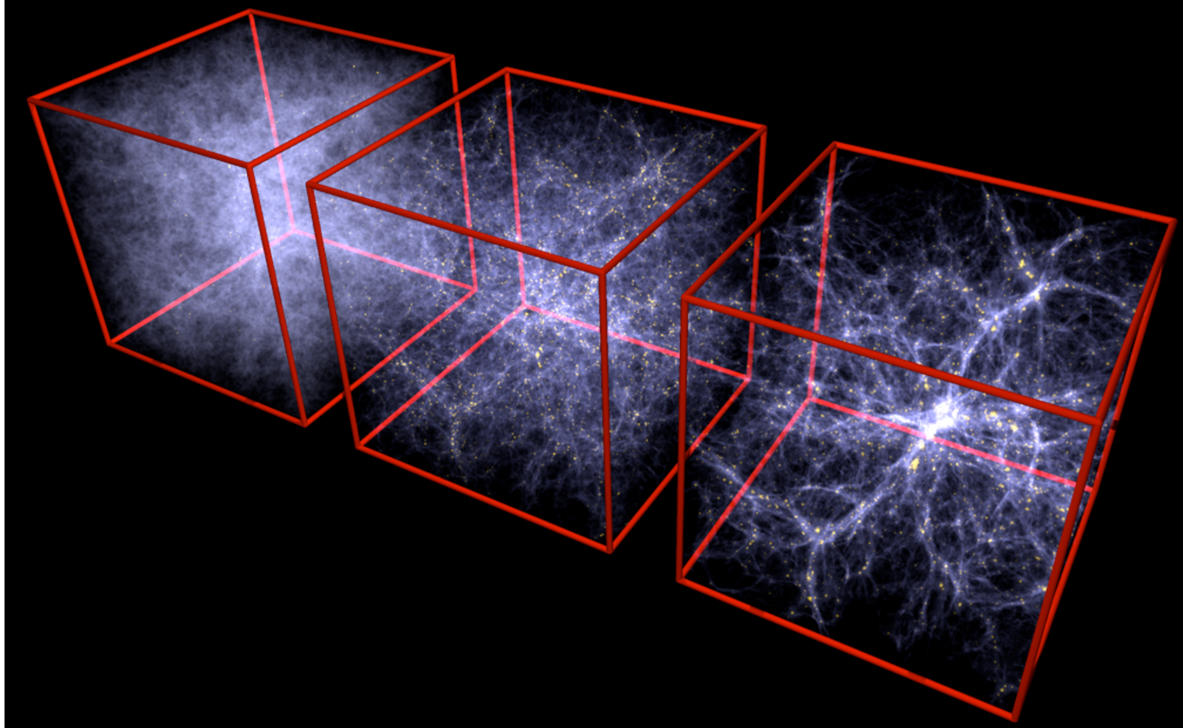
Dark Matter constraint from the Fermi-LAT diffuse data

on behalf of the Fermi-LAT collaboration
Gabrijela Zaharijas,
IPhT/CEA Saclay and Stockholm University

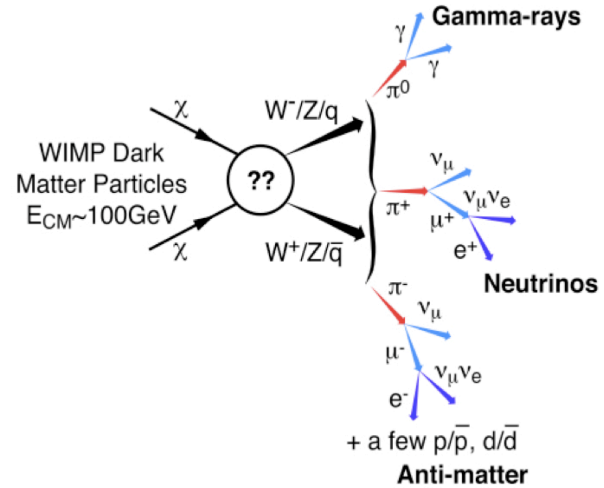


WIMP candidates: The annihilation rate comes from particle physics and automatically gives the right answer for the relic density!

→ dark matter has mass ~ EW mass scale and annihilates to Standard Model particles, with cross sections

~3 10^{-26} cm^3s^{-2}

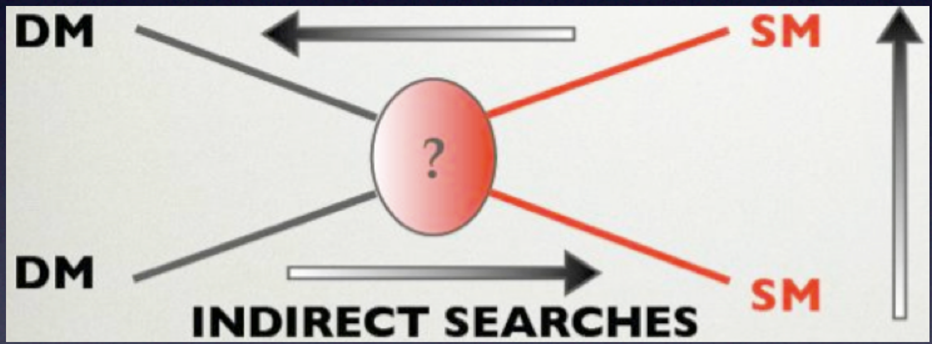
The gravitational effects of DM have been has been demonstrated from plethora of astrophysical and cosmological observations.



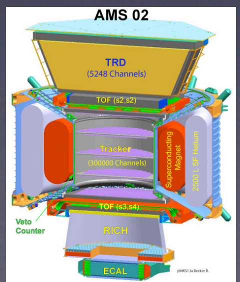
→ currently experiments are starting to explore the parameter space of WIMP models, testing this paradigm.

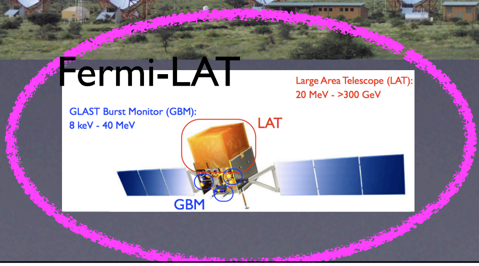
"The moment of truth for WIMP Dark Matter"

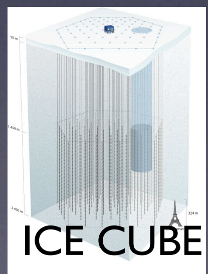
COLLIDER SEARCHES



DIRECT DETECTION

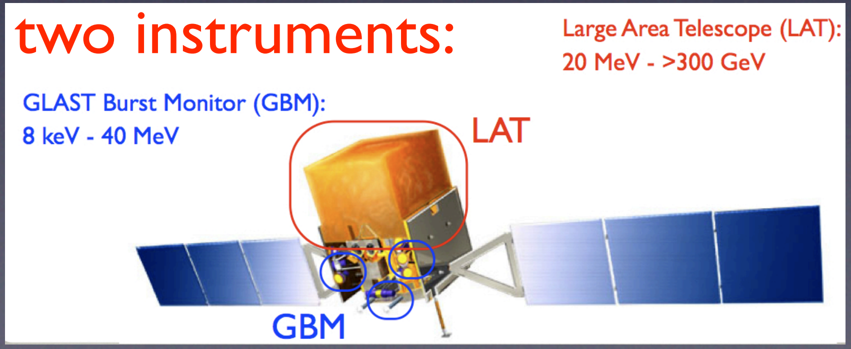


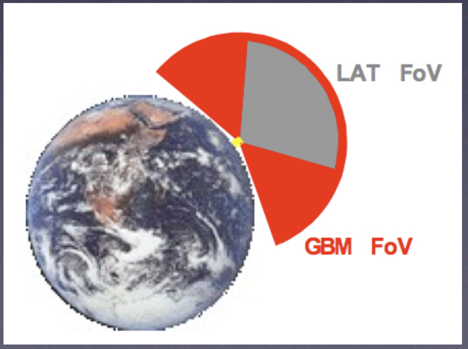




Fermi satellite

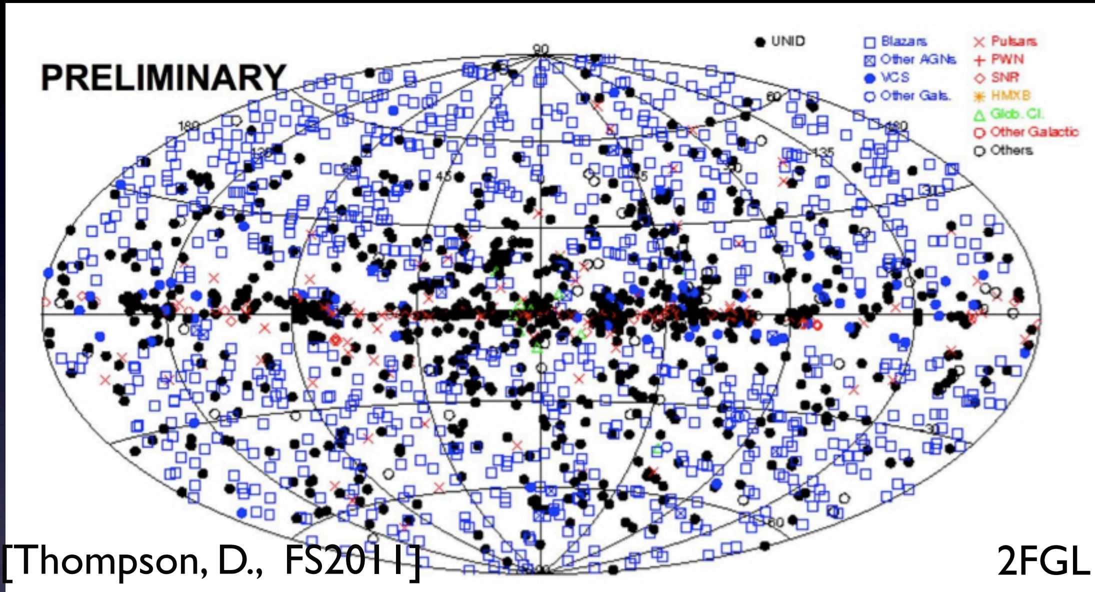
- **Key features:** Large field of view: 20% of the sky at any instant. In the survey mode exposes every part of the sky for ~30 min, every 3 hours.
- Energy range: 20 MeV to >300 GeV (LAT), includes previously unexplored energy band 10-100 GeV.
- angular resolution ~ 0.1 deg above 10 GeV
- Excellent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





Science with Fermi-LAT

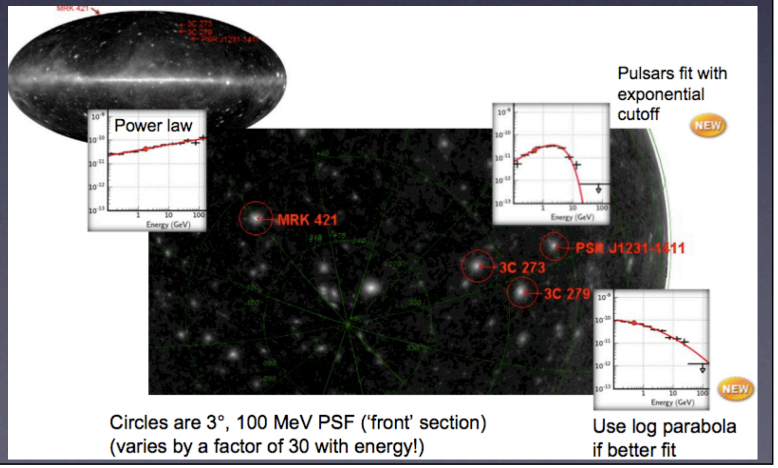
Point sources



[Thompson, D., FS2011] 2FGL

- 1450 sources in the first year catalog (1FGL).
- 1888 in 2FGL (almost ready to go)

→ *more sources + better understanding of their spectra!*



Science with Fermi-LAT

Point sources: Extra Galactic

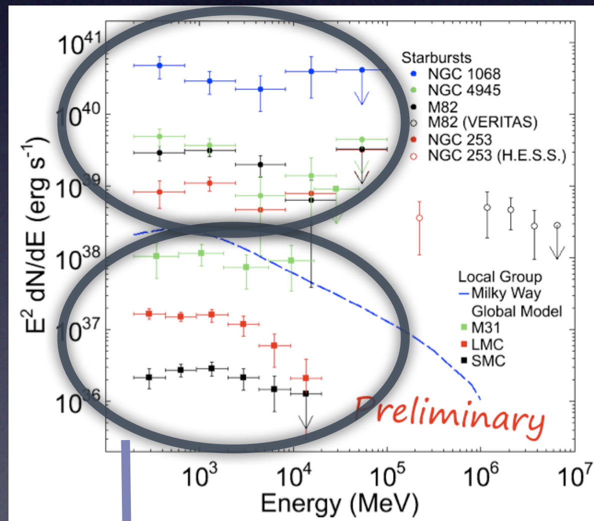
Type	Number	Percentage of total
Active Galactic Nuclei	832	44%
Candidate Active Galactic Nuclei	268	14%
Unassociated	594	32%
Pulsars (pulsed emission)	86	5%
Pulsars (no pulsations yet)	26	1%
Supernova Remnants/Pulsar Wind Nebulae	60	3%
Globular Clusters	11	< 1%
Other Galaxies	7	< 1%
Binary systems	4	< 1%
TOTAL	1888	100%

Very Preliminary - Work Still In Progress

[Thompson, D., FS2011]

- 2FGL: ~1000 AGNs (EGRET ~60)

[Bechtol, 'Beamed and Unbeamed Gamma-Rays from Galaxies' (2011)]



- local group

Science with Fermi-LAT

Point sources: Galactic

Type	Number	Percentage of total
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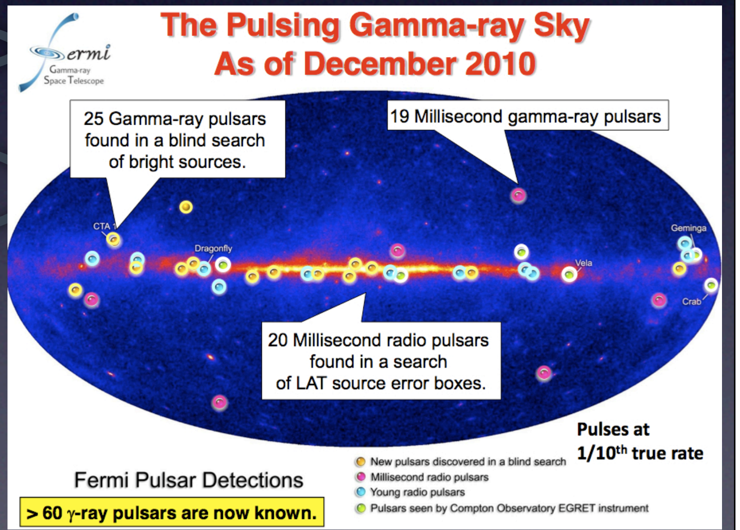
TOTAL	1888	100%

Very Preliminary - Work Still In Progress

[Thompson, D., FS2011]

Pulsars:

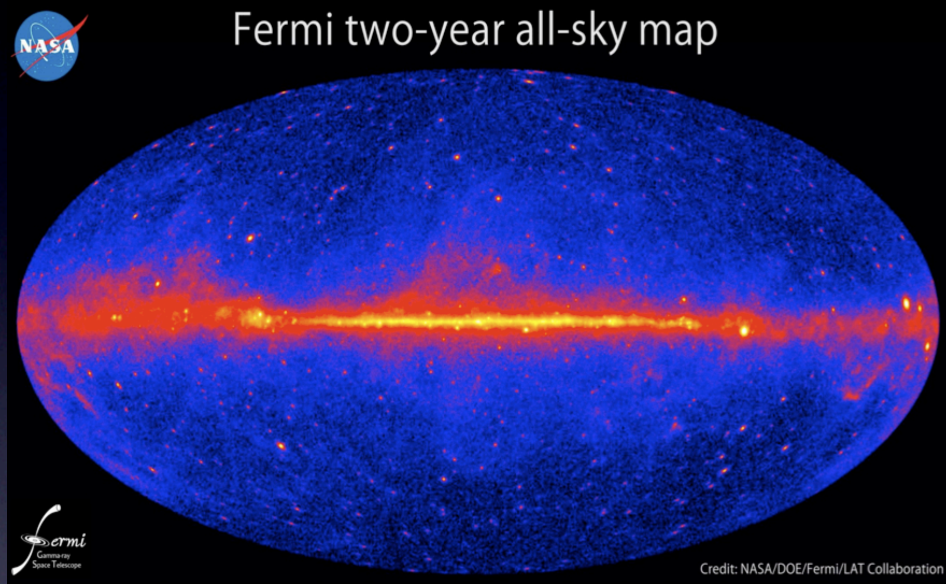
- in 1FGL: ~50 pulsars +discovery of ~10 MSPs;
- ~100 in 2FGL.



