Methods and Prospects for Indirect Dark Matter Detection

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With much thanks to:

Stefano Profumo, Dan Hooper

Fermilab Graduate Student Talk Series

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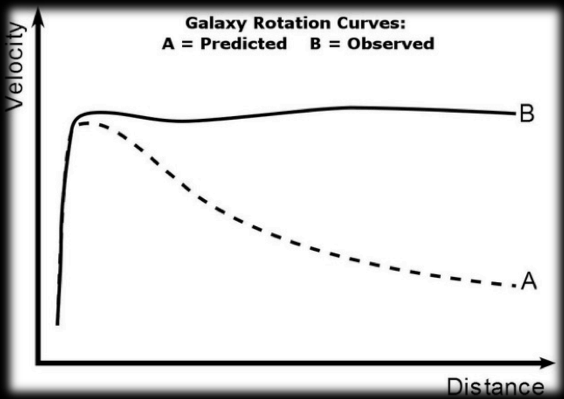
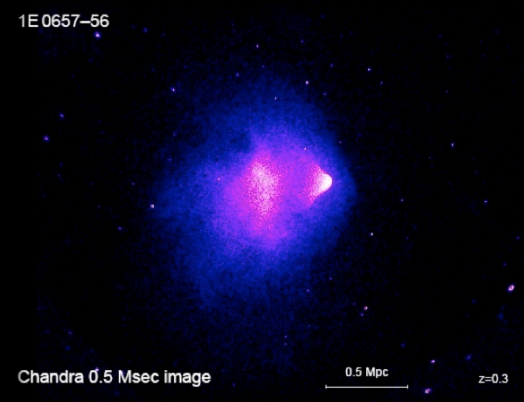
Dark Matter Astrophysics

Galactic Rotation Curves
Zwicky (1934), Rubin (1975)



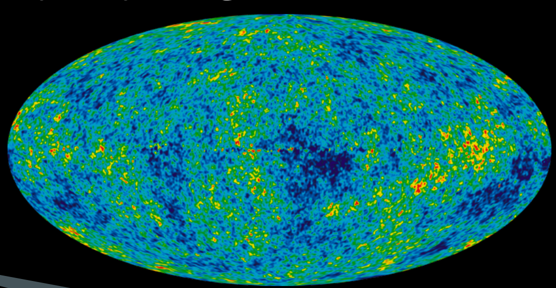


Bullet Cluster

8σ rejection of some modified gravity theories (2006)

Also:
- Baryon Acoustic Oscillations
- Gravitational Lensing
- Type IA Supernova
- Structure Formation
- Lyman-alpha Forest

Cosmic Microwave Background is consistent with ΛCDM Universe

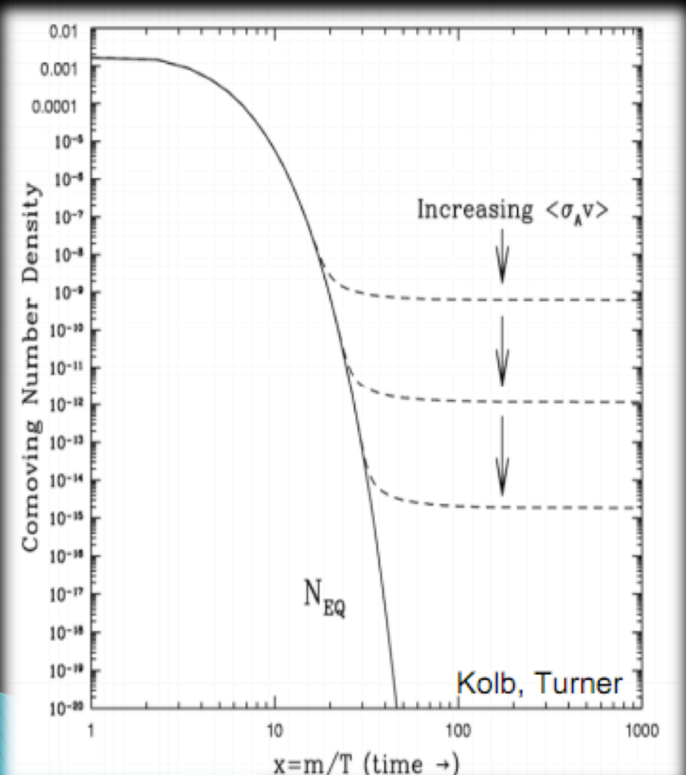


Take Home: Many *independent* astrophysical observations indicate the existence of gravitational dark matter

http://www.blandfill.com/wp-content/uploads/2009/12/Galactic-Rotation.jpg
http://upload.wikimedia.org/wikipedia/commons/e/ea/Bullet_cluster.jpg
http://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/WMAP_2010.png/800px-WMAP_2010.png

