

Hydrogen as the Rosetta Stone of Projection Metrology: A Source-Integrated DTT Synthesis of Temporal Resonance, Derived Constants, Spectroscopy, and Certification

Paper 21 in the DTT Constants and Hydrogen Program

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Abstract

This paper synthesizes the preceding Dual-Time Theory (DTT) constants program by treating hydrogen as the first system in which the main constants become simultaneously visible. The paper does not use hydrogen as an input for deriving the constants. Instead, hydrogen is positioned as a late-stage integration arena: after the reconstruction speed $c_\star$, the action-phase bridge $\hbar$, the structural integer 137, the holonomy/coupling residual $\Delta_{\mathcal{R}}$, the primitive charge character, and the temporal-inertia masses have been fixed or certified upstream, hydrogen displays how these structures combine into a coherent spectrum, length scale, magnetic scale, recoil scale, fine-structure scale, radiative scale, and residual test matrix.

The central organizing principle is source separation. Paper 11 defines an alpha-free proton-electron temporal resonance. Paper 12 reconstructs the gross Bohr/Rydberg layer only after upstream constants are frozen. Paper 13 organizes fine structure and radiative inner-time loops without feeding spectroscopy back into the fine-structure constant. Paper 14 turns hydrogen and related atoms into overconstrained differential tests of state-dependent holonomy residuals. The present paper integrates those layers into one self-contained map. It identifies which quantities are upstream constants, which are derived hydrogen scales, which are standard post-freeze quantum-electrodynamic corrections, which are new DTT residual test columns, and which quantities remain open theorem targets.

The structural dictionary is:

$c_\star \mapsto$ local completion slope, $\hbar \mapsto$ action-phase bridge, $\alpha_{\text{OS}}^{-1}(0) = 137 + \Delta_{\mathcal{R}} \mapsto$ boundary coupling response,
 $\chi_e \mapsto$ primitive negative charge character, $m_e, m_p \mapsto$ temporal inertia sectors, $k_B \mapsto$ entropy-energy bridge,
with G_{rec} and Λ_{eff} entering only when hydrogen is used as a precision probe in gravitational or cosmological environments. Once the post-freeze input object

$$\mathcal{I}_H = (c_\star, \hbar, \alpha, m_e, m_p, \chi_e, \chi_p, \mathcal{D}_H^{\text{af}}, \mathfrak{s}, \mathfrak{u})$$

is fixed, the usual hydrogen scales follow as downstream quantities:

$$\mu_H = \frac{m_e m_p}{m_e + m_p}, \quad a_\mu = \frac{\hbar}{\mu_H c_\star \alpha}, \quad E_n = -\frac{\mu_H c_\star^2 \alpha^2}{2n^2}, \quad R_H = \frac{\mu_H c_\star \alpha^2}{2h}.$$

Fine structure, Lamb shift, recoil, hyperfine splitting, isotope shifts, finite-size effects, and DTT residual columns are then treated as successive correction layers. Hydrogen thus becomes a Rosetta stone in a precise sense: it translates the abstract constant roles of projection metrology into experimentally organized observables, while preserving a strict no-backflow rule that prevents hydrogen spectroscopy from tuning the upstream constants.

The paper introduces a machine-checkable hydrogen-integration certificate $\mathcal{C}_{H,\text{Rosetta}}$. A valid certificate records the frozen upstream constants, the alpha-free temporal hydrogen datum, the post-freeze gross spectrum, the correction hierarchy, the residual-shape matrix, the source-status ledger, the unit dictionary, and a hash. It must certify that no forbidden hydrogen or spectroscopic datum entered the upstream derivation of α , m_e , m_p , $\hbar$, $c_\star$, or charge. A nonphysical toy benchmark is included to validate the certificate machinery without making a physical claim. The result is a comprehensive synthesis paper: hydrogen is no longer a collection of suggestive formulas, but a disciplined integration and falsification arena for the entire DTT constants program.

Contents

1	Reader guide and claim-status discipline	8
1.1	Why this paper comes late	8
1.2	Three assertion levels	8
1.3	Immediate non-claims	8
2	Series position and dependency graph	9
2.1	The four hydrogen papers before this one	9
2.2	Dependency graph	9
3	The constant-role dictionary	10
3.1	Overview	10
3.2	Speed: $c_\star$	10
3.3	Action: $\hbar$	11
3.4	Coupling: α	11
3.5	Charge character	11
3.6	Mass and reduced mass	11
4	Alpha-free temporal hydrogen core	12
4.1	Neutral temporal resonance	12
4.2	The quarantined tick	12
5	Post-freeze gross hydrogen spectrum	13
5.1	Reduced mass and the Coulomb envelope	13

5.2	Gross scales	13
5.3	Record-envelope interpretation	13
6	Fine, radiative, recoil, and hyperfine layers	14
6.1	Correction hierarchy	14
6.2	Fine structure	14
6.3	Radiative inner-time loops	14
6.4	Recoil and finite-size effects	14
6.5	Hyperfine and magnetic moments	15
7	Hydrogen as a constants translator	15
7.1	The translation table	15
7.2	Why hydrogen overconstrains the program	15
8	Differential holonomy residuals	16
8.1	State cycles	16
8.2	Shape columns	16
8.3	Covariance-aware comparison	16
9	Charge, magnetic, and antihydrogen interfaces	17
9.1	Neutrality and charge conjugation	17
9.2	Magnetic moments as downstream images	17
10	Mass-ratio and isotope interfaces	17
10.1	Reduced mass as the first mass-ratio test	17
10.2	Isotope shifts	17
11	Thermal, gravitational, and cosmological environments	18
11.1	Thermal populations and k_B	18
11.2	Gravitational redshift and G_{rec}	18
11.3	Vacuum background	18
12	Unit dictionary and dimensional hygiene	18
12.1	Why dimensional constants need a dictionary	18
12.2	Hydrogen dimensionless packages	19
13	Detailed Rosetta theorem chain	19

13.1 The HRS protocol	19
13.2 Minimal success versus maximal success	20
14 Hydrogen family atlas	20
14.1 Ordinary hydrogen and deuterium	20
14.2 Hydrogen-like ions	21
14.3 Muonium	21
14.4 Positronium	21
14.5 Antihydrogen	21
14.6 Rydberg states	21
15 Nuclear and proton-structure interface	21
15.1 The proton is not just a point source	21
15.2 Finite charge radius	22
15.3 Polarizability and nuclear response	22
16 Radiative derivation obligations	22
16.1 Loop families	22
16.2 Weights and counterterms	22
16.3 Logarithmic terms	22
17 Publication and reproducibility workflow	23
17.1 Files that a strong hydrogen synthesis paper should ship	23
17.2 Independent reproduction	23
18 Acceptance and failure logic	23
18.1 Acceptance logic	23
18.2 Failure logic	23
19 Machine-checkable hydrogen integration certificate	24
19.1 Certificate object	24
19.2 Required fields	24
19.3 Toy benchmark	24
20 Source firewall and no-backflow theorem	25
20.1 Forbidden upstream sources	25

21 Comparison to standard quantum theory	25
21.1 What standard theory already does	25
21.2 What DTT adds	25
21.3 What would make DTT stronger than reinterpretation	26
22 Experimental and observational roadmap	26
22.1 Tier 1: consistency checks	26
22.2 Tier 2: residual-shape tests	26
22.3 Tier 3: conjugation and environment tests	26
23 Figures and diagrams for a publication version	27
24 Remaining theorem gaps	27
24.1 Upstream gaps	27
24.2 Hydrogen-specific gaps	28
25 Conclusion	28
26 The Rosetta translation theorem	29
26.1 Translation rather than construction	29
26.2 Four possible outcomes	29
27 Constant-by-constant hydrogen dictionary	30
27.1 The speed sector	30
27.2 The action sector	30
27.3 The electromagnetic coupling sector	30
27.4 The charge sector	31
27.5 The mass sector	31
27.6 Magnetic and spin-response sector	31
27.7 Thermal sector	31
27.8 Gravity sector	31
28 State dictionary and transition dictionary	31
28.1 State records	31
28.2 Transition records	32
28.3 Transition categories	32

29 Commutative diagrams for source safety	32
29.1 The desired square	32
29.2 The forbidden square	33
30 Integration with standard bound-state theory	33
30.1 What is retained from standard physics	33
30.2 Effective Hamiltonian ledger	33
31 Experimental staging	33
31.1 Stage 0: closure of gross scales	33
31.2 Stage 1: correction hierarchy	33
31.3 Stage 2: residual-column tests	34
31.4 Stage 3: cross-system transfer	34
32 Algorithmic protocol HRS1–HRS20	34
33 Acceptance theorem and failure theorem	34
34 Extended paper-sequence synthesis table	35
A Notation ledger	36
B Claim-status ledger	36
C Source-role ledger	37
D Certificate schema sketch	37
E Referee stress tests	37
F Appendix: expanded derivation ledger for hydrogen scales	38
F.1 From temporal inertia to rest energy	38
F.2 From charge character to Coulomb envelope	38
F.3 Bohr radius as a projected length scale	38
F.4 Rydberg scale as a frequency image	39
G Appendix: detailed finite-regulator hydrogen template	39
G.1 Regulated alpha-free data	39

G.2	Resonance projector	39
G.3	Post-freeze envelope map	39
G.4	Gross-spectrum certificate table	40
H	Appendix: residual-design matrix template	40
H.1	Transition index set	40
H.2	DTT columns	40
H.3	Nuisance columns	40
H.4	Overconstraint score	41
I	Appendix: hydrogen family checklist	41
J	Appendix: glossary of source statuses	41
K	Appendix: minimal public summary	42

1 Reader guide and claim-status discipline

1.1 Why this paper comes late

Hydrogen is the most tempting system to put at the beginning of a constants program because it contains nearly every important constant in a familiar way. That temptation is dangerous. The gross spectrum contains $\hbar$, c , α , and m_e . The Bohr radius contains α and $\hbar$. The Rydberg constant contains α^2 , m_e , c , and h . Fine structure and the Lamb shift contain still higher powers and logarithms of α . Therefore, if one uses the measured hydrogen spectrum to define the inner-time tick, the Bohr radius, the Rydberg scale, or the fine-structure scale before deriving α , the derivation becomes circular.

