# Gamma-ray flux limits from brown dwarfs: Implications for dark matter annihilating into long-lived mediators

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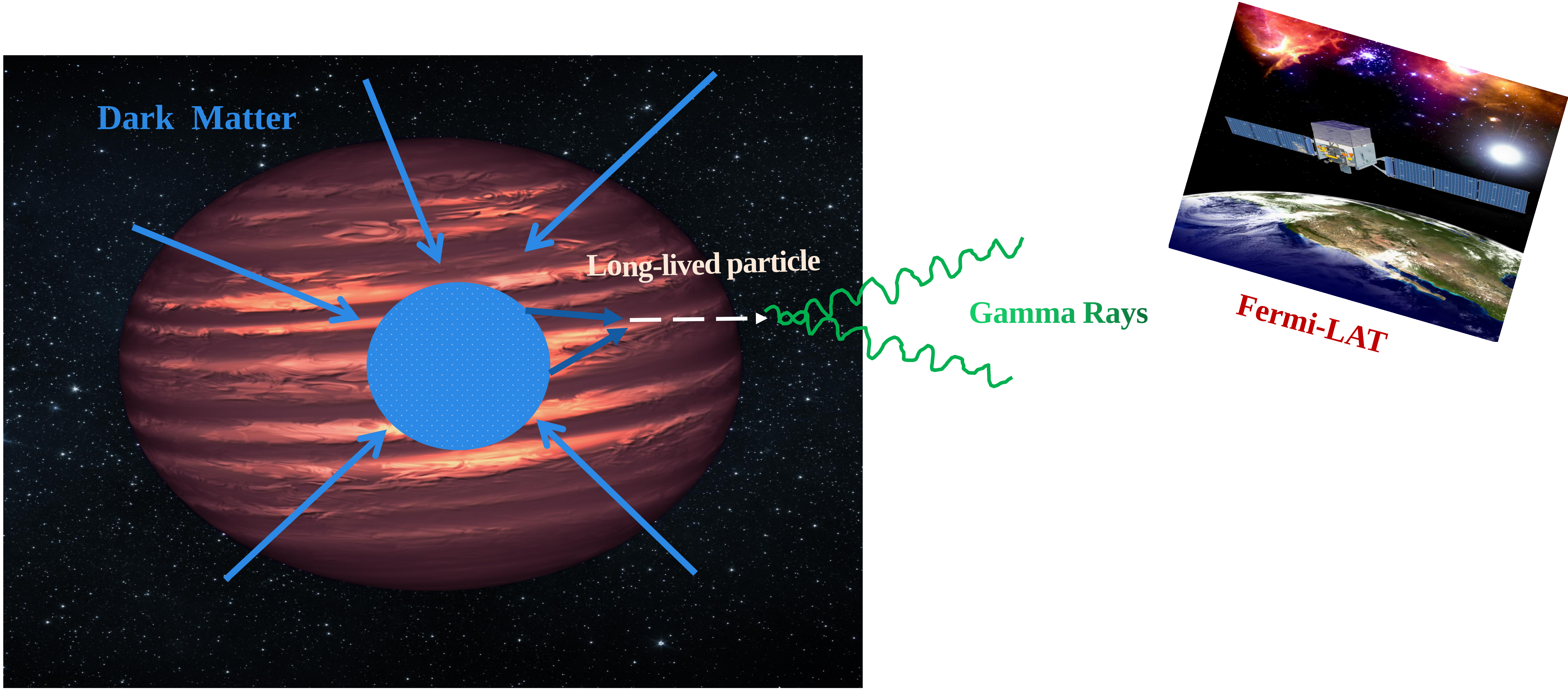
# Outlook

## Indirect detection of Dark Matter captured rate in Brown Dwarfs



# Why Brown Dwarf???

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## Advantage 1: Statistics

-- First **exoplanet discovery: 1992**

-- Estimates predict **around 300 billion exoplanets** in our galaxy!

