Legacy analysis of Milky Way dwarf spheroidal satellite galaxies: an update

A. Circiello,
M. Di Mauro, M. Ajello, C. Karwin, A. Drlica-Wagner, M. Á. Sánchez-Conde

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Fermi-LAT

Launched in June, 2008

FoV of ~1/5 of the Sky

Scans the entire sky every 3 hours

Energy range ~20 MeV – 1 TeV

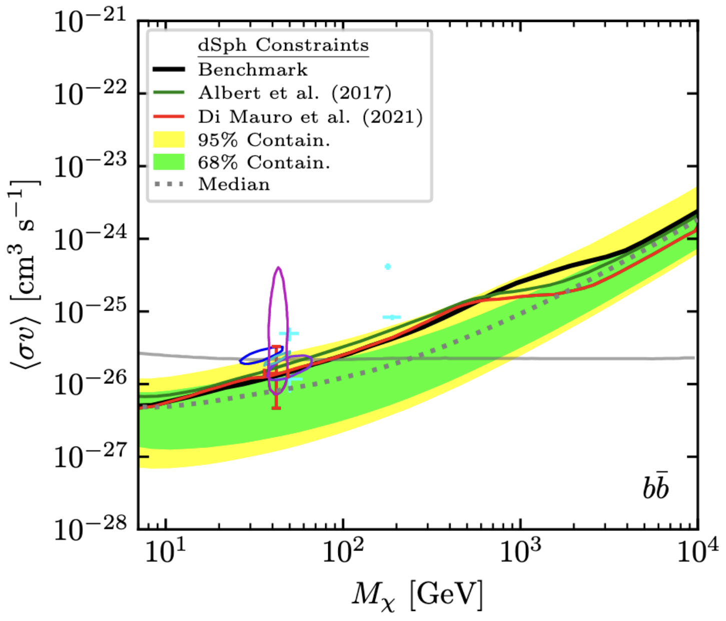
- The *Fermi*-LAT can look for signatures of annihilating/decaying WIMP DM with GeV-TeV mass

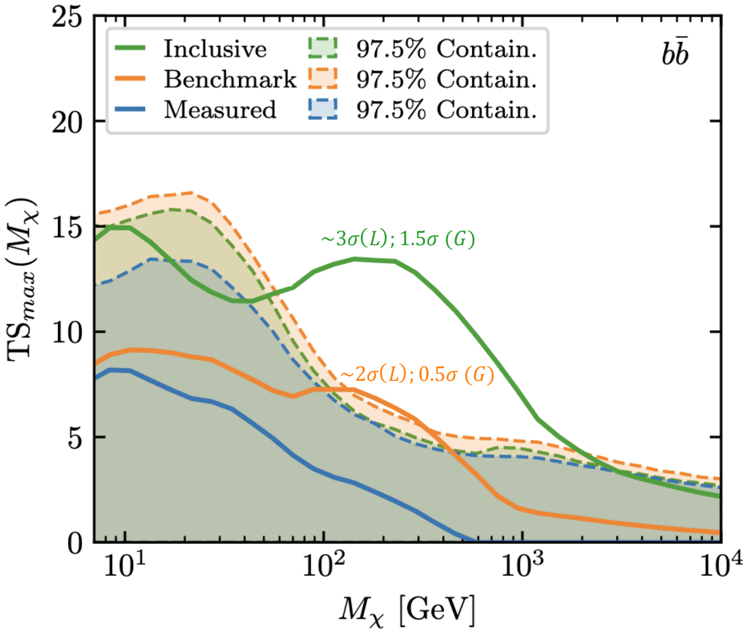
- Investigating Galactic Center, galaxy clusters, M31, isotropic ɣ-ray background, Milky Way dwarf Spheroidal satellite galaxies (dSphs)

- dSphs are especially good targets due to their high mass-to-light ratio, their proximity, and their lack of other other ɣ-ray processes

dwarf Spheroidal satellite galaxies

- 65+ detected dSphs galaxies of the MW, of which ~50 were used for the analysis
- The list of dSphs is divided in Measured, Benchmark and Inclusive samples, depending on the nature of their J-factor estimate
- Analyzes ~14 years of Fermi-LAT data, between 500 MeV and 1 TeV, assuming the PPPC4DMID framework for DM annihilation (*Cirelli et al, 2011*)
- Achieves the most stringent constraints on the cross-section for annihilation, excluding $M_\chi \lesssim 50\ GeV$ and generating slight tension with GCE results.
- Finds excesses of local significance in the combined sample over the background, although the significance is suppressed when accounting for the number of trial masses and different annihilation channels.

