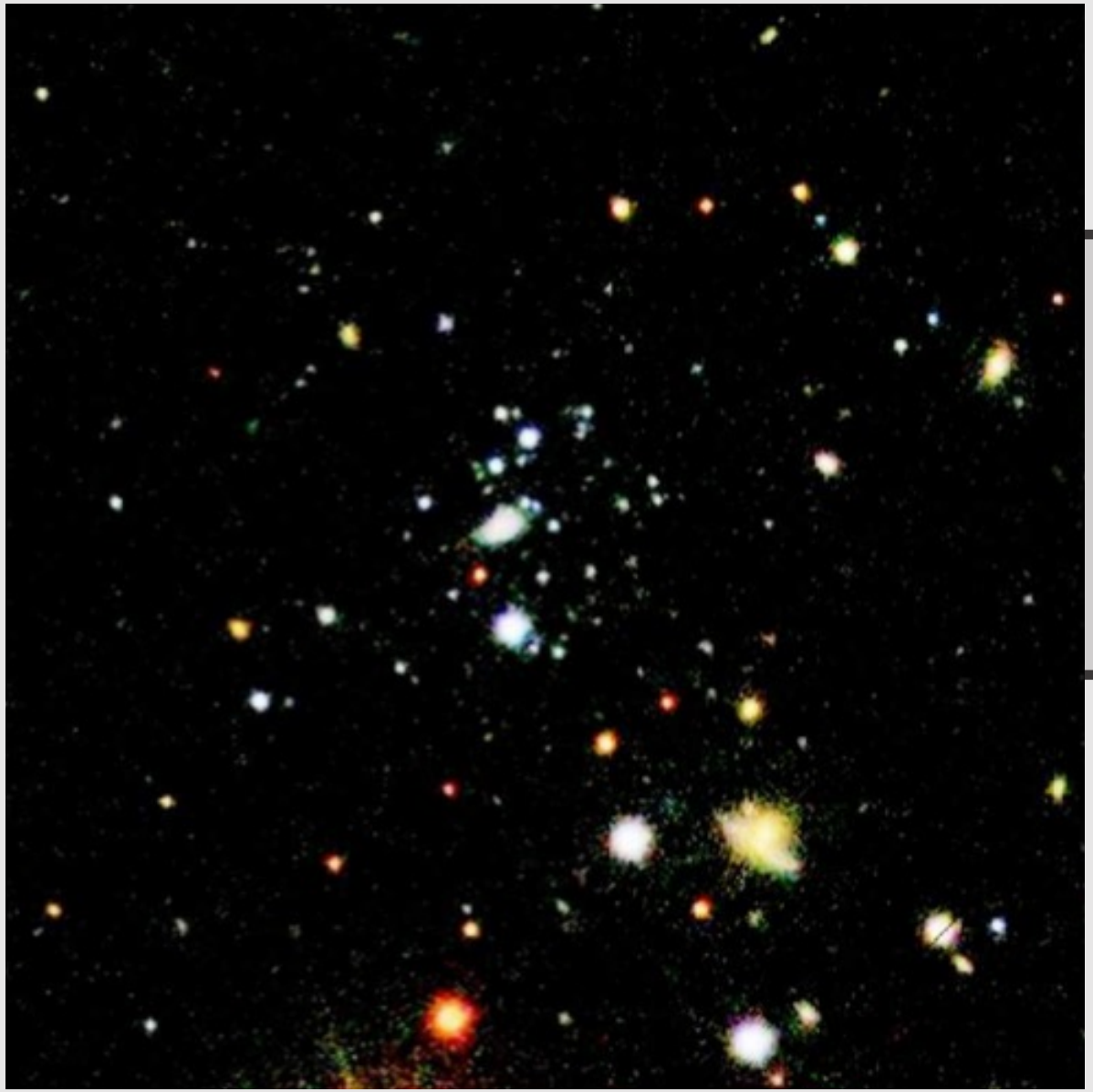


CONSTRAINING DARK MATTER ANNIHILATION WITH Fermi-LAT OBSERVATIONS OF ULTRA-FAINT COMPACT STELLAR SYSTEMS

Speaker: Antonio Circiello

Co-authors: A. McDaniel, A. Drlica-Wagner, C. Karwin, M. Di Mauro, M. Ajello, M. Sánchez-Conde

IDM - July 10, 2024

INTRODUCTION

- The Fermi-LAT is able to probe annihilating/decaying DM at the GeV-TeV energies
- MW dSphs are ideal targets due to proximity and low background
- DM content of dSphs can be gauged from scaling relations
- Fermi-LAT observations of dSphs have put stringent constraint on annihilating DM

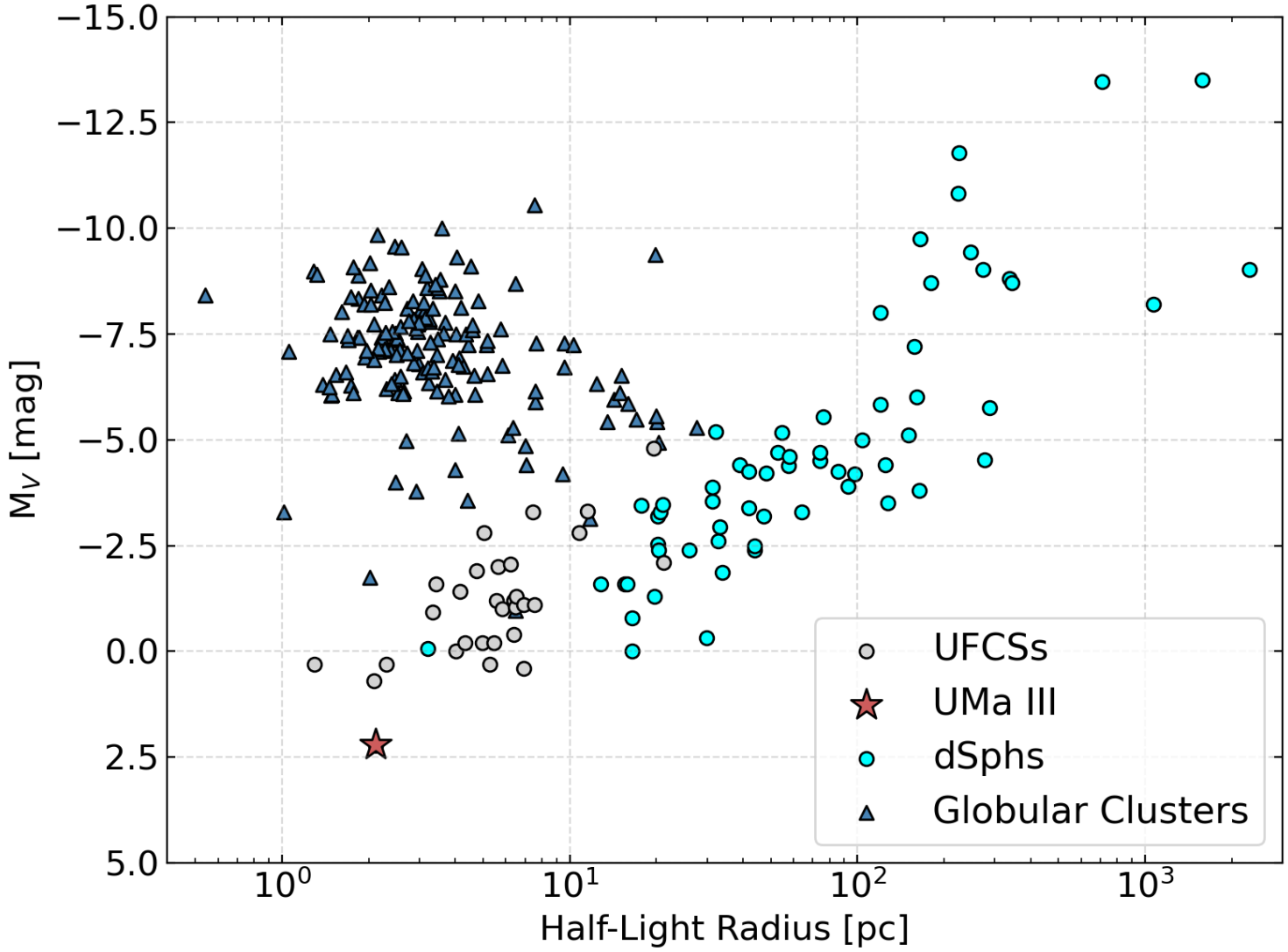
Title picture: Koposov 2 - Koposov et al. (2007)

