# On Simultaneity and Quantum Gravity

**Antoine A. J. van de Ven**
University of Twente, Enschede, The Netherlands
E-mail: antoine@vandeven.info

**Abstract.** It is proposed that a space-time theory with absolute simultaneity may help with the formulation of a consistent quantum theory of gravity. First it is shown that the proposed theory is in almost all ways equivalent to special relativity and general relativity. But because it allows non-local causal effects it is more compatible with quantum mechanics. A causal, observer-independent quantum theory of gravity that builds on the Wheeler-deWitt equation can be constructed by using the concept of absolute simultaneity.

## 1. A Space-Time Formalism with Absolute Simultaneity

In [1, 2, 3] a space-time theory was presented that was derived from the following axioms:

-Homogeneity and isotropy of space and time (linearity)

-Absolute simultaneity. Events that are simultaneous in one frame are also simultaneous in another frame.

-At least in directions perpendicular to the direction of the motion, lengths do not change.

-The roundtrip-velocity of light in vacuum is a constant (c) in inertial frames.

This leads to a theory that fits within the generalised synchronization convention of Reichenbach $T_B = T_A + \varepsilon\,(T'_A - T_A)$ where in our theory $\varepsilon$ has the frame and direction dependent value $\varepsilon = \frac{1}{2}\left(1 + \frac{\aleph}{c}\cos\alpha\right)$ where $\aleph$ can be interpreted as the velocity relative to a preferred frame and $\alpha$ indicates the angle relative to the direction of this velocity.

We can use our concept of a single universal instant to rewrite Einstein's field equations with the coordinate $T$ for which we have absolute simultaneity. This results in the ADM-formalism with a foliation at time $T$. For flat spaces the metric in our theory is equal to the ADM-metric with the shift vector $N_i$ (as defined by the ADM-formalism) equal to our velocity $\aleph_i$, and the lapse $N$ equal to $\pm 1/\sqrt{1-\aleph^2})$, which we assume to be positive for matter and negative for antimatter (and could allow for negative mass [2]). According to Reichenbach and the ADM-formalism the outcomes of experiments are independent of the choices for $\varepsilon$, the shift vector and the lapse, and this also explains why our theory is equivalent in so many ways.

Another way to show this is by using slow clock transport to synchronize clocks. By analysing the behavior of those clocks in our theory and using the shifted and local times $t(\vec{x}) = T - \vec{\aleph}\cdot\vec{x}/c^2$ caused by slow clock transport as new time coordinates, we derive the Minkowski metric and the Lorentz transformation when using those coordinates.

## 2. Quantum Gravity

To get another interpretation and formulation of relativistic quantum mechanics, we propose the following heuristic:

Reformulate the theory so that imaginary or complex equations and quantities are replaced by equations with real functionals. The number of equations and quantities will increase, but the results of the theory will be identical because it is only a mathematical reformulation. It is a heuristic method to get a new interpretation and formalism. Bohm probably used this method to get to the causal interpretation, but we can also use it for quantum gravity, in combination with our theory.

The standard way of quantizing the Hamiltonian constraint of general relativity in the ADM formalism leads to the Wheeler-DeWitt equation in which time does not appear explicitly. In our theory there is a unique time-slice which has absolute simultaneity and we use that to do the time-splitting to get to the ADM metric and the Wheeler-DeWitt equation. By replacing the complex wavefunction $\psi$ of the universe that appears in the Wheeler-DeWitt equation by $\psi = Ae^{iS}$, where $A$ and $S$ are real functionals, we can split and rewrite the Wheeler-deWitt equation into equations with only real functionals. This leads to a conservation law and an equation that looks a bit like the Einstein-Hamilton-Jacobi equation, but includes a new term for quantum effects.

With our theory of absolute simultaneity we can say that the universe has a definite 3-geometry and 3-metric $g_{ij}(\mathbf{x}, T)$ at each instant, where $T$ is our time-coordinate defined by our theory with absolute simultaneity and so what we mean with instant is absolute too and applies to the whole universe and is unique. The Wheeler-DeWitt equation holds for a specific instant, but contains no time evolution by itself. But in our formalism we can now apply classical Hamilton-Jacobi theory to get the evolution of the 3-geometry:

$\partial g_{ij}(\mathbf{x}, T)/\partial T = \partial_i N_j + \partial_j N_i + 2NG_{ijkl}\delta S/\delta g_{kl} \Big|_{g_{ij}(\mathbf{x})=g_{ij}(\mathbf{x},T)}$

Note that the initial geometry at a certain instant needs to be specified to calculate the evolution. With our theory we have a unique instant and so also a corresponding geometry at each instant indicated by $T$. Note that it doesn't work with any relativistic local time coordinate $t$ which is frame dependent and also leads to other problems. In combination with the the other equations we derived, Einstein's equation can be derived with the difference that it now includes an extra term on the right hand side that describes the effects of quantum gravity.

Holland [4] also described similar ideas for quantum gravity. He mentioned several assumptions and requirements that are needed to be able to make it work, like here, but most of those do not fit with the standard relativistic theories and viewpoints and when they are not valid or unresolved there is no correct derivation or consistent theory. Here it is proposed that our theory with absolute simultaneity makes it work and makes it possible to derive a consistent theory of quantum gravity in a similar way. In our theory the mentioned assumptions are true and the requirements are fulfilled. It can also describe the non-local effects without problems or causality violations [3], so by combining it with our theory with absolute simultaneity we have formulated a consistent quantum theory of gravity. Many things can be calculated and predicted with this theory and it is proposed to try to falsify these predictions with experiments and observations.


[1] A.A.J. van de Ven, The principle of absolute simultaneity: Testing the conventionality of simultaneity, The First International Conference on the Ontology of Spacetime, Concordia University, Montreal, Canada, May 11-14, 2004.

[2] A.A.J. van de Ven, On Absolute Simultaneity and Negative Mass, Master's Thesis, Utrecht University, 2007.

[3] A.A.J. van de Ven, Superluminal signal velocities without causality violations, The Third International Conference on the Nature and Ontology of Spacetime, Concordia University, Montreal, Canada, June 13-15, 2008

[4] P.R. Holland, The quantum theory of motion (Cambridge Univ. Press, Cambridge, 1993)