

# PROSPECTS FOR DARK MATTER DETECTION IN DWARF IRREGULAR GALAXIES

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arXiv:1609.06903  
in collaboration with [P. Salucci](#)

arXiv:1706.01843  
in collaboration with  
[V. Gammaldi & P. Salucci](#)

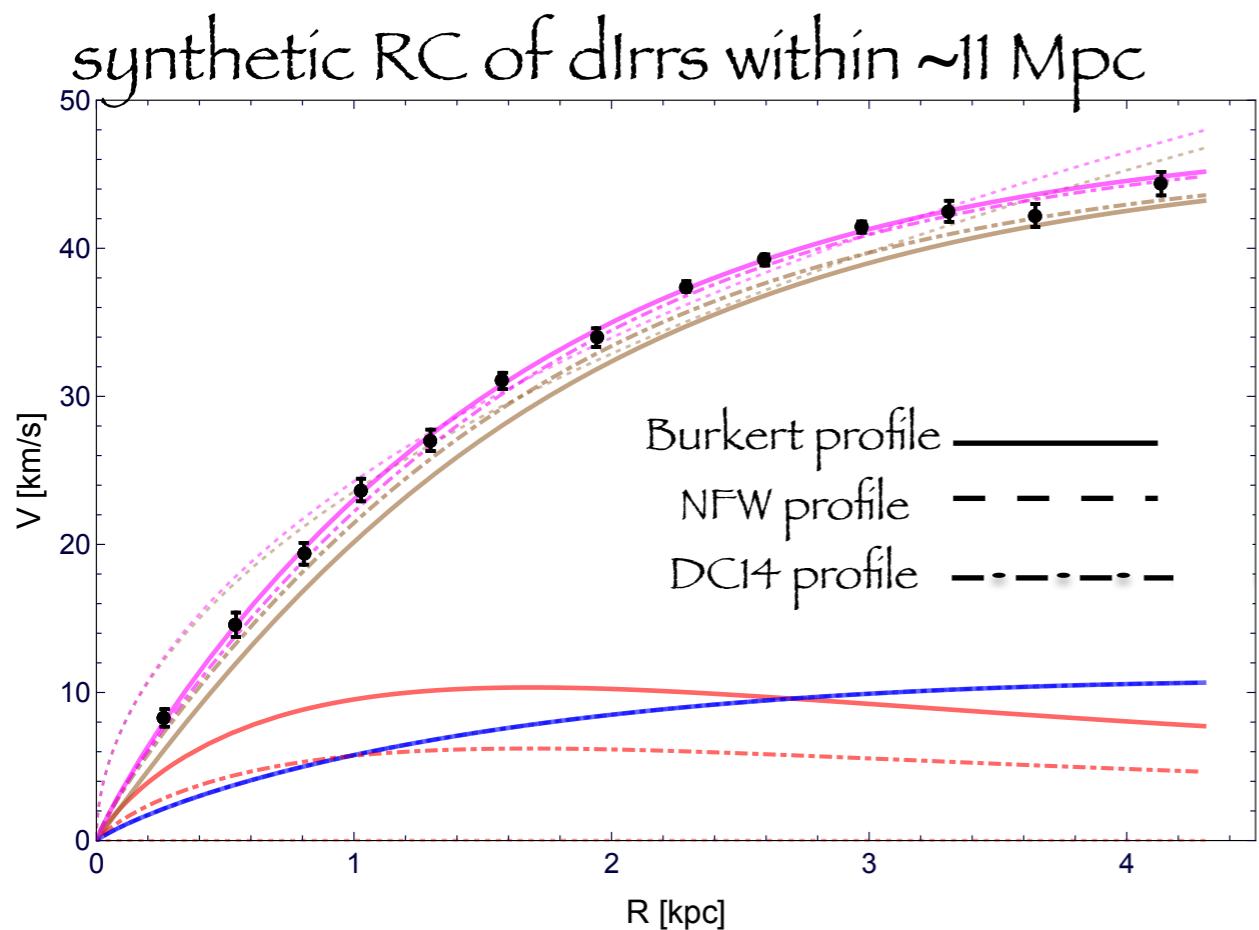
arXiv:1708.04642  
in collaboration with

[S. H. Cadena, R. Alfaro, A. Sandoval, E. Belmont, H. Leon, V. Gammaldi, P. Salucci](#)



# What are the dwarf irregular galaxies and their DM content

dIrr galaxies are rotationally supported galaxies=>well-measured kinematics=>well-defined DM profile

