Graviton as a phonon and dark energy problem

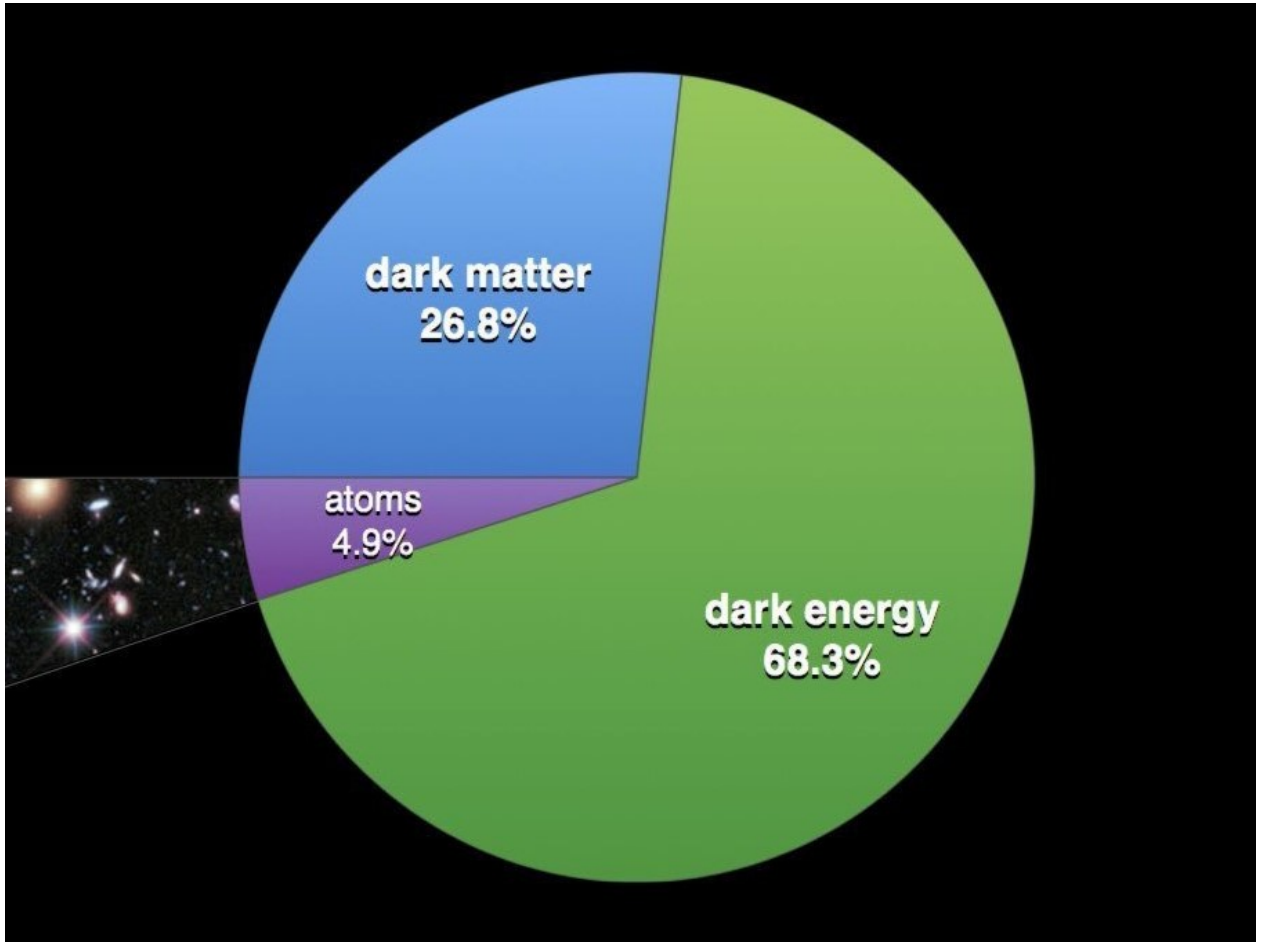
Jan Novák

Czech Technical University in Prague

10th Tux Workshop on Quantum Gravity, 17.2.2023

Dark energy

Roger Penrose: "It is not dark and it is not an energy..."



Classical explanation of the problem of dark energy

- add **cosmological constant** to Einstein equations
- introduce a new field: **scalar field** (phantom, quintom, quintessence)
- **modification of gravity**:
  1. modify the law of gravity at large distances
  2. build the models of gravity from the higher-dimensional models

Quantum gravity and accelerated expansion

1. causal set approach (with cosmological constant)
2. discrete approaches to QG (with cosmological constant)
3. metastring theory (with cosmological constant)
4. group field theory (with phantom matter)
5. string gas cosmology (with phantom matter)
6. theory based on non-commutative geometry (with new dark energy particle mitron)
7. causal dynamical triangulations (with cosmological constant)
8. holographic dark energy
9. asymptotic safety program (without dark energy)
10. entropic gravity (without dark energy)

Causal set approach

We suppose in quantum gravity that the relation

$$\Delta\Lambda\Delta V \sim \hbar$$

holds, where $\Delta\Lambda$ is a fluctuation in cosmological constant in given volume V.
The central result:

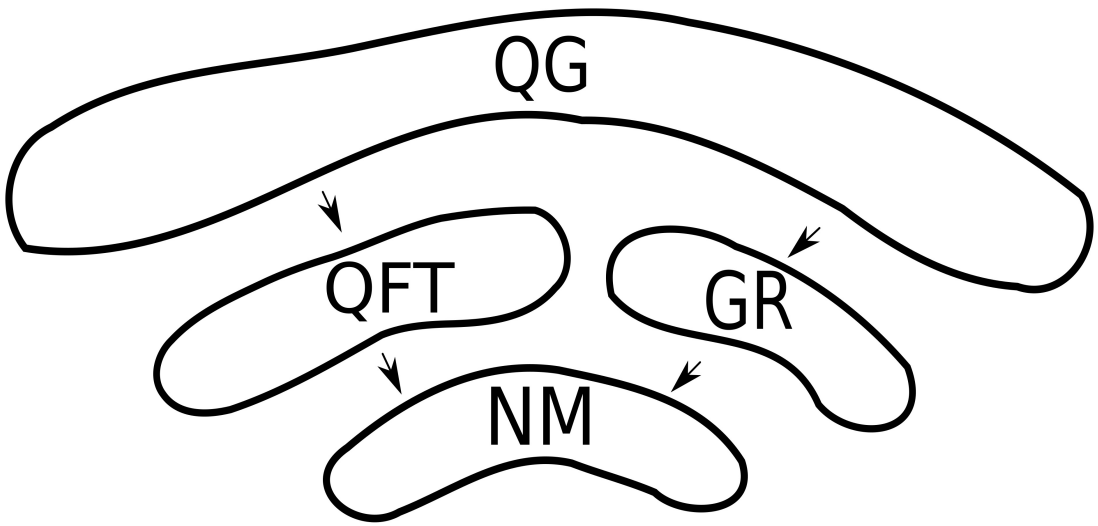
$$\Delta\Lambda \sim \frac{1}{\sqrt{V}}$$

The standard cosmological argument:

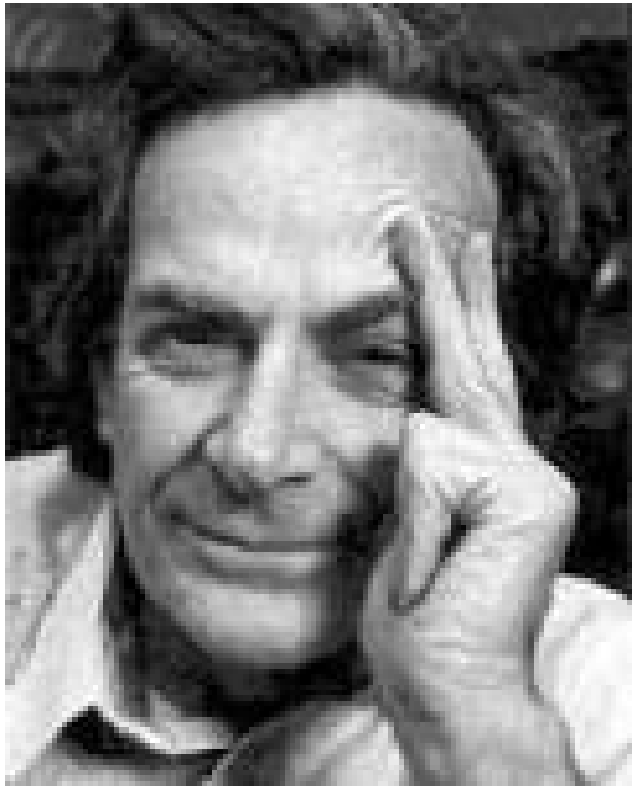
$$V \sim (H^{-1})^4 = H^{-4} \Rightarrow \Lambda \sim \frac{1}{\sqrt{V}} \sim H^2 \sim \rho_{crit}$$

It implies that Λ will be everpresent at least in $3 + 1$ dimensions, arXiv: 1903.11544.

Limits



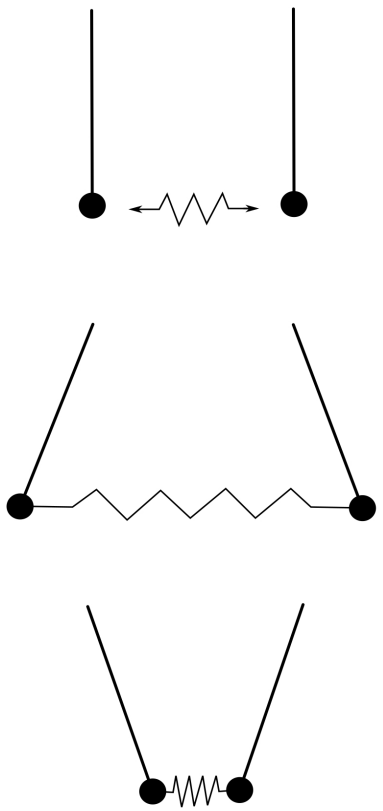
Richard P. Feynman (1918 - 1988)



"What I am going to tell you about is what we teach our physics students in the third or fourth year of graduate school... It is my task to convince you not to turn away because you don't understand it. You see my physics students don't understand it. ... That is because I don't understand it. Nobody does."

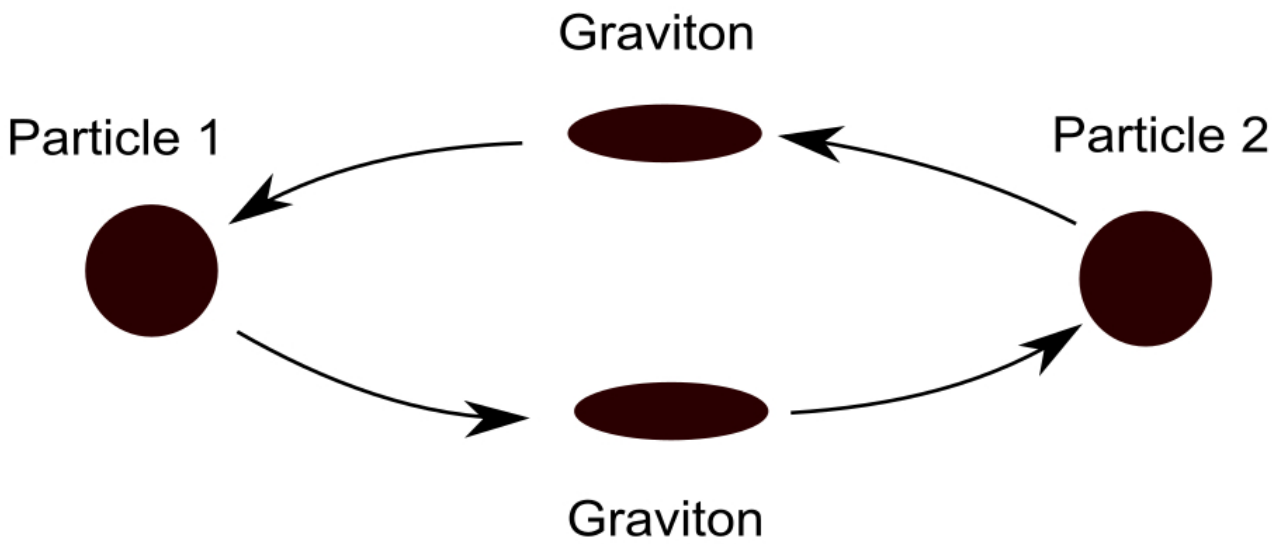
Concept of springs between massive objects

