

## 2D Random Walks of Massless Higgs Bosons

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### Abstract:

*Renormalization, or asymptotic safety, of QFTs, and other models, are mathematical techniques to ensure not only the absence of divergences and regularity of the models, but also suitable stabilized UV and IR behaviors. In general, there are not always clear microscopic interpretations of what leads to renormalizability, or asymptotic safety.*

*In this paper, and based on the multi-fold theory, we give a physical interpretation to renormalization and asymptotic safety as the result of 2D random walks of particles, multi-fold emergence of gravity effects, and multi-fold 7D space time matter induction and scattering of solitons in condensate Qballs, or in random walk patterns: at spatial scales below the multi-fold gravity electroweak symmetry breaking scales, i.e. at high energies, massless Higgs bosons are (roughly) free massless bosons propagating as CFTs, or dilatons, just as in JT or Liouville gravity, the latter being a CFT version of Einstein gravity in 2D, which is renormalizable.*

*Particles are not point particles. Within and outside the solitons or patterns, charges/colors, resulting from the symmetries of the solitons, fade away, so that fields and matter couplings are tamed and constant: everything becomes CFTs. Therefore, gravity remains asymptotically safe in the presence of the Standard Model (SM). And it is really gravity based on General relativity (GR), and the SM, i.e., Yang Mills and Maxwell theories, which are asymptotically safe, something confirmed by all their 2D versions (JT/Liouville 2D dilaton gravity, 2D QED and 2D QCD). It microscopically motivates these interactions, including 2D gravity, and why the Ultimate Unification (UU) reigns, as only “unification”, and how the SM is an effective theory. Overall, only 2D physics matters! It also show that our universe must be closed.*

*The paper argues that the embedding 7D is built by massless Higgs, which provides microscopic interpretations and motivation for multiple properties of multi-fold, as well as why GR reigns in the 7D spacetime, and spacetime induction works. In fact, we confirm this by explaining how non-commutative spacetime can recover the SM and neutrino mixing via algebra doubling.*

*With random walks, we can explain inflation, expansion of spacetime, a complex/imaginary Higgs field pre electroweak symmetry breaking, and we can guarantee unitarity of Physics, even if it may sometimes statistically appear rather non-unitary, but Hermitian or isometric, or with non-Hermitian pseudo Hamiltonians, especially in an universe with a strictly positive cosmological constant.*

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## 1. Introduction

In a multi-fold universe [1,8-10,22,186,192,193], gravity emerges from entanglement through the multi-fold mechanisms [1,191]. As a result, gravity-like effects appear in between entangled particles [1,24,25,192,193], whether they be real or virtual. Long range, massless gravity results from entanglement of massless virtual

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particles [1,26]. Entanglement of massive virtual particles leads to massive gravity contributions at very small scales [1,27]. It is at the base of the E/G Conjecture [24], and the main characteristics of the multi-fold theory [22]. Multi-folds mechanisms result in a spacetime that is discrete, with a random walk fractal structure and non-commutative geometry [1,10,23,62,77,168,199] that is Lorentz invariant [1,199], and where spacetime nodes and particles can be modeled with microscopic black holes [1,4]. 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 (SM) resulting into what we define as  $SM_G$ : the SM with gravity effects non-negligible at its scales. This can contribute to resolving several open issues with the Standard Model, and the Standard Cosmological Model, without new Physics other than gravity [1,4-64,71,72,76,77,87,98,100,102-107,113,118-149,168-205,210]. These considerations hint at an even stronger relationship between gravity and the Standard Model, as finally shown in [23,77].

*Note added on December 30, 2023: In this paper, references in italic were added on December 30, 2023.*

Among the multi-fold  $SM_G$  discoveries, the apparition of an-always in-flight, and hence non-interacting, right-handed neutrinos, coupled to the Higgs boson is quite notable. It is supposedly always around, due to chirality flips by gravity of the massless Weyl fermions, induced by 7D space time matter induction and scattering models, and hidden behind the Higgs boson or field at the entry points and exit points of the multi-folds. Massless Higgs bosons modeled as minimal microscopic black holes mark concretized spacetime locations. They can condensate into Dirac Kerr-Newman soliton Qballs to produce massive and charged particles below the energy scales of the multi-fold electroweak symmetry breaking [1,4], and as random walk patterns above these scales [1,29,36,37] thereby providing a microscopic explanation for a the multi-fold kinematics and dynamics and associated unconstrained Kaluza Klein mechanisms [23,33,34,52,63,64,191], Higgs driven inflation [1,27], the electroweak symmetry breaking, the Higgs mechanism, the mass acquisition [154,195] and the chirality of fermions (and spacetime); all resulting from the multi-fold gravity electroweak symmetry breaking. The multi-fold theory has concrete implications on New Physics like supersymmetry, superstrings, M-theory and Loop Quantum Gravity (LQG) [1,8-21,72,128,189,199].

Multi-folds are encountered in GR at Planck scales [5,6] and in Quantum Mechanics<sup>2</sup> (QM) if different suitable quantum reference frames (QRFs) are to be equivalent relatively to entangled, coherent or correlated systems [7]. This shows that GR and QM are different facets of something that they cannot well model: multi-folds [1,52,128,140].

The paper starts by discussing multi-fold spacetime reconstruction by random walks of massless Higgs bosons [1,16,27,32,33,34,62], and how it relates to the recovery of GR, including at small scales, expansion of the universe, inflation, and asymptotic safety of gravity, including with matter. It allows us to discuss our past derivations of the good behavior of gravity in UV regimes in a multi-fold universe, with or without matter [13,16,17,64]. The derivation relies on the fact that gravity and spacetime is essentially 2D in the UV regime of random walk, something corroborated by most models of quantum gravity [73-75], and in particular by the conformant properties of 2D GR, i.e. Liouville gravity that is conformant [66-70,89-91], also suitably modeled by JT gravity (See [62] and references therein), all dilaton gravity [64], with the massless Higgs boson being the dilaton in question. The fact that 2D CFTs model free massless boson propagation confirms the consistency of the model: the massless boson propagating at these scales is the massless Higgs random walk [73], remembering that paths from path integrals are random walk (See [1] and references therein on the subject). Random walks are also ideal to model (relativistic) QFT [1,62,150-153,179,191,201], including anti-particles. *Note added on December 30, 2023: They also a good way to understand why supersymmetry is unphysical.*

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<sup>2</sup> Standing in for Quantum Physics in general.

Then, we review space time matter induction and scattering of the Standard Model [23,33,34,63,171,201] and multi-fold gravity electroweak symmetry breaking [29,35,36,37], especially above the symmetry breaking and in the Ultimate Unification (UU) regime [1,28,29,64,191].

Armed with this refresher and knowledge, we can discuss the impact of the SM, or rather  $SM_G$ , the SM with non-negligible gravity effects at its scales, on the asymptotic safety of gravity. Conversely, we are ready to also discuss the behavior of Maxwell (abelian) and Yang Mills (non-abelian), i.e., the SM in the UV regime, with physical and microscopic interpretations, as well as provide additional physical / microscopic interpretations for the challenges with supersymmetry and space of dimensions larger than 4D. While based on results of the asymptotically safe gravity program [65], we have not encountered such microscopic interpretation in the literature.

2D Yang Mills, and Maxwell results are consistent with our proposed model; another interesting consistency of the approach, and indication of the SM, or  $SM_G$ , asymptotic behavior. The explanation quite naturally recovers or hints at the UU regime.

