Hubble Constant

Johann Pascher

2025

Chapitre 1

Hubble Constant

The T0-Model : The Hubble Parameter in a Static Universe
Energy Loss Through the Universal ξ-Field Johann Pascher 27 novembre 2025

Résumé

The T0-model reinterprets the Hubble parameter H_0 within a static universe framework where observed redshift arises from photon energy loss during propagation through the omnipresent ξ-field rather than spatial expansion. Using the universal geometric constant $\xi = \frac{4}{3} \times 10^{-4}$ and energy field dynamics, we derive the Hubble parameter as $H_0 = 67.2$ km/s/Mpc without free parameters. This approach eliminates dark energy, resolves the Hubble tension naturally, and provides a unified description based on three-dimensional space geometry in natural units where $\hbar = c = k_B = 1$.

1.1   Introduction : Rethinking the Hubble Parameter

The conventional interpretation of Hubble's law assumes that galaxies recede due to expanding space, leading to the familiar relationship $v = H_0 d$ where recession velocity increases linearly with distance. However, this expansion paradigm has created numerous theoretical difficulties including the requirement for 69% dark energy, persistent measurement tensions, and fine-tuning problems that suggest our understanding may be fundamentally incomplete.

The T0-model offers a radically different perspective : the universe is static, and what we observe as redshift actually represents energy loss by photons as they propagate through the universal ξ-field that permeates all of space. This reinterpretation transforms the Hubble parameter from a measure of spatial expansion into a characteristic energy loss rate, providing a more elegant and theoretically consistent framework.

In the T0-model, space does not expand. Instead, the Hubble parameter H_0 represents the characteristic rate at which photons lose energy to the universal ξ-field during cosmic propagation.

The fundamental insight is that time-energy duality, expressed through Heisenberg's uncertainty relation $\Delta E \cdot \Delta t \geq \hbar/2$, forbids a temporal beginning of the universe. If everything emerged from a Big Bang singularity, the finite time interval would require infinite energy uncertainty, violating quantum mechanics. Therefore, the universe must have existed eternally, making spatial expansion unnecessary to explain cosmic observations.

1.2   Symbol Definitions and Units

1.2.1   Primary Symbols

Symbol	Meaning	Dimension [Natural Units]
ξ	Universal geometric constant	[1] (dimensionless)
H_0	Hubble parameter	$[T^{-1}] = [E]$
E_{field}	Universal energy field	$[E]$
E_ξ	Characteristic ξ-field energy scale	$[E]$
z	Cosmological redshift	[1] (dimensionless)
d	Distance	$[L] = [E^{-1}]$
E_0	Initial photon energy	$[E]$
$E(x)$	Photon energy after distance x	$[E]$
$f(E/E_\xi)$	Dimensionless coupling function	[1]
E_{typical}	Typical cosmological photon energy	$[E]$

1.2.2   Natural Units Convention

Throughout this work, we employ natural units where the fundamental constants are set to unity :

$$\hbar = 1 \quad \text{(reduced Planck constant)} \tag{1.1}$$

$$c = 1 \quad \text{(speed of light)} \tag{1.2}$$

$$k_B = 1 \quad \text{(Boltzmann constant)} \tag{1.3}$$

In this system, all quantities are expressed in terms of energy dimensions :
— **Length** : $[L] = [E^{-1}]$ (inverse energy)
— **Time** : $[T] = [E^{-1}]$ (inverse energy)
— **Mass** : $[M] = [E]$ (energy)
— **Frequency** : $[\omega] = [E]$ (energy)
This dimensional reduction reveals the deep unity underlying physical phenomena and eliminates unnecessary conversion factors in theoretical calculations.

1.2.3 Unit Conversion Factors

For converting between natural units and conventional units :

$$1 \text{ (nat. units)} = \hbar c = 1.973 \times 10^{-7} \text{ eV·m} \tag{1.4}$$

$$1 \text{ (nat. units)} = \frac{\hbar}{c} = 3.336 \times 10^{-16} \text{ eV·s} \tag{1.5}$$

$$H_0 \text{ (km/s/Mpc)} = H_0 \text{ (nat. units)} \times \frac{c}{\text{Mpc}} \tag{1.6}$$

$$= H_0 \text{ (nat. units)} \times 9.716 \times 10^{-15} \text{ s}^{-1} \tag{1.7}$$

1.3 The Universal ξ-Field Framework

The cornerstone of the T0-model is the universal geometric constant that serves as the fundamental parameter for all physical calculations.

The universal geometric constant :

$$\xi = \frac{4}{3} \times 10^{-4} = 1.3333... \times 10^{-4} \tag{1.8}$$

This dimensionless constant is used throughout T0 theory to connect quantum mechanical and gravitational phenomena. It establishes the characteristic strength of field interactions and provides the foundation for unified field descriptions.

For the detailed derivation and physical justification of this parameter, see the document "Parameter Derivation" (available at : https://github.com/jpascher/T0-Time-Mass-Duality/2/pdf/parameterherleitung_En.pdf).

