# Boosted dark matter driven by cosmic rays and diffuse supernova neutrinos

by
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at
Dark Matter and Stars
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Based on: Phys. Rev. D **111**, 063019 (arXiv:2411.11973)

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    - Annihilation/decay of heavy DM into lighter, fast-moving DM (classic "boosted DM")
    - Scattering off energetic SM particles like cosmic source (our case: “upscattered DM”)
- Though distinct, “upscattered DM” is often grouped under “boosted DM” and thus, we too jumped on the same bandwagon.

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Typical velocity: $v \sim 10^{-3}c \quad \Rightarrow \quad K \sim \frac{1}{2}mv^2 \sim m \times 10^{-6} \quad \Rightarrow \quad K \sim 1\,\text{keV}$

Credits: https://skyandtelescope.org/
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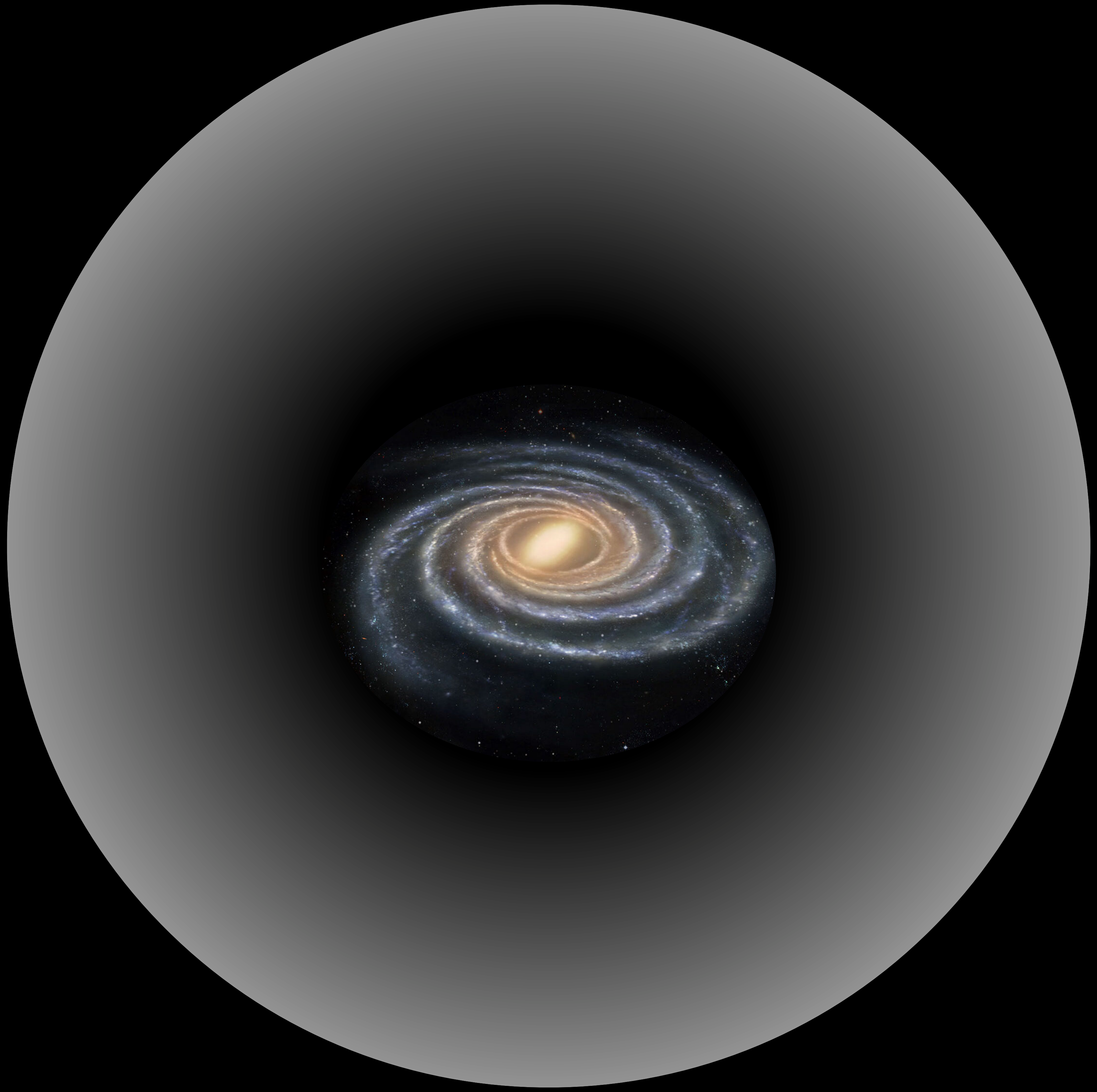
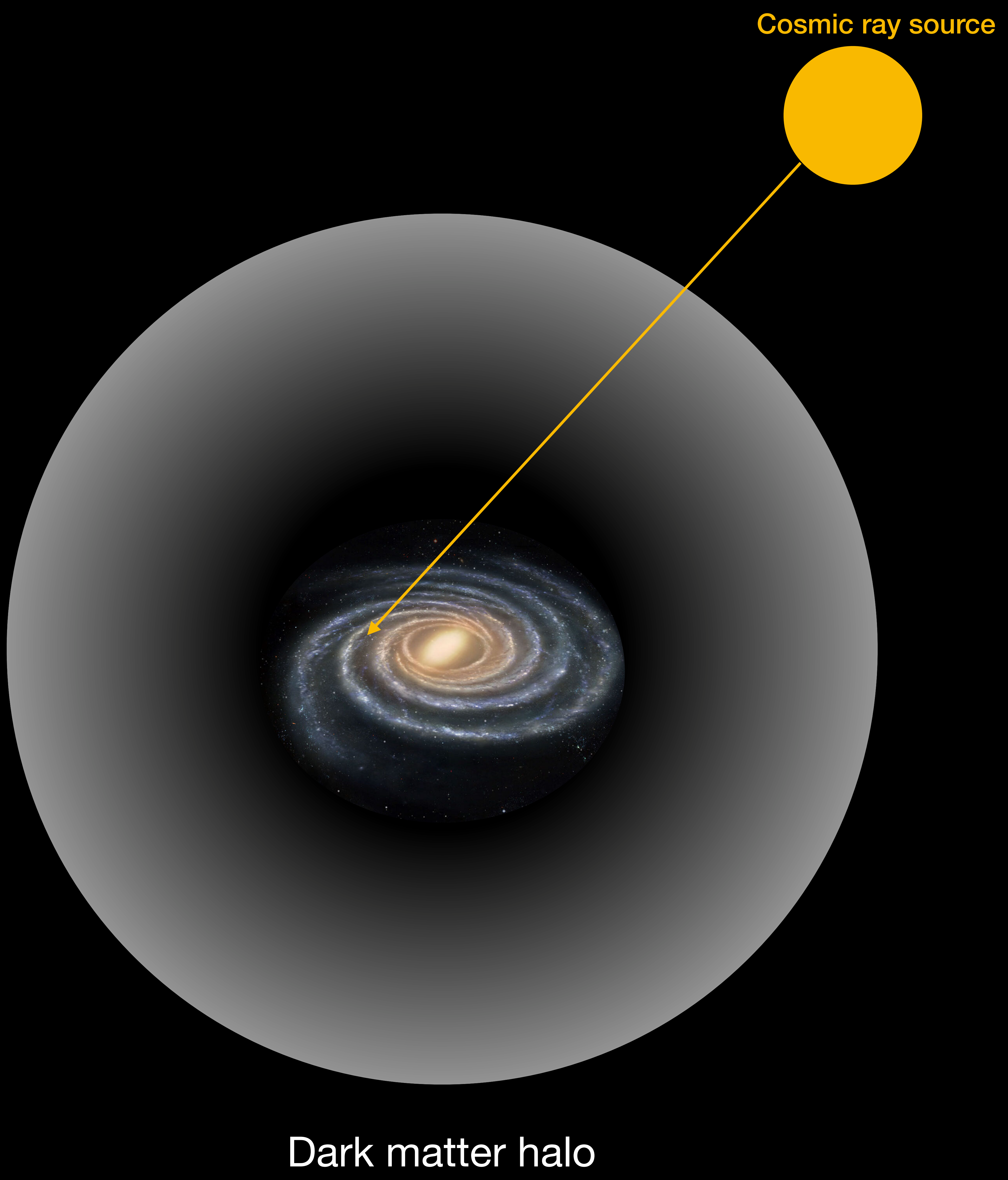