## Advantage 2: Low temperatures --- as they do not undergo nuclear fusion

-- Low temperatures allow for a **clearer signal over background for Dark Matter heating.**

-- Low core temperatures in part **prevent DM evaporation, providing new sensitivity to lighter (sub-GeV) DM.**

## Advantage 3: Exploding Research Program

-- with several upcoming **deep and sensitive optical and infrared sky surveys, such as JWST, Rubin, Roman...**

# Our Sources

- **Radius:** Comparable to the radius of Jupiter
- **Distance:** Within 11 pc from us.
- **Mass:** Larger than 25 Jupiter mass ($M > 25\ M_J$ )
- **Temperature:** T-type BDs ==> 575 K <T< 1350 K
- **Age:** Greater than 2 Gyr.

**These are important to strengthen the annihilation signal.**

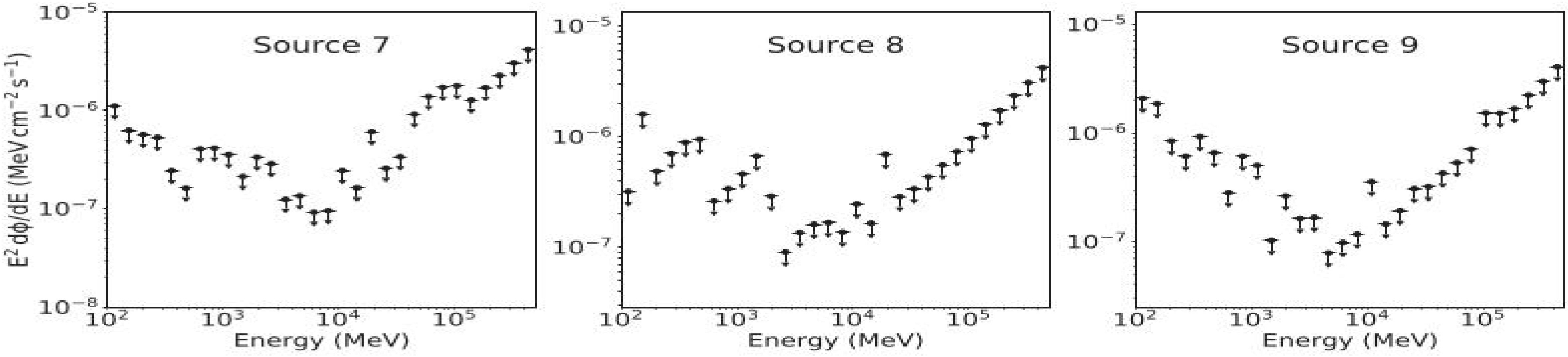
| Source Name (ID number) | $\ell$ (deg) | $b$ (deg) | Distance (pc) | Mass ($M_{♃}$) | Radius ($R_{♃}$) | Temp. (K) | Estimated age (Gyr) | Spectral Type |
|---|---|---|---|---|---|---|---|---|
| 2MASS J02431371-2453298 (Source 1) | 40.81 | -24.89 | 10.68 | 34 | 0.97 | 1070 | 1.7 | T6 |
| WISEPA J031325.96+780744.2 (Source 2) | 48.36 | 78.13 | 6.54 | 26 | 0.88 | 651 | 10 | T8.5 |
| Epsilon Indi Ba (Source 3) | -28.96 | -56.78 | 3.63 | 47 | 0.89 | 1276 | 3.5 | T1 |
| SCR 1845-6357 B (Source 4) | -78.73 | -63.96 | 3.85 | 45 | 0.88 | 950 | 3.1 | T6 |
| 2MASS J12171110-0311131 (Source 5) | -175.71 | -3.19 | 10.73 | 31 | 0.95 | 870 | 10 | T7.5 |
| WISEPC J121756.91+162640.2 A (Source 6) | -175.53 | 16.44 | 10.10 | 30 | 0.89 | 575 | 8 | T9 |
| 2MASS J04151954-0935066 (Source 7) | 63.83 | -9.59 | 5.64 | 35 | 0.91 | 750 | 10 | T8 |
| 2MASS J09373487+2931409 (Source 8) | 144.39 | 29.53 | 6.12 | 58 | 0.79 | 810 | 10 | T7 |
| WISE J104915.57-531906.1 (Source 9) | 162.33 | -53.32 | 2 | 33.5 | 0.85 | 1350 | 4.5 | T0.5 |

