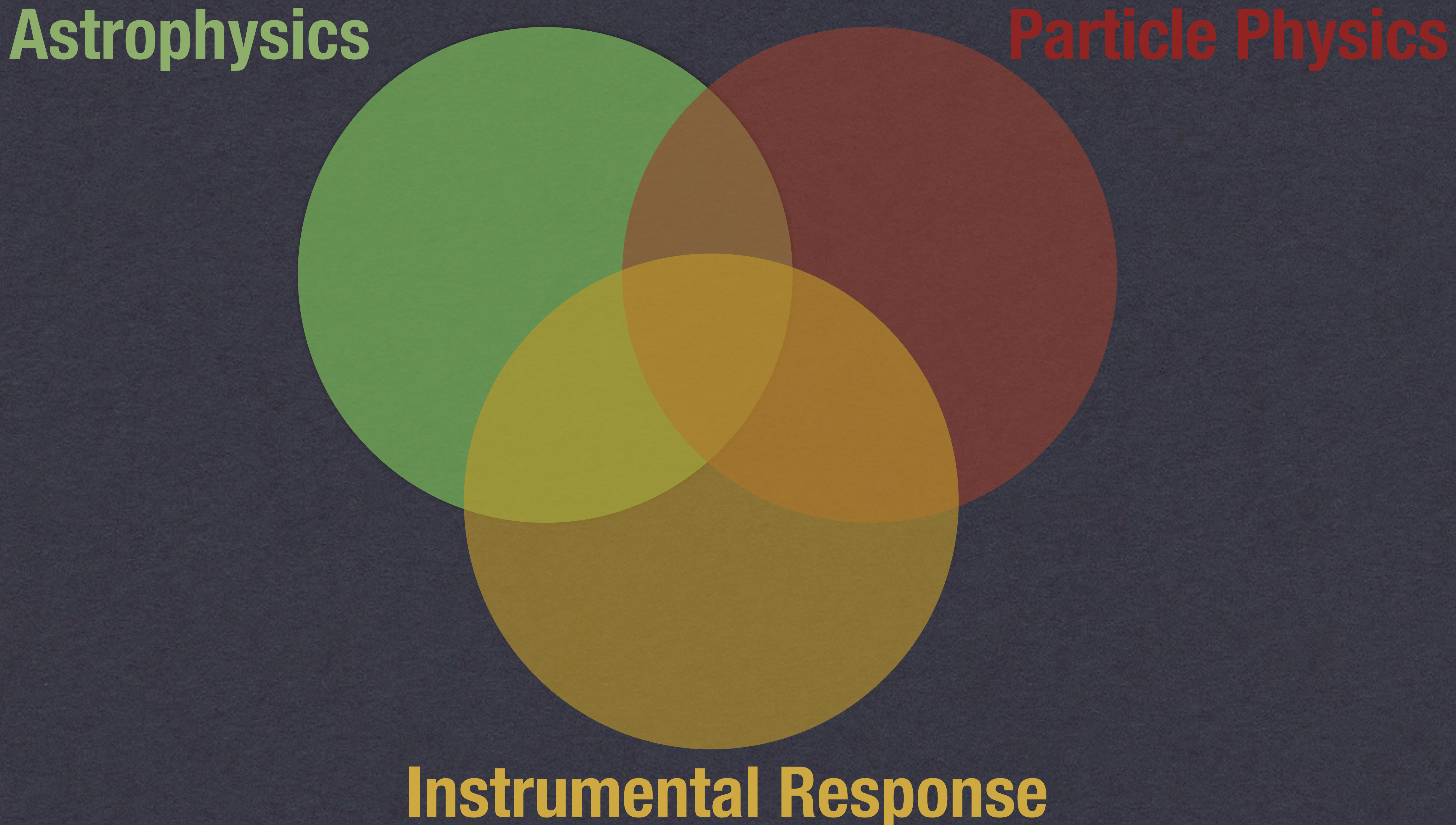
DARK MATTER INDIRECT DETECTION WITH FUTURE SPACE-BASED GAMMA-RAY TELESCOPES

TIM LINDEN

UNIVERSITY OF CHICAGO

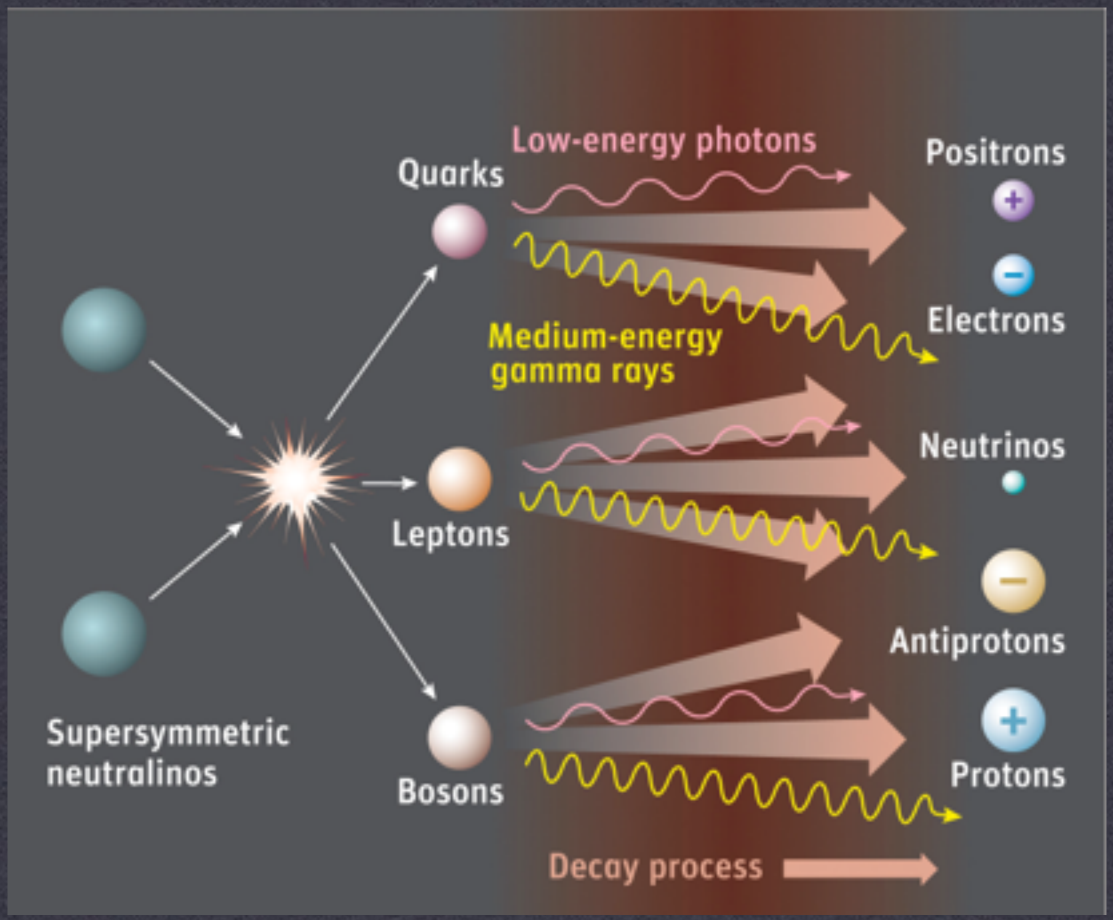
INDIRECT DETECTION OF WIMPS

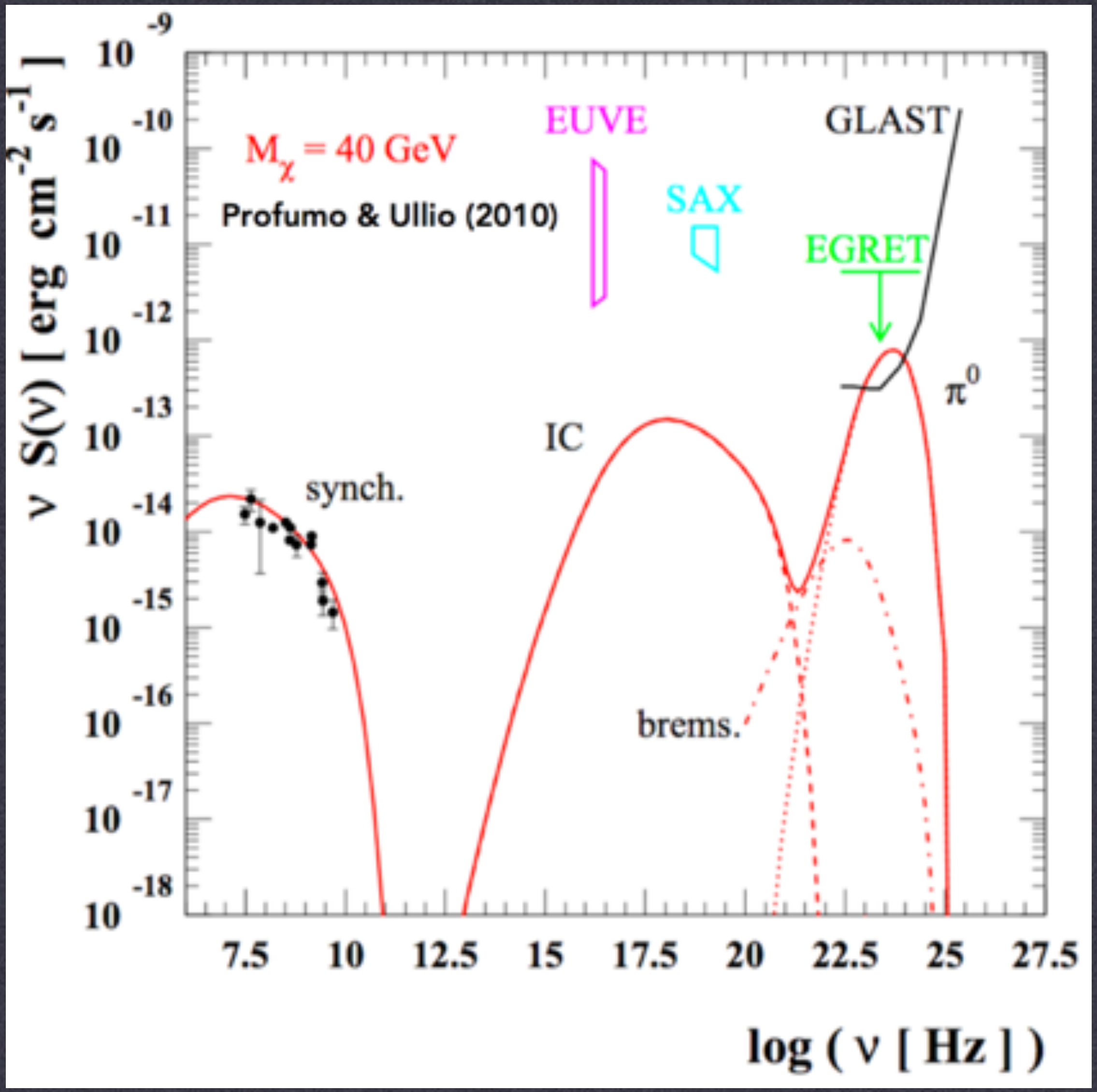


EXPECTED DARK MATTER SIGNAL

Why Do We Search in Gamma-Rays?

