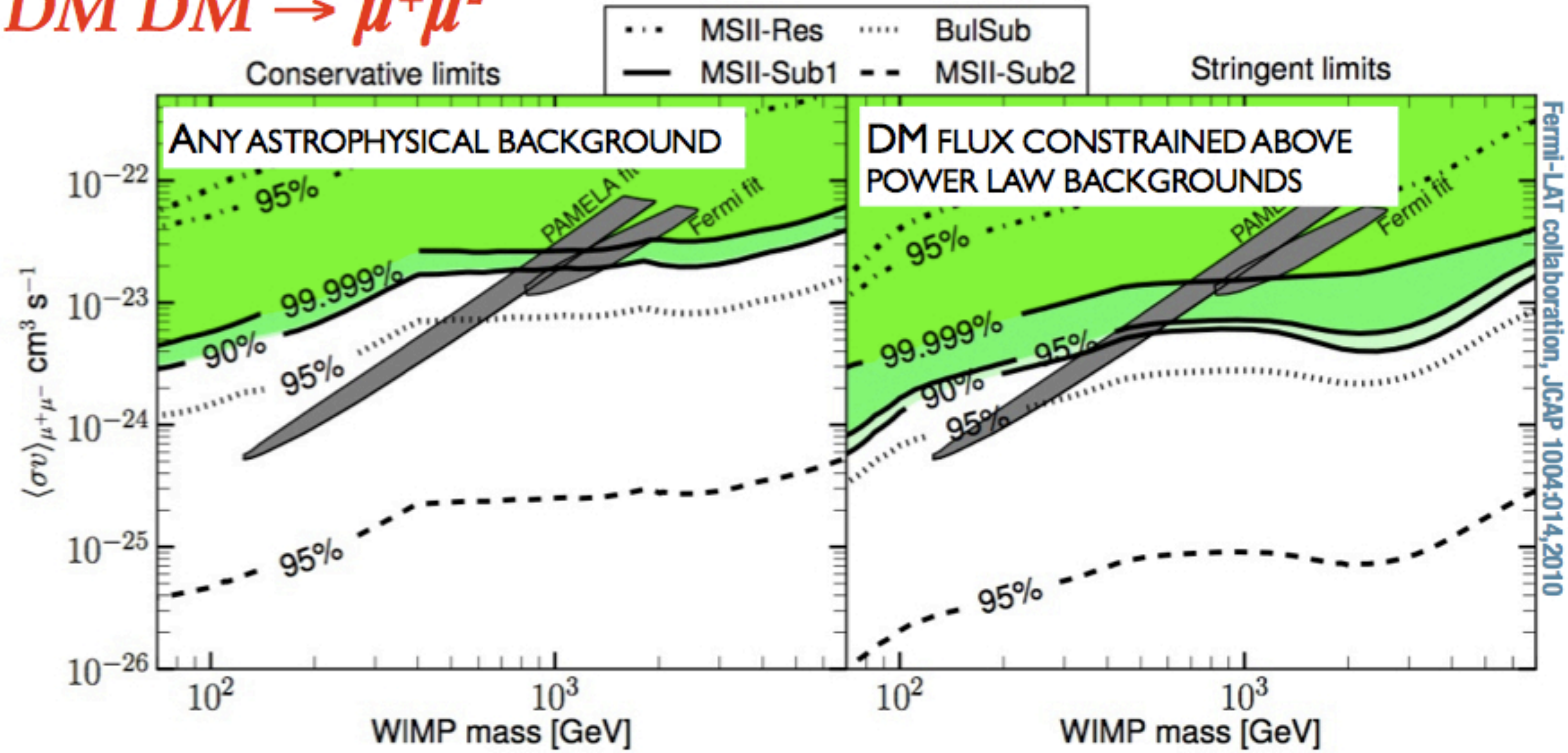
The measured spectrum at energy E_0 depends not only on particle physics, BUT due to red-shift entanglement also on the attenuation effects AND the DM halo formation history.

