The Derivation of Quantum Gravity without Additional Theory

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Abstract:

The well-proven principles of special and general relativity are permitting the derivation of the answer to the eighty-year-old question how general relativity may harmonize with quantum mechanics.

The solution is mainly found in a physical theory where it was not expected: Special relativity does neither discuss gravity nor quantum phenomena. However, it is the relative spacetime concept of special relativity which is considered to be incompatible with the absolute concepts of quantum mechanics for space and time.

The new approach is based on the discovery that the postulates of special relativity impose not only the relative concept of spacetime, but also absolute concepts for time and for space which are underlying relative spacetime. These absolute concepts reveal to be compatible with the absolute space and time concepts of quantum mechanics, and they are indicating the way how to apply the gravity concept of the Schwarzschild metric within quantum mechanics: Quantum gravity happens on particle level, not by quantization of spacetime.

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1. Introduction: Relative spacetime and the underlying absolute concept

Newton's absolute spacetime was replaced by Minkowski's spacetime concept which is only relative, that means observer-dependent: The point of view of each observer is at the coordinate origin of his own fourdimensional spacetime manifold representing the universe.

We will show that special and general relativity are providing not only relative spacetime but also the underlying observer-invariant concept, which is built on the absolute concept of proper time of mass particles. Where the relative spacetime concept failed to provide a theory for quantum gravity, the absolute concept as the more fundamental concept is compatible with quantum mechanics, permitting the smooth implementation of gravity within quantum mechanics.

In a first step (subsection **2.1**) it is pointed out that proper time **τ** is not part of the covariant spacetime manifold but an external set which forms the external basis of the spacetime manifold, and that proper time is at the origin of coordinate time.

Secondly (subsection **2.2**), we distinguish 3 categories with respect to proper time: mass particles are provided with proper time, whereas the proper time corresponding to the spacetime intervals of lightlike phenomena is zero, and vacuum without particles turns out to be timeless: The proper time of vacuum is not defined.

Accordingly, time must be produced in the form of proper time by the rest energy of mass particles. Once it has been produced, the proper time of a particle can be measured, put into a chart and synchronized in the form of coordinate time within any observer's spacetime manifold (subsection **2.3**).

The new time concept opens for gravity the access to quantum mechanics (section **4**), for this purpose we must previously replace the concept of curved spacetime of the Schwarzschild metric with the equivalent concept of gravitational time dilation (section **3**).

2. Absolute time and absolute space

2.1 Coordinate time must be derived from proper time

Starting point are the equations for time dilation: The coordinate time **t** of a particle is related with its proper time **τ** by the Lorentz factor **γ(v)**:

(1)
$$dt = \gamma(v)\, d\tau$$

and by the factor of gravitational time dilation of the Schwarzschild metric (for a far-away observer):

(2)
$$dt = \frac{1}{\sqrt{1-\frac{2GM}{c^2 r}}}\, d\tau$$

These factors establish an equivalency between **dt** and **dτ** and permit the transformation in both directions, from **dt** to **dτ** and from **dτ** to **dt**. But which one of both time concepts is the more fundamental concept from an axiomatic point of view, which one is at the origin of the other, coordinate time **dt** or proper time **dτ**?

At first sight it seems reasonable to consider that an absolute concept (such as proper time) is more fundamental than a relative, observer-dependent concept (such as coordinate time).

However, a clear confirmation of this hypothesis is provided by the definition of proper time:

> *"The time measured by a clock following a given object"***[1]**

This definition does not depend on covariant spacetime, it depends only on the object it is referring to! Proper time reveals to be an intrinsic characteristic of particles.

As proper time according to its definition is independent of spacetime, coordinate time must derive from proper time (via the time dilation equations **(1)** and **(2)**), and conversely, it would not make any sense to imagine the proper time (of a particle) as having its origin in some coordinate time (of any observer's coordinates). Proper time turns out to be an external foundation of the pseudo-Riemannian manifold of spacetime. Proper time is time before dilation, measuring and synchronization.