WIMP miracle motivates 100 GeV scale dark matter particles





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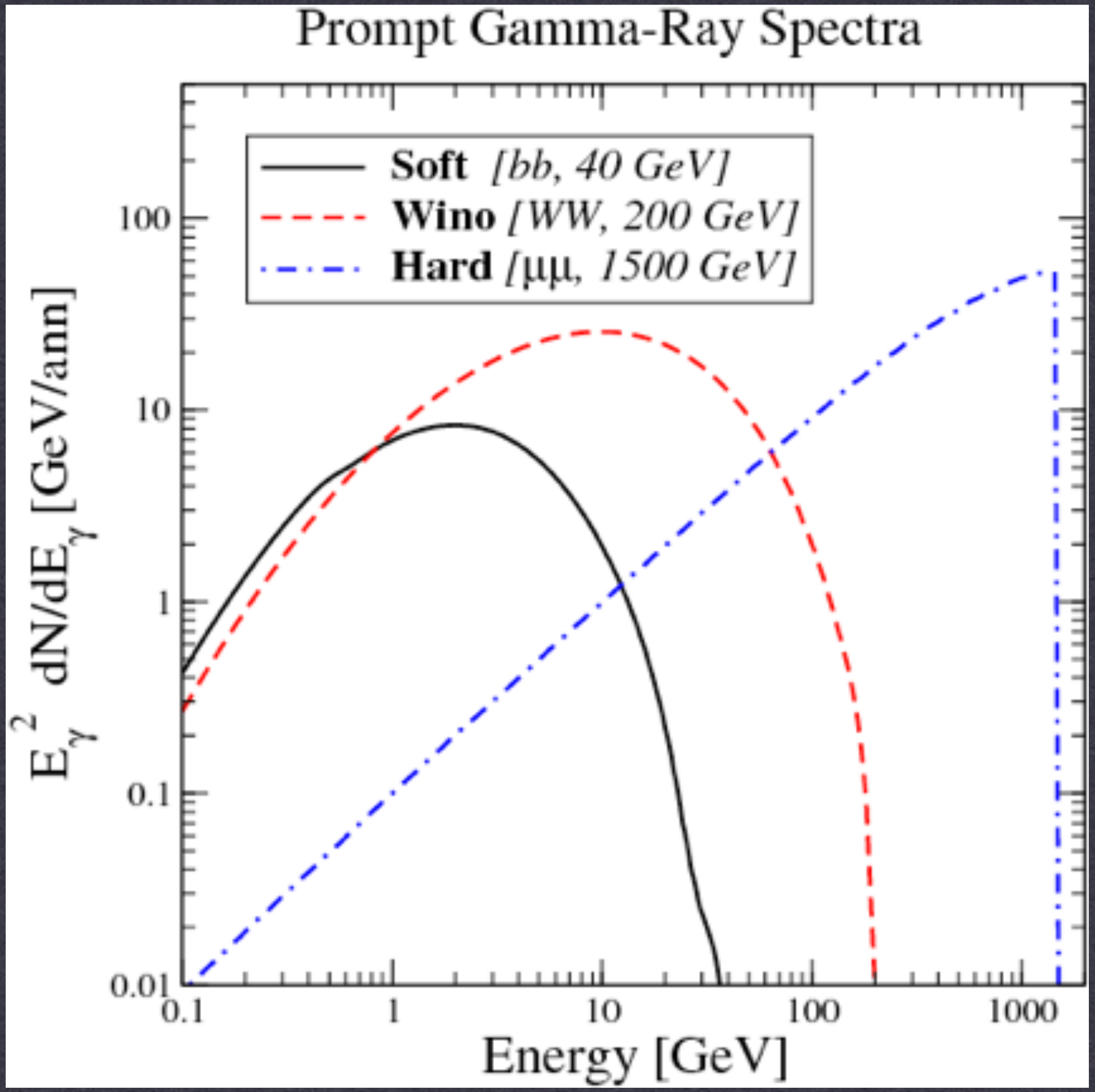
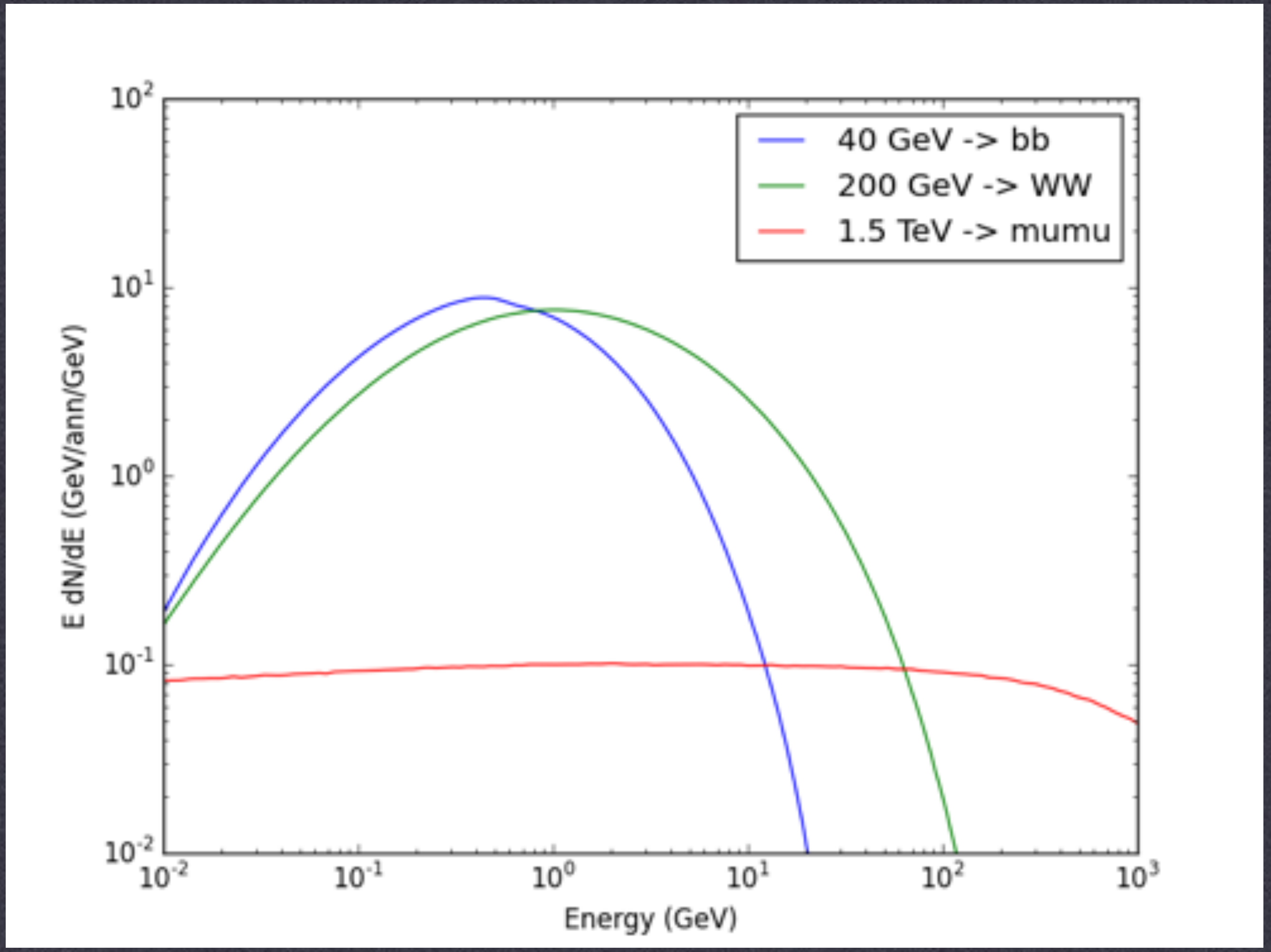




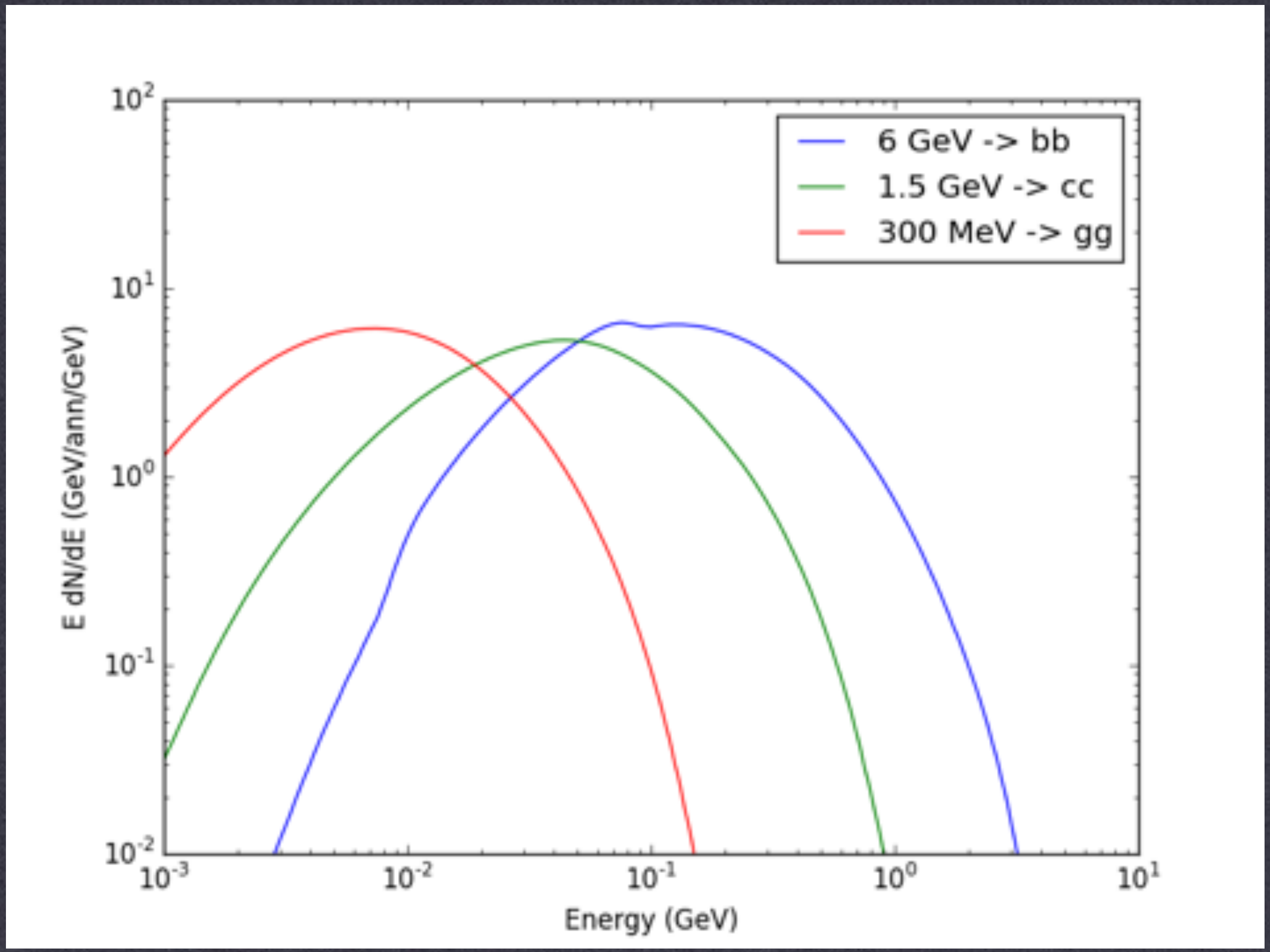
Motivates searches in the 0.1 - 1 GeV range!

