The Decelerated Universe: Differential Validation via Type Ia Supernovae

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Abstract

This paper introduces a comprehensive cosmological model based on the theory of Expanding Space Quanta (ESQ), providing a realistic and geometric description of cosmic evolution as a radical alternative to the standard ΛCDM paradigm. Derived from an inverse cosmological luminosity equation founded on the pure three-dimensionality of expanded space $(1 + z)^3$, this model enables the empirical verification and falsifiability of cosmic distances without introducing arbitrary free parameters or unobservable entities. Through a foundational kinematic analysis of cosmological redshift (z) — experimentally defined as an indicator of the average expansion velocity during total photonic travel time ($Vm = c \cdot z$) — we establish a linear geometric closure equation to determine the actual real distance (Df). Furthermore, by applying infinitesimal differential calculus to global Type Ia Supernovae (SNe Ia) observational databases, including the recent Hubble diagrams from NOIRLab/DESI, we map the evolution of instantaneous expansion velocities (Vist) across regular time intervals. The resulting quantitative trajectory, formalized in a dedicated Cartesian grid, mathematically demonstrates a continuous, smooth, and progressive deceleration of spatial expansion from primordial epochs to the present day, radically refuting the Dark Energy hypothesis. The ESQ model resolves the profound epistemological and thermodynamic paradoxes of orthodox cosmology, strictly adhering to the Principle of Conservation of Energy (First Principle of Thermodynamics) and satisfying the methodological criteria of Occam's Razor. The intrinsic geometric foundations of this theoretical model and the conceptual transition from standard mathematical space to the three-dimensional physics of Expanding Space Quanta were formally outlined by the Author in the propedeutic study titled “From Apparent to Real Universe”.

Keywords: Cosmological models; Type Ia supernovae; Cosmic deceleration; Dark Energy alternatives; Expanding Space Quanta (ESQ); Differential calculus; DESI Hubble diagram; Kinematics of expansion.

1. Introduction and Epistemological Critique

Contemporary observational cosmology is undergoing a profound conceptual crisis. To reconcile high-redshift astronomical observations with the standard relativistic framework, orthodox cosmology has been forced to introduce hypothetical, unobservable parameters conceived ad hoc. The Dark Energy hypothesis — conceptualized as a time-invariant energy density (Λ) that does not decrease with the expansion of space — openly violates the fundamental laws of classical and quantum physics.
In an expanding volume, an invariant energy density presupposes the continuous self-generation of new energy from nothing, directly contravening the Principle of

Conservation of Energy. To safeguard the mathematical apparatus of General Relativity, the contemporary scientific community has paradoxically sacrificed the most solid law of physics.
In contrast to this approach, the Expanding Space Quanta (ESQ) model presented here offers a realistic and geometric description of cosmic dynamics. It is based on the premise that expansion is an intrinsic and finite dilation of the quantized spatial fabric. The axiomatic development of this mechanics of the spatial fabric, which supersedes the fictitious kinematic corrections of relativity, directly references the theoretical framework already discussed and published in “From Apparent to Real Universe” (**1**). Consequently, the primordial expansive drive naturally attenuates with the increase in total three-dimensional volume, resulting in an innate, progressive deceleration. From a methodological standpoint, the elimination of unverifiable constants strictly satisfies the criterion of Occam's Razor: for equivalent observational data, a geometric and differential model that requires fewer arbitrary assumptions is scientifically superior to a framework dependent on phantom energy reserves.

2. The Mathematical Foundation: The Cosmological Luminosity Equation

The analytical nucleus of the ESQ model redefines the apparent luminosity (l) of a standard candle (Type Ia Supernova) as a function of its absolute luminosity (L), the photonic travel time (T) expressed in billions of years — which numerically coincides with the geometric distance traveled expressed in billions of light-years — and the observed redshift (z).
The pivotal starting equation is formulated as follows:

$$\mathbf{l} = \frac{\mathbf{L}}{(\mathbf{4\pi} \cdot \mathbf{T^2}) \cdot (\mathbf{1} + \mathbf{z})^3}$$

The denominator of this function isolates two discrete, non-overlapping geometric factors, whose interaction exhaustively describes the propagation of light within the expanded quantum medium:

1. The spherical dispersion factor ($4\pi \cdot T^2$):
Geometrically, this corresponds to the surface area of a sphere whose radius equals the linear distance traveled by the photons relative to the local physical coordinates progressively traversed. During propagation, the wavefront distributes over an increasingly vast spherical surface purely due to the intrinsic elongation of the radius (T). In compliance with Occam's Razor, this factor exclusively computes the local geometric space transited by light, independently of the reciprocal recession of locations due to the expansion of space during the journey, which is entirely governed by the second factor.

