Multi-fold Universes, Multiverses and Many Worlds

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Abstract:

There are different types of multiverses, depending on the Physical model considered. In most cases, it is impossible to falsify multiverse hypothesis. The Many Worlds interpretation (MWI) of quantum mechanics is a particular case that gives comfort to some when it comes to understanding quantum physics, and the Born rules, but it does not result into distinguishable experimental results from other interpretations. This paper evaluates multiverses at the light of the multi-fold theory.

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 are 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 a 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 (GR) at large scales. Gravity can therefore be added, in non-negligible ways to the Standard Model (SM) resulting into the SM_G. The multi-fold mechanism and the SM_G can address many open issues with the SM, and the standard cosmological model, even if the latter is modified. The SM symmetries and particles can be recovered by multi-fold space time matter induction and scattering from a ε region of 7D embedding space felt in a 4D spacetime at entry, exit and mapping to the multi-fold. In addition, the W-type multi-fold hypothesis, establishes additional multi-folds between spacetime locations in the support domain of a wavefunction, not just between entangled systems. It can also justify the Born rule.

As a result, any multi-fold multiverse will have the same physics with same particles. interactions, constants and symmetries of the SM_G. We will establish that multiverses do not interact with each other, and, in general, at the exception of the MWI, they do not contain all possible situations, including many copies of us, in any other possible situation.

On the other hand, analyzing the effects of multi-fold deactivation, measurement or an interaction that results into deactivation of the W-type multi-folds between one part of the wavefunction of the disrupted system, the observed state, and the part associated to all other options, it results in a universe-wide brane-like object, associated to the disregarded options, floating away in AdS(5): a new World, part of the Many Worlds predicted by MWI. This is a microscopic explanation supporting the MWI. And each such world has of course the same physics as well as copies of the world in other situations.

Encountering multi-fold brane-like structure in AdS(5), confirms the view of the multi-fold theory on superstrings and the M-theory. The existence of same physics imposed by multi-fold space time matter induction and scattering dooms the viability of landscape multiverses and its anthropic principle.

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1. Introduction

Over the last decades, the multiverse has been widely promoted as something that some see as a natural result of several theoretical quests, while others characterize the approach as quick ways out avoiding the tricky dead ends of many of these theories, and/or as unfalsifiable speculation of some of these theories. Some physicist take it very seriously, while others consider multiverse as pseudo-science bordering on religion. A few popular articles on multiverses can be found at [81-87],

Among the multiverse types, the Many World Interpretation (MWI), based on the work of Everett [88,89], has a special place at the heart of the foundations of quantum Physics. Yet again, while satisfying the intellectual curiosity of its proponents, it does not provide falsifiable assertions nor is it really distinguishable from all the other interpretations of quantum Physics [90-92]. MWI just addresses in a pleasing way the measurement problem, and related challenges with the quantum wavefunction collapse.

The MWI, and multiverses in general, have captured the imagination of many, including non-physicists, and recently it has inspired several movies, including the Oscar award movie "Everything Everywhere All At Once". It is probably why [81-87] include so many articles published in 2023, around the movie nomination, and wins at the Oscars It is not that we liked the movie at all, quite to the contrary.

Note added on April 28, 2025: In this paper, references in italic were added on April 28, 2025.

The present paper is put together initially in the context of the multi-fold theory, where we introduce multi-folds as ways to explain EPR entanglement, which are non-local physical effects, with local physics, and conventional tools like path integrals [1,8-10,22,*167,173,187*]. Doing so, we showed that gravity and General relativity (GR) can be seen as emerging from entanglement between virtual particles, and that entanglement, between real objects, creates gravity like fluctuations [1,6,24-26,*167,173,187*]. The multi-fold theory can recover General relativity at large enough scales [1,6,22,24-26,157,*167,173,187,205*]. It also explains many open issues with the Standard model (SM) and the Standard Cosmological Model (ΛCDM) [78], which leads us to consider that maybe our universe is multi-fold, possibly with multi-fold implemented with traversable wormholes [1-80,93-95,101-104,107,108,115,118,*121-214*]. [1,8-10,22,*155,167,173,187,205*] includes considerations on the kinematics and dynamics of multi-fold activation and deactivation associated respectively to entanglement and disentanglement.

On the other hand, we show that in multi-fold universe, quantum gravity, does not necessarily imply wavefunction collapse [94], and in fact argue also against the idea that black holes imply decorrelation [95].

In [72], with the W-type multi-fold hypothesis, we extend the notion of multi-folds to link all the spacetime locations in the support domain covered by a wavefunction to any other such location. Doing so, we can justify several of the multi-fold mechanisms [1,8-10,22,*155,167,173,187,205*], as well as provide a new quantum mechanics interpretation that naturally justifies the Born rule and the use of probabilities associated to wavefunctions.

In [93], we provide an analysis of the principle of least action and physics action path integral formalism, and discuss it in conventional as well as in multi-fold universes. Considering that path integrals are a good way to explain, and even justify, the MWI, and that MWI, path integrals and the W-type multi-fold hypothesis also explain well the Born rule, the present paper investigates if the multi-fold theory, and the W-type multi-fold hypothesis, can shed some lights on the MWI.