CAVEATS

Annihilation of ~MeV scale dark matter produces either neutrinos, or electrons

MeV scale electrons produce gamma rays primarily through bremsstrahlung radiation, which is hard to detect

* Diffusion important
* Traces gas density



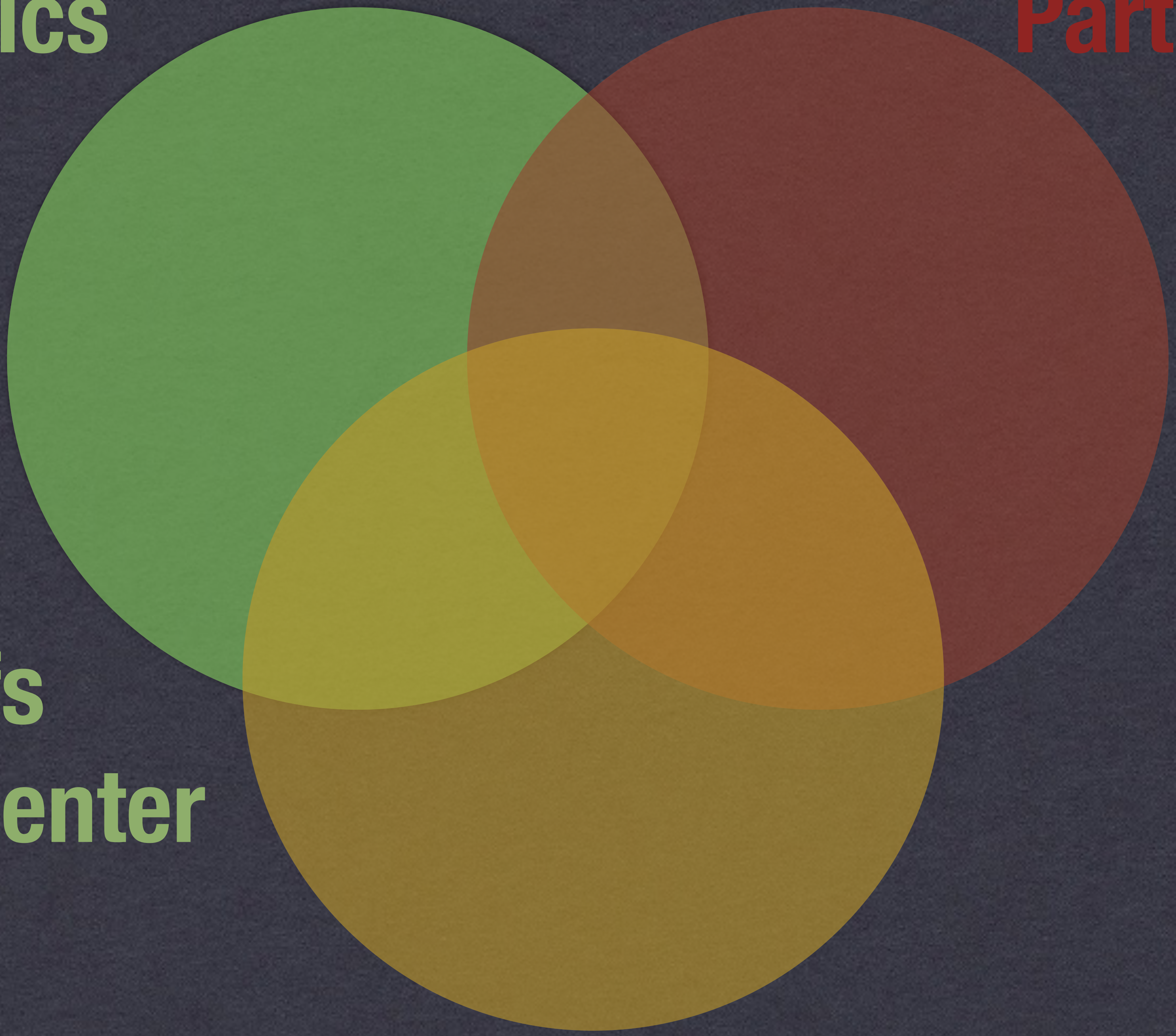
Could theoretically detect the FSR line off of an electron final state.

These models are not particularly well motivated.

INDIRECT DETECTION OF WIMPS

Astrophysics

Particle Physics

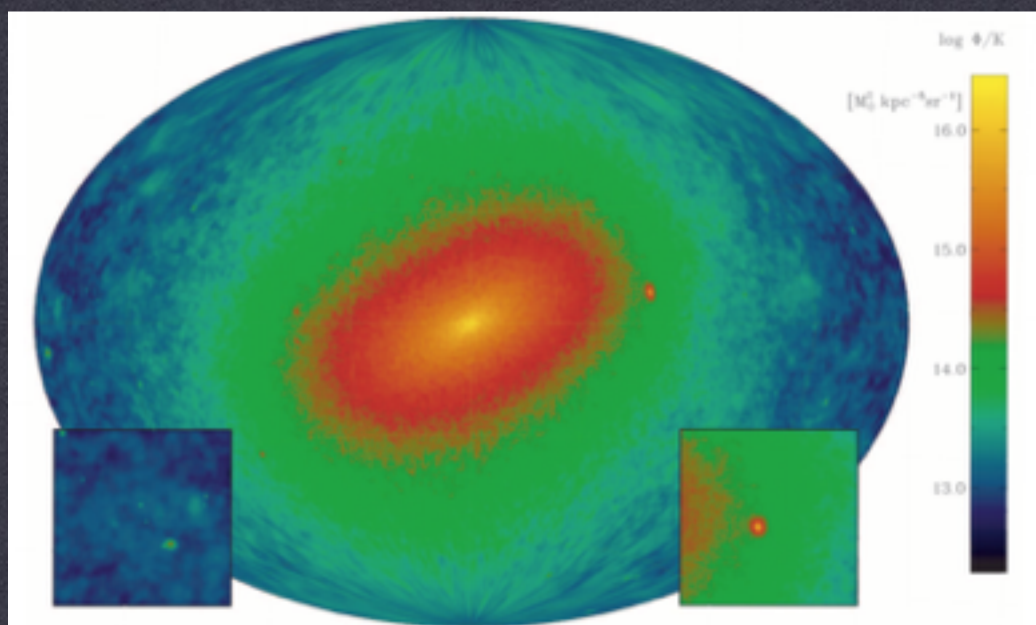


Dwarfs
Galactic Center
IGRB

Instrumental Response

DIFFERENT TACTICS FOR DIFFERENT ENVIRONMENTS

GALACTIC CENTER



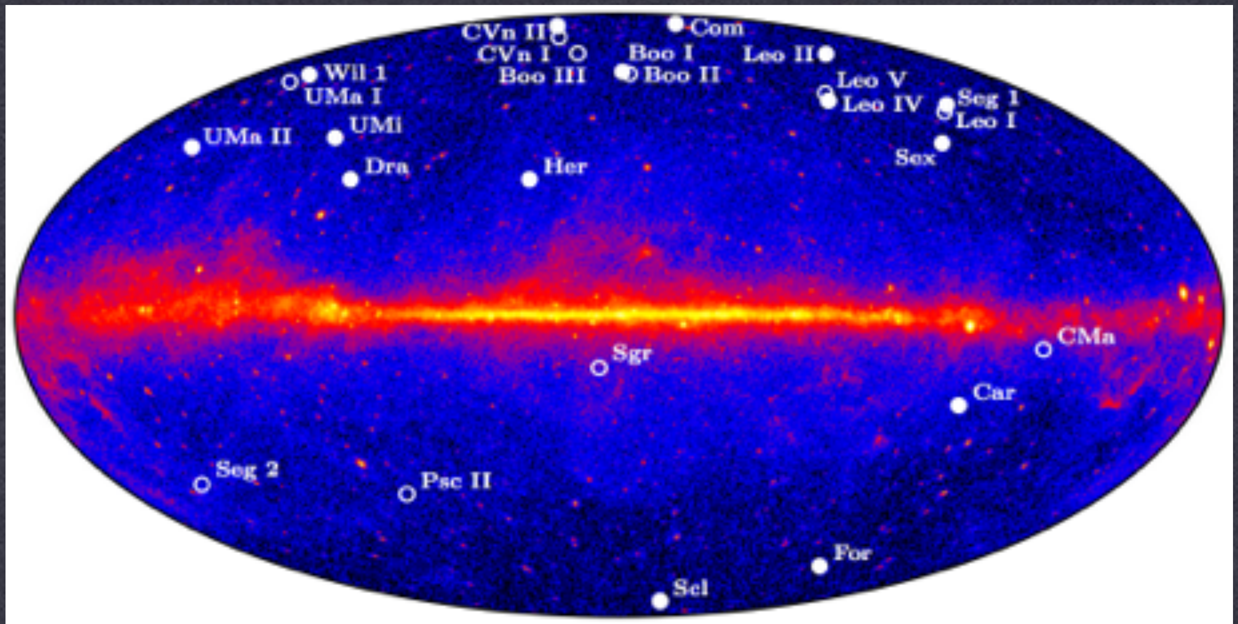
For typical parameters from an NFW profile:

$J \sim 10^{21}$ GeV^2 cm^{-5}

DWARFS

Name	GLON (deg)	GLAT (deg)	Distance (kpc)	$\log_{10}(J^{NFW})^a$ ($\log_{10}$[GeV^2 cm^{-5} sr])
Bootes I	358.1	69.6	66	18.8 ± 0.22
Bootes II	353.7	68.9	42	–
Bootes III	35.4	75.4	47	–
Canes Venatici I	74.3	79.8	218	17.7 ± 0.26
Canes Venatici II	113.6	82.7	160	17.9 ± 0.25
Canis Major	240.0	-8.0	7	–
Carina	260.1	-22.2	105	18.1 ± 0.23
Coma Berenices	241.9	83.6	44	19.0 ± 0.25
Draco	86.4	34.7	76	18.8 ± 0.16
Fornax	237.1	-65.7	147	18.2 ± 0.21
Hercules	28.7	36.9	132	18.1 ± 0.25
Leo I	226.0	49.1	254	17.7 ± 0.18
Leo II	220.2	67.2	233	17.6 ± 0.18
Leo IV	265.4	56.5	154	17.9 ± 0.28
Leo V	261.9	58.5	178	–
Pisces II	79.2	-47.1	182	–
Sagittarius	5.6	-14.2	26	–
Sculptor	287.5	-83.2	86	18.6 ± 0.18
Segue 1	220.5	50.4	23	19.5 ± 0.29
Segue 2	149.4	-38.1	35	–
Sextans	243.5	42.3	86	18.4 ± 0.27
Ursa Major I	159.4	54.4	97	18.3 ± 0.24
Ursa Major II	152.5	37.4	32	19.3 ± 0.28
Ursa Minor	105.0	44.8	76	18.8 ± 0.19
Willman 1	158.6	56.8	38	19.1 ± 0.31

