The Derivation of Quantum Gravity

René Friedrich

Abstract:

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

The key to the solution is a retrieval of the twofold nature of time, that is an absolute time concept on the one hand which is underlying the relative, observer-dependent concept of spacetime on the other hand.

The attempts to quantize spacetime revealed to imply big difficulties. We will show that the reason for these problems is the structure of space and time, and that quantum gravity must happen on particle level.

1. Introduction: Relative spacetime and the underlying absolute concept

Newton's absolute spacetime was replaced by a 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 which is representing the universe.

We will show that general relativity is 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. Whereas the relative spacetime concept failed to provide a theory for quantum gravity, the absolute concept as the more fundamental concept is 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 basis on which the spacetime manifold is built, and that proper time is at the origin of coordinate time.

Secondly (subsection **2.2**), only mass particles are provided with proper time whereas the proper time of the lightlike spacetime intervals of massless 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 (subsection **2.3**). Once it has been produced, the proper time of a particle can be measured, transformed and synchronized in the form of coordinate time within any observer's spacetime manifold.

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

---

email: *rene_friedrich@orange.fr*

2. What is at the origin of time?

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):

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

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

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

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?

a) At first sight it seems reasonable to consider the absolute concept (proper time) as more fundamental then the relative, observer-dependent concept (coordinate time).

b) A clear answer is provided by the definition of proper time which is independent of coordinate time and of covariant spacetime:

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

That means that proper time is not a mere corollary of spacetime but an intrinsic characteristic of particles.

By consequence, coordinate time must derive from proper time, 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, transformation 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.

---

[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]**

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 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 Proper time as a feature of mass particles

Proper time is a feature of mass particles only.[5] We can distinguish three categories in the universe:

a) Mass particles have timelike worldlines which are generating proper time.
b) Massless phenomena with their lightlike worldlines are generating zero spacetime intervals and zero proper time ($\tau = 0$). **[10][11][12]**
c) Vacuum between worldlines is timeless, and proper time is not defined: According to the time concept of relativity, coordinate time and proper time are linked by the velocity-dependent time dilation equation
$$dt = \gamma(v)\, d\tau$$
However, for the vacuum there is no velocity defined. By consequence it is impossible to assign to the vacuum any pair of coordinate time and proper time.

2.3 The process of the increase of the proper time of a mass particle

In order to know more about the nature of time we must have a closer look at the physical process which is at the origin of the emergence and of the flow of proper time.

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.

Looking at the three categories of subsection **2.2,** we see that only mass particles are at the origin of proper time. Mass and proper time are two aspects of the same phenomenon which is generated by rest energy. Rest energy provides mass particles with the distinctive characteristic of temporal perdurability, and the "durable" aspect of all matter is simply a manifestation of the proper time production of rest energy. This process of proper time production is so self-evident that we currently

---

[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]**

do not attach any importance to it. But this is nature of mass, the durability of mass is nothing else than proper time production.

One example for the durable aspect of mass particles: A piece of soap at time t_0 will be observed still as a piece of soap ten seconds later. What is happening? According to the equation $e = mc^2$, each particle of the object contains rest energy. Rest energy is passive and not interacting, it does not radiate or heat or move, it is "tamed" energy. The only action of rest energy is going in time direction: rest energy is maintaining its own existence, by setting in motion its own clock, it is producing proper time and aging, and its proper time is observed by a comoving observer as coordinate time.

The opposite is true for the radiation energy of massless particles: emitted radiation may be observed only once, at the absorption, it is transmitting all its energy in the form of a momentum, and it is not durable but "fugitive", moving at highest possible velocity and vanishing at its absorption by energy transformation. It does not set in motion any own clock and does not produce any proper time.

Whenever we are contemplating a mass particle (or a piece of soap composed of mass particles), we are witnessing the process of its proper time production, measuring its time with our own comoving clock. Never would it be possible to observe durably a massless particle.

Once the proper time has been generated, it may be observed in the form of coordinate time. Worldlines of mass particles and of massless phenomena are observed as part of the fourdimensional spacetime manifold. Again, time is a feature of worldlines only, the vacuum without worldlines being timeless. Simultaneity is not referring to vacuum.

This new description of what time is opens the possibility for new approaches with regard to the solution of unresolved fundamental physical problems. For this purpose, it is important to remember that the concept of proper time is more fundamental than the concept of covariant coordinate time of spacetime. While the latter is well-adapted to physical measuring, transformation and synchronization processes of all kind, the former is the underlying, invariant concept which is reflecting directly the process of generation of proper time. They are complementary. This is why for fundamental physical questions which cannot be resolved with coordinate time, proper time as the more fundamental time concept should be taken into account instead.