Fermi-LAT collaboration, JCAP 1004:014,2010



Cosmological DM constraints

DM DM → μ⁺μ⁻

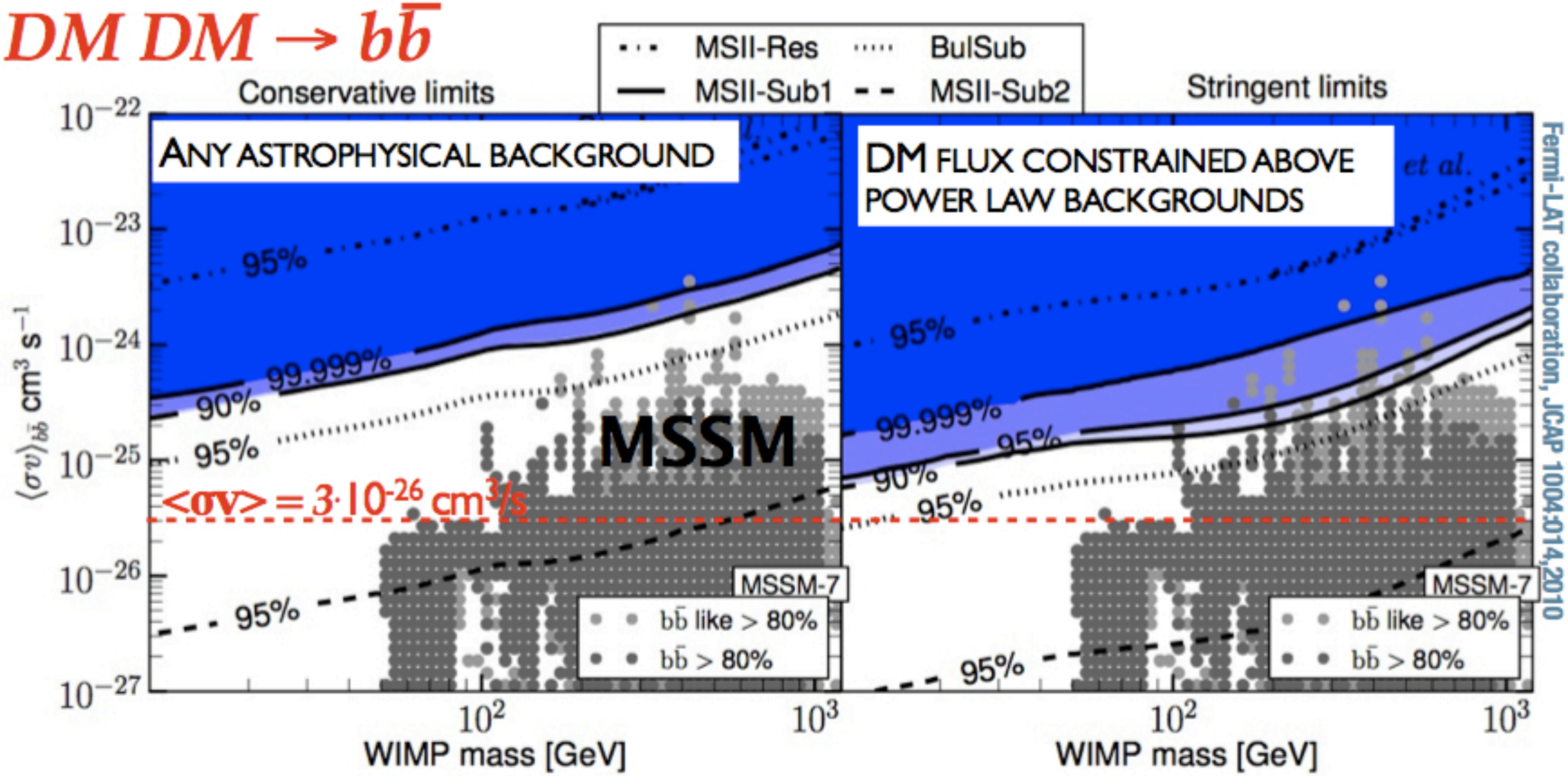


The cosmological DM signal has significant detection/constraining potential, but the total flux has uncertainties due to limitations in knowing the DM structure properties.

(spectral information could potentially also be used to disentangle DM galactic and extragalactic signatures).

Cosmological DM constraints

$DM\,DM \rightarrow b\bar{b}$



The cosmological DM signal has significant detection/constraining potential, but the total flux has uncertainties due to limitations in knowing the DM structure properties.

(spectral information could potentially also be used to disentangle DM galactic and extragalactic signatures).

Angular anisotropy studies

Overview

Using the angular information in the diffuse gamma-ray background to identify dark matter and other source classes

- in addition to the energy spectrum and average intensity, the diffuse background contains angular information
- if the diffuse emission originates from an unresolved source population, rather than from a truly isotropic, smooth source distribution, the diffuse emission will contain fluctuations on small angular scales
- if these fluctuations are different from the fluctuations expected from the Poisson noise due to finite event statistics, we could use these fluctuations to identify the presence of unresolved source populations, such as dark matter

[J. Siegal-Gaskins, IDM2010]

Analysis approach

GOAL: measure the angular power spectrum of the large-scale isotropic diffuse emission

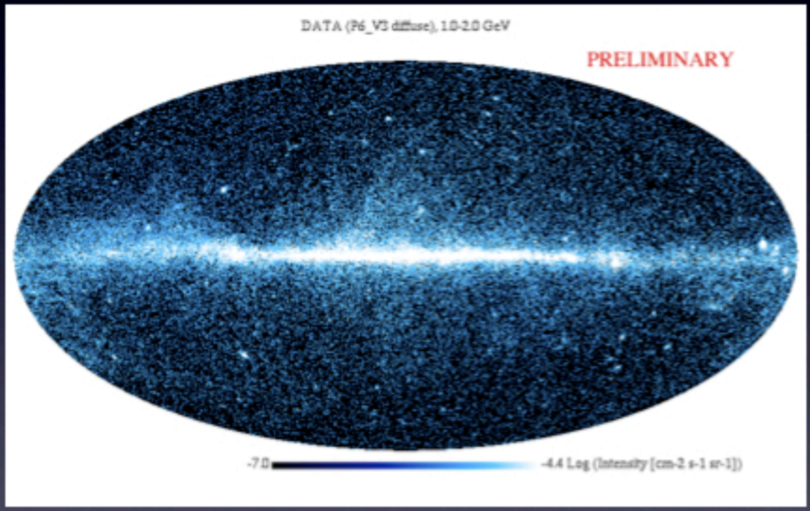
- select regions of the sky which are relatively "clean":
    - mask sources in the 11-month catalog within a 2 deg angular radius
    - mask regions of the sky heavily contaminated by Galactic diffuse emission by excluding $|b| < 30$ deg
- calculate angular power spectrum of the data in several energy bins (energy-dependence may aid in interpretation of measurement (Hensley, JSG, & Pavlidou 2009, Cuoco
- et al. 2010))
- focus on multipoles greater than ~ 100 (corresponding to angular scales < 1-2 degrees), since lower multipoles (larger angular scales) are likely more contaminated by Galactic diffuse emission
- compare results from data and simulated model (Galactic diffuse + 11-mo sources + isotropic) to identify significant differences in anisotropy properties

