Exploring Sub-GeV DM Boosted by DSNB: Insights from XENONnT and LZ Experiments

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(In collaboration with V. D. Romeri, D. K. Papoulias and R. Srivastava)

arXiv:2309.04117

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Introduction

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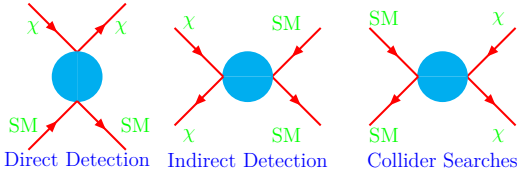
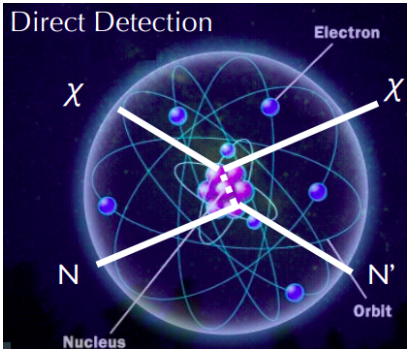
Motivation for searching the Dark Matter (DM)

- Cold DM: a non-luminous matter which occupied 27% of the mass and energy in the observable universe and which does not interact with photons and only "weakly" with ordinary matter.
- Astronomical and cosmological observations at various scales:
  - (i) Rotation curves of spiral galaxies and galaxy clusters
  - (ii) Gravitational lensing
  - (iii) Cosmic Microwave background (CMB) fluctuations



- **Direct Detection Experiments:** *XENONnT, LUX-ZEPLIN, Super-CDMS, Dark-Side, PandaX-4T, etc.*
- **Indirect Detection Experiment:** *IceCube, HESS, MAGIC, etc.*
- **Accelerator searches:** *ATLAS, CMS at CERN*

DM Direct Detection Facility



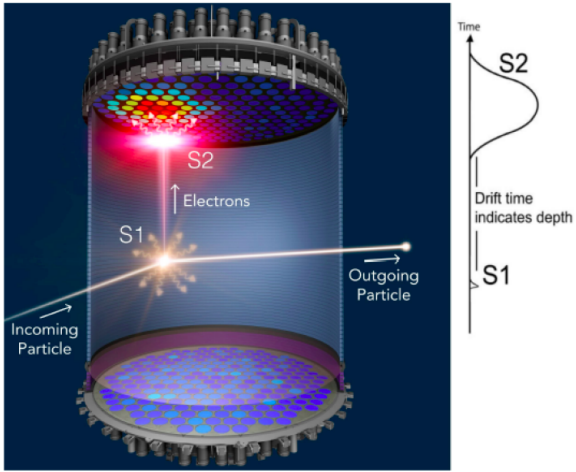


Image courtesy: Kudryavtsev, Universe, 2019

DM Landscape: A Wide Mass Range

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Ultralight
(QCD) axion, hidden photon, scalar field, fuzzy, non-thermal

Superlight
sterile ν, axino, warm DM, can be **thermal**

Light
SIMP, ELDER, can be **thermal**

WIMP
well-motivated, extensively studied, **thermal** **No firm signal yet!**

Superheavy
composite, WIMPzilla, Q-ball, Fermi-ball, dark-quark nugget, non-thermal

Astrophysical object
MACHO, PBH, non-particle

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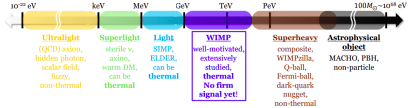

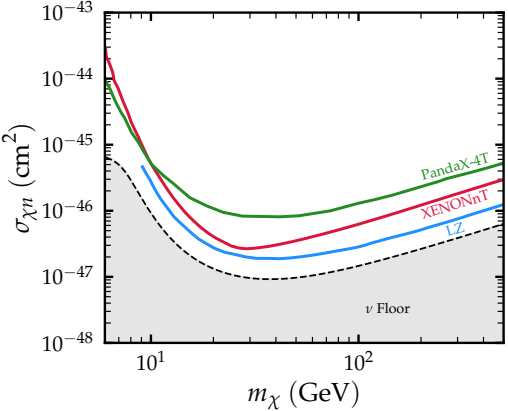

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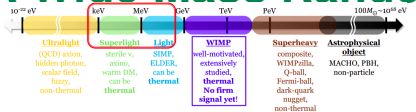

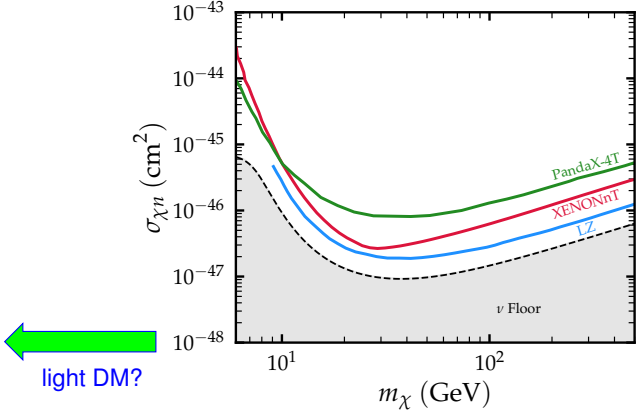

light DM?

