Trans-Planckian Censorship Conjecture: Factual in Multi-fold Universes as well as GR Universes

Stephane H. Maes[1]

March 12, 2022

Abstract:

In a multi-fold universe, gravity emerges from Entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles, whether they be real or virtual. Long range, massless gravity results from entanglement of massless virtual particles. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales. Multi-folds mechanisms also result into 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 scales than usually expected. Gravity can therefore be added to the Standard Model resulting into what we define 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 hint at an even stronger relationship between gravity and the Standard Model. Multi-folds can be encountered in GR at Plank scales, in spacetime quantization starting from the Hilbert Einstein action, and in the equivalence principle of suitable quantum reference frames in relational quantum physics. Conversely, GR and Quantum physics, including path integrals, the Born rule, and wave functions, can be recovered through different paths from multi-fold spacetime reconstruction and the W-type multi-fold hypothesis. In a multi-fold universe, GR and Quantum Physics are not incompatible, they are just different facets of multi-fold mechanisms, something that neither theory can well model.

This paper discusses the implications of the multi-fold spacetime reconstruction, or its encounter in GR, in terms of the Trans-Planckian Censorship Conjecture. We provide a microscopic explanation to the conjecture that becomes factual in a multi-fold universe and relate it to the issues of inflation, black hole physics and Planck scale Physics. The results extend to any universe described by GR, and probably to any universe with minimum length. In fact we see acceptance of TCC as another way to deduce that spacetime must be discrete or with minimum length.

1. Introduction

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

With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales and semi-classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe). Spacetime results from concretization by past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and massless Higgs and

[1] shmaes.physics@gmail.com

Cite as: Stephane H Maes, (2022), "Trans-Planckian Censorship Conjecture: Factual in Multi-fold Universes as well as GR Universes", https://shmaesphysics.wordpress.com/2022/03/13/trans-planckian-censorship-conjecture-factual-in-multi-fold-universes-as-well-as-gr-universes/, March 12, 2022.

concretized spacetime coordinates, and metrics between Reisner Nordstrom [2] and Kerr Newman [3] for massive, and possibly charged, particles – the latter being possibly extremal). Although possibly surprising, [1] recovers results consistent with others (see [4] and its references), while also being able to justify the initial assumptions of black holes from the gravity or entanglement model in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scale that make gravity non-negligible at these scales. Semi-classical models also turn out to work well till way smaller scales that usually expected.

Multi-folds[2] are encountered in GR at Planck scales [5,6] and in Quantum Mechanics[3] (QM) if different suitable quantum reference frames (QRFs) are to be equivalent relatively to entangled, coherent or correlated systems [7]. This shows that GR and QM are different facets of something that they cannot well model: multi-folds.

In general, the multi-fold theory seems to be able to provide ways to qualitatively address (fully or partially) many open issues with the SM, or rather SM_G the SM with gravity effect not negligible at its scales, and with the standard cosmological model ΛCDM [1,4-7,9-11,16,19,20,22,27,29,33,36-102].

In this paper, we start with a brief discussion of the usual motivation for the Trans-Planckian Censorship Conjecture (TCC) [8,14,18]. Then, it illustrates how a discrete, fractal, non-commutative Lorentz invariant spacetime, generated by random walks [1,9], and particle pairs creations, indeed hides effects from scales smaller than the minimum length of the spacetime, i.e. the Planck length, when it comes to inflation [1,10,11], spacetime expansion [1,6,10], Black hole physics as well as Planck scale physics.

Because Planck scale GR encounters the multi-fold theory [6], the analysis and model extends to non-multi-fold universes.

Note added on Mach 4, 2023: In this paper, numbers for references that are in italic indicate references added on March 4, 2023.

2. Challenges of Trans-Planckian Physics

If one expects that Physics is significantly different at Planck scales, one can expect that challenges will be encountered, when effects of Planck scales Physics would have large effects in larger scale Physics: a priori, these effects put in doubt models that do not account for such effects. Said differently, there are cases when it seems hard to model Physics correctly without taking account what happens at scales below the Planck scales.

Let us a consider two examples.

