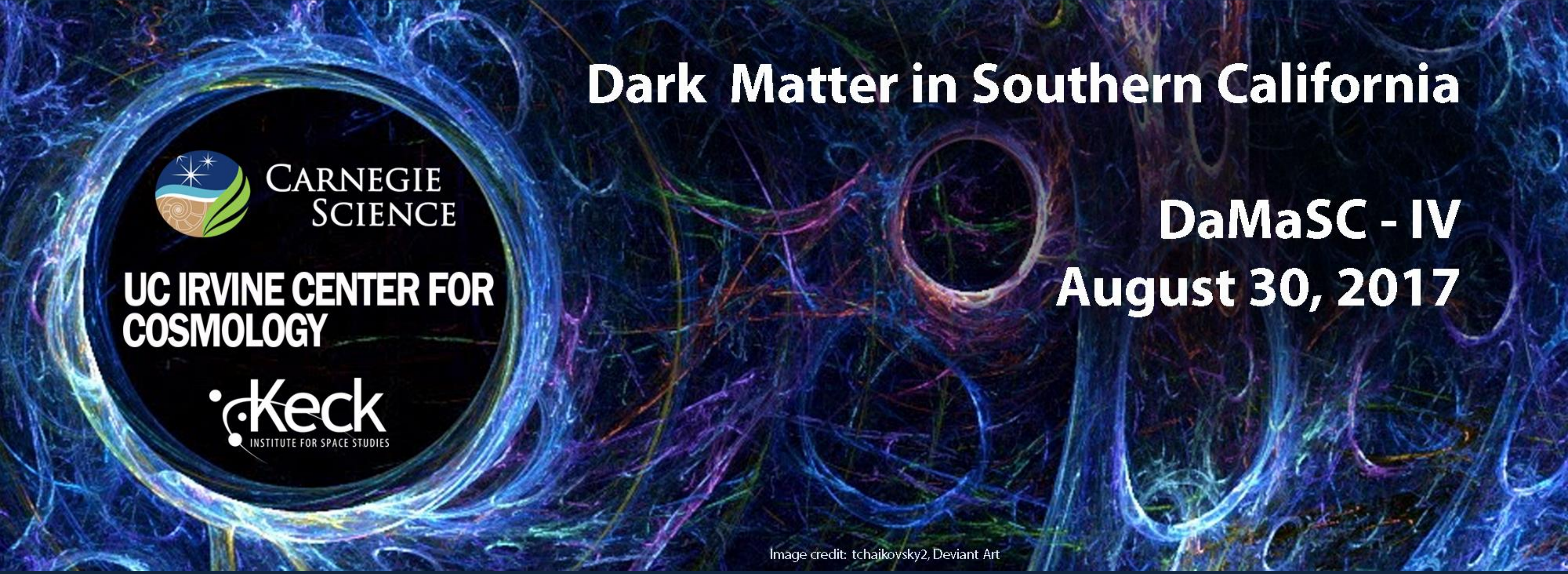


Astroparticle Anomalies

Current Hints of Possible Dark Matter Signals

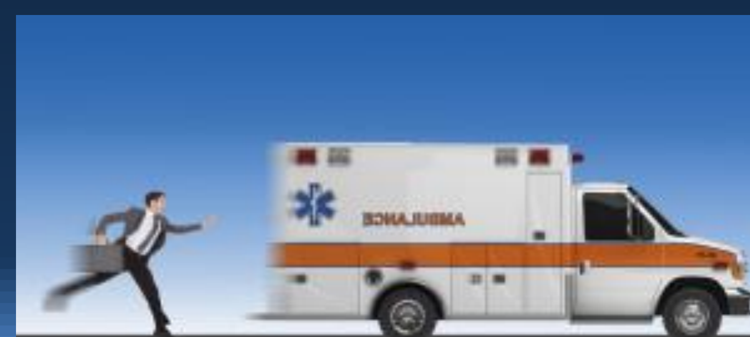
Sheldon Campbell
University of California, Irvine

What is this talk really about?

- Isn’t discussion of low-significance anomalies just

ambulance chasing?

I hope to convince you otherwise.



Motivation: Discovery Process for Low-Signal Dark Matter Detection

1. Anomalies first emerge at regions of highest sensitivity.
   - Galactic center?

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   – Which regions are next-most-sensitive depends on the scenario.
     It could be:
     - dwarf satellites for annihilating cold dark matter
     - Andromeda for very cold annihilating dark matter
     - inner halo for warm annihilating dark matter
     - outer halo for decaying dark matter

Motivation: Discovery Process for Low-Signal Dark Matter Detection

1. Anomalies first emerge at regions of highest sensitivity.

The point is:

Paying attention to weak emerging anomalies can inform about their relation and provide clues about the underlying theory which can then predict the next signals that will appear.

