FIMP from flavon portal

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(2305.03167)

JHEP 07 (2023) 143

PLANCK 2025

Why

Beyond Standard Model?

\# reasons why

- Neutrino mass
- Dark matter(!)
- Fermion mass hierarchy

and many more….

What are we doing?

- Trying to address **Fermion mass hierarchy** and **dark matter** from a common origin.

How?

Model Set up

- Gauge Group:

$$SM \otimes U(1)_{FN}$$

- Global abelian symmetry

- Particle content:
- S, flavon, a singlet complex scalar
- χ, a majorana fermion

The problem and the solution

- The problem
  - The wide range of fermion masses in the Standard Model

$m_u = 2.3 \pm 0.7$MeV	$m_c = 1275 \pm 25$MeV	$m_t = 173210 \pm 510$MeV
$m_d = 4.8 \pm 0.5$MeV	$m_s = 95 \pm 5$MeV	$m_b = 4180 \pm 30$MeV
$m_e = 0.51$MeV	$m_\mu = 105.658 \pm 38$MeV	$m_\tau = 1776.84 \pm 17$MeV

One of the solution

- Frogatt Nielson Mechanism

FN mechanism in a nut-shell

- Yukawa term in SM

$$Y^{ij}\bar{Q}_i H d_j$$

- In FN framework

$$y^{ij}\left(\frac{S}{\Lambda}\right)^{n_{ij}}\bar{Q}_i H d_j$$

Therefore

$$Y^{ij}=y^{ij}\,\epsilon^{n^{ij}}$$

where

$$\epsilon=\frac{v_S}{\sqrt{2}\Lambda}\approx 0.225$$

Flavon scenario

- The relation needed to respect U(1)$_{FN}$ symmetry is

$$n^d_{ij} = a_{Q_i} - a_H - a_{d_j}, \qquad n^u_{ij} = a_{Q_i} + a_H - a_{u_j}.$$

- The charge assignment of the fermions here are

$$\begin{pmatrix} a_{Q_1} & a_{Q_2} & a_{Q_3} \\ a_{u_1} & a_{u_2} & a_{u_3} \\ a_{d_1} & a_{d_2} & a_{d_3} \\ a_{L_1} & a_{L_2} & a_{L_3} \\ a_{e_1} & a_{e_2} & a_{e_3} \end{pmatrix} = \begin{pmatrix} 4 & 2 & 0 \\ 4 & 2 & 0 \\ 4 & 3 & 3 \\ 4 & 3 & 3 \\ 4 & 2 & 0 \end{pmatrix}$$