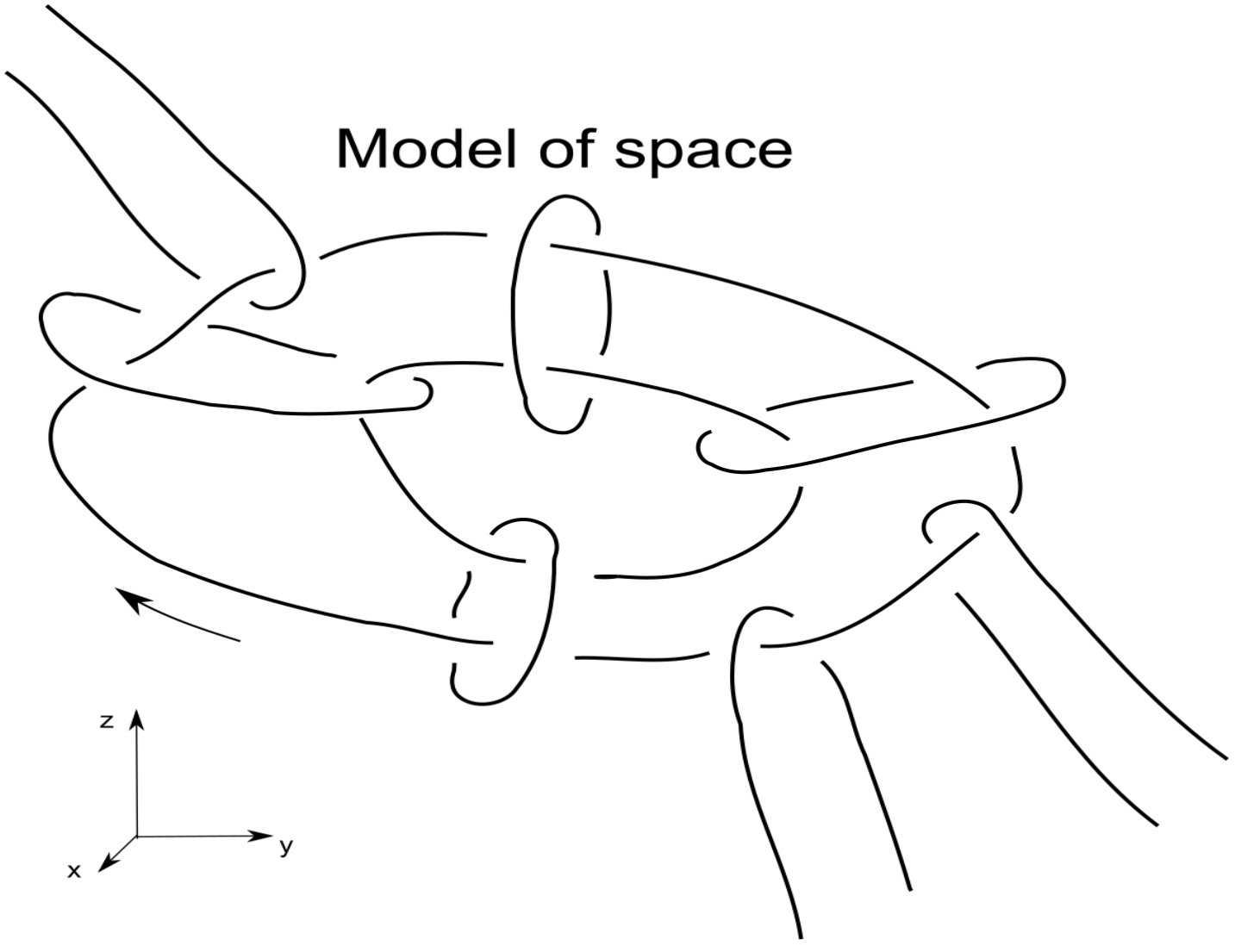
Sidney Coleman once said: "The career of a young theoretical physicist consists of treating the harmonic oscillator in ever-increasing levels of abstraction."



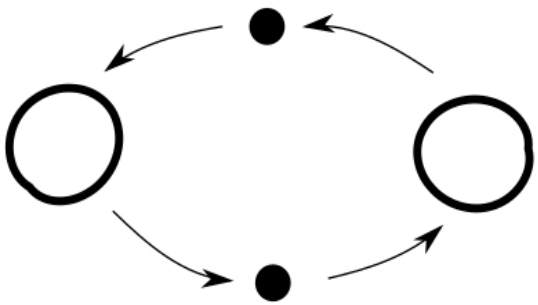
Ring Paradigm

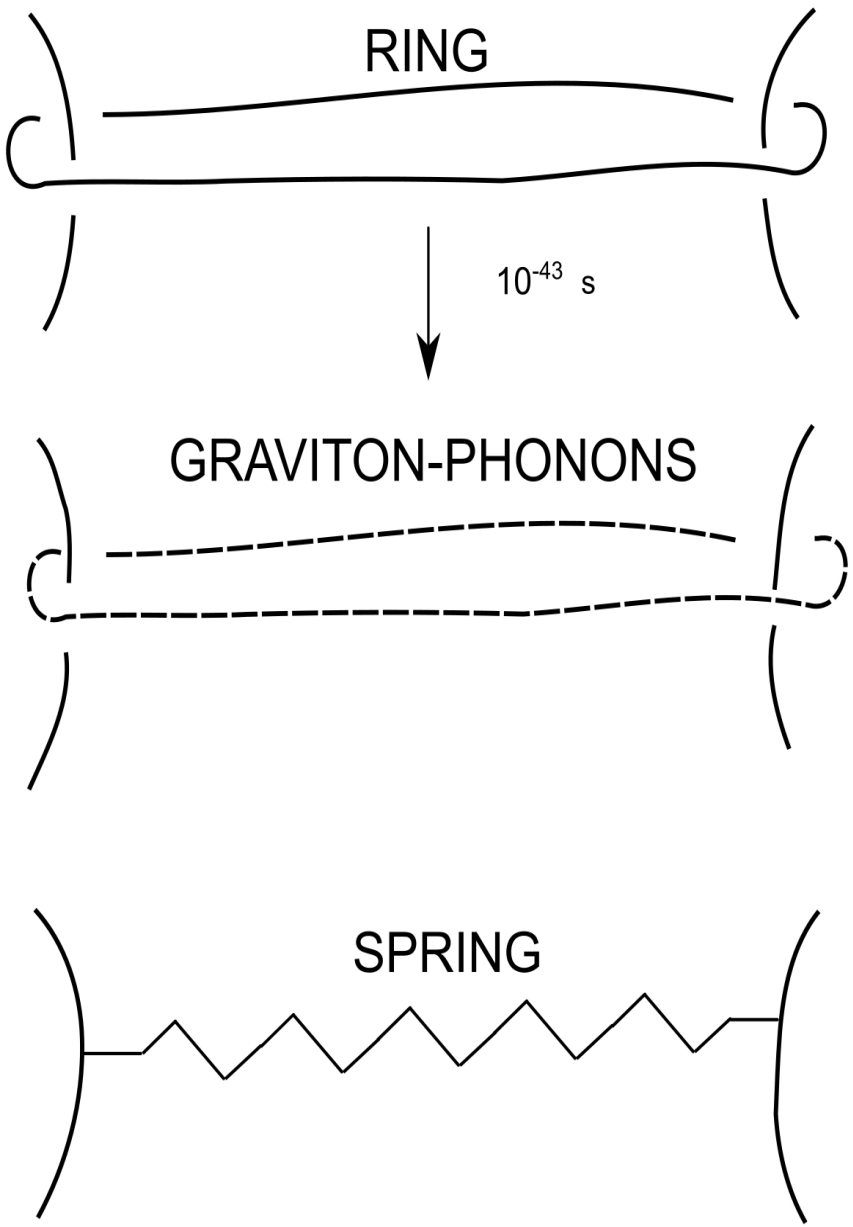
The usual picture about the gravitational interaction was that some quantum (graviton) is exchanging between every particle in the Universe. We suggest a different scheme in RP.