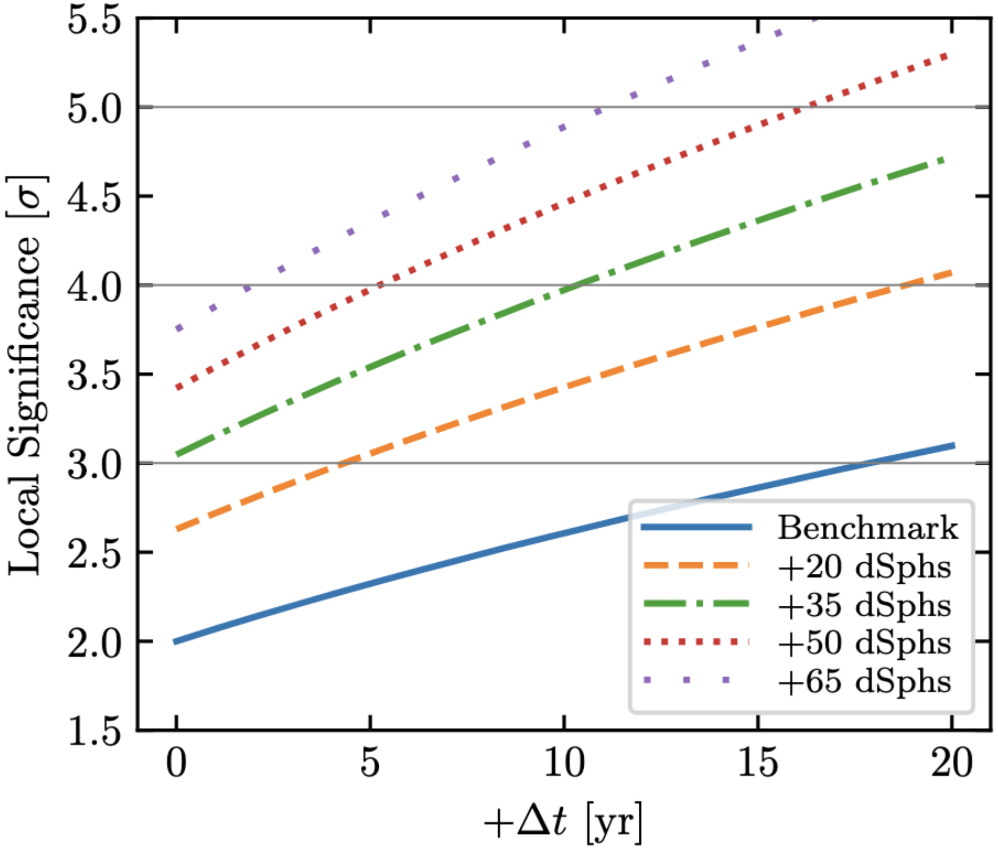




Future of dSphs studies

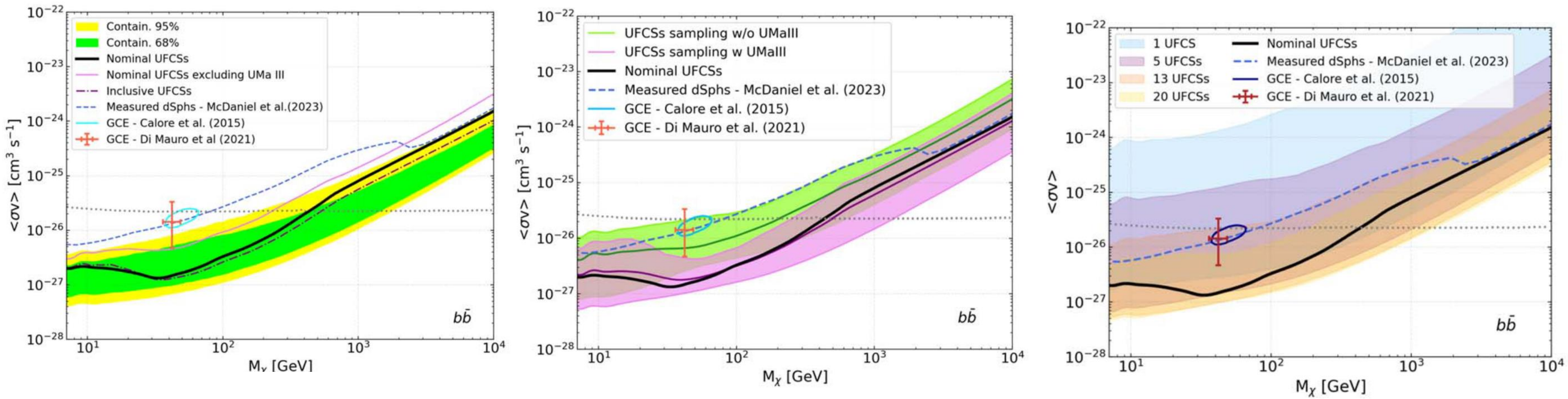
- Better sensitivity can be achieved through more years of data, a larger sample, better estimates of the J-factors and improved models for the background
- Assuming that the excess is genuine, *McDaniel et al. (2024)* predicts that it will reach the 4-5σ CL in the next 10 years with the detection of 30-60 additional dSphs
- The upcoming Legacy Survey of Space and Time (LSST) of the Vera C. Rubin Observatory is expected to detect 89 ± 20 new dSphs over the next decade (*Tsiane et al., 2025*)
- Data previews expected in 2026-2027, first Data release expected early 2028

