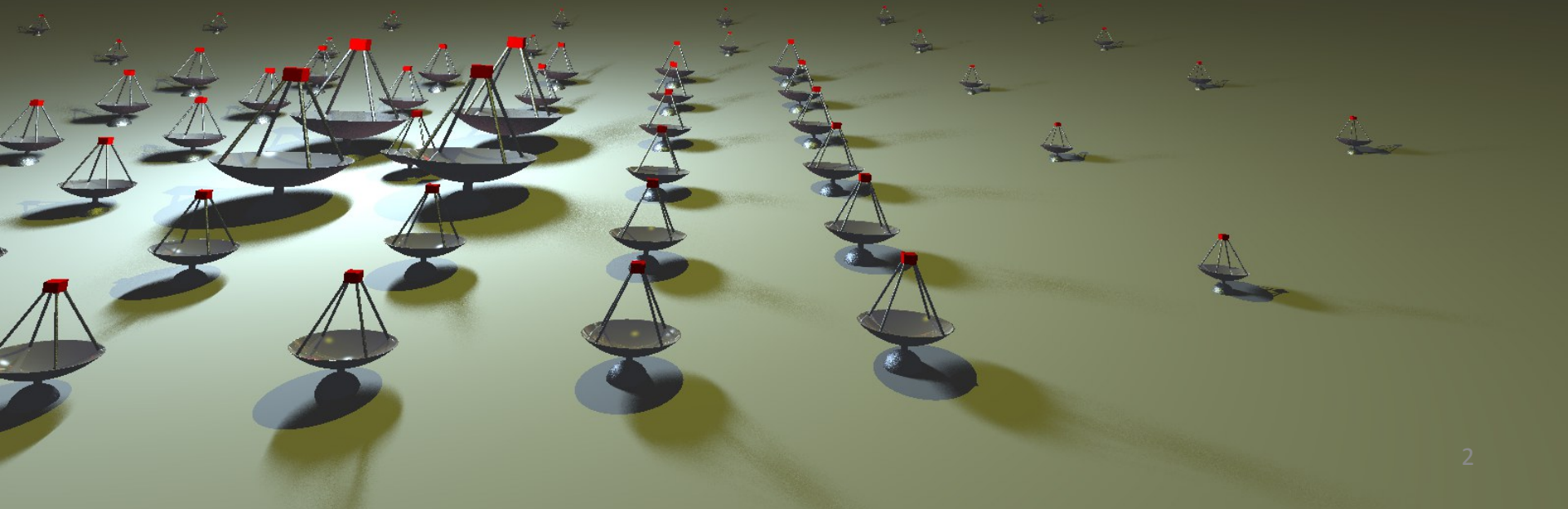
SEARCH FOR GAMMA-RAY SIGNALS FROM DWARF SPHEROIDAL GALAXIES WITH THE CHERENKOV TELESCOPE ARRAY

GONZALO RODRIGUEZ, INFN, Roma, Italy

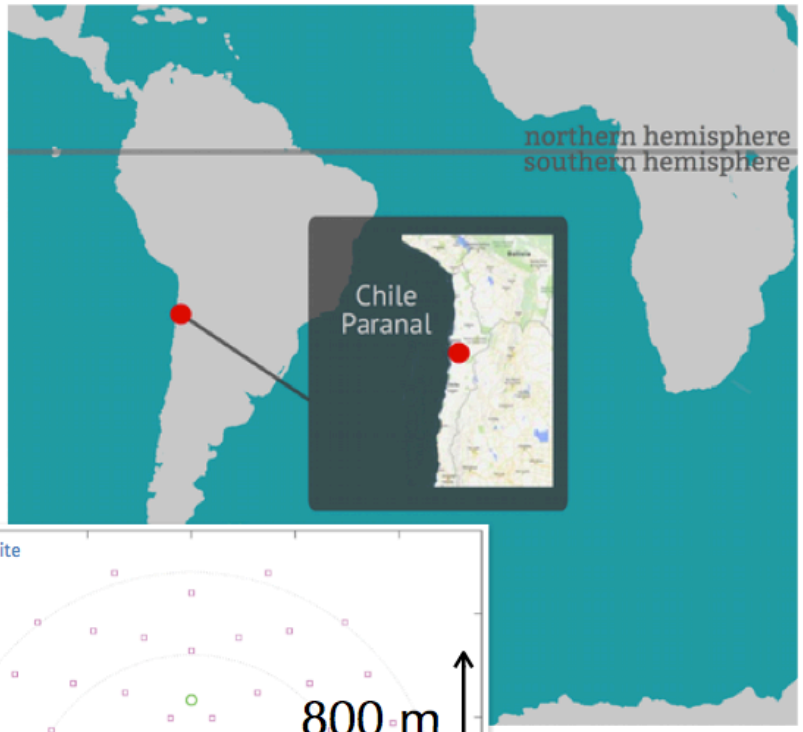
for the CTA Consortium

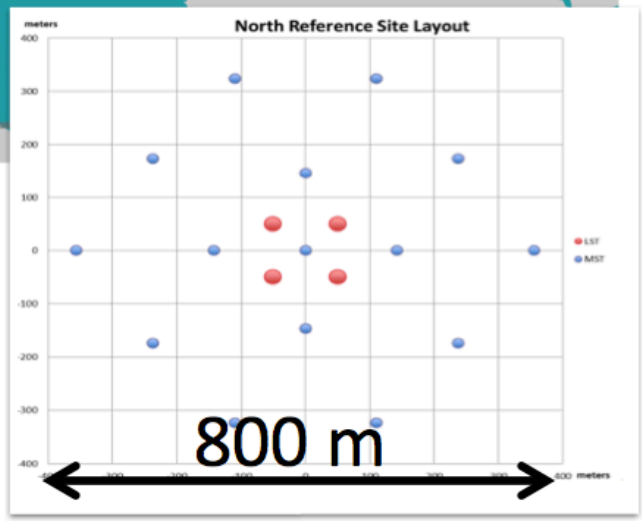
CTA PROJECT

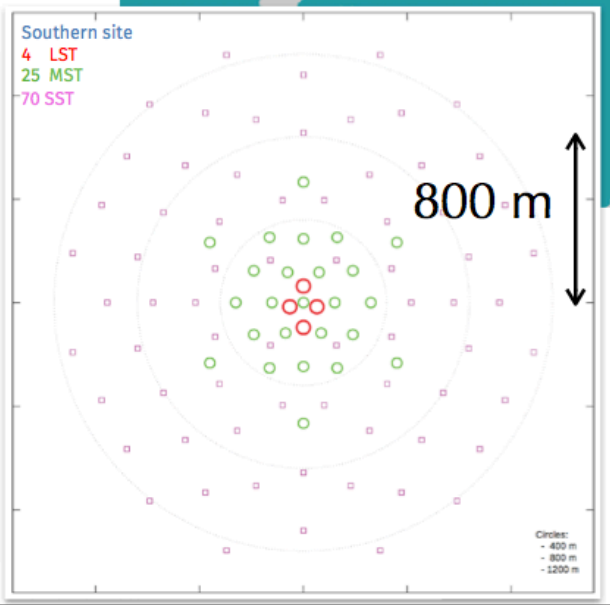
- Next generation ground based Gamma-ray observatory
- Open observatory
- Two sites with more than 100 telescopes
  - Southern Site: Near Paranal, Chile
  - Northern Site: La Palma, Canary Islands, Spain
- 31 nations, ~300M€ project + 100M€ manpower



CTA sites and example telescope layouts







23-m LST
12-m MST
4-m SST

[credit: T. Hassan, CTA consortium]

CTA Headquarters and Science Data Centre

CTA Headquarters
for Admin and observatory operations

INAF Bologna, Italy

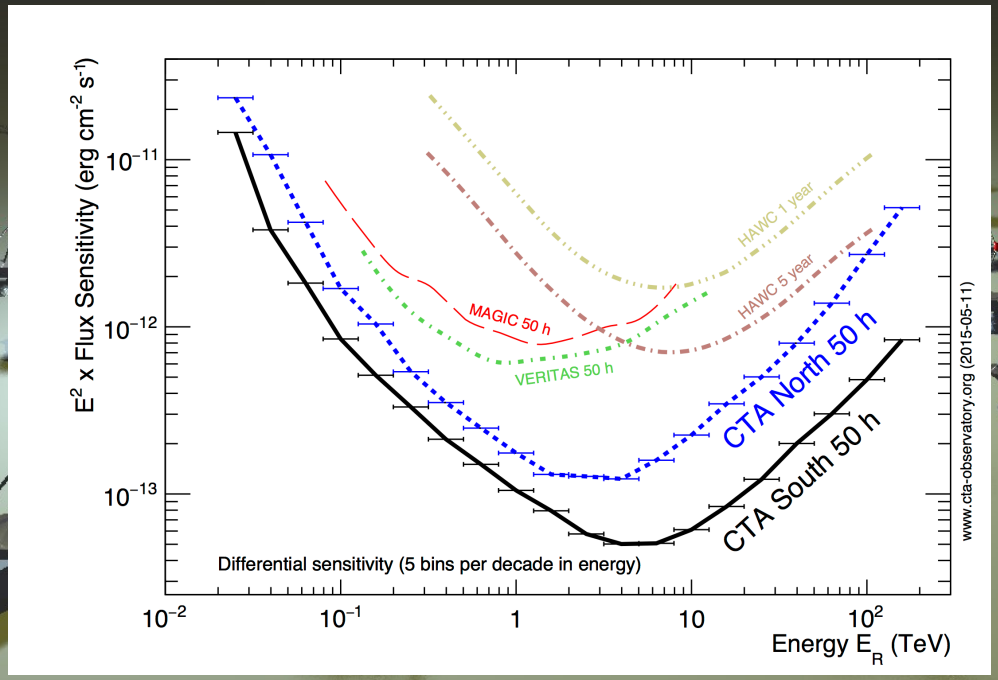
CTA Science Data Centre
for science operations and science products

