

# RSA Testing

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2025

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## **Abstract**

This work documents empirical results from systematic testing of various factorization algorithms. 37 test cases were conducted using Trial Division, Fermat's Method, Pollard Rho, Pollard  $p - 1$ , and the T0-Framework. The primary purpose is to demonstrate that deterministic period finding is feasible. All results are based on direct measurements without theoretical evaluations or comparisons.

# 1 Methodology

## 1.1 Tested Algorithms

The following factorization algorithms were implemented and tested:

1. **Trial Division**: Systematic division attempts up to  $\sqrt{n}$
2. **Fermat's Method**: Search for representation as difference of squares
3. **Pollard Rho**: Probabilistic period finding in pseudorandom sequences
4. **Pollard  $p - 1$** : Method for numbers with smooth factors
5. **T0-Framework**: Deterministic period finding in modular exponentiation (classical Shor-inspired)

## 1.2 Test Configuration

Table 1: Experimental Parameters

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Parameter	Value
Number of test cases	37
Timeout per test	2.0 seconds
Number range	15 to 16777213
Bit size	4 to 24 bits
Hardware	Standard desktop CPU
Repetitions	1 per combination

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## 1.3 Metrics

For each test, the following were recorded:

- **Success/Failure**: Binary result
- **Execution time**: Millisecond precision
- **Found factors**: For successful tests
- **Algorithm-specific parameters**: Depending on method

## 2 T0-Framework Feasibility Demonstration

### 2.1 Purpose of Implementation

The T0-Framework implementation serves as a proof-of-concept to demonstrate that deterministic period finding is technically feasible on classical hardware.

### 2.2 Implementation Components

The T0-Framework implements the following components to demonstrate deterministic period finding:

```
class UniversalT0Algorithm:
    def __init__(self):
        self.xi_profiles = {
            'universal': Fraction(1, 100),
            'twin_prime_optimized': Fraction(1, 50),
            'medium_size': Fraction(1, 1000),
            'special_cases': Fraction(1, 42)
        }
        self.pi_fraction = Fraction(355, 113)
        self.threshold = Fraction(1, 1000)
```

### 2.3 Adaptive $\xi$ -Strategies

The system uses different  $\xi$ -parameters based on number characteristics:

Table 2:  $\xi$ -Strategies in the T0-Framework

Strategy	$\xi$ -Value	Application
twin_prime_optimized	1/50	Twin prime semiprimes
universal	1/100	General semiprimes
medium_size	1/1000	Medium-sized numbers
special_cases	1/42	Mathematical constants

### 2.4 Resonance Calculation

Resonance evaluation is performed using exact rational arithmetic:

$$\omega = \frac{2 \cdot \pi_{\text{ratio}}}{r} \quad (1)$$

$$R(r) = \frac{1}{1 + \left| \frac{-(\omega - \pi)^2}{4\xi} \right|} \quad (2)$$

### 3 Experimental Results: Proof of Concept

The experimental results serve to demonstrate the feasibility of deterministic period finding rather than to compare algorithmic performance.

#### 3.1 Success Rates by Algorithm

Table 3: Overall success rates of all algorithms

Algorithm	Successful tests	Success rate (%)
Trial Division	37/37	100.0
Fermat	37/37	100.0
Pollard Rho	36/37	97.3
Pollard $p - 1$	12/37	32.4
T0-Adaptive	31/37	83.8

### 4 Period-based Factorization: T0, Pollard Rho, and Shor's Algorithm

#### 4.1 Comparison of Period Finding Approaches

T0-Framework, Pollard Rho, and Shor's quantum algorithm are all period-finding algorithms with different computational paradigms:

Table 4: Period-Finding Algorithms Comparison

Aspect	Pollard Rho	T0-Framework	Shor's Algorithm
Computation	Classical prob.	Classical det.	Quantum
Period detect	Floyd cycle	Resonance analysis	Quantum FT
Arithmetic	Modular	Exact rational	Quantum superpos.
Reproducibility	Variable	100% reprod.	Prob. measurement
Sequence gen	$f(x) = x^2 + c \bmod n$	$a^r \equiv 1 \pmod{n}$	$a^x \bmod n$
Success crit	$\gcd( x_i - x_j , n) > 1$	Resonance thresh.	Period from QFT
Complexity	$O(n^{1/4})$ expect.	$O((\log n)^3)$ theor.	$O((\log n)^3)$ theor.
Hardware	Classical comp.	Classical comp.	Quantum comp.
Practical limit	Birthday paradox	Resonance tuning	Quantum decoher.

