Q 8: Quantum Information (Concepts and Methods) II

Time: Monday 14:00–16:00 Location: e001

Q 8.1 Mon 14:00 e001

Quantum trajectories—measurement interpretation — Nina Megier[2], Walter T. Strunz[1], and •Kimmo Luoma[1] — [1]ITP, TU Dresden, Dresden, Germany — [2]Dipartimento di Fisica, Università degli Studi di Milano,Italy

Quantum measurements and the associated state changes are properly described in the language of instruments. We investigate the properties of a time continuous family of instruments associated with the recently introduced family of general Gaussian non-Markovian stochastic Schrödinger equations. We stipulate the conditions for the family of instruments to be consistent with the requirements of a time continuous quantum measurement. We find that for pure dephasing of an N -level system the additional degrees of freedom do lead to a time continuous quantum measure- ment even beyond the white noise limit. As an example we elaborate the case of Ornstein-Uhlenbeck noise.

Q 8.2 Mon 14:15 e001

Bohmian trajectories in a double slit - delayed choice analysis with entangled photons — •Jan Dziewior[1,2,3], Lukas Knips[1,2,3], Jasmin D. A. Meinecke[1,2,3], Maria Galli[4], and Harald Weinfurter[1,2,3] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]MCQST, Munich, Germany — [4]Institut für Experimentalphysik, Innsbruck, Austria

Bohmian mechanics, a realistic interpretation of quantum mechanics, ascribes reality to the positions and momenta of quantum particles at the cost of a non-local ontology. Thus, contrary to standard quantum mechanics it allows to conceive of definite particle trajectories, while being fully compatible with the standard theory in all empirical predictions. Nevertheless, the plausibility of the Bohmian picture has been frequently put into question, most prominently with a Gedankenexperiment by Englert et al.

Here, the experimental realization of this Gedankenexperiment is presented. The conditions for the occurrence of so called "surrealistic" trajectories are realized by using a pair of entangled photons, where one of the photons is sent into an optical double slit. The average trajectories are recorded using a method inspired by the weak measurement concept. By detecting the second photon before or after the first photon passed the double slit, or even after the first photon was detected, it is possible to realize a series of delayed choice scenarios, exposing the differences in the conclusions of standard and Bohmian quantum mechanics.

Q 8.3 Mon 14:30 e001

Complementarity between one- and two-body visibilities — •Christoph Dittel[1] and Gregor Weihs[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria

It has been shown for the separate (i.e. local) evolution of two entangled particles that the usual single-particle visibility is complementary to a two-body visibility built on the optimization of two-body correlators. Here we go one step further and generalize these concepts for common (i.e. global) evolutions of the two-body system. We identify two distinct two-body visibilities which both are complementary to the usual one-body interference visibility. Moreover, we show that only one of them satisfies the standard inequality associated with complementarity, while the other one entails an inequality with reversed direction. This, however, can be understood in terms of entanglement between the constituents.

Q 8.4 Mon 14:45 e001

Representing an experimental two photon state with a neural network — •Marcel Neugebauer[1], Martin Gärttner[2], Laurin Fischer[1], Alexander Jäger[1], Selim Jochim[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg — [2]Kirchhoff-Institut für Physik, Universität Heidelberg

Neural networks are mathematical models on which parameter optimization can be done in an efficient way, so that immense numbers of parameters can be handled. High dimensional optimization is also crucial to solve important problems in many body quantum physics. In particular quantum state tomography is a problem that scales exponentially in the measurement cost and in numerical optimization cost. New approaches to tackle this via the neural network representation of quantum states emerged recently. In this talk an ansatz is discussed in which a probability distribution over an informationally complete measurement is represented with a restricted Boltzmann machine. We represent the quantum state of a twin photon source with this technique and test its prediction capabilities against predictions of a maximum likelihood density matrix and actual measurement.