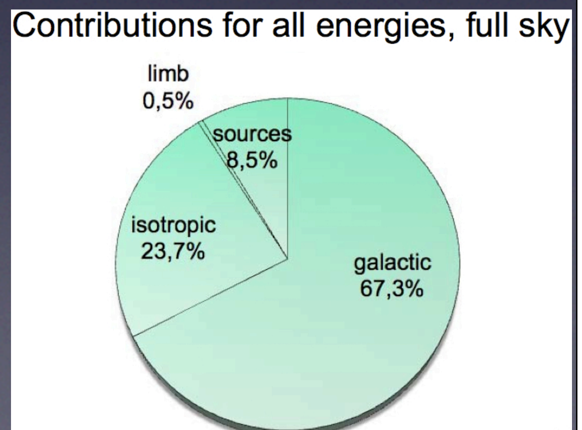
[Elliott, B., POTUS 2010]

Science with Fermi-LAT

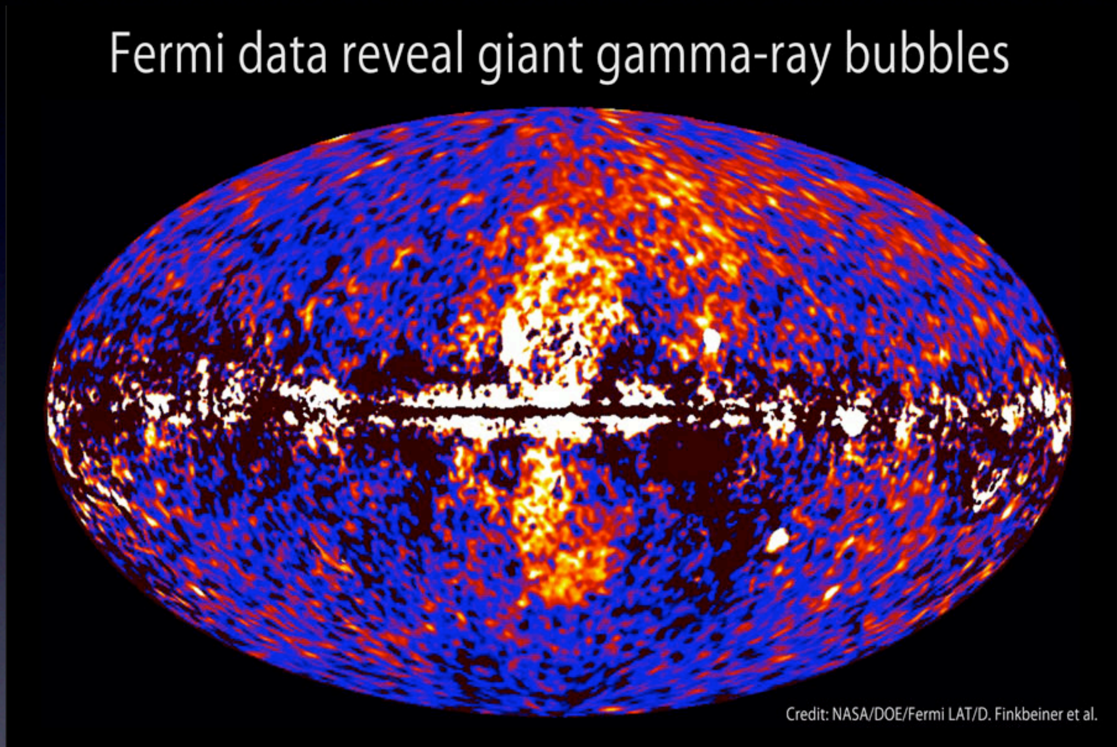
- Diffuse (whole sky) emission:



- measured *for the first time (in 10 GeV<E<10 TeV)*, with *excellent energy and angular resolution*.
- wealth of information: ~ 90% of LAT photons



Science with Fermi-LAT

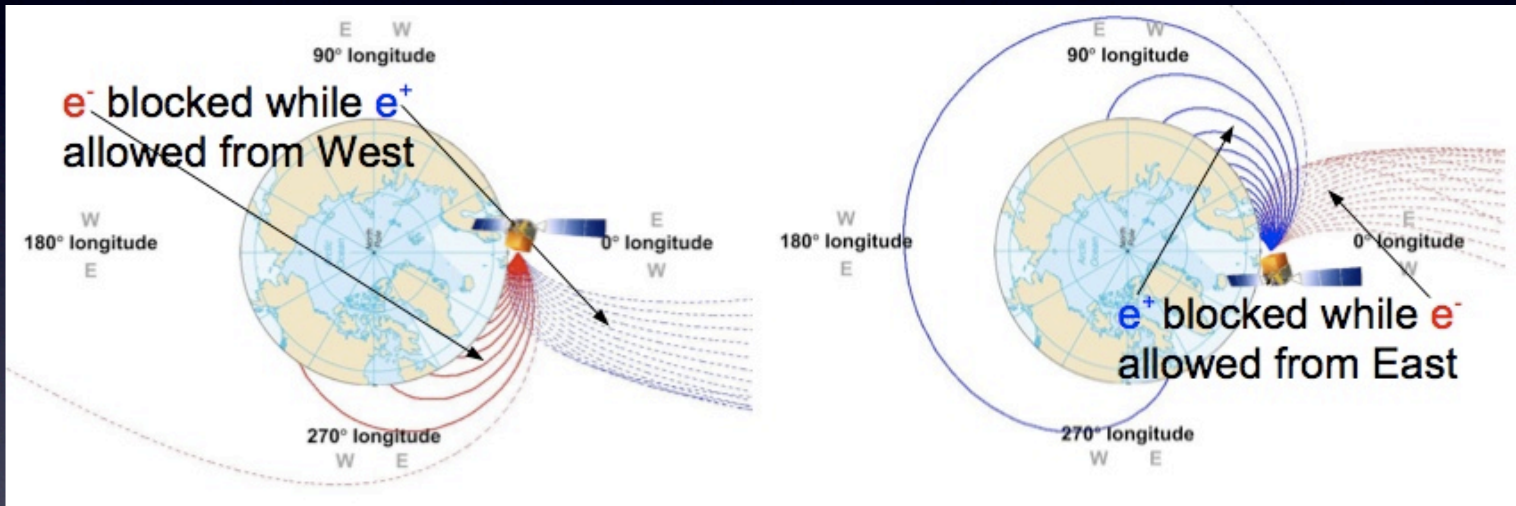


[Su, M. et al., ApJ 2010]

- residuals in the diffuse emission reveal *bubbles in the region of the Galactic Center.*

Science with Fermi-LAT

- Cosmic ray electrons and positrons

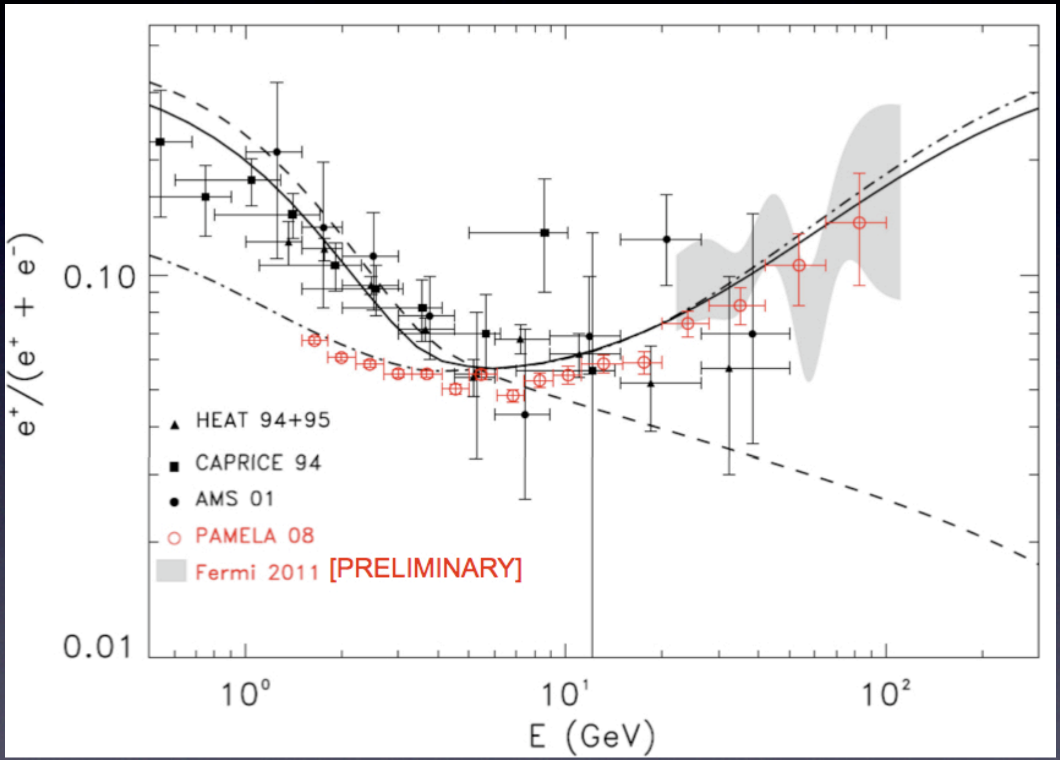


[Mitthumsiri, W., FS2011]

- Earth's magnetic field used to distinguish between electrons and positrons!

Science with Fermi-LAT

- Cosmic ray electrons and positrons

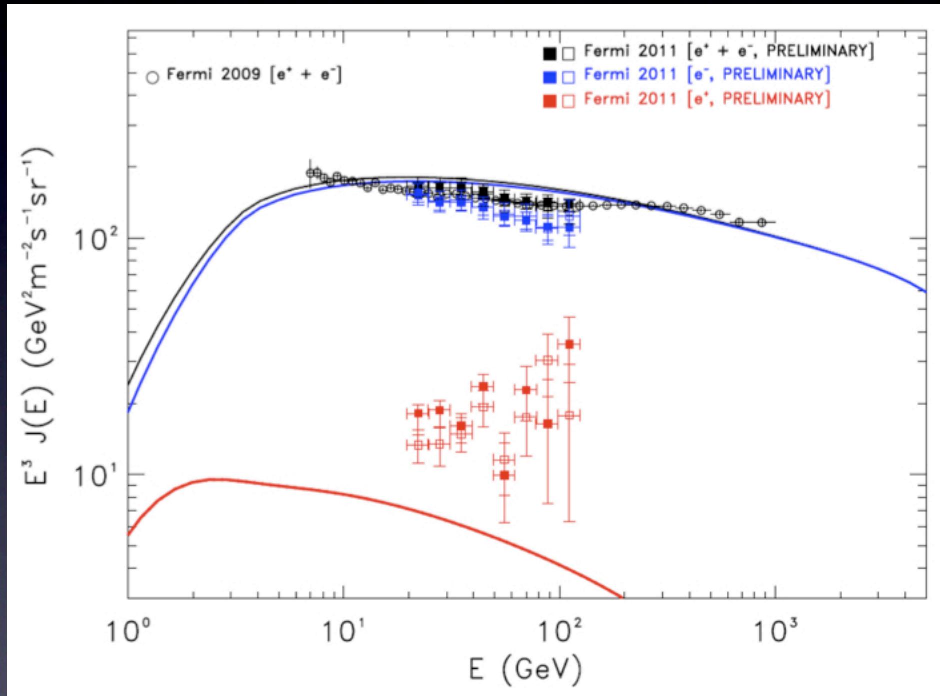


[Mitthumsiri, W., FS2011]

- Fermi-LAT confirms PAMELA positron excess.

Science with Fermi-LAT

- Cosmic ray electrons and positrons



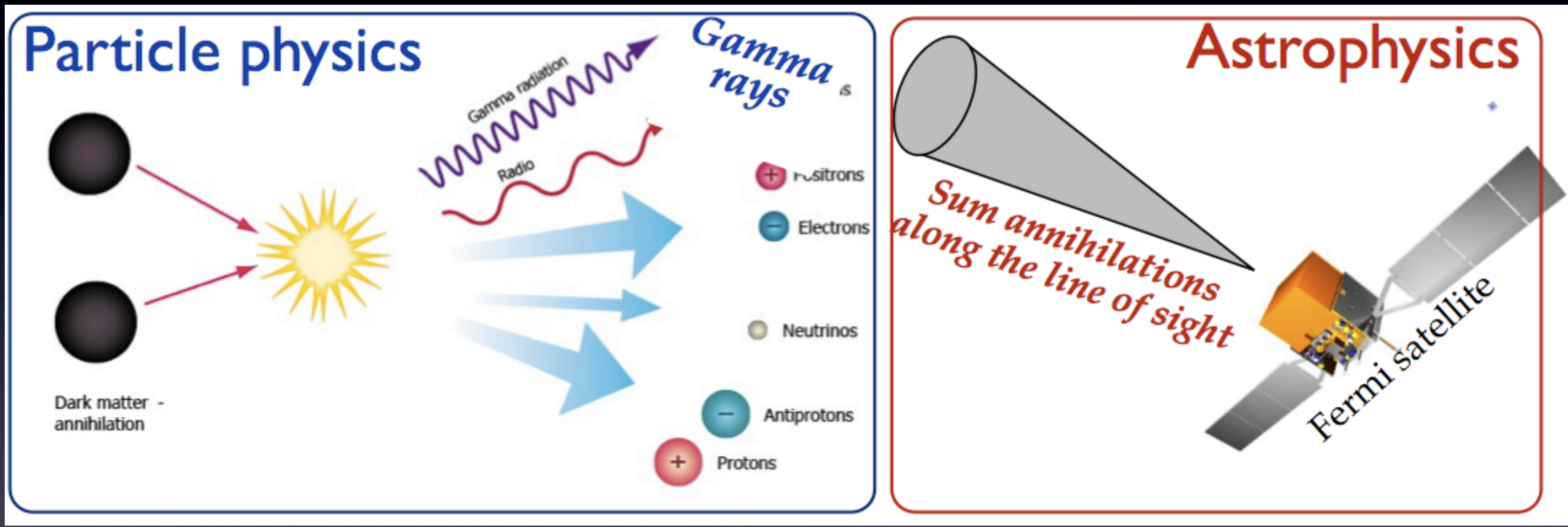
[Mitthumsiri, W., FS2011]

- and provides a measurement of electrons... refinement of CR propagation models needed.

+ GRBs, Solar system (Solar flares), ...

+ and Dark matter searches

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.

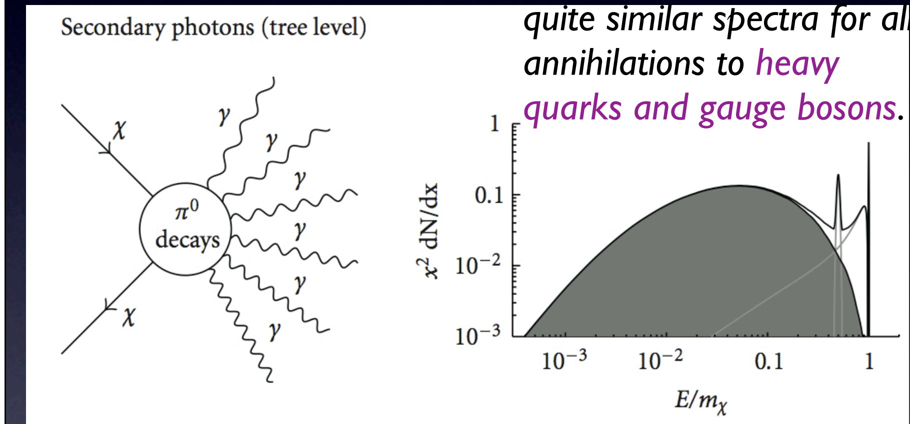
$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma,\theta,\phi) = \frac{1}{4\pi}\left[\frac{\langle\sigma v\rangle_{T_0}}{2\,M_\chi^2}\sum_f \frac{dN_\gamma^f}{dE_\gamma}B_f\right]\cdot\left[\int_{\Delta\Omega(\theta,\phi)} d\Omega' \int_{l.o.s.} dl\ \rho_\chi^2(l)\right]$$

Particle physics — Astrophysics

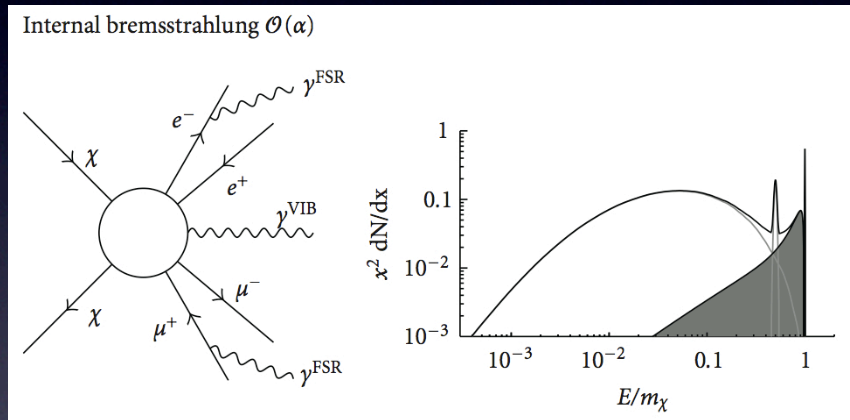
DM signal: morphology

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

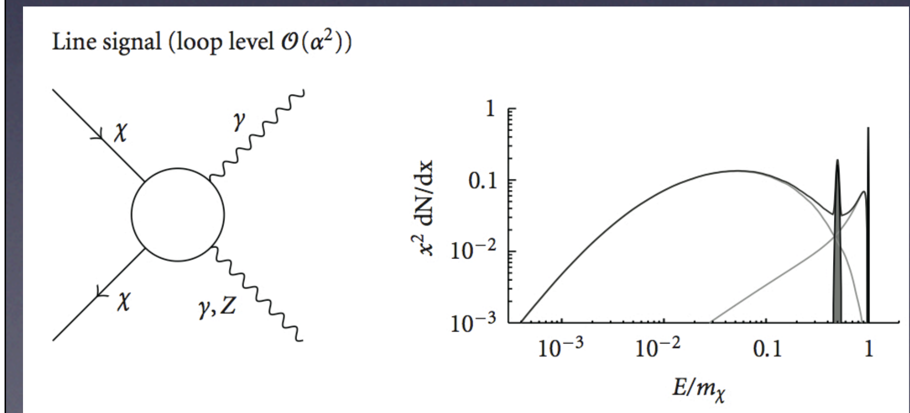
'Prompt' photons:



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



[Michael Kuhlen, Advances in Astronomym, 2010]



+ 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: morphology

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

Photons produced in radiative losses in ambient backgrounds and fields.

Important if there is a significant branching ratio to *leptons*.

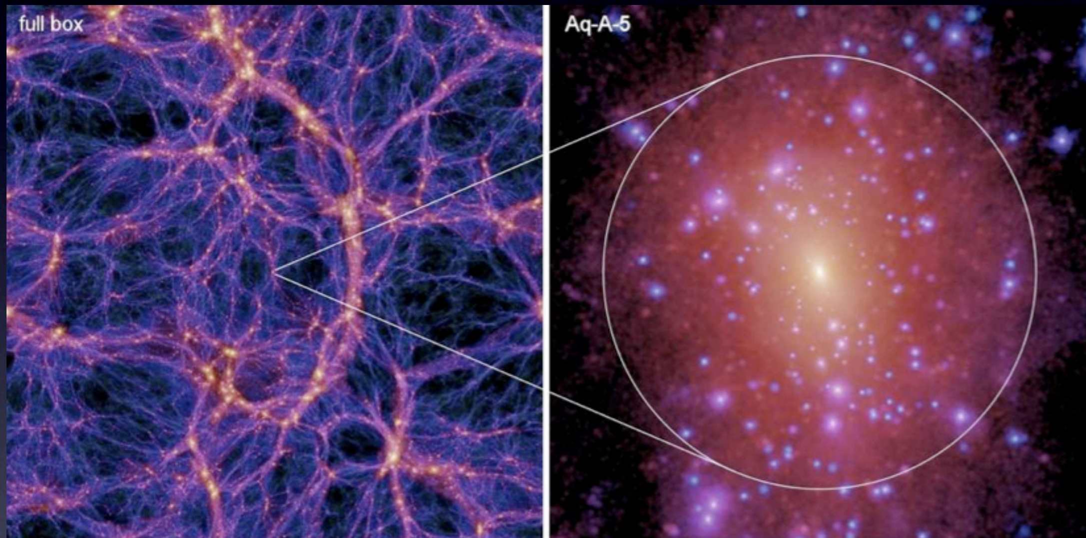
$$\chi\,\bar\chi \to \begin{cases} e^+\,e^- \\ l^+\,l^- \text{ or } \phi\,\phi \to \ldots + e^+\,e^- \\ P\,\bar P \to \ldots + \pi^\pm \to \ldots + e^\pm \end{cases}$$

ambient backgrounds and fields → Synchrotron, Inv. Compton, Bremstrahlung, Coulomb, Ionization → radio, IR, X-rays, Ɣs

In this talk, typically annihilations 100% to bbar, $\mu^+\mu^-$ (W^+W^-, $\tau\tau$).

