Multi-folds, Non-Commutative Spacetime, Spin, and All That

Stephane H. Maes[1]

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Abstract:

In the original multi-fold paper, we provided a review of lesser known details on spin, leading to the insights that spin is not a relativistic concept, even if naturally best modeled with relativity and Poincaré symmetries, and that it could also be seen as a rotation of energy, plausibly associated to rotations of the wave function. A toy multi-fold mechanism for these rotations was suggested, as food for thoughts. The multi-fold W-type hypothesis can be added to the picture as an additional source for angular momentum to potentially explains why the rotation f the wave function carries angular momentum..

In the present paper, we revisit these results and concepts. Then we discuss additional little known insights about spin. In particular, how fermions imply non-commutative spacetime, and conversely; while bosons do not. Then, we show that any theory with fermions, e.g., quantum theory, implies a non-commutative spacetime in a range of small spatial scales.

Then we discuss how one can see that quantum Physics, considered fermionic, and gravity or general relativity, considered bosonic, conventionally and in multi-fold universes. In particular we link spacetime non-commutativity, zitterbewegung with the notion of fermions and bosons, and the spin statistic theorem; providing a new derivation of the latter. Accordingly, massive fermions have sizes that feels the spacetime non-commutativity which results into zitterbewegung at energies where they are massive and transversal momentum uncertainties when massless. On the other hand, bosons, massive or massless, have sizes that hide the spacetime non-commutative effects. In multi-fold universe, spacetime is non-commutative in a spatial scale range, and this interpretation directly aligns with the toy multi-fold spin model.

The paper introduces new, but equivalent definitions for fermions and bosons, and a versions of the Weinberg-Witten theorem, that now more explicitly hints at unphysicality of gravitons.

1. Introduction

In a multi-fold universe [1,8-10,22], gravity emerges from entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles [1,24,25], whether they be real or virtual. Long range, massless gravity results from entanglement of massless virtual particles [1,26]. Entanglement of massive virtual particles leads to massive gravity contributions at very small scales [1,27]. It is at the base of the E/G Conjecture [24], and the main characteristics of the multi-fold theory [22]. Multi-folds mechanisms also result in a spacetime that is discrete, with a random walk fractal structure and non-commutative geometry [65], in a range of

[1] shmaes.physics@gmail.com

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spatial scales, that is Lorentz invariant and where spacetime nodes and particles can be modeled with microscopic black holes [1,4]. All these recover General Relativity (GR) at large scales, and semi-classical model remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model (SM) resulting into what we define as SM_G: the SM with gravity effects non-negligible at its scales. It can contribute to resolving several open issues with the Standard Model, and the standard cosmological model, without new Physics other than gravity [1,4-71,81,94,101,103,116-*189*]. These considerations hint at an even stronger relationship between gravity and the Standard Model, as finally shown in [23].

In this paper, references in italic were added on February 11, 2024.

Among the multi-fold SM_G discoveries, the apparition of an-always in-flight, and hence non-interacting, right-handed neutrinos, coupled to the Higgs boson, generated by chirality flips by gravity of the massless Weyl fermions, induced by 7D space time matter induction and scattering models, and hidden behind the Higgs boson or field at the entry points and exit points of the multi-folds. Massless Higgs bosons can be modeled as minimal microscopic black holes mark concretized spacetime locations. . They can condensate into Dirac Kerr-Newman soliton Qballs to produce massive and charged particles below the energy scales of the multi-fold electroweak symmetry breaking [1,4], and as random walk patterns above these scales [1,29,36,37] thereby providing a microscopic explanation for a the multi-fold kinematics and dynamics and associated unconstrained Kaluza Klein mechanisms [23,33,34,52,63,64,*153*], Higgs driven inflation [1,27], the electroweak symmetry breaking, the Higgs mechanism, the mass acquisition [*179*], and the chirality of fermions (and spacetime); all resulting from the multi-fold gravity electroweak symmetry breaking. The multi-fold theory has concrete implications on New Physics like supersymmetry, superstrings, M-theory and Loop Quantum Gravity (LQG) [1,8-21,66,130,*152,174*].

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 [1,52,134,144].

The paper starts by discussing the insights on spin encountered in [1], as well as the resulting toy model proposed to provide a microscopic interpretation.

Then we remember that multi-fold spacetime are non-commutative at interim small scales. Therefore we review some results linking non-commutative space and fields to spin. More precisely, we see that a non-commutative spacetime can induce fermions, and that, conversely, fermions imply a non-commutative spacetime [86], while remaining compatible with the Spin Statistics theorem [86,100]. This reasoning, and a result known through group theory so far [88], provides a new explanation for the spin statistics theorem, and the zitterbewegung of massive fermions. After all, the conventional derivations, depends on the Lorentz invariance and on the structure of the Lagrangian, or order of its field equations to model (scalars,) spinors and tensors [99,100,104,105], and resulting inconsistencies with the energy or the charge density of the system. [99] provides the axiomatic version.

