CompHS:
the dynamics of
Composite Higgses

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Why this project?

Interested in cultural exchanges...

...and in exploring physics Beyond the Standard Model!

Why do we need BSM?

Dennis Balibouse/Reuters

Ian MacNicol / AFP - Getty Images

The Higgs boson has been discovered.

The Standard Model is now complete!

Fabrice Coffrini/AFP/Getty Images

- The discovery of the Higgs boson has brought the Naturalness problem to reality! New Physics at the TeV scale needed more than before!
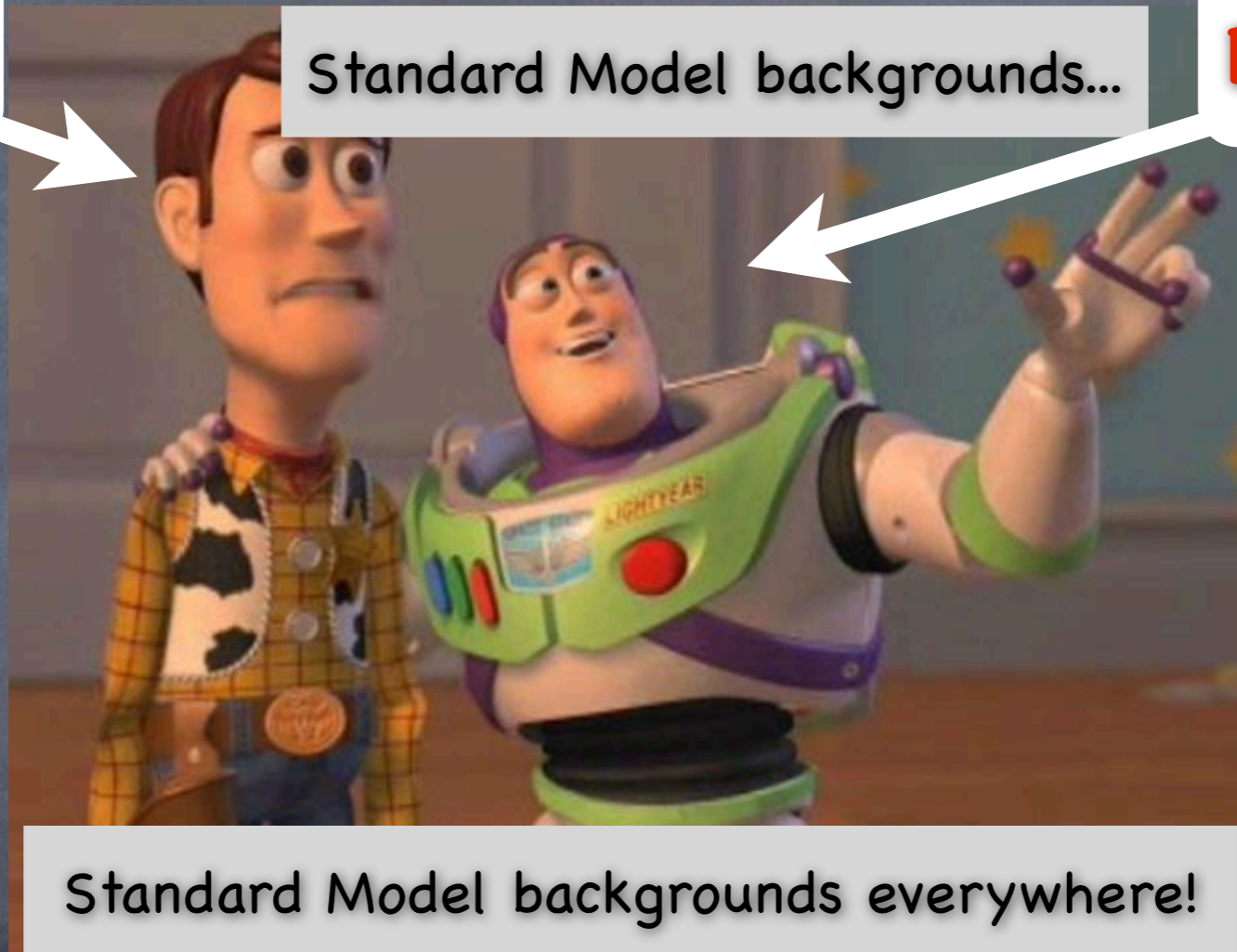
LHC perspective on New Physics

