

A Falsifiability-First Audit Program for the Photon-Primacy, Helical-Electron, and Adelic-Mass Claim Cluster

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Abstract

The photon-primacy / helical-electron / adelic-mass cluster proposes that particle rest-energies arise from photonic circulation, that electron spin is literal helical motion at twice the Compton frequency, and that mass ratios encode arithmetic structure on Bruhat–Tits trees. The literature surrounding these ideas is fragmented and lacks a systematic, falsifiability-driven audit methodology. We present a **Falsifiability-First Audit Program (FFAP)** that (i) extracts every explicit claim from the QNFO corpus, (ii) maps each claim onto a concrete experimental observable or logical kill condition, (iii) enumerates the full combinatorial test space, and (iv) derives statistically rigorous significance thresholds that respect multiple-testing constraints. Using the sixteen published records of the Trapped-Ion Ultrametric Testbed[10], the two regimes identified in the pattern-table paper[9], and the two particle catalogs (elementary vs. quasiparticle) also defined in[9], we obtain **64 distinct claim-regime-catalog triples**. Assuming a per-test Type I error of 5% the naïve family-wise error rate exceeds 96%; a Bonferroni correction yields a per-test significance level of $\alpha = 7.8 \times 10^{-4}$.

Concrete numerical audits are performed for the most salient sub-claims: the muon-electron mass-ratio integer hypothesis is falsified at $\approx 10^5 \sigma$, the tau-electron ratio requires a 5.2-fold improvement in tau-mass precision to reach 5σ , the cross-ratio $(m_\tau/m_\mu)/(m_\mu/m_e)$ is rejected at 161σ , the binary-prime-power hypothesis for the muon-electron ratio is rejected ($\delta = 0.306$), and the unextended helical-electron model fails a parameter-count audit. A feasibility projection for the trapped-ion ultrametric test shows that, under standard-quantum-limit assumptions, a depth-4 test would demand $\approx 10^{10}$ coherent cycles (≈ 11.6 days), whereas a Heisenberg-limited protocol would reduce this to ≈ 10 s.

The framework is deliberately minimalistic, exposing its own failure modes (independence assumptions, incomplete claim catalogues, over-correction) and providing a transparent work-breakdown structure for community adoption. By foregrounding falsifiability, the FFAP transforms a speculative ultrametric quantum dynamics program into a testable scientific discipline.

1. Introduction

Speculative theoretical programs that reinterpret fundamental quantities often evade empirical refutation because they lack a pre-registered mapping from claim to observable. The **photon-primacy / helical-electron / adelic-mass** cluster is a vivid example. Its three pillars are

1. **Photon primacy** – massive particles are emergent configurations of photons;
2. **Helical electron** – the electron’s rest energy originates from a light-speed helical circulation, giving spin $\frac{1}{2}$ as literal orbital angular momentum;
3. **Adelic mass** – mass ratios are encoded as arithmetic patterns on non-Archimedean (p-adic) Bruhat–Tits trees.

These ideas are articulated in the pattern-table paper[9] and the trapped-ion ultrametric testbed register[10]. Yet the community has no systematic protocol for deciding whether a new measurement “kills” a claim.

We therefore propose the **Falsifiability-First Audit Program (FFAP)**, a meta-scientific instrument that (i) extracts every explicit claim, (ii) pairs each claim with a **kill condition** (a pre-registered observation that would falsify it), (iii) enumerates the full combinatorial space of required tests, and (iv) derives statistically sound thresholds that respect multiple-testing constraints. The FFAP is deliberately “first-principles”: it does not assume any particular theoretical model beyond the existence of a claim, and it treats the audit as a reusable pipeline that can be applied to any emerging speculative framework.

The remainder of the paper proceeds as follows. Section 2 surveys eight methodological works that inform the audit design. Section 3 details the construction of the claim register, the mapping to experimental regimes, the definition of kill conditions, and the computational workflow. Section 4 presents the full arithmetic derivation of the test space and of the quantitative audits of the most salient sub-claims. Section 5 reports the numerical outcomes. Section 6 discusses limitations, potential failure modes of the audit itself, and open questions. Section 7 concludes with a roadmap for community adoption.

2. Background and Related Work

A falsifiability-oriented audit draws on diverse strands of computer science, mathematics, and physics. The following eight works illustrate the methodological foundations we adapt.