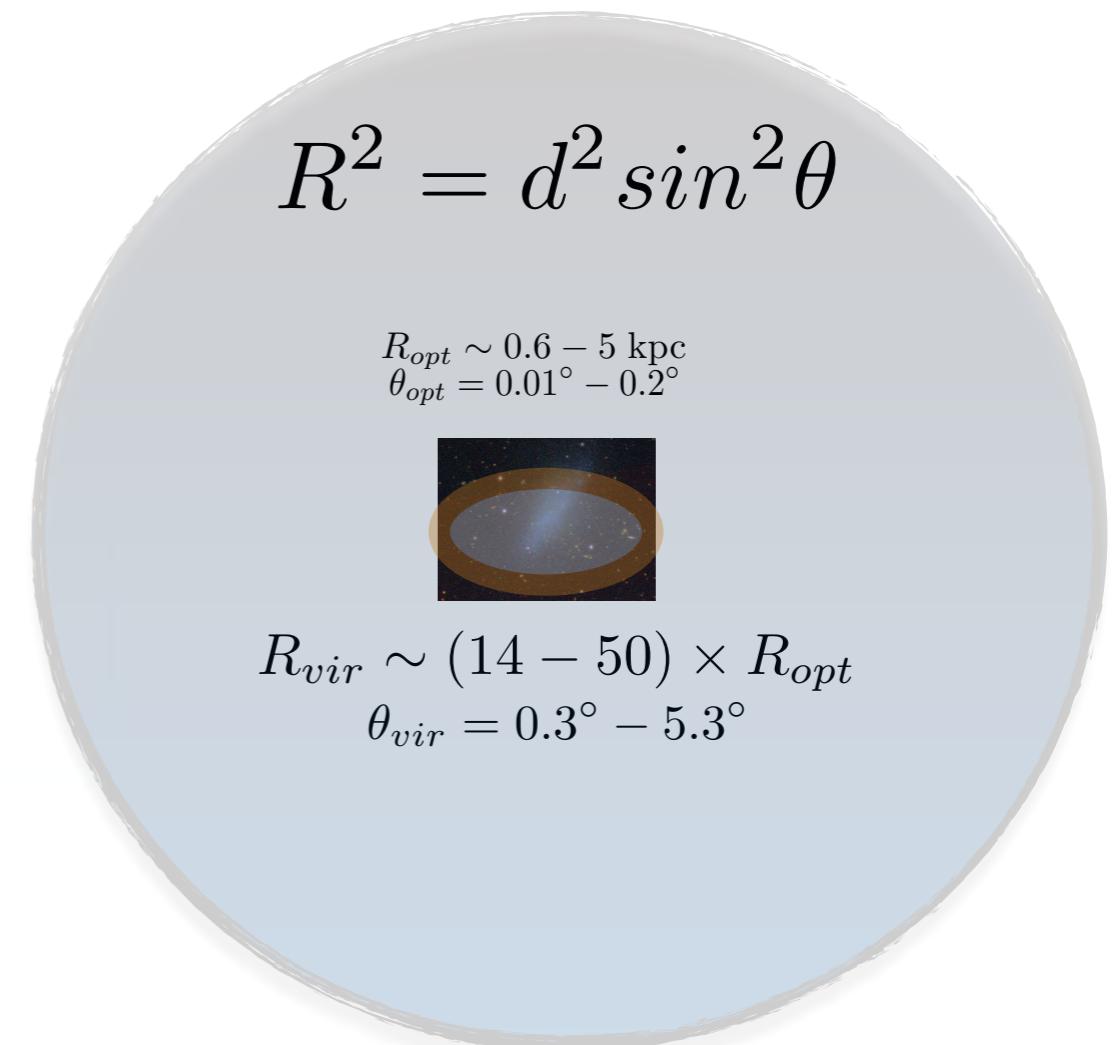


EK, Salucci MNRAS 2017, 465, p4703-4722

within  $\sim 6$  Mpc:

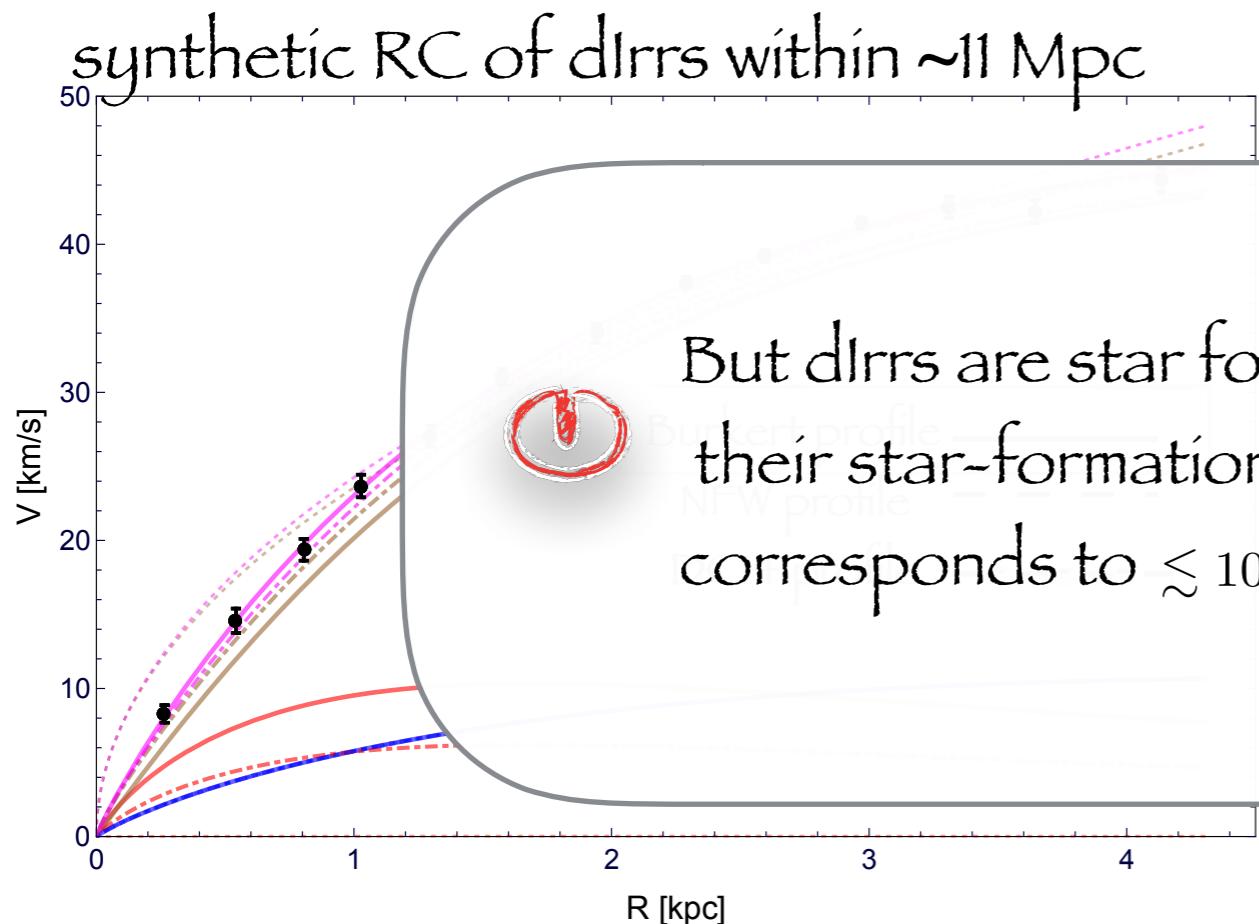
$\left. \begin{array}{l} \sim 100 \text{ dSphs} \\ \sim 490 \text{ dIrrs} \end{array} \right\}$

see catalog of nearby galaxies by Karachentsev et al. 2013  
Astron. J 145 (2013) 101



# What are the dwarf irregular galaxies and their DM content

dIrr galaxies are rotationally supported galaxies=>well-measured kinematics=>well-defined DM profile



$$R^2 = d^2 \sin^2 \theta$$

But dIrrs are star forming galaxies. On average their star-formation rate is  $\lesssim 10^{-2} M_{\odot} \text{yr}^{-1}$  that corresponds to  $\lesssim 10^{36} \text{ erg s}^{-1}$  gamma-ray luminosity

