Deriving the Multi-fold Theory from General Relativity at Planck scale

Stephane H. Maes[1]

February 22, 2022

Abstract

In a multi-fold universe, gravity emerges from Entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles, whether they be real or virtual. Long range, massless gravity results from entanglement of massless virtual particles. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales. Multi-folds mechanisms also result in a spacetime that is discrete, with a random walk fractal structure, and non-commutative geometry that is Lorentz invariant and where spacetime nodes and particles can be modeled with microscopic black holes. All these recover General Relativity (GR) at large scales, and semi-classical model remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model resulting in what we defined as SM_G. This can contribute to resolving several open issues with the Standard Model without new Physics other than gravity. These considerations hint at an even stronger relationship between gravity and the Standard Model.

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 models and hidden behind the Higgs boson or field at the entry points and exit points of the multi-folds. Massless Higgs bosons modeled as minimal microscopic black holes mark concretized spacetime location. They can condensate into Dirac Kerr-Newman soliton Qballs to produce massive and charged particles, thereby providing a microscopic explanation for a Higgs driven inflation, the electroweak symmetry breaking, the Higgs mechanism, the mass acquisition and the chirality of fermions and spacetime; all resulting from the multi-fold gravity electroweak symmetry breaking. The multi-fold theory has also concrete implications on New Physics like supersymmetry, superstrings, M-theory and Loop Quantum Gravity (LQG).

In recent papers, we encountered multi-folds in universes described by non-multi-fold physics, including when discussing how to fix challenges in the quantization of the Hilbert Einstein action by LQG, or in enforcing an equivalence across Quantum Reference Frames for coherent or entangled systems.

In this paper, starting from a paper that seeks to encounters EPR = ER beyond (asymptotic) AdS universes, we encounter the presence of multi-folds in GR field equations at Planck scales, in the form of traversable wormholes. Doing so, we also encounter hints that, at such scales, spacetime is discrete, 2D, non-commutative while Lorentz symmetric, and yet to become continuous. Doing so we even explained how the previous sentence is not self-contradictory. These results are in perfect alignment with the results obtained in the multi-fold theory, and, in particular, the multi-fold spacetime reconstruction, including the ultimate Unification (UU), the multi-fold inflation and the multi-fold gravity electroweak symmetry breaking.

Then, we derive that spacetime entanglement implies non-commutative spacetime and we clarify the meaning of the ER = EPR and QR = QM conjectures, as facets of the multi-fold theory, that is the umbrella theory that neither GR nor QM can fully model. These conjectures become factual, when seen as such facets.

The paper also proposes a re-derivation of the whole multi-fold theory from GR at Planck scales: the top-down-up-and-upper derivation of the multi-fold theory, that rigorously confirms the spacetime reconstruction, and that

[1] shmaes.physics@gmail.com

Cite as: Stephane H Maes, (2022), "Deriving the Multi-fold Theory from General Relativity at Planck scale", https://shmaesphysics.wordpress.com/2022/02/22/deriving-the-multi-fold-theory-from-general-relativity-at-planck-scale/, February 22, 2022.

multi-fold mechanism recover GR. Finally, we provide a new derivation, without any multi-fold assumptions, that gravity is asymptotically safe.

The main outcome of the paper remains: universe modeled by GR are multi-fold, and the E/G conjecture is not a conjecture but factual.

All these results are strong hints that our real universe may be multi-fold.

____

1. Introduction

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

With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales, and semi-classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe). Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for concretized spacetime coordinates, and metrics between Reisner Nordstrom [2] and Kerr Newman [3] for massive and possibly charged particles – the latter being possibly extremal). Although possibly surprising, [1] recovers results consistent with others (see [4] and its references), while also being able to justify the initial assumptions of black holes from the gravity or entanglement model in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scale that make gravity non-negligible at these scales. Semi-classical models also turn out to work well till way smaller scales than usually expected. We confirm some of these results in the present paper.

This paper reports results published in [5] that searched for hints of ER = EPR in GR beyond the AdS/CFT correspondence conjecture, or AdS spacetimes. Doing so they encounter a geometric signature of wormholes when they consider gravitational energy fluctuations within a Planck size volume. The authors of [5] conclude that, in any spacetime governed by GR, there is an equivalence[2] between virtual gravitons exchanged from a sides of the Planck size volume to the other, and the exchange of a particle, taken as a Qubit, through the wormhole equivalently hinted in-between these sides. They take it as a proof of a minimum length within spacetime with consequences in the form of an extension to the Heisenberg uncertainties. It relates to the obviousness in conventional physics that quantum gravity implies discrete [1,8], and non-commutative spacetime [11,12,16] (and

[2] Equivalence is underlined to call out explicitly the fact that [5] maintains that wormholes are not traversable and so any exchange through wormholes are just a dual equivalent. This is at the difference of what we will further derive in the present paper. *Note added on February 21, 2023: In our view, it is also symptomatic of why people playing with the ER – EPR conjecture have not derived emergence of gravity from it, as we showed in [1]. Note added on February 21, 2023: Ironically, this is also related to the mathematical duality, that recently led to the confusion with articles suggesting that researchers had created a wormhole with a quantum circuit [106]. Of course that is false and confusing mathematical analogies/dualities with real physical behavior [106-108].*

references in [16]), mostly 2D at the smallest scales [1,6,7,9,10,48], and characterized by uncertainty principles extended beyond Heisenberg [11-15], that imply minimum length spacetime, and that can conversely be used to recover GR from a discrete spacetime [17]. All these were already mentioned in [1], when we based spacetime reconstruction on a discrete graph of microscopic black holes, something further codified later with [4], the considered massless random walks to construct spacetime [1,44,45,*109,110*]. *(Throughout this paper, references added on February 21, 2023, are in italic).*

Then, our paper expands beyond the limitations of the analysis in [5]. The <u>equivalence</u> between graviton exchanges in spacetime, and qubit exchanges through a wormhole is falling short, because if actually taking place, such particle exchanges through wormhole can provide way deeper microscopic explanations of what really happens at Planck scales. We believe that the authors missed it, being instead concerned with causality problems created by wormholes, and therefore happy to subscribe to the non-traversability of wormhole: a conventional view rarely questioned, with the view that particles can't physically go through. However, we know better, both in multi-fold universes, but also in universes described by conventional physics. Secondly, because the analysis does not exactly explains what happens with entanglement when occurring across volume a bit larger. We provide an updated analysis in both cases.

Remaining with conventional physics, which is no multi-fold principle introduced yet, we encounter traversable wormholes, and as a result a discrete spacetime, non-commutative spacetime, initially dominantly 2D, as well as Lorentz symmetric. All very consistent with multi-fold theory and multi-fold reconstruction. The larger scale analysis then confirms that the traversable wormholes either are multi-folds or hints of multi-fold mechanisms, that GR cannot model beyond wormholes. The results also naturally imply hints of the W-type multi-fold hypothesis that introduces multi-folds between points of the support of a wavefunction [18]. This latter result is also an expected consequence, or a microscopic explanation, for the equivalence between entanglement and coherence as discussed in [19][3].

Doing so, we propose a new interpretation of conjectures like ER = EPR [21,22][4], and GR = QM [23], as different facets of multi-fold theory can neither can well model on their own, and we could have well speak of gravity/GR vs. quantum Physics). Both miss considerations, and can at best introduce wormholes or entanglement. The important point is that the conjectures become factual when seen as such facets.

As a result, we have another approach that squarely encounters multi-folds (like) phenomena in the real universe, at Planck scales. It is contained in the GR equations, just as we already obtained in [26], when rigorously and correctly quantizing the Hilbert Einstein Action.

At this stage, we can repeat, for the second paper in a row, that the real universe is therefore theoretically multi-fold [1,27,28], and that the E/G conjecture is factual in the real universe [24,25].

With this, we can recover the whole multi-fold theory from GR a Planck scale. It is what we call the top-down-up-and-upper derivation of the multi-fold theory.

2. Wormhole signature at Planck scales in GR

---

[3] Mutual explanation of the W-type multi-fold hypothesis because of this equivalence between coherence and entanglement, or maybe rather explanation of the equivalence between coherence and entanglement, because of the W-type multi-fold hypothesis [19,20]. One can see it either way.

[4] Note how non-traversability is emphasized in [21,22], especially in the summary in [22]. It is why ER = EPR has missed, so far, the other facet… and not discovered the (factual) E/G Conjecture [24,25].

Following [5][5], it is possible to approximate the time evolution of the gravitational energy and the spacetime geometry, across a small spacetime volume of length L. [5] does it with a semi classical model, where GR is valid till the Planck scales or around such scales.

Relying on De Witt's work [29-33], [5] interprets the time evolution of the gravitation energy as representative of the exchange of a virtual graviton from one side to another side, or the equivalent of an exchange of a particle, e.g. a Qubit, through a wormhole between the sides, the latter being in the case where the ER = EPR conjecture is valid beyond (asymptotic) AdS, or the AdS/CFT correspondence conjecture, i.e. in flat or (asymptotic) dS universes. Accordingly, two options exist: a particle exchange, quantum and virtual, i.e. a graviton[6], or a real particle, via the equivalent wormhole model, as an exchange of a Qubit of information between both sides. They are forced to phrase the latter this way, because the already explicitly stated that wormhole can't be traversed, or causality could be violated[7]. So in [5], gravity (exchange of virtual graviton) is equivalent to having a Qubit traversing a wormhole between the two points exchanging the gravity. The authors of [5] just with this are very close to the E/G conjecture [1,24,25].

When L tends towards the Planck length, they encounter, for the small volume, a relationship between the Ricci scalar curvature, and a wormhole throat radius that corresponds to [35]:

$$R(g,L) \equiv \text{Ricci scalar curvature} = -\frac{2a^2}{(a^2+r^2)^2} \tag{1}$$

and

$$R(g,L) \rightarrow \frac{-1}{(L_p)^2} \tag{2}$$

with

$$|a| = 2L_p \tag{3}$$

The curvature scalar remains bounded by $1/L_p$.

This can be geometrically understood by seeing the spacetime fluctuation as being constrained against the throat of a wormhole between the opposite sides of the Planck volume. The wormhole prevents singularities and divergences through a minimum length created by the throat.

In [5], it is also captured in an extension of Heisenberg uncertainty principle that accounts for these constraints. We had already encountered this result earlier [1,6-8,11-16], when claiming that it is obvious, in conventional

---

[5] Please don't be confused by the unconventional sign used in the GR equations in [5], and resulting opposite sign change convention versus what is typically used for Λ. Here, we use the usual sign. No idea why they decided to go their own way.

