Dark Matter Searches

with the Fermi-LAT

B. Anderson
(on behalf of the Fermi-LAT Collaboration)

ICNFP
July 2016

Oskar Klein centre

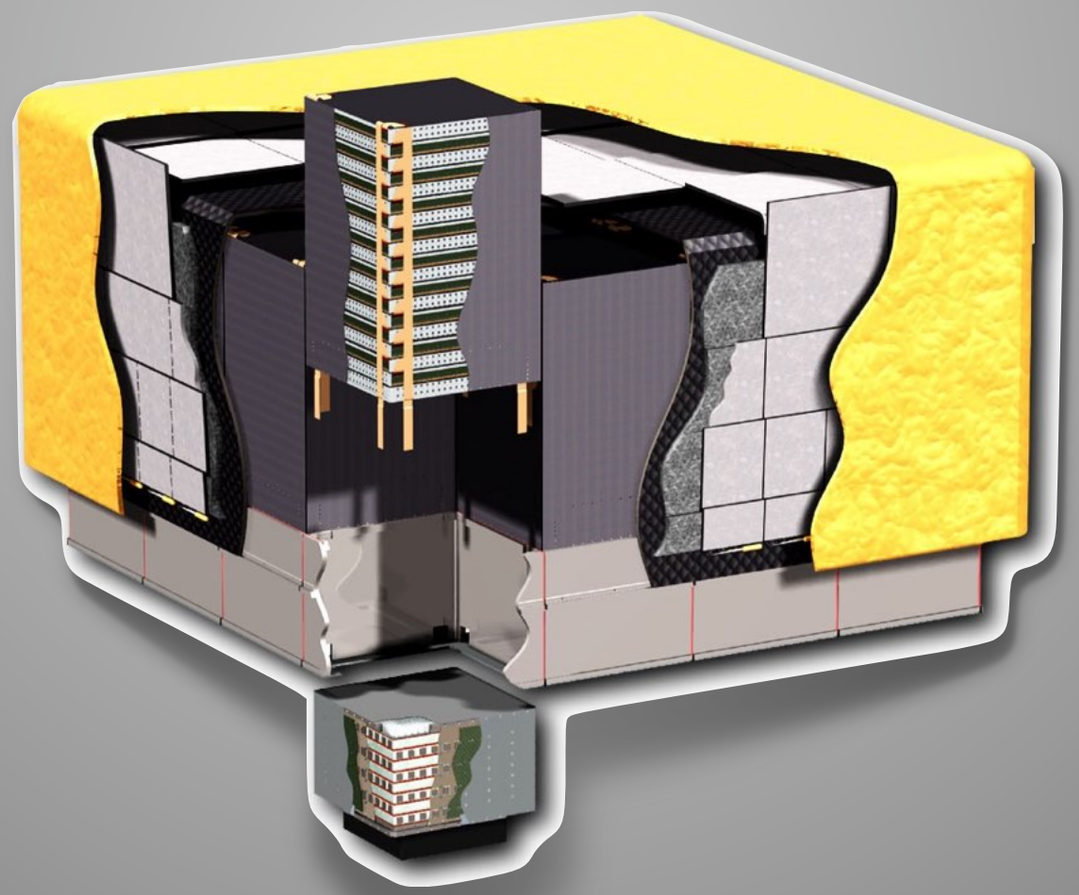
Stockholm University

The Large Area Telescope

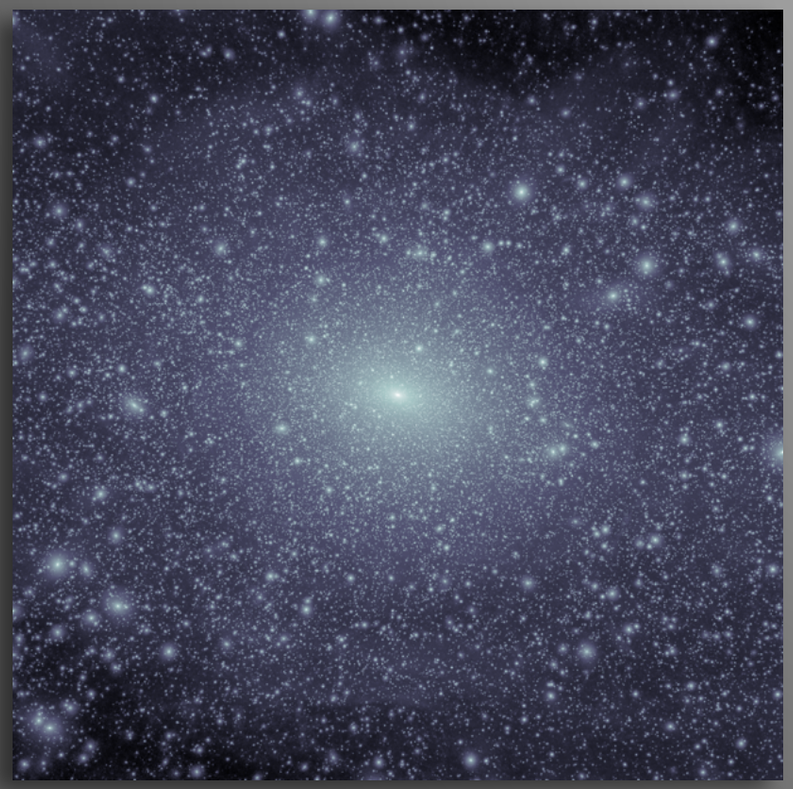
High-Energy Physics in Space

Specifications

- all-sky coverage
- public data
- ~8 years observation
  (extended through 2018)
- 30 MeV to over 300 GeV



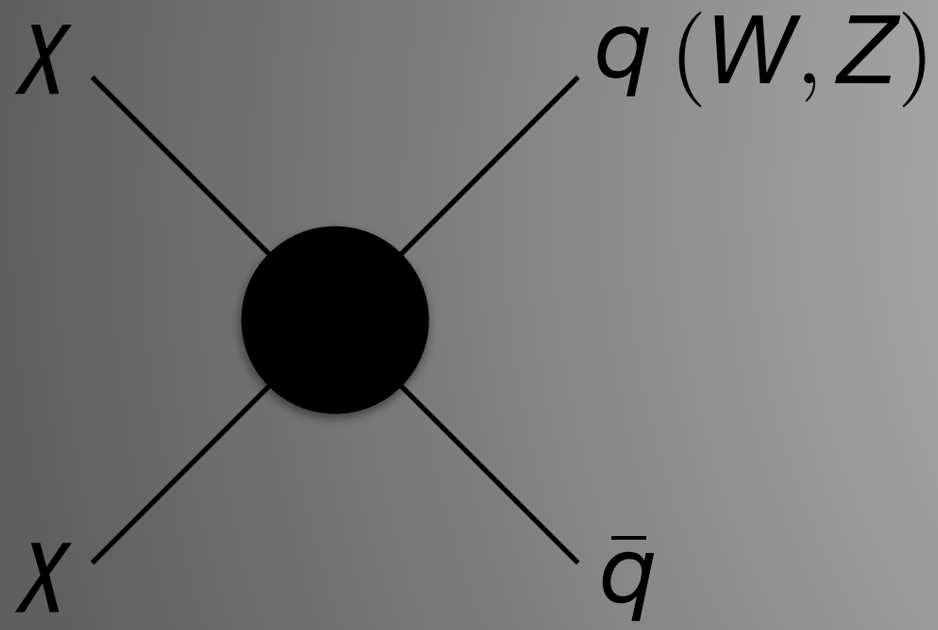
Ackerman+ [LAT Clb] 2012ApJS..203....4A44A

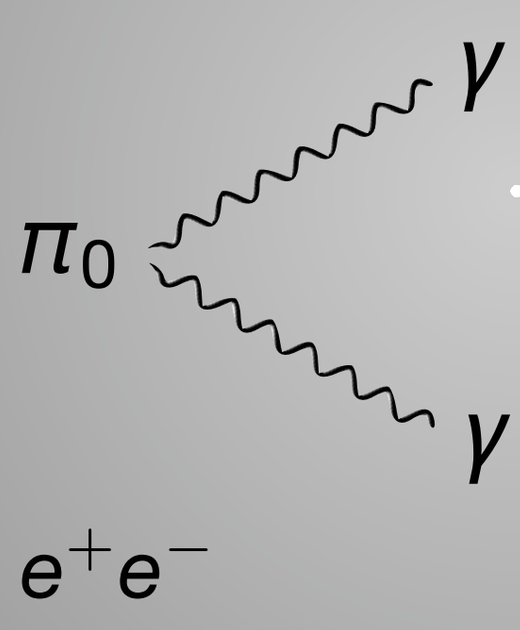


Via Lactea 2 Simulation

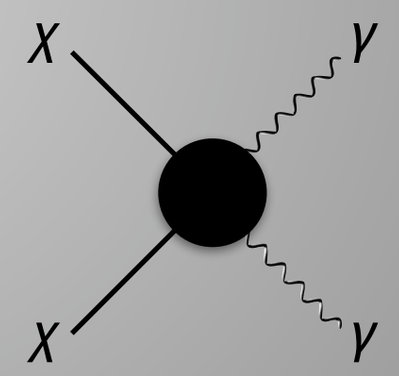
*WIMP Interaction

LAT-detectable products





or



$$\phi_s(\Delta\Omega) = \underbrace{\frac{1}{4\pi}\frac{\langle\sigma\, v\rangle}{2m^2_{\rm DM}}\int_{E_{\rm min}}^{E_{\rm max}}\frac{{\rm d}N_\gamma}{{\rm d}E_\gamma}{\rm d}E_\gamma}_{\rm particle\ physics} \times \underbrace{\int_{\Delta\Omega}\int_{\rm l.o.s.}\rho^2_{\rm DM}(r){\rm d}l{\rm d}\Omega'}_{\rm J-factor}$$

(proportional to expected flux)

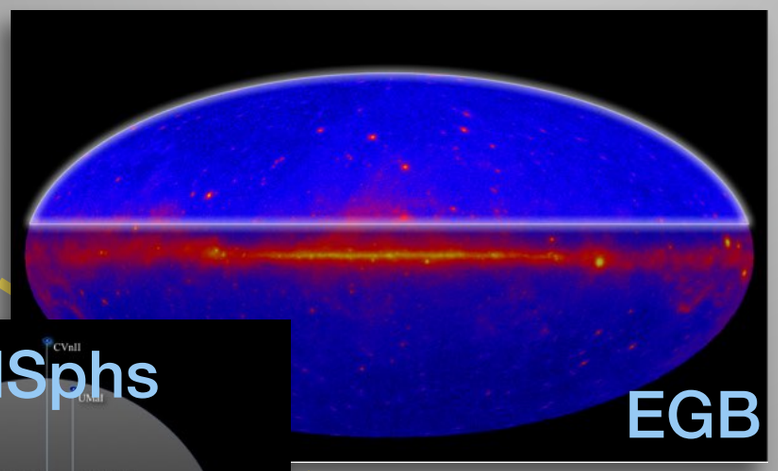
*Weakly-Interacting Massive Particle

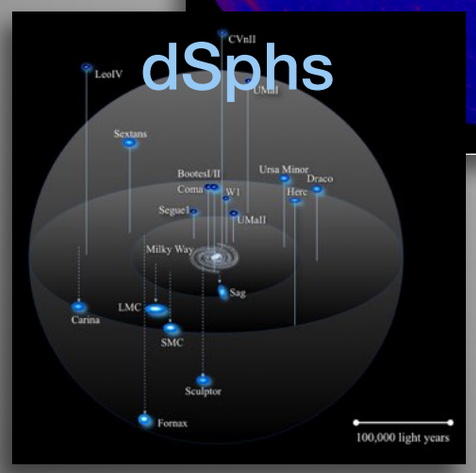
J-Factors

comparatively

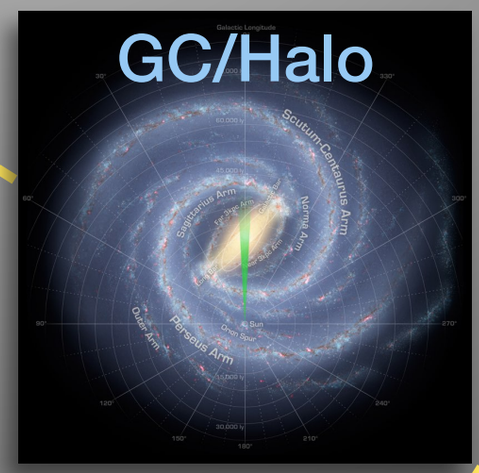
10^{19}

$10^{18\text{-}21}$



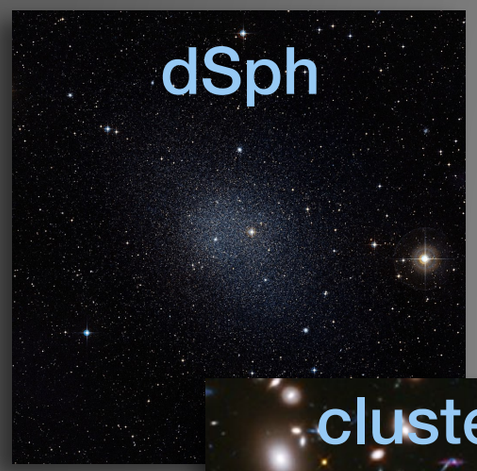


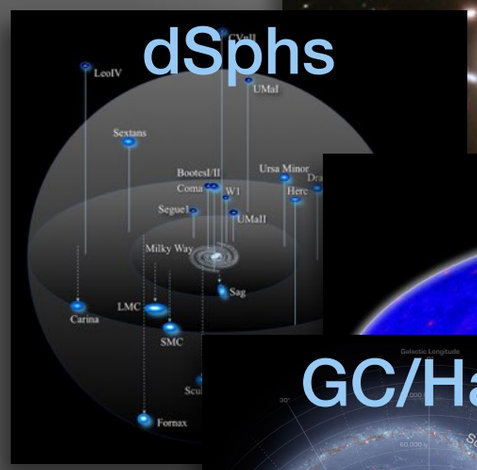
10^{20}

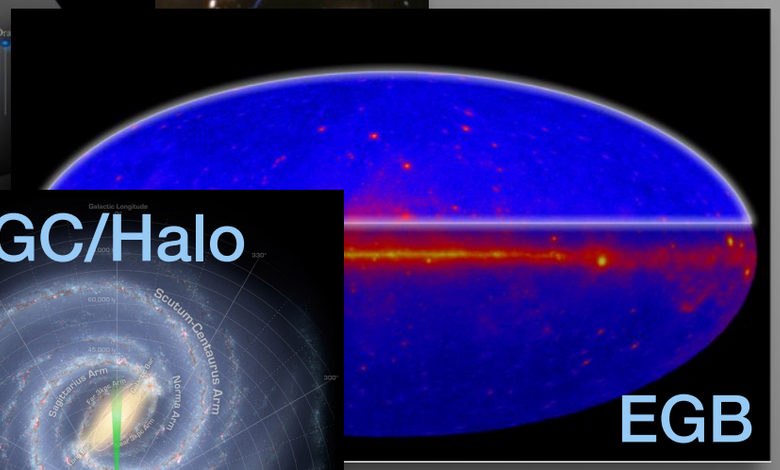


$10^{22\text{-}23}$

Status







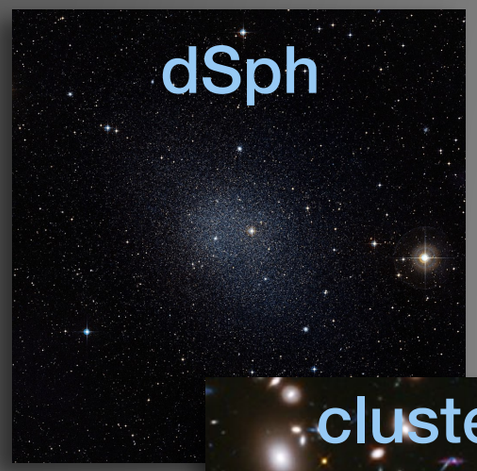
e.g.