# Search for gamma-ray emission in Fermi-LAT data

1. Analyze 13 years of data with energy range between 100 MeV to 500 GeV.

2. Perform the binned likelihood analysis but no significant excess emission is found.

=> Set 95% confidence level upper limits
=> Also perform the stacked analysis



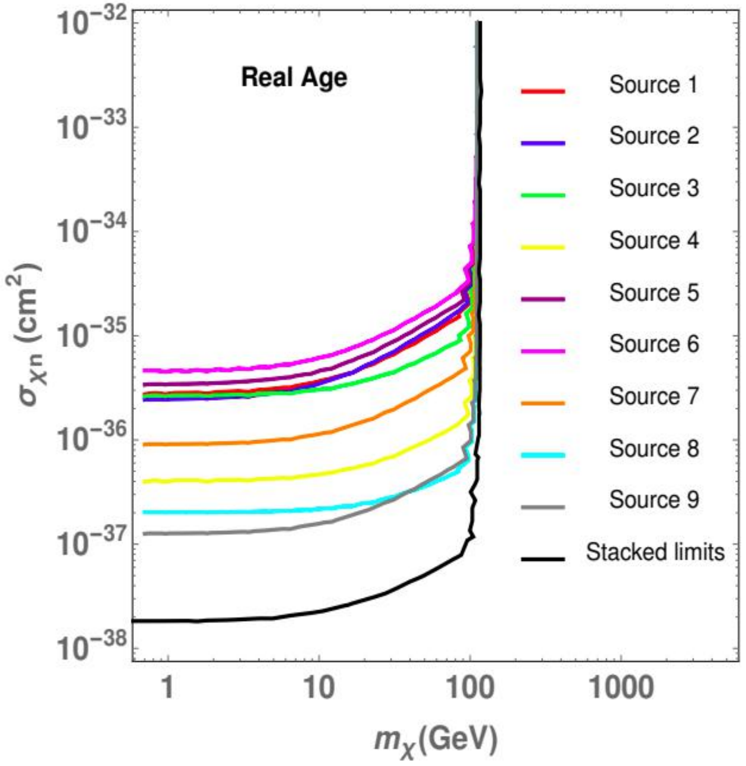

bin-by-bin differential flux upper limits at 95% C.L. for three BDs

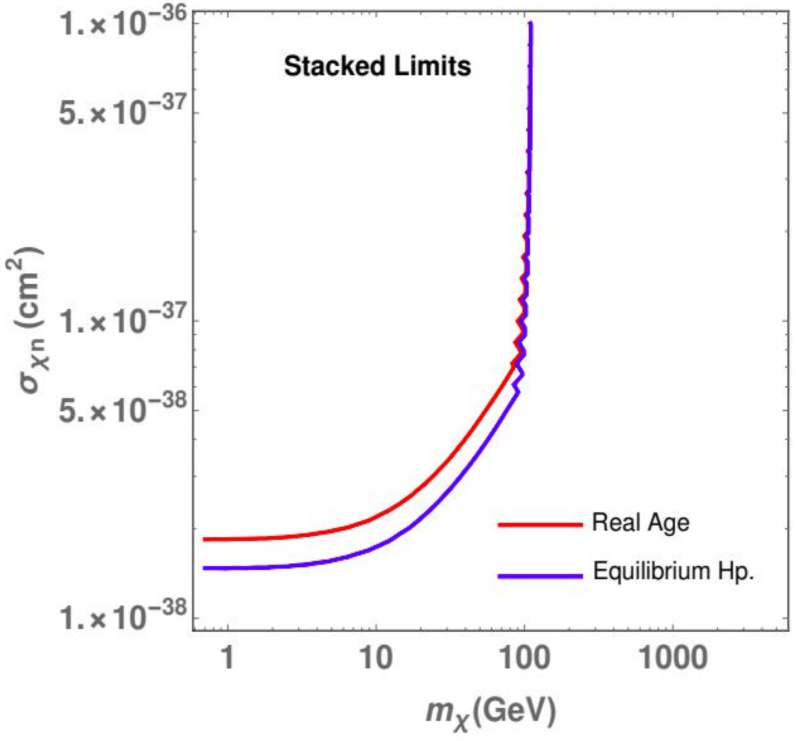
# New dark matter limits on scattering cross-section