[6] The paper analysis in [5] may appear non rigorous here, as the propagating wave may appear to be real not virtual, but they actually worked off an energy fluctuation, so indeed, it is correctly a virtual particle exchange. However, there could be also some inconsistencies in the message of the authors versus when they mention: "The exchange of a virtual graviton between two particles does not have the support of an actual theory of quantum gravity", as also discussed in [34]. So, as mentioned later, we do not exactly see the effects described in [5] as a graviton exchange, at least not as a well-defined non-perturbative particle.

[7] This problem does not exist with multi-fold mechanisms, that they be implemented by traversable wormholes, or not, as in multi-fold universes we only encounter them to support multi-fold mechanisms [1]. These do not violate causality, as they are built to enforce a principle of absolutely no supra luminosity and reconstructed spacetime is in fact a causal set [16]. Issues with other wormholes are not within the scope of our work and the multi-fold mechanisms. In fact the multi-fold theory with the 2D random walk based on causal sets [1,16,34,63,64,*108,109*].

physics, that quantum gravity implies discrete and non-commutative, first mostly 2D, spacetime, and such an uncertainty extension. With such uncertainty relationship, a minimum length (and time duration) exists and singularities are precluded, just as in a multi—fold universe with minimum length. Note that, at the difference of [11-15], the wormholes are the justification for the minimal length, because the geometrical encounter goes a step further from all these other papers.

[5] does not seem to realize these key aspects, and therefore we consider all of these as original contributions of our paper: no need to follow [11-15] to conclude the existence of a minimum length. Instead the authors of [5] see it simply as a way to justify plausibility of the ER=EPR equivalence; not that they actually discovered Planck size wormholes in GR or that, as we will argue soon in upcoming sections, that these wormholes are traversable.

3. Interpretations

Figure 1 and Figure 2 show a geometrical interpretation of the wormhole encounters in [5].

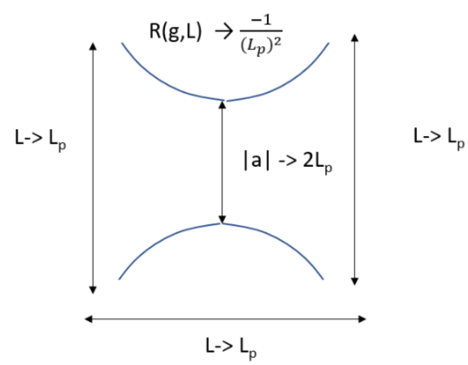


Figure 1: Wormhole section for a wormhole encountered in GR per [5], using notations of [5,35].

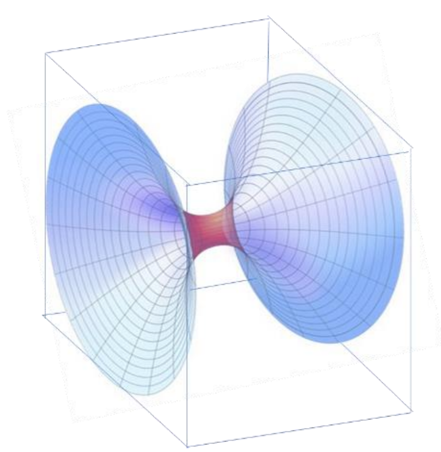


Figure 2: Wormhole in the small (Planck) spacetime volume of characteristic size L, encountered in GR per [5].

Note added on February 23, 2022: The signature we considered is based on a Ellis wormhole [60], which is traversable, without gravity effects; a perfect picture for multi-fold mechanisms or pathways between clumps as discussed later on. One could have looked at other wormholes of course, but it would be harder to explain the flows that they would create [61], or the instabilities or needs for exotic matter that they introduce [62]. Furthermore, the Ellis solution best matches the traversability introduced by adding massive (entangled) fermions in their throat as in [40], and references therein. It emphasizes how the decisions to maintain non-traversability in [5] is arbitrary as hinted in footnotes [2] and [4]. In fact the neutralization between attraction and repulsion of an Ellis drainhole [60,61] in the case of an Ellis wormhole may be why one may stick to non-traversability, but that is not correct, the Ellis wormhole is traversable and stable.

However, note that (3) is a norm, not a value. Said differently (2) can actually be a positive or negative scalar curvature both with (3) satisfied. Spherical balls of spacetime are therefore also solutions encountered at Planck scales [36]. [5] can disregard them as not of interest for their search of signs of the validity of ER=EPR. They just want to encounter wormholes, and it works because they assume discreteness and minimal length[8] associated to the wormholes.

However, we can derive (17) in [5] without requiring ER=EPR. It simply results from understanding (7) in [5], and arguing that at such scales and energy, particles are massless (remember the virtual graviton, it would be massless in GR, hence moving at *c* in GR, or alternatively, equivalent exchanges of information are also taking place at *c*). As (7) in [5] implies a minimum time, we now have a minimum length. Note you can also look at [1,11-16] for other derivations, none of them are assuming ER=EPR as initial justification.

If there is a minimum length, then the spherical solutions can't exist, when $L < L_p$, but they could exist above. The picture of spacetime that emerges is represented in figure 3.

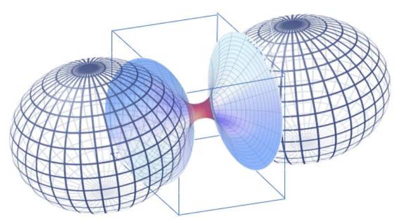


Figure 3: Solutions in [5]. Sphere have $L > L_p$. Wormholes are for $L \rightarrow L_p$.

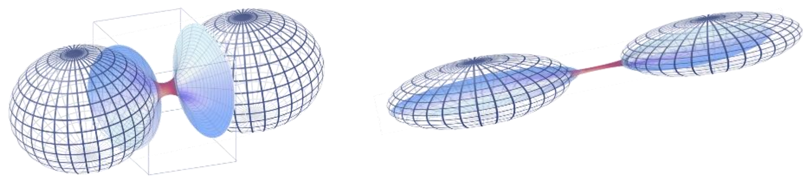
Although, not relying on ER=EPR, at the difference of [5], figure 3 is a strong reminder of [1,38], or the figure presented at [39].

According to these works, quoting [38],

> *"we argue that the emergence of classically connected spacetimes is intimately related to the quantum entanglement of degrees of freedom in a non-perturbative description of quantum gravity. Disentangling the degrees of freedom associated with two regions of spacetime results in these regions pulling apart and pinching off from each other in a way that can be quantified by standard measures of entanglement",*

[8] Duration trivially correspond to the time for light to cross L_P in the vacuum.

Figure 3 can now be seen as a particular case of figure 4, with different degrees of entanglement.



(a) (b)

Figure 4: Different shapes for different measures of entanglement. (a) corresponds to stronger entanglement than (b), according to [38,39]. It matches figures 4 and 5 in [38], resulting from figure 3 in [39], as left and right hemispheres would become less and less entangled.

Of course, [38] is for an (asymptotic) AdS universe, in the context of superstrings, or rather the M-theory, and the AdS/CFT correspondence conjecture, i.e. a conjecture that does not map to our (asymptotic) dS (de Sitter) real universe [39].

4. The real universe holds together

Can we recover similar behaviors in the real universe described by conventional physics?

First of all, it is obvious… if less communication channels exist to exchange information, mutual information must be lower in figure 4(b) than 4(a). As entanglement amounts to maximizing mutual information, you get the drift. Therefore, we affirm that the proof in [38] is, not dependent on AdS or AdS/CFT correspondence conjecture, contrary to the tone of the paper[9]. Consistently, if entanglement decreases too much, the wormhole breaks, and the spacetime clumps become disconnected: a spacetime consisting of these three regions would fall apart into two disconnected regions: two universes, unentangled. In each clump[10], gravity and entanglement can still exist… So far we do not Know how to make one universe out of disconnected universes, *(Note added on February 21, 2023: except maybe the problems attacked in some of the references in [111])*.

But, per the reasoning above, that can only be for $L > L_p$. To prevent "gravity collapse", we therefore need to assume that such breakdown never occurs: there is always the wormhole and a minimum of entanglement of a clump with at least one other clump: the spacetime and universe holds together. This is why there is a minimum length $L_p \neq 0$.

[9] See discussion about mutual information above equation (2) in [38]
[10] i.e., the left and right spheres + remnants of the wormhole.

5. Pursuing the analysis beyond [5]

5.1 Traversable wormholes

Of course, with this reasoning, in order to have it work consistently, the wormhole would have to be traversable. Otherwise, how would the wormholes, or shrunk constrictions, be relevant? Even if, in a wormhole state, no exchanges would take place, which would mean no entanglement, no information exchange; they would already just be two disconnected clumps of spacetime, and spacetime would have broken apart, and $L > L_p$, as in a dramatic phase change occurring as soon that wormholes appear, which could very well be at several order of magnitude of scale above for the spacetime Planck volume. Indeed the Ricci scalar curvature (2) is large, and negative, and will take a while, in terms of L increases, to become flat or positive. It would therefore be very hard to explains what is happening in the new phase.

Therefore, we conclude that wormholes are traversable, without explaining, for now in this section, how that is possible, and now, we will be considering the resulting consequences. [1,39-41,*111,112*] and references therein provide several options for being able to ensure traversability.

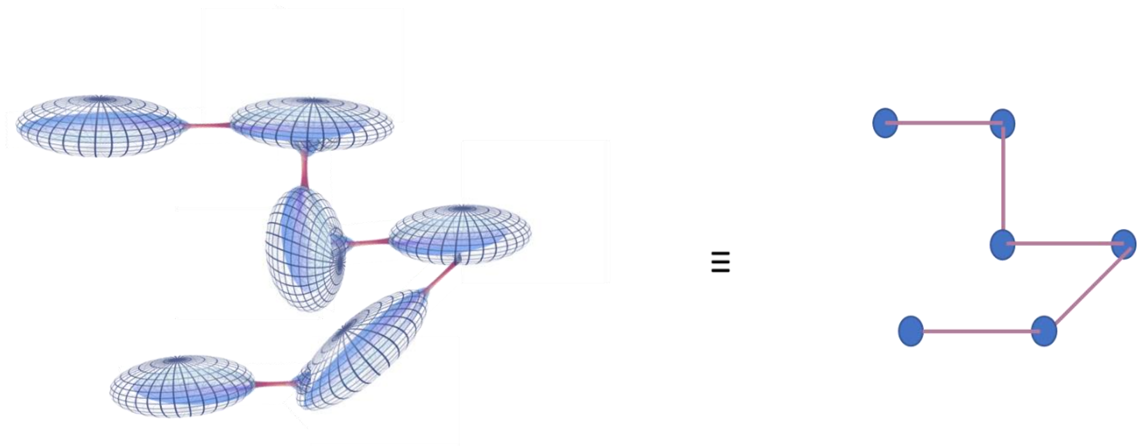
No matter what our reasoning shows that we expect traversability at Planck scales, even it was for other reasons, e.g. in case scales are too small to support the traversability motivations for wormholes presented in [1,39-41,*111,112*].

