

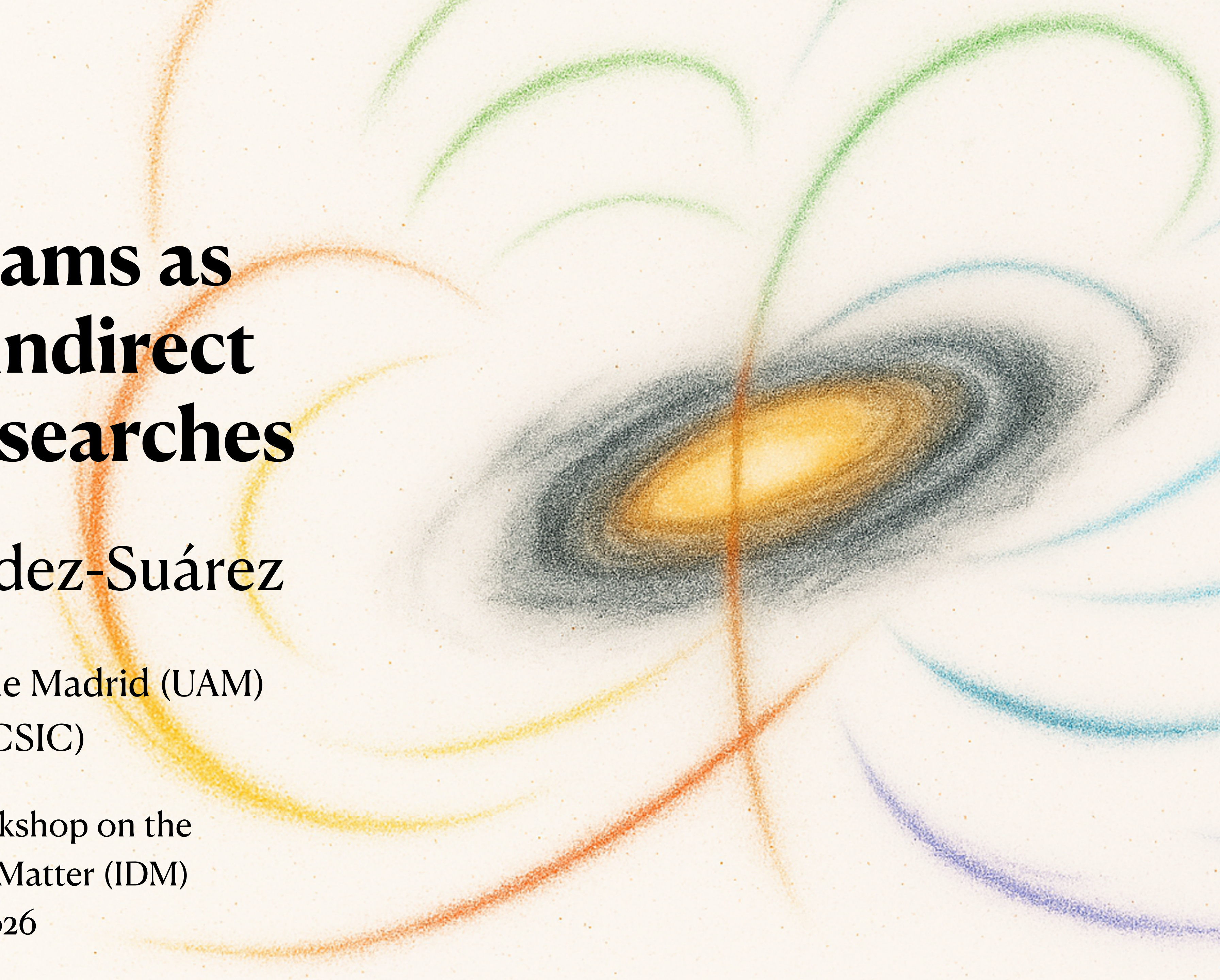
Stellar streams as targets for indirect dark matter searches

Cristina Fernández-Suárez

Universidad Autónoma de Madrid (UAM)
& IFT (UAM-CSIC)

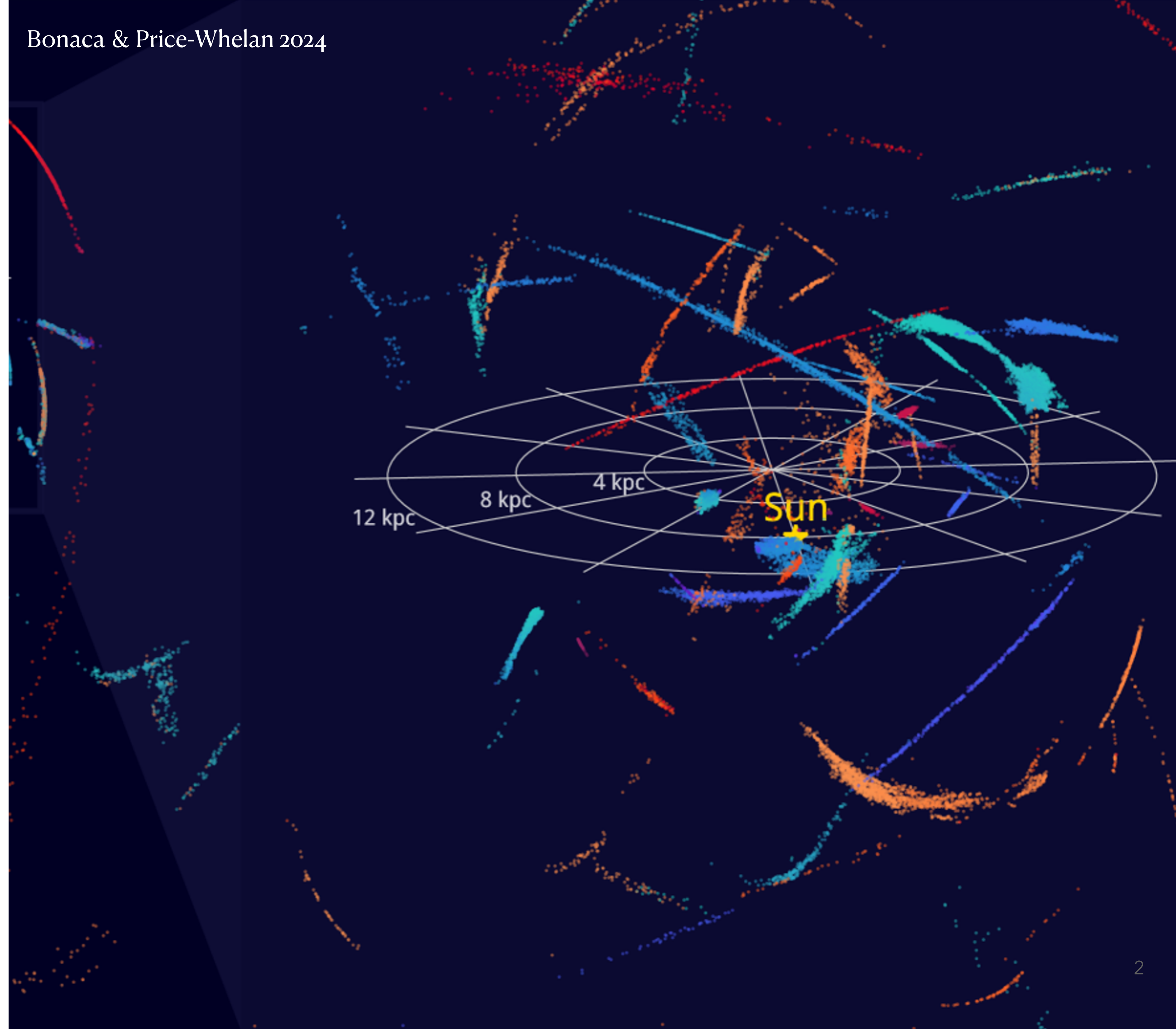
16th International Workshop on the
Identification of Dark Matter (IDM)

Zaragoza 2026



Stellar Streams in a nutshell

- * Remnants of satellites, globular clusters (GCs) or dwarf galaxies (dGs), heavily stripped in the tidal field of the host galaxy.
- * Extended structures, with lengths from 1 kpc to more than 100 kpc.
- * Range in heliocentric distance from a few kpc to 100 kpc.
- * More than 100 stellar streams have been observed around the Milky Way (MW).



A New Target for indirect dark matter (DM) searches: Stellar Streams

arXiv: 2502.15656
JCAP 09 (2025) 003

A Search for Dark Matter Annihilation in Stellar Streams with the Fermi-LAT

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- Goals:** 1) To search for WIMP-induced gamma-ray signals from the direction of the core of a sample of 11 stellar streams whose progenitor is a dG.
- 2) To demonstrate the potential of streams for indirect DM searches.

Sample Selection for DM searches

We build a sample of 11 streams most optimal for gamma-ray DM searches according to our criteria:

- * Progenitor:**

Streams whose progenitor is a dG.

- * Distance:**

Streams closest to us ($\lesssim 100$ kpc).

- * Mass:**

Streams whose stellar mass is known.

Stream	(l, b) (°)	d_{Sun} (kpc)	Length (°)	$\frac{M_*}{10^4} (M_\odot)$
<i>Golden sample</i>				
Indus	(332.26, -49.19)	16.6	18.2	3.40
LMS-1	(43.27, 55.46)	18.1	179.2	10.00
Orphan-Chenab	(264.90, 43.60)	20.0	230.6	16.00
PS1-D	(230.95, 32.67)	22.9	44.9	0.75
Turraneburra	(219.72, -40.79)	27.5	13.7	0.76
Cetus-Palca	(147.90, -67.80)	33.4	100.9	150.00
Styx	(35.40, 75.40)	46.5	60.4	1.80
Elqui	(293.88, -77.20)	50.1	10.9	1.04
<i>Silver sample</i>				
Monoceros	(180.0, 25.0)	10.6	46.9	600.00
AntiCenter	(140.0, 35.0)	11.7	57.7	0.93
Sagittarius	(6.01, -14.89)	25.0	280.0	13000.00

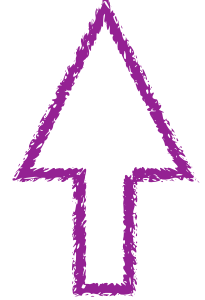
and separated in a *golden* and a *silver* samples, according to our level of confidence in them.

DM annihilation flux from stellar streams

- * We assume that all the DM is in the form of WIMPs.
- * WIMPs may be detectable in **gamma rays** since self-annihilation of WIMPs produce Standard Model particles, which can eventually yield photons, among other possible by-products.
- * Expected flux due to WIMPs annihilation (Bergström+1998) is:

$$\mathcal{F}(E, \Delta\Omega, l.o.s) = f_{pp}(E) \times J(\Delta\Omega, l.o.s)$$

Particle physics term
(DM particle mass, annihilation cross-section $\langle\sigma v\rangle$, and DM spectrum)

Astrophysical J-factor
 $J(\Delta\Omega, l.o.s) \propto \iint \rho_{DM}^2 dl d\Omega$

DM density profile

DM annihilation flux from stellar streams

$$\mathcal{F}(E, \Delta\Omega, l.o.s) = f_{pp}(E) \times J(\Delta\Omega, l.o.s)$$

Astrophysical J-factor

$$J(\Delta\Omega, l.o.s) \propto \iint \rho_{DM}^2 dl d\Omega$$

↑ DM density profile

- * We model the streams with a **truncated Navarro-Frenk-White (NFWt) DM density profile**:
- ★ We assume that the streams maintain the same density distribution as their progenitors within the core ($r \leq r_s$).
- ★ Rest of the DM outside r_s gets lost due to tidal stripping (e.g., [Aguirre-Santaella+2023](#)).

DM annihilation flux from stellar streams

$$\mathcal{F}(E, \Delta\Omega, l.o.s) = f_{pp}(E) \times J(\Delta\Omega, l.o.s)$$

Astrophysical J-factor

$$J(\Delta\Omega, l.o.s) \propto \iint \rho_{DM}^2 dl d\Omega$$

↑ DM density profile

* We consider 3 different scenarios based on different mass-to-light (M/L) ratios to estimate the DM mass at accretion time:

Low: $M/L = 2$
(same DM mass than baryonic mass)

Benchmark: $M/L = 5$

High: $M/L = 50$

* We model the streams with a **truncated Navarro-Frenk-White (NFWt) DM density profile**:

★ We assume that the streams maintain the same density distribution as their progenitors within the core ($r \leq r_s$).

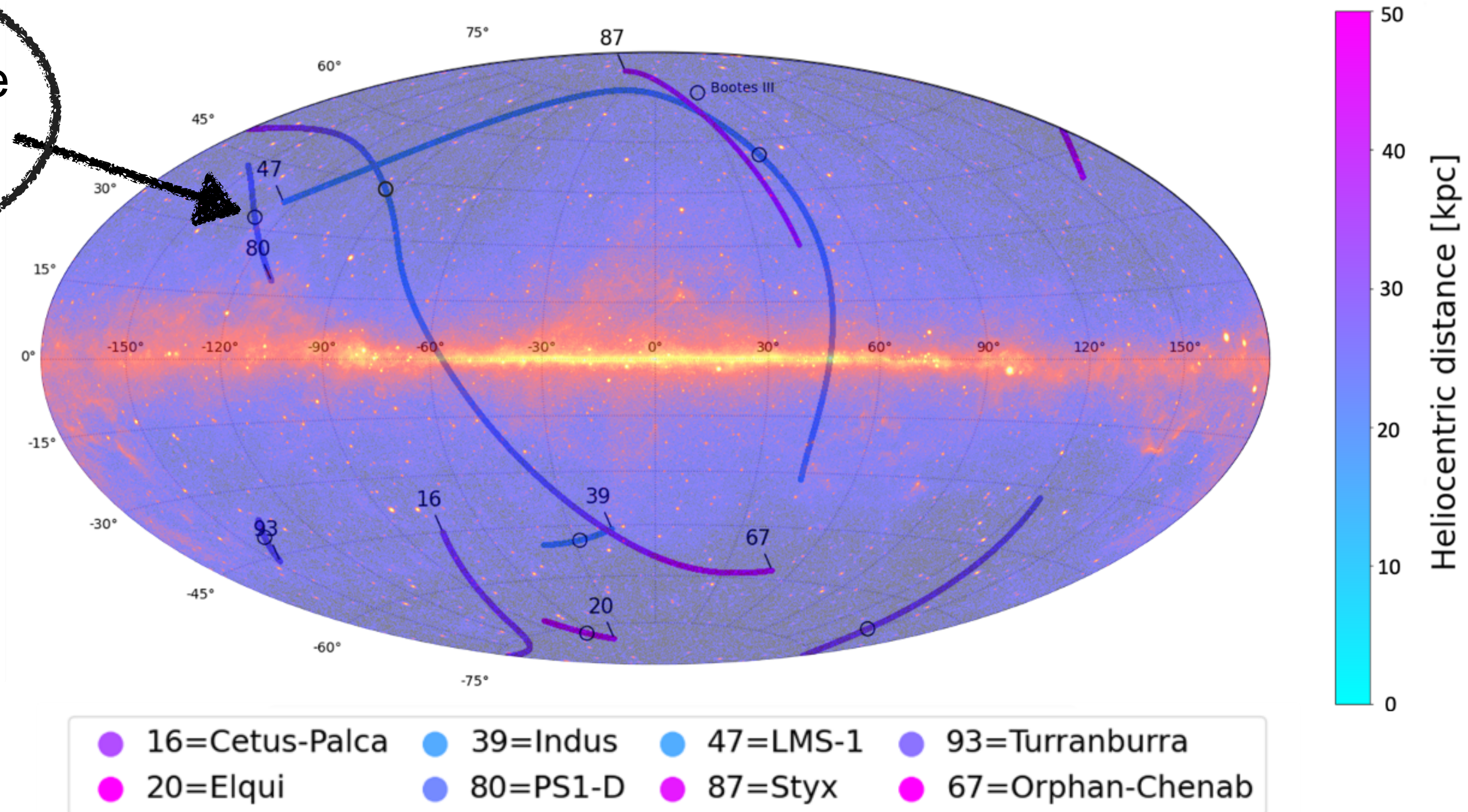
★ Rest of the DM outside r_s gets lost due to tidal stripping (e.g., [Aguirre-Santaella+2023](#)).

DM search in streams with the Fermi-LAT

- * We search for any gamma-ray signal in 15 years of Fermi-LAT data from the direction of the assumed streams' cores.

'Golden' Sample

We focus on the streams' core



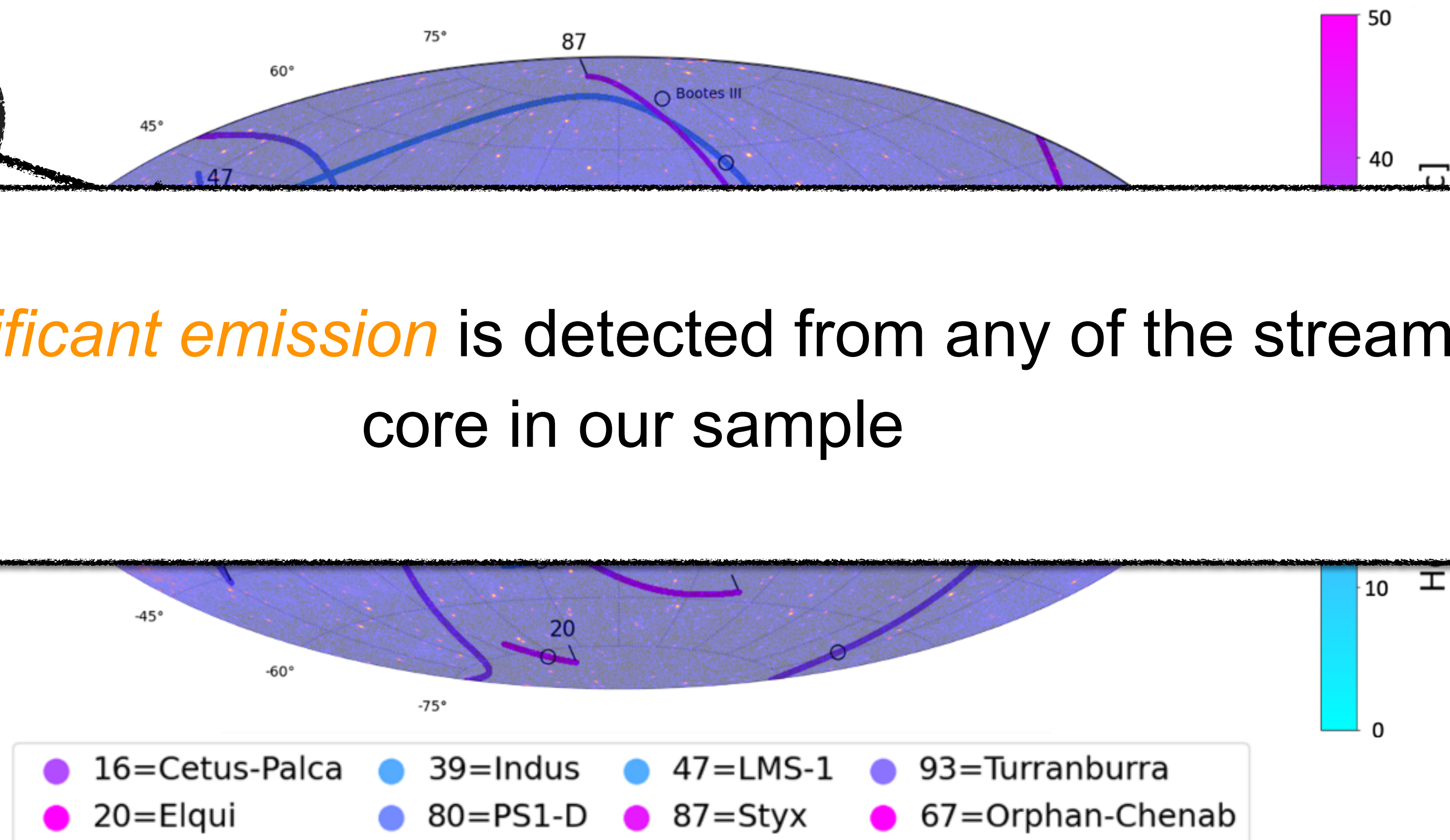
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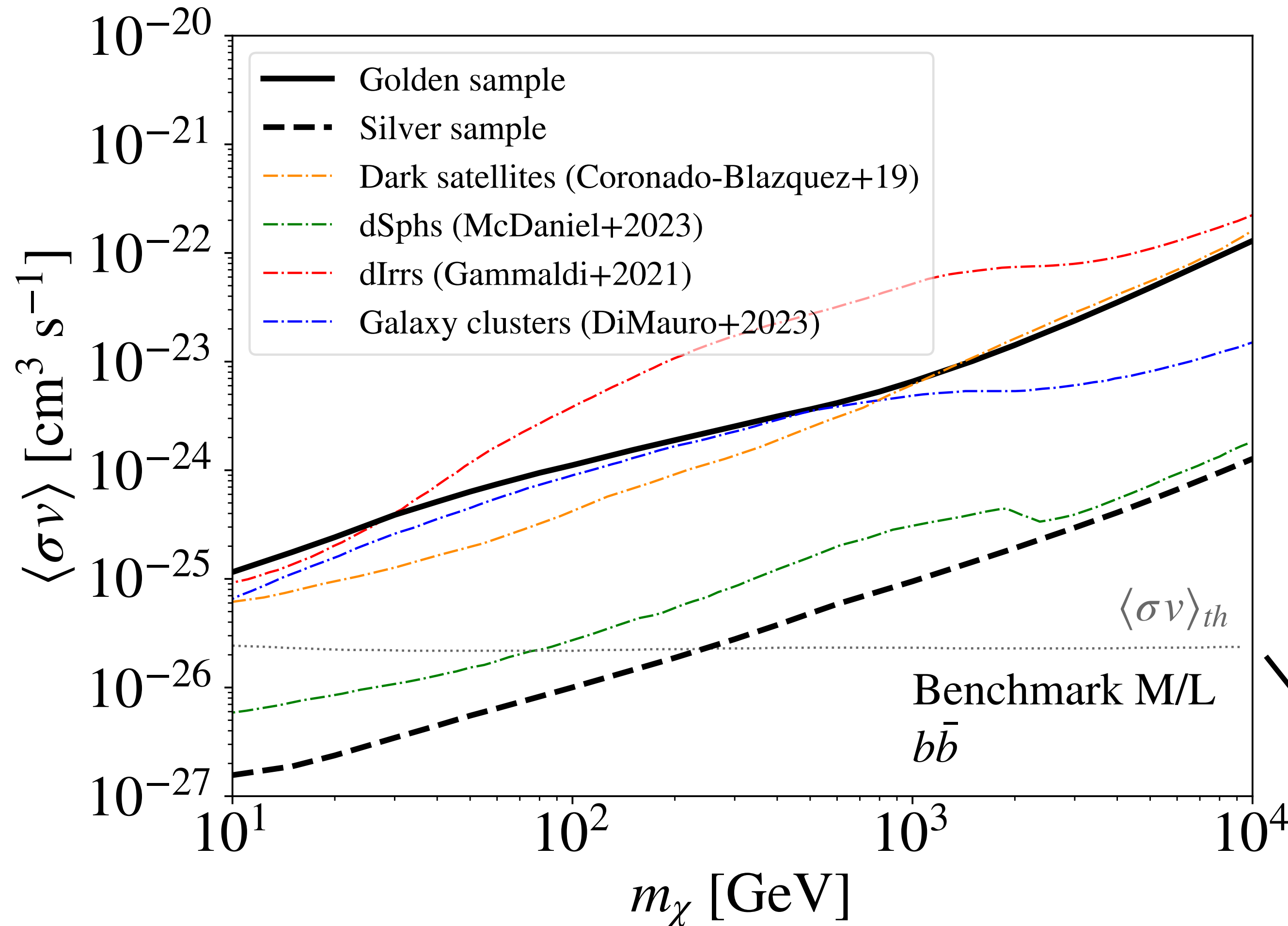
'Golden' Sample

We focus on the streams' core

No significant emission is detected from any of the streams' core in our sample



DM constraints: Comparison with other targets



* Stellar streams can potentially provide **very competitive limits**.

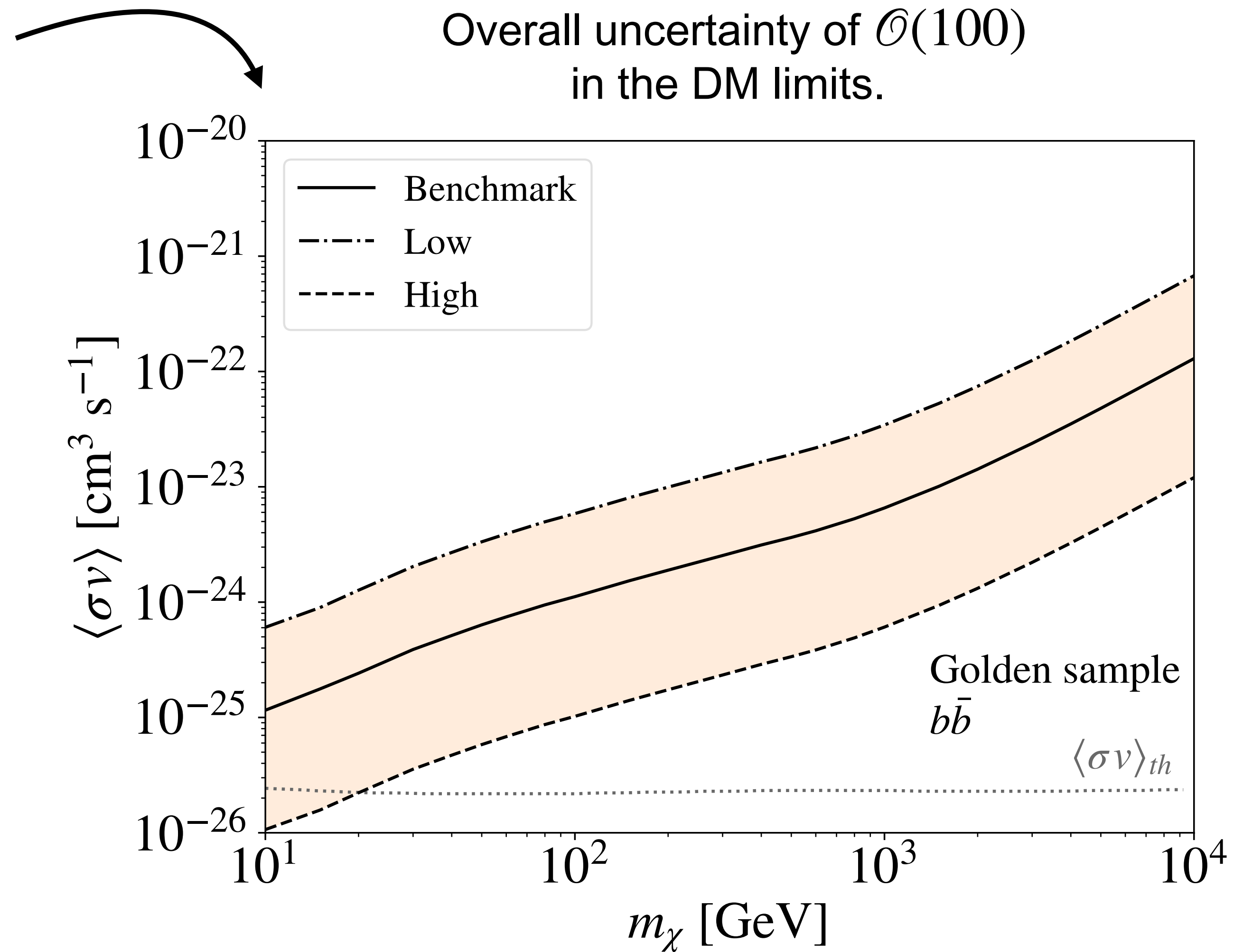
* The **golden** sample of streams improve the limits achieved with dIrr galaxies, while they are similar to those for galaxy clusters and dark satellites.

* Results for the **silver** sample would be potentially comparable with those for dSphs.

Thermal relic cross-section:
cross-section required to account for the amount of DM we observe today.

Main caveats

- * The *mass* of the streams is not well known. Uncertainties are expected to be contained within our M/L uncertainty band.
- * The *location of the streams' core* is uncertain in most cases. Already ongoing and future high-resolution spectroscopic observations (e.g. DESI) should help decreasing the uncertainty in the location of the cores of streams in our sample.
- * The underlying *DM density profile* of the streams is unclear. Work is already ongoing in this direction, that uses the AURIGA hydrodynamical simulations.

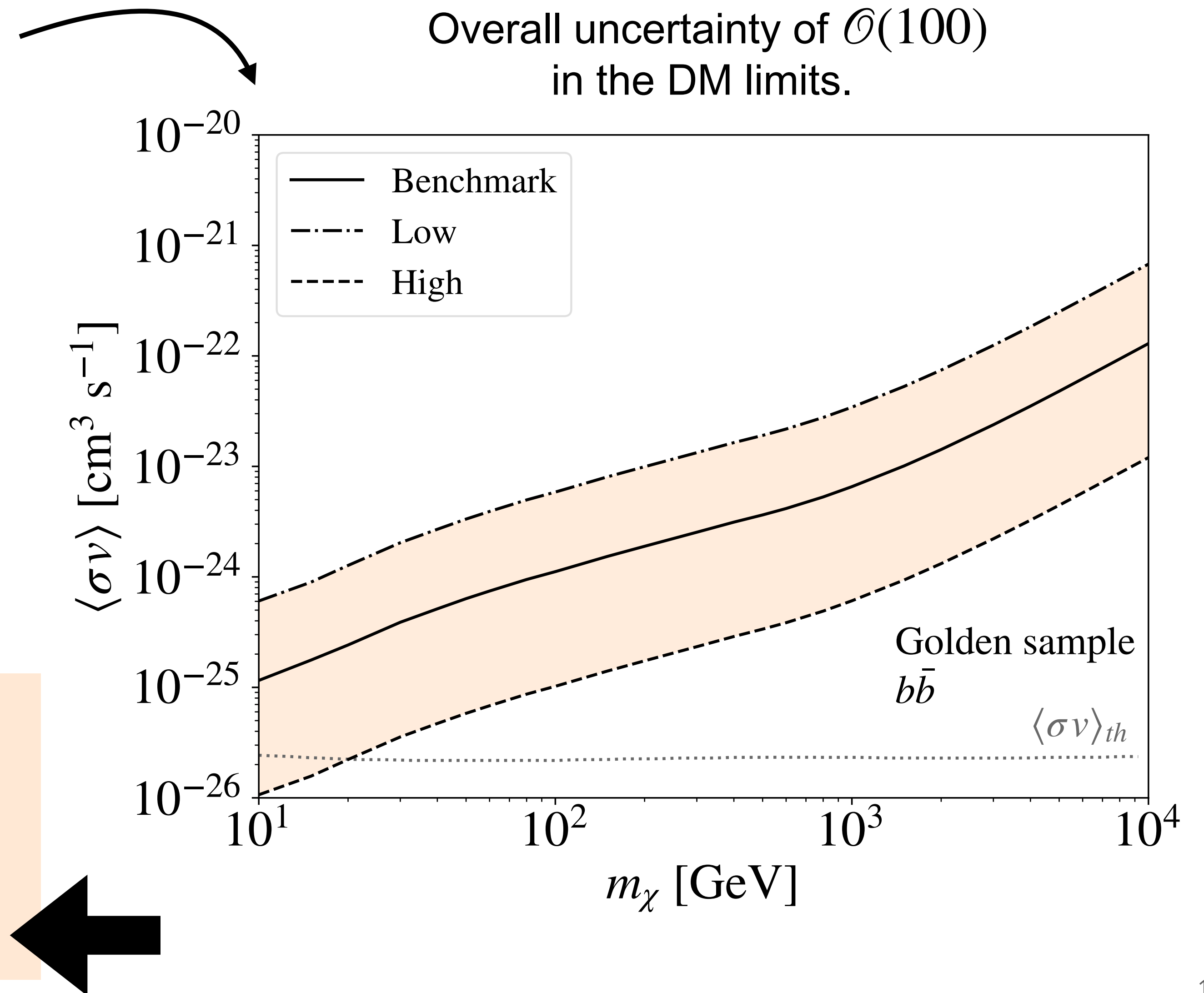


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Auriga stellar streams

- * We use the **Auriga** cosmological magnetohydrodynamic simulations, with 6 Milky Way-mass halos at ‘level 3’ high resolution. (Grand+2017, Grand+2024)

Baryonic mass particle resolution: $\sim 6 \times 10^3 M_\odot$

DM particle mass resolution: $\sim 4 \times 10^4 M_\odot$

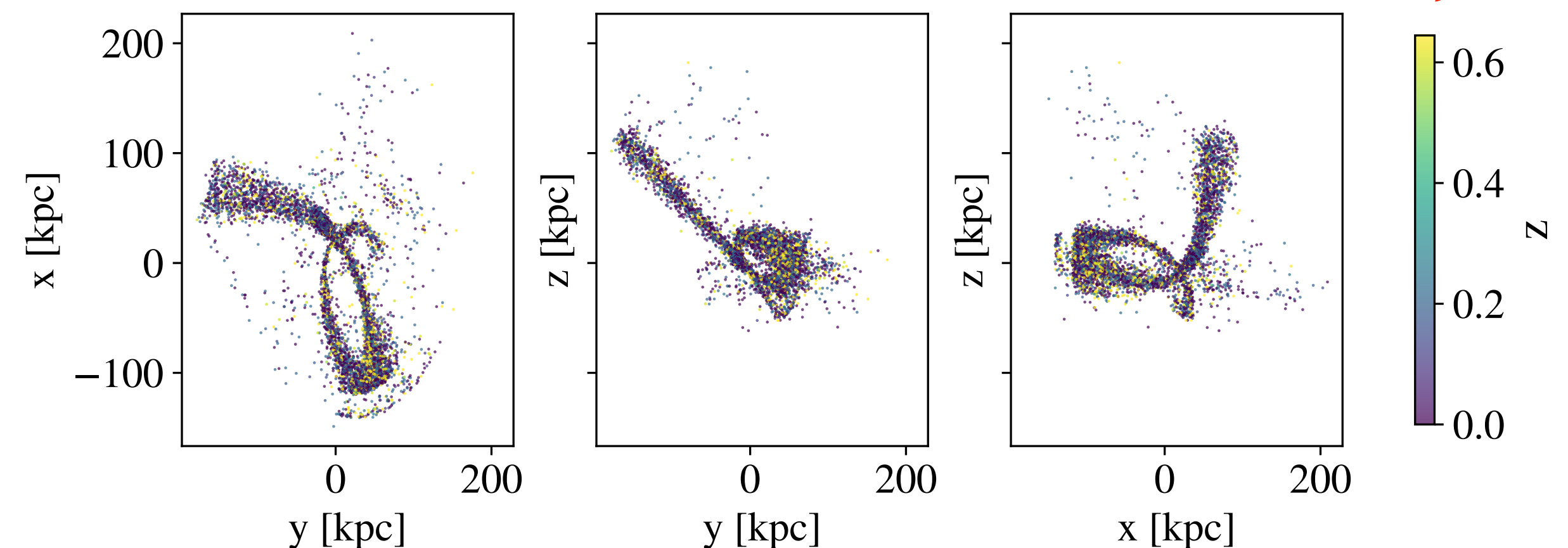
Softening length: 188 pc

- * We adopt the catalogue presented in Riley+2024 to identify streams in Auriga. The final sample is composed by ~ 100 streams.

