A minimal non-abelian dark sector (work in progress)

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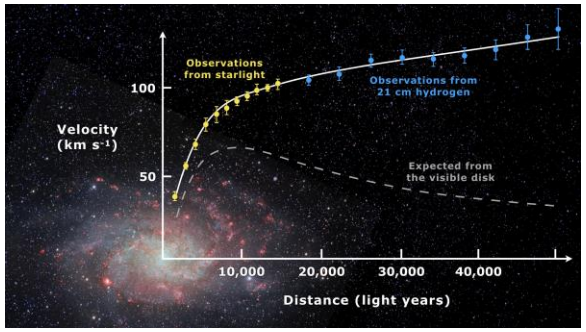
XI NExT PhD Workshop June 30, 2021

UNIVERSITY OF Southampton

Introduction

The existence of dark matter was confirm by many independent observations through its gravitational effect.

Galaxies rotation

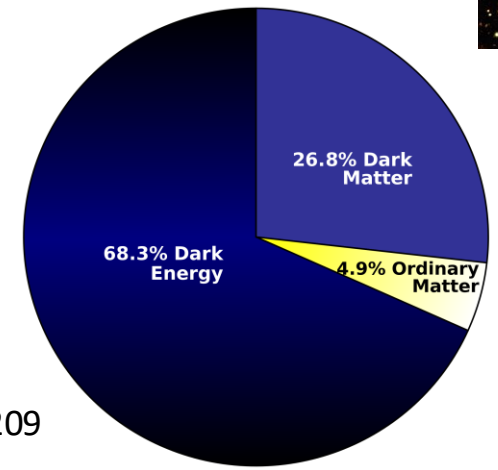


Bullet cluster

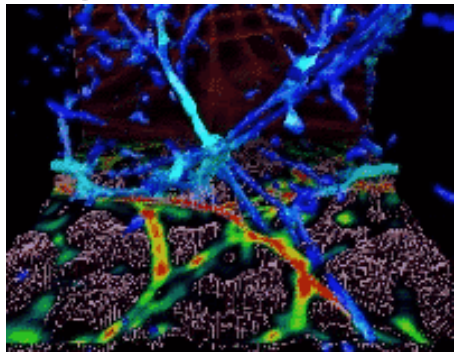
Grav. lensing

Properties of DM

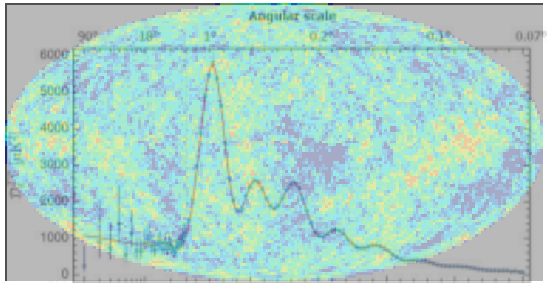
- **Neutral**
- **Non-relativistic**
- **Stable**
- **Weakly interacting with SM particles**



Large scale strucutre



CMB: WMAP & PLANCK



$\Omega_{DM}h^2 = 0.120 \pm 0.001$

N. Aghanim et al. (Planck), 2018, arXiv: 1807.06209
E. Aprile et al. (XENON1T),2018,arXiv:1705.06655
"Galaxy rotation curve." Wikipedia, 28 June 2021.

Introduction

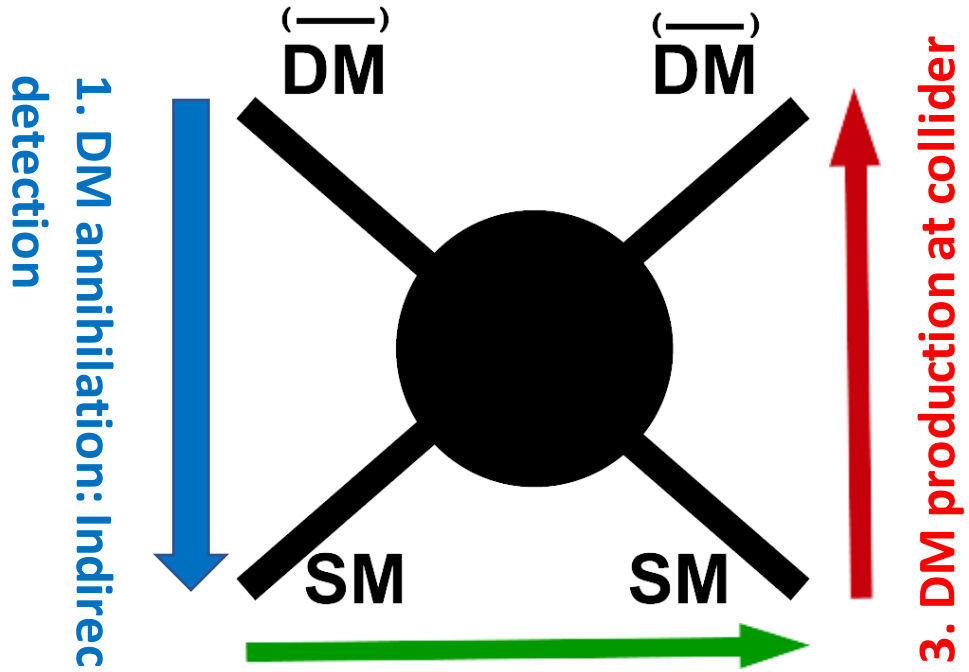
How can we observe DM?