McDaniel et al. (2024)



UFCSs

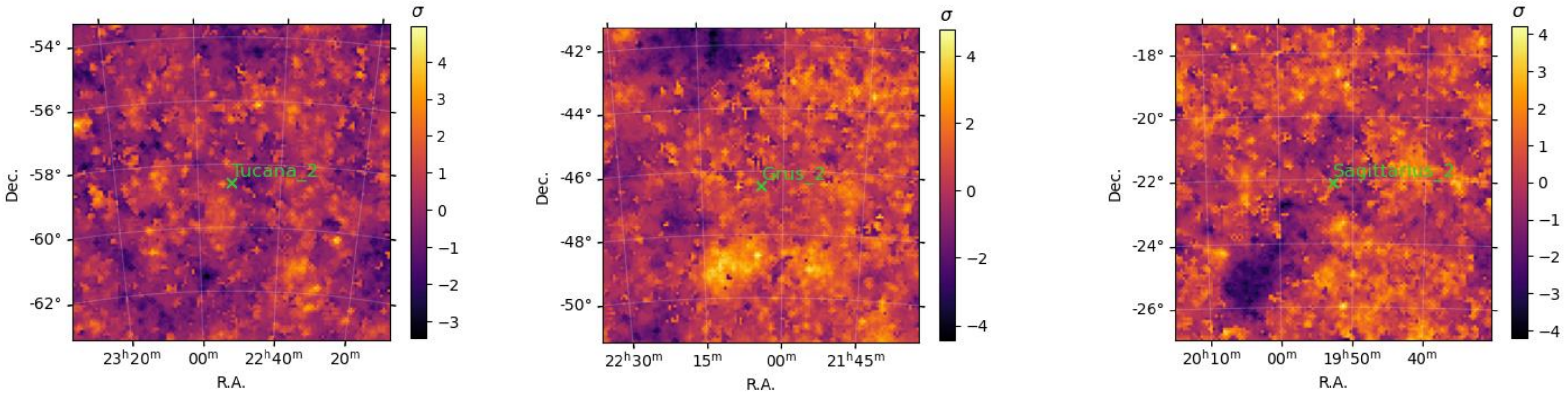
- Recently discovered Ultra-Faint Compact Stellar Systems (UFCS) blur the line between dSphs and DM-devoid satellites
- Among the faintest ($M_V > -5$) and most compact ($r_{1/2} < 30$ pc) satellites observed so far, on average closer than the dSphs
- Due to limited number of member stars, it is difficult to confirm whether they are DM-devoid or DM-dominated.
- UFCSs have the potential to put the most stringent constraints on DM properties so far.
- Even with a small number of targets confirmed to be DM-dominated, there would be a strong impact on the current ULs for the annihilation cross-section.



Can the analysis be improved?

Circiello et al. (2026)

When evaluating the PS Maps of the ROIs following the analysis methods outlined in McDaniel et al. (2024), they show margin for improvement

