Phases of UV Dark Matter Freeze-In

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Abstract

WIMPs have not yet been seen via direct detection, indirect detection, or in collider searches. Perhaps now is a good time to consider alternate mechanisms for DM production.

We investigate a new production mechanism for dark matter that consists of both a non-thermal freeze-in component as well as a hidden sector freeze-out.

Spoiler Alert!

Enhancement of the final yield can occur due to the relative importance of the **(UV)** freeze-in operator at **LATE TIMES!**

Model

Fermionic Higgs Portal

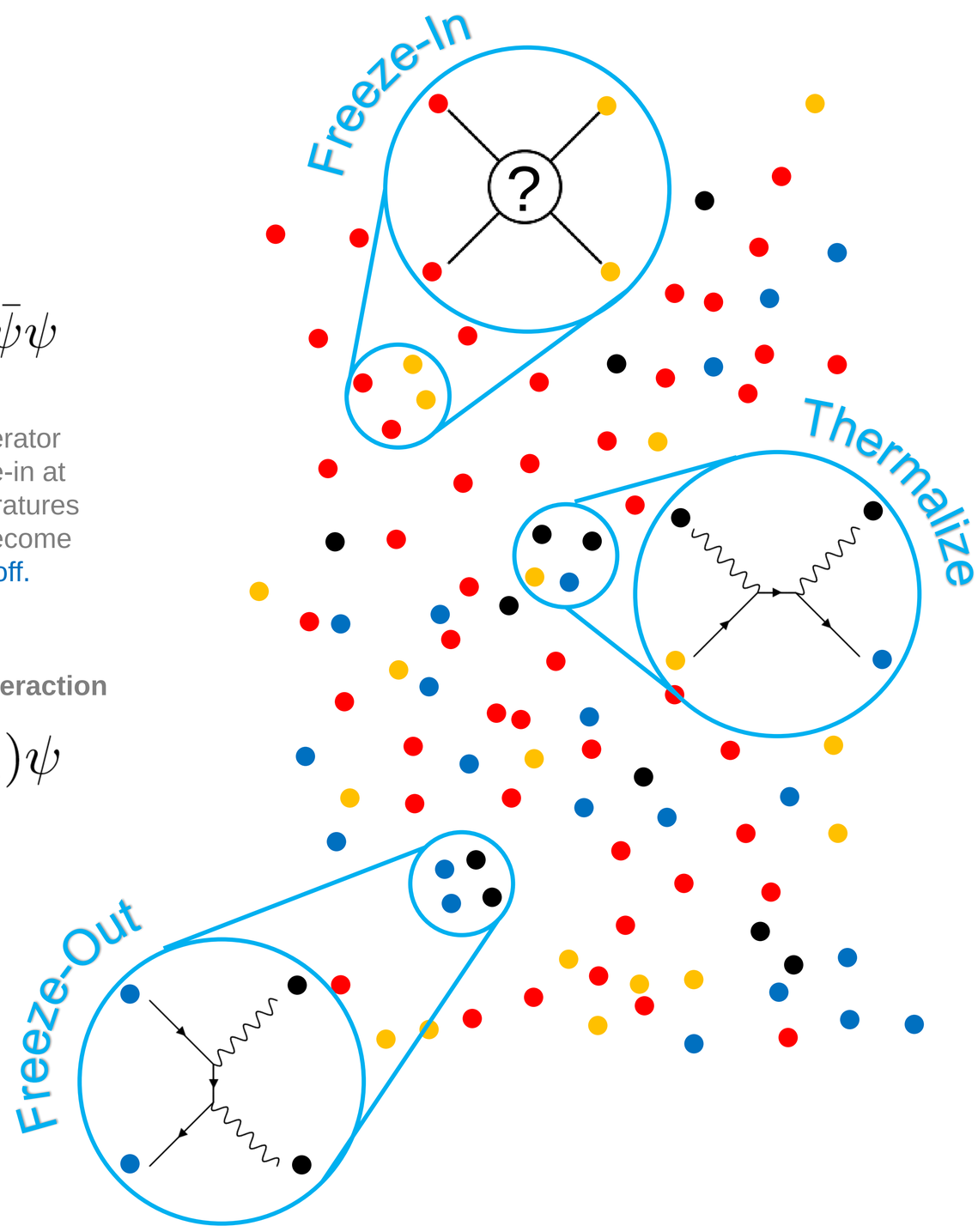
$$-\mathcal{L} \supset \frac{1}{M}|H|^2\,\bar{\psi}\psi$$

- Non-renormalizable operator
- Produces DM via freeze-in at the earliest (UV) temperatures
- Typically assumed to become inefficient as DM cools off.

