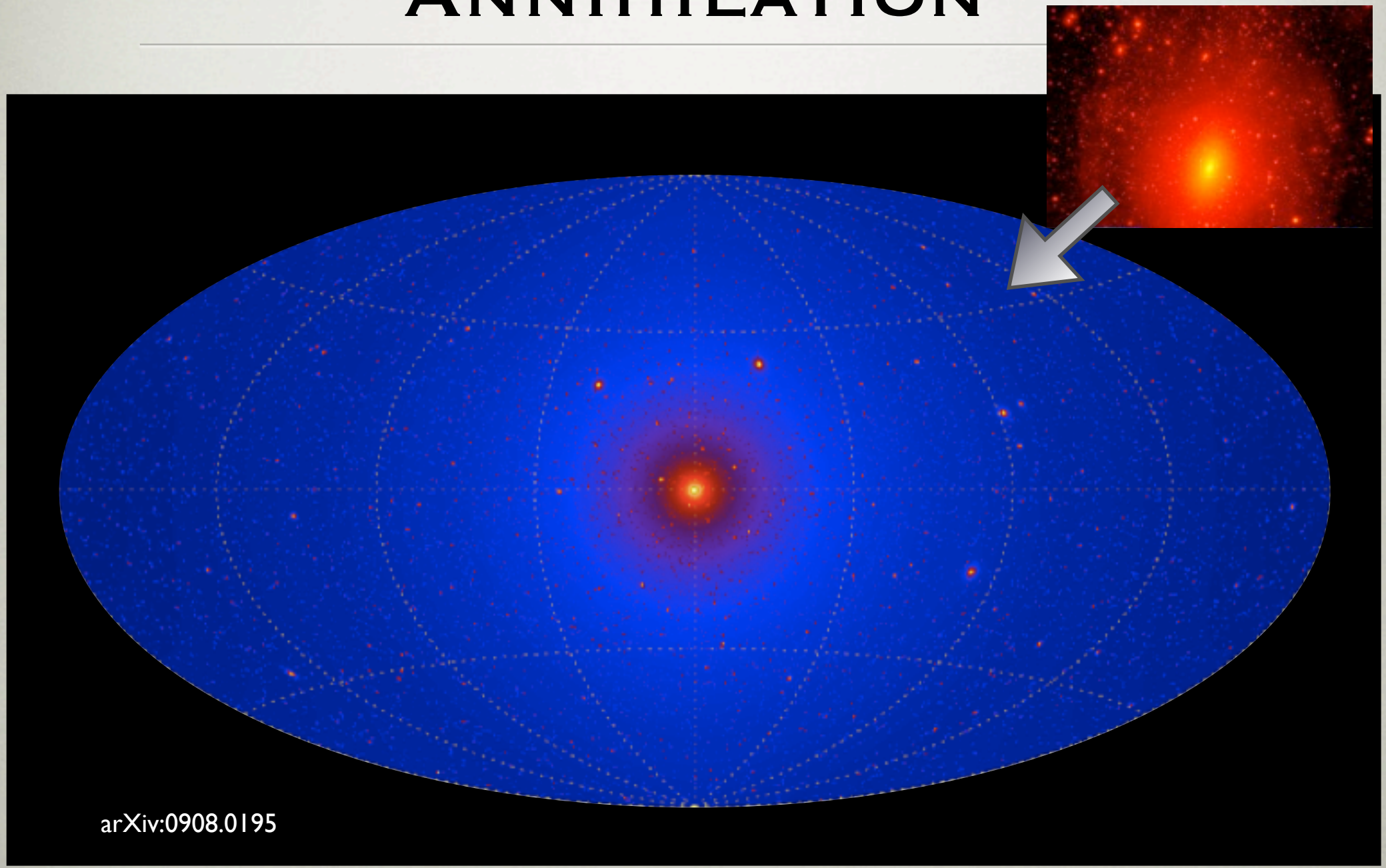
The Inner Region of the Milky Way Galaxy in High Energy Gamma Rays

Simona Murgia, SLAC-KIPAC
for the Fermi LAT Collaboration

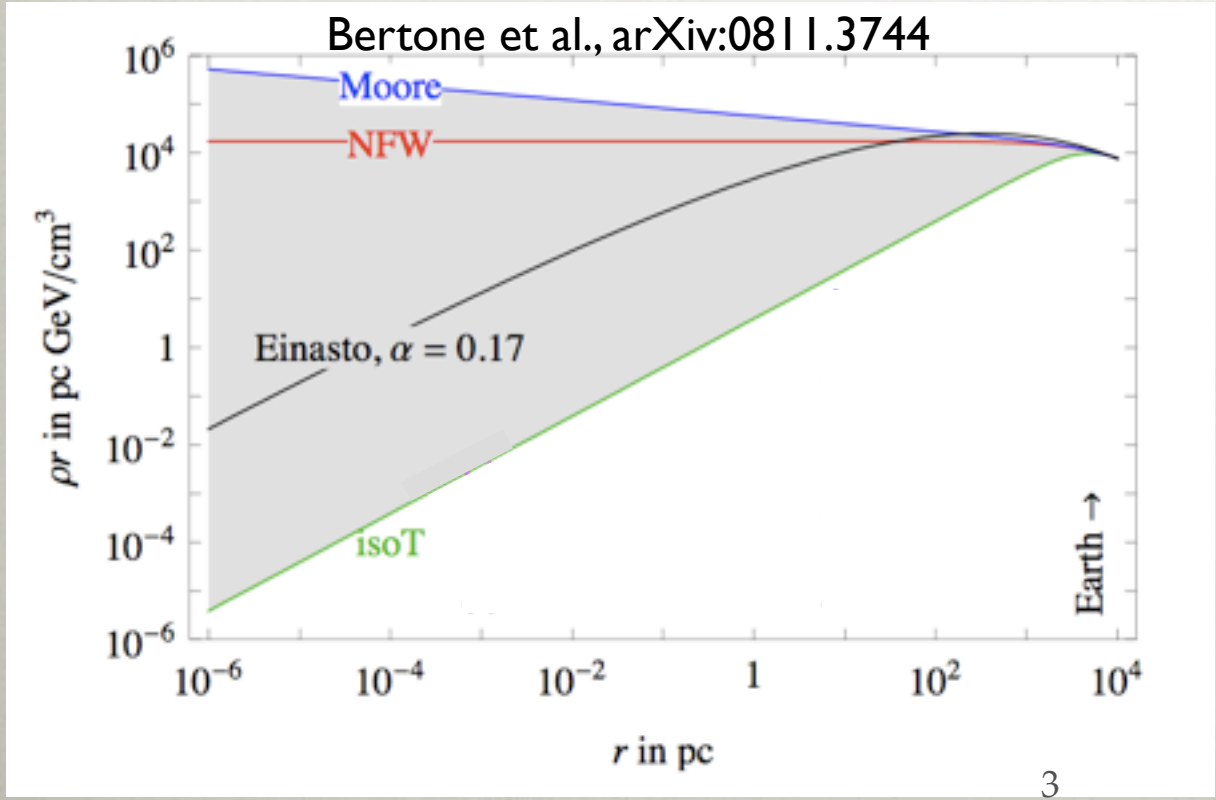
Dark Matter Signatures in the Gamma-ray Sky
Austin, Texas
7-8 May 2012

Gamma rays from DM Annihilation



Dark Matter Distribution

- The dark matter annihilation (or decay) signal strongly depends on the dark matter distribution.
- Cuspier profiles and clumpiness of the dark matter halo can provide large boost factors



NFW profile

Navarro, Frenk, and White 1997

$$\rho(r) = \rho_0 \frac{r_0}{r} \frac{(1 + r_0/a_0)^2}{(1 + r/a_0)^2}$$

$$\rho_0 = 0.3 \text{ GeV/cm}^3$$
$$a_0 = 20 \text{ kpc}, \; r_0 = 8.5 \text{ kpc}$$

- ✓ Via Lactea II (Diemand et al 2008) predicts a cuspier profile, $\rho(r) \propto r^{-1.2}$
- ✓ Aquarius (Springel et al 2008) predicts a shallower than r^{-1} innermost profile

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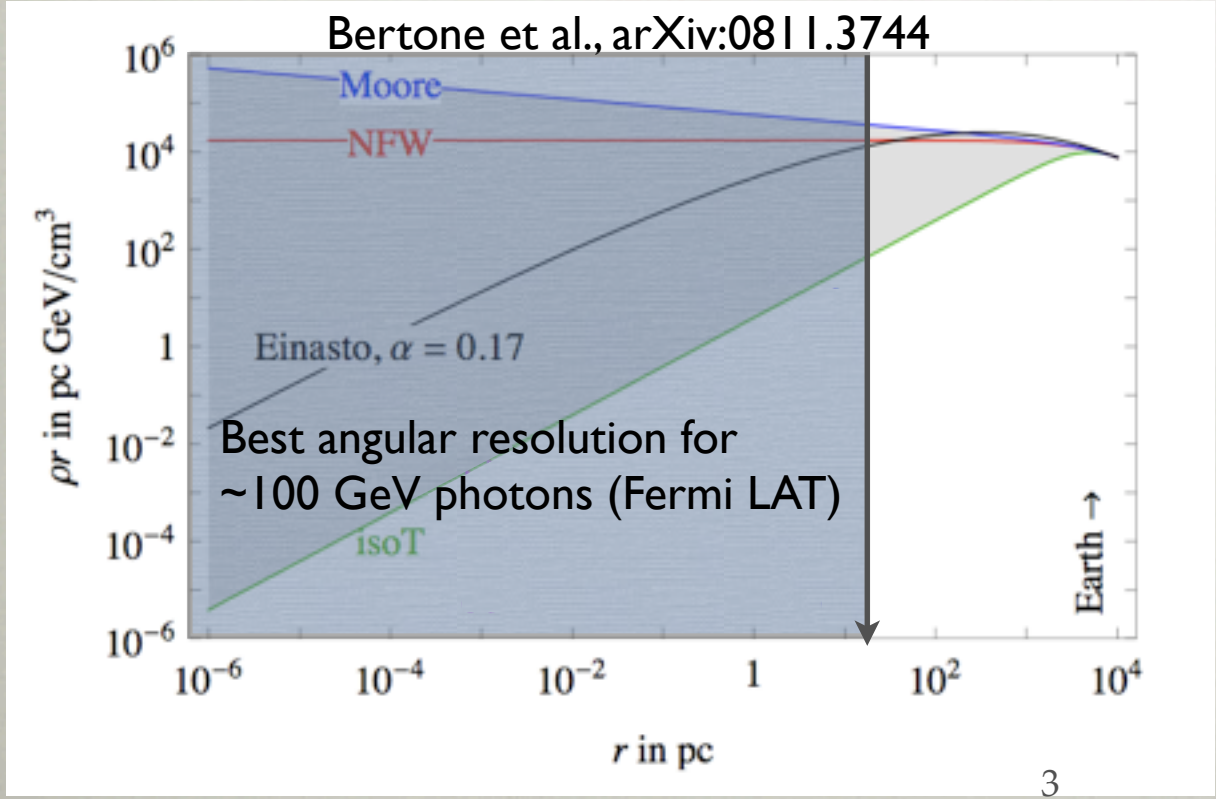

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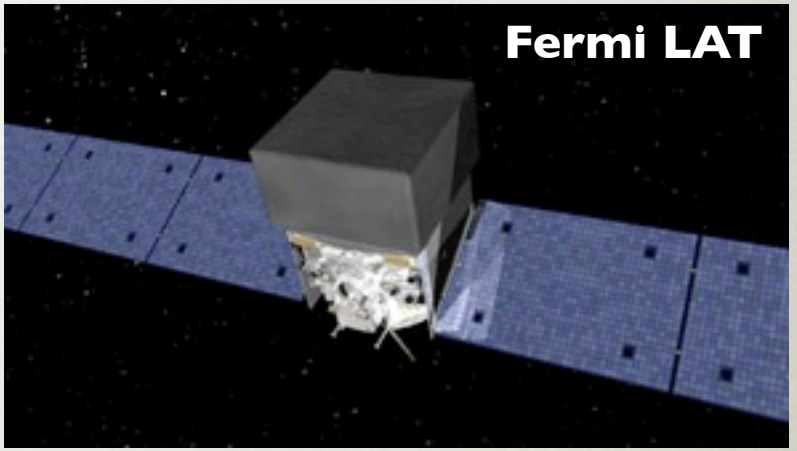
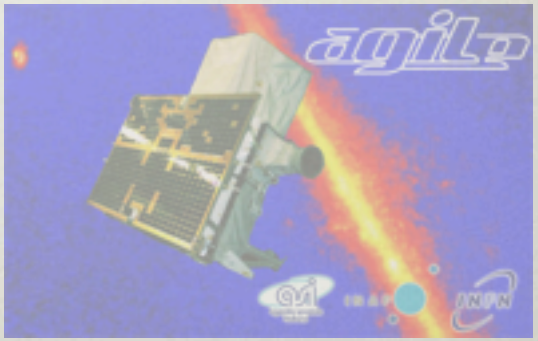
High Energy Gamma-ray Experiments

