CRITICAL COUPLINGS AND THREE GENERATIONS IN A RANDOM-DYNAMICS INSPIRED MODEL

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We consider a scenario in which physics in terms of gauge fields ends at some critical values of gauge couplings. Within this approach, the question of the smallness of fine-structure constants is converted to the question of having the strongest allowed critical couplings, accompanied with a large number of fermion generations.

1. A gauge-coupling prehistory

It is interesting that the basic ingredients of the present-day standard theory of elementary processes can be traced back to the 18th century. That was the time of Bošković's attempt*[1] to account for all known physical effects in terms of action at a distance between point particles, dynamic centres of force. His concept of force (Fig. 1) may be linked with the modern running of couplings with a distance, and his introduction of boundaries that cannot be crossed may resemble a concept of critical values of running constants. There is also a notable influence of Bošković's ideas on John Lesslie[2]. In addition to Bošković's force acting between particles of matter, Lesslie introduced a similar curve for the force acting

*Ruggero Giuseppe Boscovich, Ragusa-Dubrovnik, Croatia, 18 May 1711 — Milan, 13 February 1787. The Ruđer Bošković Institute, named after him, celebrated its 40th anniversary in Zagreb in 1990, together with the 50th anniversary of the Ph. D. of its founder Prof. I. Supek.

between two particles of light and also a separate curve for the force acting between particles of matter and particles of light (Fig. 2). This brings us very close to the

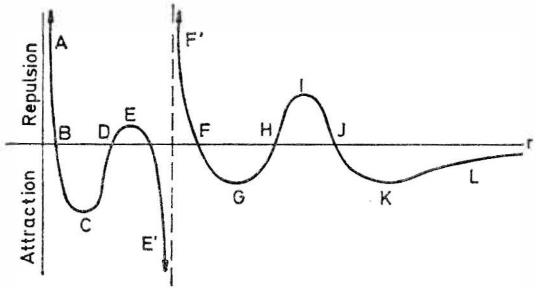

Fig. 1. Bošković's force acting between matter point-particles.

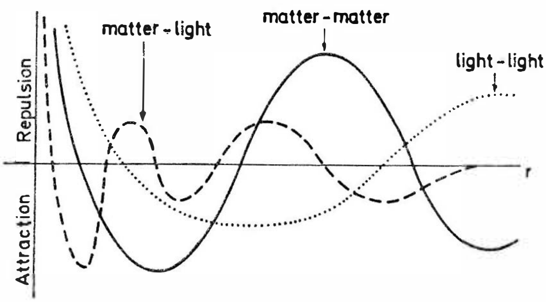

Fig. 2. Extension of Bošković's force to particles of light.

modern view of charges and couplings in present-day gauge theories: gauge bosons have self-couplings and couplings to matter fields, together with non-trivial interactions among matter fields.

2. *Basic features of the standard-model gauge theory*

Today the known interactions of elementary particles are based on the U (1) × × SU (2) electroweak gauge symmetry and SU (3) gauge symmetry for QCD. We immediately observe small factor groups, U (1), SU (2) and SU (3), each appearing only once. Obviously, the Yang-Mills Lagrangians of these different commuting factors are normalized independently, leading to one independent coupling constant for each group:

$$\mathscr{L}^{YM}_{2,3} = -\frac{1}{8g^2_{2,3}} \mathrm{Tr}\,(F_{\mu\nu}\, F^{\mu\nu}) = -\frac{1}{4g^2_{2,3}} F^a_{\mu\nu}\, F^{\mu\nu a}. \tag{1}$$

Here, use of the matrix potential

$$A_\mu = A^a_\mu \frac{\lambda^a}{2}$$

yields the Yang-Mills tensor

$$F_{\mu\nu} \equiv F^a_{\mu\nu} \frac{\lambda^a}{2} = \partial_\mu A_\nu - \partial_\nu A_\mu + \mathrm{i}\,[A_\mu, A_\nu].$$

Then the gauge transformation is characterized by the gauge function $\Lambda(x)$ in the representation $\lambda^a/2$:

$$A_\mu(x) \to A'_\mu(x) = \Lambda(x)\, A_\mu(x)\, \Lambda^{-1}(x) - \mathrm{i}\Lambda(x)\, \partial\, \Lambda^{-1}(x).$$

