An Operational Mechanism Featuring Gravity Amplification

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Abstract

The least understood property of the physical Universe is non-locality. Beyond the already revealed domain of quantum correlations, non-locality must also be operational in other phenomena. In this way, the presented work tries to interpret Newton's theory of universal gravity. The distinction of the suggested approach with respect to numerous attempts of this kind is that it is not an *ad hoc* phenomenological proposal to accommodate the observed behavior of gravitating objects. Instead, the surmised mechanism is one of the manifestations of Universe's non-locality that transpires through the locality of interactions of the previously considered cellular automaton model. This mechanism exhibits an exclusive paradox of amplification of the impact with the increase of the distance, which stems from having mediation agents in the form of stretching lines rather than restricted corpuscles. Far away from the source this produces an attraction that is inverse-linear with the distance; close to the source a certain lingering reduces the impact of these agents to regular inverse-square behavior. The considered scheme spans over immense galactic effects attributed to "dark matter" and tiny Solar system anomalies. In the cosmological scale, it accounts for flatten galaxy rotation curves and extra rapidity in the galactic clusters. In the astronomical scale, it incorporates small borderline deviations that can be responsible for the precession of planet orbits and unexpected changes of the velocity in space probes; notably, these deviations are of different signs. The non-locality of gravity confronts the concept of general relativity and challenges the existence of gravitational waves.

Keywords: cosmology, gravitation, dark matter, Pioneer's Anomaly, cellular automata

Contents

1. Introduction

The Newton law of gravitation constitutes the basis of the contemporary worldview. Thus, gravitational inconsistencies in distant cosmos detected several decades ago remain the most formidable embarrassment for modern science (see [1,2,3]). The discrepancy between the observed and expected galactic motions reaches up two orders of magnitude. Recently, some minor deviations from standard gravity have been discovered in space explorations: Pioneer's anomaly and flyby maneuvers. These small deviations pale into insignificance by the side of the deficit of gravitational force in the galactic scale, but all these incongruities urge for an explanation.

Basically, three explanations of gravitational abnormalities are considered (see, e.g., correspondingly [3,4,5]): (1) invocation of "dark matter", (2) modification of the rule of dynamics, and (3) alteration of the law of gravitation. Either of these approaches can provide some *ad hoc* remedy to the observed gravitational abnormalities. Most soothing approach to explain the deficit of gravity is to introduce yet unknown non-luminous "dark matter" that could supply the required extra attraction. However, the "dark matter" as a concept raises several objectionable points. The authoritative Standard Model for elementary particles does not mandate its abnormal properties and long-term search has not brought about firm evidences for the existence of hypothetical "dark matter" candidates (see, e.g. [6,7]). Also, strangely enough, "dark matter" always comes in some characteristic shapes of spherically symmetric halos.

A concordance of the observed and expected motions in the galactic scale can be obtained by diminishing the restraining force for small accelerations through modification of the Newtonian dynamics (MOND) (see [4]). Yet this is a purely phenomenological theory specifically designed to fix the particular inconsistency; besides that, employing this mechanism just by itself may not be sufficient [4,8].

A rather consistent way to explain the surprising galactic motions would be to revise the very theory of universal gravity. This approach, however, causes more perturbations in the worldview of physics than taking the usual suspects of elementary particles or introducing a small isolated correction to the rule of dynamics.

This paper sides with the approach of altering the law of gravitation. A novel operational mechanism for the universal gravity is suggested. This mechanism produces a plain inverse-linear dependence of the attraction force on the distance that has been already considered by a number of researches for a possible explanation of the observed gravitational abnormalities. In the cosmological scale, this mathematical dependence leads to flat galactic rotation curves and higher equilibrium velocities in the galactic clusters. In the astronomical scale, the considered mechanism reduces to an approximate inverse-square dependence. Tiny deviations from this approximation can be tested in space exploration experiments with high quantitative precision; a distinctive quality of these deviations is that they are of different signs.

Since the times of Newton there have been undertaken numerous attempts to devise a model that could substantiate the mathematical formalism of gravitation. Exclusively, the developed mechanism does not present an *ad hoc* solution. It naturally comes out from our cellular automaton model of the physical world, namely from its key part that produces Universe's non-locality. This model has been broadly described elsewhere [9-12]. Properties of gravitation in the context of this model are examined in the Appendix.

The main Section 3 analyses the various outcomes of the devised construction. To begin with, the Section 2 concerns the foundations of the phenomenon of gravity: the machinery of the "action-at-the distance" and the origin of inertia.

2. Workings of gravity

2.1 Universe's non-locality and the "action-at-the-distance"

Newton's concept of universal gravitation presupposes action-at-the-distance: any two pieces of matter in the Universe experience instantaneous mutual attraction. If gravitating objects were interacted with a delay their motions would be much more complicated. This would lead, in particular, to aberrational effects, like in the case of light. Because of the absence of such effects Laplace concluded that the speed of gravity should be at least 10^8 times greater than that of light [13].

The confrontation of far-action and local-action is not a profound philosophical question as it may appear. It is common to have a system with two different types of activities developing in two essentially different time scales. So, the "fast" events look like an action-at-the-distance to the "slow" events.

Albert Einstein who introduced a *Gedanken Experiment* with quantum correlations vehemently opposed the possibility of instantaneous interactions since in his view transcending the speed of light is absolutely forbidden. However, the world is not organized this way: the non-locality of the physical Universe in quantum phenomena is a firmly established experimental fact. Likewise, "action-at-the-distance" may seem not acceptable for gravitation. In Einstein's general relativity the impact of gravitation is supposed to be exercised with the speed of light through ripples of the curvature of the spacetime - the conjectural gravitational waves. Yet the persistent non-detection of gravitational waves (see, e.g. [14]) implicates the non-locality as well. This favors the action-at-the-distance alternative in accordance with Newton's concept.

A thorough exposition of the problem of non-locality of the Universe is given in the book [15], where "action-at-the-distance" is portrayed as the pivotal mechanism essentially involved in all physical phenomena. Besides quantum mechanics and gravitation the mechanism of non-locality must be connected to the underlying processes of the physical world, which are necessary for the control of biological organisms (see, in particular, [16]). This connection elucidates a mystifying remark by A. Eddington that "gravitation propagates with the speed of thought".

2.2 Three sides of mass in classical mechanics

Understanding of gravitation is closely related to understanding of the origin of inertia. Reducing inertia to the action-at-the-distance following the Mach principle does not seem satisfactory; it is difficult to imagine that “when the subway jerks, it is the fixed stars that through you down” [15]. In Newtonian concept gravitation is an instantaneous action between pieces of matter, while the force of inertia - resistance to acceleration – comes from the contact with the absolute space. This contact is performed locally, so the force of inertia does not have to travel from one place to another. As summarized in the Appendix, our cellular automaton model produces exactly what is commanded by the Newtonian concept: “slow” material formations, “fast” action-at-the-distance, intrinsic support of uniform motion, and an undetectable absolute frame of reference for the force of inertia. Conventional realizations of this Newtonian concept run into complications.

“Although Newtonian mechanics is the simplest theory that physics has ever constructed, and although for ordinary, medium-sized physical objects Newtonian mechanics is of the highest degree of verification, its logical structure seems to defy all attempts of a complete analysis, if it is assumed that such an analysis presupposes explicit definitions of the fundamental terms involved” [17]. The complications start with the notion of mass. According to Newton’s definition, mass is a measure of quantity of matter that is proportional to the density and volume. Many scientists had criticized this definition as an example of circular reasoning. Similarly, circular reasoning appears in attempt to define mass with the Second Law of mechanics using the notion of force. As A.N. Whitehead said: “We obtain our knowledge of forces by having some theory about masses, and our knowledge about masses by having some theory about forces” (see [17]). Despite spectacular achievements in science and technology, “…basic notions of [physics], such as the concept of mass, are entangled with serious uncertainties and perplexing difficulties that have as yet not been resolved” [17]. Perhaps, Newton meant something beyond ordinary thinking. Circular definitions are hidden in any long reasoning; the problem with mass arises because the definition of this most fundamental notion comes out too short, so the unavoidable circularity becomes conspicuous.