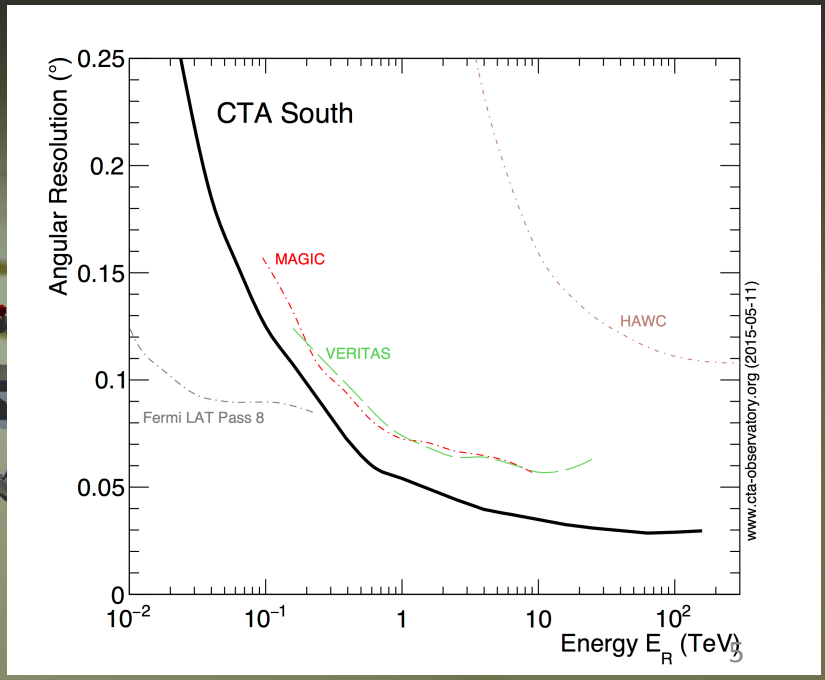
DESY Zeuthen/Berlin, Germany

CTA PERFORMANCE

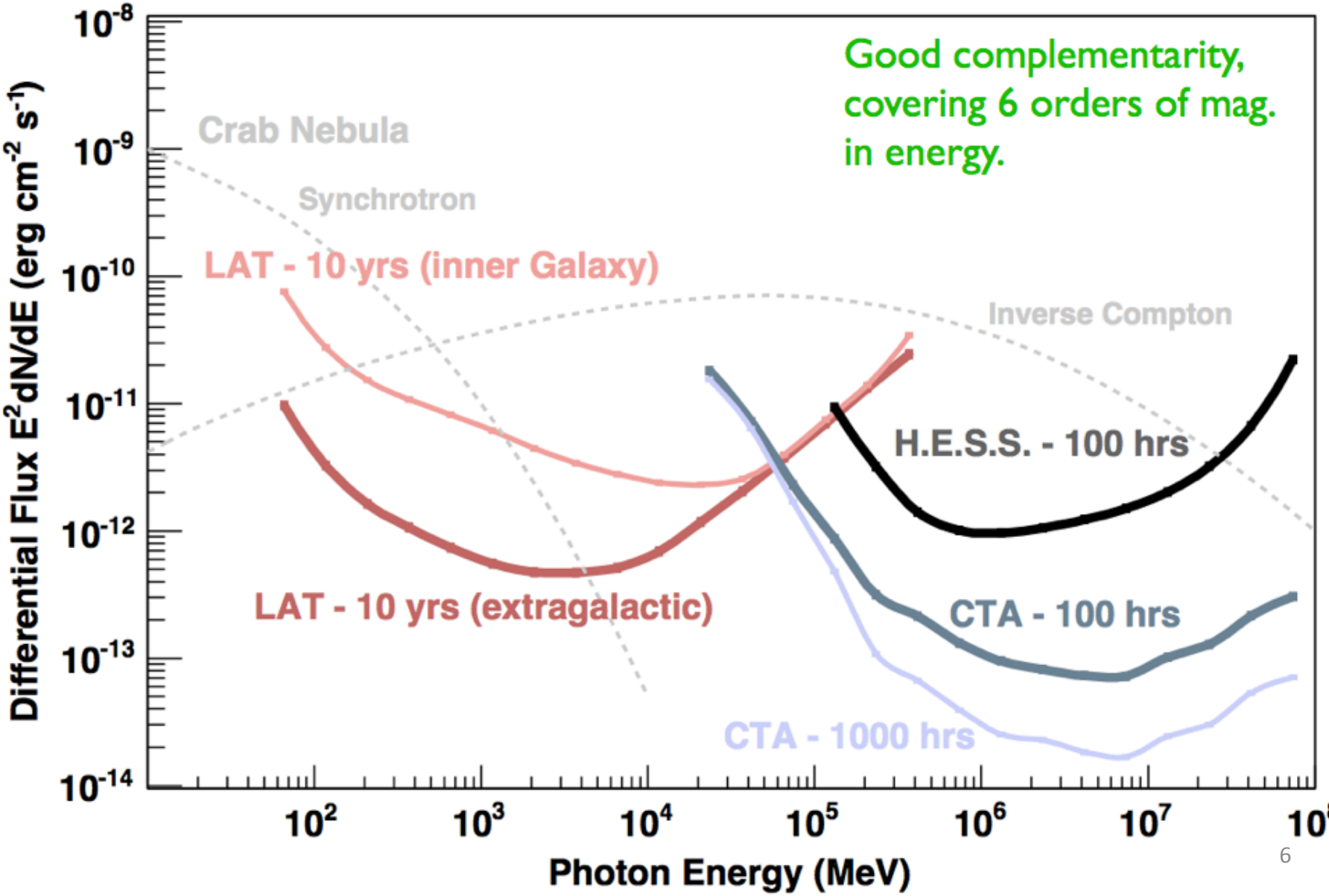
Southern Site:
- 4 Large-size telescopes
- 25 Medium-size telescopes
- 70 Small-size telescopes

Northern Site:
- 4 Large-size telescopes
- 15 Medium-size telescopes





CTA and Fermi

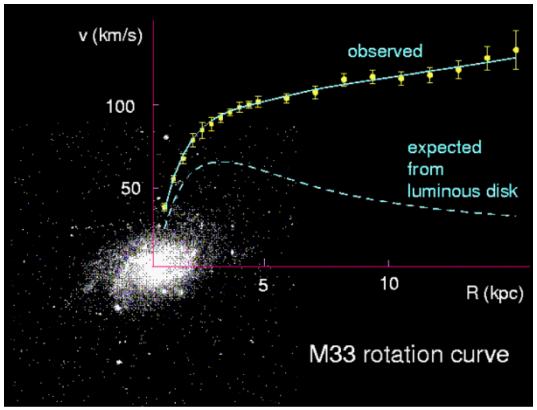


Dark Matter EVIDENCE

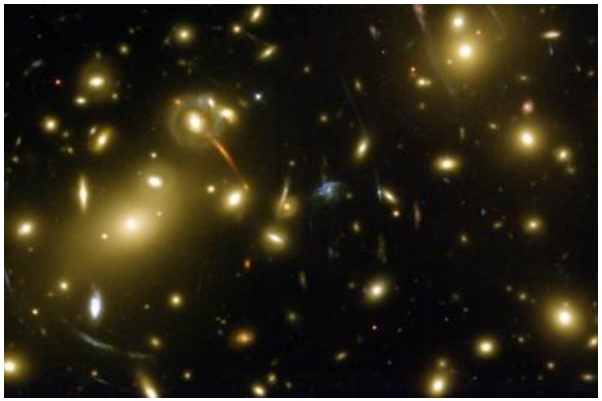
In 1933, the astronomer Zwicky realized that the mass of the luminous matter in the Coma cluster was much smaller than its total mass implied by the motion of cluster member galaxies.

Since then, even more evidence:

Rotation curves of galaxies

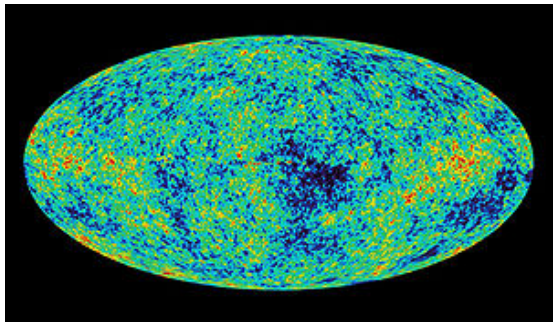


Gravitational lensing

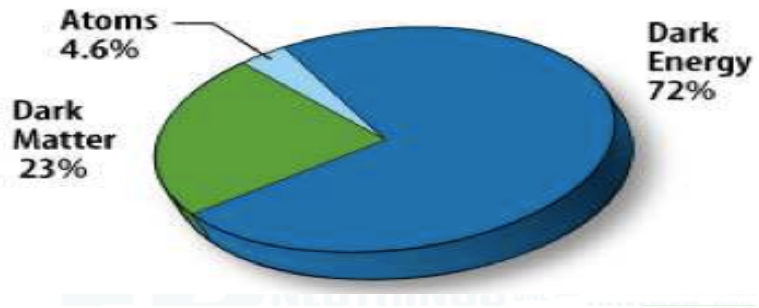


Bullet cluster

Structure formation as deduced from CMB



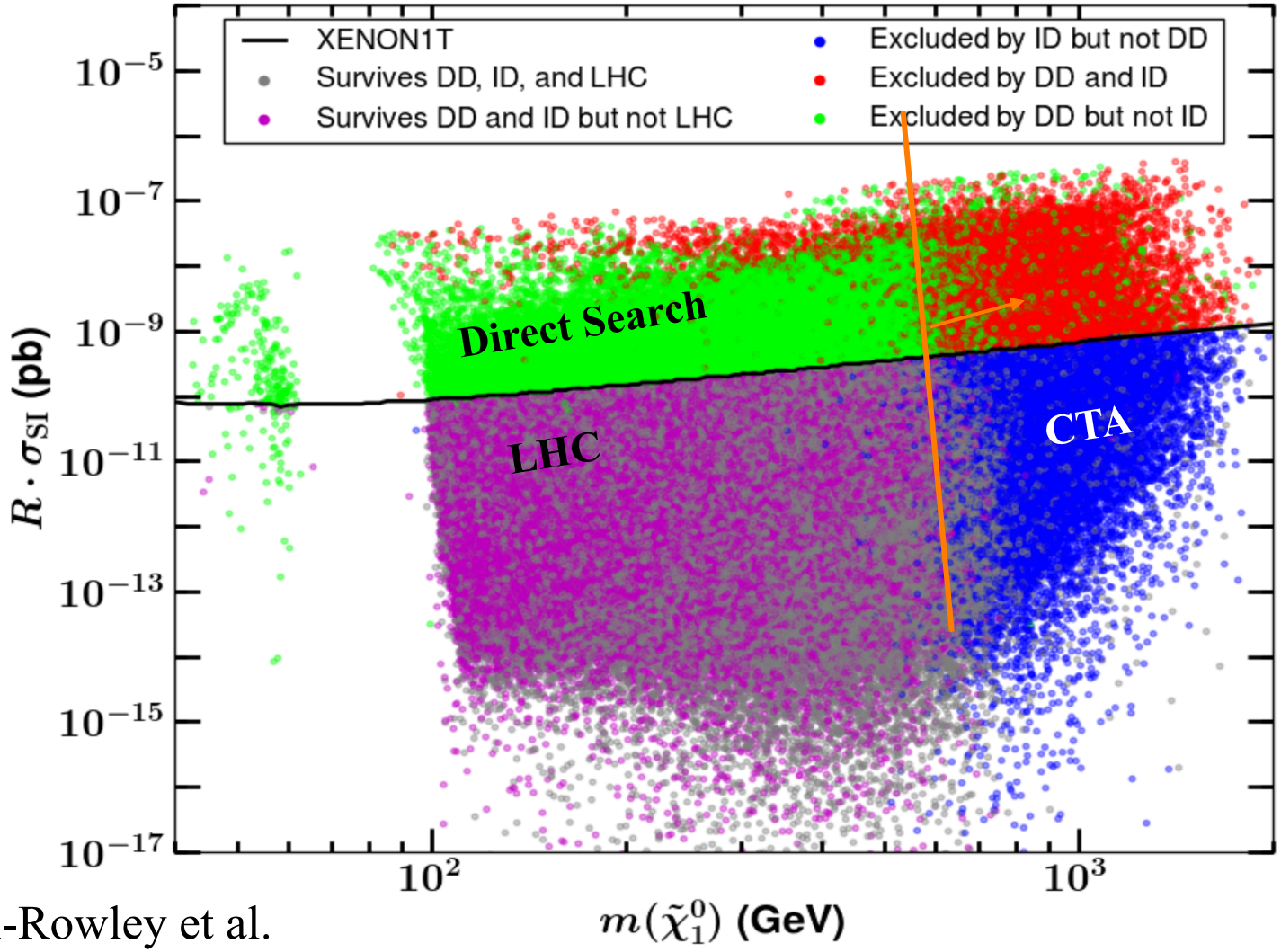
Data by WMAP imply:



