SU(2) Vector Dark Matter with a light massive mediator

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Overview

Introduction
Motivation/Goal

- Simple non-Abelian model of self interacting dark matter.
- UV complete
- light massive vector mediator
- stable/long lived dark matter
- kinetic non-Abelian portal to Standard Model
- long range interaction $\left(V \sim -\frac{\alpha_D e^{-m_{A^0} r}}{r}\right)$

Particle Content of the Model

$$SU(2) \times \mathbb{Z}_3 \xrightarrow{\langle\phi\rangle\neq 0} U(1) \times \mathbb{Z}_3 \xrightarrow{\langle H\rangle\neq 0} \emptyset$$

Particle	$SU(2)_D$	$\mathbb{Z}_3$
$\phi=(\phi^-, \phi^+, \phi^0)$	3	1
$H=(h_u^{+1/2}, h_d^{-1/2})$	2	ω

$$\mathscr{L}_{new} \supset -\frac{1}{4} W^a_{\mu\nu} W^{a\mu\nu} + |D_\mu H|^2 + |D_\mu \phi|^2 - V(H,\phi)$$

$$\begin{aligned} V(H,\phi) = & -\mu_H^2 H^\dagger H + \frac{\lambda_H}{2} \left(H^\dagger H\right)^2 \\ & - \frac{\mu_\phi^2}{2} \phi^\dagger \phi + \frac{\lambda}{4!} \left(\phi^\dagger \phi\right)^2 \\ & + \lambda_{H\phi} \left(H^\dagger H\right) \left(\phi^\dagger \phi\right) + \mu_3 H^\dagger \vec{\sigma} \cdot \vec{\phi} H \end{aligned}$$

Particle Mass Spectrum

$$\left\langle h_d^{-1/2} \right\rangle = \nu \quad \left\langle \phi^0 \right\rangle = u$$

$$\mu_H^2 = (2u^2\lambda_{H\phi} - 2u\mu_3 + \lambda_H\nu^2)/2$$

$$\mu_\phi^2 = (u^3\lambda_\phi + 6u\lambda_{H\phi}\nu^2 - 3\mu_3\nu^2)/(6u)$$

H + ϕ (7 DoF) $\rightarrow$ 1$\times$Complex Field + 2$\times$Radial Modes + 3$\times$GoldStone Bosons

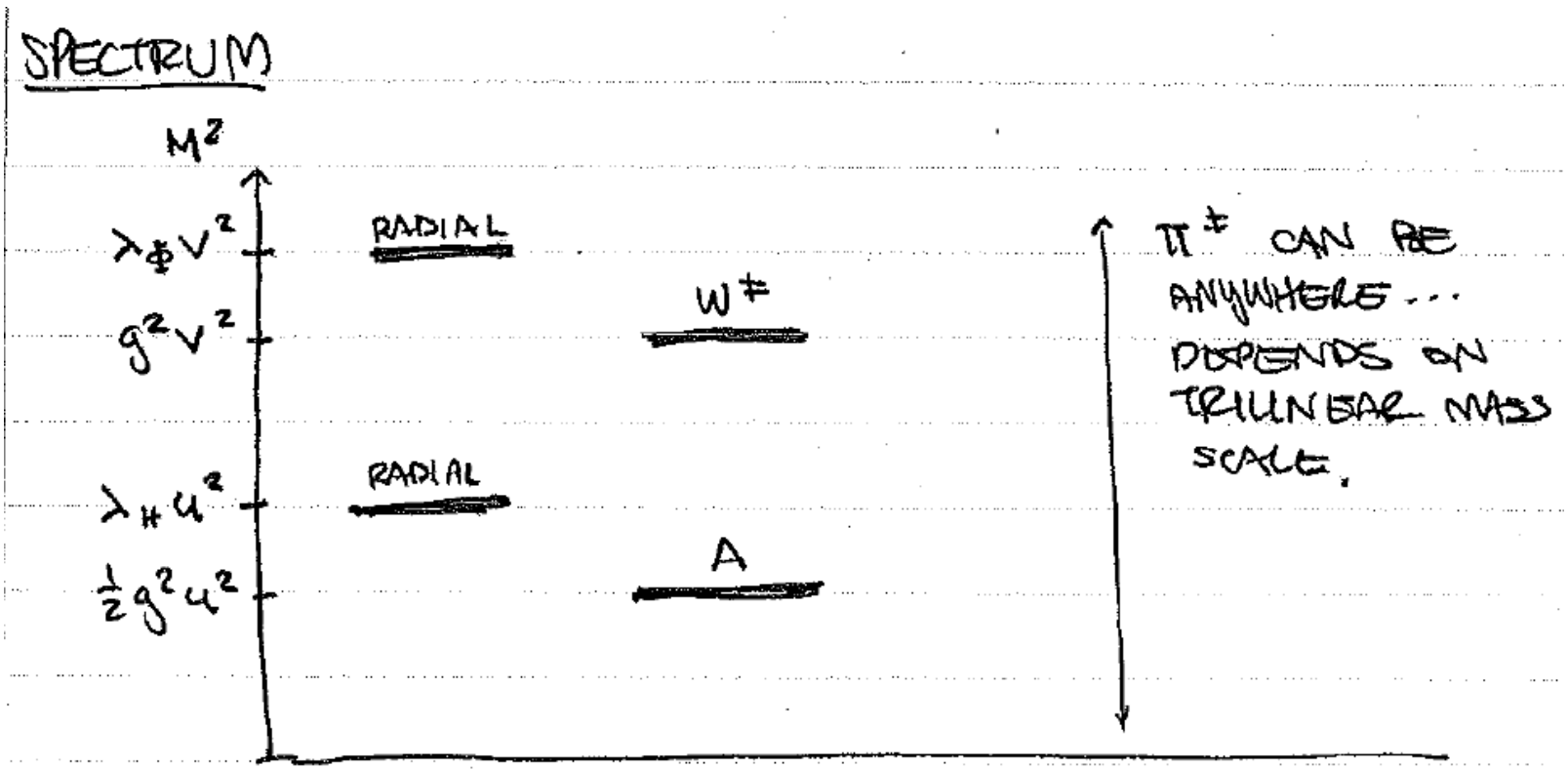
$$M^2_{h_d^{-1/2},\phi^0} = \begin{pmatrix} \lambda_H\nu^2 & (2u\lambda_{H\phi} - \mu_3)\nu \\ (2u\lambda_{H\phi} - \mu_3)\nu & (2u^3\lambda_\phi + 3\mu_3\nu^2)/(6u) \end{pmatrix}$$