The given definition of mass asserts that certain physical effects are proportional to the amount of matter. By adjusting the units of measure it is convenient to get the values of mass for different effects equal rather than proportional. The gravitational mass has two distinct aspects - active and passive, characterizing the source and the recipient parts. To consider them as a single value the law of gravitation employs the gravitational constant G. The universal law of gravitation states: any piece of matter attracts any other piece of matter with a force, F, that is proportional to the product of their masses, M_1 and M_2, and inversely proportional to the square of the distance, R, between them. Thus, a body of mass M_1 is attracted to a body of mass M_2 by a force F_1:

$$F_1 \sim \frac{M_1\,(\text{passive}) \cdot M_2\,(\text{active})}{R^2} \qquad (1)$$

Accordingly, a body of mass M_2 will be attracted to a body of mass M_1 by a force F_2:

$$F_2 \sim \frac{M_2\,(\text{passive}) \cdot M_1\,(\text{active})}{R^2} \qquad (2)$$

The equality of F_1 and F_2 required by the third law of Newton's mechanics implies M_1 (active)/ M_1 (passive) = M_2 (active)/ M_2 (passive). Denoting this relation G, we get from (1) and (2) the representation of universal gravity through the same passive mass:

$$F_1 = F_2 = G \cdot \frac{M_1\,(\text{passive}) \cdot M_2\,(\text{passive})}{R^2} \qquad (3)$$

The effect of inertia - resistance of material bodies to changes of their velocity - is measured by a force, F, proportional to the inertial mass and the rate of the velocity changes, the acceleration a: F = M (inertial) · a. The famous principle of equivalence of inertial and gravitational masses is implicit in Newton's mechanics. It allows determining all masses through their weights. Thus, the principle of equivalence is related to the proportionality of inertial and passive gravitational masses. As stated in [18], "a further distinction between active and passive gravitational mass might be made", however, this possibility is ignored. Establishing masses through their weights is possible because all the corresponding effects are merely proportional to the amount matter.

Yet inertia and gravitation are unrelated effects: the rules of mechanics can be applied independently of the universal gravity. Particularly, the second law of mechanics can be introduced without recourse to the concept of weight, for example, through measuring the pull of rotating bodies [19]. So, the proportionality of the inertial and passive gravitational masses is a lateral factor that does not incur profound physical implications as postulated by general relativity. The dynamical behavior of gravitating bodies is determined not by the passive, but by the active gravitational mass. This circumstance should not be ignored. It is the active gravitational mass that generates the decisive trait of the gravitational mechanism – action-at-the-distance.

General relativity does not incorporate active gravitational mass in its operative facilities. Instead, it relies on gravitational waves that propagate as ripples of the spacetime. It has been expected that "the experimental discovery of gravitational waves would merely confirm the obvious" and that "even more important: gravitational-wave astronomy would be a useful adjunct to optical, radio, and X-ray astronomy" [18]. However, this crucial inference of general relativity is not confirmed by experiments (see [14]). Also, spinning bodies, like a gyroscope, should behave differently depending on whether gravity is impelled by instantaneous action-at-the-distance or through propagating spacetime undulations. Experimental investigations of these effects have not yet reported conclusive results [20].

2.3 Mediation of force: stretching pulses vs. restricted corpuscles

Separated material bodies interact through emanation of mediating agents. Flying apart uniformly from a point source, mediating agents spread over a surface area proportional to R^2, so their density, and hence their impact, decreases inversely to R^2. If mediating agents are restricted corpuscles (Fig. 1-a), a force with an inverse-square dependence on the distance is created. Numerous attempts have been made since Newton's time to accommodate such kind of a scheme to gravitational attraction, but they have not led to any well-established result. "That gravitation is propagated by the action of a medium, and consequently is a process requiring time for its accomplishment, had been an article of faith with many generations of physicists" [13].

This paper presents another attempt to construct a mechanism of gravitation following the given operational scheme. The surmised mechanism has arisen from the cellular automaton model overviewed in the Appendix. For the mathematical analysis of this gravitational mechanism we will focus our attention only on the part of this cellular automaton model that yields solutions in the form of fast spreading constant phase lines (Fig. 1-b). The stretching pulses of these lines produce action-at-the-distance as they spread with a speed substantially faster than the speed of material synchro formations, the incoming pulses exercise a gravitational pull as material synchro formations tend to reposition towards the lines where phase constancy is maintained.

Figuratively, a stretching pulse acts as a harpoon that swiftly hits a target and remains effectual until the trailing rope slowly disintegrates. So, the impact of a stretching pulse can be described as an instantaneous imposition of a synchronized line, which then gradually shrinks from the rear by desynchronization. Thus, at a distance, R, an impact from such a stretching pulse will endure for an interval of time, Δt_R, between the passage of the front and rear activities with the velocities V_f and V_r:

$$\Delta t_R = R \cdot \left(\frac{1}{V_r} - \frac{1}{V_f} \right) \cong R \cdot \frac{1}{V_r} \qquad (4)$$

As will be seen, it has been determined that the front speed, V_f, is extremely high - about $10^{40} \cdot c$ (c is the speed of light); the lower rear speed, V_r, is estimated as $10^{32} \cdot c$.

The operational advantages of the spreading constant phase pulses as force mediating agents lie in the following. In general, mediation agents may encounter a problem with gravitation screening by unrelated bodies. For stretching pulses this problem does not come out: the bulk of a body is transparent to the thin 1D lines, which pierce mostly empty space between the material formations without obstruction. Thus, material bodies undergo instantaneous pairwise interactions of any elements, irrespective of possible screenings. Intermediate bodies placed between interacting bodies not only do not hinder the interaction contacts, but the intermediate bodies themselves participate in the universal gravitational attraction as well. Further, with various types of mediation agents there could be a problem of polluting the Universe with the debris of gravitation mediators that had failed to make their contact. The suggested mechanism is completely devoid of this problem. The considered mediation agents arise out of nothingness as synchronized lines and dissolve entirely without any trace through desynchronization.

The stretching pulses mechanism leads to the dependence of the attraction force on the distance that is inverse-linear rather than inverse-square. So, what does this mean?

2.4 Gravitational forces in the astronomical and cosmological scale

Two factors determine the force produced by mediating agents: the operational factor measuring their individual impacts and the geometric factor, $1/R^2$, accounting for the spread of these impacts in space. If agents mediating the attraction force were restricted corpuscles (Fig. 1-a) they would produce a fixed impact resulting in the exact inverse-square dependence on the distance: the coefficient G in (3) is a constant. The stretching pulses (Fig. 1-b) produce a changeable impact. So, the constant G in (3) has to be substituted by a transfer function G(R) expressing the dependence of the impacts on the distance:

$$F = G(R) \cdot \frac{M_1 \text{ (passive)} \cdot M_2 \text{ (passive)}}{R^2} \qquad (5)$$

The impact of a mediating agent is proportional to the time of its application. Hence, as prescribed by (4), stretching pulses exercise impacts directly proportional to the distance. There is a natural reason for a slight correction to this action: stretching pulses do not start fading away immediately, but after a certain time delay. This ensures the delivery of some minimal impact, G_0, even at a zero distance. Thus, we get:

$$G(R) = G_0 \cdot (1 + R/R_0) \qquad (6)$$

The initial stage of this transfer function has to accommodate a smooth transition from zero. A conceivable approximation would be a horizontal line as indicated in Fig. 2. To obtain the value of the gravitational force we have to multiply the geometric factor $\sim 1/R^2$ by the operational factor, a transition function like (6) with corresponding modifications. The horizontal line approximation presents Newton's inverse-square law; the gravitational constant G equals approximately the parameter G_0. The parameter R_0 is the characteristic distance for the stretching pulses mechanism, the distance where both impacts - regular Newtonian and increased by stretching pulses - become comparable.

The characteristic distance R_0 establishes a watershed between the two differing approximations for gravitational attraction determined by the transfer function regions: constant or linear. The case $R \ll R_0$ presents the astronomical scale: gravitational forces between the bodies are approximately inversely proportional to the second power of the distance. The case $R \gg R_0$ presents the cosmological scale: gravitational forces between the bodies are approximately inversely proportional to the first power of the distance.

3. Contemplating the outcomes of the stretching pulses mechanism

3.1 The faraway intensifications

3.1.1 Spherical configurations with inverse-linear gravity

We will examine the specifics of gravitational dynamics in the cosmological scale under the inverse-linear attraction force using a proportionality relationship:

$$\text{Elemental\_unit\_force} \sim (\rho \cdot dV)/R \qquad (7)$$

Here ρ is the density of the active gravitational mass, dV is an elemental volume, and R is a distance.

We will concentrate on a basic structure: a uniform sphere of radius R_E falling in the cosmological scale, $R_E >> R_0$. For Newton's inverse-square law the dependence of the gravitational force on the distance from the center of a uniform sphere is simple: inside the sphere the attraction force grows linearly, outside of the sphere it decreases as $1/R^2$. In the case of the inverse-linear law this dependence is more complicated.

