Search for Dark Matter with Fermi

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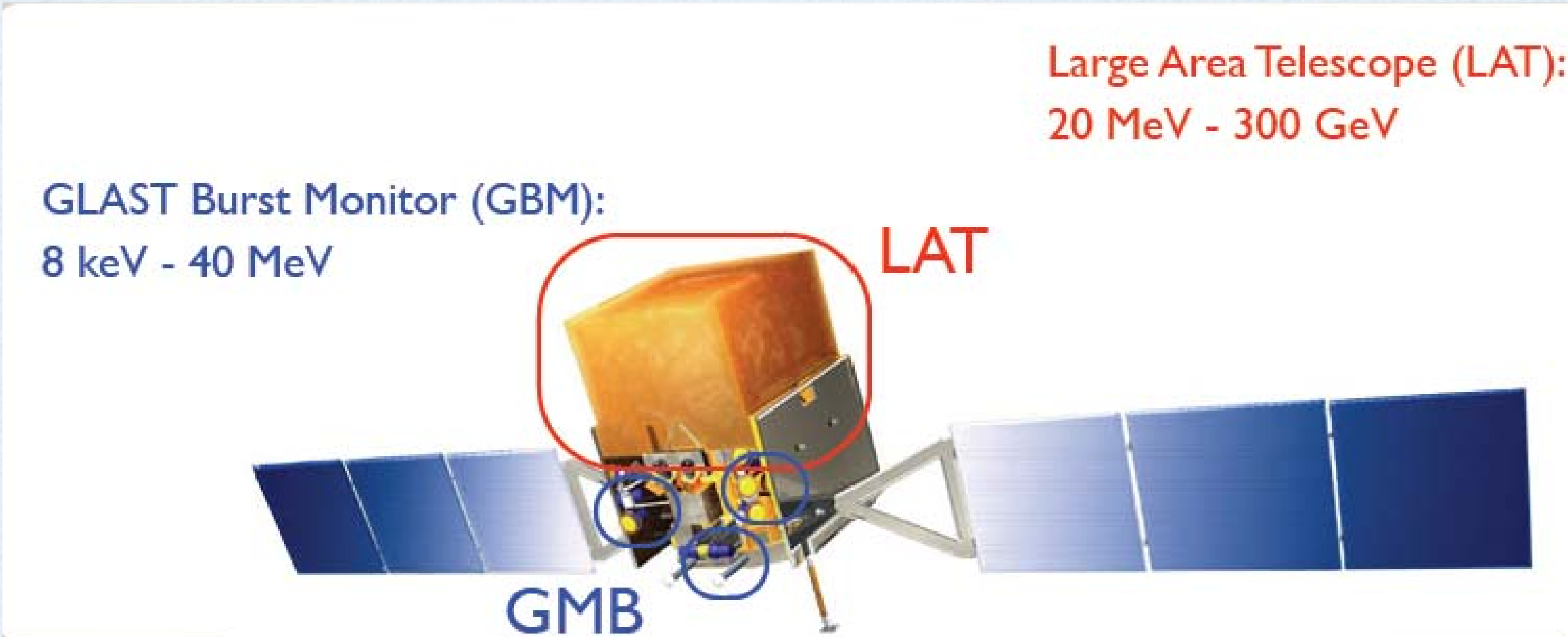
for the Fermi Collaboration

AXION-WIMP 2010
Zurich University
July 5 2010

Fermi observatory

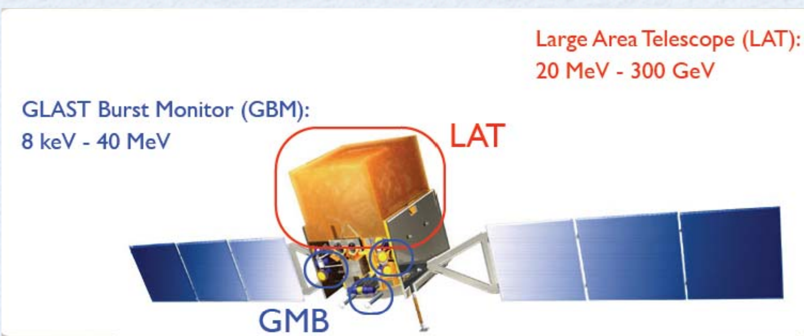


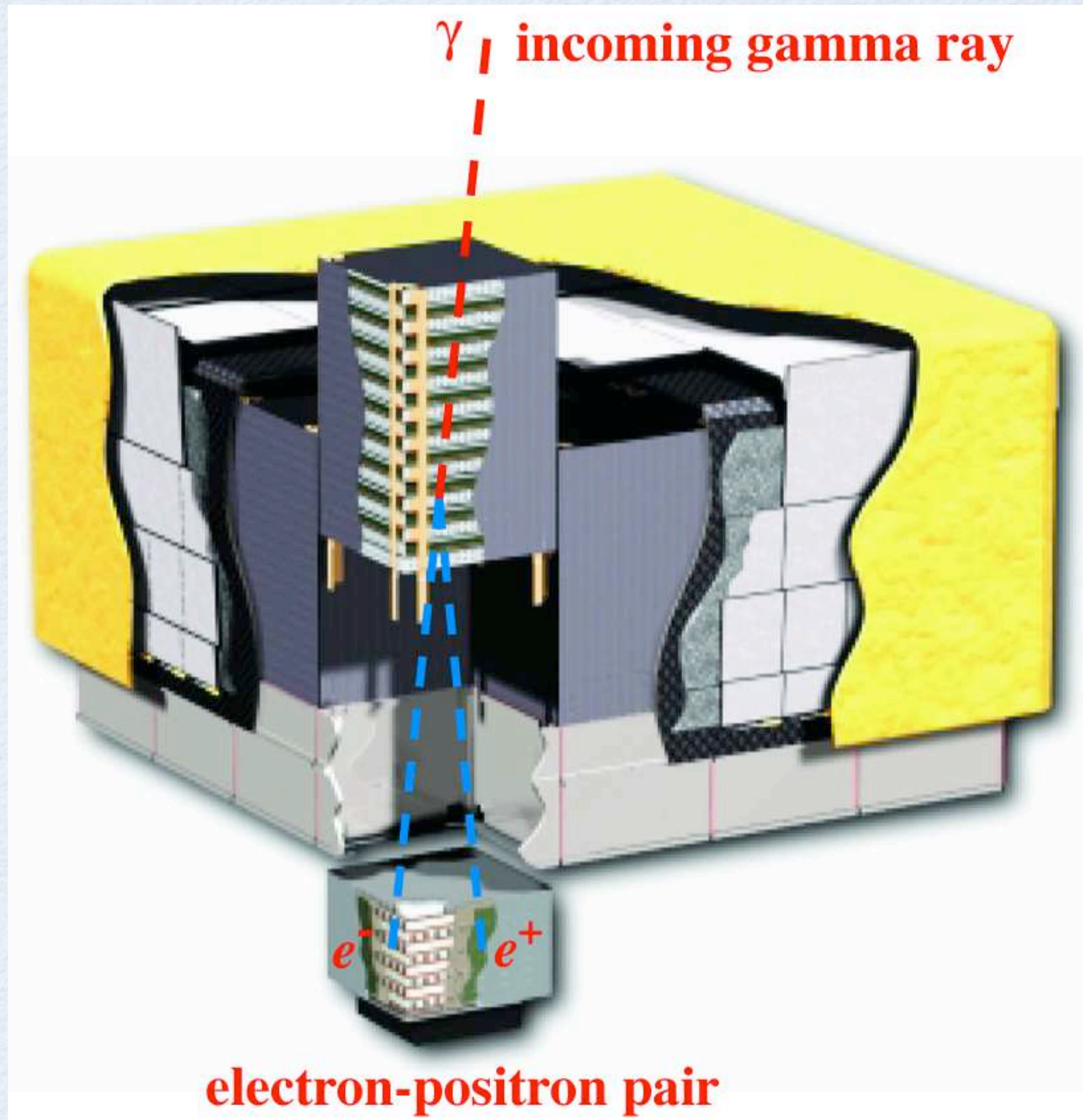
- Launched June 11, 2008
- Full sky survey
- Angular resolution about 0.1 deg. above 10 GeV
- FoV about 2.4 sr.
- Excellent charged particle background rejection