ON THE GROUND

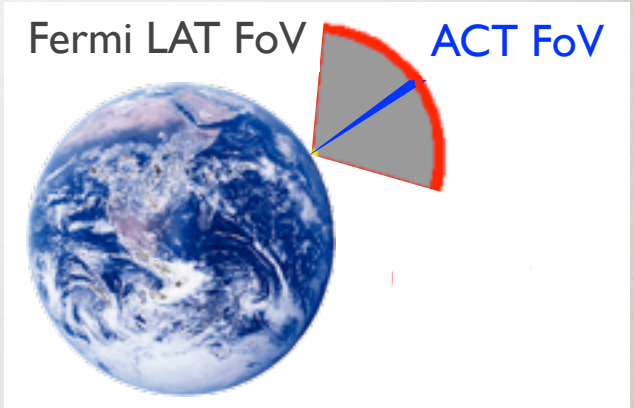
IN SPACE

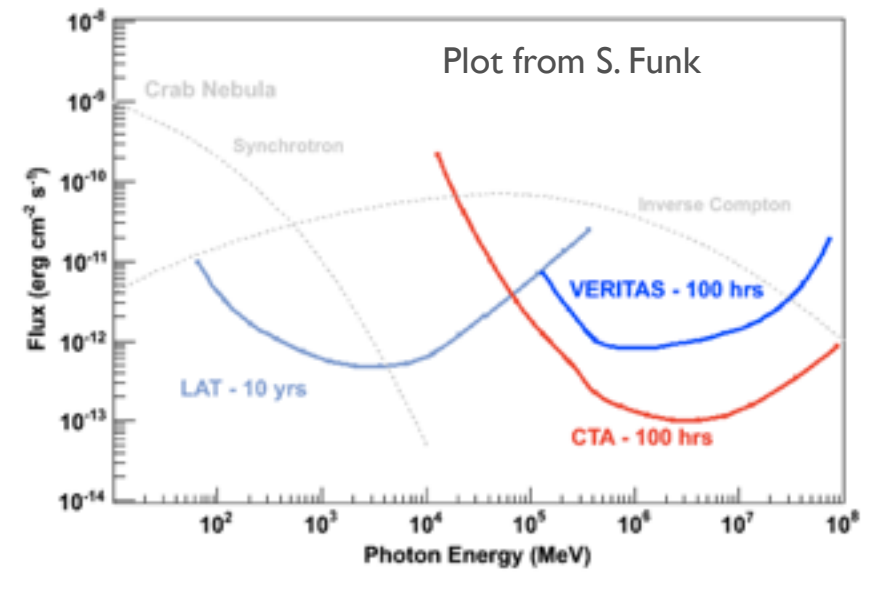


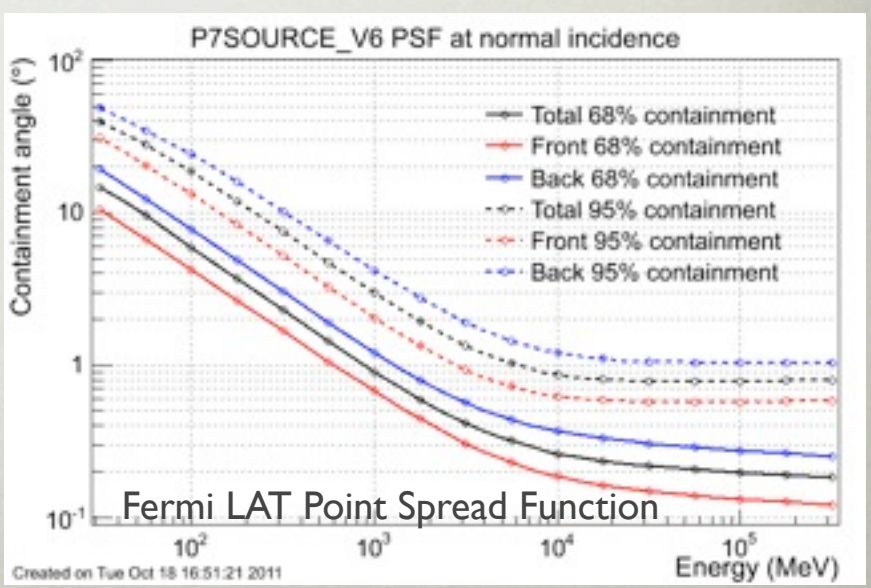


Ground vs Space Based Experiments

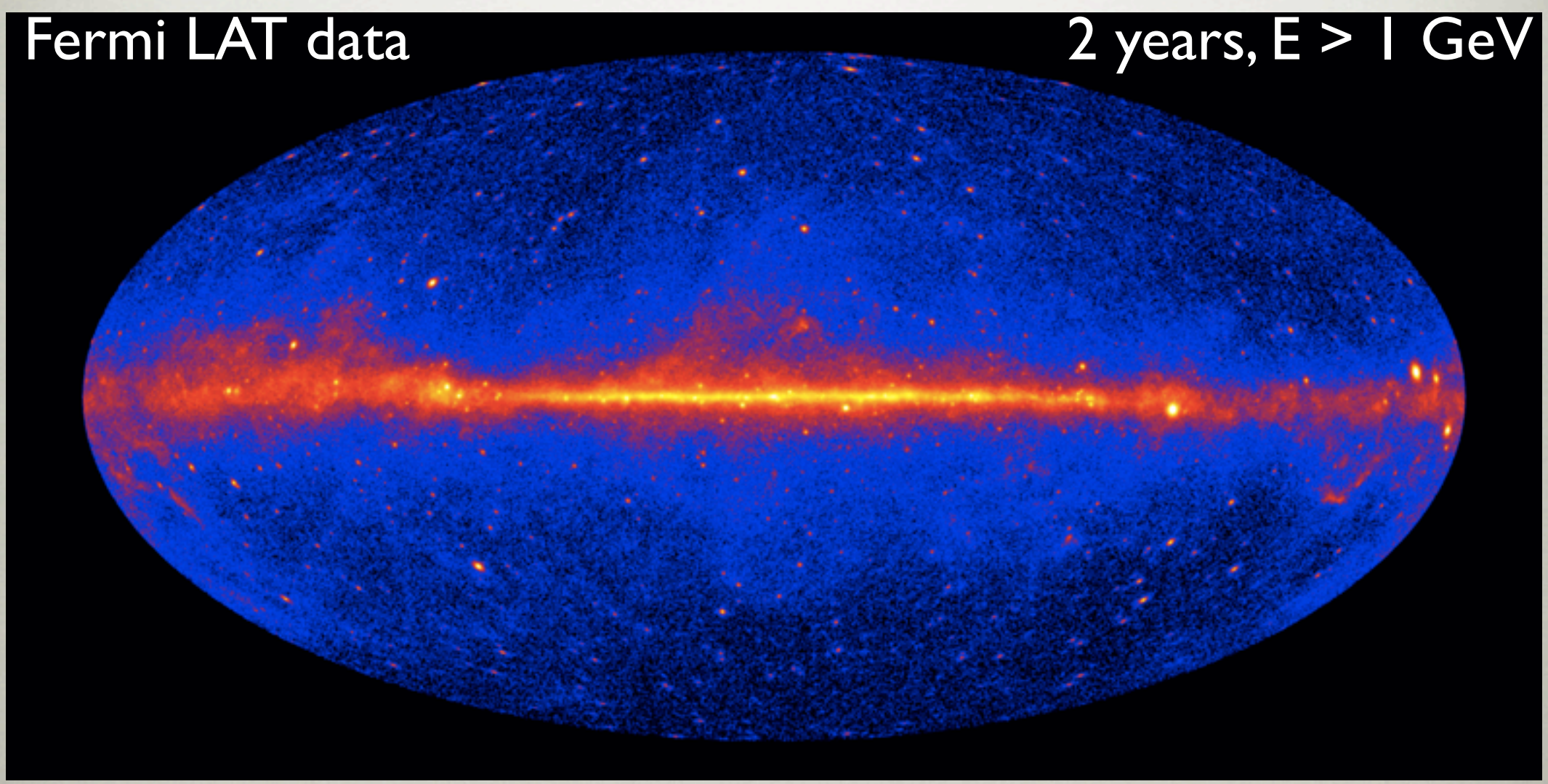
- Lower energy thresholds accessible in space, and up to ~100 TeV energies with experiments on the ground. Overlap in the ~100 GeV region
- Larger field of view, great duty cycle, and all sky coverage in space
- Single photon angular resolution: ~1° at 1 GeV (Fermi LAT), ~0.1° at 100 GeV (ACTs, Fermi LAT), ~0.05° at 1 TeV (ACTs)
- Energy resolution: ~ 8% at 10 GeV (Fermi LAT), ~15% at 1 TeV (ACTs)
- Large collecting area on the ground (high sensitivity)



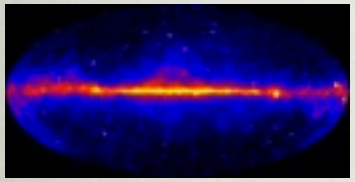




The Fermi Sky



Understanding the Gamma-ray Sky



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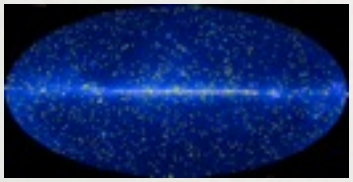
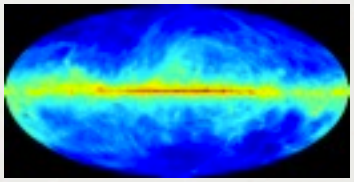


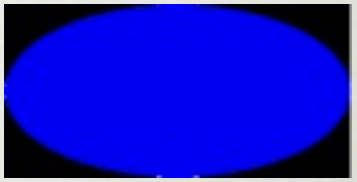
sources

+



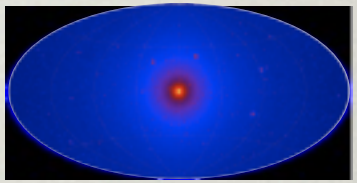
galactic diffuse

+



isotropic

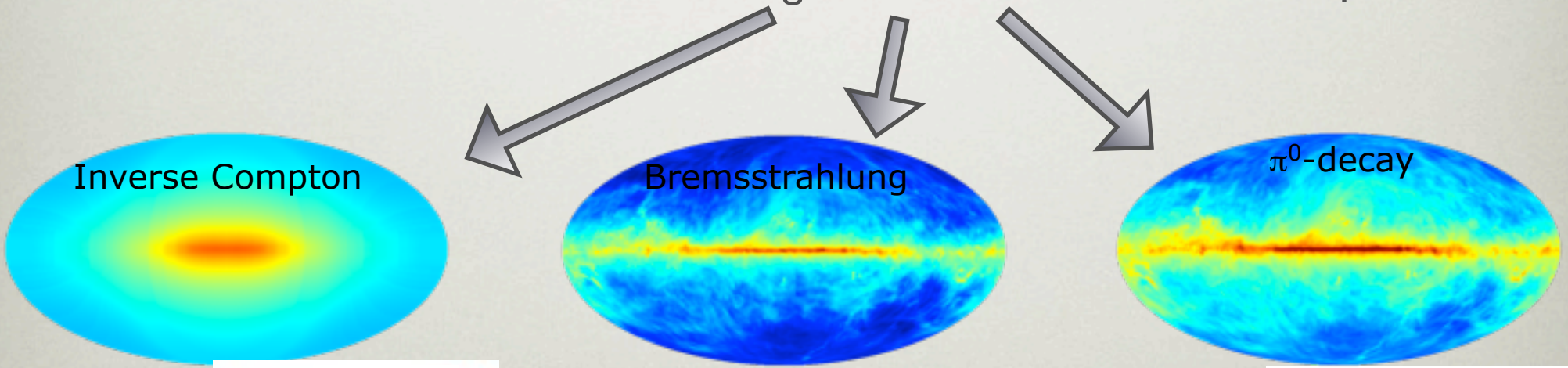
+

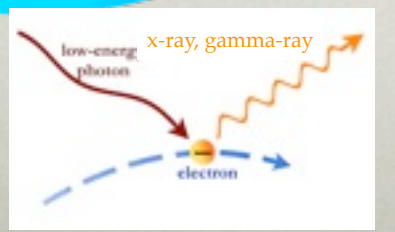


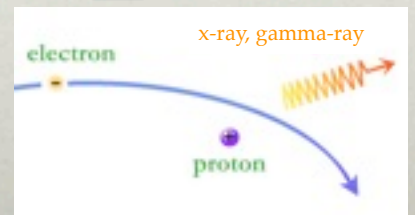
dark matter??

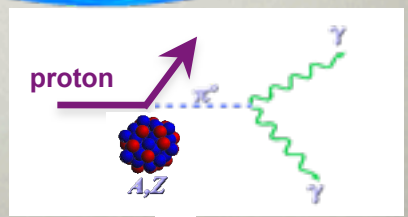
Galactic Diffuse Emission

- The diffuse gamma-ray emission from the Milky Way is produced by cosmic rays interacting with the interstellar gas and radiation field and carries important information on the acceleration, distribution, and propagation of cosmic rays.