First, let us consider an elemental spherical layer of gravitating matter of a certain radius R (Fig. 3). For the inverse-square law the force acting upon a material body anywhere inside this layer will be exactly zero; for the inverse-linear law the inside force will depend on the distance from the center, r; we will denote it F(r,R)·dR. To evaluate the integral presenting this inside force we specify a conic rim within the considered spherical layer at angle φ of angular width dφ, so all the elements of this rim will be at a fixed distance *l* from the given point, and thus produce the same force inversely proportional to *l* (Fig.3). The value of *l* is determined by the relationship: $l^2 = R^2 - 2Rr\cdot\cos\varphi + r^2$. The resultant force from the conic rim at angle φ, dF(φ; r,R), is the sum of projections of all the attraction forces from all the elements of the indicated rim:

$$dF(\varphi; r,R) \sim -\frac{\rho\cdot 2\pi R^2 dR \cdot (R\cdot\cos\varphi - r)\cdot \sin\varphi \cdot d\varphi}{(R^2 - 2Rr\cdot\cos\varphi + r^2)} \qquad (8)$$

The minus sign denotes the direction towards the center. The total force, F(r,R), will be the integral of dF(φ;r,R) over φ from 0 to π. For Newton's law, the corresponding expression for dF(φ;r,R) will look the same as (8) except that the denominator will contain the distance *l* in one unit higher power; expectedly, in this case the integral for the total force turns out 0. For the inverse-linear law, substituting cosφ = x in (8) yields

$$F(r,R)\cdot dR \sim -\frac{\rho\cdot\pi R^2 dR}{r} \cdot \int_{-1}^{+1} \frac{(x - r/R)\cdot dx}{((R^2 + r^2)/2Rr - x)} \qquad (9)$$

Evaluating the integral in (9) we get:

$$F(r,R)\cdot dR \sim -\rho\cdot 4\pi R\cdot dR\cdot [(1/3)\cdot(r/R) + (1/15)\cdot(r/R)^3 + \ldots (1/(2k-1)(2k+1))\cdot(r/R)^{k-1} + \ldots] \quad (10)$$

Thus, the inverse-linear law produces a force of attraction (10) towards the center. The factor $\rho\cdot 4\pi RdR$ is the mass of the spherical layer, M_{SL}. We can estimate the attraction force, F_0, near the center of the spherical layer, $r << R$, and the attraction force, F_b, near its boundary, $r \approx R$:

$$F_0 \sim (M_{SL}/R)\cdot(1/3)\cdot(r/R) \quad (11)$$

$$F_b \sim (M_{SL}/R)\cdot(1/2) \quad (12)$$

So, the attraction near the boundary of a hollow thin spherical layer is about half of the attraction to the same mass if it all were in the center. Note, that for Newton's inverse-square law any force inside a spherical layer strictly equals zero.

Gravitational force acting upon a point inside a uniform sphere of radius R_E at a distance r form the center, $F(r,R_E)$, comes from two separate components: attraction from the internal spherical core, $F_{core}(r)$, and attraction from the surrounding shell - external thick spherical layer, $F_{shell}(r)$: $F(r,R_E) = F_{core}(r) + F_{shell}(r)$. The obtained result (10) allows calculating $F_{shell}(r)$ by integrating the attractions of elemental spherical layers over R from r to R_E. With a substitution $\xi = r/R$ we get:

$$\int_r^{R_E} F(r,R)\cdot dR = \int_1^{r/R_E} \rho\cdot 4\pi r^2\cdot[(1/1\cdot 3)\cdot\xi + (1/3\cdot 5)\cdot\xi^3 + (1/5\cdot 7)\cdot\xi^5 + (1/7\cdot 9)\cdot\xi^7 + \ldots]\cdot d\xi/\xi^3 \quad (13)$$

This expression presents the force acting at a point at distance r from the center of a uniform spherical shell of radius R_E. Calculations go straightforward; for the polynomial terms the small integration limit r/R_E is replaced by zero:

$$F_{shell}(r) \sim \rho\cdot 4\pi r^2\cdot[-(1/3)\cdot(R_E/r) + 1/3 - ((1/1\cdot 3\cdot 5) + (1/3\cdot 5\cdot 7) + (1/5\cdot 7\cdot 9) + \ldots)] \quad (14)$$

The sum of the series, S, is evaluated as:

$$S = 1/1\cdot 3\cdot 5 + 1/3\cdot 5\cdot 7 + \ldots = \tfrac{1}{4}\cdot\{[1/(1\cdot 3)-1/(3\cdot 5)] + [1/(3\cdot 5)-1/(5\cdot 7)] + \ldots\} = 1/12 \quad (15)$$

Thus, recognizing the mass of the internal core $M_{core} = (4/3)\cdot\pi r^3\cdot\rho$, we get the external force from the surrounding shell:

$$F_{shell}(r) \sim -(M_{core}/r)\cdot(R_E/r) + 0.25\cdot(M_{core}/r) \quad (16)$$

Now, let us evaluate the internal attraction force from the core of radius r itself. For Newtonian inverse-square law, the attraction force to a sphere of a radius r outside of this sphere at a distance L from its center, $L > r$, will be $\sim M/L^2$ irrespectively of the values of r and L. For the inverse-linear law, the attraction force acting at a faraway distance, L, from the center of the sphere, L >> r, would be apparently ~ M/L. In general, to get the dependence of the attraction force at an outside point x at a distance L(x) from the center of the given sphere, F(r,L), we need to perform an integration over the volume, V, of this sphere:

$$F(r,L) \sim \iiint_V \rho \cdot dV/L(x) \tag{17}$$

Calculation of the integral (17) is a little bit strenuous exercise. The result can be obtained, in particular, through cutting the volume V by spherical bases of conic sectors at definite distances from x. Thus, we will get:

$$F(r,L) \sim -(M/L) - (M/r) \cdot 3 \cdot [(1/1{\cdot}3{\cdot}5)(r/L)^3 + (1/3{\cdot}5{\cdot}7)(r/L)^5 + \ldots] \tag{18}$$

For large distances, $L \to \infty$, this provides as expected

$$F(r, \infty) \sim -(M/L) \tag{19}$$

For a point at the surface of the internal core, L = r, taking into account the result for the sum (15), the expression (18) gives a result for the internal force:

$$F_{core}(r) \sim -(M_{core}/r) \cdot (5/4) \tag{20}$$

Finally, we have the total force, $F(r, R_E)$, acting upon a point inside a uniform sphere of gravitating matter at distance r from the center as the sum of (20) and (16):

$$F(r, R_E) = F_{core}(r) + F_{shell}(r) \sim -(M_{core}/r) \cdot (1 + (R_E/r)) \tag{21}$$

Formula (21) shows how gravitational attraction arising inside a big uniform sphere is affected by the distance, r, from the center of this sphere: $0 < r < R_E$. Since the mass of the internal spherical core grows as r^3 the force will change with r as $\sim (r^2 + R_E{\cdot}r)$. In a similar situation Newton's inverse-square law produces a simpler dependence: ~ r. Thus, the relation of the inverse-linear and inverse-square forces will be:

$$\frac{\text{Inverse\_linear\_force}}{\text{Inverse\_square\_force}} \approx 1/R_0 \cdot (r+R_E) \tag{22}$$

This comparison is valid for the cosmological scale when $R_E >> R_0$. The proportionality coefficient $1/R_0$ comes from considering (3) with regard to (5) and (6). Thus, say R_E is ten times R_0, then the inverse-linear gravitational force will exceed Newton's force by about 10 times near the center and by about 20 times at the boundary of the given sphere. Outside of this sphere the inverse-linear force will decline in accordance with the formula (18) maintaining its preponderance over Newton's force, roughly in proportion to the distance.

3.1.2 Flatness of the rotation curves

The perplexing deficit of gravity in galactic motions can be compensated assuming the inverse-linear dependence of the attraction force. The major puzzle is that the velocity of the rotating objects in spiral galaxies, V, is too high for the attraction of conventional gravity. The centripetal acceleration of an object at a distance R from the center is $\mathcal{V}^2/R$. Considering that a substantial part of the galaxy mass is around its center, the acceleration from Newton' gravity would be GM/R^2. These two accelerations should be balanced resulting in the rotation curve $\mathcal{V} \sim R^{-1/2}$. Thus, $\mathcal{V}$ has to gradually decline with R: the further is an object from the center the slower it rotates, as happens in the astronomical scale within the Solar system. Surprisingly, in the cosmological scale in galaxies the rotation curves mainly appear flat, i.e. the velocity $\mathcal{V}$ stays approximately constant irrespectively of the distance from the center. Even more, the velocity V maintains constancy beyond the edge of the visible matter. For the case of inverse-linear gravity the centripetal acceleration is to be equated with GM/R. This produces a flat rotation curve $\mathcal{V} \approx$ constant.

