Composite Higgs Dark Matter Models

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Université Claude Bernard Lyon 1

Tsinghua University

Collaboration with Tsinghua University

⇒ PICS application made it to the last stage of evaluation, but was not funded.

⇒ In 2015, Ma Teng visited IPNL for 6 months.

⇒ In January 2016, G.Cacciapaglia, H.Cai and M.Lespinasse visited Tsinghua.

Tsinghua : Wang Qing (Prof), Zhang Bin (Prof), Ma Teng (PhD), Shengzhi Zhao (PhD)
IPNL : Giacomo Cacciapaglia (CNRS), Aldo Deandrea (Prof), Haiying Cai (CDD), Mickael Lespinasse (PhD)
1 published paper, 2 in preparation.

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Motivations

- **Standard Model**
  - Very good agreement with experience
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Composite Higgs models

- → Potential comes from dynamics.
- → Higgs mass protected.
- → Could contain dark matter candidates.

What is a *Composite Higgs* model ?

Ingredients :

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2. New fermions
3. Global flavor symmetry

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Okay but where is the Higgs ?

The Higgs is a Goldstone boson, bound state of these new fermions

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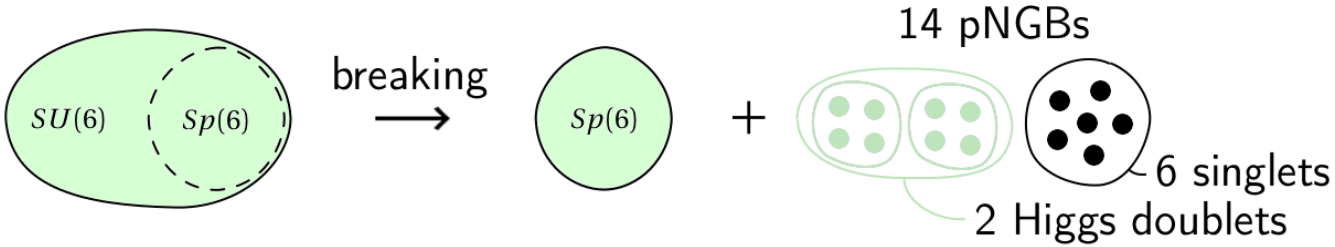
Setup

[M.Lespinasse, G.Cacciapaglia in prep.]



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→ $Sp(6)$ is the remaining symmetry after condensation

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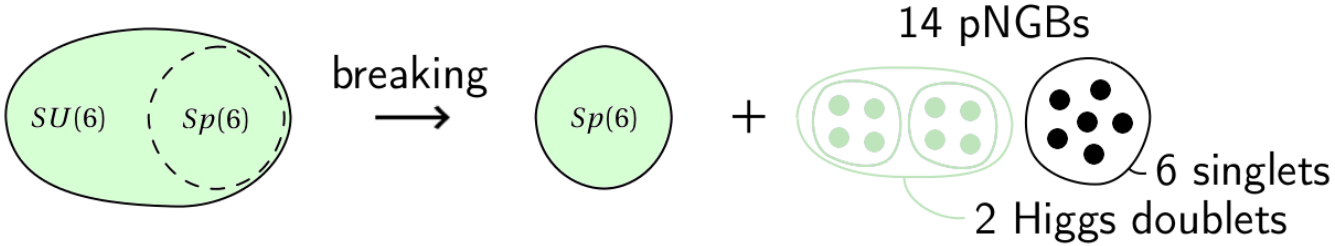

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EW symmetry :

$$\underbrace{SU(2)_L \times SU(2)_{R1}}_{SU(2)_L \times U(1)_Y} \times SU(2)_{R2} \quad \text{or} \quad \underbrace{SU(2)_L \times SU(2)_{R2}}_{SU(2)_L \times U(1)_Y} \times SU(2)_{R1}$$

Different ways of breaking $SU(6)$ down to $Sp(6)$:

- Preserving $SU(2)_L \times U(1)_Y$
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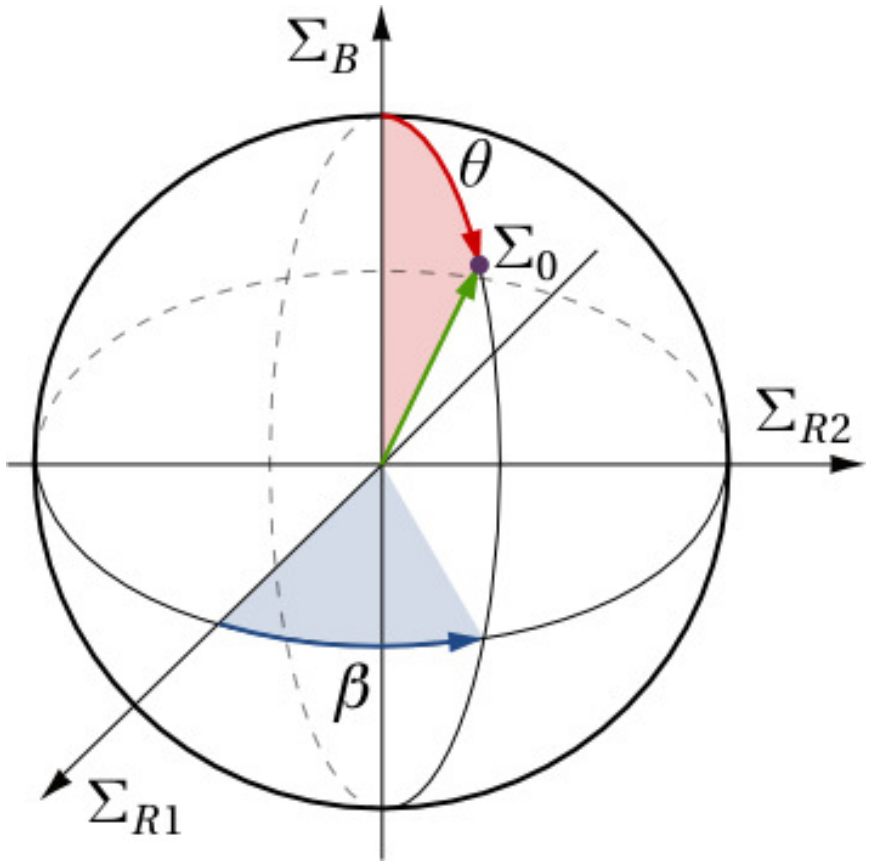
$$\Updownarrow$$

Different ways of aligning the vacuum

- Σ_B $\longrightarrow$ Preserves the EW symmetry
- $\Sigma_{R1,R2}$ $\longrightarrow$ Breaks the EW symmetry (Technicolor)

Composite Higgs vacuum : $\Sigma_0(\theta, \beta)$
$\tan\beta = \frac{v_2}{v_1}$



Some results

$\Rightarrow$ Mass term for the gauge bosons :

$$m_W^2 = 2g_1^2 f^2 \sin^2\theta \quad \text{et} \quad m_Z^2 = 2(g_1^2 + g_2^2) f^2 \sin^2\theta$$

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$$\left(m_W^{SM}\right)^2 = \frac{1}{4} g_1^2 v^2 , \quad \left(m_Z^{SM}\right)^2 = \frac{1}{4}\left(g_1^2 + g_2^2\right) v^2 \qquad \text{et donc} \quad v = 2\sqrt{2} f \sin\theta$$

Experimentally : $v \simeq 246\text{GeV}$

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$\Rightarrow$ h couplings :

$$g_{hWW} = g_{hWW}^{SM} \cos\theta \qquad g_{hZZ} = g_{hZZ}^{SM} \cos\theta$$

Dark Matter content

Where could Dark Matter came from in this model ?
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1. **The singlets ?**
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1. **The singlets ?**
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2. **One doublet ?**
   Maybe, depending on the Yukawa couplings and β angle.

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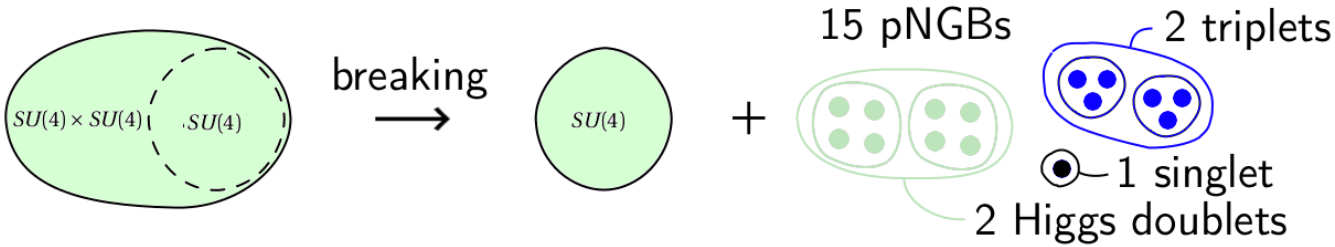
[T.Ma, G.Cacciapaglia 1508:07014]



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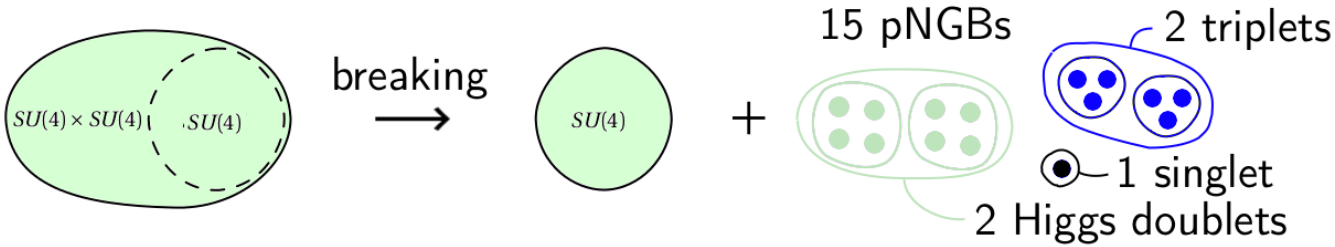

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EW symmetry embedding :

	$SU(2)_L$	$U(1)_Y$
ψ_L	2	0
ψ_R	1	$\pm$ 1/2

Symmetry breaking very similar to the $SU(6)$ case. The breaking can :

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Misalignement of the vacuum parameterized by two angles θ and β
$\tan\beta = \frac{v_2}{v_1}$

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   Yes, depending on the Yukawa couplings.

