



Fermi
Gamma-ray Space Telescope

Searches for Dark Matter with the Fermi Large Area Telescope

R. Caputo, UCSC
on behalf of the
Fermi-LAT collaboration

EPS-HEP 2015
22-29 July, 2015



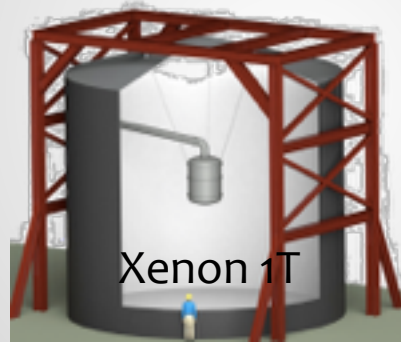


Dark Matter Searches



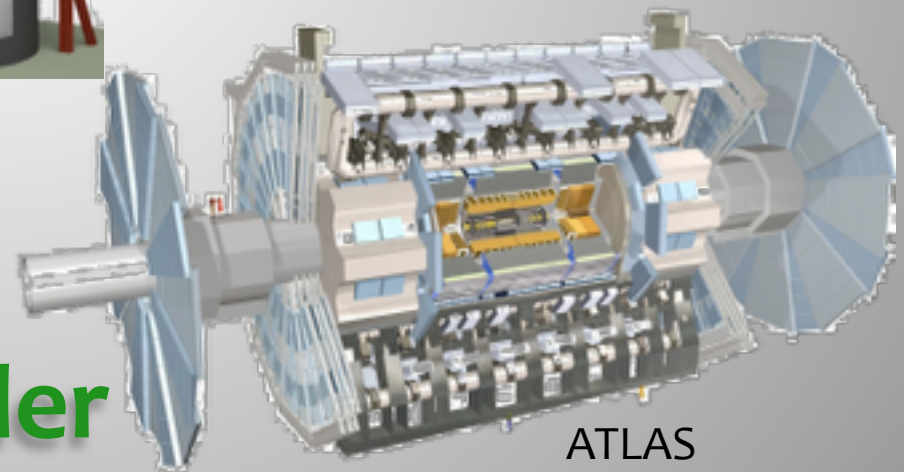
Fermi

Indirect Detection



Xenon 1T

Direct Detection



Collider

ATLAS



Fermi Gamma-Ray Space Telescope



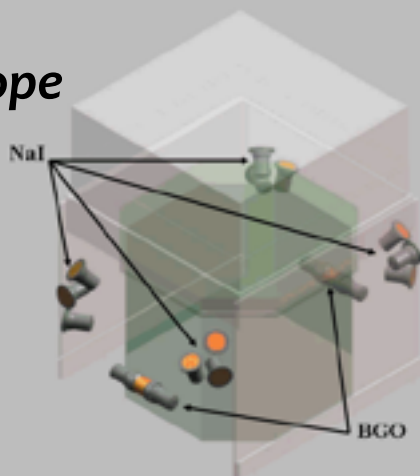
June 11, 2008

400 billion LAT triggered events
80 billion processed events



Large Area Telescope

20% sky at once
full sky 3 hours
20 MeV - >300 GeV

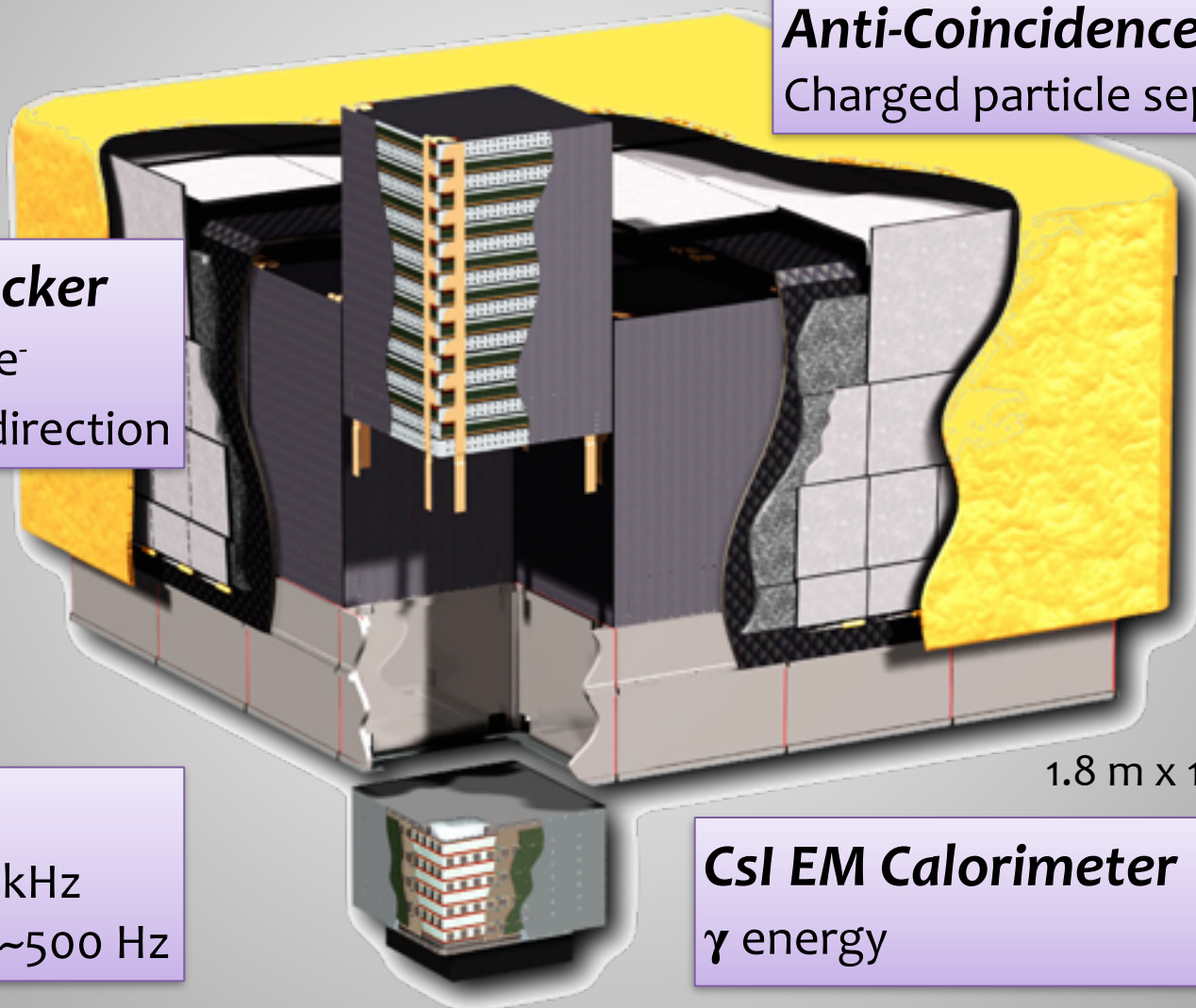


Gamma-ray Burst Monitor

full sky continuous
8 keV - 40 MeV



Fermi Large Area Telescope



Si-Strip Tracker

convert $\gamma \rightarrow e^+e^-$
reconstruct direction

Anti-Coincidence Detector

Charged particle separation

Trigger

rate: ~ 2.5 kHz
read out: ~ 500 Hz

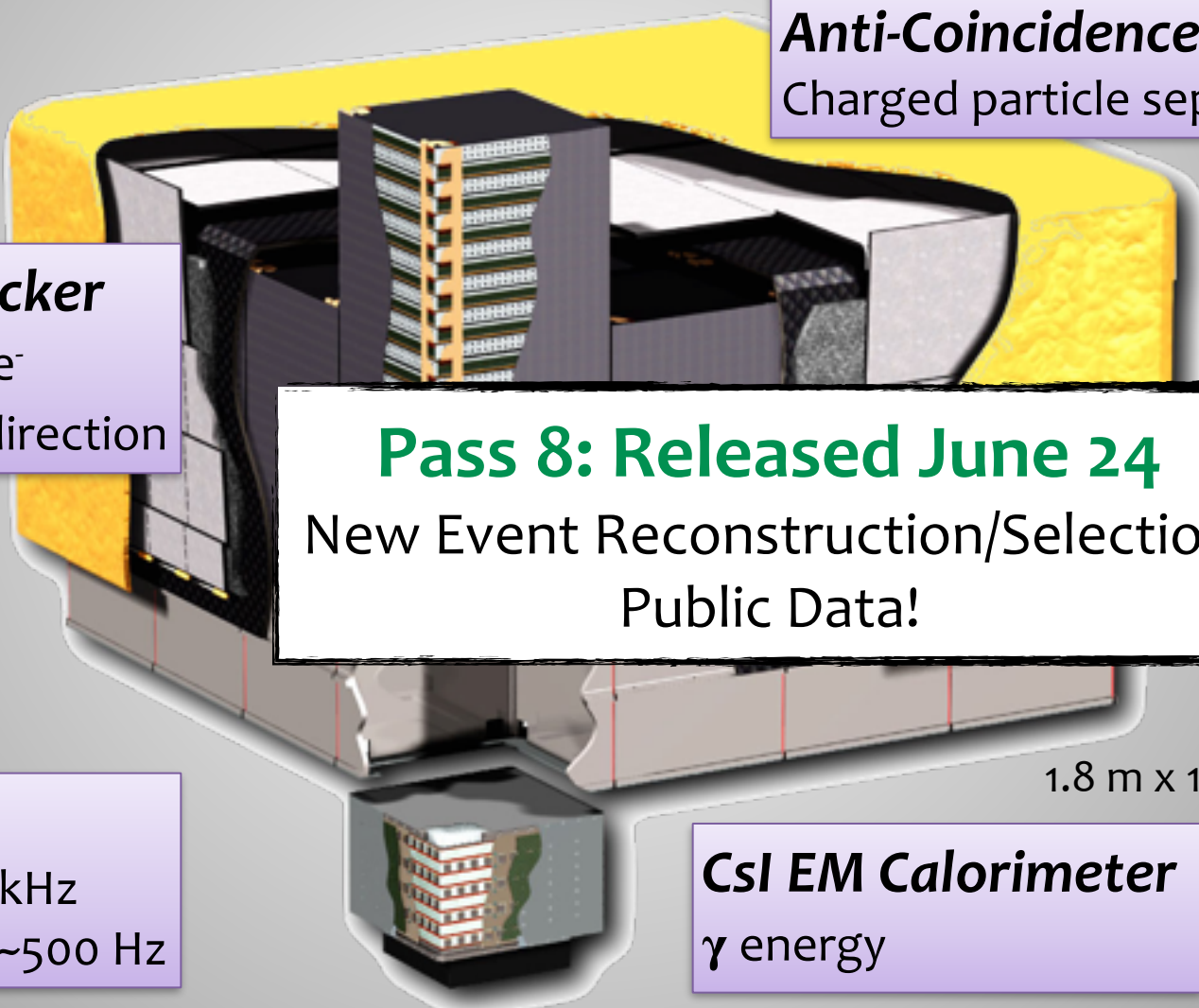
1.8 m x 1.8 m x 0.7 m

CsI EM Calorimeter

γ energy



Fermi Large Area Telescope



Anti-Coincidence Detector
Charged particle separation

Si-Strip Tracker
convert $\gamma \rightarrow e^+e^-$
reconstruct direction

Pass 8: Released June 24
New Event Reconstruction/Selection
Public Data!

