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Multi-fold Higgs Fields and Bosons

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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 without new Physics other than gravity. These considerations hint at an even stronger relationship between gravity and the Standard Model.

This paper propose that Higgs bosons live in spacetime both of the multi-fold universe and of a 7D unconstrained Kaluza-Klein (KK) flat spacetime. With such a result, we can evolve the results and understandings from our original multi-fold paper and propose that concretized spacetime location are actually Higgs bosons microscopic black holes fluctuating around minimal Schwarzschild Planck black holes associated to the Higgs field. It could explain how the Higgs acquired mass and, as a result, why reconstruction-based inflation could be modeled by Higgs bosons as inflatons, and how it is setup for the electroweak symmetry breaking. With the Higgs boson living at the edge of a 7D space embedding the multi-fold universe spacetime, and in the multi-folds, we explain why multi-fold support Higgs presence in its tenancy model, something needed in order recover the equivalence principle and gravity.

With the resulting refined multi-fold model, omni presence of the Higgs field, and absence of an energy budget to concretize spacetime can now be explained.

We also further speculate on the right-handed neutrinos in a multi-fold universe, the axion and the maximal parity breaking of the Electroweak interaction with consequences for explanations of matter vs. antimatter asymmetry via axiogenesis, and of dark matter; topics where we already know that axions are not required in multi-fold universes, although not forbidden.

In this paper, we again predict right-handed neutrinos, and their anti-particles, hidden behind the Higgs, at the entry and exit points of multi-folds.

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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

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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 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 others 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 builds on [5,6] which discuss multi-fold universes embedded in larger 7D unconstrained Kaluza-Klein (KK) flat spacetime, where it is shown that the Standard Model (SM) with gravity not negligible at its scale (SM_G) can be induced from 7D geometry. It then discusses the Higgs field, and boson, within a multi-fold universe and its potential implications on spacetime, inflation and the multi-fold mechanisms. This allows to revisit notions of spacetime locations and their concretization, possible inflation and the tenancy model for multi-fold tenancy versus the original model in the first version of [1].

In this paper, we remain at a high level of discussion of the analysis and references are generic for the subjects. It makes the points accessible to a wider audience, and keeps the door open to further papers or discussions devoted to details of interest. Yet, it requires the reader to review [1], as we do not revisit here all the details of the multi-fold mechanisms or reconstruction of spacetime. More targeted references for all the material discussed here are compiled in [1] and derived papers.

The evolution of the multi-fold theory and results can be tracked at [22].

2. Higgs and Geometrical Induction: A 7D Higgs Field

In order to support the equivalence principle in a multi-fold universe[2], we already concluded that the Higgs field must also be present in the multi-folds [7]. It was further confirmed by determining that the Higgs boson can be encountered like any SM particle, as an object in 7D unconstrained Kaluza-Klein (KK) flat spacetime [5]. As illustration, in [6], its mass is correctly derived explicitly in higher order Mie scattering estimates with the multi-folds.

Yet, we are saying something slightly different between [7] and [5,6]: not only are particles derived from the embedded spacetime; but the scalar field is omnipresent not just in the multi-fold 4D spacetime but the embedding 7D spacetime.

In general, this is not a dilaton, or radion [8], as we do not, for now, assuming compacting the extra unconstrained KK dimensions. We will revisit that in a later section.

[2] And in order to rigorously recover gravity à la [1]…

3. Multi-fold Spacetime Construction and Inflation

The theory of inflation has been proposed to address challenges with the Big Bang theory to account for uniformity observed between regions of the universe, that a priori have not had the time to know about each other (i.e. homogeneity and isotropy of universe), as well as the estimated flatness of the universe (i.e. positive curvature, quasi null). It also help address more technical issues like the low rate of magnetic monopoles (none have been observed ever, something that we explained in the context of a multi-fold universe without requiring inflation [1,9]). The original inflation proposals and good overviews of inflation can be found in [10-13].

In [1,9], we discussed how the random walks, and particle (anti-particle) pairs creation, encountered during the construction phase of a multi-fold universe can generate inflation with an exponential growth of the amount of both particles and concretized spacetime locations. Indeed, even starting from a single point, successive time clicks are used, i.e., used for a change, or skipped, i.e., awaiting a future change. When used for a change, they are associated to movements (at the speed of light) that create spacetime location and / or creations of new particles. This also includes visiting skipped locations that are then concretized, or revisiting already concretized ones; hence the generic terminology of concretizing spacetime. Quantum uncertainties also further jiggle around the random walk paths and with entanglements opens the door to dark matter effects [1,9].

