

# Quantumograph Theory Predictions

## 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  $\Psi(r,T)$**  — 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*  $\approx 55$  GHz; *square\_grid\_20x20*  $\approx 227$  GHz; *random-regular degree-4*  $\approx 43$  THz. These numbers serve as working design targets.
8. **Practical limits for annealer topologies** — chain embedding, Chimera sparsity ( $z \approx 6$ ) and denser Pegasus ( $z \approx 15$ ) affect  $T_c$ : e.g., with  $J \approx 20$  MHz and  $z \approx 6$  one expects  $T_c \approx 30$  mK; Pegasus can raise  $T_c$  to  $\approx 75$  mK. Recommendations: avoid/compensate chain embeddings and use topology-aware embedding.

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## II. Microwave / dielectric predictions

1. **Resonant microwave anomalies (dip/minimum in absorption) at  $\omega \approx \omega_{\text{char}}$**  — collective “graph-phonon” modes produce characteristic frequencies; a dip structure in  $\tan\delta(\omega)$  is predicted for  $T < T_c$ .
2. **Material-specific frequencies and temperature coefficients** — a table gives example values (PMN-PT, MoS<sub>2</sub>, BGO, PVDF-TiO<sub>2</sub>) and numerical guides (GHz values at  $T = 0.5T_c$  and sensitivity  $\Delta/\Delta T$ ).

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

**4. Threshold for  $\Delta(\tan\delta)$**  — expected topological microwave anomalies are of order  $\Delta(\tan\delta) \geq 10^{-4}$ ; the text gives SNR/noise levels and temperature-resolution requirements down to  $\lesssim 0.01$  mK for some materials.

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

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

**1. Shift in conditional probability  $\Delta P(a|b) \neq 0$**  — 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  $p_{\text{post}}$  decreases, this is an expected signature of two-boundary contributions (tradeoff: signal boost vs. statistics).

**5. Topological dependence of retro-shift** — the magnitude of  $\Delta P$  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  $\pm 1\%$  signal one needs  $M \gtrsim 62,500$  trials; for  $\pm 0.1\% \rightarrow M \gtrsim 6,250,000$ ; for  $10^{-4}$  level  $\rightarrow$  hundreds of millions (example:  $M \gtrsim 625,000,000$ ). 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).

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### **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  $\approx 1024$ , gauge randomizations  $\approx 10$ , temperature repeats  $\approx 10$ ; for annealers: samples per embedding  $\approx 10,000$ , gauge transforms  $\approx 20$ . These parameters yield target statistical errors of  $\sim 1\text{--}2\%$  per measurement point.

#### **4. Summary falsification criteria:**

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

- **CHSH / Bell:** the construction indicates that achieving  $S \approx 2.76$  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  $\alpha$  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.