

What is the Multi-fold Theory? Its Main Characteristics in a Few Words

Stephane H. Maes¹

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Abstract

We have proposed the multi-fold theory over the last two years with a fundamental initial paper then many follow ups.

The paper succinctly summarizes the theory so far in a few words.

“Just as General Relativity taught us that “spacetime tells matter how to move; matter tells spacetime how to curve”, the Multi-fold theory argues that Quantum Physics tells multi-fold spacetime to contort itself to support the needs from entanglement and no supra luminosity. The result is gravity, to support such requirements, as demanded by the content of the universe.

The multi-fold theory is about explaining and reconciling, that and all the consequences of it. These include the SM_G , i.e., the Standard Model where gravity is non-negligible at its scales, multi-fold dark matter, the E/G factual conjecture, and energy and a discrete spacetime that is 2D at small scale, Lorentz invariant, fractal and non-commutative. The SM_G potentially explains many problems with the SM.

Multiple sign hint that our real universe may be multi-fold, and that in particular multi-folds can be encountered at Planck scales in General Relativity.”

References are provided to readers interested in exploring such assertions and results.

1. Introduction

In the paper, we summarize the main principle or motto that characterized and inspired the multi-fold theory.

We also succinctly reference where an interested reader can find more information.

2. Multi-fold results and Overarching References

The multi-fold paper [1] proposes contributions to several open problems in physics, like the reconciliation of General Relativity (GR) with Quantum Physics, explaining the origin of gravity proposed as emerging from quantum (EPR- Einstein Podolsky Rosen) entanglement between particles, detailing contributions to dark matter and dark energy, and explaining other Standard Model mysteries without requiring New Physics beyond the Standard Model other than the addition of gravity to the Standard Model Lagrangian. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

¹ shmaes.physics@gmail.com

As a summary, see [1-4] for more, the whole multi-fold theory derivation, including the introduction of SM_G , can then be repeated. And so, accordingly, in a multi-fold universe, gravity emerges from Entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles, that they be real or virtual. Long range, massless gravity results from entanglement of massless virtual particles. Entanglement of massive virtual particles leads to massive gravity contributions at very small scales. Multi-folds mechanisms also result into a spacetime that is discrete, with a random walk fractal structure and non-commutative geometry that is Lorentz invariant and where spacetime nodes and particles can be modeled with microscopic black holes. All these recover General Relativity (GR) at large scales and semi-classical models remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model resulting into what we defined as SM_G . This can contribute to resolving several open issues with the Standard Model without New Physics other than gravity, i.e. no new particles or forces, or with the standard cosmological model (Λ CDM) in terms of dark matter and dark energy. These considerations hint at an even stronger relationship between gravity and the Standard Model. Multi-folds can be encountered in GR at Planck scales, in spacetime quantization starting from the Hilbert Einstein action, and in the equivalence principle of suitable quantum reference frames in relational quantum physics. Conversely, GR and Quantum physics, including path integrals, the Born rule, and wave functions, can be recovered through different paths from multi-fold spacetime reconstruction and the W-type multi-fold hypothesis. In a multi-fold universe, GR and Quantum Physics are not incompatible. They are just different facets of multi-fold mechanisms, something that neither theory can well model.

With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales and semi-classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe). Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and concretized spacetime coordinates, and metrics between Reissner Nordstrom [5] and Kerr Newman [6] for massive, and possibly charged, or colored, particles – the latter being possibly extremal). Although possibly surprising, [1] recovers results consistent with others (see [7], and its references), while also being able to justify the initial assumptions of black holes from the gravity or entanglement model in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scale that make gravity non-negligible at these scales. Semi-classical models also turn out to work well till way smaller scales than usually expected.

Multi-folds are encountered in GR, at Planck scales [8,11], and in Quantum Mechanics² (QM) if different suitable quantum reference frames (QRFs) are to be equivalent relatively to entangled, coherent or correlated systems [9]. This shows that GR and QM are different facets of something that they cannot well model: multi-folds. With the double copy behavior of Yang Mills scattering Feynman diagram [10], we also showed that multi-folds and the E/G conjecture [12] are contained in Yang Mills theory, and that Yang Mills models gravity, as far as, a duality [59,60]. New AdS/CFT conjectures can also be derived [2]. The double copy duality also allowed us to derive that GR-based gravity is asymptotically safe [13].

3. Principle and Consequences in a few words

“Just as General Relativity taught us that “spacetime tells matter how to move; matter tells spacetime how to curve”, the Multi-fold theory argues that Quantum Physics tells multi-fold spacetime to contort itself to support the needs from entanglement and no supra luminosity. The result is gravity, to support such requirements, as demanded by the content of the universe.

² Standing in for Quantum Physics in general.

The multi-fold theory is about explaining and reconciling, that and all the consequences of it. These include the SM_G , i.e., the Standard Model where gravity is non-negligible at its scales, multi-fold dark matter, the E/G factual conjecture, and energy and a discrete spacetime that is 2D at small scale, Lorentz invariant, fractal and non-commutative. The SM_G potentially explains many problems with the SM.

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4. Where to find more details?

[2] tracks all the related papers on the multi-fold theory and related topics. It is always up to date. Head there to look for updates, errata and comments to the papers and work in progress as well as relate to related relevant material.

The original multi-fold theory paper is at [1].

[3,4] provide useful compilations and overview of all the recent results. They will be updated or will have follow-up when it makes sense.

5. Conclusions

This paper enables the reader to summarize, in a few words, the main principle characterizing the multi-fold theory. It also points the reader to where always up to date more detailed or new information can be found. I may give extra insights on the philosophy behind its original formulation.

The Multi-fold principles, or motto, really generalizes Wheeler original statement characterizing General Relativity [14] and link and explains the origin of gravity.

Although it does analyze multi-fold universes, we are led to find indications that our real universe may be multi-fold. While awaiting confirmation or not, of its validation, we have great expectation from the E/G conjecture, factual in multi-fold universes: "Entanglement creates gravity effects and gravity results from entanglement". Dark matter as entanglement is a key aspect of it [1-4,15].

Multi-fold gravity is expected to have non-negligible effect on the Standard Model at its scales, what we denote as SM_G , where it can qualitatively explain many open issues and challenges with the SM and cosmology³ [1-4,16].

Some of these principles may also inspire other approaches, to recover them and projects to validate them. We sincerely hope so.

References⁴

³ Like dark energy, inflation, small cosmological constant [1-4,16], and what happened above the energy of the gravity electroweak symmetry breaking [1-4,17-20].

⁴ If only a URL is provided, at that location, any relevant update on the publication can be found.

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