Troubles mounting for multipolar dark matter

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Based on - arXiv:2312.05131 (JHEP 06 (2024) 014)
In collaboration with D. Chowdhury, P. Mondal and T. S. Ray

Parallel Session Talk @ ICHEP 2024
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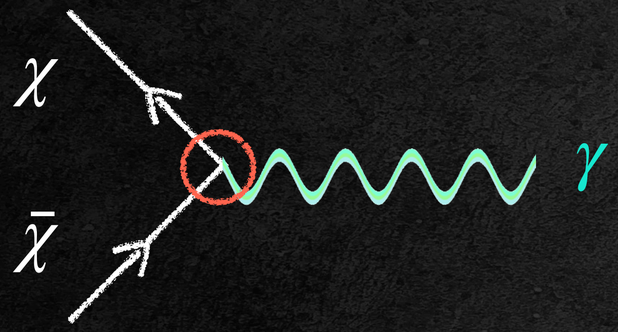
Model description:

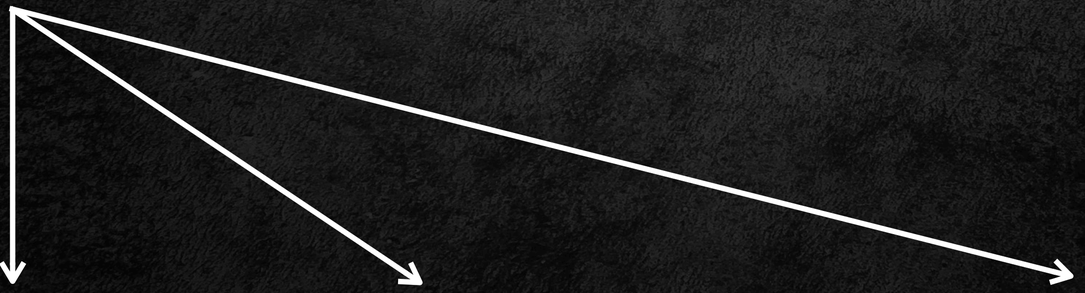
Coupling to photons through multipole moments

$$\mathscr{L}_{\text{dipole}} = \underbrace{\frac{1}{\Lambda_2}\bar{\chi}\sigma_{\mu\nu}\chi F^{\mu\nu}}_{\text{Magnetic}} + \underbrace{\frac{i}{\Lambda_3}\bar{\chi}\sigma_{\mu\nu}\gamma_5\chi F^{\mu\nu}}_{\text{Electric}}$$



$$\mathscr{L}_{\text{anapole}} = \frac{1}{\Lambda_1^2}\bar{\chi}\gamma_\mu\gamma_5\chi\,\partial_\nu F^{\mu\nu}$$

Phenomenological study



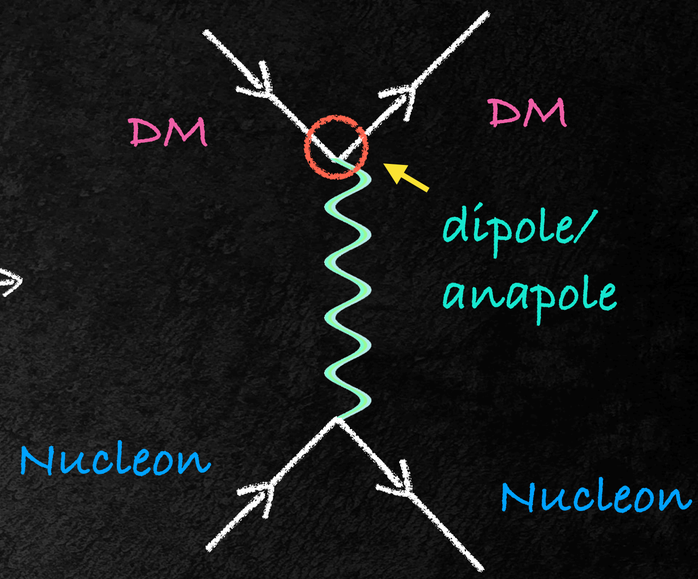
Focus of this study!

Direct detection (LZ, DS-50)

Indirect detection (Suppressed!)

