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On the quantum gravity of the electron

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Abstract. In the search for a coherent theory of quantum gravity we investigate the discrete model of the electron from the perspective of its autochthonous geometrical framework. The form of the model is a minimalist oscillation out of which evolves a continual serial transition between quantum and classical behaviour. The postulated oscillation reduces the electron of continuous physics to a series of discrete motionless events (the classical part). The geometric relations among events are energetically created by the nonlocal behaviour of the electron (the quantum part). Here we show that the discrete model provides a framework within which a coherent explanation of the cause of gravity is possible. In an ideal two-electron universe the geometrical relations of the enduring particles exhibit the features of classical gravitation. The locus of each motionless event arises from nonlocal quantum mechanical action which is subject to initial conditions that derive from the geometric relations of its immediate antecedent. The serial relative positions occupied by each electron describe curved geodesics which are deviations from their discontinuous inertial motion, in the form of reciprocal free-fall acceleration. The rate of acceleration is independent of the mass of the object. The magnitude of the gravitational effect varies as the inverse square of the distance and is proportional to the mass of the attractor. Gravitation is geometry in action; it is instantaneous, repetitious and background independent.

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1. Introduction

Quantum theory, as it is generally understood, contains an implicit assumption of continuity of motion, space and time which does not appear to be a requirement of the theory. The mathematics of quantum mechanics, like that employed throughout physics generally, is derived from set theory, at the center of which lies the continuum, which is essentially classical. The present analysis does not assume that quantum analogies of the mathematical categories of classical physics have yet been found [1]. Indeed, quantum mechanics may represent the ultimate limit in the congruence of mathematical theories and physical reality [2], which prompts the question as to whether its foundation lies beyond the scope of current mathematical representation. The present analysis seeks a description of the structure of the electron and its interactions in the absence of continuity and without forms of representation that admit continuity.

Intuition suggests that the difficulties confronted by the various programs to combine quantum mechanics and gravitation are not unconnected with the absence of a uniquely productive theory of the behaviour of matter. Such a theory, it is widely hoped, will provide an insight into the origin(s) of quantum mechanics and General Relativity [3]. The present approach to the problem of the behaviour of matter and energy, which lies behind observed phenomena, recasts the analysis in a fully discrete framework in which at the scale of elementary particles there is no continuity of space, time or matter. The Dirac equation for the electron provides a suitable starting point for the transition from continuity to discreteness. The analysis begins with negative energy states and their interpretation in the absence of continuity.

It is shown that it is possible to combine the unobservable consequences of the Dirac equation[1] in a discrete, qualitative model which leads to a simplified description of electron behaviour and structure without continuity of space, time or motion. The usual mathematical formalism is not employed. No attempt is made to replace canonical methods and Hamiltonians but rather to proceed without any formal calculations[2].

Model constraint derives from the laws of special relativity rather than symmetry arguments or energy equations. To the extent that the present theory is pregeometrical, its contents are unobservable and so the special relativistic symmetries of measured distances and durations are subordinated to the laws pertaining to mass and the speed of light. Lorentz invariance is not omitted; it will be seen that its spacetime preconditions emerge as a natural consequence of the theory. In addition, the classical definitions of energy and electric charge are used. Taking the lead from Einstein when he observed that in the absence of matter there is no

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[1] Dirac drew the distinction between observation and underlying reality, when he observed: “It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us.” and “These quantum equations are such that, when interpreted according to the general scheme of quantum dynamics, they allow as the possible results of a measurement of kinetic energy either something greater than mc^2 or something less than $-mc^2$” [4].

[2] Some geometry is employed in Section 6 in the classical part of the theory where the gravitational action of the electron is shown to obey the inverse square law.

space or time, those two quantities are not assumed to be autonomous [5]. Distance, direction and duration therefore, are taken to be unreified relations among objects, in the Leibnizian sense. There is neither vacant space nor spacetime and the notion of field is abandoned in favour of direct interparticle action.

The paper is divided into two parts. Part I concerns the electron oscillation and its nonlocal character; it is subdivided into two sections. Sections 2 deals with the physical meaning of positive and negative energy states. Section 3 outlines the biphasic oscillation of the electron which resolves into an energetic phase of actualization which is a motionless event and a zero-energy phase of pure potential. Part II concerns the classical geometry and its origin in nonlocal electron behaviour; it is subdivided into 3 Sections. Section 4 deals with inertial motion and discrete internal geometric relations. Section 5 deals with external geometric relations and accelerated motion. Section 6 deals with gravitational action and attractor connection. The theory is summarized in Section 7.