2.1. Inflation and Cosmological Considerations

While Trans-Planckian scales are many orders of magnitude below conventional Quantum Physics or (semi-) classical Physics, in a post inflation universe, pre-inflation or early-inflation effects at sub-Planckian scales are expected to have grown to cosmological scales where, therefore, they would now be observable [12,13].

---

[2] Tracked at [37-39,*85*].

[3] Standing in for Quantum Physics in general.

2.2. Black Holes Considerations

The Hawking radiation derivation [15], involves contributions from wavelength well below Planck scales: particles with finite frequency far away from the black hole would need an infinite frequency/energy if their source is the black hole horizon, i.e., following [15], to reach the horizon before going back to infinity. See also [16,*102*] for references on variations on where the radiated particles would originate.

This issue may also be related to motivating, or explaining the black hole firewall proposals [32][4].

Solutions exist, like [31], that amounts to a different variation on [15,16,*87,102*] where Hawking's radiation occurs at an radius (~effective horizon) larger than the black hole horizon[5]. It leads to the suggestion that Black hole trans-Planckian effects would be artefact of the way that the Hawking radiation is computed.

We also encountered related concerns when we encountered hints[6] of strings on a blackhole horizon in [1,17].

3. Planck Scales Physics

As part of our research, we devoted significant efforts addressing the issues of gravity asymptotic safety, i.e. being non-perturbatively renormalizable [19,20,*79,80,84*]. This was driven by the fact that:

- GR-based (perturbative) quantum gravity is non-renormalizable [21].
- Gravity becomes 2D at Planck scales [1,20,27,*79,80*] and references therein.
- Superstrings and LQG claim renormalizability without universally accepted arguments, i.e. without convincing proofs so far.
    - Handwaving about no singularities in LQG [23,24,26], and related theory with an intrinsic UV cutoff at Planck scales.
    - Handwaving about (lower orders) counter terms cancellations for strings. [25,26,30]
    - Inconsistencies of the model: a real universe dS(4) with asymptotic safe gravity is consistent with the SM [19,20,*80*], but AdS(5) (+…) isn't which means that superstrings can't characterize the SM even with AdS/CFT models [19,20,22,*80*].
- Asymptotic safety of quantum gravity seems to imply incompatibility of superstrings, supergravity, M-theory, supersymmetry in dimensions above 6D and most popular GUTs and TOEs, with the SM particles [19,20,40-42,*80*].
- The Multi-fold theory is asymptotically safe [1,19,20,*80*], and seems to apply to our real universe [1,4-7,9-11,16,19,20,22,27,29,33,36-*102*].

In that context, it is interesting to note the non-multi-fold view of asymptotic darkness presented in [28], which limits trans-Planckian Physics to blackhole scattering and life cycle, something that [28] claims that it would

[4] We are not fond of the black hole firewall proposals, especially as it is not needed, as discussed in [1,33,*96,97,103*], to address the black hole information paradox [34].
[5] The black hole would rather be a gray body, therefore with less radiations than expected, which implies a larger horizon.
[6] Note that in [1], we explained why these hints were illusions due to quantum fluctuations of the horizon. In the present context, they a priori still encompass only fluctuations at energy above Planck scales, because the minimum length cuts off any smaller fluctuations in spacetime.

preclude gravity asymptotic safety. The multi-fold model [1,4] is aligned with the Ultimate Unification (UU) [1,4,19,20,29,50,67,68,*79-81*], explains the black hole scattering and lifecycle aspects, and justifies other black hole considerations [1,4,*96*]. It prefers to see Trans-Planckian Physics as a 2D process, and as a result a renormalizable and asymptotically safe model [19,20,*79,80,84*].

Of course, our work in [1,5,6,9-11,19,20, 37-39,*79,80,84,85*], also provides additional insights in Planck scale Physics.

4. The Trans-Planckian Censorship Conjecture

The Trans-Planckian Censorship conjecture [8,14,18], is introduced to ensure that when, in quantum gravity, expansions in the background (e.g. due to inflation) become larger than Planck scales, or radiation of Trans-Planckian modes impact larger scale Physics, the Trans-Planckian quantum fluctuations remain quantum, in a way not to be contradictory with a classical picture of spacetime at larger scales [35].

