Coformal Journeys through SUSY GUTs: from Finiteness to Supergravity Models

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What's going on?

- What happens as we approach the Planck scale? or just as we go up in energy...
- What happened in the early Universe?
- How are the gauge, Yukawa and Higgs sectors related at a more fundamental level?
- **How do we go from a fundamental theory to eW field theory as we know it?**
- Why there are so many free parameters in the SM?
- How do particles get their very different masses?
- What about flavour?

- **Where is the new physics??**

Search for understanding relations between parameters

addition of symmetries.

$N = 1$ SUSY GUTs.

Complementary approach: look for RGI relations among couplings at GUT scale $\longrightarrow$ Planck scale

$\Rightarrow$ **reduction of couplings**

resulting theory: less free parameters $\therefore$ more predictive

Zimmermann 1985

Remarkable: reduction of couplings provides a way to relate two previously unrelated sectors

gauge and Yukawa couplings

Kapetanakis, M.M., Zoupanos (1993), Kubo, M.M., Olechowski, Tracas, Zoupanos (1995,1996,1997); Oehme (1995); Kobayashi, Kubo, Raby, Zhang (2005); Gogoladze, Mimura, Nandi (2003,2004); Gogoladze, Li, Senoguz, Shafi, Khalid, Raza (2006,2011); M.M., Tracas, Zoupanos (2014)

Reduction of Couplings – RoC

A RGI relation among couplings $\Phi(g_1, \ldots, g_N) = 0$ satisfies

$$\mu \, d\Phi/d\mu \; = \; \sum_{i=1}^{N} \beta_i \, \partial\Phi/\partial g_i \; = \; 0.$$

g_i = **coupling,** β_i **its** β **function**

Finding the $(N-1)$ independent Φ's is equivalent to solve the
reduction equations (RE)

$$\beta_g \, (dg_i/dg) = \beta_i \; ,$$

$i = 1, \cdots, N$

- Reduced theory: only one independent coupling and its β function
- complete reduction: power series solution of RE

$$g_a = \sum_{n=0} \rho_a^{(n)} \, g^{2n+1}$$

- uniqueness of the solution can be investigated at one-loop
  valid at all loops Zimmermann, Oehme, Sibold (1984,1985)
- The complete reduction might be too restrictive, one may use fewer Φ's as RGI constraints
- SUSY is essential for finiteness

finiteness: absence of ∞ renormalizations

$$\Rightarrow \quad \beta^N = 0$$

may be achieved through RE

RoC + SUSY = finiteness

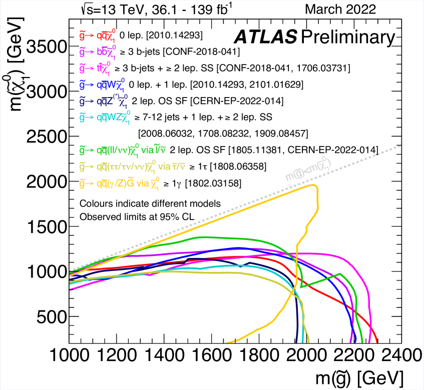
- SUSY no-renormalization theorems
- $\Rightarrow$ only study one and two-loops
- RoC guarantees that is gauge and reparameterization invariant to all loops

SUSY and RoC

Many of the reduced systems imply SUSY, even if it was not assumed a priori

Moreover: adding SUSY improves predictions $\Rightarrow$

SUSY + reduction of couplings natural



- Light SUSY in various SUSY models incompatible with LHC data
- **BUT** Different assumptions on parameters of MSSM or NMSSM lead to different predictions

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2022-013/

Predictions in $SU(5)$ FUTs – only 3rd generation

	$M_{top}^{th} \sim \mathbf{178}$ GeV	large $\tan\beta$	1993
	$M_{top}^{exp} = \mathbf{17618}$		1995

$M_{top}^{th} \sim \mathbf{174}$	$M_{top}^{exp} = 175.65.5$	heavy s-spectrum	1998
$M_{top}^{th} \sim \mathbf{174}$	$M_{top}^{exp} = 174.35.1$GeV	$M_{Higgs}^{th} \sim \mathbf{115} \sim \mathbf{135}$ GeV	2003

constraints on M_h and $b \to s\gamma$ already push up the s-spectrum > 300 GeV

$M_{top}^{th} \sim \mathbf{173}$	$M_{top}^{exp} = 172.72.9$ GeV	$M_{Higgs}^{th} \sim \mathbf{122} \sim \mathbf{126}$ GeV	2007
		$M_{Higgs}^{exp} = \mathbf{126} \pm \mathbf{1}$	2012
$M_{top}^{th} \sim \mathbf{173}$	$M_{top}^{exp} = 173.30.9$ GeV	$M_{Higgs}^{th} \sim \mathbf{121} - \mathbf{126}$ GeV	2013

Constraints from Higgs and B physics$\Rightarrow$ s-spectrum > 1 TeV.