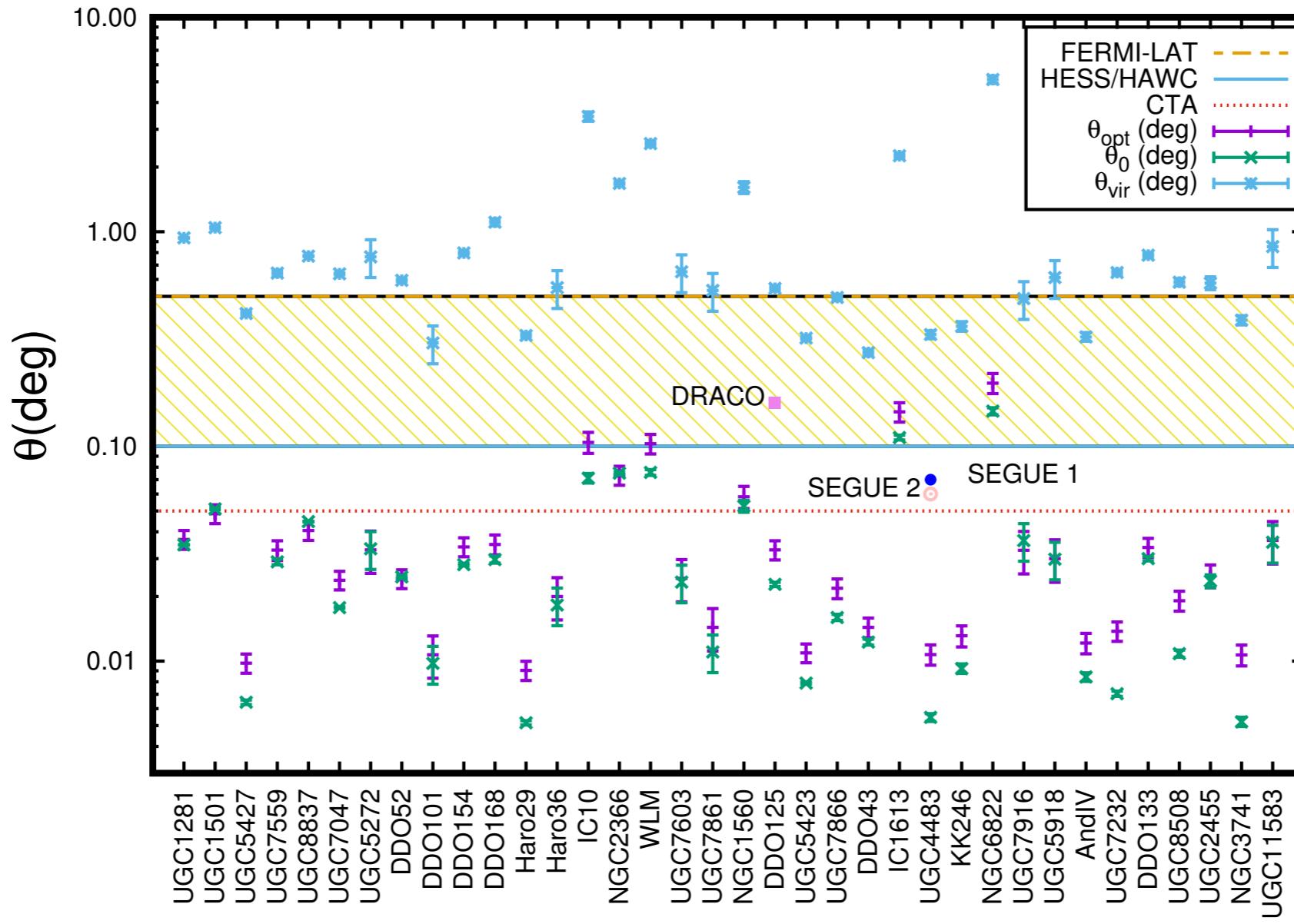
EK, Salucci MNRAS 2017, 465, p4703-4722

within ~6 Mpc:

$\begin{cases} \sim 100 \text{ dSphs} \\ \sim 490 \text{ dIrrs} \end{cases}$

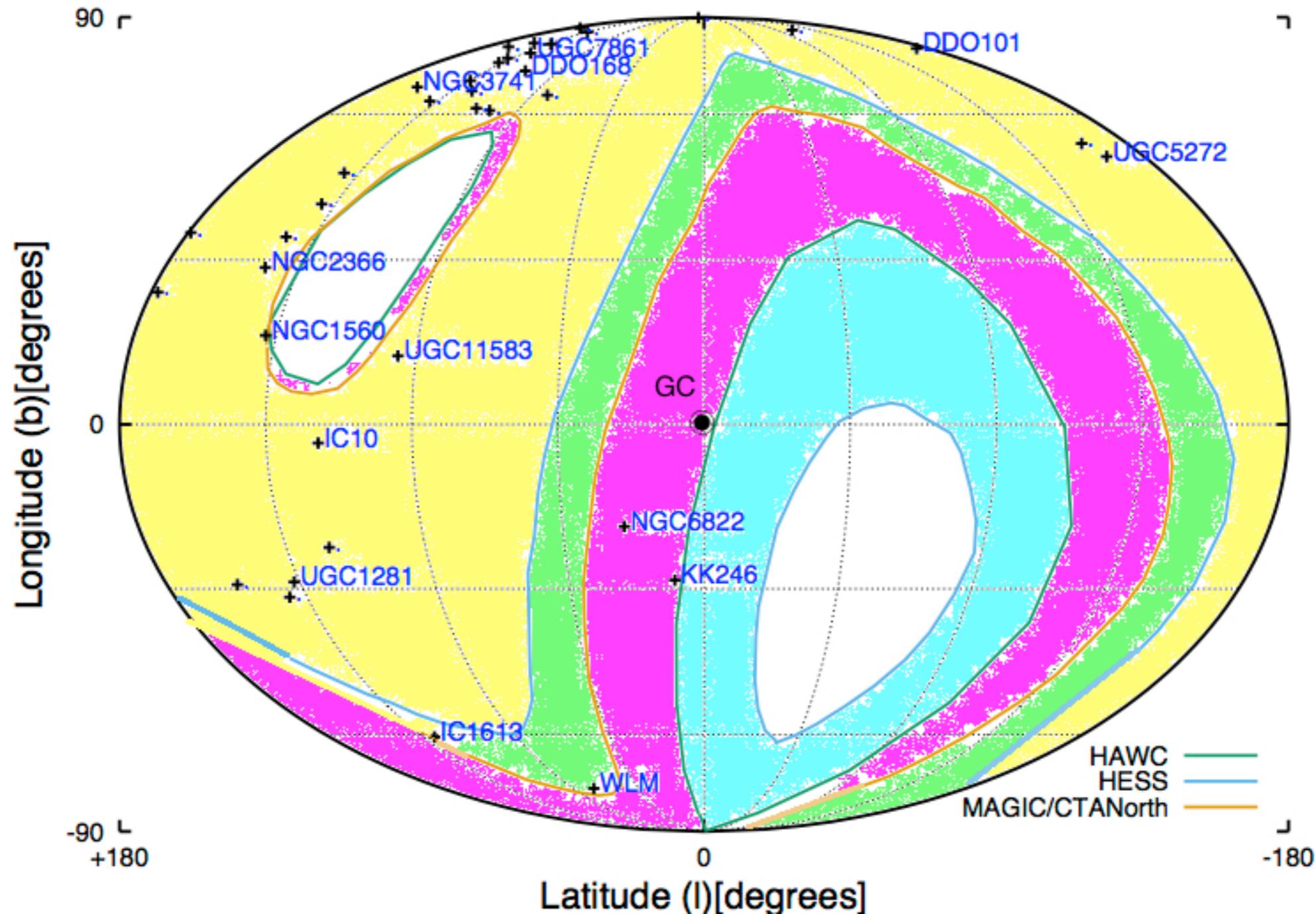
see catalog of nearby galaxies by Karachentsev et al. 2013  
Astron. J 145 (2013) 101