DM Phenomenology

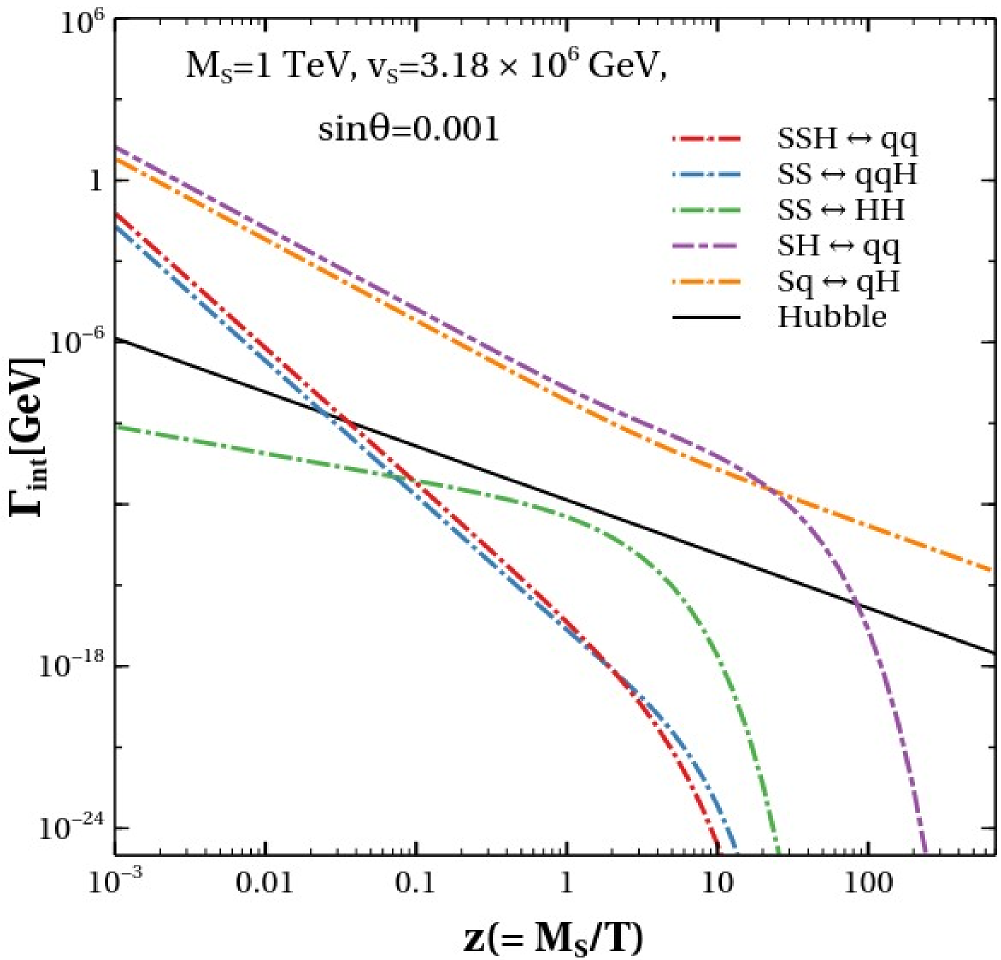
- We want a minimal model for dark matter and we chose a Majorana fermion as our candidate.
- The dark sector lagrangian looks like

