Multi-fold Gravity-Electroweak Theory and Symmetry Breaking

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Abstract:

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, whether 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 smalls scales. Multi-folds mechanisms also result in 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 model remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model resulting in what we defined as SM_G. This can contribute to resolving several open issues with the Standard Model without new Physics other than gravity. These considerations hints at an even stronger relationship between gravity and the Standard Model.

Among all the candidates for (Grand Unification Theories) GUTs, modeling of GR and quantum gravity or understanding Loop Quantum Gravity (LQG), the use of the left-handed spin connection as variable for canonical gravity (self-dual), and the gravity weak, gravity electroweak and gravity electroweak + strong unifications have proposed variations on how gravity can be described with a chiral left-handed representation, leaving room for a chiral weak theory. We used this result to justify the viability of the 7D space time natter induction and scattering of chiral fermions in a 4D multi-fold spacetime, despite the absence of chiral fermions in 5 or 7D Physics. Interestingly a model of gravity electroweak symmetry breaking, to produce such chiral gravity, i.e. spacetime and weak interactions, obtains solutions as GR at large scales, and a Higgs mechanisms with a Higgs boson coupled to right-handed neutrino, and a massless and massive bi-gravity. It is converging with the multi-fold theories. Unfortunately, these candidate theories do not seem to have evolved and panned out past the first decade of this millennium.

In this paper, we endorse one of the gravity electroweak unification, and symmetry breaking as a QFT approximation of the multi-fold Physics over a 4D multi-fold discrete spacetime generated by random walk, a 2D process at very small scale, and study how the multi-fold theory, especially the random walk spacetime reconstruction, its 2D regime and its microscopic blackholes as particles and concretized spacetime locations, provides an intriguing microscopic interpretation to predict, or explain, this gravity electroweak symmetry breaking QFT approximation. This explanation, and the convergence of different approaches (QFT, non-perturbative quantum geometry / self-dual, and multi-fold to explain each other, recover key results of multi-fold universes and the SM_G, that can potentially explain many open problems with the Standard Model (SM) and the standard cosmological model) along with a microscopic explanation for the physics behind symmetry breaking, mass generation, chiral fermions and chiral spacetime, speaks loudly to the consistency of multi-fold models, and their relevance to the SM. In our view, this approach is now a candidate to a new type of unification of quantum gravity and SM.

The model also account for the special relations between the Higgs (massless) and spacetime, something we predicted, but not conventional, the microscopic explanation of mass generation related to particles as Higgs condensation into microscopic black holes that are regularized solitons, and the relationship between the Higgs boson and the right-handed neutrino.

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This new theory, the multi-fold gravity electroweak unification and symmetry breaking, also handles the strong interaction without an additional unification mechanism. Instead of an interim unification and symmetry breaking separating electroweak and strong interactions, the strong interaction with its field and massive particles is handled by the same unification and symmetry breaking mechanisms. It could explains why there are simply no (Grand Unifications Theories) GUTs out there.

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1. Introduction

The initial multi-fold paper [10] 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, with gravity not negligible at the scales of SM i.e. SM_G [9,10]. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated. *Note added on November 14, 2022: See [73-75] for more details on the SM_G, and [76] for strong hint that the real universe may indeed be multi-fold.*

With the proposed model of [10], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales and semi classical approaches appear valid till very small scales. In [10], 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 spacetime coordinates, and metrics between Reissner Nordström [60] and Kerr Newman [61] for massive and possibly charged particles – the latter being possibly extremal). Although surprising, [10] recovers results consistent with others (see [62] 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 (GR) at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scale that make gravity significant at these scales. Semi-classical models also turn out to work well till way smaller scales than usually expected.

The present paper starts with a review of (non-multi-fold) gravity (electro)weak models, and the underlying self-dual theory, and in particular we detail the result of our preferred gravity electroweak symmetry breaking model: [1]. [1] is then revisited, and explained in the context of multi-fold spacetime reconstruction, and many of the results obtained so far, fall in place in an overall consistent story. In our view, this consistency, and alignment of the results, revives the interest for [1] and the intriguing validity, and relevance of multi-fold universe and the multi-fold gravity electroweak theory to the Standard Model (SM), or probably rather the SM_G.

The resulting multi-fold gravity electroweak symmetry breaking also handles what happens with the strong interaction, and as a result, we do not expect any new interaction, or new fundamental particle, above the gravity multi-fold electroweak symmetry breaking energy scales; other than the Ultimate Unification (UU) [10,19]. *Note added on November 14, 2022: Also consider [77-79,92] for more details on the Ultimate unification and fundamental new particle desert above the multi-fold electroweak symmetry breaking energy scales.*

2. Overview of QFT gravity (electro)weak symmetry breakings

Based on [1-4], we see that, in the presence of fermions, chiral fermions and chiral spacetime, or quantum gravity, appear in a 4D spacetime, with renormalizable QFT theories (Yang Mills), because gravity can be fully modeled with a left-handed spin connection (self-dual variables, or left-handed half chiral $SU_L(2)$). It is achieved with a left-handed representation of $SU_L(2)$ [2-4]. The right-handed $SU_R(2)$ from the original $SL(2,\mathbb{C})$ group is left available to model the chiral weak interaction post electroweak symmetry breaking as the left handed spin connection [1,4].