Thermal Relic DM vs Boosted DM

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The maximum recoil energy of the target:

$$T_r^{\max} \approx \frac{Q^2}{2m_T} \approx \frac{2m_\chi^2 m_T v_\chi^2}{(m_\chi + m_T)^2}$$

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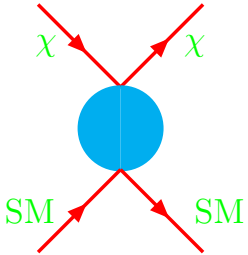

$v_\chi \approx 10^{-3}$

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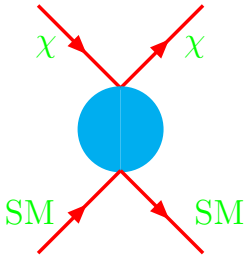

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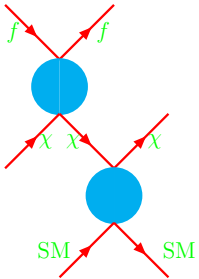

$v_\chi \approx 1$

DSNB Boosted Dark Matter

Diffuse Supernova Neutrino Background

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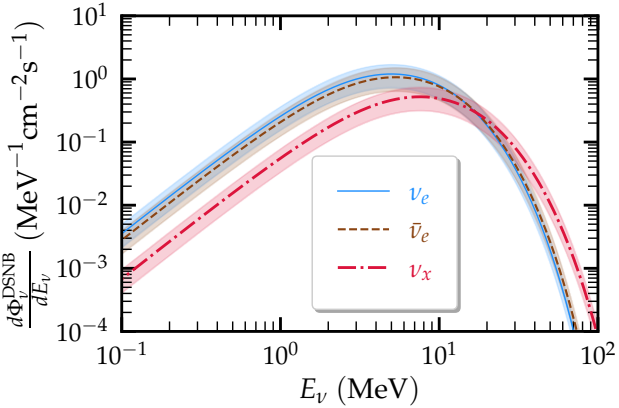
Right after the first star formation event, the Universe has been surrounded by an isotropic flux of MeV-energy neutrinos and antineutrinos of all flavors, produced from all supernovae events from the core-collapse explosions of huge stars throughout the Universe. This cumulative and isotropic flux of MeV neutrinos form DSNB.



BDM Flux At The Underground Detectors

The DSNB-boosted DM differential flux,

$$\frac{d\Phi_\chi}{dT_\chi} = D_{\rm halo} \int_{E_\nu^{\rm min}}^{E_\nu^{\rm max}} dE_\nu \frac{1}{m_\chi} \frac{d\sigma_{\nu\chi}}{dT_\chi} \frac{d\Phi_\nu^{\rm DSNB}}{dE_\nu}$$

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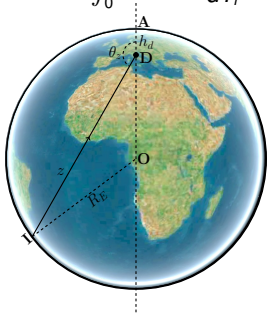
DM flux gets attenuated by the elemnts of Earth before reaching to the underground detector

$$\frac{dT_\chi^z}{dz} = -\, n_i \int_0^{T_i^{\rm max}(T_\chi^z)} \frac{d\sigma_{\chi i}}{dT_i}\, T_i\, dT_i$$

$$\frac{d\sigma_{\chi i}}{dT_i} = \frac{\sigma_{\chi i}}{T_i^{\rm max}}$$



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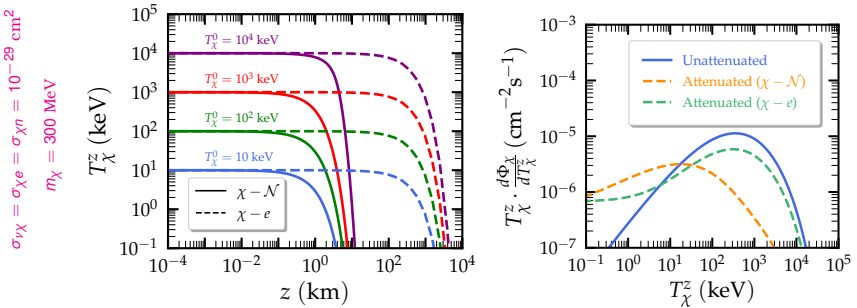