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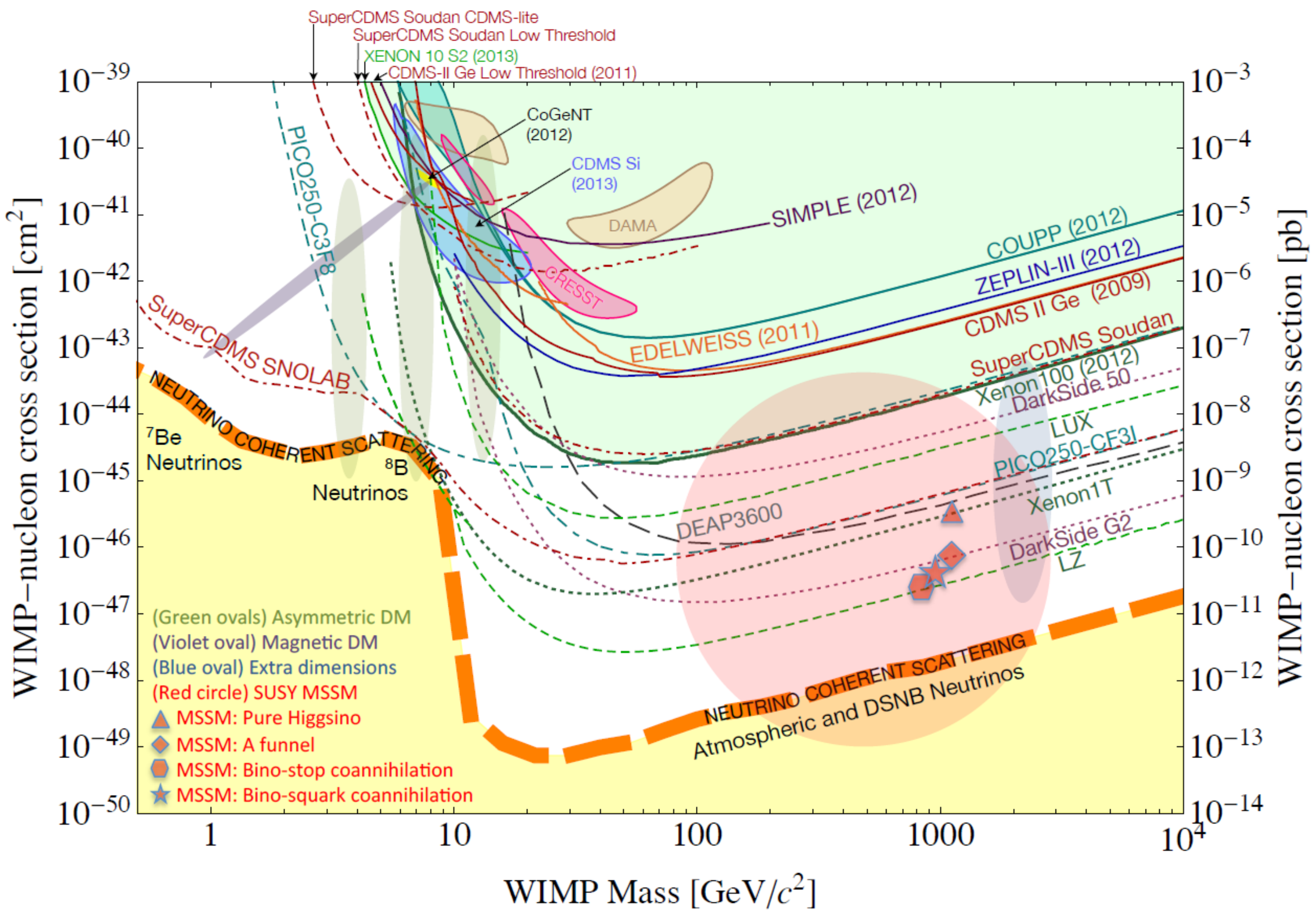
Direct Detection of Astro Particle DM

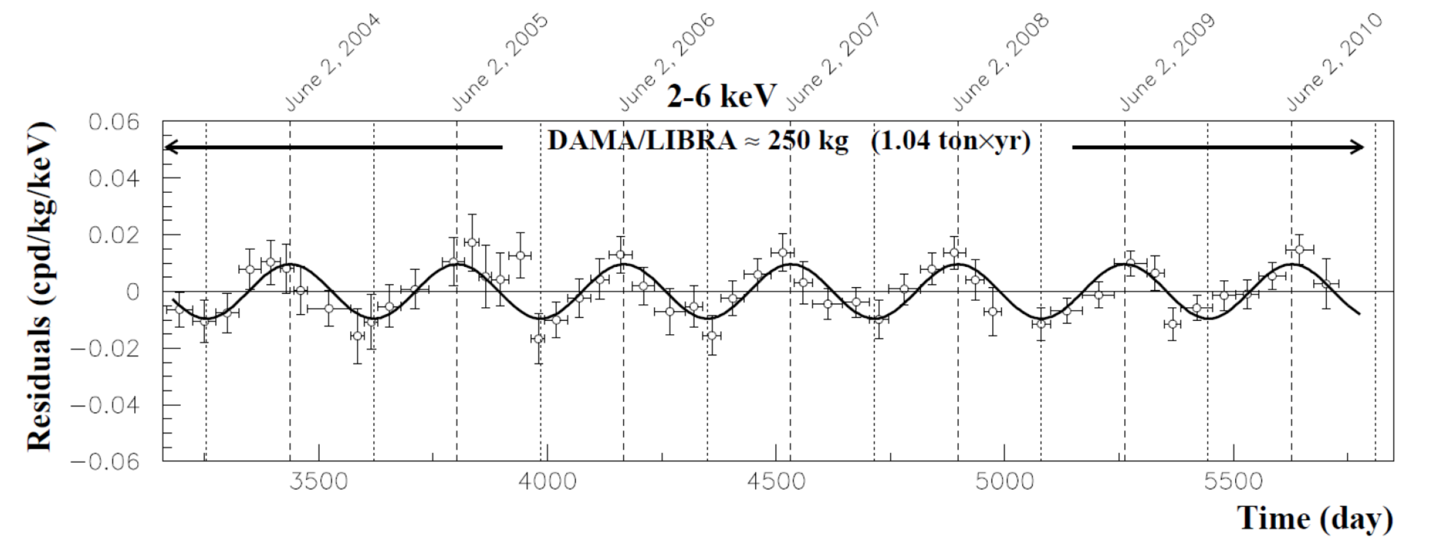
Nostalgia of anomalies from just a few years ago.