We then revisit aspects of the massless Higgs boson random walks, and see how the massless Higgs random walks allow us to also address the QFT conundrum of unitarity vs. expanding universe: Physics is unitary even if QFT models in a expanding universe is just a statistical field models of massless Higgs bosons, that may suggest non-unitary behaviors, but rather pseudo-Hermitian then Hermitian [97-99], just as non-Markovian random walks may suggest Hermitian / non-unitary behaviors Hermitian pseudo-Hamiltonian, evolving to Hermitian in a curved spacetime [98,149,155]) [62,167], which can relate to, and motivate the complex Higgs field before Multi-fold electroweak symmetry breaking [1,71,72]. Hermiticity can also be related to nonreciprocal random walk and spacetime curvature, which amounts to nonreciprocal progresses/tunneling on a lattice [98,149,155]. Therefore gravity and curvature may be modeled as Hermitian Physics. But in all those case the underlying microscopic interpretation remains Unitary with conservation of information (and energy [180]). This may lead to a microscopic new interpretation of  $2D+\epsilon$  gravity: entanglement bias direction of motion between forward, backward (and orthogonal in the bigger 3D or 4D pictures). It amounts to curvature, or GR effects, and it works despite the non-existence of conventional gravitons. 2D multi-fold gravity propagates multi-folds but as we will see it maintains a constant curvature effect (effective potentials of folds independent of  $r$ ) [196,211].

Continuing the discussion of spacetime concretized by Higgs random walks, and fractional variations, we conclude that the multi-fold theory implies Higgs, and right-handed neutrinos, in the multi-folds, consistent with [1,32,37,42,47]. This expands on [23,33,34,72,76,77], to explain the multi-fold mechanisms and principles [1,180]. It leads us to conclude that indeed the 7D embedding spacetime, seen inside-out for space time matter induction and scattering, is indeed governed by GR [33,34,63], while the AdS(5), tangent dual to spacetime may or may not be governed by it [1,14,63]. The 7D embedding space is GR flat, can just be classical, at large scales, and without Physics in it other than gravity and its geometries. SM then results from the induction/scattering unconstrained Kaluza-Klein (KK) [23,33,34,63], stable in multi-fold universes [174,191].

In [1,62,72,77], we see that, at small scales, we have a 7D non-commutative spacetime, also a result of Higgs random walks in the multi-folds. This can be seen as  $4D + 4D$  (space time + embedding extra dimensions with the time shared, otherwise 8D) (x2 to handle chirality). [72,78-81] show that with algebra doubling, non-commutative spacetime, with a pure gravity Lagrangian, derives the SM Lagrangian (with gravity), and particles, including the neutrinos (and their mixing), which do not have to be Majorana as assumed in these original papers, which was probably an unfortunate consequence of the focus at the time on Majorana neutrinos as the way forward: in multi-folds we rather only have Weyl and Dirac neutrinos<sup>3</sup>. We now have the physical interpretation for the

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<sup>3</sup> Note that the derived model does not include exotic gauge bosons, i.e., bosons beyond the SM, thereby also not suffering of proton decay as most of the GUTs, TOEs and supersymmetry. We encountered that the addition of gravity smears out the anomalies that otherwise might have allowed proton decays [1,40]. Therefore, it had to

algebra doubling used in the derivations: it is the 7D embedding space (or 8D if time sharing is too restrictive), as well as the resulting ability to handle left and right handed chirality as two spacetime copies, as in [23]. It directly matches the ability to also recover SM from 7D embedding space, with chirality tricks [23,33,34,47,63,171]. It's a different take on unconstrained KK, built on a non-commutative spacetime. We already know that these approaches are consistent with the multi-fold gravity electroweak symmetry breaking [35], the behavior above such energies, where random walk patterns define particles by space time matter induction and scattering [29,36,37], a Higgs/ right-handed neutrino isospin doublet [33-35,77,61], and the Higgs field as the fundamental construct [32,77]. The right-handed neutrino then stabilize the KK theory [174,191]. We are not aware of another microscopic interpretation for the algebra doubling trick to recover the SM, including neutrinos<sup>4</sup>. It is another key consistent confirmation of [23,33,34,47,63], between approaches that otherwise might appear to be quite different. *Note added on December 30, 2023: Interestingly, random walks and non-commutativity are key to understanding why supersymmetry is not physical: it is not and has never been a symmetry of our universe.*

Finally, we discuss a few more questions, starting with: is the analysis indeed implying that GR is asymptotically safe, and contains all these aspects, or are we just modeling (another) gravity, departing at some point from GR. We argue that GR is indeed the theory that reaches the UV regime, based on the top-down-up-and-upper [6] spacetime reconstruction [1].

At the end of all this, we examine if the discussions about the effects of matter on the gravity and the SM asymptotic safety, may open alternatives for other theories, e.g., could GUTs and supersymmetric theories with more particles, or higher dimensional theories like superstrings be saved by matter effects. Sadly for many, our past conclusions on the non-viability of these theories [13,16,17] do not seem to change. *Note added on December 30, 2023: See also [199] for a proof that there is no physical supersymmetry in our universe, or in a multi-fold universe, at any scales, including as small as 2D. This implies that none of candidate SM extensions to consider can be based on supersymmetry.*

*We like to conclude by repeating a sound bite that seems to apply very well: all what matters is 2D Physics [185], the rest are higher level approximations, and sometimes illusions.*

## 2. Multi-fold spacetime reconstruction

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imply that there are no exotic gauge boson in the non-commutative spectral SM. It is another internal consistency of our approach.

<sup>4</sup> The only existing explanations that we have found in the literature are as in [81], as a space resulting from two copies of 4D-branes (why?). [80] explains the need to do so, only to match the SM symmetries (gauge symmetry requirements); something that we do not see as a microscopic justification. [81] also argues that the two branes model a 4D spacetime open system, and 4D + 4D as a closed systems. The former can dissipate while the latter can be closed and conserve energy. While we appreciate the references to 't Hooft's work on dissipations [84-86] (we are sympathetic to some of these views as discussed in [62,72]), we question how this would be relevant to motivate the algebra doubling. *Note added on December 30, 2023: Based on the discussion in [203], we know that [213,214] propose an open quantum system between spacetime/gravity and quantum physics/SM, under that model, the 4D + 4D branes can be justified, but we do not like the decoupling between the two systems that it implies.* Also, D-branes are not physical as discussed throughout our paper and [8]. We just can't base such a key motivation on something that we argue to be unphysical. In our view, the multi-fold fact that the embedding space is 7D (or 8D if not sharing time) as seen inside-out from the 4D spacetime is much more compelling and aligned with [23,33,34,63,77,168,171].

In [1], among other things, we show that spacetime can be seen as a graph of discrete nodes that have been concretized by the random walks of particles. The nodes can be modeled as microscopic black holes. With randomness, spacetime can be Lorentz invariant even if discrete, and fractal [1,6,62,77]. Reconstruction [1,6] leads us to recover GR from the multi-fold theory, and from its spacetime reconstruction. [6] then confirms the suitability of the reasoning with:

- I) encountering (hints of) multi-folds at Planck scales from GR,
- ii) justifying this way the proposed multi-fold spacetime reconstruction,
- iii) and recovering GR in a top-down-up-and-upper approach.

As a result, we interpret the discrete nodes of Planck scale GR, or multi-fold spacetime reconstruction, as particles and concretized spacetime locations modeled as microscopic black holes [1,4].

Contrary to the expectation of many, discreteness of spacetime is consistent with the SM [1,29,36]. It ensures the proper UV regime [1,16,23], and respect of the Trans Planckian Conjecture (TCC) [83].

### 3. Massless particles random walks

Expansion of spacetime from the earliest time of the big bang, whatever its technical definition is, results from the random walks, and creation (and annihilation) of particles, of the particles, massless early, on, or at, high enough energies / small enough spatial scales [1,27]. Massless particles can occupy all the concretized spacetime locations.

[1,62] provide more insights on the actual statistical processes involved that lead to fractional Physics and a (multi) fractal spacetime in certain spatial scale ranges, something confirmed by observations of the today's universe.

### 4. Higgs as (main) massless particles involved in random walks

[1,27,32,77] show that multi-fold spacetime expansion results from the random walk of massless particles, as does inflation (when each step is associated also to maximal creation of new particles), leading to an exponential growth [1,53,62,181,191]. It ensures also asymptotic safety of gravity [16].

Multi-fold space time matter induction and scattering is an unconstrained Kaluza Klein type of model without compactification of the extra dimensions [29,36,37]. However, the multi-fold kinematics and dynamics behaves like compactification / changes of scales of the extra dimensions of the  $\epsilon$  neighborhood felt/generated by the multi-fold mechanism [1,196]. The massless Higgs boson is the associated dilaton, the theory remains stable thanks to the presence of (entangled) massive fermions, like right-handed neutrinos and anti-particles [23,174,196].

