Constraining BSM models by nonperturbative Higgs physics

René Sondenheimer

Institute of Physics
Karl-Franzens-University Graz

in collaboration with A. Maas and P. Törek

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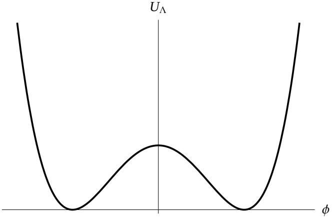

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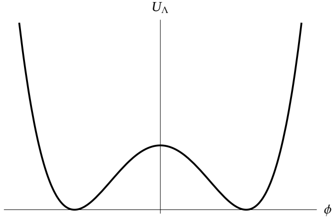

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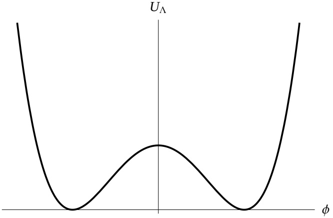

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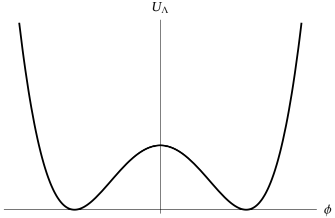

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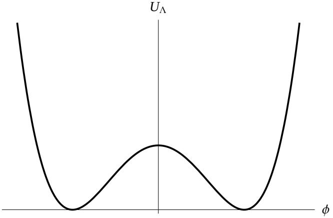

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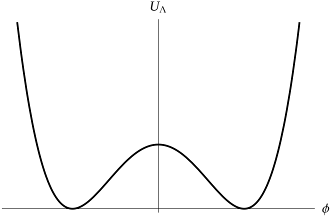

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- same number of states also seen in lattice computations
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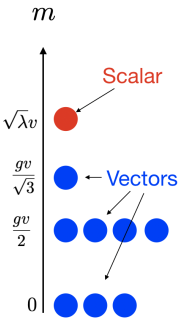
- BUT! Mismatch to lattice computations for $\mathrm{SU}(3)$
  [Maas&Törek'16,'18]

BEH physics - SU(3) with fundamental scalars

- Conventional perspective: SU(3) $\rightarrow$ SU(2)
- Mismatch conventional analysis vs lattice spectrum:



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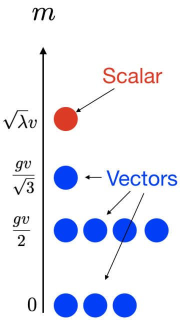

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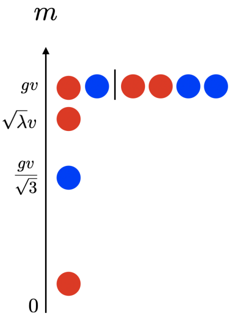

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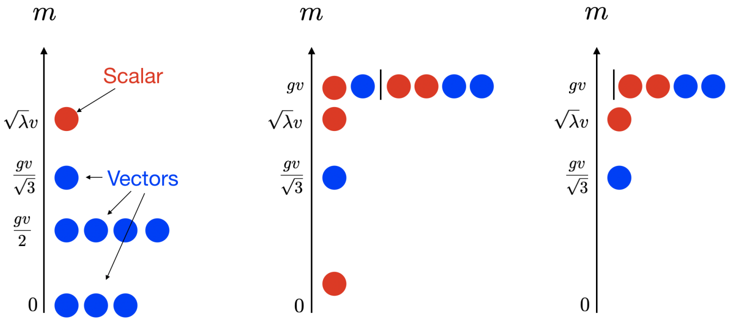

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$\Rightarrow$ Rethinking of the particle spectrum!

