Light thermal dark matter and MeV gamma-ray observation

Shigeki Matsumoto (Kavli IPMU, U. Tokyo)

Collaboration: Tobias Binder (TUM),
Sreemanti Chakraborti (LAPTH)
Yu Watanabe (Kavli IPMU).

Paper: JHEP01, 106, 2023

A part of the activities for the COSI DM WG.

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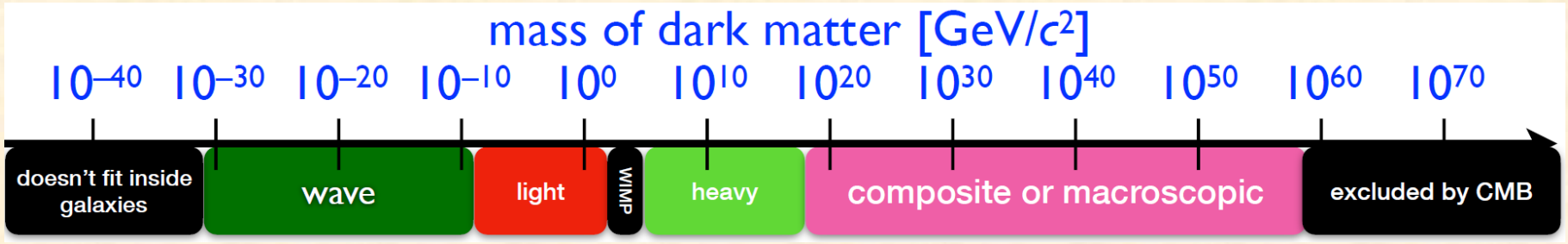
Light thermal DM is an attractive candidate, while its annihilation is severely limited by the CMB observation. A possible scenario of the DM accommodated with this limit is to have a velocity-dependent annihilation cross-section. Interestingly, such a candidate often predicts a velocity-dependent self-scattering cross-section, which enables us to solve the core-cusp (diversity) problem. Future MeV gamma-ray observations will be crucial in searching for such DMs.

Thermal dark matter



[H. Murayama, March 7, 2023]

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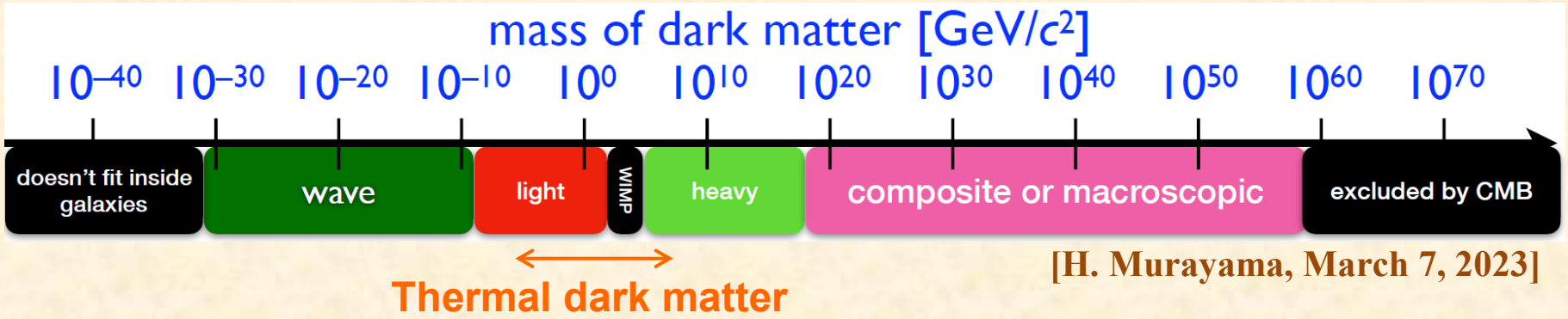

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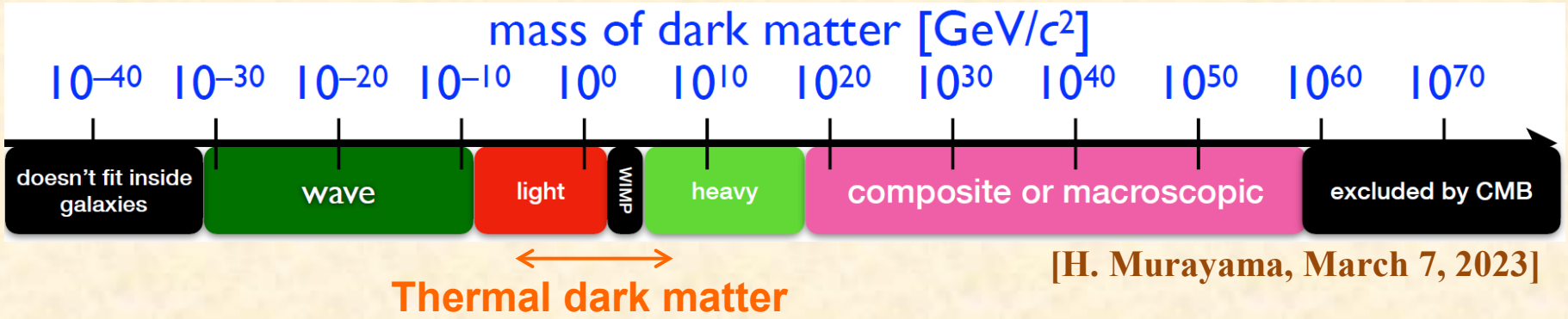

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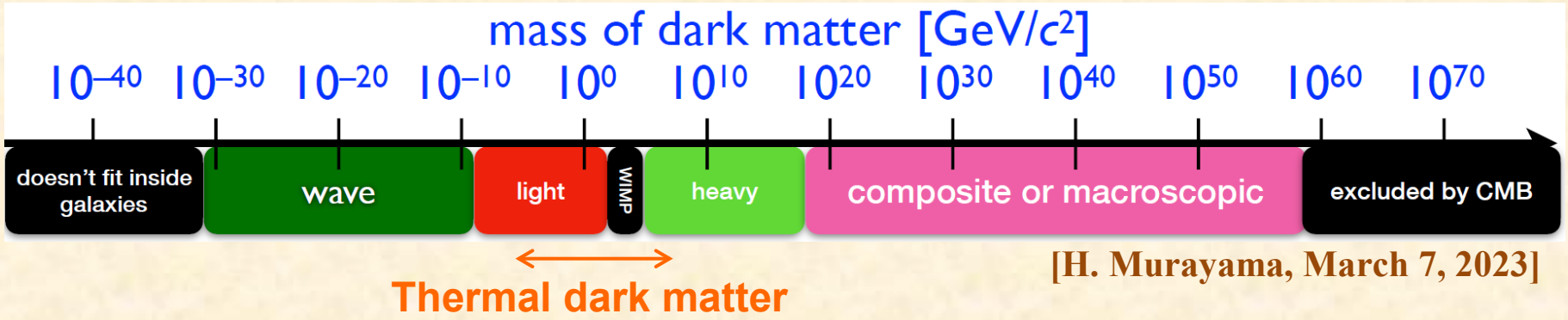

