Quantumograph Theory Predictions

Sergej Materov*

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I. Predictions for qubit platforms (QPU, annealer, gate model)

1. Single measurable energy scale $T_c = Jz/k_B$ — the central operative formula: J is the average two-qubit coupling, z is the average vertex degree; all main predictions are parameterized by this scale.

2. **Heat-capacity peak / crossover at $T \approx T_c$** — a measurable manifestation of the transition between the "correlated" and "disconnected" regimes. Protocols for temperature scans and criteria for identifying the peak are provided (steps and expected precision).

3. QPU error-rate crossover at $T \sim T_c$ — a rapid change (drop/increase) of logical and physical error rates is expected; it is proposed to measure this via RB / short logical circuits as a function of temperature.

4. Correlation-length collapse Ψ(r,T)— for $T > T_c$ correlations decay exponentially; for $T < T_c$ long-lived clustered correlations appear. A method is proposed: prepare $|+\rangle$, wait, and measure pairwise correlators.

5. DOS-driven spectral shifts in two-qubit spectroscopy — corrections to the low-mode density of states produce measurable shifts in the spectrum that can be extracted by measuring J_{ij} and the Laplacian spectrum.

6. Graph automorphisms → testable "symmetries" / spontaneous symmetry breaking — the prediction that the automorphism group determines a set of possible gauge groups; experimentally this is probed via dependence of observables on topology and tests on randomized topology. (Control: if the effect persists after topology randomization → the topological hypothesis is falsified).

7. Numerical examples / scale estimates for motifs: in Villain/Josephson approximations example frequencies/energies are given: *chimera_like*_5x5 ≈ 55 GHz; *square_grid*_20x20 ≈ 227 GHz; *random-regular degree-4* ≈ 43 THz. These numbers serve as working design targets.

8. Practical limits for annealer topologies — chain embedding, Chimera sparsity (z≈6) and denser Pegasus (z≈15) affect T_c: e.g., with *J*≈20 MHz and *z*≈6 one expects $T_c \approx$ 30 mK; Pegasus can raise T_c to ≈75 mK. Recommendations: avoid/compensate chain embeddings and use topology-aware embedding.

II. Microwave / dielectric predictions

1. Resonant microwave anomalies (dip/minimum in absorption) at ω≈ ω_{char} — collective "graph-phonon" modes produce characteristic frequencies; a dip structure in tanδ(ω) is predicted for $T < T_c$.

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*Independent Researcher, **e-mail:** sergejmaterov2@gmail.com

2. Material-specific frequencies and temperature coefficients — a table gives example values (PMN-PT, MoS_2, BGO, PVDF–TiO_2) and numerical guides (GHz values at $T = 0.5T_c$ and sensitivity Δ/ΔT).

3. Falsification threshold by frequency — the theory is considered falsified if, under prepared conditions and within experimental precision, the characteristic frequency shift ω\omegaω at T→$0.5T_c$ is smaller than **10 kHz** (falsification criterion).

4. Threshold for Δ(tanδ) — expected topological microwave anomalies are of order Δ(tanδ) ≥ 10^{-4}; the text gives SNR/noise levels and temperature-resolution requirements down to ≲0.01 mK for some materials.

5. Experimental protocol — cryo-stabilization, shielding, S21 sweeps from 0.1–10 GHz, extraction of tanδ, and requirements for temperature sensors and SNR.

III. Causality / retrocausality (two-boundary formulation) — testable signatures

1. Shift in conditional probability ΔP(a|b)≠0 — the primary operational sign of retrocausal contribution: a significant deviation of empirical P(a|b) from standard QM predictions under post-selection. Experimentally: protocols A (Bell-type delayed-choice), B (rare strong post-selection), and C (multi-qubit QPU test) are proposed.

2. Anomalies in weak values (weak-value anomalies) — weak-value distributions may show heavy tails / shifted centers; look for deviations in rare-event statistics.

3. Differences in higher-order correlators — two-point correlators typically match QM at leading order; deviations are expected to be more pronounced in three- and multi-point correlators and in joint distributions of local observables.

4. Scaling with rarity of post-selection — if the effect increases as the post-selection probability p_{post} decreases, this is an expected signature of two-boundary contributions (tradeoff: signal boost vs. statistics).

5. Topological dependence of retro-shift — the magnitude of ΔP depends on spectral dimension and *z*: higher connectivity or lower spectral dimension can enhance the effect; formulae and topology choices to maximize the signal are given.

6. Required statistics for detection — explicit numerical estimates: to detect a ±1% signal one needs M≳62,500 trials; for ±0.1% → M≳6,250,000; for 10^{-4} level → hundreds of millions (example: M≥625,000,000). These figures are derived and discussed step-by-step.

7. Falsification / control criteria — required checks: no-signalling (marginals without post-selection must match QM), physical RNG for delayed-choice, bootstrap to quantify post-selection bias, and replication across platforms (optical, superconducting, QPU).

IV. Practical thresholds, checklists and "decisive" experiment behavior

1. Topological control — always compare to a control: a randomized topology with the same degree histogram. If the effect persists on the randomized topology, the topological explanation is falsified.

2. Reporting uncertainties — in the explicit formula for $\Delta T_c/T_c$ provide separate statistical and systematic error bars; if systematics dominate, give a conservative interval.

3. Practical acquisition recommendations — for gate-model: shots ≈ 1024, gauge randomizations ≈ 10, temperature repeats ≈ 10; for annealers: samples per embedding ≈ 10,000, gauge transforms ≈ 20. These parameters yield target statistical errors of ~1–2% per measurement point.

4. Summary falsification criteria:

- microwave frequency shift at $T \rightarrow 0.5T_c$ < 10 kHz → theory falsified;
- topological effect remains on randomized topology → topological explanation falsified;
- after all mandatory control tests (no-signalling, etc.), deviations remain significant → the retrocausal hypothesis becomes a subject of increased support.

V. Additional (broader) predictions relevant to experiments

- **CHSH / Bell**: the construction indicates that achieving S≈2.76 requires "sub-atomic" connectivity (very high graph connectivity); estimated relations and corollaries about graph diameter / information transfer time are provided.
- **Emergent constants and cosmological links**: dimensionless constants like α\alphaα are, in principle, computable from the graph spectral functionals; practical tests require large-scale numerical scans of. This is a longer-term prediction but comes with a clear roadmap for verification.