Halo parameters at $z = 0$

Halo	$M_{200,\text{host}}$ ($10^{10} M_\odot$)	$R_{200,\text{host}}$ (kpc)	$M_{\star,\text{host}}$ ($10^{10} M_\odot$)	N_{stream}
Au-6	101.480	211.834	6.395	7
Au-16	150.430	241.530	9.098	18
Au-21	141.548	236.688	8.800	21
Au-23	150.374	241.501	8.996	18
Au-24	146.791	239.568	8.698	16
Au-27	169.632	251.400	9.876	24

ID = 6, Au-6



Bound mass fraction (f_b)

Fraction of mass that remains bound at a certain time t with respect to the initial subhalo mass (e.g., [van den Bosch et al. 2018](#)):

$$f_b = \frac{M(t)}{m_{200,sub}}$$

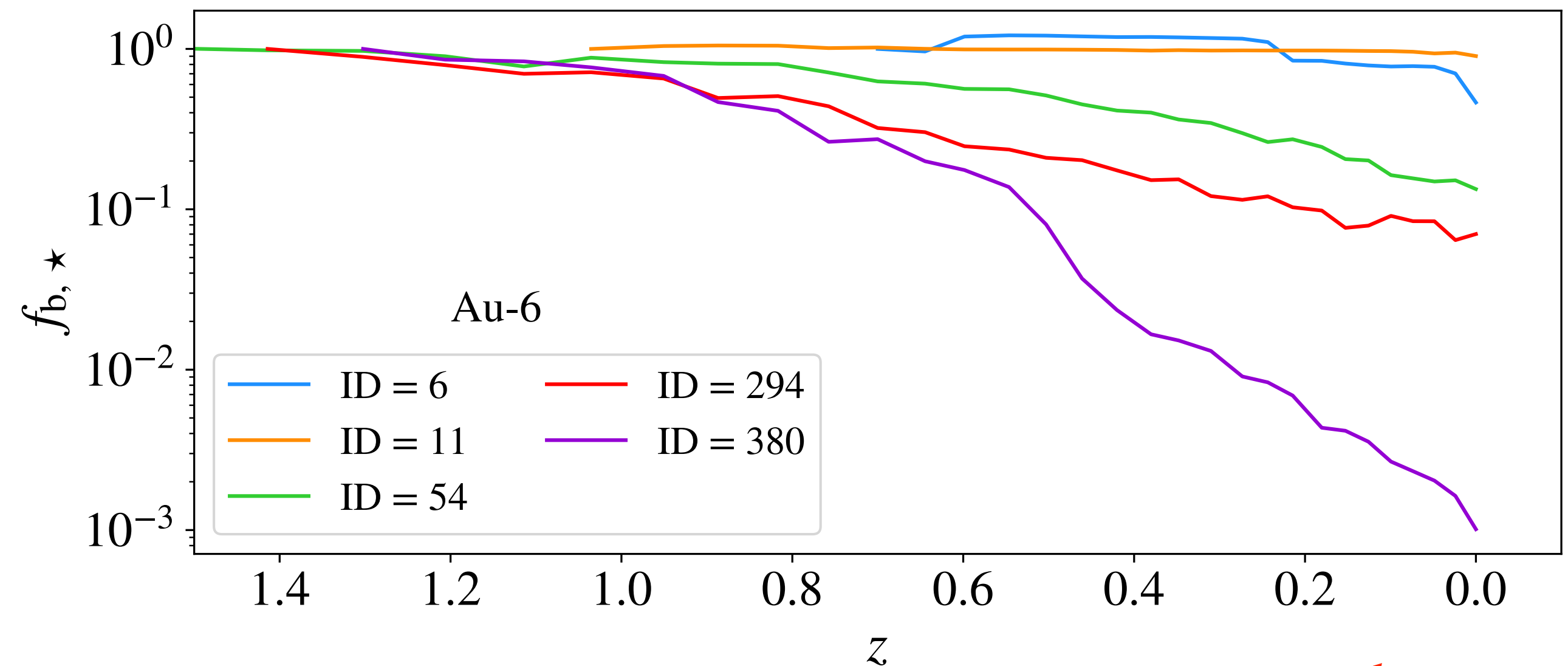
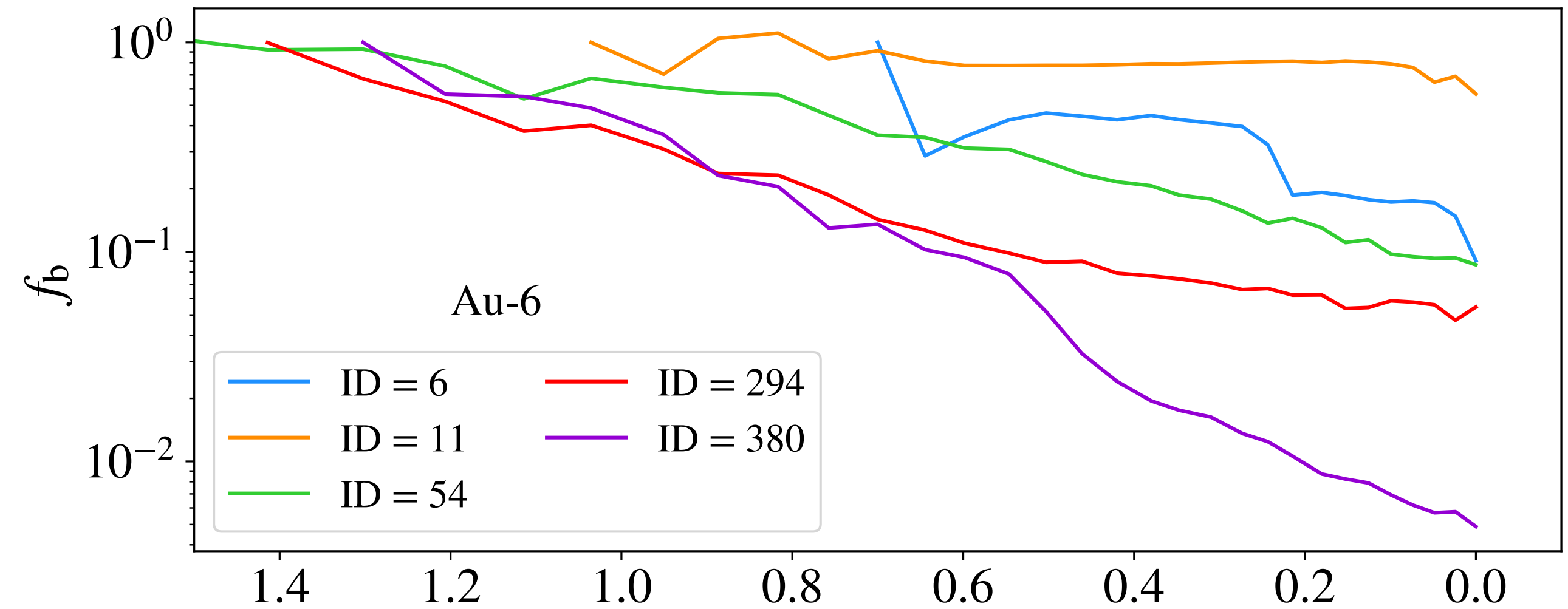
Subhalo mass at
accretion time

Bound mass fraction (f_b)

$$f_b = \frac{M(t)}{m_{200,sub}}$$

Fraction of **DM** mass that is bound to the progenitor at a certain time

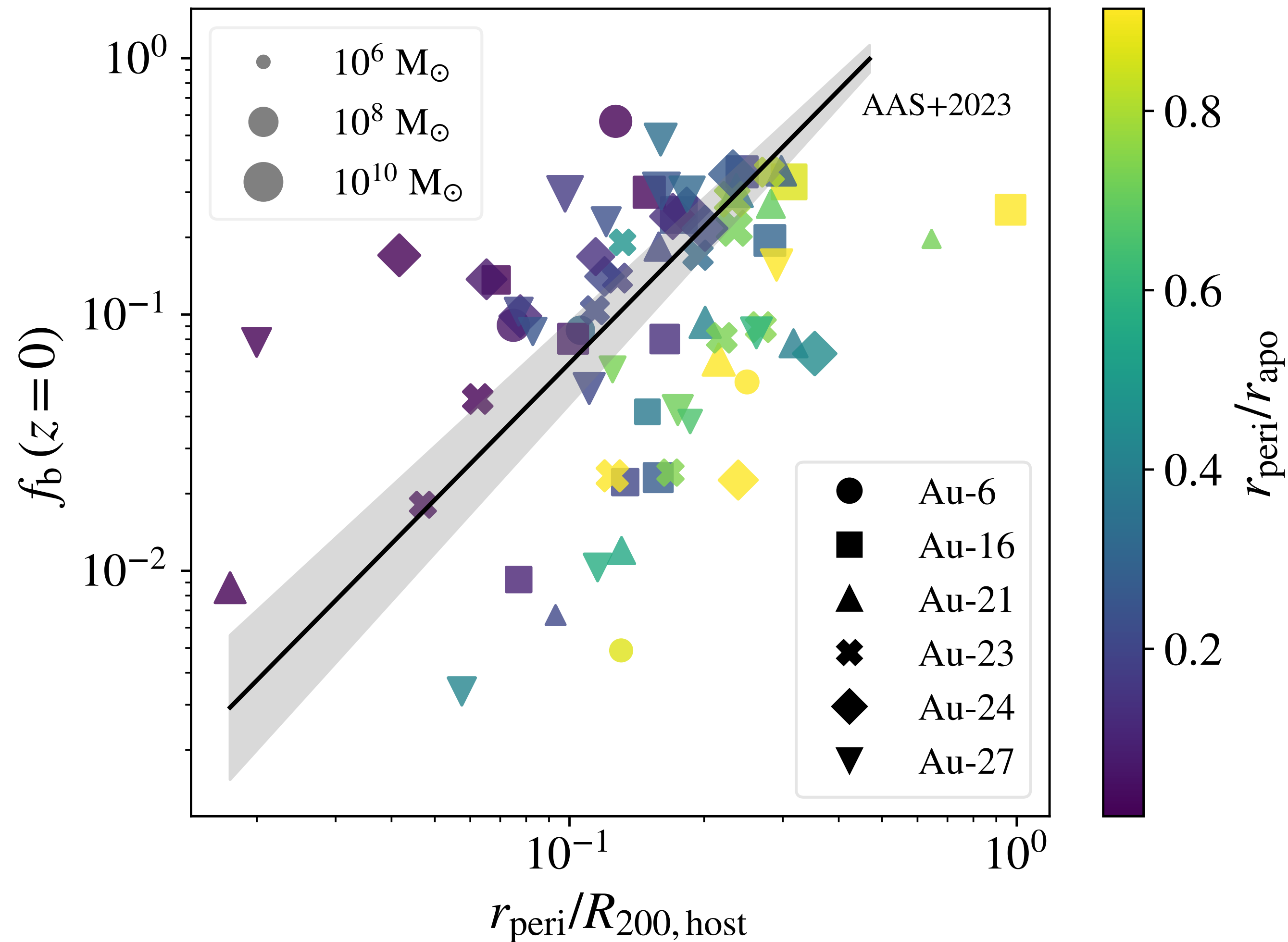
Fraction of **stellar** mass that is bound to the progenitor at a certain time



Preliminary

Bound mass fraction (f_b)

Preliminary



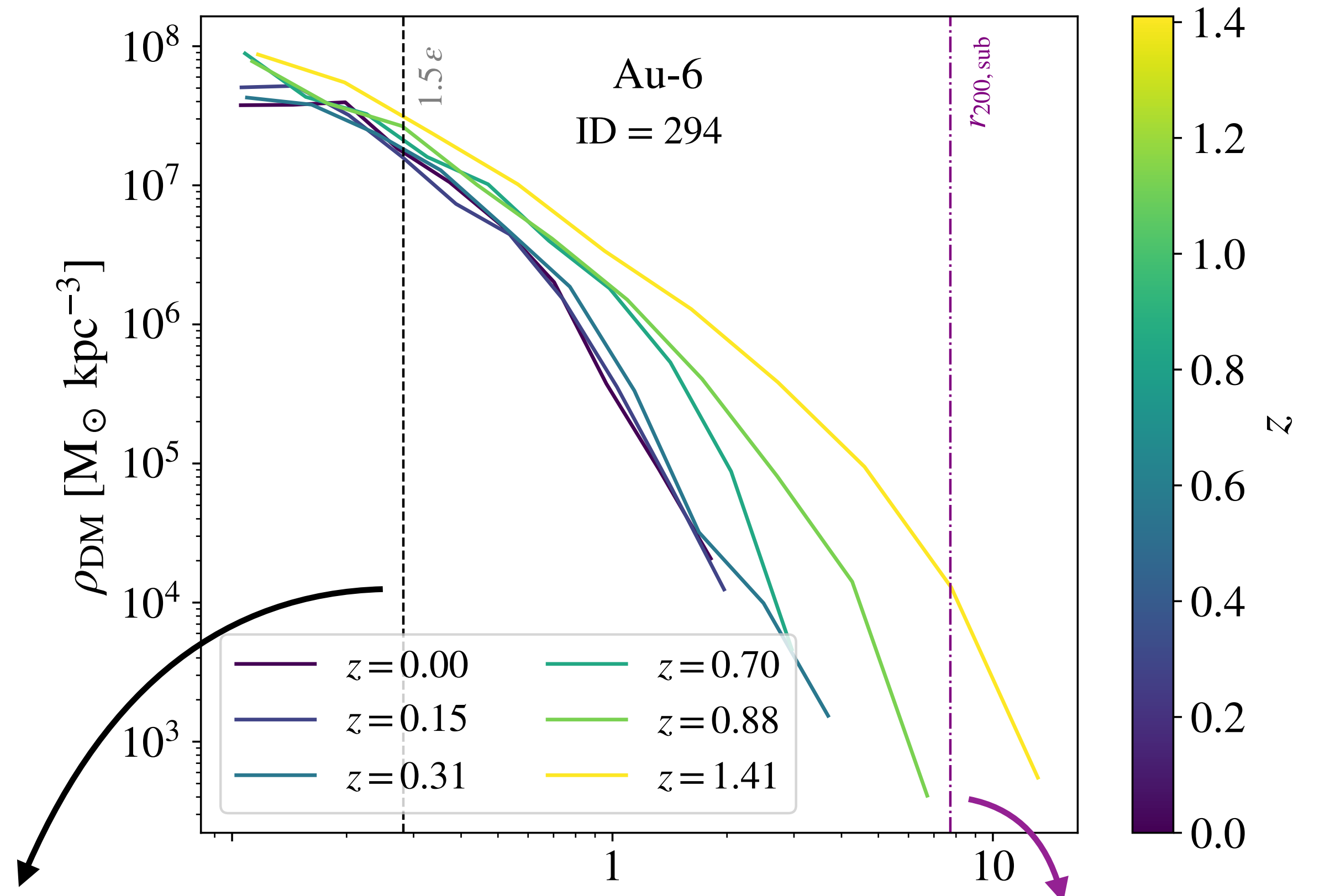
Sample of 76/104 streams after removing those not following Λ CDM expectations for their 'tidal tracks' (Aguirre-Santaella+2023, Stücker+2023)

Lower f_b values for smaller pericenters.

DM density profiles

- * From raw particle data, we build the **DM density profile** of the Auriga streams and study their temporal evolution.
- * We perform fits of each DM profile to **different functional forms**: NFW (Navarro+1996, Navarro+1997), gNFW (Hernquist+1990), NFW exp. cutoff, Einasto (Einasto 1965), Kazantzidis+2004, Errani & Navarro 2021.
- * Best-fit provided by **gNFW** (according to the reduced χ^2 distributions).

Preliminary



$1.5 \times$ softening length,
i.e. our resolution limit

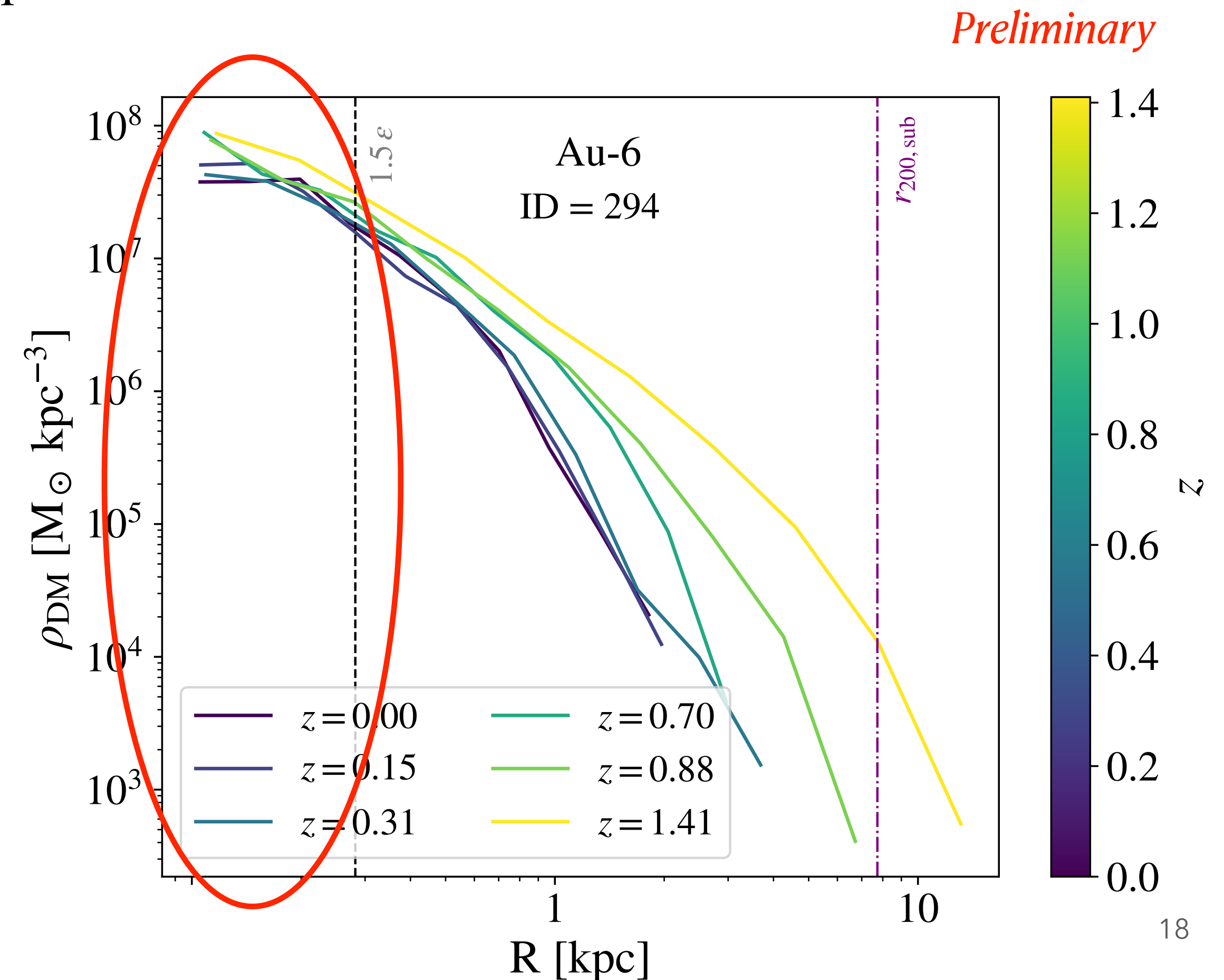
Subhalo virial radius at
accretion time
($r_{200,sub}(z_{acc})$)

DM annihilation luminosity

- * We aim to study the potential of the Auriga streams as targets for gamma-ray DM searches by computing the **DM annihilation luminosity**:

$$L_{ann} = \int_V \rho_{DM}^2(r) dV$$

- * L_{ann} is very sensitive to the inner shape of the profile, where we face resolution issues.



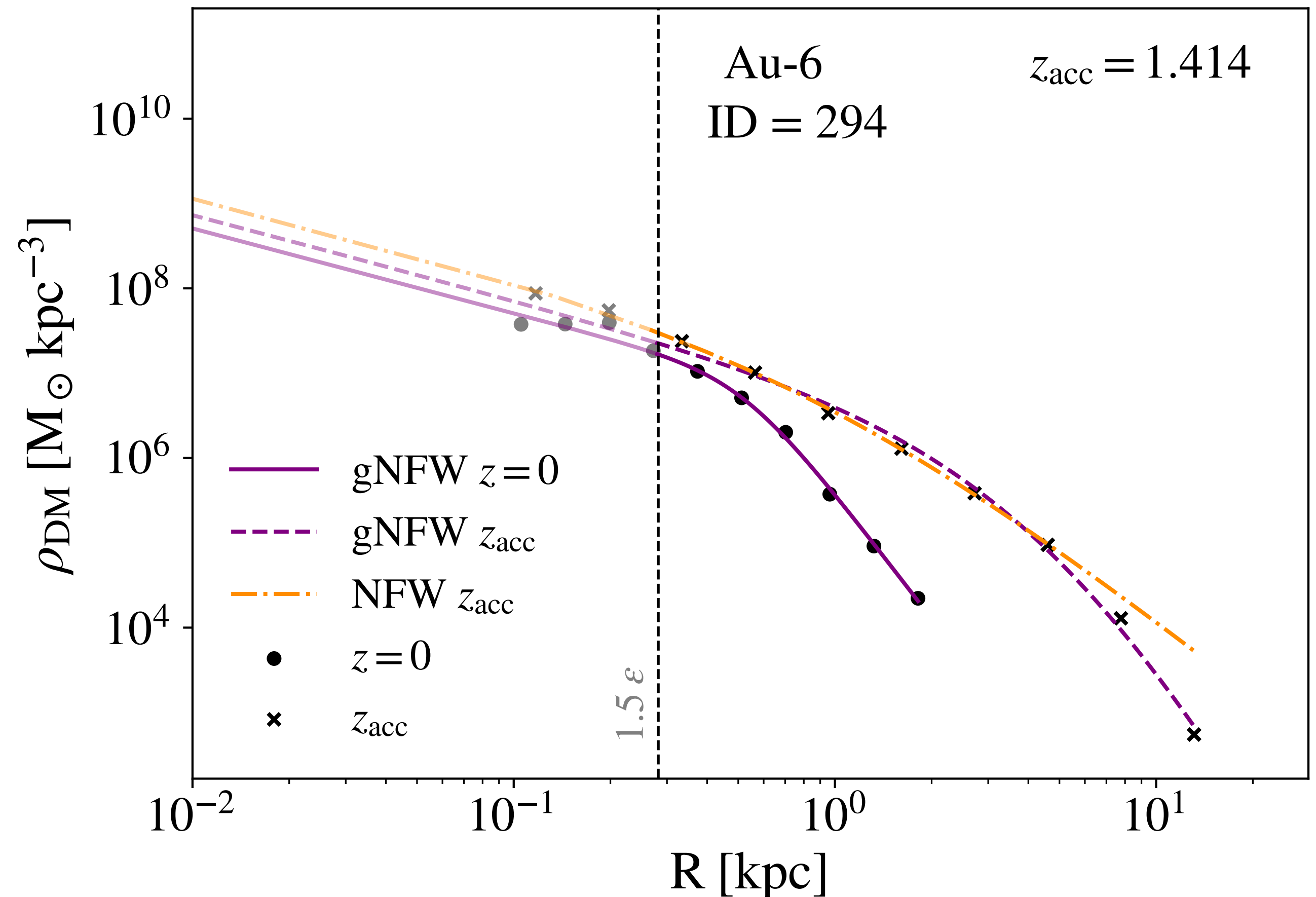
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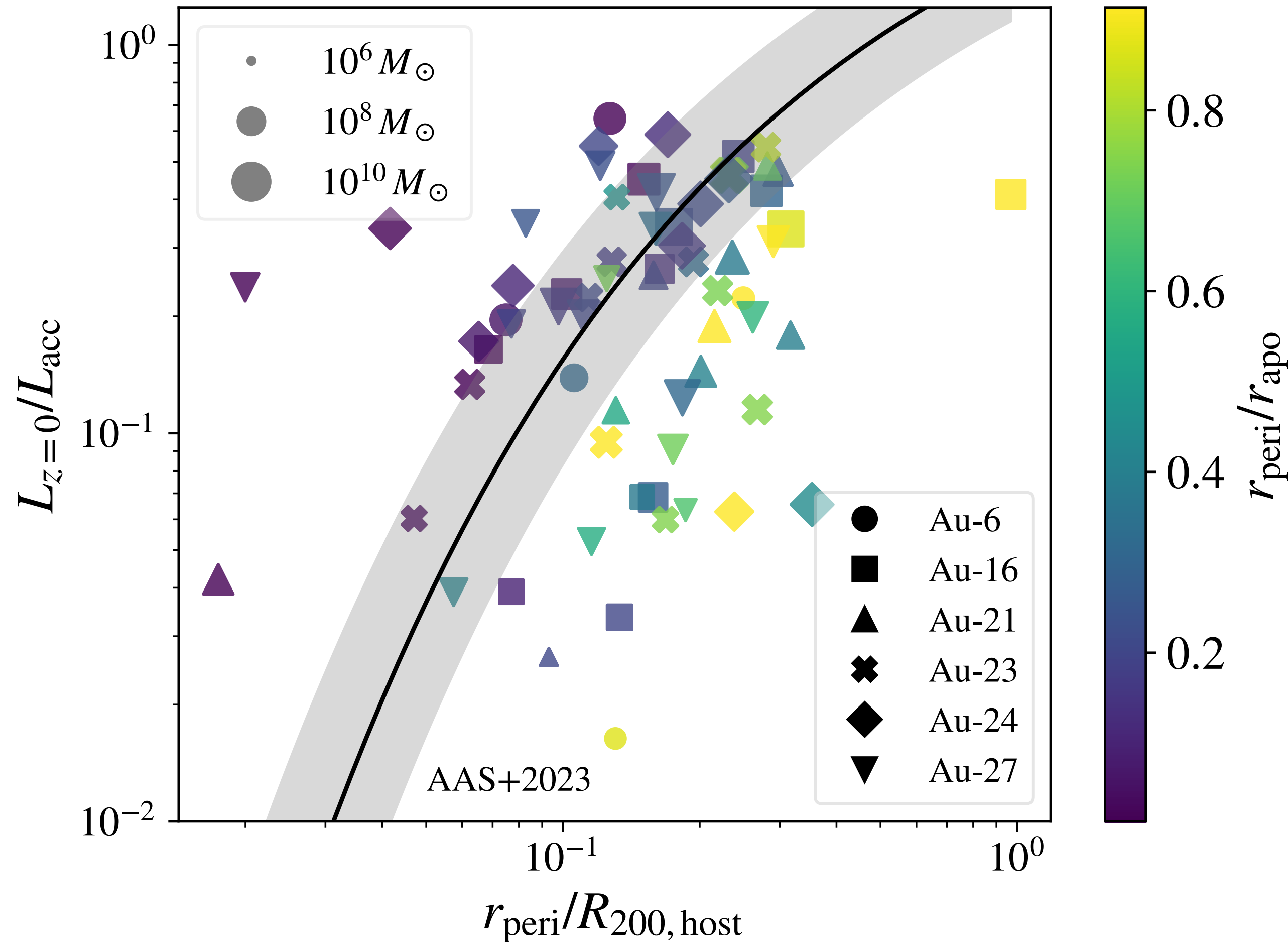
Preliminary

- * L_{ann} is very sensitive to the inner shape of the profile, where we face resolution issues.
- * Reconstruction of this region: an *inner cusp* is expected at such low-mass subhalo scales, where baryons are not expected to play a significant role (Peñarrubia+2010, Aguirre-Santaella+2023, Stücker+2023).
- * SIDM models could eventually lead to more *cored* profiles (e.g. Vogelsberger+2012, Zavala+2013, Adhikari+2022).



DM annihilation luminosity

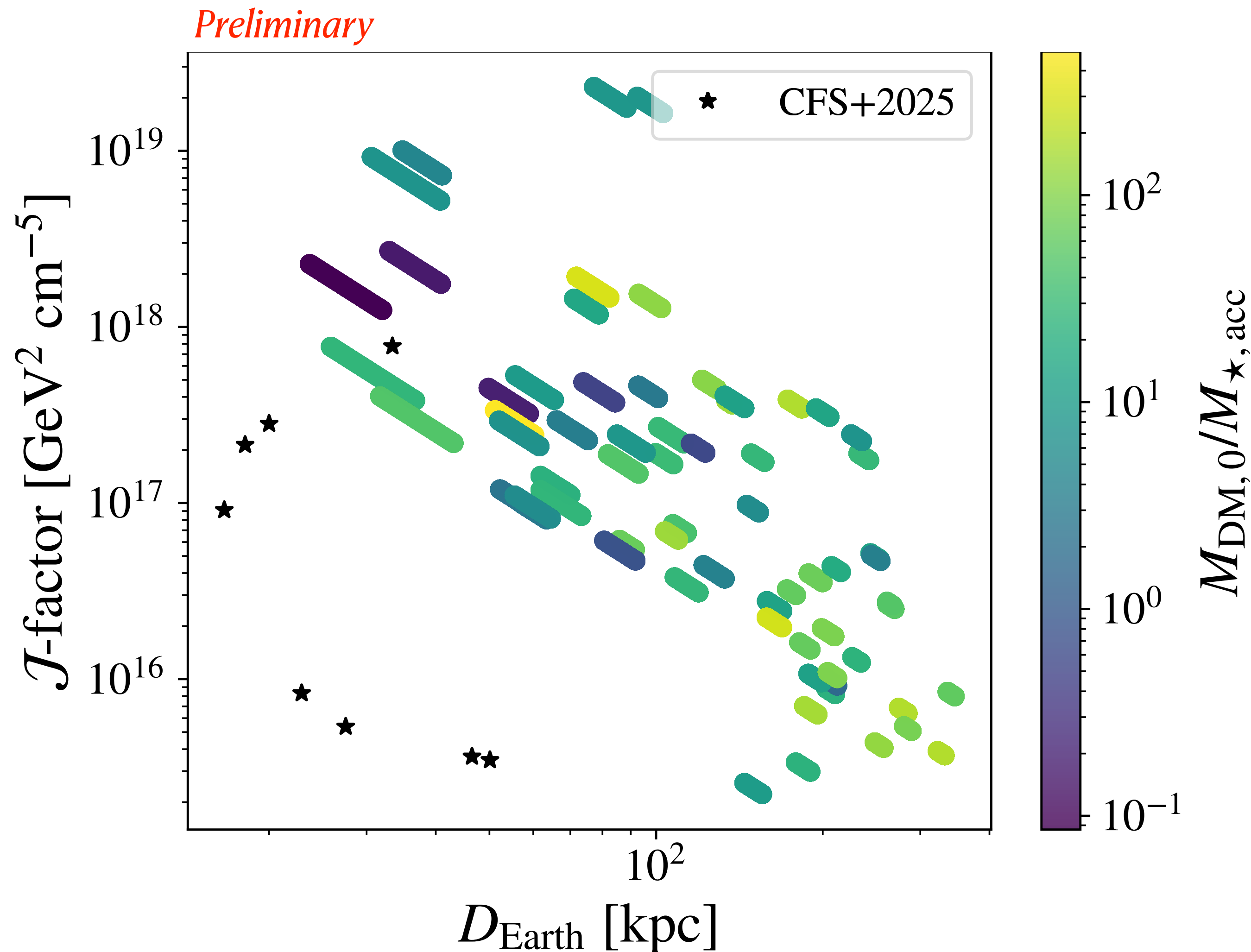
Preliminary



- * In most cases there is a significant loss of luminosity (up to $> 90\%$) due to the mass loss.
- * In some cases, the present luminosity only decreases by a small percentage of its initial value.
- * General tendency to have greater L_{ann} losses for small pericenter values and more circular orbits, as expected (Aguirre-Santaella+2023).

Sample of 76/104 streams after removing those not following Λ CDM expectations for their 'tidal tracks' (Aguirre-Santaella+2023, Stücker+2023)

Astrophysical J-factors



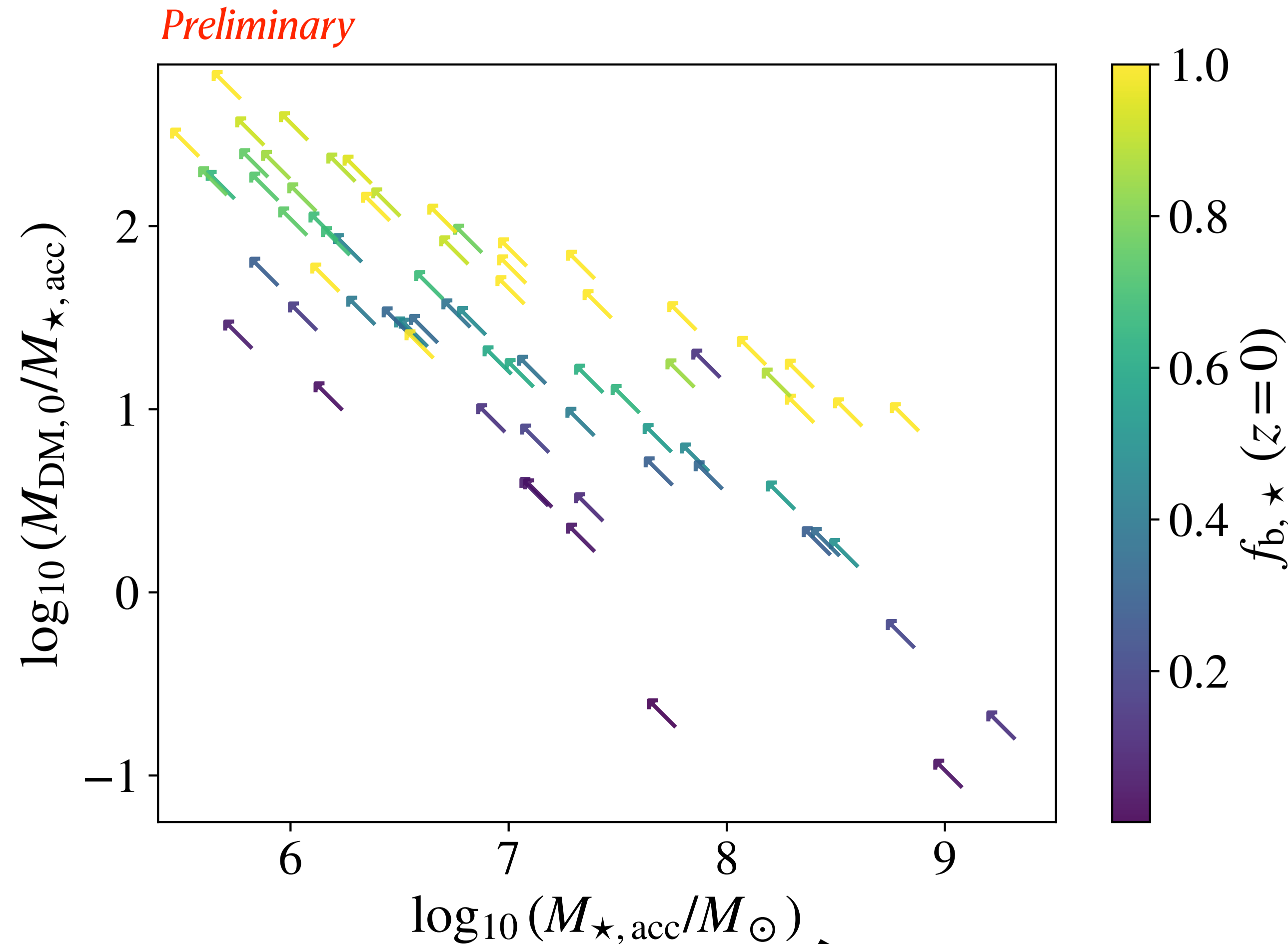
$$J = \frac{1}{D_{\text{Earth}}^2} \int_V \rho_{\text{DM}}^2(r) dV$$

Distance from the Earth to the subhalo center: 1000 realizations placing the Earth in different positions, keeping the distance to the Galactic center at 8.5 kpc.

- * J-factors reach values up to $\sim 10^{19} \text{ GeV}^2 \text{ cm}^{-5}$.
- * In **CFS+2025**, we estimated significantly lower J-factor values for our golden sample of streams. We expect the previous constraints to be improved by $\sim \mathcal{O}(10)$.

Sample of 76/104 streams after removing those not following ΛCDM expectations for their ‘tidal tracks’ (Aguirre-Santaella+2023, Stücker+2023)

DM mass estimates from observations



* An estimate of the DM mass at present may be possible starting from the observed luminous mass of the stream, i.e., a rough M/L ratio for streams.

