Searches for WIMP dark matter with the Fermi LAT

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Outline

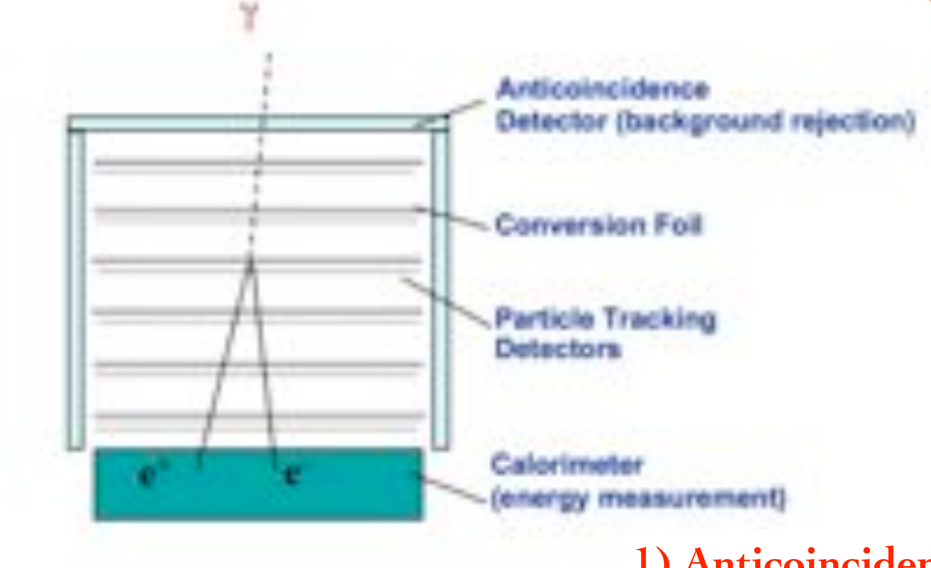
- Fermi-LAT design/performance.
- Gamma-ray sky & science with the Fermi-LAT
- Fermi-LAT as a dark matter search experiment -> focus on recent results:
    - search for spectral signatures
    - search in dwarf spheroidal Galaxies
    - in the Galactic diffuse emission
    - in the anisotropies in the gamma-ray sky

The instrument

Fermi LAT Collaboration: ~ 400 Scientific Members, NASA / DOE & International Contributions (INFN, Italy; ...).
Fermi LAT data made public within 24 hours.

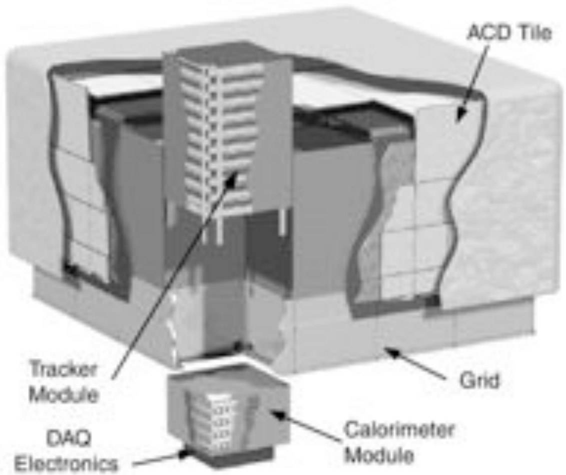
The instrument

The LAT is a **pair-conversion telescope**; individual γ rays convert to e+e– pairs, which are recorded by the instrument. By reconstructing the e+e– pair we can deduce the energy and direction of the incident γ ray.



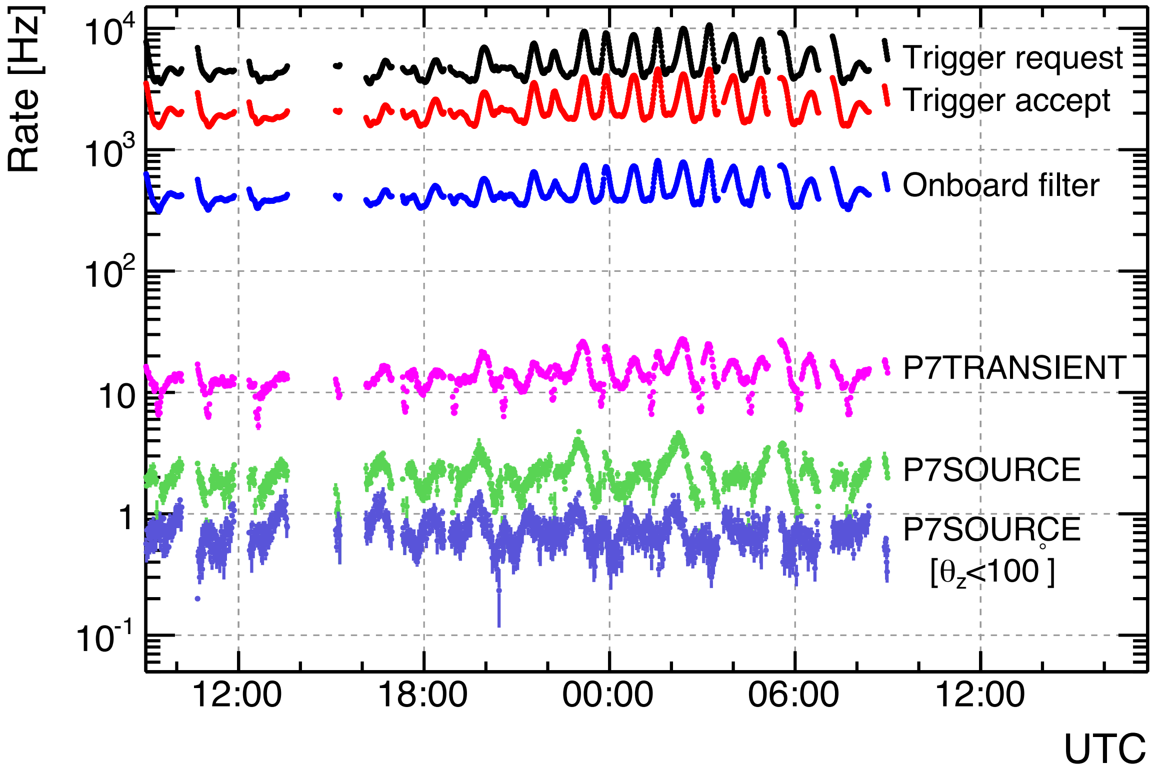
1) Anticoincidence detector: plastic scintillator tiles which produce flashes of light when hit by charged-particle cosmic rays.

2) **Tracker***:*
γ rays interacts with one of the thin **tungsten foils** and converts into an e+/e-.
The **silicon strips** alternate in the X and Y directions, allowing the progress of the particles to be tracked.



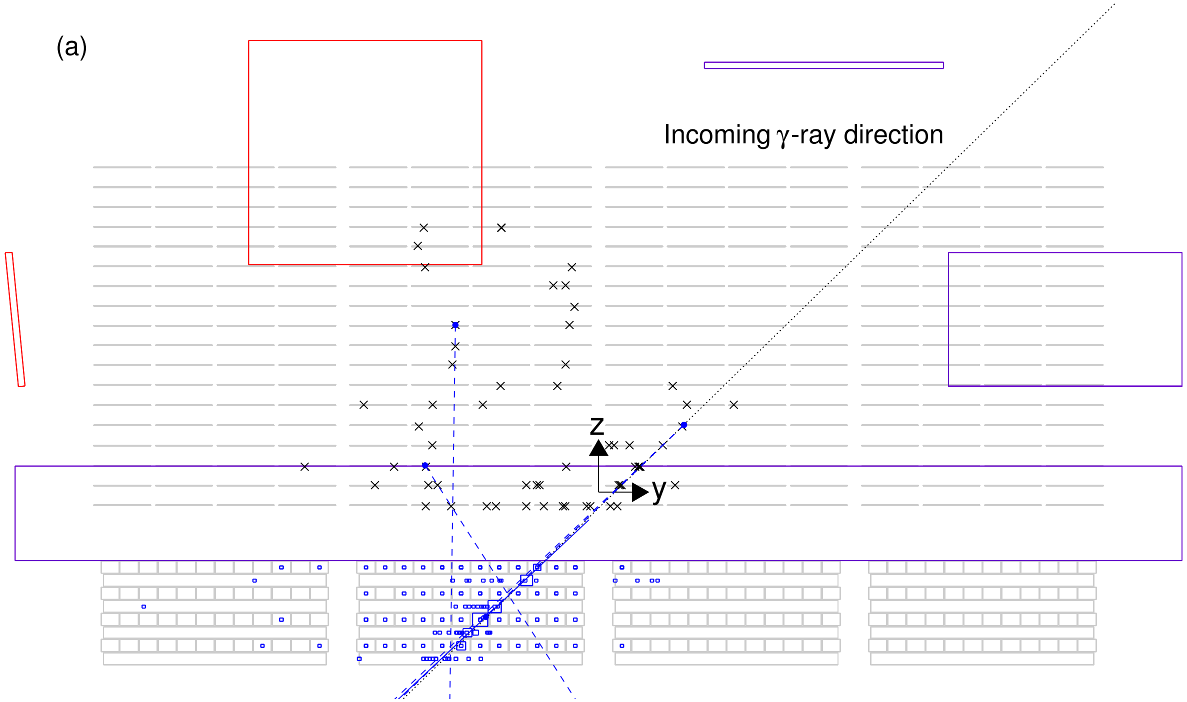
3) **Calorimeter***:* the particles are stopped by a cesium iodide calorimeter which measures the total energy deposited.

Background rejection



The flux of **charged particles** passing through the LAT is several thousand times larger than the γ-ray flux -> several stages of **event selection** are needed to purify the γ-ray content.

Event analysis



[Ackermann+, arxiv1206.1896]

The event analysis requires knowledge of the LAT, the physics of particle interactions within its volumes, and of the particle backgrounds in the Fermi orbit.

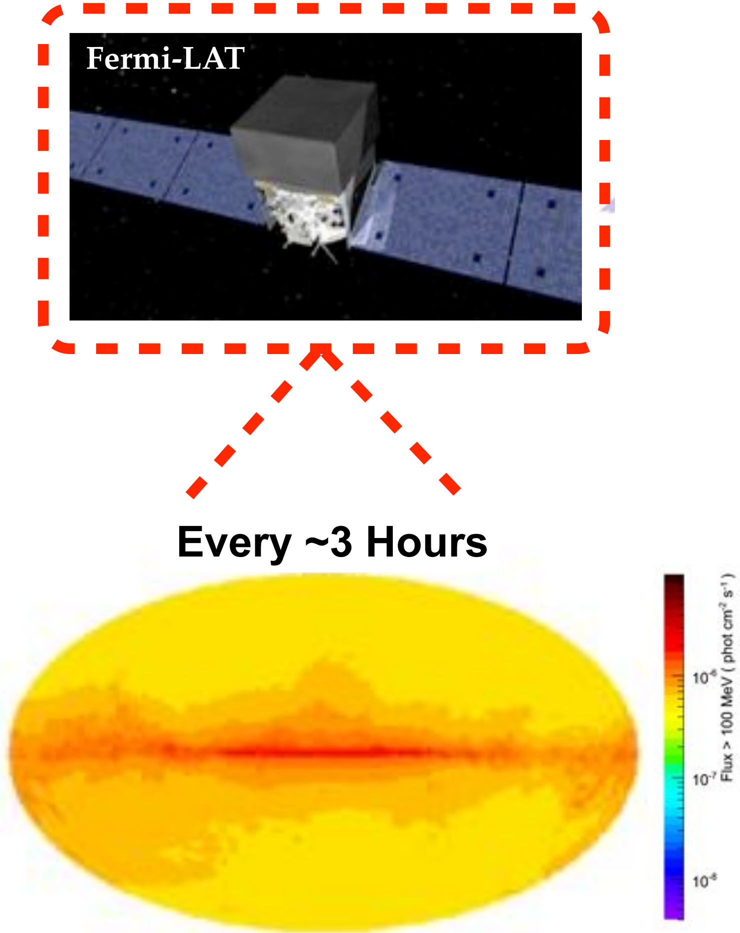
Pass 6 -> the event analysis scheme designed prior to launch.

Pass 7 -> accounts for known on-orbit effects based on the real events the LAT collected in 2 years of operation.

Changes in the event-level analysis can result in individual events being assigned slightly different directions and/or energy estimates in Pass 7 with respect to Pass 6.

Key features

- Large field of view: (in the survey mode exposes every part of the sky for ~30 min, every 3 hours)
- Energy range: 20 MeV to >300 GeV (~M_Z, ideally suited for WIMP searches).
- angular resolution ~ 0.1 deg above 10 GeV



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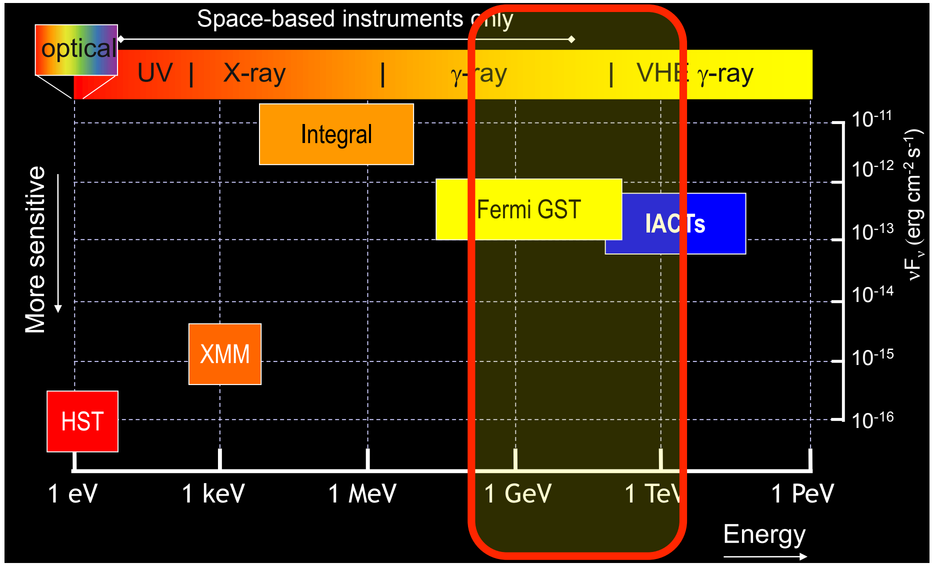

[Hilton, TeVPa 2010.]

WIMP Mass Range

gamma ray emission should unavoidably be produced ≤m_{DM}

Key features

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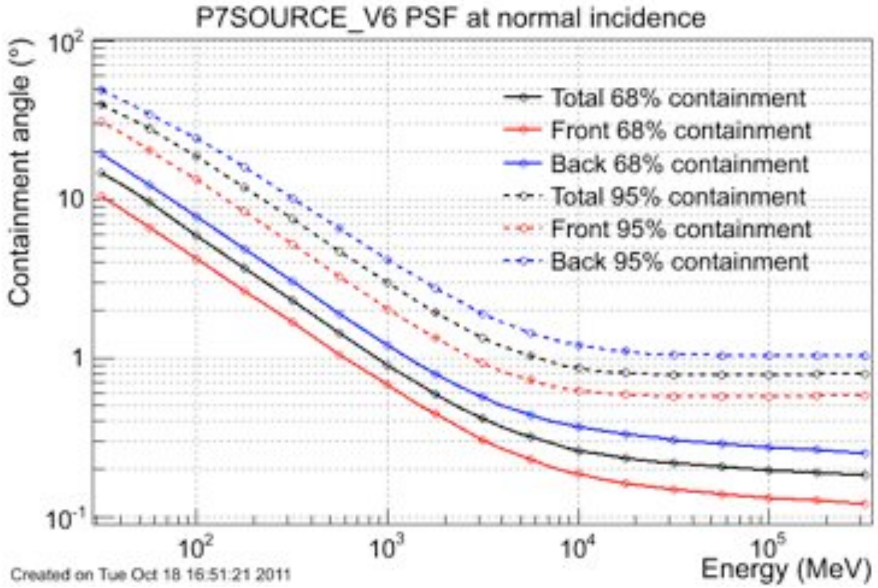


[http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm]

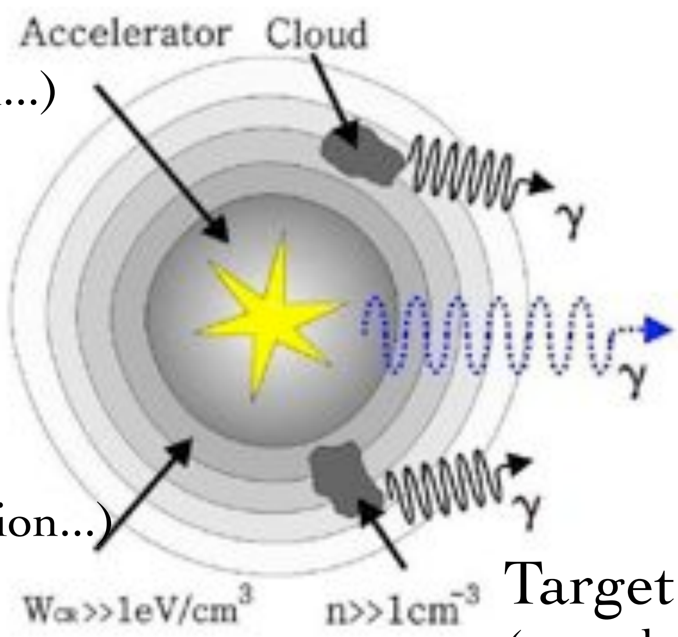
Science

Gamma ray sky:

* production due to acceleration of charged particles and their subsequent interactions with the ambient gas, radiation and magnetic fields;
* free propagation in space without deflection in the interstellar and intergalactic magnetic fields.

Accelerator
(shocks, mag. reconnection...)

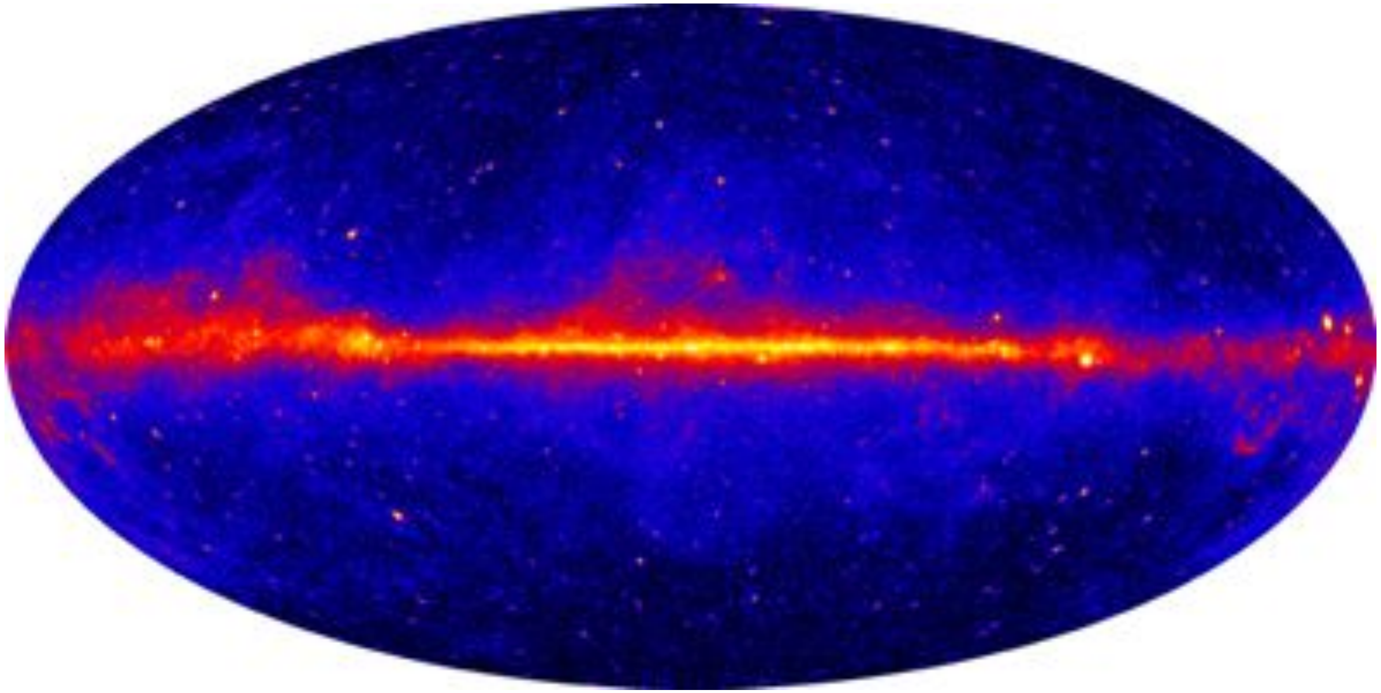
Energy source
(explosion, rotation, accretion...)



Target material
(gas, photon and magnetic fields...)

Science

1) Diffuse emission

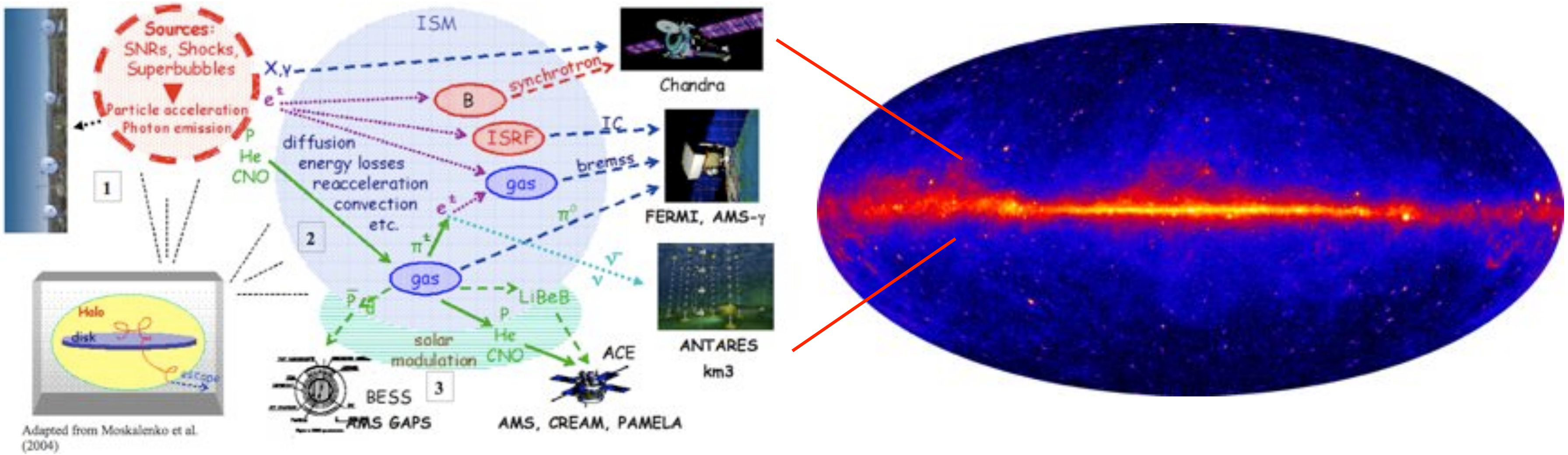


Fermi LAT three year sky map.

Majority (~90%) of LAT photons!
Thanks to large field of view and good charge particle discrimination diffuse emission was measured for the first time with this satellite at energies >~ 10 GeV.

