Journal of High Energy Physics, Gravitation and Cosmology, 2026, 12(4), 2102-2113
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

New Theoretical Concepts Related to Dark Energy

Herman A. van Hoeve

Independent Researcher, Hulst, Netherlands
Email: havanhoeve@gmail.com

How to cite this paper: van Hoeve, H.A. (2026) New Theoretical Concepts Related to Dark Energy. *Journal of High Energy Physics, Gravitation and Cosmology*, **12**, 2102-2113.
https://doi.org/10.4236/jhepgc.2026.124104

Received: April 11, 2026
Accepted: September 21, 2026
Published: September 24, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

Type Ia Supernovae act as reliable cosmic standard candles, revealing the presence of dark energy. The purpose of this paper is to introduce new theoretical concepts to explain dark energy. This research introduces a new theoretical framework to explain the observed expansion of the universe by proposing a second spacetime constant (b), in addition to having the speed of light constant (c). Constant b defines a time-invariant limit on total orbital revolutions, bounding the age of the universe when determining the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer. The constants b and c are independent; neither can be derived from the other, and both are covariant with respect to the Lorentz transformations. The value of constant b is estimated to be approximately 13.8 billion orbital revolutions, derived from an equation linking the Hubble tension to changes in the duration of the Earth's anomalistic year, which literature shows increases by one second every 400 calendar years on average. This increasing duration of Earth's orbital revolution corresponds well to having a constant maximum orbit count regarding the light-travel time from the expanding cosmic boundary. This paper introduces a theoretical framework based on multidimensional time, with one temporal dimension in everyday experience and the effects of the other temporal dimension becoming apparent only at cosmological large scales. Consequently, the light-travel time from the ever-increasing distance of the cosmic microwave background radiation is calibrated with a so-called anomalistic year clock; a clock that gradually ticks just slightly slower over time in everyday experience, but time-invariant when counting the clock's cycles, as calibrated in the present epoch of the observer.

Keywords

Dark Energy, Cosmology, Cosmological Models, Cosmic Microwave Background Radiation, Age of the Universe, Hubble Tension

1. Introduction

This paper introduces a theoretical framework based on multidimensional time, with one temporal dimension in everyday experience and the effects of the other temporal dimension becoming apparent only at cosmological large scales [1]. The temporal dimension that operates at cosmological large scales is defined by having a time-invariant limit on total orbital revolutions, bounding the age of the universe when determining the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer. Besides the speed of light being a universal constant, this paper claims that the theory of relativity continues to be adhered to when a theoretical framework based on multidimensional time is introduced, having a second spacetime constant that defines the age of the universe. Note that both spacetime constants are independent; neither can be derived from the other.

Einstein's special theory of relativity postulates (*traveling at constant speeds, excluding gravity*) [2] are extended in this section. Using these extended postulates, Section 2 describes the Lorentz transformations with the aforementioned second spacetime constant, how it can explain dark energy [3], and, for example, how it relates to the cosmic standard candles [4] measurements of Type Ia Supernovae [5] [6]. Section 3 subsequently defines the age of the universe using this second spacetime constant, an equation related to changes in the duration of the Earth's anomalistic year [7]-[10] and the Hubble tension [11] [12]. Introducing these new theoretical concepts, Section 4 explains why the cosmic microwave background radiation (CMBR) is smooth [13] and why the boundary condition at the cosmological horizon is non-symmetric [14].

Postulate 1 of Special Relativity:

The laws of physics take the same form in all inertial frames of reference, and they must be the same for any two objects no matter how fast they are moving relative to one another. Speeds are relative, and one cannot detect the difference between moving at constant speed and standing still. Any observer may claim to be standing still [2].

Extending Postulate 1: the laws of physics must also be the same for any two events, no matter how many orbital revolutions (e.g. Earth's orbit around the Sun) have passed between them. Any observation may claim to be the present epoch [3].

Postulate 2 of Special Relativity:

The speed of light in free space has the same value in all inertial frames of reference; it is constant (c). One can never obtain a speed larger than c. All other speeds are subject to this constraint, as no object can move faster than c relative to any other object [2].