This paper therefore comes after Papers 1–20. Earlier papers define the ontology of records, the metrology of bridge constants, the action-phase bridge, the local completion cone, the structural integer 137, the holonomy fraction, charge character, mass as temporal inertia, mass ratios, thermodynamic response, vacuum averaging, and gravitational response. Hydrogen is then introduced as the first complete physical arena in which those roles are translated into observable quantities.

Central slogan

Hydrogen is not the input to the constants. Hydrogen is the arena where the constants become jointly visible.

1.2 Three assertion levels

This paper uses the status discipline established in the previous manuscripts.

1. **Definitions** introduce the hydrogen integration object, constant-role dictionary, correction hierarchy, residual columns, and certificate schema.
2. **Conditional theorems** prove what follows once upstream constants and alpha-free hydrogen structure are frozen.
3. **Theorem targets** state what must still be proved to turn the integration map into a complete first-principles derivation of all hydrogen observables.

Current status

This paper is a synthesis and certification paper. It does not claim that all constants are already derived. Its completed role is to define the non-circular dependency graph from DTT constants to hydrogen observables and to specify how hydrogen can test the program without tuning it.

1.3 Immediate non-claims

The paper does not claim:

- that the measured fine-structure constant has already been derived from hydrogen;
- that the electron or proton mass has already been computed from first principles;
- that the Lamb shift is derived without importing QED coefficients;

- that the SI numerical values of dimensionful constants are pure dimensionless predictions;
- that hydrogen spectroscopy can be used to choose the branch, band, connection, or cycle in the electron holonomy certificate.

2 Series position and dependency graph

2.1 The four hydrogen papers before this one

The preceding hydrogen block has four roles:

Paper 11. Defines alpha-free proton-electron record geometry and temporal resonance. It may use phase-orientation language, neutral compatibility, and temporal Dirac-type record operators, but it cannot use the numerical fine-structure constant.

Paper 12. Reconstructs the gross Bohr/Rydberg spectrum after α , $\hbar$, $c_\star$, and masses are supplied upstream.

Paper 13. Organizes fine structure, Lamb shift, recoil, hyperfine splitting, finite-size effects, and radiative inner-time loops as correction layers.

Paper 14. Turns hydrogen, deuterium, Rydberg states, antihydrogen, muonium, and positronium into differential tests of state-dependent holonomy residuals.

The present paper does not replace those four papers. It integrates them.

2.2 Dependency graph

The non-circular dependency graph is:

$$\begin{aligned} \text{record ontology} &\rightarrow \text{projection metrology} \rightarrow (\hbar, c_\star) \rightarrow (137, \Delta_{\mathcal{R}}) \rightarrow \alpha_{\text{OS}}^{-1}(0), \\ \text{charge character} &\rightarrow (e\text{-dictionary}), \quad \text{temporal inertia} \rightarrow (m_e, m_p), \\ (c_\star, \hbar, \alpha, m_e, m_p, \chi_e, \chi_p) + \mathcal{D}_H^{\text{af}} &\rightarrow \text{hydrogen scales and spectra.} \end{aligned}$$

Figure placeholder: Non-circular dependency graph

A directed acyclic graph should show upstream constants and record structures feeding hydrogen observables. Back arrows from hydrogen spectra to α , m_e , m_p , $\hbar$, $c_\star$, or charge are forbidden.

Figure 1: Non-circular dependency graph. Placeholder key: `fig-dependency-dag`.

Firewall Warning 2.1 (No backflow). *Hydrogen observables may test upstream constants and residual shapes. They may not tune the electron holonomy certificate, the charge character, the mass certificates, the action-phase bridge, or the completion-cone speed.*

3 The constant-role dictionary

3.1 Overview

Hydrogen exposes constants because it is a bound neutral two-body record system with compact phase, charge character, temporal inertia, spin, radiation, and precision spectroscopy. The following dictionary is the backbone of the paper.

Symbol	DTT role	Hydrogen visibility
$c_\star$	local completion slope, photon one-tick benchmark	appears in rest energy, Rydberg frequency, relativistic corrections, and unit dictionary
$\hbar$	bridge between additive record action and compact phase	quantization, angular momentum, phase locking, wave-envelope scale
α	low-energy boundary coupling response, $\alpha^{-1} = 137 + \Delta_{\mathcal{R}}$	Bohr radius, binding energy, fine structure, Lamb hierarchy
χ_e, χ_p	primitive charge characters, negative and positive orientation	neutrality, Coulomb sector, emission/absorption selection rules
m_e, m_p	temporal inertia sectors / rest recurrence classes	reduced mass, recoil, hyperfine, isotope shifts
k_B	entropy-energy bridge	thermal populations, Doppler width, blackbody shifts; not needed for zero-temperature spectrum
G_{rec}	curvature-record response coefficient	gravitational redshift, clock comparison, possible precision-environment tests
Λ_{eff}	temporally averaged vacuum response	cosmological background only; not part of ordinary atomic derivation

Definition 3.1 (Hydrogen integration input). *A post-freeze hydrogen integration input is a tuple*

$$\mathcal{I}_H = (c_\star, \hbar, \alpha, m_e, m_p, \chi_e, \chi_p, \mathcal{D}_H^{\text{af}}, \mathfrak{s}, \mathfrak{u}),$$

where $\mathcal{D}_H^{\text{af}}$ is the alpha-free hydrogen record datum from Paper 11, $\mathfrak{s}$ is a source-status ledger, and $\mathfrak{u}$ is a unit dictionary. The tuple is admissible only if every upstream component is frozen before hydrogen spectroscopy is consulted.

3.2 Speed: $c_\star$

In hydrogen, $c_\star$ is not first introduced as a measured speed. It enters as the invariant completion slope of the record geometry. Once a unit dictionary is chosen, it appears in the rest energy and spectral frequency conversion:

$$E_{\text{rest}} = mc_\star^2, \quad \nu = \frac{\Delta E}{h}.$$

The gross binding scale is

$$E_H \sim m_e c_\star^2 \alpha^2.$$

The role of $c_\star$ is therefore structural in the upstream program and observational in hydrogen.

3.3 Action: $\hbar$

The action-phase bridge gives

$$\Delta\theta(\Gamma) \equiv \frac{S_{\text{rec}}(\Gamma)}{\hbar} \pmod{2\pi}.$$

Hydrogen bound states are then phase-locked record cycles. The angular and radial quantum numbers are record-envelope labels of stable phase-compatible cycles, not primitive labels assigned to orbits in a background container. The usual quantum-mechanical role of $\hbar$ is recovered downstream:

$$L^2 = \hbar^2 \ell(\ell + 1), \quad L_z = \hbar m, \quad E = \hbar \omega.$$

3.4 Coupling: α

The fine-structure constant is the dimensionless target of the earlier holonomy/coupling block:

$$\alpha_{\text{OS}}^{-1}(0) = N_3(10) + \Delta_{\mathcal{R}} = 137 + \Delta_{\mathcal{R}}.$$

Hydrogen may use α only after this value has been supplied by an upstream certificate or explicitly marked as a phenomenological input. In a complete derivation, hydrogen receives α ; it does not determine it.

3.5 Charge character

The charge paper separates

$$\chi_e \neq q_{\text{rec}} \neq \alpha \neq e_{\text{SI}}.$$

Hydrogen begins with alpha-free neutrality:

$$\chi_p \chi_e = 1, \quad \chi_p = \chi_{+1}, \quad \chi_e = \chi_{-1}.$$

Only after α , $\hbar$, and $c_\star$ are fixed does one translate charge character into the conventional Coulomb coupling or SI charge dictionary.

3.6 Mass and reduced mass

The mass paper interprets rest mass as temporal inertia:

$$mc_\star^2 = \hbar \omega_{\text{rest}}.$$

Hydrogen sees both electron and proton inertia through the reduced mass

$$\mu_H = \frac{m_e m_p}{m_e + m_p}.$$

The leading gross scale uses μ_H , while recoil and hyperfine structure expose higher-order dependence on m_e/m_p .

4 Alpha-free temporal hydrogen core

4.1 Neutral temporal resonance

Before any numerical spectral formula is allowed, hydrogen is defined as a neutral temporal record resonance. The alpha-free datum contains proton and electron record complexes, a shared record complex, compatible phase orientations, incidence data, and an observational quotient:

$$\mathcal{D}_{H,r}^{\text{af}} = (\mathcal{R}_{p,r}, \mathcal{R}_{e,r}, \mathcal{R}_{H,r}, J_r, \Theta_{p,r}, \Theta_{e,r}, \partial_r, \omega_r, \sim_{\text{obs},r}, \chi_r).$$

The safe temporal vocabulary is

$$U_p = e^{+i\theta_p}, \quad U_e = e^{-i\theta_e}, \quad \Phi_{pe} = \theta_p + \theta_e.$$

The opposite signs encode orientation language only. They do not by themselves determine α .

Definition 4.1 (Alpha-free hydrogen resonance). *A regulated alpha-free hydrogen resonance is a stable neutral record cycle $C_{H,r}$ for which:*

1. *the electron and proton characters cancel in the neutral quotient;*
2. *the relative phase obstruction $\Phi_{pe,r}$ is locked modulo 2π on the stable cycle;*
3. *a resonance projector $P_{H,r}^{\text{res}}$ is separated by a positive finite-regulator gap;*
4. *no alpha-dependent length, energy, tick, Rydberg, Bohr, or spectroscopy datum enters the construction.*

Theorem Target 4.2 (Alpha-free hydrogen theorem). *DTT should prove that the first neutral proton-electron record sector contains a canonical stable resonance class whose finite-regulator projector converges to a well-defined hydrogen record-envelope sector. This theorem must be proved without α , the Bohr radius, Rydberg data, or measured spectral lines.*

4.2 The quarantined tick

Older hydrogen notes used an inner-time tick of the form

$$\Delta t_r = \alpha \frac{\hbar}{m_e c^2}.$$

In this synthesis that formula is not discarded; it is reclassified. It is a post-freeze electromagnetic tick scale, not a pre-freeze definition of hydrogen. Once α , $\hbar$, m_e , and $c_\star$ are frozen, one may define

$$\tau_{\text{em},e} := \alpha \frac{\hbar}{m_e c_\star^2}.$$

Before that point, it is forbidden.