$\Omega_b h^2 \approx 0.02$

$\Omega_{DM} h^2 \approx 0.1$

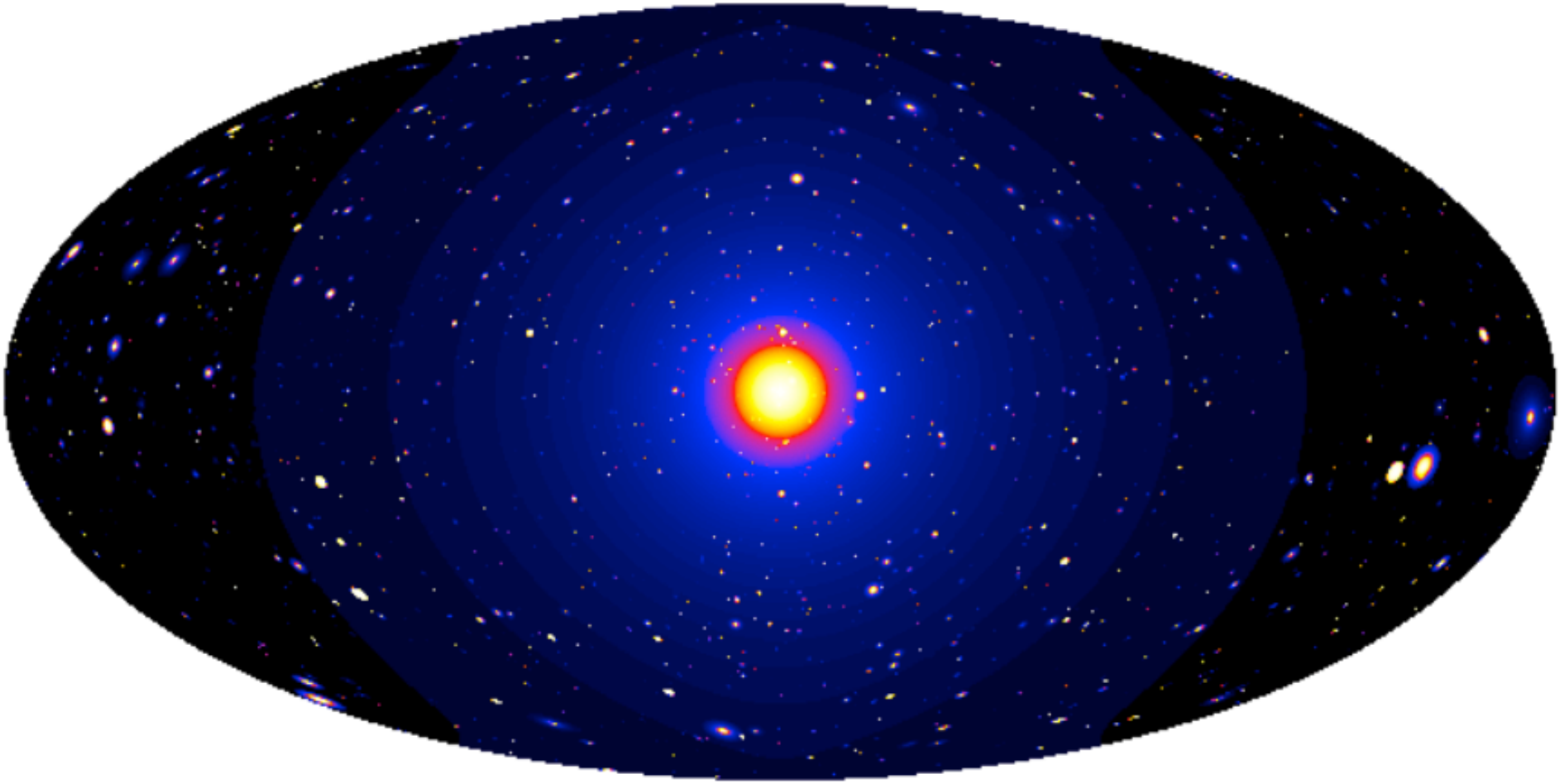
Complementarity and Searches for Dark Matter in the pMSSM



Cahill-Rowley et al.
arXiv: 1305.6921

cherenkov telescope array

Dark Matter Search Targets and Strategies



Dark matter simulation:
Pieri+(2009) arXiv:0908.0195

Dark Matter Search Targets and Strategies

cherenkov telescope array

Satellites

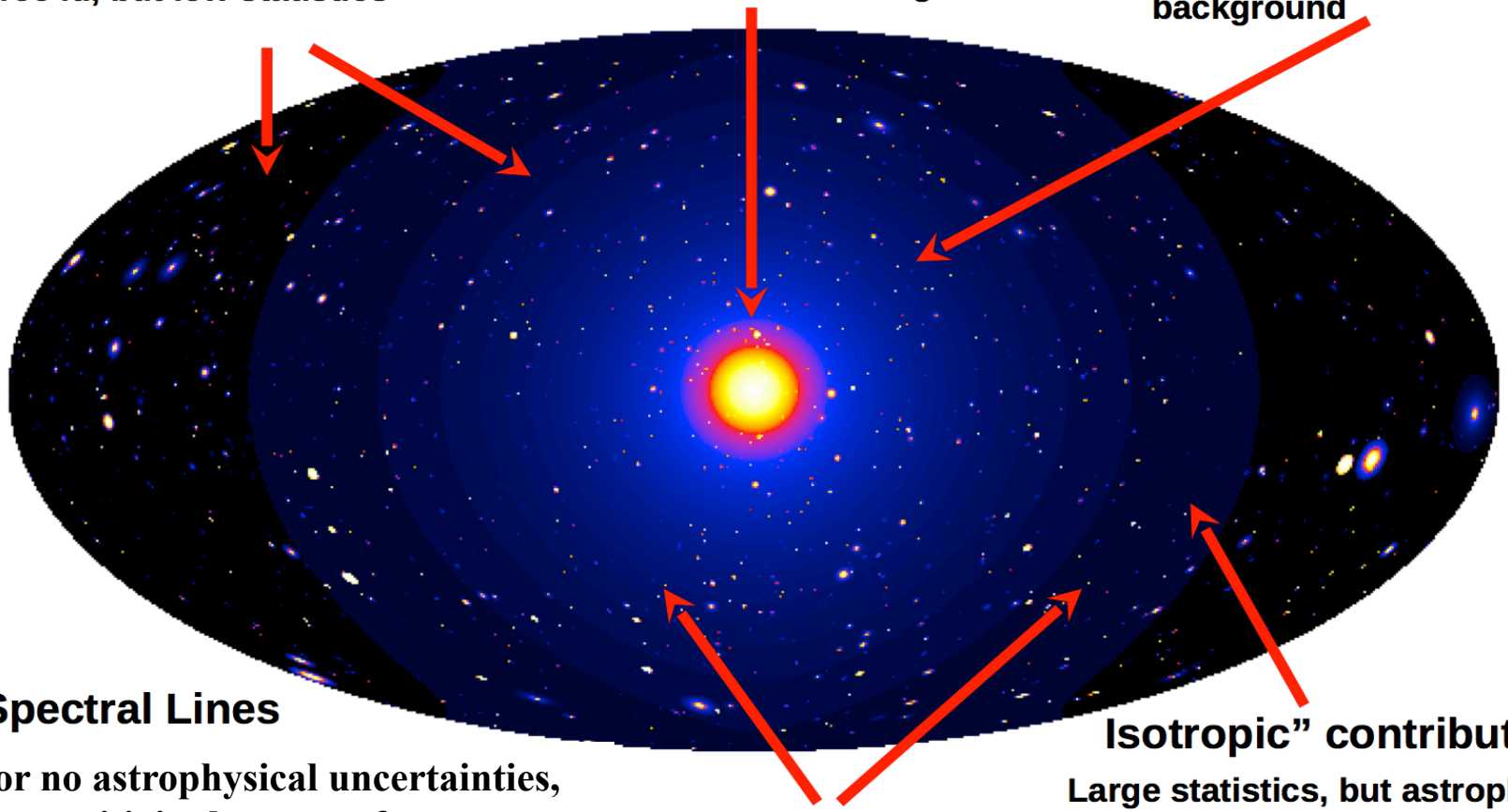
Low background and good source id, but low statistics

Galactic Center

Good Statistics, but source confusion/diffuse background

Milky Way Halo

Large statistics, but diffuse background



Spectral Lines

Little or no astrophysical uncertainties, but low sensitivity because of expected small branching ratio

Isotropic" contributions

Large statistics, but astrophysics, galactic diffuse background

Galaxy Clusters

Low background, but low statistics

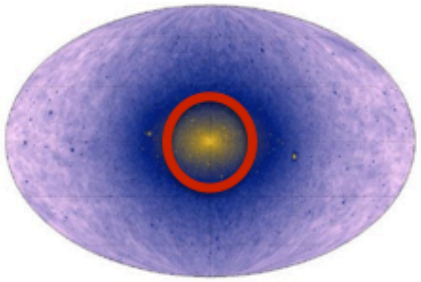
Dark matter simulation: Pieri+(2009) arXiv:0908.0195