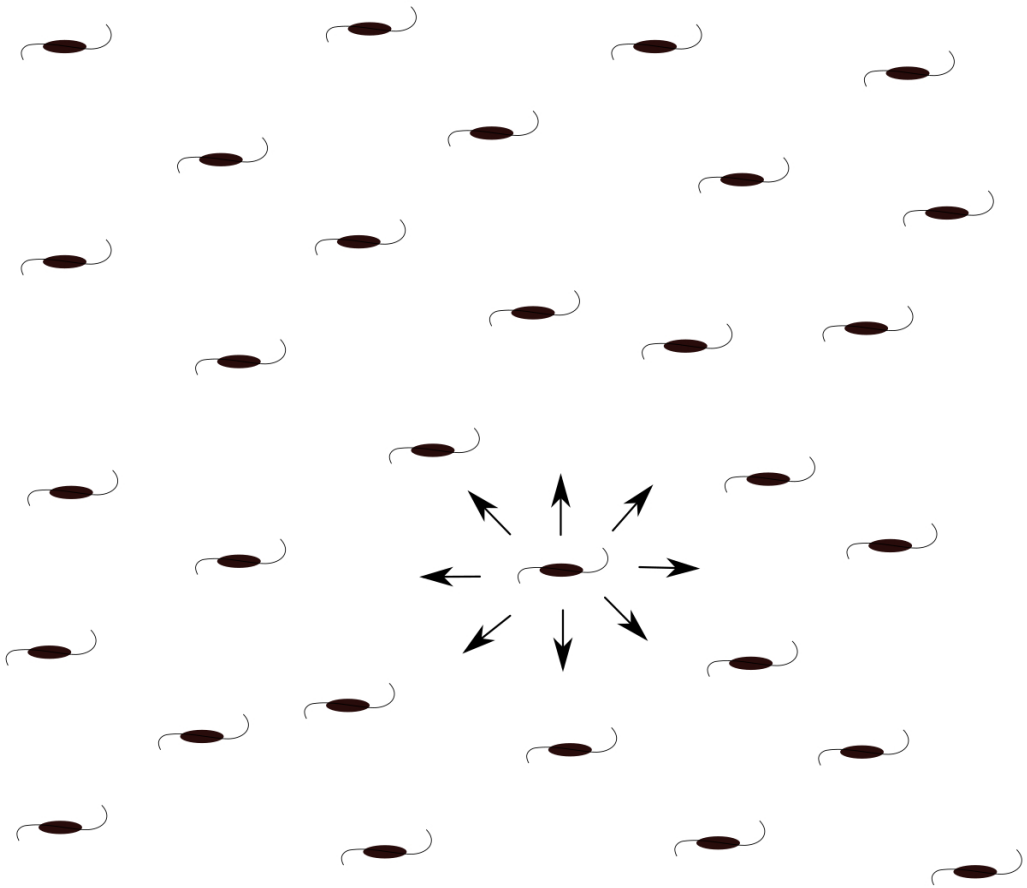

Model of space
z
y
x

We substitute the picture of the gravitons carrying the initial impulse by the creation of a gravitational ring, which tightens the objects in Planck time.



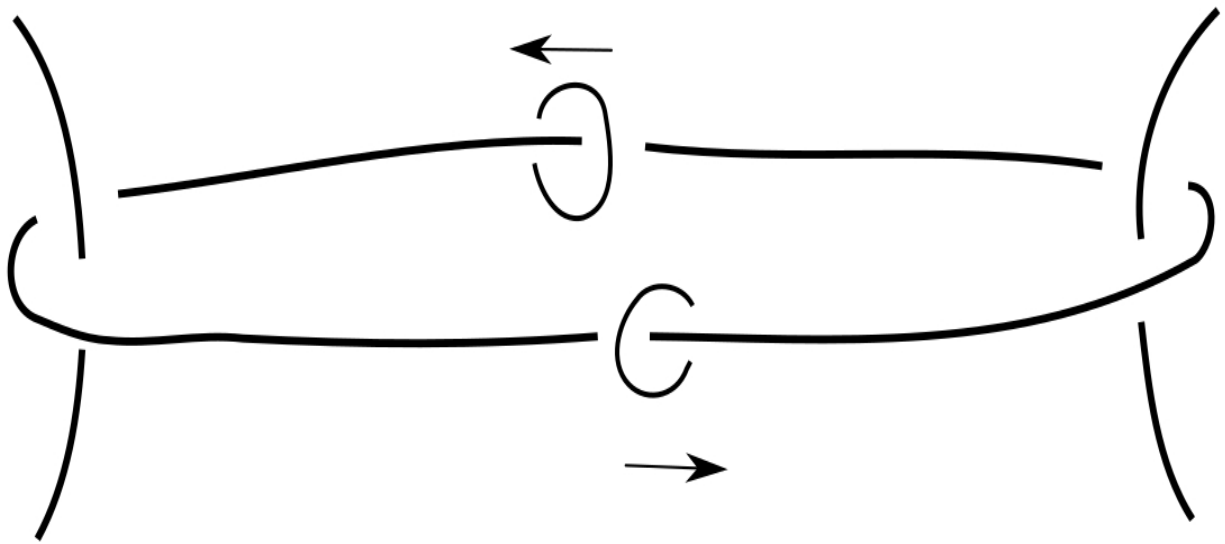

RING
10^{-43} s
GRAVITON-PHONONS
SPRING

Symmetries



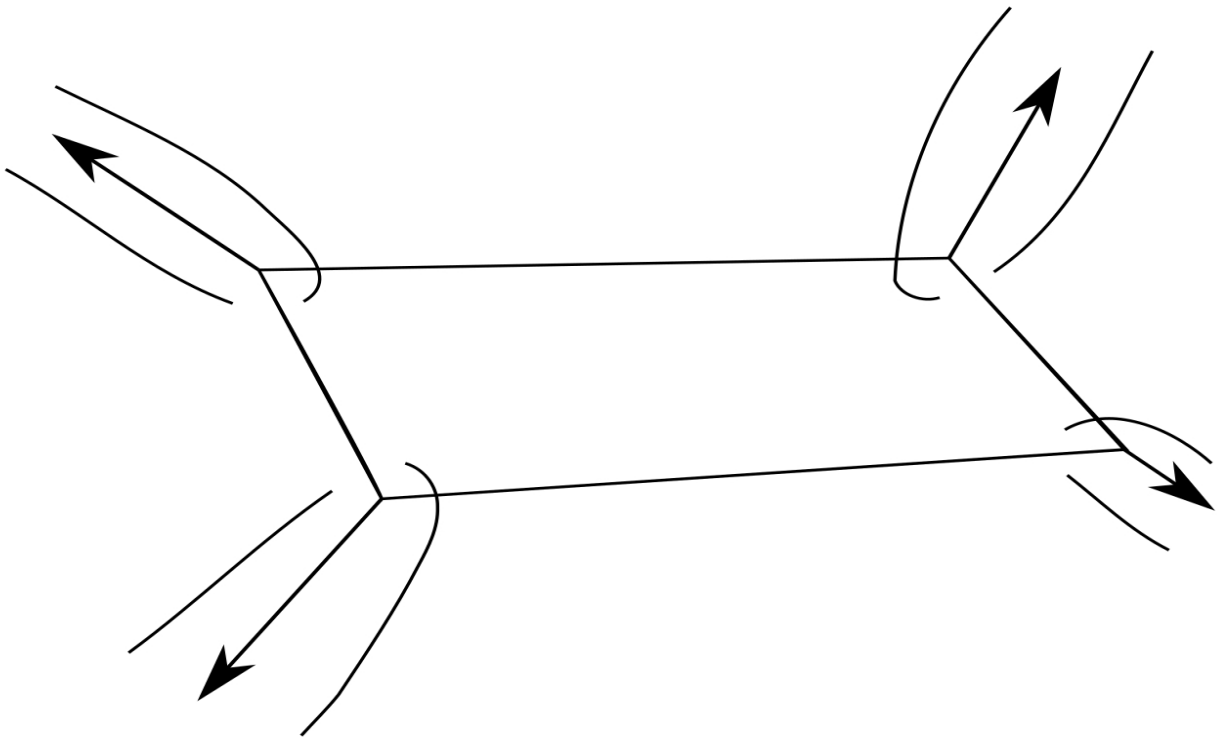
Unchanged particle sector

The elementary particles of the standard model could move only around gravitational rings.