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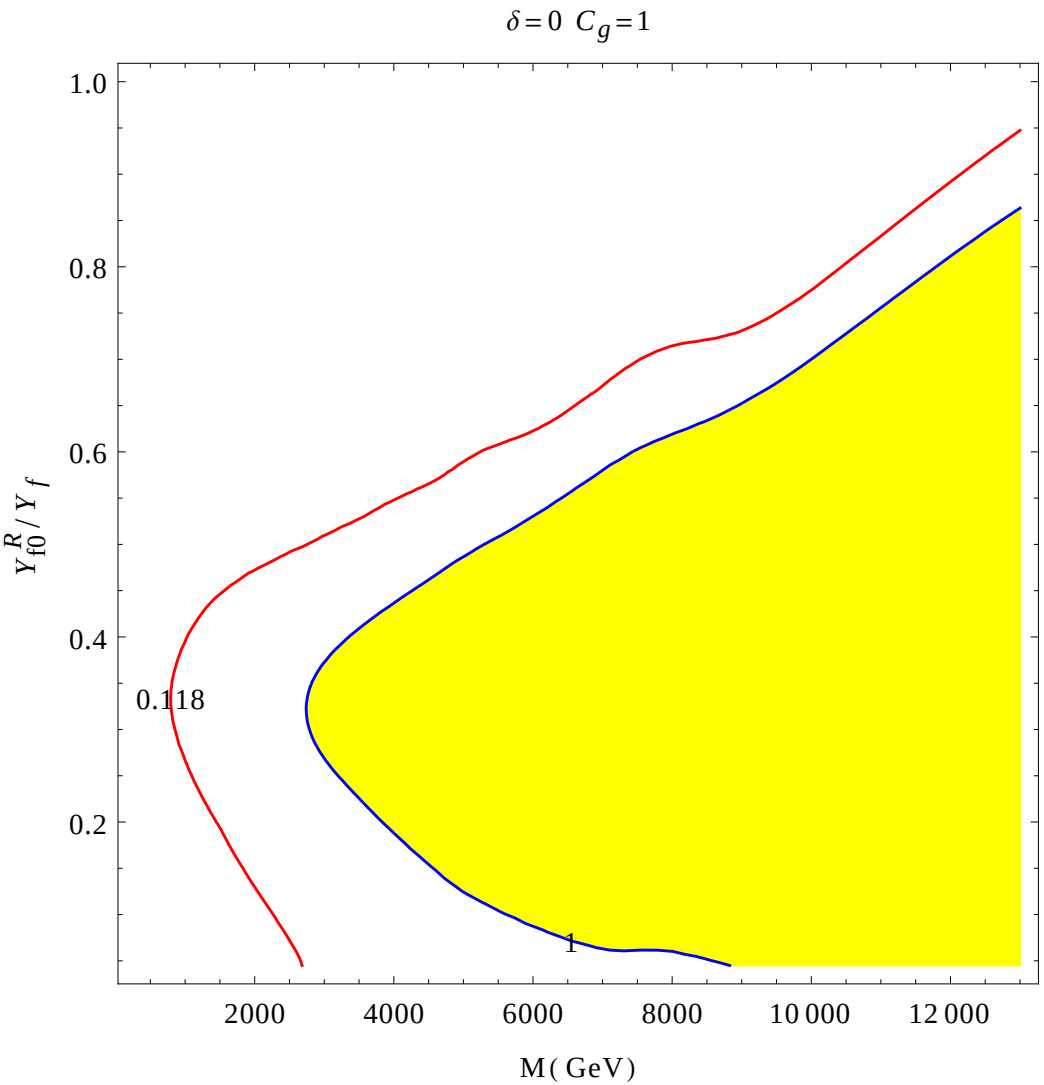
2. **The inert doublet ?**
   Yes, depending on the Yukawa couplings.

3. **The triplets ?**
   Yes, depending on the Yukawa couplings.

Calculation of relic abundance in $SU(4)_L \times SU(4)_R$ model

[T.Ma, S.Zhao, B.Zhang, G.Cacciapaglia in prep.] (preliminary)



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- $SU(6) \rightarrow Sp(6)$: minimal 2HDM case. Two singlets could be DM candidates if there is an exact symmetry which protects them.

To sum up

- Some problems of the SM we need to solve
- One appealing way to do it : Composite Higgs models
- Composite Higgs models could contain DM candidates.
- $SU(6) \rightarrow Sp(6)$: minimal 2HDM case. Two singlets could be DM candidates if there is an exact symmetry which protects them.
- $SU(4)_L \times SU(4)_R \rightarrow SU(4)_D$: Next to minimal 2HDM case. Inert doublet and triplets can be DM candidates depending on Yukawa couplings.

Thanks for your attention.