Per the multi-fold model, particles are microscopic blackholes. In the early stages, they are minimal for the charges they carry as massless particles: we did not model if only one type of particle exists (then neutral for all charge) or if different types with different charges may coexist; but we strongly emphasized a democracy of the particles: they have all the same effect on gravity and these match whatever other interactions they may entertain; all interactions have same coupling constant or effect. This is the basis for our proposal for an Ultimate Unification, instead of conventional Grand Unification Theories (GUTs) or Theories of Everything (TOEs) [1,14].

The multi-fold spacetime is therefore the result of random walks of the particles, which provides a discrete, fractal, Lorentz invariant and non-commutative spacetime at the smallest scales. In order to model spacetime creation and concretization, [1] reused the mode of microscopic blackhole and associated a minimal (Planckian Schwarzschild black hole) to each concretized spacetime location, allowing also these points to be entangled for a while with neighbors, when concretized by the walk of a same particle and not yet revisited by another. Yet we did not associate any physical entity to these spacetime locations other than being just that: spacetime locations, with a minimal black hole on it. But such an association of a minimal black hole at every concretized spacetime amounts to associating a (scalar) field to it.

For now, in the inflation phase such a field would naturally be an inflaton [15]. It is a key addition to the multi-fold models: concretized multi-fold spacetime locations are modeled by inflatons and their associated blackholes (at least during the inflation phase).

In the spirit of the approach of [1], the random walk of particles and concretization are the physical effects and the scalar inflaton field, vacuum energy density and relativistic pressure are its models in QFT and GR.

Today, in conventional Physics, we do not know for sure what field could be responsible for the cosmological inflation. Hypotheses involve small fields, large fields, hybrid fields, natural fields (e.g. due to the elusive axion) and variations or combinations of multiple fields and criteria to be satisfied for suitability non only to the inflation phase but also the slow-roll and re-heating critical to explain the hot big bang phase and match the theory to the (Λ-)CMB observations.

4. Higgs Inflation With Non-minimal Coupling

The Higgs scalar field has been proposed as a candidate [16]. The idea of a field, already used to model the electroweak symmetry breaking and the subsequent mass generation of all elementary particles (including neutrinos in a multi-fold universe [17]), is quite attractive and economical. It resulted into a plethora of analyses. We recommend [18-21] for a recent overview of the analyses, problems encountered and proposed resolutions for the approaches based on the original model of [16]: Higgs inflation with non-minimum coupling to gravity. it is required in order to match the CMB results with the Higgs potential and amounts to add a term to the Lagrangian density of the SM in:

$$\mathcal{L} = \mathcal{L}_{\mathrm{HE}} + \mathcal{L}_{\mathrm{SM}} + \zeta R\bar{\phi}\phi \quad (1)$$

Where ζ is a new coupling factor and R is the Ricci curvature scalar. SM designates the Standard Model Lagrangian (of course including the Higgs field) and HE refers to the Hilbert Einstein contribution[3] and ϕ is the Higgs scalar field. Lagrangian and actions are expressed in the Jordan frame.

This gives the additional degree of freedom needed to better match CMB results and supports adequate inflation as well as slow roll towards reheating.

It can be understood as follows: the Higgs field potential energy is modified in the presence of curvature to decrease by expanding where more matter and curvature exist, i.e. to flatten the spacetime. See section 6 for more details.

Unfortunately, other problems have since been identified with the proposal, mainly in terms of consistency of the model (inflation plateau occurring above the expected UV cutoff of the model), electroweak vacuum instability concerns and unitarity concerns [19,23]. The coupling ζ is also found to be very large, which is not a good sign.

Before exploring what happens with minimally coupled Higgs fields in multi-fold universe, let us note, for completeness, that models have also modeled Higgs inflation with supersymmetry and super strings. See references for variations and extensions in [18] (supersymmetry, e.g. [23], or supergravity), and the analysis of [24] shows a successful model for high-scale supersymmetry, and for most GUT models the non-minimal coupling Higgs inflation could be viable and consistent with slow-roll requirements. However, we know that supersymmetry and supergravity are not physical in multi-fold universe (and probably as probably as most probably also not physical in the real universe) [25]; so these results are not really helping or convincing.

