Dark matter candidates from Strong coupled theories

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The idea of Technicolor (Weinberg, Susskind)

$$SU(N)_{TC} \times SU(3)_C \times SU_L(2) \times U_Y(1)$$

The Electroweak symmetry breaks dynamically via Technicolor Strong Interactions at ~ 250 GeV by the formation of the condensate

$$\left\langle Q^{c,f} \widetilde{Q}_{c,f'} \right\rangle \neq 0 \quad \Rightarrow \quad \text{breaks EW symmetry}$$

W and Z bosons become massive.

Higgs is a composite particle

If Higgs is composite of two techniquarks

Extended Technicolor

$$\alpha_{ab}\frac{\bar{Q}T^aQ\bar{Q}T^bQ}{\Lambda^2_{ETC}} + \beta_{ab}\frac{\bar{Q}_LT^aQ_R\bar{\psi}_RT^b\psi_L}{\Lambda^2_{ETC}} + \gamma_{ab}\frac{\bar{\psi}_LT^a\psi_R\bar{\psi}_RT^b\psi_L}{\Lambda^2_{ETC}} + \dots$$

↑ Contribution to the masses of the Nambu-Goldstone bosons

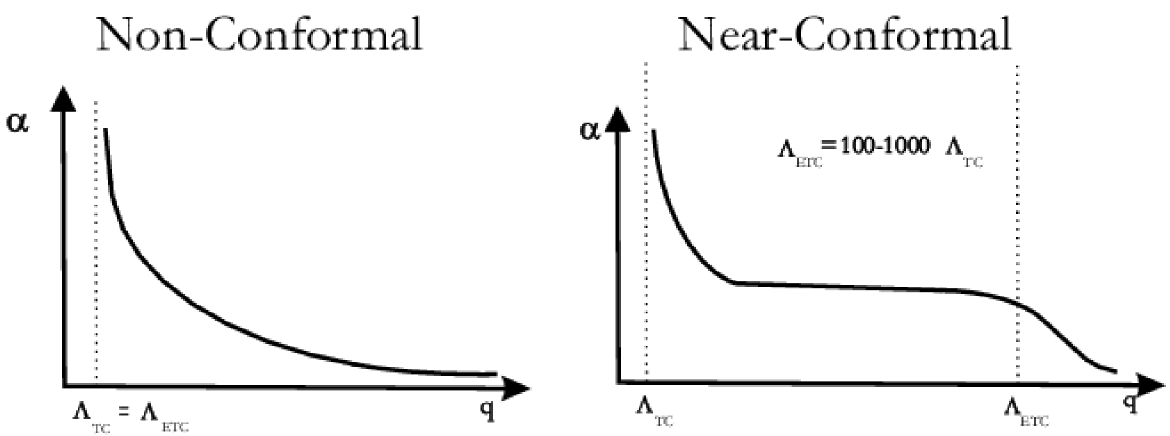
↑ Contribution to the masses of the SM fermions

↑ Contribution to the flavor changing neutral currents

The Problems of the Old Technicolor Theories

We need large α_{ab} β_{ab} and small γ_{ab}

Only way out is walking coupling!



. . . but in order to be close at the conformal window for the fundamental representation

$$N_f^c \sim 4\,N$$

The S parameter is too large!

Higher Dimensional Technicolor

F. Sannino and K. Tuominen, hep-ph/0405209 PRD (RC)
D.K.Hong, S.D. Hsu, F. Sannino, PLB597 (2004) 90 [hep-ph/0406200]
D. Dietrich, F. Sannino and K. Tuominen, hep-ph/0505059 PRD

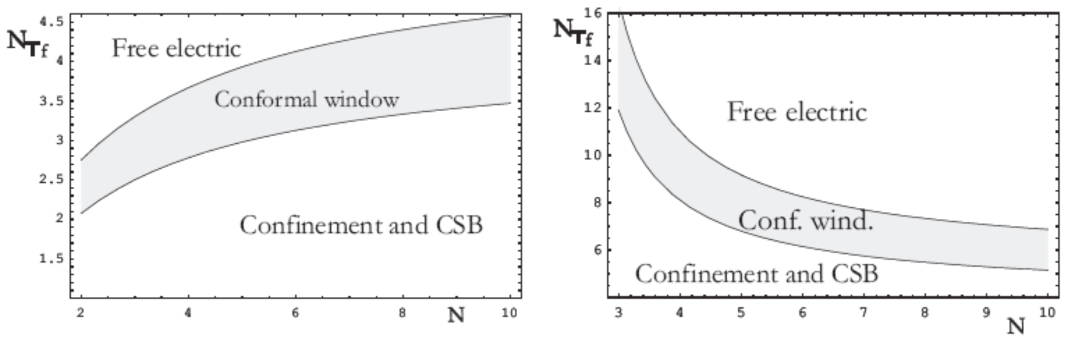


FIG. 1: Left(Right) panel: Phase diagram as function of number of N_{Tf} Dirac flavors and N colors for fermions in the two-index symmetric (antisymmetric) representation, i.e. S(A)-types, of the gauge group.