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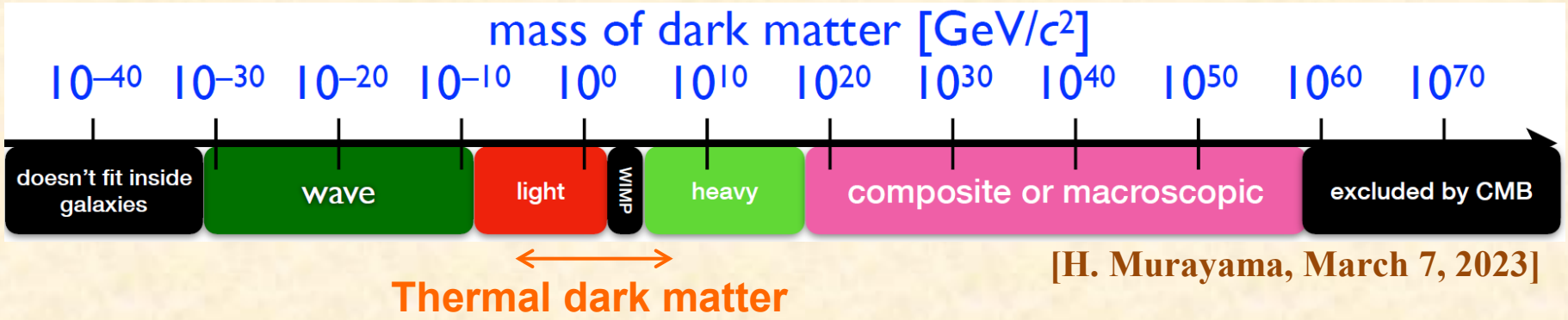

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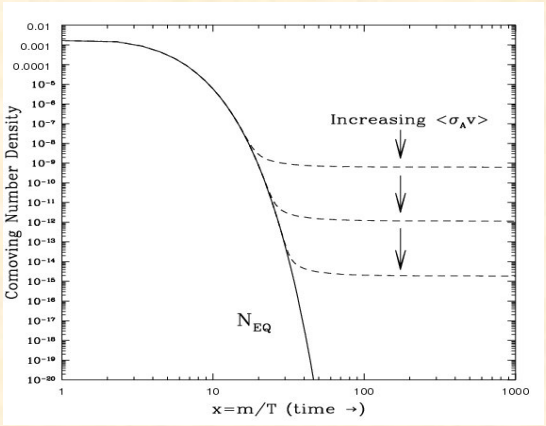

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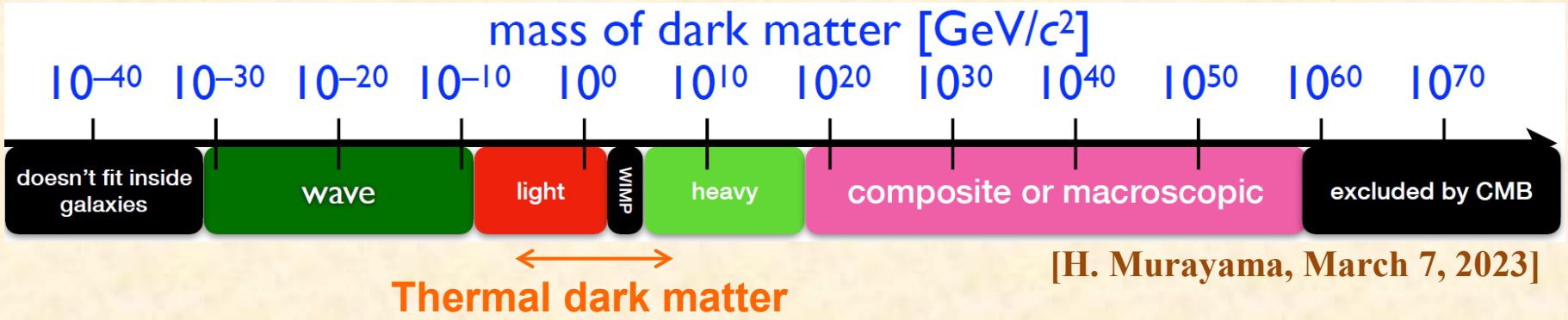

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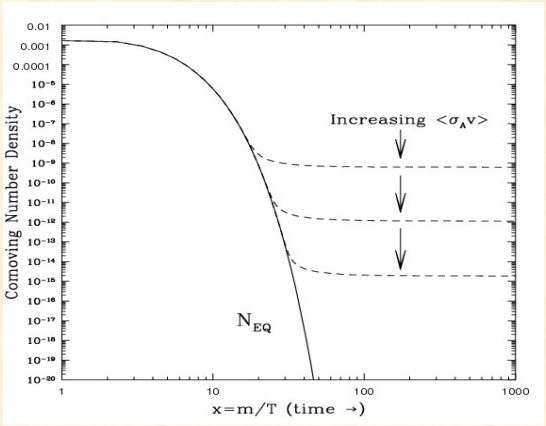

We focus on the light thermal DM, i.e., its mass is well below EW.

Detections of Light thermal DM

As in the traditional WIMP case, the strategy of detecting the light thermal DM is based on some of its elementary processes.

✓ DM production, leading to the collider detection of the DM.

✓ DM scattering, leading to the direct detection of the DM.

