

Implications of a Dark Matter-Neutrino Coupling

Andrés Olivares del Campo

Work in Collaboration with: Celine Boehm,
Sergio Palomares-Ruiz and Silvia Pascoli

MoriondEW, March 2018



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arXiv: 1711.05283

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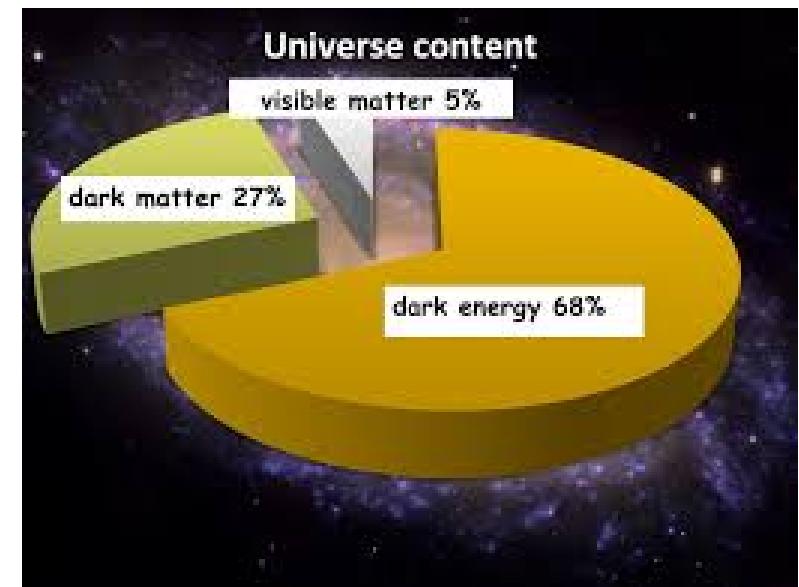
Motivation

- We do not know **why** neutrinos have **mass**



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- A particle description of DM is still **missing**



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Neutrino masses can be generated from neutrino-DM interactions

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[S. Pascoli, et. al., 1208.2732 and C. Yaguna, et.al., 1308.3655]

Gauge Invariance

- SM: $SU(3)_C \times SU(2)_L \times U(1)_Y$

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[A. Merle, et. al.,
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Dirac or Majorana neutrinos

- Concrete Model: Dirac Neutrino Portal [T. Han, et. al.,
1709.07001]

Constraints

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DM Annihilation:

$$\chi + \overset{(-)}{\chi} \leftrightarrow \nu_L + \bar{\nu}_L$$

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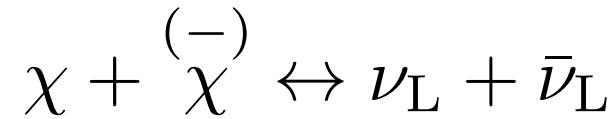
- Relic abundance

- Changes N_{eff}

[C.Boehm, et.al., 1303.6270]

Constraints

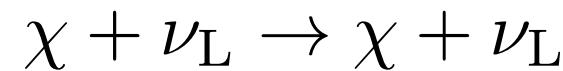
DM Annihilation:



- Relic abundance

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Collisional Damping

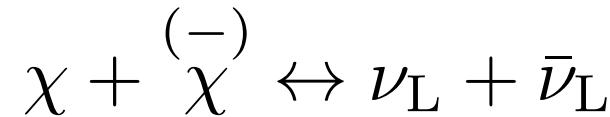


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DM Annihilation:

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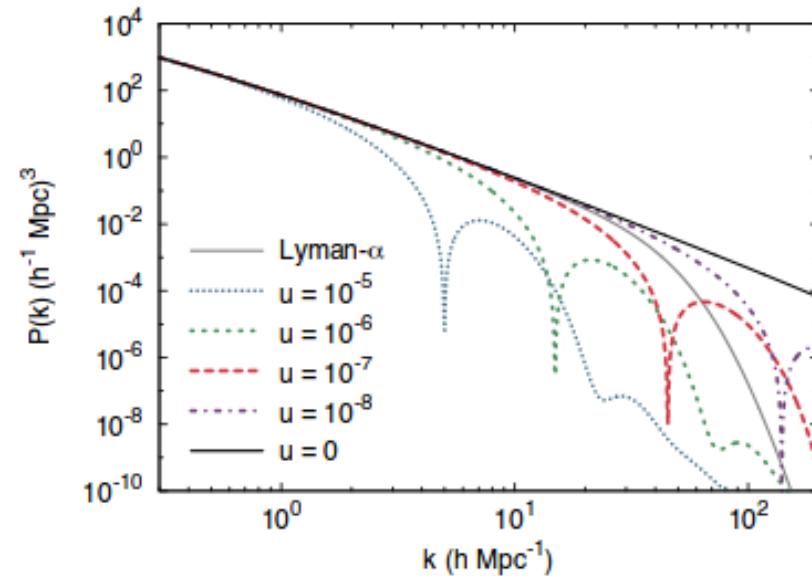
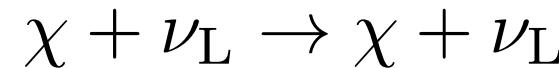
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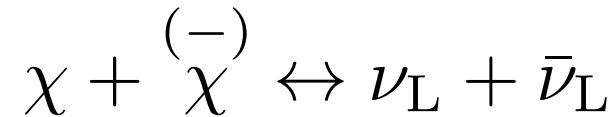
- Sets upper bound on the elastic scattering

[C.Boehm, et.al., 1401.7597]



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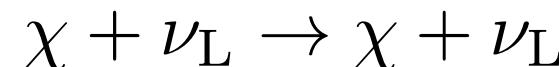


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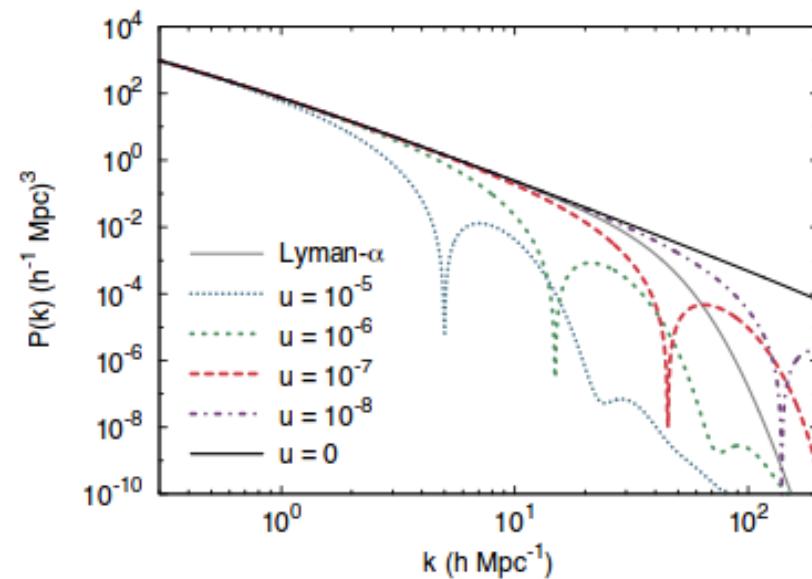
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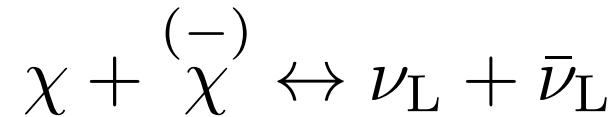