Hydrogen quarantine

The formulas $\Delta t_r = \alpha \hbar / (m_e c^2)$, $a_0 = \hbar / (m_e c \alpha)$, $R_\infty = m_e \alpha^2 c / (2\hbar)$, and any Lamb-shift or fine-structure numerical expression containing α are post-freeze phenomenology only. They may not be used to derive α , m_e , $\hbar$, $c_\star$, or charge.

5 Post-freeze gross hydrogen spectrum

5.1 Reduced mass and the Coulomb envelope

Given an admissible $\mathcal{I}_H$, define

$$\mu_H = \frac{m_e m_p}{m_e + m_p}.$$

The post-freeze Coulomb record-envelope operator is not primitive ontology; it is the low-energy envelope of the neutral temporal resonance after the constants have been supplied:

$$H_{\text{env}} = -\frac{\hbar^2}{2\mu_H} \nabla^2 - \frac{\alpha \hbar c_\star}{r}.$$

In rationalized units the same expression is a dictionary form of the primitive charge character and coupling response.

5.2 Gross scales

The Bohr scale and Rydberg scale are downstream:

$$a_\mu = \frac{\hbar}{\mu_H c_\star \alpha}, \quad E_n^{(0)} = -\frac{\mu_H c_\star^2 \alpha^2}{2n^2}, \quad R_H = \frac{\mu_H c_\star \alpha^2}{2h}.$$

For an infinitely heavy nucleus one obtains the usual formal limit $\mu_H \rightarrow m_e$ and $R_H \rightarrow R_\infty$.

Theorem 5.1 (Conditional gross-spectrum reconstruction). *Assume $\mathcal{I}_H$ is admissible and the low-energy neutral temporal resonance reduces to the Coulomb envelope operator H_{env} in the stable post-freeze limit. Then the bound-state envelope energies are*

$$E_n^{(0)} = -\frac{\mu_H c_\star^2 \alpha^2}{2n^2}, \quad n = 1, 2, \dots$$

The transition frequencies are

$$\nu_{n \rightarrow m}^{(0)} = \frac{\mu_H c_\star^2 \alpha^2}{2h} \left(\frac{1}{m^2} - \frac{1}{n^2} \right), \quad n > m.$$

Proof. The proof is the standard spectral computation for the Coulomb envelope, but its role is different. The Coulomb operator is not a fundamental input used to derive α . It is the post-freeze envelope of a neutral temporal resonance. Solving the radial equation yields the displayed eigenvalues, and dividing energy differences by $h = 2\pi\hbar$ gives transition frequencies. $\square$

5.3 Record-envelope interpretation

The wavefunction is interpreted as a projected record-envelope density. The spatial coordinate is an emergent readout coordinate of the stable record layer, not the ontological substrate of the proton-electron pair. This keeps the standard predictive machinery while allowing the DTT ontology to remain temporal/projection-based.

Figure placeholder: Temporal resonance to Coulomb envelope

Diagram showing an alpha-free proton-electron record cycle feeding a post-freeze Coulomb envelope after α , $\hbar$, c_* , and masses are supplied.

Figure 2: Temporal resonance to Coulomb envelope. Placeholder key: `fig-envelope`.

6 Fine, radiative, recoil, and hyperfine layers

6.1 Correction hierarchy

The post-freeze spectrum is organized as

$$E_{n\ell jF} = E_n^{(0)} + \Delta E_{n\ell j}^{\text{fs}} + \Delta E_{n\ell j}^{\text{Lamb}} + \Delta E_{n\ell j}^{\text{recoil}} + \Delta E_{n\ell j}^{\text{nuc}} + \Delta E_{n\ell jF}^{\text{hfs}} + \Delta E_{n\ell jF}^{\text{DTT, res}}.$$

This formula is a bookkeeping identity. It is not a claim that all terms have already been derived from DTT. The hierarchy marks which proof obligations belong to which paper.

6.2 Fine structure

The standard leading fine-structure form is

$$\Delta E_{nj}^{\text{fs}} = -\frac{\mu_H c_*^2 (Z\alpha)^4}{2n^3} \left(\frac{1}{j+1/2} - \frac{3}{4n} \right) + O((Z\alpha)^6),$$

modulo recoil and reduced-mass conventions. In DTT this term is interpreted as a post-freeze record-orientation correction combining relativistic kinetic delay, spin-orbit temporal orientation, and contact/Darwin structure.

6.3 Radiative inner-time loops

The Lamb shift is the place where overclaiming is especially dangerous. A DTT derivation must supply a loop measure, regulator scheme, subtraction/renormalization rule, state dependence, and coefficients. It is not enough to reproduce a known QED series by inserting coefficients. The target architecture is

$$\Delta E_{n\ell j}^{\text{Lamb}} = \sum_{\Gamma \in \mathcal{L}_{n\ell j}} W_{\text{loop}}(\Gamma) \mathcal{A}_{\text{loop}}(\Gamma),$$

with the loop family, weights, counterterms, and finite part derived from temporal record dynamics.

6.4 Recoil and finite-size effects

Recoil begins at the reduced-mass level and continues through higher-order corrections in m_e/m_p . Finite-size effects depend on nuclear record structure. For ordinary hydrogen they are post-freeze corrections; for the mass-ratio and proton-structure papers they become additional test channels.

6.5 Hyperfine and magnetic moments

The magnetic scales are

$$\mu_B = \frac{e\hbar}{2m_e}, \quad \mu_N = \frac{e\hbar}{2m_p}.$$

In DTT these are downstream unit-dictionary images of charge character, action-phase bridge, and temporal inertia. Hyperfine splitting tests the spin, magnetic, mass-ratio, and charge-character sectors simultaneously.

7 Hydrogen as a constants translator

7.1 The translation table

Hydrogen translates abstract constant roles into laboratory observables. The translation is many-to-one: the same constant appears in many observables, and the same observable usually contains several constants. That is why hydrogen is powerful as an integration test but dangerous as an input source.

Hydrogen quantity	Expression / scale	DTT interpretation
Compton period	$T_{C,e} = h/(m_e c_\star^2)$	temporal rest recurrence of electron
Electromagnetic tick	$\tau_{\text{em},e} = \alpha \hbar / (m_e c_\star^2)$	post-freeze charged-sector tick
Bohr radius	$a_\mu = \hbar / (\mu_H c_\star \alpha)$	spatial readout scale of temporal resonance
Gross energy	$E_n = -\mu_H c_\star^2 \alpha^2 / (2n^2)$	binding envelope from post-freeze coupling
Rydberg scale	$R_H = \mu_H c_\star \alpha^2 / (2h)$	frequency/wavenumber image of binding
Fine structure	$\sim \mu_H c_\star^2 \alpha^4$	temporal orientation and relativistic delay
Lamb shift	$\sim \alpha^5 m_e c_\star^2 \log(1/\alpha)$	radiative temporal-loop finite part
Hyperfine	$\sim \alpha^4 (m_e/m_p) m_e c_\star^2$	spin and mass-ratio interface
DTT residuals	η_{mljF}	state-cycle holonomy tests

7.2 Why hydrogen overconstrains the program

If α , m_e , m_p , $\hbar$, $c_\star$, and charge are supplied upstream, then hydrogen leaves little freedom. The same constants must fit gross transitions, isotope shifts, fine structure, hyperfine structure, Lamb shifts, Rydberg states, muonium, positronium, and antihydrogen. A successful DTT program should gain credibility not by fitting one line, but by passing many coupled checks with a frozen upstream ledger.

Criterion 7.1 (Hydrogen integration success). *The hydrogen synthesis is successful only if the same frozen upstream constants and source ledgers produce a consistent correction hierarchy across:*

H, D, H-like ions, muonium, positronium, antihydrogen, Rydberg states.

No transition may receive its own independent residual amplitude unless that amplitude is derived from a predeclared state-cycle invariant.

8 Differential holonomy residuals

8.1 State cycles

Paper 14 defines a state record cycle

$$C_a = C_{n\ell jF}, \quad a = (n, \ell, j, F),$$

with state holonomy

$$H_a = \text{br} \frac{1}{2\pi} \text{Arg} \det_{\mathcal{H}_a^{\text{low,phys}}} \text{Hol}_{C_a}(A_e).$$

The ground electron certificate supplies H_{1S} . Excited-state differences are

$$\eta_a = H_a - H_{1S}, \quad S_{a \rightarrow b} = \eta_b - \eta_a.$$

8.2 Shape columns

Predeclared residual shape columns include:

$$\begin{aligned} \eta_{nS} &= \beta_S n^{-3} + O(n^{-4}), \\ \eta_{n\ell jF}^{\text{spin}} &= \beta_\ell n^{-3} \sigma_{\ell jF} + O(n^{-4}), \\ \eta_{n,\ell=n-1} &= o(n^{-3}). \end{aligned}$$

These are not allowed to become line-by-line fitting functions. They must descend from record-cycle geometry or be rejected.

8.3 Covariance-aware comparison

For a set of transitions, define residual data

$$y_i = \nu_i^{\text{obs}} - \nu_i^{\text{QED}} - \nu_i^{\text{sys}}.$$

The DTT model supplies columns $S_A(i)$, and nuisance physics supplies columns $N_B(i)$. The design matrix is

$$X = (S_1, \dots, S_p, N_1, \dots, N_q).$$

With covariance matrix C , the generalized least-squares estimator is

$$\hat{c} = (X^T C^{-1} X)^{-1} X^T C^{-1} y.$$

The residual model is overconstrained only if

$$M - p - q \geq 2.$$

Firewall Warning 8.1 (No line-by-line fitting). *A model with one free amplitude per transition is not a prediction. It is a re-labeling of the data and fails the DTT source-firewall test.*

9 Charge, magnetic, and antihydrogen interfaces

9.1 Neutrality and charge conjugation

Alpha-free hydrogen starts from $\chi_p\chi_e = 1$. Antihydrogen reverses the charge-character orientation:

$$\chi_{\bar{p}} = \chi_{-1}, \quad \chi_{e^+} = \chi_{+1}.$$

A CPT-even DTT residual must satisfy identical spectral shifts after conventional sign conventions are applied. An orientation-sensitive residual may change sign only if the corresponding orientation functional was fixed before comparison.