With this knowledge, we now can propose a more detailed motivation for the Multi-fold spin microscopic interpretation of the toy model presented in [1], that aligns with the derivation of the spin statistics theorem, directly as the result of non-commutativity of spacetime, for Fermions; while it does not impact bosons. With this, virtual particles have different patterns of paths entering the multi-fold that make the wavefunction rotate different; and discretization of spacetime can be viewed as why or how spin is discretely quantized. Interestingly it also hints, again, that multi-folds can fill the gap between general relativity, a boson theory, and quantum physic, with its fermions; even if [6] actually shows that GR intrinsically contains the notion of non-commutative spacetime at small scales.

[2] Standing in for Quantum Physics in general.

With the multi-fold W-type hypothesis, we can also investigate an interpretation of the meaning of wavefunction rotation, and zitterbewegung of massive fermions: the multi-fold W-type hypothesis jumps across the wavefunction support domain can follow a pattern that is associated to an angular momentum. We also note that the explanation based on just zitterbewegung may not be sufficient as bosons and massless fermions do not present zitterbewegung [89,91].

At no point does the paper question, or diminish the well-established Poincaré Group representation theory. Instead the motivation is to seek a satisfactory microscopic interpretation for it other than just “internal space symmetries”. *Note added on February 11, 2024: Additional considerations on internal symmetries can be found at [184].*

2. Multi-folds and Spin - A thought from the past

Although widely accepted and validated as an essential quantum property of particles, individual and composite, spin, and its origin still remain to a large extent mysterious [72,73,79]. Attempts at explaining it microscopically today still lead to different models, or even rejecting the question as solved by group theory, i.e., symmetry considerations, and that’s it, see for example [80] [3]. In particular, it is common that spin be justified as a purely relativistic concept emerging from adding relativity to quantum mechanics to make it emerge from the Dirac equation, through the spinors. That explanation is not necessarily the full story. Yes, Dirac and Klein Gordon equations can be derived by imposing that Lagrangian behave well under Lorentz transformations (rotations and boost,) and constructing the group representations (Poincaré).

Yet, it has been shown that spin can be derived the same way from manipulating the Schrödinger’s equation to linearize it (just as Dirac equation linearizes the Klein Gordon equation) [74]: it appears that spin more fundamentally results from enforcing first order spatial derivative dependency, and fermions/spinors can also appear as representations of Galilean group transformations[4]. Later, we argue that we can interpret this first order dependency brings the sensitivity to the non-commutative spacetime, that bosons avoid.

It is not all, different analysis of relativistic quantum mechanics/QFT also lead to different views when trying to go beyond, i.e., more physical, the point of view that spin results from angular momentum conservation and representations of Lorentz transformations, and that this is all there is to know [80]. At best, it results in considering that spin is an internal or inherent (i.e., non-orbital and non-mechanical/kinetic) angular momentum.

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[3] We are fans of Peter Woit and his blog. However we disagree with his attack on [79]. Not that the work, on which [79] seems based, may warrant much considerations, but because we disagree that a group theory/symmetry answer or derivation fully justifies a physical effect. It only predicts the symmetries of the resulting effects, and, yes, sometimes this may be enough to derive its governing equation or action. Group theory is a <u>tool</u> to predict, derive or validate models or associated equations based on their predicted symmetry constraints. It rarely is the physical or microscopic interpretation itself. For some reasons [80] seems to have completely forgotten that. It is strange considering how Woit heroically took on the string theory community in the past, with not that different arguments. Power to those who are satisfied with just a mathematical explication of why it had to be so in terms of symmetries, vs. why it is so, i.e., what creates the right behavior and symmetries. We want to understand why it is so. So yes, there are no mathematical mystery behind the symmetry model and motivation for spin. Yet nobody seems to know exactly where it physically comes from; unless if satisfied with “it’s an internal spin/symmetry/notion”.

[4] And yes [80] is aware of this, although from a group point of view. It shows the correctness of the method, but again not the intuition or insight provided by [74].

It is widely accepted, and absolutely correct; yet it does not explain everything; it is just a phenomenological and mathematical explanation.