Trigger
rate: ~ 2.5 kHz
read out: ~ 500 Hz

CsI EM Calorimeter
 γ energy

1.8 m x 1.8 m x 0.7 m



Fermi-LAT γ -ray sky

Galactic Plane

Diffuse

π^0 decay
Bremsstrahlung
Inverse Compton

Point Sources

3FGL: Accepted ApJS

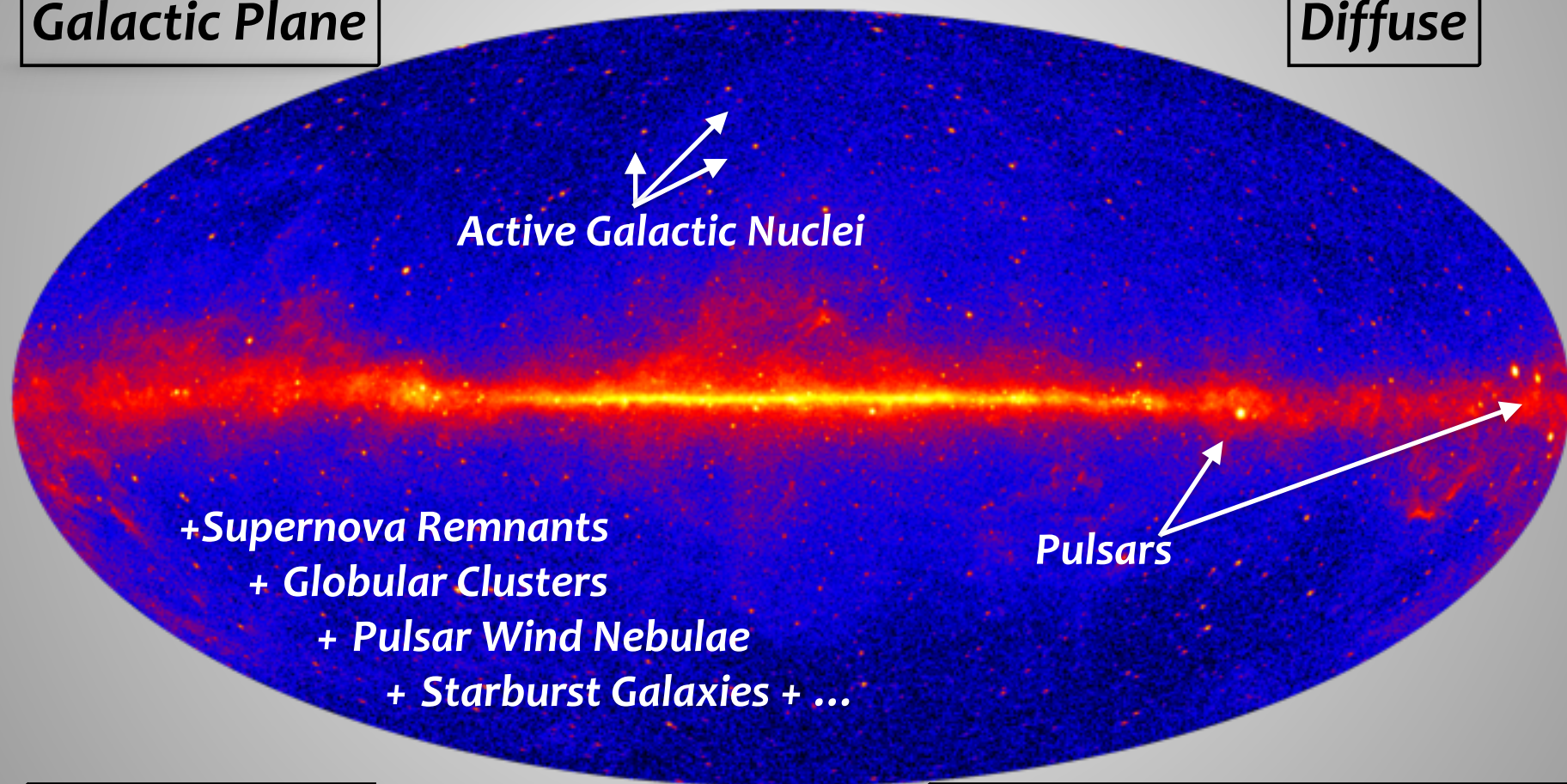
Dark Matter, Exotic Physics



Fermi-LAT γ -ray sky

Galactic Plane

Diffuse



Point Sources

3FGL: Accepted ApJS

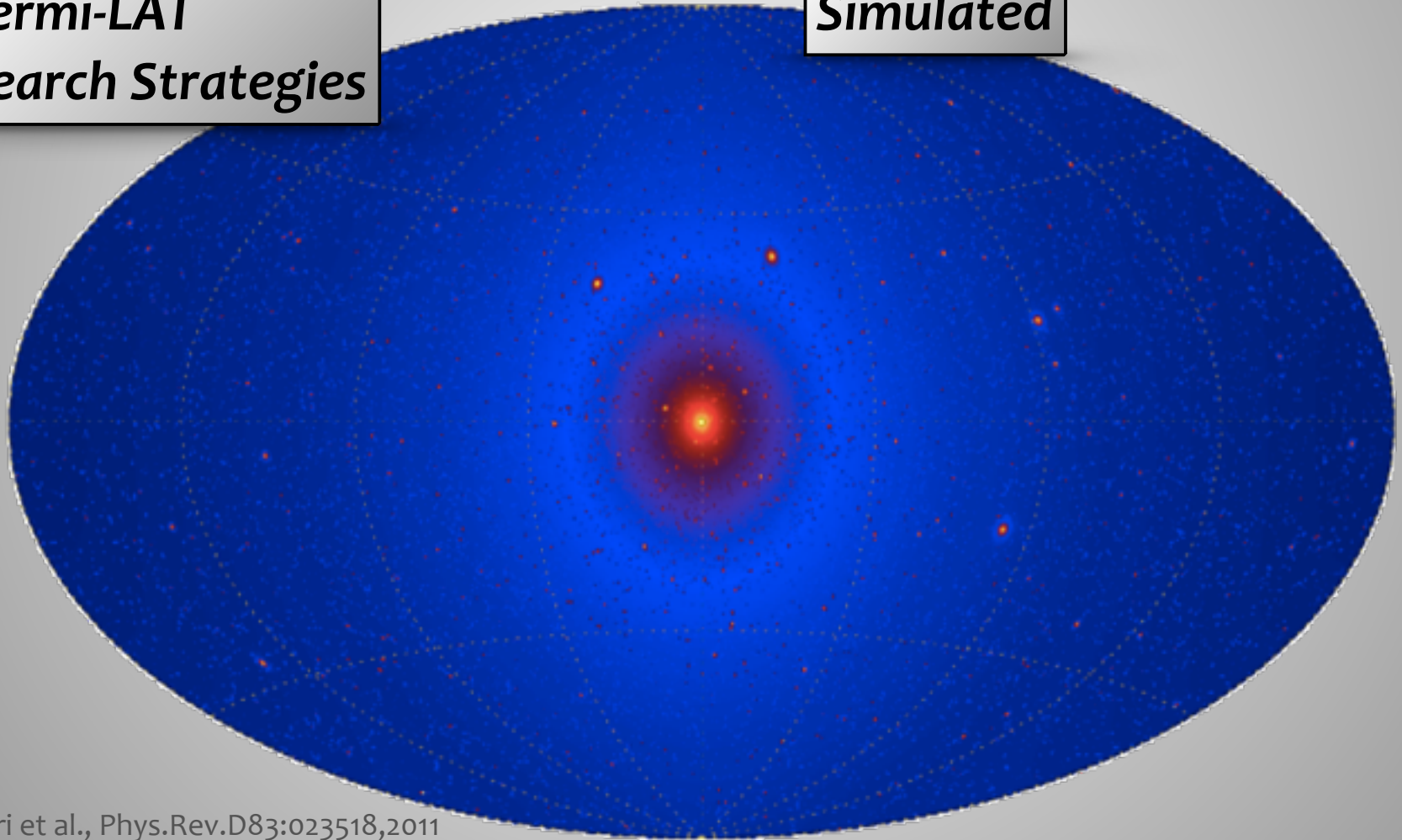
Dark Matter, Exotic Physics



Dark Matter Distribution

**Fermi-LAT
Search Strategies**

Simulated



L. Pieri et al., Phys.Rev.D83:023518,2011

R. Caputo , UCSC | EPS-HEP 2015



Dark Matter Distribution

**Fermi-LAT
Search Strategies**

**Dwarf Spheroidal
Satellite Galaxies**

Simulated

Galaxy Clusters

Milky Way Halo

Galactic Center

Spectral Lines

Isotropic Background



Dark Matter Distribution

**Fermi-LAT
Search Strategies**

