A fermionic portal to a non-abelian dark sector

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Based on 2203.04681 and 2204.03510 with
A. Belyaev, A. Deandrea, S. Moretti and N. Thongyoi

A still unresolved issue

What is dark matter?
And if it is composed of new particle(s), what are their properties?

Thousands of papers, multiple experiments, no clue yet

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One possibility: build a dark sector using the same fundamental principles of SM

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One possibility: build a dark sector using the same fundamental principles of SM

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Ingredients:

- **a new gauge symmetry**
- **a way to break it spontaneously** ⟶ massive gauge boson(s)
- **a residual $\mathbb{Z}_2$ parity** ⟶ make the lightest $\mathbb{Z}_2$-odd particle stable

and that would be enough in theory. But we'd like to detect it...

- **a portal with the SM**

Which kind of gauge group?

Abelian

- A $U(1)_D$ group: $\mathcal{L} = V_{D\mu\nu}V_D^{\mu\nu}$

A problem:

Abelian ➔ kinetic mixing ➔ not stable

Solution:

- Sequester $U(1)_D$ ➔ an exact $\mathbb{Z}_2$

$$V_D^\mu \to -V_D^\mu \quad \text{(Charge conjugation)}$$

V_D is stable, now make it massive:

- SSB ➔ complex singlet S ($S \xrightarrow{\mathbb{Z}_2} S^*$)

$$\mathcal{L} = |D_\mu S|^2 + \mu_S^2|S|^2 - \lambda_S|S|^4$$
$$m_{V_D} = \sqrt{2}g_D v_D$$

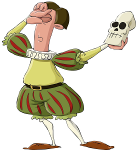
V_D^μ is a DM candidate

Need to interact with the SM:

- **Higgs portal** ➔ $V(\Phi_H, S) = \lambda|\Phi_H|^2|S|^2$

Widely studied

Lebedev, Lee & Mambrini 1111.4482,
Farzan & Akbarieh 1207.4272,
Baek, Ko, Park & Senaha 1212.2131, ...



Non-abelian

- Various possible gauge groups

$$\mathcal{L} = V^a_{D\mu\nu}V_D^{\mu\nu a}$$

- No renormalizable kinetic mixing

Limiting to $SU(N)$:

- complete SSB with $N-1$ complex scalars ➔ preserved $\mathbb{Z}_2 \times \mathbb{Z}_2'$ symmetries

Gross *et al* 1505.07480

$V_D^{\mu a}$ are all DM candidates

- Still can have **Higgs portal**

$$V(\Phi_H, S_{i,j,\dots}) = \sum_{i,j}\lambda_{ij}|\Phi_H|^2 S_i^\dagger S_j + h.c.$$

Also widely studied

Hambye 0811.0172, Diaz-Cruz & Ma 1007.2631,
Fraser, Ma & Zakeri 1409.1162, Ko & Tang 1609.02307, ...

Minimal vector DM scenario
where the Higgs portal can be small or absent*?

Non-abelian with fermion portal

* No *need* to avoid Higgs portal, but new fermions can address current anomalies

Connecting the dark sector to the SM

$SU(2)_D$ $\qquad \mathcal{V}_\mu^D = \begin{pmatrix} V^0_{D+} \\ V^0_{D0} \\ V^0_{D-} \end{pmatrix}$

$\boxed{\mathbb{Z}_2 \,:\, \{+, -\}}$

Different member of $SU(2)_D$ multiplets
transform differently under $\mathbb{Z}_2$
(we'll get back to this)

$SU(2)_L \times U(1)_Y \qquad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu \qquad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \qquad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L \qquad \begin{matrix} u_R \\ d_R\ e_R \end{matrix}$

$$\mathcal{L} = -\frac{1}{4}(W^i_{\mu\nu})^2 - \frac{1}{4}(B_{\mu\nu})^2 + |D_\mu \Phi_H|^2 + \mu^2 \Phi_H^\dagger \Phi_H - \lambda(\Phi_H^\dagger \Phi_H)^2 + \bar{f}^{\mathrm{SM}}\, i\not{D}\, f^{\mathrm{SM}} - (y\, \bar{f}_L^{\mathrm{SM}}\, \Phi_H\, f_R^{\mathrm{SM}} + h.c.)$$
$$-\frac{1}{4}(\mathcal{V}^{Di}_{\mu\nu})^2$$

