Weakly coupled baryonic Dark Matter

Andrea Mitridate

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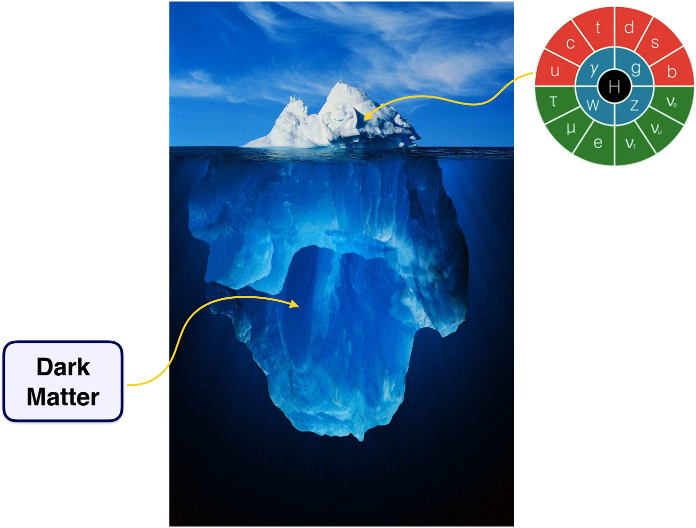
Based on an ongoing work with M. Redi

Motivations and microscopic framework



Idea [Antipin, Redi, Strumia, Vigiani '15]

DM arising as a composite state of a new confining force and stable thanks to accidental symmetries

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Motivation

In the SM the stability of massive particles is guaranteed by accidental symmetries of the renormalizable Lagrangian

- Neutrino: $\psi_l \to e^{i\theta}\psi_l \Longleftrightarrow$ lepton number
- Electron: $\psi_l \to e^{i\theta}\psi_l \Longleftrightarrow$ lepton number $+ \mathrm{U}(1)_{em}$
- Proton: $q_i \to e^{i\omega}q_i \Longleftrightarrow$ baryon number

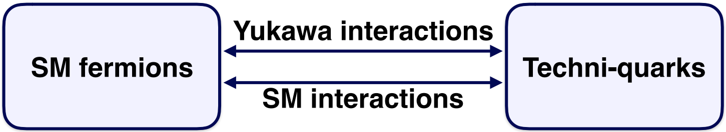
SM fermions

Degrees of freedom:

$e,\ \mu,\ \tau, \ldots + H$

Gauge symmetries:

$\mathrm{SU(3)_C} \otimes \mathrm{SU(2)_W} \otimes \mathrm{U(1)_Y}$



Degrees of freedom:

$$e,\ \mu,\ \tau,\ldots + H + \ \mathcal{Q}_{i=1\ldots N_{TC}}^{\alpha=1\ldots N_{TF}}$$

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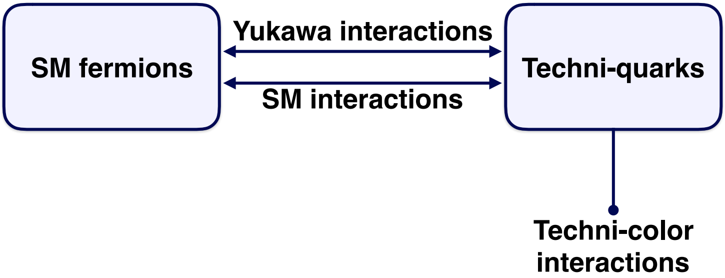

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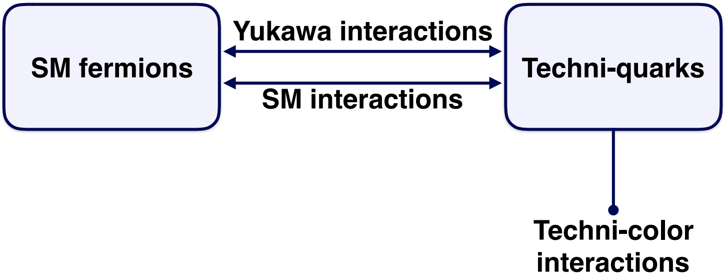