5.2 Discrete spatial spacetime with a continuous GR model

On the other hand, if wormhole are traversable, then the picture is way clearer. The change of phase really can be seen in GR (semi-classical) formalism as a condensation of spacetime into a lattice of connected clumps of spacetime. The connections between neighboring clumps are the wormholes, which allow exchanges between the discrete clumps.

Considering the size of the clumps (L going down towards L_p), this is both revealing a discrete spacetime, and a microscopic explanation of how (continuous) physics remain relevant, and jumps could take place from lattice node to lattice node: it behaves as a curious lattice with vertex or nodes being the clumps and wormholes being the edges between the nodes. This is a unique picture that in fact also provides a plausible continuous view on how the Lorentz symmetry would continue to work in what is a discrete lattice, while relaxing the arguments advanced in [1,16,46,64-68,*112,113*], of random Poisson sprinkling; but it works only if wormholes are traversable. We expect both the random Poisson sprinkling and connections as present the GR pictures around Planck scales.

If we consider maximum ER entanglement between neighboring clumps, then it is clear that, a priori, the majority of the clumps are linked only to one neighbor clump via wormhole as edge. This is shown in figure 5.



(a) (b)

Figure 5: A discrete spacetime, as a continuous semi-classical GR spacetime at ~ L_p scales. Wormholes are assumed to be traversable. Violet links indicate the wormhole connections.

This local entanglement is recovering the results that we already encountered, while correcting LQG, in the quantization of the Hilbert Einstein action [1,26]. Without it, the clumps would behave chaotically, and randomly, with random position and energy changes, and GR with a smooth classical spacetime would not be recoverable [42,43]. Confirming [26], and following [5], we see that GR field equations also do not expect the random fluctuations that plagued , even if quantum foam is not disputed at all, but as reasonable fluctuations instead of what LQG's current formulation encounters [26,41,42].

We have now encounter a microscopic explanation to the discrete spacetime at Planck scales within semi classical continuous GR, and seen how GR consistently manages to model it via wormholes / constructions of a continuous spacetime to maintain continuity and random sprinkling to ensure that the strange structure maintains Lorentz symmetries. Note that this does not mean that spacetime remains continuous, but rather it is the best way that GR can account for what happens within its continuous model.

5.3 Random walk or fractal structure

Here, we assume that all lattice nodes connected are not connected to all their neighbors only, in general, to an adjacent one. The reason being that entanglement must come from being initially a same clump that is squeezed in the into two clumps and a wormhole (see [38]). That always, or at least mostly, happens pairwise and can propagate as an expansion this way. It amounts to a random walk plus creation (split of nodes into two entangled nodes) of new spacetime nodes. It is consistent, by definition, with the reconstruction by random walk as in [1], or with a microscopic picture of an expanding universe in GR and the big bang as well as inflation [1,9,16,44,45,*109,110*]. That reasoning is not limited to multi-fold universes, once random walks pus creations of particles are the proposed processes.

More edges may be encountered at time, it does not matter, it is just (probably) not the dominant effect. As more edge appear, we have the predicted evolution from 2D to 3D then 4D, and spacetime becoming continuous and no more non-commutative (see after), Lorentz symmetric and behaving as expected from GR [1,9,10,48,*109,110*].

All these results are now encountered in Planck scaled semi-classical continuous GR.

5.4 Lorentz invariance and 4D spacetime

Relying on [46,47], if wormholes between clumps are traversable, exchange of quantum information ensures that each clump and the overall system is Lorentz symmetrical and 4D, within clumps and across the resulting lattice. It also shows the importance of the role played by wormholes (and multi-fold as discussed later), in building a Lorentz spacetime, as we emphasized in [46].

Because of the use of a continuous semi-classical model, the spacetime remains locally Lorentz invariant, if nothing else when work at scales smaller than the minimum length, something meaningless in the final theory, but allowed in GR alone, as it does not encompass on its own the minimum length. This is another example where the limitation of what can be modeled by the theory results in a facet trying to capture best what happens with a non-discrete/continuous spacetime model. It is only when we look at a slightly higher scale that we discover potential challenges Lorentz invariance, with a slightly larger scale view. In multi-fold theory, we have already addressed that this is in fact not an issue [1,16,46]. Here this provides a GR-based microscopic explanation of these considerations or the GR facets able to best account for it in GR.

5.5 Discrete time

In order to ensure that Lorentz invariance is satisfied, considering that wormholes take time to be (macroscopically) traversed.

If entanglement is to result between side-to-side dots, then, time must be clumped into discrete clicks or the time to traverse the wormholes would be non-instantaneous and the phenomena would not be entanglement or the whole analysis à la [5] would be inconsistent. The minimum would be around a Planck time unit. It is reminiscent of [27]. We will see that with the multi-fold perspective and mechanisms this is not concerning but has consequences.

5.6 2D processes and more

Picturing figure 3 in the context of figure 5, it should be clear that in figure 5, the dominant effects are now 1D (spatial) + time, i.e. 2D. This is an all too well know situation [1,6,7,9,10,48]: at very scale gravity is a 2D dominant process. It is not at all something limited to multi-fold theory. It was understood for a while before, and is encountered by all consistent theories of gravity. This results emerges from Planck scaled semi-classical continuous GR. As does the fact that, at larger scales, the process will evolve to 3D then 4D [1,10]. In fact, we are inclined to believe that 2D (and 2D + ε) gravity is relatively, and unambiguously proven renormalizable / asymptotically safe, while at any other larger number of dimension is way more challenging, because spacetime is 2D near the UV point [1,9,57,69-73,*110,111,114,115*]

Indeed, following the considerations at the end of section 5.3. Wormholes must expand in 3D spatial directions per [46]. The clumps must be distributed in a manner compatible with Lorentz symmetries, As already mentioned, it can only be achieved through a suitable random Poisson sprinkling of the nodes [1,16,46,64-68,*112,113*].

Within nodes or clumps, if a Planck volume or around, physics is 3D spatial, clumps must be Planck scale or smaller or the processes would be 4D not 2D as recovered by all consistent theories of quantum gravity [48].

The comment earlier also apply: GR does not have intrinsically a minimum length without adding the uncertainties, so from its point of view, we can have smaller scales than Planck where all appears 4D and continuous. But then quantum uncertainties impose the hard limits that ensures that the process is actually 2D.

When quantum uncertainties comes in play, the only solution, for not bouncing back to a 4D process at Planck scales, is that clumps are behaving as 0D, and therefore spacetime is discrete, as in [1] and section 5.2: the model is therefore best modeled with figure 5b when scaling up away from Lp scales. Also, it is the only way to not have to bother to introduce gravity within the clumps, or having to explain how they hold together internally. For example, Planck scales black holes, or Higgs condensate Qballs [4], can fit the 0D behavior, from the outside, without requiring the wonder what happen within these clumps. In other words, we recover also that aspect from multi-fold spacetime reconstruction derived in [1]. Other clumps might be considered like "gravitational dots" that may differ from our Higgs condensate Qballs, but we do not have any examples where it would not be equivalent to Qballs. The Higgs condensate Qballs can model SM particles [4] or concretize spacetime locations with massless Higgs as minimum Planck scales Qballs [1].

Again we have provided a derivation of these properties based solely on Planck scale continuous GR.

5.7 Non-commutative spacetime

(a)

(b)

Figure 6: It illustrates how moving say in x then y direction differs from Y then X, as the resulting node is differently connected or entangled as a result: space is non-commutative.

Figure 6 illustrates why spacetime is spatially non-commutative. Because at Planck scales, all models agree that gravity and spacetime are dominantly 2D [1,9,10,48], nodes are only linked to two nearest neighbor in the lattice as justified by progressive splits of nodes mentioned earlier.

When scale grow, more links appear and we move from 2D to 3D (more than two edges connected to each graph nodes) then 4D (up to 6 edge connected to many graph nodes)(and the dimension growth stops at 4D, as explained in [1,74]), and loses the non-commutativity for the same reasons: walking the graphs in different orders now lead to same location.

Timewise, non-commutativity also exists, because at Planck scales everything is massless and moving at *c* all the time. Measuring x then t, means that x has changed: the coordinate measured do not match the spacetime position. The same if measuring t then x. The result will always differ. Time-wise non-commutativity disappears at the same time as spatial non-commutativity as scales increase.

This is again a direct derivation of spacetime non-commutativity from continuous GR at Planck scales[11].

A history of the early days of non-commutativity can be found at [75].

5.8. Asymptotically Safe gravity

With a discrete spacetime, built as random walks dominantly a 2D spacetime process, we have in fact repeated the arguments, presented in [9,48], that GR-based gravity is asymptotically safe, without relying on multi-fold principles. GR implies asymptotic safety and semi-classical validity till Planck scales. Indeed already just the discrete nature of spacetime ensures an asymptotic safety behavior as below the minimum distance, established here, behavior will remain the same across scales.

The fact that this is obtained with GR reaching Planck scales, strongly illustrates that GR is the theory with the suitable UV point, not another intermediate theory. In other words, we can rely on it the reasoning so far to stringy argue that GR is asymptotically safe in 4D, and of course at lower dimensions.

We consider this as another independent proof that GR / gravity is asymptotically safe, and these properties contained in (the) GR facet. As a result the truncated flow equations are indeed also correct approaches to reach that conclusion [58,*124*].

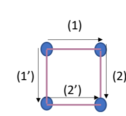
Possible implications are discussed in [9,48,57,*110,114*] and references therein. It has major potential consequences for theories like supersymmetry, superstrings, supergravity, M-Theory and most GUTs and TOEs: the possible incompatibility of such theories with the SM.

5.9 About Global Symmetries

[1,*111*], and references therein, discuss how the presence of traversable wormholes probably imply that no global symmetry can exist in the presence of GR, or gravity in general, as GR implies such wormholes. This is a result that the multi-fold theory encountered already with different arguments in [1]. We will add multi-fold considerations in a later section.

6. Encountering Multi-folds mechanisms, Mappings and the W-type Multi-fold Hypothesis

---

11 The result can also be in general derived the same way for entangled spacetime locations. 

In that figure, entanglement with the top versus with the left implies different states in the destinations between the two paths (normal and primed).

6.1 Interstitial wormholes

Consider figure 5(b), but now assume that the start and end nodes are also strongly entangled, possibly because a particle traveled from one to the other, or probably rather because it stretches across these locations), but not necessarily other interim (e.g., particle has moved on, or does not overlap). Entanglement implies immediate effects when one of the point has effect on the other. The model of 5(b), relying on the violet links, implies non-immediacy as the progression is step by step across the different wormholes. Immediacy would require another wormhole between the end points. It is shown in figure 7.