Dark matter halo

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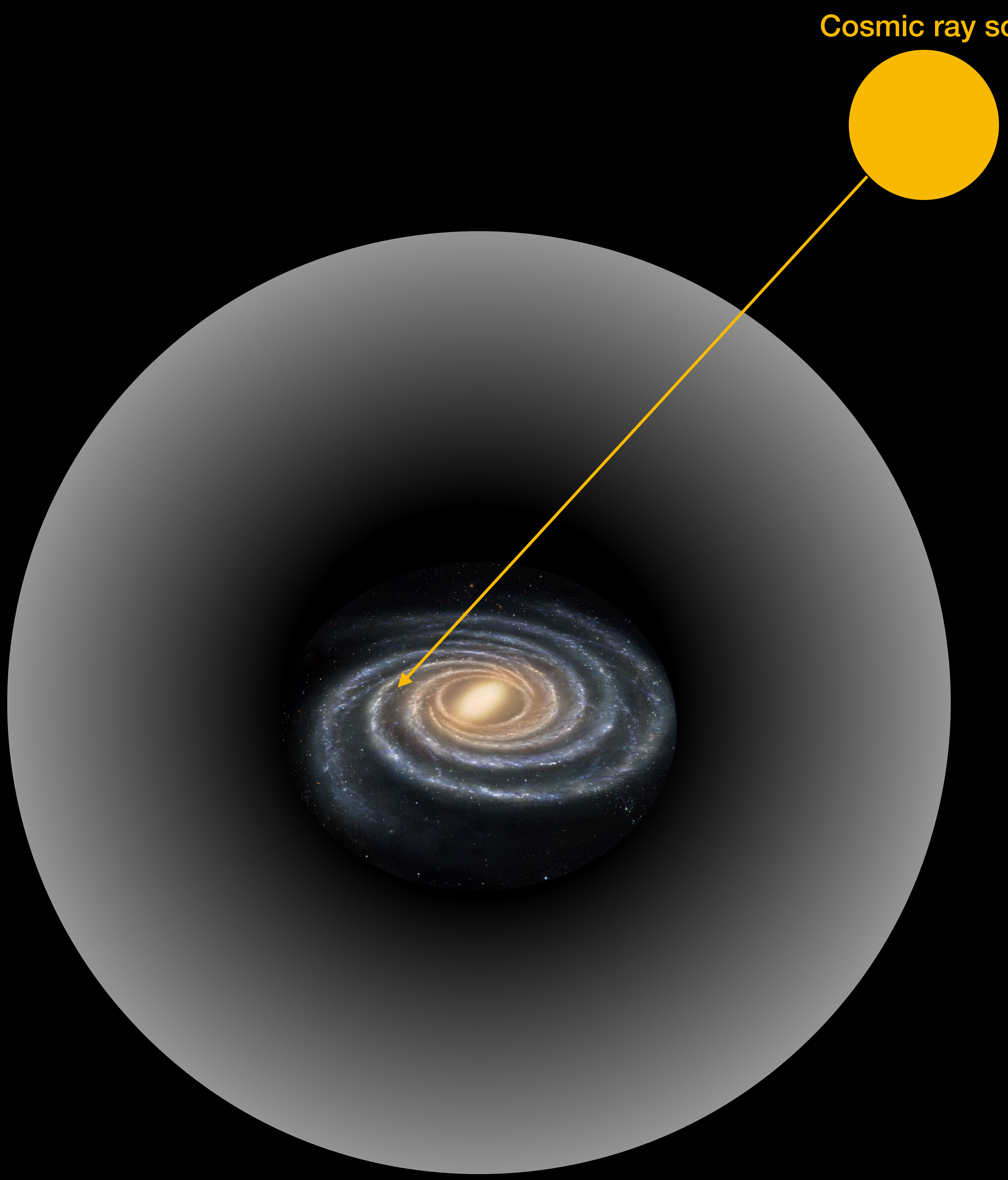


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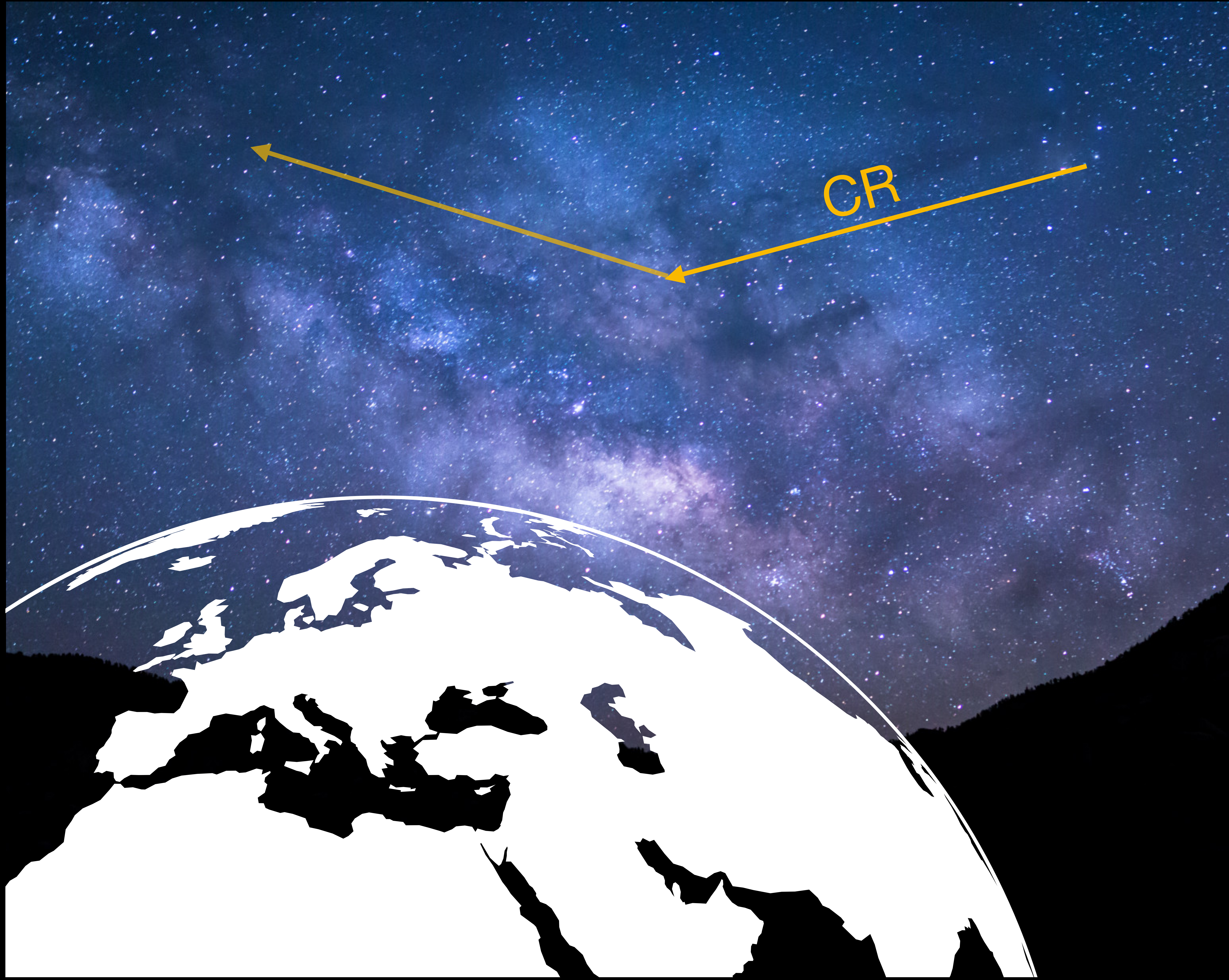


Formation of Cosmic ray up-scattered DM

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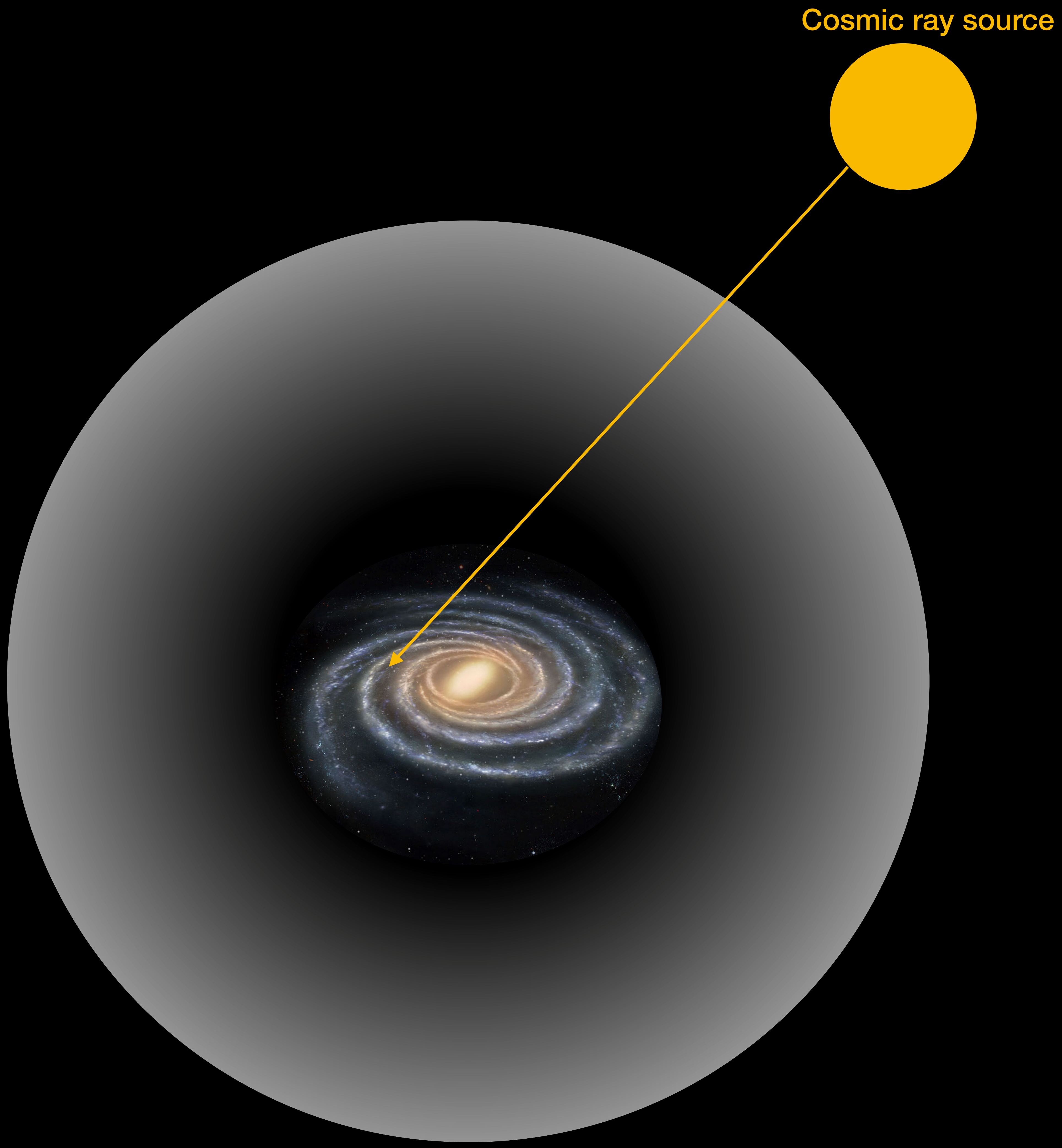