In the literature, proper time is considered to be a parameter of great importance within relativity,[1] and the idea of having recourse to intrinsic time as an absolute (invariant) concept of time is not new.[2] But such concepts are always presented within fourdimensional spacetime with space and time on equal footing.

Moreover, proper time is also believed to be a part of the spacetime geometry[3] or even to be influenced by spacetime.[4] This is in contradiction to the clear independence of proper time according to its above-mentioned definition. Time dilation is never modifying proper time, and there is no such thing as "dilated proper time". Proper time after time dilation results always in the coordinate time of observers.

2.2 The absolute time concept

Applying the absolute time concept of proper time, we may divide the universe into 4 categories:

a) Mass particles have timelike worldlines which are generating proper time. [5]

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[1] E.g. Rindler: *"A quantity of great importance"* **[2]**, Hobson, Efstathiou and Lasenby: *"The worldline of a massive particle can be described by giving the four coordinates as a function of τ .(…) For massive particles the natural parameter to use is the proper time τ",* **[3]** Wald: *"Thus, the coordinate labels themselves do not have intrinsic significance since they depend as much on which observer does the labeling as they do on the properties of spacetime itself. It is of great interest to determine what quantities have absolute, observer-independent significance, i.e., truly measure intrinsic structure of spacetime."* **[4]** and already Einstein in 1916: *"A fundamental role is played by the invariant ds".* **[5]**

[2] See e.g. the overview with regard to quantum gravity provided by Isham **[6]**

[3] E.g. Zeh: *"The three-geometry G, representing the dynamical state of general relativity, is itself the carrier of information on physical time. It contains physical time rather than depending on it*." **[7]**

[4] E.g. Kiefer*: "Since GR is background independent, there is no absolute time. Space-time influences material clocks in order to allow them to show proper time. The clocks, in turn, react on the metric and change the geometry."* **[8]**

[5] In the same sense seems to go Sexl/ Urbantke: Relativity, Groups, Particles: In 2.6 *"Proper time and time dilation"* the physical interpretation of proper time is limited to mass points, however without expressly stating that proper time is reserved to mass particles. **[9]**

b) Lightlike phenomena with their lightlike worldlines are generating zero spacetime intervals and zero proper time ($d\tau = 0$). **[10][11][12]**

c) Vacuum between worldlines is timeless, and proper time is not defined. The timelessness, that means the absence of time evolution, of the vacuum between worldlines follows directly from the structure of Minkowski spacetime.
In Minkowski spacetime, the time evolution of the coordinates of a particle (t_0; x_i) is following its worldline which depends on its velocity **v** (see equation **(1)**), the coordinates after a lapse of time **dt** are ($t_0 + dt$; $x_i + v_i dt$). In contrast, we cannot assign any velocity to vacuum points without worldline, and by consequence, it is impossible to define any time evolution .

d) These three cases a) to c) are not exhaustive. Other sources of proper time may exist.

For a closer understanding of the physical process of the generation of the proper time of a mass particle, we have to split up the proper time definition above into two parts: a) the measuring of the particle's proper time by a clock, and b) the prior emergence of this measured proper time.

a) The mere measuring process by a clock cannot be considered in *sensu stricto* as an intrinsic element of the particle, and any measurement result would be a coordinate time of the clock which is measuring.

b) Obviously, emergence of proper time must precede any measuring of proper time, otherwise there would be no proper time that could be measured. The measured proper time must have come into the world in some way.

For mass particles generating proper time, the equation

$$e = m\,c^2 \qquad (3)$$

leads to the conclusion that it is the rest energy of mass particles which generates the proper time. The durability of mass particles is in contrast with the fugacity of massless particles such as photons which are vanishing at the moment of their observation.

2.3 Spacetime, events and absolute space

We will now derive the role of coordinate time and of spacetime, starting from the absolute time concept of proper time.

As shown above, the sources of time generation are independent one from another. Each particle has its own rest energy which is generating its own discrete proper time. For this purpose, the terms coordinate time and spacetime are not needed. Proper time exists without having been measured.