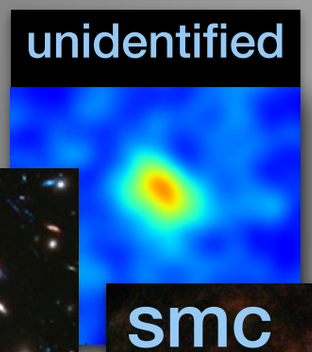
EGB
Ajello+ 2015ApJ...800L..27A
GC
Ajello+ 2016ApJ...819...44A
Halo
Ajello+ 2016ApJ...819...44A

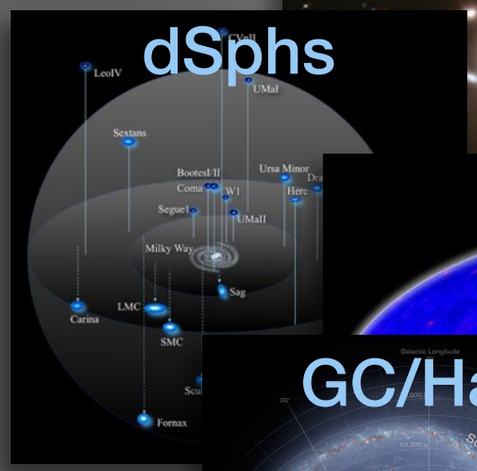
Isotropic
Ackermann+ 2015JCAP...09..008T
Lines
Ackermann+ 2012ApJ...747..121A
Unassociated Sources
Ackermann+ 2012ApJ...747..121A

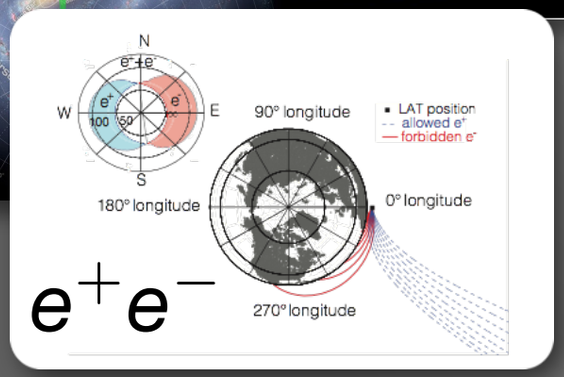
- extensive searches in standard targets

Status









e.g.

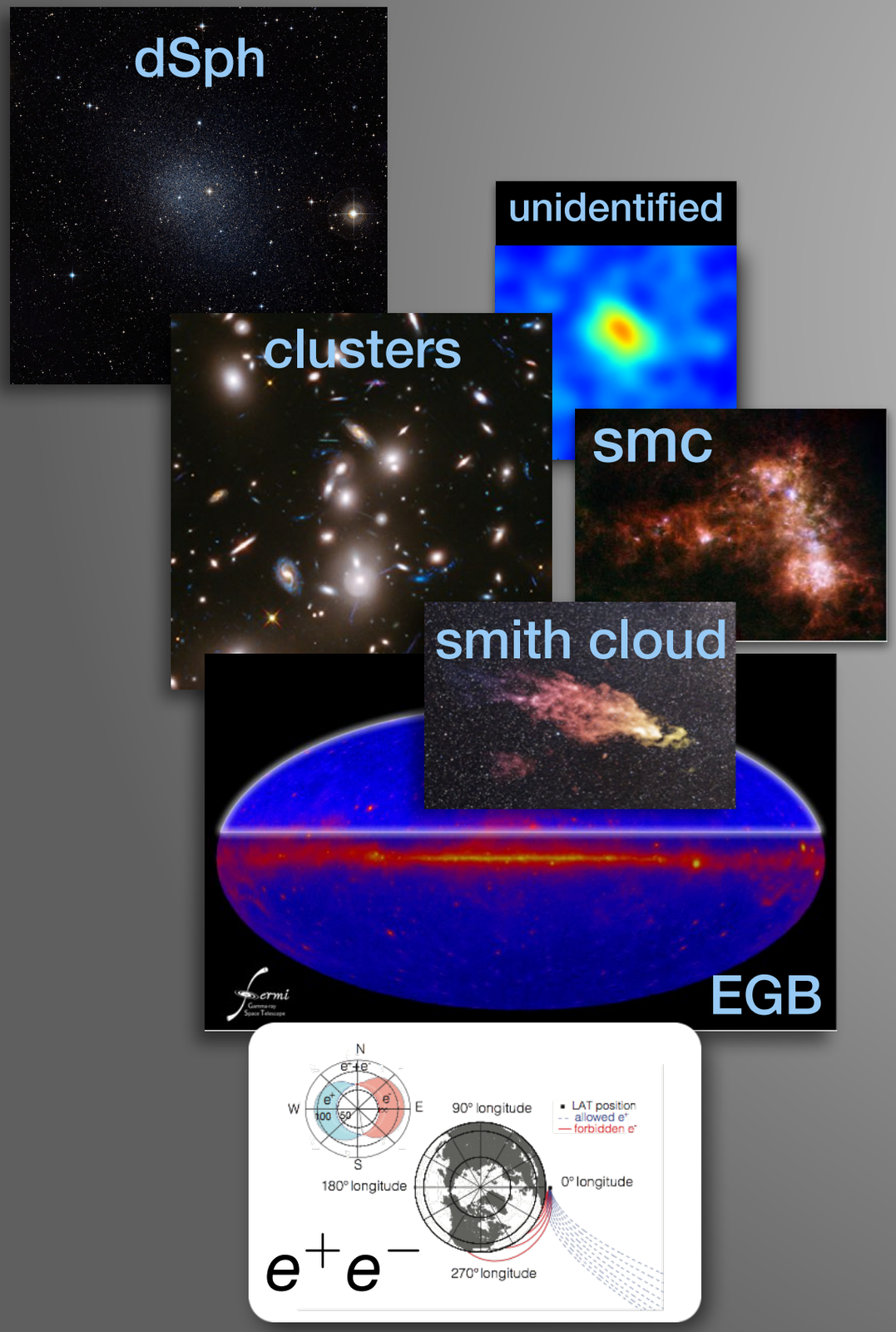
Smith Cloud
Drlica-Wagner+ 2014ApJ...790...24D

Electron-Positron
Ackermann+ 2012PhRvL.108a1103A

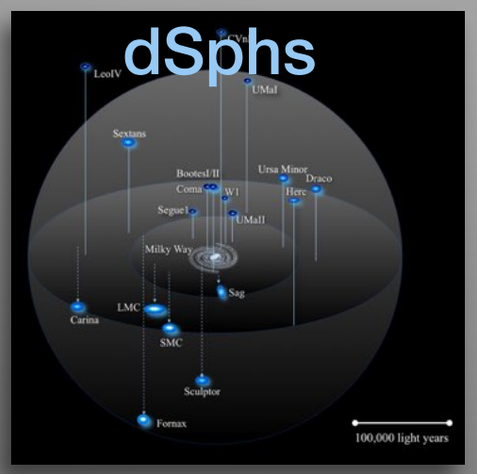
Small Magellanic Cloud
Caputo+ 2016PhRvD..93f2004C

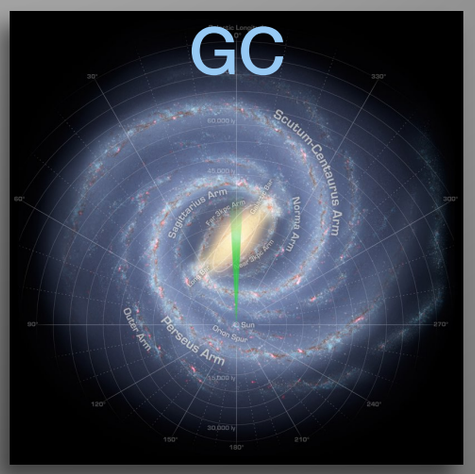
- extensive searches in standard targets
- including a few others!

Status



- extensive searches in standard targets
- including a few others!
- no clear detection
- results can be summarized by focusing on these two

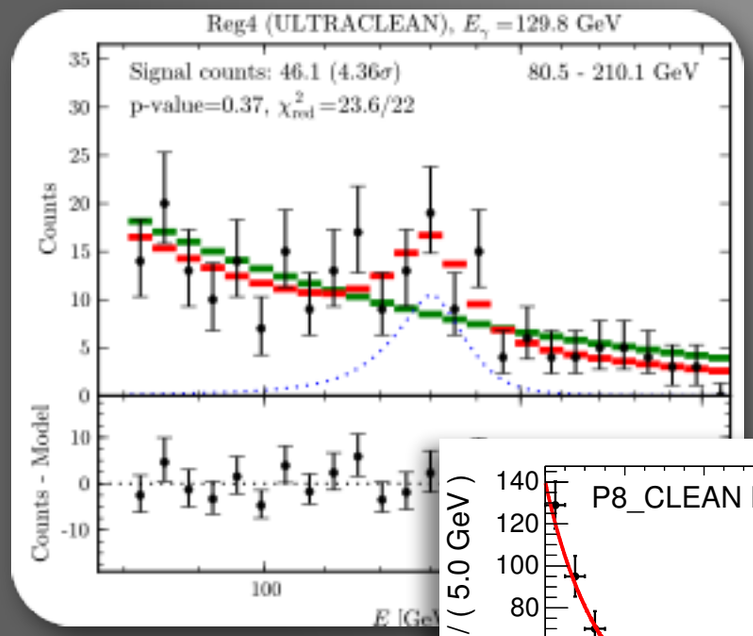




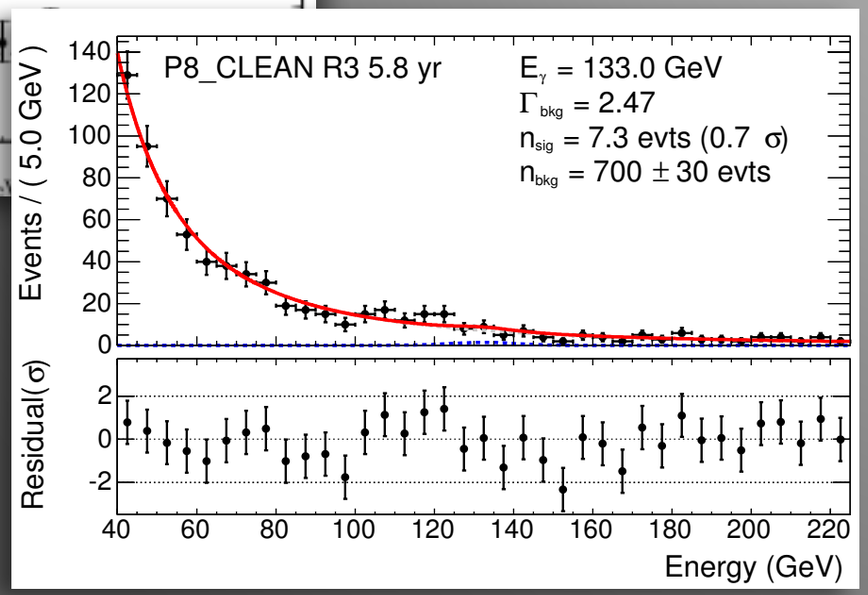
Galactic Center

first check for the unique signature

- early feature at 135 GeV, but
- present in off-regions
- significance has gone down

