Multi-folds in Yang Mills Feynman Diagrams

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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, 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. All these recover General Relativity (GR) at large scales, and semi-classical models remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model resulting into what we define as SM_G.

In QFTs, scattering amplitudes are perturbatively computed using Feynman diagrams. Recent work showed that classical scattering of massive or charged particles, or objects, and resulting wave radiation, are classically fully characterized by up to the five-point tree-level diagrams. All the loop and other order diagrams contribute quantum corrections. We explain such results in multi-fold universes. Furthermore, doing so we detail how gravitons are unphysical quasi-particles, a key difference with gauge interactions that also results into gravity QFT/EFT non renormalizability.

Yang Mills theory and gravity have many commonalities, including the double copy behavior in scattering amplitude. Besides relating this behavior to Kaluza Klein, and space time matter induction, the paper shows not only how double copy is compatible with multi-fold mechanisms, but also argues that it implies the multi-fold emergence of gravity from (virtual) entangled particle pairs, which is at the core of the multi-fold mechanisms. Furthermore, gravity contains Yang Mills, as implication of its square root of scattering amplitudes. Also, it explains why one therefore also can derive, under the right conditions, Yang Mills from the Hilbert Einstein action, as are encountered by superstrings when adding a conformance condition.

As announced by the title, we show how these results imply that GR is obtained, at the scale of the SM, from the kinematics of SM, i.e., from Yang Mills, (massless) particles. It validates one of the a priori arbitrarily imposed axiom of the multi-fold theory, and provides a microscopic explanation for the double copy behavior, which so far is unjustified in conventional QFT or superstrings. This way, the paper explains how Yang Mills contains gravity / GR, and, conversely, quantum gravity / GR contains Yang Mills, so that the E/G conjecture is satisfied. A microscopic mechanism to explain the Ultimate Unification (UU) is also discussed.

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 qualitatively explaining many other Standard Model and Standard Cosmology Model (ΛCDM) mysteries without requiring New Physics beyond the Standard Model other than the addition of gravity to the Standard Model Lagrangian [1,4-7,11-16,24,25,30-43,45-*111*,*113*]. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated. *Note added on March 18, 2023: In this paper, references in italic have been added on March 18, 2023.*

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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 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. Below the multi-fold gravity electroweak symmetry breaking, the particle black holes result from the condensation of the massless Higgs into a 7D soliton by space time matter induction and scattering. Above, the massless particles solitons result from patterns of the random walk of massless Higgs boson patterns [1,4,42,45,84,*89-91,100*].

The resulting gravity model recovers General Relativity at larger scale [1,6], 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 [1,34]. Semi-classical models also turn out to work well till way smaller scales that usually expected.

Multi-folds are encountered in GR at Planck scales [5,6] and in Quantum Mechanics[2] (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.

The paper builds on two research directions around the behavior of double copy between Yang Mills and Gravity scattering amplitudes. In a first part, based on [8], we recover in a multi-fold universe, the properties that classical scattering is fully described by the up to the five-point tree-level (zero loops) Feynman diagrams, that it be for Electromagnetism / Yang Mills or gravity. Such analyses shed lights also on why gravitons are unphysical [10,11] and GR is not a renormalizable QFT/EFT, even if multi-fold quantum gravity is asymptotically safe [12,31,52,85,*90, 92*].

Guided by [8], we then revisit the double copy behavior [9], and our initial related multi-fold analysis [10]. It turns out that [10] was right on, albeit way too terse: it focused only on arguing that double copy was compatible with the multi-fold mechanisms. It missed the bigger implications discussed in the present paper:

i) GR implies the multi-fold mechanisms, and more importantly, in multi-fold universes, gravity results from entanglement of pairs of entangled virtual SM, i.e., Yang Mills, particles [1,14-16,*93*].

ii) The Hilbert Einstein contains, under the right conditions, Yang Mills, also in relation to KK and (multi-fold) space time matter induction models [1,4,32,42,45,84,*89-91,100*].

iii) Yang Mills conversely contains gravity with its double copy, which amount to the multi-fold mechanisms for entangled SM particle pairs, real or virtual, with the latter generating massless and massive gravity, and the former the gravity fluctuations due to entanglement.

iv) The E/G conjecture is validated as factual in multi-fold universes [13], and probably in the real universe if one accepts the implications of [5,6,7]. Doing so we also resolve another mystery of the double copy by providing a microscopic explanation for it, that is missing in QFT or strings [18], as well a potential microscopic explanations for UU [1,43,*89-91,103*].

