Non-WIMP Zoology

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Ingredients for a “miracle” (WIMP):

#1) Particle is neutral + stable.

#2) Particle has weak scale annihilation cross-section.

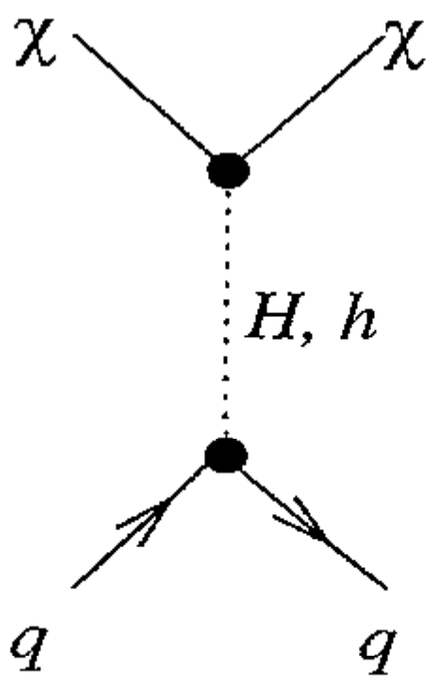
Ingredients are common in models which address the hierarchy problem.

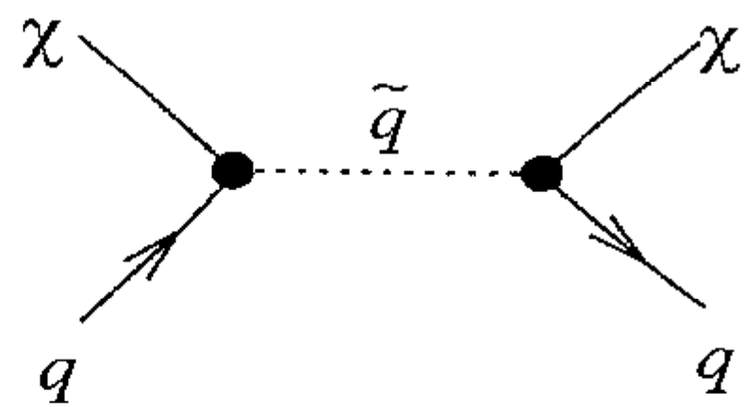
#1) Lots of examples of stabilizing symmetry!

theory	Z_2
Supersymmetry	R-parity
Extra Dimensions	KK-parity
Little Higgs	T-parity

These Z_2's often serve other purposes.

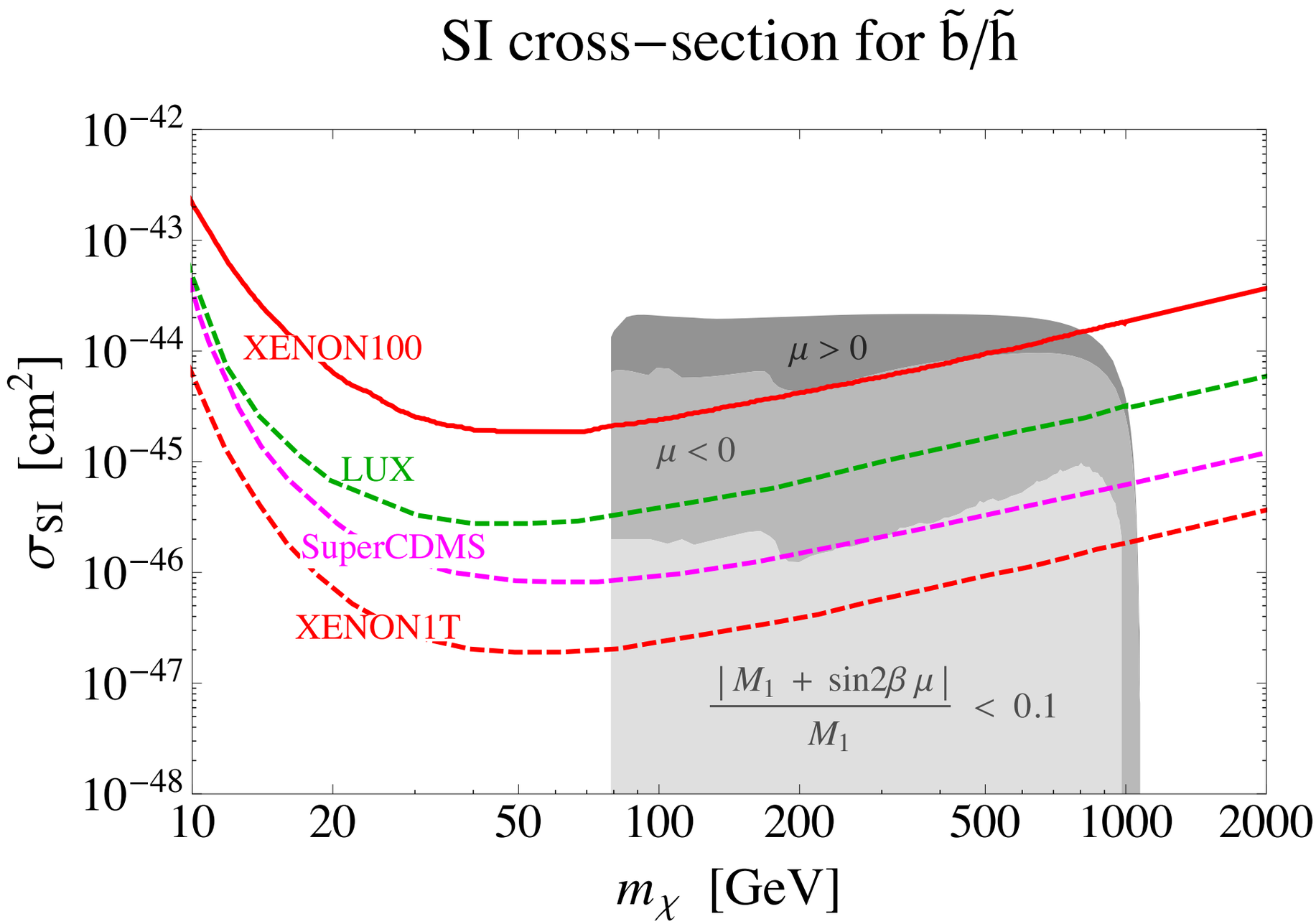
#2) Lots of weak scale masses + couplings!