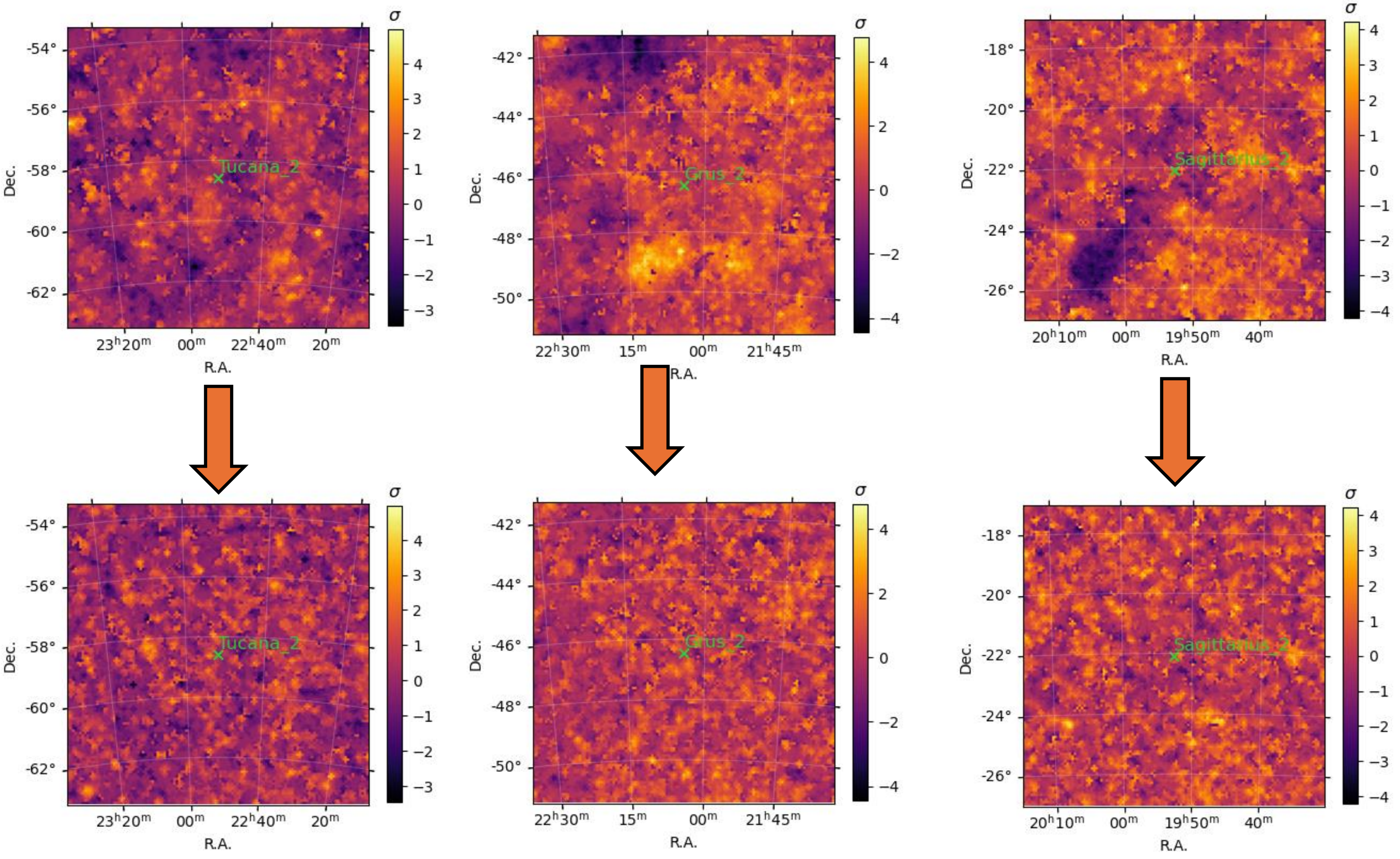


With stricter data selection and a more careful modeling we can reduce the mismatch between the models and the data:

- Add ~2 years of data
- Update to DR4
- SOURCEVETO event class
- Raise the minimum photon energy to 2 GeV
- Increase the number of blank fields (null hypothesis)
- Update the DM model (CosmiXs – Arina et al., 2023)

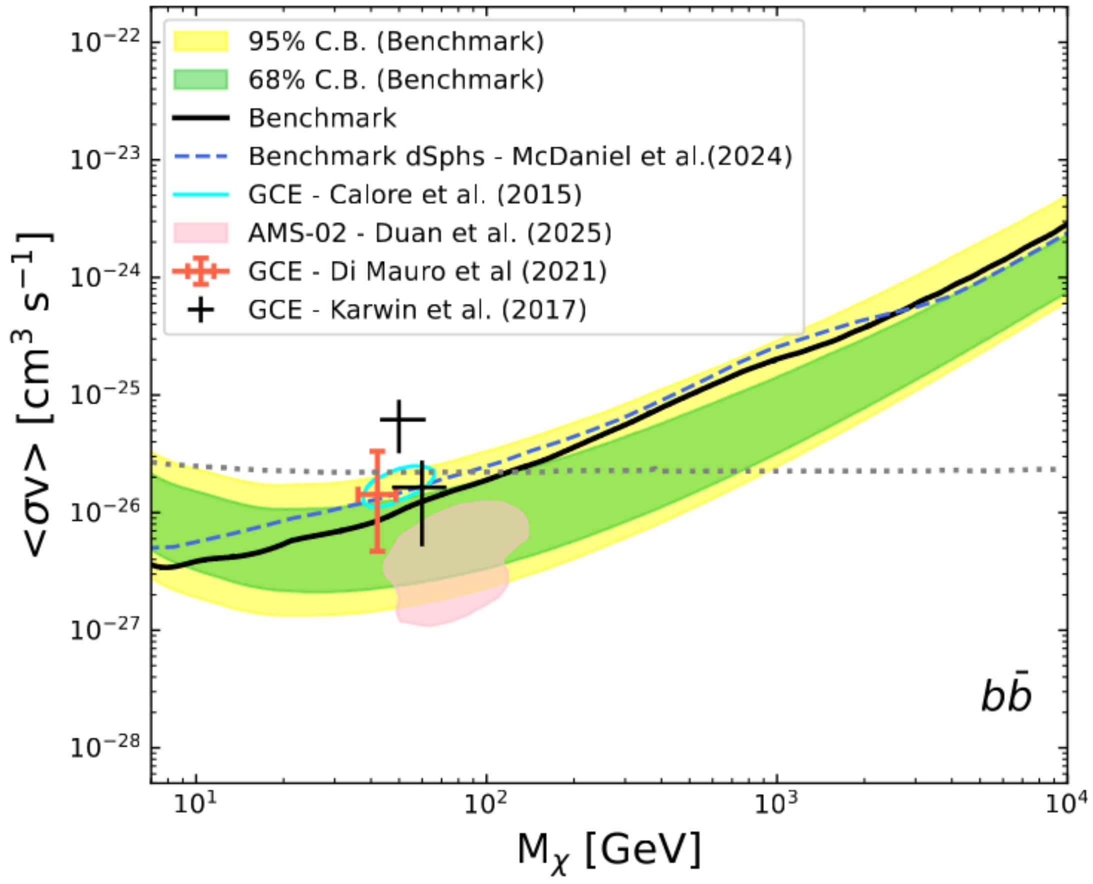
Did the models improve?

