Dark Matter & Black Holes 2025

Fermionic Freeze-in from Flavon portal

Nandini Das

Department of Physics and Astrophysics,

University of Delhi

Quick Recap: Dark Matter

- Dark Matter is a non-luminous, non-baryonic form of matter which constitutes roughly 26% of the energy density of the Universe.
- Observational evidences only strengthen its existence.
- However the nature of DM is still unknown.
- Our dark matter is a particle, here it is considered to be a fermion.
- Among the production mechanisms of dark matter, Freeze out is the most popular one, the next option is Freeze in.

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 solutions

- Frogatt Nielson Mechanism

Model Set up

- Symmetry:

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

- Global abelian symmetry

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

FN mechanism in a nut-shell

- Yukawa term in SM
- In FN framework

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

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

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

Flavon scenario

- The relation to be respected to conserve $U(1)_{FN}$ symmetry is

$$n_{ij}^{d} = a_{Q_i} - a_H - a_{d_j}, \qquad n_{ij}^{u} = a_{Q_i} + a_H - a_{u_j}.$$

- 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

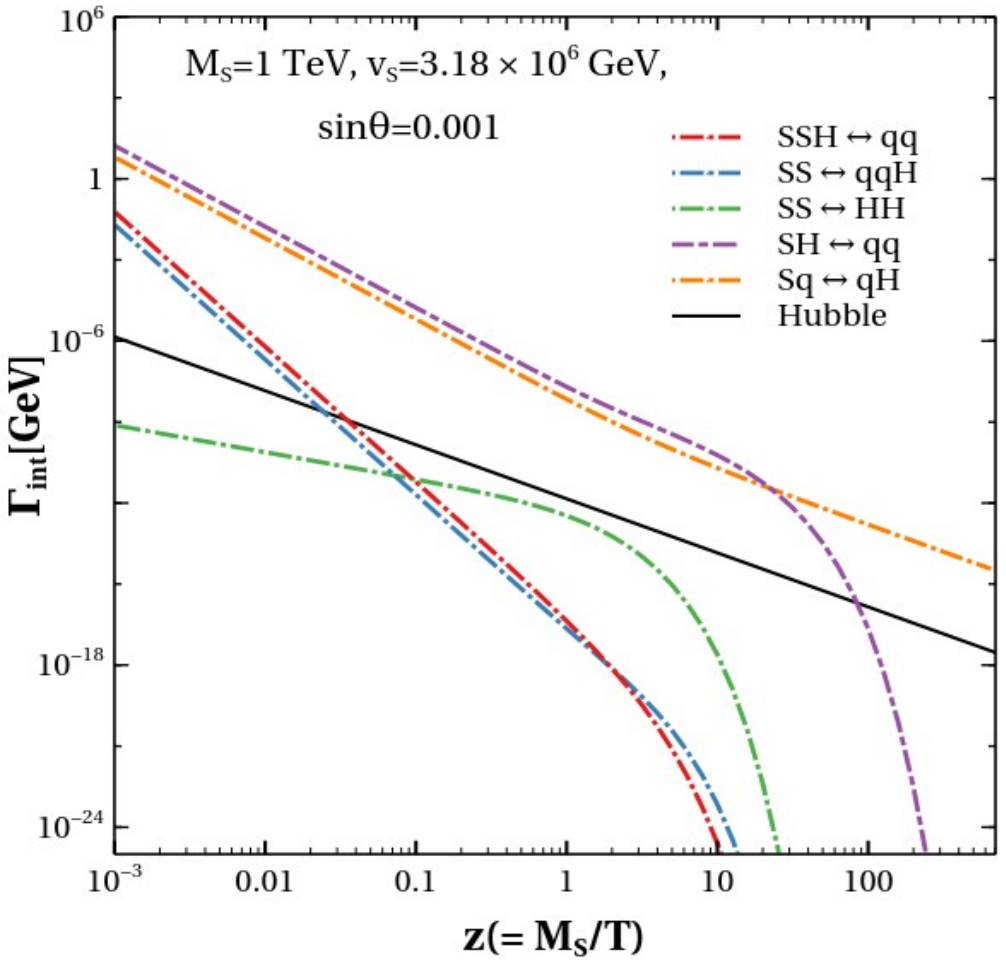
- We want a minimal model for dark matter and we chose a Majorana fermion as our candidate.
- The dark sector Lagrangian looks like