Indirect Detection at Neutrino Detectors

Constraints

DM Annihilation:

- Relic abundance



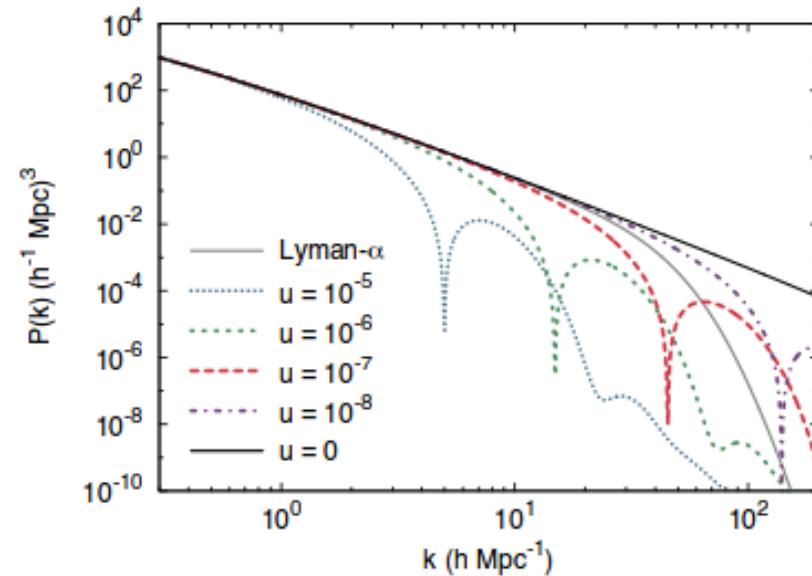
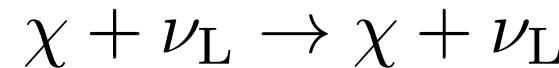
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Collisional Damping

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Indirect Detection at Neutrino Detectors

- We use data from the Super Kamiokande detector to constrain MeV DM

Results

Set up

- **Simplified model** approach, considering D=4 interactions with **left handed** neutrinos only

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 - Spin 1 mediators

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 - Dirac DM, scalar Mediator**

$$\mathcal{L}_{\text{int}} \supset - \sum_{\alpha} g_{\alpha} \bar{\chi}_R \phi \cdot L_{\alpha} + \text{h.c.}$$

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$$\mathcal{L}_{\text{int}} \supset - \sum_{\alpha} g_{\alpha} \bar{\chi}_R \phi \cdot L_{\alpha} + \text{h.c.}$$