In general, several aspects of the above applies to non-multi-fold universes. In the paper, we indicate when key results can have a broader scope. Of course [1,5-7] and [1,4-7,11-16,24,25,30-43,45-*111*,*113*] seem to argue for our real universe being multi-fold (and GR-based).

[2] Standing in for Quantum Physics in general.

2. Classical vs. Quantum Scattering Amplitudes for Gravity and EM

[8], and references therein, in particular [18], show that:

- Classical scattering for electromagnetism and gravity are fully (perturbatively) defined by up to the five-point tree-level (zero loops) Feynman diagrams.
- Any other diagrams are null for higher order tree-levels and quantum corrections otherwise.

3. Scattering Amplitudes for Multi-fold Gravity

The same properties is encountered in the multi-fold theory.

Indeed consider figure 1. *Note added on March 18, 2023: here the dynamic multi-fold considerations are aligned with [1,113].*

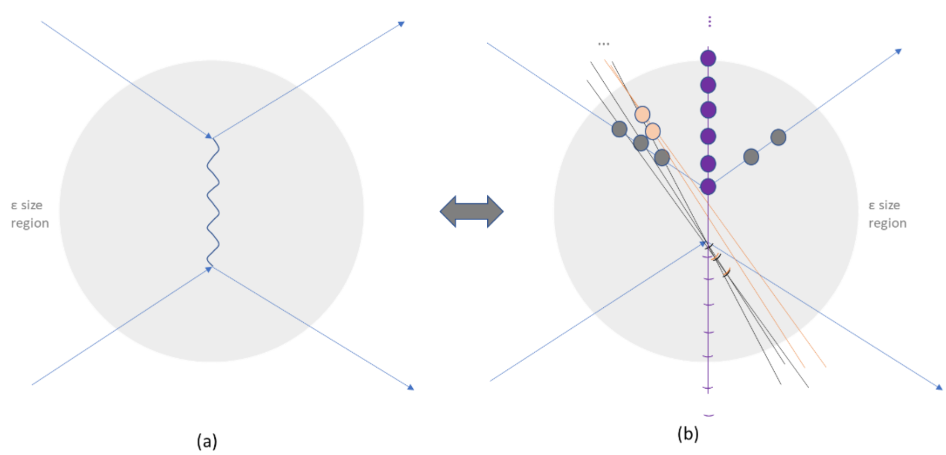

Figure 1: (a) illustrates one of the 4-point tree level Feynman diagram for gravity. The ε region captures a region compatible with the uncertainty principle where different path alternative will contribute equivalently to the path integral behind the Feynman diagram. (b) represents the corresponding non-perturbative contributions of the muti-fold mechanisms, described in [1], where the multi-fold effects are integrated over a set of past multi-folds corresponding to entangled pairs of virtual particles, and anti-particles emitted earlier by the top particle (grey). They can be equivalently exchanged by uncertainty with the orange positions from other contributing paths. Finally ending up with the violet contributions. Doing so we recover the multi-folds integrating r^{-2} from r to ~+∞. Of course, the different symmetries of the Feynman diagram can apply and the same can be done with the second particle.

When pushed to infinity, to the first order, the effects in figure 1(b) (violet) match the effective potential between the interaction points in r^{-1} expected with classical models per [1]. It is the classical scattering.

When considering the impact from another contributions from within the ε region, we obtain figure 2, the multi-fold 5-point tree level Feynman diagram for gravity.

