In a holistic perspective, time is absolute and relativity a direct consequence of the conservation of total energy

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Abstract: We are taught to think that the description of relativistic phenomena requires distorted time and distance. The message of this essay is that, in a holistic perspective, time and distance are universal coordinate quantities, and relativity is a direct consequence of the conservation of energy. Instead of the kinematics/metrics-based approach of the theory of relativity, the dynamic universe (DU) approach starts from the dynamics of space as a whole and expresses relativity in terms of locally available energy instead of locally distorted time and distance. In such an approach, e.g., the frequency of atomic clocks at different states of motion and gravitation is obtained from the quantum mechanical solution of the characteristic frequencies, and the unique status of the velocity of light becomes understood via its linkage to the rest of space. In the kinematic/metrics-based theory of relativity, we postulate the principle of relativity, Lorentz covariance, the equivalence principle, the constancy of the speed of light, and the rest energy of mass objects. The conservation of momentum and energy is honored in local frames of reference, and time and distance are parameters in frame-to-frame observations. In the dynamics-based DU, the whole space is studied as a closed energy system and the energy in local structures is derived conserving the overall energy balance. Any local state of motion and gravitation in space is related, through a system of nested energy frames, to the state of rest in hypothetical homogeneous space, which serves as the universal frame of reference. Relativity of observations appears as a direct consequence of the overall energy balance and the linkage of local to the whole—with time and distance as universal coordinate quantities. DU postulates spherically closed space and zero-energy balance of motion and gravitation. DU does not need the relativity principle or any other postulates of the theory of relativity. Primarily, the theory of relativity is an empirically driven mathematical description of observations, with postulates formulated to support the mathematics. DU relies on mathematics built on the conservation of an overall zero-energy balance as the primary law of nature, which makes DU more like a metaphysically driven theory. Both approaches produce precise predictions. The choice is philosophical—nature is not dependent on the way we describe it. © *2021 Physics Essays Publication*. [http://dx.doi.org/10.4006/0836-1398-34.4.486]

Résumé: On nous apprend à penser que la description des phénomènes relativistes nécessite une distorsion du temps et de la distance. Le message de cet essai est que dans une perspective holistique, le temps et la distance sont des grandeurs de coordonnées universelles, et la relativité est une conséquence directe de la conservation de l'énergie. Au lieu de l'approche cinématique/métrique de la théorie de la relativité, l'approche de l'univers dynamique (DU) part de la dynamique de l'espace dans son ensemble et exprime la relativité en termes d'énergie disponible localement au lieu de temps et de distance localement déformés. Dans une telle approche, par exemple, la fréquence des horloges atomiques à différents états de mouvement et de gravitation est obtenue à partir de la solution mécanique quantique des fréquences caractéristiques, et le statut unique de la vitesse de la lumière est compris via son lien avec le reste de l'espace. Dans la théorie de la relativité cinématique/métrique, nous postulons le principe de relativité, la covariance de Lorentz, le principe d'équivalence, la constance de la vitesse de la lumière et l'énergie au repos des objets de masse. La conservation de la quantité de mouvement et de l'énergie est honorée dans les référentiels locaux, le temps et la distance sont des paramètres dans les observations cadre à cadre. Dans le DU basé sur la dynamique, l'ensemble de l'espace est étudié comme un système énergétique fermé et l'énergie dans les structures locales est dérivée en conservant le bilan énergétique global. Tout état local de mouvement et de gravitation dans l'espace est lié, par un système de référentiels énergétiques emboîtés, à l'état de repos dans un espace homogène hypothétique qui sert de référentiel universel. La relativité des observations apparaît comme une conséquence directe du bilan énergétique global et du lien du local à l'ensemble – avec le temps et la distance comme grandeurs de coordonnées universelles. Le DU postule un espace sphériquement

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fermé et un équilibre énergétique zéro du mouvement et de la gravitation. Le DU n'a pas besoin du principe de relativité ou de tout autre postulat de la théorie de la relativité. Principalement, la théorie de la relativité est une description mathématique empirique des observations, avec des postulats formulés pour soutenir les mathématiques. Le DU s'appuie sur des mathématiques fondées sur la conservation d'un bilan énergétique global egal à zéro comme principale loi de la nature, ce qui fait de l'e DU une théorie davantage axée sur la métaphysique. Les deux approches produisent des prédictions précises. Le choix est philosophique – la nature ne dépend pas de la façon dont nous la décrivons.

Key words: Dynamic Universe; Theory of Relativity; Cosmology; Unified Theory; Holistic Worldview' Mach's Principle; Atomic Clocks; Absolute Time.

I. INTRODUCTION

A. Background

1. From a kinematic to dynamic approach of relativity

Relativity indicates that, in nature, something is finite. In the early 20th century, the theory of relativity was needed for describing phenomena related to high velocities indicating that velocities observed in space are finite with the speed of light as the limit. The mathematics used to describe relativistic effects required postulates like the relativity principle, Lorentz invariance, equivalence principle, and the invariance of the speed of light and the rest mass of particles. Primarily, the theory of relativity is a local observer-oriented theory. Generalization of the theory to the effects of gravitation led to an overall picture of expanding three-dimensional space with time as the fourth dimension linked to spatial dimensions to form four-dimensional spacetime. In the spacetime concept, an extension or a line-element in the fourth dimension is $ds_4 = c \cdot dt$. The fourth dimension is called time but measured in meters, $[(\mathrm{m/s}) \cdot \mathrm{s} = \mathrm{m}]$. In the expanding space, rather than 14×10^9 years of time, we are at a distance of 14×10^9 lightyears from a starting point in common, which means that the observable three-dimensional space forms a hypersphere with the radius of 14×10^9 lightyears increasing at the speed of light, c, in the fourth dimension. Accordingly, any mass m in space has momentum $\mathbf{p}_4 = m\mathbf{c}_4$ and any momentum $\mathbf{p}$ in a space direction is associated with an orthogonal momentum $m\mathbf{c}_4$ in the fourth dimension resulting in the total momentum $|\mathbf{p}_{tot}| = \sqrt{(mc)^2 + p^2}$ and the corresponding total energy $E = c\sqrt{(mc)^2 + p^2}$, like the total energy taught by special relativity. In a holistic perspective, the rest energy of mass is the energy of motion due to the expansion of space in the fourth dimension. The barycenter of the spherically closed space is not in the 3D space itself—it is at the center of the hypersphere in the fourth dimension. The dynamics of spherically closed space can be solved as that of a spherical pendulum; matter in space has got its energy of motion against release of gravitational energy in a contraction phase before the singularity turning the contraction into the ongoing expansion. The pendulum solution maintains the zero-energy balance in space; the rest energy of matter as the energy of motion in the fourth dimension is balanced by the gravitational energy arising from the barycenter representing the total mass in space.

DU describes mass as the wavelike substance for the expression of energy as indicated by the unit of energy joule, $\mathrm{J} = \mathrm{kg} \cdot (\mathrm{m/s})^2$, where mass, kilogram, is present as a first-order factor. Mass is identifiable as the substance for the expression of all energy structures as well as radiation propagating in space. The total mass in space is the primary conserver. The energy intensity, as the absolute values of the energy of motion and gravitation, has increased from essential zero far in the past to essential infinity in the singularity turning the contraction into expansion. The singularity in DU corresponds to the big bang in the standard cosmology model derived from the general theory of relativity (GR). Rather than thermal energy like assumed in the hot big bang model, singularity is an extreme excitation of energy as the rest energy balanced by gravitational energy.

2. The Dynamic Universe

The dynamic universe theory[1] (DU) is an endeavor for an understandable word view and for identifying the basis of a unified formulation of the theories in physics and cosmology. DU relies on the zero-energy principle, first applied to space as a whole, as the three-dimensional surface of a four-dimensional sphere, and further, to all local interactions in space. DU means a holistic perspective to space as a whole. Local phenomena are linked to the rest of space; motion in space is linked to the motion of space in the fourth dimension. Such an approach opens relativity as a direct consequence of the conservation of the overall energy balance in the system, e.g., the buildup of local kinetic energy in space reduces the rest energy of the object in motion. As a consequence, based on the quantum mechanical solution, the characteristic frequency of an atomic oscillator in motion is reduced. The corresponding effect occurs on the locally observed rest energy near mass centers due to local bending of space relative to the fourth dimension. There is no need for distorted time and distance needed in the kinematic solution of relativity. In the holistic perspective, relativity is relativity between local and the whole rather than relativity between an object and the observer. Everything in space is interconnected.

Both the zero-energy principle and spherically closed space are well-known ideas. Combining the two is problematic without the fourth dimension of metric nature.

The zero-energy universe has been proposed by Sciama[2] and Pascal Jordan. As a zero-energy solution consistent with the space-time concept, Tryon[3] proposed quantum fluctuation, an instant release of gravitational potential as negative quantum energy for the instant appearance of the energy of matter and radiation in the Big Bang.

In his Lectures on gravitation in the early 1960s, Feynman introduced spherically closed space as an "intriguing suggestion,"[4] allowing an equal view to the surrounding expanding space at any location in space. Also, Feynman pondered on the equality of the total gravitational energy and rest energy in space as a great mystery[5] but did not link the idea to spherically closed space.

DU is a dynamical solution linking Feynman's great mystery to his intriguing suggestion of spherically closed space. An unavoidable demand is the fourth dimension of metric nature, which allows universal, scalar time that operates equally in space dimensions and the fourth dimension closing the structure. The dynamics of spherically closed space is like that of a spherical pendulum in the fourth dimension. The energy of motion is gained against release of gravitational energy in a contraction phase and converted back to gravitational energy in the ongoing expansion phase. Maintaining the zero-energy balance, the buildup of local structures in space converts part of the momentum in the fourth dimension into momentum in space via local bending of space. Such a process occurs in several steps creating a system of nested energy frames linking the local states of motion and gravitation to the state at rest in hypothetical homogeneous space.

B. Merits of the dynamic universe

1. Understandable picture of reality

Instead of an instant Big Bang, the buildup and energization of the observable universe are described as a contraction-expansion process from essential infinity in the past to essential infinity in the future. Mass obtains the meaning of the wavelike substance for the expression of energy. In DU, phenomena that the relativity theory explains in terms of dilated time open up as phenomena occurring at different rates due to their different energy states, the states of motion and gravitation. Time and distance are used as universal coordinate quantities essential for human comprehension. Instead of fixing a local frame of reference to an observer, the frames of reference are studied as energy frames for local energy interactions. In DU framework, following the quantum mechanical solutions, the characteristic frequencies of atomic oscillators are directly proportional to the local velocity of light, which makes the velocity of light look constant when measured with atomic clocks. The local velocity of light is fixed to the velocity of space in the local fourth dimension, which guarantees a zero result in resonator type interferometric measurements like the Michelson–Morley experiment.