More analyses, phenomenological and theoretical, encouraged (and done)

MM, Kapetanakis, Zoupanos 1992; MM, Heinemeyer, Kalinowski, Kotlarski, Kubo, Ma, Olechowski, Patellis, Tracas, Zoupanos 1993-2023

Finiteness

Finiteness = absence of divergent contributions to renormalization parameters $\Rightarrow \beta = 0$

Possible in SUSY due to improved renormalization properties

A chiral, anomaly free, $N = 1$ globally supersymmetric gauge theory based on a group G with gauge coupling constant g has a superpotential

$$W = \frac{1}{2}\, m^{ij}\, \Phi_i\, \Phi_j + \frac{1}{6}\, C^{ijk}\, \Phi_i\, \Phi_j\, \Phi_k\ ,$$

Requiring one-loop finiteness $\beta_g^{(1)} = 0 = \gamma_i^{j(1)}$ gives the following conditions:

$$\sum_i T(R_i) = 3C_2(G)\,, \qquad \frac{1}{2} C_{ipq} C^{jpq} = 2\delta_i^j g^2 C_2(R_i)\,.$$

$C_2(G)$ quadratic Casimir invariant, $T(R_i)$ Dynkin index of R_i, C_{ijk} Yukawa coup., g gauge coup.

- **restricts the particle content of the models**
- **relates the gauge and Yukawa sectors**

All-loop finiteness

- One-loop finiteness $\Rightarrow$ two-loop finiteness

  Jones, Mezincescu and Yao (1984,1985)

- Cannot be applied to the Minimal SUSY Standard Model (MSSM): $C_2[U(1)] = 0$
- The finiteness conditions allow only soft supersymmetry breaking terms (SSB) terms

It is possible to achieve all-loop finiteness $\beta^n = 0$:

Lucchesi, Piguet, Sibold

1. One-loop finiteness conditions must be satisfied

   restricts irreps and relates gauge and Yukawa couplings

2. The Yukawa couplings must be a formal power series in g, which is solution (isolated and non-degenerate) to the reduction equations $C^{ijk} = g \sum_{n=0} \rho^{ijk}_{(n)} g^{2n}$

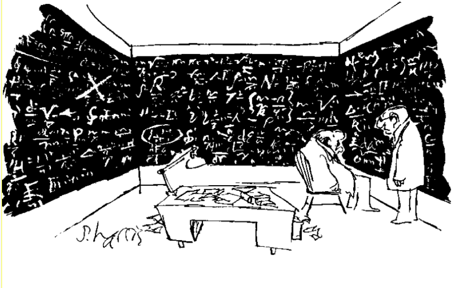
SUSY breaking soft terms

Supersymmetry is essential. It has to be broken, though…

$$-\mathcal{L}_{\rm SB} = \frac{1}{6}\, h^{ijk}\, \phi_i\phi_j\phi_k + \frac{1}{2}\, b^{ij}\, \phi_i\phi_j + \frac{1}{2}\, (m^2)^j_i\, \phi^{*\,i}\phi_j + \frac{1}{2}\, M\, \lambda\lambda + \text{H.c.}$$

h trilinear couplings (A), b^{ij} bilinear couplings, m^2 squared scalar masses, M unified gaugino mass

Introduce over 100 new free parameters ☹



"Whatever happened to *elegant* solutions?"