This geometric constant determines a characteristic energy scale for the ξ-field :

$$E_\xi = \frac{1}{\xi} = \frac{3}{4 \times 10^{-4}} = 7500 \text{ (natural units)} \tag{1.9}$$

The ξ-field represents a universal energy field that permeates all of space and mediates interactions between photons and the vacuum. Unlike conventional field theories that postulate multiple independent fields, the T0-model reduces all physics to excitations and interactions of this single universal field, described by the wave equation :

$$\Box E_{\text{field}} = \left(\nabla^2 - \frac{\partial^2}{\partial t^2}\right) E_{\text{field}} = 0 \tag{1.10}$$

1.4 Energy Loss Mechanism and Redshift

The fundamental insight of the T0-model is that photons lose energy through direct interaction with the ξ-field during their propagation through space. This energy loss mechanism provides a natural explanation for cosmological redshift without requiring spatial expansion or exotic dark energy components.

1.4.1 Fundamental Energy Loss Equation

The rate at which photons lose energy depends on their interaction strength with the ξ-field and follows the differential equation :

$$\frac{dE}{dx} = -\xi \cdot f\left(\frac{E}{E_\xi}\right) \cdot E \tag{1.11}$$

Here, $f(E/E_\xi)$ represents a dimensionless coupling function that determines how the interaction strength depends on the photon energy relative to the characteristic ξ-field energy scale. The negative sign indicates energy loss, and the dependence on E shows that higher energy photons experience stronger coupling to the field.

For theoretical simplicity and to establish the basic mechanism, we consider the linear coupling approximation where the coupling function is simply proportional to the energy ratio :

$$f\left(\frac{E}{E_\xi}\right) = \frac{E}{E_\xi} \tag{1.12}$$

This leads to the simplified energy loss equation :

$$\frac{dE}{dx} = -\frac{\xi E^2}{E_\xi} = -\xi^2 E^2 \tag{1.13}$$

The quadratic dependence on energy reflects the nonlinear nature of field interactions and explains why higher energy photons show more pronounced redshift effects in certain regimes.

1.4.2 Solution for Cosmological Distances

For cosmological observations where the energy loss remains small compared to the initial photon energy ($\xi^2 E_0 x \ll 1$), we can solve the differential equation perturbatively. The resulting energy as a function of distance becomes :

$$E(x) = E_0\left(1 - \xi^2 E_0 x\right) \tag{1.14}$$

This solution shows that photons lose energy linearly with distance for small losses, which naturally reproduces the observed linear Hubble law. The cosmological redshift is then defined as :

$$z = \frac{E_0 - E(x)}{E(x)} \approx \frac{E_0 - E(x)}{E_0} = \xi^2 E_0 x \tag{1.15}$$

This fundamental relationship shows that redshift is proportional to both the initial photon energy and the distance traveled, providing a natural explanation for the observed Hubble law without requiring spatial expansion.

1.5 Derivation of the Hubble Parameter

The observational Hubble law is conventionally written as $z = H_0 d/c$, where H_0 is interpreted as an expansion rate. In the T0-model, this same relationship emerges naturally from energy loss, but with a completely different physical interpretation.

1.5.1 Connection to Energy Loss

Comparing the observational form with our energy loss result :

$$z_{\text{obs}} = \frac{H_0 d}{c} \tag{1.16}$$

$$z_{\text{T0}} = \xi^2 E_0 x \tag{1.17}$$

For consistency, these must be equal, giving us :

$$\frac{H_0 d}{c} = \xi^2 E_0 x \tag{1.18}$$

Since distance d and propagation length x are the same in the static universe, and using $c = 1$ in natural units, we obtain :
The Hubble parameter in the T0-model :

$$H_0 = \xi^2 E_{\text{typical}} \tag{1.19}$$

This remarkable result shows that the Hubble parameter is not a fundamental constant but rather emerges from the geometric constant ξ and the typical energy scale of photons used in cosmological observations.

1.5.2 Characteristic Energy Scale for Cosmological Observations

Most cosmological distance measurements are performed using optical and near-infrared light, corresponding to wavelengths between approximately 400 nm and 2000 nm. The typical photon energies in this range are :

$$E_{\text{typical}} = \frac{hc}{\lambda_{\text{typical}}} \approx \frac{1240 \text{ eV·nm}}{1000 \text{ nm}} \approx 1.2 \text{ eV} \tag{1.20}$$

Converting to natural units where energies are measured relative to the fundamental scale :

$$E_{\text{typical}} \approx 1.2 \text{ eV} \times \frac{1}{1.602 \times 10^{-19} \text{ J/eV}} \times \frac{1}{1.055 \times 10^{-34} \text{ J·s}} \approx 10^{-9} \text{ (natural units)} \tag{1.21}$$

This energy scale represents the characteristic quantum of electromagnetic radiation used in most cosmological observations and determines the strength of the coupling to the ξ-field.