Starting on this journey, we expected that the answer would be negative: that it would say nothing really new. To our surprise, pursuing the W-type multi-fold hypothesis, along with multi-fold deactivation kinematics and dynamics [1,*155,173*], we will discover not only a potential microscopic interpretation, versus a just logical, but conceptual, model, behind the MWI, but also that such an interpretation can potentially result into a multiverse, in

AdS(5) (+…), where, as in [1,*173*], the (+…) denotes possible additional dimensions as encountered in string theory (in multi-fold theory we can just stop at AdS(5) unless if we want say to justify GR in AdS(5) also with multi-folds [14,66]) [1,14-16,18,20], and possibly explained in the multi-fold theory as in [14,66]. Accordingly when the wavefunction of a system collapses, due to selection from say interaction or observation (or spontaneous collapse, which could possibly be due to gravity as other would suggest (See references in [94)], noting that the multi-fold theory disagrees with aspects of that as discussed in [94,95] and references therein), it creates a new world in MWI. The W-type multi-fold hypothesis implies the release of an object in AdS(5) (+..), that could be seen as an image (wavefunction) of the whole universe, associated to the alternate, not selected/observed results. It includes the system in these alternate states. Beyond that, nothing else can be said other than this object, if continuing to be real, in some definition of the word, would have the same physics as ours, defined by conventional physics + multi-fold mechanisms, and constants / particles, symmetries and interactions defined by the 7D multi-fold space time matter induction and scattering [54,56,66,93]. It means that we can have Many Worlds as multiverses, but they are all governed by the same physics as our universe; no multiverse with different physics, particles or constants, as proposed by many other theories. Such released objects in AdS(5) (+…) look a lot like what superstrings call (D-)branes [96], especially knowing that these typically live also in AdS(5) (+..). However, the notion of reality (or being beable) in such a space is not well defined. For example, as the object detaches, and drifts in AdS(5), could it collide with our universe or other such objects? We will see that the MWI AdS(5) (+…) objects or multi-fold branes should not interact, and this includes no collision.

The reasoning provided above, and discussed in the paper, allows us to deduct that other multiverses, at least whose existence is justified by inflation, multiple (distributed) big bangs, natural selection based on their laws of Physics, domain walls and phase transition within the universe, superstrings and branes, should all have the same law of physics.

The paper starts with a review of the multi-fold theory, followed by a summary of the multi-fold spacetime matter induction and scattering, the multi-fold activation and deactivation, the notion of wavefunction in multi-fold universes and the W-type multi-fold hypothesis.

Then, we enumerate some of the main different types of multiverses proposed in the literature, including the MWI [113].

Armed with this material, we analyze the implication of a measurement, or state/path selection by interaction, and what it implies in the context of the W-type multi-fold hypothesis: the deactivation of the multi-folds and as a result the apparition of a AdS(5)(+..) universe scale object left on its own to possibly to drift in AdS(5) (+…). Also, we discuss its physics, and the possibility, that physics differs or not between such objects, or even that interactions could take place between them.

This discussion and the outcome of [1,4-7,23,29,43,49,51,53,60,63,66,67,93,*157,167,173,187,197,205,212*] is used to argue that all multiverse based on physics considerations will have the same physics unless, if the underling model pertains more to science fiction than actual physics.

2. Multi-fold Theory

In a multi-fold universe [1,8-10,22,*167,173,187*], 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 are real or virtual. Long range, massless gravity results from entanglement of massless virtual particles [1,25]. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales [1,26]. 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 that is Lorentz invariant and where spacetime nodes and particles can be modeled with microscopic black holes [1,4,16,27-31]. All of this recovers General Relativity (GR) at large scales [1,6,22,24-26,*157,167,173,187,205*], 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. This can contribute to resolving several open issues with the Standard Model without new Physics other than adding gravity to the SM, and having a quantum gravity model [1-80,93-95,101-104,107,108,115,118,*121-214*]. These considerations hint at an even stronger relationship between gravity and the Standard Model, as finally shown in [23].

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 is notable. It is supposedly always around right-handed neutrinos, due to 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 modeled as minimal microscopic black holes mark concretize spacetime locations. They can condensate into Dirac Kerr-Newman soliton Qballs to produce massive (and charged particles) [1,4,29,*197,212*], and behave as patterns of 2D random walks of the massless Higgs bosons when massless [29,31,60,67,*197,212*]. This providing a microscopic explanation also for a Higgs driven inflation [1,27,28], the electroweak symmetry breaking [29*,212*], the Higgs mechanism, the mass acquisition [*205*] and the chirality of fermions and spacetime [29,31,60*,212*]; all resulting from the multi-fold gravity electroweak symmetry breaking. The multi-fold theory has also concrete implications on New Physics like supersymmetry, superstrings, M-theory and Loop Quantum Gravity (LQG) [1,8-21].

The multi-fold paper [1] proposes contributions to several open problems in physics, like the reconciliation of General Relativity (GR) with Quantum Physics [1,6,22,24-26,*157,167,173,187,205*], 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 Lagrangian [1-80,93-95,101-104,107,108,115,118,*121-214*]. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

With the proposed model of [1,*155,173*], 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) [1,6,30,31,60,67,68,*154,157,190,203,204,205,208-210,212*]. Spacetime results from past random walks of particles [1,31,67,*211*]. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and concretized spacetime coordinates, and metrics between Reissner Nordström [2], and Kerr Newman [3] for massive, and possibly charged, particles – the latter being possibly extremal). Although possibly surprising, [1] recovers results which are consistent with others (see [4,*197*], and references therein), while also being able to justify the initial assumptions of black holes from the models of gravity or entanglement in a multi-fold universe.

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.

[2] Standing in for Quantum Physics in general.