In [61,64,72,185], we further discuss that gravity is essentially built on 2D random walks, and therefore dilaton based as in JT, or Liouville gravity (See [64,72] and reference there in), which is asymptotic safe, and without graviton. As scales increase, spacetime and gravity evolve to 3D, then 4D quantum gravity [203] and finally 4D GR.

Following Occam's razor principle, we propose that the (main/only) relevant massless particle involved is the massless Higgs boson. Inflation then is explained in QFT via a minimum or non-minimum coupling to gravity. One and only one major scalar field is involved. Of course, other massless, or even massive particles, of the SM (or  $SM_6$ , it's the same for that matter) may appear as fluctuations.

There may not be any real issue if more / different scalars were involved, or playing different roles. But as it is not needed, it makes little sense to suggest so, until we have reasons for doing so. So far, we can explain everything with just one scalar, and we do not have to deal with the problems of evolutions, interactions and multiple condensations of multiple scalars. It is also the reason behind our conjecture that there is no new fundamental particle above the multi-fold gravity electroweak symmetry breaking [23,30,64], other than, of course, the massless Higgs boson itself, vs. the massive Higgs boson.

Based on [23,171], we do not expect additional bosons, or fermions, to play such a role. No extra boson, non-scalar, as we lack extra interactions, considering the symmetries discussed in [23]. About fermions, no additional ones are predicted by the algebra doubling on non-commutative spacetime nor [23], and for sure they would bring in additional challenges with the need to incorporate the Pauli exclusion principle.

## 5. Ultimate Unification

[1,28-30,64] also discuss the behavior at energies (at, below, and) above the multi-fold gravity electroweak symmetry breaking, or said differently at very small spatial scales, where the ultimate unification (UU) reigns. Accordingly, all interactions become equivalent and with same intensity.

Again, in [1] we left this as possibly involving many massless particles. It turns out that, with the subsequent selection of the just the massless Higgs boson as the main relevant particle, we just have massless Higgs bosons involved. In the upcoming sections, we will deduce why this makes the most sense anyway. Consider also section 4.

## 6. 2D Processes and asymptotic safety of gravity

With the random walks and UU, processes are dominantly 2D [1,16,87], with just gravity/entanglement/QM (multi-folds), collisions (Elastic and with creations of new particles) and creations and annihilation of new particles. Gravity is well modeled by JT gravity, which becomes conformant and aligned with Liouville gravity, as discussed in [64,72], and references therein.

In [1,16,87], we show that as the spatial scale reduces, processes going to 2D is a way to justify, and prove asymptotic safety of GR (that leads to, and come from the random walks, and so contains it in its action), and is a universal property of all the well-behaved models of quantum gravity. With Liouville gravity, Einstein's GR CFT at 2D, and with 2D Hilbert Einstein gravity, we have asymptotic safety [88]. This reasoning, invoking Liouville as the limit for  $\epsilon \rightarrow 0$  of  $2D+\epsilon$  GR (See [64] and references therein), can be seen as an additional proof and separate proof of asymptotic safety of (GR-based) gravity, including a priori all its implications (incompatibilities, invalidations and unphysicality) for supersymmetry, superstrings, supergravity, M-theory and many related popular GUTs and TOEs [1,8-18,20,119,189].

Note that the 2D multi-fold mechanisms follows 2D multi-folds as in [191], in full agreement with constant fold effective potential (pre-integration in  $r$ ) for 2D GR gravity, (vs.  $1/r$  in 3D, and  $1/r^2$  in 4D, per fold pre-integration on all the folds in a multi-fold – See [1,192,193,204]).

In [16], we even suggested that in such a  $\sim 2D$  regime, the cosmological constant could become temporarily negative, which could allow us to encounter superstrings, as also able to model our universe in such a regime, but

from the outside-in view: with superstring living in the dual tangent AdS(5)+... space; they would remain unphysical anyway. *Note added in December 30, 2023: Furthermore, see [199] for a proof that supersymmetry is unphysical, in the real universe, and in a multi-fold universe, all the time and at any scale. In other words, there never were (after big bang) and is (at very small scales) a negative cosmological constant period.* Our earlier comment about the universe having to be closed is also a good indication.

2D Liouville gravity is conformant [66-70, 89-91], and so 2D Einstein gravity is asymptotically safe [88], period. In Liouville gravity, the Liouville mode  $\phi$ , or dilaton [68], is again reminiscent of the massless Higgs field in a conformant potential, just as we also encountered with (the multi-fold interpretation of) group field theory [77]. We also encountered the dilaton with the double copy discussions [52,128,140].

It is of interest to see if similar relationships exist for the rest of the Standard Model, i.e., Maxwell, Yang Mills and the Higgs mechanisms, considering how the weak interaction is easily disposed [29]? Also, what about 2D gravity and processes in the presence of matter/SM at 2D?

## 7. Conformance and CFTs

2D GR gravity is asymptotically safe for 2D, and in an  $\epsilon$  dimensional neighborhood [88], and (2D) quantum gravity, a universal property at small spatial scales of all gravity models [87], can be modeled by Liouville quantum gravity, which is a CFT (2D Conformant (quantum) field), i.e., asymptotically safe. Interestingly, CFTs can model the propagation of a free massless boson [73], which directly recovers our model of massless random walks of massless Higgs bosons.

Conformance symmetry is a property of superstrings, and CFTs can also model a free bosonic string. But again, that is an outside-in view from AdS(5) +..., which we know to be factually tangent to the multi-fold spacetime [1,14,15,18,20,63].

*Note added on December 30, 2023: It remains an outside-in view, and not a characteristics of our spacetime. In a multi-fold, or the real universe, per [189], spacetime does not become AdS at very small 2D scales contrary to the plausible option left open in [16].*

## 8. SM<sub>G</sub> as 7D Multi-fold Space Time Matter Induction and Scattering

[23,33,34,63] show how the SM particles can be seen as induced solitons, solutions in 7D of GR (7D), along with scatterings at the edge of the entry and exit (and mapping in some cases) points to the multi-folds for Higgs and right-handed neutrinos behind it. When the particle are massive, they are Higgs condensate Qballs that appear as microscopic black holes, often over extremal, which is stable because of the superconducting skin of the Qballs [4]. When particles are massless, above the energy scales of the energy scales of the multi-fold gravity electroweak symmetry breaking energy scales, they are rather patterns of random walk following the symmetries of the solitons [35-37].

Chirality is handled with spacetime orientation and chirality flips induced by gravity [23,33,34,37,63]: global or local rotations from the spinning solitons create local orientation, and then a global orientation for energy scales below the multi-fold electroweak symmetry breaking. It is part of the process of breaking the multi-fold gravity electroweak symmetry.

Solitons can be patterns both for massless and massive particles: they also define the symmetries and therefore the charges (and quantum numbers) involved à la KK. *Note added on December 30, 2023: See also [201] about internal symmetries.*

## 9. Multi-fold Gravity Electroweak Symmetry Breaking

[35] adapts multiple works to the multi-fold theory, including symmetry breaking of  $SL(2, \mathbb{C})$  into a gravity contribution  $SU_L(2)$  (that we relate to spacetime orientation) vs.  $SU_R(2)$  the chiral weak interaction post electroweak symmetry breaking [35]. Adding considerations from the non-commutative spacetime geometries, we can recover all the symmetries of GR and the SM, i.e., of the  $SM_G$  [23,77,171], including possibly internal symmetries [201]. With the multi-fold space time matter induction and scattering, we have a quasi-theory of everything, with no need any more for multiverses [190], or other anthropic principle [156], or problems of fine tuning and (mass) hierarchy [171,173,176,190].

### 9.1 Particles as Microscopic Black Holes

[1,4,37] discuss how at, and below, the spatial scale of the multi-fold electroweak symmetry breaking, the massless Higgs bosons condensate into Qballs whose skin is like superconducting, and matching the space time matter GR(7) solitons and quantum numbers/charges. The Qball skin is like superconducting preventing evaporation and other (over) extremality issues.