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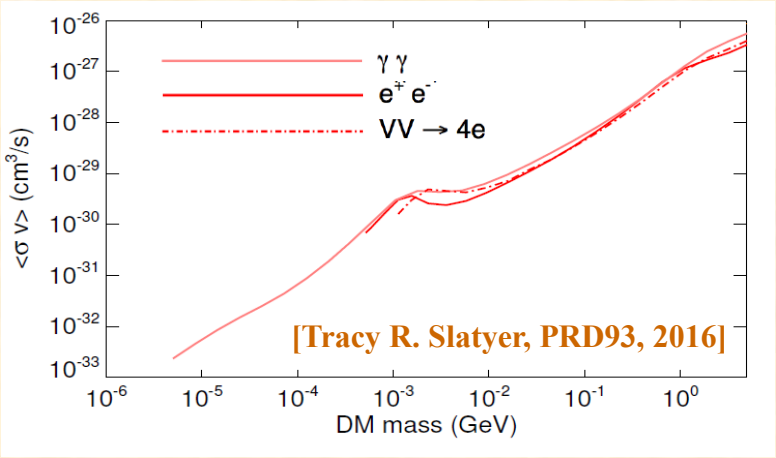
CMB constraint on DM annihilation:

DM annihilation cross-section at the recombination must be smaller than 1pb not to alter its thermal history.



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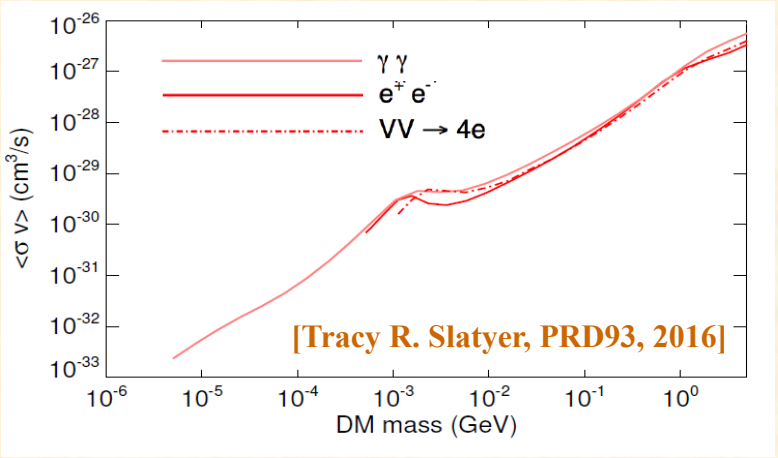

Possible solutions

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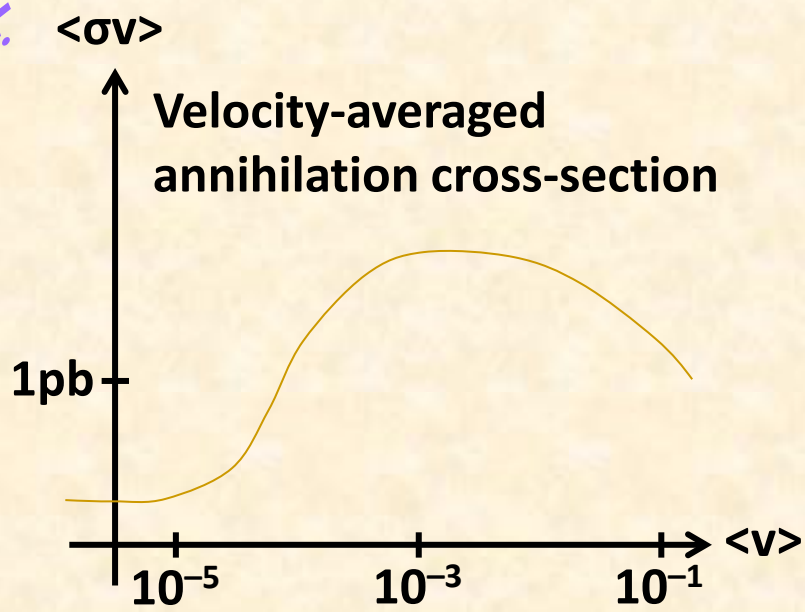

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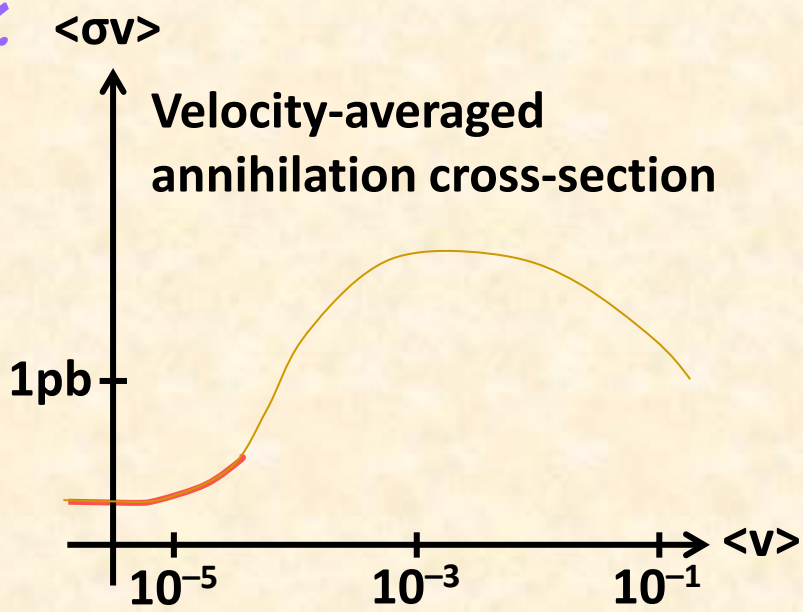

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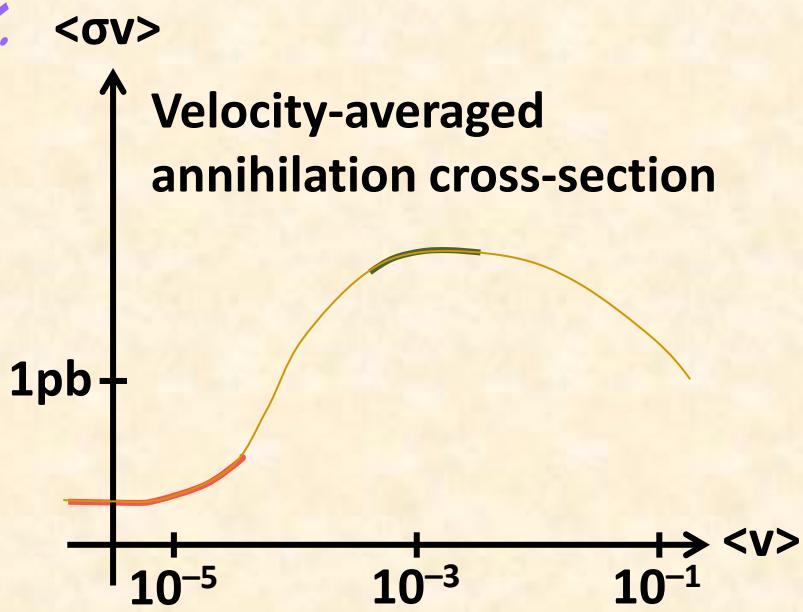