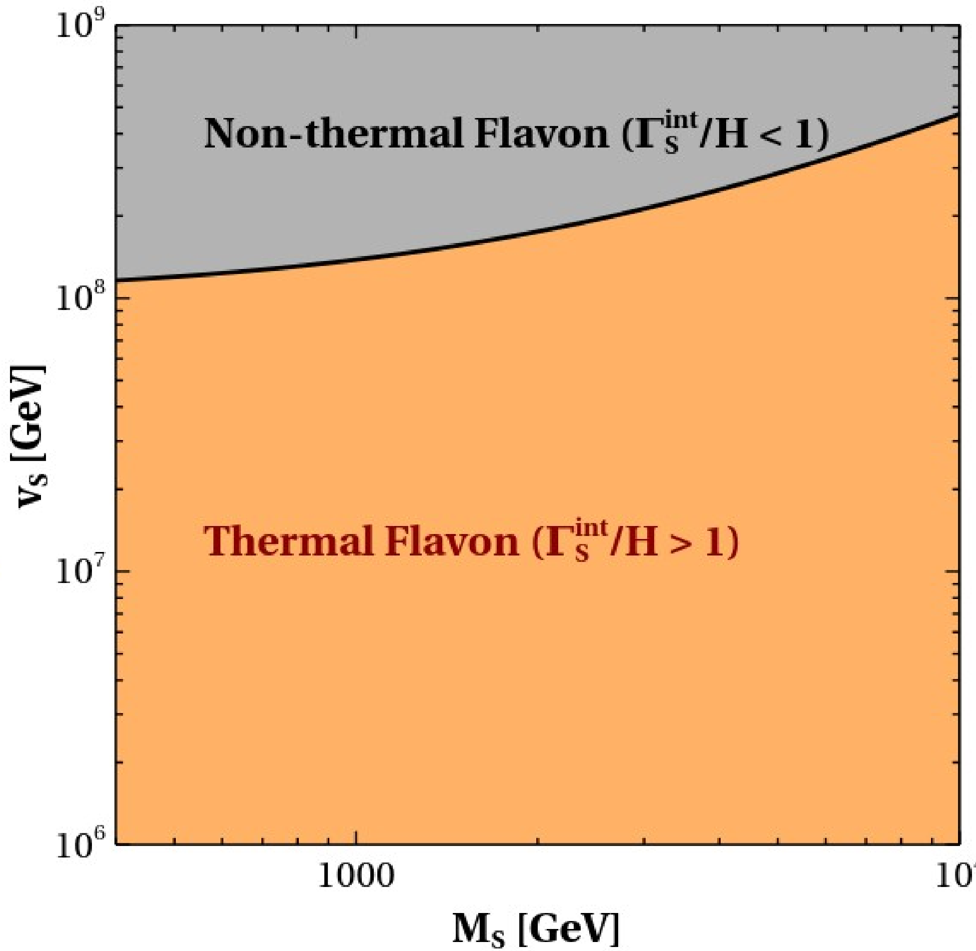
$$L_{DM}=\frac{1}{2}\bar{\chi}(i\gamma^{\mu}\partial_{\mu})\chi-y_{\chi}\left(\frac{S}{\Lambda}\right)^{2n-1}S\overline{\chi^{c}}\chi+h.c$$

