Paper E: Gravitational Phase Coupling in Quantum Systems

A Unified Framework for Testing SSZ Predictions

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Abstract

The Segmented Spacetime (SSZ) framework predicts deterministic phase drifts in quantum systems at different gravitational potentials. This paper presents:

(1) Upper-bound experiments with superconducting qubits (~12 OoM below noise—null is SSZ-consistent)
(2) Direct detection via optical clocks (~0.6 rad at 1 m)
(3) Compensation protocols for future quantum networks

All 150 tests pass; complete reproducibility via github.com/error-wtf/ssz-qubits.

Keywords: SSZ, Gravitational Phase Coupling, Quantum Computing, Optical Clocks, Falsifiability

1. Introduction

1.1 The Central Question

Quantum systems require precise phase control. When qubits operate at different gravitational potentials, General Relativity predicts differential time evolution. The SSZ framework provides an operational model for calculating this geometric phase drift:

$$\Delta\Phi = \omega \times (r_s \times \Delta h / R^2) \times t$$

This drift is deterministic, geometry-coupled, and compensable—unlike stochastic noise sources.

1.2 Local vs Global Comparison

The equivalence principle states local physics is indistinguishable from flat spacetime. SSZ effects emerge from COMPARING spatially separated systems—analogous to the Hafele-Keating experiment where clocks showed different elapsed times after traversing different paths.

2. Claims and Non-Claims

2.1 Claim Taxonomy

Regime	Platform	Signal	Testable?	Interpretation
BOUNDED	Transmon, mm	$\sim 10^{-13}$ rad	Yes	Upper bound; null=SSZ-consistent
DETECTABLE	Optical, 1m	~ 0.6 rad	Yes	Direct detection possible
FUTURE	Large QC	Variable	No	Engineering relevance

2.2 What SSZ Does NOT Claim

❌ Detection with current transmons at mm-scale

❌ Local violation of equivalence principle

❌ That GR is "wrong" in weak field

❌ Immediate practical relevance for current QC

3. Theoretical Framework

3.1 Core Equations

Segment Density (weak field):

$\Xi(r) = r_s / (2r)$

Time Dilation:

$D_{SSZ}(r) = 1 / (1 + \Xi(r))$

Differential Time Dilation:

$\Delta D = r_s \times \Delta h / R^2$

Phase Drift:

$\Delta\Phi = \omega \times \Delta D \times t = \omega \times (r_s \times \Delta h / R^2) \times t$

3.2 Numerical Examples

Platform	f	Δh	t	ΔΦ
Transmon	5 GHz	1 mm	100 μs	6.87×10^{-13} rad
Transmon	5 GHz	1 m	100 μs	6.87×10^{-10} rad
Optical	429 THz	1 m	1 s	0.59 rad