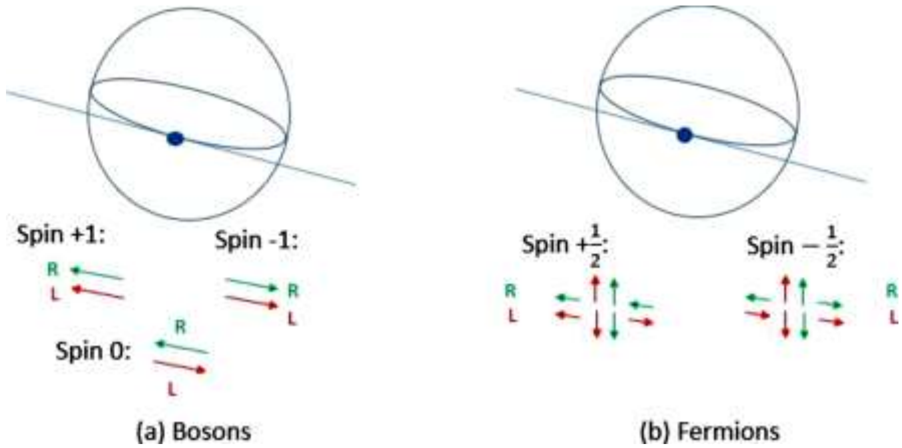

Figure 1: It illustrates possible patterns of distribution of how entangled virtual particles could enter paths in the activated folds to provide different spins (by rotating the spacetime around the folds). The virtual particles are dominated by virtual photons with two possible polarities (R and L). Entries can be along the grand circle along the direction of propagation of the virtual particles or orthogonal (to have independent contributions). This can be in any direction as virtual particles are emitted in an isotropic manner and the criteria for one pattern to another are not explained other than for symmetries of a) 360^o for bosons vs. b) 720^o for fermions, where entry patterns and polarizations of the photons have to be considered. The figure reproduced from [1]. Discreteness of spin comes from the construction/mechanism, with value conventionally deducted. Fermions differ from boson by mixing the directions (for fermions), which reduces the available spin, which can therefore only be half integer to satisfy angular momentum symmetries. As we will see the massive fermion case can be related to the conventional zitterbewegung and a multi-fold interpretation of the Compton wavelength region. Massless fermions and boson cases are motivated later in this paper.

Yet it has been shown that spin can be viewed as a circulation of energy or momentum in the wave function [75-78], i.e., a physical effect. Not much more than the wave function can rotate in a point particle world. Note that [78] presents compelling arguments that this point of view works in recovering properties of the electron spin. In our view, it means that everything may not be that fully understood.

A way to picture these results could be as the rotation of the wavefunction itself; but what if the wavefunction is unphysical as usually agreed? In a multi-fold universe, the folds surrounding a particle could be rotating spacetime locally. This is illustrated in figure 1, where we can see that different spins can be obtained with different distributions of entry to the multi-folds. If patterns are followed this way (or other variations), we could have a physical interpretation for the physical momentum or current mentioned above.

Interestingly, it allows us to treat spin as a different kind of rotation than the non-point particle while still having a physical meaning. The entry point behavior then may also relates closely to the torsion at entry [1], which also hints that, as mathematically known, torsion and spin relate and can couple or interact. Yes, the explanation is still more a handwaved curiosity, but it aims at emphasizing that this multi-fold spin model is not that implausible. More arguments will be added later.

Discreteness, or quantization, of the spin then comes from the constructed mechanisms ([1], and figure 1), and the fact that rotations are either clockwise or counterclockwise. For the rest the allowed value are then conventionally recovered as for example in [106]. Fermions would be characterized with multi-fold entries that can occur in orthogonal directions while bosons would only involve one direction. Interestingly, later in this paper, we will explain the reason for such a different behavior between bosons and fermions, and relate it directly to the zitterbewegung of massive fermions and non-commutativity of spacetime for all fermions.

Note also that if the source particle is massless and moves at c, we encounter only spin contributions aligned with its direction of propagation as discussed in [1,105,107] (See Wigner's little groups as in [108]): no longitudinal oscillation is allowed as it would have to be supra luminal at times. Entry in the multi-fold must be transversal. This is consistent with the spin of massless particles, and was not discussed in [1]. if the source is massive, and at rest, then the direction itself is probably set up by the first emitted pair of virtual particles, and therefore random until reset by other interactions.

3. Multi-fold non-commutative spacetime

Conventional physics consistently encounters the possibility that spacetime is non-commutative [1,6,68,109,*152*], and references therein. It seems a universal option for most consistent theories, although never really stated as an accepted fact by all.

In [1,6,68,81,*153*], we showed that multi-folds, and other reasonings with discrete spacetime, imply a non-commutative spacetime, as well as a non-commutative embedding 7D space [23,33,34,63,81], used for multi-fold space time matter induction and scattering, a kind of non-constrained, i.e. without dimension compactification, Kaluza Klein approach [23,33,34,52,63,64,*153*].

Interestingly, non-commutativity, via algebra doubling, allows derivation of the SM, including neutrino mixing; see [66,68,81-85] and references therein.

