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# Ring paradigm as Quantum Gravity

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**Abstract.** Construction of a model of Quantum Gravity, which will be one day in concordance with experiments, is one of the most fascinating tasks which we have in modern theoretical physics. There are common phenomenons for all of the approaches to quantum gravity, which were developed so far. We mention the non-locality, dark energy and dimensional reduction. Then we introduce the concept of nonlinear graviton and we suggest the mathematical apparatus for Quantum Gravity. We discuss further the problematics of Feynman path integral. We end with a possible experimental evidence for our approach and we pose a list of open questions.

## 1. Introduction

How to construct a theory of Quantum Gravity (QG) is today one of the most fundamental problems in theoretical physics. There are many approaches as string theory (ST), [1], loop quantum gravity (LQG), [2], causal dynamical triangulations (CDT), [3], causal set approach, (CSA), [4, 5] and many others. This problem is hard because we didn't have so far any experimental evidence about any phenomenon in QG regime.

The non-locality is one of the common features, for example, both to ST and CSA. It is a result of the facts that spacetime is fundamentally discrete and Lorentz invariance is an exact symmetry of nature, [6].

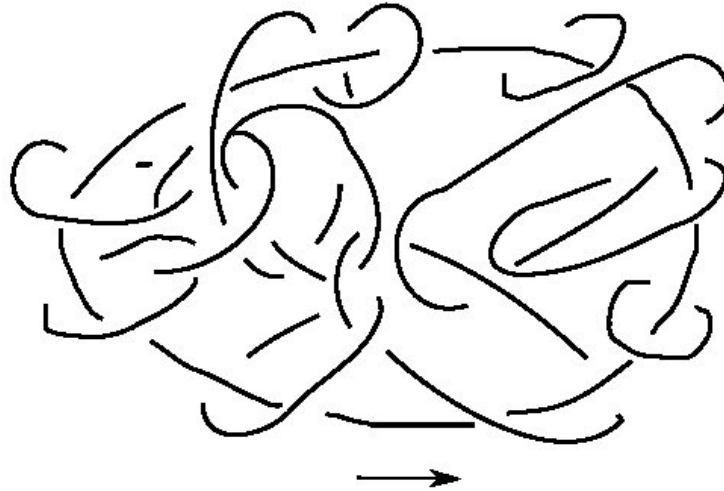
We know today only 5% from the energetical content of the Universe and this state of knowledge is definitely not satisfactory. Approximately 25% creates, so-called, DM, [7] and 70% creates DE, [8, 9, 10]. We did not find any satisfactory model of accelerated expansion so far.

Finally, in most of the physics the dimension of space is taken as a fixed external parameter. Although the notion of dimension is very old, the mathematical formalism for a space of arbitrary dimension is fairly recent. The question why our universe has so many dimensions was discussed by P. Ehrenfest in 1917,[11], who pointed out that such features as the stability of Newtonian orbits and the duality between electric and magnetic fields are unique to three spatial dimensions. We will be interested in the phenomenon, where the number of dimensions of spacetime drops at high energies. It is called the short distance dimensional reduction in quantum gravity, [12]. We have today the evidence about the dimensional reduction in ST, CSA, CDT, and at least some evidence in LQG, [26].

The structure of this work is the following: we will discuss the physical issues in the first part of this work, then we will suggest the possible mathematical apparatus and we will do the final discussion;



**Figure 1.** The Universe could be modeled as a finite structure of intersection of Hopf-linked rings, on which are traveling other rings. We suppose that there was one ring in the Big Bang and further rings were created after, which are the trajectories on which could travel particles and fields. Particle and fields could be described as vibrating rings traveling around other rings.



## 2. First remark about new paradigm

We want to show that there is hidden a philosophical concept in the foundations of ST, LQG, and CSA to QG that could lead to a new theory. We will use the knowledge that particles are not point-like objects. But the spacetime will be not continuous for us. So, ST will be just a toy model for us.