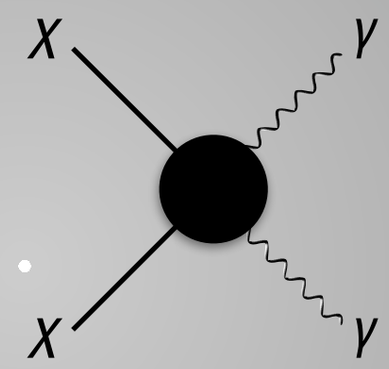


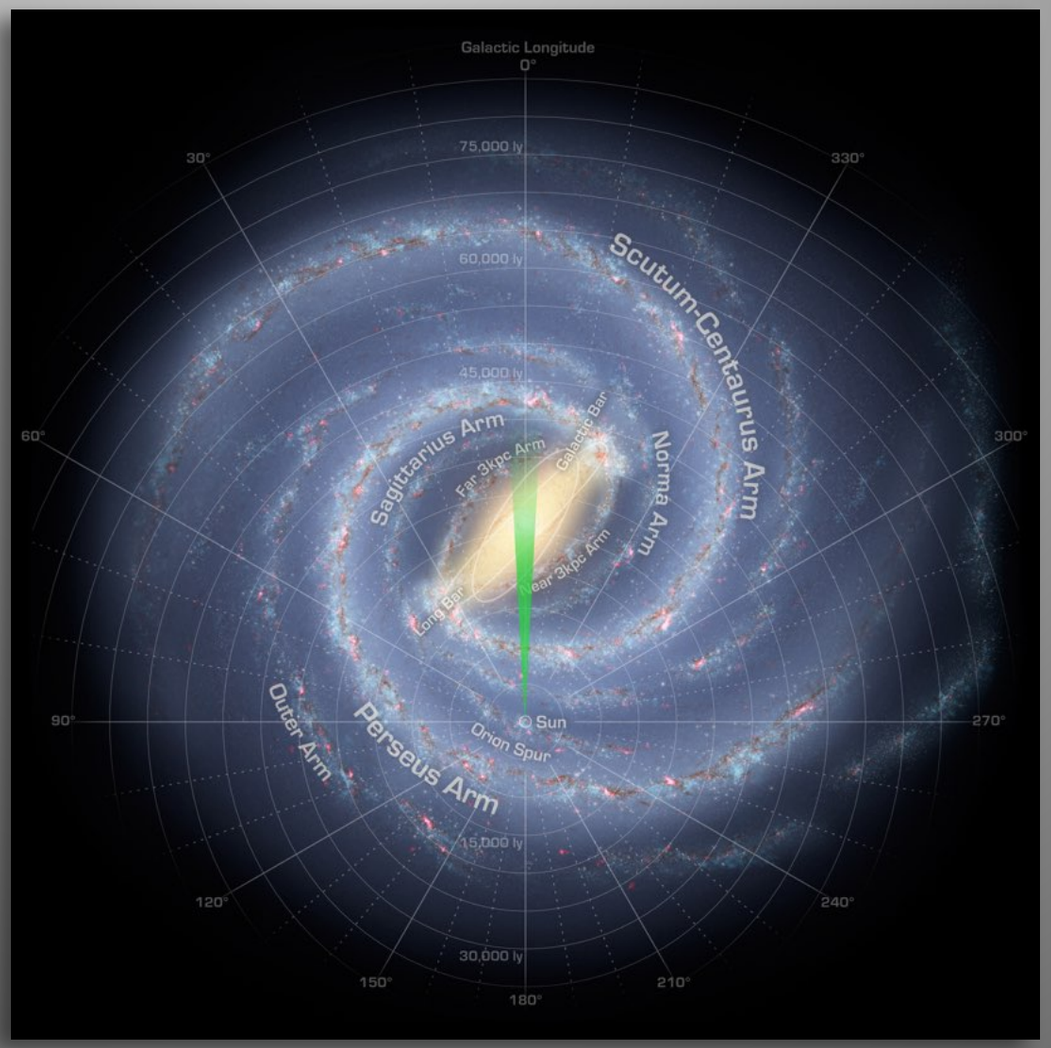
Weniger 2012



Ackermann+ [LAT Clb]
2012ApJ...747..2015arXiv150600013T

highest potential flux





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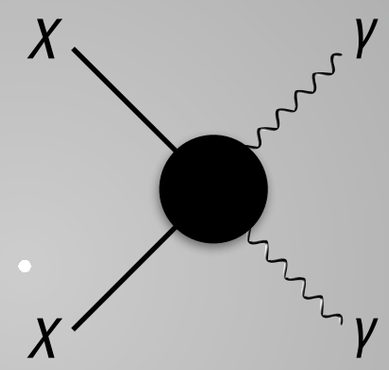
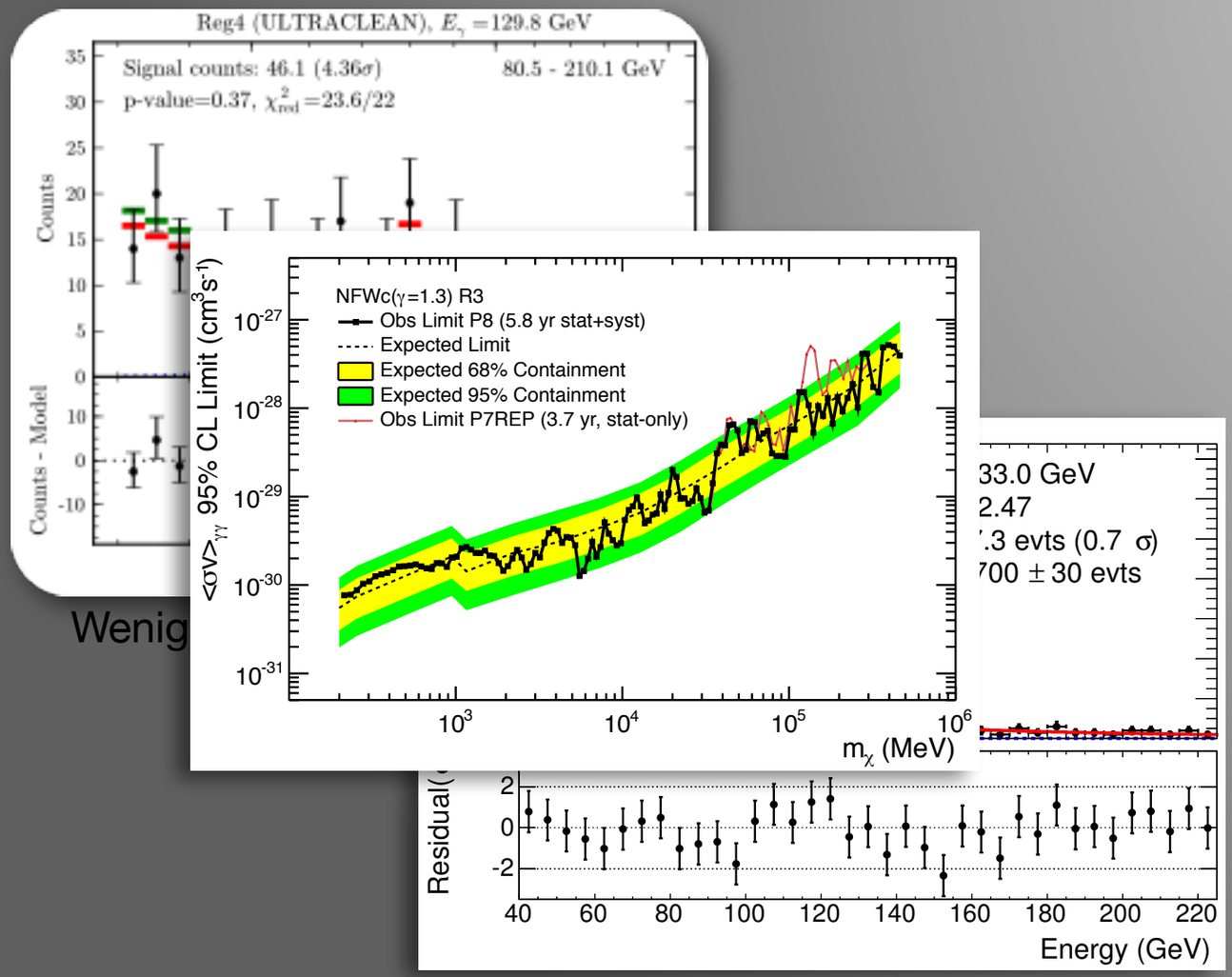
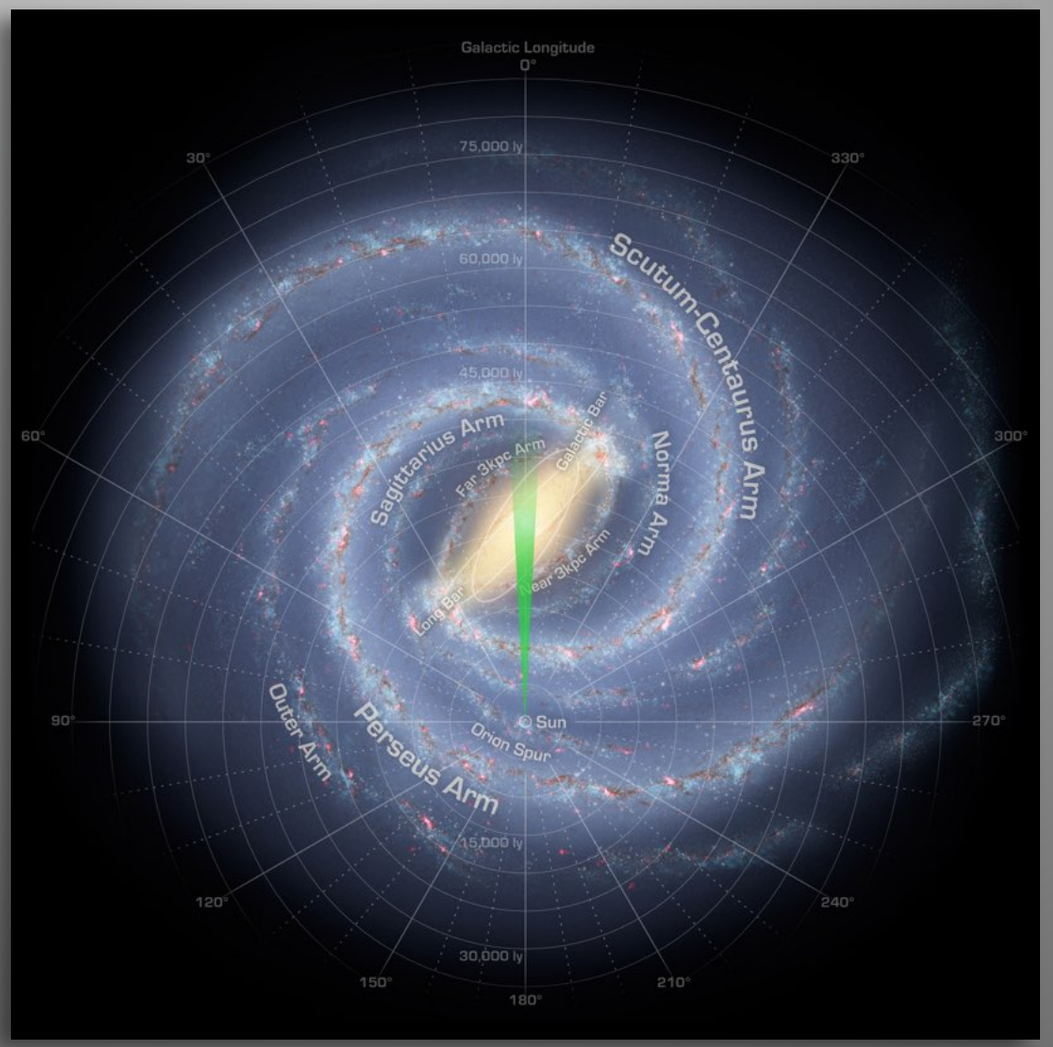




Wenig

Ackermann+ [LAT Clb]
2012ApJ...747..2015arXiv150600013T



Galactic Center

for continuum, we must model known sources

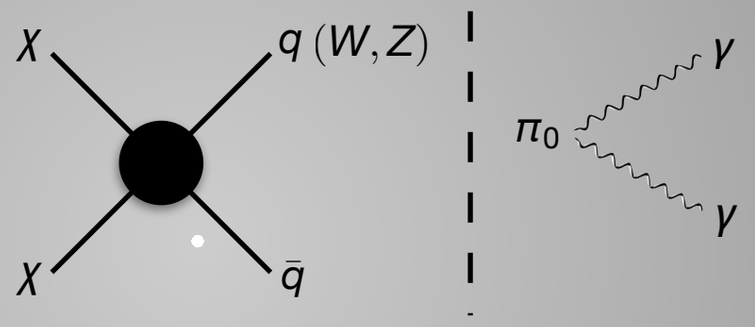
- cosmic rays + gas
- cosmic rays + light

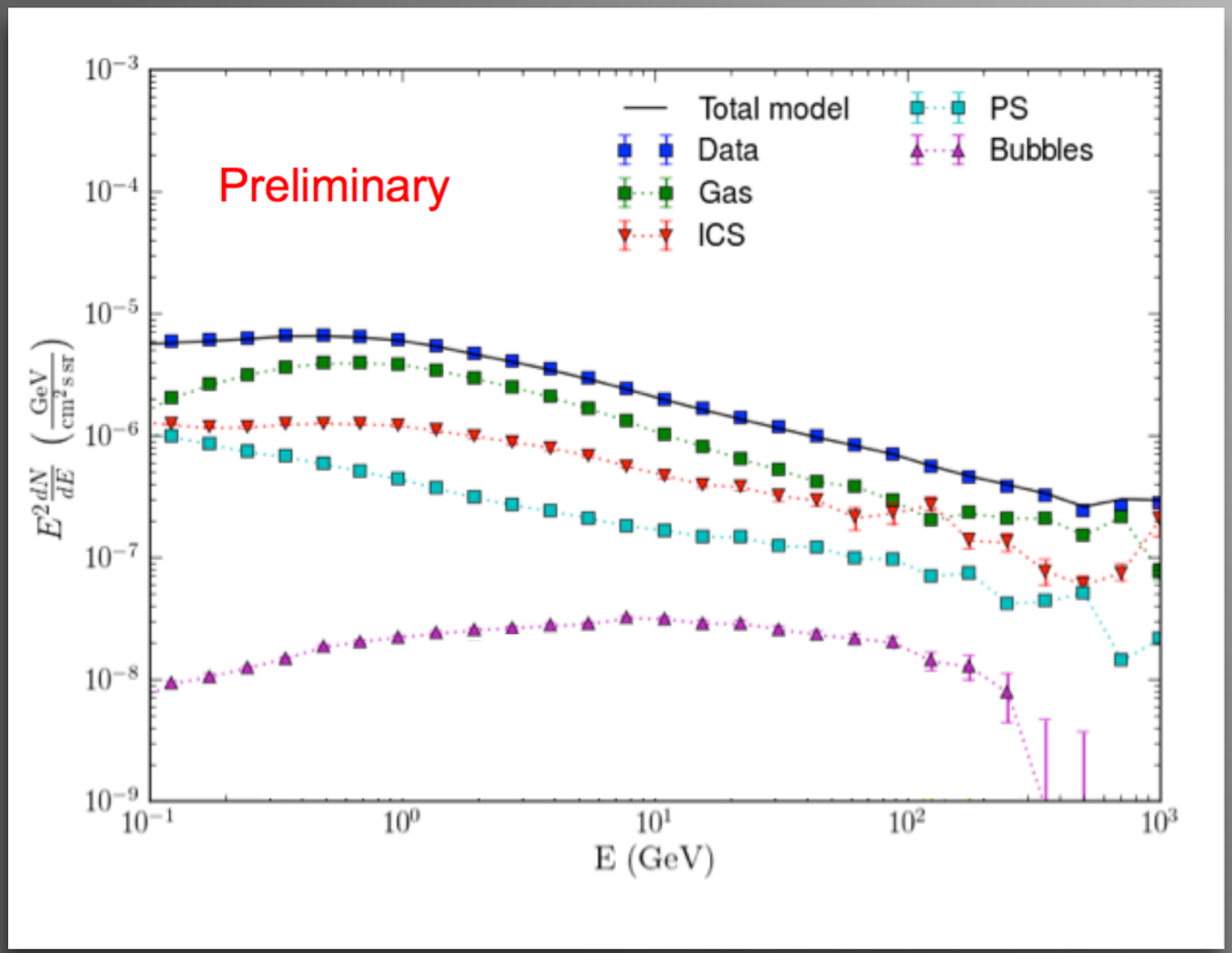
} multi-wavelength driven

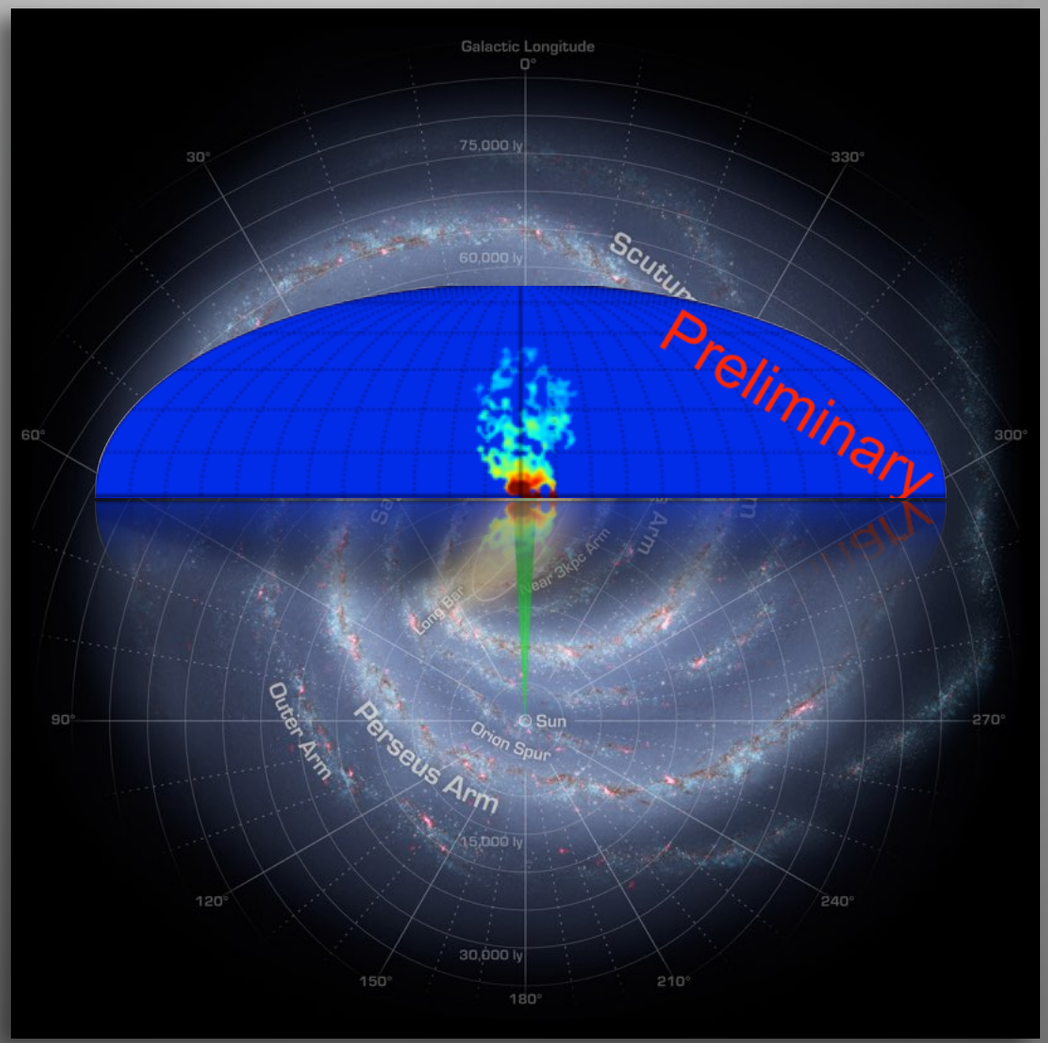
- point sources
- “bubbles”