Such couplings are mandatory to solve the hierarchy problem.

Do or die for WIMP dark matter?



In reality, we only know DM properties ...

- dark (neutral)
- around (stable)
- abundant (Ωh^2=0.11)

... not its origins or history. Leaves a big box!

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- around (stable) ✓
- abundant (Ωh^2=0.11) ?

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What is a non-WIMP? A "canonical" WIMP has at least two theory *assumptions* :

i) DM is in thermal equilibrium with SM.

→ Exception : non-thermal DM

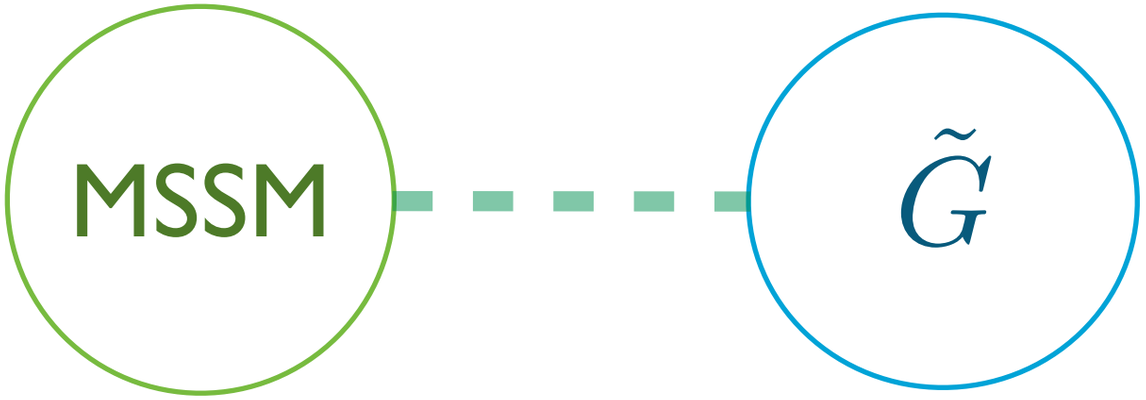
ii) DM / anti-DM are symmetric.

→ Exception : asymmetric DM

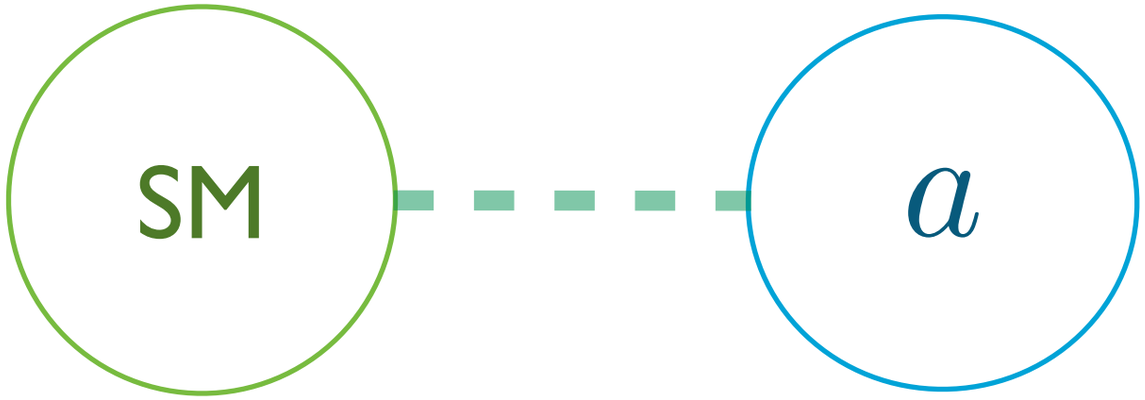
non-thermal DM

Non-thermal DM is actually quite familiar.

gravitino:



axion:

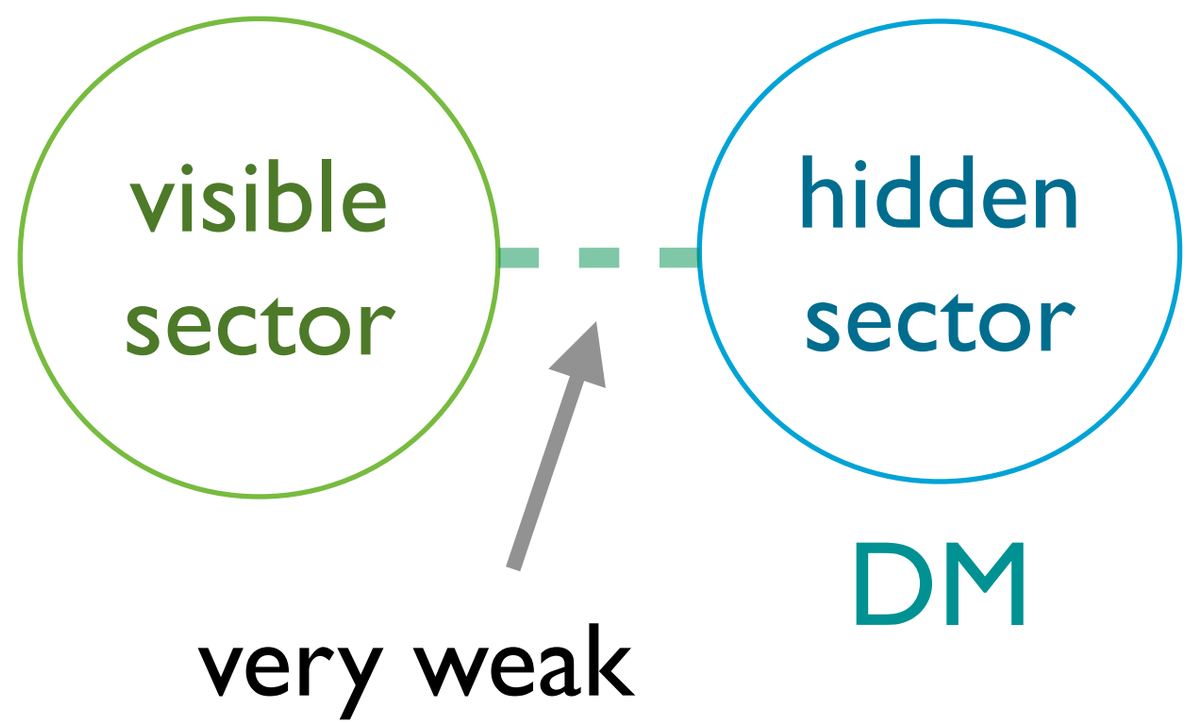


But as usual, add'l theory prejudices enter.

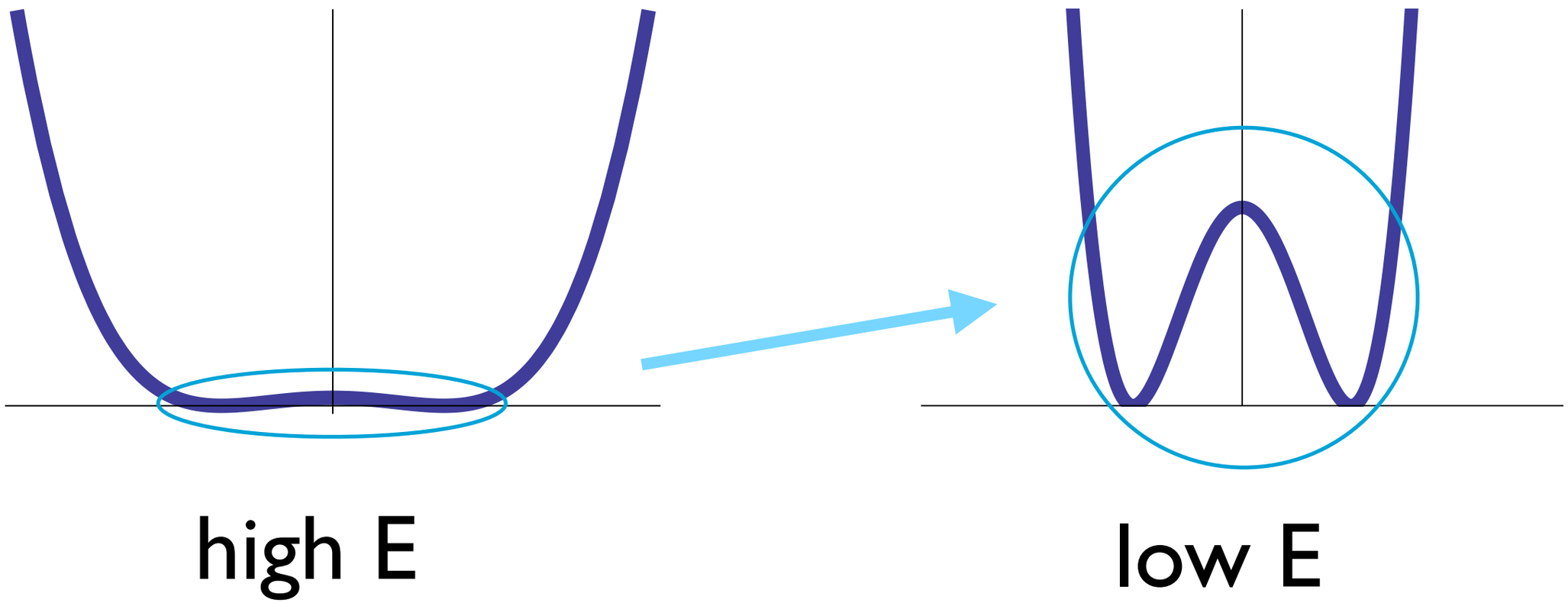
Abstract to general "hidden sector" setup.