**Dwarf Spheroidal
Satellite Galaxies**

arXiv: 1503.02320
arXiv: 1503.06209

Galaxy Clusters

arXiv: 1002.2239

**Dwarf Spheroidal
Satellite Galaxies**

arXiv: 1310.0828
arXiv: 1503.02641
arXiv: 1503.02632

**From the Fermi-LAT
Collaboration**

**External Analyses
on DES candidates**

DES candidates

Milky Way Halo

arXiv: 1205.6474

Galactic Center

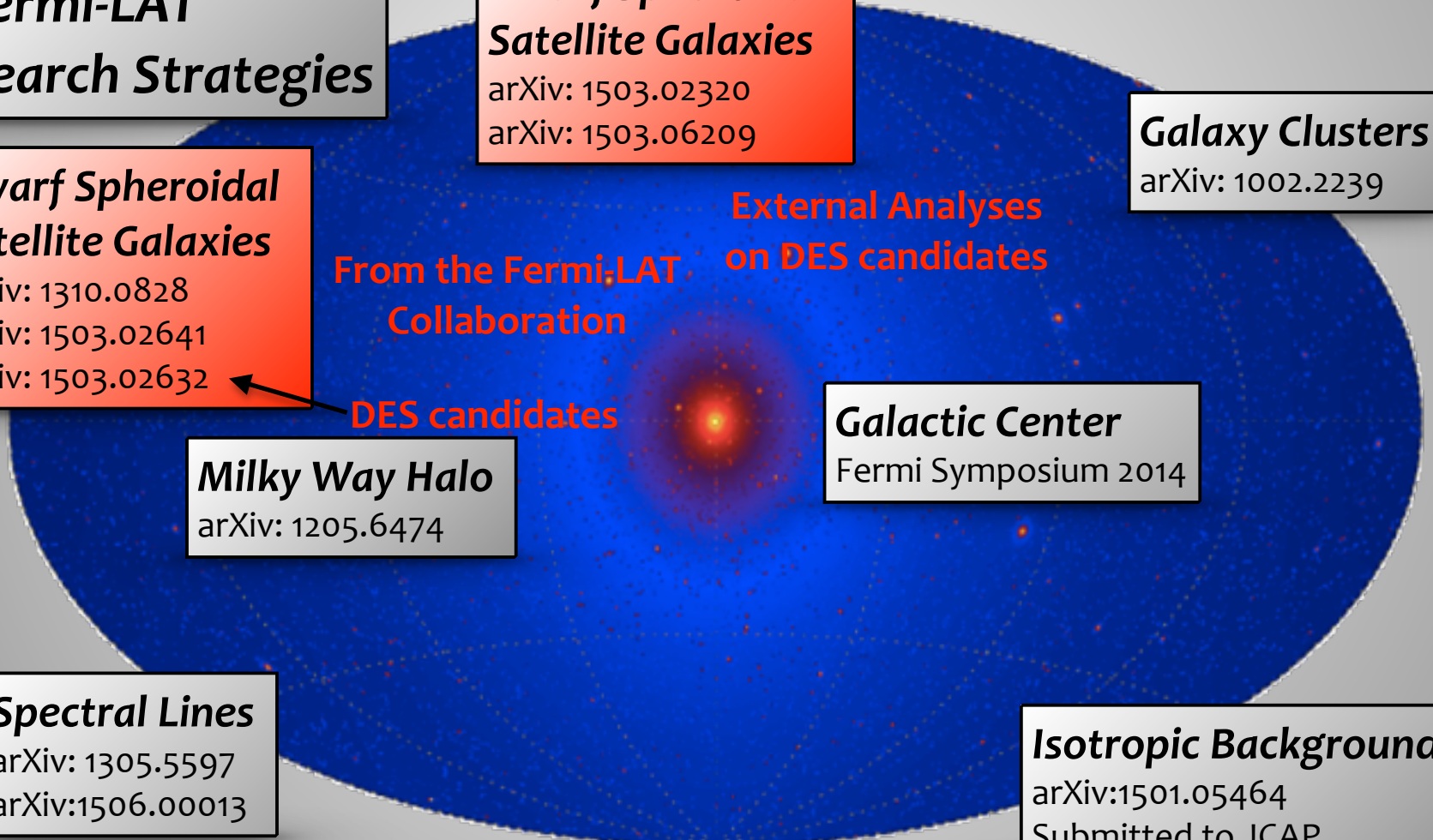
Fermi Symposium 2014

Spectral Lines

arXiv: 1305.5597
arXiv: 1506.00013

Isotropic Background

arXiv: 1501.05464
Submitted to JCAP





What is a Dwarf Spheroidal Galaxy?

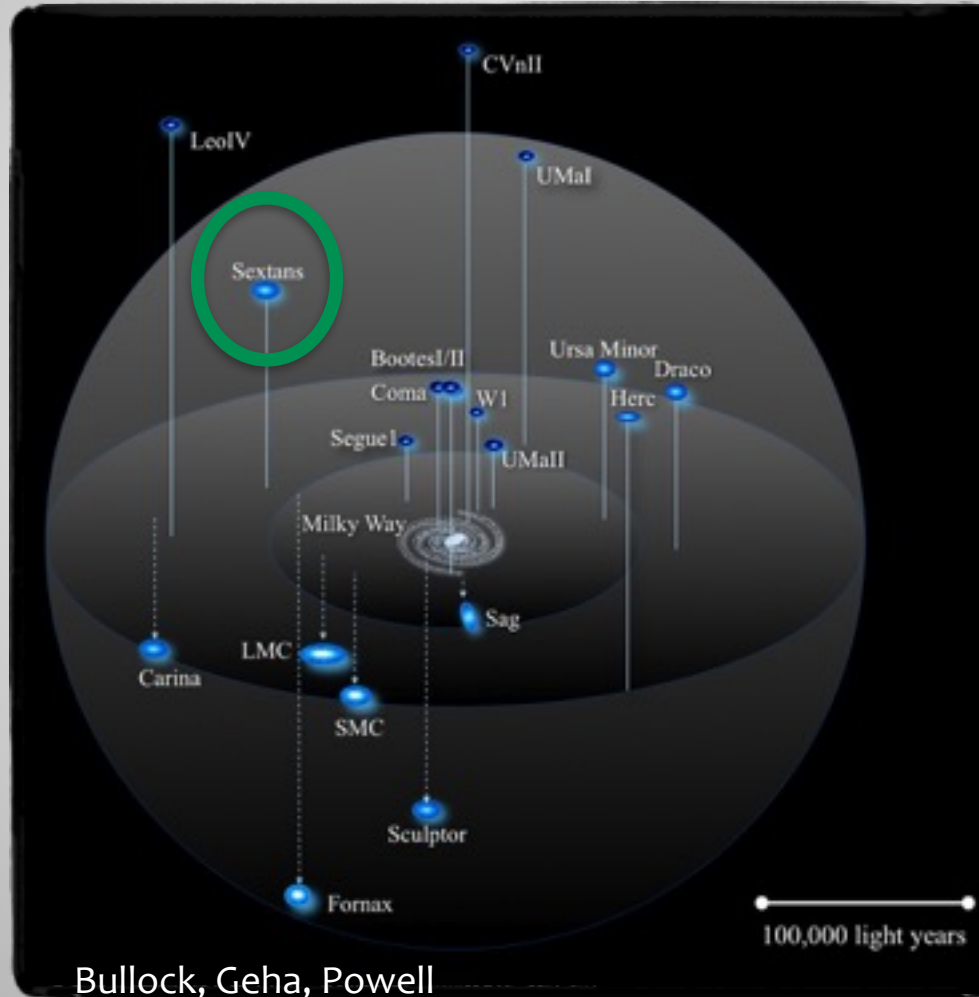
The Milky Way has many companion galaxies!

Little gas/dust/
star formation

old: >13b years

Low Luminosity

Found around
Milky Way
and Andromeda

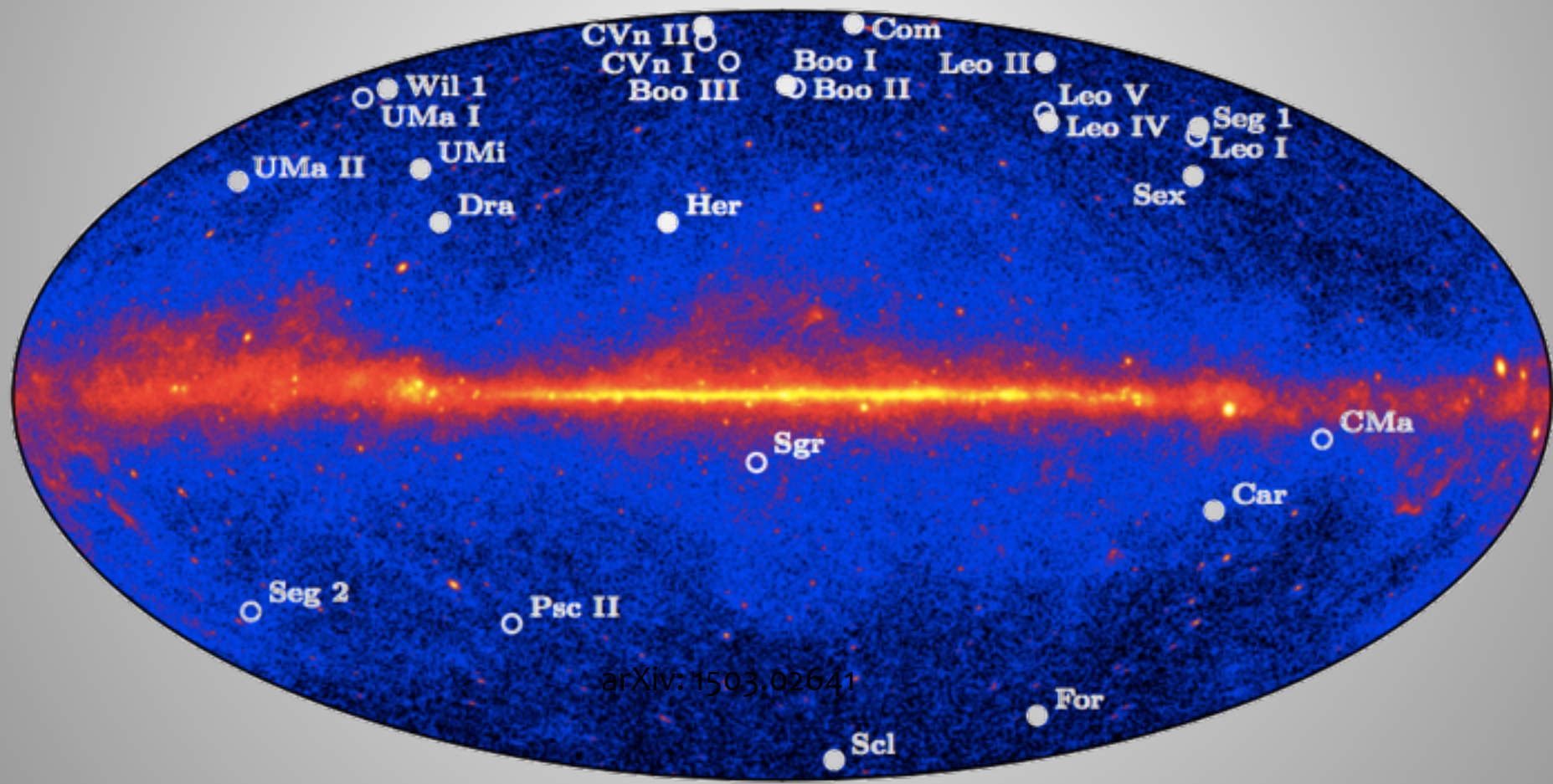


25 known dSphs

9 classical dSphs
(pre-SDSS)



