CoOL Me 2020

Cold-atom On-Line Meeting

Nov. 16-18, 2020

online (9-18 Paris time)

BOOK OF ABSTRACTS

Cold-atom On-Line Meeting

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Welcome to the conference organised by the French national research network on Cold Atoms ("GdR Atomes Froids”).

In the spirit of our network, the main goal of this conference is to offer to the French and worldwide community a snapshot of some of the most exciting developments in field of cold atoms, via a series of invited talks delivered by distinguished speakers (from France and the rest of the world).

The conference will be fully held online from **9am (Paris time) of Monday, Nov. 16th to 6 pm (Paris time) of Wednesday, Nov. 18th, 2020**.

The scientific program includes 18 invited talks, an online poster session (more than 60 contributions), and a session dedicated to Quantum Tech’ industrial companies.

Organizers : Isabelle Bouchoule (Palaiseau, F), David Clément (Palaiseau, F), Daniel Comparat (Orsay, F), Olivier Dulieu (Orsay, F), Robin Kaiser (Nice, F), Tommaso Roscilde (Lyon, F)

Contact: coolme2020 AT sciencesconf.org

This conference is supported by :

Cold-atom On-Line Meeting

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SCIENTIFIC PROGRAM : Invited Talks

Monday, Nov. 14th

8:55-9:00	Opening Remarks
Rydberg atoms	
9:00-9:30	Shannon Whitlock (University of Strasbourg, France), *Exploring complex systems dynamics with Rydberg atoms*
9:30-10:00	Daniel Barredo (Lab. Charles Farbry, IOGS, Université Paris-Saclay, France), *Quantum simulation of the transverse field Ising model with arrays of Rydberg atoms*
10:00-10:30	Discussion room (with the two speakers)
10:30-11:00	Coffee break
Magnetic atoms	
11:00-11:30	Lauriane Chomaz (Innsbruck University, Austria) *Rotons and Supersolids in ultracold quantum gases of highly magnetic atoms*
11:30-12:00	J. Schachenmayer (INSIS, University of Strasbourg, France) *Entanglement dynamics and quantum thermalization with ultracold chromium atoms*
12:00-12:30	Discussion room (with the two speakers)
12:30-14:00	Lunch break
14:00-15:30	**Poster session 1**
15:30-16:00	Coffee break
Cold molecules	
16:00-16:30	Kang-Kuen Ni (Harvard University, Cambridge, MA, USA), *Probing and controlling chemical reactions below 1 micro-Kelvin*
16:30-17:00	Maxence Lepers (Lab. Interdisciplinaire Carnot de Bourgogne, University of Bourgogne, Dijon, France), *Optical shielding of destructive chemical reactions between ultracold ground-state NaRb molecules*
17:00-17:30	Discussion room (with the two speakers)

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Tuesday, Nov. 17th

Metrology

9:00-9:30 Tanja Mehlstaüber (PTB and Leibniz University, Hannover, Germany), *Multi-ion optical clocks*

9:30-10:00 Rémi Geiger (SYRTE, Paris Observatory, France), *Precision Inertial Measurements with Cold-Atom Interferometers*

10:00-10:30 Discussion room (with the two speakers)

10:30-11:00 Coffee break

Entanglement & correlations

11:00-11:30 Benoît Vermersch (LPMMC, Univesity of Grenoble, France), *Probing mixed-state entanglement with randomized measurements*

11:30-12:00 Philipp Preiss (Heidelberg University, Germany), *Zooming in on Ultracold Few-Fermion Systems*

12:00-12:30 Discussion room (with the two speakers)

12:30-14:00 Lunch break

Chaos & integrability

14:00-14:30 Juliette Billy (Lab. Collisions Agrégats Réactivité, Paul Sabatier University, Toulouse France), *Chaos-assisted tunneling resonances in a synthetic Floquet superlattice*

14:30-15:00 J. Dubail (Jean Lamour Institute, University of Lorraine, Nancy, France), *Generalized Hydrodynamics in the one-dimensional Bose gas*

15:00-15:30 Discussion room (with the two speakers)

15:30-16:00 Coffee break

Quantum-tech industry session

16:00-16:15 Phillipe Bouyer (Muquans)

16:15-16:30 Juris Ulmanis (Alpine Quantum Technologies)

16:30-16:45 Mark Saffman (ColdQuanta)

16:45-17:00 Adrien Signoles (Pasqal)

17:00-17:30 Discussion room (with the four speakers)

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Wednesday, Nov. 18th

Atom-light interactions	
9:00-9:30	Juliette Simonet (Institute for Laser Physics, Hamburg University, Germany), *Ultrafast electron cooling in an expanding ultracold plasma*
9:30-10:00	William Guérin (Institut de Physique de Nice, Université Côte d'Azur, Nice, France), *Super- and subradiance in dilute atomic samples*
10:00-10:30	Discussion room (with the two speakers)
10:30-11:00	Coffee break
Cold atoms in cavities	
11:00-11:30	Jean-Philippe Brantut (EPFL, Lausanne, Switzerland), *Universal pair-polaritons in a strongly interacting Fermi gas*
11:30-12:00	M. Z. Huang (Lab. Kastler-Brossel, ENS, Paris, France), *Long-lived spin-squeezed states under spin dynamics*
12:00-12:30	Discussion room (with the two speakers)
12:30-14:00	Lunch break
14:00-15:30	**Poster session 2**
15:30-16:00	Coffee break
Topological phases	
16:00-16:30	M. Aidelsburger (Ludwig-Maximilians University Munich, Germany), *Floquet topological phases with ultracold atoms in periodically-driven lattices*
16:30-17:00	Sylvain Nascimbène (Lab. Kastler-Brossel, ENS, Paris, France), *Synthetic quantum Hall system with ultracold Dysprosium atoms*
17:00-17:30	Discussion room (with the two speakers)
17:30-17:45	Closing Remarks