9.2 Magnetic moments as downstream images

The Bohr and nuclear magnetons are downstream:

$$\mu_B = \frac{e\hbar}{2m_e}, \quad \mu_N = \frac{e\hbar}{2m_p}.$$

They are not primitive constants in the DTT hierarchy. Hyperfine spectroscopy is therefore an integration test of charge, $\hbar$, mass ratio, spin orientation, and proton structure.

10 Mass-ratio and isotope interfaces

10.1 Reduced mass as the first mass-ratio test

The reduced mass factor is

$$\frac{\mu_H}{m_e} = \frac{1}{1 + m_e/m_p}.$$

Hydrogen and deuterium gross spectra test mass input immediately. But the mass ratio must not be extracted from hydrogen spectra and then presented as a DTT derivation. It must come from the mass-ratio certificate or be labeled as empirical calibration.

10.2 Isotope shifts

Isotope shifts contain reduced-mass effects, nuclear-size effects, polarizability, and recoil. The DTT source ledger should split them into:

$$\Delta\nu^{\text{iso}} = \Delta\nu^{\text{redmass}} + \Delta\nu^{\text{radius}} + \Delta\nu^{\text{recoil}} + \Delta\nu^{\text{DTT,res}}.$$

Only the last term is a new DTT residual; the others are standard post-freeze contributions or separate nuclear-structure inputs.

11 Thermal, gravitational, and cosmological environments

11.1 Thermal populations and k_B

Boltzmann's constant enters hydrogen only when ensembles, thermal widths, blackbody shifts, or environmental populations are considered:

$$p_n \propto e^{-E_n/(k_B T)}.$$

In the DTT program, k_B is an entropy-energy bridge. Zero-temperature spectral structure does not need k_B , but experimental environments do.

11.2 Gravitational redshift and G_{rec}

Hydrogen clocks can test gravitational coupling through redshift and clock comparisons. But G_{rec} is not part of the ordinary hydrogen spectrum. It belongs to the curvature-record response paper and enters hydrogen only as an environmental or precision-clock probe:

$$\frac{\Delta\nu}{\nu} \simeq \frac{\Delta\Phi}{c_\star^2}.$$

11.3 Vacuum background

The cosmological constant is irrelevant for ordinary laboratory hydrogen except in extreme precision or cosmological contexts. Paper 19 supplies the temporal vacuum-averaging architecture. Hydrogen may eventually test environmental vacuum effects, but it cannot determine Λ_{eff} in the constants hierarchy.

12 Unit dictionary and dimensional hygiene

12.1 Why dimensional constants need a dictionary

The hydrogen formulas contain both dimensionless information and unit-dependent conversion factors. DTT treats this distinction as structural rather than cosmetic. The dimensionless fine-structure constant and the mass ratio m_p/m_e are legitimate numerical derivation targets. The SI numerical values of c , h , e , and k_B , by contrast, are part of the unit system once the SI defining constants are fixed. A DTT derivation of their role is therefore a derivation of a bridge structure and a calibration relation, not a derivation of a convention-free decimal.

For hydrogen this distinction is essential. The formula

$$R_H = \frac{\mu_H c_\star \alpha^2}{2h}$$

looks like it determines several constants at once. It does not. If R_H is used as an experimental input, then the formula becomes a calibration relation among already defined units and constants. If α , h , $c_\star$, and μ_H are provided upstream, the formula becomes a prediction for the gross spectral scale. The direction of use matters.

Quantity	Direction allowed in this paper	Forbidden direction
$\hbar$	action–phase bridge $\rightarrow$ hydrogen phases	hydrogen spectrum $\rightarrow \hbar$ derivation
$c_\star$	completion cone $\rightarrow$ rest/spectral scales	hydrogen lines $\rightarrow$ speed definition
α	holonomy/coupling certificate $\rightarrow$ binding	Rydberg/Bohr data $\rightarrow$ alpha certificate
m_e, m_p	temporal inertia certificates $\rightarrow$ reduced mass	isotope shifts $\rightarrow$ mass derivation
e_{SI}	unit dictionary image of charge character	measured charge $\rightarrow$ primitive character
k_B	entropy-energy bridge $\rightarrow$ thermal populations	thermal spectral fits $\rightarrow k_B$ theorem

12.2 Hydrogen dimensionless packages

Many hydrogen observables can be written as dimensionless ratios. These ratios are especially useful for testing the DTT program because they reduce unit-dictionary ambiguity. Examples include

$$\frac{E_n}{\mu_H c_\star^2} = -\frac{\alpha^2}{2n^2}, \quad \frac{a_\mu \mu_H c_\star}{\hbar} = \frac{1}{\alpha}, \quad \frac{2\hbar R_H}{\mu_H c_\star} = \alpha^2.$$

A future DTT analysis should prefer such unit-free combinations whenever possible. They expose whether the upstream dimensionless quantities are correct without confusing physical content with unit convention.

Proposition 12.1 (Dimensionless hydrogen check). *If $\mathcal{I}_H$ is fixed, then every gross hydrogen quantity can be converted into a dimensionless check of α and mass ratios by multiplying by the appropriate powers of $\hbar$, $c_\star$, and μ_H . Therefore gross hydrogen is primarily a consistency check of the upstream dictionary, not an independent source of α .*

13 Detailed Rosetta theorem chain

13.1 The HRS protocol

For clarity, the integrated hydrogen proof program is written as a numbered protocol. HRS stands for hydrogen Rosetta synthesis.

- HRS1. Define the alpha-free proton-electron record datum $\mathcal{D}_H^{\text{af}}$.
- HRS2. Prove neutral character cancellation $\chi_p \chi_e = 1$ at the record level.
- HRS3. Prove stable temporal phase-locking and resonance isolation.
- HRS4. Freeze the upstream constants $c_\star, \hbar, \alpha, m_e, m_p, \chi_e, \chi_p$ with their source ledgers.
- HRS5. Verify that α comes from the holonomy/coupling path or is explicitly marked as phenomenological.

- HRS6. Construct the post-freeze Coulomb envelope from the alpha-free resonance and the frozen coupling.
- HRS7. Derive the reduced mass and gross spectrum.
- HRS8. Add relativistic/spin orientation corrections.
- HRS9. Add radiative inner-time loop corrections.
- HRS10. Add recoil and finite-size corrections.
- HRS11. Add hyperfine and magnetic corrections.
- HRS12. Define state-cycle holonomy residuals η_{nljF} .
- HRS13. Build an overconstrained residual design matrix.
- HRS14. Compare to spectroscopy only after all preceding fields are frozen.
- HRS15. Produce a machine-readable certificate and canonical hash.
- HRS16. Record success, failure, or open-status outcomes without changing upstream fields.

Theorem Target 13.1 (Full hydrogen Rosetta theorem). *A completed DTT hydrogen theorem would prove that HRS1–HRS16 can be carried out with physical finite-regulator data, that the regulator limit exists, that the standard hydrogen correction hierarchy is recovered to the declared order, and that any DTT residual columns are derived from state-cycle geometry rather than fitted line by line.*

13.2 Minimal success versus maximal success

The minimal success of this paper is architectural: it gives a non-circular dependency graph and certificate. A maximal success of the research program would be much stronger:

upstream constants derived+hydrogen resonance proved+radiative coefficients derived+residuals predicted.

The paper deliberately does not blur those levels.

14 Hydrogen family atlas

14.1 Ordinary hydrogen and deuterium

Ordinary hydrogen is the reference system because it contains the simplest proton-electron neutral sector. Deuterium introduces nuclear mass, spin, finite-size, and polarizability changes while retaining the same electron charge and electromagnetic coupling. The comparison

$$\nu_{a \rightarrow b}^D - \nu_{a \rightarrow b}^H$$

therefore separates electron-sector constants from nuclear-sector corrections only if the reduced-mass, recoil, and finite-size ledgers are explicit.

14.2 Hydrogen-like ions

Hydrogen-like ions replace α by $Z\alpha$ in the leading Coulomb envelope. They are useful for testing the scaling of relativistic and radiative terms:

$$E_n^{(0)}(Z) = -\frac{\mu_Z c_*^2 (Z\alpha)^2}{2n^2}, \quad \Delta E^{\text{fs}} \sim \mu_Z c_*^2 (Z\alpha)^4.$$

They are not suitable as pre-freeze alpha inputs because their spectra already contain α explicitly.

14.3 Muonium

Muonium replaces the proton by an antimuon. It suppresses proton-size uncertainty and tests lepton universality, mass-ratio inputs, recoil structure, and magnetic moments. In DTT it is a test of whether temporal inertia and primitive charge character transfer consistently across lepton sectors.

14.4 Positronium

Positronium has equal masses and opposite charges. Its gross binding scale uses $\mu = m_e/2$, and annihilation channels become important. DTT should treat positronium as a charge-conjugate two-lepton temporal resonance with additional annihilation-record sectors.

14.5 Antihydrogen

Antihydrogen is the sharpest orientation test. If the residuals are CPT-even, they should match hydrogen after conventional charge-conjugation rules. If DTT predicts an orientation-sensitive residual, the orientation functional must be fixed before antihydrogen comparison.

14.6 Rydberg states

High- n , high- ℓ states suppress contact effects and magnify geometric-state-cycle structure. In the holonomy program they test whether

$$\eta_{n,\ell=n-1} = o(n^{-3})$$

or a related high- ℓ suppression law follows from state-cycle geometry.

15 Nuclear and proton-structure interface

15.1 The proton is not just a point source

The simplest hydrogen formulas treat the proton as a heavy point charge. That is a controlled approximation, not an ontology. A DTT treatment of proton structure must eventually connect to the temporal-inertia and mass-ratio papers, and perhaps to a separate hadronic record-sector theory.

15.2 Finite charge radius

The leading finite-size correction for S states has the schematic form

$$\Delta E_{nS}^{\text{radius}} \propto |\psi_{nS}(0)|^2 r_p^2 \sim \frac{r_p^2}{n^3 a_\mu^3}.$$

In this synthesis, r_p is not an upstream DTT constant. It is either an external nuclear input, a future proton record certificate output, or a nuisance parameter in spectroscopy comparisons.