3. The W-type Multi-fold Hypothesis

Multi-folds can open the door to a new interpretation of Quantum physics: the W-type of multi-fold universe, where not only entangled systems support entangled mechanisms [1,8-10,22,*155,167,173,187*], but spacetime locations covered by a same wavefunction 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 same wavefunction), except maybe between a point and an uncertainty reason around it, where jumps would not violate the no supra luminosity principle. It presents the advantage to justify the Born rule, and other quantum physics challenges in understanding it [72].

With the W-type multi-fold hypothesis, the multi-fold mechanisms allow the two entangled particles to physically encounter at a same point as paths of the path integral, hence always being indistinguishable from each other and able to be in state that reflect at any time the impact on one particle of interactions. This is also why entangled particles can be in states where they cannot be distinguished from one another.

This may also give a real notion associated to the notion of wavefunction, and its QFT equivalent.

Recent results, in [7] and references therein, and discussed in section 22 of [10], confirm such an hypothesis if quantum physics is relative and equivalent in suitable quantum reference frameworks of entangled, coherent or correlated systems.

We also see in [10*,155*] that the W-type multi-fold hypothesis motivates the multi-mold mappings that result into gravity and gravity-like effects.

4 Multi-fold Space Time Matter Induction and Scattering

Multi-folds generate, at each concretized location of the multi-fold spacetime, a ε region from a 7D embedding space that can follow GR in 7D, and be flat or Einsteinian [1,54,66]. The effects of multi-folds are essentially with a spin-2 symmetry [1,23,*155,173*], which also explains the holographic principle of gravity ,or the area laws of black holes. The spin-2 symmetry implies the embedding space effects are mostly 5D. In the 4D multi-fold spacetime, the embedding space is only felt through the multi-folds as an ε infinitesimal region, which is essentially 5D.

Particles in the 4D spacetime feel a 5D, or rather a 7D, through the ε region at entry, exit, or mapping points of the multi-folds. It is an additional reason for the tenancy principle of multi-folds [1,8-10,22,*155,167,173,187*]: as each location only sees multi-fold due to their involvement with a multi-fold, they do not see other particles, e.g., like the entangled ones, or other particles crossing the support between them, unless if already overlapping in spacetime. The (massive) Higgs boson is everywhere in spacetime, and at the entrance and exit point, is the only exception and due to the interaction with it, it can enter or exit.

5D multi-fold space time matter induction (effects of 7D, mainly 5D, geometrical objects impacting the 4D spacetime), and scattering with 7D, mainly 5D, objects when feeling the embedding space in an ε region, and encountering a 5D/7D soliton, recovers particles and interactions in the 4D multi-fold space time that match the SM particles, fields and interactions [54,56,66]. It can also be seen as a new approach: unconstrained Kaluza Klein theory. The 7D space supports the symmetries of the SM, or rather SM_G [56,66]. When massless see the details in [23,31,53,60,66,67,*212*]

In other words, we can recover the SM, or SM_G, in multi-fold 4D spacetime via multi-fold space time matter induction. The remaining challenges of chiral fermions, not available in 5D or 7D, is resolved in the 4D spacetime by

the Multi-fold gravity electroweak symmetry breaking described in [29,30,*212*] and in section 11 of [10]: it (globally) orients spacetime, and makes some microscopic black hole particles rotate. Above that energy level, it only locally exist around massless particles as patterns of Higgs random walks.

The particles exist in 4D spacetime, and only feel the multi-folds in such a 4D spacetime, therefore resolving the challenges of the absence of chirality at higher odd dimensions, of dimensions to compactify (embedding space is just no visible), or of incompatibilities between say 7D and the SM, as discussed in the next section. Higgs bosons and neutrinos are recovered together by scattering from within the multi-fold, as already encountered in previous sections [1,8-10,22,44,49-51,66,112,*155,167,173,187*].

Non-commutative theories also encountered in a multifold universe also recovers the SM [1,30,67,68,*154,157,190,196,204,205,210*].

Note that we do not say that the 7D embedding space is physical, beyond the portion built by the multi-folds, and the 4D spacetime particles ε neighborhood feeling at the points of entry, exit and mappings. This way, 4D Physics is not 7D or 5D physics, and so chiral fermions are possible (as in 4D), and we do not have a challenge of explaining why 3 large dimensions would not be visible to us, which is the reason why superstrings have to compactify their extra dimensions because they form a real embedding space, and no concept of it being locally generated as a ε neighborhood exists in their case.

[23,66,93] also shows how the SM, or SM_G, symmetries directly results from the multi-fold mechanisms.

5. Wavefunctions in a Multi-fold Universe

In [1,*173*], we explore the notion that the wavefunction may be a beable, i.e., a physical object and not just a probability distribution. It is in particular exemplified by the fact that entanglement appears to impact the spacetime and the phase space, and by the idea that maybe spin could be the result of the rotation of the wavefunction resulting from the entry of virtual particles in the multi-folds that surround a particle. This is further expanded in [68].

With the W-type multi-fold hypothesis, all the concretized spacetime locations on the support are connected via multi-folds, with the density of connections reflecting the Born probability density.

6. Disentanglement and Wavefunction Collapse in a Multi-fold Universe

[1,*8-10,22,155,167,173,187*] models multi-fold activation when entanglement takes places, and multi-fold deactivation when we have disentanglement. In the latter case, the multi-fold exit points detach from the disentangled locations and we proposed that that they contract towards the entry point, so that the associated attractive effective potential in 4D spacetime drops, at *c*. It is motivated by the principle of no supra luminosity in a multi-fold universe [1]. It is symbolically sketched in figure 1.