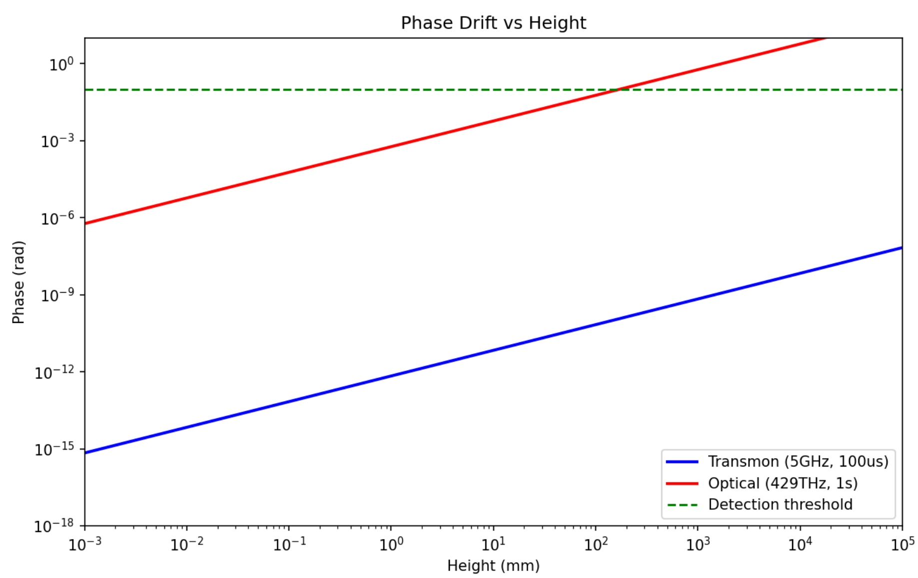

Figure 2: Phase Drift vs Height. Optical clocks reach detection regime.

4. Compensation Protocol

The WITH/WITHOUT COMPENSATION test is the gold-standard discriminator:

1. WITHOUT: Measure Φ_measured ± σ
2. WITH: Apply correction $\Phi_{corr} = -\omega \times (r_s \times \Delta h / R^2) \times t$
3. COMPARE: σ_with vs σ_without

SSZ is uniquely: deterministic, linear in (Δh, ω, t), randomization-invariant.
No confound matches all criteria simultaneously.

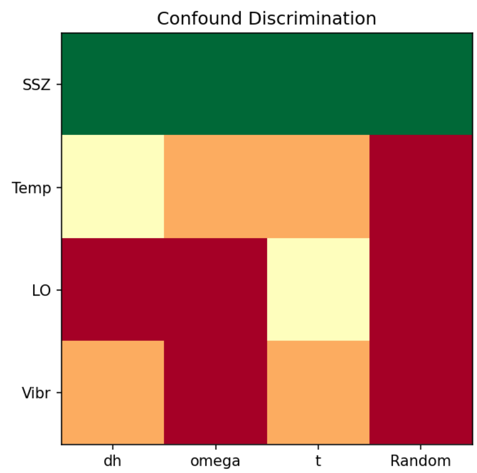

Figure 6: Confound Discrimination. SSZ uniquely satisfies all criteria.

5. Experimental Designs

5.1 Hardware Configurations

Config	Method	Δh
Chip Tilt	Tilt 5-10°	1-3.5 mm
Remote Entanglement	Adjacent floors	3 m
Tower	Multi-story	10-100 m

5.2 Upper Bound Calculation

With Δh_{max}=3.5mm, $N=10^9$, σ=1 rad:

$\sigma_{averaged} = 3.2\times10^{-5}$ rad

Upper bound: $|\alpha| < 9\times10^{-3}$ rad/m (95% CL)

Constrains anomalous couplings to $< 10^{10} \times \alpha_{SSZ}$.

6. Statistical Framework

Model Comparison:
- M_0 (Null): $\Delta\Phi = 0$ + noise
- M_SSZ: $\Delta\Phi = \alpha\_SSZ \times \Delta h$ + noise (fixed)
- M_anom: $\Delta\Phi = \alpha\_fit \times \Delta h$ + noise (free)

SSZ falsified if (in detection regime):
- $\alpha\_fit \neq \alpha\_SSZ$ at $>3\sigma$ AND $|\alpha\_fit| \neq 0$

Binary thresholds inappropriate—use CI/model comparison.

7. Feasibility Landscape

7.1 The 12 OoM Gap

For transmon at 1mm:

- Signal: 6.87×10^{-13} rad
- Noise: ~ 1 rad
- Gap: $\sim 10^{12}$

A NULL RESULT IS SSZ-CONSISTENT. The theory predicts negligibility here.