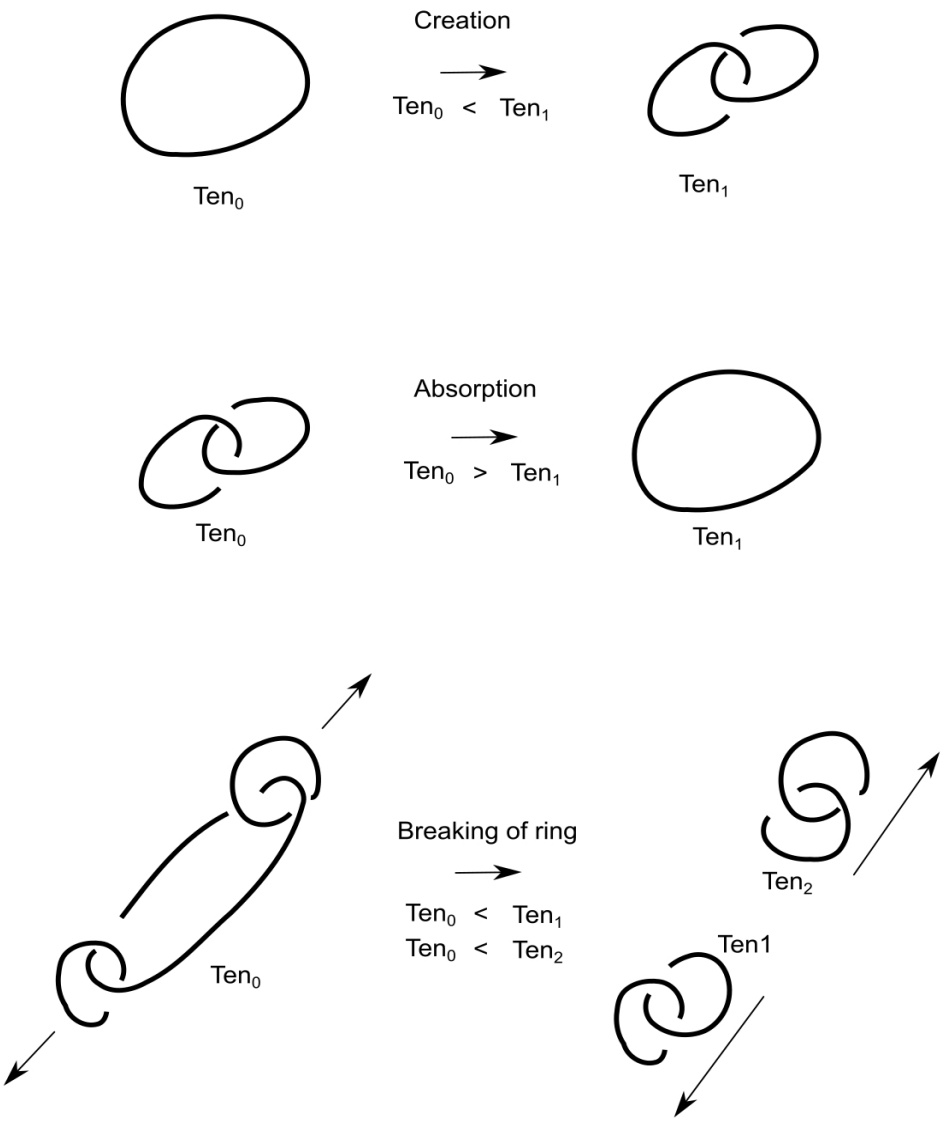


Variational principle

The ring has the shortest length from all possible configurations in space, which means a variational principle must be applied in the derivation of the field equations of RP.

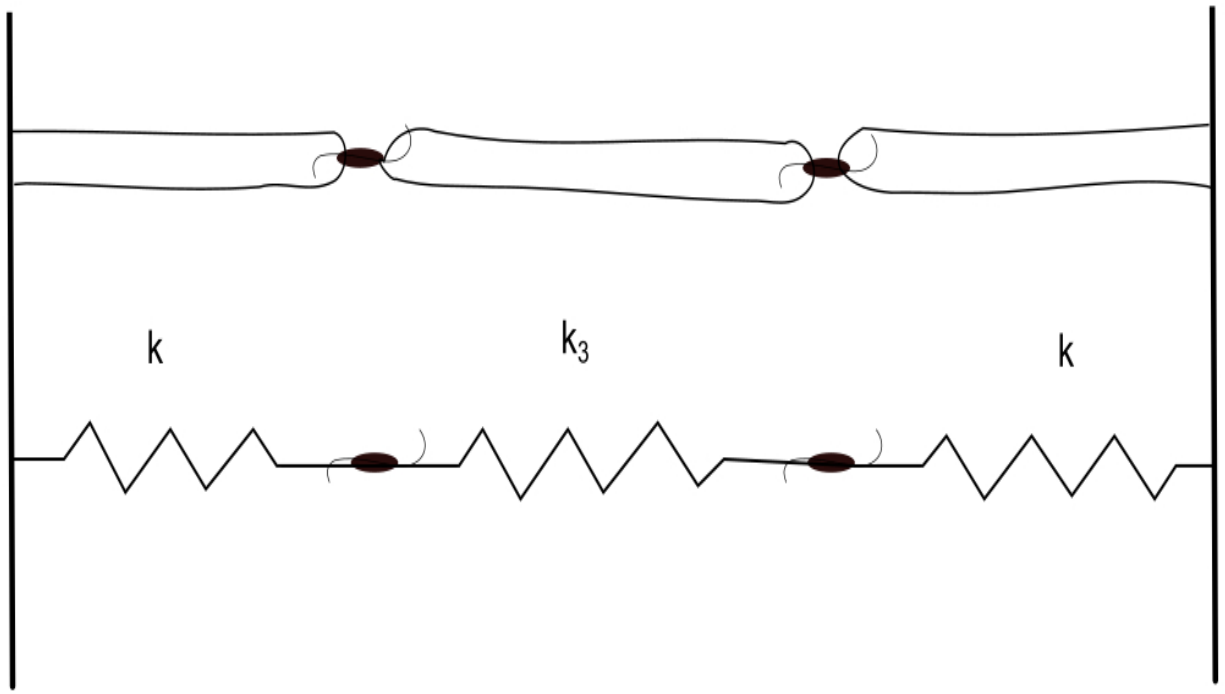


Processes with rings



Graviton as a phonon

The creation of rings in Planck time effectively gives rise to springs between the galaxies. We quantize their longitudinal vibrations and obtain the graviton-phonons, which mediate the Newtonian force.



$$H = \sum_{i=1}^{2} \frac{1}{2m} P_i^2 + \sum_{i,j=1}^{2} V_{ij} Q_i Q_j,$$

where

$$V = \begin{pmatrix} \frac{1}{2}k + \frac{1}{2}k_3 & -\frac{1}{2}k_3 \\ -\frac{1}{2}k_3 & \frac{1}{2}k + \frac{1}{2}k_3 \end{pmatrix},$$

$k, k_3 > 0$.

$$L(\psi,\dot{\psi}) = \frac{1}{2}\int \left[\dot{\psi}(x)\right]^2 dx - \frac{1}{2}\iint K(x-x')\psi(x)\psi(x')\,dxdx', \quad (1)$$

where $K(x-x') = K(x'-x)$ denotes a potential, and we keep only one dimension. It is obtained directly from the Euler-Lagrange equations that

$$0 = \frac{\partial}{\partial t}\frac{\delta L}{\delta \dot{\psi}(x)} - \frac{\delta L}{\delta \psi(x)} = \ddot{\psi}(x) + \int K(x-x')\psi(x')\,dx'. \quad (2)$$

A similarity with the equations in the finite-dimensional case can be observed:

$$L = \frac{1}{2}\sum_i \dot{q}_i^2 + \frac{1}{2}\sum_{i,j} U_{ij} q_i q_j,$$

$$0 = \ddot{q}_i + \sum_j U_{ij} q_j, \quad (3)$$

the identification is $x \leftrightarrow i$ and $\psi \leftrightarrow q$.