Dark Matter Search Targets and Strategies

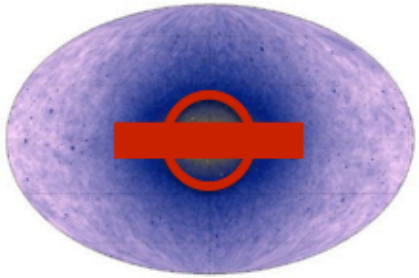
(Another way to see it)

signal strength

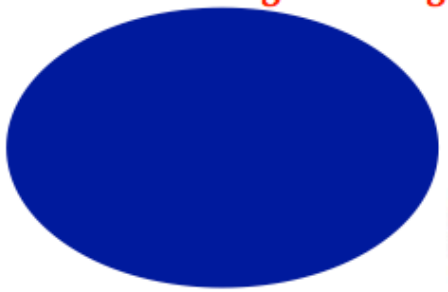
GC



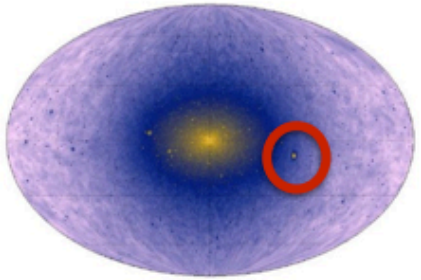
GC halo

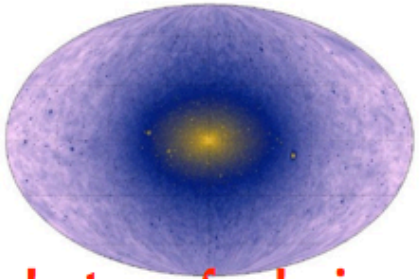


cumulative extragalactic signal



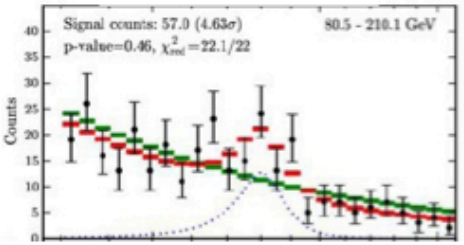
dwarf satellites





clusters of galaxies

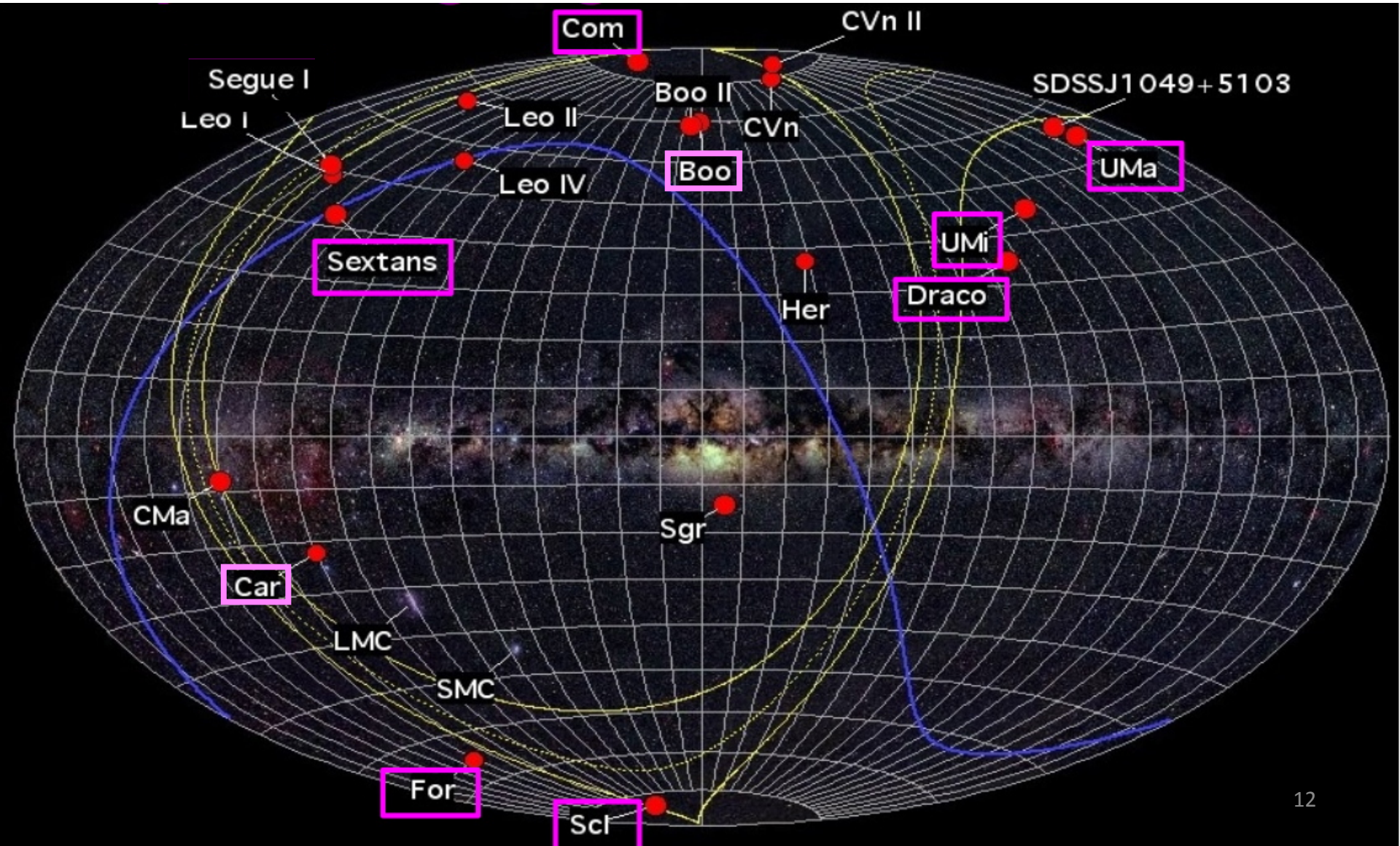
spectral line



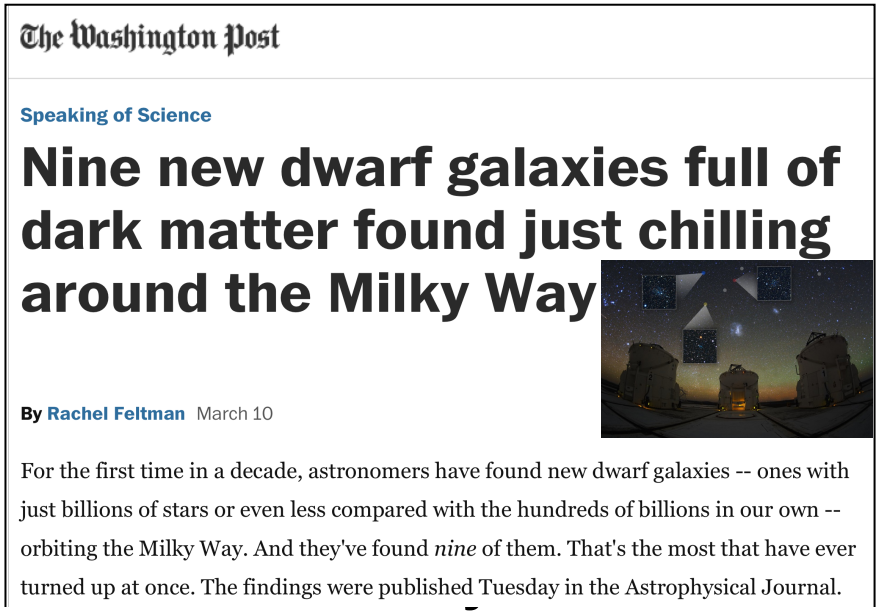
robustness

cherenkov telescope array

Classical Dwarf spheroidal galaxies: promising targets for DM detection



2015: New DES Dwarf Spheroidal Galaxies Candidates



The Washington Post

Speaking of Science

Nine new dwarf galaxies full of dark matter found just chilling around the Milky Way

By Rachel Feltman March 10

For the first time in a decade, astronomers have found new dwarf galaxies -- ones with just billions of stars or even less compared with the hundreds of billions in our own -- orbiting the Milky Way. And they've found *nine* of them. That's the most that have ever turned up at once. The findings were published Tuesday in the Astrophysical Journal.

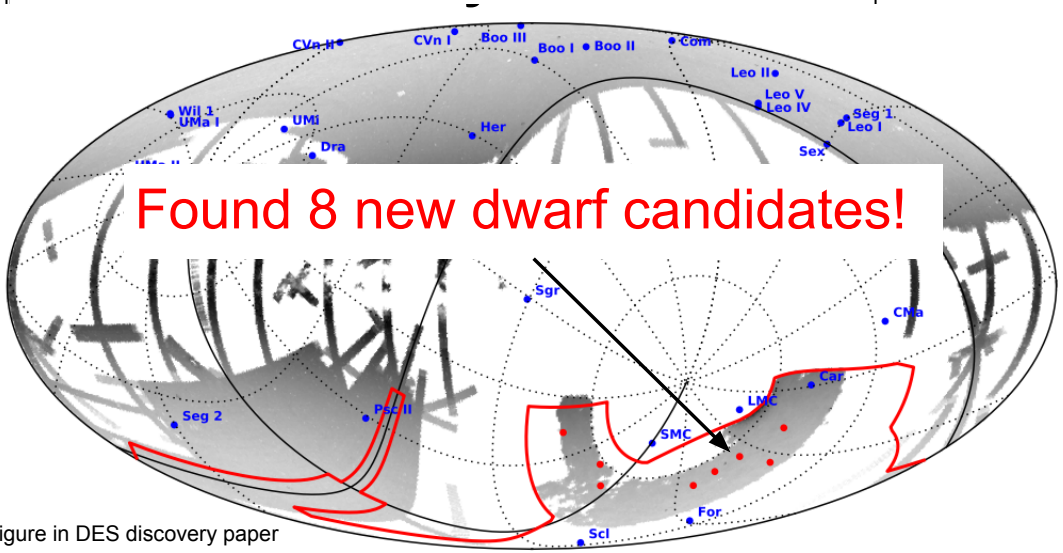


figure in DES discovery paper

LAT Collaboration – DES Collaboration agreement – Feb 2015

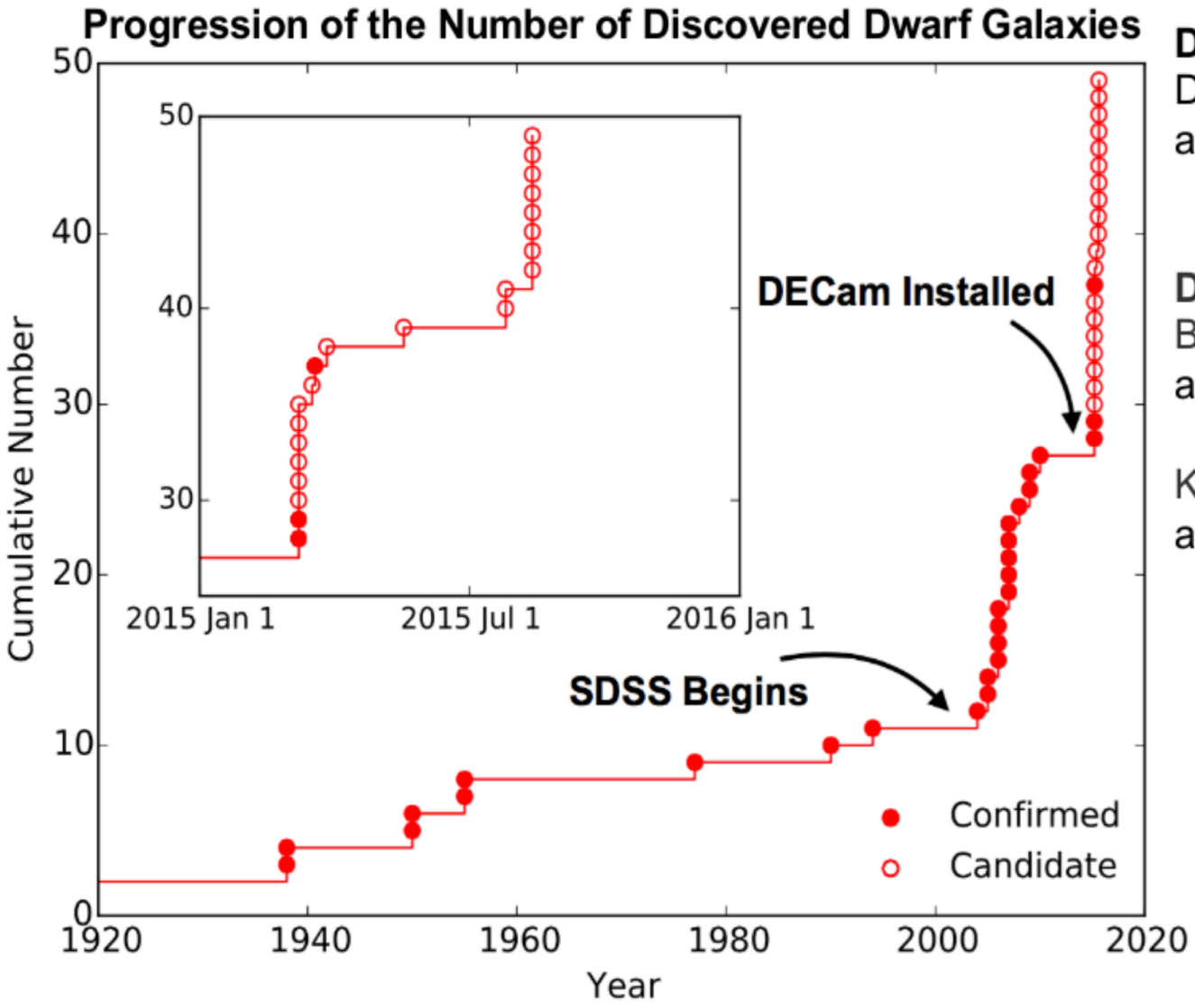
- first joint paper "Search for Gamma-Ray Emission from DES Dwarf Spheroidal Galaxy Candidates with Fermi-LAT Data" ApJL 2015, 809,L4,arXiv:1503.02632

