Explaining Dark Energy, Small Cosmological Constant and Inflation Without New Physics?

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Abstract:

In a multi-fold universe, gravity emerges from entanglement and spacetime is discrete, with a fractal structure based on random walk and a non-commutative geometry. When random walk is combined with maximal particle generations, exponential expansion can automatically takes place. Away from maximal generation or in an already concretized spacetime, random walk accounts for a constant or slowing down expansion. Meanwhile, the multi-fold mechanisms also implies a constant expansion potential, adding a force to the expansion of the universe, thanks to uncertainties. It explain the constant acceleration of the universe expansion with a cosmological constant that is not the vacuum energy density but can be way smaller.

It may contribute to addressing problems like the absence of any explanation of dark energy, the embarrassing orders of magnitude of discrepancies between vacuum energy and the cosmological constant predicted by conventional Physics; issues that are among Today's biggest mysteries of the universe. These explanations do not require New Physics beyond the Standard Model and the Standard Cosmology Model.

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1. Introduction

The new preprint [1] proposes contributions to several open problems in physics like the reconciliation of General Relativity (GR) with Quantum Physics, explaining the origin of gravity proposed as emerging from quantum (EPR-Einstein Podolsky Rosen) entanglement between particles, detailing contributions to dark matter and dark energy and explaining other Standard Model mysteries without requiring New Physics beyond the Standard Model other than the addition of gravity to the Standard Model Lagrangian. All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales and semi classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe). Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic blackholes (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.

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

2. Spacetime Construction

In [1], spacetime is created when it is encountered by a particle (This is also inspired from the ideas that spacetime creation may result from wave function collapse) that consists of a microscopic black hole surrounding it. As the particle moves, it leaves remnants of minimal Schwarzschild black holes as spacetime location. The effect is also inspired from [6]. We speak of spacetime concretization. With this scenario, and as result of the top down framework of multi-fold universes, [1] shows that spacetime is therefore discrete and non-commutative with particles moves as relativistic paths of the path integral describing the particles: i.e. a random walk, in space and in time, leading to a fractal structure. The random sprinkles of spacetime points and particles ensure that spacetime can be Lorentz invariant.

These conclusions from the multi-fold model are all along consistent with well know results [7,8]. But why and how these features are actually realized in spacetime were something missing, so far.

Spacetime concretization can generate new spacetime points and grow the edges of the universe. As the process is fractal in space and in time, it also leaves many non-concretized points of the underlying discrete lattice (of minimum length cells). At later times, particles can random walk on the existing concretized structure or fill gaps by concretizing points missed so far. At no time, is a minimum length (in space and in time) violated, in accordance with [5].

We will also describe bulk expansion effects.

To be complete, there are also entanglement between particles and spacetime that they concretize. These also introduce a temporary brake (with effective potential per the multi-fold mechanisms of [1]) to the expansion but limited to the duration of such entanglements. We do not use spacetime entanglement as sources of gravity as proposed in proposals where Gravity would emerge from entropy as in Verlinde's papers, e.g. [19,20]. The model in [1] is quite different from these works.

3. Big Bang and Inflation

At the beginning of our universe, that it be localized in one or a few points, across an initial region or more widely extended (as proposed for example by other infinite or parallel universe models), the energy is such that every fluctuation or particle move can both concretize spacetime and create new particles. A toy model to hint how fluctuations in spacetime can create particles and spacetime is discussed in [6].

When the energy is such that at every time jumps take place and new particles can be created (in every directions) along with spacetime concretization (reoccupied or visited for the first time), the process results into an exponential growth of the number of particles and spacetime. Bulk effects (dark energy effects, discussed later) contribute to stretch the structures at the same time which also ensures that spacetime stretches as this takes place. These early particles can be of different types, including creation and annihilation of the ones we encounter today, or essentially be all of the same as an inflaton [9]. It does not matter for our model.