Minimal Walking Model

$$Q = \begin{pmatrix} U_L \\ D_L \\ -i\sigma^2 U_R^* \\ -i\sigma^2 D_R^* \end{pmatrix}$$

Spontaneous Symmetry Breaking SU(4) $\longrightarrow$ SO(4)

$$\langle Q_i^\alpha Q_j^\beta \epsilon_{\alpha\beta} E^{ij} \rangle = -2 \langle \overline{U}_R U_L + \overline{D}_R D_L \rangle \qquad E = \begin{pmatrix} 0 & \mathbb{1} \\ \mathbb{1} & 0 \end{pmatrix}$$

9 Goldstone Bosons

$$\overline{D}_R U_L \ , \qquad \overline{U}_R D_L \ , \qquad \frac{1}{\sqrt{2}} (\overline{U}_R U_L - \overline{D}_R D_L)$$

Eaten by W's and Z

$$U_L U_L \ , \qquad D_L D_L \ , \qquad U_L D_L$$

carrying technibaryon number

One extra lepton family to cancel Witten's anomaly $\nu' \ \zeta$

Can the Minimal Walking Technicolor provide dark matter candidates?

In other words…

→ Provide stable, electrically neutral particles

→ Avoid violation of the Electroweak Precision Measurements

→ Give the “right” relic density

→ Avoid detection from the current dark matter search experiments like CDMS.

3 Scenarios

1.

UU, DD, UD

Electric charges y+1, y-1, y

For y = 1 DD is electrically neutral!

If DD is also the lightest technibaryon

It carries technibaryon number
It can be stable !!!

hep-ph/0608055

CK, Sannino, Gudnason

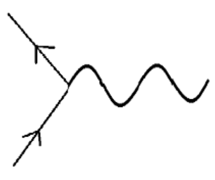
Calculation of Dark Matter Density

Ingredients

- Technibaryon-antitechnibaryon asymmetry (Nussinov ’85)
- Weak equilibration
- Baryon Number violating processes
- Electric Neutrality

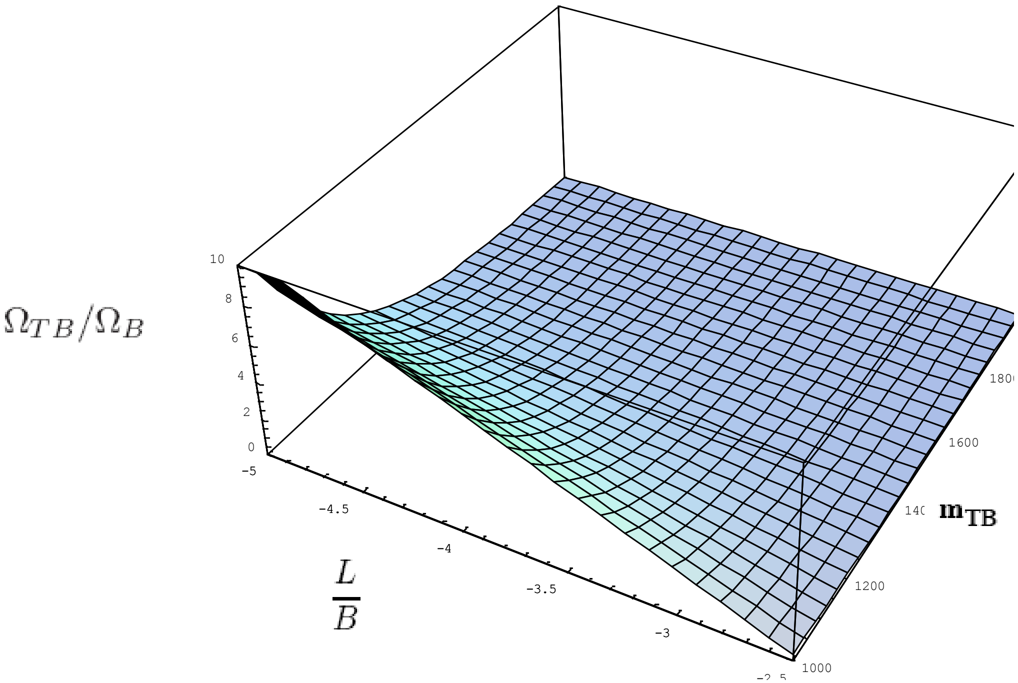
Harvey, Turner (1990)