Part I. The electron oscillation

2. The physical meaning of negative energy states

Energy is defined, as in classical physics, as the quantity that is the measure of the capacity of a system to perform work. In addition, energy is always the energy of something; it is never free of an object or system [6]. Dirac introduced the concept of positive and negative energy states with his relativistic equations for the electron, which allow the possible results of a measurement of kinetic energy to be positive or negative [4]. The mathematical representation of the allowed energy states gives them the relation of opposites, which is denoted in the usual way by positive (+) and negative (-) symbols. For the present scheme, being physical, the mathematical relation of opposites is replaced by a physical analog.

Positive energies are those usually associated with real and tangible objects such as the classical electron; physical states have positive energy. Here, the opposite of the energy of the real electron is understood to be identical with the energy of the opposite of the real electron. The opposite of the real (actual) electron is the potential electron. The potential electron is an immaterial potential to become an electron in the future. This analysis follows the Aristotelian distinction between real and potential as applied to physical objects[7]. The physical opposite of the real electron with positive energy and the usual electron properties is the potential electron with zero energy and therefore none of its usual properties.

An energy value of less than zero pertains to a potential to subsequently achieve positive energy of that magnitude. Thus, the physical analogue of the mathematical representation of positive and negative energy states is the mutual opposites of the energy states of an actual and a potential electron. The physical opposite of energy is no energy.

3. The discrete electron oscillation

The potential and actual states of the electron are coupled in a biphasic oscillation in which the actual phase emerges from the potential phase; the latter is the impetus for the former. The genesis of the energetic actual phase is its coupled zero-energy potential phase. The nature of the potential is to actualize as a real object, thus the oscillation is internally driven without any external influence.

The electron potential begins to actualize without any physical features or properties. The actualization is energetic and it takes time. Its culmination as an actual electron may include any of the usual properties of electric charge, mass and internal and external geometric relations with its own antecedent actualizations and those of other elementary particles, respectively. It is further postulated that the total energy of the ideal electron exclusively performs the work of its actualization; energy has no other role. Consequently, at the completion of actualization that

phase terminates instantaneously and therefore its energy decays to zero. The electron is then once more in the potential phase of its oscillation, from which it again begins to actualize. An electron (and every other elementary particle) is a series of actualization of its own potential.

At the termination of the actual phase of its oscillation, the electron is a discrete object. Each such complete actualization is termed an 'event' in the history of the electron. The electron in the zero-energy phase of its oscillation, is bereft of all spacetime relations, both internal and external; it is pregeometric, immaterial potential. It is unconnected with the space and time that concomitantly relate the actualized objects of the real world, which include all the electron's own antecedent actualizations. Therefore space and time are not always everywhere for the electron.

A consequence of the absence of distance, duration, motion, mass, energy and electric charge for the electron during its phase of pure potential, is that every element of the real electron and its geometric relations are rendered discrete in space and time. Serial actualizations of the electron are separated not in or by space and time but by the *absence* of space and time, which is the condition that obtains with respect to the potential phase. The zero-energy phase is a discrete vacuum to which only a single potential belongs. Being immaterial, the vacuum is devoid of matter, space and time.

Simultaneous with completion of the actual phase of the oscillation the electron acquires geometric relations with all the other actual particles of the universe, including its own antecedent actual event. Where it is and when it is follow the completion of its energetic actualization, they do not precede it. The spacetime relations of a completed actual phase are fixed. Successive actual phases do not move through space or time, each is a motionless event in relation to all other actual events, which are also motionless. Their separations are subject to the constraints of initial conditions which derive from antecedent actualizations and are part of the potential of the zero-energy phase of the electron oscillation[3]. The transition between successive actual phases, including their internal and external geometric relations, is a nonlocal quantum jump[4]. The fundamental and indivisible ideal electron of continuous physics is thereby divided into discrete motionless events, separated only by immaterial potential—there are no interphenomena. The discrete analysis extends naturally to the electrodynamic interactions[8].