# Sample of 36 dlrr galaxies



Gammaldi, EK, Salucci, arXiv:1706.01843

# Sample of 36 dlrr galaxies



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# DM indirect searches with gamma-rays

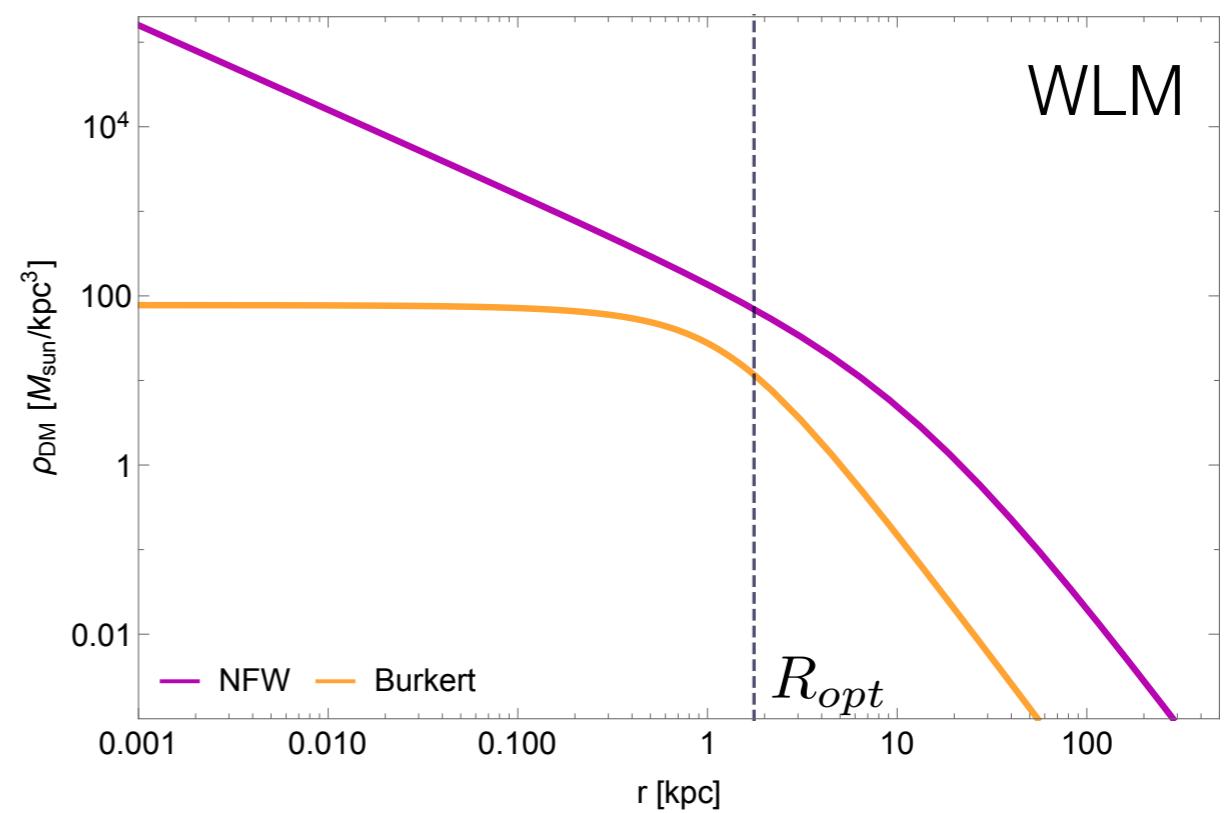
The differential photon flux for DM annihilation is given by

$$\frac{d\Phi}{dE} = \frac{1}{4\pi m_\chi^2} \sum_i \frac{N_\gamma^i}{dE} \sigma_i v \frac{1}{\Delta\Omega} \int_{l.o.s.} \rho^2(s) ds$$

