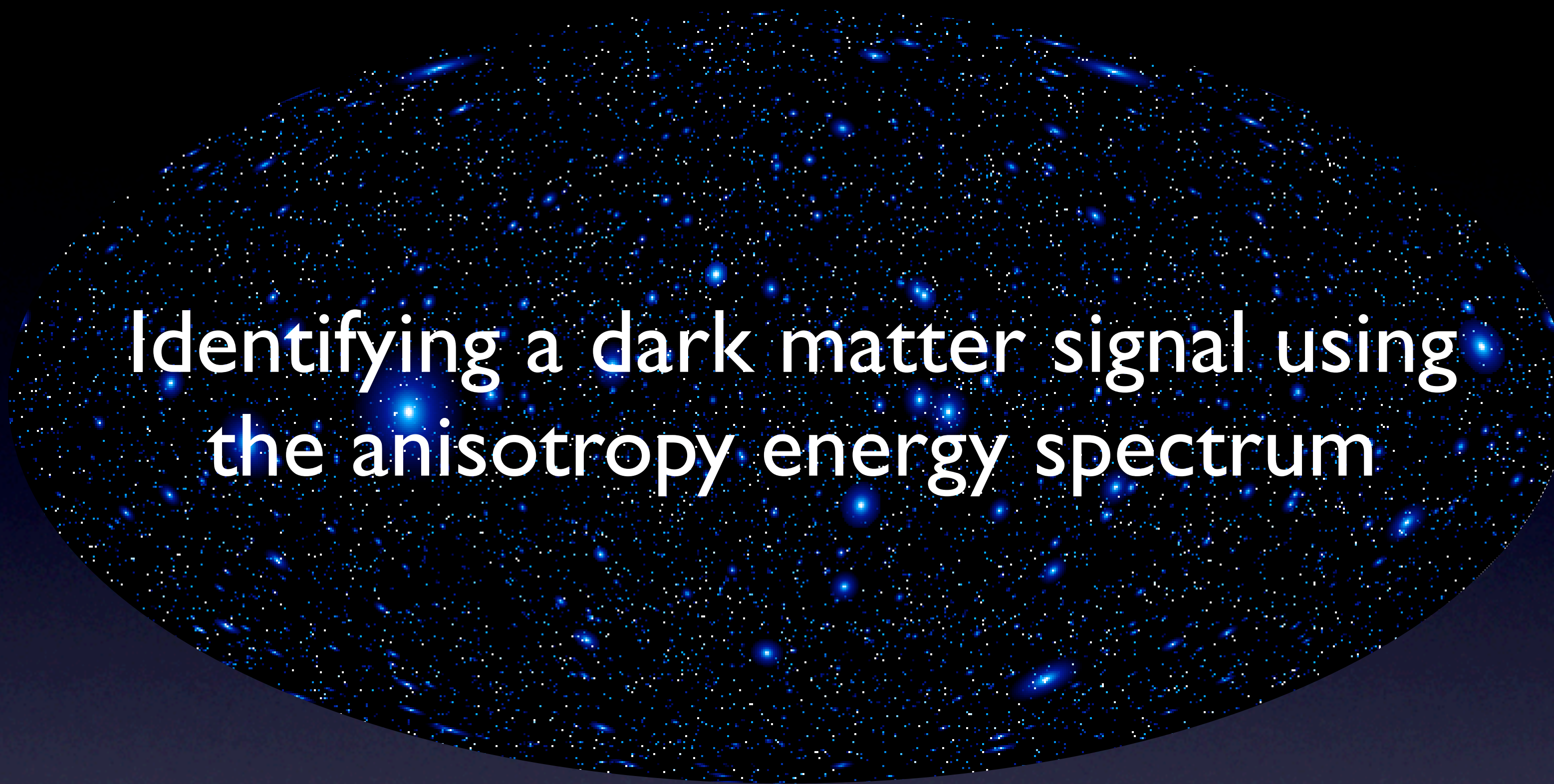

Identifying a dark matter signal using the anisotropy energy spectrum

Jennifer Siegal-Gaskins
CCAPP, Ohio State University

in collaboration with Brandon Hensley (Caltech) and Vasiliki Pavlidou (Caltech)
(see VP's talk later this session!)