Part II. The geometry of motionless events

4. Inertial change of position

4.1 Space and time creation

The emergence into the classical domain of the oscillating discrete electron is the basis for a theory of the gravitational influence among autonomous quantum objects. In the forgoing part the electron exhibits elements of nonclassical quantum behaviour. The *consequences* of the postulated quantum behaviour, which is in principle unobservable, are manifest in the classical sector. The classical effects which emerge from quantum behaviour include the all-important creation by the electron of its own internal and external spacetime relations. It is this action of spacetime creation that is the origin of both inertial and gravitational motion.

Space and time are the variables of the geometry of the distance, direction and duration that connect a motionless event to its antecedents. Unreified relational space and time are created by and attach to individual motionless events. The distance, for example, between to successive actualizations of an electron is forged by the second of the two events. To analyze it as simply the

[3] At the termination of actualization, the separation of the event from its antecedent event and those of other elementary particles becomes a connection between events. Geometric connections follow from dynamic pregeometric separations.

[4] The concept of the quantum jump is usually employed to explain transitions between states of different values of a variable. Here, the jump occurs between separate spacetime loci and other discrete stationary states of the same or different values.

distance between two points is to overlook its real importance. According to the present interpretation, there are only possible positions at which an electron might be found, at a measurement or an unobserved interaction. None of the positions for which $p > 0$ exist before the actual arrival of the electron at one of them. In the discrete scheme, Nature does not create unused vacant space or time just in case it might subsequently become useful. The position that the electron finally occupies, at the termination of each oscillation, is forged anew by its own energetic quantum behaviour. Such an interpretation of space and time is the foundation of the theory of inertia and gravitation at the scale of elementary particles.

A distinction is made between the separation of events and the connection between events, and the relation between them. Each actualizing event first separates from its antecedent and its antecedent's geometric relations. The completion of separation coincides with its acquisition of a locus in space and time and thus its connection to the geometric relations of its antecedent. Separation is a component of pregeometric, energetic actualization and is complete upon the decay of the energy of the event to zero. Separation is a nonlocal, quantum mechanical process; the connection is classical and geometrically fixed. Connections are geometric relations among motionless events at $E = 0$.

4.2 Initial conditions

Where and when an event terminates its actualization is subject to initial conditions, which are part of its potential. Only upon the termination of actualization is an event some distance and duration from its antecedent, and some direction in relation to its two immediate antecedents. Its geometric relations arise *post facto*. Crucially, initial conditions constrain all the connections among the motionless events of the electron. Quantum mechanics has revealed that even though the position at which an individual event is found cannot be known *ante facto*, the creation of that position is subject to constraints which manifest mathematically as possible positions for which $p > 0$.

Contrary to theories of continuous reality, in a universe containing just a single electron, the position of any of its newly constituted events is relative to its own antecedent actualizations. The only distance, direction and duration, in such a universe, is that which relates its own actual events. Therefore, the change of position of such an ideal electron is relative to itself, via its role in the repeated creation of the spacetime which is its own internal geometry. Internal geometric relations (IGR) are the totality of spacetime in a one-electron universe. Geometry only relates motionless events. Those relations, which may be either internal or external to the enduring electron, are always constrained by initial conditions. Events are not replicas of, but are entirely derived from, antecedent events. There is no other source for the initial conditions of an event apart from its own antecedent.

4.3 Discrete inertial motion

When commenting on the consequences of his equation for the electron, Dirac mentions two kinds of motion: "... an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us" [4]. The oscillatory motion is the motion of a quantum system—it is quantum 'motion'. Quantum 'motion' is nonlocal and in principle unobservable; it is not "... the regular motion which appears to us," it does not take place 'in space or time.' The quantum motion of the electron has a classical outcome, which is the motionless event that constitute the classical aspects of the electron. "...the regular motion which appears to us" is classical motion comprised of series of motionless events.

Classical motion emerges in a stepwise manner from the serial actualization of events. Each establishes a new position of the electron. That position is changed by the joint, temporally sequential geometrogenic action of two motionless events. Whether that 'motion' is inertial or

accelerated is due to the geometric relations among serial contiguous events. The single principle, is the creation by every motionless event of its own spacetime locus which places the event in relation to every other event, gives rise to both inertial and gravitational motion.