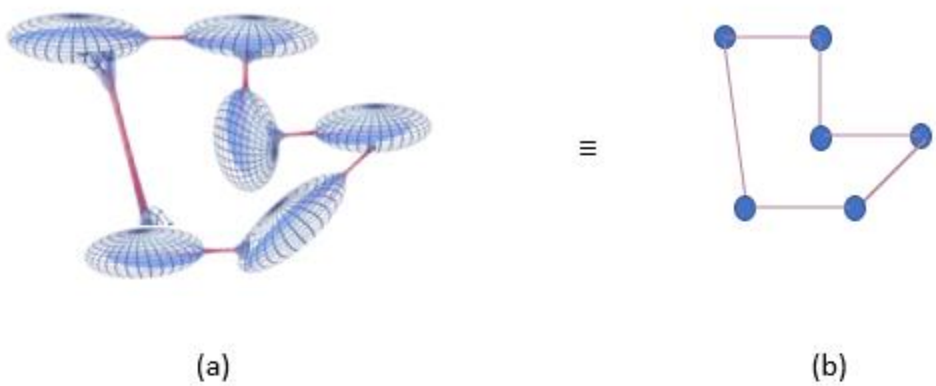


Figure 7: adds a wormhole between entangled end nodes with respect to figure 5.

Figure 8 illustrates the problem, no matter how small the time uncertainty and minimum time duration are: $5\Delta_t$ is no more almost instantaneous. So, supporting entanglement at distances imposes extra wormholes implementing Δ_t shortcuts.

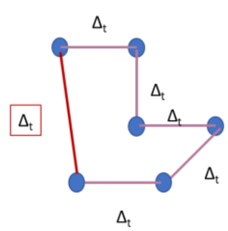


Figure 8: Only a multi-fold like shortcut between the end points can maintain consistency of entanglement no matter how distant the entangled spacetime locations are.

To do so, the wormhole would have be external/in between the lattice (i.e. interstitial outside the spacetime manifold so far), and able to be of a minimal length, à la [49], or with multi-fold mechanisms as in [1].

Interestingly, [5] continues to support this picture. As already mentioned, the Ricci scalar curvature $R(g,L)$ is large and negative at $R(g,L_p)$ in (3). When L increases it still smoothly evolves. Yet a figure like figure 5(a) shows a dominance of regions with positive Ricci scalar curvatures[12]. The only way to explain this is that there would also be a dominance of "extra" negative contributions: the interstitial wormholes.

[12] Yes, we do not expect a fast oscillation between positive and negative values of the Ricci scalar curvature.

6.2 Multi-folds

Linking multi-folds and wormholes can be addressed in different ways:

- Wormholes are traversable with mechanisms that allows them to implement multi-fold mechanisms and mappings, e.g. exotic matter, or massive entangled fermions, or massless entangled fermions with possible the help of dark energy effects and/or Casimir effects [1,39-41,*111*,*112*].
- Wormholes are just hints of Planck length out of 4D spacetime connections as in [49], directly matching figure 8.
- Multi-folds different from wormholes, e.g. not defined by GR, with the encountered wormholes are hints in GR of their existence, to the best of what GR can model. This was a possible main angle of [1], where we do not require that multi-fold be GR-based.
- A mix of wormholes, and multi-fold that are in general not traversable macroscopically, or even at the level of whole particles or wavefunctions, but that can be traversed by at least a path integral path. Traversability at such a level has typically, there are exceptions, not been considered by all the wormhole traversability analysis that we have encountered other than the multi-fold theory [1].

All these options amount to multi-fold encounters. All assume some traversability, and using the bridge or multi-fold for entanglement, and gravity, in ways that allows continuous smooth evolution through scales down to L_p.

[1] shows how doing so recovers from the traversability, a plausible model for entanglement effects, and gravity / GR as exemplified by the E/G conjecture [1,24,25,56,76].

Consistency would suggest the same principles, mechanisms or hints apply to neighboring and interstitial wormholes.

With the multi-fold mechanisms of [1], multi-fold are always supporting instantaneous path overlaps between entangled particles at the exit point. This address the delay problem mentioned earlier, in ways that wormholes implementing multi-folds may never fully match. This may or may not matter. Remember what we said about GR showing to the best of what it can model facets of the multi-folds: it is not possible to model better with GR alone. On the other hand the uncertainty principle can handle the delays with wormhole implementations of the multi-folds.

[46] hints are how multi-fold are formed as a result of the interactions between entangled systems.

Also the paths on the multi-folds can be considered as involving a ε part of any global charge, which means that the even at Planck scales the effect on global symmetries would be very small. Also, discussed in [*111*], the charge is conserved at scales covering both end points of the multi-folds, as is or implemented with wormholes. As wormholes are at Planck scales here, at any scales that we can observe, global charges will be conserved by the Planck scales effects. Of course, entanglement over larger scales will still bring the same issue, with our without wormhole implementations, and so, we recover results of [1], and a widely believed conjecture that gravity destroys global symmetries.

*Note added on February 21, 2023: And so we predicted and it seems now confirmed, that entanglement is also irreversible [116,117]. It had to be the case if the E/G conjecture is factual [*24,25,*46].*

Such break-up of Global symmetries can also explain interesting quantum quirks recently popularized by [118]:

- *Extraction of energy from local vacuum (states) [119]*
- *Energy teleportation [120,121]*

Indeed, between entangled systems, multi-folds, possibly implemented by traversable wormholes, allow transfer of state. For the second bullet it is analogous to the transfer via teleportation of other quantum states [1,122]. For the first bullet, vacuum entanglement between regions allow leakage from one region to another if energy is extracted on one side, without destroying the entanglement. Not however that multi-folds imposes that this be not between spacelike regions [1], something that is not a restriction in conventional, i.e. non-multi-fold QFT, as a result of the Reeh-Schlieder theorem [1,123].

Of course, GR only at Planck scales can allow this only at Planck scales, unless if longer wormholes exists and are traversable (and associated to entanglement). It is again because GR or quantum physics can only represent the facets of the multi-fold universe that they can model.

6.3 ER = EPR, one or the other. Same for GR = QM. It's all about E/G Conjecture

The above illustrates how ER=EPR is really a duality of theories showing the limitations of each ones: they can only provide hints of each other:

- GR has no concept of entanglement. It can only show a structure of spacetime compatible with entanglement.
- Quantum Physics is background dependent (in general, we are not talking of LQG or relative quantum reference frames as in [46]) and as such it can't capture the impacts of spacetime. So it can only introduce the notion of entanglement, and show its impact in the phase space / Hilbert space, as also seen in a Wigner formulation [1,50], even if we know that it contributes to create, and hence impact, a Lorentz spacetime [46]. Yet, that is the reflection of the hints of spacetime impact on the $\hat{x}_{(4)}$, and $\hat{p}_{(4)}$, 4-vectors operators.

So it is normal that [5] only sees the wormholes as it is the only concept it can model and can't only determine traversability on the basis of GR. Similarly, QM can't model how entanglement works, only that it is a property of the wave function / state of the entangled systems

On the other hand effects of entanglement on spacetime, Hilbert space and Phase space result from the wormholes appearing between nodes, which is the closest possible image of the multi-fold that combining GR and Quantum Physics can conjure.

[1] showed that traversability results in gravity in the main spacetime, and allows explanation of entanglement as spooky action at distance. And now we also know and see that it allows spacetime continuity in a discrete spacetime.

In conclusion the apparent possible discrepancies, albeit compatibility are reflection of the two facets of multi-fold mechanisms that neither GR nor Quantum Physics can capture completely on their own. As such we can now claim that multi-fold theory is in fact the umbrella model that encompasses both, in a consistent manner. And as such, yes if multi-folds can be modeled with wormholes, these will be traversable, because they implement multi-folds between entangled systems and because of the reasoning of section 5.1. That is in GR. These entangled systems are what ensure traversability at least for some path integral paths or because entangled right-handed neutrinos and left-handed anti neutrino enable it in the multi-folds, as discussed in [1,39-41,*111,112*].

Therefore, we have established that ER=EPR is not a conjecture, it's a characterization of the duality of Quantum Physics, and GR (also captured in the GR=QM conjecture), and it is a duality capturing, in each theory, the limited grasp that they can have of the multi-fold theory.

ER=EPR and GR = QM are factual at Planck scales in the real world, and they result from the different facets of the multi-fold theory accessible to GR and Quantum Physics. Even without the mechanisms of wormhole traversability [1,39-41,*111,112*], at Planck scales the conjectures applies. At larger scales, because macroscopic wormholes are defined by GR and traversability can be assured by [1,39-41,*111,112*], multi-folds are also hinted (remember GR can only model what it knows) between entangled systems. And so multi-folds implemented by traversable wormholes, or hinted by them apply to the real universe, or at least to GR-governed universes.

Encountering entanglements and multi-folds on one hand and traversable wormhole or multi-fold supporting path integral paths or exchange of quantum information on the other is also what we already did recently:

- In [26], we showed that quantization of the Hilbert Einstein action makes entanglement appear to model spacetime with spin networks in LQG, and thereby addressing what we consider as a misstep in LQG [42,43], that prevents it to ever connect to GR and smooth spacetime at larger scales[13].
- In [46], we showed how equivalence of quantum physics in different suitable quantum reference frames implies multi-fold or traversable wormholes. It also physically explains how quantum reference frames must transform for entangled, coherent, or correlated quantum systems, if we believe in a principle of equivalence of quantum relationships, as discussed in [46].

6.4 The W-type Multi-fold Hypothesis

The possibility, to link a node to a large set of farther away nodes, can explain how the W-type multi-fold hypothesis can be realized [18]: entanglement of spacetime locations, or phase space, occurs when wave functions or quantum fields overlap these locations and entangle them, resulting into the apparition of multi-fold effects. After all, entanglement and coherence are for all matter equivalent [51].

It is also closely linked to our mentions in [1], and section 6.3, of the impact of entanglement on the configuration and phase spaces, and as such on the Hilbert space. Evolving a rigorous model of multi-fold Hilbert space extensions is for future work.

6.5 Multi-fold gravity Electroweak symmetry breaking

Following [1,44,45], the multi-fold theory associates concretized spacetime locations as massless Higgs modeled as microscopic black holes [1,4,9,16,44,45,*109,110*], as are concretized spacetime locations [1]. The latter could correspond to the clumps encounters so far.

With Planck scale spacetime now discrete, 2D/generated by random walks, fractal, non-commutative yet still Lorentzian, and multi-folds in GR and QM, the model of particles as microscopic black holes as condensation of massless Higgs into Qballs [4,9,16,44,45,*109,110*], that are 7D space time matter induced geometrical solutions and scattered [52,53,79-81*,112*], the (real) universe, modeled by GR at Planck scales and Quantum Physics, now support the models described in [1,54,*110,111,125,127,136*] of the ultimate unification breaking into orientation of spacetime and electroweak symmetry breaking, giving rise to massive Higgs and particles [55,*111,125,127*].