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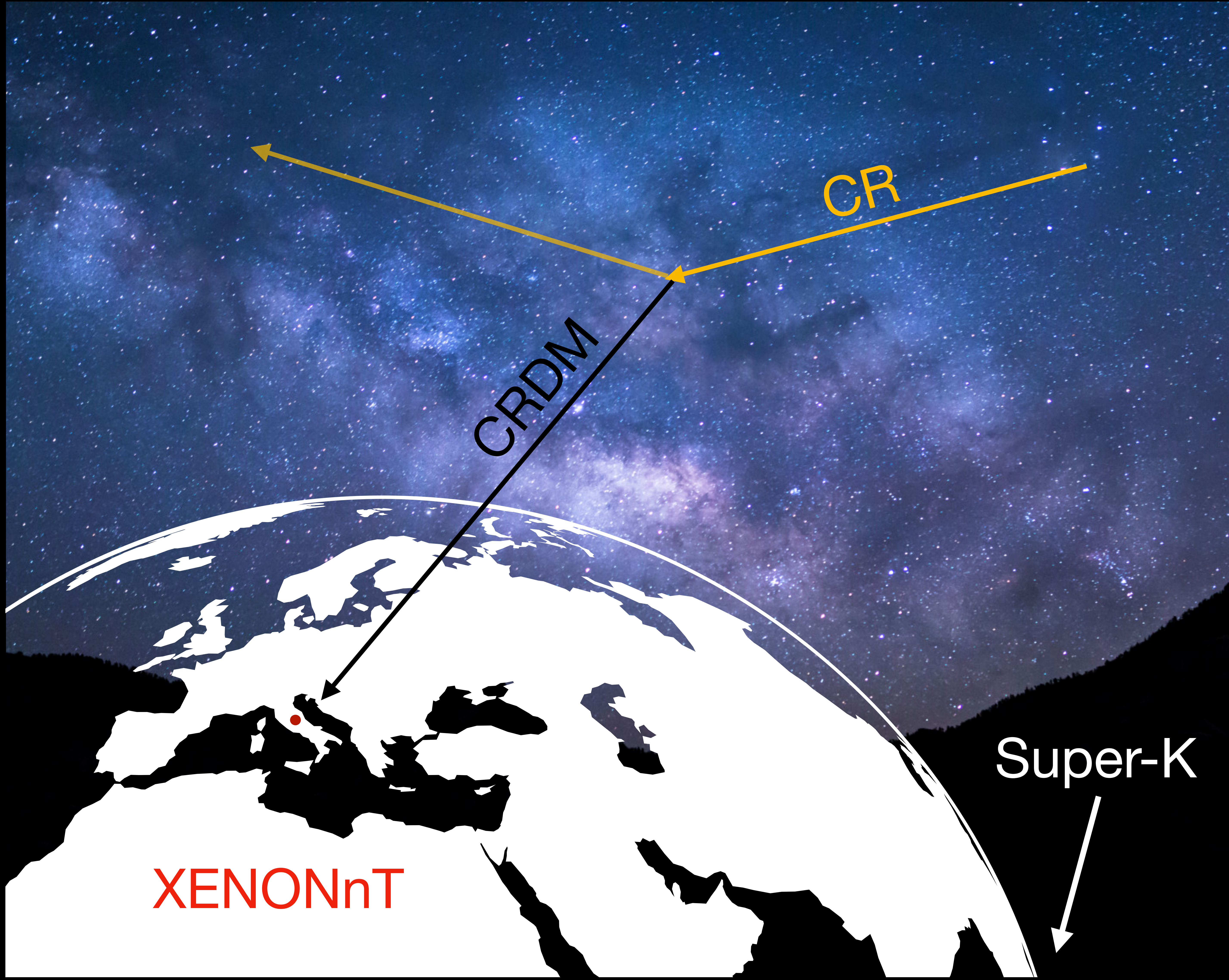