The kinetic term for A^a can be expressed in the form of a Maxwell Lagrangian:

$$-\frac{1}{4}(\partial_\mu A_\nu - \partial_\nu A_\mu)(\partial^\mu A^\nu - \partial^\nu A^\mu)$$

by rescaling

$$A^a \to g A^a$$

and consequently

$$F_{\mu\nu} \to g F_{\mu\nu} = g\,\{\partial_\mu A_\nu - \partial_\nu A_\mu + \mathrm{i}g\,[A_\mu, A_\nu]\}.$$

By this rescaling the normalization factor for $\mathscr{L}^{YM}$ is converted into the self-coupling of the Yang-Mills field.

The kinetic term of the fermion matter fields preserves gauge invariance if ∂_μ is replaced by the covariant derivative $D_\mu = \partial_\mu + \mathrm{i}gA_\mu$. Upon rescaling this replacement introduces the interaction of the gauge field with the matter field with the same universal coupling strength.

To account for the observed symmetry breaking in the electroweak sector

$$\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y \to \mathrm{U}(1)_{em},$$

one introduces scalar fields having self-interactions and Yukawa interactions with fermion fields. However, these non-gauge interactions remain arbitrary, unconstrained and have not been observed thus far. The consideration of these interactions is out of the scope of the present paper. Here we focus on gauge couplings, termed fine-structure constants.

3. *Values and running of standard-model fine-structure constants*

The gauge couplings belonging to the Lie algebra of the group product

$$\mathrm{SU}(3)_C \times \mathrm{SU}(2)_L \times \mathrm{U}(1)_Y \tag{2}$$

are

$$g_s,\ g \text{ and } g', \text{ respectively.}$$

The known relations among electroweak couplings involve the electroweak mixing angle ϑ_W and the vacuum expectation value v of the Higgs field:

$$e = \sqrt{4\pi\alpha} = g \sin\vartheta_W = g' \cos\vartheta_W$$

and

$$M_W = \frac{1}{2} vg, \quad M_Z = \frac{1}{2} v (g'^2 + g^2)^{1/2},$$

which gives

$$\sin^2\vartheta_W = \frac{e^2}{g^2} = \frac{g'^2}{g'^2 + g^2} = 1 - \frac{M_W^2}{M_Z^2}.$$

Taking the Z mass as a reference point ($M_Z = 91.176 \pm 0.023$ GeV) gives

$$\alpha_3 (M_Z) = \frac{g_s^2 (M_Z)}{4\pi} = 0.12 \begin{array}{l} +0.01 \\ -0.02 \end{array} \text{ or } \alpha_3 (M_Z)^{-1} = 8.3 \begin{array}{l} +1.3 \\ -0.6 \end{array},$$

and using

$$\alpha (M_Z)^{-1} = 128.80 \pm 0.05,$$

$$\sin^2\vartheta_W = 0.229 \pm 0.005,$$

we have

$$\alpha_2 (M_Z) = \frac{g^2 (M_Z)}{4\pi} = (29.5 \pm 0.6)^{-1},$$

$$\alpha_1 (M_Z) = \frac{g'^2 (M_Z)}{4\pi} = (99.3 \pm 0.6)^{-1}.$$

Note that the combination $1/\alpha_1 + 1/\alpha_2 = 1/\alpha$ is practically without uncertainty.

These coupling »constants« exhibit the energy dependence determined by the renormalization-group equation

(i) at the one-loop level:

$$\alpha_i^{-1} (M) = \alpha_i^{-1} (M_Z) + \frac{b_i}{2\pi} \ln \frac{M}{M_Z},$$

where we indicate the separate contributions of vector, fermion and Higgs fields, respectively:

$$b_i = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 22/3 \\ 11 \end{pmatrix} + N_{gen} \begin{pmatrix} -4/3 \\ -4/3 \\ -4/3 \end{pmatrix} + N_{Higgs} \begin{pmatrix} -1/10 \\ -1/6 \\ 0 \end{pmatrix};$$