Let's do an important case. We put $K(x-x') = -c^2 \frac{\partial^2}{\partial x^2}\delta(x-x')$ and the Lagrangian is according to the one of previous equations the following:

$$L = \frac{1}{2}\int [\dot{\psi}(x)]^2 - c^2 \left[\frac{d}{dx}\psi(x)\right]^2 \, dx \tag{4}$$

Therefore we get a normal wave equation with the velocity of propagation c (it will be later identified with the velocity of light in vacuum):

$$\frac{d^2}{dx^2}\psi(x) - \frac{1}{c^2}\ddot{\psi}(x) = 0 \tag{5}$$

We construct the standard Hamiltonian and so the conjugate momentum $\Pi(x) = \frac{\delta L}{\delta \dot{\psi}(x)} = \dot{\psi}(x)$ is needed. Further step is to introduce the annihilation and creation operators, where

$$w^2(k) \equiv \int K(x) \exp(-ikx) \, dx. \tag{6}$$

Graviton-phonon

The wave equation is derived

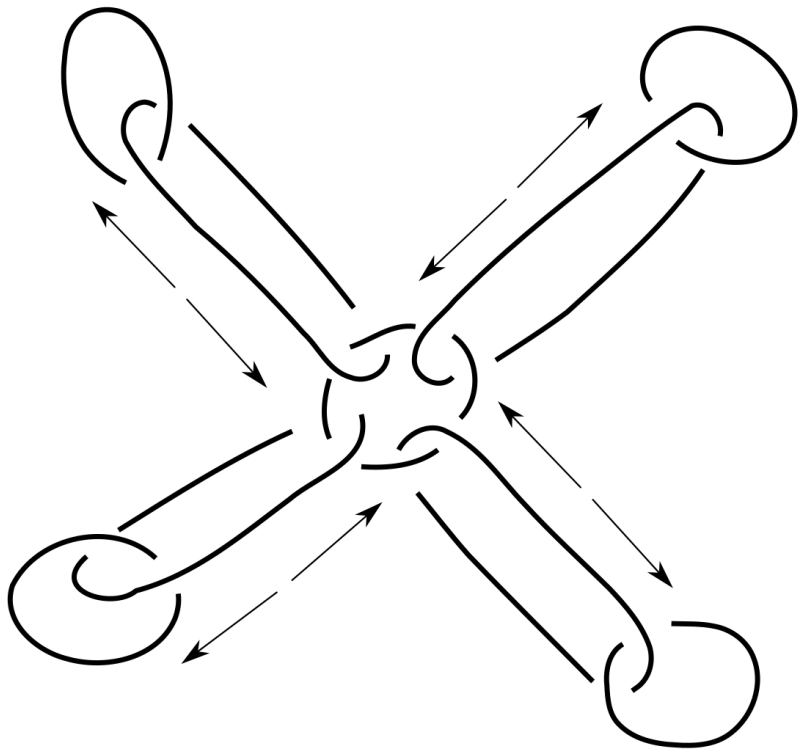
$$\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2} = 0.$$

The most important observation is that photons are the field particles for electromagnetic interaction, which we describe by Maxwell equations containing the Coulomb law, $\vec{F}_{Q_1 Q_2} = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{L^2}$. It has exactly the similar form to the formula for the Newtonian force, $F_{m_1 m_2} = G\frac{m_1 m_2}{L^2}$.
Graviton-phonons are the correct "mediators"of the **Newtonian force**!

Let's stress the result: RP could give an explanation for two facts in classical physics. We know from experiments that gravitational waves are traveling by velocity c_{gw}, which is very close to the velocity of light c with an amazing precision, $|c - c_{gw}| < 10^{-15}$. But c_{gw} should be exactly c according to RP (it was supposed in GR that $c_{gw} = c$, but there had been no reason for that). Further, the similarity of the formulas for the Coulomb and Newton laws is not accidental, but it is necessary for building **the parallelism between photons and graviton-phonons**. As we will see later, these are only the first little surprises that RP brings us.

Accelerated expansion of the Universe

The classical description is that the gravitational rings are effectively made from some material, which has an inner dependence on the deformation due to the stress. The "gravitational"material breaks at *Mpc* distances, which causes accelerated expansion in the Universe.



Modification of gravity

$$\mathscr{R}_{\mu\nu} - \frac{1}{2}\mathscr{R}\mathscr{G}_{\mu\nu} + \Lambda_r \mathscr{G}_{\mu\nu} = \frac{8\pi G \mathscr{T}_{\mu\nu}}{c_g^4}, \tag{7}$$

where $\mathscr{G}_{\mu\nu}$ is the metric and also all the other quantities have an analogous meaning as in GR. The cosmological constant Λ_r could be computed from QFT. We neglect the RHS with respect to the LHS, so

$$\mathscr{R}_{\mu\nu} - \frac{1}{2}\mathscr{R}\mathscr{G}_{\mu\nu} + \Lambda_r \mathscr{G}_{\mu\nu} = 0. \tag{8}$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{9}$$