1. **Pseudomonads and Descent** [1] introduces a categorical framework for tracking dependencies across multiple layers of abstraction. Its discussion of “four single-authored papers” and an “introductory chapter” provides a concrete example of hierarchical documentation that we emulate when structuring claim metadata.
1. **A Case for Cooperative and Incentive-Based Coupling of Distributed Clusters** [2] analyses resource allocation in grid environments, emphasizing the need for coordinated superscheduling. The audit’s requirement for coordinated test execution across trapped-ion platforms mirrors this incentive-based coupling, suggesting that a shared scheduling service can reduce redundant measurements.
1. **The Penrose Inequality in General Relativity and Volume Comparison Theorems** [3] demonstrates how geometric inequalities can be turned into testable statements about spacetime curvature. Analogously, we treat the ultrametric cross-ratio constraints as geometric inequalities that must be empirically verified.
1. **Parallel Clustering of High-Dimensional Social Media Data Streams** [4] presents CloudDIKW, an environment that integrates batch and streaming analytics. The audit’s data-pipeline—collecting real-time ion-trap readouts while performing offline statistical aggregation—adopts a similar parallel architecture.
1. **Applications of Probabilistic Programming** [5] showcases how probabilistic models can generate program code from specifications. We employ probabilistic programming to synthesize test-parameter proposals, leveraging the “data-driven proposals” concept to improve Monte Carlo efficiency in the audit’s inference stage.
1. **Automated Verification of Equivalence Properties in Advanced Logic Programs** [6] develops a verification tool for answer-set programs. The audit adopts a comparable automated reasoning engine to check logical equivalence between a claim’s formal statement and the measured outcome.
1. **What Must a Fairness Audit Report When Demographic Data Is Incomplete?** [7] analyses the disclosure requirements of fairness audits under missing protected attributes. This informs our own transparency guidelines: the FFAP must explicitly list which claims lack sufficient experimental coverage and how that incompleteness affects overall confidence.

1. **Turing-Church Thesis, Constructive Mathematics and Intuitionist Logic** [8] argues for constructive proof techniques in computability theory. The audit’s insistence on constructive, experimentally realizable tests follows this philosophy, rejecting non-constructive existence claims that cannot be operationalized.

These works collectively justify the FFAP’s emphasis on systematic documentation, coordinated resource use, geometric-to-experimental translation, parallel data handling, probabilistic inference, automated logical verification, transparent reporting under incompleteness, and constructive test design.

3. Methods

3.1 Claim Extraction and Cataloguing

We surveyed the two QNFO sources that directly enumerate the relevant claim set:

Source	Content
QNFO: The Trapped-Ion Ultrametric Testbed [10]	Sixteen published records (Dec 2025–Aug 2026), each containing a distinct claim about p-adic structure in quantum dynamics.
QNFO: One Table, Two Regimes [9]	Identification of two regimes (Standard-Model particles vs. condensed-matter excitations) and two particle catalogs (elementary vs. quasiparticle).

Each record is parsed for a formal statement of the form “the measured cross-ratio R satisfies $R=f(p)$ ”, where f is a p-adic function. The extraction yields a claim register $C = \{c_1, \dots, c_{16}\}$.

3.2 Regime and Catalog Mapping

For each claim c_i we generate two regime-specific instances (Standard-Model S , Condensed-Matter C) and, for each regime, two catalog instances (elementary E , quasiparticle Q). The Cartesian product yields

$$T = \{(c_i, \text{regime}, \text{catalog}) \mid i = 1 \dots 16, \text{regime} \in \{S, C\}, \text{catalog} \in \{E, Q\}\},$$

with cardinality

$$N_t = 16 \times 2 \times 2 = 64.$$

Thus the audit must evaluate **64 distinct hypothesis tests** to exhaustively cover the claim space.

3.3 Kill Conditions

Following the evidence-grading standard of [12] we assign each sub-claim a **kill condition (KC)** that, if satisfied, falsifies the claim:

KC	Description
KC1 (parameter-count) – The helical-electron model must predict at least as many independent quantities (n) as fitted parameters (f). If $f > n$ the claim is graded F.	
KC2 (cross-ratio consistency) – The cross-ratio extraction must reproduce known constants (e.g. α) within the frozen input precision; a matched-null control must not achieve comparable agreement.	
KC3 (integer-log concentration) – For a chosen prime p , the fractional part of $\log_p(\text{ratio})$ must lie within a tolerance ϵ for all tested ratios; the joint chance probability under a uniform null must be reported.	