* Most streams exhibit M/L ratios above the values adopted in **CFS+2025** ($M/L = 2, 5, 50$), which will be translated into an improvement of the previous constraints.

Sample of 76/104 streams after removing those not following Λ CDM expectations for their 'tidal tracks' (Aguirre-Santaella+2023, Stücker+2023)

Stellar mass at accretion time. We assume that this is the streams' stellar mass reported in observations.

Summary

CFS & Sánchez-Conde
arXiv: 2502.15656

- * First one that uses stellar streams to set WIMP DM limits.
- * Sample of 11 streams most optimal for gamma-ray DM searches.
- * No signal is detected after the analysis of 15 years of Fermi-LAT data.
- * The most reliable DM limits obtained (*golden* sample, benchmark scenario) are $\mathcal{O}(10)$ above the thermal relic cross-section for low WIMP masses.

CFS, Sánchez-Conde
& Aguirre-Santaella,
about to be submitted.

- * Auriga suite of high-resolution hydrodynamical simulations to shed light on the DM distribution within disrupted dG streams.
- * Auriga streams (~ 100) better described with gNFW profile at $z = 0$.
- * L_{ann} can decrease up to $> 90\%$ of their initial values, still being competitive targets for indirect DM searches.
- * J-factors can reach values up to $\sim 10^{19} \text{ GeV}^2 \text{ cm}^{-5}$.
- * We provide a way to estimate the DM mass from the observed luminous mass along the stream.

Stellar streams as targets for indirect dark matter searches

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Thank you!

Backup Slides

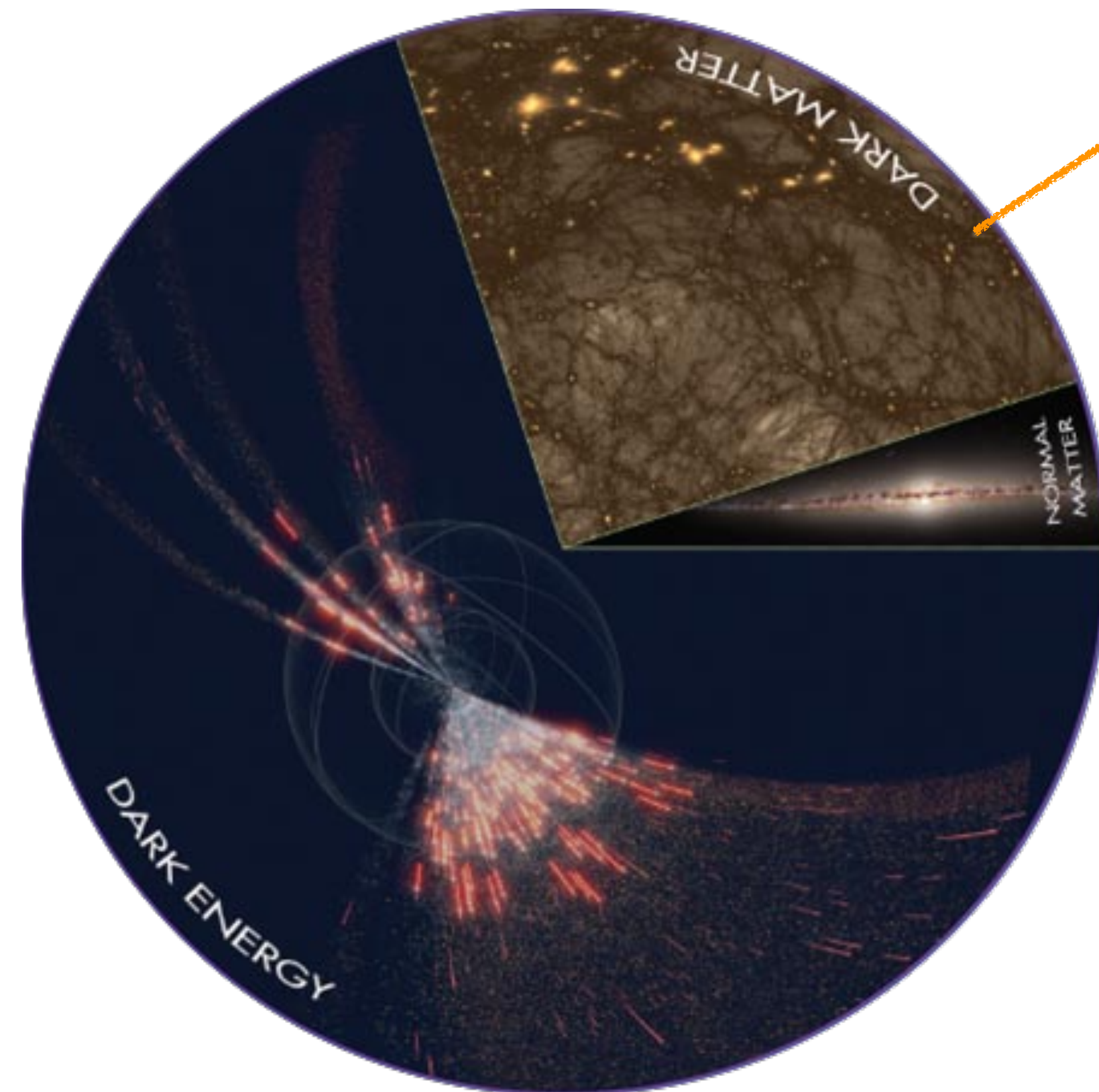
Dark matter overview

Dark matter (DM) $\sim 27\%$

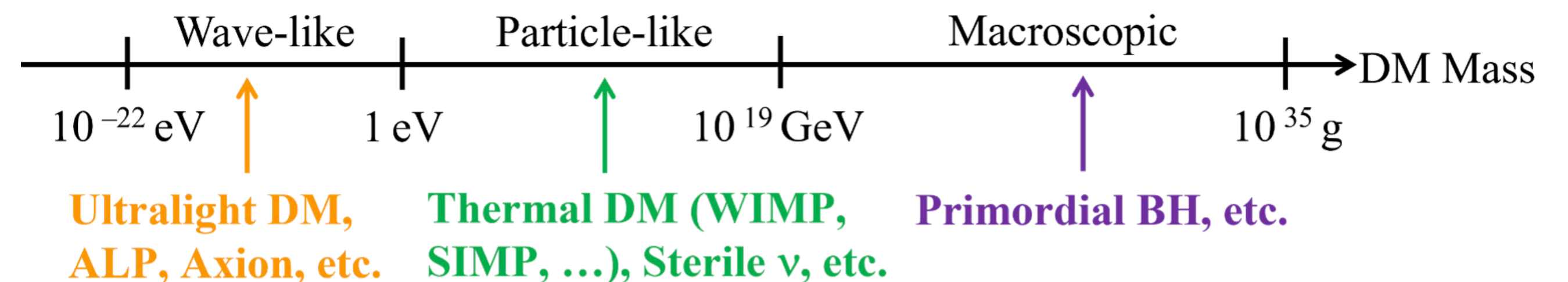
* Multiple evidence from galactic to cosmological scales.

* Properties:

- Non-baryonic
- Neutral
- Non-relativistic (cold)
- Long lifetime (at least 13.8 Gyr)
- No viable candidate in the Standard Model (SM), we need candidates beyond the SM.



Credit: American Museum of Natural History



DM annihilation flux from stellar streams

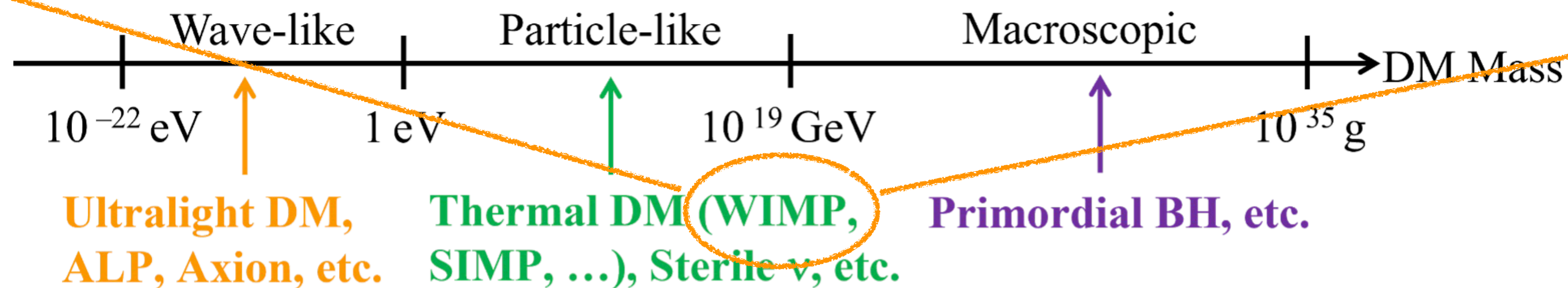
Weakly Interacting Massive Particles (WIMPs)

One of the most promising and well-motivated DM candidates (e.g. Bertone 2010): “*WIMP miracle*”.

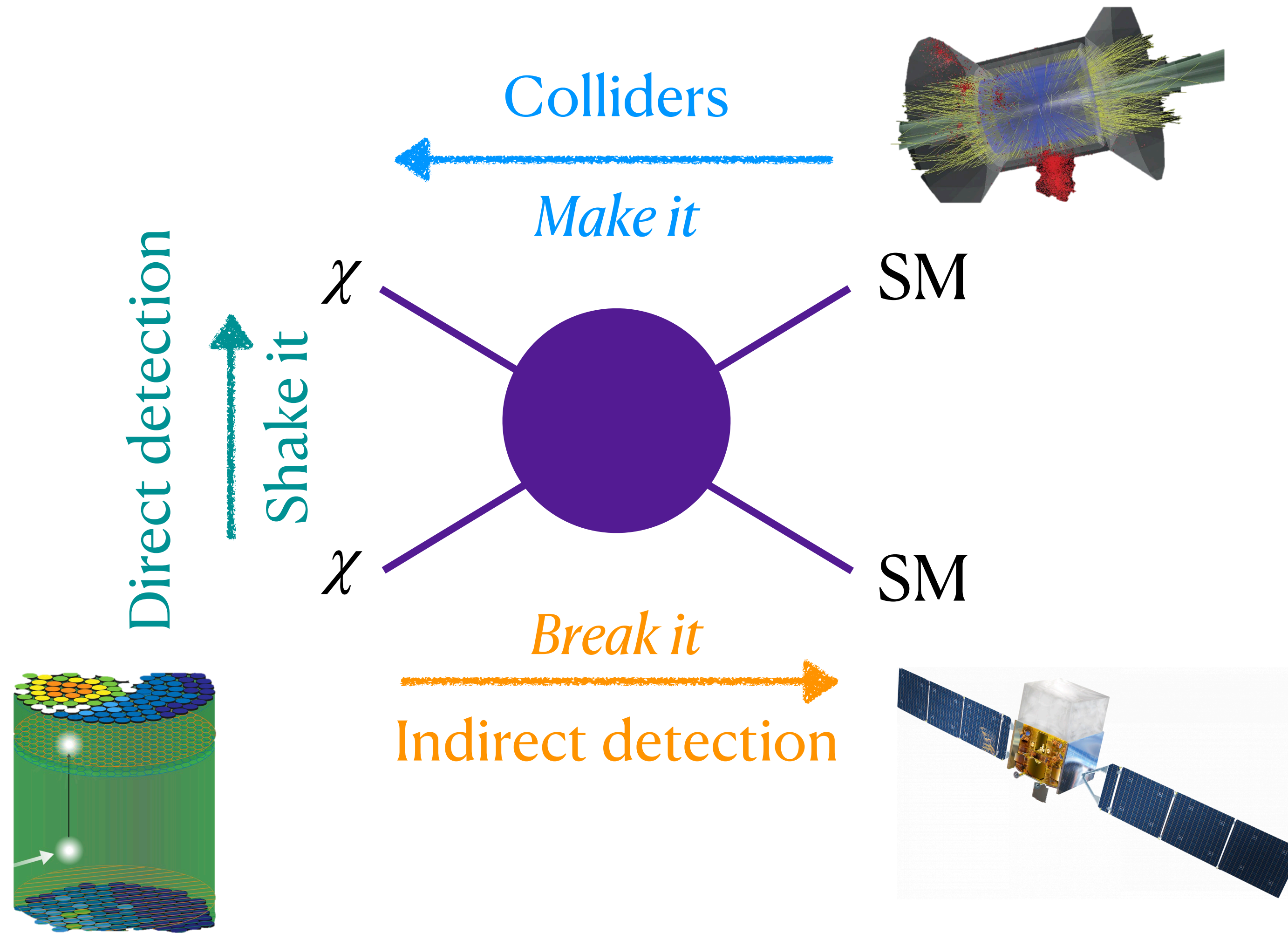
Expected to have GeV-TeV masses.

WIMPs arise in several theories beyond the Standard Model.

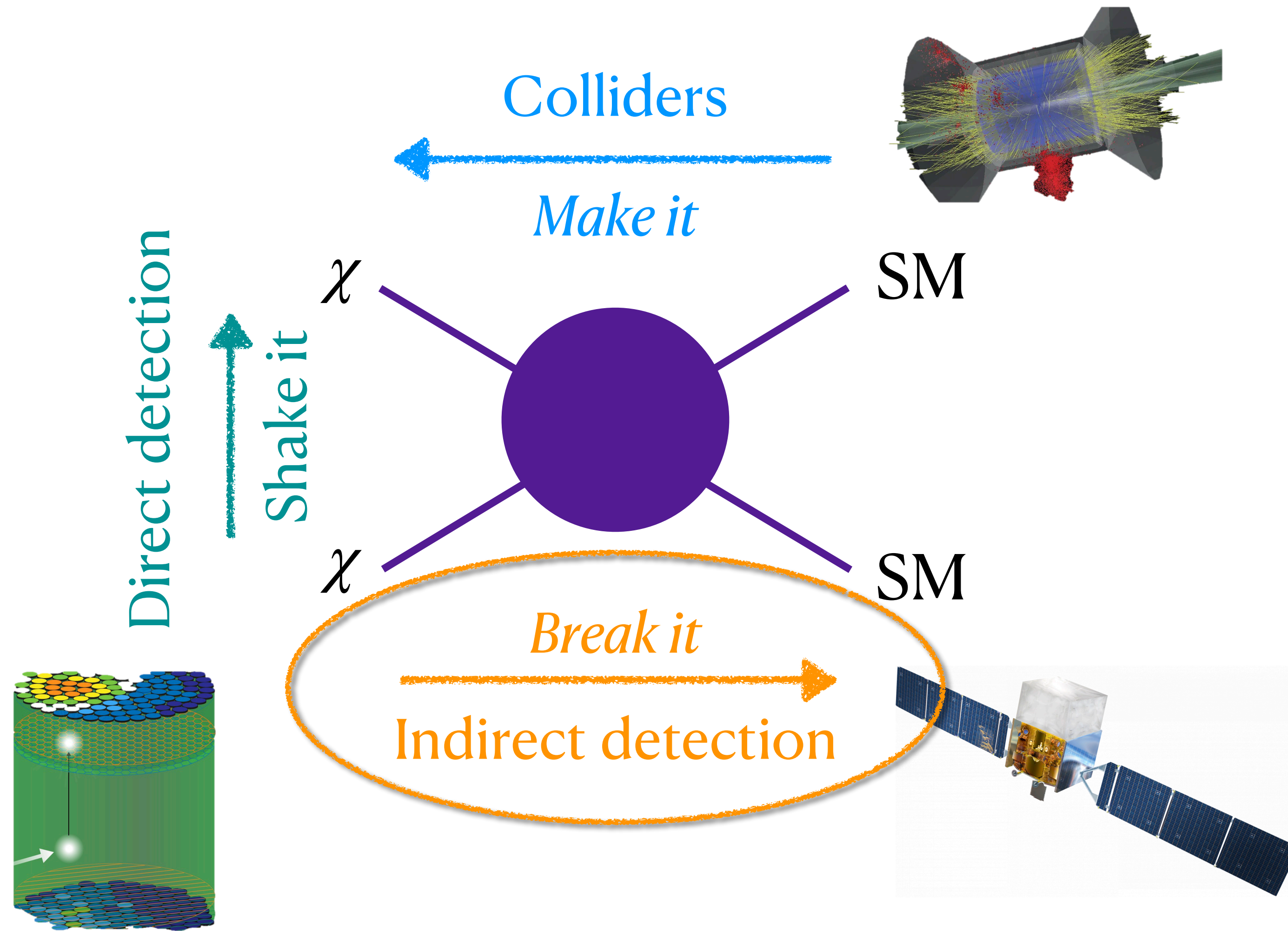
WIMPs may be detectable in **gamma rays** since self-annihilation of WIMPs produce Standard Model particles, which can eventually yield photons, among other possible by-products.



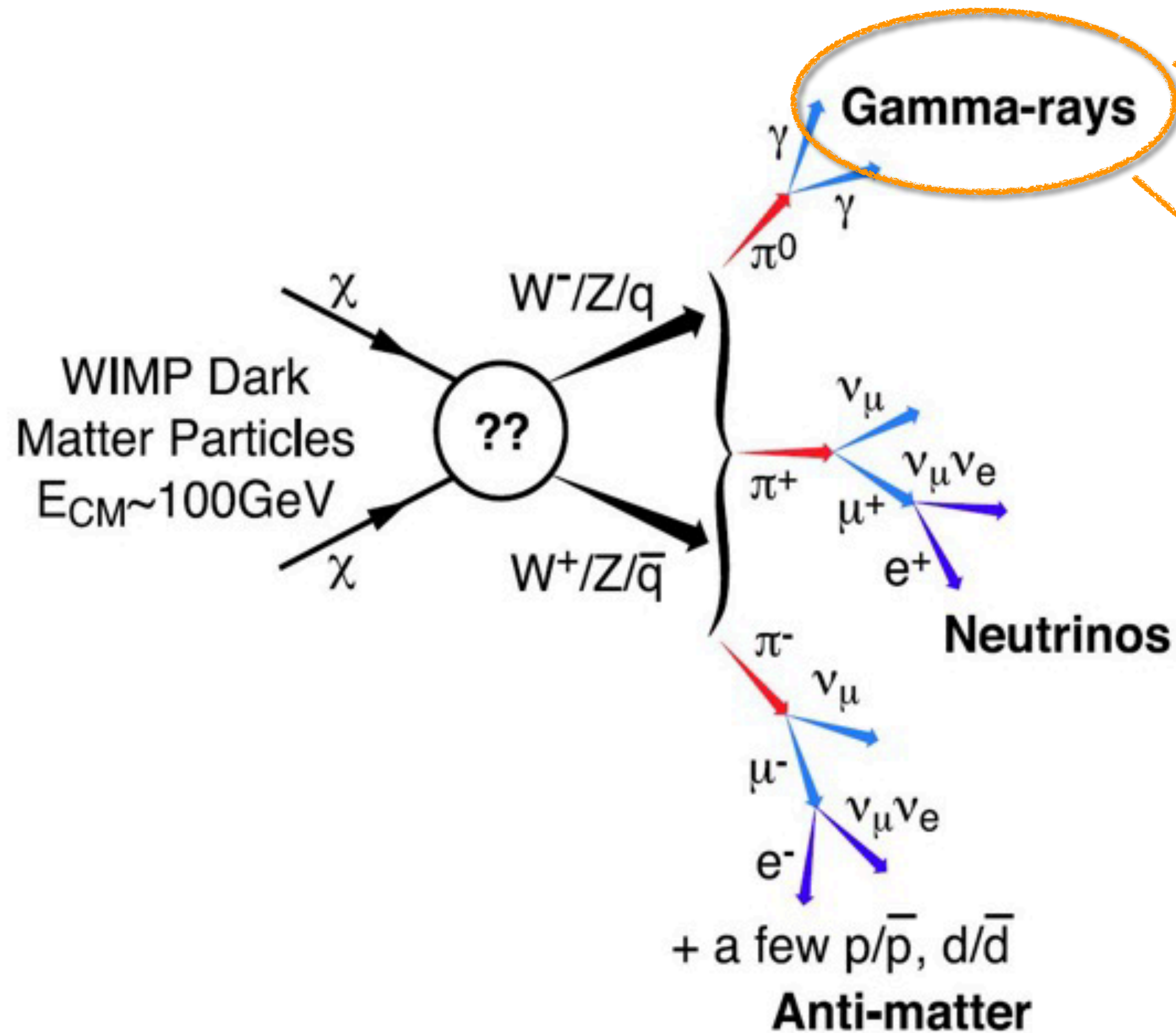
WIMPs' searches



WIMPs' searches



WIMPs' indirect detection

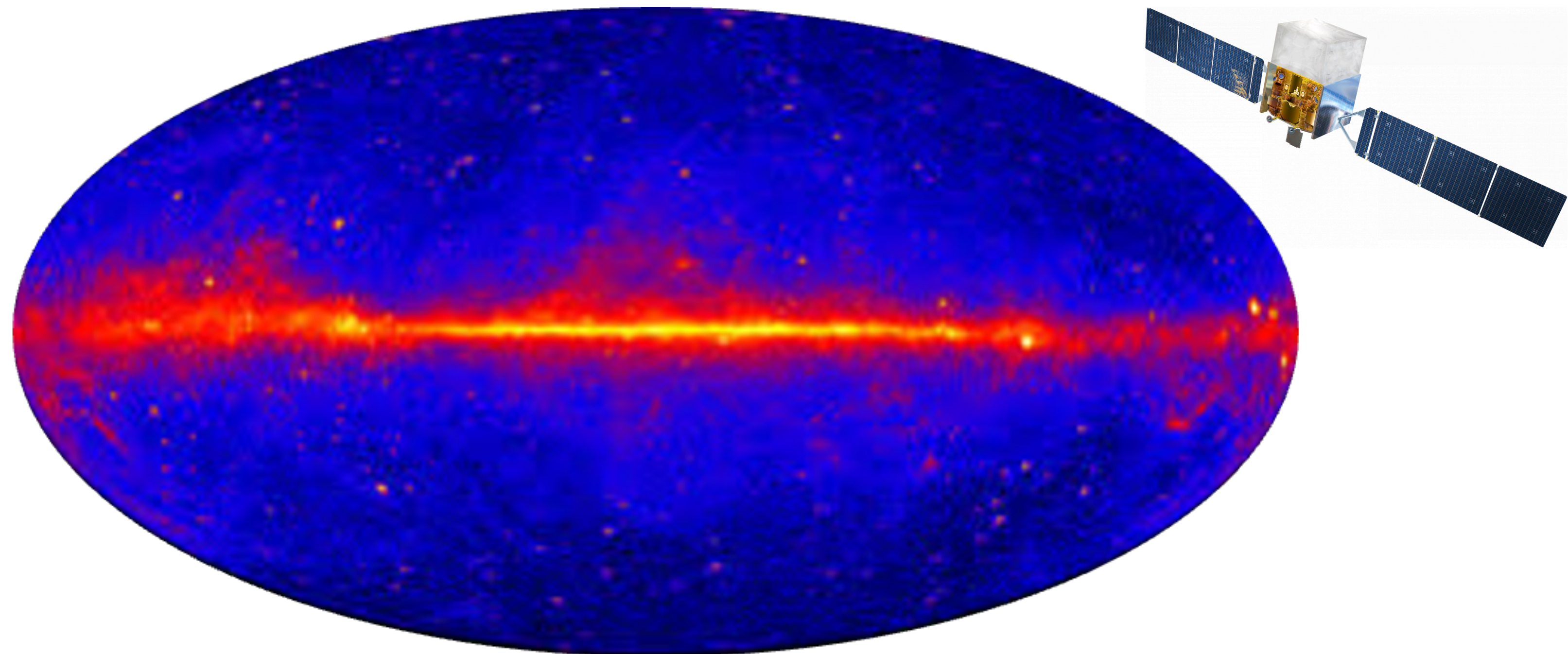


“Golden channel”

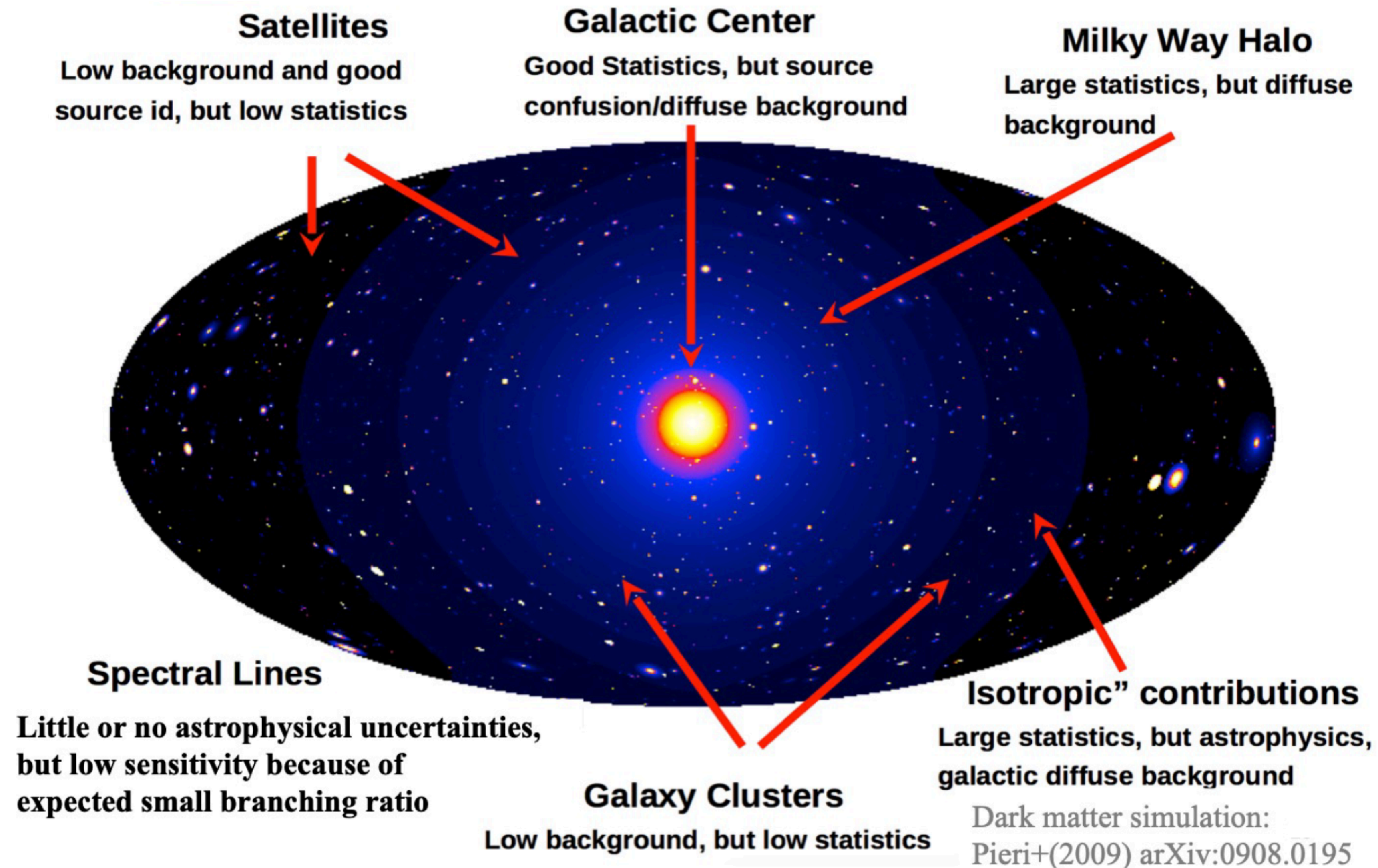
- * They are not deflected by magnetic fields.
- * They travel following almost straight lines.
- * They do not suffer from energy losses, i.e. spectral info is retained.
- * Best sensitivity of our instruments compared to other messengers.

Fermi Large Area Telescope (*Fermi*-LAT)

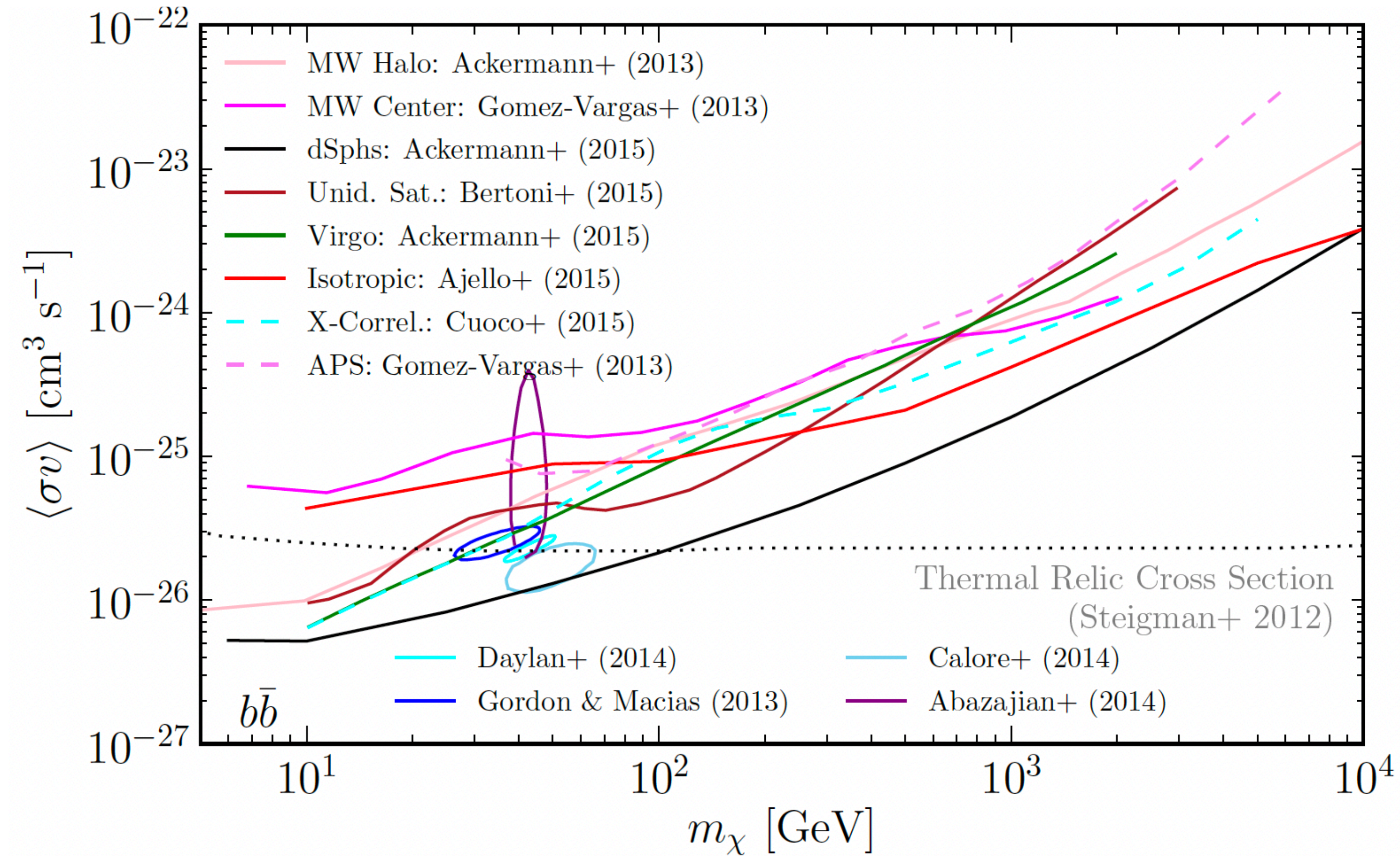
- * High-energy gamma-ray detector.
- * Launched in 2008, surveys the whole sky every three hours.
- * Mission led by NASA, with contributions from other countries. 🇺🇸 🇸🇪 🇮🇹 🇫🇷 🇯🇵
- * Energy range: 20 MeV — 300 GeV : Ideal instrument for WIMP searches!



WIMP searches with gamma rays: *where should we look?*



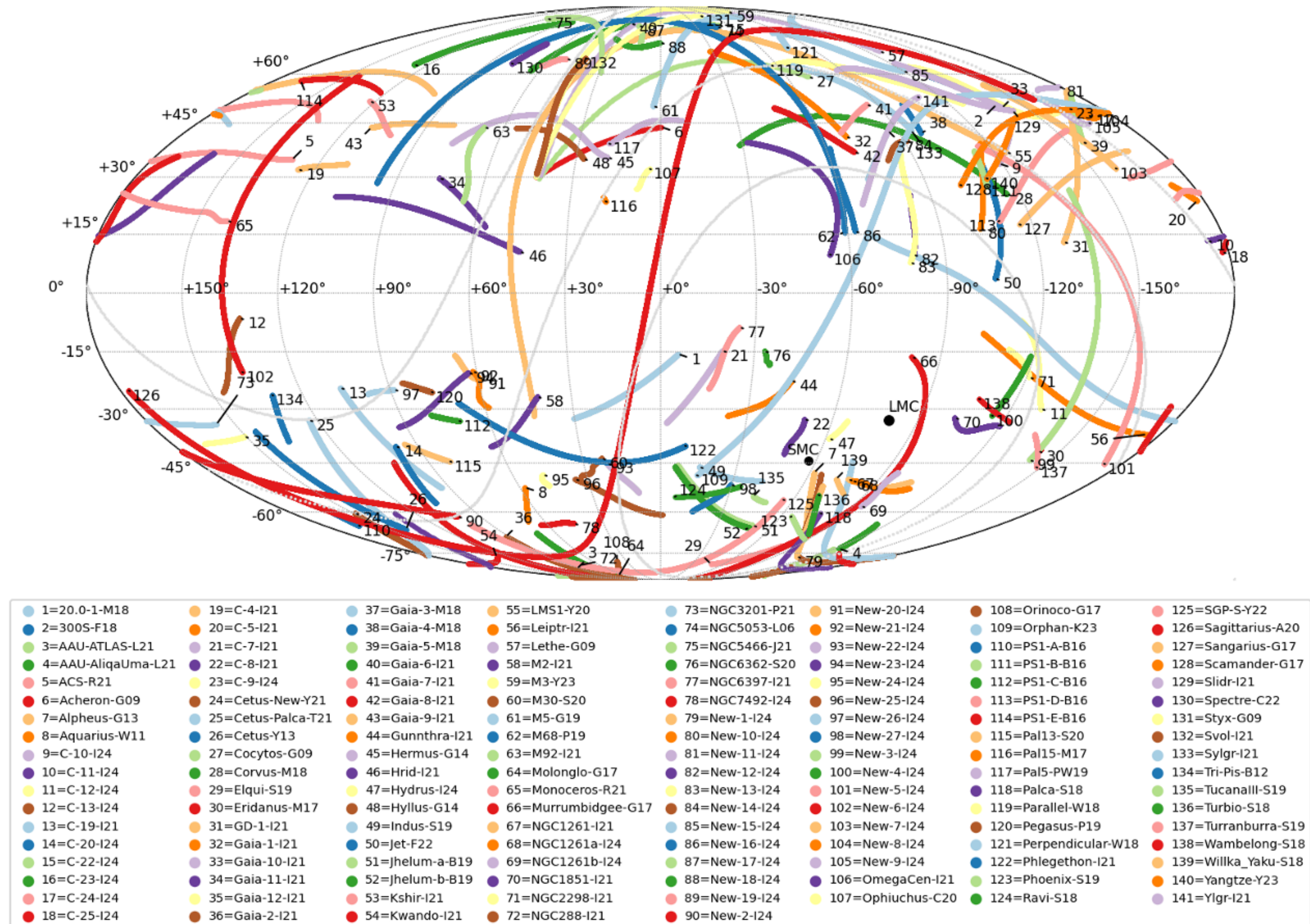
WIMP searches with gamma rays



Stellar Streams in a nutshell

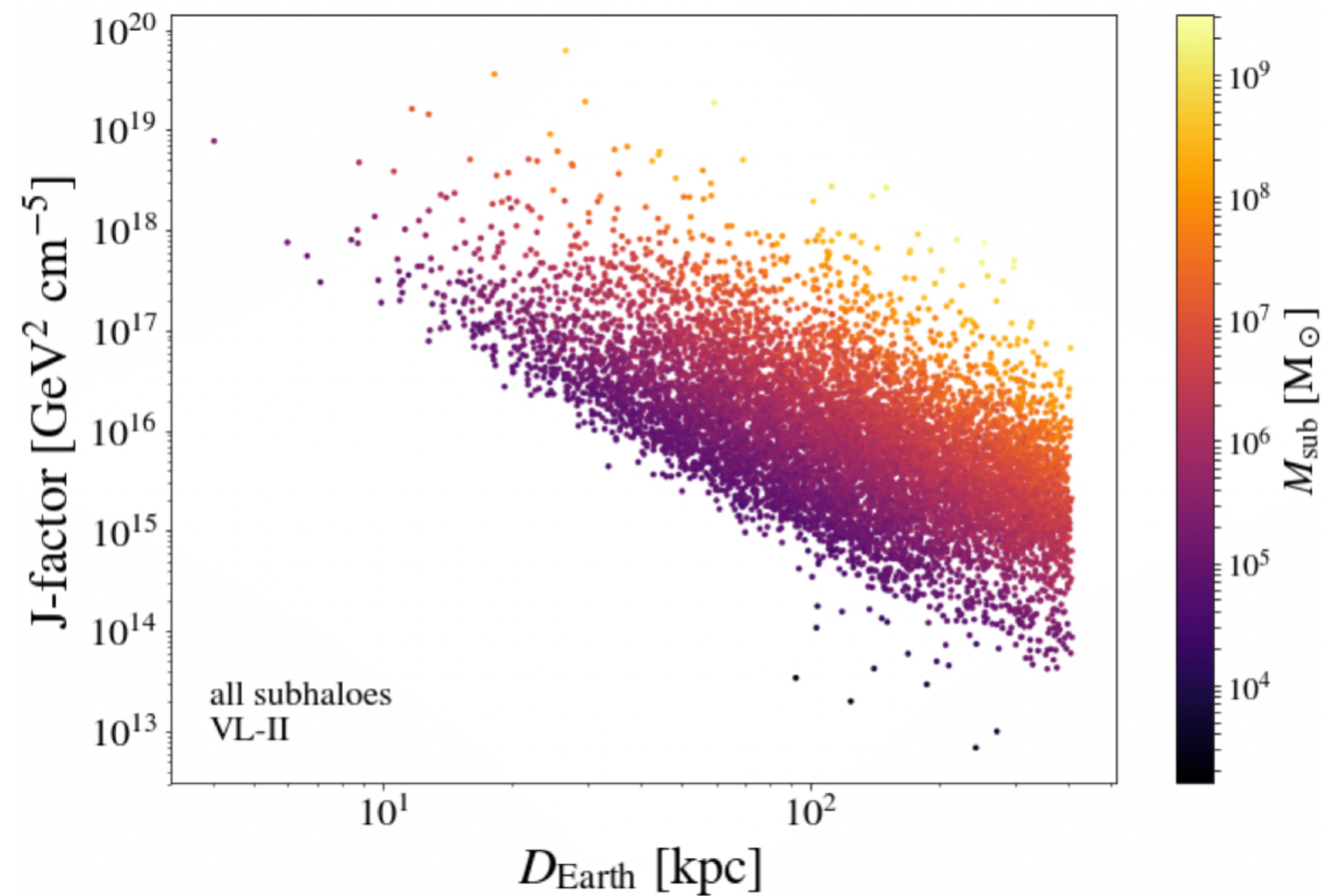
* Observed by wide and deep sky surveys, such as SDSS, Pan-STARRS, Gaia and DESI.

