



# Fundamental 2HDM Composite Dynamics

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Lyon 1

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- ① Motivations
- ②  $SU(6) \rightarrow Sp(6)$
- ③  $SU(4)_L \times SU(4)_R \rightarrow SU(4)_D$
- ④ Conclusion

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# Motivations

## ▷ Standard Model

- Very good agreement with experience
- Discovery of the last piece of the puzzle in 2012 : **a Higgs boson**
- But..... still incomplete.

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- ↪ Non natural (hierarchy problem, fine tuning).
- ↪ No dark matter candidate.

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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 ?

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- 2 New fermions
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## Okay but where is the Higgs ?

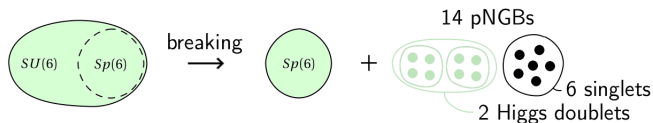
The Higgs is a Goldstone boson, bound state of these new fermions

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## Setup

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

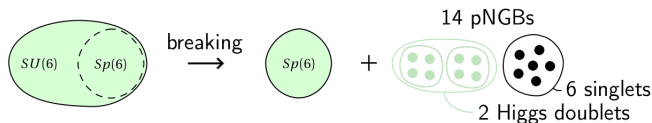


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EW symmetry :

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

or

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

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

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

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Different ways of aligning the vacuum

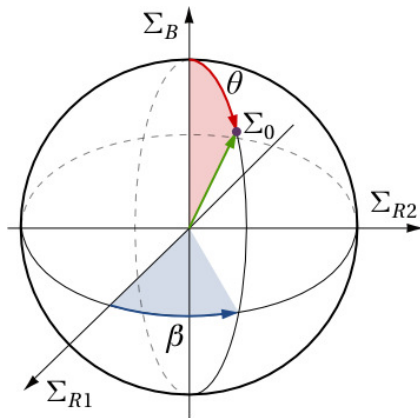
▷  $\Sigma_B \rightarrow$  Preserves the EW symmetry

▷  $\Sigma_{R1,R2} \rightarrow$  Breaks the EW symmetry (Technicolor)



Composite Higgs vacuum :  $\Sigma_0(\theta, \beta)$

$$\tan \beta = \frac{v_2}{v_1}$$



## Some results

⇒ 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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$\Rightarrow$   $h$  couplings :

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

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①

$$V(\theta, \beta) = -4C_q f^4 (Y_t^2 + Y_b^2) \sin^2 \theta - C_g f^4 \frac{3g^2 + g'^2}{2} \cos^2 \theta - 4C_m f^3 (m_L + m_R) \cos \theta$$

minimised for :

$$\cos \theta = \frac{C_m(m_L + m_R)}{4fC_q(Y_t^2 + Y_b^2) \left( 1 - \frac{3g^2 + g'^2}{16} \frac{C_g}{C_q(Y_t^2 + Y_b^2)} \right)}$$

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## ② Higgs mass

$$m_{h_1}^2 = \frac{C_q}{4} m_{\text{top}}^2 - \frac{C_g}{16} (2m_W^2 + m_Z^2)$$

## Dark Matter content

**Where could Dark Matter come from in this model ?**  
(Currently under investigation)



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Maybe. Two of them decay via anomalies, the other four mix. Is there an exact symmetry that prevents the singlets to decay ?

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② **One doublet ?**

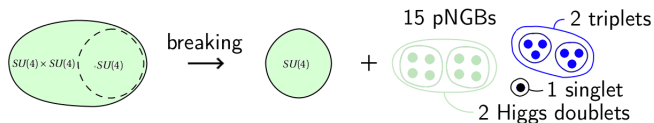
Maybe, depending on the Yukawa couplings and  $\beta$  angle.

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

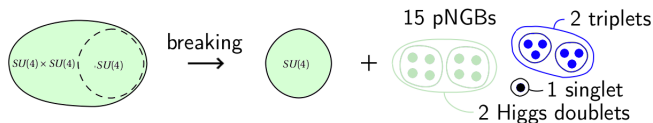


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EW symmetry embedding :

	$SU(2)_L$	$U(1)_Y$
$\psi_L$	2	0
$\psi_R$	1	$\pm 1/2$

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

- ▶ Preserve  $SU(2)_L \times U(1)_Y$
- ▶ Break  $SU(2)_L \times U(1)_Y$

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Misalignment of the vacuum parameterized by two angles  $\theta$  and  $\beta$

$$\tan \beta = \frac{v_2}{v_1}$$

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Yes, depending on the Yukawa couplings.

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Yes, depending on the Yukawa couplings.

③ **The triplets ?**

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## 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.