Dark Matter Particle Physics

- WIMP miracle predicts a particle of 100 GeV with weak interaction has correct relic density



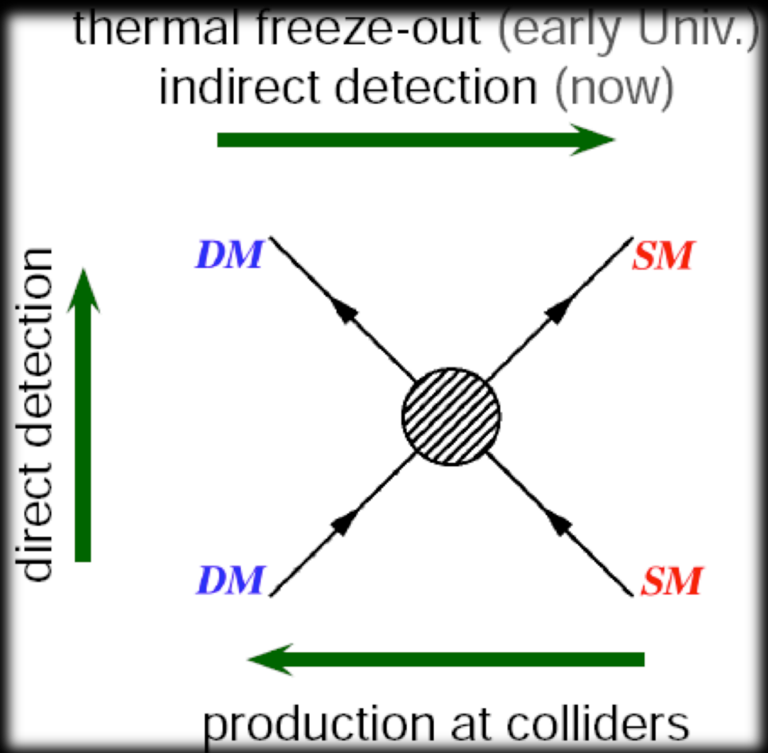
$$\Omega_h \propto \langle \sigma v \rangle^{-1} \propto \frac{M_X^2}{g_X^4}$$