where n is the $U(1)_{FN}$ charge of DM.

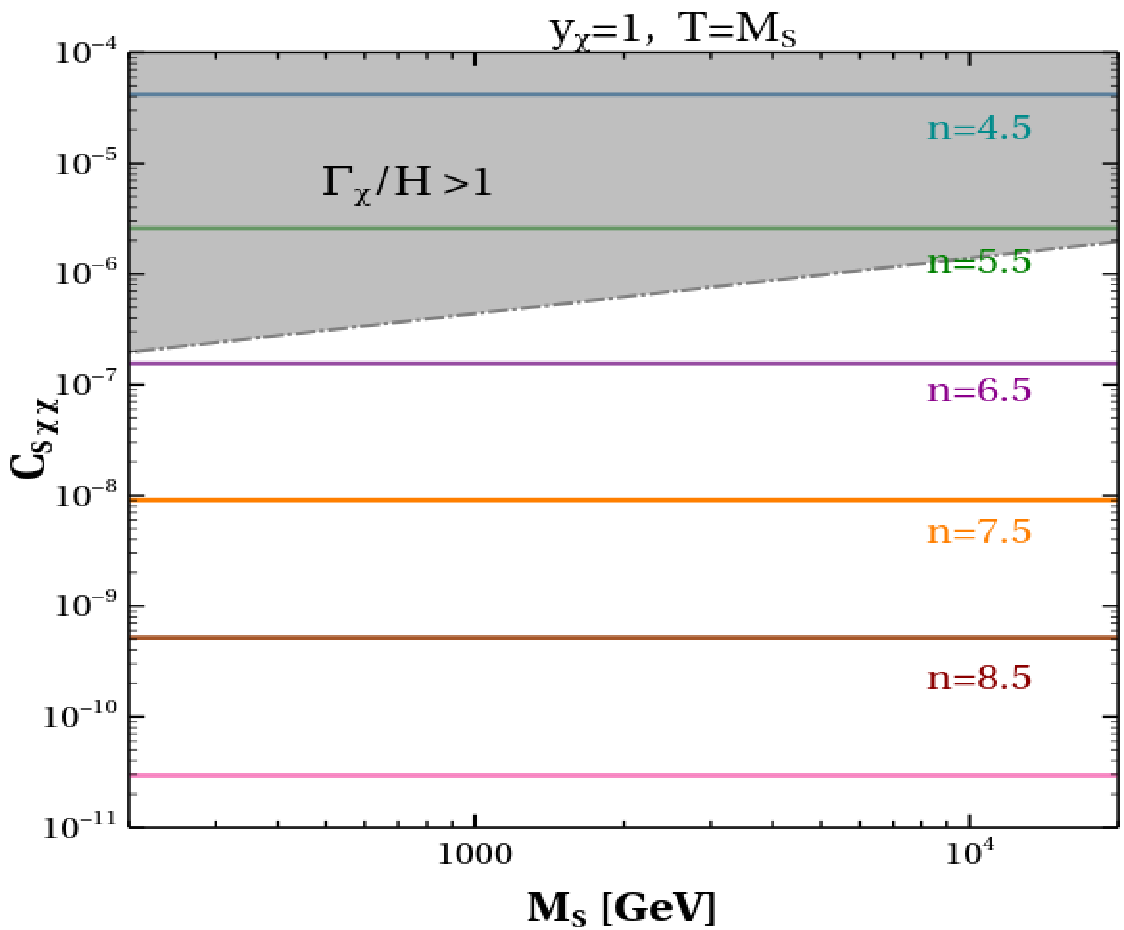
- For n being half integer, the dark matter is stable.
- For n being a little high, it can create freeze in coupling naturally.