} gamma-driven

highest potential flux





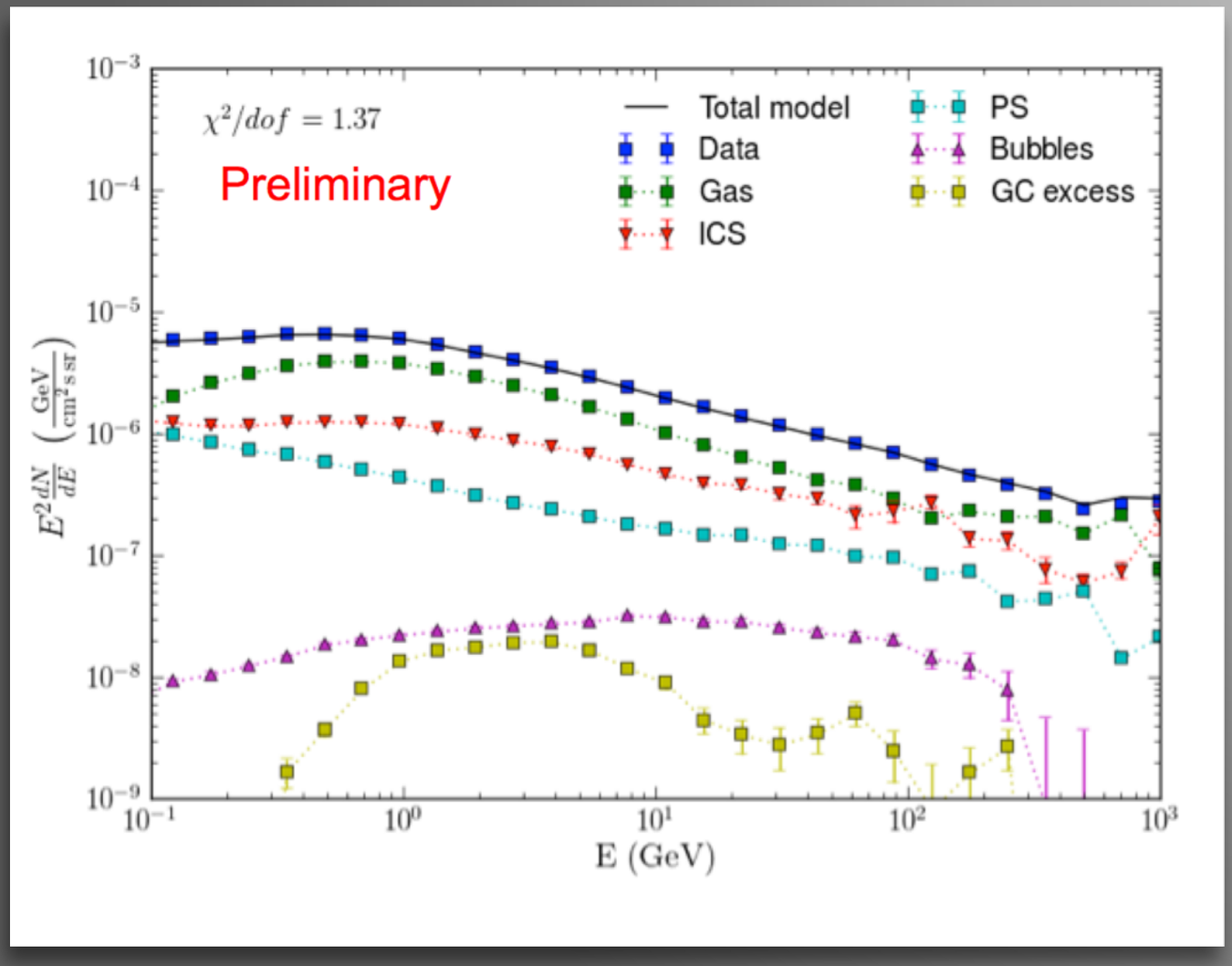


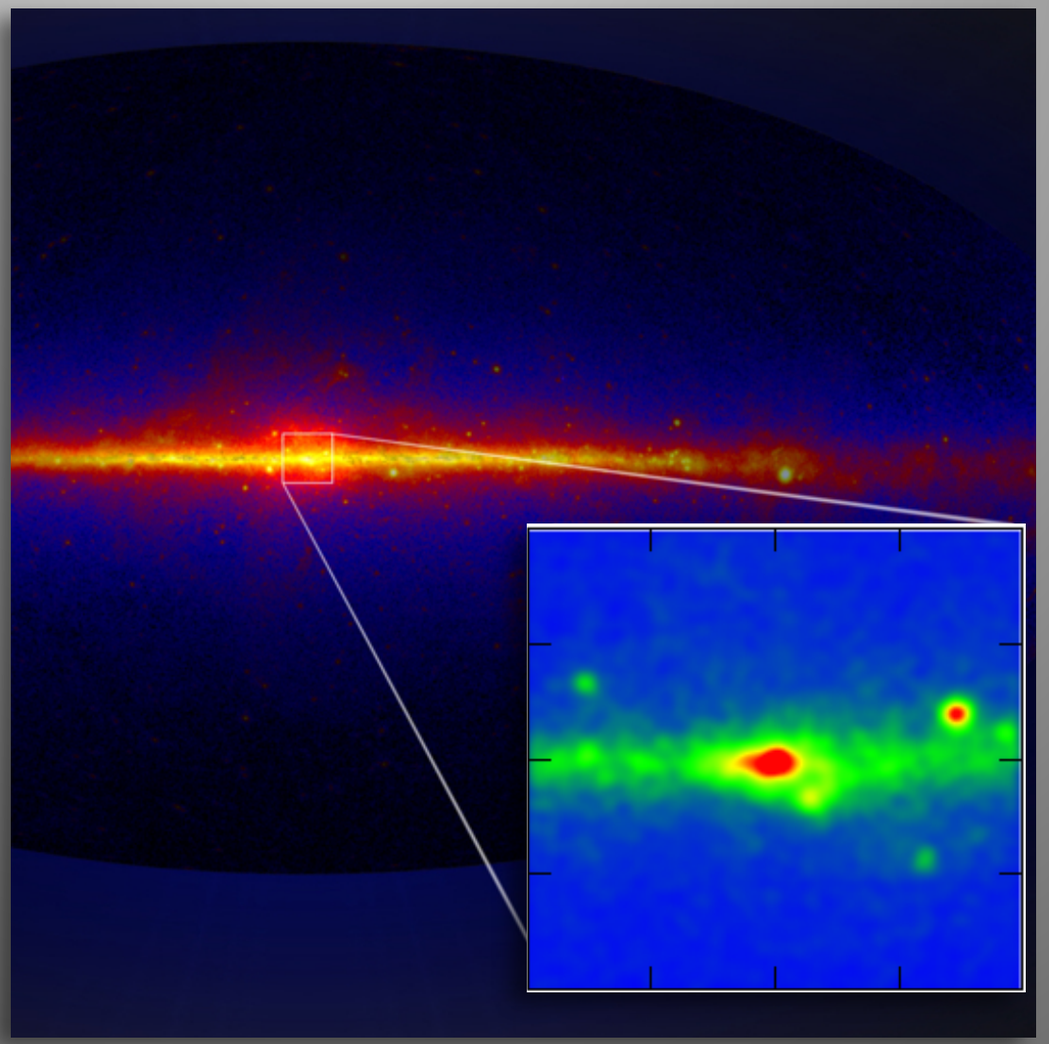
Galactic Center

highest potential flux

model known sources
- cosmic rays + gas
- cosmic rays + light
- point sources

examine what remains
- peaked at a few GeV
- extended (10 deg)
- spatially consistent spectrum?





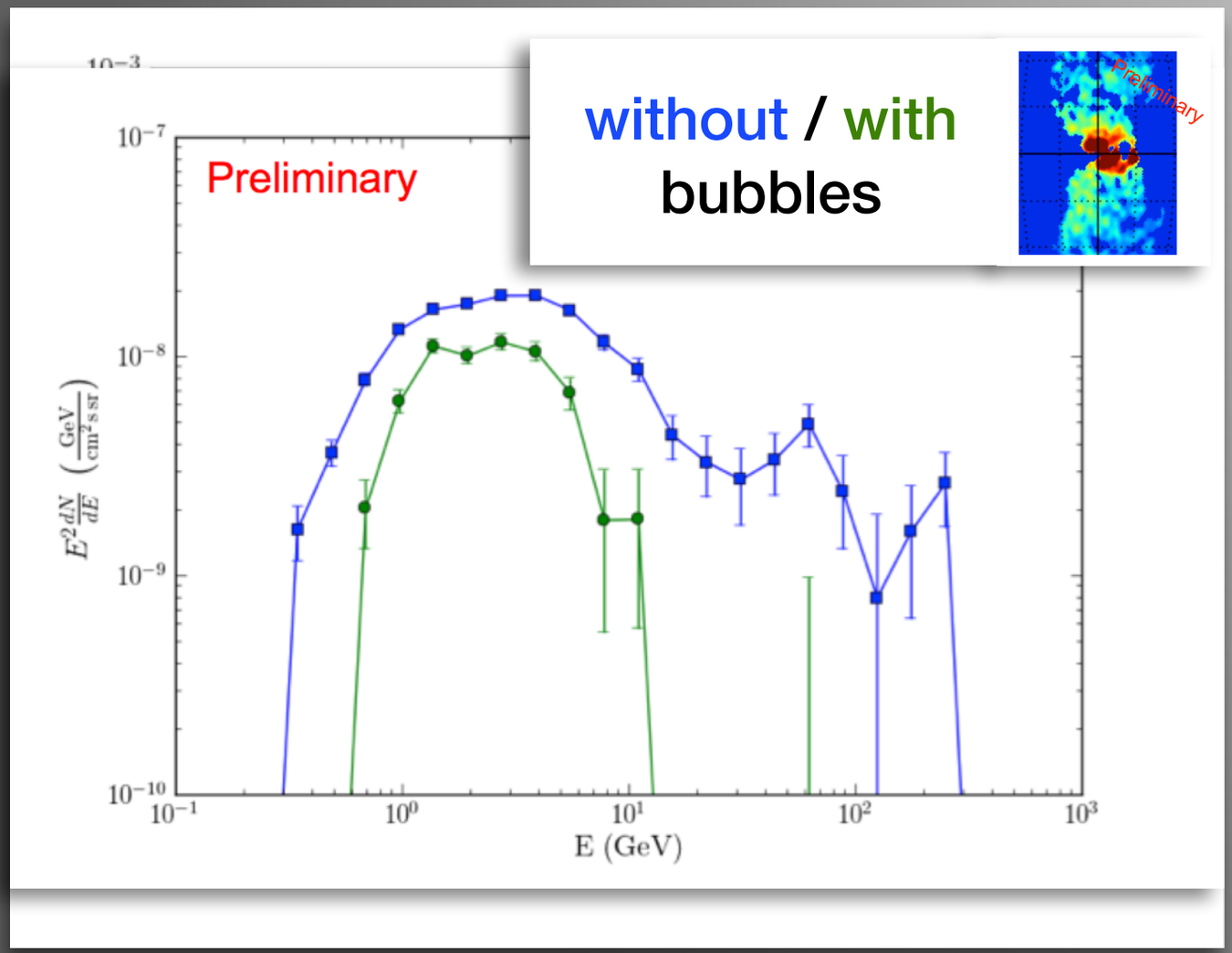
NASA/T. Linden, U. Chicago

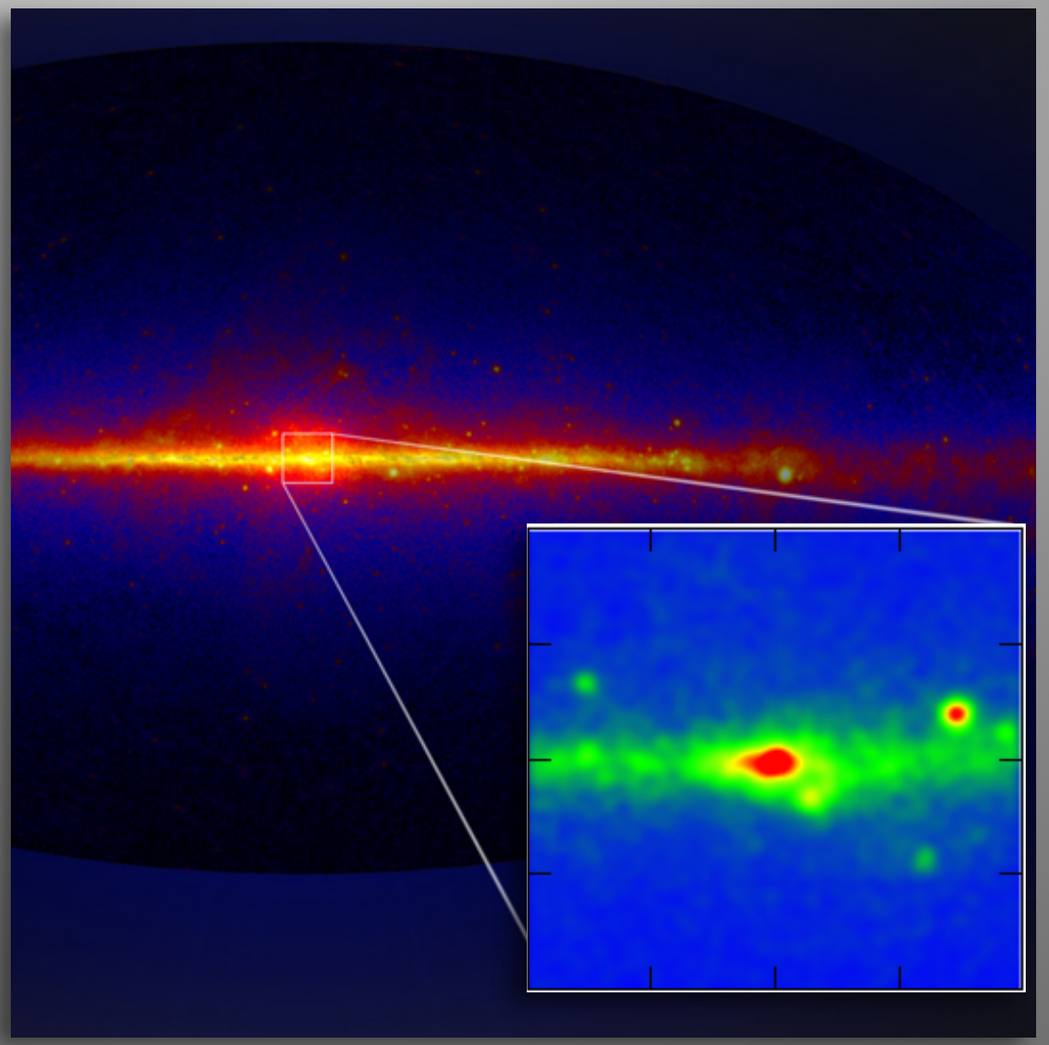
Galactic Center

highest potential flux

model known sources
- cosmic rays + gas
- cosmic rays + light
- point sources
- “bubbles”

examine what remains
- peaked at a few GeV
- extended (10 deg)
- spatially consistent spectrum?
- sharp cutoff