$SL(2,\mathbb{C})$ can be seen as the parent symmetry group before such symmetry breaking occurs. $SL(2, \mathbb{C})$ is the symmetry group for complexified Lorentz transformations on a 4D spacetime, and it can be broken into the subgroup $SU_R(2)$ (which will be associated to the weak, part of the Standard Model [13], when multiplied by SU(3) for the strong interaction and U(1) for the electromagnetism) and the subgroup $SU_L(2)$ (which is associated to gravity per [2,3]). This ability of $SL(2, \mathbb{C})$ to represent gravity is unique to 4D spacetime [2-4] and relies on the decomposition of spin connections into self-dual and anti-self-dual parts. *Note added on November 14, 2022: This is also consistent with the groups considered in [80], originally inspired in part from steps in the geometric Unity as in [1].*

As an example, but a good one, [1] provides a concrete symmetry breaking scheme proposal that results into:

- A Higgs mechanisms with a Higgs boson
- A isospin doublet spacetime spinor companion to the Higgs that can match right-handed neutrinos.
- A massless and massive bi-metric (i.e. massive and massless gravity)

Variations of the models have been discussed in a slew of related papers around the same time period as for example [11,12] and reference therein.

Note that, in some of these papers, GUTs or other models are proposed where the derived neutrinos are rather modeled with Seesaw mechanisms. It is something that, a priori, we do not need for consistency of the multi-fold models where we have a preferred proposal [10,14-18], and, therefore, while not ruling out seesaw mechanisms, we prefer avoiding such options; they are not part of the multi-fold gravity electroweak theory that we propose. We will go with our own Dirac fermion model à la [10,14], even if the other proposals could also pan out from the point of view of the present analysis (unless implying more particles, or more dimensions).

Our interest in these other gravity (electro)weak papers (and related ones cited in these references) is that it also demonstrates not only how the symmetry breaking mechanism can both separate the symmetry groups into $SU_L(2)$ and $SU_R(2)$, but also produce a Higgs mechanism with mass generation. Adding the strong interaction does not change the conclusions à la SM, when gravity is modeled as $SU_L(2)$ (or a larger group). However, Grand Unification Theory (GUT) starting with uber groups à la SO(4), and SU(4), and above like SO(5) or SO(10), remain speculative, or elusive. As far as we know, these grander theories have not pan out since these papers were published[2]. It is good, as we have previously ruled out such approaches in [19], because of their predictions of magnetic monopoles [10,25] and proton decay [10,24], and the incompatibility of supersymmetries, or larger group of particles with the SM, if gravity is asymptotically safe [33,34]. [1] does not fall under such category because it does not predict an uber symmetry group. Note added on November 14. 2022: we have since proved non-perturbatively that gravity is indeed asymptotically safe [82].

[2] The only subsequent publications encountered on the subject, or by the main related authors, do not complete this program as far as we could find out. The same is true in fact for the model of [1], except for extensions [11,12], that also try to repeat the analysis with generic Yang Mills [20], instead of just Electroweak, and therefore also attempt a GUT or TOE. Also, this work seems to potentially lead to Lisi's Exceptionally Simple ToE [21-23], which we had already rejected, by us at least, because, for example, of its prediction of proton decays [10,19,22-24]. Unfortunately, again, so far, an apparent path to nowhere.

Unfortunately, so far, [1] and the related works, compiled above, seem to have been relegated to ones among many others GUTs and TOEs models, unconfirmed by observations, with consistency issues, and also sometimes in tensions with superstrings.

It should not be so. [1] is actually entirely consistent.

In this paper, we argue that [1], fitted to the multi-fold theory, is actually a correct window to what happens above the electroweak symmetry breaking energy scales. It comes from the ability to understand these effects as involving spacetime orientation [69], space time matter induction and scattering [17,29], and particles as microscopic black holes [10,62], built from condensation of massless Higgs bosons [18,62].

Note added on November 14, 2022: these aspects are also further discussed in [79,80].

3. Microscopic models, multi-fold gravity electroweak unification and symmetry breaking

It becomes apparent in a multi-fold universe. Indeed, in multi-fold universes, everything changes. In multi-fold universes, the gravity electroweak symmetry breaking directly matches, recovers or is explained by many results of the multi-fold theory [10], and many follow-up publications that can be tracked at [8,9].

The multi-fold microscopic mechanisms can explain key aspects of the gravity-electroweak symmetry breakings. It is with the understanding that QFT and quantum physics are 4D effective theories built on a discrete random walk Lorentz invariant non-commutative spacetime, which is a 2D effect at very small scales and 4D at larger scales [5,10,26-28].