Science

1) Diffuse emission



Adapted from Moskalenko et al. (2004)

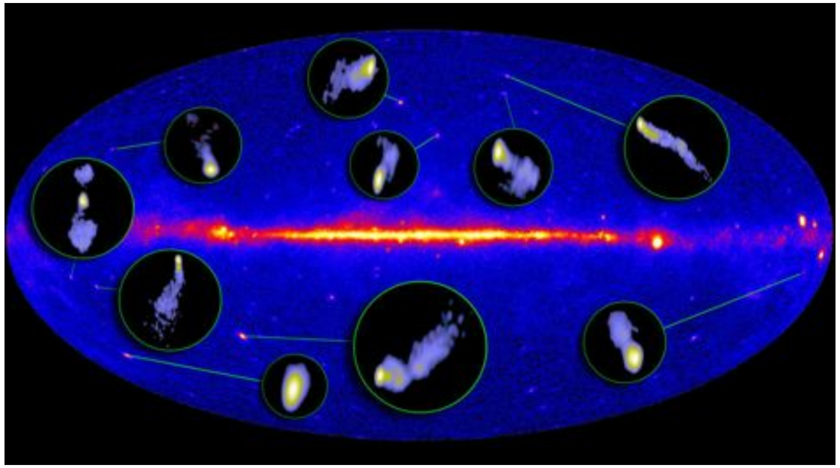
It has two components:

Galactic: interaction of CR e/nuclei with intergalactic medium and fields.

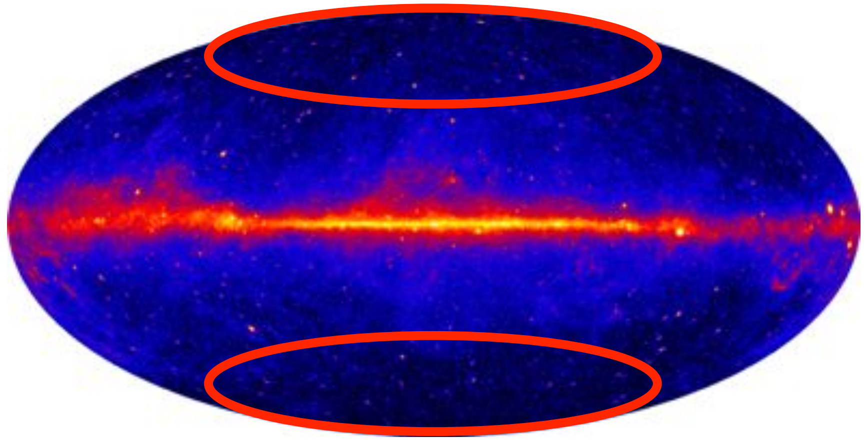
Isotropic: e.g. unresolved energetic extragalactic sources

Science

1) Diffuse emission



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



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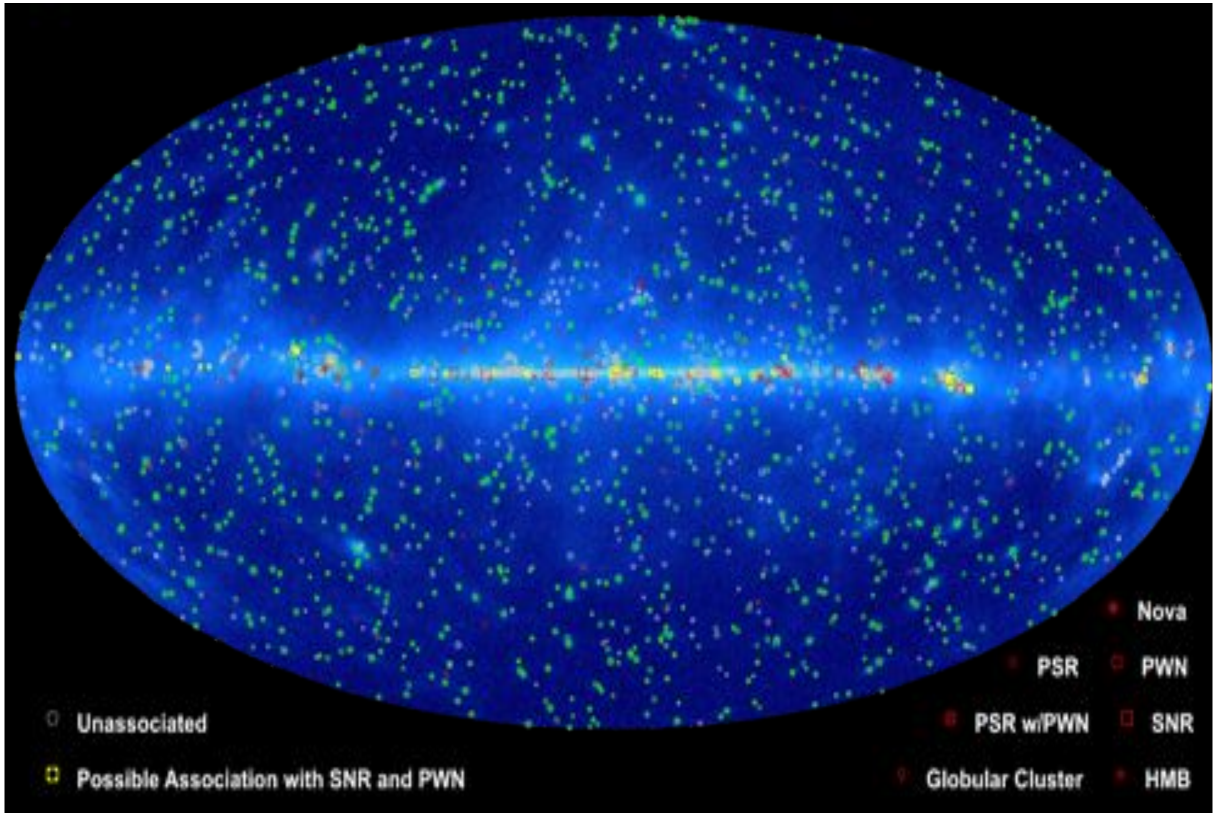
Science

2) Point sources:~1900 sources in the 2FGL.



After diffuse emission is modeled and subtracted, one can study numerous point sources.

Science

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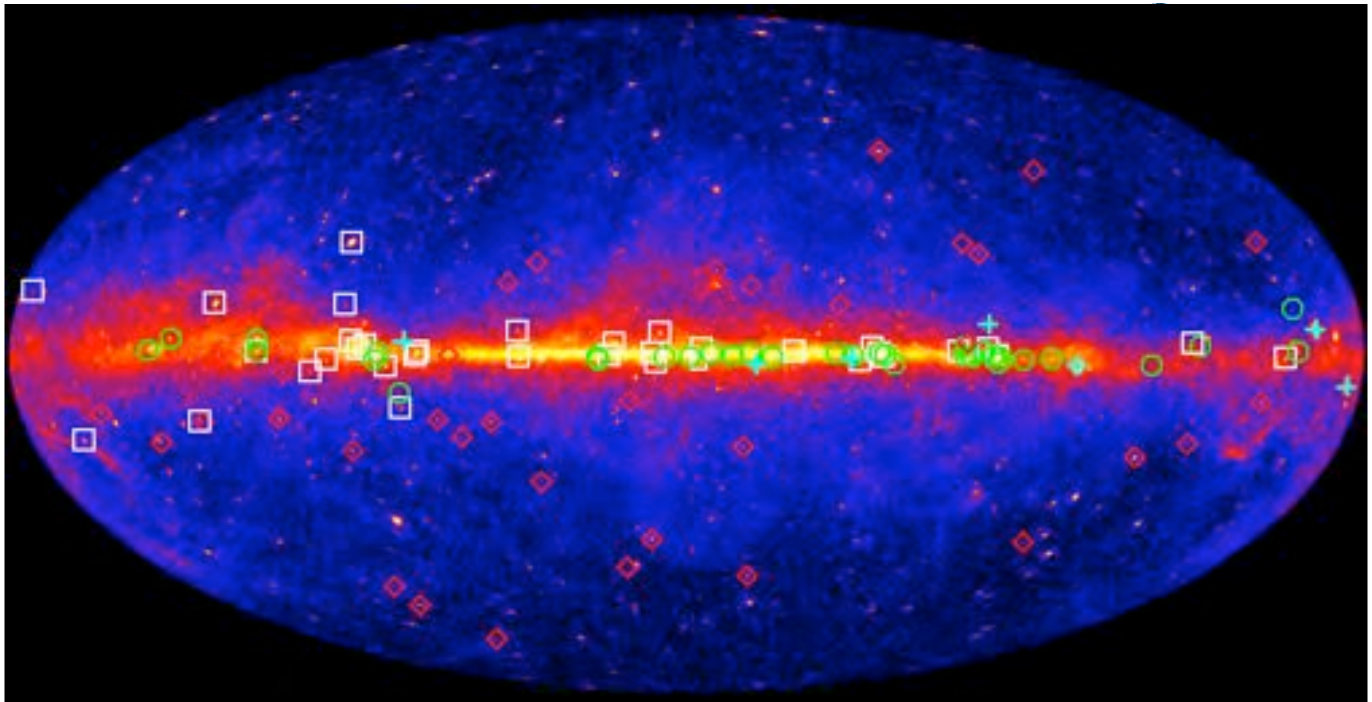

Shown above are the gamma-ray pulsars detected with the LAT superimposed on the 3 year, front-converting, ≥ 1 GeV sky map: CGRO PSRs(✚), young radio-selected (○), young gamma-selected(□), and MSPs(◇).

Pulsars are the most numerous Galactic class: currently up to 121 publicly-announced detected pulsars, https://confluence.slac.stanford.edu/display/GLAMCOG/Public+List+of+LAT-Detected+Gamma-Ray+Pulsars.

Science

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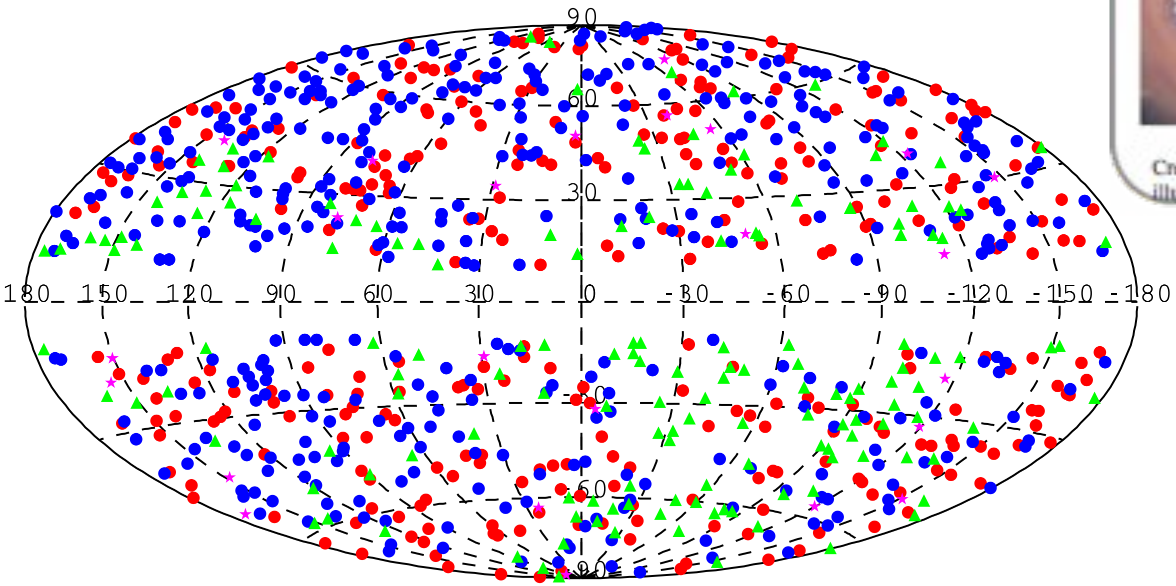
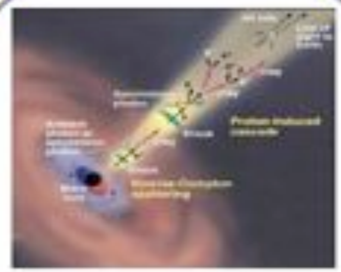


Figure 9. Locations of the sources in the Clean Sample. Red: FSRQs, blue: BL Lac objects, magenta: non-blazar AGNs, and green: AGNs of unknown type. (A color version of this figure is available in the online journal.)



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

[Ackermann+, 1108.1420]

AGNs are the most numerous source in LAT; extraGalactic/found at high latitudes.

Science

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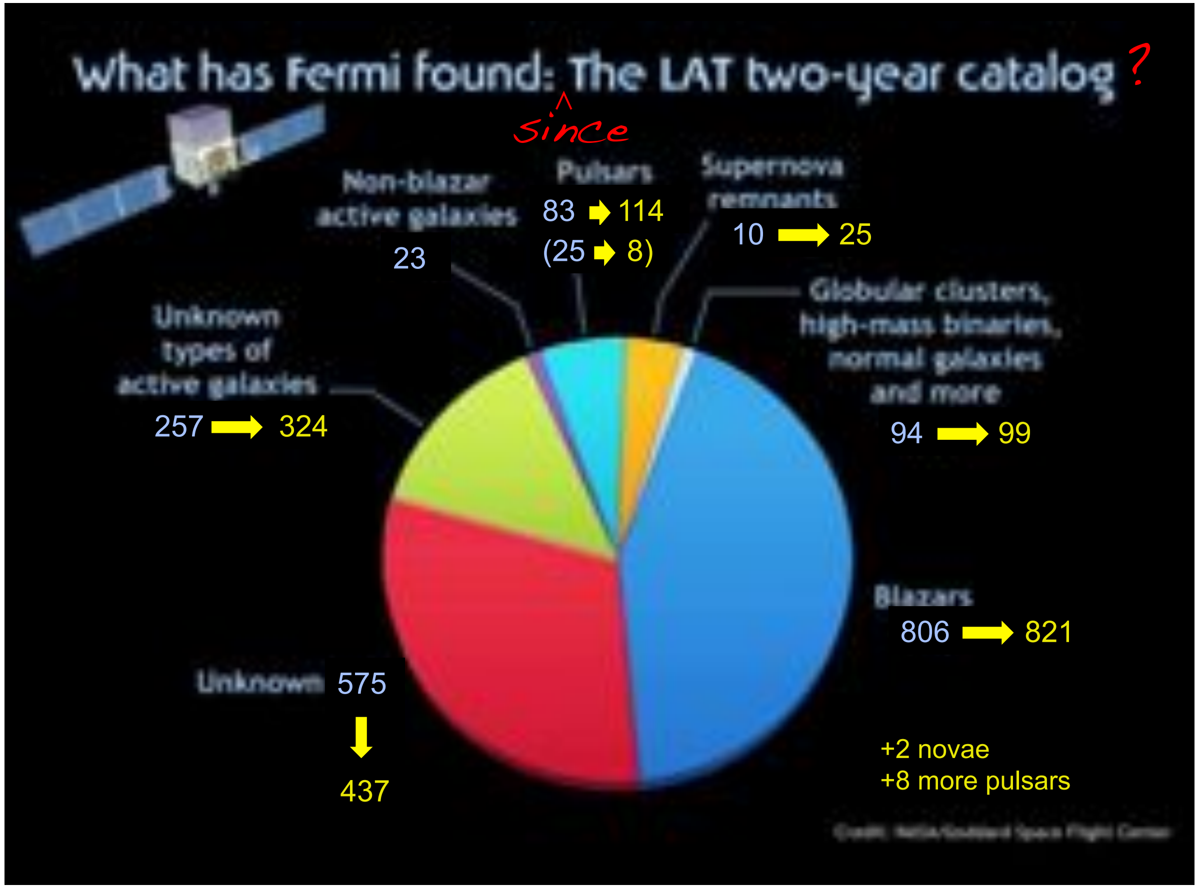

[E. Ferrara, Fermi Symposium 2012]

Science

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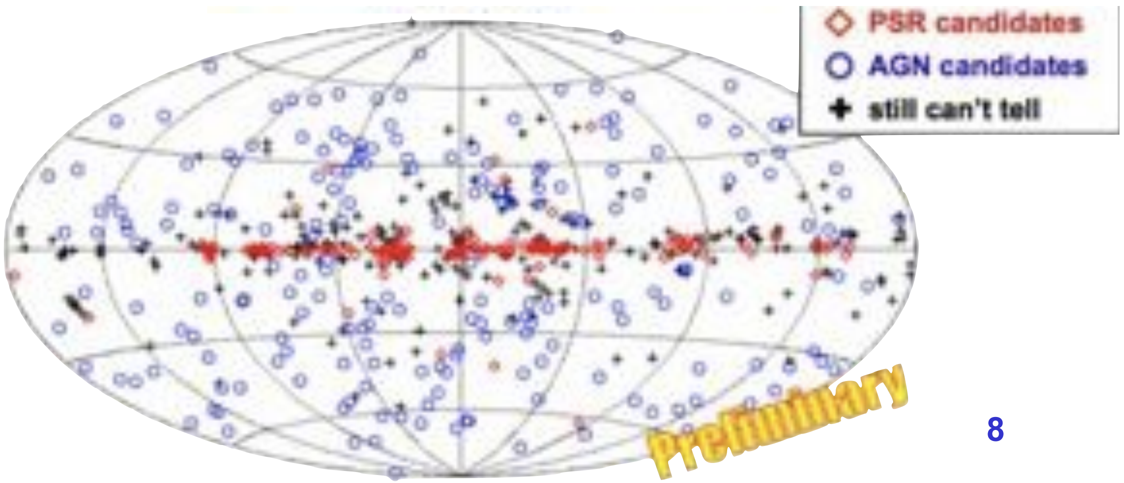


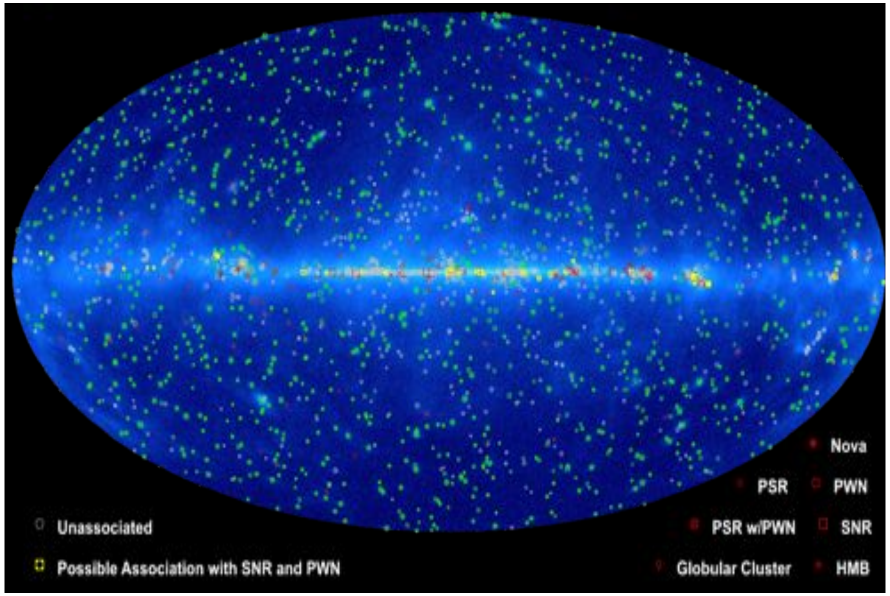
[E. Ferrara, Fermi Symposium 2012]

unIDs: not associated with any known gamma-ray emitting object.
Only AGN and pulsars are numerous enough for statistical analyses -> <~ 50% of unID's appear unclassifiable at a moment.
Dedicated multi-wavelength observations required.

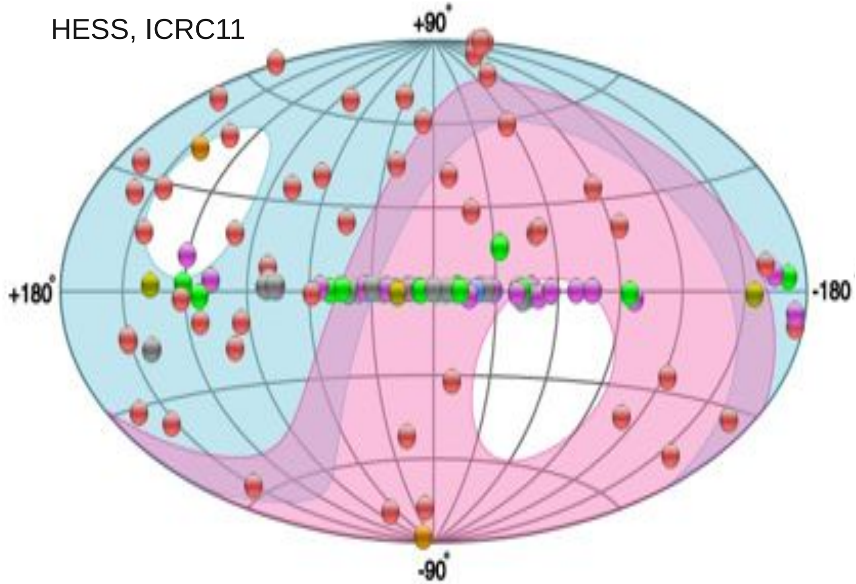
Science

2) Point sources:~1900 sources in the 2FGL.

GeV vs TeV γ-ray sky



HESS, ICRC11

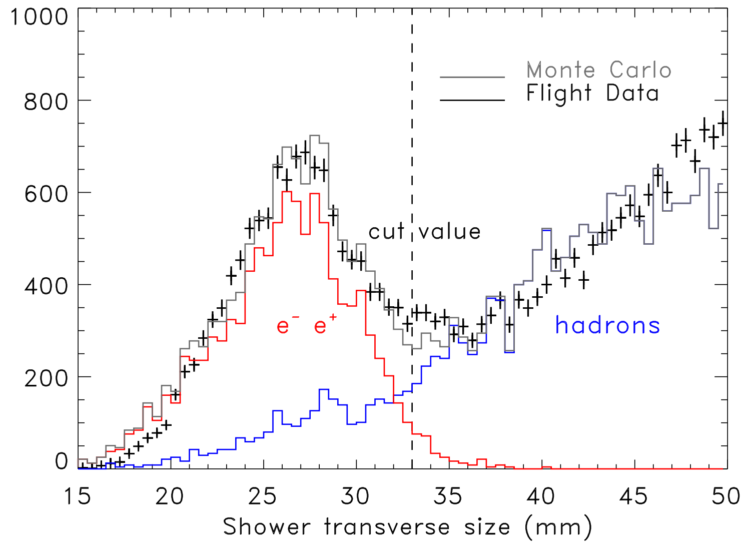


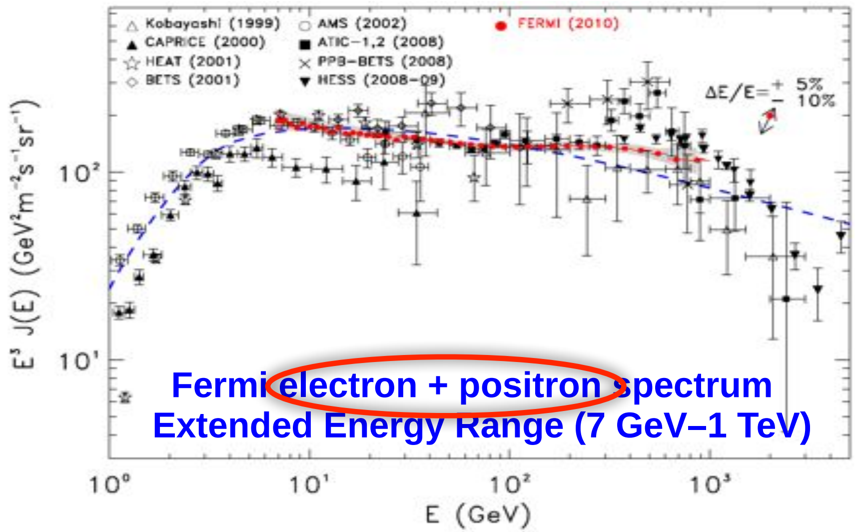
http://tevcat.uchicago.edu/

TeV ground based gamma ray detectors make pointing observations & spectral flux falls off with energy → order of magnitude more sources discovered with Fermi in ~GeV range.
e.g. ~500 sources above 10 GeV in Fermi LAT data.
Handle on their high energy emission from ACTs critical to determine properties of these source populations.

Science

3) Cosmic ray electrons/positrons.





Ackermann, M. et al., Phys. Rev. D 82, 092004 (2010)

Since it records electromagnetic cascades, the LAT is also by its nature a detector for electrons and positrons.