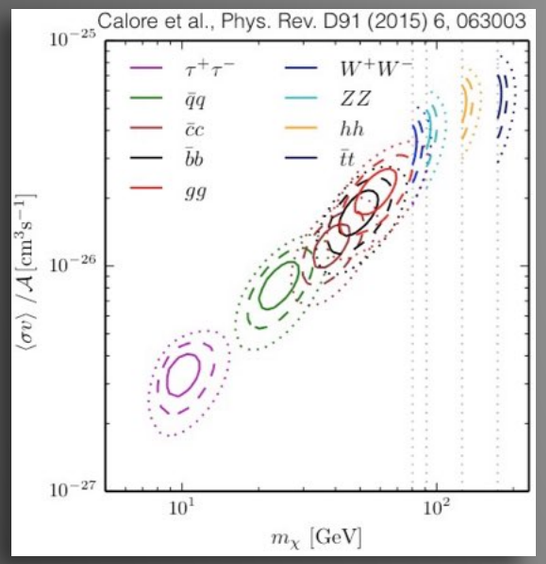
NASA/T. Linden, U. Chicago

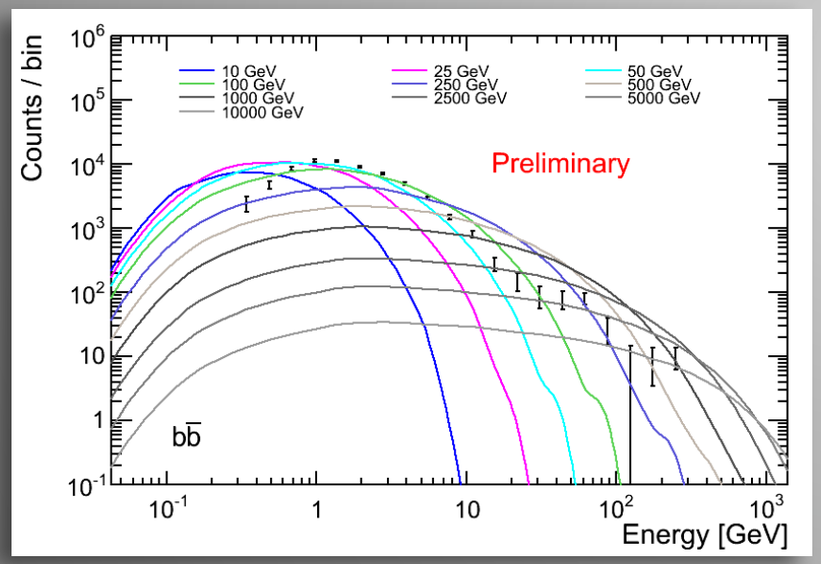
Galactic Center

potential missing pieces

- dark matter signal

highest potential flux



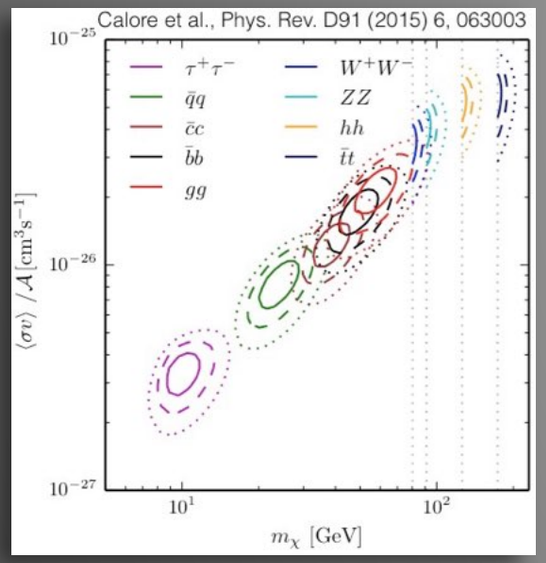


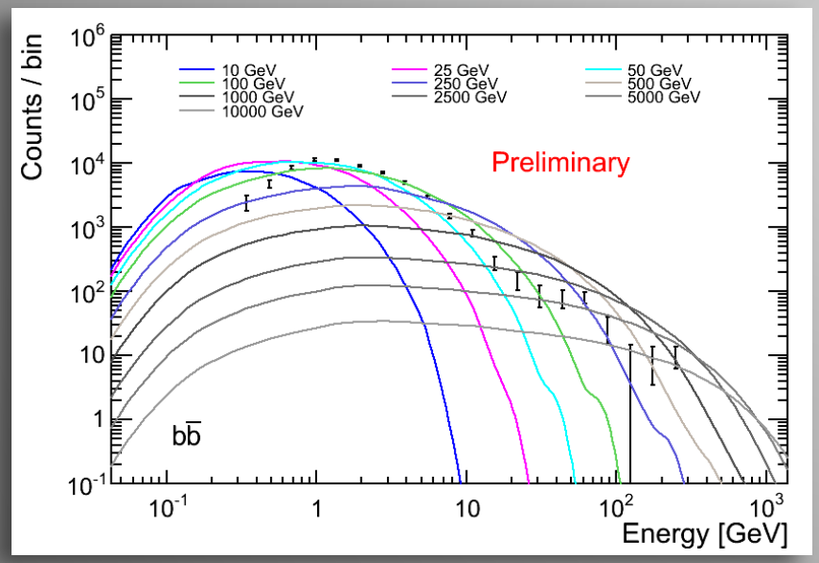
Galactic Center

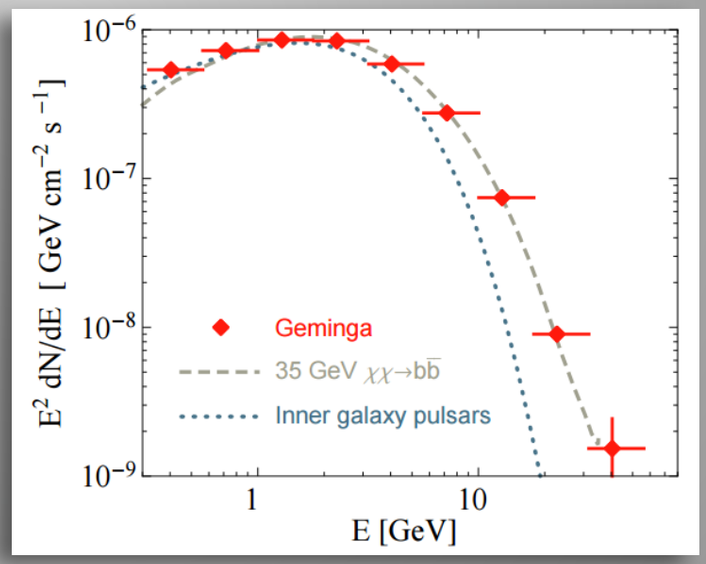
potential missing pieces

- dark matter signal
- millisecond pulsar population

highest potential flux







both models fit both the spectrum and extension

O'Leary+ (2015)
arXiv:1504.02477

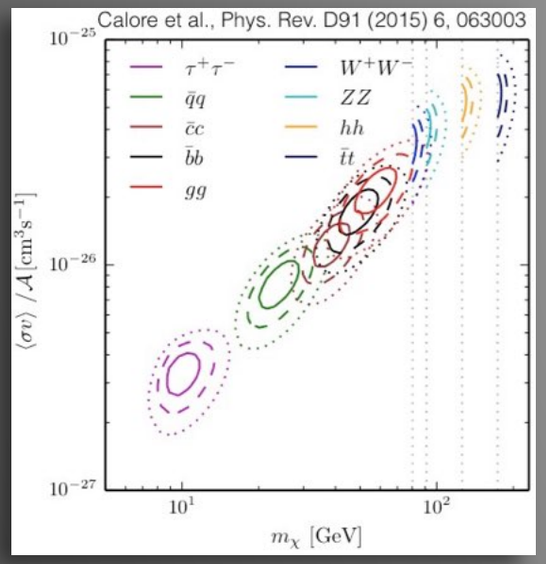
Aliu+ (2015)
2015ApJ...800...61A

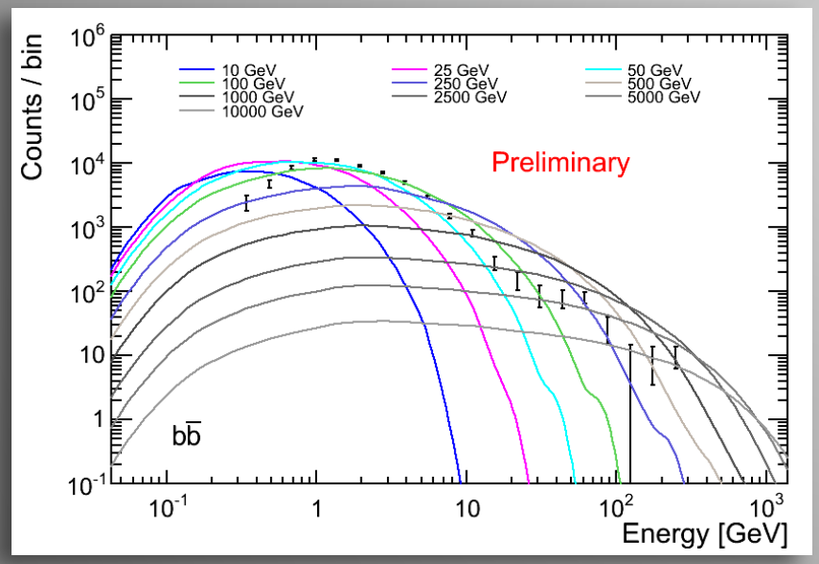
Galactic Center

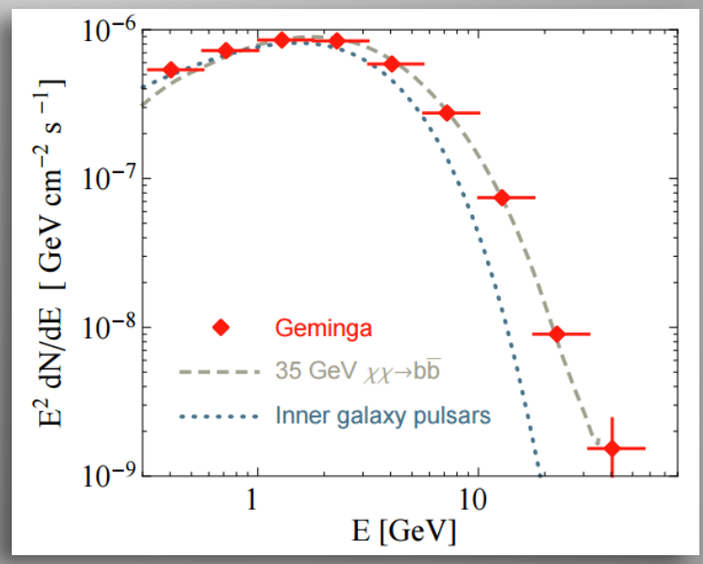
potential missing pieces

- dark matter signal
- millisecond pulsar population

highest potential flux



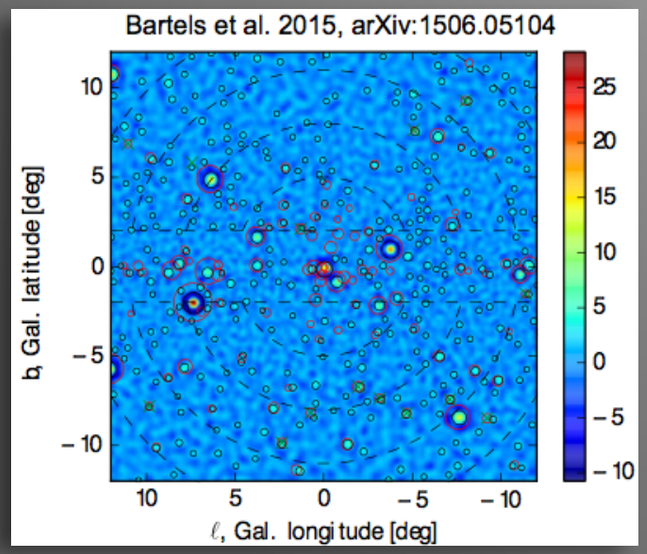




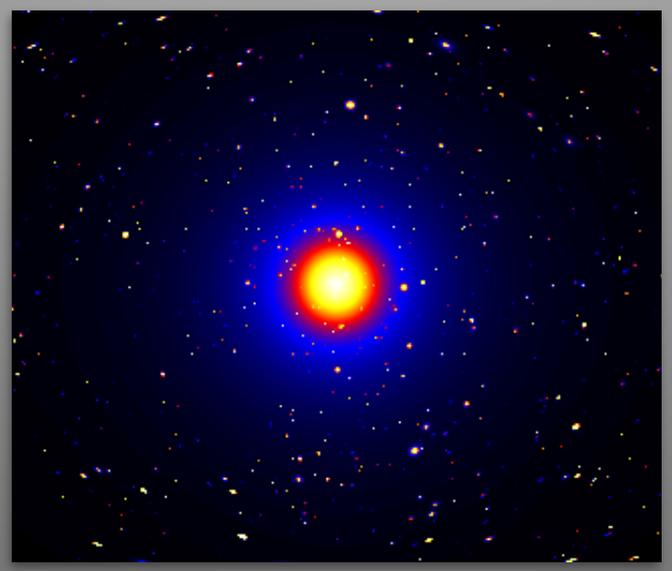
O'Leary+ (2015)
arXiv:1504.02477
Aliu+ (2015)
2015ApJ...800...61A

both models fit both the spectrum and extension
but there *is* a fundamental difference

lumpy



vs



smooth

Dwarf Spheroidal Galaxies

the cleanest targets

dSph properties

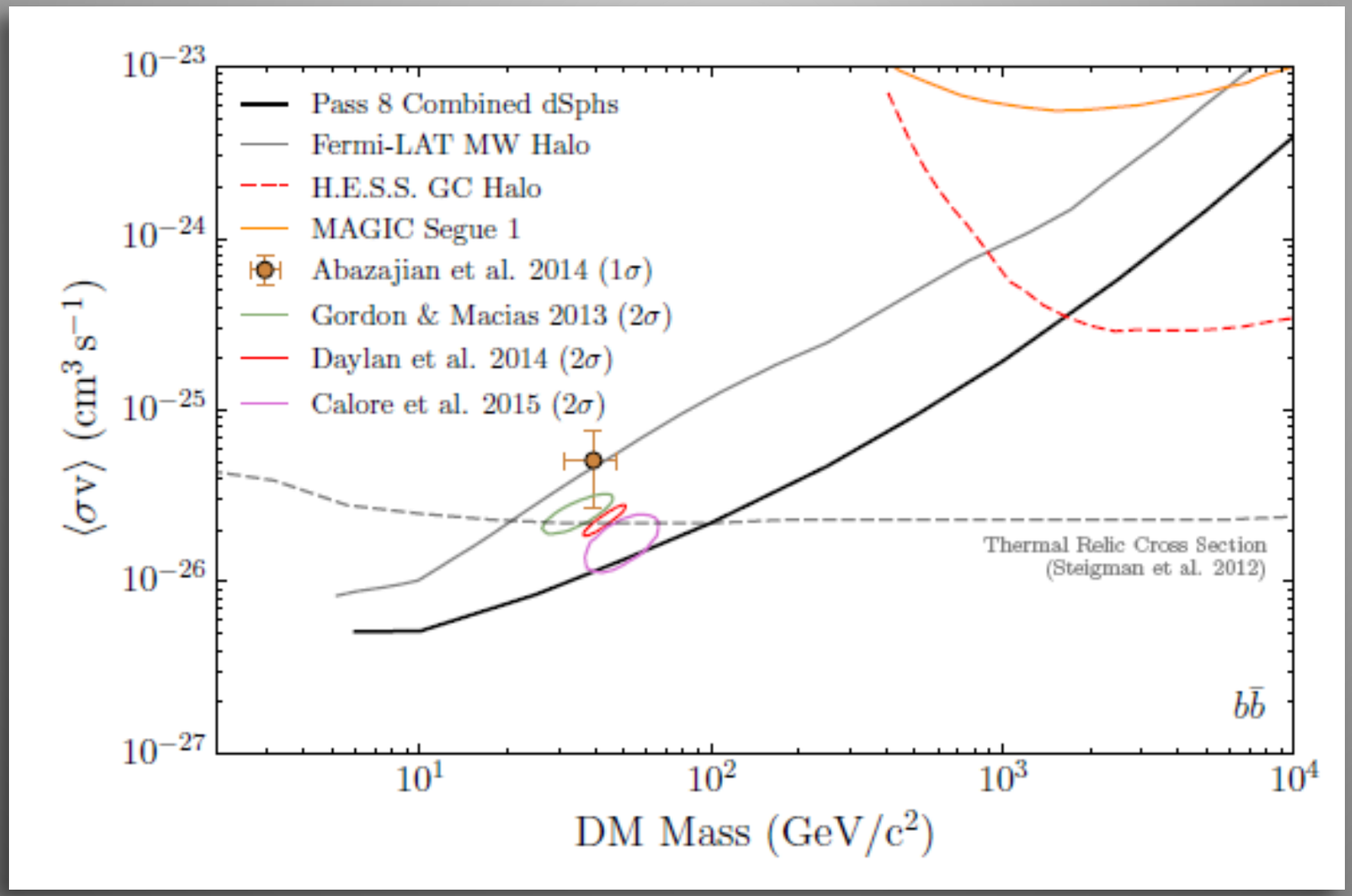
- DM-dominated (1000:1)
- 10s to 1000s of stars trace the potential
- often high latitude (low diffuse background)
- nearby (<250 kpc)
- many! (50+) allows for joint analyses