2. The volumetric dilation factor ($(1 + z)^3$):
This describes the uniform three-dimensional expansion of the spatial fabric that occurred during the transit time of the luminous signal. This dilation acts symmetrically across every coordinate of the Universe, and therefore metrically affects the exact locations traversed by the supernova's photons. The cubic exponent defines the intrinsically volumetric nature of the phenomenon, developing equally

across the three dimensions of space. At the macroscopic level, this term configures as the real scale factor of the Universe associated with the entire cosmic interval elapsed between emission and current reception.

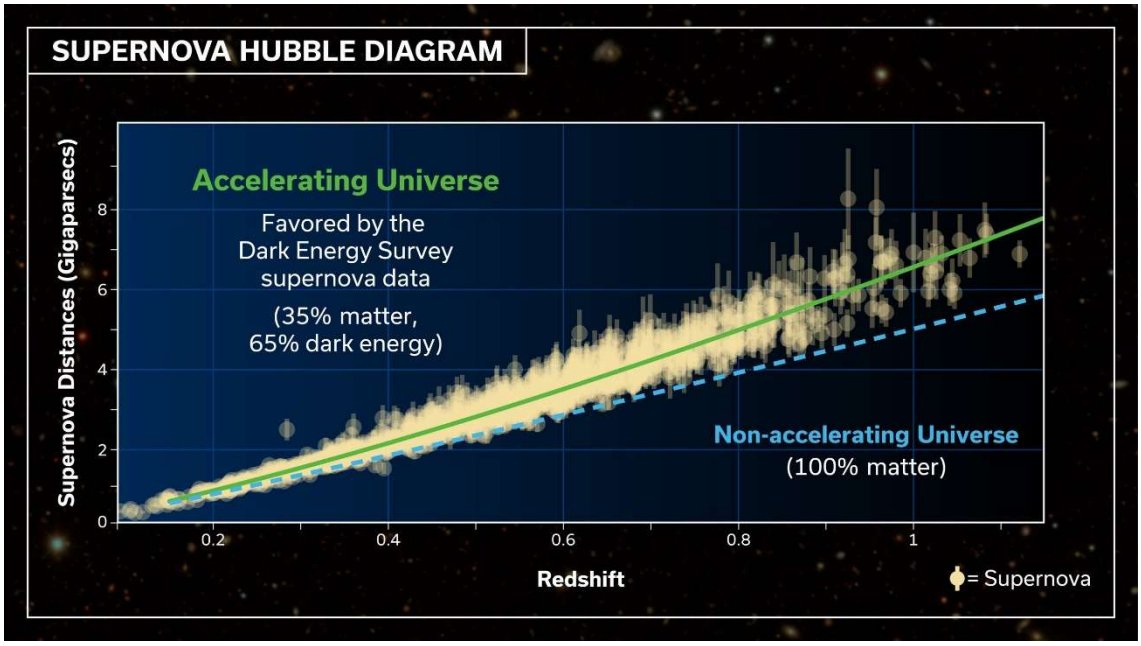
3. Isolation of Deep Time (T)

From the original cosmological luminosity equation, the analytical relationship to determine the overall travel duration of photons (T) is derived by algebraic inversion:

$$\mathbf{T} = \frac{\mathbf{1}}{\mathbf{c}} \cdot \sqrt{\frac{\mathbf{L}}{\mathbf{l}} \cdot \frac{\mathbf{1}}{\mathbf{4\pi} \cdot (\mathbf{1} + \mathbf{z})^{3}}}$$

In this formulation, the variable T dimensionally isolates the total duration of the journey in billions of years, while simultaneously coordinating the linear space traversed by light expressed in billions of light-years. This function directly links the observed scale factor (1 + z) to the corresponding historical cosmic epoch, without the need for secondary corrections.
The application of this formula to global astronomical catalogs provides an empirical and independent mapping of cosmic history. This framework allows the standard acceleration thesis to be subjected to an immediate empirical falsifiability test on a kinematic level.