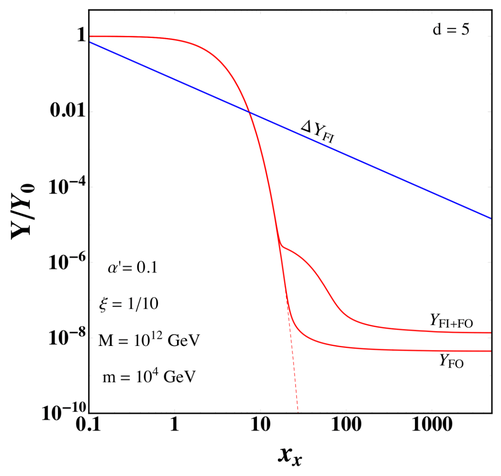
Hidden Vector Boson Interaction

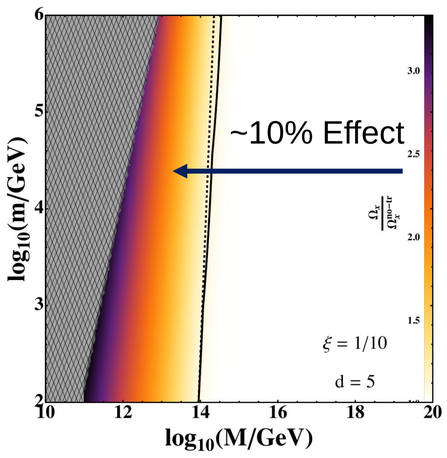
$$\mathcal{L} \supset \bar{\psi}(iD_\mu\gamma_\mu)\psi$$

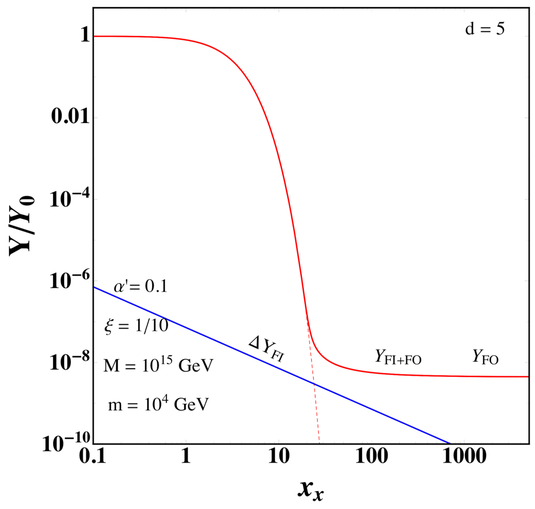
- Introduces a secondary interaction mechanism for DM
- Depletes DM via hidden freeze-in.
- Can UV transfer re-populate the hidden sector while this occurs?



If the freeze-in transfer operator mass scale is light enough, the depletion due to hidden freeze-out is diminished.







Increasing the mass-scale of the transfer operator reduces the efficiency of freeze-in, causing the results to be indistinguishable from freeze-out.

Boltzmann Equation

The relative strengths of various terms in this equation determine how effective late time UV freeze in will be.

$$\dot{n} = -3Hn$$

$$+\langle\sigma v\rangle_{ann}\left(n_{EQ}(\mathrm{T_X})^2 - n^2\right)$$

$$+\mathcal{N}_\psi\langle\sigma v\rangle_{tr}\left(n_{EQ}(\mathrm{T})^2 - n^2\right)$$

- Universe is always expanding.

- Typical freeze-out interaction:
- Entirely set by hidden sector dynamics.

- UV freeze-in interaction:
- Entirely set by visible sector dynamics.

$$\xi = \frac{\mathrm{T_X}}{\mathrm{T}} < 1$$