* More than 100 stellar streams have been observed around the Milky Way (MW).



Plot made with the Galstreams library (Mateu et al. 2018, Mateu 2023)

Sample Selection: Distance



Aguirre-Santaella &
Sánchez Conde, 2024

DM Modelling

- * We assume that the streams maintain the same density distribution as their progenitors within the core ($r \leq r_s$).
- * Rest of the DM outside r_s gets lost due to tidal stripping (e.g., [Aguirre-Santaella et al. 2023](#)).
- * We model the streams with a truncated Navarro-Frenk-White (NFWt) DM density profile.

If $\left\{ \begin{array}{l} r \leq r_s \longrightarrow \rho_{NFWt}(r) = \frac{\rho_0}{\left(\frac{r}{r_s}\right) \left(1 + \frac{r}{r_s}\right)^2} \quad \begin{array}{l} \rho_0 : \text{characteristic DM density} \\ r_s : \text{scale radius} \end{array} \\ r > r_s \longrightarrow \rho_{NFWt}(r) = 0 \end{array} \right.$

ρ_0 and r_s are obtained starting from the initial DM mass (M_{200}) and assuming the [Moliné et al. 2017](#) subhalo concentration-mass relation.

DM Modelling: M/L ratio scenarios

* Starting from the known stellar mass, we adopt three different mass-to-light (M/L) ratios to estimate the ‘original’ DM mass of each stream at accretion time, M_{200} .

Low: $M/L = 2$
 (same DM mass than baryonic mass)

Benchmark: $M/L = 5$

High: $M/L = 50$

Typical M/L for dGs: 10 – 1000

(e. g. [Mateo 1998](#),
[Sánchez-Conde et al. 2011](#),
[Guo et al. 2019](#)).

Stream	$\frac{M_{200}}{10^4} (M_{\odot})$		
	Low	Bench.	High
Indus	3.40	17.00	170.00
LMS-1	10.00	50.00	500.00
Orphan-Chenab	16.00	80.00	800.00
PS1-D	0.75	3.75	37.50
Turranburra	0.76	3.80	38.00
Cetus-Palca	150.00	750.00	7500.00
Styx	1.80	9.00	90.00
Elqui	1.04	5.20	52.00

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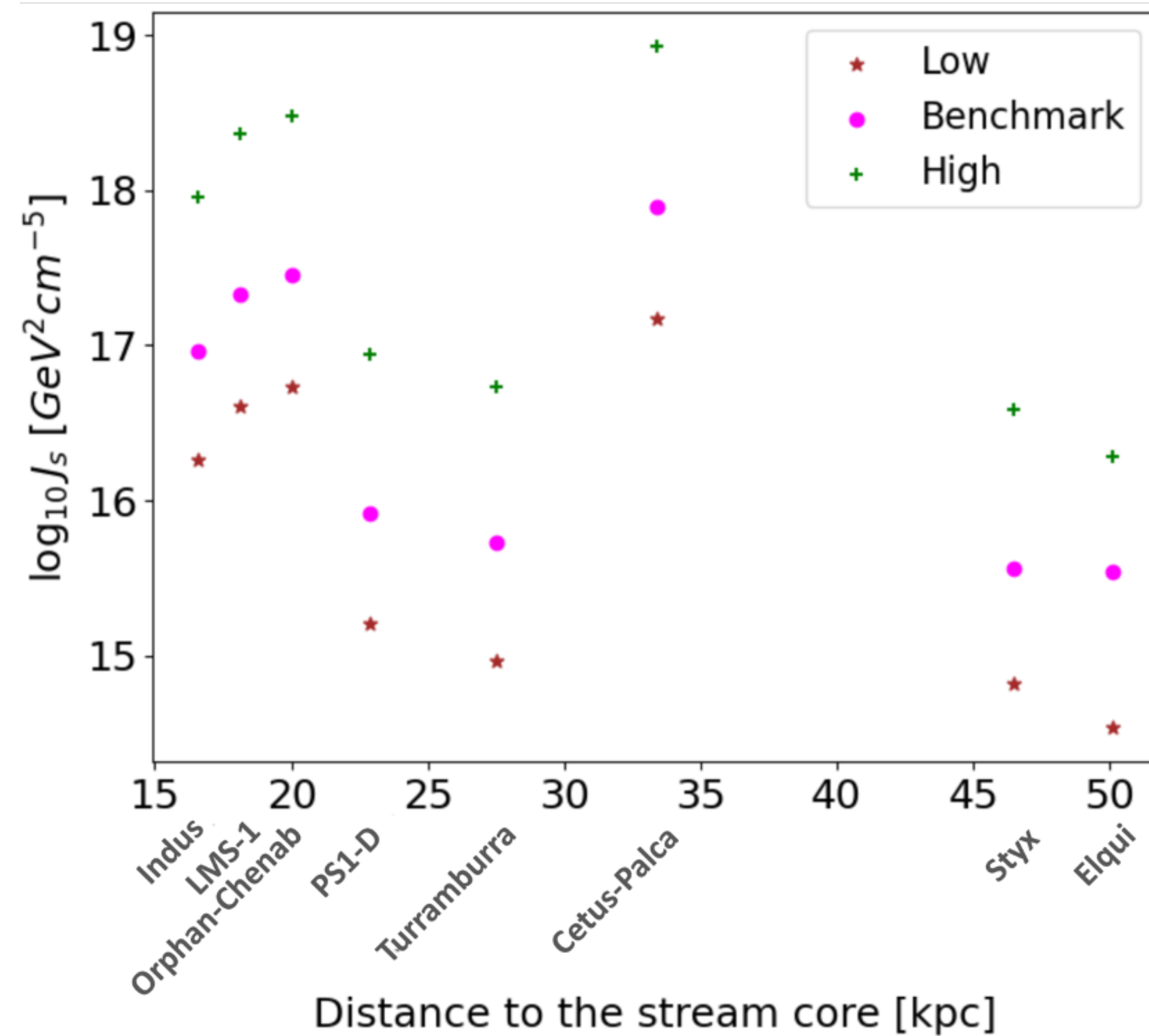
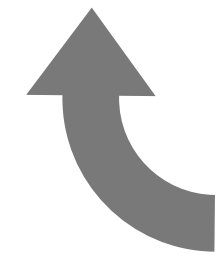
Benchmark: $M/L = 5$

High: $M/L = 50$

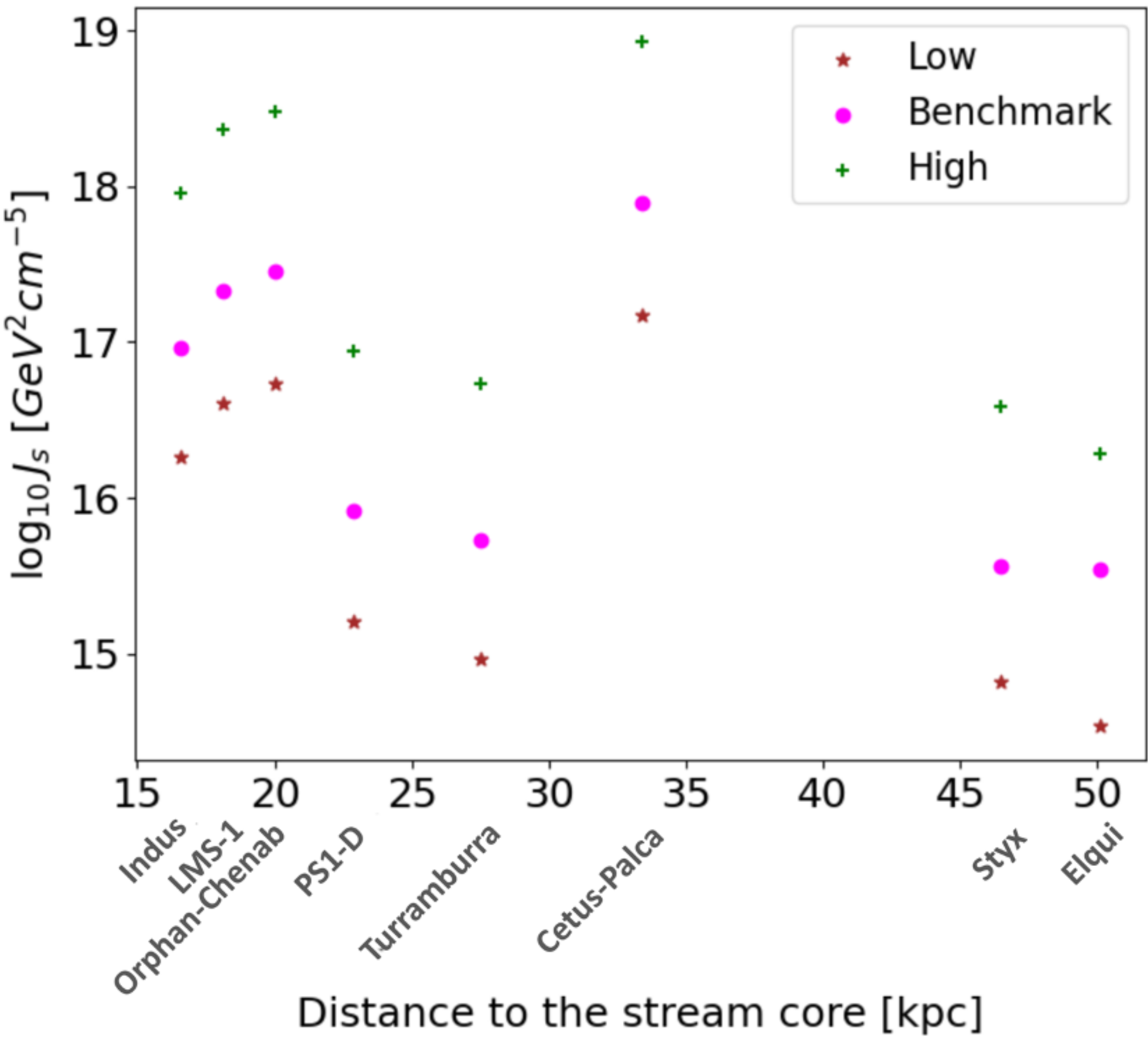
★ In cases where no estimates of the current streams’ mass is available, we consider the stellar mass of the progenitor as the stellar mass of the stream: during the stretching process, the streams lose DM while we assume that the total baryon matter content remains almost the same.

DM Modelling: Streams' J-factors

J_s : J-factor integrated
up to the scale radius r_s



DM Modelling: Streams' J-factors



This work

CFS & Sánchez-Conde, arXiv: 2502.15656

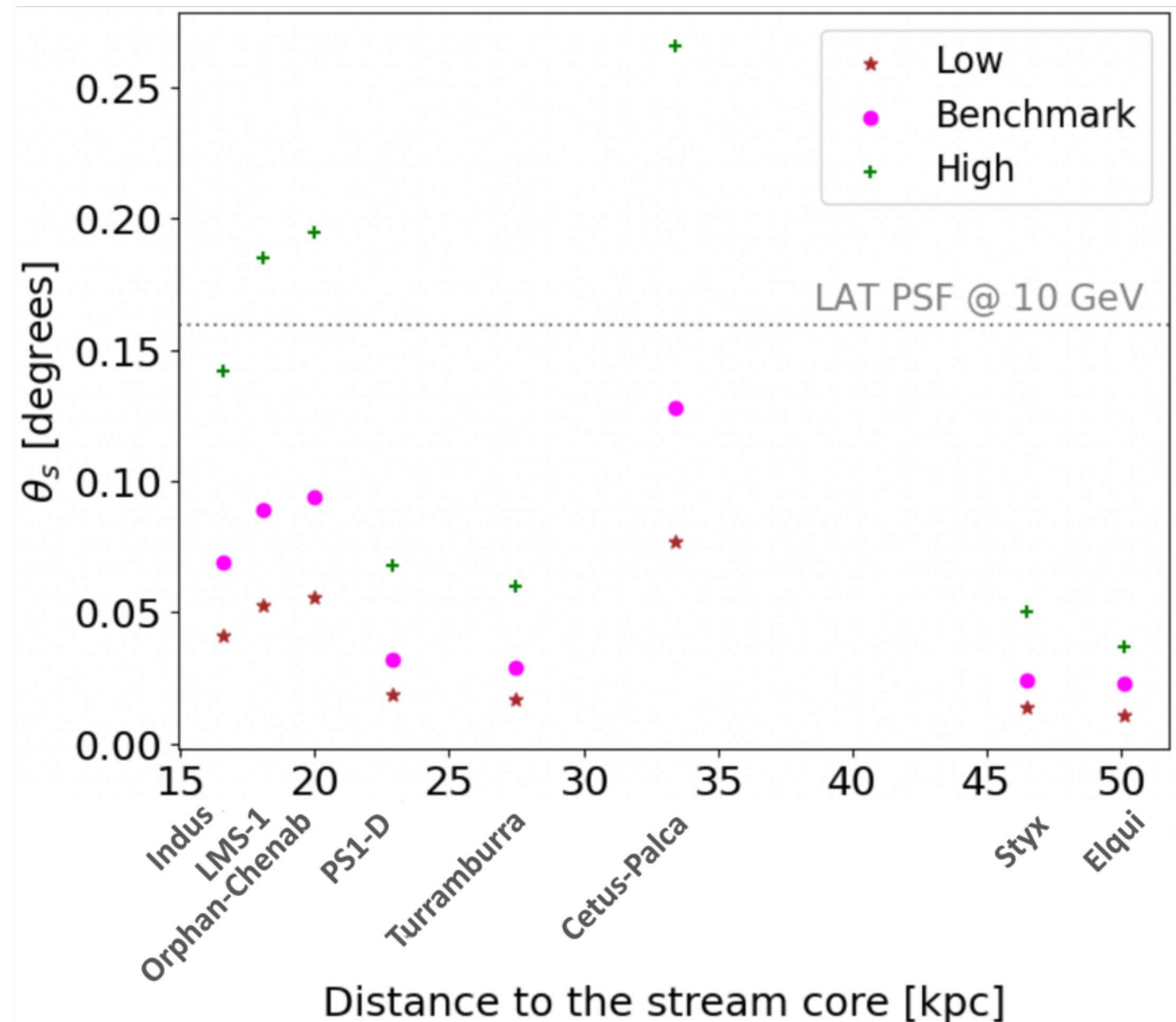
Target	Distance (kpc)	J factor (GeV ² cm ⁻⁵)
Galactic center / halo (§4.4)	8.5	3×10^{22} to 5×10^{23}
Known Milky Way satellites (§4.5)	25 to 300	3×10^{17} to 3×10^{19}
Dark satellites (§4.6)	up to 300	up to 3×10^{19}
Galaxy Clusters (§4.7)	$> 5 \times 10^4$	up to 1×10^{18}

Example of typical J-factor values for other targets

Charles, Sánchez-Conde+2016

DM Modelling: Streams' Angular sizes

* The extension in the sky of each stream's core will be given by the angle subtended by r_s : $\theta_s = \arctan\left(\frac{r_s}{d_{Sun}}\right)$



Angular resolution of the LAT at 10 GeV
(68% containment)

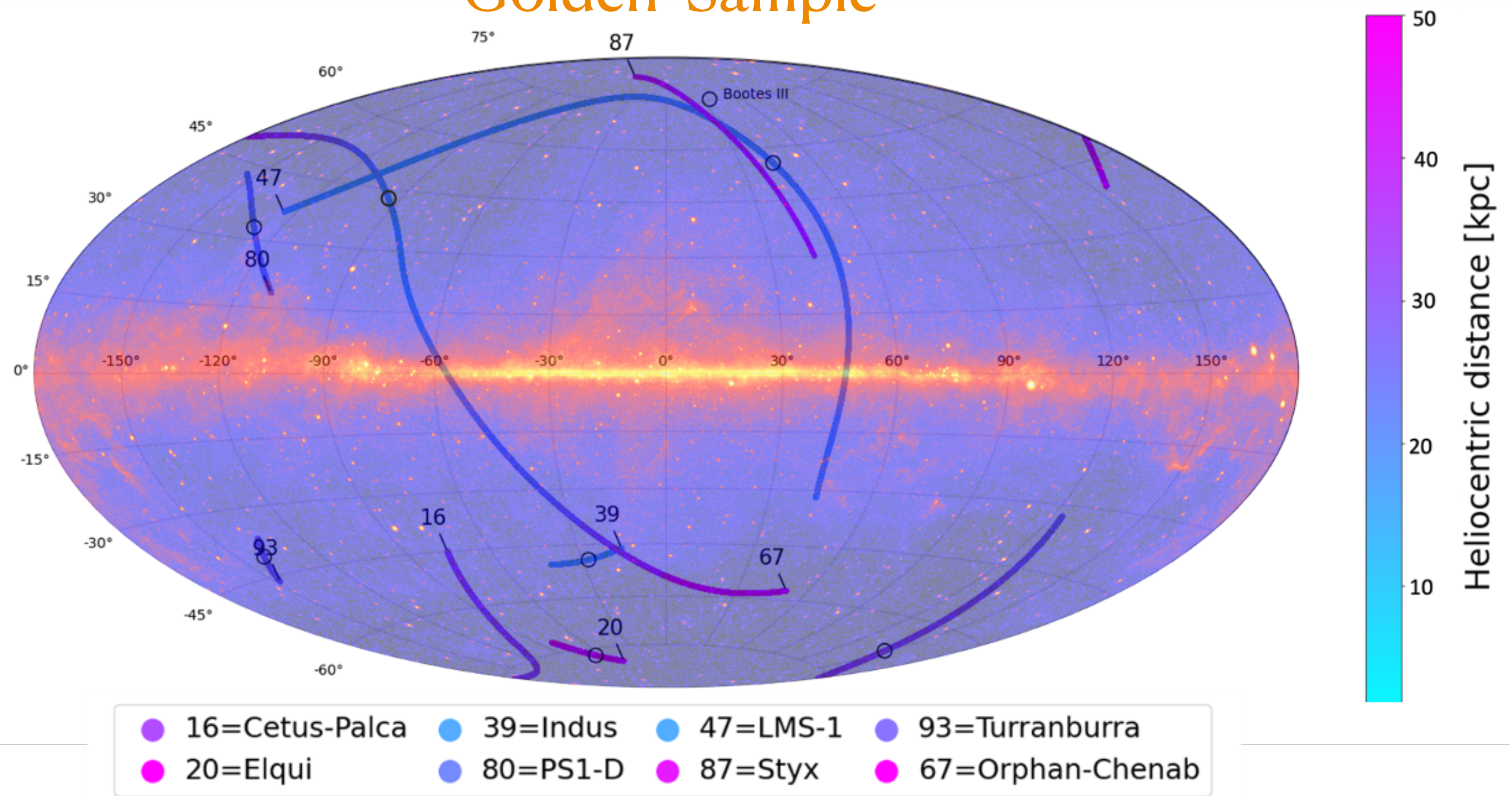
These objects are considered as
point-like sources for the LAT

Fermi-LAT Data Analysis



* We search for any gamma-ray signal in 15 years of Fermi-LAT data from the direction of the assumed streams' cores.

'Golden' Sample



Spectral analysis technical setup

Time domain (Gregorian)	2008-08-04 to 2023-04-01
Time domain (MET)	239557417 to 702032312
Energy range	500 MeV - 500 GeV
IRF	P8R3_SOURCE_V3
Event type	FRONT + BACK
Point-source catalog	4FGL-DR4
ROI size	15° x 15°
Angular bin size	0.01°
Bins per energy decade	8
Galactic diffuse model	gll_iem_v07.fits
Isotropic diffuse model	iso_P8R3_SOURCE_V3_v1.txt

- * We perform the data analysis with the Fermipy python package.
- * Sources within 3 degrees from stream's core: free normalization and spectral shape.
- * Galactic diffuse component: free normalization and spectral index.
- * Isotropic diffuse component: free normalization.

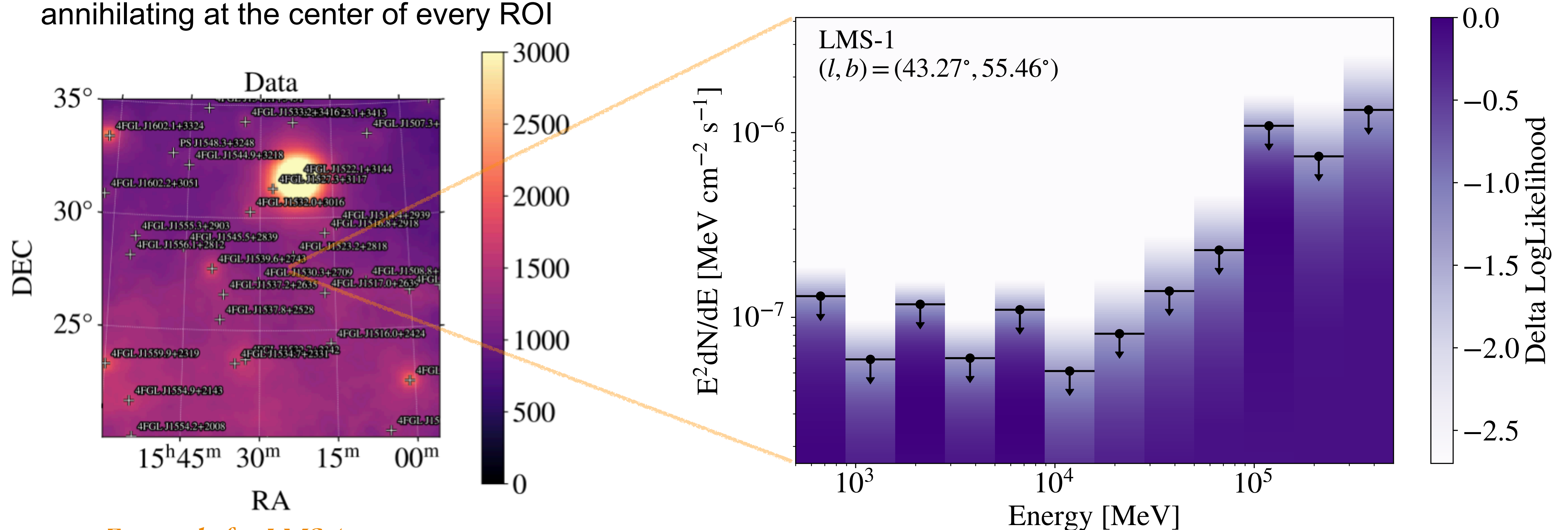
LAT Analysis Results: Flux upper limits

CFS & Sánchez-Conde
arXiv: 2502.15656

No significant emission is detected from any of the streams in our sample.

We introduce a putative DM source annihilating at the center of every ROI

Flux upper limits 95 % confidence level (C.L.)



Example for LMS-1 stream

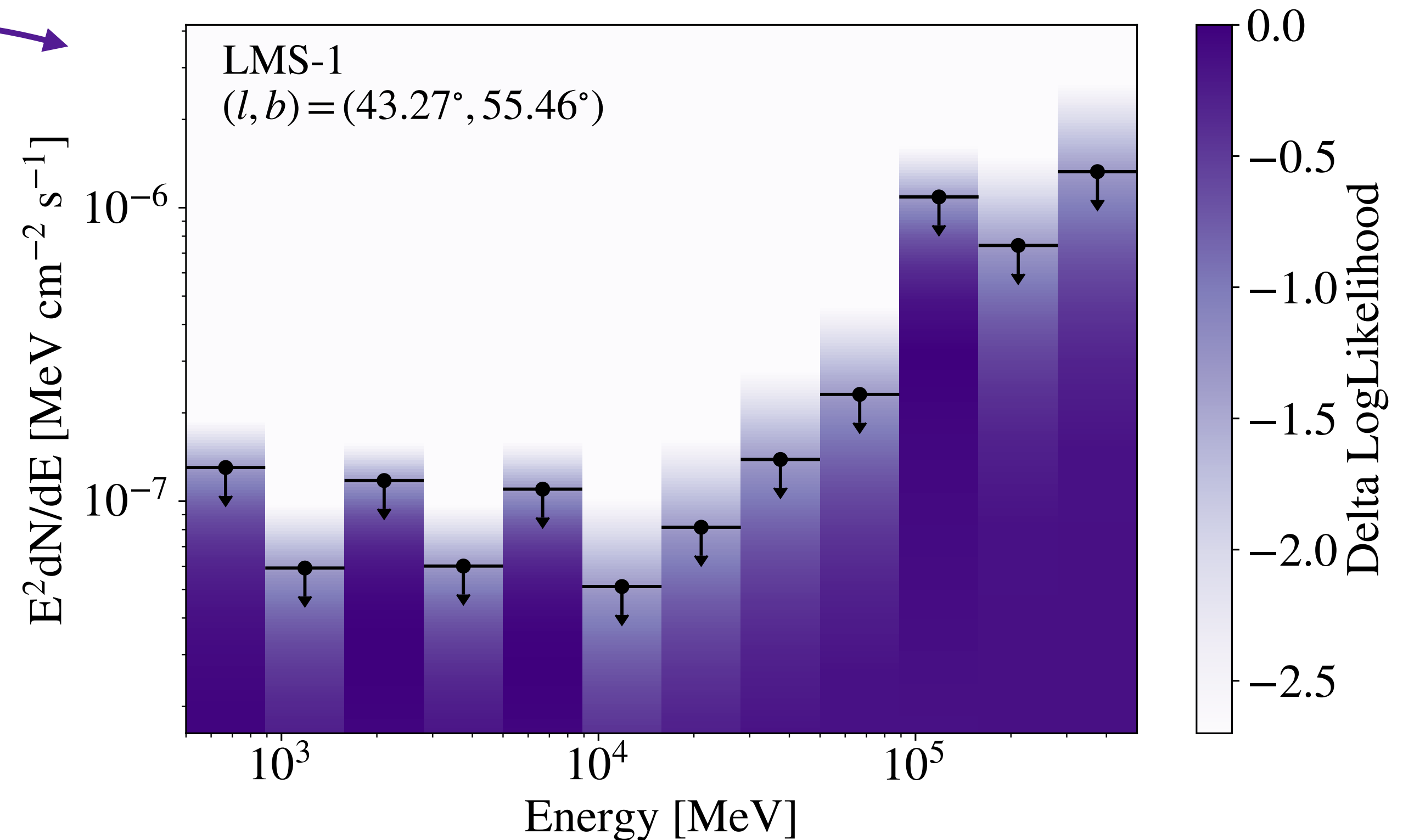
DM search in streams with the Fermi-LAT



No significant emission is detected from any of the streams' core in our sample.

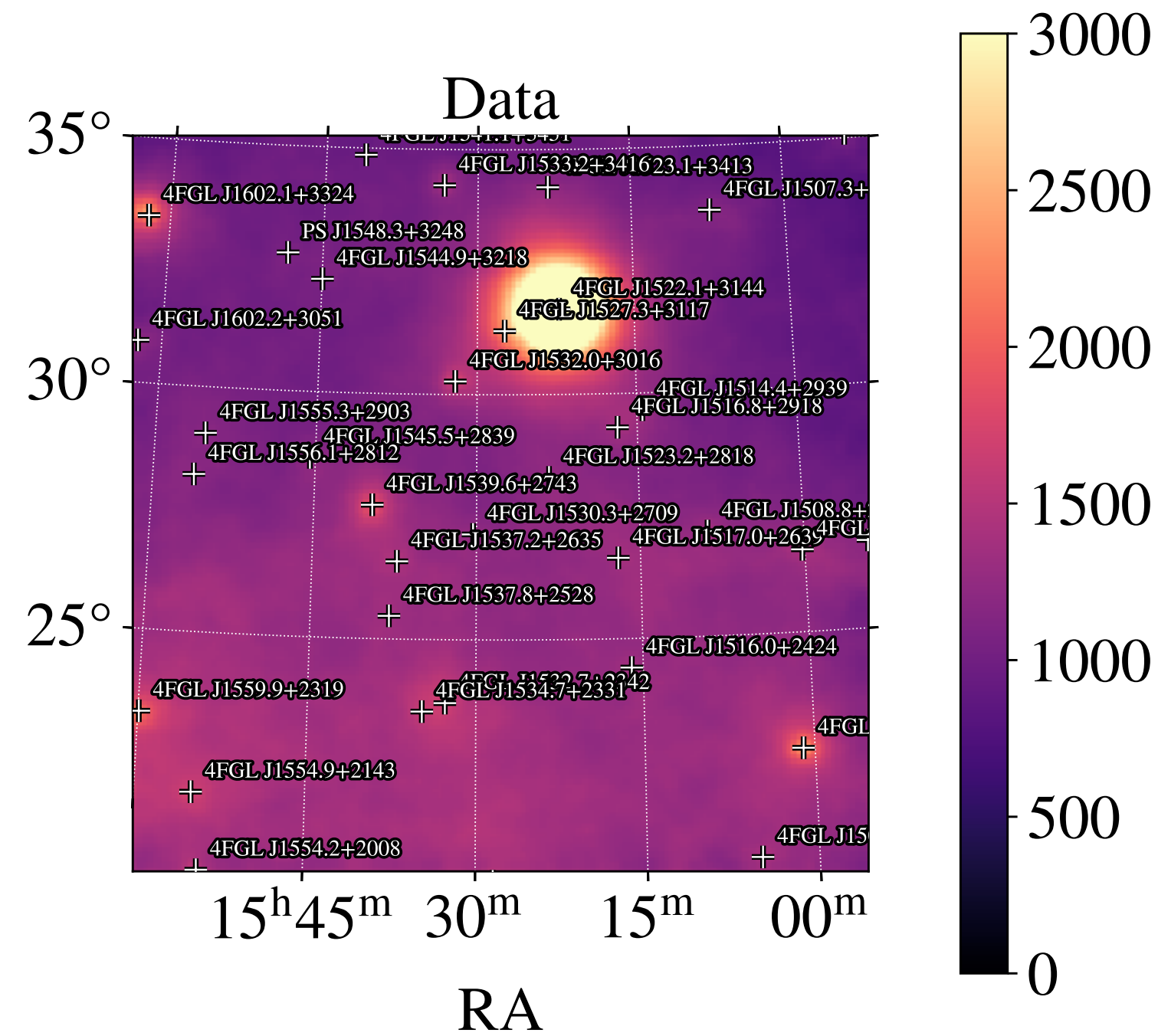
Example for LMS-1 stream

We compute **flux upper limits** at 95% confidence level (C.L.) and place constraints on the DM particle properties.