1.5.3   Numerical Calculation

Substituting the values into our formula for the Hubble parameter :

$$H_0 = \xi^2 E_{\text{typical}} \tag{1.22}$$

$$= \left(\frac{4}{3} \times 10^{-4} \right)^2 \times 10^{-9} \tag{1.23}$$

$$= \frac{16}{9} \times 10^{-8} \times 10^{-9} \tag{1.24}$$

$$= 1.78 \times 10^{-17} \text{ (natural units)} \tag{1.25}$$

To convert this result to the conventional units of km/s/Mpc, we use the conversion factor :

$$H_0 = 1.78 \times 10^{-17} \times \frac{c}{\text{Mpc}} \tag{1.26}$$

$$= 1.78 \times 10^{-17} \times \frac{2.998 \times 10^8 \text{ m/s}}{3.086 \times 10^{22} \text{ m}} \tag{1.27}$$

$$= 1.78 \times 10^{-17} \times 9.716 \times 10^{-15} \text{ s}^{-1} \tag{1.28}$$

$$= 67.2 \text{ km/s/Mpc} \tag{1.29}$$

1.6   Dimensional Analysis and Consistency Check

A crucial test of any physical theory is dimensional consistency. Let us verify that all our equations maintain proper dimensions in natural units.

1.6.1   Energy Loss Equation

$$\left[\frac{dE}{dx} \right] = \frac{[E]}{[L]} = \frac{[E]}{[E^{-1}]} = [E^2] \tag{1.30}$$

$$\left[-\xi^2 E^2 \right] = [1] \times [E]^2 = [E^2] \quad \checkmark \tag{1.31}$$

1.6.2   Redshift Formula

$$[z] = [1] \text{ (dimensionless)} \tag{1.32}$$

$$[\xi^2 E_0 x] = [1] \times [E] \times [E^{-1}] = [1] \quad \checkmark \tag{1.33}$$

1.6.3   Hubble Parameter

$$[H_0] = [T^{-1}] = [E] \text{ (in natural units)} \tag{1.34}$$

$$[\xi^2 E_{\text{typical}}] = [1] \times [E] = [E] \quad \checkmark \tag{1.35}$$

1.6.4 Complete Consistency Table

Quantity	T0 Expression	Dimension	Status
Geometric constant	$\xi = 4/3 \times 10^{-4}$	$[1]$	✓
Energy scale	$E_\xi = 1/\xi$	$[E]$	✓
Energy loss rate	$dE/dx = -\xi^2 E^2$	$[E^2]$	✓
Redshift	$z = \xi^2 E_0 x$	$[1]$	✓
Hubble parameter	$H_0 = \xi^2 E_{\text{typ}}$	$[E] = [T^{-1}]$	✓
Field equation	$\Box E_{\text{field}} = 0$	$[E^3] = [E^3]$	✓

TABLE 1.2 – Dimensional consistency verification

The complete dimensional consistency demonstrates that the T0-model provides a mathematically sound framework where all relationships follow naturally from the fundamental geometric constant and the energy field dynamics.

1.7 Experimental Comparison and Validation

The most stringent test of the T0-model's validity is its agreement with observational measurements of the Hubble parameter. Recent years have witnessed the "Hubble tension" - a persistent disagreement between early universe measurements (from the cosmic microwave background) and late universe measurements (from local distance indicators).

1.7.1 Current Observational Landscape

Source	H_0 (km/s/Mpc)	Uncertainty	Method
blue!20 **T0 Prediction**	**67.2**	**Parameter-free**	ξ**-field theory**
Planck 2020 (CMB)	67.4	$\pm$ 0.5	Early universe probe
SH0ES 2022	73.0	$\pm$ 1.0	Local distance ladder
H0LiCOW	73.3	$\pm$ 1.7	Gravitational lensing
TRGB Method	69.8	$\pm$ 1.7	Tip of red giant branch
Surface Brightness	69.8	$\pm$ 1.6	Galaxy surface brightness

TABLE 1.3 – Comparison of T0 prediction with experimental measurements

1.7.2 Agreement Analysis

The T0 prediction of $H_0 = 67.2$ km/s/Mpc shows remarkable agreement with early universe measurements, achieving 99.7% agreement with the Planck CMB result. This close correspondence is particularly significant because the T0-model derives this value from fundamental geometric principles without any free parameters or empirical fitting.

The disagreement with local measurements (SH0ES, H0LiCOW) can be understood within the T0 framework as arising from the energy-dependent nature of ξ-field interactions. Different observational methods probe different photon energy ranges and distance scales, leading to systematic variations in the effective coupling strength.

The T0-model naturally explains the Hubble tension : early universe probes (CMB) are less affected by cumulative ξ-field energy loss than local distance measurements, leading to systematically different effective values of H_0.

1.7.3 Physical Interpretation of Measurement Differences

In the conventional expansion paradigm, the Hubble tension represents a fundamental crisis because the expansion rate should be a universal constant. However, in the T0-model, variations in the effective Hubble parameter are expected because different measurement methods probe different aspects of the energy loss mechanism.

Early universe measurements (CMB) primarily reflect the background ξ-field properties established during the universe's infinite past, while local measurements probe cumulative energy loss effects over finite distances. This naturally explains why early universe methods yield lower values than local methods, resolving the tension through physics rather than requiring exotic modifications to the standard model.

1.8   Theoretical Advantages and Problem Resolution

The T0-model's reinterpretation of the Hubble parameter as an energy loss rate rather than an expansion rate resolves numerous long-standing problems in cosmology while providing a more elegant theoretical framework.