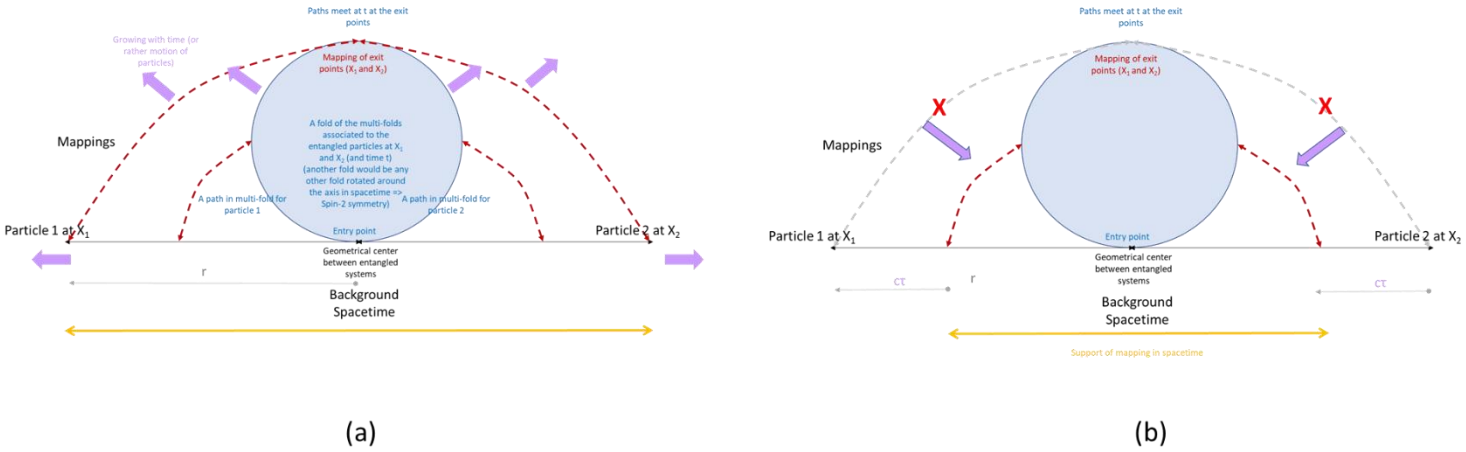

Figure 1: (a) comes from [10]. It represents the multi-folds and their evolution as the entangled particles move away from each other. (b) shows the deactivation mechanisms. Accordingly, the multi-folds mapping stop mapping to exit point and progressively collapse towards the middle point so that the corresponding effects on the support of the mappings in 4D spacetime evolves at c. The light purple arrow show the resulting deactivation as a contraction that reduces the support domain at c. τ is the time since the interaction.

In reality, to achieve that, we just need the mapping to detach at *c*. Nothing dictates more in terms of the behavior of the multi-folds in AdS(5)(+…). It could as well start floating away as shown in figure 2, as long that the mapping detaches at *c*.

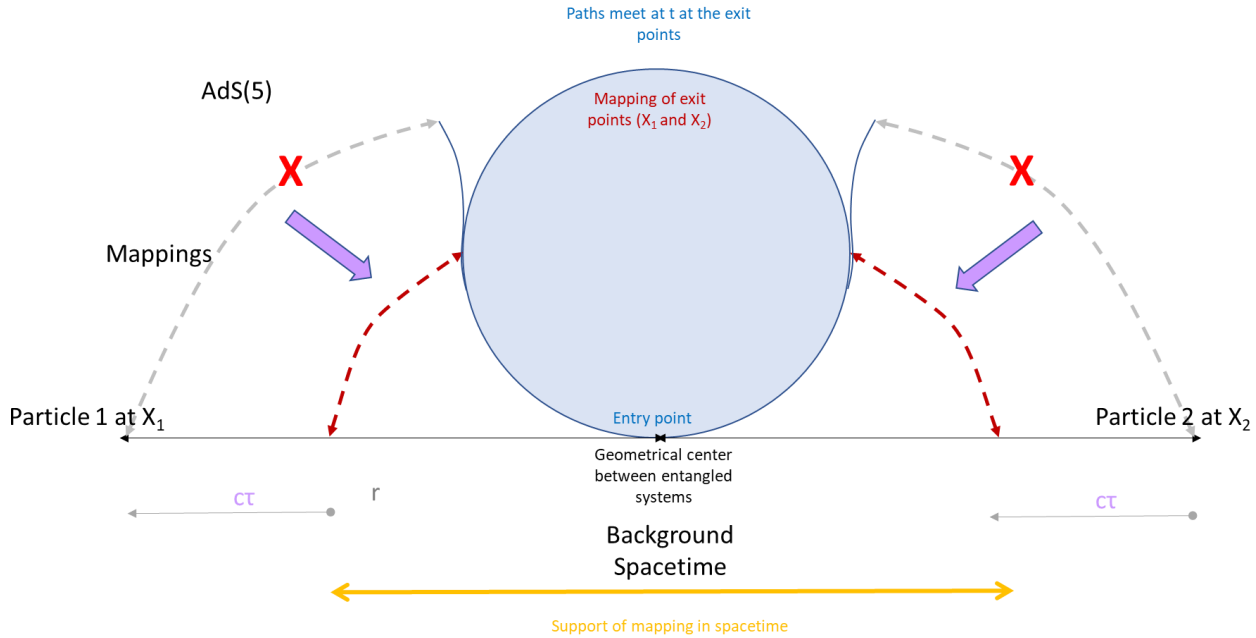

Figure 2: It shows a different possible option, where the multi- folds unwind in AdS(5) as they deactivate the mappings in ways similar to Figure 1 and [1].

