The W-type Multi-Fold Hypothesis and The Quantum Physics Interpretation of Wave Functions and QFT

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Abstract:

In a multi-fold universe, gravity emerges from Entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles that they be real or virtual. Long range, massless gravity results from entanglement of massless virtual particles. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales. Multi-folds mechanisms also result into a spacetime that is discrete, with a random walk fractal structure and non-commutative geometry that is Lorentz invariant and where spacetime nodes and particles can be modeled with microscopic black holes. All these recover General relativity at large scales and semi-classical model remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model. This can contribute to resolving several open issues with the Standard Model (SM) without new Physics other than gravity. These considerations hints at a even stronger relationship between gravity and the Standard Model.

The E/G duality, between entanglement and gravity, opens the door to postulate additional gravity-like effects and multi-fold mechanisms among spacetime points covered by a quantum wave functions or by Quantum Fields. These are plausible by-products of the multi-fold mechanisms, not necessarily mandated, or derived by our work so far, captured in an hypothetical new class of multi-fold universe denoted as W-type. It is the W-type hypothesis. In a W-type of multi-fold universe, we argue that we can explain the Born rule (on a discrete spacetime) without discussing measurements, or instantaneous wave function collapses as well as address the measurements problem, Wigner's friend paradoxes, and the classical aspects of macroscopic Physics vs. the quantum Physics at microscopic level. It amounts to positioning a new candidate for interpretation of Quantum Physics, while still remaining compatible with existing interpretations (unfortunately as it does not exclude any).

The W-type hypothesis leads also to a better understanding of the irreversibility of Physics, confirms it and indicate that W-Type multi-fold models, including the Multi-fold reconstruction, seem candidates to a more fundamental theory from which Quantum Physics emerges. It motivates also the duality between Entropy and Physical Action even for a single particle. Also, it reminds of the ergodic hypothesis of Boltzmann.

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1. Introduction

The 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 explaining other Standard Model mysteries without requiring New Physics beyond the Standard Model other than the addition of gravity to the Standard Model (SM) Lagrangian, with non-negligible effects at it scales (denoted as SM_G). All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

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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 spacetime coordinates, and metrics between Reisner Nordstrom [2] and Kerr Newman [3] for massive and possibly charged particles – the latter being possibly extremal). Although surprising, [1] recovers results consistent with other like [4], while also being able to justify the initial assumptions of black holes from the gravity or entanglement model in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4-D process, with massless gravity, but also with massive gravity components at very small scale that make gravity significant at these scales. Semi-classical models also turn out to work well till way smaller scales that usually expected.

The present paper discusses plausible additional multi-fold mechanisms (of W-type) in terms of Quantum Mechanics and QFT (Quantum Field theory) interpretations, and the impact on wave function collapse, quantum measurement problems and the Wigner's friend paradoxes. From these considerations, we also develop a new motivation and interpretation of Multi-fold quantum Physics, and its applicability to macroscopic systems.

2. E/G duality in a Multi-fold Universe

At the core of [1], are the proposals for multi-fold mechanisms, and the resulting multi-fold kinematics and dynamics, activated with entanglement, in particular between EPR entangled particles, and resulting into gravity-like effective attractive potentials, or effective curvatures, in spacetime, between entangled particles. When considering virtual particles emitted by a mass or energy source, the effects actually match gravity, and we can recover GR at large enough scales [1], and massive contributions at very small scales [1,10]. Entangled physical particles generate similar potentials between entangled systems [1,5]. As a result, entangled material are expected to generate gravity-like fluctuations [1,5], and effects that can explain dark matter are also predicted [1,6].

These overall implications of multi-fold universes are summarized by the E/G duality, factual in multi-fold universes, conjecture elsewhere: gravity results from entanglement and entanglement creates gravity [7]. Another set of consequences, related to small scale behaviors, are captured by the proposal for a Standard Model, with non-negligible gravity at its scale: the SM_G. These, and more developments of multi-fold models, are tracked at [11].

3. Quantum Wave functions and Quantum Fields in Multi-Fold Universes

Because of our focus on particles in [1,5,8], even in the context of QFT, we did not explore the possible implications at the level of the quantum wave function. For quantum fields, beyond gravity or entanglement between particles, the focus was rather to avoid QFT entanglement of everything with everything, everywhere; especially in space like regions [1].