(ii) at the two-loop level:

$$\alpha_i^{-1}(M) = \alpha_i^{-1}(M_Z) + \frac{b_i}{2\pi} \ln \frac{M}{M_Z} + \sum_{j=1}^{3} \frac{B_{ij}}{4\pi b_j} \ln \left(1 + \frac{b_j \alpha_j (M_Z)}{2} \ln \frac{M}{M_Z}\right),$$

where, additionally,

$$B_{ij} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & -136/6 & 0 \\ 0 & 0 & -102 \end{pmatrix} + N_{gen} \begin{pmatrix} 19/15 & 3/5 & 44/5 \\ 1/5 & 49/3 & 4 \\ 11/30 & 3/2 & 76/3 \end{pmatrix} +$$

$$+ N_{Higgs} \begin{pmatrix} 9/50 & 9/10 & 0 \\ 3/10 & 13/6 & 0 \\ 0 & 0 & 0 \end{pmatrix}.$$

It has been observed[3] that by running the couplings upward there is a tendency for them to meet at some unification point, indicating *grand unification* (simple unifying group with single coupling). Here the essential point is that upon embedding U $(1)_Y$, e. g. in SU (5), the g' coupling must be properly normalized:

$$\alpha_1 = \frac{g'^2}{4\pi} \to \alpha_1 = \frac{5}{3} \frac{g'^2}{4\pi}.$$

Recent analyses[4)5)] (Fig. 3) have shown that, actually, there is no single crossing for the simplest minimal standard model and that there is more chance of achieving it for a supersymmetric extension (for modified b_i and B_{ij}, see Ref. 5).

Note that the idea of unification triggered various estimates of the fine-structure constants[6]. Parisi et al.[7] showed that nonperturbative unification contained

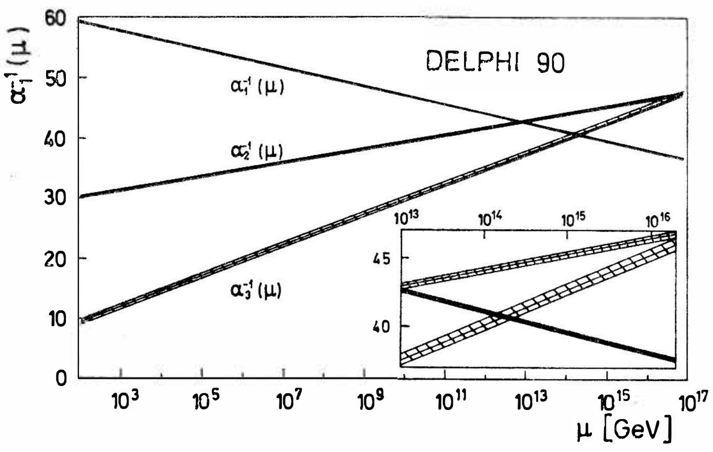

Fig. 3. Recent experiments rule out the simple SU(5) grand unification.

relations to the number of fermions. They elaborated an early suggestion by Landau that the presence of a large number of elementary fermions might offer an explanation of the small value $\alpha = 1/137$.

One can also hope to explain gauge couplings in alternatives to grand unification. Such an attempt was made by Weinberg[8] in the Kaluza-Koein model. The gauge coupling e_i at the Kaluza-Klein energy scale of 10^{17} GeV was determined by the circumference l_i of the curled-up manifold:

$$e_i = \frac{2\pi\hbar\sqrt{16\pi G}}{l_i c}.$$

In this paper we consider that the couplings are »small«, as a consequence of having a »large« number of generations — in an antiunification scenario advocated by H. B. Nielsen et al.[9]. Our consideration starts with some »random dynamics« above the fundamental (Planck) scale. Thus we recognize a criticality at the Planck scale, which could be termed »the criticality in Bošković's sense«. Our task is to extrapolate properly normalized gauge couplings from the low-energy physics (LEP) domain to the values of the critical couplings at the Planck scale.

4. *Critical couplings and number of generations*

Here we rely on a picture[9] in which physics (in terms of gauge theories) ends beyond the Planck scale (quantum gravity enters into play). Correspondingly, we can imagine some random structure beyond the Planck scale, e. g. large symmetry groups distributed randomly over space-time regions. In order to be able to perform calculations, we assume a latticized space-time, for which a *group* rather than a Lie algebra is relevant.

The large symmetry groups distributed over the fundamental lattice suffer from *collapse*[9] when going fiom the fundamental short distance to larger distances. There are two such collapses before one reaches the standard-model group (SMG)* accessible to the present-day experimental investigations.