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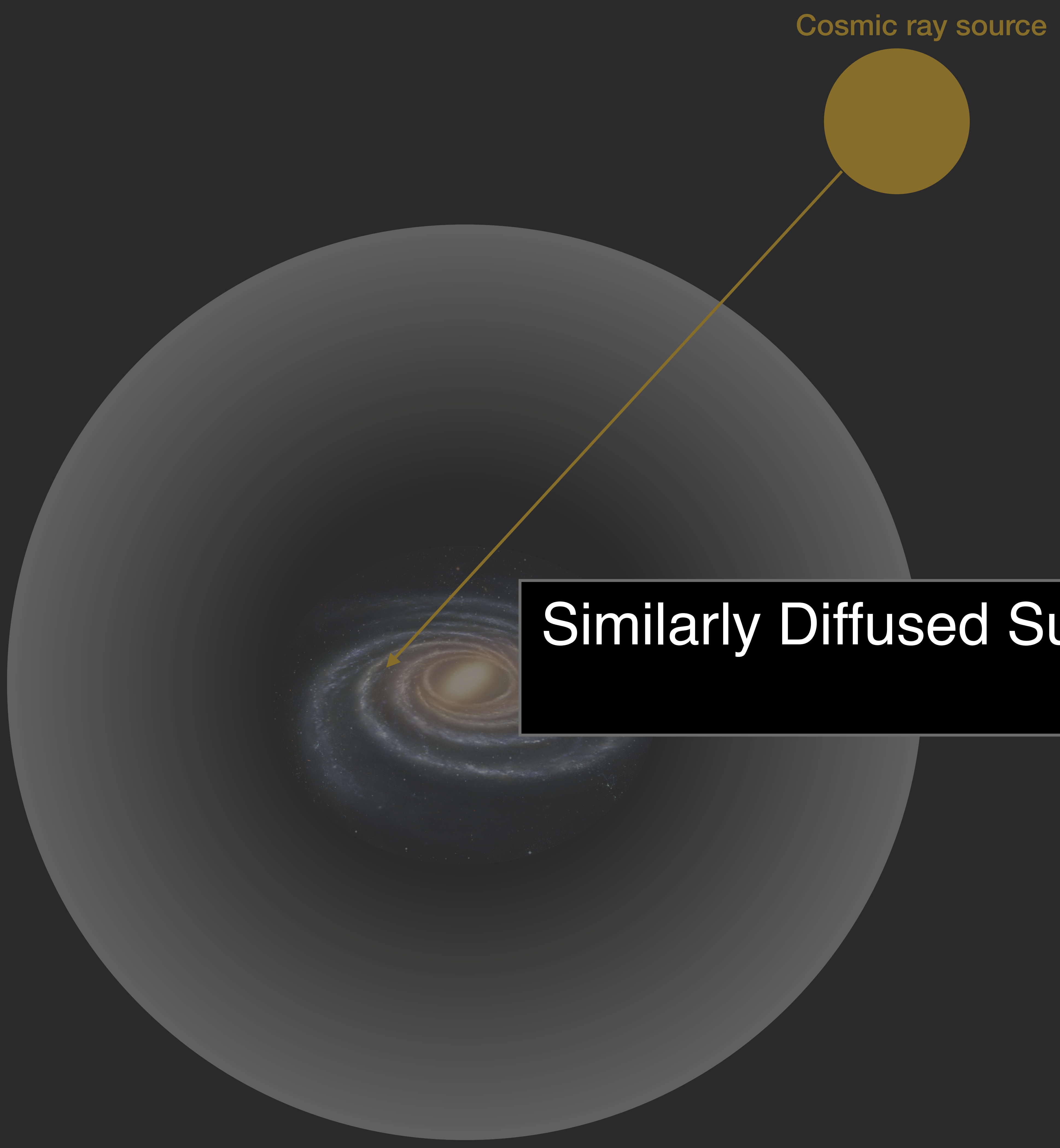
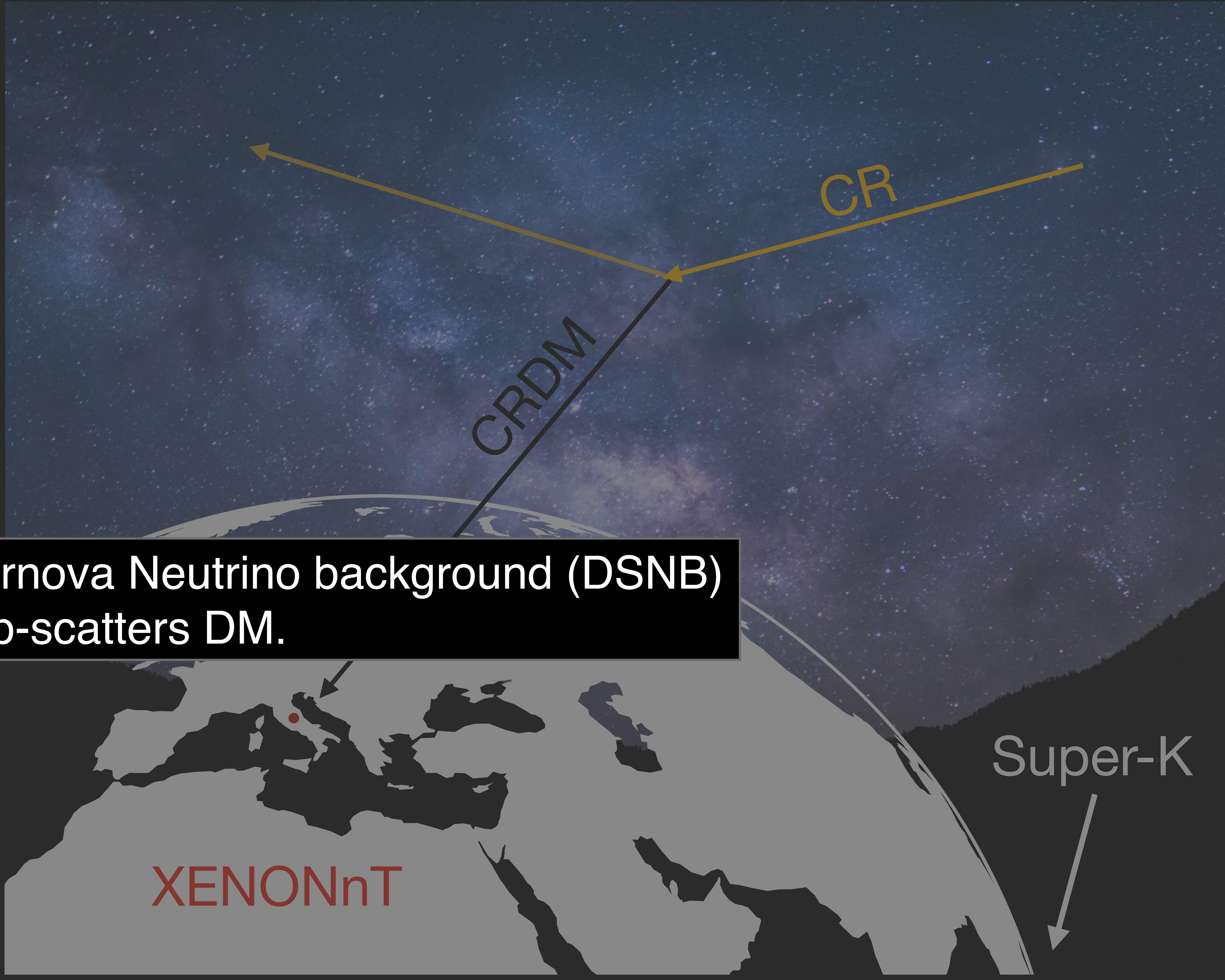



Dark matter halo

Similarly Diffused Supernova Neutrino background (DSNB) up-scatters DM.




Formation of Cosmic ray up-scattered DM

# Boosted Dark Matter Flux

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- Model independent approach
- We consider cases where the cross-section is constant and energy-dependent cross-section scalar mediated and vector mediated

# CR - Boosted Dark Matter

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$$\frac{d\Phi_\chi}{dT_\chi} = D_{\text{eff}} \frac{\rho_\chi}{M_\chi} \int_{T_i^{\min}(T_\chi)}^{\infty} \frac{d\Phi_i^{\text{LIS}}}{dT_i} \frac{d\sigma_{\chi i}}{dT_\chi} dT_i$$

where,

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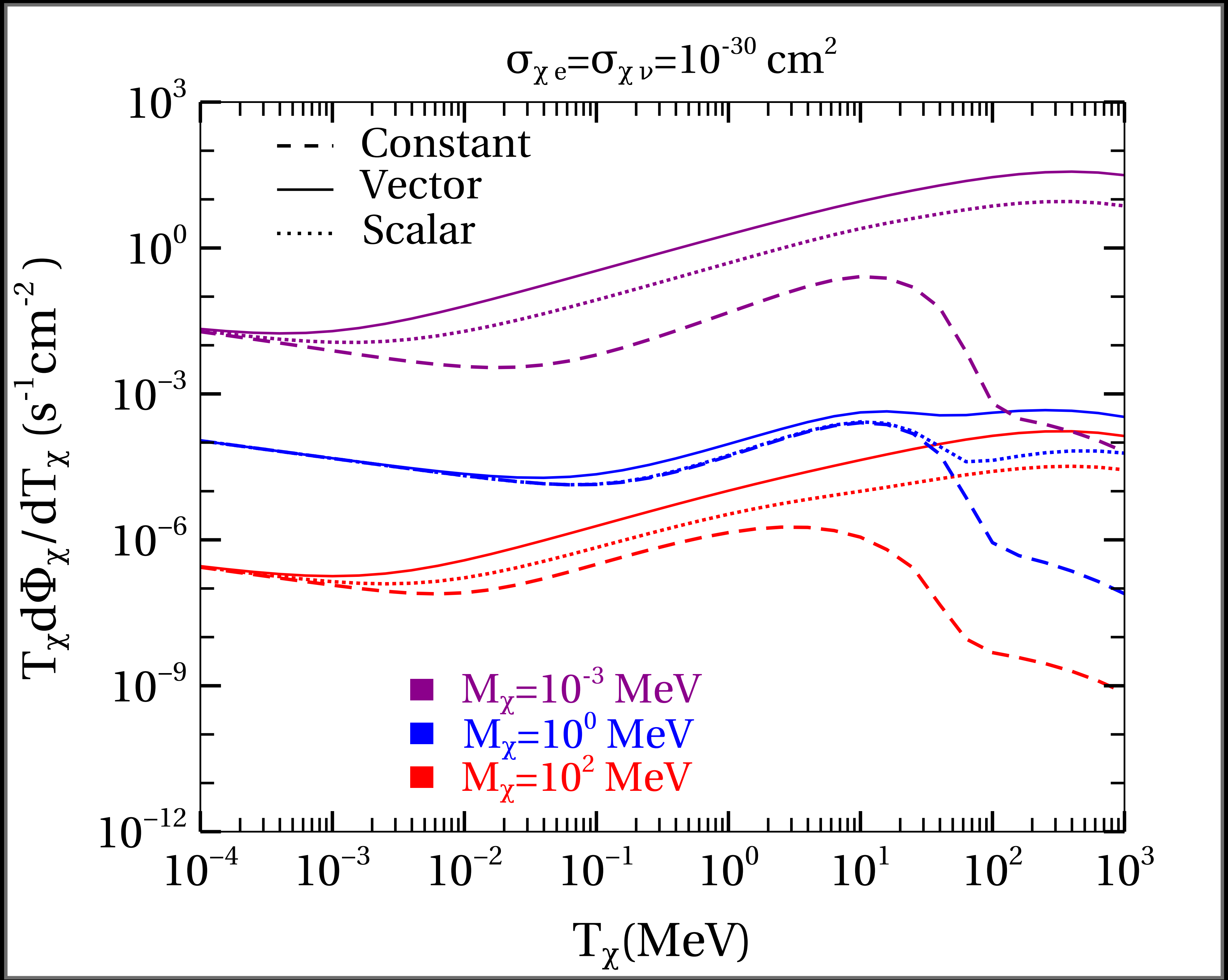