[13] This is not a result depending on, or in support of LQG, and associated spin networks and spin foam. There may be other problems. But we believe the problem that we resolve with multi-folds in [26] addresses the fundamentals of a rigorous quantization of gravity, following Dirac's approach. Hence [26] + LQG and Multi-folds rigorously characterize GR at quantum scales.

The consistency of a lattice-based SM or SM_G to be more accurate, is discussed in [80].

7. Multi-fold spacetime reconstruction and multi-fold theory re-derivation from GR

The previous sections allow us to recover from GR at Planck scales fully as in [1]:

- Reconstruction of Multi-fold spacetime as in [1]
- Re-recover GR
- Recover multi-fold mechanisms as in [1] and the E/G conjecture as factual [24,25,46]

The full multi-fold theory is recovered [1,27,28], including SM_G[14], except may be for the explanation of entanglement as due to virtual particles (and associated (optional) proposal for massive gravity contributions [1,56]). In that top(GR) down, then bottom up (Multi-fold theory then GR) approach, virtual particle entanglement as source of gravity and massive gravity become an option for a microscopic explanation of gravity. We will speak in future of it as the *top-down-up-and-upper derivation of the multi-fold theory*.

This derivation is self-consistent: the validity of GR and semi-classical model till the Planck scales results from the multi-fold mechanisms and how gravity results form them.

Furthermore, it completes, and confirms, the rigorous derivation of the multi-fold spacetime reconstruction, developed in [1], where some may have argued that some of the steps could have been more extrapolation than derivation[15].

It also reinforces the proof from [1] that multi-fold mechanisms recover GR.

Note added on February 23, 2022: Massive gravity can also be encountered by relying on The Goldstone theorem and its extensions [58]:

- *The graviton is the result of the dominantly 2D effects breaking Lorentz 4D when growing above Planck models: one does no more 4D navigate as inside clumps and neighboring wormholes. It is a quasi-particle as discussed in [34], in analogy with the phonon for example, but non-perturbatively not well-defined.*
- *The massive gravitons results from the growing beyond the scales of SM particles, where the W-type multi-fold hypothesis and associated entanglement of spacetime link all spacetime location in the support as if 4D. These are approximate symmetries and therefore associated to massive Goldstone bosons [58].*
- *As explained in [58,59], Lorentz symmetry breaking can lead to tensor particles (spin-2), therefore in agreement with the above.*

In multi-folds, the analysis is a bit different, as gravitons are unphysical, so 2D and spin-2 have different effects as do massive virtual particles at the scales of their interactions.

---

[14] SM_G stands for the Standard Model (SM) with gravity effects non-negligible at its scales [1,27,28,*87,113*].

[15] We maintain the rigorous of the derivation, but admit that the proof is in the results obtained here were we can now go back and forth between the spacetime reconstruction model and the full multi-fold mechanism as well as GR.

8. Conclusions

In this paper, we have encountered, probably in the most convincing manner so far, the presence of multi-folds in GR at Planck scales, in the form of traversable wormholes. Doing so we also encountered hints that at such scales spacetime is discrete, 2D, fractal generated by random walk, non-commutative while Lorentz symmetric, and … continuous. And doing so we even explained how that it not contradictory. These results are in perfect alignment with the results obtained in the multi-fold spacetime reconstruction, including UU, the multi-fold inflation and the multi-fold gravity electroweak symmetry breaking, and microscopic black holes as Higgs condensate Qballs.

As an aside, we also derived a relationship between spacetime entanglement and non-commutative spacetime.

We also clarified the meaning of the ER = EPR and QR = QM conjectures as facets of the multi-fold theory that is the umbrella theory that neither GR nor QM can fully / well model. Deriving ways to extend these models is for future work.

The main outcome of the paper remains: universes modeled by GR are multi-fold. It looks like our real universe is therefore well, should we say better, modeled as a multi-fold universe. Indeed, the whole multi-fold theory can be derived from GR at Planck scales. It's the *top-down-up-and-upper derivation of the multi-fold theory*.

Previous works, as tracked at [27], show that the multi-fold theory can also provide interesting contributions to open problems with SM / SMG, and to the standard cosmological model (ΛCDM) [1,9,10,16,18,24,25,27,28,39,40-45,48,52-57,74,76,77,79-104,*109-115,125-136*].

With the *top-down-up-and-upper approach,* the paper also completes, and confirms, the proof of a rigorous derivations of the multi-fold spacetime reconstruction, and the recovery of GR from multi-fold mechanisms started in [1].

Finally, we provide a derivation, without any multi-fold assumptions, that gravity is asymptotically safe in a GR-based universe.

____

References

[1]: Stephane H. Maes, (2020-2022) "Quantum Gravity Emergence from Entanglement in a Multi-Fold Universe", HIJ, Vol 2, No 4, pp 136-219, Dec 2022, https://doi.org/10.55672/hij2022pp136-219, https://shmaesphysics.wordpress.com/2020/06/09/paper-published-as-preprint-quantum-gravity-emergence-from-entanglement-in-a-multi-fold-universe/, https://shmaesphysics.wordpress.com/2022/11/09/quantum-gravity-emergence-from-entanglement-in-a-multi-fold-universe-2/, and viXra:2006.0088, (June 9, 2020).

[2]: Wikipedia, "Reissner–Nordström metric", https://en.wikipedia.org/wiki/Reissner%E2%80%93Nordstr%C3%B6m_metric. Retrieved on March 21, 2020.

[3]: Wikipedia, "Kerr–Newman metric", https://en.wikipedia.org/wiki/Kerr-Newman_metric. Retrieved on March 21, 2020.

[4]: Stephane H Maes, (2021), "More on Multi-fold Particles as Microscopic Black Holes with Higgs Regularizing Extremality and Singularities", viXra:2210.0004v1, https://shmaesphysics.wordpress.com/2021/02/28/more-on-multi-fold-particles-as-microscopic-black-holes-with-higgs-regularizing-extremality-and-singularities/, February 25, 2021.

[5]: Fabrizio Tamburini, Ignazio Licata, (2019), "General Relativistic Wormhole Connections from Planck-Scales and the ER = EPR Conjecture", arXiv:1912.12424v1.

[6]: G. ‘t Hooft, (1993), “Dimensional Reduction in Quantum Gravity”, arXiv:gr-qc/9310026v2.

[7]: Steven Carlip, (2010), “The Small-Scale Structure of Spacetime“, arXiv:1009.1136v1.

[8]: Hooft, Gerard ’t, (2016), “How quantization of gravity leads to a discrete space-time”, J. Phys.: Conf. Ser. 701 012014

[9]: Stephane H Maes, (2021), “Quantum Gravity Asymptotic Safety from 2D Universal Regime and Smooth Transition to Dual Superstrings”, viXra:2208.0151v1, https://shmaesphysics.wordpress.com/2021/02/07/quantum-gravity-asymptotic-safety-from-2d-universal-regime-and-smooth-transition-to-dual-superstrings/, January 29, 2021.

[10]: Stephane H Maes, (2021), ““Quantum Gravity Emergence from Entanglement in a Multi-Fold Universe”: 2D or 2+1D spacetime at small scales”, viXra:2103.0142, https://shmaesphysics.wordpress.com/2021/03/20/quantum-gravity-emergence-from-entanglement-in-a-multi-fold-universe-2d-or-21d-spacetime-at-small-scales/, March 20, 2021.

[11]: S. Doplicher, K. Fredenhagen and J. E. Roberts, (1994), ”Spacetime quantization induced by classical gravity”, Phys. Rev. B 331 (1994) 33.

[12]: Sergio Doplicher, Klaus Fredenhagen and John E. Roberts, (1994), ”The Quantum Structure of Spacetime at the Planck Scale and Quantum Fields”, Commun. Math. Phys. 172, 187 -220 (1995).

[13]: Garay, L.J., (1995), “Quantum gravity and minimum length”, Int. J. Mod. Phys. A, 10, 145.

[14]: Ronald J. Adler, David I. Santiago, (1999), “On Gravity and the Uncertainty Principle”, arXiv:gr-qc/9904026v2.

[15]: Shan, Gao, (2006), “A Model of Wavefunction Collapse in Discrete Space-Time”, IJTP 2006, 45, 10.

[16]: Stephane H Maes, (2021), “Multi-fold Non-Commutative Spacetime, Higgs and The Standard Model with Gravity”, viXra:2212.0037v1, https://shmaesphysics.wordpress.com/2021/04/18/multi-fold-non-commutative-spacetime-higgs-and-the-standard-model-with-gravity/, April 11, 2021.

[17]: Shan Gao, (2010-2011), “Why gravity is fundamental”, arXiv:1001.3029v3.

[18]: Stephane H Maes, (2020), “The W-type Multi-Fold Hypothesis and Quantum Physics Interpretation of wave Functions and QFT”, viXra:2207.0118v1, https://shmaesphysics.wordpress.com/2020/12/24/the-w-type-multi-fold-hypothesis-and-quantum-physics-interpretation-of-wave-functions-and-qft/, December 20, 2020.

[19]: Alexander Streltsov, Uttam Singh, Himadri Shekhar Dhar, Manabendra Nath Bera, Gerardo Adesso, (2015), “Measuring Quantum Coherence with Entanglement”, arXiv:1502.05876v4.

[20]: Lisa Zyga, (2015), “Physicists find quantum coherence and quantum entanglement are two sides of the same coin”, https://phys.org/news/2015-06-physicists-quantum-coherence-entanglement-sides.html. Retrieved on February 17, 2022.

[21]: Maldacena, Juan and Susskind, Leonard (2013). “Cool horizons for entangled black holes”. Fortsch. Phys. 61 (9): 781–811. arXiv:1306.0533

[22]: Wikipedia, “ER=EPR”, https://en.wikipedia.org/wiki/ER_%3D_EPR. Retrieved on February 21, 2022.

[23]: Leonard Susskind, (2017). “Dear Qubitzers, GR=QM”, arXiv:1708.03040

[24]: Stephane H Maes, (2020), “The E/G conjecture: entanglement is gravity and gravity is entanglement”, viXra:2010.0139v1, https://shmaesphysics.wordpress.com/2020/10/15/the-e-g-conjecture-entanglement-is-gravity-and-gravity-is-entanglement/, October 15, 2020.