Science

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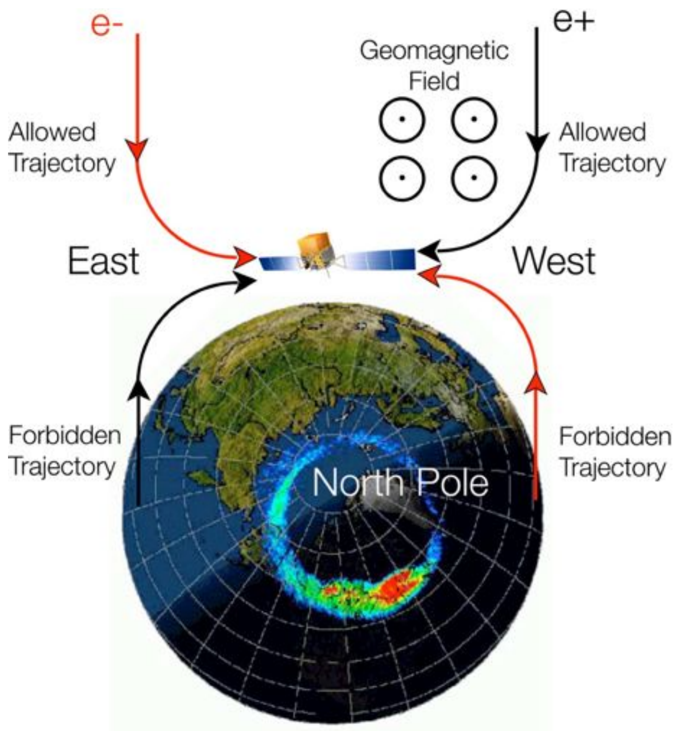
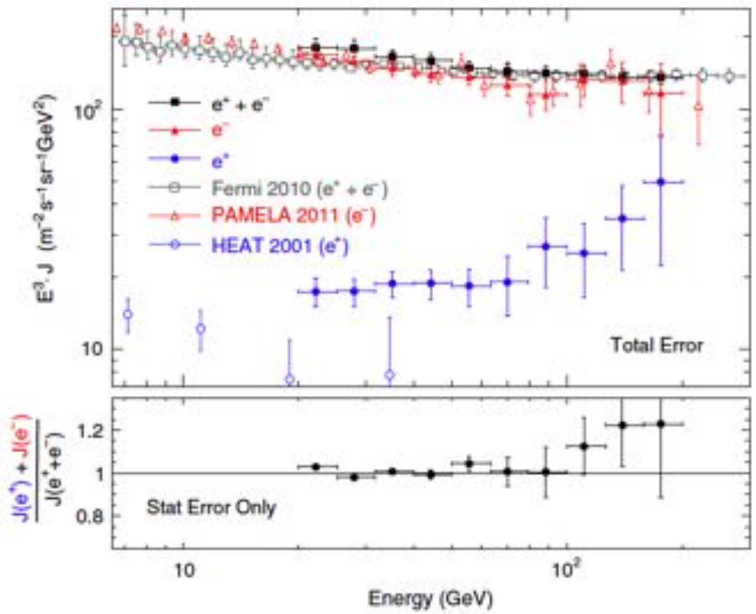




[Ackermann+, 2011, PRL 108, 011103.]

Recent search used Earth's shadow to measure independently electron AND positron spectra (note: Fermi does not carry a magnet!).
confirm PAMELA finding of an increasing positron fraction.

Dark Matter Abundance from Thermal Production

$$\Omega_{dm} = 0.23 \times \left(\frac{10^{-26}\ \mathrm{cm}^3 \cdot \mathrm{s}^{-1}}{\langle \sigma v \rangle} \right)$$

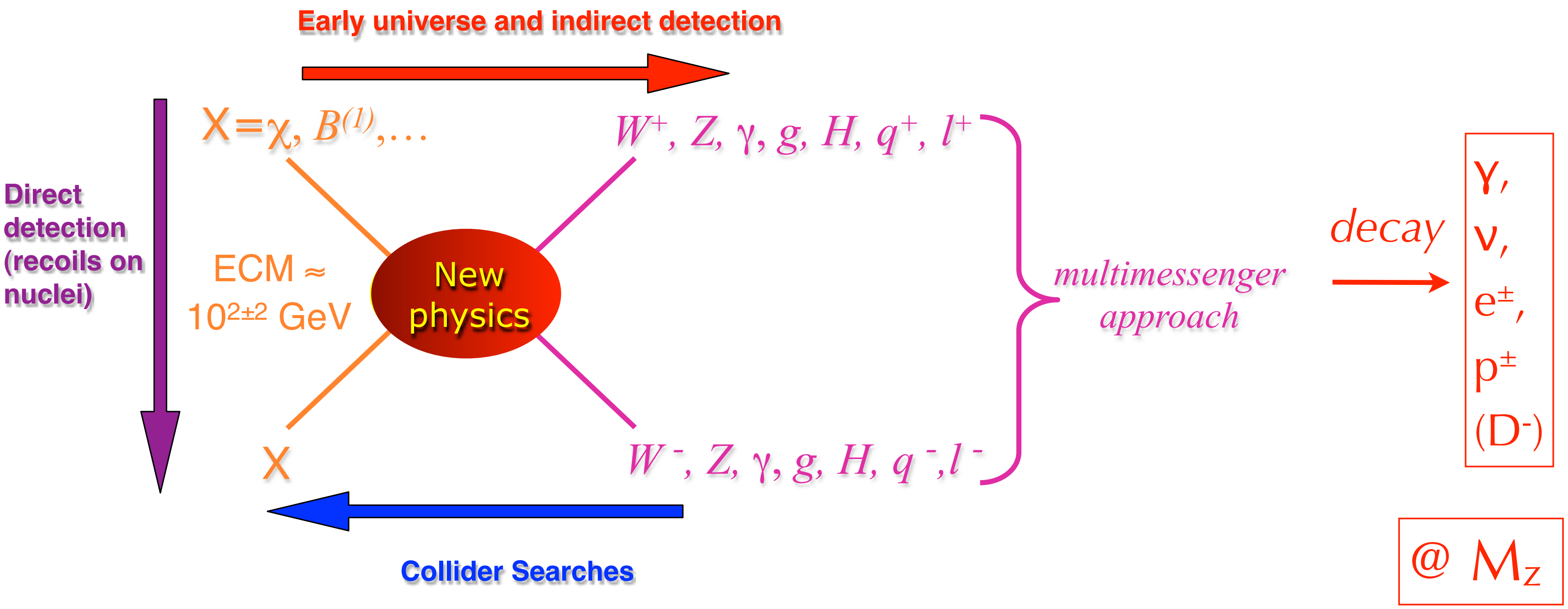
Cosmological Measurement

Weak Scale Physics

- annihilation with rates ~<sigmav>$_{fo}$ for DM with mass ~M_Z ($10^{2\pm2}$ GeV).

- WIMP: *The relic density is determined by the very same annihilation processes we hope to use to detect it.*

- How to test the WIMP hypothesis?



DM in γ rays

Gamma Ray Flux

(measured by Fermi-LAT)

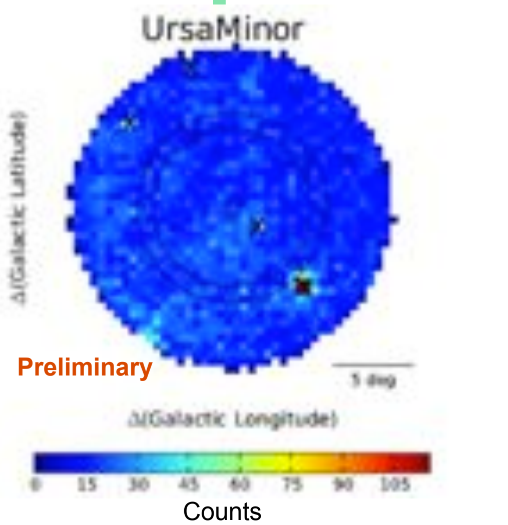
Particle Physics

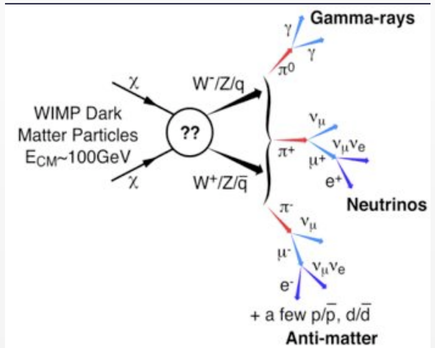
(photons per annihilation)

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma,\phi,\theta) = \frac{1}{4\pi}\frac{<\sigma_{ann}v>}{2m^2_{WIMP}}\sum_f \frac{dN^f_\gamma}{dE_\gamma}B_f$$

$$\times$$

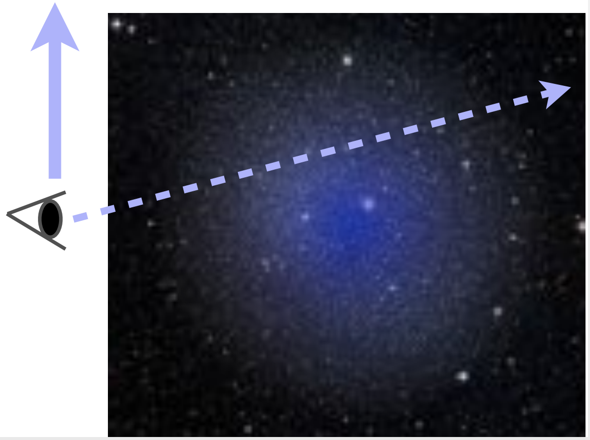
$$\int_{\Delta\Omega(\phi,\theta)} d\Omega' \int_{los} \rho^2(r(l,\phi'))dl(r,\phi')$$





Dark Matter Distribution

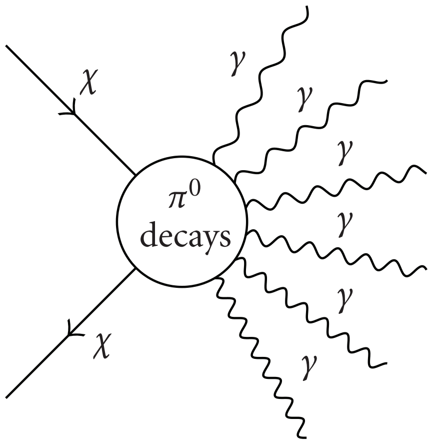
(line-of-sight integral)

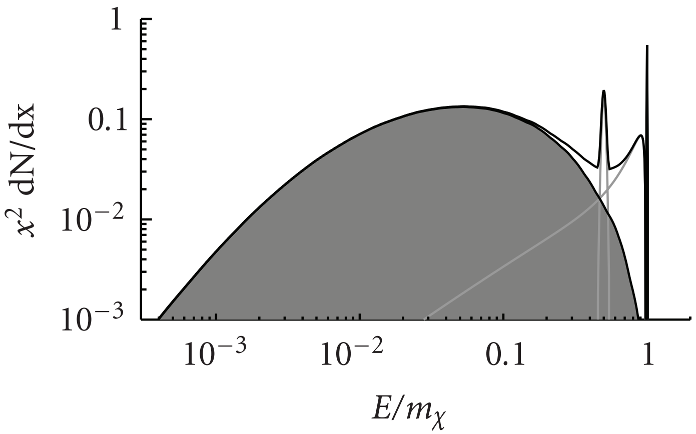


[A. Drilica-Wagner, Moriond 2012.]

DM in γ rays: spectra

Secondary photons (tree level)



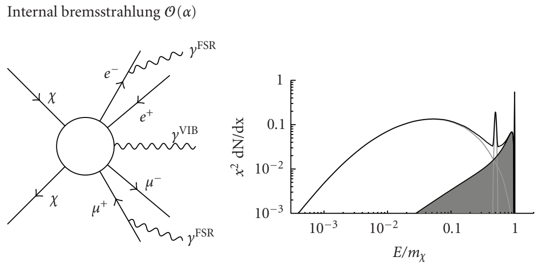


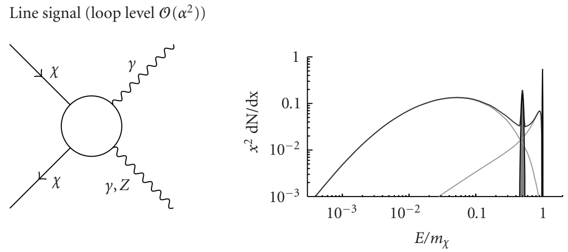
[M. Kuhlen, AA, 162083]

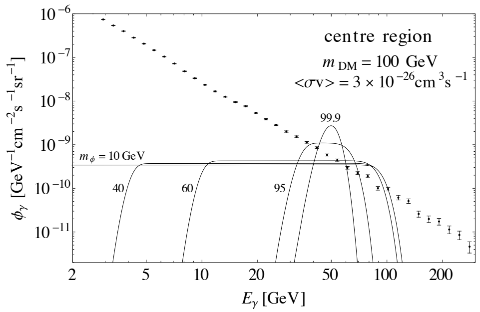
Hadronization of annihilation products and subsequent π^0 decay (*annihilations to* W, Z, q, ...channels): *high branching predicted in bulk of particle physics models, but featureless spectra.*

- *'feature-full' (hard or line shaped) emission (photons from Final State Particles (FSR) or internal states (VIB) and annihilation to a γ-ray line (two photons/Zγ) through loop processes): low signals but easier to distinguish from astrophysics radiation;*
- *gamma rays produced through electron radiative losses (annihilations to leptons states): emission correlates with ambient backgrounds and fields.*

DM in γ rays: spectra







[M. Kuhlen, AA, 162083]

[A. Ibarra et al., 2012]

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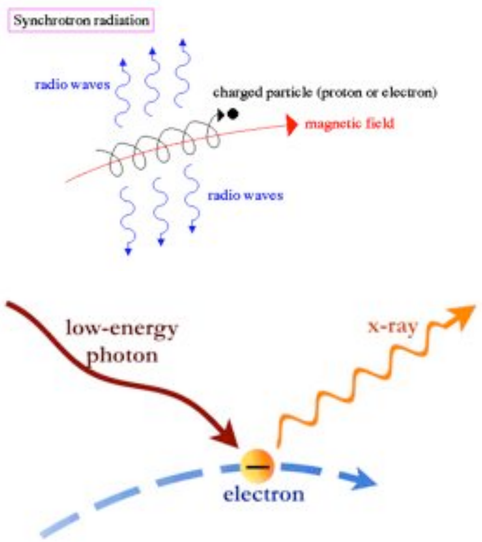
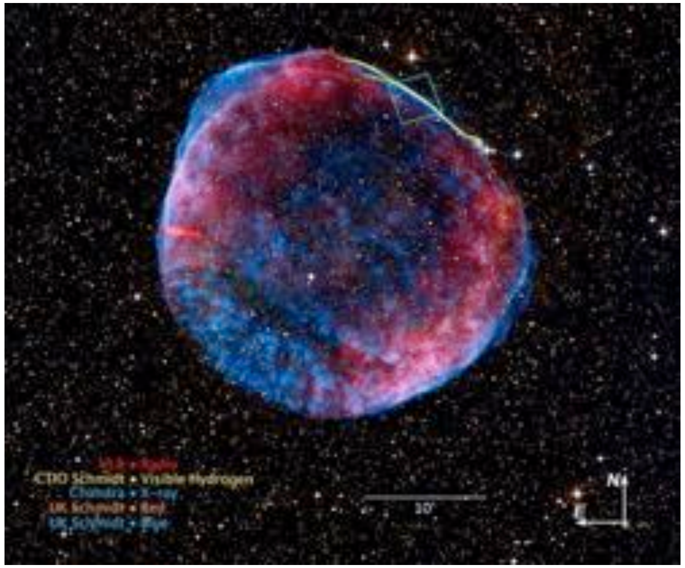
DM in γ rays: spectra





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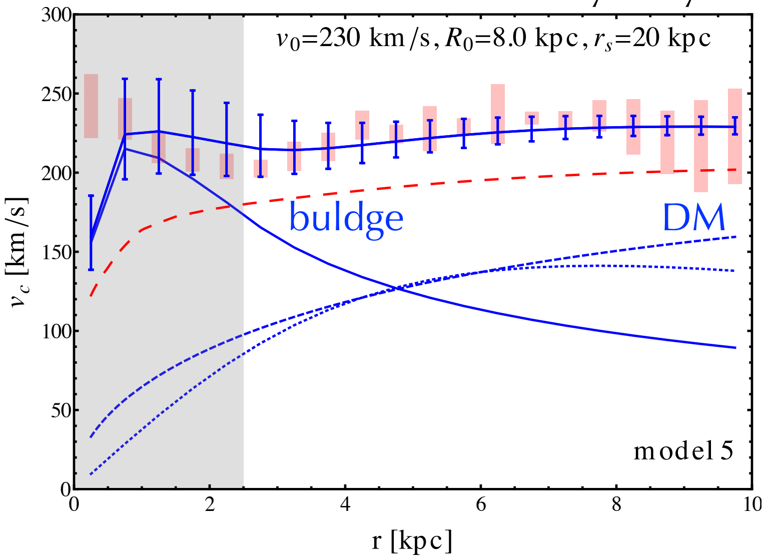
DM in γ rays: clustering

1. measure motion of stellar objects to determine the gravitational potential of DM (rotational curves, gravitational microlensing, dynamics of satellites...). ***Limited by***:
    - ***experimental sensitivity*** (i.e. faint dwarf galaxies or smaller subhalos) and
    - unreliable in ***baryon dominated systems*** (i.e. centers of halos)

Rotational curve of the Milky Way

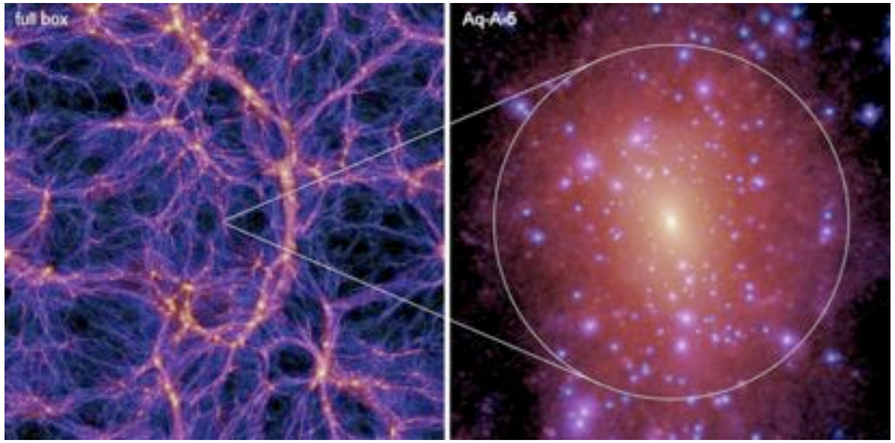


[Iocco+, JCAP 2011, 1107.5810]

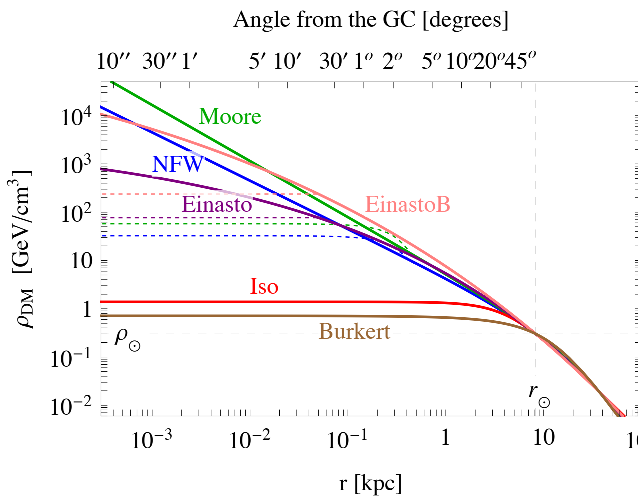
[Leo I, dwarf spheroidal Galaxy]

DM in γ rays: clustering

2. N-body simulations (Via Lactea, Eris, Millennium Simulation):
impressive agreement with measurements on large scales. Open issues:
- ***baryonic feedback*** usually not reliably included (significant progress)
- ***small scales*** unresolved: important when considering inner most regions of halos (e.g. center of our Galaxy) and
- ***limited mass resolution***: important when signal dominated by a contribution from small/unresolved halos.



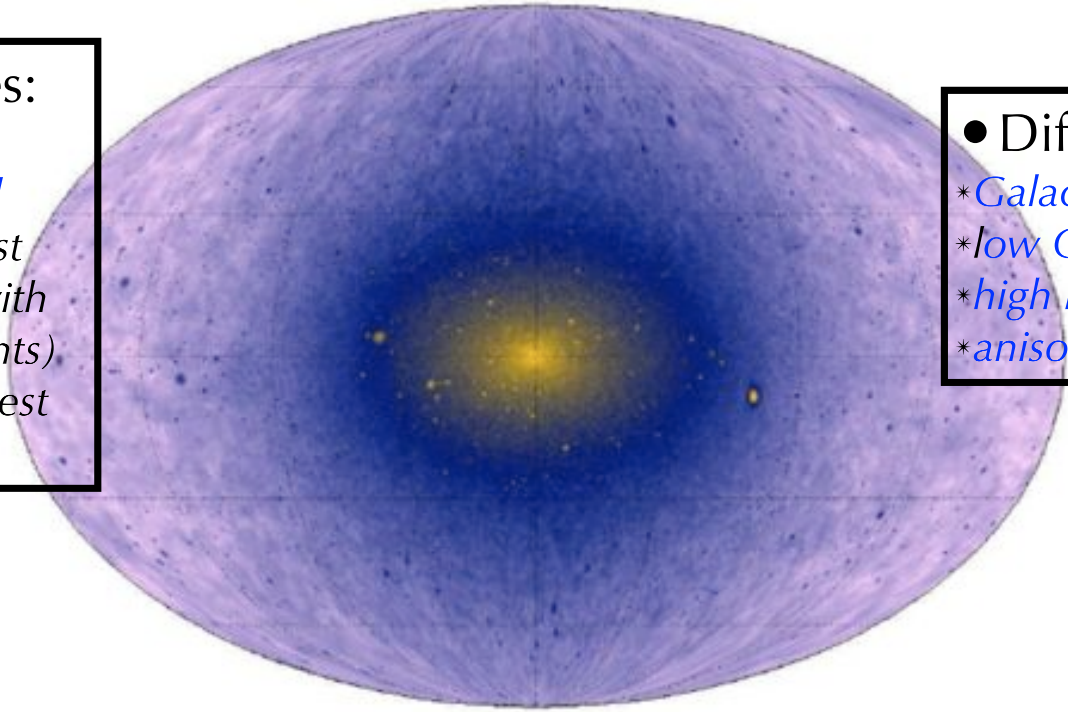
[Springel, V.+,MNRAS, 2008.]



[Cirelli, M.+, JCAP, 2011.]

- Where to look?

- γ propagate in a straight line, unaffected by Galaxy; DM clustering map (N-body simulations) is a good guide of observational targets.



[Diemand+, APJ, astro-ph/0611370]

- **Point sources:**
  - *dark satellites*
  - *dwarf spheroidal Galaxies (smallest resolved halos with stellar components)*
  - *clusters (the largest halos)*

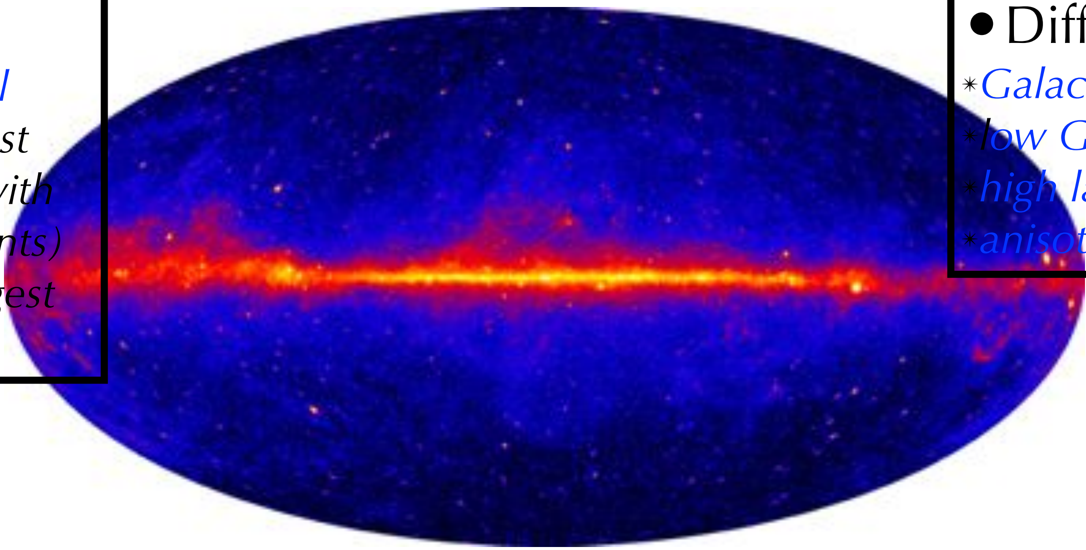
- **Diffuse emission:**
  - *Galactic Center region*
  - *low Galactic latitudes*
  - *high latitudes*
  - *anisotropies*

- **Spectral search:**
  - *all sky search for a line emission*

- DM search in el+pos signal

- However,

- what we measure does not look nothing like it --- astrophysical processes present significant background for DM searches.