ULTRA-FAINT COMPACT STELLAR SYSTEMS (UFCSs)

- Optical surveys like DES and Delve have been discovering a large number of ultra-faint compact stellar systems (UFCSs)

- Faint ($M_V > -5$) and Compact ($r_{1/2} < 30$ pc) targets, their nature is yet to be confirmed

- This work explores their potential as targets for DM annihilation studies


−15.0
−12.5
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
M_V [mag]
10^0
10^1
10^2
10^3
Half-Light Radius [pc]
UFCSs
UMa III
dSphs
Globular Clusters

An example:
Ursa Major III/UNIONS 1

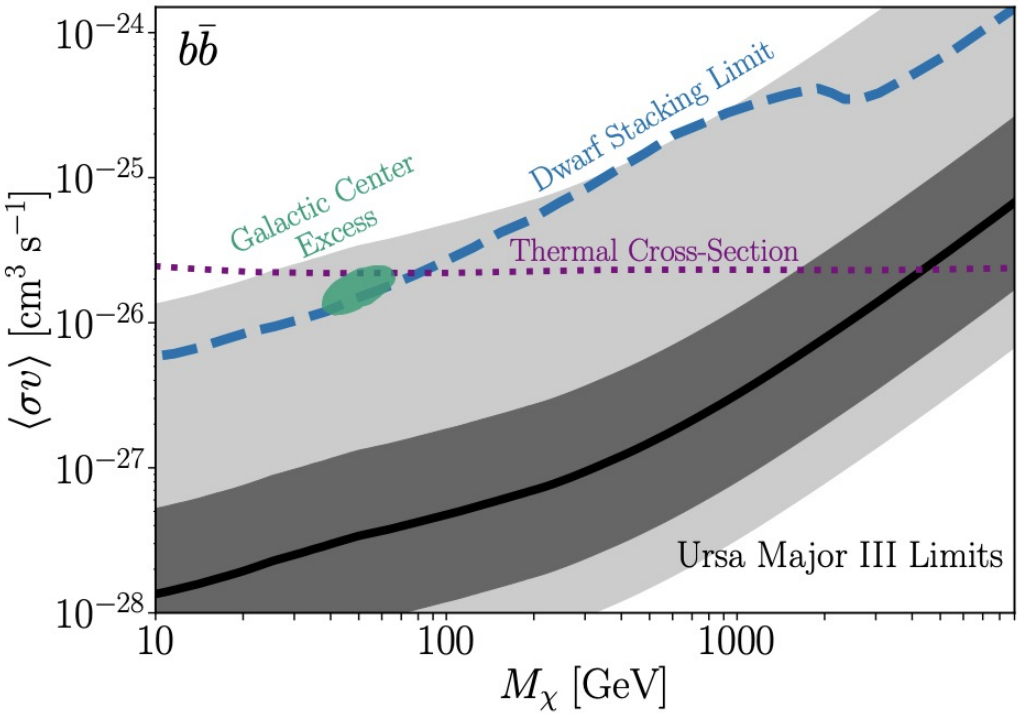
From **Errani et al. (2023b)**:
$D \sim 10$ kpc
$M_v \sim 2.2$
$r_{1/2} \sim 3$ pc
$V_d \sim 3.7$ km/s

UMa III could be the **NEAREST** and **FAINTEST** galaxy observed so far.