DM signal: morphology

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



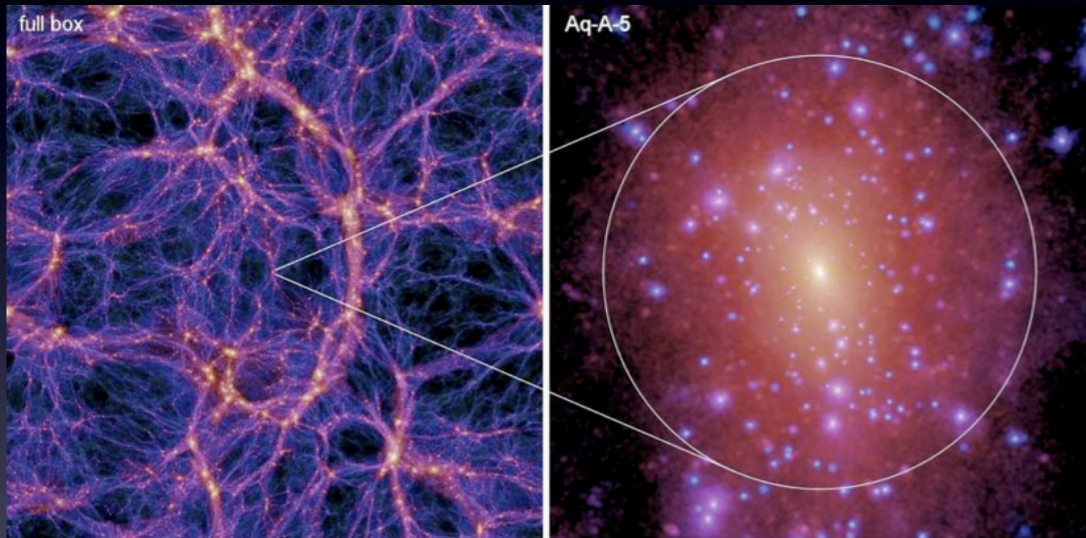
Springel, V. et al, MNRAS, 2008.

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

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



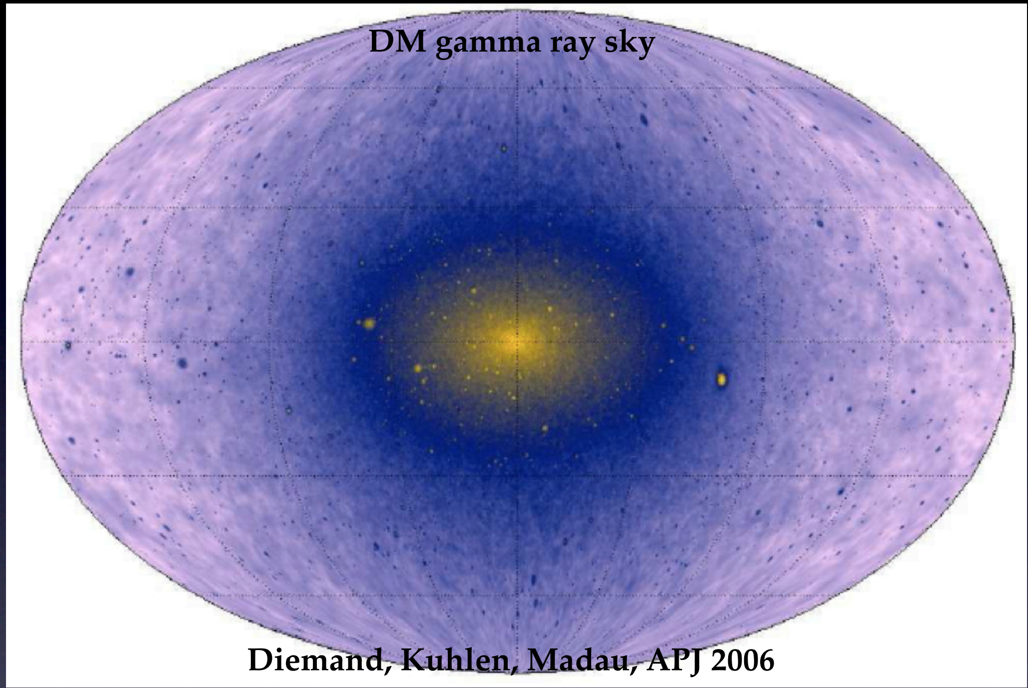
Springel, V. et al, MNRAS, 2008.

However:

- *do not resolve the inner most region* of the halo (<~100 pc);
- have *limited mass resolution* to >~10^5 M_{sol} (sub) halos.
- simulations typically do not include interaction with baryons;

Related uncertainties in estimating the DM signal can be ~ order(s) of magnitude.

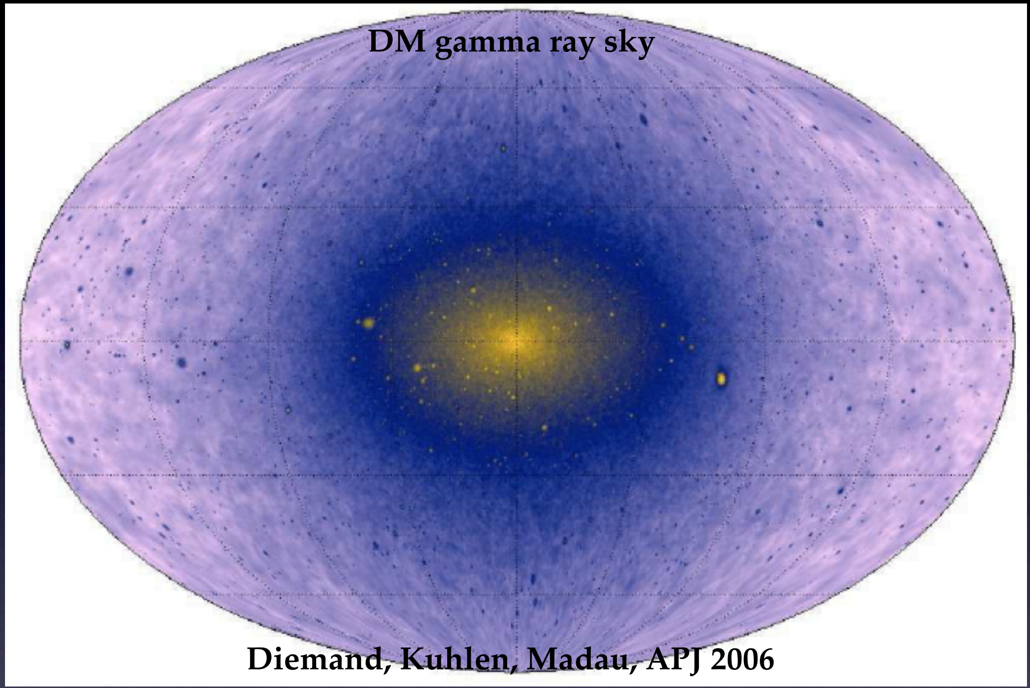
DM targets



Point sources:

* *Galactic Center*:
* *Dwarf Satellites*: the biggest Galactic subhalos (contain stars) ✔
* *Dark subhalos*: search for sources which shine only in gamma-rays
* *Galaxy clusters*: the biggest DM halos yet to form

DM targets



Diffuse emission:

* Isotropic (*extragalactic*) signal ✔
* *Galactic* diffuse emission ✔
* spectral search for a line feature all over the sky

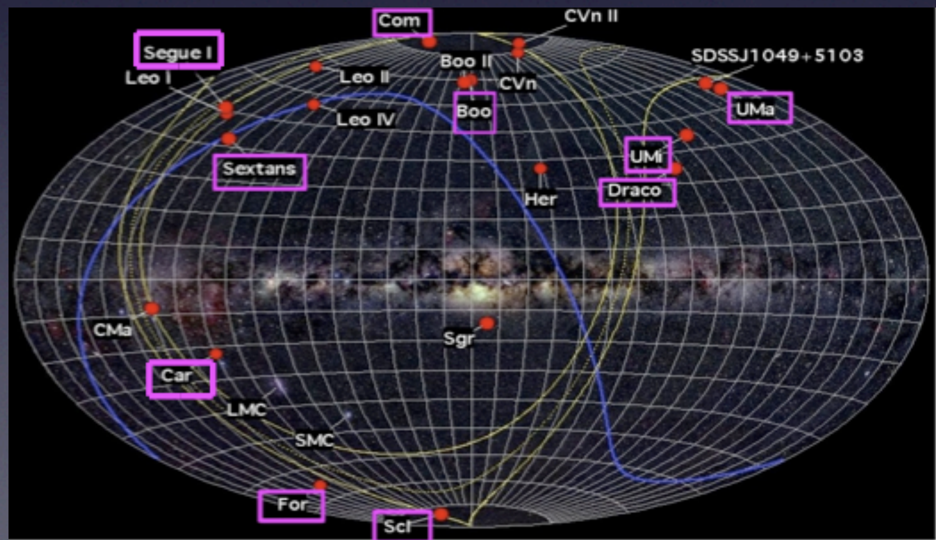
Note: *Made possible with the Fermi telescope! (good angular and energy resolution, large field of view, good charge particle rejection)*

Point sources: dwarf satellite galaxies

- Optically observed dSph are *the largest DM clumps in our halo*. ~25 have been discovered so far (many more expected).
- Dark matter dominated systems, no significant high energy gamma rays originating from astrophysical sources expected.
- DM mass determined based on kinematics of stellar component (KECK data).

- *No detection of dSph in 2 year Fermi data*

→ *upper limts on a DM component.*



The γ-ray flux from self-annihilating dark matter can be expressed as:

$$\Phi_{WIMP}(E,\Psi) = J(\Psi) \times \Phi^{PP}(E)$$

Astrophysical factor — Particle physics factor

$$J(\Psi) = \int_{l.o.s} dl(\Psi)\,\rho^2(l)$$

$$\Phi^{PP}(E) = \frac{1}{2}\frac{\langle \sigma_{ann} v \rangle}{m^2_{WIMP}} \sum_f \frac{dN_f}{dE} B_f$$

"J-factor"
From now on defined as integrated over a cone of solid angle 2.4 10^−4 sr centered on the dwarf. (~size of PSF of LAT in our region)

[Llena Garde, M., FS2011]

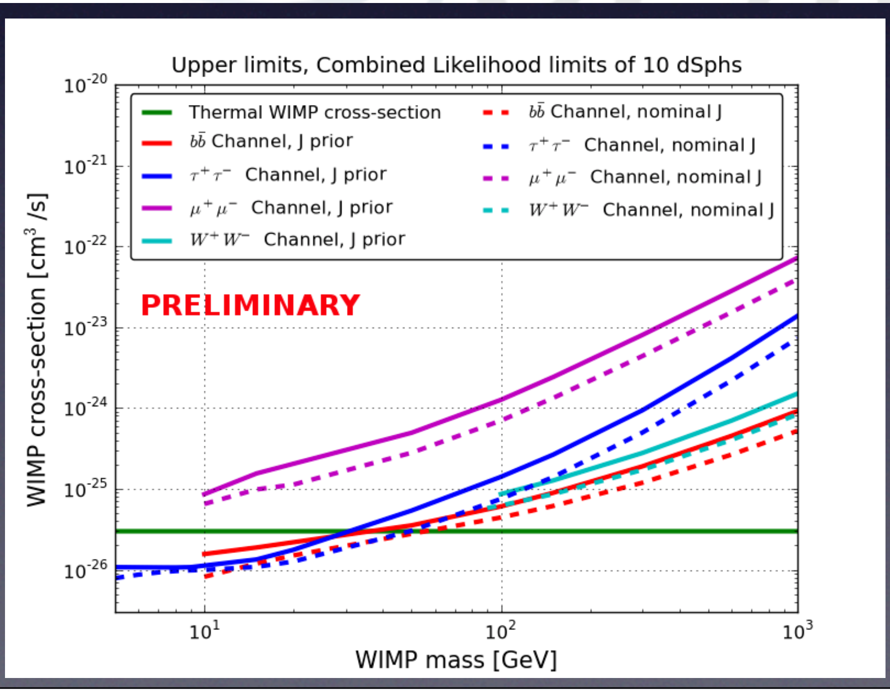
PRELIMINARY

Dwarf	J [10^19 GeV^2 cm^-5]	Error +	Error -	σ_J logNormal
Bootes I	0.16	0.35	0.13	0.73
Carina	0.06	0.02	0.01	0.10
Coma Berenices	0.16	0.22	0.08	0.30
Draco	1.20	0.31	0.25	0.10
Fornax	0.06	0.03	0.03	0.30
Sculptor	0.24	0.06	0.06	0.12
Seguel	2.00	5.95	1.49	0.59
Sextans	0.06	0.03	0.02	0.18
Ursa Major II	0.58	0.91	0.35	0.40
Ursa Minor	0.64	0.25	0.18	0.14

Combined likelihood (not data stacking) of 10 dSphs:

- *add the likelihood function of each dwarf ROI,* and keep σv as one and the same parameter across all the likelihood functions.
- *Include the uncertainties from the J-factors* by including their distribution in the likelihood fit.

$$L(<\sigma_{ann}v>, m_{WIMP}; \vec{\Theta}) =$$
$$\prod_i^N L_i(<\sigma_{ann}v>, m_{WIMP}, J_i^m, C, b_i; \vec{\Theta}_i) \frac{1}{J_i^m \sigma_{J,i}\sqrt{2\pi}} e^{\frac{-(\ln(J_i^m)-J_i^{true})^2}{2\sigma_{J,i}^2}}$$

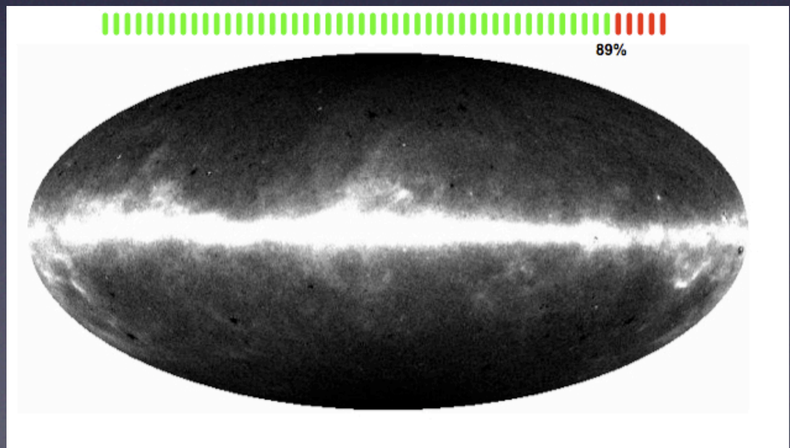


Limits: strongest indirect detection DM limits to date, probe thermal cross section for masses < 30 GeV.

[Llena Garde, M., FS2011]

Diffuse emission:

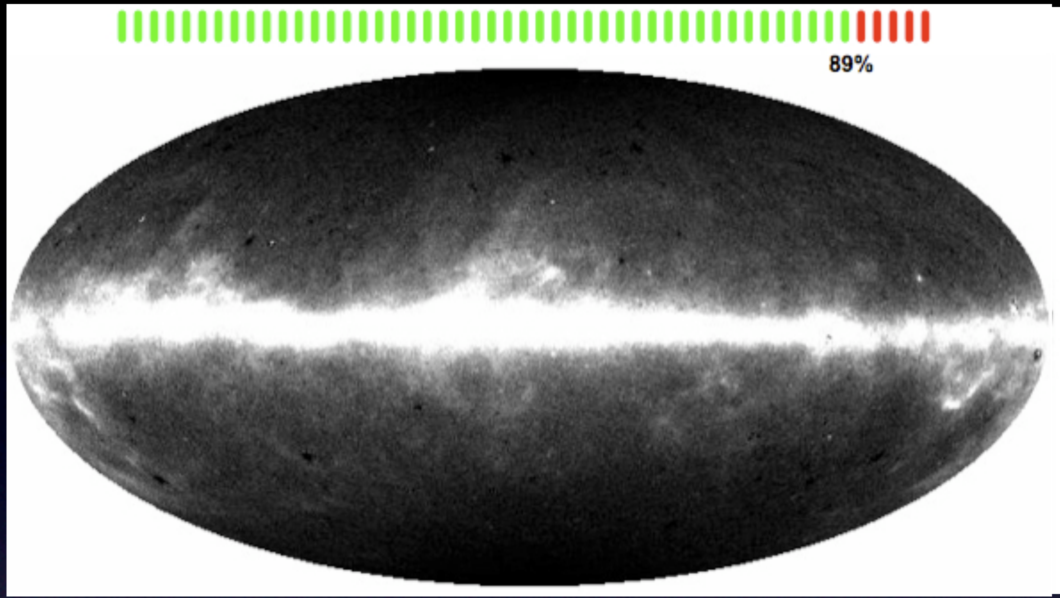
- Diffuse emission has good potential for DM searches --> probes *morphology* as well as on the DM annihilation/decay *spectral features*.
- It has good statistics (~90% of LAT photons!), but it is astrophysics (background) dominated.
- search strategies based on differences in expected morphology and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



LAT diffuse emission (point sources subtracted)

[J-M Casandjian, TeVPa2010]

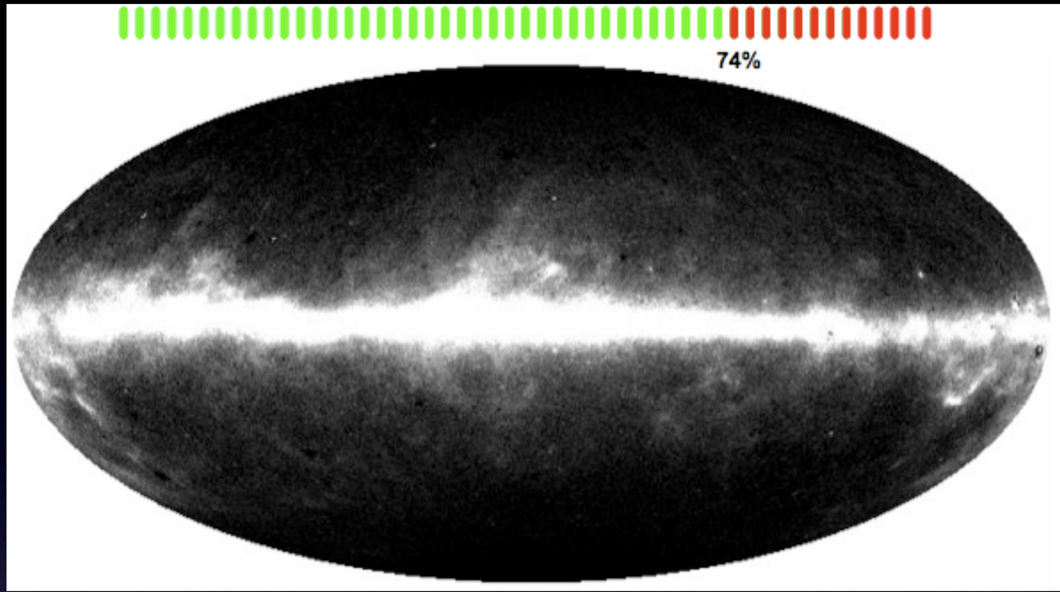
The whole sky data can be separated in components: *template fitting approach*:



[J-M Casandjian, TeVPa2010]

- Isotropic (high latitude/extragalactic) component

The whole sky data can be separated in components: *template fitting approach*:

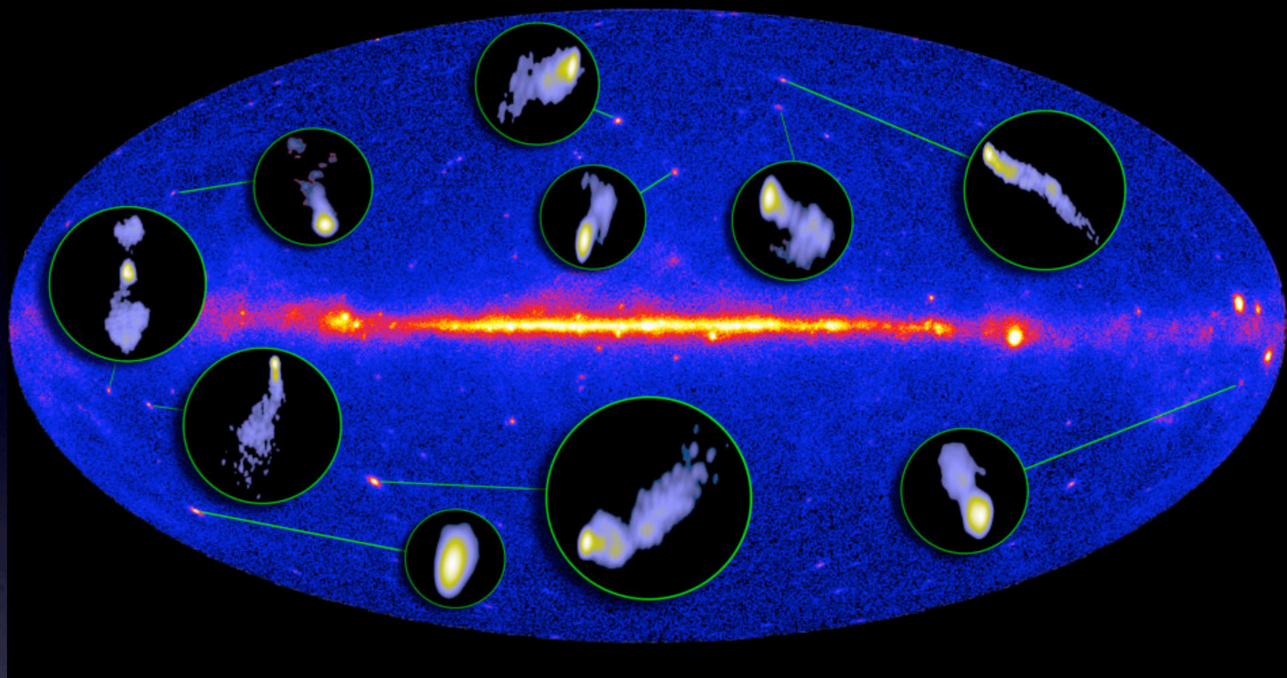


[J-M Casandjian, TeVPa2010]

- Isotropic (high latitude/extragalactic) component (15%)

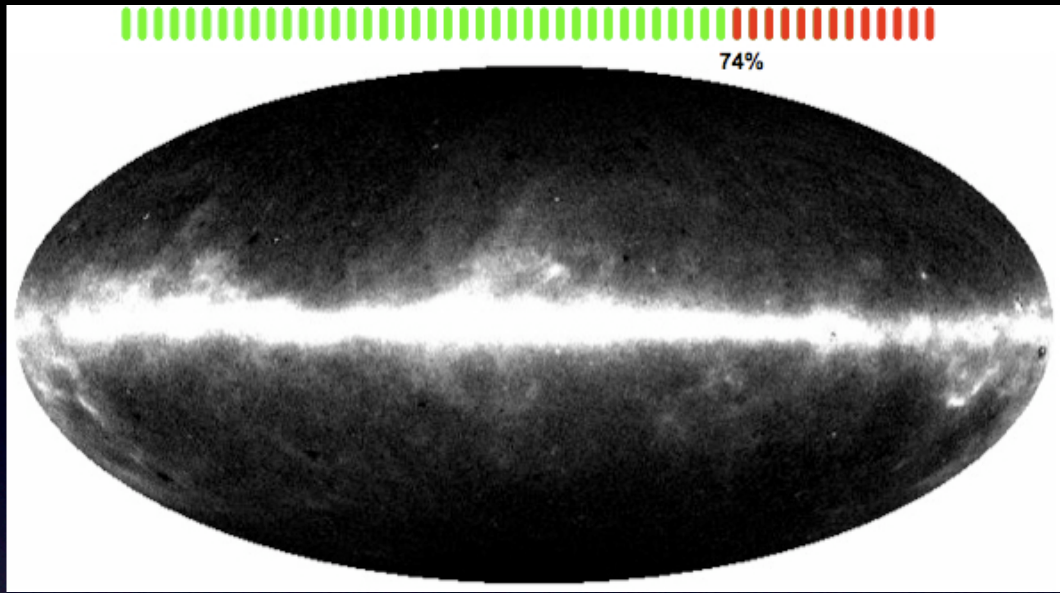
Produced by *unresolved* energetic phenomena over cosmological scales:

i) AGNs
ii) other galaxies
iii) DM?



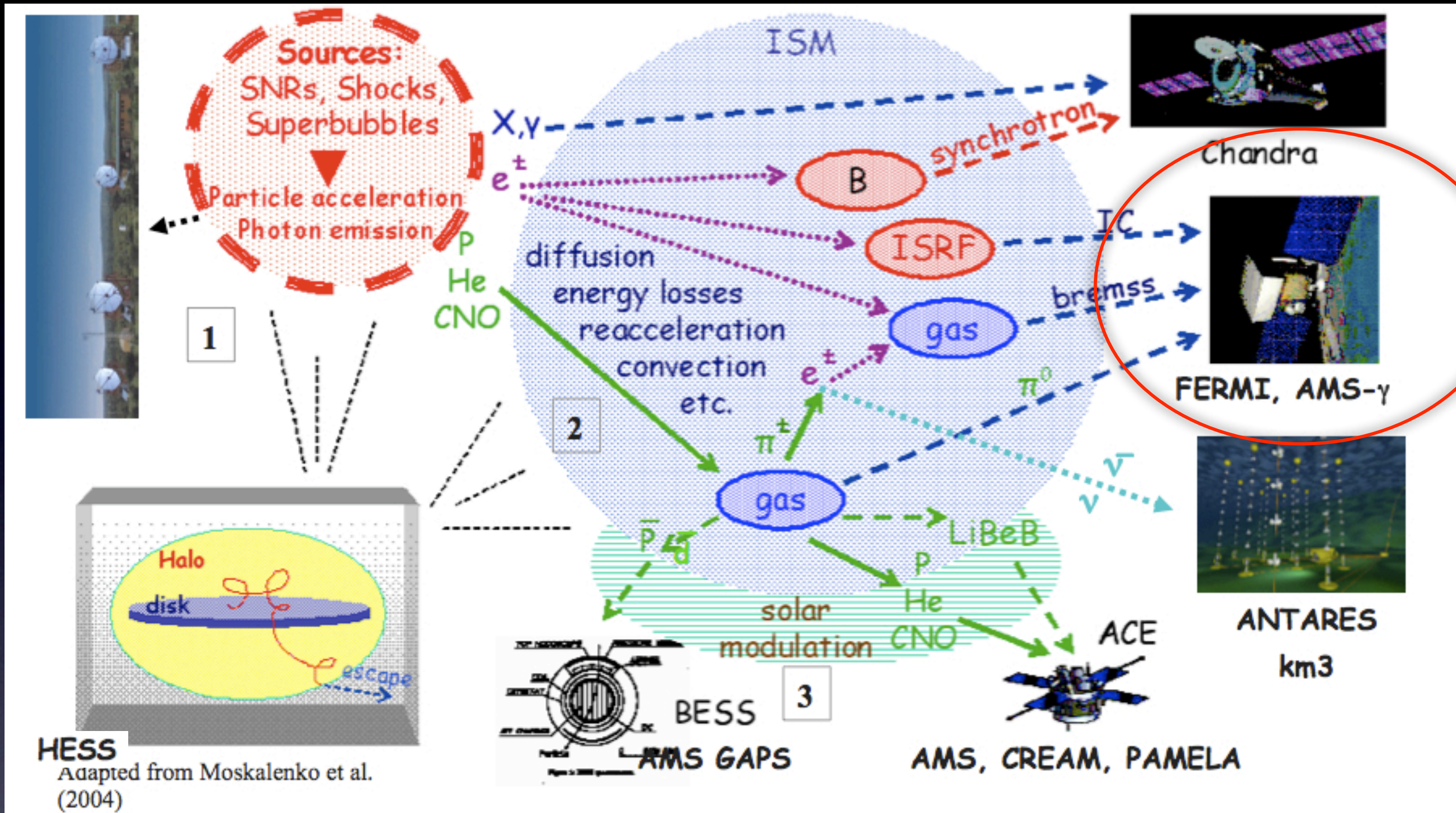
Selected Active Galactic Nuclei observed in radio by the VLBA (which has a million times better resolution than the Fermi-LAT) and gamma-rays by the Fermi-LAT.

The whole sky data can be separated in components: *template fitting approach*:



[J-M Casandjian, TeVPa2010]

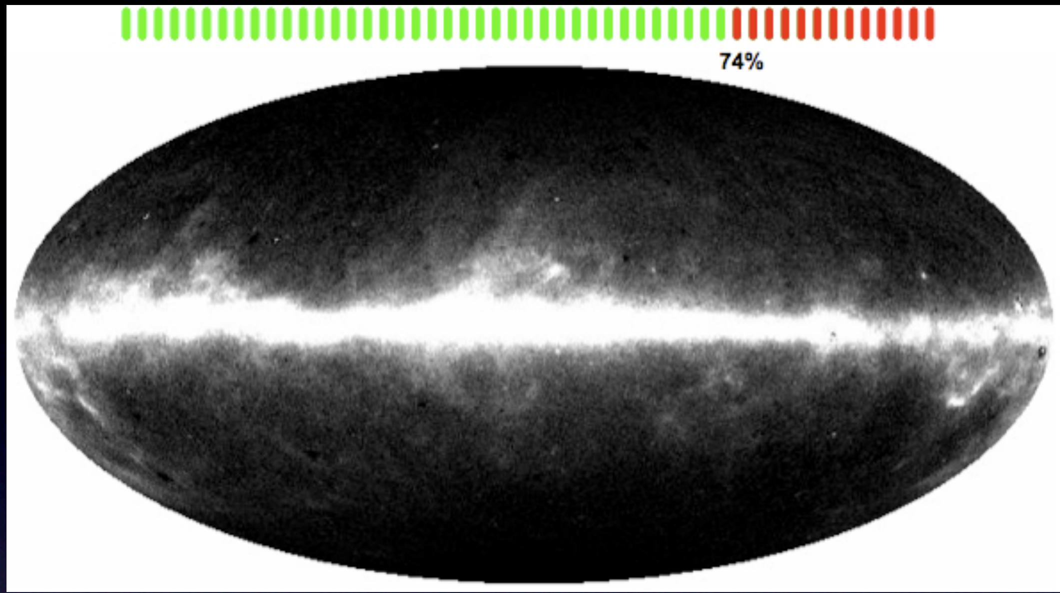
- Isotropic (high latitude/extragalactic) component (15%)
- the rest 'Galactic' diffuse emission



Galactic diffuse component: produced in interaction of cosmic rays, produced in astrophysical sources such as SNRs, with ambient medium and radiation fields:

-> *emission originates in IC, bremssthalung of electrons and π^0 decay in hadronic collisions and correlates with the gas content and ISRF distribution!*

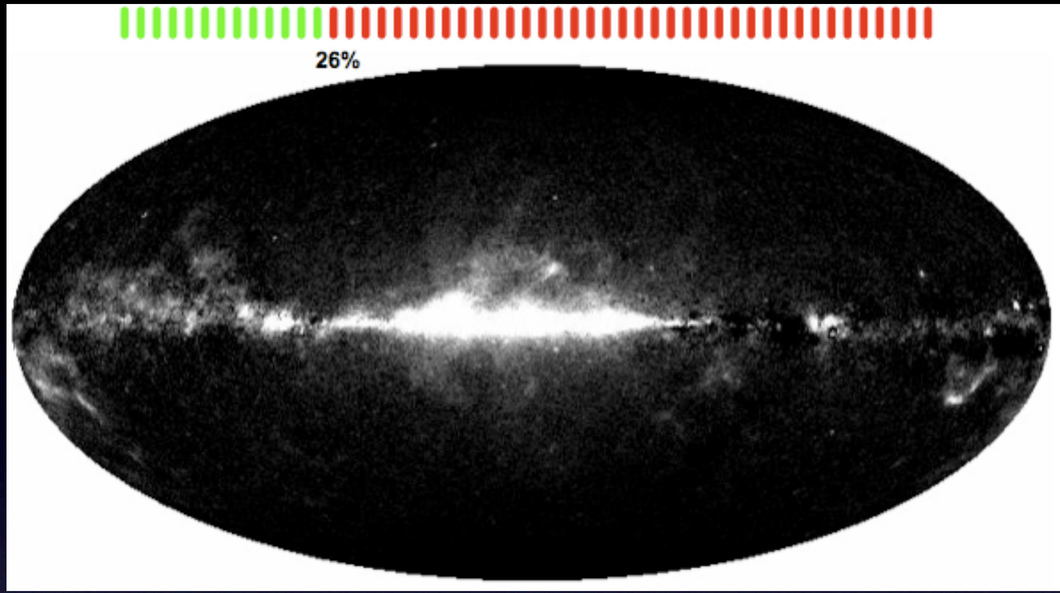
The whole sky data can be separated in components: *template fitting approach*:



[J-M Casandjian, TeVPa2010]

- Isotropic (high latitude/extragalactic) component (15%)
- the rest 'Galactic' diffuse emission: gas (π^0, bremss) & IC components
  - atomic (HI) and ionized (HII) hydrogen ~50%

The whole sky data can be separated in components: *template fitting approach*:



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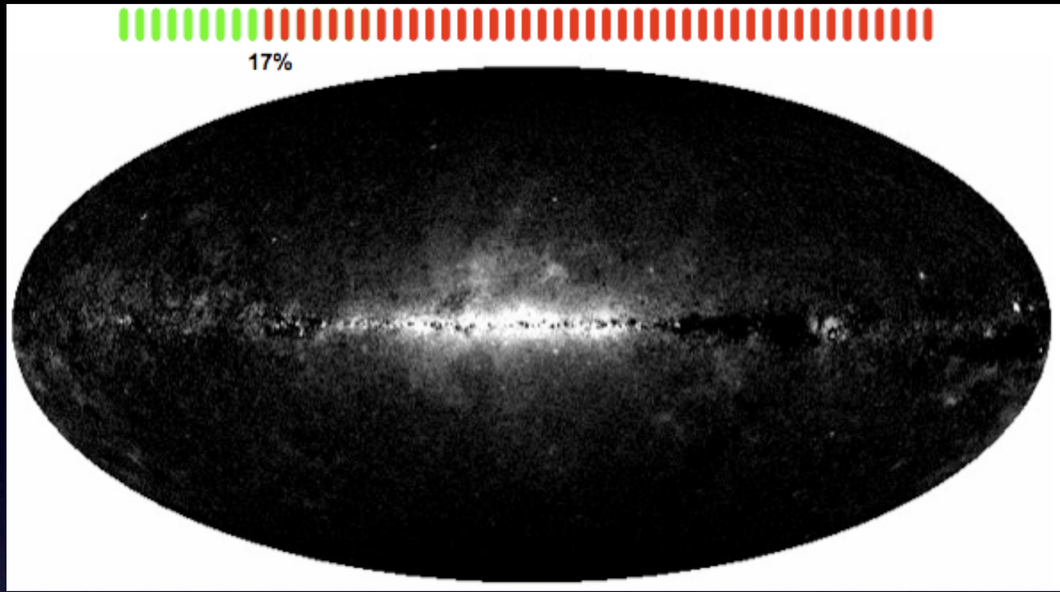

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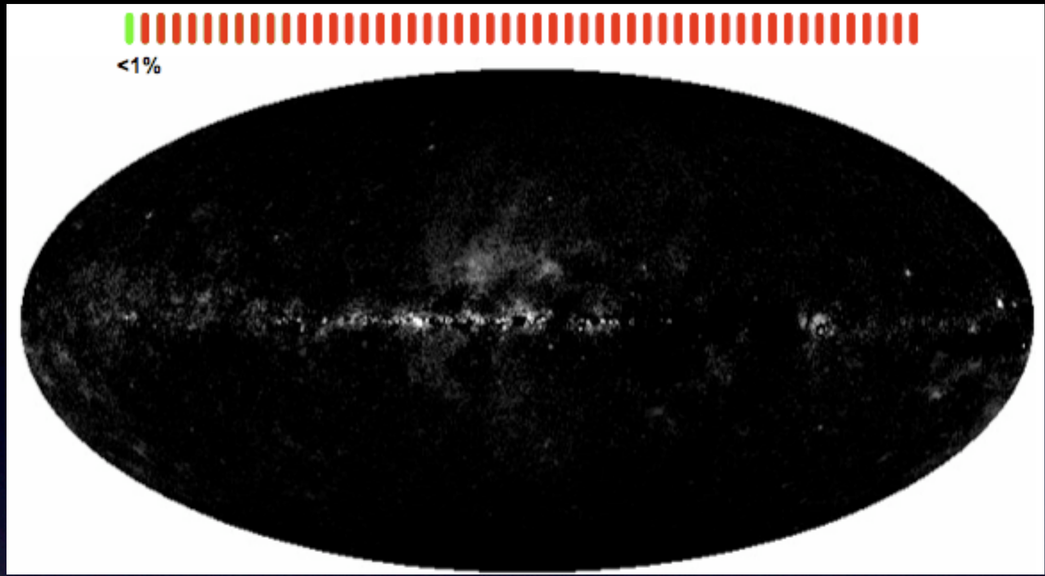