Signatures from neutralino annihilation in halo, core of the Earth and Sun

- photons,
- Anti-protons
- positrons,
- Neutrinos

Neutrino telescopes:

- Amanda
- Icecube
- Antares



Signature from energy deposition from nuclei recoil: LUX, XENON, WARP,

LHC signatures

- mono-jet
- mono-photon
- mono-Z
- mono Higgs

- VBF+MET
- soft leptons+MET
- ....

New particles and DM candidates

Goal: to create a **vector model** of dark matter with **fermion propagator** based on a new SU(2) group. This is the minimal setup.

New particles

1. Three gauge boson from a new $SU(2)_D$ ($V^0_{D\pm}, Z'$).
2. A scalar H_D: giving mass to new gauge boson.
3. D-fermions (t_D, b_D, c_D ..., τ_D, $\nu_{\tau D}$, μ_D...).
4. A scalar Φ: giving mass to SM particles and D-fermions.

DM candidates (electrically neutral and carried D-charge)

1. scalars: $h1^0_{D+}$, $h2^0_{D+}$.
2. fermions(D-neutrinos): $\nu_{\tau D}$, $\nu_{\mu D}$, ν_{eD}.
3. vectors: $V^0_{D\pm}$.

***We have three kinds of DM candidates!**

New Lagrangian

$$\begin{aligned}
\mathcal{L}_{\text{gauge}} &= -\frac{1}{4}V^{\mu\nu}V_{\mu\nu} \\
\mathcal{L}_{\text{scalar}} &= |D_\mu H|^2 + |D_\mu \Phi|^2 + |D_\mu H_D|^2 - V(H,\Phi,H_D) \\
\mathcal{L}_{\text{D-fermion}} &= \overline{F}_L i\not{D} F_L + \overline{f}_R i\not{D} f_R + \text{Yukawa terms} \\
D &= \partial_\mu - \left(igW^a_\mu T^a + ig' Y B_\mu\right) - \left(ig_D V^a_\mu T^a_D\right)
\end{aligned}$$

The mass of vector bosons

$$\begin{aligned}
M^2_W &= \frac{1}{4}g^2(v^2+v^2_\phi),\ M^2_Z = \frac{1}{4}(g^2+g'^2)(v^2+v^2_\phi), \\
M'^2_Z &= \frac{g^2_D}{4}v^2_D, \quad M^2_V = \frac{1}{4}g^2_D(4v^2_\Phi + v^2_D)
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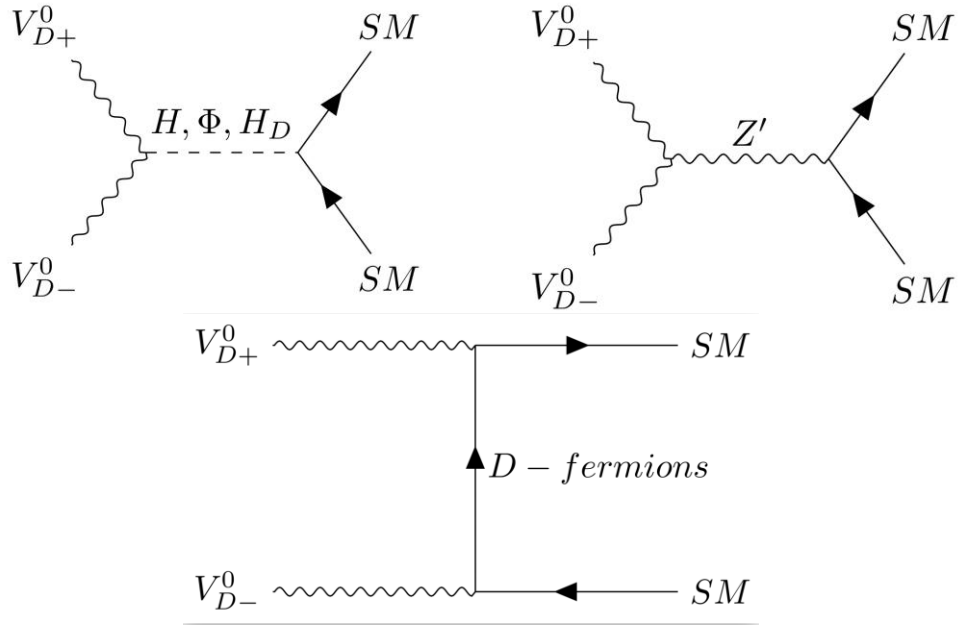
Results