*The SMG taken as the specific group S (U (2) × U (3)) defined by the set of matrices

$$\mathrm{SMG} = \left\{ \begin{pmatrix} U^2 & 0 \\ 0 & U_3 \end{pmatrix};\ U_2 \varepsilon U(2),\ U_3 \varepsilon U(3) \varLambda \det U^2 \cdot \det U_3 = 1 \right\} \subset SU(5) \qquad (3)$$

is supported empirically by the electric-charge quantization rule

$$\frac{y}{2} + \frac{d}{2} + \frac{t}{3} = 0 \qquad (\mathrm{mod}\ 1),$$

or

$$Q = T_3 + \frac{y}{2} = -\frac{t}{3} \qquad (\mathrm{mod}\ 1).$$

The duality of the SU (2) part is $d = 0$ (1) for integer (half-integer) weak isospin, and the triality of the colour representation is 1, −1, 0 (mod 3) for quarks, antiquarks and gluons/leptons, respectively.

Both of these collapses reflect the impossibility of keeping track of the identity of the group:

I. *Chaotic collapse* ends up with N_{gen} copies of the SMG

$$(SMG) \times \ldots \times (SMG) = (SMG)^{N_{gen}}. \tag{4}$$

The SMG itself is chosen as the one avoiding permutation symmetries, spoiling consistent naming of the fluctuations in the long-wavelength limit. Still, the SMG possesses outer automorphism, charge conjugation, but this can be remedied by introducing chiral fermions. Because of anomalies, one chiral fermion is not sufficient, but a whole generation is needed, including N_{gen} SMG-factors.

II. *Collapse by confusion* leads to the diagonal subgroups of (4),

$$(SMG)_{diag}, \tag{5}$$

consisting of those ordered sets of SMG elements $(g, g, \ldots, g)$ for which all componets are equal to one another. This means that a wave representing one of the experimentally accessible gauge particles is actually a wave in which the same vibration takes place in all the gauge fields, corresponding to the various SMG-factors in the direct product $SMG \times SMG \ldots SMG$. Then the naive lattice continuum formula (we actually assume the existence of a fundamental lattice with lattice constant a)

$$U(x_\mu \circ\!\!-\!\!\circ\, x_\mu + a\,\delta_\mu) \cong \exp\left(igaA^a_\mu \frac{1}{2}\,\lambda^a\right), \tag{6}$$

implies

$$(gA^a_\mu)_{Petra} = (gA^a_\mu)_{Paula} = \ldots = (gA^a_\mu)_{N_{gen}}, \tag{7}$$

for an experimentally accessible wave — a photon, say. For such a diagonal-subgroup gauge-particle wave, the original *fundamental* Lagrangian density

$$\mathcal{L} = -\frac{1}{4g^2_{Petra}}(gF^a_{\mu\nu})^2_{Petra} - \frac{1}{4g^2_{Paula}}(gF^a_{\mu\nu})^2_{Paula} - \ldots - \frac{1}{4g^2_{N_{gen}}}(gF^a_{\mu\nu})^2_{N_{gen}}$$

becomes

$$\mathcal{L} = -\frac{1}{4g^2_{diag}}(gF^a_{\mu\nu})^2_{diag}, \tag{8}$$

with

$$\frac{1}{4g^2_{diag}} = \frac{1}{4g^2_{Xetra}} + \frac{1}{4g^2_{Paula}} + \ldots + \frac{1}{4g^2_{N_{gen}}}. \tag{9}$$

We designate the last field and the last SMG-factor as N_{gen} because, as argued above, the number of these factors should be equal to the number of quark and lepton families (generations). This is bassically the assumption that each of the direct product factors SMG has just one generation attached to it. This can be regarded as an assumption inspired by random dynamics, because in random dynamics, a SMG without complex representations (of Weyl particles) would break down (by confusing with its own complex conjugate). This would exclude the trivial representation which a priori is the most easily obtainable by accident. The next most probable representation that respects the above constraints and avoids gauge and mixed anomalies is precisely the complex (reducible) representation of one generation.

