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IN A HOLISTIC PERSPECTIVE EVERYTHING IN SPACE IS INTERCONNECTED

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Abstract: Description of space as the 3D surface of a 4D ball allows a dynamic solution to the cosmological development of space and opens the linkage between local structures and space as a whole. In such a holistic perspective, all velocities in space are linked to the 4D velocity of space and the expansion of local gravitationally bound structures to the expansion of the spherical structure. Space works as a spherical pendulum: Mass in space has gained its rest energy as the energy of motion against the release of gravitational energy in a contraction phase and pays it back to gravitational energy in the ongoing expansion phase. Following the zero-energy principle, local structures in space are formed against release of the global gravitational energy via local tilting of space resulting in a system of nested energy frames that relates all energy states in space to the state of rest in hypothetical homogeneous space. The zero-energy approach referred to as the Dynamic Universe (DU) model [1], honors time and distance as universal coordinate quantities. Local gravitational systems expand in direct proportion to the expansion of space. Atomic clocks in motion or at a lowered gravitational potential run slower due to their different energy state, the state of motion and gravitation. DU produces precise, parameter-free predictions for cosmological observables and local physical phenomena in full agreement with observations and allows an understandable picture of the physical reality. Mass appears as the wavelike substance for the expression of energy and Mach's principle obtains a quantitative expression as the work an accelerating object does against the global gravitation arising from the rest of space.

Keywords: cosmology, relativity, philosophy of science, unifying theory

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1. Introduction

A primary challenge of natural sciences in the new millennium is to cure the gap between metaphysics and empiricism – and puzzle out the obstacles to a unified theory and an understandable picture of reality. Antique science flourished via its strong philosophical impact but faded away due to the lack of supporting empirical science. The fast development of mathematical physics has led to the opposite; theories are diversified, they are more like mathematical descriptions of observations; they provide precise predictions but lack a solid metaphysical basis and an understandable picture of reality. Modern science has increased our understanding of physics from elementary particles to cosmological structures and produced information that allows re-evaluation of the basis. By switching from the observer-oriented perspective of the theory of relativity to a system-oriented perspective, relativity is expressed in terms of locally available energy – without scarifying absolute time and distance as central base units in physics and coordinate quantities essential for human comprehension. Such a holistic perspective is obtained by describing the 3D space as the surface of a 4D ball with the energies of motion and gravitation in balance. For maintaining the zero-energy balance of motion and gravitation, local phenomena are linked to the rest of space; motion in space is linked to the motion of space in the fourth dimension, and local gravitation is linked to the gravitation arising from space as a whole. Relativity is a direct consequence of the conservation of the overall zero-energy balance in the system. The buildup of local kinetic energy in space is counterbalanced by a reduction in the rest energy of the object in motion which results in a reduction of the characteristic frequency of atomic oscillators. Close to mass centers in space, local bending of space reduces the local velocity of light and locally available rest energy observed, e.g., as the gravitational shift of clock frequencies. There is no need for distorted time and distance needed in the kinematic solution of relativity. In the holistic perspective, relativity is relativity between a local and the whole rather than relativity between an object and the observer. Everything in space is interconnected.

2. Energy buildup in space

Global gravitational energy

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, Figure 1. It is obtained by integrating the gravitational energy in homogeneous 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 $G = 6.67 \cdot 10^{-11}$ [$\mathrm{Nm^2/kg^2}$] is the gravitational constant, R_4 the 4-radius of space, $M_\Sigma = \Sigma m$ the total mass in space, and $M"$ the mass equivalence at the 4-center of space.

The dynamic zero-energy balance

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 towards singularity; in the ongoing expansion phase, the energy of motion is paid back to grav-

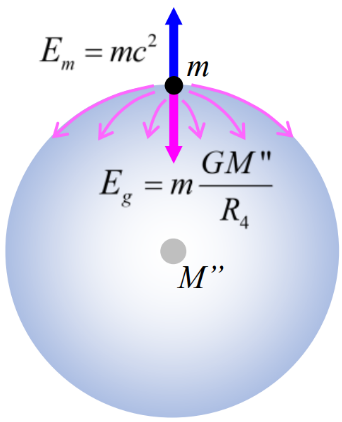

Figure 1: The dynamics of spherically closed space is determined by the balance between the energies of gravitation and motion. The rest energy of a local object is counterbalanced by the gravitational energy arising from the rest of space. The gravitational energy of mass m due to the rest of space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

itational 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. 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, Figure 2.

$$E_m + E_g = M_\Sigma c_0^2 - \frac{GM_\Sigma M''}{R_4} = 0. \tag{2}$$

As a demand of the zero-energy balance, the maximum velocity in space is equal to the velocity of space in the fourth dimension,

$$c_0 = \pm\sqrt{GM''/R_4} \approx 300\ 000\ [\text{km/s}]. \tag{3}$$

The current estimate for today's 4-radius $R_4 \approx 13.7 \cdot 10^9$ [ly], resulting in $M_\Sigma \approx 2.3 \cdot 10^{53}$ [kg] and the average mass density $\rho \approx 5 \cdot 10^{-27}$ [kg/m^3] which is the Friedmann critical mass density equivalence in DU framework. The buildup of the rest energy in the pre-singularity contraction phase cancels the assumed instant Big Bang event of the standard model of cosmology (SC). The singularity in DU is a state of extreme excitation of the energies of gravitation and motion, followed by the turn to expansion at extreme velocity (like the inflation in SC) which has gradually slowed down to the present velocity of light. The deceleration rate of the present velocity of light is $dc_4/c_4 \approx -3.6 \cdot 10^{-11}$ /year. Such a change is observable only indirectly because the frequency of atomic clocks and the rate of physical processes, in general,