Fermi observatory

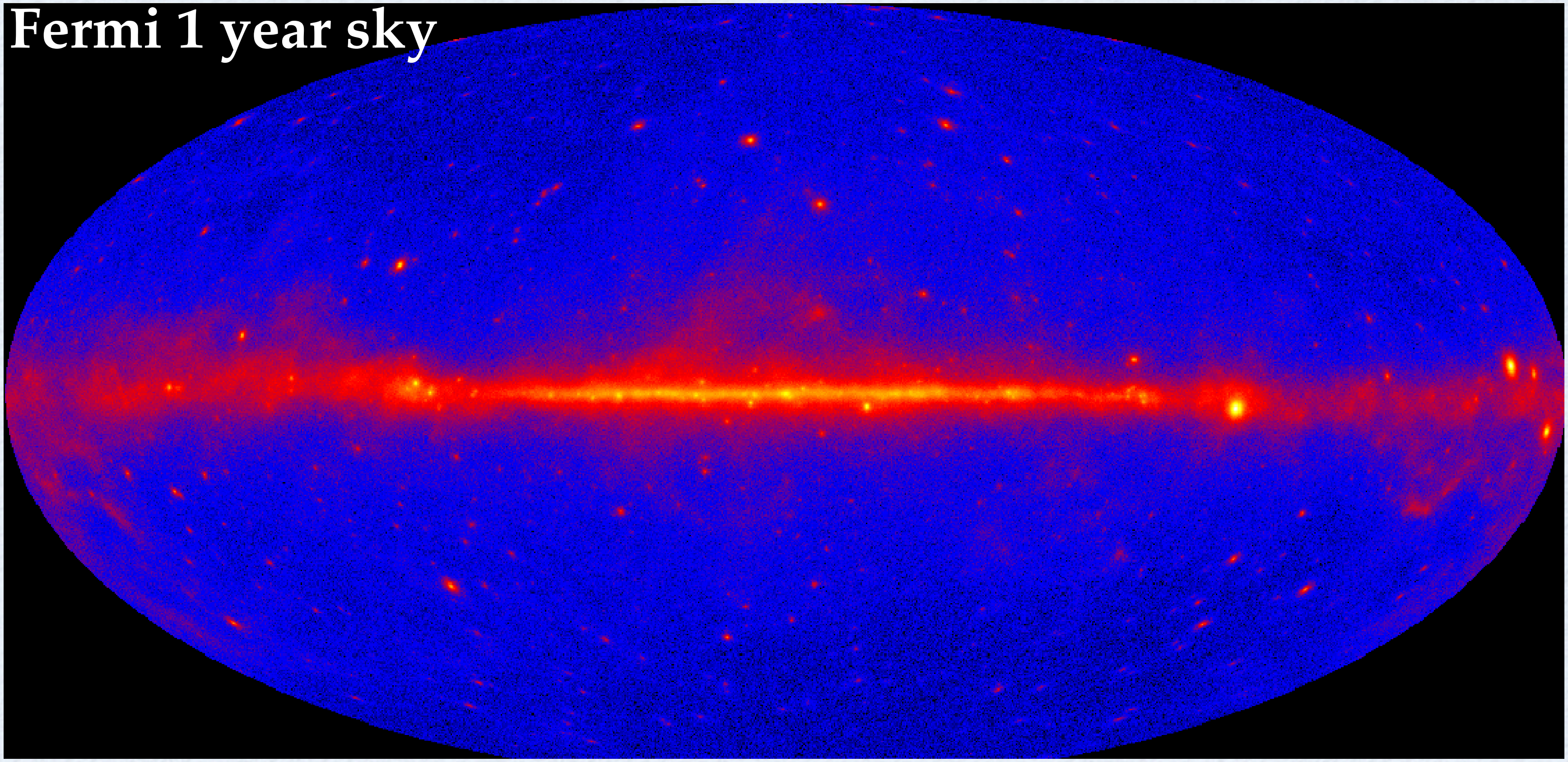
Atwood et al., LAT

Astrophys.J.697:1071-1102,2009





Fermi 1 year Sky



- 1451 sources
- 57% positionally associated
- 241 show variability

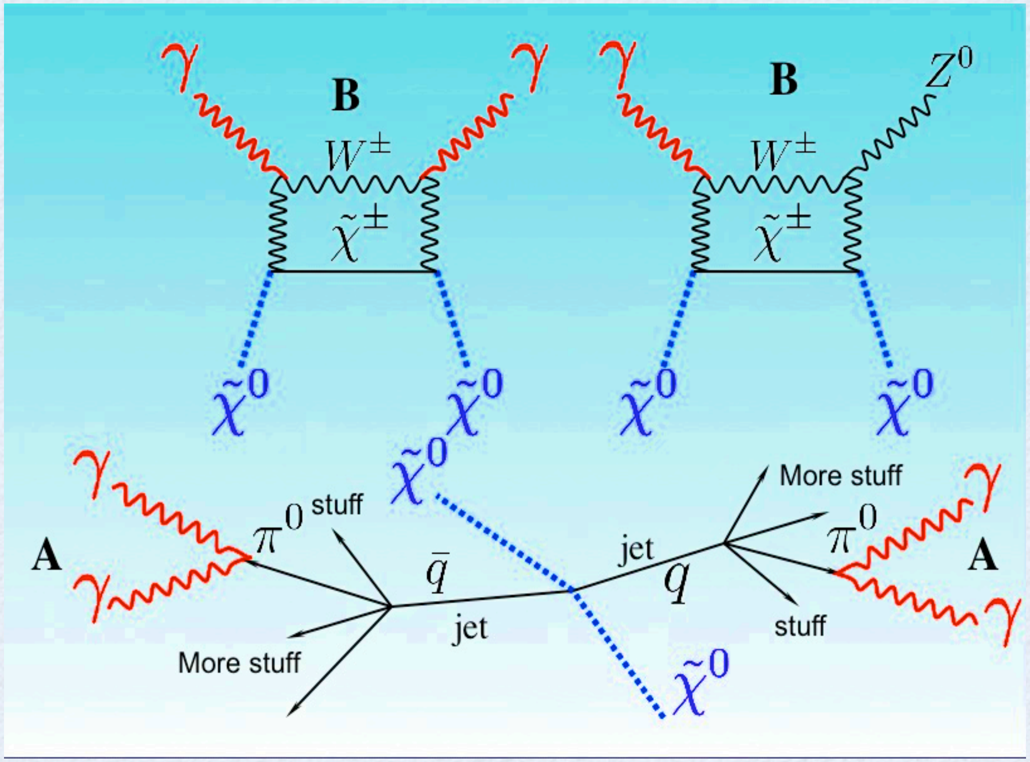
Photons from WIMP Annihilation

Flux = Particle Physics x Astrophysics

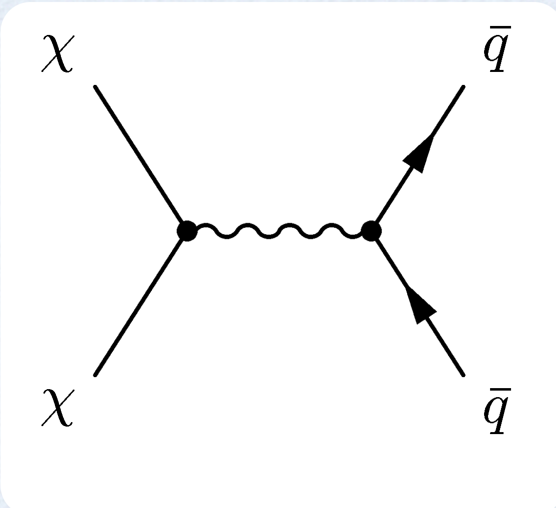
$$\frac{dN_\gamma}{dAdt} = \frac{1}{4\pi}\mathcal{P}[\langle\sigma v\rangle, M_\chi, dN_\gamma/dE]\mathcal{L}(\rho_s, r_s, \mathcal{D}).$$

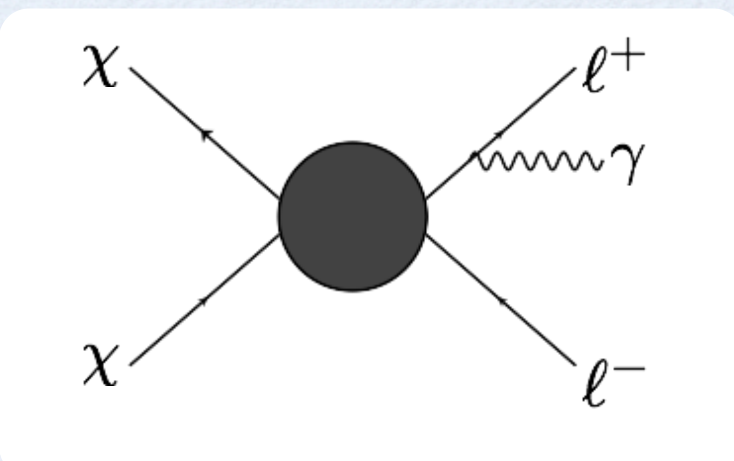
$$\mathcal{L} = \int_0^{\Delta\Omega}\left\{\int_{\mathrm{LOS}}\rho^2[r(\theta, \mathcal{D}, s)]ds\right\}d\Omega,$$