3.1. The multi-fold gravity electroweak theory

The multi-fold gravity electromagnetic theory is defined as follows:

- It is taking place in a multi-fold universe with multi-fold mechanisms, and 4D spacetime reconstruction as in [10].
- Therefore following many of the follow-up results tracked in in [8,9], in particular the SM_G applies for the SM.
- Where pre-symmetry breaking the model is 2D with random walks and concretized spacetime locations performed and occupied by massless Higgs bosons, inflation results from exponential effects of the combination of random walks, and creations of new particles (mostly massless Higgs bosons), i.e. spacetime. The dominant massless random walk regime is a 2D process.
- Where particles and spacetime locations are modeled, as microscopic black holes [10,62], minimum when massless and (beyond) extremal for massive particles. These are regularized as solitons of the Dirac-Kerr-Newman (or Dirac-Reissner-Nordström) metrics, as Qballs, or condensed Higgs boson confined inside, and superconducting edges (for the charges, or associated currents, that they carry).
    - It is such a formation of massless solitons as particles (possibly ones after the others, depending on the energy of the Higgs and energy of the particles) that could create the slow roll and reheating associated to the (new) inflation, as detailed in [18], where we also propose that the inflaton is the Higgs field minimally or non-minimally coupled to gravity (see later). This step is

just an hypothesis at this stage: what we mention in this sub—bullet is not in itself a mandated step of the multi-fold gravity electroweak evolution.

- Spacetime chirality results from the chirality of the massive particles as / when they appear[3], a direct result from Kerr-Newman extremal solutions. Fermion, and boson chirality result from spacetime chirality. Chirality at energies above electroweak symmetry breaking is achieved by local sporadic spacetime orientations as discussed in [10,62,69]. *Note added on November 14, 2022: See also [79].*
- As inflation stops, and we have a slow roll with re-heating different solitons pairs (matter/antimatter) can appear. Mostly massless, i.e., empties but with right symmetries, virtually at time massive. These "feasible solution" are induced from 7D geometries and scatterings [17,29], and bring in symmetries that define quantum numbers and conserved charges. The charges appear associated to their respective solitons.
- When enough Higgs particles can condensate, into pairs (matter/antimatter) of soliton Qballs solutions of Dirac-Kerr-Newman as in [62]. Again, these "feasible solution" are induced from 7D geometries, and scatterings, and bring in symmetries that define quantum numbers and conserved charges. The charges appear associated to their respective solitons. This corresponds to the mass generation effect for massive fermions and bosons. The condensation can be understood as resulting in massive Higgs bosons responsible for mass generation.
- The weak interaction appears, maximally chiral as dual of the spacetime chirality or orientation: the $W^{\pm}$ bosons are charged and massive and therefore with the chirality of spacetime (left-handed, e.g. [66]) and the Z^0 is neutral without charge and only mass, so no chirality). As a result, the weak interaction interacts only with left-handed fermions.
- Colors, the strong interactions is just a particular case of mass acquisition and symmetric charges from SU(3). There are no additional symmetry breakings involving SU(3) / strong interaction or with respect to electroweak or gravity electroweak interactions. *Note added on November 14, 2022: It fundamentally comes from the 3D spatial dimensions of spacetime as discussed in [17,29,80], and in comments at [6,7,83-85].*
- The weak interaction is a chiral interaction. Adding U(1) for the electromagnetism does not change much [1].
- [1] provides the group and QFT model for the symmetry breaking in a 4D spacetime that approximates and emerges from the multi-fold discrete spacetime. It models a resulting chiral spacetime [17,29,62,69], and chiral weak interaction + electromagnetism (+ strong interaction), a Higgs boson responsible for a Higgs mechanism and mass creation and right-handed neutrino(s) companion to the Higgs boson [10,14,16] (*Note added on November 14, 2022: See also [86]*). This is the QFT version, or should we say rendering, of multi-fold effects associated to Higgs as concretization of spacetime locations, massive neutrinos due to right-handed neutrinos, always in flight, no-interacting (i.e. behind the Higgs boson at the entry/exit points of the multi-folds. QFT can't model it but it can emulate the behavior.

3.2 Congruence of multi-fold theories and the multi-fold gravity electroweak model

When explaining and motivating the gravity electroweak model symmetry breaking at the light of the multi-fold universe we not only obtain microscopic explanations for the gravity electroweak symmetry breaking, and associated mass generation and the maximum chirality of the weak interaction, but we also motivate, and put in

[3] It may occur before inflation as a result of quantum fluctuations with already an excess of particles over anti-particles or post inflation, which could then result into multiverses, domain walls or cosmic strings. It does not really matter to this discussion.

perspective, many predictions made from the multi-fold mechanisms. The rest of the section lists some of the most interesting outcome.