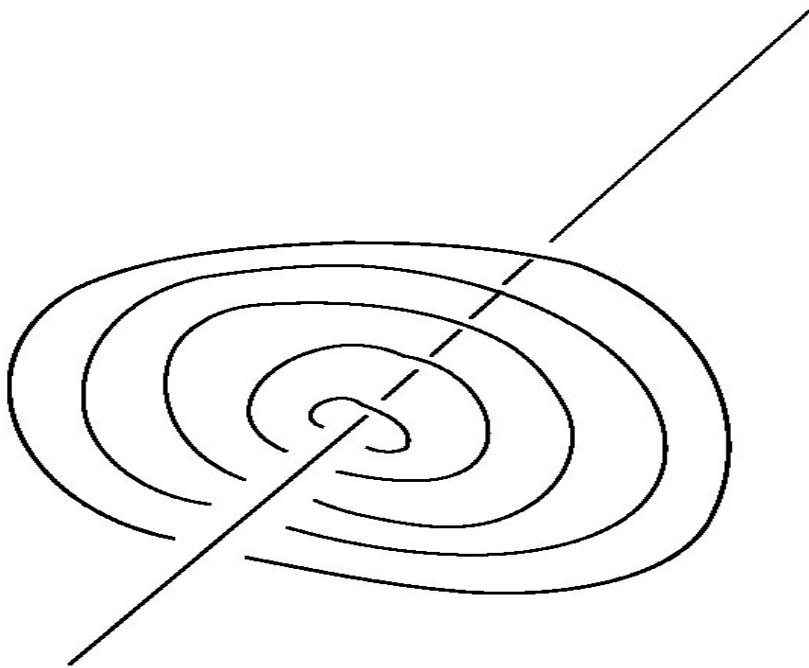
We will not use deep knowledge from LQG. But the investigations are connected to studies of the following set, where the basic objects are topologically circles and they are Hopf-linked, Figure 1. The formulation of the paradigm, which will follow leads to the mathematical investigation of this set.

Space (not spacetime!) will be discretized to objects, which are called rings. These will be deformable circles, which could be Hopf-linked. We want to argue that points are not the mathematical abstraction, which we will need. When we would discretize to points, the singularities of the type of black holes and initial singularities would be unavoidable. A motivation to this discretization comes from a philosophical branch called finitism, which avoids completed infinities altogether, [13]. And this effort to discretize to this rings is well motivated by discrete causal set theory, where we want to put particles, fields, and spacetime on equal footing. Let's stop for a moment on this key point of this paradigm.

We all know very well that general relativity (GR) is perturbatively non-renormalizable. This means that when we try to construct Feynman diagrams and deal with gravitons similarly as in QM, the theory diverges, [14].

Another fact from a different area of physics is that the notion of particles is non-unique in

**Figure 2.** Our discretization is correct according to the deep holographical principle. We see five rings, which are Hopf-linked to other rings. When there would be a sphere, which would be composed of such concentric rings inside, the number of these rings scales as the area of such a sphere.



quantum field theory in the curved background, [15].<sup>1</sup> This serves us as an inspiration for our construction of graviton on the fundamentally nonlinear level.

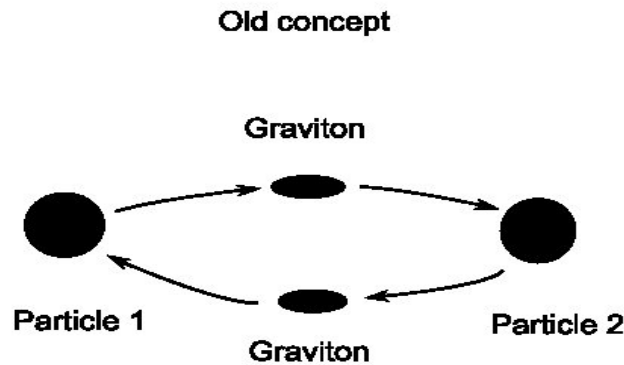
Our paradigm will come with the existence of a new object, which will be the ring, as we already said. It is a finite deformable circle, which has a finite circumference of 1 Planck length and could stretch from 2 Planck lengths to possibly macroscopic distances. Why we need this object and why it is useful to have particles, fields, and rings? The answer is that we would be possible to put particles, fields, and spacetime on the equal level. Now we will always keep any particle and field together with some trajectory, which will be part of the ring. This will enable us to model particle and fields in a unique description at the end.