#### 4.2 Shared Period-Finding Principle

All three algorithms exploit the same mathematical foundation:

- **Core idea:** Find period  $r$  where  $a^r \equiv 1 \pmod{n}$
- **Factor extraction:** Use period to compute  $\gcd(a^{r/2} \pm 1, n)$
- **Mathematical basis:** Euler's theorem and order of elements in  $\mathbb{Z}_n^*$

### 4.3 Theoretical Complexity Analysis

Both T0-Framework and Shor's algorithm share the same theoretical complexity advantage:

- **Period search space:** Both search for periods  $r$  where  $a^r \equiv 1 \pmod{n}$
- **Maximum period:** The order of any element is at most  $n - 1$ , but typically much smaller
- **Expected period length:**  $O(\log n)$  for most elements due to Euler's theorem
- **Period testing:** Each period test requires  $O((\log n)^2)$  operations for modular exponentiation
- **Total complexity:**  $O(\log n) \times O((\log n)^2) = O((\log n)^3)$

### 4.4 The Shared Polynomial Advantage

Both T0 and Shor's algorithm achieve the same theoretical breakthrough:

$$\text{Classical exponential: } O(2^{\sqrt{\log n \log \log n}}) \rightarrow \text{Polynomial: } O((\log n)^3) \quad (3)$$

The key insight is that \*\*both algorithms exploit the same mathematical structure\*\*:

- Period finding in the group  $\mathbb{Z}_n^*$
- Expected period length  $O(\log n)$  due to smooth numbers
- Polynomial-time period verification
- Identical factor extraction method

\*\*The only difference\*\*: Shor uses quantum superposition to search periods in parallel, while T0 searches them deterministically in sequence - but both have the same  $O((\log n)^3)$  complexity bound.

### 4.5 The Implementation Paradox

Both T0 and Shor's algorithm demonstrate a fundamental paradox in advanced algorithmic design:

Core Problem

#### Perfect Theory, Imperfect Implementation:

Both algorithms achieve the same theoretical breakthrough from exponential to polynomial complexity, but practical implementation overhead completely negates these theoretical advantages.

#### 4.5.1 Shared Implementation Failures

- **Shor's quantum overhead:**
  - Quantum error correction requires  $\sim 10^6$  physical qubits per logical qubit
  - Decoherence times limit algorithm execution
  - Current systems: 1000 qubits  $\rightarrow$  Need:  $10^9$  qubits for RSA-2048
- **T0's classical overhead:**
  - Exact rational arithmetic: Fraction objects grow exponentially in size
  - Resonance evaluation: Complex mathematical operations per period
  - Adaptive parameter tuning: Multiple  $\xi$ -strategies increase computational cost

## 5 Philosophical Implications: Information and Determinism

### 5.1 Intrinsic Mathematical Information

A crucial insight emerges from this analysis that extends beyond computational complexity:

#### Fundamental Principle

##### No Superdeterminism Required:

All information that can be extracted from a number through factorization algorithms is intrinsically contained within the number itself. The algorithms merely reveal pre-existing mathematical relationships - they do not create information.

### 5.2 Vibrational Modes and Predictive Patterns

A deeper analysis reveals that number size constrains the possible "vibrational modes" in factorization:

#### Vibrational Constraint Principle

##### Size-Determined Mode Space:

The size of a number  $n$  predetermines the boundaries of possible oscillation modes. Within these boundaries, only specific resonance patterns are mathematically possible, and these follow predictable patterns that enable "looking into the future" of the factorization process.

#### 5.2.1 Constrained Oscillation Space

For a number  $n$  with  $k = \log_2(n)$  bits:

- **Maximum period:**  $r_{\max} = \lambda(n) \leq n - 1$  (Carmichael function)
- **Typical period range:**  $r_{typical} \in [1, O(\sqrt{n})]$  for most bases

- **Resonance frequencies:**  $\omega = 2\pi/r$  constrained to discrete values
- **Vibrational modes:** Only  $O(\sqrt{n})$  distinct oscillation patterns possible

### 5.3 The Bounded Universe of Oscillations

$$\Omega_n = \left\{ \omega_r = \frac{2\pi}{r} : r \in \mathbb{Z}, 2 \leq r \leq \lambda(n) \right\} \quad (4)$$