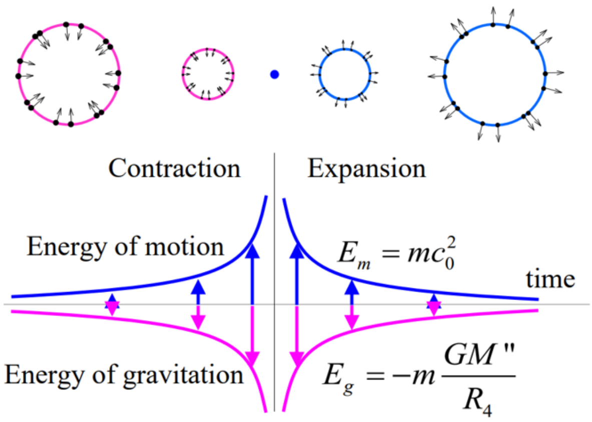

Figure 2: The buildup and release of the rest energy of matter as the energy of motion via contraction and expansion of spherically closed space.

are directly proportional to the velocity of light.

Buildup of local structures in space

For conserving the balance of the energies of gravitation and motion in a local mass center buildup, the total gravitational energy is divided, via tilting of local space, into orthogonal components with the local gravitational energy in the local space direction and the reduced global gravitational energy in the local fourth dimension. The velocity of free fall, v_{ff}, of mass m is obtained against the reduction of the velocity of space in the fourth dimension, and the corresponding kinetic energy against the release of the rest energy of the falling object and the release of local gravitational energy related to the reduction of the global gravitational energy

$$E_{kin} = \Delta E_g = E_{g(0)} \left(1 - \cos\varphi\right) = \frac{GMm}{R}, \tag{4}$$

where φ is the tilting angle of local space at distance R from mass center M, Figure 3.

The local gravitational state is characterized by the gravitational factor δ, the ratio of the local gravitational energy and the global gravitational energy

$$\delta = \frac{GMm/R}{GM''m/R_4} = \frac{\Delta E_g}{E_{g(0)}} = 1 - \cos\varphi = \frac{GM}{c_0^2 R}, \tag{5}$$

where the last form is obtained by applying equation (3). As illustrated in Figure 3, the velocity of space in the local fourth dimension, determining the local velocity of light, c, at gravitational state δ is

$$c = c_0 \cos\varphi = c_0 \left(1 - \delta\right). \tag{6}$$

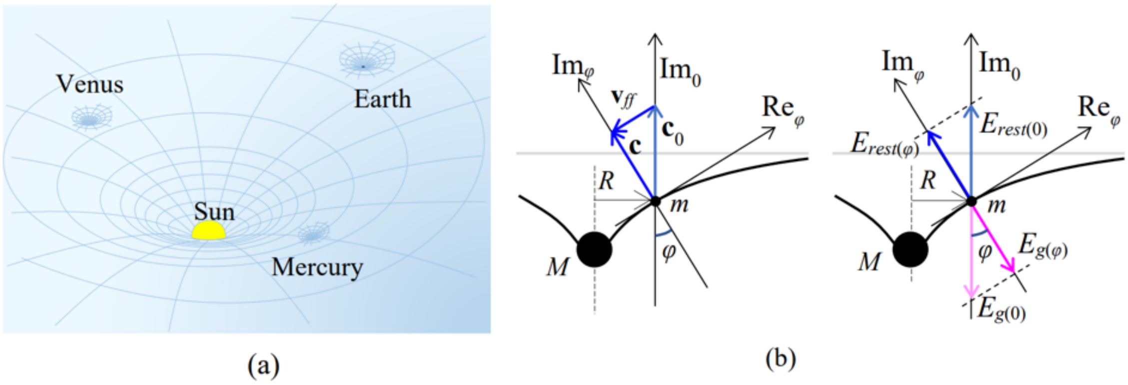

Figure 3: (a) The overall energy balance in space is conserved via tilting of space in local mass center buildup creating the kinetic energy of free fall and the local gravitational energy. (b) Due to the tilting, the velocity of free fall, $\mathbf{v}_{ff}$, is obtained against a reduction of the velocity of space in the local fourth dimension.

Any motion and momentum in space is associated with the motion and momentum of space in the local fourth dimension as orthogonal components. Using a complex quantity notation, with $\mathbf{i}$ as the imaginary unit, the quantity in the fourth dimension as the imaginary part, and the quantity in a space direction as the real part, the total momentum of mass m moving at velocity $\beta = v/c$ in space is

$$p_{total} = |\mathbf{p} + \mathbf{i}\, mc| = \sqrt{p^2 + (mc)^2} \tag{7}$$

and the total energy of motion

$$E_{m(total)} = c_0\,|\mathbf{p} + \mathbf{i}\, mc| = c_0\sqrt{p^2 + (mc)^2}, \tag{8}$$

which is formally identical to the corresponding equation in special relativity.