The rigorous formulation [35] is:

> *We conjecture that a field theory consistent with a quantum theory of gravity does not lead to a cosmological expansion where any perturbation with length scale greater than the Hubble radius traces back to trans-Planckian scales at an earlier time.*

Better yet, 35]:

> *Sub-Planckian quantum fluctuations should remain quantum.*

Note that [31], discussed in section 2.2, amounts to similar considerations: models with an effective horizon larger than the actual horizon freeze out Planckian effects: radiated particles that would have been trans-Planckian can't be traced back in time to states on the actual black hole horizon.

With this conjecture all goes well, no issue. Unless of course if one wanted to provide an actual (microscopic) explanation for the validity of the conjecture. And no, arguments à la [28] do not explain it.

5. Multi-fold universes and the Trans-Planckian censorship Conjecture

Do we fare better in multi-fold universes?

The answer is yes, and immediate. Let us consider the two use cases.

5.1 Black holes

Following the black hole radiation and entropy models, described in [1,16,33,*96,97,102*], we know that the minimum length of the multi-fold spacetime [1,6] acts as a cut-off: no smaller scale fluctuations occur. The problem is solved: the TCC applies.

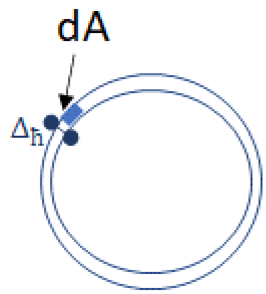

Figure 1: Per [1], entropy and Hawking radiation comes from the fluctuations of the horizon. Source: [1].

In the other case of hints of stringy entities on the black hole horizon, mentioned in [1], and in section 2.2 along with one of its footnote, the same applies: as fluctuations of the horizon are cut off with no fluctuations at scales below the minimum length, no hints of stringy behavior occurs with trans-Planckian scales. Any problem is solved, the TCC applies.

The multi-fold point of view from [1 16,33,*102*] resolves this infinite energy dilemma of section 2.2, with a model that links radiations to fluctuations of the horizon: horizon fluctuations have a minimum fluctuation, imposed by the discreteness of spacetime and particles emitted as a result do not have infinity problems.

5.2 Inflation

With the inflation and expansions of spacetime based on random walk and creation of particle and antiparticle pairs, especially massless Higgs during inflation [1,11,20,79,80], figure 2 shows that expansion is adding concretized locations, not stretching events initially smaller than the minimum length. Therefore, no effect smaller than the minimum length ever appears. Again the cutoff provided the explanation. The problem is solved, the TCC applies.

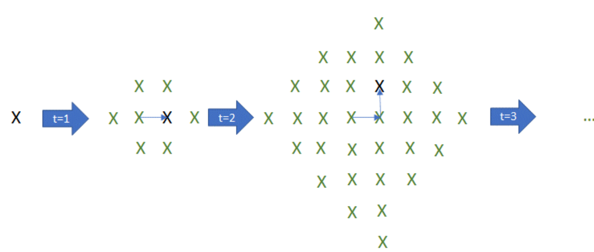

Figure 2: Illustrates the expansion of spacetime during multi-fold inflation. Expansion otherwise is due to multi-fold dark matter effects and a subset of the diagram above, due to way less particle anti particle creations. Source: [37].

5.3 Other use cases

The approach is generic: the minimum length ensures resolution of the problem in multi-fold universes.

The TCC relates also to the absence of gravitational or cosmological singularities in multi-fold universes.

6. TCC, beyond Multi-fold universes

[5,6] extends applicability of the result to any universe described by GR.

We conjecture that it could extend to any universe with minimum length[7].

7. Conclusions

This short paper provides a microscopic explanation and validation of the TCC in multi-fold universes, and in any universe described by GR, or possibly with just minimum length. Examples are detailed for black holes and for the inflation / expansion of the universe.

We would argue that our microscopic interpretation approach demonstrates the need for a discrete or minimum length spacetime. Anything else cannot explain the TCC, other than accepting it as an axiom.

____

References:

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

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

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

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

[5]: 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.

[6]: Stephane H Maes, (2022), "Deriving the Multi-fold Theory from General Relativity at Planck scale", viXra:2302.0129v1, https://shmaesphysics.wordpress.com/2022/02/22/deriving-the-multi-fold-theory-from-general-relativity-at-planck-scale/, February 22, 2022.