RGI soft terms, to all-loops

- It is possible to have all-loop RGI relations between trilinear terms h_{ijk} and Yukawa couplings C_{ijk}

$$h^{ijk} = -M \frac{dC(g)^{ijk}}{d\ln g},$$

- Then, the following relations are also RGI invariante at all-loops Hisano; Kazakov; Jack, Jones, Pickering

$$M = M_0 \frac{\beta_g}{g}, \qquad h^{ijk} = -\, M_0 \beta_{C^{ijk}},$$

$$b^{ij} = -M_0 \beta_M^{ik}, \qquad (m^2)^i_j = \frac{1}{2} |M_0|^2 \mu \frac{\partial \gamma^i_j}{\partial \mu},$$

where M_0 is a reference scale to be specified. SSB terms depend only on g and the unified gaugino mass M

M unified gaugino mass, m scalar masses, μ Higgsino mixing term

- They coincide with AMSB when $M_0 = m_{3/2}$, but charge and colour breaking vacua, tachyonic spectrum ☹

- Possible to extend the universality condition to a sum-rule for the soft scalar masses $\Rightarrow$ better phenomenology

Kawamura, Kobayashi, Kubo; Kobayashi, Kubo, M.M., Zoupanos

Soft scalar sum-rule for the finite case

Finiteness implies

$$C^{ijk} = g \sum_{n=0} \rho^{ijk}_{(n)} g^{2n} \quad \Rightarrow \quad h^{ijk} = -MC^{ijk} + \cdots = -M\rho^{ijk}_{(0)}\, g + O(g^5)$$

If lowest order coefficients $\rho^{ijk}_{(0)}$ and $(m^2)^i_j$ satisfy diagonality relations

$$\rho_{ipq(0)}\rho^{jpq}_{(0)} \propto \delta^j_i \,, \qquad (m^2)^i_j = m^2_j \delta^i_j$$

for all p and q.

The following soft scalar-mass sum rule is satisfied, also to all-loops

$$(\, m_i^2 + m_j^2 + m_k^2 \,)/MM^\dagger = 1 + \frac{g^2}{16\pi^2}\,\Delta^{(2)} + O(g^4)$$

for $i,\ j,\ k$ with $\rho^{ijk}_{(0)} \neq 0$, where $\Delta^{(2)}$ is the two-loop correction =0 for universal choice

Kobayashi, Kubo, Kawamura; Kobayashi, Kubo, Zoupanos, Kobayashi, Kubo, MM, Zoupanos

based on developments by Kazakov et al; Jack, Jones et al; Hisano, Shifman; etc

Also satisfied in certain class of orbifold models, where massive states are organized into $N = 4$ supermultiples

Several aspects of Finite Models have been studied

- $SU(5)$ Finite Models studied extensively
  Rabi et al; Kazakov et al; López-Mercader, Quirós et al; M.M, Kapetanakis, Zoupanos; etc (since the late '80's)
- One of the above coincides with a non-standard Calabi-Yau $SU(5) \times E_8$
  Kapetanakis, M.M., Zoupanos
- Finite theory from compactified string model also exists (albeit not good phenomenology)
  Ibáñez
- Criteria for getting finite theories from branes — Hanany, Strassler, Uranga
- $N = 2$ finiteness — Frere, Mezincescu and Yao
- Models involving three generations — Babu, Enkhbat, Gogoladze
  Estrada-Ramos, MM, Patellis, Zoupanos
- Some models with $SU(N)^k$ **finite** $\Longleftrightarrow$ **3 generations,** good phenomenology with $SU(3)^3$
  Ma, M.M, Zoupanos
- Relation between commutative field theories and finiteness studied
  Jack and Jones
- Proof of conformal invariance in finite theories and beta deformed $N = 4$ SYM
  Bork and Kazakov
- Inflation from effects of curvature that break finiteness
  Elizalde, Odintsov, Pozdeeva, Vernov

$SU(5)$ Finite Models only third generation

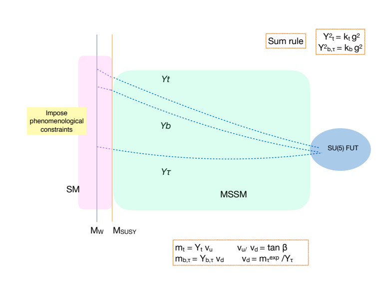
The matter content is – restricted by finiteness. Gauge and Yukawa couplings related

$$3\ \overline{\mathbf{5}} + 3\ \mathbf{10} + 4\ \{\mathbf{5} + \overline{\mathbf{5}}\} + \mathbf{24}$$

The models are finite to all-loops in the dimensionful and dimensionless sector. In addition:

- **in Yukawa sector no free parameters**
- The soft scalar masses obey a sum rule, **only 2 free parameters**
- At the M_{GUT} scale the gauge symmetry and finiteness are broken $\Rightarrow$ MSSM
- Assume two Higgs doublets of the MSSM should mostly be made out of a pair of Higgs $\{\mathbf{5} + \overline{\mathbf{5}}\}$ coupled mainly to the third generation

Kapetanakis, Mondragón, Zoupanos; Kazakov et al.