particle physics      J-factor

where J-factor depends on the DM density profile

$$\rho_{Burkert}(r) = \frac{\rho_0 r_0^3}{(r + r_0)(r^2 + r_0^2)}$$

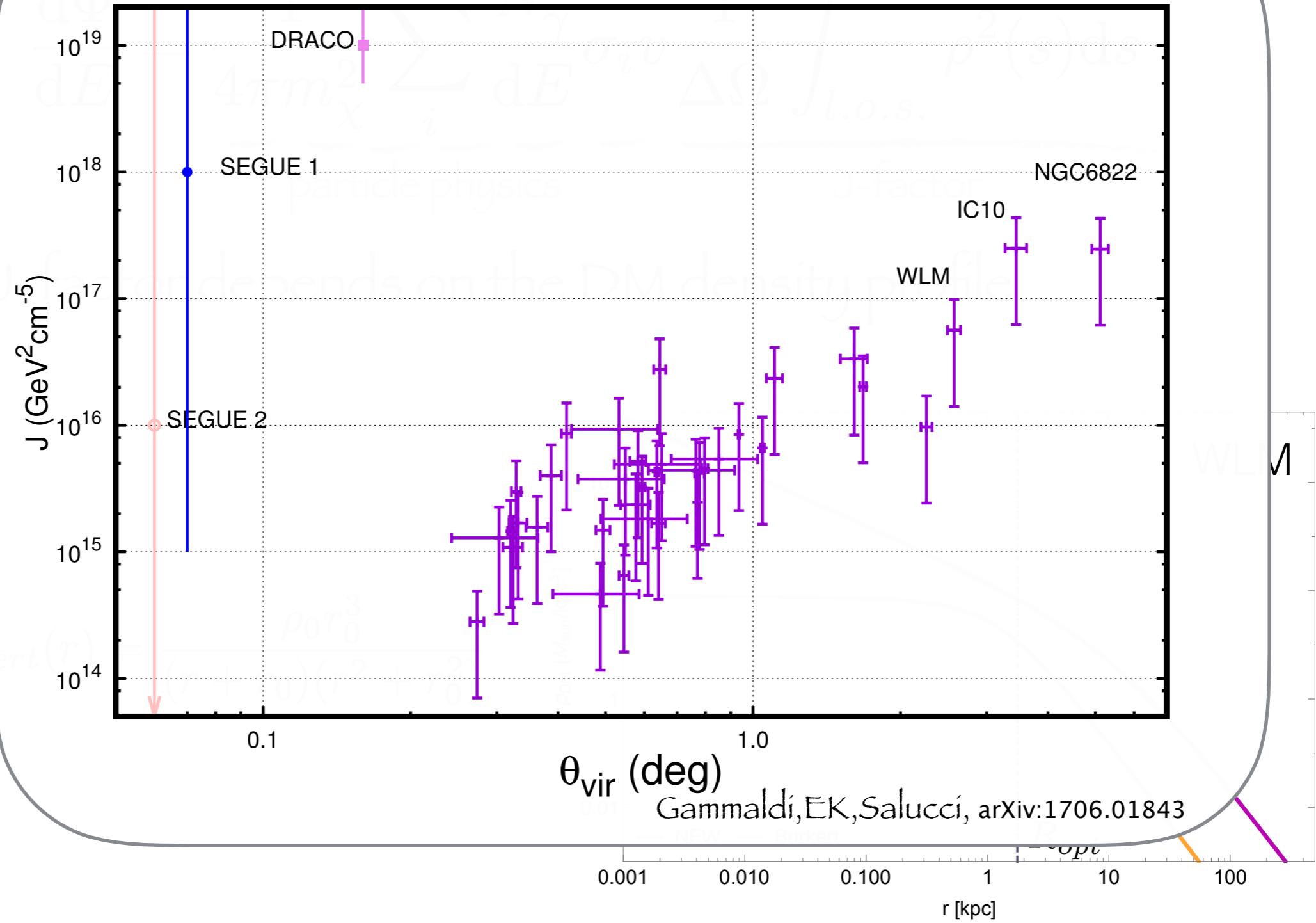


# DM indirect searches with gamma-rays

The different

where

$\rho_{Burk}$



# The astrophysical background

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- to assume that there is no astrophysical background and to analyse these galaxies in a similar way to dSphs (point-like analysis)

see Cadena, Alfaro, Sandoval, Belmont, Leon, Gammaldi, EK, Salucci for the HAWC Collaboraton, arXiv:1708.04642

- to apply masking procedure to the optical regions of dIrrs galaxies, where we have on-going star-formation (extended analysis )

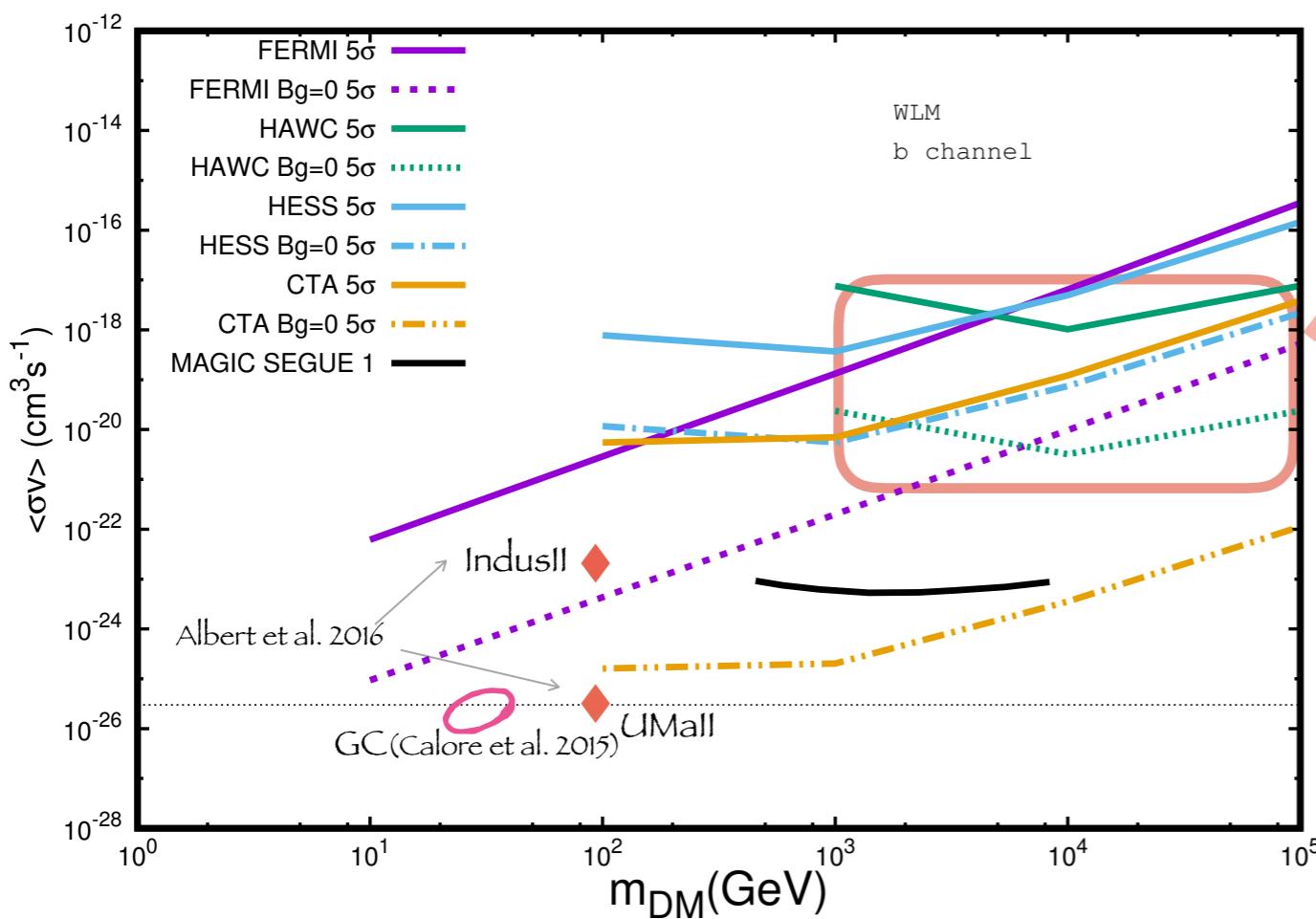
remember that in the case of the Burkert profile J-factors are not affected by masking