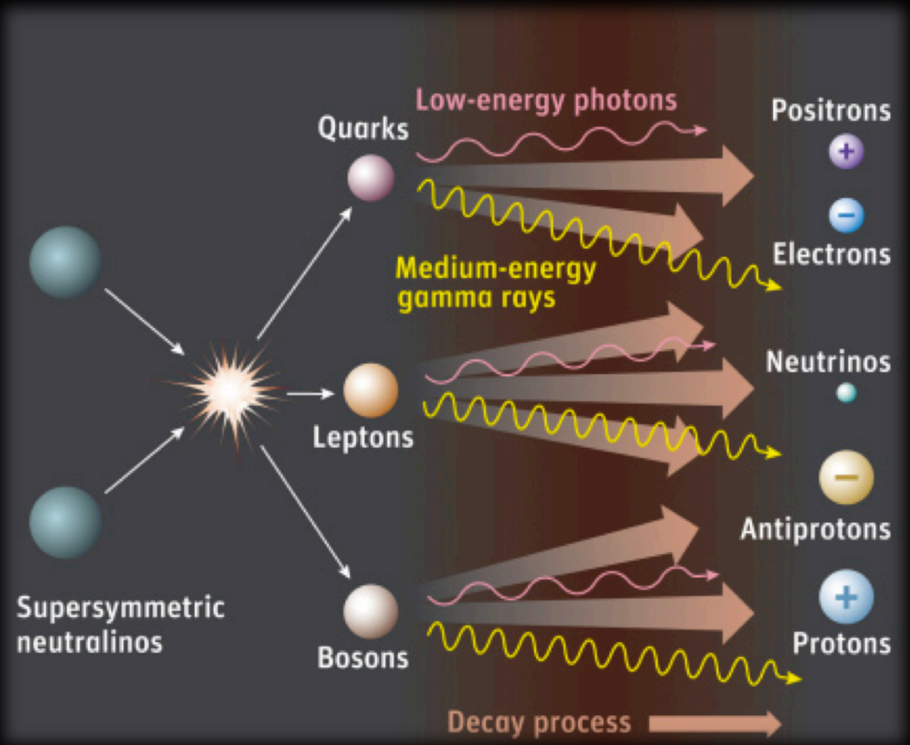
$M_X^2 = 100$ GeV

$g_X^4 = 0.6$

$=> \quad \Omega_h \sim 0.1$

Indirect vs. Direct Detection





http://www.mpi-hd.mpg.de/lin/images/research_theory5.png

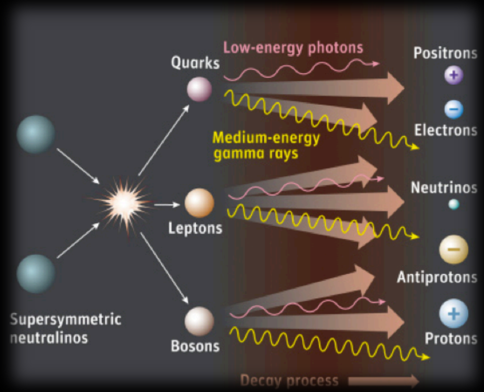
Pros and Cons of Indirect Detection

- Using the galaxy as the “detector” produces a large number of events:

$$8.47 \; x \; 10^{38} \; \frac{ann}{s} \; \left(\frac{100\ GeV}{M_{DM}}\right)^2 \; \left(\frac{<\sigma v>}{3 \; x \; 10^{-26} \frac{cm^3}{s}}\right)$$

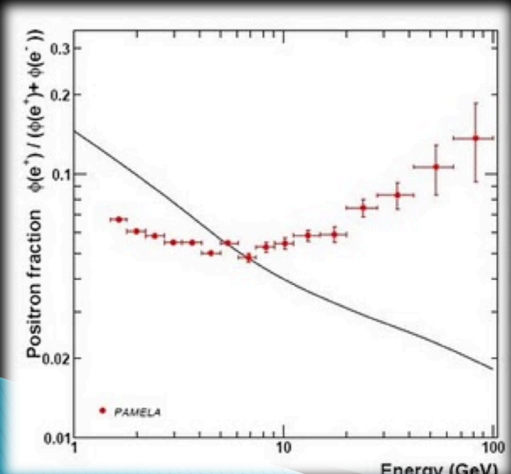
- However no single dark matter event is separable from myriad astrophysical events
- These astrophysical backgrounds are highly uncertain
- Take Home: The name of the game is differentiating dark matter from astrophysics – NOT in observing a dark matter signal

Potentially Observable Signals



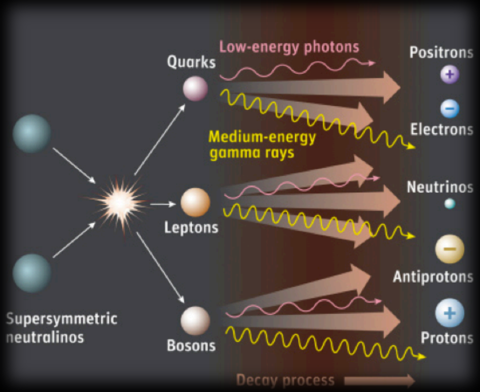
- Can detect the charged decay products themselves (PAMELA, AMS, etc.)
  - **But** are isotropic, so we lack spatial information

$$r_g = 7.65 \times 10^{-7}\ pc \left(\frac{E}{1\ GeV}\right)\left(\frac{1}{Z}\right)\left(\frac{1\mu G}{B}\right)$$



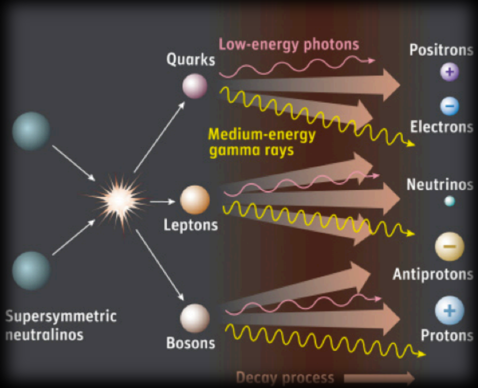
Pamela e^+/e^- Ratio

Potentially Observable Signals

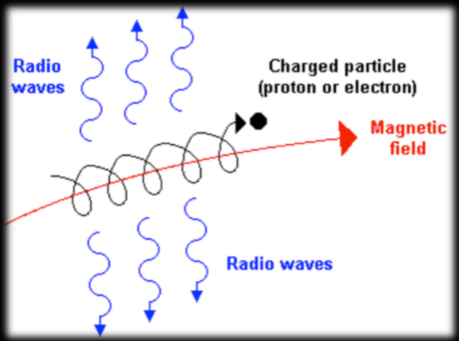


- Can detect the neutral decay products
  - γ-rays
  - Neutrinos
- Angular information is conserved