[25]: Stephane H Maes, (2021), "How the ER = EPR, GR = QM and AdS/CFT correspondence conjectures, can be explained in multi-fold theory, along with the E/G conjecture. A call to the Physics Community!", viXra:2111.0144v2, https://shmaesphysics.wordpress.com/2021/11/28/how-the-er-epr-gr-qm-and-ads-cft-correspondence-conjectures-can-be-explained-in-multi-fold-theory-and-the-e-g-conjecture-explains-and-realize-in-a-multi-fold-universe-a-call-to-the-physics-comm/, December 28, 2021.

[26]: Stephane H Maes, (2020), "Multi-folds, The Fruit From The Loops? Fixing "Oops for The Loops" May Encounter Multi-folds in General Relativity And The E/G Conjecture", viXra:2212.0206v1, https://shmaesphysics.wordpress.com/2021/12/31/multi-folds-the-fruit-from-the-loops-fixing-oops-for-loops-encounters-multi-folds-and-the-e-g-conjecturein-general-relativity/, January 1, 2022.

[27]: Stephane Maes, (2020-2022), "Web Site Tracking all Publications around the Multi-fold universe", Navigation page listing all papers. https://shmaesphysics.wordpress.com/shmaes-physics-site-navigation/.

[28]: Stephane H Maes, (2021), "The Multi-fold Theory: A synopsis", https://vixra.org/pdf/2112.0144v1.pdf, https://shmaesphysics.wordpress.com/2021/12/24/the-multi-fold-theory-a-synopsis-so-far-v2-end-of-2021/, December 24, 2021. Note that additional links will always be available at https://shmaesphysics.wordpress.com/2021/05/03/the-multi-fold-theory-a-synopsis-so-far/ to track the latest and interim versions of the synopsis, as they may be published under different tittle or URL/publication numbers.

[29]: DeWitt, B.S., (1967)"Quantum Theory of Gravity. I. The Canonical Theory.", Phys. Rev., 160, 1113. [CrossRef]

[30]: DeWitt, B.S., (1967), "Quantum Theory of Gravity. II. The Manifestly Covariant Theory.", Phys. Rev., 162, 1195.

[31]: DeWitt, B.S. (1967), "Quantum Theory of Gravity. III. Applications of the Covariant Theory.", Phys. Rev., 162, 1239.

[32]: DeWitt, B.S.; DeWitt, C.M., (1952), " The Quantum Theory of Interacting Gravitational and Spinor Fields.", Phys. Rev., 87, 116.

[33]: DeWitt, B.S., (1981), "Approximate Effective Action for Quantum Gravity.", Phys. Rev. Lett., 47, 1647.

[34]: Stephane H Maes, (2022), "Gravitational Bootstrap, S-matrix, Superstrings, and The Plausible Unphysicality of Gravitons", https://shmaesphysics.wordpress.com/2022/02/06/gravitational-bootstrap-s-matrix-superstrings-and-the-plausible-unphysicality-of-gravitons/, February 6, 2022.

[35]: Daniel Davies, (2017), "Building an Ellis Wormhole", https://theoreticalmaximum.files.wordpress.com/2017/03/ellis-wormhole.pdf. Retrieved on February 13, 2022.

[36]: Wikipedia, "Schwarzschild radius", https://en.wikipedia.org/wiki/Schwarzschild_radius#Schwarzschild_radius_for_Planck_mass. Retrieved on December 29, 2019.

[37]: van Raamsdonk, Mark (2010). "Building up spacetime with quantum entanglement", arXiv:1005.3035.

[38]: "The Entanglement Connection", https://shmaesphysics.wordpress.com/2021/11/28/how-the-er-epr-gr-qm-and-ads-cft-correspondence-conjectures-can-be-explained-in-multi-fold-theory-and-the-e-g-conjecture-explains-and-realize-in-a-multi-fold-universe-a-call-to-the-physics-comm/#comment-3523. Originally retrieved on February 13, 2022, from https://64.media.tumblr.com/8d124eacd068515fd31b545deea889b3/tumblr_nztidsInTh1sar0coo1_1280.jpg.

[39]: Stephane H Maes, (2020), “Circular Arguments in String and Superstring Theory from a Multi-fold Universe Perspective”, viXra:2103.0195v1, https://shmaesphysics.wordpress.com/2020/10/11/circular-arguments-in-string-and-superstring-theory-from-a-multi-fold-universe-perspective/, October 5, 2020.

[40]: Stephane H Maes, (2021), “Right-handed Neutrinos and Traversable Wormholes: the key to entanglement, gravity and multi-folds extensions to ER=EPR?”, viXra:2211.0173v1, https://shmaesphysics.wordpress.com/2021/04/03/right-handed-neutrinos-and-traversable-wormholes-the-key-to-entanglement-gravity-and-multi-folds-extensions-to-erepr/, April 3, 2021.

[41]: Stephane H Maes, (2020), ”Superstrings Encounter of the Second, Third or Fourth Types?”, viXra:2010.0140v1, https://shmaesphysics.wordpress.com/2020/07/19/superstrings-encounter-of-the-second-third-or-fourth-types/, July 5, 2020.

[42]: Stephane H Maes, (2021), “Oops For The Loops: Mounting LQG Woes And A Challenge To The LQG Community”, viXra:2212.0168v2, https://shmaesphysics.wordpress.com/2021/12/30/oops-for-loops-mounting-lqg-woes-and-a-challenge-to-the-lqg-community/, December 29, 2021.

[43]: Stephane H Maes, (2022), “Oops For The Loops II: Real Oops; LQG Does Not Optimize the Hilbert Einstein Action”, viXra:2301.0036v1, https://shmaesphysics.wordpress.com/2022/01/05/oops-for-the-loops-ii-real-oops-lqg-does-not-optimize-the-hilbert-einstein-action/, January 5, 2022.

[44]: Stephane H Maes, (2020), ”Explaining Dark Energy, Small Cosmological Constant and Inflation Without New Physics?”, viXra:2006.0261v1, https://shmaesphysics.wordpress.com/2020/06/19/explaining-dark-energy-small-cosmological-constant-and-inflation-without-new-physics/, June 19, 2020.

[45]: Stephane H Maes, (2020), “Multi-fold Higgs Fields and Bosons”, viXra:2204.0146v1, https://shmaesphysics.wordpress.com/2020/11/10/multi-fold-higgs-fields-and-bosons/, November 6, 2020.

[46]: Stephane H Maes, (2022), “From Quantum Relational Equivalence to Multi-folds Encounter in the Real Universe and Confirmation of the E/G conjecture”, viXra:2302.0108v1, https://shmaesphysics.wordpress.com/2022/02/12/from-quantum-relational-equivalence-to-multi-folds-encounter-in-the-real-universe-and-confirmation-of-the-e-g-conjecture/, February 7, 2022.

[47]: Philipp A Höhn and Markus P Müller, (2016), “An operational approach to spacetime symmetries: Lorentz transformations from quantum communication”, New J. Phys. 18 063026.

[48]: Stephane H Maes, (2021), “Spacetime and Gravity are 2D around Planck Scales: A Universal Property of Consistent Quantum Gravity”, https://shmaesphysics.wordpress.com/2021/03/23/spacetime-and-gravity-are-2d-around-planck-scales-a-universal-property-of-consistent-quantum-gravity/, March 20, 2021.

[49]: Yan Breek, (2020), “Geometric Discrete Unified Theory Framework”, https://www.researchgate.net/publication/341176942_Geometric_Discrete_Unified_Theory_Framework.

[50]: A. M. Ozorio de Almeida, (2006), ”Entanglement in phase space”, arXiv:quant-ph/0612029v1.

[51]: Alexander Streltsov, Uttam Singh, Himadri Shekhar Dhar, Manabendra Nath Bera, Gerardo Adesso, (2015), “Measuring Quantum Coherence with Entanglement”, arXiv:1502.05876v4.

[52]: Stephane H Maes, (2020), “Tracking Down The Standard Model With Gravity In Multi-Fold Universes”, viXra:2011.0208v1, https://shmaesphysics.wordpress.com/2020/08/30/tracking-down-the-standard-model-with-gravity-in-multi-fold-universes/, August 20, 2020.

[53]: Stephane H. Maes, (2020), "Particles of The Standard Model In Multi-Fold Universes", viXra:2111.0071v1, https://shmaesphysics.wordpress.com/2020/11/05/particles-of-the-standard-model-in-multi-fold-universes/, November 4, 2020.

[54]: Stephane H Maes, (2020), "Ultimate Unification: Gravity-led Democracy vs. Uber-Symmetries", viXra:2006.0211v1, https://shmaesphysics.wordpress.com/2020/06/16/ultimate-unification-gravity-led-democracy-vs-uber-symmetries/, June 16, 2020.

[55]: Stephane H Maes, (2021), "Multi-fold Gravity-Electroweak Theory and Symmetry Breaking", viXra:2211.0100, https://shmaesphysics.wordpress.com/2021/03/28/multi-fold-gravity-electroweak-theory-and-symmetry-breaking/, March 16, 2021.

[56]: Stephane H Maes, (2020), "Massless and Massive Multi-Gravity in a Multi-fold Universe", viXra:2010.0095v1, https://shmaesphysics.wordpress.com/2020/06/30/massless-and-massive-multi-gravity-in-a-multi-fold-universe/, June 19, 2020.

[57]: Stephane H Maes, (2020), "Renormalization and Asymptotic Safety of Gravity in a Multi-Fold Universe: More Tracking of the Standard Model at the Cost of Supersymmetries, GUTs and Superstrings", viXra:2102.0137v1, https://shmaesphysics.wordpress.com/2020/09/19/renormalization-and-asymptotic-safety-of-gravity-in-a-multi-fold-universe-more-tracking-of-the-standard-model-at-the-cost-of-supersymmetries-guts-and-superstrings/, September 18, 2020.

References added on February 23, 2022:

[58]: Wikipedia, "Goldstone boson", https://en.wikipedia.org/wiki/Goldstone_boson. Retrieved on April 6, 2019.

[59]: Ian Low, Aneesh V. Manohar, (2001-2002), "Spontaneously Broken Spacetime Symmetries and Goldstone's Theorem", arXiv:hep-th/0110285v2.

[60]: Wikipedia, "Ellis wormhole", https://en.wikipedia.org/wiki/Ellis_wormhole. Retrieved on February 23, 2022.

[61]: Wikipedia, " Ellis drainhole", https://en.wikipedia.org/wiki/Ellis_drainhole. Retrieved on February 23, 2022.

[62]: Encyclopedia Galactica, "Wormholes - A Layman's Guide", https://www.orionsarm.com/eg-article/48545a0f6352a. Retrieved on February 23, 2022.

[63]: Wikipedia, "Causal sets", https://en.wikipedia.org/wiki/Causal_sets. Retrieved on January 26, 2022.

[64]: Summate Surya, (2019), "The causal set approach to quantum gravity", arXiv:1903.11544v2.

