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Corrigendum

Erratum to “Spontaneous mass generation and the small dimensions of the Standard Model gauge groups $U(1)$, $SU(2)$ and $SU(3)$” [Nucl. Phys. B 915 (2017) 262–284]

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Abstract

We point out an error in our previous work, that affects the claims made for the special Lie groups and for the $SO(N_c)$ groups of lowest dimension, which are therefore retracted.

Our earlier results stand for larger-dimension $SO(N_c)$, as well as for $Sp(N_c)$ and $SU(N_c)$ classical Lie groups.

1. Introduction

In our original publication [1] we intended to study why the Standard Model was built with groups of very small dimension,

$$SU(3)_c \times SU(2)_L \times U(1)_Y \ . \tag{1}$$

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We found that under the hypothesis that the coupling constants $\alpha_s = \pi a_s$ and the O(MeV) fermion masses were equal for all Lie groups at the GUT scale 10^{15} GeV, and compatible with light quarks charged under $SU(3)_c$ acquiring a constituent mass of about 300 MeV (as we know happens in QCD), then fermions charged under larger groups were heavy.

One of the elements of the needed computation is the running of the coupling constant down from the Grand Unification scale. The one-loop running of the coupling constant $-\mu \frac{da_s}{d\mu} \simeq \beta_1 a_s^2 + ...$ is given by the β_1 coefficient, which was quoted in Equation (18) of the original work to be

$$\beta_1 = \frac{1}{6}(11N_c - 2N_f) \tag{2}$$

This formula is specific to $SU(N_c)$, but for other groups one should use the more general

$$\beta_1 = \frac{1}{6}(11C_G - 2N_f) \tag{3}$$

(with an appropriate normalization for the group generators T^a) in terms of the Casimir of the adjoint representation of the group, C_G. For the unitary groups, C_G is directly the number of colors, $C_G = N_c$, and both equations are identical. However, in general, it is only proportional to, and not equal to N_c. It unfortunately happens that the constant of proportionality, absent in our original computer codes, is numerically small for the special Lie groups examined, so that, although they are of large dimension, they end up evading our argument (as shown in our newer work [2]). This seems to also be the case for the orthogonal groups of relatively low dimension, $SO(4)$ to $SO(9)$: we initially obtained very large masses for fermions charged under these groups, and this is no more the case, our mechanism only starts working at $N_c = 10$ and above for $SO(N_c)$.

2. Retracting statement

Thus, our results for the special Lie groups G_2, F_4, E_6 and E_7, as well as low-dimension $SO(N_c < 10)$ are not correct. We apologize for any confusion created to the reader. The computations for larger-dimension orthogonal $SO(N_c)$ and symplectic $SP(N_c)$ groups are qualitatively correct, but affected by relatively unimportant numerical inaccuracies, documented in [2].

Finally, it is obvious that the results for the most important family of Lie groups in particle physics, the unitary groups $SU(N_c)$, are not affected at all so the original calculation stands. We have in any case recalculated them in [2] with the running coupling taken at two- instead of one-loop accuracy, to improve on the resulting mass scale as a function of N_c.

References

[1] G. García Fernández, J. Guerrero Rojas, F.J. Llanes-Estrada, Nucl. Phys. B 915 (2017) 262, https://doi.org/10.1016/j.nuclphysb.2016.12.010.

[2] F.J. Llanes-Estrada, A. Salas-Bernárdez, Commun. Theor. Phys. 71 (2019) 410, https://doi.org/10.1088/0253-6102/71/4/410.