FM 20: Entanglement: Many-Body States II

Time: Monday 16:30–18:30 Location: 2004

FM 20.1 Mon 16:30 2004

Single-shot holographic compression from the area law — •Henrik Wilming[1] and Jens Eisert[2] — [1]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

The area law conjecture states that the entanglement entropy of a region of space in the ground state of a gapped, local Hamiltonian only grows like the surface area of the region. We show that, for any quantum state that fulfills an area law, the reduced quantum state of a region of space can be unitarily compressed into a thickened surface of the region. If the interior of the region is lost after this compression, the full quantum state can be recovered to high precision by a quantum channel only acting on the thickened surface. The thickness of the boundary scales inversely proportional to the error for arbitrary spin systems and logarithmically with the error for quasi-free bosonic systems. Our results can be interpreted as a single-shot operational interpretation of the area law. The result for spin systems follows from a simple inequality showing that probability distributions with low entropy can be approximated by distributions with small support, which we believe to be of independent interest. We also discuss an emergent approximate correspondence between bulk and boundary operators and the relation of our results to tensor network states.

FM 20.2 Mon 16:45 2004

Symmetry-adapted decomposition of tensor operators and the visualization of coupled spin systems — David Leiner[1], •Robert Zeier[1,2,3], and Steffen J. Glaser[1,4] — [1]Technische Universität München, Department Chemie, Lichtenbergstrasse 4, 85747 Garching, Germany — [2]Adlzreiterstrasse 23, 80337 München, Germany — [3]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8), 54245 Jülich, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), Schellingstrasse 4, 80799 München, Germany

We study the representation and visualization of finite-dimensional, coupled quantum systems. In order to establish a generalized Wigner representation, multi-spin operators are decomposed into a symmetry-adapted tensor basis and they are mapped to multiple spherical plots that are each assembled from linear combinations of spherical harmonics. We explicitly determine the corresponding symmetry-adapted tensor basis for up to six coupled spins 1/2 (qubits) using a first step that relies on a Clebsch-Gordan decomposition and a second step which is implemented with two different approaches based on explicit projection operators and coefficients of fractional parentage. Our approach is illustrated with various examples for the cases of four to six coupled spins 1/2. We also treat the case of two coupled spins with arbitrary spin numbers (qudits) and highlight a quantum system of a spin 1/2 coupled to a spin 1 (qutrit). Our work offers a much more detailed understanding of the symmetries appearing in coupled quantum systems. http://arxiv.org/abs/1809.09006

FM 20.3 Mon 17:00 2004

Semiclassical approach in Bose-Hubbard models: from eigenstate statistics to self trapping dynamics — •Remy Dubertrand[1], Mathias Steinhuber[1], Juan-Diego Urbina[1], Klaus Richter[1], and Steve Tomsovic[2] — [1]Institut für Theoretische Physik Universität Regensburg Universitätsstraße 31 D-93053 Regensburg — [2]Department of physics and astronomy, Washington State Univ ersity, Pullman, WA USA

Semiclassical techniques from quantum chaos have been recently generalised to describe many-body interacting bosonic systems written as second quantised models. To understand many-body coherent effects I will motivate how to build a quantum/classical correspondence. This will be used first to describe the eigenstates following a statistical approach. This involves more precisely the connection with Berry's ansatz of ensembles of eigenstates represented by Gaussian distributions with an universal covariance matrix. In particular this allows us to go beyond the naive Random Matrix Theory's approximation. A second, more recent, application aims at studying the far from equilibrium dynamics, where the semiclassical perspective enables one to fully characterise the self trapping transition (well beyond the truncated Wigner range of validity) using quantum signatures, e.g. entanglement properties of the eigenstates.

FM 20.4 Mon 17:15 2004

Many-body localization in the two-dimensional Bose-Hubbard-model — •Andreas Geissler[1,2] and Guido Pupillo[1,3] — [1]ISIS, University of Strasbourg, Strasbourg, France — [2]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany — [3]IPCMS, University of Strasbourg, Strasbourg, France

Some experiments [1,2] already have shown signatures of many-body localization (MBL) for the bosonic Hubbard model in one and two dimensional ultracold atomic gases in optical lattices. A proper theoretical understanding of the MBL phenomenon depends on knowledge about the full eigenstate spectrum. Therefore, commonly used exact numerical studies have been limited to small system sizes. Applying a recently extended beyond-Bogoliubov quasiparticle expansion [3] I have performed a detailed finite size scaling analysis of the quasiparticle eigenstate fractal dimension and gap ratio showing Berezinskii-Kosterlitz-Thouless (BKT) scaling consistent with recent predictions [4]. The low energy mobility edge terminates at the MBL transition. Furthermore, I present theoretical results for a recent experiment [2] showing comparable signatures of localization while suggesting that the observed localization also strongly depends on the confining potential.