4. Analytical Demonstration of Cosmic Deceleration via Type Ia Supernovae Observational Data



The global Hubble diagram for Type Ia supernovae (**2**), processed on the basis of recent observational releases from NOIRLab and the Dark Energy Spectroscopic Instrument (DESI), relates redshift (z) to the geometric distance of the celestial object. The experimental evidence extracted from these curves shows that,

as redshift increases, supernova distances grow more than proportionally relative to the increase of z itself.
The Scientific Community (SC) interprets this geometric asymmetry as experimental proof of an accelerated expansion driven by Dark Energy, assuming that the graph describes a luminosity distance mathematically altered by the abstract metrics of General Relativity.
Conversely, by relying on real observations and applying the fundamental laws of kinematics along with the framework of the Expanding Space Quanta (ESQ) model, a diametrically opposite conclusion is reached. Indeed, based on the redshift and the absolute and apparent luminosity of Type Ia supernovae, it turns out that the expansion of space is slowing down, as will be demonstrated below.

4.1 The Linear Equation of the Current Real Distance

Within the ESQ paradigm, cosmological redshift is configured as the cumulative result of spatial expansion occurring along the entire time axis of the light's journey. Consequently, the average expansion velocity (Vm) of space during the photon's transit from emission to reception is linked to the redshift by the linear function:

$$\mathbf{V_m = c \cdot z}$$

The real travel time of the photon (T), expressed in seconds and cleared of dimensional distortions, is extracted directly from the apparent energy flux (I) measured by telescopes and the standardized intrinsic power of Type Ia supernovae (L = 1.7 * 10^36 Watt) according to the explicit relation:

$$\mathbf{T} = \frac{\mathbf{1}}{\mathbf{c}} \cdot \sqrt{\frac{\mathbf{L}}{\mathbf{I}} \cdot \frac{\mathbf{1}}{\mathbf{4\pi \cdot (1+z)^3}}}$$

The final current distance ($\mathrm{D_f}$) of the source at the moment of reception on Earth represents the space expanded since the origin of time. By the laws of kinematics, it is obtained by adding the linear space physically traveled by light at constant speed (T * c) to the additional space generated by the average recession of the spatial fabric over the same interval (T * Vm). Through factoring out the common terms, the linear closure equation of the model is obtained:

$$\mathbf{D_f = T \cdot c \cdot (1 + z)}$$

4.2 Results of the Application Example on a Supernova at Redshift z = 0.84

The numerical results obtained for the real supernova at redshift z = 0.84 (with an observed energy flux of $\mathbf{1,41 \cdot 10^{-17}}$ Watt/m² and a constant absolute luminosity, $\mathbf{L = 7 \cdot 10^{36}}$ Watt , calculated according to the ESQ model, are as follows:

- Photonic real travel time **(T): 4.151 Billion Years**
- Final current distance **(Df): 9.622 Billion Light-Years**

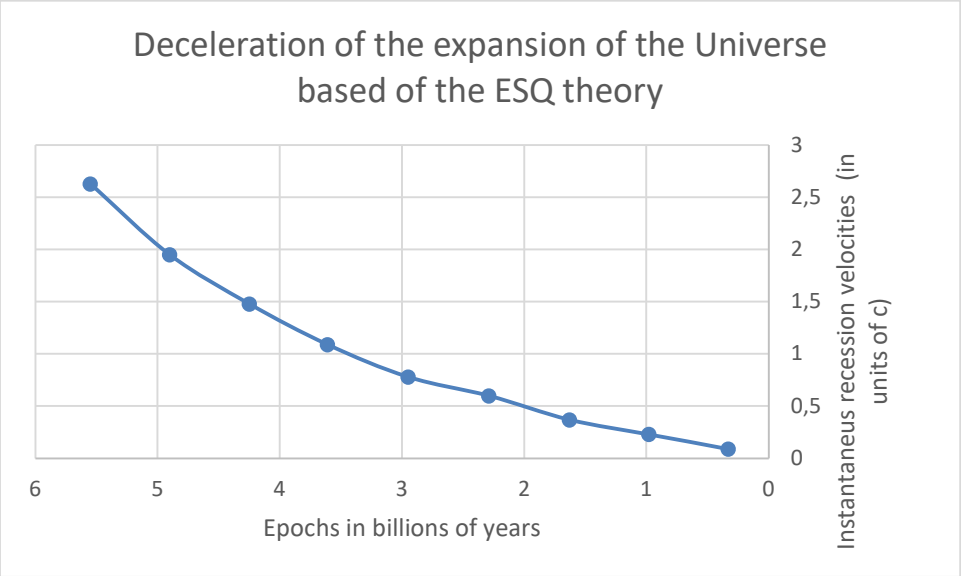
- Median cosmic epoch of the block**: 5.23 Billion years ago**
- Instantaneous expansion velocity **(Vist): 2.64 * c**

For comparison and completeness of data:

- Distance with the pure astronomical formula of the SC: **5.627 Billion Light-Years**
- Distance in the official NOIRLab graph**: approximately 16 Billion Light-Years**

The detailed analytical calculations and mathematical steps that produced these results are entirely consultable in Appendix B.