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SCIENTIFIC PROGRAM :

Poster Session 1

Monday, Nov. 16th, 14h00-15h30

Quantum simulation

P01 - R. Alhyder, *Impurity immersed in a double Fermi sea*
P02 - P. Bataille, *Adiabatic spin-dependent momentum transfer in an SU(N) degenerate Fermi gas*
P03 - R. Chicireanu, *Dynamics of strong and weak localizations in disordered quantum systems*
P04 - X. Turkeshi, *Measurement-induced criticality in (2+1)-dimensional hybrid quantum circuits*
P05 - N. Euler, *Certification of high-dimensional entanglement in ultracold atom systems*
P06 - A. Fedorov, *Quantum computing with qudits on a graph*
P07 - J.-B. Gerent, *Transport and coupling of a ultra-cold atomic gas with a nano-structured surface*
P08 - Y. Guo, *Ultracold atoms in strong disorder: towards the Anderson transition*
P09 - A. Hegde, *Quantum simulation of dynamical gauge fields using ultracold atomic mixtures*
P10 - V. Kasper, *Universal quantum computation and quantum error correction with ultracold atomic mixtures*
P11 - E. Orignac, *Lieb-Liniger variational ansatz and one-dimensional dipolar gases*
P12 - G. Pecci, *Probing the BCS-BEC crossover with persistent currents*
P12bis - Z. Ristivojevic, *Exact Results for the Boundary Energy of One-Dimensional Bosons*
P13 - R. Veyron, *Characterization of a quantum gas microscope with a sub-wavelength resolution based on AC Stark shifts*

Non-equilibrium dynamics

P14 - G. Baio, *Stability of optomechanical self-structured phases and dissipative solitons of cold atoms with optical feedback*
P15 - T. Comparin, *Quench Spectroscopy: Low-energy excitations from real-time dynamics*
P16 - Y. Guo, *Supersonic Rotation of a Superfluid: A Long-Lived Dynamical Ring*
P17 - K. Jachymski, *Inelastic collision dynamics of a single cold ion immersed in a Bose-Einstein condensate*
P18 - H. Kurkjian, *Elementary excitations in superfluid Fermi gases*

Ultracold Molecules

P19 - A. Pandey, *Interaction potentials and ultracold scattering cross sections for the $^{7}Li^{+}$-^{7}Li ion-atom system*
P20 - G. Quéméner, *Controlling 3-body collisions of ultracold dipolar molecules using an electric field*

Quantum metrology

P21 - M. Andia, *Mercury optical lattice clock with a 2D magneto-optical trap*

- P22 - G. Baclet, *Molecular gas spectroscopy in hollow core fibers for atomic cooling using Telecom laser systems*
- P23 - J. Bernard, *Progress towards the development of a cold-atom inertial measurement unit for onboard applications*
- P24 - F. L. Constantin, *THz-wave Electrometry Based on Lightshift Measurements with Cold Trapped HD$^+$ Ions*
- P25 - O. Rousselle, *Simulation of the GBAR experiment (Gravitational Behaviour of Antihydrogen at Rest*

Light-matter interaction, quantum optics

- P26 - P. Azam, *Fluids of light in atomic vapor*
- P27 - S. Garcia, *Nonlinear quantum optics with Rydberg atoms in an optical cavity*
- P28 - C. Garcion*, Accurate measurement of the Casimir-Polder interactions*
- P29 - H. Eneriz, *Cavity QED with Bose-Einstein Condensates in a running wave resonator*
- P30 - R. Kaiser, *Ground-state coherence vs orientation: competing mechanisms for light-induced magnetic self-organization in cold atoms*
- P31 - M. Schemmer*, Unraveling two-photon entanglement via the squeezing spectrum of light traveling through nanofiber-coupled atoms*
- P32 - D. Wellnitz, *Collective Dissipative Molecule Formation in a Cavity*

Poster Session 2

Wednesday, Nov. 18th, 14h00-15h30

Quantum simulation

- P01 - G. De Rosi, *Beyond-Luttinger-liquid thermodynamics of a one-dimensional Bose gas with repulsive contact interactions*
- P02 - G. Hercé, *Certifying the adiabatic preparation of ultracold lattice bosons in the vicinity of the Mott transition*
- P03 - B. Irsigler, *Topological Mott transition in a Weyl-Hubbard model with dynamical mean-field theory*
- P04 - L. Lavoine, *Observation of the algebraic localization-delocalization transition in a one-dimensional disordered potential with a bias force*
- P05 - V. Mancois, *Absorption spectroscopy and atom number measurement of subwavelength volumes of cold atoms*
- P06 - M. Martinez, *Chaos-assisted long range hopping for quantum simulation*
- P07 - G. Masella, *Supersolid Stripe Crystal from Finite-Range Interactions on a Lattice*
- P08 - H. Riechert, *Constructing U(1) gauge symmetry in electronic circuits*
- P09 - X.Z. Chen, *Towards Cold Atom Experiments in the Chinese Space Station*
- P10 - G. Spada, *The polarized Fermi-Hubbard superluid at large order*
- P11 - A. Ténart, *Hanbury-Brown and Twiss bunching of phonons and of the quantum depletion in a strongly-interacting Bose gas*
- P12 - M. Tylutki, *Vortex Reconnections across the BEC-BCS Crossover*
- P13 - G. Valenti-Rojas, *Synthetic Flux Attachment*
- P14 - J. Walker, *Dynamics of Optomechanical Droplets in a Bose-Einstein Condensate*