Typically, the density of visible matter in galaxies rapidly decreases with moving away from the center. Therefore, to explain the flat rotation curves with regular gravity it is necessary to assume that galaxies contain a substantial amount of invisible "dark matter". Strangely, "dark matter" always embodies luminous matter and transpires in a form of spherically symmetric haloes. With the suggested mechanism the explanation of the halo configurations of the "dark matter" is obvious: the amplification of the gravitational attraction is due to stretching pulses stemming from the luminous matter, so it will always appear that the alleged "dark matter" surrounds the original material structures.

The idea that the deficit of gravity in galactic motions can be explained assuming the inverse-linear dependence of the attraction force rather than "dark matter" has been considered and discussed in different variations by a number of researchers (see, e.g. [21]). The work [21] indicates a specific drawback of this approach: the masses of the galaxies do not scale appropriately with the Tully-Fisher law, an empirical relationship between the galaxy luminosity and its rotational speed. Theoretical considerations of this subject as presented in [21] assume that the attraction force to a sphere in the case of inverse-linear law is inversely proportional to the distance from the center of this sphere, 1/R, in parallel with Newton's law where this attraction is inversely proportional to the square of the distance, $1/R^2$, for any size of the sphere. This Newton's theorem is true for the inverse-square dependence, but its straightforward transference to the inverse-linear dependence should be restrained. The inverse-linear force is exercised just by a point source, or by a finite sphere at infinite distance. The situation with finite spheres and finite distances is more complicated as expressed by formula (18). In these circumstances, especially for non-uniform densities, the consideration of Tully-Fisher relationship might involve geometric factors lessening the scaling restrictions.

Another distinctive thing that affects the dynamics of galaxies under the inverse-linear gravity is the influence of the surrounding shell of gravitating matter. As can be seen from the formula (16) for the inverse-linear gravity this influence appears quite substantial, while in Newton's case it will be zero. The presented analysis is applicable to spherical shells with a uniform density of matter. In configurations with non-uniform distributions the surrounding shell can produce unusual actions, and even exercise repulsion rather than attraction. This, for example, can explain an atypical absence of "dark matter" near galaxy center as has been recently reported for galaxy NGC3379 [3]. One also should bear in mind a possible influence of external shell when interpreting observations that may not be completely compatible with straightly inferred distributions of the "dark matter".

3.1.3 Equilibrium velocities in galactic systems

The velocities of motions of galaxies in clusters and superclusters surpass the limits that can be handled by conventional gravity even more drastically. Thus, it has been evaluated that the amount of "dark matter" required to maintain the observed galactic motions might exceed the amount of luminous matter in about 100 times. Galactic systems do not have well-defined orbiting components to directly verify the gravitational balance. In this situation it is only possible to rely on the comparison of statistical characteristics of these systems.

For a mechanical system in dynamical equilibrium moving in a limited space under the action of Newtonian attraction force there is a simple relationship between the average speed of the gravitating objects and spatial layout of their mass, i.e. between average kinetic, T, and potential, U, energies:

$$2 \cdot T = -U \tag{23}$$

So, if the value of T is too high to be matched with U one may assume that an extra "dark matter" is needed to hold the integrity of the galactic systems.

The relationship (23) is a particular case of a more general notion of mechanics presented by the virial theorem (see, e.g. [22]). Let us consider how this notion can be applied to systems with inverse-linear gravity. To simplify the theoretical analysis, we substitute this inverse-linear dependence, 1/R, with an approximation where the distance exponent slightly exceeds 1:

$$\frac{1}{R} \approx \frac{1}{R^{1+\varepsilon}} \tag{24}$$

The exact inverse-linear law corresponds to $\varepsilon = 0$, while in this consideration ε is treated as a small positive value. The Newtonian inverse-square law turns up at $\varepsilon = 1$. Employing the approximation (24) facilitates the comparisons.

Derivation of the virial theorem in [22] starting with averaging the parameters of the system using Newton's law of dynamics utilizes the expression:

$$2 \cdot T = \sum_i \mathbf{R}_i \cdot \frac{\partial U}{\partial \mathbf{R}_i} \qquad (25)$$

The sum is taken over all objects of the system. The components of the force are determined as partial derivatives of the potential function U; the condition $U(R) \rightarrow 0$ when $R \rightarrow \infty$ is not satisfied for the 1/R force, but fulfils for the case $1/R^{1+\varepsilon}$. For the force presented as $1/R^{1+\varepsilon}$ the equation (25) yields:

$$2 \cdot T = \sum_i GM_i/R^{\varepsilon} \sim GM/R^{\varepsilon}_{average} \qquad (26)$$

Here M_i are masses of individual objects and M is the total mass of the system. The mean value of $R_{average}$ is somewhere within the range of distances between the objects. For the Newtonian inverse-square gravity, $\varepsilon = 1$, further elaboration of (26) would lead to the common formulation of the virial theorem (23).

The comparison of statistical dynamics of galactic systems under the inverse-square and inverse-linear laws of gravity can be conveniently performed with the expression (26). The assumption of equilibrium required for the validity of the statistical evaluation of the motions of galactic systems implies that these systems have to be compact. In such systems without wide variations of distances between the galaxies the values of $R_{average}$ should be relatively close for different ε. With this supposition the expression (26) shows that the average kinetic energy for the case of small ε would be substantially bigger than for the case $\varepsilon = 1$.

Thus, the inverse-linear gravity produces substantially higher velocities of galactic motions than the inverse-square gravity. On the other hand, the relationship (26) indicates that sticking to the inverse-square gravity the explanation of higher than expected galactic velocities would require substantially more total mass for the galaxy systems.

The deficits of gravity discovered in both types of stellar motions – rotational velocities in spiral galaxies and average velocities of galaxies in clusters – result from the same inverse-linear behavior of gravity in the cosmological scale. The alleged appearance of "dark matter" in galactic systems implies that the operational range of the suggested stretching pulse mechanism spreads out well beyond the typical size of galaxies.

3.2 The nearby deflections

3.2.1 Precession of planetary orbits

In a short range, in the astronomical scale, the mechanism of stretching pulses delivers at the onset a constant impact bringing in the ordinary inverse-square attraction (see Fig. 2). It is natural to expect smoothed transitions to and from this constancy. So, investigations of the initial borderline variations could provide an underpinning for the anticipation of a further increase of gravity.

One of the most impressive achievements of Einstein's theory of general relativity is the explanation of precession of the planetary orbits that has exactly accounted for a perplexing advancement of the perihelion of Mercury. There are several other explanations of precession of the planetary orbits due to possible tiny deviations from Newton's law [13], but these explanations are less satisfactory because of a fewer accuracy and extraneous predictions.

Our mechanism readily produces an explanation for the precession of the close planetary orbits since its initial gravitational attraction goes slightly below Newton's law. Subsequently, the gravitational attraction increases as it undergoes a transition from inverse-square to inverse-linear dependence. This increase of gravity may be related to surprising findings for distant regions of the solar system - the so-called "Pioneer Anomaly" to be discussed in the next section. The two effects - the precession of planetary orbits and the "Pioneer Anomaly" - come from divergences of different signs. Markedly, Einstein's theory of gravitation predicts the exact value for the advancement of the perihelion of Mercury. So, it may not be capable to account for an effect of an opposite sign.

Any small deviation from the inverse square dependence of the attraction force leads to precession of the ideal elliptical orbits (see, [22]; particularly, exercise 3-b in Chapter 3, §15). Considering a quadratic correction to the transfer function (6), the attraction force in the area near the Sun, $F_{near}(R)$, would be

$$F_{near}(R) \sim -\frac{M_{Sun}}{R^2} + \frac{M_{Sun} \cdot \chi}{R^4} \tag{27}$$

where M_{Sun} is the mass of the Sun and χ is some undefined coefficient. After appropriate transformations that bring (27) in agreement with the notation of [22], the value for $\delta\varphi$ – a change per one revolution of the angle for the elliptic orbit axis direction – is obtained:

$$\delta\varphi \approx -\frac{2 \cdot \pi \cdot \chi}{p^2} \tag{28}$$

Here p is the parameter of the ellipse: semi-length of the chord going through the focus perpendicularly to the major axis (p = (Aphelion·Perihelion)/ Semi-major axis). Using the formula (28) we can compare the results for the advancements of the perihelion for different planets (data for the Table 1 have been taken from [23]). As the coefficient χ is unknown, we have used the Mercury data as a reference point for the proportionality calculations with (28).