DWARFS: EFFECTIVE AREA IS KEY



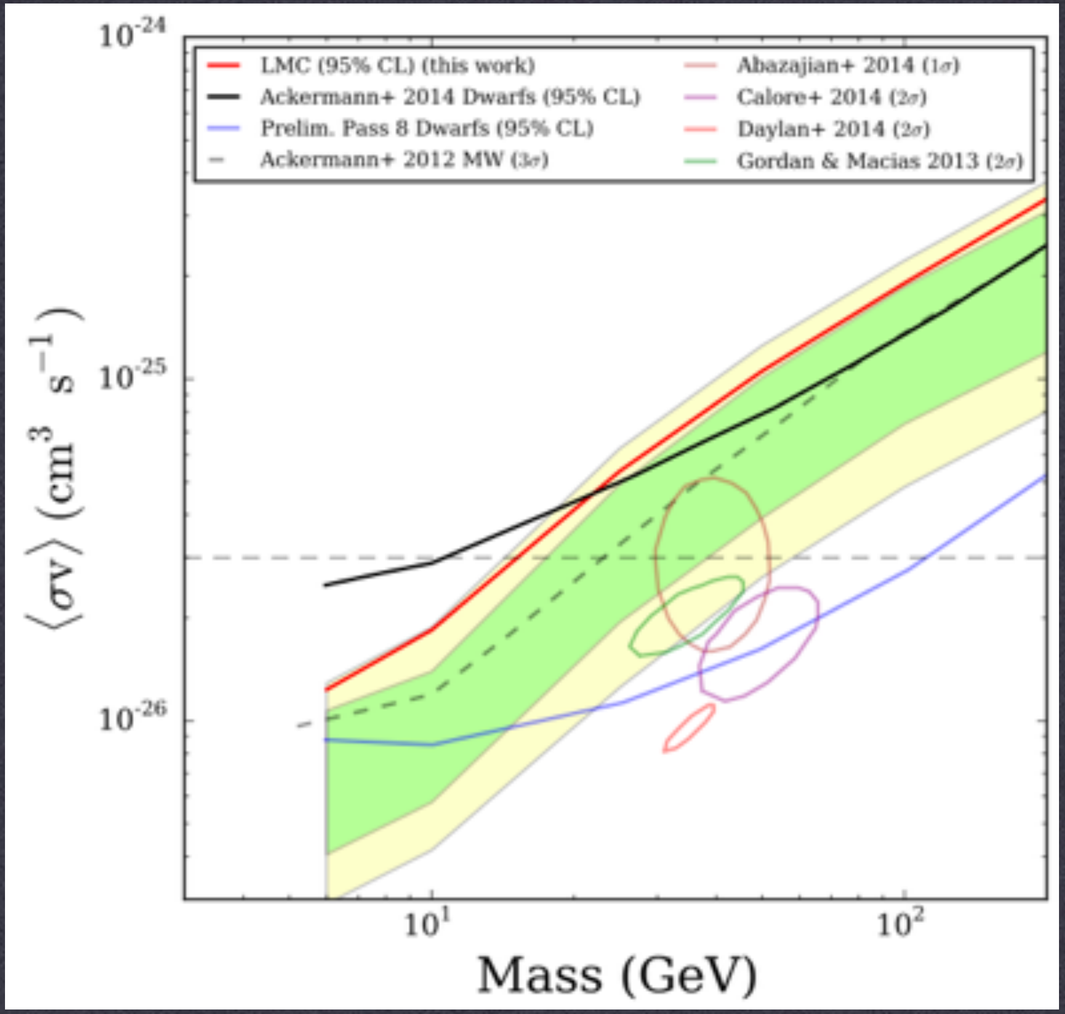
Backgrounds in dwarf galaxies are minimal.

Furthermore, the Fermi-LAT angular resolution places us in a convenient regime where the uncertainties from the J-factor of various dwarfs is minimized.

Thus, the key issue is the total exposure of dwarf spheroidal objects. Effects from angular and energy resolution are secondary.

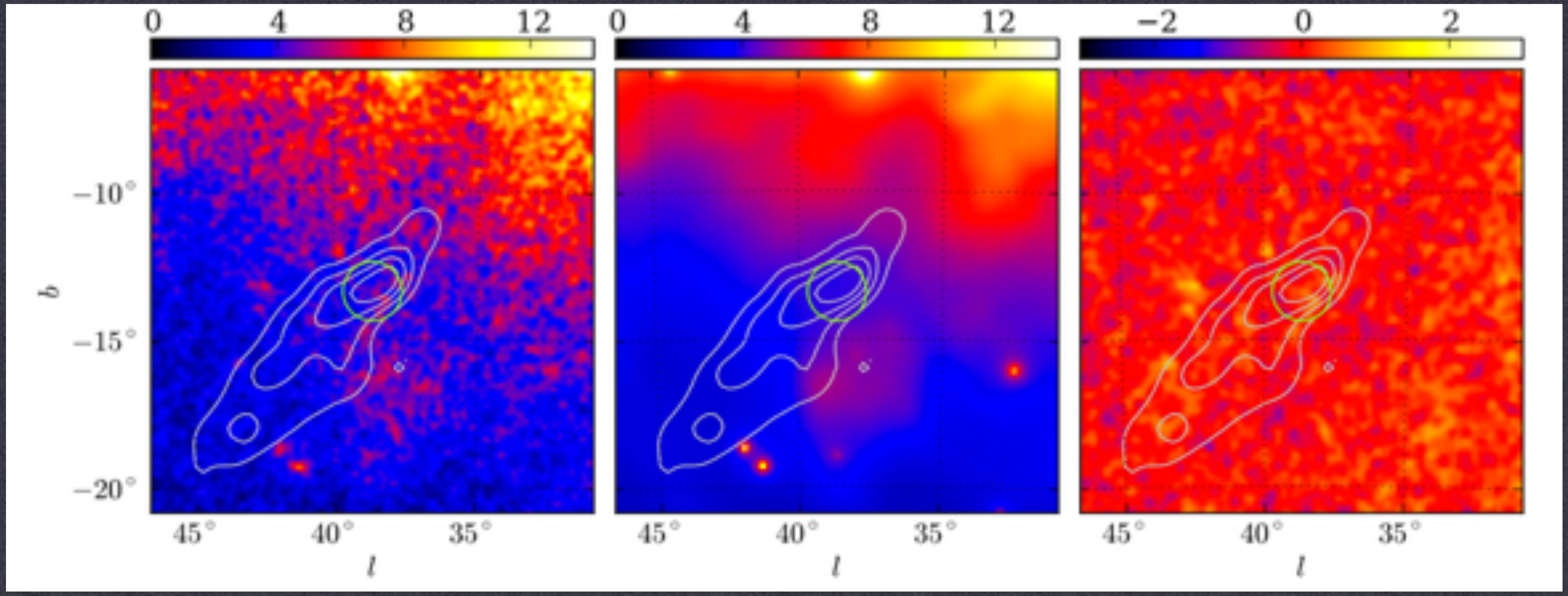
DWARFS: EFFECTIVE AREA IS KEY

This gives great future discovery potential - we are still in a linear regime for data gathering, and limits are improving quickly with time.



Can look for new targets:

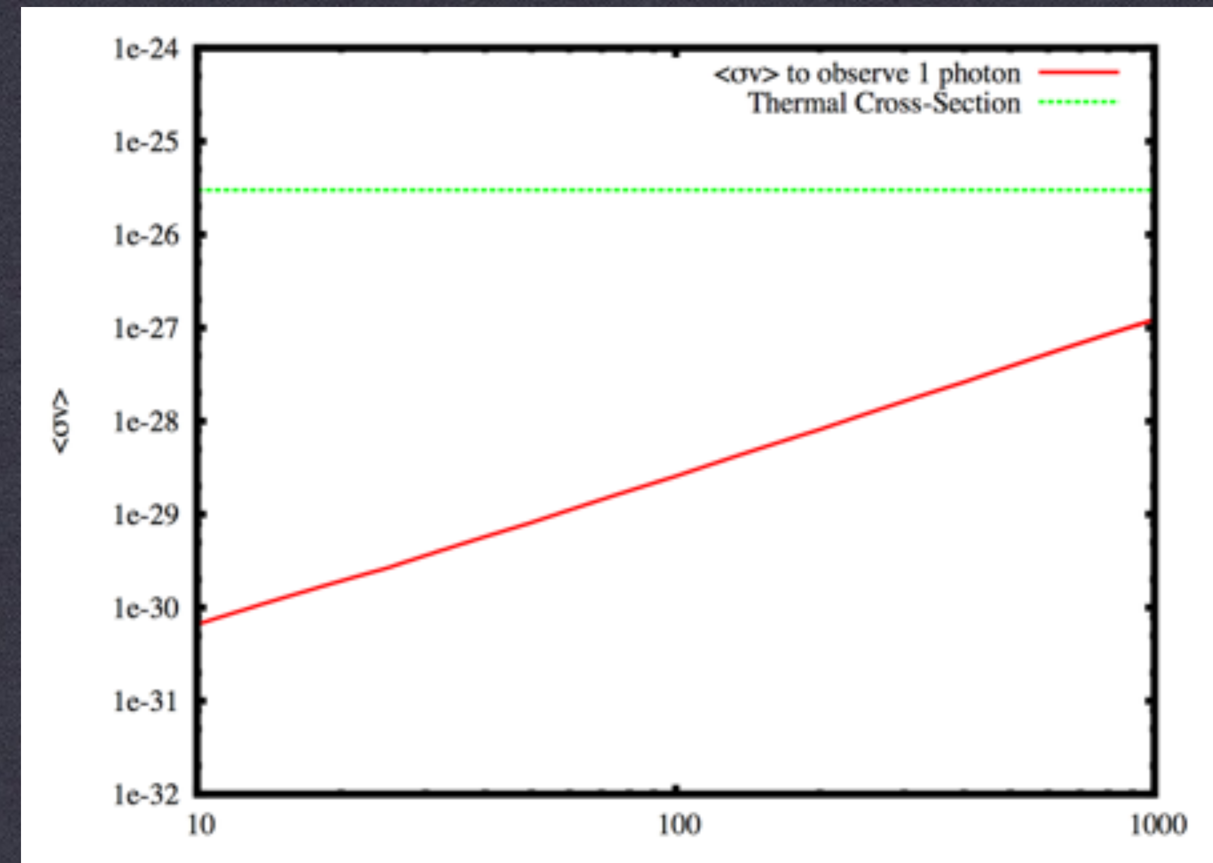
* New dwarfs
* LMC/SMC
* High Velocity Clouds