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Set up

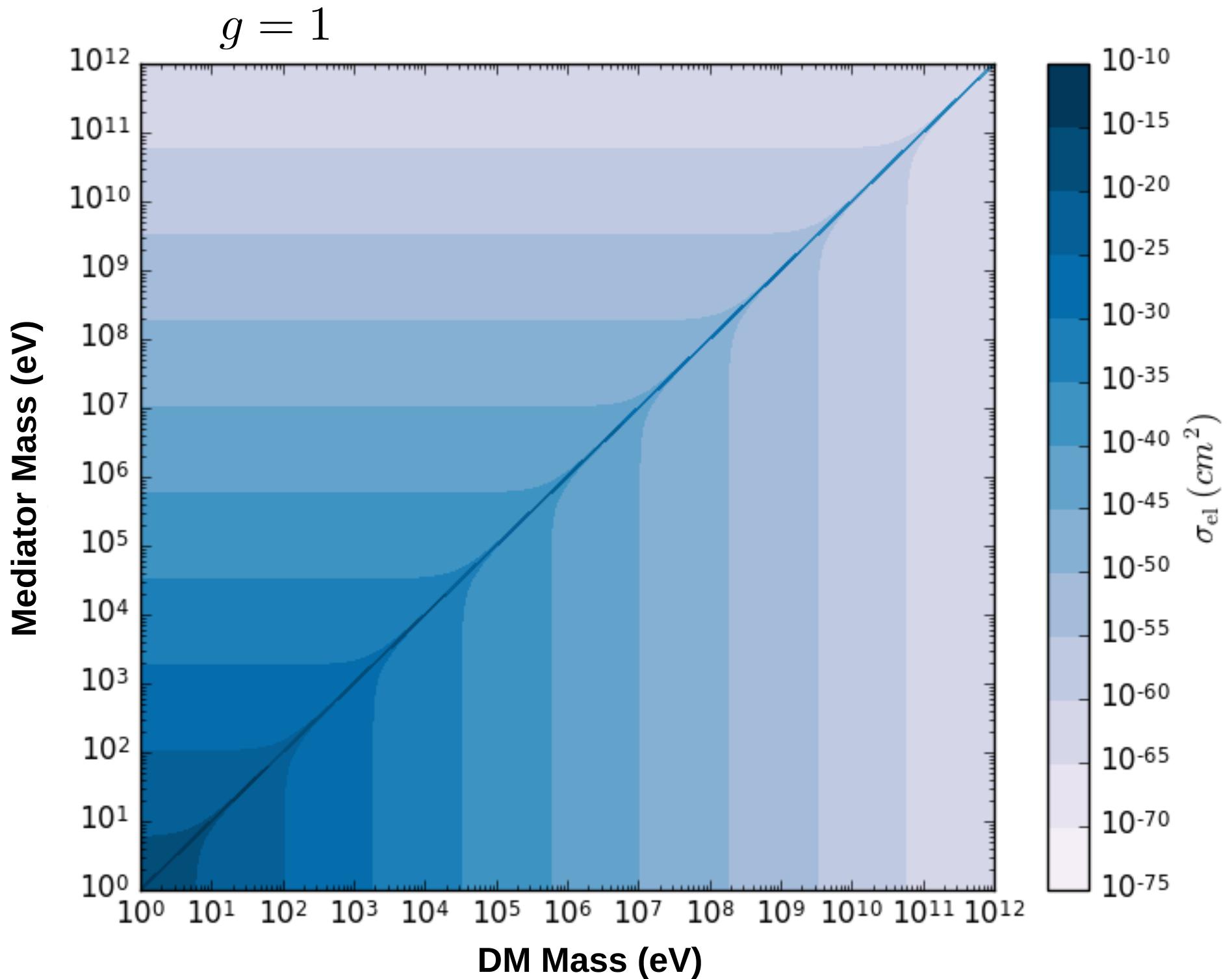
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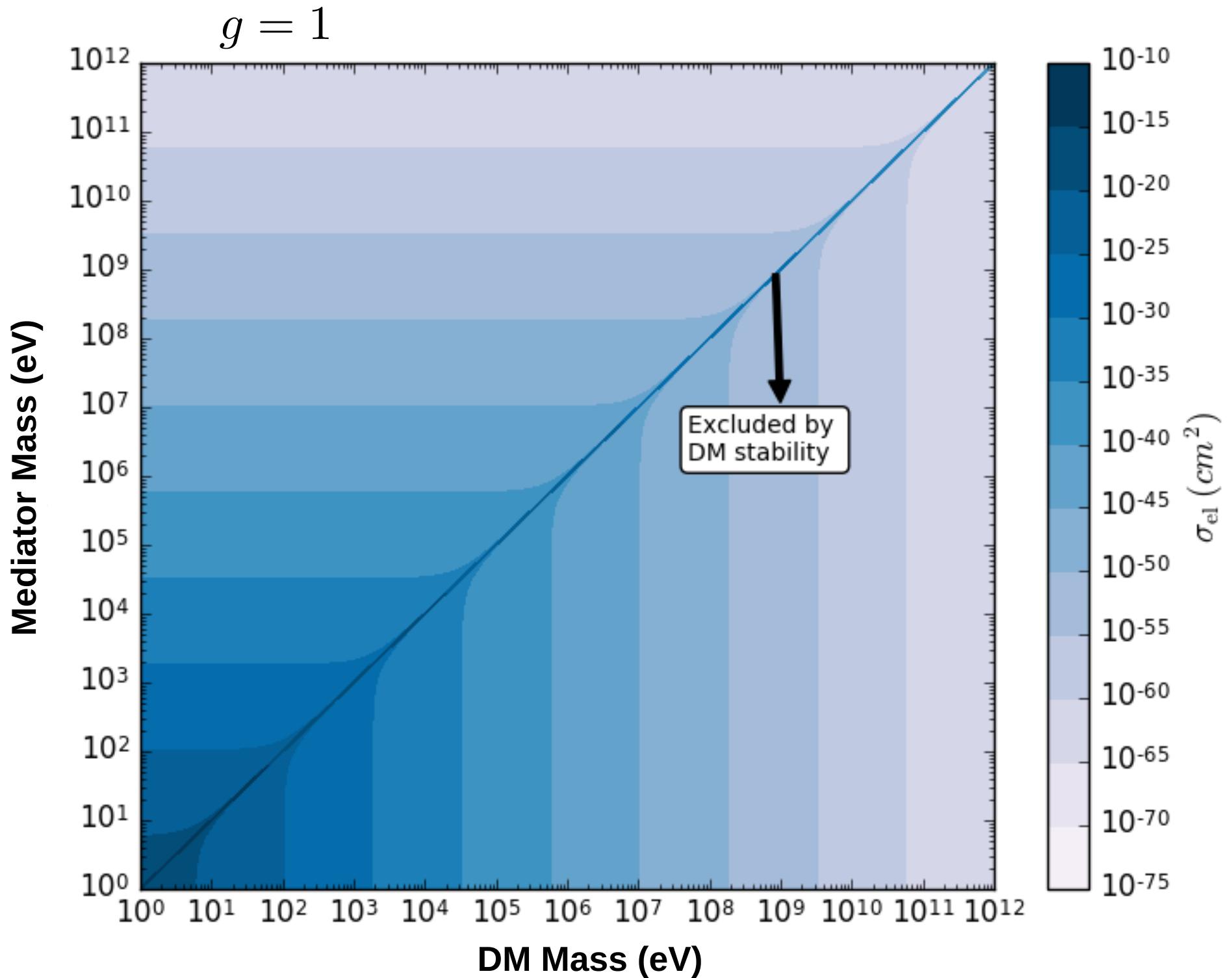
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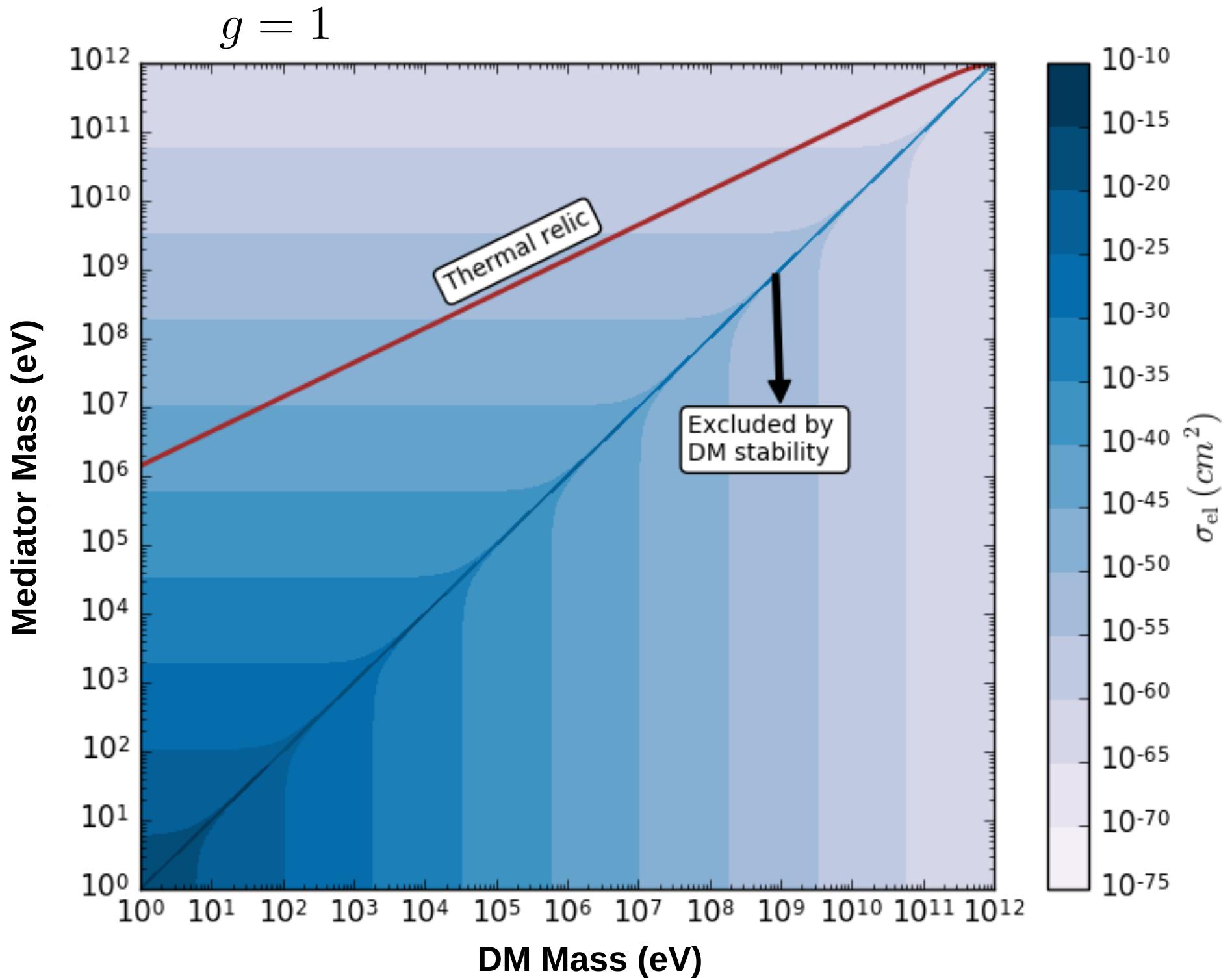
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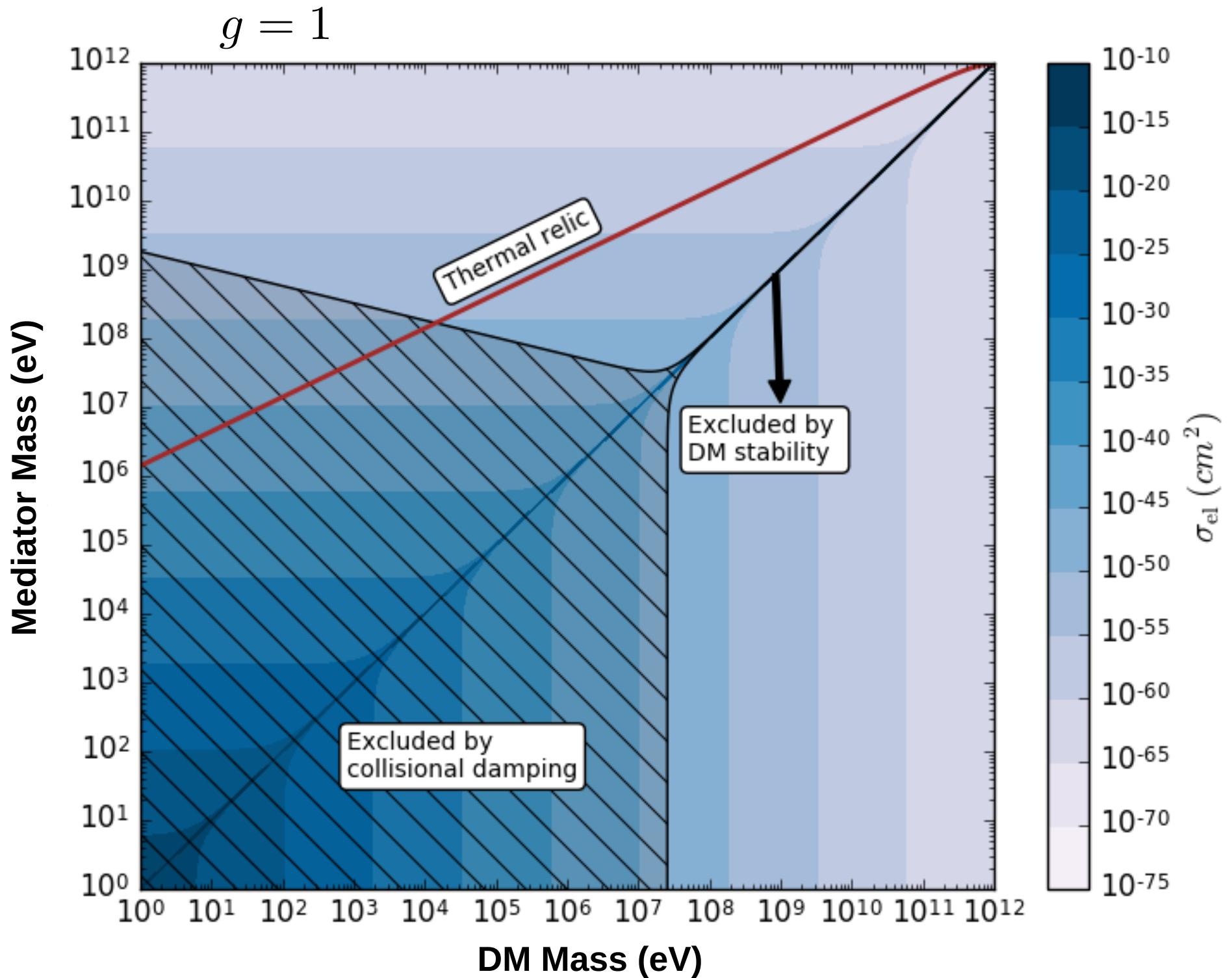
$m_{\phi} > m_{\text{DM}}$