The multi-fold gravity electroweak model recovers, encompasses and is fully compatible with the notion of Ultimate Unification (UU) and its democratization of interaction strengths. UU is primarily achieved with a massless Higgs boson as its main particle that models [10,18,19]. Before multi-fold gravity electroweak symmetry breaking, other particles appear only as quantum fluctuations and essentially interact only through interactions that are all behaving equivalently to gravity are consistently present. *Note added on November 14, 2022: See also [77-79,92].*

In a multi-fold universe, the model of [1] recovers the positioning of the right-handed neutrino as living at the entry and exit points of the multi-folds, at the edge of spacetime, behind the massive Higgs boson [14,16,18]; and the particles encountered in the 7D space time matter induction and scattering model [17,29] (One of them was identified in [17] as potentially the resulting massive neutrino: the M* in [31]), with all the necessary caveats[4]. Interestingly, both Higgs and M* are seen, from the multi-fold spacetime, as at the edge and within the 7D (5D in [31]) embedding universe [17]. It could be the interpretation of doublet companions encountered in [1]. It may also not be, we just mention it for information. On this basis we can now motivate better the tenancy and interactions within fold that we proposed in [10,18,65]:

- Higgs field and bosons are present and interacting in multi-folds because multi-folds are spacetime, which consists of concretized (or concretizable) spacetime locations. As multi-folds accept only a particle per fold (we have one different instance per particle), the fold itself brings in the Higgs and its interactions that ensures that massive particles remain massive in the multi-folds. It can also be seen as: the soliton also has paths in the multi-folds, where its carries its Higgs condensate, and maintains its mass. It is also why the Higgs appears as particle from the embedding 7D universe in [17,18].
- Per [14, 16-18], and the above, the right-handed neutrinos are restricted to the living only within the folds and seen through the entry/exit points. Therefore, they do not interact with anything in spacetime (as nothing interact in the multi-folds) except at time with the left-handed neutrinos due to their path on their multi-folds where the Higgs mediate an interaction among them.
- *Note added on November 14, 2022: See also [80,86,87] for more details on how this would allow multi-folds to possibly be implemented via wormholes, which would now be traversable, with the right-handed neutrino and its anti-particles.*
    - *It is also that requirement that could justify the principle that multi-folds are associated only to non-hierarchical entanglements, as proposed in [10]: entanglements of the right-handed article and its anti-particles at entry and exit of the multi-folds implies that the multi-fold must have originated at the point of entanglement.*
- This also provides tantalizing hints about the matter / anti-matter asymmetry problem [38].

We already had that spacetime concretization by random walk result into minimum Schwarzschild black holes [10] expected to be associated to massless Higgs bosons, which models the Higgs field [18]. The random walks of these particles, a 2D process, explains the 2D regime [5,10,28,] of gravity at very small scale, at the beginning of the universe and during inflation [10,26], as well as the Lorentz invariance of spacetime despite it being discrete [10]: randomness justifies the Lorentz invariance and non-commutativity models it towards larger scales.

[4] The particles mentioned in [17], as derived in [31], were examples, not endorsement of the model of [31], and so no claim that the approach indeed leads to the neutrino (tau) matching M*.

Fundamentally, we see that at the scale of random walks, random walks are the microscopic phenomena that Higgs potentials try to model[5]. *Note added on November 14, 2022: more details on the resulting fractal structure of spacetime are provided in [88].*

Particles surrounded by, and behaving as, microscopic blackholes are proposed in [10], as a result of the multi-fold mechanisms, as well as a direct way to recover classic and semiclassical spacetime. It explains why and how to understand the massless bosons that characterize spacetime, and say their role in inflation [18]. In [10,32,62] (and its references to non-multi-fold analyses, classical as well as quantum), this view is further detailed. There, most spinning and charged particles appear as Kerr-Newman or Reissner-Nordström black holes with singularities regularized through solitons, of the corresponding metrics, which are Qballs resulting from Higgs field condensation, i.e. lots of confined massless Higgs bosons, within the soliton and superconducting effects at the edge of the Qball, that confines the condensed Higgs bosons, therefore giving it masses.

As expected, with proposed condensation, we recover the Brout–Englert–Higgs mechanism [70], mass generation, and the Electroweak symmetry breaking, when the Higgs potential (i.e., a model of the random walk, their interaction and the energy of the massless Higgs bosons, as hinted in [18,34]) allows formation of solitons that capture the massless Higgs, and result into confinement of dense accumulations of these massless Higgs particles. As a result massive particle appears and release their binding energy, resulting in phase transition (that may contribute to a re-heating). Symmetries are associated (in 7D) to the solitons, and fields and these may associate charges (or currents in 4D) to the solitons, resulting from these symmetries. Of course, particles appear in entangled pairs of particle and anti-particles (unless, if already involved in an interaction). The Higgs condensation amounts to particles "swallowing a massive Higgs boson" that can now be considered as massive in terms of such interactions with other particles.