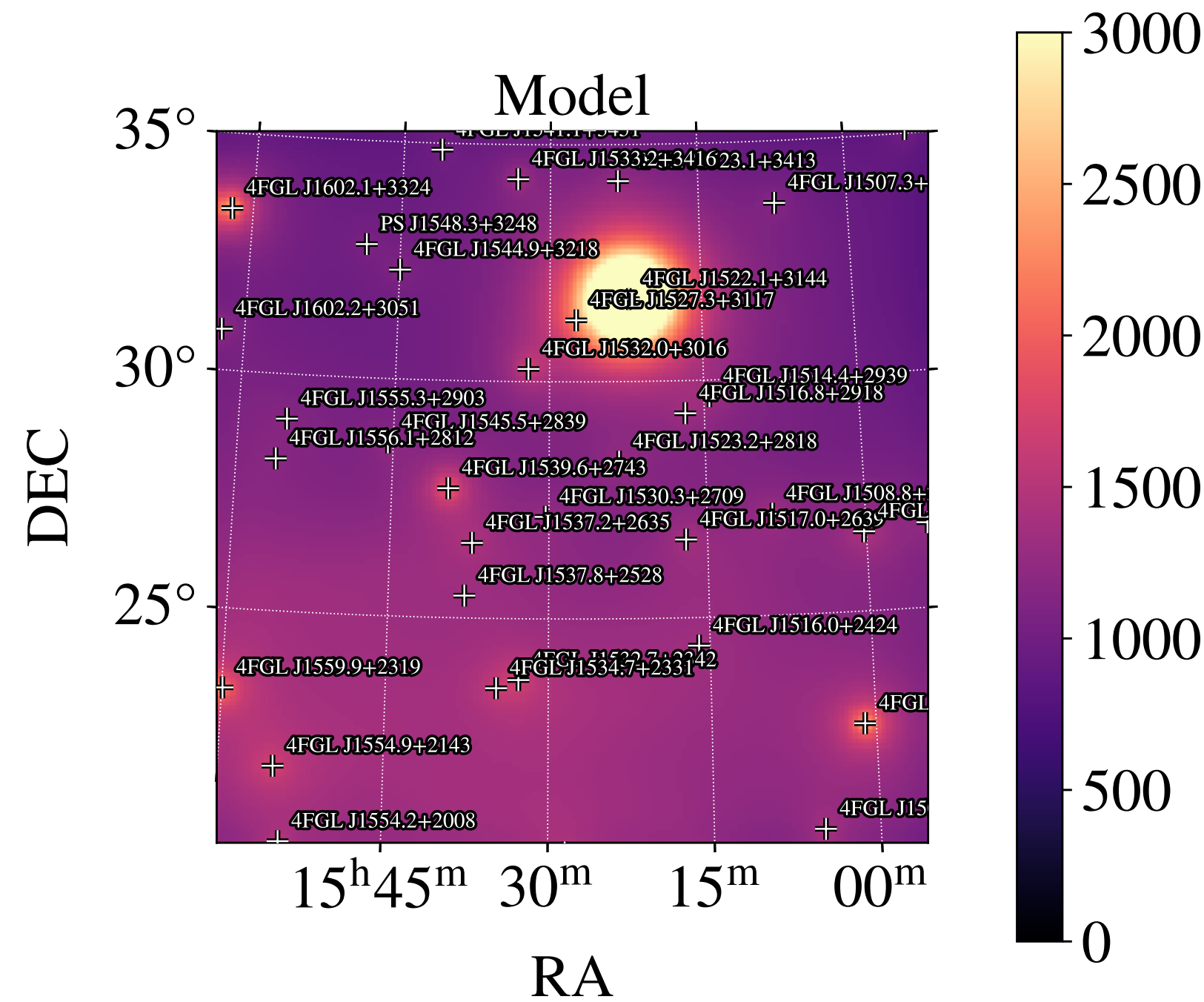


LAT Analysis Results: Example of skymaps

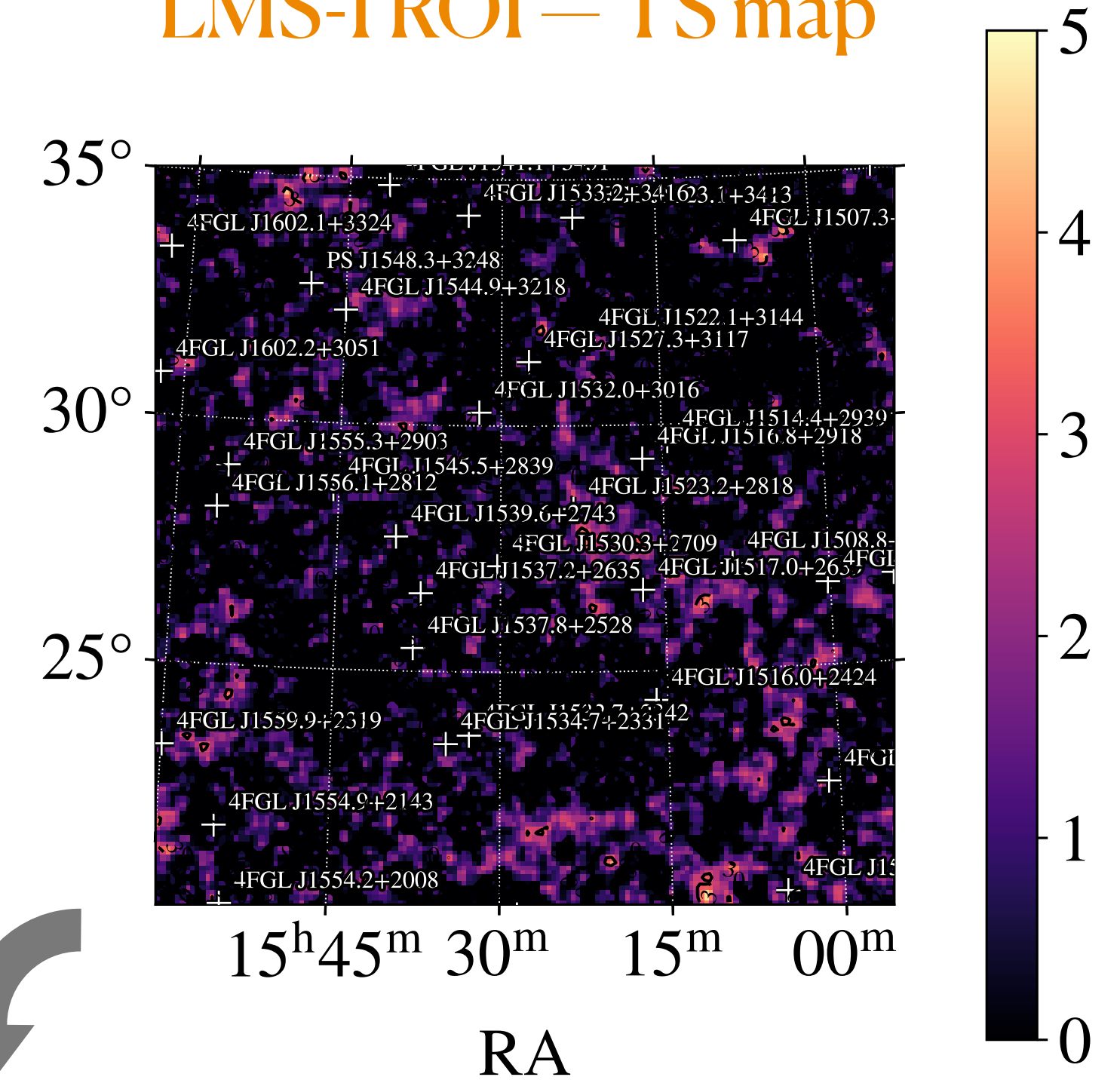
LMS-1 ROI — Data map



LMS-1 ROI — Model map



LMS-1 ROI — TS map



Test statistic (TS): positive deviations with respect to the model

$$TS = -2 \log \left(\frac{\mathcal{L}(H_1)}{\mathcal{L}(H_0)} \right)$$

← Likelihood of the alternative (existing DM source) hypothesis
← Likelihood under the null (no source) hypothesis

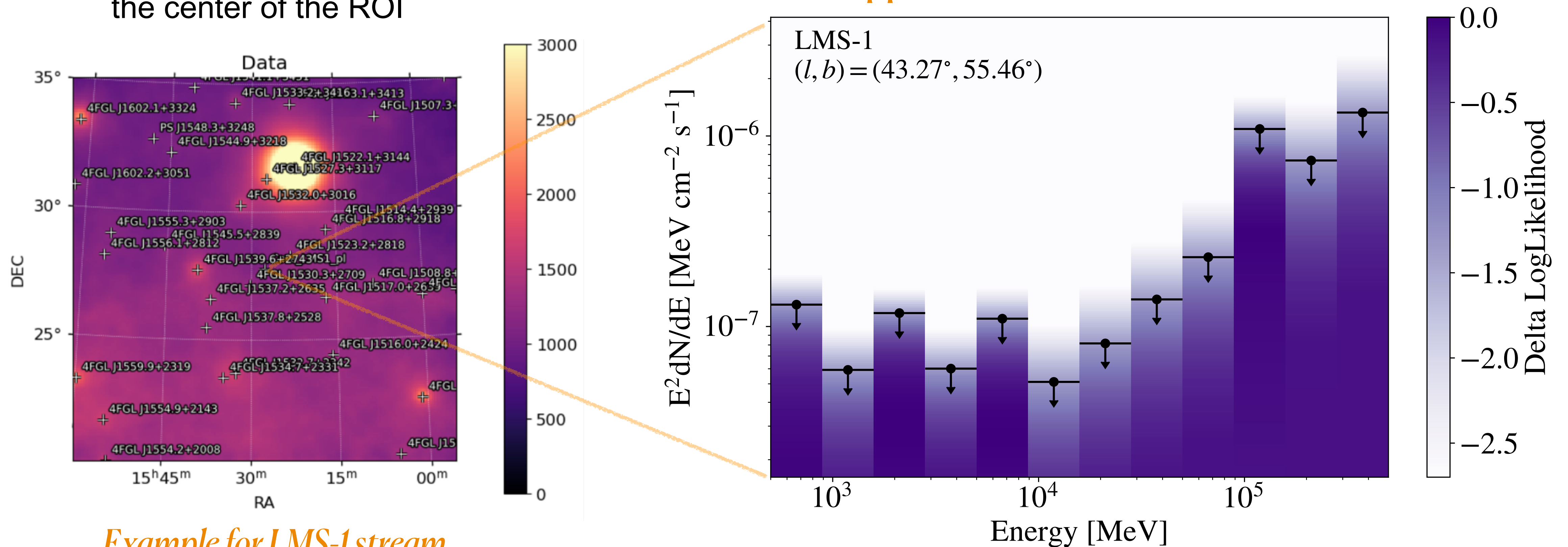
$$TS \sim \sigma^2$$

Analysis Results:

Flux upper limits with a *Power Law*

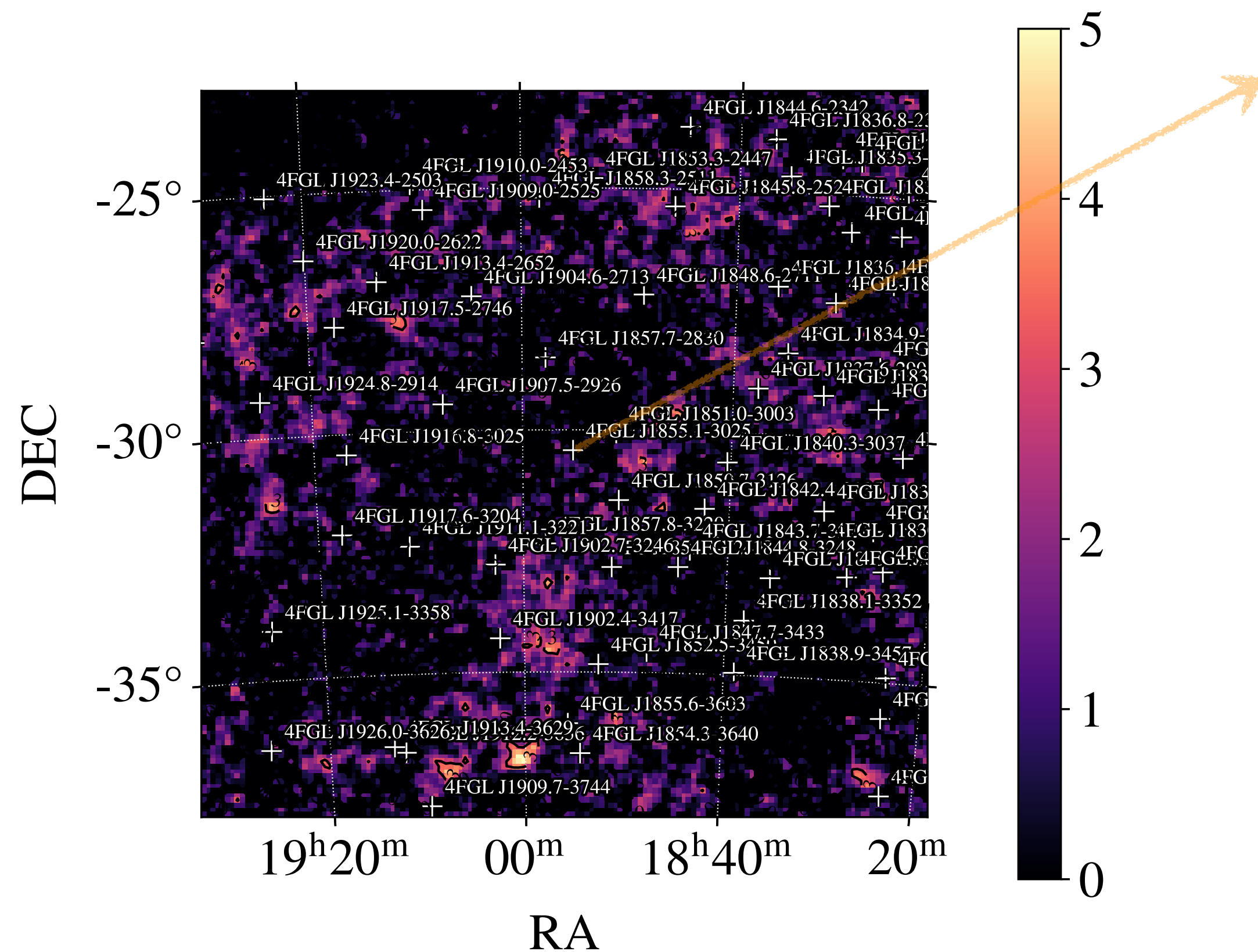
We introduce a power law source at the center of the ROI

Flux upper limits 95 % confidence level (C.L.)



Example for LMS-1 stream

LAT Analysis Results: Sagittarius (Sgr) stream



TS map for Sgr

- * The source **4FGL J1855.1-3025** is detected ~ 0.2 degrees from Sgr core. It is associated with the globular cluster M54 in the 4FGL-DR4 catalog.
- * Current discussion about the origin of this emission (millisecond pulsars inside M54 or DM annihilation at the core of Sgr). We will investigate in the future whether this emission could be due to DM associated to Sgr in some way.
- * By introducing a putative DM source at the exact location of Sgr core, we find no emission.

DM Constraints

- * In the absence of a gamma-ray signal from the direction of the streams' cores, we place constraints on the DM particle properties.
- * We set constraints on the $\langle\sigma v\rangle$ for DM masses from 10 to 10^4 GeV in the $b\bar{b}$ and $\tau^+\tau^-$ annihilation channels.

Diagram illustrating the equation for the velocity-averaged annihilation cross-section $\langle\sigma v\rangle$ and its components:

$$\langle\sigma v\rangle = \frac{8\pi \cdot m_\chi^2 \cdot F_{min}}{J \cdot N_\gamma}$$

- DM particle mass** (pink arrow pointing to m_χ^2)
- Minimum detection flux, i.e., flux upper limits from our LAT analysis** (blue arrow pointing to F_{min})
- J-factor from our DM modelling** (purple arrow pointing to J)
- DM spectrum for a particular annihilation channel integrated within an energy range (Cirelli+11)** (orange arrow pointing to N_γ)

Velocity average annihilation cross-section (green arrow pointing to the equation)

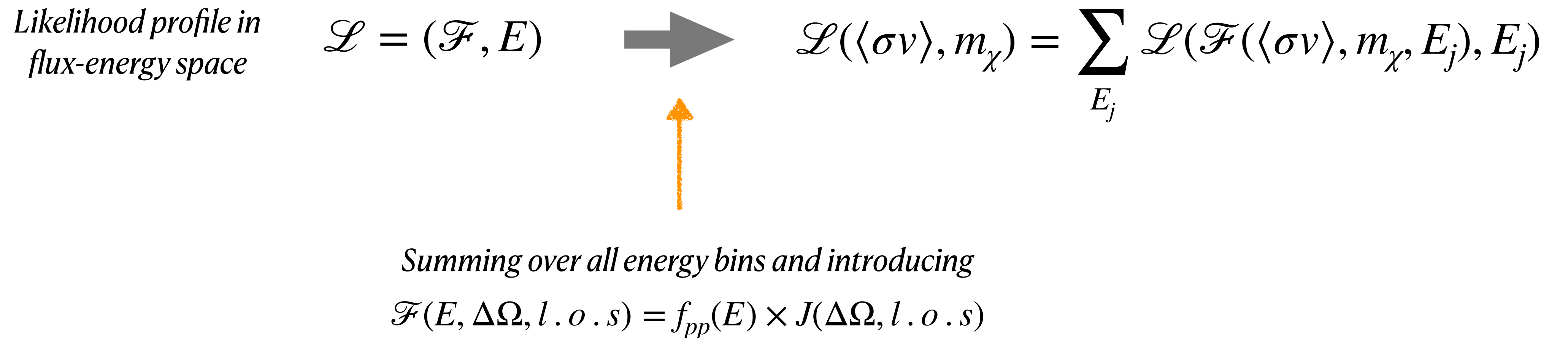
$$J(\Delta\Omega, l.o.s) \propto \iint \rho_{DM}^2 dl d\Omega$$

DM Constraints

- * In the absence of a gamma-ray signal from the direction of the streams' cores, we place constraints on the DM particle properties.
- * We set constraints on the $\langle\sigma v\rangle$ for DM masses from 10 to 10^4 GeV in the $b\bar{b}$ and $\tau^+\tau^-$ annihilation channels.
- * Individual log-likelihood profile for each stream as a function of DM mass and $\langle\sigma v\rangle$:

Likelihood profile in flux-energy space

$$\mathcal{L} = (\mathcal{F}, E) \quad \xrightarrow{\quad} \quad \mathcal{L}(\langle\sigma v\rangle, m_\chi) = \sum_{E_j} \mathcal{L}(\mathcal{F}(\langle\sigma v\rangle, m_\chi, E_j), E_j)$$



Summing over all energy bins and introducing
 $\mathcal{F}(E, \Delta\Omega, l.o.s) = f_{pp}(E) \times J(\Delta\Omega, l.o.s)$

DM Constraints: Combined Likelihood Analysis

- * Once the individual analysis of each stream is done, we combine the results obtained for each one by summing together the individual log-likelihood profiles independently for each energy bin, to obtain a global likelihood:

Combined likelihood for a particular DM annihilation channel as a function of the DM mass and $\langle\sigma v\rangle$ for all targets

DM parameters
($\langle\sigma v\rangle$ and m_χ)

Parameters in the background model
(i.e., the nuisance parameters)

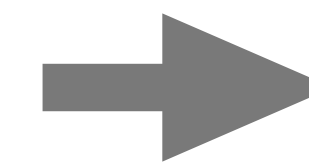
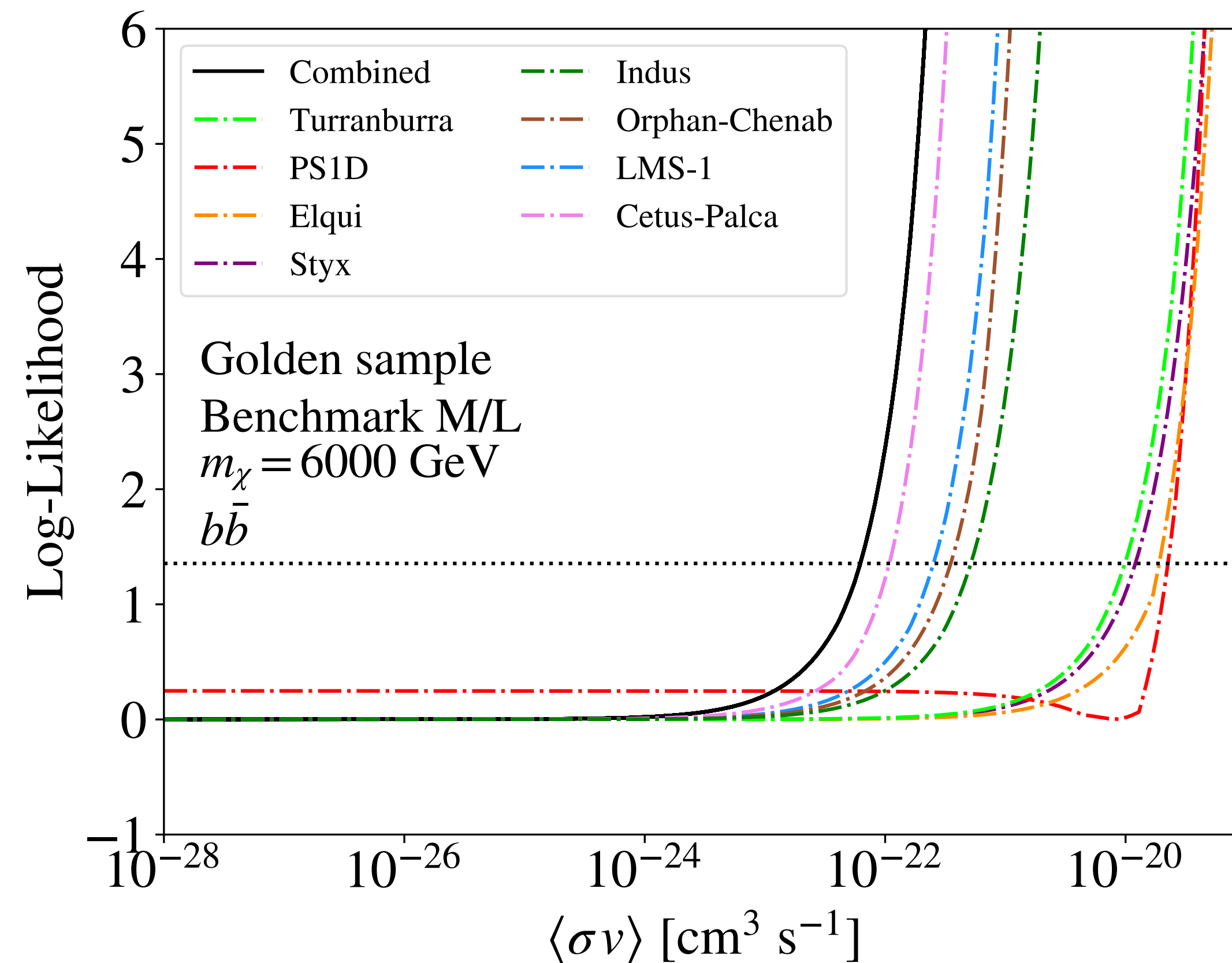
$$\log(\mathcal{L}_j(\mu, \theta_j | \mathcal{D}_j)) = \sum_i \log(\mathcal{L}_{i,j}(\mu, \theta_{i,j} | \mathcal{D}_{i,j}))$$

i : index of each target in the list
 j : index of each energy bin of the LAT data ($\mathcal{D}$)

Same methodology used e.g. in previous LAT dwarf analysis (e. g. *Albert et al. 2016, McDaniel et al. 2024*).

Individual and combined log-likelihood profiles

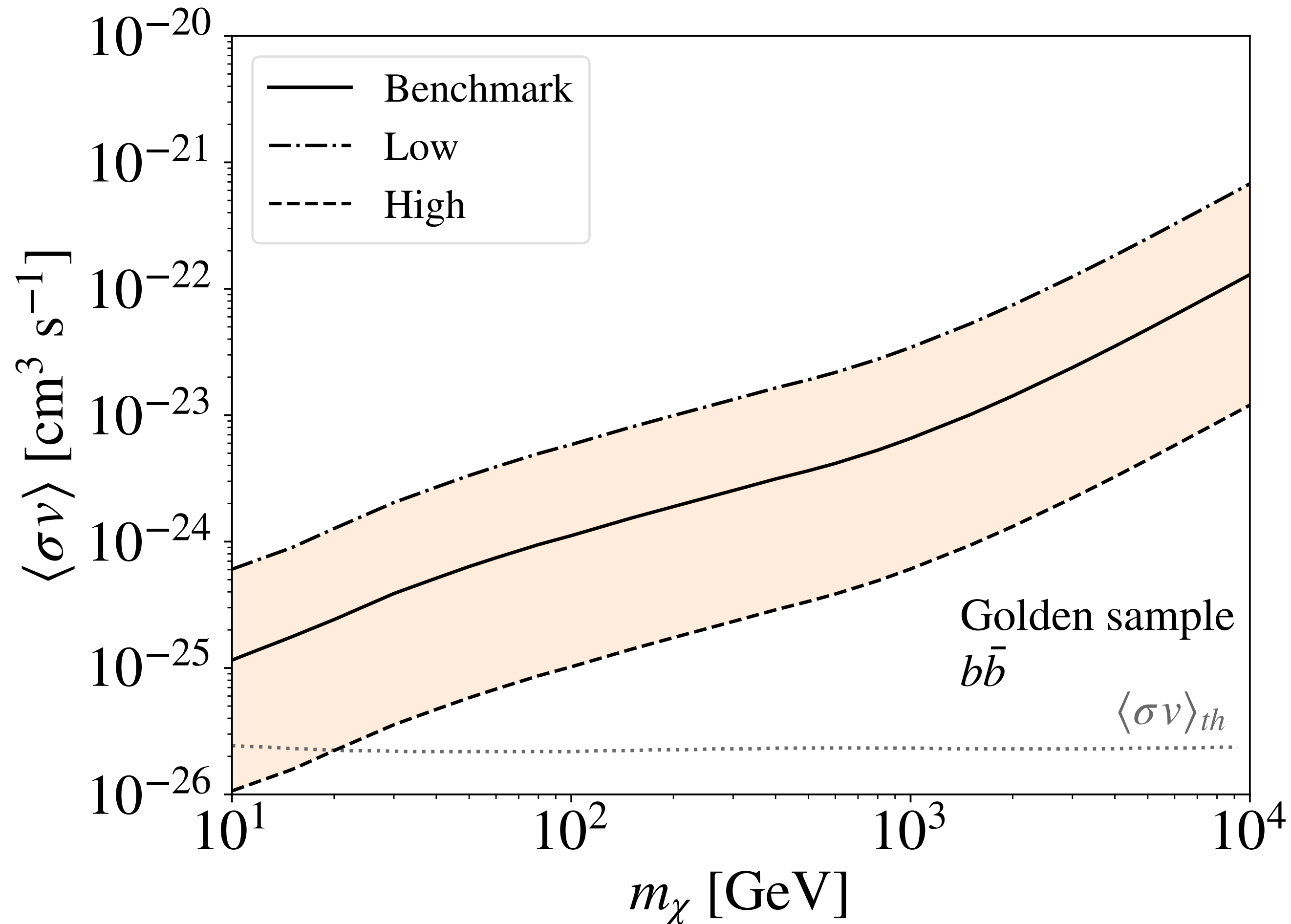
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The value of $\langle\sigma v\rangle$ for which
 $\Delta\mathcal{L} = 2.71/2$ is used to set the 95%
C.L. upper limits on $\langle\sigma v\rangle$

Example of the log-likelihood profiles for a particular DM mass and annihilation channel

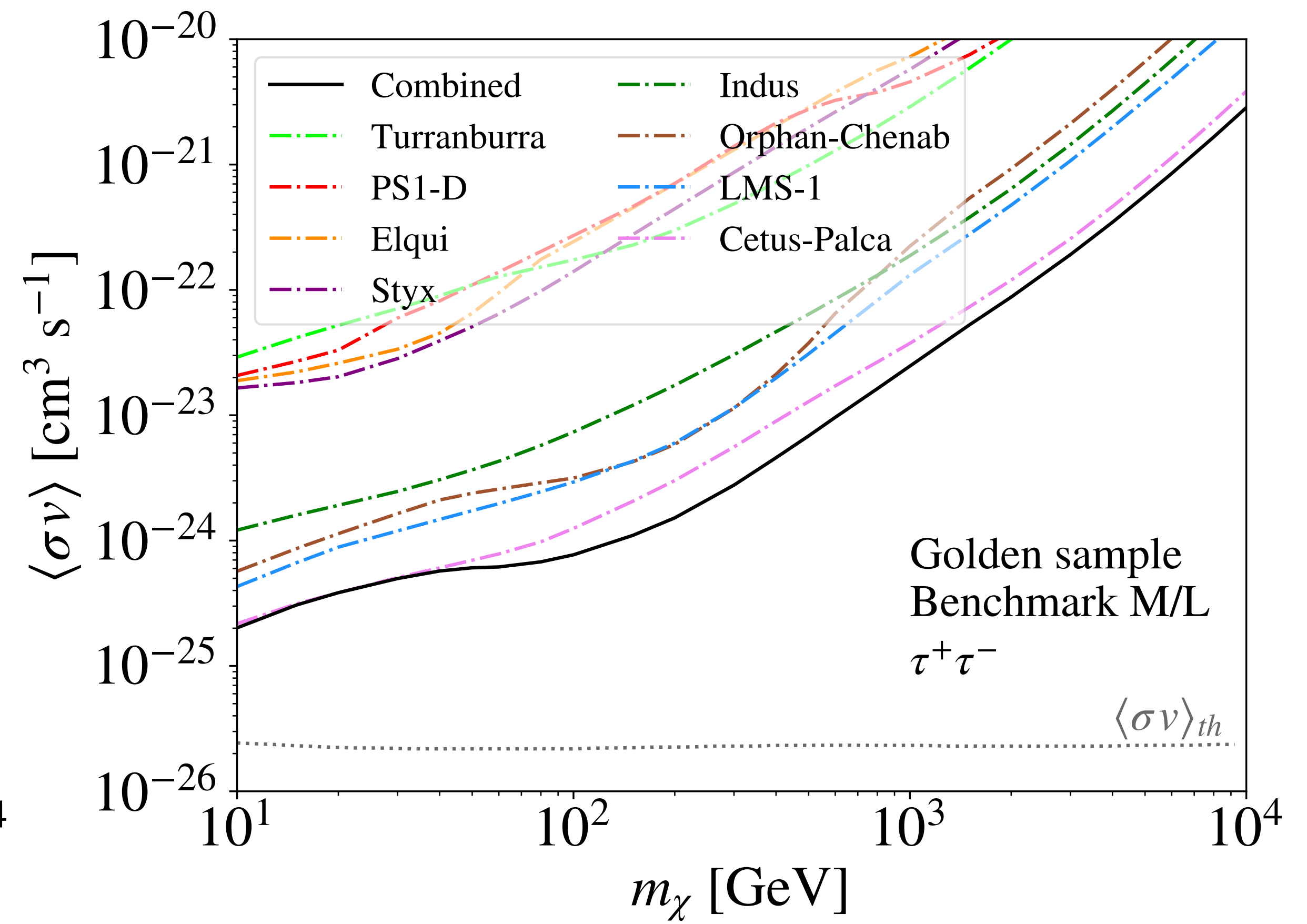
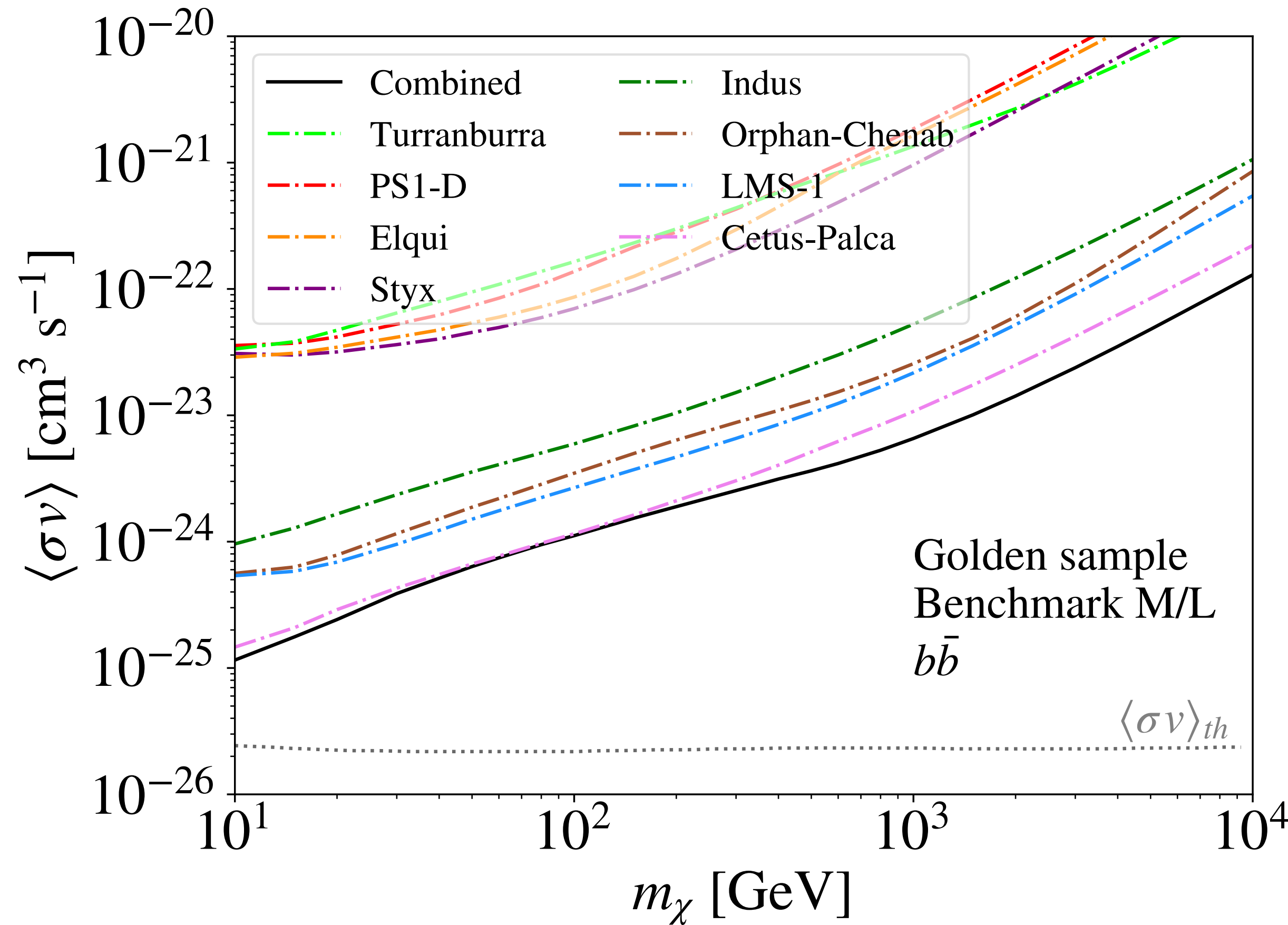
DM constraints: Golden Sample, M/L scenarios



- * Overall uncertainty of $\mathcal{O}(100)$ in the DM limits.
- * The combined constraints for the Benchmark scenario are $\mathcal{O}(10)$ above the thermal relic cross-section for the lowest considered WIMP masses.
- * DM limits reach the thermal relic cross-section at lower masses when considering the High scenario.

