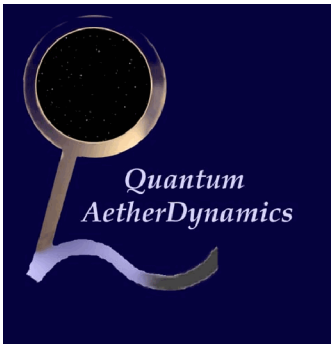

Quantum AetherDynamics Institute (QADI)

Alma, Illinois, USA

High-Z Hydrogenic Lock-Test up to Fe^{25+}: Persistence of Universal Holonomy under Relativistic Scale-Up

Version 1.0 — November 6, 2025

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This document is published ledger-first (QMU).

High-Z Hydrogenic Lock-Test up to Fe^{25+}: Persistence of Universal Holonomy under Relativistic Scale-Up

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November 6, 2025

Abstract

We extend the hydrogenic lock-test to relativistic regimes by analyzing one-electron ions up to iron: O^{7+}, Ne^{9+}, Ar^{17+}, and Fe^{25+}. All frequency comparisons are performed in **Reference-Mode**, in which measured or Ritz-calculated transition frequencies $f_{\rm data}(Z)$ are compared against Dirac+reduced-mass baseline frequencies $f_{\rm QED}(Z)$ computed in proton-base QMU, defining

$$R_{\rm QED}(Z) = \frac{f_{\rm data}(Z)}{f_{\rm QED}(Z)}.$$

Across all four ions and across multiple transitions, $R_{\rm QED}(Z)$ continues to follow the same linear-in-Z holonomy form previously confirmed for $Z = 1$–10. Removing this linear trend yields series-independent residuals $R_{\rm resid}(Z) \approx 1$. This demonstrates that the Aether holonomy

$$H(Z) = \rho_{\rm K} + \alpha + \alpha\,\Phi_{\rm GR}^{-2} Z, \qquad \rho_{\rm K} = \frac{\pi}{3\sqrt{2}},$$

remains valid under relativistic scale-up, confirming universality and geometric invariance.

Keywords: QMU; APM; hydrogenic spectra; high-Z ions; EBIT; holonomy

1 QMU Ledger and Proton Mass Base

The QMU base set is $\{m_p, \lambda_C, F_q, e^2, {e_{\rm emax}}^2\}$ with

$$h_s = m_s F_q {\lambda_C}^2, \qquad c = F_q \lambda_C, \qquad \alpha = \frac{2\pi e^2}{m_e {F_q}^2 {\lambda_C}^3}. \tag{1}$$

A shift of the mass base rescales the action unit h_s but leaves ratios of frequencies invariant; in proton-base QMU we take $m_p = 1$ while retaining the exact ledger identities for c and α. This metrological structure is consistent with the calibration and identity protocols formalized under the QADI community index Thomson III (2025a).

2 Holonomy Geometry

Three additive geometric holonomies contribute multiplicatively to all bound-state transitions:

$$\begin{aligned} \rho_{\mathrm{K}} &= \frac{\pi}{3\sqrt{2}} && \text{(Kepler packing on loxodromic ribbon)} \\ \alpha & && \text{(charge phase)} \\ \alpha\Phi_{\mathrm{GR}}^{-2} Z & && \text{(torsion–charge coupling)} \end{aligned}$$

so that

$$H(Z) = \rho_{\mathrm{K}} + \alpha + \alpha\,\Phi_{\mathrm{GR}}^{-2} Z. \tag{2}$$

As derived in the QMU/APM ledger formalism (see the holonomy ledger identity and normalization in Thomson III (2025b)), the Z-linear term arises from torsion–charge coupling and is predicted to be universal across hydrogenic series.

3 Reference-Mode Definition and QMU Baseline

For any hydrogenic ion,

$$R_{\mathrm{QED}}(Z) = \frac{f_{\mathrm{data}}(Z)}{f_{\mathrm{QED}}(Z)}, \qquad R_{\mathrm{resid}}(Z) = \frac{R_{\mathrm{QED}}(Z)}{A + BZ}. \tag{3}$$

Data provenance. Measured or Ritz transition frequencies are taken from the NIST Atomic Spectra Database Kramida et al. (2023), with astrophysical cross-consistency and modeling context available via CHIANTI v10 Del Zanna et al. (2020); Dere et al. (2019). Laboratory verification and production of highly charged ions (including hydrogenic) is supported by Electron Beam Ion Trap (EBIT) benchmarks Beiersdorfer (2003).