The first thing what we need to do is to prove that our discretization is correct according to a deep principle, the so-called holographical principle. It states that the area of any surface  $S$  enclosing a volume  $V$  measures the information content of the underlying theory in the volume  $V$ . Our discretization is in concordance with this principle, as we depicted in Figure 2. The number of rings scales as the area of the enclosed volume.

An urgent question comes to our mind. Is this discretization just a mathematical tool or a real physical object? We claim that it is not a mathematical abstraction.

<sup>1</sup> For mathematical topics in algebraical quantum field theory see [16, 17, 18].

**Figure 3.** We see two particles, which exchange gravitons according to the old picture.



### 3. A key note about nonlinear graviton

What we have done so far is an artificial discretization. So what does it have to do with gravity? We need to mention the standard picture of GR and quantum mechanics (QM). According to GR is a matter moving in 4 dimensional continuous spacetime  $(M, g)$  described by topological variety  $M$  with a metric  $g$ . As was quoted by J.A.Wheeler, matter says to the spacetime how to curve and spacetime says to matter how to move, [19].

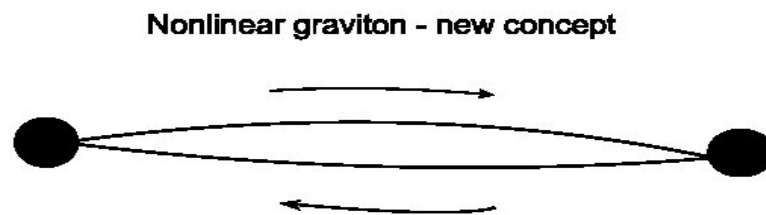
On the other hand particles jump up on this manifold according to the quantum field theory and are interacting with each other by exchanging the elementary particles of fields. They locally curve the spacetime. These two pictures are incompatible.

What we have in our minds as a picture for description of gravity are some elementary particles exchanging gravitons, Figure 3.

Do we have any experimental evidence that gravitons really exist? It is interesting that detection of the inflationary gravitational wave background, [20], would provide us with direct observational confirmation of the fact that gravity must be quantized. While on the purely theoretical level there is no doubt that it should be so, in particular, if one treats gravity as a low-energy effective QFT, there is so far no evidence for the quantum nature of gravity. Discovery of the inflationary gravitational wave background would be revolutionary. We could always pose a question, is it possible to observe just one graviton in some apparatus as we could observe just one photon? It is only an academic question because one graviton has the too tiny effect to be observable in any possible experiment with interferometers. But we want to indicate that the answer is no. It is not possible to observe an effect of just one graviton, because the picture, which we have in our mind, from the standard QM is incorrect.

Let's consider Figure 4. We have two particles (we don't say now, how we want to model

**Figure 4.** The old picture of particles exchanging gravitons is incorrect according to Ring paradigm (we give a name to this approach to QG). When we switch on the extragravity (which is the unification of all 4 interactions), an element of space - ring - is created between these two particles. Other particles could then travel on this trajectories. The important thing is that these trajectories are created in Planck time.



them) and we switch on the gravity. Then a ring (trajectory or element of space) is created between these two particles, which links it. This link will create an attractive force between these two particles. We could think about it as a spring between them, although it does not have properties of a linear spring. It simultaneously creates a trajectory for exchanging other fields and particles, so a creation of other 3 interactions.