  • analysis of observations of 8 new Dwarf Spheroidal Galaxies found by DES:

    Bechtol, et al. arXiv:1503.02584

    also found by Koposov, et al. arXiv:1503.02079

Dwarf Spheroidal Galaxies: Growing number of known targets



DES Year 2 Data:
Drlica-Wagner+,
arXiv:1508.03622

DES Year 1 Data:
Bechtol+:
arXiv:1503.02584

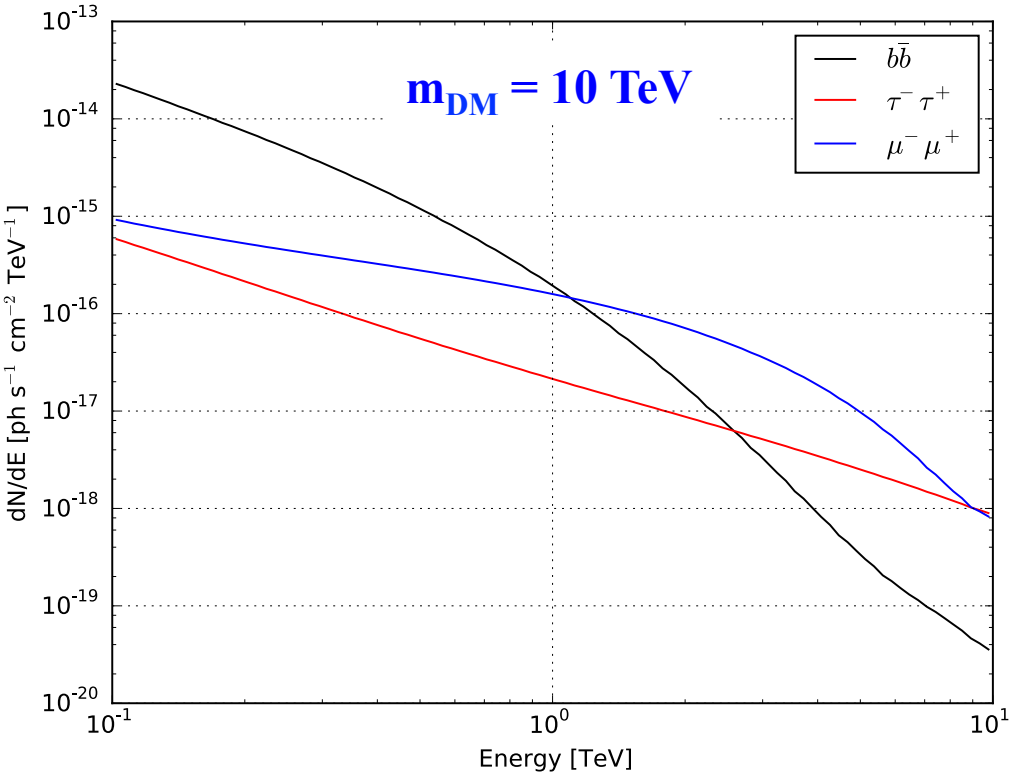
Koposov+:
arXiv:1503.02079

Gamma rays Flux

M. Cirelli et al.

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

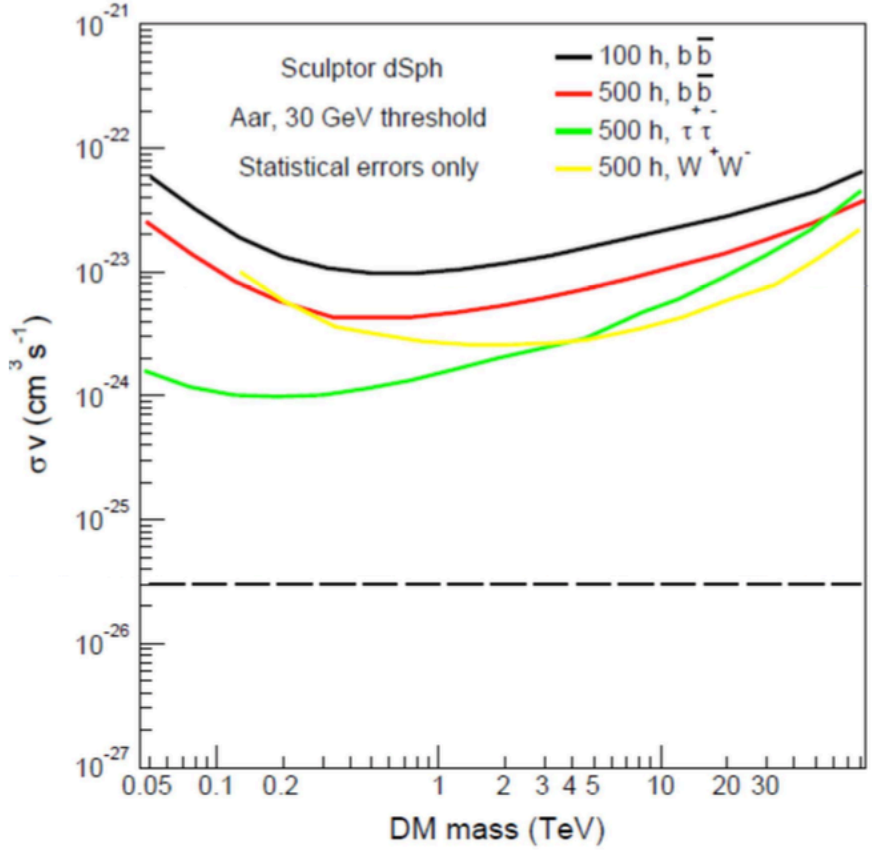
Sculptor: $\log_{10}(J(\alpha=0.5^0)) = 18.55$



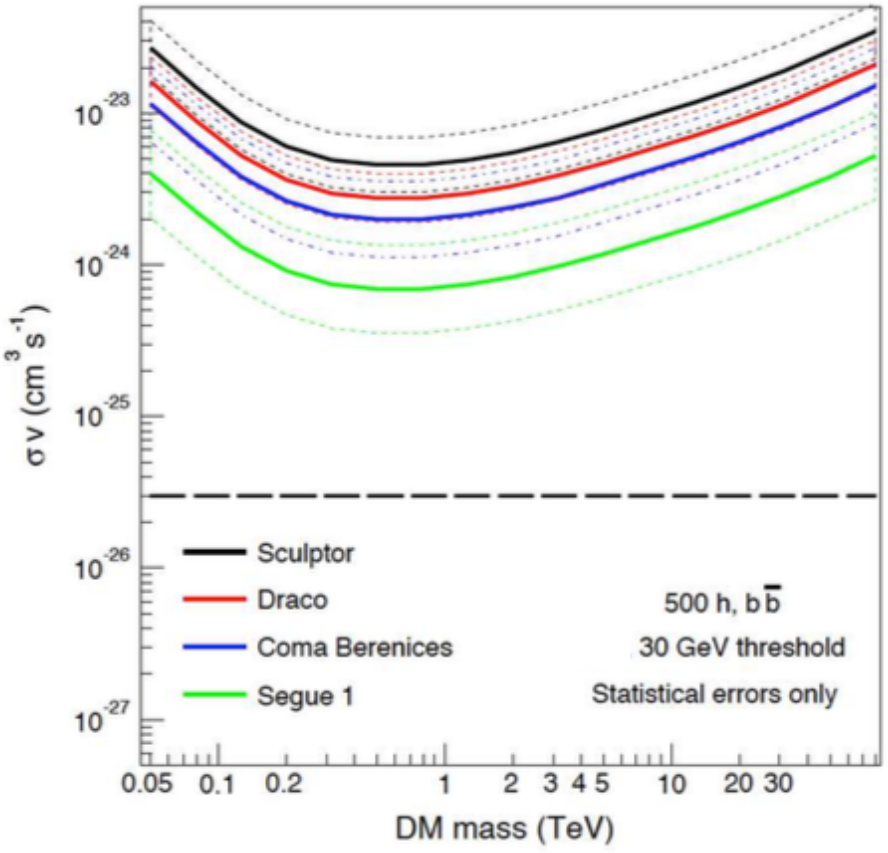
Since no signal from source is detected
We calculate the CL at 95%

