Oops For The Loops II: Real Oops; LQG Does Not Optimize the Hilbert Einstein Action

Stephane H. Maes[1]

January 5, 2021

Abstract:

This paper is an evolution of "Oops for the Loops". As such it overlaps and repeats the first few sections of the original paper, and then, adds a new section, demonstrating the issues. This is to ensure that the analysis reaches best the audience of interest, not mixing issues. The analysis also resulted from work done on the multi-fold theory which resulted into a proposal from multi-fold mechanisms.

The multi-fold theory obvious overlaps with, and relates to other theories like superstrings, and quantum gravity e.g.., Loop Quantum Gravity (LQG). Considerations about some of these other theories have been published, including lessons learned and recommendations to fill gaps, or address issues in strings, QFT and LQG. Our initial analysis of LQG focused more on similarities and the gap of particles and entanglement modeling. We had not yet encountered an analysis, unrelated to the multi-fold theory, which argues that there would be a technical error in LQG quantization scheme, which may also explain why LQG does not seem to be able to recover GR, and a classical smooth spacetime so far.

The paper "Oops for the Loops" pointed out and amplified the arguments against the LQG approach encountered so far.

The original new contribution, of this paper, illustrates how the LQG quantization scheme does not extremize the Hilbert Einstein Action, even under the classical expectations of (pseudo)Riemannian geometry. Hence the need for amendments to the approach that the LQG community must be investigated, before LQG can be trusted as a suitable model for many aspects of quantum gravity.

A proposal to that effect is sketched in another paper published in parallel, in the same time frame.

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, its main differentiator with other approaches, expressed in the new variables.

The paper builds on [23,24], published at the same time, but adding a section to [24], devoted to illustrating how the issues identified in [9,24] indeed affect what LQG extremizes. The outcome is different from the Hilbert Einstein action extremization, and this impacts the spacetime modeled by LQG. In particular we illustrate that the current approach selected by LQG in general leads to discontinuous and non-smooth spacetimes. This can explain why no smooth classical manifold has ever been encountered at large scales by LQG. It also raised concerns about many of the results touted by LQG. There is clearly a need to find ways to remediate these issues.

[23] added to [24], by showing that a way to tame and address the discontinuities, and lack of smoothness, resulting from [24], and detailed in the present paper, can be to invoke entanglement, between spin networks,

[1] shmaes.physics@gmail.com

Cite as: 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.

that would constrain the paths considered to extremize the Hilbert Einstein action (or its Hamiltonian formulation), somehow hinting at the E/G conjecture [1,38], and the multi-folds.

Note added on January 4, 2023: Since, [42] hints that indeed multi-folds can be encountered in the Hilbert Einstein action at Planck scales.

The multi-fold theory itself has been proposed in [1], and is able to address interesting open issues with the Standard Model (SM), strings and the standard cosmological model [1,21,22,28,35,36,38-101].

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 [37].
- 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.

[42] 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.

More considerations on the relationship and point of view of the multi-fold theory with respect to other rival quantum gravity theories, GUTs and TOEs can be found at [1,22,28].

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 not-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 January 4, 2023: 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 [97,98]. 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).

[96] discusses aspects of these latter considerations in terms of asymptotic safety of gravity [1,35,47,48,51,52,60,65,67,90].

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 on [11] 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 [31,32], and that therefore there would be no issues [5-7]. *Note added on January 4, 2023: the multi-fold recovery of black hole entropy and Page curve is discussed in [1,99-101].*
- The LQC (Loop Quantum Cosmology) big bounce discussions [5-7] are still problematic (and dependent on the Immirzi parameter) [33] but maybe less critical to the viability of LQG.
- 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 January 4, 2023: [96] 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 of [18] 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, but this does also 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 introduce new solutions that have physical implications that are not explained, justified, or validated.

Note added on January 4, 2023: 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 [98] for Multi-fold universes.

6. Oops for the 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 their 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 in the UV regime, its main focus.