2. Clear postulates and illustrative notations

DU relies on the zero-energy principle, which means double-entry energy-bookkeeping; for gaining energy of motion potential energy is released, and vice versa. Energy-buildup of space reveals the rest energy of matter as the energy of motion due to the motion of space in the fourth dimension, the direction of the radius of the 4D sphere closing space. Maintaining the zero-energy balance, the buildup of local structures in space converts part of the momentum in the fourth dimension into momentum in space via local bending of space. Such a process occurs in several steps linking the local states of motion and gravitation to the state at rest in hypothetical homogeneous space. DU favors complex function notations comprising the real part that expresses the effects in space directions, and the imaginary part expressing the effects in the fourth dimension.

3. Phenomena that are explained better than by current theories

The energy-bookkeeping of space requires that all gravitationally bound local systems expand in direct proportion to the expansion of space. Early planets have been closer to the Sun, which gives an obvious explanation to the faint young Sun paradox, liquid water on Mars, and the higher ocean temperatures required by the early geological development of the Earth. The development of the number of days in a year can be followed from coral fossils originating back to 1×10^9 years. A precise match with data is obtained by combining the effect of tidal interactions with the effects of the increase in the length of a day and the length of a year due to the expansion of space.

Following the energy-bookkeeping, in free fall, kinetic energy is obtained against the release of rest energy of the falling object which cancels the buildup of "relativistic mass" as suggested by the equivalence principle. Celestial mechanics in DU predicts perihelion advance equal to that in general relativity but cancels the instability of orbits near the critical radius of black holes as predicted by GR. Near the critical radius, DU predicts slow stable orbits that maintain the mass of the black hole. The DU prediction gives an excellent match to the periods observed around Sgr A* at the center of Milky Way.[6]

The cosmological appearance of space in DU is clear-cut; distance definitions are given in closed, parameter-free form. The observed Euclidean appearance of galaxy space is confirmed, and the prediction for the magnitude-redshift relation of Supernovae Ia observations matches accurately with observations without dark energy or other experimental parameters. The expansion of space is not accelerating but decelerating due to the work expansion does against the gravitation of the structure.

4. Planck's constant and the nature of quantum and matter wave

Without any assumptions tied to DU, Planck's equation can be formally solved from Maxwell's equations by solving the energy that a single electron transition in a one-wavelength dipole emits into a cycle of electromagnetic radiation. A point source can be regarded as a one-wavelength dipole in the fourth dimension where space moves the distance $cdt = \lambda$ in one cycle. The solution links Planck's constant to primary electrical constants and the velocity of light and discloses the nature of the fine structure constant as a pure numerical factor. Removing the velocity of light from Planck's constant, $h_0 = h/c$, reformulates Planck's equation into the form $E = h_0/\lambda \cdot c^2$, formally equal to the rest energy of mass $m = h_0/\lambda$ as the mass equivalence of a quantum of radiation, the counterpart to the Compton wavelength $\lambda_C = h_0/m$ as the wavelength equivalence of mass m.

The reformulation does not change physics but allows an illustrative picture of the nature of mass, quantum and the expressions of energy. Following the new formulation, e.g., quantum states (like solutions of Schrödinger's equation in closed systems) appear as energy minima of mass wave states fulfilling relevant resonance conditions. The de Broglie wave can be described as a mass wave carrying the momentum of a moving mass object—much in the way de Broglie was looking for.

5. Ontological considerations

The zero-energy approach of the DU balances the rest energy of any mass object in space with the gravitational energy of the rest of space. Unification of physics is obtained via unified expressions of energy. The number of postulates needed in DU is radically smaller than that in contemporary physics. In DU, the zero-energy principle applies in all branches of physics; there are no conflicting postulates between different branches.

This paper summarizes the basic principles and outcomes of the DU theory. A detailed mathematical derivation is documented in the author's book *The Dynamic Universe—Toward a unified picture of physical reality* and the historical path guiding to DU is tracked in the book "The Short History of Science—or the long path to the union of metaphysics and empiricism."[7]

II. THE ZERO-ENERGY BALANCE OF MOTION AND GRAVITATION

A. Primary energy buildup in space

The primary energy buildup is described as a contraction-expansion process of spherically closed space. The rest energy appears as the energy of motion obtained against the release of gravitational energy in the contraction of spherical space toward singularity; in the ongoing expansion phase, the energy of motion is paid back to gravitational energy. Such an interpretation assumes a metric fourth dimension, representing the direction of the 4-radius of space and time as a universal scalar allowing the study of velocity and momentum equally in the three space directions and in the fourth dimension.

The gravitational energy of mass m in spherically closed space is expressed in terms of the mass equivalence $M'' = 0.776 \cdot M_\Sigma$ at the center of the 4D sphere closing space, Fig. 1. It is obtained by integrating the gravitational energy in homogeneous space

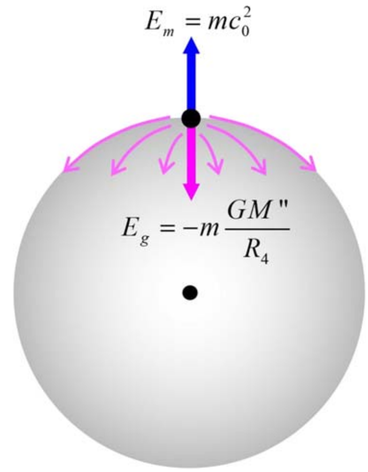

FIG. 1. (Color online) The dynamics of spherically closed space is determined by the balance between the energies of gravitation and motion. The rest energy of a local object is counterbalanced by the gravitational energy arising from the rest of space. The gravitational energy of mass m due to the rest of space is expressed as the effect of the mass equivalence M'' representing the total mass M_Σ at the 4-center of space.

$$E_{g(m)} = -\frac{2}{\pi}\frac{GmM_\Sigma}{R_4}\int_0^\pi \frac{\sin^2\theta}{\theta}\,d\theta = -\frac{0.776 \cdot GmM_\Sigma}{R_4} = -\frac{GmM''}{R_4}, \tag{1}$$

where $G = 6.67 \times 10^{-11}$ (Nm^2/kg^2) is the gravitational constant, R_4 is the 4-radius of space, and $M_\Sigma = \Sigma m$ is the total mass in space. Applying the zero-energy principle, the sum of the total gravitational energy and the total energy of motion, expressed as $E = c|\mathbf{p}|$ in the fourth dimension, the direction of the 4-radius, is zero

$$E_m + E_g = c \cdot M_\Sigma c - GM_\Sigma M''/R_4 = 0, \tag{2}$$

which means that the velocity in contraction is obtained against release of gravitational energy and released back to the energy of gravitation in the expansion phase, Fig. 2.

The 4D velocity of space in the contraction and expansion is

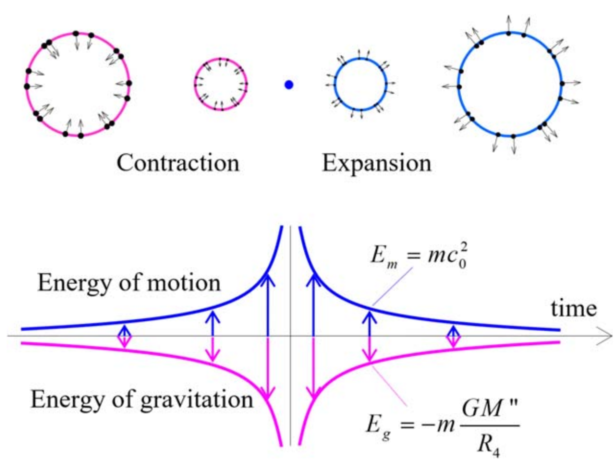

FIG. 2. (Color online) The buildup and release of the rest energy of matter as the energy of motion via contraction and expansion of spherically closed space.

$$c = \pm\sqrt{GM''/R_4} \approx 300\,000\,(\mathrm{km/s}). \tag{3}$$

The numerical value is obtained by applying the average mass density $\rho = 5 \times 10^{-27}$ (kg/m^3), which is the Friedmann critical mass equivalence in the DU framework, the gravitational constant $G = 6.67 \times 10^{-11}$ (Nm^2/kg^2), and R_4 = Hubble radius $\approx 13.7 \times 10^9$ (l.y.). It is convenient to use the complex quantity notation with the real part expressing quantities in space directions and imaginary part expressing the related quantity in the fourth dimension. Combining the rest momentum related to motion in the imaginary dimension, with the momentum in a space direction, the total energy of motion can be expressed as

$$E_m = c|\boldsymbol{p}^{¤}| = c|\mathbf{p} + \mathbf{i}\,mc| = c\sqrt{p^2 + (mc)^2}, \tag{4}$$

which is formally equal to the expression of total energy in special relativity but without any assumptions related to the theory of relativity. As a consequence of the conservation of the total energy, the maximum velocity in space and the velocity of light is equal to the velocity of space in the fourth dimension, $c = c_4$. The buildup of mass centers in space is associated with local bending of space in the fourth dimension which results in a reduction of the local velocity of light, observed as gravitational lensing and a reduction of the rest momentum and a corresponding reduction of the characteristic frequencies of atomic oscillators near mass centers in space.

B. From Big Bang to continuous buildup and release of energy

The buildup of the rest energy in the presingularity contraction phase cancels the assumed instant Big Bang event of standard model of cosmology (SC). The singularity in DU is a state of extreme excitation of the energies of gravitation and motion, followed by turn to expansion at extreme velocity (like the inflation in standard cosmology), which has gradually slowed down to the present velocity of light. The deceleration rate of the present velocity of light is $dc_4/c_4 \approx -3.6 \times 10^{-11}$/year. Such a change is observable only indirectly, because the frequency of atomic clocks and the rate of physical processes in general are directly proportional to the velocity of light. Following the zero-energy principle, the local velocity of light is a function of the local gravitational potential. Accordingly, also the ticking frequency of atomic clocks is a function of the local gravitational potential.

C. Linkage to GR space

1. Stress-energy tensor

In DU, the rest energy of a mass object in space is counterbalanced by the gravitational energy arising from the rest of space, $E = mc^2 = GM''m/R_4$. Due to the spherical geometry of space, the balance of the complementary energies appears in the fourth dimension. For making sense with velocity, momentum and the corresponding energy of motion in the fourth dimension, the fourth dimension shall be studied as a metric dimension.

