Boosting Asymmetric Charged DM via Thermalization

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Tel-Aviv University

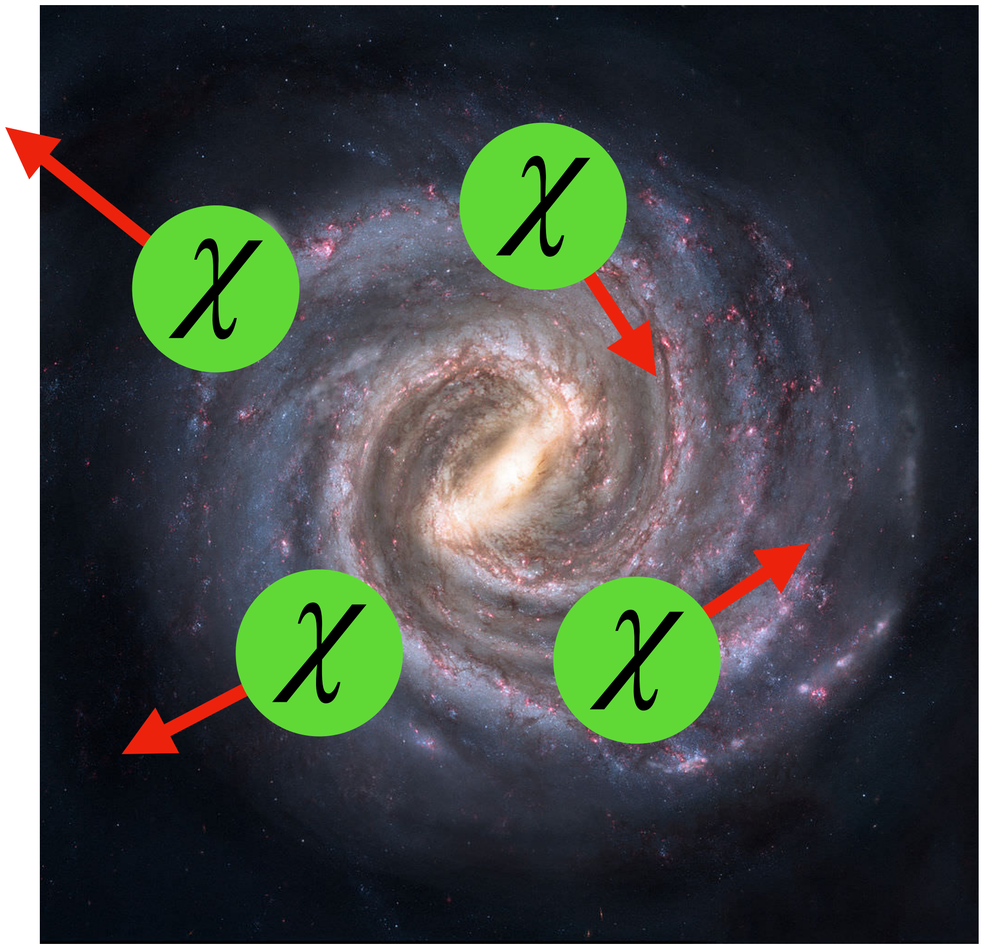
with Michael Geller (TAU)

[2210.03126]

CERN New Physics from Galaxy Clustering, 21/11/2022

Motivation

The DM velocity distribution — taken as a truncated Maxwellian distribution, with DM escape velocity $v_{\rm esc} \sim 10^{-3} c$



