Vector Strongly Interactive Massive Particles as Dark Matter

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Motivation and main idea

- ΛCDM provides an excellent description of structure formation.

- However small scales controversies with simulations : "Core VS Cusp", "Missing satellites" and "Too big too fail" problems.

  $\rightarrow$ Self interacting DM as a solution? $\dfrac{\sigma_{\text{self}}}{m_X} \simeq 0.1 - 10\ \text{cm}^2.\text{g}^{-1}$

- The WIMP paradigm is strongly challenged by experiments

- Still no evidence of SUSY

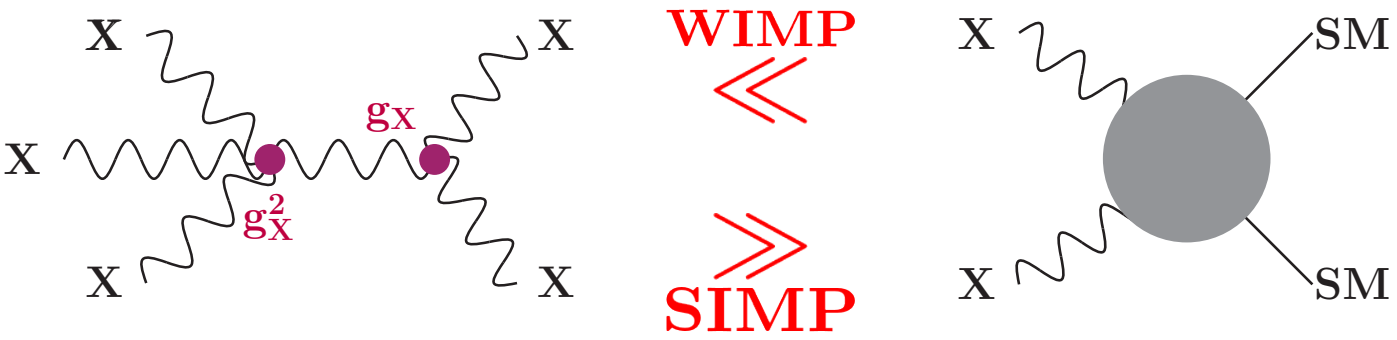
  $\rightarrow$ Is the EW scale well motivated?

Can we have a thermal DM scenario addressing these issues?

The Strongly Interactive Massive Particles miracle

- In the SIMP mechanism [E. Kuflik et al. 14', N. Bernal et al. 15'], the DM density (n_X) evolution is given by the Boltzmann equation :

$$\frac{dn_X}{dt} = -3Hn_X - \underbrace{\langle\sigma v^2\rangle_{3\to 2}}\left(n_X^3 - n_X^2 n_X^{\rm eq}\right) - 2\underbrace{\langle\sigma v\rangle_{\rm ann}}\left(n_X^2 - (n_X^{\rm eq})^2\right)$$



- Is the dark sector **secluded** from the SM ? The **$3 \to 2$ heat the DM**
  Hot DM in conflict with structure formation !
  $\to$ **Need for interactions with SM !**

- Relic density :

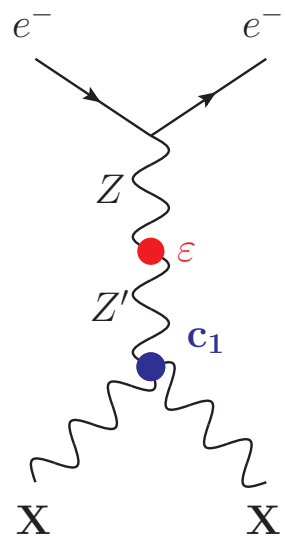
$$\Omega_X h^2 \simeq 0.3\left(\frac{m_X}{100\ \text{MeV}}\right)^{3/2} g_X^{-3}$$

Theoretical setup

Starting from an extended dark gauge structure $\mathbf{SU(2)_X} \times U(1)_{Z'}$