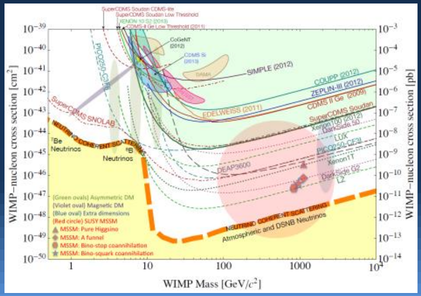


Direct Detection of Astro Particle DM

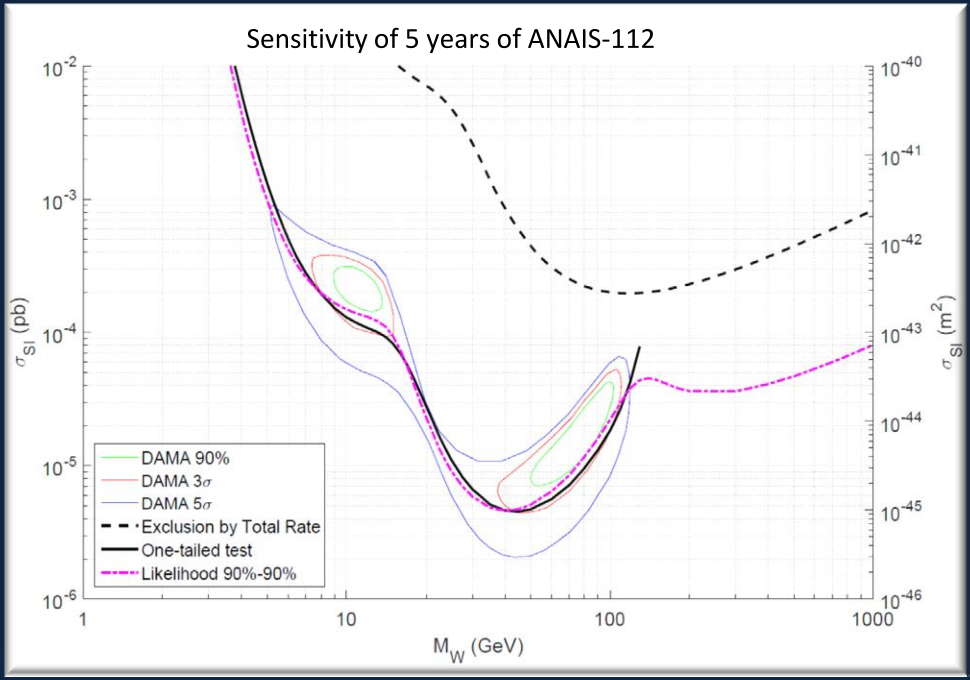
Nostalgia of anomalies from just a few years ago.

Only the DAMA annual modulation continues to grow in significance.



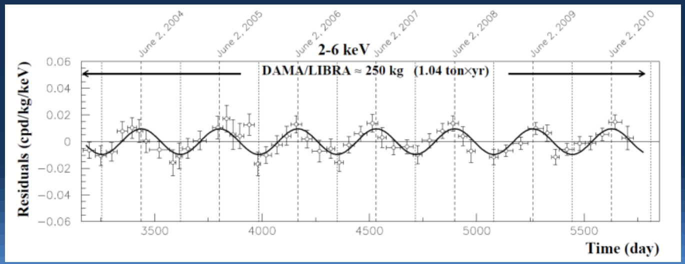


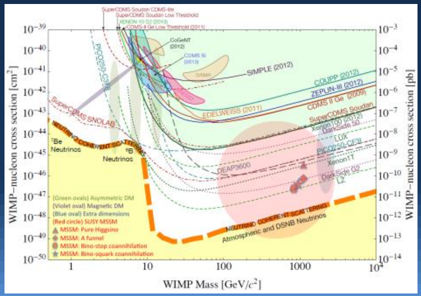
Direct Detection of Astro Particle DM



New NaI crystal experiments are coming on line to probe the source of the DAMA anomaly:

1. ANAIS-112
2. SABRE
   - 2 detectors – north & south hemispheres
   - 1 in Gran Sasso near DAMA
   - 1 in Australia
3. COSINUS
   - New technique using NaI as a cryogenic calorimeter capable of particle-by-particle discrimination.





Anomalies in Astrophysical Radiation

We have some things to discuss….

Anomalies in Astrophysical Radiation

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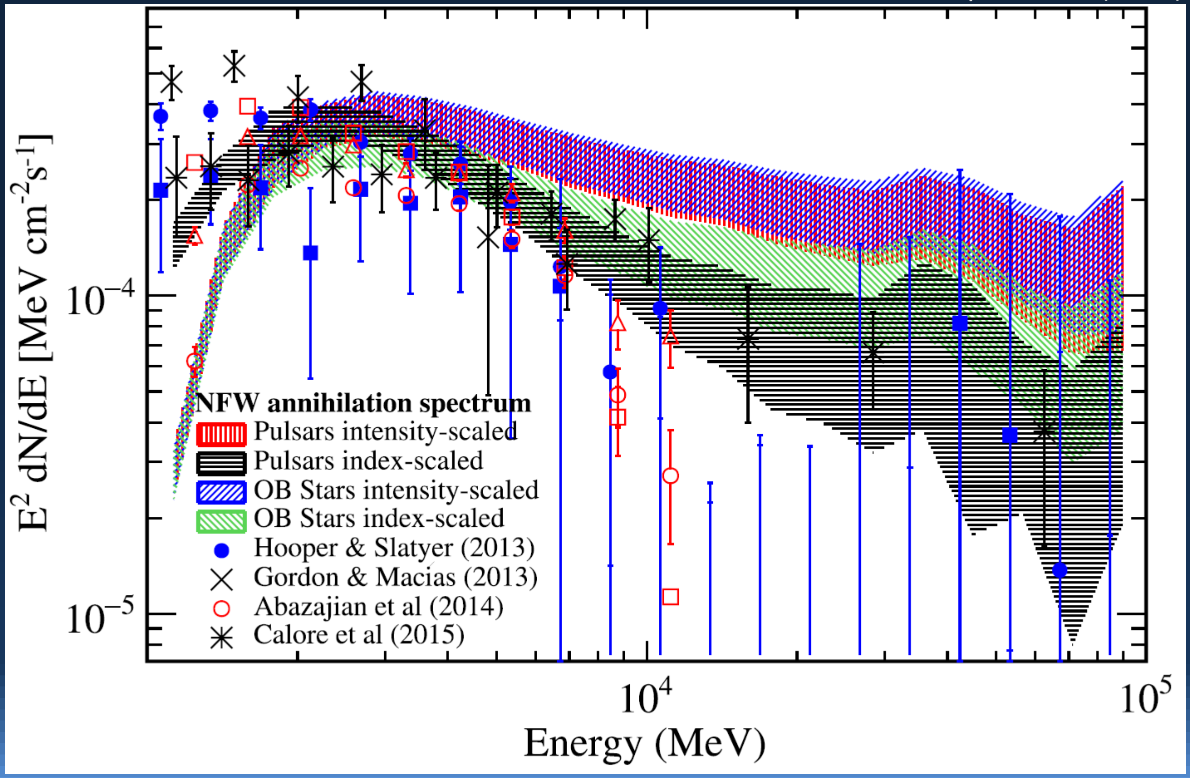
The 3.5 keV X-ray line remains an interesting anomaly for dark matter enthusiasts to watch.