DM constraints: Golden Sample, Benchmark case

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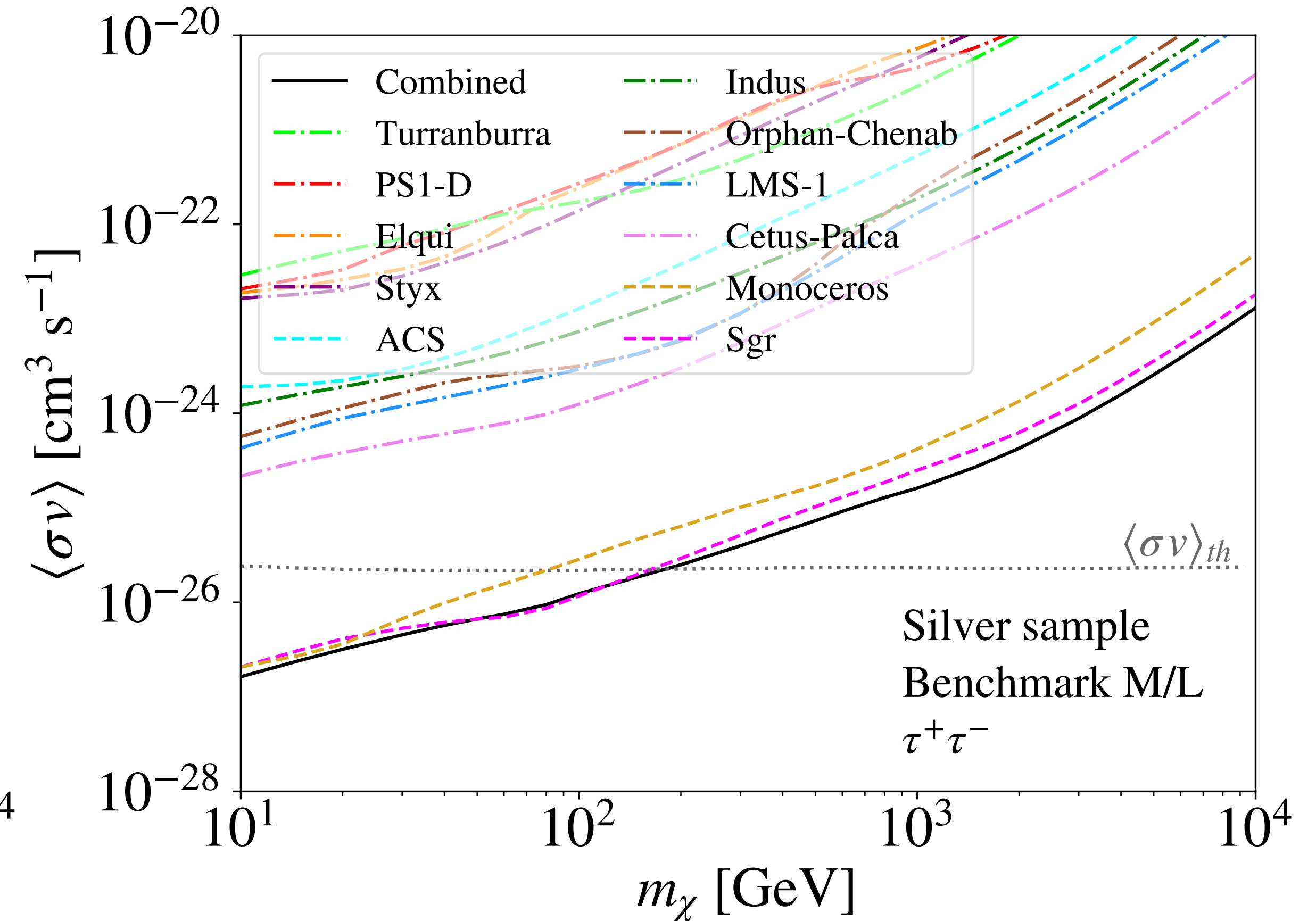
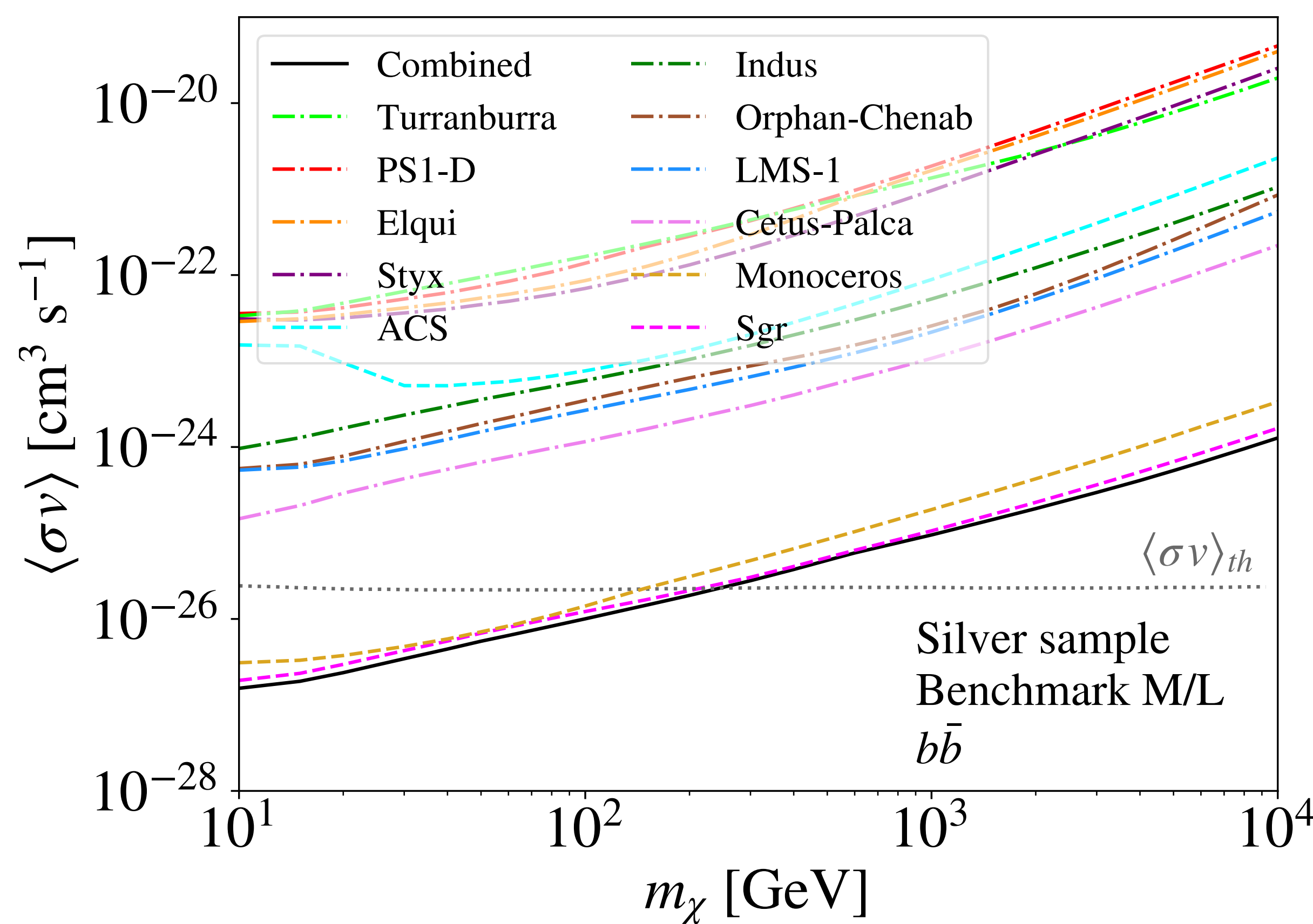


* The Cetus-Palca stream dominates the combined result.

* The combined constraints are $\mathcal{O}(10)$ above the thermal relic cross-section for the lowest considered WIMP masses and both channels.

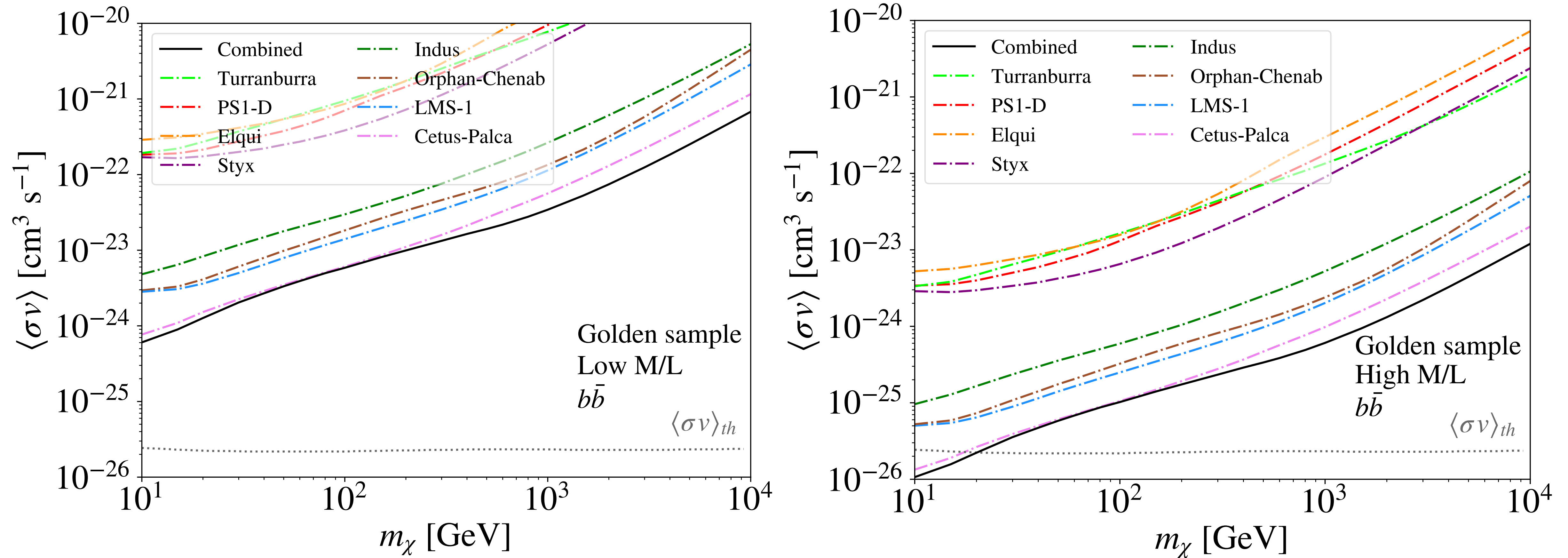
DM constraints: Silver Sample, Benchmark case

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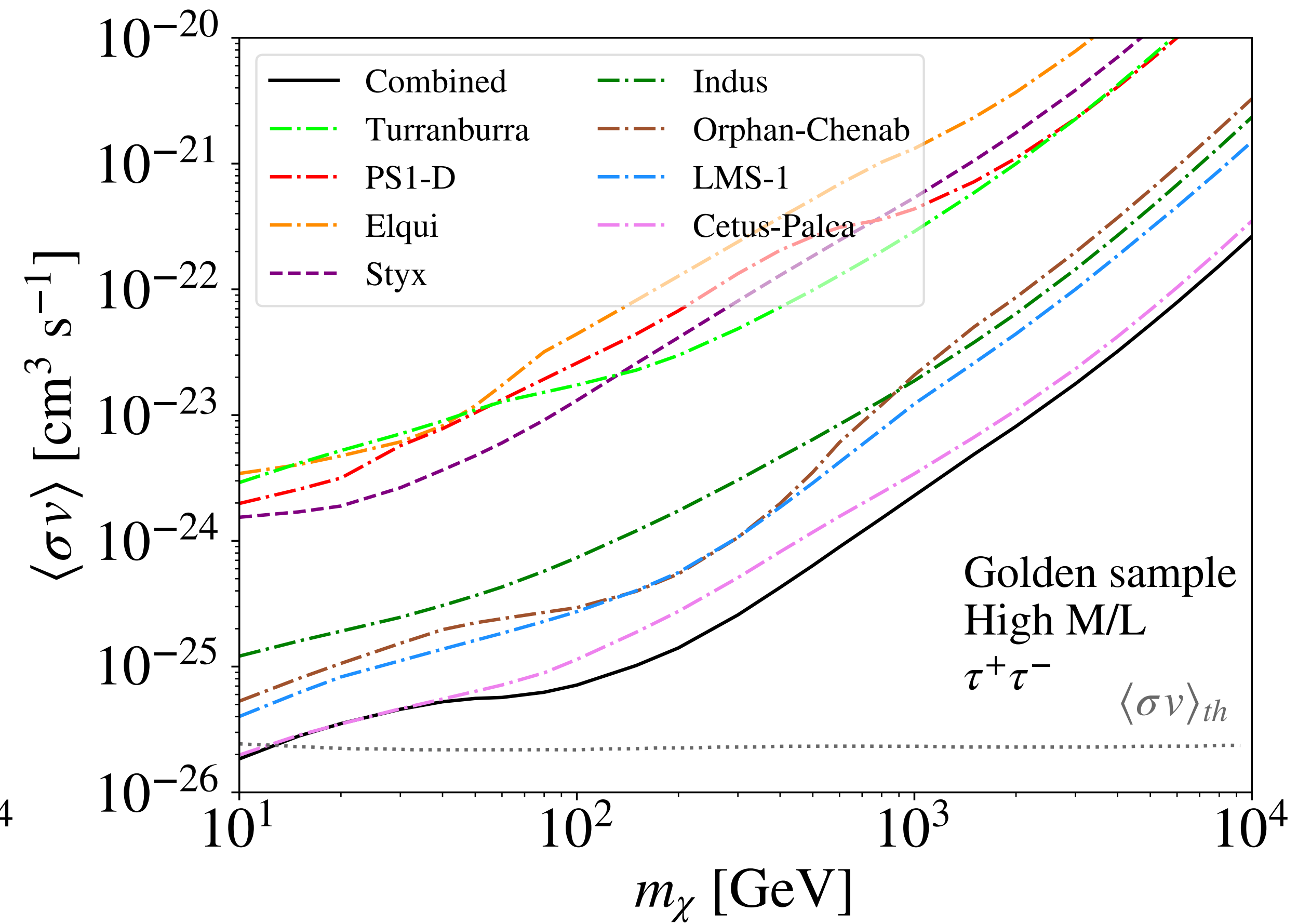
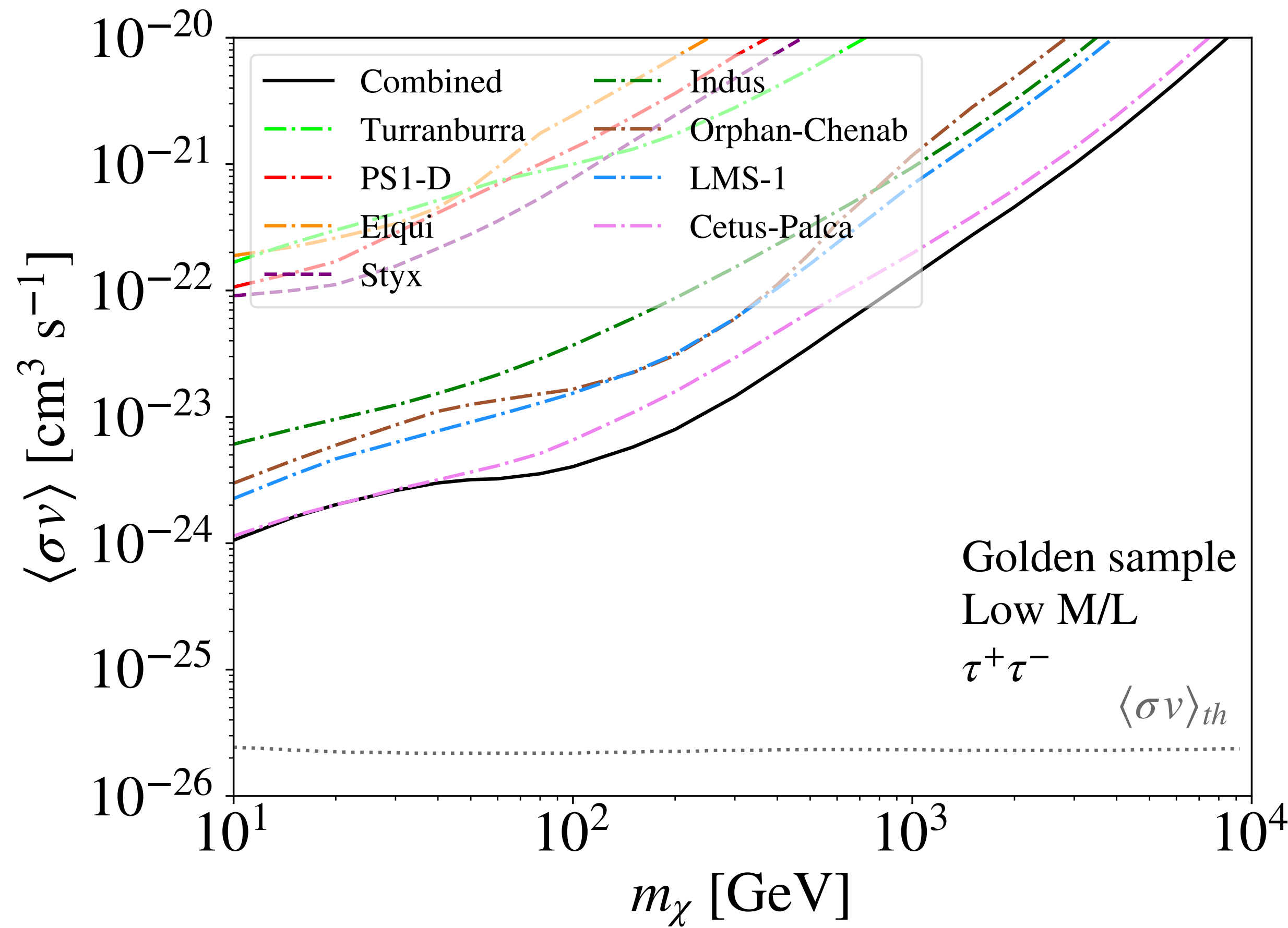


- * The Monoceros and Sagittarius streams dominate the combined DM limits.
- * This sample allows to rule out WIMPs up to ~ 200 GeV for both channels.

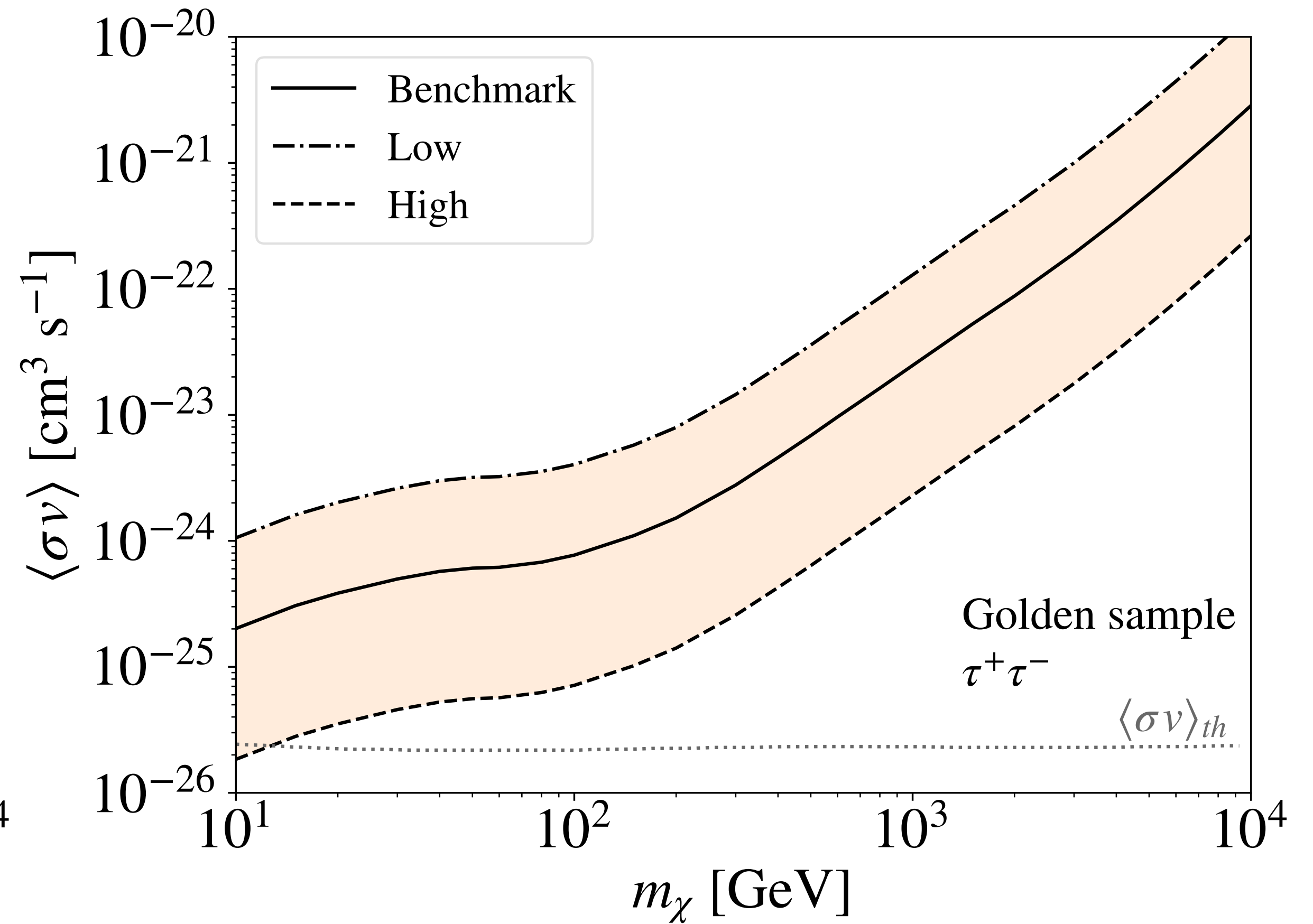
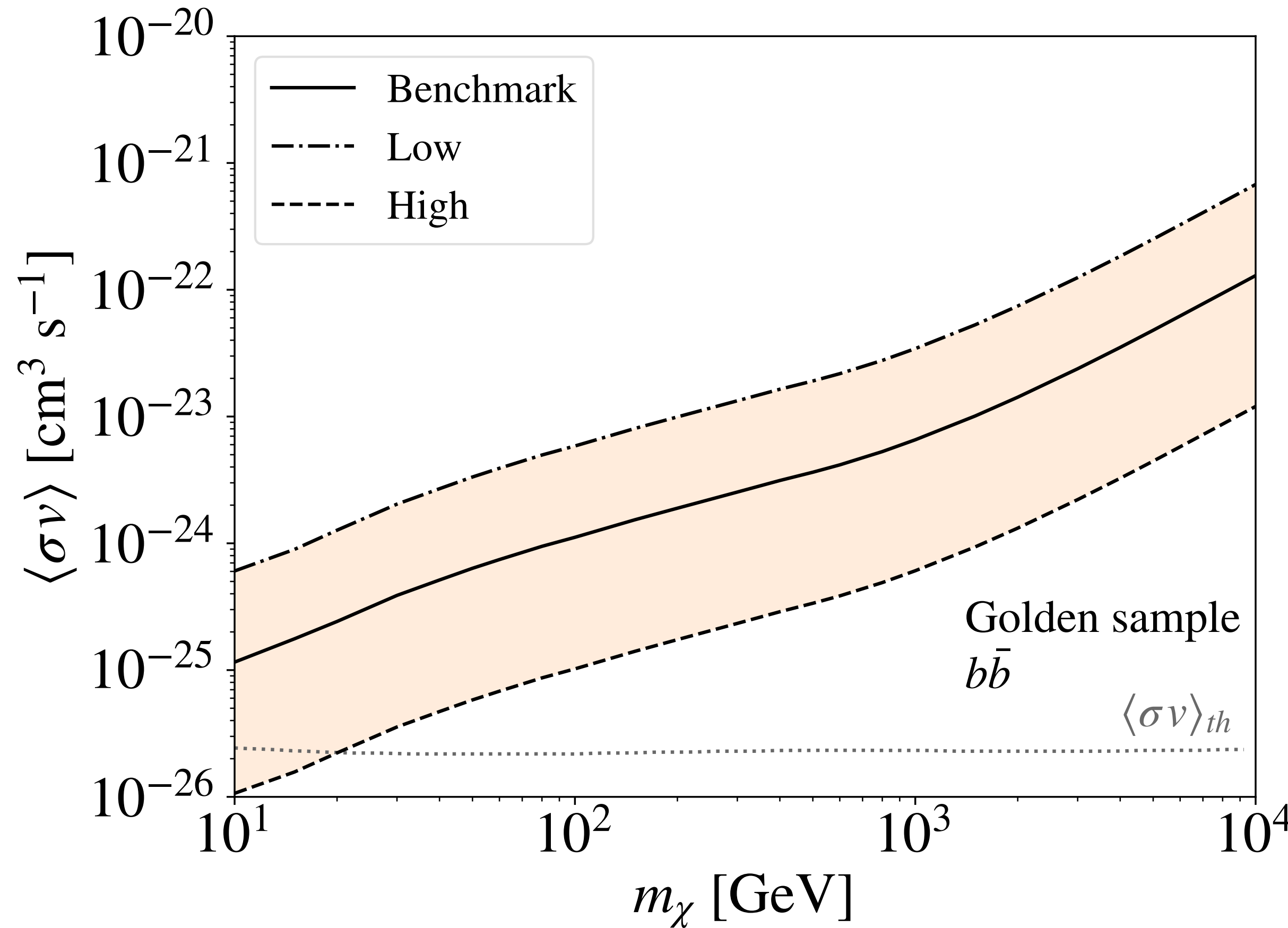
DM constraints: Golden Sample, Low and High cases



DM constraints: Golden Sample, Low and High cases

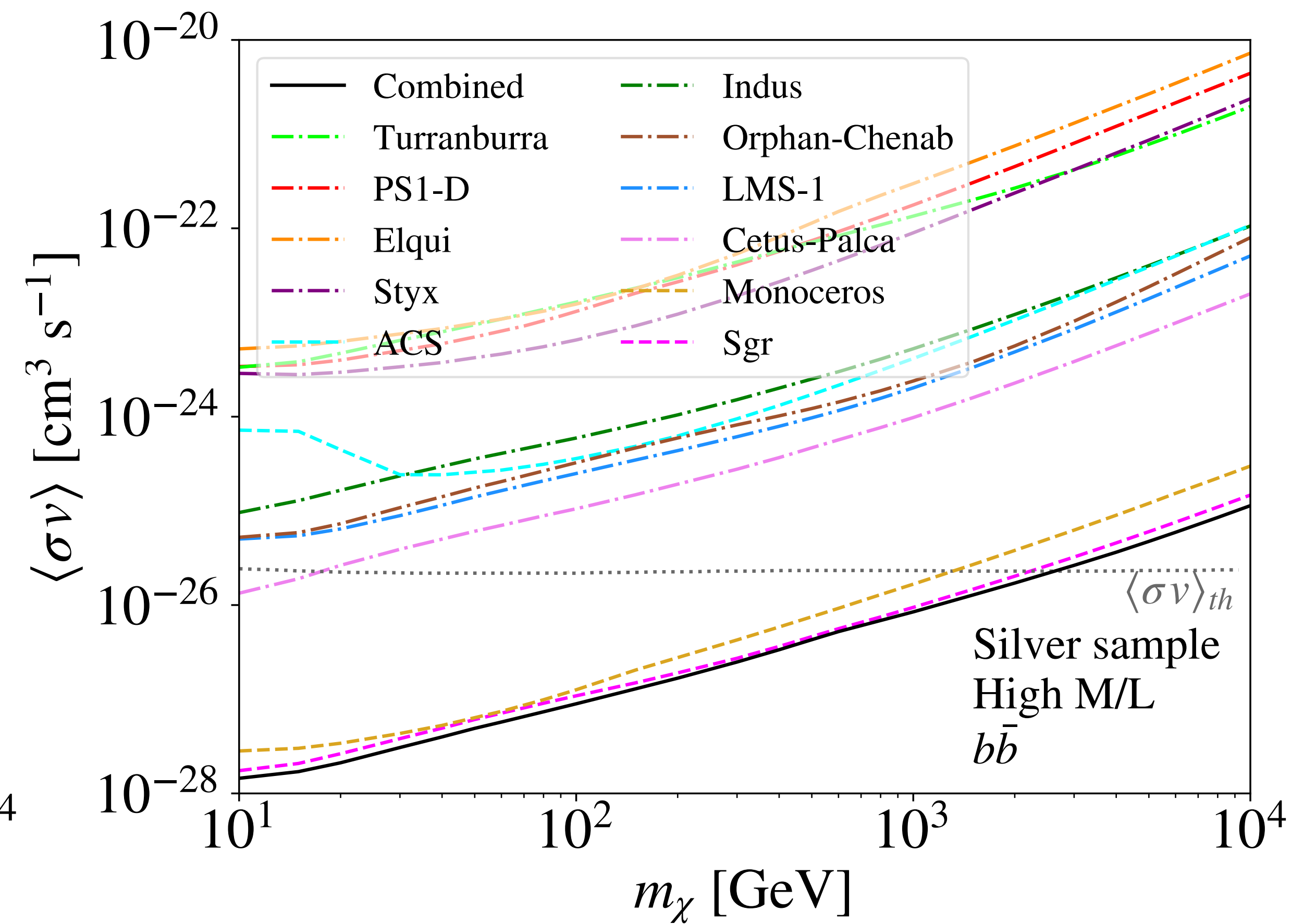
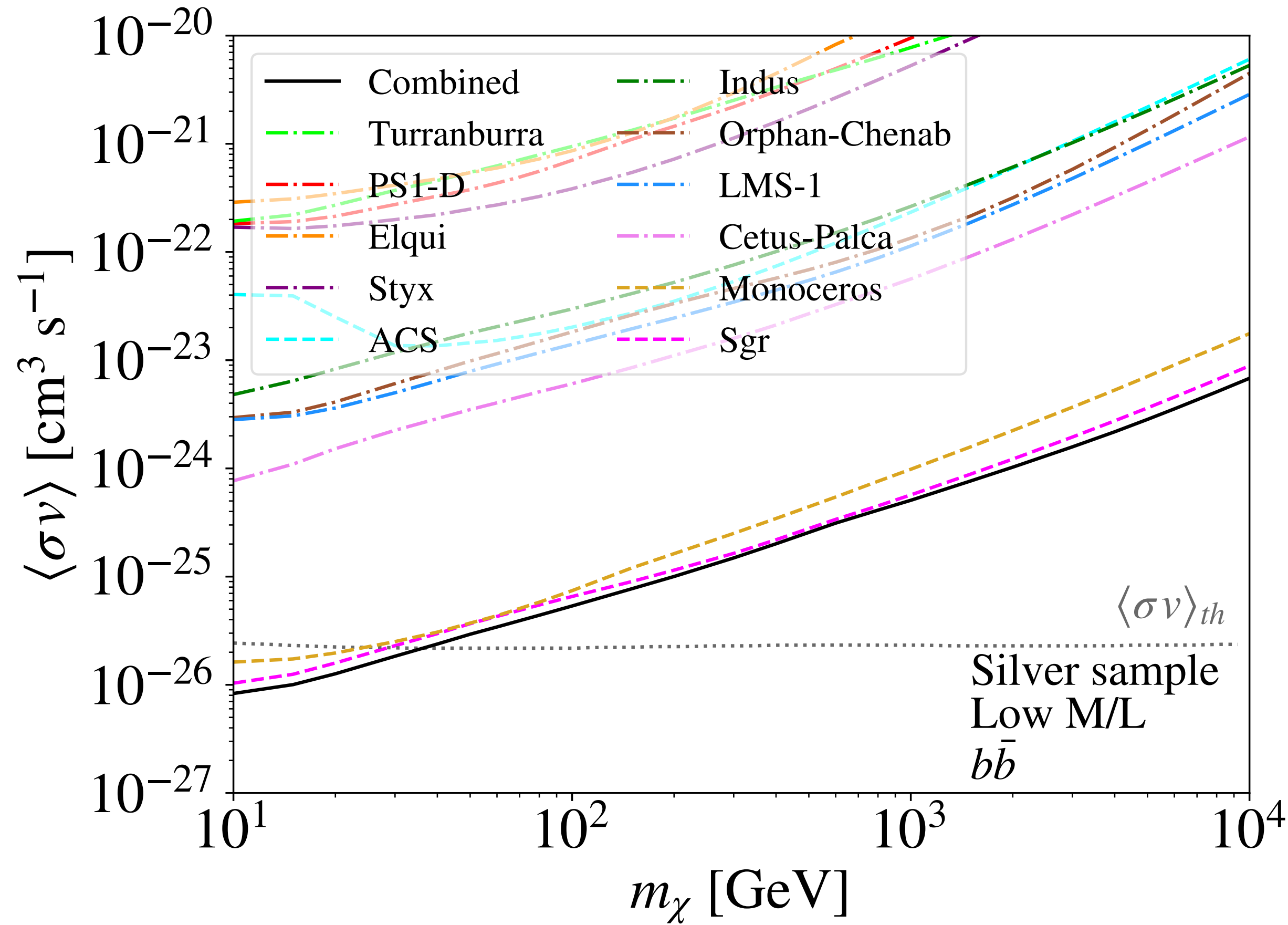


DM constraints: Golden Sample, M/L scenarios

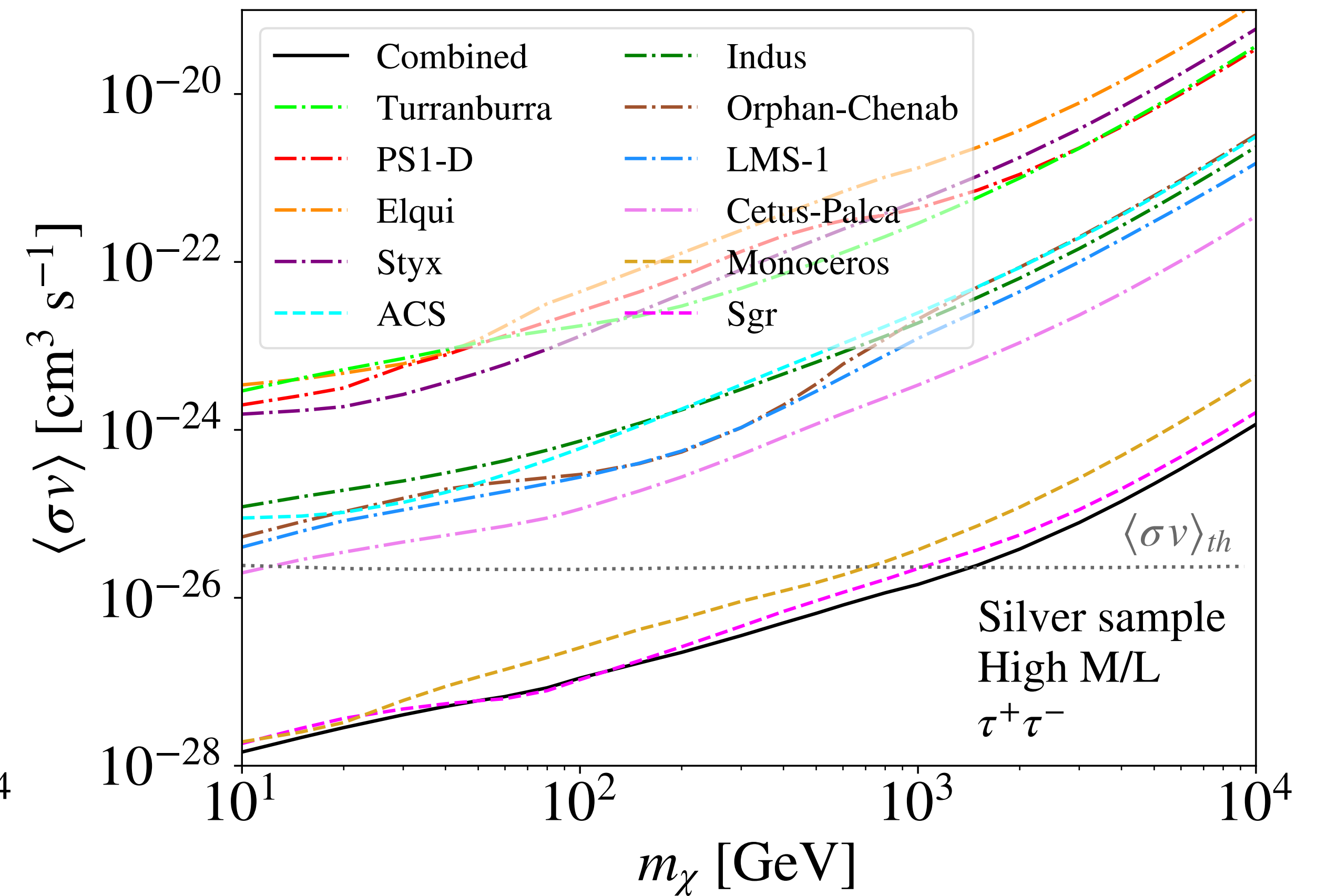
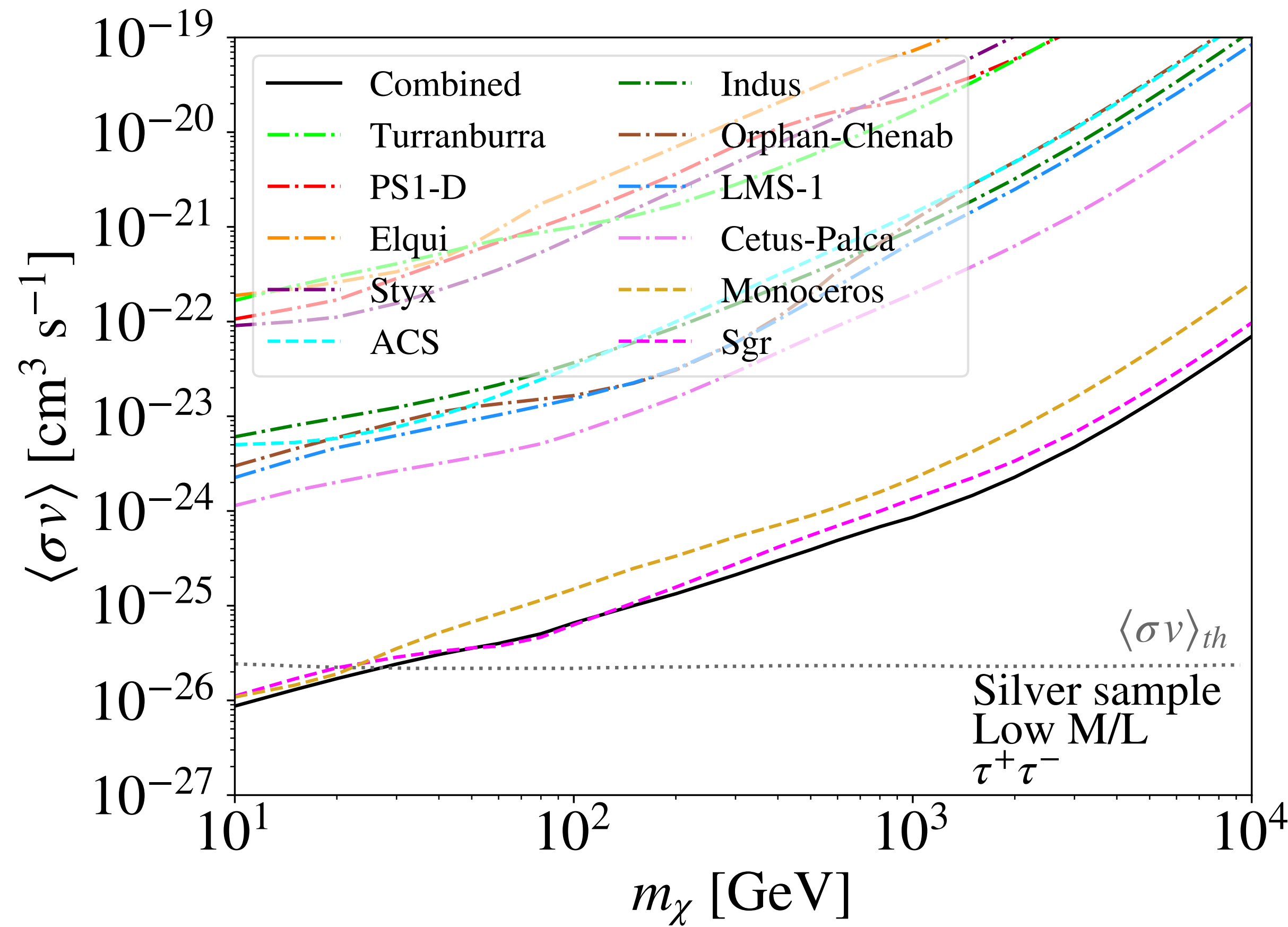


