Multi-folds, The Fruit From The Loops? Fixing "Oops for The Loops" May Encounter Multi-folds in General Relativity And The E/G Conjecture

Stephane H. Maes[1]

January 1, 2022

Abstract:

In a recent paper, we discussed the details and consequences of an analysis that argues a technical error in the LQG (Loop Quantum Gravity) quantization scheme that may also explain why, so far, LQG can't recover GR and a classical smooth spacetime so far.

In the present paper, we sketch a possible way forward (E/G-LQG) to address these issues. Doing so introduces new terms in the Quantum Gravity Hamiltonian with constraints that are reminiscent of entanglement, or correlation. It links entanglement and quantum gravity as in the E/G conjecture and provides hints of multi-fold mechanisms.

This analysis result from work done on the multi-fold theory which resulted in a proposal from multi-fold mechanisms. 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 models 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, i.e. no new particles or forces. These considerations hints at an even stronger relationship between gravity and the Standard Model.

Hints of the role of entanglement in quantum gravity, derived with the LQG Dirac constrained Hamiltonian program, and its quantization, and also relatable to Lagrangian with LQG spin foams, is a significant result that significant progresses our understanding of the relationship between GR and multi-folds: it could be a way forward to evolve from a qualitative to quantitative multi-fold theory. The multi-folds and the E/G conjecture is actually present in the Hilbert Einstein action. It is just well hidden, and as a quantum effect, it could, understandably, only be discovered when proceeding with the quantization of GR.

1. Introduction

LQG [5-7] is a quantum theory of gravity built on a reformulation of GR using new variables [8]. It is a background-independent quantum theory of gravity in terms of loop solutions expressed in the new variables.

[23] discussed issues encountered in the literature with the LQG quantization scheme.

The present paper reuses most of [23], adding at the end a section dedicated to entanglement and multi-folds. The following references provide details on the multi-fold theory [1,22,43,44,54], and how it helps address open issues with the Standard Model (SM), and the standard Cosmological Model [1,21,22,24-26,39-95].

[1] shmaes.physics@gmail.com

Cite as: Stephane H Maes, (2022), "Multi-folds, The Fruit From The Loops? Fixing "Oops for The Loops" May Encounter Multi-folds in General Relativity And The E/G Conjecture", 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.

2. Multi-fold Analysis of LQG

The multi-fold paper [1], and the following-up analysis [3], discuss the alignments and differences between LQG and the multi-fold theory, mainly in terms of:

- Alignment between multi-fold theory and LQG:
  - Discrete spacetime
  - Non-commutative geometry
  - The idea of spacetime reconstruction, part of a family of such activities, like those studied in [27].
- Gaps of LQG, from a multi-fold point of view:
  - Particle modeling and tracking beyond fields à la QFT
  - Entanglement modeling

Of course, the LQG spacetime reconstruction and recovery is based on a quite different approach.

Note added on December 28, 2022: [41] provides a subsequent encounter of multi-folds in GR at Planck scales and confirmation of the multi-fold spacetime reconstruction, recovering GR. This is directly relevant to this paper.

3. A Problem with the LQG Quantization Scheme

While checking for any recent progress in LQG, we encountered [9], where Urs Schreiber answered a question asking why LQG + SM was not usually not listed as a TOE.

He made the following troubling observations [9], that we rephrase here in our own way as follows:

- Barrett's theorem shows a requirement for continuous and smooth mapping of loops on smooth manifolds to smooth curves to use these curves as representation of the original holonomies. Smoothness seems critical to the proof of the Barrett's theorem [10] (or generalizations like [13]), and ensure the ability to revert/recover the original information.
- LQG uses holonomies of not-continuous or smoothly stitched together, curves called generalized connections ,as one of the (new) configuration space variables (Hilbert pre-quantization), and fluxes of tetrads as the other variables. Then, it quantizes using the constraints.
- The constraints that generate spatial diffeomorphisms are not suitable operators (equation (122) in [11] and step (123) also in [11]). So, in order to generate the Hamiltonian, the quantization relies on these holonomies and unitary transforms of the diffeomorphisms [11,12]. The latter mapping is a priori not weakly continuous, therefore violating the premises of the Stone-Neumann Theorem [19].
- [9] also criticizes the differences between the quantization results for simple QM problems, and QFT/QM [12,14] as well as the non-separability of the Hilbert Space used at that stage (pre-quantization) by LQG.

