<u>Potential Evidence of Evolving Spacetime Dimensions from DESI</u>

Ervin Goldfain

Global Institute for Research, Education and Scholarship (GIRES), USA

E-mail ervingoldfain@gmail.com

Abstract

Recent results from the *Dark Energy Spectroscopic Instrument* (DESI) indicate that Dark Energy (DE) may be weakening over time. The potential evolution of DE raises a major challenge to standard cosmology, which is built on the assumption that DE represents the *cosmological constant* (CC) of Einstein's equations. Here we point out that DESI's findings support the conjecture that, a) well above the range of electroweak interactions spacetime dimensionality is *continuous and runs with the observation scale*, and b), the energy content of the CC comes from the cumulative contribution of energies stored in the fractal structure of Dark Matter/Cantor Dust.

Key words: Dark Energy, Dark Matter, DESI, cosmological constant, spacetime fractality, scale-dependent continuous dimensions, neutrino oscillations.

As argued in [3], Hamiltonian formulation of classical field theory can be formally mapped to the Riemannian geometry of classical gravitation. Taking advantage of this property, [3] has examined the possibility that the onset of Hamiltonian chaos in the ultraviolet (UV) sector of field theory and primordial cosmology generates the energy scales associated with the *cosmological constant* (Λ) and the *electroweak sector of particle physics* $(M_{EW} = v \approx 246 \text{ GeV})$. Staying consistent with the geometry of fully developed chaos, we argue in [3] that these two scales reflect the cumulative contribution of energies stored in the fractal/continuous dimensionality of spacetime above v. As a result, both Standard Models of particle physics and cosmology can be interpreted as non-trivial attractors of the UV to infrared (IR) flow.

This UV regime of particle physics and cosmology is well characterized by the concept of *non-vanishing Kolmogorov entropy* (S_K) and the emergence of spacetime having *continuous dimensionality* $[\varepsilon(\mu) = 4 - D(\mu) << 1]$, in which μ stands for the dimensionless observation scale. The surge of Kolmogorov entropy in nonintegrable systems and unstable systems outside equilibrium is associated with increasing complexity in phase-space. A prerequisite of this process is the mechanism of *decoherence,* which drives the transition from quantum to classical behavior. The expectation is that global thermalization of instabilities occurs at the endpoint of the phase-space flow, a state corresponding to the onset of *effective field theory*.

Ramping up S_K upon lowering the observation scale μ follows from the continuous dimensional deviation of spacetime ε as encoded in [2, 6]

$$D_H(\mu) = -\frac{S_K(\mu)}{\log \varepsilon(\mu)} \Rightarrow S_K(\mu) = \log[\varepsilon(\mu)^{-D_H(\mu)}] \quad (1)$$

$$\varepsilon(\mu) = 4 - D(\mu) \propto \frac{m^2(\mu)}{\Lambda_{UV}^2} << 1 \quad (2)$$

Here, D_H is the Hausdorff dimension of phase-space trajectories, m is a mass parameter and Λ_{UV} the large UV cutoff of the theory. Relation (2) is rooted in the Dimensional Regularization technique of Quantum Field Theory, in the transition to Hamiltonian chaos of nonintegrable dynamical systems as well as in the emergence of nontrivial fixed points in the Ginzburg-Landau model of critical behavior [2].

Following [3] and (A4) of the Appendix section, a relationship may be established between (2) and the cosmological constant Λ, where the latter is expressed as function of the scalar curvature of the vacuum R,

$$\boxed{-D_H(\mu)\frac{[a_1+a_2\,\varepsilon_{\min}(\mu)]}{\beta_\rho(\mu)} \Leftrightarrow \sqrt{R}=\sqrt{4\Lambda}} \tag{3}$$

Here, $\varepsilon_{\min}(\mu)$ is a *local minimum* of dimensional deviation, ρ denotes the phase-space measure (line, area, volume) and $\beta_\rho(\mu)=d\rho/d\mu$ is the beta-function of its flow relative to the observation scale.