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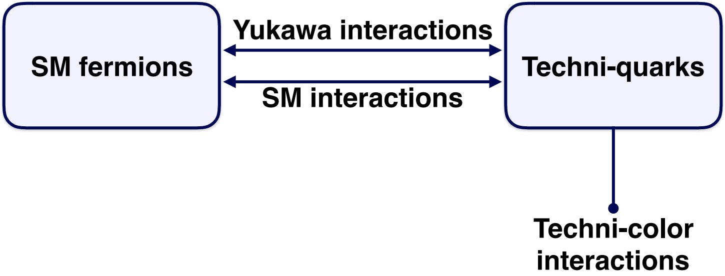

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TCq transform in vectorial representations of the SM

$$\Updownarrow$$

$\Psi_L \equiv \left(\mathcal{Q}_L^1, \ldots, \mathcal{Q}_L^n\right)$ e $\Psi_R \equiv \left(\mathcal{Q}_R^1, \ldots, \mathcal{Q}_R^n\right)$ **transform in the same SM representations**

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Renormalizable Lagrangian of the model

$$\mathcal{L} = \mathcal{L}_{\rm SM} - \frac{|\mathcal{G}^A_{\mu\nu}|^2}{4g^2_{\rm TC}} + \bar{\Psi}_i \left(i\not{D} - m_i\right) \Psi_i + \left[H\bar{\Psi}_i(y_{ij}P_L + \tilde{y}_{ij}P_R)\Psi_j + h.c.\right]$$

Accidental symmetries:

Techni-bayon number

$$\Psi_i \to e^{i\alpha}\Psi_i$$

Species number

$$\Psi_i \to e^{i\alpha_i}\Psi_i$$

G-parity

$$\Psi_i \to e^{-i\pi J_2}\Psi_i^c$$

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Symmetries breaking sources:

- Dimension 6 operators

- Dimension 5 operators
- Yukawa couplings

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Techni-mesons

$$\Pi = \bar{\mathcal{Q}}^i_\alpha \mathcal{Q}^\beta_i$$

Techni-baryons

$$B = \epsilon^{i_1,\ldots,i_N} \mathcal{Q}^{\{\alpha_1}_{i_1} \mathcal{Q}^{\alpha_2}_{i_2} \ldots \mathcal{Q}^{\alpha_N\}}_{i_N}$$

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- Species number (if $\alpha \neq \beta$)
- G-parity

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- Techni-baryon number (lightest TCb)
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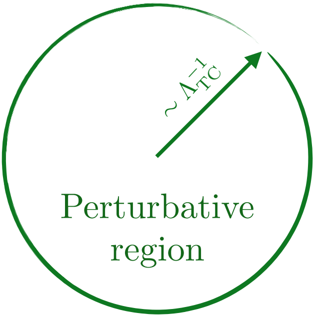
Running TC coupling

$$\overline{\alpha} \simeq \frac{1}{\ln(\frac{\mu}{\Lambda_{TC}})}$$



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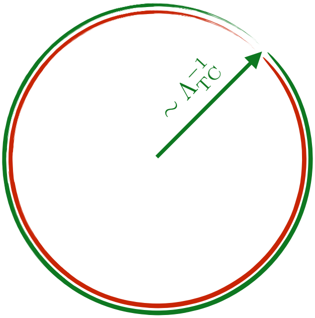

$$\begin{cases} m_{\Pi}^2 \sim m_{tq}\Lambda_{\rm TC} + \alpha_i \Lambda_{\rm TC}^2 \\ m_B \sim N\Lambda_{\rm TC} \end{cases}$$

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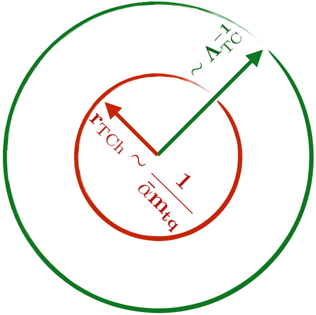
- $m_{tq} > \Lambda_{\mathrm{TC}}$ & $\bar{\alpha} m_{tq} \gg \Lambda_{\mathrm{TC}}$



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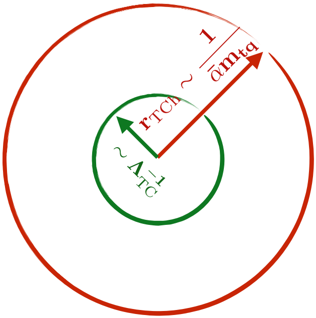