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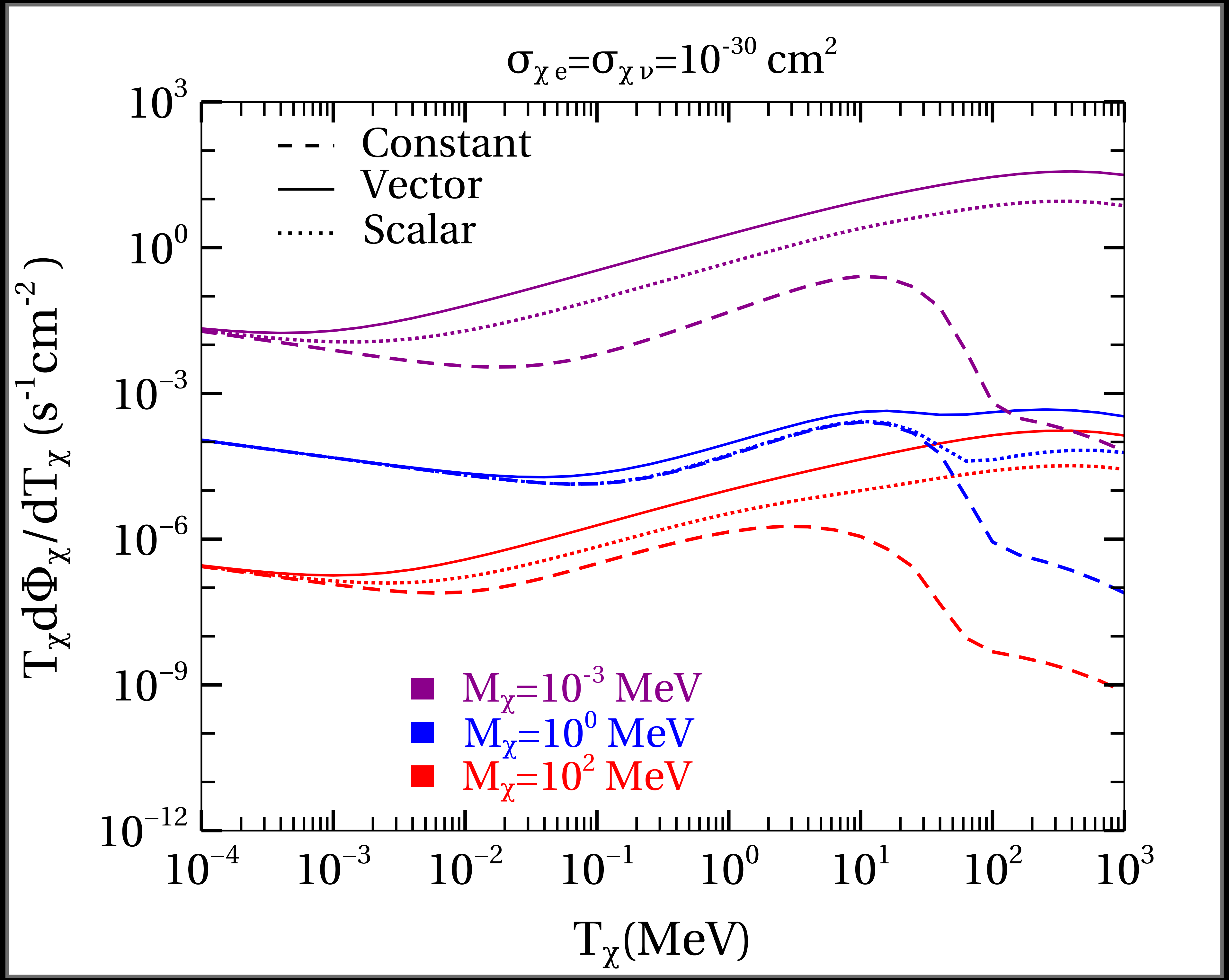


CRe + Neutrinos
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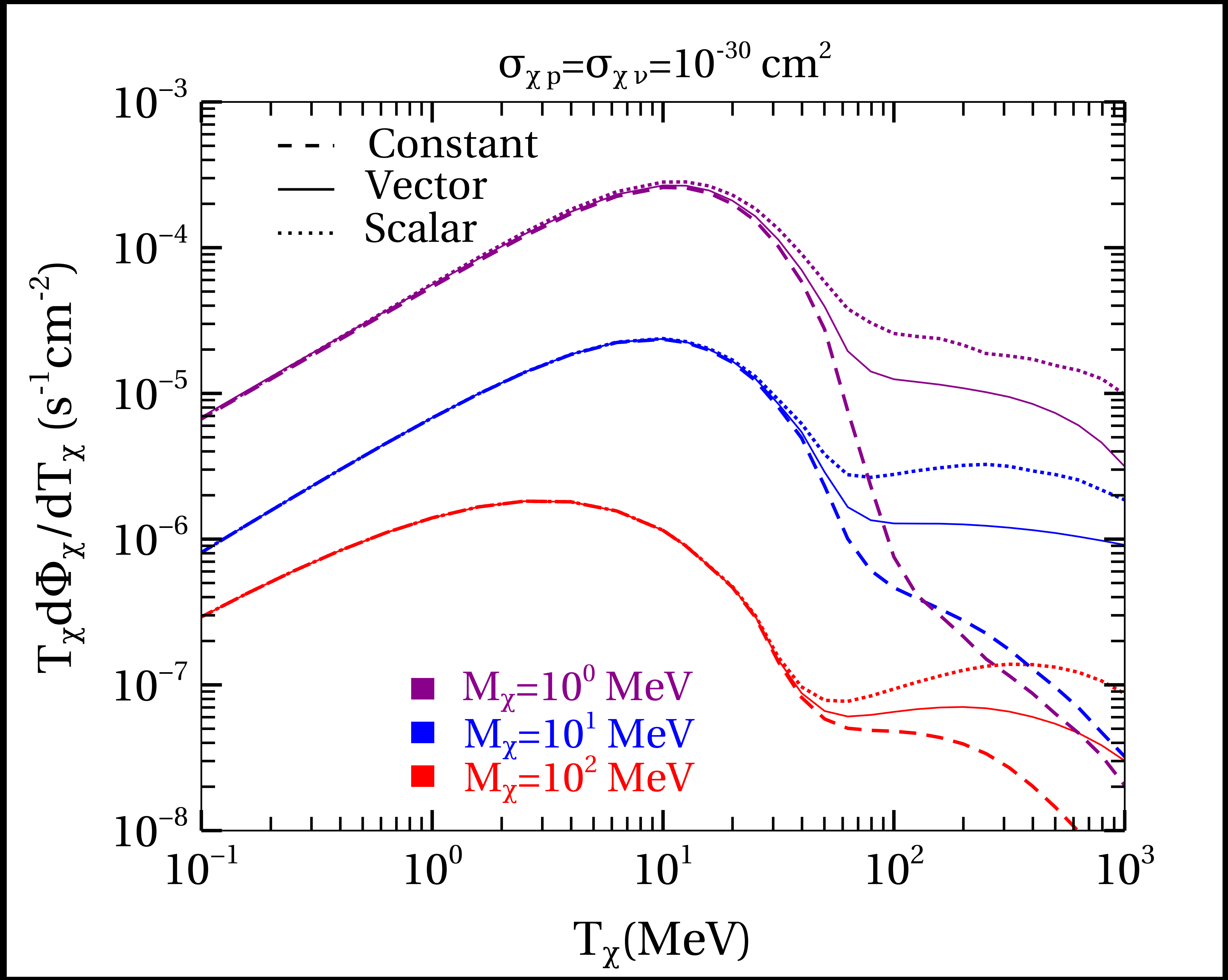


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DM number density

CR flux

Differential cross-section

where,

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# Boosted Dark Matter in Detectors

$$\frac{dR}{dE_R} = t_{\text{exp}} \mathscr{E}(E_R) N_{\text{T}} \int_{T_\chi^{\text{min}}(E_R)}^{\infty} \frac{d\Phi_\chi^{\text{tot}}}{dT_\chi} \frac{d\sigma_{\chi i}}{dE_R} dT_\chi$$

Number of target nuclei

Boosted DM flux

Differential cross-section

where,

$$T_\chi^{\text{min}}(E_R) = \left(\frac{E_R}{2} - M_\chi\right)\left[1 \pm \sqrt{1 + \frac{2E_R(m_i + M_\chi)^2}{m_i(2M_\chi - E_R)^2}}\right]$$