Extra Conditions for technicolor

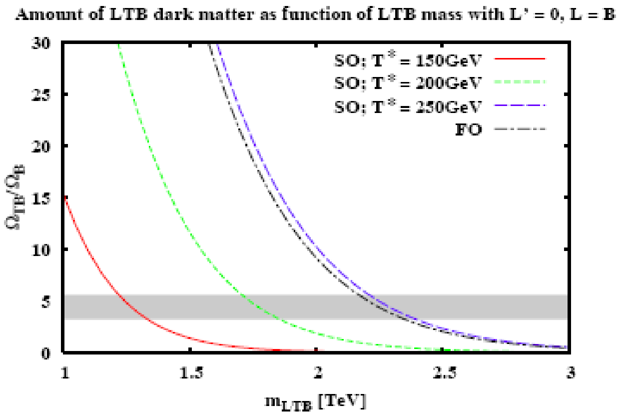


TB-L and TB-L’, B-L, B-TB are conserved per family

$$(u_L d_L d_L \nu_L)^3 U_L D_L U_L \zeta_L \longrightarrow \text{vacuum}$$



$$\frac{\Omega_{TB}}{\Omega_B} = \frac{3}{2}\frac{TB}{B}\frac{m_{TB}}{m_p}$$



2. Majorana Technibaryons

For y=1, D is neutral

Because D transforms under the adjoint representation,

$D_L^\alpha G^\alpha \quad D_R^\alpha G^\alpha$ are colorless!!

Seesaw

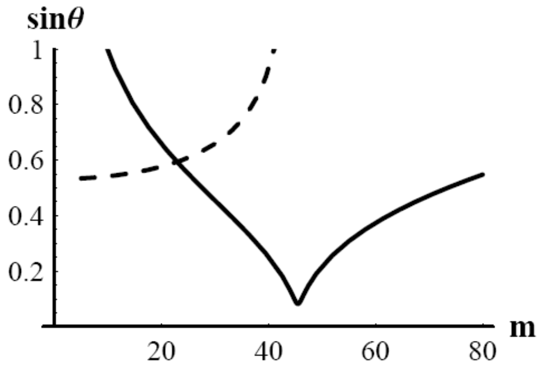
$$L_{mass} = -\frac{1}{2}\left(\psi_L^\dagger \psi_R^{c\dagger}\right)\begin{pmatrix} M & m_D \\ m_D & 0 \end{pmatrix}\begin{pmatrix} \psi_L^c \\ \psi_R \end{pmatrix} + h.c.$$

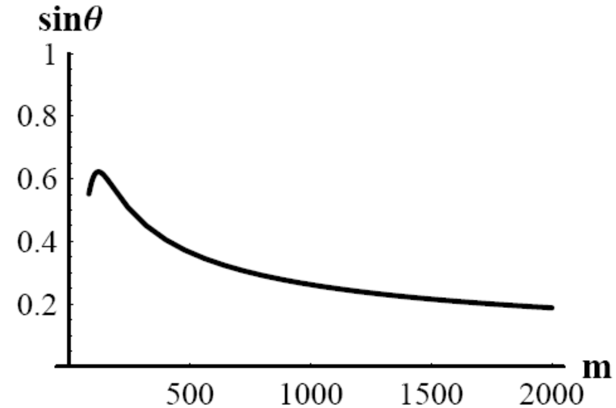
$$N_1 = \cos\theta \begin{pmatrix} \psi_L \\ \psi_L^c \end{pmatrix} + \sin\theta \begin{pmatrix} \psi_R^c \\ \psi_R \end{pmatrix},$$

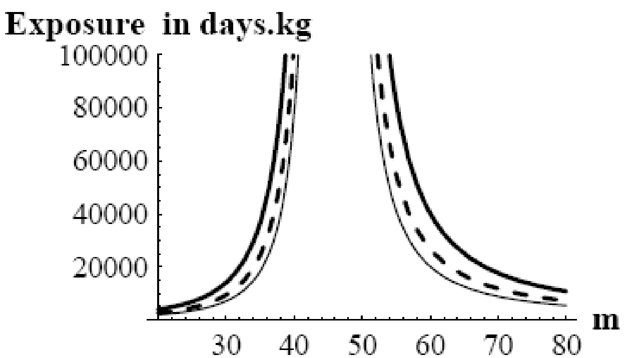
$$N_2 = \sin\theta \begin{pmatrix} i\psi_L \\ -i\psi_L^c \end{pmatrix} + \cos\theta \begin{pmatrix} -i\psi_R^c \\ i\psi_R \end{pmatrix}$$