This is on top of the LQG challenges typically encountered in the industry about a) the inability to recover GR, smooth macroscopic spacetime, or black hole physics without fixing a free parameter, the Immirzi parameter [5-7,15], b) and questions about the big bounce prediction before the big bang [5-7,15], c) as well as how matter/fermions are modeled by LQG [6,7,15]. The dependency on the Immirzi parameter, and associated quantization schemes, is an often raised concern [34].

Note that arguments have also often been raised about the apparent contradiction between discrete spacetime and Lorentz invariance. [1,21] showed that both are not incompatible. Therefore, this one does not require more discussion. Even if the LQG community also provided different attempts at addressing that latter criticism, we rather believe in the [1,21] point of view.

Note added on December 28, 2022: Finally, arguments have been raised that the cosmological constant would not result from gravity only but requires to also include the Standard Model fields [15], which relates also to Witten argument that GR can't be quantized, in de Sitter-like universes, without a proper cosmological constant model [96,97]. A key push back against quantizing gravity "stand alone", as done by LQG (and resulting from not being able to well model matter fields, or particles).

Note added on December 22, 2022: [95] discusses aspects of these latter considerations in terms of asymptotic safety of gravity [1,24,25,46,47,50,51,59,64,66].

4. Details of the Mapping Issue

The cusp of the issues, identified in [9]. seems to be section 4.1.2 in [11], and the discussion between equation (122) and step (123), also in [11].

The interpretation of Urs [9] matches what is mentioned in section 4.1.2. in [11]: no smooth mapping any more for generalized connections. The use of Gelfand's triplet space to define the Kinematic Hilbert space, the algebra of kinematic observables, physically relaxes the smoothness requirement on the affine connections by allowing any number of segments to be stitched together on a path without any condition of smoothness or continuity. As such the algebra, and the space of "generalized affine", is not any more representative of the physical spacetime where the GR and Ashtekar's classical models live (prior to quantization).

The proposed formalism of section 4.1.2 has wide ranging implications. It is also the cause of the lack of weak continuity encountered for (122), that prevents the definition of self-adjoint operator and implies, per [18], that a different representation from what is usually encountered for quantization [12]: a very concerning result, considering the subsequent implication of this, even for modeling a particle or a scalar field [12] that can't be, so far, convincingly beaten back into shape [14].

It is now really unclear what the mapping is; not only is it not smooth but it's also being mucked with, by the Polymer quantization steps, in a even more nontrivial way. Doing so may have helped progressing the quantization program, but it certainly does not address the non-continuity/smoothness, that it obfuscates, and that seems also linked to the non-self-adjoint behavior of diffeomorphism operators.

A priori, it seems that the spin network representations may have lost the ability, or at least the justification, to encode smooth manifold connections and in such case, it is unclear, at least, what it still represents. Mappings may not be used in semiclassical / macroscopic / IR Regime, recovery. But it is in the setup of LQG spin networks. So this issue is certainly involved and fundamental. Even if one can justify or clean up the polymer quantization challenges (see the next section), the selection of such quantization does not address, and in fact worsen, the loss of smoothness issues with the mappings.

5. LQG Answers so far

Most of these criticisms in section 3, were known by the LQG community, and addressed, at least in ways that satisfy, to some extent, the LQG community, albeit not always outside the LQG community:

- [3] addresses the non-separability of Hilbert space showing that is essentially (quasi) separable, and arguing, correctly, in our opinion, that, in any case, this is not an issue, and non-separability should not invalidate the theory.
- The quantization scheme, known as the Polymer quantization [12,14], is different from QFT and Quantum Physics quantization à la Schrödinger. Something that is a challenge on its own. But, at least, [14] provides a discussion, and there is a LQG point of view on the issue.
- It is also argued that LQG recovers the black hole entropy without involving the Immirzi parameter [35,36], and that therefore there would be no issues [5-7]. *Note added on December 28, 2022: the multi-fold recovery of black hole entropy and Page curve is discussed in [1,98-100].*
- The LQC (Loop Quantum Cosmology) big bounce discussions [5-7] are still problematic (and dependent on the Immirzi parameter) *[37]* but maybe less critical to the viability of LQG. *(References added on 1/5/21)*
- Fermion coupling and handling is supported by LQG [6,7,15] but it says nothing about it something seen as an issue by many [5,15] about how does the SM impact spacetime reconstruction, quantization and behaviors, and conversely. The view outside the LQG community is that both influence each other. *Note added on December 28, 2022: [95] provide some related analysis.*

For the rest, the LQG community argues that the theory is work in progress and that, indeed, progress is taking place, albeit slowly, but that the direction is promising [15].

Note that there also are discussions, which could be seen as endorsement of the LQG quantization algorithm in [18]. Also, [18] refers to the Bohr quantization, invoked as analogous to the Polymer Quantization. However, one may be able to argue that the Bohr quantization does not have to worry about smoothness recovery, while LQG has to connect to GR, in IR. The author also studied, in other papers, regular connections among generalized connections and uniqueness of invariant states in holonomy/fluxes, but none of those address the issue at hand, they address different questions! For example, and not denying the mathematical rigor of [18], arguing "*The continuity is lost, when the cylindrical functions have been used to form basic variables. Of course, since the continuity is lost already at the level of the algebra, and not only at that of representations, this does not weaken the results reviewed in the present articles*", as in [18], does not render the discontinuity behaviors physical. It is these discontinuities that seem unphysical.

Also, this Twitter discussion [20] discusses the motivations of generalized connections, not their physical suitability. All these are purely statements of suitable mathematical definition of the proposals, not of their physicality, and as such, they do not address the concerns: we did not say that the variations introduces are not mathematically rigorously defined. We are saying that they have physical implications that are not explained, justified, or validated.

Note added on January 3, 2022: See [15] for an answer to the cosmological constant arguments by Rovelli. Unfortunately, it does not put that controversy to rest. Our point of view was presented in [97] for Multi-fold universes.

6. Oops for Loops?

Unfortunately, with the above (section 5), we do not believe that any of the answers, or other developments of LQG that we have encountered, have addressed what is the main issue that interpellated us in [9] and section 4: the loss of the smoothness and continuity of the generalized connections and therefore the physical meaning in terms of spacetime or applicability of Barrett's theorem, and its impact on spin networks (and, as result, spin foam [6,7]: the consistency and relationships between the two imply continued concerns for spin foam also).

We would have expected answers or arguments as the ones provided to the other issues discussed in section 5, so that the LQG community would:

- (1) Argue why the addition of unphysical (non-smooth and / or not continuous) paths can still contain in the generalized connections the original information about spacetime in the case of LQG, despite violating Barrett's condition for it to be guaranteed. In our view it is not obvious, but let's see.
- (2) Argue that Barrett's theorem is not if-and-only-if, and that the LQG scheme (123) in [11] would still provide the required equivalence for the proposed mappings, smooth or not. It would still require to also explain why the noisy, not continuous and not smooth additions to the space of possible paths is acceptable.
- (3) Explain why the quantization scheme would remain valid without further fixes or concern about the introduction of the generalized connections.. That is probably, consciously or not, the approach of justifying, and fixing after the fact, the polymer quantization as in [14]. So maybe [14] is indeed the LQG answer to [9].
- (4) Or reformulate the model, e.g., without generalized connections, or a variation to them bringing back physicality, and quantization schemes, to fit the Barrett's theorem, while not introducing unphysical noise, and, maybe, if needed or possible, address the challenges to the Polymer quantization. This is what is probably needed if the previous bullet fails, or does not apply. At this stage, it is unclear to us how that would be achieved.

Otherwise, it seems that if the noisy mapping issue is real, as it seems to be, and not addressed in LQG, spin networks, and spin foams. These models may have lost connection, no pun intended, with spacetime. Therefore, it would not be surprising that LQG cannot recover GR, or a macroscopic smooth spacetime, as it is unclear what its model characterizes. It puts LQG at risk of being unphysical, i.e., a nice mathematical exercise disconnected from the real universe, not just for the IR regime but for the whole theory including UV, its main focus.