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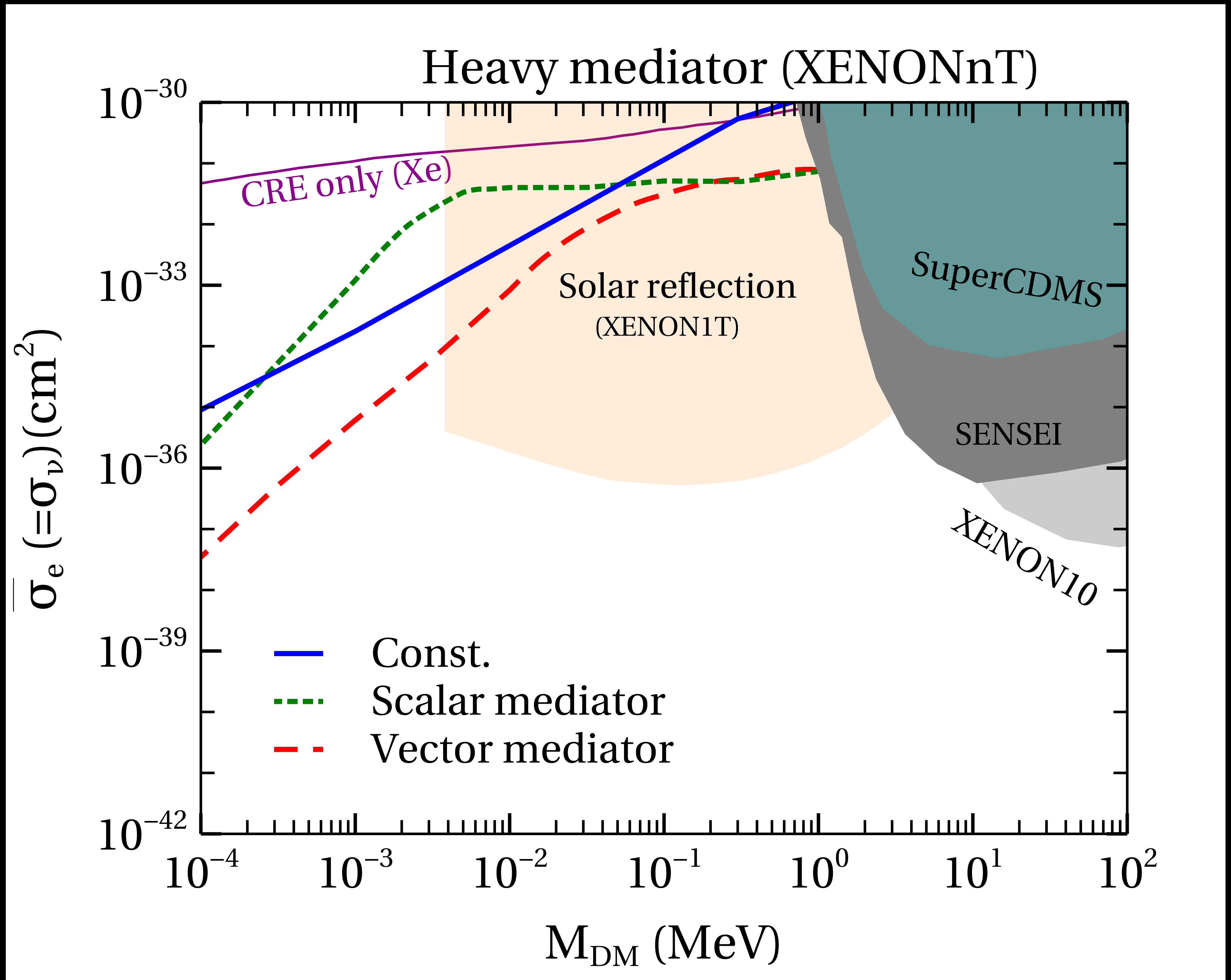
- For nucleon recoil rate, we express it in terms of electron equivalent energy as