[1] C. D'Errico et al., PRL 113, 095301 (2014)
[2] J.-y. Choi et al., Science 352, 1547 (2016)
[3] A. Geissler et al., PRA 98, 063635 (2018)
[4] A. Goremykian et al., PRL 122 040601 (2019); P. Dumitrescu et al., PRB 99 094205 (2019); A. Morningstar et al., arXiv:1903.02001

FM 20.5 Mon 17:30 2004

Shareability of USp⊗USp symmetric states — •Zoltán Zimborás[1], Michael Keyl[2], Thomas Schulte-Herbrüggen[3], and Robert Zeier[3,4] — [1]Wigner Research Centre for Physics, H-1021 Budapest, Hungary — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [3]Technical University Munich, Department of Chemistry, Lichtenbergstrasse 4, 85747 Garching, Germany — [4]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8), 54245 Jülich, Germany

It is notoriously hard to calculate entanglement measures for generic quantum states. Therefore, from the beginning of entanglement theory it has been useful to consider examples of entangled states with high symmetry, since representation theoretic methods can then be used to greatly simplify the computations of the measures and the characterization of entanglement properties. In the present work, we continue this program by studying states that are invariant with respect to $\mathrm{USp}(2n)\otimes\mathrm{USp}(2n)$ transformations. This symmetry defines a two-parameter family of states in any $2n \times 2n$ dimensional bipartite Hilbert-space. The two free parameters are related by partial transposition in much the same way as isotropic and Werner states, but unlike those states the studied family also contains a region with bound entangled states. Using group theoretical methods, we calculate the one-distillability and two- and three-shareability regions for this set of states, and discuss how these relate to mean-field many-body problems.

FM 20.6 Mon 17:45 2004

Searching for a generalization of the I3322 Bell inequality — •Fabian Bernards[1], Denis Rosset[2], and Otfried Gühne[1] — [1]Universität Siegen, Siegen, Germany — [2]Perimeter Institute, Waterloo, Canada

We present a symmetric and extremal Bell inequality for three parties and three measurements per party with two outcomes each. Further, we investigate the relevance of the Bell inequality, i.e whether it can detect states as entangled that could not be detected with previously known Bell inequalities and discuss whether it can be regarded as a generalization of the I3322 inequality.

FM 20.7 Mon 18:00 2004

Positive maps and matrix polynomial inequalities from the symmetric group — •Felix Huber — ICFO Barcelona, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain

We introduce a hierarchy of positive (but not completely positive) maps acting upon multipartite quantum systems of finite-dimensions. The construction arises from irreducible representations of the sym-

metric group and can either be seen as a non-linear generalisation of the universal state inversion, or as a lifting of the generalized shadow inequality as introduced by Rains to that of an operator inequality. When applied to multiple copies of some given state, it yields a positive but not completely positive map that is non-linear.

FM 20.8 Mon 18:15 2004

Shell structure and deterministic preparation of microscopic two dimensional systems — •Luca Bayha, Marvin Holten, Ralf Klemt, Keerthan Subramanian, Philipp Preiss, and Selim Jochim — Physics Institute, Heidelberg University, Germany

The interplay between strong paring and shell structures arising from finite numbers creates very rich physics. For example the state of fermions in the BEC-BCS crossover is determined by the competition between pairing and single particle gaps. Here I will present our progress on quantum simulation of such mesoscopic fermionic systems using ultracold atoms. We recently archived the deterministic preparation of up to 12 fermions in the ground state of a two dimensional trap and observed the shell structure of the sample. We use a Feshbach resonance to tune interactions and study the finite size BEC-BCS crossover. For filled shells there is a minimal required attraction for pairing to overcome the single particle gap. Thus the ground state of the BEC-BCS crossover undergoes a quantum phase transition from normal to superfluid. This phase transition is accompanied by a Higgs mode. Remarkably, we found a precursor of this mode in a microscopic system consisting of only 6 fermions. Doing spectroscopy we observed mode softening close the critical binding energy of the many body system. This mode consists mainly of pair excitations, which we show by measuring the full counting statistics. In the future we plan to investigate the system using momentum and spin resolved single particle imaging. This will give insight into the pairing mechanisms, entanglement and correlations of the strongly interacting Fermi gas.