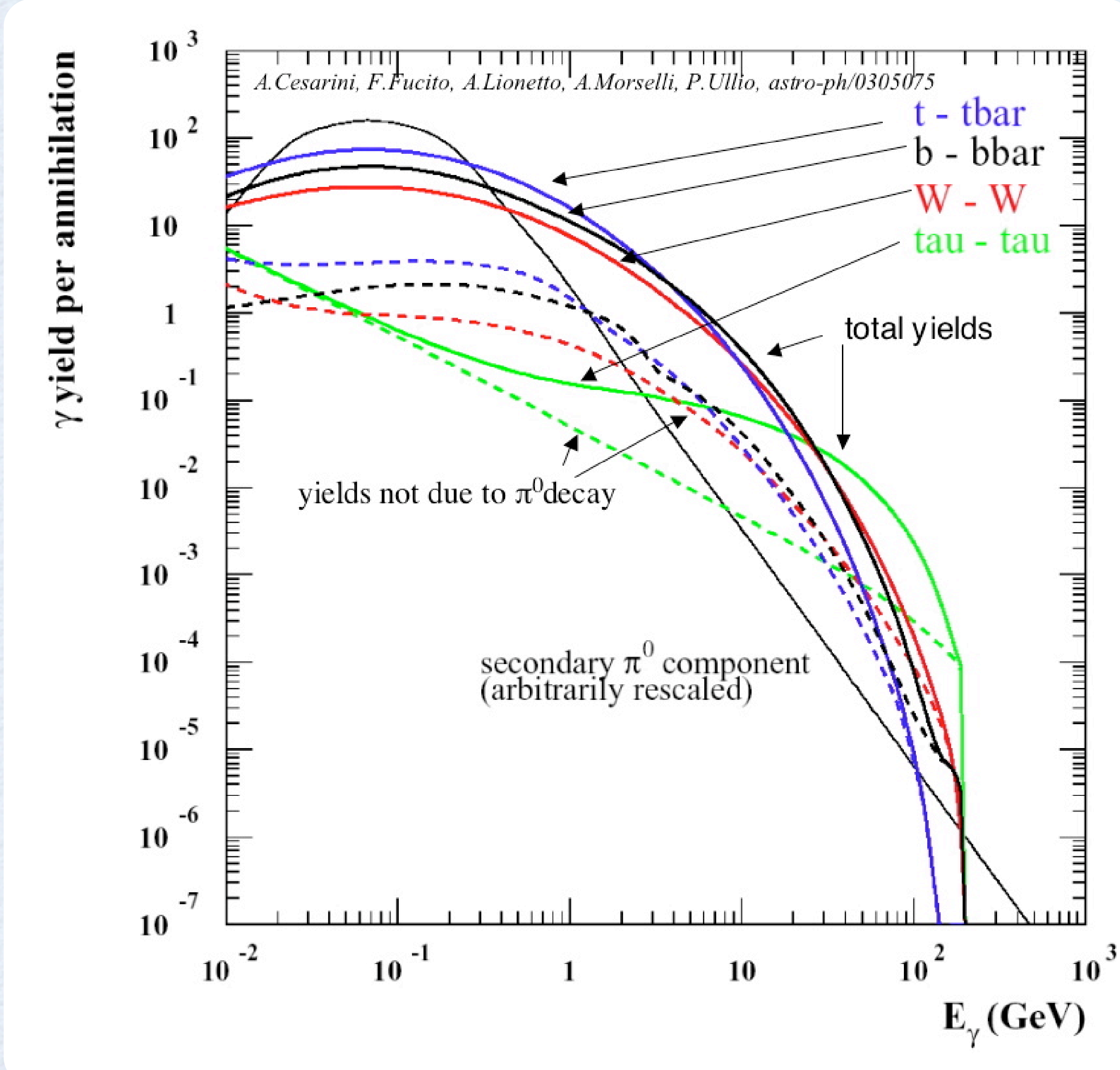
Relic abundance set by annihilation cross section



Gamma-ray yield from WIMPs





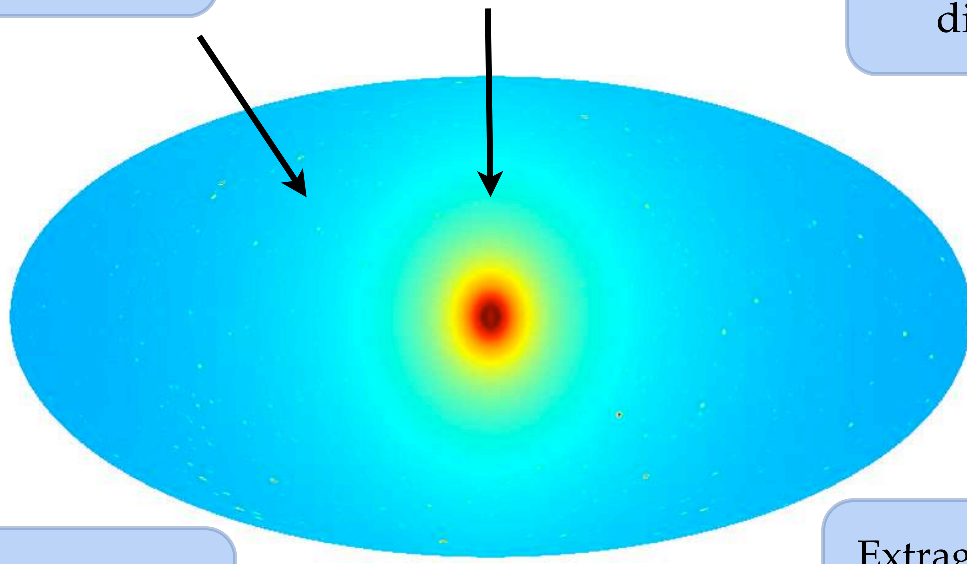


Search Strategies

Satellites: Low bkgd, good source id, low statistics

Galactic center: Good statistics, source confusion/ diffuse backgrounds

Halo: Good statistics but diffuse backgrounds

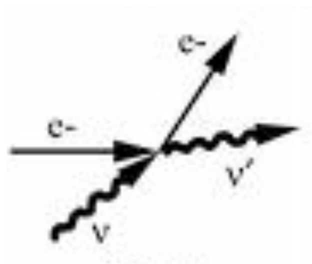


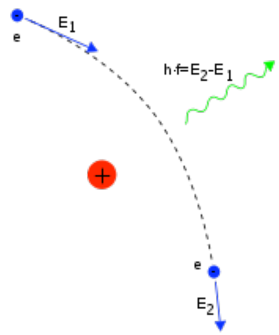
Spectral lines: Good source id, low statistics

Extragalactic: Good statistics, diffuse bkgds and astrophysics

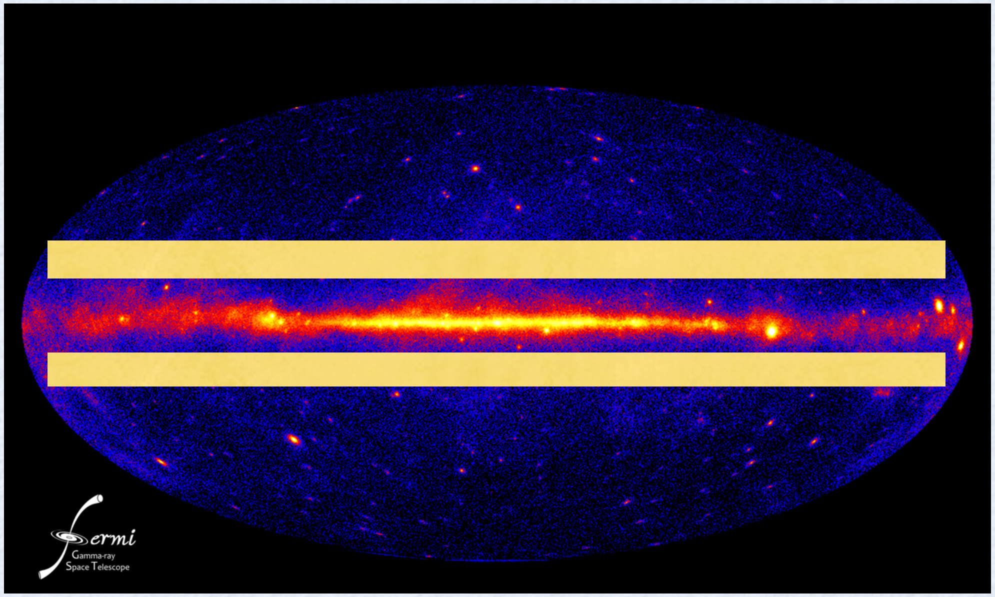
Galaxy clusters: Low backgrounds but low statistics