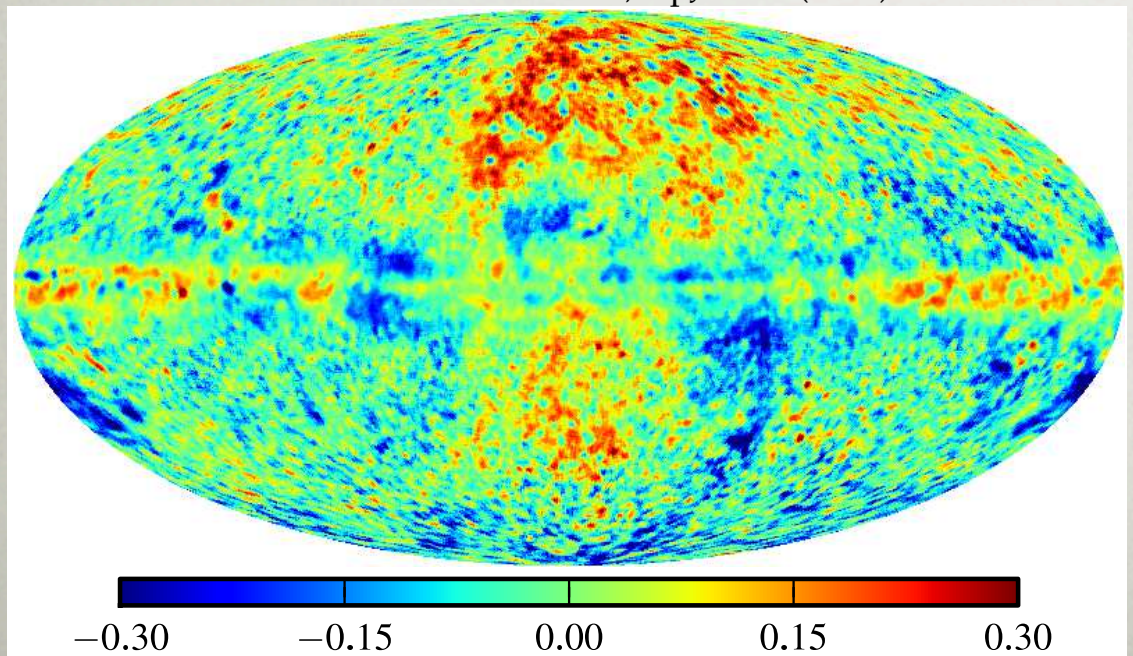
All Sky Modeling

- Cosmic ray origin, propagation, and properties of the interstellar medium can be constrained by comparing the data to predictions.
- Generate models (in agreement with CR data) varying CR source distribution, CR halo size, gas distribution (GALPROP, http://galprop.stanford.edu) and compare with Fermi LAT data (21 months, 200 MeV to 100 GeV)

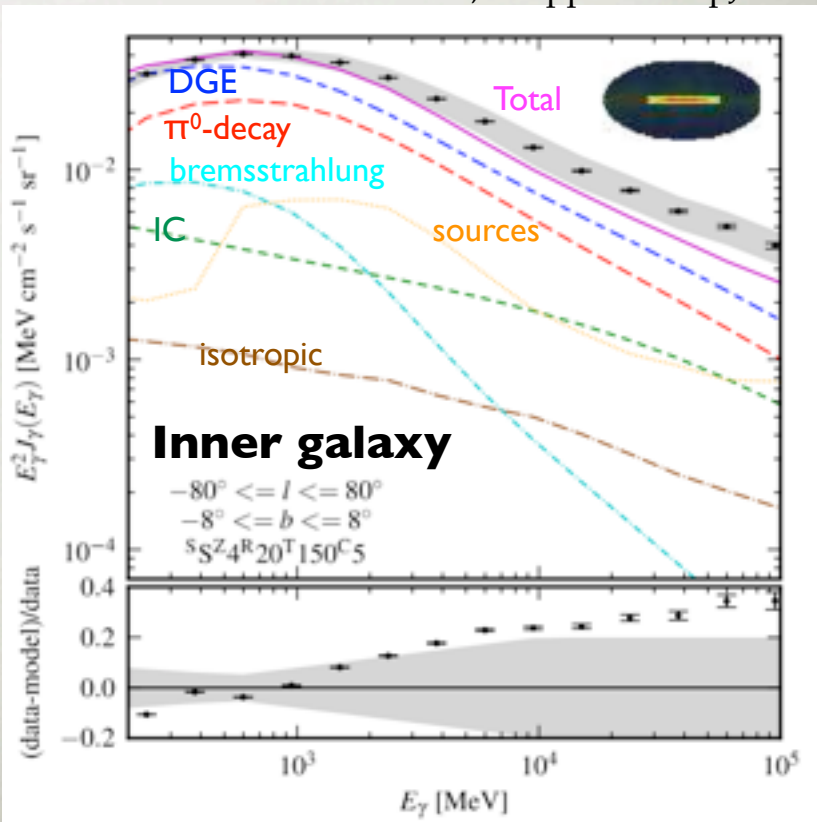
On a large scale the agreement between data and prediction is overall good, however some extended excesses stand out.

(data - prediction)/prediction) for example model

Fermi LAT Collaboration, ApJ 750 3 (2012)



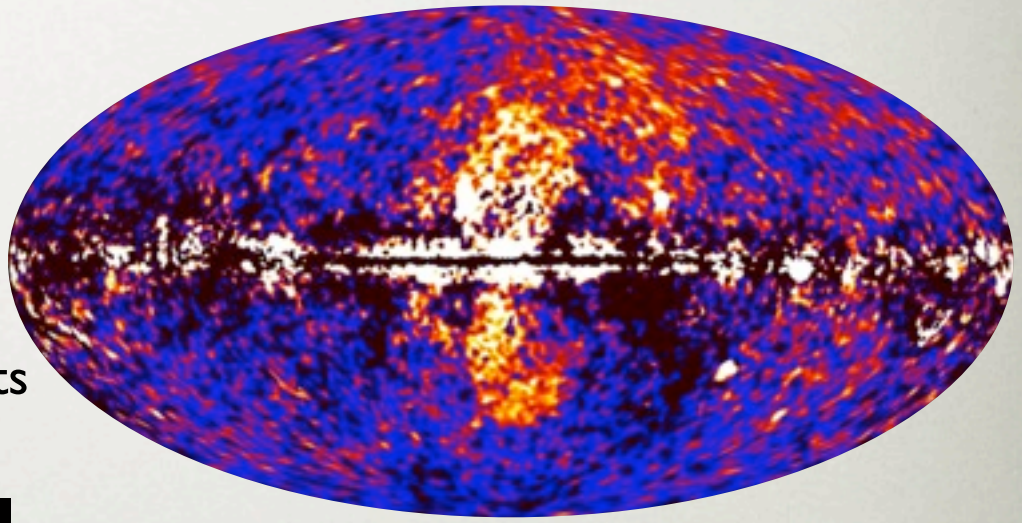
Fermi LAT Collaboration, to appear in ApJ

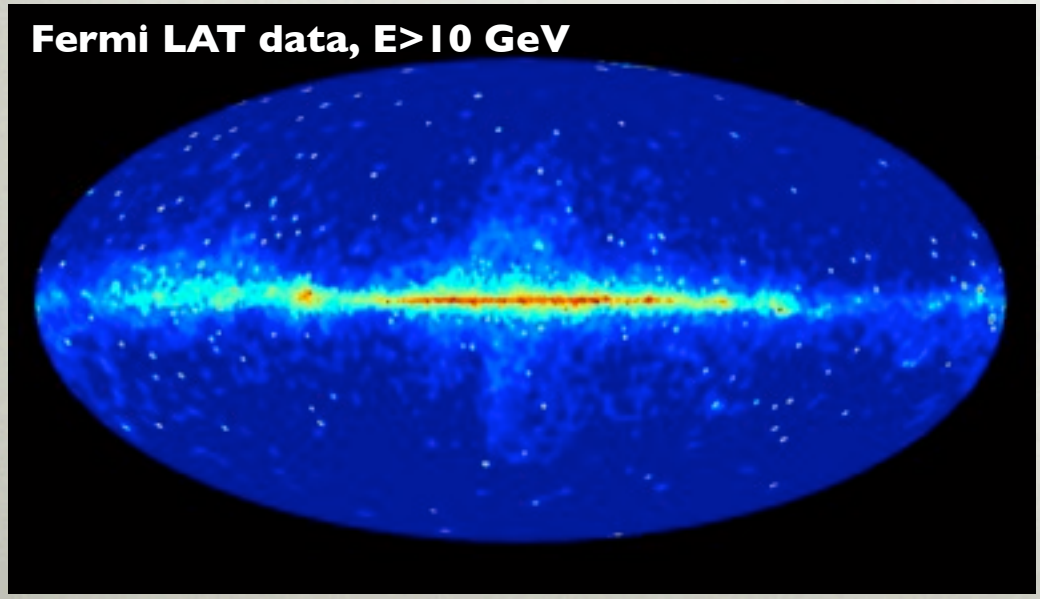


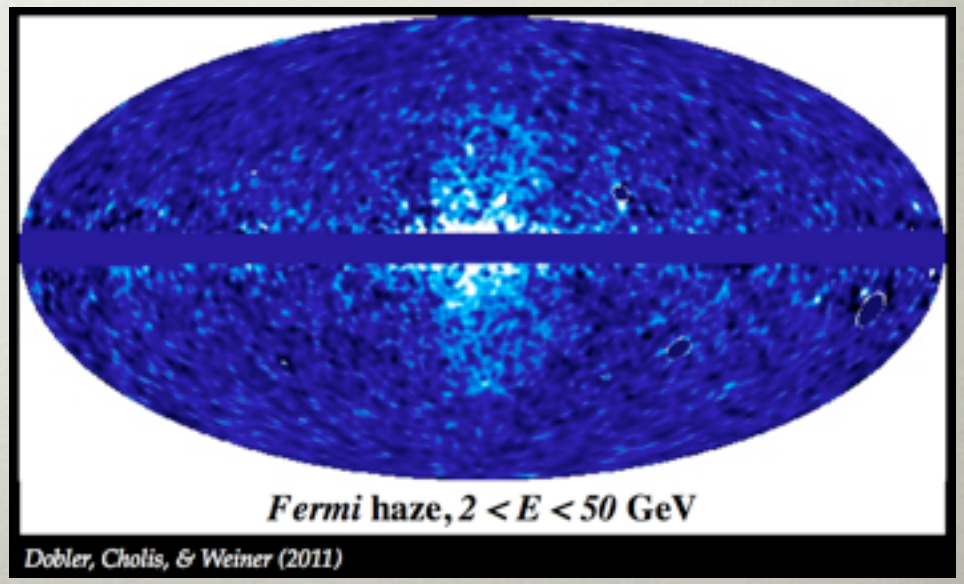
Extended Lobe-like Features in the Fermi Sky

- Gamma-ray bubbles (Su et al 2010):
  - very extended (~ 50° from plane)
  - hard spectrum (~E^{-2}, 1-100 GeV)
  - sharp edges
  - possible counterparts in other wavelengths (ROSAT, WMAP, and Planck)
- Outflow from the center of the Milky Way: jets from the supermassive black hole? starburst?

"Gamma-ray Bubbles"
Su, Slatyer, and Finkbeiner (2010)





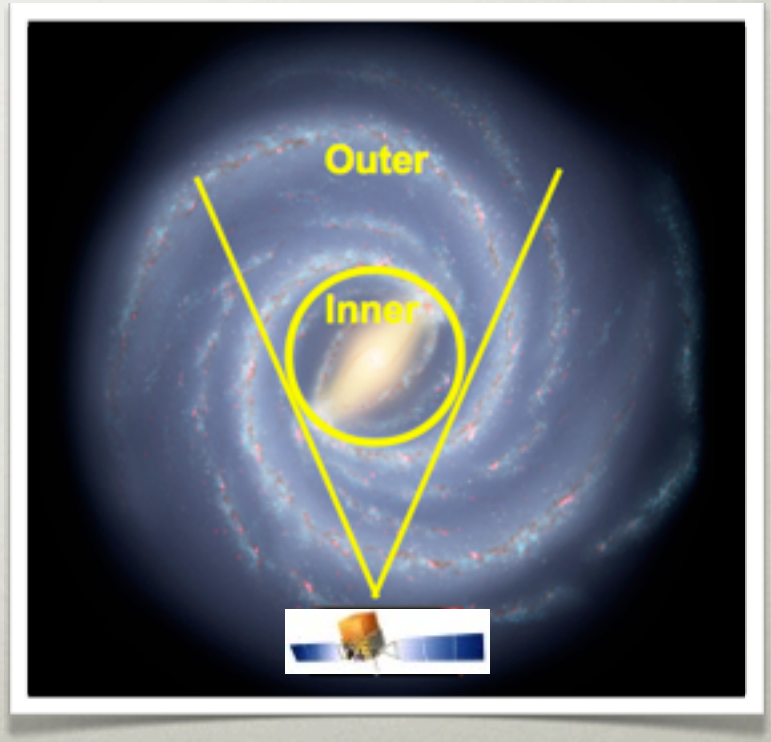


Galactic Center Region

☺ Steep DM profiles predicted by CDM ⇒ Large DM annihilation/decay signal from GC!