5. Inflation with Higgs Field Minimally Coupled to Gravity

We already know that without additional considerations, minimally coupled Higgs fields do not work to explain inflation. The main problem to realize the minimal Higgs inflation without any ultra-violate modification is the lack of tuning parameter as ζ in the non-minimal coupling case. Modelling well the Higgs potential the potential becomes tricky [42].

Work has also been done for Higgs inflation in conjunction with asymptotically safe gravity [27], driven by considerations from [20]. In general, it has been shown that non-minimally coupled schemes may work with now a way smaller ζ. Furthermore, minimally coupled schemes are shown to work [26].

Note that asymptotically safe gravity has also been considered for other inflaton schemes that the Higgs, e.g. [27,28].

[3] Interestingly, this is already an example of $\mathrm{SM_G}$, SM with a non negligible gravity contribution at the SM scales, as we have argued throughout [1] and the papers compiled in [22].

6. Multi-fold Inflation Modeled at QFT Scales by Higgs Field (non) Minimally Coupled to Gravity

Justification of the non-minimal coupling to gravity is also trickier in a multi-fold universe: the model that give repulsive pressure for a uniform field in GR gives the same with the multi-fold mechanisms. For conventional GR it can be argued that this is a plausible, and one of the simplest, form of quantum correction. In a multi-fold universe, all such quantum corrections effects are also already accounted for.

It is therefore a bit harder to justify larger scale QFT modeling with the non-minimum coupling, other than an attempt by the QFT approximations to model the effects of the random walk by emphasizing that were curvature increases with many particles, the effect is larger, possibly because of the extra effects of multi-fold dark energy that increases near high curvature or where lots of matter, including lots of massless Higgs, as discussed in [9].

In a multi-fold universe, gravity is asymptotically safe [25], so both options are acceptable.

In the minimal coupling case, Of course the field representation is just an approximation of these microscopic effects. Therefore it is hard to say if the QFT approximation should rather use the minimal or non-minimal representation. We would like to say that with the non-minimal coupling, we can cover all bases.

Therefore, we expect that the quantum walk inflation in multi-fold universes (per the construction phase [1,9can be modeled in QFT by a non-minimally coupled Higgs that may be minimally coupled. But can be along the lines of [26].

Note added on March 28, 2021: Considering how [37] anticipates our multi-fold gravity electroweak symmetry breaking [38], it behooves to us to emphasize that this is another reason why a non-minimally coupling could very well also be suitable to model the multi-fold effects. In fact, in general it is more often encountered conventionally than the minimal coupling of [20]. It is only that microscopic justification was a bit trickier until [38,39], where we see that indeed the density of Higgs bosons is probably the trigger for the gravity electroweak symmetry breaking, with Higgs bosons condensing into Kerr-Newman solitons to produce massive particles. Under these considerations non-minimally coupled models may even make more sense!

Note added on April 12, 2021: Additional interesting arguments can be found in [40] (and in Feynman's lectures on gravitation [41]).

6.1 Consistency and stability

Asymptotic safety ensure scale invariance of gravity. The model should not have the inconsistencies of plateauing, and it is not doing it beyond validity of the model.

6.2 Slow roll in Multi-fold Universes

In a multi-fold universe, the inflation, takes place as long that there is enough energy to make the involved particle walk randomly, at almost every time click, and create new particle pairs. When that is reduced, the process stops being exponential, and rather evolves towards a tamer random walk and vacuum fluctuations; i.e. a slow roll. It corresponds to the QFT model which identifies slow roll as taking place when the kinetic energy of the inflaton becomes larger than the field potential.

As discussed, we have not modeled yet what are the particle involved, other than that they all have zero mass during inflation and follow the principle of democratization of interactions from UU [1,14]. It could be a new particles, a set of massless version of most of the SM particles, massless Higgs bosons etc. Or they must just all be only massless Higgs. As, whenever spacetime locations are concretized, a minimum microscopic blackhole associated to the Higgs field is left at these locations. More details will be provided in future works that can always be tracked at [22].

6.3 Re-heating in multi-fold universes

Re-heating results from symmetry breaking, starting from the UU as in an universe in inflation, temperature and energy density lowers. As a result particles and interactions diversify. Electroweak symmetry break up occurs at lower temperature and all particle acquire their masses; including the Higgs.