Note added on January 5, 2022: [32] provides a proof that LQG quantized as it is so far does not model the Hilbert Einstein Action and therefore does not provide a suitable model for quantum gravity at all regimes.

We would also argue that the significant dependency of the quantization schemes (for a given Immirzi parameter type or value) further exacerbates the concern that the noise of the quantization scheme dominates. Indeed [34], shows disparate results with different scheme all ultimately relying on generalized connections but different on the holonomy functions selected. This also seems directly related in our view to challenges coming from not satisfying Barrett's theorem and its generalizations.

7. E/G-LQG: Fixing LQG = Entanglement, E/G Conjecture?

With the introduction of generalized connections [11], it seems that LQG loses the continuity and smoothness "physical requirement" of the classical Ashtekar model, pre-quantization, and when discontinuity are not physically expected or justified.

Proceeding as done by LQG[2], should therefore still be subject to (an) additional constraint(s) aimed at penalizing non-smooth, or discontinuous spacetime, and therefore generalized connections that would be discontinuous, or non-smooth; something that we understood as the reflection of drawing a connection on a non-smooth spacetime

[2] This is all indicated, as we know about the consistency and uniqueness of the representations associated to connections/holonomies and diffeomorphism [18,31]. It is therefore logical to add constraints to it rather than to rework a new scheme, or new suitable background independent variables in lieu of connections/tetrads, or holonomies/fluxes.

manifold. Such a cost function would increase the Hamiltonian of connections that are discontinuous or non-smooth. A physical justification would be that spacetime locations are (locally) entangled, so that position and derivatives at least over several "discrete" spacetime points (per LQG discreteness of spacetime) are correlated, and evolving consistently. Such term would be present in the Hilbert Einstein action, when quantized, and revealed by the generalized connections introduced in its quantization [11].

There is a multi-fold physical justification for such a term. Consider the multi-fold reconstruction [1] and associated models of associated random walk [1,21,24,25]. Random walks imply that concretized spacetime locations are, for a while at least and within a (large) neighborhood, entangled, which smoothens spacetime. This would be aligned with the extra constraint when defining the quantized Hamiltonian. We also encountered this in [50].

Achieving this, and maintaining it as long as physically justified (i.e. till another random walk revisit an already concretize location) requires a way to smooth between points, no matter how random fluctuations are, or terminate immediately such behavior when needed. This can only be achieved with external shortcuts like multi-folds or wormholes as discussed in [1,26]. Explicit multi-folds (entanglement) between spin network nodes may also warrant considerations, although we have not fully baked such an approach.

Note that such a formulation in terms of entanglement is needed:

- As an extra constraint to ensure that the original physical constraints of smoothness and continuity are respected, something that was lost with the introduction of generalized connections in section 4.1.2 of [11].
- As a constraint expressed via entanglement because the Ashtekar variables and section 4.1.2 in [11] are entirely formulated in terms of the new variable, no more the spacetime, which does not provide ability to express derivative or continuity limits in spacetime variables.
- As a constraint expressed via entanglement rather than correlations because correlations are notably ensemble properties, not continuity or smoothness guarantee instance by instance.

Note added on January 5, 2022: The use of extra constraints directly reflects the need to eliminate the extra terms or options from equations (1) and (2) in [32]. It also provides a quick theoretical algorithm to not include in the path integral (and Feynman diagrams) the not smooth or discontinuous connections. However such algorithm is probably not practical. The concept of adding constraints or implementing multi-folds between nodes (inspired by [33]) are more promising ways forward.

Here, we will not attempt to model the actual constraints or the actual impact on LQG quantification, spin networks or spin foam, however we believe that this is amazingly aligned with [1,2], when understood as impacting the spacetime locations. Formulating a suitable constraint and pursuing the corrected LQG, i.e., E/G-LQG, would probably best done by the LQG community if they agreed with our conclusions. Solutions may be obtainable by treating this more as a constraint on top of existing solutions, e.g. spin networks, formalism that would count out unsuitable holonomies or entangle (e.g. via multi-folds) graphs vertex to enforce entanglement. We will wait to see what will be proposed.

