Quantum gravity via Lorentz-invariant gravity

René Friedrich, Strasbourg[1]

Abstract

Gravity was modeled by Einstein and Grossmann as the curvature of spacetime, but all attempts to quantize curved spacetime have failed. Curved spacetime revealed to be not compatible with quantum mechanics.

However, an alternative model for gravity does exist: Gravitational time dilation. It will be shown here at the example of the Schwarzschild metric that gravity may be expressed not only in the form of spacetime curvature, but also in the form of gravitational time dilation in flat, uncurved R^3 space - both concepts are perfectly equivalent. Instead of acting on spacetime, gravitational time dilation is acting on worldlines, and worldlines are becoming the central element of quantum gravity.

In quantum gravity, in order to be Lorentz-invariant, worldlines must get rid of their spacetime coordinates. For this purpose, they must not be parameterized by the coordinate time of some arbitrary observer, but rather by their respective proper time. Gravitational time dilation is slowing down this proper time parameter of the worldlines of particles and of quantum systems.

The result: Thanks to the Lorentz-invariant parametrization of worldlines, general relativity harmonizes seamlessly with quantum mechanics, or in short: GR "likes" QM.

1. Introduction

The impossibility of the quantization of curved spacetime does not necessarily imply the incompatibility of gravity and quantum mechanics.

For this purpose, we must distinguish between the theories of special and general relativity on the one hand and their respective mathematical framework on the other: In 1905, Einstein published the theory of special relativity **[1]**, and in 1908, Minkowski provided special relativity with a geometrical interpretation in the form of spacetime **[2]**. A few years later, in 1913, Einstein and Grossmann developed a pseudo-Riemannian spacetime manifold as a geometrical model for the description of the principles of general relativity, in particular the equivalence principle **[3]**. In both cases, a physical idea was developed first, and then an appropriate mathematical framework was searched for it.

Accordingly, it will be shown here at the example of the Schwarzschild metric that curved spacetime is not indispensable for the description of general relativity, and that gravity may be expressed not only in the form of spacetime curvature but also in the form of gravitational time dilation in flat, uncurved space. Gravitational time dilation is perfectly equivalent with gravity, and it is not acting on spacetime but on worldlines **(section 3)**.

These worldlines - in order to make them compatible with both general relativity and quantum mechanics - must receive a Lorentz-invariant parametrization. That means that the worldlines - after having been parameterized in a first observational step by the coordinate time of the observer -, must be reparameterized in a second step by their respective proper time **(section 2)**.

[1] rene_friedrich@orange.fr

A description of the universe of quantum gravity is based on the fact that gravity is acting on the proper time parameter of the worldlines **(section 4)**. Surprisingly, time generation and gravitational time dilation reveal to be two complementary effects of the action of the rest energy of mass particles **(section 5)**.

2. The fundamental role of proper time

The proper time equation

$$d\tau = dt\sqrt{1-\frac{v^2}{c^2}}$$

is complemented by the inverse equation of time dilation

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

Proper time is time before time dilation, and coordinate time is time after time dilation. Both are linked by the Lorentz factor **γ(v)**, and - not to forget - by gravitational time dilation which provides a second time dilation factor.

The key question is: From an axiomatic point of view, which time concept is the more fundamental one, coordinate time **dt** or proper time **dτ?** The answer to this question is surprisingly clear and results from the definition of proper time:

> *"The time measured by a clock following a given object"* **[4]**

This definition of proper time does not refer to spacetime but only to the object, the particle. Instead of the particle, we may consider its rest energy mc^2 as the generator of proper time, according to the action of a point particle:

$$S = mc^2\int d\tau$$

Each particle generates independently its own proper time, its own aging, which subsequently may be observed and synchronized in the form of coordinate time:

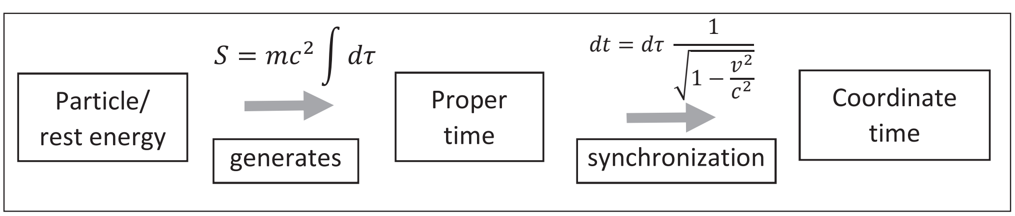

Fig. 1: The particle at the origin of time generation

Conversely, from the point of view of experimental physics, proper time is not observable and may only be determined by calculation, based on the measured coordinate time, providing the following order:

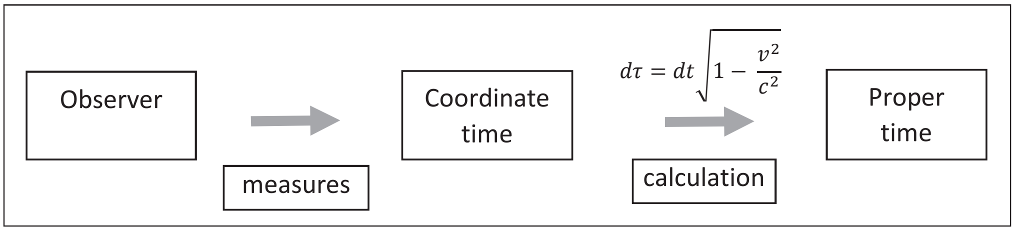

Fig. 2: The point of view of the observer and of experimental physics

By consequence, coordinate time is deriving from the fundamental parameter of proper time. In a first step, the observer is measuring the coordinate time, from which in a second step may be retrieved by calculation the underlying proper time. Unfortunately, the current theories of quantum gravity are limited to the first step, and this is why they are not leading to any solution: In spacetime manifolds, worldlines are parameterized by coordinate time which corresponds to the clock of an observer.

For fundamental questions such as quantum gravity, it is crucial to make the second step: For this purpose, the measured worldlines must be reparameterized by their respective proper time. The result is a huge number of worldlines without any common coordinate system, each worldline is parameterized by its own clock:

$$S_{cumulated} = \sum_{n} m_n c^2 \int d\tau_n$$

At first sight, this might seem meaningless because there is no clock of reference. But according to general relativity, this is how the world is structured: there is no universal time axis, and each particle is aging individually according to its own clock and by this generating its own proper time.

The action of a point particle

$$S = mc^2 \int d\tau$$

is Lorentz-invariant and compatible with quantum mechanics, describing the aging process of particles and of quantum systems with mass: There is no more reference to spacetime, and spacetime is nothing else than the "observer interface" which is procuring to the observer the access to the universe of quantum gravity.

3. Gravity in uncurved space

How is it possible to represent gravity in such a Lorentz-invariant universe of worldlines without spacetime? The answer is surprisingly clear and simple: Curved spacetime is only one possible model for the description of gravity, and gravity may also be described as gravitational time dilation in flat, uncurved space.

In order to prove the full equivalence of gravity and gravitational time dilation, we start off with the Schwarzschild metric of curved spacetime:[2]

[2] Following the current sign convention (- + + +)

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

Now we denote by **C** the gravitational time dilation of the clock of a particle in a gravity field with reference to a far-away observer:

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

By inserting C into the equation above, we get a modified form of the Schwarzschild metric:

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

Now we compare this equation with the equation of flat Minkowski metric **[5]**:

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

We see that the Schwarzschild metric and the Minkowski metric are very similar: The term *dt* becomes *Cdt* and the term *dr* becomes $\frac{dr}{C}$. C is the only difference between curved and uncurved spacetime - between spacetime with and without gravity. If C = 1, we get the Minkowski metric, and if C is smaller than 1, this is an indicator of gravity within Schwarzschild metric. By consequence, gravity may be completely described as gravitational time dilation, no other element whatsoever is having any impact on gravity, and gravity and gravitational time dilation are perfectly equivalent.