Table 1. Precessions of planetary orbits in arc seconds per century

	General Relativity	Observations	Stretching Pulses Mechanism
Mercury	43.0	43.1 ± 0.5	43.1 (reference point)
Venus	8.6	8.4 ± 4.8	11.3 (calculated with (28))
Earth	3.8	5.0 ± 1.2	5.9 (calculated with (28))

By establishing the value of χ through the Mercury data, we can evaluate the decrease in Sun's gravitational attraction for different planets. According to (27), the gravitational force for a planet at a distance R from the Sun is decreased relatively to the force of Newton's law by a small fraction:

$$\text{Relative Decrease of Gravity} \approx \frac{\chi}{R^2} \qquad (29)$$

For Mercury, the 43.1 arc seconds of precession for century translates into 10^{-6} radians of $\delta\varphi$ per one revolution. The parameter p for Mercury in Astronomical Units (AU) is 0.37. Having (28), we evaluate $\chi = 0.66{\cdot}10^{-7}{\cdot}\,(\mathrm{AU})^2$, and then compile the results using (29).

Table 2. Relative decreases of gravity with respect to Newton's law

	Distance in AU	Fraction of force below the inverse-square value
Mercury	0.39	$4.3{\cdot}10^{-7}$
Venus	0.72	$1.3{\cdot}10^{-7}$
Earth	1.0	$0.7{\cdot}10^{-7}$
Mars	1.52	$0.3{\cdot}10^{-7}$

For elongated orbits the situation with the precession appears more complicated. Thus, the orbit of the asteroid Icarus, which spans from 0.19 AU perihelion to 1.97 AU aphelion, has the rate of precession five times less than predicted by our proportionality calculations using (28), yet the results based on general relativity are satisfactory. In our view, this may happen because in a wider range the dependence of gravitational attraction on the distance does not follow exactly the simplified quadratic deviation assumed in (27). For celestial objects on oblong elliptic orbits the effects due to suspected increased gravity could be more tangible. An emblematic example of such an object presents Halley's Comet. After taking into account all possible factors, the prediction of perihelion of Haley's Comet 1986 was accurate up to about six hours [24]. It could be inquisitive to redo these calculations considering the supposition of the additional gravity.

3.2.2 Space probes: the "Pioneer Anomaly" and flybys

Modern space technology allows for experimental investigations of gravity utilizing spacecrafts as artificial celestial bodies. The velocities of the spacecrafts are measured directly by Doppler's shifts with high accuracy sufficient to handle very small changes.

An intriguing happening that has raised recently a great interest presents what is called the "Pioneer Anomaly" [25]. In 1972 and 1973 the Pioneer 10 and 11 spacecrafts were launched to explore the outer solar system. Yet the baffling peculiarities in Pioneers 10 and 11 motions overshadow their achievements as the first missions to Jupiter and Saturn. By 1980 Pioneer 10 had passed a distance of ~ 20 AU (Astronomical Units) from the Sun an anomaly in the Doppler signal showing a deviation of its trajectory became evident. It was anticipated that an additional gravity of some previously undiscovered planet would pull the spacecraft out of course, but instead of pointing outside of the solar system the appearing force pointed inwards. Similar things happened to Pioneer 11 at the opposite side of the solar system.

Possible explanations are combined in four categories: misunderstanding of how the gravity works, misunderstanding of inertia and forces, malfunctions on board of the spacecraft, and defects of the tracking station on Earth. Technical causes are still not completely excluded [26], so deliberations on new fundamental physical notions should be reserved.

For the suggested mechanism of gravitation the "Pioneer Anomaly" could be used to test the main trait of this mechanism - perfect spherical symmetry. Other explanations, for example, employing "dark matter" may not necessarily imply spherical symmetry, while this mechanism foresees the same increases of gravity at the same distances from the Sun in all directions. This anticipation has been already backed up by the data from the opposite flights of Pioneers 10 and 11. Further verification of this property could be instrumental with flights orthogonal to the ecliptic plane.

Certain gravitational irregularities have been observed in the planetary flyby maneuvers. These maneuvers present an indispensable well-elaborated technique to handle energy problems in the interplanetary missions; they are used to change orbital velocity of a spacecraft by its gravitational interaction with a planet [27].

Velocities of the spacecrafts in these maneuvers are calculated and detected with a very high degree of accuracy. And the observed effect came as a great surprise: spacecrafts in flybys suddenly accelerate for no apparent reason. This acceleration in flybys is not a sporadic effect, it appears systematically. Thus, the space probes *Galileo, NEAR*, *Cassini-Huygens* and *Rosetta,* all experienced unexplained boosts of 3.9 mm/s, 13 mm/s, 0.11 mm/s and 2 mm/s respectively. The observed excess in velocity is much larger than the errors in measurement. After canceling out all possible explanations, it remains to assume that the answer may lie in abnormal properties of gravity [27].

The alleged gravitational abnormalities in the "Pioneer Anomaly" and flyby maneuvers should be somehow related [28]. For the suggested gravitational mechanism its impact as shown in Fig. 2 goes first below and then above the horizontal line of Newton's approximation. Again, the deviation in the "Pioneer Anomaly" is of an opposite sign to that in the flyby effect: at far-off distances where gravitation is above Newton's law a spacecraft undergoes deceleration, at short distances where gravitation is below Newton's law a spacecraft acquires an extra boost.

It is important to emphasize the possibility of applying flyby maneuvers to the investigation of fine details in the gravitational field configurations. A flyby encounter can be treated as an elastic collision of a spacecraft and a planet. Thus, flyby experiments can be used analogously to scattering experiments in nuclear physics probing a field surrounding a given body.

3.3 Hypotheses and speculations

3.3.1 The astronomical-cosmological watershed

The presented analysis shows the mathematical principles to which the suggested gravitation mechanism obeys. Realizing this mechanism in a broader context would need further operational hypotheses. At this time we just can resort to tentative speculations.

As expressed by formula (6) and delineated in Fig. 2 the gravitational impact is determined by two major parameters, G_0 and R_0. The parameter G_0 is approximately equal to the gravitational constant G in Newton's law (3). The parameter R_0, the watershed between the astronomical, inverse-square, and cosmological, inverse-linear, cases, is the inverse of the slope in the main part of the transfer function (6).

To evaluate R_0 let us manipulate with the data on the precession of planetary orbits (Table 2) and on the "Pioneer Anomaly" [25]. It appears that the transfer function for the gravitational attraction to the Sun should have an inflection point somewhere between Mercury and Jupiter. Say, this occurs in the middle at ~ 2.5 AU. So, it is reasonable to assume that in the region of Jupiter the relative deviation of the transfer function would be about the same as for Mercury, $\sim 4{\cdot}10^{-7}$, but of the opposite sign. In fact, taking the value for Pioneers extra deceleration near Jupiter from data in [25] as $\sim 1{\cdot}10^{-13}$ km/sec^2 and relating it to Newton's attraction at this distance we actually get the fraction of the same absolute value $\sim 4{\cdot}10^{-7}$.

As the distance grows the transfer function in Fig. 2 should become more flat. Thus, its tangent in the cosmological region, $1/R_0$, would be less than its tangent in the astronomical region. The latter can be estimated using the above-indicated deviations from Newton's law for Mercury and Jupiter. Thus, we get

$$R_0 \; > \; \frac{5\text{ AU} - 0.4\text{ AU}}{4{\cdot}10^{-7} - (-4{\cdot}10^{-7})} \; \approx \; 100 \text{ light-years} \qquad (30)$$

The obtained specification of 100 light-years as a lower bound for the borderline between astronomical and cosmological regions looks reasonable. This means the following: when distances are somehow below 100 light-years the movements of celestial bodies would go in accord with Newton’s law; when the distances are far above 100 light-years explanations of the movements of celestial bodies appeal to “dark matter”.

The range of the astronomical scale can be evaluated also on the basis of microphysics considerations. The transfer function (6) gets a plateau instead of gradual rising from zero since the desynchronization of constant phase lines is delayed. This delay can be related to the shortest time characterizing microscopic events of about 10^{-25} sec - the time for light to cross the proton. In this time interval, the desynchronization process propagating with the speed of $10^{32}\cdot c$ will spread over 2000 AU. Thus, the plateau in the transfer function (6), and hence Newton’s law of gravitation, could span over such a distance.

3.3.2 Ultra small distances

Our considerations do not impose any particular conditions on the gravitational force at very short distances. Although general suppositions entail that in a short-range the deviations of gravitational force from Newton’s inverse-square law should be substantial.

Several clues of suspected deviations from Newton’s law have led to the search for a “fifth” force [29]. A new type of low-mass gravitation-coupling particle was suggested producing a force of about a percent of gravity in a range of few hundred meters. However, numerous experiments undertaken in search of the “fifth” force did not provide positive results.