15.3 Polarizability and nuclear response

At higher precision, proton polarizability and two-photon exchange effects enter. These belong to a nuclear response ledger. They must not be mistaken for electron holonomy residuals.

Criterion 15.1 (Residual separation). *A DTT residual claim is admissible only after ordinary nuclear-size, recoil, polarizability, and QED nuisance directions have been projected out or included in the covariance model.*

16 Radiative derivation obligations

16.1 Loop families

A temporal-loop derivation must specify the loop family

$$\mathcal{L}_{n\ell j}^{(r)}$$

over the finite record complex. The index r matters: without finite-regulator loop data there is no way to distinguish a derived loop coefficient from an imported QED coefficient.

16.2 Weights and counterterms

A radiative certificate must supply

$$(W_{\Gamma,r}, A_{\Gamma,r}, C_{\Gamma,r})_{\Gamma \in \mathcal{L}_{n\ell j}^{(r)}}$$

where W is the loop weight, A is the loop amplitude, and C is the subtraction/counterterm contribution. The finite part must be regulator-stable and state-dependent in the right way.

16.3 Logarithmic terms

Logarithms such as $\log(1/\alpha)$ cannot be inserted by dimensional guesswork. They must arise from a scale interval, matching calculation, or regulator sum. A strong DTT Lamb-shift theorem would identify the temporal-loop mechanism that generates the logarithmic range.

17 Publication and reproducibility workflow

17.1 Files that a strong hydrogen synthesis paper should ship

A future physical version of this paper should ship:

1. the LaTeX manuscript;
2. a machine-readable $\mathcal{C}_{H,Rosetta}$ certificate;
3. hashes of upstream certificates;
4. a script recomputing gross scales;
5. a script checking source firewall and no-backflow;
6. a residual-design matrix with covariance metadata;
7. a notebook or script reproducing all tables from frozen inputs.

17.2 Independent reproduction

Two independent implementations should agree on the gross scales and no-backflow status before any spectroscopy comparison is made. Any difference in unit convention must be resolved at the unit-dictionary layer, not by changing upstream physical values.

18 Acceptance and failure logic

18.1 Acceptance logic

The hydrogen synthesis supports the DTT program if:

1. the upstream constants are frozen and source-clean;
2. the alpha-free hydrogen datum is independently constructed;
3. the post-freeze gross spectrum is recovered;
4. correction layers are either derived or accurately labeled as standard inputs;
5. residual columns are predeclared and overconstrained;
6. hydrogen-family comparisons do not force upstream retuning.

18.2 Failure logic

The synthesis fails as a strong claim if:

- hydrogen spectroscopy is needed to choose the electron holonomy branch or phase;
- the alpha-free datum secretly contains α -dependent scales;
- residuals require one parameter per transition;
- the same upstream constants cannot pass H, D, muonium, positronium, antihydrogen, or Rydberg comparisons within the declared status level;
- radiative coefficients are merely copied from QED while being described as derived.

Scientific value of failure

A failed frozen hydrogen certificate is still scientifically useful. It would identify exactly which DTT bridge, constant, correction layer, or residual-shape assumption breaks under precision atomic comparison.

19 Machine-checkable hydrogen integration certificate

19.1 Certificate object

The paper defines the hydrogen Rosetta certificate

$$\mathcal{C}_{H,\text{Rosetta}} = (\mathcal{I}_H, \mathcal{D}_H^{\text{af}}, \mathcal{S}_{\text{gross}}, \mathcal{S}_{\text{corr}}, \mathcal{X}_{\text{res}}, \mathfrak{q}_{\text{source}}, \mathfrak{q}_{\text{unit}}, \mathfrak{q}_{\text{no-backflow}}, h_H).$$

Here $\mathcal{S}_{\text{gross}}$ stores gross-spectrum scales, $\mathcal{S}_{\text{corr}}$ stores correction-layer status, $\mathcal{X}_{\text{res}}$ stores residual shape columns, and the $\mathfrak{q}$ -ledgers store source status, unit dictionary, and no-backflow validation.

19.2 Required fields

A valid certificate must include:

1. upstream constants and whether each is derived, certified, calibrated, or phenomenological;
2. alpha-free hydrogen datum hash;
3. post-freeze value ledger for $c_\star, \hbar, \alpha, m_e, m_p, \chi_e, \chi_p$;
4. derived gross scales μ_H, a_μ, E_n, R_H ;
5. correction hierarchy status;
6. residual shape matrix and overconstraint count;
7. source-firewall scan;
8. unit dictionary;
9. independent reproduction notes.

Protocol 19.1 (Hydrogen Rosetta validation). *Given a candidate $\mathcal{C}_{H,\text{Rosetta}}$:*

1. *verify that **physical_claim** is false unless every upstream certificate is populated;*
2. *verify that alpha-containing hydrogen formulas appear only in post-freeze fields;*
3. *recompute the gross scales from the frozen constants;*
4. *check that the residual matrix has more transitions than free DTT amplitudes;*
5. *verify that no forbidden source token appears in upstream or alpha-free fields;*
6. *compute a canonical hash excluding the hash field itself.*

19.3 Toy benchmark

The package includes a nonphysical toy certificate in internal units:

$$c_\star = 1, \quad \hbar = 1, \quad \alpha = \frac{1}{10}, \quad m_e = 1, \quad m_p = 9.$$

Then

$$\mu_H = \frac{9}{10}, \quad a_\mu = \frac{100}{9}, \quad R_H = \frac{9}{4000}, \quad E_1 = -\frac{9}{2000}.$$

The toy benchmark is not a physical claim. It exists only to prove that the certificate arithmetic and no-backflow checks are executable.

20 Source firewall and no-backflow theorem

20.1 Forbidden upstream sources

Before the relevant upstream certificate is frozen, the following may not be used:

- measured hydrogen, deuterium, muonium, positronium, or antihydrogen transitions;
- Rydberg constant or Bohr radius values;
- Lamb-shift or fine-structure numerical data;
- electron anomaly, von Klitzing constant, Josephson constant, atom recoil extraction of α ;
- measured charge normalization, measured electron mass, measured proton mass, or Penning-trap mass ratios;
- gravitational redshift data or cosmological fits for hydrogen clock environments.

Theorem 20.1 (No-backflow theorem). *Assume the upstream certificates for $c_\star$, $\hbar$, α , charge, m_e , and m_p are frozen with canonical hashes before any hydrogen spectroscopy fields are populated in $\mathcal{C}_{H,\text{Rosetta}}$. Assume further that the source-firewall scan verifies that no forbidden source token or numerical proxy appears in the upstream fields. Then hydrogen comparison data can affect only the post-freeze validation status, not the upstream constants themselves.*

Proof. The certificate is a directed object. The hash of each upstream component is computed before hydrogen observables are attached. The post-freeze fields are downstream functions of these frozen components plus declared correction models. Since the validation protocol forbids rewriting upstream fields after comparison, spectroscopy can only accept, reject, or constrain downstream residual models. It cannot alter the frozen constants without changing the hashes and invalidating the certificate. $\square$

21 Comparison to standard quantum theory

21.1 What standard theory already does

Standard nonrelativistic quantum mechanics and QED explain hydrogen with extraordinary precision once the constants and nuclear inputs are given. The DTT synthesis does not replace this achievement. It reorganizes the origin and status of the constants and interprets the Hilbert-space/wavefunction structures as projected record-envelope structures.

21.2 What DTT adds

DTT adds three kinds of claims:

1. **Ontological reinterpretation:** hydrogen is a temporal resonance projected into spatial record envelopes.
2. **Constants architecture:** constants are upstream bridge/certificate outputs rather than arbitrary inserted parameters.
3. **Residual tests:** state-dependent holonomy residuals may generate overconstrained spectroscopy signatures after the ground electron certificate is frozen.

21.3 What would make DTT stronger than reinterpretation

DTT becomes more than reinterpretation only if it supplies at least one of the following:

- a physical electron certificate giving the measured $\Delta_{\mathcal{R}}$ without hidden input;
- an internal electron/proton mass certificate or mass-ratio certificate;
- a finite-regulator derivation of radiative coefficients in hydrogen;
- a predeclared residual shape that survives overconstrained spectroscopy better than null residuals and standard nuisance models.

22 Experimental and observational roadmap

22.1 Tier 1: consistency checks

The first tests are consistency checks of the dependency graph: gross hydrogen, deuterium, and hydrogen-like ion spectra should be reproduced after constants are supplied. Failure here indicates a dictionary or convention error rather than a new DTT effect.

22.2 Tier 2: residual-shape tests

The second tests are residual-shape tests across multiple transitions. Useful channels include:

$$1S-2S, \quad 2S-nS, \quad 2S-nD, \quad \text{Rydberg circular states}, \quad \text{H/D isotope pairs}.$$

The DTT claim requires fixed shape columns, not one amplitude per line.

22.3 Tier 3: conjugation and environment tests

Antihydrogen, muonium, positronium, and gravitationally separated clocks can probe orientation, mass, recoil, and environmental response in ways ordinary hydrogen alone cannot.

Channel	Primary constants tested	Failure mode
Gross H/D spectrum	$\alpha, \hbar, c_{\star}, m_e, m_p$	wrong dictionary or upstream constants
Fine structure	α , spin orientation, relativistic delay	wrong correction hierarchy

Lamb shift	radiative temporal loops, α powers	fitted coefficients or wrong finite parts
Hyperfine	charge, magnetic moments, mass ratio, proton structure	missing spin/mass layer
Antihydrogen	charge-conjugation orientation	post-hoc branch rule
Rydberg states	high- ℓ residual suppression	wrong state-cycle geometry
Muonium/positronium	mass-ratio and recoil structure	hidden mass input
Clock redshift	c_* , gravitational response	wrong environmental bridge

23 Figures and diagrams for a publication version

Figure placeholder: Hydrogen constants wheel

Hydrogen at the center, with spokes to c_* , $\hbar$, α , charge, masses, k_B , G , and Λ . Each spoke should be labeled as upstream, downstream, or environmental.

Figure 3: Hydrogen constants wheel. Placeholder key: `fig-rosetta-wheel`.

Figure placeholder: Source firewall around upstream certificates

A firewall diagram showing forbidden arrows from hydrogen spectra into the alpha, mass, charge, $\hbar$, or speed certificates.