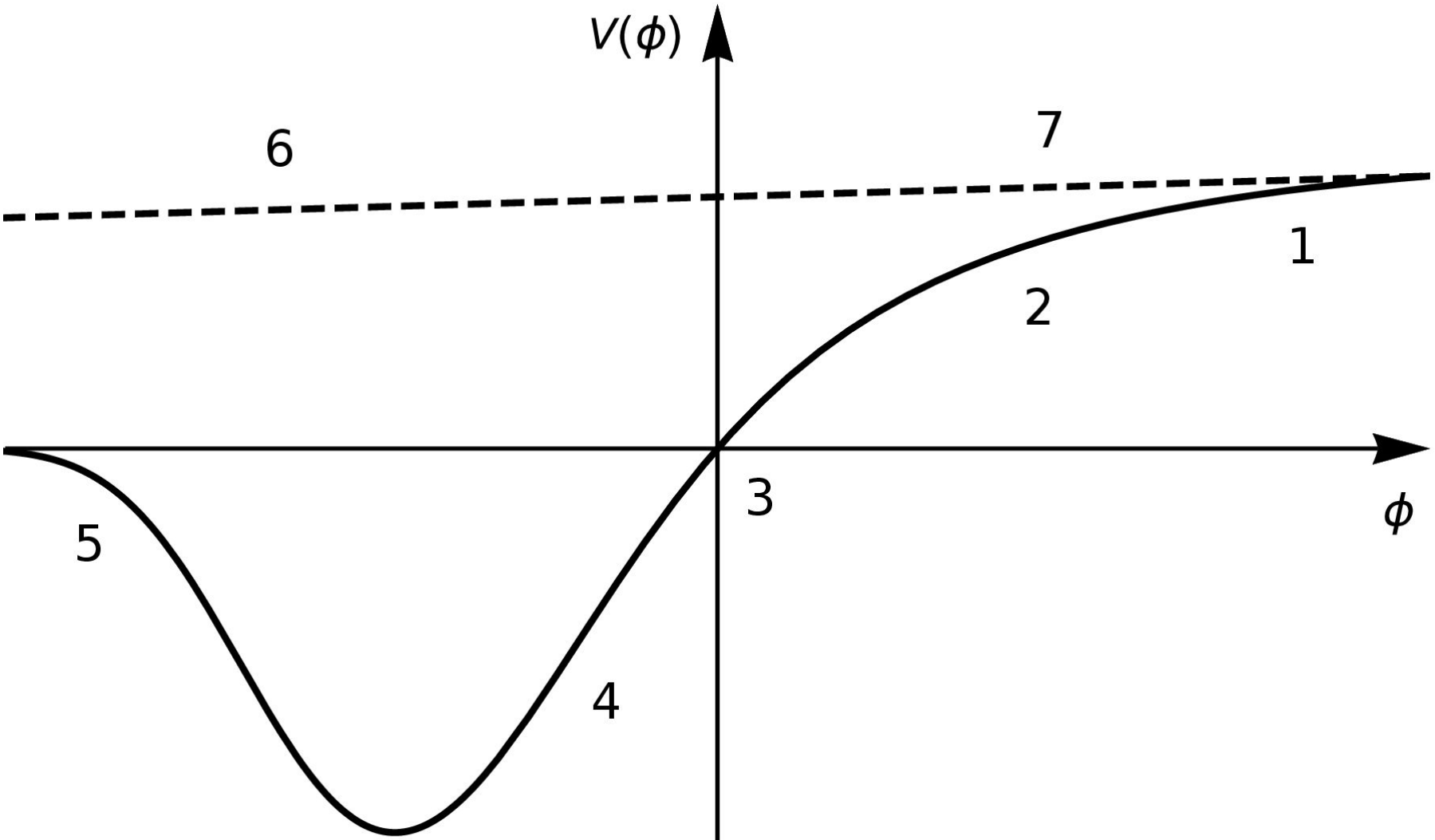
A new cosmological constant term Λ appeared approximately 8 billion years after Big Bang due to the QG phenomenon (actually $\Lambda = \Lambda_b$ in our previous notation):

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{10}$$

Application of the paradigm

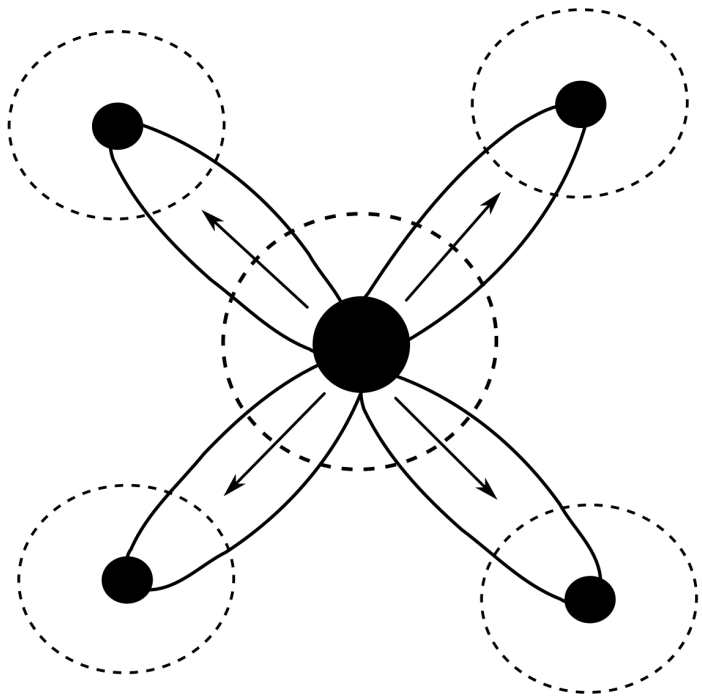
1. singularity theorems
2. cyclic universes
3. black hole information paradox
4. dimensional reduction
5. curvature of the universe
6. EPR-paradox
7. determinism of physical theories