Of course the model discussed here is based mainly on the view that (massless) gravity and gravity changes propagate at *c*, and nothing is supra luminous. In the case of just entanglement effects, we know that the global wavefunction collapse but we do not know if something would also immediately collapse on the support domain of the multi-fold mappings (See [1]). In the discussion here, we assume that it is happening also at *c*. Some other

behaviors could be supported. It does not really matter because of the rest of our arguments presented in upcoming sections.

Now, considering the W-type multi-fold hypothesis, when the wavefunction collapses due to interactions, or measurement, the W-type multi-folds between the different support locations are similarly deactivated. As the wavefunction lives in a Hilbert space, the figure 2 and support is now possibly understood as also in the Hilbert space.

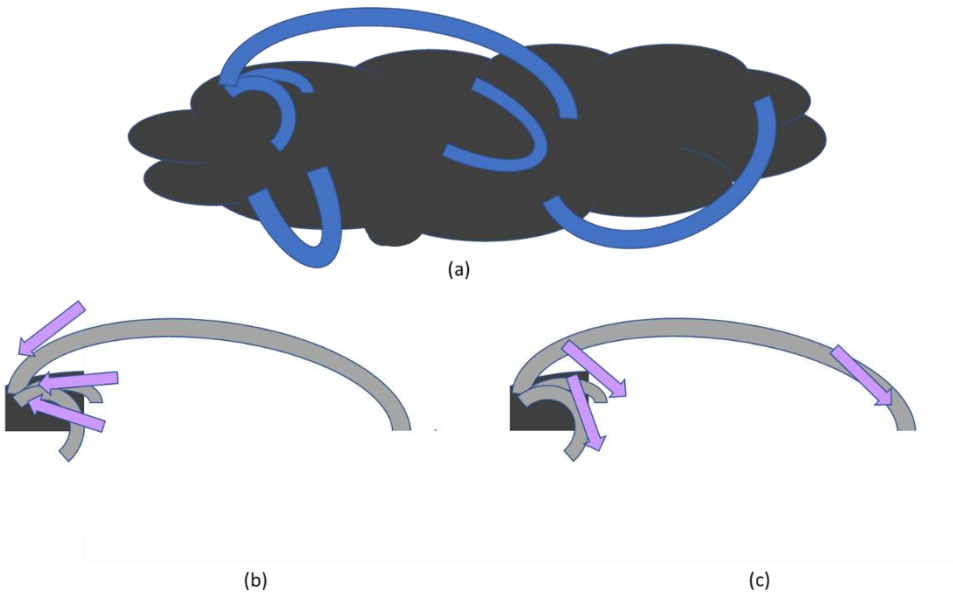

Figure 3: (a) shows a wavefunction support domain in spacetime and / or Hilbert space with a few of the W-type multi-folds. (b) When interaction or observation takes place, the W-type multi-folds deactivate towards the state observed or selected. But of course, it can also have equivalently W-type multi-folds deactivating towards the non-selected states (c).

In figure 3, multi-folds can deactivate towards the selected state (b), or towards the position of the non-selected states as in figure 3 (c).

7.Multiverses

Multiple theories have led to proposals for multiverses, and different types of multiverses exist. See for example [81-87,97,98], for a list of different multiverse types. It is not our objective here to classify them, just to consider them broadly in terms of their Physics.

In many of these cases, different universes appear connected (different inflation regions with domain walls) or disconnected (e.g. different causally separated inflation regions, regions in eternal inflation) in space, in time (e.g. cyclic universe), in higher dimensions / embedding spaces (D-branes), in theory (infinite amount of big bangs, anthropic universe [97,116], superstrings multiverses etc.), and it is usually proposed that Physics may be different in each multiverse.

What seems to captivate the crowds is that in all the multiverse one can also imagine that there are copies of ourselves, and of everything, just in different situations and contexts. You, wearing blue or grey today, with 1, 2 or three arms, you are sick or healthy, rich or poor, dead or alive or never born, married or single, etc.

The MWI is a particular case of multiverse, where a new World appear every time an interaction selects a quantum state, branching out a world with the measured/selected state, versus all the other options.

8. MWI

For example, the MWI is described in [88,89], and there is a large literature on the subject. The following references provide some entry points [88.89,99].

A simple way to look at it, and the perspective we want to take here, is that wavefunctions evolve by considering that say a particle, or a set of particles, follows any possible allowed paths, or combination of allowed paths. Some say classical paths but it is not correct, tunneling are classic-like path, but classically forbidden. We discuss aspects of this in [1].

As interactions, including observations or measurements, select at a given time a given path, the wavefunction collapses, and the path integral will restart counting all possible paths from the selected state at the selected time, and location. In the MWI, our universe, or our World, selects that path/state(s), and continues from there. However, instead of having a true collapse, and an end of the other paths that have not been selected, in the MWI, these paths can continue. They just continue in another world, where these other states are selected instead. And so, at every step of the way, all over the universe, whenever an interaction takes place, and / or a state is selected, the world bifurcates between two (or more) worlds, and we live in the reality associated to the selected state. Another reality continues to exist in the other world that corresponds to the state or states not selected. Expanding on it, whenever you take a decision or do something, there is another copy of you that does something different, or nothing. It is a bit crazy, it is captivating, and it has captivated many.

In the view of some, MWI should be seen as a different view of reality, and our mind perception [100]. According to them, all copies of ourselves would be the real actual us.

9. A Multi-fold Microscopic Interpretation of the MWI

After proposing the W-type multi-fold hypothesis [72], we were inclined to see our approach as a different interpretation of the wavefunctions, the Born rule and Quantum Physics in general, that competes without much more to say with the other points of views, or interpretations, of quantum mechanics. We also expected that any further progress would first require progress in, or validation of, the multi-fold mechanisms.