Detection through celestial capture (Sun, Neutron star)

Dark matter Capture:



Halo
DM

gravitationally
focused

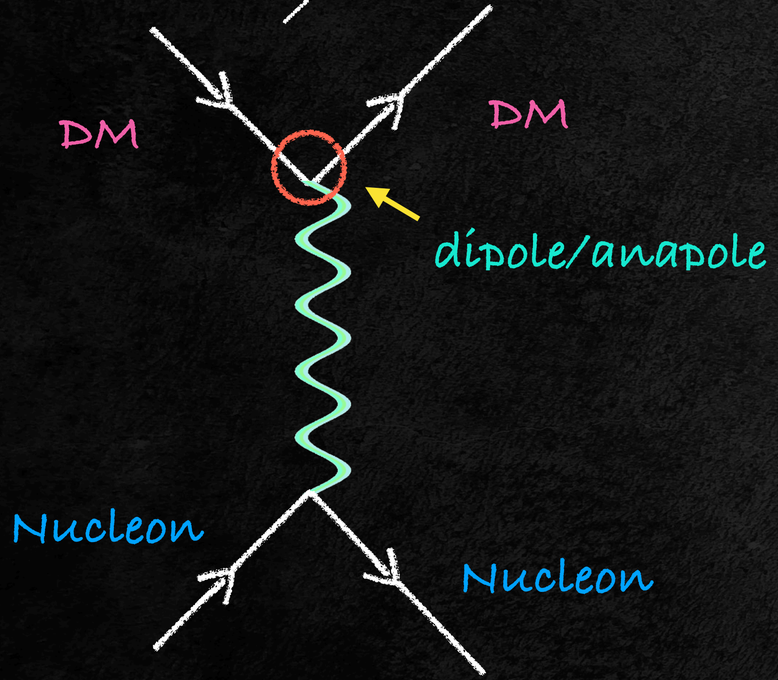
multiple
scattering

Captured
DM
($v_f < v_{esc}$)

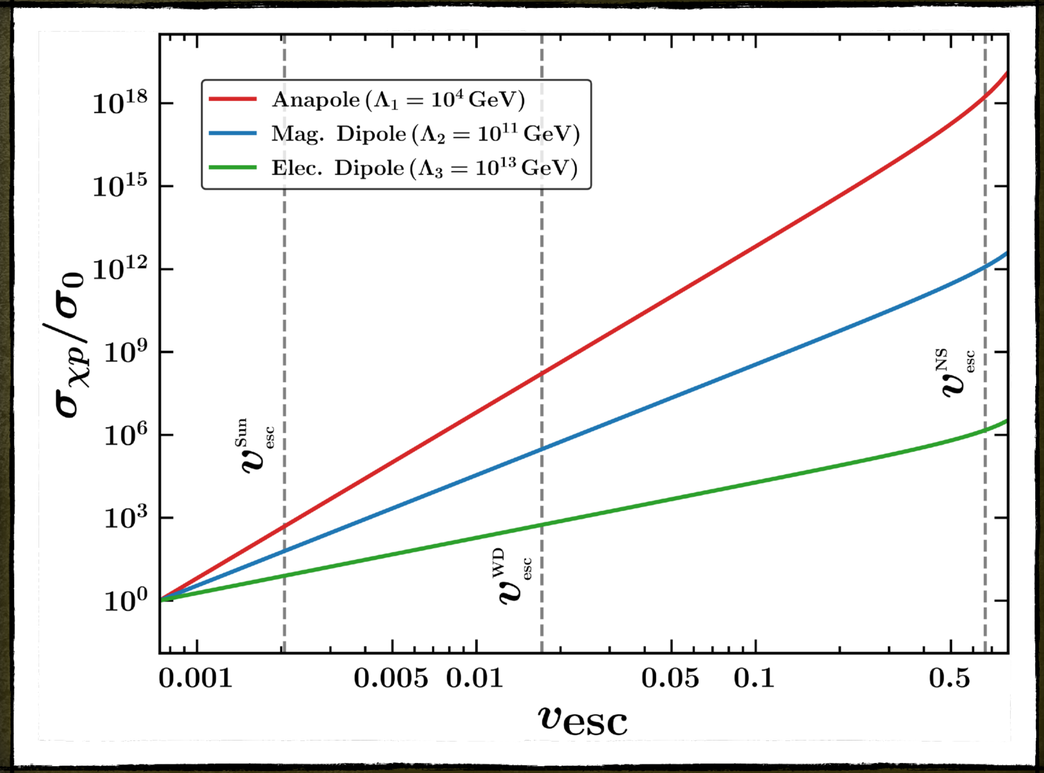
Outcomes :

- Heating of celestial objects
- Annihilation signatures
- Black Hole formation
- Supernova ignition, ...