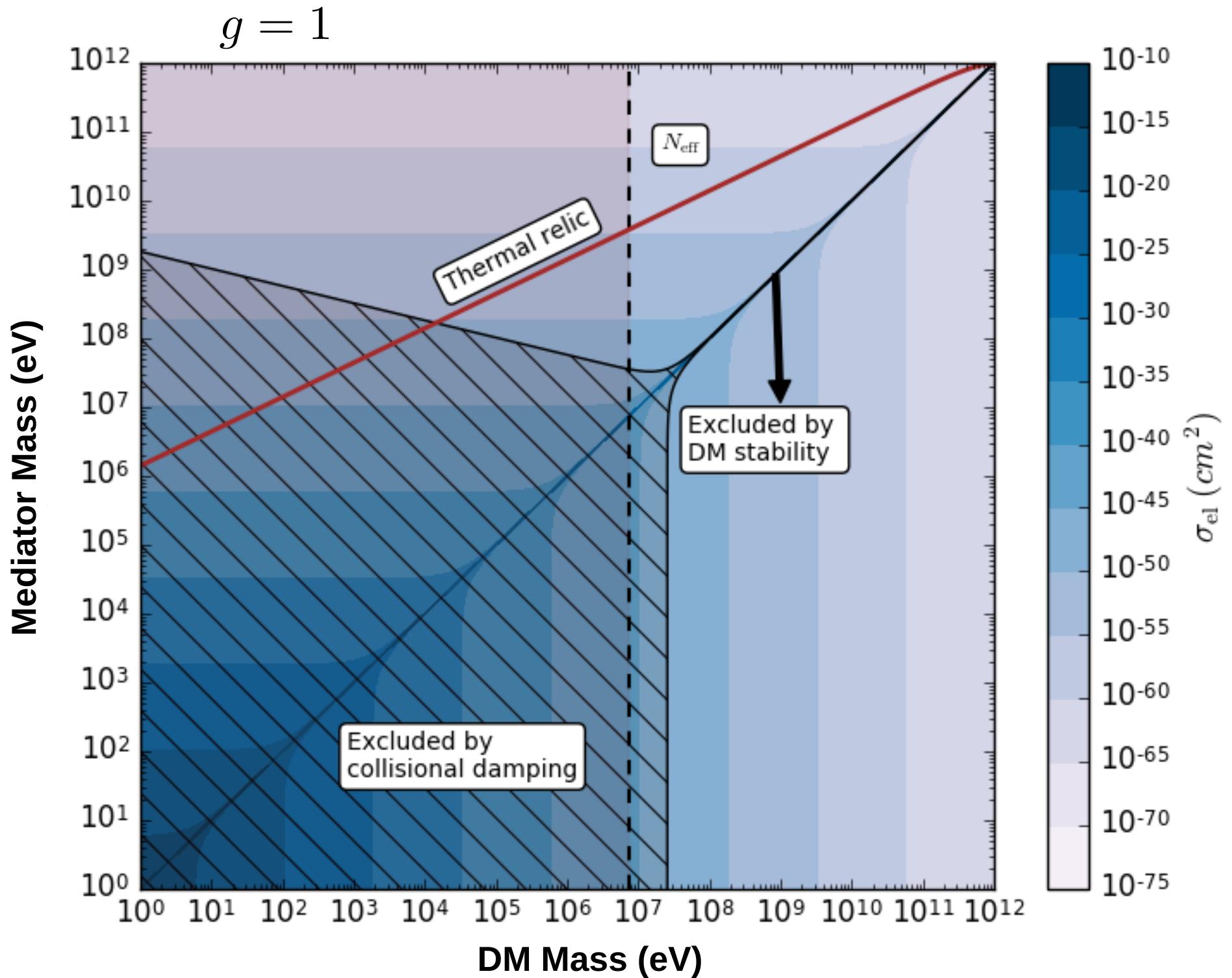
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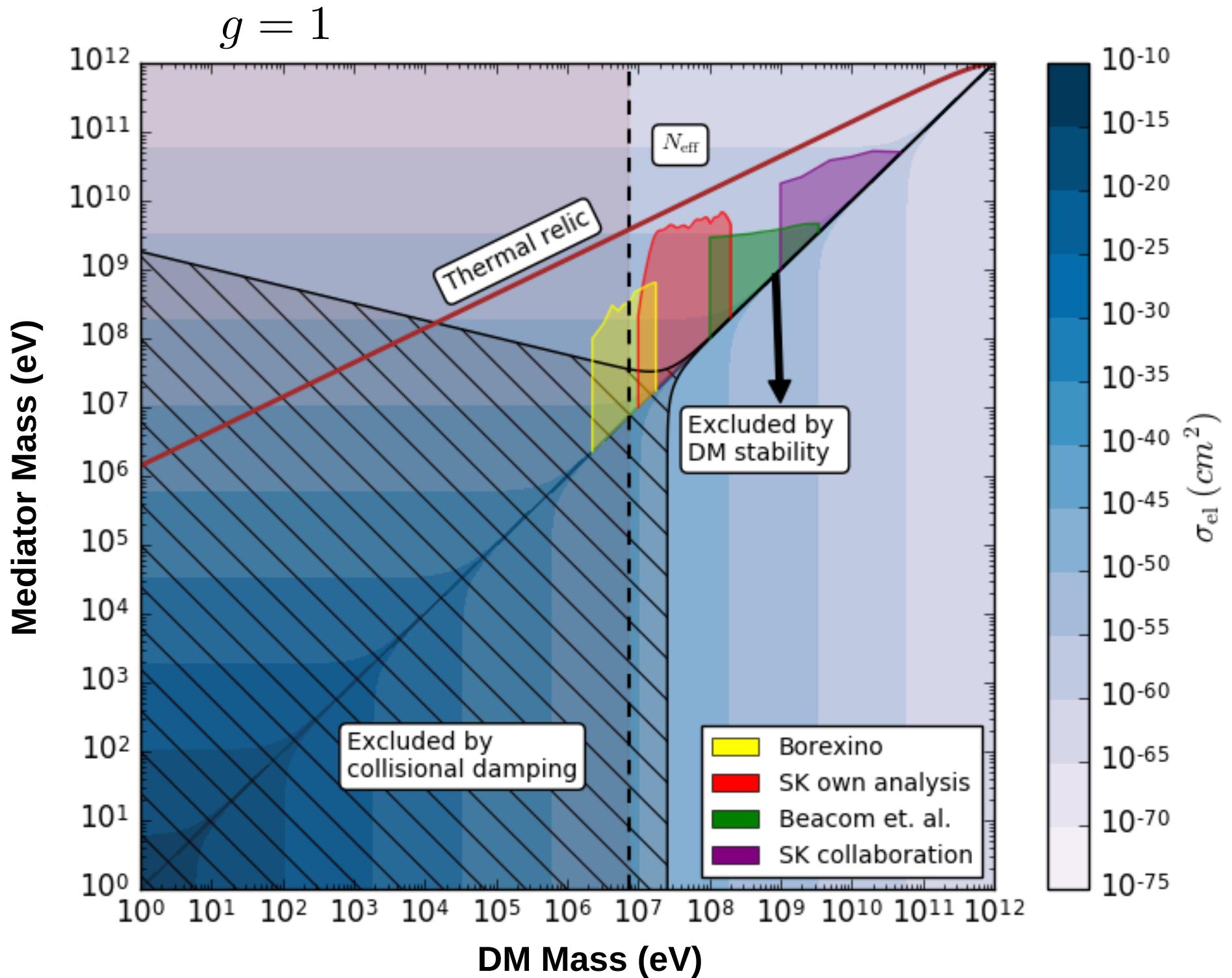