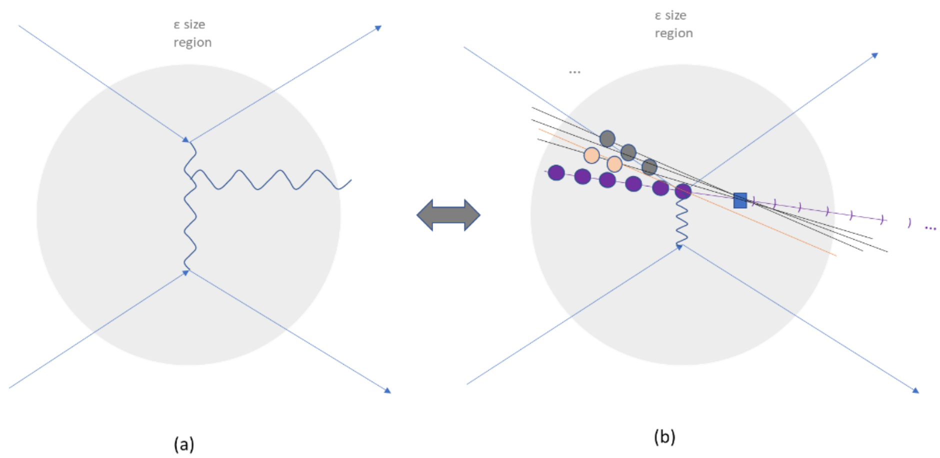

Figure 2: (a) illustrates one of the 5-point tree level Feynman diagram for gravity. The ε region captures a region compatible with the uncertainty principle where different path alternatives contribute equivalently to the path integral behind the Feynman diagram. (b) represents the multi-fold mechanisms, described in [1], where the multi-fold effects are integrated over a set of past multi-folds corresponding to entangled pairs of virtual particles and anti-particles emitted earlier by the top particle (grey). They can be equivalently exchanged by uncertainty with the orange positions from other contributing paths. Finally ending up with the violet contributions, which radiates. The exchanges can be made for any position. Of course, the different symmetries of the Feynman diagram can apply and the same can be done with the second particle.

Again, when pushed to infinity[3], to the first order, the effects in figure 1(b) (violet) match the effective potential between the interaction points in r^{-1} expected with classical models per [1]. It is the classical radiation effect. No other construct is required between the vertices.

The corrections to all these are the deltas between say the grey and orange corresponding source positions in figure 1, (for all the cases) that becomes a 1-loop correction, as they can be model by a repeat of figure 1(b) and 2(b) with contributions from another set of points within the ε region. Many compensate across the different points. Any additional discrepancy can be a 2-loop correction (additional pairs of vertex point exchanging radiations/interactions, i.e. sources vertex), etc. The same applies for figure 2, that can also be corrected with additional interaction points.

The zero loop 4-point functions are classically understandable as in figure 1. The 1-loop and higher order involve multiple point of interaction, and rely therefore on the Heisenberg uncertainty principle. They are quantum effects.

5-point function involve radiated particles, as shown in figure 2(b), that can come from anywhere with the ε region, but only from one location at a time. The zero loop case covers the radiation contributions that are modellable classically as they involve the well-defined picture à la figure 2(b), and one source of wave, with that source being anywhere within ε. Classically, of course $\varepsilon \rightarrow 0$, and $\hbar \rightarrow 0$. Higher order loops are again quantum.

Beyond 5 point functions, the diagrams are only quantum corrections to radiation because they involve 2 or more spacetime locations deltas, i.e. they rely on the uncertainties or, equivalently, multiple paths as source of the radiated waves. Therefore, we can predict that any term that would be without ħ must disappear in these terms to handle the case where $\hbar \rightarrow 0$.

[3] It is not entirely that clean, because only a finite distance is integrated but that is true for all gravity use cases, unless if it was generated by a eternally static source. So the handwaving here does not matter. [1,6,*113*] argue recovering GR no matter what, but multi-fold are now dynamic.

No other contribution needs to be considered in a perturbative classical model for radiation/waves, in agreement with the overview presented and reported in [8,18] for wave modeling.

We recover the results of [8] and references therein.

Furthermore, when expanding to many orders, in the multi-fold theory, we expect that this process converges rapidly, at the difference of QFT/EFT quantum gravity [1,52,*114*]. We will come back to this.

It is also important to understand that multi-folds are intrinsically non-perturbative: they show the full physical effect of the dynamic multi-folds. In this section and the discussion above, we extracted as figures 1 and 2, different specific perturbative-like contributions from the non-perturbative model.