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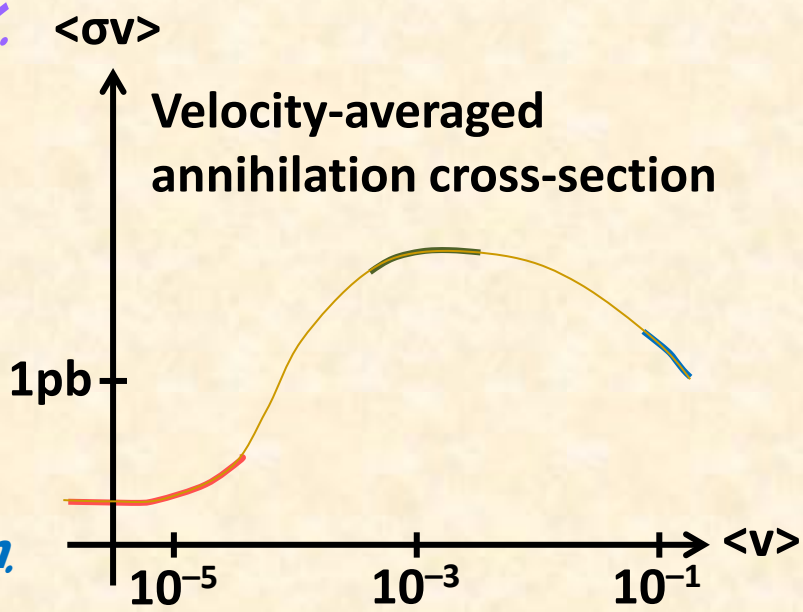

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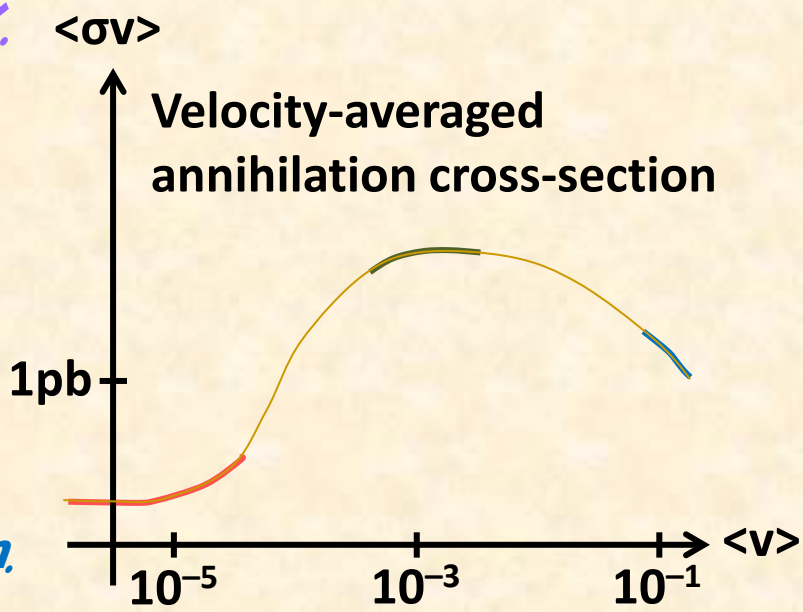

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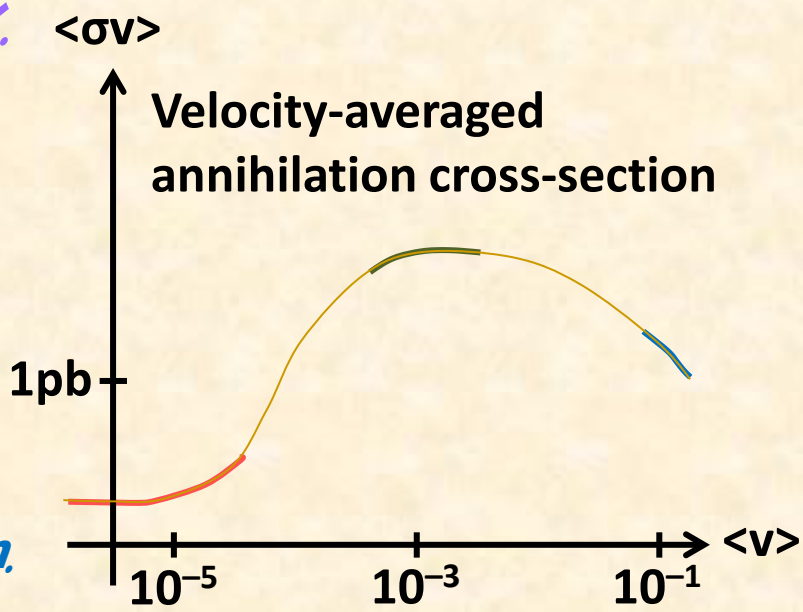

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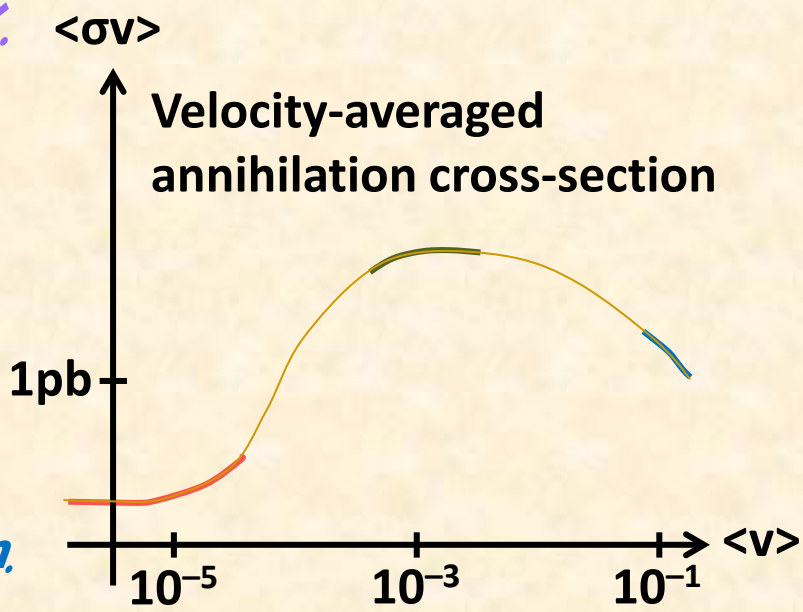

