Quantum Gravity from the point of view of covariant relativistic quantum theory.

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Abstract

In the light of a recent novel definition of a relativistic quantum theory [1, 3, 4], we ask ourselves the question what it would mean to make the gravitational field itself dynamical. This could lead to a couple of different viewpoints upon quantum gravity which we shall explain carefully; this paper expands upon some ideas in [2] and again confirms ones thought that we are still far removed from a (type one) theory of quantum gravity.

1 Introduction.

The search for a theory of quantum gravity is one of new principles of nature and involves the question if and how the superposition principle should be applied to spacetime itself. It has taken me a while to convince myself that an operational approach towards this question is a dead one and that quantum theory should be reformulated in a geometric language. Recently, I have done so [1, 3, 4] and have proven a *deformation* of the theory, defined as a series of Feynman diagrams, to be *finite* (analytic) for a suitable range of the coupling constant. Not only did I not require an infinite renormalization of the parameters of the theory, but the entire deformed series converged as well [3]; this remarkable result relied upon a few novel physical insights which the reader might want to learn about in the respective publications. Crucial in this entire story was the presence of a classical spacetime metric and therefore, a quantum theory of the spacetime metric appears to call for a super metric: a metric on the space of all Lorentzian geometries. Those, who keep on insisting upon a Feynman integration theory are facing the question of the canonical character of the "measure" where the latter has to be understood in some limiting, rather than a fundamental, sense since the space of all spacetimes is not locally compact in any known Hausdorff topology. This is not the only worry one has regarding such discrete constructions: one has also to show that the limiting kinematical configurations are arbitrarily close to any classical spacetime in a suitable sense implying that the action principle at hand converges too. There is a very important distinction here between gravity and all other action principles in field theory, which is that the latter all depend upon first derivatives only while the former depends upon second derivatives of the metric field. There is,

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a discretization procedure invented by Regge, which can account for the second derivatives in a distributional sense but it requires flexibility in the degrees of freedom of the discrete structure (a simplicial manifold) so that, locally, on the $n-2$ simplices, where n is the dimension of the simplicial manifold, the deficiency angles go to zero sufficiently fast. The "curvature" of the approximating simplicial manifolds then converges to the Ricci scalar in a weak distributional sense. I am unaware of any suitable substitute for the Ricci tensor and Riemann curvature in this kinematical framework. I am also unaware of any approach to quantum gravity which manages to offer a suitable answer to these elementary matters of principle: the measure in the causal dynamical triangulations approach heavily depends upon the kinematical restrictions which, moreover, do *not* approximate any classical spacetime. Indeed, not only is it clear that Regge's scheme does not apply, the "local" curvature is a diverging quantity in the distributional sense when the continuum limit is taken.

What I have described above can be called "quantum gravity type one" where there is no classical metric background on which computations are performed. One can of course maintain that the universe consists also out of classical degrees of freedom providing one with a dynamical classical background on which it is possible to regard the quantization of the gravitational force as the quantum theory of a spin two particle. This can be called "quantum gravity type two"; such a theory has long been believed to be impossible due to the non-renormalizability of the gravitational force on a Minkowski background. It his here that our novel nonunitary quantum theory may offer a way out since the theory is finite, a result which does not depend at all on the structure of the Feynman diagrams as has been shown in [3]. In particular, loops played no special role at all in our analysis and were treated on pair with other internal legs which shows that quantum gravity type two is a perfectly safe theory in our framework. A detailed proof of this statement awaits further publication aimed to elucidate the power of our framework. So, this paper is about quantum gravity type one, not type two which is a theory in our hands.

2 Quantum gravity type one.

Personally, I have never made a choice between both types, both reflect different world views, which in my opinion were equally valid, see a philosophical account [2] on the matter. The fact that type two did not seem to work out technically has always been regarded by me with the necessary amount of scepticism since in my opinion, QFT did not work for QED nor the standard model either. Only sloppy and overprotective field theorists could take something like that seriously, but I was rigorous and not even protective regarding my deepest beliefs. So I have always felt that on the level of relativistic particle theory, we were lacking a few crucial insights, see [2, 1, 3, 4] on that account. What I knew already for a long time was that ultimately type one was going to be the most difficult to realize and I see no objection why our novel fremework shouldn't realize a type two theory for suitable backgrounds. I will come back to that issue in a forthcoming publication given that some other things have to be straightened out first in our approach. These notes are about obstacles one will meet regarding the formation of a type one theory, but a real theory, not just something we can all pull out of our hats within five minutes but which lacks canonical beauty and predictive power.

In our approach so far, there are two remaining open questions (all others have been answered thoroughly): (a) what is an appropriate substitute for unitarity (b) why should local gauge invariance be a principle of nature? In particular, why should ghost particles show up in the theory and why should the interaction structure be limited in some peculiar way? I have at this point no good answer to those two, but maybe future investigations will elucidate these matters. The confusion around these topics is, in my opinion, the work of an entire generation of post war physicists who did abandon mathematical rigour culminating in the renormalization generation of 't Hooft and Veltman. It is not gratuitious that these gentlemen are Dutchman as indeed it requires some form of talent to sell Heineken, one of the world's worst beers and secondary to any Belgian beer, to the public. The same holds for their renormalization results, they have a flair of mathematical ingenuity, but deep down it is all arbitrary nonsense. As I have shown [3], they have been missing quite some important *physics* which evaporates the distinction between non-renormalizable and renormalizable theories. Indeed, I may speculate already at this point that quantum gravity type two is *not* going to have anything to do with supergravity and supersymmetry in particular. Good, let us return to type one which is further ahead of us.