4. Classical Electromagnetic scattering

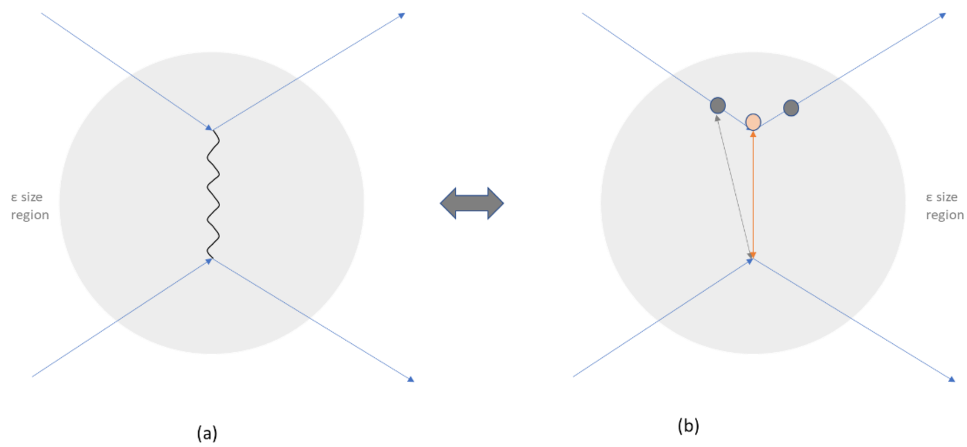

Figure 3: (a) illustrates one of the 4-point tree level Feynman diagram for electromagnetism. The ε region captures a region compatible with the uncertainty principle where different path alternative will contribute equivalently to the path integral behind the Feynman diagram. (b) represents QED mechanisms as classical vertex to vertex effect (pink) with a virtual photon actually originating from another spacetime location. However at the difference of figure 1, no integration is needed at the level of the diagram, and it is rather contained in the Feynman diagram rules. Of course, the different symmetries of the Feynman diagram can apply and the same can be done with the second particle.

[8] and references therein, especially [17,18], extend this result to classical electromagnetism.

We now want to use the approach of figures 1 and 2, to recover the same result in electromagnetism. It is illustrated in figure 3.

Following QED, a photon reaching the second particle reaches the other vertex originating from a different spacetime location (grey). It can be corrected to the classical model (pink).

There is no simple and QED equivalent to figure 3, because photons do not interact with each other (other than if annihilating at very high energies). Radiations (4-points, zero loop) can be seen as adding the result of mechanisms as in Larmor radiation [*95*], due to the accelerations associated to interaction/scattering with say a coulomb field (coulomb, or Rutherford scattering), or beyond QED, but that is not relevant here. So 5-point exists only with loops (e.g. with a one loop QED vertex correction on a particle path).

Again the process followed in figure 3 is non-perturbative, and we extract from it the different order of perturbations, by looking at all possible contributions from the ε region, which is quite different way to look at typical perturbative Feynman diagram justification.

As for figure 1 and 2, the corrections are the deltas between say the grey and orange corresponding source positions in figure 3, (for all the cases), that becomes a 1-loop correction. Again that is achieve with the addition of a pair of points in figure 3(b) to capture the non-compensations, but these will a priori come from the vertex, instead of in-between as gravity more easily can do. Many compensate across the different points. Any additional discrepancy can be a 2-loop correction etc. The same applies for radiation. We essentially repeat the analysis of section 3. These are indeed quantum corrections because they involve 2 or more spacetime locations deltas, i.e. rely really on the uncertainties or, equivalently, multiple paths.

No other contribution that 0-loop 4-point and 0-loop 5-point (zero amplitude in QED) functions needs to be considered in a perturbative classical model of radiation. The rest are quantum contributions with ħ factors.

We recover the results of [8] and references therein.

The non-perturbative reasoning also explains why the Feynman diagram rules are universal, even beyond particles[4]: it is always that reasoning that is behind the path integrals. We realize it is not a presentation that we have ever encountered in the literature. Maybe it would clarify what happens for many.

Note also that QCD and the weak interaction, i.e., non-abelian Yang Mills, can have more radiating low order diagrams. However, it does not really matter for our discussion here as none of these interactions have a non-quantum aspect. However, the characterization of the perturbative Feynman diagrams vs. multi-fold interactions hold for all of these SM interactions.

5. Differences between Gravity and Electromagnetism, or Yang Mills, QFT

The differences between the 4-point and 5-point diagrams (and any other corrections) between gravity and Electromagnetism, or Yang Mills, are as striking as the similarities.

EM (classical and Quantum), and Yang Mills, or QFT in general are very clean: one exchange a well-defined[5] virtual particle between vertices that comes from elsewhere, and correct, and we are done. Multi-fold gravity is messy: one must integrate a whole bunch of (dynamic) multi-fold contributions from the whole relevant past, in order to capture all the contributions at a spacetime location under consideration, that are then integrated to provide the resulting effective potential (See [1]). And so are the corrections. It is also illustrating how GR is non-linear [1,*113*].

As a result, the graviton is never well formed, but it is rather an infinite sum of many incomplete multi-fold additions. This is true at all order.

[4] For example, superstrings or LQG have similar diagrams and rules. *Note added on March 18, 2023: An possibly interesting justification of this universality is provide in [105].*

[5] Granted that as we mentioned in [1,24], the notion of virtual particle is not championed but most. We argue that it is a problem of QFT instead of a feature.