Internal symmetries can also be handled this way, relying on properties of the inside of black holes, as well as anti-particle distinctions from particles [201].

### 9.2 Above the symmetry breaking

[29] discusses behaviors above the mass gap, and evolution to UU [1,28-30,64]. There, no massive particle exists, other than as fluctuations (they may exist as such, but only temporarily, and subject to the uncertainty principle), and spacetime orientation is local and fluctuating. *Note added on December 30, 2023: Per [11,21,64,199], the spacetime fluctuations are rapidly suppressed, instead of creating baby universe as proposed by others.*

Massless particles, sharing symmetries with their massive counterpart when expected, are now the result of random walk patterns that reproduced the induced symmetries of the associated 7D solitons, including internal symmetries.

#### 9.2.1 Higgs and only Higgs massless bosons – The microscopic interpretation of UU

Along with the discreteness of spacetime, the fact that, in a multi-fold theory, particles are not point particles is key to suitable behaviors at very small spatial scales.

Another important lesson of the proposed multi-fold model is that, at energies above the multi-fold gravity electroweak symmetry breaking, induced and scattered SM particles are massless and can be seen as random walk patterns, e.g., currents, of massless Higgs following respective soliton symmetries induced from 7D, and with the symmetries carrying relevant charges/colors. The massless Higgs boson remains as the only fundamental massless particle, whose behavior, induced by space time matter induction and scattering renders the other particles.

At spatial scales large enough ( $\sim$  the multi-fold gravity electroweak scale), one can track interactions between the particles, e.g., via exchanges of patterns of gauge bosons, and entanglement across particles, also responsible for gravity, via multi-fold mechanisms and the E/G conjecture [1,24-26].

At smaller spatial scales, one can see inside or in between/outside the patterns. Only massless Higgs bosons are relevant. Charges and other particle quantum numbers, as symmetries of the Qballs, or of the random walk patterns, are no longer apparent, or relevant at these scales, only gravity, random walks and collisions (elastic or with creation/annihilation of particles). It is the UU regime [1,28-30,64]. These aspects are illustrated in Figure 1.

This is really to be understood as the key physical, and microscopic interpretation of UU, and UV/asymptotic safe behavior of all Physics. With all of the above it should now be clear why only gravity remains relevant, and how the other interactions, and associated particles, reduce to solely similar interactions at such scales. The approach answers another question: how does Physics, at different scales, coexist in Today's (/macroscopic) physics without contradiction, while being able to influence the same process? In other words, how can we have UV and IR and interim Physics considerations coexist, and play a role, while we observe only Physics between IR and an interim scale. It is because all particle Physics involves the interactions between random walks of massless Higgs bosons, sometimes walking in soliton patterns, when massless, or condensing into a Higgs condensate when massive. Small scale effects impact larger scale ones as needed. One can understand why larger spatial scale effects can appear as particles or QFTs, yet, after all, 2D physics is all what matters [185].

Gravity interactions can be modeled as Liouville or JT gravity, when scales are so small that all the processes are dominantly 2D [1,16,87,136]. At such spatial scales we don't even have gravitons (as unphysical quasi particles), as perturbations of spacetime could only be longitudinal, which does not work with massless carriers. Yet, Liouville or JT gravity still work, as the limit of GR for  $2D + \epsilon$ , with  $\epsilon \rightarrow 0$  [64].

The random walks, as well as W-type multi-fold hypothesis effects, are possible candidates to support local hidden variable models compatible with the violations of the Bell inequalities [64], possibly leading to a more deterministic model at the smaller scales. That is because less interactions, mostly gravitational like, and mostly collisions and creation/annihilation are involved at the lowest scales. Everything remains quantum though, because of the particle creation / annihilation, the reliance on the uncertainty principle at the beginning of multi-fold spacetime reconstruction [1], and the non-commutativity of spacetime leading to it and at the core of quantization [1,77,157-159,212].

*Note added in December 30, 2023: See [203] for a proof that gravity is quantum, not classical or just stochastic.*

*In later papers, we also show that QFT, in up to 4D spacetime, is equivalently modeled by random walks described as quantum cellular automata [179,206-208]. It is also one of the way to understand why Physics is not, and never was, supersymmetric [203].*

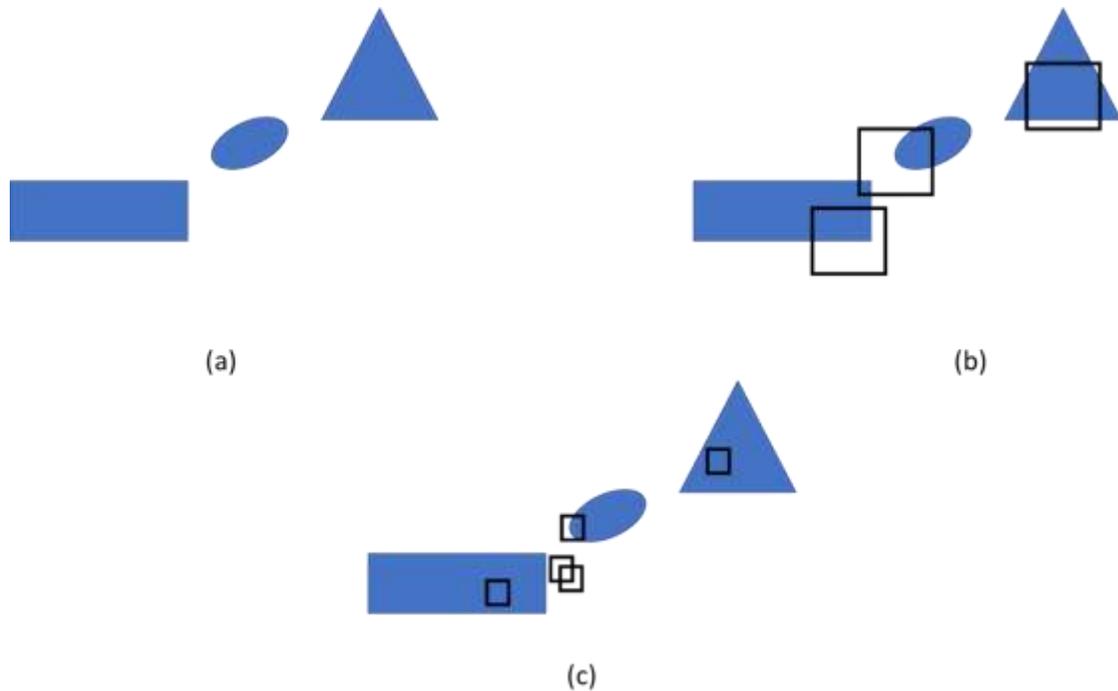


Figure 1: Massless Higgs bosons fill the discrete spacetime everywhere with random walks, ultimately as 2D processes. In the blue region they follow patterns defining the geometry of the blue region. At lower energies they will condensate according to these shapes, to preserve the symmetry even if size may change. (a) illustrates different solitons with symmetries/quantum numbers. At roughly the spatial scales of the multi-fold gravity electroweak scales, interactions and charges are present and tracked. (b) illustrates observations at spatial scales significantly smaller than the multi-fold gravity electroweak scales, where interactions may be weakening but are still partially tracked. (c) illustrates way smaller scales where one do not see any more the charges or particles types and exchanges seen and conserved at larger scales. Interactions are now only between the massless bosons that occupy the whole space, randomly in the while areas and randomly, even if following patterns at larger scales. This explains the UU behavior dominated only by random walks with gravity, collisions, particle creations and annihilations, and entanglement, exactly as proposed in [1,28]. Note that, without us explicitly providing this figure, these principles were already encountered in papers like [26,29,37]. This analysis can't be produced with point particle models.

