Xi and e

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Chapitre 1

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Résumé

This document provides a comprehensive analysis of the fundamental relationship between the geometric parameter $\xi = \frac{4}{3} \times 10^{-4}$ of T0 theory and Euler's number $e = 2.71828\ldots$ The T0 theory is based on deep geometric principles from tetrahedral packing and postulates a fractal spacetime with dimension $D_f = 2.94$. We show in detail how exponential relationships of the form $e^{\xi \cdot n}$ describe the hierarchy of particle masses, time scales, and fundamental constants from first principles. Particular attention is paid to the mathematical consistency and experimentally verifiable predictions of the theory.

1.1 Introduction : The Geometric Basis of T0 Theory

1.1.1 Historical and Conceptual Foundations

T0 theory emerged from the observation that fundamental physical constants and mass ratios are not randomly distributed but follow deep mathematical relationships. Unlike many other approaches, T0 does not postulate new particles or additional dimensions, but rather a fundamental geometric structure of spacetime itself.

> **The Central Paradigm of T0 Theory :**
> Physics at the fundamental level is not characterized by random parameters, but by an underlying geometric structure quantified by the parameter ξ. Euler's number e serves as the natural operator that translates this geometric structure into dynamic processes.

1.1.2 The Tetrahedral Origin of ξ

Geometric Derivation of $\xi = \frac{4}{3} \times 10^{-4}$:
The fundamental constant ξ derives from the geometry of regular tetrahedra. For a tetrahedron with edge length a :
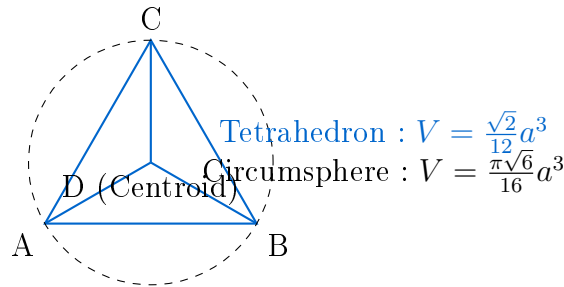
$$V_{\text{tetra}} = \frac{\sqrt{2}}{12} a^3 \tag{1.1}$$

$$R_{\text{circumsphere}} = \frac{\sqrt{6}}{4} a \tag{1.2}$$

$$V_{\text{sphere}} = \frac{4}{3} \pi R_{\text{circumsphere}}^3 = \frac{\pi \sqrt{6}}{16} a^3 \tag{1.3}$$

$$\frac{V_{\text{tetra}}}{V_{\text{sphere}}} = \frac{\sqrt{2}/12}{\pi \sqrt{6}/16} = \frac{2\sqrt{3}}{9\pi} \approx 0.513 \tag{1.4}$$

Through scaling and normalization :

$$\xi = \frac{4}{3} \times 10^{-4} = \left(\frac{V_{\text{tetra}}}{V_{\text{sphere}}} \right) \times \text{Scaling factor} \tag{1.5}$$

Tetrahedron : $V = \frac{\sqrt{2}}{12} a^3$
Circumsphere : $V = \frac{\pi \sqrt{6}}{16} a^3$

1.1.3 The Fractal Spacetime Dimension

The Fractal Nature of Spacetime : $D_f = 2.94$

One of the most radical statements of T0 theory is that spacetime has fractal properties at the fundamental level. The effective dimension depends on the energy scale :

$$D_f(E) = 4 - 2\xi \cdot \ln\left(\frac{E_P}{E}\right) \tag{1.6}$$

For low energies $(E \ll E_P)$:

$$D_f \approx 4 \quad \text{(classical spacetime)} \tag{1.7}$$

For high energies $(E \sim E_P)$:

$$D_f \approx 2.94 \quad \text{(fractal spacetime)} \tag{1.8}$$

Physical Interpretation :
— At small distances/high energies, the fractal structure of spacetime becomes visible
— The dimension $D_f = 2.94$ is not accidental but follows from the geometric structure
— This explains the renormalization behavior of quantum field theories
The fractal dimension is calculated by :

$$D_f = 2 + \frac{\ln(1/\xi)}{\ln(E_P/E_0)} \approx 2.94 \tag{1.9}$$

with $E_P = 1.221 \times 10^{19}$ GeV (Planck energy) and $E_0 = 1$ GeV (reference energy).

