Viable Lattice Spacetime and Absence of Quantum Gravitational Anomalies in a Multi-fold Universe

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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 that 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 at large scales and semi-classical model remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model. This can contribute to resolving several open issues with the Standard Model (SM) without new Physics other than gravity. These considerations hints at a even stronger relationship between gravity and the Standard Model.

The Nielsen Ninomiya theorem predicts incompatibility of the conventional Standard Model with 4D discrete, lattice spacetimes per the Nielsen Ninomiya theorem, because of the weak interaction and the neutrino chiral asymmetries in SM. A priori, it would be problematic for the viability of the multi-fold universe reconstruction if it were to represent the real universe, and support or recover the Standard Model, as in the Standard Model with gravity, that is not negligible at the Standard Model scales (SM_G). It would also invalidate our lattice-based claims of proof of the Mass gap for Yang Mills theories. Even more problematic, quantum gravitational anomalies would obstruct entanglement: quantum entanglement would not be possible in a discrete 4D universe. It simply would destroy, as impossible and inconsistent, the multi-fold mechanisms and the multi-fold spacetime reconstruction.

This paper discusses the consistency of multi-fold models with respect to these issues, as well as the implications for gravitational anomalies in multi-fold universes. The resolution relies on gravity induced flips of chiral fermions in multi-fold universes, that we already used to explain the neutrino mass and absence of proton decay observations. The resulting (spontaneous) chiral symmetry breaking handles consistency concerns with the weak interaction on lattices, and problems with Dirac fermion doubling in QCD. The gravitational anomaly cancellations, or smearing, also directly relate to the feasibility of simulations, e.g. Monte Carlo simulations of multi-fold universes, or even the possibility that the universe itself could be a simulation.

Finally, the paper also derives non-invariance of the weak hypercharge under non-negligible gravity is also an important new result of SM_G, a results that does not change anything to observable weak interaction physics.

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1. Introduction

The new preprint [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

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than the addition of gravity to the Standard Model Lagrangian. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales and semi classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe). Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and spacetime coordinates, and metrics between Reisner Nordstrom [2] and Kerr Newman [3] for massive, and possibly charged, particles – the latter being possibly extremal). Although surprising, [1] recovers results consistent with other like [4], 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 4-D process, with massless gravity, but also with massive gravity components at very small scale that make gravity significant at these scales. Semi-classical models also turn out to work well till way smaller scales that usually expected.

The present paper discusses the implications of multi-fold mechanisms and SM_G, on chiral fermions, especially neutrinos, and how this relates to the Nielsen Ninomiya no-go theorem for 4D lattices and to quantum gravitational anomalies. As a result, the consistency of multi-fold models can be ascertained: even number of chiral fermion species, doubling of Dirac fermions in QCD and compatibility with the weak interaction.

2. The Nielsen Ninomiya No-Go Theorem

The Nielsen Ninomiya No-Go Theorem is summarized in [5] and detailed with different proofs and reasoning to motivate it in [6-9]. Accordingly, a lattice for an even dimensional (e.g. 4D) spacetime, requires the same number of species (including all quantum number) of left and right-handed chiral fermions (i.e., massless Weyl fermions) on the lattice with certain assumptions (action periodic at boundary, local, translation invariant and Hermitian action including exact conservation of discrete valued quantum number(s) (chiral charge in a finite region). Locality also constraints the type of anomalies that the theory can entertain it cannot support nonlocal anomalies which do not result into the no-go situations.

The main implication seems to be that the weak interaction and therefore the Standard Model (SM) cannot be implemented or simulated on a lattice, at least without violating one of the assumptions mentioned above. Indeed in the conventional SM, right-handed neutrinos and left-handed anti-neutrinos are missing, and the remaining charged fermions are assumed Weyl fermions, for the weak interaction, with different hypercharges associated to right and left-handed Weyl fermions; something forbidden by the theorem. Because it interacts only with left-handed fermions, the weak interaction therefore expected to not be implementable on a lattice.

Also, a Dirac fermion doubling problem is encountered by lattice QCD; preventing its simulation of chiral symmetric QCD over lattices and therefore another potential inconsistency with a discrete spacetime.

Note that although derived with a regular lattice the Nielsen Ninomiya No-Go Theorem holds, or is expected to hold, in the case an “amorphous” lattice.

3. A priori concerns with the Nielsen Ninomiya No-Go Theorem in a Multi-fold Universe

If the theorem were true in a (4D) multi-fold universe, we are confronted with the following problems, to name a few:

- The multi-fold universe reconstruction models would lead to a universe with a spacetime (discrete, fractal with random walk, Lorentz invariant and non-commutative) incompatible with SM [1]. The random walk fractal spacetime can be seen as fitting the amorphous lattice situation or a regular lattice with (many) missing (not yet concretized [1]) nodes.
- Our extended model for SM_G, see the latest development at [12], that includes non-interacting (in flight) right-handed neutrinos, and otherwise no need for sterile neutrinos or Majorana neutrinos, seems to fall apart [1,10,11,13].