Top, Bottom, and Higgs mass: Predictions

Predictions:

- **FUTB:** $M_{top} \sim 172 \sim 174$ GeV Theoretical uncertainties $\sim 4\%$
- large $\tan\beta$
- $M_H = \sim 121 - 126$ GeV
- LSP neutral

- Radiative eW symmetry breaking
- Δb and $\Delta\tau$ included resummation done. Depend mainly on $\tan\beta$ and unified gaugino mass M.
- LSP as CDM very constrained

Now constraints

Facts of life:

- Correct masses for top and bottom
- Higgs mass also in experimental range
- B physics observables

$\mathrm{BR}(b \to s\gamma) SM/MSSM : |BRbsg - 1.089| < 0.27$

$\mathrm{BR}(B_u \to \tau\nu) SM/MSSM : |BRbtn - 1.39| < 0.69$

$\Delta M_{B_s} SM/MSSM : 0.97 \pm 20$

$\mathrm{BR}(B_s \to \mu^+\mu^-) = (2.9 \pm 1.4) \times 10^{-9}$

Results:
Heavy s-spectrum

Explore possibilities of detection
$\Rightarrow$ s-spectrum challenging even for FCC

Heinemeyer, Kalinowski, Kotlarski, MM, Patellis, Tracas, Zoupanos; Heinemeyer, MM, Tracas Zoupanos, Phys.Rept. (2021)

All-loop FUT $SU(5)$ mass matrices – flavour

It is possible to determine the minimum amount of phases and their positions

Kusenko, Shrock (1994)

The mass matrices for the model are:

$$M_u = \begin{pmatrix} g_{114}\left\langle \mathcal{H}_4^5 \right\rangle & g_{121}\left\langle \mathcal{H}_1^5 \right\rangle & 0 \\ g_{211}\left\langle \mathcal{H}_1^5 \right\rangle & 0 & g_{232}\left\langle \mathcal{H}_2^5 \right\rangle \\ 0 & g_{322}\left\langle \mathcal{H}_2^5 \right\rangle & g_{333}\left\langle \mathcal{H}_3^5 \right\rangle \end{pmatrix} = \frac{2}{\sqrt{5}} g_5 \begin{pmatrix} \left\langle \mathcal{H}_4^5 \right\rangle & \left\langle \mathcal{H}_1^5 \right\rangle & 0 \\ \left\langle \mathcal{H}_1^5 \right\rangle & 0 & \left\langle \mathcal{H}_2^5 \right\rangle \\ 0 & \left\langle \mathcal{H}_2^5 \right\rangle & e^{i\phi_3}\left\langle \mathcal{H}_3^5 \right\rangle \end{pmatrix},$$

$$M_d = \begin{pmatrix} \bar{g}_{114}\left\langle \bar{\mathcal{H}}_{45} \right\rangle & \bar{g}_{121}\left\langle \bar{\mathcal{H}}_{15} \right\rangle & 0 \\ \bar{g}_{211}\left\langle \bar{\mathcal{H}}_{15} \right\rangle & 0 & \bar{g}_{232}\left\langle \bar{\mathcal{H}}_{25} \right\rangle \\ 0 & \bar{g}_{322}\left\langle \bar{\mathcal{H}}_{25} \right\rangle & \bar{g}_{333}\left\langle \bar{\mathcal{H}}_{35} \right\rangle \end{pmatrix} = \sqrt{\frac{3}{5}} g_5 \begin{pmatrix} \left\langle \bar{\mathcal{H}}_{45} \right\rangle & \left\langle \bar{\mathcal{H}}_{15} \right\rangle & 0 \\ e^{i\bar{\phi}_1}\left\langle \bar{\mathcal{H}}_{15} \right\rangle & 0 & \left\langle \bar{\mathcal{H}}_{25} \right\rangle \\ 0 & e^{i\bar{\phi}_2}\left\langle \bar{\mathcal{H}}_{25} \right\rangle & e^{i\bar{\phi}_3}\left\langle \bar{\mathcal{H}}_{35} \right\rangle \end{pmatrix}.$$