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$\boxed{\text{SSB: } \langle \Phi_D \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v_D \end{pmatrix}}$

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Higgs portal: $\Phi_H^\dagger \Phi_H \Phi_D^\dagger \Phi_D$

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Kinetic mixing: $\mathcal{V}_D^{\mu\nu a} W^b_{\mu\nu}$

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$\boxed{\mathbb{Z}_2 : \ \{+, -\}}$

Kinetic mixing: $\frac{\kappa_W}{\Lambda^4} \mathcal{V}_D^{\mu\nu a} W^b_{\mu\nu} \Phi^\dagger_{Dk} (\sigma^a)_{kl} \Phi_{Dl} \Phi^\dagger_{Hi} (\sigma^b)_{ij} \Phi_{Hj}$

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- **fundamental of $SU(2)_D$**
  $\to$ interacts with $\mathcal{V}^D_\mu$

$\boxed{\mathbb{Z}_2 : \{+, -\}}$

Introducing a fermion

$SU(2)_L \times U(1)_Y$ $\quad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu \quad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \quad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L \quad \begin{matrix} u_R \\ d_R\ e_R \end{matrix}$

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Introducing a fermion

- **fundamental of $SU(2)_D$**
  $\rightarrow$ interacts with $\mathcal{V}^D_\mu$
- **Vector-like***
  $\rightarrow$ no anomalies

* abelian case with VL fermions in DiFranzo, Fox & Tait 1512.06853

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Introducing a fermion

- **fundamental of $SU(2)_D$**
  $\rightarrow$ interacts with $\mathcal{V}^D_\mu$
- **Vector-like**
  $\rightarrow$ no anomalies
- **Charged under $U(1)_Y$**
  $\rightarrow$ interacts with SM

doublet of $SU(2)_D$

singlets of $SU(2)_L$

$SU(2)_L \times U(1)_Y$ $\quad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu$ $\quad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$ $\quad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L$ $\quad u_R \; d_R \; e_R$ $\quad \psi_D \; \psi$

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$\boxed{|D_\mu \Phi_D|^2}$

$\boxed{-\bar{\Psi}_L \Phi_D f_R^{\mathrm{SM}}}$

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can be small

suppressed

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$\boxed{\mathbb{Z}_2 : \{+, -\}}$

The only* $\mathbb{Z}_2$-odd neutral massive particles are the D-charged gauge bosons $V^0_{D\pm}$

$\longrightarrow$ dark matter

* unless Ψ is a neutrino partner

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can be small $\qquad$ suppressed

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$\boxed{\mathbb{Z}_2 : \{+, -\}}$ ← Reminder: what is the origin of $\mathbb{Z}_2$?

$$SU(2)_L \times U(1)_Y \qquad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu \qquad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \qquad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L \qquad \begin{matrix} u_R \\ d_R \; e_R \end{matrix} \qquad \psi_D \; \psi$$

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$$\underbrace{-\lambda_{\Phi_H\Phi_D} \Phi_H^\dagger \Phi_H\; \Phi_D^\dagger \Phi_D}_{\text{can be small}} \underbrace{- \mathcal{V}_D^{\mu\nu a} \Phi_{Dk}^\dagger (\sigma^a)_{kl} \Phi_{Dl} \left(\frac{\kappa_W}{\Lambda^4} W^b_{\mu\nu} \Phi_{Hi}^\dagger (\sigma^b)_{ij} \Phi_{Hj} + \frac{\kappa_B}{\Lambda^4} B_{\mu\nu} \Phi_H^\dagger \Phi_H \right)}_{\text{suppressed}}$$