It is also important to re-emphasize that Figure 1 illustrates a fundamental difference between the multi-fold theory and conventional physics like QFT, or with superstrings. QFT is stuck to only being able to consider 1(a) cases across all scales. Superstrings (and branes) can kind of only cover use cases 1(a) and 1(b), e.g., for branes. Neither can fully model Planck scales / 1(c), probably a shock for supporter of superstrings. *Note added on December 30, 2022: Other, but related, considerations then lead us to assert that stability of QFT/SM with gravity may require that our universe be multi-fold [181], while [1,8-18,20,119,199] show how superstrings are not physical, and the universe is not and can't be supersymmetric.*

### 9.2.2 Electroweak and QCD above multifold gravity electroweak symmetry breaking

[1,28-30,37,64] discuss the behavior of the Electroweak interaction and QCD interactions, at energies above the multifold gravity electroweak symmetry breaking energy scales, on the way to UU, which takes over at smaller

scales as described in section 9.2.1. [29] details how the electroweak interaction ends up only as QED at very small spatial scales.

There, we have seen that scalars, especially involved in Higgs mechanisms, work against asymptotic freedom at small scales [144]. So, again, increasing the number of scalar species would go against the model encountered here, hence our comments earlier that we probably have only the massless Higgs remaining at the highest energies. Adding scalar species could threaten the good behavior of gravity and the SM in the UV regime. It is not something that we could then just brush away as a problem of an effective theory. Our analysis so far shows that both GR and SM, or  $SM_G$ , are directly built on the underlying 2D random walks. Their UV behaviors have to correctly meet and connect with 2D random walks, and cannot just misbehave above a certain cut off scale, without us having random walk models to explain these behaviors and taming such inconsistencies.

*Section added on March 29, 2023:*

### *9.2.3 The SM is an effective theory at small enough scales*

*The analysis in the paper so far, and figure 1, allow us to provide a microscopic interpretation and description of how the SM is to be understood as an effective theory down to small scales that can still be significantly above Planck scales.*

*Indeed, we encounter discrete (4D  $\rightarrow$  2D) random walks of massless Higgs bosons, on a discrete (multi fractal [1,62], non-commutative [77,168,99], yet Lorentz symmetric [1,23,29]), as spatial scales decrease. It renders the SM, and other  $U(1) \times SU(2) \times SU(3) \times SL(2, \mathbb{C})$  symmetries, no more relevant to the Physics at such spatial scales, as is shown in figure 1 (1(c)). And so, 4D gravity, 4D Yang Mills and 4D electromagnetism/Electroweak are replaced by UU and 2D random walks and 2D discrete gravity (modeled as JT or Liouville gravity for a while but to be understood and eventually modeled essentially as multi-fold entanglement effects, and as in [98,149,155]) and 2D Physics. 2D Physics and random walks is all what matters [185].*

## 10. 2D Gauge Theories?

We would like to also check the consistency of our approach when it comes to Yang Mills and Maxwell theory (the weak part of the electroweak interaction was addressed in [29]), in 2D spacetime. The discrete aspect was addressed in [29,36,37]. If our proposed model is right, we would expect that these two types of interactions disappear as pure fields, i.e., in the absence of charged/colored fermions, with the reasoning of figure 1. When fermions are present in the theory, which requires to be at large enough scales, hints of charge / color sometimes appear, leading to possible non-zero fields.

In the literature, e.g., [95] and references therein, we can see that with QFT (hence on continuous spacetime and with point particles):

- In 2D, and without fermions, there are no pure Maxwell fields
- In 2D, with fermions, Maxwell interactions exist but anomalously.
- In 2D, and without fermions, there are no pure Yang Mills fields
- In 2D, YM interactions exist without anomalies, but they are hard to model.

At very small scale (case of figure 1(c)), in 2D, fermions are not relevant, and not seen as existing at such scales: there are no Maxwell interactions till we raise in spatial scales. The same applies for Yang mills. It is exactly what we predicted in terms of our approach, with figure 1. It is why Yang Mills and Maxwell fields are also asymptotically safe / renormalizable / well behaved in UV regime and can be modeled as CFTs (and that means also the electroweak interaction per [29]). All this is contained in the 4D QFT model of the SM, as we earlier explained that it had to be.

These results are consistent with the analysis we provided above: at small spatial scales, when spacetime appears 2D, there is only gravity / entanglement, collisions and particle creation/annihilation. When the scale is smaller than the scale of the particles, an impossibility in QFT with its point particles, yet QFT could be associated to scales smaller than a fraction of the Compton wavelength [160], we see that figure 1 implies no fermion and disappearing fields.

In [29], we noted that QED at 2D can confine. That is different, the confinement scales extend beyond the size of the fermions, as in figure 1(b) or 1(c), and so confinement is indeed possible, without conflict with our analysis.

## 11. SM + gravity asymptotic safety

[13,65], and references therein, especially [93,94], argue incompatibility between more matter than the SM, and other factors like a too large number of spacetime dimensions and the feasibility of asymptotic safety of gravity. A key aspect is that the presence of the SM changes fixed point position or viability.

In this section, we will revisit these results, provide physical interpretation for the behaviors, something that we believe to be a first versus just reporting results of computations or numerical simulations. Our goal is to ensure that our reasoning, including the asymptotic safety proofs, based on 2D random walks [16] and the double copy duality [17], can support the presence of SM / SM<sub>6</sub>.

For discussion, we refer to the behavior analyses reported in [65] as our guideline, and what we recover.

The presented analyses are high level and similar to what we did for QCD, Maxwell and Yang Mills interactions in [29]. We believe they are convincing enough though.

### 11.1 Effects of adding particle species on asymptotic safety

Adding scalars species, which are bosons, and therefore can each overlap, i.e., pile up upon each other ad infinitum, without any repulsion, unless they were charged, which does not matter when considering cases à la figure 1(c). The impact is therefore a potential dramatic increase of the gravity effects at each concretized spacetime location, only limited by the allowed fluctuations, uncertainties and black holes / foam suppression [64,199]. This increases the gravity effects around any source, and goes against the asymptotic safety behavior. In our model only one scalar type exists, and its effect is compatible with gravity still remaining asymptotically safe with a scalar species only, or with SM, as argued in [65,93,94]. Adding more scalar species can have a destabilizing effect, hence the value of the approach relying only on massless Higgs boson (one species only) whenever a scalar field is involved in the SM, or the Standard cosmological model. It motivates our view than in the multi-fold theory, all the scalar effects are due just to the massless Higgs boson. After renormalization, we will model this as one scalar species attraction via gravity/entanglement (repulsion being through propagation, creation/annihilation and multi-fold dark energy effects [1,27]).

Adding fermions species also means effects going against the asymptotic safety, due to Pauli's exclusion principle. Around any source, or studied concretized location, we have an onion structure of massless fermions and anti-fermions (think of the QED vacuum polarization with pairs of virtual electrons and positrons), themselves patterns of massless bosons. The (virtual) fermions are locked in place in their "orbits". Again, they increase the gravity effects, because of inside contributions of the scalars locked in place. With two  $\frac{1}{2}$  spin options (per Pauli's principle), the effects could be twice the one of a scalar species, per fermion species after renormalization.

Adding gauge bosons, there is no exclusion principle anymore. Per section 10, no Maxwell / Yang Mills field exist except when "feeling" the fermions. At very small scales, it amounts to dilution of energy, anywhere, and hence smoothing out the gravity effects, this time going along asymptotic safety. Where fermions are "felt", bosons surround the charged / colored ones, again smoothing the fermion effects.

Despite the qualitative handwaving, the direction and even the ratios  $\sim(1,2,4)$  match [65,93,94], where computations are done rigorously for the gravity asymptotic program.

## 11.2 Effects of adding particle species on gravity vs cosmological constant

Consistent with the observations reported in [65], increases of the number of scalars would provide more opportunities for stronger gravity. The dark energy effects decrease when more scalars are added.

Fermions and bosons, with imposed patterns on the scalars, create group fluctuations and hence dark energy effects per [1,27]. These effects increase when the number of bosons or fermions species increase.

Overall, all this is constrained by the small (strictly) positive cosmological constant and suppressed foam/baby universe effects [64,199].

## 11.3 Impact of gravity and SM on Higgs interactions

Adding scalars and fermions increase the gravity effects. Gravity facilitates Higgs interactions, by pulling fermions and Higgs together. Therefore, the addition of SM particles does not screen or prevent the Yukawa potentials of the SM.