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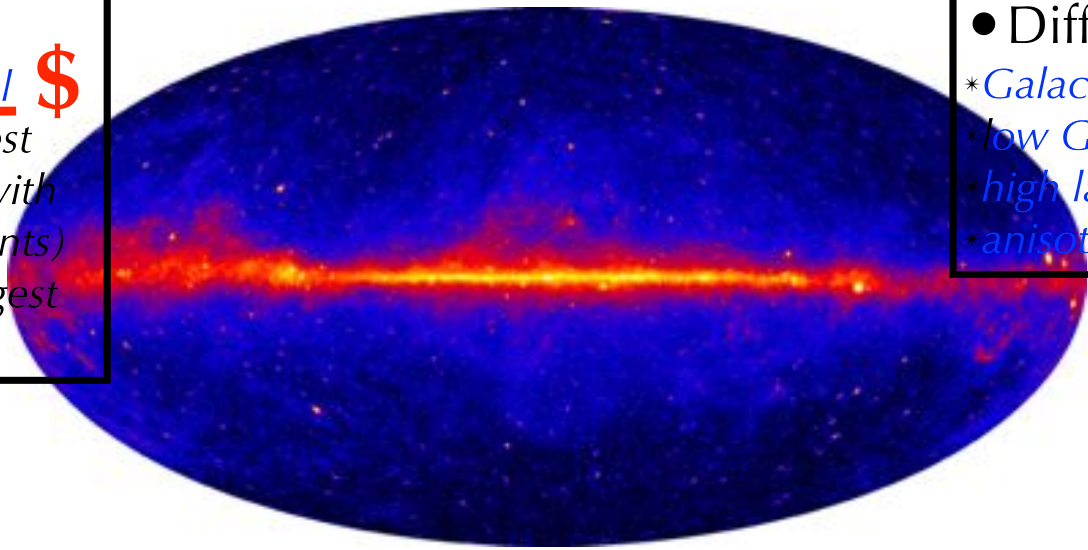

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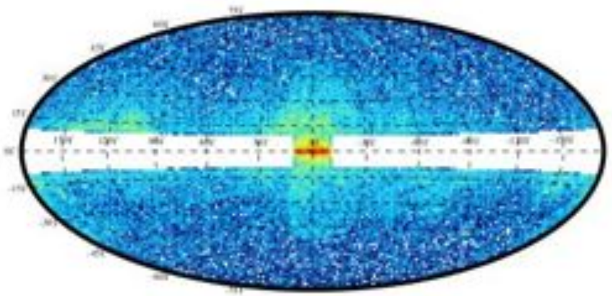
Spectral line search

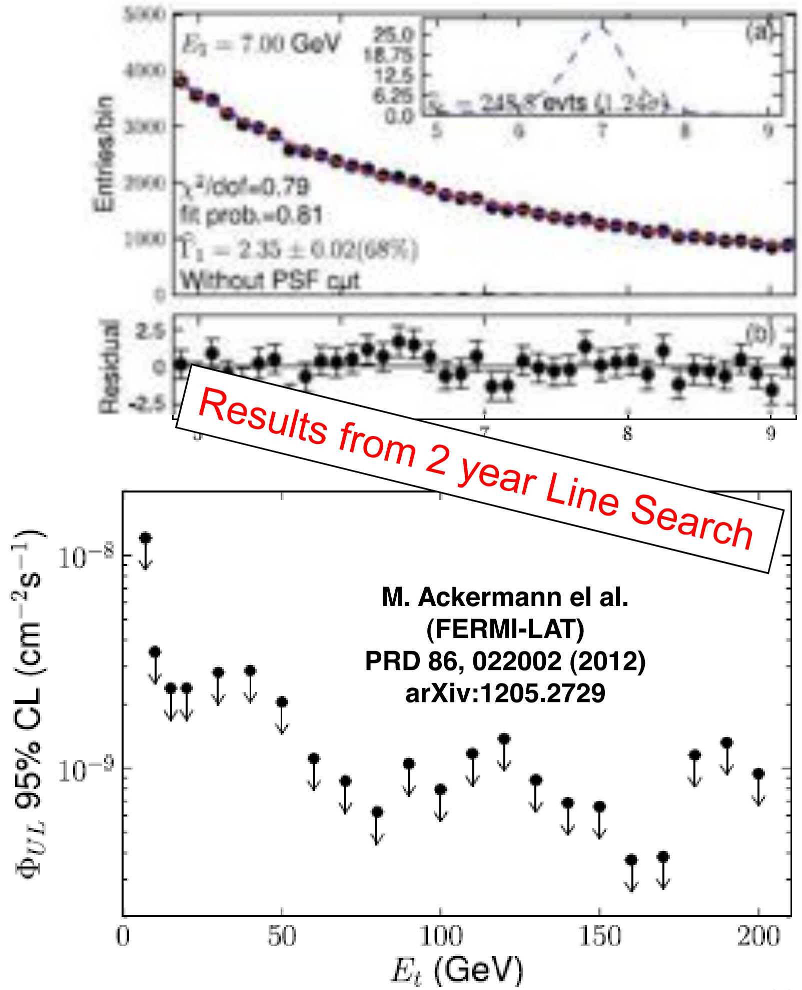
Advantage: sharp, distinct feature
Disadvantage: low predicted counts

Sliding window technique: model bkg as single power law

2 yr analysis Fermi LAT looked at the whole sky data and found no evidence of a line.



$|b| > 10^\circ$ plus $|\ell|, |b| < 10^\circ$



Results from 2 year Line Search

M. Ackermann el al. (FERMI-LAT) PRD 86, 022002 (2012) arXiv:1205.2729

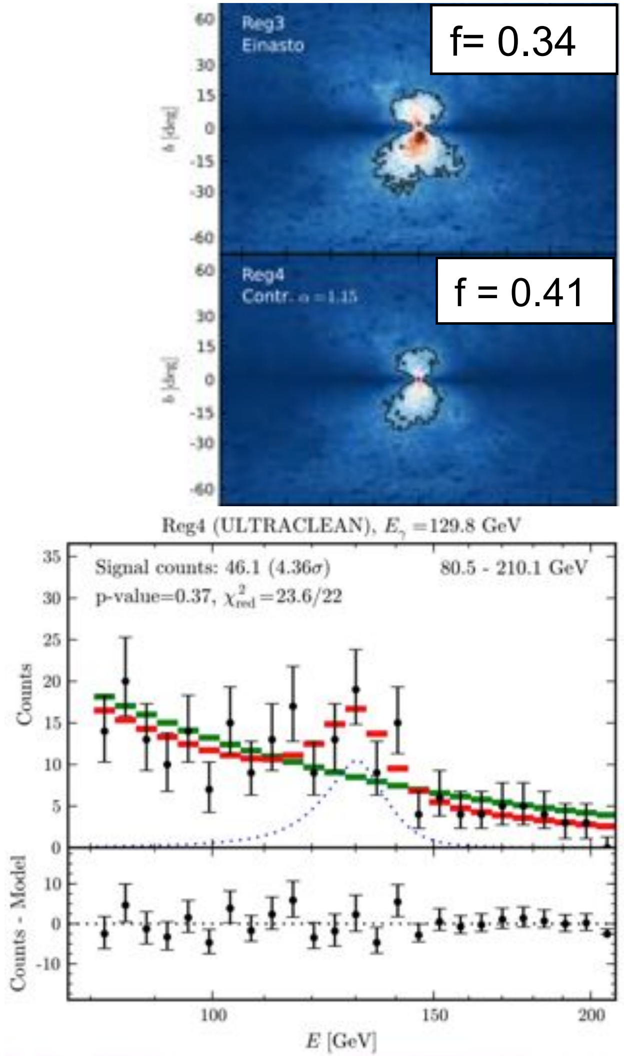
Spectral line search

Weniger+ 2012: Evidence for a narrow spectral feature in 3.5 yr data near 130 GeV in optimized ROIs near the Galactic center.

- Signal is particularly strong in 2 out of 5 test regions with

S/N> 30%-60%.

- Some indication of double line (111 &130 GeV), Su+, 2012.



C. Weniger JCAP 1208 (2012) 007 arXiv:1204.2797

Spectral line search

Fermi LAT's 4yr line search:

1) Optimize ROI for a variety of DM profiles (R_{GC}):

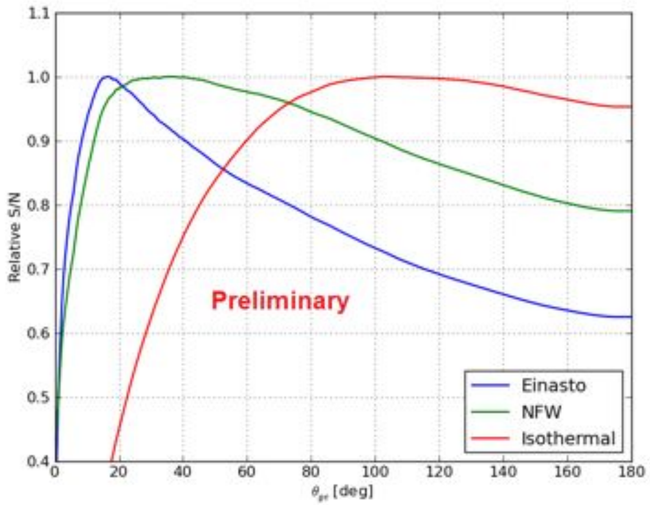
R3 (3° Circle)

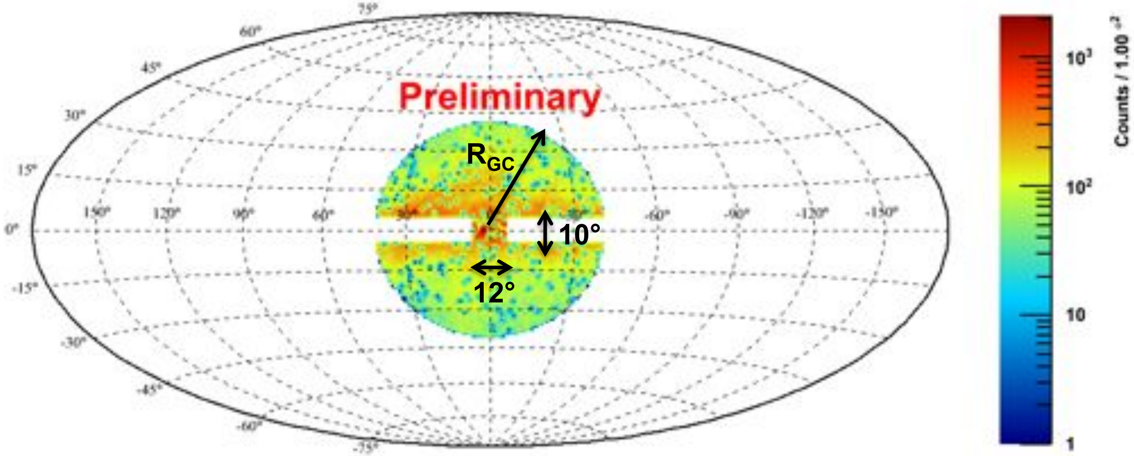
R16 (Einasto Optimized)

R41 (NFW Optimized)

R90 (Isothermal Optimized)

R180 (DM Decay)





Spectral line search

Fermi LAT's 4yr line search:

2) Improved Energy Resolution Model

Previously modeled line with a triple Gaussian fit ("1D PDF").

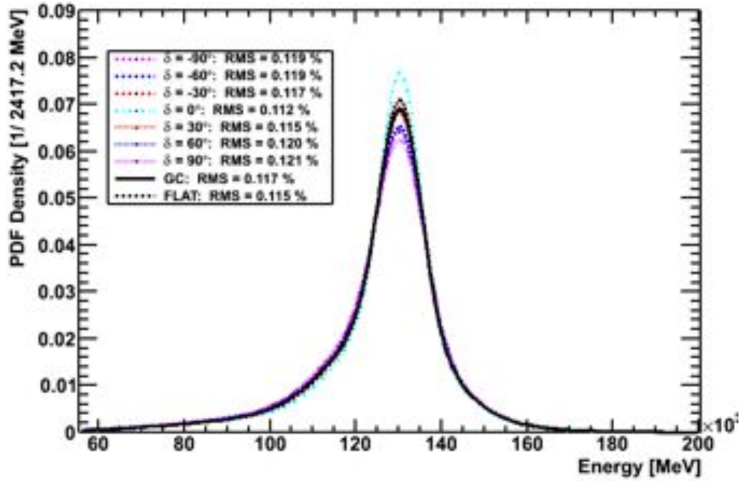
The θ-averaged PDF weighted for observing profile varies moderately with declination.

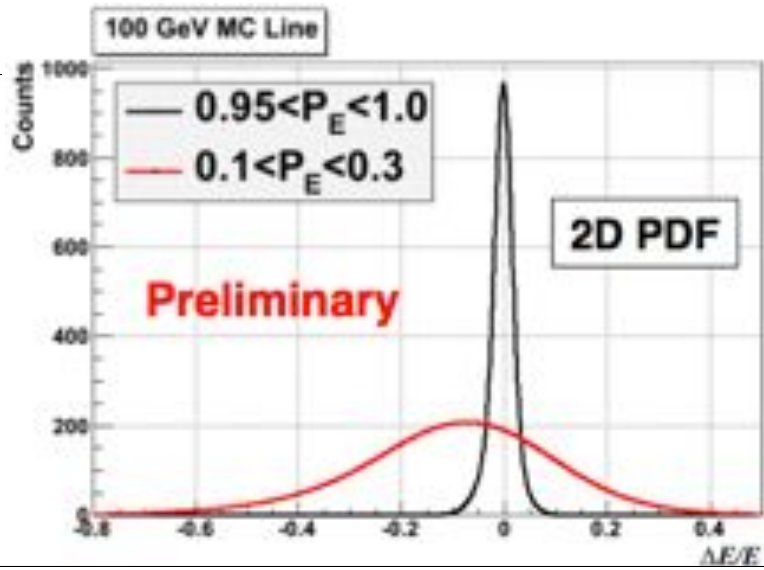
-> use a 2 dimensional PDF, which increases statistical power by ~15%: add a 2nd dimension to line model: PE.

PE is the probability that measured energy is close to the true energy.

"**2D PDF**" (a function of both energy and PE).

Similar to public IRF description, which uses cosθ instead of PE.





Spectral line search

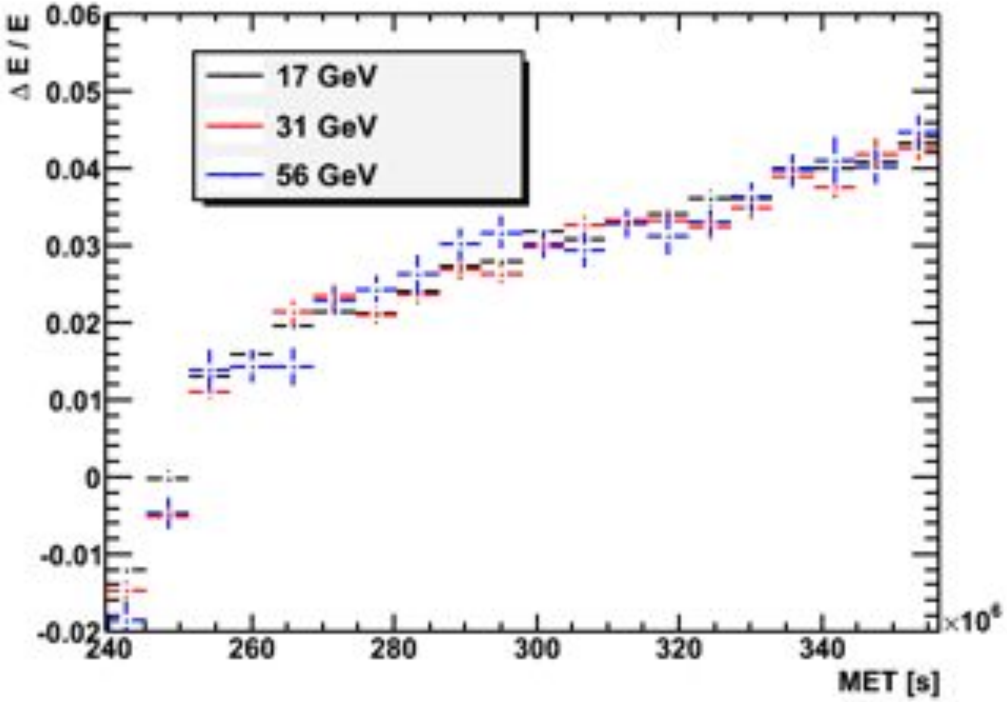
Fermi LAT's 4yr line search:

3) Data Reprocessing with Updated Calibrations

Corrects for loss in calorimeter light yield because of radiation damage (~4% in mission to date). This corresponds to a ~5% change in the energy scale at 130 GeV ->135 GeV.

80%+ overlap in events between original and reprocessed samples.

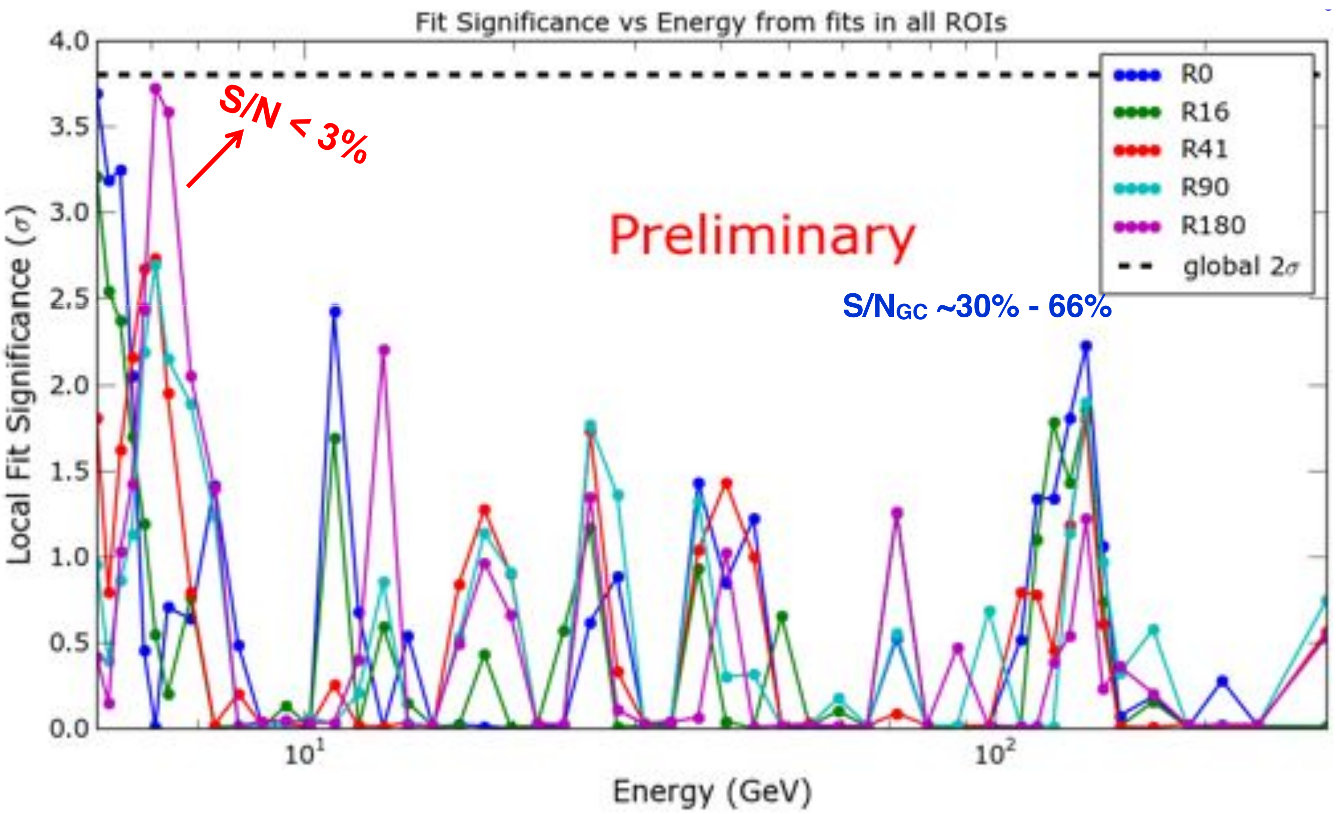
Energy Shift v. Time



Spectral line search

No signal found in a blind search.

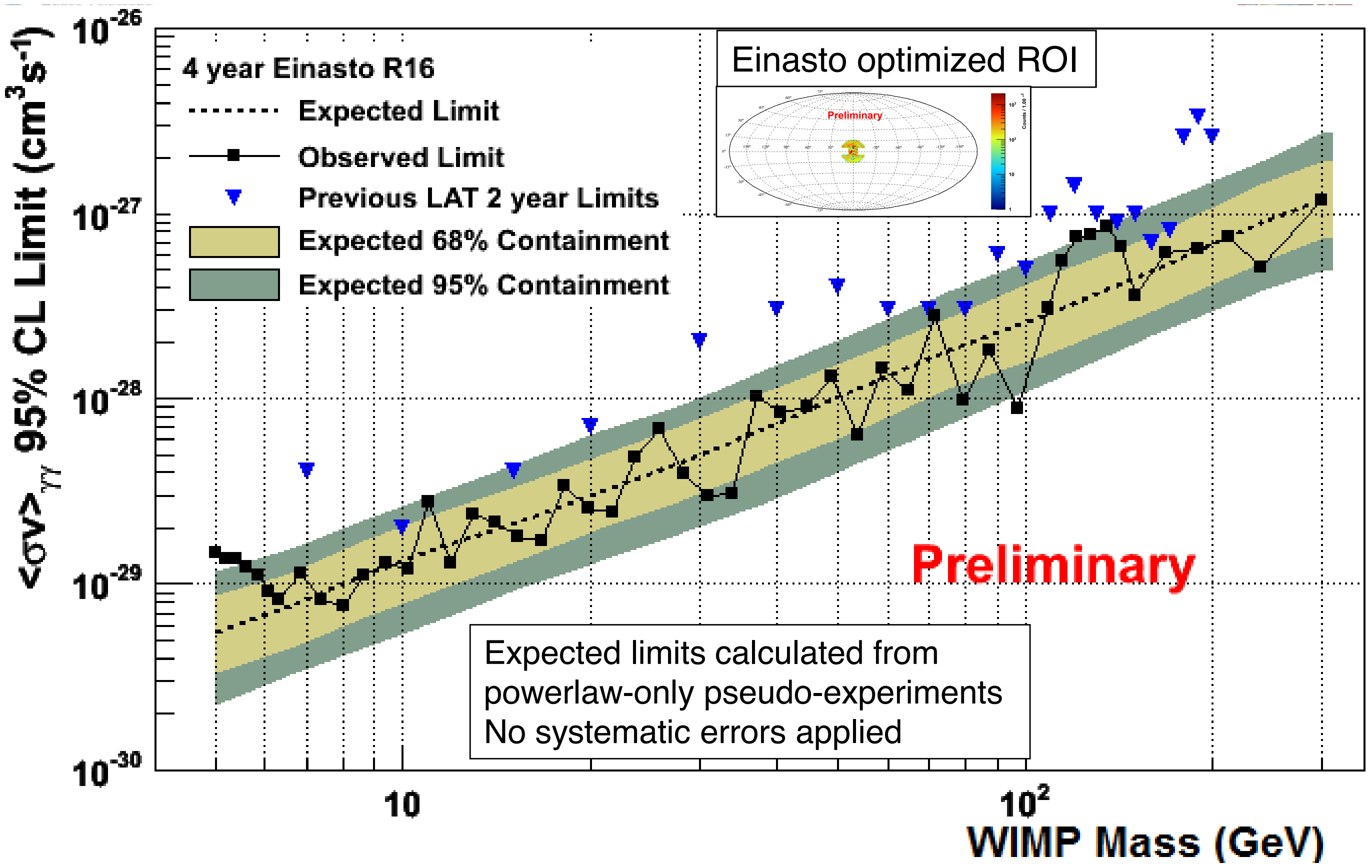
The huge statistics at low energies mean small uncertainties in the collecting area can produce statistical significant spectral features.



