Freezing in with Lepton Flavored Fermions

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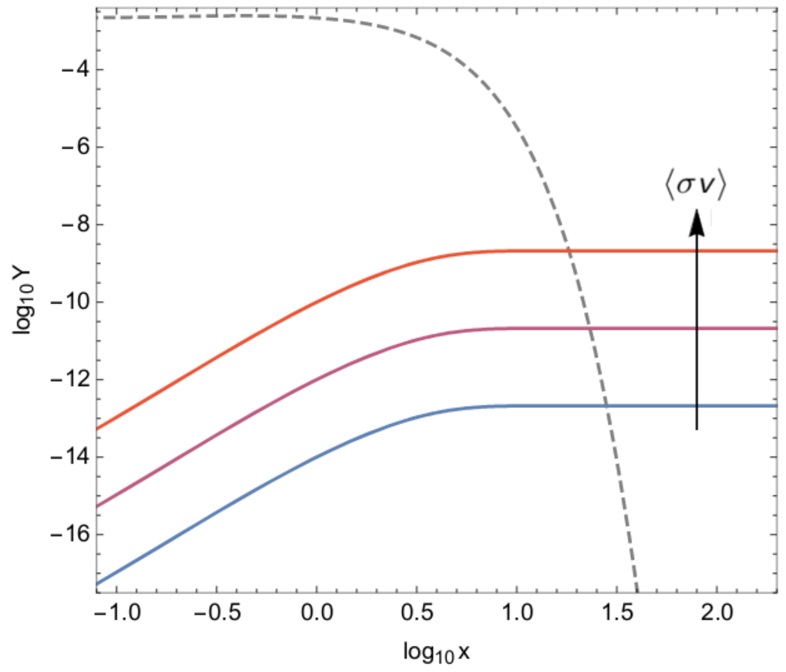
Freeze-in DM & Minimal Flavor Violation (MFV)

- Freeze-in
  - Non-thermalized: **small couplings**
  - Negligible initial abundance



- Small couplings make detection difficult

Electron Yukawa is a *small* parameter in the SM

Minimal Flavor Violation

$$\mathcal{L}_{SM} \supset i\bar{L}\not{D}L + i\bar{e}_R\not{D}e_R + \bar{L}Y_l e_R H$$

$$L\sim\begin{pmatrix} l_e \\ l_\mu \\ l_\nu \end{pmatrix}, \qquad e_R\sim\begin{pmatrix} e_R \\ \mu_R \\ \tau_R \end{pmatrix}$$

$$L\sim(3,1),\ e_R\sim(1,3), Y_l\sim(3,\bar{3})$$

$$G_{LF}\sim SU(3)_L \otimes SU(3)_{e_R}$$

- Flavor violation only arise from SM Yukawas

Lepton flavored DM under MFV

- Introduce a chiral, fermionic DM transforming nontrivially under flavor group:

$\chi_L \sim (3,1)_{G_{LF}} \sim (\chi_1, \chi_2, \chi_3)_L, \quad \chi_R \sim (1,3)_{G_{LF}} \sim (\chi_1, \chi_2, \chi_3)_R$, where $G_{LF} \sim SU(3)_L \otimes SU(3)_{e_R}$

$$\mathcal{L} \supset \underbrace{\frac{1}{2\Lambda_{MFV}}(\bar{\chi}_L \sigma_{\mu\nu} Y_l \chi_R) B^{\mu\nu}}_{\text{Magnetic dipole moment } (MDM)} + \underbrace{\frac{i}{2\Lambda_{MFV}}(\bar{\chi}_L \sigma_{\mu\nu} \gamma_5 Y_l \chi_R) B^{\mu\nu}}_{\text{Electric dipole moment } (EDM)} + \underbrace{\frac{1}{2\Lambda_{MFV}}(\bar{\chi}_L \sigma^{\mu\nu} Y_l \chi_R) H^\dagger H}_{\text{H-mediated}}$$

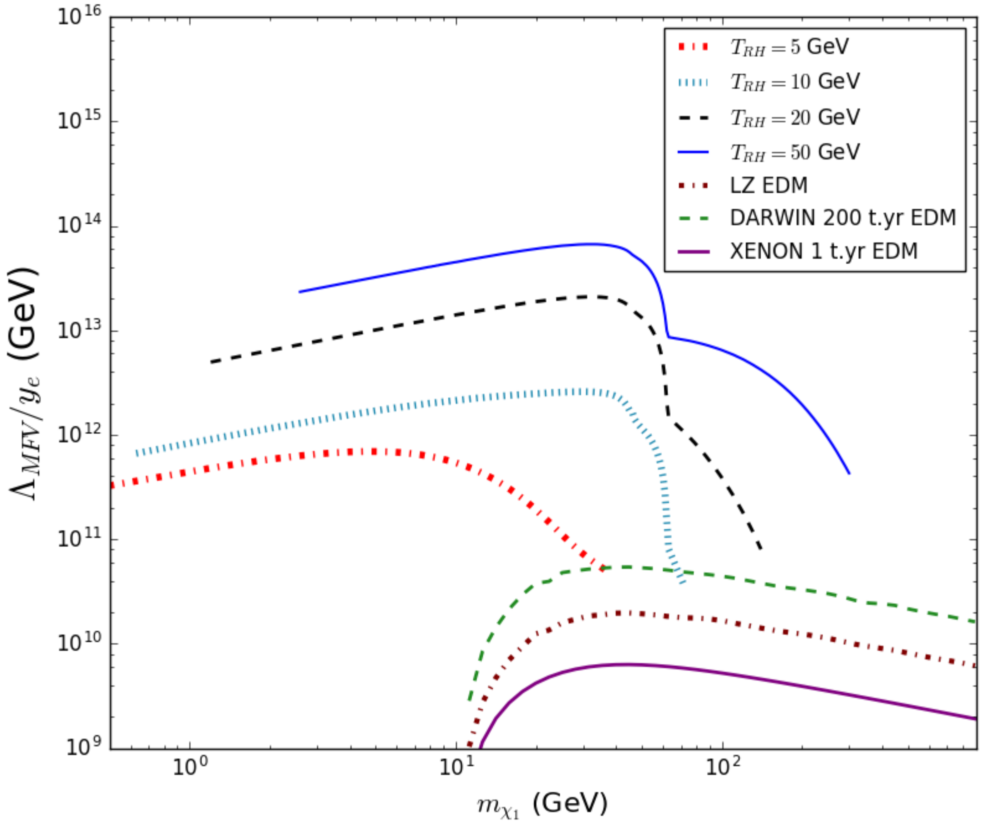
and the masses of the DM partners get related by:

$$m_\chi(\bar{\chi}_L \sigma_{\mu\nu} Y_l \chi_R) \Longrightarrow m_{\chi_1} : m_{\chi_2} : m_{\chi_3} = m_e : m_\mu : m_\tau$$

Stability?	Detection
$\mathcal{O}_{decay} = \chi L \ldots \bar{L} \ldots e_R \ldots \bar{e}_R \ldots Y_l \ldots Y_l^\dagger \ldots \mathcal{O}_{weak}$ ○ MFV + Lepton number conservation renders certain DM representations stable up to all orders.	○ UV freeze-in: dependent on reheating temperatures ○ Photon mediated $\Longrightarrow$ Enhancement in direct detection signals

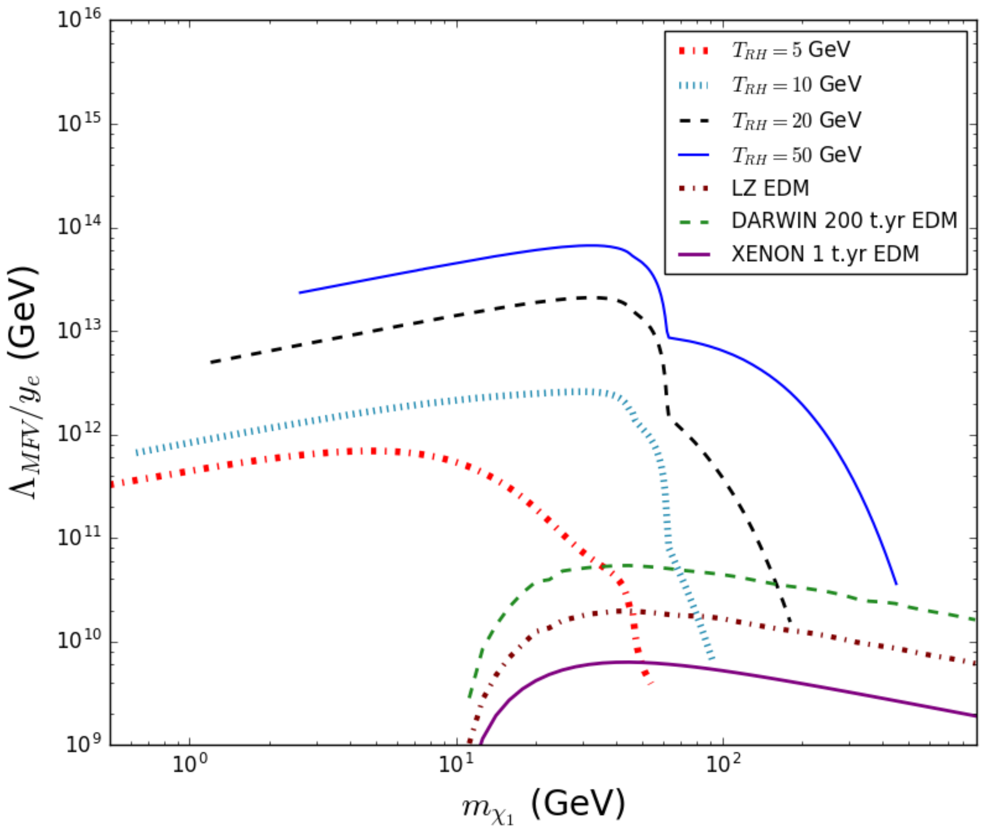
Results: $G_{LF} \sim SU(3)_L \otimes SU(3)_{e_R}$

- Conditions:
  - $\Lambda_{MFV} > T_{RH}$
  - $m_{\chi_1}, m_{\chi_2}, m_{\chi_3} < \Lambda_{MFV}$
  - The lightest DM partner χ_1 also has the smallest coupling, form the complete relic abundance ($m_{\chi_2} \gg T_{RH}$)
- Future direct detection experiments will probe parts of the parameter space



Results: $G_{LF} \sim SU(2)_L \otimes SU(2)_{e_R}$

- Conditions:
  - $\Lambda_{MFV} > T_{RH}$
  - $m_{\chi_1}, m_{\chi_2} < \Lambda_{MFV}$
  - The lightest DM partner χ_1 also has the smallest coupling, and forms the complete relic abundance ($m_{\chi_2} \gg T_{RH}$)
- XENON1T already rules out parts of the parameter space with future experiments probing it more extensively.



Thank you!