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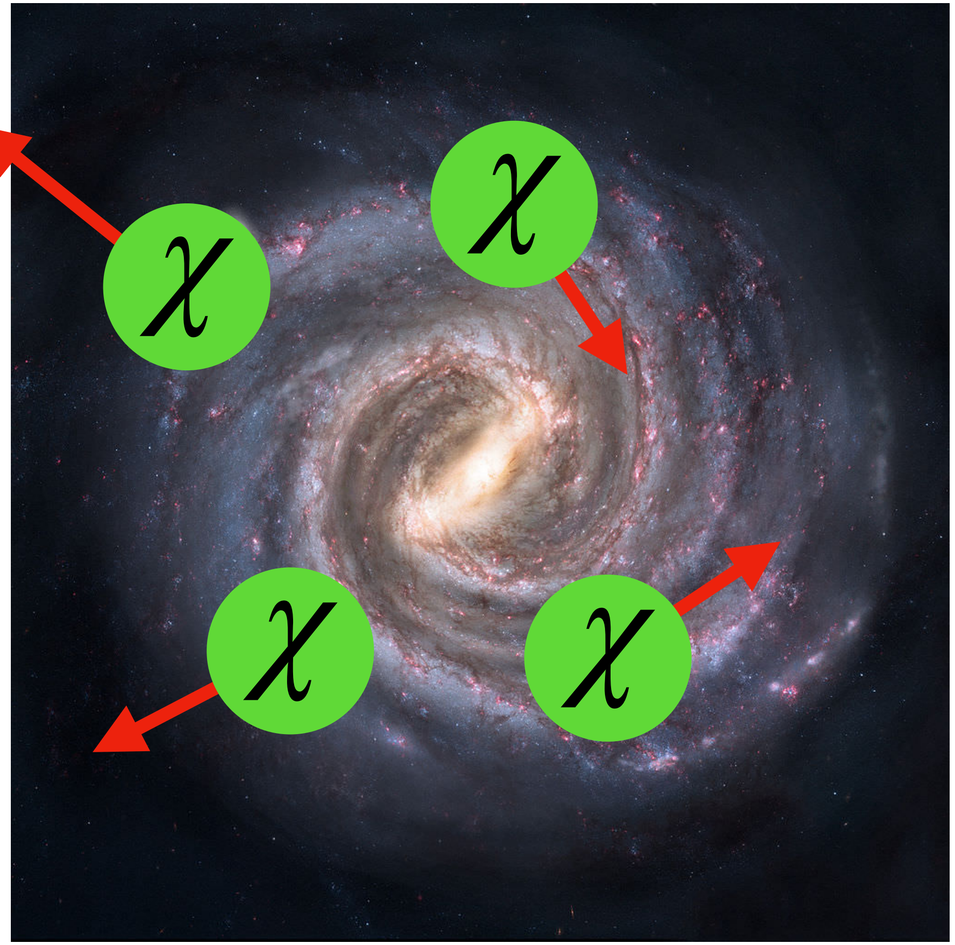
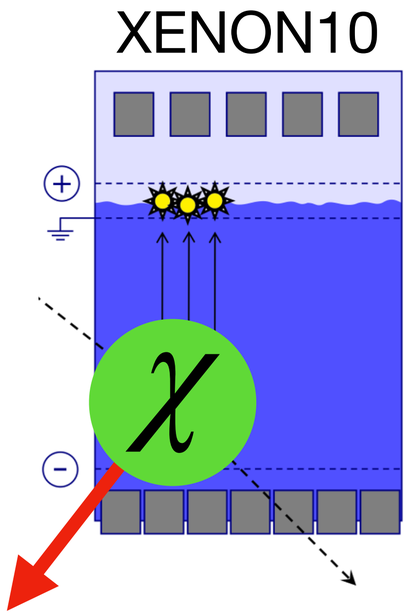
The DM velocity distribution — taken as a truncated Maxwellian distribution, with DM escape velocity $v_{\rm esc} \sim 10^{-3}c$

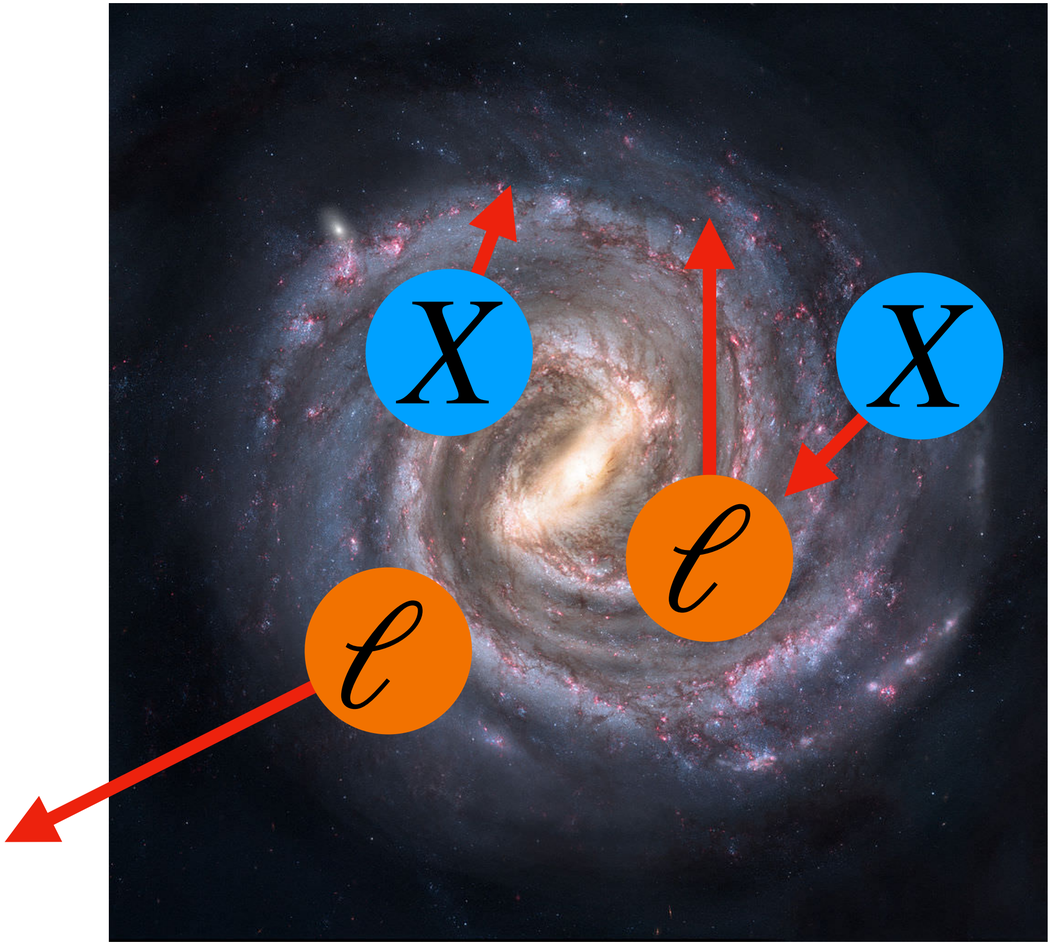
Direct-detection experiments are limited by the $v_{\rm esc}$, preventing lighter DM to pass the detection threshold. **Lighter DM masses are difficult to probe!**





