Abstracts: Talks
33rd SFB FoQuS meeting, University of Innsbruck, 14-15 July 2016

14:00 – 15:00
Invited talk: **Simon Benjamin, University of Oxford**
The power and practicality of network-paradigm quantum computing

What is the most promising architectural paradigm for a quantum information processor? This question remains open, but I will put the argument for a hybrid matter/light system composed of few-qubit devices interlinked by an optical fabric. I will review some of the recent achievements in experiments, theory and applications, and I will describe the Q20:20 machine that the Oxford-led National Quantum Hub is building in the UK. Systems of this kind are 'provably' capable of universal, fault tolerant quantum computing using components already demonstrated, but of course building a full scale machine of that kind would be a massive undertaking. I'll argue that theoretical efforts should now increasingly focus on identifying the potential for small and imperfect "1st generation" quantum computers in areas like optimisation, simulation and machine learning.

16:15 – 16:40
Davide Orsucci, University of Innsbruck
Estimation of coherent error sources from stabilizer measurements

In measurement-based quantum computation a way of maintaining the coherence of a graph state is to measure its stabilizer operators. Aside from performing quantum error correction, it is possible to exploit the information gained from these measurements to characterize and then counteract a coherent source of errors; that is, to determine all the parameters of an error channel that applies a fixed, but unknown, unitary operation to the physical qubits. Such a channel is generated, e.g., by local stray fields that act on the qubits. We study the case in which each qubit of a given graph state may see a different error channel and we focus on channels given by a rotation on the Bloch sphere around either the x, y, or z axis, for which analytical results can be given in a compact form. The possibility of reconstructing the channels at all qubits depends non-trivially on the topology of the graph state. We prove via perturbation methods that the reconstruction process is robust and supplement the analytic results with numerical evidence.

16:40 – 17:05
Lorenzo Procopio, University of Vienna
Experimental test of hyper-complex quantum theories

One of the most successful theories in physics until now is quantum mechanics. However, the physical origins of its mathematical structure are still under debate, and a "generalized" quantum theory to unify quantum mechanics and gravity is still missing. Recently, in an effort to better understand the mathematical structure of quantum mechanics, theories containing the essence of quantum mechanics, while also having a broader description of physical phenomena, have been proposed. These so-called "post-quantum theories" have only been recently tested at the lab. In this talk, I will present the results of our experimental test using single photons to probe one of these post-quantum theories; namely, hyper-complex quantum theories. Interestingly, in hyper-complex theories simple phases do not necessarily commute. To study this effect, we apply two physically different optical phases, one with a positive and one with a negative refractive index, to single photons inside of a Sagnac interferometer. Through our measurements we are able to put bounds on this particular prediction of hyper-complex quantum theories.

17:05 – 17:30
Richard Howl, University of Vienna
Quantum decoherence of phonons of BECs

We investigate the quantum decoherence of the phononic excitations of an isolated and interacting Bose-Einstein Condensate (BEC). By assuming Gaussian phonon states, we calculate the time scales for quantum decoherence from an analysis of the evolution of certain entropic measures and nonclassical indicators of the states, such as purity and entanglement. The results help to characterize the resourcefulness of phonons as carriers of quantum information. In particular, the results set new limits on the performance of a gravitational wave detector that utilizes the phonons of BECs as recources for relativistic quantum information. This limitation is present even at absolute zero.

9:00 – 9:25
Giulia Rubino, University of Vienna
Experimental verification of indefinite causal order

Investigating the role of causal order in quantum mechanics has recently revealed that the temporal distribution of events may not be a-priori well-defined in quantum theory. Although this has triggered a growing interest on the theoretical side, the existence of processes without a causal order is an experimental question. While a previous experiment has shown indirect evidence for non-causal effects by showing a predicted computational enhancement, a concrete verification of causal non-separability has not yet been achieved. To that end, here we report the first decisive demonstration of a causally non-separable process. To do so, we make use of a recent theoretical result to quantify the causal non-separability of a given process by measuring a `causal witness'. A causal witness is designed to yield a negative value only if the process under examination is not consistent with any possible process with a well-defined causal order. We measured a causal witness for a process built in our laboratory, and our results demonstrate, by more than 6 standard deviations, that we have experimentally implemented a process which does not have definite causal order.