TAKE HOME MESSAGE

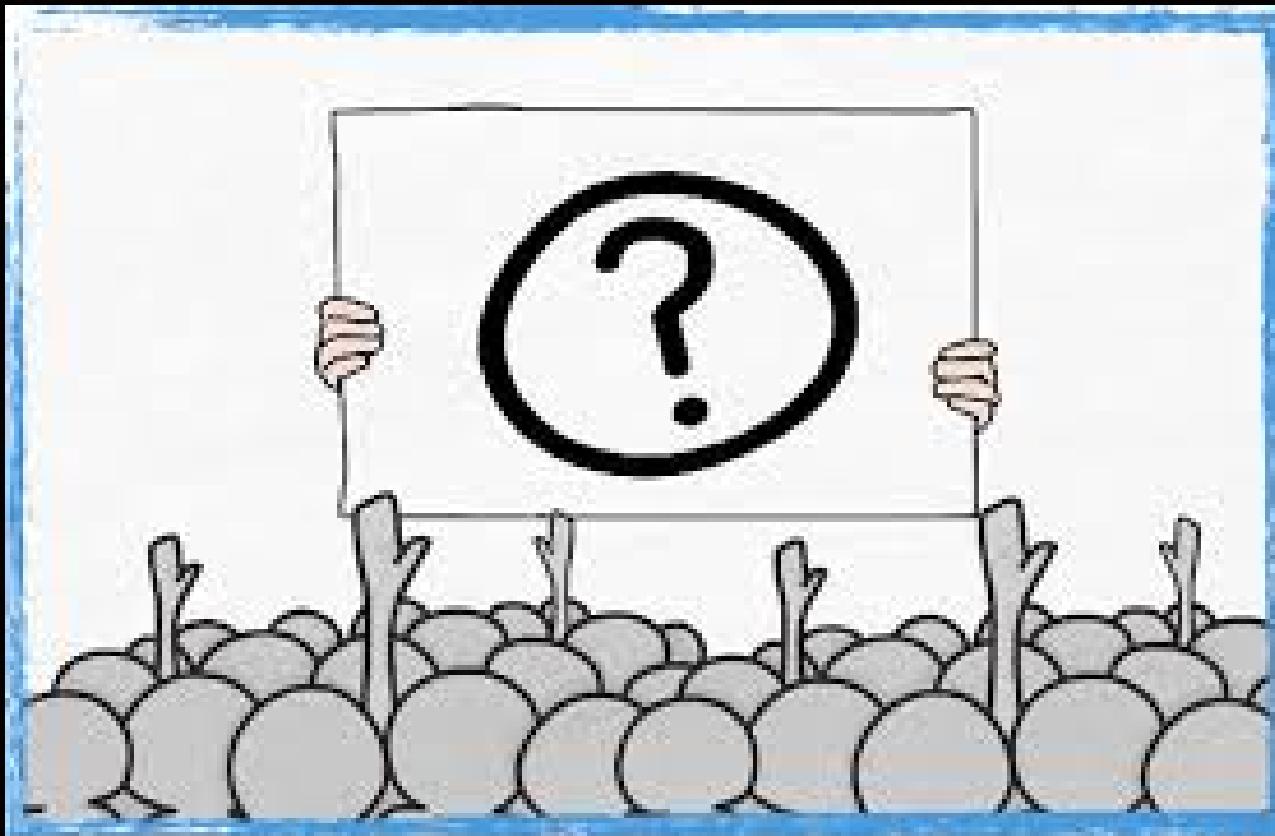
The **complementarity** between **cosmology** and **indirect detection searches** is a powerful tool to constrain the parameter space of **different DM models**

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The **complementarity** between **cosmology** and **indirect detection searches** is a powerful tool to constrain the parameter space of **different DM models**

Particularly relevant for
light DM and mediator masses

Thanks for listening



Questions?