## 11.4. Asymptotically safe SM / SM<sub>G</sub>

The previous subsections confirm, as claimed in [65,93,94], that the SM does not damage the asymptotic safety of gravity, or of the SM, considering the 2D regime. We recover our result of [17]: GR-based gravity and SM, i.e., SM<sub>G</sub> are asymptotically safe.

Coming back to the number of scalars involved, we see why our Occam's razor principle is in fact important. If other scalars are involved, despite not being needed, the SM<sub>G</sub> risks becoming unstable and hence asymptotically unsafe in UV regime.

In the upcoming sections, we will still investigate a few related questions.

## 12. Matter and 2D gravity/SM at 2D

In the 2D regime (technically at all regimes [185], but at lower energy other models, like QFT or GR may be easier and more powerful), only UU with the Higgs massless boson matters, as shown in figure 1(c). The SM random walk patterns are typically and statistically not visible at these scales. Only random walks matters along with collisions, creation and annihilation of scalars, and gravity effects due to entanglement. The rest can still happen but essentially as fluctuations.

So the fundamental question, based on the previous sections, is: does the scalar (massless Higgs boson) presence impact the UV fixed points at such scales? We have seen in sections 9 and 10 that a scalar field goes against asymptotic safety (and freedom). However as the true physical theory are the random walks, not the QFTs/CFTs built on it, the latter are just approximations, we expect that, around spatial scales of the size of the discrete random lattice, it will make no differences at all: any divergence is contained and overall behavior is then scale independent.

## 13. More on random walks and Unitarity of Physics

In [1,4,35,62], we argue that Higgs as a complex/imaginary scalar field can reflect an underlying (time) fractional model, which are associated to complex potential, instead of just a hint of spontaneous symmetry breaking, and instability [62,179,209] (or the chirality flips of the neutrinos due to gravity as discussed in [1,42,47,61], as also argued in the literature. A consequence of fractional spacetime, is that Physics does not (or may not) appear unitary anymore, but instead Hermitian, we will revisit. Of course it also results in a (multi-fractal) fractal structure for spacetime, within ranges (no larger than  $\sim 70$  Mpc), that we now can justify [62].

[1,62] statistically model that with Levy random walks and non-Markovian evolutions, which captures random walks with foraging (interactions/collisions, creations or annihilation of particles), and past history impact, hence not exactly Markovian processes. Levy processes are unitary. Time fractional effects lead to pseudo-Hamiltonian that is not unitary, but spacetime fractional combination of both brings it back to Hermitian physics [167]. Based on [98,149,155], the dependency on past history is what can be seen as leading to the effect of an effective curvature, a gravity effect. It is consistent: entanglement creates gravity, gravity relates to (effective) curvature, JT / Liouville / graviton 2D gravity mix it all together and random walks reflect it through its non-Markovian behavior at small scales / 2D. Yet everything is fundamentally unitary Physics.

It is interesting to note that it relates to concerns and proposition recently revisited in the community: is Physics unitary in a universe in expansion [96]; just like others raised issues about Thermodynamics in a universe in expansion (See [97] and references therein). The loss of unitarity was already encountered in [1,4,62]: fractional (non-Markovian and foraging) random walk result in non-unitary QFT in the continuity limit/approximation. We discussed it in the previous paragraph. It may also be aligned with the fact that these random walks are our main microscopic interpretation behind the expansion of multi-fold universes [1,27]. As mentioned in [68], one could again argue that this impacts only the continuous approximations taken for larger scales: random walk, UU physics and particle/antiparticles creations (and annihilation) are quantum and unitary. The underlying physics is indeed unitary, even if lost in say QFT models that try to add the universe expansion into their model. Considering the creation and annihilation of particles, its relation to unitarity can be addressed both with unitary and (statistical) nonunitary approaches in quantum field theory [101], which shows unitary and non-unitary ways to look at it, with the lesson, that, as expected, its unitarity can be considered as preserved, with entanglement, and hence gravity, also always present (e.g., because of pair creations).

We also have from [98,165,166], the possibility that irreversibility of multi-fold dynamics and kinematics may also lead to such non-Hermitian result [1], with physics now becoming pseudo Hermitian instead of unitary, then possibly Hermitian again with effective curvatures [98,149,155]. These effects may warrant a future analysis.

In an expanding multi-fold universe, adding concretized spacetime locations can appear to amount as adding new dimensions to the phase space, as spacetime locations are concretized with Higgs bosons (massless at very small scales). However, at larger scales, it rather expands the boundary of the Hilbert space (for a finite or closed universe), (*Note added on December 30, 2023: which our universe, and multi-fold universe must be [199]*), and only ratios of wave function amplitude matter for most particle physics. However if the question raised in [97,99] is: how do absolute amplitudes know how to “readjust” as spacetime expands? Then, in our view, there is a multi-fold answer provided the multifold W-type hypothesis [100]: with multi-folds always connecting all the points of the support domain between any location, no matter how far away (e.g., a galaxy away), the Born probability rule ensure i) adjusting the norm, ii) unitarity of the absolute amplitude evolution and Physics. A (pair of) photon(s) appearing in a faraway galaxy is another problem. Yes it adds dimensions to the Hilbert space or phase space of the system, but the problem can be handled, just as for new Higgs expanding spacetime: creation of a pair of particle and antiparticle does not add information yet. Yes it adds a Qubits, but nothing else till it encodes something. We have just an unknown Qubit.

The isometry proposal of [97,99], could make sense when trying to capture, with QFT/QM, an evolving Hilbert state space, in an expanding universe: keep the rest unitary and add a dimensions where newly created particles and antiparticles (massless Higgs bosons) appear, but not yet adding any new information (hence in fact preservation of unitarity).

In conclusions, Physics is most probably ultimately unitary as deduced from the argument of microscopic interpretation of random walk discussed above. As multi-fold universes seem to match our real universe [6], the result applies also in our real universe in expansion. Isometric/Hermitian symmetry are then plausible results of higher scale approximations, just as encountered also with non-unitary and non-Hermitian pseudo Hamiltonian operators with the time fractional Schrödinger equation, but recovered Hermitian when we consider the spacetime fractional Schrödinger equation [167].

## 14. Random walks, Higgs bosons in the multi-fold manifolds, their behaviors, and GR in the 7D embedding space

With massless bosons engaged in random walks, which concretize spacetime locations, we can revisit the proposal and analysis provided in [1,23,77,168,191]<sup>5</sup>. Accordingly, multi-folds consist of the same material or structure as the regular spacetime, i.e., they are also concretized locations by massless Higgs boson random walks. It especially matters when discussing non-commutativity of spacetime.

Following [1,27,32,77,191], and how the embeddings space is an inside-out  $\epsilon$  neighborhood growth from the multi-fold spacetime [23,33,34,63], the multi-folds are composed of massless Higgs bosons, pre/above (and at and below) multi-fold gravity electroweak symmetry breaking, with all the same implications on the manifold of the multi-folds. Below multi-fold gravity electroweak symmetry breaking, the Higgs boson can condensate. Those who condensate accumulate at the entry and exit points, which explains the behavior proposed [1,191], but with a

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<sup>5</sup> It is how we primitively inferred non-commutativity of the 4D spacetime [1,191,199], even if other arguments exist [1,77,201].

wavefunction present in the multi-folds that maintains masses on paths across the multi-folds via interaction with the Higgs, through the mechanisms of the multi-fold W-type hypothesis (and ensures the entanglement of these points for mapping) [191]. Their presence throughout the multi-fold path can be seen as a result of the mapping mechanisms from the support where concretized spacetime locations are occupied also by Higgs bosons. *Note added on December 30, 2023: More details can be found at [1,191].*

It explains why the Higgs presence in the multi-fold is needed, and not an anomaly of the proposal, despite the tenancy model for the multi-folds [1,9]. Because of the isospin doublet property with Neutrinos [35,77], right-handed neutrinos are also associated to the Higgs, behind it, i.e., in the multi-folds, as proposed in [1,32,37,42,47], and key to stabilize the (quantized) underlying unconstrained KK + multi-fold mechanics proposal [174,191].

