Quantum Gravity: Motivations and Alternatives

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Abstract

The mutual conceptual incompatibility between General Relativity and Quantum Mechanics / Quantum Field Theory is generally seen as the most essential motivation for the development of a theory of Quantum Gravity. It leads to the insight that, if gravity is a fundamental interaction and Quantum Mechanics is universally valid, the gravitational field will have to be quantized, not at least because of the inconsistency of semi-classical theories of gravity. The objective of a theory of Quantum Gravity would then be to identify the quantum properties and the quantum dynamics of the gravitational field. If this means to quantize General Relativity, the general-relativistic identification of the gravitational field with the spacetime metric has to be taken into account. The quantization has to be conceptually adequate, which means in particular that the resulting quantum theory has to be background-independent. This can not be achieved by means of quantum field theoretical procedures. More sophisticated strategies, like those of Loop Quantum Gravity, have to be applied. One of the basic requirements for such a quantization strategy is that the resulting quantum theory has a classical limit that is (at least approximately, and up to the known phenomenology) identical to General Relativity.
However, should gravity not be a fundamental, but an induced, residual, emergent interaction, it could very well be an intrinsically classical phenomenon. Should Quantum Mechanics be nonetheless universally valid, we had to assume a quantum substrate from which gravity would result as an emergent classical phenomenon. And there would be no conflict with the arguments against semi-classical theories, because there would be no gravity at all on the substrate level. The gravitational field would not have any quantum properties to be captured by a theory of Quantum Gravity, and a quantization of General Relativity would not lead to any fundamental theory. The objective of a theory of 'Quantum Gravity' would instead be the identification of the quantum substrate from which gravity results. The requirement that the substrate theory has General Relativity as a classical limit – that it reproduces at least the known phenomenology – would remain.
The paper tries to give an overview over the main options for theory construction in the field of Quantum Gravity. Because of the still unclear status of gravity and spacetime, it pleads for the necessity of a plurality of conceptually different approaches to Quantum Gravity.

Keywords:	Quantum Gravity, Covariant Quantization, Canonical Quantization, Loop Quantum Gravity, String Theory, Emergent Gravity, Emergent Spacetime, Pregeometry, Quantum Causal Histories
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