The Kerr-Newman and Reissner-Nordström solutions associated to particles are typically extremal, or beyond (aka over extremal), when massive [10], and they are regularized as discussed above [32]. As discussed in [32], and in particular based on [35,36], an isolated Kerr-Newman and Reissner-Nordström solutions, imply chiral particles (fermions and bosons) and mass (i.e. extremality) imply a chiral spacetime dictated by the spacetime chirality of the particle and conversely[6]. The physical interpretation of spacetime chirality is understood as spacetime orientation [62,69], and, at this stage, as random walks, mostly of massive Higgs bosons, but also other massive particle, with a propensity to walk turning along as the black hole spins. Other spinning fluctuations also align with the black hole spin. It is aligned with the analysis of complementarity or symmetry breaking of gravity studied in [1-4]. We just encountered the microscopic and physical interpretation of what it means to say that SL(2, $\mathbb{C}$) on a 4D spacetime can be broken into the subgroup $SU_R(2)$, associated to electroweak and part of the Standard Model [13], and the subgroup $SU_L(2)$ associated to gravity. The split results from the fact that extremal rotating black holes create a (half-)chiral spacetime and prefer chirally aligned interactions and particles, at least when involving masses. Massive bosons are limited to the Weak interaction with, as expected, left-handed $W^{\pm}$ bosons, that only interacts with left-handed fermions (and right-handed anti fermions). This is why the weak interaction is maximally chirally broken. The orientation is (quasi) global (within a phase).

Note added on November 14, 2022: [29,g] then discuss the viability of such a maximally interaction over a discrete spacetime. This in turn is key to satisfying the mass gap for Yang Mills interactions and ensure viability of the SM as a renormalizable QFT theory [10,71,79].

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[5] It is therefore natural to expect that related microscopic effects can should also explain mass generation, Higgs mechanisms and Electroweak symmetry breaking.

[6] For example, consider the recent observation of the polarization of the photons resulting from the magnetic field near a rotating black hole (M-87*) as discussed in [37] and many other new articles, with a first picture of a black hole in polarized light. Of course, the resulting picture is for a macroscopic non-extremal black hole, but it gives an idea of the polarization of spacetime.

One could repeat the mechanism above for energies above the gravity electroweak symmetry breaking scales. In such cases, the same occurs when virtual massive particles are temporarily realized, but the resulting spacetime orientation is only local and temporary.

At this stage, the preference for left-handed versus right-handed seems to just be chance: the first massive particles, would determine the chirality of spacetime locally. Even if the particles then disappear other fluctuations occurring around would have to align. However, as particles appear in pairs of particle and antiparticles, the effects would have canceled until some matter-antimatter asymmetry enters in play [39] so that the first stable excess decides on the spacetime chirality. In [10,38], we suggested[7] that this asymmetry results from difference in gravity induced helicity/chirality flips between neutrinos and anti-neutrinos, at scales where they are massless Weyl fermions, with stronger motivations presented in [69]. Therefore, for example, the first massive neutrino, as a quantum fluctuation or at Electroweak symmetry breaking, that did survive in excess, due to the matter-antimatter asymmetry, defined the chirality of spacetime: left-handed or right-handed. Based on the left-handed properties of the Standard Model (SM), the first deficit of anti-matter would have been a massive right-handed massive anti-neutrino and spacetime became left-handed, and stayed that way. Just as for conventional theories of inflation, these effects are phase transitions that can appear locally very early on, distributed in time later on, or distributed and completely independent of each other. The latter two cases is typically expected to possibly lead to the introduction of domains walls, multiverses or even spacetime defaults, like cosmic strings, as possibly recently discovered by NanoGrav. See [40,41] for a discussion[8]. If we want to reduce these domain walls complications, we can pick up the first option: spacetime chirality orientation may be due to fluctuations before inflation[9] really took on. It could explain a whole universe with left-handed spacetime. Yet other distribution or defaults in when exiting of inflation or in the process of the electroweak phase transition could still result into such domains walls, multiverses or cosmic strings.

Later, at the end of inflation when energy lowers enough to allow energetically advantageous formation of massive particles, accumulations of massless Higgs bosons in random walk will condensate into stable regularized solitons: the different elementary particles and anti-particle pairs with corresponding charges and quantum numbers associated to every stable soliton solutions[10]. It includes massive chiral fermions and bosons as well as

[7] This hypothesis is based on the different ways that antimatter see entanglement effects of the virtual pairs that it emitted, because anti-particle can be considered as perturbatively going back in time in interactions and time is not reversible in multi-fold universes [10,51,67]. This analysis does not depend on [38], only the observed asymmetry [39]. It could ultimately be another mechanism that explains such matter antimatter asymmetry, with no impact on the validity of our explanation for the origin of spacetime chirality.

[8] The jury is still out on what to make of the NanoGrav results, and if the observations would be signs of cosmic strings primordial black holes, or something else. In particular, even if they were about cosmic strings, it is important to understand that cosmic strings do not imply superstrings, as discussed in [40]. If it turns out to be cosmic strings, we believe that they could be understood as signs of gravity electroweak symmetry breaking default due to distributed selection of chirality of spacetime. These would lead to different regions with different spacetime orientations, not with antimatter vs matter. It will be for future work, for us, to try to model what would happen if a neutrino originating from a region with one orientation enters in a region of other orientation. Different scenarios could be envisaged, from quick annihilation to chirality flip, due to gravity, i.e., expanding on [14,16]. It could therefore be observable, in the former case, or not.

