

# Our real universe is macroscopically 4D. Hints come from every directions & show that it had to be so

Stephane H. Maes<sup>1</sup> 

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## Abstract:

*In the multi-fold theory, spacetime results from 2D (fractal) processes at very small spatial scales then growing to 4D at larger spatial scales, where we naturally recovered a 4D macroscopic, and at large enough microscopic scales. So far, we invoked stability of GR reconstruction to justify 4D. In a recent paper, we argued that we have almost all the elements for a theory of everything, based on the multi-fold least action principle and multi-fold space time matter induction and scattering. There, we essentially assumed 4D at large enough scales, rather than deriving it.*

*This paper organizes past considerations before expanding and adding to them. The analysis is based both on conventional, and on multi-fold considerations. The conclusions are that the spacetime is 4D at large enough microscopic, and at macroscopic, scales, and only with 2D and 3D behaviors at the smallest spatial scales. At 4D, it can be continuous and equipped with notions of Hamiltonians, volume, areas or dot products / metrics / distances. It is not (asymptotic) AdS, and it has only one time dimensions.*

*In the course of our analysis, we encounter a few nuggets. This paper provides a rigorous proof of why multi-fold spacetime reconstruction by random walk is 4D, and only 4D at large enough scales, and why (multi-fold) dark energy effects do not grow additional dimensions. Relying on random walks, and quantum cellular automata based on them, to model QFTs, we predict challenges in formulating QFTs at spacetime dimensions of 5 and above, except maybe for some CFTs, or when built using the random walks of extended objects like strings or branes in their AdS spacetime. This analysis extends to the QFT world. The case of dS universe is discussed.*

*Our analysis of Kaluza Klein (KK) dimensions leads us to propose that the Higgs presence in the multi-fold is also understandable as related to Higgs as dilaton in KK, and in the double copy between gravity and gauge fields..*

*We also explain why, on the other hand, AdS could be generated via the random walks of strings or extended objects, or non-conservative random walks, up to way higher dimensions, where one can still encounter (unphysical) supersymmetric or conformant fields. It infers why that story stops at 10D/11D, and fields misbehave at 26D for bosonic strings.*

*The paper includes some analyses of QCD and Electroweak interactions at spatial scales where spacetime appears 2D and 3D, and additional considerations on the mass gap in different dimensions.*

*Coupled with the Multi-fold Least Action principle, our universe has to be 4D at large enough spatial scales. No other physical solution is possible.*

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## 1. Introduction

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<sup>1</sup> [shmaes.physics@gmail.com](mailto:shmaes.physics@gmail.com)

*Note added on August 1, 2025: References in italic denote comments added on August 1, 2025, unless if noted otherwise.*

It is intuitively obvious that we live in a 4D spacetime. However, once Physics gets involved, many other options may exist, and some may lead to questioning the 4D assertion. Are we in 4D, or in universes with more, but hidden dimensions, and if they are hidden, how are they hidden to our sense, and / or to most common Physics? If there were extra dimensions, are these extra dimensions small, e.g., compact or compactified, or large in a suitable embedding or tangent (dual) space? Or are they ghost dimensions, e.g., only interacting with dark matter or dark energy? Or could we live in a smaller dimension spacetime, yet get the impressions of living in 4D (Everything indicates a dimensionality reduction at high energies as discussed in [1,8-10,16,22,82,83,259,265,279,326])? Are there multiple time directions? Is our universe asymptotic de Sitter (dS), or anti de Sitter (AdS) (*Note added on August 1, 2025: By now, we know that our real universe, and multi-fold universes, are not supersymmetric [13-15,250,262,296,307,308], and therefore not AdS [1,8-20,22,62,80-83,250,262,268,296,307,308], and that the cosmological constant / dark energy effect of our real universe is strictly positive, even if possibly time varying [33,250,296,307,308]*)? In fact, is our spacetime continuous, or discrete, or even fractal, i.e., with non-integer dimensions (There are many indications that a multi-fold universe but also our real universe is discrete, non-commutative and fractal (See [1,8-10,22,30,31,60,64,259,265,276,279,282,296,296,307,308] and references therein))?

Then, could it be that there are other universes in a multiverse, assuming that the option makes any sense (It doesn't beyond the MWI (Many Worlds Interpretation) [177]) would have other dimensions? Can we move across all these dimensions, or multiverses, and experience changes in dimensions, etc.?

Also, what to make of hints that physics would be of lower dimensions at small scales [1, 1,8-10,16,22,82,83,259,265,279,326] and references therein? Per [84,177], no move across multiverses. Yet, multi-fold mechanisms take some of a particle path integral paths across multi-folds in a 7D embedding space [1,23,49,51,62,77,268].

This subject sound like a bonanza for science fiction, or a minefield for your career, and sanity, even if some well-respected physicists have spent efforts on this. Among the most notable ones, let us call out explicitly Ehrenfest [170,171], and Tegmark [167]. These famous papers are mostly focused on classical Physics, which makes sense for a macroscopic analysis. There are in fact ways to see that at large enough microscopic scales, the scales of the QFT, SM and SM<sub>6</sub>, spacetime is also 4D and it can be used to justify the macroscopic 4D spacetime.

*In comments on the web site tracking all the development of the multi-fold theory [8], we provided arguments on why we know that our real universe is macroscopically 4D, and why it had to be so. It was a review of existing related papers. Here we put all the arguments into a consistent story and add to it.*

Therefore, in this paper, we review experimental, simulation and theoretical justifications that spacetime is 4D at large enough scales, to convince the reader that our real universe is not only macroscopically 4D, but also that it just had to be 4D, except at very small scales, where we then need to understand what it means to be essentially processes of smaller dimensions, and some of the implications. Also, we will show that spacetime cannot be physically of higher dimensions, even if mathematically such spaces could exist. Embedding, tangent or compact dimensions may exist, we will see when and what that means, but their unphysicality must then be very clearly understood: no spacetime Physics takes place in these dimensions, again something to explain. Finally, we will argue against multiple time dimensions, or scales [96,166,167,172]. *Note added on August 1, 2025: [351] has been recently pushed by the popular scientific press as discussed in [351]. In [351], another popular blog succinctly took it down as non-sense [328].*

Throughout the paper, we will turn back to the spacetime reconstruction model by random walks, introduced in [1,63,89,177,265] for multi-fold universes but also encountered in what seems to be any GR-based universe, i.e., most probably our real universe [6,177,296,307]. We use it to unambiguously, in our view, justify a 4D spacetime

(at spatial scales large enough for GR) as the only stable possibility, and provide a microscopic interpretation for the results from [122-124], invoked in [1,265], which simulated numerically GR spacetime (construction) with causal triangulation, and showed 4D as the emerging stable spacetime solution.

We want to call out explicitly a key contribution of this paper. We use random walks, and interaction potentials discussed in Appendix B, to justify why quantum cellular automata, based on random walks, are suitable to equivalently model QFTs, and why QFTs become problematic in 5D spacetime and above, except maybe for some CFT or supersymmetric constructs, which might be associated to the random walks of extended objects. (*Note added on August [1]: By now, we know, that our real universe, and multi-fold universes, are not supersymmetric*[1,8-20,22,62,80-83,250,262,268,296,307,308]). We also use random walks to predict 2D and 3D QED and QCD behaviors, e.g., QED confinement at high energies, which allow us to understand what happens at energies above the electroweak symmetry breaking, especially in terms of the chiral symmetry breaking and its impact on masses [1,4,29,52,53,60,63,259,265,279,289,296,303,307]. We will also show how such a model can equip spacetime with dot products, i.e., metrics, or distances, and with 2-forms, i.e., areas [b58] and become apparently continuous.

Random walks of strings, and other extended objects, can create AdS [13-15,308], and be dense in way larger dimensions, so that fields built on such backgrounds can exist under certain circumstances as for example SUSY fields and CFTs, as supersymmetry and conformance are superstrings symmetries. But none of those are physically useful in multi-fold or conventional spacetime [1,8-20,22,62,80,81,250,259,265,308]. They are just mathematical fields, unphysical [1,8-20,22,62,80-83,250,262,265,296,307,308]. The good behavior does not extend to bosonic strings at 26D. It is for the same reasons, and discussed in Appendix C.

In general, in this paper, we assume an asymptotically<sup>2</sup> de Sitter (dS) spacetime with positive curvature / cosmological constant, unless if / where specified explicitly otherwise. *Note added on August 1, 2025: It is motivated by the strictly positive cosmological constant, or dark energy derived in [b47,b58]. We changed the sentence as follows we assume ~~an asymptotically flat or~~ (intentionally stroked through) an asymptotically de Sitter (dS) spacetime, because [296,307] have eliminated asymptotic flat spacetime as a physical option.*

## 2. Experimental Indications Of A 4D spacetime In Our Macroscopic Universe

### 2.1 Our World And Our Physics

We, humans, are clearly 3D spatial beings. We perceive 3D and time evolution, and already have challenges really imagining just a 4D spacetime. To date, we have not observed extra dimensions, whether large or compact, nor any macroscopic reductions in dimensionality. Assuming that other dimensions exist, it is unclear who or what would detect or perceive them, although some argued that they might under influence, other than maybe particles, or through physical effects at the Standard Model (SM) scales or below. For sure, superstrings assume such Physics beyond the SM [357]. Holographic effects might also be ways to perceive the impact of them [358].

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<sup>2</sup> Although in many of the (earlier) papers, compiled in [8], we do not bother to add an asymptotic qualifier, it is rigorously needed when matter is present in the spacetime. Across all the papers compiled in [8], and here, it is always the intention, and justified for example because matter locally perturbs dS, and AdS, behaviors.

To the best of our knowledge, so far, there has been no detection of any extra dimension (e.g., Kaluza Klein/(super)strings/Kasner/Wess–Zumino–Witten/supersymmetry) in any physics experiment. In particular, with particle physics and colliders like the LHC [99-102,342-344], where, so far, no loss/leakage of energy or momentum has been detected, nor the formation of microscopic black holes, easier to form if there were more dimensions, and therefore a potential sign of the existence of such extra dimensions – but also requiring new Physics beyond the SM, [100,102-105,107,178,179,316,317], or other signs or holographic mechanisms [358] or strings [101], or via gravitational waves [107] or gravitons [107-109]. It’s all about detecting leakages in energy or momentum, different behaviors (resonance, standing wave behavior, etc.) between gravitational waves and light waves, or unexpected particles appearing as the result from heavier KK particles, or microscopic black hole decays [100]. Also, no higher dimensional black hole, with different symmetry, or say topological stars, due to higher dimensions, have been observed either [100-102,179-181,100,359,360].

To our knowledge, no recent paper has reported changes since these references.. To the contrary, experimentations hint always at maximum 4D. We use maximum because, as already mentioned, we know that dimensions reduction seems to take place at the smallest spatial scales [1,8-10,16,22,82,83,259,265,279,326].

## 2.2 The Standard Model Holds The Fort

The Standard Model (SM) has passed most of the challenges thrown at it. Recently, some have hoped for cracks in the SM, but few have held [54-57,59]. In fact, in the multi-fold theory, we claim that most of the cracks are not cracks, and might be explained with the SM with gravity non negligible at its scales ( $SM_G$ ), or multi-fold mechanisms and effects [1-98,118,177,184,185,196]. Needless to say, the continued success of the SM is to the desperation of many Physicists looking for New Physics, especially the supersymmetry, Superstring and other GUTs aficionados. Indeed, no new Physics, and no supersymmetry, significantly reduces the theoretical arguments for additional dimensions predicted by superstrings and M-theory.

Furthermore, it gives growing credence that supersymmetry and superstrings at dimensions higher than 6 are not compatible with the SM, something that we have also recovered in multi-fold theory. See [1,11,13,18,20,43] and references therein. *Note added on August 1, 2025: In any case, we know by now that supersymmetry is not physical* [1,8-20,22,250,259,262,265,279,296,307,308].

## 2.3 Confirmations Of General Relativity

Most people have heard of the alleged incompatibilities between General relativity and Quantum Physics, with the understanding that one is classic, the other quantum, or the former is with real numbers while the latter involves mathematical operators, and quantum frameworks like superposition, coherence or entanglement. For example, it is often suggested that superposition, or even coherence, may not coexist with GR/gravity, something that we do not agree with, beyond the usual effects of interactions on superposition or entanglement. See [78,183,261] and references therein.

Superstring is seen by many as the quantum evolution of the GR framework [14], while Loop Quantum Gravity (LQG) is sold as a competing quantization of the Hilbert Einstein action and spacetime, as in [19]. None have gone anywhere, beyond fantastic theoretical mathematical frameworks, and many challenges as we pointed out for example in our multi-fold work [1,5,21,35,43,184]. In fact we have challenged their physicality cross the board [1,8-20,22,62,81,250,259,262,265,279,296,205,307,308].

Needless to say that most physicists believe and hope for signs of breaking GR, to make some progress. Yet, GR has survived almost all the tests thrown at it. An up-to-date list and entry points to classic and recent tests of GR can be found at [112,113], including very recent ones like [114-118,185,187-190]. Almost every few months, new confirmation variations are now reported. All these tests and results were for GR in 4D spacetime.

## 2.4 Experimental Proof Of 4D Spacetime

4D quantum Hall conductance effects [119-121] have been observed and they can be considered as a proof that our universe has a 4D spacetime<sup>3</sup>.