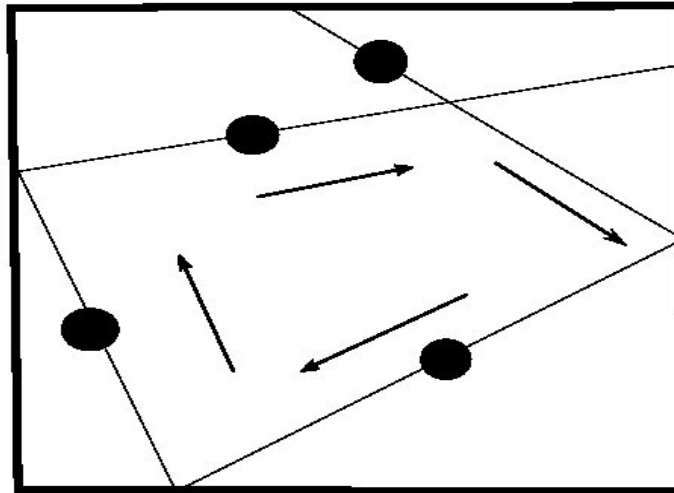
One question immediately comes to our minds. Is it not a contradiction with the basic principles of QM? We do not say that a particle has a trajectory in QM. We speak about probabilities. So, let's consider some particle knocked in the box as in Figure 5.

It is a well-known fact that we could not localize it. The explanation by Ring paradigm (RT) is that there are randomly created trajectories in the box and the particle jumps from one trajectory to other as we depicted it. (These trajectories create in Planck time from 2 Planck lengths to possibly arbitrary distances and they are changing in Planck time.)

We now just go forward. What we want to draw ultimately is a more advanced version of a Feynman diagram as in Figure 6.

There are two trajectories with opposite orientation, then a trajectory is created in Planck time between these two trajectories. Particles (vibrating rings) are coming on the first ring, then a vibrating ring is traveling in-between and two particles originate on the second ring.

**Figure 5.** There is a particle knocked in a box at the figure. It jumps from one trajectory to other trajectory. The trajectories are parts of rings, which are created between the walls of the box and they are changing in Planck time.



#### 4. The mathematical apparatus

The physical consideration motivated us for studying the following mathematical problem. We will call, that a circle  $S^1 \subset \mathbb{R}^3$  with finite length and finite circumference (we have a picture of the torus in our mind), which could be deformed, is a ring:

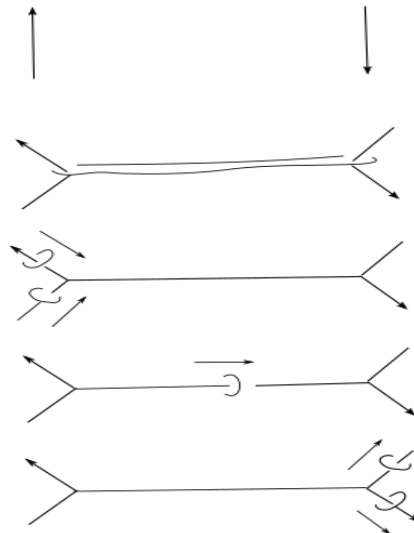
we have a finite collection of  $N$  rings  $S^1$  in  $\mathbb{R}^3$ , which could not touch. Describe how all non-homeomorphic structures, which could be constructed from these finite collections of rings, [21], [22], [23]; Every two rings could be linked only once, they could not be knotted or twisted (when we have a differentiable structure on the ring). We do not consider any Brunnian type of link in 3 and more rings.

We have immediately one bound from below on the number of non-homeomorphic structures when we map the linkage of rings to finite connected graphs on  $N$  vertices. We simply exchange two rings, which are Hopf-linked by two vertices connected by an edge. So the number of linkage of  $N$  rings is at least so big as the number of connected graphs on  $N$  vertices. This is the well-known sequence 1, 1, 2, 6, 21, 112, 853, ...

