

# “Quantum Gravity Emergence from Entanglement in a Multi-Fold Universe”: 2D or 2+1D spacetime at small scales

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## Abstract:

*This short note presents a clarification to statements provided in our paper “Quantum Gravity Emergence from Entanglement in a Multi-Fold Universe”, with respect to the dimensional reduction of quantum gravity proposed by ‘t Hooft.*

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## 1. Motivations

In [1], and subsequent multi-fold theory papers, e.g. [2], tracked in [3,4], we stated that G. ‘t Hooft proposed that gravity behaves as if it had 2D degrees of freedom [5]. Multiple readers asked about this, as [5] explicitly states 2+1D.

## 2. Clarification

Yes, [5] recovered degrees of freedom associated to a 2+1D spacetime, which may appear inconsistent with our statements made in [1,2].

We should have been clearer that 2+1D in [5] indeed implies 2D spacetime at very small scales. Indeed if at these scales, all particles are massless (e.g. because we are above the electroweak energy scale), their speed is fixed at  $c$ . The resulting process is therefore 2D.

In fact, it is consistent with most quantum gravity theories per [6]. \_\_\_\_\_

**References:** (most references come from popular science to make the discussion more approachable)

[1]: Stephane H. Maes, (2020), "Quantum Gravity Emergence from Entanglement in a Multi-Fold Universe", [vixra:2006.0088v1](https://arxiv.org/abs/2006.0088v1), <https://vixra.org/pdf/2006.0088v1.pdf> (June 9, 2020). (See also <https://shmaesphysics.wordpress.com/2021/03/01/quantum-gravity-emergence-from-entanglement-in-a-multi-fold-universe/>).

[2]: 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://arxiv.org/abs/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.

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- [3]: 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/>.
- [4]: Stephane Maes, (2021), “Current Review – All Publications around the Multi-fold universe – February 2021”, <https://osf.io/8b69k>, <https://shmaesphysics.wordpress.com/shmaes-physics-site-navigation/>, February 15, 2021. (More recent updates available at the URL).
- [5]: G. 't Hooft, (1993), “Dimensional Reduction in Quantum Gravity”, arXiv:gr-qc/9310026v2.
- [6]: Steven Carlip, (2010), “The Small Scale Structure of Spacetime”, arXiv:1009.1136v1.