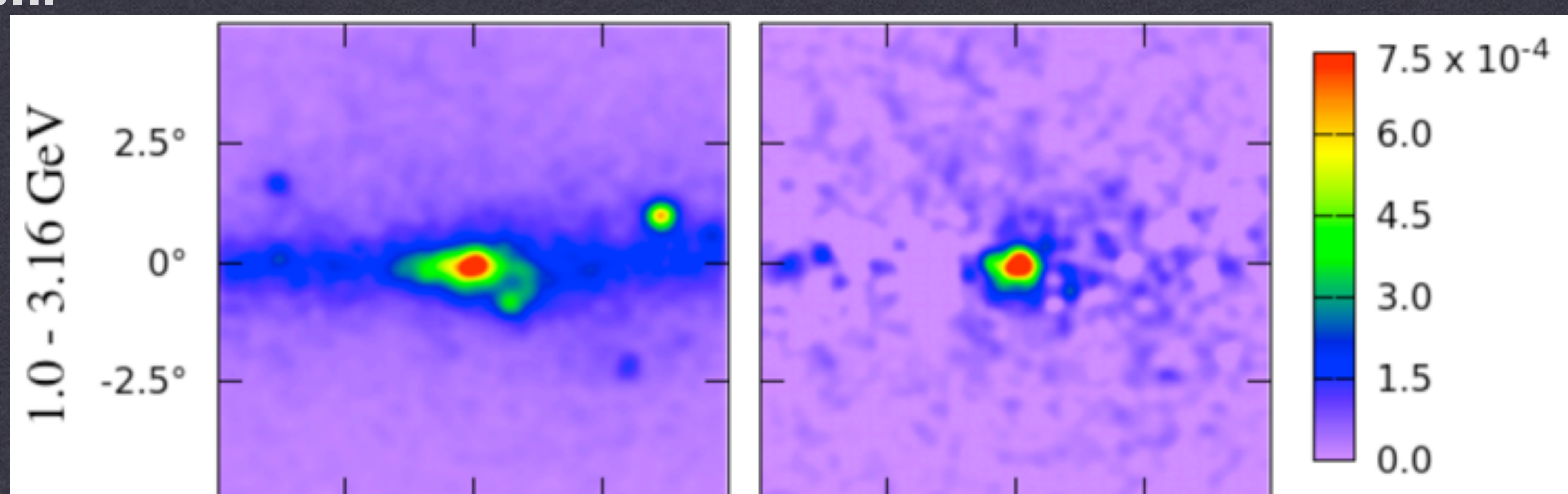
GC: ANGULAR AND ENERGY RESOLUTION IS KEY

Unlike dwarf spheroidal galaxies, the GC provides plenty of photons.

The gamma-ray signal from the galactic center currently provides ~10^4 photons with a typical energy of 1 GeV



The difficulty is to determine the source of these events. This requires enhanced angular resolution.



GALACTIC CENTER

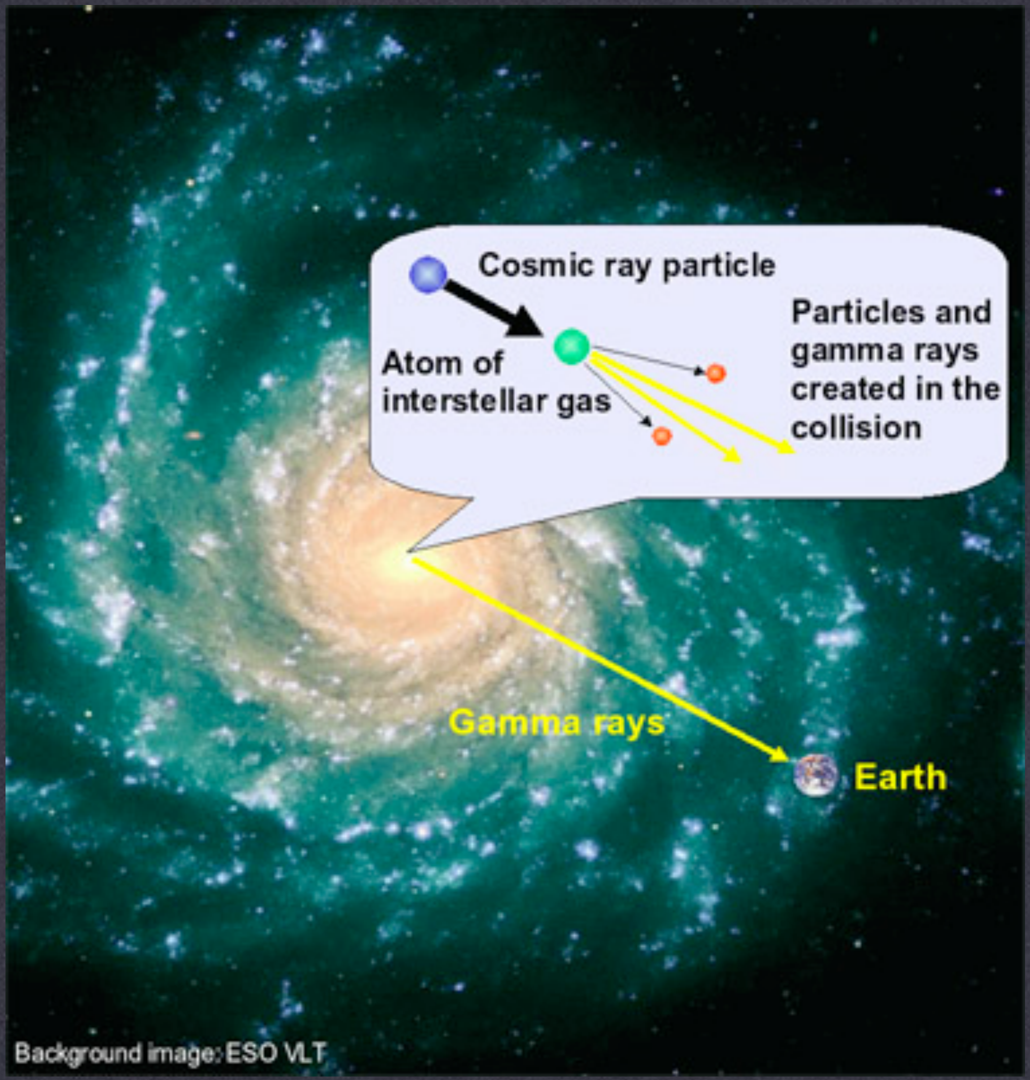
Galactic Center Backgrounds:

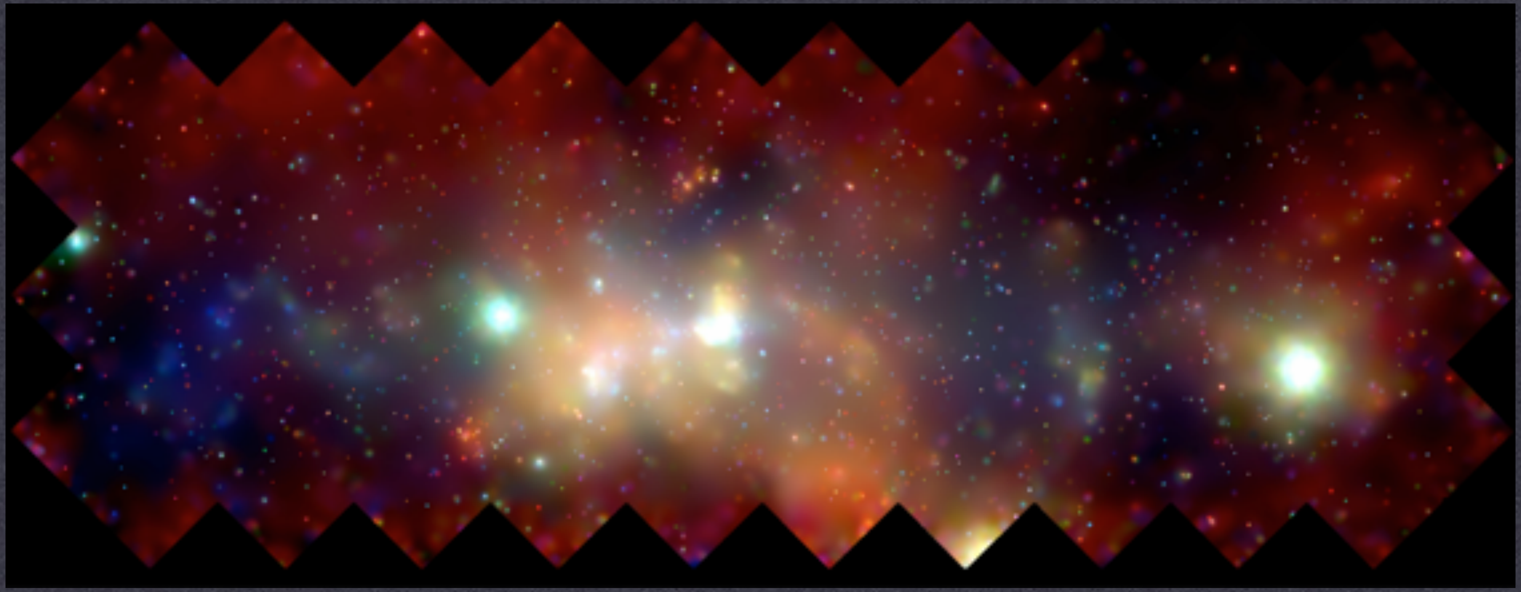
* Point Sources (SNR, pulsars, etc.)

* Hadronic Interactions (pp -> π^0 -> $\gamma\gamma$)