[J-M Casandjian, TeVPa2010]

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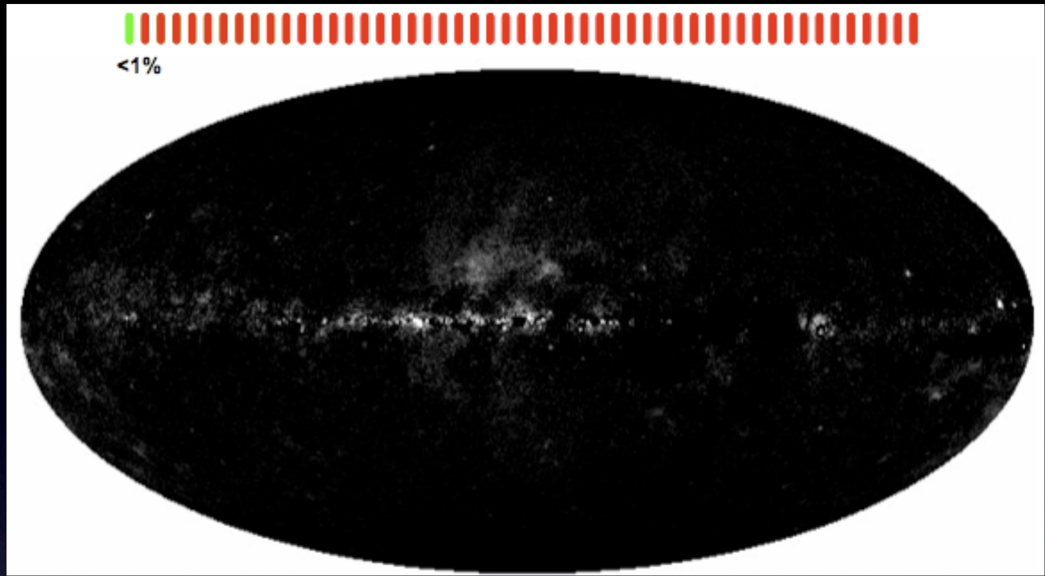
  - atomic (HI) and ionized (HII) hydrogen ~50%
  - molecular hydrogen ~10%
  - inverse compton (ISRF) ~10%
  - residuals <1 %; in part correlate with the dark gas (traced by the dust)



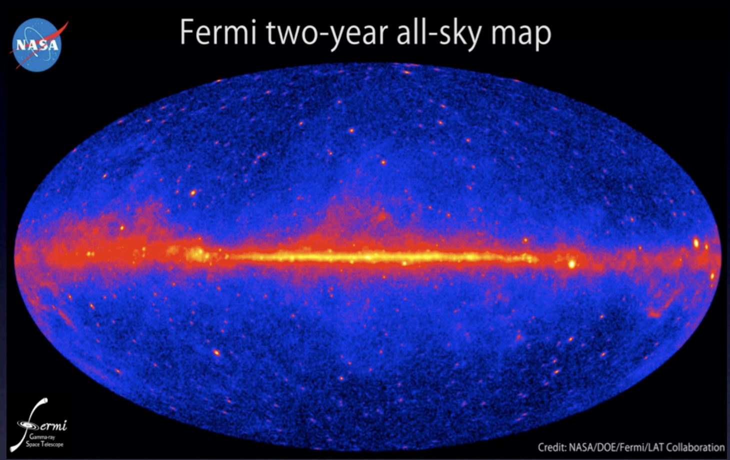
[J-M Casandjian, TeVPa2010]

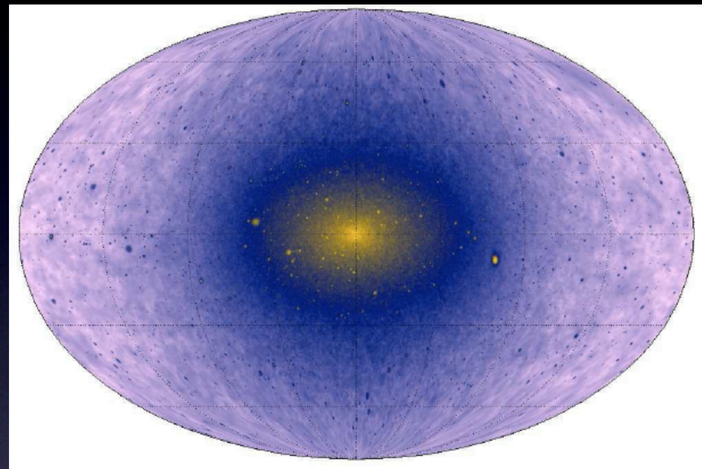
→The diffuse emission can be modeled with a linear combination of various templates (one of the main tools used in the analysis).

‘Diffuse’ DM searches by the Fermi team

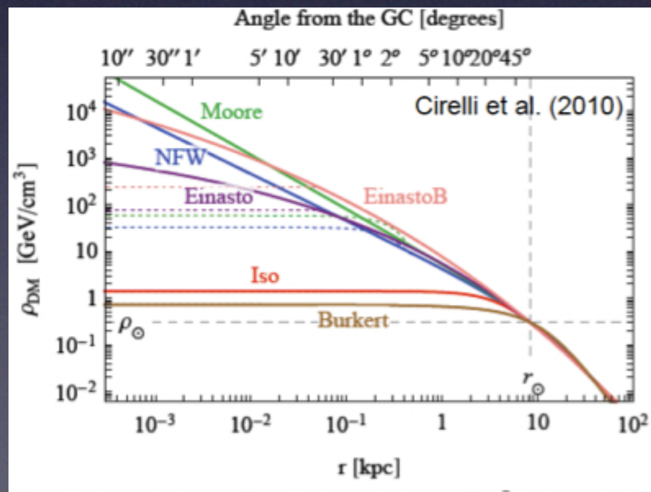
- analysis of the diffuse emission in terms of DM signal from the DM halo of our Galaxy.
- analysis of the diffuse Extragalactic (Isotropic) signal to study DM annihilation at the cosmological scales, by using:
  - the *intensity and spectral shape* of the signal or
  - *angular anisotropies*.

Galactic Halo analysis





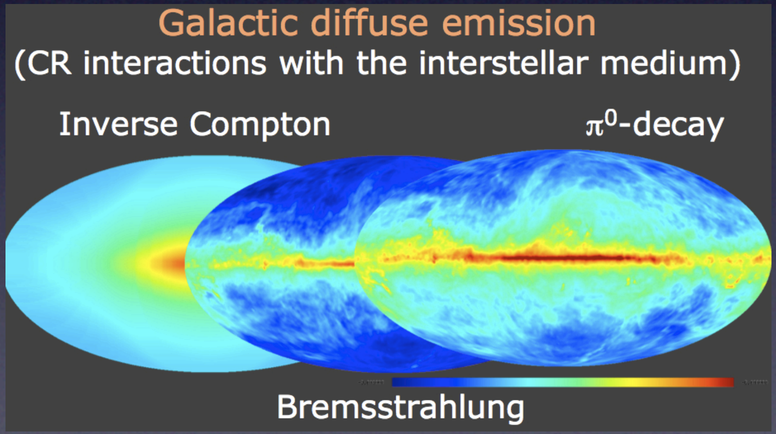
- DM annihilation in the Milky Way halo is one of the prime targets for DM search: *large dark matter density and the proximity of the region.*
- + *DM density is relatively well understood at distances* > 1 kpc (few degrees) from the GC.
- *Modeling of the astrophysical diffuse emission, and estimates of the systematic uncertainty involved,* represents the main difficulty in setting DM limits.

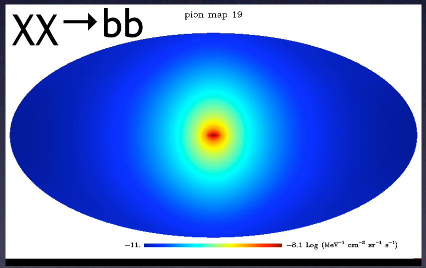


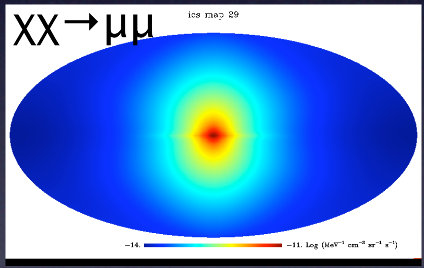
Main idea

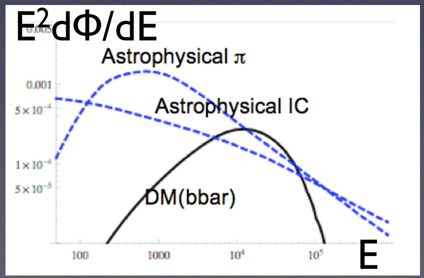
To the set of *astrophysical templates*, we add a *DM template*, and perform *a full sky spatial and energy fit* to the 2 year Fermi data.

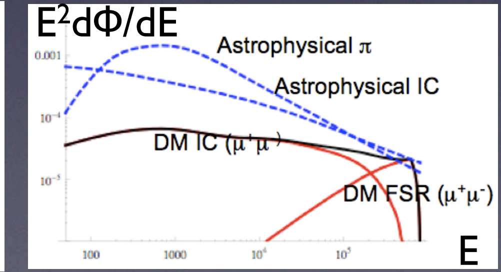
In this way, by using both, spectral and spatial features of the models we can, to some extent, *break degeneracy* between DM and astrophysical diffuse emission.



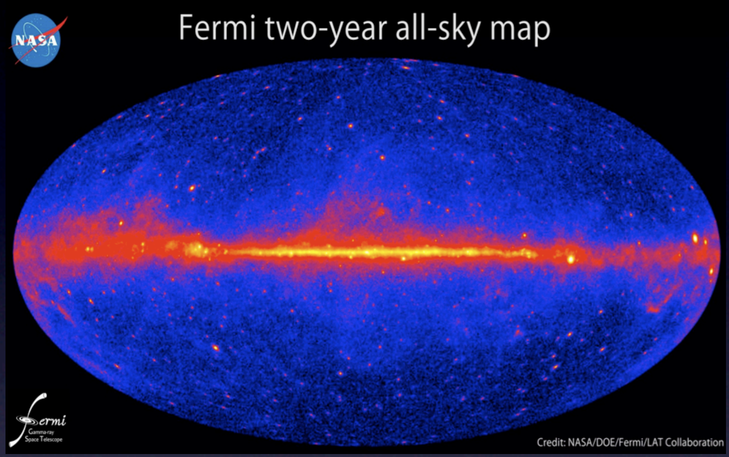


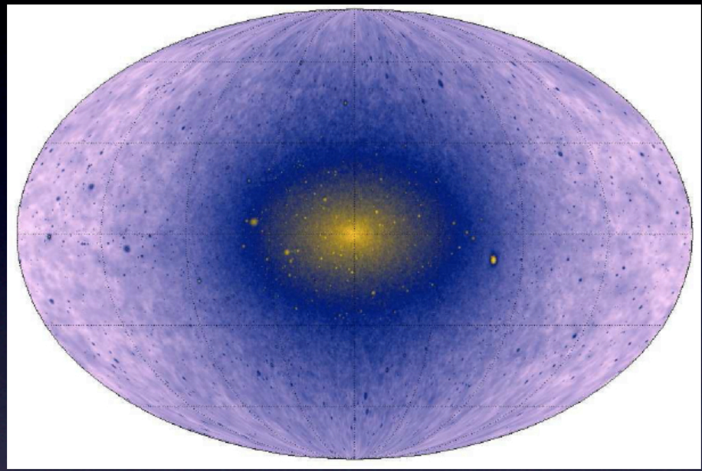






Analysis procedure



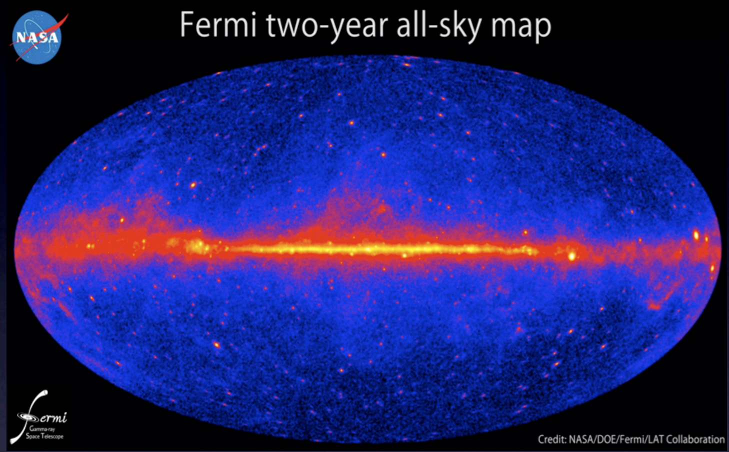


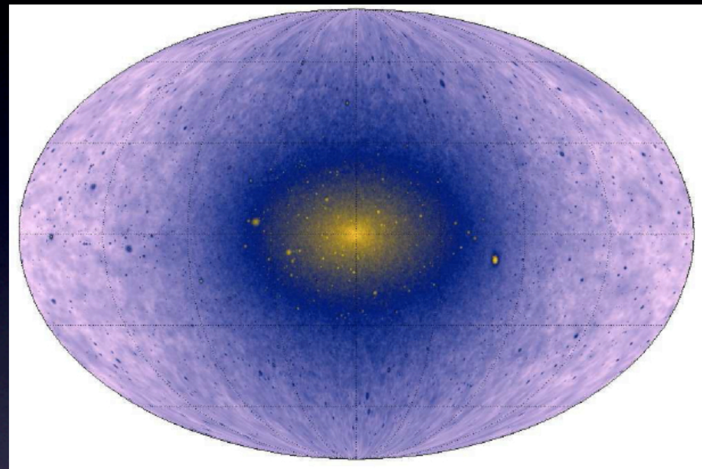
Two types of limits:

1) conservative DM limits, *set using the data alone*: $n_{DM} - 3(5)\sqrt{n_{DM}} > n_{data}$

2) Limits set by using *a 'reference' astrophysical* model for the background.

Analysis procedure





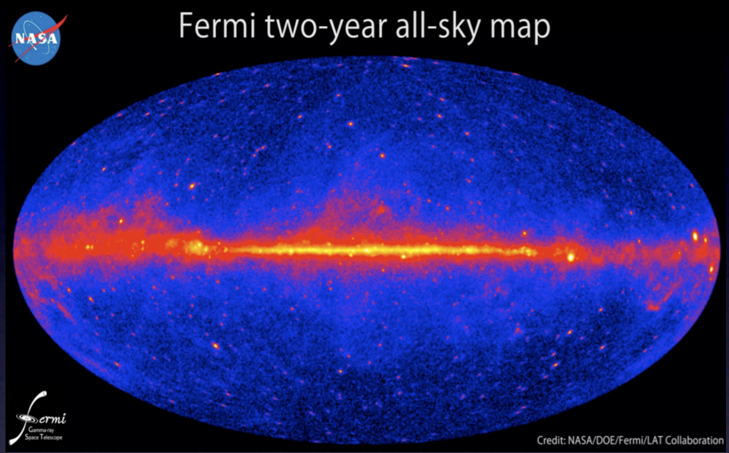
Limits set by using a 'reference' astrophysical model for the background.

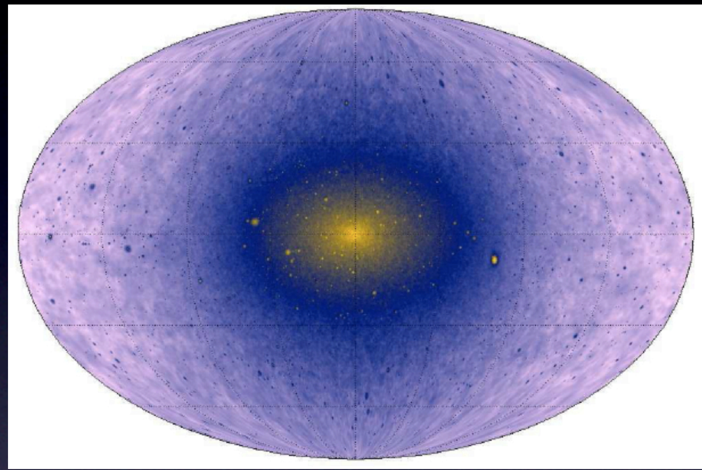
Steps:

1) components of the diffuse emission are *modeled with CR propagation code GALPROP*.

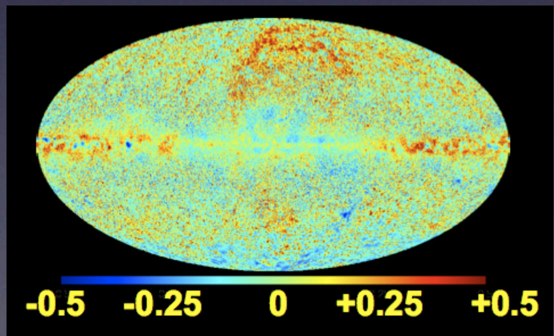
- cosmic ray source distribution, as obtained by direct observation of SNR or their tracers (i.e. pulsars)
- + measurements of cosmic ray spectra: p, He, e+-; secondary/primary ratio (B/C), for propagation parameters; radioactive cosmic ray nuclei, for halo height.

Analysis procedure





residuals of one of the astrophysical models from this set.



Limits set by using a 'reference' astrophysical model for the background.