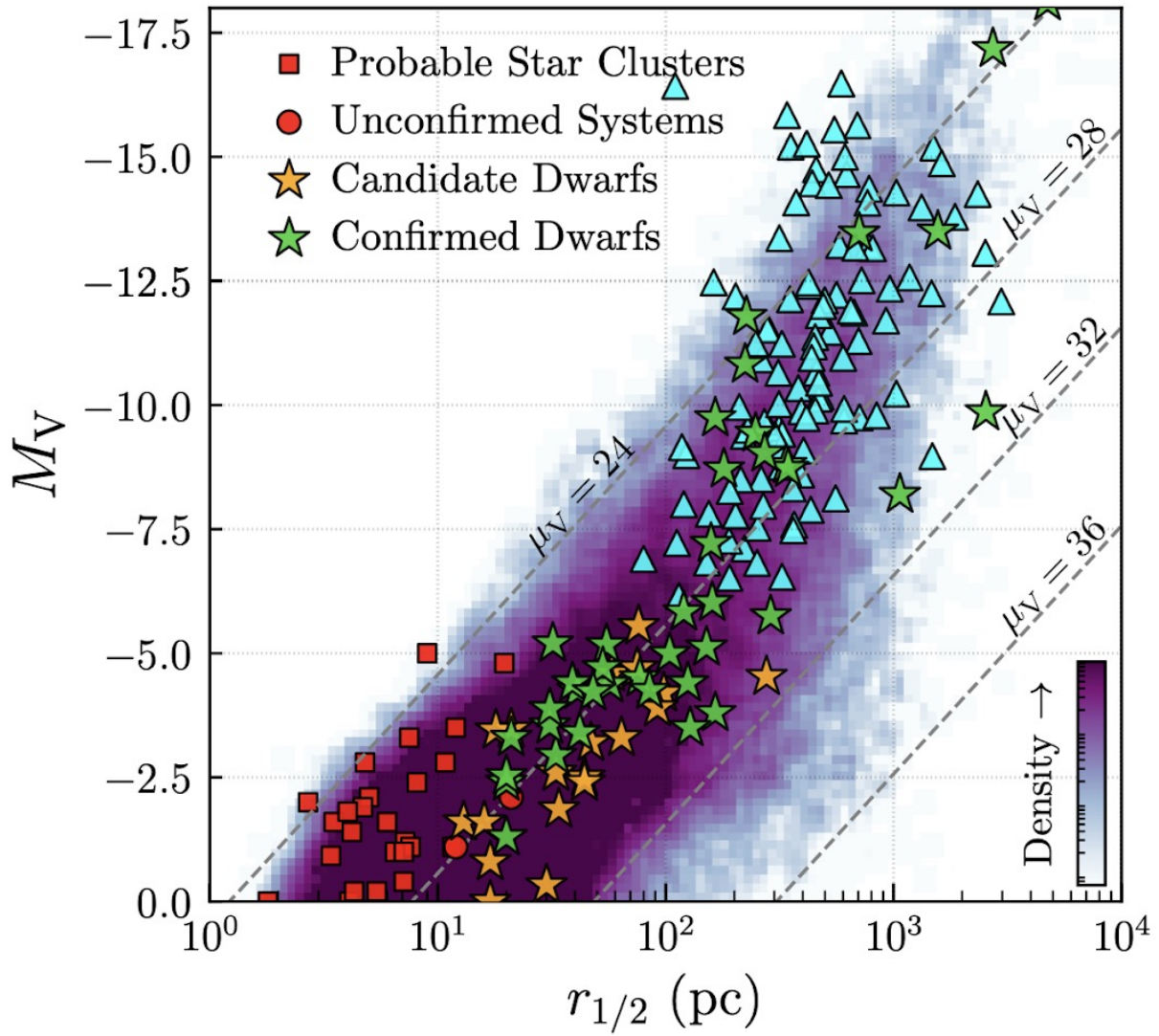
Measurements of V_d are uncertain, though simulations hint at the presence of a DM subhalo

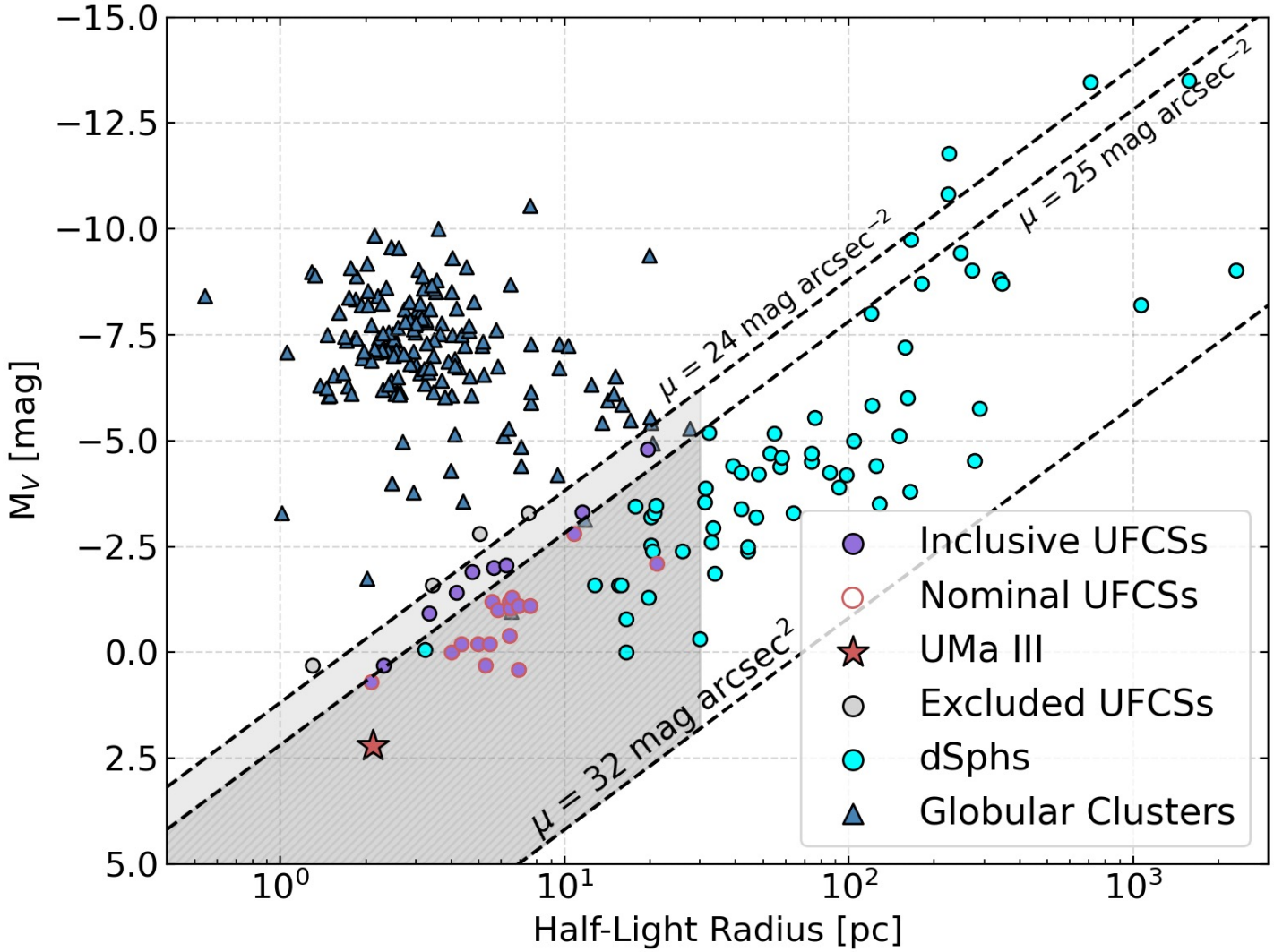
Crnogorčević & Linden, assuming DM-domination, showed that **UMa III can put strong constraints on DM annihilation**