Therefore:

- The graviton is an illusion, or quasi particle that cannot exist in a non-perturbative mode and therefore is unphysical. It recovers results as in [10,11,16]
- However, the graviton can often still be a good model to abstract what happens, as long that it is considered at low perturbative order.

This complex image is what we mean when we use the term graviton in this paper rather than the multi-folds attached to entangled particles or living in AdS(5) (or as closed strings in AdS(5)++) [1,31,32,37,54,56].

This result explains the unphysicality of the graviton, despite supporting gravity scattering, discussed in [10,11,16].

In quantum gravity modeled as QFT/EFT, instead of as multi-folds, we need to implement figure 1(b) and 2(b) with figure 3(b) (and the equivalent à la 3(b) of 2(b), when relevant), and similarly for more-point functions. That requires at each order an infinite number of corrections (the infinite number of integrand contributions (each multi-fold)). This is why GR appears non-renormalizable and diverging at every order: it requires always new corrections at higher order, also implying divergences across all orders [*114*]. Again, the challenge is immediately understandable, and it is simple to explain with the multi-fold gravity model.

Multi-fold gravity does not have that problem as shown in [1,12,31,52,85,*90,92*]. For example, in multi-fold theory as we have shown that spacetime becomes a 2D process at very small scales, and, as a result, gravity is asymptotically safe[6] [1,12,40,*90,92*]. It is consistent with 2D GR as discussed in [85,*90-92*] and references therein. [6,85] provides another way to look at arguments of asymptotic safety of multi-fold gravity, and GR-based gravity. Mathematically, it can also be understood as the result of the additional degrees of freedom brought by the many multi-folds, in each multi-fold perturbative diagram, which free us from the need to add diverging and compensating terms at all orders . That is why it can be asymptotically safe, and converge faster compared to any attempt of a Quantum gravity modeled as QFT/EFT.

The complexity, and unphysicality, of the graviton in turns is an alternate way to explains in our view the possible absence of convergence of the processes, divergence, and non-renormalizability of QFT / EFT gravity: It also clarify what we meant in [1,10,11,37,85,*113*], when arguing that it is a perturbative quasi particle, but not a non-perturbative one. It is non-perturbatively unphysical, because living out of spacetime as multi-folds [1,31,32,37,54,56].

On the other hand, the cleanliness of the Electromagnetic or Yang Mills analysis explains without further ado why these theories (Electromagnetism and Yang Mills) are renormalizable[7], at least in spacetime of dimensions 4D or smaller. It's that simple. *Note added on March 18, 2023: See for example [33,89-92,110] and references therein. It's also how we can see non-linear aspects of GR, and explains effects like frame-dragging and Lens-Thirring [1,113].*

6. Revisiting the double copy behavior of Yang Mills scattering

[6] For sure gravity is asymptotically safe in a multi-fold universe, but also, based on [5-7], most probably in our physical universe. *Note added on March 18, 2023: See [85,92] for other hints.*

[7] The reasoning is not multi-fold-based for electromagnetism, and Yang Mills. The gravity reasoning is based on multi-fold mechanisms. So for anybody not yet willing to follow [5-7], one would still argue that the many relationships between multi-fold results and conventional, i.e., non-multi-fold results or challenges, hints that the analysis made here may be a relevant conjecture.

[8,18] relates the discussion above to the double copy behavior of Yang Mills theory and, hence the electroweak theory, pre-electroweak symmetry breaking and the electromagnetism, post electroweak symmetry breaking[8]. We already encountered it in [9,10].

As mentioned in [9], the double copy behavior of Yang Mills scattering, provides a recipe to rearrange the scattering amplitudes of the Feynman diagram of Yang Mills scattering into product of interaction terms associated to Yang Mills charges[9], as scattering[10], times a kinematic contribution describing the "configuration" of the momentums. If the Yang Mills interaction terms are replaced by another copy of the kinematic terms, one recovers gravitational scattering. All are in spacetime of the same dimension. Details can be found at [17,19-23].

Interestingly, the double copy behavior covers many different theory variants, including superstrings [23]. The double copy leads to pure Einstein gravity if the envisaged colored particles are massless. When they are massive, additional degrees of freedom appear, including a dilaton (massless scalar) and a Antisymmetric 2-form (massless scalar)[11].

