

Colin Blake

Research overview | Equational theories for quantum circuits

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I study which equations suffice to prove that two quantum circuits implement the same operation. My work concerns qudits, controlled operations and circuit fragments, using categorical presentations, normal forms and rewriting.

Selected results

Exact qudit circuits in every finite dimension.
A finite family of local axiom schemata gives a sound and complete equational theory for exact unitary circuits in every dimension at least two. Primitive value-control makes controlled operations part of the circuit language; the diagrammatic shapes of the rules do not depend on the dimension.

A Complete Equational Presentation of Qudit Circuits via Polycontrolled PROPs.
MFCS 2026 - **Best Student Paper Award.** Paper and DOI

Simpler rule sets for circuit fragments.
Six near-Clifford fragments share a PROP treatment with structural wire permutations. Completeness transfers from earlier presentations, while separating interpretations show which remaining rules are indispensable. Minimality holds in all arities for qubit Clifford, real Clifford and CNOT-dihedral circuits, and in bounded ranges for the other fragments.

Simpler Presentations for Many Fragments of Quantum Circuits.
FSCD 2026. Paper and DOI

Phase-affine normal forms for prime-dimensional qudits.
A complete equational theory extends reversible affine circuits with bounded-degree diagonal phase polynomials over prime fields. Unique phase-affine normal forms connect semantic circuit equality to derivable equality, generalising the role of phase polynomials in CNOT-dihedral circuits.

Completeness for Prime-Dimensional Phase-Affine Circuits.
Preprint, 2026. arXiv:2603.06466

Research software

minimality-auto. A Python command-line tool for searching for invariants that separate one equation from the rest of a supplied complete theory. Bundled theories, examples and JSON output support reproducible bounded searches. Exact combinatorial witnesses are distinguished from floating-point numerical evidence; an unsuccessful search does not establish derivability.

Doctoral research

PhD in Computer Science, Université de Lorraine, MOCQUA (Inria / LORIA), since October 2024. Supervisors: Simon Perdrix and Miriam Backens. Expected completion: 2027.

Publications and talks: colin-blake.eu/publications

For the ornament, see https://github.com/kevinraymond/florilegium