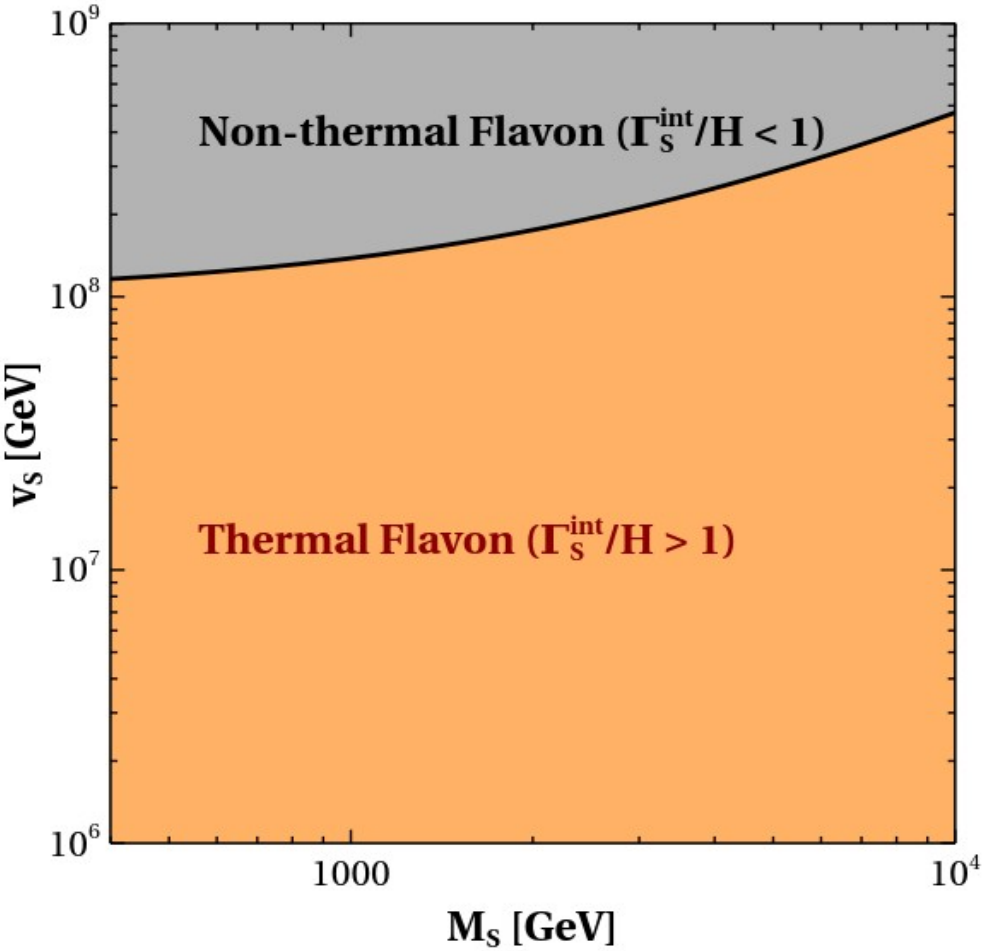
$$L_{DM} = \frac{1}{2}\bar{\chi}(i\gamma^{\mu}\partial_{\mu})\chi - y_{\chi}\left(\frac{S}{\Lambda}\right)^{2n-1} S\overline{\chi^{c}}\chi + h.c$$