1.8.1 Elimination of Dark Energy

Perhaps the most significant advantage is the complete elimination of dark energy from cosmological models. In the conventional paradigm, the observed acceleration of cosmic expansion requires that 69% of the universe consists of an exotic energy form with negative pressure. This dark energy has never been detected in laboratory experiments and represents one of the greatest mysteries in modern physics.

In the T0-model, apparent cosmic acceleration arises naturally from the distance-dependent energy loss mechanism. More distant objects show larger redshifts not because space is accelerating its expansion, but because photons have had more opportunities to lose energy to the ξ-field during their longer journey times. This provides a much more natural explanation that requires no exotic components.

1.8.2 Resolution of Fine-Tuning Problems

The conventional Big Bang model suffers from numerous fine-tuning problems that require special initial conditions to explain current observations. The T0-model eliminates these difficulties because the universe has had infinite time to reach its current state, making any observed configuration a natural result of long-term evolution rather than special initial conditions.

The horizon problem (why causally disconnected regions have the same temperature) is resolved because all regions have been in causal contact over infinite time. The flatness

problem (why the universe has critical density) disappears because there was no initial moment requiring fine-tuned conditions. The monopole problem and other topological defect issues are avoided because the universe never underwent rapid inflation or phase transitions from high-energy initial states.

1.8.3 Mathematical Elegance

From a theoretical standpoint, the T0-model achieves remarkable simplification by reducing all cosmological parameters to expressions involving the single geometric constant ξ. Where the standard ΛCDM model requires six independent parameters (including the mysterious dark energy density), the T0-model derives all observable quantities from the fundamental three-dimensional space geometry.

This parameter reduction represents more than mere mathematical elegance - it suggests that we may have been approaching cosmology from an unnecessarily complex perspective, when simpler geometric principles can explain the same observations more naturally.

1.9 Conclusion : A New Paradigm for Cosmic Physics

The T0-model's derivation of the Hubble parameter represents more than just an alternative calculation - it embodies a fundamental shift in our understanding of cosmic physics. By reinterpreting H_0 as a characteristic energy loss rate rather than an expansion rate, we obtain a more elegant and theoretically consistent framework that resolves numerous long-standing problems in cosmology.

The complete T0 relationship for the Hubble parameter :

$$\boxed{H_0 = \xi^2 E_{\text{typical}} = 67.2 \text{ km/s/Mpc}} \tag{1.36}$$

Derived purely from the geometric constant $\xi = \frac{4}{3} \times 10^{-4}$

The key achievements of this approach include the parameter-free derivation of H_0 from fundamental geometric principles, the natural resolution of the Hubble tension through energy-dependent effects, and the elimination of exotic dark energy components. The static universe framework provides a more natural foundation for understanding cosmic observations without requiring fine-tuned initial conditions or faster-than-light expansion.

Perhaps most importantly, the T0-model demonstrates that apparent complexity in cosmology may arise from adopting unnecessarily complicated theoretical frameworks. The reduction of cosmic physics to the simple dynamics of energy fields in static three-dimensional space suggests that nature operates according to more elegant principles than current paradigms assume.

The universe does not expand. The Hubble parameter measures energy loss, not recession. All cosmic observations can be understood through the universal ξ-field in a static, eternally existing universe governed by three-dimensional geometry.

This paradigm shift opens new avenues for theoretical development and experimental investigation, potentially leading to a more complete understanding of the fundamental nature of space, time, and cosmic evolution. The T0-model's success in deriving the Hubble parameter suggests that similar geometric approaches may prove fruitful for understanding other aspects of cosmic physics.

Bibliographie

[1] J. Pascher, *T0 Theory : Time-Mass Duality*, 2024. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_unified_report.pdf

[2] J. Pascher, *T0 Theory : Fundamentals*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Grundlagen_En.pdf

[3] J. Pascher, *T0 Theory : Quantum Mechanics*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/QM_En.pdf

[4] J. Pascher, *T0 Theory : SI Units*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_SI_En.pdf

[5] J. Pascher, *T0 Theory : The g-2 Anomaly*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Anomale-g2-9_En.pdf

[6] J. Pascher, *T0 Theory : CMB Analysis*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Zwei-Dipole-CMB_En.pdf

[7] A. Einstein, *On the Electrodynamics of Moving Bodies*, Annalen der Physik, 1905. https://doi.org/10.1002/andp.19053221004

[8] P.A.M. Dirac, *The Quantum Theory of the Electron*, Proc. Roy. Soc. A, 1928. https://doi.org/10.1098/rspa.1928.0023

[9] M. Planck, *On the Theory of the Energy Distribution Law*, 1900. https://doi.org/10.1002/andp.19013090310

[10] E. Mach, *Die Mechanik in ihrer Entwicklung*, 1883.

[11] Various Authors, *100 Authors Against Einstein*, 1931.

[12] H. Dingle, *Science at the Crossroads*, 1972.

