

COMPUTE

nonCommutative polynOMial oPtimisation for qUanTum nEtworks

25

papers to date

12

papers in flagship venues across physics, CS and mathematics

4

open-source libraries

5

postdoc positions created

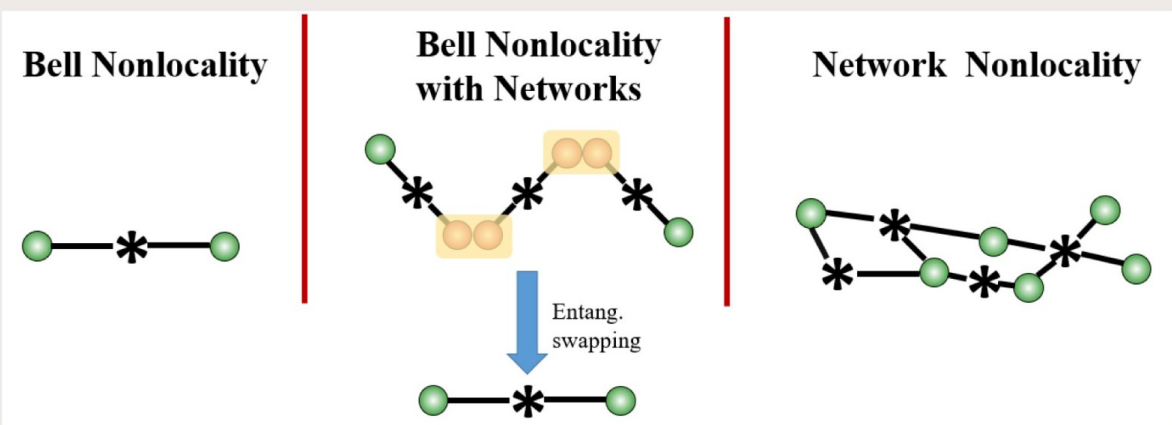
50

researchers at our Bad Honnef workshop

Realizing the potential of quantum networks

Real quantum networks exist, but experiments still mostly replay the two-party Alice-and-Bob scenario. COMPUTE gives genuine multi-source networks a theory of their own, protocols that survive noise, and the mathematics to certify both.

At mid-term we proved that quantum networks succeed at distributed computing tasks classical ones cannot solve, put compiled Bell tests on a quantitative footing, and turned noncommutative polynomial optimisation into working software.



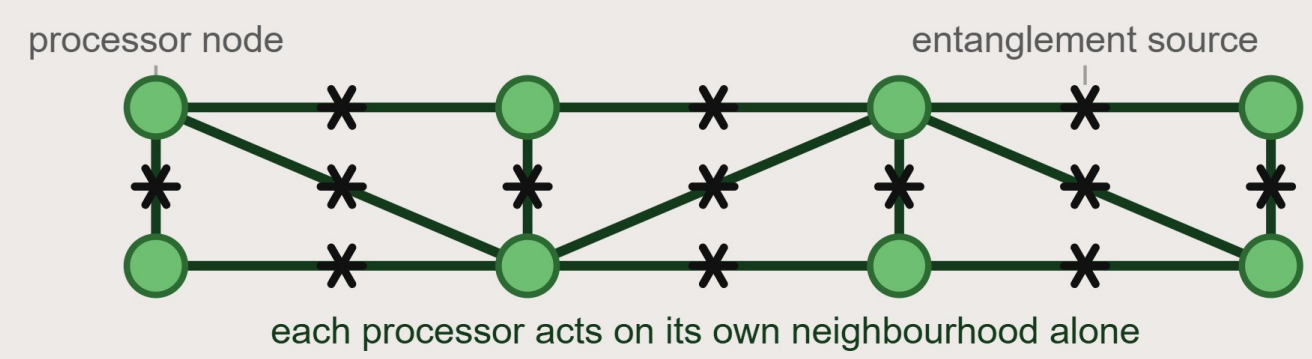
From single-source Bell scenarios to genuine multi-source networks: the setting COMPUTE works in.

Objectives → status

- Establish a coherent framework*
Done: noncommutative polynomial optimisation
- Enable quantum protocols*
Ongoing: noise-robust certification (WP2)
- Advance distributed quantum computing*
Done: proven advantage in the LOCAL model
- Bridge the two communities*
Done: 9 joint papers, 4 libraries, 1 workshop

WP1 · T1.2 · Inria · LAAS-CNRS

Quantum networks out-compute classical ones



In the LOCAL model each processor sees only its own neighbourhood. We exhibited problems that a network sharing entanglement solves strictly faster than any classical distributed algorithm, and faster than a single quantum processor.

- Distributed Quantum Advantage for Local Problems, *STOC 2025*, doi:10.1145/3717823.3718233
- Online Locality Meets Distributed Quantum Computing, *STOC 2025*, doi:10.1145/3717823.3718211
- New communication-complexity bounds from information causality, *QIP 2025*