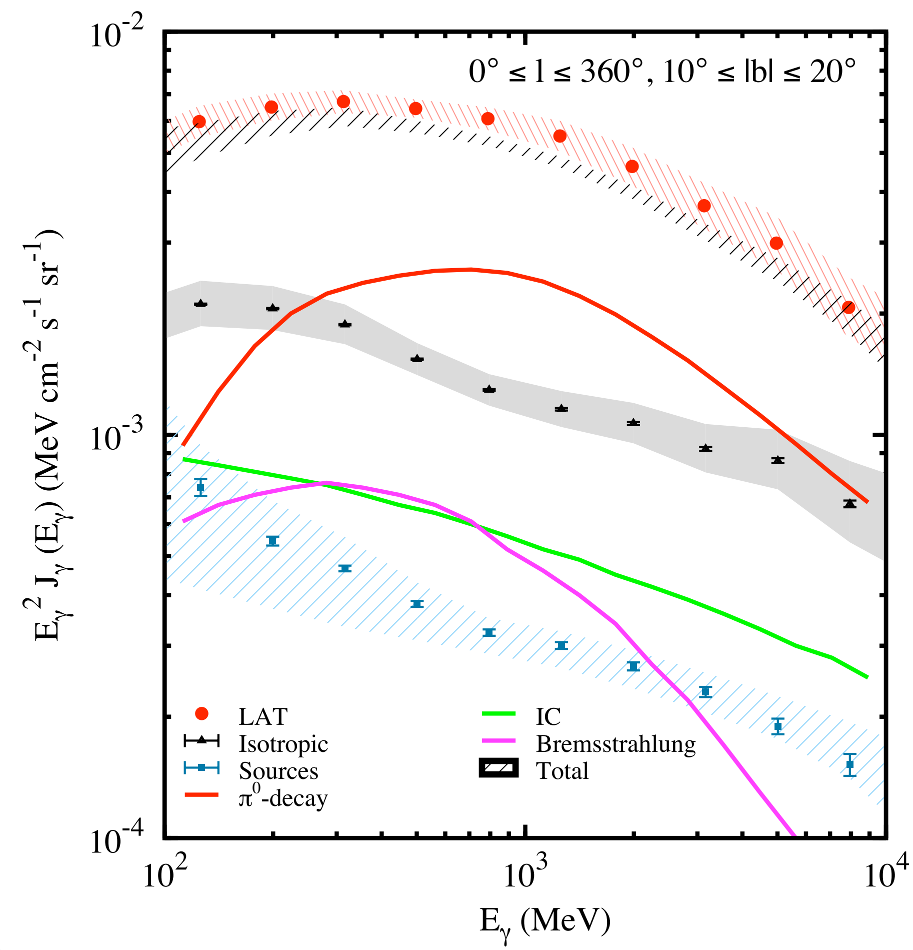
Diffuse Galactic Emission





$$\pi^0 \rightarrow \gamma\gamma$$

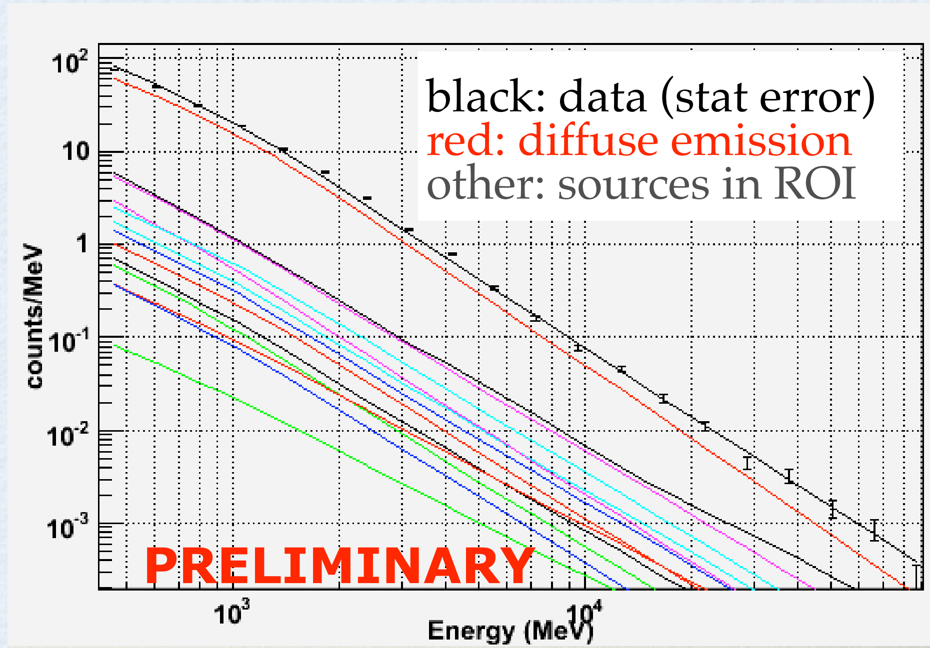


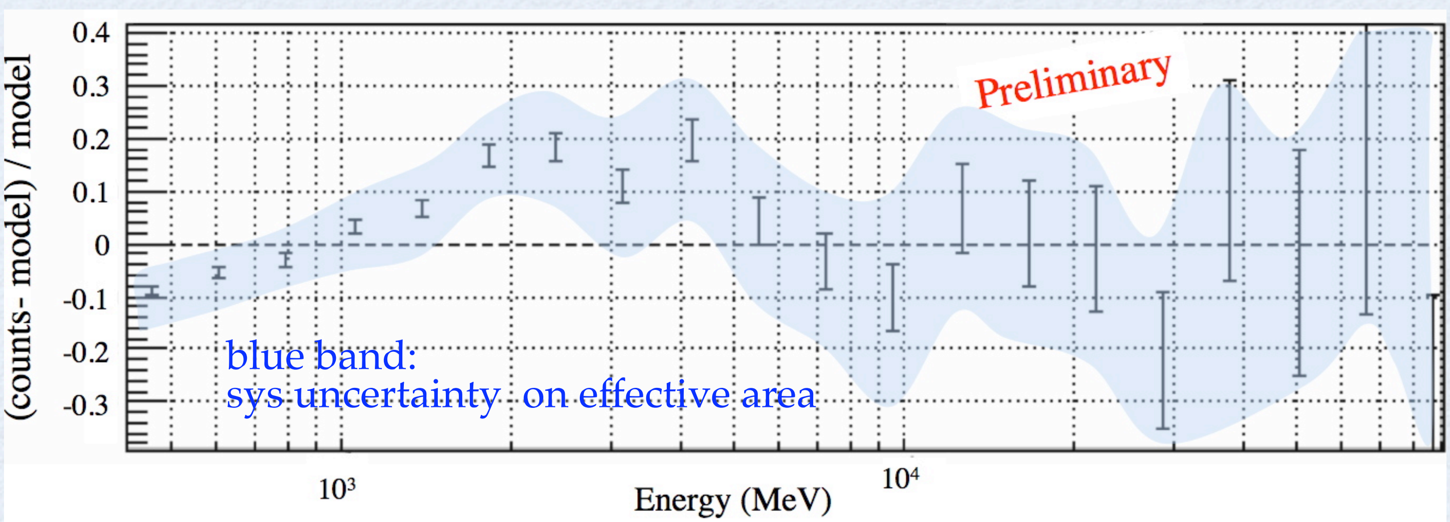


Fermi collaboration, PRL 2009

Search for DM in the GC

- Expected steep central profile and close proximity
- Source confusion: near or along the line of sight to the GC
- Diffuse emission modeling: challenge to model





Vitale & Morselli,
Fermi collaboration
arXiv:09123828

Lines from Galaxy: Theory

- Dark Matter annihilates to gamma-X

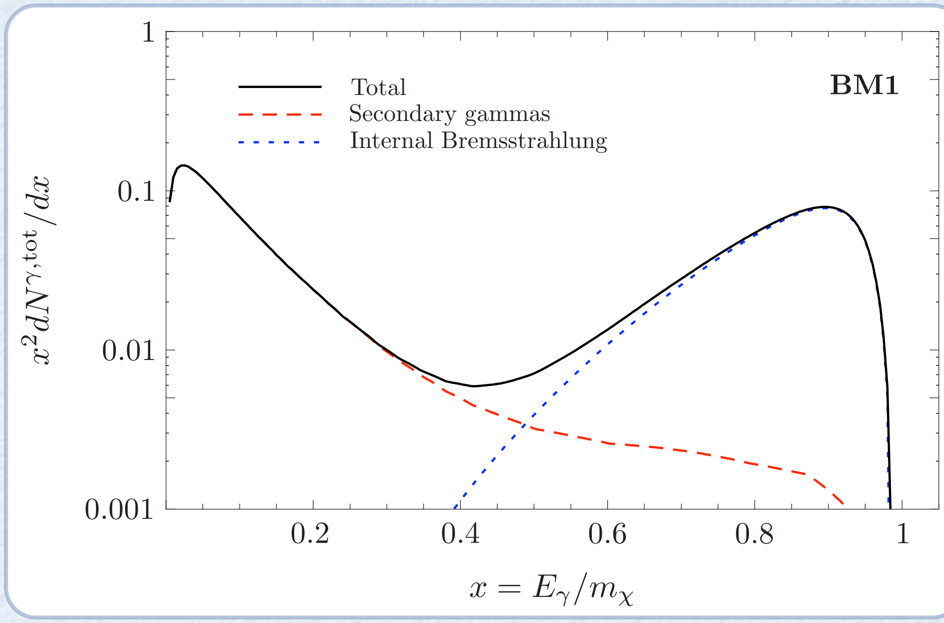
$$E_\gamma = m_\chi \left(1 - \frac{m_X^2}{4m_\chi^2}\right)$$