It is important to also realize that, throughout [1,68,81,*153*], we have seen non-commutativity of multi-fold spacetime as a property at interim scale between 2D discrete spacetime and 4D continuous spacetime. So we are not claiming that it is the feature to use in 2D spacetime at Planck scales, indeed there spatial non-commutativity is meaningless, nor at the scales say of the SM (e.g., at energy below the scales of the energy of the gravity electroweak symmetry breaking). Yet some effects may be reflected across scales, and one may have to always be careful to see if this needs to be taken into considerations. For examples, particles with sizes way smaller or larger than the range of scales where spacetime appears non-commutative do not require non-commutative theory.

For example, [81], reported on proposals made to detect violations of the Pauli exclusion principle, as a way to probe Planck scale gravity. It has been shown that in many cases the Spin Statistics theorem remains valid on a non-commutative spacetime [81,86]. In [1,101], we also encountered other plausible violations of C, P and T. [81,86,112] recovers consistent results.

Note added on February 11, 2024: [1,152] further discuss reasons why spacetime is non-commutative and why this actually contribute to our claim that supersymmetry is unphysical, i.e., it does not apply, in our real universe, and does not characterizes its Physics.

4. Fermions, bosons, Physics and non-commutative spacetime

4.1 Spacetime is bosonic and Quantum physics is fermionic

The mechanisms proposed in figure 1 reminds us early on of non-commutativity, in the sense that the cross product of vectors would give a new direction of entry for Fermions. We did not explore in [1], or in the following papers [68,81], a relationship between non-commutativity and fermions, but the existence of one would not be surprising considering that, as discussed in section 3, we contend that the SM is contained in a non-commutativity of spacetime (at a spatial scale range), and of the 7D embedding space.

It turns out that there is a whole philosophy behind this with, apparently attributed to E. Witten [110,111]: gravity and spacetime are have a bosonic spacetime underpinning, and quantum Physics, and matter, is fermionic or non-commutative. We refer to [111], for a detailed analysis and compilation of justification of such a point of view, and we certainly agree based on the following:

- Gravity and spacetime are Bosonic. Indeed:
  - Gravitons (concrete/physical, or mathematical concepts as we argued so far in the multi-fold theory [1,18,124,125,*176,177*]) are bosons, or closed bosonic strings
  - The multi-fold spacetime reconstruction models spacetime, and gravity, with 2D random walks of massless Higgs bosons: again bosons [1,16,27,32,62,81].
  - Per [23,29,33,34,52,63,64,81,*153,156*], the 3 other SM forces are modeled by bosons, and there are no other forces, till now [23,30,36,48-50].
  - As discussed in [1,16,23,29,36,70,81,103,*164*], the dimension reduction of gravity processes ends up with 2D processes in most theory with well-behaved UV regimes. These can be modeled also as CFTs, which modeled the 2D propagation / random walk of massless boson [1,71,81].
  - Classical physics only understands Boltzmann, or at best Bose Einstein statistics, where particles interchange do not change the sign of the overall wavefunction (field).
- On the other hand fermions are purely quantum entities and imply a non-commutative spacetime[110,111]:
  - Per the Dirac (or Schrödinger + Pauli) equations and notions of spinors that define massive fermions. They lead to the introduction of a zitterbewegung, that consists of an oscillation as fast as c around (and hence transversal to) the direction of movement [89]. The region where it occurs correspond to a ball of radius equal to the Compton wavelength. It is usually understood as resulting from interferences between positive and negative energy wave components. As a result, the momentum in the direction of motion is uncertain due to the orthogonal momentum and position: spacetime is now non-commutative:
    $$[x,y] \propto (\lambda_{Compt})^2 \qquad (1)$$
    Where x is the direction of motion and y and orthogonal one [111]. [88] provides a rigorous computation of [x,y], if the position of an electron is covariant, purely based on symmetry / group considerations. Note that as J-P. Antoine was one of my PhD. Advisors, I can only recommend this book.
    We discuss more about zitterbewegung below, and how it relates to massless fermions, bosons and spacetime non-commutativity.
  - Conversely, [111,88] shows that a non-commutative spacetime with the generalized uncertainty principle, as discussed in [1,6,13,17,68,129,*152*] and references therein, recovers the $\hbar/2$ spin of fermion.
  - Per [23,33,34,52,63,64,66,68,81-85,*153,156*], the complete spectra and properties of the other particles, the fermions of the SM, are the result of a combination of space time matter induction, and of non-commutative doubled algebra; the latter being needed predict all their properties, making non-commutative key to the SM fermions.