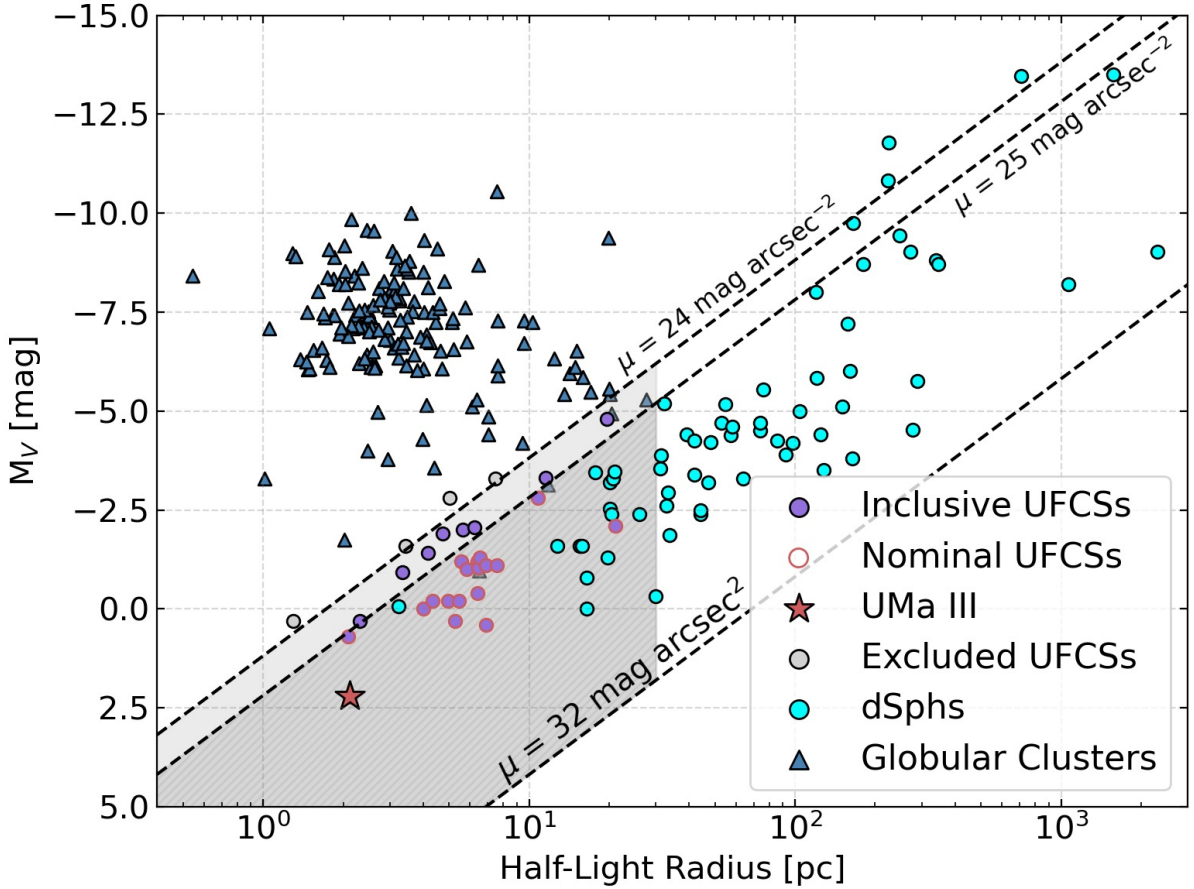
Crnogorčević & Linden (2023)



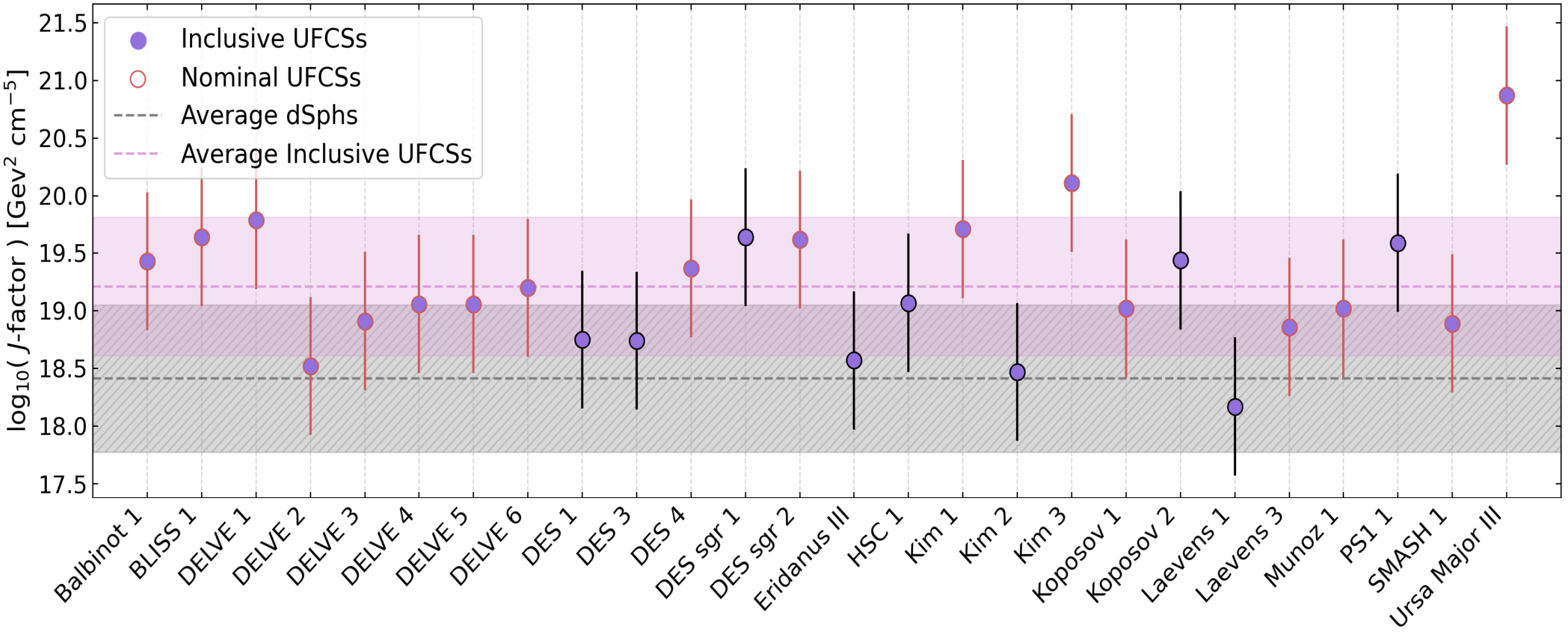
Manwadkar & Kravstov (2022)