* Bremsstrahlung

* Inverse Compton Scattering

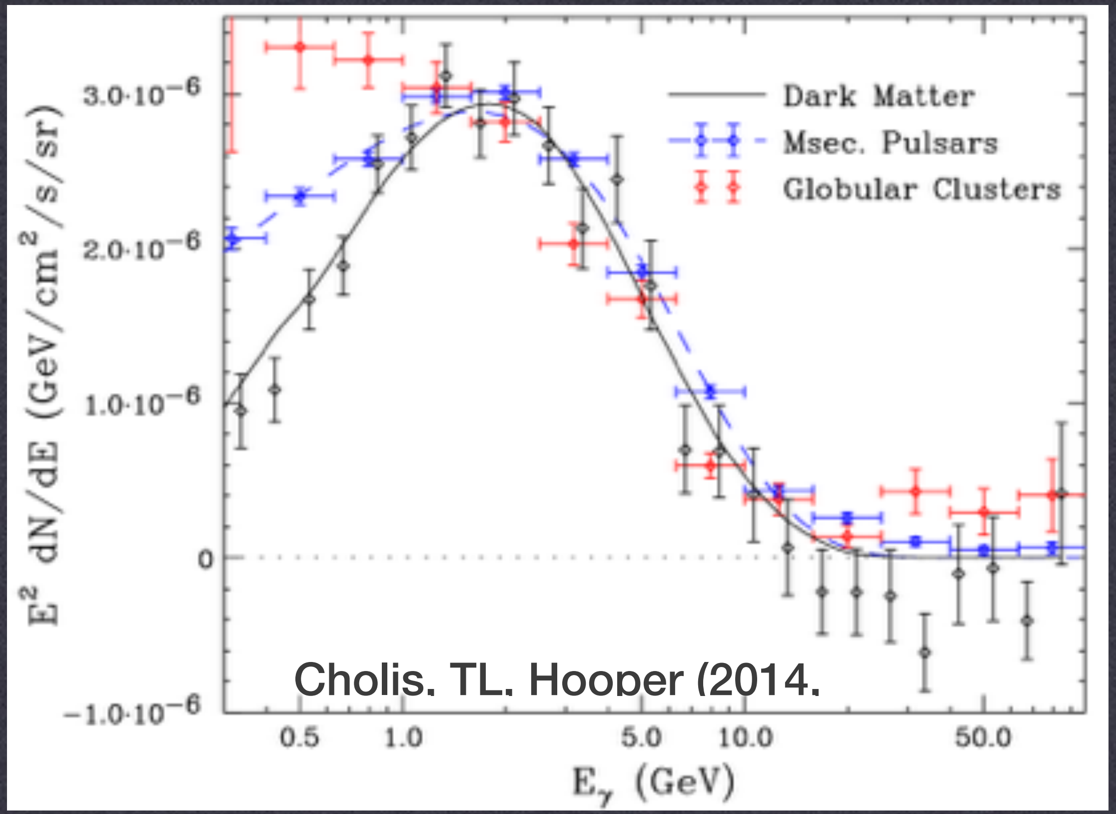


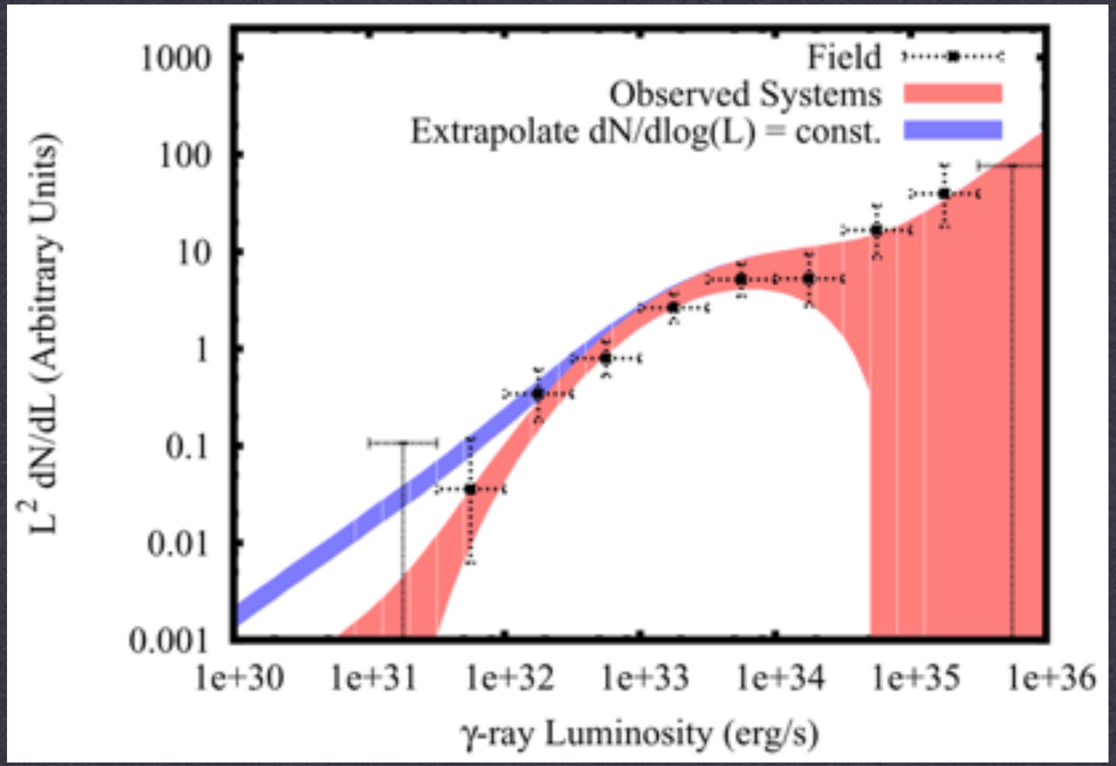


EXAMPLE: MSPS

- MSPs match the spectrum of the GC signal at high energies.
- At low energies, spectral differences abound, but measurements are hard here.
- Most observed MSPs are relatively bright, they may be detectable in the GC with future telescopes.

- Much larger than Fermi energy resolution!





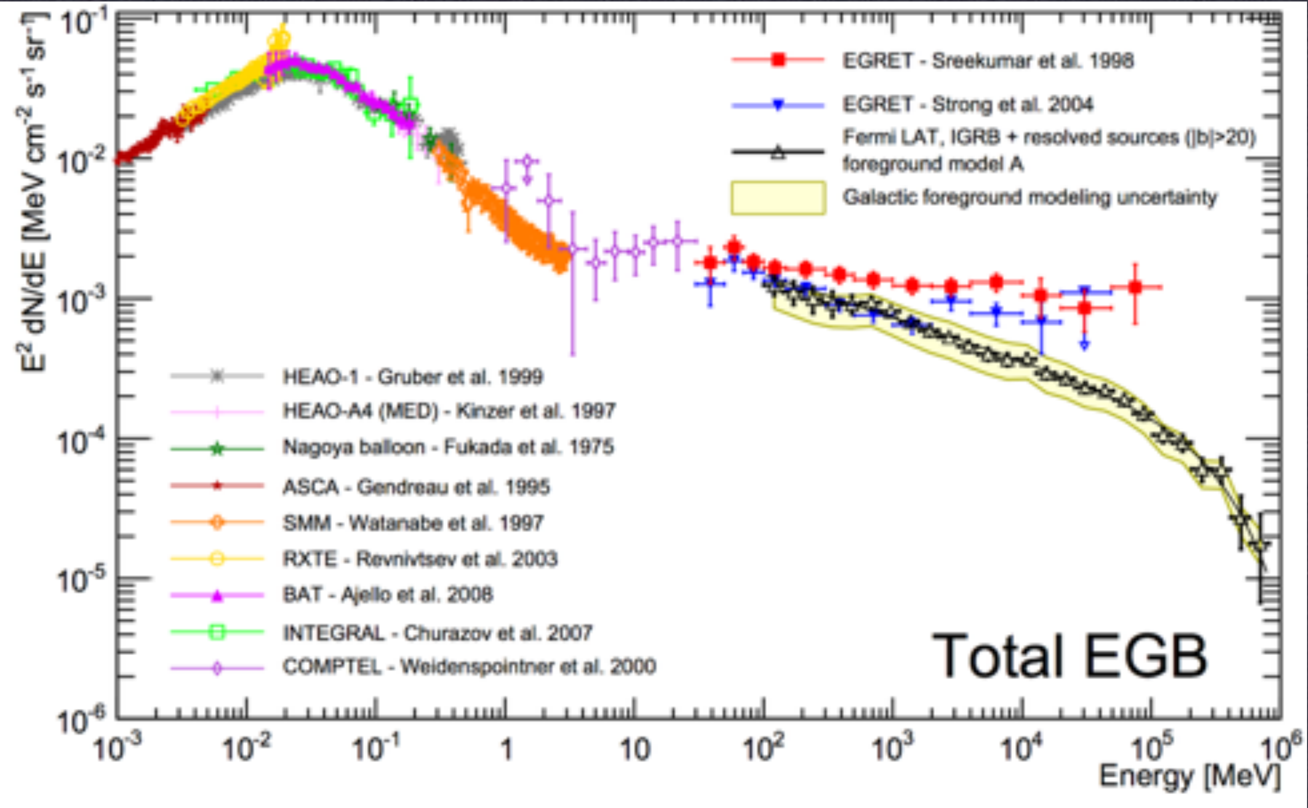
TS VALUES AS A FUNCTION OF ENERGY

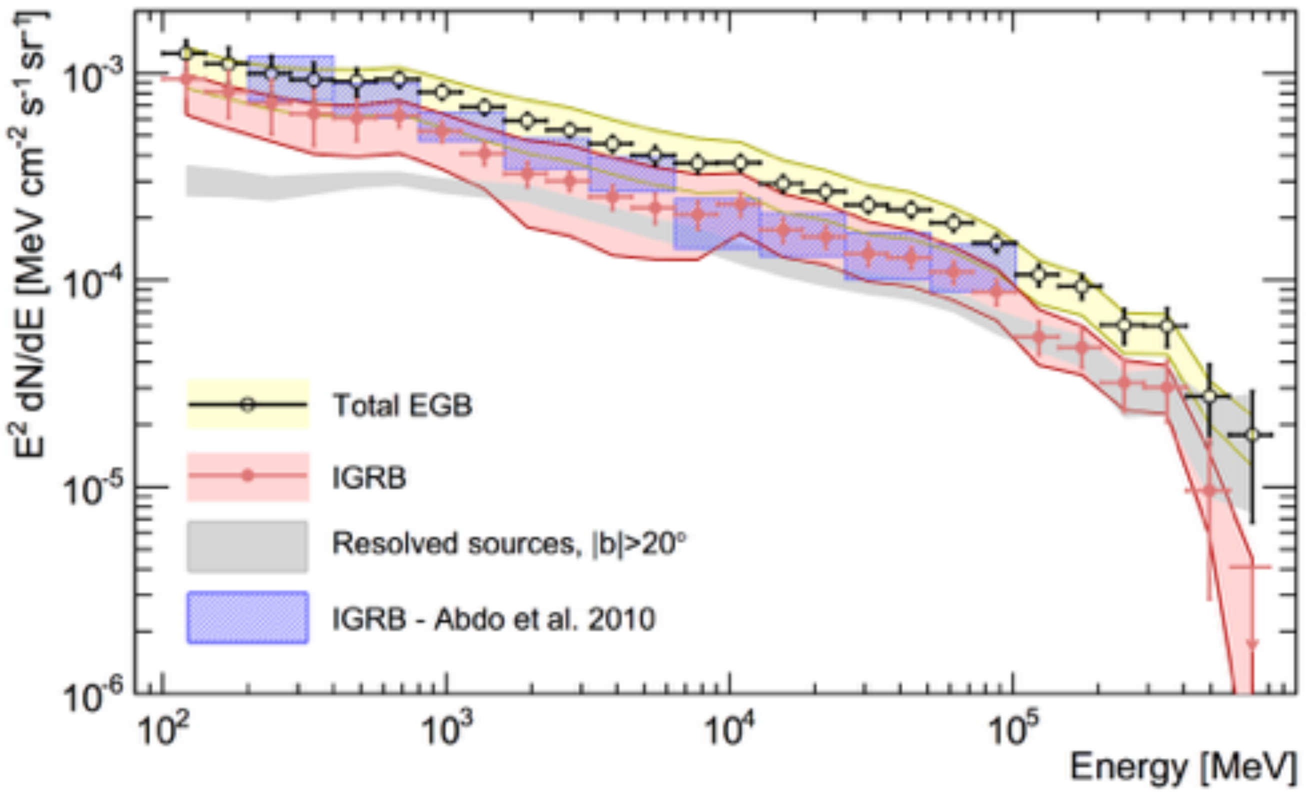
- 3FGL Sources with Power Law Spectral Index between 2.0 - 2.1
  - TS (0.1 - 0.3 GeV) = 6.37
  - TS (0.3 - 1.0 GeV) = 34.45
  - TS (1 - 3 GeV) = 65.82
  - TS (3-10 GeV) = 68.16
  - TS (10 - 100 GeV) = 38.06
- Rough Indication that PSF is critical for point source observation and analysis. Small Instruments operating at low energies are highly powerful for point source extraction.