With our previous analysis, we anticipate that some such constraint will recover GR and macroscopic or semi-classical spacetime. For the rest it keeps most LQG will keep most of its current formalism, which many consider mathematically rigorous.

It is interesting that recovering Physical connections with the quantization of the Hilbert Einstein action leads to the E/G conjecture [27] and multi-fold like mechanisms as a hidden constraint only revealed by the quantization process. These subtleties could explain why the E/G conjecture and relationship between spacetime/gravity and entanglement, although suspected [1,28-30] were never noticed in the Hilbert Einstein action so far. It also increases a lot the potential relevance of multi-fold mechanisms in the real universe. Seeing these concepts appearing could only occur while quantizing GR as entanglement is solely a quantum concept. There was no reasonable way to encounter this while laying out GR or its formulation in terms of Ashtekar's new variables [8].

It is the first time that we manage to see the multi-fold mechanism and action hidden within GR and the Hilbert Einstein action. Considering the rigor behind LQG, so far we were concerned that the LQG process did not provide any such hint. Problem solved! *Note added on December 28, 2022: See [41] for a derivation that encounters multi-folds at Planck scales in GR, and hence the Hilbert Einstein action. It also recovers GR from multi-folds. The works reinforce each other conclusions, and in particular the idea that adding entanglement to fix the LQG issue goes in the right direction. In such a model, multi-folds are implemented as traversable wormholes [26,41]*

Comment added on January 5, 2022: We would hope that E/G-LQG would reduce the dependency on the subsequent quantization schemes [34], as the noisy effects are reduced but that remains to be seen, just as we would then like to see if Immirzi-independent models of black holes, singularities and bounces converge or, once and for all, allow setting of the actual value.

8. Conclusions

This short paper show how to fix an issue reported in [9,23]. Doing so relies on adding a constraint to counter the non-physical effects introduced by generalized connections [11]. The fix, if suitable, reveals that the E/G conjectures and multi-fold-like mechanisms are actually contained, well hidden, in the Hilbert Einstein action, when it is rigorously quantized. We needed so as [1] showed recovery of the Hilbert Einstein action from multi-folds.

We proposed a recipe to salvage LQG, leading to E/G-LQG, and doing so we motivated the relevance of the multi-fold theory [1,22] in the real universe, and it could probably be a theoretical starting point to bring more quantitative aspects to the multi-fold theory. This is for future work.

In our view, it could have fundamental impact on the foundations of LQG, in particular spin networks, and motivate why LQG has so far been unable to recover a semi classical regime with a smooth or macroscopic spacetime governed by Einstein's GR field equations. This goes to the core of the criticism addressed to LQG as in [15].

A multi-fold-inspired proposal is for future work.

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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]: 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.

[3]: Winston Fairbairn, Carlo Rovelli, (2004), "Separable Hilbert space in Loop Quantum Gravity", arXiv:gr-qc/0403047v2.

[4]: Earman, John S., (2020), "Quantum Physics in Non-Separable Hilbert Spaces", http://philsci-archive.pitt.edu/18363/1/Quantum%20Physics%20on%20Non-Separable%20Spaces%2011.3.20.pdf.

[5]: Wikipedia, “Loop Quantum Gravity”, https://en.wikipedia.org/wiki/Loop_quantum_gravity. Retrieved on June 15, 2020.

[6]: Carlo Rovelli, (2007), “Quantum Gravity”, Cambridge University Press.

[7]: Carlo Rovelli and Francesca Vidotto, (2014), “Covariant Loop Quantum Gravity: An elementary introduction to Quantum Gravity and Spinfoam Theory”, Cambridge University Press.

[8]: Ashtekar A. and Ranjeet S. Tate, (1991), “Lectures on nonperturbative canonical gravity”, World Scientific Pub Co Inc.

[9]: Usr Schreiber, “Comments to “Why is Standard Model + Loop Quantum Gravity usually not listed as a theory of everything””, Physics StackExchange, https://physics.stackexchange.com/questions/67211/why-is-standard-model-loop-quantum-gravity-usually-not-listed-as-a-theory-of-e/360010#360010, September 29, 2017. Retrieved on December 27, 2021.