[65]: Joe Henson, (2006), "The causal set approach to quantum gravity", arXiv:gr-qc/0601121v2.

[66]: Wikipedia, "Causal sets", https://en.wikipedia.org/wiki/Causal_sets, Retrieved on April 16, 2021.

[67]: Math pages, "Stochastic Sprinkling", https://www.mathpages.com/home/kmath726/kmath726.htm. Retrieved on April 16, 2021.

[68]: Luca Bombelli, Joe Henson, Rafael D. Sorkin, (2006), "Discreteness without symmetry breaking: a theorem", arXiv:gr-qc/0605006v1.

[69]: Harold Erbin, (2015), "Notes on 2d quantum gravity and Liouville theory", https://www.lpthe.jussieu.fr/~erbin/files/liouville_theory.pdf.

[70]: Deniel Grumiller, (2008), "3D quantum gravity?", https://publik.tuwien.ac.at/files/PubDat_170179.pdf. Retrieved for this paper on February 20, 2021.

[71]: S. Weinberg, (1979), "Ultraviolet divergences in quantum theories of gravitation", In "Hawking, S.W., Israel, W.: General Relativity", 790-831, Cambridge University Press, Cambridge .

[72]: Assaf Shomer (2007). "A pedagogical explanation for the non-renormalizability of gravity", arXiv:0709.3555v2.

[73]: Yoshihisa Kitazawa, (1995), "Quantum Gravity is Renormalizable near Two Dimensions", arXiv:hep-th/9505193v1.

[74]: Stephane H. Maes, (2021-2022), "Our real universe spacetime is 4D". Multiple comments / threads in the comment section of https://shmaesphysics.wordpress.com/2020/09/19/renormalization-and-asymptotic-safety-of-gravity-in-a-multi-fold-universe-more-tracking-of-the-standard-model-at-the-cost-of-supersymmetries-guts-and-superstrings/.

[75]: Heller, M., Lambert, D., & Madore, J., (1998), "A Brief History of Noncommutative Space-Time", Acta Cosmologica, vol. 24, p.51.

[76]: Stephane H Maes, (2020), "Gravity-like Attractions and Fluctuations between Entangled Systems?", viXra:2010.0010v1, https://shmaesphysics.wordpress.com/2020/06/25/gravity-like-attractions-and-fluctuations-between-entangled-systems/, June 24, 2020.

[77]: Wikipedia, "Lambda-CDM model", https://en.wikipedia.org/wiki/Lambda-CDM_model. Retrieved on August 14, 2022.

[78]: Wikipedia, "Asymptotic safety in quantum gravity", https://en.wikipedia.org/wiki/Asymptotic_safety_in_quantum_gravity, Retrieved for this paper on September 18, 2020.

[79]: Stephane H Maes, (2021), "Multi-fold Embeddings, Space Time Matter Induction or Gravity Asymptotically Safe and The AdS/CFT Correspondence Conjecture, they all can recover the Standard Model", viXra:2212.0120v1, https://shmaesphysics.wordpress.com/2021/12/20/multi-fold-embeddings-space-time-matter-induction-or-gravity-asymptotically-safe-and-the-ads-cft-correspondence-conjecture-they-all-can-recover-the-standard-model-or-smg/, December 20, 2021.

[80]: Stephane H Maes, (2020), "Viable Lattice Spacetime and Absence of Quantum Gravitational Anomalies in a Multi-fold Universe", viXra:2205.0143v1, https://shmaesphysics.wordpress.com/2020/12/13/viable-lattice-spacetime-and-absence-of-quantum-gravitational-anomalies-in-a-multi-fold-universe/, December 4, 2020.

[81]: Stephane H Maes, (2022), "Can Chirality Flips Occur in a Multi-Fold Universe? What About Conservation Laws? II", viXra:2204.0152v2, https://shmaesphysics.wordpress.com/2022/08/20/can-chirality-flips-occur-in-a-multi-fold-universe-what-about-conservation-laws-ii/, August 20, 2022 and Stephane H Maes, (2020), "Can Chirality Flips Occur in a Multi-Fold Universe? What About Conservation Laws?", viXra:2204.0152, https://shmaesphysics.wordpress.com/2020/12/07/can-chirality-flips-occur-in-a-multi-fold-universe-what-about-conservation-laws/, December 6, 2020.

[82]: Stephane H. Maes, (2022), "Comment on LQG, Superstrings, Supersymmetry and most GUTs/TOEs, all have big problems exposed by the Multi-fold Theory", https://shmaesphysics.wordpress.com/2021/12/27/the-multi-fold-theory-a-synopsis/#comment-3293. Published on January 9, 2022.

[83]: Stephane H. Maes, (2020), "Comment on why no supersymmetry", https://shmaesphysics.wordpress.com/2020/10/11/circular-arguments-in-string-and-superstring-theory-from-a-multi-fold-universe-perspective/#comment-934. Published on October 12, 2020.

[84]: Stephane H Maes, (2021), "The String Swampland and de Sitter Vacua: A Consistent Perspective for Superstrings and Multi-fold Universes", viXra:2208.0078v1, https://shmaesphysics.wordpress.com/2021/01/12/the-string-swampland-and-de-sitter-vacua-a-consistent-perspective-for-superstrings-and-multi-fold-universes/, January 9, 2021.

[85]: Stephane H Maes, (2020), "Dualities or Analogies between Superstrings and Multi-fold Universe", viXra:2006.0178v1, https://shmaesphysics.wordpress.com/2020/06/14/dualities-or-analogies-between-superstrings-and-multi-fold-universes/, June 14, 2020.

[86]: Stephane H Maes, (2020), "Alignments and Gaps Between Multi-fold Universes And Loop Quantum Gravity", viXra:2006.0229v1, https://shmaesphysics.wordpress.com/2020/06/19/multi-fold-universes-analysis-of-loop-quantum-gravity/, June 18, 2020.

[87]: Stephane H. Maes, (2022), "What is the Multi-fold Theory? Its Main Characteristics in a Few Words", vixra:2207.0172v1, https://shmaesphysics.wordpress.com/2022/07/28/what-is-the-multi-fold-theory-its-main-characteristics-in-a-few-words/, July 28, 2022.

[88]: Stephane H Maes, (2020), "Explaining Dark Matter Without New Physics?", viXra:2007.0006v1, https://shmaesphysics.wordpress.com/2020/06/19/explaining-dark-energy-small-cosmological-constant-and-inflation-without-new-physics/, June 21, 2020.

[89]: Stephane H Maes, (2020), "Multi-Fold Universe Dark Matter Successful Explanation and the "Too Thin Universe" but "Too Strong Gravity Lensing by Galaxy Clusters"", viXra:2102.0079v1, https://shmaesphysics.wordpress.com/2020/09/15/multi-fold-universe-dark-matter-successful-explanation-and-the-too-thin-universe-but-too-strong-gravity-lensing-by-galaxy-clusters/, September 14, 2020.

[90]: Stephane H Maes, (2020), "Multi-Fold Universe Dark Matter Effects Survive Low-Mass Galaxies with Dark Matter Deficits and Excesses", viXra:2105.0042v1, https://shmaesphysics.wordpress.com/2020/10/14/multi-fold-universe-dark-matter-effects-survive-low-mass-galaxies-with-dark-matter-deficits-and-excesses/, October 14, 2020.

[91]: Stephane H Maes, (2020), "Multi-Fold Dark Matter Effects and Early Supermassive Black Holes", viXra:2105.0041v1, https://shmaesphysics.wordpress.com/2020/10/15/multi-fold-dark-matter-effects-and-early-supermassive-black-holes/, October 15, 2020.

[92]: Stephane H Maes, (2020), "Derivation of the Equivalence Principle in a Multi-fold Universe", viXra:2010.0090v1, https://shmaesphysics.wordpress.com/2020/06/29/derivation-of-the-equivalence-principle-in-a-multi-fold-universe/, June 19, 2020.

[93]: Stephane H Maes, (2020), "Progress on Proving the Mass gap for Yang Mills and Gravity (maybe it's already proved…)", viXra:2006.0155v1, https://shmaesphysics.wordpress.com/2020/06/12/progresses-on-proving-the-mass-gap-for-yang-mills-and-gravity-maybe-its-already-proven/, June 12, 2020.

[94]: Stephane H Maes, (2020), "Gravity Induced Anomalies Smearing in Standard Model so that Protons May Never Decay, Except in Black holes", viXra:2006.0128v1, https://shmaesphysics.wordpress.com/2020/06/13/gravity-induced-anomalies-smearing-in-standard-model-so-that-protons-may-never-decay-except-in-black-holes/, June 13, 2020.

[95]: Stephane H Maes, (2022), "Gravity or Magnetic Monopoles? You Cannot Have Both! II", viXra:2006.0190v2, https://shmaesphysics.wordpress.com/2022/08/20/gravity-or-magnetic-monopoles-you-cannot-have-both-2/, August 20, 2022; Stephane H Maes, (2020), "Gravity or Magnetic Monopoles? You Cannot

Have Both!", viXra:2006.0190, https://shmaesphysics.wordpress.com/2020/06/15/gravity-or-magnetic-monopoles-you-cannot-have-both/, June 15, 2020.

[96]: Stephane H Maes, (2020), "Right-handed neutrinos? Mass? Ask Gravity", viXra:2007.0018v1, https://shmaesphysics.wordpress.com/2020/06/21/right-handed-neutrinos-ask-gravity/, June 23, 2020.

[97]: Stephane H Maes, (2020), "Strong CP Violation Tamed in The Presence of Gravity", viXra:2007.0025v1, https://shmaesphysics.wordpress.com/2020/06/23/strong-cp-violation-tamed-in-the-presence-of-gravity/ , June 21, 2020.

[98]: Stephane H Maes, (2020), "Gravity Dictates the Number of Fermion Generations: 3", viXra:2007.0068v1, https://shmaesphysics.wordpress.com/2020/06/24/gravity-dictates-the-number-of-fermion-generations-3/, June 24, 2020.

[99]: Stephane H Maes, (2020), "Gravity Stabilizes Electroweak Vacuum – No Bubble of Nothing to Worry About!", viXra:2007.0173v1, https://shmaesphysics.wordpress.com/2020/06/24/gravity-stabilizes-electroweak-vacuum-no-bubble-of-nothing-to-worry-about/, June 24, 2020.

[100]: Stephane H Maes, (2020), "More Matter Than Antimatter, All Falling Down", viXra:2010.0121v2, https://shmaesphysics.wordpress.com/2020/07/05/more-matter-than-antimatter-all-falling-down/, July 5, 2020. (V2: April 8, 2021)

[101]: Stephane H Maes, (2020), "No Conventional Sterile Neutrinos In a Multi-fold Universe: just SMG business as usual", viXra:2103.0202v1, https://shmaesphysics.wordpress.com/2020/10/02/no-conventional-sterile-neutrinos-in-a-multi-fold-universe-just-smg-business-as-usual/, October 1, 2020.