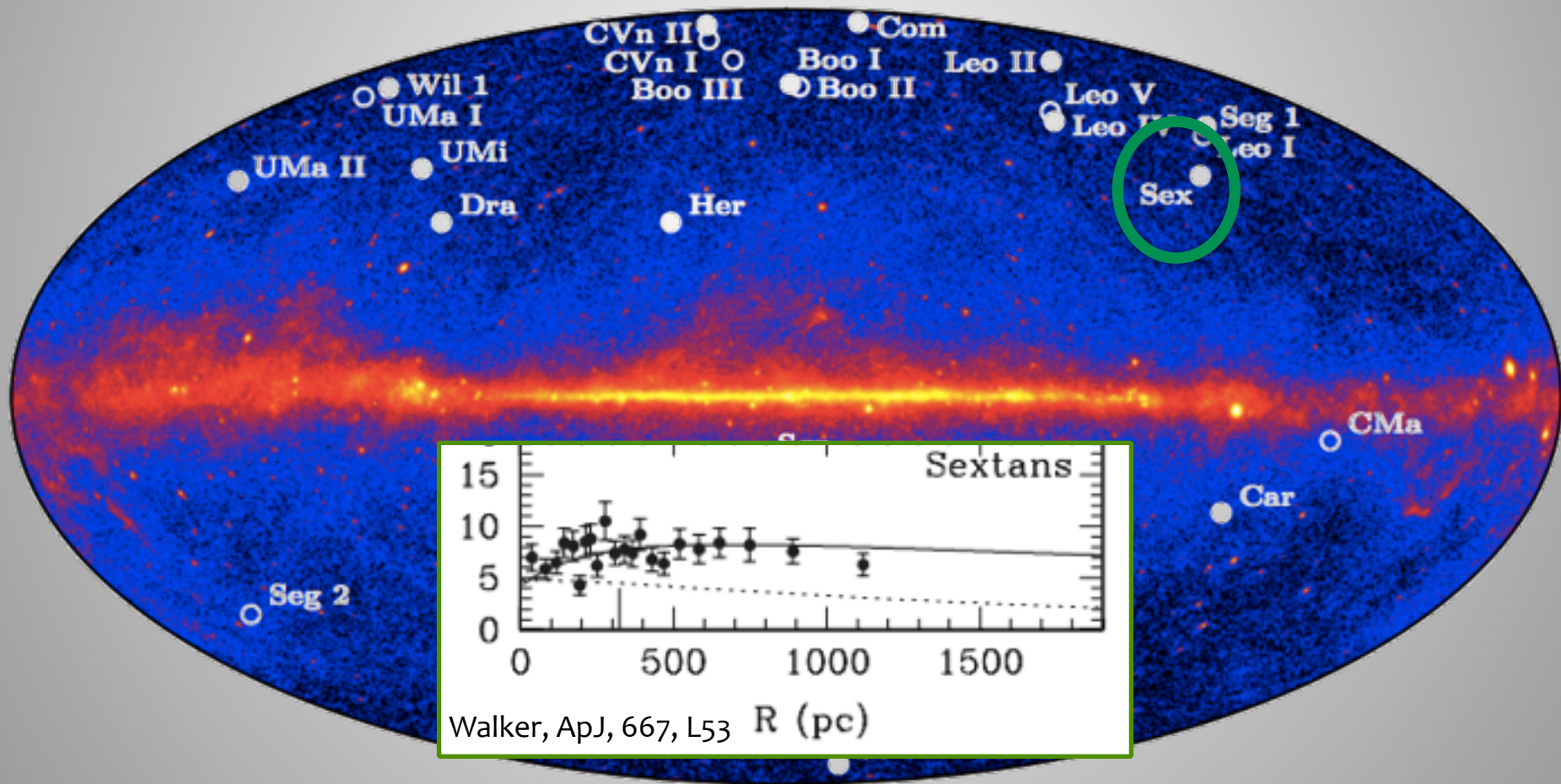
Confirmed Dwarf Spheroidal Satellite Galaxies