JSG & Pavlidou, PRL, 102, 241301 (2009); arXiv:0901.3776
Hensley, JSG, & Pavlidou, on arXiv soon!

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Overview

- cold dark matter models predict an abundance of substructure in the halo of the Galaxy

Springel et al. (Virgo Consortium)

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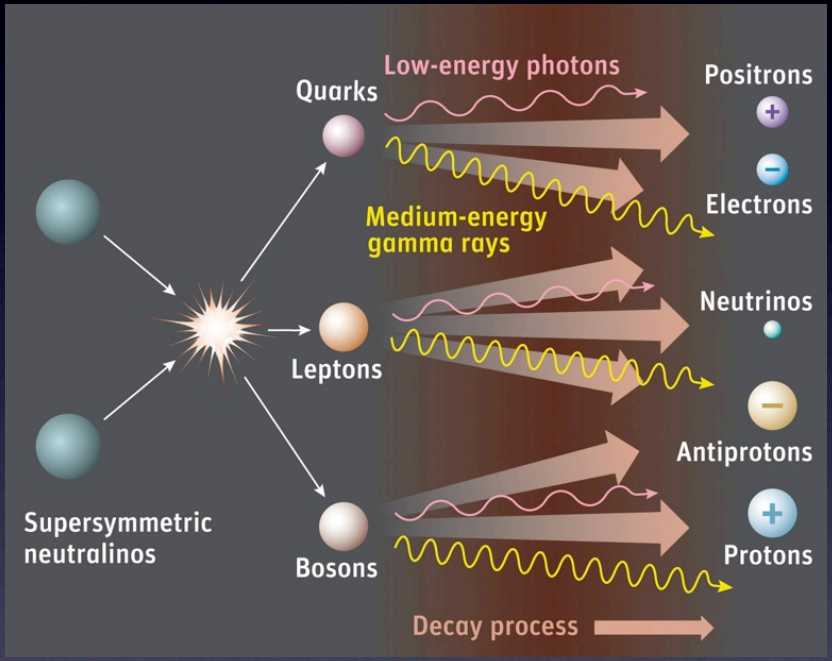
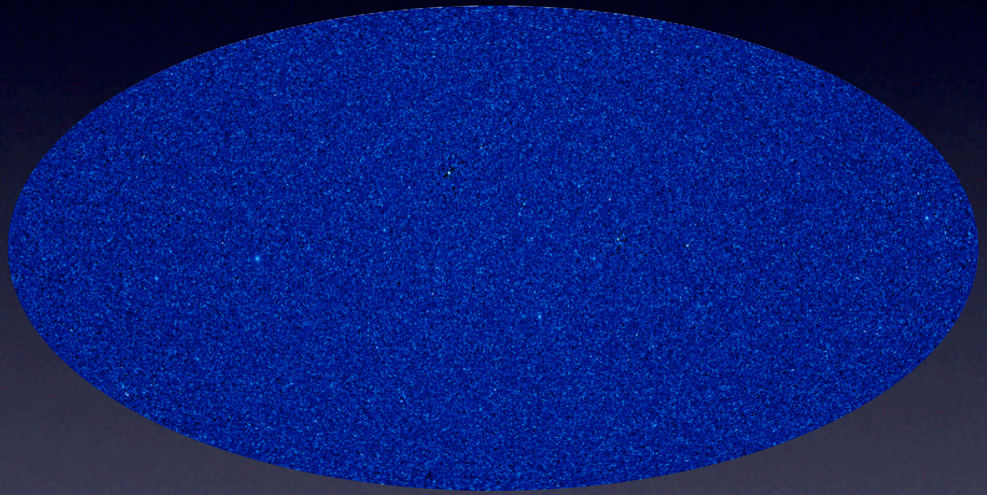
- annihilation of dark matter particles produces gamma-rays which could be detected by Fermi



Credit: Sky & Telescope / Gregg Dinderman

Overview

- cold dark matter models predict an abundance of substructure in the halo of the Galaxy
- annihilation of dark matter particles produces gamma-rays which could be detected by Fermi
- few if any subhalos will be detectable individually, but collectively Galactic substructure will produce a significant flux of diffuse gamma-rays
- this diffuse emission will be virtually isotropic on large angular scales, thus in Fermi data will appear as a contribution to the extragalactic gamma-ray background (EGRB)