Of course, the repeated confirmations of GR, as in the previous subsection, experimentally indicates a macroscopic 4D spacetime.

## 2.5 Simulations

In [1,265], we already justified a 4D spacetime as the lowest number of dimensions where a stable spacetime at large enough scales, can be reconstructed using causal quantum gravity reconstruction [122-124].

The multi-fold spacetime reconstruction [1,6,265] is based on random walks, and through the top-down-up-and-upper model, it recovers GR [1,6,63,89,177,265,296,303,307]. As a result, multi-fold universes can be seen as well approximated by causal quantum gravity reconstruction, as random walk will always be causal, by definition and construction. As the approach of [122-124] triangulates GR at small scales, and GR contains multi-folds at Planck and at small scales [6], this is a good argument for multi-fold universes. If one agrees that [6] implies that GR-based universes are therefore multi-fold, this paragraph implies that our real universe is 4D at large enough scales. *Note added on August 5, 2025: The arguments presented in Appendix B of [307], show that one can easily triangulate by building on the path of the 2D random walks. Note also that if we consider nondifferentiable manifolds, 2D random walks remain suitable way to model GR, as discussed in [319,320], and references therein: one can also generalize GR with triangulation. Note that [319] and references therein focus on generalization of the singularity theorems, which is fine for conventional GR, but one needs to remember that in a multi-fold universe, we have no cosmological or gravitation singularities.*

If the reader is reluctant to buy these arguments, we still argue that [6,31,63,177,296,303,307] shows that a GR spacetime has a 2D then fractal random walk-like structure at small scales that must be causal (see the required progression between clumps of spacetime and linking constrictions in [6,63,296,303,307]). So, causal reconstruction, with triangularization compatible with Regge Calculus [125,126], are appropriate ways to simulate GR. [126] also assumes a causal discretization.

As we will see later, 2D random walks are also equivalent in modeling relativistic QM, and QFT.

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<sup>3</sup> Some may argue that this remains compatible with dimensions  $\geq 4$ , just as for 2D Hall effects. Upcoming sections address the cases with more dimensions 4. Note the effects of 4D quantum Hall conductance effects are not to be confused with 2D quantum Hall effects.

## 2.6 . The Huygens' Principle Says It All For Our Macroscopic Spacetime

The Huygens' principle [131] is only valid in odd space dimensions (3 or larger, with 1 as degenerate case, where no other path exists) [129-131] (in particular [129], Chapter VI, page 689 in the 1989 edition). It would create a problems for Optics, and classical Electromagnetism, if our spacetime wasn't 4D or less, for classical Physics, and its quantum origins at large enough scales.

Note that, to some extent, the Huygens' principle can be thought to be generalized by the path integrals formalism ([1,77] and references therein). That formulation is not subject to even vs. odd dimension restrictions, as it works off the wave function that captures all the required history and / or because of derivations as in [77]. Yet this is how topological material and effects for 2D systems can significantly vary, as for example with Quantum Hall effects. As an example, consider [168].

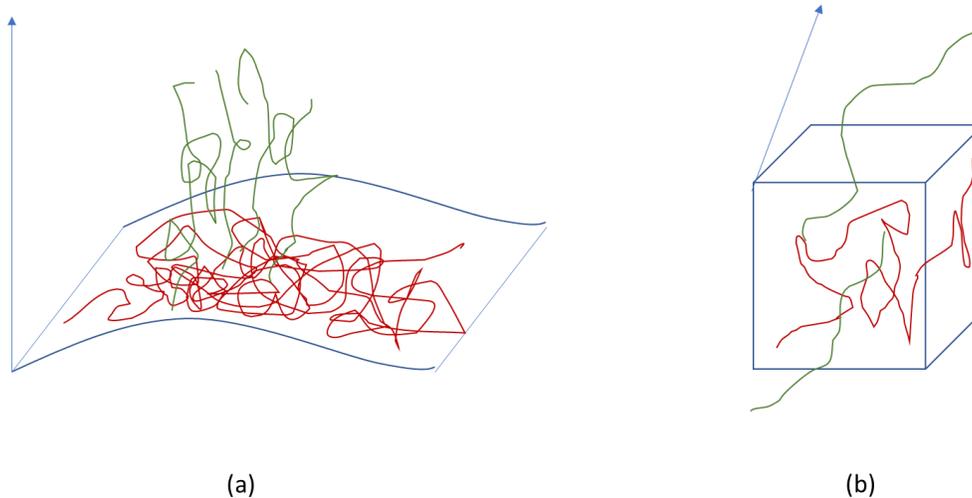
As we will revisit later, we have different behavior for QFTs in 2D and 3D, e.g., QED, with confinement and chiral anomalies/symmetry breaking, as discussed in [60,63,136,174,289,303]. These different behaviors confirm, in case there is any doubt remaining, that our macroscopic spacetime is not 2D or 3D; QED does not typically present confinement behavior, in macroscopic spacetime.

So at this stage, at best, the remaining options for macroscopic spacetime dimensions would be 4D, 6D, 8D and above.

## 3. 4D And Only 4D In Macroscopic Spacetime Reconstruction And Dark Energy Effects

### 3.1 Integer Dimensions MUST Be 4D

At the time of writing [1], we also argued spacetime reconstruction based on random walks up to 4D, and that 5D and above does not occur, because such spacetime is too large to support sufficient / strong enough interactions (through random walks). We will revisit it here, and after. In particular, Appendix B discuss potentials like the Coulomb potential in different dimensions.



*Figure 1. (a) sketches a 2D random walk from which random walk are started in the third dimension. With 2D random walks covering ever point of the 2D manifold, the 3D contributions can appear dense in 3D space. (a) is a good example of random walk with particle creations as in [1,265]. (b) shows the case from 3D spatial to 4D spatial (the slanted arrow). Because random walks are only dense in 3D, the coverage in 4D spatial is very sparse. It will get sparser and sparser as we raise in dimensions, e.g., repeating the process from (b), as (b) repeated it from (a).*

We can rigorously support the 4D and only 4D argument because, above spacetime 4D ( $\geq 3D$  spatial), random walks on discrete spacetime are not 100% recurrent, per Polya's random walk theorem [127,128], a theorem already used, albeit differently, in [177], when arguing against the existence of multiverses as universe with any possible content, in any possible state, or with any possible Physics, e.g., physical laws and constants.

For spatial  $D \leq 2$ , random walks can expand to other dimensions with a stable construct: i.e., spatial  $D \leq 3$ , as new particles can always come back to the same starting point, and feed more particles/paths into the new dimension, there and around. In the case of spatial  $D=3$ , it is the last integer spatial dimension that can be systematically fed from 2D random walks, as they can be dense in 2D. For any integer value larger than, or equal to, 4, as spatial dimensions, any attempt to create another spatial dimension is starved off by the lack of new random walks/particles fed into it in the neighborhood of a starting point in that dimension, and so, at best, there is too much diluted within it to have interactions or anything else taking place. The principle is sketched in Figure 1. This is always true, except, maybe under the right circumstances close enough to the seeding 3D spacetime, where there may be enough density.

*Comment added on August 1, 2025: Then, creating a continuous- looking spacetime, then with a dot product and therefore metrics, because of entanglement, and areas/Hamiltonian/conjugate/volumes, i.e., a symplectic-looking manifold as done in [307]. This reasoning works by construction with discrete spacetime, and non-commutative [b58], as well as non-differentiable manifolds [319,320], albeit, we have argued from a multi-fold point of view the foam should remain well behaved [5,19,21,184].*

So for spatial  $D \geq 3$ , any such expansion to another spatial dimension dilutes the density too much to build a stable spacetime where physical interactions take place: the coverage is not dense. Spatial  $D=3$  or spacetime  $D=4$  is therefore the only possible integer dimension can be stable, as lower spatial dimensions will automatically grow into larger dimensions, and beyond, no dense and stable spacetime can be created. Non-integer parts can exists to characterize the fractal nature of the random walks, but that matters only at microscopic scales. See section 3.2.

It explains why, in [1,265], random walks, a 2D spacetime process must grow to 3D then 4D, and then stop without any growth beyond. Also, it explains why the multi-fold dark energy effects [1,8-10,22,27,62,259,265,279] expand spacetime but do not grow extra dimensions, even if pushing out of spacetime, into what can be seen as a larger embedding space (e.g., 5D or rather 7D) [1,27,62,296,303,307]. *Note added on August 1, 2025: In [307], we link these dark matter effect to spacetime non-commutativity: they are one and the same, and need each other to exist and they underlie GR. This directly related to the quantum nature of gravity [273], albeit different from was some believe that it means, where non-commutativity is essential [30,64,77,250,282,296,301,303,307] (Note added on October 31, 2025:, as interestingly explained in [361]).*

And so, we were correct in [191] to state that if the dimensions were larger, not enough collisions would take place, and we would not have enough interactions for agglomeration/clumping of structures due to gravity, or creation of bound structure with gravity or electromagnetism etc. and so we would be challenged to explain the current large structures of the universe, or even possibly bound and composite structures like atoms and molecules. Again we will revisit in upcoming sections, and provide alternate ways to reach and prove the same conclusions. As already mentioned, considering random walks / moves of higher dimensional objects like strings or branes, can, for the same reasons, may support the generation of higher dimensional spacetime, and a priori these will be continuous, unless if the strings and branes were discrete, something less common in superstrings/M-theory, even if they also encounter hints that spacetime is discrete, when extending to strings the reasoning of [64,250,282,289,296,303,307,362].

Interestingly, we believe that one could also argue that the lack of enough density at any spatial dimension 4 or above, will result into diluted and non-existent spacetime, except possibly in a/some region close to the underlying, say 3D spatial, manifold. This recovers another result that is widely known in Kaluza Klein and behind the String theories automatic compactification of the additional dimensions, and the string T-duality [192-195]. It is also well exemplified in [132], where it is argued that a fifth dimension must automatically compactified (and any higher ones). We just saw why: extra dimension can only occur this way, if density is sufficient, which may require additional context on how spacetime is constructed (that would justify feeding enough in such growth). For the reasons discussed so far and in upcoming sections, we argue that creation of a fifth dimension does not happen [289,296,303,307] in a typical universe conventional or multi-fold, but it might occur if extended objects like strings or branes are involved in the random walks. Note that this is not preventing, or constraining, the multi-fold mechanisms with kinematics and dynamics dictated by the motions of entangled particles [251].

Also, as discussed later on, binding forces like gravity, Coulomb potential and QCD interactions weaken with as spatial dimensions increase. (See Appendix B) Coupled with reduced density it makes it difficult for matter to interact in larger spatial dimensions  $d$  ( $d \geq 4$ ), and prevent orbits and bound elements: space is too sparse while attraction is also weaker. There would be no atoms, no molecules, no chemistry and no life in such universes.

Although, relying on just a simple extension to Polya's random walk theorem, and evolution of potentials like the Coulomb potential, discussed in Appendix B, we believe that such arguments of why our spacetime is macroscopically 4D (even if build by 2D random walks), and stable and not a smaller (it would always be able to grow additional dimensions if at  $D < 4$ , due to multi-fold dark energy effects / non-commutativity [1,8-10,22,27,30,64,250,259,265,279,289,297,303,307]) or larger (won't be able to grow into larger dimensions [132]). This is the answer as to why the multi-fold dark energy effects do not create new dimensions, a question that we received regularly after publication of [1,27]. These are original arguments and results presented this paper.

It means that spacetime of 1D, 2D or 3D (with positive curvature / dark energy, to justify the random walk spacetime reconstruction, expanding the universe<sup>4</sup>) will **always** become 4D, when left on its own unless if limited

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<sup>4</sup> The case of negative cosmological constant and asymptotic AdS spacetime is more tricky for our model. [1,8-10,22,63,250,259,265,276,279,296,307] show that multi-folds and random walks are only compatible with positive cosmological constant / curvature. *(Note added on August 1, 2025: we have removed or null per [296,307]).* We

externally by other physical constraints into 1D or 2D (e.g., like spacetime available in topological materials). It is aligned with [77,177].

Again, because we recover GR from multi-fold spacetime reconstruction, and encounter multi-fold in GR (and Yang Mills [7,58])[1,6,265,307], we can argue that the same questions can be asked, and similarly answered, in conventional physics, i.e., non-multi-fold, and for conventional, and unexplained, dark energy. [1,6,265,296,303,306,307] ensures that the explanation is actually the same. We will recover more conventional, and multi-fold consequences in the upcoming sections.

### 3.2 What About (Multi-)Fractal Considerations?

In [1,30,31,63,64,282,289,296,303,307], we argue that spacetime is discrete, non-commutative, and fractal at very small scales, a direct result of random walks with foraging / Levy walks, and, possibly, some entanglement between concretized spacetime locations [1,16]. And yes, it is also Lorentz symmetric and non-commutative, possibly non associative [1,265], this is not important here. In [1,31,63] and references therein, we also argue that, at large enough scales, such a fractal spacetime can appear to have integer dimensions, and then be continuous, as soon that the random walks and non-commutative effects become hidden by a high enough density of concretized spacetime locations, and quantum uncertainties [30,64,296]. *Note added on August 1, 2025: In addition in [307], we explain how the resulting manifold can be equipped with dot product, metrics and areas, volumes, Hamiltonians / symplectic structure, on differentiable or non-differentiable manifolds.*

So, all of the discussions in section 3, and some of the considerations in section 2, can be with  $(n+\epsilon)$  D dimensions instead of  $nD$  dimensions, with  $n \in \mathbb{N}$ , without having to bother about  $\epsilon$ . The outcome are the ultimately same at large scale. Indeed, the fractal non-integer dimension component is relevant and visible only at very small microscopic scales (and otherwise possibly in the distribution of matter at cosmological scales [1,265]). This paper focuses on macroscopic considerations. In this paper, we will not bother with additional fractal concerns, considering them addressed by the comments made here.

