Q 23: Quantum Information: Concepts and Methods IV

Time: Tuesday 14:30–16:30 Location: P 2

Q 23.1 Tue 14:30 P 2

Entanglement and extreme spin squeezing of unpolarized states — •Giuseppe Vitagliano[1], Iagoba Apellaniz[1], Matthias Kleinmann[1], Bernd Lücke[4], Carsten Klempt[4], and Geza Toth[1,2,3] — [1]Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Wigner Research Centre for Physics, H-1525 Budapest, Hungary — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

We present optimal criteria to detect the depth of entanglement in macroscopic ensembles of spin-j particles using the variance and second moments of the collective spin components. The class of states detected goes beyond traditional spin-squeezed states by including Dicke states and other unpolarized states. The criteria derived are easy to evaluate numerically even for systems of very many particles and outperform past approaches, especially in practical situations where noise is present. We also derive analytic lower bounds based on the linearization of our criteria, which make it possible to define spin-squeezing parameters for Dicke states. In addition, we obtain also an analytic lower bound to the condition derived in [A.S. Sorensen and K. Molmer, Phys. Rev. Lett. 86, 4431 (2001)]. We also extend our results to systems with fluctuating number of particles.

Q 23.2 Tue 14:45 P 2

Witnessing the metrological efficiency with few expectation values — •Iagoba Apellaniz[1], Matthias Keinmann[1], Otfried Gühne[2], and Géza Tóth[1,3,4] — [1]Department of Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany — [3]IKERBASQUE, Basque Foundation for Science, E-48013 Bilbao, Spain — [4]Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, Hungary

In quantum metrology, the precision of parameter estimation plays a central role. For a given quantum state, the quantum Fisher information characterizes the best achievable precision, hence it is very important to obtain it in an experiment. We show how to estimate the quantum Fisher information as a figure of merit of metrological usefulness based on a few expectation values. Our approach is optimal since it gives a tight lower bound on the quantum Fisher information for the given incomplete information. We apply our method to the results of various multi-particle quantum states prepared in experiments with photons, trapped-ions and cold atomic ensembles, such as spin-squeezed states and Dicke states. Based on a few operator expectation values, our approach can also be used for detecting and quantifying entanglement in very large systems.

Q 23.3 Tue 15:00 P 2

Superfast maximum likelihood reconstruction for quantum tomography — •Jiangwei Shang[1,2], Zhengyun Zhang[3], and Hui Khoon Ng[1,4,5] — [1]Centre for Quantum Technologies, National University of Singapore, Singapore 117543, Singapore — [2]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — [3]BioSyM IRG, Singapore-MIT Alliance for Research and Technology (SMART) Centre, Singapore 138602, Singapore — [4]Yale-NUS College, Singapore 138527, Singapore — [5]MajuLab, CNRS-UNS-NUS-NTU International Joint Research Unit, UMI 3654, Singapore

Conventional methods for computing maximum-likelihood estimators (MLE) often converge slowly in practical situations, leading to a search for simplifying methods that rely on additional assumptions for their validity. In this work, we provide a fast and reliable algorithm for MLE reconstruction that avoids this slow convergence. Our method utilizes an accelerated projected-gradient scheme that allows one to accommodate the quantum nature of the problem in a different way. We demonstrate the power of our approach by comparing its performance with other algorithms for n-qubit state tomography. In particular, an 8-qubit situation that purportedly took weeks of computation time in 2005 can now be completed in under a minute for a single set of data, with far higher accuracy than previously possible. The same algorithm can be applied to general optimization problems over the quantum state space; the philosophy of projected gradients can further be utilized for optimization contexts with general constraints.

Q 23.4 Tue 15:15 P 2

Time evolution of spin systems in a generalized Wigner representation — •Balint Koczor, Robert Zeier, and Steffen J. Glaser — Department Chemie, Technische Universität München, Lichtenbergstrasse 4, 85747 Garching, Germany

Phase-space representations as Wigner functions are a powerful tool for describing the time evolution of infinite-dimensional quantum systems and have been widely used in quantum optics and beyond. We present a phase-space representation for finite-dimensional quantum systems as coupled spin systems, for which much less is known. This representation is convenient for visualizing arbitrary operators and provides a novel approach for describing and predicting the time evolution without using matrices. Our approach relies on linear combinations of spherical harmonics transforming naturally under local rotations as well as decompositions of operators into sums of tensor products. We illustrate our appraoch with multiple examples for coupled spins systems consisting of up to three spins 1/2.