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$\boxed{\text{If } y' = 0}$ the Φ_D potential has a global custodial symmetry $SU(2)'_D$

$$SU(2)_L \times U(1)_Y \qquad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu \qquad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \qquad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L \quad \begin{matrix} u_R \\ d_R \; e_R \end{matrix} \qquad \psi_D \; \psi$$

$$\mathcal{L} = -\frac{1}{4}(W^i_{\mu\nu})^2 - \frac{1}{4}(B_{\mu\nu})^2 + |D_\mu \Phi_H|^2 + \mu^2 \Phi^\dagger_H \Phi_H - \lambda(\Phi^\dagger_H \Phi_H)^2 + \bar{f}^{\rm SM}\, i\not{D}\, f^{\rm SM} - (y\, \bar{f}^{\rm SM}_L\, \Phi_H\, f^{\rm SM}_R + h.c.)$$

$$-\frac{1}{4}(\mathcal{V}^{Di}_{\mu\nu})^2 + |D_\mu \Phi_D|^2 + \mu_D^2 \Phi^\dagger_D \Phi_D - \lambda_D (\Phi^\dagger_D \Phi_D)^2 + \bar{\Psi} i\not{D}\Psi - M_\Psi \bar{\Psi}\Psi - \cancel{(y' \bar{\Psi}_L \Phi_D f^{\rm SM}_R + h.c)}$$

$$-\underbrace{\lambda_{\Phi_H\Phi_D}}_{\text{can be small}} \Phi^\dagger_H \Phi_H\, \Phi^\dagger_D \Phi_D - \mathcal{V}^{\mu\nu a}_D \Phi^\dagger_{Dk} (\sigma^a)_{kl} \Phi_{Dl} \underbrace{\left(\frac{\kappa_W}{\Lambda^4} W^b_{\mu\nu} \Phi^\dagger_{Hi} (\sigma^b)_{ij} \Phi_{Hj} + \frac{\kappa_B}{\Lambda^4} B_{\mu\nu} \Phi^\dagger_H \Phi_H \right)}_{\text{suppressed}}$$

Connecting the dark sector to the SM

$SU(2)_D$ $\qquad \mathcal{V}^D_\mu = \begin{pmatrix} V^0_{D+} \\ V^0_{D0} \\ V^0_{D-} \end{pmatrix}$ $\qquad \Phi_D = \begin{pmatrix} \varphi^0_{D+\frac{1}{2}} \\ \varphi^0_{D-\frac{1}{2}} \end{pmatrix}$ $\qquad \Psi = \begin{pmatrix} \psi_D \\ \psi \end{pmatrix}$

When $y' \neq 0$ Explicit breaking: $SU(2)'_D \to U(1)_c$

global charge conjugation

$SU(2)_L \times U(1)_Y$ $\qquad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu$ $\qquad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$ $\qquad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L$ $\qquad \begin{matrix} u_R \\ d_R \; e_R \end{matrix}$ $\qquad \psi_D \; \psi$

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$$-\frac{1}{4}(\mathcal{V}^{Di}_{\mu\nu})^2 + |D_\mu \Phi_D|^2 + \mu_D^2 \Phi_D^\dagger \Phi_D - \lambda_D(\Phi_D^\dagger \Phi_D)^2 + \bar{\Psi} i\not{D}\Psi - M_\Psi \bar{\Psi}\Psi - (y' \bar{\Psi}_L \Phi_D f_R^{\rm SM} + h.c)$$

$$-\lambda_{\Phi_H\Phi_D}\, \Phi_H^\dagger \Phi_H\, \Phi_D^\dagger \Phi_D - \mathcal{V}_D^{\mu\nu a} \Phi_{Dk}^\dagger (\sigma^a)_{kl} \Phi_{Dl} \left(\frac{\kappa_W}{\Lambda^4} W^b_{\mu\nu} \Phi_{Hi}^\dagger (\sigma^b)_{ij} \Phi_{Hj} + \frac{\kappa_B}{\Lambda^4} B_{\mu\nu} \Phi_H^\dagger \Phi_H \right)$$

can be small $\qquad$ suppressed

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When $\langle \Phi_D \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v_D \end{pmatrix}$ SSB: $SU(2)_D \times U(1)_c \to$ global $U(1)$ $\quad$ $\mathbb{Z}_2$ is a subgroup of $U(1)$

diagonal part: $\exp(i\phi\tau_3)$

$SU(2)_L \times U(1)_Y$ $\quad \mathcal{V}_\mu = \begin{pmatrix} W^+ \\ W_3 \\ W^- \end{pmatrix}, B_\mu$ $\quad \Phi_H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$ $\quad \begin{pmatrix} u \\ d \end{pmatrix}_L \begin{pmatrix} \nu \\ e \end{pmatrix}_L$ $\quad \begin{matrix} u_R \\ d_R \; e_R \end{matrix}$ $\quad \psi_D \; \psi$