see Gammaldi, EK, Salucci arXiv:1706.01843

# Results

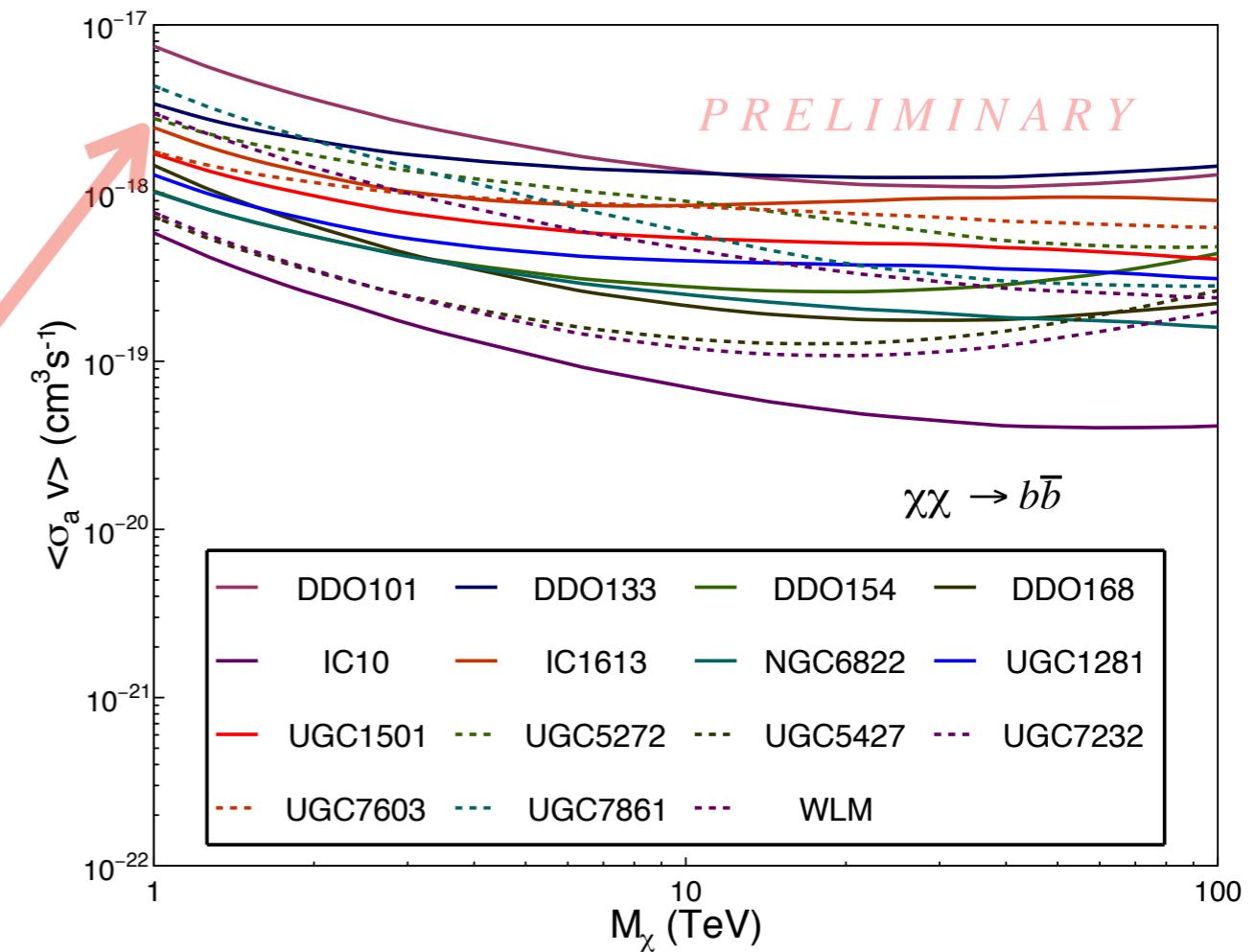
## Prospects

The PSF background is obtained by integration of the differential sensitivity on the energy range of each instrument and then scaling it for an extended source, for details see Funk&Hinton [arXiv:1205.0832]



Gammaldi, EK, Salucci, arXiv:1706.01843

## Point-like analysis with HAWC (preliminary results)



Cadena, Alfaro, Sandoval, Belmont, Leon, Gammaldi, EK, Salucci  
for the HAWC collaboration, arXiv:1708.04642