Our Idea

$U(1)_D$ Dark Sector



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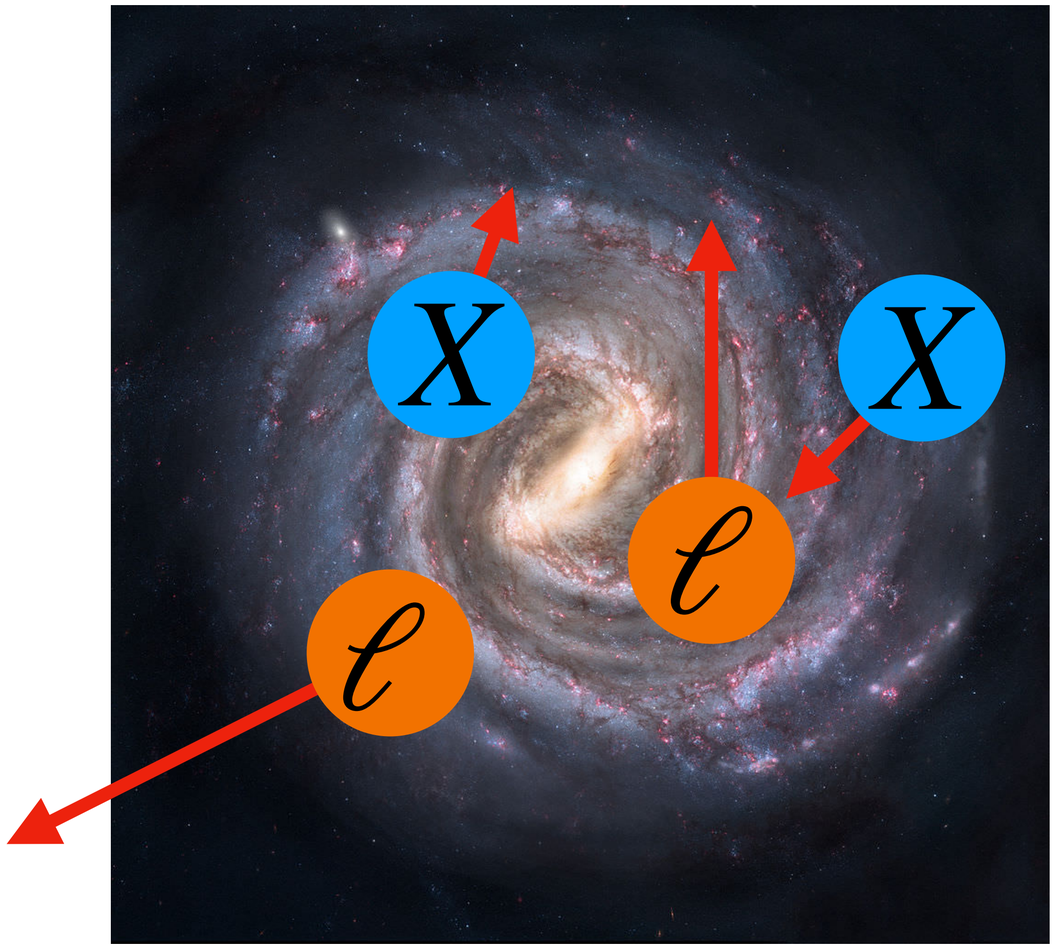
heavy $q' = +1$ X

ℓ light $q' = -1$



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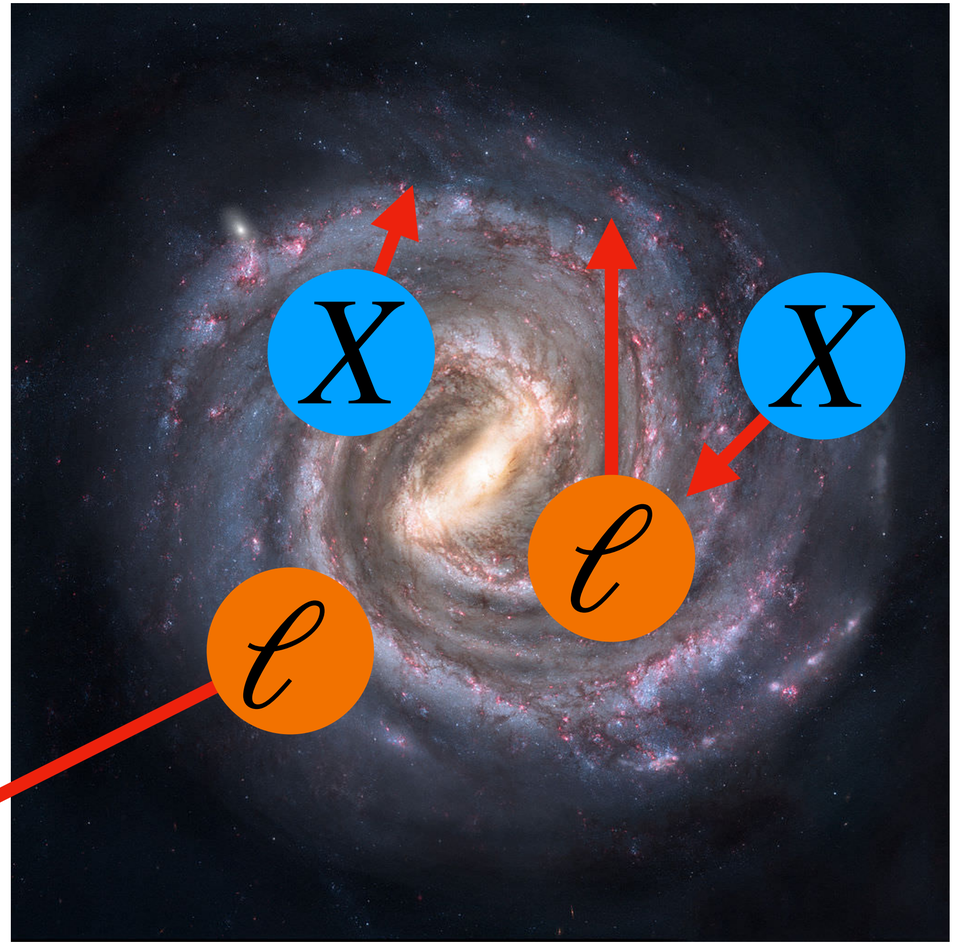
thermalization $m_X \gg m_\ell$