Cyclic universe

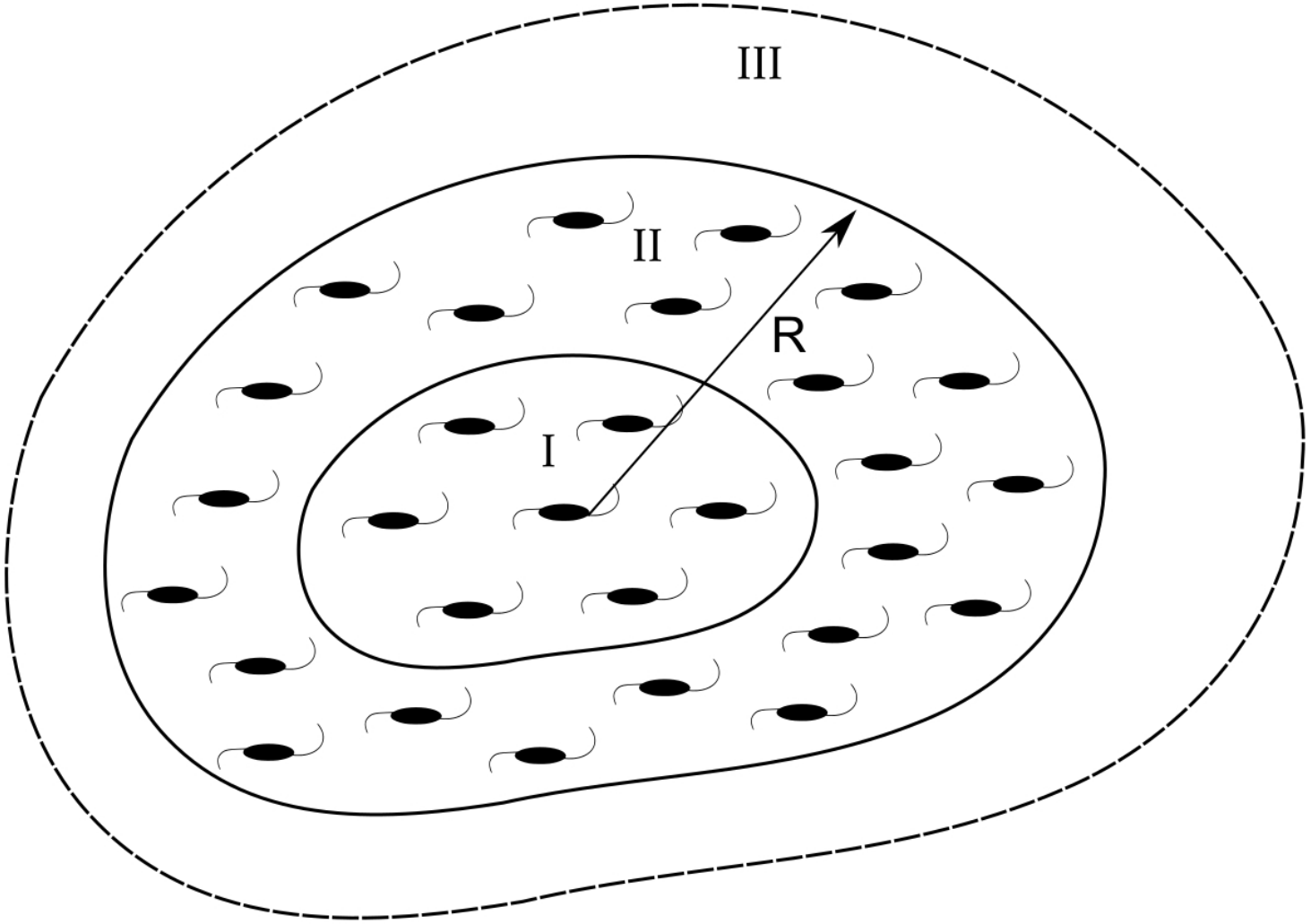


Black hole information paradox

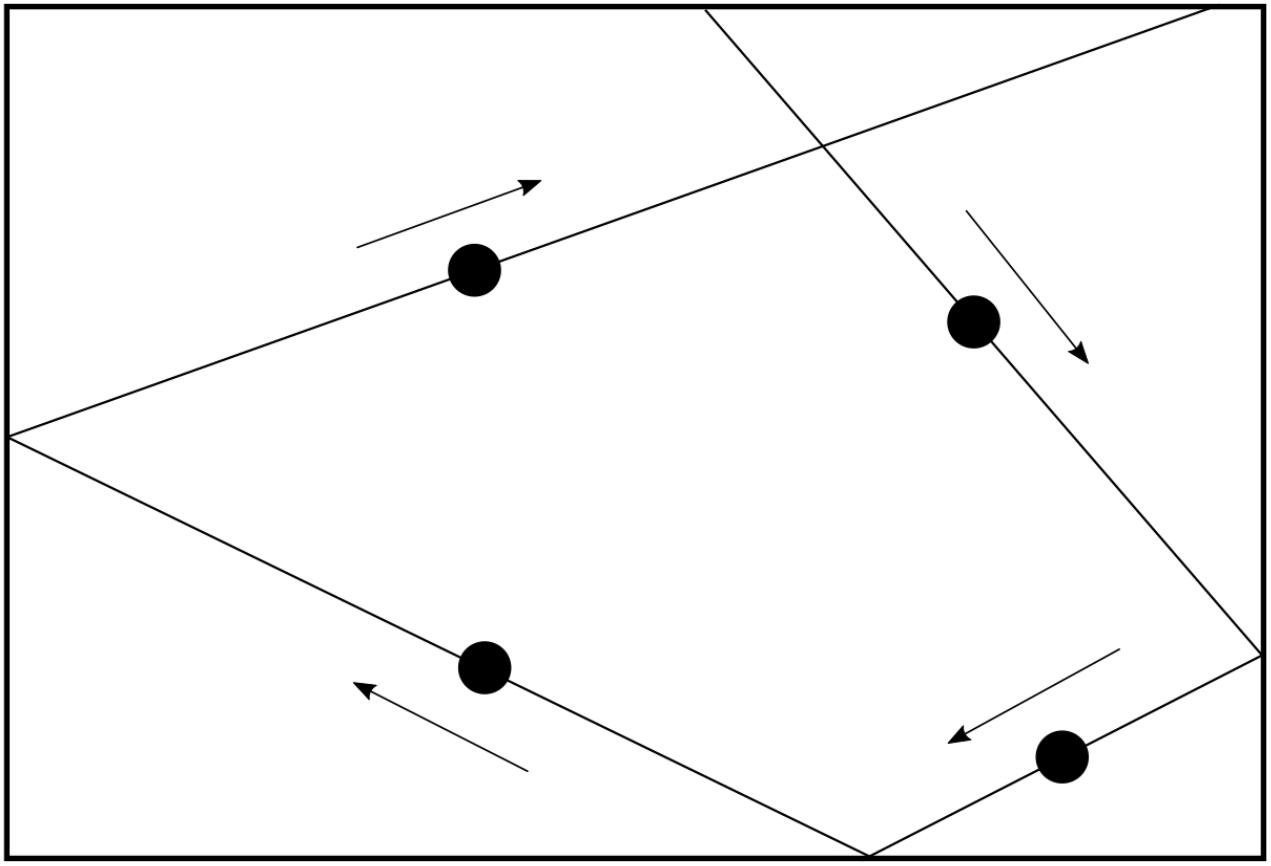
RP is a highly non-local theory, and the rings are sticking out of the horizon for any black hole. It means that the information could travel at superluminal speed from the interior of the black hole. This gives us a full solution of the information paradox on the non-perturbative QG level.



Curvature of the Universe



RP is built on the postulate that the elementary particles move only at the pre-prepared lanes. This could have serious consequences for the determinism of physical theories.



Generalization of transformations

$$t' = \frac{t - \frac{x}{v}\frac{v^2}{c^2}\epsilon - \frac{x}{v}\frac{v^2}{c_g^2}}{\sqrt{1 - \frac{v^2}{c^2}\epsilon - \frac{v^2}{c_g^2}}},$$

$$x' = \frac{x - tv}{\sqrt{1 - \frac{v^2}{c^2}\epsilon - \frac{v^2}{c_g^2}}},$$

where $\epsilon = \epsilon(v)$ denotes some step function defined by the prescription

$$\epsilon(v) = \begin{cases} 1 & \text{for } v \leq c, \\ 0 & \text{for } v > c. \end{cases}$$

Work for future

- scalar field in classical cosmology
- Lorentz violating theories

Albert Schweitzer: "Example is not the main thing in inluencing others, it is the only thing."

Book Two faces of Johny Newman

Seven points of the KAHCG system:

1. We live in the Universe, which is controled by natural laws. It is noone will, noone wanted it. But the Universe was born and we are here. It is a gift, which we got. We are here from the reason that we create new things. We give joy to other people and decorate the world around us.
2. We will find the true meaning from our existence, if we learn to help to other people. If someone has some abilities, he got it from the reason to help others.
3. Someone who knows KAHCG respects his relatives. He learns how to forgive. There is nothing that we could not forgive instead of crimes against humanity.

4. I am not killing anything what I inevitably need for my life. Every plant and animal's species have its place and function on the planet. I respect the life as a miracle in the Universe. I realize that I must protect the life in all its forms on Earth and possibly on all other places in the Universe.
5. I don't lie, I don't steal I don't cheat if I don't need it to the protection of all other KAHCG rules.
6. I come to realize that I must assist in advances in science and art, and protect peaceful coexistence of people on this planet including cultural heritage of all ethnics.
7. When I want to follow these rules, I use the mental meditation: ARLAN GOOT, OUNLY FARS GOOT IN DIS JUNIVEERS. JAA, KEJT Y ALEKS. EETO YE KAHCG!

Mnemonic rule: (st)ring theory

Thank You for paying attention! (Some pictures were taken from the web and some were created by myself.)

jan.novak@johnynewman.com