Since dimensional deviation ε is considered a continuous and arbitrarily small variable, it may be equally well thought of as an *infinite string* of component deviations as in

$$\varepsilon=\sum_1^\infty \varepsilon_i=\frac{1}{\Lambda_{UV}^2}\sum_1^\infty m_i^2 << 1 \tag{4}$$

By (3) and (4), it is conceivable that $\varepsilon_{\min}(\mu)$ may be cast in the following form

$$\varepsilon_{\min}(\mu) = \sum_1^\infty \varepsilon_{i,\min}(\mu) = \frac{1}{\Lambda_{UV}^2} \sum_1^\infty m_{i,\min}^2(\mu) \propto \frac{\Lambda(\mu)}{\Lambda_{UV}^2} \tag{5}$$

or

$$\boxed{\sum_1^\infty \frac{m_{i,\min}^2(\mu)}{\Lambda(\mu)} = O(1)} \tag{6}$$

The string of component deviations $\varepsilon_{i,\min}(\mu)$ acts as an infinite ensemble of scalar fields clustered into a large-scale Cantor Dust structure emerging from topological condensation and matching the behavior of Dark Matter. By (6), one concludes that, on scales far larger than the electroweak scale, *the energy content of the cosmological constant comes from the cumulative contribution of energies stored in the Dark Matter/Cantor Dust.* Although a highly speculative scenario, this conjecture points nevertheless to an attractive path towards unifying DE and Dark Matter into a single and coherent framework.

It is also apparent that, by (6), *the cosmological constant necessarily runs with the observation scale,* in line with DESI's findings [1].

We close by emphasizing that the interpretation outlined here matches the view of the CC as outcome of *neutrino oscillations* [4], as well as the picture of Dark Matter/Cantor Dust transitioning to neutrino condensates through *field bifurcations* (fig. 1) [5].

$$(Dark\ Matter) \Rightarrow \begin{pmatrix} (\nu,\bar{\nu})_\tau \\ (\nu,\bar{\nu})_\mu \\ (\nu,\bar{\nu})_e \end{pmatrix}_L \Rightarrow \begin{pmatrix} (\tau^-,\nu_\tau)_L \\ (\tau^-)_R \\ (\mu^-,\nu_\mu)_L \\ (\mu^-)_R \\ (e^-,\nu_e)_L \\ (e^-)_R \end{pmatrix} \Rightarrow \begin{pmatrix} (t\bar{t})_{L,R} \\ (b\bar{b})_{L,R} \\ (s\bar{s})_{L,R} \\ (c\bar{c})_{L,R} \\ (d\bar{d})_{L,R} \\ (u\bar{u})_{L,R} \end{pmatrix}_{(\alpha\bar{\alpha})}$$

Fig. 1 Bifurcations of Dark Matter into neutrinos and charged fermions [5]

<u>APPENDIX: The Vacuum Equations of General Relativity</u>

The vacuum equations of General Relativity correspond to $T_{\mu\nu}=0$ and read

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R+\Lambda g_{\mu\nu}=0 \qquad \text{(A1)}$$

Taking the trace of (A1) by contracting both sides with the metric $g^{\mu\nu}$ leads to

$$g^{\mu\nu}R_{\mu\nu}-\frac{1}{2}g^{\mu\nu}g_{\mu\nu}R+\Lambda g^{\mu\nu}g_{\mu\nu}=0 \tag{A2}$$

in which

$$g^{\mu\nu}g_{\mu\nu}=4 \tag{A3}$$

On account of (A3), (A2) simplifies to

$$R=4\Lambda \tag{A4}$$

and

$$R_{\mu\nu}=\Lambda g_{\mu\nu} \tag{A5}$$

References

1. https://arxiv.org/pdf/2503.14743

2. Goldfain, E. (2025), Three Routes to the Dynamics of Continuous Spacetime Dimensions, preprint https://www.researchgate.net/publication/388483112

3. Goldfain, E. (2021), Cosmological and Fermi scales from Hamiltonian Chaos, preprint https://www.researchgate.net/publication/355173171

4. Goldfain, E. (2006), Derivation of the Cosmological Constant from the Physics of Neutrino Oscillations, preprint https://www.researchgate.net/publication/252522549

5. Goldfain, E. (2024), On the Bifurcation Structure of Particle Physics, preprint https://www.researchgate.net/publication/384145207

6. Goldfain, E. (2019), On the Emergence of Spacetime Dimensions from Kolmogorov Entropy, preprint https://www.researchgate.net/publication/336047781