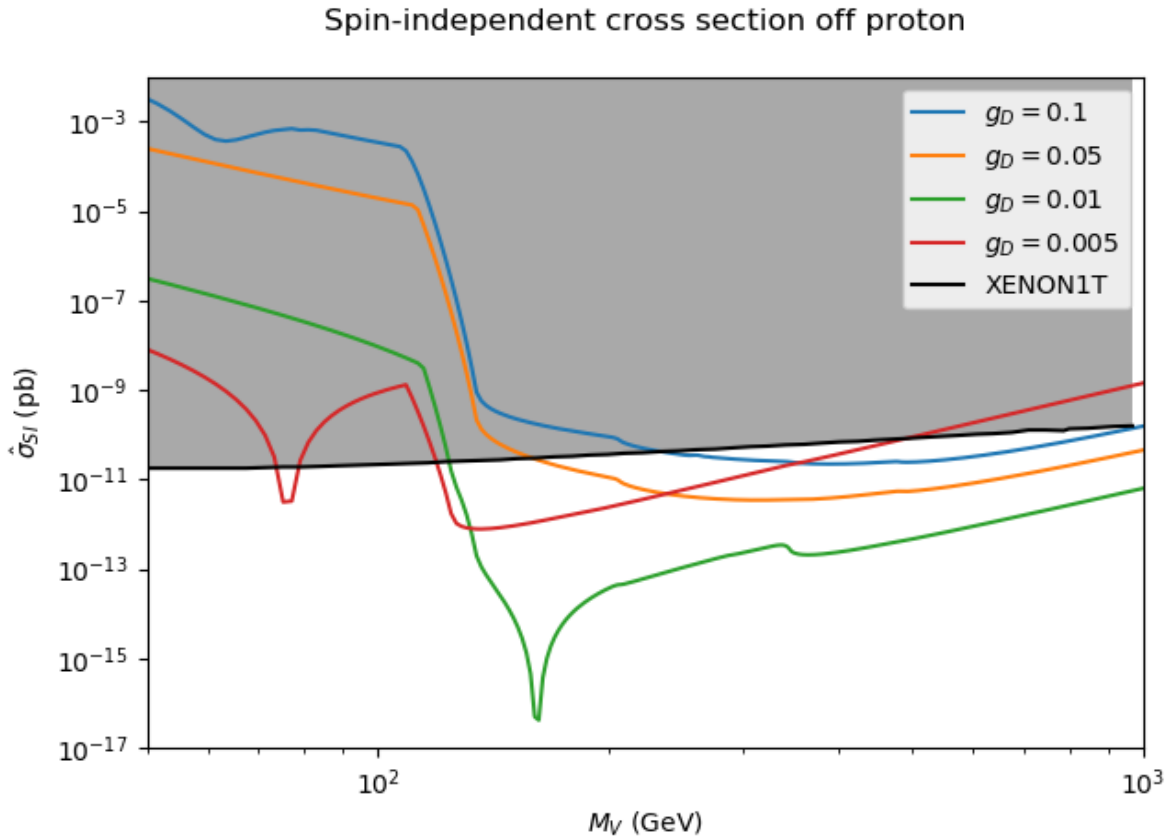
Example: Vector dark matter **Packages:** LanHEP, CalcHEP, micrOMEGA.

Feynman diagrams



Direct Detection

DM annihilation



Future plan

- Dark matter (collider & non-collider) phenomenology
- Z' phenomenology (Z' --> leptons)
- We can explain neutrino mass (Interaction of D-neutrinos and SM-neutrinos)
- Matter-antimatter asymmetry (new source of CP violation from D-fermion sector)

Thank you

Backup

Input parameters

We have 19 input parameter (independent) and 16 dependent ones

These are used in model implementation
And scanning in **micrOMEGA**

Scalar masses

Scalar couplings

Scalar couplings

Scalar couplings