4. Multi-fold salvation

It turns out that our chirality flip mechanisms [1,10,11, 13,14,31], and its use to associate masses to the neutrinos implies that the neutrino is a Dirac fermion, even if its right-handed may always be in flight / at the entry points of the multi-folds. As a result, there are no Weyl fermions post Higgs mechanism, and electroweak symmetry breaking: a multi-fold spacetime can be discrete, and remain compatible with the weak interaction and SM_G.

Indeed and in addition, the chirality flips apply to all the fermions involved in weak (or electroweak) interactions, meaning that in the presence of gravity, chiral symmetry is broken for the weak interaction and the weak hypercharge is not conserved. Yet, as weak interactions only occur with left-handed fermions, this has no apparent effects: the non-conservation event do not impact interactions that do conserve weak hypercharge. The non-invariance of the weak hypercharge in the presence of gravity able to switch chirality is a new result.

Such a (spontaneous) break of the chiral symmetry, also ensure the absence of Dirac fermion doubling in QCD [5-8,29,30] and explains strong interaction confinement. The consistency of a discrete spacetime is also essential to the Yang Mills mass gap problem solution we proposed [21]. These QCD considerations will be further discussed, and expanded, in a future paper.

5. Quantum Gravitational Anomalies

As also mentioned in [6], the same number of Weyl fermion of each chirality species also cancels quantum chiral / axial gravitational anomalies for gravity that acts as QED à la Adler–Bell–Jackiw for fermions in a QED fields [14-17,27,28], because of cancelling contributions from the different chiral fermion loops (we do not discuss non-local anomalies here). It has several consequences:

- It confirms the anomaly smearing due to gravity that we proposed in [13], with a different path to derive the same outcome: the lepton and baryon number chiral anomalies are canceled and so these symmetries are harder to violate in SMG. We used this to justify the absence of observed proton decay. Conventional approach would probably be more comfortable with the reasoning of this paper.
- It has been argued that gravitational anomalies obstruct entanglement from existing in 4D spacetime [18]! With our result, the gravitational anomaly is canceled and entanglement is possible. This is rather critical as without it, the whole multi-fold theory would have been totally moot, and entanglement would not exist in the real universe.

Note that this does not affect the neutral pion decay into two photons modeled in [27] and observed experimentally [14], that constitutes the main observation of chiral anomalies involves primarily charged meson (charged Kaon/anti-kaons) or charged baryons/anti-baryons (protons) loops, in the chiral loops, and anomalies due to the π^0 electromagnetic field. The broken chirality symmetry of the QCD vacuum ensure non-zero contributions, in fact, something independent of the fermions involved. This is not affected by the reasoning presented in this paper that does not necessarily cancel these effects. However, in the already mentioned future QCD paper, we expect to tie together the vacuum chiral symmetry breaking of QCD, confinement, the mass gap problem and gravity, and to provide microscopic explanations for the spontaneous chiral symmetry breaking of the QCD vacuum.

6. Monte Carlo and other simulations

As a side note, the elimination of quantum gravitational anomalies, modeled by analogy with thermal quantum Hall conductance effect, where similar anomalies are encountered, avoids the typical problem of negative sign in Monte Carlo simulations and the huge computational complexities that result [19-21]. Note that the elimination of the gravitational loop does not affect other physical situations where such anomalies are encountered like in particular 2D and 4D thermal quantum Hall conductance effects.

The reasoning presented here does not necessarily imply that anomalies are smeared by eliminating chiral fermions in solid states / condensed material physics: these involve quasi particles and different phenomena (e.g. [19,24,25]. This is especially important as these effects can be seen as a unique 4D spacetime effect, demonstrating direct a 4D spacetime, and so, in itself, of interest to anybody trying to confirm experimentally that our real universe has a 4D spacetime.

Multi-fold universes can be numerically simulated and, if that is what you would like to dream of, it could still possible that we would live in a simulation As the problems of simulation might not require intractable large amount of computing that the sign problem could otherwise create [19].

7. Conclusions

We have shown that the multi-fold model and SM_G, the standard model with non-negligible gravity at it scale, maintain consistency when it comes to chirality and discrete spacetime in a 4D multi-fold universe spacetime: there is no chiral fermion doubling problem on a discrete multi-fold spacetime, neutrinos and weak interactions à la SM, can coexist. The mass gap problem is indeed resolved in a multi-fold universe [21], and right-handed neutrinos can exist in flight due to gravitational induced chirality flips in a discrete multi-fold spacetime [1,10,11,13,31].

Also, we derived non-invariance of the weak hypercharge under non-negligible gravity that can flip chirality as in [1,31]. It is also an important new result of SM_G, a results that does not change anything to observable weak interaction physics as no weak interaction takes place with the right-handed fermions.

In fact, in a 4D multi-fold universe spacetime, there are no Adler–Bell–Jackiw -like gravitational anomalies, because of fermion chirality flips due to gravity, which smear or prevent such anomalies.

Monte Carlo simulations do not have to run amok on such anomalies, and therefore the idea that our universe may be a simulation also remains possible, something that we do not advocate but that certainly also relates to previous papers on modeling the universe as a neural network [22,23].

As we will discuss in upcoming papers, the handling of the Nielsen Ninomiya No-Go Theorem with gravity has farther reaching impact on the understanding QCD and generic Yang Mills confinement, spontaneous symmetry breaking and resolution of the mass gap problem, that is not just in a multi-fold universe.

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