Since Kev Abazajian already discussed it in detail in the previous talk, I will not discuss it further.

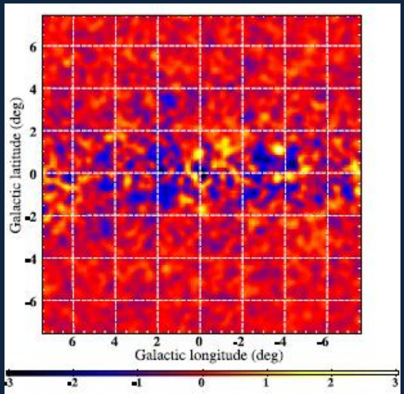
GeV Galactic Center Excess (GCE)

Recent new analyses by the Fermi-LAT collaboration confirmed the robustness of the excess.

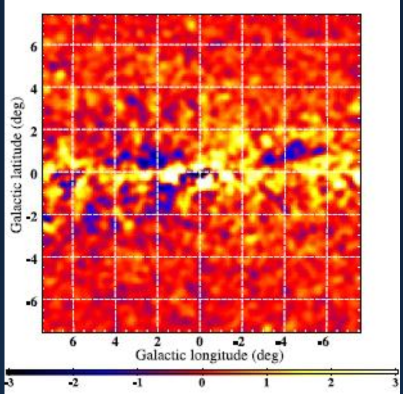
Fermi-LAT Collab, ApJ 819:44 (2016)



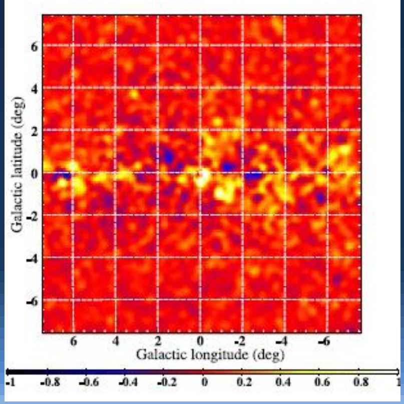
1-1.6 GeV



1.6-10 GeV

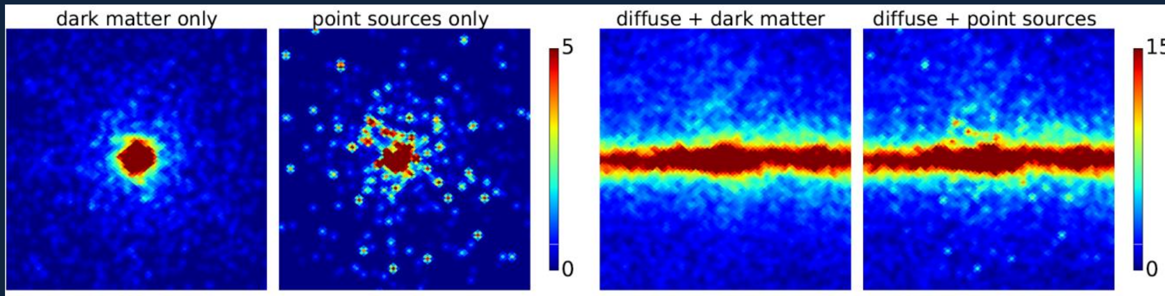


10-100 GeV

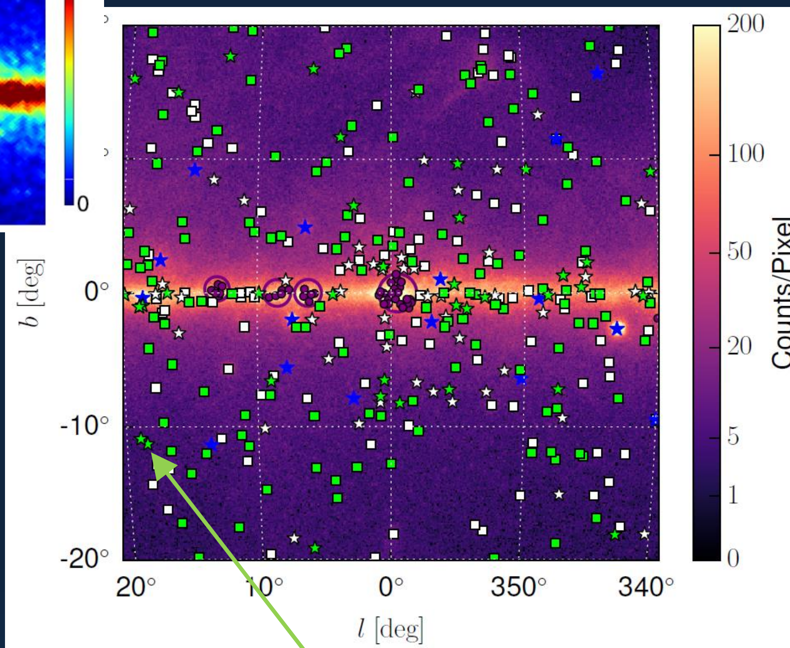


Evidence for Pulsar Origin of GCE

Lee+, JCAP 1505, 056 (2015) & PRL 116, 051103 (2016)