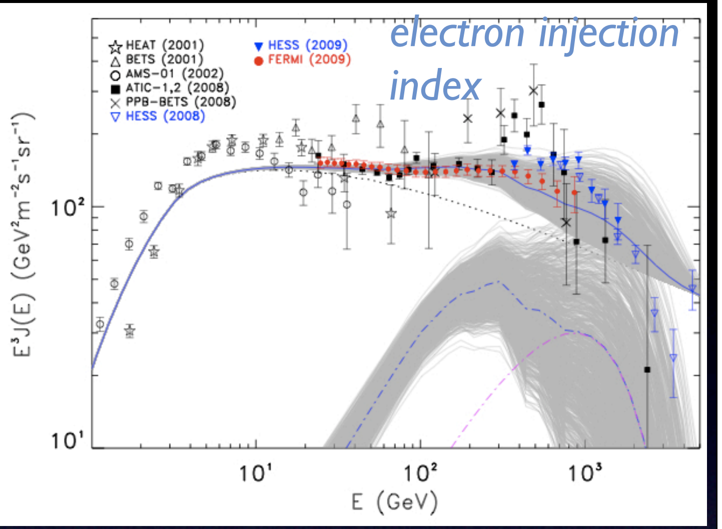
Steps:
2) perform a *template fitting to the data*, to marginalize over uncertainties in the gas/ISRF maps.
This defines a set of refined (physical) models which all fit the data reasonably well on large scales

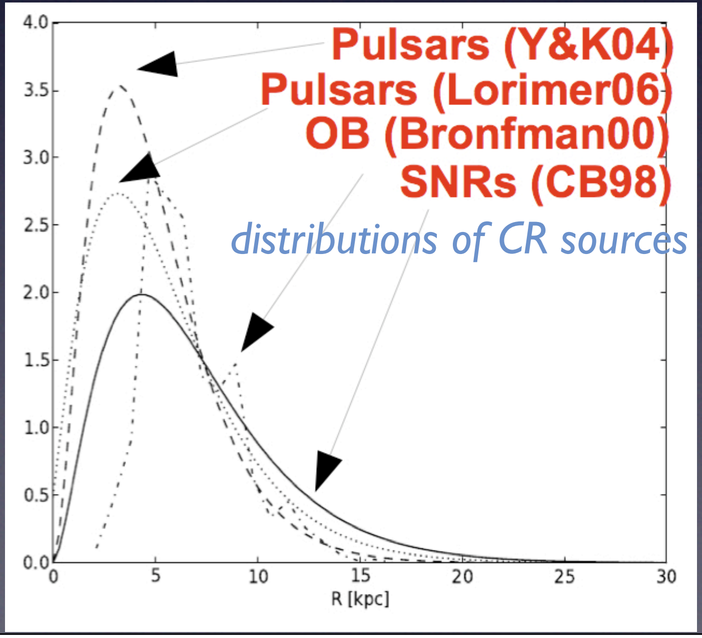
Limits set by using a 'reference' astrophysical model for the background.

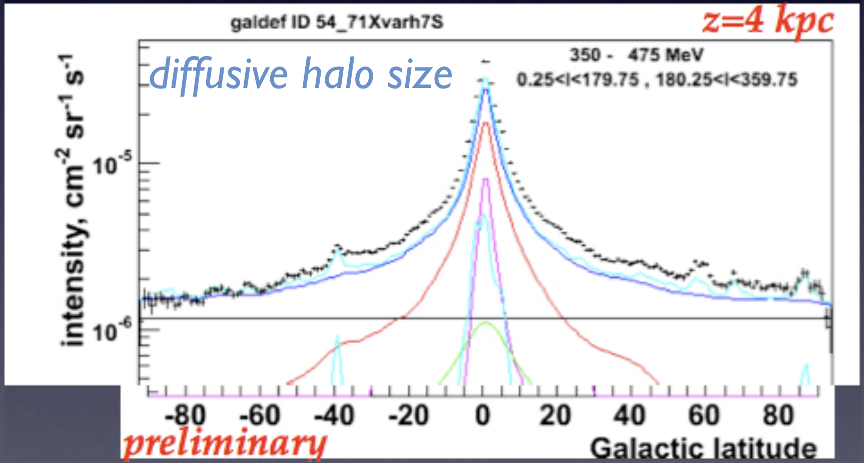
Steps:

3) We choose among these models *a reference model* which allows for the biggest contribution of DM (i.e. *weakest DM limits*).

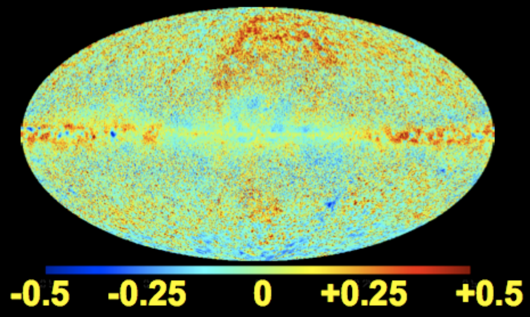
The most critical CR parameters in this respect (the ones which have the strongest degeneracy with the DM signal): *distributions of CR sources, diffusive halo size* and *electron injection index.*

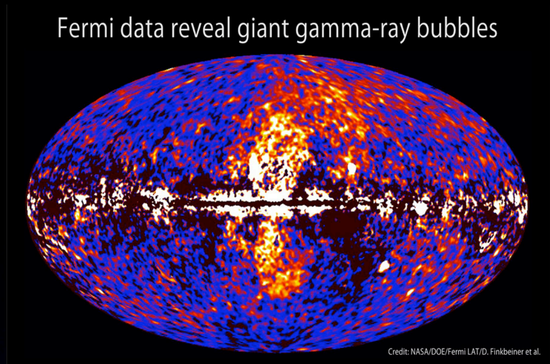






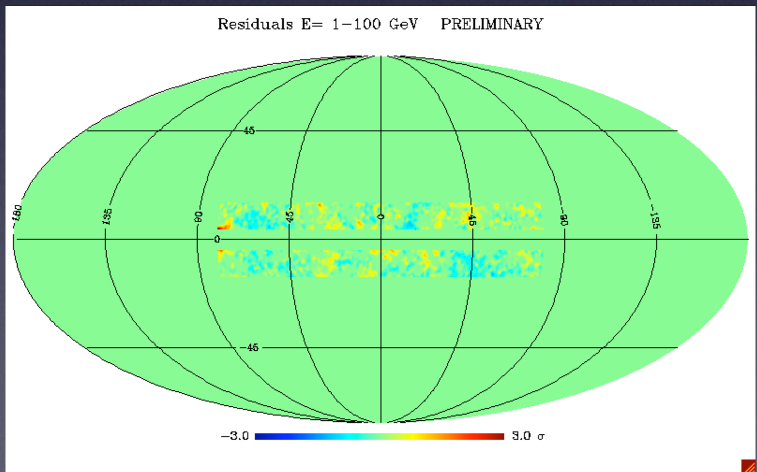
ROI

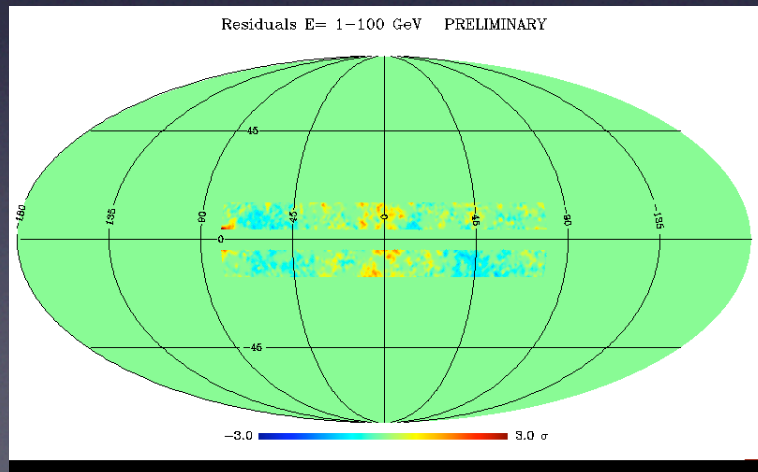


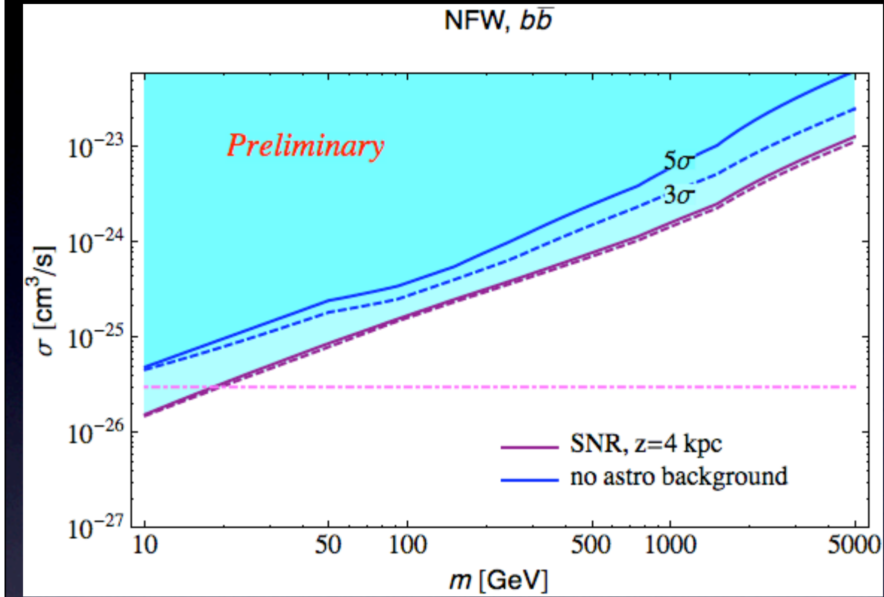


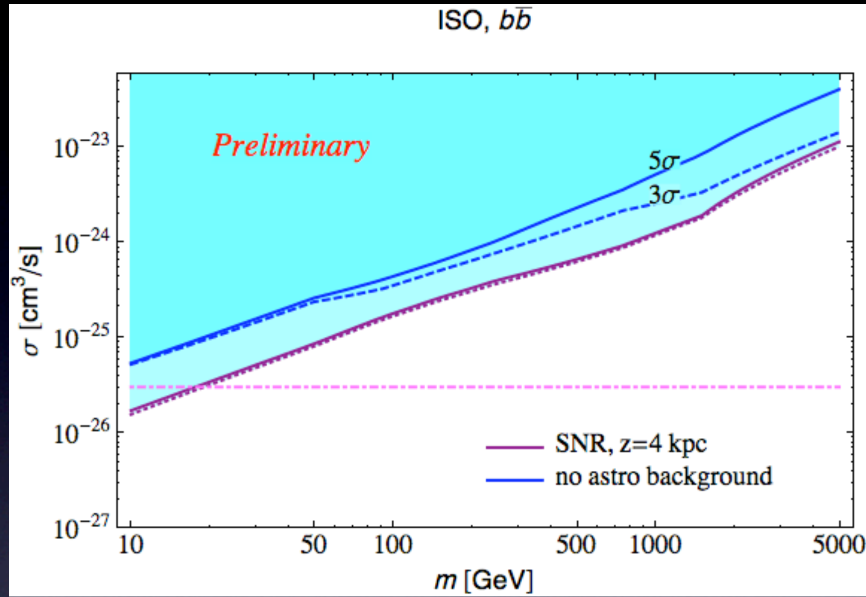
For this study we choose a low latitude region *5° <|b|<15° and |l|<80°*.

→ to minimize residual effects from unmodeled structures in the sky, most notably the Fermi lobes.
(We assume that lobes are not of DM origin, as in standard DM models one cannot explain the high latitude of this signal+sharp edges; for work along these lines see: Dobler et al, 1102.5095)
→ to leave out the outer Galaxy: difficult to model and at the same time does not affect much searches for DM annihilation)



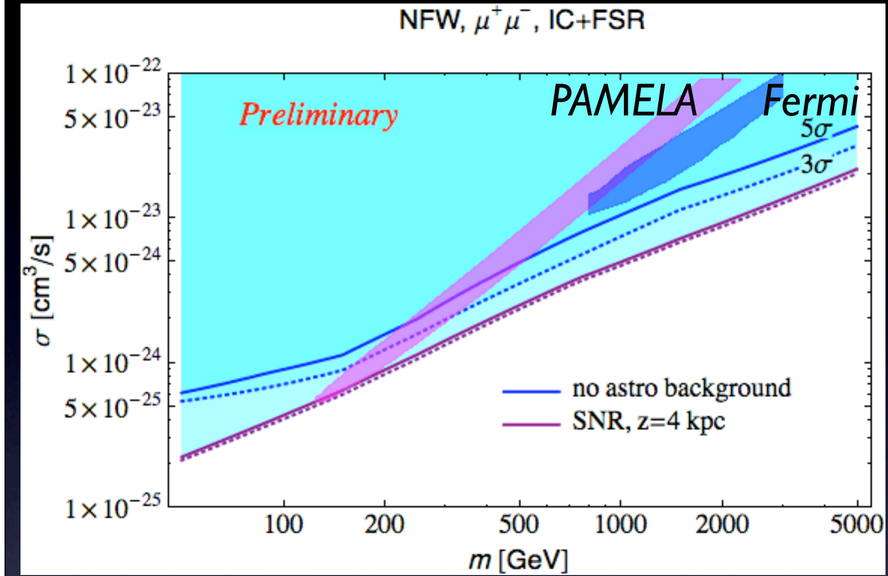


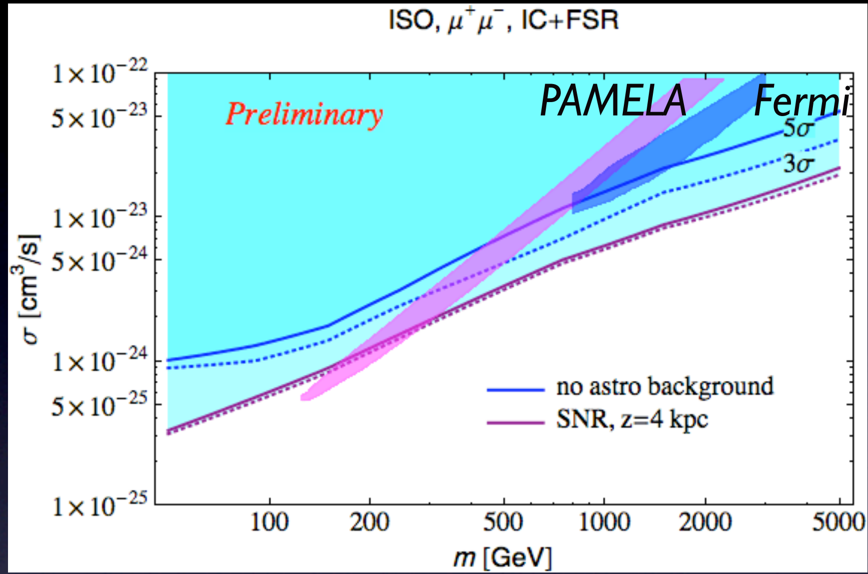




[GZ, FS2011]

- as expected, limits do not depend much on the DM profile assumed
- good constraining potential of this approach, freeze-out value reached for low masses.





[GZ, FS2011]

- as expected, limits do not depend much on the DM profile assumed
- good constraining potential of this approach, freeze-out value reached for low masses.

Limits set by using a 'reference' astrophysical model for the background.

Steps:

5) by varying CR parameters one at a time from this reference models we probe how much the limits would change given the uncertainties in these parameters.

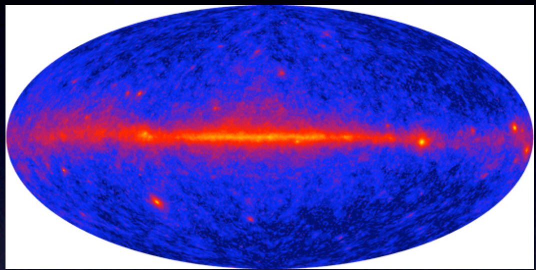
Uncertainties <~40%.

Parameter	$\delta\sigma/\sigma$ [%]
Alfven Velocity [30; **44**; 50] km s^{-1}	[5.; **REF**; 1]
Nucleon Injection Index I [**1.75**; 2; 2.2; 2.4]	[**REF**; 0.5; 2.; 5]
Gas maps [**Ts=100000K, Magcut=5**; Ts=150K, Magcut=2]	[**REF**; 8]
Electron Injection Index II [1.8; 2; 2.2; **2.4**; 2.6]	[41; 33; 18; **REF**]
Diffusion Coefficient [5.e28; **7.1e28**; 1e29]	[13; **REF**; 11]
Halo Height [4; 10] kpc	[**REF**; 20]
CR Source Distribution [SNR; Yus]	[**REF**; 35]
Galactic Winds [0; 800] km h^{-1}	[**REF**; 31]

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

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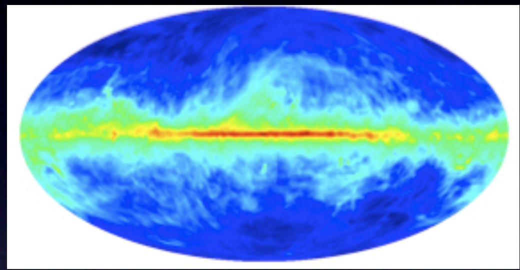
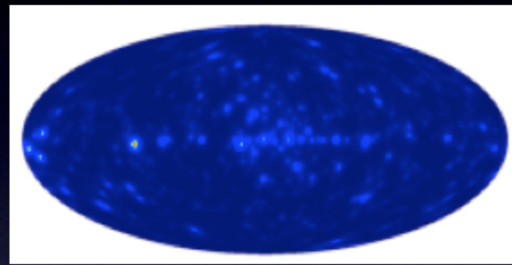