- See the Fermi-Dirac statistics and the Spin Statistics theorem [99,100,104,105]. It is preserved in non-commutative spacetime [81,86]. In fact, we would argue that non-commutativity introduces notions of rotations, key to spin, before the spacetime orientation of multi-fold gravity electroweak symmetry breaking [23,29,35,36]. These are key to define chiral fermions or introduce spin ½ symmetries (where one need to rotate 720 to come back the starting point).

4.2 Re-deriving the Spin Statistic Theorem

We can explain the spin statistics theorem as follows. Consider a particles with fast additional transversal momentum in additional to conventional quantum uncertainties, around an average momentum in the direction of motion. If two such particles (a and b) exists, the probability that they both, are in the same state with one at position 1 and the other at position 2, or conversely → 0. That is true even with the associated uncertainties. To understand this consider the distribution of all possible transversal momentum with velocities between 0 and *c*.

As a result:

$\Psi(x_a^\mu,p_b^\nu,x_a^\sigma,p_b^\tau) + \Psi(x_b^\mu,p_b^\nu,x_a^\sigma,p_a^\tau) \rightarrow 0$ for any combination of acceptable p_a^ν and p_b^τ. (2)

p_n^ν includes the momentum of particle n, with a longitudinal component and a transversal component governed by the Heisenberg uncertainty principle as well as an additional orthogonal component (e.g., due to zitterbewegung or spacetime confusion due to spacetime non-commutativity). Because of the order of non-enumerability of the combinations with the latter, there are no chance to flip a pair of particle from one state with the uncertainties and additional transversal uncertainties. And, this must be for any Ψ associated to fermions, i.e., particles with such transverse oscillations, while the integral of all the (1) over all possible p_a^ν and p_b^τ, must still be 1. Without the latter term, the order of non-enumerability is lower and modellable with distributions.

In quantum mechanics or QFT. The wave function of the system is therefore antisymmetric under permutation of the particles: we have fermions. This holds for massless or massive fermions.

Therefore, per (1), bosons cannot have such transversal oscillations, or their wave function would be antisymmetric and they would be fermions.

This is a totally new way to derive the spin statistic theorem, and our way to recover [88,111]. It is on solid footing. Note that the deduction can also be based on just accepting [88,111].

In the next section we will relate this model, denoted as (**), to the zitterbewegung of massive fermions, the need of non-commutative spacetime for massless fermions and the size of fermions and bosons. An important point is that we cannot just attribute the transverse momentum variations on the usual Heisenberg uncertainty as otherwise (massive) bosons would also have zitterbewegung (see next section), and the reasoning behind (1) would require the momentum to oscillate in the direction of propagation. Fully recovering the link to spacetime non-commutativity requires section 5. For now, believe us that it is essential, or rely on [88,111] where massive fermions imply non-commutative spacetime, and non-commutative spacetime implies ħ/2 particles, i.e., Fermions

4.3 Gravity vs. Quantum Physics

Therefore, it is tempting, to argue that it is why GR and Quantum Physics are incompatible, and why supersymmetry is seen by as the savior, by putting bosons and fermions on equal footing, and often requiring same amount of fermionic and bosonic degrees of freedom / species [87,*152*]. Even if in our view, supersymmetry seems by now unphysical because 1) supersymmetry is not compatible with (asymptotic) (4D) de Sitter spacetime 2) supersymmetry is not compatible, with more dimensions and gravity asymptotic safety, something that we have consistently encountered as applying to multi-fold universe and our real universe [1,12-20]. *Note added on February 11, 2024: [152] provides an extensive analysis and proof that there is no supersymmetry in an accelerating expanding universe multi-fold universes, or like our real universe as [152] also discusses and shows that the cosmological constant must be strictly positive, even if small.*

Yet, the above shows us that any theory that hopes to reconcile (quantum) gravity and quantum Physics must be able to encounter fermionic for (conventional or non-bosonic) matter, and bosonic behaviors in spacetime. The former implies a non-commutative spacetime behavior. Let us try to explain and reconcile the latter.

5. Zitterbewegung and non-commutativity of spacetime – Putting it all together

To that effect, let us revisit [88], which provides an interesting analysis. It shows that if the position of fermions is covariant, something expected, then spacetime must be non-commutative. That is quite a result, even if probably not that well known.

[111] popularizes this result, and provides an easier physical interpretation based on Dirac's derivation of its famous equation, at least for a spacetime with minimum length, as is a multi-fold discrete spacetime. It is the result of the zitterbewegung of relativistic massive electrons [89,90] and the resulting fuzziness amounts to non-commutativity of its position. Our first fermion sub-bullet in section 4, gives the microscopic physical interpretation. It is a fundamental property of the Dirac equation [90]. As [90] notes, it is widely admitted that the zitterbewegung of the electron explains its spin and magnetic momentum, and as summarized in [88], this is results into the apparent larger wavefunction, related also to Heisenberg uncertainties, of the electron and its Compton wavelength. Again it is probably not as well known that in such a formalism, the electron position is non-commutative. The same can be extended to any fermion, as they all come from the Dirac equation.