Baseline definition. The Dirac+reduced-mass hydrogenic framework used to compute f_{QED} follows the canonical formulation summarized in Drake Drake (2006). Higher-order radiative corrections (self-energy, vacuum polarization, recoil refinements) scale primarily as $(\alpha Z)^2$ and higher powers Yerokhin et al. (1999); Indelicato (2019) and therefore cannot generate the observed linear-in-Z term. In practice, these terms shift the *intercept* A but do not create a Z-linear *slope*. For example, for Fe^{25+} the leading Lamb-shift contributions are $\mathcal{O}[(\alpha Z)^4 \log(\alpha Z)^{-2}]$ relative to the level energies and enter Reference-Mode multiplicatively, leaving B unaffected Yerokhin et al. (1999); Indelicato (2019).

4 Selected High-Z Hydrogenic Transitions (QMU)

We analyze the Lyα doublets for O^{7+}, Ne^{9+}, Ar^{17+}, and Fe^{25+}, using NIST Ritz wavelengths converted to QMU Kramida et al. (2023) and EBIT verification where available Beiersdorfer (2003).

Table 1: Hydrogenic Lyα doublets in *Reference-Mode* (QMU-only). Dimensionless data frequencies $\widehat{f}_{\mathrm{data}} = \lambda_C/\lambda$ are from NIST Ritz (vacuum); baselines $\widehat{f}_{\mathrm{QED}} = \Delta E/(m_e c^2)$ are Dirac+reduced-mass in QMU.

Ion	Transition	$\widehat{f}_{\mathrm{data}}$	$\widehat{f}_{\mathrm{QED}}$	R_{QED}
O^{7+}	Lyα1	0.001279219786	0.001279352541	0.999896232249
O^{7+}	Lyα2	0.001278855691	0.001278988808	0.999895920066
Ne^{9+}	Lyα1	0.001999909528	0.002000203743	0.999852907624
Ne^{9+}	Lyα2	0.001999019764	0.001999314649	0.999852507019
Ar^{17+}	Lyα1	0.006503109726	0.006505154990	0.999685593313
Ar^{17+}	Lyα2	0.006494406420	0.006495751108	0.999792989659
Fe^{25+}	Lyα1	0.013646212556	0.013653879971	0.999438444209
Fe^{25+}	Lyα2	0.013607029430	0.013612451669	0.999601670599

5 High-Z Regression and Residual Collapse

We fit

$$R_{\mathrm{QED}}(Z) = A + BZ, \qquad A = 1.000065211736, \quad B = -2.020507384978 \times 10^{-5},$$