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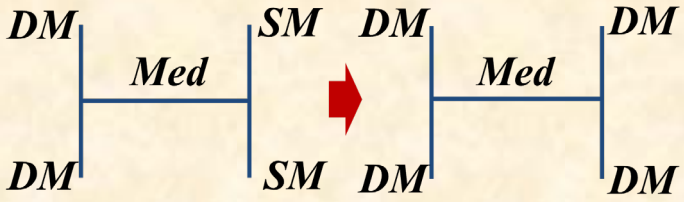

(Non-trivial velocity dependence)

Detecting the DMs at MeV-g observation

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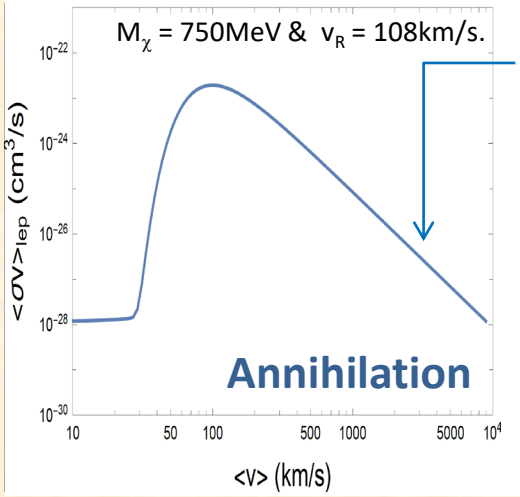

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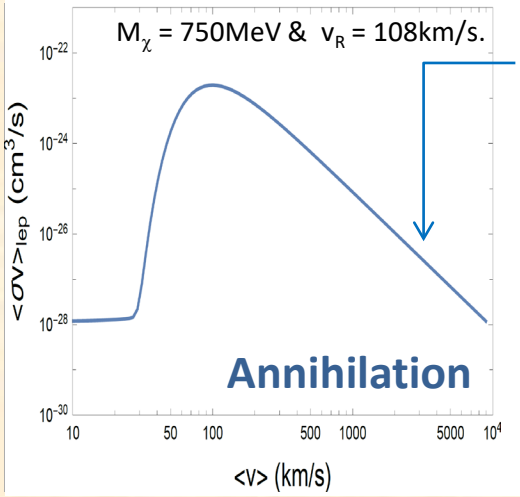

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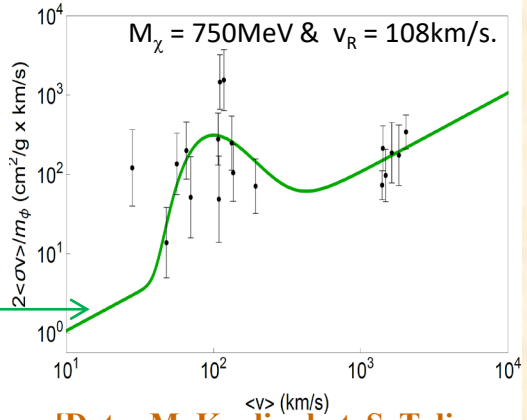

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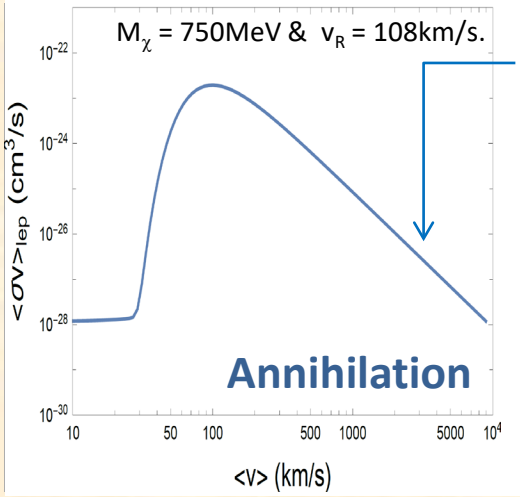

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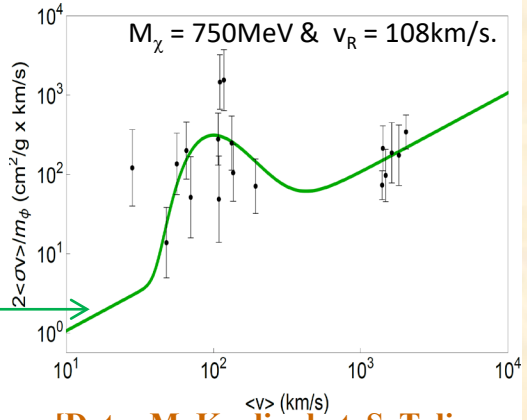
[N. Chu, C. G.-Cely, H. Murayama, PRL122, 2019]



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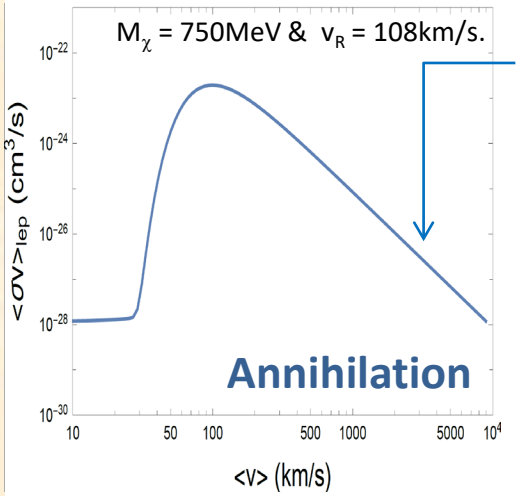

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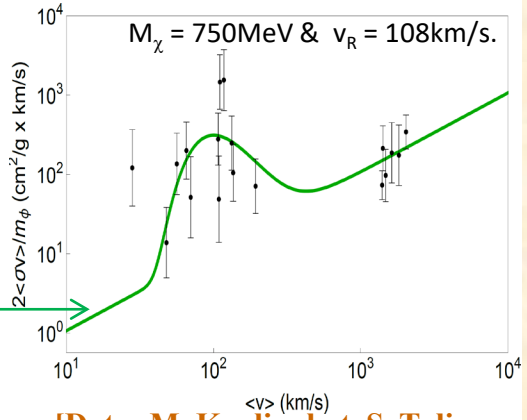