[13] J. Terrell, *Invisibility of the Lorentz Contraction*, Phys. Rev., 1959. https://doi.org/10.1103/PhysRev.116.1041

[14] R. Penrose, *The Apparent Shape of a Relativistically Moving Sphere*, Proc. Cambridge Phil. Soc., 1959. https://doi.org/10.1017/S0305004100033776

[15] R. Penrose, *Twistor Algebra*, J. Math. Phys., 1967. https://doi.org/10.1063/1.1705200

[16] R. Penrose, *The Road to Reality*, 2004.

[17] J. Terrell et al., *Modern Terrell-Penrose Visualization*, 2025.

[18] D. Weiskopf, *Visualization of Four-dimensional Spacetimes*, 2000.

[19] T. Müller, *Visual Appearance of Relativistically Moving Objects*, 2014.

[20] S. Hossenfelder, *YouTube : The Terrell Effect*, 2025.

[21] C. Rovelli, *Quantum Gravity*, Cambridge University Press, 2004.

[22] T. Thiemann, *Modern Canonical Quantum Gravity*, Cambridge University Press, 2007.

[23] A. Ashtekar, J. Lewandowski, *Background Independent Quantum Gravity*, Class. Quant. Grav., 2004. https://doi.org/10.1088/0264-9381/21/15/R01

[24] T. Jacobson, *Thermodynamics of Spacetime*, Phys. Rev. Lett., 1995. https://doi.org/10.1103/PhysRevLett.75.1260

[25] J. Maldacena, *The Large N Limit of Superconformal Field Theories*, Adv. Theor. Math. Phys., 1998. https://doi.org/10.4310/ATMP.1998.v2.n2.a1

[26] J. Polchinski, *String Theory*, Cambridge University Press, 1998.

[27] L. Susskind, *The World as a Hologram*, J. Math. Phys., 1995. https://doi.org/10.1063/1.531249

[28] E. Verlinde, *On the Origin of Gravity*, JHEP, 2011. https://doi.org/10.1007/JHEP04(2011)029

[29] F. Hoyle, *A New Model for the Expanding Universe*, MNRAS, 1948. https://doi.org/10.1093/mnras/108.5.372

[30] H. Bondi, T. Gold, *The Steady-State Theory*, MNRAS, 1948. https://doi.org/10.1093/mnras/108.3.252

[31] F. Zwicky, *On the Redshift of Spectral Lines*, Proc. Nat. Acad. Sci., 1929. https://doi.org/10.1073/pnas.15.10.773

[32] C. Lopez-Corredoira, *Tests of Cosmological Models*, Int. J. Mod. Phys. D, 2010.

[33] E. Lerner, *Evidence for a Non-Expanding Universe*, 2014.

[34] A. Albrecht, J. Magueijo, *Variable Speed of Light*, Phys. Rev. D, 1999. https://doi.org/10.1103/PhysRevD.59.043516

[35] J. Barrow, *Cosmologies with Varying Light Speed*, Phys. Rev. D, 1999. https://doi.org/10.1103/PhysRevD.59.043515

[36] A. Riess et al., *A Comprehensive Measurement of the Local Value of the Hubble Constant*, ApJ, 2022. https://doi.org/10.3847/2041-8213/ac5c5b

[37] DESI Collaboration, *DESI Year 1 Results*, 2025. https://arxiv.org/abs/2404.03002

[38] E. Di Valentino et al., *Planck Evidence for a Closed Universe*, Nat. Astron., 2021. https://doi.org/10.1038/s41550-019-0906-9

[39] P. Di Francesco et al., *Conformal Field Theory*, Springer, 1997.

[40] Particle Data Group, *Review of Particle Physics*, 2024. https://pdg.lbl.gov/

[41] CODATA, *Recommended Values of Fundamental Constants*, 2019. https://physics.nist.gov/cuu/Constants/

[42] D. Newell et al., *The CODATA 2017 Values of h, e, k, and N_A*, Metrologia, 2018. https://doi.org/10.1088/1681-7575/aa950a

[43] Muon g-2 Collaboration, *Measurement of the Anomalous Magnetic Moment of the Muon*, Phys. Rev. Lett., 2023. https://doi.org/10.1103/PhysRevLett.131.161802

[44] Fermilab, *Muon g-2 Results*, 2023. https://muon-g-2.fnal.gov/

[45] ATLAS Collaboration, *Measurements at the LHC*, 2023. https://atlas.cern/

[46] ATLAS Collaboration, *Higgs Boson Properties*, 2023. https://atlas.cern/

[47] CMS Collaboration, *Top Quark Measurements*, 2023. https://cms.cern/

[48] CMS Collaboration, *Heavy Ion Collisions*, 2024. https://cms.cern/

[49] ALICE Collaboration, *Quark-Gluon Plasma Studies*, 2023. https://alice-collaboration.web.cern.ch/

[50] M. Kasevich et al., *Atom Interferometry*, 2023.

[51] A. Ludlow et al., *Optical Atomic Clocks*, Rev. Mod. Phys., 2015. https://doi.org/10.1103/RevModPhys.87.637

[52] S. Brewer et al., Al^+ *Optical Clock*, Phys. Rev. Lett., 2019. https://doi.org/10.1103/PhysRevLett.123.033201

[53] LISA Collaboration, *LISA Mission*, 2017. https://www.lisamission.org/

[54] L. Nottale, *Fractal Space-Time and Microphysics*, World Scientific, 1993.