If the couplings for the »fundamental« fields (7) are all taken to be equal at the fundamental scale to some critical coupling at that scale:

$$g_{Petra} = g_{Paula} = \ldots = g_{N_{gen}} = g_{crit},$$

one obtains for the observed coupling

$$\frac{1}{g^2_{diag}} = \frac{1}{g^2_{crit}} N_{gen} \text{ or } g_{diag} = \frac{g_{crit}}{\sqrt{N_{gen}}}.$$

This reveals a major point of our model: the gauge coupling constants are »small« because the number of families is »large«. This presupposes that individual gauge-group factor couplings at the fundamental scale are of order unity. Similar ideas have been used in Ref. 7.

In an attempt to compare the values of the coupling constants for different groups, we invoke the criticality in Bošković's sense (criticality at the point at which some fields disappear).

The criticality of the gauge coupling constants at the Planck scale means that a Planck-scale laboratory would find the couplings at the border line between the Coulomb (photon) and the strong coupling (confining) phase. A simple theory for calculating at such a phase boundary, applicable in both phases, is the mean-field approximation (MFA). This is suggested because the (lowest order) MFA »approximates away« all long-range effects. Since $g_{crit\ MFA}$ predicts the disappearance of a group (loss of ability to deliver subgroups), all groups from which gauge symmetry can be inherited should satisfy

$$\alpha_G(\mu) \leq \alpha_{G\ crit\ MFA}.$$

The use of the first order MFA is a way of implementing the restriction that the critical phase is to be determined on the basis of the behaviour of a field theory as observed at a scale that can be accommodated in a Planck-scale laboratory. We adopt the critical β-values calculated for U (2) and U (3) lattice gauge theories in the MFA[10]:

$$\frac{1}{3}\beta_{U(3)crit\ MFA} = 7.30/9 = 0.81, \quad \frac{1}{2}\beta_{U(2)crit\ MFA} = 3.45/4 = 0.86. \tag{10}$$

In the plaquette ($\square$) lattice action

$$\mathscr{S}_{\square} = \sum_r \beta_{\square r} \operatorname{Re} \operatorname{Tr}(U_{\square r}),$$

the coefficients $\beta_{\Box r}$ to the $\mathrm{Tr}\,(U_{\Box r})$ terms take quenched random values on the plaquettes; we have what is called a gauge glass. The sum over representations is often approximated by only considering the plaquette (or flux) variable $U_\Box$ in the smallest (as measured by the dimension or the quadratic Casimir) non-trivial representation. For smooth actions, the smaller the representation r, the more important the term $\beta_{\Box r}\,\mathrm{Re\,Tr}\,(U_{\Box r})$. For a simple group it is reasonably clear which representation is smallest in the sense that it dominates in the plaquette action. In the case of the non-simple SMG = S (U (2) × U (3)), it is less obvious which representation dominates in the action and therefore one should use the several irreducible representations that compete for being the »smallest«. There is therefore no single critical $\beta = 2/g^2$ value for the non-simple SMG. The three representations assumed to be most relevant,

$$l_L = \left(-\frac{1}{2}, 2, 1\right) \stackrel{\mathrm{def}}{=} (2, 1), \quad \bar{d}_L = \left(\frac{1}{3}, 1, 3\right) \stackrel{\mathrm{def}}{=} (1, 3), \quad q_L = \left(\frac{1}{6}, 2, 3\right) \stackrel{\mathrm{def}}{=} (2, 3),$$

lead to the lattice action of the form

$$\mathcal{S} = \sum_{\Box} \sum_{r(2,1),\,(1,3),\,(2,3)} \beta_{\Box r}\,\mathrm{Re\,Tr}\,(U_{\Box r}).$$

The action is guaranteed real by the inclusion of the conjugate representations. This is the reason for the appearance of the Re-sign in the last expression.

