Bound state spectrum of Brout-Englert-Higgs theories

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& L. Egger, A. Maas [arXiv:1701.02881]
& A. Maas, P. Törek [arXiv:1709.07477, arXiv:1710.01941]

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BEH physics

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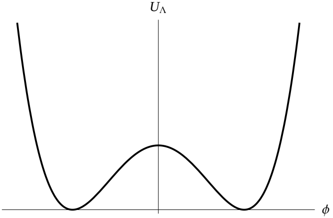

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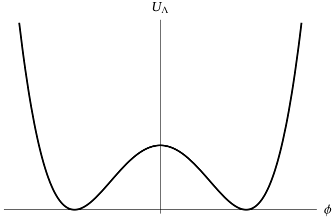

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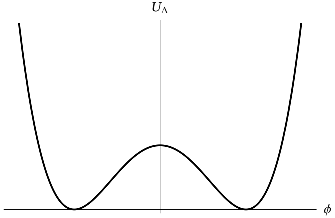

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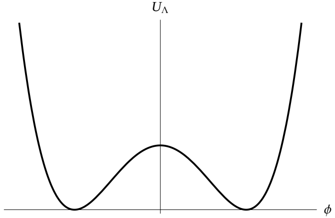

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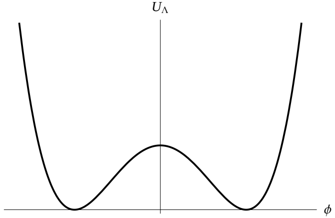

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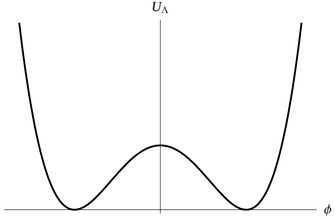

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- same number of states also seen in lattice computations
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- BUT! Mismatch to lattice computations for $\mathrm{SU}(3)$
  [Maas&Törek'16,'18]

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$\Rightarrow$ Rethinking of the particle spectrum!

Fröhlich-Morchio-Strocchi mechanism

1. Construct a gauge-invariante operator

$$\mathcal{O}(x) = (\phi^\dagger \phi)(x)$$

[Fröhlich et al '80,'81]

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$$\langle (\phi^\dagger \phi)(x)\, (\phi^\dagger \phi)(y) \rangle = v^4 + v^3 \langle \varphi \rangle + v^2 \langle \varphi^2 \rangle + v \langle \varphi^3 \rangle + \langle \varphi^4 \rangle$$

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$$\langle (\phi^\dagger \phi)(x)\, (\phi^\dagger \phi)(y) \rangle = v^2 \langle h(x) h(y) \rangle + \langle h(x) h(y) \rangle^2 + \mathcal{O}(g, \lambda)$$

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- Confirmed on the lattice for $\mathrm{SU}(2)$-Higgs theory [Maas'12]

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$$\mathcal{L} = -\frac{1}{4} W_{i\,\mu\nu} W_i^{\mu\nu} + (D_\mu \phi)^\dagger D^\mu \phi - U(\phi^\dagger \phi)$$

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- Mapping of local to global multiplets in the Standard Model

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Beyond the Standard Model

- $\mathrm{SU}(N > 2)$ gauge theory + Higgs in fundamental representation

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- Also mismatches between the fluctuation and bound state spectrum for other representations or gauge groups

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	$W^\mu_\pm$	m_W	2			
	Z^μ	m_Z	1			
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0^+	h	m_h	1	O_{0+}	m_h	1
	φ^a	$\sim w$	6	O_{0-}	m_h	1
	σ_i	$\sim w$	8	$O_{\pm1+}$	$\sim w$	$1/\bar{1}$
	$\tilde{\sigma}_i$	$\sim w$	3	$O_{\pm1-}$	$\sim w$	$1/\bar{1}$
	$\bar{\sigma}_i$	$\sim w$	1			
1^-	A^μ	0	1	O_{0+}	0	1
	$W^\mu_\pm$	m_W	2	O_{0-}	0	1
	Z^μ	m_Z	1	$O_{\pm1+}$	$\sim w$	$1/\bar{1}$
	X^μ_i	$\sim w$	6	$O_{\pm1-}$	$\sim w$	$1/\bar{1}$
	Y^μ_i	$\sim w$	6			
	G^μ_i	0	8			

[Maas,RS,Törek'17]

Beyond the Standard Model - Multi-Higgs models

- Mapping of local to global multiplets works for 2HDM! [Maas,Pedro 16]
- But constraints for $\mathrm{SU}(5)$ GUT

$$\mathrm{SU}(5) \xrightarrow{\langle\Sigma\rangle\sim w} \mathrm{SU}(3)\times\mathrm{SU}(2)\times\mathrm{U}(1) \xrightarrow{\langle\phi\rangle\sim v} \mathrm{SU}(3)\times\mathrm{U}(1) \qquad (w \gg v)$$

- Global symmetry: $\mathrm{U}(1)$~~$\rtimes\mathbb{Z}_2$~~

J^P	Field	Mass	Degeneracy	Operator	Mass	Degeneracy
0^+	h	m_h	1	O_0	m_h	1
	φ^a	$\sim w$	6			
	σ_i	$\sim w$	8	$O_{\pm1}$	$\sim w$	$1/\bar{1}$
	$\tilde{\sigma}_i$	$\sim w$	3			
	$\bar{\sigma}_i$	$\sim w$	1			
1^-	A^μ	0	1	O_0	0	1
	$W^\mu_\pm$	m_W	2			
	Z^μ	m_Z	1	$O_{\pm1}$	$\sim w$	$1/\bar{1}$
	X^μ_i	$\sim w$	6			
	Y^μ_i	$\sim w$	6			
	G^μ_i	0	8			

[Maas,RS,Törek'17]

Conclusions & Outlook

- Observable spectrum must be gauge invariant
- Non-Abelian gauge theory: composite operator
- FMS mechanism provides a mapping of local to global multiplets
- Same results in leading order for the standard model and 2HDM
- BSM model building may be affected

Thank you for your attention!