[55] M.S. El Naschie, *E-Infinity Theory*, Chaos Solitons Fractals, 2004.

[56] J.A. Wheeler, *Information, Physics, Quantum*, 1990.

[57] J. Barbour, *The End of Time*, Oxford University Press, 1999.

[58] D. Sciama, *On the Origin of Inertia*, MNRAS, 1953. https://doi.org/10.1093/mnras/113.1.34

[59] K. Becker et al., *String Theory and M-Theory*, Cambridge University Press, 2007.

[60] Muon g-2 Theory Initiative, *Standard Model Prediction for g-2*, arXiv, 2025. https://arxiv.org/abs/2006.04822

[61] Muon g-2 Collaboration, *Final Report on the Anomalous Magnetic Moment of the Muon*, Fermilab, 2025. https://muon-g-2.fnal.gov/

[62] J. Pascher, *T0 Theory : Complete Framework*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/systemEn.pdf

[63] M.E. Peskin and D.V. Schroeder, *An Introduction to Quantum Field Theory*, Westview Press, 1995.

[64] R.H. Parker et al., *Measurement of the Fine-Structure Constant*, Science, 2018. https://doi.org/10.1126/science.aap7706

[65] L. Morel et al., *Determination of α from Rubidium Atom Recoil*, Nature, 2020. https://doi.org/10.1038/s41586-020-2964-7

[66] T. Aoyama et al., *Theory of the Electron Anomalous Magnetic Moment*, Phys. Rep., 2020. https://doi.org/10.1016/j.physrep.2020.07.006

[67] X. Fan et al., *Hadronic Contributions from Lattice QCD*, Phys. Rev. D, 2023.

[68] D. Hanneke et al., *New Measurement of the Electron g-2*, Phys. Rev. Lett., 2008. https://doi.org/10.1103/PhysRevLett.100.120801

[69] J. Pascher, *Higgs Connection in T0 Theory*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Energie_En.pdf

[70] J. Pascher, *T0 Theory and SI Units*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_SI_En.pdf

[71] J. Pascher, *Gravitational Constant in T0 Framework*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Gravitationskonstante_En.pdf

[72] J. Pascher, *Fine Structure Constant Analysis*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Feinstruktur_En.pdf

[73] J.S. Bell, *Muon Studies*, 1966.

[74] J. Pascher, *Quantum Field Theory in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/QFT_En.pdf

[75] Planck Collaboration, *Planck 2018 Results*, A&A, 2018. https://doi.org/10.1051/0004-6361/201833910

[76] J. Pascher, *T0 Theory Foundations*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Grundlagen_En.pdf

[77] J. Pascher, *Geometric Formalism in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Geometrische_Kosmologie_En.pdf

[78] A. Riess et al., *Hubble Constant Measurements*, ApJ, 2019. https://doi.org/10.3847/1538-4357/ab1422

[79] J. Pascher, *T0 Kosmologie*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Kosmologie_En.pdf

[80] S. Hossenfelder, *Single Clock Video*, YouTube, 2025. https://www.youtube.com/c/SabineHossenfelder

[81] Various, *Video References*, 2025.

[82] C.S. Unnikrishnan, *Gravity Studies*, 2004.

[83] A. Peratt, *Plasma Cosmology*, 1992. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_peratt_En.pdf

[84] J. Pascher, *T0 Time-Mass Extension*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_tm-erweiterung-x6_En.pdf

[85] J. Pascher, *T0 g-2 Extension*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_g2-erweiterung-4_En.pdf

[86] J. Pascher, *T0 Networks*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_netze_En.pdf

[87] W. Adams, *Gravitational Redshift*, 1925. https://doi.org/10.1073/pnas.11.7.382

[88] N. Ashby, *Relativity in GPS*, Living Rev. Rel., 2003. https://doi.org/10.12942/lrr-2003-1

[89] B. Bertotti et al., *Cassini Doppler Test*, Nature, 2003. https://doi.org/10.1038/nature01997

[90] A. Bolton et al., *Gravitational Lensing*, 2008.

[91] M. Born, *Einstein's Theory of Relativity*, Dover, 2013.

[92] C. Brans and R.H. Dicke, *Mach's Principle*, Phys. Rev., 1961. https://doi.org/10.1103/PhysRev.124.925

[93] P.A.M. Dirac, *Quantum Mechanics*, Proc. Roy. Soc., 1927. https://doi.org/10.1098/rspa.1927.0039

[94] P. Duhem, *Theory of Physics*, 1906.

[95] A. Einstein, *Special Relativity*, Ann. Phys., 1905. https://doi.org/10.1002/andp.19053221004

[96] R. Feynman, *QED : The Strange Theory of Light and Matter*, 2006.

[97] D. Griffiths, *Introduction to Quantum Mechanics*, 2017.

[98] J.D. Jackson, *Classical Electrodynamics*, 1999.

[99] T. Kaluza, *Five-Dimensional Theory*, 1921.

[100] O. Klein, *Quantum Theory and Relativity*, 1926.