Q 23.5 Tue 15:30 P 2

Wigner tomography of operators in multi-qubit systems — •David Leiner, Robert Zeier, and Steffen J. Glaser — Department Chemie, Technische Universität München, Lichtenbergstrasse 4, 85747 Garching, Germany

Arbitrary quantum-mechanical operators of a coupled multi-qubit system can be visualized using a Wigner-type representation composed of multiple spherical functions [1]. Building on this approach, we develop a general methodology to experimentally measure these spherical functions. The spherical functions are recovered by computing expectation values of axial spherical tensor operators rotated for a discrete set of angles. Experimental results using nuclear magnetic resonance spectroscopy are presented and visualized for up to three qubits.

[1] A. Garon, R. Zeier, and S. J. Glaser, Physical Review A, 91(4):042122, 2015

Q 23.6 Tue 15:45 P 2

Multiqubit State Tomography from a Physical Perspective — •Lukas Knips[1,2], Christian Schwemmer[1,2], Nico Klein[1,2], Jonas Reuter[3], Géza Tóth[4,5,6], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching — [2]Department für Physik, Ludwig-Maximilians-Universität, D-80797 München — [3]Bethe Center for Theoretical Physics, Universität Bonn, D-53115 Bonn — [4]Department of Theoretical Physics, University of the Basque Country UPV/EHU, P.O. Box 644, E-48080 Bilbao, Spanien — [5]IKERBASQUE, Basque Foundation for Science, E-48013 Bilbao, Spanien — [6]Wigner Research Centre for Physics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Ungarn

We show how the statistical nature of measurements alone easily causes unphysical estimates in quantum state tomography. Multinomial or Poissonian noise results in eigenvalue distributions converging to the Wigner semicircle distribution for already a modest number of qubits. This fact enables to estimate the influence of finite statistics to state tomography as well as the number of measurements necessary to avoid unphysical solutions. More importantly knowing the impact of statistical noise on the eigenvalue distribution directly leads to a physical state estimate with minimal numerical effort. Combining ideas from random matrix theory with pertubation theory, one can immediately obtain a physically motivated estimate together with confidence regions for the state estimate as well as for interesting figures of merit like the fidelity.

Q 23.7 Tue 16:00 P 2

Compressed sensing in quantum state tomography — •Carlos Riofrio and Jens Eisert — Dahlem center for complex quantum systems, Freie Universität Berlin, 14195 Berlin, Germany

As quantum systems get closer to technological applications, the problem of identifying, certifying, and characterizing them becomes more difficult. In fact, a complete characterization of a quantum system requires a computational effort that grows exponentially with the system size. New paradigms that allow for efficient signal processing must be developed and tested in order to overcome this problem. In this talk, we argue that the compressed sensing methodology addresses this issue and present an overview of the most recent developments in quantum state tomography. We show a complete analysis based on experimental data for a 7-qubit system of trapped ions that encodes a single logical qubit in a color code, in which highly incomplete data is observed. In addition, we study the problem of model selection in quantum tomography and observe that for an appropriately chosen regime, compressed sensing is compatible with our heuristic model selection protocol.

Q 23.8 Tue 16:15 P 2

Guaranteed recovery of quantum processes from few measurements — •Martin Kliesch[1,2], Richard Kueng[2], Jens Eisert[3], and David Gross[2] — [1]University of Gdansk, Poland — [2]University of Cologne, Germany — [3]Freie Universität Berlin, Germany

Quantum process tomography is the task of reconstructing unknown quantum channels from measured data. In this work, we introduce compressed sensing-based methods that facilitate the reconstruction of quantum channels of low Kraus rank. The measurements are obtained from sending pure states into the channel and measuring expectation values of observables without the use of ancilla systems. We prove recovery guarantees for three different reconstruction algorithms that using an essentially optimal number of measurements. The reconstructions are based on a trace, diamond, and ℓ_2-norm minimization, respectively. Our recovery guarantees are uniform in the sense that with one random choice of measurement settings all quantum channels can be recovered equally well. Moreover, stability against arbitrary measurement noise and robustness against violations of the low-rank assumption is guaranteed. Numerical studies demonstrate the feasibility of the approach.