☹ Good understanding of the conventional astrophysical background is crucial to extract a potential DM signal from this complex region of the sky:

- source confusion: many energetic sources near to or in the line of sight of the GC
- diffuse emission modeling: large uncertainties due to the overlap of structures along the line of sight, difficult to model



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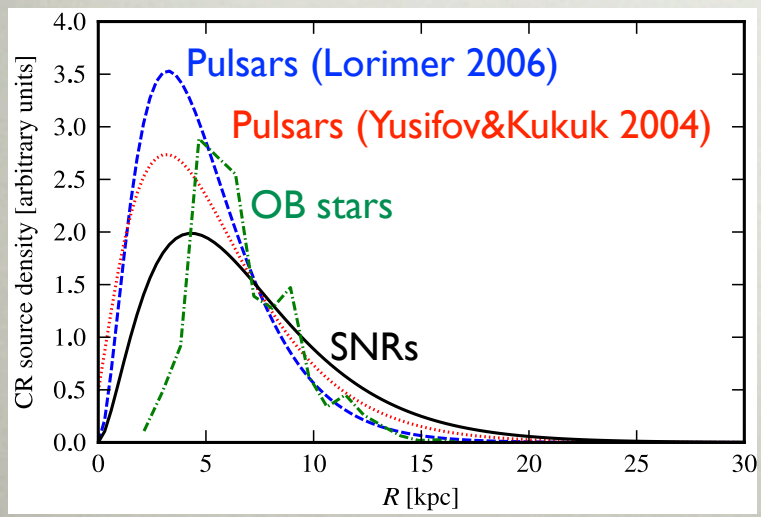
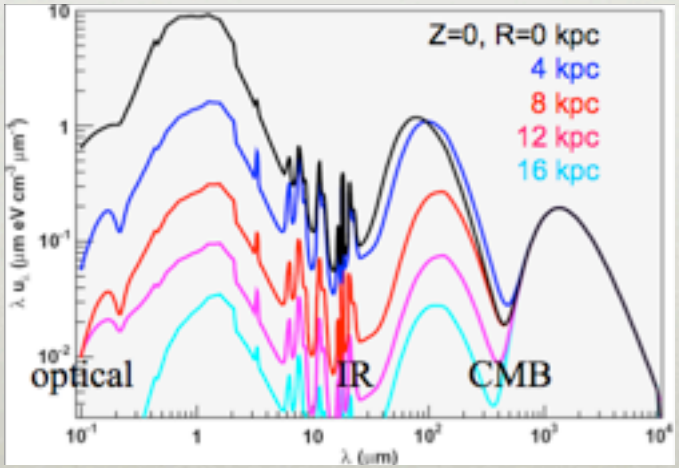
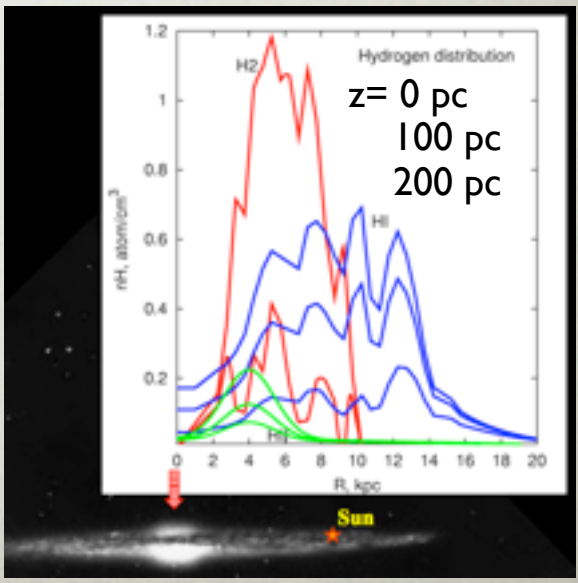
Cosmic ray source density



Interstellar radiation field

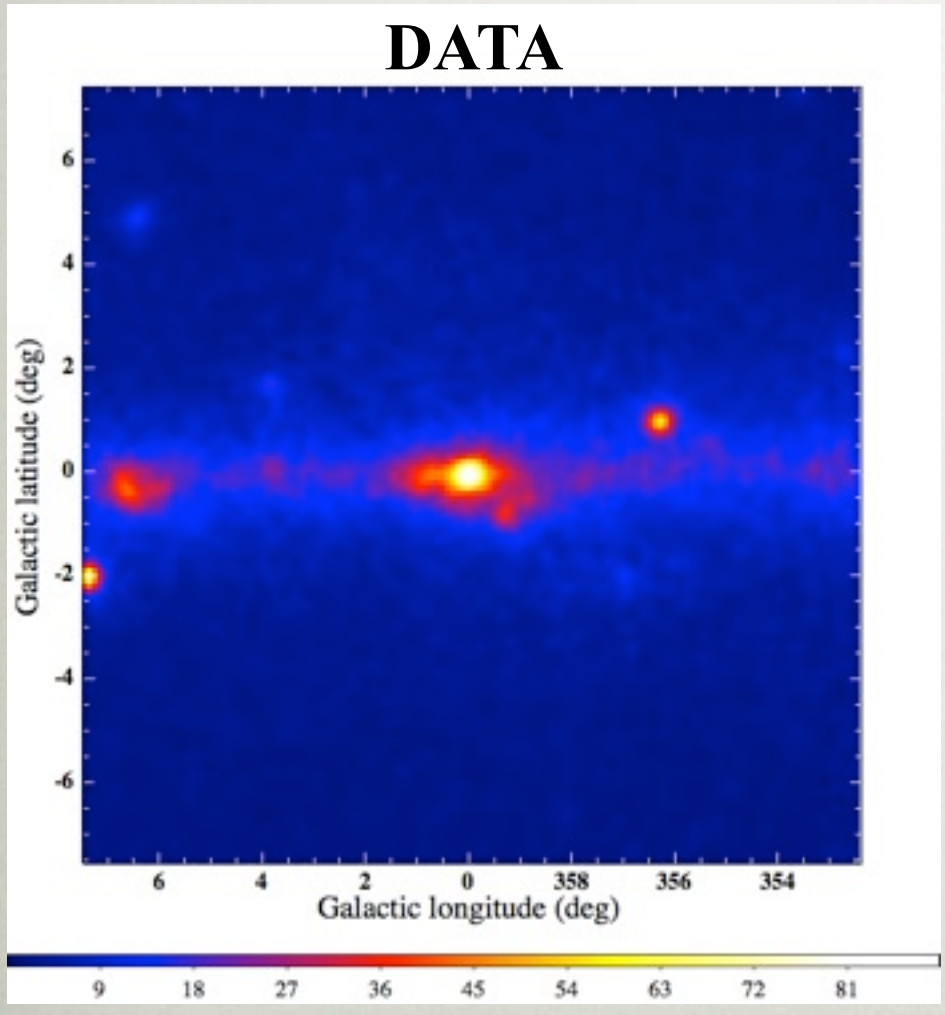


Average gas density



Fermi's View of the Inner Galaxy (15°x15° region)

Fermi LAT preliminary results with 32 months of data, E>1 GeV (P7CLEAN_V6, FRONT):



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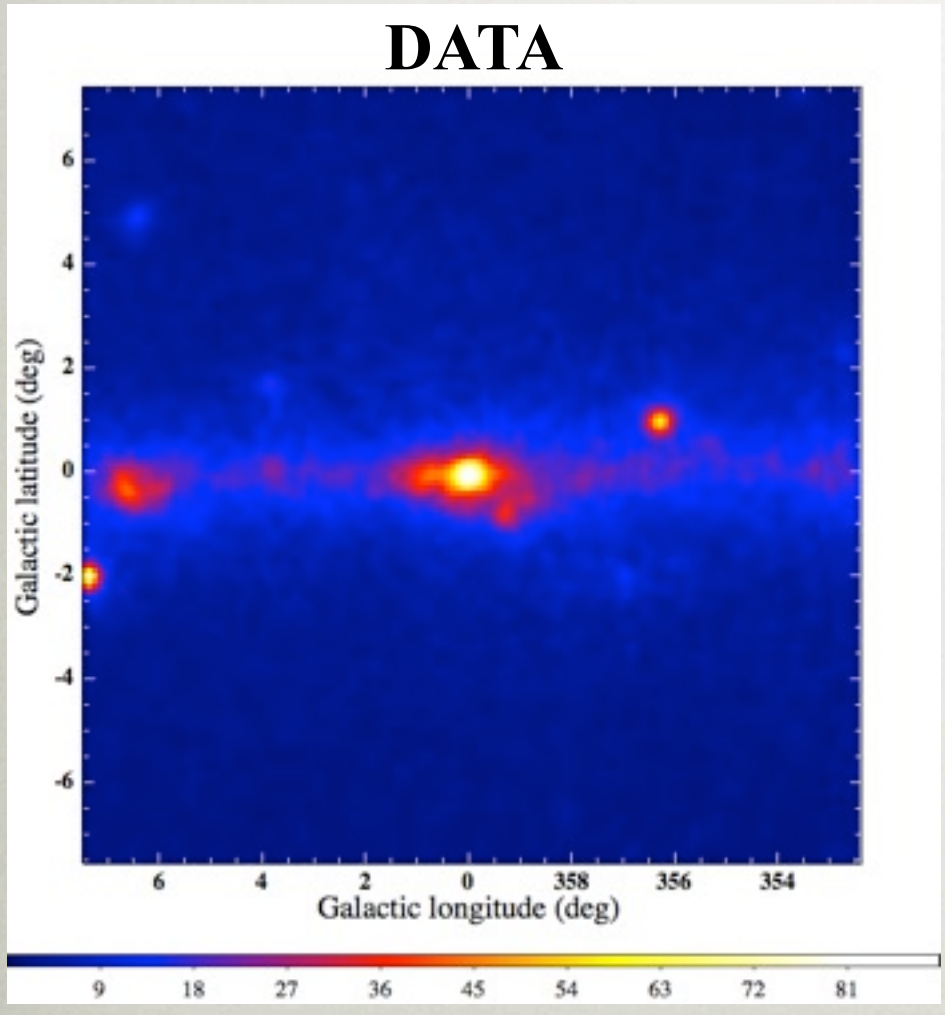

- Galactic diffuse emission model: all sky GALPROP model tuned to the inner galaxy

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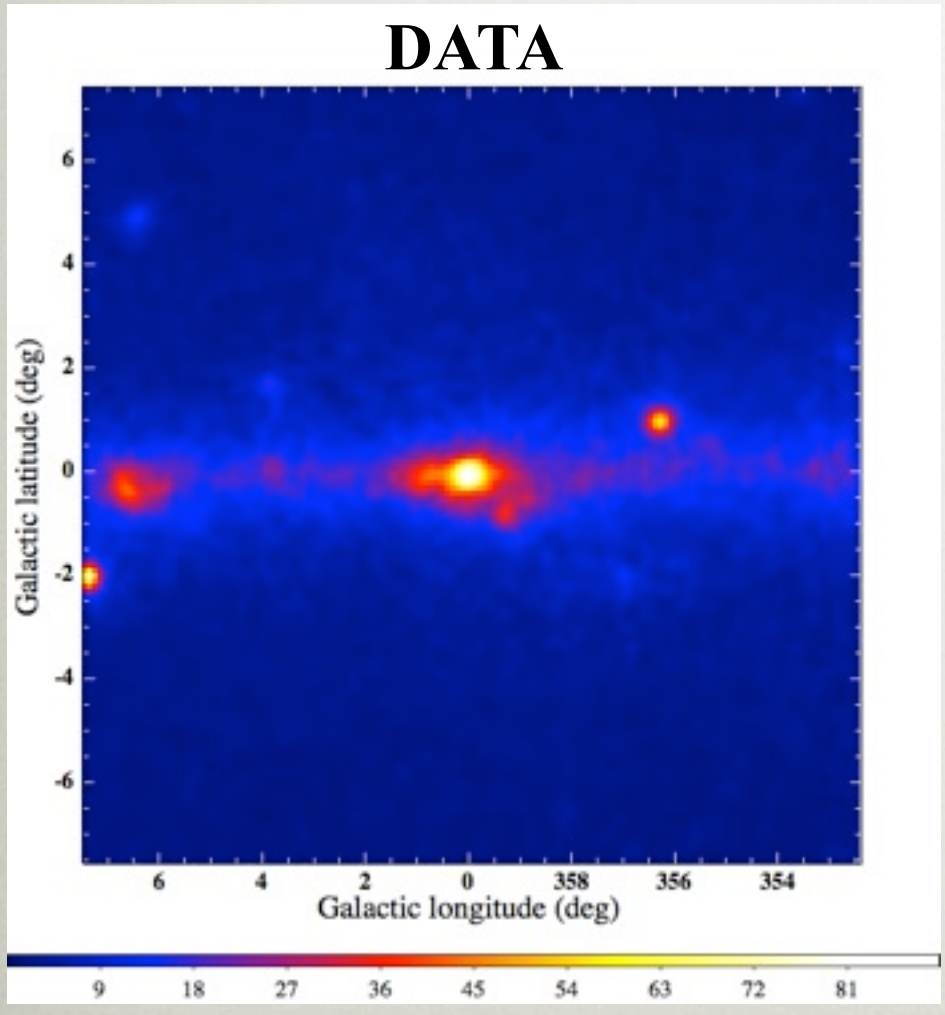