Spectral line search

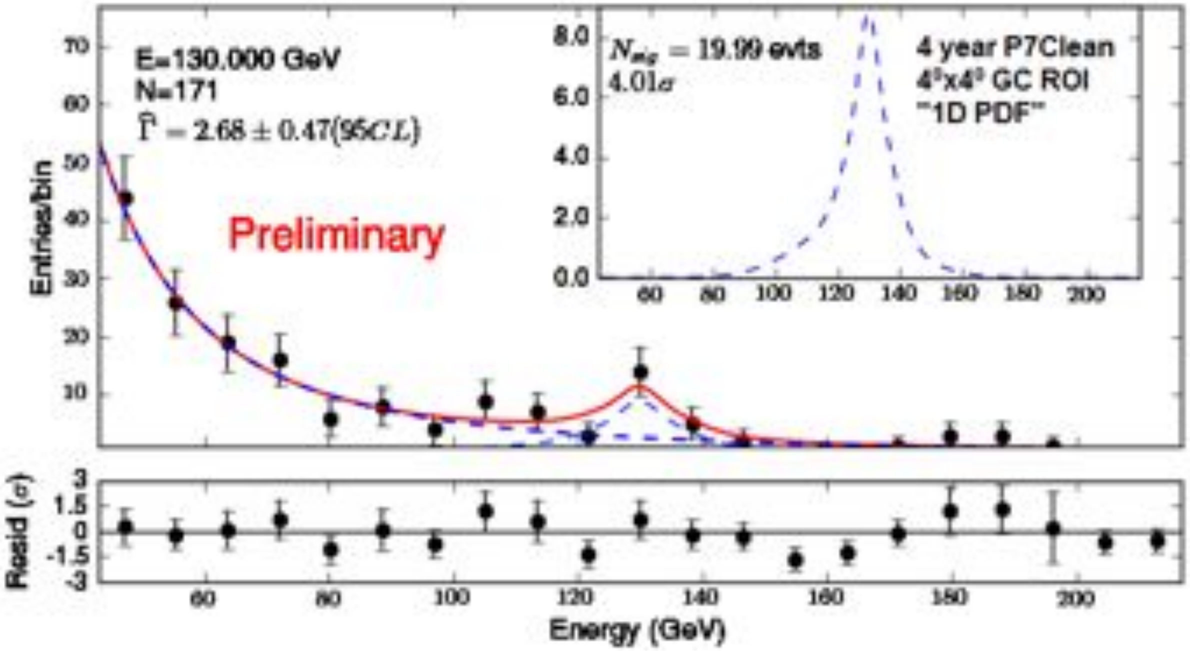
No signal found in a blind search.

95% CL $<\sigma v>_{\gamma\gamma}$ Upper Limit for the Einasto optimized ROI R16



Spectral line search

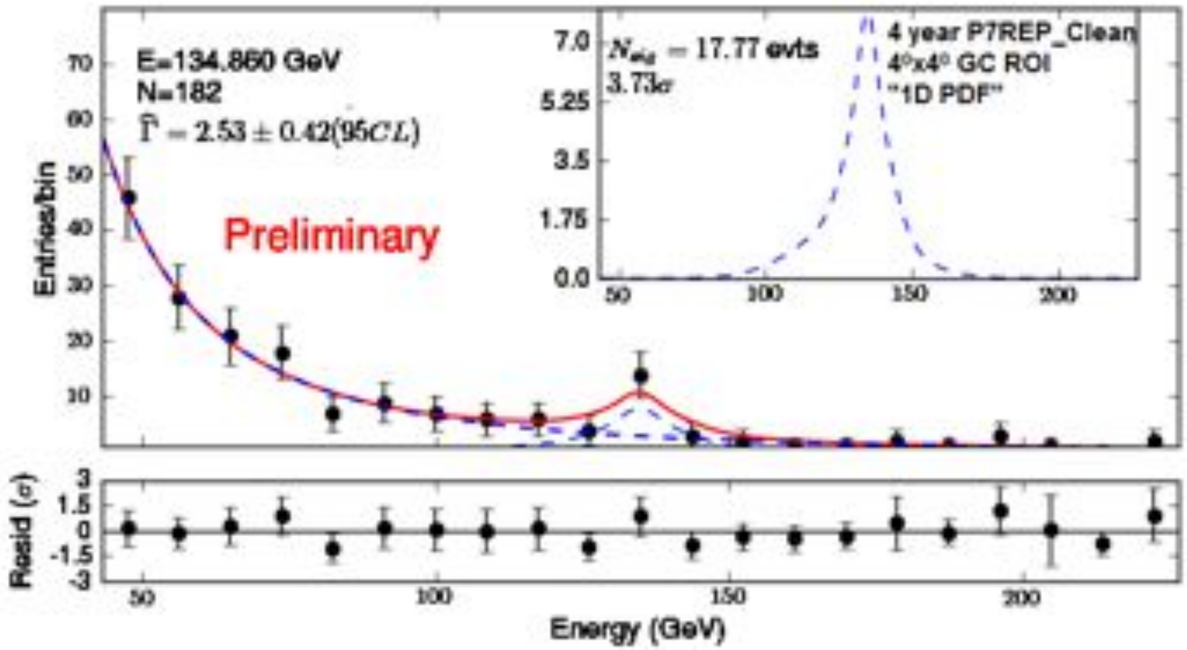
Exploring the tentative signal at 135 GeV.



4.01σ (local) 1D fit at 130 GeV with 4 year un-reprocessed data; 4°x4°GC ROI and 1D PDF

Spectral line search

Exploring the tentative signal at 135 GeV.

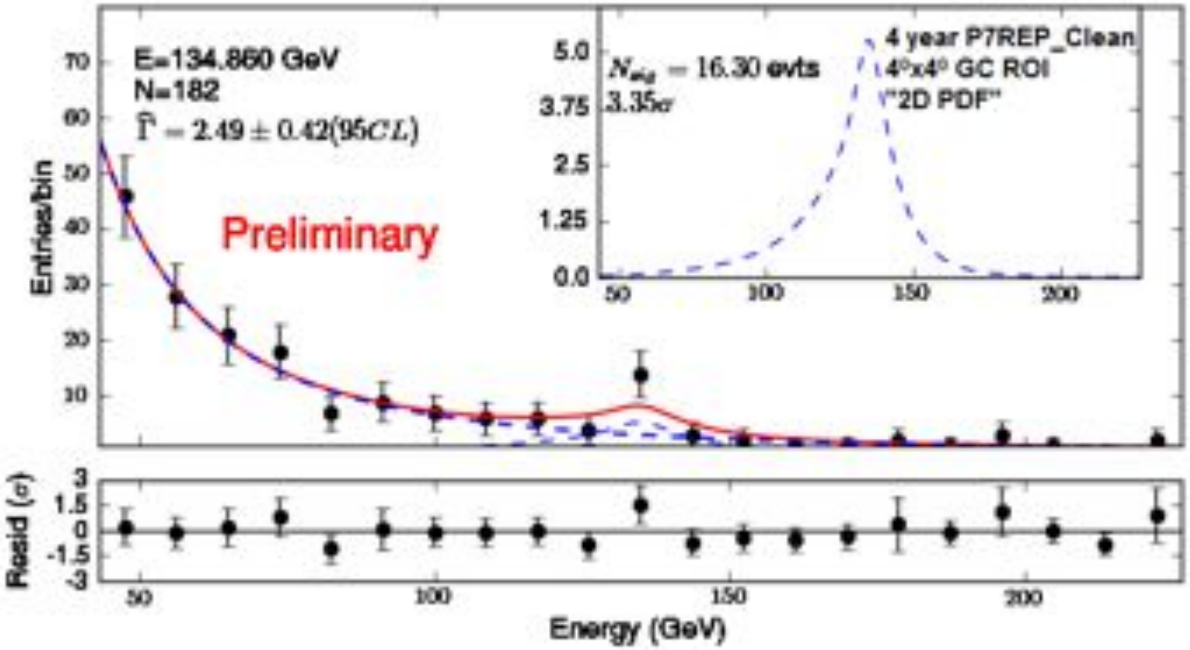


4.01σ (local) 1D fit at 130 GeV with 4 year un-reprocessed data; 4°x4°GC ROI and 1D PDF

3.73σ (local) 1D fit at 135 GeV with 4 year reprocessed data; 4°x4°GC ROI, 1D PDF

Spectral line search

Exploring the tentative signal at 135 GeV.



4.01σ (local) 1D fit at 130 GeV with 4 year un-reprocessed data; 4°x4°GC ROI and 1D PDF

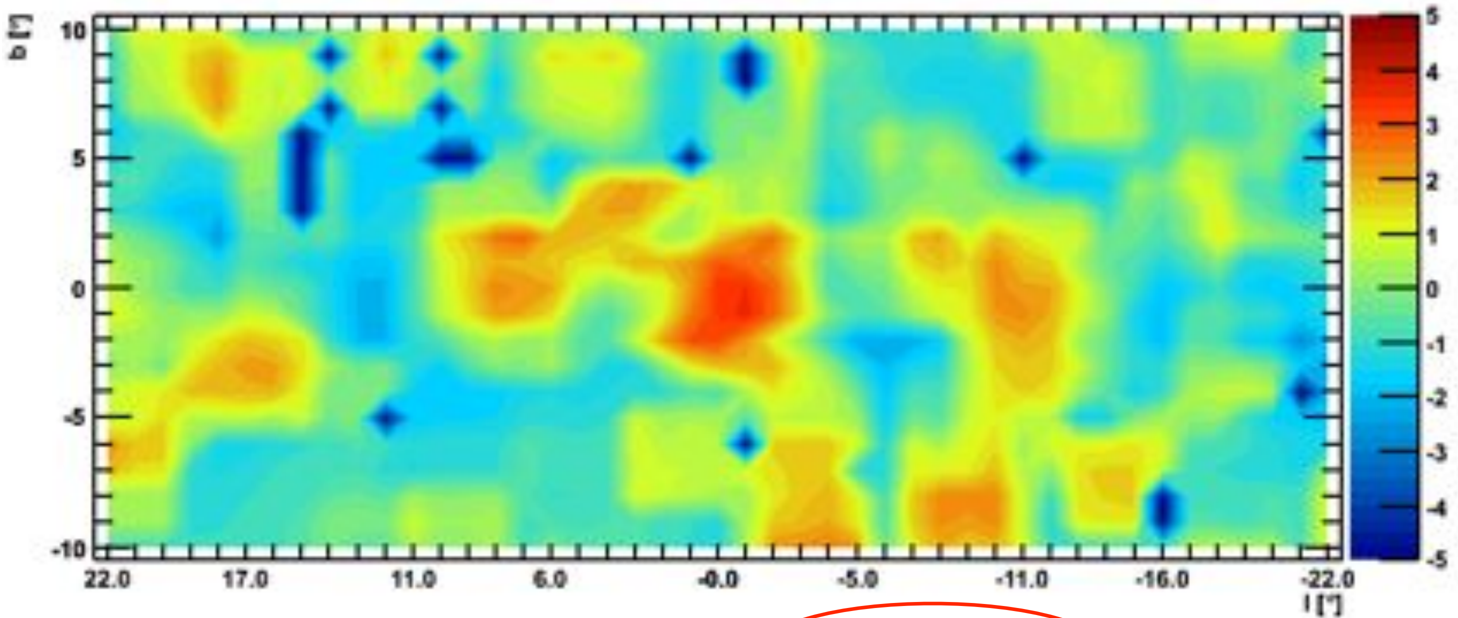
3.73σ (local) 1D fit at 135 GeV with 4 year reprocessed data; 4°x4°GC ROI, 1D PDF

3.35σ (local) 2D fit at 135 GeV with 4 year reprocessed data; 4°x4°GC ROI, 2D PDF

<2σ global significance after trials factor

Spectral line search

Location of the excess at 135 GeV:

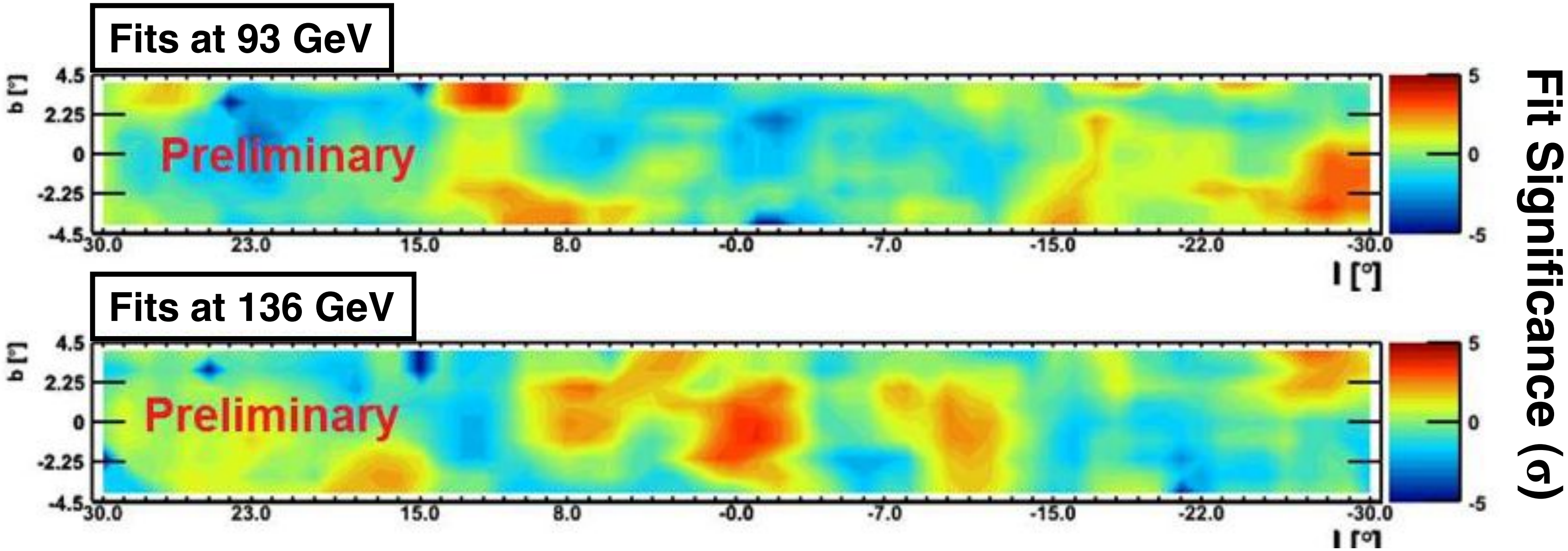


Signal significance in fit to powerlaw + 1D signal PDF at 135 GeV for 4°x4° boxes near the Galactic Center in 1° steps.

3-4σ (local) excesses near the Galactic center. Largely within 4° of Galactic plane. (However, be wary of interpretation in view of limited statistics~ few tens of photons)

Spectral line search

The Galactic plane:



Find similar features at other energies along the GP.

Excess near 135 GeV is one of the largest and near GC, but is not otherwise unique.

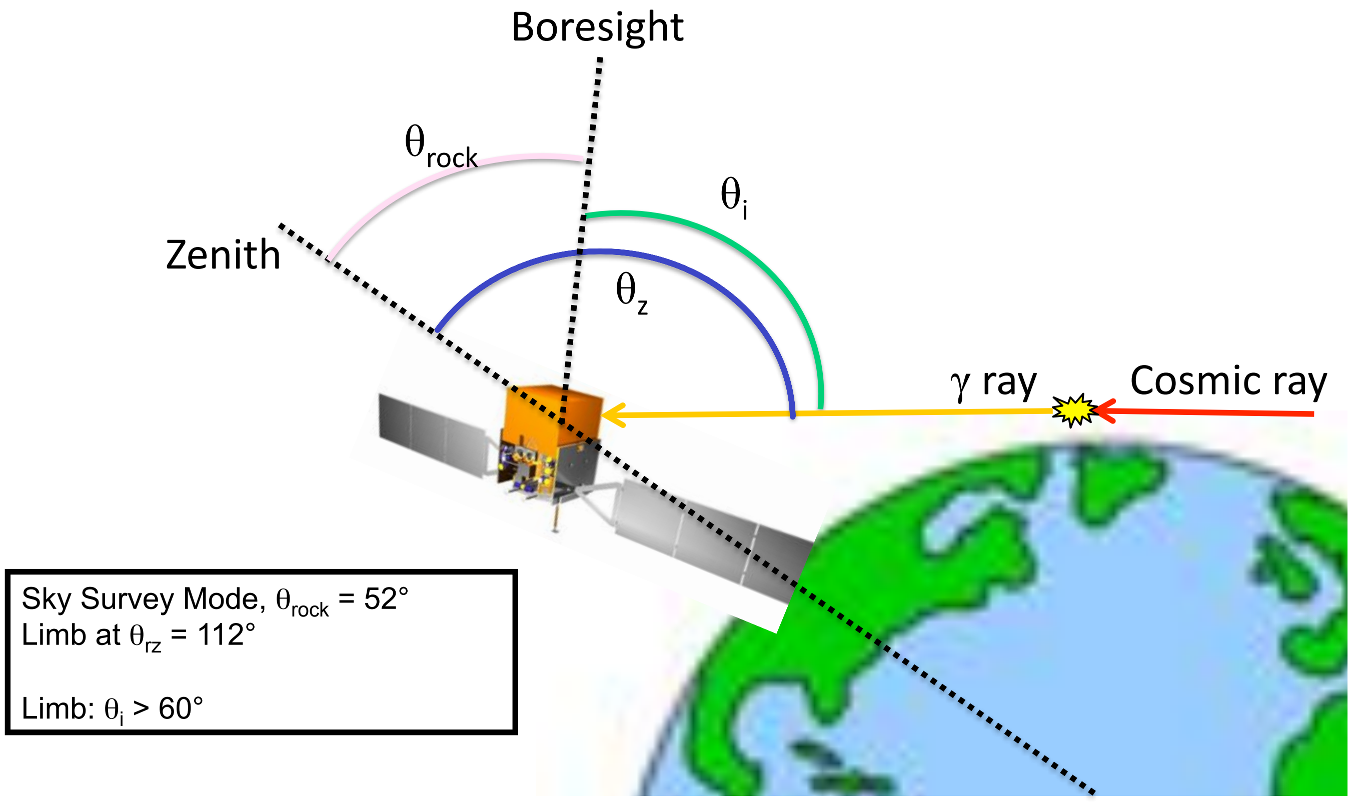
Spectral line search

The Earth Limb:

it is a bright, well understood source.

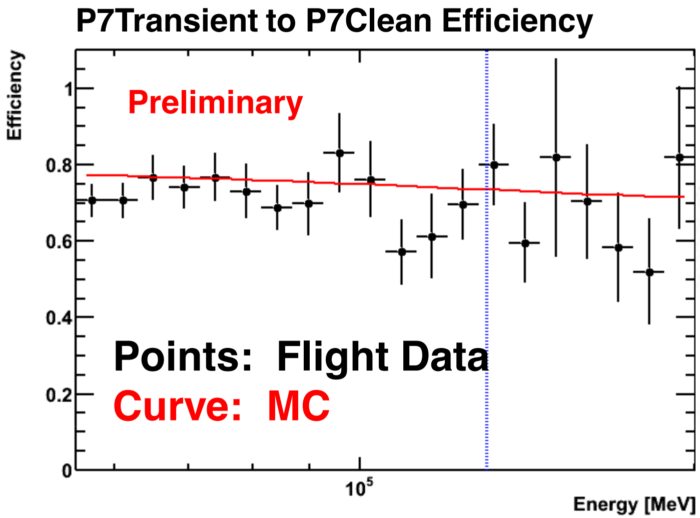
gamma rays from CR interactions in the atmosphere -> expected to be a smooth power-law

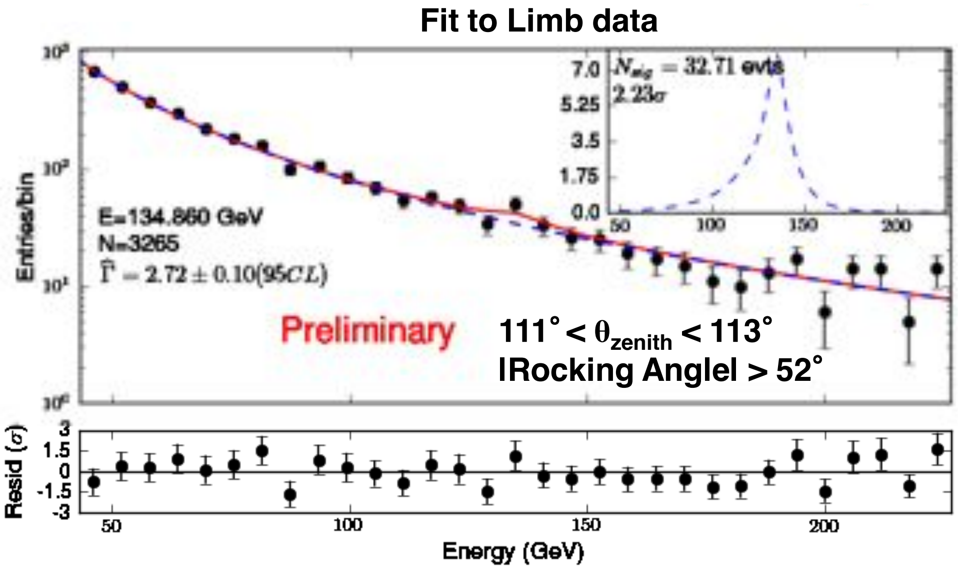
-> Valuable Control Sample.



Spectral line search

The Earth Limb as a Control Sample:





Line-like feature in the limb at 135 GeV, ~2.2σ,

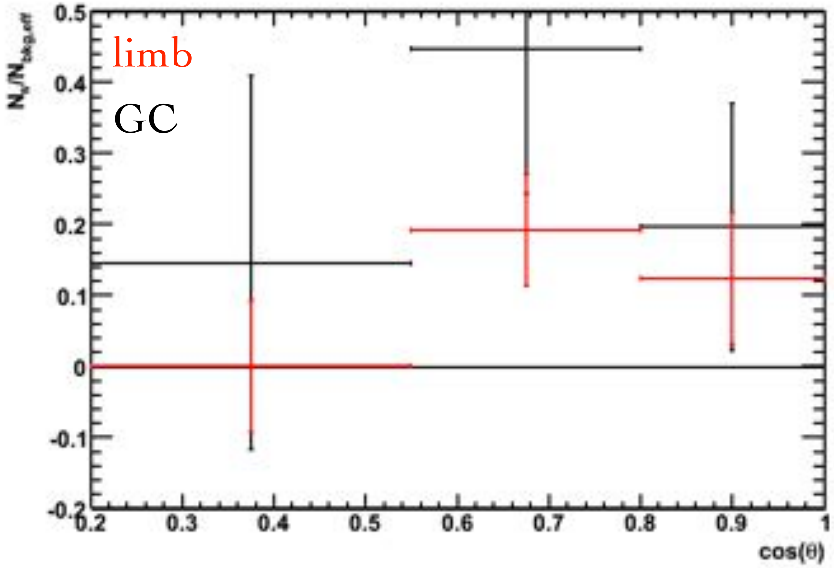
S/N$_{limb}$ ~15%, while S/NGC ~30% - 66%

The Earth Limb is unique in that it can be seen in the loose P7TRANSIENT event class at high energies. This allows us to use it to measure efficiencies for tighter event classes as a function of energy.