The hard reality:

Standard Model all the way up?
The TeV scale is a qualitative argument.
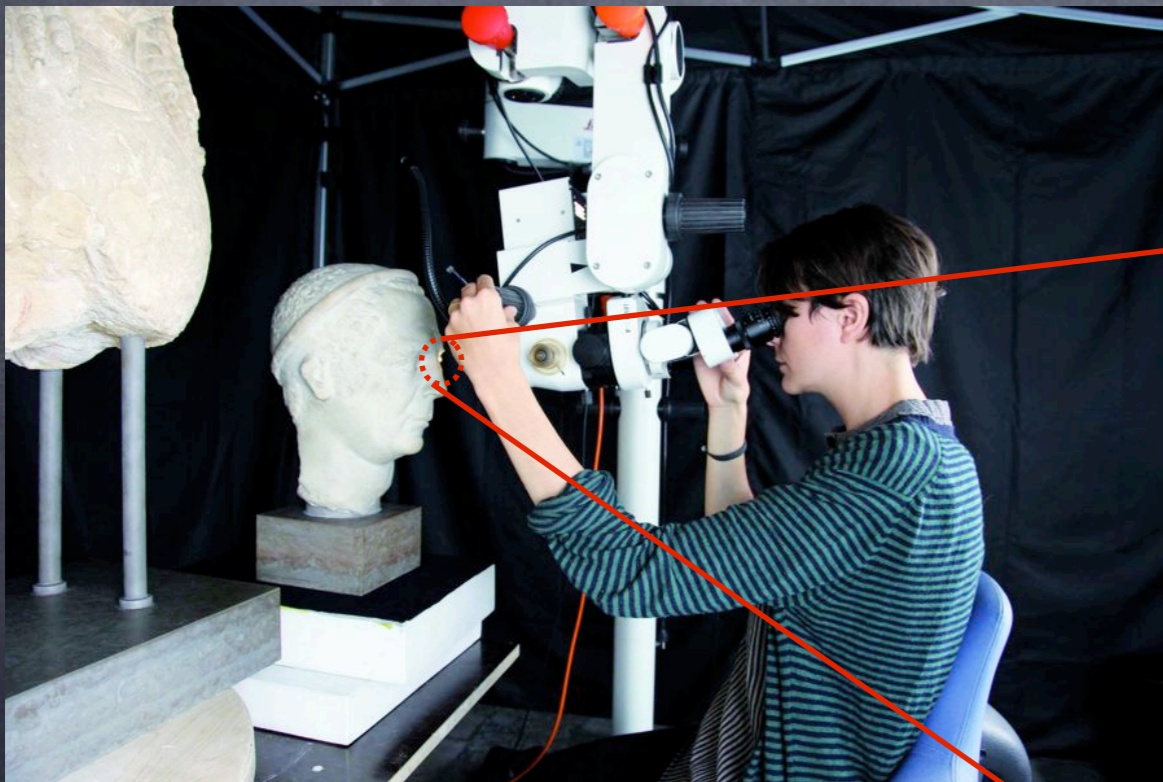And, BSM signals may be not so easy to spot!

History teaches us that surprises are possible!

- for centuries we believed that ancient Greek cities were all standard stone and dust.

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Photos: Ny Carlsberg Glyptotek, Copenhagen

History teaches us that surprises are possible!

- for centuries we believed that ancient Greek cities were all standard stone and dust.

- recent detailed analysis of the decayed temples and statues showed that ancient Greece was in TECHNICOLOUR!

PHOTO COURTESY STIFTUNG ARCHÄOLOGIE, MUNICH

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Can the Higgs be a composite state of a confining dynamics?