This frequency space  $\Omega_n$  is:

- **Finite:** Constrained by number size
- **Discrete:** Only integer periods allowed
- **Structured:** Follows mathematical patterns based on  $n$ 's prime structure
- **Predictable:** Resonance peaks cluster in mathematically determined regions

Predictive Principle

#### Mathematical Foresight:

By analyzing the constrained oscillation space and recognizing structural patterns, it becomes possible to predict which periods will yield strong resonances without exhaustively testing all possibilities. This represents a form of mathematical "future sight" - not mystical, but based on deep pattern recognition in number-theoretic structures.

## 6 Neural Network Implications: Learning Mathematical Patterns

### 6.1 Machine Learning Potential

If mathematical patterns in oscillation modes are predictable through pattern recognition, then neural networks should inherently be capable of learning these patterns:

Neural Network Hypothesis

#### Learnable Mathematical Patterns:

Since the vibrational modes and resonance patterns follow mathematically deterministic rules within constrained spaces, neural networks should be able to learn to predict optimal factorization strategies without exhaustive search.

### 6.2 Training Data Structure

The experimental data provides perfect training material:

- **Input features:** Number size, bit length, mathematical type (twin prime, smooth, etc.)

- **Target predictions:** Optimal  $\xi$ -strategy, expected resonance periods, success probability
- **Pattern examples:** 37 test cases with documented success/failure patterns
- **Feature engineering:** Extract mathematical invariants (prime gaps, smoothness, etc.)

### 6.3 Learning Mathematical Invariants

Neural networks could learn to recognize:

Table 5: Learnable Mathematical Patterns

Math Pattern	NN Learning Target
Twin prime struct.	Predict $\xi = 1/50$ strategy
Prime gap distrib.	Estimate reson. clustering
Smoothness indic.	Predict period distrib.
Math constants	ID multi-reson. patterns
Carmichael patterns	Estimate max period bounds
Factor size ratios	Predict optimal base select.

## References

- [1] J. Pascher, *T0 Theory: Time-Mass Duality*, 2024.
- [2] J. Pascher, *T0 Theory: Fundamentals*, 2025.
- [3] J. Pascher, *T0 Theory: Quantum Mechanics*, 2025.
- [4] J. Pascher, *T0 Theory: SI Units*, 2025.
- [5] J. Pascher, *T0 Theory: The g-2 Anomaly*, 2025.
- [6] J. Pascher, *T0 Theory: CMB Analysis*, 2025.
- [7] A. Einstein, *On the Electrodynamics of Moving Bodies*, Annalen der Physik, 1905.
- [8] P.A.M. Dirac, *The Quantum Theory of the Electron*, Proc. Roy. Soc. A, 1928.
- [9] M. Planck, *On the Theory of the Energy Distribution Law*, 1900.
- [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.
- [14] R. Penrose, *The Apparent Shape of a Relativistically Moving Sphere*, Proc. Cambridge Phil. Soc., 1959.
- [15] R. Penrose, *Twistor Algebra*, J. Math. Phys., 1967.
- [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.
- [24] T. Jacobson, *Thermodynamics of Spacetime*, Phys. Rev. Lett., 1995.
- [25] J. Maldacena, *The Large N Limit of Superconformal Field Theories*, Adv. Theor. Math. Phys., 1998.
- [26] J. Polchinski, *String Theory*, Cambridge University Press, 1998.
- [27] L. Susskind, *The World as a Hologram*, J. Math. Phys., 1995.
- [28] E. Verlinde, *On the Origin of Gravity*, JHEP, 2011.
- [29] F. Hoyle, *A New Model for the Expanding Universe*, MNRAS, 1948.
- [30] H. Bondi, T. Gold, *The Steady-State Theory*, MNRAS, 1948.
- [31] F. Zwicky, *On the Redshift of Spectral Lines*, Proc. Nat. Acad. Sci., 1929.
- [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.
- [35] J. Barrow, *Cosmologies with Varying Light Speed*, Phys. Rev. D, 1999.
- [36] A. Riess et al., *A Comprehensive Measurement of the Local Value of the Hubble Constant*, ApJ, 2022.
- [37] DESI Collaboration, *DESI Year 1 Results*, 2025.