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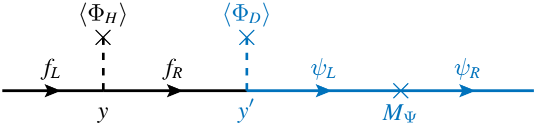
$$-\frac{1}{4}(\mathcal{V}^{Di}_{\mu\nu})^2 + |D_\mu \Phi_D|^2 + \mu_D^2 \Phi_D^\dagger \Phi_D - \lambda_D(\Phi_D^\dagger \Phi_D)^2 + \bar{\Psi} i\not{D} \Psi - M_\Psi \bar{\Psi}\Psi - (y' \bar{\Psi}_L \Phi_D f_R^{\rm SM} + h.c)$$

$$\underbrace{-\lambda_{\Phi_H \Phi_D} \Phi_H^\dagger \Phi_H\; \Phi_D^\dagger \Phi_D}_{\text{can be small}} \underbrace{- \mathcal{V}_D^{\mu\nu a} \Phi_{Dk}^\dagger (\sigma^a)_{kl} \Phi_{Dl} \left(\frac{\kappa_W}{\Lambda^4} W^b_{\mu\nu} \Phi_{Hi}^\dagger (\sigma^b)_{ij} \Phi_{Hj} + \frac{\kappa_B}{\Lambda^4} B_{\mu\nu} \Phi_H^\dagger \Phi_H \right)}_{\text{suppressed}}$$

The fermionic portal

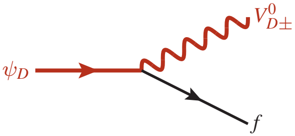
$$-\mathcal{L}_f = (y\, \bar{f}_L^{\mathrm{SM}}\, \Phi_H\, f_R^{\mathrm{SM}} + y'\, \bar{\Psi}_L \Phi_D f_R^{\mathrm{SM}} + h.c) + M_\Psi \bar{\Psi}\Psi \quad \text{with} \quad \Psi = \begin{pmatrix} \psi_D \\ \psi \end{pmatrix}$$



$$\mathcal{M}_F = \begin{pmatrix} y\frac{v}{\sqrt{2}} & 0 \\ y'\frac{v_D}{\sqrt{2}} & M_\Psi \end{pmatrix}$$

$\mathbb{Z}_2$-odd ψ_D is DM-SM mediator

$\mathbb{Z}_2$-even ψ mixes with SM



$$\begin{pmatrix} f^{\mathrm{SM}} \\ \psi \end{pmatrix}_{L,R} = \begin{pmatrix} \cos\theta_{fL,R} & \sin\theta_{fL,R} \\ -\sin\theta_{fL,R} & \cos\theta_{fL,R} \end{pmatrix} \begin{pmatrix} f \\ F \end{pmatrix}_{L,R}$$

The hierarchy between mass eigenstates is always $m_f < m_\psi \le m_F$

The portal can be with any SM fermion(s) and with any number of VL fermions

maybe a portal in the lepton sector can explain anomalies and muon $(g-2)$?

Case study: top portal w/o Higgs mixing

The VL fermion is composed of top partners and there is no mixing between scalars

Case study: top portal w/o Higgs mixing

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$$\Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T$$

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$$\boxed{\Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T}$$

$$\boxed{\sin\theta_S = 0}$$

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Representative benchmarks: $\begin{cases} g_D = 0.05, 0.5 \\ m_T = 1600 \text{ GeV} \\ m_H = 1000 \text{ GeV} \end{cases}$ g_D: strong or weak cosmological constraints; m_T, m_H: heavy enough to evade LHC constraints

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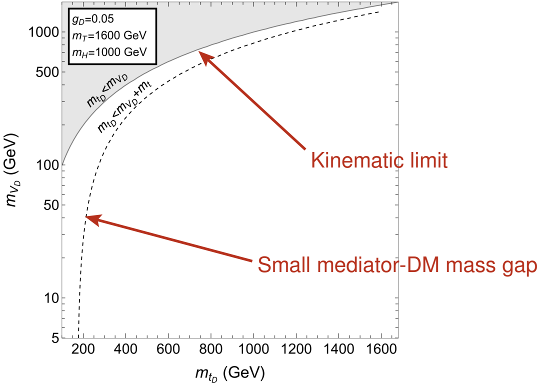