But because we can also permute the Hopf-linked rings on the given ring, the number of non-homeomorphic structures of linkage of  $N$  rings is bigger than the number of connected graphs on  $N$  vertices.

The map of the linkage of  $N$  rings to the finite connected graphs is illustrated on the Figure 7. We claim that the apparatus for RT is hidden in a theory of so called plabic graphs, [24] and [25], because we will need algebraic classification of these Hopf linked rings. We want to conclude that we need to find an apparatus, how to work with the RT. These plabic graphs should enable it to us, [26].

**Figure 6.** We need to draw an advanced version of Feynman diagram in RT. We switch on extragravity at the beginning, then a ring is created in Planck time between these two rings. Particles collide on these rings on the left, then a particle is propagating on the ring between these two rings and finally two new particles are created on these rings on the right.



There were formulated different approaches to QM during 20th century. One of the most successful reformulations is due to R. Feynman, so called path integral, [27, 28, 29]. The following expression under the integral must be integrated over all trajectories:

$$U(x_b, t_b; x_a, t_a) = \int_{x(t_a)=x_a}^{x(t_b)=x_b} e^{iS[x(t)]/\hbar} Dx(t), \quad (1)$$

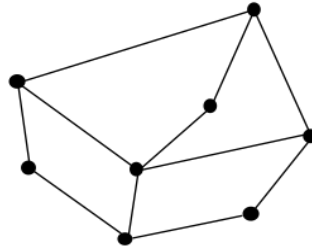
where  $S$  in the argument of the exponential is the classical action and we integrate from point  $(t_a, x_a)$  to  $(t_b, x_b)$  in spacetime. The problematic step in the mathematical formulation is the division of the interval and the limiting process. The Feynman path integral was in the full generality never constructed. We suggest a possible resolution of this problem by changing the set over which we integrate, [30]. We simply use a discrete set, as is depicted in Figure 8 and 9.

## 5. Conclusion

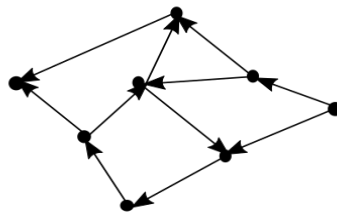
We introduced a concept of nonlinear graviton in this work. Our construction is evidently highly nonlocal and as we want to show now, it could give us a possibility to solve the longstanding problem of dark energy.

The possible qualitative explanation of the problem of DE, [31, 32, 33, 34, 35, 36], is in breaking of the rings on big distances. We can use the mechanical analogy, when a spring between two objects breaks, then these objects start to accelerate, Figure 10.

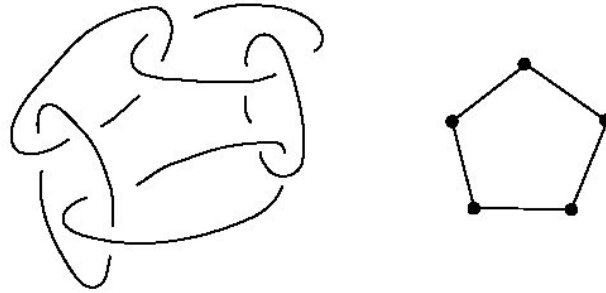
**Figure 7.** We can change the structure of intersection of Hopf-linked rings for a connected graph, where every vertex is a ring and there is an edge between two vertices, if the two rings are linked with a common ring. This could get us in touch with so called plabic graphs.