Figure 4: Source firewall around upstream certificates. Placeholder key: `fig-source-firewall`.

Figure placeholder: Hydrogen correction hierarchy

Energy ladder beginning with gross Bohr levels and adding fine structure, Lamb shift, recoil, hyperfine, nuclear, and DTT residual columns.

Figure 5: Hydrogen correction hierarchy. Placeholder key: `fig-correction-ladder`.

24 Remaining theorem gaps

24.1 Upstream gaps

The hydrogen synthesis is only as strong as the upstream certificates. The major unresolved tasks are:

Figure placeholder: Overconstrained residual matrix

Rows are transitions; columns are predeclared DTT shape functions and ordinary nuisance directions. The figure should show why one amplitude per line is rejected.

Figure 6: Overconstrained residual matrix. Placeholder key: `fig-residual-matrix`.

1. physical electron certificate for $\Delta_{\mathcal{R}}$;
2. coupling-correspondence proof connecting the determinant phase to $\alpha_{\text{OS}}^{-1}(0)$;
3. electron mass certificate;
4. proton temporal-inertia or mass-ratio certificate;
5. charge-character-to-electromagnetic-response proof;
6. radiative loop coefficient derivation.

24.2 Hydrogen-specific gaps

Hydrogen-specific gaps include:

- proof that the alpha-free temporal resonance reduces to the Coulomb envelope;
- derivation of finite-size and proton-structure corrections in record terms;
- derivation of Lamb-shift finite constants from temporal loops;
- derivation of residual shape columns from state-cycle geometry;
- independent validation across H, D, muonium, positronium, antihydrogen, and Rydberg states.

25 Conclusion

Hydrogen is the right synthesis system because it forces the entire DTT constants program to meet in one experimentally overconstrained place. But it must be used in the right logical order. If hydrogen defines α , m_e , $\hbar$, or c , then it becomes circular. If those constants are certified upstream and hydrogen is used downstream, then the atom becomes a Rosetta stone: it translates abstract projection-metrological roles into spectra, lengths, frequencies, splittings, loops, and residual tests.

The final DTT hydrogen theorem target can be summarized as

$$\boxed{\mathcal{I}_H \text{ frozen upstream} \quad + \quad \mathcal{D}_H^{\text{af}} \text{ alpha-free} \quad \implies \quad \text{hydrogen spectrum plus residual test matrix.}}$$

A successful program must then pass the no-backflow test:

$$\boxed{\text{hydrogen validates or falsifies upstream constants; it does not tune them.}}$$

26 The Rosetta translation theorem

26.1 Translation rather than construction

The most important logical distinction in this synthesis is the difference between a construction theorem and a translation theorem. A construction theorem produces an upstream object from DTT primitives: for example a local completion cone, an action–phase bridge, a charge character, a mass recurrence certificate, or an electron holonomy certificate. A translation theorem takes those already constructed objects and expresses their consequences in a physical system. Hydrogen is primarily a translation theorem.

Theorem 26.1 (Hydrogen Rosetta translation theorem). *Assume the following data are fixed before hydrogen spectroscopy is consulted:*

1. *a local completion-cone speed $c_\star$,*
2. *an action–phase bridge $\hbar$,*
3. *a primitive charge-character assignment $\chi_e = -1$, $\chi_p = +1$,*
4. *a low-energy electromagnetic coupling $\alpha_{\text{OS}}(0)$,*
5. *temporal-inertia certificates for m_e and m_p , or a frozen mass-ratio certificate together with one mass scale,*
6. *an alpha-free hydrogen temporal resonance datum $\mathcal{D}_H^{\text{af}}$,*
7. *a unit dictionary and source-firewall ledger.*

Then the gross hydrogenic scales

$$\mu_H, \quad a_\mu, \quad E_H, \quad R_H, \quad \tau_{\text{em},e}, \quad \mu_B, \quad \mu_N$$

are downstream functions of the frozen data. They may be computed, compared, corrected, or falsified, but they cannot consistently be used to modify the frozen upstream data without violating the dependency graph.

Proof. Every displayed hydrogenic scale is an algebraic expression in the upstream constants and in the reduced two-body record mass. The certificate explicitly records those expressions as directed edges from frozen upstream nodes to downstream scale nodes. If the graph is acyclic and no upstream node has an incoming edge from a downstream hydrogen observable, hydrogen spectroscopy cannot alter the upstream values. A disagreement can reject a downstream model, a correction hierarchy, or an upstream certificate already fixed elsewhere; it cannot justify post-hoc retuning inside the same certificate. $\square$

26.2 Four possible outcomes

A hydrogen Rosetta paper can end in four scientifically distinct ways.

1. **Closure.** The frozen constants, standard bound-state theory, and any predeclared DTT residuals match the comparison data within covariance.
2. **Downstream failure.** The gross constants are accepted, but a correction layer such as radiative loops, nuclear structure, or residual columns fails.

3. **Upstream falsification.** A frozen upstream certificate predicts a value that cannot be reconciled with many independent hydrogen and non-hydrogen tests.
4. **Firewall failure.** The supposed prediction used hidden spectroscopy or CODATA inputs; in that case there is no valid test because the construction was circular.

27 Constant-by-constant hydrogen dictionary

27.1 The speed sector

The hydrogen dictionary receives the invariant speed through three channels. The first is photon propagation: transition records couple to the null one-tick class. The second is relativistic kinematics: fine structure, recoil, and time dilation require the completion cone. The third is clock comparison: transition frequencies can be transported between gravitational potentials only after the causal clock structure is fixed.

The hydrogen role of $c_\star$ is therefore not a numerical SI definition. It is a structural role: it converts temporal record completion into spatial readout and supplies the null boundary for radiation records. In post-freeze formulas one may write $c_\star$ wherever conventional theory writes c , but the DTT claim concerns the cone and one-tick class, not the decimal convention for metres per second.

27.2 The action sector

The hydrogen role of $\hbar$ is to convert additive action around stable record loops into compact phase. This is why hydrogen spectroscopy is fundamentally a phase comparison. The gross spectrum, semiclassical quantization, angular momentum labels, and transition phases are all downstream manifestations of

$$\Delta\theta = S/\hbar \pmod{2\pi}.$$

The synthesis should therefore avoid saying that $\hbar$ is inferred from a hydrogen line. A hydrogen line can calibrate a unit dictionary or test consistency; it is not the source of the structural bridge.

27.3 The electromagnetic coupling sector

Hydrogen is exquisitely sensitive to α , but this sensitivity is precisely why it is dangerous as an upstream source. In the DTT program the strongest route is:

$$\alpha_{\text{OS}}^{-1}(0) = N_3(10) + H_e,$$

where $N_3(10) = 137$ is the structural integer and H_e is the frozen electron holonomy fraction. Hydrogen then receives α and amplifies it into a hierarchy of scales:

$$E_H \propto \alpha^2, \quad \Delta E_{\text{fs}} \propto \alpha^4, \quad \Delta E_{\text{Lamb}} \sim \alpha^5 \log \alpha^{-1}.$$

This amplification makes hydrogen a powerful test but a poor non-circular constructor unless carefully quarantined.

27.4 The charge sector

The hydrogen charge dictionary has three layers. First, the exact character statement $\chi_p\chi_e = 1$ gives neutrality. Second, the primitive record normalization q_{rec} fixes how compact charge characters couple to record connections. Third, the SI image e_{SI} appears only after the unit dictionary. A safe hydrogen synthesis must always state which layer is being used.

27.5 The mass sector

The electron mass fixes the principal energy scale; the proton mass fixes reduced-mass, recoil, hyperfine, and isotope corrections. The proton-electron mass ratio is dimensionless and therefore a strong theoretical target. In hydrogen, however, this ratio should be treated as frozen input or as a separately certified output. It must not be reverse engineered from spectroscopy inside the same proof.

27.6 Magnetic and spin-response sector

Magnetic response combines charge, action, mass, and spin orientation. The synthesis should distinguish three sublayers:

1. exact spin/orientation labels such as j, F, m_F ,
2. magnetic moment scales such as μ_B and μ_N ,
3. dimensionless g -factors and nuclear magnetic moments, which require separate response theory or empirical input.

27.7 Thermal sector

Thermal shifts are not fundamental changes of $\hbar$ or α . They are environmental response effects. DTT may model finite stability, thermal record multiplicity, and phase diffusion, but a thermal fit is not an upstream constants derivation unless the bridge theory for k_B and the environment model are frozen independently.

27.8 Gravity sector

Hydrogen clocks test gravitational response. They do not determine G by themselves. The curvature-response coefficient belongs to Paper 20, while hydrogen supplies precise clock records that can probe redshift, equivalence, and possible environment-dependent deviations.

28 State dictionary and transition dictionary

28.1 State records

For each hydrogenic state label $a = (n, \ell, j, F, m_F)$, introduce a record-cycle representative

$$C_{a,r} = C_{n\ell j F m_F, r}.$$

The state is not merely the label. It is a stable equivalence class of regulated record cycles with an envelope description, spin/orientation data, and a transition interface.

Definition 28.1 (Hydrogen state certificate). *A regulated hydrogen state certificate consists of*

$$\mathcal{S}_{a,r} = (C_{a,r}, P_{a,r}, E_{a,r}, \Phi_{a,r}, \mathbf{q}_{a,r}, h_{a,r}),$$

where $C_{a,r}$ is the state record cycle, $P_{a,r}$ the selected state projector, $E_{a,r}$ the post-freeze energy model, $\Phi_{a,r}$ the phase/orientation data, $\mathbf{q}_{a,r}$ the quality ledger, and $h_{a,r}$ the hash.

28.2 Transition records

A transition certificate compares two state records:

$$\mathcal{T}_{a \rightarrow b,r} = (\mathcal{S}_{a,r}, \mathcal{S}_{b,r}, \gamma_{ab,r}, \nu_{ab,r}, \mathbf{q}_{ab,r}, h_{ab,r}).$$

The photon record $\gamma_{ab,r}$ is constrained by the null completion cone. The frequency $\nu_{ab,r}$ is computed from the post-freeze energy difference and the action-phase bridge:

$$\nu_{ab,r} = \frac{E_{a,r} - E_{b,r}}{h}.$$

28.3 Transition categories

Hydrogen transitions should be grouped before comparison:

- gross optical transitions such as $1S \rightarrow 2S$,
- S-S transitions sensitive to contact-like residuals,
- S-D transitions that separate angular and contact effects,
- fine-structure intervals sensitive to spin and relativistic orientation,
- hyperfine transitions sensitive to magnetic and nuclear structure,
- Rydberg transitions sensitive to high- ℓ suppression and long-range fields,
- isotope and antihydrogen transitions sensitive to mass/nuclear/orientation changes.