Fröhlich-Morchio-Strocchi mechanism

1. Construct a gauge-invariante operator

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

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

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FMS mechanism in the weak sector

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

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- Mapping of local to global multiplets in the Standard Model
  $\to$ phenomenological implications

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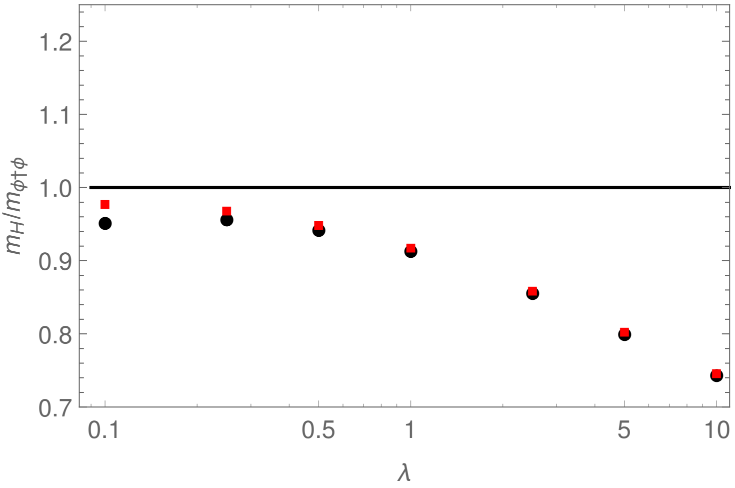
- Compute properties of n-point functions on both sides of the FMS relation

Nonperturbative checks of FMS

Preliminary!



$g_w = 0.654$ $g_w = 0.924$

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	$O_{\pm1}^\mu$	$\underbrace{F_\mathrm{f}\cdots F_\mathrm{f}}_{N-2}\cdot A_\mathrm{f}$	A_s^μ	1

- Nonperturbative check for $N=3$ on the lattice
  [Maas,Törek'16,'18]

[Maas,RS,Törek'17], [RS'19 in prep.]

Beyond the Standard Model

- $\mathrm{SU}(N > 2)$ gauge theory + Higgs in fundamental representation
- Local and global symmetry group do not match: $\mathrm{SU}(N)$ vs $\mathrm{U}(1)$

J^P	$\mathrm{SU}(N)$ invariant	$\mathrm{SU}(N-1)$ invariant	el. Fields	Multiplicity
0^+	$\phi^\dagger\phi$	h	h	1
	$\phi^\dagger D^2\phi$	h, (A_s^2), $(\lvert A_\mathrm{f}\rvert^2)$		
	$\mathrm{tr}F^2$	$(\mathrm{tr}F_\mathrm{a}^2)$, $(\lvert F_\mathrm{f}\rvert^2)$, (F_s^2)		
	$O_{\pm1}$	$\underbrace{F_\mathrm{f}\cdots F_\mathrm{f}}_{N-1}$		
1^-	$\phi^\dagger D^\mu\phi$	A_s^μ	A_a^μ	$(N-1)^2-1$
	$\phi^\dagger F^{\mu\nu}D_\nu\phi$	$(F_\mathrm{f}^{\mu\nu}A_{\mathrm{f}\nu})$, $(F_\mathrm{s}^{\mu\nu}A_{\mathrm{s}\nu})$	$A_\mathrm{f}^\mu, A_\mathrm{f}^{\dagger\mu}$	$2(N-1)$
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- Nonperturbative check for $N = 3$ on the lattice
  [Maas,Törek'16,'18]
- Also mismatches between spectra for other representations or gauge groups

[Maas,RS,Törek'17], [RS'19 in prep.]

Beyond the Standard Model - $\mathrm{SU}(5)$ GUT

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

J^P	$\mathrm{SU}(5)$ invariant	$\mathrm{SU}(3)\times\mathrm{U}(1)$ invariant	el. Fields
0^+			h $+18$ fields with $m\sim w$
1^-			A^μ $W^{\pm\mu}$ Z^μ $G^\mu(8)$ $+12$ Leptoquarks with $m\sim w$

[Maas,RS,Törek'17], [RS'19 in prep.]

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	O_{0-}		$+18$ fields with $m\sim w$
	$O_{\pm1+}$		
	$O_{\pm1-}$		
1^-	O^μ_{0+}		A^μ
	O^μ_{0-}		$W^{\pm\mu}$
	$O^\mu_{\pm1+}$		Z^μ
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- Similar considerations for $\mathrm{SO}(10)$, $\mathrm{E}(6)$, $\cdots$

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- Similar considerations for $\mathrm{SO}(10)$, $\mathrm{E}(6)$, $\cdots$
- Rethinking of GUT construction!

[Maas,RS,Törek'17], [RS'19 in prep.]

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
- BSM model building can be affected

Thank you for your attention!