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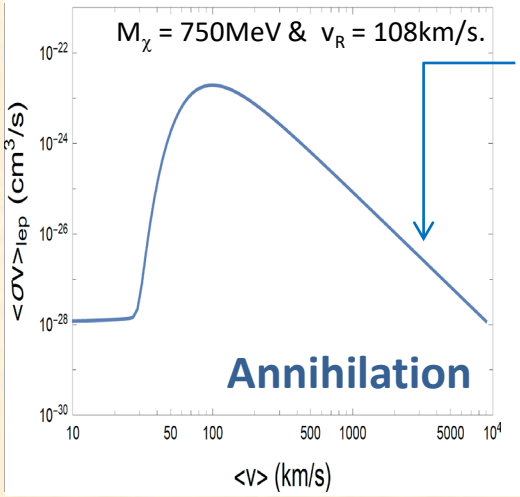

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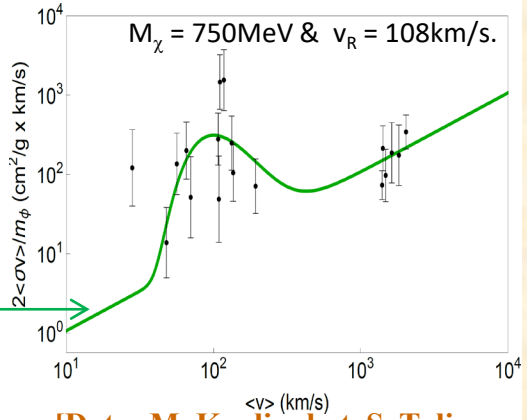

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Parameter region?

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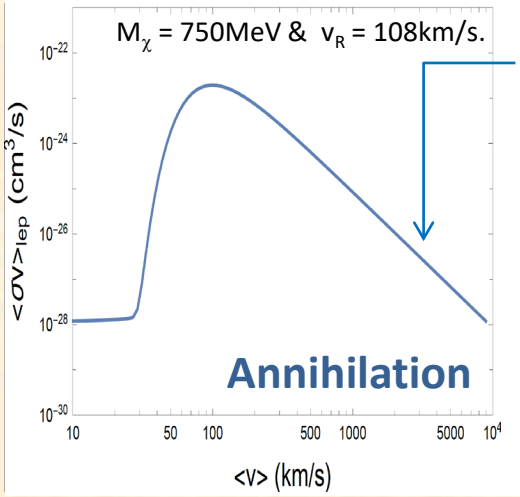

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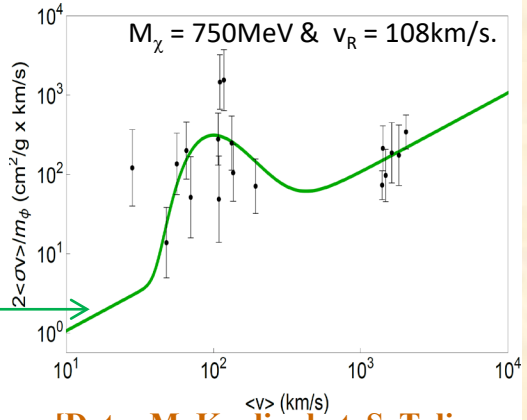

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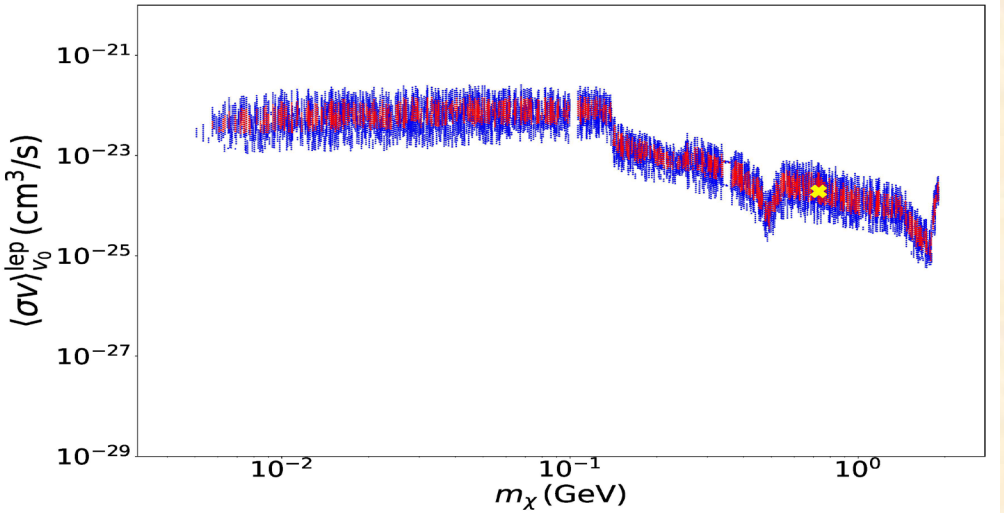

[T. Binder, S. Chakraborti, S. M., Y. Watanabe, JHEP01, 2022.]

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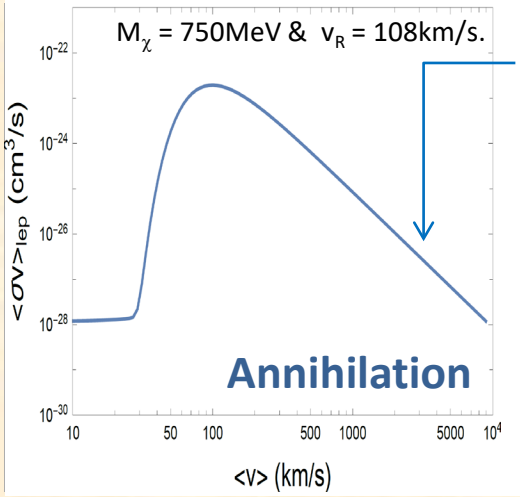

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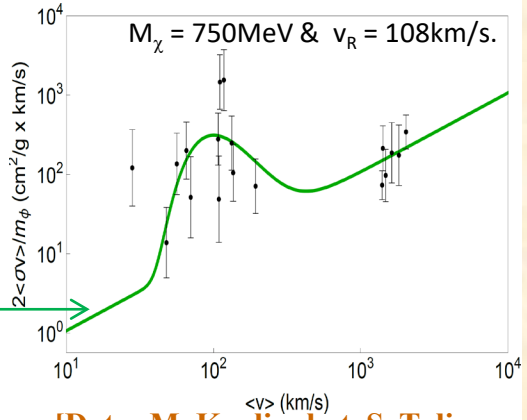
[N. Chu, C. G.-Cely, H. Murayama, PRL122, 2019]



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Parameter region?