WP0–WP2 · Inria · Ljubljana · TU Darmstadt

Noncommutative polynomial optimisation for networks and compiled tests

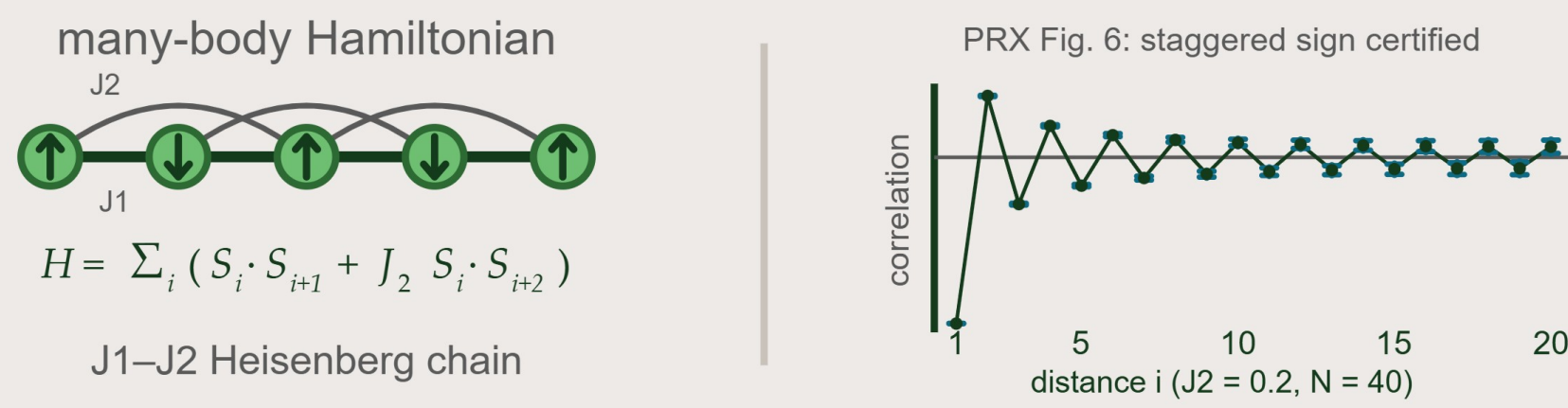


These hierarchies bound what a quantum network can produce, whether its parties are separated in space or by cryptography. We proved them complete for tree networks, and gave the first quantitative soundness bounds for compiled Bell games, bipartite then multipartite.

- Quantum inflation and source-transfer hierarchies are complete for tree networks, *arXiv:2609.19310*
- Bipartite compiled Bell games via the sequential NPA hierarchy, *QIP 2026*, *arXiv:2507.17006*
- All multipartite compiled nonlocal games, *QIP 2026*, *arXiv:2509.25145*
- Quantitative Tsirelson theorems, *arXiv:2505.22309*
- Also: real-vs-complex gap *Rep. Prog. Phys.* 89, 070503 (2026) · graph states *npj Quantum Inf.* 11, 90 (2025) · gate certification *arXiv:2510.09575*

WP3 · T3.2 · Inria · LAAS-CNRS · ICFO · Ljubljana

Certified answers for many-body systems



Noncommutative polynomial optimisation turns many-body questions into semidefinite programs whose solutions carry rigorous bounds, climbing from ground states to steady states, phase diagrams, and now the bulk spectral gap.

- Certifying Ground-State Properties of Many-Body Systems, *Phys. Rev. X* 14, 031006 (2024)
- Certifying steady-state properties of open quantum systems, *Phys. Rev. Research* 7, 033237 (2025)
- Mapping phase diagrams of quantum spin systems through SDP relaxations, *arXiv:2507.03137*
- The bulk spectral gap is semi-decidable: a convergent family of certified upper bounds, *arXiv:2606.03836*

One toolbox underneath: noncommutative polynomial optimisation

MATHEMATICAL FOUNDATIONS

- Quantitative semidefinite certificates for ground-state energies of Pauli Hamiltonians, *arXiv:2605.29959*
- Complete upper-bound hierarchies for the spectral minimum, *arXiv:2402.02126*
- Convergence rates for polynomial optimisation on set products, *arXiv:2505.18580*
- Order-2 quantum Wasserstein distance via the moment–SOS hierarchy, *arXiv:2506.20006*
- Positivstellensätze and moment problems with universal quantifiers, *Math. Oper. Res.* (2025)
- Sums of squares certificates for polynomial moment inequalities, *Found. Comput. Math.* (2025)
- Certifying optimality of Bell inequality violations, *SIAM J. Optim.* 34 (2024)
- Positivity of state, trace and moment polynomials, *Operator Theory* (2024)
- Cross-positive linear maps, positive polynomials and sums of squares, *J. Algebra* 688 (2026)

OPEN-SOURCE SOFTWARE

NCTSSOS

Inflation–NPA and tensor-symmetry SOS methods
github.com/wangjie212/NCTSSOS

thermoNPA

Thermal and open-system SDP relaxations
github.com/Lumorti/thermoNPA

many_body_certification

Certification tools for many-body systems
github.com/jansendavid/many_body_certification

sdp_for_phaselearning

Phase-diagram learning by SDP
github.com/jansendavid/sdp_for_phaselearning



Members:

- Marc-Olivier Renou
Inria Saclay Île-de-France (coordinator)
- Victor Magron
LAAS-CNRS
- Mariami Gachechiladze
TU Darmstadt
- Antonio Acín
ICFO, Institut de Ciències Fotòniques
- Igor Klep
University of Ljubljana

Building the community:

- WE-Heraeus workshop:** “Operator Theory and Polynomial Optimization in Quantum Information Theory”, Bad Honnef, March 2025, 50 participants from all five partners.
- Gaspard Monge Visiting Professorship:** Igor Klep at Inria Saclay / École Polytechnique, February 2025 – January 2026, with a dedicated seminar series.
- Mobility:** three postdoc secondments between partners, 77 weeks in total; five new fellowships funded by the project.
- Outreach:** *Revista Española de Física* article; Inria and École Polytechnique features; public talk in Girona; summer-school lecture in Bari.
- Quantum Flagship links:** QSNP (security proofs for QKD) and PASQUANS2 (certification of quantum simulators).