Exploration

Baryon Asymmetry from the Minimal Fractal Manifold

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Abstract

Baryon asymmetry represents the observed excess of matter over antimatter and is conjectured to follow from the Sakharov conditions for baryogenesis. Our brief note highlights a surprising connection between baryon asymmetry and the minimal fractality of spacetime near the Fermi scale. This connection is likely to emerge from the non-equilibrium regime of dimensional fluctuations in the early Universe.

Keywords: Baryon asymmetry, baryogenesis, non-equilibrium, statistical mechanics, minimal fractal manifold, dimensional fluctuations.

It is known that locality, Lorentz-invariance and causality are cornerstone principles of both Quantum Field Theory and the Standard Model (SM). These principles enable the underlying symmetry of particles and antiparticles and are consistent with the *CPT* (*charge-parity-time reversal)* invariance of quantum interactions. Yet all astrophysical evidence shows that matter dominates antimatter in the current Universe, with no consensus among theorists on why this is the case.

In 1967, Sakharov formulated a set of three conditions necessary to generate the baryon asymmetry in the early Universe, namely:

1) the baryon number (*B*) conservation is violated,
2) the discrete symmetries of charge conjugation (*C*) and charge-parity (*CP)* are also violated,
3) interactions occur outside thermodynamic equilibrium.

The third Sakharov condition hints to an intriguing relationship between baryon asymmetry and the concept of *minimal fractal manifold*, the latter denoting a spacetime continuum endowed with arbitrarily small and scale-dependent deviations from four-dimensions ($\varepsilon = 4 - D << 1$). There are well-motivated reasons to believe that dimensional fluctuations driven by ε occur *out-of-equilibrium* and are *asymptotically compatible* with the internal structure and dynamics of the SM [1-3].

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The magnitude of baryon asymmetry is measured by the *baryon to entropy ratio*

$$\eta = \rho_b - \rho_{\bar{b}} = \frac{n_b}{s} - \frac{n_{\bar{b}}}{s} = O(10^{-10}) \tag{1}$$

where $n_b, n_{\bar{b}}$ are baryon and antibaryon densities (numbers per unit volume) and s the entropy density (entropy per unit volume) [4]. Since, up to a first-order approximation, ε reflects the departure from thermodynamic equilibrium, it is reasonable to conjecture that the creation of baryons and antibaryons from quark and antiquark confinement scales linearly with ε. Hence, in line with the third Sakharov criterion, we take

$$\rho_b \sim \rho_{\bar{b}} \sim O(\varepsilon) \tag{2}$$

Furthermore, because the dimensional deviation ε flows with the energy scale, it likely reaches its maximal value close to the formation of the cosmic microwave background (CMB). Applying the Planck law of black-body radiation to the CMB one finds [5]

$$\varepsilon_{\max} = O(10^{-5}) \tag{3}$$

By (2) and (3), the baryon to entropy ratio may be estimated as

$$\boxed{\eta = \Delta O(\varepsilon) = O(\varepsilon_{\max}^2) = O(10^{-10})} \tag{4}$$

well within the bounds of recent experimental observations [4, 6-7].

We are currently working on a sequel that attempts to bridge the gap between baryon asymmetry and self-organized criticality [8].

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2) References [1 – 12] listed in https://www.prespacetime.com/index.php/pst/article/view/1634/1564
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7) https://www.mpi-hd.mpg.de/lin/events/group_seminar/inflation/lim.pdf
8) E. Goldfain, "Baryon Asymmetry from Self-Organized Criticality" (*in progress*).