However, massless fermions, e.g., above the multi-fold gravity electroweak symmetry breaking, also carry half integer spins. Yet no zitterbewegung exists (set m=0 to the oscillation frequency and model say in [89,90]) [102]). Indeed, massless particles move at *c*, so that there is no room any more for transversal oscillations. It shows that the zitterbewegung is, at the minimum, not sufficient to microscopically explain the spin.

We argue that in the limit where m -> 0, non-commutativity replaces zitterbewegung, or said differently, transversal momentum and position uncertainties still takes place in a non-commutative spacetime, i.e., at high enough energies, where the confusion (particle propagates at *c* in the x directions, but because of non-commutativity of spacetime of that is spent in the y direction, even if physics sees it as if moving at *c* in x; it is how non-commutativity beats the limitation of (**) based on just Heisenberg uncertainties mentioned earlier), and uncertainty between spatial directions plays the same role as zitterbewegung in (**). In the absence of zitterbewegung, the uncertainty is less an oscillation (more random), hence the absence of an observable zitterbewegung. This provides another explanation of why spacetime must be non-commutative for fermions to exist (as proven in [88,111]), especially as they acquire mass as described in [35,36,29]. It also shows why, and confirms that neutrinos are not massless at energy scales below the electroweak symmetry breaking, if one assumes that at such scales spacetime does not appear non-commutative, or that such effect becomes negligible. They are also no Majorana fermions, at such scales, but only Dirac fermions with oscillations of the latter explained by their Weyl fermion components per Penrose's analysis of Weyl fermion oscillations as in [113].

Despite the clever proposal of de Broglie [91,92], we note also that bosons (massless or massive) have no zitterbewegung [93], which is demanded by (**), and therefore no effect from a non-commutative spacetime à la (**), aka [88,111]. That is why it is purely a fermionic concept. By definition, bosons must not have their motion remaining affected by the non-commutativity of spacetime.

Furthermore, [88,111] shows that starting from non-commutativity of spacetime, implies ± 1/2 ħ angular momentum; which by the way may also provide a new explanation for why no 3/2 ħ spin elementary particle exists: it is not encountered by their derivation, and aligns with the Weinberg-Witten theorem [114]. Note that is different from composite, where it may exist by combinations of legit angular momenta, or quasi-particles, again within the confine of [113]. As explained in [113], the graviton avoid the theorem in GR (at the cost of raw renormalizability), as do supersymmetries in higher dimensions to allow say 3/2 ħ *(Note added on February 11, 2024: But supersymmetry is unphysical per [152] and reference, and so that loophole disappears)*.

At this stage, an important conclusion is that any quantum theory or theory involving fermions, as encountered in our real universe, must support zitterbewegung for the massive fermions, to physically explain where their antisymmetric behavior under exchange of particles, i.e., Pauli exclusion principle. In turn, this requires that in order to be quantum or support Fermion, a theory must be associated to an orthogonal momentum or position uncertainty that implies zitterbewegung when massive, but requires the need of non-commutative spacetime at some scales where the fermions are massless. *Note added on February 11, 2024: Per [152], it also means that fermion compatible / quantum theories can't be physical and supersymmetric, because non-commutativity is required at massless and massive scales, i.e., below and above the energy scales of the electroweak symmetry breaking, and it "kills" supersymmetry in a universe with positive dark energy effects, which [152] shows must always be the case..*

A lesson of the discussion above is also that bosons have wave functions of sizes, e.g., massless Higgs bosons and photons [1,4], that is either smaller than the scales at which the spacetime is dominantly non-commutative (e.g. above 2D spatial scales, which is universally encountered [70 and where non-commutativity of spacetime is meaningless, and below some higher spatial scale per [1,68,*152*]), or larger than non-commutativity scales (e.g. massive bosons, such scales exists as spacetime becomes semi-classical [1,68,*152]*). This way they are not sensitive to the associated transversal uncertainties. On the other hand, fermions, at least massless, have sizes of the scale where spacetime non-commutative effects matters. Massive ones may be larger if they get their zitterbewegung from the uncertainty felt by their massless shell.

Referring to section 2, the distinction between bosons and fermions (massless or massive), can be understood also as coming from the possibility to express the wavefunction equation of fermions with a linear dependence in the spatial derivative, as mentioned in section 2 [1,74]. The second order derivative encountered for bosons implies smaller wavefunction support domain (e.g., for massless for sure) due to the resulting higher spatial frequency content, or larger domains (due to the square of the wavefunction norm appearing in equation like Klein Gordon) than fermions whose equations have an intermediate spatial frequency content (first spatial derivative, no wave function term if massless). This is an interesting physical interpretation of why [74] works.