arXiv:1503.02641

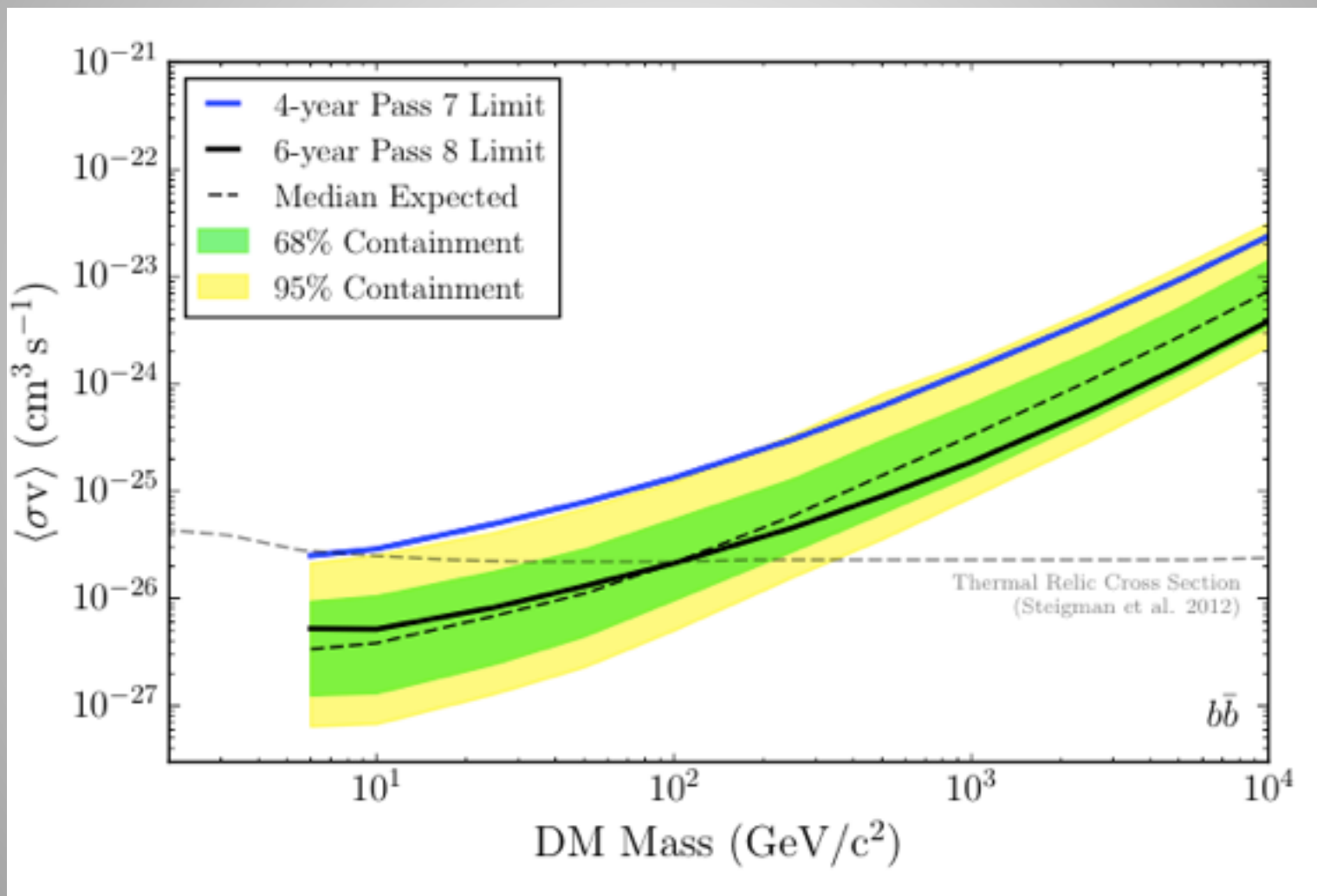


Confirmed Dwarf Spheroidal Satellite Galaxies



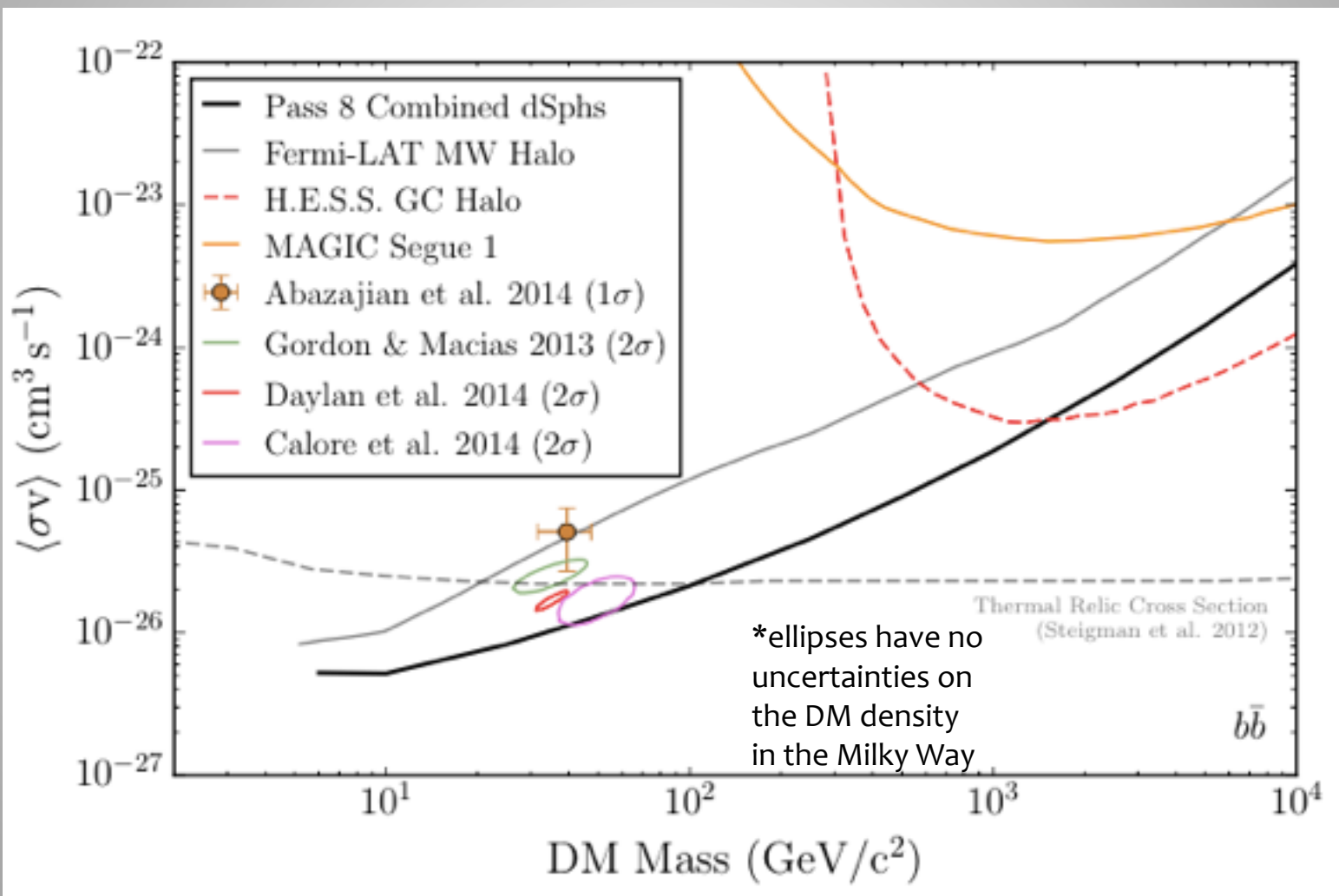


Dwarf Spheroidal Satellite Galaxies: Combined



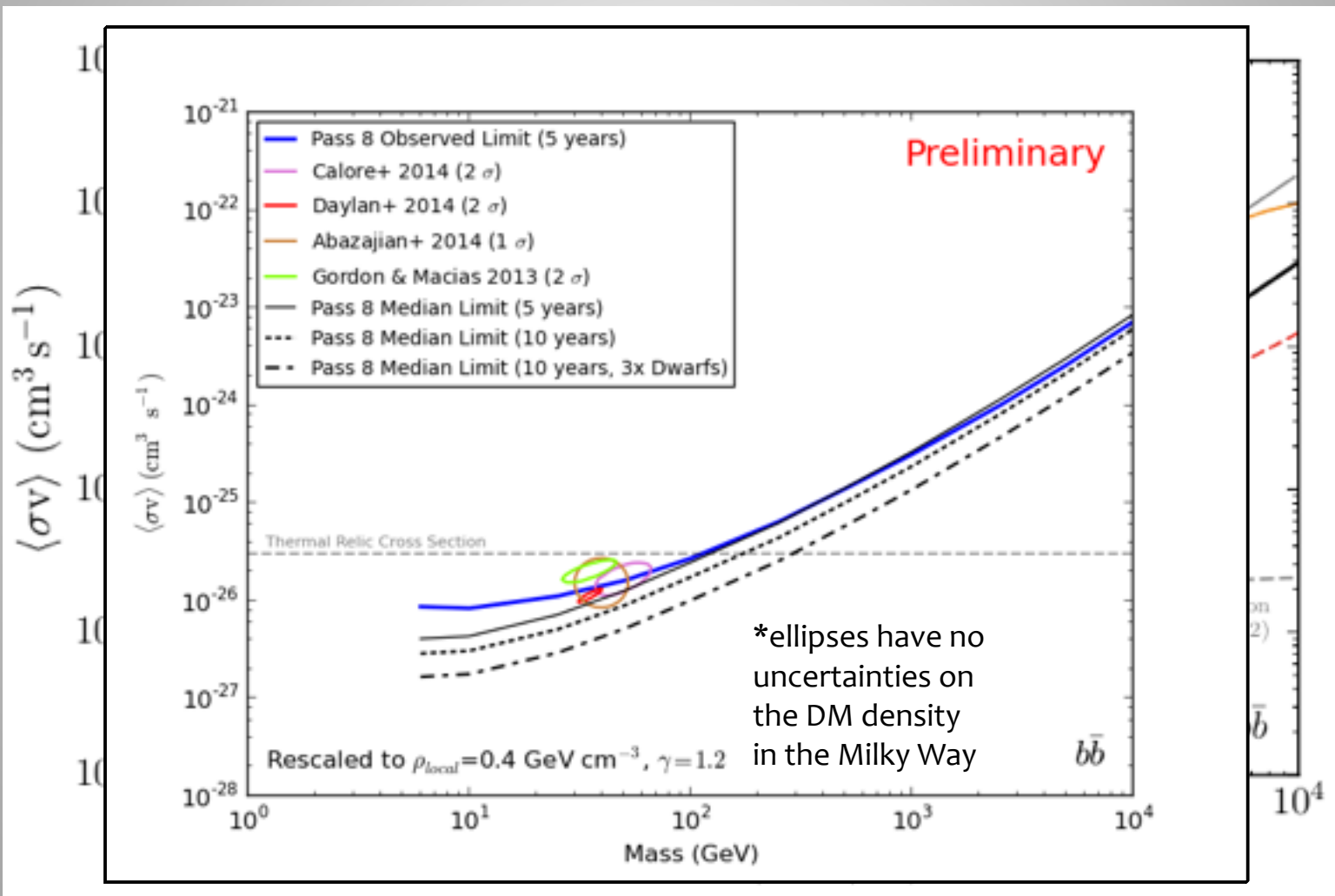


Dwarf Spheroidal Satellite Galaxies: Combined



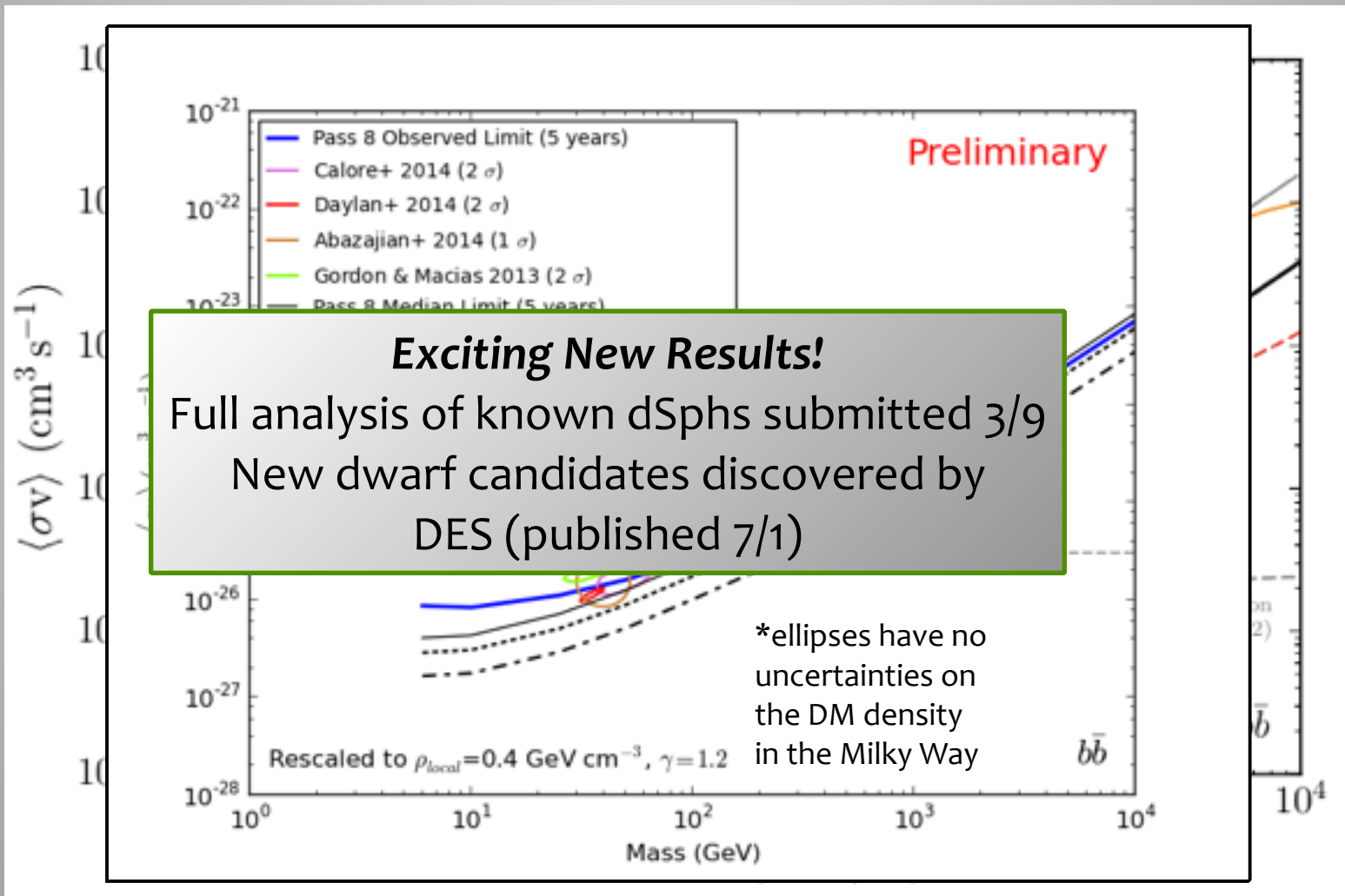


Dwarf Spheroidal Satellite Galaxies: Combined





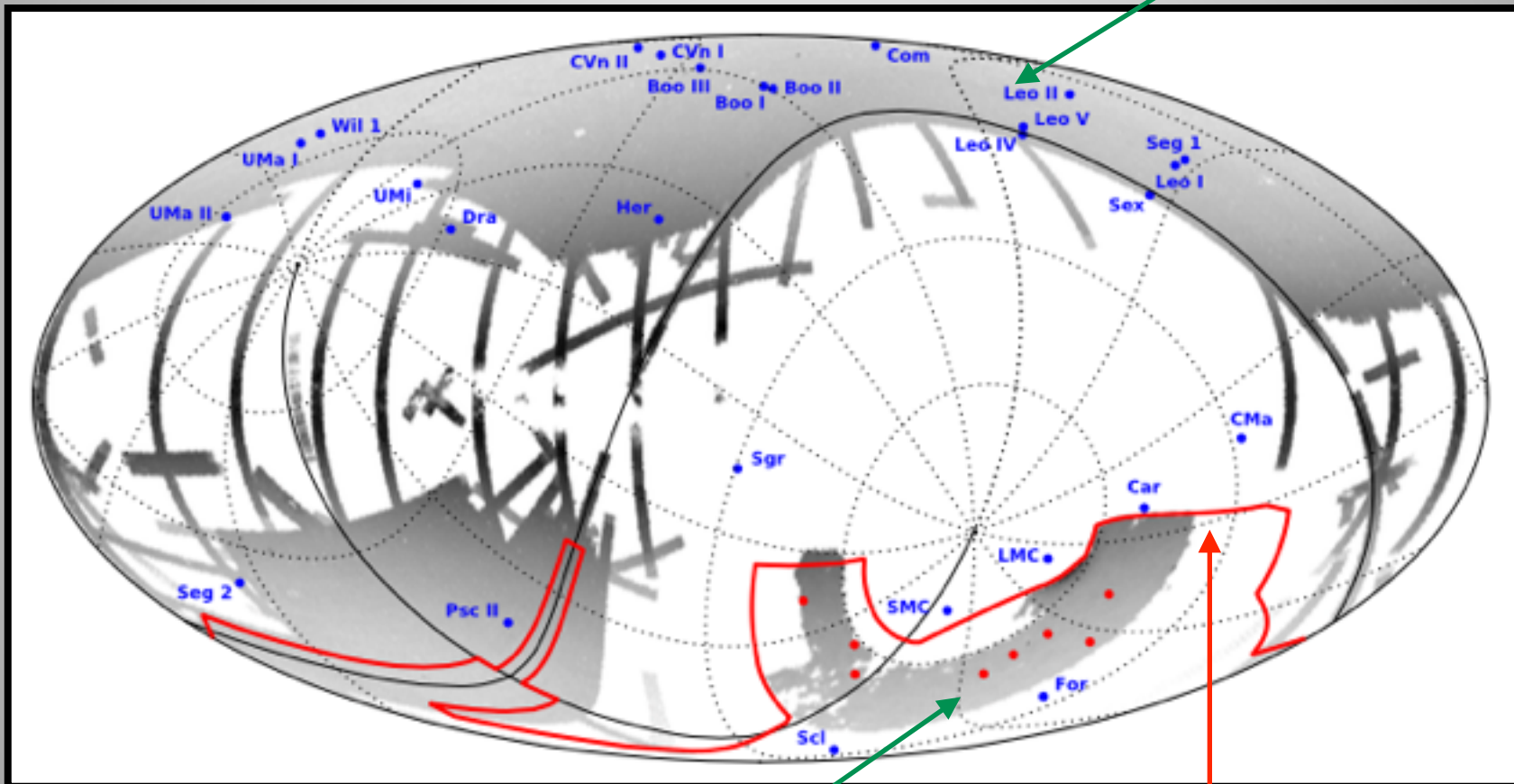
Dwarf Spheroidal Satellite Galaxies: Combined





DES Dwarf Candidates

SDSS sky coverage $\sim 14\text{k deg}^2$



DES Year 1 Annual Release: new $\sim 1.5\text{k deg}^2$

Total DES Survey: 5k deg^2

Koposov et al: ApJ, 805:130 (2015), arXiv: 1503.02079

DES Collaboration: ApJ, 807:50 (2015), arXiv: 1503.02584 12