thermal:

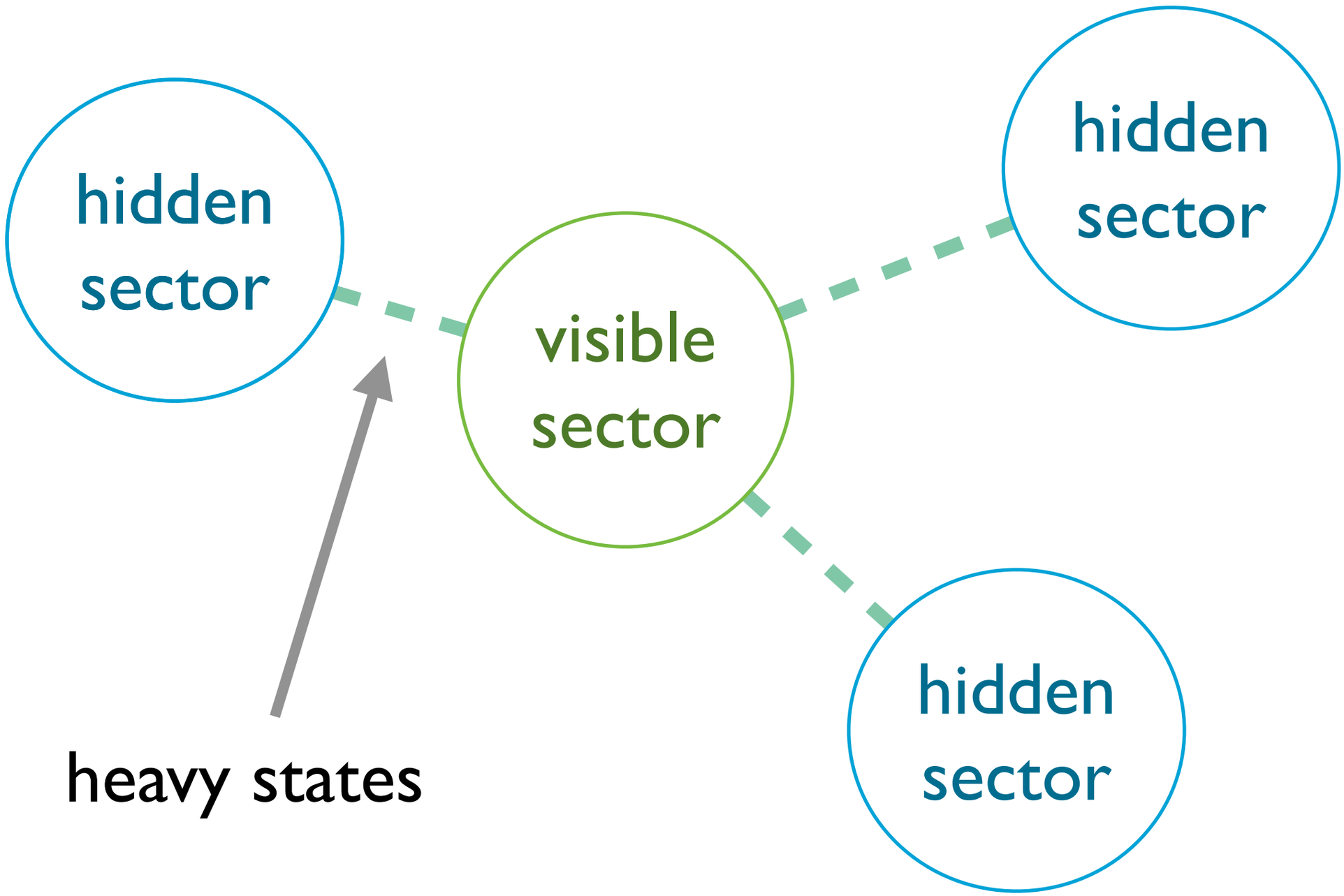
non-thermal:



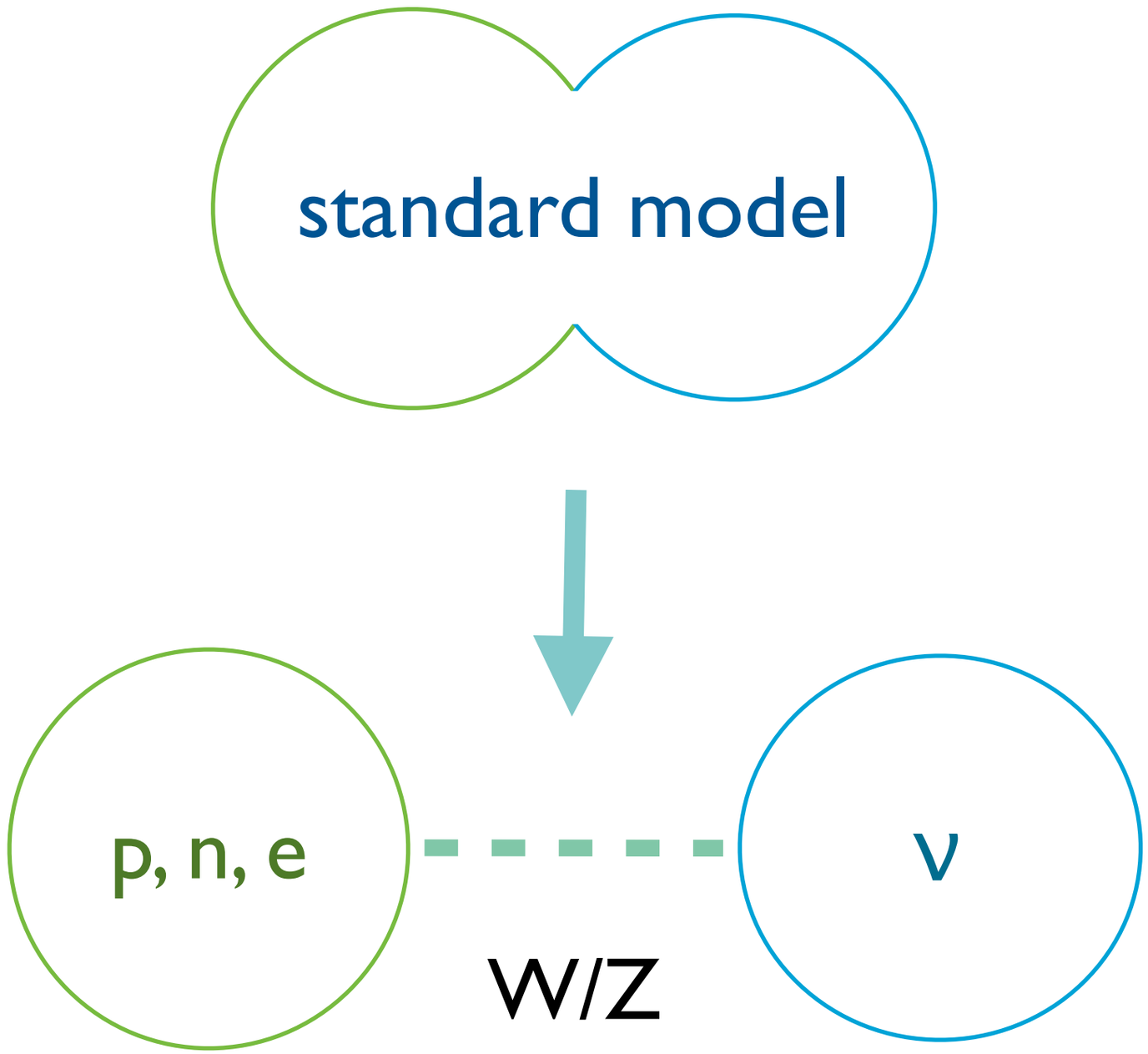
“Hidden sectors” very naturally arise when going from high energy to low energy.



Effective theories yield “hidden valleys”.