Dwarf Spheroidal Galaxies

the cleanest targets

joint dSph analysis

- 15 targets
- 4th generation collaboration analysis
- 60 mo. Pass 8 data
- thermal exclusion to 100 GeV

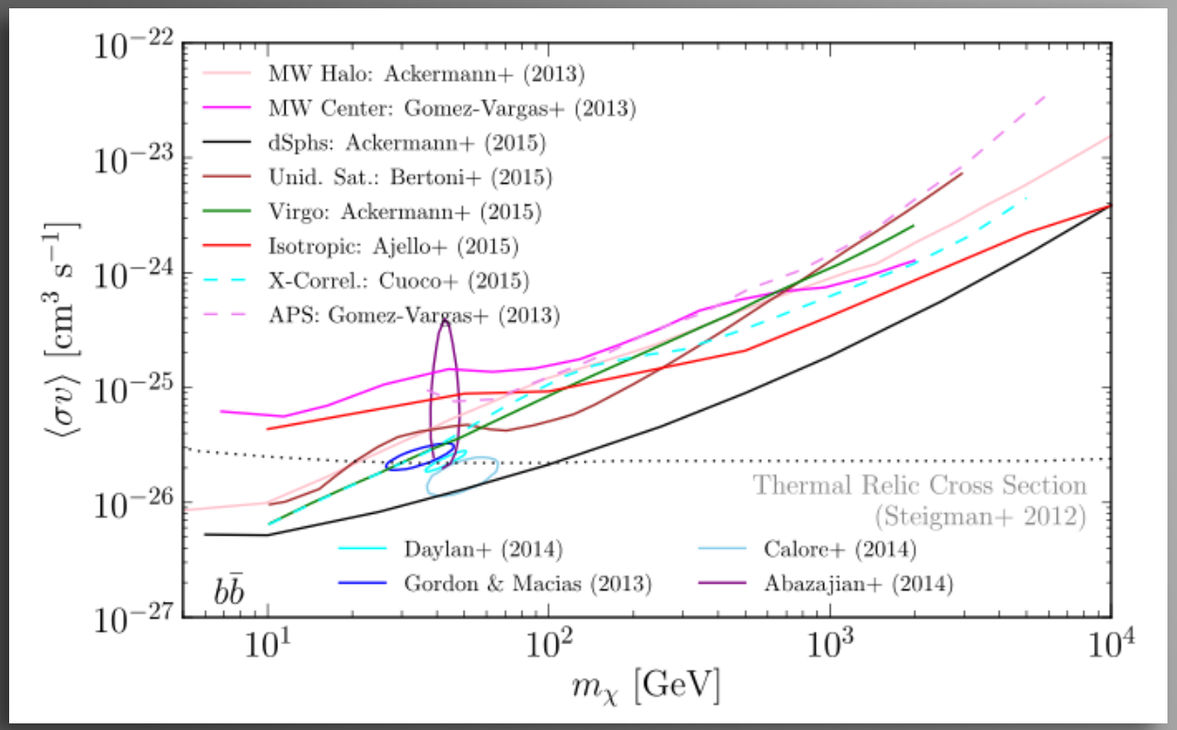


Recent papers:

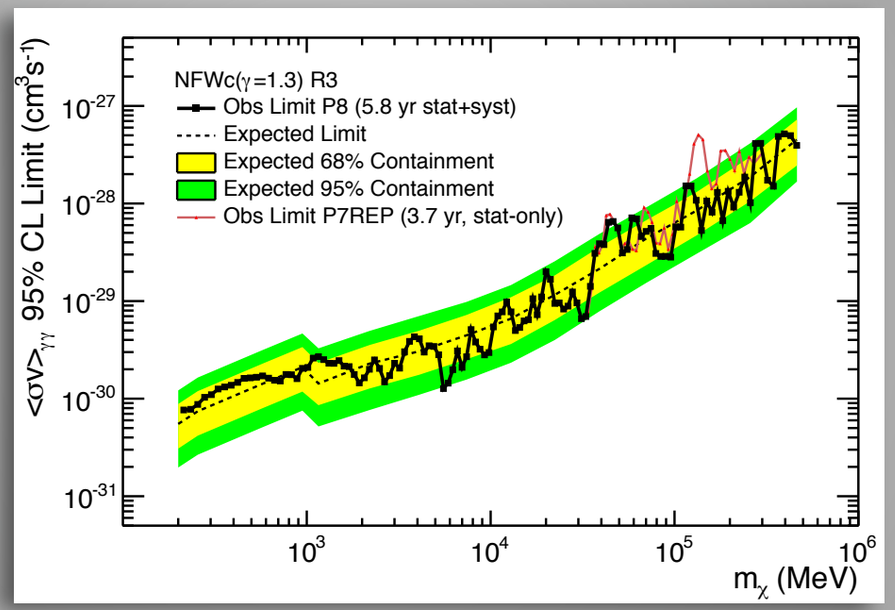
LAT: Ackermann+ [LAT Clb] 2015PhRvL.115w1301A
Drlica-Wagner+ [LAT + DES Clbs] 2015ApJ...809L...4D
Geringer-Sameth+ 2015PhRvL.115h1101G

Status Summary

Charles+ [LAT Clb]
2015arXiv150600013T



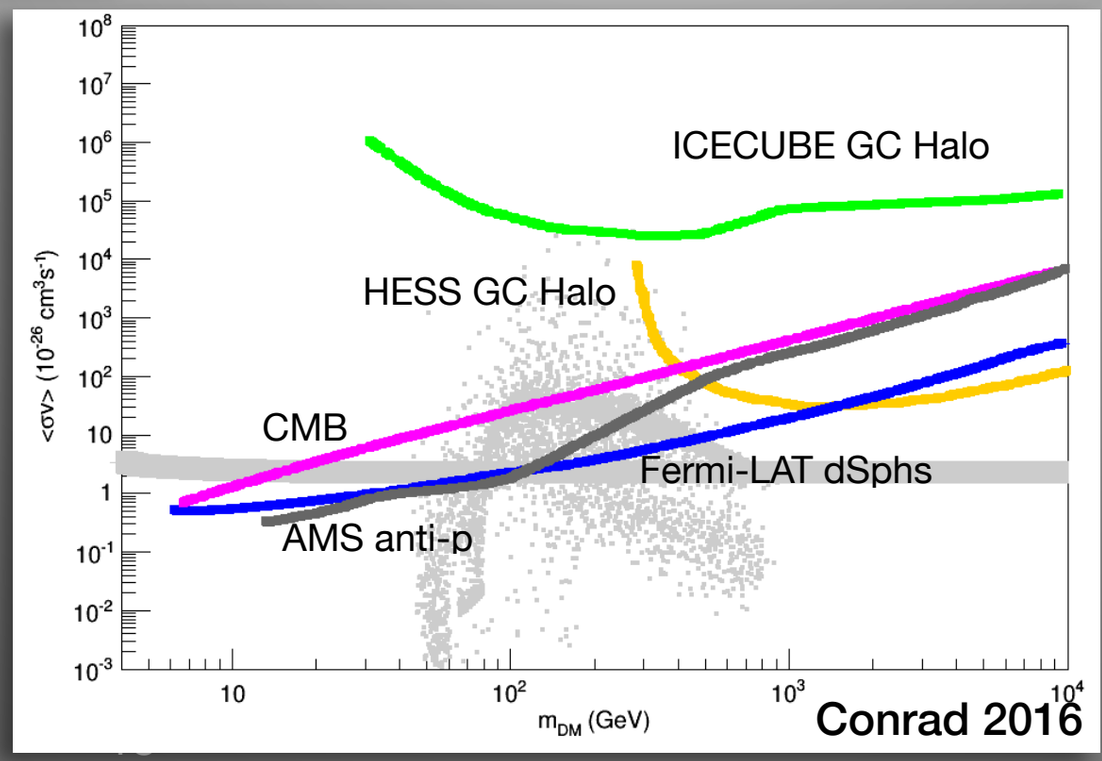
what can the LAT say about WIMPs?



Ackermann+ [LAT Clb]
2012ApJ...747..2015arXiv150600013T

in context

- at the forefront in sensitivity for this mass range
- beginning to pressure thermal WIMPs
- still some potential for detection



the future

two big questions

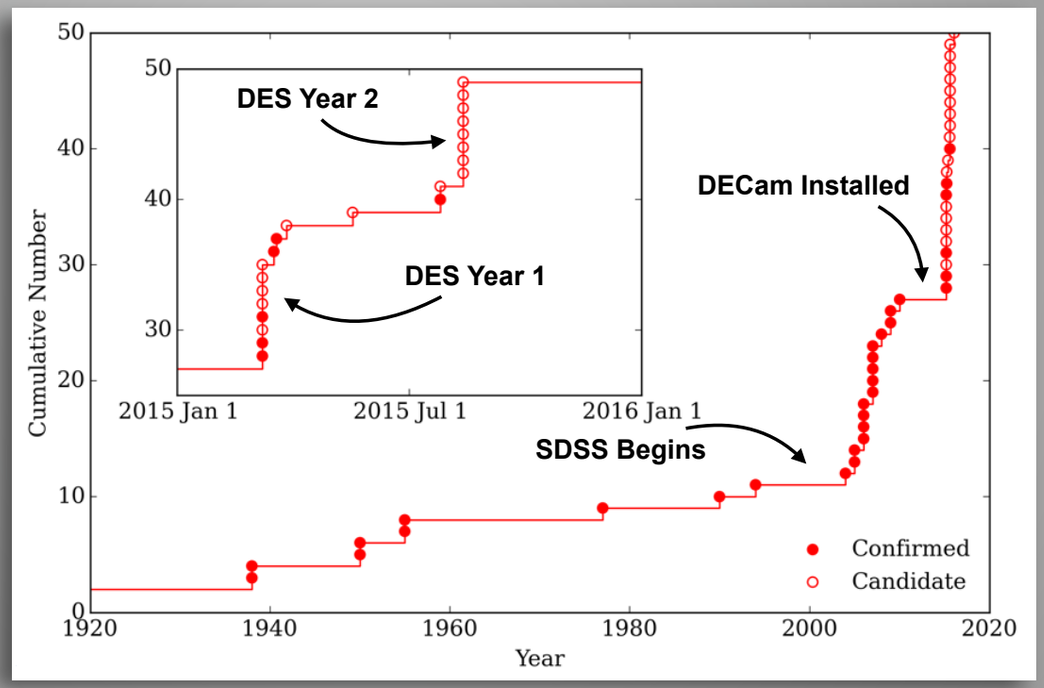
- there are a few hints — can they be resolved?
- if we don’t see anything, what ultimate limits can we expect?

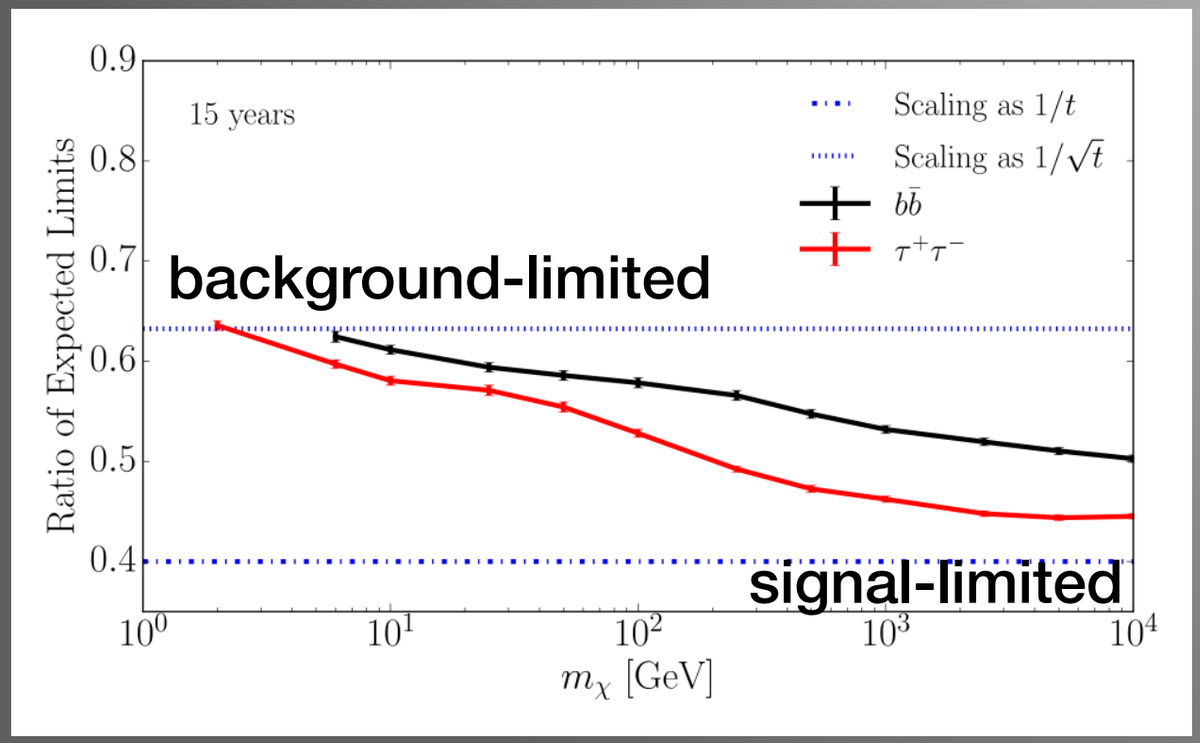
Projected Limits

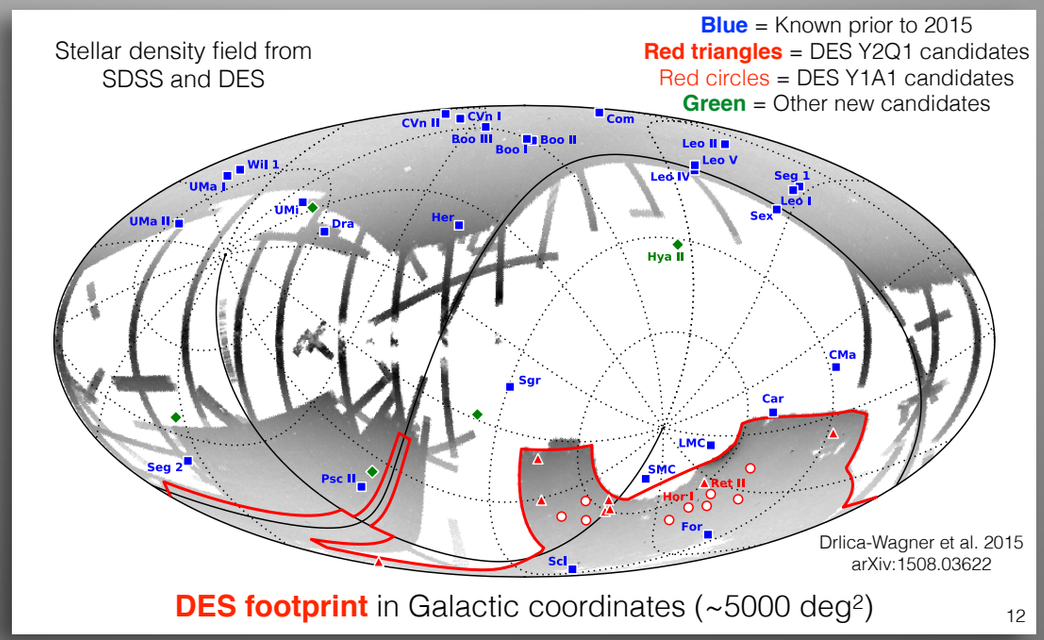
the dSph advantage

beating sqrt(t)