In order to avoid confinement, (9) implies

$$\beta_{1,3} \geq \beta_{U(3)crit\;MFA} = 3 \times 0.81, \tag{11}$$

$$\beta_{2,1} \geq \beta_{U(2)crit\;MFA} = 2 \times 0.86. \tag{12}$$

These couplings are related to low-energy (LEP) couplings:

$$\begin{aligned} \frac{1}{g_3^2} &= \frac{1}{2}(\beta_{1,3} + 2\beta_{2,3}), \\ \frac{1}{g_2^2} &= \frac{1}{2}(\beta_{2,1} + 3\beta_{2,3}), \\ \frac{1}{g_1^2} &= \frac{1}{10}(3\beta_{2,1} + 2\beta_{1,3} + \beta_{2,3}), \; [\mathrm{SU}\,(5) \text{ normalized}]. \end{aligned} \tag{13}$$

Matching to LEP couplings can be achieved in two stages:

(i) By simple running from M_W to M_{Pl} and neglecting $\beta_{2,3}$, we obtain

$$\begin{aligned} \alpha_3^{-1}(M_{Pl}) &= 77.55 - 8.39\,N_{gen} \Rightarrow N_{gen} \leq 3.29, \\ \alpha_2^{-1}(M_{Pl}) &= 75.94 - 8.39\,N_{gen} \Rightarrow N_{gen} \leq 3.96, \\ \alpha_1^{-1}(M_{Pl}) &= 59.84 - 8.39\,N_{gen} \Rightarrow N_{gen} \leq 2\,84. \end{aligned} \tag{14}$$

(ii) Including $\beta_{2,3}$ on $x \cdot 100\%$ plaquettes and $\beta_{1,3} \times \beta_{2,1}$ on $(1-x) \cdot$ $\cdot\ 100\%$ statistically, and assuming the saturation of the inequalities in (11) and (12), we obtain

$$
\begin{aligned}
\frac{1}{g_3^2} &= \frac{1}{2}\,[3\,(1-x) + 2 \times 6x] \times 0.81\, N_{gen}, \\
\frac{1}{g_2^2} &= \frac{1}{2}\,[2\,(1-x) + 3 \times 6x] \times 0.86\, N_{gen}, \qquad (15) \\
\frac{1}{g_1^2} &= \frac{1}{10}\,[2 \times 3\,(1-x) + 3 \times 2\,(1-x) + 6x] \times 0.83\, N_{gen}.
\end{aligned}
$$

Matching the expressions (15) with the corresponding RHS in (14) results in three lines (Fig. 4) in the (xN_{gen}, N_{gen}) plane[11]. Using the extra free parameter x reveals remarkable features: (1) the intersection of the three lines, (2) the intersection at

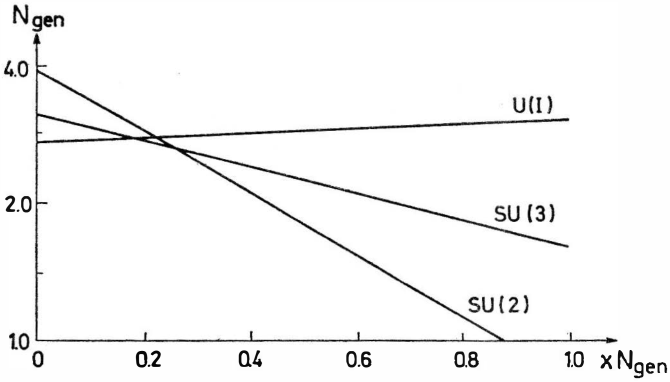

Fig. 4. Interaction of the three lines corresponding to the three gauge couplings, as given by Eqs. (14) and (15).

an integer $N_{gen} = 3$ and (3) the parameter x small and positive, as expected. These features indicate the validity of our model assumptions: criticality of couplings at the Planck scale, N_{gen} direct-product SMG-factors and the necessity of having a mechanism (»confusion«) by which the SMG copies at the fundamental scale cannot be distinguished at the LD scale (only a linear combination corresponding to the diagonal group provides massless particles at phenomenological energies).

Inspection of our results shows that at $\mu_{Pl} = 1.22 \times 10^{19}$ GeV couplings are just on the verge of confining. This point coincides with the point where gravity should be on the border-line between weak- and strong-coupling »phases«. If, in looking at theories with successively longer and longer regularization scales (block spinning), confinement of a gauge group is encountered at a certain scale, there will be no degrees of freedom from this gauge group remaining at longer-distance scales. The confining scale of QCD is an example. This is a rather general argument for the necessity of avoiding confiningly strong coupling constants if we want to see anything of the Yang-Mills degrees of freedom at longer distances. This is explicitly implemented in this article by requiring that, for gauge-group degrees of freedom seen phenomenologically, the actual gauge couplings (at all energies above those of present experiment) are weaker than the critical ones.