[10]: J. W. Barrett, (1991), “Holonomy and Path Structures in General Relativity and Yang-Mills Theory”, International Journal of Theoretical Physics, Vol. 30, No. 9.

[11]: Alejandro Perez, (2004-2005), “Introduction to Loop Quantum Gravity and Spin Foams”, arXiv:gr-qc/0409061v3.

[12]: Nirmalya Kajuri, (2015), “Aspects of polymer quantization”, PhD Thesis, The Institute of Mathematical Sciences, Chennai, HOMI BHABHA NATIONAL INSTITUTE. http://www.hbni.ac.in/phdthesis/phys/PHYS10200904004.pdf.

[13]: Urs Schreiber and Konrad Waldorf, (2014), “Parallel Transport and Functors”, arXiv: 0705.0452v5. https://arxiv.org/abs/0705.0452.

[14]: Abhay Ashtekar, Jerzy Lewandowski, and Hanno Sahlmann, (2002), “Polymer and Fock representations for a Scalar field”, arXiv:gr-qc/0211012v1.

[15]: skydivephil, (2021), “String Theory or Loop Quantum Gravity? David Gross vs Carlo Rovelli”, YouTube, https://www.youtube.com/watch?v=AUyylR5RPZw. December 19, 2021. Retrieved on December 28, 2021.

[16]: Stephane H Maes, (2021), “Loop Quantum Gravity and concerns with its "polymer" quantization. Has it ever been addressed or answered/justified?”, https://www.reddit.com/r/AskPhysics/comments/rq212r/loop_quantum_gravity_and_concerns_with_its/?utm_source=share&utm_medium=web2x&context=3.

[17]: Johannes Thueringen, (2015), “Discrete quantum geometries and their effective dimension”, Ph.D. Thesis, Humboldt-Universitaet zu Berlin.

[18]: Christian Fleischhack, (2015), “Kinematical Uniqueness of Loop Quantum Gravity”, arXiv:1505.04404v1.

[19]: Wikipedia, “Stone–von Neumann theorem”, https://en.wikipedia.org/wiki/Stone%E2%80%93von_Neumann_theorem. Retrieved on July 10, 2020.

[20]: Twitter exchange between Urs Schreiber and John Carlos Baez, (November 14 – 16, 2018), https://twitter.com/johncarlosbaez/status/1063449073372545025. Retrieved on December 29, 2021.

[21]: 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.

[22]: Stephane H Maes, (2021), ”The Multi-fold Theory: A synopsis”, viXra:2112.0144v1, 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.

[23]: Stephane H Maes, (2021), "Oops For The Loops: Mounting LQG Woes And A Challenge To The LGQ Community", viXra:2212.0168v1, https://shmaesphysics.wordpress.com/2021/12/30/oops-for-loops-mounting-lqg-woes-and-a-challenge-to-the-lgq-community/, December 29, 2021.

[24]: 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.

[25]: 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.

[26]: 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.

[27]: Johannes Thuringen, (2015), "Discrete quantum geometries and their effective dimension", Ph.D. Thesis, Humboldt-Universitat zu Berlin".

[28]: 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.

[29]: van Raamsdonk, Mark (2010). "Building up spacetime with quantum entanglement". Gen. Rel. Grav. 42 (14): 2323–2329. arXiv:1005.3035

[30]: 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.

[31]: Jerzy Lewandowski, Andrzej Okolow, Hanno Sahlmann, Thomas Thiemann, (2005-2006), "Uniqueness of diffeomorphism invariant states on holonomy-flux algebras", arXiv:gr-qc/0504147v2.

References added on January 5, 2021

[32]: Stephane H Maes, (2022), "Oops For The Loops II: Real Oops; LQG Does Not Optimize the Hilbert Einstein Action", 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.

[33]: Stephane H Maes, (2020), "Entangled Neural Networks from Multi-fold Universes to Biology", viXra:2207.0174v1, https://shmaesphysics.wordpress.com/2020/12/31/entangled-neural-networks-from-multi-fold-universes-to-biology/, December 25, 2020.