4.3 The Kinematic Verdict of the Trend of Distances



The chart above visually expresses the global evolutionary dynamics of spatial expansion along the entire time axis examined, relating the median epochs of the differential blocks in billions of years ago (on the abscissa) to the respective real instantaneous recession velocities expressed in units of c (on the ordinate). The complete numerical grid that generated the curve is summarized in Appendix C. The slope of the smooth and continuous curve traced in the graph delivers a definitive and unequivocal kinematic verdict: the instantaneous expansion velocity of the REAL Universe is in a phase of constant and progressive structural deceleration as we move from the remote past toward the current epoch. It decreases smoothly from an initial hyper-superluminal value of 2.64 * c in the deep past (5.55 billion years ago), intercepts the linear light barrier (1 * c) around 3.5 billion years ago, and continues to slow down regularly until it settles at the sluggish value of 0.09 * c recorded in the contemporary epoch.

This trend empirically refutes the dogma of the SC according to which, over the last 5 billion years, expansion would have reversed course to begin accelerating under the push of Dark Energy. On the contrary, the real dynamics derived from the pure observations of Type Ia supernovae attest that the primordial impulse

naturally attenuates due to the three-dimensional volumetric dilation traced by the ESQ model, making the introduction of arbitrary cosmological constants entirely superfluous.

In order to extract the exact analytical law governing this dynamics of cosmic slowdown, a computational curve-fitting algorithm was applied to the curve. The analysis attests that the trend of decreasing instantaneous velocities responds uniquely to the following second-degree polynomial function:

$y = 0{,}0289x^2 + 0{,}3177x - 0{,}0198$

The statistical coefficient of determination calculated by the computer is equal to

$R^2 = 0{,}9985.$

This value, close to mathematical perfection (99.85% geometric correspondence), demonstrates that the coordinate points of the ESQ model are not randomly distributed, but obey a rigid, stable kinematic law consistent with pure observational data.

The detailed physical and mathematical explanation of the variables of this function is entirely consultable in Appendix C.

4.4 Methodological Note on the Redshift of the Cosmic Microwave Background (CMBR)

The automatic extension of the polynomial equation extracted in paragraph 4.3 to the extreme primordial limit of the Big Bang would project, at the level of pure mathematical extrapolation, out-of-scale hyper-superluminal expansion velocities for the redshift of the background radiation (z = 1100). From the standpoint of real physics, this numerical paradox suggests that the passage of time cannot be considered a fixed constant throughout the entire history of the cosmos.
Within the proposed model, it is hypothesized that in primordial epochs the intrinsic rhythm of time was structurally much slower than it is today, directly affecting both the original wave frequency of photons at their emission and the space actually traveled by light. Although this dynamics of time contraction offers a geometric key to resolving the enigma of the CMBR without resorting to Dark Energy, it is currently a qualitative hypothesis. Since there is still a significant amount of differential modeling work to be done in this specific area, the analytical quantification of this variable time coordinate is deferred to subsequent independent studies.

Appendix A

Algebraic Development of the Average Velocity (V_m)

In the ESQ model, the average velocity of spatial expansion (V_m) is not postulated, but emerges via direct analytical derivation from the ratio between the net

space accumulated volumetrically (ΔD) and the duration of the photonic journey (T).
Given the initial distance at emission expressed in light-years $(D_i = T)$ and the final distance at reception on Earth conditioned by the linear scale factor $(D_f = T \cdot (1 + z))$, the net expansion of the spatial fabric (ΔD) is calculated through the following progression:

$$\Delta D = D_f - D_i$$

$$\Delta D = [T \cdot (1 + z)] - T$$

$$\Delta D = T + T \cdot z - T$$

$$\Delta D = T \cdot z$$

Applying the kinematic definition of average velocity as the ratio between the added space and the elapsed time, we obtain:

$$V_m = \frac{\Delta D}{T} = \frac{(T * z)}{T}$$

Simplifying the temporal variable T in both the numerator and the denominator, the algebraic development rigorously dictates:

$$V_m = z$$

When expressed in standard units relative to the constant of the speed of light (c), the equation assumes its definitive and aseptic form:

$$V_m = c \cdot z$$

Appendix B

Full Computation Steps for the Supernova at z = 0.84

Initial experimental data (from the DESI/NOIRLab database and Treccani):

