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Ihr Zeichen
Ihre Nachricht vom
Unser Zeichen

Erlangen, January 7, 2016

Subject: Report on the thesis of Mehdi Assanioussi

Dear colleagues,

I was asked to report on the PhD thesis

New Dynamics for Canonical Loop Quantum Gravity

submitted by Mehdi Assanioussi. I find that the thesis presents a set of new and important results and it is definitely up to the standards that one should uphold for a PhD thesis. My detailed report is below.

Assanioussi's thesis makes progress in implementing the constraint equations of general relativity in loop quantum gravity, an approach to the quantization of gravity. While this sounds fairly technical, it is important progress. In a Hamiltonian formulation of general relativity, the constraint equations play a double role. On the one hand, they encode the content of Einstein's equations and thus the dynamical law of gravity. On the other hand they express the invariance of the theory under changes in the Hamilton formulation due to changes in the spacetime split, i.e., they insure general covariance. Thus they are of paramount importance in the theory, and consequently in any attempt to quantize it.

The most complicated of the constraint equations in general relativity is the so called Hamilton constraint. Therefore it was seen as a breakthrough when it was shown in the 90's by Lewandowski, Thiemann and others, that this equation could be formulated and solved in loop quantum gravity. There were however persistent doubts as to the consistency of this formulation. On the one hand, it was not straightforward to check the anomaly freeness, i.e., general

covariance, since the formulation relied on the other constraints already being solved. On a more technical level, it was not straightforward to find a selfadjoint quantum constraint. Finally, the action was extremely complicated since one part of the constraint could only be quantized in a rather indirect way.
These questions are central for LQG but little progress has been made up until recently. Part of the problem is that some of the issues are the technically highly complicated. The thesis under consideration represents real progress in this area. In my opinion, the three key insights that are presented are as follows:

1. The quantization of the Hamilton constraint in the thesis starts from formulation using spatial Riemann curvature: This allows quantization in a direct way, leading to a simpler operator. There are additional benefits I will describe below.
2. A different Hilbert space and a different regularization are used in the thesis: As a result, symmetric constraint operators are easy to obtain, anomaly freeness may be checked in a stronger sense, and a systematic exploration of solution space is simplified.

These insights apply both, in case of pure gravity, and to gravity with matter. In the latter case it is possible to deparametrize the theory and obtain a genuine Hamiltonian that generates time evolution. For this case the thesis

3. develops a perturbation theory that allows to obtain the spectral decomposition of the Hamiltonian starting from that of the curvature operator. This is of great practical importance.

The thesis contains many further insights. Examples are: A new way to treat inverse volume, and complete avoidance of the volume operator in the case of the deparametrized theory. A method to quantize square roots of certain sums of densities of weight 2 (section IV.2.2.1), proof of anomaly freeness of the constraint operator (section III.4.1) and the beginning of an analysis of the solution space in the pure gravity case (section III.4.2).
The thesis also contains some examples for numerical calculations. These are interesting in their own right and also nicely illustrate the potential of the new developments: They are only possible because of the local nature of the Lorentzian part of the constraint which is obtained by using Riemann curvature (see 1. above).

The results of the thesis are free of errors as far as I can see. They have been partially published in three publications. The presentation in the thesis is clear and concise. This is not an easy feat given the nature of the material.

The results, taken together, open the door for future development, thus the title of the thesis seems quite fitting to me. A further classification of the solution space (pure gravity case), and a numerical investigation of the spectrum of the Hamiltonian (with scalar field) are now in reach. The use of Regge calculus might also make it easier to make contact with the covariant approach to loop quantum gravity (spin foams).

There are certainly open questions raised by the material in the thesis, for example about the meaning of the solutions of the constraint with zero volume, or about the fact that the scale in the spectrum of the curvature operator is very high. But it is natural for such questions to arise, given the amount of new material presented, and further work will clarify such issues.

In summary, I find that the thesis presents a set of new and important results and it is definitely up to the standards that one should uphold for a PhD thesis.

I hope this report is helpful for your purposes. If you have any questions regarding my report, please do not hesitate to contact me.

Yours sincerely,

Prof. Dr. Hanno Sahlmann