EXTRAGALACTIC BACKGROUND

- The intensity of the IGRB continues to decrease, as more sources are discovered and removed from the IGRB intensity.

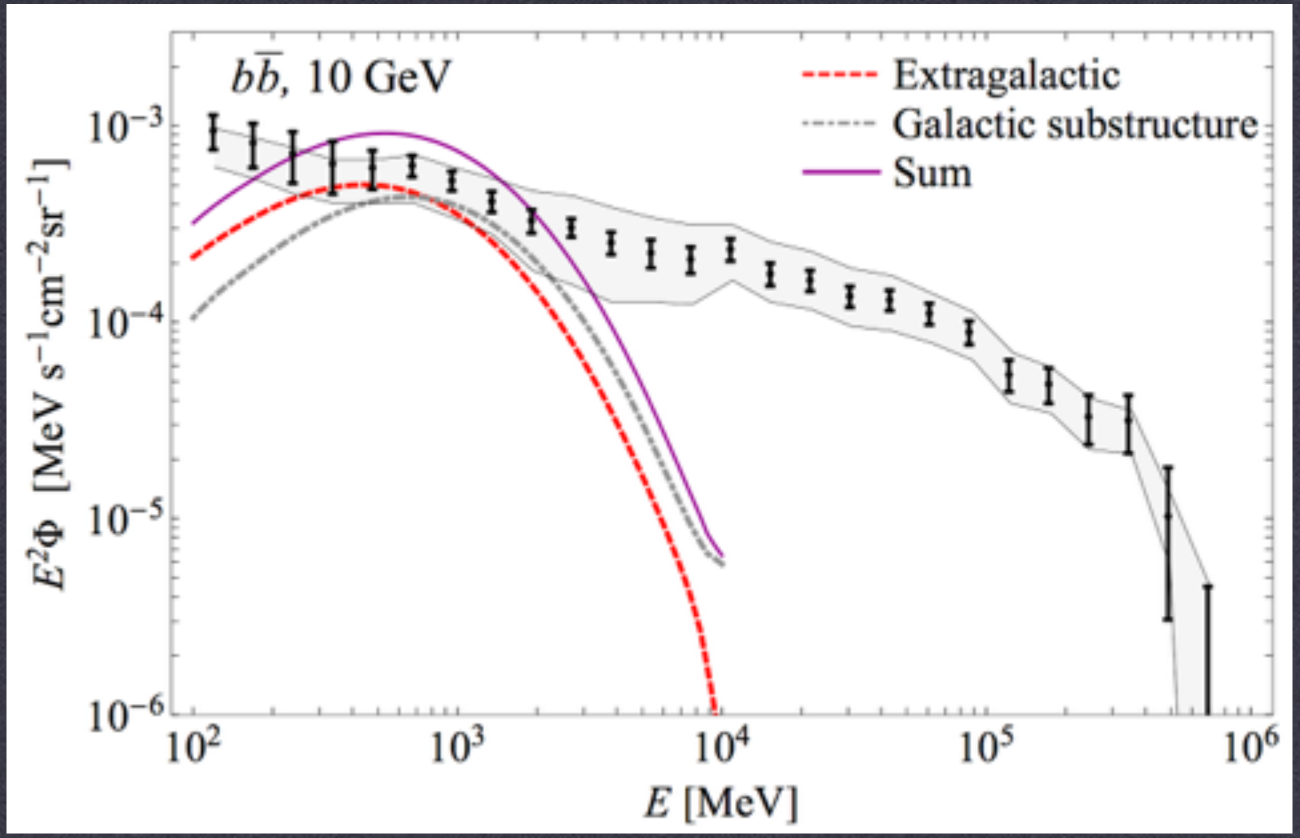
- Additionally, subtraction of the CR background is a major uncertainty, an instrument capable of effectively removing proton backgrounds is highly beneficial for this measurement.

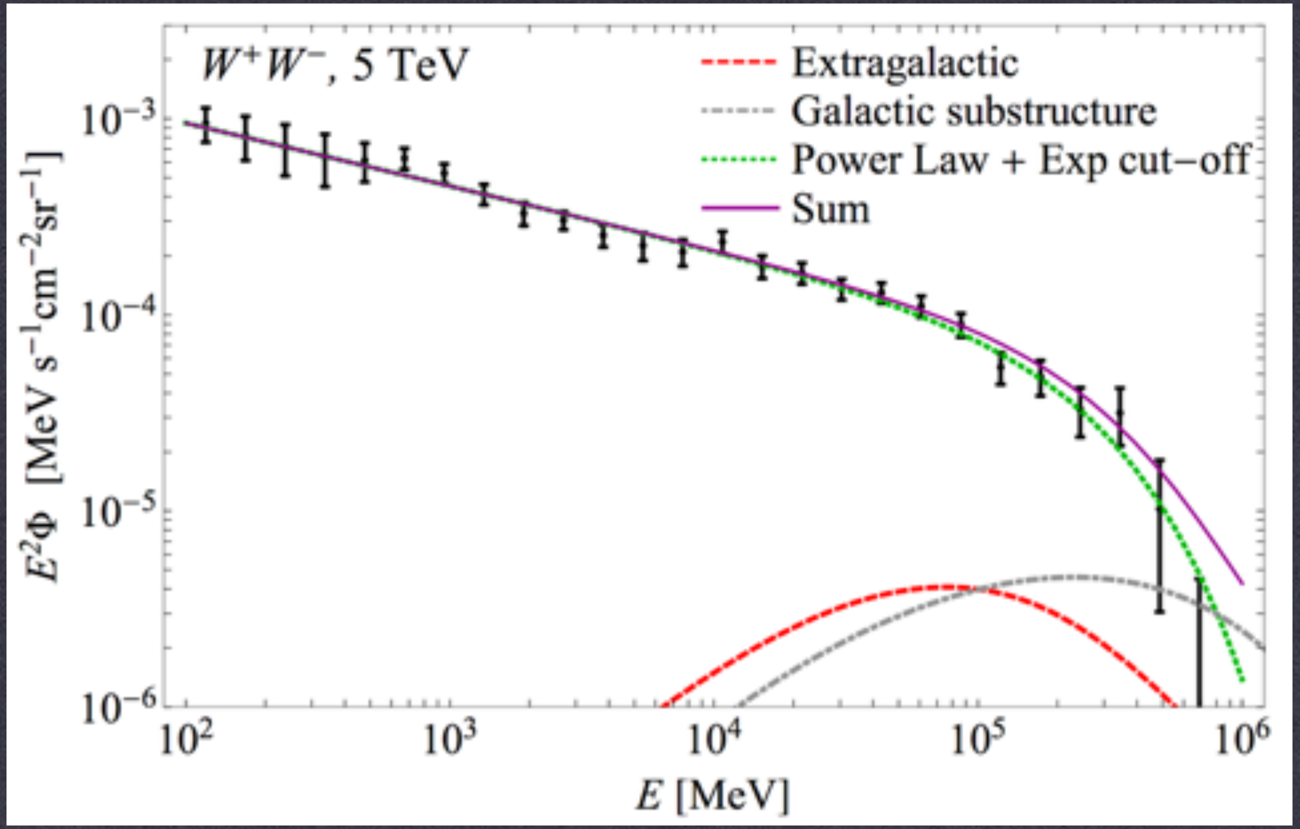




EXTRAGALACTIC BACKGROUND

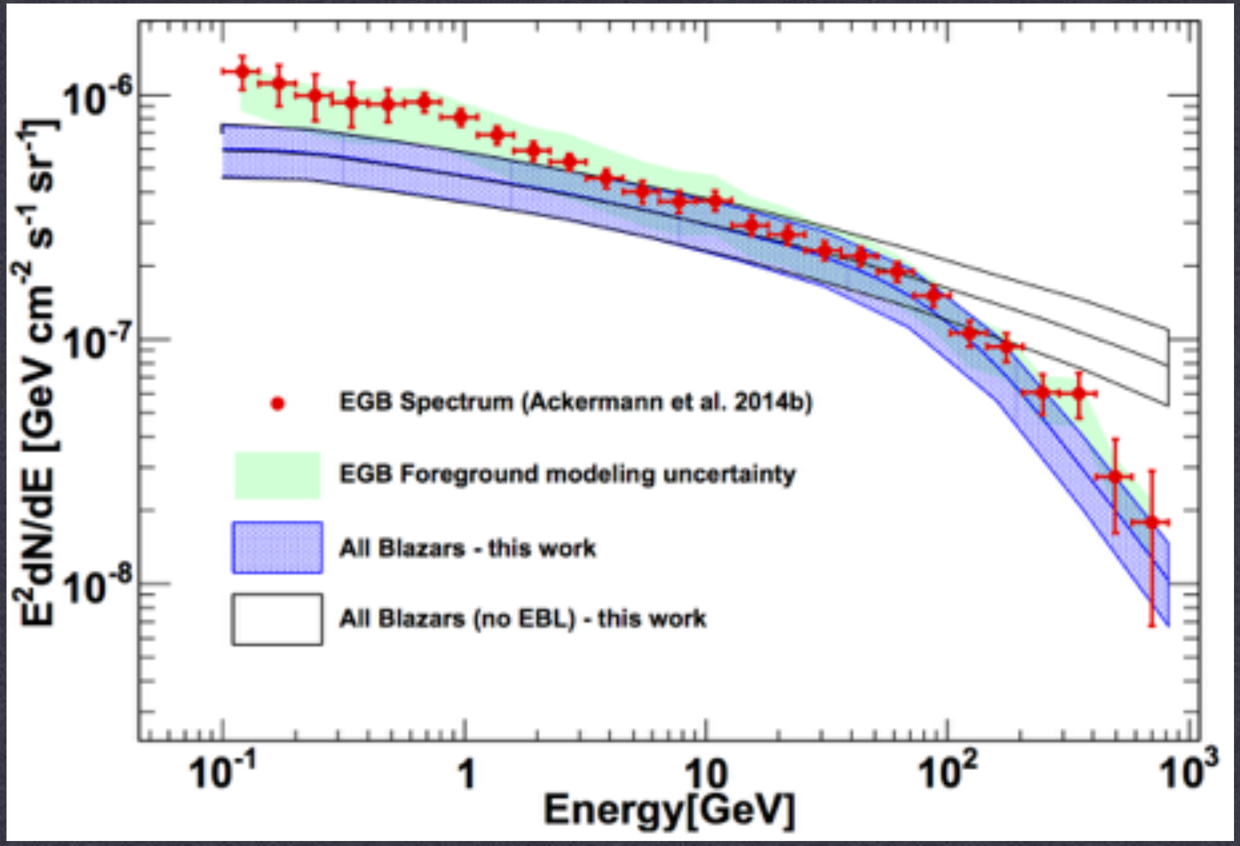
- This implies that dark matter annihilation limits from the extragalactic background can increase more quickly than sqrt(t), even though we are not in a statistically limited regime.