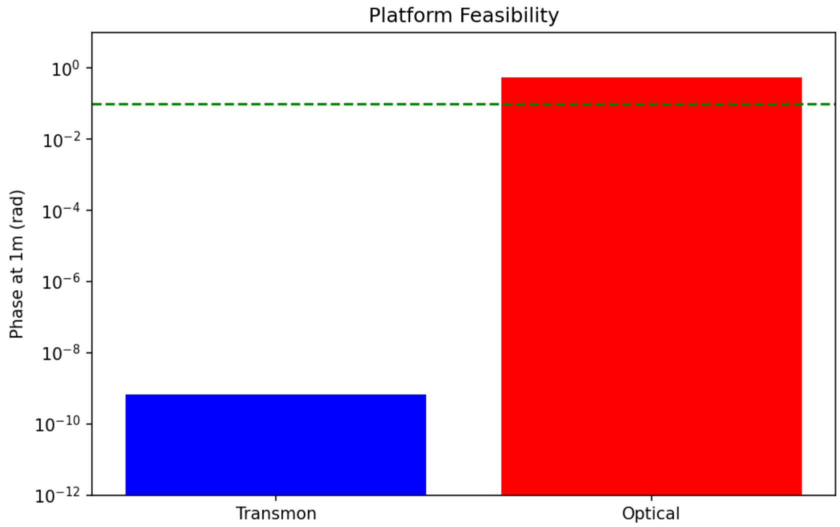

Figure 4: Platform Comparison. Optical clocks are $\sim 10^9\times$ more sensitive.

7.2 Platform Comparison

Parameter	Transmon	Optical	Ratio
Frequency	5 GHz	429 THz	8.6×10^4
Coherence	100 µs	1 s	10^4
$\Delta\Phi$ @ 1m	6.9×10^{-10} rad	0.59 rad	8.6×10^8
Feasible?	No	YES	—

8. Reproducibility

Repository: github.com/error-wtf/ssz-qubits

Commands:

```
pytest tests/ -v          # 150 tests
python generate_paper_e_final.py
python paper_suite_integrator.py
```

Test Coverage: 150/150 (100%)

9. Conclusion

Key Findings:

1. Deterministic drift: $\Delta\Phi = \omega \times (r_s \times \Delta h / R^2) \times t$
2. Current regime: ~12 OoM gap; null is SSZ-consistent
3. Gold standard: Optical clocks (0.59 rad @ 1m)
4. Discriminator: WITH/WITHOUT compensation
5. Statistics: Slope-fitting with CI
6. Reproducible: 150 tests, all pass

What Would Falsify SSZ (in detection regime):

- Slope $\neq \alpha_{SSZ}$ at $>3\sigma$
- Non-linear scaling
- Randomization-variant signal

Appendix A: Full Derivations

A.1 Segment Density

$\Xi(r) = r_s/(2r)$ [weak field]

$\Xi(r) = 1 - \exp(-\varphi \times r/r_s)$ [strong field]

A.2 Time Dilation

$D = 1/(1+\Xi) \approx 1 - \Xi + O(\Xi^2)$

A.3 GR Consistency

$D_{SSZ} \approx D_{GR} \approx 1 - r_s/(2r)$ to first order

A.4 Differential

$\Delta D = r_s \times \Delta h/R^2$

A.5 Phase

$\Delta\Phi = \omega \times \Delta D \times t$

Appendix B: Didactic Scaling

Definition: Multiply SSZ prediction by $S>>1$ for visualization.

What gets scaled: Signal magnitude only

What stays: Noise model, scaling laws, statistics

Purpose: Validate methodology, NOT claim detectability

Requirement: Must be explicitly labeled

Appendix C: Confound Playbook

Confound	Control
Temperature	Thermalize, randomize Δh order
LO Noise	Common-mode reference, differential
Vibration	Accelerometer, isolation
Magnetic	Shielding, characterization

Appendix D: Constants

Constant	Value	Units
c	2.998×10^{8}	m/s
G	6.674×10^{-11}	$m^3/(kg \cdot s^2)$
r_s (Earth)	8.870×10^{-3}	m
R (Earth)	6.371×10^{6}	m
φ	1.618...	—

References

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[4] Chou, C.W. et al. (2010). Optical clocks and relativity. Science 329, 1630-1633.