<u>Three Routes to the Dynamics of Continuous Spacetime Dimensions</u>

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Abstract

This brief report is a bird-eye view of the paths leading to the concepts of *evolving fractal spacetime* and *continuous dimensionality,* far beyond the range of Effective Field Theory.

Key words: complex dynamics, continuous spacetime dimensions, dimensional fluctuations, Physics beyond Effective Field Theory, primordial cosmology.

Cautionary remark: The reference section mainly includes our own contributions in order to stimulate independent exploration and unbiased analysis.

- *Complex dynamics* (CD) of collective systems with many degrees of freedom is characterized by non-linear, dissipative and non-local interactions between components, by the emergence of instability and chaos, the tendency to self-organize and adapt, to generate unforeseen outcomes and patterns, to unfold on multiple scales, display memory effects and an endless game of cooperation and competition [1 - 2].
- Implementing CD in theoretical physics requires use of unconventional tools such as the analysis of chaos and multifractal geometry, non-extensive statistics, self-organized criticality, and fractional dynamics.

Here are few examples of settings where CD is fully applicable:

- **Far-from-equilibrium physics** of collective systems with many degrees of freedom [3 - 6].
- The onset of **decoherence** and transition from quantum to classical behavior in field theory [7].

- The nearly universal existence of **<u>nonintegrable phenomena</u>** and the subsequent transition to chaos [8 - 10].

There are essentially *three routes* linking CD to the continuous and evolving dimensionality of spacetime far above the electroweak scale, namely:

1) **<u>Dimensional Regularization</u>** procedure of Quantum Field Theory [11 - 12].
2) The emergence of **<u>nontrivial attractors</u>** in the Renormalization Group theory of phase transitions [12, 15 - 16].
3) **<u>Hamiltonian Chaos</u>** in the phase-space of nonintegrable systems and the corresponding onset of fractal spacetime [13 - 14].

The last two decades have consistently shown that both CD and evolving spacetime dimensionality can lead to key developments in high-energy theory, statistical physics, self-organized systems, fractional dynamics, astrophysics and cosmology, fluid physics, plasma physics and condensed matter.

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