[7] Any GR universe has a minimum length per [6], at least if it also supports Quantum Mechanics.

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

[8]: Wikipedia, "Trans-Planckian problem", https://en.wikipedia.org/wiki/Trans-Planckian_problem. Retrieved on January 30, 2021.

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

[10]: 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.

[11]: 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.

[12]: Robert H. Brandenberger, (2011), "Introduction to Early Universe Cosmology", arXiv:1103.2271v1.

[13]: R. H. Brandenberger, (1999), "Inflationary cosmology: Progress and problems," arXiv:hep-ph/9910410v1.

[14]: Robert Brandenberger, (2021), "Trans-Planckian Censorship Conjecture and Early Universe Cosmology", arXiv:2102.09641v2.

[15]: Hawking, S. (1974), "Black hole explosions?", Nature 248, 30–31.

[16]: Stephane H Maes, (2020), "Comments to "Yes, Stephen Hawking Lied To Us All About How Black Holes Decay"", https://osf.io/v7thb/, https://shmaesphysics.wordpress.com/2020/07/11/comments-to-yes-stephen-hawking-lied-to-us-all-about-how-black-holes-decay/, July 11, 2020.

[17]: G. 't Hooft, (1990), "The Black Hole Interpretation of String Theory", Nuclear Physics B335 (1990) 138-154.

[18]: Alek Bedroya, Robert Brandenberger, Marilena Loverde, Cumrun Vafa, (2019), "Trans-Planckian Censorship and Inflationary Cosmology", arXiv:1909.11106v3.

[19]: 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.

[20]: 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.

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

[22]: 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.

[23]: Not Even Wrong, (2006), "LQG for Skeptics", https://www.math.columbia.edu/~woit/wordpress/?p=330. Retrieved on December 27, 2021.

[24]: Hermann Nicolai, Kasper Peeters, (2006), "Loop and spin foam quantum gravity: a brief guide for beginners", arXiv:hep-th/0601129v2.

[25]: nLab, "string theory FAQ", https://ncatlab.org/nlab/show/string+theory+FAQ. Retrieved on March 13, 2022.

[26]: nLab, "quantum gravity", https://ncatlab.org/nlab/show/quantum+gravity. Retrieved on March 13, 2022.

[27]: Stephane H Maes, (2021), "Spacetime and Gravity are 2D around Planck Scales: A Universal Property of Consistent Quantum Gravity", viXra:2211.0001v1, https://shmaesphysics.wordpress.com/2021/03/23/spacetime-and-gravity-are-2d-around-planck-scales-a-universal-property-of-consistent-quantum-gravity/, March 20, 2021.

[28]: The Reference Frame, (2009), "CERN: Weinberg on asymptotic safety", https://motls.blogspot.com/2009/07/cern-weinberg-about-asymptotic-safety.html?m=1. Retrieved on September 1, 2020.

[29]: 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.

[30]: Physics Forum, (2004), "Gravitons + String theory, Javier's input", January 1, 2004. https://www.physicsforums.com/threads/gravitons-string-theory.23238/post-200931.

[31]: Steven B. Giddings, (2015-2016), "Hawking radiation, the Stefan-Boltzmann law, and unitarization", arXiv:1511.08221v3.

[32]: Wikipedia, "Firewall (physics)", https://en.wikipedia.org/wiki/Firewall_(physics). Retrieved on December 19, 2019.

[33]: 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.

[34]: Wikipedia, "Black hole information paradox", https://en.wikipedia.org/wiki/Black_hole_information_paradox. Retrieved on January 5, 2019.

[35]: Alek Bedroya, Cumrun Vafa, (2019-2021), "Trans-Planckian Censorship and the Swampland", arXiv:1909.11063v3.

[36]: Wikipedia, "Lambda-CDM model", https://en.wikipedia.org/wiki/Lambda-CDM_model. Retrieved on February 3, 2019.

[37]: 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 1, 2022.

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

[39]: 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.

[40]: 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.

[41]: 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.

[42]: 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.

[43]: 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.

[44]: 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.

[45]: 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.

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

[47]: 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.

[48]: 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.

[49]: 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.