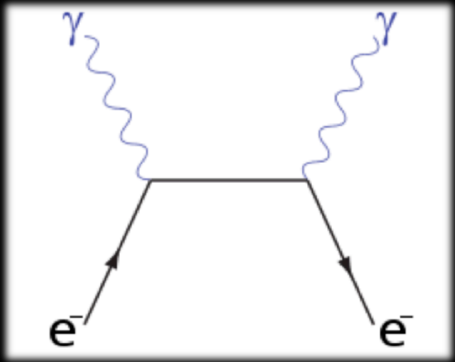
Potentially Observable Signals



- Can detect interactions between the charged annihilation products and the Galactic medium



  - Synchrotron Radiation
  - Inverse Compton Scattering



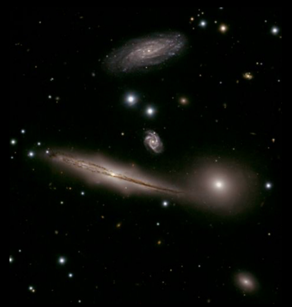
- Partial conservation of angular information

Where Would we look for Dark Matter? (the incomplete list)

- Galactic Center
  - + Relatively Nearby
  - + Large Dark Matter Density
  - – Huge Astrophysical Uncertainties

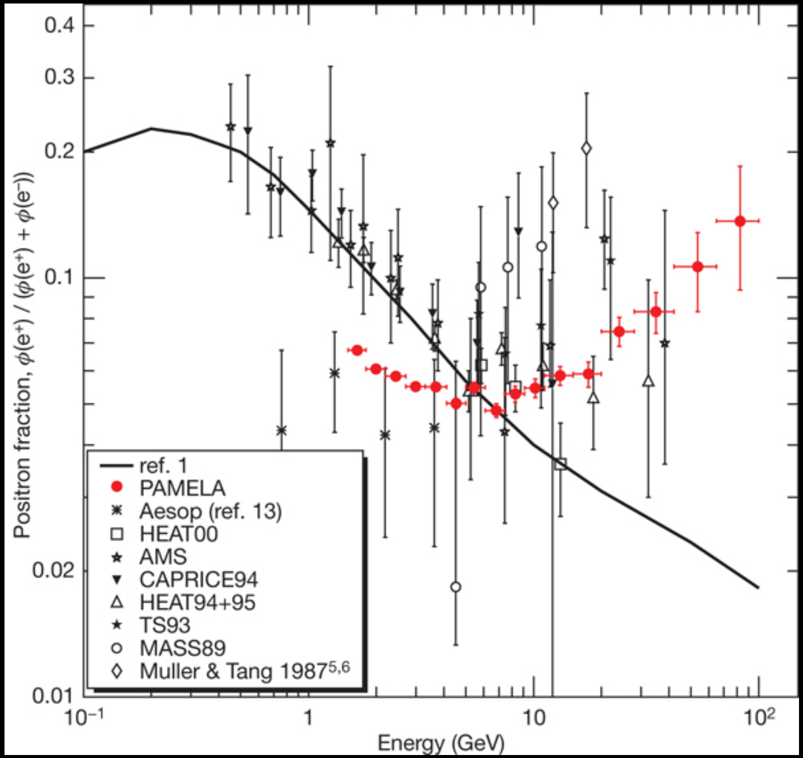
- Dwarf Galaxies
  - + Very small astrophysical background
  - – Smaller Dark Matter Flux
  - – ICS and Synchrotron radiation weak

- Galaxy Clusters
  - + Largest dark matter densities in universe
  - – Very distant, thus local flux may still be small