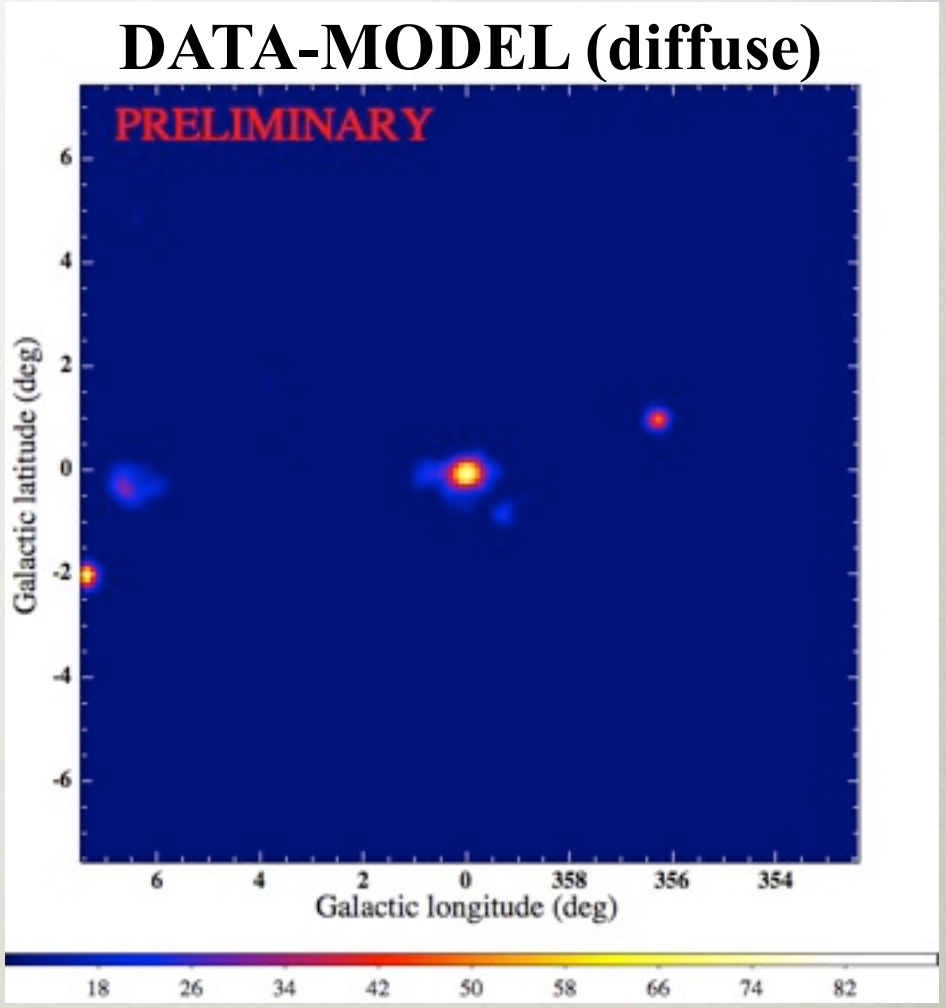

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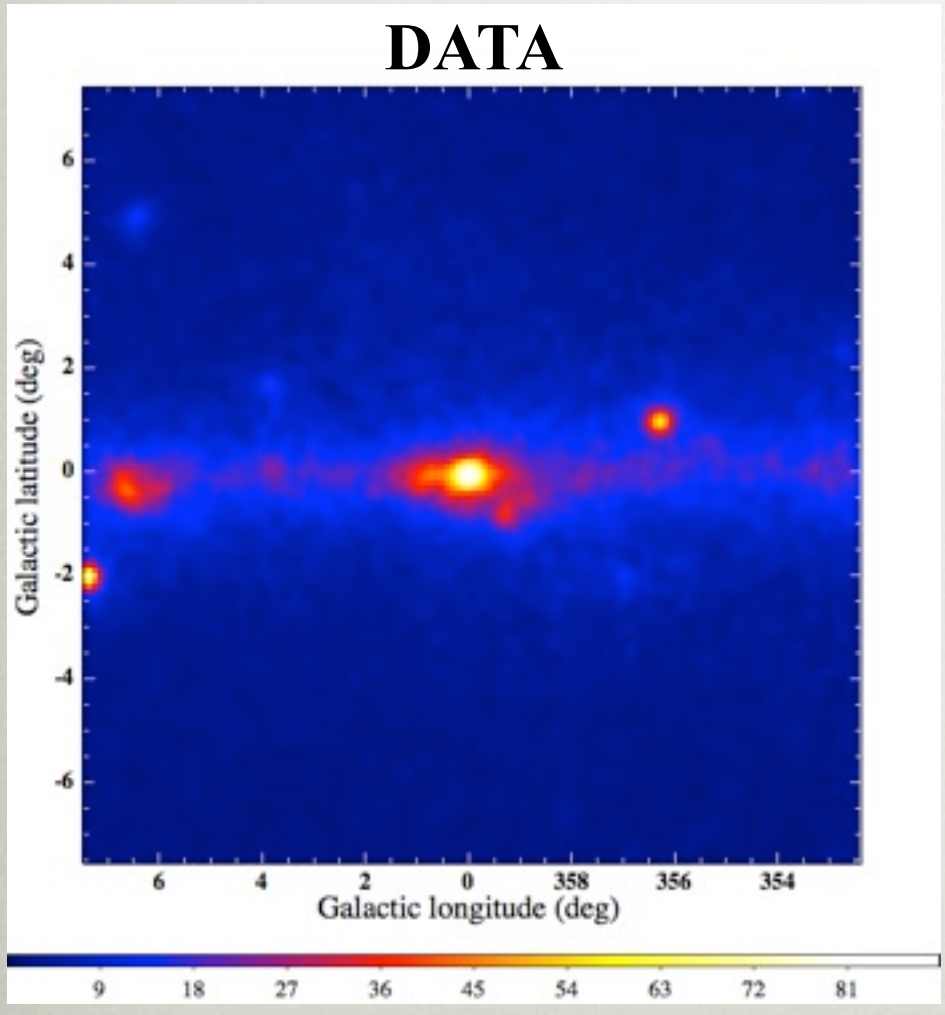

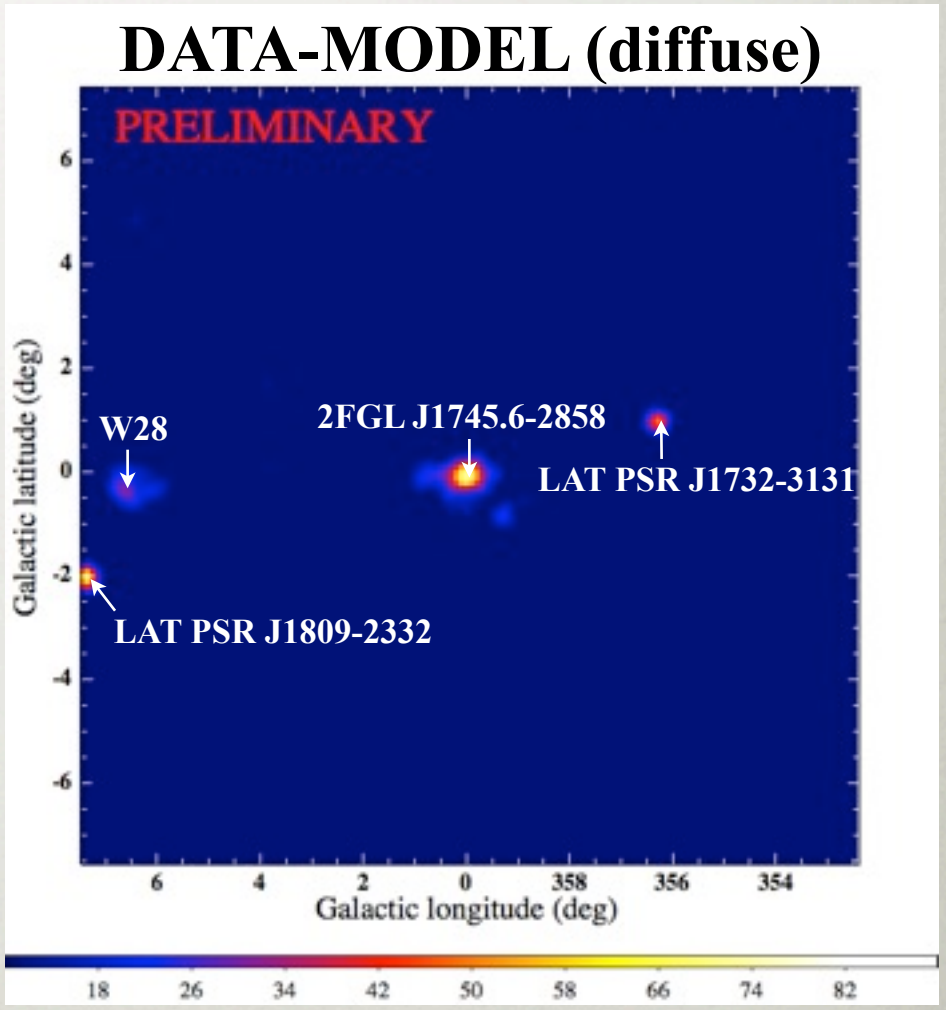

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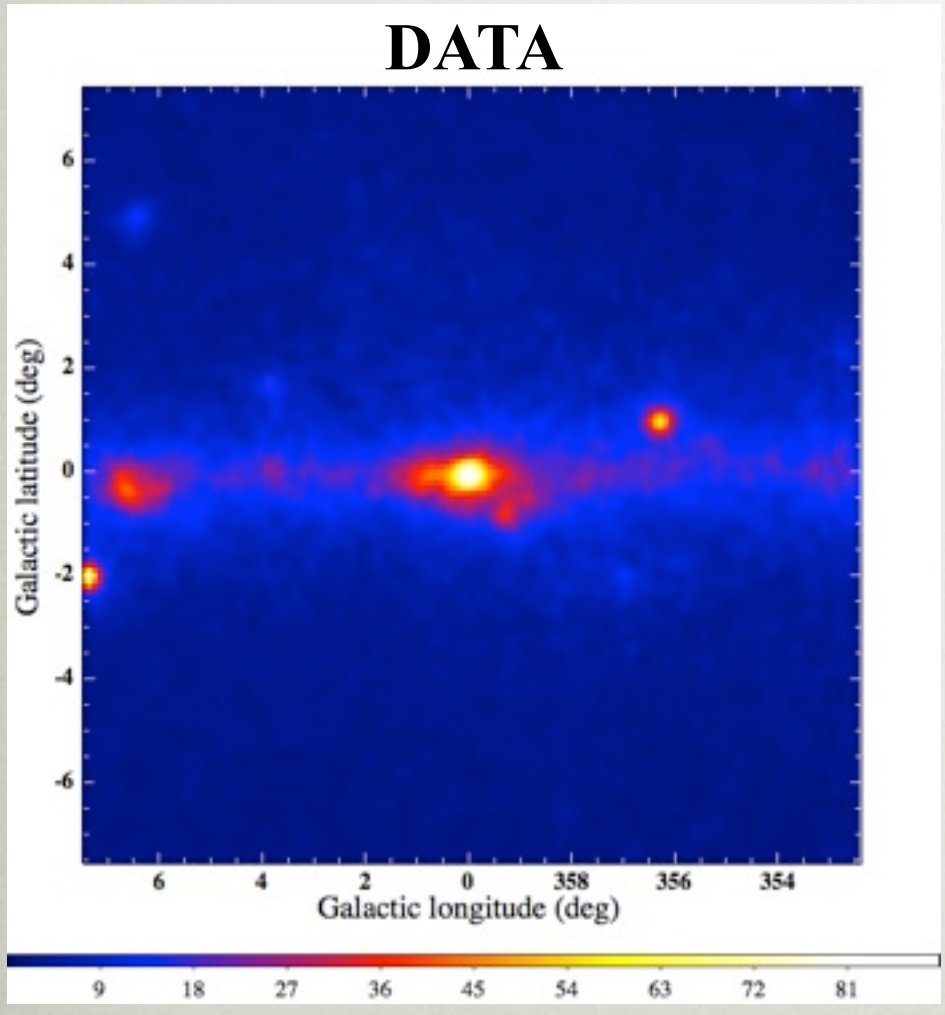