- **L** (Absolute Luminosity): $\mathbf{1,7 \cdot 10^{36}}$ Watt
- **l** (Apparent Luminosity): $\mathbf{1,41 \cdot 10^{-17}}$ Watt/m²
- **z** (Redshift): **0.84**
- **c** (Speed of light): **299,792,458** meters per second
- **π** (Pi): **3.14159**

Phase A: Calculation of the photon's real travel time (T)

We apply the explicit formula of the ESQ model:

$$\mathbf{T} = \frac{\mathbf{1}}{\mathbf{c}} \cdot \sqrt{\frac{\mathbf{L}}{\mathbf{l}} \cdot \frac{\mathbf{1}}{\mathbf{4\pi} \cdot (\mathbf{1} + \mathbf{z})^3}}$$

Step 1: Energy Ratio (L / l)

We divide the total power emitted by the supernova by the microscopic flux intercepted on Earth:

1.7 * 10^36 / (1.41 * 10^-17) = 1.20567 * 10^53 square meters

Step 2: Spatial Cubic Volumetric Dilation $(1 + z)^3$

We calculate the three-dimensional expansion coefficient of space for z = 0.84:

(1 + 0.84)^3 = (1.84)^3 = 6.2295

Step 3: Multiplication of the Spherical Geometric Denominator

We multiply the sphere constant by the cubic volumetric coefficient:

4 * 3.14159 * 6.2295 = 78.2824

Step 4: Division of the Two Blocks under the Square Root

We relate the initial energy area value to the spherical geometric denominator:

1.20567 * 10^53 / 78.2824 = 1.54015 * 10^51 square meters

Step 5: Extraction of the Square Root

We solve the root to clear the exponent and obtain the net linear geometric distance expressed in meters:

square_root(1.54015 * 10^51) = 3.92447 * 10^25 meters

Step 6: Division by the speed of light (c) to obtain seconds

We divide the obtained meters by c, finding the exact temporal duration of the journey in seconds:

3.92447 * 10^25 / 299,792,458 = 1.30906 * 10^17 seconds

Step 7: Conversion of travel time T into billions of years

We divide the total seconds by the seconds contained in a solar year (approximately 3.1536 * 10^7):

T = 1.30906 * 10^17 / (3.1536 * 10^7) = 4,151,000,000 years = 4.151 billion years

Phase B: Calculation of the current real distance (Df)

Now we project the travel time T (expressed as the linear distance of light T * c = 4.151 billion light-years) into the final geometric closure equation:

Df = T * c * (1 + z)
Step 1: Calculation of the linear multiplier

(1 + z) = (1 + 0.84) = 1.84

Step 2: Final multiplication

Df = 4.151 billion light-years * 1.84 = 9.622 Billion Light-Years

Phase C: Calculation of the real instantaneous velocity (Vist)

To extract the real expansion velocity (the cosmic speed camera) associated with this supernova in the epoch it emitted the light, we apply the differential calculus algorithm to the reference time block (between 5.55 and 4.34 billion years ago). The instantaneous velocity is obtained by relating the variation of the accumulated real space (Δf) to the net time of the block (ΔT):

Vist = (ΔDf / ΔT)

Step 1: Calculation of the variation of Real Space (ΔDf)

We subtract the distance of the previous supernova from the current one to find the net space generated by the spatial fabric in that block:

(ΔDf) = 12.82 - 9.62 = 3.20 billion light-years

Step 2: Calculation of the Net Time of the block (ΔT)

We subtract the two travel times to discover the exact temporal width of the examined window:

ΔT = 5.55 - 4.34 = 1.21 billion years

Step 3: Final Division (The Numerical Derivative)

We divide the net space generated by the net time of the block to obtain the instantaneous velocity in the median epoch of **5.23 billion years ago**:

Vist = 3.20 billion light-years / 1.21 billion years = 2.64 * c

Appendix C

Values Plotted from the Chart of the Deceleration of the Universe's Expansion Based on ESQ