Global symmetries:
$$\mathcal{G} \rightarrow \mathcal{H}$$

Georgi, Kaplan
1984

U   U

Gauge symmetries:
$$\mathcal{G}_{\mathrm{SM}} \rightarrow U(1)_{\mathrm{em}}$$

Example:
$$SU(4) \rightarrow Sp(4) \sim SO(5)$$

U   U

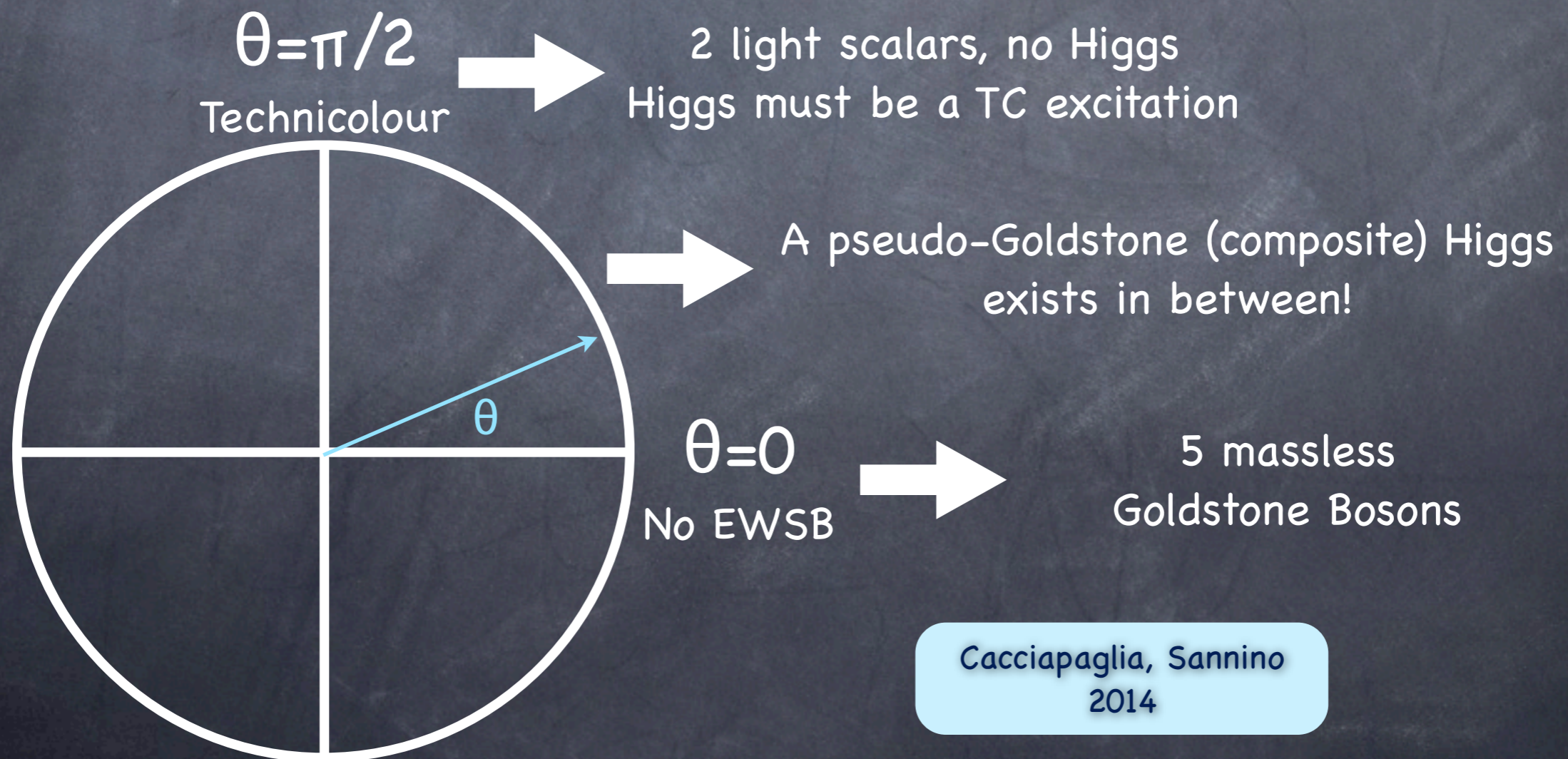$$SU(2)_{\mathrm{L}} \times U(1)_{\mathrm{Y}} \rightarrow U(1)_{\mathrm{em}}$$

15 – 10 = 5 pseudo-Goldstone Bosons (i.e. light scalars)

3 eaten, 1 is the Higgs, 1 extra singlet

The question is:
how is the breaking aligned?