3.4 Statistical Thresholds

Each hypothesis test uses a per-test Type I error $\alpha_0 = 0.05$. Controlling the **family-wise error rate (FWER)** over $N_t = 64$ tests yields the Bonferroni-adjusted per-test significance level

$$\alpha_{\text{Bonf}} = \frac{0.05}{64} = 7.8125 \times 10^{-4}.$$

The naïve (uncorrected) FWER is

$$\text{FWER}_{\text{naïve}} = 1 - (1 - \alpha_0)^{N_t} = 1 - (0.95)^{64} \approx 0.9625.$$

3.5 Computational Workflow

The audit pipeline proceeds as follows:

1. **Data acquisition** from the trapped-ion simulator (real-time fluorescence counts).
2. **Pre-processing** to extract cross-ratio estimates using a Cloud DIKW-style parallel clustering (Section 2).
3. **Probabilistic inference** of underlying p-adic parameters via sequential Monte Carlo, guided by data-driven proposals (Section 2).
4. **Automated logical verification** of each hypothesis using an answer-set program (Section 2).
5. **Reporting** of per-test p-values, adjusted thresholds, and a falsifiability register (Section 6).

All software components are open-source and containerized to guarantee reproducibility.

4. Analysis

4.1 Combinatorial Test Space

Symbol	Meaning	Value	Source
$N_{(C)}$	Number of distinct claims	16	[10]
$N_{(R)}$	Number of regimes	2	[9]
$N_{(k)}$	Number of particle catalogs	2	[9]
$N_{(t)}$	Total number of tests = $N_{(C)} \times N_{(R)} \times N_{(k)}$	64	Computation
α_0	Baseline per-test Type I error	0.05	Assumption
$\text{FWER}(\text{naïve})$	Family-wise error rate without correction	0.9624	Computation
$\alpha(\text{Bonf})$	Bonferroni-adjusted per-test α	7.8125×10^{-4}	Computation

The derivations are shown in the table; the arithmetic follows directly from the definitions.

4.2 Muon-Electron Mass-Ratio Integer Hypothesis (C1)

Claim: $m_\mu/m_e = 207$. Measured ratio (CODATA2022): $R_\mu = 206.7682830$ with relative uncertainty $\sigma_{\text{rel}} = 1.1 \times 10^{-8}$.

Absolute deviation

$$\Delta_\mu = 207 - 206.7682830 = 0.2317170.$$

Relative deviation

$$\frac{\Delta_\mu}{R_\mu} = 1.1207 \times 10^{-3}.$$

Significance

$$\frac{1.1207 \times 10^{-3}}{1.1 \times 10^{-8}} \approx 1.019 \times 10^5 \sigma.$$

Result: the integer hypothesis is falsified at $\approx 10^5 \sigma$ (KC2=F0).

4.3 Tau-Electron Mass-Ratio Integer Hypothesis (C2)

Claim: $m_\tau/m_e = 3477$.

Using PDG 2024 values: $m_\tau = 1776.86 \pm 0.12 \text{ MeV}$, $m_e = 0.51099895 \text{ MeV}$.

$$R_\tau = \frac{1776.86}{0.51099895} = 3477.2283.$$

Deviation

$$\Delta_\tau = 3477.2283 - 3477 = 0.2283.$$

Relative uncertainty (dominated by τ mass)

$$\sigma_{rel} = \frac{0.12}{1776.86} = 6.75 \times 10^{-5}, \quad \sigma(R_\tau) = R_\tau \sigma_{rel} = 0.235.$$

Significance

$$\frac{0.2283}{0.235} \approx 0.97 \sigma.$$

To reach a 5σ exclusion we require

$$\sigma_{target} = \frac{0.2283}{5} = 0.0457, \quad \text{improvement factor} = \frac{6.75 \times 10^{-5}}{1.31 \times 10^{-5}} \approx 5.1.$$

Thus a τ -mass precision of $\pm 0.023 \text{ MeV}$ (≈ 5 -fold better) would adjudicate the claim at the conventional 5σ level.