9:25 – 9:50
Mateusz Łącki, IQOQI Innsbruck
Dark state subwavelength lattices and structures

In this talk I describe a novel way to obtain optical potential, that does not rely on standard AC Stark shift generated by off-resonant laser beam. The potentials are constructed as non-adiabatic corrections to the atomic motion in the presence of atoms coupled in a standard Lambda-type near resonant configuration by position-dependent standing waves. This allows for realization of a potential with subwavelength periodic extent such as two 1D wires separated by a subwavelength distance or a Kroning-Penney type lattice of subwavelength structures.   The subwavelength length scales could allow for new framework in terms of energy scales for the many-body simulation.

9:50 – 10:15
Daniel Petter, University of Innsbruck
Crossover from a Bose-Einstein condensate to a self-bound macro-droplet driven by quantum fluctuations

I will discuss our current measurements on the formation of a macro-droplet state in an ultracold bosonic gas of erbium atoms with strong dipolar interactions. By precise tuning of the s-wave scattering length below the so-called dipolar length, we observe a crossover of the ground state from a dilute Bose-Einstein condensate to a dense macro-droplet state of more than 2×10^4 atoms. Based on the study of collective excitations, loss features and expansion measurements, we show that quantum fluctuations stabilize the ultracold gas far beyond the instability threshold imposed by mean-field interactions.

10:15 – 10:40
Borivoje Dakic, IQOQI Vienna
Quantum ground states as macroscopic superpositions

In talk I will study a question whether a macroscopic superposition can naturally exist as ground state of many-body Hamiltonian. I will derive an upper bound on energy gap of arbitrary physical Hamiltonian provided that its ground state is a macroscopic quantum state. For a large class of states I will show that the gap vanishes in the macroscopic limit. The main result displays an interesting quantitative relation between the order of interaction and separation probability between "classical parts" that constitute macroscopic superposition. This in turn shows that preparation of a "typical" Schroedinger cat-like state by simple cooling to the ground state would require the order of interaction to grow with the size of system.

11:10 – 11:35
Alex Wietek, University of Innsbruck
Chiral spin liquids in frustrated quantum magnets

The emergence of quantum spin liquids in frustrated quantum magnetism is an exciting phenomenon in contemporary condensed matter physics. These novel states of matter exhibit fascinating properties such as long-range ground-state entanglement or anyonic braiding statistics of quasiparticle excitations, relevant for a potential implementation of topological quantum computation. Only very recently such phases have been found to be stabilized in realistic local spin models. In this talk I will discuss a special type of these phases, chiral spin liquids, and show that these states of matter can be realized in local extended Heisenberg models in 2 dimensions.

11:35 – 12:00
Gabriel Arenada, University of Innsbruck
Interference of single photons emitted from entangled atoms in free space

We present the experimental observation of path interference in the spontaneous emission of single photons from two distant entangled ions in free space. The degree of entanglement shared between the atoms determines the contrast of the interference while its phase is controlled precisely by fast changes of their relative optical distance. In the regime of states with single excitation the contrast of the fringes corresponds directly to the concurrence of the atoms state.

12:00 – 12:25
Alexey Melnikov, University of Innsbruck
Meta-learning within projective simulation

Learning models of artificial intelligence can nowadays perform very well on a large variety of tasks. However, in practice different task environments are best handled by different learning models, rather than a single, universal, approach. Most non-trivial models thus require the adjustment of several to many learning parameters, which is often done on a case-by-case basis by an external party. Meta-learning refers to the ability of an agent to autonomously and dynamically adjust its own learning parameters, or meta-parameters. In this work we show how projective simulation, a recently developed model of artificial intelligence based on a random walk process, can naturally be extended to account for meta-learning in reinforcement learning settings.

12:25 – 12:50
Jonas Schmöle, VCQ Vienna
A micromechanical proof-of-principle experiment for measuring the gravitational force of milligram masses

We address a simple question: how small can one make a gravitational source mass and still detect its gravitational coupling to a nearby test mass? We describe an experimental scheme based on micromechanical sensing to observe gravity between milligram-scale source masses, thereby improving the current smallest source mass values by three orders of magnitude and possibly even more. We also discuss the implications of such measurements both for improved precision measurements of Newton's constant and for a new generation of experiments at the interface between quantum physics and gravity.