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

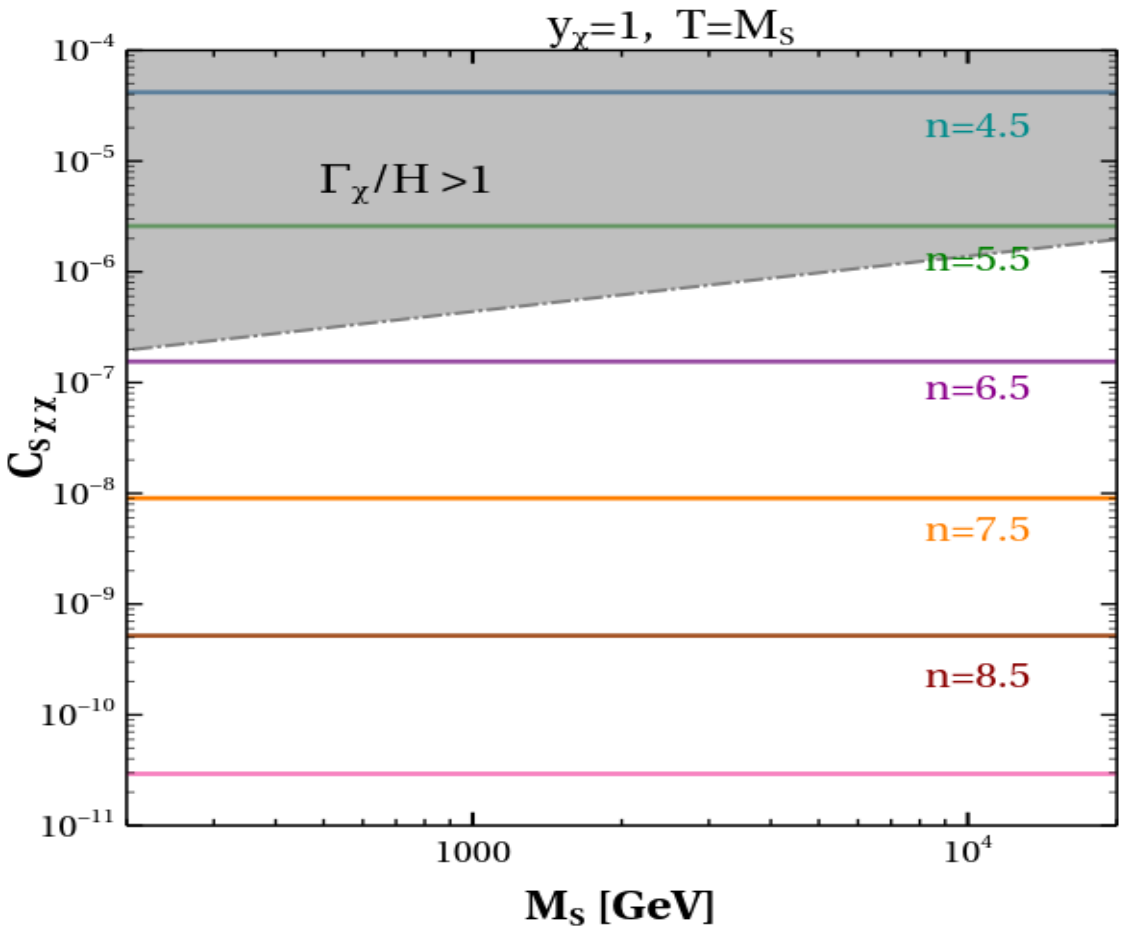
- For n being half integer, the dark matter is stable.
- For n being a little high, it can create freeze in coupling naturally.