Interaction rate Enhancements:



- Due to momentum dependent coupling, the scattering cross-section is enhanced



- High dark matter flux due to gravitational focusing

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Capture Rate

Capture probability after N scattering

Area of the object

$$C = \sum_N \pi R^2 \; p_N \left(\frac{\rho_\chi}{m_\chi}\right) \int_0^{u_{esc}} du \frac{f(u)}{u}\left(u^2 + v_{esc}^2\right) g_N(u)$$

Probability of N time scattering

DM flux

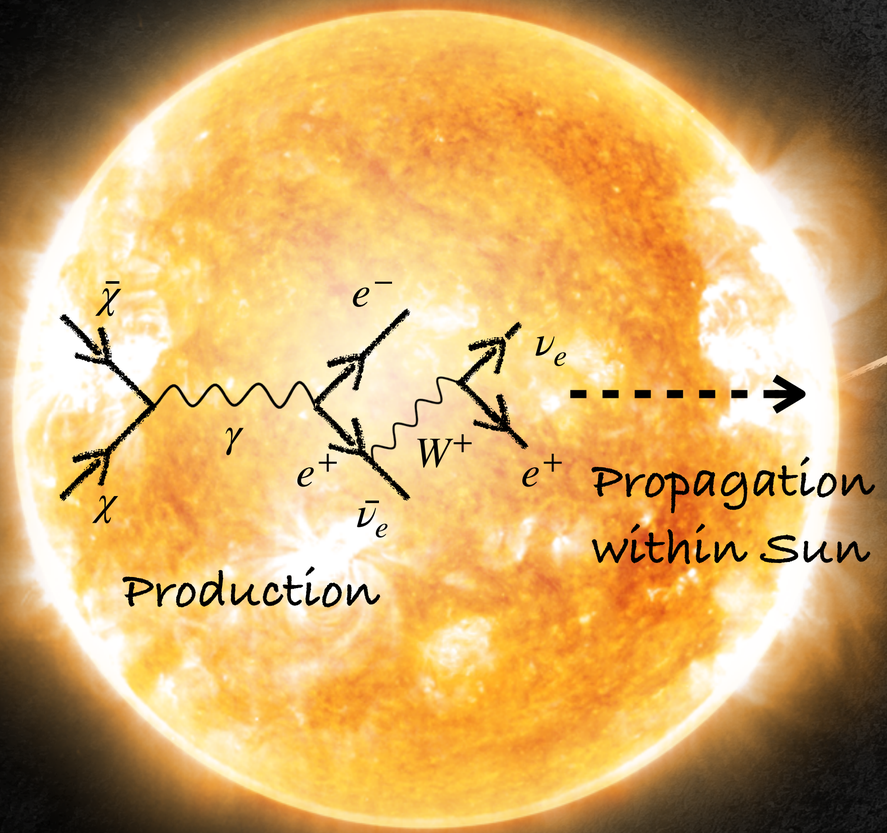
Sources of uncertainties

- DM density (upto a scaling !!)
- DM velocity distribution (Not linear scaling !!)

discussed in

DB, Sarkar @ PRD 107 (2023) 6, 063010 (2211.16982)

Neutrinos from Sun:

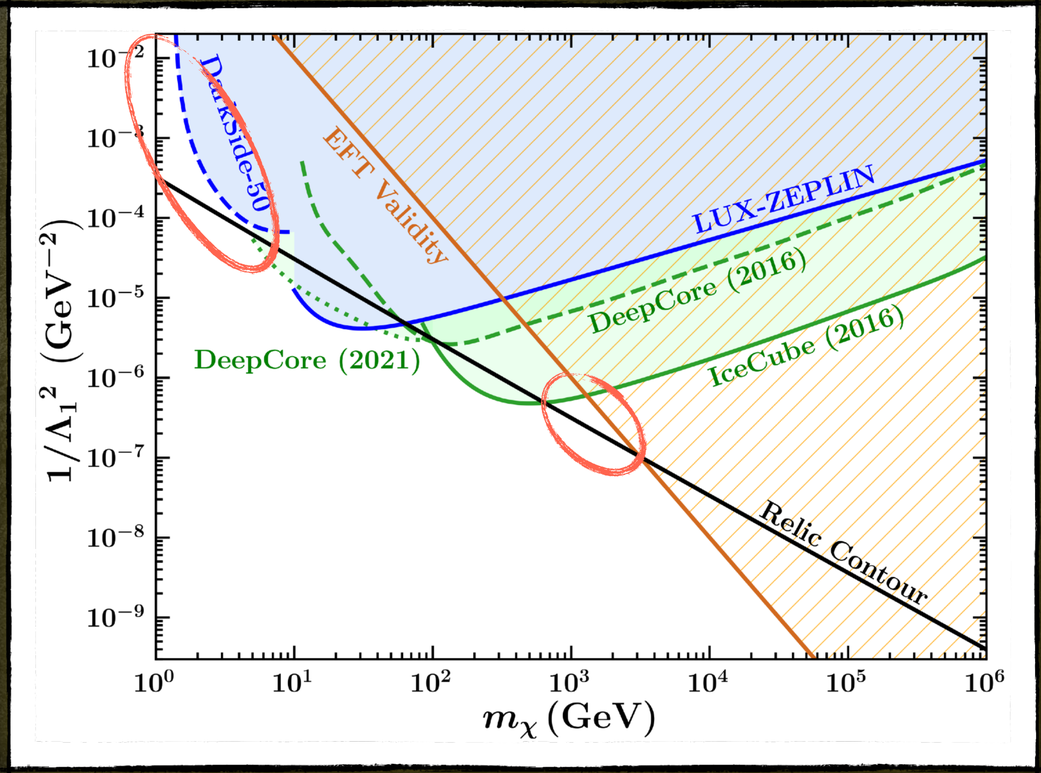


Propagation in vacuum

Earth

Detection at IceCube

Anapole DM



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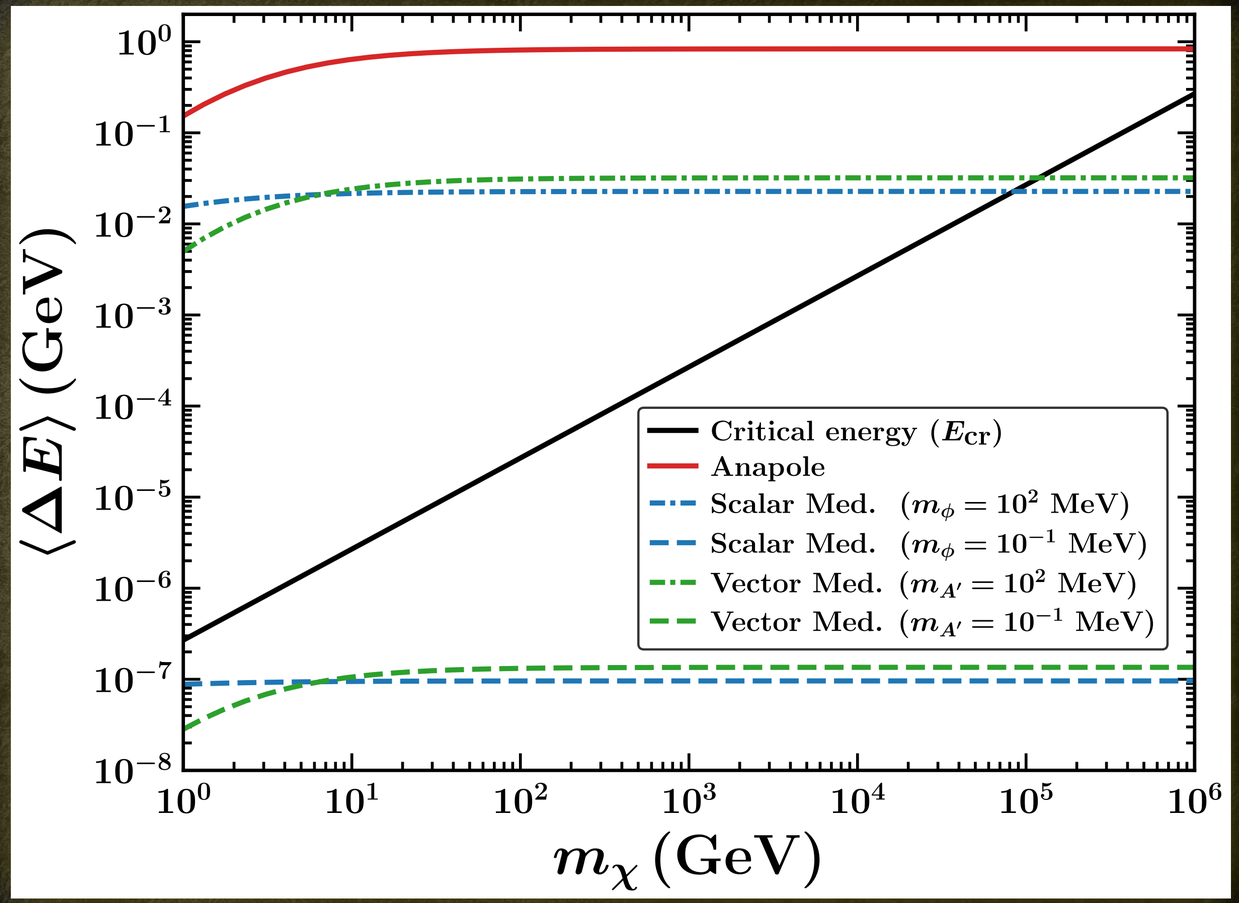
Neutron Star Heating:

Capture:

- Usually suppressed for light mediators due to soft scattering.

- For these models, due to momentum dependency, the energy transfer becomes sufficient!



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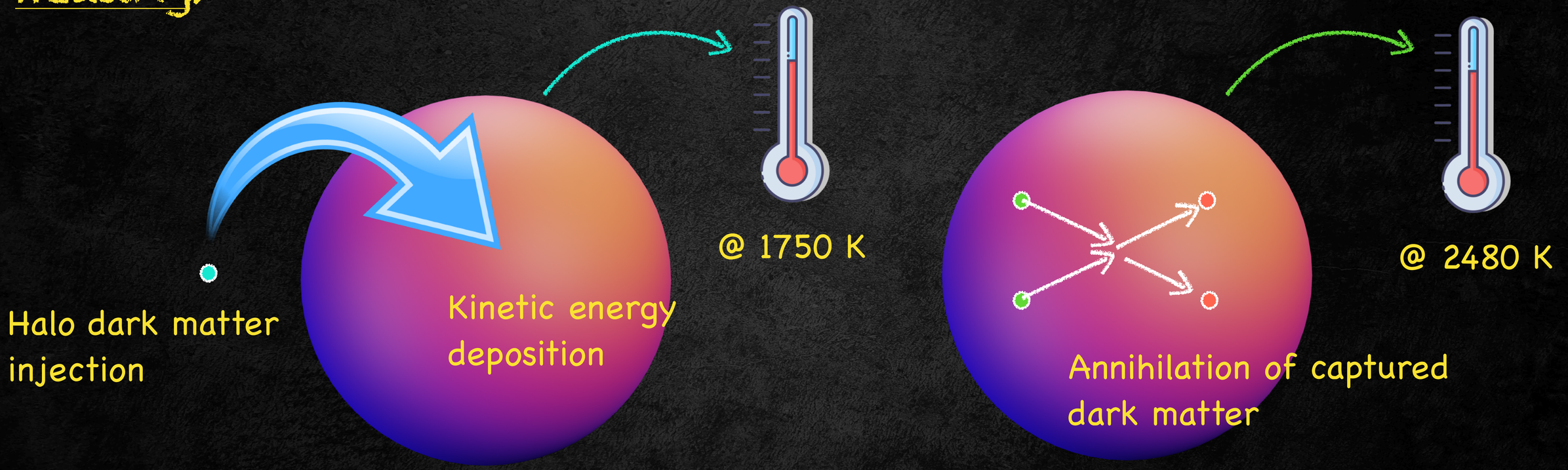
Neutron Star Heating:

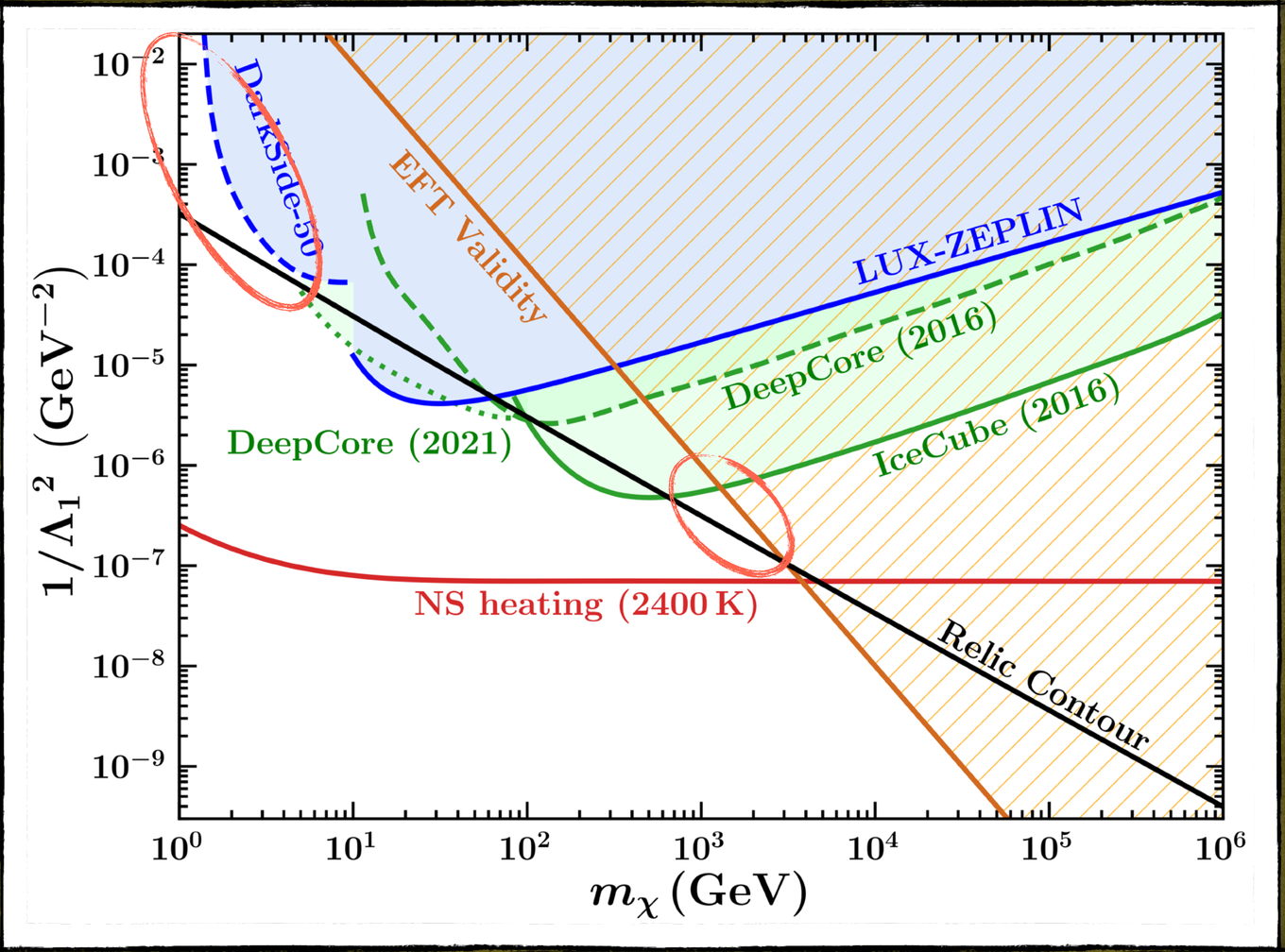
Heating:



Kinetic heating

Annihilation heating

Results:



- Red line is the sensitivity limit Obtained by probing the dark heating of cold neutron stars that can be detected @ James Webb