Related to this, the considerations on imaginary mass for the massless Higgs field (Tachyonic), and in space and time fractional quantum mechanics hints at the correctness of the model [31,63,89,289]: it happens with random walks of massless bosons, and only Hermiticity is certain.

## 4. Implications Of Asymptotically Safe Gravity

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extend this to show incompatibility with superstrings in same spacetime, something also agreed by most in the string community. See [1,15,250,265,308] and references therein. A negative curvature, à la AdS, would require a background curvature shaped this way through initial conditions, or other processes, like expanding from a D-1 boundary that is flat or dS [62,197], or model/vacua down lifting (vs. the uplifting encountered with string theories and quintessence, where supporters try to encounter a positive cosmological constant, while strings are incompatible with such cosmological sign). It is consistent with [15,308] and references therein. To explain AdS(5) as in [1,265], the spacetime would rather be constructed by the multi-folds, who live in AdS(5)(+...), where the (+...) is to allow additional dimensions for superstrings, which could attempt model the gravitons or multi-folds [1,58,80,81]. We will revisit this later in section 10, where we will see that 5D+ can exist in an AdS space. This had to be as we have to support AdS(5) as tangent dual to multi-fold spacetime, as well as the mathematics of superstrings, supergravity and M-theory.

[63,198-200] show that, when it comes to compactified dimensions, if quantum gravity is asymptotically safe, something typically not agreed upon by strings theorists, then supersymmetry (and its MSSM – minimal supersymmetric SM [201,250]) with/and dimensions higher than 6D (macroscopic or compact / compactified) are not compatible with the SM (5D/6D may be, but remember that these are questionable when considering the other arguments on macroscopic dimensions above 4D / 3D spatial).

There are many polarized views on asymptotic safety of gravity, some are discussed in [16,17,63,73], and references therein. Based on our work in multi-fold universes, we have concluded that GR-based gravity is asymptotically safe, even in the presence of matter in the form of the SM [16,17,53,60,63,289,296,303]. It means that superstrings, supersymmetries, and most GUTs and TOEs, are ruled out, as are essentially dimensions above 6D, that they be macroscopic, or compact/compactified.

Because of [1,5-10,22,58,259,265], and in general all the cases where a multi-fold universe appears to well explain or answer problems with the SM, Physics in general, and the Standard Cosmological model [1,74], as reminded in Appendix A, we believe that our real universe is multi-fold or multi-fold-like, i.e., often well modeled with multi-folds. So the results above imply that our real universe spacetime is macroscopically (and microscopically)  $D \leq 6$ . To be sure, let us continue to analyze up to 8D. Dimensions above 8D are certainly not good candidates (this is in part because we consider superstrings, supergravity and M-theory as unphysical [1,8-20,22,62,81,250,296,305,307,308]).

Per the Huygens' principle, even spatial dimensions are not good. So we need to drop 5D and 7D. Also, note the work of [132], that shows how a 5D macroscopic can't coexist with a 5D isotropic universe but would instead compactify. This is due to the desire to have the 5D Ricci tensor null, i.e., a flat 5D spacetime (or Einsteinian spacetime). In a multi-fold universe, our derivation of [132] goes as follows. The compactification is because in 5D there is no matter present, except for a negligible 4D perturbation, as discussed in [1,8-10,49,51,62,259,265,268,279] and references therein, especially suited for an inside out embedding model with no physics in the multi-folds encountered in multi-fold universes [1,8-22,259,265,268,279]. This result can be extended to any additional dimension above 4D. So 6D and 8D would (probably) also be compactified, as we already proposed in section 3.1.

## 5. QFT And Dimensions

### 5.1 QFT In Different Dimensions

There is ample literature on QFT in  $0(+1)$  to  $3(+1)$ , the first number is for spatial and the  $(+1)$  is for temporal dimensions. See for example [133-138,202], and many courses on quantum field theory. Some have also proposed QFT on fractal spacetime. See for example [139].

In[154], Edward Witten is quoted as saying: "Traditionally it was thought that interacting quantum field theory couldn't exist above four dimensions, and there was the interesting fact that that's the dimension we live in. But one of the offshoots of the string dualities of the 1990s was that it was discovered that quantum field theories actually exist in five and six dimensions. And it's amazing how much is known about their properties."

Yet, we would argue that one knows very little about QFT in higher spacetime dimensions (5D and above)<sup>5</sup>. [144] shows that it is not possible to have a perturbative, renormalizable, and hence consistent, QFT theory for  $D > 4$ . Non perturbative renormalization may be possible, but not certain. Yang Mills is asymptotically safe in 5D; technically up to  $D < 5.26$ . See [145-149,197] and references therein. Such 5D QFT means either KK compactification (Yang Mills [146], or supersymmetry (super yang Mills [150]) / super gravity (Chern-Simons [203])).

Some super Yang Mills and SUSY may exist at 5D, and at some dimensions above (e.g., 5D, 6D and 10D super Yang Mills [151,152]). They usually involve CFTs [144,152]. One can also consider higher dimensions with Topological QFT [c50] / Chern-Simons [153]. For 6D, we have for example [142,204,205].

It is apparent that typical QFTs start to have has problems above 4D, with only an asymptotically safe 5D Yang Mills theory that can be formulated, predictably based on the leakage model discussed in [14,86,197]. Besides, at 5D and above, we have only supersymmetric (SUSY) at 6D, and above, and, or Chern-Simons / topological [364] fields that appear automatically as components of systems of higher supergravity [155,250]. The link to supergravity and superstring is key, as we already explained that when extended structure appear, instead of  $\sim$  point particles like massless Higgs bosons, the density issues with higher dimensional random walks reduce, and it is possible to recover potentially sensible Physics in higher dimensions. A string-like structure, or tube, would now extend the theorem to accommodate 7D spacetime/Physics, and branes would support more. *Note added on August 1, 2025: But it does not matter, as supersymmetry is not physical per [250,262,296,307].*

The unphysicality of supersymmetry [1,8-20,22,62,81,250,262,296,305,307,308] precludes the physicality of all these cases. They are at best mathematical theories built on the random walks and fluctuations of extended objects, and therefore the theories do not have to be able to be well behaved. Indeed, we know that supersymmetry is not acceptable in our real spacetime as a consequence of section 4, and [1,8-20,22,62,81,250,262,296,305,307,308]. It seems that QFTs and related CFTs/Chern-Simons/Topological fields/SUSY maybe trying to tell us something: there is not conventional / non supersymmetric physical (i.e., physically acceptable and relevant) QFT above 5D (Yang Mills), because there is no need for it. It wouldn't model Physics with its infinite variable integration calculus (following the terminology and point of view of [140]). Below it works fantastically, with QFT including QED, the most accurate theory out there. It is in line with Wigner famous paper on the astounding capabilities of mathematics to model Physics [206]. Maybe it also goes the other way around, no need for mathematical models that can't represent well aspects of our world... In fact, 5D Yang mills is explainable either by the ability to model Hadrons via KK compactification (towards 4D) [207] and references therein, or, as a Physical mechanism and model, by the physical leakage (from 4D) model proposed in [14,197]. Or, maybe, (and up to 7D), the QFT encountered reflect the multi-fold mechanisms in the apparent embedding space built by and to support the multi-folds, and their Kinematics and Dynamics [1,8-10,22,23,49,51,62,77,259,265,268,279]. So, there we go, there is a physical reason to have 5D, or less Yang Mills, and nothing else formulable, and appropriately behaving.

Anyway, we take from the above another very strong hint that that our (macroscopic) spacetime is 4D.

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<sup>5</sup> Note that there are different electromagnetic (Maxwell equations in higher dimensions), QED and KK-like electromagnetic proposals in higher dimensions, e.g., [132,208-210]. It is not that this is hard to achieve, especially with classical equations. But quantum stability, consistency, viability, absence of ghosts and renormalizability or asymptotic safety are the unknown, and in general not satisfied. We will not dedicate much more here only stating that renormalizability of QED so far works for  $D \leq 4$ , and, to our knowledge, it is not the case for higher dimensions [327]. Simply put, it is not modeling Physics, so it does not have to anyway. Our reasoning with quantum walks justified these challenges without being restricted to perturbative QFT constructions / analyses.

## 5.2 Explaining QFT Dimensional Limitation With Random Walks

Since [1,8-10,22,30,60,63,64,89,177,258,259,265,280], we are keen to argue that random walks behind all Physics, including gravity and spacetime reconstruction, with its 2D random walk and (multi) fractal, non-commutative, yet Lorentz symmetric structure at very small scales, its concretization, inflation, expansion, behind particles, the multi-fold gravity electroweak symmetry breaking, the ultimate unification (UU), and of course QFTs that supposedly model much of it. *Note added on August 1, 2025: See also [282,290,296,303,307]. These references reinforce that view.*

In section 3.1, we saw that random walks, once involved in spacetime reconstruction, also explain why spacetime must be 4D, and nothing else, if we accept multi-fold reconstruction [1,6,63,265,296,307], or the Planck scale structure extracted from [6,307], even without any multi-fold discussion. A reader not liking any of these arguments can just rely on [122-124], if accepting causality, and GR, as the triangle progression used in [122-124] can then be equivalently modeled by random walks on a discrete spacetime [211]. This is exploiting the Lorentzian properties of spacetime, especially aligned with one generated by random walks [1,23,30,60,177,265]. However, while this can also handle non-smooth, i.e., non-differentiable spacetime, can it also explain QFTs, and dimensions able to accommodate them?

QFTs are built on spacetime, in a background-dependent manner, an issue associated by LQG supporters for modeling quantum gravity (see [1] and reference therein), and they characterize at higher scales the effects of the random walks of particles involved in UU [1,6,43,59,60,63,67,177,265,296,303,307]. Therefore, a priori, we can expect that QFTs are also modellable with random walks. Otherwise, our approach would just be inconsistent. Furthermore, we know that 2D CFTs model free boson random walks. See [63,82,212] and references therein.

Fortunately for us, and as a confirmation of the analysis in the previous paragraph, it has recently been shown that spatial 1D (quantum) random walks model well QFTs in 2D spacetime [156]. With random walks in 2D spacetime, we know that we can model free bosons, with say CFTs [63,82,212], or [159,160], and references therein. However, the approach of [156] has challenges modeling particles in higher dimensions than 1d spatial. With random walk quantum cellular automata in 2D, we know that we can model free bosons e.g., applying in [156] the symmetric construct of [158], or considering the boson random walk story from [63,82,212] and reference therein. But it, the straightforward repeat of the approach of [156], does not work not for fermions.

The challenges with fermions has since been addressed in [157,158], with a trick that allows automatic model / simulation of fermions and bosons by (quantum) random walks, via the quantum cellular automata. QFTs up to 4D spacetime can therefore be modeled by random walks through quantum cellular automata.

*Note added on August 1, 2025: See also other derivations showing the equivalence between (2D) random walks and relativistic QM / QFT [334].*

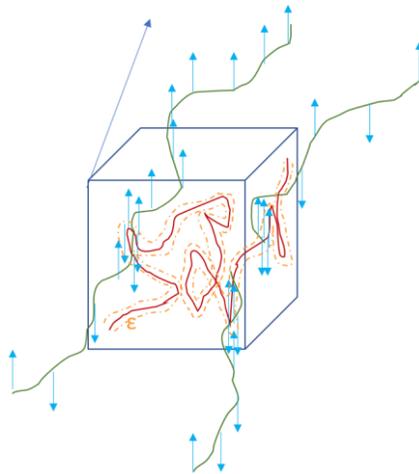
With this, fortunately, the consistency of (multi-fold) spacetime reconstruction model is confirmed. *Note added on August 1, 2025: Fermions appear at different scales from bosons, like the massless Higgs bosons and massless gauge bosons, and are built on them [64,296].*

Here is how to see that 4D spacetime is the dimensional limit for QFT:

- QFTs are based on continuous calculus and background dependent on a continuous well behaved spacetime manifold. They can well approximate discrete spacetime physics [1,53,265,276,294,301,307] (on a random lattice built by random walk), but that is true only if the random walks that model the QFTs can be dense enough to the continuous manifold approximated by its (re)construction by random walks (the ones that model the spacetime [1,6,265,296]).