Extending Postulate 2: with respect to the temporal dimension at cosmological large scales, spacetime also abides by having a second universal constant (b), which defines a time-invariant limit on total orbital revolutions (e.g., Earth's orbit around the Sun), bounding the age of the universe when determining the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer. One can never obtain a time span greater than *b*. All time spans are subject to this constraint, as two events cannot be further apart than *b* [3].

The value of *c*: the speed of light in vacuum is approximately 0.3 gigameters per second.

The value of *b*: the age of the universe is approximately 13.8 billion Earth's orbital revolutions [12].

2. Lorentz Transformations Can Explain Dark Energy

Lorentz transformations are a set of equations related to the position and time in various inertial frames of reference. The principle of relativity states that the laws of physics are the same in every inertial frame of reference; thus, being background-independent, the speed of light is constant. Section 2.1 discusses the Lorentz transformations with the speed of light constant *c*. Section 2.2 discusses the Lorentz transformations with the second spacetime constant *b*, as defined in Section 1, and Section 2.3 discusses how *b* can explain dark energy. Section 2.4 discusses, for example, how *b* relates to the cosmic standard candles [4] measurements of Type 1a Supernovae [5] [6].

2.1. Einstein's Special Theory of Relativity

The laws of physics are covariant with respect to the Lorentz transformations. All observers use the same value *c*, including when the relative speeds become large [2].

With $|V_x| \le c$ and $V_x > 0$ when x is moving away from the observer.

With $|V_y| \le c$ and $V_y > 0$ when y is moving away from the observer.

The space direction of V_x being the opposite of V_y.

$$V = \frac{V_x + V_y}{1 + \left(\frac{V_x \times V_y}{c^2}\right)} \tag{1}$$

V = relative speed between x and y [m·s^{-1}]

V_x = relative speed between x and observer [m·s^{-1}]

V_y = relative speed between y and observer [m·s^{-1}]

c = speed of light in vacuum, 0.3×10^9 [m·s^{-1}]

2.2. Lorentz Transformations with a Second Spacetime Constant

With respect to the temporal dimension at cosmological large scales, Lorentz transformations are also necessary when the laws of physics are extended with a second spacetime constant (*b*). All observers, at any time, use the same value *b* when measuring the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer [3].

$$T = \frac{T_x + T_y}{1 + \left(\frac{T_x \times T_y}{b^2}\right)} \tag{2}$$

With $|T_x| \le b$ and $T_x > 0$ when x is in the future of the observer.
With $|T_y| \le b$ and $T_y > 0$ when y is in the past of the observer.
Note that the time-direction of T_x being opposite of T_y.

T = relative time span between x and y [billion orbital revolutions]

T_x = relative time span between x and observer [billion orbital revolutions]

T_y = relative time span between y and observer [billion orbital revolutions]

b = time-invariant maximum orbit count, 13.8 [billion orbital revolutions]

The temporal dimension that operates at cosmological large scales is defined by means of having a time-invariant maximum orbit (e.g. Earth's orbit around the Sun) count, bounding the age of the universe when determining the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer. The literature shows that the duration of the Earth's anomalistic year increases on average by one second every 400 calendar years [7]-[10]; see Section 3.1.

2.3. Explaining Dark Energy

This research shows that the value of the Hubble constant (H_0), interpreted here as the relative rate of the expansion of the universe, correlates with Equation (2).

Note that Einstein's cosmological constant has a very small positive value, curving the universe just slightly; when compared to the 13.8-billion-year-old age of the universe, this leads to minute observed curvatures. At the current observed relative rate of expansion of the universe, it takes approximately one billion years for an unbound large-scale structure to grow by approximately 7% [5] [15].

With respect to the temporal dimension at cosmological large scales, the relative time span between one billion years in the future and the observed cosmic microwave background radiation (CMBR) can be calculated by means of Equation (2).

$$T = \frac{T_x + T_y}{1 + \left(\frac{T_x \times T_y}{b^2}\right)} \approx \frac{1 + 13.8}{1 + \left(\frac{1 \times 13.8}{13.8^2}\right)} \approx \frac{14.8}{1.072} \approx 13.8$$

T = relative time span between x and y [billion orbital revolutions]

T_x = one billion years in the future of the observer, 1 [billion orbital revolutions]

T_y = CMBR is in the past of the observer, 13.8 [billion orbital revolutions]

b = time-invariant maximum orbit count, 13.8 [billion orbital revolutions]

Thus, the relative time span between one billion orbital revolutions (Earth's orbit around the Sun) in the future and the CMBR remains at 13.8 billion orbital revolutions. The aforementioned calculated correction factor of 1.072 aligns well with the observed relative rate of expansion of the universe in everyday experience; it takes one billion years for an unbound large-scale structure to grow by approximately 7% [5] [15]. The dark energy is nothing more than the calculated correction factor ($T_x \times T_y / b^2$) in Equation (2).