As illustrated in Figure 4, the buildup of momentum in space is counterbalanced with a reduction of the rest momentum p_{Im} of the moving object

$$p_{\mathrm{Im}(\beta)} = p_{\mathrm{Im}(0)}\sqrt{1-\beta^2} \tag{9}$$

which means that the rest energy of an object moving at velocity β is reduced as

$$E_{rest(\beta)} = c_0\left|p_{\mathrm{Im}(0)}\right| = E_{rest(0)}\sqrt{1-\beta^2}. \tag{10}$$

Combining the effect of the gravitational state on the local velocity of light, the rest energy of mass m moving at velocity $\beta = v/c$ at gravitational state δ is

$$E_{rest(\delta,\beta)} = E_{rest(0,0)}\,(1-\delta)\,\sqrt{1-\beta^2} \tag{11}$$

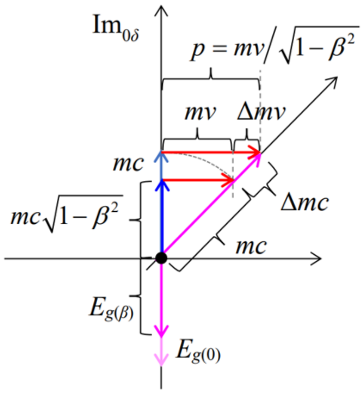

Figure 4: In DU space, buildup of velocity v at constant gravitational potential requires insertion of the energy $c_0 \Delta mc$ which results in the total energy $E_{tot} = c_0 (m + \Delta m) c$, and momentum $\mathbf{p} = (m + \Delta m) \mathbf{v}$ in the direction of the real axis (in a space direction)

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The system of nested energy frames
Mass center buildup 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. The energy structure of space can be illustrated as a system of nested energy frames extending from hypothetical homogeneous space to any local structure, Figure 5. In each step, the energy available in a subframe formed is reduced.

3. Relativity in DU framework

In DU, relativity is a direct consequence of the conservation of the zero-energy balance in space. The quantum mechanical solution of the frequency of atomic oscillators is

$$f = \frac{E_{e(rest)}}{h} F \left[\alpha, \Delta \left(n, j \right) \right], \tag{12}$$

where $E_{e(rest)}$ is the rest energy of the oscillating electrons, α is the fine structure constant, and $\Delta(n, j)$ gives the difference of the quantum states related to the oscillation. In the DU framework, the rest energy is a function of the local state of motion and gravitation as given in equation (11) which means that, in a local frame, the frequency of a clock moving at velocity β at gravitational potential δ is

$$f = f_0 \left(1 - \delta \right) \sqrt{1 - \beta^2}, \tag{13}$$

where f_0 is the frequency of the clock in the parent frame of the local energy

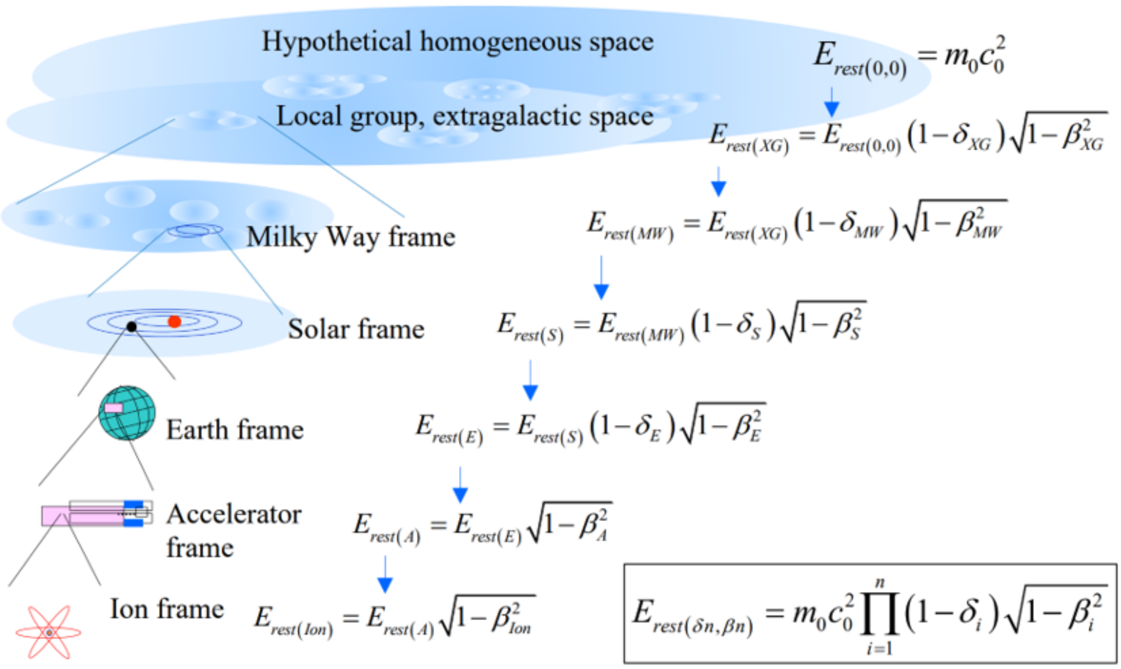

Figure 5: The system of nested energy frames. The rest energy in the nth (local) frame is subject to reductions due to the motions and gravitational states of the local frame in all its parent frames – and is finally related to the rest energy the object would have at rest in hypothetical homogeneous space.