- With [158], we see that, after the trick of picking symmetric and antisymmetric sub-Hilbert spaces, we have reached the end of the mathematical tricks to address the fermion modeling challenges.
- To go further, e.g., to 5D, and avoid the no-go theorem of [156], we have to construct a 4D QFT as in [158], and a 1D random walk to start in the 5<sup>th</sup> dimension at each point. However, per the Polya's theorem, the 4D QFT is at best dense in the 4D spacetime, which will further reduce the density in 5D (and further more in larger dimensions): QFTs can't be define consistently above 4D, yet it could for a while, hence 5D may be possible as for 5D Yang Mills where it is explained by leakage [14,86,197]. Higher dimensions are less and less dense, and suitable except possibly at very small scale (UV point); and so the yang Mills limit at 5.26 for example (See [197] and references therein). This is illustrated in Figure 2. Such forays in some fifth dimensions are explicitly encountered with the multi-fold mechanisms [1,6,8-10,22,265,296], and the multi-fold dark energy effects [1,27,63,265,307], and discrete spacetime non-commutativity [307]. But they are inside out, not widespread beyond random walks in the multi-fold to support entanglement (or the wavefunction as in [68]), vs. theories build on a full, even if compactified, space.
  - Note that Yang Mills can then be interpreted as the result of the fact that in higher dimensions, if spacetime is supersymmetric, superstrings and extend objects have actions that include GR and Yang Mills (particles and) interactions. See [14] and references therein, and overview and references in Appendix C.

Of course, just as leakage can help, it is possible that other mechanisms would allow some higher dimensional models (we already saw earlier that some exist at 10D, see the mention of super Yang Mills), like walks of extended objects. As we will discuss in section 10, muti-folds can generate AdS(5) and fields, and alternatively their superstring analogies can provide more dense regions longer. This is how to explain the other exceptions.



*Figure 2. Fields in 5D spacetime can be defined by the random walks through the quantum cellular automata. But the random walks are not dense in the space of the 5D spacetime: we do not have a continuous QFT. Along the path dense in 4D spacetime, in an external region  $\epsilon$  in the 5D spacetime, density can be enough (where there hasn't been enough distance to diffuse and lower density, there may still be the possibility for a (local) QFT, that can itself repeat by random walk in the fifth dimension). These forays in fifth dimension, are related to multi-fold dark energy effects and (discrete) spacetime non-commutativity [307].*

Also, and although we have not yet explored this idea further, the possible relationship between supersymmetry and non-conservative random walks could also contribute to making super Yang Mills available in higher dimensions [213,214], where random walk crossings annihilate and generate new ones in opposite directions; something that may be seen as introducing a fermion for every boson (i.e.,  $\sim$  fermionization, the opposite of

bosonization<sup>6</sup>), and could increase the density to way higher levels (in fact up to stable 9D, and with extra dimensional effect discussed above. See <sup>6</sup>). It could be worth investigating as another way, or another contribution to explain the SUSY fields and their ability to have higher dimensional limits. It may be for future work, but it is interesting that it also stops at 10D as for superstring theories (11D with the M-Theory). *Note added on August 1, 2025: Since this was written, considerations on the proposed supersymmetry/random walk analysis can be found at [250], where we provide more motivations for modeling supersymmetry this way. But density and repulsion considerations remain a good argument.*

Note that the quantum cellular automata are walking on regular lattice, not the random partially concretized lattice encountered in [1]. However, it should not matter for the discussion here as the objective is neither to discuss discreteness, or reconstruction, but just model suitably QFTs; and, for QFTs, we do this at larger enough scales versus Planck scales. As the steps are very small, at larger scales one can't distinguish the random (Poisson) sprinkling from the regular lattices [1,6,7,9,10,23,30,60,250,265,268].

However, tying the limit of a stable spacetime to 4D, via random walks, and 4D QFTs via random walks in quantum cellular automata matters. It is why QFT on continuous spacetime, and especially Yang Mills, and the SM built on it, can model so well Physics in a 4D spacetime, especially if it is itself built by random walks [1,16,60,63,82,83,177,258,265,296], thereby providing an answer to Wigner marveling at the efficiency of Mathematics to model Physics [206,256]. It is also why spacetime evolves smoothly towards UV fixed points, CFTs and the right behaviors of a dominantly 2D process for spacetime at very small scales, where the model holds. It's all the same, and if, as we stated in [1,5-7,14,58,196,197], gravity contains Yang Mills, and Yang Mills contains gravity, all also contained in the Hilbert Einstein action, it was obvious and expected that Yang Mills had to be modellable by random walks. We have now shown how. We have also discussed options for 5D Yang Mills and super Yang Mills in higher dimension, without attaching physicality to what happens in 5D and above.

*Note added on August 1, 2025: Random walks and QFT also imply non-commutative discrete spacetime, as does GR [1,6,30,64,250,265,282,296,301,307,355,361].*

In addition, the fact that what is known about higher dimensional QFTs, when they may exist, is mostly based on CFTs and/or UV point considerations (or possibly as SUSY, and topological / Chern-Simons versions), can be justified in our approach as follows: at very small scales, random walks emanating from 4D spacetime are dense around the source, as illustrated in Figure 2 (and key to the analysis in [14]). That is why leakage is possible, and this is where QFT can still be well modeled. Above only random walks of extended objects like strings or branes could help higher dimension QFTs, a mathematical-only concept, and it is why higher dimensional CFTs, the symmetry of superstrings, or field typically expect supersymmetry, which is required for consistent superstrings or super gravity (See Appendix C). *Note added on August 1, 2025: [265,296,307] show that supersymmetry is not physical. So, considerations about extended objects and superstrings, supergravity or M-theory are purely mathematical. Also, we already know that superstrings are unphysical, not just on the basis of supersymmetric considerations [1,8-20,22,62,80,81,250,259,265,308]. Appendix C may also help.*

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<sup>6</sup> Fermionization requires dense and strongly interacting bosons: stopping the random walks, and duplicating into two new random walks flying apart bosons. Such a strong annihilation and a spatial separation amounts to a Pauli exclusion principle [215,216], i.e., a fermionic behavior: we may have a dense enough supersymmetric theory. It would be of interest to see up to what dimension the density is ensured. With the need to now combine two walks densely enough, one could argue that it go up to 9D spatial ( $(3D + 1D) \times 2 + 1D$  for the 2 random walk starting points). Supersymmetry allows extended objects like strings and branes and therefore higher dimensions than 4D. With et consideration above, the limit for branes is therefore 9D spatial in a 10 D space (adding time). The branes can therefore be embedded in a maximally 11D space, as for the M-theory, where the extra dimension allows 11D for supergravity. For references refer to [1,23,62,63,235,250,265,289] and references therein. The case of 26D, for bosonic strings, is consistent with our model. It is discussed in Appendix C.

Of course, reverting to our arguments above, at the smallest spatial scales, spacetime becomes 2D (we will explain that absence of contradiction later on). At 2D, all is well modeled by random walks and well behaved. UV points may exist, and be scale invariant as CFTs etc. See [1,8-10,13,16,17,60,63,82,83,177,258,259,265,279,296,301,307].

An important consequence of this analysis is that spacetime is constructed and structured by random walks [1,6,43,60,63,67,82,83,177,258,259,265,279,282,289,296,301,303,307]. Now, we see that such structure can model QFTs at the same dimensions: random walks (Levy and variations) are the fundamental construct of Physics (and its random fractal discrete (non-commutative) spacetime, for spacetime/gravity, and QFTs (and possibly even supersymmetry, even if unphysical [13,15,16,258,296,307]) [1,23,30,31,60,63,64,89,258,307]. In fact, a supersymmetry-compliant spacetime like (asymptotic) AdS may also result from superstring random walks as discussed above, and in section 10. In any case we are not stating that higher dimensional fields do not exist, but rather that they are harder to define, construct, or model, and, arguably, with more tricky or problematic behaviors, because not constrained by physicality. It is mainly because of the use of random walks of extended objects, and supersymmetry that introduces stronger interactions (repelling) between the random walks, as discussed earlier in this section.

## 6. Chirality

Without Lorentz invariance of the chiral matrix  $\gamma^5$  in odd dimension  $D \geq 5$ , it is not possible to define (physical) chiral fermions in spacetime where  $D \geq 5$ , and  $D$  is odd. The SM involves chirality and chiral fermions. See e.g., [23,60,137]. Therefore, it is clear that our universe cannot be a macroscopic spacetime with  $D$  odd and  $D \geq 5$ . Interestingly this recovers the requirements for satisfying Huygens' principle, typically considered with light/optics and electromagnetic waves, i.e., bosons.

## 7. Space Time Matter Induction and Scattering and the SM

### 7.1. Kaluza-Klein Dreams and Dilemmas

[1,8-10,22,23,29,30,49,51,62-64,77,258,265,279,303] show how the SM, or more correctly the  $SM_G$ , i.e., the SM with gravity effects not negligible at its scales [1,8-10,259,265,279], implies that between 7D (unconstrained Kaluza Klein (KK). See [49,51,62] and references therein), or 11D (conventionally constrained KK. See [62] and references therein) embedding spaces, as the SM requires  $1D + 2D + 4D$ , to add to the 4D spacetime, to capture respectively electromagnetism, weak and strong interactions) in to recover the SM interactions via induction/KK mechanisms.

As shown in references cited in [49,51,62], even if constrained KK could induce the SM, and no other problems is encountered, like stability problems [217] (albeit it may be addressed with fermions in the multi-fold theory [177]) of the dilaton [161], the number of 11 dimensions is problematic for so many reasons: e.g., incompatibility with QFT generated by 2D random walks (give or take the possible exception of a super symmetric, or super conformal field) as discussed so far, incompatibility with the SM (e.g., if gravity is asymptotically safe), and incompatibility with chiral fermions (and chiral interactions), incompatibility with the Huygens' principle, etc.), uncertainty in terms of renormalizability / asymptotic safety.

The renormalizability and chirality may be circumvented by introducing superstrings, supergravity or the M-theory, but we are back to the same issues due to supersymmetry and dimensions  $> 6$  still make the solution incompatible with the SM, if gravity is asymptotically safe, which we claim that it is in a multi-fold universe and in a conventional universe [1,6,13,16,17,63]. *Note added on August 1, 2025: Then we now know that supersymmetry is not/never physical [250,296,307,308].*

In addition, (a) dilaton particle(s) must be accounted for when the dimension compactifies, or the volume of compactified part varies [161]. No such dilaton is known in the SM, except maybe as Higgs field<sup>7</sup>, as proposed for example in papers like [162], a little bit like the inflaton proposals based also on the Higgs, as proposed (conventionally and in multi-fold theory) in [27,28], and references therein.

There seems just no way out for constrained KK theories: we can't be in a constrained (i.e., conventional) KK spacetime that supports the SM. We should not assume that conventional KK are physical, just as we already concluded that related superstrings and their Calabi-Yau manifolds [163], playing an analogous role to KK extra dimensions, are not physical, including, besides the challenges of incompatibility with the SM if gravity is asymptotically safe, the incompatibility of supersymmetry, and of superstrings, with de Sitter spacetime, i.e., spacetime with positive curvature, or the string swampland problem [1,11-18,20,81,250,265,296,307,308].

## 7.2 The Multi-fold Space Time Matter Induction And Scattering Along With The Gravity Electroweak Symmetry Breaking: KK, The Rebirth

The multi-fold theory proposes a variation on the 5D space time matter induction, which is an unconstrained KK, without compactification [166-168].

Let us summarize the principles (reusing text from [10]).

Multi-folds generate at each location a 7D embedding space that can follow GR in 7D, and be flat or Einsteinian [1,49,60,62,268]. The effects of multi-folds are essentially with a spin-2 symmetry [1,23,265,268], which also explains the holographic principle of gravity [1,85,265], or the area laws of black holes. The spin-2 symmetry implies the embedding space effects are mostly 5D because paths on the multi-folds are essentially a grand circle on each fold. In the 4D multi-fold spacetime, the embedding space is only felt (inside out) through the multi-folds as  $\epsilon$  infinitesimal and essentially 5D.

No Physics takes place in the multi-folds, except for the massless and massive (when they exist) Higgs bosons and right-handed neutrinos, per [1,9,10,265,268] and references therein

Particles in 4D spacetime feel essentially a 5D, but it is actually a 7D when it comes to the symmetries of the solutions/solitons induced or scatterings, spacetime through the  $\epsilon$  region at entry, exit, or mapping points. It is an additional reason for the tenancy principle discussed in [1,9,10,265]: as each location only sees multi-fold due to their involvement with multi-folds, they do not see other particles, e.g., like the entangled ones, or other particles crossing the support between them, unless if they are already overlapping (wavefunction wise) in spacetime. The (massive) Higgs boson everywhere in spacetime and at the entrance and exit being the only exception, and due to

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<sup>7</sup> It may be a role played by the Higgs in multi-fold theory as we will discuss later. This would be the best possible justification of why the Higgs field appears, and exists in multi-folds [28,29,268,296,302,303]. So far, we had explained the consequences of the Higgs being associated to the multi-folds, but not so much why it was that way. The reader should assume that, going forward, this is a plausible aspect of the mainstream multi-fold theory. *Note added on August 1, 2025: More details exist in [28,29,268,279,289,296,302,303].*

the interaction with it to enter or exit. Then, let us also consider the discussion of dilaton from the previous footnote, and again towards the end of this section.

Multi-fold 5D space time matter induction (actually effects of 7D, but mainly 5D when it comes to dominant solitons geometries, geometrical objects impacting the 4D spacetime), and scattering with 5D/7D objects, when feeling the embedding space in an  $\epsilon$  region, and encountering a 5D/7D soliton, recovers particles and interactions in the 4D multi-fold spacetime that match the SM particles, fields, interactions and symmetries [23,29,30,49,51,62,64,77,177]. It can also be seen as an unconstrained Kaluza Klein theory. The 7D space can now support, and explain, the symmetries of the SM [23,51,62,77,17]. The multi-fold least action principle ensure that the SM, or SMG, is always what it is supposed to be [77].