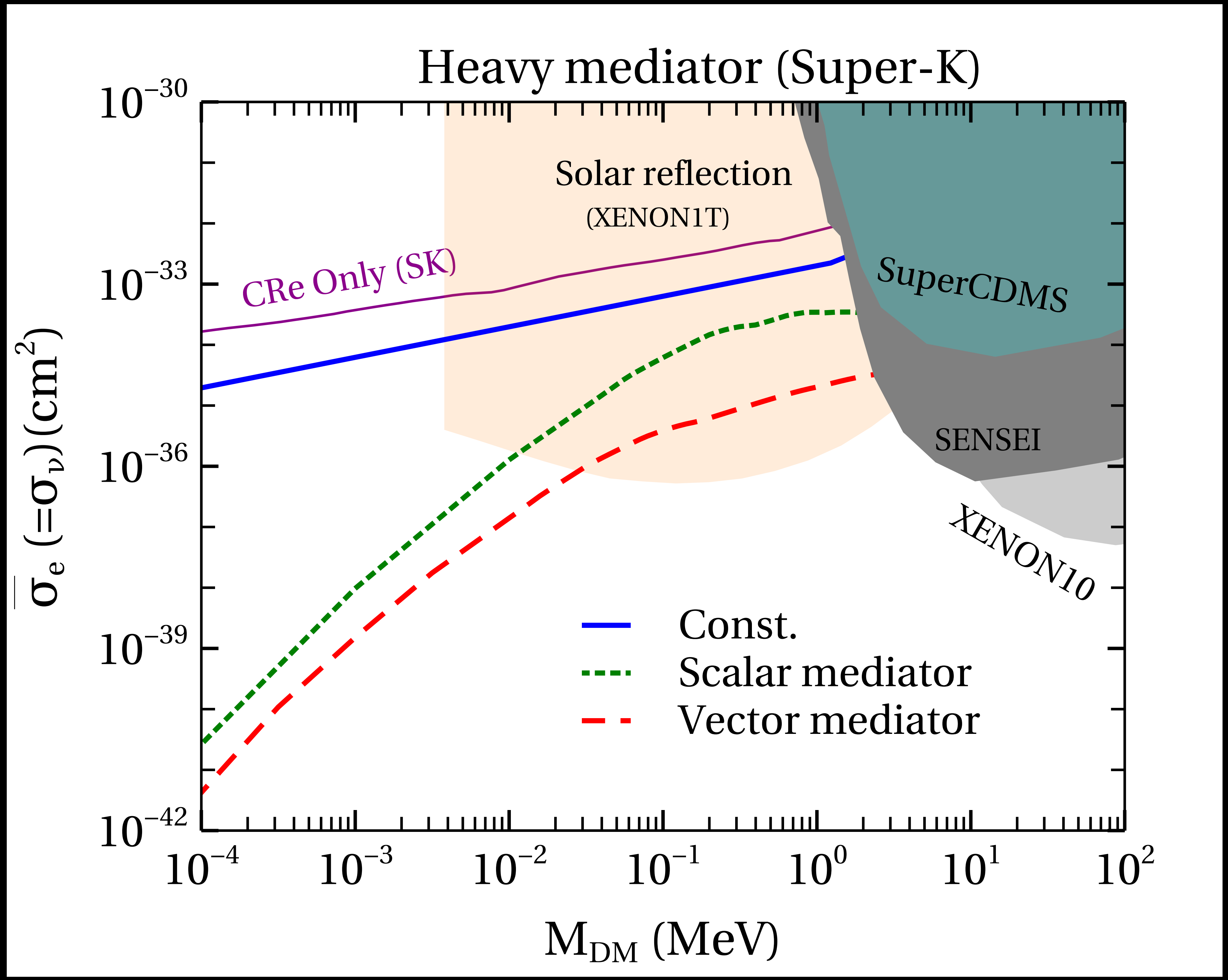
$$E_R = \mathcal{Q}(E_N)E_N$$

Lindhard quenching factor

# Constraint in CRe + Neutrinos (Electrophilic) case

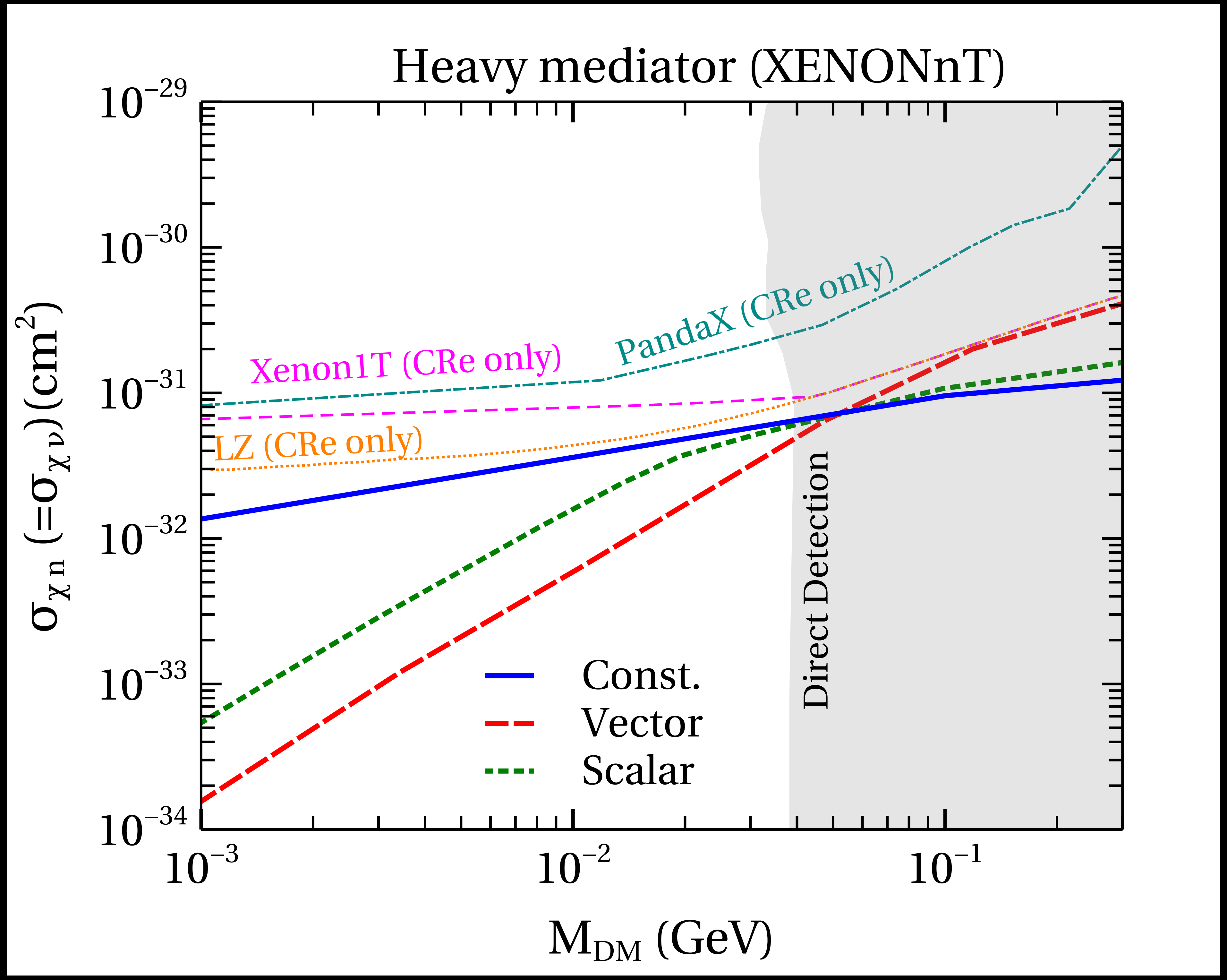



XENONnT




Super-Kamiokande

# Constraint in CRp + Neutrinos (Nucleophilic) case

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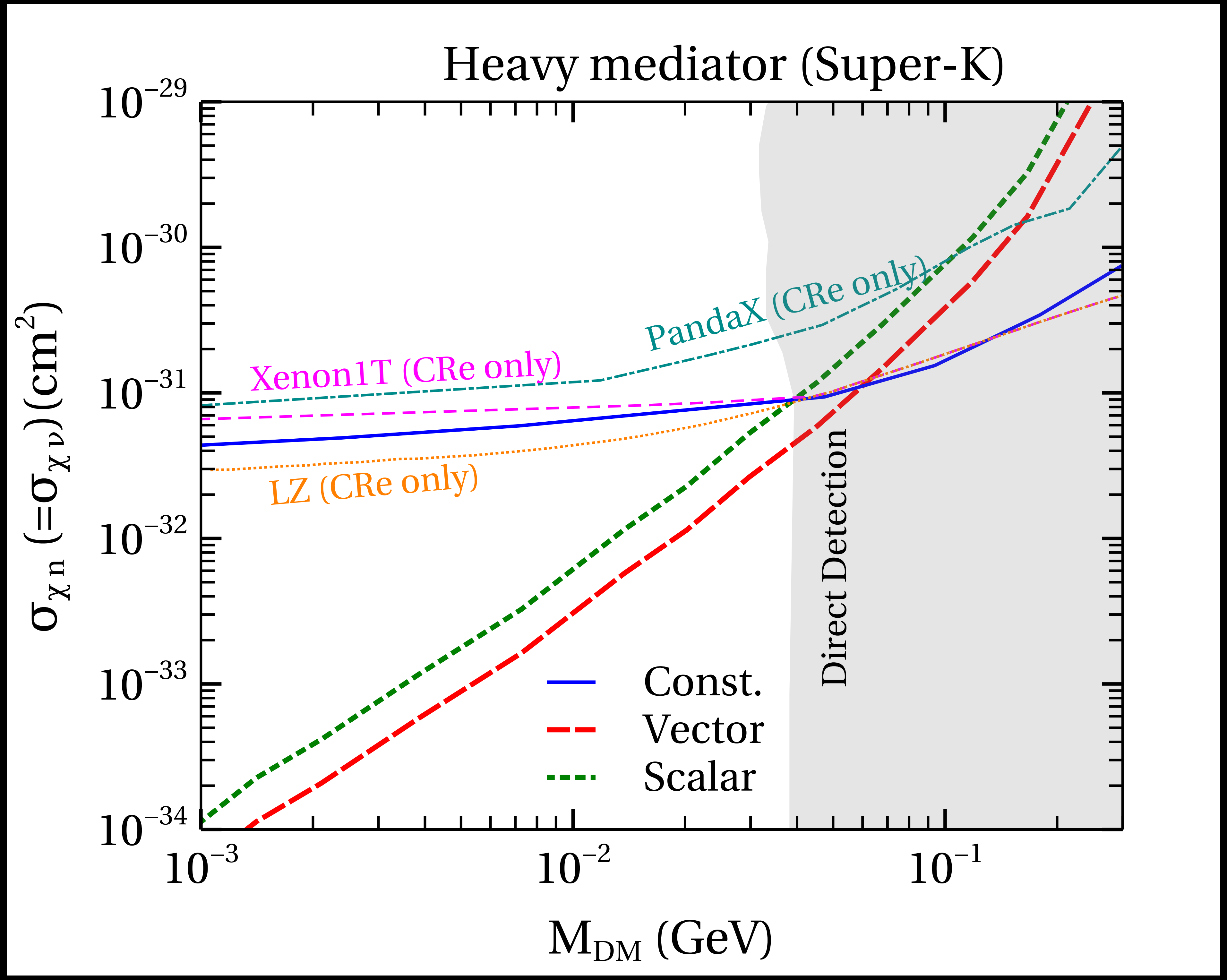



Super-Kamiokande

# References

[1] T. Bringmann and M. Pospelov, “Novel direct detection constraints on light dark matter,” Phys. Rev. Lett. 122 no. 17, (2019) 171801, arXiv:1810.10543 [hep-ph].

[2] V. De Romeri, A. Majumdar, D. K. Papoulias, and R. Srivastava, “XENONnT and LUX-ZEPLIN constraints on DSNB-boosted dark matter,” JCAP 03 (2024) 028, arXiv:2309.04117 [hep-ph].

[3] D. Bardhan, S. Bhowmick, D. Ghosh, A. Guha, and D. Sachdeva, “Bounds on boosted dark matter from direct detection: The role of energy-dependent cross sections,” Phys. Rev. D107 no. 1, (2023) 015010, arXiv:2208.09405 [hep-ph].


Thank you!

Backup 1

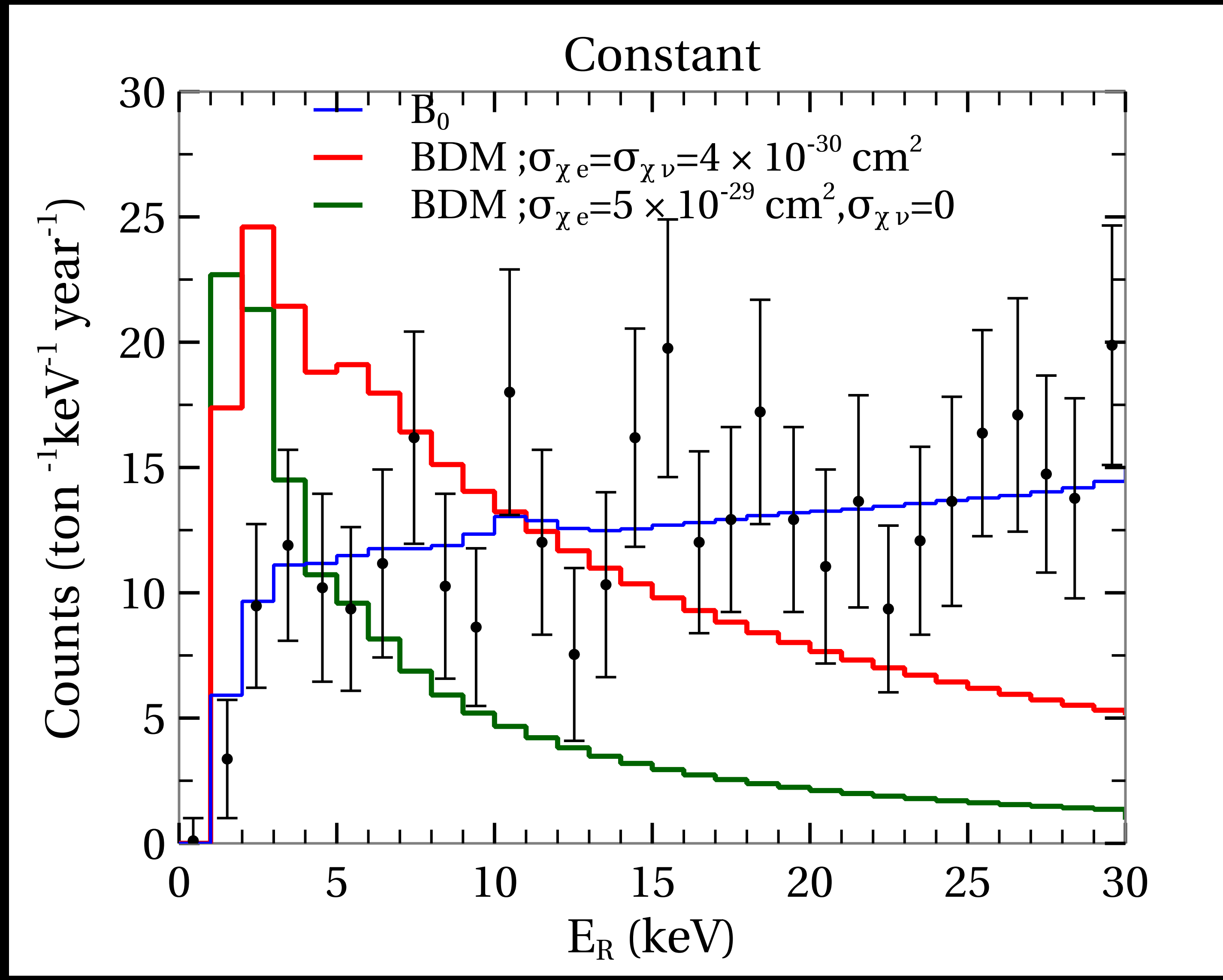
$$\frac{dR}{dE_N} = t_{\exp}\mathscr{E}(E_N)N_{\mathrm{T}}\int_{T_\chi^{\min}(E_N)}^{\infty}\frac{d\Phi_\chi^{\mathrm{tot}}}{dT_\chi}\frac{d\sigma_{\chi i}}{dE_N}dT_\chi$$