JSG 2008

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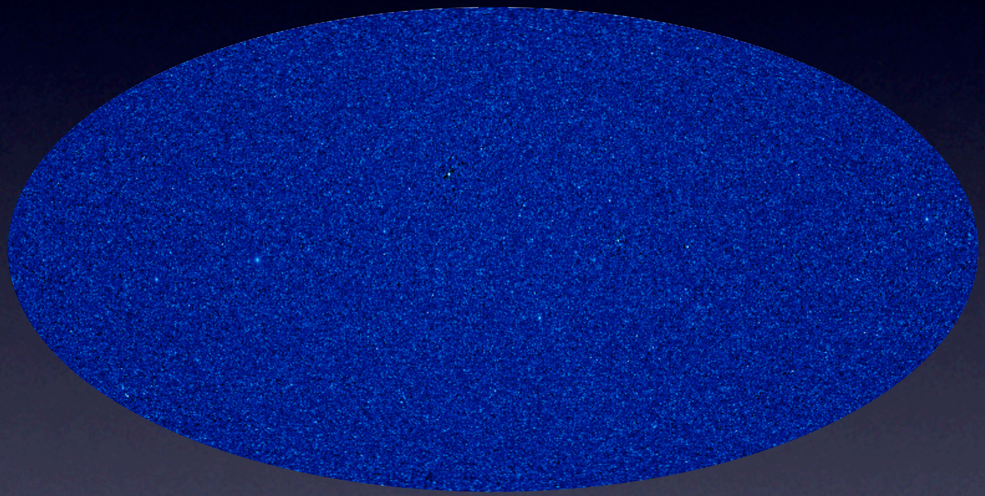

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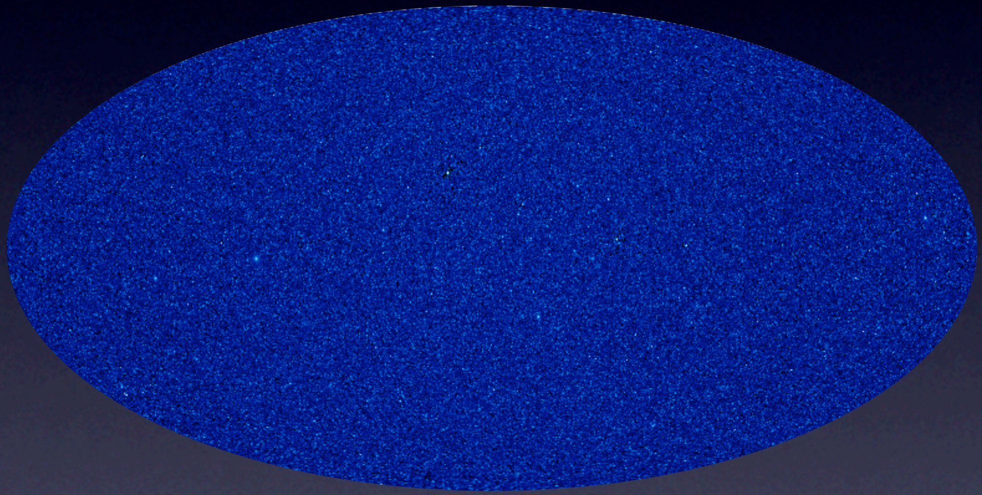
- the anisotropy energy spectrum can probe a large region of dark matter parameter space