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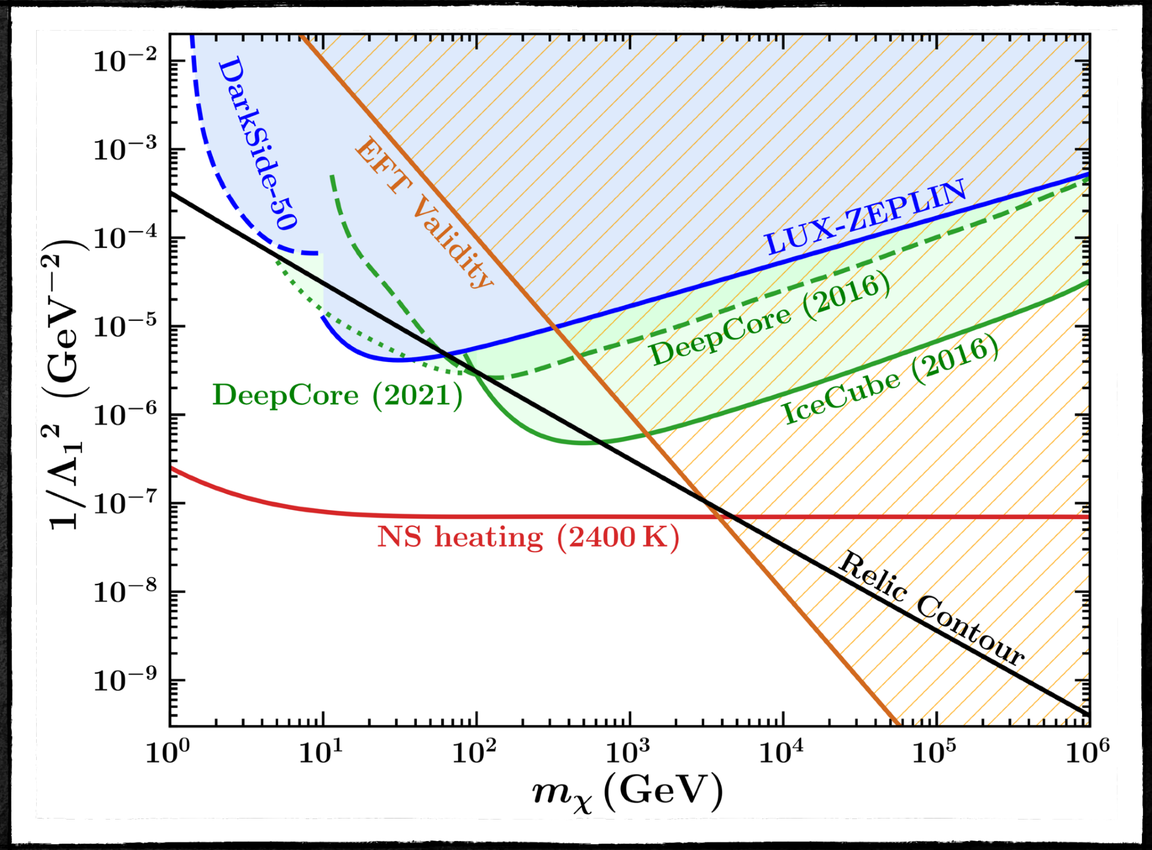
Conclusion:

- Momentum dependent DM coupling can be probed in dense stellar atmosphere

- For anapole DM, the neutrinos from captured DM inside the Sun can rule out a portion of DM parameter space that is allowed by direct detection

- Any possible detection of 2400K NS in the near future can hopefully detect or rule out the parameter space that is yet to be discovered!