DES Dwarf Candidates

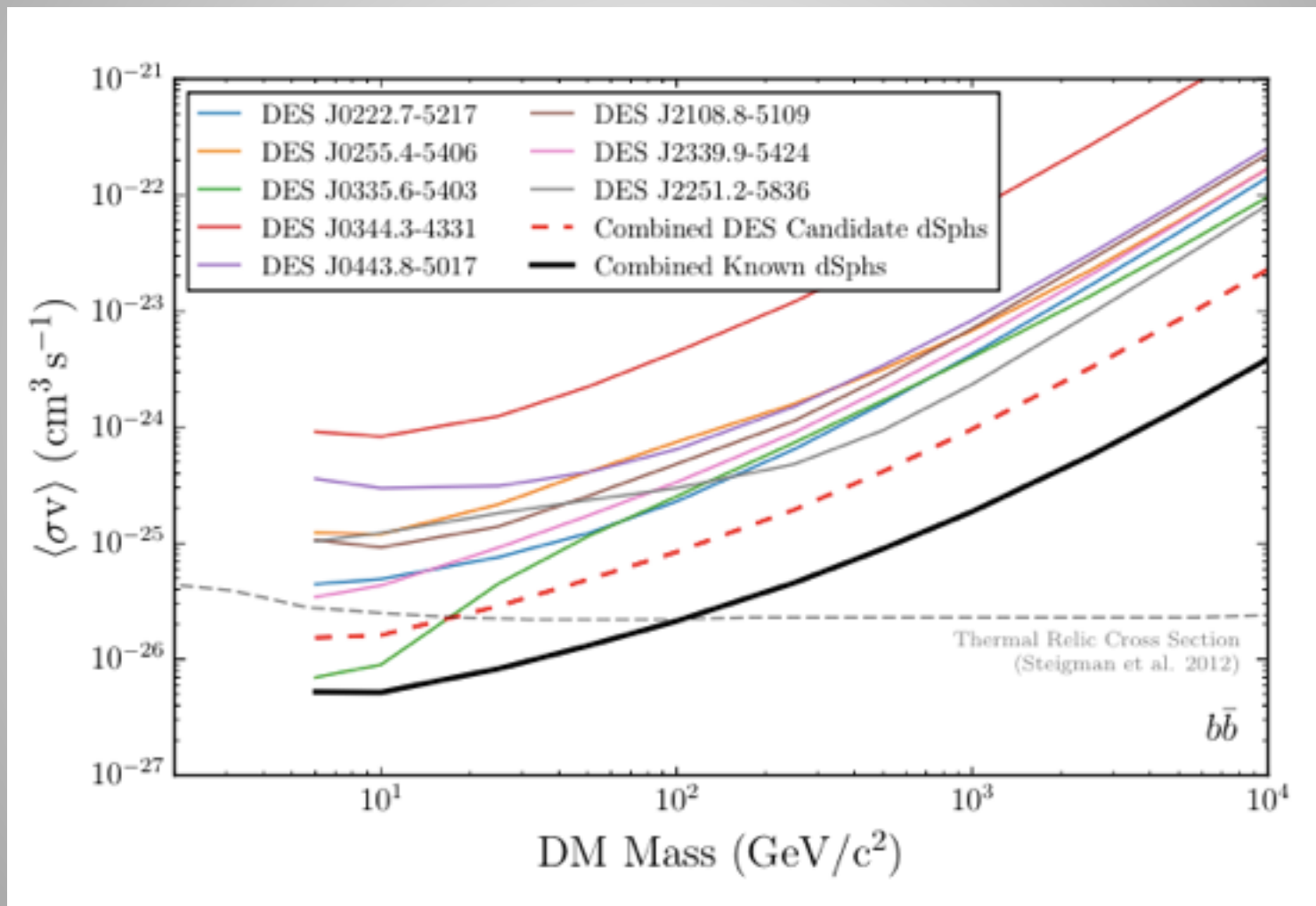
<i>Name</i>	<i>(lon, lat)</i> <i>[deg]</i>	<i>distance</i> <i>[kpc]</i>	<i>log₁₀(Est. J)</i> <i>log₁₀[GeV²/cm⁵]</i>
<i>DES J0222.7-51217</i>	<i>(275.0,-59.6)</i>	<i>95</i>	<i>18.3</i>
<i>DES J0255.4-5406</i>	<i>(271.4,-54.7)</i>	<i>87</i>	<i>18.4</i>
<i>DES J0335.6-5403</i>	<i>(266.3,-49.7)</i>	<i>32</i>	<i>19.3</i>
<i>DES J0344.3-4331</i>	<i>(249.8,-51.6)</i>	<i>330</i>	<i>17.3</i>
<i>DES J0443.8-5017</i>	<i>(257.3,-40.6)</i>	<i>126</i>	<i>18.1</i>
<i>DES J2108.8-5109</i>	<i>(347.2,-52.4)</i>	<i>69</i>	<i>18.3</i>
<i>DES J2251.2-5836</i>	<i>(328.0,-52.4)</i>	<i>58</i>	<i>18.8</i>
<i>DES J2339.9-5424</i>	<i>(323.7,-59.7)</i>	<i>95</i>	<i>18.4</i>