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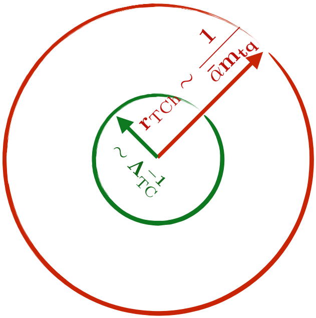

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Example of $\mathrm{SU}(N)_{\mathrm{TC}}$ model

$$\Psi = \underbrace{\overbrace{(1,3)_0}^{V} \oplus \overbrace{(1,1)_0}^{N}}_{\Rightarrow N_{TF}=4} \qquad N = 3$$

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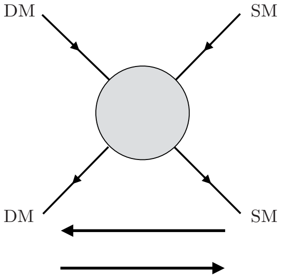
DM candidates

Techni-mesons:

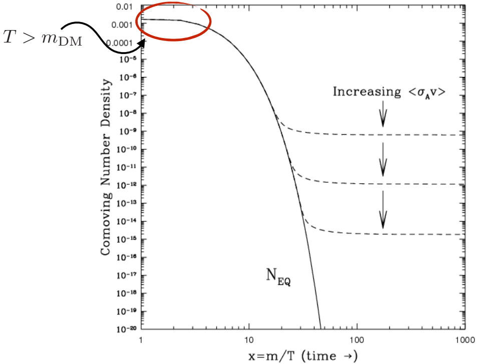
$$V\overline{V} = (1,1)_0, \quad N\overline{V} = (1,3)_0, \quad V\overline{N} = (1,3)_0$$

Techni-baryons:

$$VVN = (1,1)_0, \quad VNN = (1,3)_0, \quad VVV = (1,3)_0, \quad NNN = (1,1)_0$$



$$\Gamma_A \sim \langle \sigma_A v \rangle n_{DM}$$

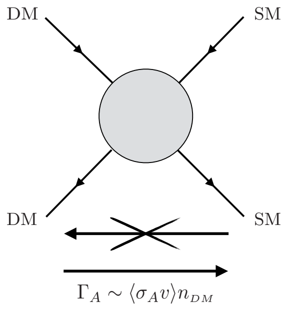


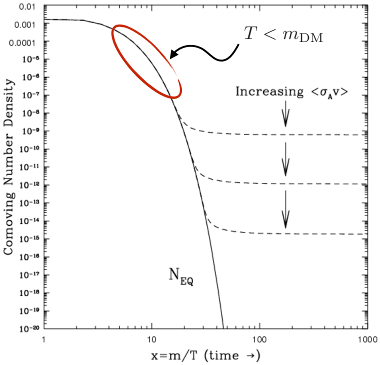
Freeze out

$$\frac{m_{DM}}{T_{f.o.}} \simeq \ln \left[0.38 m_{DM} m_{PL} \langle \sigma_A v \rangle \right]$$

Relic abundance

$$\Omega_{DM} h^2 \simeq \frac{10^{-10}\,\mathrm{GeV}^{-2}}{\langle \sigma_A v \rangle}$$





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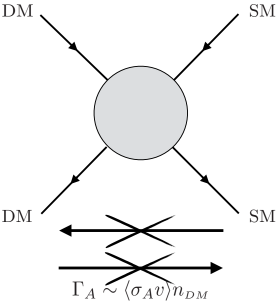

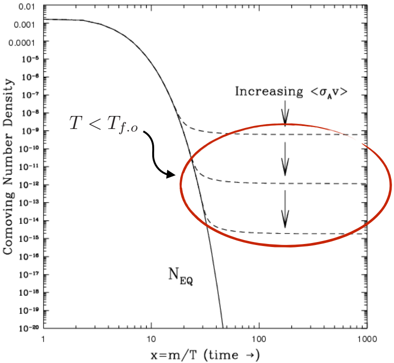

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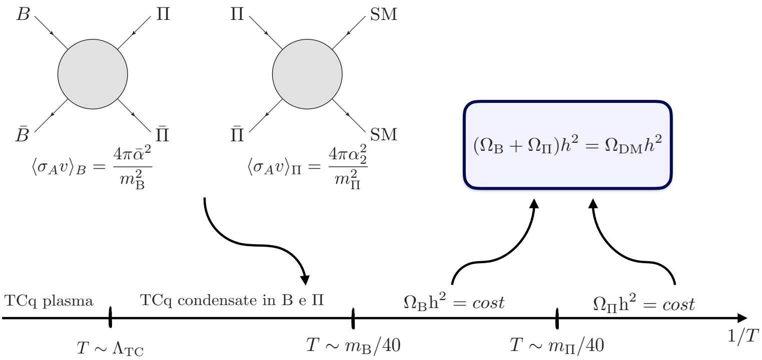
Light techni-quarks ($m_{tq} < \Lambda_{TC}$)