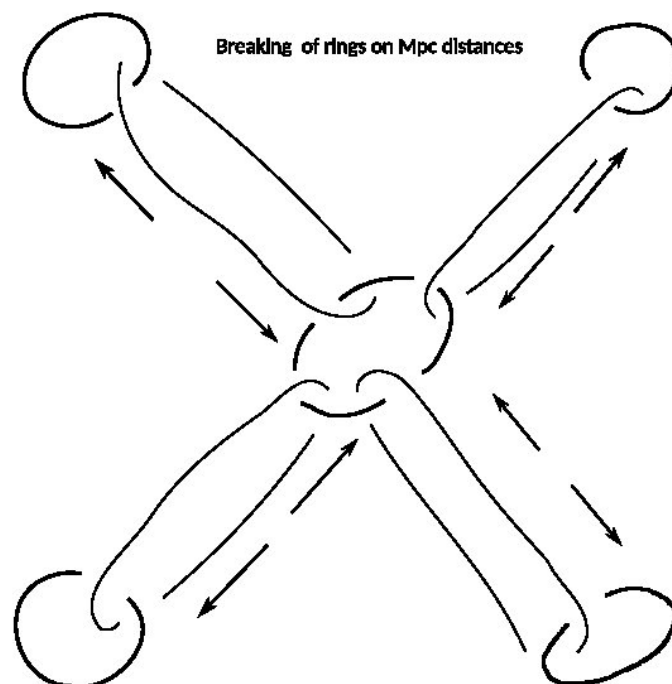
**Figure 8.** Whole connected graph could be oriented. We can induce an orientation for the plabic graph as well.



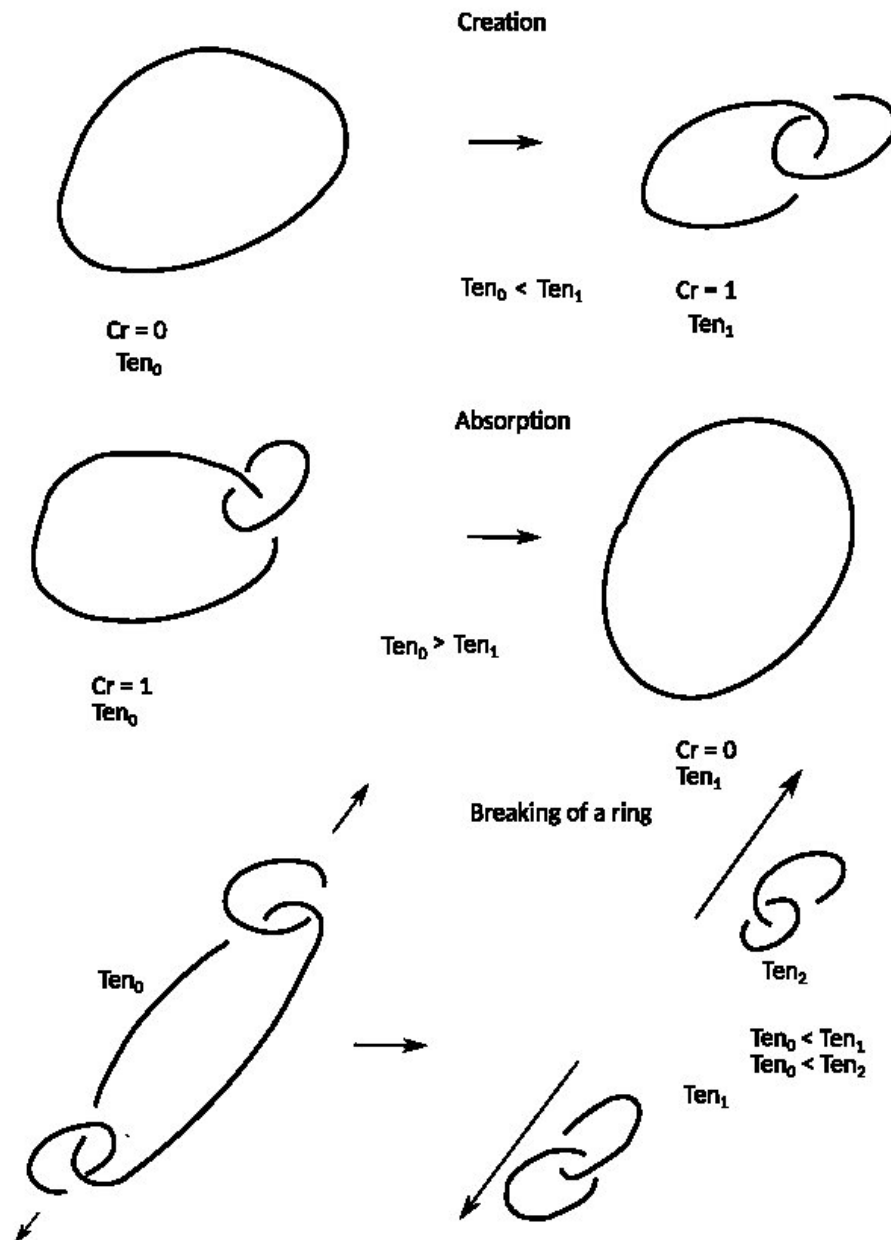
**Figure 9.** Duality between a structure of intersection of Hopf- linked rings and connected graphs.