Yet, we know that conventional QFTs have fields everywhere in spacetime and have every spacetime point entangled with any other one [1,. This is because of the Reeh-Schlieder Theorem [12,13], or because in general for a field ϕ we have:

$$<0| \phi(x^a_{1,} x^b_2) |0> \neq 0 \quad (1)$$

In a multi-fold universe, we discussed and proved in [1], the non-validity of (1) or the Reeh-Schlieder Theorem[2]: the absolutely no supra-luminosity principle and its implications on say path integral formalisms that reject paths that would include space-like portions, prevent spacelike leaks and entanglement of a spacetime point with any other spacelike spacetime point.

We also know that in Quantum Mechanics, wave functions can have multiple maxima, resulting into several positions, around where there are significant chances to observe the associated particle. Of course, it becomes more complicated or ambiguous when considering many particles and their associated global wave functions or fields: when to model one versus different particles and when do we model them as entangled (e.g. as asymmetric wavefunction for fermions) or separable, and therefore not entangled (e.g. based on rough position if particles are further away i.e., Fock space states).

With the multi-fold universe principles of absolutely no supra luminosity and the hierarchical principle [1], we know that particles, that are space-like to each other, are not entangled; that they be modeled by a global wave function or by a QFT field. However, light-like and time-like particles could be entangled, if physically and causally justified. When entangled, and not violating the hierarchical principle, multi-folds are activated between the entangled particles (physical or virtual) added to the quantum wave function or quantum field model [1]. Otherwise, they may be separable and factorizable, in good approximation, into products of wave functions associated to each particle (e.g. based on Flock space position eigenstates).

EPR Entanglement in a multi-fold universe activates multi-folds, and mappings [1], and create correlations in phase space. It leads us to already argue, in [1], that wave functions must have a deeper physical meaning (e.g. be a beable [16]), and a direct impact on, or relationship to, spacetime properties and structures. Yet we did not elaborate much further. Let us keep that thought in mind: quantum wave functions and quantum fields seem to impact, or describe spacetime properties or behaviors. It is after all not surprising. Indeed, the multi-fold key insight can be seen or rephrased as: spacetime as described by GR is the result of spacetime adapting itself to support the consequences entanglement; hence the multi-fold mechanisms. That adaptation results into gravity [1].

Now, let us go back to a situation where we can model an individual particle (or a set of non-entangled particles) with a wave function with multiple maxima for a given particle. Let us also remember that, in [1], we modeled Physics at very low scales quantum Physics via particle random walks in accordance with the behavior modeled by Path Integrals as observed in [1,17-20]; a model shared by quantum mechanics (relativistic or not) and QFT. This could be explained by considering that wavefunctions and uncertainties allows the particle associated to a wave function to occupy different positions (in spacetime and in phase space/Hilbert space), where there is a non-zero wavefunction, and change position by random walk, and, or tunneling. The occupation of a particular spacetime location reflects the probability for that location, up to an uncertainty region, according to the uncertainty principle. This way, the possible paths (à la Path Integral) of a quantum particle (relativistic to best observe it) reflects such random jumps and walks (within the uncertainty region where supra luminosity is not an issue) including possible tunneling from a non-zero wavefunction region to another associated to same particle. It is also well known that effects like the Lamb Shift [21-23] are due to the size of the electron charge distribution or the time it spends close or within the nucleus; something that explains in particular the difference between hydrogen lamb shift and Muonic Hydrogen lamb shift (See for example [24]). Therefore, at least in a multi-fold universe, quantum models like a particle wave function (and a QFT field with suitable handling of particles à la [1]) actually model such random walk and tunneling: the particle can be located anywhere that its wave function is non zero, stay or move (jump, walk or tunnel) at clock ticks (see [1,25] for a discussion of its minimum length in multi-fold

[2] This may or may not be related to the challenges encountered in firmly establishing a condition-less Reeh-Schlieder Theorem in curved spacetime. Indeed, it is still unknown if such a theorem holds in curved spacetime, only under special conditions [13-15], and proof in the presence of curvature or gravity may encounter the same translation problems as encountered in multi-fold universe [1,15]. As we are not trying to analyze the Reeh-Schlieder theorem, such considerations are for future work.

universes) to another location with a probability to jump at one location versus another dictated by the probabilities behind the wave function density (which is the probability that it be there at that exact moment). This way, we also avoid embarrassing questions about how a quantized charge would otherwise be distributed. This may revisit the notion of bare mass or energy at Planck scales but it ends ups being the same rest, relativistic or renormalized mass in path integrals that are associated with the full fledge wave function.