Q 8.5 Mon 15:00 e001

Detecting entanglement with two product observables — •Nikolai Wyderka[1], Mariami Gachechiladze[2], and Otfried Gühne[1] — [1]Naturwissenschaftlich Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany — [2]Institut für Theoretische Physik, Universität zu Köln

Entanglement is one of the most important features of quantum mechanics and is a key ingredient for applications in quantum cryptography, quantum computing and quantum metrology. As such, the experimental verification of entanglement is a necessary, yet challenging task. It is therefore of interest to find a way of detecting entanglement with as little effort as possible.

In this talk, we consider the case of bipartite systems and the measurement of two product observables. We find necessary and sufficient conditions for these observables to be able to detect entanglement in qubit-qubit and qubit-qutrit systems, and show that the same conditions fail for larger-dimensional systems.

Q 8.6 Mon 15:15 e001

Quantum tetrachotomous states in phase space — •Namrata Shukla[1], Naeem Akhtar[2], and Barry C. Sanders[2,3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]University of Science and Technology, Shanghai, China — [3]Institute for Quantum Science and Technology, University of Calgary, Calgary, Canada

The well-studied quantum optical Schrödinger's cat state is a superposition of two distinguishable states, with quantum coherence between these macroscopically distinguishable states being of foundational and, in the context of quantum-information processing, practical use. We refer to these quantum-optical cat states as quantum dichotomous states, reflecting that the state is a superposition of two options, and we introduce the term quantum multichotomous state to refer to a superposition of multiple macroscopically distinguishable options. For a single degree of freedom, such as position, we construct the quantum multichotomous states as a superposition of Gaussian states on the position line in phase space. Using this nomenclature, a quantum tetrachotomous state (QTS) is a coherent superposition of four macroscopically distinguishable states. We define, analyze, and show how to create such states, and our focus on the QTSs is due to their exhibition of much richer phenomena than for the quantum dichotomous states. Our characterization of the QTS involves the Wigner function, its marginal distributions, and the photon-number distribution, and we discuss the QTS's approximate realization in a multiple-coupled-well system.

Q 8.7 Mon 15:30 e001

The shape of higher-dimensional state space – Bloch sphere analog for a qutrit — Christopher Eltschka[1], Marcus Huber[2], Simon Morelli[2], and •Jens Siewert[3,4] — [1]University of Regensburg, 93053 Regensburg, Germany — [2]IQOQI Vienna, Austrian Academy of Sciences, 1090 Vienna, Austria — [3]University of the Basque Country UPV/EHU, 48080 Bilbao, Spain — [4]IKERBASQUE Basque Foundation for Science, 48013 Bilbao, Spain

The Bloch sphere as a geometric representation of the state space for qubits is an ubiquitous tool to gain deeper insight and intuitive understanding of quantum-mechanical phenomena. Unfortunately, even for the next more complex system, the qutrit, such a geometric representation (rather than cross sections or projections) is not known. This is difficult because, in order to serve as a model for the state space, it should display a number of desirable properties, such as different surface parts corresponding to pure or mixed states, convexity, insphere and outsphere with the corresponding radii, pure states should form a connected set, etc. [1]. We show that, based on the Bloch representation of qutrit states, such a model can be constructed that captures many of the geometric features discussed in Ref. [1].

[1] I. Bengtsson, S. Weis, K. Zyczkowski, Geometry of the Set of Mixed Quantum States: An Apophatic Approach. In: P. Kielanowski et al (eds) Geometric Methods in Physics. Trends in Mathematics. Birkhäuser, Basel, 2013.

Q 8.8 Mon 15:45 e001

Representing quantum states on neuromorphic hardware — •Julius Vernie[1], Marcel Neugebauer[1], Laurin Fischer[1], Andreas Baumbach[2], Martin Gärttner[2], Selim Jochim[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

Artificial Neural Networks have already successfully been used to reproduce the results of quantum mechanical experiments. Spiking Neural Networks are now offering a promising new approach in this field. Especially, they can be implemented physically in the form of neuromorphic hardware, which leads to a great increase of computation speed compared to emulations on classical hardware. In our current work, we are training a neuromorphic computer to reproduce the results of quantum mechanical experiments and looking for new ways to encode quantum information, leading to more efficient predictions for complex quantum systems.