[J. Siegal-Gaskins, IDM2010]

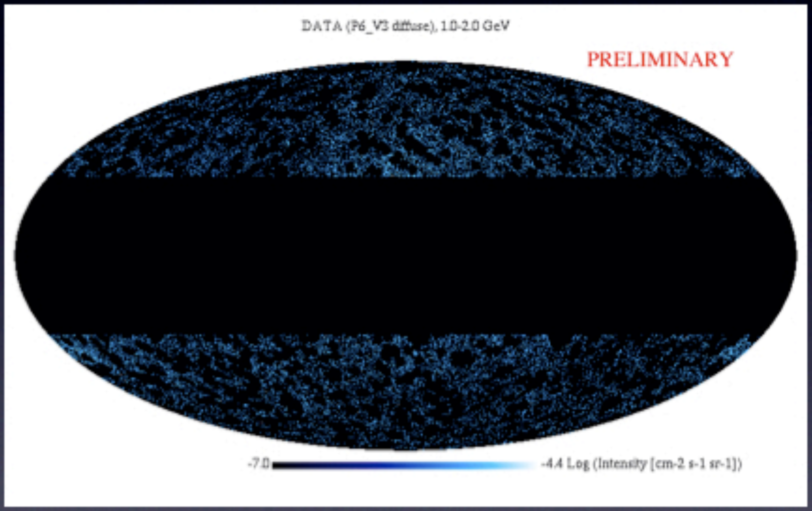
Diffuse gamma-ray intensity

1 - 2 GeV

All-sky map



Masked-sky map used in this analysis

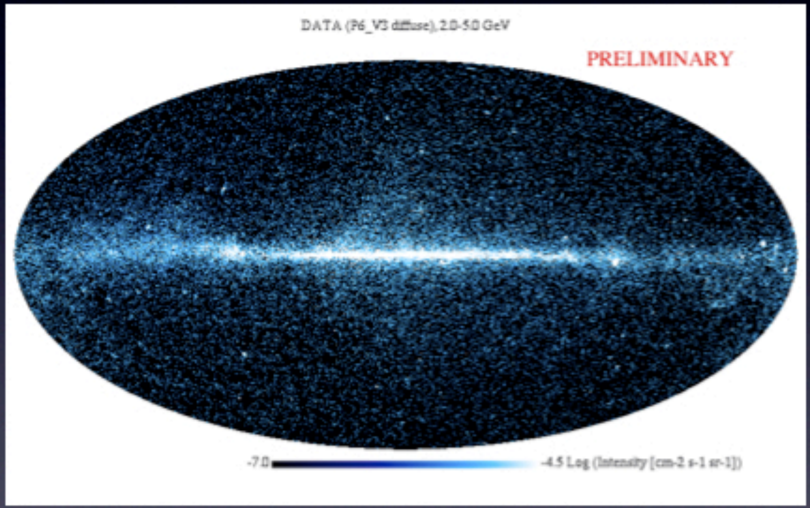


[J. Siegal-Gaskins, IDM2010]

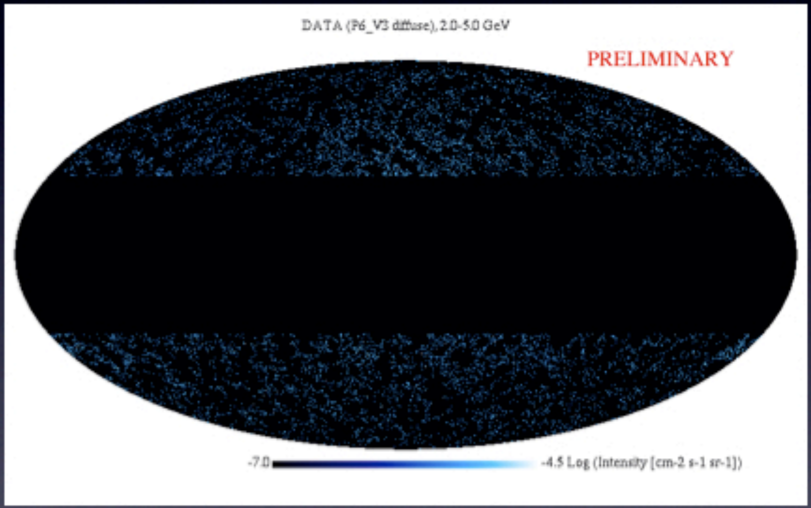
Diffuse gamma-ray intensity

2 - 5 GeV

All-sky map



Masked-sky map used in this analysis

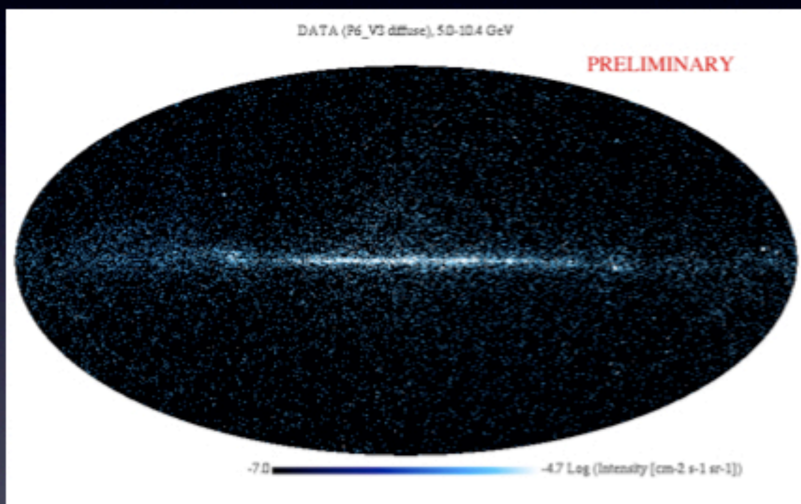


[J. Siegal-Gaskins, IDM2010]