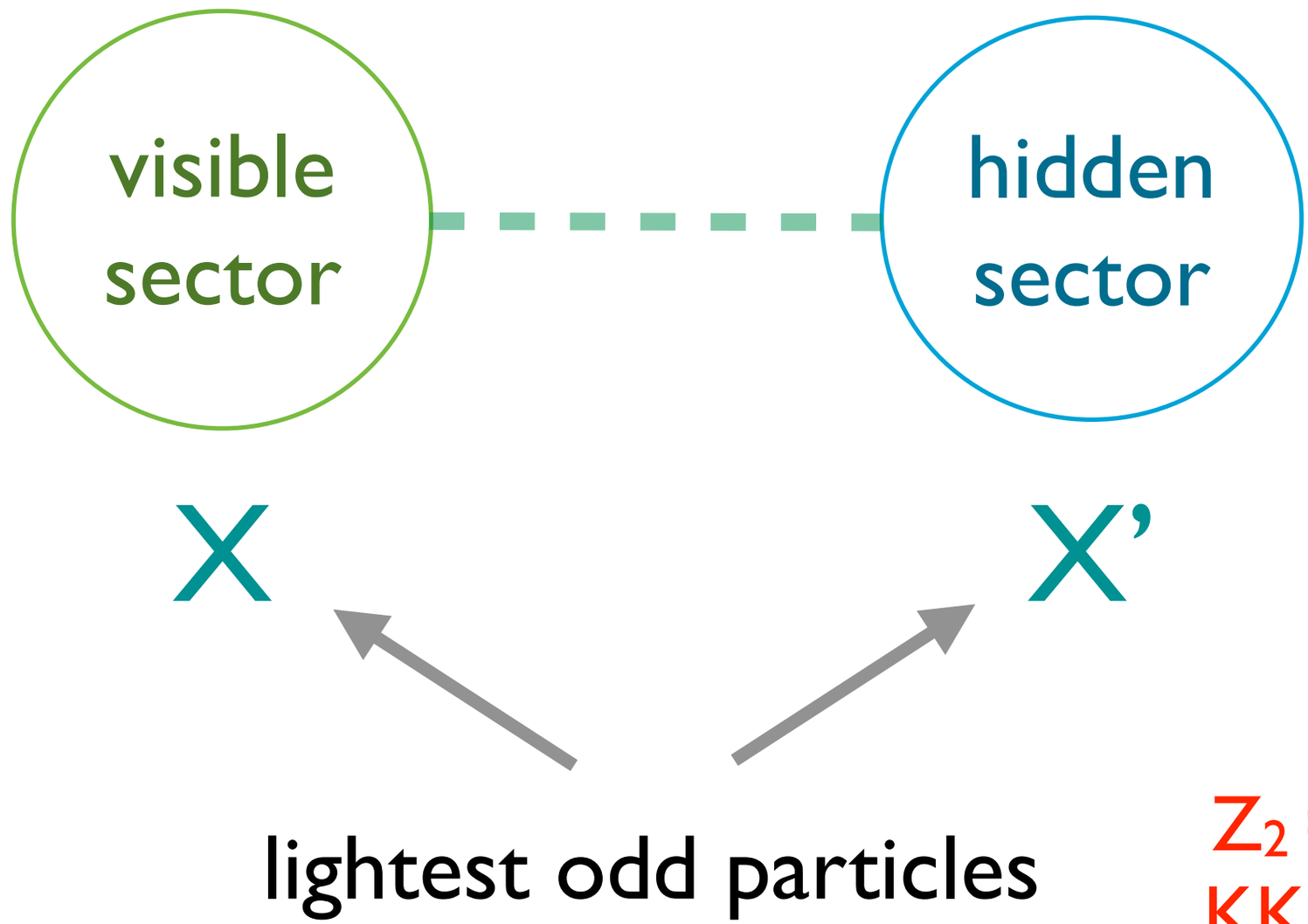


For example, even in the standard model...



The below setup arises very commonly.

Assume a Z_2 symmetry in sectors.



Z_2 = R-parity, KK-parity, etc

Different cosmological variations allowed:

(m > m') $X \to X' + \ldots$

(DM)

may include SM fields

(m' > m) $X' \to X + \ldots$

(DM)

Non-thermality + BBN implies 10^{-13} sec < τ < 1 sec.

Heavier state (X or X') can originate via freeze-out or any number of modes:

- out of equilibrium scattering or decays
- scalars relaxing to origin of potential
- topological defects via phase transition
- ... ???

What are there phenomenological signals for these cosmological scenarios?

- Direct detection is not required!

- Hidden degrees of freedom (N_{eff})

- How about X decays?

$$X \to X' + \ldots$$

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cosmic rays?

LHC?

X = long-lived charged massive particle?

Search for Stopped Gluinos in pp collisions at $\sqrt{s} = 7$ TeV

The CMS Collaboration*

Abstract

The results of the first search for long-lived gluinos produced in 7 TeV pp collisions at the CERN Large Hadron Collider are presented. The search looks for evidence of long-lived particles that stop in the CMS detector and decay in the quiescent periods between beam crossings. In a dataset with a peak instantaneous luminosity of 1×10^{32} cm^{-2}s^{-1}, an integrated luminosity of 10 pb^{-1}, and a search interval corresponding to 62 hours of LHC operation, no significant excess above background was observed. Limits at the 95% confidence level on gluino pair production over 13 orders of magnitude of gluino lifetime are set. For a mass difference $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} > 100\,\mathrm{GeV}/c^2$, and assuming BR($\tilde{g} \to g\tilde{\chi}_1^0$) = 100%, $m_{\tilde{g}} < 370\,\mathrm{GeV}/c^2$ are excluded for lifetimes from 10 μs to 1000 s.

By ascertaining the lifetime of extremely long-lived CHAMPs we can extend LHC reach.

τ = 1 sec $\mathcal{O}/m_{\mathrm{GUT}}$

τ = 3 hrs $\mathcal{O}/m_{\mathrm{Pl}}$

LHC can probe the GUT scale!

asymmetric DM

Asymmetric DM kills 2 birds with 1 stone.

bird #1 = dark matter of universe

bird #2 = baryon asymmetry of universe

To accommodate $\Omega_{\rm DM}/\Omega_{\rm B} \sim 5$, take:

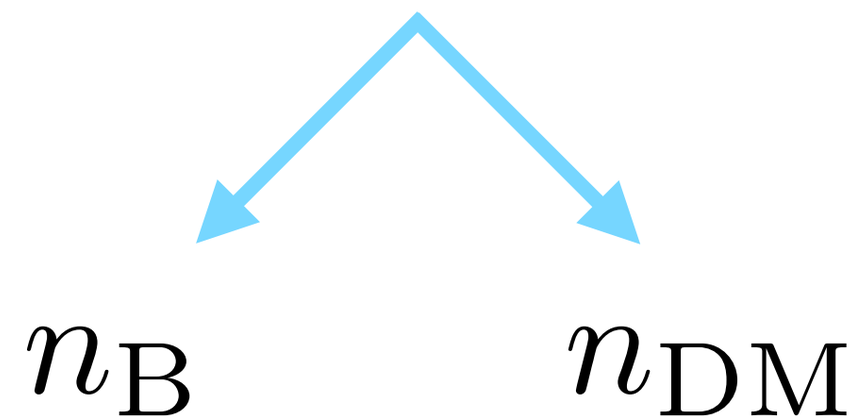
$$m_{\rm DM}/m_{\rm B} \sim 5 \qquad\qquad n_{\rm DM} \sim n_{\rm B}$$