Segue 1: 23 kpc
J-Factor 19.5

Galactic Center: 21.5
Best Dwarfs: 19.5

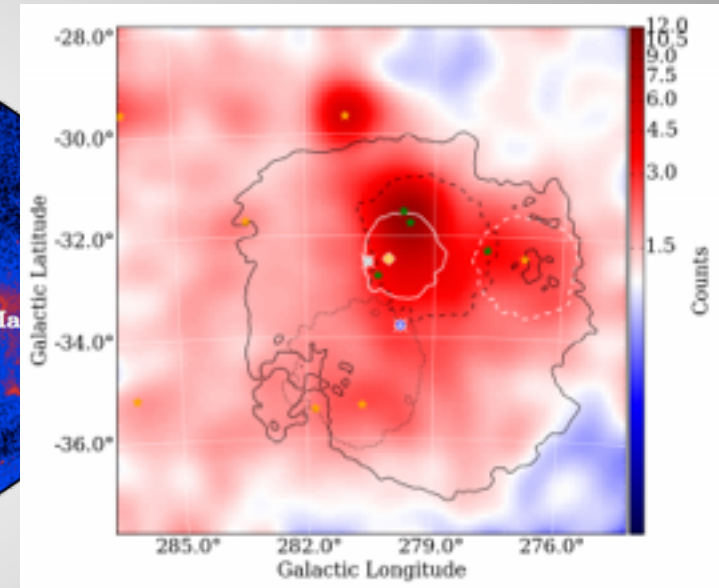
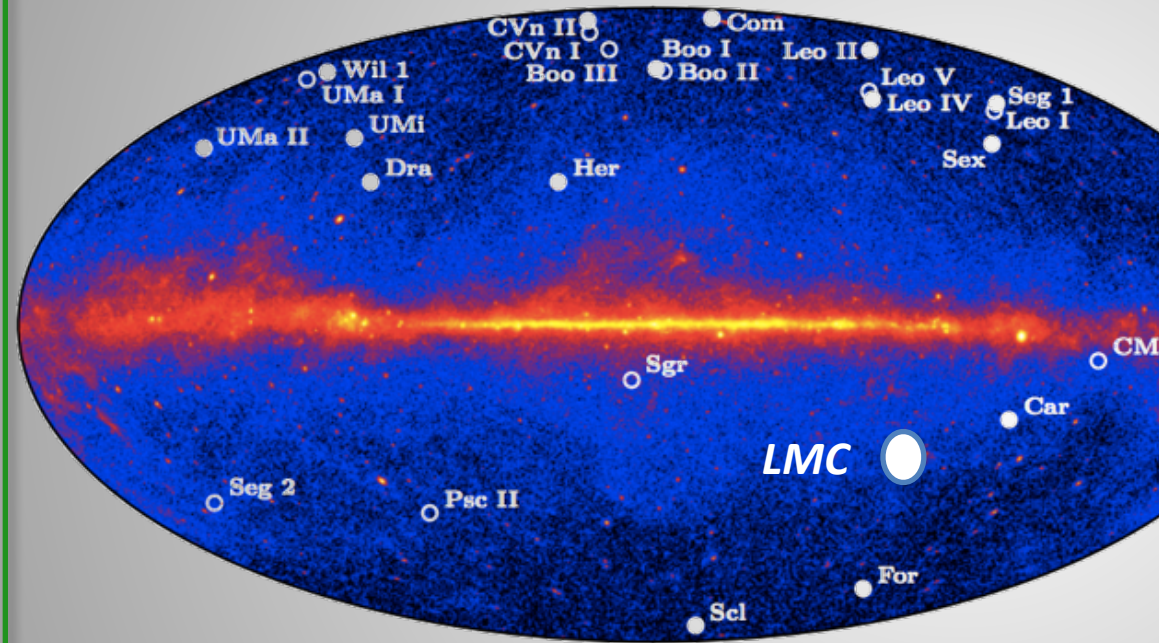


Fermi-LAT Results





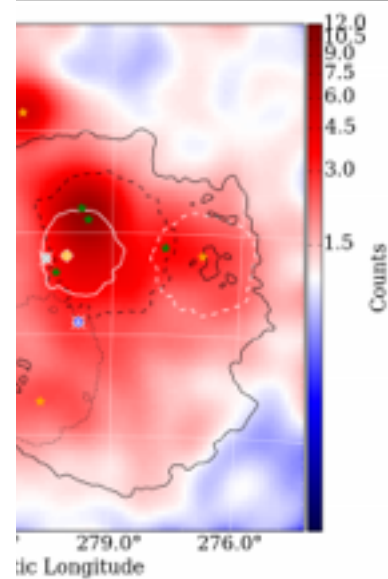
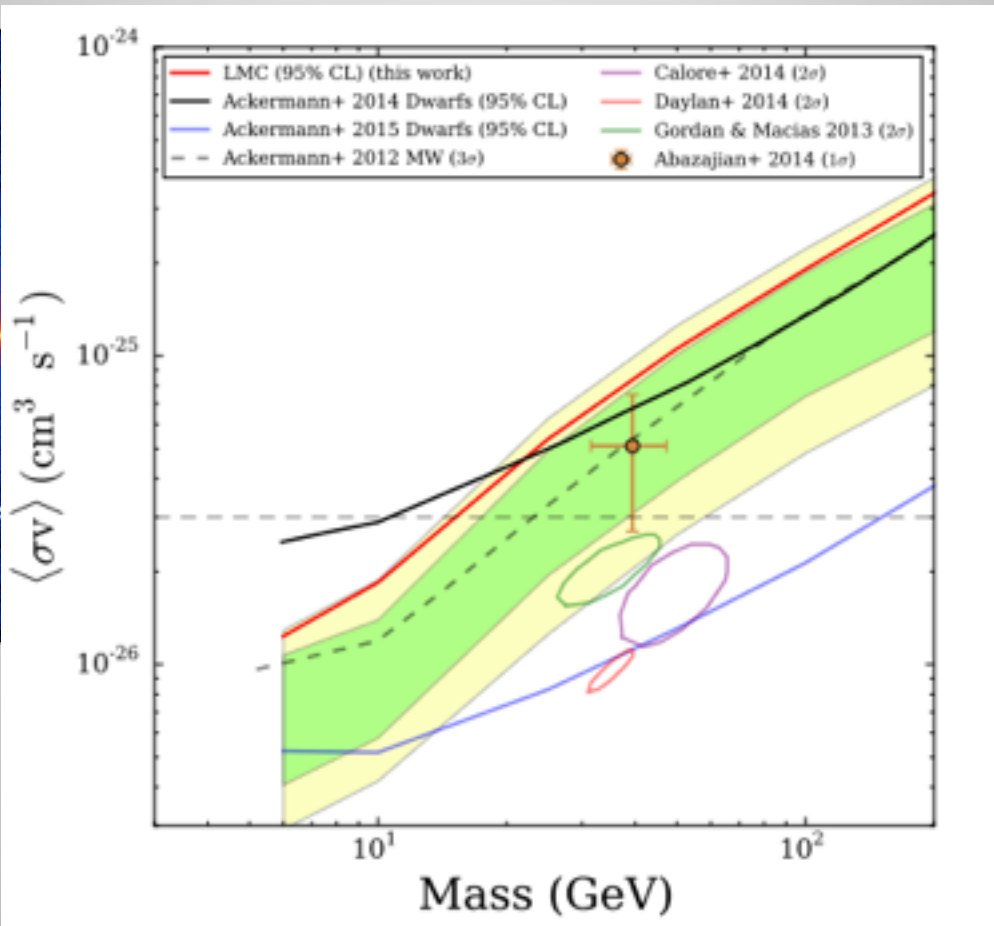
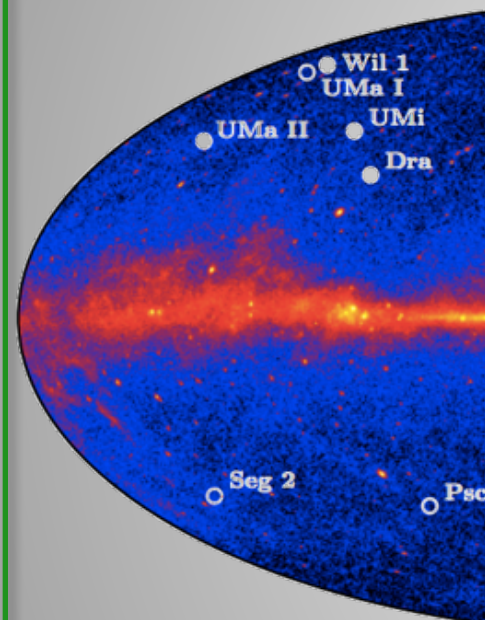
Large Magellanic Cloud