Dwarf Spheroidal Galaxies: CTA Sensitivity

500h, Sculptor, different channels



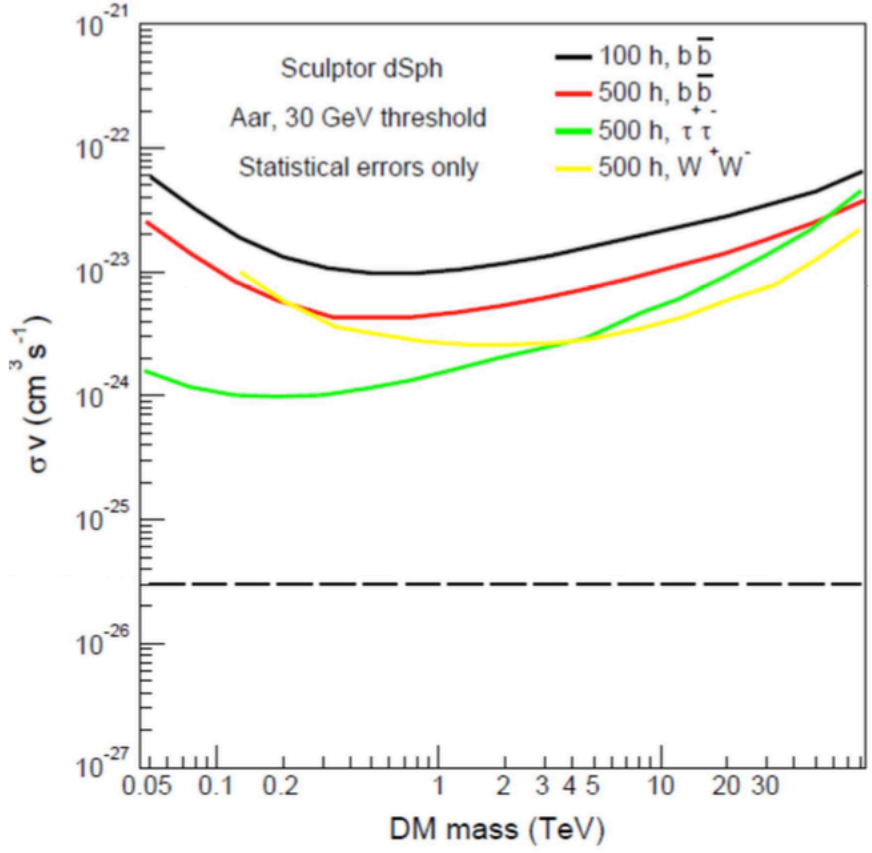
500h, bb, different dSphs



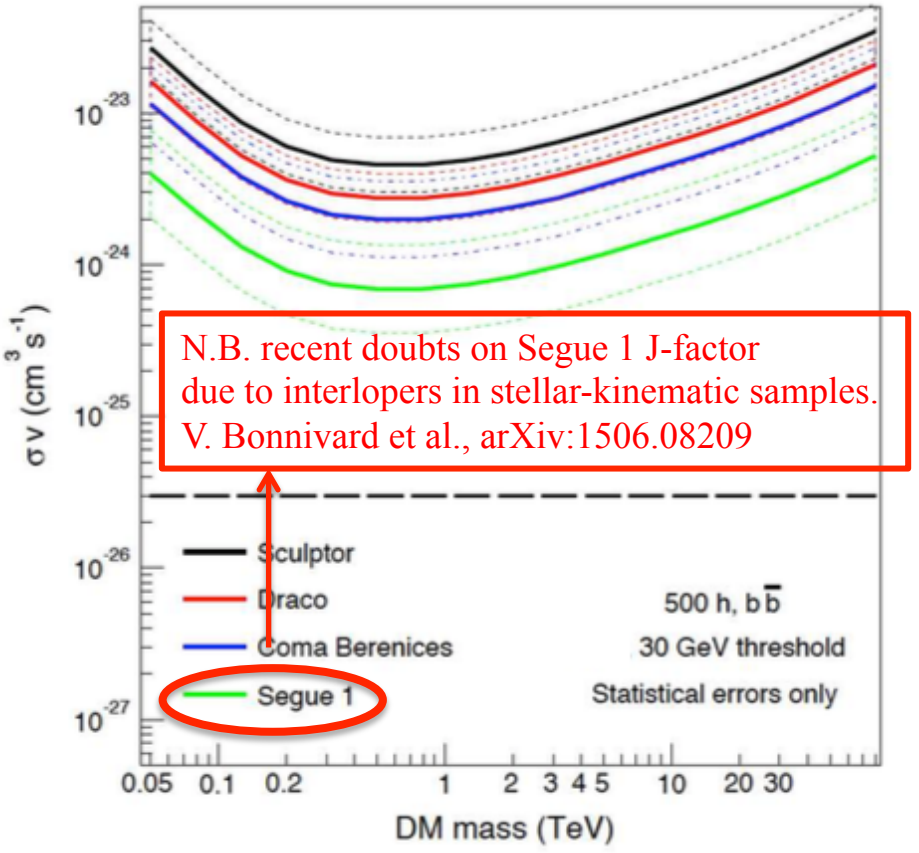
Carr et al. 2015 (CTA Consortium)
arXiv:1508.06128

Dwarf Spheroidal Galaxies: CTA Sensitivity

500h, Sculptor, different channels



500h, bb, different dSphs



Carr et al. 2015 (CTA Consortium)
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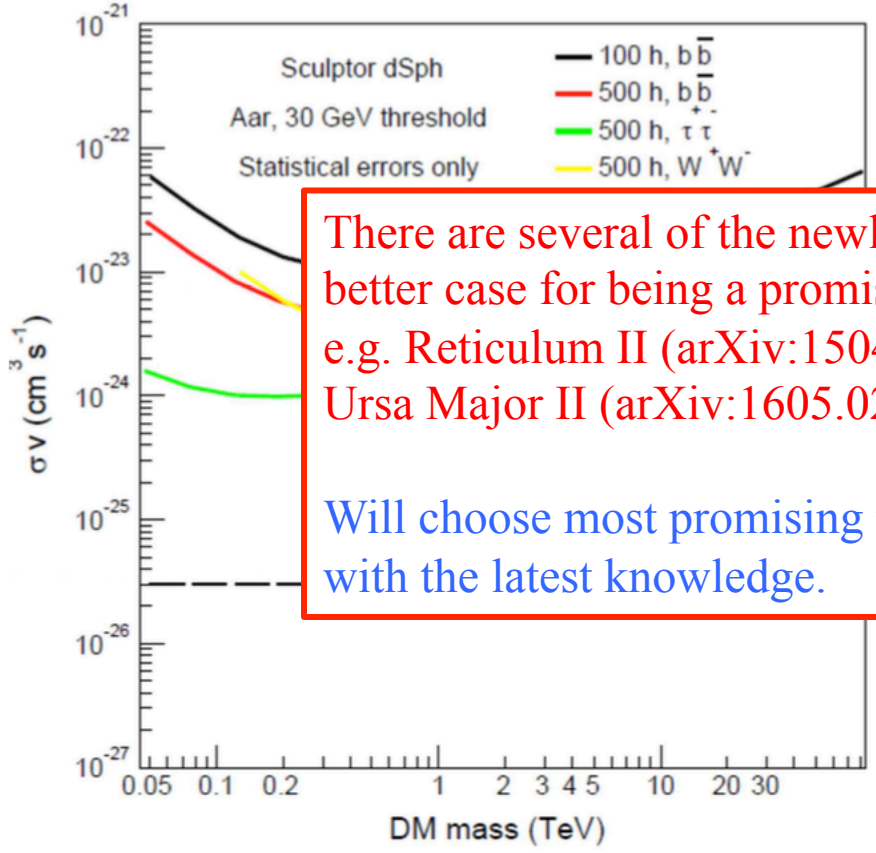
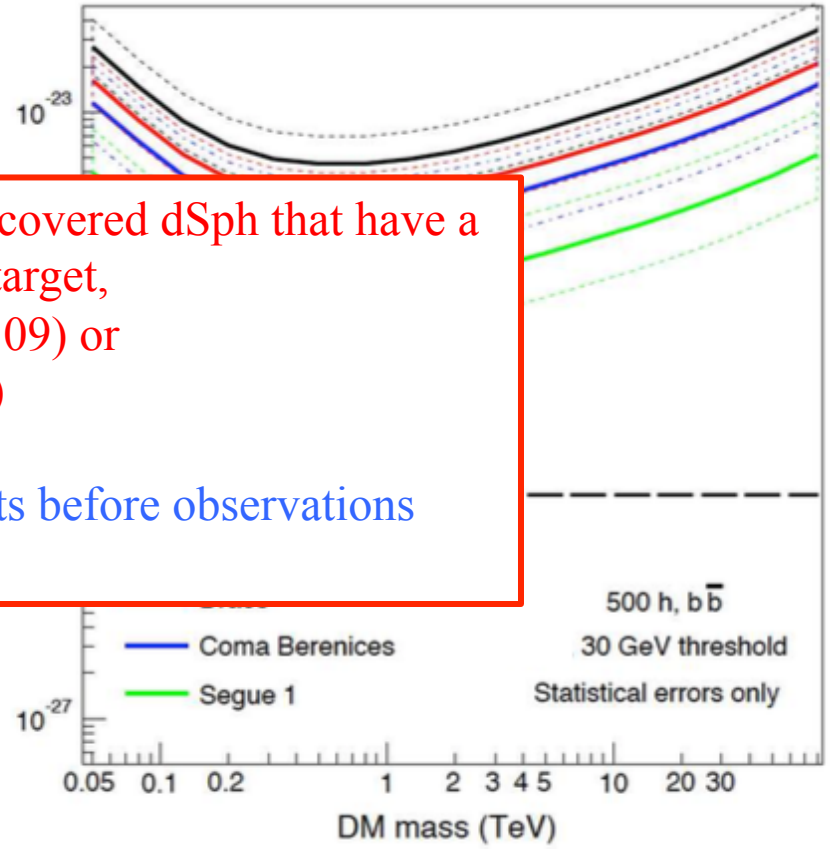
Dwarf Spheroidal Galaxies: CTA Sensitivity

500h, Sculptor, different channels



500h, bb, different dSphs



There are several of the newly discovered dSph that have a better case for being a promising target,
e.g. Reticulum II (arXiv:1504:03309) or
Ursa Major II (arXiv:1605.02793)