Non-equilibrium dynamics

- P15 - L. Benini, *Loschmidt echo singularities as dynamical signatures of strongly localized phases*
- P16 - M. Gaudesius, *Self-oscillating atomic clouds in Magneto-Optical Traps*
- P17 - L. Mazza, *Strong correlations in lossy one-dimensional quantum gases: from the quantum Zeno effect to the generalized Gibbs ensemble*

- P18 - J. Schneider, *Spreading of Correlations and Entanglement in the Long-Range Transverse Ising Chain*
- P19 - Y. Trifa, *Multi-spin cat state in small arrays of large dipolar spins*

Ultracold molecules

- P20 - T. Xie, *Optical Shielding of Destructive Chemical Reactions between Ultracold Ground-State NaRb Molecules*
- P21 - X. Xing, *Parity-dependent charge exchange in $LiBa^+$ experiment*

Quantum metrology

- P22 - T. Battard, *Electron Electric Dipole Moment in matrix*
- P23 - S. Lellouch, *Circulating pulse cavity enhancement as a method for extreme momentum transfer atom interferometry*
- P24 - C. Leprince, *Bragg pulses shaping in an atomic interferometer*
- P25 - M. Robert-De-Saint-Vincent, *Shelving spectroscopy of the strontium intercombination line*

Light-matter interaction, quantum optics

- P26 - M. Bosch Aguilera, *Light-mediated strong coupling between a mechanical oscillator and atomic spins 1 meter apart*
- P27 - T. Cantat-Moltrecht, *Cavity-Enhanced Microscope for Cold Atoms*
- P28 - I. Ferrier-Barbut, *Storage and release of light in subradiant excitations of a dense atomic cloud*
- P29 - R. Journet, *Narrow-line spectroscopy to cool strontium atoms*
- P30 - P. Lassègues, *Intensity correlations and light scattered by a cold atomic cloud*
- P31 - P. Schneeweiss, *Imaging and Localizing Individual Atoms Interfaced with a Nanophotonic Waveguide*
- P32 - A. J. Park, *Towards Quantum Simulation of Light-Matter Interfaces with Strontium Atoms in Optical Lattices*

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INVITED TALKS

Exploring complex systems dynamics with Rydberg atoms

Shannon Whitlock*[1]

[1]Université de Strasbourg – Université de Strasbourg, CNRS : UMR7006 – France

Abstract

From financial markets and neuronal activity in the brain to the way forest fires and diseases spread, the dynamics of complex systems are governed by critical events and emergent phenomena that are exceedingly difficult to understand or predict from underlying principles. We recently discovered that a gas of ultracold atoms continuously driven to strongly-interacting Rydberg states by an off-resonant laser field displays all the hallmarks of complex systems dynamics in a highly-controllable experimental system: (i) At early times we observe rapid growth of Rydberg excitations that has a striking correspondence with the spreading of diseases empirically observed in epidemics [1]; (ii) At later times we find that the system evolves toward a self-organised critical (SOC) state, a phenomenon that has been conjectured to explain the abundance of scale-invariant systems found in nature [2]. I will discuss how these experiments can be understood in terms of an emergent atomic network that bridges the gap between mathematical models and empirical observations. This provides the opportunity to identify general principles governing non-equilibrium dynamics and to learn how seemingly universal properties emerge from microscopic physical details.

T. M. Wintermantel *et al*, arXiv:2007.07697 (2020)

S. Helmrich *et al*, Nature, 577, 481-486 (2020)

*Speaker

Quantum simulation of the transverse field Ising model with arrays of Rydberg atoms

Daniel Barredo*[1]

[1]Laboratoire Charles Fabry – Institut d'Optique Graduate School (IOGS), CNRS, Université Paris Saclay – France

Abstract

Rydberg atoms in arrays of optical tweezers are by now among the most promising platforms for quantum simulation of many body quantum systems [1]. We use this experimental platform to implement the antiferromagnetic Ising model with a transverse field [2] in two different 2D geometries, namely a square and a triangular lattice, with up to _˜200 atoms [3]. By dynamically tuning the Hamiltonian we coherently drive the system across a phase transition and directly probe antiferromagnetic order. Individual control and readout of the qubits allows us to measure scalable order parameters, such as the staggered magnetization, during the dynamics. We compare these observables with state-of-the-art numerical simulations for up to 100 particles, where results are still theoretically tractable. This critical benchmark of the quantum simulation demonstrates that our platform is suitable to investigate spin models in regimes that can no longer be studied numerically, and where concepts such as geometrical frustration or spin liquids are not well understood.

References:

A. Browaeys and T. Lahaye, Nat. Phys. **16**, 132 (2020).

V. Lienhard *et al.*, Phys. Rev. X **8**, 021070 (2018).

P. Scholl *et al.*, in preparation.

*Speaker

Rotons and Supersolids in ultracold quantum gases of highly magnetic atoms.