−15.0
−12.5
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
M_V [mag]
10^0
10^1
10^2
10^3
Half-Light Radius [pc]
$\mu = 24$ mag arcsec^{-2}
$\mu = 25$ mag arcsec^{-2}
$\mu = 32$ mag arcsec^2
Inclusive UFCSs
Nominal UFCSs
UMa III
Excluded UFCSs
dSphs
Globular Clusters



- 26 targets in Inclusive sample
- 17 targets in Nominal sample
- No spatial coincidence with 4FGL-DR3, Roma-BZCat, CRATES, WIBRaLS


Inclusive UFCSs
Nominal UFCSs
Average dSphs
Average Inclusive UFCSs
log10(J-factor) [Gev2 cm−5]
21.5
21.0
20.5
20.0
19.5
19.0
18.5
18.0
17.5
Balbinot 1
BLISS 1
DELVE 1
DELVE 2
DELVE 3
DELVE 4
DELVE 5
DELVE 6
DES 1
DES 3
DES 4
DES sgr 1
DES sgr 2
Eridanus III
HSC 1
Kim 1
Kim 2
Kim 3
Koposov 1
Koposov 2
Laevens 1
Laevens 3
Munoz 1
PS1 1
SMASH 1
Ursa Major III

Fermi-LAT ANALYSIS

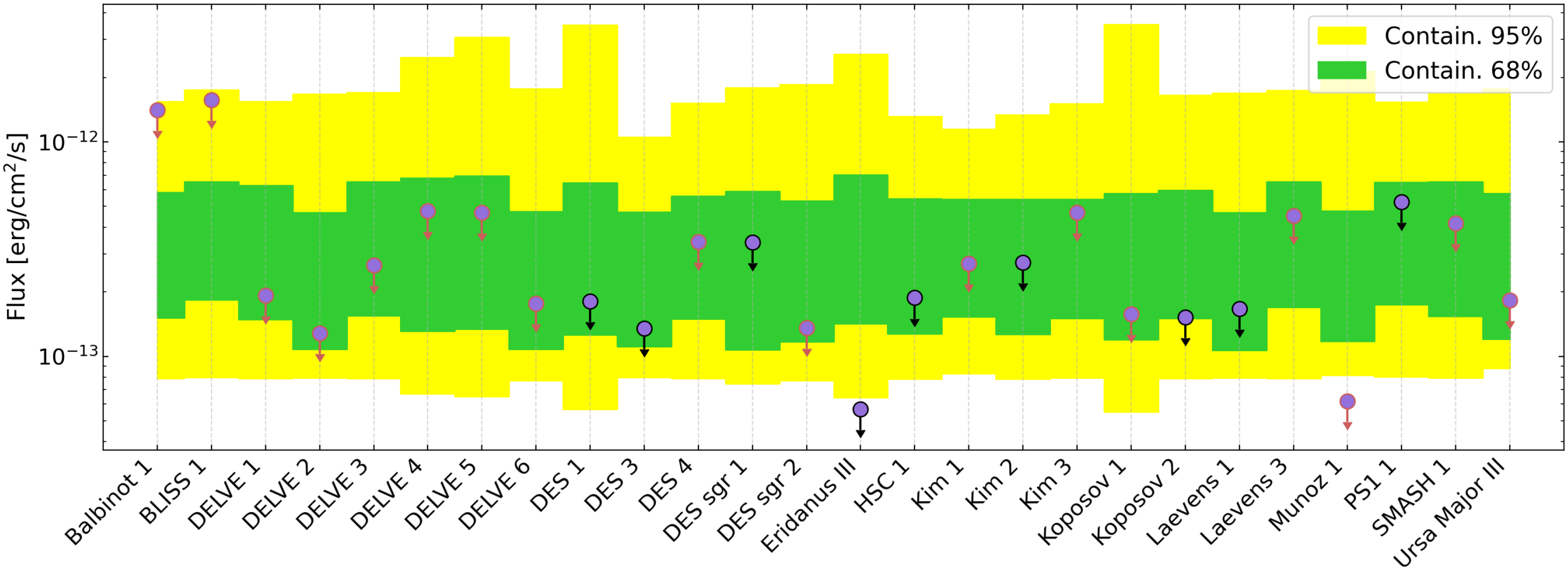
Follows directly McDaniel et al. (2023)

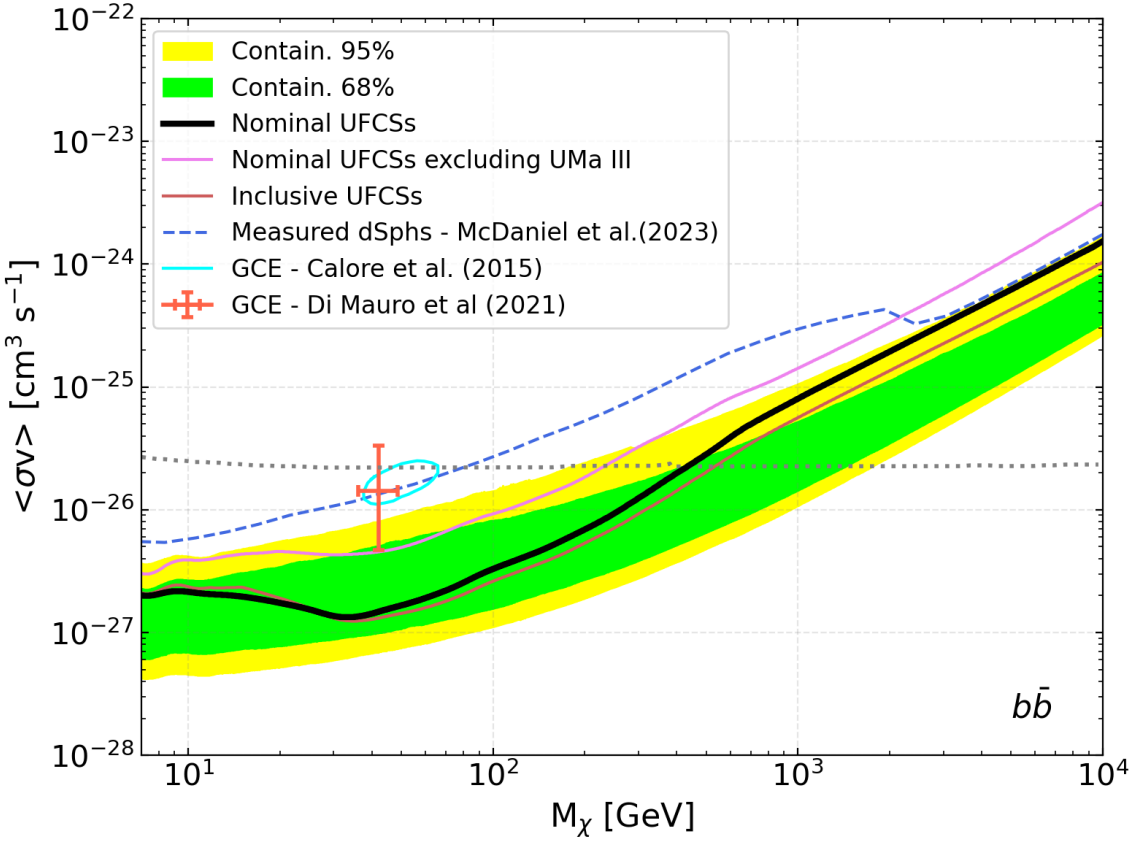
- 14.3 years of data
- Energy range: [500 MeV; 1 TeV]
- 8 energy bins per decade
- 10°x10° ROI
- 0.1° pixel size
- Joint Likelihood Analysis