JSG 2008

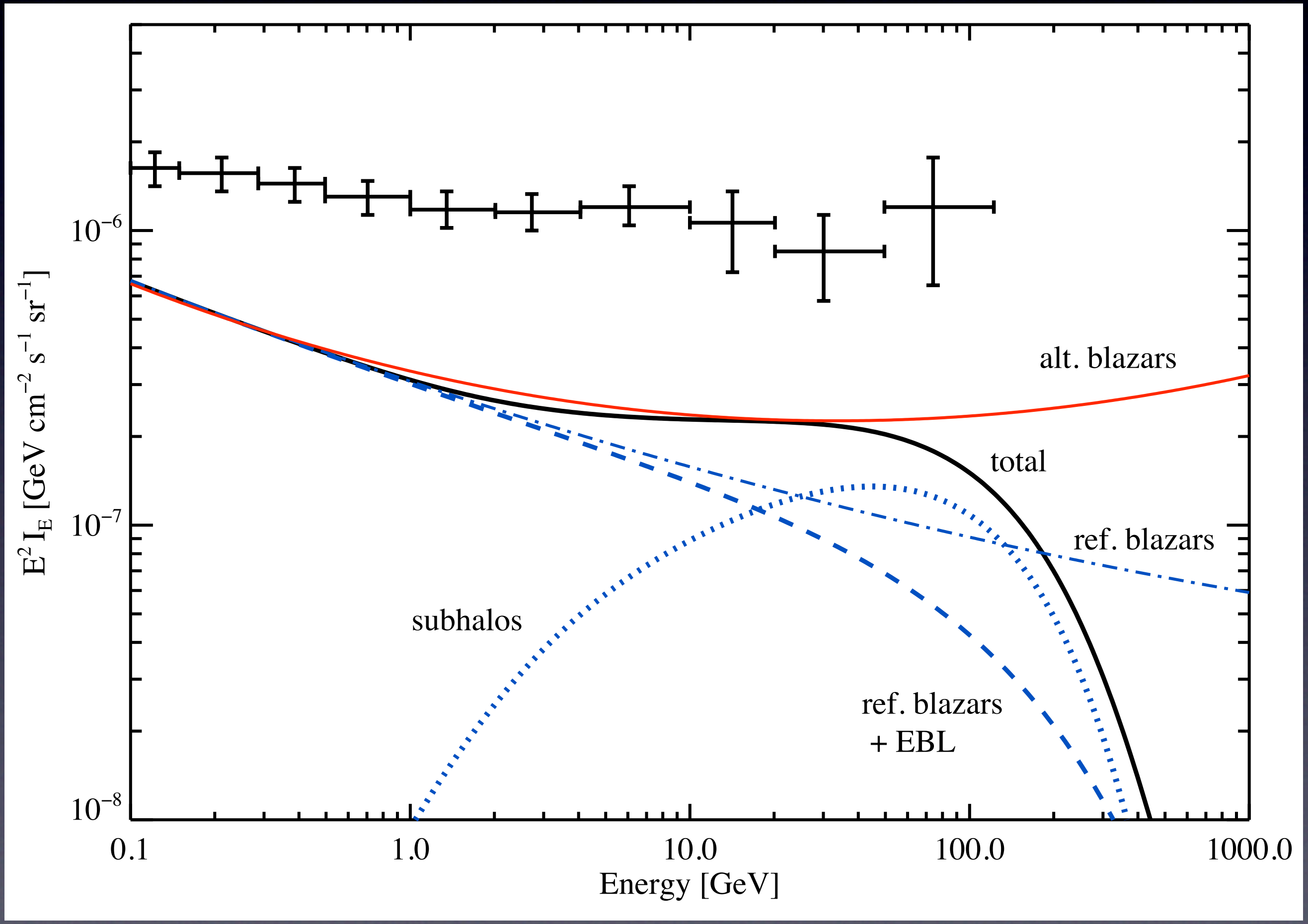
The intensity energy spectrum
(or why we need anisotropy too)

what contributes to the "total" measured emission?

interactions with the extragalactic background light (EBL) may substantially attenuate extragalactic gamma-rays above ~ 10 GeV, producing an exponential cutoff in the observed spectrum

#1: ref. blazar model w/ DM
#2: alt. blazar model w/o DM
intensity spectra are degenerate!

example isotropic diffuse intensity spectrum



JSG & Pavlidou 2009

The angular power spectrum

$$\delta I(\psi) \equiv \frac{I(\psi) - \langle I \rangle}{\langle I \rangle} \Rightarrow \delta I(\psi) = \sum_{\ell,m} a_{\ell m} Y_{\ell m}(\psi) \Rightarrow C_\ell = \langle\, |a_{\ell m}|^2 \rangle$$

- for these source classes, we use the angular power spectrum of intensity fluctuations in units of mean intensity (dimensionless)
  - independent of intensity normalization, avoids uncertainty in intensity of signal
  - avoids different amplitude angular power spectra in different energy bins