[50]: 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.

[51]: 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.

[52]: 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.

[53]: 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.

[54]: 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.

[55]: 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.

[56]: 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.

[57]: 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.

[58]: 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.

[59]: 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.

[60]: 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.

[61]: 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.

[62]: 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.

[63]: 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)

[64]: 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.

[65]: 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.

[66]: 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.

[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 & 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), “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.

[69]: 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.

[70]: 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.

[71]: 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.

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

[73]: Stephane H Maes, (2020), “Implicit Multi-Fold Mechanisms in a Neural Network Model of the Universe”, viXra:2012.0191v1, https://shmaesphysics.wordpress.com/2020/09/12/implicit-multi-fold-mechanisms-in-a-neural-network-model-of-the-universe/, September 12, 2020.

[74]: Stephane H Maes, (2020), “Interpretation of “Neural Network as the World””, viXra:2012.0197v1, https://shmaesphysics.wordpress.com/2020/09/14/interpretation-of-neural-network-as-the-world/, September 14, 2020.

[75]: 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.

[76]: Stephane H Maes, (2020), "Area Laws Between Multi-Fold Universes and AdS", viXra:2010.0207v1, https://shmaesphysics.wordpress.com/2020/08/10/area-laws-between-multi-fold-universes-and-ads/, August 10, 2020.

[77]: Stephane H Maes, (2020), "A Multi-fold Universe Genesis Inspired By Explosive Total Collision: The Source Of The Big Bang?", viXra:2208.0082v1, https://shmaesphysics.wordpress.com/2021/01/17/a-multi-fold-universe-genesis-inspired-by-total-explosion-collision-the-source-of-the-big-bang/, January 12, 2021.

References added on March 4, 2023

[78]: 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.

[79]: 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.

[80]: 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.

[81]: 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.

[82]: 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.

[83]: 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.

[84]: 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.

[85]: 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.

[86]: 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.

[87]: 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.

[88] 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.

[89]: 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.

[90]: 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.

[91]: 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.

[92]: 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.

[93]: 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.

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

[95]: Stephane H Maes, (2022), "Comments on Multi-fold mechanisms as Hermitian vs. Unitary processes", https://shmaesphysics.wordpress.com/2020/06/25/gravity-like-attractions-and-fluctuations-between-entangled-systems/#comment-4359, July 27, 2022.

[96]: 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.

[97]: 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.

[98]: Stephane H Maes, (2023), "A qualitative hint that the multi-fold dark energy effect could fit the cosmological constant estimate", https://shmaesphysics.wordpress.com/2020/06/19/explaining-dark-energy-small-cosmological-constant-and-inflation-without-new-physics/#comment-6021, January 30,2023.

[99]: Stephane H. Maes, (2023), "The Multi-fold Least Action Principle, a Quasi Theory Of Everything", https://shmaesphysics.wordpress.com/2023/02/19/the-multi-fold-least-action-principle-a-quasi-theory-of-everything/, February 19, 2023.

[100]: Stephane H. Maes, (2022), “Article questioning the Big Bag based on early galaxies encountered by JWST”, https://shmaesphysics.wordpress.com/2021/01/17/a-multi-fold-universe-genesis-inspired-by-total-explosion-collision-the-source-of-the-big-bang/#comment-4577, August 21, 2022.

[101]: Stephane H. Maes, (2022), “Comments and answer to questioning the Big Bag based on early galaxies encountered by JWST”, https://shmaesphysics.wordpress.com/2021/01/17/a-multi-fold-universe-genesis-inspired-by-total-explosion-collision-the-source-of-the-big-bang/#comment-4604, August 26, 2022.

[102]: Stephane H Maes, (2020), “Different approaches to compute Hawking Black Holes Decay”, viXra:2208.0009v1, https://shmaesphysics.wordpress.com/different-approaches-to-compute-hawking-black-holes-decay/, August 1, 2022. (Originally published July 11, 2020).

[103]: Stephane H. Maes, (2023), “Yeah or Nay on Black Holes as Explanation for Dark Energy?”, https://shmaesphysics.wordpress.com/2023/03/01/yeah-or-nay-on-black-holes-as-explanation-for-dark-energy/, March 1, 2023.