The applicability of Newton’s law to gravitational force at ordinary small distances had been verified in the famous Cavendish’s experiments. Now, following the string theory suggestions and involving different particles there have appeared ideas that the inverse-square behavior of gravity could break below the centimeter range. Yet no such deviations have been found.

As to our gravitation mechanism, the suggested operational scheme definitely shows that gravitational attraction in the microscopic scale could not develop at all. This leaves the question on the onset of the gravitational transfer function open.

3.3.3 Ultra large distances

Evidently, the mediating capacity of stretching pulses cannot go unrestrictedly over the whole range of distances. Beyond the main mode of the disappearance of stretching pulses by fading away due to the desynchronization beginning at the source, a possible scenario could also include loss of the synchronization of stretching pulses all along their way. Under these circumstances, a saturation plateau would cut off the growth of the transfer function after a certain interval as shown in Fig. 2. Possibly, beyond the saturation point, at very large distances, the gravitational attraction between the galaxies will look again Newtonian, yet with a significantly increased gravitational constant.

Another vital question is how far can the stretching pulses go by themselves with respect to the size of the Universe. If the stretching pulses can extend over the whole Universe a curious effect may arise. In unbounded 3D space the agents of gravitational action spread over area increasing as ~ R^2. As long as the Universe is considered bounded as 3D surface of a 4D hypersphere the gravitational agents after initial R^2 spreading will be concentrated in a narrow area at the site diametrically opposite to the source. So, in these extremely remote areas gravitational impact would be significantly increased. This hypothetical far side concentration of a gravitational impact might produce an appearance of the effects associated with the black holes.

4. Concluding remarks

Since Newton had established the mathematical principles for the universal gravity there had been undertaken many attempts to devise an operational mechanism that could these principles implement. However, none of these attempts succeeded. The portrayal of gravity by Einstein's theory of general relativity is just another mathematical description of this phenomenon rather than an operational mechanism.

The presented paper suggests a mechanism of gravitation with a particular type of mediation agents in the form of stretching pulses. The mathematical description of the given operational scheme corresponds to a common inverse-linear modification of Newton's law that has been already explored in view of the observed gravitational abnormalities. This modification effectively confronts the foremost puzzle of modern physics - a huge deficit of gravitational attraction in the cosmological scale appearing as the so-called "dark matter". Equally well it can treat the alleged tiny gravitational anomalies in the astronomical scale.

The vital distinction of this work is that the surmised mechanism of gravitation does not introduce an *ad hoc* solution to fix certain observed peculiarities. Instead, this mechanism naturally arises from the intrinsic non-locality of a general cellular automaton model of the physical world that has been developed earlier with absolutely no relationship whatsoever to the problems of gravitation.

The workings of gravitation stay separately from the rest of physics. For traditional physics it is not clear why gravity is so much weaker than the other forces of Nature. All physical theories encounter insurmountable difficulties trying to unify gravitation with different phenomena. These difficulties are in the heart of the crisis of modern physics (see, e.g. [30]).

In our case the situation is quite the opposite. In the developed cellular automaton model of the physical Universe the phenomenon of gravitation appears as an intrinsic component of the whole system - an inherent part of its non-locality. Thus, it becomes not easy to separate the description of gravitation out of the whole picture of the physical world. In this respect, to view the general properties of gravitation in a broader context we have to refer to the Appendix.

5. Appendix: A cellular automaton framework placing gravitation among the four fundamental forces of Nature

1. **The distributed operational machinery.** The idea of representing the physical world with cellular automata was conceived by K. Zuse and E. Fredkin [31,32]. A cellular automaton is a regular grid of nodes whose states are transformed in discrete steps depending on the states of the surrounding neighbors (see e.g. [33, 34]). Potentials of the cellular automata for the representation of the physical world are best envisioned with the famous Conway's "Game of Life", which generates intriguing patterns using a simple rule. Certain patterns in this cellular automaton, "gliders", present stable relocating configurations; thus, it is tempting to find a cellular automaton rule producing a number of stable relocating configurations, which could be identified with elementary constituents of matter. Hopefully, the behavior of these material formations could go with the established laws of physics. So, the phenomena of the physical world are expected to emerge from the underneath cellular automaton transformations, similarly to what supposedly appears from the virtual activities of quantum vacuum.

2. **The undetectable absolute space of cellular automata.** The cellular automaton construction for the physical Universe is a high-tech resurrection of the classical concept of ether that has been discarded, perhaps "undeservedly" (see [35]). The specificity of cellular automata is that motion of their material formations is performed through reconfigurations over the medium rather than by passing through it. This elucidates the seemingly scholastic proposition of Lorentz and Poincaré that absolute motion exists but is undetectable. The absolute nature of motion being hidden, the notorious confrontation with the postulate of relativity for a cellular automaton ether is avoided.

Realization of the material formations by cellular automata resolves the principal problem of inertia. The uniform motion of material formations is supported by the underlying cellular automaton mechanism. So, material bodies get uniform motion for "free" and maintain it without any perceptible cause in accordance with the first law of mechanics. The inertial mass is a measure of action required to change the uniform motion of a body, it is proportional to the amount of material formations involved. This corresponds to Newton's view on classical mechanics, and substantiates his presumably illogical definition of mass as a product of density by volume.

3. **The prerequisite of mutual synchronization.** Realization of the cellular automaton model of the Universe involves two major concerns. First: trying to find a cellular automaton rule that can produce the required complex behavior of physical objects seems impossible. Second: it is not clear whether local transformations can account for the apparent non-locality of the Universe. A total trial-and-error search for the desired cellular automaton mechanism by intensive computer simulations is hopeless. Adhering to a cogent guiding principle, one should think of this mechanism not as of a model to be simulated, but as of a construction to be actually implemented. In the first place, implementation of such a construction needs a distributed clock; it has to be robust, and hence fault-tolerant. This requirement removes any arbitrariness in the choice of the

primitive rule of Nature. The cellular automaton mechanism underlying the physical world must contain a grid of mutually synchronizing circular counters; the state of the system is characterized by a distribution of the phases θ ($0 < \theta < 2\pi$) defining the relative states of the counters. Astoundingly, but this approach solves the problem.

It turns out that the whole richness of the physical world condenses in a plain sentence: "All physical phenomena are different aspects of the high-level description of distributed processes of mutual synchronization in a network of digital clocks" [11]. The developed model was named CAETERIS (Cellular Automaton EThER InfraStructure). Workings of this model have been presented in several publications starting [9], in various aspects they are described in [10, 11,12, 36, 37]. The essence of the mutual synchronization activities is described by the following equation:

$$\frac{\partial \vartheta}{\partial t} = -b\vartheta + D_1\Delta\vartheta + D_2\Delta^2\vartheta + D_3\Delta^3\vartheta \qquad (\mathrm{mod}\, 2\pi) \qquad (31)$$

These mutual synchronization activities with certain additional conditions demonstrate two tracks in the arrangement of the physical world as depicted in Fig. 4. One of them reveals the marvels of non-locality.

4. **Spectrum of elementary particles in the form of traveling wave solutions.** A number of areas of physics use media similar to cellular automata, like Ising's model, lattice in quantum chromodynamics, and various condense matter systems. Most closely the cellular automaton ether resembles the model of quantum vacuum, where elementary particles of matter are stable and transient "excitons". The synchronization activity of the "excitons" in the CAETERIS model shows a collection of helicoidal traveling wave solutions (Fig. 4). With an appropriate interpretation one can see that these CAETERIS "excitons" exactly correspond to the spectrum of stable elementary particles (Fig. 5).

Furthermore, the material synchro formations of the CAETERIS enjoy the corresponding physical properties as well. Those include: the law of inertia as traveling waves synchro formations get their uniform motion for "free" from the cellular automaton mechanism, an upper bound on the speed of the material synchro formations – the speed of light, antimatter as dual solutions having an opposite sense of rotation, slight asymmetry between matter and antimatter, and hence prevalence of the matter, which arises from the necessity for an arbitration protocol. A curious reader can delve into detailed comparisons and find parallels with other properties of the physical world.

5. **Operational machinery due to fast spreading diffusion.** Quantum entanglement is the foremost physical phenomenon, which definitely points out that the Universe possesses the property of non-locality. The surmised action-at-the-distance in gravitation is another indication of the physical manifestation of this property. On the other hand, non-locality plays a vital role in biological information processing [36]. The operational background of non-locality is indispensable for the overall organization of the Universe. No general model of Nature, the so-called Theory-of-Everything (see [38] for the most recent developments), can fulfill its aspirations if it does not have non-locality.

