Spacetime and Gravity are 2D around Planck Scales: A Universal Property of Consistent Quantum Gravity

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Abstract:

This short paper shows that General Relativity (GR) combined with Quantum Physics implies spacetime and quantum gravity with 2D degrees of freedom at very small scales.

The result is obtained independently of any other assumption on the underlying theory of quantum gravity other than the existence of quantum fluctuations, the formation of black holes if masses or energy sources are very high, and the properties of interactions with and among Black holes.

Implications include universality of particles as microscopic black holes, asymptotic safety of quantum gravity for consistent theories and physical justifications, and hints of a physical justification for chirality of spacetime, and massive fermions/particles; something that will be exploited to explain the early universe, and the absence of GUTs in upcoming publications.

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1. Introduction

In [1], we derived that at very small scales, quantum gravity and spacetime appears as 2D processes, then 3D before being 4D at larger scales. It results from the random walks introduced as part of the spacetime reconstruction phase.

We relied on this result to assert that quantum gravity is asymptotically safe in multi-fold universe [2,3]. Then, relied on the quasi-universality of 2D regimes in quantum gravity theories, as in [4,5] with the caveats of [6] for [5], to justify that 2D regimes, and asymptotic safety are universal and not limited to multi-fold universes [2,3].

In the present paper, we show that such a 2D regime is in fact entirely derivable simply from basic combination of GR and Quantum Physics. When semi-classical, the emerging microscopic black holes and their interaction qualifies how 2D comes into play and hints at the apparition of chirality of spacetime.

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2. Universality of Microscopic Black Holes at High Energy or Small Scales

It is possible to show with GR (General Relativity) and Quantum Physics that Asymptotic Safety can be achieved. This is obtained as follows:

- Quantum introduces uncertainties and fluctuations.
- At very high energy, and hence very small scales, fluctuations will have very specific results, according to these theories. 2 options should be considered though:
  - At the beginning of the universe, i.e. coming from a high temperature environment, fluctuations results into tiny curvatures of spacetime, or very high energy massless particles (pairs) (or their excitations): we are above the electroweak symmetry breaking energy: most effects involve massless particles. If with spin (rotating), and / or charged, they will be close to extremal. Any massive fluctuation will certainly be extremal when rotating (i.e. with spin), with the state spin 0 particles possibly seen as combining opposite spin effects (except for the massless Higgs that does not rotate at all and are rather a (minimum) Schwarzschild black hole). So this covers any particle that is not massless (i.e. associated by fluctuation with the Higgs field before electroweak symmetry breaking), or the massive Higgs (i.e. Today's Higgs boson associated with Higgs field post electroweak symmetry breaking).
  - In later epochs, e.g. post electroweak symmetry breaking and mass acquisition, at very small scales, fluctuations will again appear as very temporary particles / excitations of massive or massless particle (pairs) in a possible background spacetime. Extremality is similar.
- So high energy and/or small scales quantum fluctuations in energy content / spacetime , result in microscopic black holes that are the virtual, or sometimes physical, particles. Interactions at these scales are in and with a spacetime filled with black holes that are extremal, beyond extremal or at least close to it, depending on the model [12].
- In [1,7], we detailed how, in fact, which is a consistent proposal in a multi-fold universe[2]. It was based on [8-11] that illustrate plausible consistency in conventional non-multi-fold models. In all cases the challenges of singularities or rings of singularities are addressed, and avoided by solitons (of Higgs) with superconducting edges that hide these effects and regularize the solutions; but externally everything appears as black holes.
- These black holes will interact mostly through scattering, which we know are matching particle interactions, when using Kerr-Newman or Reissner-Nordström metrics [1,7,17,18,22]. It also applies to Schwarzschild metrics modeled as limits to charge and rotation going to zero, or seen as sum of two black holes which rotate in opposite directions.

This result was already hinted in [13,14].

3. Universality of 2D processes at High Energy or Small Scales

The interactions, described in section 3, are mostly black hole to black hole (higher scale/lower energy objects rather providing the semi-classical curvature background). These are essentially 2D processes, because interacting or orbiting a Kerr-Newman, Reissner-Nordström, or in the limit Schwarzschild blackhole, amounts to a 2D CFT model [1], as scattering become elastic and massless boson walks (e.g. massless Higgs) are modeled by 2D CFT [25].