Summary of Results

Spin 0 and $\frac{1}{2}$

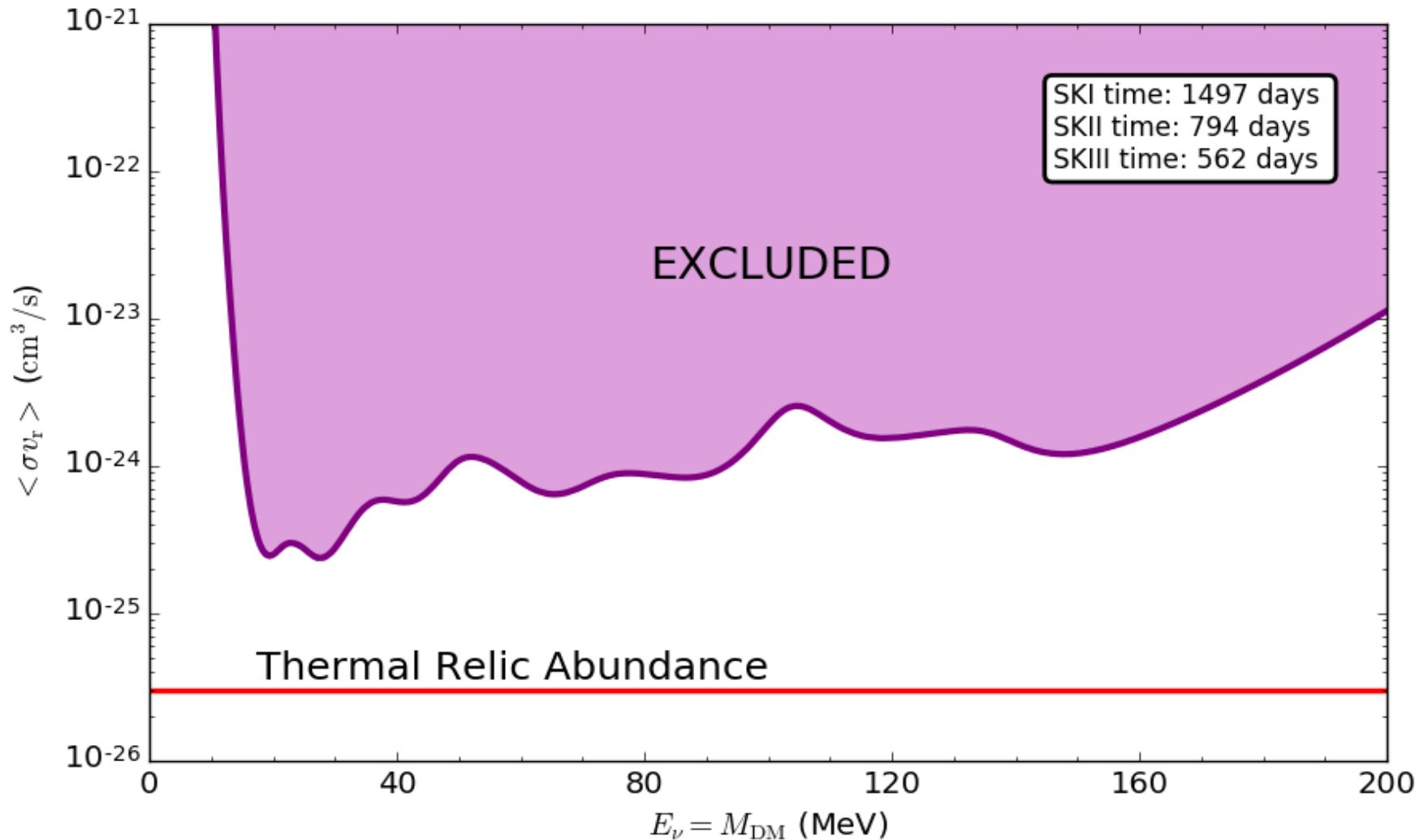
Scenario	Lagrangian (\mathcal{L}_{int})	$\sigma \mathbf{v}_{\text{T}}$	σ_{el}
Complex DM Dirac Mediator	$- g \chi \overline{N_R} \nu_L + \text{h.c.}$	$\frac{g^4}{12\pi} \frac{m_{\text{DM}}^2}{(m_{\text{DM}}^2 + m_N^2)^2} v_{\text{CM}}^2$	$\frac{g^4}{32\pi} \frac{m_{\text{DM}}^2 y^2}{(m_N^2 - m_{\text{DM}}^2)^2}$
Real DM Dirac Mediator		$\frac{4g^4}{15\pi} \frac{m_{\text{DM}}^6}{(m_{\text{DM}}^2 + m_N^2)^4} v_{\text{CM}}^4$	$\frac{g^4}{8\pi} \frac{m_{\text{DM}}^6 y^4}{(m_N^2 - m_{\text{DM}}^2)^4}$
Complex DM Majorana Mediator		$\frac{g^4}{16\pi} \frac{m_N^2}{(m_{\text{DM}}^2 + m_N^2)^2}$	$\frac{g^4}{32\pi} \frac{m_{\text{DM}}^2 y^2}{(m_N^2 - m_{\text{DM}}^2)^2}$
Real DM Majorana Mediator		$\frac{g^4}{4\pi} \frac{m_N^2}{(m_{\text{DM}}^2 + m_N^2)^2}$	$\frac{g^4}{8\pi} \frac{m_{\text{DM}}^6 y^4}{(m_N^2 - m_{\text{DM}}^2)^4}$
Dirac DM Scalar Mediator	$-g \overline{\chi_R} \nu_L \phi + \text{h.c.}$	$\frac{g^4}{32\pi} \frac{m_{\text{DM}}^2}{(m_{\text{DM}}^2 + m_\phi^2)^2}$	$\frac{g^4}{32\pi} \frac{m_{\text{DM}}^2 y^2}{(m_{\text{DM}}^2 - m_\phi^2)^2}$
Majorana DM Scalar Mediator		$\frac{g^4}{12\pi} \frac{m_{\text{DM}}^2}{(m_{\text{DM}}^2 + m_\phi^2)^2} v_{\text{CM}}^2$	$\frac{g^4}{16\pi} \frac{m_{\text{DM}}^2 y^2}{(m_{\text{DM}}^2 - m_\phi^2)^2}$
Vector DM Dirac Mediator	$- g \overline{N_L} \gamma^\mu \chi_\mu \nu_L + \text{h.c.}$	$\frac{2g^4}{9\pi} \frac{m_{\text{DM}}^2}{(m_{\text{DM}}^2 + m_N^2)^2}$	$\frac{g^4}{4\pi} \frac{m_{\text{DM}}^2 y^2}{(m_{\text{DM}}^2 - m_N^2)^2}$
Vector DM Majorana Mediator		$\frac{g^4}{6\pi} \frac{m_N^2}{(m_{\text{DM}}^2 + m_N^2)^2}$	