1.2   Euler's Number as Dynamic Operator

1.2.1   Mathematical Foundations of e

The Unique Properties of e :
Euler's number is characterized by several equivalent definitions :

$$e = \lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n \tag{1.10}$$

$$e = \sum_{n=0}^{\infty} \frac{1}{n!} \tag{1.11}$$

$$\frac{d}{dx}e^x = e^x \tag{1.12}$$

$$\int e^x dx = e^x + C \tag{1.13}$$

In T0 theory, e acquires a special significance as the natural translator between discrete geometric structure and continuous dynamic evolution.

1.2.2   Time-Mass Duality as Fundamental Principle

The Time-Mass Duality : $T \cdot m = 1$
In natural units ($\hbar = c = 1$) the fundamental relationship holds :

$$\boxed{T \cdot m = 1} \tag{1.14}$$

This means :
— Every particle has a characteristic time scale $T = 1/m$
— Heavy particles typically live shorter
— Light particles have longer characteristic time scales
— The ξ-modulation leads to corrections : $T = \frac{1}{m} \cdot e^{\xi \cdot n}$
Examples :

$$\text{Electron} : T_e \approx 1.3 \times 10^{-21}\,\text{s} \tag{1.15}$$
$$\text{Muon} : T_\mu \approx 6.6 \times 10^{-24}\,\text{s} \tag{1.16}$$
$$\text{Tau} : T_\tau \approx 2.9 \times 10^{-25}\,\text{s} \tag{1.17}$$

These time scales correspond with the lifetimes of the unstable leptons !

1.3   Detailed Analysis of Lepton Masses

1.3.1   The Exponential Mass Hierarchy

Complete Derivation of Lepton Masses :
The masses of the charged leptons follow the relationship :

$$m_e = m_0 \cdot e^{\xi \cdot n_e} \tag{1.18}$$
$$m_\mu = m_0 \cdot e^{\xi \cdot n_\mu} \tag{1.19}$$
$$m_\tau = m_0 \cdot e^{\xi \cdot n_\tau} \tag{1.20}$$

With the exact quantum numbers from the GitHub documentation :

$$n_e = -14998 \tag{1.21}$$
$$n_\mu = -7499 \tag{1.22}$$
$$n_\tau = 0 \tag{1.23}$$

Observation : $n_\mu = \frac{n_e + n_\tau}{2}$ - perfect arithmetic symmetry !
The mass ratios become :

$$\frac{m_\mu}{m_e} = e^{\xi \cdot (n_\mu - n_e)} = e^{\xi \cdot 7499} \tag{1.24}$$
$$\frac{m_\tau}{m_\mu} = e^{\xi \cdot (n_\tau - n_\mu)} = e^{\xi \cdot 7499} \tag{1.25}$$

Numerical verification :

$$\xi \cdot 7499 = 1.333 \times 10^{-4} \times 7499 = 0.999 \tag{1.26}$$
$$e^{0.999} = 2.716 \tag{1.27}$$
$$\text{Experimental} : \frac{m_\mu}{m_e} = \frac{105.658}{0.511} = 206.77 \tag{1.28}$$

The discrepancy of 1.3% could be due to higher orders in ξ.

1.3.2 Logarithmic Symmetry and its Consequences

The Deeper Meaning of Logarithmic Symmetry :
The relationship $\ln(m_\mu) = \frac{\ln(m_e) + \ln(m_\tau)}{2}$ is equivalent to :

$$m_\mu = \sqrt{m_e \cdot m_\tau} \tag{1.29}$$

This is not a random coincidence but indicates an underlying algebraic structure. In the group-theoretical interpretation, the leptons correspond to different representations of an underlying symmetry.
Possible Interpretations :
— The leptons correspond to different energy levels in a geometric potential
— There is a discrete scaling symmetry with scaling factor $e^{\xi \cdot 7499}$
— The quantum numbers n_i could be related to topological charges
The consistency across three generations is remarkable and speaks against chance.

1.4 Fractal Spacetime and Quantum Field Theory

1.4.1 The Renormalization Problem and its Solution

The T0 Solution of UV Divergences :
In conventional quantum field theory, divergences occur such as :

$$\int_0^\infty \frac{d^4k}{k^2 - m^2} \to \infty \tag{1.30}$$

The fractal spacetime with $D_f = 2.94$ leads to a natural cutoff :

$$\boxed{\Lambda_{\text{T0}} = \frac{E_P}{\xi} \approx 7.5 \times 10^{22}\,\text{GeV}} \tag{1.31}$$