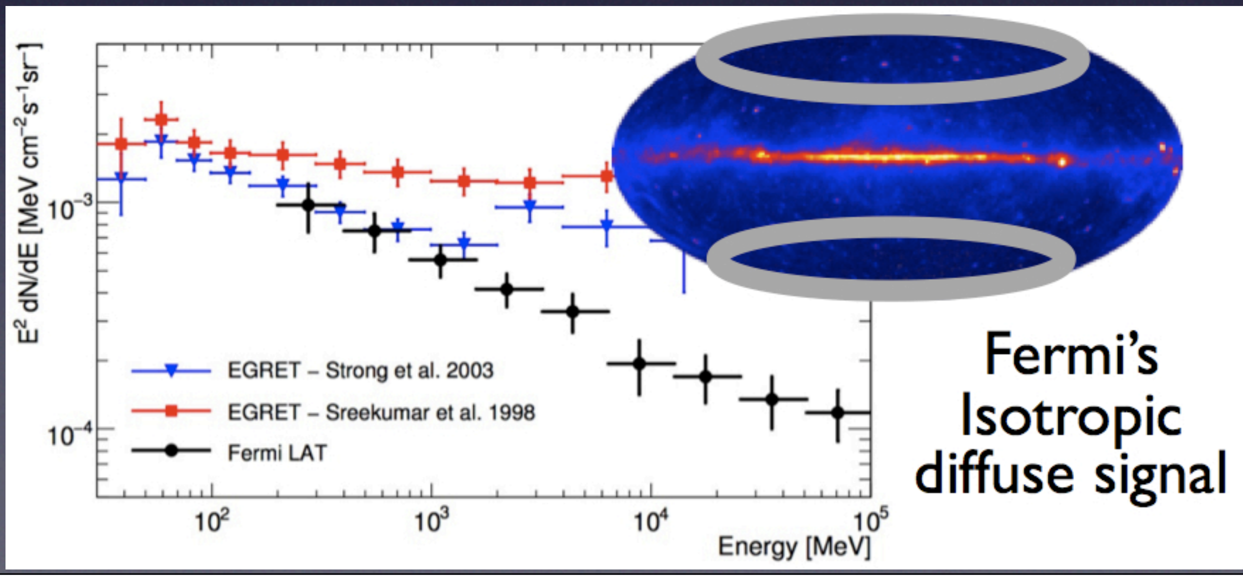
galactic diffuse emission

\-

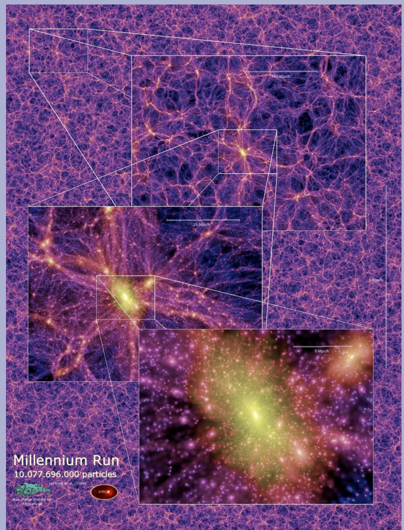


point sources

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

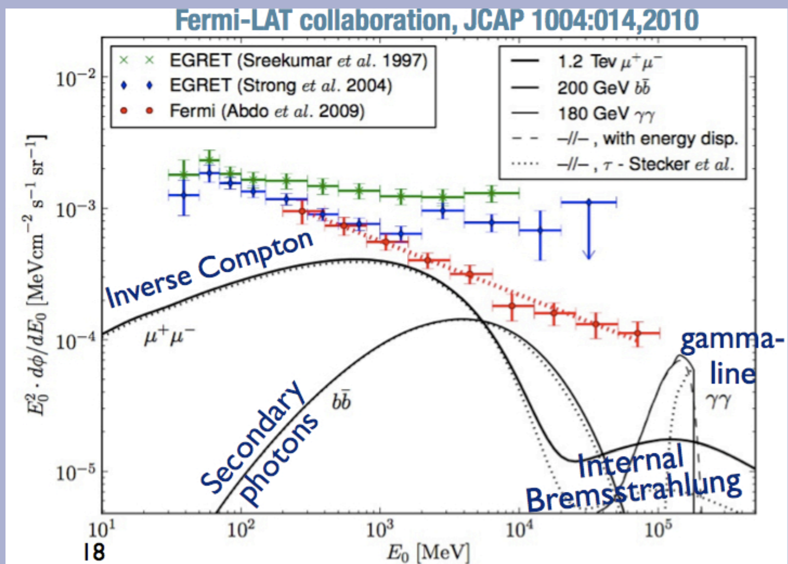


Predictions for the DM extragalactic signal:



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

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

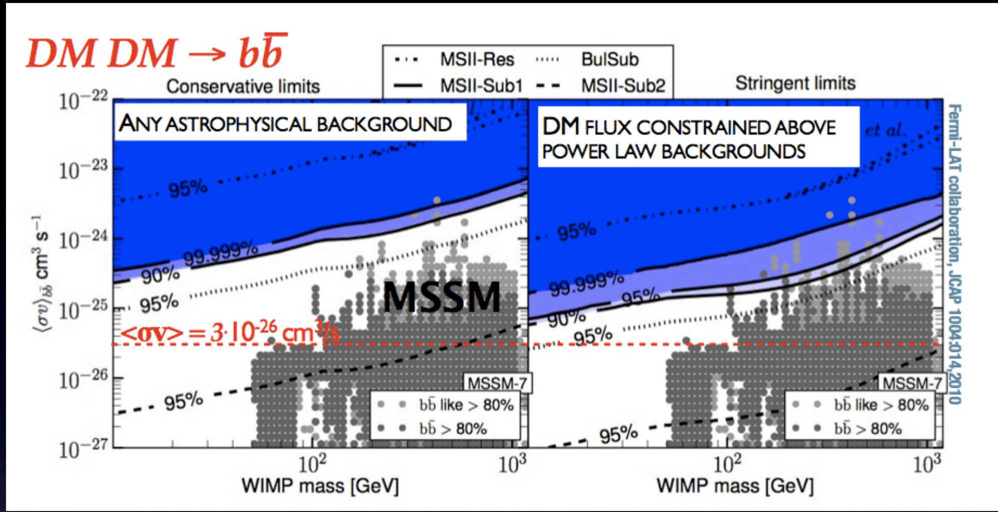


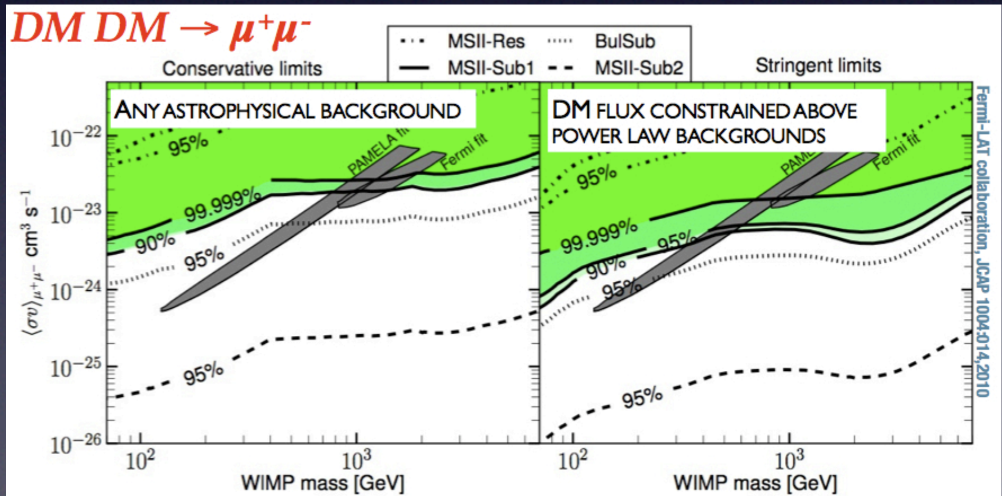
Δ^2: describes clustering properties of DM: number of halos of a given mass, at a given red-shift and the inner structure of halos -- N body simulations. Depends sensitively on the resolution of N-body simulations, as DM halos should form down to 10^-6 M_{sol}.

τ: attenuation of photons due to pair production on Extragalactic Background Light

dN/dE: DM annihilation spectrum at emission.

Limits from the 1st year Fermi data:



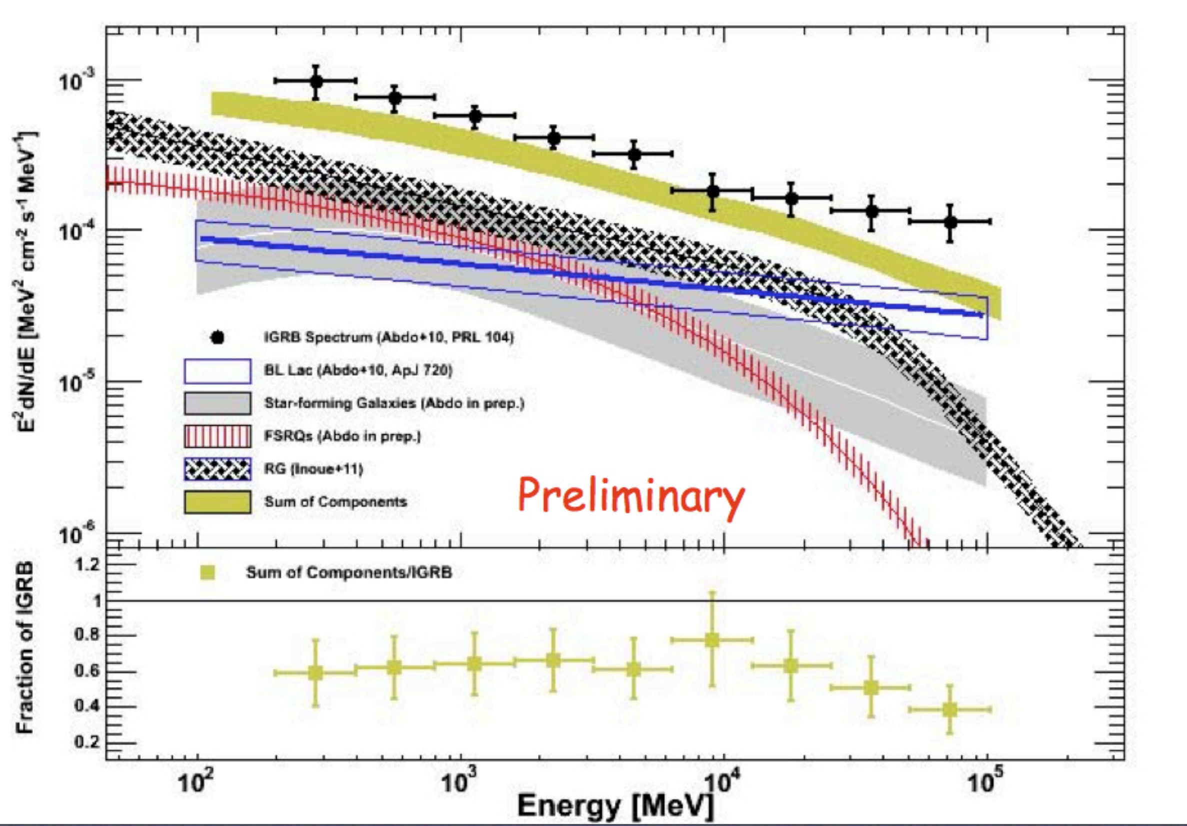


Large uncertainties in the prediction of the DM signal.

Astrophysical contributions unconstrained.

However significant progress in the second year of Fermi-LAT, both in terms of the improved 2nd year data, and improved modeling of astrophysical and DM signals!

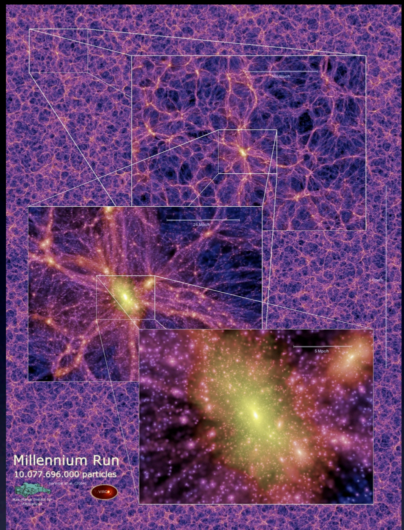
Fermi observed ~1000 of AGNs (BL Lacs, FSRQ, RG) and 4+3 galaxies! Based on the observed source classes one can infer *the contribution of unresolved members to the IGRB!*



[Ajello, M., FS2011]

→ studies *indicate that the majority of the IGRB does not originate from members of the source classes already detected by Fermi.*

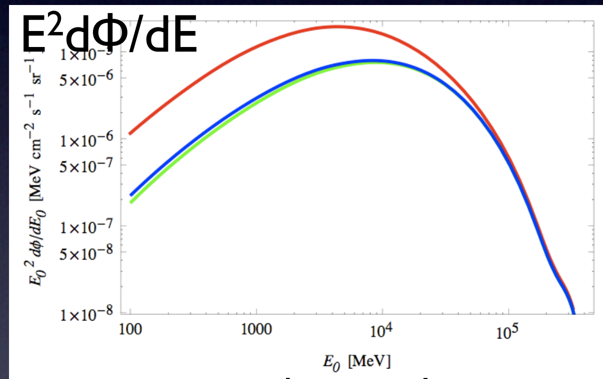
Predictions for the DM extragalactic signal:

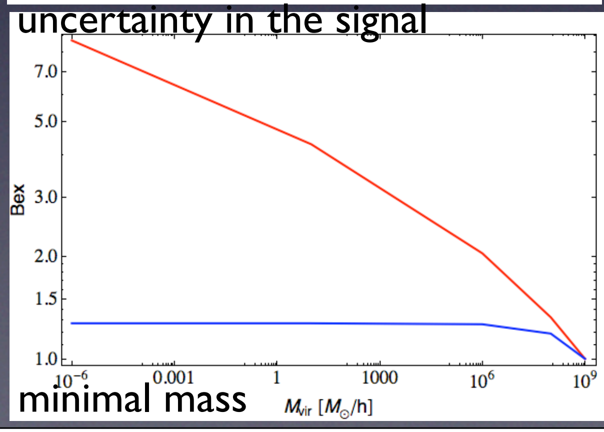


$$\frac{d\phi_\gamma}{dE_0} = \frac{\sigma v}{8\pi}\frac{c}{H_0}\frac{\bar{\rho}_0^2}{M_\chi^2}\int dz\,(1+z)^3\frac{\Delta^2(z)}{h(z)}\frac{dN_\gamma(E_0\,(1+z))}{dE}e^{-\tau(z,E_0)}$$

Issues: *prediction and uncertainty* in the DM signal from N-body simulation results (limited by computer power).

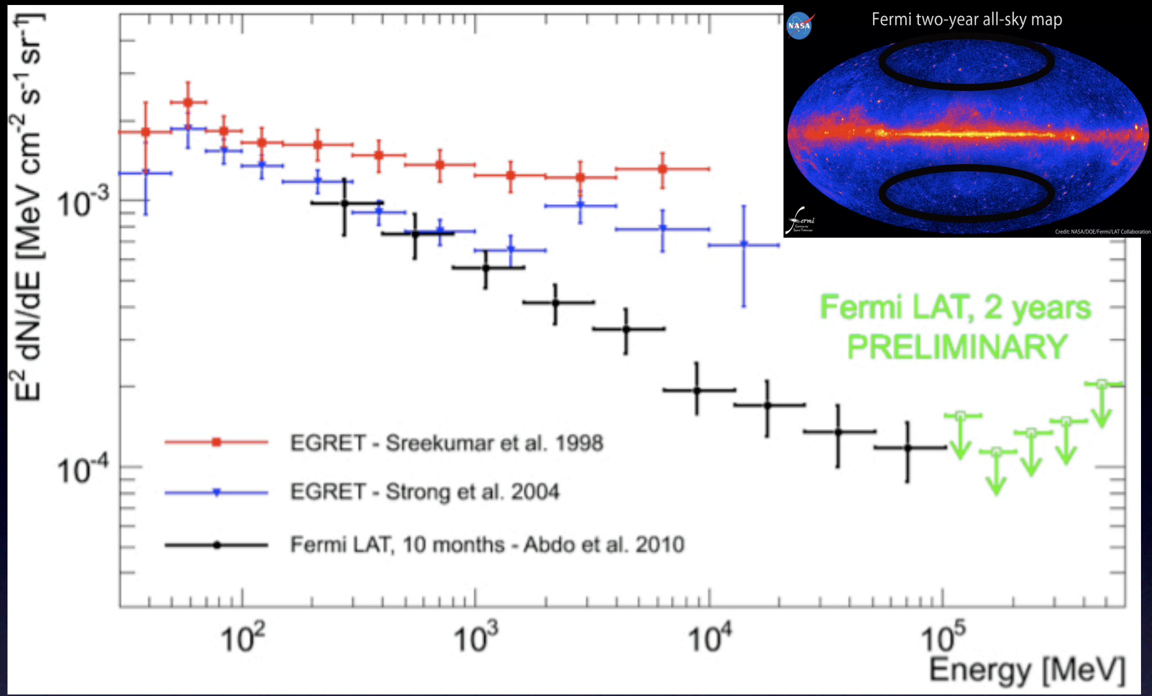
Astrophysical and cosmological uncertainties' (Serpico, Gustafsson, Sefusatti, GZ):





Theoretical reassessment of the predictions for extragalactic DM signal:

- full error budget
- impact of non-standard cosmologies
- the impact on the spectra when different simulations and theoretical assumptions are varied.



[Ackermann M., 2011]

1st year IGRB spectrum extends to 100 GeV.

2nd year spectrum with extended energy range expected during the summer.

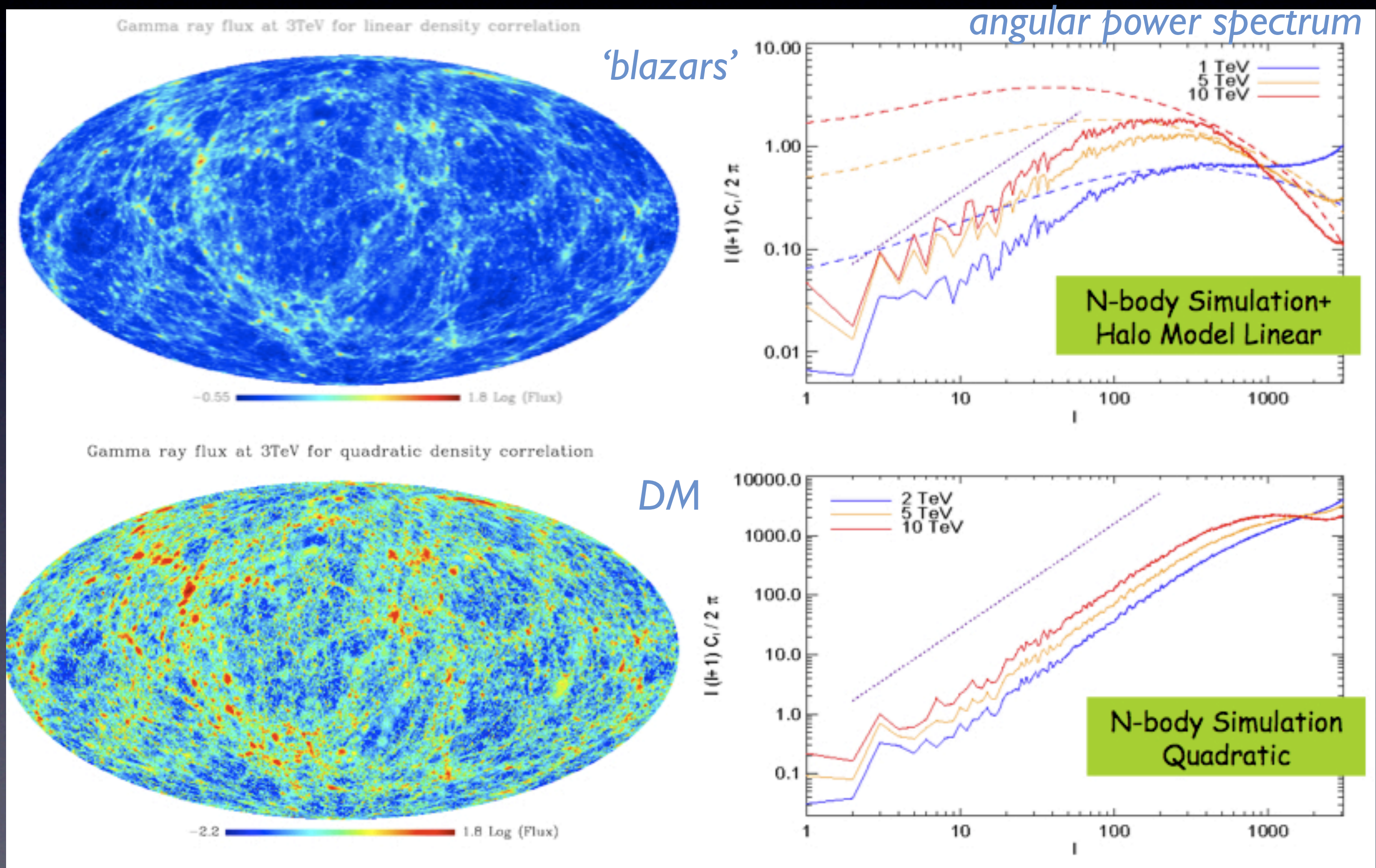
→ *updated DM limits from 2yr data shortly after.*