The anisotropy energy spectrum

- 'the anisotropy energy spectrum' = the angular power spectrum of the total measured emission at a fixed angular scale (multipole) as a function of energy:

$$C_\ell^{\rm tot}(E) = f_{\rm EG}^2(E)C_\ell^{\rm EG} + f_{\rm DM}^2(E)C_\ell^{\rm DM} + 2f_{\rm EG}(E)f_{\rm DM}(E)\cancel{C_\ell^{\rm EG\times DM}}$$

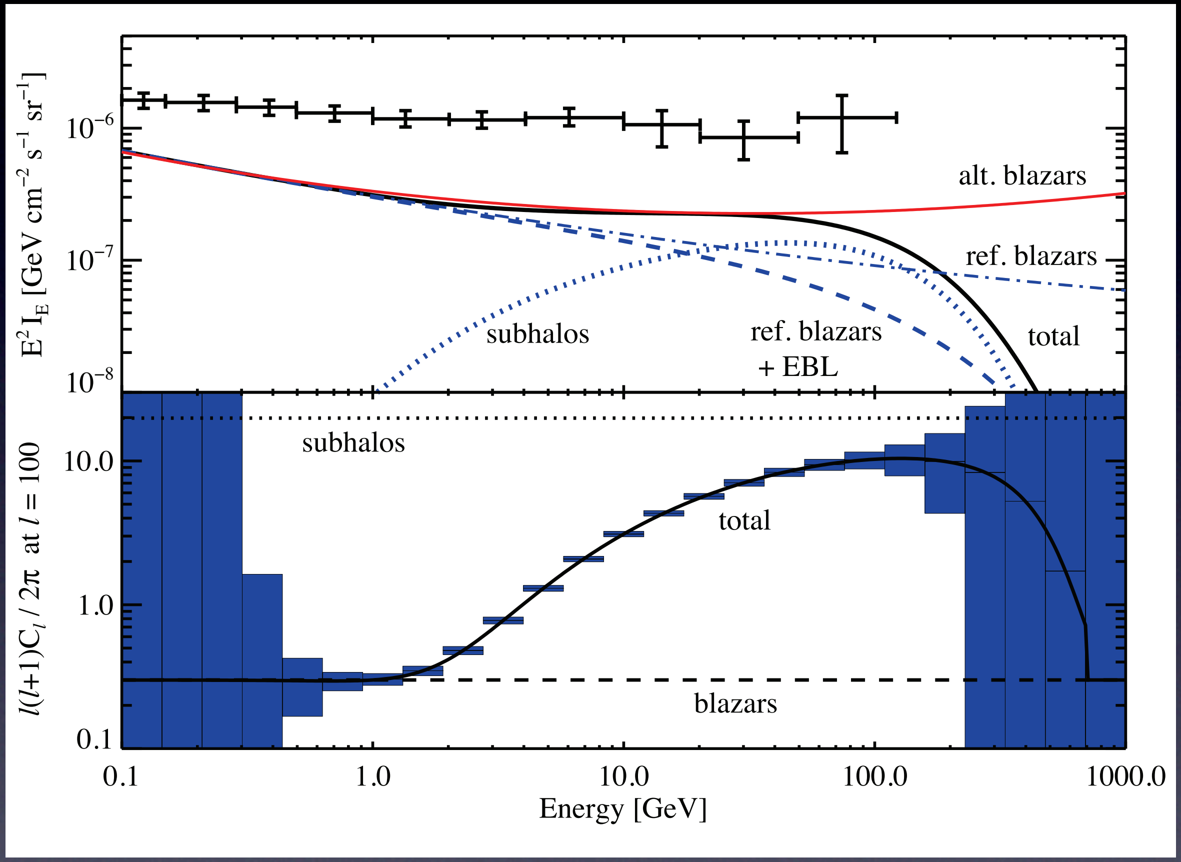
- the anisotropy energy spectrum of a SINGLE source population is flat in energy as long as the angular distribution (and hence angular power spectrum) of the emission from a single source population is independent of energy

- a transition in energy from an angular power spectrum dominated by the EGRB to one dominated by Galactic dark matter will show up as a modulation in the anisotropy energy spectrum

- this is a generally applicable method for identifying and understanding the properties of contributing source populations (NOT just for dark matter!)