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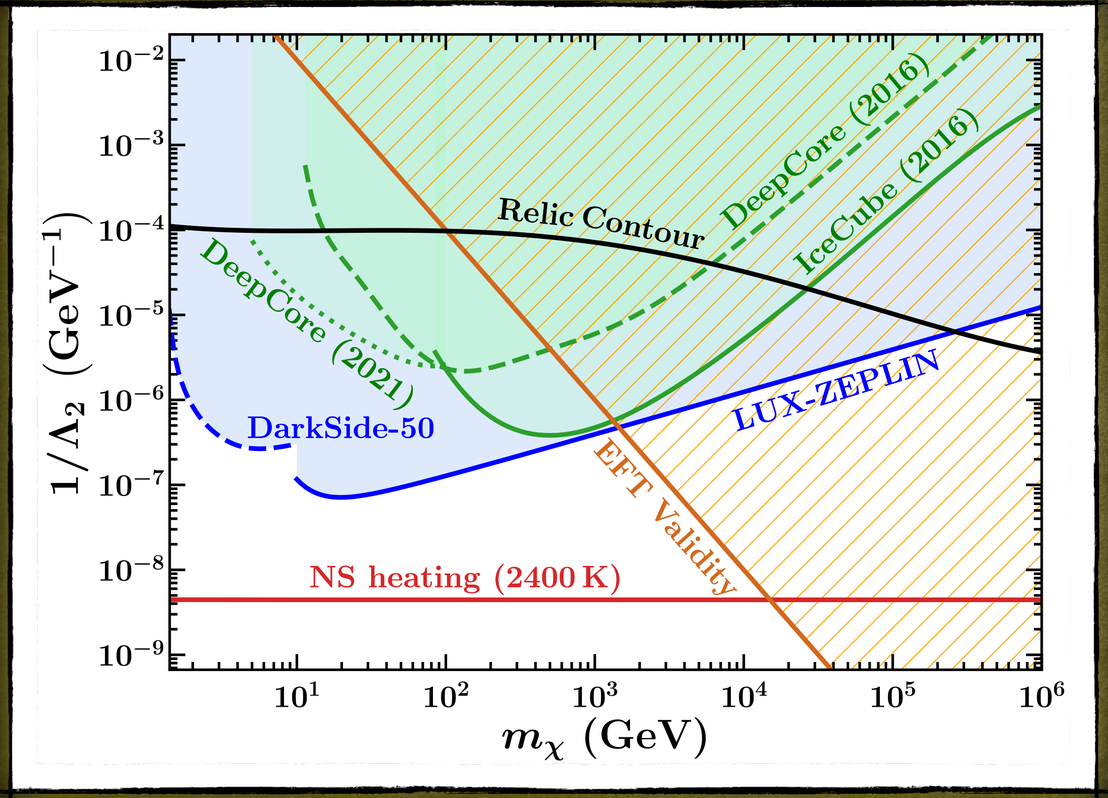
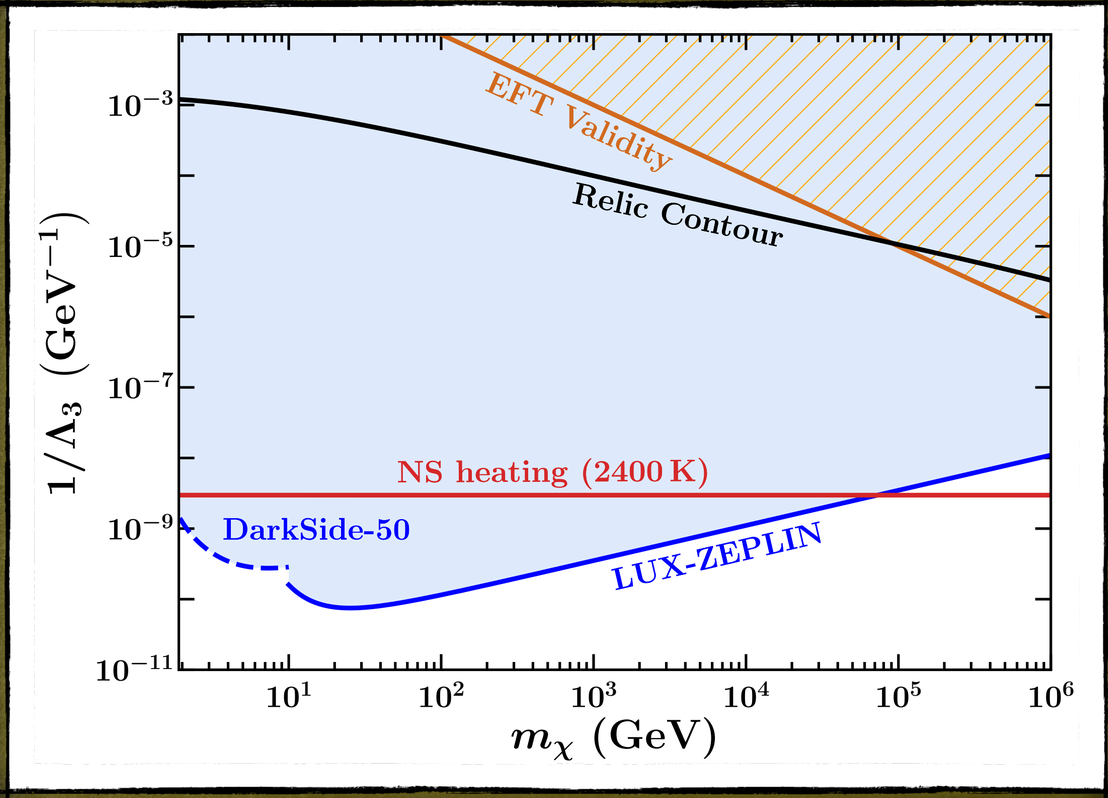
Thank You

Back up Slides

Results:



Magnetic dipole



Electric dipole

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