**We translate the Fermi-LAT gamma-ray flux upper limits**

**------- Set bounds on the scattering cross section, $\sigma_{\chi n}$ as a function of the DM mass, $m_\chi$ .**

**------- For long-lived mediators =====>** $10^8\ \mathrm{m} \simeq R_\star \lesssim L \lesssim d_\star \theta_{68\%} \simeq 10^{14}\ \mathrm{m}$




**$m_\chi$ = 1 GeV and $\sigma_{\chi n} = 10^{-38}$ cm$^2$**

| Source | $t_{eq}$ [Gyr] |
|---|---|
| 1 | 0.46 |
| 2 | 0.36 |
| 3 | 0.33 |
| 4 | 0.38 |
| 5 | 0.39 |
| 6 | 0.36 |
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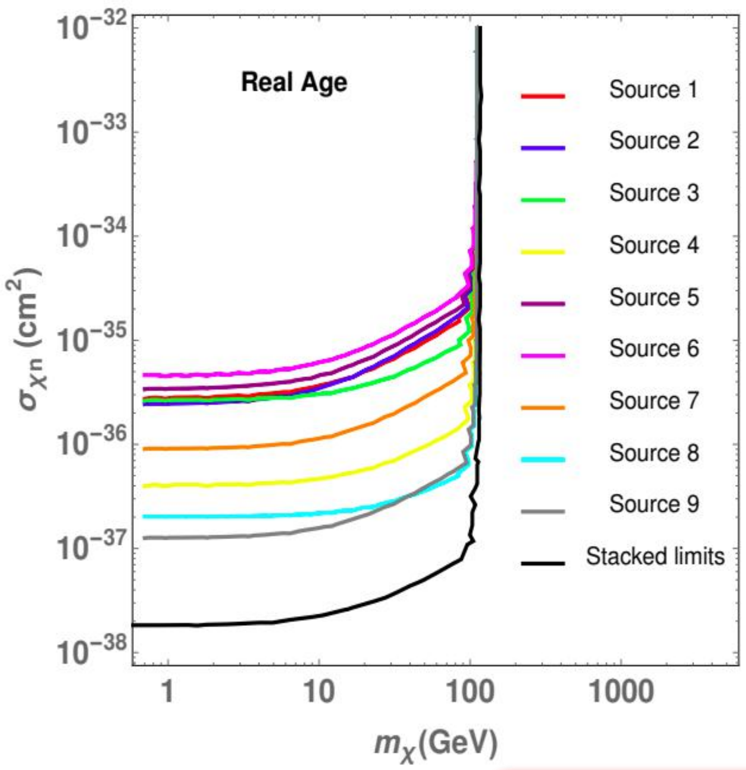