frame. Equation (13) is the DU replacement of Schwarzschild's equation for the time dilation in general relativity

$$dt = dt_0 \sqrt{1 - 2\delta - \beta^2}. \tag{14}$$

In the Earth's gravitational frame, the difference between equations (13) and (14) 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. Bending of the light path passing a mass center as well as the Shapiro delay are direct consequences of the slower velocity of light and the increased distance due to the dent around a mass center. The motion of a mass center in its parent frame, like the Earth in the solar gravitational frame draws the local dent with the motion thus conserving the velocity of light at a fixed gravitational state in the Earth gravitational frame, which gives a simple explanation to the zero-result in the early experiments on the velocity of light like the Michelson-Morley experiment. 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.
Rather than relativity between an object and the observer like in the SR/GR framework, relativity in DU is relativity between a local and the whole. Any state of gravitation and motion in space has its history that links it to the state of rest in the local frame, the state of the local frame in the parent frame, and finally to the state of rest in hypothetical homogeneous space. Time and distance are universal coordinate quantities of the observational reality essential for an understandable picture of physical reality.

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 $cdt = \lambda$ (equal to the 4D line element in the SR/GR framework) in one cycle

$$h = 1.1049 \cdot 2\pi^3 e^2 \mu_0 \cdot c. \tag{15}$$

The solution links Planck's constant to primary electrical constants; the unit charge e and vacuum permeability μ_0, and shows that the velocity of light, c, is a hidden factor in the Planck constant. We define the intrinsic Planck constant by removing the velocity of light from h as $h_0 = h/c$, which allows writing the Planck equation in the form

$$E = \frac{h_0}{\lambda} c^2 = m_\lambda c^2, \tag{16}$$

where the quantity $h_0 = h/c$ has the physical dimension of kilogram [kg] and is the mass equivalence of a quantum of radiation or a cycle of radiation emitted by a unit charge transition in the emitter. The mass equivalence of radiation is the counterpart of the Compton wavelength $\lambda_m = h_0/m$ as the wavelength equivalence of mass m. The reformulation does not change physics but allows an illustrative picture of the nature of mass and quantum, and the unified expressions of energy:

$$\text{Rest energy of mass} \quad E = \frac{h_0}{\lambda_m} c^2 = mc^2. \tag{17}$$

$$\text{Electromagnetic radiation} \quad E = \frac{h_0}{\lambda} c^2 = m_\lambda c^2. \tag{18}$$

$$\text{Coulomb energy} \;\; E = \frac{e^2\mu_0}{4\pi r}\, c^2 = \alpha \frac{h_0}{2\pi r}\, c^2 = m_{EM} \cdot c^2. \tag{19}$$

As shown by a detailed analysis, the factor c^2 in equations (16 to 19) is the product of the 4D velocity c_0 of homogeneous space and the local velocity of light c equal to the 4D velocity of local space. In the Earth's gravitational frame c differs from c_0 at ppm-level. 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 the relevant resonance conditions. The de Broglie wave is described as a mass wave carrying the momentum of a moving mass object – much in the way de Broglie was looking for.

4. Cosmological consequences

Dynamics of the expansion

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

$$c_0 = \frac{dR_4}{dt} = \left(\frac{2}{3} GM''\right)^{1/3} t^{-1/3} = \frac{2}{3}\frac{R_4}{t}, \tag{20}$$

where t is the time from the singularity. Today, the 4-radius R_4 is about 14 billion light-years. Due to the faster expansion in the past, the age of the expanding space is about 9.3 billion 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, Figure 6. Atoms and material objects do not expand. 2.8 cm of the measured 3.8 cm annual increase of 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 in their infancy, which offers an obvious solution to the early faint Sun paradox.

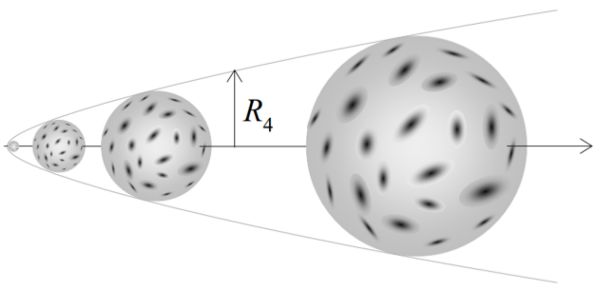

Figure 6: In DU, all gravitationally bound local systems like galaxies and planetary systems expand in direct proportion to the expansion of space.