The role which is left to coordinate time and to spacetime is not to provide a definition or a fundamental concept of time, because such definition and fundamental concept exists already within the concept of proper time. But there is one important missing function which is not included in the concept of proper time - the synchronization:

Example: Two particles A and B are moving with constant velocity, and they are approaching the same point P in space. If they will go through P at the same time, there will be a particle event, if they go through P one after the other, no particle event will occur. The question if there will be a particle event or not cannot be answered by considering only proper time. For the answer, an observer is required who will chart and synchronize both proper times in his own spacetime coordinates.

This is the only role of spacetime: Spacetime submits the proper time of the different particles to a sort of "weighting process". It is not a generator of an original time concept. However, what is true for time must also be true for space: Space coordinates are the result of the observer-dependent synchronization process combining space and time to a common concept, they cannot represent an original space concept, that means that there must be an absolute space concept which is underlying spacetime. We will see in section **3** that the model of curved spacetime of the Schwarzschild metric is compatible with an absolute, flat space concept.

In summary, spacetime is "weighting" the absolute time of the particles, and by this it is applying a symmetry (the Lorentz symmetry) where space and time are dimensions on equal footing. However, this symmetry of relative time and relative space is limited to Lorentz symmetry, and it is based on the respective absolute concepts for time and space.

2.4 How to solve fundamental questions about time

We saw above in subsection **2.3** that the time concept of general relativity is twofold: On one hand, the fundamental concept of the proper time of the particles, and on the other hand the concept of coordinate time which seems to be much more appropriate for the daily time-measuring use. Accordingly, we must distinguish two categories of physical questions:

The measurement of time can only be performed by the means of coordinate time. Whenever we are using a clock we are comparing the time of physical processes with the coordinate time of this clock.

Questions about time which are not requiring measurements cannot be resolved with mere measuring tools: For such questions with fundamental character we must refer to the fundamental concept of time which is proper time.

Example: The time reversibility of massless phenomena such as radiation and fields (see **[13][14][15]**). Massless phenomena with their lightlike worldlines are generating zero spacetime intervals and zero proper time ($d\tau = 0$)**[10][11][12]**. The question of time reversibility is not a mere question of measurement, and this is why attempts to solve the question by the means of coordinate time must fail. We must take into account the original absolute concept of proper time, and with this concept the solution of the radiation problem is simple to see: empty spacetime intervals ($ds = 0$) of massless phenomena are symmetric and time reversible with respect to proper time. The same principle must apply by analogy to fields propagating at velocity $v = c$.

In the same way, we will see that also the problem of quantum gravity is only a problem of time: We may not try to apply a relative time concept on fundamental questions about time.

The absolute concepts for time and space lead to a gravity concept which is no longer in contradiction with quantum mechanics: In section **3** we will show that gravity may be expressed in terms of time, more precisely: as gravitational time dilation in flat space, and in section **4** we will show that such an expression is compatible with quantum mechanics.

3. Description of gravity as gravitational time dilation instead of curved spacetime

Currently gravity is described as curved spacetime. This description has practical advantages for many physical purposes. But there is a second different concept which opens the way to quantum gravity - we will show that the concept of gravitational time dilation in a flat space manifold is equivalent to the concept of curved spacetime:

In a two-particle universe, the Schwarzschild metric of curved spacetime of a particle with mass **m** which is moving within the gravity field of a particle with mass **M** is:

(4) $$ds^2 = -c^2(1 - \frac{2GM}{c^2 r})dt^2 + \frac{dr^2}{1-\frac{2GM}{c^2 r}} + r^2(d\Theta + sin^2\Theta\, \mathrm{d}\phi^2)$$

The equation of gravitational time dilation of the clock of the particle **m** with reference to a far-away observer is:

(5) $$C = \frac{\tau}{t} = \sqrt{1 - \frac{2GM}{c^2 r}}$$

By inserting gravitational time dilation **C** into equation **(4)**, we get the Schwarzschild metric for curved spacetime:

(6) $$ds^2 = -c^2(Cdt)^2 + \left(\frac{dr}{C}\right)^2 + r^2(d\Theta + sin^2\Theta\, \mathrm{d}\phi^2)$$

while the metric for flat Minkowski spacetime has the following form: **[16]**

(7) $$ds^2 = -c^2dt^2 + dr^2 + r^2(d\Theta + sin^2\Theta\, \mathrm{d}\phi^2)$$

We see that the curvature of spacetime depends exclusively on time dilation **C**, and it is the action of **C** on time **dt** and on radial displacement **dr** which is transforming flat spacetime metric into curved spacetime. By consequence, the description of the Schwarzschild metric by gravitational time dilation is perfectly equivalent to the description by curved spacetime. Any spacetime curvature may be expressed as a function of the modulation of the time parameter in flat space. The field of gravity may be represented as a field of time dilation: A particle is attracted by gravity because it tends to maximize its own time dilation with respect to the other particles.

The relation between mass and time reveals to be twofold: Mass particles are producing (proper) time, and their gravitation field is slowing down the time of other particles.

4. Quantum gravity

4.1 No quantization of spacetime

According to the explanations above in subsection **2.2 c)**, the vacuum of spacetime is timeless, that means it does not have any time evolution. The observer is observing a fourdimensional manifold which does not reflect any physical manifold. In particular, the observer is assigning to certain vacuum points in spacetime a coordinate time which is not subject to any time evolution. The apparent continuity of spacetime in spacelike direction does not seem to be based on any underlying continuous physical manifold.

The quantization of spacelike hypersurfaces (e.g. by the foliation of spacetime) seems to be impossible. Instead, we must look for a quantum gravity concept on particle level.

4.2 Quantum gravity

The Schwarzschild metric and quantum mechanics are harmonizing because we express gravity as a function of time (gravitational time dilation in flat space, see section **3**), time being a classical parameter in quantum mechanics. Moreover, we discovered the absolute concepts for time and space which are underlying relative spacetime and which are compatible with the corresponding concepts of quantum mechanics.

As a first rough outline, the consequences in quantum mechanics which are due to the absolute concepts for space and time and due to gravity are mainly limited to seven principles:

1. Quantum mechanics is timeless, except where proper time is defined by some physical process.
2. The proper time of lightlike phenomena (such as fields) is zero.
3. Proper time is generated by mass particles, and coordinate time is a function of the generated proper time and of lightlike phenomena. Without any defined proper time there can be no coordinate time.
4. The single absolute time concept of quantum mechanics must be replaced by two complementary time concepts: a) the measured coordinate time and b) the proper time of all concerned particles and lightlike phenomena.
5. Instead of quantization of spacetime, quantum gravity must happen on particle level: The time evolution frequency parameters of each independent quantum system must follow its own proper time parameter.
6. The space manifold of quantum mechanics remains flat.
7. Schwarzschild metric within quantum mechanics: The attractive force of gravity in flat space consists in the tendency of particles within a gravity field to maximize their own gravitational time dilation.

5. Conclusion

The access door gravity is using for entering into quantum mechanics is the proper time parameter of particles, as the time and space curvature of gravity may be entirely described by gravitational time dilation. That means that the impact of gravity on quantum mechanics is limited to an action on the proper time parameter of particles. The time parameter in quantum mechanics is classical, and thus the result is a semi-classical solution for quantum gravity. The two fundamental, well-proven theories of general relativity and quantum mechanics remain entirely intact.

The discovery of quantum gravity would not have been possible without the clarification of five crucial features of the space-time geometry of special and general relativity:

1. The definition of proper time is independent of spacetime (see above subsection **2.1**).

2. Minkowski spacetime is not continuous in spacelike direction (see above subsection **2.2 c)**).

3. Time and space are not on equal footing, the similarity of time and space is strictly limited to Lorentz symmetry (see above subsection **2.3**).

4. Fundamental questions about time which are not requiring any measurement of time cannot be resolved with coordinate time, instead proper time as the more fundamental time concept must be taken into account (see above subsection **2.4**).

5. Curved spacetime is only one possible model for the Schwarzschild metric which can also be described by gravitational time dilation in a flat space manifold (see above section **3**).

References:

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