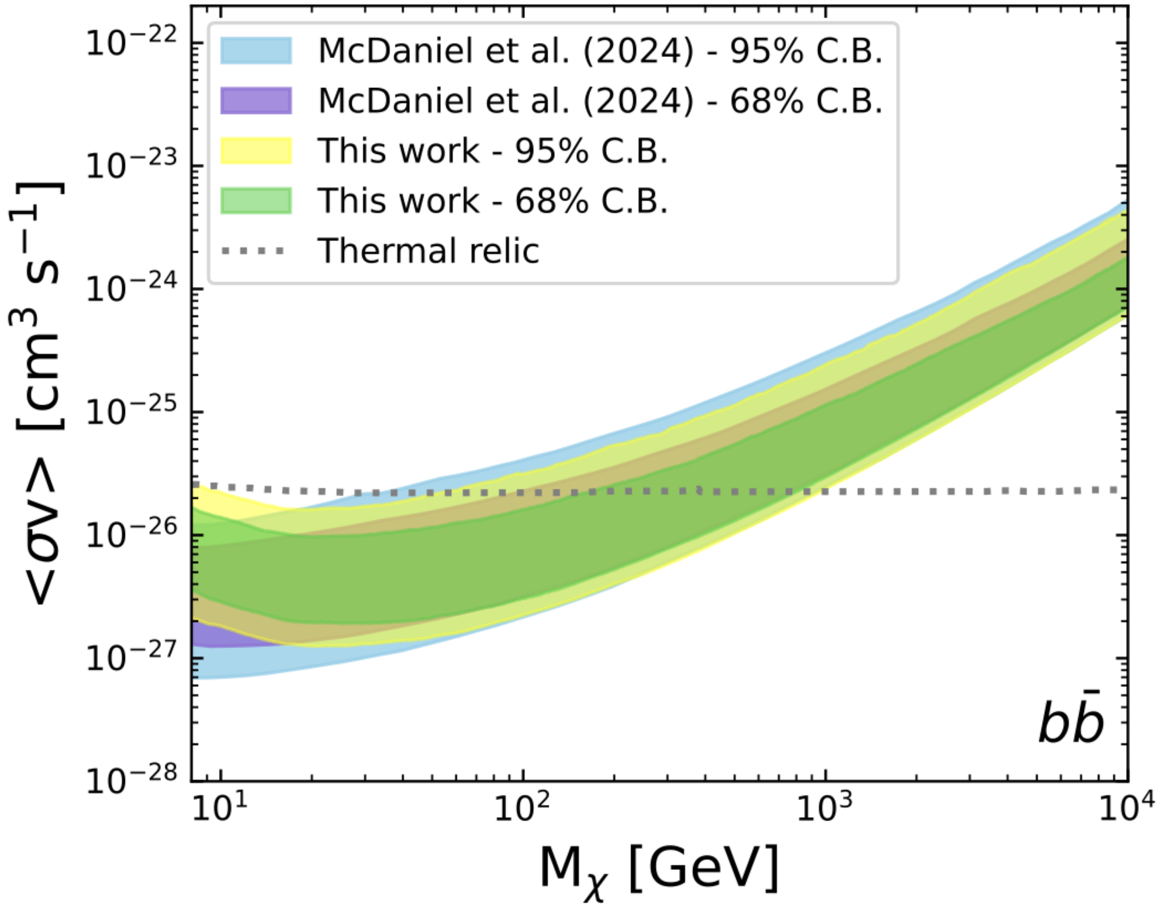
Circiello et al. (2026)



What happened to the sensitivity?