boosted ℓ



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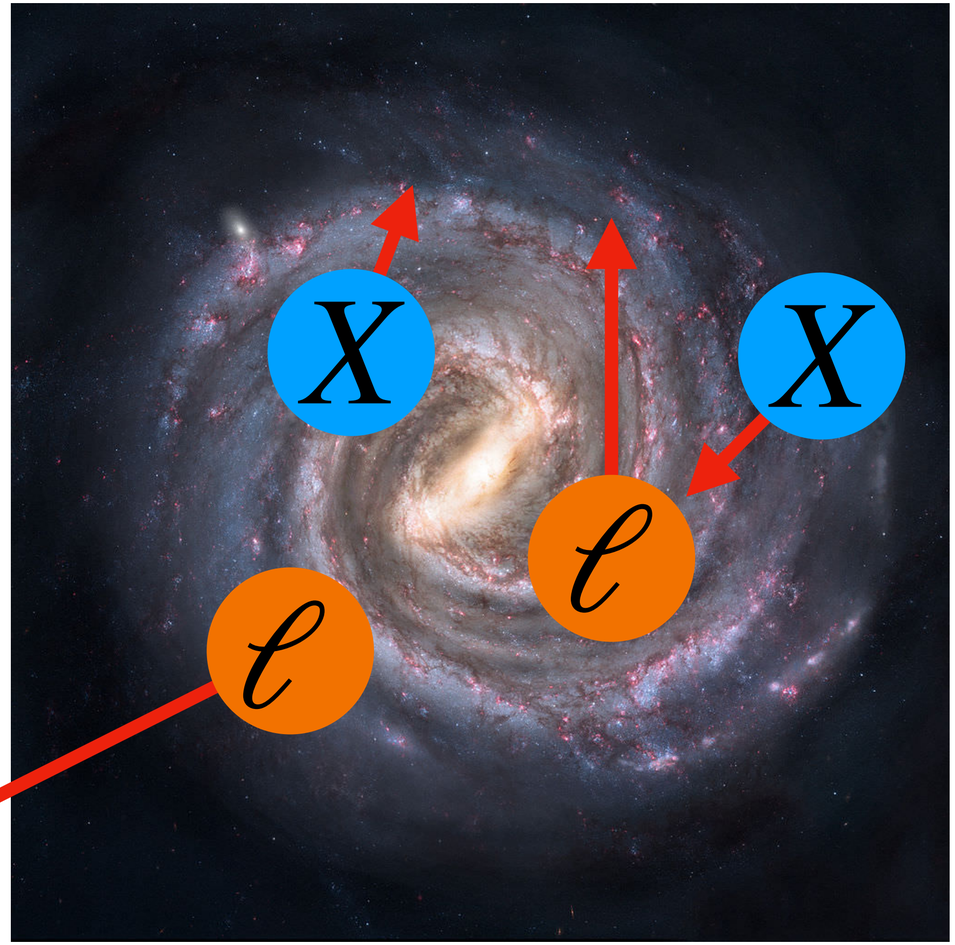
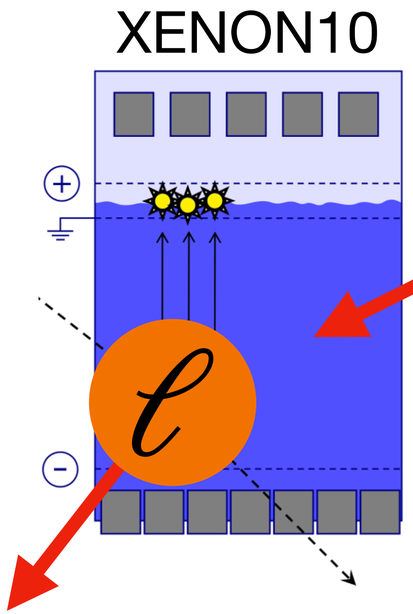
boosted $\ell \Longrightarrow$ **detectable at low DM masses (sub-MeV)**