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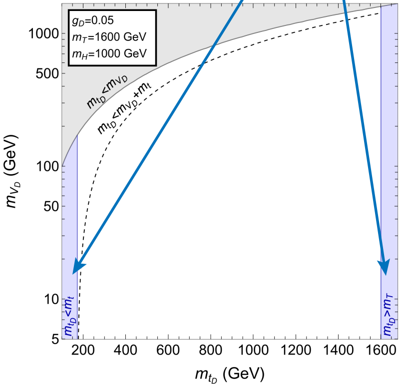

Mediator mass bounded from below and above

Case study: top portal w/o Higgs mixing

The $\boxed{\text{VL fermion is composed of top partners} \quad \Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T}$ and there is $\boxed{\text{no mixing between scalars} \quad \sin\theta_S = 0}$

Representative benchmarks:
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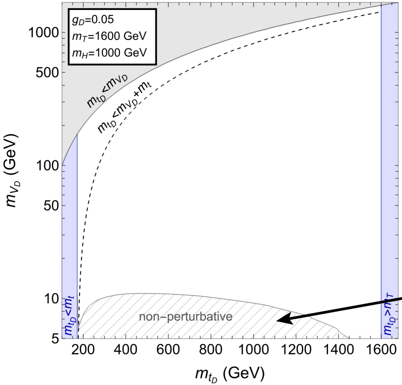
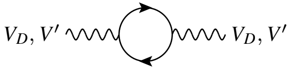


Mediator mass bounded from below and above

Light DM in non-perturbative region



$$\frac{m_V^{\text{pole}} - m_V}{m_V} > 50\%$$

Case study: top portal w/o Higgs mixing

The $\boxed{\text{VL fermion is composed of top partners}\quad \Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T}$ and there is $\boxed{\text{no mixing between scalars}\quad \sin\theta_S = 0}$

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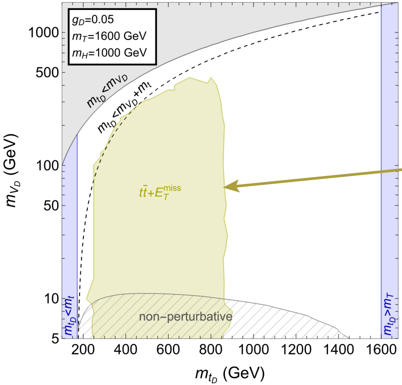
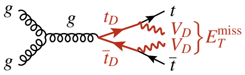


Mediator mass bounded from below and above

Light DM in non-perturbative region

LHC constrains m_{t_D} for $m_{t_D} - m_{V_D} \gtrsim m_t$

(bounds almost independent on g_D, m_T and m_H)



Recast

A. M. Sirunyan *et al.* [CMS], **Search for top squarks and dark matter particles in opposite-charge dilepton final states at $\sqrt{s} = 13$ TeV**, Phys. Rev. D **97** (2018) no.3, 032009, arXiv:1711.00752 [hep-ex]

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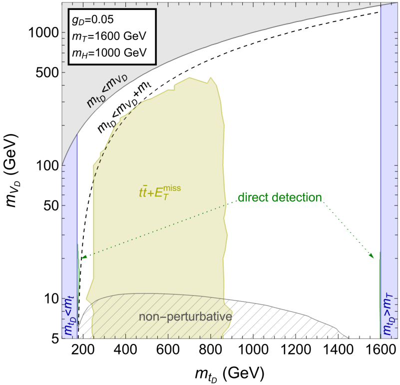

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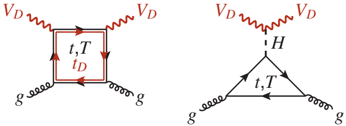
Very weak direct detection constraints
(mostly for $m_{t_D} \sim m_t$ or $m_{t_D} \sim m_T$ and light DM)



$\propto \frac{\Omega_{\rm DM}}{\Omega_{\rm DM}^{\rm Planck}}$

E. Aprile *et al.* [XENON],
Dark Matter Search Results from a One Ton-Year Exposure of XENON1T,
Phys. Rev. Lett. **121** (2018) no.11, 111302, arXiv:1805.12562 [astro-ph.CO]