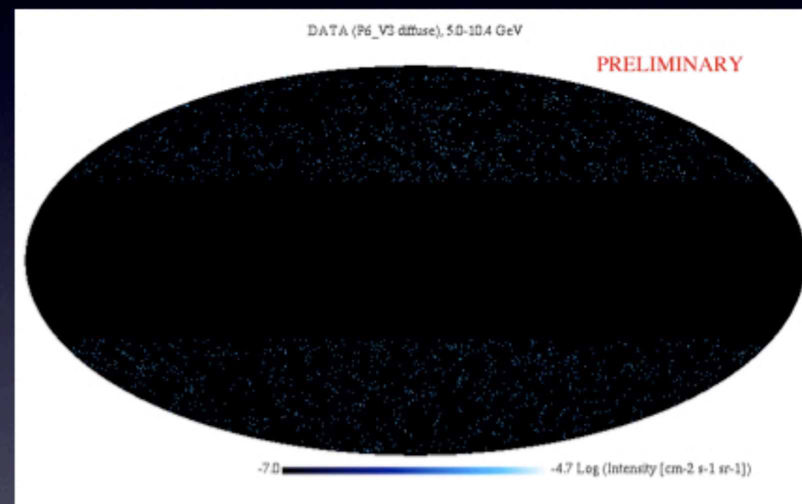
Diffuse gamma-ray intensity

5 - 10 GeV

All-sky map



Masked-sky map
used in this analysis

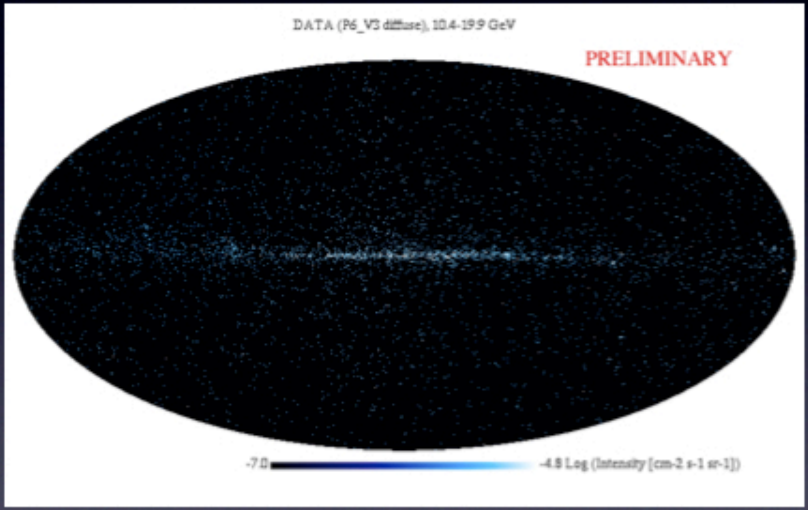


[J. Siegal-Gaskins, IDM2010]