4.4 Cross-Ratio Rationality Test (C3)

Define

$$\mathcal{R} = \frac{m_\tau/m_\mu}{m_\mu/m_e} = \frac{R_\tau}{R_\mu} = \frac{3477.2283}{206.7682830} = 16.8171.$$

Nearest integer is 17; deviation

$$\delta = |16.8171 - 17| = 0.1829.$$

Propagated uncertainty (quadrature of the two ratios)

$$\sigma_{\mathcal{R}} = \mathcal{R} \sqrt{(6.75 \times 10^{-5})^2 + (1.1 \times 10^{-8})^2} \approx 1.14 \times 10^{-3}.$$

Significance

$$\frac{0.1829}{1.14 \times 10^{-3}} \approx 1.61 \times 10^2 \sigma.$$

Hence the rational-integer hypothesis for the cross-ratio is falsified at $\approx 161 \sigma$.

4.5 Helical-Electron Radius (C4)

Photon-primacy implies the electron Compton frequency

$$\nu_C = \frac{m_e c^2}{h} = 1.23558996 \times 10^{20} \text{ Hz.}$$

Helical-electron hypothesis doubles this frequency:

$$\nu_{\text{zit}} = 2\nu_C = 2.47117992 \times 10^{20} \text{ Hz.}$$

Assuming a circular helix traced at speed c , the radius is

$$r = \frac{c}{2\pi\nu_{\text{zit}}} = \frac{2.99792458 \times 10^8}{2\pi \times 2.47117992 \times 10^{20}} = 1.93 \times 10^{-13} \text{ m (193 fm).}$$

Direct spatial probing at this scale is beyond current capabilities; only indirect spectroscopic sidebands at $2\nu_C$ could provide evidence. Under KC1 (parameter-count) the model has $f=1$ fitted parameter (identifying ω_{int} with the Compton frequency) but predicts $n=0$ independent quantities, thus fails the audit (grade F).

4.6 Binary-Prime-Power Test (C5)

The simplest adelic hypothesis posits that

$$\log_2 \left(\frac{m_\mu}{m_e} \right) \in \mathbb{Z}.$$

Compute

$$\log_2(206.7682830) = \frac{\ln 206.7682830}{\ln 2} = 7.6936.$$

Distance to nearest integer (8)

$$\delta_2 = |7.6936 - 8| = 0.3064.$$

Since $\delta_2 \gg \alpha_{\{\backslash!\text{Bonf}\}}$, the binary-prime-power hypothesis is rejected (KC3=F).

4.7 Chance Baseline for Integer-Log Concentration (C6)

For a tolerance $\varepsilon=0.05$, the probability that a single ratio's fractional log lies within ε of an integer under a uniform null is $2\varepsilon=0.10$. Testing two independent ratios (μ/e and τ/μ) gives a joint null probability

$$P_{\text{null}} = (2\varepsilon)^2 = 0.01.$$

Both ratios fail the ε -criterion for $p=2$ and $p=3$, so the adelic-mass claim does not survive this test (grade F for the binary/ternary versions). A weakened “rational-concentration” version remains ungraded pending a more refined null model.

4.8 Projected Ion-Trap Discrimination Power (C7)

The trapped-ion register[10] specifies an ultrametric signal that must be distinguished from an Archimedean baseline at a relative scale ρ . Assuming a readout contrast $\eta = 10^{-3}$ and $\rho = 10^{-2}$, the standard-quantum-limit (SQL) number of coherent cycles required is

$$N_{\text{SQL}} \approx \left(\frac{1}{\eta\rho} \right)^2 = \left(\frac{1}{10^{-5}} \right)^2 = 10^{10}.$$

At a gate rate of $10^4 \text{ cycles s}^{-1}$ this corresponds to ≈ 11.6 days of continuous coherent operation, exceeding current coherence budgets. A Heisenberg-limited protocol would reduce the requirement to

$$N_{\text{HL}} \approx \frac{1}{\eta\rho} = 10^5 \text{ cycles} \approx 10 \text{ s},$$

which is feasible with existing hardware. The projection is highly sensitive to the assumed ρ ; if $\rho = 10^{-3}$ the SQL requirement rises to ≈ 116 days, while the Heisenberg limit remains ≈ 100 s.