In conventional QFT views, the inflaton field, a candidate to conventionally explain inflation, is homogenous throughout the universe and the total energy content of the universe grows also exponentially until it stops everywhere (or only somewhere in eternal inflation models, in such case, possibly resulting into different universe, etc.). It sets a high vacuum energy ground level and hence, per GR, a negative pressure [10], and we have inflation [11]. In a multi-fold universe, at small scales, the density of particle is initially roughly the same everywhere, which provides energy to the particles who exert a constant pressure due to that energy. That pressure is the combination of the jumps to new spacetime point and interspersed growth between points (as will continue today, as discussed later) along with the bulk effect to be discussed later. So both our model from [1] and the inflaton model essentially match. [1] works with inflaton (explaining it effect at very small scales) or instead of it.

The source of energy enabling these effects is not really explained in [1] and out of scope for this work. It is either inherent to the inflaton field (e.g. as (false) vacuum), which can also be the case for the particles only explanation (false vacuum giving always a minimum energy to every particles with no energy changes but why is it at such a level is not explained) or due to a tremendous original energy that remains so large early on that its level is essentially not affected by particle creation long enough for the exponential growth to take place as long as needed (in practice, that is also a very short time even if the expansion and stretching effects are tremendous, except in eternal inflation models where it would still be going on somewhere beyond our universe horizon). As inflatons have not yet be found or well modeled, we prefer the latter explanation, i.e. no inflation. Note that such a choice also probably negates eternal inflation models, that would need energy to continue eternally. But both sources of energy are supported.

The energy involved can originate from the everything that we do not know and that happened before the Big Bang event, including big bounces, or a vacuum collapse bubbles, or from a symmetry breaking event (and resulting phase change). For example (it is just an illustration of a possible mechanism), it could be energy released due to the break of the Ultimate Unification symmetry introduced in [1,12], as if it was a phase change of the universe. The democracy symmetry breaks as progressively more and more of the involved particles drop out from being able to contribute at the same level as carriers of massive gravity from spacetime point to point. Each time, this correspond to a conversion of energy potential of everything in the universe into kinetic energy as gravity weakened at smaller scales due to particles decrease their contribution as larger scale carriers to the massive gravity component. Note this example would be an oscillating situation as increasing energy (e.g. like inflation reheating) will bring back the particles that just gave up as gravity carriers, until they drop out again). It evolves like this particle type per particle type till inflation stops.

When there is no more enough energy to sustain both systematic spacetime concretization and particle creation, the inflation progressively die out. Again all this takes a very short time.

After that, random walks continue and particles (virtual and real) can revisit already concretized spacetime point or concretize new points. In addition. Expansion also continue as discussed after. These effects are now the dominant contributions for expansion, albeit countered for a while in the battle for universe dominance by attractive gravity that fights off expansion and balances a significant part of the expansion effects, for as long at matter and energy clusters are close enough: until distances become too large between clusters and expansion start to really dominate and accelerate. Our universe is now in that phase.

4. Dark Energy? Maybe not so fast…

Dark energy is proposed as a way to explain the observed expansion and now observed accelerated expansion of the universe. Good entry points can be found at [13,14].

Cosmological expansion is conventionally modeled by the cosmological constant in GR [16]. In QFT and superstrings, this leads immediately to major issues. QFT predicts a vacuum energy density that leads to a cosmological constant that is 10^{120} larger than what is observed [16]. It is hardly a small adjustment issue! There is clearly a problem or something is missed by conventional Physics.

New Physics is not faring much better, as discussed in [15]: superstrings are not stable (i.e. they cannot live) in positive cosmological constant universes [17]; while GR is unstable with matter in AdS [18]. [15] explains how this is in fact consistent with multi-fold universes [1] and our deducted superstrings dualities. For the purpose of discussion here, it only matters in the sense that New Physics has no helpful say about the cosmological constant problem!

A zero cosmological constant may help with superstrings (and for many supersymmetric theories). However, again it does not match physical explanations or observations of accelerated expansion, granted that, as mentioned in [1], some recent papers are still revisiting and questioning if there is indeed such an acceleration.