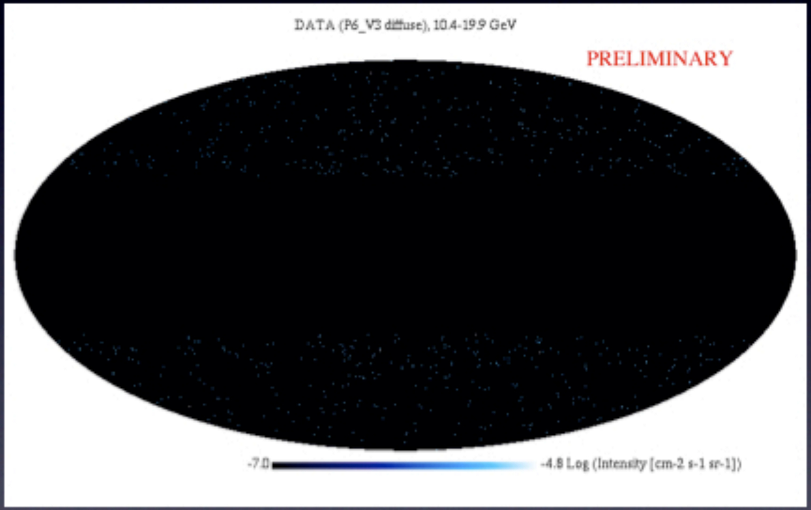
Diffuse gamma-ray intensity

10 - 20 GeV

All-sky map



Masked-sky map used in this analysis

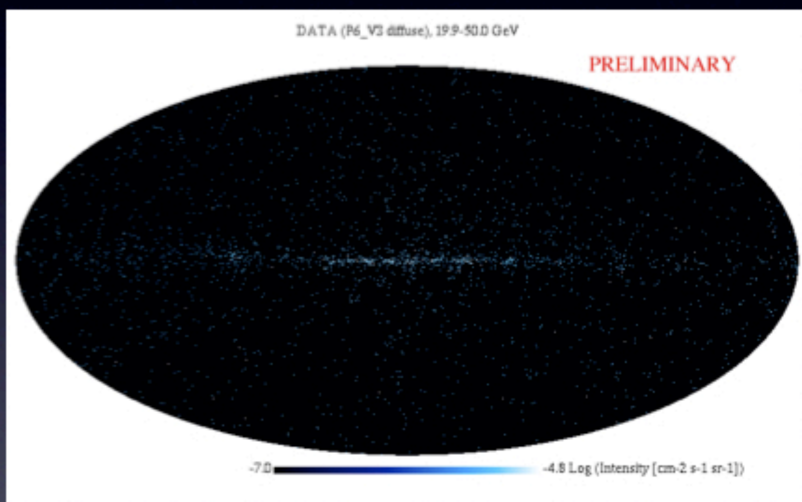


[J. Siegal-Gaskins, IDM2010]

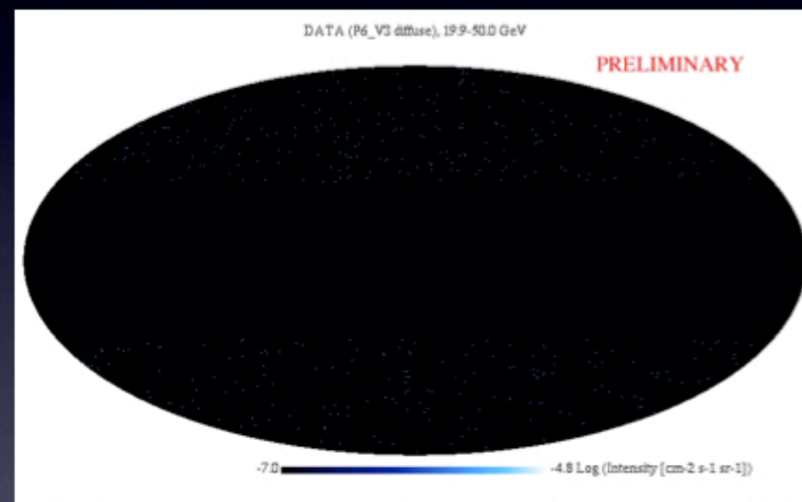
Diffuse gamma-ray intensity

20 - 50 GeV

All-sky map



Masked-sky map used in this analysis



[J. Siegal-Gaskins, IDM2010]

Model

- GAL: Galactic diffuse model (gll_iem_v02.fit)
- CAT: 11-month source catalog
- ISO: isotropic background = Fermi-measured large-scale isotropic diffuse + unrejected charged particles (isotropic_iem_v02.txt spectrum template)

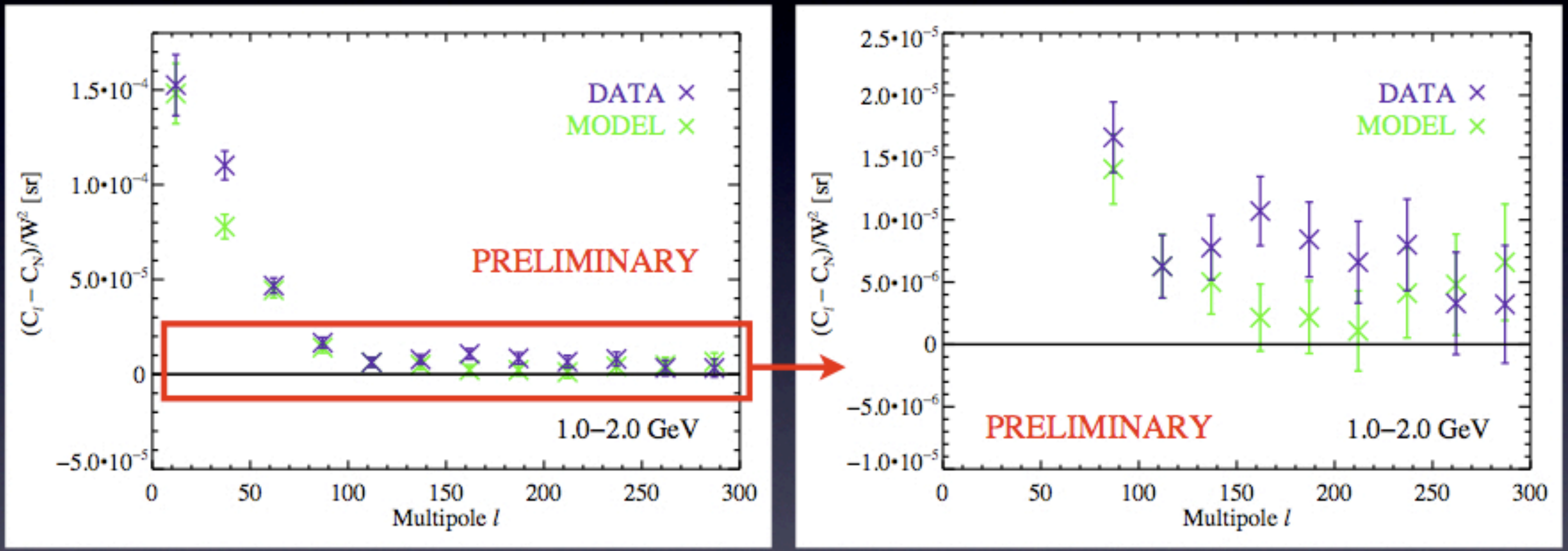
- MODEL = sum of GAL, CAT, and ISO

[J. Siegal-Gaskins, IDM2010]

Data and Model Comparison

fluctuation angular power spectra

1 - 2 GeV



•at multipoles greater than ~ 100 angular power above the photon noise level is measured in the data.