The CAETERIS model shows the origin of non-locality with ease. Besides the traveling wave “exciton” solutions this model includes underneath processes due to very fast spreading diffusion solutions. In the CAETERIS model, the elementary particles - “excitons”- come from the parabolic partial differential equation (31) describing the phase diffusion in the cellular automaton mechanism of distributed synchronization. The non-locality originates from the paradoxical property of the parabolic equations: the diffusion impact spreads instantaneously.

The physical reason for the mathematical paradox of the instantaneity in parabolic equations is that these equations describe spreading of smoothed macroscopic values, like “temperature”, “density”, or “phase amassment”. These values are formed by an averaging process that incurs temporal delays while outlying microscopic activities can stretch significantly faster. “Instantaneous” impact takes place below the “slow” averaged amassment of phases in the course of mutual synchronization. The representation of spreading diffusion by parabolic equations is a mathematical idealization, which in a strict physical sense is deficient. So, behind such a simplified presentation of diffusion by parabolic equations there should be a very fast propagating wave mechanism [39].

The opinion that “the action-at-the-distance” is inadmissible from the philosophical standpoint is flawed. There is absolutely nothing outlandish in having a system with two types of processes developing in substantially different time scales. This is a typical situation for relatively slow material systems under essentially faster information control. Thus, besides gravitation and quantum mechanics the non-locality effects are determinedly involved in biological information processing producing trains of ultra-fast diffusion waves for a reference beam of the holographic Universe [36].

6. **Two global periodic processes in the Universe.** Disregard of non-locality leads to major disorientation of modern physics. "The construction of the world seems to be based on two pure numbers, α and ε, whose mystery we have not yet penetrated" [40]. The factor $\alpha = 1/137$, the fine structure constant, appears in relation to interaction of matter with electromagnetic radiation. The number $\varepsilon \sim 10^{40}$ characterizing the relative strength of gravitational interaction is more mysterious: "A simple mathematical theory may lead to numbers like ½ or 8π, but hardly to a non-dimensional number of extravagant order of magnitude 10^{41}".

Presumably, from the standpoint of the CAETERIS model the two dimensionless parameters of the physical world: $\alpha = 1/137$ and $\varepsilon \sim 10^{40}$ are artifacts of the construction. The former parameter is somehow associated with the fraction of the cycle of circular counters that must be put aside for the purpose of fault-tolerance. The latter parameter characterizes the isolated aspect of the spreading diffusional impact. The two types of solutions in relation to these parameters are completely different (Fig.4). Helicoidal traveling waves correspond to material and electromagnetic processes developing in the interval of speeds $(1/137 - 1) \cdot c$. The stretching diffusion produces an “instantaneous” finite impact at $t \to 0$. The diffusional waves that create the ensuing effects of non-locality happen to propagate with speed about $10^{40} \cdot c$.

Accordingly, the CAETERIS model features two kinds of global periodic processes: the sequence of slow mater creations interpreted as Big Bangs and generation of trains of diffusion waves serving as the reference beam for the holographic mechanism of the Universe. In the aspect of the global constitution of the Universe the developed model turns to combine all seemingly disjoint controversial astrophysical facts into a coherent cosmological picture, see [36, 37] for consideration of the general cosmological issues. As to this paper it is important to point toward one of the results of these considerations regarding the "action-at-the-distance" of the stretching pulse mechanism (see formula (4)). Initially, stretching pulses apply their gravitational impact with the velocity, V_f, of $10^{40} \cdot c$, which represents the extreme swiftness of the front spreading activity. It has been determined that a relatively slower removal of this impact by the succeeding rear activity, the desynchronization process, occurs with the velocity, V_r, of $10^{32} \cdot c$.

It is worthwhile to call attention to one of the most prominent cosmological consequences of the CAETERIS model. The "slow" periodic process, succession of Big Bangs, among other things gives an explanation the alleged acceleration of the Universe that has led to the concept of "dark energy". The situation is very simple: slow moving galaxies detected in the faraway cosmos had come from a previous Big Bang. This eradicates "dark energy", a substance even more mysterious than "dark matter".

7. **The distinction of gravitation from the rest of physics.** Gravitation is associated with the fast diffusion of phase. Commonly, diffusion processes handle monotonic parameters, like temperature and density, while the spread of gravitation use the periodic parameter of phase. However, as soon as the range of phase changes is significantly less than 2π the periodic nature of phase is not of importance. In contrast to gravitation, other types of material interactions involve sophisticated synchronization relationships, so they essentially deal with phase periodicity. These interactions show what is called local and global gauge invariance. The parameters comprising these synchro activities are not affected by different transformations that shift any phases by 2π and/or keep intact relative distribution of phases in the whole.

Gravitational force has the following characteristic properties: (1) long range, (2) instantaneous action-at-the-distance, (3) omnipresence, and (4) universal applicability to all sorts of material formations. Gravitational force is the cementing power of the Universe binding all the pieces of matter. Gravitation cannot be screened or modulated by any material process. The other three forces of Nature are basically different from gravitation in all aspects, except for the long range of electricity.

Electrostatic force resembles gravitation, as Coulomb's law looks mathematically equivalent to Newton's law. In the CAETERIS model the electrostatic force could be exercised as an "action-at-the distance" with stretching mediation agents as well. These mediating agents could be in the form of fast propagating cylinders emanating from the kernels; the generatrices of these cylinders come with circularly advancing phases having different senses of rotation determining the sign of electric charge. The scheme of stretching pulses is sensitive to jittering of their sources. For gravitation, this is a minor issue. For electrostatics, the falling apart stretching cylinders lead to vivid effects of electrodynamics. At the outset we have considered a hypothesis that intersecting electrostatic stretching cylinders can generate gravitational constant phase lines as a secondary effect with a possible connection to "dark matter" (see a brief description and reference in [36]). Hypothetically, this could be of significance for the "Pioneer Anomaly" if it is a real physical effect. Long-range influences related to electrical effects might be involved in cosmological processes more than currently considered.

8. **Forces maintaining material synchro-formations.** The integrity of the traveling wave solutions presenting material synchro formations (Fig. 4) is provided by short-range forces against two basic ways of destruction: gentle separating of different parts of the kernel and restructuring of the whole kernel. The former transformations are associated with the so-called weak force, the latter – with the so-called strong force.

Synchronization presents a weak constraint that joints the kernels as if some delicate adhesive holds them together. Breaking up a kernel could be responsible for radioactive decay. Let us consider the momentous situation for the phase dependence in the kernel of a neutron. As shown in Fig. 5, taking the neutron kernel apart naturally produces the well-known scheme for neutron disintegration.

When kernels undergo significant transformations beyond slight separation of their parts substantial disturbances in material synchro activities can be generated. This might happen, for example, as a result of a head on collision of kernels with opposite sense of rotation for dual solutions of matter and antimatter. The disappearance of these material formations can be described in terms of conservation of mass-energy using the famous relationship: $E = mc^2$. Keeping together elementary synchro formations of matter involves complex issues that are associated with the strong force. Requirements for specific rotary shape impetuses in creation of kernels' helicoidal patterns translate into rotational restrictions – the conservation laws for charge, baryon, and lepton numbers.

9. **Falsification tests.** Following Karl Popper's ideas, a scientific theory to be established requires formulating an experimental test that could falsify it. As a theory withstands such negation attempts it becomes more and more acceptable. The presented mechanism of gravitation contains the distinctive property of non-locality: gravitational impact is exercised almost instantaneously producing what is called "action-at-the-distance". This translates into a categorical assertion that gravitational waves cannot exist. So far the suggested hypothesis withstands this test.

Besides the absence of gravitational waves our analysis allows making also a different firm prediction that "dark matter" particles do not exist: Fig. 5 shows the entire spectrum of stationary synchro formations and leaves no room for any other stable particle of this type. The upcoming investigations of elementary particles with a new powerful installation: the Large Hadron Collider (LHC) [41] are aimed, in particular, at revealing the "dark matter" in the form of Weakly Interacting Massive Particles (WIMP) that must be stable. Therefore, searching for WIMPs presents another falsification test for the whole surmised scheme of gravitation. Of course, the developed mechanism with amplified gravity makes the concept of the "dark matter" superfluous by itself.