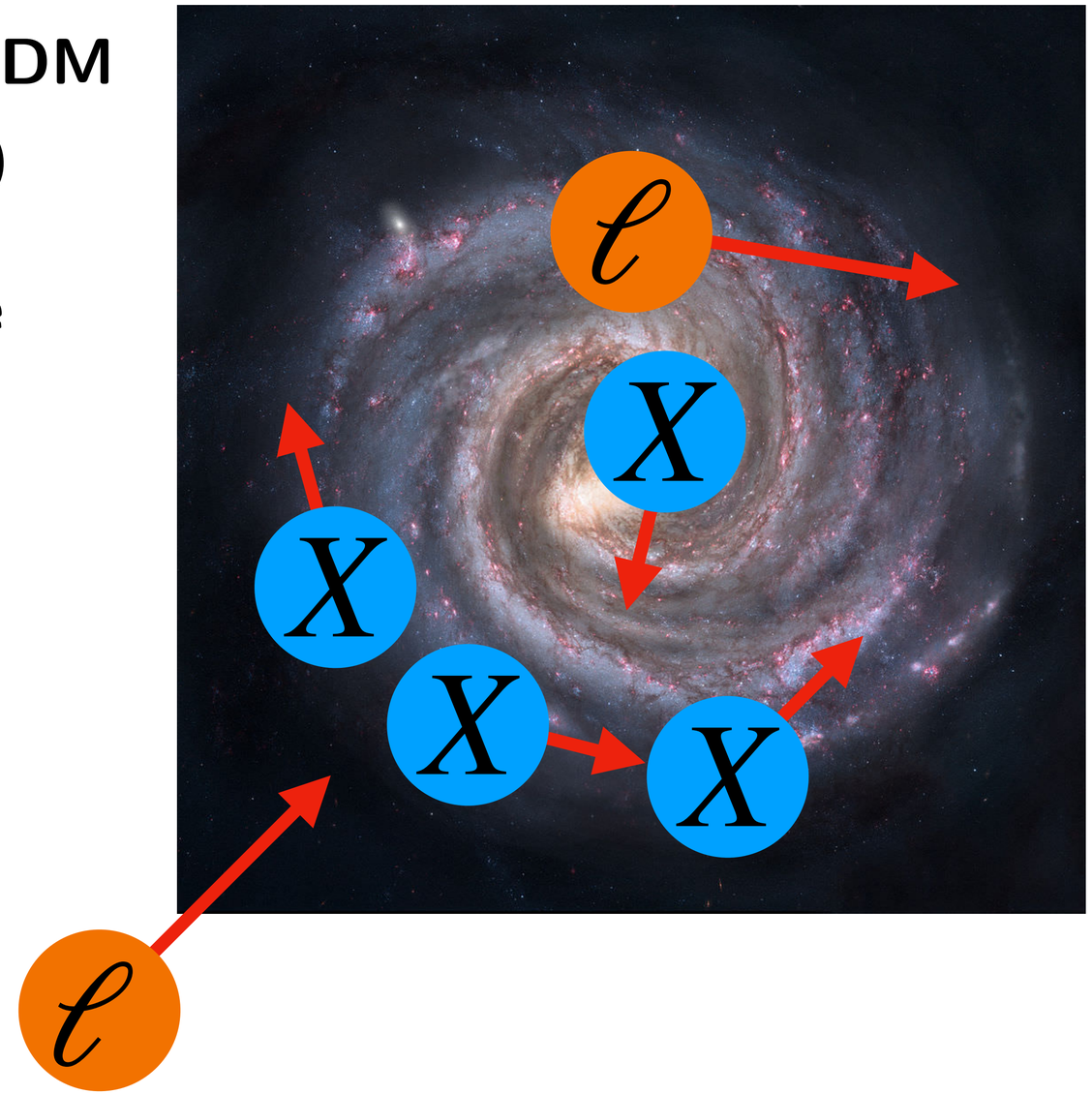




Our Idea

boosted $\ell \Longrightarrow$ **detectable at low DM masses (sub-MeV)**

charged $\ell \Longrightarrow$ **cannot escape the galaxy**



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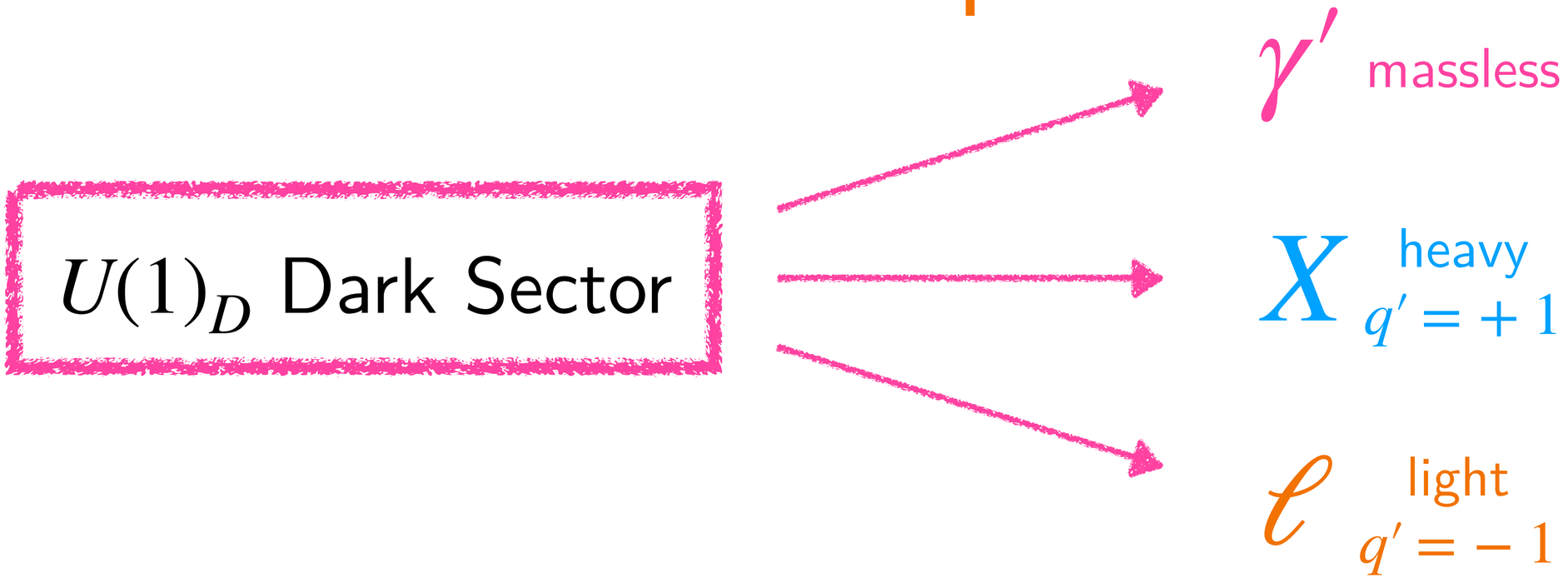

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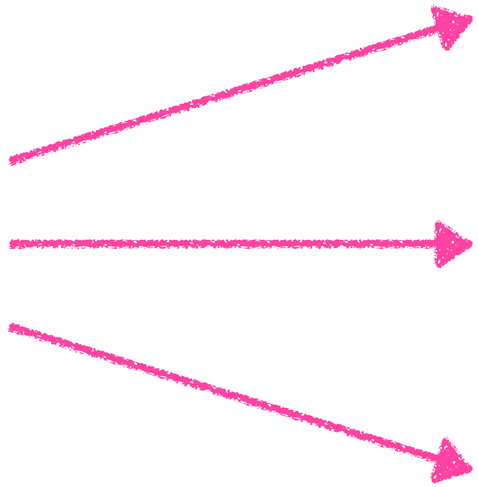

γ' massless

kinetic mixing with γ

X heavy $q' = +1$ $q_{\rm QED} = Q$

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Asymmetric DM:
no $\bar{X}$ and $\bar{\ell}$

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Asymmetric DM:
no $\bar{X}$ and $\bar{\ell}$

Makes up **5% of DM**

the rest of DM

neutral CDM χ

Galactic MCP Distribution

We treat the X and ℓ plasmas as ideal gases in thermal and hydrostatic equilibria.

Hydrostatic equilibrium:

$$\frac{d}{dr}\left(P_X + P_\ell\right) = -\rho_{\rm MCP}\,\nabla\Phi$$

CDM potential

Ideal gas law:

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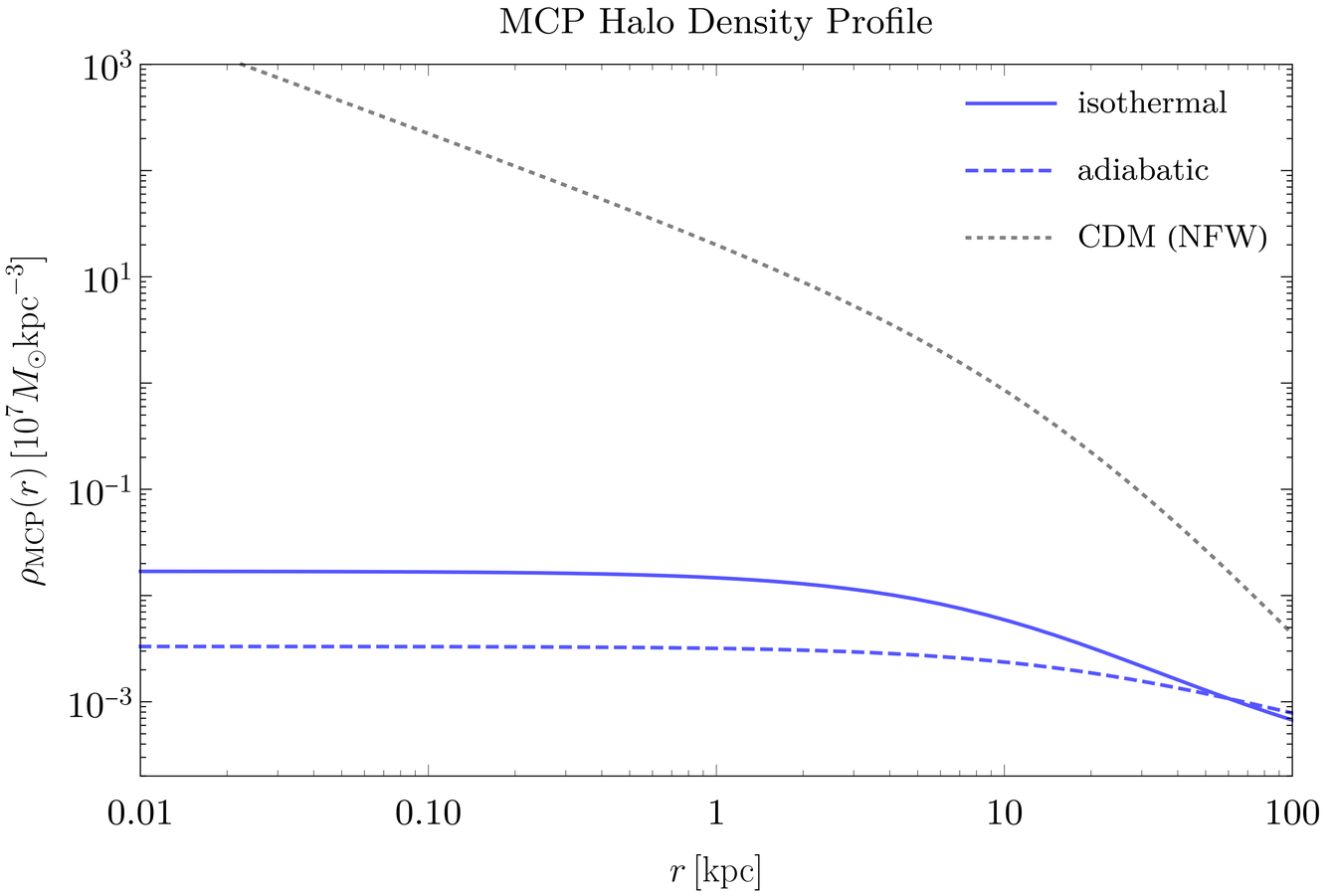