Thermalisation of S





Condition for non-thermal DM



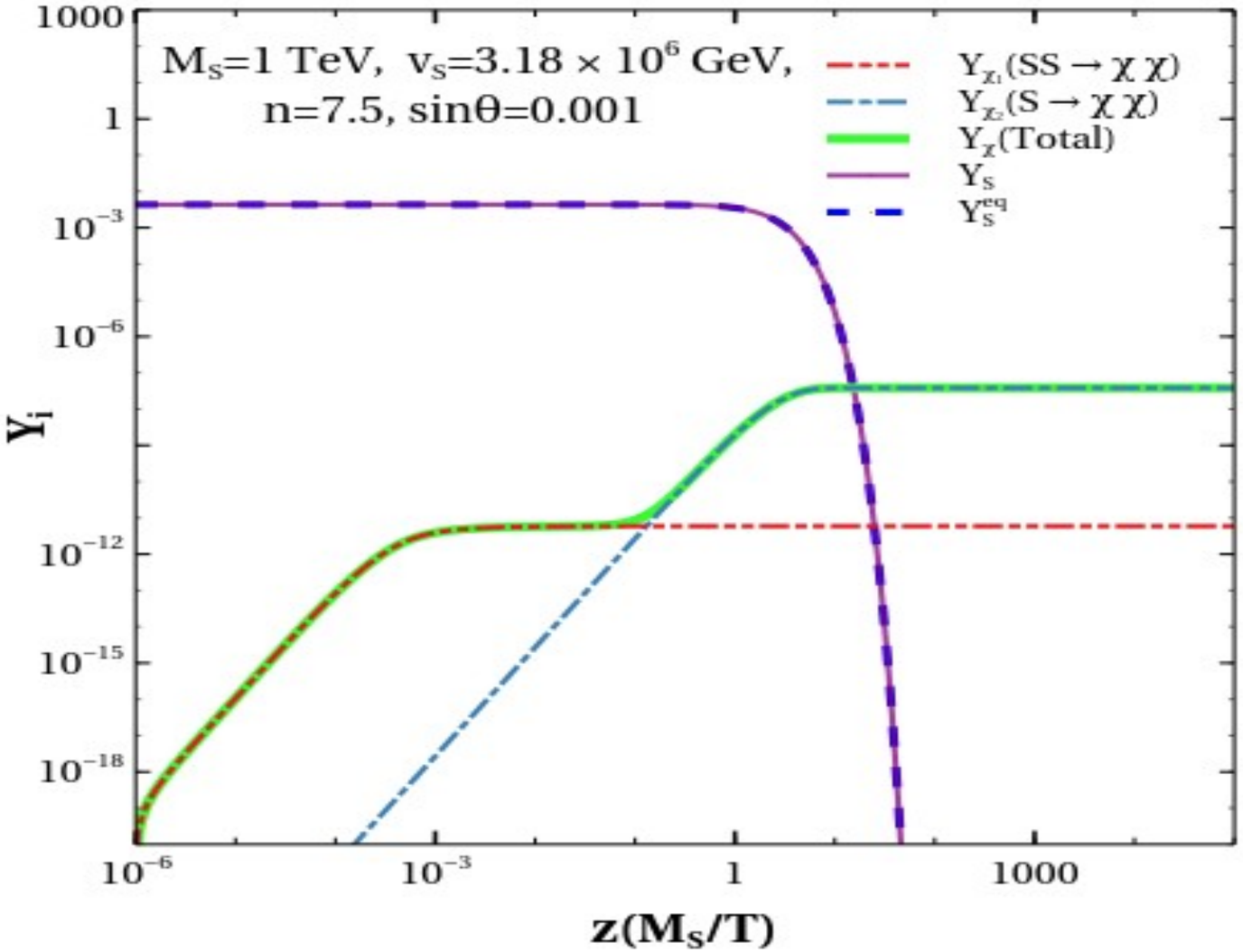
Boltzmann equation

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

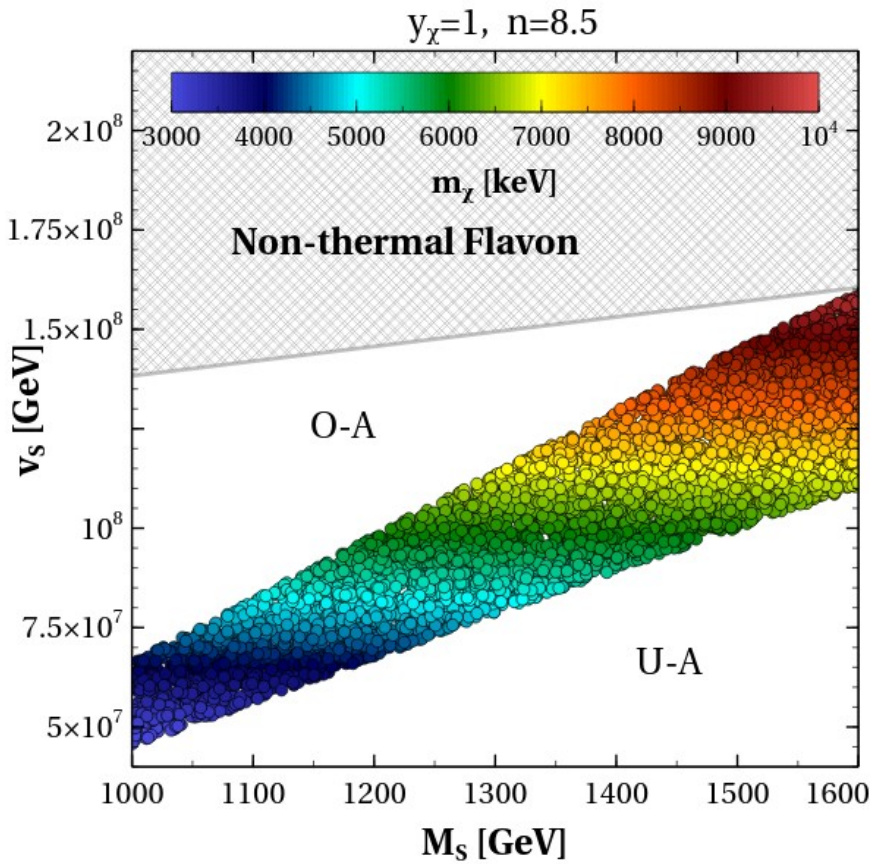
$$\frac{dY_S}{dz} = -\frac{\langle \Gamma(S \to \chi\chi) \rangle}{H\, z} Y_s(z) - \frac{4\pi^2}{45} \frac{M_{Pl} M_S}{1.66} \frac{\sqrt{g(z)}}{z^2} \langle \sigma v_{SS \to \chi\chi} \rangle Y_S^2(z)$$