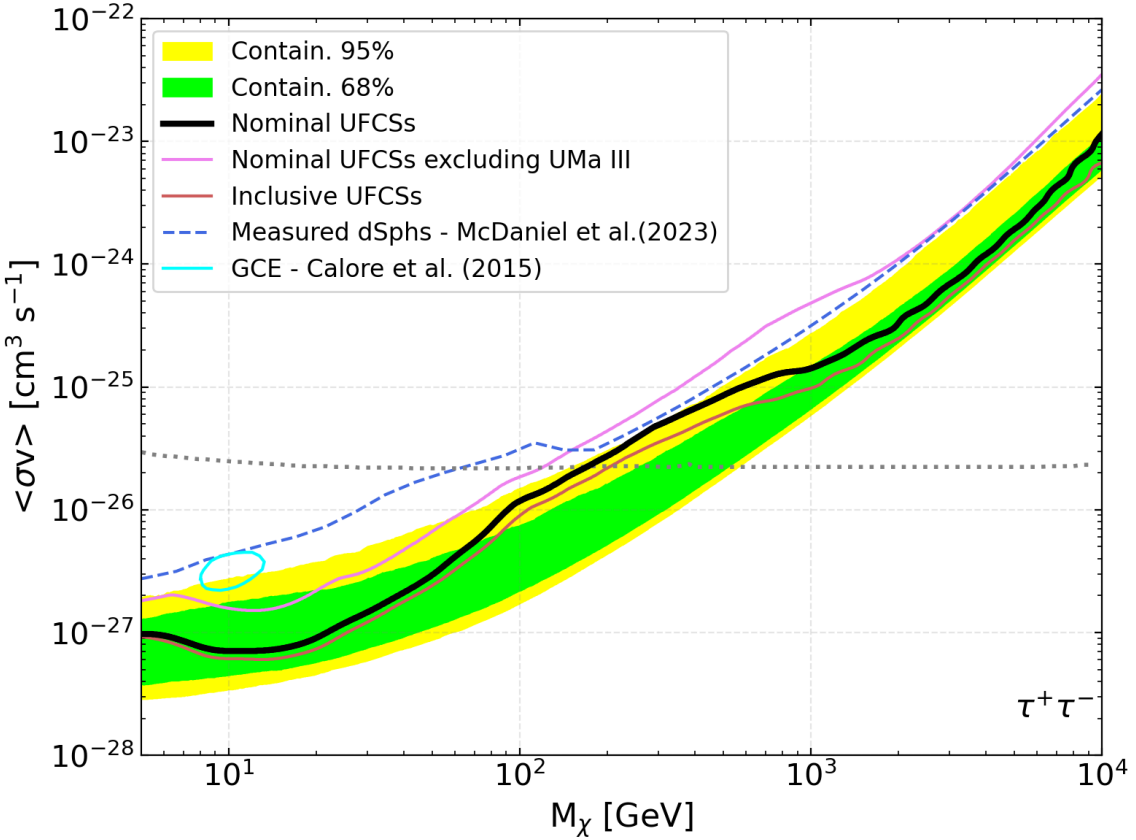
PREPROCESSING → TS PROFILES → STACKING

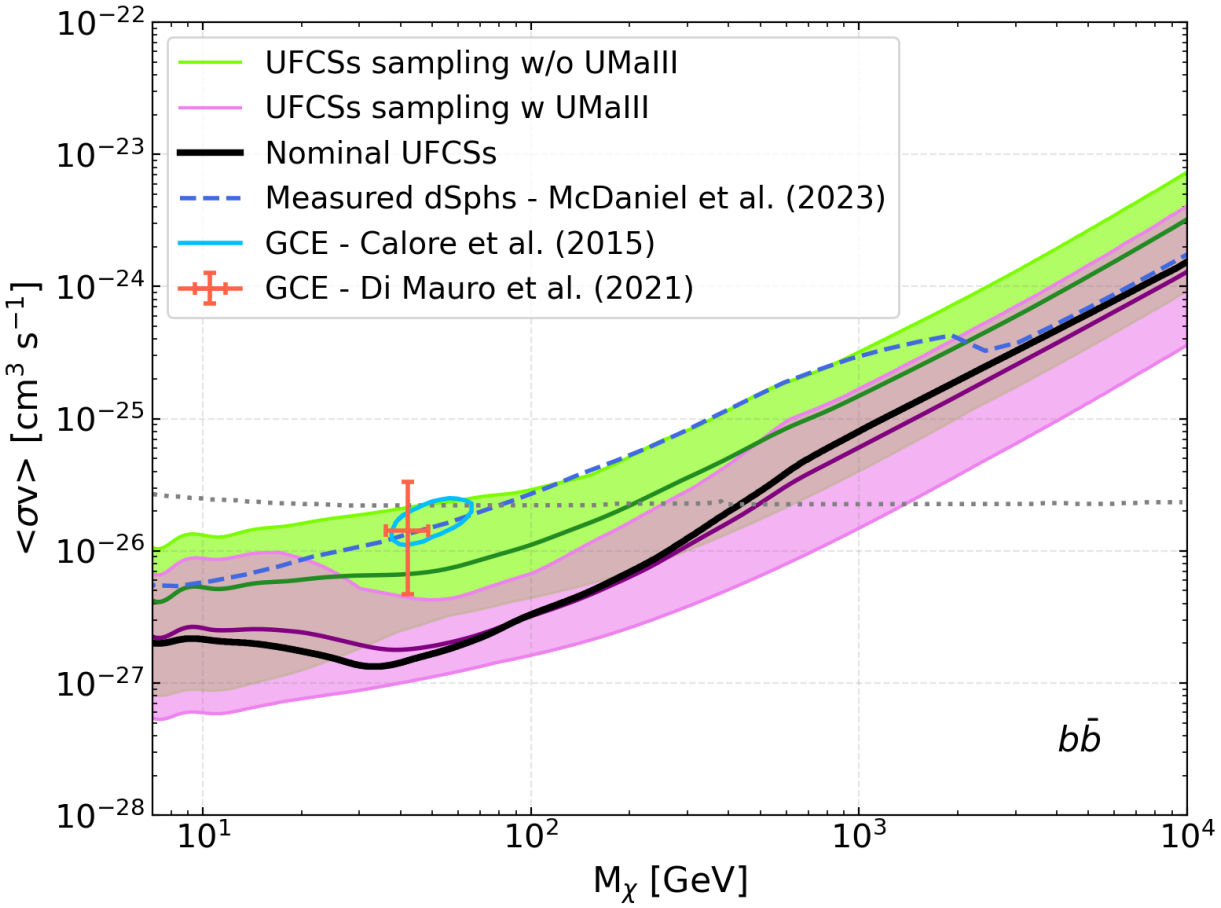
Compare to the background from 'blank-fields':

