

# Exploring Ultraviolet Freeze-in: a new paradigm for dark matter production

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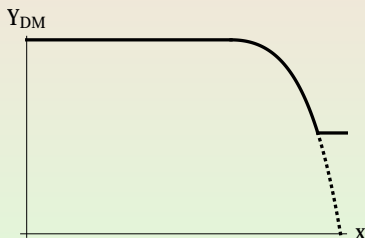
JHEP **1503**, 048 (2015) [arXiv:1410.6157 [hep-ph]]



## The Canonical story of Dark Matter

Thermal history of dark matter :

- DM in thermal equilibrium with SM when  $T \gg m_{\text{DM}}$
- As  $T$  falls below  $m_{\text{DM}}$ ,  $n_{\text{DM}}$  is Boltzmann suppressed
- But before  $n_{\text{DM}} \rightarrow 0$ , it is rescued by freeze-out, when  $\Gamma_{\text{ann}} < H$
- $\rho_{\text{DM}}$  falls like  $a^{-3}$ , eventually dominating over radiation.

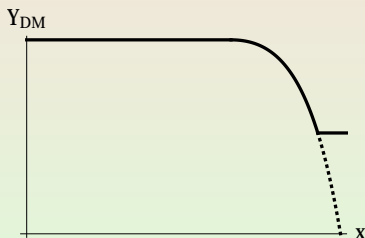


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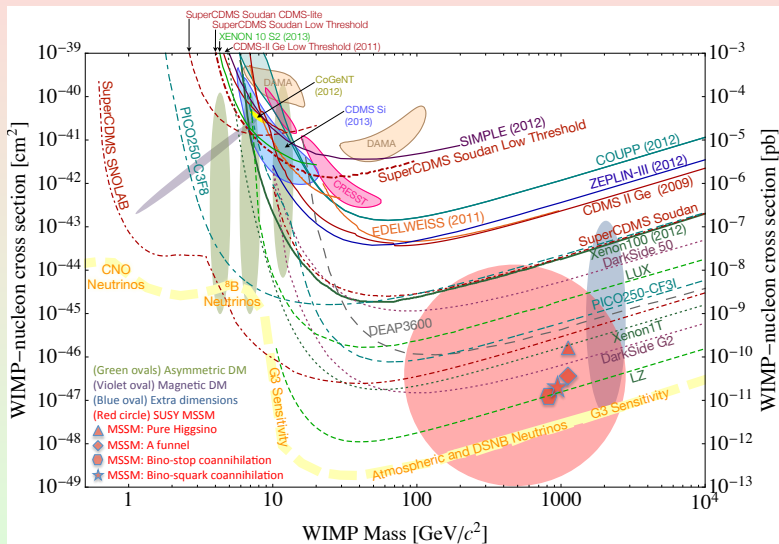
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**WIMP miracle!**

With  $m_{\text{DM}} \sim m_W$  and  $\sigma_{\text{DM}} \sim 1/m_W^2$ , observed relic abundance is roughly reproduced.



Current and Future sensitivity for detecting WIMPs

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What is the thermal history of a FIMP?

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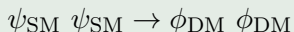
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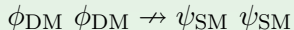
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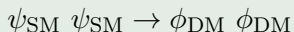
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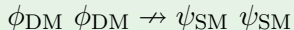
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- Details of DM production is sensitive to size and nature of coupling to SM

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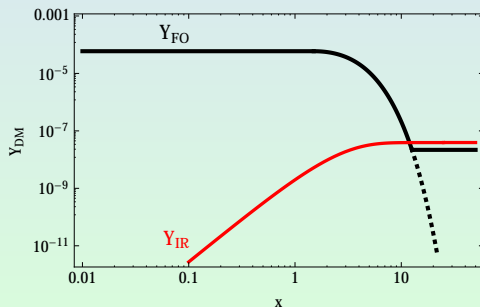
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### Disadvantages:

- DM candidates with renormalisable and extremely feeble coupling to SM are not very generic and potentially unnatural.