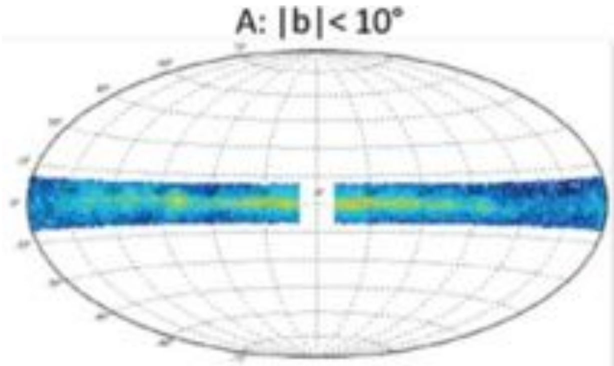
The efficiency at ~115 GeV is 0.57/0.75 = 75% of the MC prediction. This would imply a 30% boost in signal at 130 GeV relative to the prediction from nearby energy bins.

Spectral line search

8°x8° box around GC



No significant feature at 135 GeV seen in inverse ROI searches.



Appears when LAT is pointing at the Limb.

The features in the Earth Limb accounts for about 30% of the excess in a smaller 8°x8° box.

Not enough to explain all of the feature near the GC, however when accounted for they reduce the significance of the GC feature by up to 30%-50%.

But no signal in the inverse ROI!

Maybe distributions of cut variables in specific ROIs effect cut efficiencies.

- LAT made changes to increase the Limb dataset –> Pole-pointed observations each week.

Spectral line search

Near term prospects:

Fermi LAT: improved event analysis (pass8) and weekly limb observations.

Call for white papers on possible modifications to the observing strategy.

HESS 2: 50 hours of GC observation enough to rule out signature or confirm it at 5 sigma (if systematics are under control); Observations start in March 2013.

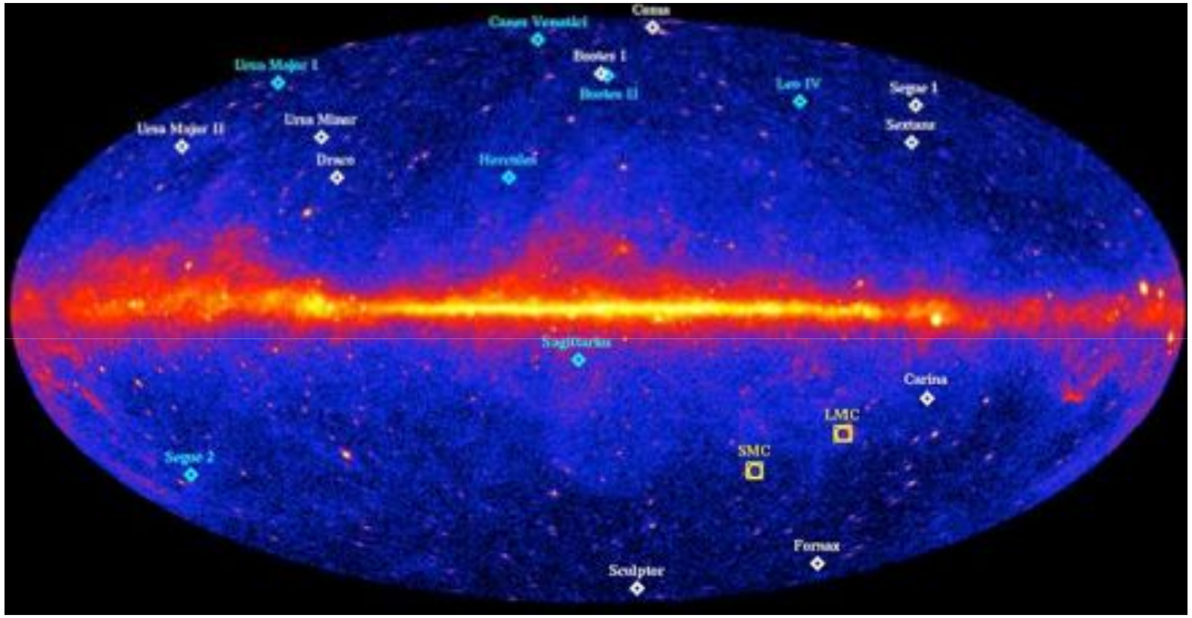
More details:

E. Charles @ Closing in on DM: http://indico.cern.ch/conferenceTimeTable.py?confId=197862#20130128

or A. Albert @ http://fermi.gsfc.nasa.gov/science/mtgs/symposia/2012/program/fri/AAlbert.pdf

Dwarf spheroidal galaxies

- Dark-matter dominated objects:
- 100 - 1000 times more dark than visible matter
- Multi-wavelength observations show no basis for astrophysical gamma-ray production
- Relatively nearby (25 - 150kpc)
- High galactic latitudes (minimize astrophysical foregrounds)



No evidence for a gamma ray signal from these objects yet.

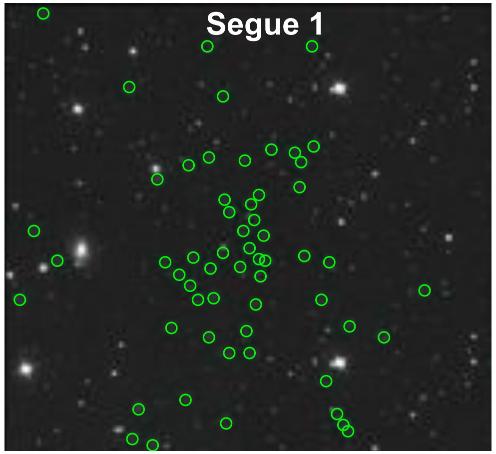
Dwarf spheroidal galaxies

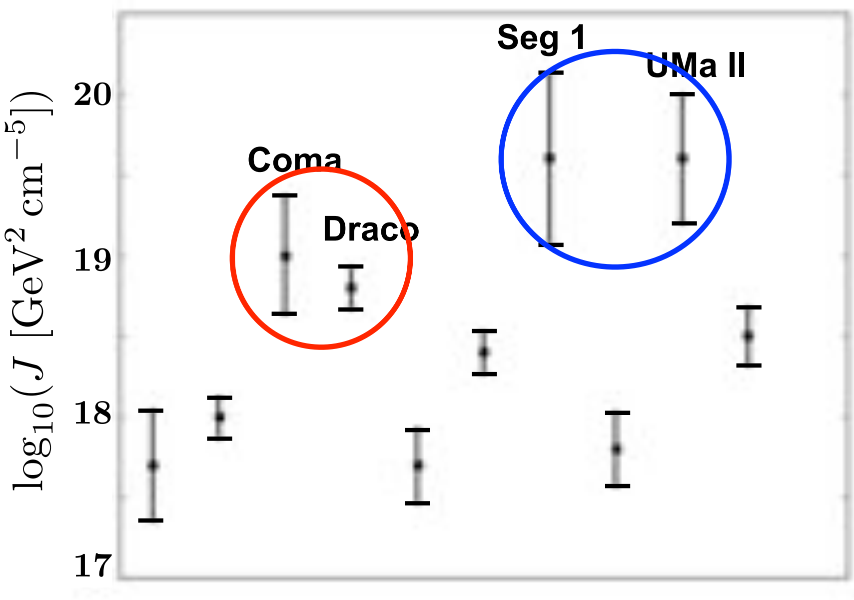
Dark matter content determined from stellar velocity dispersion

– Classical dwarfs: thousand stars

– Ultra-faint dwarfs: <~ 100 stars

- Fit stellar velocity distribution of each dwarf (assuming an NFW profile)
- Calculate the J-factor by integrating out to a radius of 0.5 deg (large enough to be insensitive to the inner profile behavior (core vs. cusp)
- **Include the J-factor uncertainty as a nuisance parameter in the joint likelihood.**





Dwarf spheroidal galaxies

* Include statistical uncertainties from stellar kinematic data.

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma, \phi, \theta) = \frac{1}{4\pi}\frac{<\sigma_{ann} v>}{2m^2_{WIMP}}\sum_f \frac{dN^f_\gamma}{dE_\gamma}B_f$$

$$\times$$

$$\int_{\Delta\Omega(\phi,\theta)} d\Omega' \int_{los} \rho^2(r(l,\phi'))dl(r,\phi')$$

$$L(D\,|\,\mathbf{p_m}, \{\mathbf{p_k}\}) = \prod_k L_k^{\mathrm{LAT}}(D_k\,|\,\mathbf{p_m}, \mathbf{p_k})$$

$$\times \frac{1}{\ln(10) J_k \sqrt{2\pi}\sigma_k} e^{-(\log_{10}(J_k) - \overline{\log_{10}(J_k)})^2/2\sigma_k^2}$$

Shared by all dwarfs
(dark matter particle parameters)

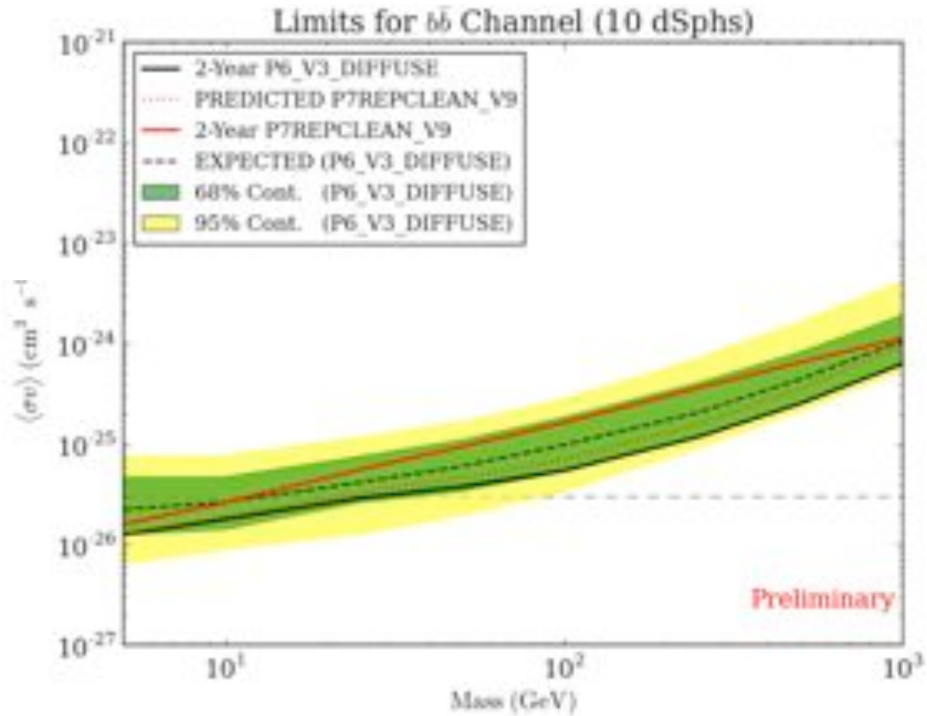
Fit for each dwarf
(background sources)

Uncertainty in J-factor

Dwarf spheroidal galaxies

- Update the analysis with an improved understanding of the instrument (reprocessed Pass 7)
- Leads to a statistical reshuffling of gamma-ray-classified events and higher limits.

Both Pass 6 and Pass7 measurements lie within the 68% containment region of a statistical sample.

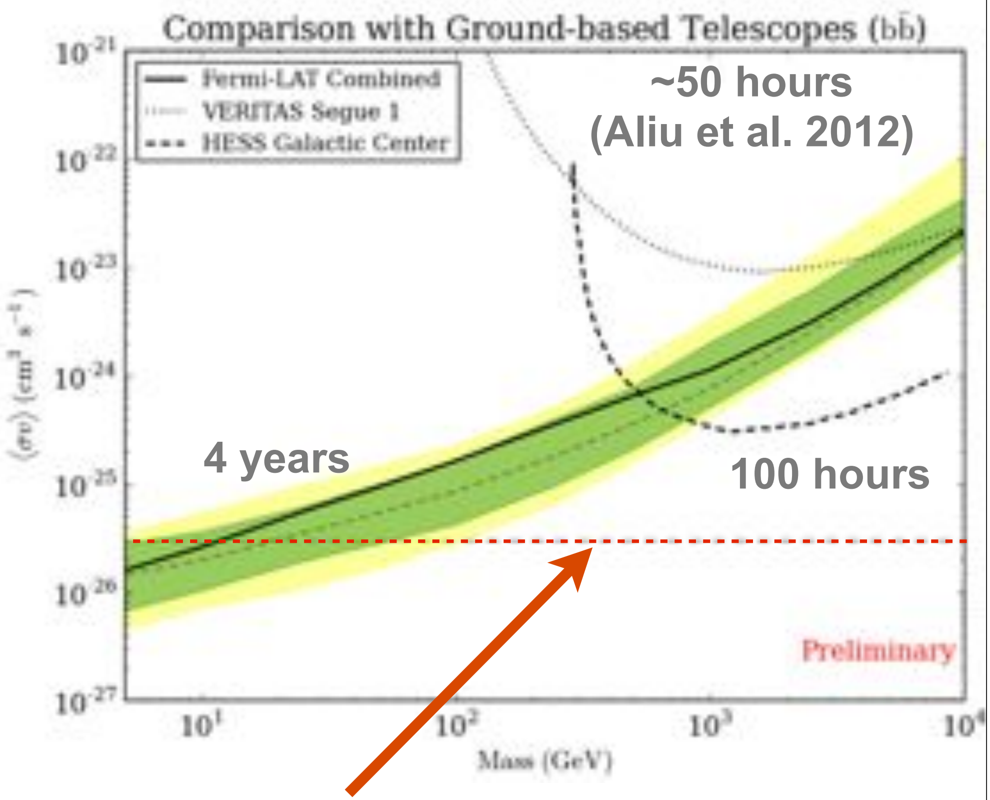


Green and yellow regions calculated by running full analysis pipeline on realistic sky simulations to calculate expected sensitivity.

Dwarf spheroidal galaxies

4 years of Pass 7 data yields higher limits than 2 years of Pass 6 data; however, the two are statistically consistent with predictions.

Immediate improvements are expected from updated diffuse and point source background models.



$$\langle \sigma v \rangle = 3 \times 10^{-26} \mathrm{cm}^3\, \mathrm{s}^{-1}$$

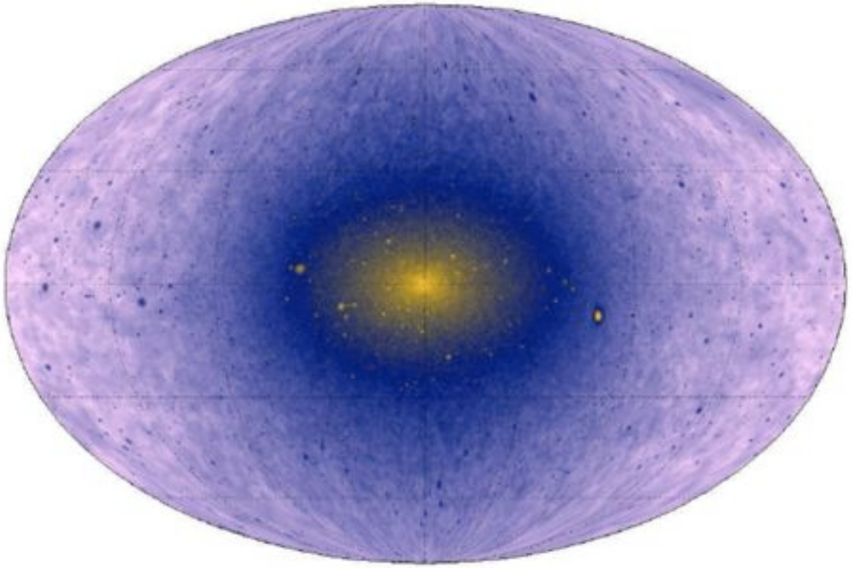
MW halo as a DM target

- DM annihilation signal is expected to be high in the inner regions of our halo
  - Sun is 'only' ~8 kpc away from the GC
  - DM content of the Milky Way is high

~ 'opposite' to previous cases: strong signal predicted in generic DM models but astrophysical bckgds high.

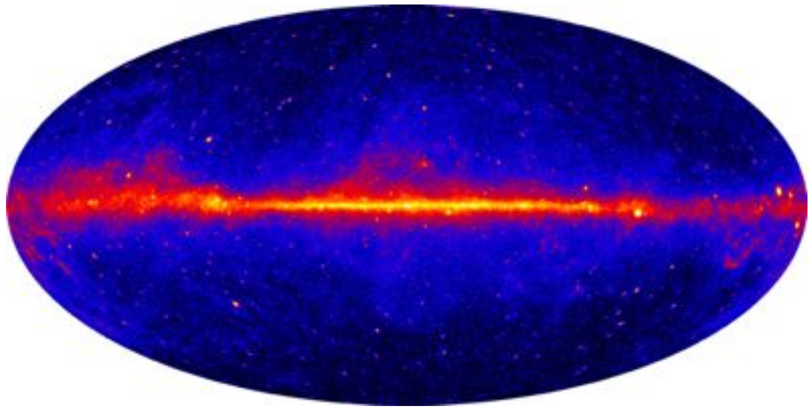
Due to the high quality Fermi LAT and charged CR data (PAMELA/CREAM) we have a decent handle on astrophysical modeling.

Predicted DM signal



Diemand et. al, APJ, 2006.

Fermi sky map - three year data.

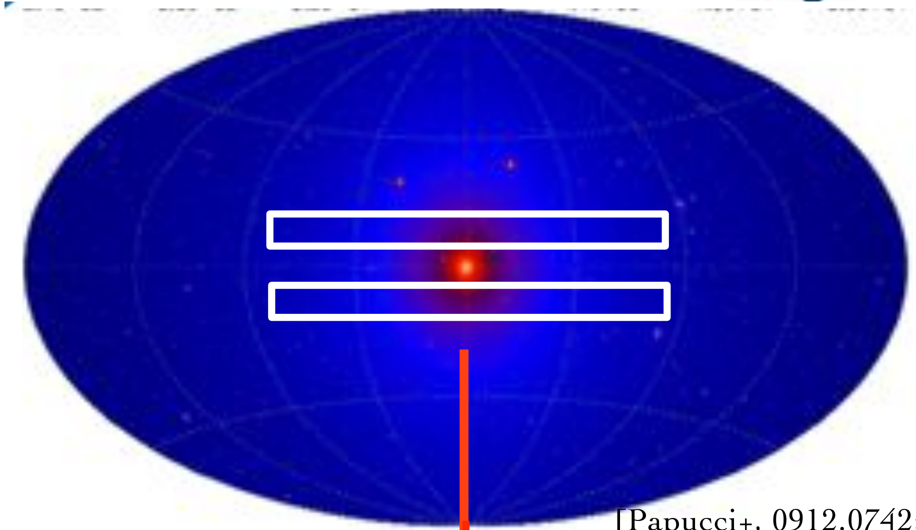


MW halo as a DM target

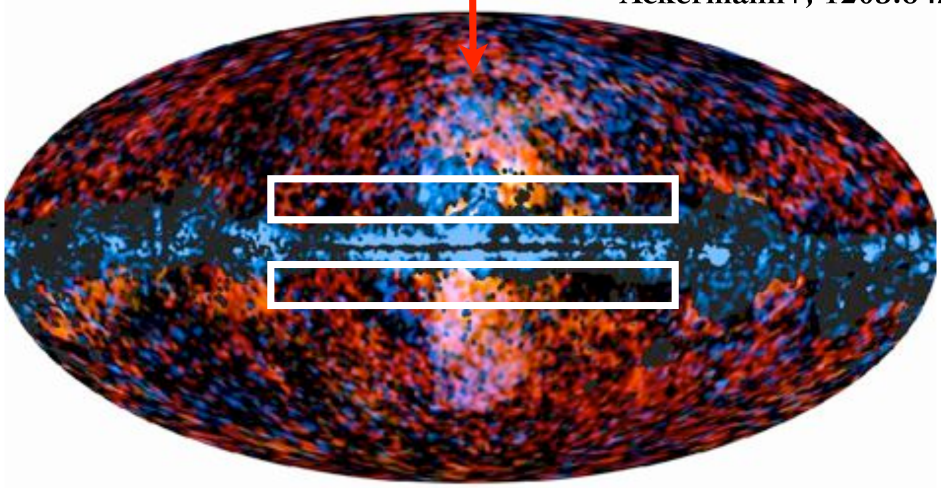
Analyze bands 5° -15° off the plane

⁕ minimize DM profile uncertainty (which is the highest in the Galactic Center region)

⁕ limit astrophysical uncertainty by masking out the Galactic plane, cutting-out high latitude emission from Fermi lobes/Loop I



[Papucci+, 0912.0742;
Cirelli+, 0912.0663
Ackermann+, 1205.6474]



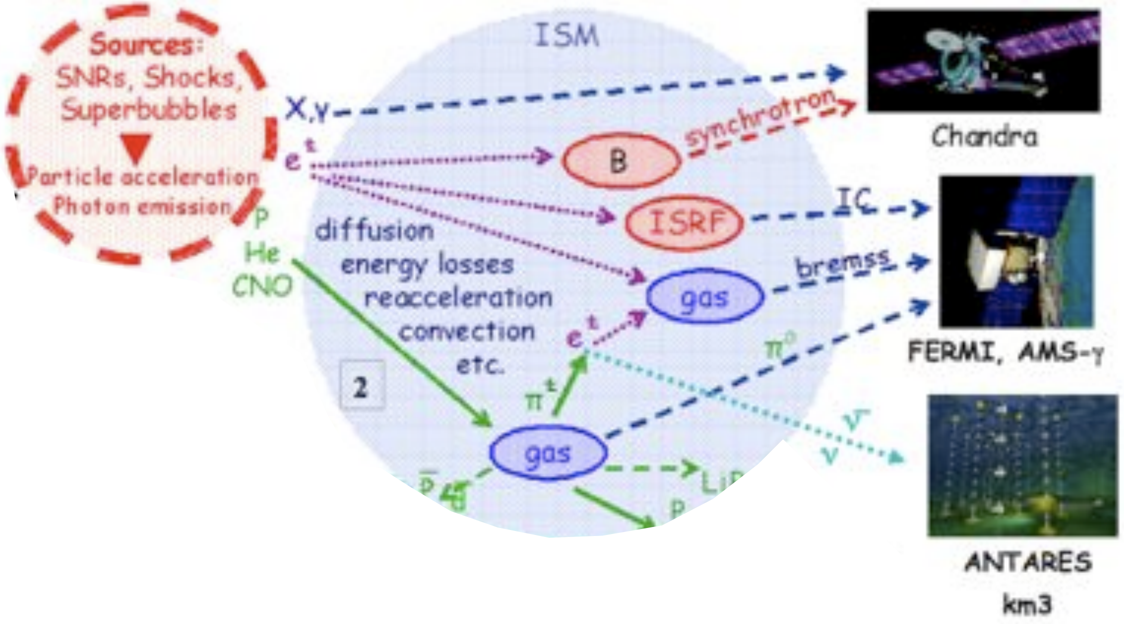
- Two approaches:

– More conservative - Assume all emission from dark matter (no astrophysical model)

– More accurate - Fit dark matter source and astrophysical emission simultaneously

MW halo as a DM target

- Majority of the diffuse emission is due to CR interacting with the ISM
  - three component in the LAT energy range: Inverse Compton and bremssthralung emission from cosmic ray electrons and decay of pions (produced in CR proton scatterings with the gas).
  - many parameters needed to describe it: distribution of CR source, injection spectra, gas maps, CR propagation parameters...

