Curriculum Vitæ June $30^{th}$, 2005 **Stephen S. Bullock**


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## RESEARCH INTERESTS

- quantum circuits models for quantum computing; quantum logic synthesis
  - applications of Lie theory
  - numerical analysis and simulation ($< 14$ qubits)
  - synthesis exploiting quantum measurement as a gate
- multi-partite entanglement theory and implications for circuit design

## EXPERIENCE

| Title/Program | Employer | Years |
|---|---|---|
| National Research Council (NRC) Postdoc, mathematics | National Institute of Standards and Technology | Summer2003-present |
| Term Assistant Professor, mathematics | University of Michigan | Fall2000-Summer2003 |
| Teaching-Research Assistant | Cornell University | Fall98-Spring00 |
| Teaching Assistant | Notre Dame University | 1996-97 academic year |
| Teaching Assistant | Cornell University | Fall94-Spring96 |

## EDUCATION

| Degree | University | Awarded | comment |
|---|---|---|---|
| Ph.D. | Cornell University | May, 2000 | mathematics, under Birgit Speh |
| M.A. | Cornell University | August, 1996 | differential geometry |
| B.S. | University of Georgia | June 1994 | summa cum laude, $\Phi\beta\kappa$ |

## MATHEMATICAL SPECIALTIES

### Lie Groups, Lie Theory

- Structure theory of real groups, Satake & Vogan diagrams, representation theory
- Locally symmetric Riemannian manifolds

### Riemannian geometry and smooth topology

- de Rham cohomology, sheaf cohomology, Lie algebra cohomology, Hodge theory
- nonpositive curvature, esp. locally symmetric Riemannian manifolds

## PUBLISHED ARTICLES

[12] S.S. Bullock, D.P. O'Leary, and G.K. Brennen, Asymptotically Optimal Quantum Circuits for $d$-level Systems, *Physical Review Letters* **94** 230502 (2005).

[11] S.S. Bullock, G.K. Brennen, D.P. O'Leary, Time Reversal and $n$-qubit Canonical Decompositions. *Journal of Mathematical Physics* **46** 062104 (2005).

[10] G.K. Brennen, D.P. O'Leary, and S.S. Bullock, Criteria for Exact Qudit Universality. *Physical Review A* **71** 052318 (2005).

[9] G.K. Brennen, S.S. Bullock, Stability of Global Entanglement in Thermal States of Spin Chains. *Physical Review A* **70** 052303 (2004).

[8] S.S. Bullock, Note on the Khaneja Glaser Decomposition. *Quantum Information and Computation* **4(5)** 396 (2004).

[7] V.V. Shende, S.S. Bullock, I.L. Markov, Recognizing Small-Circuit Structure in Two-Qubit Operators. *Physical Review A* **70** 012310 (2004).

[6] V.V. Shende, I.L. Markov, S.S. Bullock, On Universal Gate Libraries and Generic Minimal Two-qubit Quantum Circuits. *Physical Review A* **69** 062321 (2004).

[5] S.S. Bullock, G.K. Brennen, Canonical Decompositions of n-qubit Quantum Computations and Concurrence. *Journal of Mathematical Physics* **45(6)** 2447 (2004).

[4] S.S. Bullock, I.L. Markov, Smaller Circuits for Arbitrary n-qubit Diagonal Computations. *Quantum Information and Computation*, **4(1)** 027 (2004).

[3] S.S. Bullock, I.L. Markov, An Arbitrary Two-qubit Computation in 23 Elementary Gates. *Physical Review A* **68** 012318 (2003).

[2] S.S. Bullock, Unreduced Gaussian weighted $L_2$ cohomology of locally symmetric spaces. *New York Journal of Mathematics* **8** 241 (2002).

[1] S.S. Bullock, Weighted $L_2$ cohomology of asymptotically hyperbolic manifolds. *New York Journal of Mathematics*, **7** 7 (2001).

## DRAFTS

[a] Vivek V. Shende, Stephen S. Bullock, Igor L. Markov, Synthesis of quantum logic circuits, `http://www.arxiv.org/abs/quant-ph/0406176`, to appear in *IEEE Transactions on Computer Aided Design*

[b] Dianne P. O'Leary, Stephen S. Bullock, QR factorizations using a restricted set of rotations, `http://math.nist.gov/~SBullock`, submitted to *Electronic Transactions on Numerical Analysis*

## SERVICE

[I] Organized NIST MCSD *Quantum Information Theory and Practice Seminar* (QITaP) from September 2004 to June 2005.

[II] Reviewer for APS *Physical Review A*, *Physical Review Letters*, and (infrequently) IEEE *Transactions on CAD*

## INVITED TALKS & COMPUTER SCIENCE CONFERENCE PAPERS

| Title | Coauthors | Venue | Date |
|---|---|---|---|
| Quantum Circuit Design | | NRC Board of Assessment of NIST Programs | January 13, 2005 |
| Matrix decompositions & quantum circuit design | Vivek Shende (a) Igor Markov (a) | 2nd Feynman Festival | August 21, 2004 |
| Time-reversal symmetry and entangled eigenstates | Gavin Brennen (p) Dianne O'Leary (a) | UMdCP Quantum Info. & Coherence Seminar | May 4, 2004 |
| Time-reversal symmetry and concurrence dynamics | Gavin Brennen Dianne O'Leary | NIST QuIBEC seminar, radiation physics | April 21, 2004 |
| "Entanglement Capacity of $n$-qubit Quantum Computations" | Gavin Brennen | SPIE symposium, QC&Iii www.spie.org | April 13, 2004 |
| "Finding Small Two-qubit Circuits" | Igor Markov Vivek Shende | SPIE symposium, QC&Iii www.spie.org | April 14, 2004 |
| Time-reversal and the CCD matrix decomposition | Gavin Brennen Dianne O'Leary | NIST QuITaP seminar Math.Comp.Sci.Div. | March 25, 2004 |
| *KAK* decompositions & entanglement dynamics | - | Cornell Lie Theory seminar | March 5, 2004 |
| Gaussian weighted $L_2$ cohomology | - | Loc.Sym.Space Conf. M.F.Oberwolfach | Oct. 3, 2003 |
| Symmetry Groups of the n-tangle and Maximal Concurrence | Gavin Brennen | Institute for Defense Analyses, CSS | Sept. 8, 2003 |
| "An Arbitrary Two-Qubit Quantum Computation in 23 gates" | Igor Markov | Design Automation Conf. (www.dac.com) | July 2003 **B.P.A. nominee** |
| Weighted $L_2$ cohomology | - | **AMS** midwest section meeting, d.g. session | March 2002 |

## COMPUTER SKILLS

Proficient with [i] LaTeX $2_\varepsilon$, [ii] C++, [iii] MatLab, [iv] Linux

## REFERENCES

Isabel Beichl (superviser) .................... isabel.beichl@nist.gov
Birgit Speh (thesis adviser, pure mathematician) .................... speh@math.cornell.edu
Dianne O'Leary (applied mathematician) .................... oleary@cs.umd.edu
Igor Markov (computer scientist) .................... imarkov@eecs.umich.edu
Bei Lok Hu (physicist) .................... hub@physics.umd.edu

## MISCELLANY

Hobbies: jogging, investing, vegetable gardening.

Languages: English, German

Citizenship: USA