- ~20 new targets from the dark energy survey (DES)
- similar in character (southern hemisphere)
- waiting on spectroscopic follow-up for J-factors







Charles+ [LAT Clb]
2015arXiv150600013T

Drlica-Wagner+
2015ApJ...813..109D

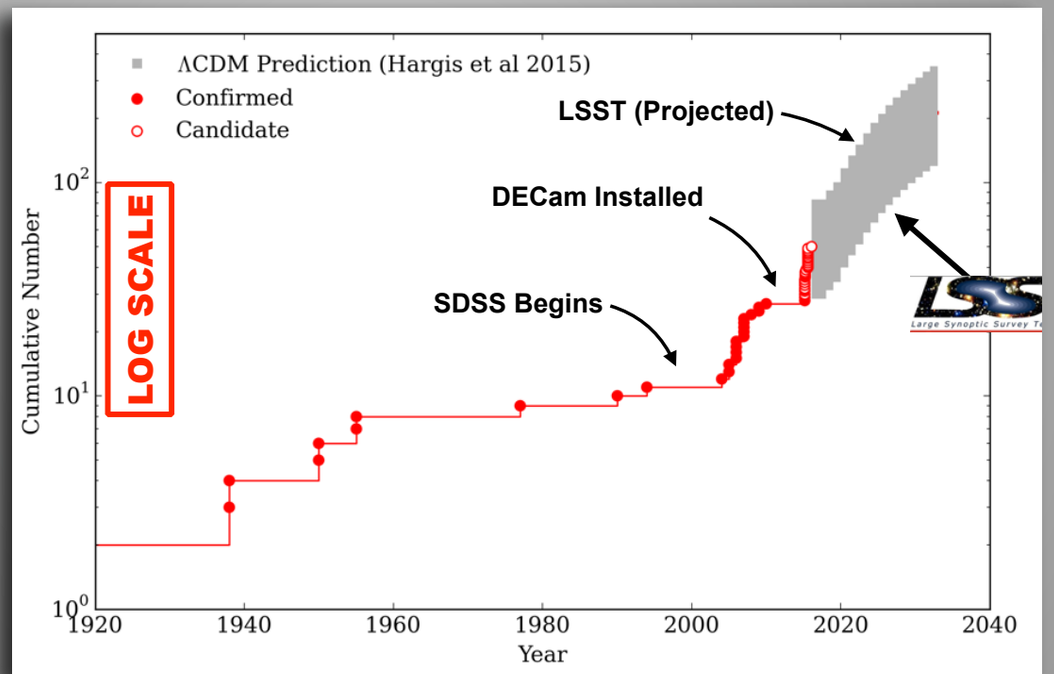
Bechtol+
2015ApJ...807...50B

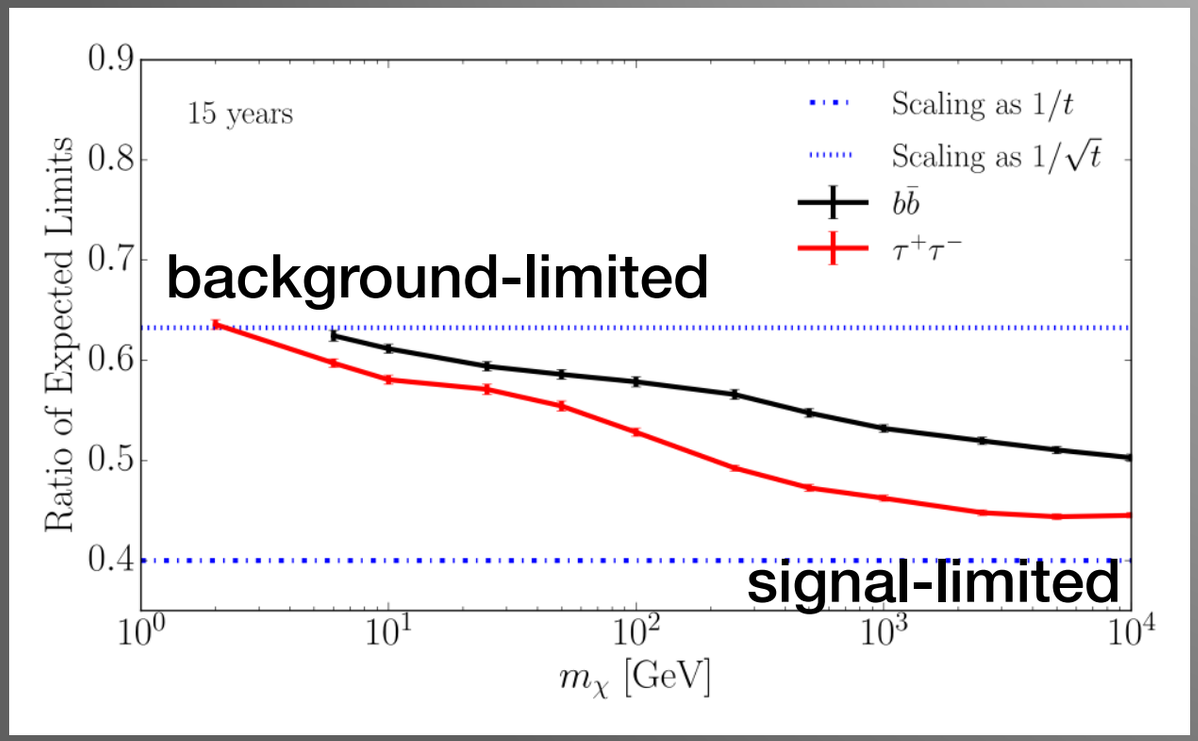
Projected Limits

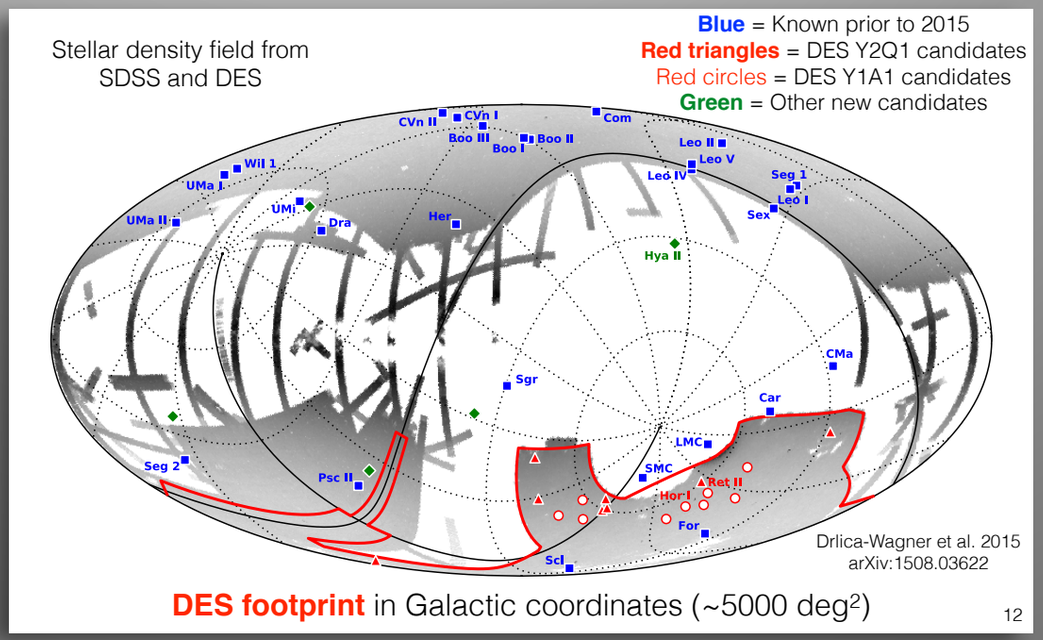
the dSph advantage

beating sqrt(t)

- ~20 new targets from the dark energy survey (DES)
- similar in character (southern hemisphere)
- waiting on spectroscopic follow-up for J-factors
- even more with LSST