In other words, we can recover the SM in multi-fold 4D spacetime via space time matter induction. The remaining challenges of chiral fermions, not available in 5D or 7D, is resolved in the 4D spacetime by the Multi-fold gravity electroweak symmetry breaking [4,9,10,29,30,52,53,60,64,63,296,303,307]: it (globally) orients spacetime, and makes some microscopic black hole particles rotate. Above that energy level, it only locally exist around massless particles as patterns of Higgs random walks. *Note added on August 1, 2025: Consider also the details and interpretation described in [303].*

The particles exist only in 4D spacetime, and only feel the multi-folds from such a 4D spacetime, therefore resolving the challenges of the absence of chirality in higher odd dimensions, of dimensions to compactify (embedding space is just no visible), or of incompatibilities between say 7D and the SM: spacetime is 4D even, chirality and Huygens's principle are making sense, QFT are well defined and behaved, it is the normal number of dimensions for a GR-based stable spacetime (if flat or dS) etc. [318,331,377-381], yet taking advantage of KK induction and scattering effects from 7D, dominantly 5D, in a  $\epsilon$  region. Gravity can be asymptotically safe [13,16,17,60,63,82,83]. Higgs and neutrinos are recovered together by scattering from within the multi-fold, as already discussed in previous sections [50,49,96,233].

Non-commutative theories in a multi-fold universe are key to ensure that we can fully recovers the SM [1,30,63,64]. *Note added on August 1, 2025: QFTs on a discrete spacetime imply non-commutativity (because of the resulting discontinuous paths in the path integral), which is key to ensure the possibility physicality of fermions [6,30,64,282,294,296,299-301].*

Note that we do not say that the 7D embedding space is physical, beyond the portions ( $\epsilon$  neighborhood) seen offered (inside out) by the multi-folds, that the 4D spacetime particles feel at the points of entry, exit and mappings [1,265,268]. This way, 4D Physics is not 7D or 5D physics, and so chiral fermions are possible (as in 4D), and we do not have a challenge of explaining why 3 large, i.e., not compactified, dimensions would not be visible to us, which is one of the reason, (besides the automatic compactification discussed in section 3) why superstrings have had to compactify their extra dimensions because they do not have a mechanism to hide large extra dimensions and they need some Physics into them. Also it does not hurt that extra dimensions are expected to automatically compactify [132,192-195]. Such compactification is key to the superstring dualities.

In the multi-fold case, we have no physics in the multi-fold (other than with the Higgs) and only feelings of  $\epsilon$  neighborhoods, nothing to see or feel macroscopically, other than the 4D consequences [1,8-10,22,265,268,279].

As already mentioned, the dilaton is not needed in the multi-fold space time matter induction and scattering. However, we know that in the multi-fold theory, the Higgs boson appears in the multi-folds (See the tenancy model in [1,9,10,268]), including in front of (entangled) right-handed neutrinos, and their anti-particles at the entrance and exist of the multi-folds [29,41,49,96,233]. The latter ensures traversability of any wormhole implementation of multi-folds, if wormholes are to be involved [6,233], and stability of the underlying KK solution, because of the presence of fermions [96]. While there is no compactified dimension, and no volume is being modified in any dimension, are involved, multi-folds follow the entangled particles mapped in the embedding space, and the multi-folds have their own kinematics and dynamics of expanding to follow the attached entangled particles [1,8-

10,22,76,259,265,268,279]. So, in a multi-fold universe, there might still be a dilaton in waiting, and the Higgs could implement this dilaton, just as it can implement the inflaton in [28], or account for the dilaton/scalar of the double copy gravity when particles are massive [58,196,197], and 2D gravity [1,16,17,28,63,67,84,251,265,279,289,296,302,307], making it all consistent. It also has the unique advantage to explain why Higgs is naturally in the 4D spacetime and multi-folds [1,8-10,265,268,279,296,307,482]. This explanation is presented for the first time in this paper, even if mentioned, by topic, in passing in past papers.

At this stage, we have established that in a multi-fold universe, spacetime is 4D at large enough scales, and it seems (/feels) embedded in a 7D spacetime generated / felt in an  $\epsilon$  neighborhood at each entry, exit or points mapped to the multi-folds. It is 7D, which is required to support the symmetries of the SM or  $SM_G$ [23], and support space time matter induction and scattering.

As the embedding 7D spacetime is a  $\epsilon$  neighborhood created by the multiple-folds, it is and will be a extra 3D spatial dimensions, dense enough to support the right fields there: the massless Higgs boson , i.e., the dilaton associated to the multi-fold dynamics following the attached entangled particles (or in the case of the W-type multi-fold hypothesis, following the evolution of the wavefunction [68]).

## 8. 2D, 3D, 4D? Can We Try To Get Our Acts Together?

In all consistent theories of gravity, we see a dimension reduction of spacetime / gravity [1,82,83,218,219] to 2D or 3D. The 2D to 3D evolution is discussed in [1,82,83], and relates, for example, with the transformation essentially to everything massless above the multi-fold gravity electroweak symmetry breaking [53,63,60,303], give or take massiveness, due to chiral symmetry breaking and confinement as long that confinement exists [53,60,63,289,296,302,303], which justifies what seems to be a reduction to 3D that then evolves into a reduction to 2D. Around when reduced to 3D scales, conventional physics also tells us that spacetime is non-commutative [220], just as in the multi-fold theory [1,23,30,31,63,64,265,282,288,289,296,303,307].

A Random walk is inherently 2D (time and direction) with, at larger scale considerations, the plane where it moves then the volume, at even larger spatial scales, as illustrated in Figure 3.

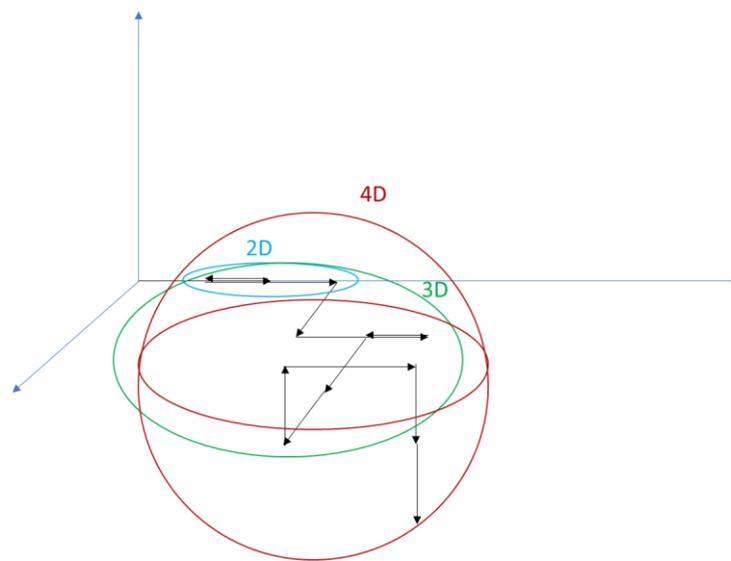


Figure 3. It illustrates how random walks are initially at lowest spatial scales a 2D process, then a 3D then eventually a 4D process. Also, per [83], when massless, 3D appears 2D as all particles move at  $c$ , making the 2D process dominant till larger spatial scales [1,265].

Note added on August 1, 2025: [289,303] shows that attempts at creating additional dimensions and non-commutativity are essentially equivalent, and a source to the multi-fold dark energy effects [1,8-10,22,27,30,33,64,75,259,265,270,279,296,305,307,308], which may be time varying. So multi-fold dark matter effects results (partially at least) from non-commutativity of a discrete spacetime [6,282,303,307].

So with 2D physics, we have asymptotic safety of gravity and renormalization/asymptotic safety of QFTs/Yang Mills/SM, or  $SM_G$  as discussed in [16,17,30,31,53,63,73,289,296,303], along with UU [1,6,43,60,63,67]. And 2D Physics is all that matters [258].

All this means that spacetime is macroscopically 4D, not 2D, but when looked from the point of view of small enough spatial scales, it appears 2D (then 3D, when increasing the spatial scales), as well as for multi-fold universe: non-commutative while Lorentz invariant thanks to the randomness of the walks leading to realized locations according to Poisson distributions that preserve Lorentz invariance [1,23,30,31,32,63,64].

It matters. For example, when considering and applying the Polya's random walk theorem, the spacetime is to be understood as 4D, not 2D. Indeed the 2D processes develop in a 4D spacetime (built in real time or by previous random walks; anything larger stalls and withers immediately), that is reconstructed and concretized [1,6,31,63,64,177], as well as not in a larger dimension spacetime (5D and above), per section 3. Note added on August 1, 2025: [296,303,307] also show how (entangled) random walks can then equip the resulting spacetime with dot products, distances, area and Hamiltonian/conjugate variables. Our reasoning in that paper (Appendix B in [307]), does not require differentiability, which makes the reasoning more generic than in the references relied on in [307], and suitable for a spacetime actually discrete, non-commutative, fractal and possibly not smooth [1,8-10,22,31,30,60,64,89,259,265,276,279,282,294-296,307,308,319,320].

Note added on August 1, 2025: Appendix B in [307] explains how spacetime with distances, areas and Hamiltonian, in a continuous smooth/differentiable or not, can emerge from dense enough 2D random walks. The fact that in our universe QED does not confine at SM and larger spatial scales, and spacetime appears continuous, shows that the processes of Appendix B in [307] must take place, otherwise QED would confine, as it does in 2D and 3D (see after and also appendix B here, and [60,63,296,303,307]). Physically this is because in Figure 3, we not just have motion in new dimensions (thwarted when going in the fourth spatial one), but also the density in each of the existing dimension is such that jumping along a path or across paths of random walks are equivalent, as hinted in Figure 4. When that is the case spacetime is really 4D and continuous at large enough macroscopic scales, and the constructs discussed in Appendix B of [307] can be developed.

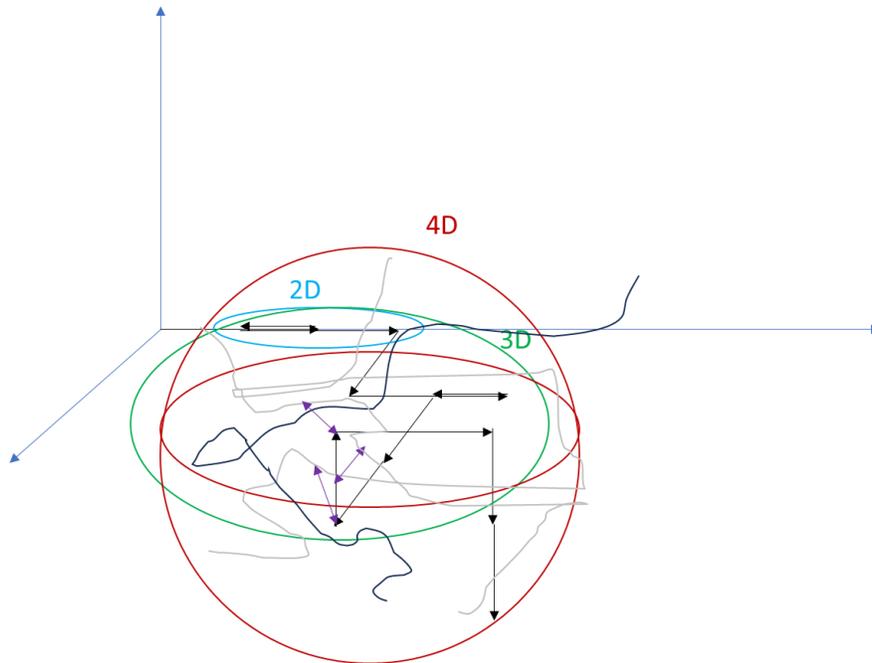


Figure 4: This figure shows a denser case of Figure 3, where, as hinted in purple/violet, distances between random walks concretized locations is equivalent/same order as the ones on a random walk path. Then jumps (think of [6], and figure 6) are no more linear but become 3D then 4D, then continuous.

## 9. Bound States, Stability, Orbits, Collisions And Escapes

As we will see the go-to papers on this focused on classical / semi classical Physics [167,170,171]. We will extend the analysis to cover also quantum Physics, and QFT, relying on the 2D random walks. It is a key contribution of this work.

### 9.1 Ehrenfest's Approach For The Conventional Universe

Inspired by the papers of Ehrenfest [170,171,321], Tegmark provides his own analysis of the spacetime dimensionality [167]. These authors show that spacetime must be 4D if we want to have stable bound states with closed orbits, as encountered with, for examples, atoms and galaxies in our real universe.

Here are a few key highlights:

- Ehrenfest showed that [170,171]:
  - At spatial dimensions strictly larger than 3, no bound state (classical atoms, cosmic or quantum (Schrödinger)) can exist because interacting systems always end up colliding or escaping away

from each other, never entering into stable / closed orbits [169,170,322,323] The system is always unstable<sup>8</sup>.