In turn, the random walks, of the Higgs bosons, explain the dynamics and kinematics of the multi-folds attached to the entangled particles: they grow as the Higgs follows the entangled particles and the entangled particles move away from each other [1,191]; as well as the hierarchical principle [1] that requires initial local interactions, as already discussed in [76]. Even the proposed deactivation, at  $c$ , of the multi-fold as proposed in [1] makes sense, as it is associated with Higgs returning to spacetime, along with any charge, energy and momentum. The Higgs boson and right-handed neutrinos on the other hand are (probably) released through the entry and exit point (and mapping where they appeared through their mapping and paths to/in the multi-fold), but entanglement across them, and therefore some multi-folds may subsist.

Another consequence is that the presence of massless Higgs bosons in the 7D embedding space, as in the 4D multi-fold spacetime, explains why the apparent 7D embedding space appears governed by GR, even if it is empty and devoid of Physics - hence the tenancy model for multi-folds, and flat GR in 5D/7D of the multi-fold space time matter induction and scattering approach. *Note added on December 30, 2023: Again, more details can be found at [191].*

From a purist point of view, one still has to then motivate how / why GR works: that means additional multi-folds: 3 (for extra dimensions) or 7 dimensions for whole space, which can then be used twice to model left and right chirality: see [1,14,63,191]. It is based on the assumptions that multi-fold are the same for higher dimensions [191]. With results like [1,6], where multi-folds encounter GR, GR encounters multi-folds, and seems valid down to Planck scales, GR (classic) can be used in the 7D embedding space, especially as no Physics / interactions (besides GR) take place in that space: we recover the Ricci flat (or Einsteinian flat) equations of the multi-fold space time matter induction [191]. This result does not immediately extend to AdS(5) as dual tangent space [1,14,63]. That is because the latter is an outside-in view that does not imply (massless) Higgs bosons in AdS(5). Instead multi-folds live there and they could be modeled, in AdS(5) +..., as superstrings, to be understood as a mathematical model option, not ad physical solutions. Strings could be an outside-in approximation of the multi-folds (via gravitons or closed strings) [1,14,63]. It is consistent with what we have learned so far about the challenges for superstrings and supersymmetric solutions [1,13-18,20,199].

An astute reader should have noticed that this is, to our knowledge, the first time that a physical/microscopic interpretation for unconstrained (i.e., without compactified dimensions) Kaluza Klein models, or space time matter induction and scattering, has been provided, other than: "hey look it works!" [161-163]. In particular we do justify and recover: GR in spacetime, but also (flat - classical) GR in the 7D embedding space.

## 15. Justifying the derivation of SM, including neutrinos, from non-commutative spacetime

## 15.1 Encountering $SM_G$

In [1,77,191,199], and references therein, we discuss how spacetime is non-commutative, and models built on that can derive the SM Lagrangian, and properties of its particles, including neutrinos and neutrino mixing. They can be Dirac fermions, even if Majorana in the original papers. To do so, these papers rely on algebra doubling, which amounts to duplicating 4D spacetime, with or without time sharing, with the local ( $\epsilon$  neighborhood) embedding space [72,78-81].

As already mentioned in the introduction, no physical interpretation is provided in the (conventional) literature other than:

- The need to support the SM symmetries (ensured by 7D and therefore 8D spaces), something we already established in [23,33,34,63].
- Doubled (two sheets) 4D branes managing a dissipation model: a possible story but not really convincing, because not really motivated to our taste. Yet this is consistent with how some of the models have taken place in the literature for the coexistence of gravity and QFT (see an earlier footnote, and [203,213,214] and references therein): what bothers us is that spacetime is not a different system from the SM: they all just 2D random walks of Higgs boson, that aspect is lost in the spacetime vs. quantum matter open quantum system approach. And ultimately as we are ruling superstrings, M-theory and supersymmetry as unphysical, a model relying on D-branes is simply not consistent with our view.

Instead, in the context of the 4D multi-fold spacetime, and 7D embedding space used for multi-fold spacetime and matter induction and scattering, or unconstrained KK, we can interpret the approach way more convincingly, by showing that it is in fact the 4D multi-fold spacetime + the 3D extra dimensions of the 7D embedding space (or + 4D if time is not shared) [1,16,87,136]. The derivation of [72,78-81], is now corroborating our multi-fold space time matter induction and scattering approach. We favor this over the 4D spacetime duplication for each chirality as this is missing the space time matter induction aspect. All this recovers the  $SM_G$  [23,33,34,63,77,168,130,131].

In terms of the embedding spacetime. at larger scale as for the 4D spacetime, we recover a 7D Lorentz space (or 8D), and GR (flat), as already established in section 14.

It explains why apparently fundamentally different approaches are actually related to the same aspects of Physics. We plan an upcoming dedicated paper on this subject. Watch [8] for future updates.

We are not aware of other satisfactory microscopic interpretations for the algebra doubling trick to recover the SM, including neutrinos. In our view, it is again a sign in favor of the multi-fold approach.

## 15.2 Violations or no violation of Pauli Exclusion Principle?

Other recent papers have suggested the possibility that a non-commutative spacetime would lead to observable effects of violations of the Spin Statistic Theorem, in the form of violation of the Pauli exclusion principle, albeit so far nothing has been observed [109-111].

While we would love to see a detected effect, which would prove non-commutativity of spacetime, we are concerned that the effects fall again as the black squares in figure 1(c): they are at way smaller spatial scales than the SM, let alone nuclei and atoms, where spacetime appear continuous, Lorentzian and commutative. As a result we tend to predict that no violation of the Pauli Exclusions Principle will ever be detected by the proposed experiments, or any other of the kind. Indeed at the scales where it would really matter, only massless bosons

matter, not affected by the exclusion principle. Note that as discussed in [1,77,199], non-commutativity may occur till way larger spatial scales than Planck scales, yet below the SM scales. Therefore, we would argue that no violation exist in any case, because fermions are always at spatial scales larger than the non-commutative spacetime.

Yet, this analysis is not in our view in contradiction with the previous analysis of section 15.1. There we discuss the source of the geometry of solitons (in 7D) that create, à la KK, the symmetries, and hence particles and fields and their symmetries, of the SM<sup>6</sup>.

Our view that the Pauli exclusion principle and Spin Statistics Theorem should/could remain valid in a non-commutative spacetime is validated in [112].

## 16. GR asymptotic safe, or another theory?

By now, the reader may be convinced that we have indeed proven, again, asymptotic safety of gravity and SM/SM<sub>G</sub>. But have we, or have we argued that a different set of theories, modeling the microscopic 2D regimes, have these properties?

We argue that we have proven asymptotic safety of GR, Yang Mills and SM, i.e., SM<sub>G</sub>. Indeed we have shown that physics reduces to 2D dominant processes and that both GR and Yang Mills contains these models and behave properly. See also [6,64]. It confirms the validity of the arguments presented in [13,16,65], and no contradiction with our results in [17].

Furthermore, with [6], we have shown that our multi-fold results fully apply to the real universe, if governed by GR, or at least to a GR governed universe.

## 17. What about the incompatibilities of other theories with asymptotic safety of gravity?

Now that we have established the asymptotic safety of GR-based gravity, we can wonder about supersymmetric or higher dimensional theories.

Could we argue that the work above can be repeated to allow the theories rejected in [13,16,17,65,93,94], and references therein, to remain compatible, post SM particle additions and corrections. Our answer is no. Simply because based on [65,93,94], we see agreement of our analysis with the all the simulations out there. They all indicate a similar evolution, where adding for example the MSSM (minimally Supersymmetric SM) vs. just the SM destroys asymptotic safety. In 4D, with just the SM, its effects remain within the limits to keep asymptotic safety. In higher dimensions, or with more particles à la super partners, we are coming from worse conditions. There is just no hope that arguing additional considerations as in section 11 would help. *Note added on December 30, 2023:*

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<sup>6</sup> And if there is a link, we would rather be inclined to conjecture that anti-commutativity could relate to determining the nature of solitons being boson, or not, (due to its symmetries at non-commutative scales), rather than exceptions to the properties of fermions like Pauli's exclusion principle.

See [199] for a definitive handling of supersymmetry: at any scale and for any dimensions, supersymmetry is not physical in multi-fold universes and in our real universe; period. Then, [179] settles the 4D dimension of spacetime.