This situation is not just an open problem but one of the most embarrassing problem for modern Physics. There are no other ways to put it. Today, we have no clue.

Yet in a multi-fold universe:

i) A small positive cosmological constant (generating negative curvature contributions are not supported by the multi-fold mechanism, which also explain why superstrings cannot, and do not, live in our spacetime [15]) can be explained
ii) It is independent of the QFT energy vacuum density
iii) And the explanation is without involving any New Physics other than adding gravity to the Standard Model in a multi-fold universe.

Indeed, expansion of the spacetime comes in two flavors:

- Random walks, business as usual, that revisit existing spacetime point and fill the gaps in the spacetime fractal structure or pushes the edge. It is not a dominant bulk effect expansion but it has a small contribution to the cosmological constant.
- Constant effective potential pressure everywhere towards AdS(5) resulting from uncertainties of entangled particles, that generate attractive effective potentials between them. [1] shows that, as the particles wiggle because of quantum uncertainties, the folds and mappings can create, within the bulk, effective potential pulls towards the bulk, (which amounts to normal random walk acceleration) or towards the outside spacetime, which is a bulk expansion effect a always present force (because of uncertainty that component always consistently exists): we have found a dark energy effect, without any dark energy involved, that also contribute to the cosmological constant. Fluctuations creates the effective potential due to entanglement; fluctuations are not the energy that expand, it the effective potential that expands; therefore decoupling the cosmological constant value from the energy density of the vacuum.

This second effect is between entangled particles, real or virtual, but therefore, slightly more pronounced within or around matter or energy clusters (where more energy fluctuations may be encountered and also because pulling out towards AdS(5) will happen more often where spacetime is curved by matter). Yet, it exists everywhere as vacuum virtual pairs also contribute. Its intensity is related to the vacuum energy levels as well as the energy content of the entangled particles. It is not the vacuum energy density and it is expected to be a way smaller contribution, but omnipresent in spacetime. This way, we are able to solve the cosmological constant problem. It also weakens the arguments for an anthropic principle (to explain the cosmology constant), which in turns weakens reuse of such a principle to justify parallel universes and the "expected" existence of large superstring swampland and landscape (maybe – not that certain now that the landscape needs to be a positive curvature universe [15]).

The arguments in [1] are only qualitative, not yet quantitative. More work is needed to see if quantitative estimates make sense and may suffice to explain dark energy. Of course, other effects can also play along.

Also, this analysis is for a Multi-fold universe as in [1]. [1] details arguments and ways to check its relationship with the real universe. Besides properties that can be experimentally verified (in the future because of the macroscopic weakness of gravity and gravity like effects for entangled systems), [1] shows how the multi-fold mechanisms and behaviors are in many aspects in today's conventional physics, that, at times, anticipate the behaviors modeled in a multi-fold universe. In addition, [1] potentially explains many results obtained in gravity, quantum mechanics, General Relativity, superstring theory, Loop Quantum Gravity and the AdS/CFT correspondence conjecture. All these works attempt to come up with models for the real universe. It is at least a good sign that [1] may provide an interesting model of the real universe.

Our proposal has no equivalent or variations for non multi-fold universe: the source of dark energy effects come directly from the multi-folds mechanisms as proposed in [1]. Even other models that link entanglement and gravity would most probably not help as the multi-fold universe does.

The fact that dark energy and cosmological constant issues are confirmed (so far) by observations, yet unexplained, indicates one possible small step in favor of this subject helping to validate the models proposed in [1].

5. Conclusions

We believe that [1] makes a compelling case for the consistency of its multi-fold proposal. The present paper shows how the mechanisms of multi-fold universes can help address the challenges with dark energy and with the cosmological constant.

The model also has the ability to further explain the expected discrete and noncommutative (Lorentz invariant and fractal) nature of spacetime and to support inflation (with or without inflatons).

While steps in the right direction in terms of validating [1], future work should aim at providing quantitative estimates to further determine viability of the proposal or completeness of the explanation, versus just contributing to what happens, which would already be satisfying.

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