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 [30], 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. Real Oops for the Loops

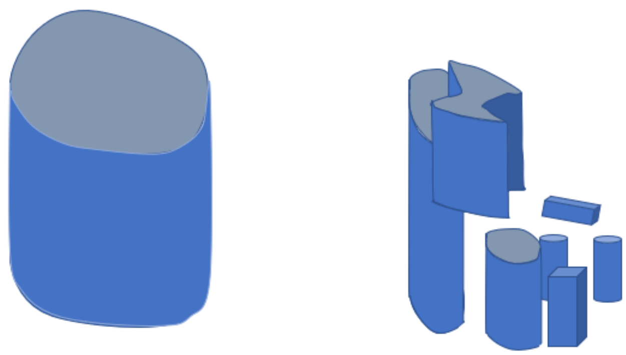
This is the new contribution of this paper vs. [23,24].

Let us stay with [11] for the ease of arguments. The (extended/generalized[2]) Hilbert Einstein action formulated with the Ashtekar new variables, and generalized in LQG, is provided by equation (23) in [11]. It is equivalent, for GR solutions, to equation (3) in [11].

The extremization amounts to optimize the manifold surfaces deltas, versus flat manifolds, for infinitesimal manifold volumes. When expressed in terms of Ashtekar's variable, it amounts to defining the surfaces and volumes in terms of connections and fluxes of tetrads. Still to be extremized.

Independently of the algebra, mapping theorems, category theory, representation theorems, semi-analytic models brought in by LQG and behind [9], the implementation of the Dirac quantization program [11,25] for quantization, amounts to considering the constraints as part of the total Hamiltonian. Section 4.1.2 expands the set of connections to generalized (discontinued or smooth) used to define the Hilbert space of the theory. Post quantization, these are the conjugate variables (along with tetrads (fluxes)) used to compute the path integrals of the Hilbert Einstein action (and variations).

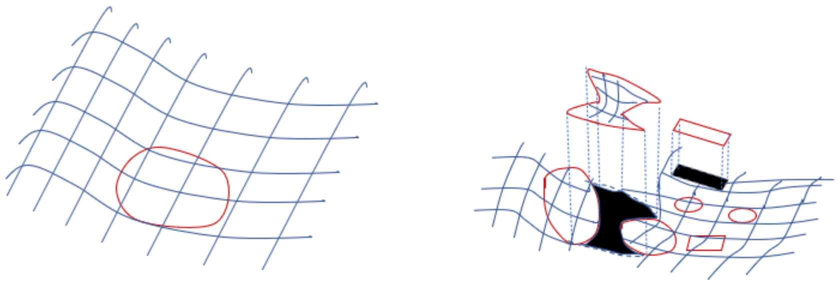
By expanding the space of admissible paths, it amounts to considering contributions not only of volumes defined by smooth connections and tetrad flux (Figure 1a), but also volumes as in Figure 1b when extremizing the action.



(a) (b)

Figure 1: Examples in a reduced dimensional example. (a) is an example of infinitesimal volumes associated with smooth connections while (b) is an example of infinitesimal volume also considered once generalized connections are used. These volumes correspond to connections with the same mean direction for the normal to the surface they define. This can be repeated for any preferred normal direction.

[2] Because of the Immirzi parameter, and generalization of Ashtekar-Barbero/Self Dual Palatini action derived from Einstein Cartan, Holtz and Plebanski actions. See references in [11] for a starting point as well as [1,2]. The extra term is shown the generalize the action, but to equate zero for Einstein GR solutions, therefore resulting into the same extremization and solutions with just richer path integrals to optimize.



(a) (b)

Figure 2: In brown, we see the corresponding (extended) connections involved in Figure 1. In 2b, discontinuities amount to connections in different manifolds resulting into bubbles of compact manifolds. One may have only bubbles, or a (set of) dominant manifold as in 2a. Non smoothness introduces angles and cusps in the different brown curves. The black regions are "empty" i.e., no part of a defined manifold

When tracing them back to the action captured by equation (23) in [11], one sees that the manifolds that would support Figure 1 (b), as shown for example in Figure 2 (b), are no more smooth continuous manifolds and therefore also no more (pseudo)Riemannian as we can encounter in Figure 2 (a). To understand this, imagine in this lower dimensional example that the "generalized" connections are drawn (closed) and composed as in section 4.1.2 in [11] (brown). Discontinuities of the connections can imply different bubbles of disconnected compact manifolds of a first manifold, with edges that can be smooth or not, or different regions within a same manifold.