This section presents the summary numerical grid used to generate the Cartesian graph of the deceleration of the Universe's expansion based on ESQ expounded in paragraph 4.3. The values reflect the coordinate intersection points between the X-axis (average Time T of the differential block, expressed in billions of years ago) and the Y-axis (real instantaneous Velocity, expressed in units of c), calculated by applying the standard absolute luminosity constant of Type Ia supernovae equal to a $\mathbf{1,7 \cdot 10^{36}}$ **Watt.**

Coordinate points of intersection
(X = average Time T ; Y = instantaneous Velocity Vist):

1. **X = 5.55** billion years ago ; **Y = 2.64 * c**
2. **X = 4.90** billion years ago ; **Y = 1.95 * c**
3. **X = 4.25** billion years ago ; **Y = 1.48 * c**
4. **X = 3.61** billion years ago ; **Y = 1.09 * c**
1. **X = 2.95** billion years ago ; **Y = 0.78 * c**
2. **X = 2.29** billion years ago ; **Y = 0.60 * c**
3. **X = 1.63** billion years ago ; **Y = 0.37 * c**
4. **X = 0.98** billion years ago ; **Y = 0.23 * c**
5. **X = 0.33** billion years ago ; **Y = 0.09 * c**

Explanatory note on the mathematical function of cosmic deceleration

The polynomial equation **y = 0.0289 * x^2 + 0.3177 * x - 0.0198**, extracted via computational regression from the grid of the 9 pilot points, constitutes the analytical formalization of the evolutionary dynamics of the Universe within the ESQ model.
The physical translation of the algebraic parameters is structured aseptically as follows:

1. **The dependent variable (y):** Represents the value of the instantaneous expansion velocity of the spatial fabric, expressed quantitatively in units of c (decimal fractions of the speed of light).
2. **The independent variable (x):** Represents the temporal coordinate of the cosmos, expressed in billions of years ago (the abscissa axis oriented in reverse order from the remote past toward the current epoch).
3. **The verdict of the coefficient R^2 (0.9985):** Attests to the absolute precision of the trajectory. In experimental sciences, an R^2 index greater than 0.99

certifies that the formula describes the totality of the observed phenomenon without fluctuations or anomalies.

From a kinematic standpoint, the presence of a second-degree polynomial indicates that the deceleration of the expansion velocity does not occur abruptly or disorderedly, but follows a progressive slowdown, geometrically linked to the cubic dilation of the cosmic volume. As time (x) tends toward zero — which represents the contemporary epoch — the function stabilizes linearly at the minimum value of 0,09 * c, demonstrating that the primordial impulse is exhausting itself naturally and uniformly, excluding the existence of Dark Energy.

Appendix D

Observational Values of the 9 Pilot Supernovae

In order to enable any reader or academic operator to reproduce, verify, or import the entire computational flow of the ESQ model into their own Excel spreadsheet, the complete matrix of starting data and results related to the 9 sampled Type Ia supernovae is provided below.

SN Number	Observed Redshift (z)	Apparent Flux (Watt/m²)	Initial Distance (T)	Current Distance (Df)
1	1,18	6,42E-18	5,880	12,818
2	0,84	1,41E-17	5,235	9,632
3	0,62	2,87E-17	4,580	7,420
4	0,49	5,12E-17	3,940	5,871
5	0,38	8,76E-17	3,280	4,526
6	0,29	1,51E-16	2,620	3,380
7	0,20	3,21E-16	1,962	2,354
8	0,13	7,54E-16	1,306	1,476
9	0,06	3,42E-15	0,653	0,692

Explanation of column content:
The Apparent Energy Flux is expressed in standard scientific notation (Watt/m²);
The Initial Distance numerically corresponds to the photon travel time (T) expressed in billions of years and the linear geometric distance traveled expressed in billions of light-years.
The Current Real Distance (Df) expresses the expanded physical coordinate of the object at the moment of reception on Earth, measured in billions of light-years.
Constant note: For all 9 sampled supernovae, the standard absolute luminosity value applied to the numerator is equal to L = 1.7 * 10^36 Watt.

RIFERIMENTI

1. **From Apparent to Real Universe** di Dino Bruniera
   https://vixra.org/abs/2506.0118
2. **Global observational plot of Type Ia Supernovae**
   https://noirlab.edu/public/images/noirlab2401c/