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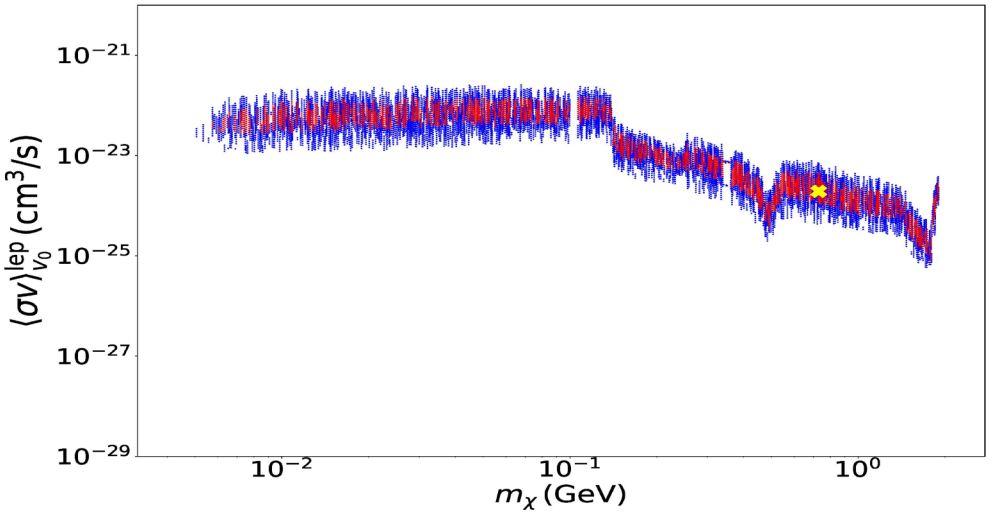
Indirect dark matter detection?



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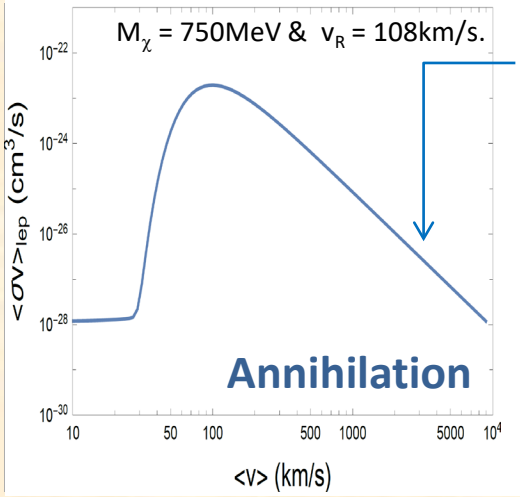

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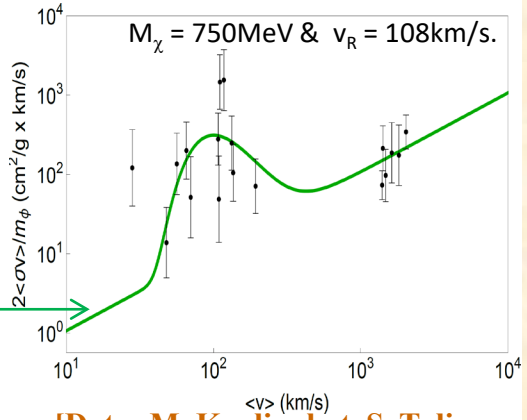

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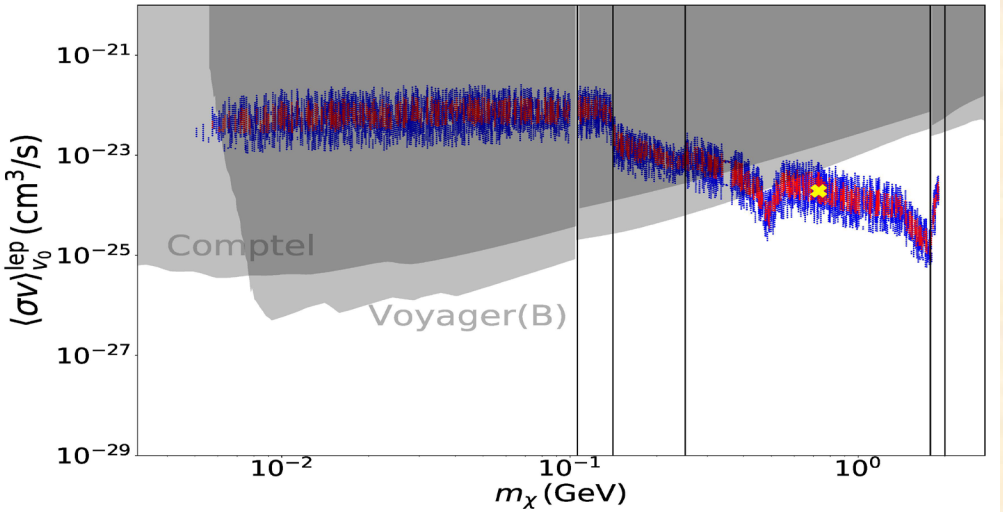

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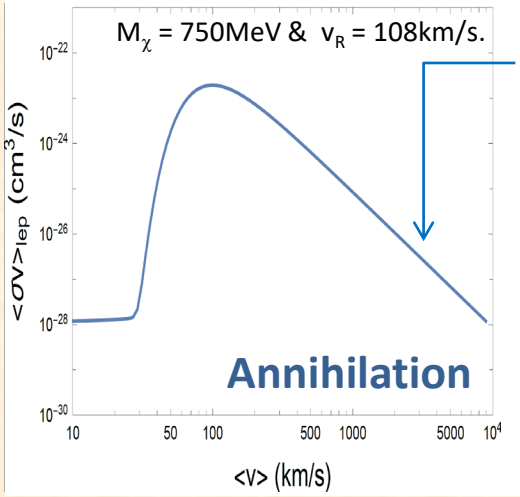