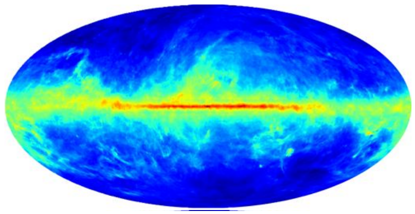


Adapted from Moskalenko et al. (2004)

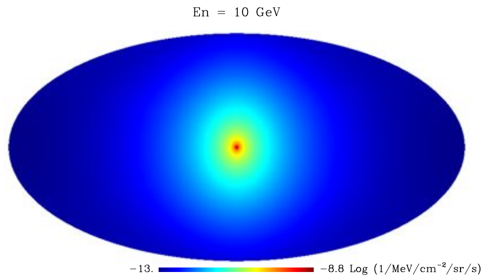
MW halo as a DM target

For each set of *parameters which enter a CR propagation equation* (size of the diffusion zone, diffusion index, etc) we produce *the three components of the Galactic diffuse emission.*

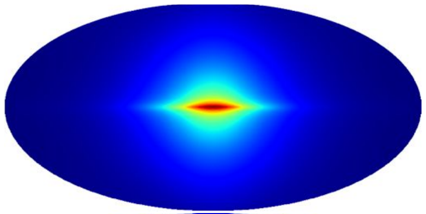
π^0, bremss

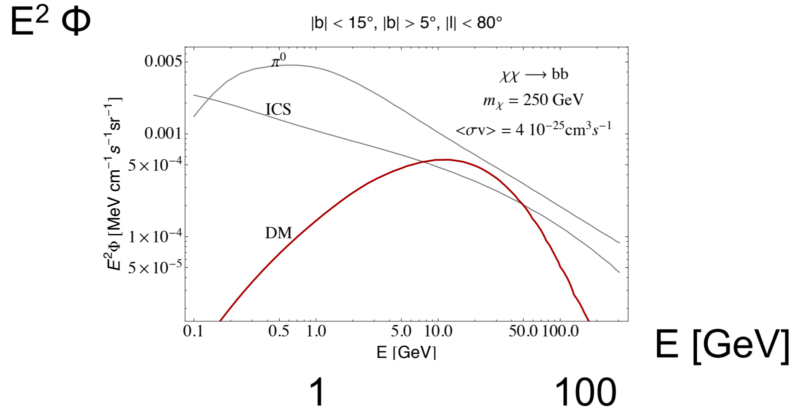


DM



IC



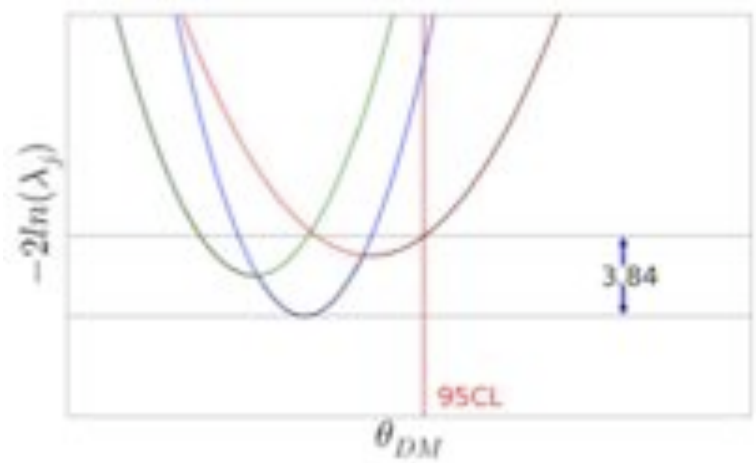


We *fit these templates to the data,* leaving their overall normalizations as a free (linear!) parameters of a fit (incorporating both morphology and spectra).

MW halo as a DM target

The profile likelihood method is used to combine all the models on a grid, and to derive the DM limits marginalized over the astrophysical uncertainties.

LogLikelihood vs DM normalization (σv)
for a *fixed* DM model and a mass:



Different curves correspond to *different sets of non-linear parameters* - *different grid points!*

For each DM normalization then, the best fit linear parameters are found, and the overall likelihood of the model.

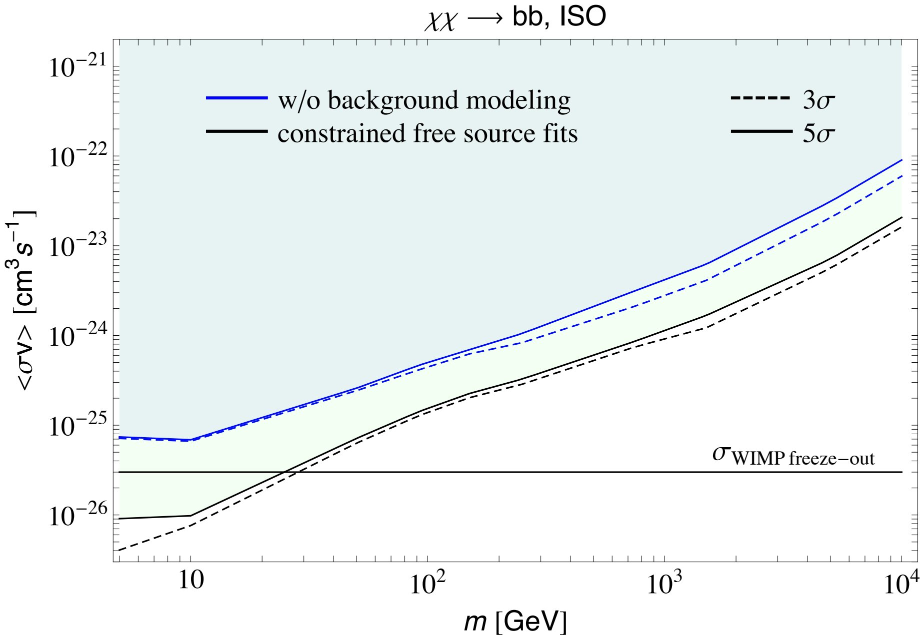
MW halo as a DM target

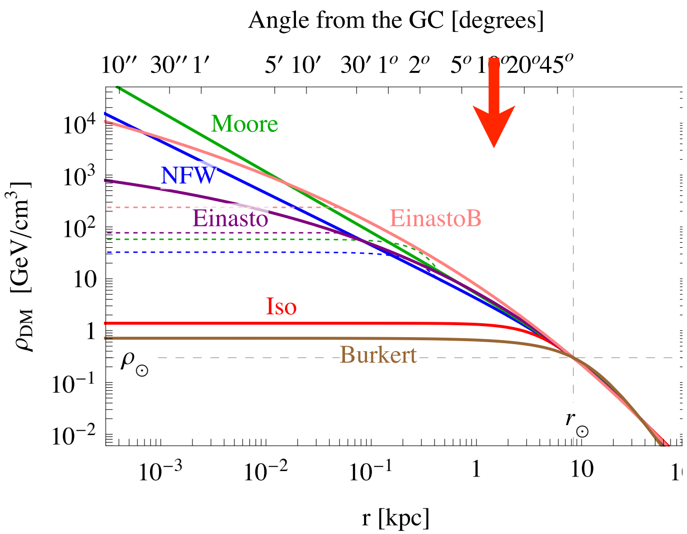
Limits on DM annihilation cross section, obtained after marginalization over a large set of astrophysical parameters together with DM component.

for ISOthermal DM profile and bbar channel (generic for most of particle physics models).

- Blue: limits obtained without any modeling of conventional astrophysical emission.
- generic WIMP models constrained below ~20 GeV.

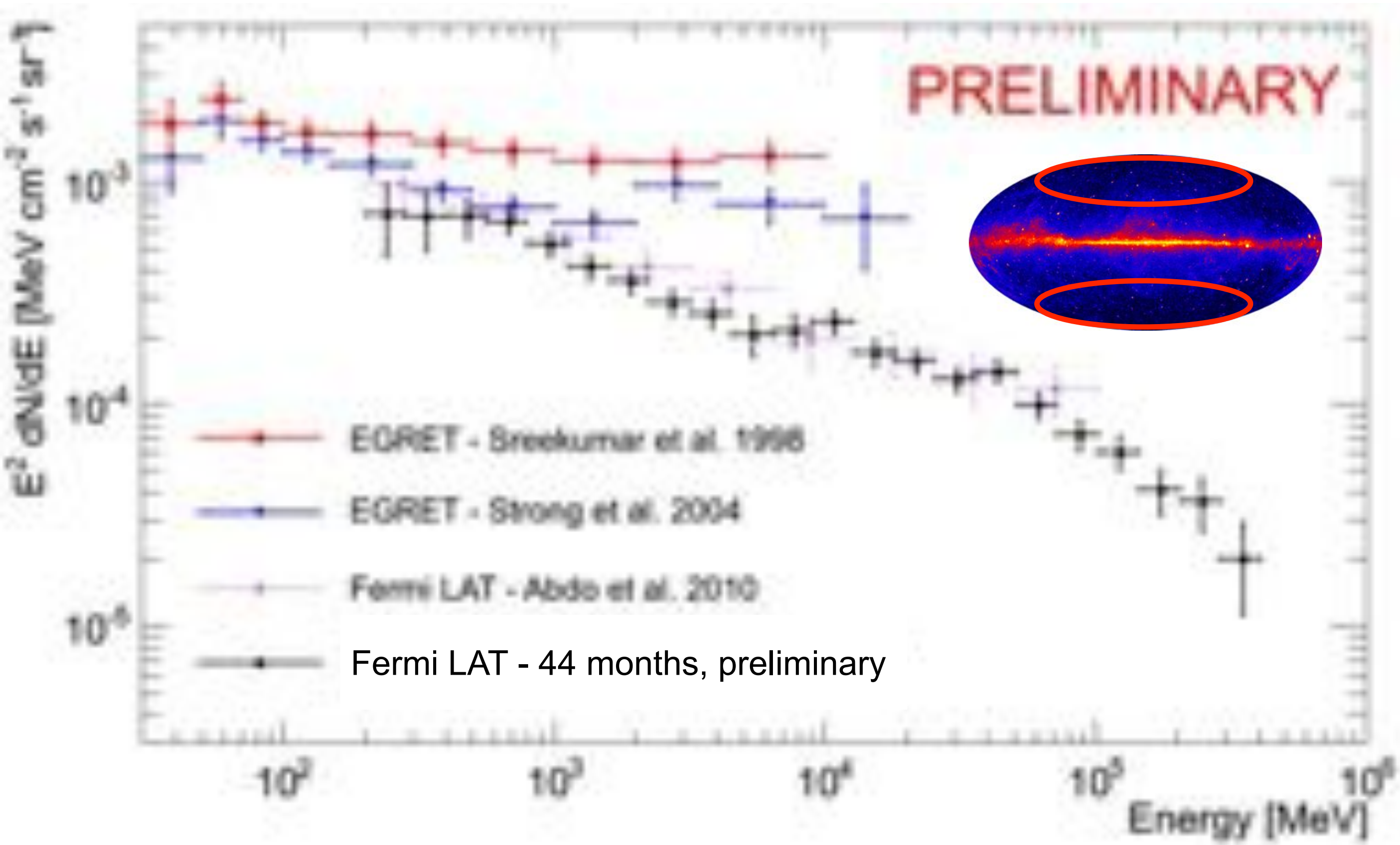
remaining uncertainty on the DM distribution in the Galaxy! follow up work.





Extra-Galactic sky

Spectrum of the isotropic diffuse emission (supposedly of an extraGalactic origin) has recently been measured to high energies <~400 GeV.

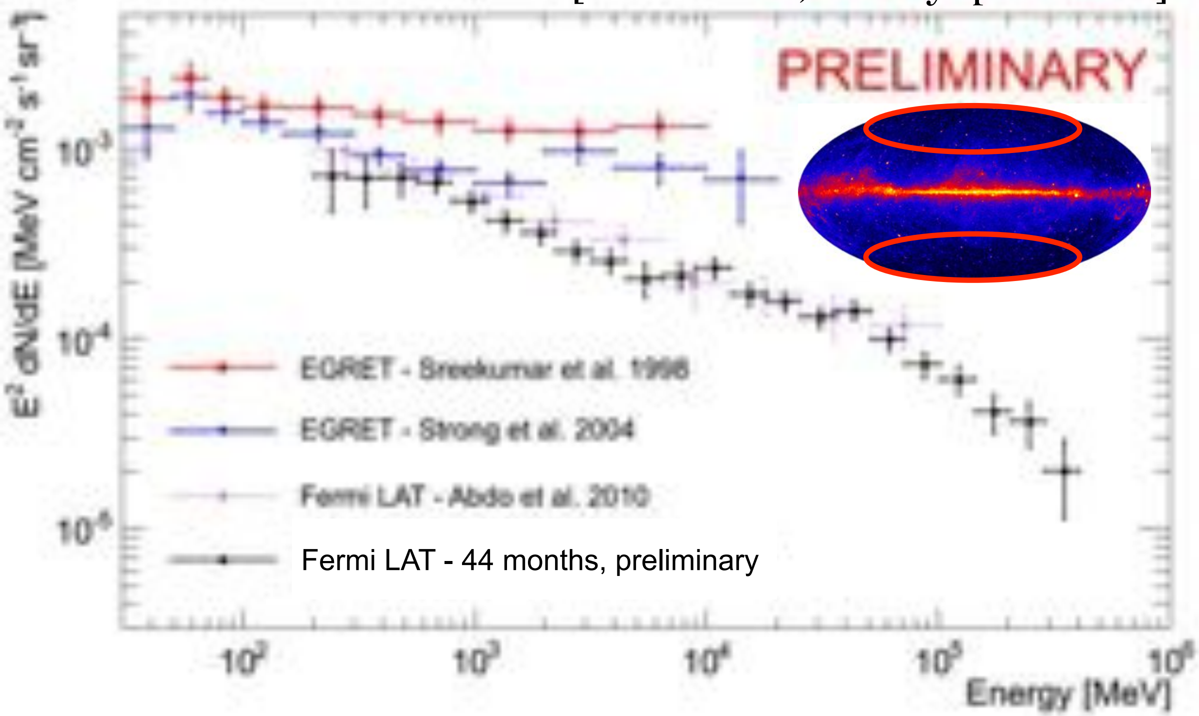


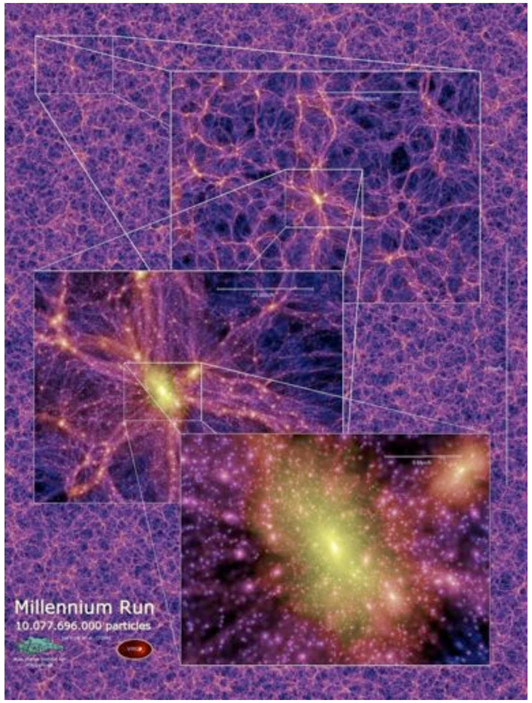
Extra-Galactic sky

Contributions from many source classes
– Normal galaxies (radio and star-forming)
– Active galactic nuclei (FSRQ & BL LACs)
– Dark matter?

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

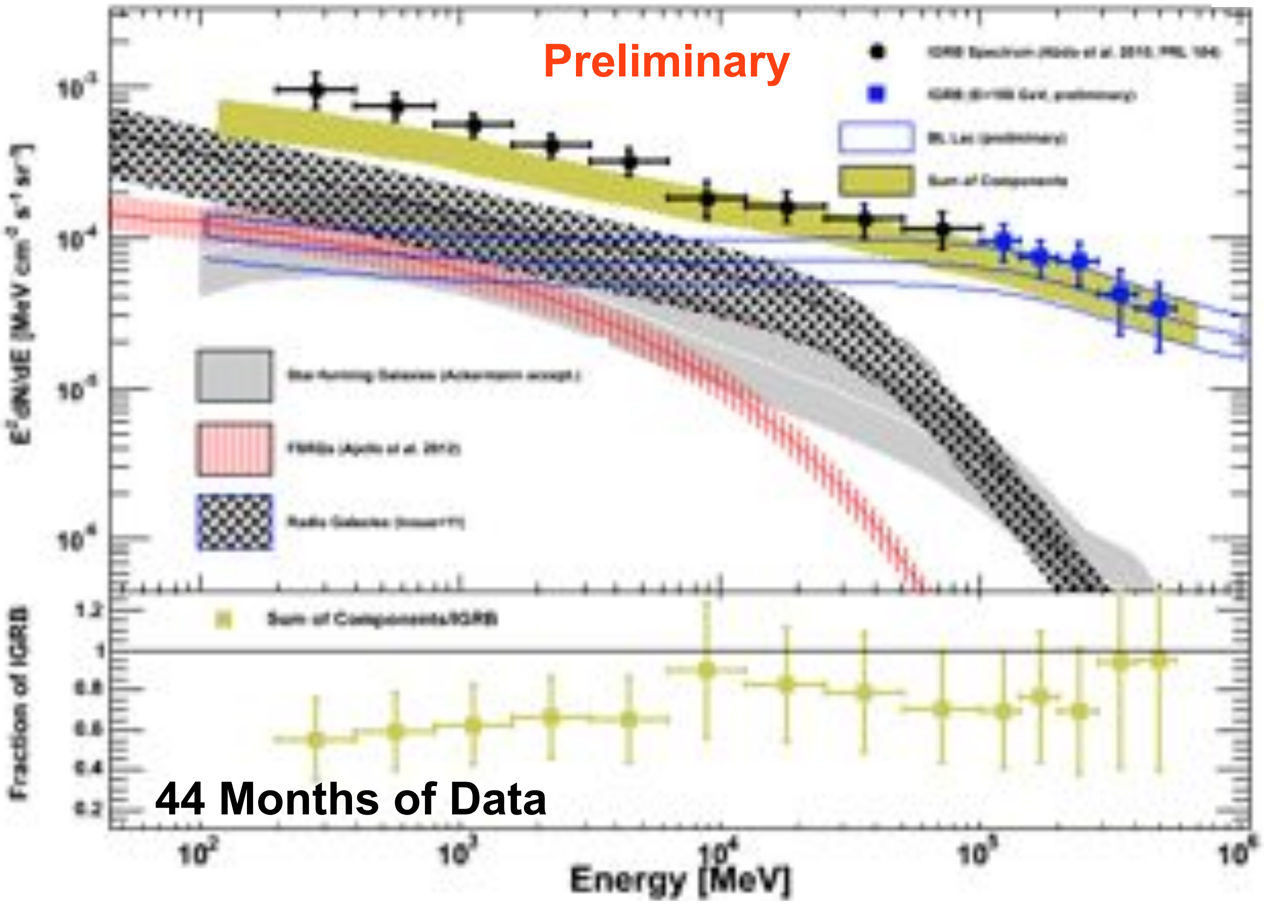
[M. Ackermann, Fermi symposium 2012]





Extra-Galactic sky

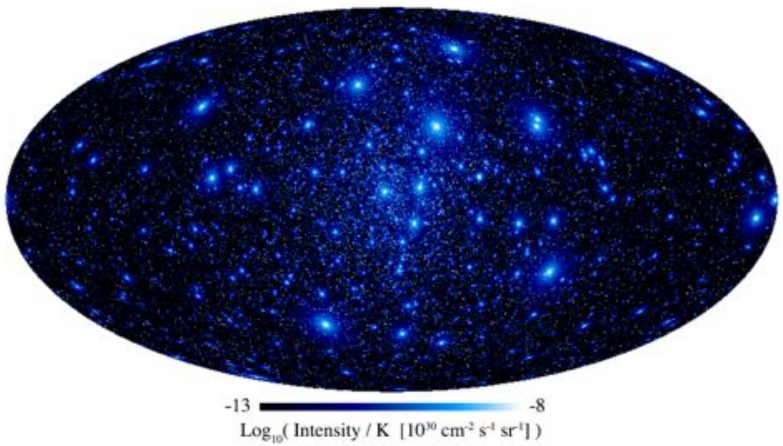
Fermi measured from the first time >500 sources above 10 GeV!
enough source classes to have good statistical sample and study their bulk properties!



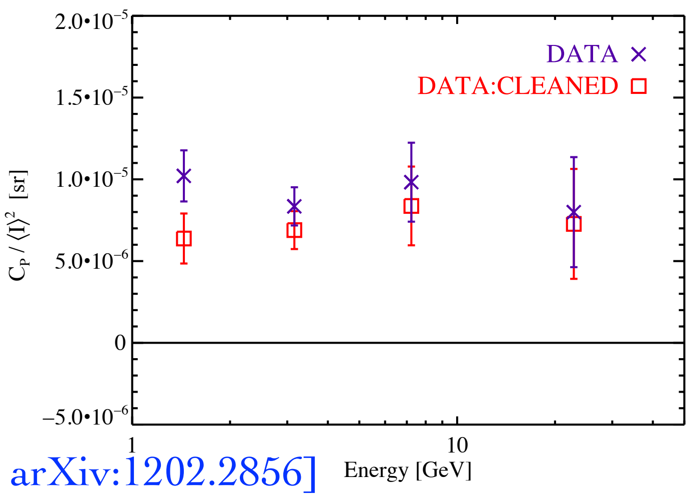
Extra-Galactic sky

Isotropic spectrum flux can be used to constrain the total extragalactic DM signal (summed over all DM halos and red shifts). -- work in progress.

However one can use an additional handle: **small angular scale fluctuations in the diffuse gamma-ray background** -> measured for the first time with the Fermi LAT!