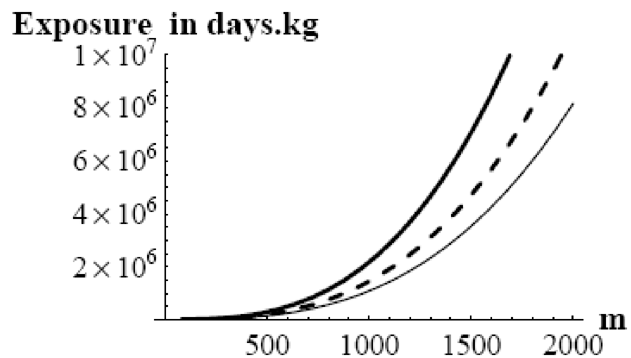
The Technibaryon number is broken. There is a Z_2 R-parity as in neutralinos.

hep-ph/0703266 CK









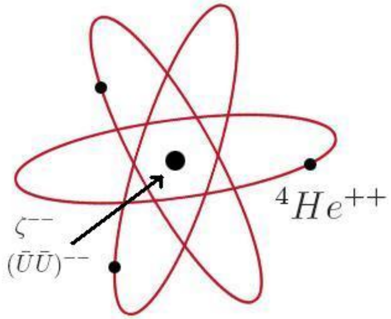
It is far from being ruled out by CDMS

3. **For y=1, D is neutral, U has charge +2, ζ -2**

If UU or ζ are the lightest particles of the TC sector

Bound states $^{4}He^{++}\zeta^{--}$ or/and $^{4}He^{++}(\bar{U}\bar{U})^{--}$

For a technibaryon of mass
~TeV, the binding energy is ~1.6 MeV



Khlopov, CK: arXiv:0710.2189

We Can calculate the relic density

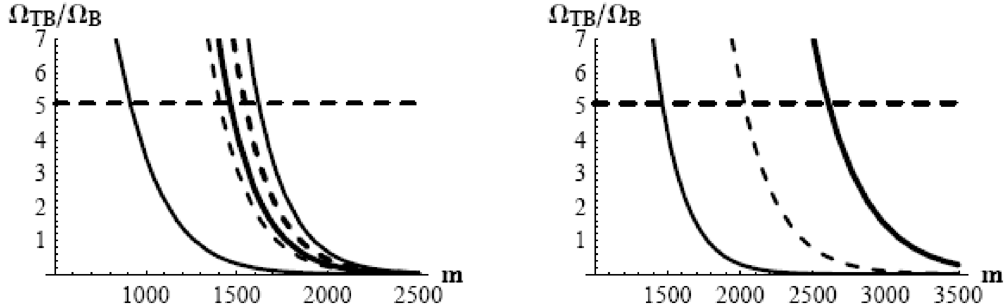
it does not violate the SBBN

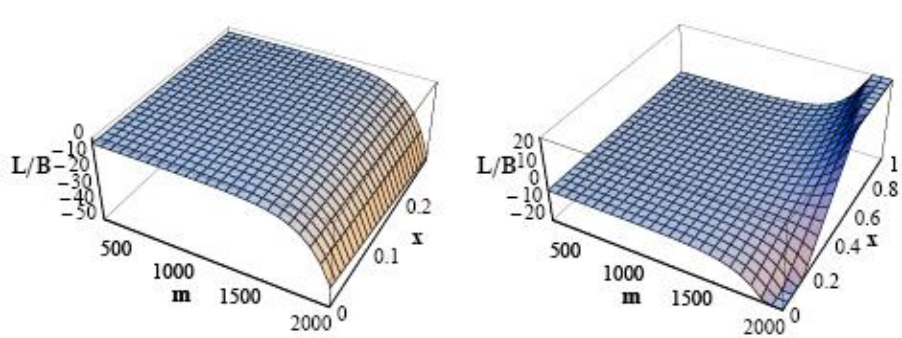
No Anomalous Helium Isotope

It is not ruled out by Dark matter experiments

It can provide a possible explanation for the difference between CDMS and DAMA results

Relic density





Conclusions

- The new technicolor theories are not ruled out by the electroweak measurements. They don’t have the problems of the old baroque theories. They can be tested soon at LHC.
- The minimal walking technicolor model can provide different dark matter candidates, one similar to neutralino and one of SIMP type.
- The dark matter candidates are not ruled out by any observations or direct search dark matter experiments.
- Indirect signatures.