[9] The success in using Bose Einstein Condensate (BEC) to simulate inflation [72], the early universe [63], or even dark matter [64], assuming the models accurate, could be linked to the fact that spacetime indeed seems to be boson matter, where the bosons are primarily Higgs bosons, massless during random walk and inflation or even after as realized spacetime locations [10,18]. There are many more related BEC comments at [8]. Note added on November 14, 2022: See for example like for example [89,90] or the paper [91].

[10] These are most probably dictated by inductions and scattering from 7D geometries per [17,29].

colored gluons. Each type of stable solitons can release energy as condensation takes place; leading to iterative reheating and the slow roll of the inflation potential.

The mass creation, Higgs mechanisms and Electroweak symmetry breaking is the result of the Higgs condensation into superconducting solitons that behave as microscopic black holes [62]. It coincides with the alignment of the massive chiral fermions and bosons with the chirality of spacetime and therefore, it is also at that moment that we see the gravity electroweak symmetry breaking resulting into a maximally chiral weak interaction. Formation of massive colored solitons occurs at the same time. There is no earlier existence of colors and associated particles and interactions, other than as quantum virtual or physical fluctuations. *Note added on November 14, 2022: See [79] for more details and the associated prediction of asymptotic freedom behaviors. It is also why our universe is colorless (independently of say confinement considerations which rather work only at energies closer/below the gravity electroweak symmetry breaking energy scale).* In fact, before that moment, no charge of any type existed other than as fluctuations or virtual effects at the larger scale of the massless solitons, (including for gluons); we are really in the mode of the Ultimate Unifications (UU) that was predicted in [10,19] based on the behavior of extremal black holes as particles and massive gravity considerations. This provides the microscopic interpretation of why and how UU is implemented: all charges in general are captured at larger scales in the solitons symmetries. Below the spatial scale of the solitons everything is not essentially charged. Massless solitons are smaller than massive ones, yet larger at some point than the UU scales. UU and the gravity electroweak symmetry (implemented by UU particles, massless Higgs boson at concretized spacetime locations, and modeled as minimal Schwarzschild black holes, and broken by the condensations of the massless Higgs bosons into massive solitons) explain why no (interim) GUT (unifying electroweak and strong interactions before unification with gravity) and no supersymmetry or Uber symmetry exist [19]; and therefore probably no magnetic monopole [25] or proton decay [24]. With this, we now know why no suitable GUT was so far successfully proposed and why no related particles or events (e.g. proton decay or magnetic monopole) were ever observed. Before gravity electroweak symmetry breaking UU reigns without charges (and when charge appear in fluctuations, per democracy of all the interactions of UU, all particles share similar interaction intensities), they only exist at the soliton scale levels (for massless particles). Similarly, at very small scales (below the gravity electroweak scale), UU reigns with massless Higgs bosons involved in random walks in spacetime or within solitons that confines them. In both cases, Physics is essentially 2D processes, possible compatible also with superstring modeling this regime beyond its Hagedorn temperatures [5,32]. The fact that these 2D processes are compatible with the massless Higgs random walk is already encountered in [5,49], where [49] shows that 2D CFT can represent a free massless boson path integral in 2D [50]. *Note added on November 14, 2022: This really recovers UU and the desert of new fundamental particles discussed in [10,19,77-79,92].*

The SM symmetry group is recovered by multiplying $SU_{Weak}(2)$ by SU(3) and U(1) (See [1] for the latter), for SM without gravity, where $SU_R(2)$ appears instead of just $SU_{Weak}(2)$, originating from the right-handed spin connection left available when $SL(2,\mathbb{C})$ is broken by the first excess of massive chiral neutrinos)[11]. In our view, it also justify

[11] The complex symmetries before the symmetry breaking can also be understood as associated to extensions of the Hilbert Einstein actions to actions equivalent (on-shell and classically), but with different impact in quantum mechanics where torsion in matter and coupling to fermions (i.e. 4 fermion interactions) result from its introduction [1,42,44]. This phase transition can be seen as a transition from a Hilbert Einstein action to a Plebanski action with an Immirzi parameter that becomes imaginary post Gravity-Electroweak symmetry breaking, which gives a maximally chiral spacetime that corresponds to the $SU_L(2)$ self-dual representation of the Ashtekar formulation of quantum gravity (and GR) [45], where fields only take values in $SU_L(2)$, and $SU_R(2)$ values can be ignored [1-4]. The ignored values can be recovered in the classical Einstein equations by adding the complex conjugate of the left-handed part into the expressions of the equations of motion, something that does not changes their solutions on shell. This ability to rely on the self-dual implies a 4D spacetime post symmetry breaking, as mentioned earlier. It is both a confirmation that multi-fold spacetime is 4D and another challenge to any theory that would propose otherwise.

rather referring to SM_G, the Standard Model with gravity non-negligible at its scales. It is another example that gravity matters at the level of the SM.