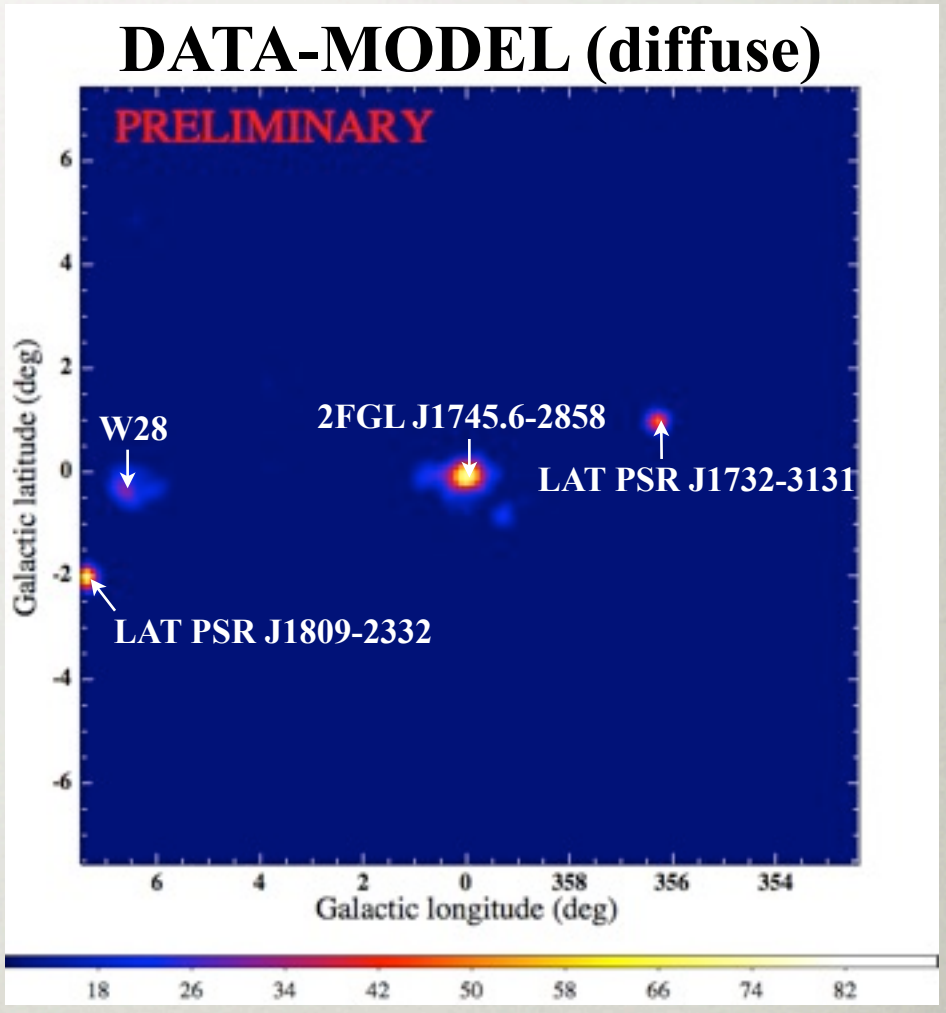

- Galactic diffuse emission model: all sky GALPROP model tuned to the inner galaxy
- ➡ Bright excesses after subtracting diffuse emission model are consistent with known sources.

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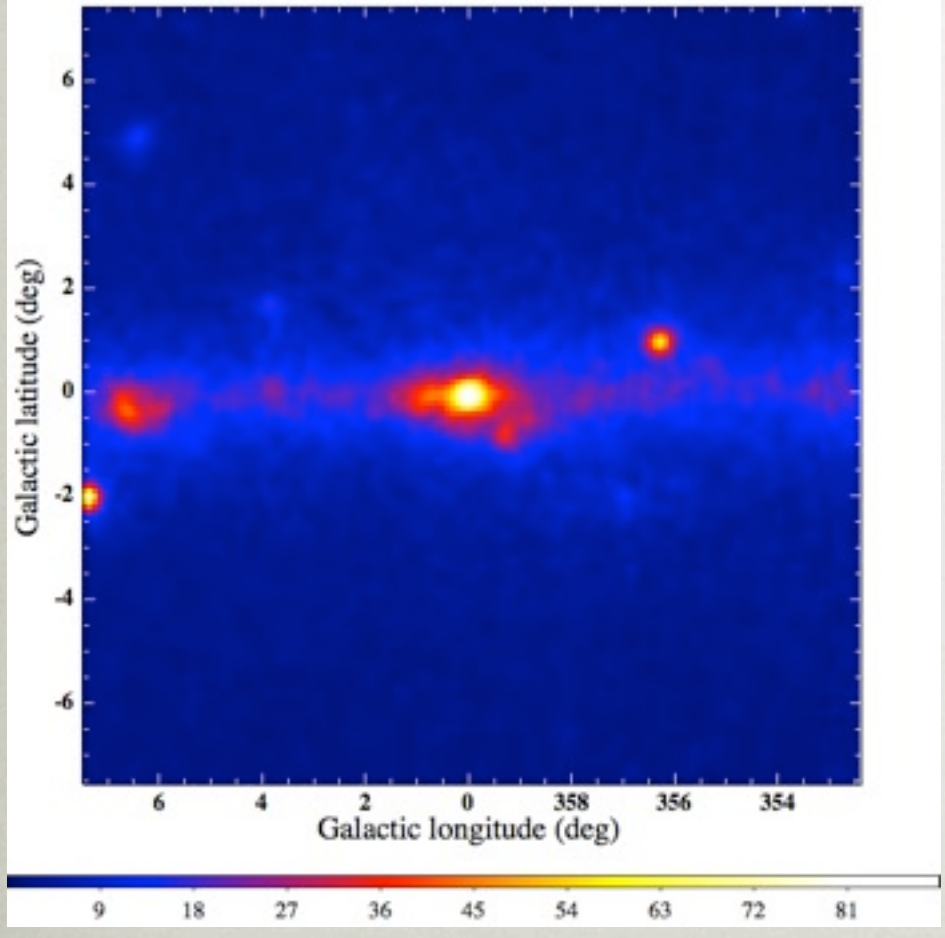
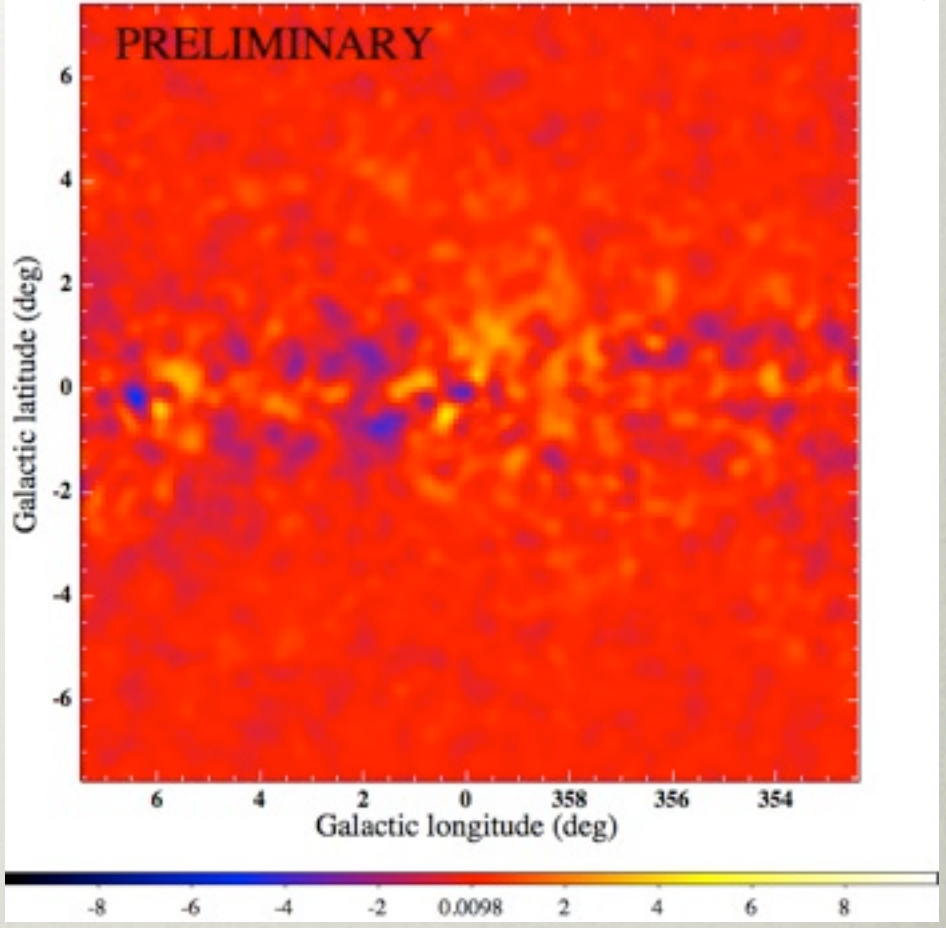
DATA



DATA-MODEL (diffuse+sources)



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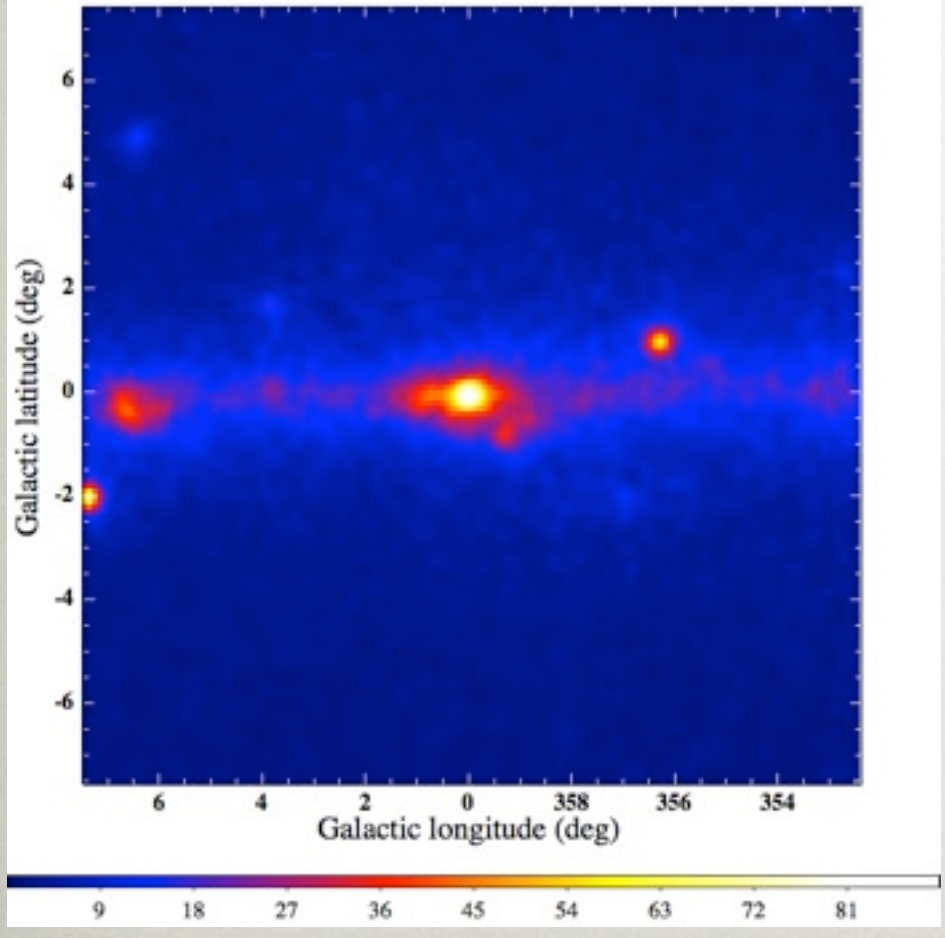