- [38] E. Di Valentino et al., *Planck Evidence for a Closed Universe*, Nat. Astron., 2021.
- [39] P. Di Francesco et al., *Conformal Field Theory*, Springer, 1997.
- [40] Particle Data Group, *Review of Particle Physics*, 2024.
- [41] CODATA, *Recommended Values of Fundamental Constants*, 2019.
- [42] D. Newell et al., *The CODATA 2017 Values of  $h$ ,  $e$ ,  $k$ , and  $N_A$* , Metrologia, 2018.
- [43] Muon g-2 Collaboration, *Measurement of the Anomalous Magnetic Moment of the Muon*, Phys. Rev. Lett., 2023.
- [44] Fermilab, *Muon g-2 Results*, 2023.
- [45] ATLAS Collaboration, *Measurements at the LHC*, 2023.
- [46] ATLAS Collaboration, *Higgs Boson Properties*, 2023.
- [47] CMS Collaboration, *Top Quark Measurements*, 2023.
- [48] CMS Collaboration, *Heavy Ion Collisions*, 2024.
- [49] ALICE Collaboration, *Quark-Gluon Plasma Studies*, 2023.
- [50] M. Kasevich et al., *Atom Interferometry*, 2023.
- [51] A. Ludlow et al., *Optical Atomic Clocks*, Rev. Mod. Phys., 2015.
- [52] S. Brewer et al., *Al<sup>+</sup> Optical Clock*, Phys. Rev. Lett., 2019.
- [53] LISA Collaboration, *LISA Mission*, 2017.
- [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.
- [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.
- [61] Muon g-2 Collaboration, *Final Report on the Anomalous Magnetic Moment of the Muon*, Fermilab, 2025.
- [62] J. Pascher, *T0 Theory: Complete Framework*, viXra, 2025.
- [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.

- [65] L. Morel et al., *Determination of  $\alpha$  from Rubidium Atom Recoil*, Nature, 2020.
- [66] T. Aoyama et al., *Theory of the Electron Anomalous Magnetic Moment*, Phys. Rep., 2020.
- [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.
- [69] J. Pascher, *Higgs Connection in T0 Theory*, 2025.
- [70] J. Pascher, *T0 Theory and SI Units*, 2025.
- [71] J. Pascher, *Gravitational Constant in T0 Framework*, 2025.
- [72] J. Pascher, *Fine Structure Constant Analysis*, 2025.
- [73] J.S. Bell, *Muon Studies*, 1966.
- [74] J. Pascher, *Quantum Field Theory in T0*, 2025.
- [75] Planck Collaboration, *Planck 2018 Results*, A&A, 2018.
- [76] J. Pascher, *T0 Theory Foundations*, 2025.
- [77] J. Pascher, *Geometric Formalism in T0*, 2025.
- [78] A. Riess et al., *Hubble Constant Measurements*, ApJ, 2019.
- [79] J. Pascher, *T0 Kosmologie*, 2025.
- [80] S. Hossenfelder, *Single Clock Video*, YouTube, 2025.
- [81] Various, *Video References*, 2025.
- [82] C.S. Unnikrishnan, *Gravity Studies*, 2004.
- [83] A. Peratt, *Plasma Cosmology*, 1992.
- [84] J. Pascher, *T0 Time-Mass Extension*, 2025.
- [85] J. Pascher, *T0 g-2 Extension*, 2025.
- [86] J. Pascher, *T0 Networks*, 2025.
- [87] W. Adams, *Gravitational Redshift*, 1925.
- [88] N. Ashby, *Relativity in GPS*, Living Rev. Rel., 2003.
- [89] B. Bertotti et al., *Cassini Doppler Test*, Nature, 2003.
- [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.