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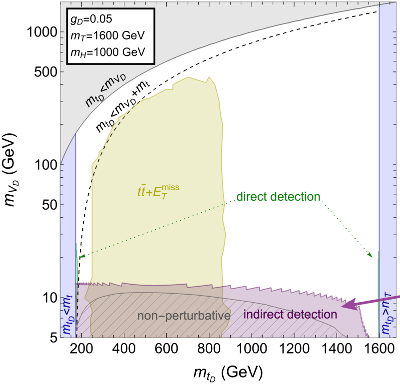

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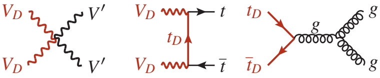
Indirect detection constrains light DM



$$\propto \left(\frac{\Omega_{\rm DM}}{\Omega_{\rm DM}^{\rm Planck}}\right)^2$$

N. Aghanim *et al.* [Planck], **Planck 2018 results. VI. Cosmological parameters,** Astron. Astrophys. **641** (2020), A6, arXiv:1807.06209 [astro-ph.CO]

Case study: top portal w/o Higgs mixing

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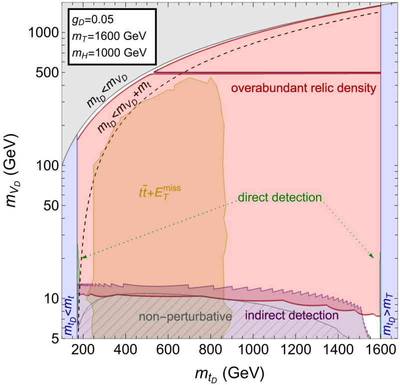

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Strong constrain from relic density
$\rightarrow$ the model “lives” on the red contours $(\Omega_{\rm DM}^{\rm Planck})$

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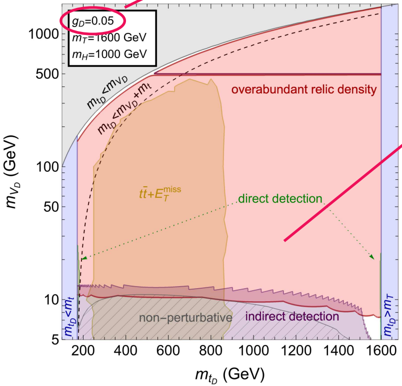

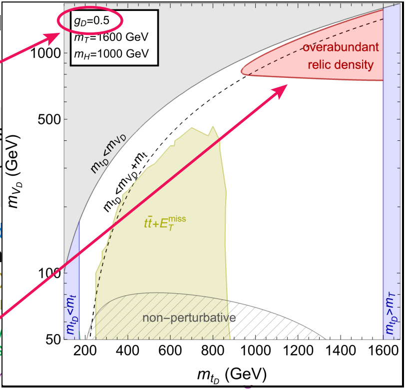

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→ the model "lives" on the red contours ($\Omega_{\rm DM}^{\rm Planck}$)

→ overabundant region shrinks for larger g_D

→ and ID constraints vanish

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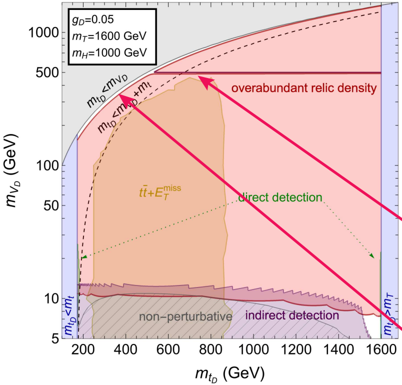

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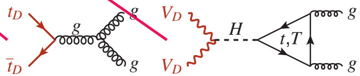

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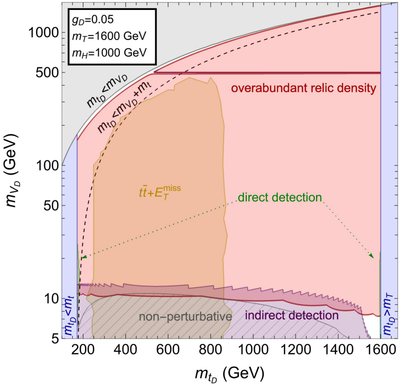