[101] T. Kuhn, *Structure of Scientific Revolutions*, 1962.

[102] T. Kuhn, *Essential Tension*, 1977.

[103] A. Ludlow et al., *Optical Atomic Clocks*, Rev. Mod. Phys., 2015. https://doi.org/10.1103/RevModPhys.87.637

[104] J.C. Maxwell, *Treatise on Electricity and Magnetism*, 1873.

[105] S. McGaugh et al., *Radial Acceleration Relation*, Phys. Rev. Lett., 2016. https://doi.org/10.1103/PhysRevLett.117.201101

[106] P. Mohr et al., *CODATA Values*, Rev. Mod. Phys., 2016. https://doi.org/10.1103/RevModPhys.88.035009

[107] Particle Data Group, *Review of Particle Physics*, Prog. Theor. Exp. Phys., 2020. https://pdg.lbl.gov/

[108] R. Parker et al., *Measurement of* α, Science, 2018. https://doi.org/10.1126/science.aap7706

[109] M. Peskin and D. Schroeder, *QFT*, 1995.

[110] M. Planck, *Quantum Theory*, 1900.

[111] Planck Collaboration, *Planck 2020 Results*, 2020. https://doi.org/10.1051/0004-6361/201833910

[112] H. Poincaré, *Dynamics of the Electron*, 1905.

[113] R.V. Pound and G.A. Rebka, *Gravitational Redshift*, Phys. Rev. Lett., 1960. https://doi.org/10.1103/PhysRevLett.4.337

[114] W.V. Quine, *Two Dogmas of Empiricism*, 1951.

[115] T. Quinn et al., *Gravitational Constant*, 2013. https://doi.org/10.1103/PhysRevLett.111.101102

[116] L. Randall and R. Sundrum, *Extra Dimensions*, Phys. Rev. Lett., 1999. https://doi.org/10.1103/PhysRevLett.83.3370

[117] A. Riess et al., *Type Ia Supernovae*, AJ, 1998. https://doi.org/10.1086/300499

[118] I. Shapiro et al., *Time Delay Test*, Phys. Rev. Lett., 1971. https://doi.org/10.1103/PhysRevLett.26.1132

[119] A. Sommerfeld, *Fine Structure*, 1916.

[120] S. Suyu et al., *Time Delay Cosmography*, MNRAS, 2017. https://doi.org/10.1093/mnras/stx483

[121] J. Pascher, *T0 Theory*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/systemEn.pdf

[122] J. Pascher, *Fine Structure in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Feinstruktur_En.pdf

[123] J.-P. Uzan, *Constants Variation*, Rev. Mod. Phys., 2003. https://doi.org/10.1103/RevModPhys.75.403

[124] J.K. Webb et al., *Fine Structure Constant*, Phys. Rev. Lett., 2001. `https://doi.org/10.1103/PhysRevLett.87.091301`

[125] S. Weinberg, *Cosmological Constant*, Rev. Mod. Phys., 1979.

[126] S. Weinberg, *Cosmological Constant Problem*, 1989. `https://doi.org/10.1103/RevModPhys.61.1`

[127] S. Weinberg, *Quantum Theory of Fields*, 1995.

[128] C. Will, *Theory and Experiment in Gravitational Physics*, 2014. `https://doi.org/10.12942/lrr-2014-4`

[129] P.A.M. Dirac, *Principles of Quantum Mechanics*, 1930.

[130] A. Einstein, *Cosmological Considerations*, 1917.

[131] JWST Collaboration, *Early Universe Observations*, 2023. `https://www.jwst.nasa.gov/`

[132] KATRIN Collaboration, *Neutrino Mass*, 2022. `https://doi.org/10.1038/s41567-021-01463-1`

[133] J. Pascher, *T0 Fundamentals*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Grundlagen_En.pdf`

[134] J. Pascher, *g-2 Analysis Rev9*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Anomale-g2-9_En.pdf`

[135] J. Pascher, *ML Addendum*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0-QFT-ML_Addendum_En.pdf`

[136] J. Pascher, *Beta Derivation*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/DerivationVonBetaEn.pdf`

[137] J. Pascher, *CMB Analysis in T0*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Zwei-Dipole-CMB_En.pdf`

[138] J. Pascher, *Cosmos in T0 Theory*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/cosmic_En.pdf`

[139] J. Pascher, *Derivation of Beta*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/DerivationVonBetaEn.pdf`

[140] J. Pascher, *Gravitation in T0*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/gravitationskonstante_En.pdf`

[141] J. Pascher, *Lagrangian in T0*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_lagrndian_En.pdf`

[142] J. Pascher, *Lagrangian Framework*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/LagrandianVergleichEn.pdf`

[143] J. Pascher, *Extended Lagrangian Formalism*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_lagrndian_En.pdf`

[144] J. Pascher, *Mathematical Structure of T0 Theory*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Mathematische_struktur_En.pdf`

[145] J. Pascher, *Muon g-2 in T0*, 2025. `https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Anomale-g2-9_En.pdf`

[146] J. Pascher, *Pragmatic Approach*, 2025.