When interpreted in the light of Gauss's divergence theory or simply as the physical linkage of pressure and energy content, the stress-energy tensor in general relativity depicts such a spherical symmetry and energy balance in the fourth dimension. On the cosmological scale, in homogeneous space, the stress-energy tensor can be expressed in the form

$$(T^{\mu\nu})_{\mu,\nu=0,1,2,3} = \begin{pmatrix} mc^2/dV & 0 & 0 & 0 \\ 0 & F_{11}/dA & 0 & 0 \\ 0 & 0 & F_{22}/dA & 0 \\ 0 & 0 & 0 & F_{33}/dA \end{pmatrix}, \tag{5}$$

where the energy density mc^2/dV is the rest energy of mass m in volume dV and, in homogeneous space, the local net force densities F_{11}/dA, F_{22}/dA, and F_{33}/dA in the three space directions are equal to zero. The energy content of volume dV is equal to the pressure uniformly from all space directions, which can be interpreted as the opposite of integrated gravitational force from whole space. Once the global gravitation on element mc^2/dV appears in the element related to the fourth dimension in the stress tensor, the center of gravity must be in the fourth dimension at equal distance from any space location. Such a situation means spherically closed space.

Einstein drew a similar conclusion in his Berlin Writings in 1914–1917:[8] "… If we are to have in the universe an average density of matter which differs from zero, however small may be that difference, then the universe cannot be quasi-Euclidean. On the contrary, the results of calculation indicate that if matter be distributed uniformly, the universe would necessarily be spherical (or elliptical)."

For conserving the balance of the energies in the local mass center buildup, the total gravitational energy is divided, via the tilting of local space, into orthogonal components with the local gravitational energy in a space direction and the reduced global gravitational energy in the fourth dimension. This means a reduction of the local rest energy of objects and consequently, e.g., reduction of the characteristic frequencies of atomic oscillators in tilted space, Fig. 3. Conservation of momentum and energy suggests that the precise expression of the energy of motion shall be written as

$$E_m = c_0|\mathbf{p}^{¤}| = c_0|\mathbf{p} + \mathbf{i}\,mc| = c_0\sqrt{p^2 + (mc)^2}, \tag{6}$$

where c_0 is the 4-velocity in homogeneous space and c is the 4-velocity in local space. Accordingly, the famous equation for the rest energy, $E = mc^2$, obtains the form

$$E_{rest} = c_0 mc, \tag{7}$$

which means that the rest energy is a function of the local velocity of light, c, determined by the local bending of space and the rest mass m, which is a function of the velocity in space. This is exceeding important; the rate of many physical processes, like the ticking frequency of atomic clocks, is proportional to the local velocity of light which can be expressed in terms of the local gravitational potential. Also, the reduced velocity of light together with the increased distances in tilted space give a natural explanation to the Shapiro time delay and the bending of light paths passing mass centers in space.

2. Critical mass density

Based on measurements of microwave background radiation by the Wilkinson Microwave Anisotropy Probe (WMAP), the mass density in space is essentially equal to Friedmann's critical mass density

$$\rho_c = \frac{3H_0^2}{8\pi G} \approx 9.2 \times 10^{-27} \quad (\mathrm{kg/m^3}), \tag{8}$$

where G [$\approx 6.67 \times 10^{-11}$ ($\mathrm{Nm^2/kg^2}$)] is the gravitational constant and H_0 is the Hubble constant [$\approx$70 (km/s)/Mpc]. In the framework of Standard Cosmology, such a condition means "flat space" expanding with the energies of motion and gravitation in balance. Assuming the volume of space as the volume of a 3D sphere with radius $R_H = c/H_0$, the total mass in space and the velocity of light can be expressed as

$$M = \rho_c \frac{4\pi R_H^3}{3} = \frac{3c^2 4\pi R_H^3}{R_H^2 3 \cdot 8\pi G} = \frac{c^2 R_H}{2G} \Rightarrow c^2 = \frac{2GM}{R_H}, \tag{9}$$

respectively.

Solved from the Friedmann's critical mass density, the rest energy of mass m and the total mass $M = \Sigma m$ in SC space are

$$mc^2 = \frac{2GMm}{R_H}; \quad 1/2Mc^2 = \frac{GM^2}{R_H}; \quad c = \sqrt{\frac{2GM}{R_H}}. \tag{10}$$

Formally, the last form in Eq. (10) describes c as the Newtonian escape velocity at distance R_H from mass M at the barycenter representing the total mass in space. This means that the rest energy, as the Newtonian kinetic energy of mass m, is counterbalanced with the global gravitational energy arising from hypothetical mass M at distance R_H from mass m anywhere in space. Such a solution is possible only in 3D space which is the surface of a 4D sphere with radius R_H. The factor ½ in the rest energy Mc^2 in Eq. (10) comes from the numerical factors used in Einstein's field equations for making them consistent with Newtonian gravitation at a low gravitational field in 3D space.

III. COSMOLOGICAL CONSEQUENCES

A. The development of the expansion of space

DU gives a precise prediction for the development of the rate of the expansion of space

$$c_0 = \frac{dR_4}{dt} = \left(\frac{2}{3}GM''\right)^{1/3} t^{-1/3} = \frac{2}{3}\frac{R_4}{t}, \tag{11}$$

where t is the time from the singularity. Today, the 4-radius R_4 is about 14×10^9 light years. Due to the faster expansion in the past, the age of the expanding space is about 9.3×10^9 present years.

All gravitationally bound local systems, as well as the wavelength of electromagnetic radiation propagating in space, expand in direct proportion to the expansion of space, Fig. 4. Atoms and material objects do not expand. 2.8 cm of the measured 3.8 cm annual increase in the Earth to Moon distance comes from the expansion of space and only 1 cm from tidal interactions. Earth and Mars have been closer to the Sun at their infancy, which offers an obvious solution to the early faint Sun paradox.

B. Cosmological observables

1. Optical distance

In DU space, everything is interconnected. The rest energy of any mass object in space is balanced with the gravitational energy arising from the rest of space. All gravitationally bound systems in space expand in direct proportion

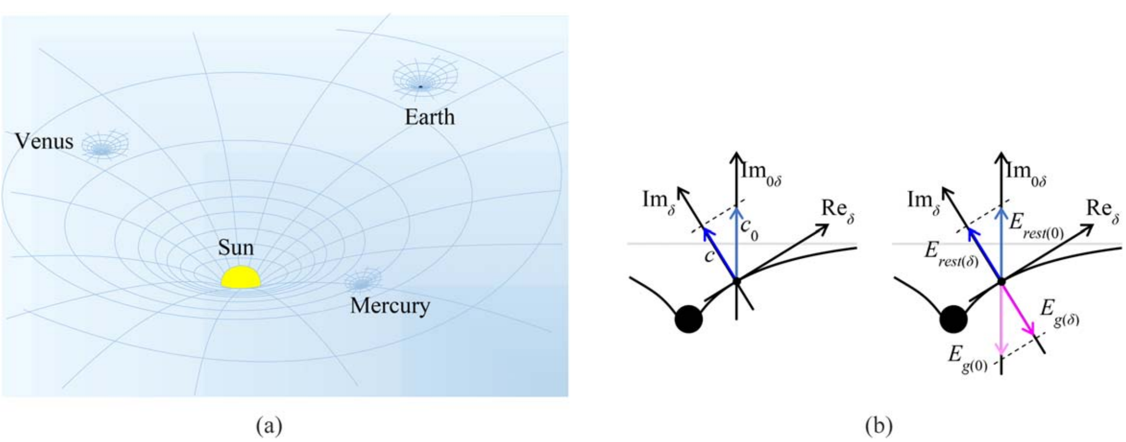

FIG. 3. (Color online) (a) The overall energy balance in space is conserved via tilting of space in local mass center buildup creating the kinetic energy of free fall and the local gravitational energy. (b) Due to the tilting, the velocity of space in the local fourth dimension is reduced compared to the 4-velocity of the surrounding nontilted space. The buildup of dents in space occurs in several steps; dents around planets are dents in the larger dent around the Sun—which is a local dent in the much larger Milky Way dent.

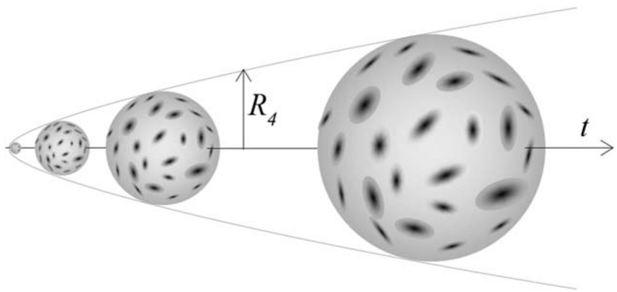

FIG. 4. In DU, all gravitationally bound local systems like galaxies and planetary systems expand in direct proportion to the expansion of space.

to the expansion of the 4-radius of space. The linkage of the velocity of light in space to the expansion velocity of space in the fourth dimension means, e.g., that the optical distance in space is equal to the increase in the 4-radius during light traveling time from the object. Such a situation allows a simple, closed form expression for the optical distance versus redshift

$$D = R_0 \frac{z}{1+z}, \tag{12}$$

where R_0 is the 4-radius of space at the time of the observation, Fig. 5.

The optical distance applies to angular size distance and when corrected with Doppler dilution, to the luminosity distance. In DU, luminosity distance applies directly to the observed bolometric magnitudes (without reduction to the emitter's rest frame by the K-correction like in SC) and produces precise predictions, e.g., to Ia supernovae magnitudes without hypothetical dark energy. In DU, there is no basis for the reciprocity[9] of Standard Cosmology.

2. Euclidean appearance of galaxy space

The spherical geometry, the linkage of the velocity of light to the expansion velocity, and the linkage of the size of quasars and galaxies to the expansion of space result in Euclidean appearance of galactic space, supported by observations on double radio source galaxies and quasars,[10] Fig. 6.

3. Magnitude of standard candle

DU produces a precise prediction for the magnitude of standard candles without mass density, dark energy, or any other adjustable parameters

$$m_{DU} = M + 5\log\left(\frac{R_4}{10\text{pc}}\right) + 5\log(z) - 2.5\log(1+z). \tag{13}$$

DU prediction applies to bolometric magnitudes excluding the "conversion to emitters rest frame" applied in standard cosmology via the K-correction. Unlike commonly stated in the literature, the K-correction is not just a technical correction. K-correction is used to compensate losses due to atmospheric attenuation and spectral mismatch of filters or

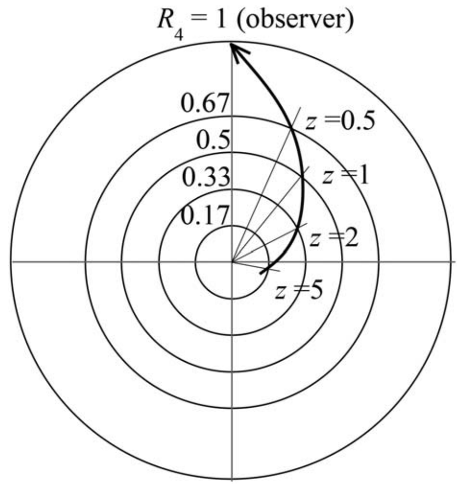

FIG. 5. Light path in expanding space. The optical distance is the integrated tangential component of the of light path. The radial direction in the picture, is the fourth dimension showing the development of the expansion.

photographic plates, which are technical corrections. Also, K-correction converts the observed magnitudes of the objects into their respective rest frames, which, in Standard Cosmology, means an extra $(1+\text{z})^2$ reduction to the observed power density due to losses by redshift. The resulting reduction of power density corresponds to $5\log(1+z)$ correction to the observed magnitudes. The inclusion of the redshift effect in the K-correction was first introduced by Hubble and Tolman in 1935[11] and is still the praxis "as the conversion to emitter's rest frame" in Standard Cosmology.[12]

The magnitude prediction in Standard Cosmology is based on power loss proportional to the co-moving distance squared and the effects of redshift by factor $(1+z)$ due to the Doppler effect and another $(1+z)$ due to dilution based on Planck's equation. Physically, following Max Planck's concluding, the Planck equation describes energy conversion at the emission,[13] which means that the energy carried by a cycle of radiation do not change when the wavelength is increased but is diluted as observed as the Doppler effect. In DU, the magnitude prediction applies to bolometric magnitudes. It is based on the optical distance (12) and Doppler dilution, which results in $5\log(1+z)$ difference[b]) compared to the SC prediction that applies to magnitudes "converted to emitter's rest frame" by factor $5\log(1+z)$ in the K-correction.