Lauriane Chomaz*[1]

[1]Institut für Experimentalphysik - Universität Innsbruck – Technikerstraße 25/4, A-6020 Innsbruck, Austria

Abstract

Ultracold quantum gases realize an exquisite platform to study few- and many-body quantum phenomena. The achievement of quantum degeneracy in gases of atoms possessing large magnetic dipole moments has opened up new research directions where long-range anisotropic dipole-dipole interactions are competing with short-range contact interactions. Within the last few years, thanks to a fine control of this interaction competition and the subsequent occurrence of a unique stabilization mechanism based on quantum fluctuations, experiments using magnetic lanthanide atoms proved novel many-body quantum states. These include liquid-like droplets, roton excitations and, most recently, supersolids. In my talk, I will present recent results of my group in relation to the discovery and exploration of such states using gases of erbium and dysprosium in cigar-shaped traps with transverse magnetization. In the case of a regular superfluid state, the anisotropic dipole-dipole interaction may induce the existence of roton excitations along the cigar axis. The softening of these excitations under the reduction of the contact interaction strength drives a transition to density modulated states, stabilized by quantum fluctuations. The transition is relatively smooth, and, in an intermediate regime of interaction parameter, the superfluid order is maintained in the density-modulated ground-state, yielding a supersolid. In this paradoxical state, both crystal and phase excitations can come at play, yielding intriguing properties and dynamical behaviors.

*Speaker

Entanglement dynamics and quantum thermalization with ultracold chromium atoms

Johannes Schachenmayer*[1]

[1]Institut de Science et díngénierie supramoléculaires – université de Strasbourg, Centre National de la Recherche Scientifique : UMR7006 – France

Abstract

Experimental setups with ultracold magnetic atoms have made it possible to observe coherent far-from-equilibrium dynamics of large-spin lattice models with dipolar long-range interactions in clean and controllable environments. Here, we analyze such dynamics in an experiment with chromium atoms trapped in a 3D optical lattice. We show that this experiment observes the time-dependent build-up of entanglement between the atoms. We find that the longer-time relaxation of the setup is well explained by coherent "quantum thermalization". To model this experiment we developed a new numerical approach that is well suited for ultracold magnetic atom experiments.

*Speaker

Probing and controlling chemical reactions below 1 micro-Kelvin

Kang-Kuen Ni*[1]

[1]Harvard University – United States

Abstract

Advances in quantum manipulation of molecules bring unique opportunities, including the use of molecules to search for new physics, harnessing molecular resources for quantum engineering, and exploring chemical reactions in the ultra-low temperature regime. In this talk, I focus on the latter topic where we work toward a detailed microscopic picture of molecules transforming from one species to another and reveal several surprises along the way. By preparing quantum-state-selected KRb molecules at a temperature of 500 nK, we observed reactions proceeding through a long-lived intermediate, which provides a handle to steer with light the reaction pathway away from its natural course. The long lifetime of the intermediate is expected to lead to a statistically distributed reaction outcome where all channels are explored. We developed quantum state mapping of correlated product-pairs to precisely benchmark statistical theory.

*Speaker

Optical shielding of destructive chemical reactions between ultracold ground-state NaRb molecules

Maxence Lepers*[1]

[1]Laboratoire Interdisciplinaire Carnot de Bourgogne [Dijon] – Université de Technologie de Belfort-Montbeliard, Université de Bourgogne, Centre National de la Recherche Scientifique : UMRCNRS 6303 – France

Abstract

I will present a method to suppress the chemical reactions between ultracold bosonic ground-state 23Na-87Rb molecules based on optical shielding. By applying a laser with a frequency blue-detuned from the transition between the lowest rovibrational level of the electronic ground state X 1Sigma+ (vX=0, jX=0), and the long-lived excited level b 3Pi0 (vb=0, jb=1), the long-range dipole-dipole interaction between the colliding molecules can be engineered, leading to a dramatic suppression of reactive and photoinduced inelastic collisions, for both linear and circular laser polarizations. I will demonstrate that the spontaneous emission from b 3Pi0 (vb=0, jb=1) does not deteriorate the shielding process. This opens the possibility for a strong increase of the lifetime of cold molecule traps, and for an efficient evaporative cooling. I will also discuss the validity of the proposed mechanism for alkali-metal diatomics with sufficiently large dipole-dipole interactions.

*Speaker

Multi-ion optical clocks

Tanja Mehlstäubler*[1,2]

[1]Physikalisch-Technische Bundesanstalt – Germany
[2]Leibniz Universität Hannover – Germany

Abstract

Trapped and laser-cooled ions allow for a high degree of control of isolated atomic quantum systems. They are the basis for modern atomic clocks, quantum computers and quantum simulators. In our lab we have demonstrated excellent control of ion Coulomb crystals, i.e. many-body systems with complex dynamics, for precision spectroscopy and fundamental tests of physics. This paves the way to novel ultra-precise optical frequency standards, for applications such as relativistic geodesy, and towards quantum simulators in which complex dynamics becomes accessible with atomic resolution.

*Speaker

Precision Inertial Measurements with Cold-Atom Interferometers

Remi Geiger*[1]

[1]Systèmes de Référence Temps Espace – Institut National des Sciences de l'Univers, Observatoire de Paris, Université Paris sciences et lettres, Sorbonne Universite, Centre National de la Recherche Scientifique : UMR8630 – France

Abstract

Cold-atom inertial sensors target several applications in navigation, geoscience, tests of fundamental physics and gravitational wave astronomy. The operation of these sensors is based on atomic interferometry taking advantage of superpositions between quantum states of different momentum of an atom. These superposition states are obtained by means of optical transitions with two (or more) photons communicating momentum to the atom and acting as beam splitters and mirrors for the matter waves. This talk will focus on the cold-atom gyroscope instrument developed at the SYRTE laboratory, which currently represents the state of the art of atomic gyroscopes with a short-term sensitivity of 40 nrad/s/sqrt(Hz), limited by vibration noise, and a long term stability of 0.3 nrad/s. We will present the key techniques based on cold-atom manipulation to reach such performances. In particular, we will describe a recently reported method to suppress the recombination of parasitic interferometers, a prerequisite for reaching high accuracy measurement.