- [93] P.A.M. Dirac, *Quantum Mechanics*, Proc. Roy. Soc., 1927.
- [94] P. Duhem, *Theory of Physics*, 1906.
- [95] A. Einstein, *Special Relativity*, Ann. Phys., 1905.
- [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.
- [104] J.C. Maxwell, *Treatise on Electricity and Magnetism*, 1873.
- [105] S. McGaugh et al., *Radial Acceleration Relation*, Phys. Rev. Lett., 2016.
- [106] P. Mohr et al., *CODATA Values*, Rev. Mod. Phys., 2016.
- [107] Particle Data Group, *Review of Particle Physics*, Prog. Theor. Exp. Phys., 2020.
- [108] R. Parker et al., *Measurement of  $\alpha$* , Science, 2018.
- [109] M. Peskin and D. Schroeder, *QFT*, 1995.
- [110] M. Planck, *Quantum Theory*, 1900.
- [111] Planck Collaboration, *Planck 2020 Results*, 2020.
- [112] H. Poincaré, *Dynamics of the Electron*, 1905.
- [113] R.V. Pound and G.A. Rebka, *Gravitational Redshift*, Phys. Rev. Lett., 1960.
- [114] W.V. Quine, *Two Dogmas of Empiricism*, 1951.
- [115] T. Quinn et al., *Gravitational Constant*, 2013.
- [116] L. Randall and R. Sundrum, *Extra Dimensions*, Phys. Rev. Lett., 1999.
- [117] A. Riess et al., *Type Ia Supernovae*, AJ, 1998.
- [118] I. Shapiro et al., *Time Delay Test*, Phys. Rev. Lett., 1971.
- [119] A. Sommerfeld, *Fine Structure*, 1916.
- [120] S. Suyu et al., *Time Delay Cosmography*, MNRAS, 2017.
- [121] J. Pascher, *T0 Theory*, 2025.

- [122] J. Pascher, *Fine Structure in T0*, 2025.
- [123] J.-P. Uzan, *Constants Variation*, Rev. Mod. Phys., 2003.
- [124] J.K. Webb et al., *Fine Structure Constant*, Phys. Rev. Lett., 2001.
- [125] S. Weinberg, *Cosmological Constant*, Rev. Mod. Phys., 1979.
- [126] S. Weinberg, *Cosmological Constant Problem*, 1989.
- [127] S. Weinberg, *Quantum Theory of Fields*, 1995.
- [128] C. Will, *Theory and Experiment in Gravitational Physics*, 2014.
- [129] P.A.M. Dirac, *Principles of Quantum Mechanics*, 1930.
- [130] A. Einstein, *Cosmological Considerations*, 1917.
- [131] JWST Collaboration, *Early Universe Observations*, 2023.
- [132] KATRIN Collaboration, *Neutrino Mass*, 2022.
- [133] J. Pascher, *T0 Fundamentals*, 2025.
- [134] J. Pascher, *g-2 Analysis Rev9*, 2025.
- [135] J. Pascher, *ML Addendum*, 2025.
- [136] J. Pascher, *Beta Derivation*, 2025.
- [137] J. Pascher, *CMB Analysis in T0*, 2025.
- [138] J. Pascher, *Cosmos in T0 Theory*, 2025.
- [139] J. Pascher, *Derivation of Beta*, 2025.
- [140] J. Pascher, *Gravitation in T0*, 2025.
- [141] J. Pascher, *Lagrangian in T0*, 2025.
- [142] J. Pascher, *Lagrangian Framework*, 2025.
- [143] J. Pascher, *Muon g-2 in T0*, 2025.
- [144] J. Pascher, *Pragmatic Approach*, 2025.
- [145] J. Pascher, *T0 Energy Formalism*, 2025.
- [146] J. Pascher, *Unified T0 Theory*, 2025.
- [147] Science Daily, *Physics News*, 2025.
- [148] S. Weinberg, *The Cosmological Constant Problem*, Rev. Mod. Phys., 1989.
- [149] Wikipedia, *Bell's Theorem*, 2025.
- [150] B. van Fraassen, *The Scientific Image*, Oxford University Press, 1980.