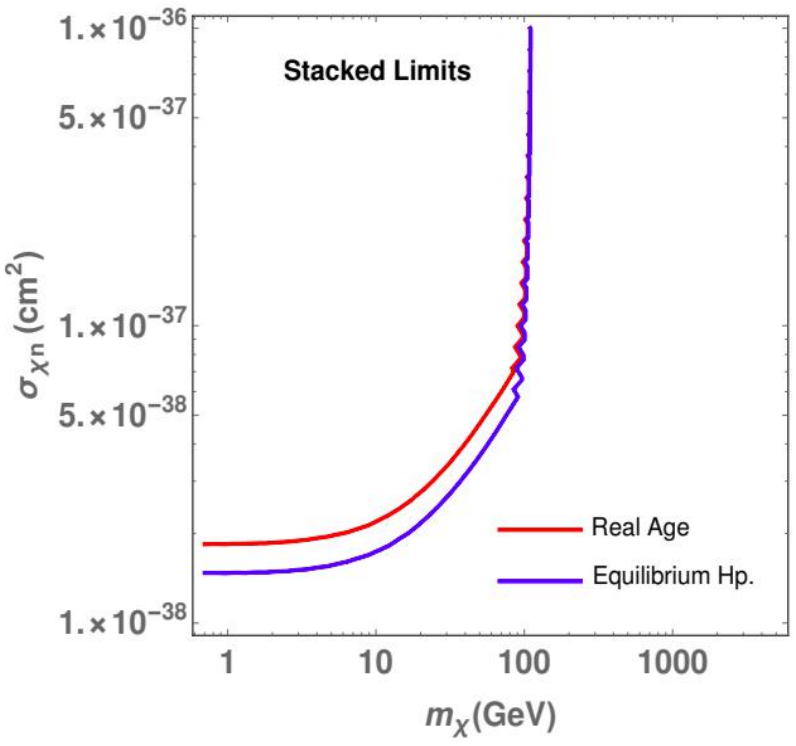


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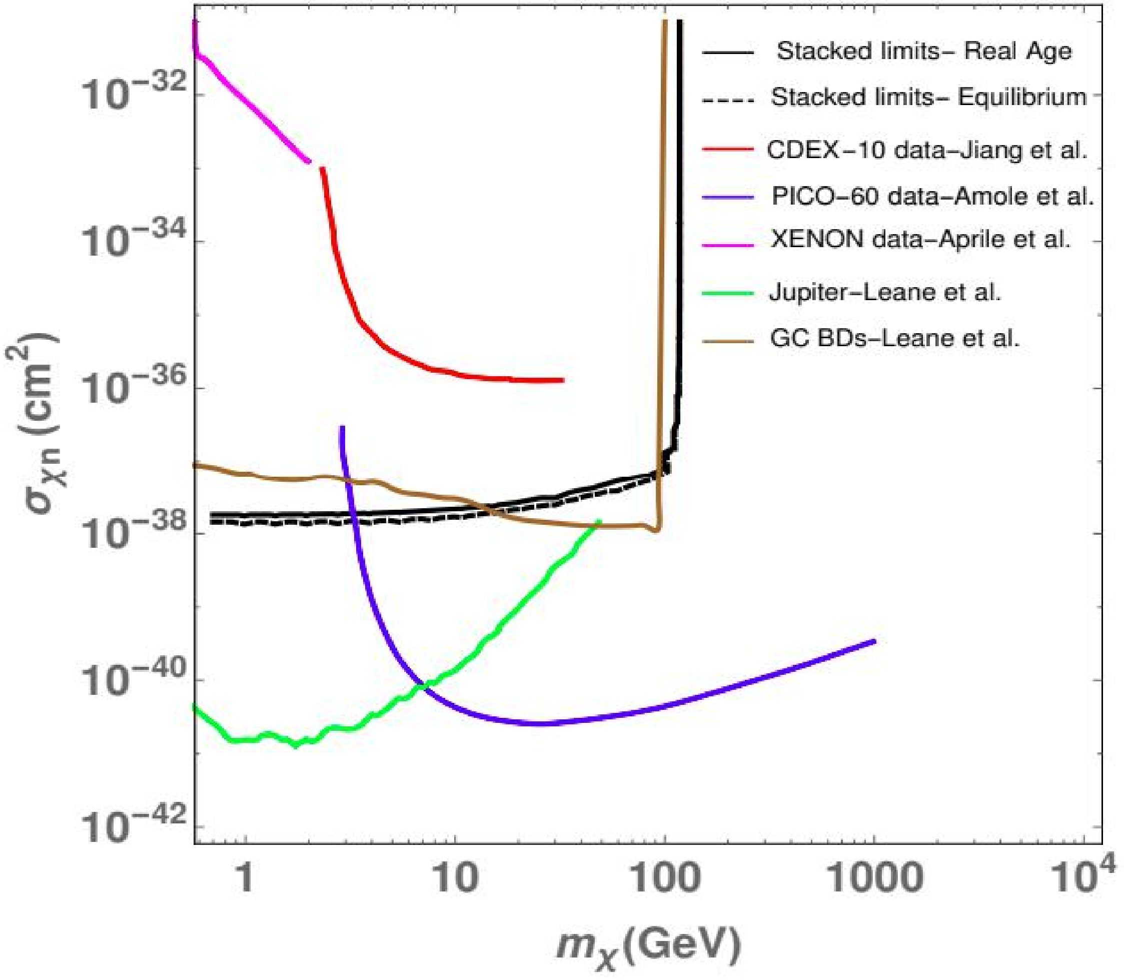
**Our sources are in equilibrium**