The anisotropy energy spectrum at work

neutralino mass = 700 GeV



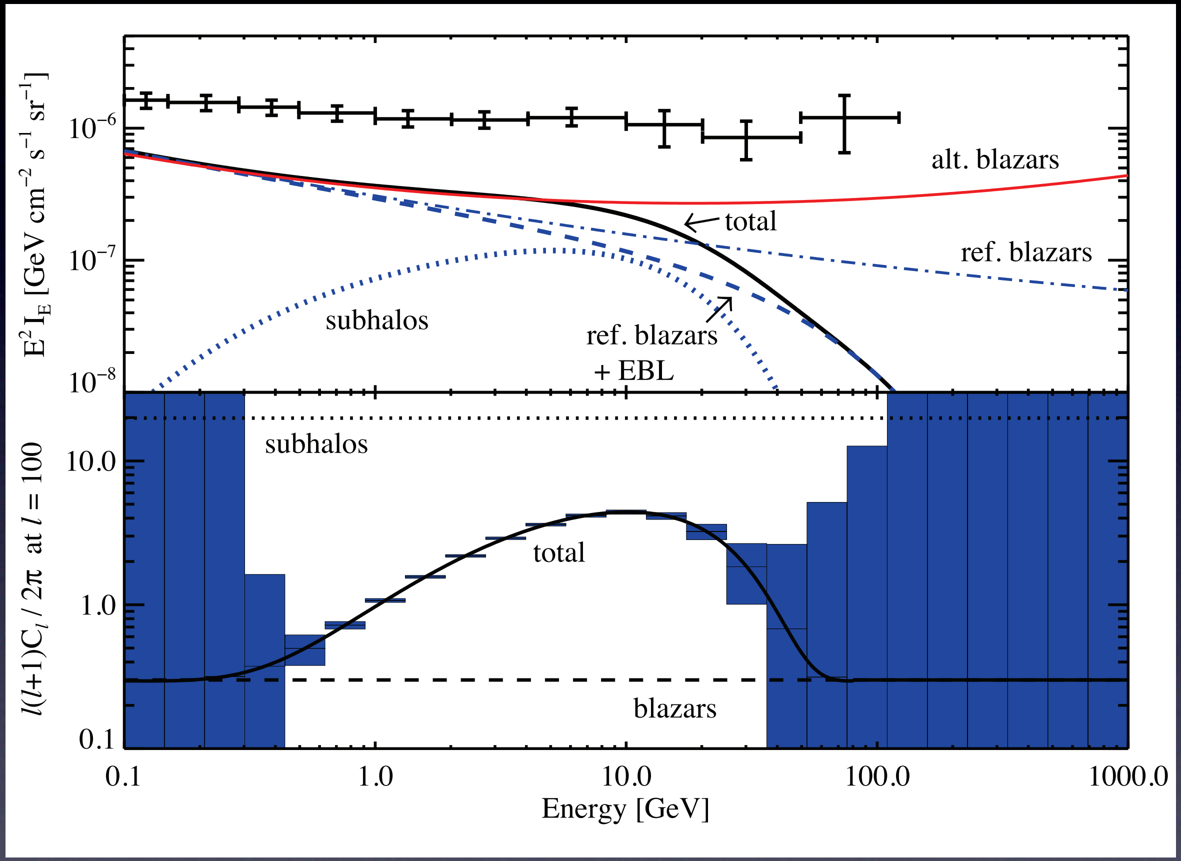
JSG & Pavlidou 2009

- 1-sigma errors
  - 5 years of Fermi all-sky observation
  - 75% of the sky usable
  - N_b/N_s =10 !!!!
- error bars blow up at low energies due to angular resolution, at high energies due to lack of photons

- Galactic dark matter dominates the intensity above ~20 GeV, but spectral cut-off is consistent with EBL attenuation of blazars
- modulation of anisotropy energy spectrum is easily detected!

The anisotropy energy spectrum at work

neutralino mass = 80 GeV



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  - 5 years of Fermi all-sky observation
  - 75% of the sky usable
  - N_b/N_s =10 !!!!
- error bars blow up at low energies due to angular resolution, at high energies due to lack of photons

- Galactic dark matter never dominates the intensity and spectral cut-off is consistent with EBL attenuation of blazars
- modulation of anisotropy energy spectrum is still strong!