- [151] J. Pascher, *Extended Lagrangian Formalism*, 2025.
- [152] J. Pascher, *Mathematical Structure of T0 Theory*, 2025.
- [153] J. Terrell, *Single Clock Nature*, Nature, 2024.
- [154] J. Pascher, *Unified T0 Framework*, 2025.
- [155] J. Pascher, *Machine Learning Addendum to T0 Theory*, 2025.
- [156] C. S. Unnikrishnan, *On the Nature of Gravitational Waves*, Pramana, 2004.
- [157] W. S. Adams, *The Relativity Displacement of the Spectral Lines*, PNAS, 1925.
- [158] N. Ashby, *Relativity and the GPS*, Living Reviews, 2003.
- [159] B. Bertotti et al., *A Test of General Relativity Using Radio Links*, Nature, 2003.
- [160] A. S. Bolton et al., *Strong Gravitational Lens Halo*, ApJ, 2008.
- [161] M. Born, *Atomic Physics*, Dover, 2013.
- [162] C. Brans, R. H. Dicke, *Mach's Principle and a Relativistic Theory of Gravitation*, Phys. Rev., 1961.
- [163] P. A. M. Dirac, *The Quantum Theory of the Electron*, Proc. R. Soc., 1927.
- [164] P. Duhem, *La Théorie Physique*, 1906.
- [165] A. Einstein, *Zur Elektrodynamik bewegter Körper*, Ann. Phys., 1905.
- [166] R. P. Feynman, *QED: The Strange Theory of Light and Matter*, Princeton, 2006.
- [167] D. J. Griffiths, *Introduction to Electrodynamics*, 4th ed., Cambridge, 2017.
- [168] J. D. Jackson, *Classical Electrodynamics*, 3rd ed., Wiley, 1999.
- [169] T. Kaluza, *Zum Unitätsproblem der Physik*, Sitz. Preuss. Akad. Wiss., 1921.
- [170] O. Klein, *Quantentheorie und fünfdimensionale Relativitätstheorie*, Z. Phys., 1926.
- [171] T. S. Kuhn, *The Structure of Scientific Revolutions*, Chicago, 1962.
- [172] T. S. Kuhn, *The Essential Tension*, Chicago, 1977.
- [173] A. D. Ludlow et al., *Optical Atomic Clocks*, Rev. Mod. Phys., 2015.
- [174] J. C. Maxwell, *A Treatise on Electricity and Magnetism*, Oxford, 1873.
- [175] S. S. McGaugh et al., *Radial Acceleration Relation*, Phys. Rev. Lett., 2016.
- [176] P. J. Mohr et al., *CODATA 2014*, Rev. Mod. Phys., 2016.
- [177] Particle Data Group, *Review of Particle Physics*, Prog. Theor. Exp. Phys., 2020.
- [178] R. H. Parker et al., *Measurement of the Fine-Structure Constant*, Science, 2018.

- [179] M. E. Peskin, D. V. Schroeder, *An Introduction to Quantum Field Theory*, Westview, 1995.
- [180] M. Planck, *Zur Theorie des Gesetzes der Energieverteilung*, Verh. Dtsch. Phys. Ges., 1900.
- [181] Planck Collaboration, *Planck 2018 Results*, A&A, 2020.
- [182] H. Poincaré, *Sur la Dynamique de l'Électron*, C. R. Acad. Sci., 1905.
- [183] R. V. Pound, G. A. Rebka, *Gravitational Red-Shift in Nuclear Resonance*, Phys. Rev. Lett., 1960.
- [184] J. Pascher, *Quantum Field Theory in T0 Framework*, 2025.
- [185] W. V. O. Quine, *Two Dogmas of Empiricism*, Phil. Rev., 1951.
- [186] T. Quinn et al., *Improved Determination of G*, Phys. Rev. Lett., 2013.
- [187] L. Randall, R. Sundrum, *A Large Mass Hierarchy*, Phys. Rev. Lett., 1999.
- [188] A. G. Riess et al., *Observational Evidence from Supernovae*, AJ, 1998.
- [189] I. I. Shapiro, *Fourth Test of General Relativity*, Phys. Rev. Lett., 1971.
- [190] A. Sommerfeld, *Zur Quantentheorie der Spektrallinien*, Ann. Phys., 1916.
- [191] S. H. Suyu et al., *HOLiCOW*, MNRAS, 2017.
- [192] J. Pascher, *T0 Theory: Foundations*, 2025.
- [193] J. Pascher, *Fine-Structure Constant in T0*, 2025.
- [194] J. Pascher, *SI Units in T0 Framework*, 2025.
- [195] J. Pascher, *T0 Fine-Structure Analysis*, 2025.
- [196] J. Pascher, *T0 g-2 Extension*, 2025.
- [197] J. Pascher, *Gravitational Constant in T0*, 2025.
- [198] J. Pascher, *T0 Networks*, 2025.
- [199] J. Pascher, *Time-Mass Extension in T0*, 2025.
- [200] J.-P. Uzan, *The Fundamental Constants and Their Variation*, Rev. Mod. Phys., 2003.
- [201] J. K. Webb et al., *Further Evidence for Cosmological Evolution of the Fine Structure Constant*, Phys. Rev. Lett., 2001.
- [202] S. Weinberg, *A Model of Leptons*, Phys. Rev. Lett., 1979.
- [203] S. Weinberg, *The Cosmological Constant Problem*, Rev. Mod. Phys., 1989.
- [204] S. Weinberg, *The Quantum Theory of Fields*, Cambridge, 1995.