- For spatial dimension of 3, there can exist stable orbits in Newton gravity [169,170], and in GR [170,171]. It is a miracle, in the words of Ehrenfest, that closed orbits exist in curved spacetime, and escapes to infinity are also possible, as is the hydrogen atom, including with relativistic effects as in [170,171] and references therein. Also, it is only in spatial 3D that the fine structure constant is dimensionless [170,171], per QED, our most precise physics theory so far. A fine structure constant function of the units selected is not what we observe in our universe.
- For spatial dimension of 2, escape to infinity are not impossible, but the gravitational potential does not vanish/become constant at infinity, which excludes this option for our real universe. Also while one may have stable circular trajectories, they are not closed and hence not orbit [170,171].
- For spatial dimensions of 1, we recover 2D gravity like JT gravity (see section 12), orbits imply no relative motion, and therefore they are unstable. Only going from 2D to larger scales à la Multi-fold spacetime reconstruction makes it physical [1,6,265,296,303,307]
- [171] and references therein also mention Withrow's biological consideration, i.e., the need to be able to link neurons without intersections, something possible in our universe, as another reason why 2D spatial can't support enough complexity: systems built in 2D cannot be complex enough for life, or many other systems. The need to support neurons crossing (and not intersecting) between complex bodies and brains is motivated for example in [234]. Without this capability, no perception of a 3D world would be manageable with 2D neural network representations, as seemingly encountered in the brain.

All this indicates that our spacetime must be 4D, i.e., 3D spatial. As discussed at the smallest scales it is 1D spatial evolving to 2D spatial then 3D and stopping there.

Appendix B provides some considerations on the interaction potentials e.g., Coulomb potential, in different dimensions.

## 9.2 A Random Walk Qualitative Perspective On Stability And Bound States For QFTs In Higher Dimensions

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<sup>8</sup> We note that [169] criticizes using stability as criterion. The authors argue that systems, or particles, which exist and are stable in a larger dimensional spacetime, may be unstable in 4D spacetime, and therefore that this may not be a valid criteria to decide on the spacetime, or a system, dimensionality. It may be adequate for their examples and considerations, but it does not apply here. Indeed, such an argument seems unapplicable to the discussion here as Ehrenfest showed that there is just no stability for any spatial dimension above 3D spatial: we don't have an issue of stable system becoming unstable at a lower spatial dimension. [169] also argues that higher dimensions remove singularities, think of black holes, which may be a criteria against 3D spatial when black holes are singular. It is unclear if this really helps, as such higher dimension black holes would have to form without enough gravitation interactions (see Appendix B), and stable orbits. In any case [169] propose another experimentation, which may be realizable in the future. We believe however that the point is moot with the results reported in sections 2.3 and 2.4. *Note added on August 1, 2025: Furthermore, we know that multi-fold universes have no cosmological or gravitational singularities, and argue that our universe would not have any naked singularity. So singularities may not be the best criteria either [1,4,66,182,b16,b29,b35,b40].*

Section 9.1 analyzes bound states for classical and simple quantum mechanical systems. As we also focus on QFTs in different dimensions (e.g., see section 5), it would be good to validate the implications of the above for QFTs, if at all.

The absence of guaranteed recurrences of random walks in  $D \geq 4$  spacetime, means that interactions weaken rapidly at these dimensions (and closed orbits are impossible). While the paths may still be dense in  $D=4$ , as explained in earlier sections, they certainly aren't for dimensions above 4, unless maybe if associated to SUSY, CFTs. Topological fields or strings/branes (i.e., extended objects, discussed earlier, which elevate the density to higher dimensions). Therefore, virtual particles, i.e., carriers of QFT interactions, do not always reach the other parties, hence reducing the intensity of the interaction as the spatial dimension increases. Actual dependencies in the distance between particles are discussed in Appendix B.

As a result, stable closed orbits become impossible above a certain dimension, which we would expect to be above  $D=4$  spacetime (as no more dense enough) for QFT (without extended objects). It is what section 9.1 obtains. While [1,60,98] argue for a mass gap and Yang Mills viability in a 4D \*discrete\* spacetime [60], here we conjecture that around 5D we would not have stable orbits, and therefore no gluon balls and no mass gap: Yang Mills in 5D would probably only exist via spacetime fluctuations (leakage) due to quantum uncertainties [14,86,197], not really because 5D force carriers would be sufficient, they need to be complemented by the leakage effects, and won't exist far away between 5D (generalized) charge carriers. Overall, we see some relation to results like [173].

At spatial 2D, i.e.,  $D=3$ , the only other reasonable spatial dimension to consider, interactions are maximized. Escape becomes harder and we would rather have confinement. Again this is consistent with section 9.1. Also, it is consistent with for example 3D QED, and the Schwinger model, now behaving similarly to the strong interaction with confinement [60,63,136,174-176] (and axial chiral symmetry breaking, this being more a consequence of the apparition of confinement (See discussions in [60,296,303,307] and references therein). It motivates UU [1,8-10,22, 6,43,59,60,63,67,177,259,265,279,296,303,307], and the dark matter conjecture [59,303].

With this reasoning, and stronger possibilities to form bound states, we expect QCD at 3D and 2D to have a mass gap way more naturally than in 4D [1,60,98], but we would need further work to decide if discreteness remains a requirement. It may be the object of future work. If Physics is a guidance, discreteness of the 2D, and 3D, spacetimes, implies that it remains probably a requirement. Also, the absence of actual closed orbits may not favor orbits as in figure 5 of [60]. We suspect that it prevents guaranteeing a mass gap, without involving stable gluon balls. This analysis is complementing our mass gap resolution papers [60,98].

### 9.3 About QCD And QED/Electroweak Below The Gravity Electroweak And Chiral Symmetry Breakings At Higher Energies

In [1,4,29,52,53,60,63,b10,b16,b30,b40,b47,b54,b58], we distinguish between behaviors below and above the (multi-fold) gravity electroweak symmetry breaking. When raising in energy, or looking at smaller and smaller spatial scales, we loosely model a transition from mostly massive particles (with Higgs condensation) to massless particles resulting from random walk patterns of massless Higgs, and recognizing some interim plasma state if density is high enough at high enough energy, so that confinement breaks, or is irrelevant as we can't distinguish freedom from confinement if all particles are densely packed, before potentially reaching a very densely packed BEC [60,63,296,303,307,308,315].

It is well known that confinement and associated chiral symmetry breaking convey mass to particles or environment by adding energy content to the soup of quarks present in particle (e.g., hadrons or nucleons) or

plasma. See [60,221] and references therein. *Note added on August 1, 2025: The mechanisms and microscopic interpretations are described in [60,63,296,303,307,308,315].*

Also, in 2D QED, the Schwinger process shows exactly how interacting massless fermions cancel out massless bosons, leaving a massive boson / photon, due to chiral symmetry breaking and associated confinement. See [60,63,136,175,176] and references therein. Also, in [63,137], we see that fermions are key to the existence of Maxwell and Yang Mills interactions, via these massive bosons that reflect confinement. Going smaller in spatial scales, confinement and chiral symmetry breaking continues until densities / pressures render confinement meaningless, or until quark gluon plasma forms with loosened confinement (and hence with massless particles (*Note added on August 1, 2025: it is consistent with [296,303,307], where plasma formation can be seen as a path to forcing masslessness*)) [60,221,222], or when one reach dimensions smaller than the fundamental particles and UU starts to dominate [1,6,43,60,63,67], and everything at these scales appears massless. These are slight additional details added to the story told so far in previous papers [1, 6,43,60,63,67]. Here, what is important is to understand that, above the gravity electroweak symmetry breaking energy scales, we do not have a Higgs condensate any more, and particles instead consist of random walk patterns, but they may keep inertial mass coming from the energy associated to the confinement/chiral symmetry breaking and/or anomalies (think the extra energy resulting from the axial chiral current [b93] impacting the random walk patterns; this is where our tentative image of spin may also help [1,64], as it may allow us to imagine this as the energy of an extra vortex. With the caveat that we are not claiming that such vortex is how to see axial chirality current, symmetry breaking, and possible associated anomalies. *Note added on August 1, 2025: See [296,303,307] for more details on what we propose that actually happens*).

## 10. About AdS vs. dS

### 10.1 Spacetime with Negative Curvature / Cosmological Constant

There are many indications that our spacetime is slightly asymptotically dS (de Sitter), with a strictly positive spacetime curvature and cosmological constant. It is therefore not asymptotically AdS. Here are some entry points of experimental confirmations [1,18,27,223,259,265,279] and references therein, although we must admit that the subject remains controversial, and, at times, some argue that it is actually flat. *Note added on August 1, 2025: by now we have shown that the cosmological constant must be strictly positive [250,289,296,307]. Flatness is not an option.*

In [1,8-20,62,81], we discussed how AdS[5](+...) <sup>9</sup> can be seen as the space created by multi-folds and where multi-folds, or possibly gravitons (as implemented by multi-folds [1,58,80,81,197]) and superstrings (as approximation of the multi-folds) live. It is involved in the AdS/CFT correspondence conjecture, and can relate to our spacetime via the AdS/(C)QFT correspondence (AdS/CFT<sub>YMC2G</sub>) [YMADS] [197], or the multi-fold factual AdS/CFT correspondence [1,8-20,62,81,197].

It has been shown, see references in [1,8-10,14,15,16,250,265,279,308], that superstrings (and supersymmetry) can only exist in spacetimes with negative (or flat) cosmological constant. It has also been shown that it is not possible to compactify gravity from superstrings or supergravity to a 4D (asymptotic) spacetime [224,225]. The

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<sup>9</sup> (+...) is added to allow for extra dimensions needed by superstrings, supergravity or M-theory as in the conventional AdS/CFT correspondence conjecture. However, it is not needed in the multi-fold theory and its factual AdS/CFT correspondence [1,8-20,259,265,279].

combination of this with the 2 paragraphs above indicates that our spacetime is macroscopically 4D asymptotic dS, and not (asymptotic) AdS (4 or 5)(with or without (+...)).

## 10.2 (Asymptotic) dS Spacetime

Fields can be defined on asymptotic dS(4) spacetime, including some supersymmetric ones [226], but the latter would not be unitary, which is a quantum theory challenge, albeit something that may be acceptable with hermicity considerations instead, as discussed in [1,63,65,77] and references therein. *Note added on August 1, 2025: We know by now that supersymmetry is non-physical, so these are only mathematical constructs. Note also that a unitary supersymmetric field has now been found [329], but it is non-interacting, as it should be per [341]. Free-only unitary fields do not match our observed universe where we have (at least) 4 interactions. The lack of time like killing spinors (Simply because energy is not conserved as the metric changes over time, at the difference of AdS which is static. A more rigorous analysis can be found, for example, in [365]. It is also why unitarity can be a challenge [341]. While a challenge for all QFT models, for supersymmetric field, we need repelling or non-conservative random walks, as the most fundamental underlying physical interpretation [59,250,369,370], something forbidden as unitary fields can't be interacting [341]. Indeed, this means that no local perturbation or rescaling with dS isometry can address this lack of interaction: Physically meaningful supersymmetry can't exist. This is a strong new argument to add to those compiled in [250,296,307].), and of a well-defined S-matrix (due to horizons, and the absence of asymptotic states) in dS(4) means that standard renormalization group (RG) techniques and unitarity arguments fail. This differ from flat space, or AdS(4), and undermines the construction of interacting SUSY QFTs, which rely on these properties for consistency [330,341,362-366]. Again, we have an unphysical purely mathematical theory. [364] provides another topological example of supersymmetric field in dS, but at larger dimensions (9+1). Note that there are some unitary possibilities for some supersymmetric-like half spin particles [367,368], but again this are purely unphysical considerations per all our analyses, and they do not explicitly encounter supersymmetry but rather unitary representations of a Spin group. CFTs, also related to supersymmetry and the AdS/CFT correspondence conjecture, also present problems in dS.*

To be fair, such a dS spacetime also presents problems, as already discussed for example with black holes in asymptotic dS/expanding universes as in [75], a topic still confusing to many, as exemplified in several references in [75]. *Note added on August 1, 2025: [182] should put this to rest. We also know by now that non-commutativity and dS spacetime are closely linked [307]. Non-commutativity, related to spacetime discreteness, contributes to ensuring no singularities at all. We expect that the real universe has no cosmological or gravitational singularity.*

Another puzzling set of challenges comes from Witten [227], who argues against achievability of realistic precision Physics in (asymptotic<sup>10</sup>) de Sitter universe, unless if we can precisely explain the cosmological constant. We will not discuss here such challenges, only point out that, in our view, the multi-fold theory can achieve the required precise explanation, at least qualitatively for now [1,27]. We may revisit in a future paper. *Note added on August 1, 2025: See [6,27,64,307,325] for more on this.*

So far, our conclusions are that our universe is macroscopically dS(4), because of the strictly positive dark energy effects, constant or time-varying, it does not matter [1,8-22,27,265,268,279,296,307]. It means a finite closed universe, instead of an infinite universe as with AdS(4). *Note added on August 1, 2025: It also means a universe which is stable with matter [318,331,377-381], vs. the instabilities of AdS [1,14,18,265,332]. [318,381] implies initially a state with only massless ultra relativistic fields, which is consistent with 2D random walks of massless Higgs bosons, and UU. The problem of radiation at the horizon, and constraints to stability for instabilities within the horizon is in our view related to the challenge to selecting a god-like observer of the dS universe. When*

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<sup>10</sup> Realistic is for the asymptotic case.

considering  $dS$  as a whole, within and outside the cosmological horizon, we argue that the stability holds and Hawking's radiation at the horizon are not relevant: the horizon is fictitious or said otherwise, what seems to be radiated inwards never occurs because its out-falling component can't catch up with the horizon expanding at  $c$  [1,8-10,22,32,66,259,265,279]. To understand, consider Hawking's popular explanation and the multi-fold Hawking radiation proposal [1,8-10,22,32,66,88,238,239,259,265,279]. We may further detail the latter in an upcoming paper.