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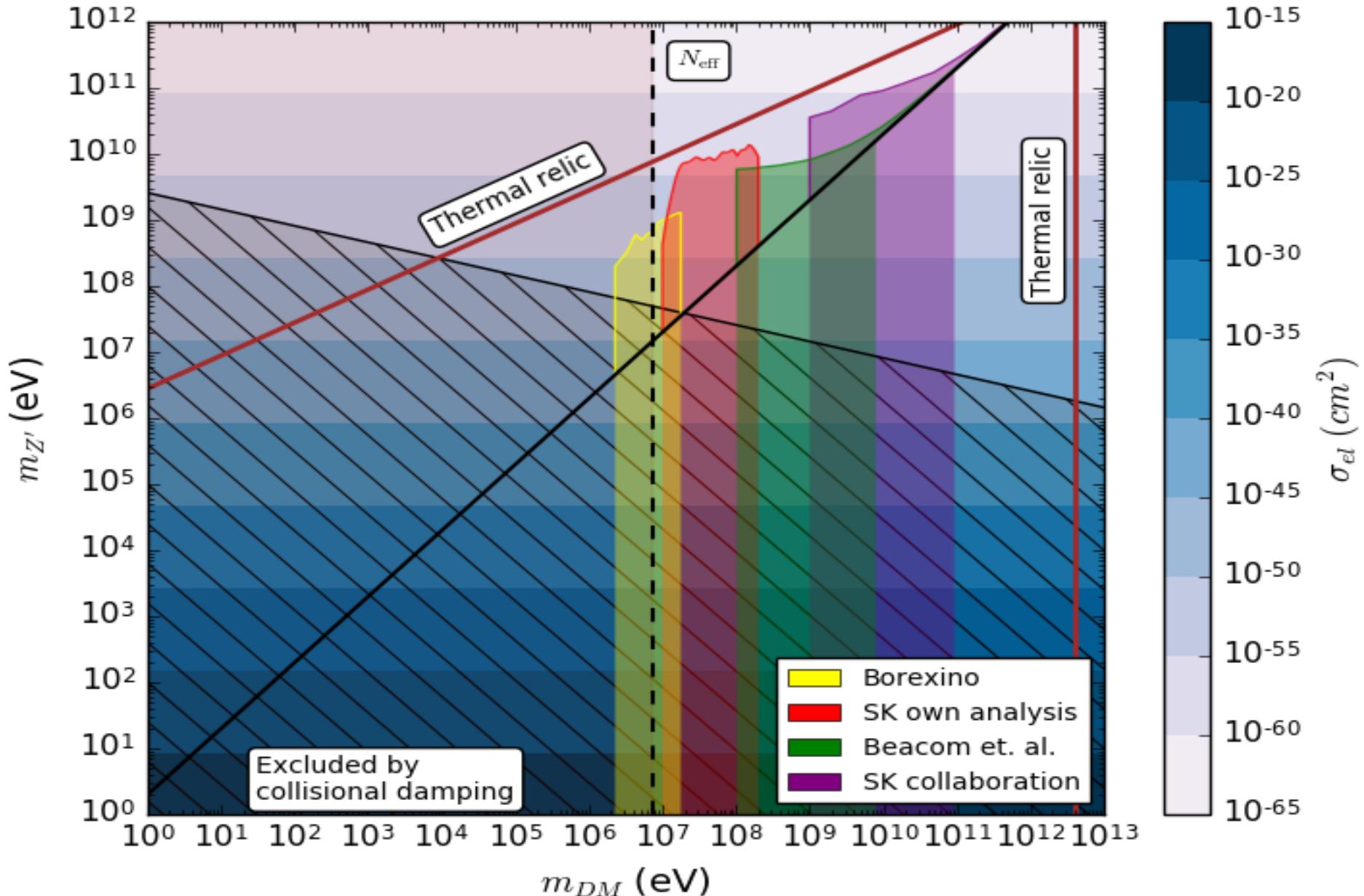
Spin 1

Scenario	Lagrangian (\mathcal{L}_{int})	$\sigma \mathbf{v}_r$	σ_{el}
Complex DM Vector mediator	$-g_\chi Z^\mu ((\partial_\mu \chi)\chi^\dagger - (\partial_\mu \chi)^\dagger \chi)$ $-g_\nu \bar{\nu}_L \gamma^\mu Z'_\mu \nu_L$	$\frac{g_\chi^2 g_\nu^2}{3\pi} \frac{m_{\text{DM}}^2}{(4m_{\text{DM}}^2 - m_{Z'}^2)^2} v_{\text{CM}}^2$	$\frac{g_\chi^2 g_\nu^2}{8\pi} \frac{m_{\text{DM}}^2 y^2}{m_{Z'}^4}$
Dirac DM Vector Mediator	$-g_{\chi L} \bar{\chi}_L \gamma^\mu Z'_\mu \chi_L - g_{\chi R} \bar{\chi}_R \gamma^\mu Z'_\mu \chi_R$ $-g_\nu \bar{\nu}_L \gamma^\mu Z'_\mu \nu_L$	$\frac{g_\chi^2 g_\nu^2}{2\pi} \frac{m_{\text{DM}}^2}{(4m_{\text{DM}}^2 - m_{Z'}^2)^2}$	$\frac{g_\chi^2 g_\nu^2}{8\pi} \frac{m_{\text{DM}}^2 y^2}{m_{Z'}^4}$
Majorana DM Vector Mediator	$-\frac{g_\chi}{2} \bar{\chi} \gamma^\mu Z'_\mu \gamma^5 \chi$ $-g_\nu \bar{\nu}_L \gamma^\mu Z'_\mu \nu_L$	$\frac{g_\chi^2 g_\nu^2}{12\pi} \frac{m_{\text{DM}}^2}{(4m_{\text{DM}}^2 - m_{Z'}^2)^2} v_{\text{CM}}^2$	$\frac{3g_\chi^2 g_\nu^2}{32\pi} \frac{m_{\text{DM}}^2 y^2}{m_{Z'}^4}$
Vector DM Vector Mediator	$-g_\chi \frac{1}{2} \chi^\mu \partial_\mu \chi^\nu Z'_\nu + \text{h.c.}$ $-g_\nu \bar{\nu}_L \gamma^\mu Z'_\mu \nu_L$	$\frac{g_\chi^2 g_\nu^2}{\pi} \frac{m_{\text{DM}}^2}{(4m_{\text{DM}}^2 - m_{Z'}^2)^2} v_{\text{CM}}^2$	$\frac{g_\chi^2 g_\nu^2}{8\pi} \frac{m_{\text{DM}}^2 y^2}{m_{Z'}^4}$