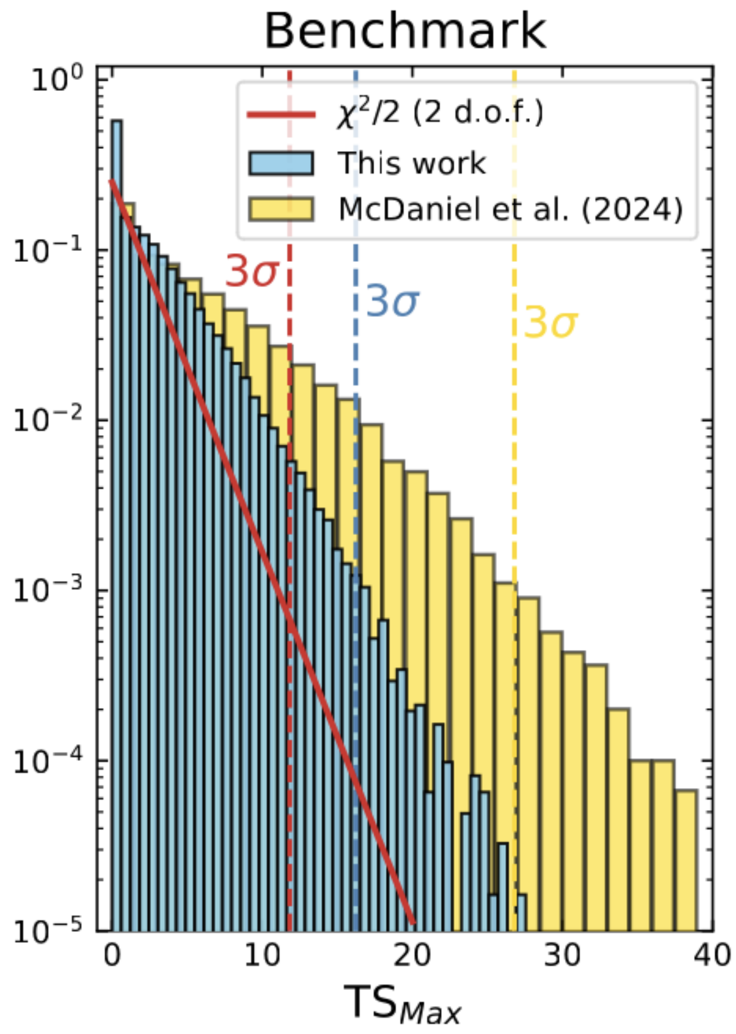
The changes to the analysis have marginal effects on the ULs for the cross-section of annihilation, suggesting that we haven't affected the sensitivity.





Null hypothesis (blank fields)

- We use the blank fields analysis to characterize the null hypothesis (i.e., signal only due to the background).
- We analyze combinations of 6500 blank fields
- The width of the distribution of the null hypothesis has become smaller with the new analysis



Results 2 – Significance excesses

Circiello et al. (2026)

This produces an increase of the local (effect equivalent to ~10 years of additional data) and global significances (~doubled) for the Benchmark and Inclusive sample.

McDaniel et al. (2024)

$b\bar{b}$	M_χ [GeV]	p_{local}	p_{global}
Measured	8.4	8.9×10^{-2} $(1.4\,\sigma)$	2.0×10^{-1} $(0.8\,\sigma)$
Benchmark	180.5	1.7×10^{-2} $(2.1\,\sigma)$	2.4×10^{-1} $(0.7\,\sigma)$
Inclusive	289.4	6.0×10^{-4} $(3.2\,\sigma)$	5.2×10^{-2} $(1.6\,\sigma)$