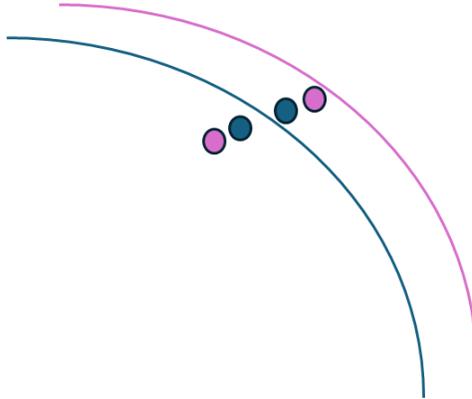


Figure 5: In an expanding (asymptotic)  $dS$  universe, the cosmological horizon expands at  $c$ . The entangled pairs move apart with a direction orthogonal to the horizon that is smaller, or equal, to  $c$ . The horizon expands and catches up with most particles that would have been beyond the cosmological horizon, separated from the other particle in the pair. Eventually it would do so for all of them. There is no Hawking effect that would render the spacetime unstable.

### 10.3 AdS QFTs and all that

As already mentioned, there are supersymmetric, (super)conformant, topological and Chern-Simons fields at higher dimensions, typically supersymmetric, and many associated to AdS spaces. A quick reading of section 5, skipping the footnote where we already hinted of what is to come here, should surprise the reader: how can such fields exist if we have shown that random walks does not cover such spacetime densely enough?

We explained how  $5D+\sim$  fields could exist thanks to leakage mechanisms [86] due to quantum fluctuations, or CFTs could exist close to the seeding  $D-2$ <sup>11</sup> spatial space with random walk translation of that seeding space. But it has limits. That latter statement contains an alternate model that we already mentioned as the random walk of extended objects: if spacetime was to be generated by superstrings (think also of branes), then these superstrings, or branes, e.g., as in [14,15,308], provide a background field of their dimensions, or their own random walks can generate a denser coverage of larger dimensions spaces, as we now have extended object "walking" (and undulating as they do so). So, it should not be surprising that AdS(5), and higher dimensions space (10, 11, 26) could exist, (some) with associated fields, always expected to be supersymmetric, conformant (and/or topological). Indeed other cases would not be justifiable by this arguments as superstrings are supersymmetric and conformant, at least not if not accompanied by a sensible symmetry breaking justifications. An example of not making sense is discussed in Appendix C.

<sup>11</sup> One of the -2 is for the time dimension.

Remember that in section 5, we did not say that QFT can't (mathematically) exist in higher dimensions. We said that they are problematic, and hard to construct or define, and, arguably, with problematic (physical) behaviors or properties. By this, we imply that they cannot be physical. They are therefore irrelevant when evaluating options for the macroscopic dimensions of our spacetime.

In multi-fold universes, AdS(5) is constructed by the multi-folds [1,8-10,22,62,259,265,268,279], and where multi-folds can live (modellable as gravitons or strings), and other "Worlds" from MWI can also float away if we were to accept the MWI [177]. It is an outside view. The random walks of the multi-folds / strings and "Worlds", can be dense enough to ensure that AdS(5) exists in a dense and stable enough manner: random walks are recurrent with  $D > 0$  spatial objects "walking", as for the strings and branes earlier. We have discussed earlier the dimensions supported by superstrings and the M-theory.

Finally, AdS is (macroscopically) unstable with matter [18,332]. This is clearly not the case in our universe.

## 11. What about more time dimensions?

The example of [168] shows that similar behaviors as with the Huygens' principle extend from hyperbolic equations (waves) to parabolic equations, e.g., the Schrödinger's equation. The Huygens' principle is a boundary conditions to set to have a well posed problem for hyperbolic equations [129]. [166] extends the analysis to elliptic, parabolic, hyperbolic and ultra hyperbolic, with 0, 1 or multiple temporal dimensions, to argue that multiple time dimensions would result into ill posed problems for the most relevant physics phenomena described by some of these equations. That would lead to unpredictability of the outcome for the systems they describe. This is again something that we do not observe in our universe. So the conclusion is simple: our universe has only one time dimension. This argument is not just classical as for example quantum mechanics can also be described by such equations.

Even as a macroscopic result, we argue that it also applies microscopically. Indeed, in addition to the above, [95,172] shows that particle stability would disappear, if we had more than one dimension in time. Decay would happen easily. In particular, proton decay becomes possible, something we argued as not possible [1,41,259,265,279]. Even photons would become unstable. Tachyons could exist, and even, all particle could behave like tachyon, which leads to causality violation and numerous paradoxes that we do not observe. This is not what we observe in the universe.

With the multi-fold theory, or just the  $SM_G$ , we already argued that that proton is stable because of the impact of gravity [1,41,259,265,279]. Proton decay has never been observed [228], and the  $SM_G$  can apply to our conventional universe, following the feel good arguments of Appendix A, that multi-fold Physics looks like it could well model our real world, albeit still mostly qualitatively [1-98,118,177,182-185,191,196,197,232,233,235-249,250-315,318,334,346,348-350,352,355]. Furthermore, photon decay is incompatible with the SM, it has never been observed, and, especially if rapid, it would be essentially going against the concept of long range interactions as the electromagnetism [229,231]. Tachyons have never been observed, with the exception of falsified observations due to equipment errors [230], and create myriads of paradoxes. *Note added on August 1, 2025: Note that imaginary / complex masses for the Higgs field (and complex scalar field) [8,9,89,289] are not modeling tachyon particles, but rather system instabilities, as discussed in [b54] and references therein.*

*Note added on August 1, 2025: Discussions and examples of some multiple time dimensions theories can be found in [353,354].*

Note that in the multi-fold model of [1,6,307], and even the initiation of spacetime creation, as in [1,265,318,381], the 2D random walks [1,8-10,22,63,89,177,259,265,279,303,207] concretize the time, along with entanglement [232]. Indeed, another way to understand it is to consider [1,6,265,307], where each time click is associated to a jump from one spacetime clump to another (see Figure 6), and time is therefore determined by the minimum length, and  $c$ . There is no room for a second click definition (distance & wormholes being traversed with 1 time click [1,6], a bit à la [106]). Yes, in AdS(5) the multi-fold mechanisms introduce a scale factor (radius of the fold spheres) that has some time signature, but it is traveled both ways, i.e., not unidirectional as is time, and it contributes to creating an AdS space rather than being a time dimension [1].

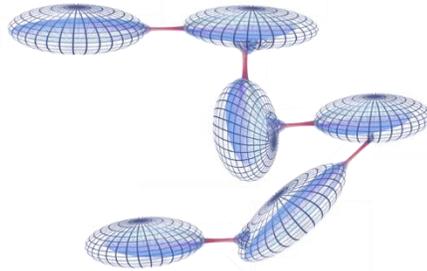


Figure 6. This figure, originally from [6], shows how the jump from clump to clump takes place by traveling the clumps (1/2 then 1/2) or / + the wormhole, sketching why random walks, in multi-fold universe, and in conventional universe generates time, as in [1,232].

All this indicate only one time dimension.

*Note added on August 1, 2025: [351] proposes different times scales associated to different Physics. Each plays a dominant role depending on the scale of Physics and events considered. In our view it makes little sense and more importantly, it means one dominant time when considering particular Physics at a given scale. So it is still essentially a 4D spacetime macroscopically, including conventional quantum scales. It is not as multiple time dimensions discussed above. See [350] and references therein for more details and examples of criticism of the proposal.*

*Note: Section added on August 1, 2025, and October 27, 2025:*

## 12. Other Exotic Considerations

*In this section, we list a few additional theories related to the universe and its dimensions:*

- *Multiverses are discussed in [177] and references therein.*
  - *These concepts do not correspond to extra dimensions. They are other regions of spacetime, i.e. 4D per the present paper, or disconnected space bubbles each of 4D dimensions (e.g., many worlds), in most cases unreachable (and unverifiable).*
  - *Parallel universes are being addressed in [349] and references therein. They make no sense in our view as already discussed in [67].*
  - *Macroscopic dimension remains 4D, because of the ability to recover all Physics without fine tuning as in [77]*
- *Anti-universe: An anti-universe running back in time preserving CPT and possibly explaining dark matter effects, e.g., [339,340].*

- *The anti-universe would be an unreachable symmetry of our universe, just with time reversed. If true, it would mean that the universe remains macroscopically 4D.*
- *Dark dimensions, one or more extra dimensions interacting or responsible for dark matter and/or dark energy, but not interacting with normal matter, and therefore invisible [335-338].*
  - *No confirmed at all. The approaches propose dark contributors as particles feeling and (some) going (partially) into the dark dimensions. Per [59], we do not believe that this is a correct model, for all the reasons discussed there, inspired from UU [1,6,43,60,63,67,265,303], and so far also reinforced by the absence of any hidden valley discovery, even if it is expected to be hard to find them [345].*
  - *Furthermore, analyses of particle collisions in particle colliders have not detected any leak in higher dimensions, that would result of their existence or of dark matter or dark energy source encountering them [100,343,344].*
    - *The recent CERN four dimensional ghost are not resonances in 4D, but resonances of 4 degrees of freedom involving 2 position and 2 momentum(i.e., in a 4D phase space), and degrading the accelerated beams [342].*
    - *No microscopic black hole has ever been discovered either. See [348] and references there in. We explain this with [289,303]. Accordingly, such black holes should never appear but rather be part of the evolution(towards UU) described the [1,8-10,43,259,265,279,303].*
- *Higher dimensions in colliders: [100,342,344]*
  - *The last secondary bullet above applies also.*
  - *Per [100], it would imply / include heavier versions of the SM particles, with same properties as the SM particles. It is not likely per [1,6,43,59,60,63,67].*
- *2D gravity, e.g., JT gravity, is well behaved (i.e., renormalizable /asymptotically safe), and without gravitons. It illustrates that gravity is 2D, due to entanglement between massless Higgs bosons [346]. This is another confirmation of that at the smallest scales and highest energies spacetime is 2D.*
  - *The dilaton involved in 2D gravity models as JT gravity [1,16,28,43,63,67,84,,251,259,265,279,296,302]. In multi-fold universes, dilatons are the massless Higgs boson.*
  - *Interestingly, it seem possible to encounter non-paradoxical CTC with 2D random walks, as discussed in [352]. Time-travel, here we go (Note, probably not [257]).*

*As we can see, there is no contradiction between 2D at smallest scales and 4D macroscopic spacetime. Also no contradiction with [167,170,171], as ultimately the Physics they rely on derives at larger scales from 2D physics. Earlier we explained how we go from say 2D to 3D, then 4D, with 2D random walks (and not beyond per here and [289,296,307]. And, Appendix B in [307] finalizes how a 4D spacetime (also apparently continuous and smooth or not), can appear in the process.*

## 13. Conclusions

Spacetime is 2D, generated by 2D random walks of massless bosons. But, the paper has strongly established that our real universe spacetime is macroscopically 4D, relying on a compilation of a broad set of arguments and considerations including experimental and simulation results, confirmation of GR in 4D, considerations on QFTs, on stable bound systems, on Huygens' principle, on chirality and on well posed physical problem described by (partial differential) equations in multiple dimensions. These results hold for conventional as well as for multi-fold universes. They apply at large enough scales, macroscopic or large enough microscopic, i.e., they also apply to

conventional QFTs. It can be viewed as a compilation, and review of a non-exhaustive set of well-known facts, interspersed with some multi-fold notes, some original to this paper. It is important as, in our view, it establishes once and for all that macroscopically our spacetime is 4D, and it is asymptotic dS, with a (*Note added on August 1, 2025: strictly*) positive curvature, or cosmological constant, which could vary in time, and with only one time dimension.

We also detailed an original proof that spacetime must be 4D, based on its proposed (multi-fold) random walk construction and Polya's random walk theorem. While, a priori a multi-fold result, the encounter of multi-folds in GR and Yang Mills seems to indicate that such results should also hold for conventional universes, especially as the multi-fold theory seems to explain, or partially address, some of the open problem with the SM, and the Standard Cosmological Model [1-98,118,177,182-185,191,196,197,232,233,235-249,250-315,318,334,346,348-350,352,355], even if the latter is to evolve for example to account for a possibly time-varying dark energy [33,276,305,307].