*Speaker

Probing mixed-state entanglement with randomized measurements

Benoit Vermersch*[1]

[1]LPMMC – CNRS and University Grenoble Alpes, LPMMC Grenoble – France

Abstract

Recently, protocols based on statistical correlations of randomized measurements were proposed to probe entanglement in synthetic quantum systems. This includes protocols to access Renyi entropies, many-body state fidelities, out-of-time-ordered correlators (OTOCs) and topological invariants. In this talk, I will first give an introduction to randomized measurements. Then, I will present our protocol for measuring mixed-state entanglement based on the positive partial transpose (PPT) condition, and the experimental demonstration with trapped ions.

*Speaker

Zooming in on Ultracold Few-Fermion Systems

Philipp Preiss*[1]

[1]Physikalisches Institut, Heidelberg University (UHEI) – Im Neuenheimer Feld 226 69120 Heidelberg, Germany

Abstract

The emergence of collective modes from single-particle excitations is one of the most striking features of strongly interacting systems. Understanding such excitations is an ongoing challenge in nuclear physics, correlated electron systems, and high-energy physics. Ultracold atoms in optical potentials provide a unique setting to precisely study the appearance of collective excitations in a tunable laboratory environment.

Here we experimentally observe the "birth" of a collective mode in a few-body system of ultracold fermions. Using optical tweezers, we deterministically prepare few fermions in the ground state of a two-dimensional trap. This system exhibits a shell structure of stable "magic" numbers of 2,6,12... particles. We perform many-body spectroscopy through a modulation of the interaction strength and find correlated two-particle excitations that can be identified as the precursor of the Higgs mode in a two-dimensional Fermi gas.

We can now probe such few-body complexes with particle-resolved imaging in momentum space, which will pave the way towards imaging the formation of individual Cooper pairs in the BEC-BCS crossover.

*Speaker

Chaos-assisted tunneling resonances in a synthetic Floquet superlattice

Juliette Billy*[1], Maxime Arnal[2], Gabriel Chatelain[1], Maxime Martinez[3], Nathan Dupont[1], Olivier Giraud[4], Denis Ullmo[5], Bertrand Georgeot[3], Gabriel Lemarié[3], and David Guéry-Odelin[1]

[1]Laboratoire Collisions Agrégats Réactivité – CNRS Université de Toulouse Paul Sabatier – France
[2]Laboratoire Collisions Agrégats Réactivité – CNRS Université de Toulouse Paul Sabatier – France
[3]Laboratoire de Physique Théorique – CNRS Université de Toulouse Paul Sabatier – France
[4]Laboratoire de Physique Théorique et Modèles Statistiques – CNRS, Université Paris Sud, Université Paris Saclay – France
[5]Laboratoire de Physique Théorique et Modèles Statistiques – CNRS, Université Paris Sud, Université Paris Saclay – France

Abstract

The field of quantum simulation, which aims at using a tunable quantum system to simulate another, has been developing fast in the past years as an alternative to the all-purpose quantum computer. So far, most efforts in this domain have been directed to either fully regular or fully chaotic systems. Here, we focus on the intermediate regime, where regular orbits are surrounded by a large sea of chaotic trajectories. We observe a quantum chaos transport mechanism, called chaos-assisted tunneling, that translates in sharp resonances of the tunneling rate and provides previously unexplored possibilities for quantum simulation. More specifically, using Bose-Einstein condensates in a driven optical lattice, we experimentally demonstrate and characterize these resonances. Our work paves the way for quantum simulations with long-range transport and quantum control through complexity.

*Speaker

Generalized Hydrodynamics in the one-dimensional Bose gas

Jerome Dubail*[1]

[1]CNRS – CNRS : UMR7198 – France

Abstract

I will give a brief introduction to "Generalized Hydrodynamics", a hydrodynamic description of one-dimensional integrable systems discovered in 2016. I will describe the theory in the context of the one-dimensional Bose gas, where it is particularly simple. I will briefly review how "Generalized Hydrodynamics" is successfully used to describe modern cold atoms experiments.

One experimental effect that is not taken into account in the 2016 theory is the atom losses: I will discuss perspectives on how to include these. As an aside, I will comment on the validity of Tan's contact relation in the one-dimensional Bose gas.

*Speaker

Ultrafast electron cooling in an expanding ultracold plasma

Juliette Simonet*[1]

[1]Institut für Laserphysik - Universität Hamburg – Germany

Abstract

Strong-field ionization of a quantum gas by ultrashort laser pulses allows creating electrons and ions with tunable excess energy. A single femtosecond laser pulse focused to a micrometer-sized waist can ionize up to several thousand atoms out of a Bose-Einstein condensate, thus triggering the formation of strongly coupled ultracold plasmas. We report on the observation of electron cooling in an expanding microplasma from initially 5000 K electron temperature to about 1 K within a few hundred nanoseconds. Our experimental setup grants access to the electronic kinetic energy distribution with meV resolution. Furthermore, we have performed numerical simulations of the collective Coulomb driven plasma dynamics which are in excellent agreement with the measurements. The simulations reveal an efficient energy transfer to the ionic system within the first ten picoseconds.