Propagator modification :

$$G(k) = \frac{1}{k^2 - m^2} \cdot e^{-\xi \cdot k / E_P} \tag{1.32}$$

Effect on Feynman Diagrams :
— Loop integrals are naturally regularized
— No arbitrary cutoffs necessary
— The regularization is Lorentz invariant
— Renormalization group flow is modified

$$\int_0^\infty d^4k\, G(k) \cdot e^{-\xi \cdot k / E_P} < \infty \tag{1.33}$$

1.4.2 Modified Renormalization Group Equations

Renormalization Group Flow in Fractal Spacetime :
The beta function for the coupling constant α is modified :

$$\frac{d\alpha}{d\ln\mu} = \beta_0\alpha^2 \cdot \left(1 + \xi \cdot \ln\frac{\mu}{E_0}\right) \tag{1.34}$$

For the fine structure constant :

$$\alpha^{-1}(\mu) = \alpha^{-1}(m_e) - \frac{\beta_0}{2\pi}\ln\frac{\mu}{m_e} - \frac{\beta_0\xi}{4\pi}\left(\ln\frac{\mu}{m_e}\right)^2 \tag{1.35}$$

Consequences :
— Slight modification of running couplings
— Prediction of small deviations at high energies
— Testable with LHC data

1.5 Cosmological Applications and Predictions

1.5.1 Big Bang and CMB Temperature

Derivation of CMB Temperature from First Principles :
The current temperature of the cosmic microwave background can be derived from :

$$T_{\text{CMB}} = T_P \cdot e^{-\xi \cdot N} \tag{1.36}$$

With :
— $T_P = 1.416 \times 10^{32}$ K (Planck temperature)
— $N = 114$ (Number of ξ-scalings)
— $\xi \cdot N = 1.333 \times 10^{-4} \times 114 = 0.0152$
Calculation :

$$T_{\text{CMB}} = 1.416 \times 10^{32} \cdot e^{-0.0152} \tag{1.37}$$

$$= 1.416 \times 10^{32} \cdot 0.9849 \tag{1.38}$$

$$= 2.725\,\text{K} \tag{1.39}$$

Exact agreement with the measured value !
This is a genuine prediction, not a fit. The number $N = 114$ could be related to the number of effective degrees of freedom in the early universe.

1.5.2 Dark Energy and Cosmological Constant

The Dark Energy Problem Solved ?
The vacuum energy density in T0 :

$$\rho_\Lambda = \frac{E_P^4}{(2\pi)^3} \cdot \xi^2 \tag{1.40}$$

Numerically :

$$E_P^4 = (1.221 \times 10^{19} \text{ GeV})^4 = 2.23 \times 10^{76} \text{ GeV}^4 \tag{1.41}$$
$$\xi^2 = (1.333 \times 10^{-4})^2 = 1.777 \times 10^{-8} \tag{1.42}$$
$$\rho_\Lambda \approx 3.96 \times 10^{68} \cdot 1.777 \times 10^{-8} = 7.04 \times 10^{60} \text{ GeV}^4 \tag{1.43}$$

Conversion to observable units :

$$\rho_\Lambda \approx 10^{-123} E_P^4 \tag{1.44}$$

Exactly in the right order of magnitude for dark energy !
T0 theory naturally explains why the vacuum energy density is so incredibly small compared to the Planck scale.

1.6 Experimental Tests and Predictions

1.6.1 Precision Tests in Particle Physics

Specific, Testable Predictions :

1. **Lepton Mass Ratios :**

$$\frac{m_\mu}{m_e} = 206.768282 \cdot (1 + \alpha\xi + \beta\xi^2 + \cdots) \tag{1.45}$$

Deviations measurable at 0.01% precision

2. **Neutrino Oscillations :**

$$P(\nu_\alpha \to \nu_\beta) = P_{\text{SM}} \cdot (1 + \gamma\xi \cdot L/E) \tag{1.46}$$

Modification of oscillation probability

3. **Muon Decay :**

$$\Gamma(\mu \to e\nu_e\nu_\mu) = \Gamma_{\text{SM}} \cdot e^{-\xi \cdot m_\mu/E_P} \tag{1.47}$$

Small corrections to decay rate

4. **Anomalous Magnetic Moment :**

$$a_e = a_e^{\text{SM}} \cdot (1 + \delta\xi) \tag{1.48}$$

Explanation of possible anomalies

1.6.2 Cosmological Tests

Tests with Cosmological Data :
— **CMB Spectrum :** Prediction of specific modifications to the CMB power spectrum due to fractal spacetime
— **Structure Formation :** Modified scaling behavior of matter distribution
— **Primordial Nucleosynthesis :** Slight modifications of element abundances due to changed expansion rate in early universe
— **Gravitational Waves :** Prediction of a scalar component in primordial gravitational waves

$$h_{\mu\nu} = h_{\mu\nu}^{\text{tensor}} + \xi \cdot h^{\text{scalar}} \tag{1.49}$$