Fluctuation anisotropy energy spectrum

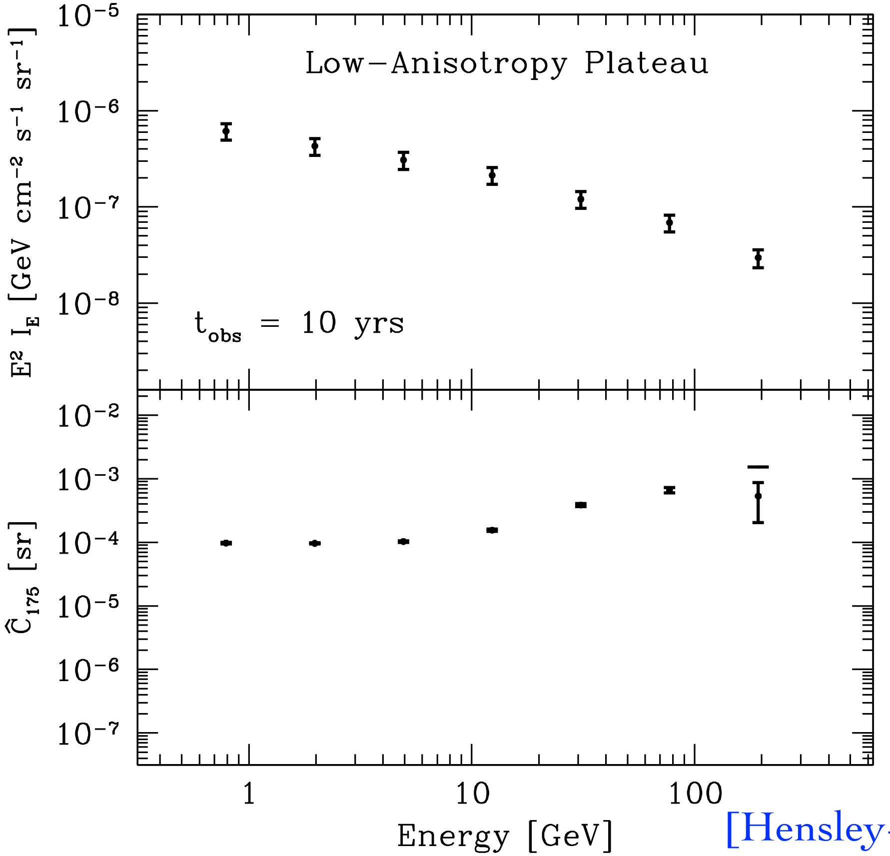


[Ackermann+, arXiv:1202.2856]

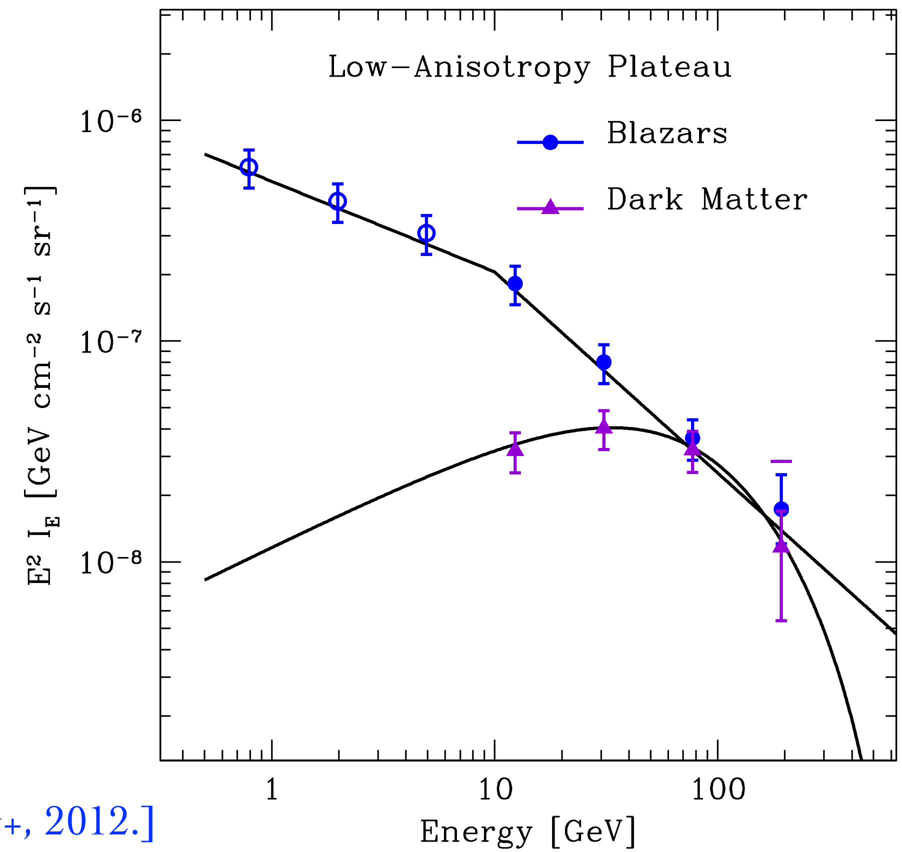
Extra-Galactic sky

or, one case use BOTH intensity spectrum and the anisotropy spectrum to RECONSTRUCT the components of the energy spectrum.

Example observed intensity spectrum and anisotropy energy spectrum

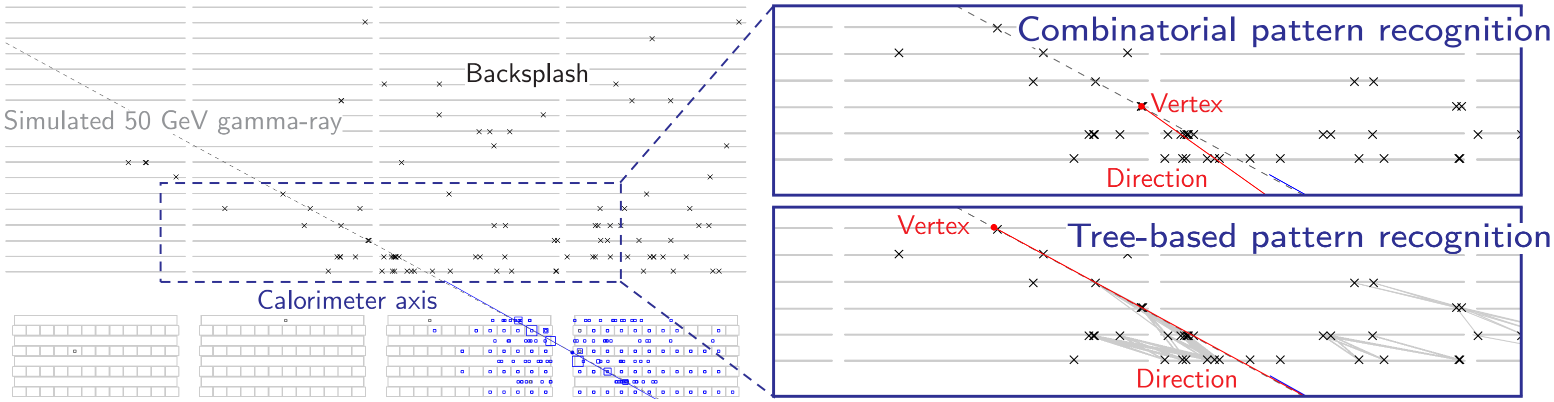


Decomposed energy spectra



[Hensley+, 2012.]

Future: pass8



Pass 8 will approach the full scientific potential of the LAT. Lower backgrounds and better control over the systematic uncertainties.

Extension of the energy reach:

Below 100 MeV: improved energy resolution and background rejection

Above 100 GeV: less tracking confusion, better compensation for calorimeter saturation (->spectra above 1 TeV).

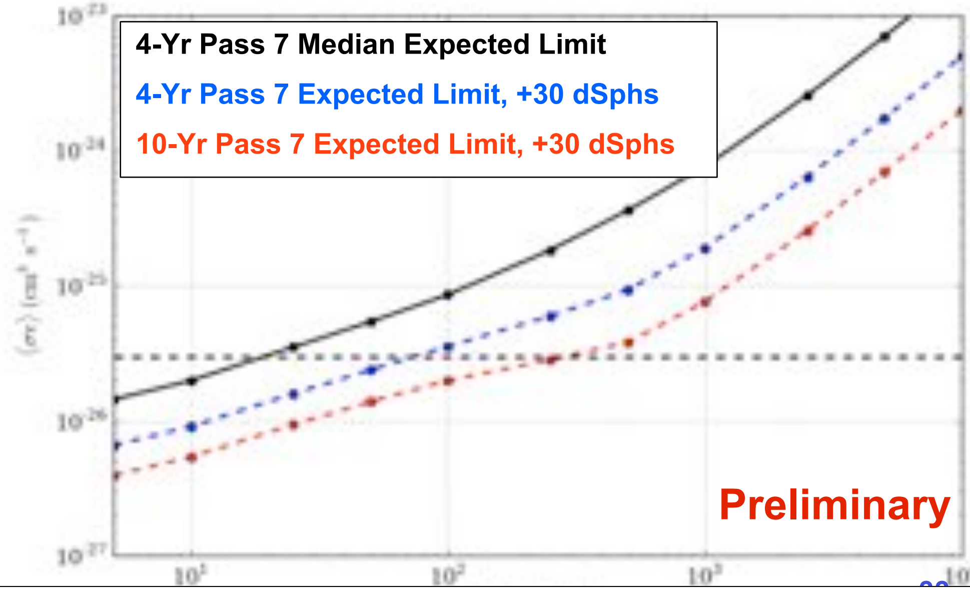
Better high-energy Point Spread Function.

Recover calorimeter-only events for science analysis (substantial effective area increase above 20 GeV).

Future: more gamma ray sources

The best is yet to come
– A better understanding of the instrument
– A better understanding of the astrophysics (2800 sources expected by 5 years of the LAT); high energy follow ups by ACTs and low energy instruments (Xray, radio)...
–> new source classes ?

Globular Cluster 47 Tuc (DES Collaboration)



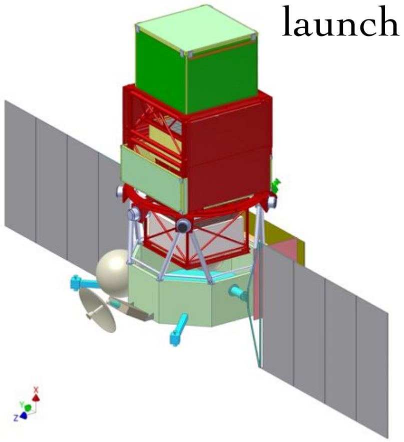
Future: near term experiments

The best is yet to come

– CTA: a ~km2 array of ACTs

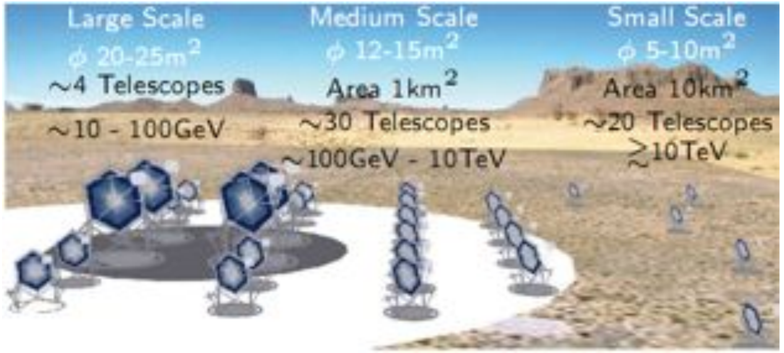
– Gamma-400: Uses technology similar to Fermi Large Area Telescope, but will have better angular and energy resolution

+ lower energy experiments SKA, nuSTAR...



launch planned for 2018.

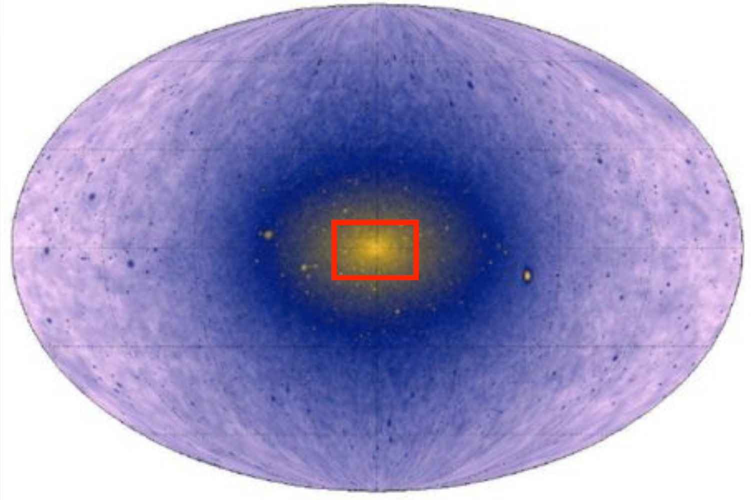
currently in design phase foreseen to be operative a few years from now.



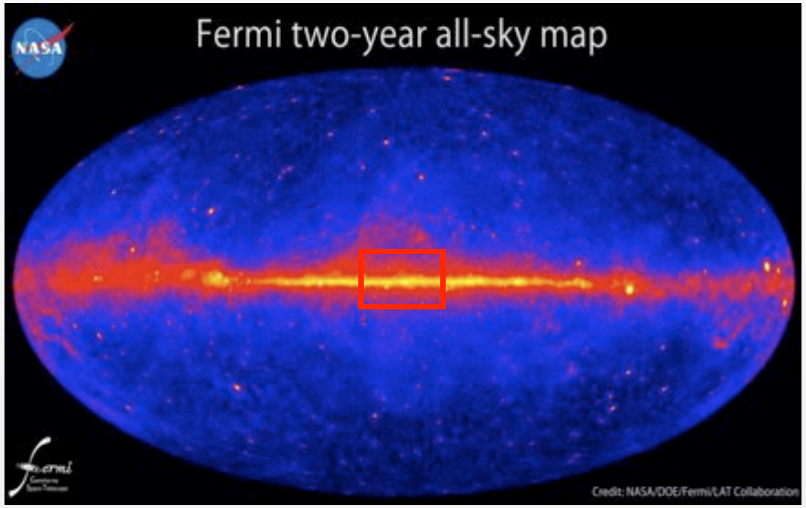
Extra slides

How about the Galactic center region?

Predicted DM gamma ray signal.

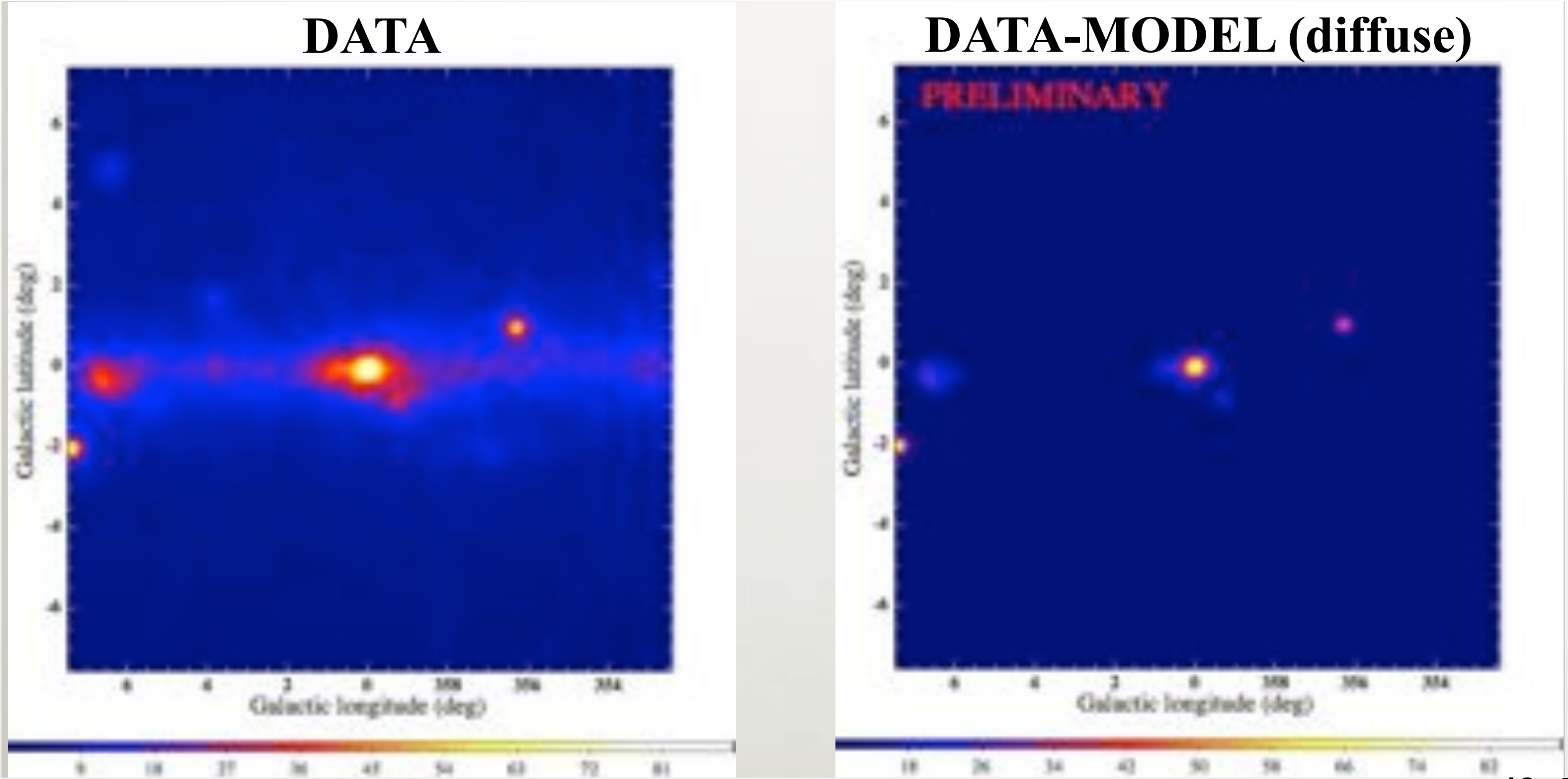


Diemand et. al, APJ, 2006.



Signal expectation potentially the highest ($\sim\rho^2/d^2$)
but astro background emission harder to model: strong interplay between *diffuse emission* and *numerous point sources*!

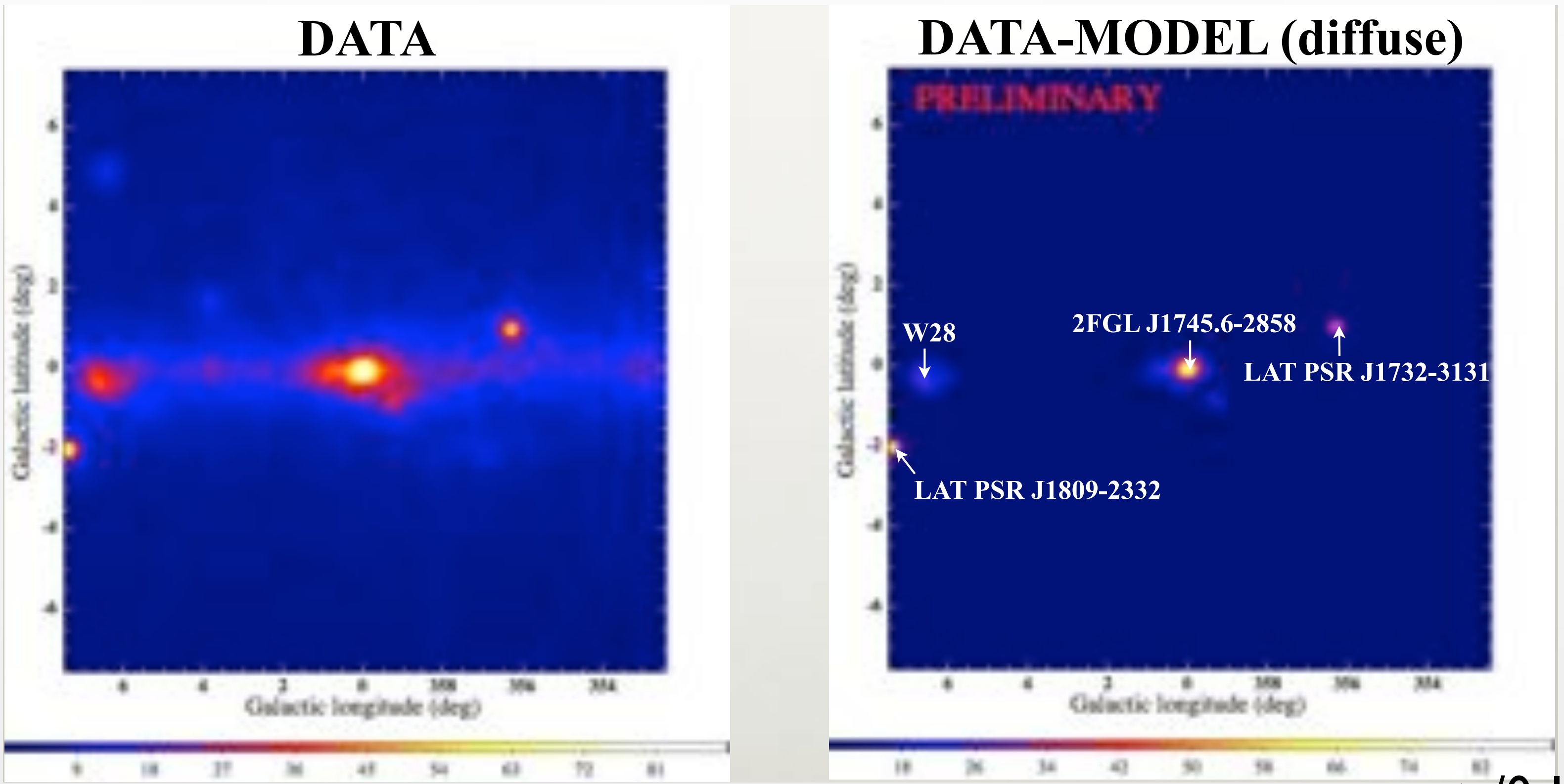
Modeling of the GC region



counts/0.1 deg^2

data: 32 months of data, E>1 GeV (P7CLEAN_V6, FRONT)
ROI: 15x15 deg.
Galactic diffuse emission model: all sky GALPROP model tuned to the inner galaxy.

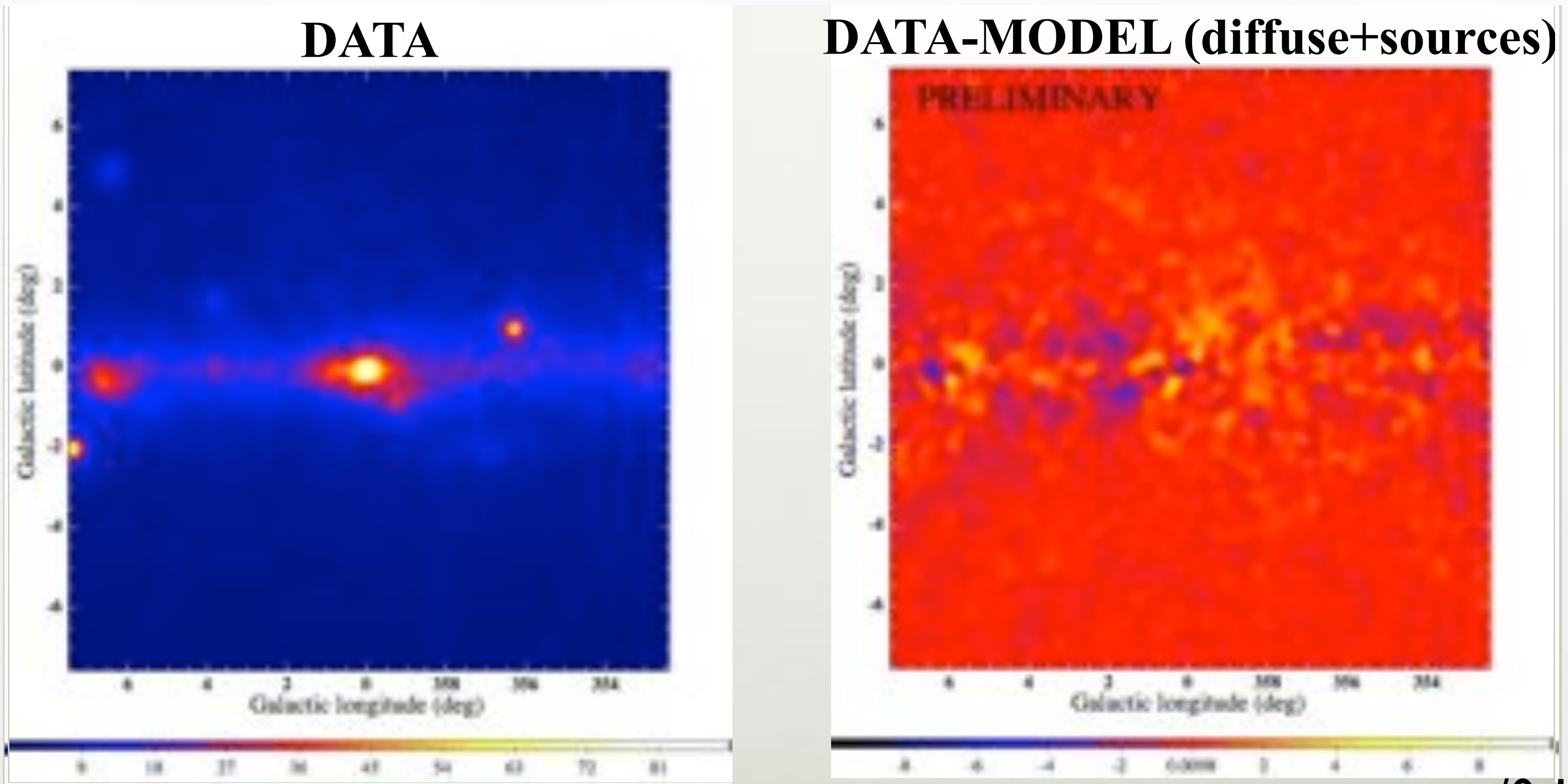
Modeling of the GC region



counts/0.1 deg^2

Bright excesses after subtracting diffuse emission model are consistent with known sources.

Modeling of the GC region



counts/0.1 deg^2

Diffuse emission and point sources account for most of the emission observed in the region → one also expect other un-modeled astro contributions: e.g. unresolved pulsars... work on astro modeling and different ways to test for DM signals in progress!