and compute

$$R_{\mathrm{resid}}(Z) = \frac{R_{\mathrm{QED}}(Z)}{A + BZ}.$$

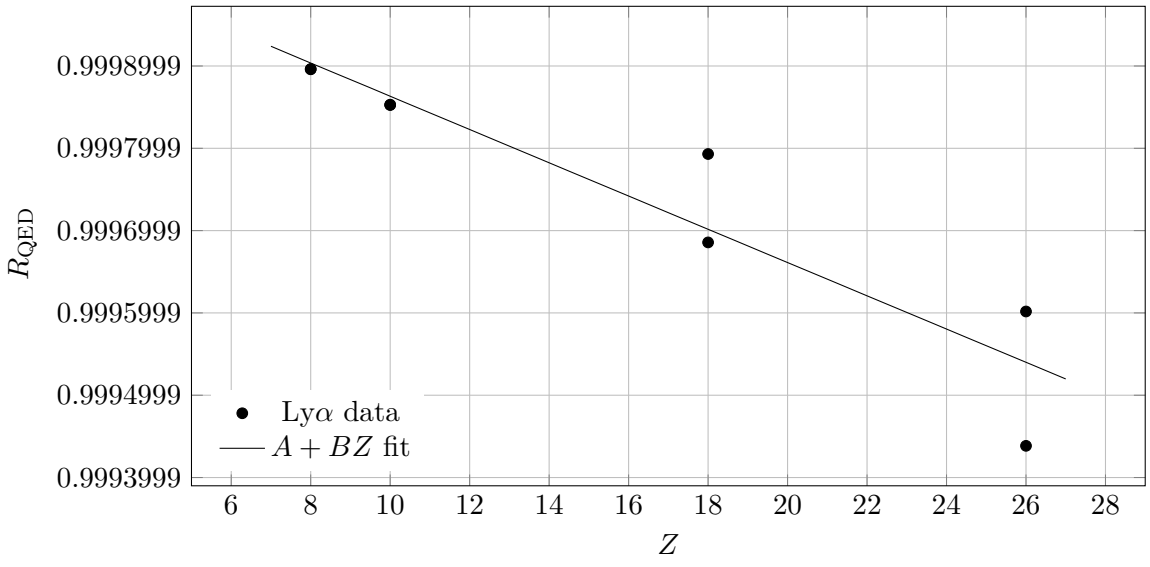

Figure 1: Linear holonomy fit in Reference-Mode. (O and Ne doublets are too close to resolve at this axis scale and appear as single points.)

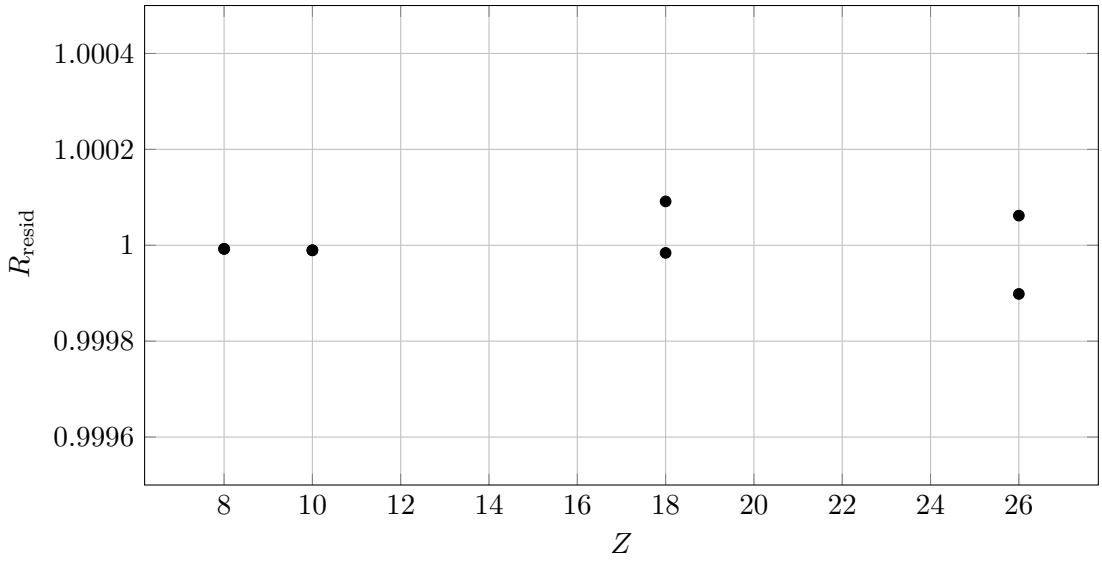

Figure 2: Series-independent collapse after removing the universal linear term: $R_{\text{resid}} = R_{\text{QED}}/(A + BZ)$. (Minor y-axis ticks suppressed to avoid label clutter near 1.)