With respect to the temporal dimension at cosmological large scales, distant galaxies do not disappear in the future beyond the cosmological horizon. For example, the relative time span between one billion years in the future and the observed galaxy HD1, which is approximately 13.47 billion years old [16], can be calculated by means of Equation (2).

$$T = \frac{T_x + T_y}{1 + \left(\frac{T_x \times T_y}{b^2}\right)} \approx \frac{1 + 13.47}{1 + \left(\frac{1 \times 13.47}{13.8^2}\right)} \approx \frac{14.47}{1.071} \approx 13.5$$

T = relative time span between x and y [billion orbital revolutions]

T_x = one billion years in the future of the observer, 1 [billion orbital revolutions]

T_y = galaxy HD1 is in the past of the observer, 13.47 [billion orbital revolutions]

b = time-invariant maximum orbit count, 13.8 [billion orbital revolutions]

2.4. Cosmology with Type Ia Supernovae and Distant Quasars

Utilizing new theoretical frameworks, this study examines how they correlate with Type Ia supernovae and distant quasar measurements to map the expansion of the universe and investigate dark energy. Type Ia supernovae originate from galactic white dwarf explosions with known physics. The uniform peak luminosity can be used as a calibration rod, thus determining the expansion rate of the universe by using the inverse-square law of light to accurately calculate extragalactic distances, thus building the cosmic distance ladder [17]. By combining these distance measurements with galactic redshifts, one can determine the expansion rate of the universe, a value known as the Hubble constant (H_0). Type Ia Supernovae are thus used as cosmic standard candles [4] to measure the distance and redshift of exploding stars. Their luminosity-redshift measurements were the foundational data set used to discover the accelerating expansion of the universe in 1998 [5] [6], revealing the presence of dark energy. Note that distant quasars [18] are another set of cosmic beacons, energized by supermassive black holes in the early universe, which also reveal the presence of dark energy.

This paper must explain how new theoretical concepts of dark energy relate to supernovae and quasar measurements, which trace how the scale of the universe and the distances between galaxies change over cosmic time. Three primary datasets are analyzed: low- and high-redshift supernovae, alongside high-redshift quasars.

Using low-redshift Type Ia supernovae to map the local cosmic distance ladder typically limits accurate measurements to approximately 1.5 billion light-years. For the Hubble Constant (H_0), calibrating these low-redshift supernovae is helpful to minimize cosmic bias [19]. Note, however, that these limited light-travel times are insufficient for evaluating this paper's new theoretical concepts related to dark energy; the hypothesized additional temporal dimension (see Section 1) becomes apparent only at larger scales.

With respect to high-redshift datasets, the Type Ia supernova SN UDS10Wil (nicknamed SN Wilson), whose light took approximately 10.4 billion years to reach Earth, is a heavily studied event [20]. Although high-redshift Type Ia supernovae are not used as the primary anchor of the cosmic distance ladder, they act as distant indicators. Recent studies by researchers at Charles University [21] and Yonsei University [22] claim that observations of cosmic time dilation in distant Type Ia supernova light curves imply that the passage of cosmic time varies throughout the evolution of the universe. Consequently, the rate of proper time is not constant, but rather is time-dependent. More studies are required to confirm or falsify these controversial findings. If confirmed, then this would align with the methodological framework of this paper.

Similarly, a recent study published in the *Monthly Notices of the Royal Astronomical Society* [23] detected cosmological time dilation in the variability timescales of high-redshift quasars. If validated, *i.e.*, by establishing quasars as reliable cosmic clocks, then these findings align with the theoretical concepts of this paper and highlight the value of further research.

Studies of Type Ia supernovae and distant quasars are important observational pillars of modern cosmology, mapping the expansion history of the universe and probing the nature of dark energy. To evaluate the validity of extending the postulates of relativity with a second invariant parameter (as described in Section 1), additional observations are required. The validation of double relativity, which has two universal spacetime constants, aims to provide a theoretical explanation for dark energy [24].