Extra Galactic diffuse signal

- DM limits from the *angular anisotropy* of the signal

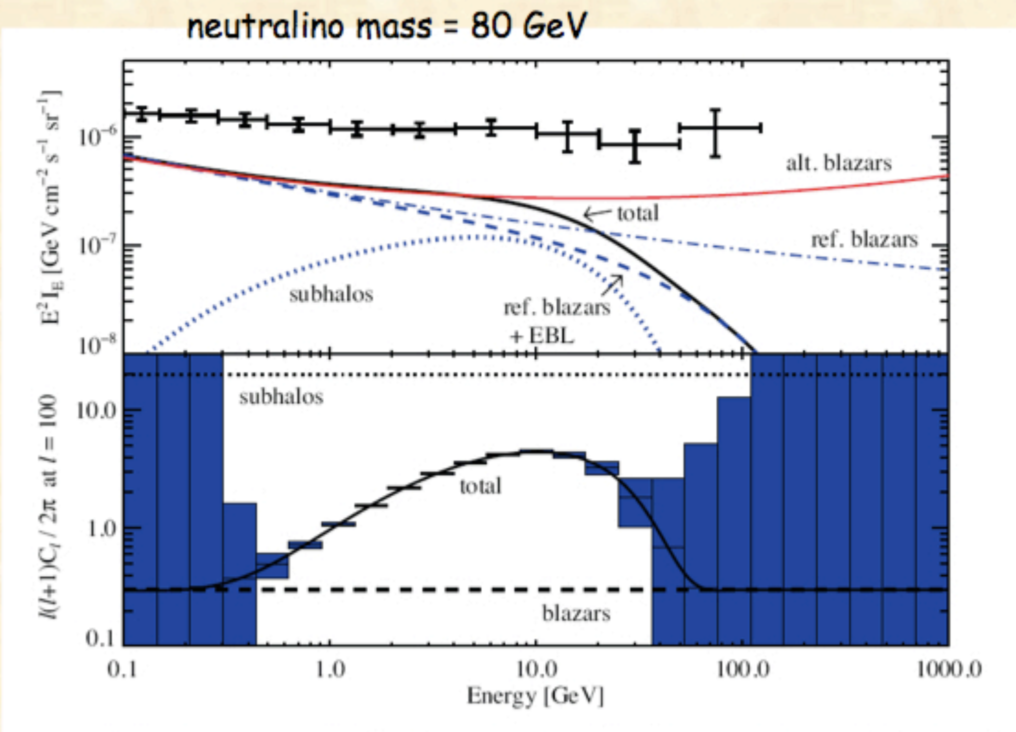
Angular power spectrum - expectation

$$I(\psi) = \sum_{\ell,m} a_{\ell m} Y_{\ell m}(\psi) \qquad C_\ell = \langle |a_{\ell m}|^2 \rangle$$



[Cuoco et al., JCAP]

‘Anisotropy energy spectrum’ uses information both on angular ansiotropies and energy spectrum - a way to *break degeneracy between different source classes!*



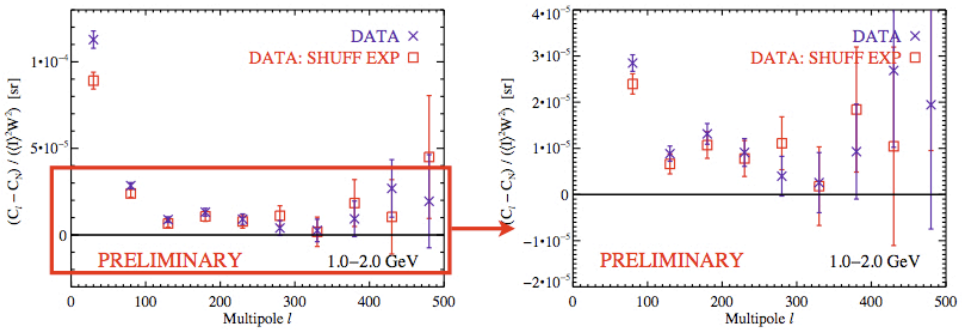
the anisotropy energy spectrum characterizes intensity fluctuations at a **fixed** angular scale as a function of energy

C_ℓ vs. E
(at a fixed ℓ)

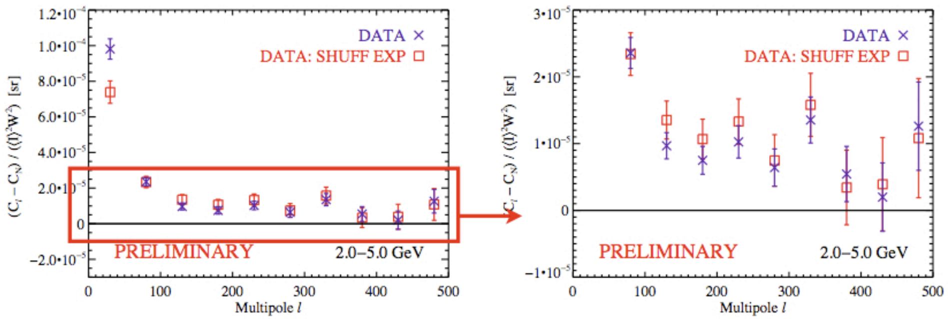
J. Siegal-Gaskins, V. Pavlidou, Phys.Rev.Lett.102:241301,2009.

Angular power spectra of the Fermi data

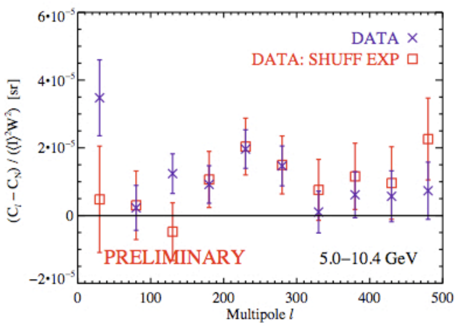
1 - 2 GeV



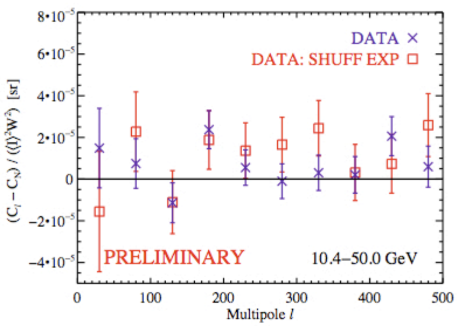
2 - 5 GeV



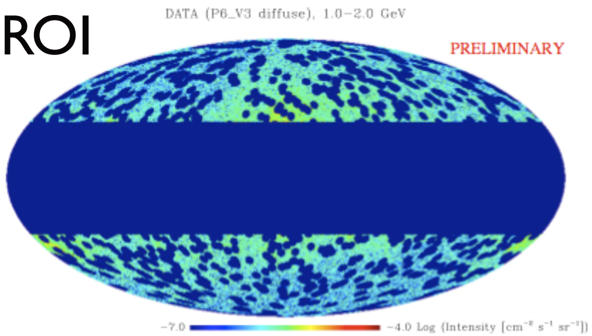
5 - 10 GeV



10 - 50 GeV



ROI



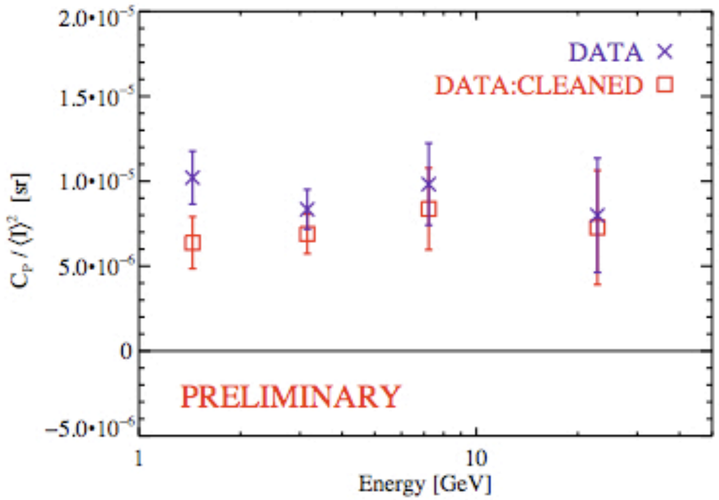
Significance
6.5σ
7.2σ
4.1σ
2.7σ

[Siegal-Gaskins, J., FS2011]

Energy dependence of anisotropy

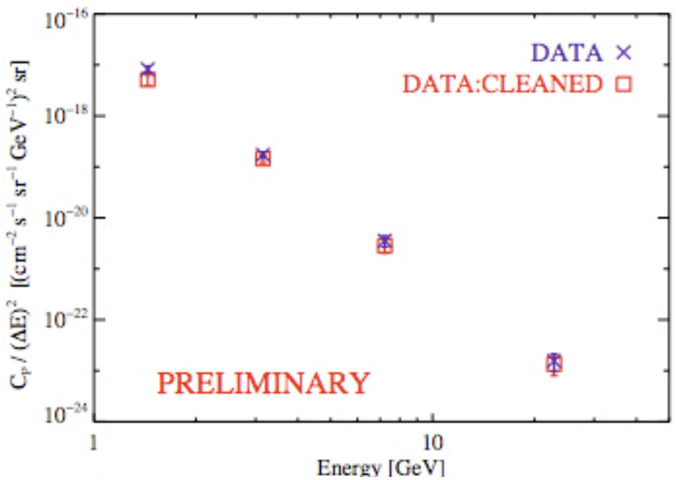
Fluctuation anisotropy energy spectrum

- consistent with no energy dependence, although mild or localized energy dependence not excluded
- consistent with all anisotropy contributed by one or more source classes contributing same fractional intensity at all energies considered



Intensity anisotropy energy spectrum

- consistent with that arising from a source class with power-law energy spectrum with $\Gamma = -2.40 \pm 0.07$
- implied source spectral index is good agreement with mean intrinsic spectral index of blazars inferred from detected members

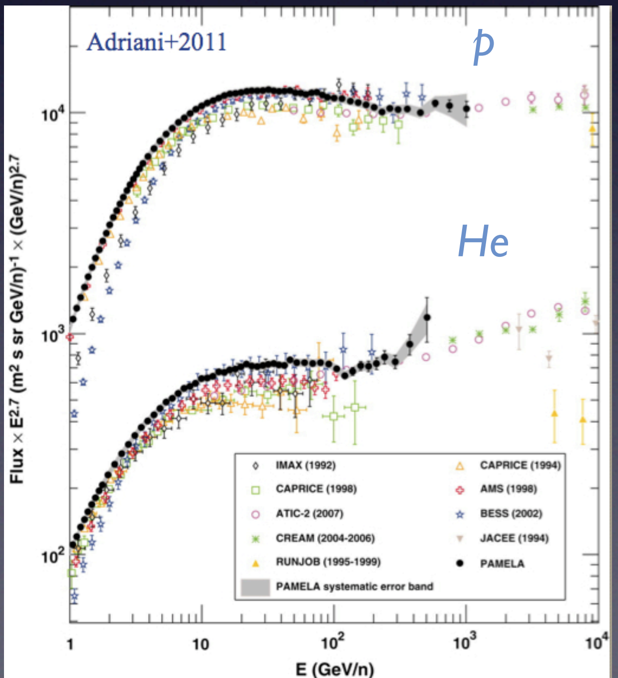


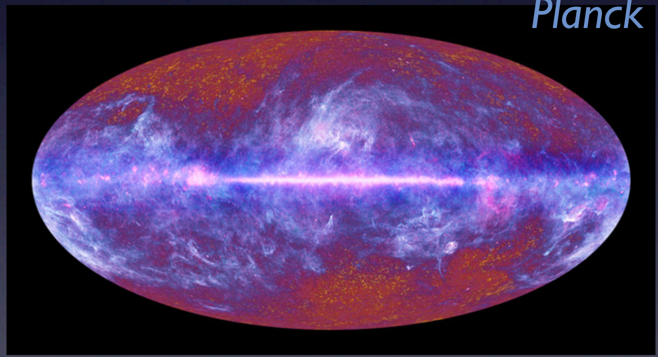
Measured angular anisotropy consistent by being contributed to only by blazar population. DM constraints should be coming up this summer.

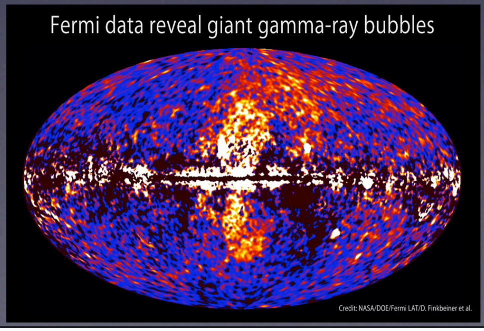
[Siegal-Gaskins, J., FS2011]

Summary (01)

- Fermi telescope is providing valuable scientific input to astrophysics and DM communities. It is starting to probe thermal annihilations cross section (WIMP paradigm).
- Studies of the *diffuse data* in terms of DM signatures are promising and just starting to be exploited.
- The DM limits set from the Galactic diffuse emission are not 'statistics limited'... Complementary probes and theoretical studies will improve sensitivity due to better understanding of the astrophysical emission.







Summary (02)

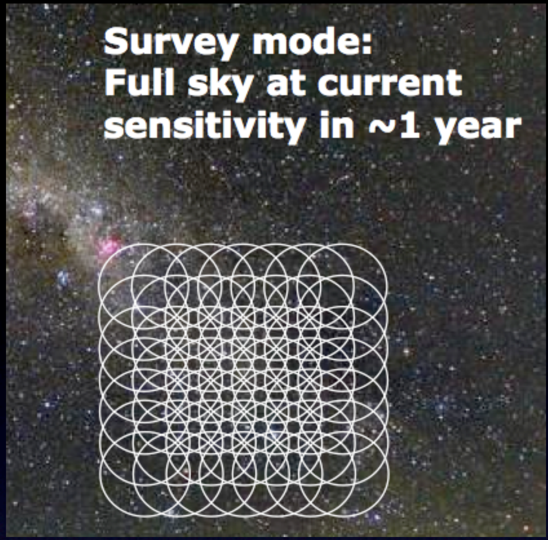
2nd year limits on cosmological/high latitude DM annihilation are coming soon, and will be improved:

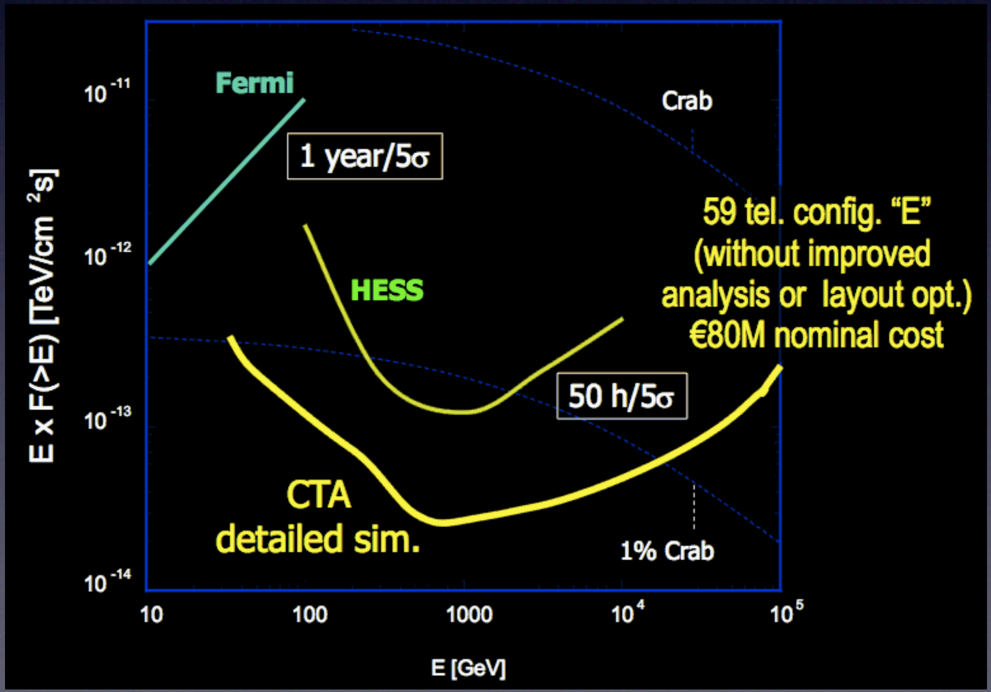
- As Fermi continues to detect faint extragalactic sources, less of them will contribute to the non-resolved isotropic emission, increasing the sensitivity to DM search.
- Increased number of detected sources will also lead to improved modeling of the extragalactic source populations and our understanding of the background.
- complementarity of studies intensity and angular power spectra valuable to understand contribution of different source classes to the isotropic background signal.

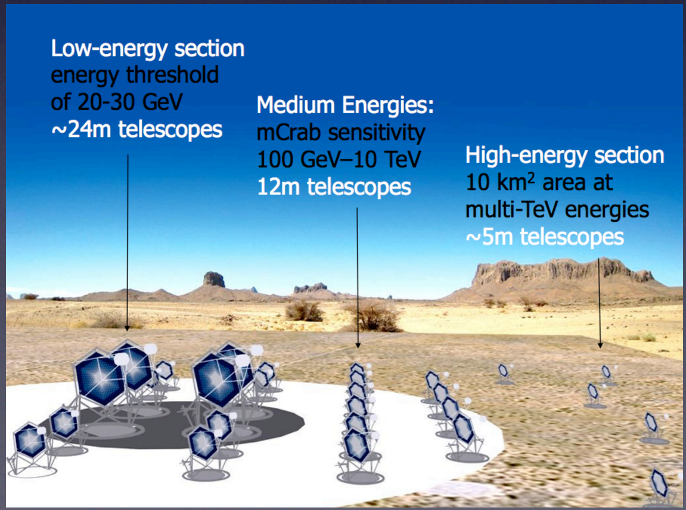
Future experiments

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 *diffuse* emission.







[J. Hinton, TeVPA 2010.]