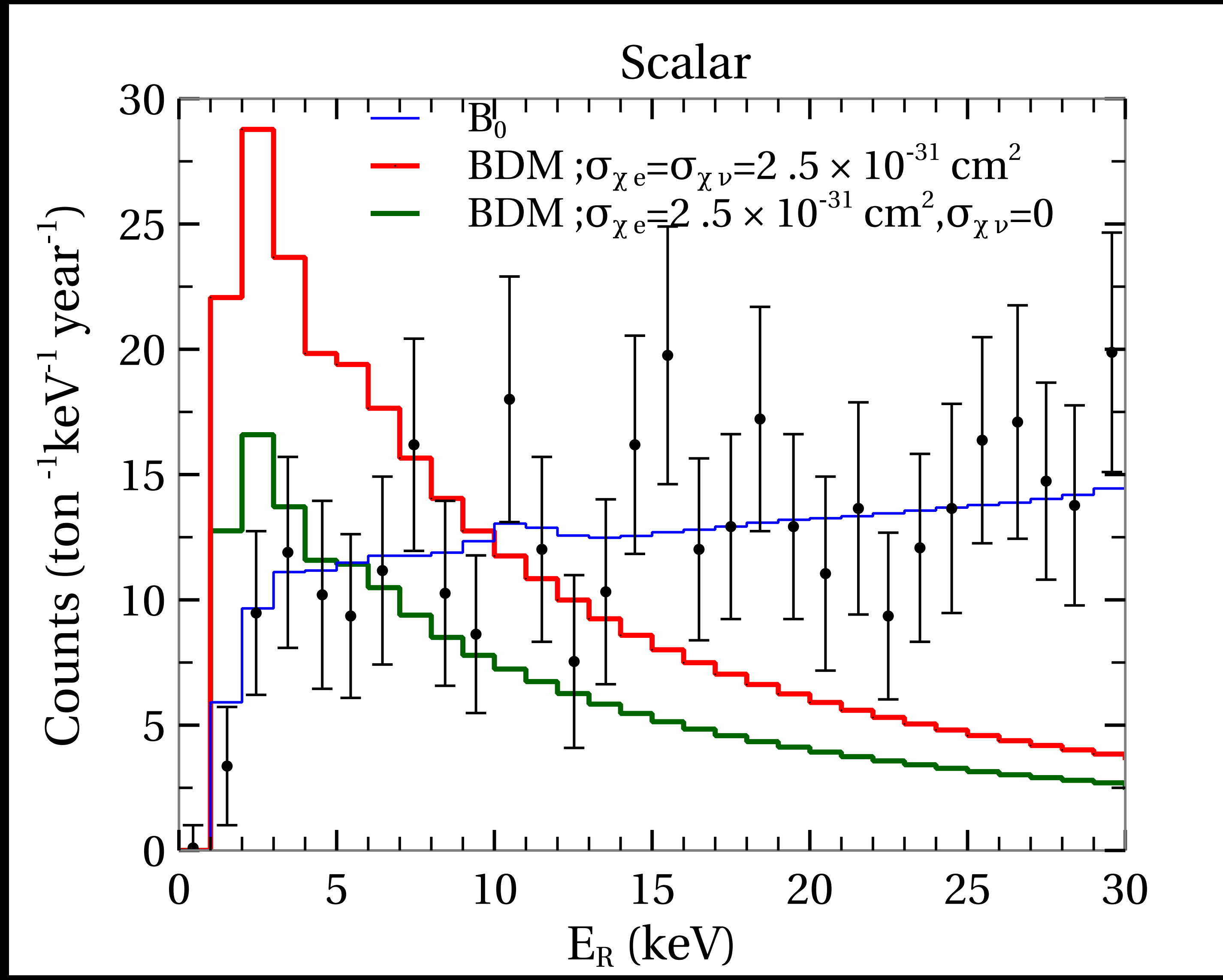
$$\frac{dR}{dE_R} = \frac{dR}{dE_N}\frac{1}{Q(E_N) + E_N\frac{dQ}{dE_N}}$$

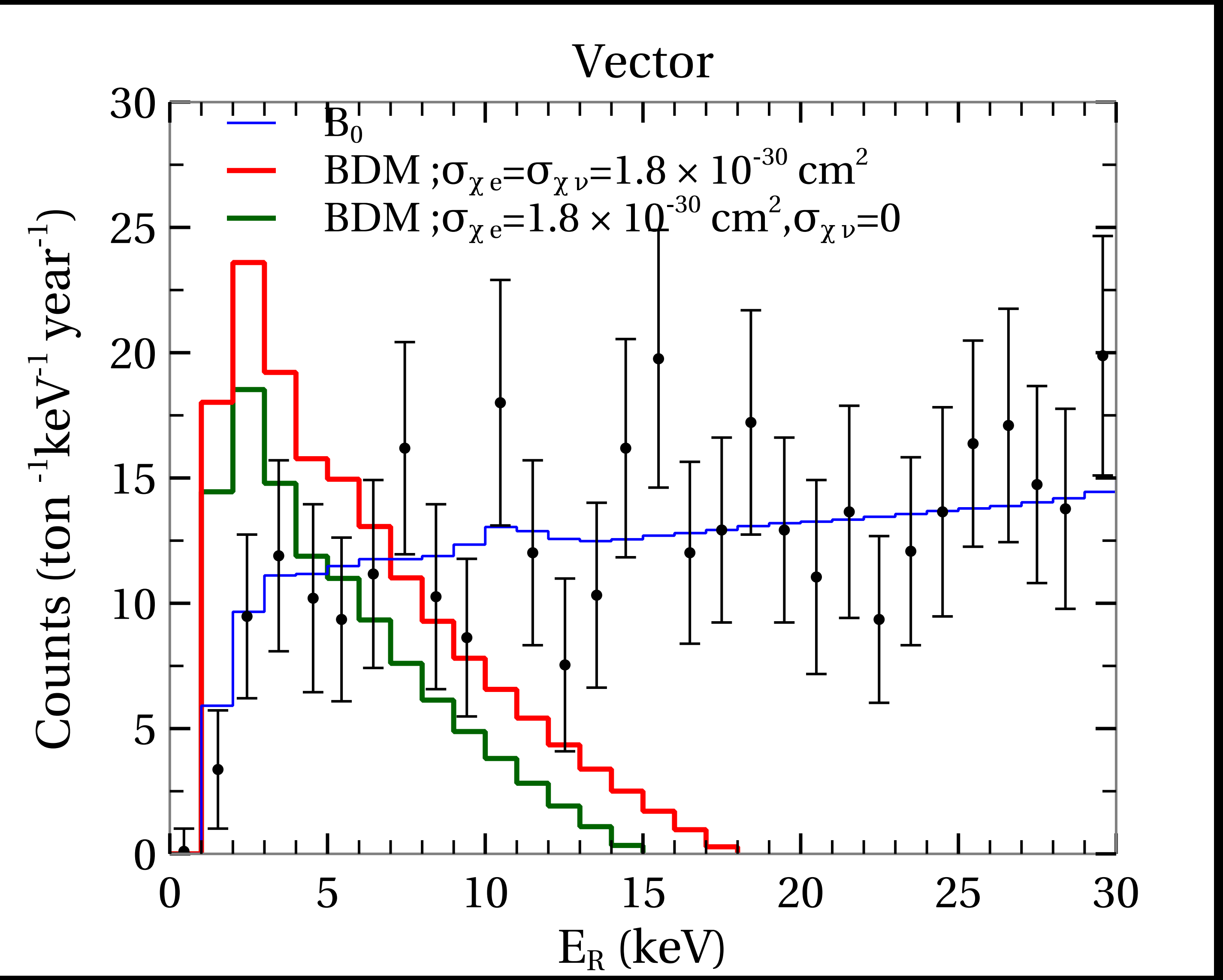
$$R \propto \Phi_{CRe}\sigma_{\chi e}^2 + \Phi_{DSNB}\sigma_{\chi e}\sigma_{\chi\nu}$$

$$Q(E_N) = \frac{k(1 + 3\epsilon^{0.15} + 0.7\epsilon^{0.6} + \epsilon)}{1 + k(1 + 3\epsilon^{0.15} + 0.7\epsilon^{0.6} + \epsilon)}, \quad \epsilon = 11.5Z^{-7/3}(E_N/\mathrm{KeV}), \quad k = 0.145$$

# Backup 2

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