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DM constraints: Silver Sample, Low and High cases

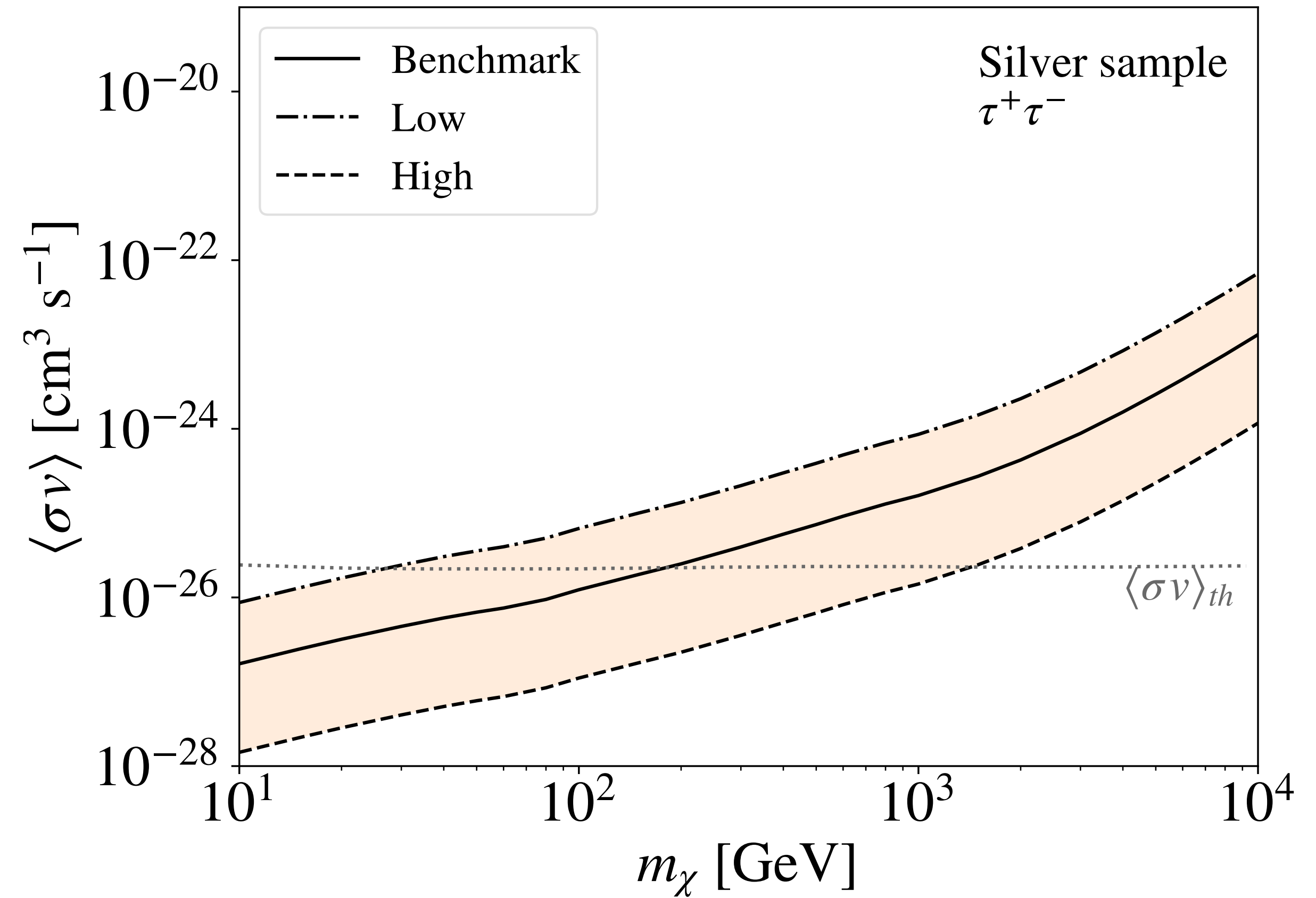
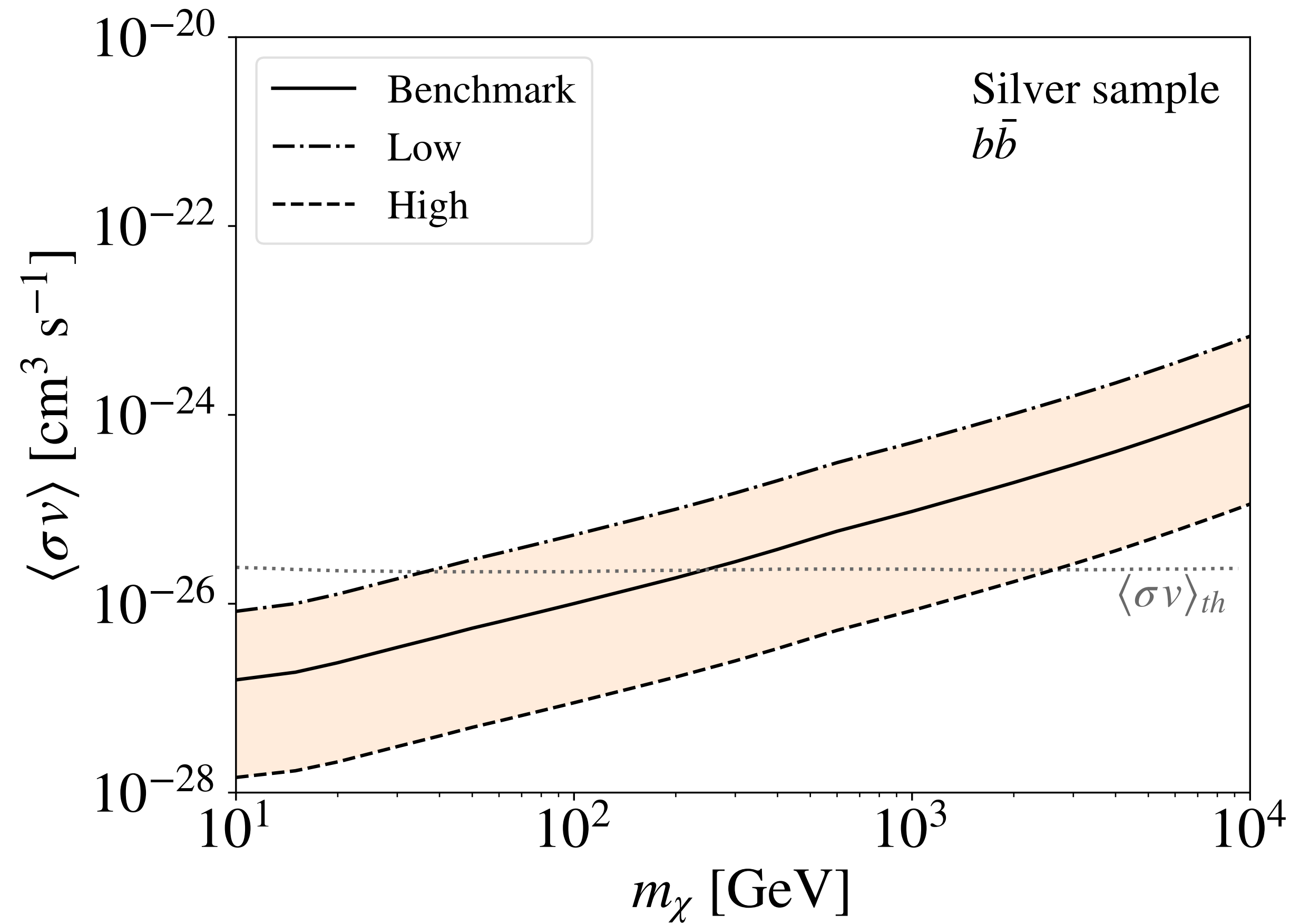


DM constraints: Silver Sample, Low and High cases

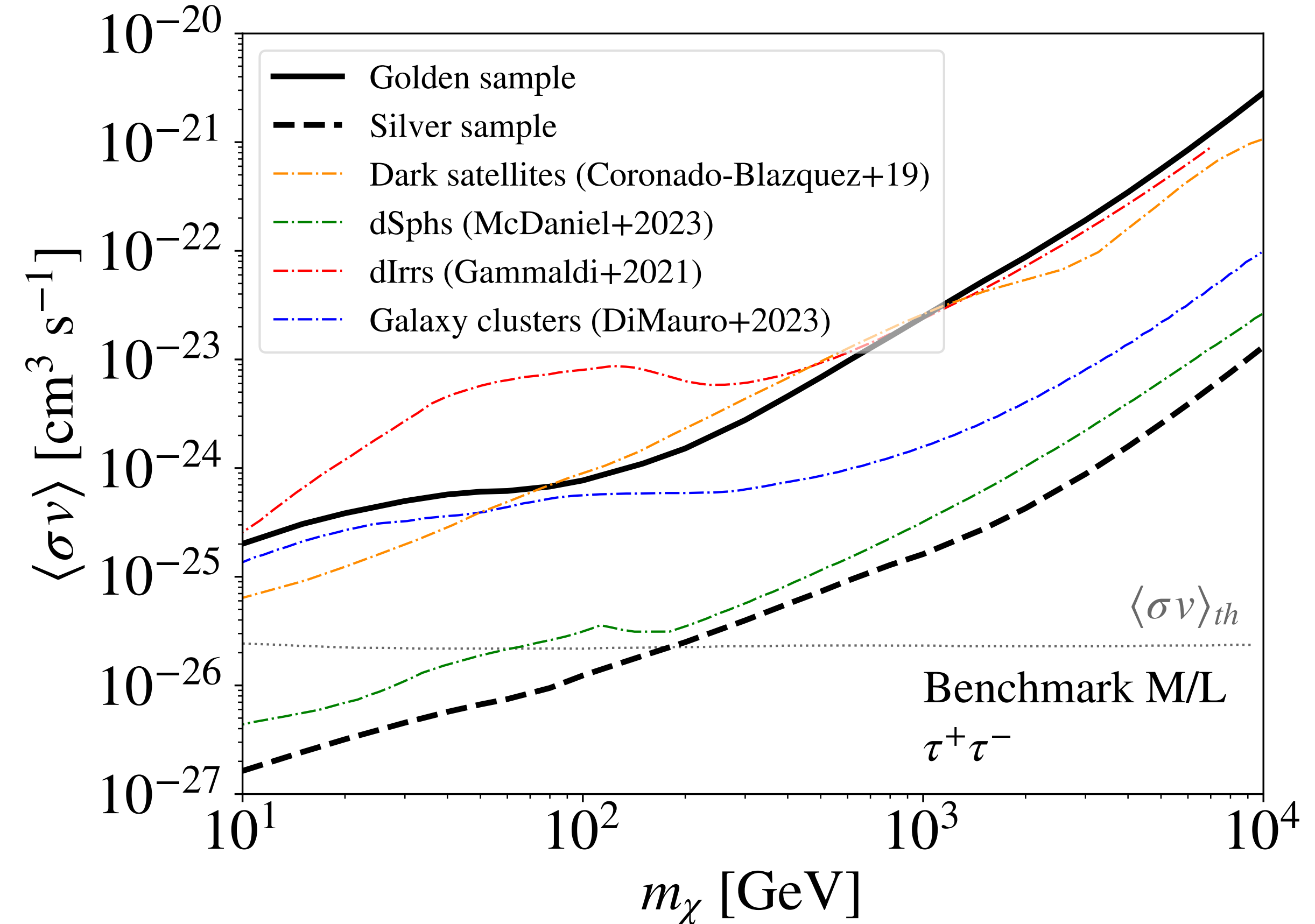
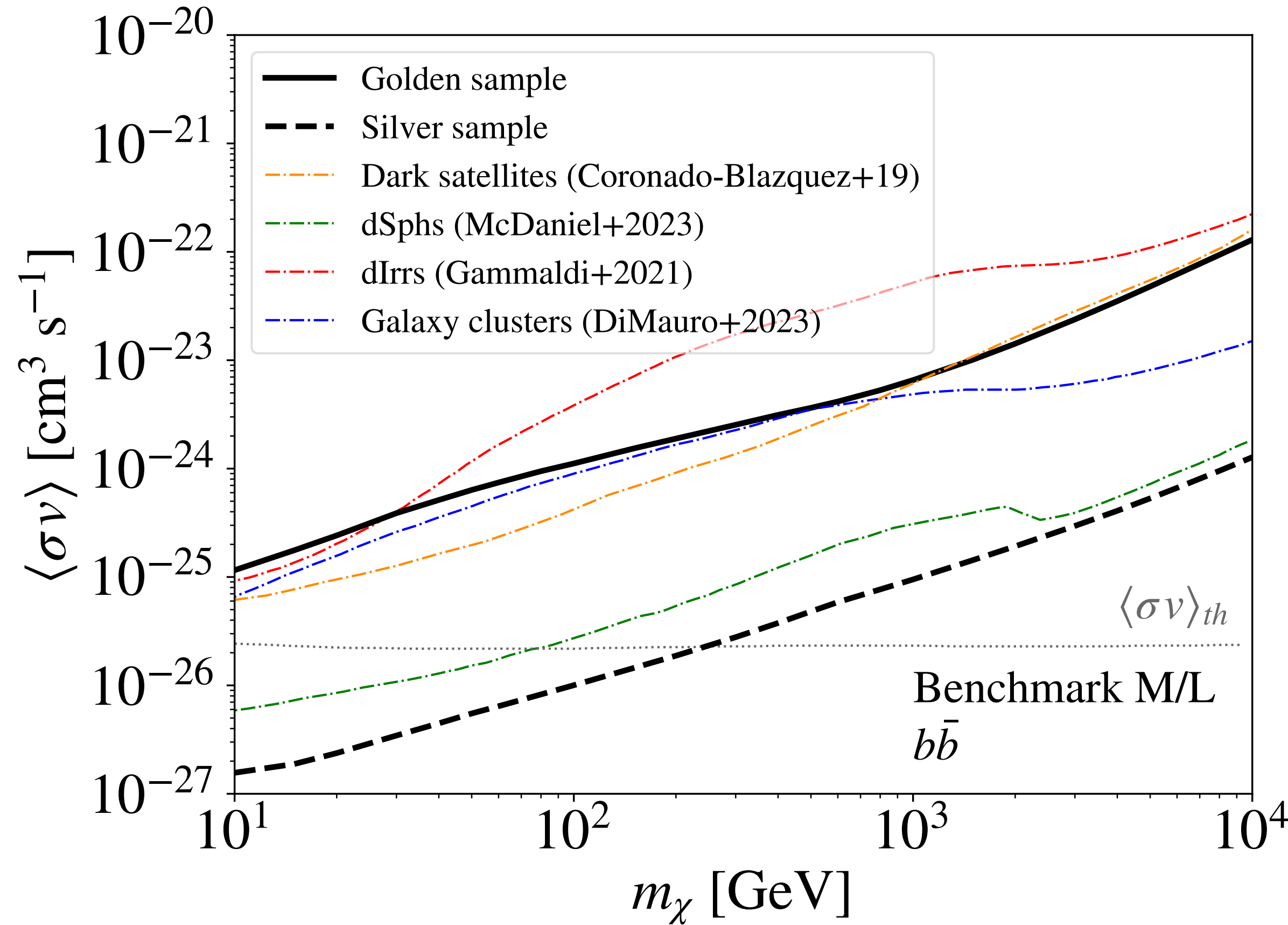


DM constraints: Silver Sample, M/L scenarios

CFS & Sánchez-Conde
arXiv: 2502.15656



DM constraints: Comparison with other targets



- * The **golden** sample of streams improve the limits achieved with dIrr galaxies, while they are similar to those for galaxy clusters and dark satellites.
- * Results for the **silver** sample would be potentially comparable with those for dSphs.

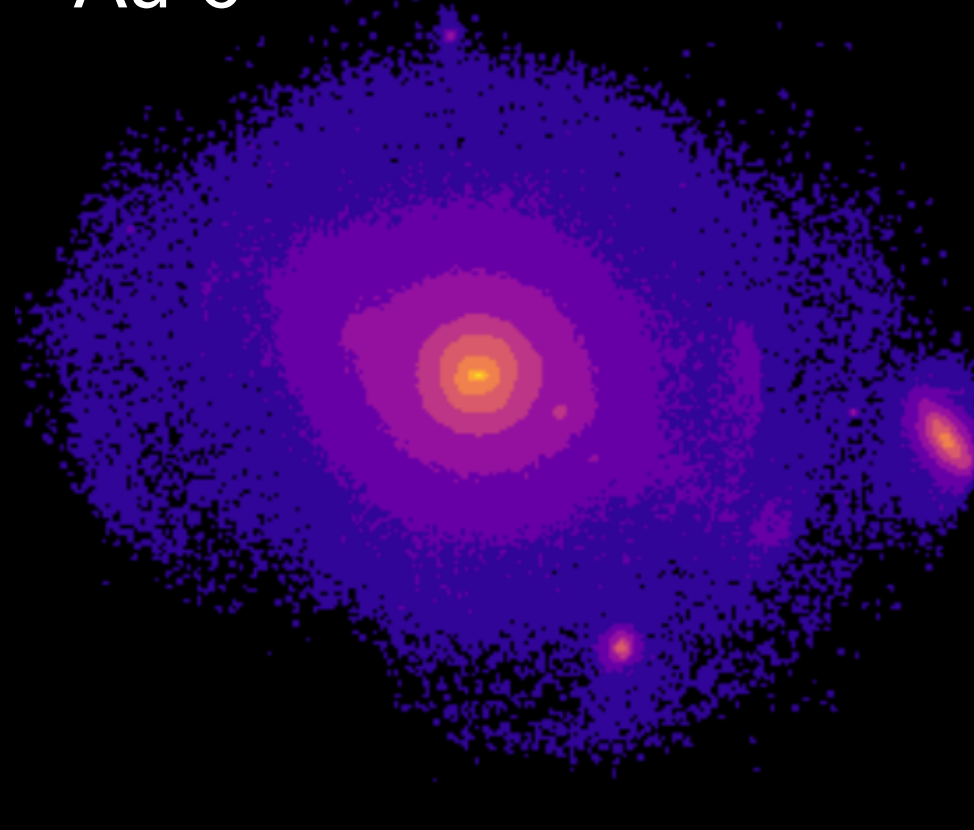
Auriga simulations

(Grand+2017. Grand+2024)

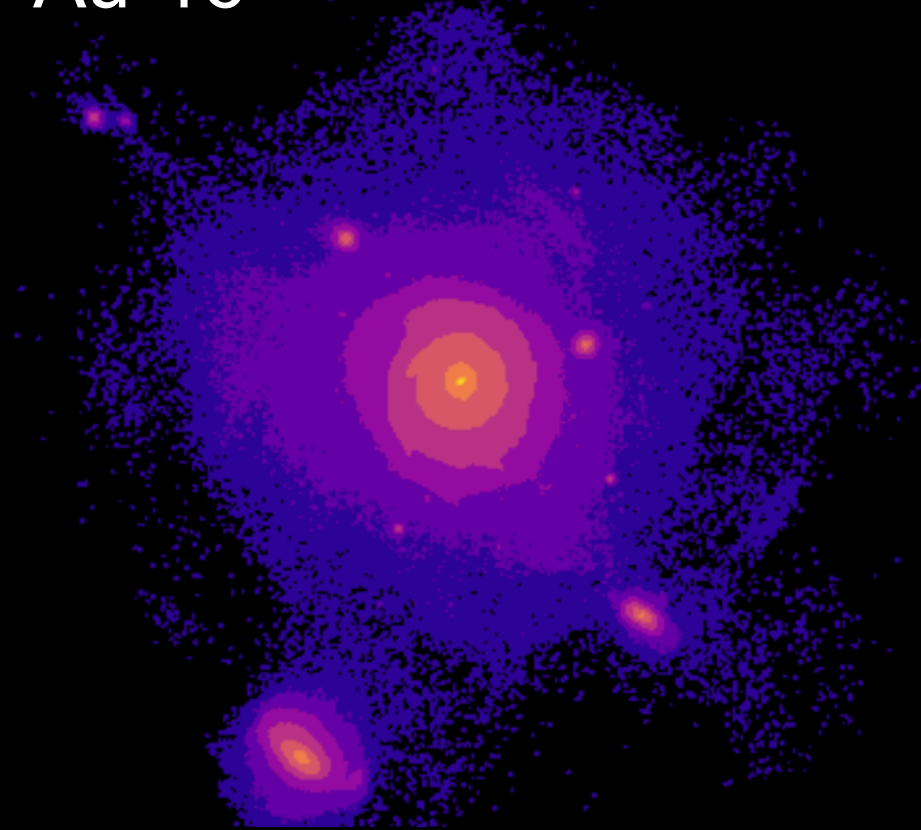
Auriga is a suite of cosmological magneto-hydrodynamic (MHD) zoom-in simulations of galaxy formation.

6 simulations of Milky Way-mass halos at 'level 3' high resolution (Au-6, Au-16, Au-21, Au-23, Au-24, Au-27).
(Baryonic mass particle resolution: $6.7 \times 10^3 M_\odot$, DM particle mass resolution: $3.6 \times 10^4 M_\odot$, Softening length: 188 pc)

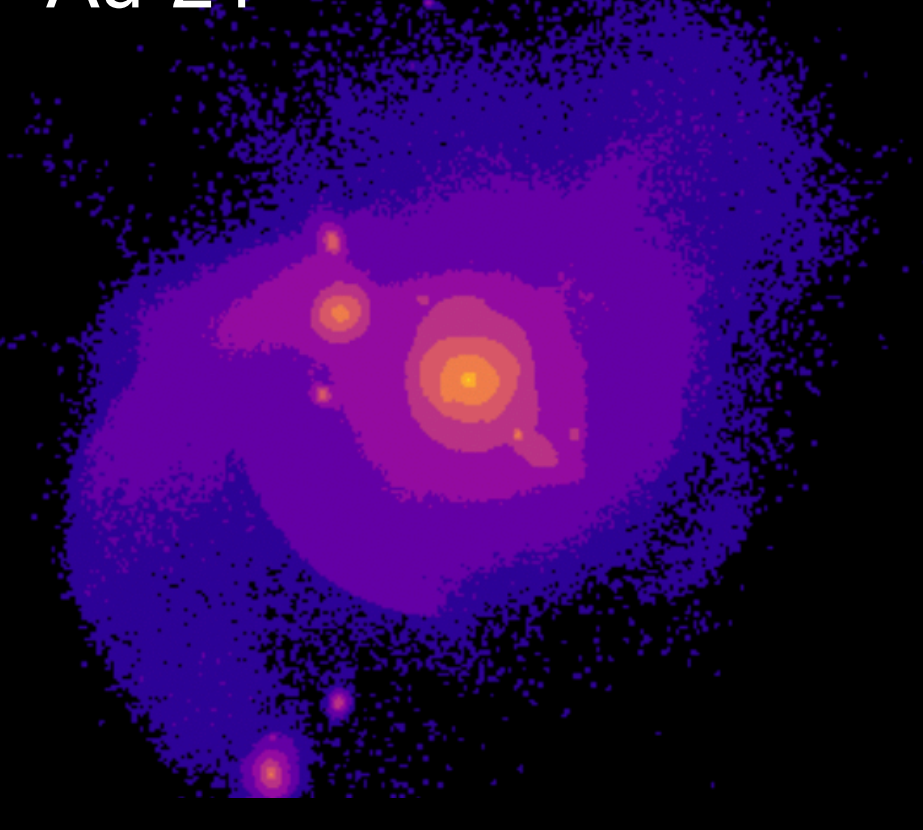
Au-6



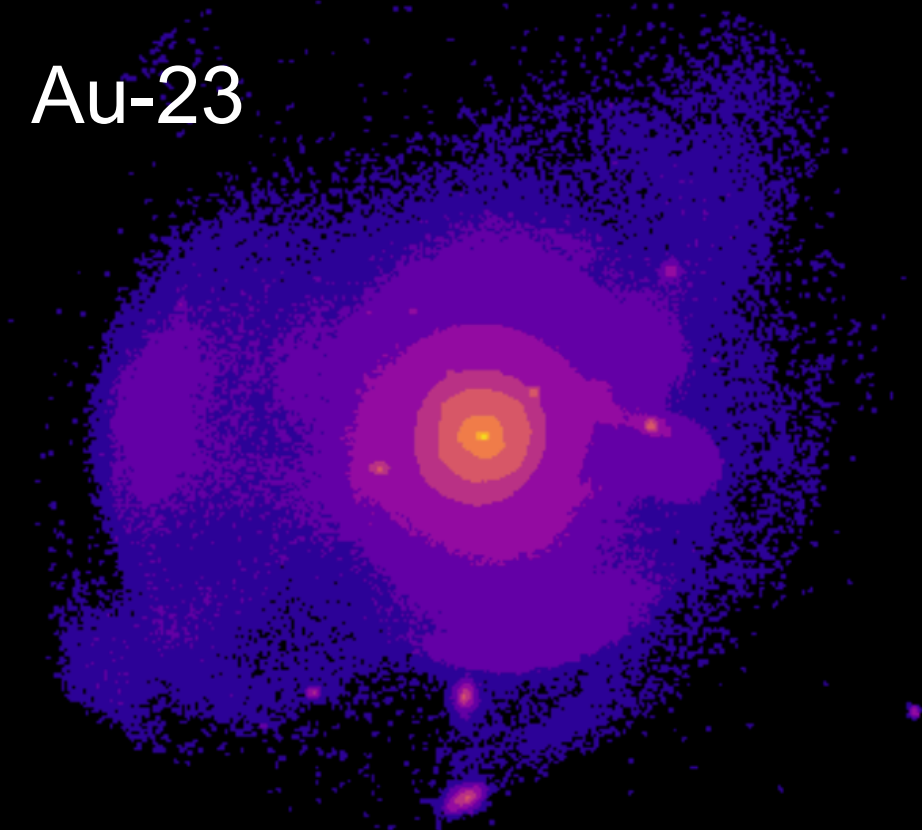
Au-16



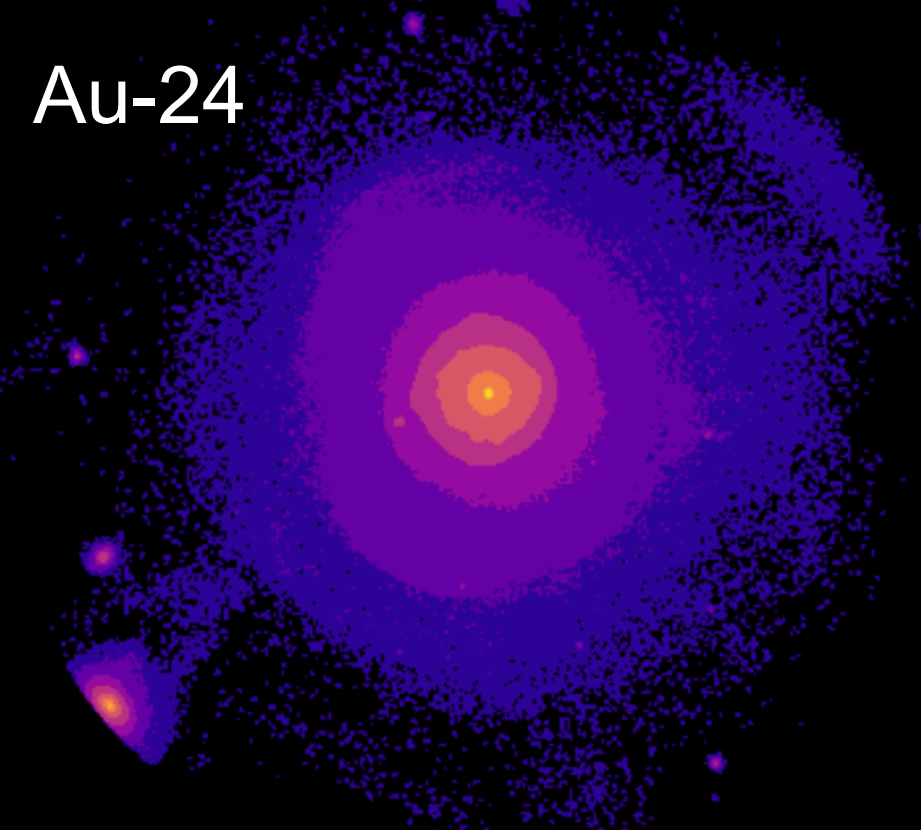
Au-21



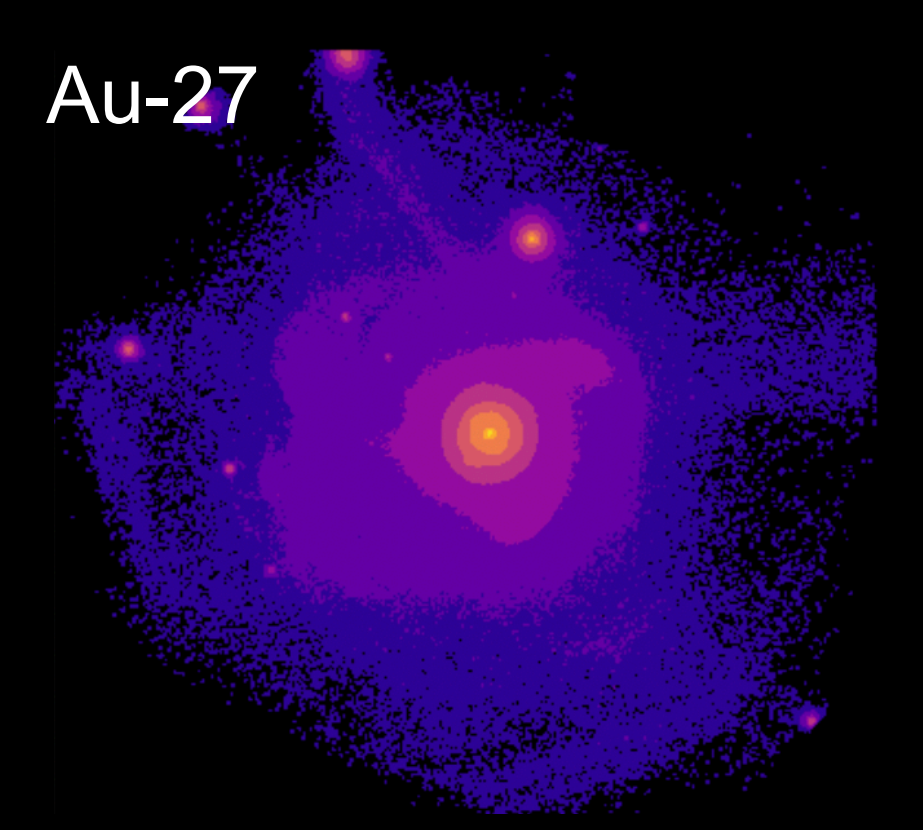
Au-23



Au-24



Au-27



Stellar density at $z = 0$

Identifying stellar streams in Auriga

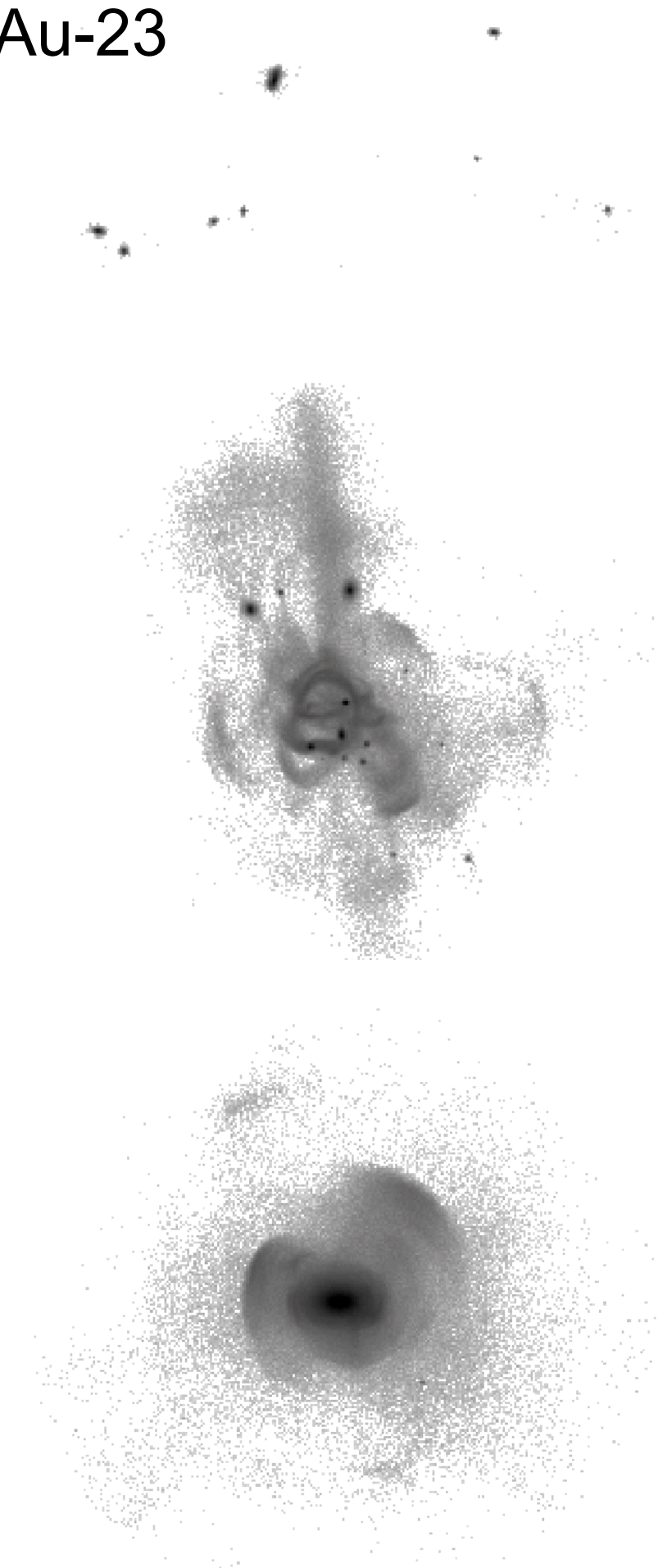
* We adopt the catalogue presented in [Riley et al. 2024](#) that classify accretion events as follows:

Au-23

Intact: those subhalos that have experienced little or no disruption.

