Koide's Formula follows from Nonlinear Dynamics of Quantum Fields

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Abstract

In this brief report we argue that Koide's formula arises from universal attributes of nonlinear dynamics in field theory. Feigenbaum scaling not only provides a natural paradigm for generating particle masses and coupling charges, but also a basis for understanding the family structure of fermions.

A notorious shortcoming of the Standard Model (SM) for high-energy physics is its inability to explain the family structure of particle physics from first principles. Over the years, the elusive origin of SM parameters has inspired many attempts of deriving empirical formulas. These models seek to find best-fit approximation for masses of leptons and quarks but typically fail to offer compelling reasons as of why fermion replication occurs in the first place.

Koide's prescription for charged lepton masses is a prime example of this endeavor. It reads [1]

$$3(m_e + m_\mu + m_\tau) = 2(\sqrt{m_e} + \sqrt{m_\mu} + \sqrt{m_\tau})^2 \qquad (1)$$

As it is known, SM is a theoretical framework that successfully describes non-linear interaction of leptons, quarks and gauge fields. The relevance of universal transition to chaos and of Feigenbaum scaling in particle physics has been extensively discussed in [2-4]. Recently, non-equilibrium evolution and transition to complex behavior in field theory were linked to the physics of hadronization in infrared quantum chromodynamics [5], the mechanism of mass generation and chiral symmetry breaking in SM [6].

With reference to [3, 6] and using $m_e = m_\mu \overline{\delta}^{-4}$ and $m_\mu = m_\tau \overline{\delta}^{-2}$ leads to the polynomial equation

$$(1+\overline{\delta}^{-2}+\overline{\delta}^{-6}) = 4(\overline{\delta}^{-1}+\overline{\delta}^{-3}+\overline{\delta}^{-4}) \qquad (2)$$

(2) is solved by a Feigenbaum constant which falls near the numerical value attributed to hydrodynamic flows, namely $\overline{\delta} = 4.043$ [7].

References

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