Thermodynamic Considerations

Efficient thermalization:

$$t_{\rm th} \lesssim t_{\rm gal}$$

thermalization time

age of the galaxy

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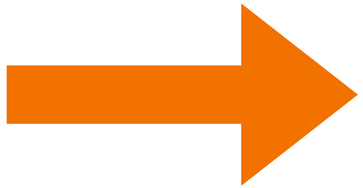

Upper limit on m_ℓ

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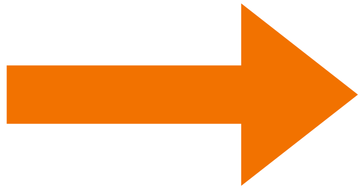

Upper limit on m_ℓ

Neglect cooling effects:

$$E_{\rm cool} \lesssim \frac{1}{3} E_{\rm MCP}$$

energy lost to cooling

total MCP energy

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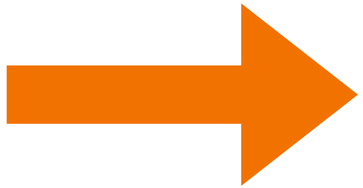

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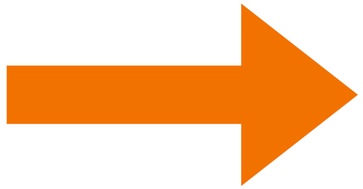

Lower limit on m_ℓ

Direct-detection Prospects

Scattering rate in electron-recoil based experiments (XENON10, SENSEI):

$$R_{1\to 2} = n_\ell^{\rm loc} \int d^3\boldsymbol{\beta}_\ell g_\ell\left(\boldsymbol{\beta}_\ell\right) \sigma v_{1\to 2}$$