From then on, the hot big bang takes place and can follows its post inflation chronology.

6.4 Electroweak vacuum stability

[29] shows how concerns with electroweak false vacuum and instabilities are addressed in a multi-fold universe; thereby alleviating the concern with Higgs inflation.

7. Higgs Boson and Multi-fold universe

Massive Higgs particles are now like a sea of Higgs located at every spacetime location. They also extend, near the infinitesimal edge boundary only, we assume, in the 7D unconstrained KK flat spacetime. As a result, they do not have to enter in energy or quantum number conservation budgets as they interact with fermions to give them mass and flip their chirality. It happen at every concretized spacetime location. Note that Higgs boson that temporary appear into real particles before decaying do respect all conservation laws.

Every concretized spacetime location therefore is characterized by a minimal black hole associated to the Higgs field that creates pairs of virtual Higgs, and absorbs virtual Higgs back and forth. With quantum fluctuations it also consists of exchange back and forth with surrounding concretized spacetime locations, so that creation and annihilation is not tracked as associated to a specific location but within a fluctuating region. This contribute to how non-commutativity and Lorentz invariance was already recovered [1]. More details will be provided in future work that can always be tracked at [22].

The microscopic minimum black holes are what is sometimes misnamed as the fabric of spacetime.

When multi-folds are activated [1], they consists of the same fabric of spacetime and as so the same processes take place in the multi-folds. This ensures that paths in the multi-fold will also involve interactions with the Higgs boson and as a result involve particles with the same mass as in the multi-fold spacetime. It is essential to recovering the equivalence principle [7] and gravity derivation from multi-fold mechanisms [1].

It justifies the clarification or update to the multi-fold tenancy models of [1] described in [7]: all laws of Physics apply equally to each fold. Only one particle lives in a folds (hard partitioning based tenancy model); particles appearing in a same multi-fold are in fact in different instances and they never interact other than at entry and exit points. However, this does not hold for the Higgs boson, which is present at every location of the multi-folds and therefore ensuring that electroweak is also broken in the multi-folds (post electroweak symmetry breaking, and that all particle keep their mass in the multi-folds.

The comments about energy and quantum number conservation also explains why any energy involved in the multi-fold dynamics (and their kinematics and dynamics beyond the prescriptions of [1]) do not have to be tracked: the budgets and details occur in the embedding spacetime.

8. Multi-fold Right-handed Neutrinos, CP violation and Maximal P Symmetry Breaking by the Electroweak Interaction

All the previous section are proposals for an evolution of our multi-fold model.

This section however is in our view much more speculative, as not as well derived from constructive considerations, themselves derived from [1], that also meet QFT models that must be recovered at higher scales. So this section should be treated as such, and will certainly require further work. It aims at expanding on a comment made in [6] about right-handed neutrinos (and left-handed anti neutrinos) in multi-fold universes. Future work will details this. As always these future work can be tracked in [22].

In [17,30], we argued the existence of the right-handed neutrino, always in-flight, never available for interaction and appearing only as part of the interactions with the Higgs boson so that neutrinos acquire mass.

The right-handed neutrinos is created, even if temporarily in the mass generating Higgs interaction; yet not observed. What if this is only happening in the multi-folds: the Higgs is present in the multi-folds, right-handed neutrinos appear and disappear on the paths in multi-folds of a left-handed neutrino, giving it mass in the multi-folds but not exiting the multi-folds. Real particles in the multi-fold spacetime interact with right-handed neutrinos through the Higgs (in 7D)[4] only through quantum fluctuations at entry, exit points of the folds or when mapped to a multi-fold.

No energy is lost, for entangled particles with real path in the multi-fold, because of the same arguments as in [1]: path can have as small probability as desired and everything is recovered in the deactivation mechanisms of the multi-fold, with just a twist: exit always flips the right-handed path to a left-handed one first. Continuing down this speculative path, a possible reason could be the right-handedness of the gravity representation discussed in [5] that prevents right-handed neutrino representations in multi-fold spacetime (which is used for the electroweak interaction post symmetry breaking).