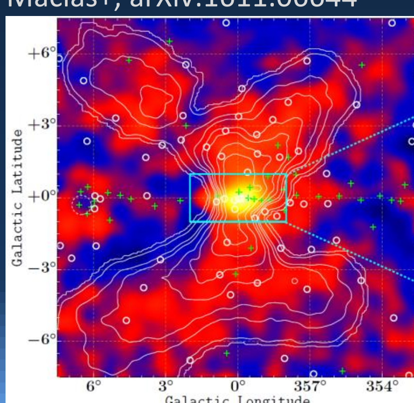
Fermi-LAT Collab, arXiv:1705.00009



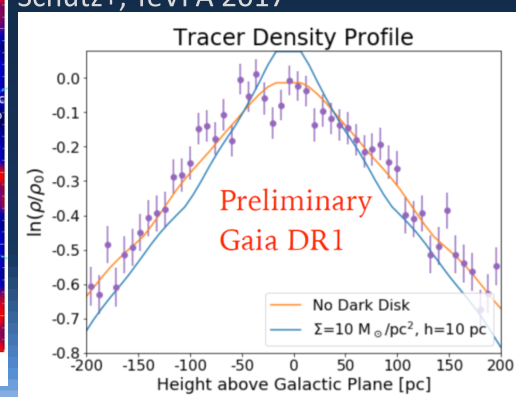
green star = new PSR candidate

1. With current foreground models, the distribution of the excess behaves more like unresolved point sources than a diffuse dark matter profile.
2. Many new pulsar candidates are emerging in the region.
3. The excess may be correlated with the X-shaped bulge.
   - suggests stellar population origin --> pulsars.
   - dissipative dark matter could also do this, but no dark disks in Gaia data.

Macias+, arXiv:1611.06644

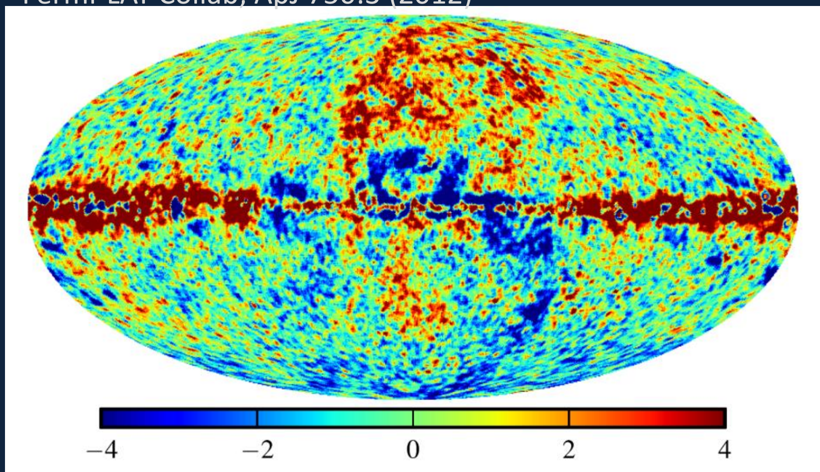


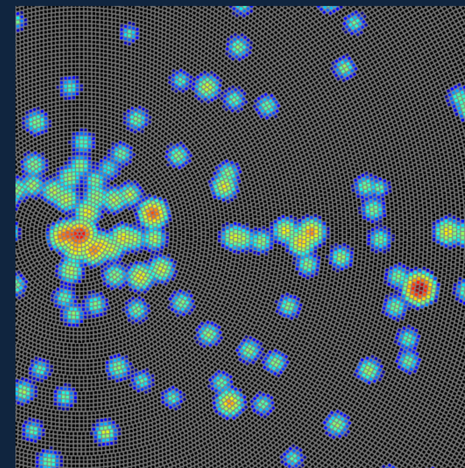
Schutz+, TeVPA 2017

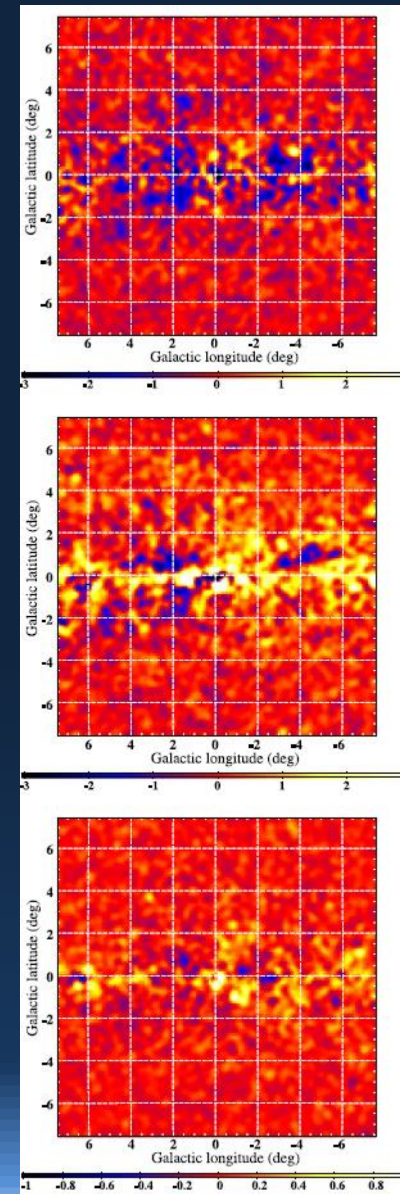


Caution for Pulsar Interpretation

Fermi-LAT Collab, ApJ 750:3 (2012)