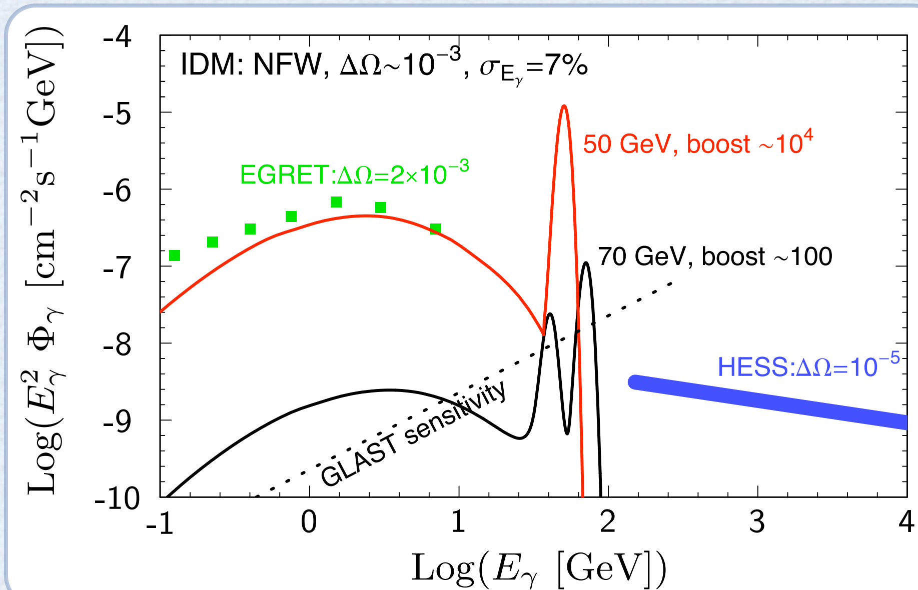
- Neutralino branching ratios in the range 10^{-3} -- 10^{-5}

- Dark Matter Models with enhanced lines emission may be visible to Fermi (e.g. Gustafsson et al. PRL 2007)

- Photons from radiative corrections may also give significant high energy photons

- Decay of gravitinos also may give visible lines (Ibarra and Tran, 2007)

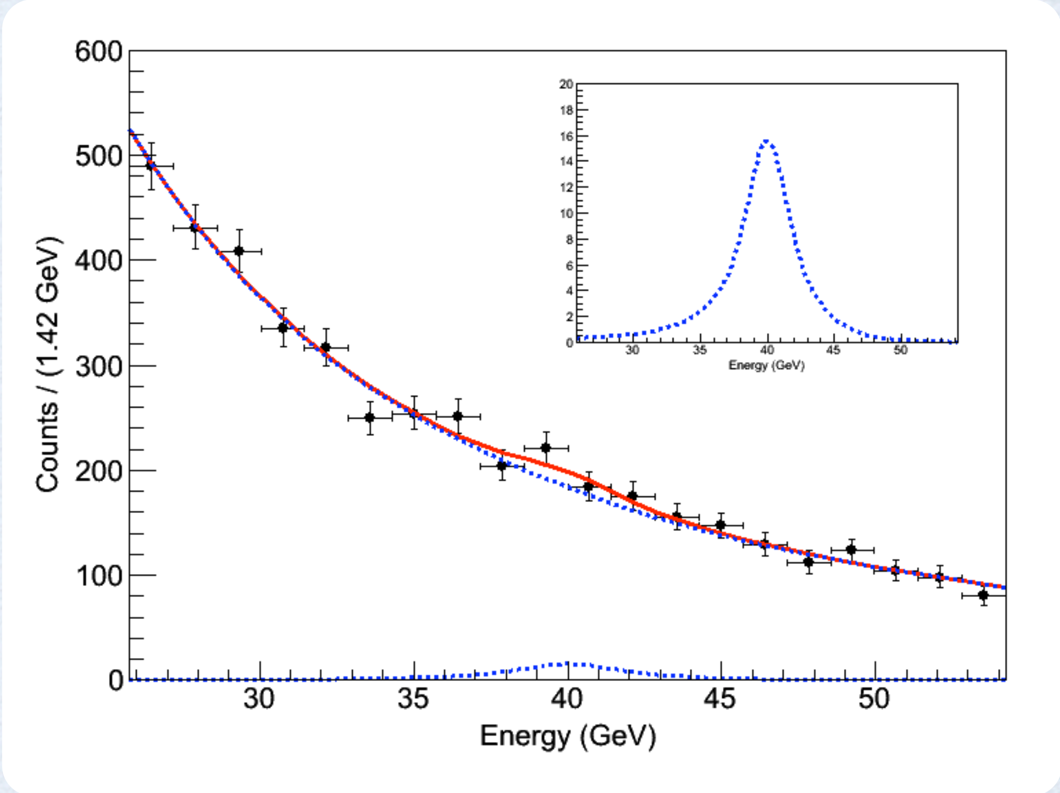




Fermi Constraints on Lines from Galaxy

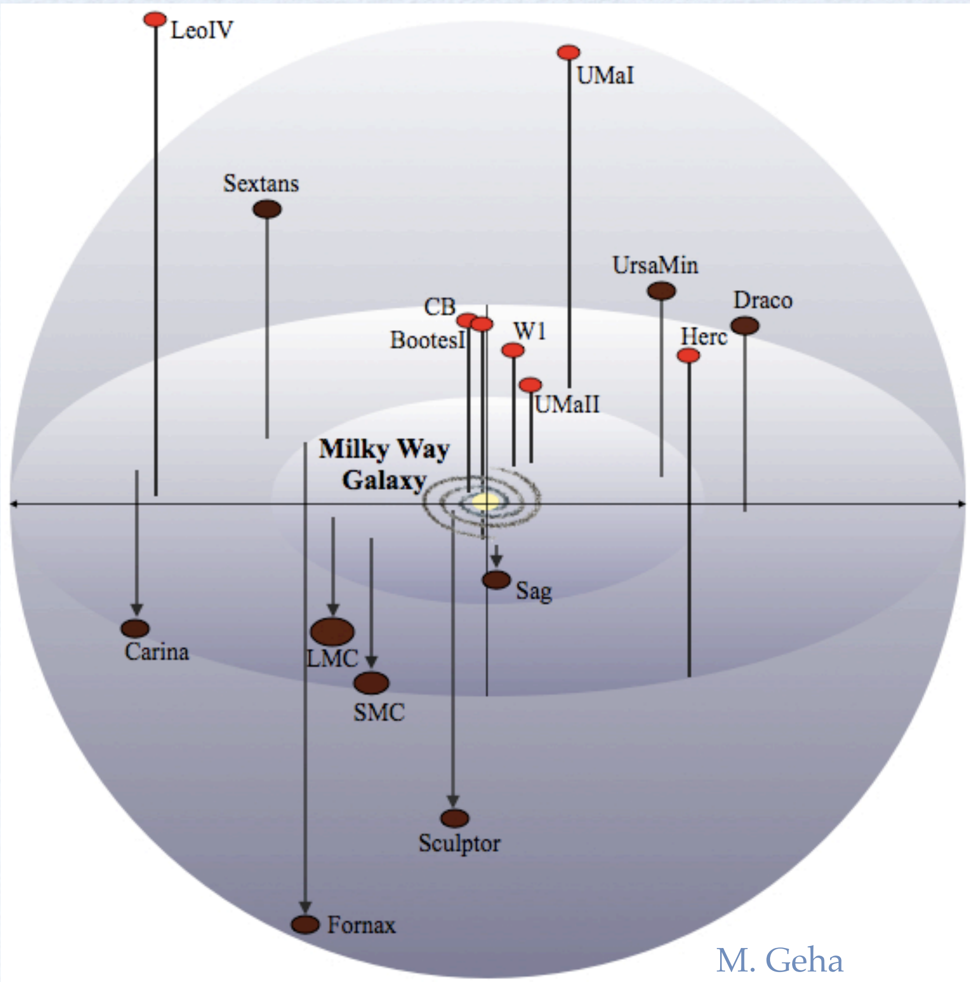
$$L\left(\bar{E}|f,\Gamma\right) = \prod_{i=0}^{n_{tot}} f\cdot S\left(E_i\right) + (1-f)\cdot B\left(E_i,\Gamma\right)$$

- Limits obtained in the energy range 30-200 GeV
- Search region b > 10 degrees and a region right around the GC
- 11 months of data
- Obtained cross section upper limits of order 10^{-27} cm^3 s^{-1}