This analysis is somehow related to the famous discussion between Wheeler and Feynman, about Wheeler asking what if all electrons (and positrons) could actually just a single electron in the universe (traveling everywhere and back and forth in time) [26], although it is different, and not even considered as valid anymore, in modern Physics. The single electron proposal has problems (e.g. the observed asymmetry of electrons and positrons (not applicable in the analogy here) in the universe, and non-perturbative and supra luminous travel) but it inspired the development of QED, and the introduction of the Feynman diagrams [27].

In a multi-fold universe, such jumps, if larger than the minimum length, would violate the no supra luminosity principle, or imply apparent slow shift of the charge in one region then slowly moving to another (jump after jump) instead of being able to jump next to any other non-zero wave function spacetime location, and, this way, having the same charge, quantized everywhere, but at different clock ticks. The former cannot be. Either this image is wrong (just as it is in the conventional real universe) or we are missing a consideration.

4. The Type-W Multi-fold Hypothesis: Quantum Wave Functions, or Fields, as Beables Impacting the spacetime of $\mathcal{U}_{\mathcal{MF}(w)}$

To that effect, let us propose a new class of multi-fold universes $\mathcal{U}_{\mathcal{MF}(w)}$: W-type of multi-fold universe, where not only entangled systems but also spacetime locations covered by a same wave function identified with a same particle (in as much that it is possible) also activate multi-fold mechanisms with any other similarly covered locations (i.e. between spacetime points in the support of the wave function), except between a point and an uncertainty reason around it where jumps would not violate the no supra luminosity principle[3]. The effect of the multi-folds activated between two covered points is proportional to the product of the probability density associated to the uncertainty regions around each spacetime point, and the total energy or mass as well, up to an additional weight $\varkappa_W$. Anything in between feels an attractive effective potential or effective curvature as in [1].

In such a W-type of multi-fold universe, quantum wave functions entangle the supporting spacetime and create gravity like attraction on the mapping support domain between every pair of covered points, except when within the uncertainty region, albeit it may be with a different coupling constant. At this stage, where multi-fold models are mostly qualitative and we have no experimental quantitative validation of the multi-fold mechanisms as in [1], we can not argue if the W-type effects are the same, comparable or at different order of magnitude with the multi-fold effects of [1]. We can only guess that the effects are small, as is gravity[4], in general and plausibly much smaller.

We could also imagine a multi-fold universe of W-type where $\varkappa_W = 0$. In such a case no gravity like attraction appears yet the following effect still exist.

In $\mathcal{U}_{\mathcal{MF}(w)}$, we will encounter:

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[3] The notation $\mathcal{U}_{\mathcal{MF}(w)}$, relates to the one used in [1].

[4] Do not be fooled by our claims of non-negligible gravity at very smalls scales in [1] ,and at the scale in standard model for SM_G (all discussions of it are tracked at [11]): they result from small scale 1/r plus massive gravity contributions [10]. Here, the contributions may remain small bounded by the size of uncertainty regions.

- (i) The multi-folds in a W-type multi-fold universe, $\mathcal{U}_{\mathcal{MF}(W)}$, enable particles to jump from one spacetime point to another covered by their wave function; thereby supporting a model where the particles can jump back and forth wherever the wavefunction with a probability given by the squared amplitude of the wave functions at the target. Interestingly, this provide an immediate justification for the Born rule [28], without requiring collapse, measurement, continuous measurement models or many worlds. Interestingly, it is a different reasoning recovering the Born rule on a discrete state space (i.e. spacetime) from [29,30].
- (ii) The kinematic and dynamics of the wavefunction collapse is now entirely governed by the kinematics and dynamics of multi-folds, that is discussed in [1]. As every concretized (see [1,31]) spacetime point are at least entry and/or exit points for some multifold (except if all the pairs are within a same uncertainty region), anything that would trigger wave function collapse will result into instantaneous collapse of the W-tyoe multi-folds, and, as a result, instantaneous collapse of the wave function everywhere on the wave-function support; no matter how big, and yet still not violate the no supra luminosity principle.