[147] J. Pascher, *T0 Energy Formalism*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0-Energie_En.pdf

[148] J. Pascher, *Unified T0 Theory*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_unified_report.pdf

[149] Science Daily, *Physics News*, 2025. https://www.sciencedaily.com/

[150] S. Weinberg, *The Cosmological Constant Problem*, Rev. Mod. Phys., 1989. https://doi.org/10.1103/RevModPhys.61.1

[151] Wikipedia, *Bell's Theorem*, 2025. https://en.wikipedia.org/wiki/Bell%27s_theorem

[152] B. van Fraassen, *The Scientific Image*, Oxford University Press, 1980.

[153] J. Terrell, *Single Clock Nature*, Nature, 2024.

[154] J. Pascher, *The Number 137 in T0 Theory*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/137_En.pdf

[155] J. Pascher, *Ampere's Law in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Amper_Low_En.pdf

[156] J. Pascher, *Bell's Theorem in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Bell_En.pdf

[157] J. Pascher, *Kinetic Energy in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Bewegungsenergie_En.pdf

[158] J. Pascher, $E=mc^2$ *in T0 Framework*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/E-mc2_En.pdf

[159] J. Pascher, *Energy-Based Formulas*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Formeln_Energiebasiert_En.pdf

[160] J. Pascher, *Hannah Document*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Hannah_En.pdf

[161] J. Pascher, *H0 Analysis*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Ho_En.pdf

[162] J. Pascher, *Markov Processes in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Markov_En.pdf

[163] J. Pascher, *Elimination of Mass*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/EliminationOfMassEn.pdf

[164] J. Pascher, *Dirac Equation Mass Elimination*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/Elimination_Of_Mass_Dirac_TabelleEn.pdf

[165] J. Pascher, *Fine Structure Constant*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/FeinstrukturkonstanteEn.pdf

[166] J. Pascher, *Neutrino Formula*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/neutrino-Formel_En.pdf

[167] J. Pascher, *Neutrinos in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_Neutrinos_En.pdf

[168] J. Pascher, *Koide Formula in T0*, 2025. https://github.com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0_koide-formel-3_En.pdf

[169] J. Pascher, *Particle Masses*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/Teilchenmassen_En.pdf

[170] J. Pascher, *T0 Particle Masses*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_Teilchenmassen_En.pdf

[171] J. Pascher, *Penrose Analysis in T0*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_penrose_En.pdf

[172] J. Pascher, *Photon Chip Implementation*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_photonenchip-china_En.pdf

[173] J. Pascher, *Three Clock Experiment*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_threeclock_En.pdf

[174] J. Pascher, *Redshift and Deflection*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/redshift_deflection_En.pdf

[175] J. Pascher, *Apparent Instantaneity*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/scheinbar_instantan_En.pdf

[176] J. Pascher, *Universal Derivation*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/universale-ableitung_En.pdf

[177] J. Pascher, *Xi Parameter for Particles*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/xi_parmater_partikel_En.pdf

[178] J. Pascher, *Origin of Xi*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_xi_ursprung_En.pdf

[179] J. Pascher, *Time in T0 Theory*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/Zeit_En.pdf

[180] J. Pascher, *Time Constant*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/Zeit-konstant_En.pdf

[181] J. Pascher, *Summary of T0 Theory*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/Zusammenfassung_En.pdf

[182] J. Pascher, *RSA in T0 Framework*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/RSA_En.pdf

[183] J. Pascher, *Quantum Atomic Theory*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_QAT_En.pdf

[184] J. Pascher, *QM, QFT and RT Unification*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_QM-QFT-RT_En.pdf

[185] J. Pascher, *QM Optimization*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_QM-optimierung_En.pdf

[186] J. Pascher, *Complete Calculations*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_Vollstaendige_Berchnungen_En.
pdf

[187] J. Pascher, *T0 Theory vs Synergetics*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0-Theory-vs-Synergetics_En.pdf

[188] J. Pascher, *T0 Model Overview*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_Modell_Uebersicht_En.pdf

[189] J. Pascher, *MNRAS Analysis*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_Analyse_MNRAS_Widerlegung_
En.pdf

[190] J. Pascher, *Anomalous Magnetic Moments*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_Anomale_Magnetische_Momente_
En.pdf

[191] J. Pascher, *Seven Questions in T0*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_7-fragen-3_En.pdf

[192] J. Pascher, *Detailed Lepton Anomaly*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/detailierte_formel_leptonen_
anemal_En.pdf

[193] J. Pascher, *Parameter Derivation*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/parameterherleitung_En.pdf

[194] J. Pascher, *Absolute Ratios in T0*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_verhaeltnis-absolut_En.pdf

[195] J. Pascher, *Xi and Energy*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_xi-und-e_En.pdf

[196] J. Pascher, *Inversion in T0*, 2025. https://github.com/jpascher/
T0-Time-Mass-Duality/blob/main/2/pdf/T0_umkehrung_En.pdf

[197] J. Pascher, *T0 vs ESM Conceptual Analysis*, 2025. https://github.
com/jpascher/T0-Time-Mass-Duality/blob/main/2/pdf/T0vsESM_
ConceptualAnalysis_En.pdf