This work

$\bar{b}b$ channel			
Sample	M_χ [GeV]	p_{local}	p_{global}
Measured	112.5	5.8×10^{-2} (1.6σ)	2.7×10^{-1} (0.6σ)
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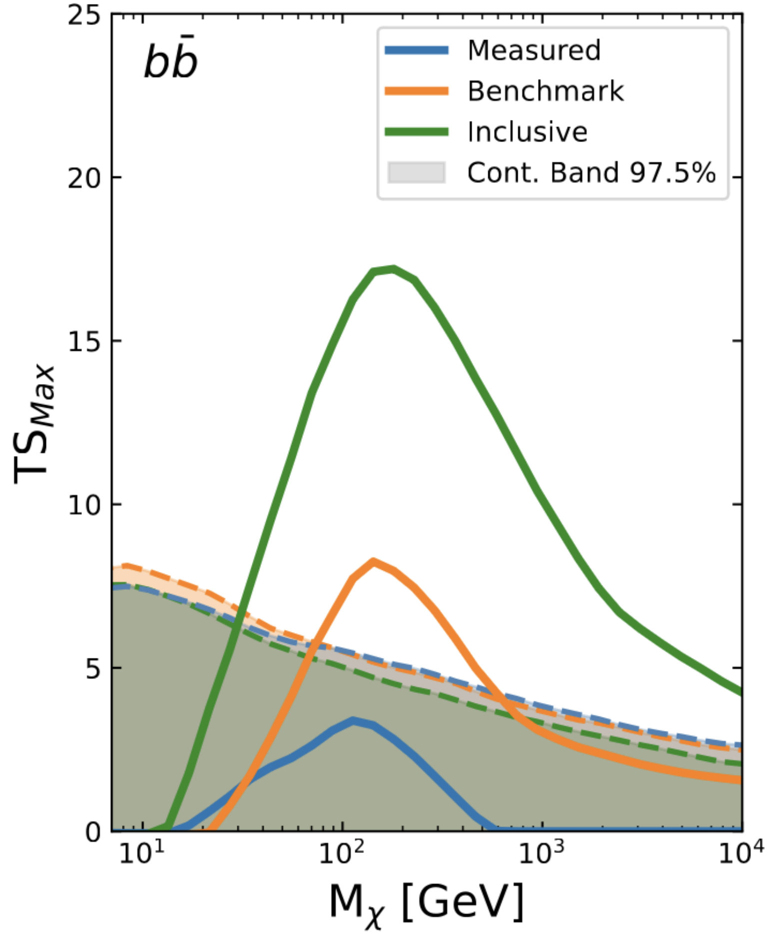

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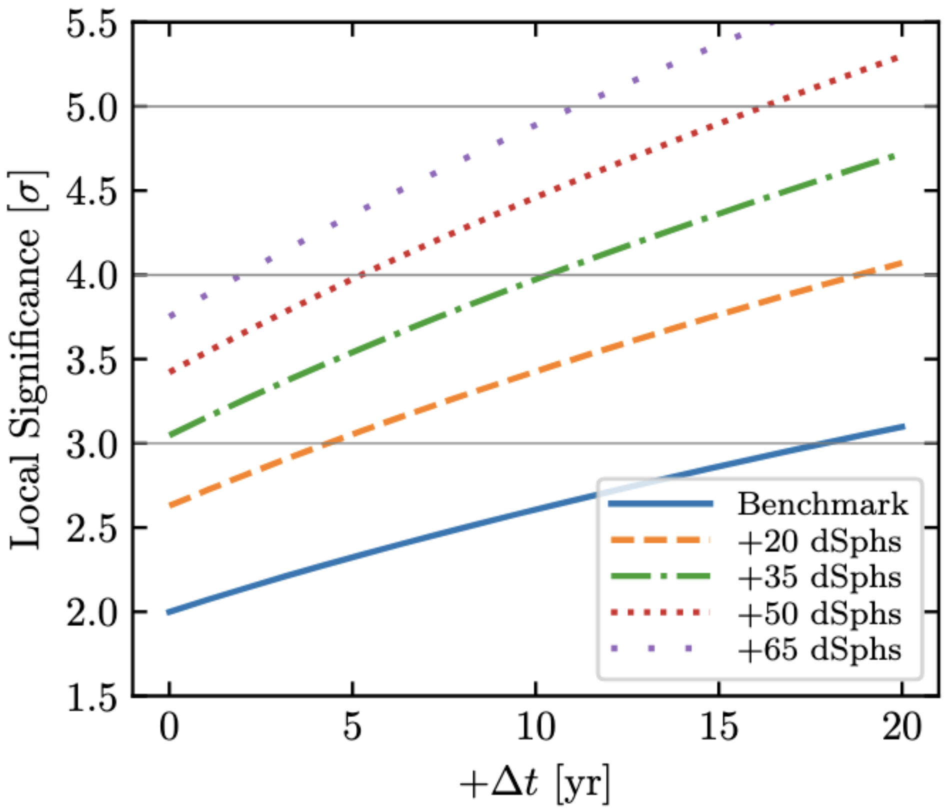
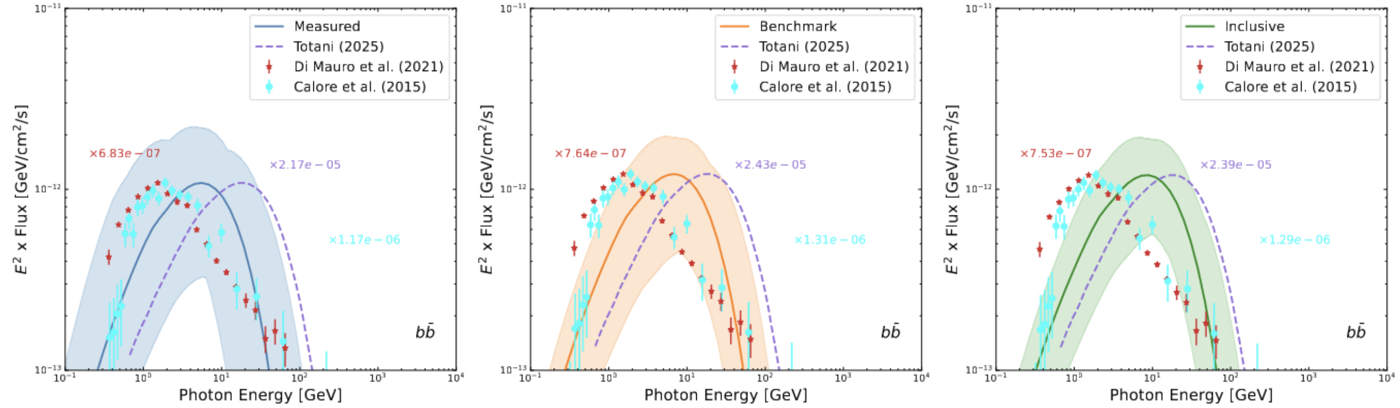
Predictions from McDaniel et al. (2024)