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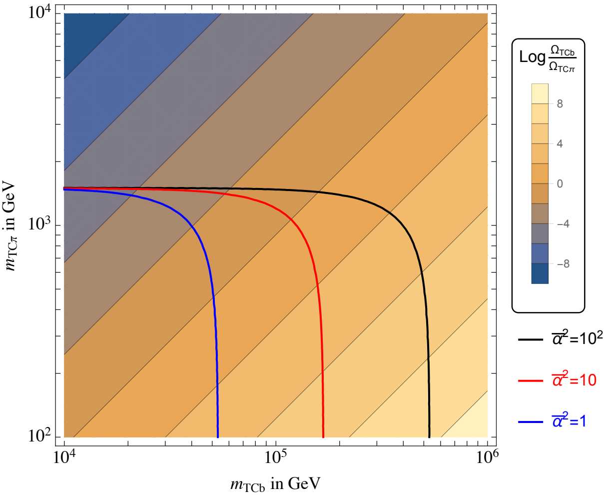
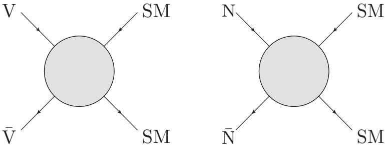


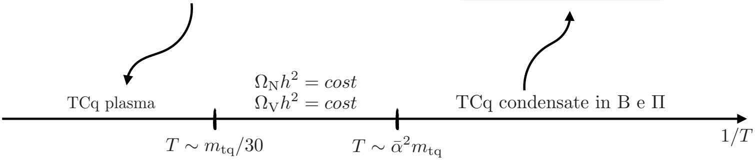
Heavy techni-quarks ($m_{tq} > \Lambda_{TC}$)

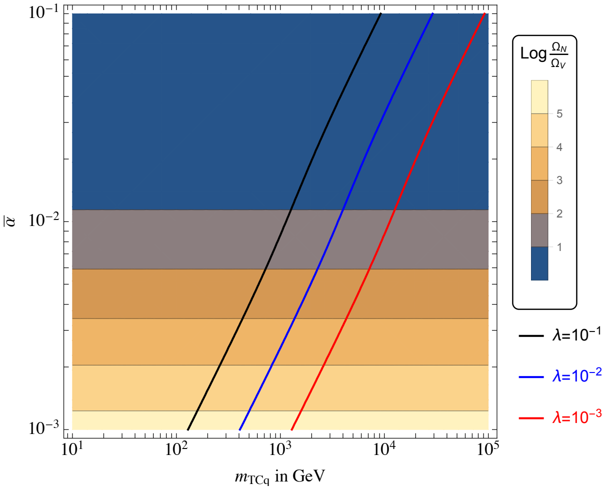


$$\langle\sigma_A v\rangle_V = \frac{32}{27}\frac{\pi\bar{\alpha}^2}{m_V^2} + \frac{215}{288}\frac{\pi\alpha_2^2}{m_V^2}$$

$$\langle\sigma_A v\rangle_N = \frac{32}{27}\frac{\pi\bar{\alpha}^2}{m_N^2}$$

$$\lambda(\Omega_V + \Omega_N)h^2 = \Omega_{\text{DM}}h^2$$




10^{-1}
10^{-2}
10^{-3}
$\overline{\alpha}$
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
m_{TCq} in GeV
Log $\frac{\Omega_N}{\Omega_V}$
5
4
3
2
1
$\lambda=10^{-1}$
$\lambda=10^{-2}$
$\lambda=10^{-3}$