3. The Age of the Universe Defined by an Equation

The age of the universe is defined as the maximum time span during which the light emitted could have traveled freely from the cosmological horizon to the observer. The maximum distance in the present epoch defines the size of the observable universe and is measured by means of the cosmic microwave background radiation. The age of the universe is estimated to be approximately 13.8 billion Earth's orbital revolutions [12]. This paper claims that there is a time-invariant limit on total orbital revolutions b, bounding the age of the universe when determining the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer. The value of the constant b can be derived from an equation related to changes in the duration of the Earth's anomalistic year and the Hubble tension. Section 3.1 discusses the temporal evolution of Earth's anomalistic period and Section 3.2 discusses the Hubble tension.

3.1. Temporal Evolution of Earth's Anomalistic Period

The anomalistic year is the time taken for the Earth to complete one revolution through its elliptical orbit with respect to the extreme points of that elliptical orbit, *i.e.*, to complete one full revolution around the Sun with respect to its own elliptical orbit's orientation instead of against the background of fixed stars. With respect to these extreme points, the perihelion is where the Earth is closest to the Sun, and the aphelion is where the Earth is farthest from the Sun. The anomalistic year is usually defined as the time between the perihelion passages.

The duration of the anomalistic year of epoch *J*2011.0 has been determined to be approximately 3.1558433 × 10^7 seconds [25]. Note that the orbital period of Earth for an anomalistic year is slightly larger than a Julian year *Jy* of 365.25 days, approximately 1.0000264 *Jy*.

The literature shows that over the period 4000 BC to AD 6000, the duration of the Earth's anomalistic year increases on average by one second every 400 calendar years [7]-[10][1]. This constant change in the duration of the anomalistic year corresponds well to having a time-invariant count of Earth's orbital revolutions when measuring the time span during which the light emitted could have traveled freely from a specific cosmological large distance (close to the CMBR) to the observer. This time-invariant orbit count can be calculated using Equation (3).

$$b_{local} = \frac{J_{cal} - 2000}{10^9} \times \frac{a_{anom}}{\Delta a_{anom}} \tag{3}$$

b_{local} = local time-invariant orbit count, 12.623 [billion orbital revolutions]

J_{cal} = calendar year numbering [−]

a_{anom} = duration of Earth's anomalistic year for epoch *J*2011.0, 3.1558433 × 10^7 [s]

Δa_{anom} = average delta of Earth's orbital period compared to epoch *J*2000.0 [s]

Compared to the present duration of Earth's anomalistic year, the value of the orbital period (*a*) changes on average by one second every 400 orbital revolutions of Earth around the Sun [7]-[10]. Synchronizing Δa_{anom} with the calibration of a so-called anomalistic year clock leads to a clock that gradually ticks just slightly slower over time in everyday experience, but is rather time-invariant when counting the clock's cycles at cosmological large scales, as calibrated in the present epoch of the observer. At any time between 4000 BC and AD 6000, the time span during which the light emitted could have traveled freely between a specific cosmological large distance ($a \times b \times c$ = *number of seconds of Earth's anomalistic year in the present epoch of the observer* × 12.623 × 10^9 × 0.3 × 10^9) and Earth is aligned with having a time-invariant orbit count. Using this anomalistic year clock, continuously calibrated with Earth's orbital period in the present epoch of the observer, leads to this time-invariant count of 12.623 billion orbital revolutions. Thus, Equation (3) shows that the number of revolutions of the hand on this clock dial plate is rather time-invariant when measuring at cosmological large time scales, *i.e.*, close to the age of the universe of 13.8 billion orbital revolutions [12].

The time-invariant value of b_{local} over a period of 1 × 10^4 years is calculated by means of Equation (3) to be 12.623 billion orbital revolutions. This research extrapolates this beyond 1 × 10^4 years, making the value of b_{local} also time-invar-

[1] https://en.wikipedia.org/wiki/Year

iant over a much longer period. All observers on Earth measure changes in the duration of the anomalistic year to correspond to having a time-invariant orbit count b_{local} [3].

3.2. The Hubble Tension as a Correction Factor

This section introduces the Hubble tension as a correction factor between Earth's time-invariant count b_{local} of 12.623 billion orbital revolutions and the age of the universe, measured to be approximately 13.8 billion Earth's orbital revolutions [12].