•the excess power in the data suggests a contribution from a point source population not present in the model.

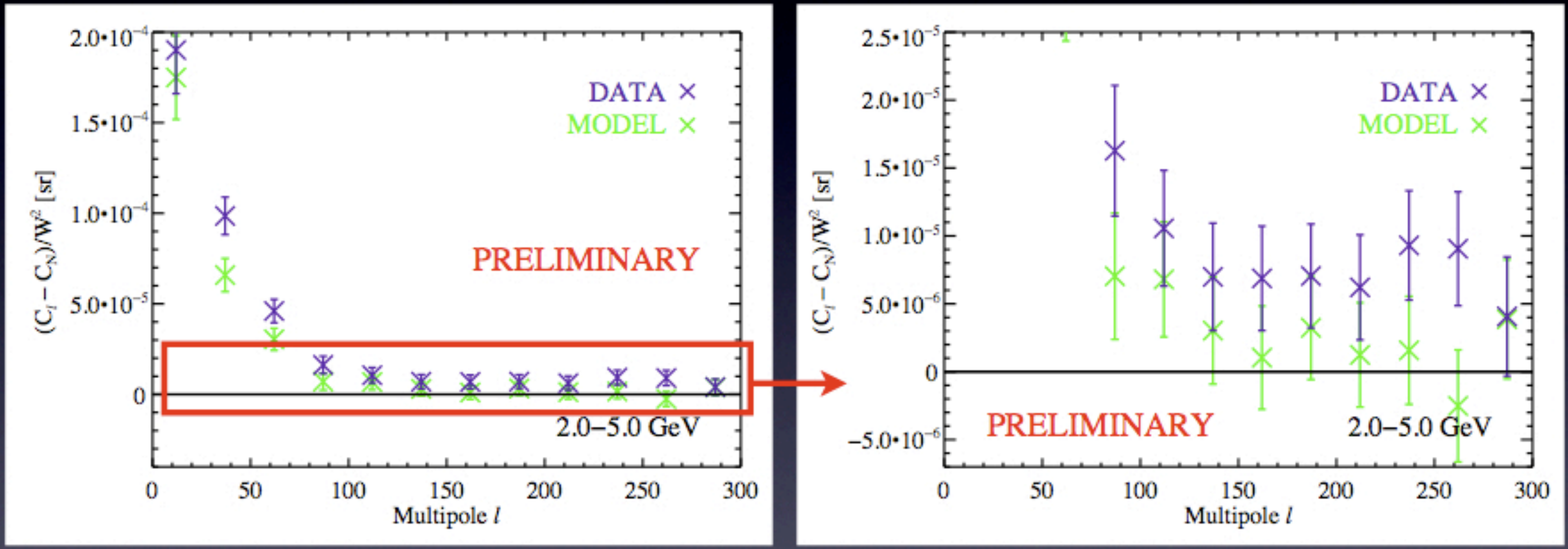
•at multipoles less than ~ 100 angular power above the noise is seen in the data and model, and is likely due to contamination from the Galactic diffuse

[J. Siegal-Gaskins, IDM2010]