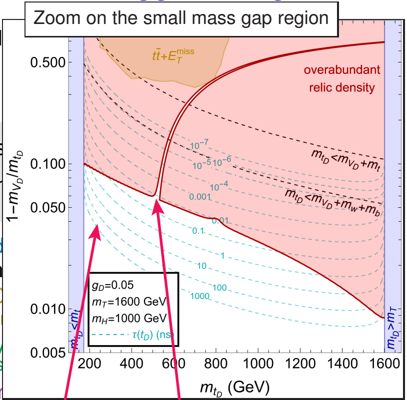

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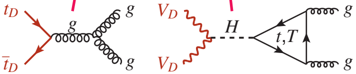

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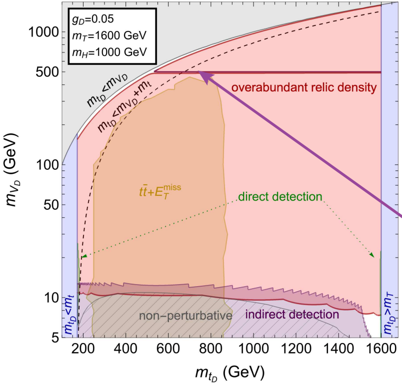
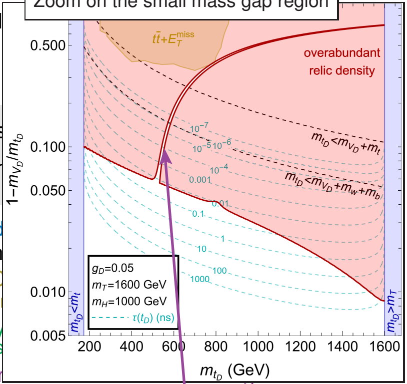


Zoom on the small mass gap region



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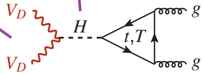
→ the model "lives" on the red contours ($\Omega_{\rm DM}^{\rm Planck}$)

→ overabundant region shrinks for larger g_D

→ and ID constraints vanish

→ effective (co-)annihilation processes

→ on the H_D pole, exclusion from ID

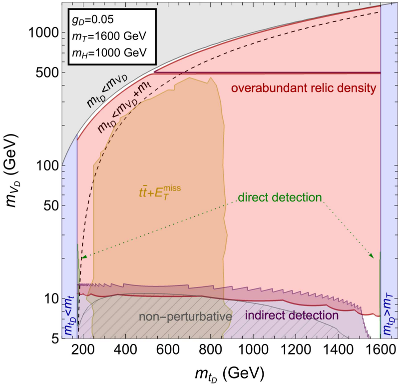


Case study: top portal w/o Higgs mixing

The VL fermion is composed of top partners and

$$\Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T$$

Representative benchmarks: $\left\{ \begin{array}{l} g_D = 0.05, 0.5 \\ m_T = 1600 \text{ GeV} \\ m_H = 1000 \text{ GeV} \end{array} \right\}$ h



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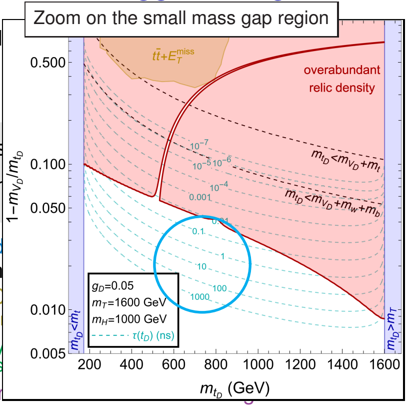


Strong constrain from relic density

→ the model “lives” on the red contours $(\Omega_{\text{DM}}^{\text{Planck}})$

→ overabundant region shrinks for larger g_D

→ and ID constraints vanish

→ effective (co-)annihilation processes

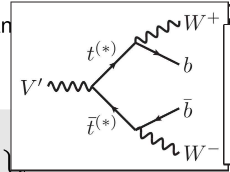
→ on the H_D pole, exclusion from ID

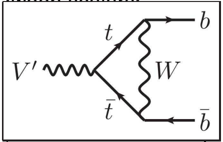
The mediator t_D can be long lived

Case study: top portal w/o Higgs mixing

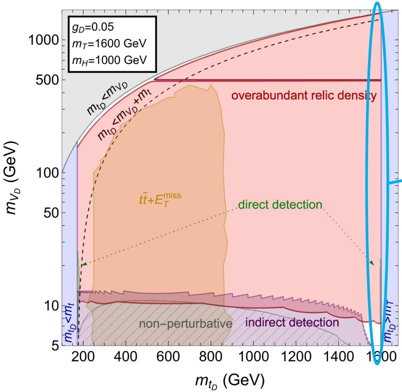
The VL fermion is composed of top partners an[...]