Therefore, a new definition for fermions is a particle with additional transversal momentum uncertainties beyond the Heisenberg uncertainty principle. Bosons on the other hand are particles which strictly respect the Heisenberg uncertainties bound.

6. Multi-fold theory, a non-supersymmetric bridge between GR/quantum gravity and Quantum Physics

The invocation of Compton wavelength and wider than point like structure in the earlier discussion is consistent with our model of particles as microscopic black hole that emulate 7D induced geometric solitons as massless Higgs patterns, at energies above the scales of the multi-fold gravity electroweak symmetry breaking, and as superconducting Qballs of Higgs condensates below [1,4,29,33,34,36,37,63,81]. It is interesting that [91] models of the electron zitterbewegung is also related to the Higgs field, something that the multi-fold particle can relate to [4,35]. And even with the challenges of the photon model [91,92], the Higgs structure aligns also. The Higgs provides the pattern or condensate giving mass to the particles. The microscopic black holes rotate as a result of the multi-fold mechanisms, and jump according to the multi-fold W-type hypothesis within the region of the Compton wavelength, which practically reflects the result of the wavefunction rotation and produces an angular momentum; otherwise, the rotation of a quantum wavefunction would be unphysical in conventional quantum physics.

As discussed in section 3, a multi-fold universe has a non-commutative spacetime. It is in fact appearing at a scale where fermions become/are meaningful, as explained by figure 1 in [81]. At smaller scale it stops being non-commutative, no matter what, because spacetime and gravity becomes 2D [1,6,aaaaa16,70,81,103,*170*]. At larger scales, we recover semi classical and classical spacetime, and therefore non-commutativity is no more apparent.

With that in mind, it seems appropriate to repeat our claim from [1,6,7] that the multi-fold theory seems to combine suitably quantum theory and GR: they are not incompatible theories, and by this we do not just mean something like [94,*157,162,173,186*].

7. The multi-fold spin model and non-commutative multi-fold spacetime

Interestingly, and as hinted at the beginning of section 1, figure 1 can now be explained with simple geometric hand waving.

Considering figure 1, a fermion, initially massless will move at *c*. Let us only consider transversal moves (vertical in that picture) with respect to figure 2 in [1], due to spacetime noncommutativity. The direction of x now appears as y, and preferred entry in the muti-folds (although a different fold in practice), when entering the multi-folds, emitted virtual particles can be seen either as coming from the fermion propagating along the x axis of propagation, then perpendicular to the x axis.

With massive particles, the same effect occurs due to the zitterbewegung traversal oscillations.

Even if we are in a spacetime fully non-commutative, i.e., no just within the support domain of a fermions, but at smaller or larger scales, the pattern of figure 1(a) also does not encounter the non-commutative effects, and spin is always integer.

It is also interesting to see that the toy multi-fold spin model recovers its version of the Weinberg-Witten theorem [114]: 3/2 $\hbar$ and above fermionic spins are unnatural with the explanation of figure 1(b) (Why would there be further ratios between the different directions), or 2 $\hbar$ and above bosonic are unnatural with the explanation of figure 1(a), for the same reasons. With this analysis, we see more hints that gravitons are unphysical, as hinted in previous papers [1,124,125], and in several other papers compiled in [8].

8. Wavefunction rotation

When, and if, figure 1 applies, one could interpret that the entry into multi-folds may have the following effects (one implying the other, with no assumption of which is the cause and which is the effect):

- (i) The entries contribute angular momentum to the microscopic black hole à la [1,4,29,36,37].
- (ii) The entries, or rotation of the microscopic black holes, rotate the wavefunction of the particle.
- (iii) Multi-fold W-type hypothesis jumps are biased to impart an angular momentum to the region occupied by the particle, which is modeled by a rotation of the wave function

We expect a combination of all this.

Note that (iii) is consistent with [78,95-98], while not requiring that the wavefunction be requiring to be physical or beable. Fundamentally, we added to this not just zitterbewegung, or non-commutative uncertainties, but also, or maybe rather, multi-fold W-type hypothesis jumps, following a rotating pattern. That model also works to explain boson behaviors.

Both fermions and bosons have ultimately rotations within the Compton wavelength region. So shouldn't we also encounter a non-commutative effect for bosons as in the first fermion sub bullet in section 4? The answer is no. The wavefunction / multifold rotation in bosons can result from rotation of the whole Qball [4] to provide spin without the zitterbewegung oscillations, while fermions combine orthogonal (zitterbewegung / non-commutative) oscillations. As discussed in section 4, (**) links this directly to Pauli's exclusion principle. The zitterbewegung and non-commutativity at the fermion scales introduces orthogonal contributions that reduce the spin to ½ ħ (not higher odd multipliers of half integers).