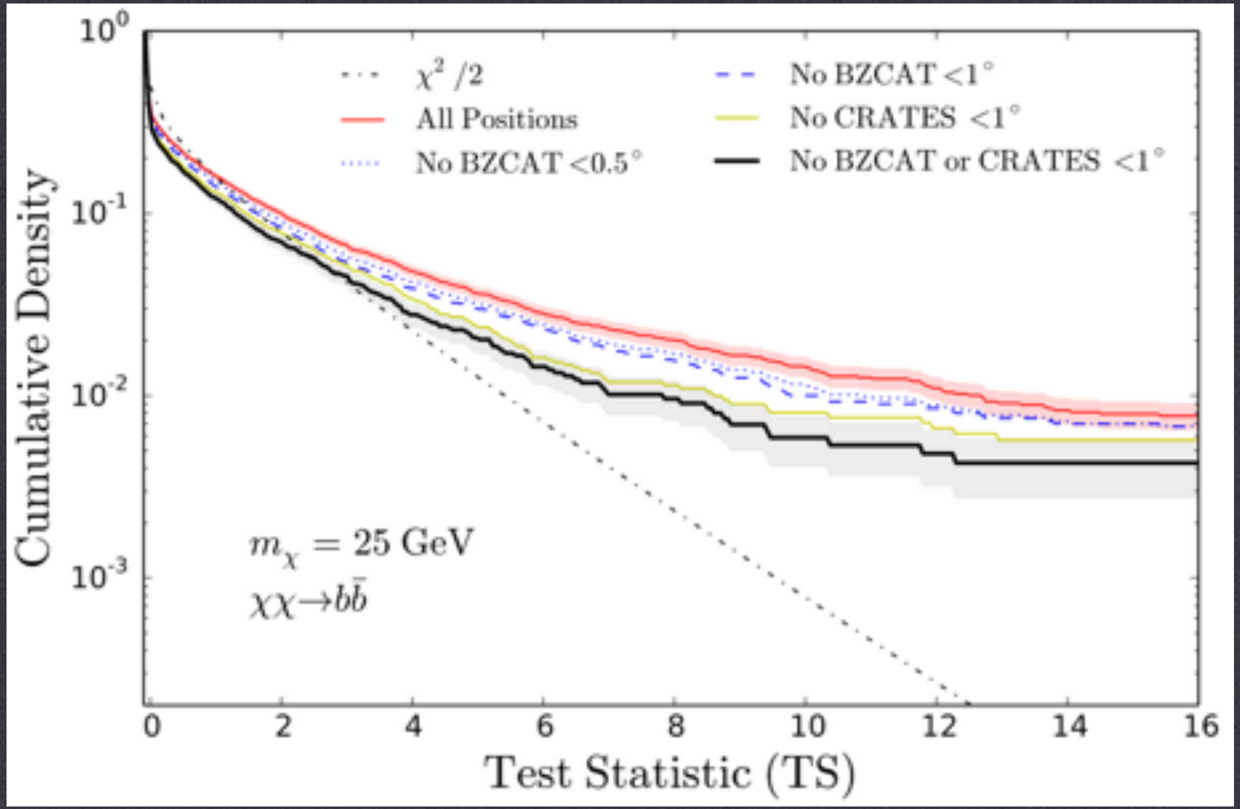




BACKGROUND BLAZARS

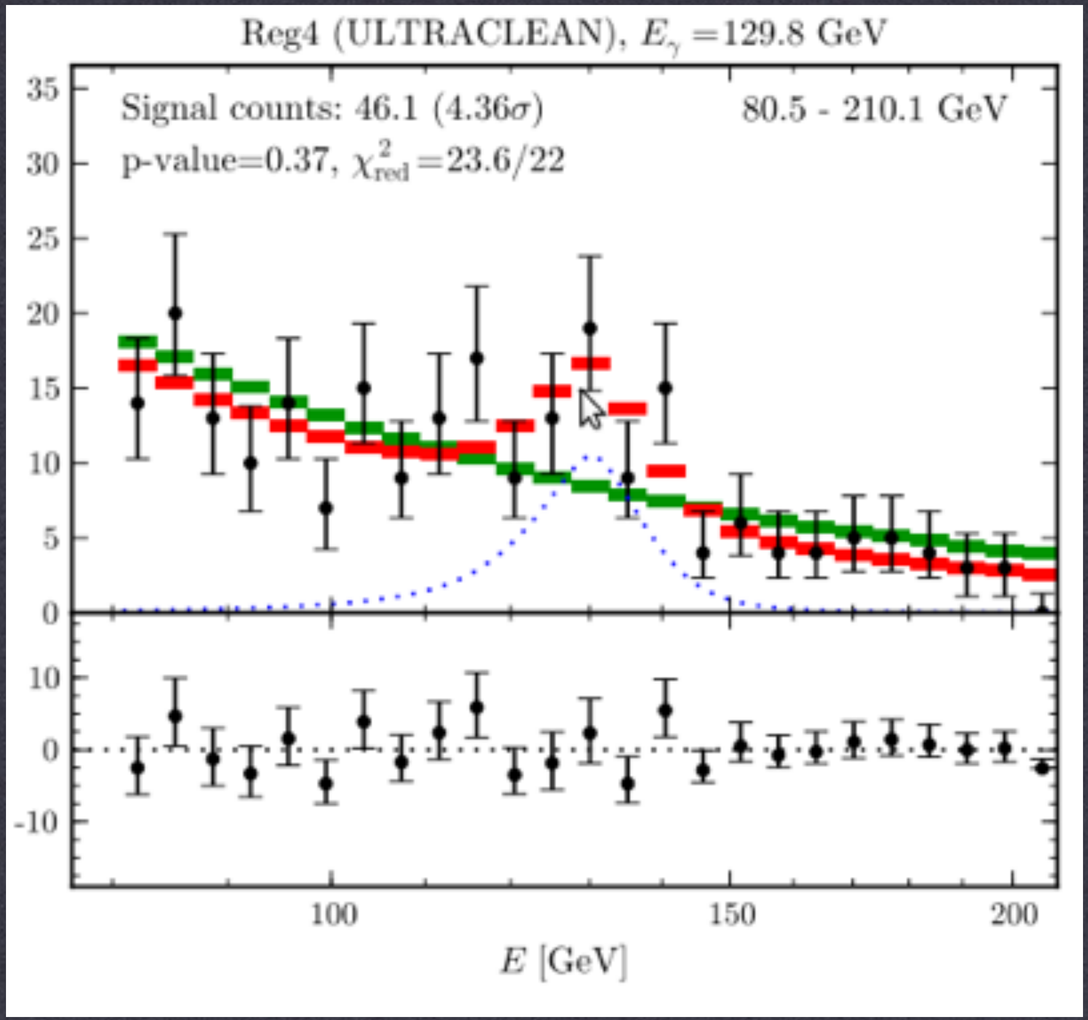
- Statistically, we know that much of this background is due to blazars
- In fact nearly 50% of the sources with TS ~ 10 — 25 are consistent with the position of known radio blazars
- More discoveries await, and this limit will continue to improve

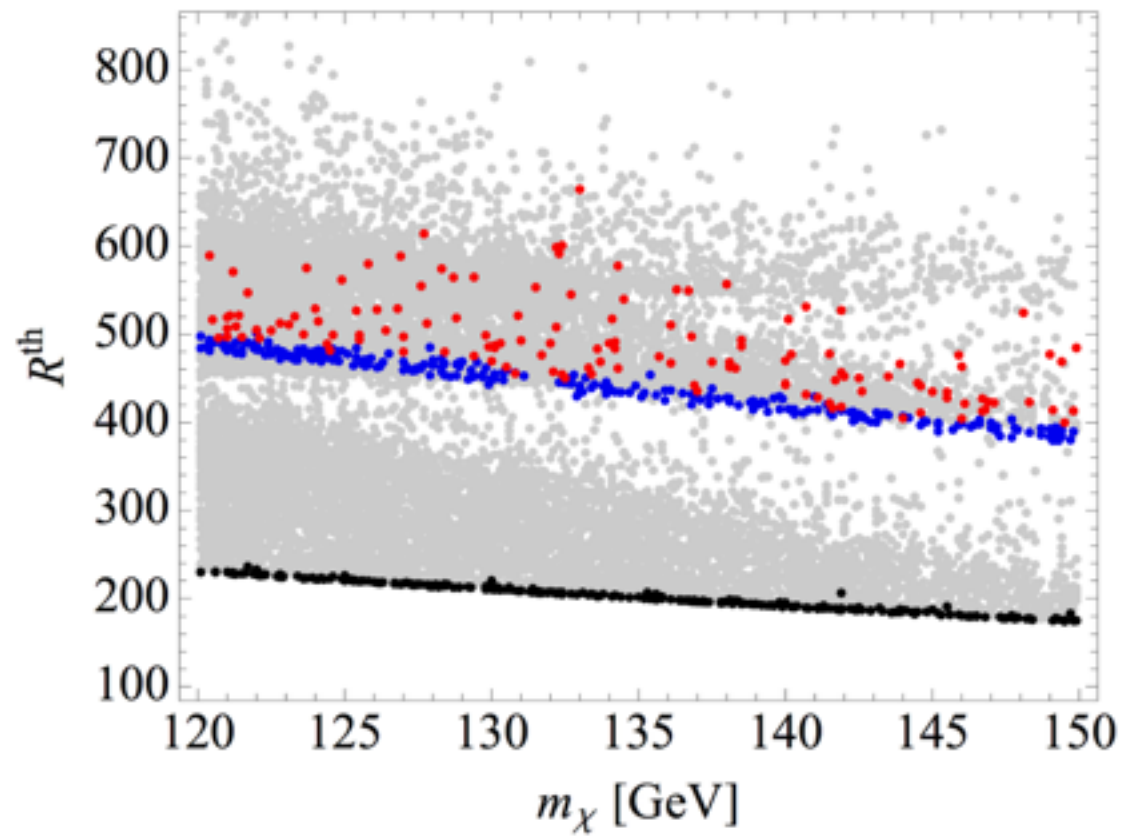




GAMMA-RAY LINES

- Gamma-Ray Lines may always pop up!
- Would be a strong smoking-gun signal for dark matter annihilation
- Can be difficult to predict, many MSSM models would provide lines that are very difficult to detect
- Lines at low energies stem from low mass dark matter, less motivated.





MULTIWAVELENGTH COMPLEMENTARITY

- Upcoming Experiments Will Improve our Sensitivity in all Targets!
  - Dwarfs
    - DES
  - Galactic Center
    - Gaia
    - Pan-Starrs
    - Missing Pulsar Problem / Radio Pulsars
  - Extragalactic Background
    - Multiwavelength detection of Extragalactic Sources

CONCLUSIONS (1/2)

- **What Instrument Would I Build for Indirect Detection:**
  - Energy Range (0.1 GeV - 10 GeV)
  - Large Field of View (key for dwarf studies)
  - High angular resolution throughout the energy range
    - Note, could sacrifice angular resolution in some sky regions (e.g. dwarfs, but keep angular resolution along the plane)
  - Energy Resolution is helpful, but not critical

CONCLUSIONS (2/2)

- Smoking Gun Signals
  - Gamma-Ray Line
  - Individual Detection in Multiple Dwarfs (J-factor / TS correlation)
  - A consistent detection in multiple sources (dwarfs/GC/IGRB)

- Current observations are just beginning to probe the thermal relic cross-section. Lots of models exist just below the surface.

- Even if dark matter is observed by LHC/Direct Detection, these above observations will be critical for proving that the observed signal is dark matter.