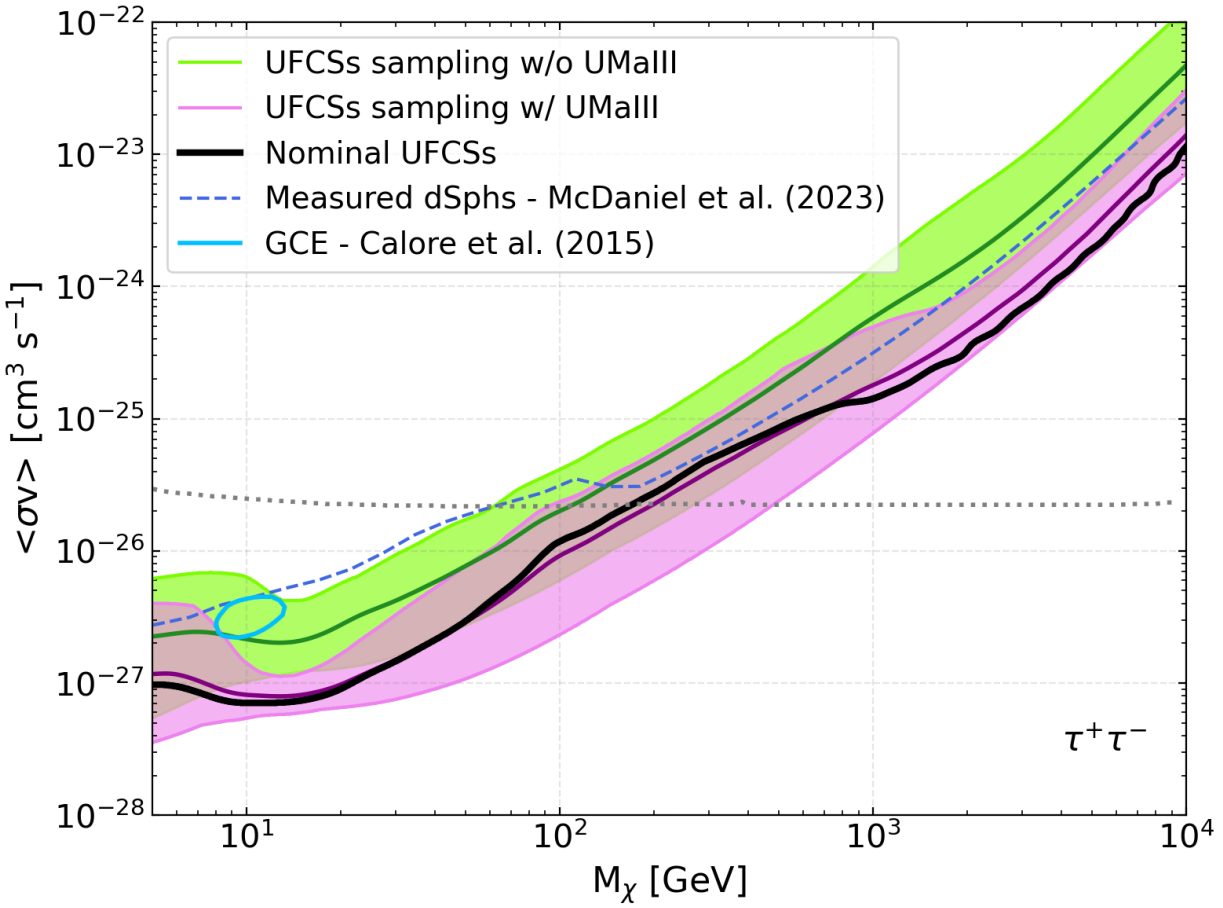
- Randomly selected regions $(b > |15°|)$ of the sky with no known or potential ɣ-ray source
- Selection of empty regions from McDaniel et al. (2023) (https://figshare.com/articles/dataset/24058650/1)
- Used to accounts for background effects due to undetected sources and imperfect modeling of the diffuse emission