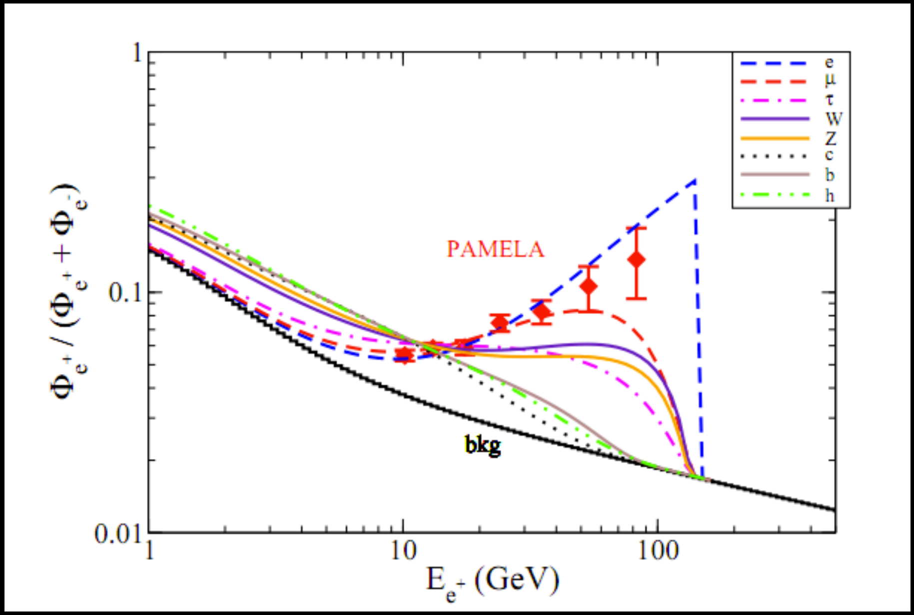


Results (Charged Particles)

PAMELA Positron Excess



Dark Matter?