Note that, per [23], lots of work has been done on the BCJ duality and double copy. Yet, as pointed out explicitly in [18]: *"However, the microscopic origin of these relations, either in field theory or string theory, is still unknown"*. We will remediate this in the following sections, building on [10].

7. Here we go again, the Kaluza Klein (KK) and Spacetime Matter Induction connection

A first way is to look at the double copy behavior is to see it as implying that Yang Mills scattering is in fact gravity scattering in another spacetime (of same dimension). That is no different from the Kaluza Klein (KK) theory [26]. With the correct extra dimensions, one can recover Yang Mills or the Standard Model [27,28,31]. In constrained KK, where these extra dimensions are compactified, dilatons, or massless scalars, automatically appear [29]. This is why it appears here this way. A cynical reader may therefore also infer that this again shows that such (constrained) KK with compactified dimensions are therefore not physical, in a GR-based universe, as they modify gravity in 4D spacetime: they are at best effective theory. It recovers results we obtained separately about superstrings, supergravity and M-theory [1,12,31,32,53,54,56].

In [25,30,31], we introduced a multi-fold reasoning to use unconstrained KK, i.e. the space time matter induction and scattering, to derive the SM particles from a 7D spacetime embedding the multi-fold spacetime. They are 7D geometrical solution (solitons) of 7D GR, and associated scattering effects at the entry and exit of multi-folds (and mappings) [16,30]. Here, Yang Mills / SM works with a 7D (= 4D + 4D -1D if time is a shared dimension along the

[8] We will mostly speak of Yang Mills from now on.
[9] In general, colors.
[10] This is very important. The Jacobi relationship exposes the S, T and U dualities / symmetries of the Feynman scattering diagrams. This must be exposed (as the BCJ duality) to make it work. It is key to our reasoning too.
[11] These extra particles are due to differences in degrees of freedom between the theories. It is difficult to justify them microscopically. We may consider they are not present in some analyses. In our case we will see that it actually does not interfere with our conclusions. In fact at energies above the multi-fold gravity electroweak symmetry breaking, the particles involved are dominantly massless, ensuring that gravity is GR-based at high energy and low enough spatial scales. These other particles do not matter when gravity is influential enough. At very large spatial scales, effects are classical, and again these particles do not matter, as the duality does not play any macroscopic relevant role. It is further discussed in section 11.

lines of [31]) embedding space. And as already mentioned at energies above the multi-fold gravity electroweak symmetry breaking, particles are random walk pattern also resulting from induction and scattering.

As KK constrained or unconstrained relies on GR in spaces with extra dimensions, it is clear that the Hilbert Einstein actions implies the Yang Mills action (with freedom to select colors[12] and couplings). And all are a priori suitable mechanisms to derive the Standard Model. In [32], we had already shown differently that Yang Mills is contained in Hilbert Einstein, and may have unnecessarily excited everybody as a divine sign when encountered within the different superstring actions. Here, we explicitly see that, contrary to what may be expected, its appearance in superstrings was not just because of the conformance symmetry of strings, or the conformance condition (see [32] and references therein), but also because it is fundamentally implied by the Hilbert Einstein action.

In [41,*89,90,94,100*], we complementarity show, and explain, how multi-folds, and associated non-commutativity of spacetime recovers also the SM, or rather SM_G, particles.

8. Double copy compatibility with multi-fold gravity

[10] addresses that issue. It provides a multi-fold argument: the multi-fold mechanisms [1,17] associated to entangled virtual pairs of particles and anti-particles emitted by a source, implies involving the two particles, hence the double particle contributions. At the time, we were satisfied with just that result.

Let us go one level further with this analysis.

According to figure 4, multi-fold gravity scattering amplitude is indeed the square of the kinematic scattering amplitude of the corresponding Yang Mills particle, at least when they are all massless, i.e. above the energy levels of the multi-fold gravity electroweak symmetry breaking energy scales [38].

In [10], we thought this was trivial, so we just stated in words. But figure 4 has many more consequences. We should have drawn it in [10], and continued the analysis.

[12] That is in fact directly related to the dimension of the KK expanded or embedded space. QCD, with its colors, comes from our 4D spacetime. See [25,30,31,33,*94*]. The amount of generations is dictated by gravity per [1,63].