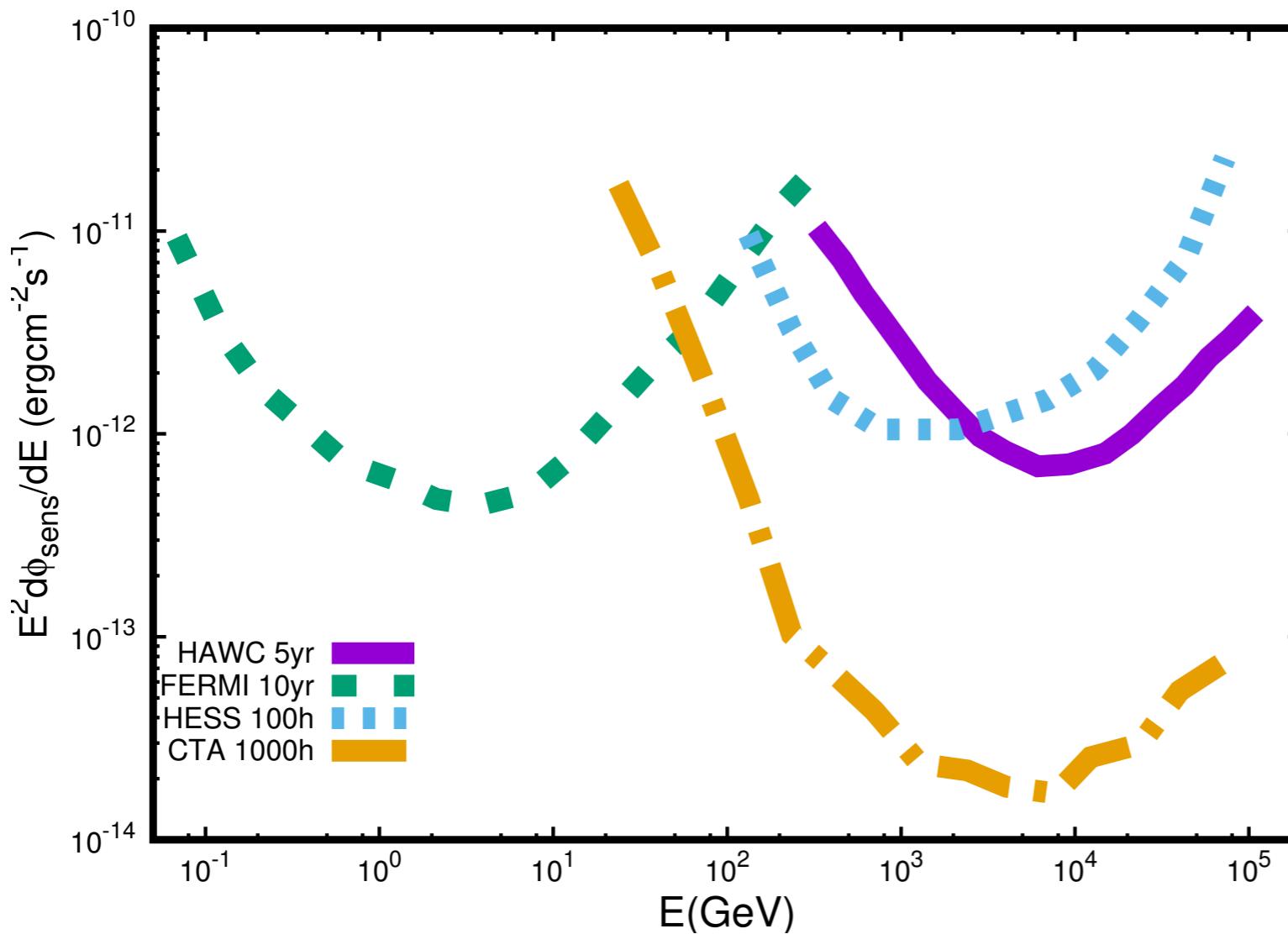


# Back Up Slides

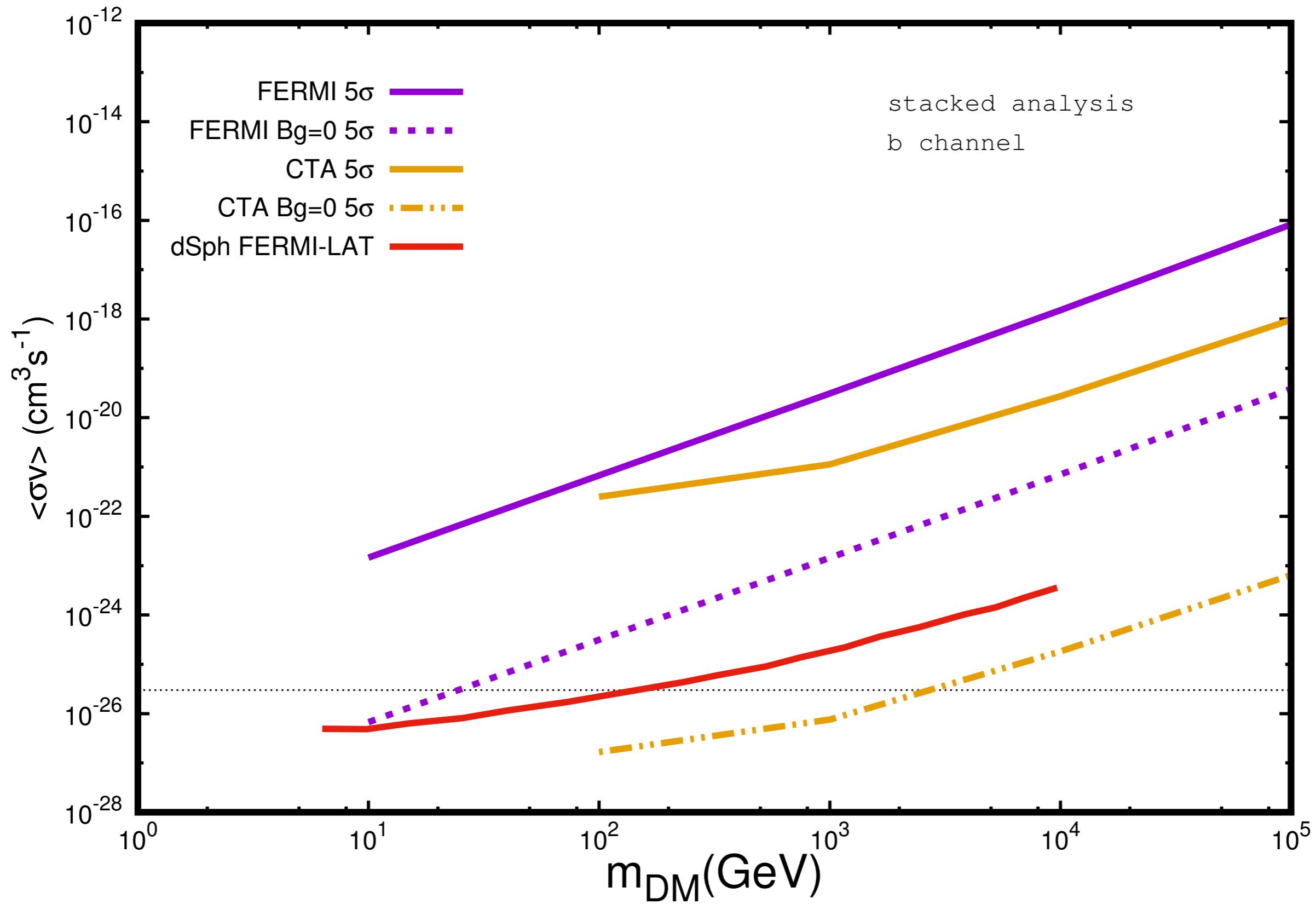
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# Gamma-ray telescopes