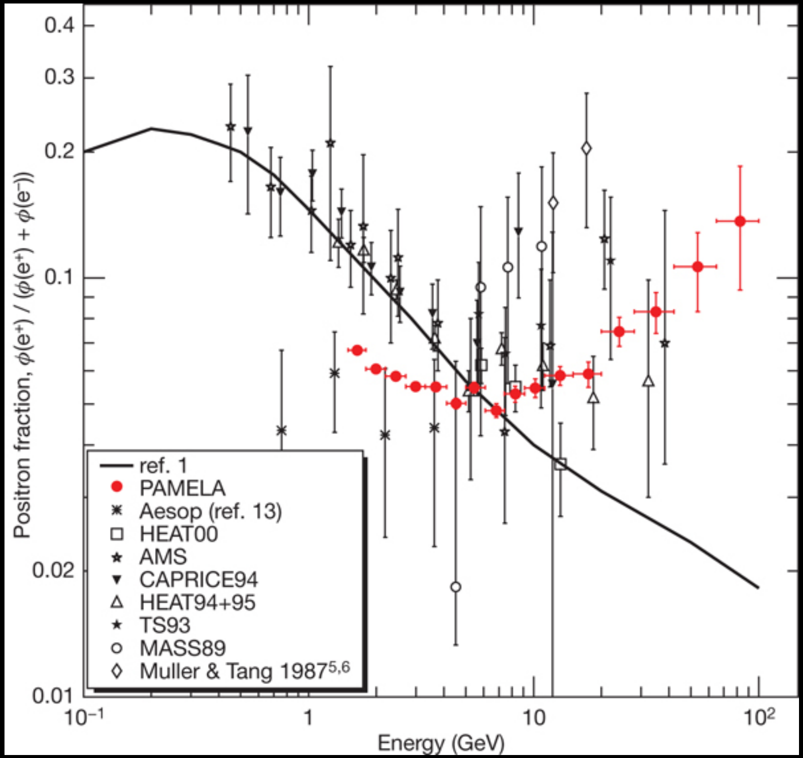


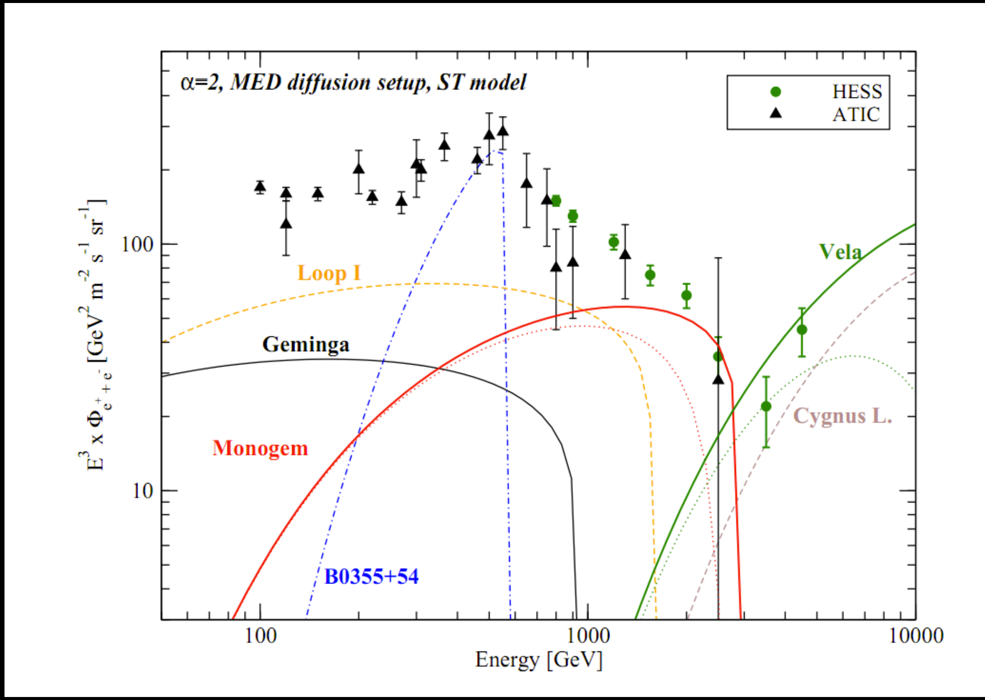
Barger et al. (2009)

Results (Charged Particles)

PAMELA Positron Excess

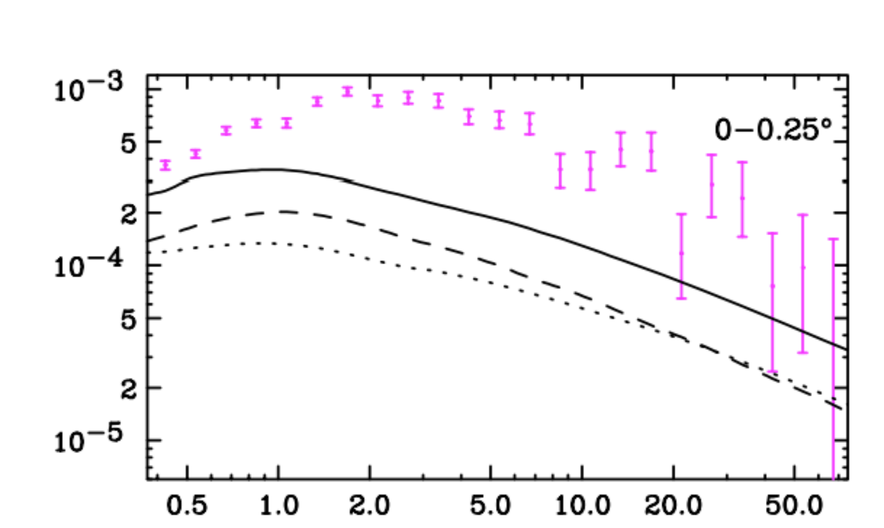
Or not?





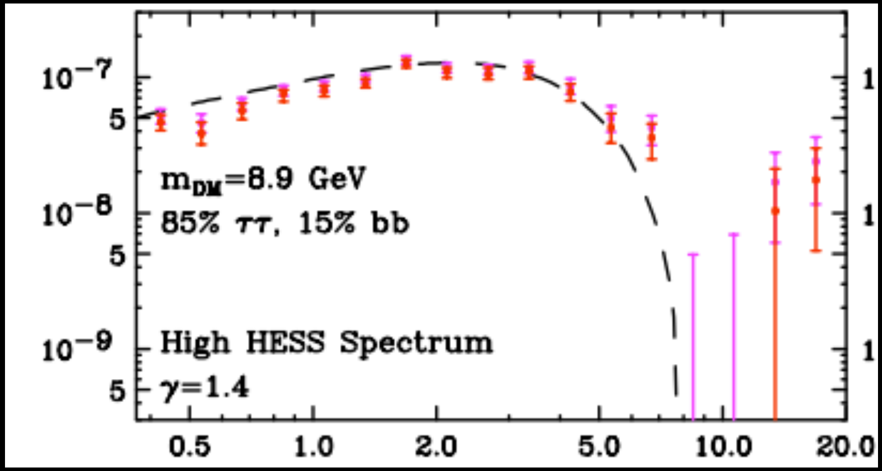
Profumo (2008)

Results (Gamma-Rays)