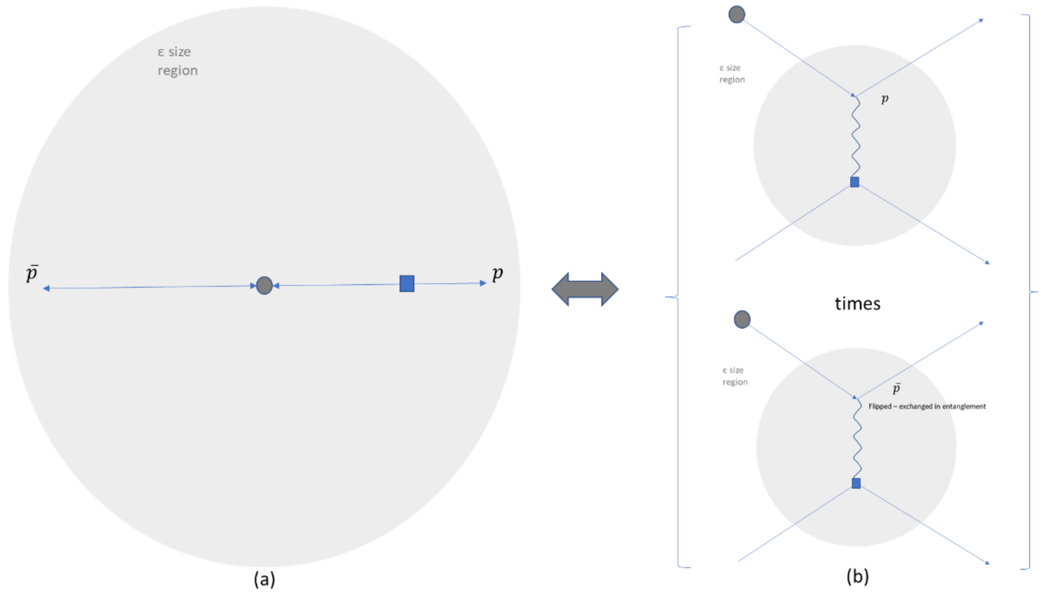

Figure 4: (a) sketches the pair of entangled virtual particle and anti-particle that are emitted by the source (grey) as encountered on the mapping support (blue square) [1]. (b) shows that within the scattering ε region, the interaction can be with the virtual particle, or its entangled anti-particle moving in the opposite direction form (a). It results that multi-fold gravity scattering amplitude is indeed the square of the kinematic scattering amplitude of the corresponding SM particle. It is a product because uncertainty and "switch" are therefore rending kinematics independent of each other's, within the uncertainty region. Per [1,10,36], the model and duality also applies to multi-fold entanglement between real particles.

9. Microscopic Interpretation of the Double Copy behavior

As mentioned earlier, there are still no known conventional, i.e., non multi-fold-based, microscopic explanation to the double copy behavior.

In a multi-fold universe, [10] and figure 4, provide such an explanation: the multi-fold mechanisms, and the quantum uncertainty or the different quantum paths in path integrals, as captured in Feynman diagrams, imply that scattering amplitude only consider the positions and momentums of the entangled pairs of virtual particles and anti-particles; which are interchangeable, and as such independently affected by the uncertainties, hence the scattering amplitudes are the square of the kinematics scattering amplitudes and does not involve the contributions of any other interactions.

The double copy duality exists in a non-perturbative way [10,*112*]. It means that the relationship with multi-folds holds for the non-perturbative Yang Mills theory, as it makes sense per the considerations presented above.

10. Multi-fold mechanisms and Multi-fold gravity emergence is contained in Yang Mills scattering amplitude

It is also clear that sections 8 and 9 amount to encountering the multi-fold mechanisms, and the multi-fold gravity in Yang Mills, and the SM, which is a Yang Mills model. Figure 4 implies that gravity results from the multi-fold mechanisms appearing between pairs of entangled virtual particles and anti-particles from the SM[13]. With massless virtual particles, the emergent gravity is massless[1,34]. With massive particles, the emergent gravity is massive [1,34]. On the other hand, nothing restricts the double copy behavior of Yang Mills scattering and the Feynman diagrams, to virtual or real particles. Entangled particles create gravity fluctuations [1,36].

Therefore, these mechanisms imply the E/G conjecture [13,35], gravity fluctuations between entangled systems [1,36], and the SM_G, the standard model with non-negligible gravity effects at the scales of the SM [1,14-16].

In particular, figure 4 indicates the suitability of the axiom of energy sources being surrounded by entangled pairs of virtual particles and anti-particles, subject to the multi-fold mechanisms [1,10], instead of dedicating say entangled pairs of gravitons to do the job. [1,10,11,37], and section 5, had already reached the same conclusion. As a result massive gravity contributions are also expected.