Cosmological distances
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 of the 4-radius during the light traveling time from the object. Such a situation allows a simple, closed-form expression for the optical distance versus redshift

$$D = R_0 \frac{z}{1+z}, \tag{21}$$

where R_0 is the 4-radius of space at the time of the observation, Figure 7.

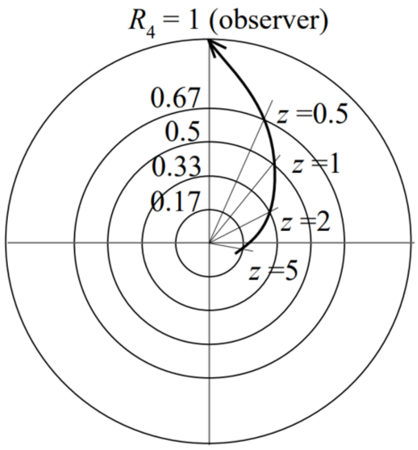

Figure 7: Lightpath in expanding space. The optical distance is the integrated tangential component of the lightpath. The radial direction in the picture is the fourth dimension showing the development of the expansion.

The optical distance applies to the angular size distance and when corrected with the 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 [2] of Standard Cosmology.

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 the Euclidean appearance of galactic space, supported by observations on galaxies and quasars [3], Figure 8.

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

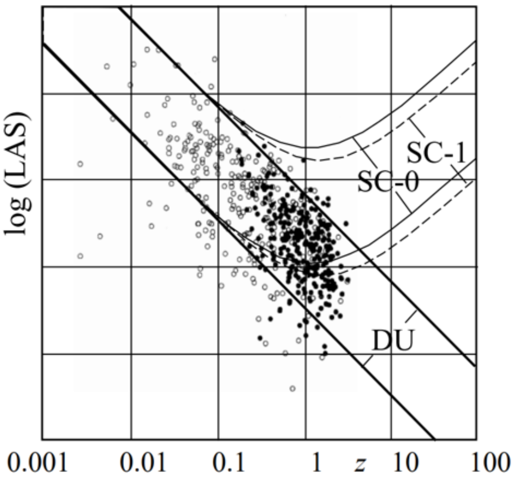

Figure 8: Angular size of galaxies (open circles) and quasars (filled circles). The data points fall well between the Euclidean DU prediction lines. The SC-0 and SC-1 curves showing increasing angular sizes for z higher than 1 are the Standard Cosmology predictions without and with dark energy, respectively.

$$m_{DU} = M + 5\log\left(\frac{R_4}{10\text{pc}}\right) + 5\log(z) - 2.5\log(1+z)\,. \tag{22}$$

The DU prediction applies to bolometric magnitudes excluding the "conversion to emitters rest frame" applied in standard cosmology via the K-correction. K-correction is used to compensate for losses due to atmospheric attenuation and spectral mismatch of filters or photographic plates, which are technical corrections. Also, K-correction converts the observed magnitudes of the objects into their respective rest frames, which, in SC, means an extra $(1+z)^2$ reduction to the observed power density. 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 [4] and is still the praxis "as the conversion to emitter's rest frame" in Standard Cosmology [5].

The magnitude prediction in standard cosmology is based on power loss proportional to the comoving distance squared and the effects of redshift by the factor $(1+z)$ due to the Doppler effect and another $(1+z)$ due to dilution based on Planck's equation. Physically, the Planck equation describes energy conversion at the emission [6], which means that the energy carried by a cycle of radiation does not change when the wavelength is increased but is diluted as observed via the Doppler effect. In DU, the magnitude prediction applies to bolometric magnitudes. It is based on the optical distance (21) and Doppler dilution, which together result in a $5\log(1+z)$

difference [1] compared to the SC prediction that applies to magnitudes "converted to emitter's rest frame" by the factor $5\log(1+z)$ in the K-correction.

Figure 9(a) shows the K-corrected observations (dots) of Ia supernovae by Riess et al. [7], and the DU prediction (22) (solid line) corrected by factor $5\log(1+z)$ to correspond to the K-corrected magnitudes. Figure 9(b) shows the K-corrections applied by Riess et.al. to the observed magnitudes.