With this, we also repeated and clarified how to relate this 4D macroscopic spacetime to our claims, and the result of most consistent quantum gravity approaches, that the universe spacetime encounters dimensionality reduction to 3D then 2D. The conclusions being that there is no contradiction. It is a process statement, qualifying what influences locally at very small scales, but that, per the above, unfolds in a 4D spacetime reconstructed by the random walks. Any additional dimension beyond 4D is immediately thwarted. Macroscopically fractal and non-commutative considerations are also not apparent [1,8-10,259,265,279], beyond, for fractals, the distribution of matter in the universe in a range of scales, and the possible effect on the time-varying cosmological constant [1,89,265,276] (and the underlying result of 2D random walks, linked to QFT as discussed above and in [333]), and for non-commutativity, the existence of fermions, strictly positive constant / dark energy effects, possibly time varying, discrete spacetime [1,8-10,22,31,63,251,256,259,265,272,279,288,289,296,299,301,303,307,334], (and therefore the possibility of better TOE, and mass gaps [60,98,355,356]), SM or SM<sub>G</sub> as (multi-fold) space time matter induction and scattering [1,8-10,23,29,30,49,51,62-64,77,259,265,279,303], and the unphysicality of supersymmetry [14,250,262,296,307,308].

Reusing random walks and quantum cellular automata built on them, and their ability to simulate QFTs, we justify the challenges, not claims of non-existence, to define higher dimensional QFTs (5+ D spacetime) that would be defined, stable, renormalizable or asymptotically safe (and interacting, unitary etc.). We also identified possible exceptions for some CFTs, which were also justified as the only places where random walks would provide enough density, unless if due to the random walk of extended objects [347], like multi-folds, strings or branes, which explains some higher dimensional SUSY, supersymmetric, topological [364], and super conformant fields. Also, we discussed associated dimension limits for branes.

On the other hand, at lower spacetime dimensions (<3D), QFTs are way better behaved, with strong interactions, bound states, plausible mass gap, confinement and chiral asymmetry. Needless to say that this provides a concrete microscopic interpretation to the ability to model QFTs with random walks (including for AdS). Also, it allows us to expand a bit on the story for QCD, electroweak and UU further above the multi-fold gravity electroweak symmetry breaking, better detailing massive behaviors due to chiral symmetry breaking and confinement at energies above it, and until confinement is broken, or until spatial scales are smaller than the relevant particle size (i.e., microscopic black hole horizon, or  $\sim$  Compton wavelength) (See figure 1 in [63]) [63,267,288,296,303].

We showed how the transition from 2D to 3D then 4D then not 5D can be understood, and how it can then lead to emergence of all the distances/metrics, areas/volumes/Hamiltonians and continues, differentiable or not, manifolds.

With the notions of superstring background, think also branes, and strings random walks, supersymmetric, or conformant, QFTs can be envisaged under the right circumstances till at least way larger dimensions, removing any doubt that such may be encountered and why, considering the previous arguments. Upper limits also exist. These fields are purely mathematical, not physical, as exemplified in Appendix C. They also can be explained coming from

the QFT random walk models with non-conserving random walks, which introduce supersymmetry, and its explosion of the numbers of random walks, even out of a single one, so that density can be achieved till higher dimensions like 5 or 6 D at least [250]. Multi-folds as extended bodies, and other "Worlds" from MWI, can also construct AdS(5).

On the flip side we can predict that 26D is unphysical and fields in it will not behave well, something confirmed for bosonic strings, and a basis for introducing supersymmetry.

In our analysis of the Kaluza Klein, we recognized that multi-folds also introduce dynamics and kinematics that should justify a dilaton. We argued that the Higgs boson plays (also) that role, justifying why it had to appear in the multi-folds, and embedded 7D space locally created by the multi-folds that induces the  $SM_G$  via space time matter induction and scattering, and felt inside out as a  $\epsilon$  neighborhood in the 4D spacetime [1,8-10,22,259,265,268,279]. Doing so, we can also explain the dilaton that appears in the double copy duality between gravity and gauge fields when massive particles appear, and the Higgs in multi-folds.

Finally, we added considerations on the mass gap resolution in dimensions other than 4D, complementing our resolutions in [1,60,98].

Overall, our paper goes beyond the classical papers of Ehrenfest [170,171], and Tegmark [167], which are mostly focused on classical Physics. With the 2D random path/QFT duality, we showed that at large enough microscopic scales, the scales of the QFT, SM and  $SM_G$ , spacetime is also 4D, and it can be used to justify the macroscopic 4D spacetime.

Combined with [23,77], our universe is 4D at large spatial scales. It just had to be so.

## Appendix A: The multi-fold theory

For more details on the latest developments, updates to papers, discussion and the full story only succinctly summarized here, please consider the complete list of papers compiled at [8]. In particular while some more recent references are provided, the focus in this appendix is not to provide our latest findings. There are rather tracked on that web site [8].

In a multi-fold universe [1,8-10,22,259,265,279], gravity emerges from entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles [1,24,25], whether they are real or virtual. Long range, massless gravity results from entanglement of massless virtual particles [1,25]. Entanglement of massive virtual particles leads to massive gravity contributions at very small scales [1,26]. It is at the base of the E/G Conjecture [24], and the main characteristics of the multi-fold theory [22]. Multi-folds mechanisms [268] 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 [1,4,16,27,30,32,43,59,60,63,,64,177,259,265,279,296,303,307]. All these recover General Relativity (GR) at large scales, and semi-classical model remain valid till smaller scale than usually expected [1,6,259,265,279,307]. 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 without new Physics other than gravity. These considerations hint at an even stronger relationship between (multi-fold) gravity and the Standard Model, as finally shown in [23].

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 right-handed

neutrinos, due to chirality flips by gravity of the massless Weyl fermions, induced by 7D space time matter induction and scattering models [1,23,29,30,49,51,62-64,77,259,265,279,303], 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 [1,4,289], thereby providing a microscopic explanation for a Higgs driven inflation [27], the electroweak symmetry breaking [29,303], the Higgs mechanism, the mass acquisition [29,53,60,63,296,303,307] and the chirality of fermions and spacetime [29,53,60,63,303]; all resulting from the multi-fold gravity electroweak symmetry breaking [29,303]. The multi-fold theory has also concrete implications on New Physics like supersymmetry, superstrings, M-theory and Loop Quantum Gravity (LQG) [1,8-21,b1,259,265,279,308].

The multi-fold paper [1,265] 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, and the 2D massless Higgs boson random walks. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

With the proposed model of [1,265], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales, and semi-classical approaches appear valid till very small scales. In [1,265], 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) [1,8-10,22,31,60,259,265,276,279,295,296,307,308]. Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and concretized spacetime coordinates, and metrics between Reissner Nordström [2], and Kerr Newman [3] for massive, and possibly charged, particles – the latter being possibly extremal) [4,289]. Although possibly surprising, [1,265] recovers results consistent with others (see [4], and its references), while also being able to justify the initial assumptions of black holes from the models of gravity or entanglement in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scales, which make gravity non-negligible at these scales. Semi-classical models also turn out to work well till way smaller scales than usually expected.

Multi-folds are encountered in GR at Planck scales [5,6] and in Quantum Mechanics<sup>12</sup> (QM) if different suitable quantum reference frames (QRFs) are to be equivalent relatively to entangled, coherent or correlated systems [7,58]. This shows that GR and QM are different facets of something that they cannot well model: multi-folds.

Considering results as in [6,58,307], and our answers to so many open issues with the SM and the  $\Lambda$ CDM can be qualitatively explained with the SM<sub>6</sub> and multi-fold mechanisms, as discussed in [1-98,118,177,182-185,191,196,197,232,233,235-249,250-315,318,334,346,348-350,352,355], we can then argue that these conclusions can apply to our real universe, especially considering how the multi-fold mechanisms recover GR [1,265], and can be encountered in GR at Planck scales [6,307], with the spacetime reconstruction [1,31], and with the top-down-up-and-upper derivation of the multi-fold theory [6,307].

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<sup>12</sup> Standing in for Quantum Physics in general.

## Appendix B: SM (Coulomb, QCD, (Electro)Weak), and Gravity potentials in Different Spatial Dimensions

At the core of Ehrenfest arguments is the modeling of the Coulomb potential for QED / Electromagnetism, and its corresponding distance dependency for the weak (/electroweak) and strong interactions, *as for example discussed in [307]*. For QCD, we are similarly inspired as in [60], while the weak interaction is dominated with the exponential weakening à la Yukawa, at energies below the gravity electroweak symmetry breaking (For energy above, the dependency can be as for QED, as they unify in one unified interaction, carried by massless bosons). At large scale, where GR / Newton gravity is a good model, the gravity potential has similar behaviors [1,265,357].

Accordingly, when decreasing the spatial scale, the coulomb potentials evolves in  $\ln(1/r)$ , then  $r$ , as spacetime dimensions become essentially 3D then 2D [324,357], resembling QCD. As a result, QED and QCD, i.e., the SM interactions, essentially confine [60,63], unless if/when percolating in a very dense plasma state where confinement becomes meaningless because of the density.

Going to smaller spatial scales, GR based gravity on the other hand becomes independent of the distance when in 2D spacetime [325]. As a result, only gravity remains relevant. It is the essence of the Ultimate Unification (UU) [1,6,8-10,22,31,43,59,60,63,67,259,265,279,296,303,304,307], and why 2D gravity like JT / dilaton gravity is such a good model for some studies of quantum gravity [1,16,28,43,63,67,84,251,259,265,279,296,302].

At larger scales, the gravity & Coulomb potentials evolve in  $1/r^{D-3}$  [357]. As a result, as  $D$  increases, the interactions between charges decrease, amplifying the lower density effects due to 2D random walks (the Polya's theorem [127,128]), discussed in section 3, and (further) preventing QFTs to be defined in high dimensions.

## Appendix C: What about $D=26$ for Bosonic Strings?

Based on this paper, one may be surprised that bosonic strings (open and closed) live in a 26D space (with 1 time dimension). Reasoning and derivations are mentioned to, and relied on, in [14], based on [371-376], and many other materials on quantum gravity, strings and supersymmetry.

When imposing that the Weyl invariance, inherent to, and apparent only in the Polyakov formulation of the string action, must hold and that string on a background spacetime / background of field must be independent of its curvature/behavior, at low energy, one cancel the conformance anomaly introduced by quantization, if  $D = 26$ .  $D=26$  is also required to ensure Lorentz invariance. At other  $D$ , conformance symmetry is lost, and our criterion of independence from above fails.

In such a space, open strings include models of Tachyons and massless bosons modeled by Yang Mills interactions, while closed strings model a Tachyon and a massless spin-2 particle, reminiscent of the graviton, and the GR equation is encountered. In [14], we argued that this, encountering GR and gravitons behaviors, (and Yang Mills with Yang Mills carriers)) is not surprising. The tachyon and the presence of ghosts is a concern. Ghosts and tachyon instability still need to be addressed.

These discovery were the origin of the claims that strings is a good candidate model for quantum gravity, the SM and for a TOE (Theory of Everything).

Interestingly, in multi-fold theory, multi-fold seem to play the role of gravitons as quasi particles (sometimes massive when associated to entangled massive particles), and becoming closed string within the dual/cotangent AdS(5) (+...) space [1,8-20,22,58,62,80,81,250,251,259,265,279]. What lives in that space is not physical.

When super-symmetrizing the action, by adding a minimally coupled fermion contribution for each boson, and repeating the steps above, the superstrings now requires a spacetime  $D=10$ , where ghosts are well treated, and the conformance anomaly and tachyons disappear. And we have Lorentz invariance. It is the reason for involving supersymmetry in string theory/M-Theory, along with super gravity [250]. The good behavior, including putative renormalizability, because of the Weyl Conformance, and the fact that the action includes gravitons for GR, bosons, described by Yang Mills, and super symmetric fermions (and conversely for bosons) is the main reason while the Physics community drank the cool aid, with many claiming that superstring is the best theory we have so far for gravity and TOE. Alas, it was not to be, as discussed in [1,8-20,22,58,62,80,81,250,251,259,265,279], and proven in [250,296,307,308] and reference therein. No experiment has ever encountered any sign of supersymmetry or any supersymmetric particle. *Note added on August 1, 2025: [250,296,307] also showed that supersymmetry breaking are not of any help, as the main arguments against supersymmetry apply especially well at the smallest possible spatial dimensions, i.e., the highest possible energies: there was never supersymmetry in our universe, so nothing to break.*

Based on our analysis in this paper, the random walk of extended objects (D-branes) in  $D=10$  can justify 10D spaces (and 11D for the M-theory when adding supergravity). It can be supersymmetric, but it is meaningless as it contains no Physics and no particles (other than, in some cases, within the multi-fold) outside 4D.

So AdS(5) (+...) works up to 10D or 11D. Any extra dimension can be mathematically added, and have misbehaving strings and extended objects, which are unphysical and misbehaved, per the string analysis mentioned above. 26D, and other dimensions are possible, but misbehaved: when  $D \neq 26$ . They have no well behaved path of extended objects random walk as far away from  $D=10$  or 11. Therefore, when  $D \neq 26$ , fields can't be modeled by any type of random walks. And so, it is not surprising that they also includes ghosts, tachyon, instabilities and a Weyl anomaly. At  $D=26$ , only the Weyl anomaly, and Lorentz invariance, can be addressed. As argued, yes one can build mathematical "fields" but they are just not physical at such high dimensions, even if, because suited to model gravity, that they obvious include [14], they can hint at some physical behavior within such spaces like multi-folds as hints of gravitons as quasi particle, while no graviton particle actually exists in our 4D spacetime [1,8-20,22,58,62,80,81,250,251,259,265,279].

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