Interestingly, the derivation of the QFT model of gravity electroweak symmetry breaking proposed in [1] derives a bi-gravity with a massive graviton. The existence of massive and massless gravity contributions is also encountered in multi-fold universes where they directly result from the multi-fold mechanisms, and the involvement of entangled virtual pairs of massive and massless particles [10,15]. The associated emergence of the massive Higgs boson and massive right-handed neutrinos that are respectively spacetime scalars and spinors and isospin doublets companions recovers exactly the strange spacetime related role of the Higgs and the right-handed neutrino at the edge of spacetime and multi-folds (and hence a non-interacting right-handed neutrino that is always in flight and behind the Higgs boson). As we discussed earlier, it is an interesting physical interpretation of the correspondence between spacetime scalars and isospin spinors vs. spacetime spinors and isospin singlets that directly supports the model we had developed both for Higgs bosons and right-handed neutrinos[12] in multi-fold universes [10,14,16,18], resulting from the 7D space time matter induction and scattering proposed in [17,29]. Recovering these results certainly shows the consistency and pertinence both of the multi-fold models but also the notion of gravity electroweak symmetry breaking. Our induction model [17] already relied on [1-4] to justify that 7D induced effects in 4D multi-fold spacetime can be rendered chiral by gravity flips, despite the absence of chirality (no chiral fermions or matrix) in 7D (or odd dimensions). The mechanisms of symmetry breaking [1], and the associated microscopic model presented here, confirm how it is achieved: the resulting solitons forming in multi-fold spacetime from 7D objects can spin along or opposite to spacetime chirality; therefore defining their chirality and allowing Weyl fermions for fermions (represented by spinors) and chiral boson (with chirality defined per their orientation vs. spacetime).

Furthermore, the microscopic mechanisms that we propose, do not require additional particles due to the breaking of spacetime chirality in addition to the breaking of the electroweak symmetry. The massive and massless gravity can be associated to gravitons, but these are actually the multi-folds living outside of spacetime [10,46]. Yet massive gravity results from the massive virtual particles rendered possible by the gravity electroweak symmetry breaking, even for virtual particles before symmetry breaking. We do not expect that other particles are involved or resulting from the gravity electroweak symmetry breaking. *Note added on November 14, 2022: See also [93].*

3.3 No-go theorems, Multi-fold aversion for uber symmetries and 4D spacetime

It is important to note that the QFT approximation of symmetry breaking proposed in [1] is consistent with Coleman-Mandula no-go theorem [11,47] because it does mix groups that involve internal spaces (isospin) not associated with a (spacetime) metric.

Also, the gravity electroweak / UU model does not consist of an uber-symmetry across strong and electroweak interactions, and therefore it does not lead to problematic magnetic monopoles, supersymmetry, multiple dimensions and other problems [10,24]. The absence of conventional symmetry breaking, other than the Higgs mechanisms, also allow the model to not have to introduce addition bosons à la Goldberg.

The fact that self-dual and anti-self-dual decomposition does not work in dimensions of spacetime other than 4D [4] is a key indication that electroweak and gravity will coexist as a chiral spacetime (our definition), and chiral electroweak theory with chiral fermions, only if spacetime is 4D. Therefore, assuming that the gravity electroweak theory is correct, we recover results that we had already presented, both from Multi-fold or conventional point of

[12] The multi-fold mechanisms allow a story for right-handed neutrinos as Dirac fermions that do not interact (always in flight) [10,14, 16-18].

views, that indicate that a multifold universe or the real universe is 4D [6,7], and that, outside the 2D gravity regime [5,10], there is no physicality to supersymmetry, superstrings, M-theory and derived or related GUTs and TOEs that require spacetimes with more than 4D, large or compactified. By now, we have encountered multiple independent analyses that result in this same conclusions, they can be tracked at [8,9]. The 4D results presented here are not directly tied to previous arguments that argued about the number of SM particles, the asymptotic safety of quantum gravity [33,34], de Sitter vacua being in the superstring swampland [10,48], or to other previous analyses of superstrings and supersymmetry tracked at [8,9,54].

Note added on November 14, 2022: About 4D, see also [83-85].

3.4 SM_G

The concept of gravity-electroweak and UU interaction coupled with the model of particles as microscopic black holes, and the multifold mechanism that renders gravity non-negligible at SM scales that makes SM_G, defined as SM with gravity non-negligible at its scales, fully motivated and with it, offers potential answers to multiple open problems with SM and the standard cosmology model [8,9].

Note added on November 14, 2022. See also [73-75].

4. Putting it all together

At this stage we have encountered a multi-fold microscopic explanation for:

- UU is dominated by massless Higgs bosons and no other particle or charges other than as quantum fluctuations. The principle of democracy of interactions in UU regime applies when such particles appear as fluctuations.
- Massless and massive particles as microscopic black holes and massive particle as Kerr Newman or Reissner Nordström regularized black holes defined by soliton solutions (induced from 7D). Massive ones are formed by Higgs condensation behind superconducting Qball edges. The soliton symmetry define any associated charges. At very small spatial scales, charges are not present (they only appear at the associated soliton scales).
- Spacetime structures built by random walk of massless Higgs bosons with massless Higgs bosons at concretized locations.
- Inflation slow roll with reheating and massless particles then massive creations , the latter being through the Higgs condensation into the solitons mentioned above.
- Gravity electroweak and electroweak symmetry breaking with early spacetime chirality selection, and simultaneous mass generation and electroweak chiral symmetry breaking.
- The Higgs mechanism is implemented by Higgs boson condensation.
- Mass generation per the Higgs boson condensation mechanisms described above and modeled as the Higgs mechanism.
- Right-handed neutrino and neutrino mass generation[13] as a non-interacting (in-flight) Dirac fermion isospin companion to the Higgs boson.