Example: The time reversibility of radiation and fields (see **[13][14][15]**). As we saw above, proper time is produced by mass particles, and massless particles with their lightlike worldlines are generating zero spacetime intervals and zero proper time. The solution of the radiation problem is simple to see: empty spacetime intervals ($ds = 0$) of massless particles are symmetric and time reversible with respect to proper time. The same principle must apply by analogy to fields propagating at velocity $v = c$.

3. Quantum gravity

3.1 No quantization of spacetime

According to the nature of time and the explanations above in subsection 2.3, the vacuum of spacetime is timeless, only the worldlines of particles are generating proper time, and only the worldlines of particles and massless phenomena may be subject to coordinate time. That implies the absence of continuous spacelike hypersurfaces, and the quantization of a relative spacetime manifold (e.g. by the foliation of spacetime) seems to be impossible.

Instead, we must look for a quantum gravity concept on particle level.

3.2 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 m which is moving within the gravity field of a particle M is:

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

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

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

By inserting gravitational time dilation C in the above equation, we get the Schwarzschild metric for curved spacetime:

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

while the metric for flat Minkowski spacetime has the following form: **[19]**

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

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 force of gravity may be represented as a force 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.

3.3 Quantum gravity

As a first rough outline, the consequences for quantum mechanics are mainly limited to four principles:

1. The space manifold of quantum mechanics is flat.
2. Quantum mechanics is timeless, and no proper time and no coordinate time is defined, at the only exception of mass particles and lightlike phenomena.
3. Proper time is generated exclusively by mass particles, and the proper time of lightlike phenomena is zero. Coordinate time is a function of the proper time of mass particles and of lightlike phenomena. All other processes have no proper time and by consequence no coordinate time.

4. Gravity is observed as an action on space and time coordinates of particles, in accordance with the Schwarzschild metric.

In practice, this means that two complementary time concepts instead of one must be used: a) the measured coordinate time and b) the proper time of all concerned particles and lightlike phenomena which has been retrieved according to the equation of the Schwarzschild metric.

4. 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 an action on the proper time parameter of particles - without any further impact on quantum phenomena. The time parameter in quantum mechanics is considered to be classical, and thus the result is a semi-classical solution for quantum gravity.

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

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

2. If fundamental physical questions cannot be resolved with coordinate time, proper time as the more fundamental time concept should be taken into account instead (see above subsections **2.1** and **2.3**).

3. Time and space are not on equal footing, the similarity of time and space is strictly limited to Lorentz symmetry. In particular, the fourdimensional spacetime manifold is not continuous through space, (and foliation methods cannot be applied) because proper time (and by this coordinate time) is a feature of worldlines only, the vacuum being timeless (see above subsection **2.2**).

4. 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 subsection **3.2**).

References:

[1] Landau/ Lifshitz, The Classical Theory of Fields, 1951, § 1.3. Proper time, p.8

[2] Wolfgang Rindler, Relativity, Special, General, Cosmological, 2001/2006, p.65

[3] M. P. Hobson, G. P. Efstathiou and A. N. Lasenby, General Relativity, 2006, p.15,16, fig.1.11

[4] Robert M. Wald, General Relativity, 1984, p.7

[5] A. Einstein, The Foundation of the general theory of relativity, Annalen der Physik 49 (1916) 769, p. 780.

[6] C.J. Isham, Canonical Quantum Gravity and the Problem of Time, 1992, n°2.3, p.16, arXiv:gr-qc/9210011

[7] H. Dieter Zeh, The physical basis of the direction of time, Springer 2007, p.163

[8] Claus Kiefer, Quantum Gravity, Oxford 2012, p.145

[9] Sexl/ Urbantke: Relativity, Groups, Particles, Springer-Verlag Wien 1992/2001

[10] Wolfgang Rindler, Relativity, Special, General, Cosmological, 2001/2006, 3.5 Light cones and intervals

[11] Sexl/ Urbantke: Relativity, Groups, Particles, Springer-Verlag Wien 1992/2001, 4.3 Photons: Doppler effect and Compton effect

[12] James B. Hartle: Gravity, Addison Wesley 2003, p.91

[13] John Archibald Wheeler, Richard Feynman: Interaction with the absorber as the mechanism of radiation, Review of Modern Physics 1945 p.157

[14] Huw Price, The asymmetry of radiation: Reinterpreting the Wheeler-Feynman argument, Foundations of Physics, vol. 21 (1991) n°8 p.959

[15] H. Dieter Zeh, The physical basis of the direction of time, Springer 2007, p.17

[16] Wolfgang Rindler, Relativity, Special, General, Cosmological, 2001/2006

[17] Sexl/ Urbantke: Relativity, Groups, Particles, Springer-Verlag Wien 1992/2001, sect.2.6.

[18] A. Einstein, On the electrodynamics of moving bodies, Annalen der Physik 17 (1905), end of ch.4

[19] Robert M. Wald, General Relativity, 1984, p.271