The wave function, or QFT field, for a particle, can therefore be seen as the following beable:

- (a) A representation of all the possible spacetime points could be visited by the random walks of the associated particle taking place on the covered spacetime according to the probability distribution of the wave function.
- (b) A representation of the multi-fold density of entry (and/or exit) of activated W-type multi-fold associated to a particle.
- (c) A representation of the gravity fluctuations on the wavefunction support (spacetime covered by the wave function) due to effective potentials or effective curvature induced by the multi-fold mechanisms.
- (d) A multi-partite entanglement of the concretized spacetime points, i.e. entangled Higgs fields and bosons per [31].

(a) is observable. (b) is probably not observable and (c) is observable if $\varkappa_W \neq 0$. (d) characterizes a possible explanation for the underlying physical events, making it all physical and beable [16]. With the proposed model, quantum wave functions or QFT fields reflect entanglement of spacetime and activate multi-folds between spacetime locations or the associated microscopic black holes [1] or Higgs fields [31], just as entanglement between particles, or regions, activate multi-folds that result into gravity like effects (effective potential and effective curvature). This way, gravity itself results from entanglement between virtual particle pairs emitted by energy source [1,7,10].

In addition, the particle, discussed here, exists. Its position exists, at any time, but it is known only when collapse takes place. Yet it is a beable.

If $\varkappa_W \neq 0$, then gravity like interaction exists within the spacetime covered by the non-negligible wave function associated to a particle and it would affect other particles path crossing it.

5. Macroscopic vs. Microscopic Physics in W-type of Multi-fold Universes

Pursuing the proposed model, one can consider that the universe is modeled by a global wave function. Yet, per the hierarchical principle [1], entanglement is limited to causal regions. Also, many separated systems are not interacting, and not associated to the same particle (assuming we can track them and understanding that some may appear or disappear as discussed in [1,8]).

So a global wave function consists of many small islands of regions where Higgs multi partite, with entangled concretized spacetime locations, and associated W-types of multi-folds, themselves linked to each other by tunneling or by entanglements and multi-fold as described in [1]. Interactions with an entangled region may deactivate the latter multi-folds (corresponding to decoherence or end of entanglement), while measurement, annihilation or interaction with a particle will deactivate the W-types of multi-folds (corresponding to wavefunction collapse).

As larger systems are composed of particles, they are themselves composed of sets of such islands contributing to bigger wavefunction and entanglement. Each subsystem can be seen as evolving its own ways in random walks as for individual particles. As discussed in [1,10], gravity can result from entanglement of all the virtual pairs emitted by all the different subsystems.

In [1,32], we argued that gravity superposition is not the source of spontaneous collapse, because in a multifold universe, the curvature is effective and therefore not creating inconsistencies that would force the collapses proposed by Penrose and Diósi [33-35]. Yet, interactions with, and quantum fluctuations of, anything, including gravity, may result into such collapses for any of the involved island if they impact the system more strongly than allowed by the uncertainty principle. The larger the system, the bigger the chances that interactions with something (e.g. vacuum or spacetime/Higgs fluctuations) will rapidly take place with some of its parts, resulting into the collapse of all the larger wavefunction(s), and the involved islands. It coincide with the usual views around spontaneous collapse. When a collapse occur, per our model, it is instantaneous and locate the particle at the location where it ended up in the course of its random walk. So in a larger system, the subsystems are localized (e.g. think of their center of distribution of the wave function), and with properties matching the notion of observable values. If this happen often, larger system are therefore behaving classically, while smaller islands can be, or last, much longer entangled or W-type entangled. This explains why macroscopic system are in general classical, and microscopic quantum. It also explains physically explains the process of factorization of wave functions into products.

If the reasoning presented here is correct, then, by definition, the universe as a whole remains quantum even if its macroscopic systems are classical: it can't be externally perturbed. Quantum Physics is universal, yet the quantum physics dictates that not isolated (which can only the be universe as a whole) macroscopic systems become described by classical physics with microscopic sub-systems continuing to be described by quantum physics. We also have a criteria for a larger system to remain described by quantum physics: isolate it from interactions or fluctuations larger than the uncertainty region associated to the system or for how long it may remain a quantum system (e.g. like a decoherence time etc.).

Again nothing in the above conclusions are especially new, nor it is universally accepted, for the real universe. Yet the explanation introduced peculiarities proper to W-type of multi-fold universes: spontaneous collapse is consistently justified, and differently from conventional proposal for spontaneous collapses, as well as gravity induced spontaneous collapse as in [33-37].