The two flavors of asymmetric dark matter :

sharing

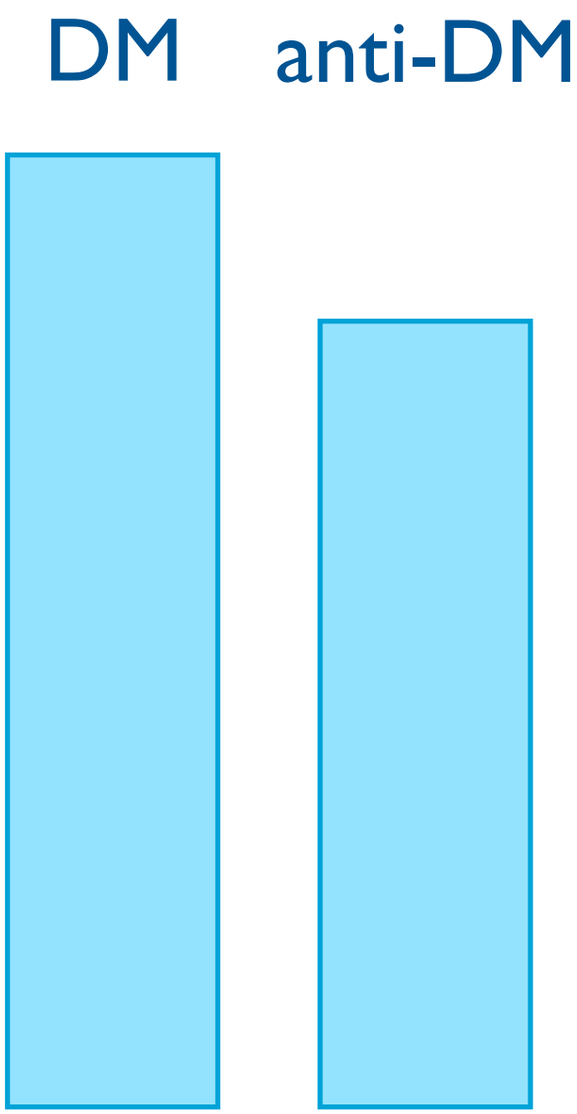
$$n_{\mathrm{B}} \longleftrightarrow n_{\mathrm{DM}}$$

cogenesis



How to make asymmetric DM: jerry-rig dark matter onto conventional baryogenesis.

The symmetric component annihilates away when the dark matter freezes out.



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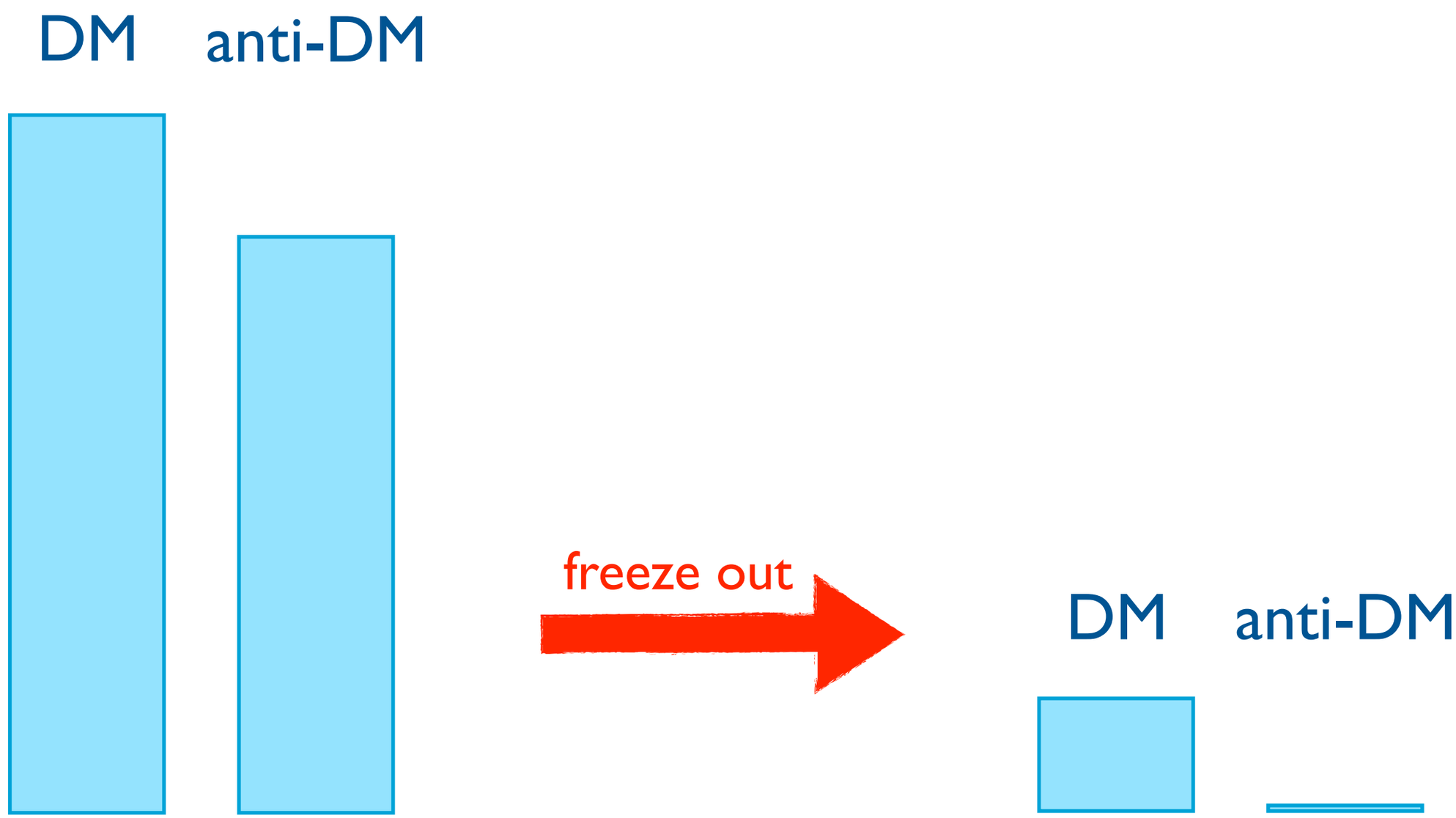