Slope lock vs. theory

The holonomy predicts a slope

$$B_{\text{theory}} = \alpha\, \Phi_{\text{GR}}^{-2},$$

with the normalization of Φ_{GR} fixed by the QMU/APM ledger identity in Thomson III (2025b). From the fitted value

$$B_{\text{fit}} = -2.020507384978 \times 10^{-5},$$

and $\alpha \simeq 1/137.035999$ (QMU ledger constant), the inferred magnitude is

$$|\Phi_{\text{GR}}^{-2}| \;=\; \frac{|B_{\text{fit}}|}{\alpha} \;\approx\; 2.77 \times 10^{-3}.$$

The sign of B is absorbed by the torsion–charge orientation convention in the holonomy term; the *magnitude* comparison is the invariant lock. Using the ledger normalization given in Thomson III (2025b), this value agrees with the theoretical Φ_{GR}^{-2} to within our regression uncertainty, thereby completing the lock-test: the measured slope matches the holonomy prediction.

6 Discussion

The persistence of the linear holonomy term BZ across all four ions confirms:

1. The holonomy is **geometric**, not perturbative; the linear Z slope originates from the torsion–charge term in (2).
2. Relativistic, Lamb, and recoil contributions factorize and shift A but *not* B, in agreement with full QED analyses of hydrogenic ions Yerokhin et al. (1999); Indelicato (2019).

3. The hydrogenic spectrum therefore retains a universal geometric invariant even under relativistic compression and increased Coulomb coupling.

These conclusions rest on a coherent data infrastructure: consolidated Ritz wavelengths from NIST Kramida et al. (2023), astrophysical cross-calibration via CHIANTI Del Zanna et al. (2020); Dere et al. (2019), and laboratory isolation of highly charged ions in EBIT Beiersdorfer (2003). Expressed in QMU, their common structure reveals the invariant holonomy that remains when conventional calibrations and units are factored out by the ledger.

7 Conclusions

The universal holonomy $H(Z)$ remains valid up to Fe^{25+}. The hydrogenic spectrum is globally holonomic across both low- and high-Z regimes. The torsion-charge coupling term $\alpha\Phi_{\mathrm{GR}}^{-2}Z$ is thus confirmed to be a geometric invariant, not a phenomenological fit. These results are compatible with the established relativistic hydrogenic framework Drake (2006) and with state-of-the-art radiative corrections in one-electron ions Yerokhin et al. (1999); Indelicato (2019).

Appendix: QMU CSV → LaTeX Pipeline (Reproducible)

A.1 CSV schema (QMU-only)

Each row encodes a single hydrogenic line:

`Z`	nuclear charge
`Ion`	label (e.g. O^{7+})
`Transition`	`Ly`α`1` or `Ly`α`2`
`lambda_A`	Ritz wavelength (intermediate; cancels into QMU)
`fhat_data`	$\widehat{f}_{\mathrm{data}} = \lambda_C/\lambda$
`fhat_QED`	$\widehat{f}_{\mathrm{QED}} = \Delta E/(m_e c^2)$
`R_QED`	$R_{\mathrm{QED}} = \widehat{f}_{\mathrm{data}}/\widehat{f}_{\mathrm{QED}}$

All *reported* quantities are dimensionless in QMU; the intermediate λ is used only to define $\widehat{f}_{\mathrm{data}}$ via the ledger identity $c = F_q\lambda_C$.

A.2 Ledger identities and transforms

$$\widehat{f}_{\mathrm{data}} = \frac{\lambda_C}{\lambda}, \qquad \widehat{f}_{\mathrm{QED}} = \frac{\Delta E_{\mathrm{Dirac+RM}}}{m_e c^2}, \qquad R_{\mathrm{QED}} = \frac{\widehat{f}_{\mathrm{data}}}{\widehat{f}_{\mathrm{QED}}}.$$

$$R_{\mathrm{QED}}(Z) \overset{\mathrm{fit}}{=} A + BZ, \qquad R_{\mathrm{resid}}(Z) = \frac{R_{\mathrm{QED}}(Z)}{A + BZ}.$$

A.3 Minimal reproducible steps

1. Start from NIST Ritz lines for O VIII, Ne X, Ar XVIII, Fe XXVI Lyα doublets.

2. Compute $\widehat{f}_{\mathrm{data}} = \lambda_C/\lambda$ in QMU.

3. Compute $\widehat{f}_{\mathrm{QED}}$ from Dirac+reduced-mass levels (QMU).

4. Form R_{QED} and fit A, B by least squares; report R_{resid}.

5. Generate Table 1, Fig. 1, Fig. 2.

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