The age of the universe is close to the value of Hubble time (t_H), the inverse of the Hubble constant (H_0). The value of Hubble time is the age the universe would have been if the expansion of space had been linear. However, the expansion is not linear, as observations show that Einstein's cosmological constant has a minute positive value, curving the universe just slightly [5] [15]. This curvature is so small that the effect is detectable only with large time spans, e.g., 10 billion years. The age of the universe is approximately 13.8 billion years [12], which is eminently leading to the very small observed curvature.

Multiple methods have been used to determine the Hubble time (t_H). Estimates based on late universe data (cosmic distance ladder measurements) cluster at around (13.3 ± 0.3) billion years [26] [27], and estimates based on early universe data (cosmic microwave background radiation) cluster at around (14.5 ± 0.2) billion years [26] [27]. The estimated uncertainties have shrunk, but the range of measured values has not, to the point that the disagreement between late universe and early universe data is statistically significant. This discrepancy is called the Hubble tension [27].

This paper introduces a theoretical framework based on multidimensional time, with one temporal dimension in everyday experience and the effects of the other temporal dimension becoming apparent only at cosmological large scales [1]. This theoretical framework naturally accommodates the Hubble tension through temporal evolution effects [11] [12]. The mismatch between the more locally measured expansion rate of the universe and the one inferred from cosmic microwave background radiation is hereby defined as a ratio, introducing a factor that accounts for this statistically significant difference [3].

$$r_{ht} = \frac{t_{H,cmbr}}{t_{H,local}} \tag{4}$$

r_{ht} = Hubble tension ratio, 1.09 [−]

$t_{H,cmbr}$ = Hubble time t_H based on early universe data, 14.5 ± 0.2 [billion years]

$t_{H,local}$ = Hubble time t_H based on late universe data, 13.3 ± 0.3 [billion years]

To account for the observed difference between the early- and late universe derived values of the Hubble time, r_{ht} is introduced as a correction factor to calculate the value of the cosmic microwave background radiation (CMBR) time-invariant orbit count (b_{cmbr}) out of the locally derived time-invariant orbit count (b_{local}) in Equation (3).

$$b_{cmbr} = r_{ht} \times b_{local} \quad (5)$$

b_{cmbr} = CMBR time-invariant orbit count, 13.8 [billion orbital revolutions]

b_{local} = local time-invariant orbit count, 12.623 [billion orbital revolutions]

r_{ht} = Hubble tension ratio, 1.09 [−]

The value of r_{ht} is estimated to be around (1.09 ± 0.04), and thus the value of b_{cmbr} is estimated to be around (13.8 ± 0.5). This research defines the value b_{cmbr} as a time-invariant maximum orbit count; see also Section 2.2.

Based on the best fit to the measured data from the Planck spacecraft, the age of the universe in the present epoch is measured to be approximately (13.787 ± 0.020) billion years [12]. This paper shows that the value of the observed age of the universe also derives from Equation (5), thus seemingly aligning the local time-invariant orbit count b_{local}, corrected with the Hubble tension ratio r_{ht}, with the measured age of the universe (CMBR).

Additional studies are required to understand the implications of the alignment between changes in Earth's gravitationally induced spin around the Sun and the corresponding size of the observable universe as measured from Earth, *i.e.*, further defining this manifestation of gravity itself.

4. Explaining Cosmic Microwave Background Data

The previous sections discussed new theoretical concepts related to dark energy, *i.e.*, the postulate of having a time-invariant limit on total orbital revolutions b when measuring the time span during which the light emitted could have traveled freely from the cosmological horizon to the observer.

This section explains why the cosmic microwave background radiation (CMBR) is smooth [13] and why the boundary condition at the cosmological horizon is non-symmetric [14].

4.1. Smooth Cosmic Microwave Background

The cosmic microwave background radiation has been observed to be smooth [13], even when comparing areas of the universe that should not have been in contact.

This paper introduces a theoretical framework based on multidimensional time, with one temporal dimension in everyday experience and the effects of the other temporal dimension becoming apparent only at cosmological large scales [1]. With respect to the temporal dimension at cosmological large scales, having two independent physical spacetime constants (c and b), neither of which can be derived from the other, explains that the whole universe is in contact [3] [24]. Namely, the extension of postulate 2 in Section 1 states that, with respect to the temporal dimension at cosmological large scales, the relative time span between two events cannot be further apart than the time-invariant maximum orbit count b.