It is obviously a key result that complements [1,5-7], where we encounter multi-folds at the core of GR.

11. Pure Einstein Gravity and Masslessness

As mentioned in section 6, the double copy brings sometimes extra degrees of freedom, captured in massless scalars like dilatons, and antisymmetric 2-forms [18,20]. It may not be an issue.

If we consider the period, or scales, with energy above the Multi-fold (gravity) electroweak symmetry breaking [38], then all particles are massless. As discussed in [18], in such a case, the double copy leads to pure Einstein gravity without additional scalars. At these early times, i.e., high energy or low spatial scales, we encounter the multi-fold mechanisms, and the SM based on the multi-fold gravity of [1], recovering the multi-folds from Yang-Mills theory above the multi-fold gravity electroweak symmetry breaking energy scale. A nice complement to [5-7] that does so at Planck scales.

Above the electroweak spatial scale, or after Multi-fold (gravity) electroweak symmetry breaking, the scalars could be interpretated as shadow effects of the massless Higgs boson random walk encountered at very small scales, and behind the in multi-fold spacetime reconstruction [1,12,39-42,*89-91*], or as goldstone bosons resulting from the symmetry breaking [*115*]. The latter may be explored in a future paper. The massless Higgs boson explains inflation effects and spacetime expansion[1,6] at spatial scales smaller than the electroweak symmetry breaking and imply the fact that gravity is GR-based (2D GR), but we need to also remember that at small scales space time is random, discrete and non-commutative [1,12,42,*89-92-100*].

As such, the massless scalars can be considered to be part of the model of the Higgs field during inflation, slow roll, multi-fold gravity electroweak symmetry breaking, including condensation into massive particles [4,12,38,39,41,42, *89-92-100*]. This is not a unique idea. It has been explored by other with different variations of Yang Mills and Gravity. Consider for example [29,44], respectively for KK or different variations of double copy with supergravity and super Yang Mills and different symmetry breaking schemes.

Also, below the spatial scale, and/or above the energy scale of the multi-fold gravity electroweak symmetry breaking, the kinematic-only model is consistent with the Ultimate Unification (UU), when it appears, as proposed in [1,43,*89-92,103*]. In fact, the democratic interaction mechanisms for all the particles could be explained by the

[13] Other explanations may exist, but none have been proposed so far [18]. So, in the absence of alternative, we argue that at least the compatibility, and match of behavior, is remarkable. Coupled with [5-7], it looks like it could close the deal in favor of the multi-fold explanation.

double copy becoming the driver of all scattering (no more color/charge scattering) which could result from a too high density overlap of the microscopic Higgs Qballs condensate such that colors can no more be distinguished and only conserved, per charge conservation, while at the same time particles become entangled and so scattering move from colored scattering to gravity scattering [*90,91*].

Alternatively, one may just ignore them, these extra massless scalars, as irrelevant to the tree level diagrams as proposed in [20]. That proposal may be what should then be relied on in a universe that is not multi-fold.

12. Conclusions

The paper reached very important result. First we showed why perturbative classical field wave radiation in scattering is fully described by up to 5-point tree-level (0-loop) Feynman diagrams of the scattering. The approach holds for QFT, and we saw the analogous for multi-fold gravity, for which the result also holds. However the derivation of the result indicated fundamental differences between QFTs like Yang Mills and Electromagnetism that are renormalizable and quantum QFT/EFT gravity which isn't. The analyses of the Feynman diagrams may also have broader interest for QFT. In particular, it allows us to reiterate our view that QFTs should consider (real and virtual) particle-based models, instead of considering them as unphysical, and consider entanglement as modeled among real or virtual particles.

Returning to the double copy behavior of Yang Mills scattering, we expanded on our past results of compatibility with multi-fold theory, related it to KK theories, and used it to derive, that not only Yang Mills is included in the Hilbert Einstein action, but also that multi-fold mechanisms, multi-fold gravity, and the E/G conjecture are actually contained in the Yang Mills theory. It is another indication that our real universe may be multi-fold, if well described by Yang Mills theory.

As a result, multi-fold gravity based on the emission of entangled pairs of virtual SM particles, and anti-particles and massive gravity contributions, seem more plausible than gravitons, that we already suspected to be unphysical and at best only perturbative quasi particles.

Most of these results, following [5-7] and [1,4-7,11-16,24,25,30-43,45-*111,113*], seem also good candidate to sketch what happens in our real universe.

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