In some ontological interpretations of standard quantum mechanics the collapse of the superposed positions at which an electron might be found in a measurement, to the one at which it is actually found, employs the concept that prior to collapse the electron is spread among all the possible positions from which it collapses to just one position. It goes from quantum mechanically being everywhere for which $p > 0$ to actually being just there. The electron quasi-classically *shrinks* from being everywhere to being at a single locus.

By contrast, in the present scheme, the electron goes from being nowhere to actually being at a locus. Therefore, a more appropriate analogy than a collapse is a pregeometrical growth from its own private vacuum of pure potential, which is nowhere because $E = 0$, to a region of the order of the size of its classical diameter. By contrast with the notion of an inward collapse, the transition from having no geometric relations with anything to being some definite distance and duration from everything is achieved by an organic, pregeometrical, quantum mechanical growth towards everything. Because the oscillation of the discrete electron begins when $E = 0$, the separation for each actualization actively grows, not from somewhere but from nowhere,. The change of position of the electron, like all its properties, occurs as the result of a separation in the absence of a geometric background. Background independence of the electron is absolute, it includes its own internal geometry in addition to the geometry of the universe external to itself.

4.4 Internal geometric relations and inertial motion

For a single electron, the geometry of the connection between an actual event and its own immediate antecedent is its IGR. Because the antecedent of an actualizing event is at zero energy the formation of their pregeometric separation is unilaterally energetic. The zero-energy antecedent event supplies the initial conditions, which include the constraints upon the formation of its own geometric connection to its antecedent. The actualizing event supplies the energy. Unlike models of absolute space and time, whether of fixed or dynamical metric, in the present scheme the spacetime that constitutes the IGR of the electron is not merely generated by the electron, but it is, in a sense, private to the electron. The locus of each motionless event is only ever occupied by that event—it creates, occupies and owns it.

Immediately before the actualization of an event is complete it is separated from, but still unconnected to its antecedent. The pregeometric separation grows into a geometric connection as the event becomes fully actual. The separation develops in accordance with its initial conditions that only indirectly constrain the geometric relations that are yet to characterize the connection between them. Each unit of distance and its straight-line representation, has a beginning and an end—it is not a part of a continuous coordinate. It begins at the terminus of an energetic event and ends at the origin of the same event's initial conditions, which is its antecedent event. Since the actual phases of the electron oscillation are separated by the absence of space and time, the inertial change of position of the electron cannot be described by a continuous geodesic. Figure 1 depicts four serial events in the time evolution of a single inertial electron. Event 3 is the source of initial conditions for event 4. Everything that event 3 'grew into relation with' influenced the initial conditions for event 4. The separation of event 3 from event 2 constrains the separation of event 4 from event 3. Distance, direction and duration that connect events 4 and 3 are constrained by the *origin* of the connection between events 3 and 2. The distance and duration constraints underlie a uniformity of 'motion', or change of position of the electron. The direction constraint underlies the 'straight line' of Newtonian inertial motion. Since there are no external constraints on the motion of the ideal, bare electron, its motion is inertial—it obeys Newton's first law. Initial conditions constrain the properties of each event in the life of the inertial electron through the tendency to reproduce those of its antecedent.

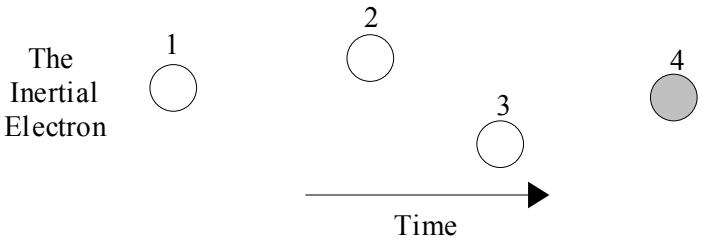


Figure 1. Three zero-energy (open circles) and one actualizing event (shaded circle) in the time evolution of the inertial electron, of the one-electron universe. The absence of continuity of distance, duration and direction is indicated by the irregularity of the relative positions of each event.