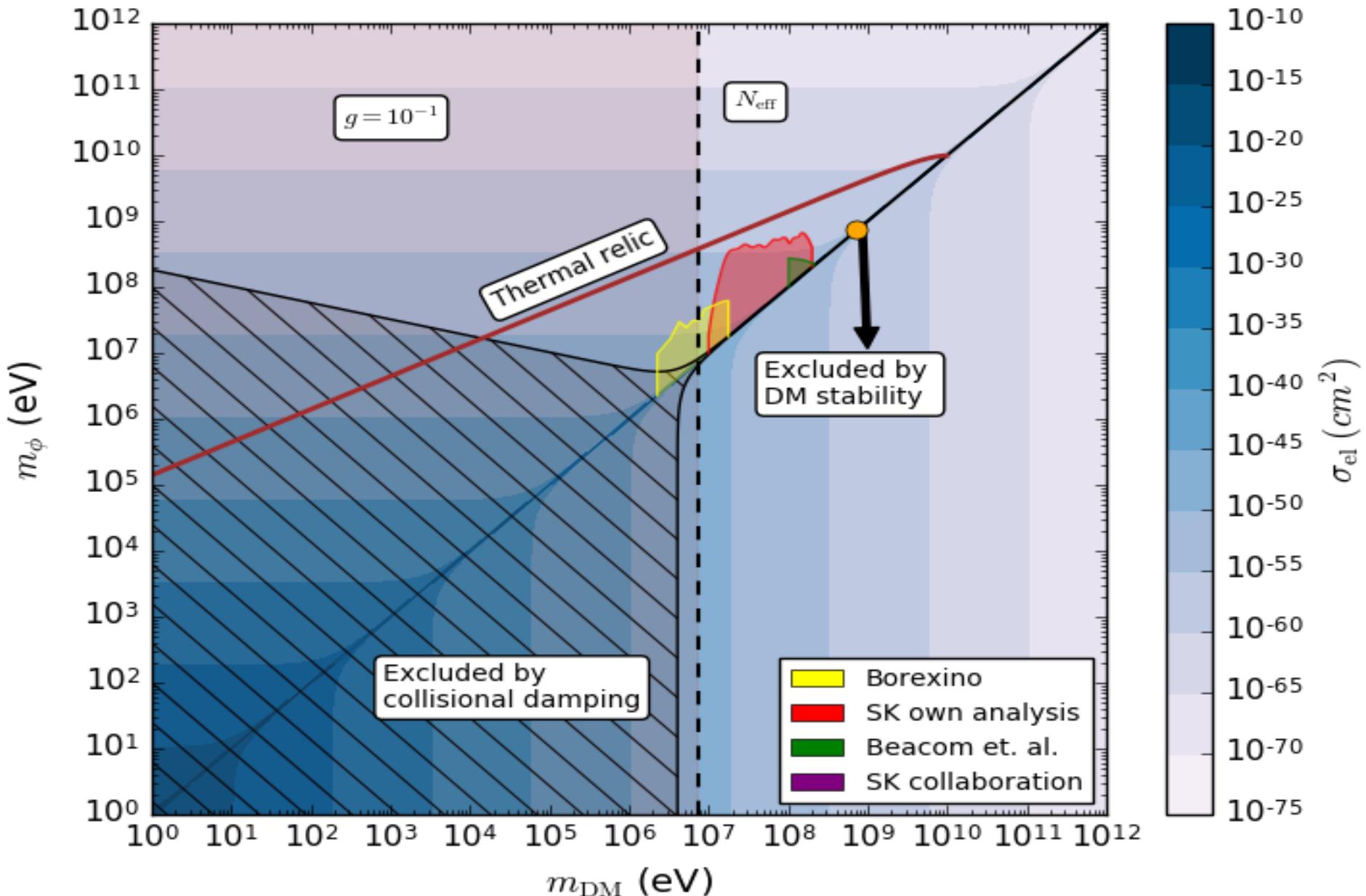
SK Updated Plots



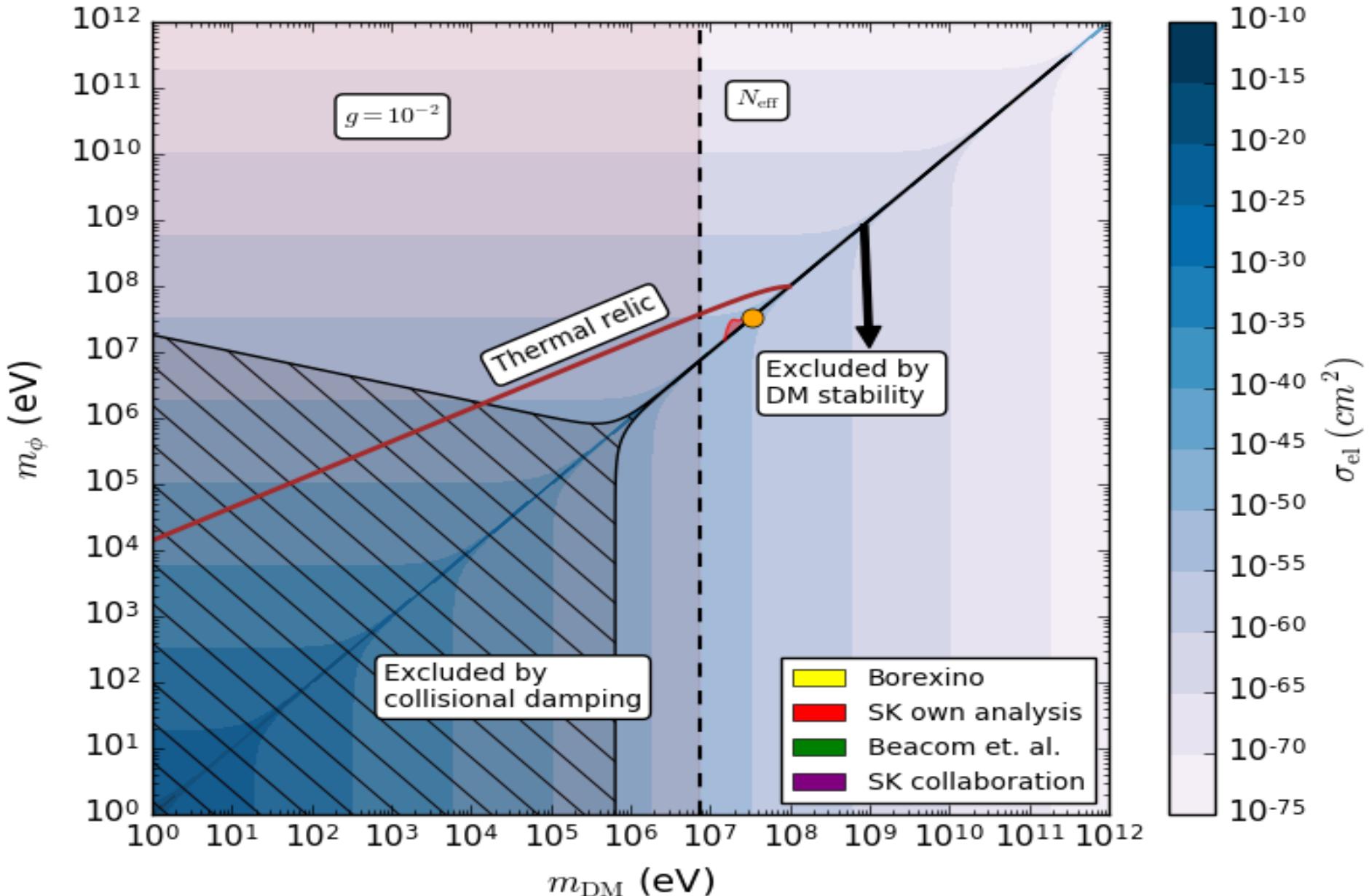
Dirac DM, Vector Mediator



Small coupling (I)



Small coupling (II)



Small coupling (III)