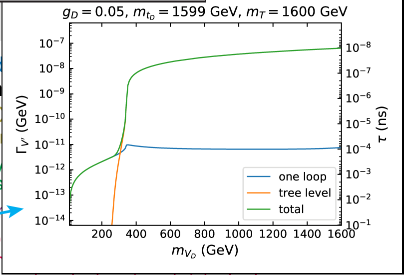
$$\Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T$$





Representative benchmarks: $\begin{cases} g_D = 0.05, 0.5 \\ m_T = 1600 \text{ GeV} \\ m_H = 1000 \text{ GeV} \end{cases}$





Med[...]
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→ th[...]
→ overabundant region shrinks for larger g_D
→ and ID constraints vanish
→ effective (co-)annihilation processes
→ on the H_D pole, exclusion from ID

The mediator t_D can be long lived, and V' too

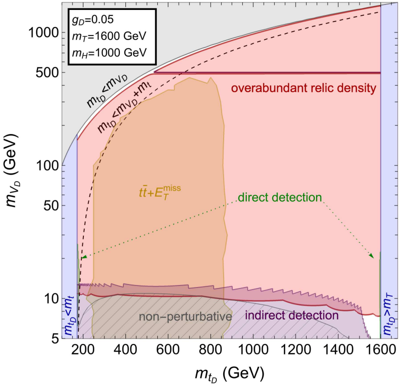
Case study: top portal w/o Higgs mixing

The **VL fermion is composed of top partners** and there is **no mixing between scalars**

$$\Psi = \begin{pmatrix} t_D \\ T \end{pmatrix} \quad \text{with} \quad m_t < m_{t_D} \leq m_T \qquad\qquad \sin\theta_S = 0$$

Representative benchmarks: $\begin{cases} g_D = 0.05, 0.5 \\ m_T = 1600 \text{ GeV} \\ m_H = 1000 \text{ GeV} \end{cases}$

- $g_D = 0.05, 0.5$: strong or weak cosmological constraints
- $m_T = 1600$ GeV, $m_H = 1000$ GeV: heavy enough to evade LHC constraints



Mediator mass bounded from below and above

Light DM in non-perturbative region

LHC constrains m_{t_D} for $m_{t_D} - m_{V_D} \gtrsim m_t$
(bounds almost independent on g_D, m_T and m_H)

Very weak direct detection constraints
(mostly for $m_{t_D} \sim m_t$ or $m_{t_D} \sim m_T$ and light DM)

Indirect detection constrains light DM

Strong constrain from relic density
→ the model "lives" on the red contours ($\Omega_{\rm DM}^{\rm Planck}$)
→ overabundant region shrinks for larger g_D
  → and ID constraints vanish
→ effective (co-)annihilation processes
  → on the H_D pole, exclusion from ID

The mediator t_D can be long lived, and V' too

just a simple realization of the model template
multiple features and signatures

Fermion Portal Vector Dark Matter

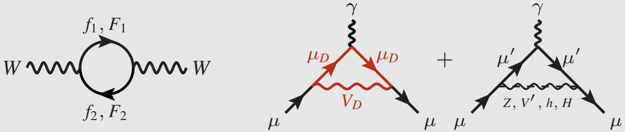
FPVDM

Summary

- A model of **non abelian vector DM** with a **fermion portal** which does not require the Higgs portal
- A **template scenario** with new collider and cosmological implications (example in the **top sector**)
- Different possible **origins of the $\mathbb{Z}_2$ parity** with interesting phenomenological developments

Outlook

- **Different realizations** to study **current anomalies** (LFU, $(g-2)_\mu$, $m_W \ldots$)



- Study of different **theoretical embeddings**
- Effects on **vacuum stability**, **EWPT**...
- Further analysis of **cosmological implications** and scenarios for **future colliders**