Thermalisation of S





Condition for non-thermal DM



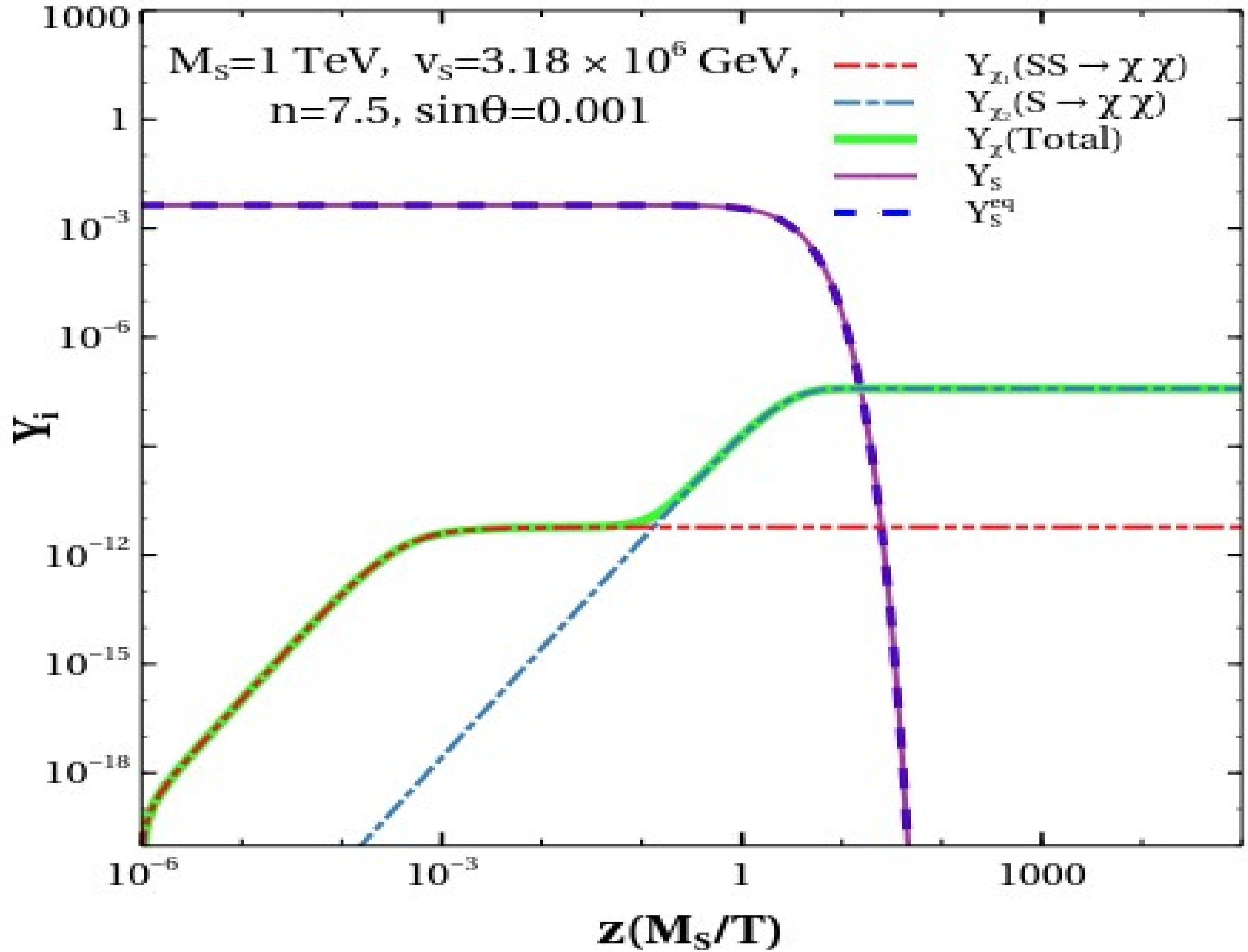
Boltzmann equation

$$\frac{dY_\chi}{dz} = \frac{\langle \Gamma(S \to \chi\chi) \rangle}{H\,z} Y_s(z) + \frac{4\pi^2}{45} \frac{M_{Pl} M_S}{1.66} \frac{\sqrt{g(z)}}{z^2} \langle \sigma v_{SS \to \chi\chi} \rangle Y_S^2(z)$$

$$\frac{dY_S}{dz} = -\frac{\langle \Gamma(S \to \chi\chi) \rangle}{H\,z} Y_s(z) - \frac{4\pi^2}{45} \frac{M_{Pl} M_S}{1.66} \frac{\sqrt{g(z)}}{z^2} \langle \sigma v_{SS \to \chi\chi} \rangle Y_S^2(z)$$