Implications of Nuclear Form Factor

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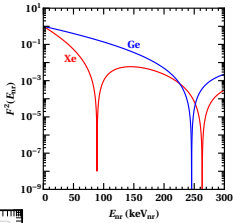
The spin independent DM-nuclei scattering cross section can be written as,

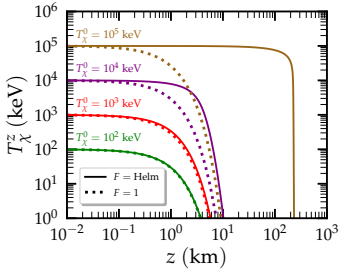
$$\sigma^{\rm SI}_{\chi\mathcal{N}}(q^2) = \frac{\mu^2_{\chi\mathcal{N}}}{\mu^2_{\chi n}} A^2 \sigma_{\chi n} F^2(q^2)$$

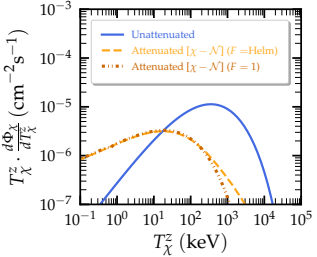


(Helm, 1956)

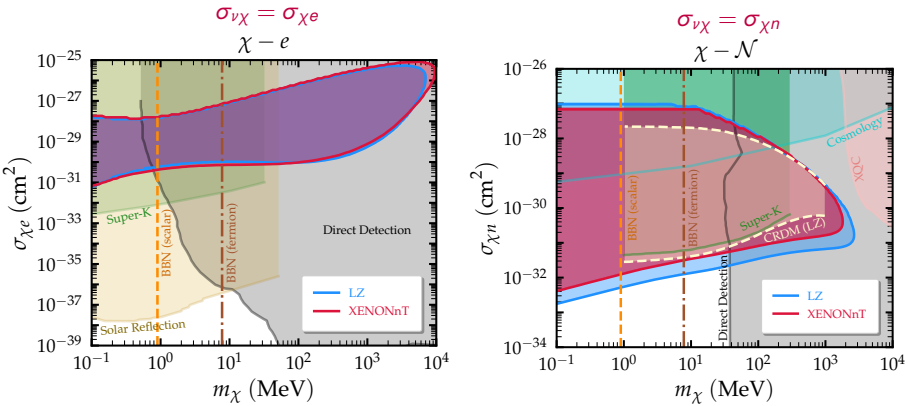
$\sigma_{\nu\chi} = \sigma_{\chi e} = \sigma_{\chi n} = 10^{-29}$ cm^2

$m_\chi = 300$ MeV





Resulting Limits



A. Majumdar et al., arXiv: 2309.04117

Conclusions

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- ☞ DSNB Boosted DM produces a subdominant, semi-relativistic component of Galactic DM.

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- ***Although a significant part of our constraints lie in a region of parameter space already probed by other searches, these results highlight the complementarity and significance of the LZ and XENONnT data in probing the sub-GeV DM parameter space.***

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THANK YOU

Extras

Simulations of events

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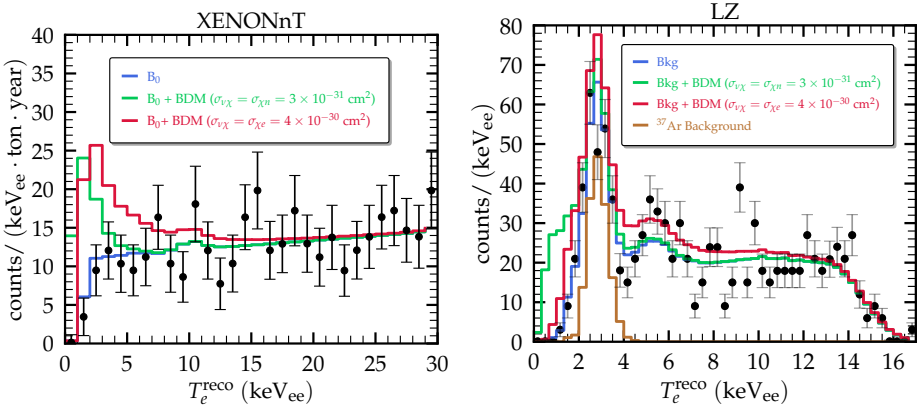
$m_\chi = 300$ MeV



Effect of Earth attenuation in the resulting limits