**We are getting the maximum signal strength for this model independent analysis**

# Comparison with other literature studies




1. BDs have the unique advantage to **probe the sub-GeV range with sensitivity scattering cross-section of $10^{-38}$ cm$^2$** .

2. Limits obtained from Jupiter is five order of magnitude more stringent but the **distance is ~5 AU**. Thus, our bounds apply to **much wider parameter space.**

3. Bounds from **GC population rely both on the assumed DM density profile and the model of the BD population toward the Galactic center region.**

4. Besides astrophysical bounds, **we compare our results with DM direct detection experiments.**

5. Our chosen sources **could provide stronger limits in sub GeV range.**

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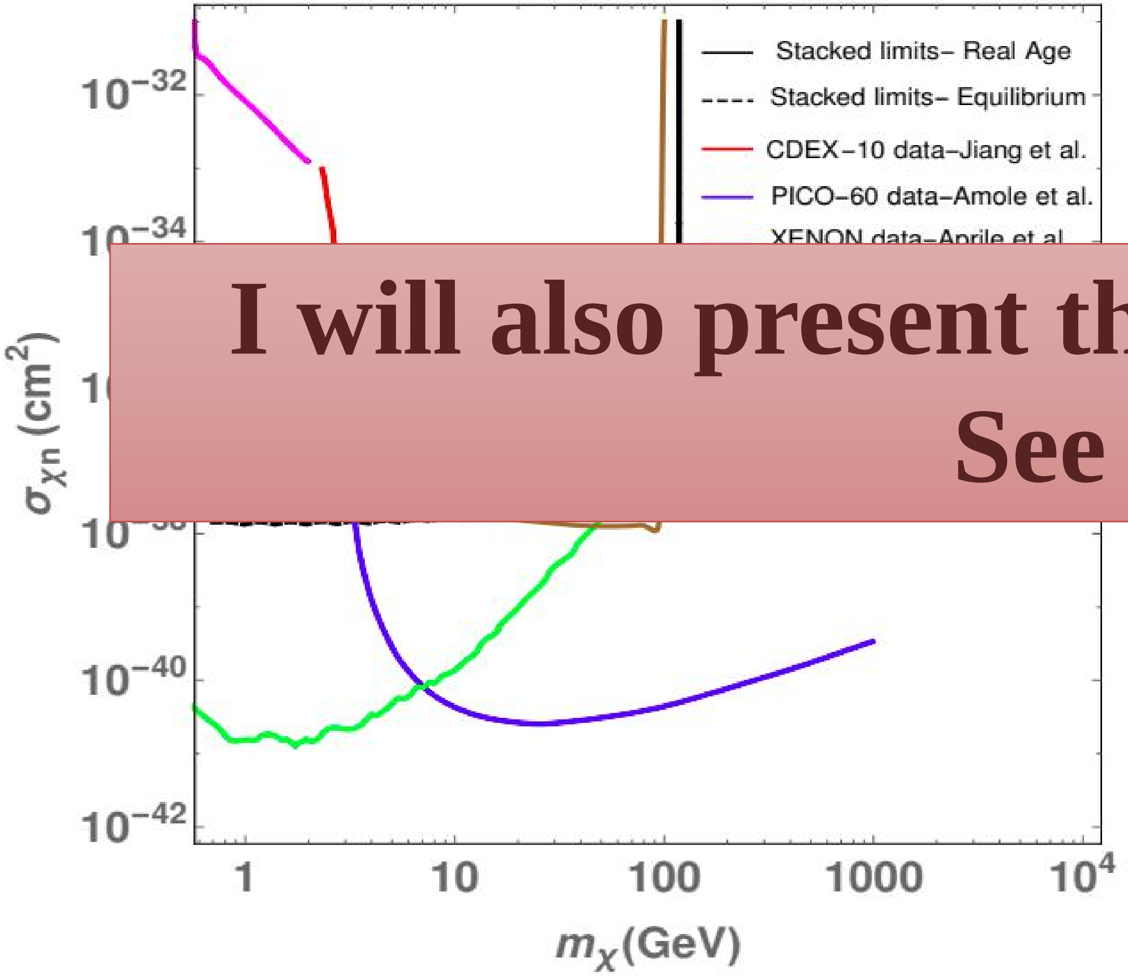