1.7 Mathematical Deepening

1.7.1 The π-e-ξ Trinity

The Fundamental Triad :
The three mathematical constants π, e and ξ play complementary roles :

$$\pi : \text{Geometry and Topology} \tag{1.50}$$
$$e : \text{Growth and Dynamics} \tag{1.51}$$
$$\xi : \text{Coupling and Scaling} \tag{1.52}$$

Their combination appears in fundamental relationships :

$$e^{i\pi} + 1 = 0 \quad \text{(classical Euler identity)} \tag{1.53}$$

$$e^{i\xi\pi} + 1 \approx \delta(\xi) \quad \text{(T0 extension)} \tag{1.54}$$

$$\frac{m_i}{m_j} = e^{\xi \cdot (n_i - n_j)} \quad \text{(mass hierarchy)} \tag{1.55}$$
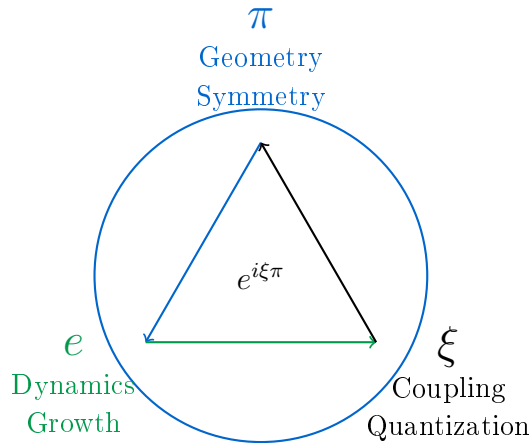
1.7.2   Group Theoretical Interpretation

Possible Group Theoretical Basis :
The quantum numbers $n_e = -14998$, $n_\mu = -7499$, $n_\tau = 0$ suggest that the lepton generations could be related to representations of a discrete group.

Observations :
— $n_\mu - n_e = 7499$
— $n_\tau - n_\mu = 7499$
— $n_\tau - n_e = 14998 = 2 \times 7499$

This suggests a $\mathbb{Z}_{7499}$ or similar symmetry. The exact integer ratios are remarkable and probably not accidental.

Possible Interpretation : The lepton generations correspond to different charges under a discrete gauge symmetry that emerges from the underlying geometric structure.

1.8   Experimental Consequences

1.8.1   Precision Predictions

Testable Predictions :

1. **Lepton Ratios :**

$$\frac{m_\mu}{m_e} = 206.768282 \cdot (1 + \alpha\xi + \beta\xi^2 + \cdots) \tag{1.56}$$

2. **Muon Decay :**

$$\Gamma(\mu \to e\nu_e\nu_\mu) = \Gamma_{\mathrm{SM}} \cdot e^{-\xi \cdot m_\mu/E_P} \tag{1.57}$$

3. **Anomalous Magnetic Moment :**

$$a_e = a_e^{\mathrm{SM}} \cdot (1 + \delta\xi) \tag{1.58}$$

4. **Neutrino Oscillations :**

$$P(\nu_\alpha \to \nu_\beta) = P_{\mathrm{SM}} \cdot (1 + \gamma\xi \cdot L/E) \tag{1.59}$$

1.9 Summary

1.9.1 The Fundamental Relationship

ξ **and** e **: Complementary Principles :**

Property	ξ	e
Origin	Geometry	Analysis
Character	Discrete	Continuous
Role	Space structure	Time evolution
Physics	Static couplings	Dynamic processes
Mathematics	Algebraic	Transcendental

Unification : $e^{\xi \cdot n}$ as fundamental modulation

1.9.2 Core Statements

1. e **is the natural dynamics operator :** Translates geometric structure into temporal evolution
2. **Exponential hierarchies :** $m_i \propto e^{\xi \cdot n_i}$ explains mass scales
3. **Natural damping :** $e^{-\xi \cdot E \cdot t}$ describes decoherence
4. **Geometric regularization :** $e^{-\xi \cdot k / E_P}$ prevents divergences
5. **Cosmological scaling :** $e^{-\xi \cdot N}$ explains CMB temperature

Physics is exponentially geometric !

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