Phys.Rev.Lett.104:091302,2010

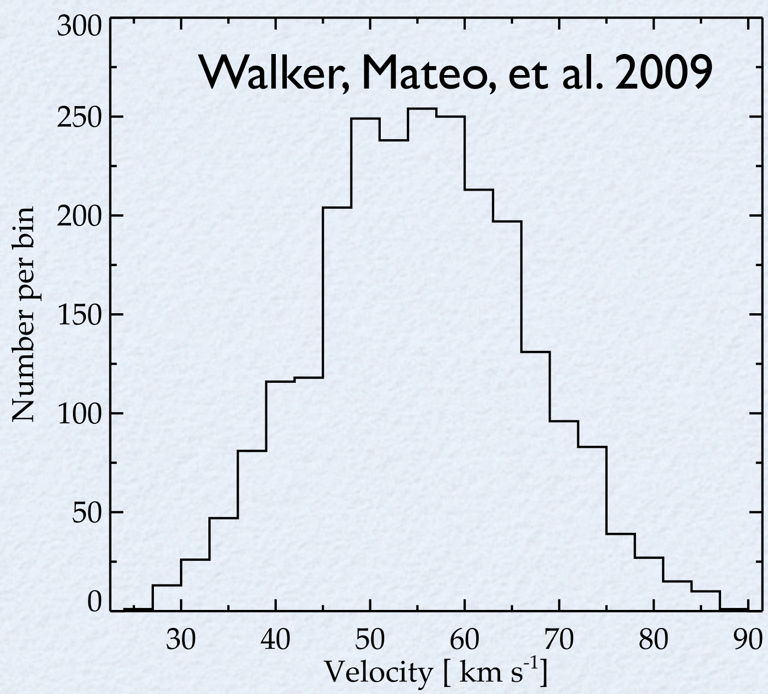
Milky Way dwarf spheroidals

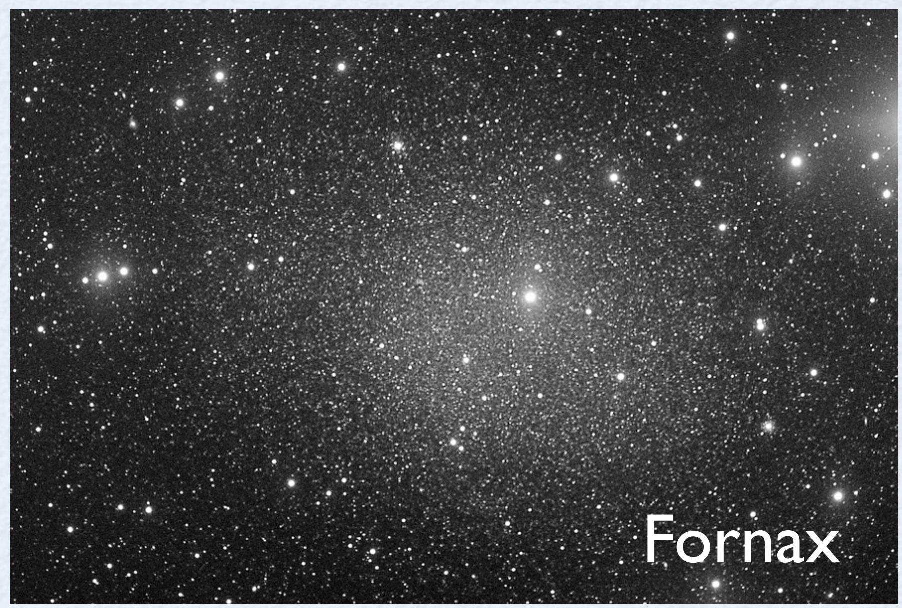


Satellite	Year Discovered
LMC	1519
SMC	1519
Sculptor	1937
Fornax	1938
Leo II	1950
Leo I	1950
Ursa Minor	1954
Draco	1954
Carina	1977
Sextans	1990
Sagittarius	1994
Ursa Major I	2005
Willman 1	2005
Ursa Major II	2006
Bootes I	2006
Canes Venatici I	2006
Canes Venatici II	2006
Coma Berenices	2006
Segue 1	2006
Leo IV	2006
Hercules	2006
Bootes II	2007
Leo V	2008
Segue 2	2009

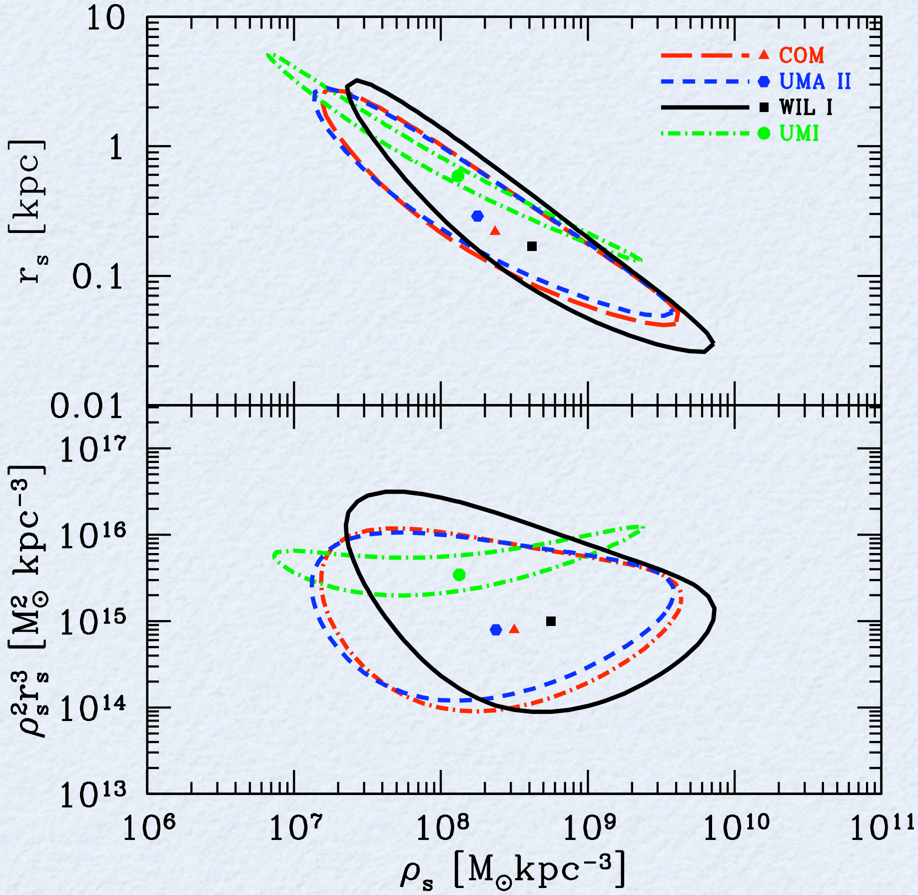
dwarf spheroidals (dSph)

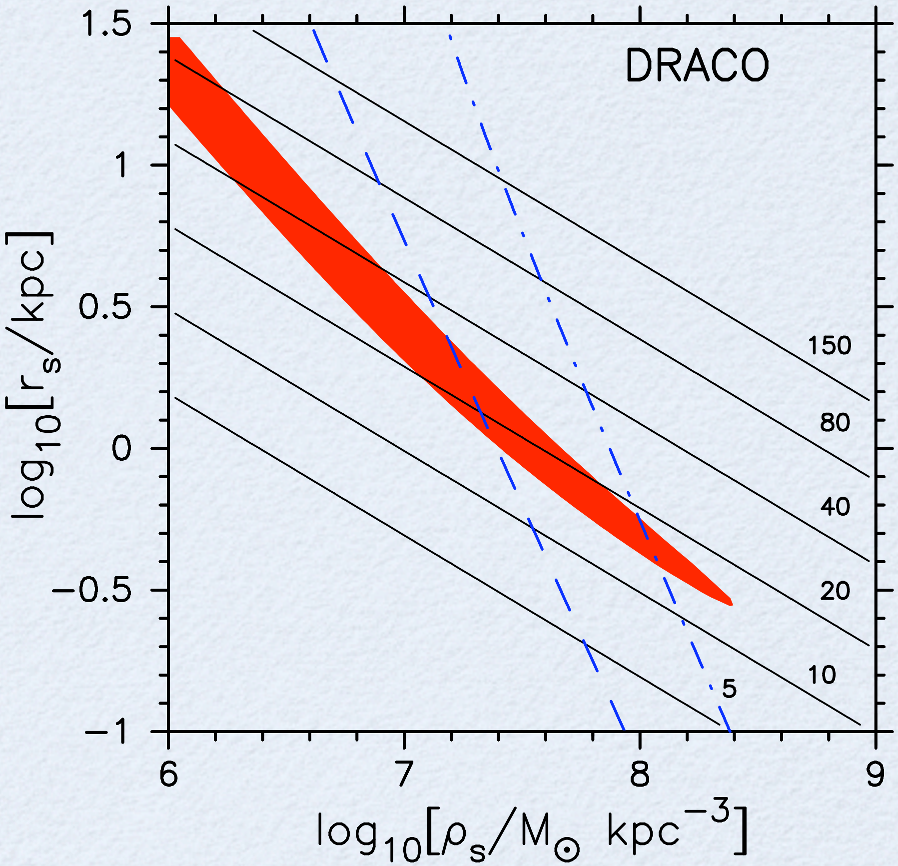
- Nearest galaxies to the Milky Way
- Most dark matter dominated objects known
- Dark matter distributions constrained from stellar kinematical data
- Not rotation and mildly elliptical-- dark matter distributions not as complicated