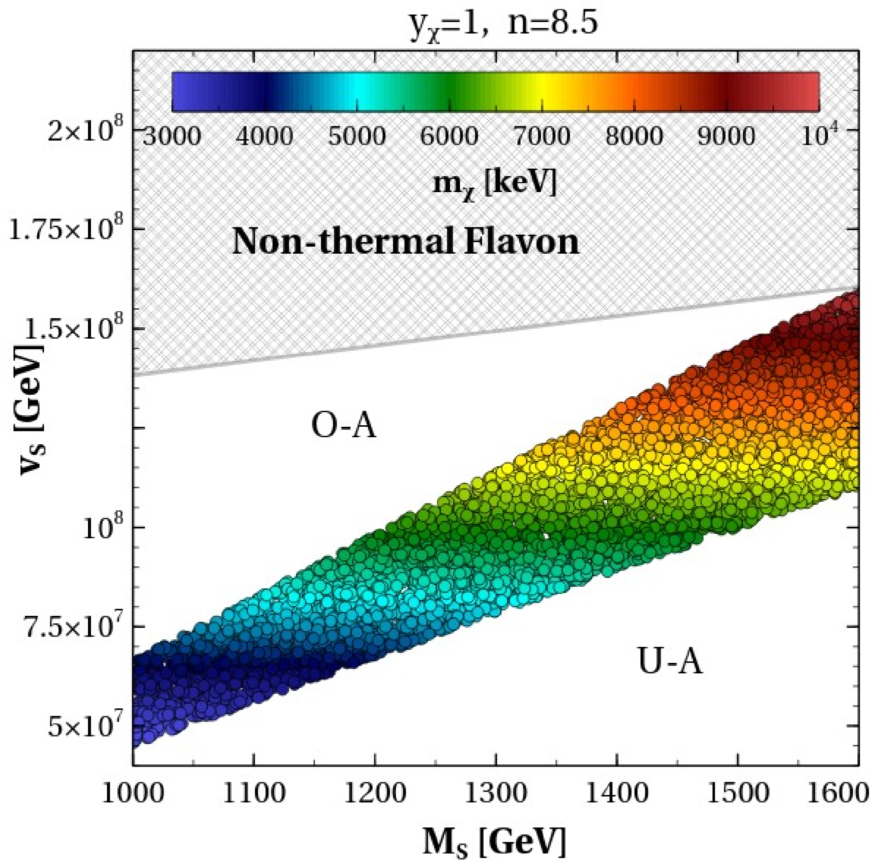
$$+ \, other\ terms$$

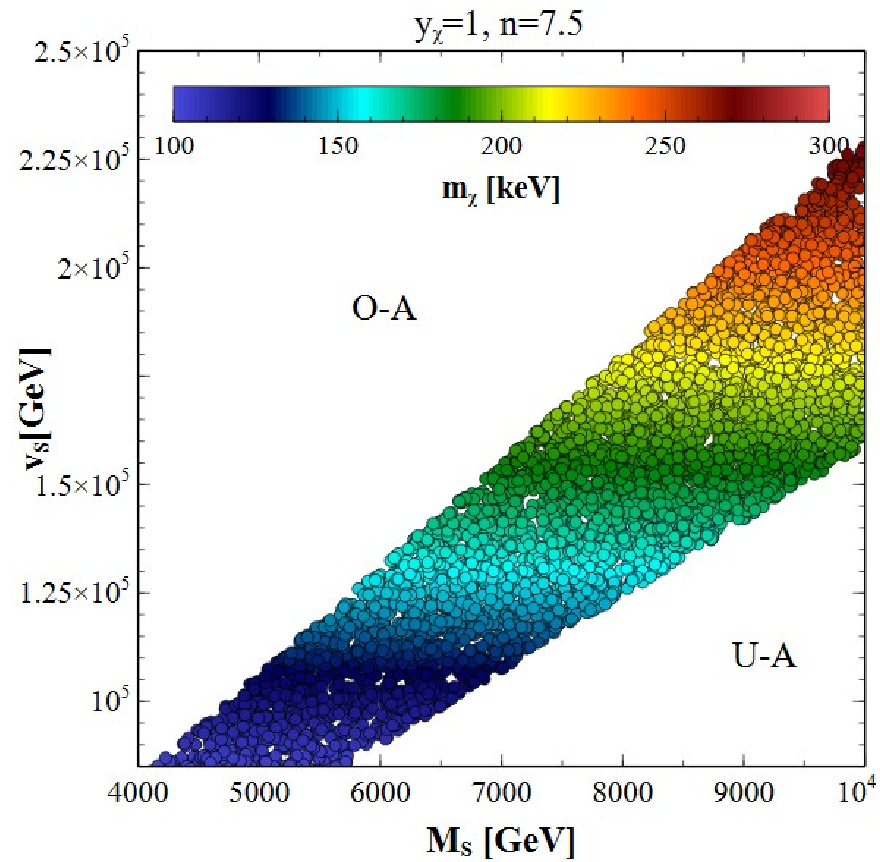
How it looks



M_S=1 TeV, v_S=3.18 × 10^6 GeV,
n=7.5, sinθ=0.001
$Y_{\chi_1}(SS \to \chi\chi)$
$Y_{\chi_2}(S \to \chi\chi)$
Y_χ(Total)
Y_S
Y_S^{eq}
Y_i
z(M_S/T)
1000
1
10^{-3}
10^{-6}
10^{-12}
10^{-15}
10^{-18}
10^{-6}
10^{-3}
1
1000

DM abundance





Summary

- In this work, we have proposed a unified solution to the fermion mass hierarchy and a FIMP dark matter within a class of $U(1)_{FN}$ extensions of the Standard Model.
- We have shown a preferred range for the DM mass, which is (100-300) keV and (3-10) MeV, corresponding to n = 7.5 and 8.5 respectively.

Thank You