$$m^2_{\pi^\pm} = \frac{\mu_3\left(4u^2 + \nu^2\right)}{2u}$$

$$\text{DM} \rightarrow m^2_{A^\pm} = g_D^2\left(\frac{\nu^2}{4} + u^2\right)$$

$$\text{light mediator} \rightarrow m^2_{A^0} = g_D^2\nu^2/4$$

Hierarchy



Dark Matter Stability

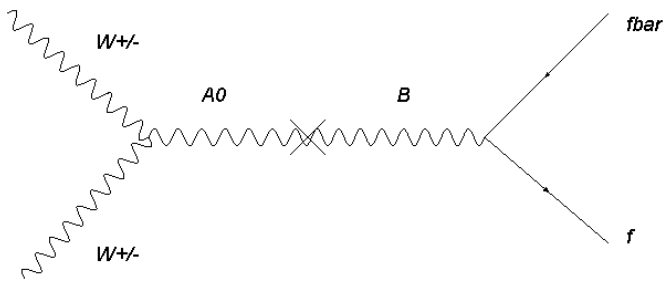
- No $\mathbb{Z}_3 \rightarrow \Delta\mathcal{L} = \left(\mu_4 H^\dagger \vec{\sigma} \cdot \vec{\phi} \tilde{H} + h.c.\right)$
- induces mixing between $\left(h_u^{1/2}, h_d^{-1/2}, \phi^\pm, \phi^0\right)$
- gives $W^\pm \rightarrow A^0 A^0$ at 1 loop level
- with $\mathbb{Z}_3$ μ_4 term is forbidden, cannot write gauge&$\mathbb{Z}_3$ invariant $\Delta Q_D = \pm 1$ operator

Portal to Standard Model

non-Abelian Kinetic Mixing Portal

$$\Delta\mathcal{L}_{mix} = -\epsilon\frac{\vec{\phi}\cdot\vec{W}_{D\mu\nu}B^{\mu\nu}}{\Lambda}$$

$$\Delta\mathcal{L}_{mix} = -\epsilon\frac{H^{\dagger}\vec{\sigma}\cdot\vec{W}_{D\mu\nu}HB^{\mu\nu}}{\Lambda^2}$$



Future Perspectives

- long range interaction $\left(V \sim -\frac{\alpha_D e^{-m_{A^0} r}}{r}\right)$
- SUSY extension
- Unification (E_6) with SM GUT(SU(5)/SO(10))/SUGRAs to obtain GUT for VSIDM and SM GUT, leading to interesting phenomenology
- Vector non-abelian SIDM as the origin of the radiative (canonical/inverse seesaw)neutrino mass
- Collider signatures
- Thermal Dark Matter $\left(W^+W^- \to A^0A^0\right)$

Conclusions

- Simple non-Abelian Self-interacting vector dark matter model with light vector mediator
- portal to SM through non-Abelian kinetic mixing
- SUSY version, include in GUT, connection to neutrino mass
- long range interaction $\left(V \sim -\frac{\alpha_D e^{-m_{A^0} r}}{r}\right)$