After the rotation in the Higgs sector, the matrices in the MSSM basis are:

$$M_u = \frac{2}{\sqrt{5}} g_5 \begin{pmatrix} \widetilde{\alpha}_4 & \widetilde{\alpha}_1 & 0 \\ \widetilde{\alpha}_1 & 0 & \widetilde{\alpha}_2 \\ 0 & \widetilde{\alpha}_2 & e^{i\phi_3}\widetilde{\alpha}_3 \end{pmatrix} \left\langle \mathcal{K}_3^5 \right\rangle ,$$

$$M_d = \sqrt{\frac{3}{5}} g_5 \begin{pmatrix} \widetilde{\beta}_4 & \widetilde{\beta}_1 & 0 \\ e^{i\bar{\phi}_1}\widetilde{\beta}_1 & 0 & \widetilde{\beta}_2 \\ 0 & e^{i\bar{\phi}_2}\widetilde{\beta}_2 & e^{i\bar{\phi}_3}\widetilde{\beta}_3 \end{pmatrix} \left\langle \bar{\mathcal{K}}_{35} \right\rangle ,$$

where $\widetilde{\alpha}_i$ and $\widetilde{\beta}_i$ refer to the rotation angles in the up and down sector, respectively.

Estrada-Ramos, MM, Patellis, Zoupanos (2024)

FUTs

- Finiteness provides us with an UV completion of our QFT
- Boundary conditions for RGE of the MSSM
- RGI takes the flow in the right direction for the third generation and Higgs masses
  Taking into account experimental constraints
  $\Rightarrow$ susy spectrum high
- Experimentally challenging

Heinemeyer, Kalinowski, Kotlarski, MM, Patellis, Tracas, Zoupanos, (2021)

- Are there other finite models?
  Different finite and reduced (non-finite) models analyzed: minimal and finite $SU(5)$, $SU(3)^3$, $SO(10)$...
- Can it give us insight into the flavour structure?
- When were these theories realized?
- **Can we connect FUTs to a more fundamental theory?**

Soft SUSY Breaking Puzzle

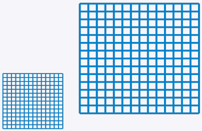
- In FUTs no assumptions on how the SSB are, just RoC and finiteness conditions
- The SSB terms coincide with that of Anomaly Mediated Susy Breaking AMSB, identifying $M = M_{3/2}$
- in FUTs the sum rule is crucial to get good phenomenology $\rightarrow$ regions with no tachyonic spectra and/or charge and colour breaking minima
- AMSB clearly has no RoC assumptions
- How come? Connection?

AMSB

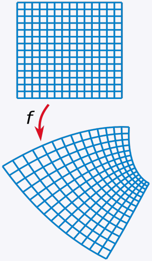
- SUSY breaking induced by conformal anomaly
- RGI relations in β functions
- Tachyonic spectrum

Scale, conformal, and Weyl invariance

Scale invariance



Conformal invariance, preserves angles



- Scale and conformal act in flat space time
- Conformal appears in many physical systems, phase transitions
- Weyl invariance: rescaling of the metric, no change in coordinates. Needs curved space

Conformal invariance in flat spacetime (unitary theories $d \leq 10$) implies Weyl invariance in a general curved background metric

Farnsworth, Luty, Prilepina JHEP (2017)

Conformal operators in SUSY

1. Scale invariance must be verified, encoded in the scaling coefficients S_g and $S_{C_{ijk}}$.
2. The chiral R current must be conserved at the quantum level, so the $\theta = 0$ component within the multiplet $J_{\alpha\dot{\alpha}}$ must be zero.
3. There must exist marginal operators that will induce the theory to manifest in a superconformal regime.
Local primary operators whose anomalous dimension is zero.

$$\beta_g^{(1)} = g^3 \Big[\sum_i T(R_i) - 3C_2(G) - \sum_i T(\phi_i)\gamma(\phi_i) \Big] = g^3 S_g,$$

$$\beta_y^{(1)} = y \Big[- d_W + \sum_i [d(\phi_i) + \frac{1}{2}\gamma(\phi_i) \Big] = y S_y,$$

d_W and $d(\phi_i)$ are the canonical dimensions of the superpotential and the superfields, S_g and S_y the scaling coefficients.