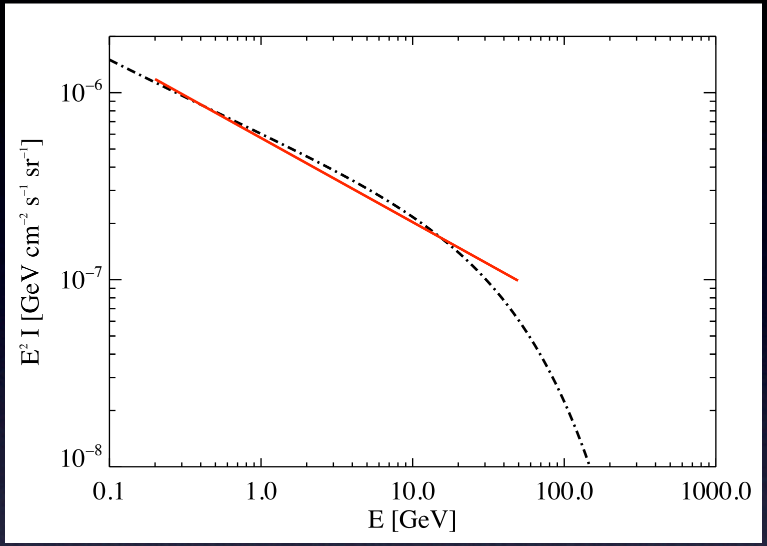
A simple test to find multiple populations

- we assume the large-scale isotropic diffuse (IGRB) is composed primarily of emission from blazars and dark matter
- we fix the anisotropy properties of both populations, fix the blazar emission to a reference model, and vary the dark matter model parameters (mass, cross-section, annihilation channel)
- we define a simple, 'model-independent' test criterion:

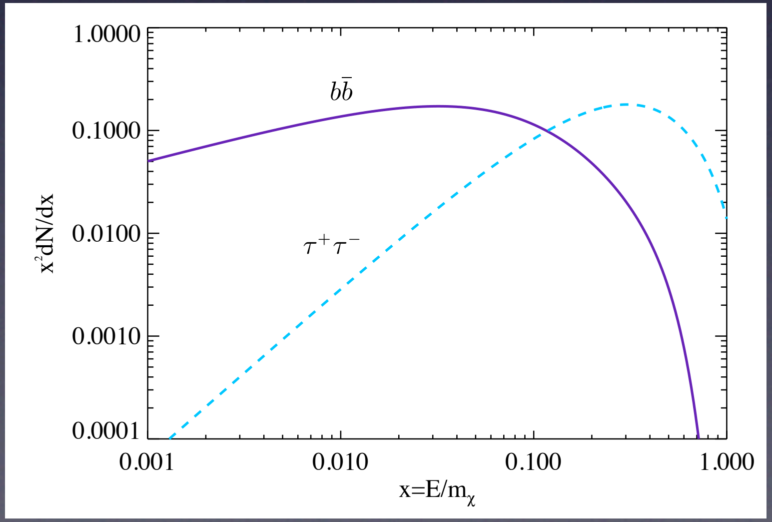
  is the anisotropy energy spectrum at E ≥ 0.5 GeV consistent with a constant value, equal to the weighted average of all energy bins?

- dark matter model is considered detectable if this hypothesis is rejected by a χ^2 test at the 3-σ level
- NB: this test is not optimized to find specific dark matter models; tailored likelihood analysis could significantly improve sensitivity!