Example: $$SU(4) \to Sp(4) \sim SO(5)$$

∪   ∪

$$SU(2)_{\mathrm{L}} \times U(1)_{\mathrm{Y}} \to U(1)_{\mathrm{em}}$$

θ=π/2   ➡   2 light scalars, no Higgs
Technicolour   Higgs must be a TC excitation

➡   A pseudo-Goldstone (composite) Higgs
exists in between!

θ

θ=0   ➡   5 massless
No EWSB   Goldstone Bosons

Do we have a dynamical model for this?

$SU(2)_{\mathrm{TC}}$ with 4 Weyl doublets Q_i

$< Q_i Q_j >$ condenses and breaks

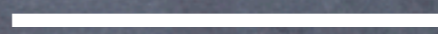$SU(4) \rightarrow Sp(4) \sim SO(5)$ (proven on the lattice)

Lewis, Pica, Sannino
2011

Do we have a dynamical model for this?

$SU(2)_{\rm TC}$ with 4 Weyl doublets Q_i

Spectrum:

vector resonances
ρ and a

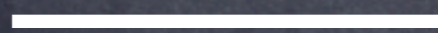$$m_a = \frac{3.3 \pm 0.7}{\sin\theta}\ \mathrm{TeV}$$

$$m_\rho = \frac{2.5 \pm 0.5}{\sin\theta}\ \mathrm{TeV}$$

} Lattice results!
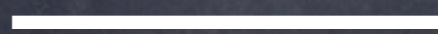
Hietanen, Lewis, Pica, Sannino 2014

scalar singlet

$$m_\eta = \frac{m_H}{\sin\theta}$$

Galloway, Evans, Luty, Tacchi 2010

Higgs

$$m_H = 125\ \mathrm{GeV}$$

Not a prediction!

Do we have a dynamical model for this?

$SU(2)_{\text{TC}}$ with 4 Weyl doublets Q_i

For sin θ = 0.2 (typical value):

vector resonances
ρ and a

$m_a = 16.5 \pm 3.5 \text{ TeV}$

$m_\rho = 12.5 \pm 2.5 \text{ TeV}$

Lattice
results!

scalar singlet

$m_\eta = 625 \text{ GeV}$

Higgs

$m_H = 125 \text{ GeV}$

Not a prediction!

A lot can be learned
exploiting the interplay between:

- Desired symmetry breaking pattern.

- Fundamental dynamics.

- Lattice data.

- Extra dimension modelling - via the AdS/CFT

As a starting project, we are interested in Top partners (i.e. coloured spin-1/2 composites)

More complicated models are needed.

> Ferretti, Karateev
> 2013

Examples with 2 species of techni-fermions exist

> Barnard, Gherghetta, Ray
> 2013

Carries colour

$$\chi \, Q^i \, Q^j \rightarrow 6$$

of SU(4)

$$\bar{\chi} \, \bar{Q}^i \, Q^j \rightarrow 15 \oplus 1$$

- Composites couple to the Higgs.

- Standard fermions mix with the composites.

As a starting project, we are interested in Top partners (i.e. coloured spin-1/2 composites)

Expertise of the team:

- Phenomenology of Composite Higgs models (S.J.Lee, T.Flacke, H.Cai)

- Chiral lagrangians (A.Deandrea)

- Higgs Physics (G.Drieu La Rochelle)

- Extra dimensions and model building (G.Cacciapaglia, T.Flacke)

- Models of fundamental dynamics (G.Cacciapaglia and F.Sannino's group at CP3 Origins, Odense)