Note that introducing the second constant b also means that the laws of physics do not break down at the maximum time span in the past, the so-called Big Bang

[28]. The value of b is time-invariant, a new theoretical concept embedded in physics [3].

4.2. Non-Symmetric Boundary at the Cosmological Horizon

One would expect that at the largest scales of the observable universe symmetry should prevail and any one direction should be similar. However, experimental observations of fluctuations in cosmic microwave background radiation show that the random motion (heat) in these large-scale modes is not symmetric; there is a preferred direction [14]. The Wilkinson Microwave Anisotropy Probe (WMAP) images show evidence of a non-symmetric boundary condition. Namely, the red tilt in the amplitudes of energy density fluctuations in the cosmic microwave background radiation temperature is a deviation from perfect scale-invariance, having slightly smaller amplitude as the wavelength decreases.

Having two independent physical spacetime constants (c and b) explains that the observable universe is finite (closed) with respect to the temporal dimension at cosmological large scales, with all inertial frames of reference tilting towards the direction of the observer [3] [24].

Note that, as the theory of relativity is inherently background independent, one could also describe the observed acceleration of the expansion of the universe as being an ever faster shrinking of space itself compared to the static boundary of the universe [3] [24]. The theory of relativity allows for this without jeopardizing any physical law. Thus, the above-mentioned inward tilting, always in the direction towards the observer, may indeed explain this non-symmetric aspect.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Kletetschka, G. (2025) Three-Dimensional Time: A Mathematical Framework for Fundamental Physics. *Reports in Advances of Physical Sciences*, **9**, Article 2550004. https://doi.org/10.1142/s2424942425500045

[2] Einstein, A. (1905) Zur elektrodynamik bewegter körper. *Annalen der Physik*, **322**, 891-921. https://doi.org/10.1002/andp.19053221004

[3] van Hoeve, H.A. (2024) Introducing a 2nd Universal Space-Time Constant Can Explain the Observed Age of the Universe and Dark Energy. *World Journal of Mechanics*, **14**, 9-22. https://doi.org/10.4236/wjm.2024.142002

[4] Fernie, J.D. (1969) The Period-Luminosity Relation: A Historical Review. *Publications of the Astronomical Society of the Pacific*, **81**, 707-731. https://doi.org/10.1086/128847

[5] Riess, A.G., Filippenko, A.V., Challis, P., Clocchiatti, A., Diercks, A., Garnavich, P.M., *et al.* (1998) Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant. *The Astronomical Journal*, **116**, 1009-1038. https://doi.org/10.1086/300499

[6] Perlmutter, S., Aldering, G., Goldhaber, G., Knop, R.A., Nugent, P., Castro, P.G., *et al.* (1999) Measurements of Ω and Λ from 42 High-Redshift Supernovae. *The Astro-*

physical Journal, **517**, 565-586. https://doi.org/10.1086/307221

[7] U.S. Naval Observatory Nautical Almanac Office and Her Majesty's Nautical Almanac Office (2010) Astronomical Almanac for the Year 2011. U.S. Government Printing Office, C2, L8.

[8] Simon, J.L., Bretagnon, P., Chapront, J., Chapront-Touze, M., Francou, G. and Laskar, J. (1994) Numerical Expressions for Precession Formulae and Mean Elements for the Moon and the Planets. *Astronomy and Astrophysics*, **282**, 663-683.

[9] Taff, L.G. (1985) Celestial Mechanics: A Computational Guide for the Practitioner. A Wiley-Interscience Publication, 103 p.

[10] Urban, S.E. and Seidelmann, P.K. (2013) Explanatory Supplement to the Astronomical Almanac. University Science Books, 587 p.

[11] LIGO Scientific Collaboration and Virgo Collaboration (2016) Tests of General Relativity with GW150914. *Physical Review Letters*, **116**, Article ID: 221101.

[12] Aghanim, N., Akrami, Y., Ashdown, M., Aumont, J., Baccigalupi, C., Ballardini, M. *et al.* (2020) Planck 2018 Results-VI. Cosmological Parameters. *Astronomy & Astrophysics*, **641**, A6.

