Conformal Standard Model

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Theoretical drawbacks of SM

- Hierarchy problem – quantum corrections
  $m^2 \sim \Lambda^2 \Rightarrow$ why $m \ll M_P$?
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- Most popular proposal:
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- 10 years ago the Conformal Standard Model (CSM) was proposed

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- assumptions:
- Conformal symmetry 'softly broken'
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- the model viable to M_{Pl}
- no low energy supersymmetry

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- vacuum stable up to M_{Pl} (in the SM unstable above 10^{10} GeV)
- all masses logarithmically running
- a set of additional complex scalars:
  - one scalar mixing with the usual Higgs
  - several sterile scalars
  - phases of scalar fields very light and extremely weakly coupled
    candidates for DM

The Model

A. Latosiński, A. Lewandowski, K.A.M., H. Nicolai, JHEP 1510 (2015) 170

- $\mathcal{L} = \mathcal{L}_{kin} + \mathcal{L}'$:

$$\begin{aligned}\mathcal{L}' \;:=\; & \Big(\bar{L}^i \Phi Y^E_{ij} E^j + \bar{Q}^i \epsilon \Phi^* Y^D_{ij} D^j + \bar{Q}^i \epsilon \Phi^* Y^U_{ij} U^j + \\ & + \bar{L}^i \epsilon \Phi^* Y^\nu_{ij} \nu^j_R + y_M \varphi_{ij} N^{iT} \mathcal{C} N^j + \text{h.c.}\Big) \\ & - m^2_\Phi (\Phi^\dagger \Phi) - m^2_\phi \mathrm{Tr}(\varphi \varphi^\star) \\ & - \lambda_1 (\Phi^\dagger \Phi)^2 - 2\lambda_3 \mathrm{Tr}(\varphi\varphi^\star)(\Phi^\dagger\Phi) - \lambda_2 \left(\mathrm{Tr}(\varphi\varphi^\star)\right)^2 \\ & - \lambda_4 \mathrm{Tr}(\varphi\varphi^\star\varphi\varphi^\star)\end{aligned}$$

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- $\phi = \phi_{ij}$, $Y^M \sim O(1)$, $Y^\nu_{ij} \sim O(10^{-6})$ (see-saw)
  $m_{\Phi,\phi} \sim 100 - 1000$ GeV

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  SSB of the lepton number symm. $\langle\varphi\rangle \neq 0$
- phases of ϕ_{ij} – (pseudo)GBs of global lepton number symmetry

$$L^i \to e^{\mathrm{i}\alpha} L^i, \;\; E^i \to e^{\mathrm{i}\alpha} E^i, \; \nu^i_R \to e^{\mathrm{i}\alpha} \nu^i_R, \;\; \varphi_{ij} \to e^{-2\mathrm{i}\alpha} \varphi_{ij}$$

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- we have shown that if we impose vanishing of quadratic divergences at one scale Λ then all masses assumed small at Λ remain small in the whole interval (M_W, M_{Pl}) – 'soft breaking' of conformal symmetry
- in supersymmetry quadratic divergences vanish identically by construction for all scales

The Model

- vanishing of quadratic divergences

$$f_H = \frac{9}{4}g_w^2 + \frac{3}{4}g_y^2 + 6\lambda_1 + 12\lambda_3 - 6y_t^2 = 0 \text{ (at } \Lambda)$$

$$f_\phi = 14\lambda_2 + 4\lambda_3 + 8\lambda_4 - |y_M|^2 = 0 \text{ (at } \Lambda)$$

Phenomenology

- no other new particles at LHC except standard Higgs 125 GeV (M_1) and the new scalar (M_2) – they are mixtures of the doublet and $\mathrm{Tr}(\phi_{ij})$ with the mixing angle β

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- baryogenesis through (resonant) leptogenesis - $\eta \sim 10^{-10}$ very easy to obtain from new phases in Y_ν^{ij}
- phases of new scalars – very light, very weakly coupled, good candidates for CDM

Phenomenology – examples

$\|y_M\|$	M_N	$M_{h'}$	t_β	$\Gamma_{h'}$	$h' \to OP$	$h_0 \to OP$
0.56	545	378	424	-0.3	0.59	0.69
0.54	520	378	360	-0.3	0.59	0.68
0.75	1341	511	1550	0.25	0.73	0.91
0.75	2732	658	3170	-0.16	0.74	0.99
0.82	2500	834	2925	0.15	0.74	0.98

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- the model has several more parameters than SM (MSSM 116) and uses quantum symmetry breaking (conformal anomaly)
- vacuum is stable up to M_{Pl}
- baryogenesis (through resonant leptogenesis) easily accommodates $\eta \sim 10^{-10}$

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- CSM has definite (unique) predictions for LHC – besides the Higgs one new scalar with the Higgs BRs (plus invisible), other scalars and right-chiral neutrinos (masses $\sim$ 1 TeV) too weakly coupled to be visible

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- CSM has definite (unique) predictions for LHC – besides the Higgs one new scalar with the Higgs BRs (plus invisible), other scalars and right-chiral neutrinos (masses $\sim$ 1 TeV) too weakly coupled to be visible
- extremely light and naturally weakly coupled phases – CDM candidates