Experiment	Fermi-LAT	HESS I (II)	HAWC	CTA North/South
E range	20 Mev - 300 GeV	0.03- 100 TeV	0.1-100 TeV	0.02-200 TeV
$\Delta E$	10%	15%	50%	10%
FoV (deg)	> 50	5 (3.2)	wilde	10
$\theta_{\text{PSF}}$ (deg)	0.1 – 0.5	0.1	0.1	0.05
$A_{\text{eff}}(\text{cm}^2)$	$10^4$	$1(6) \times 10^6$	$10^5$	$10^{10}$
$t_{\text{exp}}$	10yr	100 h	5 yr	1000 h
$\phi_{\text{bg}}^{\text{PSF}}(\text{ph cm}^{-2}\text{s}^{-1})$	$1.31 \times 10^{-7}$	$7.65 \times 10^{-11}$	$3.18 \times 10^{-11}$	$3.09 \times 10^{-10}$



$$\chi = \frac{\phi_{\gamma}^{\text{Halo-DM}} \sqrt{\Delta\Omega_{\text{WLM}}^{\text{Halo}} A_{\text{eff}} t_{\text{exp}}}}{\sqrt{\phi_{\gamma}^{\text{Halo-DM}} + \phi_{\text{Bg}}^{\text{ext}}} } > 5$$



# Background of extended sources

$$\chi = \frac{\phi_{\gamma}^{\text{Halo-DM}} \sqrt{\Delta\Omega_{\text{WLM}}^{\text{Halo}} A_{\text{eff}} t_{\text{exp}}}}{\sqrt{\phi_{\gamma}^{\text{Halo-DM}} + \phi_{\text{Bg}}^{\text{ext}}}} > 5$$

$$\phi_{\text{bg}}^{\text{ext}} = \phi_{\text{bg}}^{\text{PSF}} \sqrt{\Delta\Omega_{\text{PSF}}^2 + \Delta\Omega_{\text{Halo}}^2}$$

Funk&Hinton [arXiv:1205.0832]

Experiment	Fermi-LAT	HESS I (II)	HAWC	CTA North/South
$\phi_{\text{WLM}}^{\text{ext}} (\text{ph cm}^{-2} \text{s}^{-1})$	$3.53 \times 10^{-6}$	$5.12 \times 10^{-8}$	$2.12 \times 10^{-8}$	$8.27 \times 10^{-7}$

Name	$\langle J \rangle_{\text{opt}} (\text{GeV}^2 \text{cm}^{-5})$	$\langle J \rangle_{\text{vir}} (\text{GeV}^2 \text{cm}^{-5})$
UGC1281	$5.65 \times 10^{15}$	$8.46 \times 10^{15}$
UGC1501	$4.05 \times 10^{15}$	$6.61 \times 10^{15}$
UGC5427	$7.00 \times 10^{15}$	$8.56 \times 10^{15}$
UGC7559	$1.17 \times 10^{15}$	$1.68 \times 10^{15}$
UGC8837	$1.46 \times 10^{15}$	$2.47 \times 10^{15}$
UGC7047	$3.30 \times 10^{15}$	$4.29 \times 10^{15}$
UGC5272	$2.79 \times 10^{15}$	$4.42 \times 10^{15}$
DDO52	$2.04 \times 10^{15}$	$3.25 \times 10^{15}$
DDO101	$8.80 \times 10^{14}$	$1.29 \times 10^{15}$
DDO154	$3.30 \times 10^{15}$	$4.54 \times 10^{15}$
DDO168	$1.68 \times 10^{16}$	$2.34 \times 10^{16}$
Haro29	$2.57 \times 10^{15}$	$2.99 \times 10^{15}$
Haro36	$2.57 \times 10^{15}$	$3.77 \times 10^{15}$
IC10	$2.01 \times 10^{17}$	$2.49 \times 10^{17}$
NGC2366	$1.26 \times 10^{16}$	$2.02 \times 10^{16}$
WLM	$4.35 \times 10^{16}$	$5.62 \times 10^{16}$
UGC7603	$3.22 \times 10^{15}$	$4.90 \times 10^{15}$
UGC7861	$7.04 \times 10^{15}$	$9.30 \times 10^{15}$
NGC1560	$2.29 \times 10^{16}$	$3.34 \times 10^{16}$
DDO125	$5.18 \times 10^{14}$	$6.48 \times 10^{14}$
UGC5423	$1.14 \times 10^{15}$	$1.46 \times 10^{15}$
UGC7866	$1.16 \times 10^{15}$	$1.49 \times 10^{15}$
DDO43	$1.99 \times 10^{14}$	$2.80 \times 10^{14}$
IC1613	$7.41 \times 10^{15}$	$9.70 \times 10^{15}$
UGC4483	$1.51 \times 10^{15}$	$1.69 \times 10^{15}$
KK246	$1.24 \times 10^{15}$	$1.57 \times 10^{15}$
NGC6822	$1.90 \times 10^{17}$	$2.46 \times 10^{17}$
UGC7916	$2.72 \times 10^{14}$	$4.64 \times 10^{14}$
UGC5918	$1.16 \times 10^{15}$	$1.81 \times 10^{15}$
AndIV	$8.67 \times 10^{14}$	$1.09 \times 10^{15}$
UGC7232	$2.44 \times 10^{16}$	$2.75 \times 10^{16}$
DDO133	$2.91 \times 10^{15}$	$4.18 \times 10^{15}$
UGC8508	$4.46 \times 10^{15}$	$5.17 \times 10^{15}$
UGC2455	$1.57 \times 10^{15}$	$2.36 \times 10^{15}$
NGC3741	$3.60 \times 10^{15}$	$4.00 \times 10^{15}$
UGC11583	$3.50 \times 10^{15}$	$5.40 \times 10^{15}$