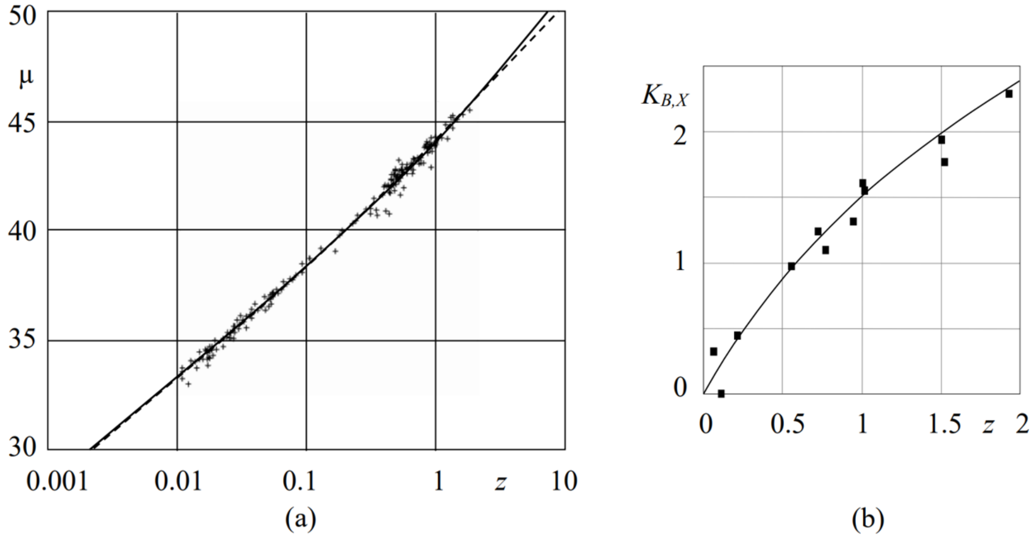

Figure 9: (a) Distance modulus $\mu = m - M$, vs. redshift for Riess et al. "high-confidence" dataset [7]. SC prediction is shown by the dashed line. The DU prediction (solid curve) is based on equation (22) corrected with $5\log(1+z)$ to correspond the data points converted to emitter's rest frame. (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 $5\log(1+z)$ correction "converting observations to emitter's rest frame".

An ideal bolometric detector is a wideband detector with flat spectral response. Detection systems, based on multi-bandpass filters, produce closest to bolometric magnitudes by matching each filter 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, J by Tonry et al. [8], is shown in Figure 10. The envelope curve shows a complete match to the DU prediction (22)

[1] In the redshift range $0\ldots 2$, 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".

for bolometric magnitudes. The SC prediction (dashed curve) deviates from the envelope curve by factor $5\log(1+z)$.

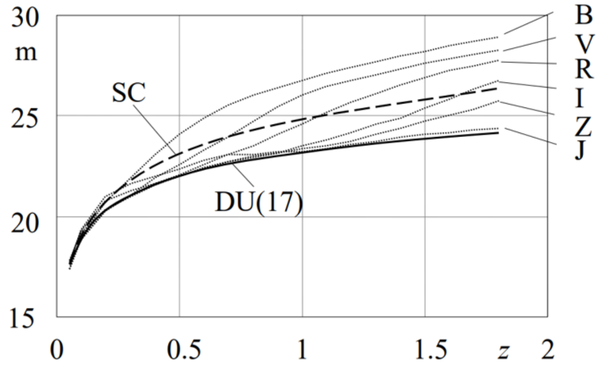

Figure 10: Observed magnitudes in bandpass filters B, V, R, I, Z, J by Tonry et al. The data is collected from Table 7 in [8] (dotted curves). The envelope curve shows the bolometric magnitude with a complete match to the DU prediction (22) (solid curve). The SC prediction (dashed curve) deviates from the envelope curve by the factor $5\log(1+z)$.

Supernova light-curve broadening

The duration of distant supernova explosions is observed as being proportional to the redshift as $T_z = T_0(1+z)$ [9]. In standard cosmology, the broadening is referred to as cosmological time dilation. Supernova explosions are considered standard candles which means that we can assume that the duration of an explosion corresponds to a fixed number of cycles measured with an atomic clock at the time of the event. The ticking frequency of atomic clocks is directly proportional to the velocity of light, which decreases with the expansion of space. Light redshifted by z has been emitted when the velocity of light was $c_z = c_0\sqrt{1+z}$, and the ticking rate of clocks $f_z = f_0\sqrt{1+z}$, respectively. It means that the duration of an explosion was $dt_z = dt_0 \big/ \sqrt{1+z}$ compared to the duration of a similar explosion at $z \approx 0$.
The expansion of space during an explosion is

$$dR_z = c_z dt_z = c_0\sqrt{1+z} \cdot dt_0 \big/ \sqrt{1+z} = c_0 dt_0 \tag{23}$$

which means that the expansion of space during an explosion is independent of the redshift. Expansion dR_z at redshift z corresponds to expansion $dR_{0(z)} = dR_z(1+z)$ at the time of the observation, and the corresponding observed time, Figure 11,

$$dt_{0(z)} = dR_{0(z)} \big/ c_0 = c_0 dt_0 / c_0 = dt_0(1+z)\,. \tag{24}$$

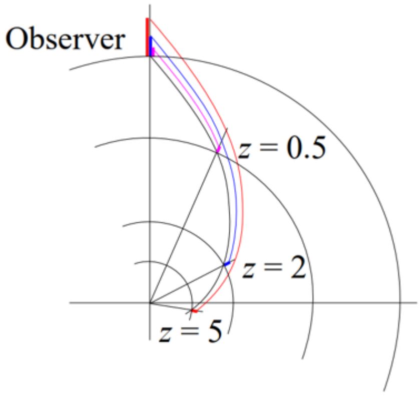

Figure 11: The duration of a supernova explosion has been shorter in the past, but it is observed lengthened.