5. External geometric relations and accelerated motion

In a two-electron universe, each ideal, bare, non-interacting electron has internal and external geometric relations. As in the one-electron universe, everything an event 'grows into relation with' influences the initial conditions for the ensuing event. In figure 2, event B of e1 'grew into

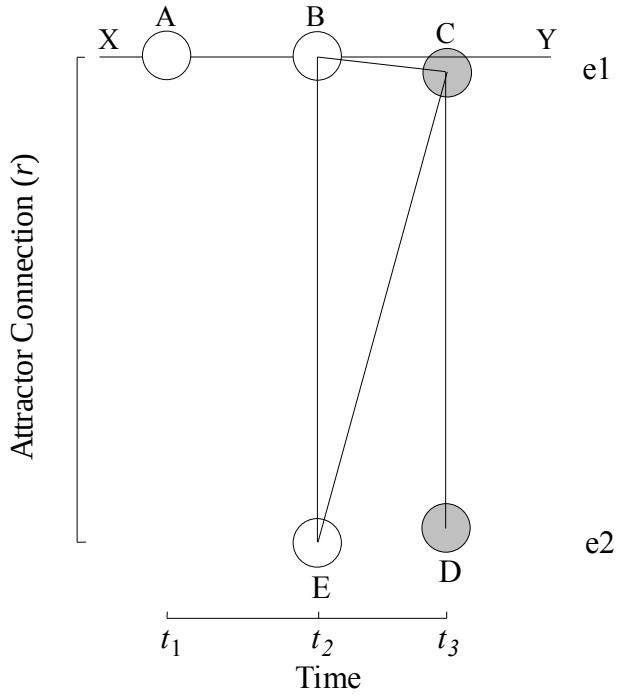


Figure 2. Two ideal, bare electrons of the two-electron universe. Electron e2 is introduced to the system at time *t*2. Two zero-energy (open circles) and one actualizing event (shaded circles) of electron e1 and one each of e2.

relation with' event A (its antecedent event, of e1) and simultaneously with event E of electron e2, newly arrived at *t*2. The separation of event B from event A produces its IGR. The separation of event B from event E produces its external geometric relations (EGR).

Event B has no physical connection with either A or E prior to the completion of its separation from both. Serial actual phases of the electron oscillation are separated from each other by the *absence* of space and time of the potential phase. The actualization of an event occurs in total physical isolation—it is private. Initial conditions for event C are influenced by everything

that event B 'grew into relation with'. The separations of event C (from B and E) do not distinguish the internal separations of B from either A or the external separation from E—neither takes priority over the other; each is a component of the geometric properties of B. The dynamical growth, from nowhere to somewhere, of the separations of C occurs in relation to B, A and E. Heuristically, the distance and direction of the connection CB is 'modeled on' AB and the distance and direction of CE is 'modeled on' BE.

Since the separation of B from A is unilaterally energetic its influence is confined to event B; it has no effect on event A. By contrast, the separation of events B and E is bilaterally energetic. Thus the separation affects both events by becoming a part of their EGR. The tendency of event C to reproduce the geometry of event B constrains the distances CE and CB. If the distance CE is modelled on the distance BE, and CB on BA, then the position of event C will be a deviation from the inertial geodesic XY. Electron e1 will be closer to electron e2 at *t*3. Electron e2 undergoes a reciprocal process, thus the connection CD is reduced from both ends to BE. The separations of C from B and D will be part of the source of the initial conditions for the event immediately subsequent to event C, of e1. The distance between the members of each pair of events subsequent to the pair C and D tend to become shorter with each ensuing pair of events. Electrons e1 and e2 are therefore in discrete free-fall acceleration towards each other. Initial conditions for each motionless event of the two electrons are influenced by the EGR of the other. The influence of IGR tend to produce tangential, or inertial change of locus. The influence of EGR tend to produce radial, or gravitational change of locus. As in Newton's first law, the influence of EGR impels the deviation from inertial motion.

5.1 The equivalence principle—inertia and gravitation

The process that generates the deviation from inertial change of position of each electron is quantum mechanically endogenous to each. Electron e1 is 'attracted' to e2 not by a process at-a-distance, but by a nonlocal effect on a local process.. The distant effect is not on the actualizing event directly but on its initial conditions through its antecedent. The effect of the object at a distance is exerted indirectly on a process which is autochthonous to the body whose inertial change of position deviates towards the source of the effect. The geometry of inertial and gravitational 'motion' are each the consequence of the influence but not the action of objects at a distance. The first is its own antecedent event, the second is an event in the life of the other electron. The second is transmitted through the first by a combination of the internal and external geometric relations of the antecedent event. Gravitational and inertial 'motion' are each affected by objects at a distance, they differ only in the consequent geometry of the geodesic of the particle. The active growth of the event is geometrically equally inclusive of its antecedent and the event of the attractor which is contemporary with its antecedent.