*Speaker

Super- and subradiance in dilute atomic samples

William Guerin*[1]

[1]Université Côte d'Azur, CNRS, Institut de physique de Nice – CNRS : UMR7010, Université Côte d'Azur (UCA) – France

Abstract

When a photon is sent onto an atomic ensemble, it interacts collectively with the N atoms of the sample and not simply with one of them. This can result in measurable modifications in the scattering rate, the emission diagram or the temporal dynamics of the scattering. We study these collective effects experimentally and theoretically. In particular, we are investigating these effects with a dilute cold-atom sample (distance between atoms much larger than the wavelength), a low-intensity laser beam (linear-optics regime), and a large detuning (low optical thickness), when the very existence of any collective effects is somewhat counter-intuitive [1].
I will present our recent results in this context. By studying the temporal decay of the scattered light from a cold-atom cloud, we have directly observed subradiance [2,3,4] and superradiance [5], corresponding respectively to slower and faster decay than the natural lifetime of the excited state. This is the first clear and direct observation of many-body subradiant decay, 60 years after its prediction by Dicke. This is also the first observation of superradiance in the linear-optics regime.

We have also studied the collective response at the switch-on of the driving laser and put in evidence collective Rabi oscillations, which exhibit a superradiant damping rate and a splitting of the oscillation frequency [6,7].

References

W. Guerin, M. T. Rouabah, R. Kaiser, J. Mod. Opt. **64**, 895 (2017)

W. Guerin, M. O. Araújo, R. Kaiser, Phys. Rev. Lett. **116**, 083601 (2016)

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*Speaker

T. S. do Espirito Santo, P. Weiss, A. Cipris, R. Kaiser, W. Guerin, R. Bachelard, J. Schachenmayer, Phys. Rev. A **101**, 013617 (2020)

Universal pair-polaritons in a strongly interacting Fermi gas

Jean-Philippe Brantut*[1], Hideki Konishi[1], Kevin Roux[1], Victor Helson[1], and Timo Zwettler[1]

[1]EPFL – Switzerland

Abstract

I will present the observation of strong coupling between photons in a high-finesse cavity and pairs of atoms in a strong interacting Fermi gas, using photo-association to long range molecular states. The interplay of strong light-matter and strong interparticle interactions yields well-resolved dressed states, pair-polaritons. We observe a universal correspondence between the light-matter coupling strength and the strength of atom-atom interactions independent of the photo-association transition used, in spite of a three orders of magnitude difference between the Fermi energy of the gas and the scale of light-matter interactions. In the dispersive regime, the onset of pair-polaritons makes it possible to probe pair correlations repeatedly over an individual sample using fast, minimally destructive, few photons light pulses. This opens fascinating perspectives for quantum simulation, from real-time, quantum limited investigation of many-body physics, to the manipulation of interactions using quantized fields.

*Speaker

Long-lived spin-squeezed states under spin dynamics

Meng-Zi Huang*[1,2]

[1]Laboratoire Kastler Brossel – École normale supérieure - Paris, Université Paris sciences et lettres, Centre National de la Recherche Scientifique, École normale supérieure - Paris : FR684, Sorbonne Universite : UMR8552 – France

[2]Institute of Quantum Electronics [ETH Zürich] – Switzerland

Abstract

Using quantum nondemolition (QND) measurement in a fiber Fabry-Perot cavity, we have generated 8.1(9) dB metrological spin squeezing in a cloud of 2E4 ultracold rubidium atoms trapped on a chip. We observed the time evolution of the squeezed states on unprecedented timescales, showing that metrological squeezing is preserved for one second. The experiment also reveals a surprising amplification effect in the final cavity measurement of the spin state, resulting from a subtle interplay between the cavity coupling and the spin dynamics due to cold collisions. Spin dynamics such as these are an important factor in real atomic clocks that previous proof-of-principle squeezing experiments had not been able to address. Our results open up encouraging perspectives for squeezing-enhanced atomic clocks in a metrologically relevant stability regime.

*Speaker

Floquet topological phases with ultracold atoms in periodically-driven lattices

Monika Aidelsburger*[1,2]

[1]Ludwig-Maximilians-Universität München – Germany
[2]Munich Quantum Center for Science and Technology (MCQST) – Germany

Abstract

Topological phases of matter exhibit remarkable electronic properties that offer unique possibilities for applications. A prominent example is the robust quantization of the Hall conductivity in quantum Hall insulators. A widespread technique for generating topological band structures in synthetic systems, such as ultracold atoms in optical lattices, is Floquet engineering [1]. This method relies on the periodic modulation of the system's parameters to emulate the properties of a non-trivial static system and facilitated the realization of two paradigmatic topological lattice models: the Hofstadter and the Haldane model. Moreover, it inspired ideas for implementing complete lattice gauge theories [2].
The rich properties of Floquet systems, however, transcend those of their static counterparts [3]. The associated quasienergy spectrum can exhibit a non-trivial winding number, which leads to the appearance of anomalous chiral edge modes even in situations where the bulk bands have zero Chern numbers, hence, altering the well-known bulk-edge correspondence. A full classification of Floquet phases requires a new set of topological invariants. We have studied the rich Floquet phase diagram of a periodically-modulated honeycomb lattice using bosonic atoms. The novel properties of anomalous Floquet phases mentioned above open the door to exciting new non-equilibrium phases without any static analogue [4].