FUT = Conformal

SUSY $\mathcal{N} = 1$ gauge theory in $d = 4$, with gauge group G and superpotential

$$W = m_{ij}\Phi_i\Phi_j + C_{ijk}\Phi_i\Phi_j\Phi_k$$

which satisfies conditions to be all-loop finite. Then, if a fixed point associated with an energy scale μ^* exists, the theory is invariant under the superconformal group at that point.

1. The one-loop beta functions of the dimensionless sector are proportional to the scaling coefficients S_g and $S_{C_{ijk}}$,

$$\beta_g^{(1)} = \beta_{ijk}^{(1)} = 0 \therefore S_g = S_{C_{ijk}} = 0$$

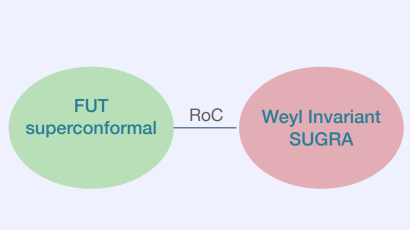
   This makes the scale invariance around $\mu^* = M_{GUT}$ explicit.

2. Cancellation of anomalies within the current supermultiplet is a consequence of finiteness, in particular, the chiral R symmetry is conserved at the quantum level
3. $\mathcal{O}_1 = C_{ijk}\phi_i\phi_j\phi_k$,
   is a marginal operator at the fixed point $\mu^* = M_{GUT}$.
   $S_g \propto S_C$ and the canonical dimension matches the anomalous dimension

LE Reyes-Rodriguez, MM, arXiv:2605.04378

What about SUSY breaking?

We assume connection between flat space conformal invariance and curved space Weyl invariance



FUT corresponds to a low energy N=1 effective SUGRA model

- This theory should exhibit Weyl invariance
- Φ_i fields in visible sector, X in hidden sector
- Evaluate the effects of RoC on this super-Weyl invariant framework
- If gravity effects suppressed $\Rightarrow$ Conformal anomaly contributions should dominate
- Eliminate direct couplings between the X and Φ fields in the superpotential W and the Kähler potential K
- Construct scale invariant action

Kähler Potential

Then, the Kähler potential is

$$K = -\bar{M}^2 \ln\left(1 - \frac{f(\Phi, X)}{\bar{M}^2}\right),$$

where $\bar{M}$ is a high reference scale close to Planck scale, $f(\Phi, X)$ is a function of both the hidden and visible sector fields, $f = \Phi\bar{\Phi} + X\bar{X}$.

- Lagrangian and action possess Weyl invariance
- No tree-level terms arising from gravity that would break SUSY are induced
- Equivalent to to some type of Kähler potentials of no-scale supergravity in d = 4, when no gauge singlets are present

Now soft terms are not gravity dominated
How do they look like?

Now apply RoC

What happens if to these SUSY breaking sector we apply RoC?

- How are soft-breaking terms generated?
  Holomorphic regularization, SUSY breaking encoded in the renormalization amplitudes of the matter fields $\mathcal{Z}$
- Analyze the wave function renormalization of the fields

$$\mathcal{Z} = \mathcal{Z}_0(\mu)[1 + C(g, C^{ijk}, \Lambda_W/\mu)], \quad C^{ijk}(\varphi, g) = \alpha(\varphi)C^{ijk}(g),$$

  $\mathcal{Z}_0(\mu)$ info of renormalization scale, Λ_W cutoff, function C dependence on the dimensionless couplings and the Weyl compensator $\alpha(\phi)$.
- Use the solutions to the reduction equations, RGI invariance required

$$C^{ijk} = \sum_{n=0} \sigma^{ijk}_{(n)} g^{2n+1}, \quad h^{ijk} = -M\frac{dC(g)^{ijk}}{d\ln g}$$

- Define a dimensionless coupling $\bar{h}^{ijk} \equiv \frac{h^{ijk}}{\varphi} \propto C^{ijk}$ and calculate the individual terms $\mathcal{Z}^j_i$
- The RoC solution induces the breaking of the conformal symmetry
  $\Rightarrow$ SUSY breaking generated through the conformal anomaly
  No dependence on conformal compensator
- We recover the same expressions for soft breaking parameters found in FUTs, i.e. AMSB