5.2 The speed of quantum gravity

The gravitational action that curves the geodesic of the electron is complete upon the decay of the energy of the event to zero. In the case of real rather than ideal electrons, observability or information transfer from the event to an observer is limited by the speed of light. Photons are emitted from the potential phase of the oscillation[8], which follows the completion of the gravitational action of the actual phase. The reciprocal influence of each electron on the position of the other is complete at $\dot{E} = 0$, which is simultaneous with the emission of the photon. If the electrons are separated in space and not interacting electromagnetically with each other, the transfer of real photons (at the speed of light) begins when the gravitational action is complete and the distance, direction and duration of the connection is established. Therefore the gravitational action of the electron is independent of the distance between attractors. The gravitational effect of the electron is independent of the electromagnetic sector, which includes the constraint of the speed of light. Quantum gravitation is therefore effectively instantaneous.

The speed of gravitation among celestial objects is controversial. Experimental observations, without exception, indicate that the speed of gravitational attraction far exceeds that of light. The speed of propagation is too great to determine but is not less than $2x10^{10}c$[9]. According to the present analysis nothing moves at any speed through space or time. The quantum gravitational effect arises from the discrete geometric growth of the space and time relations among quantum objects. As in General Relativity, gravity is not a force and like Newtonian gravity its geometric effect is instantaneous. The distance between contiguous events in the life of the electron occurs discretely and instantaneously by a nonlocal process. Gravity is a quantum effect of the continual renewal of discrete geometry.

5.3 One-body gravitation

The process of the dynamics leading to the geometry of spacetime, which connects the event to its antecedent, is influenced by the bilateral energetic separation of the two electrons. Here, being bilateral simply entails reciprocity. An ideal body composed of a large number of non-interacting elementary particles will exert a regional gravitational influence among the particles, not because it is a single massive body, but because of its individual constituent elementary particles. Multilateral energetic separation occurs within such a single body; each elementary particle influences the geodesic of all the others. One oscillating elementary particle in the absence of another exerts no gravitational influence; there are no inertial geodesics other than its own. Spacetime in such a universe only extends to the IGR of the single electron, which are entirely inertial.

5.4 Mass and the rate of gravitational free-fall.

The deviation of the unaccelerated geodesic of e1, due to the electron at E (shown in figure 2), is affected by the contributions to initial conditions of two events, one being the origin of IGR (B) and the other EGR (E). If instead of one electron at e2, there were two oscillating electrons, indefinitely close together, the deviation from the inertial geodesic of e1 is separately and additively influenced by both electrons at E, via their separate contributions to the initial conditions for event C. If two attractor electrons were situated equidistant from a third, all in a straight line, then the resultant effect on the geodesic of the third electron would be zero, because each would neutralize the effect of the other. Consequently, if two attractor electrons were situated together their effect on the third would be double that of each alone. Acceleration due to gravity of the electron is thus directly proportional to the number of oscillating particles that comprise the attractor. Since the attractor electrons are of equal mass, the acceleration is also proportional to the mass of the attractor. However, if two attractors of the same mass were composed of unequal numbers of oscillating particles then their gravitational effects would be unequal and proportional to the number of oscillators.

If there were two electrons at E the gravitational influence of a single attractor electron at B separately attracts each. The single attractor at B influences the initial conditions of the two events at E separately and independently of one another; they each experience free fall acceleration towards e1. Consequently, bodies composed of different numbers of oscillating particles experience the same rate of acceleration ‘in a given gravitational field’. Accordingly, the rate of gravitational acceleration is independent of the mass of the object and the number of its constituent oscillators. The observation that the zero-mass photon exhibits gravitational free fall, as observed in astronomical gravitational lensing, is consistent with the independence of mass and the gravitational response.

6. Gravitational action and the attractor connection

Here we investigate the relation between gravitational action and the geometric attractor connection in the two-electron universe.