Days in a year

Perhaps the most convincing cosmological support for the linkage of planetary systems to the expansion of space comes from paleo-anthropological data available back to almost 1000 million years in the past. Fossil layers preserve both the daily and annual variations, thus giving the development of the number of days in a year [10, 11]. According to the standard cosmology model, the orbital radius of the Earth is constant, which means that the reduction in the number of days in a year comes only from the tidal interaction which increases the length of a day via reduced rotation speed of the Earth. In the DU framework, the orbital radius and the length of a year increase with the expansion, which compensates a part of the tidal effect on the number of days in a year. The tidal effect on the lengthening of a day is about 2.5 ms/100y [12]. A change of 2.5 ms/100y is too fast when compared to the data from coral fossils. When corrected with the increase in the length of a year by 0.6 ms/100y due to the expansion of space, we end up with the lengthening 1.9 ms/ 100y which gives a perfect match to the coral fossil data, Figure 12. The 0.6 ms/100y correction due to the expansion is based on the expansion corresponding to Hubble constant 71 (km/s)/Mpc.

Further observational evidence on the development of the Earth's rotation is available from ancient Babylonian and Chinese eclipse observations extending almost 3000 years back [13]. The average lengthening of a day calculated from the eclipse observations is 1.8 ms/100y which is about 0.7 ms/100y less than the estimated effect of tidal friction. Adding the effect of the lengthening of a year, 0.6 ms/100y, we end up to 1.9 ms/100y, which is essentially the same as the result from coral fossils.

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. When the result is corrected with the change in the clock frequency, 0.3 ms/100y, we get 1.8 ms/100y, which is

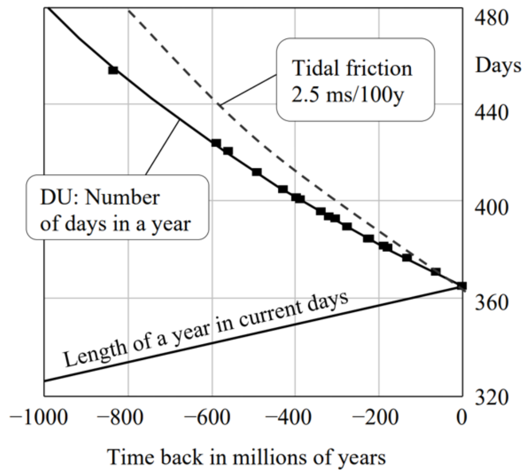

Figure 12: The development of the length of a year in the number of days. Black squares are data points from [10, 11]. The DU prediction combines the effects of tides and the change in the length of a year due to the expansion of the solar system.

in a good agreement with the solar eclipse and coral fossil data, Figure 13.

The faint young Sun paradox

At the time of the early development of the planets about 4 billion years ago, solar insolation is estimated to be about 25% fainter than it is today [14]. 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 [15], Figure 14.

Distances to the moon and planets

The distance of the Moon has been monitored in the Lunar Laser Ranging program since the 1970s [16]. In the DU framework, 2.8 cm of the measured 3.8 cm annual increase of the Earth to Moon distance comes from the expansion of space and only 1 cm from the tidal interactions.

Reported analyses of transponder measurements of planetary distances apply an "Einstein effect" to eliminate the expansion shown by the direct transmission time data [17]. The "Einstein effect" is justified as a relativistic correction for matching the timescales in measurements at different epochs. In the DU framework, there is no basis for time-scale corrections; in the transponder measurement, the number of clock cycles is directly proportional to the distance just as applied in the case of Laser Ranging in the Earth to Moon distance monitoring.

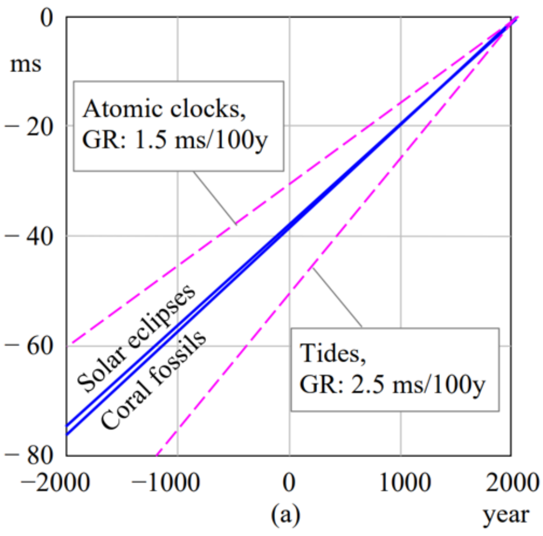

Figure 13: Lengthening of a day obtained from solar eclipses and coral fossil data is 1.8 ms/100/y and 1.9 ms/100y, respectively (solid lines in (a) and (b)). Atomic clock measurement for the lengthening of a day is 1.5 ms/100y if assumed that the frequency of the clock is unchanged (dashed line in (a)). In the DU framework, the frequency of an atomic clock has been higher in the past. The corrected lengthening of a day is 1.8 ms/100y, consistent with the solar eclipse and coral fossil results (dashed line in (b)). According to the standard model, the lengthening of the day is due to tidal interactions, which give about 2.5 ms/100y prediction to the lengthening of a day (dashed line in (a)). In DU, the lengthening of a year shall be taken into account, which together with the tidal effects results in the 1.9 ms/100y lengthening of the day (dashed line in (b)).