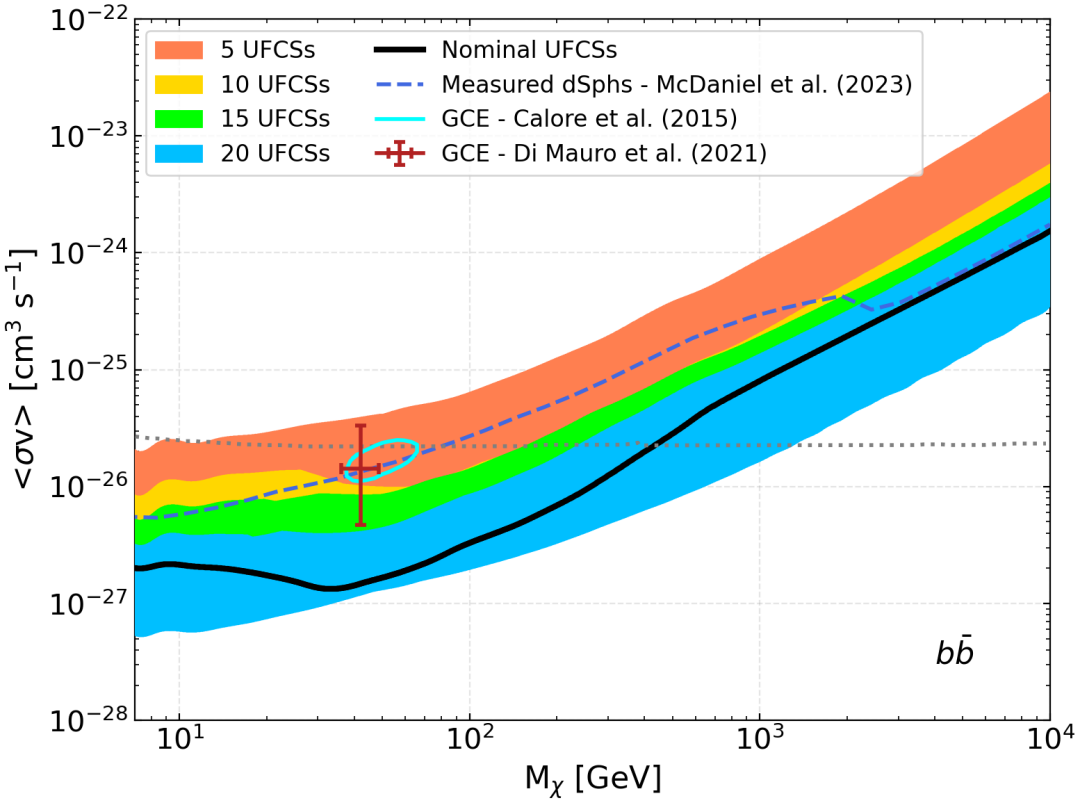

Contain. 95%
Contain. 68%
Flux [erg/cm^2/s]
10^{-12}
10^{-13}
Balbinot 1
BLISS 1
DELVE 1
DELVE 2
DELVE 3
DELVE 4
DELVE 5
DELVE 6
DES 1
DES 3
DES 4
DES sgr 1
DES sgr 2
Eridanus III
HSC 1
Kim 1
Kim 2
Kim 3
Koposov 1
Koposov 2
Laevens 1
Laevens 3
Munoz 1
PS1 1
SMASH 1
Ursa Major III

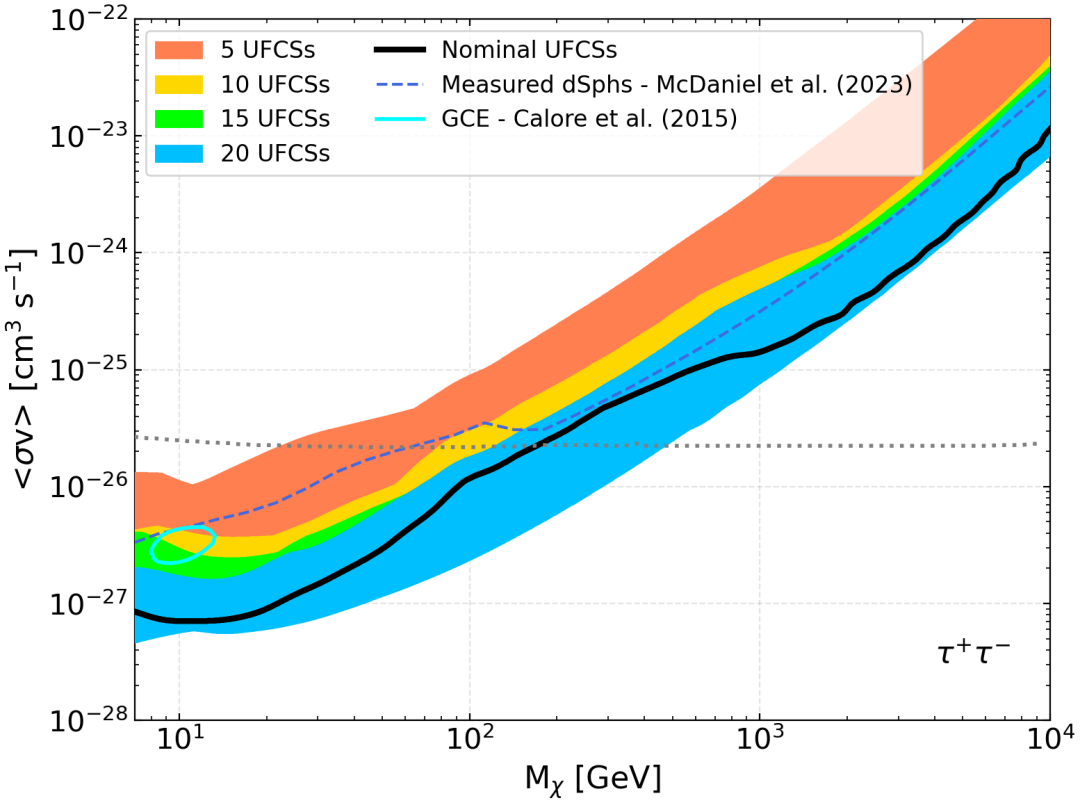

Contain. 95%
Contain. 68%
Nominal UFCSs
Nominal UFCSs excluding UMa III
Inclusive UFCSs
Measured dSphs - McDaniel et al.(2023)
GCE - Calore et al. (2015)
GCE - Di Mauro et al (2021)
$b\bar{b}$
$<\sigma v>$ [cm^3 s^{-1}]
M$_\chi$ [GeV]


Contain. 95%
Contain. 68%
Nominal UFCSs
Nominal UFCSs excluding UMa III
Inclusive UFCSs
Measured dSphs - McDaniel et al.(2023)
GCE - Calore et al. (2015)
$\tau^+\tau^-$
$<\sigma v>$ [cm^3 s^{-1}]
M$_\chi$ [GeV]


UFCSs sampling w/o UMaIII
UFCSs sampling w UMaIII
Nominal UFCSs
Measured dSphs - McDaniel et al. (2023)
GCE - Calore et al. (2015)
GCE - Di Mauro et al. (2021)
$b\bar{b}$
$<\sigma v>$ [cm^3 s^{-1}]
M$_\chi$ [GeV]


UFCSs sampling w/o UMaIII
UFCSs sampling w/ UMaIII
Nominal UFCSs
Measured dSphs - McDaniel et al. (2023)
GCE - Calore et al. (2015)
$\tau^+\tau^-$
$<\sigma v>$ [cm^3 s^{-1}]
M$_\chi$ [GeV]


5 UFCSs
10 UFCSs
15 UFCSs
20 UFCSs
Nominal UFCSs
Measured dSphs - McDaniel et al. (2023)
GCE - Calore et al. (2015)
GCE - Di Mauro et al. (2021)
$b\bar{b}$
$<\sigma v>$ [cm^3 s^{-1}]
M$_\chi$ [GeV]


5 UFCSs
10 UFCSs
15 UFCSs
20 UFCSs
Nominal UFCSs
Measured dSphs - McDaniel et al. (2023)
GCE - Calore et al. (2015)
$\tau^+\tau^-$
$<\sigma v>$ [cm^3 s^{-1}]
M$_\chi$ [GeV]

- UFCSs have the potential to put the most stringent constraints on DM properties so far.

- Improvement on dSphs even if only a part of the sample is confirmed to be DM dominated

- Our results emphasize the importance of precise observation on the UFCSs to determine their DM content empirically

Arxiv: 2404.01181

THANKS