Definition 1 *When* $E = 0$ *the space of motionless events is Euclidean.*

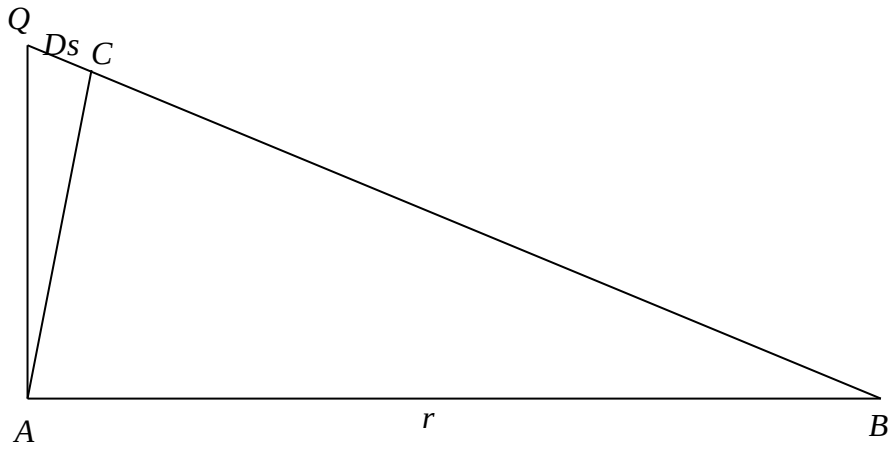
Definition 2 *The gravitational geodesic of an electron is the result of the distance and duration plus the direction which marks its deviation from the evolution of its inertial change of position. When the connection of the electron to the attractor is orthogonal to its inertial geodesic at an event, the gravitational action is the deviation from inertial change of position which tends to maintain the geometry of the attractor connection with its antecedent.*

Definition 3 *The gravitational action* (*S*e) *is defined to be*

$$Se = \frac{Ds}{r} \tag{1}$$

where r is the distance to the attractor and Ds is the deviation from the expected geodesic for purely inertial change of position of the electron, as shown in figure 2.

Theorem 1. *Suppose the distance between the constituent motionless events of an inertial electron is kept constant, then the gravitational action affected by a simultaneous event of a second electron varies inversely as the square of the distance between them.*



Proof Let *AQ* be the unit of distance and *r* be the distance between two simultaneous actual events *A* and *B*, such that *r* is normal to each inertial geodesic and the direction of inertial change of position be from *A* towards *Q*.

Let *Q* be the position of an actual event and *A* be its antecedent whose connection forms an imaginary inertial geodesic *AQ*.

The introduction of a second electron at event *B* affects the actual geodesic *AC* (Def.2).

so that $$QC = QB - BC \tag{2}$$

since $AB = BC$ (Def. 2) then by Pythagoras' theorem

$$QB^2 = AB^2 + AQ^2 \tag{3}$$

since *AQ* is the unit of distance, let

$$AQ = 1 \tag{4}$$

then $$QB^2 = AB^2 + 1 \tag{5}$$

$$QB = \sqrt{AB^2 + 1} \tag{6}$$

since $$AB = BC \tag{7}$$

then (by eq. 2) $$QC = \sqrt{AB^2 + 1} - AB \tag{8}$$

QC is the deviation from the counterfactual inertial geodesic, which is a function of the curvature of the actual geodesic, designated *Ds*. *AB* is the attractor connection, designated *r*.

Then by substitution

$$Ds = \sqrt{r^2 + 1} - r \tag{9}$$

The gravitational action (*Se*) is given by *Ds* in relation to *r* (by def. 1).

Then $$Se = \frac{Ds}{r} = \frac{\sqrt{r^2+1} - r}{r} \tag{10}$$

It can be readily shown that for $r \geq 2$

$$Se^{(r)} = r^2 Se^{(2r)} \tag{11}$$

Thus, *Se* obeys the inverse square law

■

6.1 The accuracy of the inverse square relation

The accuracy of the inverse square relation between *Se* and *r*, for $Se^{(r)} = r^2 Se^{(2r)}$, where $r = 2^n$ and *n* = 1, 2, . . . , x, as determined by the number of significant decimal places, increases from 1 place for $r = 2^1$ to 12 places for $r = 2^{11}$, is shown in figure 4.