Obviously, the set covered in Figures 1b and 2b is a superset of respectively Figures 1a and 1b.

When evaluating the action path integral resulting from the quantization of (23) in [11], we therefore have:

$$\mathcal{PI}_{(\text{Quantized LQG à la 4.12 in [11]})}(S_q) = \mathcal{PI}_{(\text{à la figure 1b})}(S_q) = \mathcal{PI}_{(\text{à la figure 1a})}(S_q) + \mathcal{PI}_{(\text{paths with at least one non-smooth/continuous connection})}(S_q) \quad (1)$$

Where $\mathcal{PI}(S_q)$ designates the path integral for the quantized action.

It corresponds to a classical action S_{cl} expressed as:

$$I(S_{cl})(A_g, E_g) = I((23)\text{ in [11]})(A_g, E_g)_{|\text{if Ag is smooth/continuous}} + I\big(((23)\text{ in [11] on manifold with bubbles \& bubbles only}\big)(A_g, E_g) \quad (2)$$

where A_g may not be smooth and continuous (generalized connection) and E_g reflects the associated tetrads in smooth manifold or in bubbles.

Extremization of (2) is therefore not equivalent to the extremization of (23) in [11], nor the original Hilbert Einstein action (or the variations considered equivalently by Ashtekar's work[3]). In fact, not only is the extremum a priori different, but also, one would argue that the second term of (2) is probably often dominant or non-negligible, as it includes all perturbations from the first terms, and then many other terms. In any case, it cannot just be

[3] The reasoning is the same as essentially it changes the integrand function, but not the issues with the infinitesimal volumes and variables (on manifolds) used for the computation.

disregarded and will impact results of the extremization. Again expected continuity or smoothness constraints have been removed, and nothing indicates that extremization will be achieved by continuous and smooth solutions.

All this shows that LQG quantized à la 4.1.2 in [11], inherently generates quantum foam-like spacetime (no pun intended, and no relation to spin foam), as suggested in section 4, and published in [23,24]. Now, spacetime is a set of dynamically changing manifolds of bubbles, per the ADM framework [26]. It also shows, based on the same issue, but a rather different reasoning, the insight of [9].

LQG IR regime is therefore typically condemned to recover non-smooth manifolds, which are not (pseudo) Riemannian and therefore it won't be able to recover GR either.

Because this is so fundamentally affecting all aspects of the quantized theory, the same discrepancy, captured in (1) for the path integrals also renders questionable other quantum gravity and UV regimes of LQG: even if we could expect quantum foam in the UV regime [27], as pointed out initially by Wheeler [29], there are no justification anymore to assume that LQG correctly characterizes them (again the second term in (1) has no reason to be a priori negligible). Even results like big bounce, or absence of singularity etc., may result from the contributions of that second term. All these results will have to be reviewed and updated when/if a fix can be found that will rework the quantization.

Note that while our result implies that spacetime may not a priori consist of quantum foam as envisaged so far by LQG, it does not mean that such structure does not exist either after a proper new quantization process (but it would be way more constrained at least if implementing ideas as in [15]), or due to the vacuum fluctuations of other fields, like matter/SM fields). It also relates to comments about the cosmological constant presented in [24].

8. A way forward?

Following the analysis presented in section 7, we must provide a way stronger conclusion than what was proposed in [24]. In our reading, LQG, as is, does not provide a trustworthy model. This issue must be corrected and in the meanwhile, LQG must be taken with a grain of salt.

We continue to suspect that there may be a not too disruptive resolution, as we know that other related discrete reconstruction schemes work [17,21], and provide results aligned with many aspects of LGQ (and the multi-fold theory [1,22]).