29 Commutative diagrams for source safety

29.1 The desired square

The safe synthesis is summarized by a commuting square:

$$\begin{array}{ccc} \text{DTT primitives} & \xrightarrow{\text{Can}} & \text{upstream certificates} \\ \downarrow & & \downarrow \\ \text{alpha-free hydrogen records} & \xrightarrow{\text{Rosetta}} & \text{hydrogen observables.} \end{array}$$

The left vertical arrow means that the same record ontology supports hydrogen. The right vertical arrow means that upstream certificates become inputs to downstream hydrogen formulas. The bottom arrow is the translation layer. There is no arrow from the lower-right corner back to the upper-right corner.

29.2 The forbidden square

The forbidden pattern is:

$$\text{hydrogen line data} \longrightarrow \alpha \longrightarrow \Delta_R \longrightarrow \text{claim of DTT derivation.}$$

This pattern fits the constant to hydrogen and then pretends it was derived. A certificate must explicitly rule it out.

30 Integration with standard bound-state theory

30.1 What is retained from standard physics

The synthesis does not discard ordinary quantum mechanics or QED. Instead, it separates levels:

1. DTT supplies a proposed source of the constants and record ontology.
2. Standard bound-state theory supplies the effective Hamiltonian and radiative calculation layer once constants are fixed.
3. DTT residual columns, if any, must be predeclared and tested against the residual left after the standard layer.

30.2 Effective Hamiltonian ledger

A useful post-freeze Hamiltonian ledger is

$$H_H = H_0 + H_{\text{fs}} + H_{\text{rad}} + H_{\text{recoil}} + H_{\text{nuc}} + H_{\text{hfs}} + H_{\text{env}} + H_{\text{DTT, res}}.$$

The term $H_{\text{DTT, res}}$ is allowed only if its operator form or residual column is fixed before comparison with spectroscopy.

31 Experimental staging

31.1 Stage 0: closure of gross scales

Stage 0 checks that the frozen upstream constants reproduce the gross scales a_μ , E_H , and R_H under the declared unit dictionary. This is a consistency check, not a new prediction.

31.2 Stage 1: correction hierarchy

Stage 1 checks the conventional correction hierarchy. If the DTT program claims a temporal-loop derivation of a correction coefficient, that coefficient must be derived before fitting. Otherwise the coefficient remains part of the standard QED/nuclear input.

31.3 Stage 2: residual-column tests

Stage 2 tests DTT residual columns such as S-contact, spin-holonomy, Rydberg-tail, isotope-boundary, and orientation-sensitive columns. A model survives only if the residual vector lies in the predeclared column space within covariance.

31.4 Stage 3: cross-system transfer

Stage 3 tests whether the same frozen constants and residual principles transfer to deuterium, muonium, positronium, hydrogen-like ions, and antihydrogen without retuning.

32 Algorithmic protocol HRS1–HRS20

Protocol 32.1 (Hydrogen Rosetta synthesis protocol). *A complete implementation should follow this order.*

- HRS1. Freeze the upstream record ontology and alpha-free hydrogen datum.*
- HRS2. Freeze c_* or its calibration certificate.*
- HRS3. Freeze $\hbar$ or its action–phase bridge certificate.*
- HRS4. Freeze α from the electron holonomy/coupling route or declare it as external calibration.*
- HRS5. Freeze charge character and charge-unit dictionary.*
- HRS6. Freeze electron mass and proton/electron mass ratio inputs.*
- HRS7. Freeze environmental response constants used in the comparison.*
- HRS8. Serialize all upstream certificates and record hashes.*
- HRS9. Construct the downstream hydrogen dependency graph.*
- HRS10. Verify no backflow edges from hydrogen observables.*
- HRS11. Compute reduced mass and gross scales.*
- HRS12. Construct the correction hierarchy ledger.*
- HRS13. Declare which correction coefficients are derived, standard, fitted nuisance, or open.*
- HRS14. Build transition and state certificates.*
- HRS15. Build nuisance and DTT residual design matrices.*
- HRS16. Verify overconstraint $M - p \geq 2$.*
- HRS17. Freeze the Rosetta certificate hash.*
- HRS18. Only then import experimental transition data.*
- HRS19. Fit or bound declared residual columns.*
- HRS20. Publish success, failure, or ambiguity without modifying upstream certificates.*

33 Acceptance theorem and failure theorem

Theorem Target 33.1 (Hydrogen Rosetta acceptance theorem). *A hydrogen Rosetta certificate is acceptable as a non-circular synthesis if it satisfies all of the following: upstream certificates are*

frozen; the alpha-free hydrogen datum is source-clean; the unit dictionary is fixed; the dependency graph is acyclic; no hydrogen observable tunes upstream constants; derived scales are recomputed exactly from frozen inputs; correction terms are status-labeled; residual columns are predeclared; the comparison is overconstrained; and the certificate hash is produced before importing comparison data.

Theorem 33.2 (Failure theorem). *If a hydrogen Rosetta certificate uses alpha-containing hydrogen formulas, measured spectra, Bohr/Rydberg scales, Lamb-shift numerics, or fitted residuals to select an upstream constant or certificate field before freeze, then it cannot support a derivation claim for that upstream constant.*

Proof. The derivation claim requires that the upstream object be determined without the target phenomenon. If the target phenomenon is used to select the upstream object, then the construction is not independent of the target. The source-firewall ledger records such dependence as a pre-freeze forbidden edge; the certificate is rejected. $\square$

34 Extended paper-sequence synthesis table

Paper	Upstream result	Hydrogen use in Paper 21
1	Projection realism and records	Supplies the ontology of hydrogen as stable record resonance.
2	Projection metrology	Supplies constants-as-bridges classification.
3	Structural $\hbar$	Converts hydrogen record action into phase.
4	Record action	Supplies action around temporal record segments.
5	Finite stability	Supplies $\hbar_{\text{eff}}$ and phase-anomaly diagnostics.
6	Completion cone $c_\star$	Supplies photon null class and relativistic structure.
7	Structural 137	Supplies integer part of α^{-1} .
8	Holonomy fraction	Supplies residual certificate route for α .
9	Coupling correspondence	Explains why holonomy response is inverse coupling.
10	Physical electron certificate	Freezes the future physical electron value.
11	Alpha-free hydrogen	Supplies neutral temporal resonance datum.
12	Bohr reconstruction	Supplies gross spectrum translation.
13	Fine/Lamb structure	Supplies correction hierarchy and radiative targets.
14	Differential holonomy tests	Supplies residual spectroscopy design matrix.
15	Charge character	Supplies $\chi_p\chi_e = 1$ and charge-unit layer.
16	Electron mass	Supplies temporal inertia and Compton recurrence.

17	Mass ratio	Supplies m_p/m_e as dimensionless temporal hierarchy target.
18	Boltzmann bridge	Supplies environmental thermal response layer.
19	Vacuum averaging	Supplies coarse-grained vacuum source context.
20	Curvature response	Supplies gravitational redshift/clock interface.

Table 5: How Papers 1–20 feed the Paper 21 hydrogen synthesis.

A Notation ledger

Symbol	Meaning
$\mathcal{D}_H^{\text{af}}$	alpha-free hydrogen temporal record datum
$\mathcal{I}_H$	post-freeze hydrogen input object
$\mathcal{C}_{H,\text{Rosetta}}$	hydrogen integration certificate
$c_\star$	local completion speed / invariant reconstruction slope
$\hbar$	action-phase bridge constant
α	low-energy electromagnetic coupling after upstream freeze
$\Delta_{\mathcal{R}}$	holonomy/coupling residual in $\alpha_{\text{OS}}^{-1}(0) = 137 + \Delta_{\mathcal{R}}$
χ_e, χ_p	primitive electron/proton charge characters
μ_H	hydrogen reduced mass
η_a	state-dependent holonomy residual relative to ground sector

B Claim-status ledger

Claim	Status	Discharge requirement
Hydrogen is a temporal resonance	theorem target from Paper 11	alpha-free finite-regulator resonance proof
Gross Bohr spectrum follows post-freeze	conditional theorem	upstream constants and Coulomb-envelope reduction
Fine structure hierarchy	post-freeze target	record derivation of spin/relativistic corrections
Lamb shift hierarchy	theorem target	finite-regulator loop measure and coefficients
DTT residual columns	theorem target	state-cycle holonomy derivation and overconstrained test
No-backflow	certificate theorem	frozen hashes and source-firewall validation

C Source-role ledger

Source layer	Allowed role	Forbidden role
Projection metrology Action/ $\hbar$ papers	constants as bridge roles action-phase bridge and stable-limit $\hbar$	numerical fitting of constants using hydrogen to define $\hbar$
Completion-cone paper	c_* as reconstruction slope	using hydrogen spectroscopy to define c
Structural 137 paper Holonomy/coupling papers	flat integer $N_3(10) = 137$ alpha certificate architecture	providing $\Delta_{\mathcal{R}}$ using hydrogen line fits before freeze
Hydrogen/SMM ontology	alpha-free temporal resonance language	deriving α from an alpha-containing tick
Hydrogen spectroscopy notes	post-freeze phenomenology	upstream alpha or mass derivation

D Certificate schema sketch

Listing 1: Sketch of the hydrogen Rosetta certificate.

```
{
  "schema_name": "dtc_paper21_rosetta_certificate_schema",
  "physical_claim": false,
  "upstream_certificate_hashes": {
    "c_star": {"status": "frozen_or_toy", "value": "..."},
    "hbar": {"status": "frozen_or_toy", "value": "..."},
    "alpha": {"status": "post_freeze", "value": "..."},
    "m_e": {"status": "frozen_or_toy", "value": "..."},
    "m_p": {"status": "frozen_or_toy", "value": "..."}
  },
  "alpha_free_hydrogen_hash": "...",
  "derived_hydrogen_scales": {"reduced_mass": "...", "bohr_radius_reduced": "...", "E1": "..."},
  "correction_hierarchy": ["gross", "fine_structure", "lamb", "recoil", "hyperfine", "dtc_residual"],
  "residual_shape_matrix": {"M": 0, "p_DTT": 0},
  "nuisance_matrix": {"p_nuisance": 0},
  "source_firewall_report": {"forbidden_pre_freeze_tokens_found": [], "spectroscopy_used_pre_freeze": false},
  "no_backflow_graph": {"backflow_edges": []},
  "comparison_stage": "post_freeze_only"
}
```

E Referee stress tests

1. **Circularity test.** Does any upstream field use α -dependent hydrogen formulas?

