Heavy Quarks, the Origin of Mass, and CP Violation for the Universe

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Abstract

A Higgs-like new boson with mass around 126 GeV is discovered during 2012. However, it could still be the dilaton of scale-invariance violation, which can only be ruled out after the LHC restarts with the 13 TeV run in 2015, by observing the vector boson fusion or Higgs-strahlung production processes. With the existence of already three generations of chiral quarks, i.e. left and right-handed components carry different electroweak charges, if a 4th generation of quarks exist, the LHC has pushed the mass limits beyond 700 GeV, which is considerably beyond the nominal unitarity bound, hence the associated Yukawa coupling is in the non-perturbative domain. This would not be easily compatible with a 126 GeV Higgs boson. We argue, however, that a scale-invariant "gap equation" can be constructed, where massless input is guaranteed by gauge invariance. A nontrivial numerical solution is found for Yukawa coupling above 4pi or so, hence dynamical electroweak symmetry breaking can be achieved by strong Yukawa coupling. In turn, because the gap equation is scale invariant, this strong coupling solution is compatible with a 126 GeV dilaton, which would be a true messenger from energies much higher than the electroweak scale. We note that extending from 3 to 4 generations, the quark sector may have enough CP violation for generating the matter dominance of the Universe. This is seen most easily through the so-called Jarlskog invariant. We offer some speculation on the possible phenomena pertaining to heavy chiral quarks as massive as a couple of TeV.