Asymmetric DM models employ two distinct global symmetries.

$$U(1)_{B-L} \times U(1)_X$$

Acts on SM.

Acts on hidden sector.

Break the symmetry to $U(1)_{B-L+X}$ with

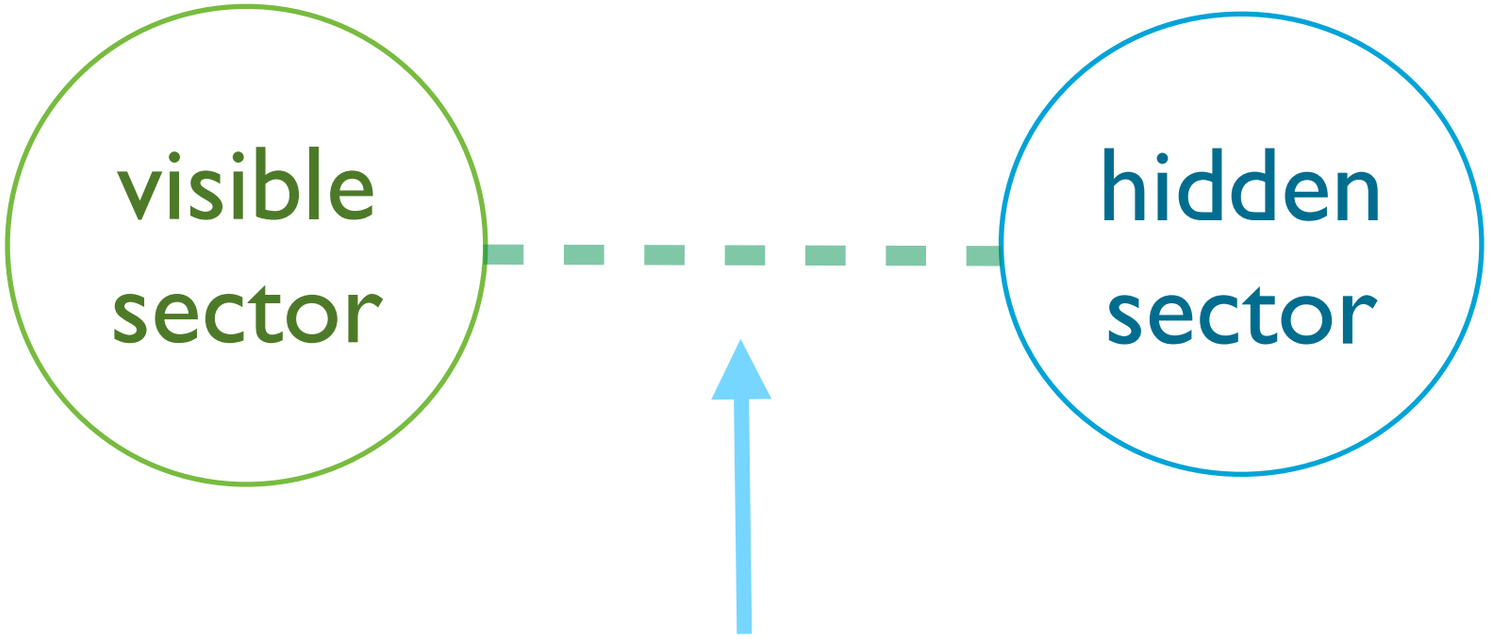
$$\mathcal{O}_{B-L}\mathcal{O}_X$$

where we have defined

$$\mathcal{O}_{B-L} = LH_u, QLD^c, \ldots$$

and so $-n_{B-L} = n_X \neq 0$ by symmetry.

Asymmetric DM models have a similar structure as non-thermal models...



$$\mathcal{O}_{B-L}\mathcal{O}_X$$

...except B-L and X preserving ops allowed.

conclusions

- There are many options besides WIMPs.

- There are many non-WIMPs beyond SUSY.

thanks!