[102]: Stephane H Maes, (2021), "New Physics with LHCb to explain loss of lepton universality, or just gravity?", viXra:2103.0191v1, https://shmaesphysics.wordpress.com/2021/03/29/new-physics-with-lhcb-to-explain-loss-of-lepton-universality-or-just-gravity/, March 29, 2021.

[103]: Stephane H. Maes, "A bold prediction on the muon anomalous magnetic moment, and expected results to be published on April 7, 2021 by the Fermilab Muon g-2, and its explanation", viXra:2104.0030v1, https://shmaesphysics.wordpress.com/2021/04/01/a-bold-prediction-on-the-muon-anomalous-magnetic-moment-and-expected-resulted-to-be-published-on-april-7-2021-by-the-fermilab-muon-g-2-and-its-explanation/, April 1, 2021.

[104]: Stephane H Maes, (2021), "New Physics is often not so new", https://shmaesphysics.wordpress.com/2021/04/27/new-physics-is-often-not-so-new/, April 27, 2021.

References added on February 21, 2023

[105]: Natalie Wolchover, (2022), "Physicists Create a Holographic Wormhole Using a Quantum Computer. The unprecedented experiment explores the possibility that space-time somehow emerges from quantum information, even as the work's interpretation remains disputed", QuantaMagazine, https://www.quantamagazine.org/physicists-create-a-wormhole-using-a-quantum-computer-20221130/?s=09. November 30, 2022.

[106]: Stephane H. Maes, (2022), "Confusing mathematical duality to predict quantum computing algorithm, with building a wormhole", https://shmaesphysics.wordpress.com/2020/10/11/circular-arguments-in-string-and-superstring-theory-from-a-multi-fold-universe-perspective/comment-page-1/#comment-5093, November 30, 2022, and subsequent comments.

[107]: Daniel Jafferis, Alexander Zlokapa, Joseph D. Lykken, David K. Kolchmeyer, Samantha I. Davis, Nikolai Lauk, Hartmut Neven & Maria Spiropulu, (2022), "Traversable wormhole dynamics on a quantum processor", Nature volume 612, pages 51–55.

[108]: Ping Gao, Daniel Louis Jafferis, (2019 – 2021), "A Traversable Wormhole Teleportation Protocol in the SYK Model", arXiv:1911.07416v4.

[109]: Stephane H Maes, (2022), "Multi-fold Discrete Fractal Spacetime, and the Viability of Local vs. Non-Local Hidden Variable Viability", https://shmaesphysics.wordpress.com/2022/10/30/multi-fold-discrete-fractal-spacetime-and-the-viability-of-local-vs-non-local-hidden-variable-viability/, October 30, 2022.

[110]: Stephane H Maes, (2022), "2D Random Walks of Massless Higgs Bosons as Microscopic Interpretation of the Asymptotic Safety of Gravity, and of the Standard Model", https://shmaesphysics.wordpress.com/2022/12/28/2d-random-walks-of-massless-higgs-bosons-as-microscopic-interpretation-of-the-asymptotic-safety-of-gravity-and-of-the-standard-model/, December 28, 2022.

[111]: Stephane H Maes, (2022), "The Replica Trick, Wormholes, Island formula, and Quantum Extremal Surfaces, and How the AdS/CFT Correspondence Conjecture, and Hence the M-theory, Encounters Multi-folds", https://shmaesphysics.wordpress.com/2022/09/20/the-replica-trick-its-wormholes-islands-and-quantum-extremal-surfaces-and-how-the-ads-cft-correspondence-conjecture-and-hence-the-m-theory-encounters-multi-folds/, September 26, 2022.

[112]: Stephane H. Maes, (2022), "Justifying the Standard Model U(1) x SU(2) x SU(3) Symmetry in a Multi-fold Universe", https://shmaesphysics.wordpress.com/2022/08/08/justifying-the-standard-model-u1-x-su2-x-su3-symmetry-in-a-multi-fold-universe/, August 8, 2022.

[113]: Stephane H Maes, (2022), "Understanding the Multi-fold theory principles and the SM_G", https://shmaesphysics.wordpress.com/2022/03/11/understanding-the-multi-fold-theory-principles-and-the-sm_g/, March 11, 2022.

[114]: Stephane H Maes, (2022), "A Non-perturbative Proof of the Asymptotic Safety of 4D Einstein Gravity, With or Without Matter", https://shmaesphysics.wordpress.com/2022/05/04/a-non-perturbative-proof-of-the-asymptotic-safety-of-4d-einstein-gravity-with-or-without-matter/, May 4, 2022.

[115]: Stephane H. Maes, (2022), "A Better Quantum Extremal Surface and Island Interpretation that explains the Associated Massive Gravity", https://shmaesphysics.wordpress.com/2022/12/03/a-better-quantum-extremal-surface-and-island-interpretation-that-explains-the-associated-massive-gravity/, December 3, 2022.

[116]: University of Amsterdam, (2023), "Scientists Prove That There Is No "Second Law of Entanglement"", https://scitechdaily.com/scientists-prove-that-there-is-no-second-law-of-entanglement/. Retrieved on February 18, 2023.

[117]: Ludovico Lami, Bartosz Regula, (2023), "No second law of entanglement manipulation after all", Nature Physics volume 19, pages184–189.

[118]: Charlie Wood, (2023), "Physicists Use Quantum Mechanics to Pull Energy out of Nothing. The quantum energy teleportation protocol was proposed in 2008 and largely ignored. Now two independent experiments have shown that it works.", QuantaMagazine, https://www.quantamagazine.org/physicists-use-quantum-mechanics-to-pull-energy-out-of-nothing-20230222/, February 22, 2023.

[119]: Masahiro Hotta, (2008), "Quantum Measurement Information as a key to Energy Release from Local Vacuums", arXiv:0803.2272v3.

[120]: Nayeli A. Rodríguez-Briones, Hemant Katiyar, Raymond Laflamme, Eduardo Martín-Martínez, (2022), “Experimental activation of strong local passive states with quantum information”, arXiv:2203.16269v1.

[121]: Kazuki Ikeda, (2023), “First Realization of Quantum Energy Teleportation on Superconducting Quantum Hardware”, arXiv:2301.02666v3.

[122]: IBM Research, "Quantum Teleportation", https://researcher.watson.ibm.com/researcher/view_group.php?id=2862. Retrieved March 7, 2019.

[123]: Wikipedia, "Reeh-Schlieder theorem", https://en.wikipedia.org/wiki/Reeh-Schlieder_theorem, Retrieved Nov. 19, 2019.

[124]: Astrid Eichhorn, Marc Schiffer, (2022), “Asymptotic safety of gravity with matter”, arXiv:2212.07456v1.

[125]: Stephane H. Maes, (2022), “Invalidation and Proof of the Mass Gap, and Viability of The Standard Model on a Discrete Spacetime”, https://shmaesphysics.wordpress.com/2022/07/15/invalidation-and-proof-of-the-mass-gap-and-viability-of-the-standard-model-on-a-discrete-spacetime/, July 15, 2022.

[126]: Stephane H. Maes, (2022), “Multi-folds, Non-Commutative Spacetime, Spin, and All That”, https://shmaesphysics.wordpress.com/2022/12/31/the-principles-of-quantum-mechanics/, December 31, 2022.

[127]: Stephane H Maes, (2022), “2D Random Walks of Massless Higgs Bosons as Microscopic Interpretation of the Asymptotic Safety of Gravity, and of the Standard Model”, https://shmaesphysics.wordpress.com/2022/12/28/2d-random-walks-of-massless-higgs-bosons-as-microscopic-interpretation-of-the-asymptotic-safety-of-gravity-and-of-the-standard-model/, December 28, 2022.

[128]: Stephane H Maes, (2022), “Unruh effects, Hawking Black Hole Evaporation, Quantum Corrected Larmor Formula, Numbers of Particles in Curved Spacetime: “Same-Same, but Just A Bit Different””, https://shmaesphysics.wordpress.com/2022/07/25/unruh-effects-hawking-black-hole-evaporation-quantum-corrected-larmor-formula-numbers-of-particles-in-curved-spacetime-same-same-but-just-a-bit-different/, July 25, 2022.

[129]: Stephane H. Maes, (2022), “Time-Varying Multi-fold Dark Energy Effects and Implications for the Hubble Tension”, https://shmaesphysics.wordpress.com/2022/11/13/time-varying-multi-fold-dark-energy-effects-and-implications-for-the-hubble-tension/, November 13, 2022.

[130]: Stephane H Maes, (2022), “Hints of Multi-fold Dark Matter Effects in the Universe”, https://shmaesphysics.wordpress.com/2022/03/14/hints-of-multi-fold-dark-matter-effects-in-the-universe/, March 14, 2022.

[131]: Stephane H Maes, (2022), “Multi-fold Dark Matter and Energy Effects Fit The Ratios to Normal Matter in the Universe”, https://shmaesphysics.wordpress.com/2022/08/14/multi-fold-dark-matter-and-energy-effects-fit-the-ratios-to-normal-matter-in-the-universe/, August 14, 2022.

[132]: Stephane H Maes, (2022), “Direction of Possible Multi-folds Corrections to the W Boson Mass”, https://shmaesphysics.wordpress.com/2022/04/08/direction-of-possible-multi-folds-corrections-to-the-w-boson-mass/, April 8, 2022.

[133]: Stephane H Maes, (2022), “Multi-folds in Yang Mills Feynman Diagrams”, https://shmaesphysics.wordpress.com/2022/04/05/multi-folds-in-yang-mills-feynman-diagrams/, April 5, 2022.

[134]: Stephane H. Maes, (2022), “A Conjecture: No Dark Matter will be discovered at LHC, or elsewhere”, https://shmaesphysics.wordpress.com/2022/07/08/a-prediction-no-dark-matter-will-be-discovered-at-lhc-or-elsewhere/, July 8, 2022.

[135]: Stephane H. Maes, (2022), “Multi-fold Gravity can Violate P-Symmetry. It is Aligned With Observations of Asymmetry of the Orientation of Tetrahedra of Galaxies”, https://shmaesphysics.wordpress.com/2022/12/10/multi-fold-gravity-can-violate-p-symmetry-it-is-aligned-with-observations-of-asymmetry-of-the-orientation-of-tetrahedra-of-galaxies/, December 10, 2022.

[136]: Stephane H. Maes, (2022), “A Conjecture: No Dark Matter will be discovered at LHC, or elsewhere”, https://shmaesphysics.wordpress.com/2022/07/08/a-prediction-no-dark-matter-will-be-discovered-at-lhc-or-elsewhere/, July 8, 2022.