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[2] Conversely, this reasoning also motivates [1,7]: even without the multi-fold theory, or the analyses of [8-11], it is clear (too much energy for a given volume) that particles (physical or virtual) end up existing as microscopic black holes for very high energy fluctuations. In itself, it motivates our models of particles as microscopic black holes.

As a result, we recover the spacetime conclusions of [1-3] about gravity and spacetime behaving as 2D processes at very small scales. The result does not depend on any particular considerations coming from particular QFT models, and certainly without any superstrings or other quantum gravity considerations.

It was also hinted at in [14,17-19][3]. As described in [6], even [13] arrived at that results with its model of dimension reduction at very smalls scales, where effects are dominated by massless particles under our current considerations. [4] compiles a set of quantum gravity theories agreeing with this 2D process outcome; therefore confirming universality across models, and / or a criteria for suspicion of theory that do not produce such an outcome.

Another derivation, showing universality across theories can be found for example at [24], and many others, universal or bound to a model, can be found as papers or remarks in the literature.

4. Some implications

4.1 Universality of asymptotically safe Quantum Gravity

The fact that 2(+ε)D is asymptotically safe, see e.g. [20-21], proves universally that, no matter what the theory of quantum gravity, under consideration, is, to be correct, it will have a 2D regime, and, therefore, it must be asymptotically safe. Arguing that it is not, as has been widely done in the literature (See references in [2,3]), means that such models are relying on incorrect or incomplete quantum gravity models, or assumptions. Of courses as already widely discussed in [2,3], these have significant implications for superstrings, supersymmetry, M-Theory and many popular GUTs (Grand Unification Theory) and TOEs (Theory Of Everything); reducing for example their plausible physicality to the 2D regime, in the best case for superstrings or supersymmetry, and that is in fact no guarantee to be consistent either[4].

The analysis and relations to microscopic black holes, in conjunction with models like [1,8-11] provide physical justifications of why quantum gravity is physically asymptotically safe [3,6]. Ironically, an opposite result from the one obtained by [14], that was also using microscopic black hole as models for trans-Planckian events.

Note added on October 31, 2022: More discussions of 2(+ε)D asymptotic safety can be found in [28]. A non-perturbative proof of asymptotic safety in 4D is provide in [29].

4.2 Chiral massive fermion, Chiral spacetime and more

Furthermore, for external microscopic black holes, we see that the modeled spacetime, and massive fermions and bosons are chiral [15,16][5], when involving extremal blackholes: anything near an extremal (spinning) black hole

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[3] [17-19] add to [1,7]: particles, modeled as black holes produce only few particles, not larger black holes. This also matches the observation and models of particle physics, instead of black hole mergers, resolving what otherwise might be an objection to our proposal.

[4] Indeed, the reduction to 2D is a dominant process statement, not an implication that spacetime is actually 2D. As such [2,3] (and references relied upon) probably limit superstrings and superstrings as, at best, approximations of the 2D regime and not actually a better model than QFT or certainly not better than our multi-fold reconstruction models [1]. We know that as scale increase it will appear 3D then 4D and continuous. The reason for 4D spacetime is discussed in [1,26].

[5] Black holes are modeled isolated in [15,16].

must spin with same chirality as the black hole. This is also what orients spacetime as discussed in [1,7,27]. *Note added on 10/31/22: See also [30].*

This result will be exploited in an upcoming paper (to be posted at [23]), to explain chirality of massive particles (fermions and bosons), and the interactions such bosons carries (weak) and rewrite the history of the early universe in terms of its high energy symmetry breakings. In future works, we will also explain why GUTs do not exist.

5. Conclusions

We have proven the universality across consistent quantum gravity theories of particles as microscopic black holes, spacetime, and gravity at very small scales as 2D processes, asymptotic safety of such quantum gravity and unavoidability of chirality of spacetime and massive particles, fermions and bosons. At larger scales, it goes to 3D then 4D.

Upcoming work will show how in the context of multi-fold universes, this can rewrite the history of the early universe, and address the challenges of the absence of any hint of GUTs and TOEs.

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