However, following our analysis of the principle of Least Action, and our formalism to provide a generic justification for it and for path integrals [1,93], we couldn't help but wonder if therefore more can be said on the MWI. And indeed more can be said.

Consider the moment of interaction when the wavefunction collapses, or when our reality shifts to a specific world with a new starting point for future paths. At that exact moment, the W-type multi-fold on the wavefunction support domain are deactivated: they detach from our path, and from all the other paths at that time, and per the above, the muti-fold mappings also detach progressively from our spacetime at c, granted, as mentioned above,

that the kinematics and dynamics of the multi-folds may behave differently, which does not really matter. What matters is that we now have multi-folds, i.e., pieces of a 4D spacetime in AdS(5)(+…) space. It is symbolically sketched in figure 4 (b).

Figure 4: (a) shows the universe's wavefunction as a bundle of W-type multi-folds associated to everything in the universe, including spacetime and particles. (b) shows the behavior at interaction where some of the W-type multi-folds deactivate towards the selected state à la figure 3(b) and equation (1). (c) shows the shows the behavior at interaction where some of the W-type multi-folds deactivate towards the non-selected states à la figure 3(c) and equation (2). In (c), all the W-type multi-folds rebuild the wavefunction and spacetime per [7], just we can see that the bundle of W-type multi-folds are in fact the wavefunction and that with spin the wavefunction and entanglement across the support domain rebuilds a Lorentz spacetime [7].

Now, in reality, we also know that in quantum physics, there is really only one wavefunction for the entire universe, which is essentially the product of the wavefunction for the collapsed system times the wavefunction for everything else.

So we have:

$$\sum_i \varphi_i \otimes \psi(rest\ of\ universe) \rightarrow \Phi_{selected} \otimes \psi(rest\ of\ universe) \quad (1)$$

Where → denotes transformation due to the measurement/observation or interaction.

The rest, who is supposed to be collapsed, or terminated in the path integrals is

$$\sum_i \varphi_i \otimes \psi(rest\ of\ universe) \rightarrow \sum_i \Phi\_unselected_i \otimes \psi(rest\ of\ universe) \quad (2)$$

And, $\sum_i \ \Phi\_unselected_i \otimes \psi(rest\ of\ universe)$ is what disconnects as W-type multi-folds deactivate towards the selected state, but remains defined by a bundle of W-type multi-folds as in figure 4(c).

So, in reality, one can see what floats away in AdS(5)(+…) as a copy of our universe, where all the other options exist. And this takes place every time an interaction, observation, measurement, or whatever fixes a state or (a) path(s) in the path integral of the universe (and its subsystem undergoing the interaction). That objects contains all the W-type multi-folds between all the spacetime locations of the universe wavefunction where it matters and between all the spacetime locations for the alternate options/states of the system, had that selection not been made. That is the full alternate universe or "other world". Per [7], the bundle of W-type multi-folds is the universe wavefunction, and the same entanglement of all the spacetime locations along with the presence of some non-zero spin particles, implies a Lorentz spacetime and hence the same universe as the "selected one", with SM (SM_G) physics. In the multi-fold theory, the spacetime is macroscopically 4D [*160*], and the 4D objects (particles or spacetime locations) sees 7D ε regions everywhere created by the multi-folds. It applies also to any of the MWI alternate world, and therefore the Physics is the same SM_G as in our world, with same symmetries [23,66,93] and multi-fold space time matter induction and scattering [23,31,53,60,66,67,212].

So, it turns out that the W-type multi-fold hypothesis, and the multi-fold deactivation mechanism explicitly encounter MWI, in the form of these AdS(5)(+…) objects. Anybody familiar with superstrings and M-theory, will see the analogy of such object with branes; of course a multi-fold version of it, as it is not (exactly) a string story. It is a lot like when we had also encountered superstrings as candidates for living in AdS(5)(+…), and possibly characterizing, from that angle, the multi-fold mechanisms as gravitons, as well as hinting with the AdS/CFT correspondence conjecture at the actually factual AdS/CFT correspondence encountered with multi-fold universes [1,14-16,18,20,58,101,102,*167,173,187*].

More work may be warranted on this, but, a priori, we can immediately identify a difference with conventional D-branes [96]: we do not expect them to interact (gravitationally or otherwise), be aware of each other, or combine into say higher dimensional branes or packed branes: because the multi-fold brane-like results encountered above split from one another by collapses, and, by definition or construction, no entanglement exists any more between each other, hence no multi-fold between them. No entanglement means no gravity between them and no interaction. Also, and at the difference of other multiverse speculations, and bubble universe collisions, where interaction occurs all the time, we never observed subsequent World collisions, as this would mean merging path integral paths with paths that have not been selected. For these reasons, we assert that no interaction takes place between MWI multi-fold branes.

Yes, we are back to having very little more that could be falsifiable about what happens past the collapse, except for what we have just mentioned, and the surprise that we may have actually provided a microscopic explanation for the MWI. Doing so, in our view, we have boosted the plausibility, or even the validity of the MWI (interpretation). It is also interesting that we have re-encountered superstrings as multi-fold branes, again in a rather surprising manner, but again aligned with our view that these are unphysical, living mathematically and maybe physically in a space that has no effect on our 4D spacetime and its physics. The latter rather results from 7D multi-fold space time matter induction and scattering.