Here, one immediately faces a couple of problems regarding the fact that standard formulations of quantum mechanics are *not* covariant. This is seldomly highlighted, but the problem is really everywhere: in the path integral approach, it is in the non-covariance of the measure, in the Heisenberg approach, it resides in the non-covariance of the total Hamiltonian and therefore the vacuum state, and finally in the Schrodinger approach, it is blatanly visible because the probability density does not transform as a density under coordinate transformations of space. For examples and more in depth comments regarding those issues, see [2]. In field theory for example, one will obtain that distinct lattice regularizations, in either different choices of "measure", will give rise to different continuum limits and we wish physics to be devoid of such ambiguity. In that respect is our quantum theory generally covariant: it does not depend upon geometrical structures or coordinate choices which have to be imported. There is no choice of vacuum state, no Hamiltonian, no measure, everything has been poored in a manifest spacetime language. This, of course, is a great starting point for some ideas regarding a quantum gravity type one theory to mature. So, up till now, *every* approach to quantum gravity suffers from one of these drawbacks: in the discrete theories based upon the Feynman path integral, such as causal sets and causal dynamical triangulations, one remains with the choice of the measure associated to the particular regularization scheme. Some researchers accept this as a fact they have to live with, most of them are not even aware of the issue.

So, how can we extend our novel line of thought to spacetime itself? For example, how to define the momenta of the theory which have to serve for a gravitational uncertainty principle and what are the constraints upon the momenta replacing the on-shell mass condition for relativistic particles? Clearly, in a continuum theory of the universe some infinite dimensional integration would have to be performed which again will lose its appeal through the noncanonical character of the limit of measures (the limiting measure does not exist). Hence, if one were to have to define a quantum theory for the gravitational field, one should resort to the choice of a preferred discrete structure as being really there and not just being some approximation to the continuum situation. This is the main reason why I have always thought a quantum gravity type one theory to be discrete in some sense; a feature which is not mandatory at all in our setup for the type two graviton theory.

In a discrete universe, one obviously does abandon local Lorentz covariance in a well defined sense, albeit this does not need to have disastrous implications upon the physics defined on it. It is an important kinematical question to ask oneself how close two (discrete) universes are and I have adressed this question in my PhD work [5] where I have defined and investigated to some extend a Gromov distance on "Lorentz geometries". Albeit I have been very humble about the applications of this work in the past, given the recent importance of the metric in defining quantum theory, it occured to me that this Gromov distance could be of direct physical significance too when defining geodesics and therefore the Fourier transform on a space of spacetimes. This could even be calculated exactly for finite universes albeit it would become a very complex task to do so when considering large universes. Apart from the technical complications associated to such scheme, there is an immediate philosophical issue regarding the Riemannian nature of this Gromov super metric. Why should it not be a Lorentzian one albeit the natural criterion for closeness immediately leads one to a Riemannian instead of Lorentzian structure. In the latter case could one entertain concepts such as the "cause of causality" where, as explained in [2], it would be better to speak about the evolution of properties rather than causality. Strictly speaking, there is no need for time in the evolution of geometries since time already lives inside the universe, so a Riemannian distance will do just fine.

I can ensure the reader that the Gromov distance is canonical and given the finiteness of the space of kinematical structures, we should obtain a fairly unique definition of the Fourier transform which allows one to define the quantum theory. In a sense, this "weakens" my objection against the rather arbitrary character of the quantum measure by means of choice of a kinematical regularization scheme, given that we have chosen here some finite structures ourselves in the construction of the theory. Of course, the choice of measure has still many more degrees of freedom than merely picking out a kinematical structure as often the uniform measure does not provide one with suitable convergence properties. Moreover, as we did notice in [3], unitarity is dead which supports the idea that the quantal measure will not be obvious or canonical either. Therefore, our scheme appears to have the least amount of freedom and to be the most canonical possible. These considerations immediately imply that a quantum universe can have only a finite extend and that therefore, the full universe needs to have classical components. So, our type one quantum theory also leads one to consider a classical-quantum universe, see [2] for further thoughts about these issues.

3 Conclusions.

The intention of this short note was to highlight how our novel covariant quantum theory solves the issure of nonrenormalizability of the graviton theory and offers a new perspective on quantum gravity type one as well. Both of these facts deserve to be mentioned since they are somewhat remarkable; of course, prior to making all these issues concrete, further investigation of our theory should be made. In particular, we will first adress the issue of QED on a general background as well as non-abelian gauge theories. But sometimes, it is good to express ones vision which may stimulate other researchers to join you on this path. People interested in learning why the operational approach is a dead one technically should consult [6], this work still contains many other ideas which I still stand by, especially regarding consciousness and the arrow of time. It shows pretty clearly how the construction of a covariant Heisenberg type theory leads to a myriad of technical problems.

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