Figure 7(a) shows the K-corrected observations (dots) of Ia supernovae by Riess *et al.*,[14] and the DU prediction (13) (solid line) corrected by factor $5\log(1+z)$ to correspond the K-corrected magnitudes. Figure 7(b) shows the K-corrections applied by Riess *et al.* to the observed magnitudes.

An ideal bolometric detector is a wideband detector with flat spectral response. Detection systems, based on multi

[b])In the redshift range 0–2, compared to DU optical distance, the comoving distance in SC is higher by the factor $\approx\sqrt{1+z}$, resulting in extra attenuation by the factor (1+z). Another $(1+z)$ difference comes from the application of both Doppler and Planck dilutions in SC. DU prediction applies to bolometric magnitudes, SC prediction to bolometric magnitudes corrected with the factor $5\log(1+z)$ included in the K-correction as "the conversion to emitter's rest frame."

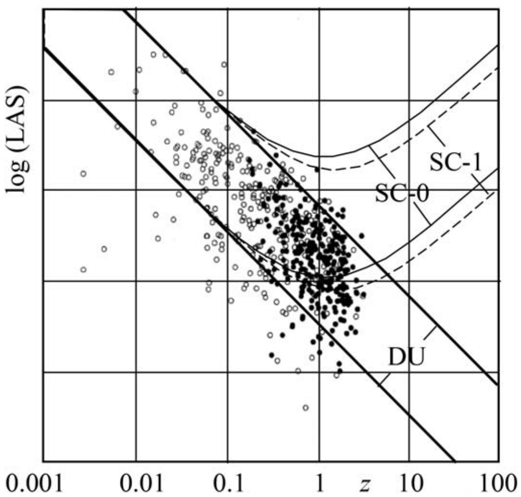

FIG. 6. Angular size of galaxies (open circles) and quasars (filled circles). The data points fall well between the Euclidean DU prediction lines. The SC-0 and SC-1 curves showing increasing angular sizes for $z \gg 1$ are the Standard Cosmology predictions without and with dark energy, respectively.

bandpass filters, produce closest to bolometric magnitudes by matching the filter used to the redshift of the object observed or by following the envelope curve obtained from the minimum magnitude readings of each filter channel over the whole redshift range. Such an analysis, based on observed magnitudes in bandpass filters B, V, R, I, Z, and J by Tonry *et al.*,[15] is shown in Fig. 8. The envelope curve shows a complete match to the DU prediction Eq. (13) for bolometric magnitudes. The SC prediction (dashed curve) deviates from the envelope curve by factor 5log(1+z).

4. Days in a year

Perhaps the most convincing cosmological support for the linkage between the size of planetary systems and the expansion of space comes from the prediction for the development of the number of days.

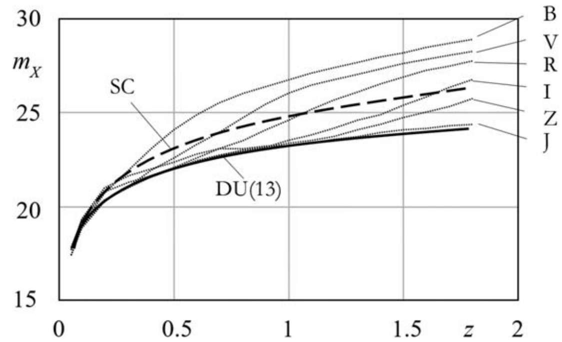

FIG. 8. Observed magnitudes in bandpass filters B, V, R, I, Z, and J by Tonry *et al*. The data are collected from Table 7 in Ref. 15 (dotted curves). The envelope curve shows the bolometric magnitude with a complete match to the DU prediction Eq. (13) (solid curve). The SC prediction (dashed curve) deviates from the envelope curve by factor 5log(1+z).

A unique possibility for studying the long-term development of the Earth's rotation comes from paleo-anthropological data available back to almost 1000×10^6 years in the past. Fossil layers preserve both the daily and annual variations, thus giving the number of days in a year.[16,17] The lengthening of a day for the past 2700 years is also available from ancient Babylonian and Chinese eclipse observations.[18,19] The average lengthening of a day obtained from the eclipse observations is 1.8 ms/100y, which is about 0.7 ms/100y less than the estimated effect of tidal friction, 2.5 ms/100y. The length of a day has been measured with atomic clocks since 1955. An announced result for the lengthening by NASA is 1.5 ms/100y.

According to SC/GR, planetary systems do not expand with the expansion of space, and atomic clocks conserve their frequencies. It means that the length of a year is assumed unchanged, and the length of a day is affected only by tidal interactions with the Moon and Sun.

In DU framework, planetary systems expand in direct proportion to the expansion of space and the frequency of atomic clocks slows down in direct proportion to the

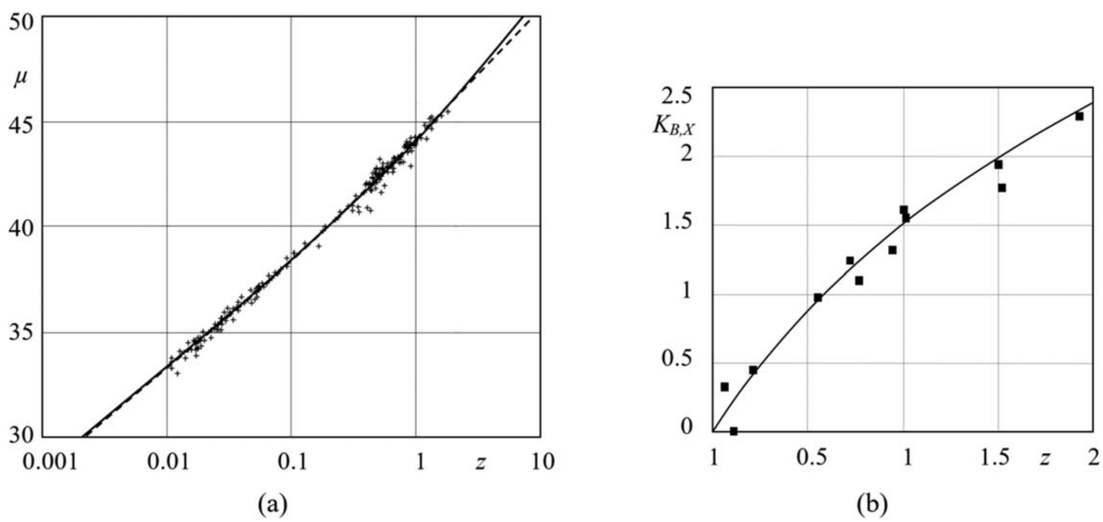

FIG. 7. (a). Distance modulus $\mu = m - M$, vs redshift for Riess *et al*. "high-confidence" dataset and the data from the HST.[14] SC prediction is shown (dashed line), DU prediction (solid curve) based on Eq. (13) is corrected with 5log(1+z) to correspond the SC prediction converted to emitter's rest frame. (b) Average $K_{B,X}$-corrections (black squares) collected from the $K_{B,X}$ data in Table 2 used by Riess for the K-corrected distance modulus data shown in (a). The solid curve gives the 5log(1+z) correction "converting the observations to emitter's rest frame."

decrease in the velocity of light. As a consequence, the length of a year, the length of a day, and the frequency of atomic clocks change with the expansion of space. Combining the change in the length of a year, 0.6 ms/100y, with the effect of tidal friction on the length of a day, 2.5 ms/100y we obtain 1.9 ms/100y which precisely matches the value obtained from the coral fossil data and is essentially the same as the result calculated from ancient solar eclipses (1.8 ms/100y), Fig. 9. Correcting the atomic clock measurement by NASA with the DU correction due to the change of the frequency of atomic clocks, we get to 1.9 ms/100y.

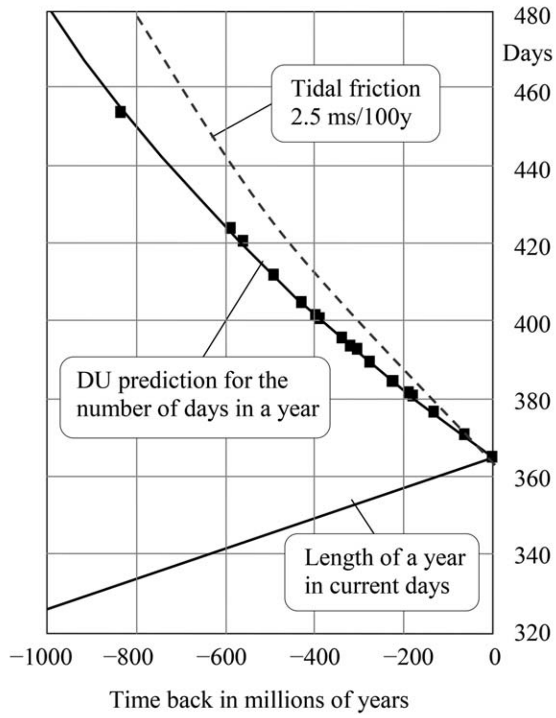

FIG. 9. The development of the length of a year in the number of days. Black squares are data points from Refs. 16 and 17.

5. The faint young Sun paradox and the lunar distance

At the time of the early development of the planets about 4×10^9 years ago, solar insolation is estimated to be about 25% fainter than it is today.[20] Based on geological observations, the temperature of oceans on the Earth has been about 30–40 °C. Also, there is evidence of liquid water on Mars at that time. According to DU, Earth and Mars have been about 30% closer to the Sun than they are today. Combining that with the fainter luminosity of the Sun, 30–40 °C ocean temperature on the Earth and liquid water on Mars are well in line with the DU prediction.