**Figure 10.** We can model dark energy in RT.



**Figure 11.** The basic processes with rings are creation, absorption and breaking of a ring.



This phenomenon is connected with the problem of background independence because we will define the notion of time on the effectively 1-dimensional object -ring. So, we will not have a fixed background in RT- paradigm. And as we wrote to Figure 11, there are few natural parameters which could describe the rings. When the ring stretches, the  $Ten$  parameter decreases. When the ring contracts, the  $Ten$  parameter increases. Finally, we must not forget that we want to model expanding Universe, where time is flowing in one direction. This parameter  $Ten$  will

enable it.<sup>2</sup>

There are depicted 3 processes on this Figure 11. We want to model the false vacuum, therefore we introduced the creation of rings and absorption of rings (creation and decay of particles). The expansion of the Universe could be modeled by the expansion of the outer ring, which is caused by absorption of rings on this ring. The cause of this phenomenon is generated by the first process in Figure 11.

We presented that our approach could solve the problem of the mathematical formulation of the Feynman path integral. The possible resolution is in changing the set over which we integrate into a discrete set, which is more natural.

People try to find the QG theory in many ways. Someone breaks the Lorentz invariance or try to search for higher dimensions. (See [37, 38, 39] for some arguments against higher dimensions.) Contrary to these works is our argument simple and useful? We introduced a new object, which we call a ring. We gave arguments for an RT, which could be a way to QG and simultaneously unified theory of all interactions. We discussed the whole series of issues: physical, philosophical, and mathematical; Our work has one immediate consequence: fundamental gravitational interaction is traveling by velocity bigger than the velocity of light, although we could not send any information by this velocity with known particles and fields;

We will end with a short list of questions:

What is the origin of the first ring in the Universe? Could it mean that we really should prefer "bouncing-type" of models in cosmology, [40, 41], or we should consider just one vibrating ring at the beginning? Could we search ( if the answer is yes) for evidence of models with "bounce" in space-based gravitational wave experiments?<sup>3</sup>

QM is formulated in the language of probabilities, but GR is a geometrical theory. So, how we get rid of the probabilistic picture of QM?

GR is defined in 4-dimensional spacetime. What are the details of the limit to GR and to QM?

When we create the Hopf-linkage of rings, there is not a physical vacuum between these rings. We build the 3 - dimensional space from the effectively 1 - dimensional objects on which is defined the notion of time. We see that it is necessary to do a double embedding. What are the mathematical details of this embedding?

What is the relation of RT to geometrical twistor theory, [42]? How it is related to non-commutative geometry, [43]? How can we use topos theory, [44, 45]?

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<sup>2</sup> There is also a parameter Cr, which denotes the number of Hopf-linked rings on given ring.

<sup>3</sup> We put the word bounce into quotation marks, because bouncing models are computed in classical approximation. But we are arguing by full QG approach.

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