Connections

FUTs connects through Weyl invariance to a no-scale SUGRA theory with AMSB

No-scale SUGRA

- Spontaneous SUSY breaking along a flat direction, with vanishing energy. $M_{3/2}$ gravitino mass sets the scale of SUSY breaking
- Scalar masses are generated through radiative corrections with the coupling to gaugino masses, via RG running
- Connection to superstrings
- Hidden sector connected to inflation

No-scale SUGRA models connected to Starobinsky inflation

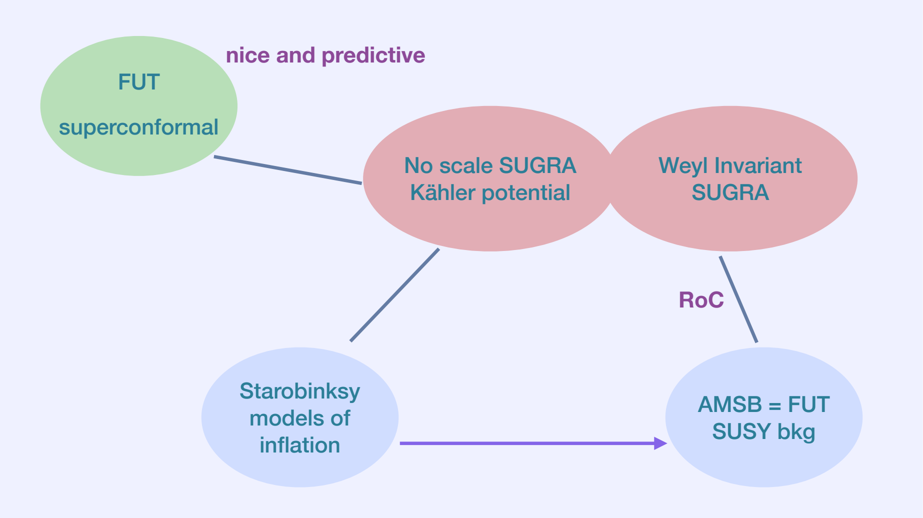
Starobinsky inflation

- Modifies General Relativity adding a R^2 term, gravity coupled to a scalar field
- Gives inflation with a potential with a flat plateau and slow-roll
- Inflation ends as scalaron oscillates towards the potential minimum, generating SM (or BSM) particles and reheating
- Predictions consistent with observed data

and now connection to all-loop Finite Theories via RoC

M.M. and L.E. Reyes-Rodriguez arXiv:2605.04378

No-scale SUGRA, Starobinsky and FUTs



No-scale SUGRA, Starobinsky and FUTs

- No scale-SUGRA models have been proposed addressing Dark Matter, neutrinos, g-2, GUTs, etc

  e.g. Antoniadis, Ellis, Nanopoulos, Olive, García et al ($\sim$ 2009 - 2026), Forster and King (2022), Pallis (2013)...

- Start with Starobinsky models, use FUT solutions calculate DM abundance
  cure overabundance problem?
  Not so easy –
  work in progress with M.G. García and J.A. Morales

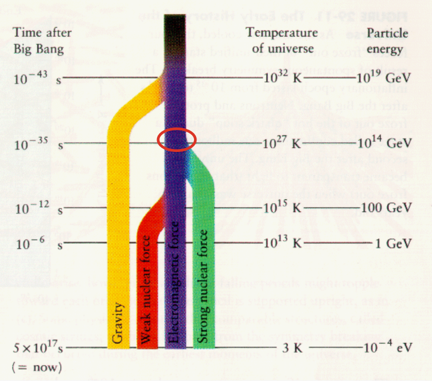


Image credit: Karl Gebhardt.

Conclusions

- Reduction of couplings: powerful principle implies Gauge Yukawa Unification
- Finiteness, $\beta_i = 0$ at all orders, $\Rightarrow$ reduces greatly the number of free parameters
  $\Rightarrow$ predictive models
- Soft breaking SUSY terms AMSB-like
  but soft scalars satisfy a sum rule among $\Rightarrow$ good phenomenology
- Drastic reduction in the number of free parameters

- Now, connection to a more fundamental theory:

  FUT = superconformal $\Rightarrow$
  Weyl invariant SUGRA $\Rightarrow$
  no-scale SUGRA models
- no-scale SUGRA $\Rightarrow$ Starobinsky inflation
  - We have now a connection FUT-SUGRA-cosmology