9. Gravitons?

The reasoning above is compatible with a figure 1(a) leading to a spin 2, which leads to non-renormalizability, although harder to justify why it would be 2 instead of 1. We argue that it is another hint that gravitons are not physical as discussed in [1,124,125], and in several other papers compiled in [8].

10. Conclusions

This paper progresses a toy multi-fold microscopic explanation for the spin of particles, as the result of how virtual particles emitted by the particle enter the multi-fold and confer rotation as a result to the microscopic black hole or the wavefunction of the particle. In the latter case, this is also understood as implying that angular momentum builds from the zitterbewegung, spacetime non-commutativity and multi-fold W-type hypothesis jumps that provide an angular momentum to the region occupied by the particle.

Relying on the not that well known works of others, we reviewed how a spacetime non-commutative property, at certain scales [1,70,*152*], is essential to unify gravity / GR / spacetime and Quantum Physics, and how in fact it is required by fermions, the essence of quantum physics, but not by bosons, which typically model gravity and spacetime as well as classical Physics. We provided references and our own justification for such statements. In fact we showed that any theory with fermions requires a non-commutative spacetime as some related spatial scale. One would expect that includes any quantum theory. *Note added on February 11, 2014: This reinforces arguments presented [152] that Physics in an universe in accelerated expansion can never be supersymmetric, and that supersymmetry is unphysical, a result already encountered many times [1,12-20].*

A new, definition of bosons and fermions has been proposed, equivalent to the integer vs. half integer ħ spin, and their supported permutation statistics

These results do not require a multi-fold universe, and, in fact, many are conventional. We noted also that we provide a different original way to derive the spin statistics theorem. This may not seem ground shattering, we think that it complements and addresses Feynman's statement that the lack of intuitive motivation for proofs of the theorem, something we discussed earlier, "probably means that we do not have a complete understanding of the fundamental principle involved" [115]. We would like to think that our derivation contributes to a better / new understanding.

In that context, we saw that the zitterbewegung explanation for spin may not be sufficient, as there is no zitterbewegung for bosons or massless fermions, even if they carry fields that could fill the role. We provided an extended explanation relying on non-commutativity of spacetime as predicted by the multi-fold theory, and many other gravity theories. The presence versus the absence of transversal uncertainty, for fermion vs. bosons due to the involved scales works, and it is then aligned with Galilean derivation of spin, the multi-fold and particles as Qballs and the multi-fold spin pictures to distinguish fermion from boson behaviors. With it, it is microscopically understandable why no need for non-commutativity or no zitterbewegung for bosons, and why no cases of figure 1(b) for them.

The fact that the multi-fold theory provides explicitly a non-commutative spacetime at small but large enough scales, coinciding with the fermion patterns, and the fact that multi-folds can now link a microscopic explanation of spin to non-commutativity, is an encouraging consistency sign on our road to show how gravity and quantum physics relate, epitomized in our view by the E/G conjecture [1,22,24,*186*].

In a multi-fold model, we also justified the discrete nature of spin, based on the construction of the multi-fold spin model. We also encountered a variation of the Weinberg-Witten theorem, that more explicitly support the unphysicality of gravitons, without the loopholes of the theorem so far for GR [114].

Overall, we have progressed a lot the toy model of [1], with now an understanding on how the proposed entry pattern could exist, i.e., directly linked to non-commutativity of the position of fermions, as well as what rotation of the wave function may mean vs. zitterbewegung (periodic oscillation) or transversal uncertainty (massless case due to non-commutative spacetime) . The latter is due to the progress we made in multi-fold theory since [1], as tracked in [8,9,10,22].

Having encountered multi-folds at Planck scales in GR-based gravity [6], indicated that our real universe may be multi-fold. It has been further reinforced with results like [1,5,6,7,52] and the possible resolution of so many problems with SM and the standard cosmological model as discussed in [1,4-71,81,94,101,103,116-*189*].

The fact that non-commutative spacetime can support a spin Statistics theorem is essential. Otherwise, observation of the Pauli exclusion principle would be inconsistent with the need for fermions to encounter a non-commutative spacetime. But we have gone beyond and confirmed that (spatial) non-commutativity of spacetime is required on the support domain of the wavefunction of fermions, and that it and the zitterbewegung differences between bosons and fermions are enough to recover the Pauli exclusion principle and spin statistics theorem and the multi-fold and Qball rotations differences in the multi-fold spin model.

These statements confirm that at some interim scale (that statement is spatially meaningless in 2D spacetime), spacetime is noncommutative, for any theory with fermions, e.g., quantum theories. *Note added on February 11, 2024: this is further confirmed in [152].*

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