[13] Albrecht, A. and Magueijo, J. (1999) Time Varying Speed of Light as a Solution to Cosmological Puzzles. *Physical Review D*, **59**, Article 043516. https://doi.org/10.1103/physrevd.59.043516

[14] Land, K. and Magueijo, J. (2005) Examination of Evidence for a Preferred Axis in the Cosmic Radiation Anisotropy. *Physical Review Letters*, **95**, Article 071301. https://doi.org/10.1103/physrevlett.95.071301

[15] Sloan Digital Sky Survey Press Office (2012) Astronomers Measure the Universe's Deceleration before Dark Energy Took Over. Astronomy Magazine. https://www.astronomy.com/science/astronomers-measure-the-universes-deceleration-before-dark-energy-took-over/

[16] Harikane, Y., Inoue, A.K., Mawatari, K., Hashimoto, T., Yamanaka, S., Fudamoto, Y., *et al.* (2022) A Search for H-Dropout Lyman Break Galaxies at Z ~ 12-16. *The Astrophysical Journal*, **929**, Article 1. https://doi.org/10.3847/1538-4357/ac53a9

[17] Krauss, L. and Starkman, G. (1999) Teaching about Cosmology. AIP Publishing.

[18] Schmidt, M. (1963) 3C 273: A Star-Like Object with Large Red-Shift. *Nature*, **197**, 1040-1040. https://doi.org/10.1038/1971040a0

[19] Dhawan, S., Jha, S.W. and Leibundgut, B. (2018) Measuring the Hubble Constant with Type Ia Supernovae as Near-Infrared Standard Candles. *Astronomy & Astrophysics*, **609**, A72. https://doi.org/10.1051/0004-6361/201731501

[20] Jones, D.O., Rodney, S.A., Riess, A.G., Mobasher, B., Dahlen, T., McCully, C., *et al.* (2013) The Discovery of the Most Distant Known Type IA Supernova at Redshift 1.914. *The Astrophysical Journal*, **768**, Article 166. https://doi.org/10.1088/0004-637x/768/2/166

[21] Vavryčuk, V. (2025) Time Dilation Observed in Type Ia Supernova Light Curves and Its Cosmological Consequences. *Galaxies*, **13**, Article 55. https://doi.org/10.3390/galaxies13030055

[22] Yoon, S.J., Park, I., Zee, W.B.G., Chung, C., Moon, J.S., Paudel, S., *et al.* (2026) SN Ia Population Machine. I. A Unified Cosmological Simulation-Binary Synthesis Framework Establishing Non-Universal Delay-Time Distributions and Cosmic Progenitor-channel Dominance Crossover. arXiv:2604.24846.

[23] Brewer, B.J., Lewis, G.F. and Li, Y. (2025) Revisiting the Cosmological Time Dilation of Distant Quasars: Influence of Source Properties and Evolution. *Monthly Notices*

of the Royal Astronomical Society, **537**, 809-816.
https://doi.org/10.1093/mnras/staf044

[24] Van Hoeve, H.A. (2011) The Special Theory of Double Relativity. *The Journal of Cosmology*, **13**, 4087-4117.
https://thejournalofcosmology.com/VanHoeveRelativity1.pdf

[25] United States Naval Observatory, Nautical Almanac Office, Great Britain, Nautical Almanac Office, Engineering Research Council (Great Britain), Science Research Council (Great Britain), Rutherford Appleton Laboratory, Council for the Central Laboratory of the Research Councils (Great Britain) and Great Britain and Hydrographic Office (2011) The Astronomical Almanac for the Year 2011. US Government Printing Office.

[26] Mann, A. (2019) One Number Shows Something Is Fundamentally Wrong with Our Conception of the Universe.
https://www.space.com/hubble-constant-discrepancy-explained.html

[27] Jedamzik, K., Pogosian, L. and Zhao, G. (2021) Why Reducing the Cosmic Sound Horizon Alone Can Not Fully Resolve the Hubble Tension. *Communications Physics*, **4**, Article No. 123. https://doi.org/10.1038/s42005-021-00628-x

[28] Kragh, H. (2012) Naming the Big Bang. *Historical Studies in the Natural Sciences*, **44**, 3-36. https://doi.org/10.1525/hsns.2014.44.1.3