Results 3 – Expected M_χ

The peaks in significance in the three samples show better agreement on the expected values of M_χ, and are compatible with the DM interpretation of the Galactic center excess and the anti-proton excess.



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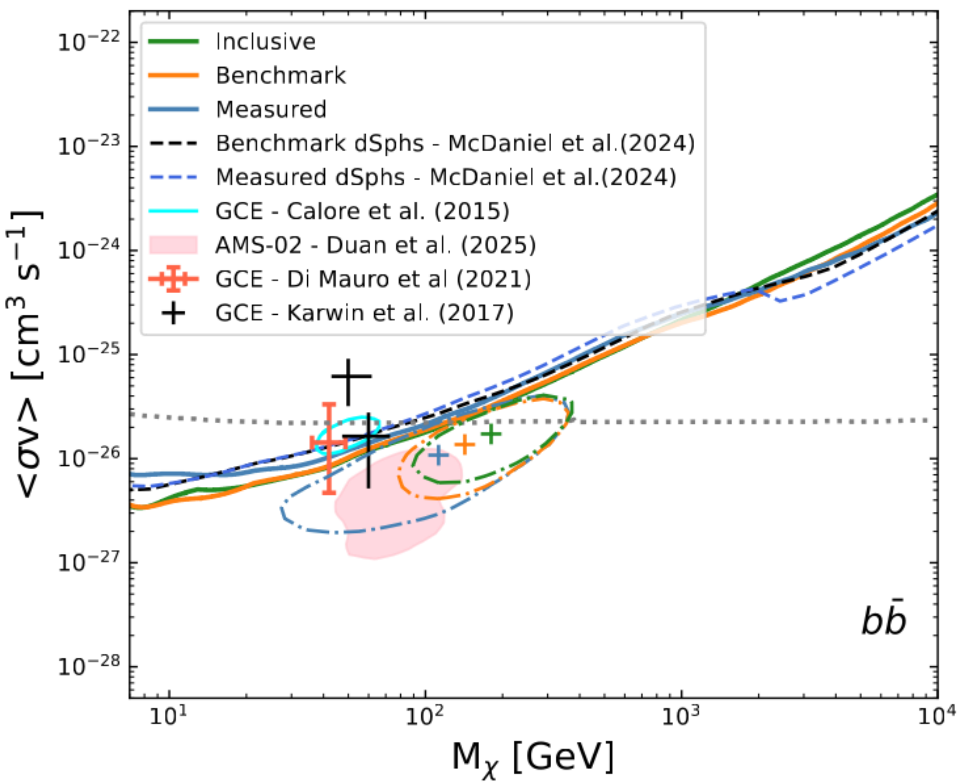

In summary…

- Analyses of *Fermi*-LAT data coincident with the dSphs have put some of the most stringent constraints on annihilating DM in the GeV - TeV range, and highlighted the presence of small local significance excesses

- In the next decade we expect to double or more the size of the sample of detected dSphs, thanks to LSST, which could rule-out/confirm the γ-ray excess

- In preparation for the upcoming data we can improve our analysis methods, applying stricter data selection and using PS and TS Maps to refine the models

- We obtain a better modeling of the blank fields, which produces a rise in the local and global significance of the results, corresponding to ~10 years of additional data, without affecting the sensitivity to DM signals

- Additionally, the predictions on the DM candidate mass are in better agreement between the samples and with the GCE and anti-proton excess determinations

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SCAN ME

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