The distance of the Moon has been monitored in the Lunar Laser Ranging program since 1970s.[21] In DU framework, 2.8 cm of the measured 3.8 cm annual increase in the Earth to Moon distance comes from the expansion of space and only 1 cm from the tidal interactions.

IV. MOTION AND GRAVITATION IN LOCAL SPACE

A. Momentum as complex function

1.Constant gravitational potential

Any motion in space is associated with the motion of space in the fourth dimension. It is convenient to express the momentum and energy as complex quantities with the momentum in the fourth dimension as the imaginary part and the momentum in a space direction as the real part. In the complex function presentation, the total energy of motion is

$$E_m^{¤} = c_0|\mathbf{p} + \mathbf{i}mc| = c_0|\mathbf{p}^{¤}|, \tag{14}$$

where symbol ¤ is used as the notion of a complex function, c_0 is the velocity of light in hypothetical homogeneous space, and c is the local velocity of light (in locally bent space). $\mathbf{p}$ is the momentum in space, and $\mathbf{p}^{¤}$ is the complex total momentum. For mass m at rest in a local frame $\mathbf{p} = 0$, Eq. (14) gives the rest energy. For electromagnetic radiation $\mathbf{i}mc = 0$, and the energy is $E = c_0|\mathbf{p}|$. For a moving mass object with momentum $\mathbf{p}$ in space the total energy of motion is

$$E = \mathrm{Mod}\{E_m^{¤}\} = c_0 \cdot \sqrt{p^2 + (mc)^2} = c_0(m + \Delta m)c. \tag{15}$$

In the Earth gravitational frame, c is estimated as $c \approx 0.999\ 999 \cdot c_0$. Equation (15) conveys the total energy expression of special relativity without any assumptions behind the relativity theory. A detailed analysis of momentum $\mathbf{p} = (m + \Delta m) \cdot \mathbf{v}$ shows that the part $m \cdot \mathbf{v}$ of the momentum is the real part of the rotated rest momentum mc, and $\Delta m \cdot \mathbf{v}$ the real part of $\Delta mc^{¤}$, the addition to the rotated rest momentum completing the total momentum, Fig. 10.

In spherically closed space, any motion is central motion relative to the 4-center of the structure. The work done by the central force against the gravitational force due to the rest of space in the fourth dimension is observed as the reduction of the rest energy of the moving object. This is the quantitative explanation of Mach's principle.

The rest momentum and the corresponding rest energy of the moving object is reduced as

$$E_{rest(v)} = E_{rest(0)}\sqrt{1 - \beta^2}, \tag{16}$$

where $\beta = v/c$. Equation (16) means, e.g., that atomic clocks in motion run slower—exactly in the way predicted by special relativity, however, not because of dilated time but as the consequence of reduced rest energy. Also, Eq. (16) means that the frame of reference where velocity v is observed is the energy frame where the kinetic energy was created. In laboratory experiments like those made in accelerators, the observer is at rest relative to the system studied, which makes the observer-bound SR predictions for relativistic effects in the system equal to the DU predictions. In the case of satellite clocks, the velocity of the clocks is obtained in the Earth Centered Inertial frame (ECI-frame), where the observer on the Earth is subject to the rotational velocity in Earth. Accordingly, the SR prediction for the effect of the relative velocity between satellite clocks and the observer's clock does not apply.

2. Momentum in free fall

The gravitational energy balancing the rest energy of a test mass m arises from all mass in space that is represented by mass equivalence $M'' = 0.776 \cdot M_{tot}$ at the center of the 4D sphere, the barycenter of spherically closed space. Buildup of local mass centers means removal of mass from the symmetry to build up a mass center in a specific space direction. At distance R from the local mass center M in space, the global gravitational energy arising from M'' is reduced as

$$E''_{g(\delta)} = \frac{GM''m}{R''}\left(1 - \frac{GM}{Rc_0^2}\right) = E''_{g(0)}(1-\delta), \tag{17}$$

which balances the local rest energy at distance R from the mass center

$$E_{\mathrm{rest}(\delta)} = E''_{g(\delta)} = E_{\mathrm{rest}(0\delta)}(1-\delta), \tag{18}$$

where $E''_{\mathrm{rest}(0\delta)}$ is the rest energy of mass m at rest far from the local mass center M, Fig. 10. The reduction of the local rest energy, $\Delta E_{\mathrm{rest}} = c_0 \Delta mc$ is converted to the kinetic energy in free fall from homogeneous space to distance R from mass center M.

Combining the effects of motion and gravitation, the rest energy in a local gravitational frame the rest energy in gravitational potential $\delta = GM/Rc^2$ and velocity $\beta = v/c$ is expressed

$$E_{\mathrm{rest}(\beta,\delta)} = E_{\mathrm{rest}(0\delta,0)}(1-\delta)\sqrt{1-\beta^2}. \tag{19}$$

As illustrated in Fig. 11, the reduction of the rest energy by local gravitation is associated with a reduced velocity of light. Observing that the frequency of atomic oscillators is directly proportional to the rest momentum of the oscillating electrons, the prediction for the frequency of a clock moving at velocity β at gravitational potential δ is

$$f_{(\beta,\delta)} = f_{(0\delta,0)}(1-\delta)\sqrt{1-\beta^2}. \tag{20}$$

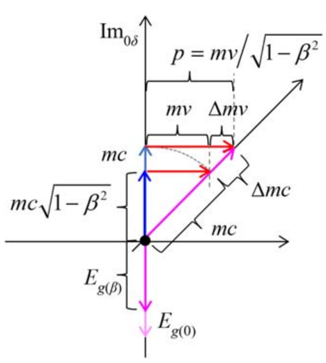

FIG. 10. (Color online) In DU space, buildup of velocity v at constant gravitational potential requires insertion of energy $c_0 \cdot \Delta mc$, which results in the momentum in the direction of real axis and total energy $E_{\mathrm{tot}} = c_0 \cdot (m + \Delta m)c$, and the total momentum $\mathbf{p} = (m + \Delta m)\mathbf{v}$ in the direction of the real axis (space direction). Energy $c_0 \Delta mc$ is the energy insertion from the accelerating system resulting in the kinetic energy.

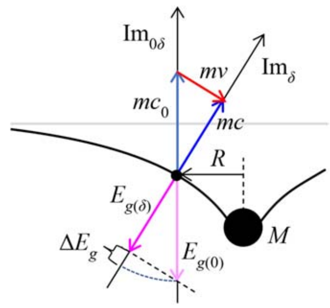

FIG. 11. (Color online) Buildup of velocity v in free fall in a gravitational field is obtained against reduction of the local 4-velocity of space; there is no mass insertion, and the momentum is $\mathbf{p} = mv$. The kinetic energy of free fall is equal to the gravitational energy released $E_{kin} = \Delta E^*_g = E^*_{g(0)} - E^*_{g(\delta)} = c_0 \cdot m\Delta c$.

Equation (20) is the DU replacement of Schwarzschildian equation for the time dilation in general relativity

$$dt = dt_0\sqrt{1 - 2\delta - \beta^2}. \tag{21}$$

In the Earth gravitational frame, the difference between Eqs. (20) and (21) appears only in the 18th to 20th decimal. In DU space, the local velocity of light is locked to the local 4D velocity of space. A mass center like the Earth, orbiting the Sun in space, draws a dent in space with the orbital motion and conserves the local velocity of light at a fixed distance from the center. The local 4-velocity of space serves as the reference for the velocity of light in any moving frame, which explains the early experiments, like the Michelson–Morley experiment, on the velocity of light.

B. The system of nested energy frames

The buildup of mass centers in space occurs in several steps. Following the conservation of the overall balance of the energies of motion and gravitation, the rest energy of mass m in any local frame can be related to the rest energy of mass m at rest in hypothetical homogeneous space

$$E_{\mathrm{rest}(\beta,\delta)} = E_{\mathrm{rest}(0,0)}\prod_{i=0}^{n}(1-\delta_i)\sqrt{1-\beta_i^2}. \tag{22}$$

A characteristic feature defining an energy frame is the local exchange of potential energy and kinetic energy. Figure 12 illustrates the system of nested energy frames for primary structures in space and relates the rest energy of an ion in an accelerator on the Earth to the rest energy the electron would have at rest in hypothetical homogeneous space.

As a fundamental difference to contemporary physics, DU defines energy as the primary quantity and force a derived quantity as the gradient of potential energy and the time derivative of momentum.[22] The equation of motion in the n:th frame in the system of nested energy frames obtains the form

$$\mathbf{F}_{DU} = \frac{d\mathbf{p}_\delta}{dt} = \frac{c_0}{c} m_0 \prod_{i=1}^{n}\sqrt{1-\beta_i^2}\cdot\left(1-\beta^2\right)^{-3/2}\cdot\mathbf{a}. \tag{23}$$

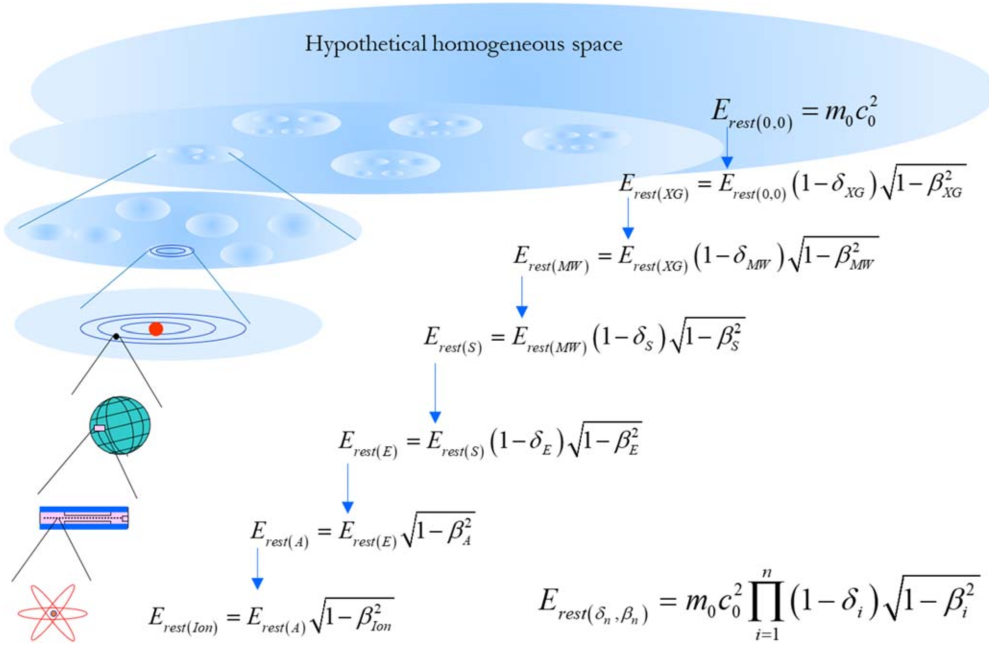

FIG. 12. (Color online) The system of nested energy frames. The rest energy in the n:th (local) frame is subject to reductions due to the motions and gravitational states of the local frame in all its parent frames—and is finally related to the rest energy the object would have at rest in hypothetical homogeneous space.