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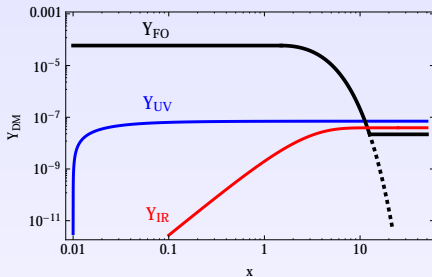
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## BSM Example: Heavy $Z'$

Consider an extension of SM by a  $U(1)$ -factor, broken at high scale  $\Lambda$ . If some visible sector states and the fermionic DM,  $\chi$ , are both charged under  $U(1)'$ :

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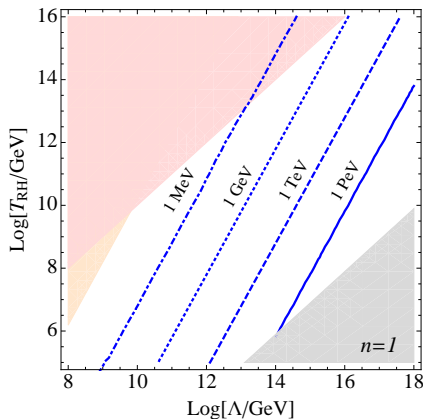
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$$\Omega_{\text{DM}} = \frac{m_\chi Y_{\text{DM}} S}{\rho_{\text{crit}}} \simeq 0.2 \times \left( \frac{m_\chi}{1 \text{ TeV}} \right) \left( \frac{T_{\text{RH}}}{10^{10} \text{ GeV}} \right)^3 \left( \frac{10^{12} \text{ GeV}}{\Lambda} \right)^4$$

## Constraints

- Effective Field Theory breaks down  $T_{\text{RH}} > \Lambda$
- The observed relic abundance cannot be achieved
- The freeze-in DM comes into thermal equilibrium with SM particles  $Y_\chi \sim Y_{\text{SM}}$

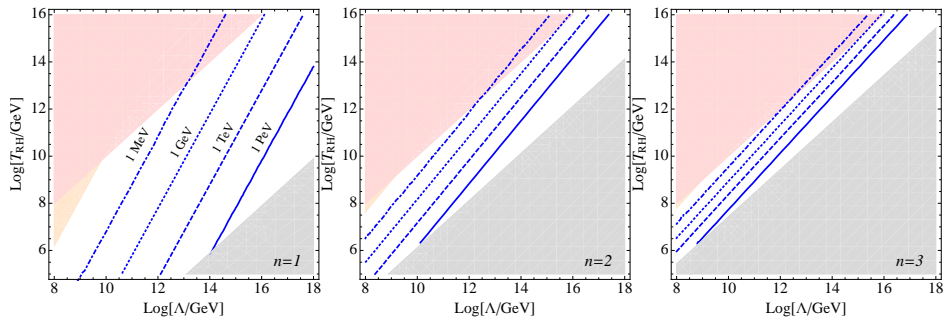
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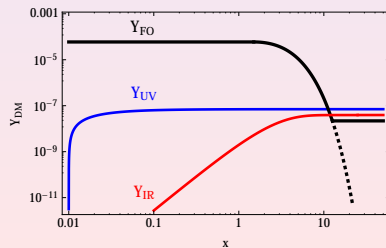
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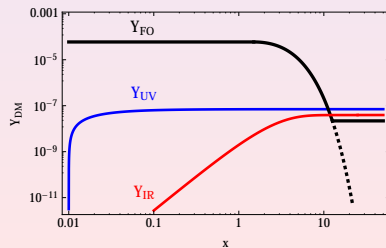
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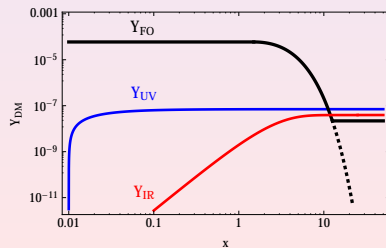
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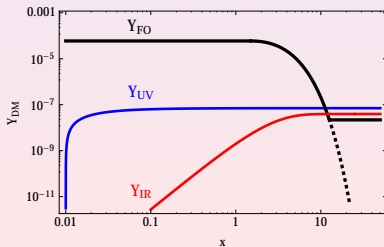
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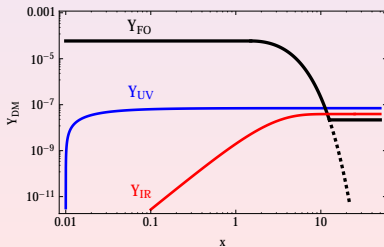
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- In UV freeze-in a wide range of  $m_{DM}$  allowed up to 0.4 keV
- $m_{DM}$  strongly correlated with  $T_{RH}$  and  $\Lambda$ , potentially opening window to UV physics.