Orbital decay

In the 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, Figure 15(a). 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 [18, 19]. The only difference is that DU predicts orbital decay for eccentric orbits only, GR predicts decay for circular orbits, too, Figure 15(b). To the author's knowledge, all observations on orbital decay are related to orbits with non-zero eccentricity.

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

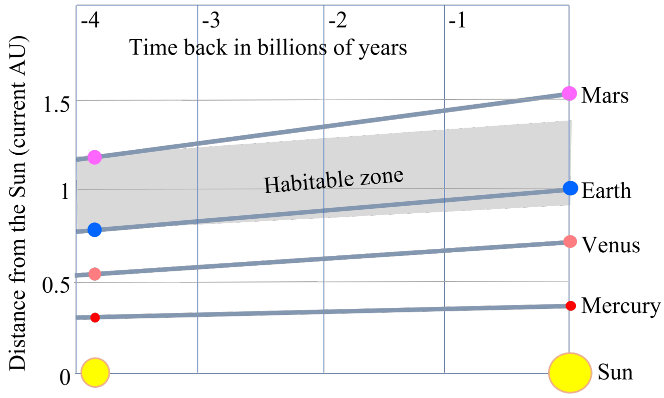

Figure 14: The development of the habitable zone in the expanding solar system. The expansion overcompensates the fainter solar luminosity in the past; the early temperatures on the planets have been higher than they are today [15]

$$\frac{dP}{dt}_{(DU)} \approx 120 \cdot \frac{G^{5/3}}{c^5}\left(\frac{P}{2\pi}\right)^{-5/3}\left(2 \cdot \frac{\sqrt{1+e_{0\delta}}-\sqrt{1-e_{0\delta}}}{\left(1-e^2\right)^2}\right) \cdot \frac{m_p m_c}{\left(m_p+m_c\right)^2}\left(m_p+m_c\right)^{5/3} \tag{25}$$

$$\frac{dP}{dt}_{(GR)} \approx 123 \cdot \frac{G^{5/3}}{c^5}\left(\frac{P}{2\pi}\right)^{-5/3}\left(\frac{1+(73/24)\,e^2+(37/96)\,e^4}{\left(1-e^2\right)^{7/2}}\right) \cdot \frac{m_p m_c}{\left(m_p+m_c\right)^2}\left(m_p+m_c\right)^{5/3} \tag{26}$$

5. Philosophical considerations

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 the 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 the complementary energies of motion and gravitation. The anti-energy of the rest energy of a localized mass particle is the negative gravitational energy arising from all other mass in space.

Inertia and Mach's principle

In the 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 the DU framework,

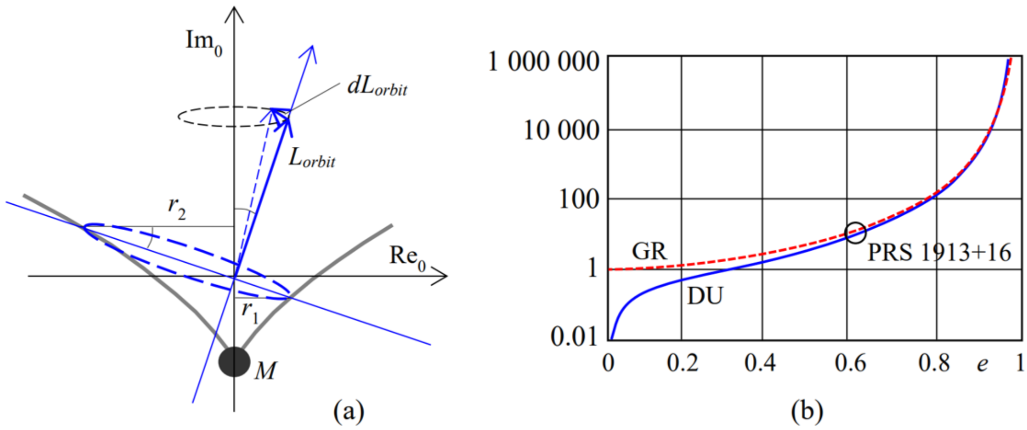

Figure 15: (a) In the DU framework the orbital decay of binary stars is calculated from the energy related to the rotation of orbital angular momentum due to the periastron advance. (b) The eccentricity factor of the decay of binary star orbit period in equations (25) for DU and (26) for GR, respectively. 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 the DU prediction, the eccentricity factor goes to zero at zero eccentricity.

the "relativistic mass increase" Δmc introduced in the 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. Electromagnetic radiation propagating at the velocity of light in space moves like in a satellite orbit around the barycenter of whole space; radiation is weightless but not massless.

Occam's razor
DU omits all central postulates of the relativity theory and standard cosmology like the relativity principle, Lorentz covariance, equivalence principle, the constancy of the velocity of light, dark energy, an 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 [20, 21]. 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.

Aristotle's entelecheia and the linkage of local to the whole
In the spirit of Aristotle's entelecheia, the primary energy buildup is described as the "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. In the kinematic analysis of SR, a velocity in space is related to an observer, but in the dynamic analysis of DU, 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 space as a whole.

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