Data and Model Comparison

fluctuation angular power spectra

2 - 5 GeV

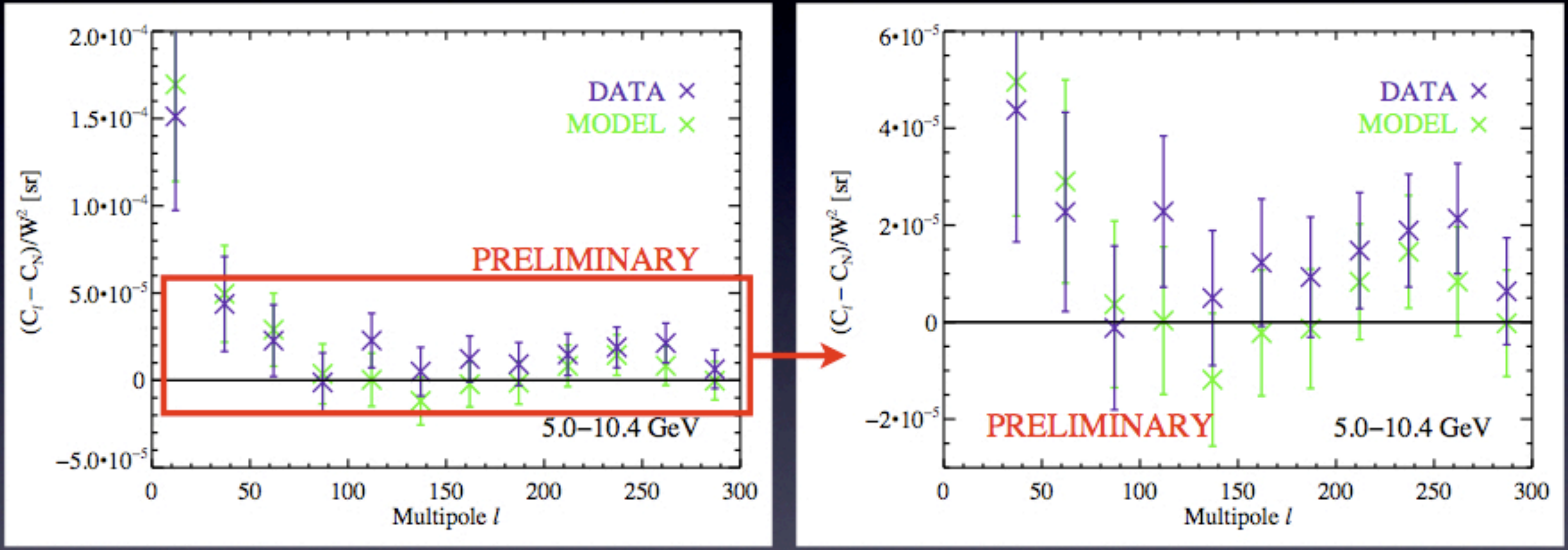


[J. Siegal-Gaskins, IDM2010]

Data and Model Comparison

fluctuation angular power spectra

5 - 10 GeV

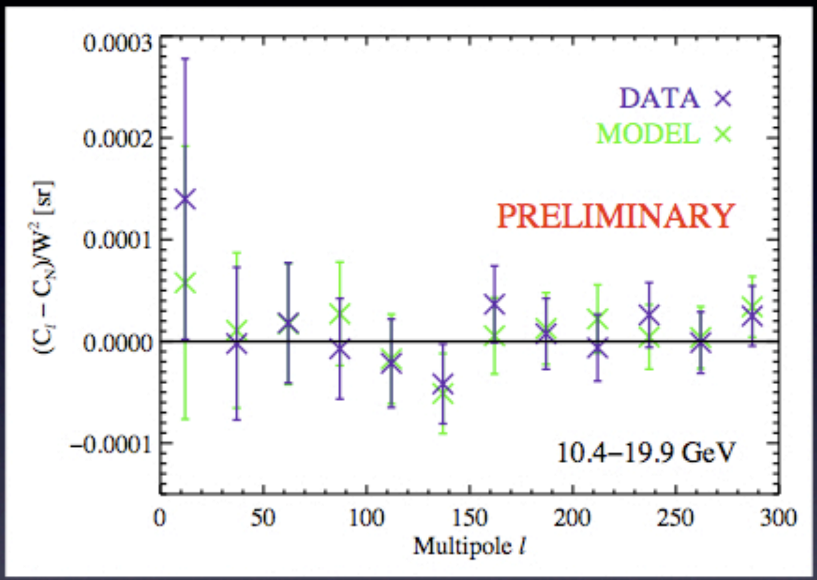


[J. Siegal-Gaskins, IDM2010]

Data and Model Comparison

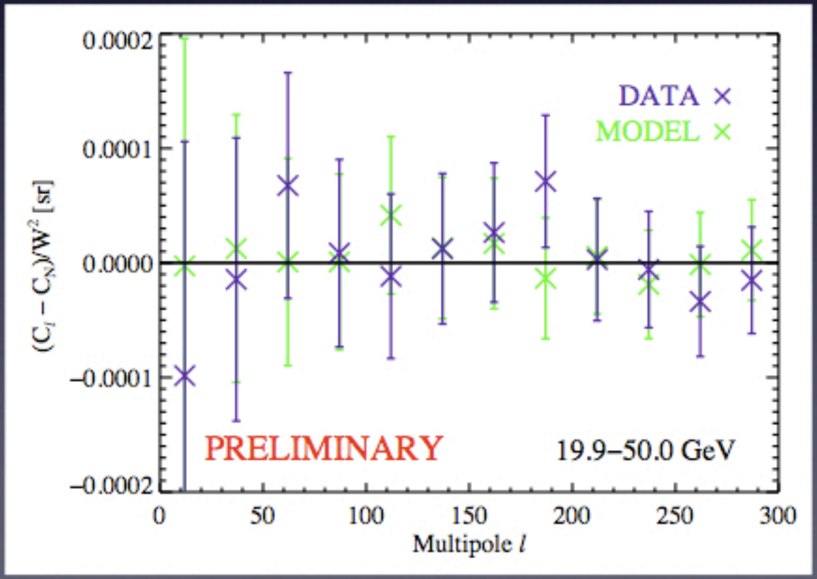
fluctuation angular power spectra

10 - 20 GeV



NB: due to decreasing photon statistics, the amplitude of anisotropies detectable by this analysis decreases with increasing energy, hence the measurements at higher energies currently do not exclude the presence of anisotropies at those energies at the level detected at 1 - 10 GeV