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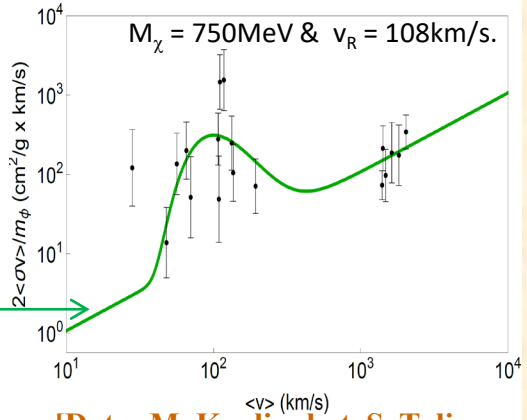

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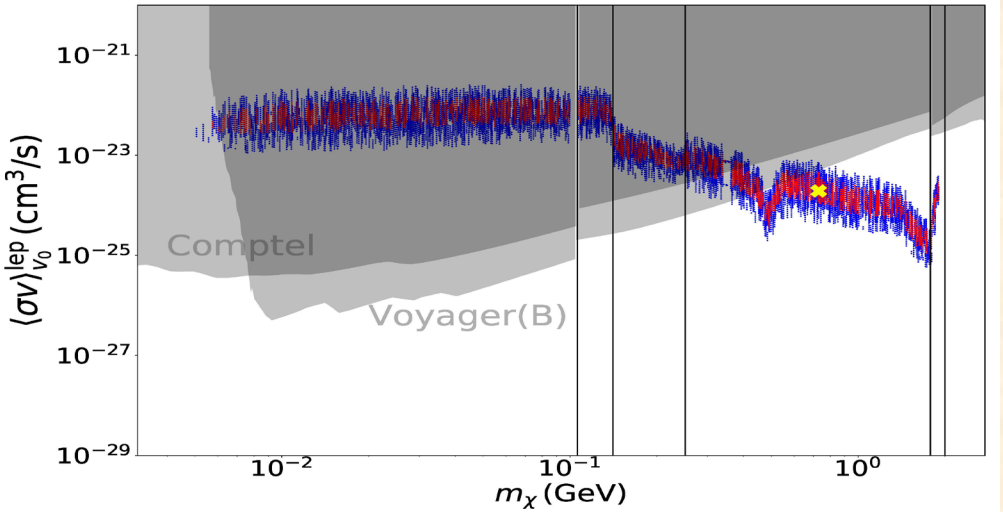

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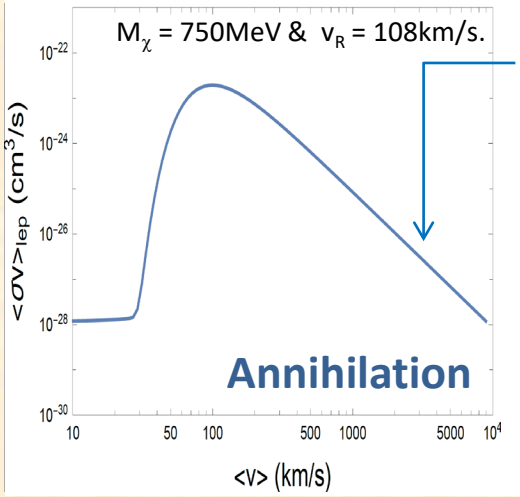

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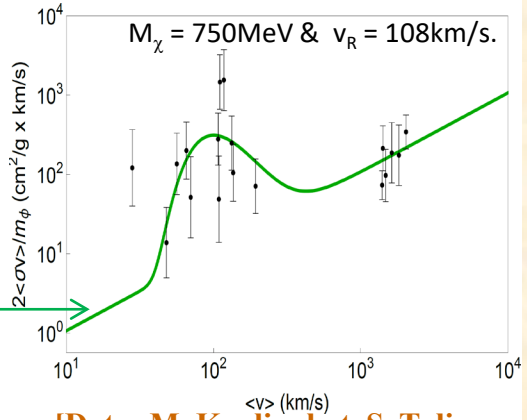

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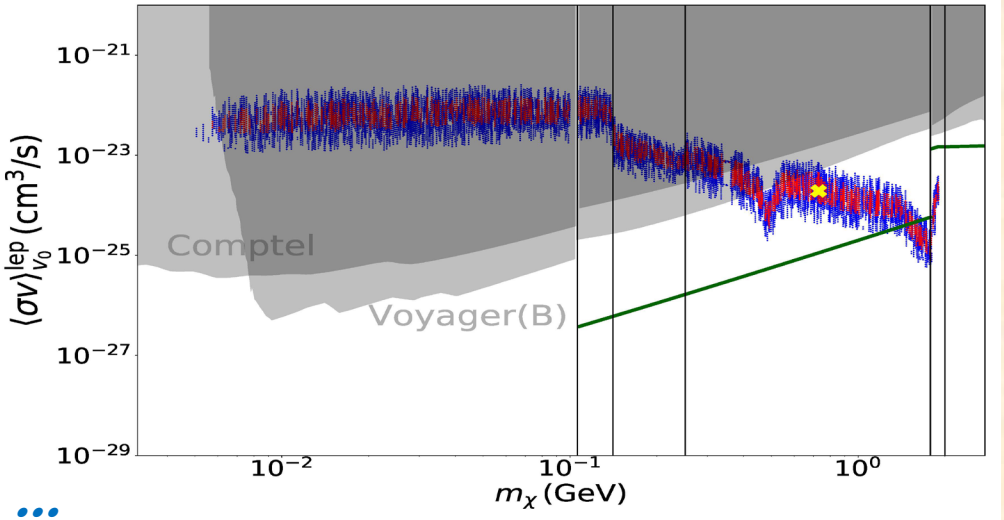
Future MeV-γ observation?

✓ COSI, AMEGO, GRAMS, GECCO, …



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Summary

We discussed a light thermal DM focusing on the following 3 aspects.

- ✓ The CMB constraint severely limits light thermal DM. Consistent with the freeze-out mechanism, a possible solution for satisfying the CMB limit is to have a velocity-dependent annihilation.
  [Another solution is to use other processes for the freeze-out.]

- ✓ Light thermal DM with velocity-dependent annihilation also often predicts a velocity-dependent self-scattering, which may solve the diversity problem of the small-scale structure of the universe.
  [Caveat: The diversity problem may be solved in another way.]

- ✓ Indirect DM detection at the MeV-g observation will play a crucial role in searching for a light thermal DM with velocity-dependent annihilation, which is expected to be well-developed in the future.
  [Collider and direct DM detections are, of course, also important.]