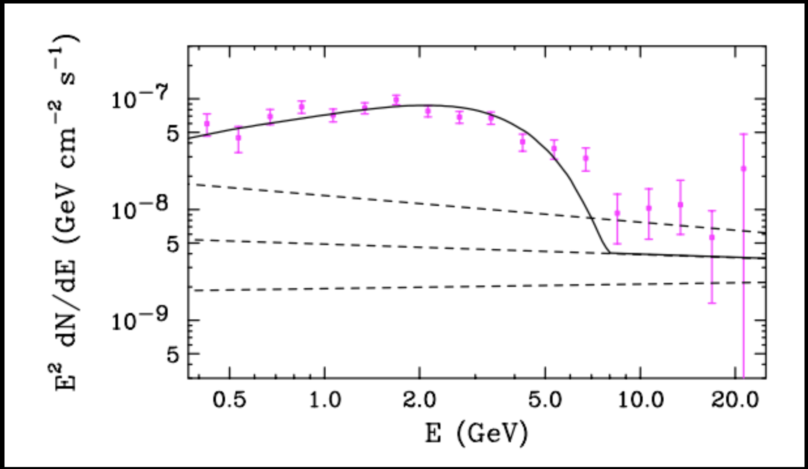


Hooper & Goodenough (2010)

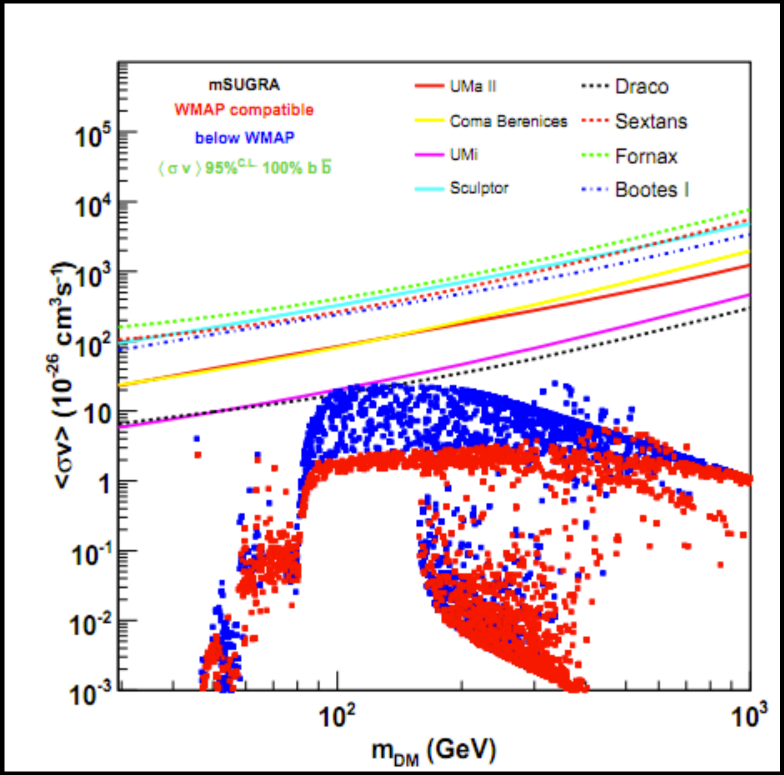
Dark Matter?

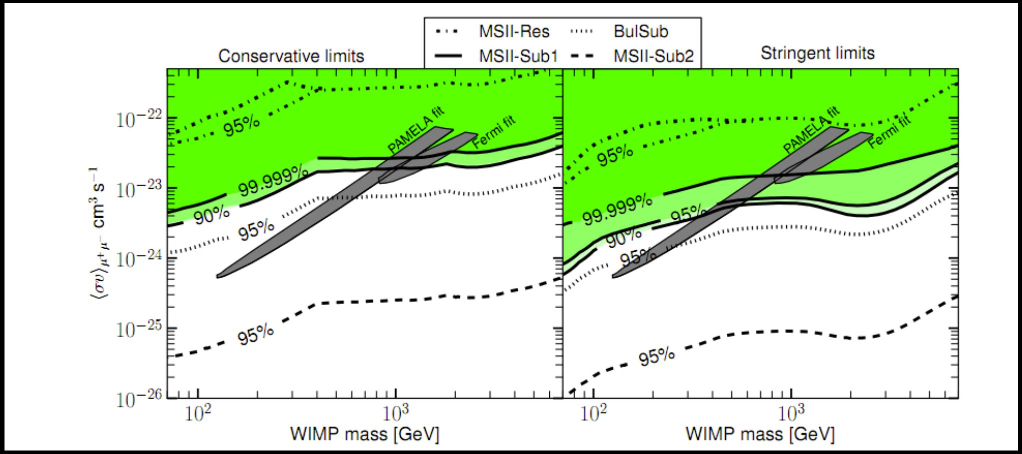


Or the galactic center?