Omitting the effects of the gravitational state on the local velocity of light and the effect of motion on the rest mass, Eq. (23) reduces into

$$\mathbf{F}_{SR} = \frac{d\mathbf{p}_\delta}{dt} = m\left(1-\beta^2\right)^{-3/2} \cdot \mathbf{a}, \tag{24}$$

which is equivalent to the equation of motion in special relativity, and further, by omitting the effect of motion on the relativistic mass we return to Newton's law of motion

$$\mathbf{F}_{\text{Newton}} = \frac{d\mathbf{p}_\delta}{dt} = m \cdot \mathbf{a}. \tag{25}$$

C. Celestial mechanics in DU space

1. Orbital precession and black holes

The DU prediction for the precession (in addition to interaction with other planets) of the orbit of the planet Mercury is the same 43 arcseconds/100 years given by the Schwarzschild's solution of general relativity. In textbooks, the Schwarzschild solution is generally solved for a single revolution which allows omitting a small cumulative term increasing the orbital radius. For orbits close to black holes, the cumulative term is large enough to throw the orbiting object out of the system in one revolution, which prevents orbits with the radius shorter than three times the Schwarzschild critical radius. When calculated for about one million cycles, similar instability is found for the orbit of Mercury in Schwarzschild's solution, Fig. 13(a).

The DU solution of the orbit around a mass center does not have cumulative terms like the Schwarzschild solution. Unlike in the Schwarzschild solution, orbits with radii close to the critical radius are stable, Fig. 13(b).

In DU space, the orbital period has its minimum at the radii 2 times the DU critical radius $r_0 = GM/c^2$, which is half of the Schwarzschild critical radius. Orbital velocities in orbits with radius approaching the DU critical radius approach zero, which allows the mass at the slow orbits maintain the mass of the black hole. Figure 14 illustrates the orbital period close to the critical radius of Sagittarius A* at the center of the Milky Way. The calculated minimum

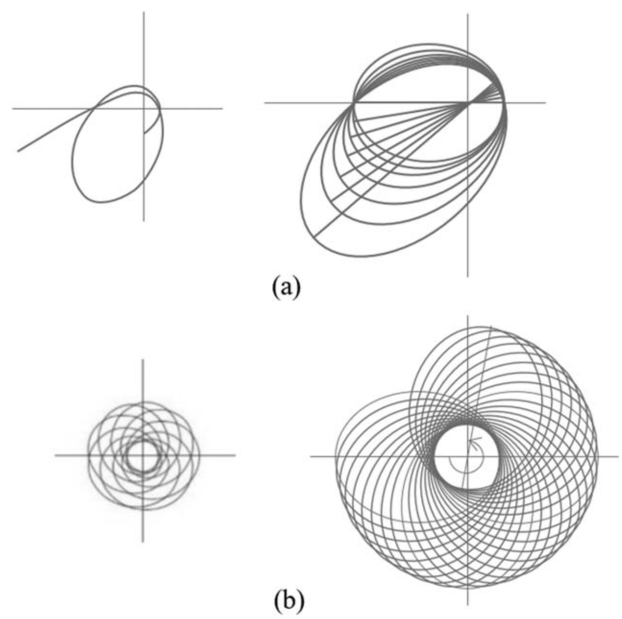

FIG. 13. Development of the orbital precession for a near black hole obit characterized by $r/r_0 = 20$ and $e = 0.5$, and for Mercury obit with $r/r_0 = 4{\cdot}10^7$ and $e = 0.2$. ($r_0 = GM/c^2$). (a) In Schwarzschild space, the orbiting object escapes when the cumulated precession exceeds 45°. (b) In DU space, orbits are stable. Mass at slow orbits near the critical radius maintains the mass on the black hole.

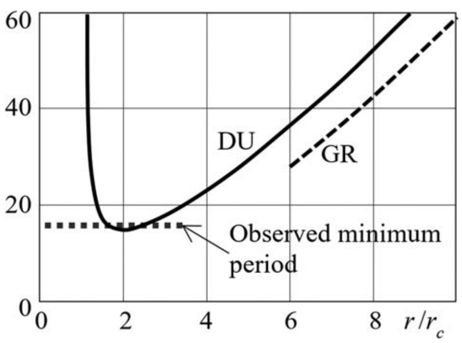

FIG. 14. Predictions for the period of circular orbits around Sgr A* in the center of Milky Way. The shortest observed period is 16.8 ± 2 min by Gentzel *et al.*,[6] which is close to the minimum period of 14.8 minutes predicted by the DU. In GR space, the suggested explanation for the observed "too fast" periods is a rotating black hole referred to as the Kerr black hole.

period in DU space is 14.8 min, which is short enough to explain the observed 16.8 min orbits.[6]

2. Orbital decay

In DU framework, the decay of the period of an elliptic orbit can be solved as a consequence of the periastron rotation and the related rotation of the orbital angular momentum in the fourth dimension, Fig. 15. Interestingly, the prediction derived from the rotation of the 4D orbital angular momentum gives essentially the same prediction as the GR prediction based on the change of the quadrupole moment.[23,24] The only difference is that DU predicts orbital decay for eccentric orbits only, GR predicts decay for circular orbits, too, Fig. 16. In the author's knowledge, all observations on orbital decay are related to orbits with nonzero eccentricity.

The possible energy radiation (gravitational radiation) by the rotating 4D angular momentum in the DU has not been analyzed

$$\mathrm{DU}: \frac{dP}{dt}_{(DU)} \approx 120 \cdot \frac{G^{5/3}}{c^5}\left(\frac{P}{2\pi}\right)^{-5/3} \left(2 \cdot \frac{\left[\sqrt{1+e_{0\delta}} - \sqrt{1-e_{0\delta}}\right]}{(1-e^2)^2}\right) \cdot \frac{m_p m_c}{(m_p+m_c)^2}(m_p+m_c)^{5/3}, \tag{26}$$

$$\mathrm{GR}: \frac{dP}{dt}_{(GR)} \approx 123 \cdot \frac{G^{5/3}}{c^5}\left(\frac{P}{2\pi}\right)^{-5/3} \left(\frac{1+(73/24)e^2+(37/96)e^4}{(1-e^2)^{7/2}}\right) \cdot \frac{m_p m_c}{(m_p+m_c)^2}(m_p+m_c)^{5/3}. \tag{27}$$

V. MASS AND ELECTROMAGNETIC RADIATION

A. From Maxwell's equations to Planck's equation

Unlike generally understood, formally, Planck's equation can be derived from Maxwell's equations. Applying the standard solution of the Hertzian dipole, the energy emitted

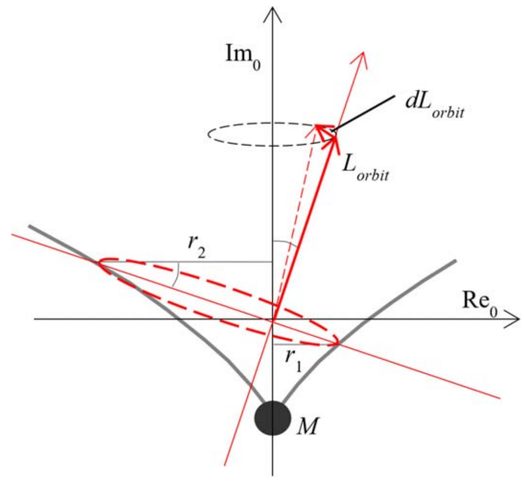

FIG. 15. (Color online) In DU framework, the orbital decay of binary stars is calculated from the energy related to the rotation of orbital angular momentum due to the periastron advance.

by a single oscillation of N electrons in one-wavelength dipole into a cycle of electromagnetic radiation is

$$E_\lambda = N^2 \cdot A \cdot 2\pi^3 e^2 \mu_0 c \cdot f, \tag{28}$$

where A is the geometrical factor of the dipole which for a Hertzian dipole is $A = 2/3$, e is the electron charge, μ_0 is the vacuum permeability, c is the velocity of light, and $f = c/\lambda$ is the frequency of the radiation emitted. [Observe that Eq. (28) applies the vacuum permeability $\mu_0 = c^2/\varepsilon_0$ instead of vacuum permittivity ε_0 most commonly used.]

In DU framework, a point emitter, like an atom, moves the distance of one wavelength in the fourth dimension in a cycle (equal to the 4D line element cdt in the GR spacetime formalism). A point emitter can be considered as a one wavelength dipole in the fourth dimension with isotropic emission pattern suggesting A close to 1. For a single electron transition ($N = 1$) with $A = 1.1049$, Eq. (28) becomes

$$E_\lambda = 1.1049 \cdot 2\pi^3 e^2 \mu_0 c \cdot f = h \cdot f, \tag{29}$$

where the factor $1.1049 \cdot 2\pi^3 e^2 \mu_0 \cdot c = 6.62607 \times 10^{-34}$ (Js) is equal to Planck's constant h. An important message of Eq. (29) is that the Planck constant h has the velocity of light as a "hidden" internal factor. Defining the *intrinsic Planck constant* $h_0 = h/c$, Planck's equation obtains the form

$$E_\lambda = h \cdot f = h_0 c \cdot f = \frac{h_0}{\lambda} cc = m_\lambda c^2, \tag{30}$$

where the quantity $h_0/\lambda = m_\lambda$ is referred to as the *mass equivalence of electromagnetic radiation*. In DU framework, including the conversion factor c_0/c (estimated of the order of ppm) in factor A, Eq. (30) is written in the form

$$E_\lambda = c_0 \frac{h_0}{\lambda} c = c_0 m_\lambda c = c_0 |\mathbf{p}|. \tag{31}$$

Applying the intrinsic Planck constant, the Compton wavelength, as the *wavelength equivalence of mass* appears as the counterpart of the *mass equivalence of electromagnetic radiation*

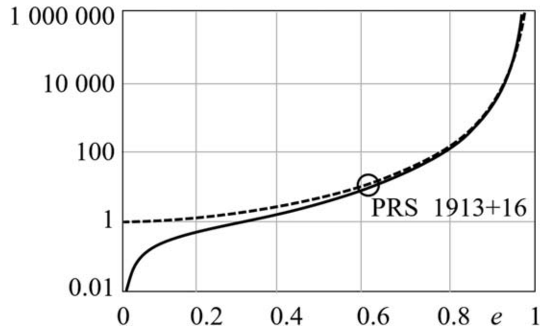

FIG. 16. The eccentricity factor of the decay of binary star orbit period. At the eccentricity $e=0.616$ of the PSR $1913+16$ orbit, the eccentricity factor of the GR and DU for the orbit decay are essentially the same. According to DU prediction, the eccentricity factor goes to zero at zero eccentricity.

$$\lambda_{\text{Compton}} \equiv \frac{h}{mc} = \frac{h_0}{m} = \lambda_m, \tag{32}$$

allowing the wave expression of the rest energy as

$$E_{\text{rest}} = c_0 mc = c_0 \frac{h_0}{\lambda_m} c. \tag{33}$$

The breakdown of Planck's constant into primary electrical constants discloses the physical nature of the fine structure constant α as a pure numerical or geometrical constant without connections to other natural constants

$$\begin{aligned}\alpha &\equiv \frac{e^2\mu_0 c}{2h_0 c} = \frac{e^2\mu_0}{2\cdot 1.1049\cdot 2\pi^3 e^2\mu_0} \\ &= \frac{1}{4\cdot 1.1049\cdot \pi^3} \simeq \frac{1}{137.0360}.\end{aligned} \tag{34}$$

In DU, mass obtains the role of the wavelike substance for the expression of energy. Mass expresses energy via motion, gravitation, or Coulomb energy, which for unit charges e can be expressed

$$E_C = \frac{e^2}{4\pi\varepsilon_0 r} = \frac{e^2\mu_0}{4\pi r}c^2 = c_0\alpha\frac{\hbar_0}{r}c = c_0 m_C c, \tag{35}$$

where m_C is the mass equivalence of unit Coulomb energy.