A. Eckardt, Phys. Mod. Phys. 89, 311 (2017)

C. Schweizer *et al.*, Nat. Phys. 15, 1168-1173 (2019)

T. Kitagawa *et al.*, Phys. Rev. B 82, 235114 (2010)

K. Wintersperger *et al.*, Nat. Phys. 16, 1058-1063 (2020)

*Speaker

Synthetic quantum Hall system with ultracold Dysprosium atoms

Sylvain Nascimbène*[1]

[1]Laboratoire Kastler Brossel (LKB (Lhomond)) – Université Pierre et Marie Curie (UPMC) - Paris VI, CNRS : UMR8552, École normale supérieure [ENS] - Paris, Université Pierre et Marie Curie [UPMC] - Paris VI – 24 rue Lhomond, F-75231 Paris CEDEX 05, France

Abstract

A quantum Hall system is characterized by the quantization of its Hall conductance, and its robustness with respect to material imperfections. In this talk I will present the realization of a synthetic quantum Hall system using ultracold atoms of Dysprosium, in which a synthetic dimension is encoded in the electronic spin J=8. Dynamics in this dimension is induced by laser-induced spin couplings, and the Doppler effect occuring in these processes leads to a spin-orbit coupling, interpreted as an artificial magnetic field. We show that our system reproduces several characteristic features of Landau levels. We observe a clear distinction between bulk states – with inhibited motion due to limited energy dispersion – and edge modes, free to move in one direction only. We also probe the system excitations, via the measurement of cyclotron and skipping orbits. We finally probe the Hall response of the system, and make the connection to topological properties of the lowest energy band.

We plan to extend this technique to a genuine two-dimensional geometry, which is more adapted for the investigation of interacting many-body phases. The atomic motion will be restricted to the dark state of an optical transition J -> J. The gauge field will arise from the spatial variation of the dark state. We will present first experimental results on the preparation of the atomic gas in the optical dark state.

*Speaker

CoOL Me 2020

Cold-atom On-Line Meeting

Nov. 16-18, 2020

online (9-18 Paris time)

POSTER SESSION 1

Impurity immersed in a double Fermi sea

Ragheed Alhyder*[1]

[1]Laboratoire Kastler Brossel – École normale supérieure - Paris, Centre National de la Recherche Scientifique, École normale supérieure - Paris : FR684, Sorbonne Universite, Centre National de la Recherche Scientifique : UMR8552 – France

Abstract

In this work we present a variational calculation of the energy of an impurity immersed in a double Fermi sea of noninteracting fermions. We show that in the strong-coupling regime, the system undergoes a first-order transition between polaronic and trimer states. Our result suggests that the smooth crossover predicted in previous literature for a superfluid background is the consequence of Cooper pairing and is absent in a normal system.

*Speaker

Adiabatic spin-dependent momentum transfer in an SU(N) degenerate Fermi gas

Pierre Bataille*[1], Andrea Litvinov[1], Isam Manai[1], John Huckans[2], Fabrice Wiotte[1], Albert Kaladjian[1], Olivier Gorceix[1], Etienne Maréchal[1], Bruno Laburthe-Tolra[1], and Martin Robert-De-Saint-Vincent[1]

[1]Laboratoire de Physique des Lasers – CNRS : UMR7538, Université Sorbonne Paris nord – France
[2]Bloomsburg University – United States

Abstract

Fermionic alkaline earth atoms are a new platform to study the physics of strongly correlated quantum many-body systems. An important interest arises from their large spin in their ground state combined with spin-independent interactions, that makes possible the study of quantum magnetism with an enlarged SU(N) symmetry.
Our project focuses on fermionic strontium 87. Due to their purely nuclear spin (F=9/2), strontium atoms are highly insensitive to magnetic fields. Thus, SU(N) magnetism cannot be either controlled or probed using standard tools that make use of magnetic fields, such as a Stern-Gerlach measurement.

Fortunately, strontium possesses narrow and ultra-narrow optical transitions, used in the context of optical atomic clocks, and which provide unique handles in the context of quantum magnetism. One can use the tensor light shift associated with these narrow transitions to synthesize an effective magnetic field which can even be spatially tailored. This has been applied to separate the different spin components in a so-called Optical Stern-Gerlach [1].

I will present the new method that our group has developed to separate the spin states of an SU(N) degenerate Fermi gas of 87Sr using the 1S0 to 3P1 transition, which is fairly narrow with its 7 kHz linewidth [2]. It is an adiabatic protocol in which the atoms in two well-defined Zeeman states are Raman-diffracted in well-defined directions using a simple retro-reflected beam, in sigma+/sigma- configuration. It inherently relies on spin-orbit coupling and benefits from the narrow linewidth of the transition. Moreover, it involves nearly dark states, which further reduces spontaneous emission. We can currently measure the population of up to four spins states in a single shot. Because this scheme allows the simultaneous measurement of spin-resolved momentum distributions with negligible distortion, it should enable new correlation measurements for the study of SU(N) quantum magnets [3].

S. Taie, Y. Takasu, S. Sugawa, R. Yamazaki, T. Tsujimoto, R. Murakami, and Y. Takahashi, Phys. Rev. Lett. 105, 190401 (2010).

P. Bataille, A. Litvinov, I. Manai, J. Huckans, F. Wiotte, A. Kaladjian, O. Gorceix, E. Maréchal, B. Laburthe-Tolra, and M. Robert-de Saint-Vincent, Phys. Rev. A 102, 013317 (2020).

G. M. Bruun, O. F. Syljuåsen, K. G. L. Pedersen, B. M. Andersen, E. Demler, and A. S. Sørensen, Phys. Rev. A 80, 033622 (2009).