Real left-handed neutrinos can interact with Higgs to generate right-handed neutrinos only due to fluctuations making then see/feel the multi-folds that surround them; yet enough to gain mass[5]. Being hidden in at the entry and exit of multi-folds can explain their lower mass and absence of other interaction considering the multi-fold tenancy principle [1], with the updates from [7].

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[4] Through the Higgs, is actually very important: 7D spacetime does not support chiral fermions (See the related discussion in [5] and how it is handled to still recover chiral fermions in the 4D multi-fold spacetime).

[5] The low mass values may be due to these complications in the mechanisms that effectively renders the interaction with the Higgs as if with a smaller coupling; except maybe for the neutrino tau.

A chirality preference at the entry point of the multi-fold, maybe resulting by the presence of in-flight right-handed neutrinos, or left-handed anti-neutrinos, would entail and explain CP violation (by gravity or Physics in general as it affect somehow spacetime, and why torsion in matter is not only supported but may be possibly always present [1]. Such systematic violation of CP symmetry, along with all the observations made so far [31], could mean that, perhaps, it is more reasonable to conclude that CP symmetry does not exist in our universe, than that the violations result from symmetry breaking by an unknown mechanism. As a result, particles like the axion may not be motivated anymore by the Peccei Quinn mechanism [31,32], that we already questioned in [1,33]. It removes it as a candidate for dark matter, and matter antimatter asymmetry (via axiogenesis [35]), especially as we have alternative explanations in multi-fold universes respectively in [1,34] and [36].

Similar considerations could possibly explain the maximal parity breaking of the Electroweak interaction, i.e. the fact that $W^{\pm}$ only couple to left-handed fermions, and the Z^0 boson couples unequally to left and right-handed fermions. Understanding, modeling, and validating this is for future work.

At this stage, and as announced earlier, this section is a conjecture. We do not have a concrete explanation or justification on how and why the filtering out of a chirality versus the other takes place, other than an effect of the in-flight right-handed neutrinos. Consider for example, the Higgs Boson and the right-handed neutrinos: if this phenomena occurs around any particle and at any concretized spacetime location, then systematic P violation occurs everywhere in multifold spacetime. As Higgs is C-symmetric, spacetime and physics could be systematically violating CP symmetry. Alternatively, it could be a refinement (asymmetric for chirality) of the multi-folds or their dynamics: even if correct our conjecture just move the unexplained to another problem…

Note that the presence of Higgs field in 7D unconstrained KK spacetime may also lead to models to trigger the big bang or electroweak symmetry breaking via events taking place in these extra dimensions. We do not have a concrete proposal but wanted to note as food for thoughts that for examples dimension collapses in the embedded universe would result into mass acquisition by the Higgs, but, as far as we know, this does not fit well the chronology of a big bang with inflation or the large dimensions of the AdS(5) and 7D unconstrained KK. Yet it would be worth exploring this in the future.

9. Conclusions

We have shown how in a multi-fold universe, we can build a QFT model of inflation that relies on the Higgs (field and boson), and consistently relates to our multi-fold constructive model [1]. Doing so we clarified the details of concretized spacetime locations with microscopic black holes that are now identified as related to the Higgs field, which concretize spacetime, is responsible for the random walks and inflation, in addition to mass generation.

Associating the Higgs field to the embedding 7D unconstrained KK flat spacetime allow us to explain why multi-fold mechanisms, Higgs interactions and Higgs inflation can seemingly violate some conservation rules. It also provides a physical justification to the multi-fold tenancy rule updates that we introduced with respect to the original model in [1] in order to recover the equivalence principle [7], and rigorously derive gravity from the multi-fold mechanisms [1].

Doing so led us to propose explanations on a fundamental CP and P symmetry violation by multi-fold mechanisms with proposal to explain the absence of right-handed neutrinos in interactions (yet their involvement in mass generation), as well as the maximal violation of P symmetry by the electroweak interaction. One is a conjecture on the behavior of the multi-fold entry and exit points another explains that relying on always in-flight non-interacting, except via the Higgs, right-handed neutrinos, and the anti-neutrinos, located at such multi-fold entry and exit points, along with the Higgs, e.g. blocked behind it. In fact we conjecture that a multi-fold universe may simply not be CP symmetric as a result. It would have broad implications on motivating the axion and relying on it to explain mater antimatter asymmetry (via axiogenesis) or dark matter. These problems were already separately addressed in multi-fold universes without the need of axions.

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