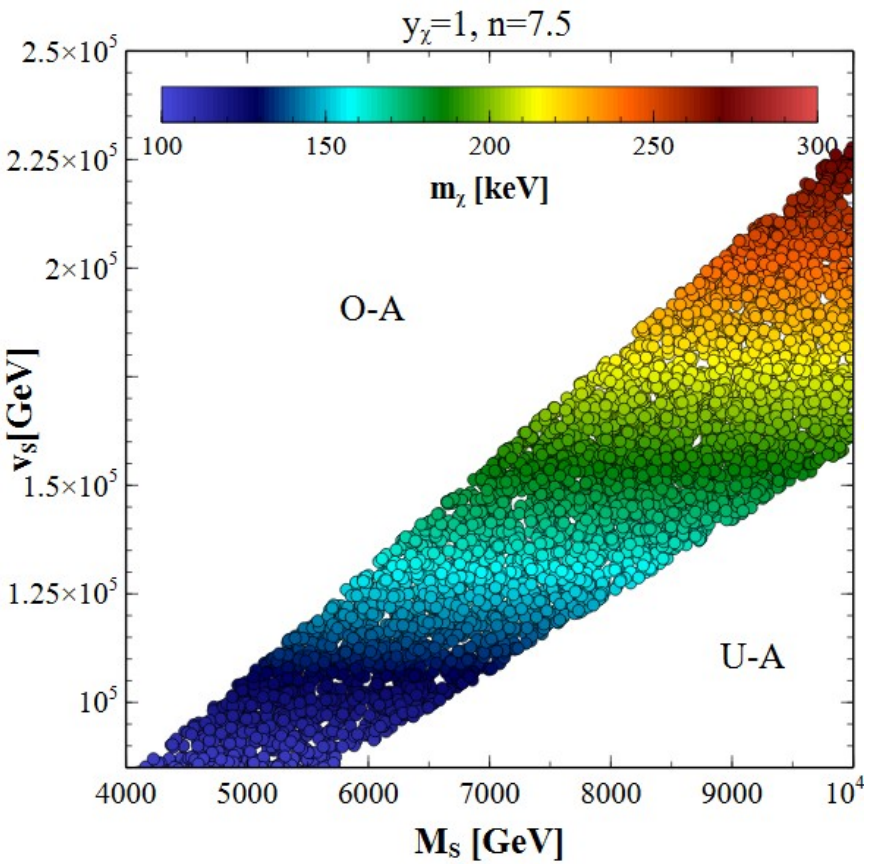
$$+ other\ terms$$

Evolution under B. Eq.



DM abundance





Summary

- We found a unified solution to fermion mass-hierarchy and dark matter problem.
- For n=7.5 and n=8.5, we found dark matter in MeV and keV mass range satisfying 100% of relic density.

Based on

- FIMP dark matter from flavon portals

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Thank You