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**See you there!**

... **M** ... **rd** **the Galactic center region.**

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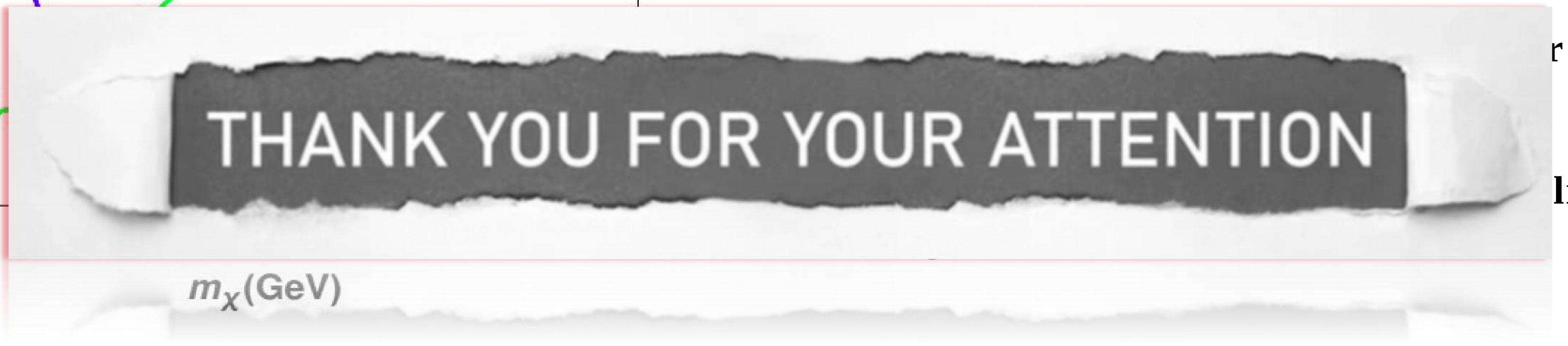

# Code is publicly available on GitLab and ESCAPE OSSR

**The code and data to reproduce the results of this study are available on GitLab,**
**https://gitlab.in2p3.fr/francesca.calore/brown-dwarfs-gamma,**
**10.5281/zenodo.7596302**

**The code is also onboarded in the ESCAPE OSSR as a part of Dark Matter Test Science Project (TSP)**
**and is in full agreement with the Open Science Uptake of EOSC-Future.**