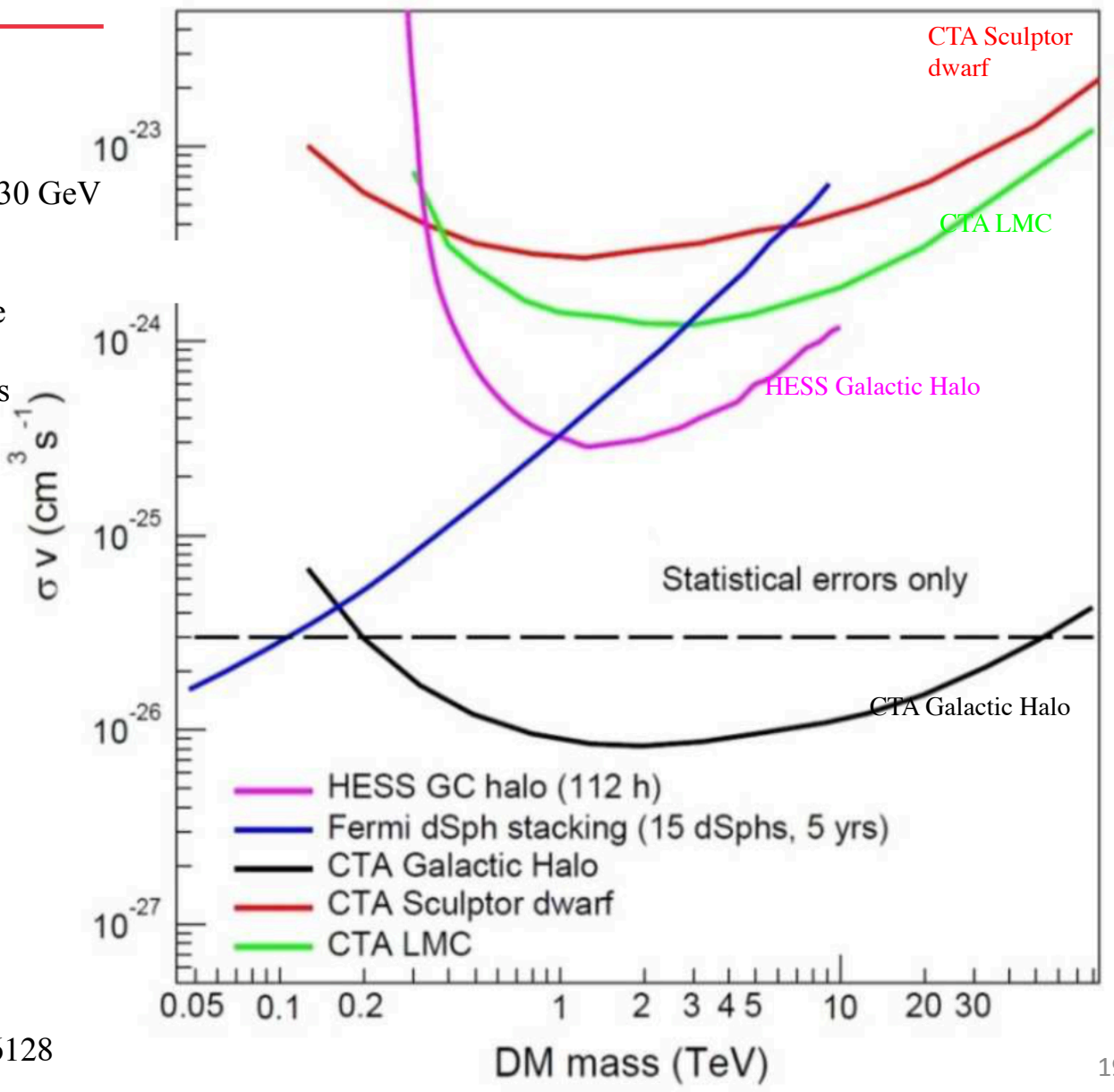
Will choose most promising targets before observations with the latest knowledge.

Carr et al. 2015 (CTA Consortium)
arXiv:1508.06128

HESS, FERMI, CTA DM upper-limits

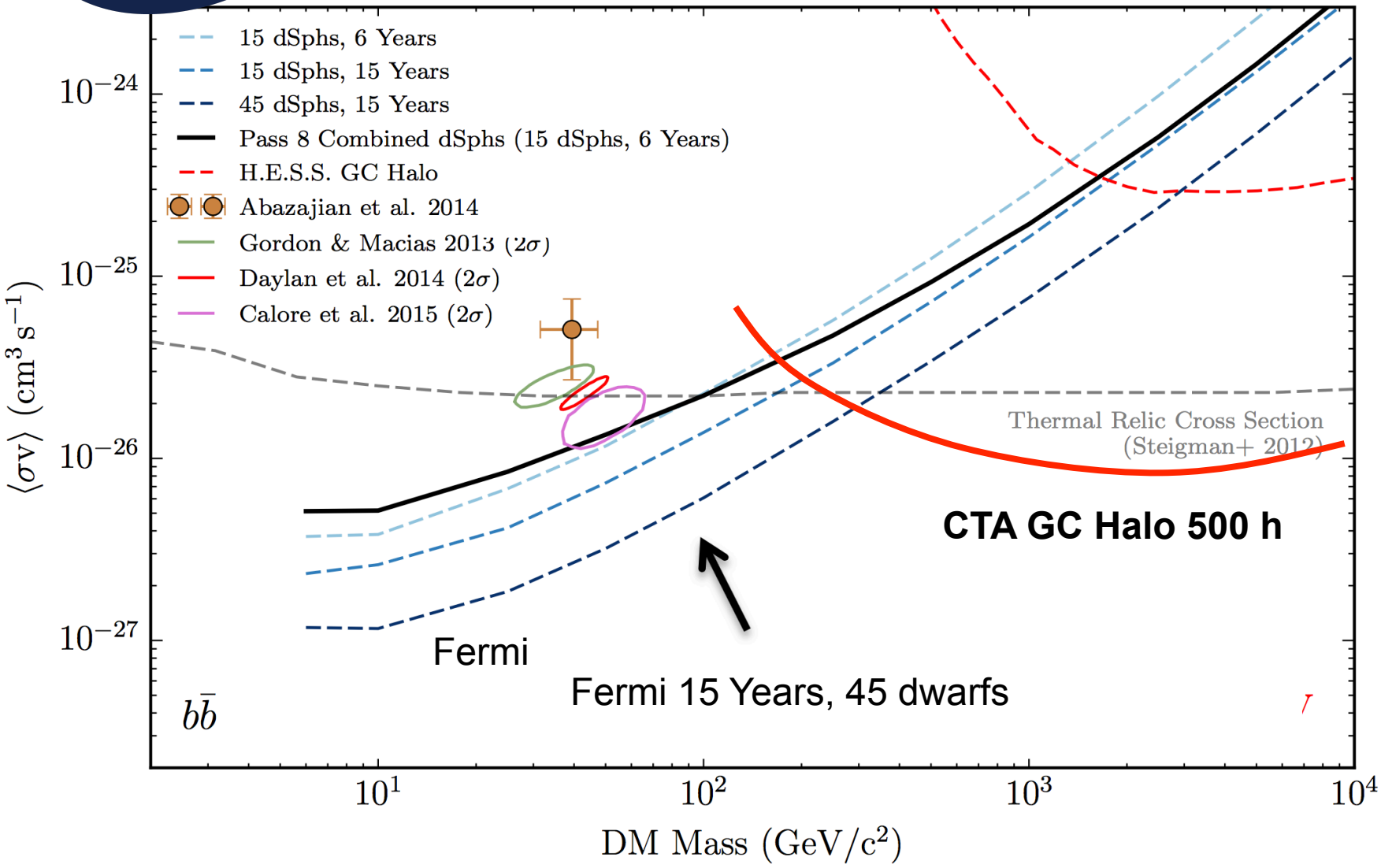
CTA 500 hr, statistical only, NFW, 30 GeV

Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section



Carr et al. 2015 arXiv:1508.06128

DM limit improvement estimate in 15 years (2008- 2023)

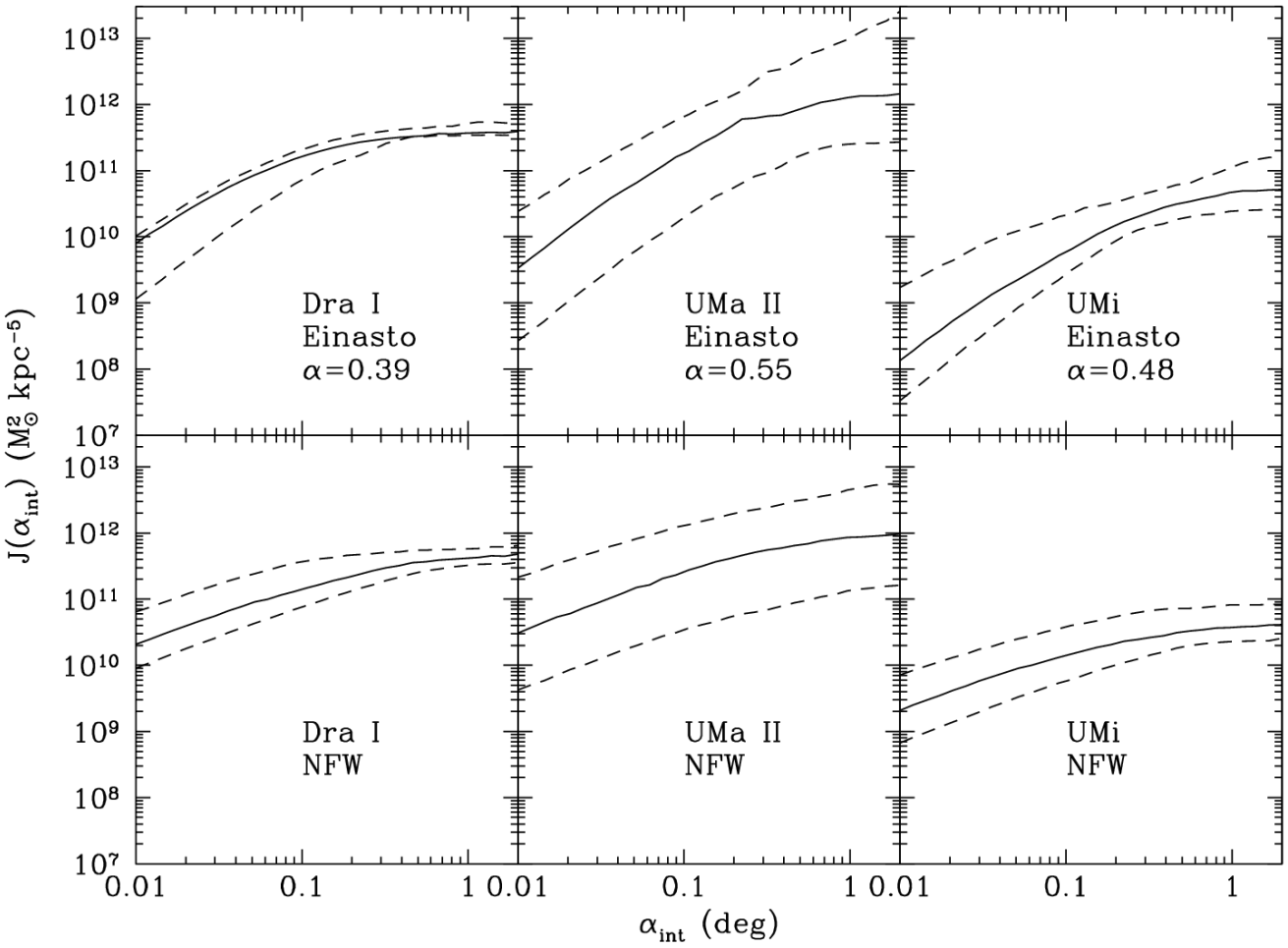


CTA sensitivity curve from Carr et al. 2015 500 hr, statistical only, NFW, 30 GeV threshold arXiv:1508.06128

Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section

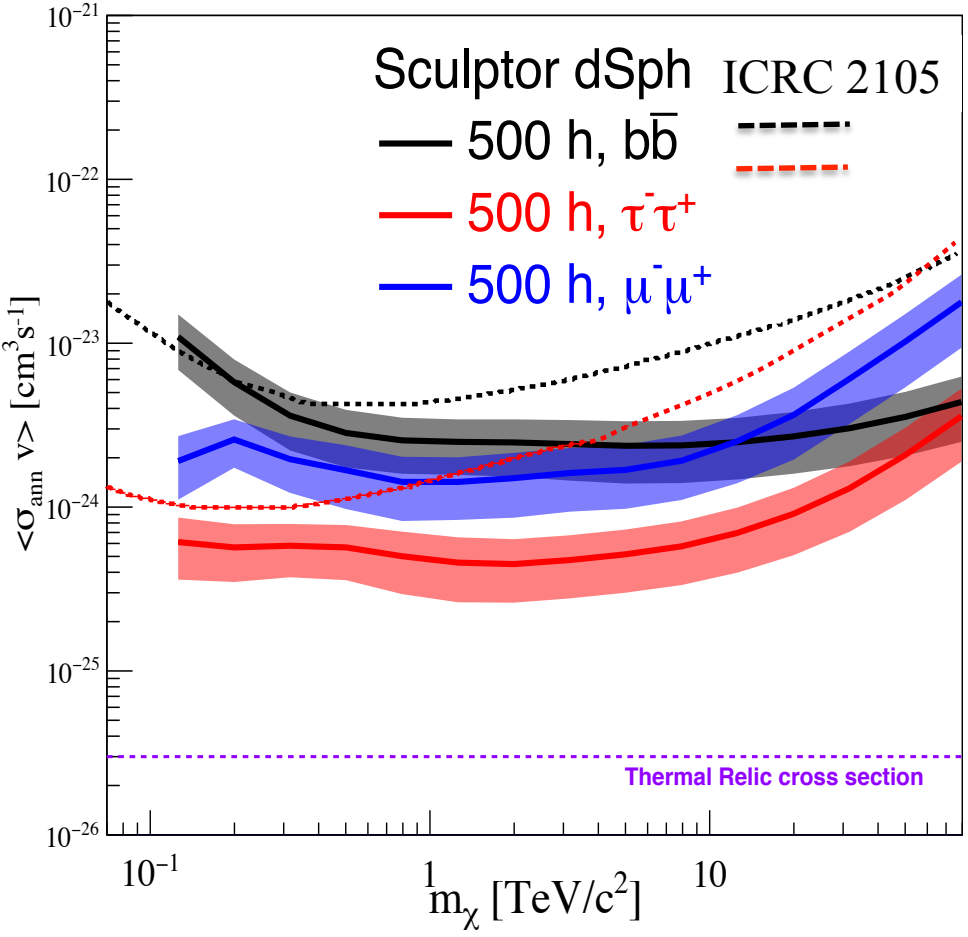
Update analysis, J-factors

- J-factor profiles obtained with the MCMC of CLUMPY (Charbonnier+ 2012, Bonnivard+ 2016) on kinematic data and surface brightness of each dSph.
- Calculations done with different DM profiles (here Einasto and pure NFW shown).
- List of targets under analysis: CBe, DraI, Seg1, TriII, UMaII, UMi.

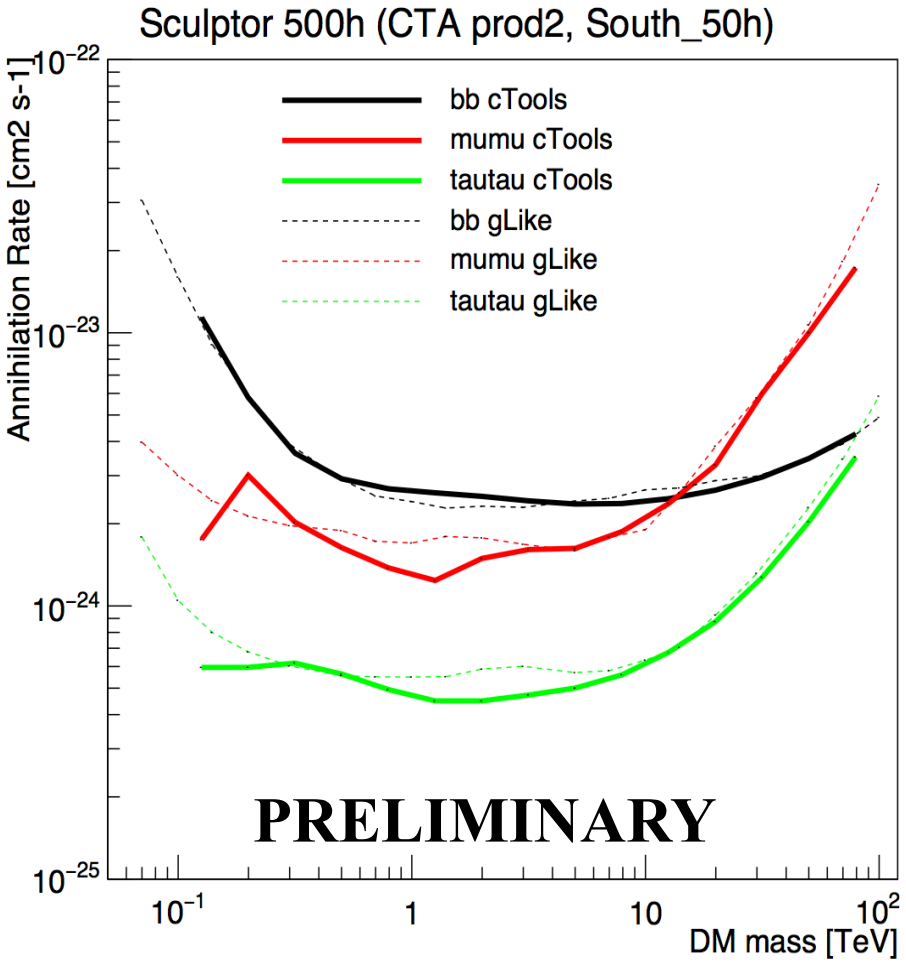


Update analysis (to be finalized yet)

CTOOLS vs Carr et al. ICRC2015



CTOOLS vs gLike



Summary

- CTA will improve the sensitivity to DM annihilation for a range of interesting DM masses.
- CTA angular resolution means some dwarf spheroidal galaxies could be resolvable, and the point source assumption no longer valid.
- Together with Fermi, CTA will be able to exclude thermal WIMPs within the mass range from a few GeV up to a few tens of TeV.
- For heavy WIMPs (>TeV) CTA will provide unique observational data to probe parameter space not reachable by the other experiments.
- CTA is complementary instrument to LHC and direct DM searches probing some non-overlapping regions of DM particle parameter space.

Summary

- Dwarf spheroidal galaxies observations with CTA will be valuable for providing robust legacy constraints (in case of no detection) and (in any case) for testing/ extending DM searches conducted by CTA with other targets (e.g. GC and LMC).

- Dwarf spheroidal galaxies have no expected astrophysical background and good source identification.

- New ultra-faint dwarf spheroidal galaxies will be discovered with the next generation of sky surveys.

- The best constrained/most promising dwarf spheroidal galaxies known at the time of observation will be chosen.

Proposed Scheduling for Key Science Project

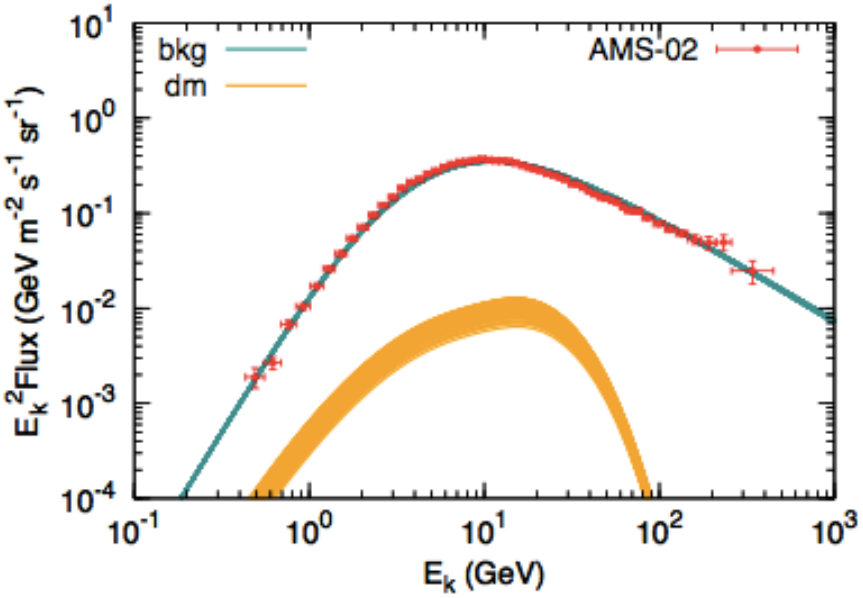
Table 4.1 – Strategy for dark matter observations over ten years with CTA. The first three years are devoted to the deep observation of the Galactic Centre (GC) together with the observation of the best ultra-faint dwarf galaxy. In case of non-detection of the GC, observations starting in the fourth year focus on the most promising target at that time to provide legacy constraints.

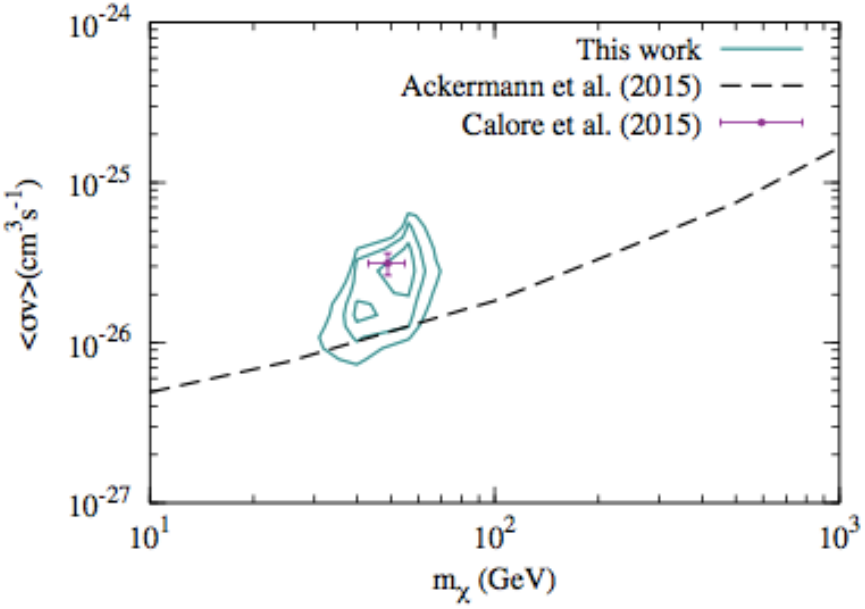
Year	1	2	3	4	5	6	7	8	9	10
Galactic halo	175 h	175 h	175 h							
Segue 1 (or best) dSph	100 h	100 h	100 h							
				in case of detection at GC, large σv						
Segue 1 (or best) dSph				150 h	150 h	150 h	150 h	150 h	150 h	150 h
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
				in case of detection at GC, small σv						
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
				in case of no detection at GC						
Best Target				100 h	100 h	100 h	100 h	100 h	100 h	100 h

CTA Consortium, in prep.

RECENT NEWS FROM AMS-02 PROTON/ANTIPROTON

arXiv:1610.03071 ➔ 4.5σ, mass ~ (50 - 100 GeV
arXiv:1610.03840 ➔ 8.0σ, mass ~ (30 – 70) GeV





Good agreement with Fermi gamma–ray excess from Galactic Center
And weak GeV emission signal in the directions of Reticulum 2 and Tucana III