What about the analysis of section 12, and figure 1? Does it matter, or can we go down to 2D and avoid the whole problem, especially knowing that say superstrings also encounter 2D processes, 2D gravity and 2D Yang Mills? Our answer is again no. All what the arguments provide is argue that (super)strings, for the same reasons, are well behaved in the UV regime, when seeing outside-in the 4D spacetime, from AdS(5)+... . But our spacetime is 4D, as discussed in [1,102-107,179], and reference therein, and supersymmetry is not physical [12,189,199]. *Note added on December 30, 2023: With [199], there is not even an option for some coexistence at the smallest possible 2D spatial scales.*

About the spacetime dimensions. We know that our spacetime is 4D [1,102-107,179] and references therein. We also know that pure gravity, i.e., without matter, can be asymptotically safe at dimensions higher than 4 [65], but with increased difficulties [13,16,17,65,93,94]. From [107,108] and reference therein, we know that gravity and Physics is unstable in more than 4D spacetime (3D spatial): bound structure can't exist, including solitons or soliton patterns [164,179].

Alternatively with the evolution of gravity in  $(1/r)^{d-1}$ , with  $d$  as the spatial dimensions, i.e., where  $D = d+1$  is the spacetime dimension [108], it is fair to expect that gravity asymptotic safety is losing strength to combat the negative effects of SM (or even worse MSSM), rendering the asymptotically safe SM and gravity theories more incompatible in higher  $D$ . It is aligned with [102-107,179]

Therefore, it does not look like the analysis above can make gravity asymptotically safe in higher dimensions, nor that it can handle more particles even in 4D. Arguing symmetry breaking responsible for not encountering the super partners yet at LHC does not help [199]. In the UV regime, they have to be counted no matter what, as they will be able to pop up and be encountered as energy ranges increase. *Note added on December 30, 2023: Again for more details refer to [199].*

## 18. Conclusions

We have shown that random walks, with foraging, of massless Higgs boson at very small spatial scale, where Physics is essentially, and as a result, 2D, justifies good behavior, i.e., asymptotic safety, of 4D gravity as well as of the SM / SM<sub>G</sub>, i.e., 4D Yang Mills and Maxwell fields (as well as for the Weak (and therefore electroweak fields). The presence of SM particles does not change these conclusions. SM particles are considered to be soliton patterns of such massless Higgs boson random walks at spatial scales when massless below the spatial scales of the multi-fold gravity electroweak symmetry breaking, and condensates of these massless Higgs boson particles after symmetry breaking; all preserving the symmetries and relevant quantum numbers, including internal symmetries.

This analysis allow us to predict the direction of effects on the asymptotic safety of (gauge) bosons, fermions and scalar species, in alignment what multiple models and computations of asymptotic safety projects. Also, it provides a microscopic interpretation of why and how the transition to UU occurs, that ultimately justifies the random walk regime where only random walks, collisions, creation and destruction of massless bosons and entanglement, itself responsible for gravity, matters at and around Planck scales.

With the consistency of recovering GR top-down-up-and-upper, and from multi-fold spacetime reconstructions, and the proper consistent and corroborating 2D behavior of Yang Mills and Maxwell fields, we argue that GR and SM / SM<sub>G</sub> are indeed the theory that are asymptotically safe, as we had already independently established in [17], using the Yang Mills/Gravity double copy duality.

Ensuring robust asymptotic safety of  $SM_G$ , the SM with non-negligible gravity effects at its scales, encourages minimizing the number of scalar species involved in random walks, UU and the multi-fold gravity electroweak symmetry breaking, leading us to going beyond invoking Occam's razor to predict that there is only one massless scalar boson species, the massless Higgs boson, involved in all these effects, including inflation slow roll, JT/Liouville dilaton gravity, dilaton for unconstrained multi-fold mechanisms and their kinematics and dynamics, complex/imaginary Higgs scalar field above the electroweak symmetry breaking, and electroweak symmetry breaking, even if the multi-fold model could allow multiple or different species involved in each of these events. It reinforces our prediction that no additional interaction or fundamental particle will be found at energy scales above the multi-fold gravity electroweak symmetry breaking [30]. If many more scalar species were involved, asymptotic safety may become jeopardized, and the consistency of theory risks collapse.

Also, the effects of SM on gravity do not help alleviate the incompatibility of theories requiring more particles than the SM, e.g., MSSM, or more dimensions. Asymptotic safety of gravity, proven by now, is problematic for supersymmetric, superstrings and many popular GUTs and TOEs: they are and remain incompatible with asymptotic safety of gravity. *Note added on December 30, 2023: By now, supersymmetry has also been proven as unphysical in our universe (and of course in multi-fold universes).*

Figure 1 goes a long way to explain the impact of the multi-fold model, its fundamental differences with QFT and superstrings, and why, as already encountered for example in [29], we know that the transition UU is not a conventional symmetry breaking (even if with a Goldstone boson if we construe the massless Higgs boson as dilaton to fulfill that role), and with a transition that extends over a range of spatial scales. It also shows how Physics at different scales can coexist when analyzing the Physics in the real world. The principle of figure 1 are also useful to understand QCD and electroweak behaviors at energies above the multi-fold electroweak symmetry breaking energy scales, as discussed for example in [26,29,37].

Beyond the notions of embedding and multi-fold space time matter induction, we saw that the inside-out  $\epsilon$  neighborhood of the 7D embedding spacetime is also built on similar random walks of massless Higgs boson, which provides more microscopic interpretations of the multi-fold properties, and kinematics/dynamics, adding to the insights gleaned in [76]. *Note added on December 30, 2023: More to come in [191].*

With the non-commutativity of the multi-fold spacetime and the 7D embedded  $\epsilon$  neighborhood, we provide a microscopic interpretation, so far missing in the literature, to the algebra doubling process that recovers, also à la KK, the  $SM_G$ , including neutrino mixings, and without having to assume Majorana behaviors, which we do consider to be a resounding consistency check of, and complement to, the results obtained in [23]. *Note added on December 30, 2023: with this we have a quasi-Theory of everything, without any need of Anthropic principles, multiverses, or answers to concerns of fine tune-ins and mass hierarchy problems. Note that we acknowledge the proposed motivation of an open quantum system of  $4D + 4D$  brane, but we explained why it is not satisfactory to us. Especially now that we have convinced ourselves that superstrings, M-theory and supersymmetry are not physical in our spacetime.*

This paper gives us also a microscopic explanation on why the embedding 7D space, used for multi-fold space time and matter induction and scattering, is governed by GR, as a flat manifold without any further Physics within it. Interestingly, this is at the difference of the dual tangent AdS(5), where GR may reign, but not necessarily. All this provide extra consistency check for many of our past results tracked at [8].

The multi-fold Gravity electroweak symmetry breaking, and non-commutative spacetime lead to the existence of neutrino associated the Higgs boson, as weak isospin doublet [35,42,61], and key to understanding what happened to the right-handed neutrino [47,61,76], and matter antimatter asymmetry [46] as well as the plausibility that multi-folds can be implemented by traversable wormholes [76,191].

We cannot stop emphasizing the importance of random walks and discrete spacetime, along with figure 1, in ensuring proper UV behavior for  $SM_G$  and the properties of gravity, spacetime and SM. We believe that it would be

warranted that the arsenal of literature aiming at studying renormalization, consider a framework where at, and near, UV fixed points, Physics becomes discrete and with scale effects à la figure 1.

We argue that, with random walk UU physics that includes models for inflation and expansion, Physics is Unitary, no matter what even if the universe expands; leaving the door for some multi-fold irreversibility though. Isometry, pseudo hermicity, hermicity etc. are expected to rather be higher scale modeling considerations, not fundamentals of Physics. They would not lead to reconsider for example the black hole information paradox.

Finally, we used figure 1, to argue that noncommutativity may not necessarily result in observable violations of Pauli's exclusion principle contrary to some recent proposal.

Meanwhile, 2D gravity consideration lead us to conclude that the universe must be closed, through a different reasoning from [1], and [199]

But the main message is: Only 2D Physics matters [185].

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