[34]: Suddhasattwa Brahma, Michele Ronco, Giovanni Amelino-Camelia, Antonino Marciano, (2016), "Linking loop quantum gravity quantization ambiguities with phenomenology", arXiv:1610.07865v1.

[35]: Jibril Ben Achour, Amaury Mouchet, Karim Noui, (2014), "Analytic Continuation of Black Hole Entropy in Loop Quantum Gravity", arXiv:1406.6021v1.

[36]: Jibril Ben Achour, Karim Noui, Alejandro Perez, (2016), "Analytic continuation of the rotating black hole state counting", arXiv:1607.02380v1.

[37]: Jibril Ben Achour, Julien Grain, Karim Noui, (2014), "Loop Quantum Cosmology with Complex Ashtekar Variables", arXiv:1407.3768v1.

References added on December 28, 2022

[39]: Stephane H Maes, (2021), "More on Multi-fold Particles as Microscopic Black Holes with Higgs Regularizing Extremality and Singularities", 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.

[40]: 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", 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.

[41]: 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.

[42]: Stephane H Maes, (2022), "From Quantum Relational Equivalence to Multi-folds Encounter in the Real Universe and Confirmation of the E/G conjecture", 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.

[43]: Stephane Maes, (2020-22), "Web Site Tracking all Publications around the Multi-fold universe", Navigation page listing all papers, https://shmaesphysics.wordpress.com/shmaes-physics-site-navigation/.

[44]: 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.

[45]: 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.

[46]: 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.

[47]: 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.

[48]: 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.

[49]: 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.

[50]: 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.

[51]: Stephane H Maes, (2020), "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.

[52]: 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.

[53]: 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.

[54]: 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.

[55]: 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.

[56]: 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.

[57]: 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.

[58]: 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.

[59]: 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.

[60]: 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.

[61]: 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.

[62]: 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.

[63]: 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.

[64]: 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.

[65]: 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.

[66]: 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.

[67]: 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.

[68]: 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.

[69]: 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.

[70]: 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.

[71]: 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.

[72]: 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.

[73]: 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.

[74]: 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.

[75]: 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)

[76]: 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.

[77]: 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.

[78]: 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.

[79]: 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.

[80]: 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.

[81]: 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.

[82]: 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.

[83]: 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.

[84]: 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.

[85]: 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.

[86]: 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.

[87]: 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.

[88]: 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.

[89]: Stephane H. Maes, (2022), “Explaining Imbalance of Tidally Ejected Stars from Open Stars Clusters Without MOND”, https://shmaesphysics.wordpress.com/2022/11/19/explaining-imbalance-of-tidally-ejected-stars-from-open-stars-clusters-without-mond/, November 19, 2022.

[90]: 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.

[91]: 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.

[92]: 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.

[93}: 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.

[94]: 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.

[95]: 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.

[96]: Edward Witten, (2001), “Quantum Gravity In De Sitter Space”, arXiv:hep-th/0106109v1

[97]: Stephane H Maes, (2022), “Comments on quantization of GR in dS”, https://shmaesphysics.wordpress.com/2020/10/11/circular-arguments-in-string-and-superstring-theory-from-a-multi-fold-universe-perspective/#comment-3242.

[98]: Stephane H Maes, (2020), “Multi-Fold Black Holes: Entropy, Evolution and Quantum Extrema”, viXra:2105.0136v1, https://shmaesphysics.wordpress.com/2020/11/01/multi-fold-black-holes-entropy-evolution-and-quantum-extrema/, October 31, 2020.

[99]: 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.

[100]: 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.

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Appendix A: Any concerns for spacetime discreteness?

Note also that the discreteness of spacetime in LQG somehow results from the choice of generalized connections as modeled on Cyl / Cyl*. Although it is a possible dependency; it can be shielded from issues we raised in this paper. [1,17,21] provide other arguments for discreteness, so we are not questioning these results. But it is always good to understand when results depends on questionable steps.

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Acknowledgments

We want to thank the reddit /r/AskPhysics community members who have helped in discussing [16] the LQG aspects of the issue [23].