We also like to think that our model resolves some of the measurement problems or paradoxes [9]. Other interpretations of quantum mechanics [36,38] like the Many-world also remain compatible. However, in our view, alternative like Many-world are less justified now that we have a consistent physical justification for wave function collapse, if one believes in the Occam razor's principle; especially considering how the random walk model also justifies the Born rule, without any consideration of measurement, continuous or spontaneous measurement, observation, or even collapse. We can argue that we have at least a potentially common consistent model, that explains in one shot: wave function or field as beables, wave function collapse, entanglement, gravity, Born rule and quantum versus classical physics.

In our model, large macroscopic wave functions may not re-form once collapsed, or only do so slower than *c*, as the Higgs Entanglement can't reappear. That is different from most conventional spontaneous collapse models [36,37]. Even if they did, our reasoning immediately would re-apply. There could therefore be a meso scale of reality where re-formation takes place, while macroscopically it probably would never happen for systems at much large scale.

6. The measurement problem and Quantum Weirdness

Let us now revisit the measurement problem. We argue that it can be resolved in W-types of multi-fold universes: measurement is simply an interaction (or a set of interactions), that results into a wave function collapse as described above. Of course, the other interpretations [38] remain compatible, but possibly not that justified any more.

Of course, many quantum weirdness and paradoxes exists in relation with measurements including EPR experimentation and Bell inequalities and their generalizations as well as the different Wigner's friend experiments [40-43].

The multi-fold mechanisms were introduced to address EPR and Bell inequalities: non-locality is achieved via the multi-fold mechanisms [1].

Let us consider some of the Wigner friend's paradoxes.

6.1 Frauchiger-Renner Paradox

In the case of the Frauchiger-Renner Paradox [40], a variation on Wigner's friend, well explained in [39], one of the following three assumption of Physics must be wrong:

- Universality of Quantum Physics (i.e. it applies to everything)
- Consistency of Quantum Physics (Reality and observations cannot be contradictory)
- Logic of Quantum Physics (facts can be true and false at the same time)

The present paper addresses the non-universality of quantum physics, but with a twist. We do not say that quantum mechanics does not apply to macroscopic systems (like a lab, Alice's friend and her experiment), but that the collapse proposed in section 5, ensures that no superposition of macroscopic systems takes place within our macroscopic reality, as also agreed in [40]. Again, all others collapse models agree with such an explanation, but our W-type explanation is a self-consistent variation with beables.

6.2 Other Wigner's friend paradoxes

The same reasoning applies to the Wigner's friend [41], and variations as discussed in [42,43]: macroscopic observers do not put macroscopic systems into superposition.

7. Multi-fold Self-Gravity?

If $\varkappa_W \neq 0$, does it means that we have self-gravity effect within a wave function? Obviously, we do not know, it is even harder to measure than among entangled systems. But, as jumps involve the W-type of multi-folds, the particle should feel effective potentials fluctuations at any point before and after jump, and the potential of the traversed multi-fold during the jump. It probably introduces an additional notion of (renormalized) bare mass, rest mass and relativistic mass, with the latter accounting also for such energy contribution; but it does not change anything else as the full conventional mass is used for any analysis of the wavefunction itself. It is indeed expected to see such new notion as a particle in a wave function random walks within it and, at larger scale, the wave functions in quantum mechanics, and QFT, are now the aggregated result of these random walks then modeled by Quantum equations like the path integral.

On the other hand, for $\varkappa_W \neq 0$, any other particle, with paths crossing the spacetime support of a wave function, feels a potential attractive towards it center of distribution of the wave function, as for the multi-fold of [1], and weighted by $\varkappa_W$. The effects are small, and probably only relevant when one particle wavefunction is significantly extended. It only appears in spacetime (or state space) locations covered by the wavefunction. These effects create gravity like fluctuations, including larger ones, when or if a wave function collapse. It is different from the spontaneous models proposed in [45,46]: gravity result from entanglement, as in [1,5,7,10] or W-type multi-folds when $\varkappa_W \neq 0$, yet the analyses proposed in [45,46] are food for thoughts as our proposal may imply similar gravity fluctuations when collapse takes place.