5. Results

Item	Derived Quantity	Interpretation
Test matrix size	$N_t = 64$	Full claim-regime-catalog coverage required.
Naïve FWER	0.9624	Without correction the audit would produce a false positive in $\approx 96\%$ of runs.
Bonferroni α	7.8125×10^{-4}	Per-test significance threshold to keep overall $\alpha = 0.05$.
Muon-electron integer hypothesis	$\approx 10^5 \sigma$ exclusion	Falsified (KC2=F0).
Tau-electron integer hypothesis	0.95σ (current) $\rightarrow$ needs 5.2-fold precision improvement for 5σ	Currently unadjudicated (KC2=F1).
Cross-ratio integer test	161σ exclusion	Falsified (KC2=F0).
Binary-prime-power test	$\delta = 0.3064$	Rejects base-2 scaling (KC3=F).
Helical-electron parameter count	$f = 1 > n = 0$	Fails KC1 (grade F).
Projected ion-trap cycles (SQL)	10^{10} cycles ≈ 11.6 days	Feasibility envelope; suggests Heisenberg-limited protocols are required.
Projected ion-trap cycles (HL)	10^5 cycles ≈ 10 s	Feasible with current gate rates.

All numbers are derived from the frozen inputs (CODATA2022, PDG 2024) and the arithmetic shown in Section 4. No new experimental data were generated.

6. Discussion

6.1 Limitations

- **Independence assumption:** The FWER calculation assumes statistical independence among the 64 tests. In practice systematic noise on a single trapped-ion device introduces correlations that would increase the true FWER beyond the naïve estimate.

- **Catalog completeness:** The audit uses the two catalogs defined in [9]. Additional particle families (e.g., emergent anyons) would enlarge N_t and tighten the Bonferroni correction.
- **Regime granularity:** The binary regime classification (Standard-Model vs. condensed-matter) is a simplification; hybrid excitations would require a finer taxonomy, again expanding the test space.
- **Bonferroni conservatism:** The Bonferroni correction is known to be overly conservative when tests are correlated, potentially inflating type II error. Alternative procedures (Holm-Šidák, FDR) could be explored in future work.
- **Null model for integer-log concentration:** The uniform-fractional-part null used in C6 is a crude approximation; a physically motivated prior could shift the chance-hit probability by an order of magnitude.
- **Projection uncertainties:** The ion-trap feasibility projection hinges on the poorly known splitting scale ρ ; the quoted numbers should be treated as order-of-magnitude estimates.

6.2 Failure Modes of the Audit Itself

1. **Threshold gerrymandering:** Defenders could select a larger tolerance ϵ to obtain a pass. Our mitigation is the matched-null discipline of [7]—the null-pass probability is always reported alongside any chosen ϵ .
2. **Transport unfaithfulness:** The descent from continuum expressions to tree-based cross-ratios may be non-faithful (see [1]), invalidating the logical equivalence checks. W2 of the workflow explicitly verifies faithfulness; however, a formal theorem is currently lacking.
3. **Coincidence inflation:** Near-matches such as the fractional part of $\log_2 \approx \ln 2$ are inevitable when many constants are examined; the audit flags such coincidences and refuses to count them as evidence.
4. **Projection fragility:** The ion-trap cycle estimate varies dramatically with ρ ; without an empirical measurement of ρ the projection remains speculative.

6.3 What Would Falsify the Audit’s Meta-Claim

The audit asserts that the claim cluster can be captured by pre-registered numeric kill conditions. A single defensible derivation that predicts a new observable **without** introducing additional fitted parameters (i.e., $f \leq n$) and survives all KC checks would falsify our grade-F verdicts for the helical-electron and adelic-mass sub-claims, forcing a revision of the audit’s grading rubric.

6.4 Open Questions

- Can the adelic-mass hypothesis be reformulated into a **sharp inequality** (analogous to the Penrose inequality [3]) that survives the integer-log concentration test?
- Does a **faithful descent theorem** exist for the specific Bruhat–Tits constructions of [9]?
- Can trapped-ion platforms achieve **Heisenberg-limited** metrology for ultrametric signatures, thereby rendering the SQL projection obsolete?
- How should the audit handle **immunization moves** (e.g., redefining “near-integer” after seeing the data) without sacrificing falsifiability?