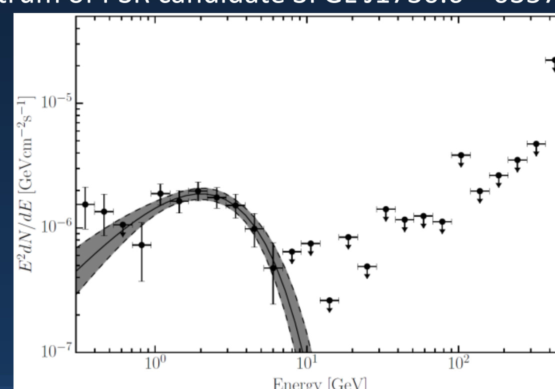






- I'm currently skeptical of arguments that depend on the small-scale distribution of pixels.
  - current foreground models still produce highly correlated residuals.
  - point source mis-modeling introduces point-source-sized structure near G.C.
- The number of observed LMXBs already suggests ~4-23% of the excess is from pulsars.
  (Haggard+, JCAP 05 (2017) 056)

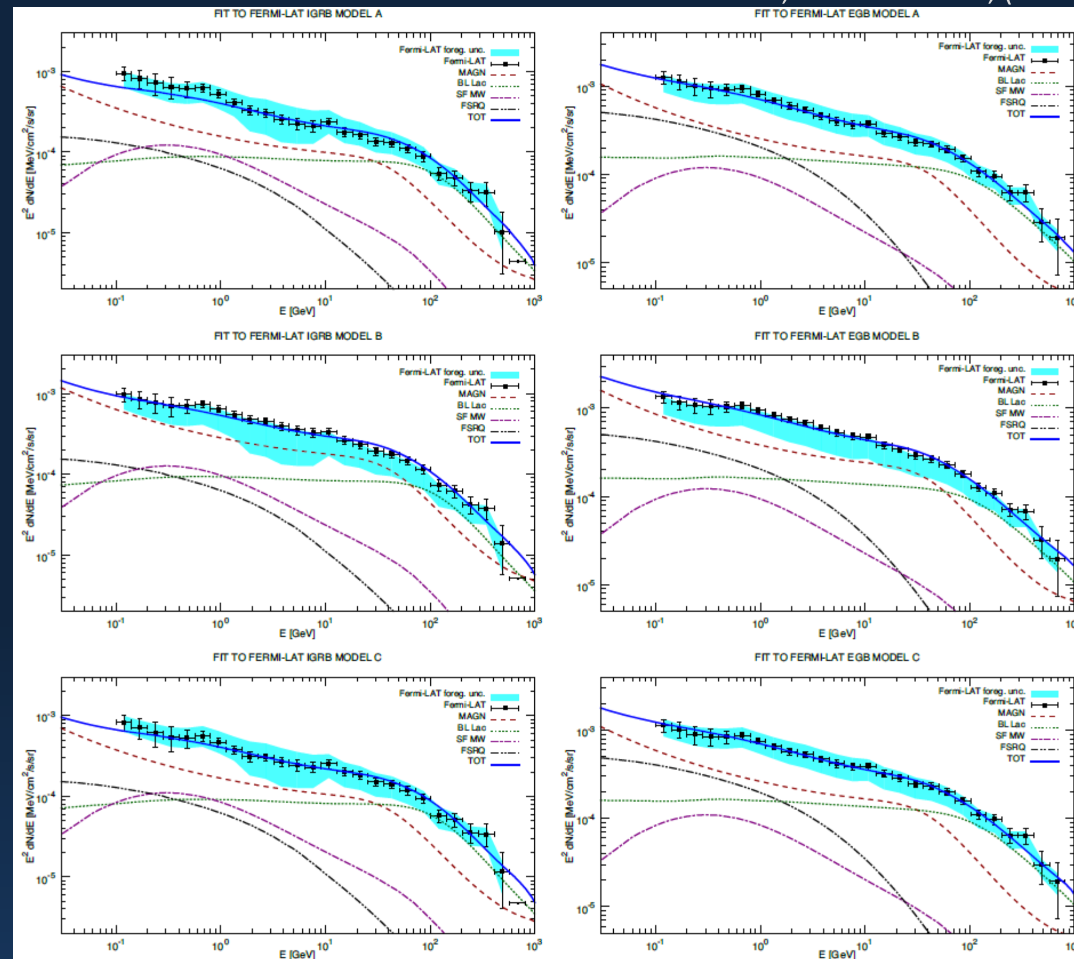
Spectrum of PSR candidate 3FGL J1730.6—0357

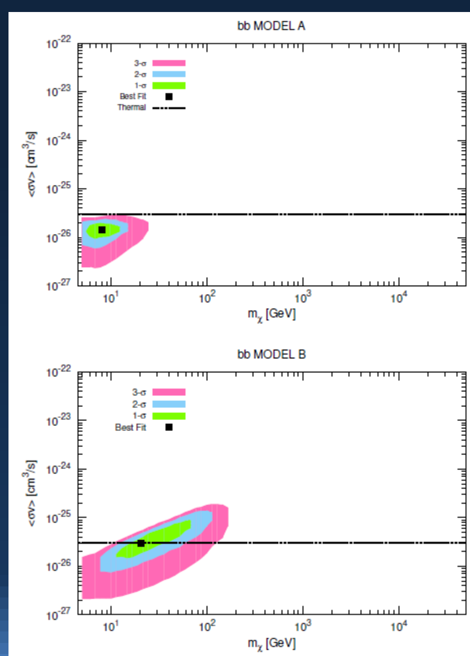


GCE in the Dark Matter Halo? Yes!