In addition to our arguments above, note that the absence of interaction comes from the fact that the wavefunction of the rest of the universe has now two identical components: one which is our reality, one which is detached and characterizes a similar universe. What happens later in the latter component has no impact on our reality.

10. More on Multiverses and their Physics

We saw that multi-fold universes, and the W-type multi-fold hypothesis, provide a microscopic interpretation for the MWI, and the appearance of Many Worlds. Doing so, we do not even have to really assume physicality of the wavefunction, only that the wavefunction is associated to a bundle of W-type multi-folds, which are real as they are bundles of spacetime extensions [1,8-10,72], and that it defines a universe wavefunction that is associated to its spacetime.

Can we also say more about the multiverse? To do so, we must be able to follow one way or another a certain taxonomy. For this, we will discuss the set proposed in [97,98]:

- The MWI falls under the category of many worlds of quantum measurements in [97], and as level 3 in [98].
    - At this stage, our paper has shown that MWI is possible in a multi-fold universe with W-type multi-folds, and we have provided a microscopic interpretation for it.
    - With the real universe, [1,5-7,63,64] could imply the same conclusions, if we also accept the W-type multi-fold hypothesis [72].
    - Such a multiverse contains many copies of everything in every possible situation and context.
- The quilted multiverse of [97], a level 1 multiverse in [98], relies on the idea that if a universe is infinite it will have multiple copies of everything, and regions with such copies, doppelgänger of others could be, even if loosely defined, considered as different multiverses, at least for [97].
    - This assumption relies on a view of ergodicity that would implies encountering any possibility of everything.
    - In a multifold universe, spacetime is at very small scales evolving as a 2D process (random walks) then a 3D process before becoming 4D at larger scales [1,6,16,31,72,103,104,*157,160,166*]. These 2D and 3D processes are in a 4D spacetime, as is the real universe [*160*]. Per Polya's random walks theorem, random walks visiting every point with a probability 1, is not possible in discrete space, as are multi-fold universe [1,6,31,32,53,60,73], with spatial dimensions ≥ 3 [105,106]. Even with finite possible combinations of configurations in the state space, there is no guarantee of encountering a copy of everything or of cosmic repetitions. Instead, the multi-fold space time matter induction and scattering ensure the same physics everywhere [23,29,54,56,66,93,*212,216*].
    - With the real universe, [1,5-7,63,64] imply the same conclusions.
    - If the universe is finite, which it seems to be as if is closed as result of the positive cosmological constant [*154,157,205*] and resulting positive curvature, that it be real or multi-fold, there is no cosmic repetitions, and the laws of physics are the same everywhere.
    - As these universes are defined as causally separated, no interaction takes place between the multiverses.
- The inflationary multiverse of [97,*215*], or universe of level 2 in [98], beyond the horizon of the universe, or if the universe started from many places instead of one.
    - Multiverses are just different regions, causally separated, of the same universes and so not interacting.
    - In a multi-fold universe, this is a possible situation where the inflation has many seeds and/or some region eternally inflate [97]. The multi-fold space time matter induction and scattering ensure the same physics everywhere [23,54,56,66,93,*212,215,216*].
        - Indeed, different physics (particles, interactions, constants, symmetries) would require phase transitions, and domain walls or regions separated by horizons. But in every regions, symmetries and particles come from the same multi-fold mechanisms. Phase transitions, as for example above or below the ultimate Unification (UU) [1,43,56,59,60,71,72], or above and below the muti-fold gravity electroweak symmetry breaking [1,29,52,53,56,59,60,72,73,*212*] change the particles and interaction presents,

not the presence or absence of multi-folds. So, in our view, the options discussed in [84] are not encountered.
        - The suggestion that different minima exists in other pockets of the universe does not work in a multi-fold universe and furthermore, we have shown that no false electroweak vacuum exists either and that ours is stable [1,47]. Even if there was another one, it would tunnel back to our values. But there are none: our universe specifies the value [107].
    - For the same reasons as discussed before, there are no multiple copies of everything in such multiverses.
    - As causally separated, no interaction takes place between the multiverses.
    - With the real universe, [1,5-7,63,64] imply the same conclusions.
- Higher dimension multiverses and strings as in [97]. It is probably level 4 in [98].
    - Multi-fold universes involve unconstrained Kaluza Klein (KK) embeddings, as discussed in [23,29,54,56,66,93,*157,212,216*]. At every point of multi-fold entry exit or mapping, i.e., at every concretized spacetime location in practice, one feels a 7D embedding ε region. It is what gives, via space time matter induction and scattering, the SM, SM_G, its constants and symmetries. The embedding universe does not really exist. It is something felt due to the multi-folds. One cannot speak of a higher 7D dimensional space where multiverses would exist, even if 7D flat geometric solitons are behind the SM , SM_G, and the SM symmetries come from 7D spacetime symmetries imprinted by the multi-fold symmetries [23].
    - Adding compactified KK or superstring dimensions at every point also does not amount to multiverses at each points, other than pictorially maybe.
    - In the real universe, [1,5-7,63,64] imply the same conclusions.
    - We have argued the challenges encountered by superstrings, supersymmetry and related theories (M-theory) [1,14-16,18,20,58,101,102,*154,157,205*]. At best, they exist in AdS(5)(+..), but are not physical to our universe. They also do not dictate the properties of spacetime and physics therein. That is dictated by (multi-fold) 7D space time matter induction.
        - Based on the multi-fold theory, superstring approximate multi-folds as gravitons or closed strings in AdS(5)+(…) [101,102].
        - Based on the previous sections, they may also approximate other Worlds in MWI with D-branes [96].
- Hovering multiverses in [96], probably also level 4 in [98].
    - In multifold-universes, we encounter MWI, with multi-fold branes for other Worlds in MWI, that can be seen as approximated by D-branes. They all have the same Physics [*216*] and they do not interact with each other. But yes, also our universe is such a brane (even without MWI).
        - There are multiple copies of everything in a MWI multiverse.
        - In branes resulting from a different model, we can't say anything.
    - In the real universe, [1,5-7,63,64] imply the same conclusions.
    - Such multiverse suffers from the same issues of superstrings, supersymmetry and M-theory discussed above: they are unphysical, i.e., not part of the real universe (or of the multi-fold universe).
        - As such it is hard to state that there are no multiple copies in different branes. It's possible but nonphysical anyway.
    - Cyclic universes as in [97] (result of collisions between branes), fall under this category. We have explained that in our view, branes as MWI do not interact. Of course, superstring based branes could, but as repeated above, this idea has problems and branes are unphysical.
        - Broader cycle universe definitions are not multiverses.
- Black holes as multiverses in [97]:

    - In [1,70,71,79,108,*154*], we encountered such baby universes through the replica trick and explaining the behavior of black hole evaporation and their lifecycle: they are the Wheeler's bags of gold proposed of the conventional approaches as in [71,108] and references therein.
    - Per our analysis in [1,70,71,108,*154*], this is probably not what happen. But if it did, such multiverse has the same physics in all its universes and no multiple copies. With a true Wheeler's bag of gold, we discuss in [71,108] how interaction is between multiverses is small, but may exist to some extent.
    - In the real universe, [1,5-7,63,64] implies the same conclusions. After all, the baby universes and Wheeler's bags of gold are introduced in the non-multi-fold conventional replica trick approaches, and unlikely [*154*].
    - Models where our expanding universe would be the interior of a black hole are not multiverses [109,110,*217-220*].
- Pure level 4: the landscape multiverse in [97] and mathematical multiverses, level 4, in [98]:
    - There is no room for the landscape in a multi-fold universe: the models of superstrings and supersymmetry are unphysical [1,14-16,18,20,58,101,102,*154,157,205*].
    - In the real universe, [1,5-7,63,64] implies the same conclusions.
    - In string theory, one could imagine a case, where level 2 multiverses, as in [98], have different compacted dimensions and geometries, resulting into different physics, with some impossible, some unstable and some, one, like ours. It is also often related to what is called the anthropic principle [97,116]: the universe is what it is because we are in it. All other possible universes with other physics or constants do not have us in them, and many may not even be possible. It is behind the string landscape and swampland model in [15] and references therein.
    - Again, because of the problems encountered by KK (See the stability issue in [111][3]), and superstrings, we consider that such theories are not physical. They are purely mathematical and do not impact the physics in our universe, for which the multi-fold space time matter induction and scattering ensure the same physics everywhere [23,54,56,66,93].
    - The answer to the question of multiple copies is the same as for hovering and cyclic multiverses. Depending on the model consider, it is possible but they are unphysical anyway.
- The broader mathematical multiverse of [98], is by definition a mathematical exercise, not a physical one, other than if one believe that anything that mathematics (consistently) model may physically exist. It is not our view. Stating that mathematics represent incredibly well our physical world does not mean that any mathematical model is a universe… Even if one wanted to stretch the idea of an infinite universe with everything happening with a probability 1 as discussed above. Quantum computing universality also does not help here [97,98,113]. It is closely related to the confusions created by GR=QM [1,14] and references therein, and the discussions of wormhole created by a chip as in [114].

If the reader does not subscribe to the bullet that we systematically repeated as "In the real universe, [1,5-7,63,64] implies the same conclusions", the reader will have to decide what to accept or object for the different multiverses above, as, as far as we can tell for now, it will be hard to experimentally validate any of these proposals any time soon. We found it already amazing that we managed to find a model supporting so clearly MWI, with multiple copies of everything, and we are quite happy to have been able to argue that the other plausible physical multiverses have all the same physics and no multiple copies.

For completeness, we should also mention the CPT universe and its anti-universe going back in time proposal [117-120] that made the news a little while ago when high energy muon neutrinos detections in Antarctica, led some to propose that it was the best situation. The ANITA observations have since been explained more conventionally. Our

[3] Note that in the multi-fold unconstrained KK case, the theory is stable thanks to the presence of fundamental fermions in the multi-folds: the right-handed neutrinos and anti-neutrinos [112].

view is that [1,8-10,22,*167,173,187*] has shown that in the multi-fold theory, entanglement and gravity may break CPT symmetry. So the need for a CPT-universe as om [117] may be moot.

So no endorsement of different domains with different physics, or of the anthropic principle and the landscape multiverse [1,15,97,116]. In our view, our analysis, and past results on strings have invalidated all these concepts.

11. Conclusions

This paper started with the humble objective to position multi-fold and MWI, and frankly with the view that MWI would probably just be an alternate interpretation, which can't be really validated. As we progressed, we have provided a microscopic interpretation for MWI indicating that the W-type multi-fold hypothesis seems to strongly imply the validity of the MWI.

We have also shown that each of the alternative worlds in the MWI can be seen as a, non-interacting, multi-fold version of branes in AdS(5)(+…), a bit like (closed) superstrings, can be seen as an image of the multi-folds in AdS(5)(+…).

In terms of plausible multiverse options, interactions do not exist from one to another multiverse, and Physics is the same in all, which closes the door to using a landscape multiverse to support the anthropic principles; possibly shattering another hope or way forward of the string community.

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