

# **General Relativity as Multifractal Analogue of the Standard Model**

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## *Abstract*

We have recently shown that the Standard Model of particle physics (SM) may be configured as a *multifractal set*, with all field components acting as primary generators of this set. The goal of this brief note is to point out that a multifractal description of General Relativity (GR) is also possible, starting from the definition of the metric tensor and relativistic interval. This finding paves the way to an unforeseen homeomorphism between the structure of SM and classical gravity.

**Key words:** Standard Model, General Relativity, Multifractal Set, Generalized Dimension.

## **1. Multifractals: a concise overview**

As it is known, the *box-counting dimension* defines the main scaling property of fractal structures and is a measure of their self-similarity. Multifractals are global mixtures of fractal structures, each characterized by its local box-counting dimension. Self-similarity of multifractals is accordingly defined in terms of a *multifractal spectrum* describing the overall distribution of dimensions. In the language of chaos and complexity theory, multifractal analysis is the study of *invariant sets* and is a powerful tool for the characterization of generic *dynamical systems*.

In the recursive construction of multifractal sets from  $i=1,2,\dots,N$  local scales  $r_i$  with probabilities  $p_i$ , the definition of the box-counting dimension leads to

$$\sum_{i=1}^N p_i^q r_i^{\tau(q)} = 1 \quad (1)$$

Here,  $q$  and  $\tau(q)$  are two arbitrary exponents and the latter is typically presented as

$$\tau(q) = (1-q)D_q \quad (2)$$

where  $D_q$  plays the role of a *generalized dimension*.

## **2. GR as topological analogue of SM**

Consider now the field makeup of the SM, formed by 16 *independent* “flavors”: two massive gauge bosons ( $W, Z$ ), gluon ( $g$ ), the Higgs scalar ( $H$ ), neutrinos, charged leptons and quarks. The SM structure can be conveniently organized in the  $4 \times 4$  matrix

$$SM = \begin{pmatrix} W & \nu_e & \nu_\mu & \nu_\tau \\ Z & e & \mu & \tau \\ g & u & c & b \\ H & d & s & t \end{pmatrix} \quad (3)$$

Note that photon ( $\gamma$ ) is absent from (3) as it is built from the underlying components of the electroweak sector, whereby  $\gamma = \gamma(W_\mu^3, B_\mu)$  and  $B_\mu = B_\mu(W_\mu^3, Z)$  [1].

It was shown in [2, 3] that, near the electroweak scale  $M_{EW}$ , the spectrum of particle masses  $m_i$  entering the SM satisfies the “closure” relation

$$\sum_{i=1}^{16} \left( \frac{m_i}{M_{EW}} \right)^2 = 1 \quad (4)$$

Note that (3) shares the same formal structure with the metric tensor of GR, that is,

$$GR = \begin{pmatrix} g_{00} & g_{01} & g_{02} & g_{03} \\ g_{10} & g_{11} & g_{12} & g_{13} \\ g_{20} & g_{21} & g_{22} & g_{23} \\ g_{30} & g_{31} & g_{32} & g_{33} \end{pmatrix} \quad (5)$$

under the most general assumption that  $g_{\mu\nu} \neq g_{\nu\mu}$ . Starting from the GR definitions of interval and proper time leads to ( $c=1$ )

$$\sum_{\mu=0}^3 \sum_{\nu=0}^3 g_{\mu\nu} \frac{dx^\mu}{d\tau} \frac{dx^\nu}{d\tau} = 1 \quad (6)$$

Comparing (1), (4) and (6) reveals the following mapping

$$GR : (p_i \Rightarrow g_{\mu\nu}, q=1, D_q \rightarrow \infty, \tau(q)=2) \quad (7)$$

$$SM : (p_i \Rightarrow 1, q=0, D_q = \tau(q)=2)$$

A couple of conclusions may be drawn from (7):

- GR may be viewed as a topological analogue of the SM, defined by a unitary exponent  $q$  and a singular generalized dimension  $D_q$ .
- The spectrum of particle mass scales ( $m_i/M_{EW}$ ) and the four-vector of differential coordinates ( $dx^\mu/d\tau$ ) form the basis for the multifractal representation of SM and GR, respectively.

## **References**

[1] see e.g., Maggiore, M. “*A Modern Introduction to Quantum Field Theory*”, Oxford University Press, 2005.

[2] Goldfain, E. “*Introduction to Fractional Field Theory*”, Aracne Editrice, 2015. Same reference can be located at:

[https://www.researchgate.net/publication/278849474\\_Introduction\\_to\\_Fractional\\_Field\\_Theory\\_consolidated\\_version](https://www.researchgate.net/publication/278849474_Introduction_to_Fractional_Field_Theory_consolidated_version)

[3] <http://prespacetime.com/index.php/pst/article/view/638/636>