- Parameter space of dark matter interpretation is consistent with GC excess.
- If non-DM, non-pulsar explanation, it requires another coincidence.

Di Mauro & Donato, PRD91 123001, (2015)

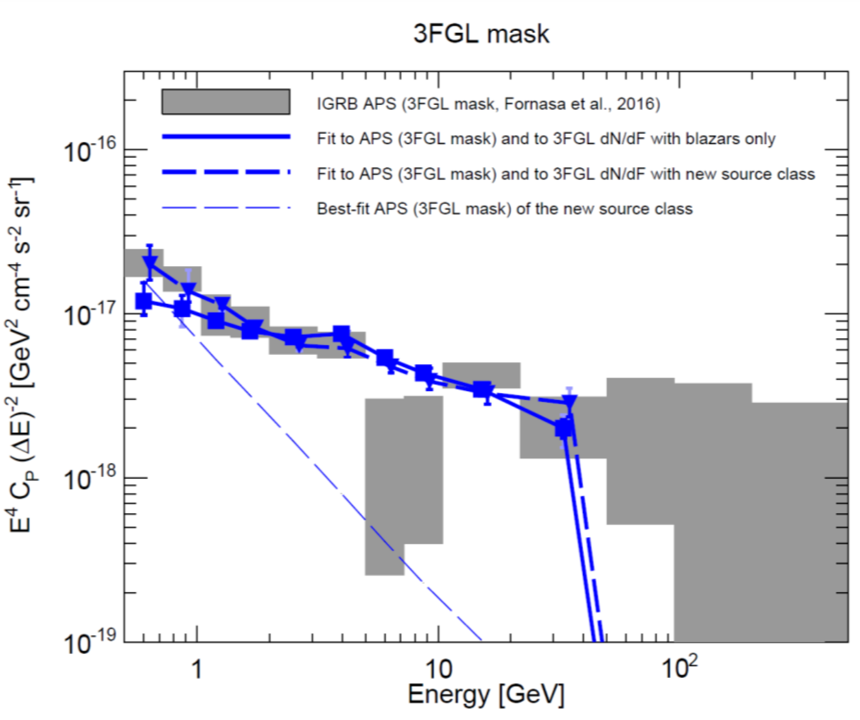




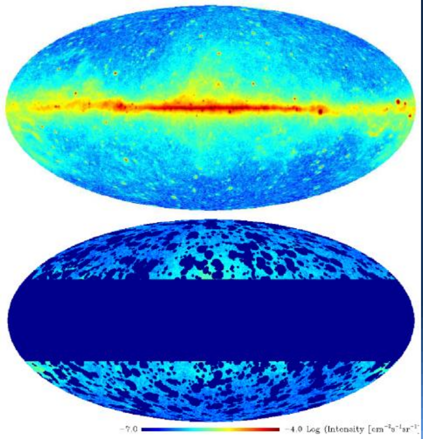
Power Spectrum of High-Latitude γ Rays

Fornasa+, PRD94, 123005 (2016); Ando+, PRD95, 123006 (2017)

- At high energies, structure is consistent with unresolved population of extragalactic blazars.
- Below 1 GeV prefers a new source, not consistent with any known emitter.
- Can be accounted for by dark matter, but precise characterization needs a new analysis that doesn't assume the source is Poissonian.



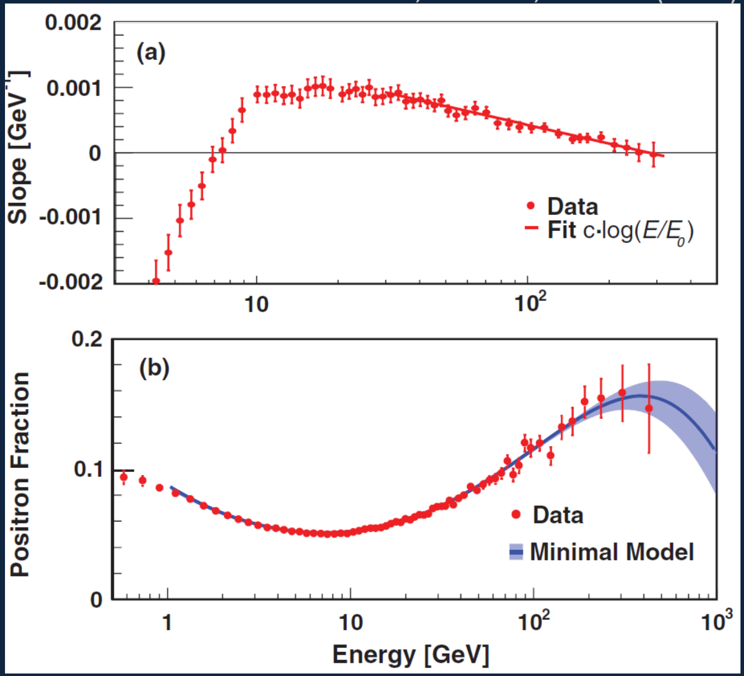
Cross-correlating Fermi-LAT γ rays with galaxy catalogs (2MASS, LRGs, SDSS) and with cosmic shear are producing positive detections. These would also contain information about dark matter contributions, but interpretation is tricky.



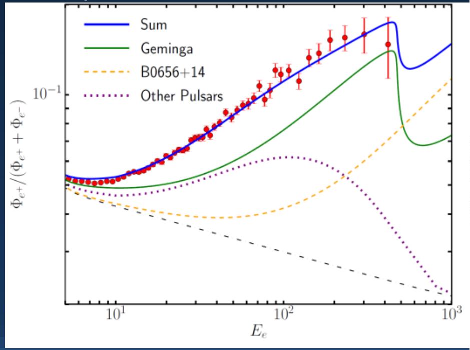
Positron Excess?