[13] Chirality flips induced by gravity at scales where the fermions are massless temporarily generates the right-handed neutrinos and possibly the matter-antimatter asymmetry. See details at [10,69].

- Around the same time, apparition of colored charge and strong interaction with gravity electroweak symmetry breaking and therefore absence of a separate GUT regime.
- With chiral fermions, including right-handed neutrinos, it is consistent to support SM on a discrete space time [59].

Note added on March 28, 2021: Note also that another paper discuss modeling electroweak symmetry breaking and inflation with a Higgs field non-minimally coupled to gravity. The approach is in our view complementary to [1], with a non-global model. It also opens the door to possibly considering variations of [68] where the Higgs field can also be non-minimally coupled to gravity. We therefore assume that the coupling to gravity can be minimal or non-minimal. The initial choice of minimal coupling to gravity was based on what seems the most justifiable microscopic model for the inflation usable in [18]. Now that we see that indeed the density of Higgs bosons is probably the trigger for the gravity electroweak symmetry breaking, with Higgs bosons condensing into Kerr-Newman and Reisner Nordström solitons to produce massive particles. Under these considerations non-minimally coupled models may even make more sense.

Note added on November 14, 2022: Congruent analyses, based on different methos, hint at Higgs being the UU particle responsible for random walk and Higgs condensation. They are provided in [94]. The complex nature of the Higgs scalar field (imaginary mass), provide also such a hint [10,62,88].

5. Conclusions

The result we have obtained in this paper are very compelling and may constitute the basis explaining SM (chirality of the weak interaction and microscopic interpretation of the electroweak symmetry breaking, along with QCD tagging along), SM_G, the early universe and absence of GUTs, replaced by a 2D random walk UU regime. It is quite a step derived from our multi-fold hypotheses [10] that initially just aimed at modeling entanglement, and saw the emergence of gravity and GR from entanglement. *Note added on November 14, 2022: It is also very consistent with the derivation of the SM /SM_G symmetries [80], and analysis of QCD and the Electroweak interactions above the gravity electroweak symmetry breaking energy scales [89].*

It is to be noted that many times throughout the multi-fold program so far, we have explained that the conclusions obtained for multi-fold universe can extend to other situations, especially often whenever a SM_G (i.e. gravity non-negligible at SM scales) makes sense. We believe that this paper added weight to the view that the overall model proposed so far may indeed be relevant to the real universe, even if aspects of the multi-fold mechanisms do not pan out to match our universe. *Notes added on November 14, 2022: Yet [76] strongly hints that our real universe may be multi-fold.*

With this paper, we completed, for now, a unification program across modern theoretical Physics and high energy particle Physics; at least in terms of multi-fold universes and a proven consistency of the proposal that has interesting outcome and microscopic justifications. Our quest should now move to:

- Validating if our real universe could be multi-fold as well as.
    - A tentative way forward is in term of the detection of gravity like fluctuations among entangled systems, especially macroscopic systems as encountered with quantum material [10,52]
    - or by confirming multi-fold dark matter effects [10,53].
- Exploring the consequences of the multi-fold W-type hypothesis for quantum physics [51]:
    - E.g. could the W-type hypothesis coupled with multi-fold effects, and random walks, make quantum physics less mysterious and humanly more understandable?

    - An item for future discussion: is it the particle (i.e. the microscopic black holes) that jumps, or massless Higgs bosons? We believe in the former, but it may be interesting to explore what the latter would mean.
- Evolving from a qualitative model to a quantitative model.
    - It could involve an evolution of ER=EPR conjecture (and other holographic principles) where wormholes are now traversable [54,55,56], or build on related models of emergence of gravity from entanglement [57] or Planck size segments between entangled particles [58].
    - It could evolve fully modeling the contributions of the multi-fold paths
    - It could also involve crafting a fiber bundle inspired global approach; possibly with extensions to handle the novelty of our multi-fold approach, vs. working of effective attractive potentials. This is work in progress.
- Exploring and confirming some applications or science fictions ideas that could be enabled by the multi-fold mechanism [10].

While our approach throughout the work so far has been unconventional, we hope that the results and consistency again obtained in this paper will motivate review and investigation by the Physics community to validate, or invalidate, our proposals (e.g. Multi-fold theory, SMG, gravity electroweak theory etc., as in [8,9]) or apply our approaches adapted to mainstream models like QFT. There are ample opportunities for theoretical, but also experimental, falsification or validation.

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