In our picture, the desert prevails almost up to the Planck scale at which point the physics becomes very complicated, and the SMG gauge group turns out to be the diagonal subgroup of the fundamental gauge group SMG × SMG × ... ... × SMG. As the direct product SMG-factors have stronger couplings than the diagonal subgroup accessible to experiment by a factor (number of SMG-factors)[1,2], it can happen that these gauge groups confine even at the Planck scale.

Using the relation

$$\alpha_{i\, diag}^{-1}(M_{Pl}) = 2\pi \frac{2}{g^2_{crit\ MFA}} N_{gen}, \tag{16}$$

we obtain the reduction of couplings by $\sqrt{3}$ at M_{Pl} (Fig. 5), which, when run to the LEP scale, manifests in small values of the observed couplings. Thus, within our approach, the usual question »why is the fine-structure constant so weak?« is converted to the almost opposite question[9] »why have fine-structure constants their strongest allowed (saturated) values?«.

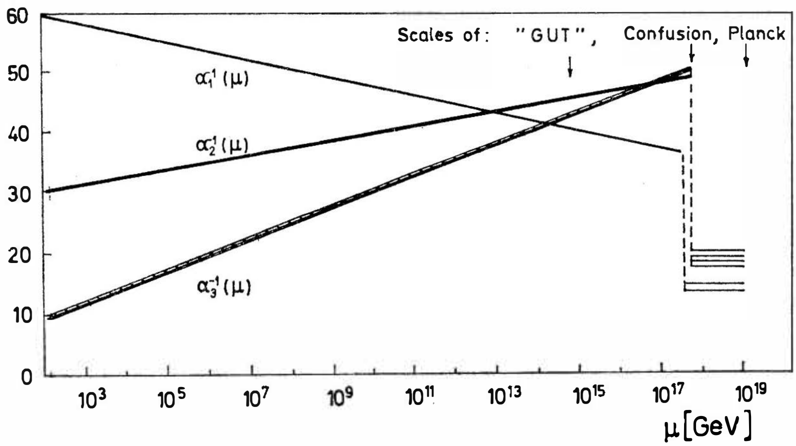

Fig. 5. Reduction of the factor N_{gen} at the fundamental scale, which leads to small couplings at the LEP scale.

The fact that stronger gauge couplings obscure small gauge-symmetry breakings quite easily (wash them out by larger quantum fluctuations) may be taken as mild evidence for random dynamics[9].

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References

1) Rogerio Josepho Boscovich, *Theoria Philosophiae Naturalis*, Venice, 1763;
2) Following Ž. Dadić, *Ruđer Bošković* (in Croatian and English) Školska knjiga, Zagreb, 1987; J. Lesslie, *On Heat and Climate* (written in 1790, published in 1819). Lesslie was a disciple of John Robinson, who taught Bošković's theory at the University of Edinburgh as of 1785;
3) H. Georgi and S. L. Glashow, Phys. Rev. Lett. **32** (1974) 438;
4) J. Ellis, S. Kelley and D. V. Nanopoulos, Phys. Lett. **B260** (1991) 131;
5) U. Amaldi, CERN-PPE/91-44;
6) S. L. Glashow and D. V. Nanopoulos, TH.3070-CERN, 1981;
7) L. Maiani, G. Parisi and R. Petronzio, Nucl. Phys. **B136** (1978) 115,
8) S. Weinberg in *Inner Space/Outer Space*, ed. by E. W. Kolb et al., University of Chicago Press, 1986;
9) H. B. Nielsen, NBI-HE-89-01 and NBI-HE-91-04;
10) J.-M. Drouffe and J.-B. Zuber, Phys. Rep. **102** (1983) 96;
11) D. L. Bennett, H. B. Nielsen and I. Picek, Phys. Lett. **B208** (1988) 275.

KRITIČNA VEZANJA I TRI GENERACIJE U MODELU INSPIRIRANOM SLUČAJNOM DINAMIKOM

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Razmatrana je situacija u kojoj fizika u smislu baždarnih polja završava na određenim kritičnim vrijednostima baždarnih vezanja. U okviru ovog pristupa, pitanje male veličine konstanti fine strukture postaje pitanje postizanja najjačih dozvoljenih kritičnih vezanja praćenih velikim brojem fermionskih generacija.