- AMS-02 measurement is increasing in significance.
- Too bright to be consistent with GCE.
- Most dark matter interpretations ruled out by lack of γ rays from dwarf satellites.
- Recently, HAWC detected an inverse-Compton halo around Geminga and PSR B0656+14.
- Energetics are at the magnitude needed to account for the excess of positrons (details still uncertain).
- Geminga could make using positrons for searching for dark matter difficult.

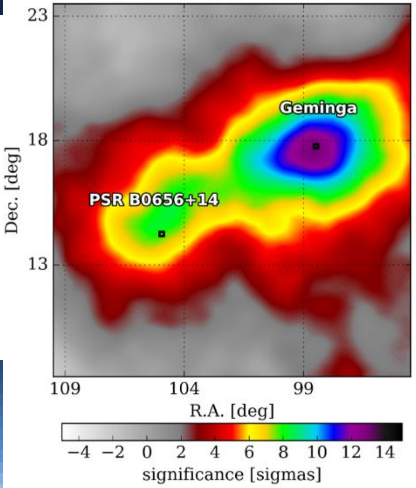
AMS-02, PRL 113, 121101 (2014)



Hooper et al., arXiv:1702.08436



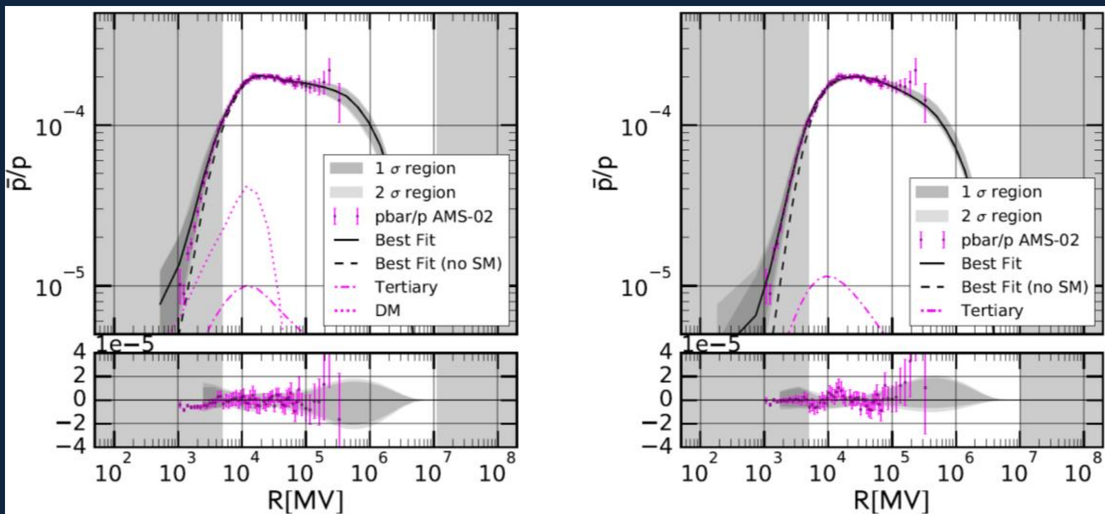
HAWC Collab, arXiv:1708.08213



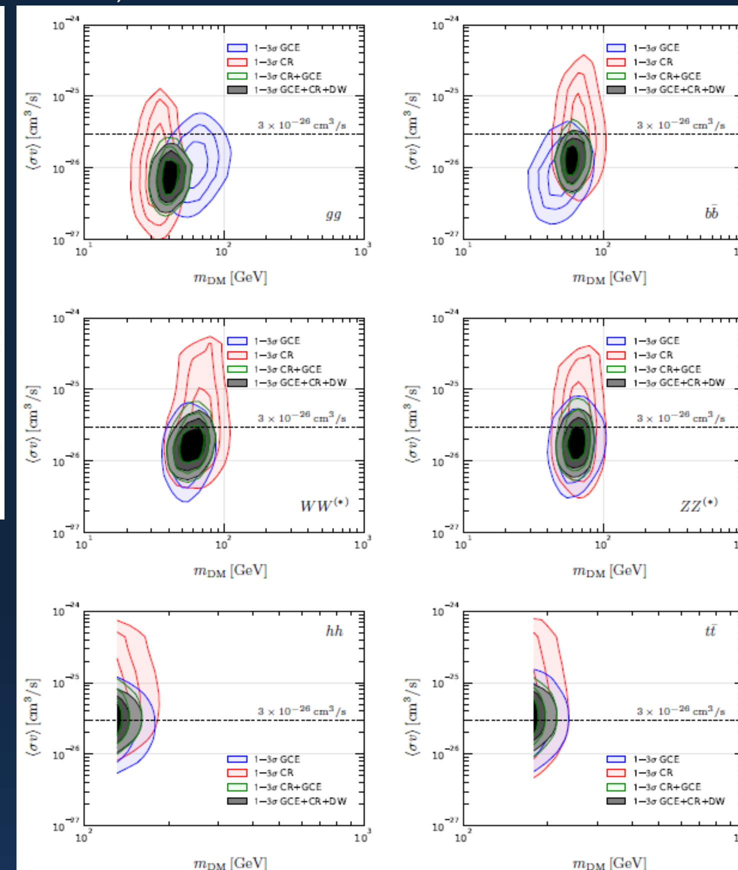
Antiprotons Excess

Cuoco+, PRL 118, 191102 (2017)

with DM | without DM



Cuoco+, arXiv:1704.08258



- AMS-02 measurements of antiproton flux is now very precise.
- Again, the observed excess is consistent with the GC excess.

Final Comments

- A coherent picture appears to possibly be emerging of dark matter annihilation. In many ways, this appears like a WIMP signal we have been looking for.
- Significance of this scenario is still weak, but strengthened by correlated observables.
- Also notable where the signal is not seen:
  - dwarf satellite γ rays,
  - synchrotron in M31 and M33.
- If we're seeing dark matter, we will expect existing excesses to grow in significance, and other GC-like excesses to continue to emerge elsewhere.