local MCP distribution

QFT matrix-element
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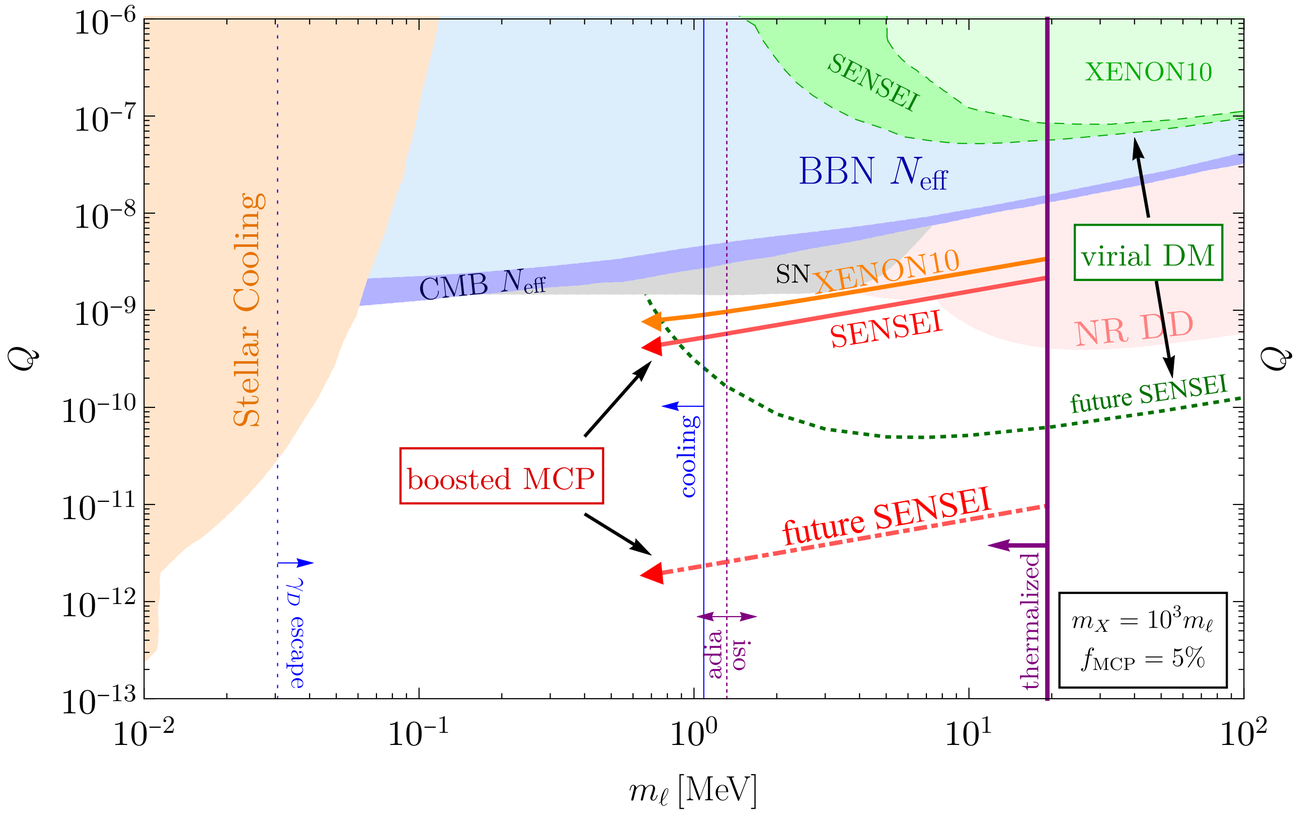
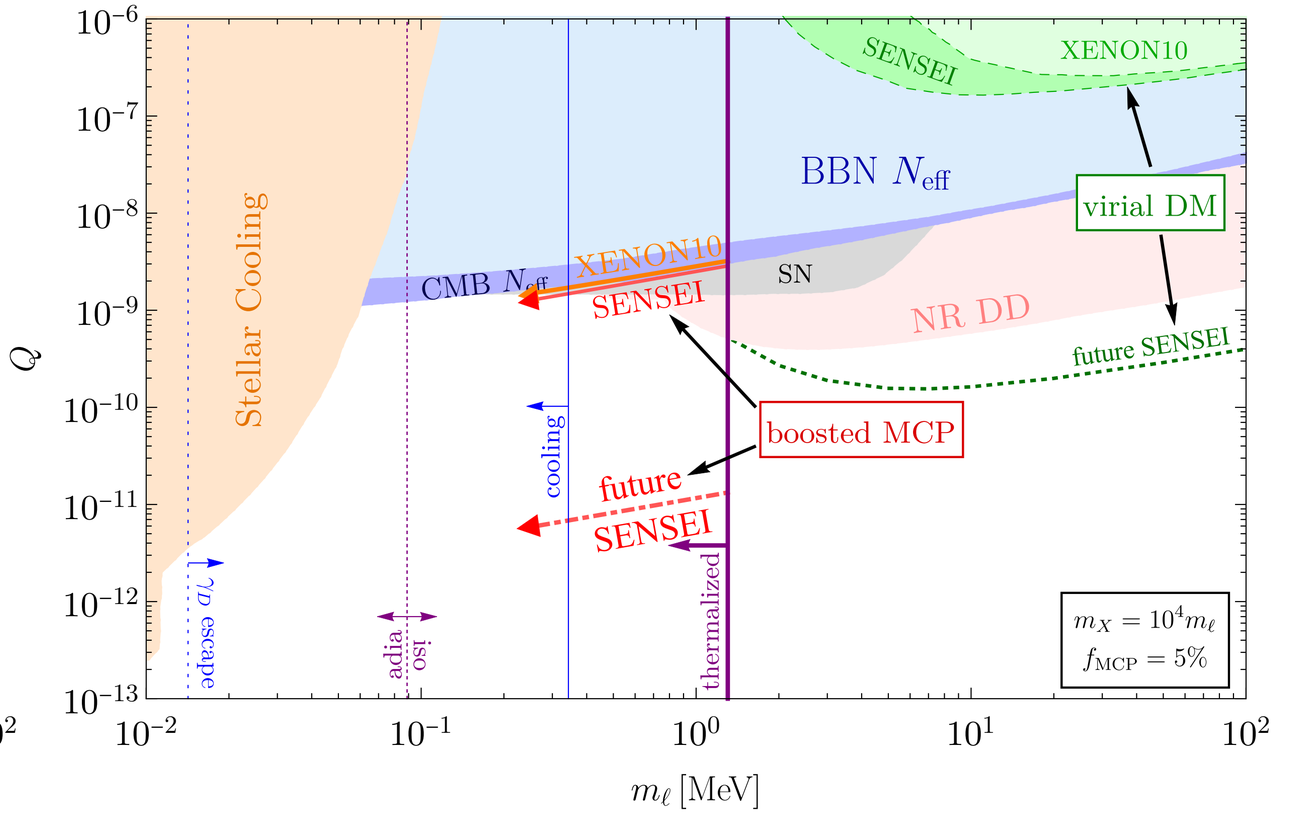
$$g_\ell\left(\boldsymbol{\beta}_\ell\right) \sim e^{-mv^2/2T_\ell}$$

MB velocity-distribution with
no escape velocity cutoff!

Detector Reach and Predictions





Thank you for your attention