reference blazar intensity spectrum



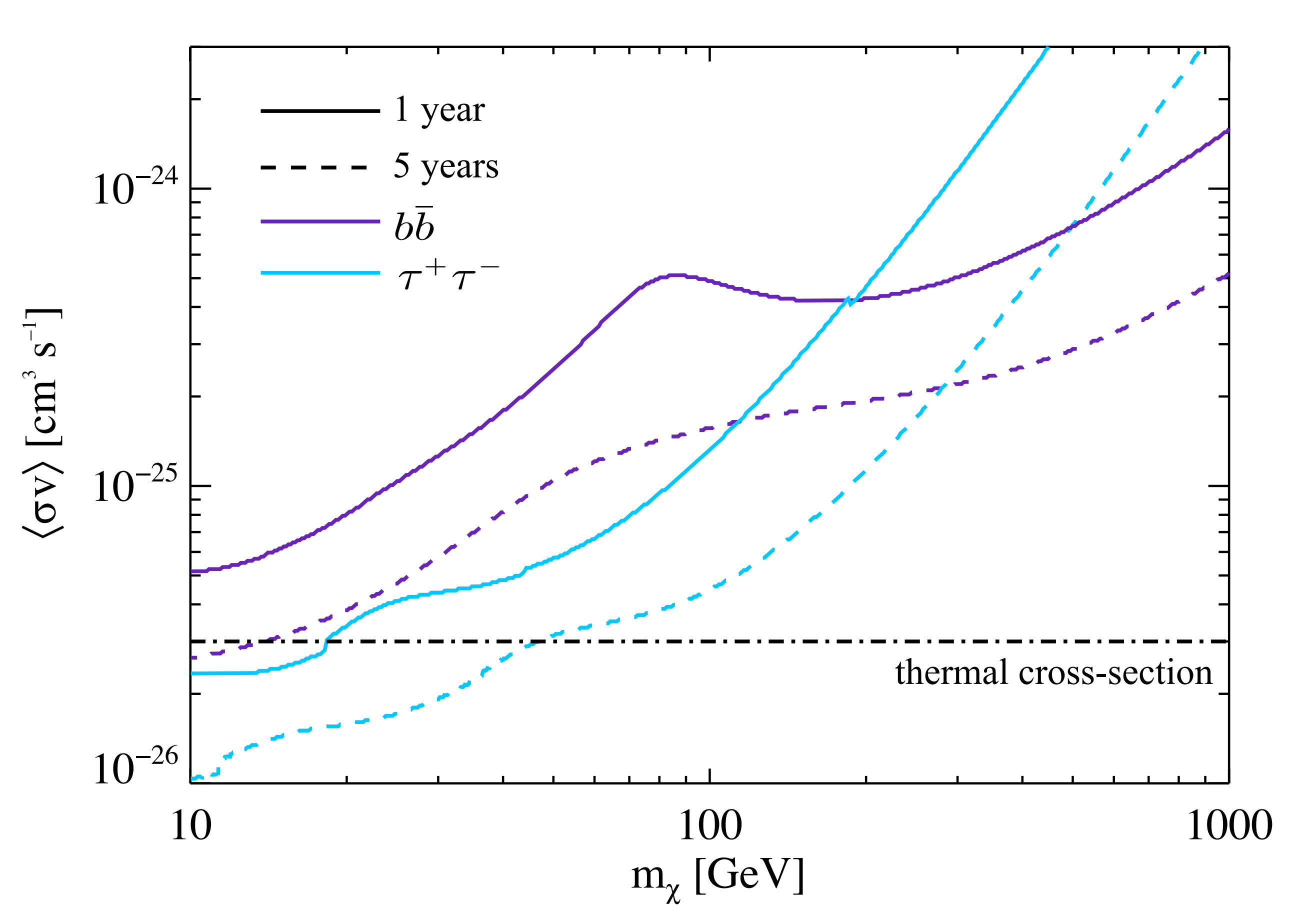
dark matter annihilation spectra



Hensley, JSG, & Pavlidou (2009)

Sensitivity of the anisotropy energy spectrum

- DM produces a detectable feature in the anisotropy energy spectrum for a substantial region of parameter space in this scenario
- technique could probe cross-sections close to thermal; extends the reach of current indirect searches
- NB: this test is highly sensitive to choice of test parameters (multipole, energy binning) and assumed dark matter and blazar angular power spectra amplitudes!



Hensley, JSG, & Pavlidou (2009)

dark matter models above the solid/dashed curves are detectable by this test!

Summary

- a modulation in the anisotropy energy spectrum robustly indicates a transition in energy in the spatial distribution of contributing source population(s)
- combining anisotropy and energy information can enable the detection of unresolved source populations that are subdominant in the intensity, such as dark matter, without requiring a firm prediction for the expected signal
- the anisotropy energy spectrum is sensitive to a large parameter space of dark matter models, and could extend the reach of current indirect dark matter searches