Charles+ [LAT Clb]
2015arXiv150600013T

Drlica-Wagner+
2015ApJ...813..109D

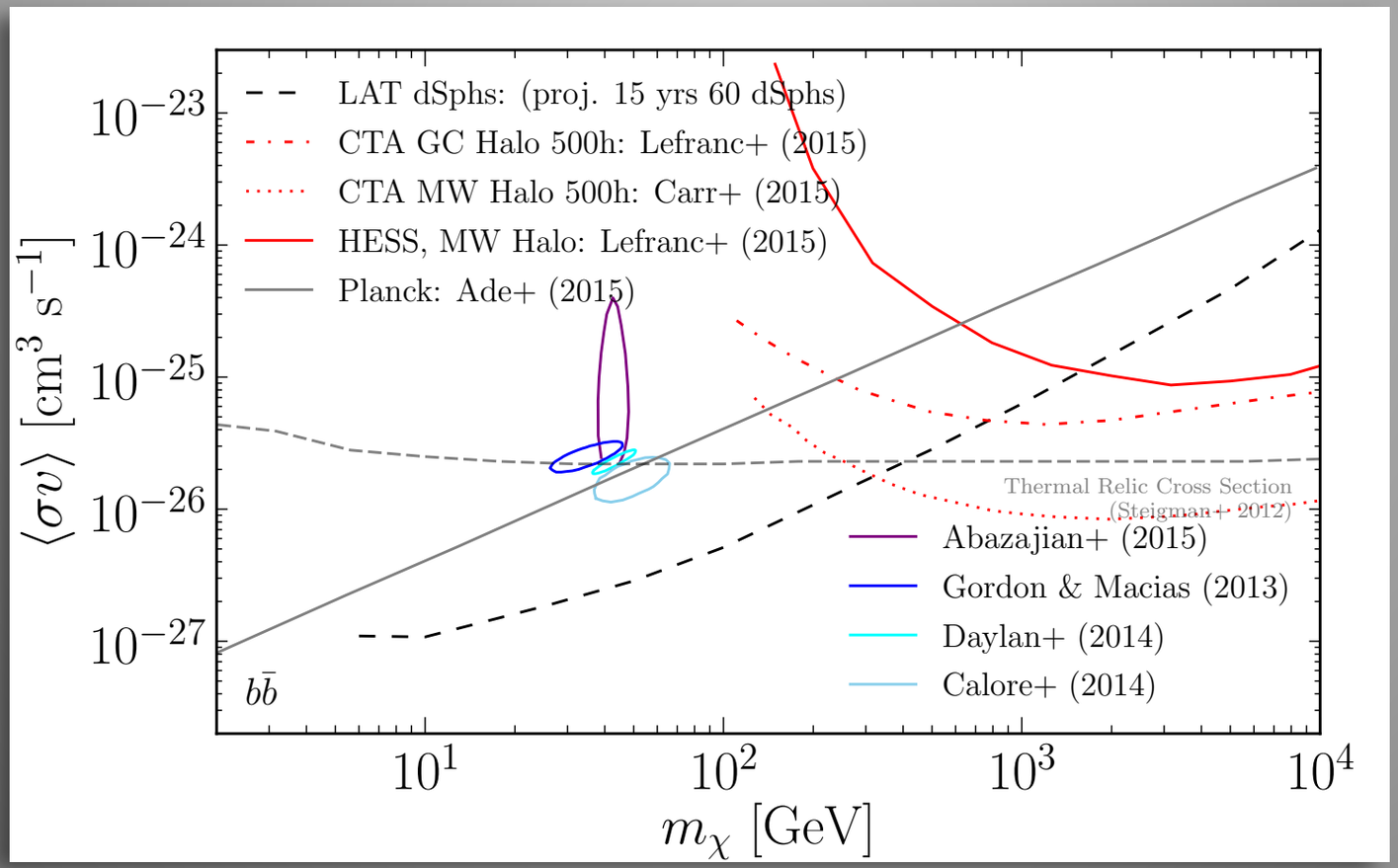
Bechtol+
2015ApJ...807...50B

Projected Limits

the dSph advantage

15 years, 60 dSphs

- should conclusively address GC models
- can reach thermal to 100s of GeV



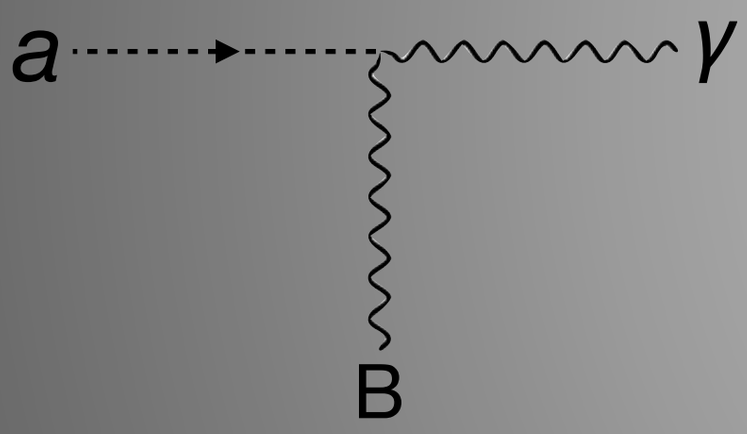
Charles+ [LAT Clb]
2015arXiv150600013T

beyond WIMPs

Axion-Like Particles

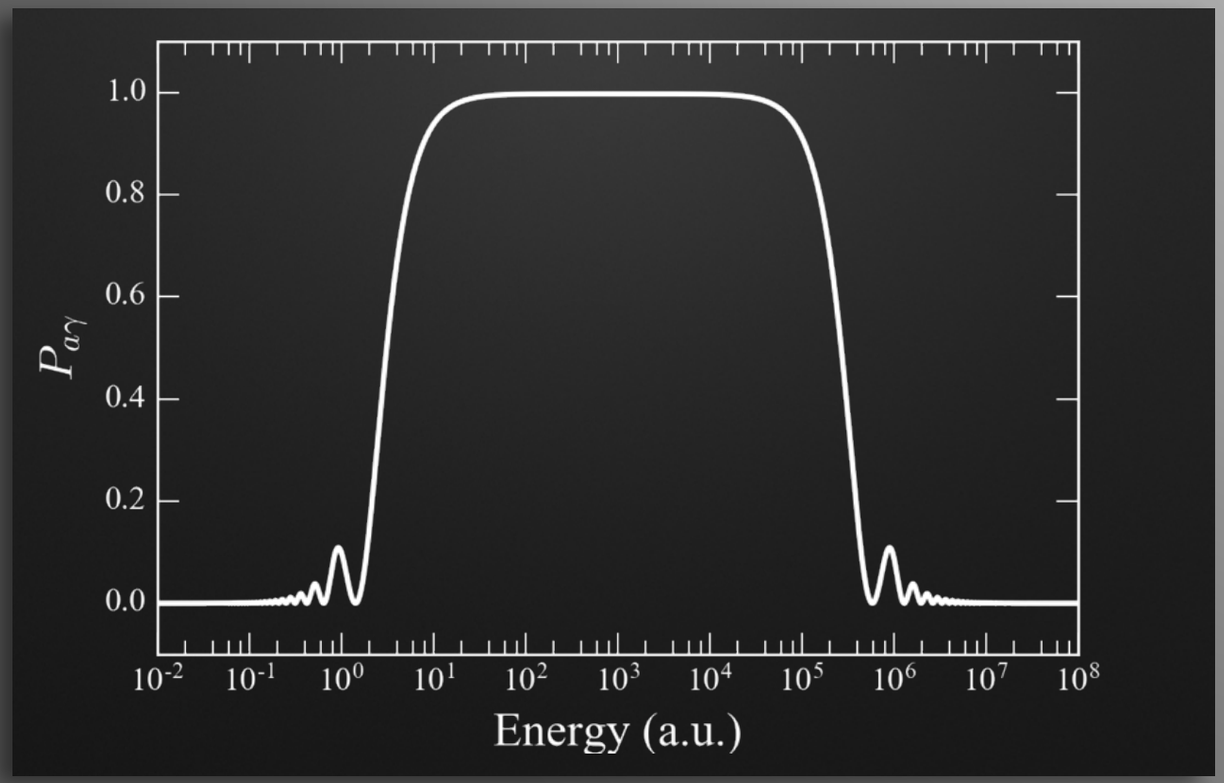
in theory

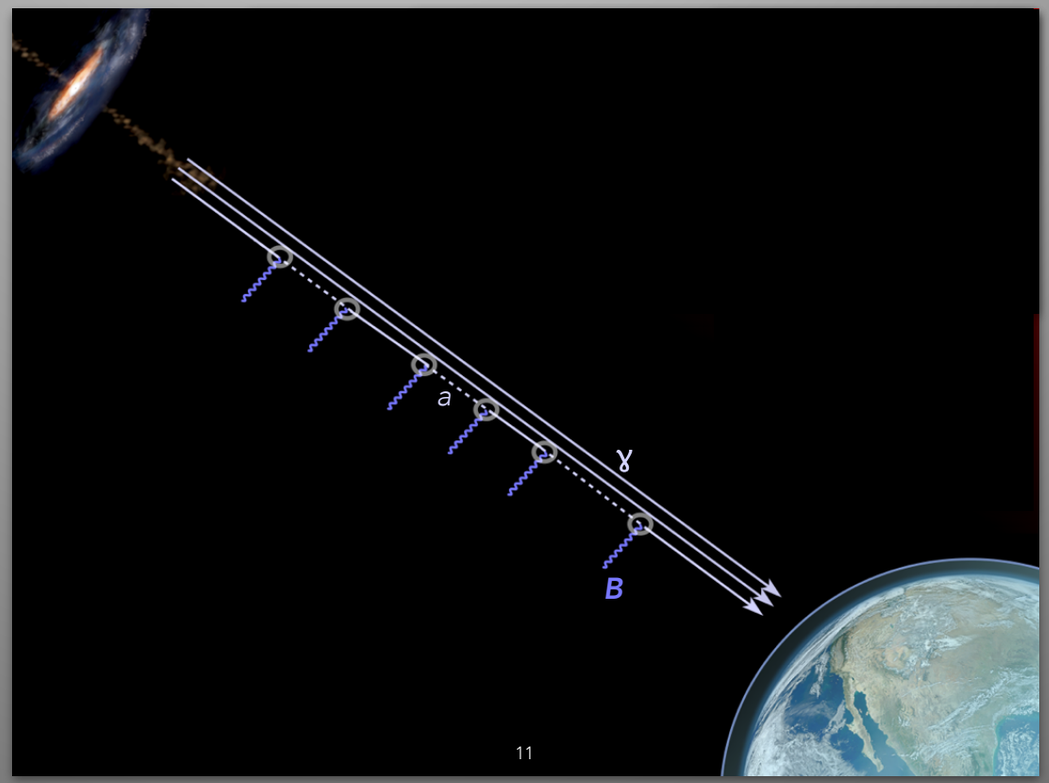
$$\mathcal{L}_{a\gamma} = -\frac{1}{4} g_{a\gamma} F_{\mu\nu} \tilde{F}_{\mu\nu} = g_{a\gamma} \mathbf{E} \mathbf{B} a$$



by mixing with ALPs, gammas can

- survive propagation when they should not
- acquire spectral irregularities

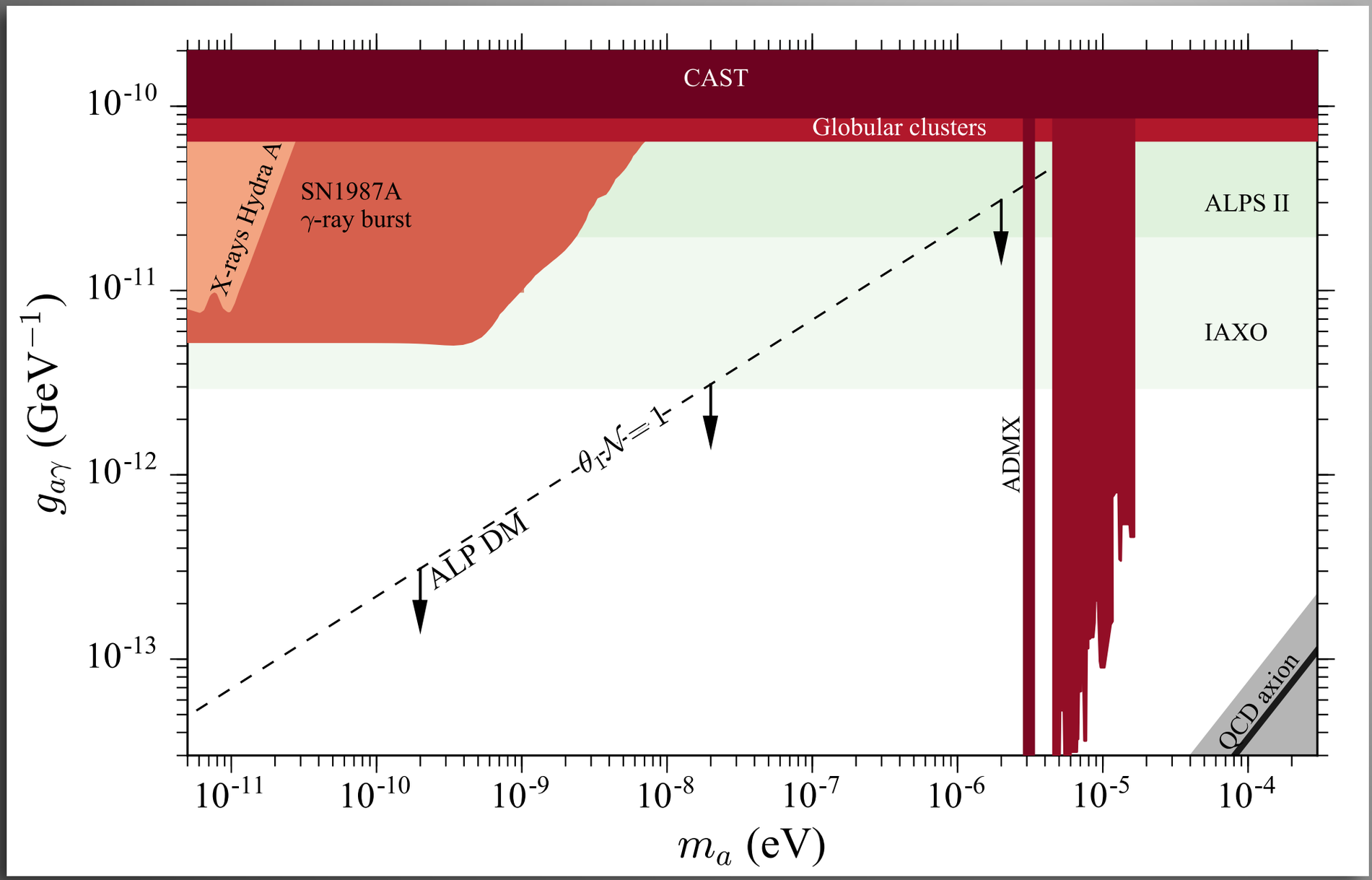




Meyer 2016

Axion-Like Particles

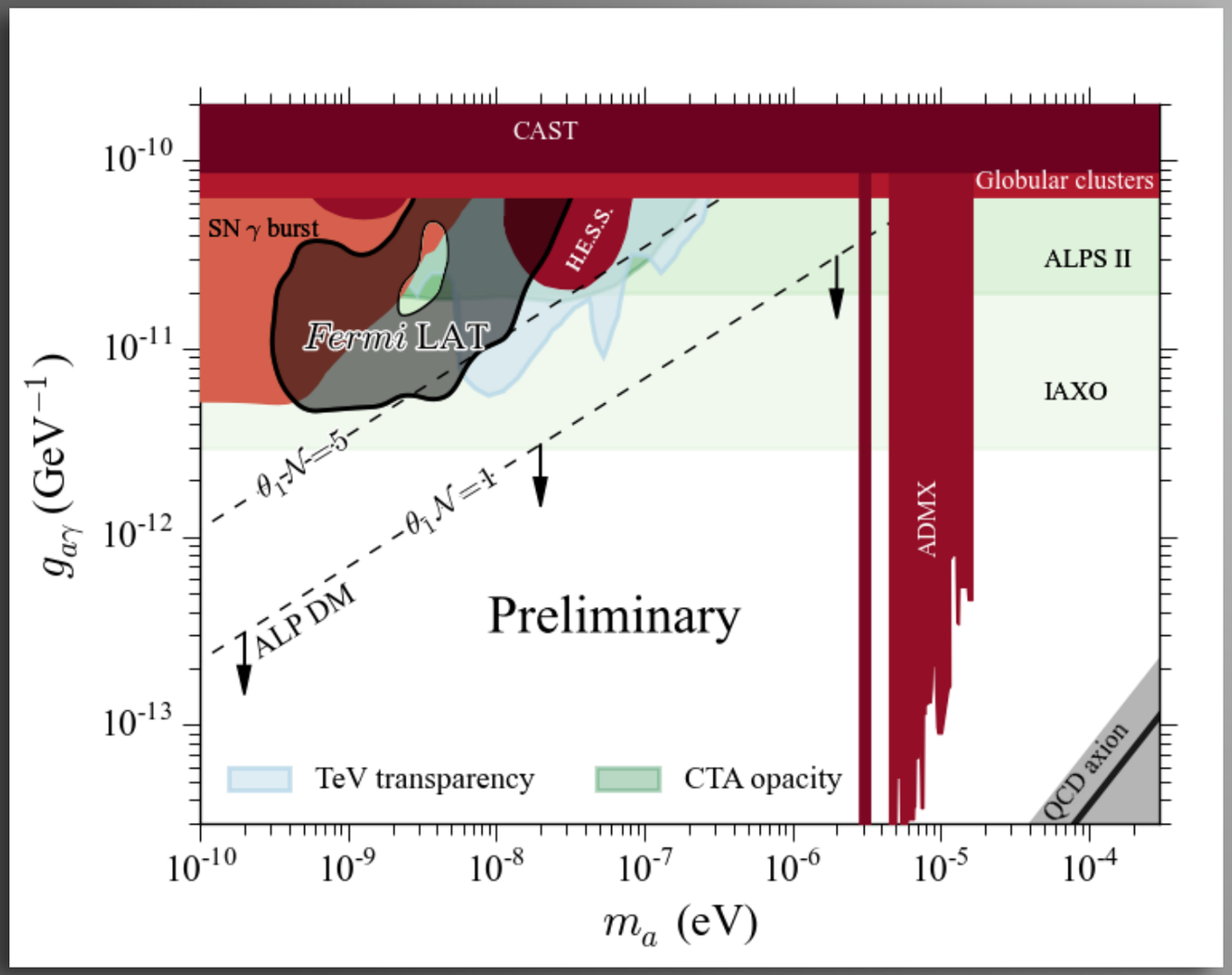
in practice



Axion-Like Particles

in practice

Meyer+ [LAT Clb] 2016PhRvL.116p1101A...813..109D



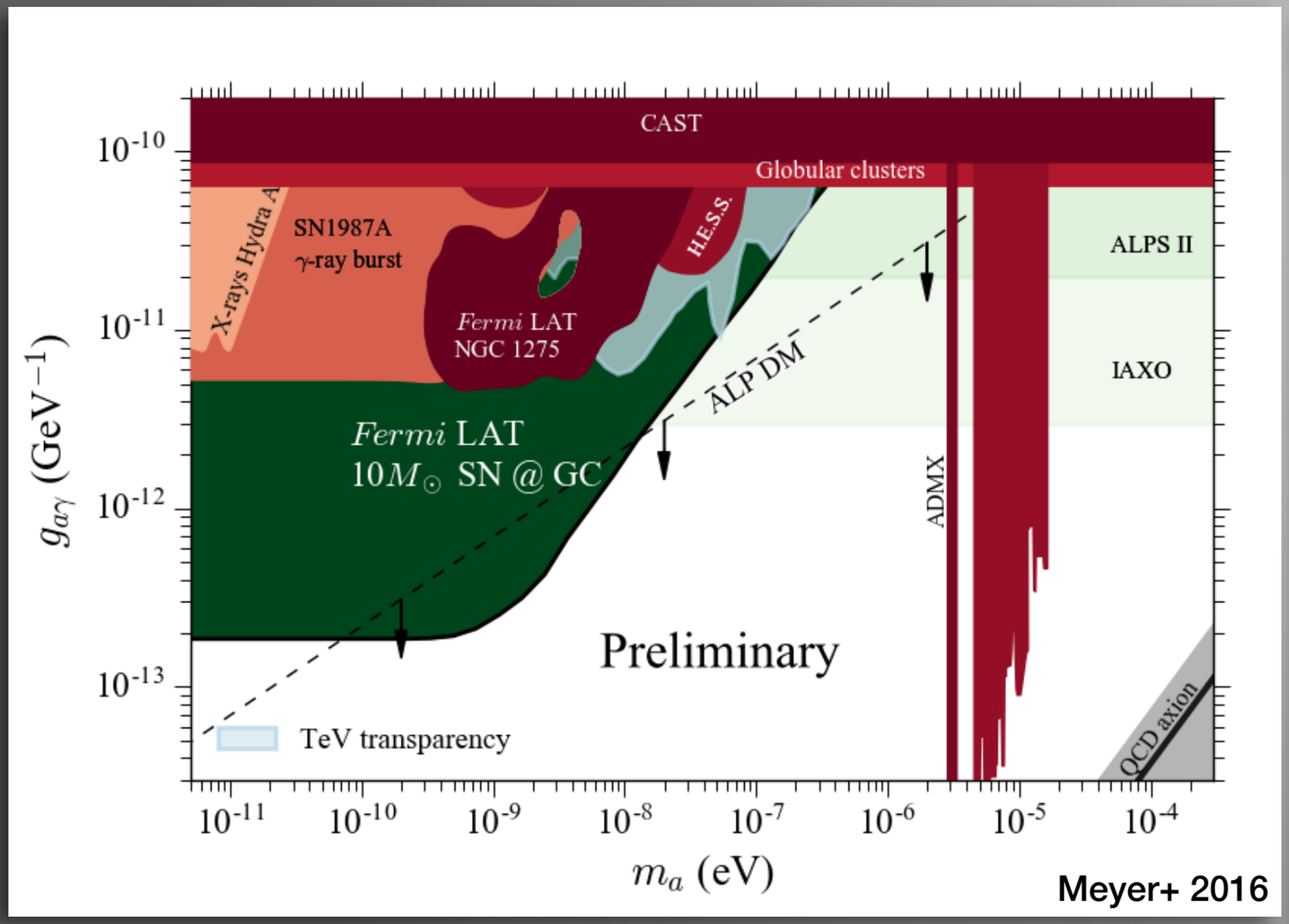
Hubble image of NGC 1275

analysis of NGC 1275

- no significant spectral irregularities
- strongly pressures models which fit EBL attenuation in IACT data

Axion-Like Particles

in practice



Meyer+ 2016


NASA/ESA

in case of a Milky Way supernova

- ALP conversion would allow photons to escape much earlier, becoming gamma rays again in the galactic magnetic field
- if it happens in the LAT lifetime, we can actually constrain ALP DM

summary

- the LAT has been an invaluable resource for indirect DM searches
- the field is driven by analyses of dSphs and the GC
- the potential of new targets (dSphs) and events (galactic supernovae) will keep things exciting