Example of $\mathrm{SO}(N)_{\mathrm{TC}}$ model

$$\Psi = \underbrace{\overbrace{(1,2)_{-1/2}}^{L} \oplus \overbrace{(1,\bar{2})_{1/2}}^{L^c} \oplus \overbrace{(1,1)_0}^{N}}_{\Rightarrow N_{TF}=5} \qquad N = 3$$

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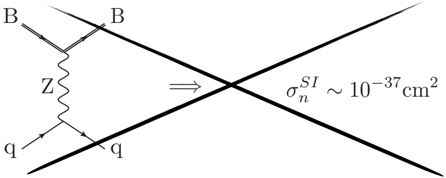
$$\mathcal{L}_{Yuk.} = yNL \cdot H + \tilde{y}NL^c \cdot H^\dagger$$

$$\Downarrow$$

$$L = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix} \qquad L^c = \begin{pmatrix} \psi_3 \\ \psi_4 \end{pmatrix}$$

Dark Matter candidate

$$B \sim \frac{1}{\sqrt{2}}\left(\psi_2\psi_3\psi_4 + \psi_1\psi_2\psi_4\right) \in (1,2)_{1/2}$$



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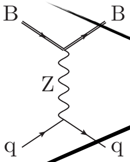
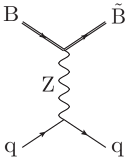


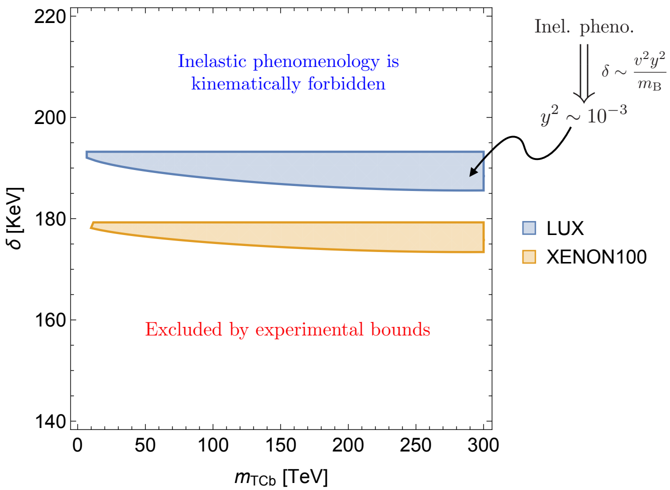
$$\Longrightarrow \quad \sigma_n^{SI} \sim 10^{-37}\text{cm}^2$$



$$m_L \sim m_N < \Lambda_{TC}$$

$$\Downarrow$$

$$\delta \equiv m_{\tilde{B}} - m_B \sim \frac{y^2 v^2}{m_B}$$


Inelastic phenomenology is kinematically forbidden
Excluded by experimental bounds
Inel. pheno.
$\delta \sim \frac{v^2 y^2}{m_B}$
$y^2 \sim 10^{-3}$
LUX
XENON100
δ [KeV]
m_{TCb} [TeV]
220
200
180
160
140
0
50
100
150
200
250
300

Example of $\mathrm{SO}(N)_{\mathrm{TC}}$ model with $m_N \gg \Lambda_{TC}$

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$$\mathcal{L}_{Yuk.} = yNL \cdot H + \tilde{y} NL^c \cdot H^\dagger$$

$$\Downarrow \qquad (m_N \gg \Lambda_{TC})$$

$$\mathcal{L}_{Yuk.} \simeq \frac{y^2}{m_N}(L \cdot H)^2 + \frac{\tilde{y}}{m_N}(L^c \cdot H^\dagger) + \frac{2y\tilde{y}}{m_N} L \cdot H L^c \cdot H^\dagger$$

$$\Downarrow$$

$$\delta \sim \frac{y^2 v^2}{m_N}$$

Possible TCb DM candidates at the TeV scale formed as non-relativistic bound states of heavy techni-quarks.

Possible Majorana DM candidates with inelastic phenomenology also for $\mathcal{O}(1)$ Yukawa couplings.

Indirect detection becomes interesting for TCb at the TeV scale?

Can we found a model that explain the di-photon excess and gives a TCb dark matter at the TeV scale?

A more accurate study of the non perturbative effects arising from TC interactions in the non-relativistic regime is needed to understand the LHC phenomenology.

Thank you for your attention!

Relic abundance for $\mathrm{SO}(N)_{\mathrm{TC}}$ models in the heavy TCq regime