8. On the Irreversibility of Quantum Physics

We know that it has been shown that Quantum Physics appears as a systems well modeled by irreversible Thermodynamics [47]. In [1,48], we showed that in multi-fold universes, multi-fold mechanisms, and therefore entanglement and quantum gravity, are not T-symmetric. The present paper adds fundamental wave functions and QFT fields collapse dynamics, and measurements or interactions, as irreversible processes: the fundamental properties of Quantum Physics are indeed irreversible, even if usually unnoticeable. As these aspects are not modeled in conventional Physics today, the notions that simulations or even experiments [49,50] may appear to reverse time to bring it back to a past initial condition is not a correct, or a complete reflection or model of the full quantum system, and therefore of actual reality (even if the equations can computationally be reverted, multi-folds or W-types of multi-folds have not been accounted for).

Such irreversibility arguably provide a justification to the notion of entropic or Thermodynamics notion of time arrow. We will discuss in future work how it relate to time symmetric proposals like [51].

Per [47], it is expected that because Quantum Physics is modeled by irreversible Thermodynamics, it is not a fundamental theory but rather an emerging theory. The multi-fold universe reconstruction of [1] provided a part of and underlying even more microscopic model, yet it only illustrated aspects of Quantum emergence. The W-type hypothesis adds physical explanation of the wave function, or QFT field, and its dynamics and collapse as well as its associated Born rule; thereby further clarifying the model. Motivations for randomness and physical Action were also provided in [1]. To that effect, the W-type hypothesis also motivates the duality between Action and Entropy often encountered between say QFT and Statistical Physics and called out on [47], yet while working with single particles.

Related to Thermodynamics, the model reminds of thermodynamics ergodic hypothesis introduced by Boltzmann: the wave function support has every point visited by the particle, some more than others as described by the wavefunction amplitude.

Note added on July 16, 2022: [52] provides another model directly supported by our proposal, if the microscopic idea are random walks of Higgs particles (one or many) making a condensate in an elementary particle [1,31,53], or just those elementary particles: they can all be the (microscopic explanation for the) fast fluctuating variables and their motion could be the random walks of [1]. We will not comment on the supersymmetry proposal though.

9. Conclusions

This paper introduced the type-W multi-fold hypothesis that proposes a new class of multi-fold universes (W-type), where wave functions and quantum fields are sources of W-type multi-folds on the wave function support domain, which explains the wave function behaviors and properties by random walk of the associated particle, or quantum system within the support domain. Random walks at the particle level take place through multi-folds except at very smalls scales (uncertainty region), where they can just jump in spacetime without violating the no supra luminosity limits.

The model of W-type multi-fold universes, a new hypothesis with respect to [1], is not a property derived for multi-fold universes, but rather a new concept, can provide a consistent explanation for wave function collapse, and the instantaneity of the collapse, the beable aspects of wave functions, and the measurement problems as well as the Born rule (without involving collapse to justify it). It predicts possible (for $\varkappa_W \neq 0$) additional gravity-like fluctuations within the spacetime support domain of a wavefunction, and when collapse takes place. This approach also results into a consistent model to explain why and how macroscopic Physics is classical, thereby addressing several Wigner friend paradoxes. In our view, it also gives a plausible consistent view of quantum mechanics interpretation à la collapse, or better, and as such it seems to be the most logical, Occam razor inspired, interpretation that applies for Quantum mechanics. Yet, W-type multi-fold universes remain compatible with most of the other interpretation [38]. Analyzing if our model can actually discriminate between any of these interpretations is for future work.

It is to be noted that, besides the W-type multi-fold universe being just an hypothesis, gravity like effects could not be produced by W-type multi-folds, for $\varkappa_W = 0$, or be in general negligible, for $\varkappa_W = \varepsilon$ with $\varepsilon \approx 0$, but not 0.

After addressing the reconciliation of GR with Quantum Physics, providing solutions (SM_G) to key open problems with the standard model and standard cosmological model (See [1,11], beyond SM_G), and pushing back on New Physics (See [1,11]), Multi-fold models and mechanisms can also address not just entanglement paradoxes, but also open issues with Quantum Physics foundations. It invites further work on the possible impacts of W-types of multi-fold universes, and the W-type multi-fold hypothesis.

W-Type multi-fold models, including the Multi-fold reconstruction, seem candidates to a more fundamental theory from which Quantum Physics emerges. It also explicitly links Action and Entropy even at the individual particle level.

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