Also, note that we do not dispute the LQG approach and quantization program. It is elegant and in our view convincing as well as aligned with others [17]. We dispute the unmitigated use of generalized connections and the Gelfand triplet involving Cyl and Cyl*.

[23] offers our perspective and proposal on a way forward[4]. Interestingly the reasonings presented in [24] and section 7 of this paper, lead to plausible solutions that hint to the entanglement hidden in the quantization of the Hilbert Einstein action and in particular mechanisms consistent with the multi-fold mechanisms.

[4] This paper and [23,24] are essentially published simultaneously. First [24], while [23] and this paper were developed in parallel even if published sequentially. This is why these papers are cross referencing each other and adding sections to a common text from [24]. It just reflected the desire to rapidly communicate what we encounter while acknowledging that the different papers could have different audiences, and that all may not be received the same way by different communities.

9. Conclusions

This paper builds on [23,24] to show that the hunches of [9,24] are indeed correct, and that one can rigorously argue that LQG, quantized as is currently, does not model correctly quantum gravity. This statement holds for IR but also for UV regimes, and could have implications on many of the results of LQG and Loop Quantum Cosmology (LQC) like bouncing universe, the absence of spacetime singularities, etc. They should all be treated with a grain of salt until the challenges are addressed by LQG.

Per [34], the issues we presented do not seem to have been addressed, or circumvented so far, despite [9] having been around for a while now.

We recommend that the reader considers [23] for a proposal for E/G-LQG, with additional constraints aimed at correcting the issues disused in section 7. These constraints also hint at entanglement and multi-folds hidden at quantization in the Hilbert Einstein action; also an important results. We believe that such idea, other any other resolution, are better evolved by the LQG community, than ourselves. We do not expect follow up publication on our side.

____

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).Higgs

[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]: Urs 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, (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.

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

[25]: P. A. M. Dirac, (1964), “Lectures on Quantum Mechanics”, New York: Belfer Graduate School of Science, Yeshiva University.

[26]: R. M. Wald, (1984), “General relativity”, Chicago University Press.

[27]: Wikipedia, “Quantum foam”, https://en.wikipedia.org/wiki/Quantum_foam. Retrieved on January 5, 2022.

[28]: Stephane Maes, (2020-2021), "Web Site Tracking all Publications around the Multi-fold universe", Navigation page listing all papers. https://shmaesphysics.wordpress.com/shmaes-physics-site-navigation/.

[29] John Archibald Wheeler, (1955), "Geons", Phys. Rev. 97, 511.

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

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

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

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

[34]: Abhay Ashtekar, Eugenio Bianchi, (2021), "A Short Review of Loop Quantum Gravity", arXiv:2104.04394v1.

[35]: 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.

[36]: 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.

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

[38]: 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.

[39]: 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.

References added on January 4, 2023:

[40]: 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.

[41]: 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.

[42]: 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.

[43]: 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.

[44]: 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/.

[45]: 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.

[46]: 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.

[47]: 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.

[48]: 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.

[49]: 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.

[50]: 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.

[51]: 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.

[52]: 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.

[53]: 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.

[54]: 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.

[55]: 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.

[56]: 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.

[57]: 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.

[58]: 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.

[59]: 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.

[60]: 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.

[61]: 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.

[62]: 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.

[63]: 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.

[64]: 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.

[65]: 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.

[66]: 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.

[67]: 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.

[68]: 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.

[69]: 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.

[70]: 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.

[71]: 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.

[72]: 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.

[73]: 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.

[74]: 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.

[75]: 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.

[76]: 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)

[77]: 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.

[78]: 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.

[79]: 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.

[80]: 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.

[81]: 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.

[82]: 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.

[83]: 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.

[84]: 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.

[85]: 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.

[86]: 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.

[87]: 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.

[88]: 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.

[89]: 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.

[91]: 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.

[92]: 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.

[93]: 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.

[94}: 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.

[95]: 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.

[96]: 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.

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

[98]: 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.

[99]: 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.

[100]: 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.

[101]: 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.

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.