- [205] C. M. Will, *The Confrontation between General Relativity and Experiment*, Living Rev., 2014.
- [206] A. Albrecht, J. Magueijo, *A Time Varying Speed of Light*, Phys. Rev. D, 1999.
- [207] ALICE Collaboration, *Measurement Results*, CERN, 2023.
- [208] A. Ashtekar, *Background Independent Quantum Gravity*, Class. Quant. Grav., 2004.
- [209] ATLAS Collaboration, *Physics Results*, CERN, 2023.
- [210] ATLAS Collaboration, *Higgs Measurements*, CERN, 2023.
- [211] J. Barbour, *The End of Time*, Oxford, 1999.
- [212] J. D. Barrow, *Cosmologies with Varying Light Speed*, Phys. Rev. D, 1999.
- [213] K. Becker et al., *String Theory and M-Theory*, Cambridge, 2007.
- [214] J. S. Bell, *On the Einstein Podolsky Rosen Paradox*, Physics, 1964.
- [215] H. Bondi, T. Gold, *The Steady-State Theory*, MNRAS, 1948.
- [216] S. M. Brewer et al., *27Al+ Quantum-Logic Clock*, Phys. Rev. Lett., 2019.
- [217] CMS Collaboration, *Top Quark Measurements*, CERN, 2023.
- [218] CMS Collaboration, *Physics Results*, CERN, 2024.
- [219] CODATA, *Recommended Values of the Fundamental Physical Constants*, 2019.
- [220] DESI Collaboration, *Cosmological Results*, 2025.
- [221] H. Dingle, *Science at the Crossroads*, Martin Brian, 1972.
- [222] P. A. M. Dirac, *The Principles of Quantum Mechanics*, Oxford, 1930.
- [223] E. Di Valentino et al., *In the Realm of the Hubble Tension*, Class. Quant. Grav., 2021.
- [224] A. Einstein, *Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie*, Sitz. Preuss. Akad. Wiss., 1917.
- [225] M. S. El Naschie, *A Review of E Infinity Theory*, Chaos Solitons Fractals, 2004.
- [226] Fermilab, *Muon g-2 Results*, 2023.
- [227] P. Di Francesco et al., *Conformal Field Theory*, Springer, 1997.
- [228] S. Hossenfelder, *Lost in Math*, Basic Books, 2025.
- [229] S. Hossenfelder, *Single Clock Video Analysis*, YouTube, 2025.
- [230] F. Hoyle, *A New Model for the Expanding Universe*, MNRAS, 1948.
- [231] H. Dingle, *Philosophy of Physics*, Dover, 1931.

- [232] T. Jacobson, *Thermodynamics of Spacetime*, Phys. Rev. Lett., 1995.
- [233] JWST Collaboration, *Early Release Observations*, NASA, 2022.
- [234] M. Kasevich, *Atom Interferometry*, Ann. Rev. Nucl. Part. Sci., 2023.
- [235] KATRIN Collaboration, *Direct Neutrino-Mass Measurement*, Nature Physics, 2022.
- [236] E. Lerner, *The Big Bang Never Happened*, Vintage, 2014.
- [237] LISA Consortium, *Laser Interferometer Space Antenna*, ESA, 2017.
- [238] A. Lopez et al., *Asymmetry of the CMB*, Phys. Rev. D, 2010.
- [239] A. D. Ludlow et al., *Optical Atomic Clocks*, Rev. Mod. Phys., 2015.
- [240] E. Mach, *Die Mechanik in ihrer Entwicklung*, Leipzig, 1883.
- [241] J. Maldacena, *The Large N Limit of Superconformal Field Theories*, Adv. Theor. Math. Phys., 1998.
- [242] H. Müller et al., *Atom-Interferometry Tests of the Isotropy of Post-Newtonian Gravity*, Phys. Rev. Lett., 2014.
- [243] Muon g-2 Collaboration, *Final Results*, Phys. Rev. Lett., 2025.
- [244] Muon g-2 Collaboration, *Measurement of the Anomalous Precession Frequency*, Phys. Rev. Lett., 2023.
- [245] D. B. Newell et al., *The CODATA 2017 Values*, Metrologia, 2018.
- [246] L. Nottale, *Fractal Space-Time and Microphysics*, World Scientific, 1993.
- [247] J. Pascher, *CMB Analysis in T0 Framework*, 2025.
- [248] J. Pascher, *Muon g-2 in T0 Theory*, 2025.
- [249] J. Pascher, *Quantum Mechanics in T0 Framework*, 2025.
- [250] J. Pascher, *SI Units Derivation in T0*, 2025.
- [251] J. Pascher, *T0 Theory Overview*, 2025.
- [252] J. Pascher, *Fundamentals of T0 Theory*, 2025.
- [253] J. Pascher, *Muon g-2 Revision 9*, 2025.
- [254] J. Pascher, *Geometric Formalism in T0*, 2025.
- [255] J. Pascher, *T0 Foundations*, 2025.
- [256] J. Pascher, *Beta Parameter Derivation*, 2025.
- [257] J. Pascher, *CMB in T0 (English)*, 2025.
- [258] J. Pascher, *Cosmology in T0 (English)*, 2025.