3 DM candidates = $\mathbf{SU(2)_X}$ gauge fields $\vec{\mathbf{X}}$

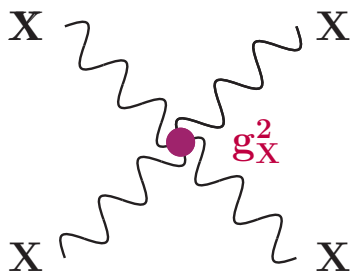
- $SU(2)_X$ broken by dark doublet Φ : $|D_\mu \Phi|^2 \supset \frac{\mathbf{g_X^2} v_X^2}{2} \vec{\mathbf{X}}_\mu \cdot \vec{\mathbf{X}}^\mu$
- Z' coupled though **kinetic mixing** with SM hypercharge :
  $\mathcal{L} \supset \frac{1}{2} \sin \boldsymbol{\epsilon} Z'_{\mu\nu} B^{\mu\nu} + \frac{m_{Z'}^2}{2} Z'_\mu Z'^\mu$
- Introduction of a **Chern-Simons** effective coupling :
  $\mathcal{L}_{\mathrm{CS,EFT}} = \mathbf{c_1} \epsilon^{\mu\nu\rho\sigma} Z'_\mu \vec{\mathbf{X}}_\nu \cdot (\partial_\rho \vec{\mathbf{X}}_\sigma - \partial_\sigma \vec{\mathbf{X}}_\rho)$
- DM-SM kinetic equilibrium ensured by scattering

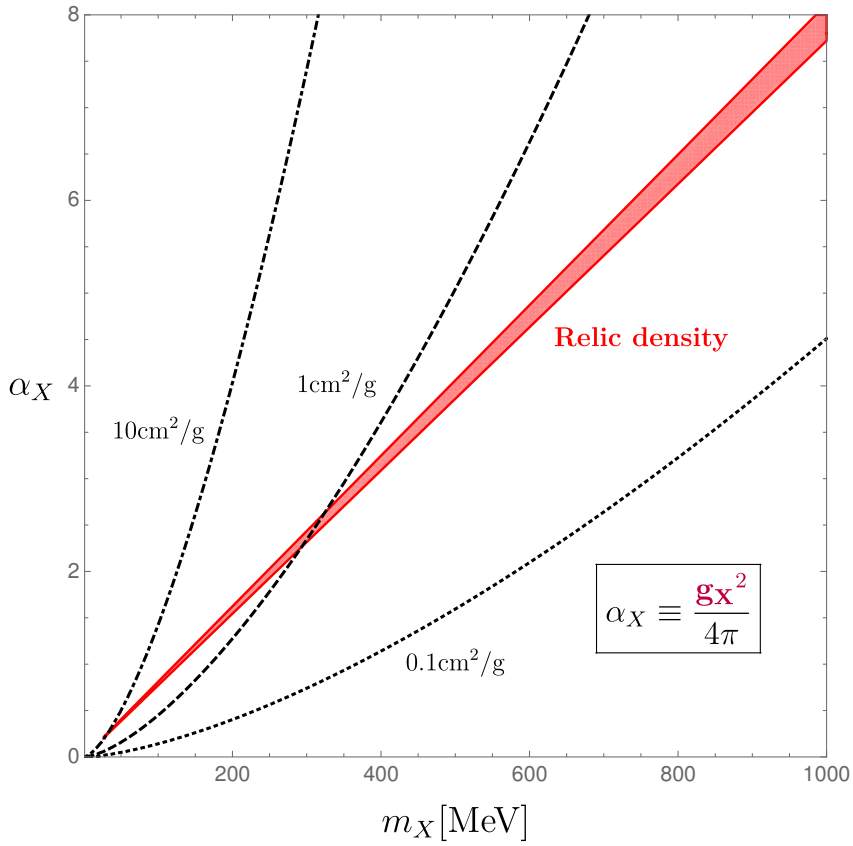


Relic density and self interacting DM

Self interaction cross section :

$$\frac{\sigma_{\rm self}}{m_X} = 0.05\ {\rm cm}^2 \cdot {\rm g}^{-1} \left(\frac{100\ {\rm MeV}}{m_X}\right)^3 \mathbf{g_X^4}$$





Conclusion

Summary

- What ? Self interacting DM candidate
- Why ? Potential solution to the small scales controversies.
- How ? Non abelian gauge field as DM and the SIMP mecanism

Didn't have time to talk about (feel free to discuss!) :

- Constraints on the parameter of the model.
- UV completion $\rightarrow$ loop generation of the Chern-Simons coupling.
- Resonances and forbidden channel contributions to the relic density.
- Other subtleties of the model ...

Thank you for your attention!