Moreover, it follows from the equivalence of gravity and gravitational time dilation that gravity may not only be represented as curved spacetime but also in the form of gravitational time dilation in flat space.

4. Quantum gravity

As a result, the universe of quantum gravity has the following characteristics:

a) Space: The underlying manifold is R^3 space, and the spacetime of general relativity is serving as a sort of "observer interface" which is procuring to the observer the access to the universe of quantum gravity (see **section 2**).

b) Time: The universe of quantum gravity is timeless wherever there is no proper time expressly defined, in accordance with the following 4 main categories:

- Quantum systems of mass particles are generating proper time.
- The spacetime interval of lightlike phenomena such as photons in vacuum, electromagnetic fields and gravity fields is zero, and also their proper time is zero.**[6][7][8]** Their worldline is a degenerate zero worldline which is time symmetric because a worldline with zero length cannot have any asymmetry.
- Vacuum between worldlines is not defined and thus timeless.
- Special characteristics apply to interactions of lightlike phenomena with mass, such like photons propagated through media.

c) And this is how gravity is acting on the worldlines of quantum systems which are parameterized by their respective proper time: Gravity in the form of gravitational time dilation is modulating the time parameter of the worldlines of quantum systems.

Example: In the diagram below, the quantum system near the gravity source has a slower proper time frequency.

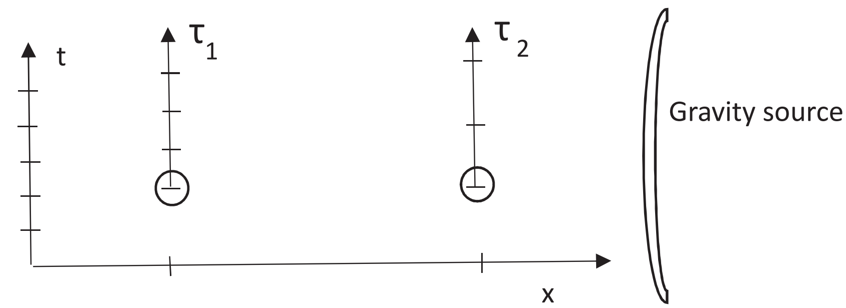

Fig. 3: Quantum gravity: Two quantum systems with mass near a gravity source, with indication of the scale of the respective proper time parameter of the mass particles

5. **Gravity as a field of time dilation**

We saw that gravity may be described as a field of gravitational time dilation surrounding the worldlines of mass particles. Also, in **section 2** we saw that time is generated by mass particle worldlines in the form of proper time. That means that there is a twofold effect of mass particles (or more precisely: of their rest energy):

- The rest energy of mass particles produces proper time,
- And at the same time, the rest energy of mass particles slows down the proper time frequency of other particles within its gravity field. Gravitation and gravitational time dilation may be considered as a side effect which is surrounding the time generation process of the particle.

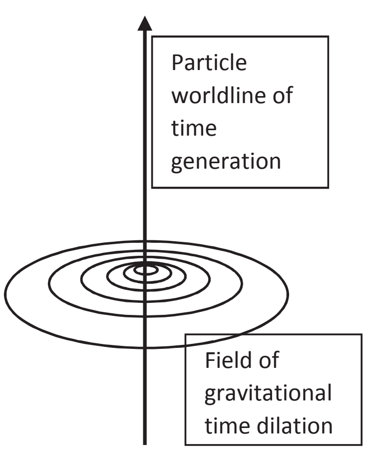

Fig. 4: Gravity as a field of time dilation, surrounding the time generation process of the particle

6. References

[1] Albert Einstein: On the Electrodynamics of Moving Bodies, Annalen der Physik 1905

[2] Hermann Minkowski: Space and Time (1908), in: Space and Time, Minkowski's Papers on Relativity, Minkowski Institute Press 2012

[3] Albert Einstein, Marcel Grossmann: Outline of a Generalized Theory of Relativity and of a Theory of Gravitation, 1913

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

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

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

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

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