Results (Gamma-Rays)



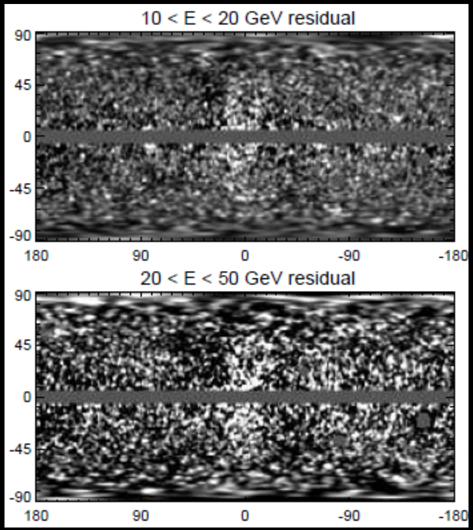


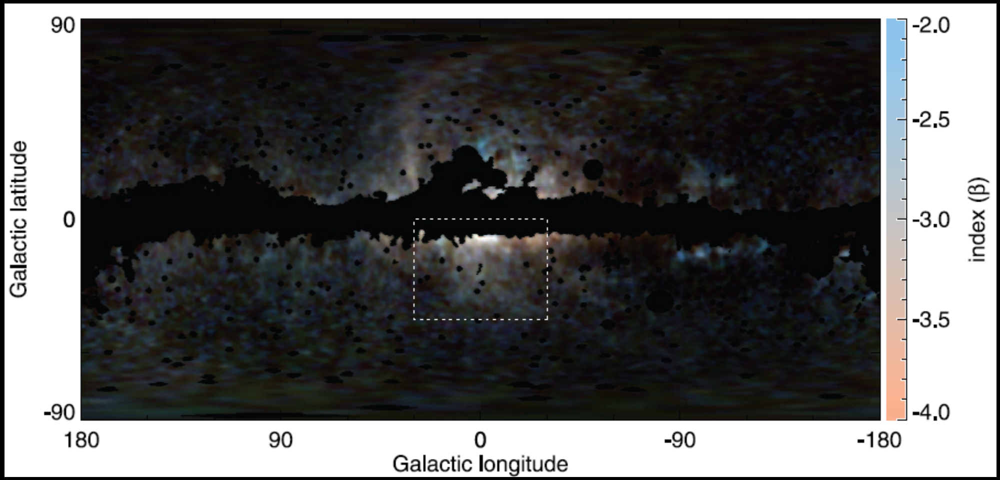
Extragalactic Diffuse

Dwarf Galaxies

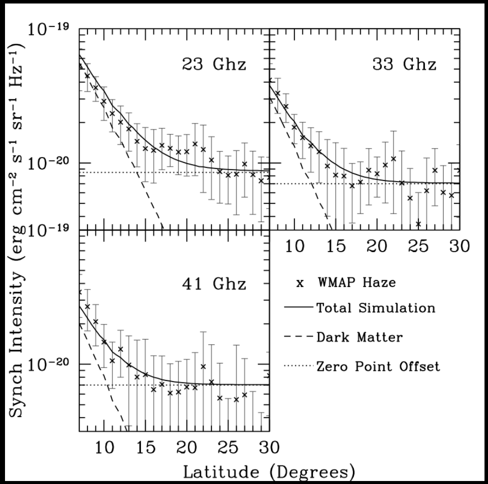
The Fermi Collaboration (2010)

Results Indirect Detection





"Fermi Bubbles" – Circular bubbles above and below the galactic center 2-50+ GeV



"WMAP Haze" – Excess of Synchrotron Radiation from below the galactic center with approximately spherical symmetry (23 – 41 Ghz)

Dobler & Finkbeiner (2010)
Dobler et al. (2007)
Hooper & Linden (2010)

Conclusions

- The "game" in indirect detection is not building detectors large enough to observe the products of dark matter annihilation – it's separating these signals from astrophysical signals

- This requires an ensemble of multi-component and multi-messenger observations.

- However, we are quickly closing in on the cross-sections of thermal relic WIMPs