B. The frequency of atomic oscillators

The quantum mechanical solution of the emission/absorption frequency of atomic oscillators can be expressed in terms of the rest energy of the oscillating electrons, the Planck constant, and the quantum numbers characterizing the energy states related to the oscillation

$$f_{(n1,n2)} = \frac{\Delta E_{(n1,n2)}}{h} = \frac{E_{(e)\text{rest}}}{h}\Delta F(\alpha, n, l, m_l, m_s), \tag{36}$$

where $\Delta E_{(n1,n2)}$ is the difference of the rest energy of an electron in the two energy states relevant to the emission/absorption process, h is the Planck constant, m_e is the rest mass of the electron of the atom in the local energy frame, and c is the local velocity of light. The function $\Delta F(\alpha,n,l,m_l,m_s)$ is determined by the fine structure constant α and the quantum numbers characterizing the energy states in question. Applying the intrinsic Planck constant, Eq. (36) reduces to the form

$$f_{(n1,n2)} = \frac{m_e c}{h_0}\Delta F(\alpha, n, l, m_l, m_s), \tag{37}$$

which means that the characteristic frequency of an atomic oscillator is directly proportional to the rest mass of the oscillating electrons and the local velocity of light. In DU framework, the rest mass is affected by motion as

$$m_{\text{rest}(n)} = m_{(0,0)} \prod_{i=0}^{n} \sqrt{1-\beta_i^2}, \tag{38}$$

and the local velocity of light by the local gravitational state as

$$c = c_{(n)} = c_{(0,0)} \prod_{i=0}^{n} (1-\delta_i), \tag{39}$$

which give the general expression to the characteristic frequency

$$f_{(\beta_n,\delta_n)} = f_{(00,00)} \prod_{i=0}^{n} (1-\delta_i)\sqrt{1-\beta_i^2}, \tag{40}$$

where $f_{(00,00)}$ is the frequency of the oscillator at rest in hypothetical homogeneous space. In a local energy frame, the frequency can be expressed as

$$f_{(\delta,\beta)} = f_{(0\delta,0)}(1-\delta)\sqrt{1-\beta^2}, \tag{41}$$

where $f_{(0\delta,0)}$ is the frequency of the oscillator at rest ($\beta=0$) in the parent frame, excluding of the gravitational interaction ($\delta=0$). Equation (41) applies to all clocks moving on the Earth and in near space. Equation (41) is the DU replacement of the dilated time in Schwarzschild space used to explain the changing clock frequencies in the Earth gravitational frame in the GR framework

$$dt = dt_0\sqrt{1-2\delta-\beta^2}. \tag{42}$$

In the Earth gravitational frame, Eqs. (41) and (42) give equal predictions up to the 18th to 20th decimal.

Closed systems like accelerators or centrifuges are subframes in the Earth gravitational frame. The clock frequency in such frames is

$$f_{(\delta,\beta)} = f_{(0\delta,0)}\left(1-\delta_{sf/\text{Earth}}\right)\sqrt{1-\beta_{sf/\text{Earth}}^2}\sqrt{1-\beta_{sf}^2}, \tag{43}$$

where $\delta_{sf/\text{Earth}}$ and $\beta_{sf/\text{Earth}}$ are the gravitational factor and velocity of the subframe in the Earth gravitational frame, respectively, and β_{sf} is the velocity of the clock in the subframe. When related to the frequency $f_{(sf=0)}$ of a reference clock at rest relative to and at the same gravitational state as the subsystem, Eq. (43) can be expressed as

$$f_{(\beta,\delta)} = f_{(sf=0)}\sqrt{1-\beta_{sf}^2}, \tag{44}$$

which corresponds to the time dilation equation in the framework of special relativity

$$dt = dt_0\sqrt{1-\beta^2} \tag{45}$$

relating the "flow of time" in the clock's frame of reference to the flow of time in the observer's frame of reference.

In DU, time is a universal coordinate quantity, and the frequency of atomic clocks is determined by the local state of gravitation and motion. In DU, there are no twin paradoxes or relativity of simultaneity challenging human logic.[25]

C. The velocity of light

In the DU framework, the velocity of light is linked to the local 4D velocity of space, which is a function of the local gravitational state. Bending of the light path passing a mass center as well as the Shapiro delay are direct consequences of the slower speed of light and the increased distance due to the dent around a mass center. A motion of a mass center in its parent frame, like the Earth in the solar gravitational frame draws the local dent with the motion, which conserves the velocity of light at a fixed gravitational state in the Earth gravitational frame.

The frequency of atomic clocks is directly proportional to the local velocity of light which means that the velocity of light is observed unchanged when measured with atomic clocks. The signal transmission time, e.g., from a satellite to a receiver on the rotating Earth can be calculated from the actual distance from the satellite at the time the signal is sent to the location of the receiver at the time the signal is received. Such a calculation conveys the Sagnac correction needed in the GR/SR framework as a separate correction for the motion of the receiver during the signal transmission.

VI. ONTOLOGICAL CONSIDERATIONS

A. The nature of quantum

The wavelike nature of mass used to express the energy of electromagnetic radiation via mass equivalence $m_\lambda = h_0/\lambda$ or $m_\lambda = \hbar_0 k$ conveys many of the features obtained with the concept of wave function in the standard formalism of quantum mechanics. Energy eigenstates of electrons in atoms are considered discrete energy states. Resonant mass wave states show the same energy states, not as discrete energy states but as the energy minima of states fulfilling a resonance condition. Identification of Planck's equation as the energy conversion equation at the emitter and absorber instead of an intrinsic property of radiation, has important consequences in cosmology, especially on the interpretation of the effect of Planck's equation on the dilution of redshifted radiation.[26]

The solution of Planck's equation from Maxwell's equations as the energy emitted to a cycle of electromagnetic radiation by a unit charge transition in the emitter re-establishes Planck's original interpretation of the equation as the energy conversion equation at the emitter and absorber. In principle, an emitter may be isotropic or directional; in the first case the radiation emitted from a point source is spread uniformly to all space directions, in the latter case it is observed as a localized photon like in the emission from a laser.

Absorption of a quantum of radiation is symmetric with the emission; the minimum condition for absorption is that the energy carried by a cycle of radiation within the capturing area of the receiving absorber or "antenna" is enough to result in an electron transition corresponding to the energy characteristic of the wavelength of the radiation.

As given by Maxwell's equations, the energy emitted into a cycle of radiation by an emitter with N oscillating electrons is

$$E_\lambda = N^2\frac{h_0}{\lambda}c_0 c \quad \left(= N^2 hf\right), \tag{46}$$

where N^2 is the intensity factor. A "quantum receiver" is not energy selective but wavelength selective like any radio antenna.

B. From Compton wavelength to de Broglie wavelength

In DU framework, localized mass objects can be described as "Compton wave resonators." At the state of rest, the momentum of the resonator, as the sum of opposite waves, appears in the fourth dimension as the rest momentum. When the resonator moves at velocity βc in space, the rest momentum of the resonator is

$$\mathbf{p}_{\mathrm{rest}(\beta)} = \mathbf{i}\, mc\sqrt{1-\beta^2}. \tag{47}$$

In the local frame, in the direction of the motion, the momentums of the Doppler shifted front and back waves are

$$\mathbf{p}_{\mathrm{rest}(\beta)\rightarrow} = \tfrac{1}{2}\cdot\frac{mc\sqrt{1-\beta^2}}{1-\beta}\,\hat{\mathbf{r}} \tag{48}$$

and

$$\mathbf{p}_{\mathrm{rest}(\beta)\leftarrow} = \tfrac{1}{2}\cdot\frac{mc\sqrt{1-\beta^2}}{1+\beta}\,\hat{\mathbf{r}}, \tag{49}$$

respectively, resulting in a net wave with momentum in the local frame

$$\begin{aligned}\mathbf{p}\hat{\mathbf{r}} &= \mathbf{p}_{\mathrm{rest}(\beta)\rightarrow} + \mathbf{p}_{\mathrm{rest}(\beta)\leftarrow}\\ &= \frac{m\beta}{\sqrt{1-\beta^2}}c\,\hat{\mathbf{r}} = \frac{m}{\sqrt{1-\beta^2}}\beta c\,\hat{\mathbf{r}} = m_{\mathrm{eff}}\mathbf{v},\end{aligned} \tag{50}$$

which is the momentum carried by the de Broglie wave in space. The momentum wave can be interpreted as a wave with mass $m\beta/\sqrt{1-\beta^2} = \beta m_{\mathrm{eff}}$ propagating at velocity c, or mass $m/\sqrt{1-\beta^2} = m_{\mathrm{eff}}$propagating at velocity $\beta c = v$. The momentum wave is observed propagating "beside" the moving object in the local frame, giving an obvious explanation to the double slit experiment, Fig. 17.