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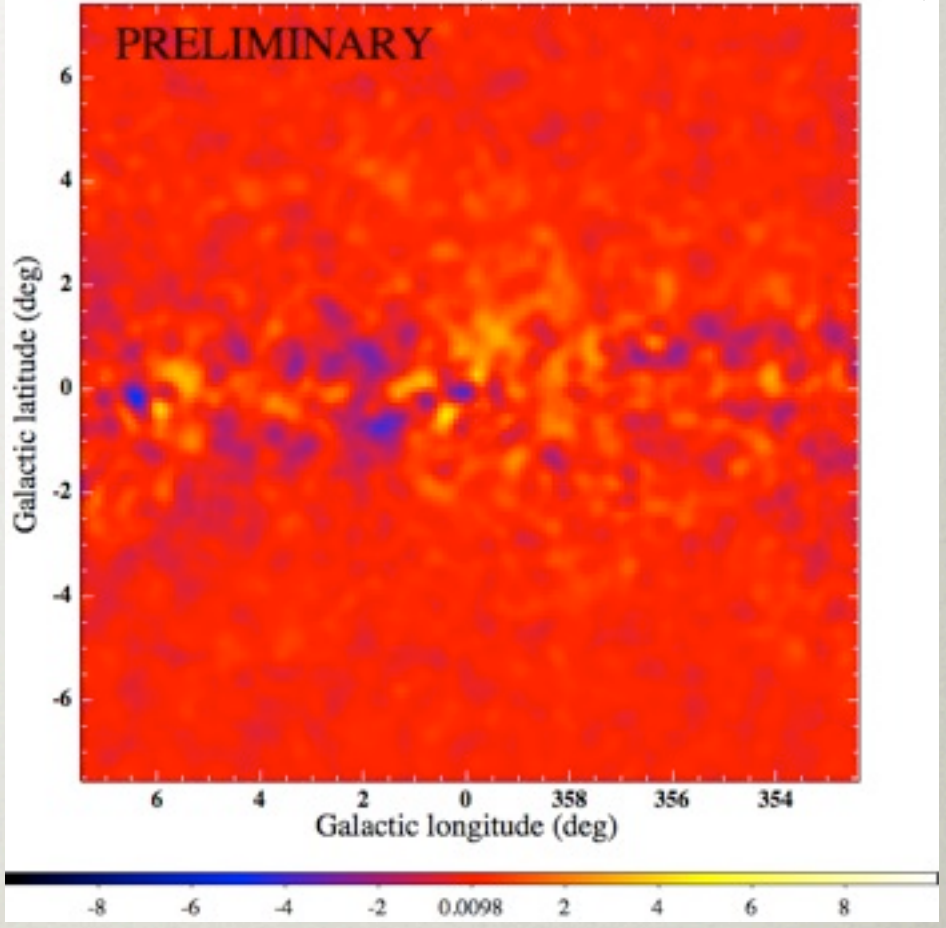
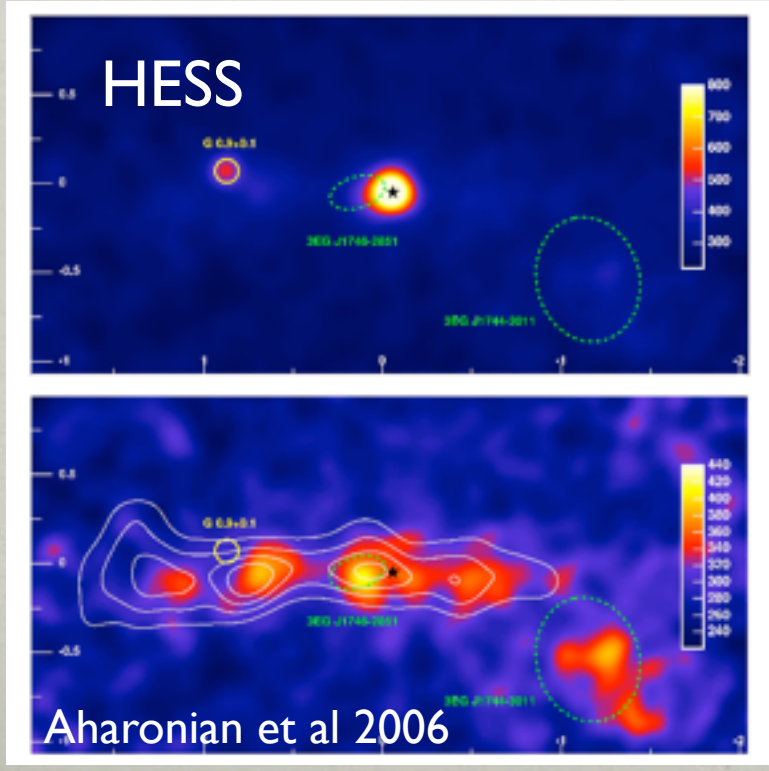
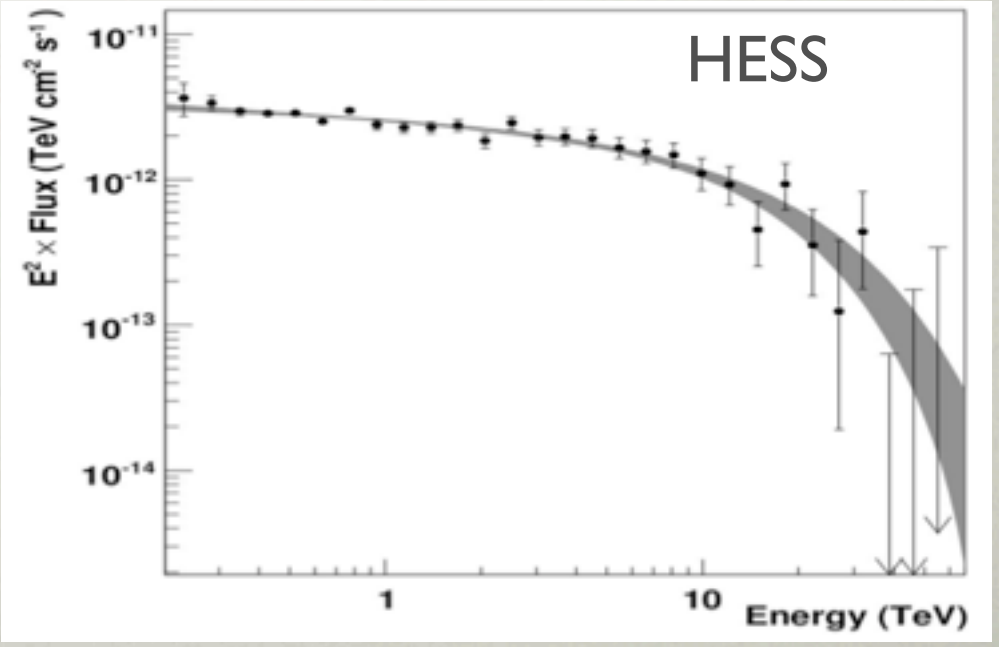


➡ Diffuse emission and point sources account for most of the emission observed in the region.

H.E.S.S., MAGIC, VERITAS: Galactic Center Source

- Consistent spectrum observed by HESS (>100 hrs), MAGIC and VERITAS (~ 25 hrs, large zenith angle observations)
- GC source spectrum consistent with astrophysical particle accelerators





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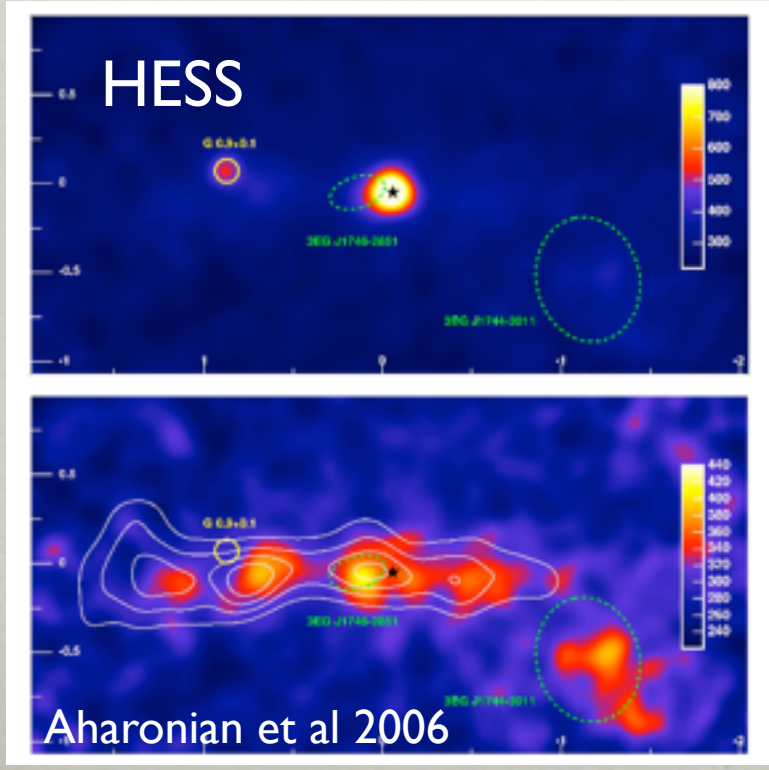
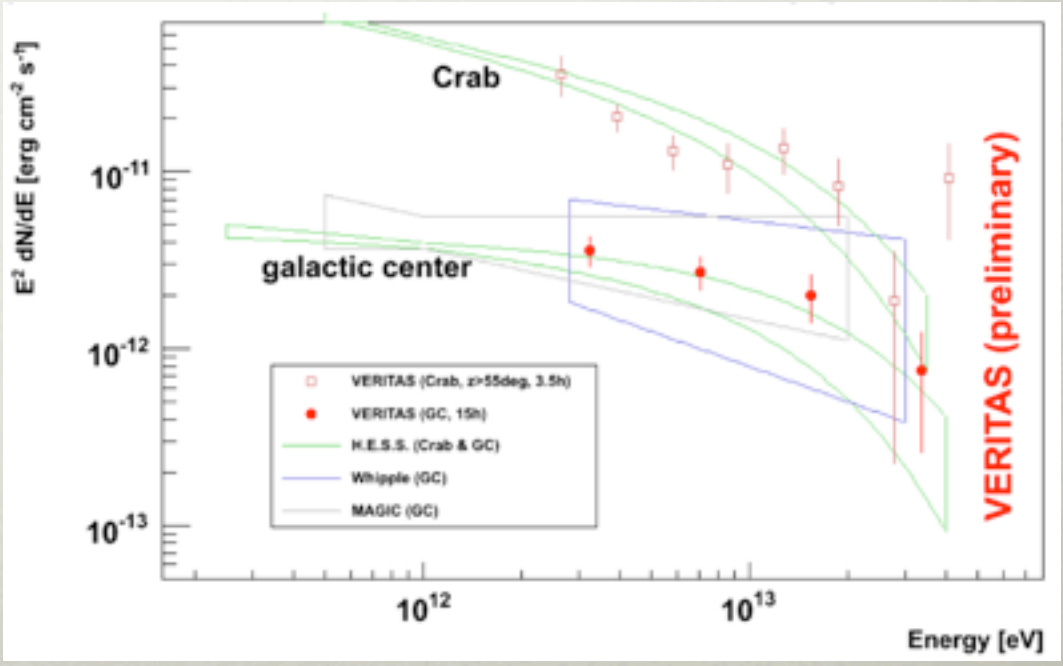
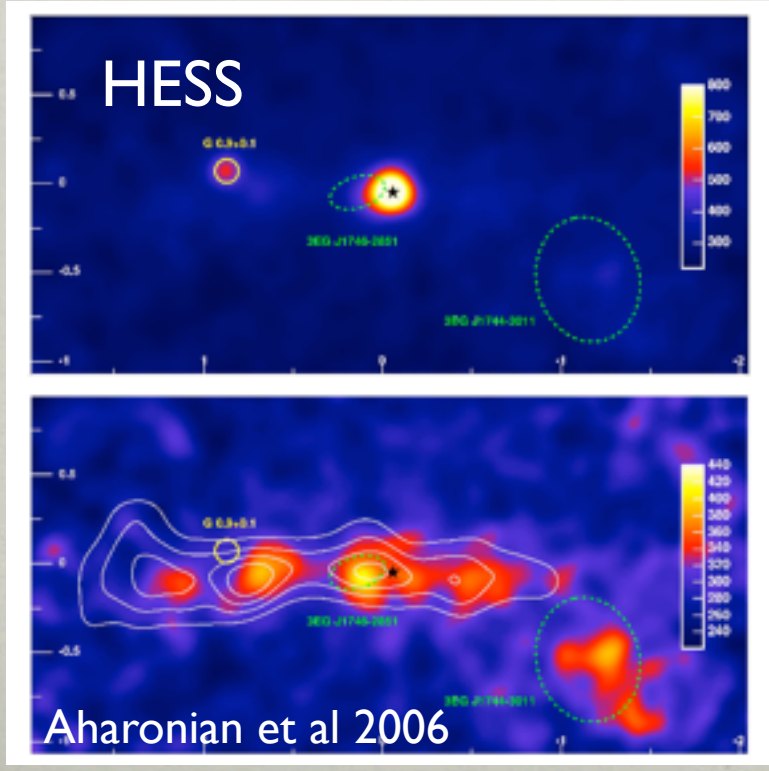
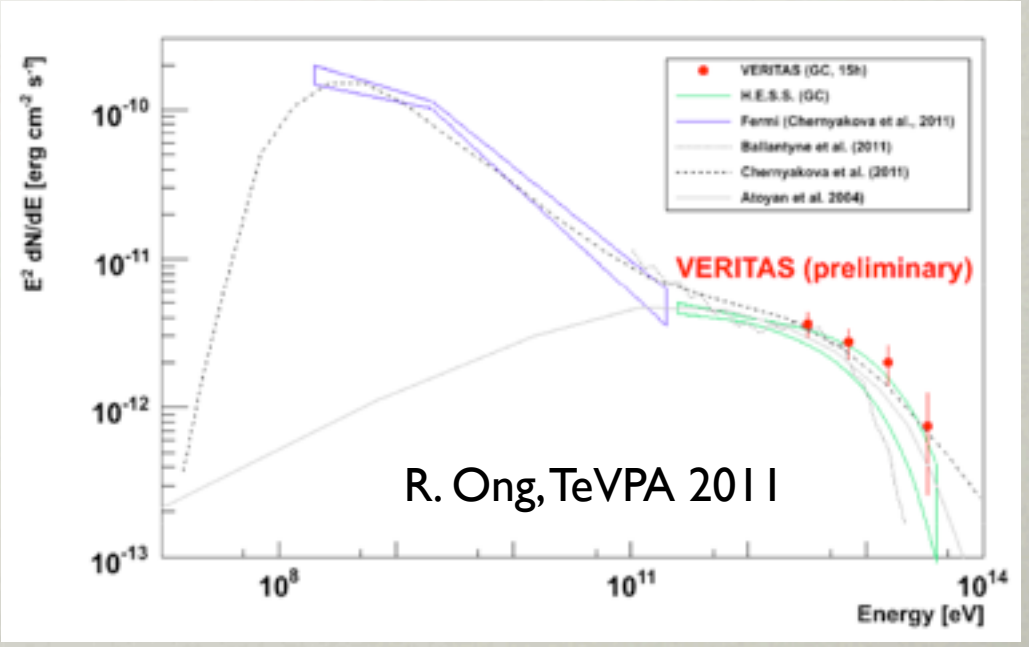