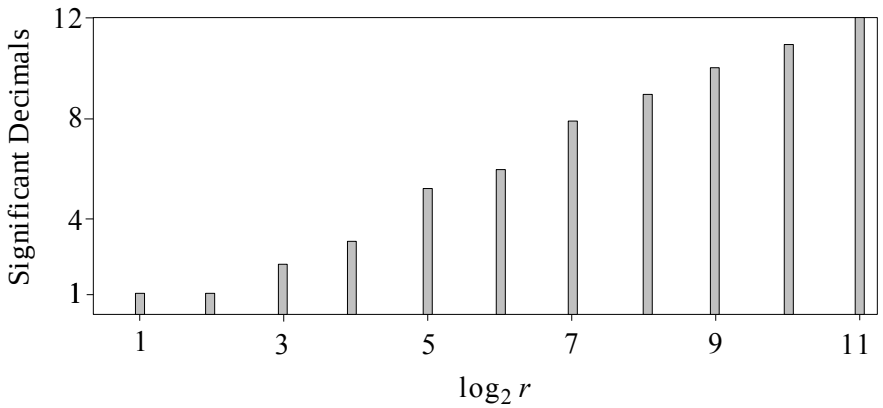


Figure 4. A plot of the attractor distance (*r*) and the number of significant decimals of the $1/r^2$ relation for the function *Se* of equation (11).

6.2 Background independence

The process of actualization fulfils a formal requirement of General Relativity, which has provided a major focus in the search for a theory of quantum gravity. That requirement is background independence.

Each actualization begins in a pregeometric vacuum state which is a necessary consequent of being at $E = 0$. Under those conditions the electron is geometrically unconnected to its own antecedent events and the completed actualizations of every other elementary particle in the universe. Those complete actualizations that are geometrically related constitute the background of the action of actualization. The electron is therefore fully independent of the background while the action of gravitation curves its discrete, discontinuous geodesic. Time and space are not always everywhere for an elementary particle.

Just as unreified space is not an objective container in which particles move, neither is the vacuum a container for virtual particles. Each elementary particle oscillates through a state in which it itself is a total vacuum, when every element of its physical existence has vanished, and terminates in the energetic creation of the spacetime separations which then geometrically relate them. The electron is then once more in a state of dependence upon the background. The background always remains where and when it is, but it is nowhere for the potential phase of the oscillation, including its own vacuum state.

The discrete differentiation of the morphology of the electron is an aspect of its background independence. What happens at actualization precedes the position at which it occured. Indeed, while it was happening it has no position. Nothing quite happened at the position it subsequently acquires. Its undifferentiated potential forges all the features of its morphology without first having a geometric connection to anything, including itself. Upon completion, its energy decayes to zero, thus simultaneously achieving its instantaneous dedifferentiation into a quantum vacuum state and so abandoning its classical spacetime locus.

7. Summary

The present analysis provides a framework within which an explanation of the cause of gravity is possible. The explanation is united by a common principle with Bohr's assertion that prior to a measurement the quantum system cannot be said to possess a value of the variable. The cause of gravity is the quantum behaviour of the elementary components of the objects involved and is somewhat iconoclastic of the usual concepts of space and time. The concept expounded by Leibniz that space and time are simply relations among objects is here extended to include the energetic creation of space and time by matter itself. The object both warps and creates spacetime, repeatedly. There is no space lying in wait for the arrival of matter, which is consistent with the concept that space is simply geometric relations and therefore cannot precede the arrival of the matter it relates. In the absence of matter there is no space. The emergence of matter from the quantum vacuum energetically creates its own geometric relations with all the objects of the universe, including itself, not chaotically, but constrained by the potential it has inherited from its antecedent. Those geometric relations constitute the sum total of all space and time from the perspective of the individual enduring particle.

Gravitation is the temporal maintenance of the spatial orderliness among enduring objects. Newton's first law pertains to the temporal maintenance of the spatial orderliness among the components of a single enduring object unaffected by gravitational influence. Which is to say, the geometric state of the combined frequency, distance and direction that connect the component events of the single enduring object perseveres except insofar as it is compelled to change by forces impressed[5]. Geometry guides quantum behaviour in the nonlocal production of the enduring object's next motionless event. That behaviour is blind to the distinction between the classical internal and external geometry embedded in its initial conditions; they are equivalent

[5]After Newton.

parts of a single given. Gravitation is geometry in action.

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