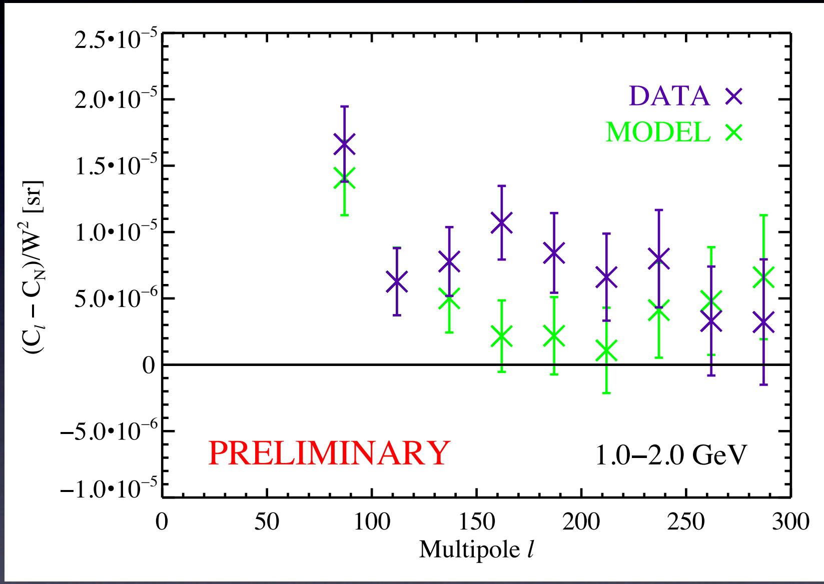
20 - 50 GeV



Comparison with (rough) predictions

fluctuation angular power spectra

1 - 2 GeV



fluctuation angular power spectra

predictions for C_ℓ at l = 100 for a single source class (LARGE UNCERTAINTIES):

- blazars: ~ 1e-4
- starforming galaxies: ~ 1e-7
- dark matter: ~ 1e-4 to ~ 0.1

measured fluctuation C_ℓ of ~ 1e-5 at multipoles above ~ 100 at low energies falls generally in the range predicted for some astrophysical source classes and some dark matter scenarios for emission from a single source class

[J. Siegal-Gaskins, IDM2010]

Summary and future prospects

- The DM signal from our halo is potentially a strong DM search tool (due to the strength of the signal). It heavily relies on the models of the diffuse emission, as DM searches are degenerate in part with some features of the astrophysical signal (e.g. CR source distribution, and halo size).
- DM limits obtained by using the Fermi isotropic flux are quite strong, but not the most robust.
  - The isotropic flux will get lower as Fermi continues to detect faint extragalactic sources, increasing the sensitivity to DM search.
  - Increased number of detected sources will also lead to improved modeling of the extragalactic source populations and our understanding of the background.
- Modeling of the new (unresolved) source populations, using the Galactic diffuse data and angular anisotropies are critical for DM search. The angular anisotropy studies, already detected a contribution from a new source contribution, under study.

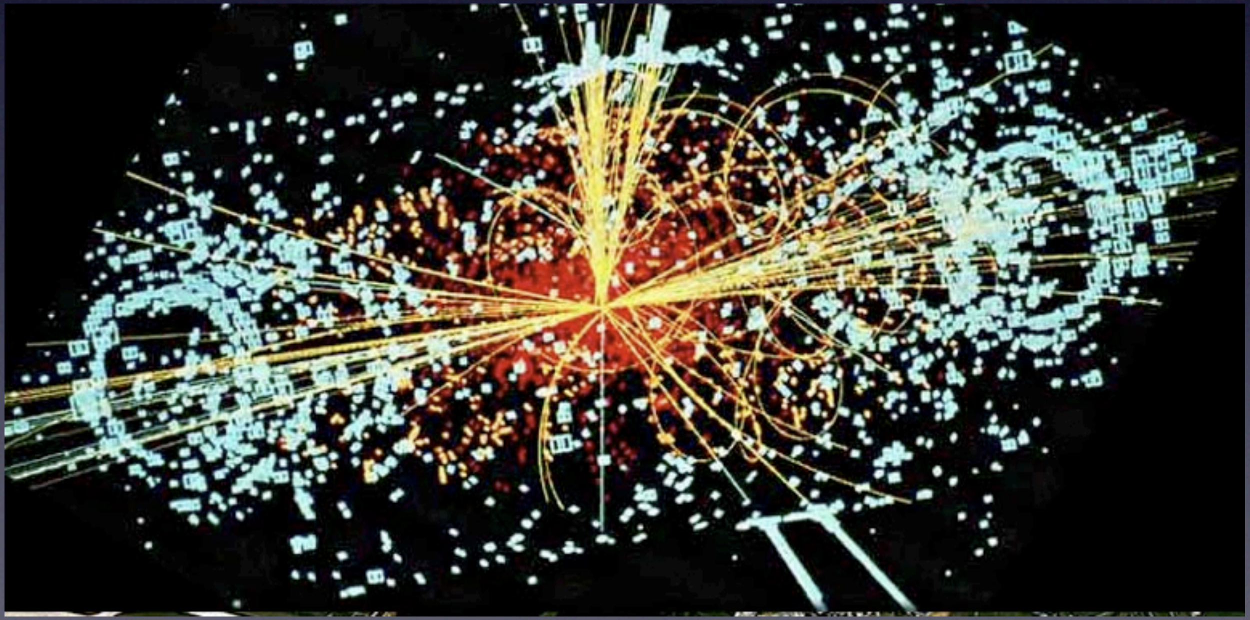
Future prospects

- Cosmic ray experiments (*AMS02, CREAM*...), are expected to improve our knowledge of the cosmic ray propagation in our Galaxy.

- *Planck* will determine cosmological parameters with improved sensitivity and aid in the predictions for the DM cosmological signal. The measure the dust content of our Galaxy will improve our modeling of the gas content, and therefore that of the Galactic diffuse emission. Multiwavelength studies with synchrotron band will also bring in improvements.

Future prospects

- *LHC* is expected to give us first hints of the new physics at the EW breaking scale soon, and hopefully aid us in where to look (in terms of the energy spectra) for the dark matter signatures.



Future prospects

- *CTA*, a kilometer square array of Cerenkov telescopes will have a sensitivity improvement of over order of magnitude with respect to Fermi and current ACTs. It will have a superior angular resolution and due to the large number of telescopes employed, might also have a significant potential to measure extended (diffuse) emission.