Stellar streams: they have experienced tidal disruption and produce coherent structures, having lost at least 3% of their stellar mass.

Phase-mixed: as disrupting satellites continue to evolve, they eventually become phase-mixed systems that are spatially smooth.

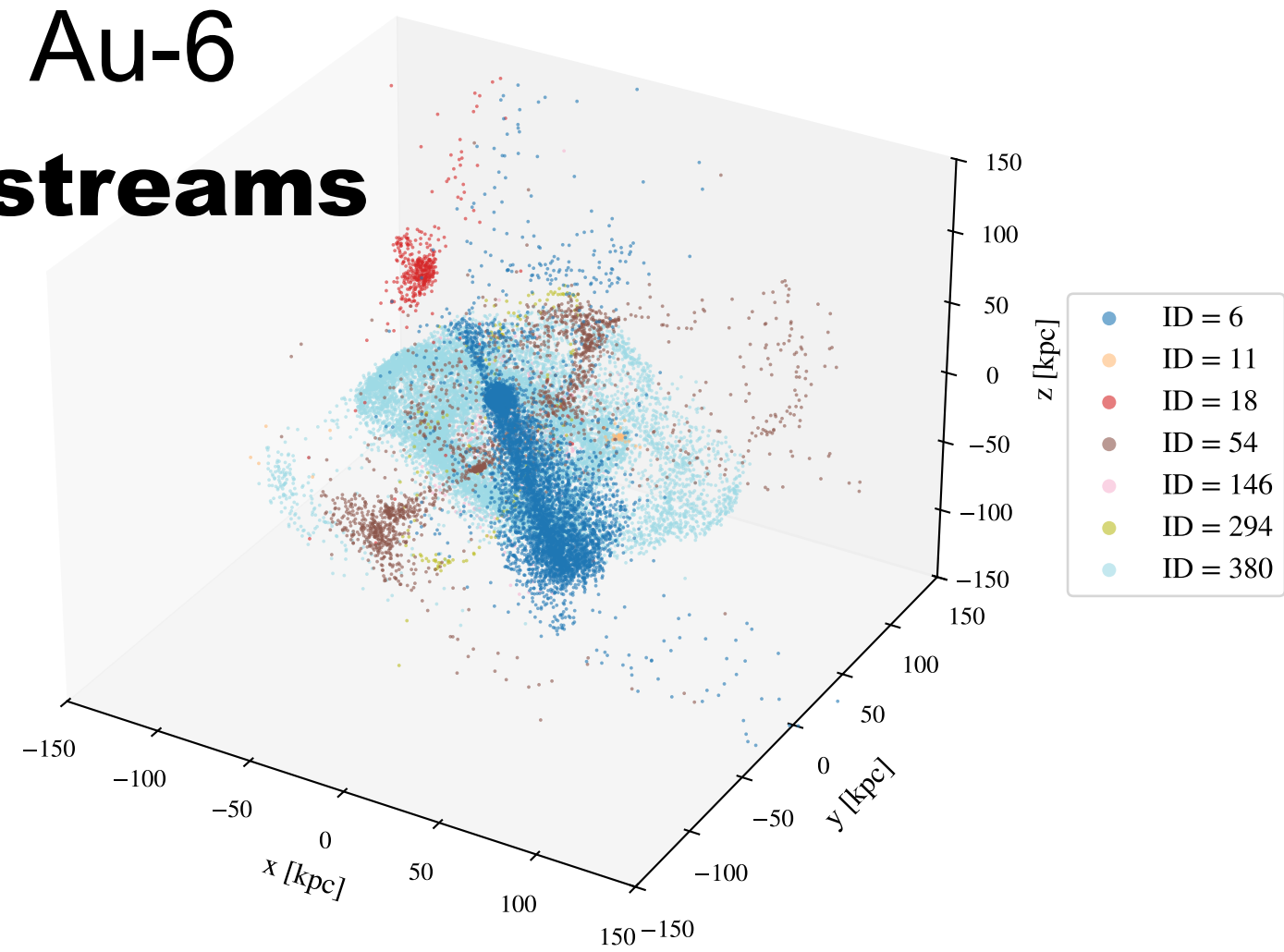


Auriga stellar streams

We adopt the catalogue presented in
Riley+2024 to identify streams in Auriga

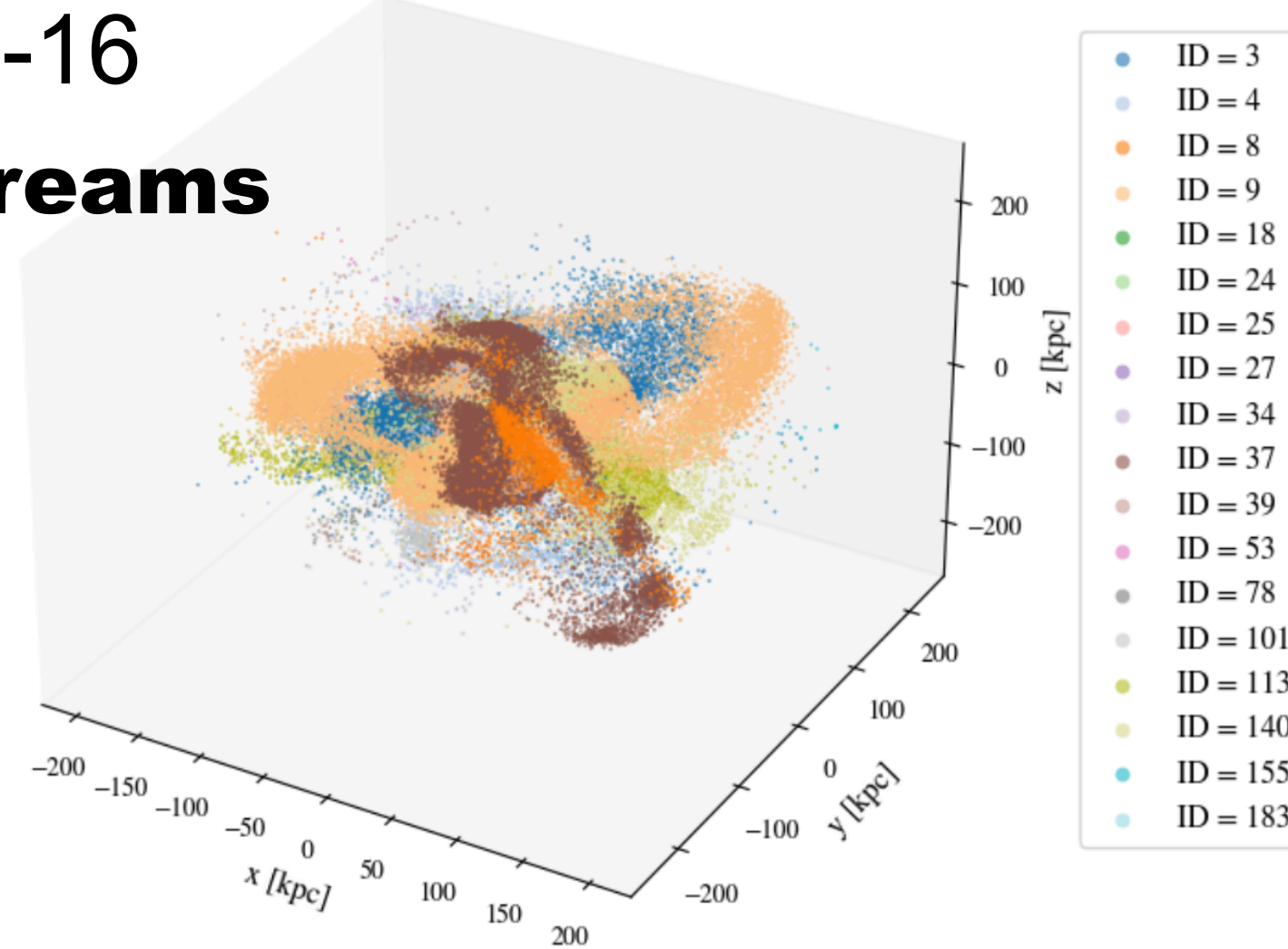
Au-6

7 streams



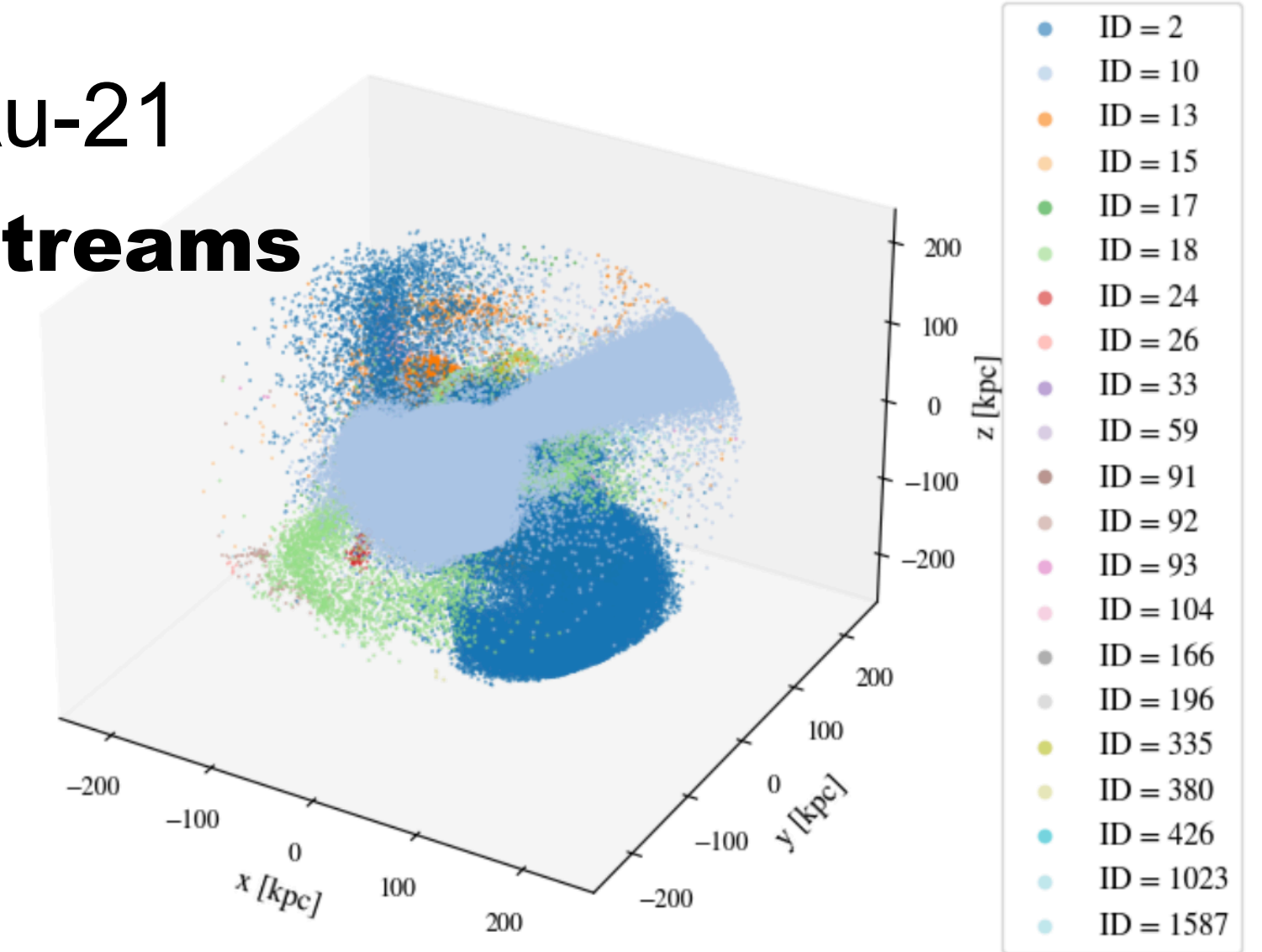
Au-16

18 streams



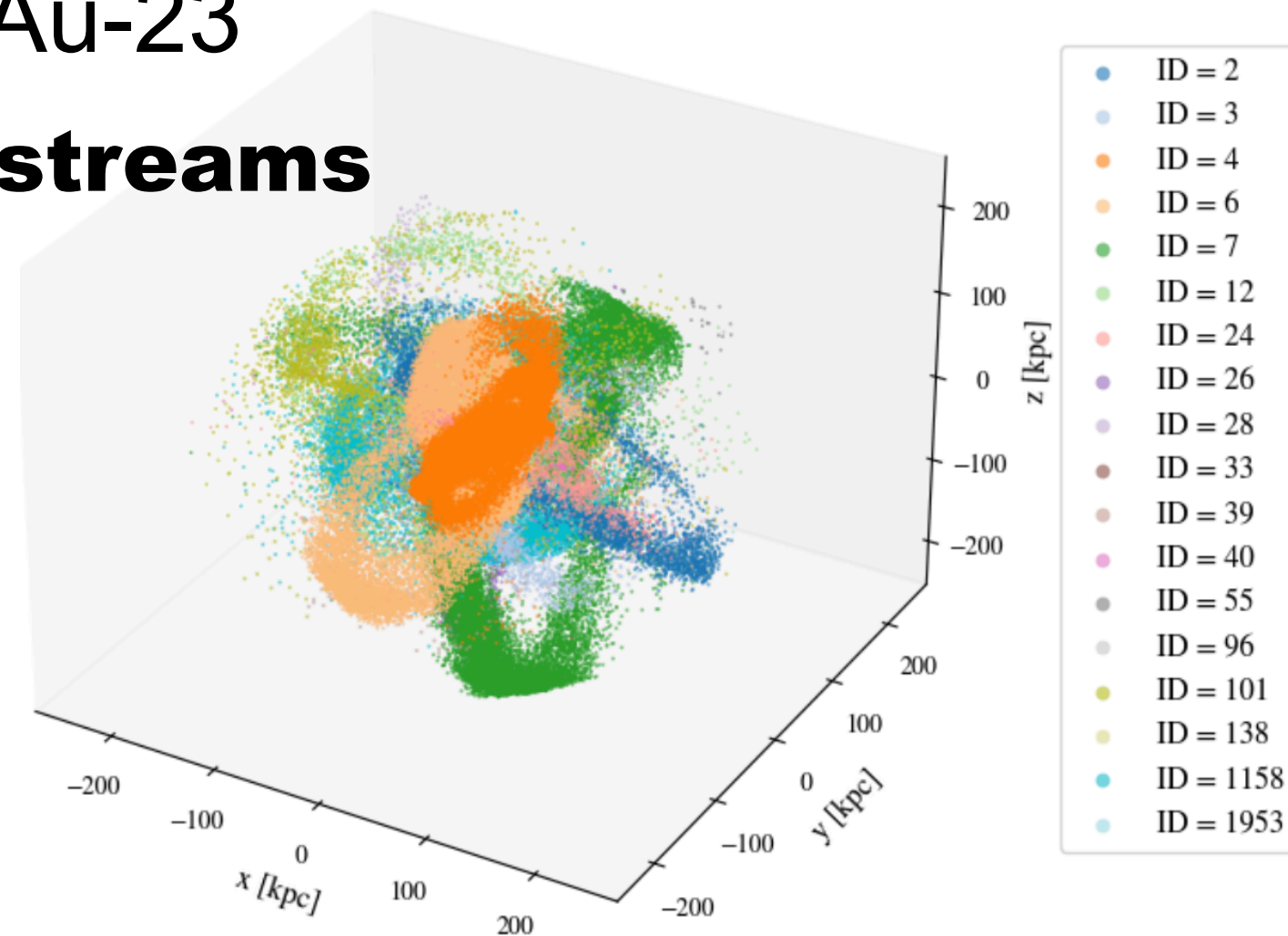
Au-21

21 streams



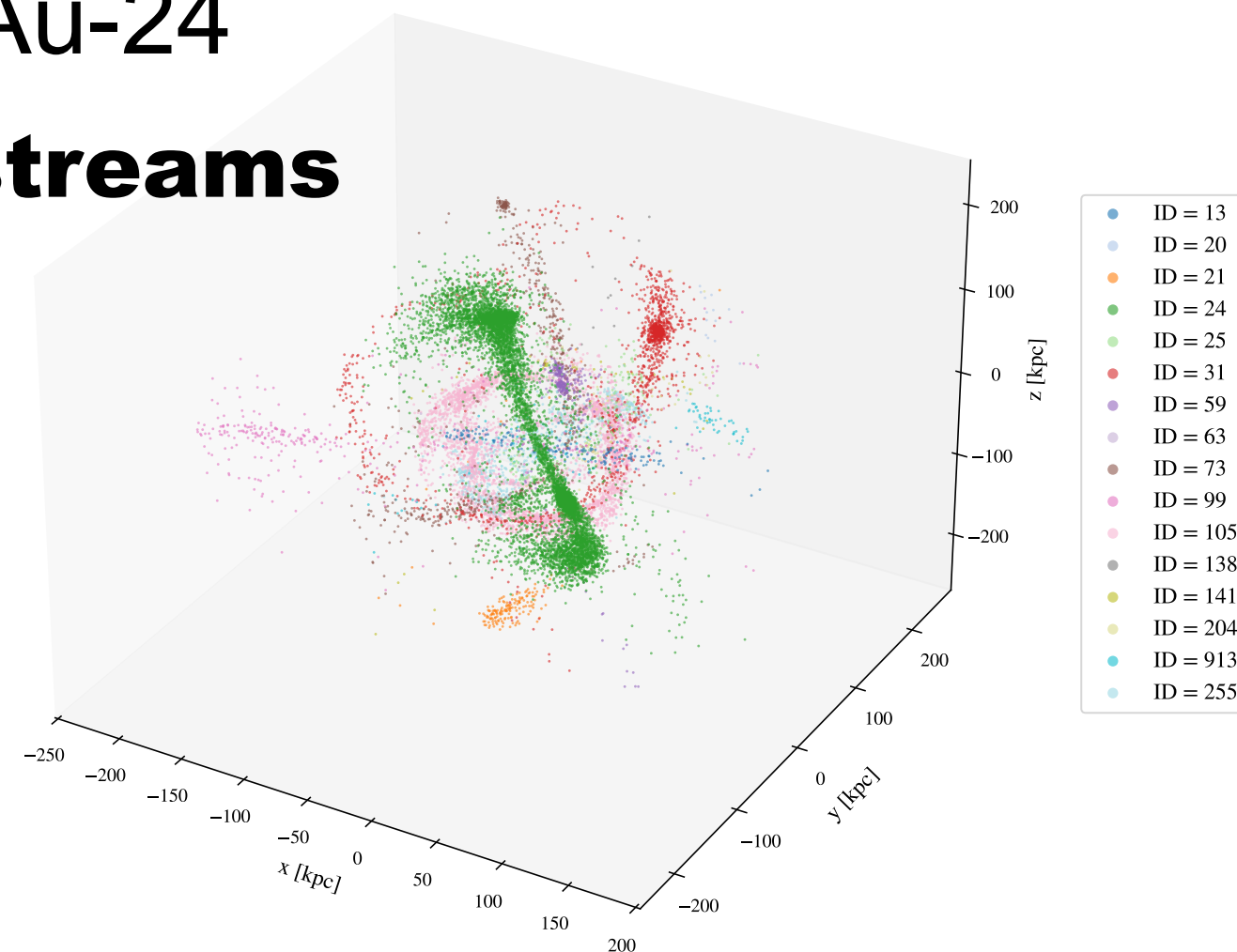
Au-23

18 streams



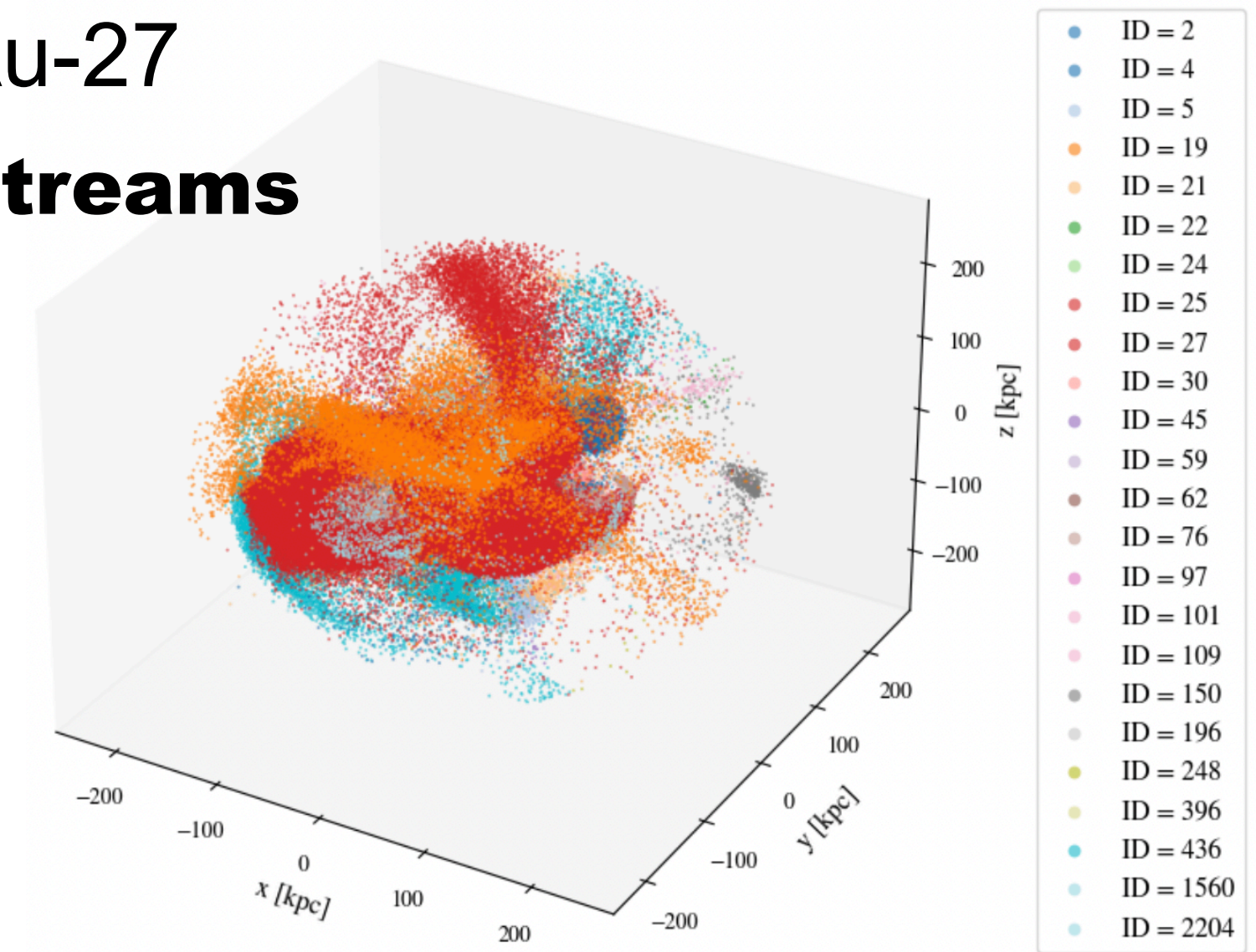
Au-24

16 streams

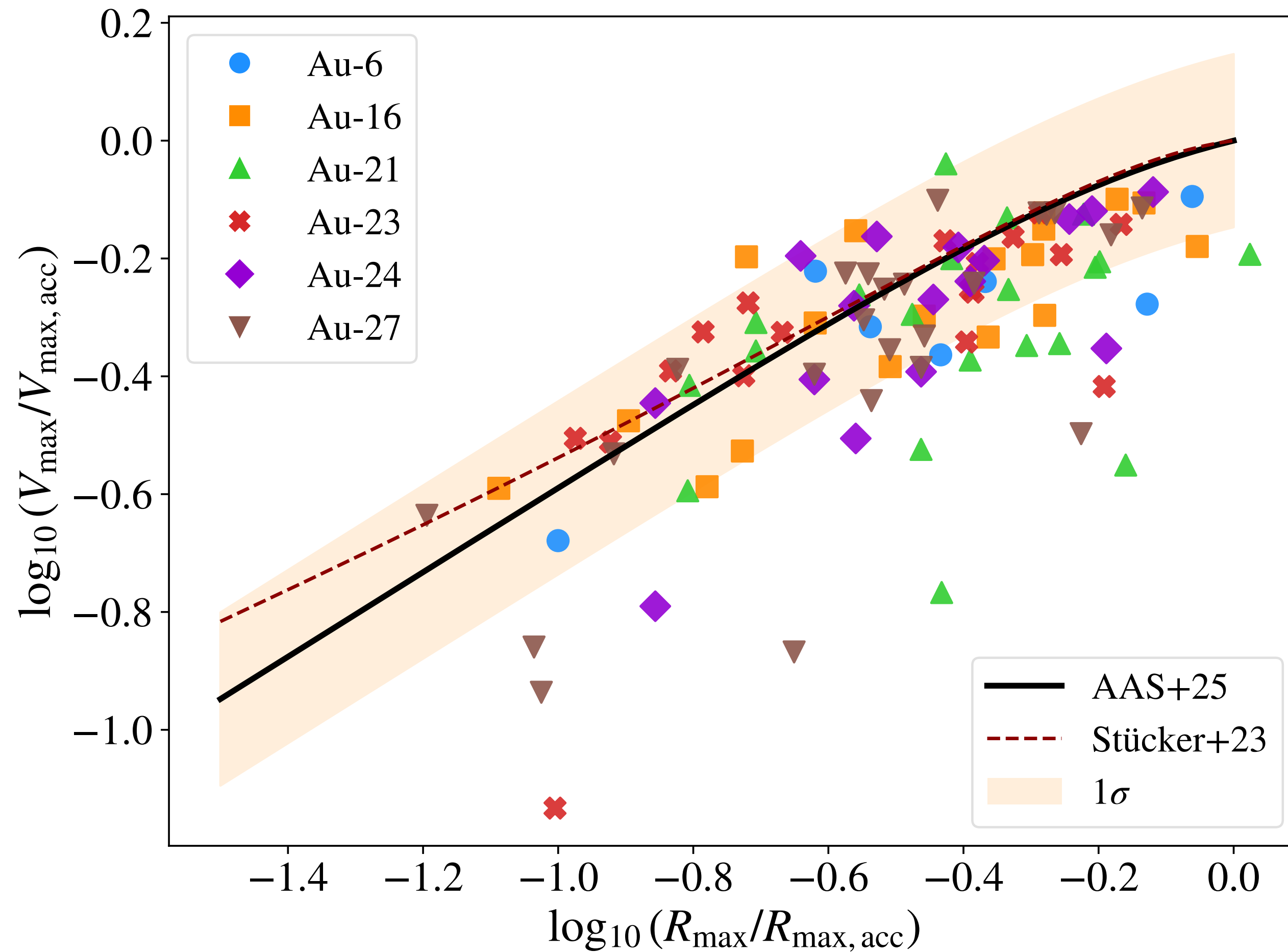


Au-27

24 streams



Tidal track

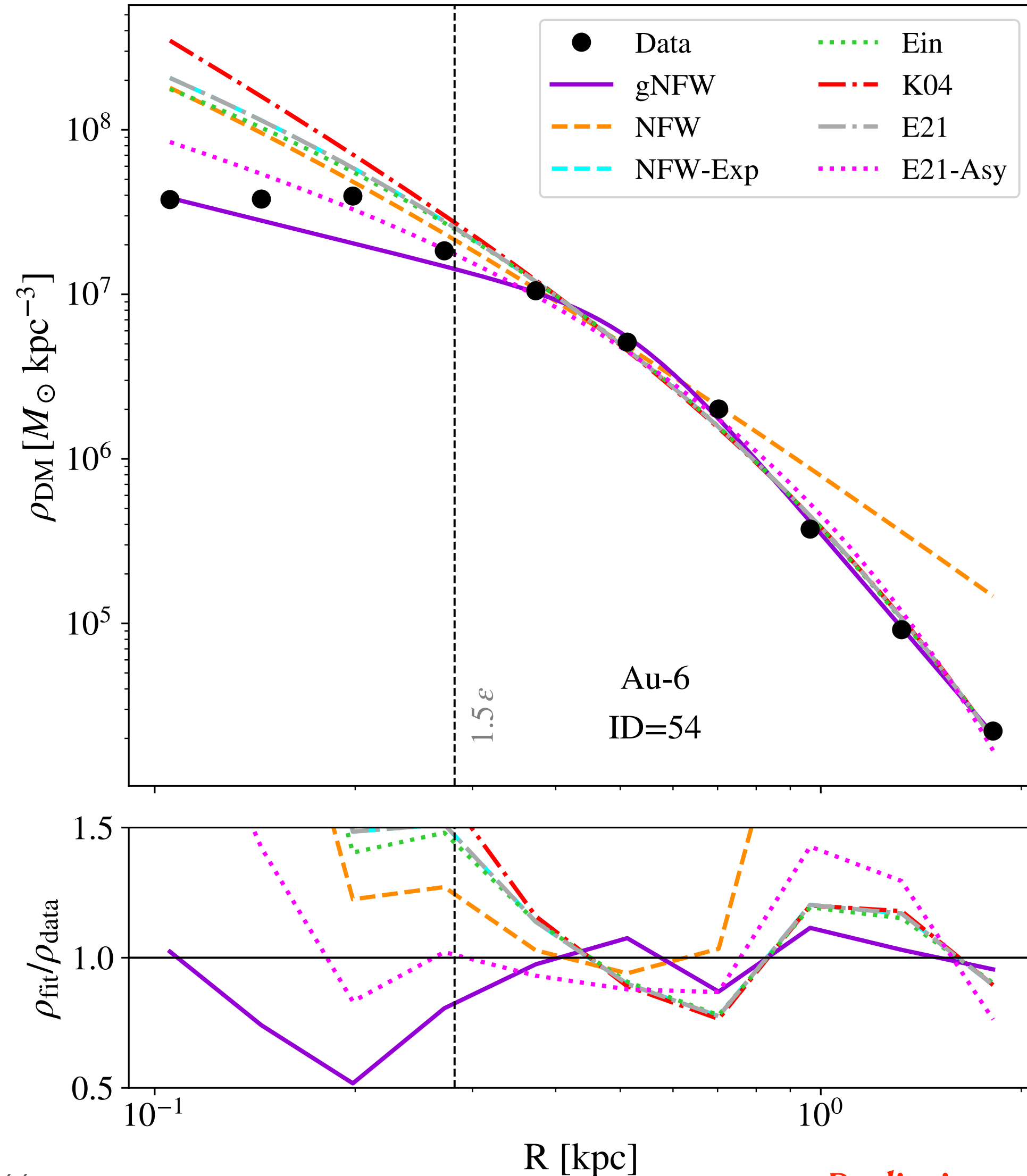


$V_{\max}$: maximum value of the spherically-averaged rotation curve. It describes the maximum rotation velocity within a subhalo, that is, the maximum circular velocity reached by DM within it.

$R_{\max}$: comoving radius at which the maximum rotation velocity is achieved.

Preliminary

DM density profiles



* We perform fits of each DM profile to different functional forms: NFW (Navarro+1996, Navarro+1997), gNFW (Hernquist+1990), NFW exp. cutoff, Einasto (Einasto 1965), Kazantzidis+2004, Errani & Navarro 2021.

* Best-fit provided by gNFW (according to the reduced χ^2 distributions).

$$\rho_{\text{gNFW}}(r) = \rho_0 \left(\frac{r}{r_s} \right)^{-\gamma} \left[1 + \left(\frac{r}{r_s} \right)^{\alpha} \right]^{(\gamma-\beta)/\alpha}$$

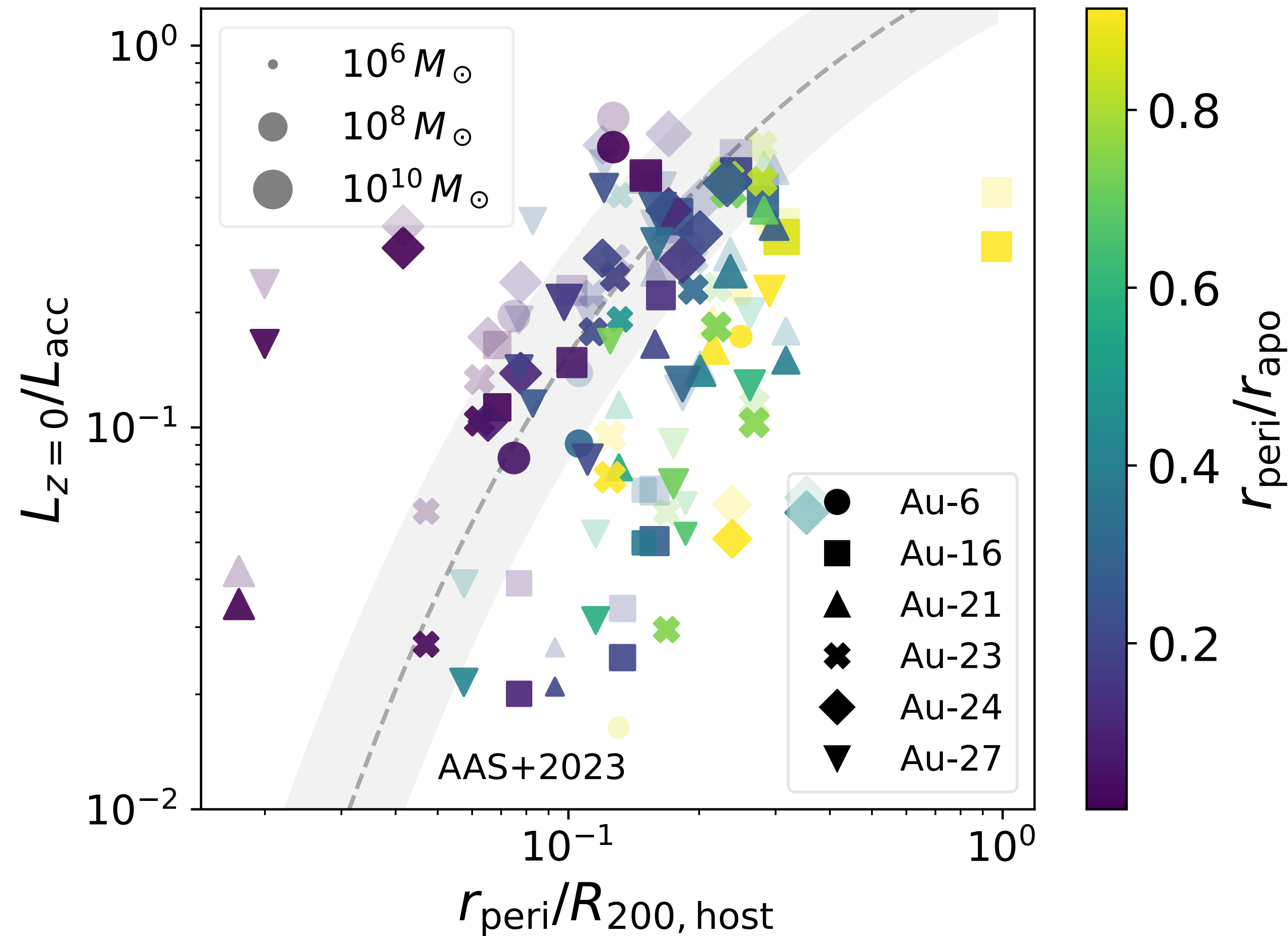
γ : inner slope

β : outer slope

α : regulates the transition between the inner and outer slope

The usual NFW profile is a specific form of this model with $\alpha = \gamma = 1$ and $\beta = 3$

DM annihilation luminosity with an inner core



* Reconstruction of the innermost region assuming a core instead of a cusp. For example, SIDM models could eventually lead to more cored profiles (e.g. [Vogelsberger+2012](#), [Zavala+2013](#), [Adhikari+2022](#)).

* We obtain a moderate reduction in the expected DM annihilation luminosity compared to the cusp scenario (shown in the background as more transparent points).

Preliminary