Dark Matter distribution of dSphs

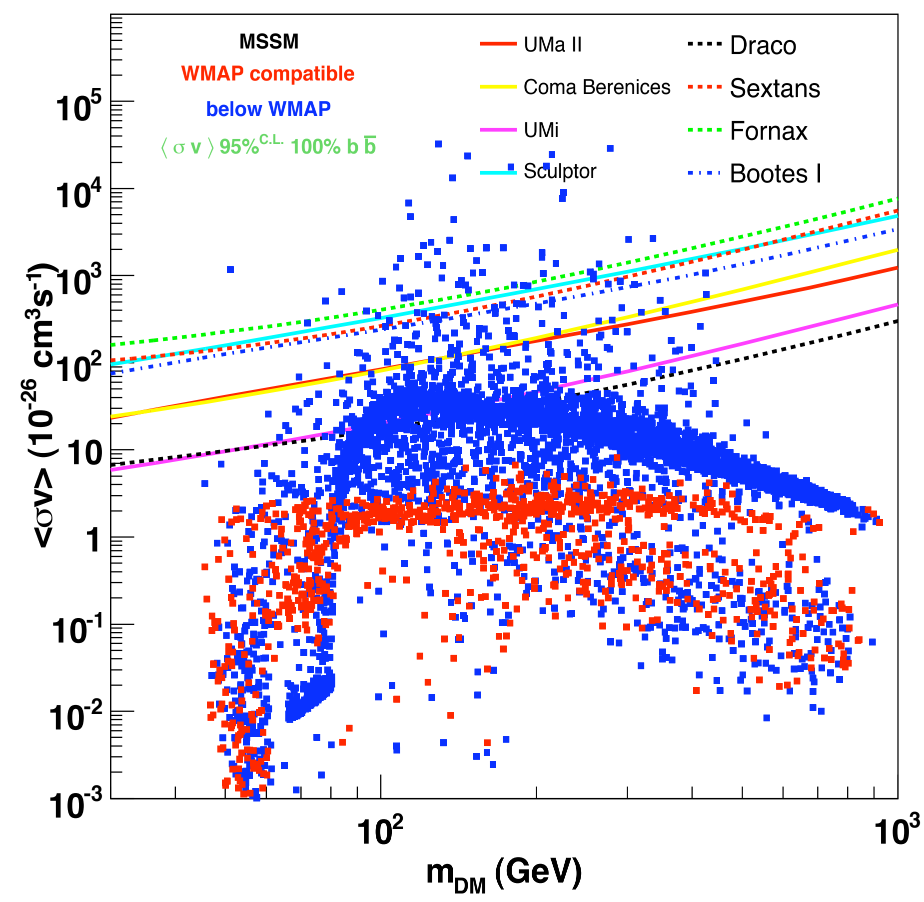


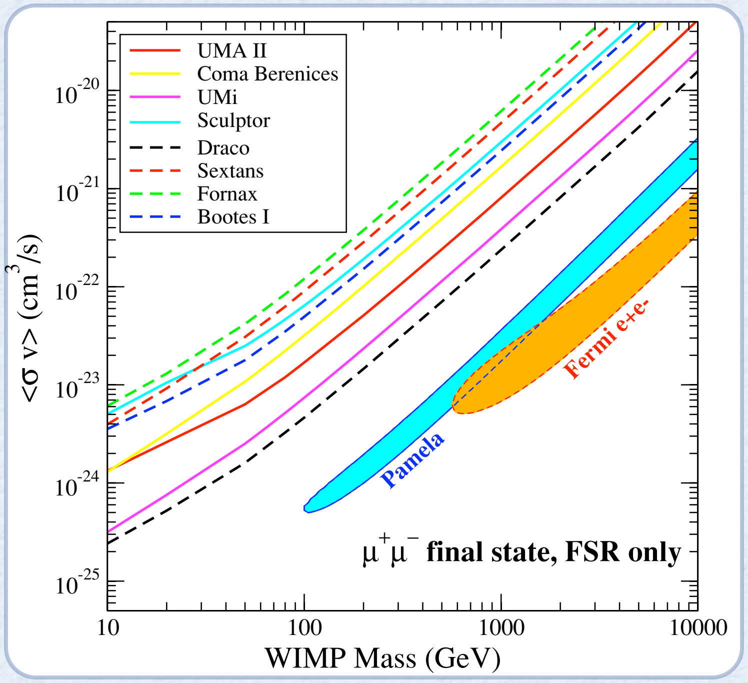


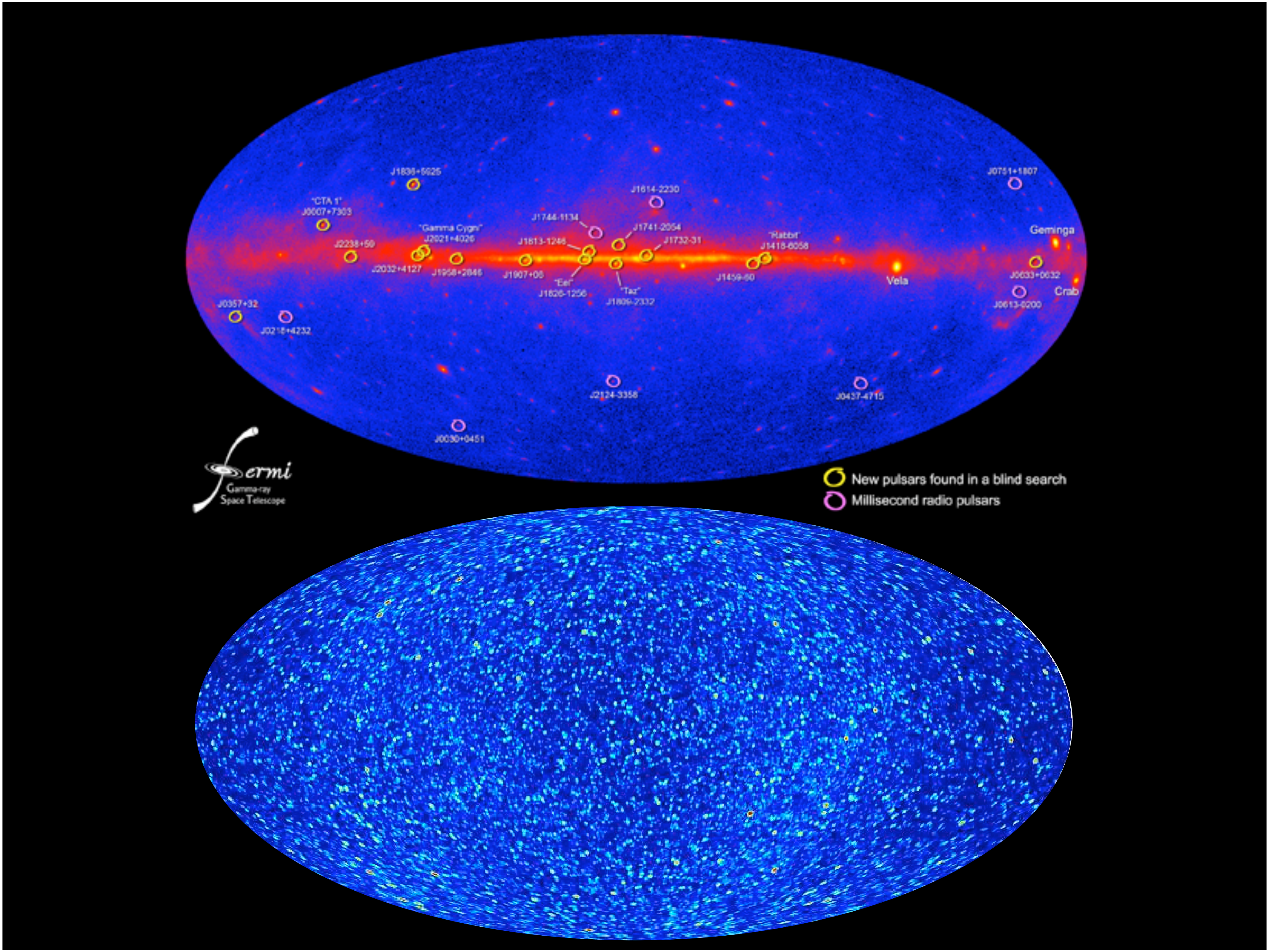
Strigari et al. 2007, 2008

Limits from dSphs

- Consider a 10 degree ROI around each dSph
- Assume a power law fit to the flux from a dSph
- Normalizations consistent with zero-- no fluxes yet detected from dSphs