2. **Dimensionful-constant test.** Are SI numerical values treated as unit calibration rather than pure derivations?
3. **Residual-fit test.** Are spectroscopy residuals overconstrained?
4. **QED-compatibility test.** Does the paper respect standard QED success where constants are already supplied?
5. **Failure-mode test.** Does the paper say what would falsify the strong DTT claim?

F Appendix: expanded derivation ledger for hydrogen scales

F.1 From temporal inertia to rest energy

The mass paper defines rest mass through temporal recurrence rather than through a primitive inertial scalar. In the stable post-freeze limit one has

$$E_{\text{rest}} = mc_{\star}^2 = \hbar\omega_{\text{rest}}.$$

For the electron and proton this gives two rest recurrence classes

$$\omega_e = \frac{m_e c_{\star}^2}{\hbar}, \quad \omega_p = \frac{m_p c_{\star}^2}{\hbar}.$$

Their ratio is dimensionless:

$$\frac{\omega_p}{\omega_e} = \frac{m_p}{m_e}.$$

Hydrogen uses the individual masses through the reduced mass, but the stronger DTT target is the ratio. If m_p/m_e is derived by the temporal hierarchy paper and one mass scale is calibrated by a unit dictionary, the other follows.

F.2 From charge character to Coulomb envelope

The alpha-free hydrogen datum supplies only neutral charge-character structure. It does not by itself specify a Coulomb potential. The Coulomb envelope arises only after the primitive charge character is connected to the boundary coupling response. In rationalized form the envelope coupling is represented by

$$V(r) = -\frac{\alpha \hbar c_{\star}}{r}.$$

The appearance of α in this expression marks it as post-freeze. The logical chain is:

$$\chi_e, \chi_p \quad + \quad \text{boundary-response theorem} \quad + \quad \alpha_{\text{OS}}(0) \quad \Longrightarrow \quad V_{\text{env}}(r).$$

If this chain is not proved, the Coulomb envelope may still be used phenomenologically, but it cannot be claimed as a first-principles DTT output.

F.3 Bohr radius as a projected length scale

The Bohr radius is a derived spatial readout scale:

$$a_{\mu} = \frac{\hbar}{\mu_H c_{\star} \alpha}.$$

In standard language it is the characteristic length of the Coulomb ground-state envelope. In DTT language it is the outer-record spatial scale produced when an alpha-free temporal resonance is read through the post-freeze metric, action, mass, and coupling dictionaries.

F.4 Rydberg scale as a frequency image

The Rydberg scale is not a new constant in the DTT hierarchy. It is a frequency/wavenumber image of binding:

$$R_H = \frac{\mu_H c_\star \alpha^2}{2h}.$$

Thus the Rydberg constant is downstream of μ_H , $c_\star$, α , and h . Using the measured Rydberg scale before deriving α is therefore equivalent to importing a highly precise alpha proxy.

G Appendix: detailed finite-regulator hydrogen template

G.1 Regulated alpha-free data

At regulator r , the hydrogen resonance begins with a finite record datum

$$\mathcal{D}_{H,r}^{\text{af}} = (V_{H,r}, E_{H,r}, F_{H,r}, \partial_r, \omega_r, J_r, \Theta_{p,r}, \Theta_{e,r}, \chi_{p,r}, \chi_{e,r}, \sim_{\text{obs},r}).$$

Here $V_{H,r}$ are record vertices, $E_{H,r}$ record morphism edges, $F_{H,r}$ comparison two-cells, ∂_r incidence data, ω_r weights, J_r the selected complex structure inherited from the upstream complexification layer, and $\Theta_{p,r}, \Theta_{e,r}$ phase-orientation maps. The alpha-free condition is implemented by a source scan and by the absence of alpha-dependent scales in the field definitions.

G.2 Resonance projector

The resonance projector should be obtained from a structural mixed operator

$$K_{H,r}^{\text{mix}} = K_{H,r}^{\text{neutral}} + K_{H,r}^{\text{lock}} + K_{H,r}^{\text{stability}},$$

where the first term enforces neutral character, the second enforces phase locking, and the third enforces record stability. A finite-regulator resonance band is admissible if there exists a window $I_{H,r}$ such that

$$P_{H,r}^{\text{res}} = \mathbf{1}_{I_{H,r}}(K_{H,r}^{\text{mix}})$$

has stable rank and a gap

$$g_{H,r} = \text{dist}(I_{H,r}, \sigma(K_{H,r}^{\text{mix}}) \setminus I_{H,r}) > 0.$$

G.3 Post-freeze envelope map

After the upstream constants are frozen, the envelope map has the form

$$\text{Env}_r : (\mathcal{D}_{H,r}^{\text{af}}, \mathcal{I}_H) \longrightarrow H_{\text{env},r}.$$

A valid envelope map must be functorial under regulator comparison and invariant under relabeling of record cells. It must not depend on measured spectral residuals. The continuum envelope is obtained only if

$$\|\Phi_{r'r} H_{\text{env},r} - H_{\text{env},r'} \Phi_{r'r}\| \rightarrow 0$$

along the declared regulator trajectory.

G.4 Gross-spectrum certificate table

A physical hydrogen gross-spectrum certificate should include a table of the form

r	$\text{rank } P_{H,r}^{\text{res}}$	$g_{H,r}$	$\mu_{H,r}$	$a_{\mu,r}$	$R_{H,r}$	$\Delta_{r,r'}$
r_1	...	...	...	...	...	...
r_2	...	...	...	...	...	...
r_3	...	...	...	...	...	...

This paper provides the table format. A future physical computation must populate it.

H Appendix: residual-design matrix template

H.1 Transition index set

Let $\mathcal{T}$ be a finite set of transitions

$$\mathcal{T} = \{i : a_i \rightarrow b_i\}_{i=1}^M.$$

For each transition define a residual after subtracting standard post-freeze theory and declared systematics:

$$y_i = \nu_i^{\text{obs}} - \nu_i^{\text{base}} - \nu_i^{\text{sys}}.$$

Here ν_i^{base} includes all correction layers that are not being tested as DTT residuals.

H.2 DTT columns

A DTT column is admissible only if it is specified before data fitting. Examples include

$$S_{\text{contact}}(i) = \left(n_{b_i}^{-3} \mathbf{1}_{\ell_{b_i}=0} - n_{a_i}^{-3} \mathbf{1}_{\ell_{a_i}=0} \right),$$

$$S_{\text{spin}}(i) = n_{b_i}^{-3} \sigma_{b_i} - n_{a_i}^{-3} \sigma_{a_i},$$

$$S_{\text{ryd}}(i) = \rho_{b_i}^{\text{high-}\ell} - \rho_{a_i}^{\text{high-}\ell}.$$

The exact definitions of σ_a and ρ_a must come from state-cycle geometry.

H.3 Nuisance columns

Nuisance columns may include Rydberg-scale adjustment, proton-radius direction, reduced-mass uncertainty, recoil convention, finite-size correction, field shifts, or systematic offsets. They must be included explicitly so that DTT residuals are not absorbing ordinary uncertainties.

H.4 Overconstraint score

The basic overconstraint score is

$$\Omega_{\text{oc}} = M - p_{\text{DTT}} - p_{\text{nuisance}}.$$

A strong residual claim requires $\Omega_{\text{oc}} \geq 2$, with covariance conditioning checked. A better claim requires independent classes of transitions, not merely many nearly identical lines.

I Appendix: hydrogen family checklist

System	Constants sized	empha-	Main nuisance	DTT use
H	$\alpha, m_e, m_p, \hbar, c_\star$		proton radius, Lamb shift	reference integration
D	reduced mass, nuclear structure		deuteron radius, polarizability	isotope separation
H-like ions	$Z\alpha$, relativistic terms		nuclear size, strong fields	scaling tests
Muonium	lepton masses, charge		muon lifetime, recoil	mass/charge universality
Positronium	equal masses, annihilation		annihilation channels	lepton resonance symmetry
Antihydrogen	charge conjugation, orientation		trap/systematics	CPT/orientation test
Rydberg H	high- n , high- ℓ geometry		external fields	residual suppression test
Molecular ions	mass ratios, vibration		molecular theory	mass hierarchy tests

J Appendix: glossary of source statuses

Derived. Obtained from a DTT theorem or finite-regulator certificate without empirical backflow.

Certified. Frozen in a machine-checkable certificate with source-firewall validation.

Calibrated. Fixed by a unit dictionary or external convention; not a dimensionless derivation.

Phenomenological. Inserted from experiment for comparison or modeling, not claimed as derived.

Post-freeze. Allowed only after the relevant upstream certificate is frozen.

Quarantined. Useful for later phenomenology but forbidden in upstream derivation layers.

Target. A theorem, computation, or certificate that remains to be supplied.

K Appendix: minimal public summary

A concise public-facing explanation of this paper would be:

Hydrogen is the atom where the constants meet, but it should not be used to smuggle the constants into the theory. In DTT the speed of light is a reconstruction slope, Planck's constant is the action-phase bridge, the fine-structure constant is a boundary coupling/holonomy output, charge is a compact character, and mass is temporal inertia. Once these ingredients are fixed independently, hydrogen translates them into the Bohr radius, Rydberg scale, spectral lines, fine structure, Lamb shift, and hyperfine splitting. Therefore hydrogen is the Rosetta stone of projection metrology: it shows how the languages of phase, action, charge, mass, geometry, and spectroscopy translate into one another. It is a testbed, not a shortcut.

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