C. Quantum states as energy minima of resonant mass wave structures

Applying the concept of a mass wave, the principal energy states of an electron in hydrogenlike atoms can be solved by assuming a resonance condition of the de Broglie wave in a Coulomb equipotential orbit around the nucleus. The Coulomb energy of Z electrons at distance r from the nucleus is

$$E_{\mathrm{Coulomb}} = -Z\alpha \frac{h_0}{2\pi r} c_0 c = -Z\alpha \frac{\hbar_0}{r} c_0 c. \tag{51}$$

For a resonance condition, the de Broglie wavelength $n\lambda_{dB} = 2\pi r$, which is equal to the wave number boundary condition $k_{dB} = n/r$. The energy of an electron as the sum of kinetic energy and Coulomb energy in a Coulomb equipotential orbit with radius r is $E_n = E_{kin} + E_{\mathrm{Coulomb}}$ and can be written in the form

$$E_n = \hbar_0 k_m c_0 c \left[\sqrt{1 + \left(\frac{n}{k_{dB} r} \right)^2} - 1 - \frac{Z\alpha}{k_{dB} r} \right]. \tag{52}$$

The solution of Eq. (52) is illustrated in Fig. 18; for each value of n, the total energy E_n is a continuous function of r. The "quantized" energy states are energy minima of E_n for each value of n. The minima are obtained by derivation of Eq. (52)

$$E_{Z,n} = -mc_0 c \left[1 - \sqrt{1 - \left(\frac{Z\alpha}{n} \right)^2} \right] \approx -\left(\frac{Z}{n} \right)^2 \frac{\alpha^2}{2} mc^2 \tag{53}$$

showing the "relativistic" minima with an approximation equal to the solution obtained from Schrödinger's equation.

VII. PHILOSOPHICAL CONSIDERATIONS

A. The essence of mass

Breaking down Planck's constant into its constituents opens up the essence of mass as the wavelike "substance" for the expression of energy. Mass is not a form of energy, but it expresses the energy related to motion and potentiality. In DU framework, mass is conserved also in annihilation; the mass equivalence of the emitted photons is equal to the rest mass of annihilated particles. The total mass in space is the primary conservable. The contraction of space builds up the excitation of complementary energies of motion and gravitation. The anti-energy for the rest energy of a localized mass particle is negative gravitational energy arising from all other mass in space.

B. Inertia and Mach's principle

In DU framework, inertial work is the work done against the global gravitational energy via the interaction in the fourth dimension, which means a quantitative explanation of Mach's principle. Inertia is not a property of mass; in DU framework, the "relativistic mass increase" Δm introduced in SR framework is the mass contribution by the accelerating system to the buildup of kinetic energy. In the complex quantity presentation, the real part of kinetic energy increases the momentum observed in space, and the imaginary part of kinetic energy reduces the global gravitational energy and the rest energy of the moving object, which is observed as the reduced ticking frequency of atomic clocks in motion.

Any motion in space is central motion relative to the barycenter of space in the center of the 4D sphere defining space. Inertial work can be understood as the work that the central force created by motion in space does against the global gravitational force in the fourth dimension. Energy objects like photons or electromagnetic radiation propagating at the velocity of light in space move like at a satellite orbit around the barycenter of whole space: They are weightless but not massless.

C. Occam's razor

DU omits all central postulates of the relativity theory Standard Cosmology like the relativity principle, Lorentz

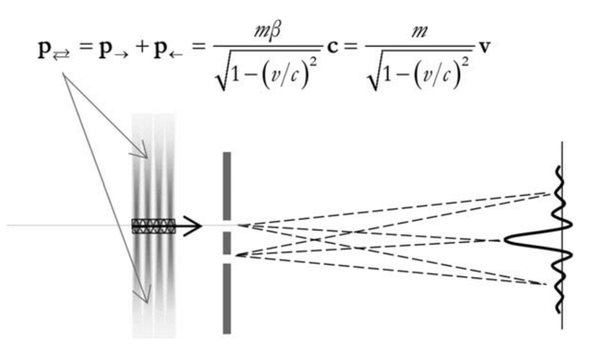

FIG. 17. The momentum of an object moving at velocity βc is the momentum as the sum of the Doppler shifted front and back waves, which can be described as the momentum of a wave front propagating in the local frame in parallel with the propagating mass object.

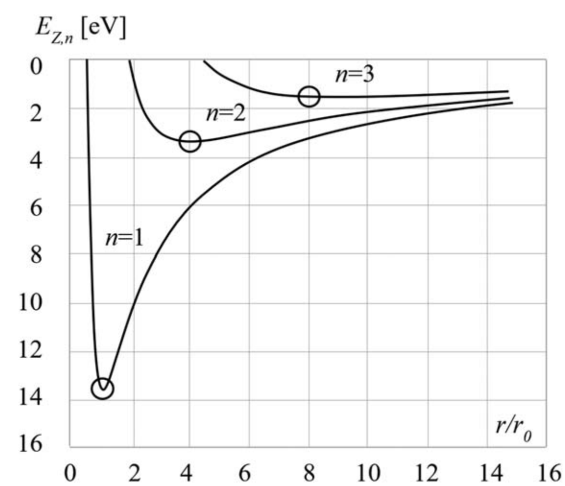

FIG. 18. Total energy of electron in hydrogenlike atoms for principal quantum number $n = 1$, $n = 2$, $n = 3$ according to Eq. (52). Orbital radii of the energy minima are $r/r_{Bohr} = 1$, $r/r_{Bohr} = 4$, and $r/r_{Bohr} = 8$, respectively.

covariance, equivalence principle, the constancy of the velocity of light, dark energy, instant big bang, inflation hypothesis, and the space-time concept and replaces them with the assumption of zero-energy balance in spherically closed space. DU gives at least as precise predictions as SR/GR/SC but uses fewer postulates and more straightforward mathematics.[27,28] Most importantly, DU uses time and distance as universal coordinate quantities essential for human comprehension and offers a framework for a unified framework for physics from cosmology to quantum phenomena.

D. Aristotle's entelecheia and the linkage of local to whole

In the spirit of Aristotle's entelecheia, the primary energy buildup is described as "actualization of potentiality," the conversion of gravitational energy into the energy of motion—and follows the same, as the zero-energy principle, in all interactions in space. Any state of motion in space has its history that links it, through the system of nested energy frames, to the state of rest in hypothetical homogenous space. Velocity in space can be related to an observer in a kinematic sense, but in a dynamic study, a state of motion is related to the state where the energy building up the kinetic energy was released. There are no independent objects in space, any local object is linked to the rest of space; the rest energy of any energy object is balanced by the global gravitational energy arising from all mass in space.

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[1] T. Suntola, *The Dynamic Universe, Toward a Unified Picture of Physical Reality*, 4th ed. (Physics Foundations Society, Espoo, 2018); https://physicsfoundations.org/data/documents/DU_EN_978-952-68101-3-3.pdf
[2] D. W. Sciama, Mon. Not. R. Astron. Soc. **113**, 34 (1953).
[3] E. D. Tryon, Nature **246**, 396 (1973).
[4] R. Feynman, W. Morinigo, and W. Wagner, *Feynman Lectures on Gravitation* (during the academic year 1962–63) (Addison-Wesley Publishing Company, Boston, MA, 1995), p. 164.
[5] R. Feynman, W. Morinigo, and W. Wagner, *Feynman Lectures on Gravitation* (during the academic year 1962–63) (Addison-Wesley Publishing Company, Boston, MA, 1995) p. 10.
[6] R. Genzel, R. Schödel, T. Ott, A. Eckart, T. Alexander, F. Lacombe, D. Rouan, and B. Aschenbach, Nature **425**, 934 (2003). [PMC]
[7] T. Suntola, *The Short History of Science, or the Long Path to the Union of Metaphysics and Empiricism*, 3rd ed. (Physics Foundations Society, Espoo, 2018); https://physicsfoundations.org/data/documents/History_EN_978-952-68101-7-1.pdf
[8] A. Einstein, "The structure of space according to the general theory of relativity," Berlin Years: Writings **6**, 370 (1914).
[9] J. M. H. Etherington, Philos. Mag. **15**, 761 (1933).
[10] K. Nilsson, M. J. Valtonen, J. Kotilainen, T. Jaakkola, Astrophys. J. **413**, 453 (1993).
[11] E. Hubble and R. C. Tolman, Astrophys. J. **82**, 302 (1935).
[12] A. Kim, A. Goobar, and S. Perlmutter, "A generalized K correction for type IA supernovae: Comparing R-band photometry beyond $z = 0.2$ with B, V, and R-band nearby photometry - NASA/ADS (harvard.edu)," PASP **108**, 190 (1996).
[13] T. Suntola, Proc. SPIE **5866**, 18 (2005).
[14] A. G. Riess, L.-G. Strolger, J. Tonry, S. Casertano, H. C. Ferguson, B. Mobasher, P. Challis, A. V. Filippenko, S. Jha, W. Li, R. Chornock, R. P. Kirshner, B. Leibundgut, M. Dickinson, M. Livio, M. Giavalisco, C. C. Steidel, T. Benítez, and Z. Tsvetanov, Astrophys. J. **607**, 665 (2004).
[15] J. L. Tonry, B. P. Schmidt, B. Barris, P. Candia, P. Chalis, A. Clocchiatti, A. L. Coil, A. V. Filippenko, P. Garnavich, C. Hogan, S. T. Holland, S. Jha, R. P. Kirshner, K. Krisciunas, B. Leibundgut, W. Li, T. Matheson, M. M. Phillips, A. G. Riess, R. Schommer, R. C. Smith, J. Sollerman, J. Spyromilio, C. W. Stubbs, and N. B. Suntzef, Astrophys. J. **594**, 1 (2003).
[16] J. W. Wells, Nature **197**, 948 (1963).
[17] J. W. Wells, *Paleogeophysics*, edited by S. K. Runcorn (Academic Press, London, 1970).
[18] F. R. Stephenson and L. V. Morrison, Philos. Trans. R. Soc. A **351**, 165 (1995).
[19] F. R. Stephenson, L. V. Morrison, and C. Y. Hohenkerk, Proc. R. Soc. A **472**, 401600404 (2016).
[20] J. N. Bahcall, M. H. Pinsonneault, and S. Basu, e-print https://arxiv.org/abs/astro-ph/0010346 (2001).
[21] J. O. Dickey, P. L. Bender, J. E. Faller, X. X. Newhall, R. L. Rickleff, J. G. Ries, P. J. Shelus, C. Veillet, A. L. Whiplle, J. R. Wiant, J. G. Williams, and C. F. Yoder, Science **265**, 482 (1994).
[22] T. Suntola, Int. J. Astrophys. Space Sci. **2**, 66 (2014).
[23] P. C. Peters and J. Mathews, Phys. Rev. **131**, 435 (1963).
[24] J. M. Weisberg and J. H. Taylor, ASP Conf. Ser. **328**, 25 (2005).
[25] A. Styrman, Phys. Essays **31**, 256 (2018).
[26] R. C. Tolman, Proc. Natl. Acad. Sci. U. S. A. **16**, 511 (1930).
[27] A. Styrman, "Economical unification as a method of philosophical analysis," Ph.D. thesis, University of Helsinki (2016).
[28] A. Styrman, "Only a unified ontology can remedy disunification," J. Phys.: Conf. Ser. **1466**, 012001 (2020).