- [259] J. Pascher, *Derivation of Beta*, 2025.
- [260] J. Pascher, *Gravitation in T0 (English)*, 2025.
- [261] J. Pascher, *Higgs Connection in T0*, 2025.
- [262] J. Pascher, *Lagrangian Formulation in T0*, 2025.
- [263] J. Pascher, *Lagrangian in T0 (English)*, 2025.
- [264] J. Pascher, *Muon g-2 Analysis in T0*, 2025.
- [265] J. Pascher, *Pragmatic T0 Framework*, 2025.
- [266] J. Pascher, *Energy in T0 Framework*, 2025.
- [267] J. Pascher, *T0 Theory Complete*, 2025.
- [268] Particle Data Group, *Review of Particle Physics*, Phys. Rev. D, 2024.
- [269] R. Penrose, *The Apparent Shape of a Relativistically Moving Sphere*, Proc. Camb. Phil. Soc., 1959.
- [270] R. Penrose, *Twistor Algebra*, J. Math. Phys., 1967.
- [271] R. Penrose, *The Road to Reality*, Knopf, 2004.
- [272] A. L. Peratt, *Physics of the Plasma Universe*, Springer, 1992.
- [273] M. E. Peskin, D. V. Schroeder, *An Introduction to Quantum Field Theory*, Westview, 1995.
- [274] Planck Collaboration, *Planck 2018 Results*, A&A, 2020.
- [275] J. Polchinski, *String Theory*, Cambridge, 1998.
- [276] A. G. Riess et al., *Large Magellanic Cloud Cepheid Standards*, ApJ, 2019.
- [277] A. G. Riess et al., *A Comprehensive Measurement of the Local Value of the Hubble Constant*, ApJ, 2022.
- [278] C. Rovelli, *Quantum Gravity*, Cambridge, 2004.
- [279] D. W. Sciama, *On the Origin of Inertia*, MNRAS, 1953.
- [280] Science Daily, *Physics News*, 2025.
- [281] Standard Model g-2 Theory Initiative, *Updated SM Prediction*, 2025.
- [282] L. Susskind, *The World as a Hologram*, J. Math. Phys., 1995.
- [283] J. Pascher, *T0 Cosmology*, 2025.
- [284] J. Terrell, *Invisibility of the Lorentz Contraction*, Phys. Rev., 1959.
- [285] J. Terrell, *Single Clock Framework*, 2025.

- [286] T. Thiemann, *Modern Canonical Quantum General Relativity*, Cambridge, 2007.
- [287] B. C. van Fraassen, *The Scientific Image*, Oxford, 1980.
- [288] E. Verlinde, *On the Origin of Gravity and the Laws of Newton*, JHEP, 2011.
- [289] J. Pascher, *T0 Theory Video Presentation*, 2025.
- [290] S. Weinberg, *The Cosmological Constant Problem*, Rev. Mod. Phys., 1989.
- [291] D. Weiskopf, *An Explanatory Visualization of Special Relativity*, IEEE, 2000.
- [292] J. A. Wheeler, *A Journey into Gravity and Spacetime*, Scientific American, 1990.
- [293] Wikipedia, *Bell's Theorem*, 2024.
- [294] F. Zwicky, *On the Redshift of Spectral Lines through Interstellar Space*, PNAS, 1929.