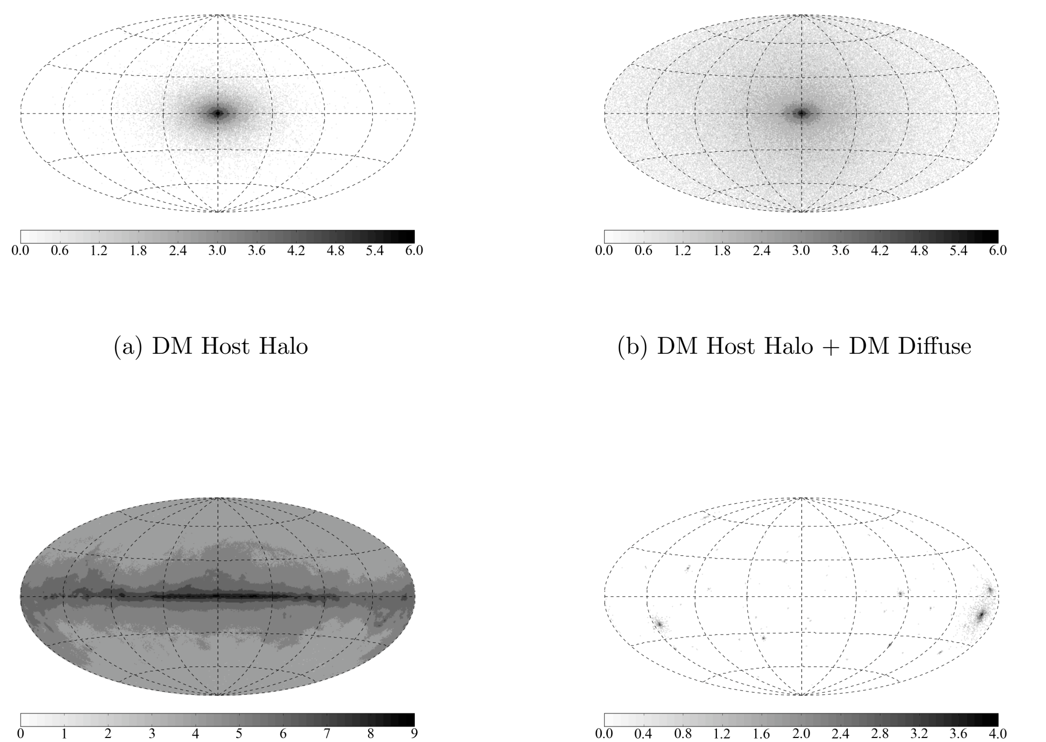


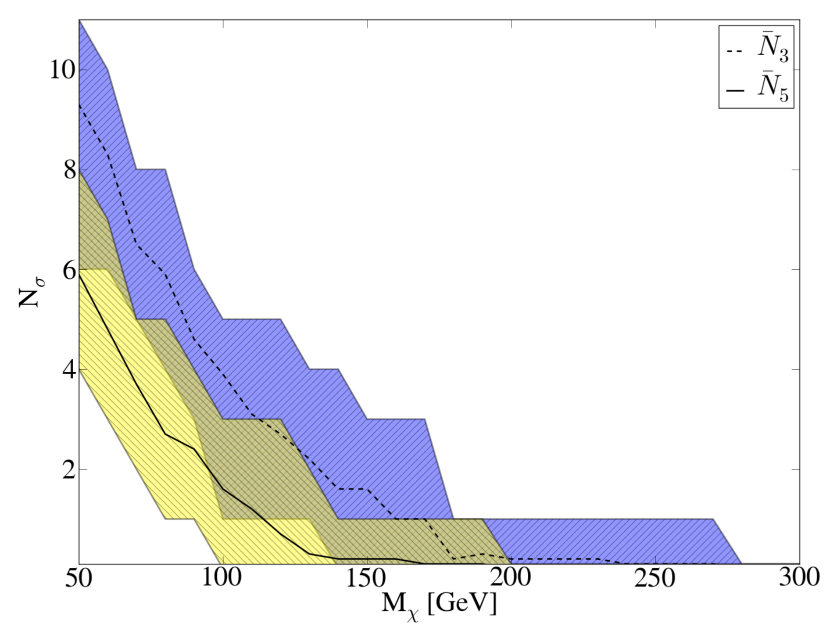

J1836+5925
"CTA 1"
J0007+7303
J2238+59
"Gamma Cygni"
J2021+4026
J2032+4127
J1958+2846
J1907+06
J1813-1246
J1744-1134
J1614-2230
J1741-2054
J1732-31
"Eel"
J1826-1256
"Taz"
J1809-2332
"Rabbit"
J1418-6058
J1459-60
Vela
J0751+1807
Geminga
J0633+0632
Crab
J0613-0200
J0357+32
J0218+4232
J2124-3358
J0437-4715
J0030+0451
fermi
Gamma-ray
Space Telescope
New pulsars found in a blind search
Millisecond radio pulsars

Search for dark subhalos

- Idea: Search for objects that only shine because of dark matter annihilation
- Some satellites could be within a few kpc of the Sun, and their extension may be resolved by the LAT
- Search criteria:
  - More than 20 degrees from Galactic plane
  - No counterpart at other wavelengths
  - Emission constant in time
  - Spatially extended: 1 degree radial extension

Detectable subhalos

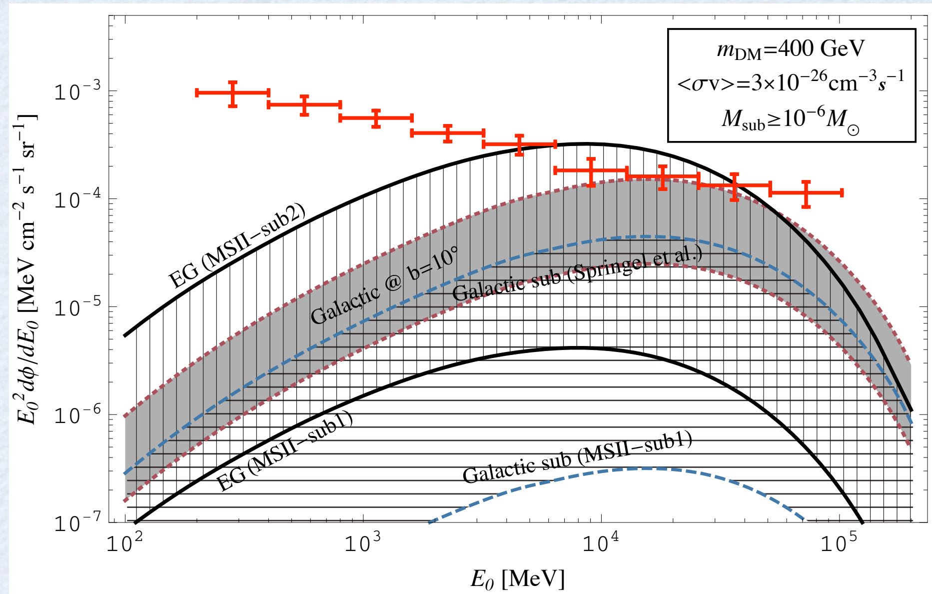


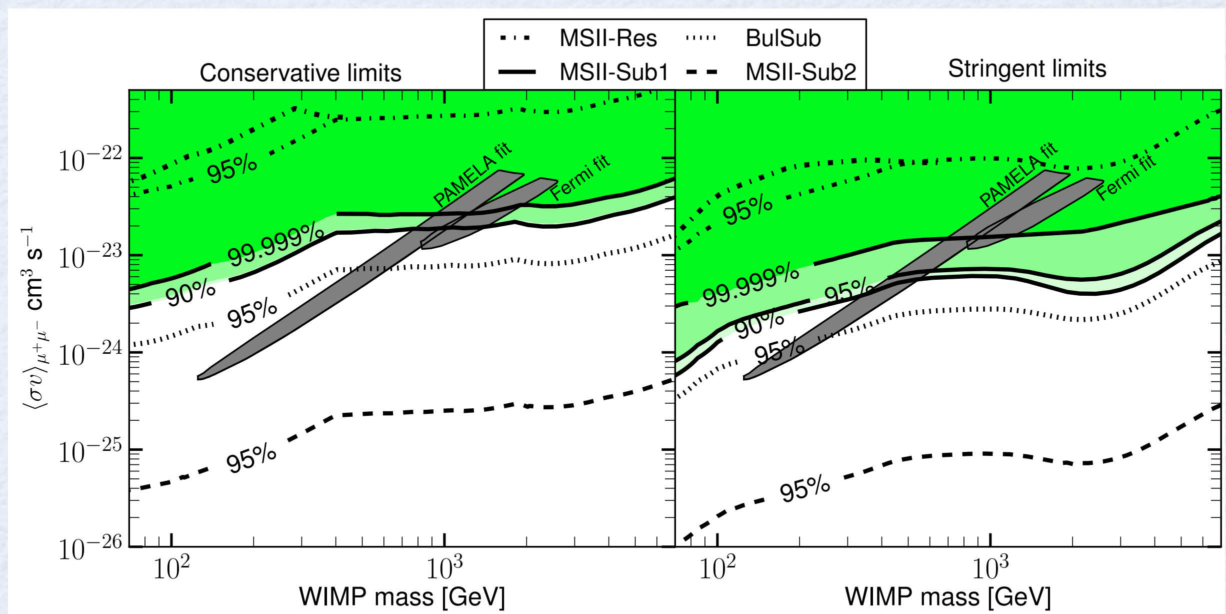


Anderson et al., arXiv:1006.1628

Cosmological WIMPs

- Cross section limits derived from measurement of power law extragalactic spectrum
- Energy range of 20-100 GeV
- Some uncertainties due to the distribution of dark matter
- Possible to exclude DM interpretation of the Fermi, Pamela electron spectrum





Conclusions and Outlook

- With 1+ years of data no discovery to report
- However interesting limits on dark matter, particularly those models with high annihilation cross sections that explain other data sets
- Astrophysical backgrounds uncertain-- Fermi will attempt to understand them in the coming years and determine what their impact is on dark matter studies
- Improvements are expected:
  - Charged particle contamination
  - Photons below 200 MeV
- Fermi is a 5-10 year mission... More results on the way!