M. Buckley, et al.,
Phys. Rev. D, 91.102001, (2015)
arXiv: 1502.01020
R. Caputo, UCSC | EPS-HEP 2015



Large Magellanic Cloud



J-factor:
 $\log_{10} J \sim 20$
 Distance: 50 kpc

M. Buckley, et al.,
 Phys. Rev. D, 91.102001, (2015)
 arXiv: 1502.01020



Dark Matter Distribution

Search Strategies

Simulated

Galaxy Clusters

**Dwarf Spheroidal
Satellite Galaxies**

Galactic Center

Milky Way Halo

Spectral Lines

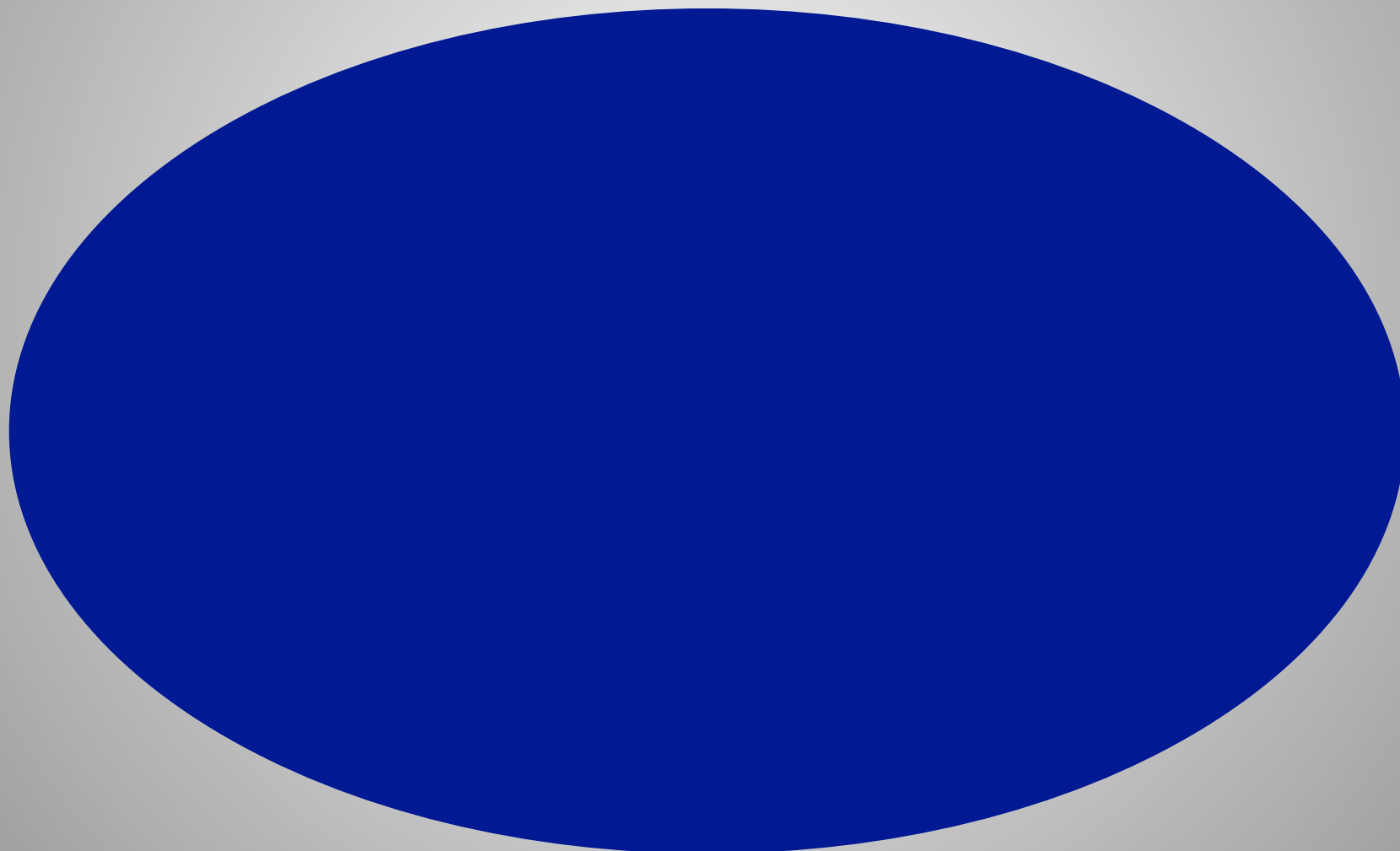
Isotropic Background

arXiv:1501.05464

Submitted to JCAP



Isotropic γ -ray Background





Isotropic γ -ray Background

Extragalactic γ -ray Background =
Isotropic Diffuse γ -ray Background + resolved sources

- + **Blazars**
- + **Gamma Ray Bursts (GRBs)**
- + **Radio Galaxies**
- + **Star Forming Galaxies**
- + **Galaxy Clusters (ul)**
- + **Cascades (ul) + ...**



Isotropic γ -ray Background

Extragalactic γ -ray Background =
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+ **Blazars**

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+ **Galaxy Clusters (ul)**

+ **Cascades (ul) + ...**

**Dark Matter
Annihilation/Decay**



Isotropic γ -ray Background

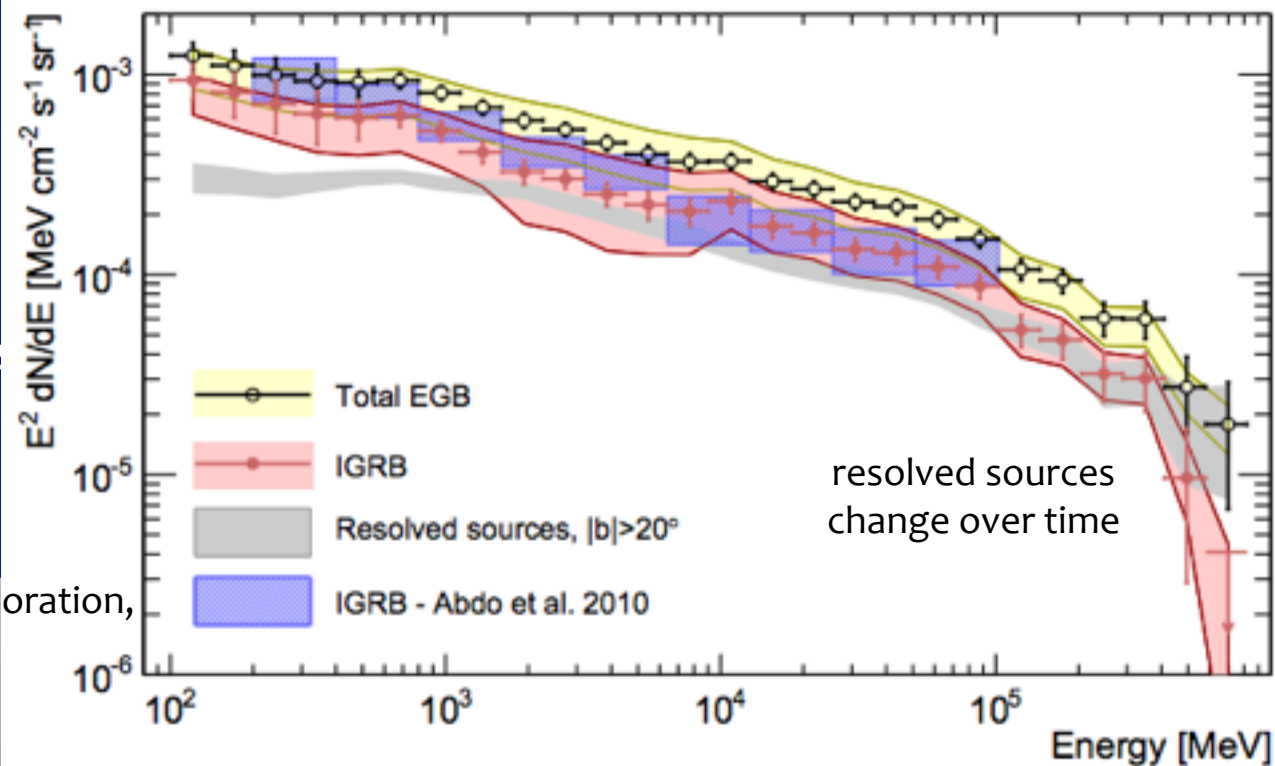
Extragalactic γ -ray Background =
Isotropic Diffuse γ -ray Background + resolved sources





Isotropic γ -ray Background

Extragalactic γ -ray Background =
Isotropic Diffuse γ -ray Background + resolved sources



+Blaz
+

atter
decay

Fermi-LAT Collaboration,
Accepted ApJ
arXiv: 1410.3696



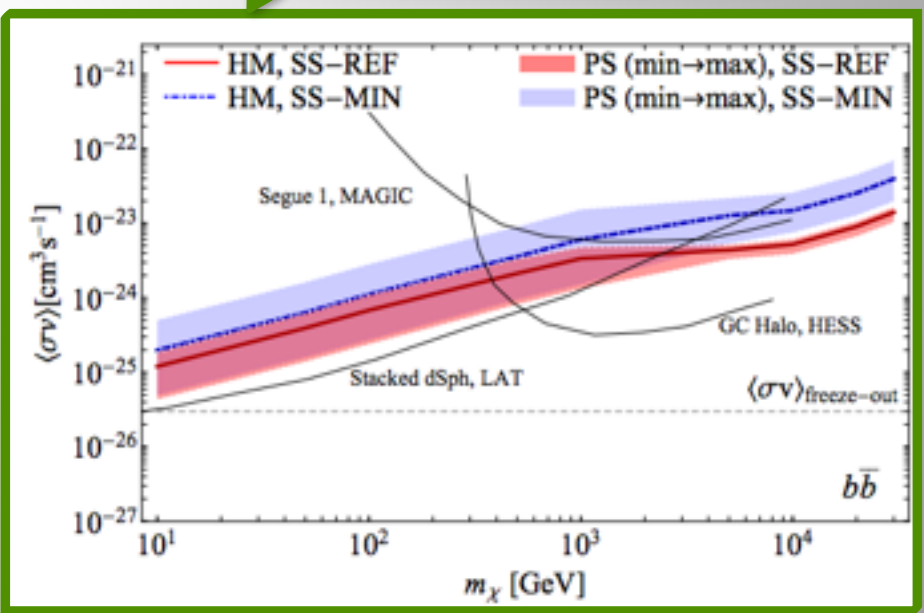
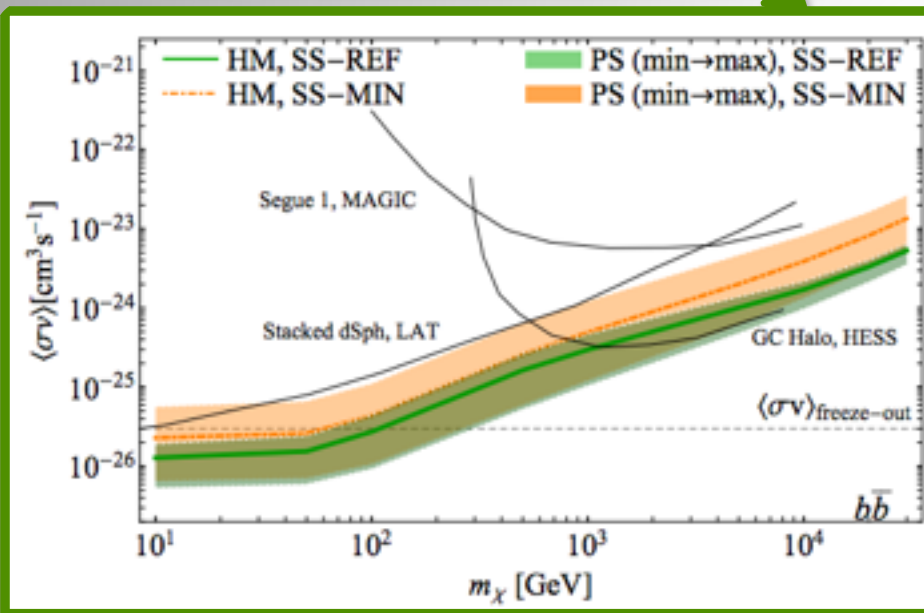
Isotropic γ -ray Background

Two Models:

Halo Model (HM)
Power Spectrum (PS)

Two Scenarios:

Boost: 3x (SS-MIN)
Boost: 15x (SS-REF)





Summary

Dark matter annihilations/decay can produce gamma rays detectible by Fermi-LAT

Indirect detection searches are a crucial component to understanding the dark matter puzzle.

Fermi-LAT is the first instrument to reach thermal relic annihilation cross sections

No definitive signal yet... stay tuned.



Thank you!

BACKUPS