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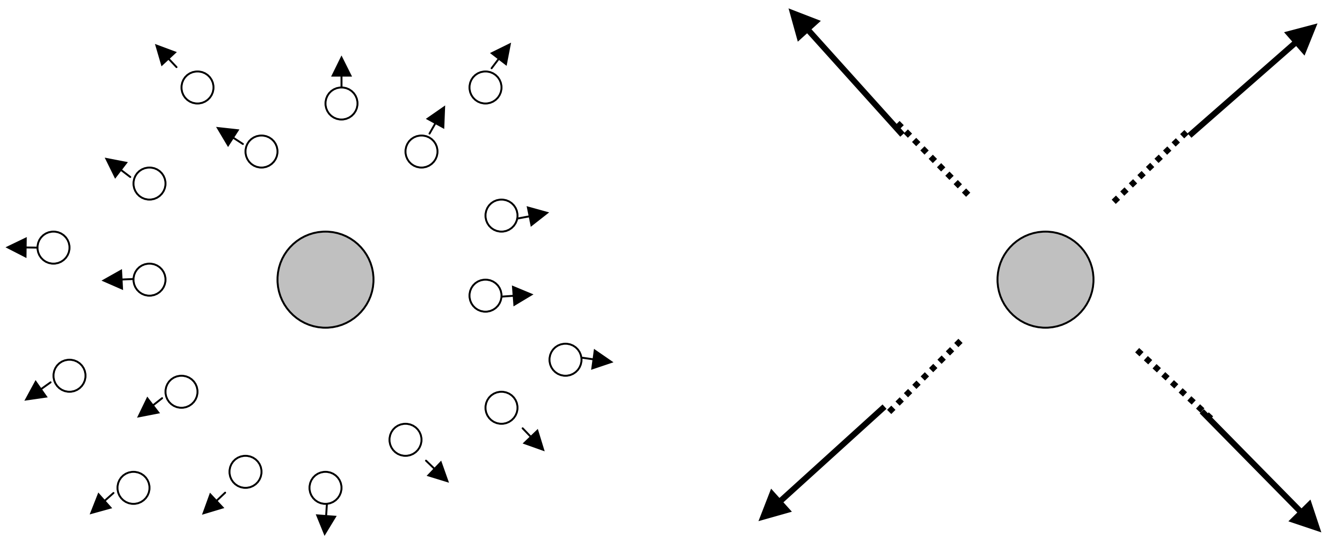


(a) (b)

Fig. 1

Different types of mediation agents:
restricted corpuscles and stretching pulses

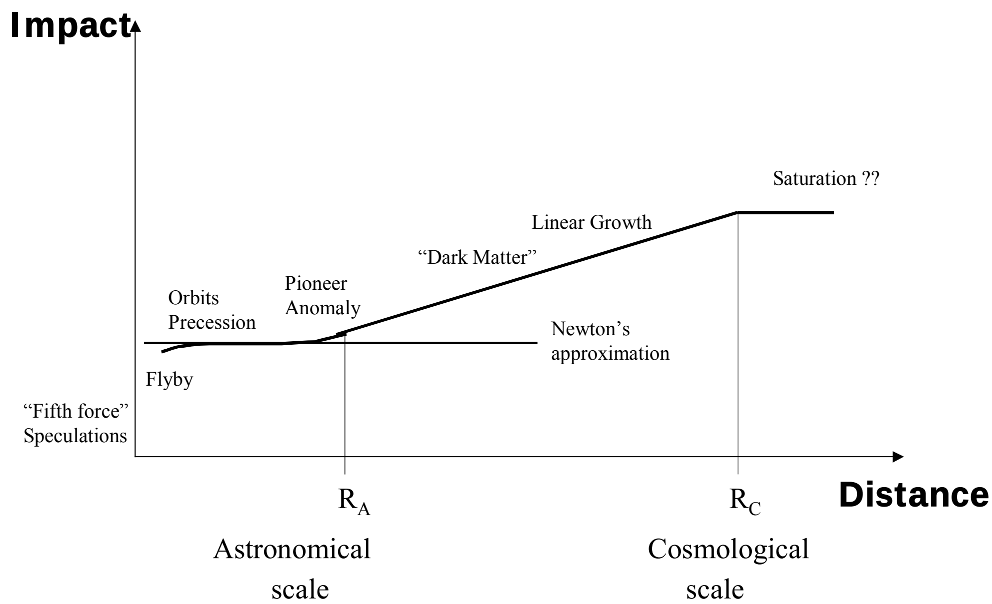


Fig. 2

Impact – distance diagram: the transfer function
for the gravitational mechanism with stretching pulses

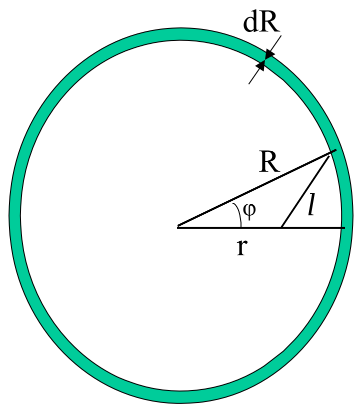
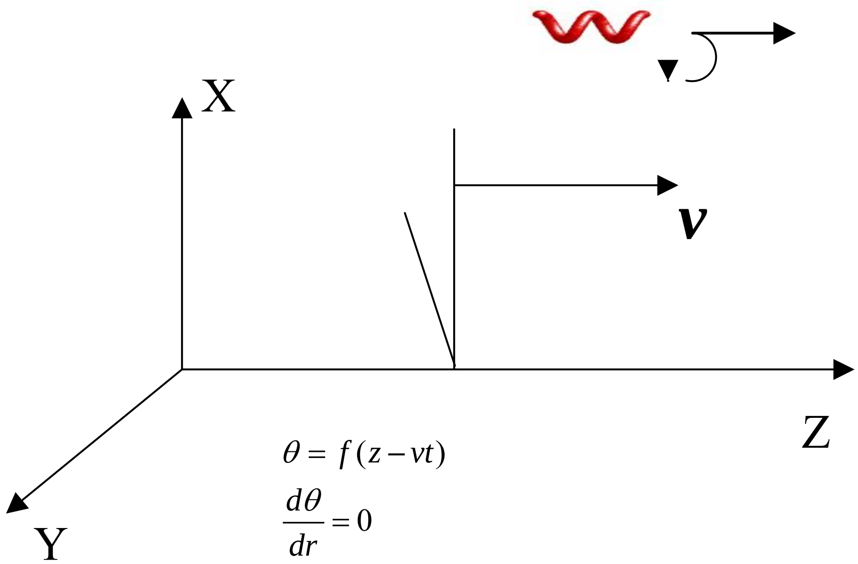


Fig. 3

Towards the analysis of the inverse-linear gravity: an elemental spherical layer



The phase congruence condition for kernels:

Maximum speed - c

$$\theta = f(z - vt)$$

$$\frac{d\theta}{dr} = 0$$

$$\frac{d\theta}{d\varphi} = const$$

$(^1/_{137} - 1) \cdot c$

$$D_2\lambda^4 + D_1\lambda^2 + v\lambda - b = 0$$

Traveling waves – “quasi-particles” of matter

$$\theta = \frac{1}{(2D_1 \cdot \sqrt{\pi t^3})} \cdot \exp(-\frac{R^2}{4D_1 \cdot t} - bt)$$

$10^{40} \cdot c$

“Instantaneously” stretching phase lines – fast operational background

Fig. 4

Two types of the CAETERIS solutions:
ponderable material synchro formations and feeble non-locality

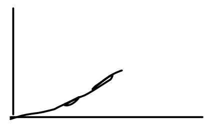
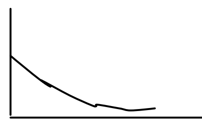
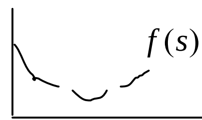
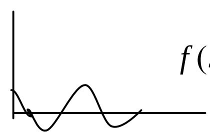
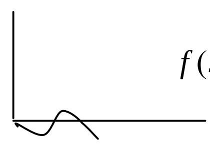
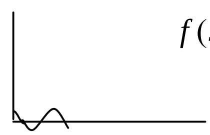
TYPES OF KERNELS	PHASE DEPENDENCES	PROPAGATION	
		intermittent **V < C**	**continual** **V = C**
Real exponents	Θ		
increasing	 $f(s) = A_1 e^{\frac{b}{v}s}$	Proton	Electro-Magnetic Field
decreasing	 $f(s) = A_2 e^{-\frac{v}{D_1}s}$	Electron	
combination	 $f(s) = A_1 e^{\frac{b}{v}s} + A_2 e^{-\frac{v}{D_1}s}$	Neutron → $e^- + \nu + p^+$	Photon
Imaginary exponents	θ		Neutrinos
	 $f(s) = A_3 \cos\sqrt{\frac{D_1}{D_2}}s$		*electron*
	 $f(s) = A_3 \cos\sqrt{\frac{D_1}{D_2}}s$		*tauon*
	 $f(s) = A_5 \cos\sqrt{\frac{D_3}{D_4}}s$		*muon*

Fig. 5

Stationary traveling wave solutions
correspond to the whole spectrum of stable elementary particles