Introduction to "Fractional Dynamics and Physics Beyond Effective Field Theory (Part 2)"

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Abstract

This is the Introduction section of the upcoming sequel to "Fractional Dynamics and Physics Beyond Effective Field Theory (Part 1)", available at https://vixra.org/pdf/2401.0108v2.pdf

Key words: complex dynamics, fractal spacetime, fractional dynamics, effective field theory, far-from-equilibrium phenomena, primordial cosmology.

1. Introduction and Motivation

According to [1], there is a tentative path leading from Dimensional Regularization procedure of Quantum Field Theory to *fractal spacetime*, on the one hand, and to *fractional dynamics*, on the other. Both concepts require passage to a spacetime endowed with *continuous dimensions,* which are conjectured to flow with the observation scale. These findings offer unforeseen insights on the deep ultraviolet sector of Effective Field Theory (EFT). At the same time, they are manifestly at odds with the majority of Standard Model extensions, Quantum Gravity theories or field unification models.

In a nutshell, Fractional Dynamics reflects the onset of complex behavior in systems evolving in far from equilibrium conditions. To appreciate the alleged impact of fractional dynamics beyond EFT, let us look at two textbook examples:

1) **Perturbative Quantum Field Theory (QFT)** is an archetype of EFT which lies at the foundation of the Standard Model for particle physics. Although astonishingly successful in matching results from collider data, QFT is confronted by many drawbacks. It is known, for instance, that amplitude computations are at best *asymptotic expansions*, meaning that Feynman diagrams fail to uncover the true dynamics of the theory. Non-

perturbative QFT methods have been partially successful, yet it is fair to say that, for the most part, the underlying physics of QFT remains unknown. In addition, there are several caveats and patches needed to secure self-consistency demanded by the principles of QFT [see e.g. 2-5].

2) Another often cited paradigm of an EFT is **General Relativity (GR)**, whose validity rests on the principle of *general (or diffeomorphism) covariance*. This principle asserts that all physical laws must take the same mathematical form regardless of the coordinate system used by observers in arbitrary relative motion. Stated differently, general covariance means invariance of physical laws under all possible coordinate transformations. An implicit assumption of general covariance is that any coordinate transformation and its inverse are smooth /analytic functions that can be differentiated arbitrarily many times. However, it is known that there is a plethora of *non-differentiable curves and surfaces* in Nature, as abundantly discovered since the introduction of fractal geometry in 1983. The unavoidable conclusion is GR assigns a preferential status to differentiable

transformations, which is at odds with the very spirit of general covariance. In addition, the singularity problem, the relentless instability of the transient regime of GR, and the N-body problem are likely tied to the transition from deterministic to a self-sustained complex evolution in the primordial stages of Universe formation [see e.g. 6-9]

A fair question to ask at this point is: *What motivates the belief that fractional dynamics can overcome the limitations of EFT listed above*? As argued in [8-9], the reason is that fractional dynamics and the continuous dimensionality of spacetime follow from the **nonintegrability** of Hamiltonian equations of motion at all levels of observation. Nonintegrability is a consequence of phase-space fragmentation, it appears to be nearly universal and represents a key marker of **emergent behavior** in large systems of nonlinearly coupled components.

The sequel to [1] is organized in the following way: next section elaborates on the nonintegrability of Hamiltonian dynamics and the roots of fractal spacetime above the scale of the Standard Model. Section three and four detail the route from fractional dynamics to the Dimensional Reduction conjecture and multifractal clustering in particle physics and primordial cosmology. The last section delves into the genesis of Dark Matter as large-scale condensate of continuous dimensions.

References

1. https://vixra.org/pdf/2401.0108v2.pdf

2. Duncan, A. The Conceptual Framework of Quantum Field Theory, Oxford Univ. Press, 2012.

3. https://arxiv.org/pdf/hep-th/9704139.pdf

4. https://arxiv.org/pdf/2307.06114.pdf

5. https://arxiv.org/pdf/math-ph/9809011.pdf6.

6. https://www.researchgate.net/publication/364678235

7. https://www.researchgate.net/publication/366580553

8. https://www.researchgate.net/publication/371029930

9. https://www.researchgate.net/publication/369814408