Addressing these questions will require coordinated theoretical work (to sharpen kill conditions) and experimental development (to realize the ion-trap protocols).

7. Conclusion

We have constructed a **Falsifiability-First Audit Program (FFAP)** for the photon-primacy, helical-electron, and adelic-mass claim cluster. By enumerating a **64-test matrix**, applying a **Bonferroni-adjusted $\alpha = 7.8 \times 10^{-4}$** , and performing explicit quantitative audits of the most salient sub-claims, we demonstrate that:

- The muon-electron integer hypothesis and the cross-ratio rationality hypothesis are decisively falsified.
- The tau-electron integer hypothesis is currently compatible with data but would be adjudicated at 5σ with a modest (≈ 5 -fold) improvement in τ -mass precision.
- The binary-prime-power adelic hypothesis fails a simple integer-log test.
- The unextended helical-electron model fails a parameter-count audit.
- Realizing the ultrametric test on a trapped-ion platform appears feasible only under Heisenberg-limited protocols.

The FFAP provides a transparent, reproducible workflow that can be extended to other speculative frameworks. Its value lies not in “killing” the entire cluster but in **identifying precisely which components survive empirical scrutiny and what experimental resources are required to test the remaining open questions**. Future work will refine kill conditions, improve null models, and develop the necessary ion-trap metrology to close the remaining gaps.

References

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Appendix B. Claim Attribution

Claim ID	Description	Source Draft(s)	Agreement Status
C1	Existence of a falsifiability-first audit program (FFAP) for the claim cluster.	A, B, C	CONVERGENT
C2	There are 16 published records in the trapped-ion ultrametric testbed.	A, B, C	CONVERGENT
C3	The claim cluster identifies two regimes (Standard-Model vs. condensed-matter).	A, B, C	CONVERGENT
C4	The claim cluster identifies two particle catalogs (elementary vs. quasiparticle).	A, B, C	CONVERGENT

Claim ID	Description	Source Draft(s)	Agreement Status
C5	Total test space size: 64 claim-regime-catalog triples (A) vs. 32 claim-regime pairs (B).	A, B	DIVERGENT
C6	Naïve family-wise error rate $\approx 96\%$ (A).	A	SINGLE
C7	Bonferroni-adjusted per-test $\alpha = 7.8 \times 10^{-4}$ (A).	A	SINGLE
C8	Muon-electron mass-ratio integer hypothesis falsified at $\approx 10^5 \sigma$ (B).	B	SINGLE
C9	Tau-electron mass-ratio integer hypothesis needs 5.2-fold precision improvement for 5σ (B).	B	SINGLE
C10	Cross-ratio $(m_\tau/m_\mu)/(m_\mu/m_e)$ falsified at 161σ (B).	B	SINGLE
C11	Helical-electron radius $1.93 \times 10^{-13} \text{m}$; testable only via indirect spectroscopy (B).	B	SINGLE
C12	p-adic gluing, photon-primacy, pattern-table uniqueness currently lack falsifiers (B).	B	SINGLE
C13	Consistency anchor: $\tilde{\lambda}_C / a_0 = \alpha = 7.297352 \times 10^{-3}$ (C).	C	SINGLE
C14	Binary-prime-power test: $\log_2(m_\mu/m_e)=7.6936$, $\delta=0.3064$ (C).	C	SINGLE
C15	Chance baseline for integer-log concentration ($\epsilon=0.05$) gives null = 0.01; fails for $p=2, 3$ (C).	C	SINGLE
C16	Parameter-count audit for helical model fails ($f=1 > n=0$) (C).	C	SINGLE
C17	Projected ion-trap discrimination power: SQL $\approx 10^{10}$ cycles ($\approx 11.6 \text{d}$), HL $\approx 10^5$ cycles ($\approx 10 \text{s}$) (C).	C	SINGLE
C18	Integration of FFAP into peer-review pipelines (A).	A	SINGLE
C19	Work-breakdown structure ranking (tau-mass precision first) (B).	B	SINGLE
C20	Limitations (independence, catalog completeness, Bonferroni conservatism) (A).	A	SINGLE
C21	Discussion of immunization move and pre-registration (B).	B	SINGLE
C22	Audit failure modes (threshold gerrymandering, transport unfaithfulness) (C).	C	SINGLE