Galactic Center Source: GeV/TeV

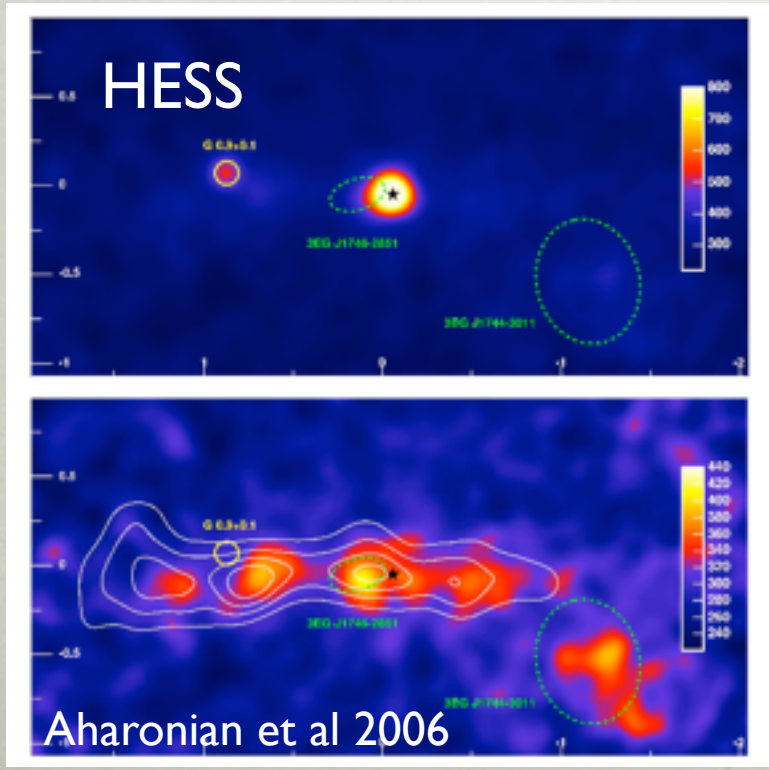
- GeV/TeV spectrum compatible with gamma-ray production from protons accelerated in Sgr A* and diffusing in the interstellar medium
- No time variability

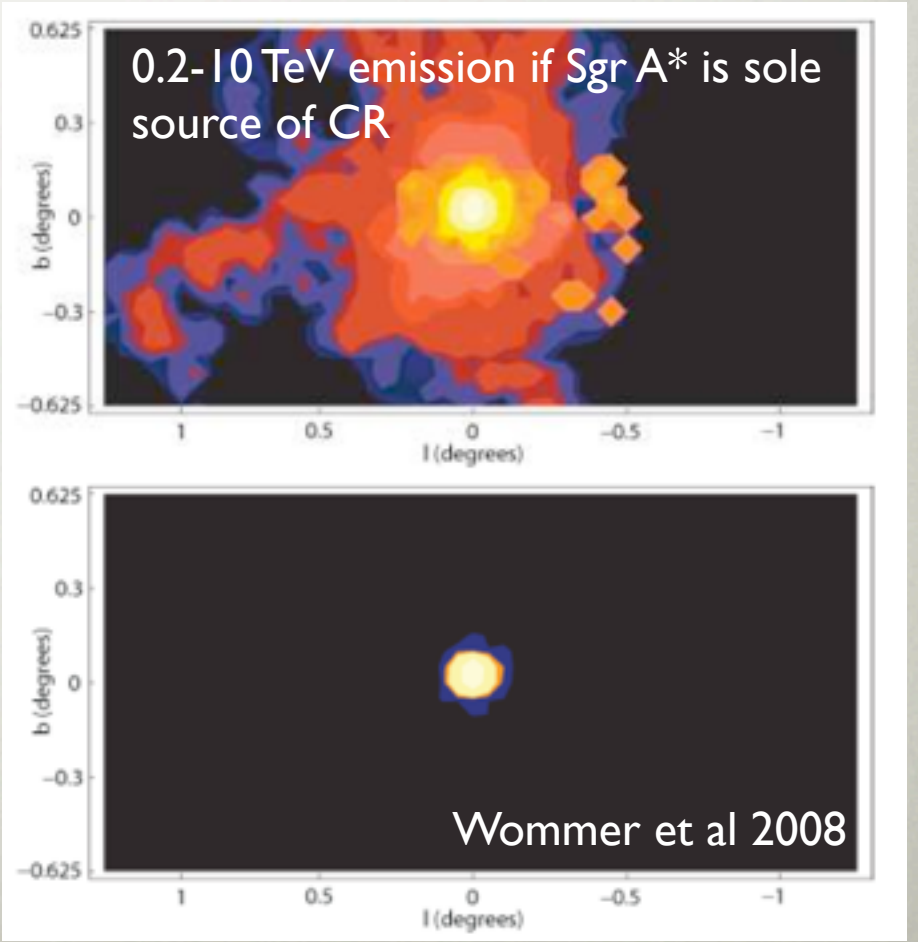




Diffuse TeV Emission

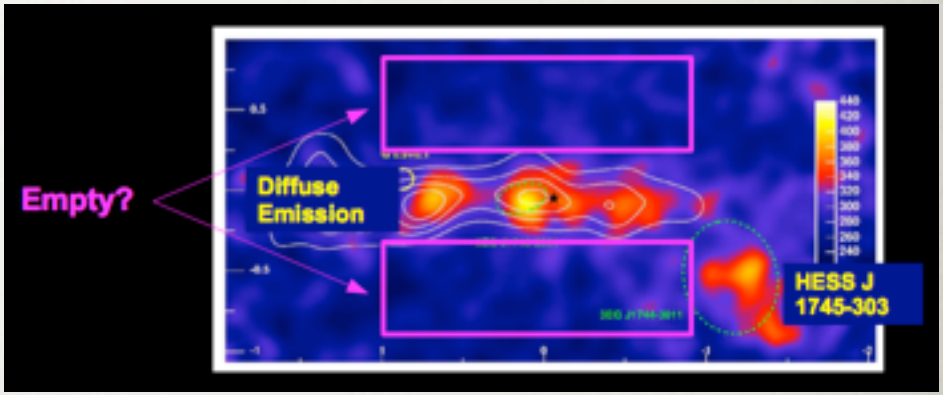
- Single source of cosmic rays does not seem to explain the observed diffuse emission in the galactic ridge observed by HESS

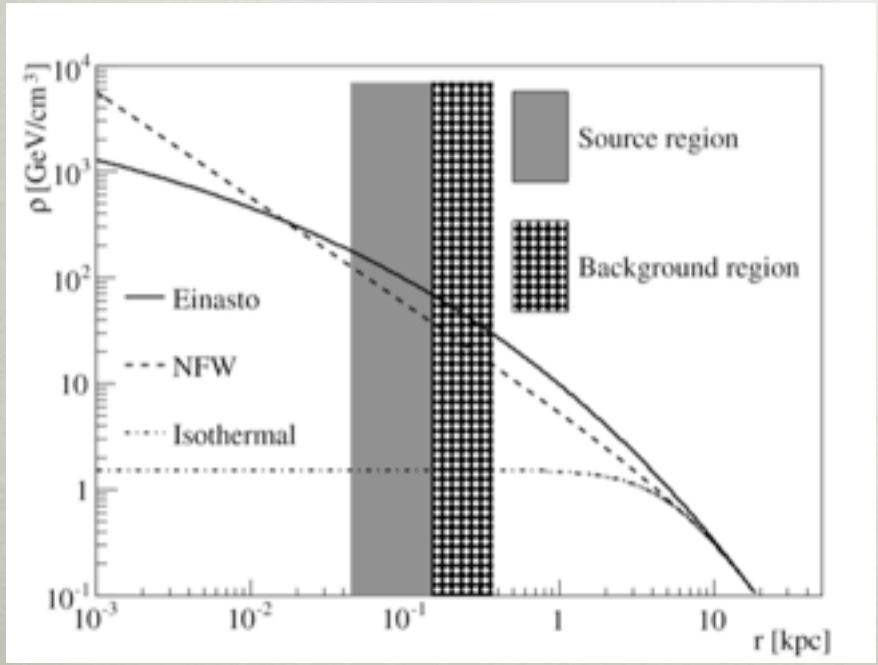




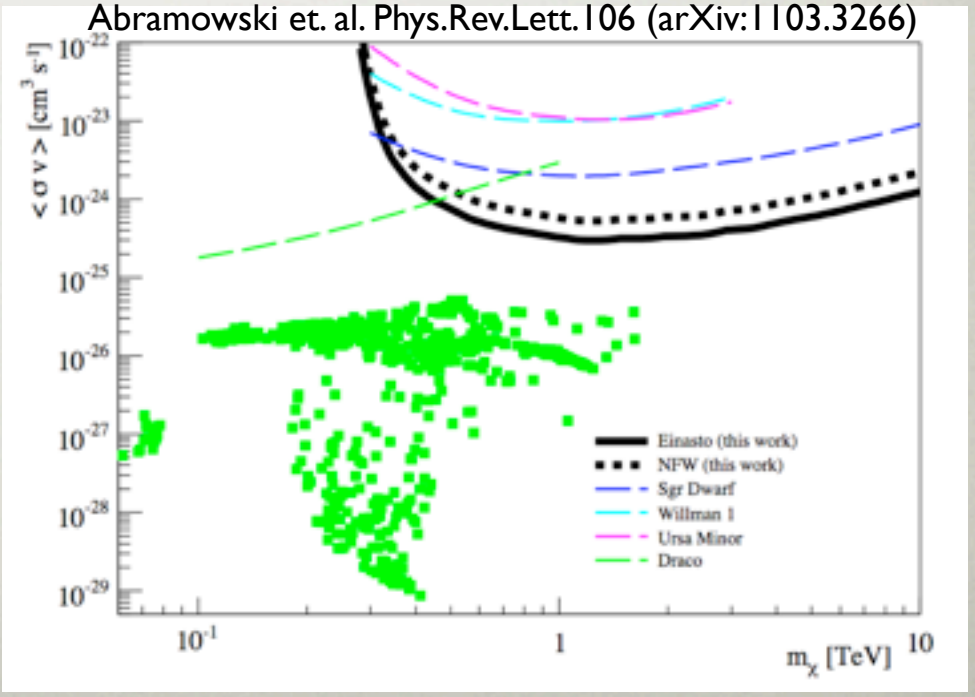
H.E.S.S.: Galactic Halo

- GC is complicated by astrophysics, look away from it!
- Signal region: relatively close to GC but "free" from astrophysical background
- Select a region where the contribution from DM is smaller for background subtraction (background region)
- Small dependence on DM profile





Abramowski et. al. Phys.Rev.Lett.106 (arXiv:1103.3266)



Conclusions

- Preliminary results from Fermi LAT show that most of the emission from a 15°x15° region around the direction of the Galactic center can be modeled in terms of diffuse emission and sources. Papers are forthcoming and will include dark matter results
- Interesting constraints on the nature of dark matter have been determined by HESS with very high energy gamma rays
- Our knowledge of the conventional astrophysical background is uncertain. This is currently a big limitation for the search of dark matter in the Galactic center with gamma rays, which otherwise has huge potential for discovery or for setting constraints.
- In addition, better understanding of the dark matter density distribution in the Galactic center is essential in interpreting observations.

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Thank you!