*Speaker

Dynamics of strong and weak localizations in disordered quantum systems

Radu Chicireanu*[1]

[1]PhLAM laboratory, CNRS, Universite de Lille (PhLAM) – CNRS, Université de Lille – Laboratoire PhLAM - UMR 8523 Université de Lille, Cite Scientifique Bât. P5, Bureau 58,, France

Abstract

The transport and localization properties of disordered quantum systems are greatly affected by symmetries. We present a novel technique which allows the realization an artificial gauge field in a synthetic (temporal) dimension of a disordered, periodically driven (Floquet) quantum system, which allows to control the Time-Reversal Symmetry properties of the Kicked Rotor, a paradigmatic model of classical and quantum chaos. Using this technique, we recently realized the first observation and characterization of a direct 'microscopic' interference smoking gun of the Anderson Localization, the so-called "Coherent Forward Scattering" (CFS) effect – thus confirming its very recent theoretical prediction. This result is complemented by an accurate measurement of the universal scaling function b(g) in two different universality classes. The Coherent Forward Scattering effect, together with the "Coherent Backscattering", CBS (its weak-localization counterpart), can be extremely valuable tools for future probing novel phenomena, emerging from the interplay of many-body effects or symmetry properties with the Anderson physics.

*Speaker

Exploring weak- and strong-ergodicity breaking with lattice gauge theories

Marcello Dalmonte*[1]

[1]ICTP, Trieste – Italy

Abstract

In this talk, I will present two applications of lattice gauge theories in the study of ergodicity-breaking in low-dimensional statistical mechanics models.
The first example concerns the recent observation of anomalously slow dynamics in atom arrays, where ground state atoms are laser-coupled to Rydberg s-states. I will discuss how the constrained dynamics describing such systems is exactly equivalent to the lattice Schwinger model - quantum electrodynamics in one-dimension - in the presence of a topological angle. Beyond serving as demonstration of the first large-scale quantum simulation of a gauge theory, this connection enables an immediate interpretation of the observed dynamics as string inversion. Based on this, I will describe a generic phenomenological framework capturing such slow dynamics basic on simple field theoretical insights, relating this to 'weak-ergodicity-breaking', and discuss immediately available extensions in more than one-dimension.

The second example concerns instead ergodic-non-ergodic transitions in the context of disorder quantum systems. I will present a numerical analysis of the spectral properties of Abelian lattice gauge theories in one-dimension, and discuss how those are sharply different from spin models without local symmetries (such as the Heisenberg model). In particular, the concomitant effect of Coulomb law and disorder leads to sharp signatures of non-ergodic behavior, depicting a very different scenario from the one observed in 1D and debated in a series of recent works.

The talk is based on:

arXiv:1902.09551

arXiv:1912.09403
arXiv:2003.11073

*Speaker

Certification of high-dimensional entanglement in ultracold atom systems

Niklas Euler*[1]

[1]Kirchhoff-Institute for Physics Heidelberg – Germany

Abstract

Preparing strongly entangled quantum states with high confidence is a key requirement for the implementation of uprising quantum technologies, like quantum encryption protocols. To certify the entanglement available in any prepared state, reliable methods for its experimental detection are needed. One such method has been introduced recently and demonstrated with entangled photon pairs [J. Bavaresco, Nature Physics 2018], allowing one to extract the entanglement dimension, a measure for bipartite entanglement. In cold-atom systems, which represent the most advanced platform for quantum simulation, these methods cannot be applied directly due to limited readout capabilities. Here we present an adaptation of the scheme to ultracold atoms in optical lattices utilizing measurements in two experimentally accessible bases and study its robustness with respect to experimental imperfections and noise. We also extend the method to multipartite systems, enabling the certification of genuine tripartite entanglement.

*Speaker

Quantum computing with qudits on a graph

Aleksey Fedorov*[1], Evgeniy Kiktenko[2], and Anastasia Nikolaeva[1]

[1]Russian Quantum Center – Russia
[2]Russian Quantum Cener – Russia

Abstract

Building a scalable platform for quantum computing remains one of the most challenging tasks in quantum science and technologies. However, the implementation of most important quantum operations with qubits (quantum analogues of classical bits), such as multiqubit Toffoli gate, requires either a polynomial number of operation or a linear number of operations with the use of ancilla qubits. Therefore, the reduction of the number of operations in the presence of scalability is a crucial goal in quantum information processing.
One of the most elegant ideas in this direction is to use qudits (multilevel systems) instead of qubits and rely on additional levels of qudits instead of ancillas. Although some of the already obtained results demonstrate a reduction of the number of operation, they suffer from high complexity and/or of the absence of scalability.
We show a strong reduction of the number of operations for the realization of the Toffoli gate by using qudits for a scalable multi-qudit processor. This is done on the basis of a general relation between the dimensionality of qudits and their topology of connections, that we derived.

*Speaker

Transport and coupling of a ultra-cold atomic gas with a nano-structured surface

Jean-Baptiste Gerent*[1], Romain Veyron[1], Vincent Mancois[1], Guillaume Baclet[1], Simon Bernon[1], and Philippe Bouyer[1]

[1]Laboratoire Photonique, Numérique et Nanosciences – Université de Bordeaux, Institut dÓptique Graduate School, Centre National de la Recherche Scientifique, Institut dÓptique Graduate School, Institut dÓptique Graduate School, Institut dÓptique Graduate School, Institut dÓptique Graduate School, Institut d'Optique Graduate School – France

Abstract

Atomic physics and solid-state devices have been greatly affected by one another and developed on nearly parallel tracks for several years but not quite together. In order to close this gap, hybrid systems between cold atoms and solid state physics have recently emerged. In this context, we propose to couple an ultra-cold quantum gas with a nano-structured surfaces that generate sub-wavelength potentials with tailored electromagnetic properties.
To push toward this goal, we developed a novel method to transport and then trap an ultra-cold atomic cloud in close vicinity of a surface. We present hereafter the early stage atom chip produced, and some test on the transport sequence.
In parallel, we implemented a dynamic sub-wavelength imaging system that is key ingredient to image sub-wavelength potentials. It involves an accordion lattice that is composed of two superimposed optical lattices, one at 1064 nm and one at 1529nm, whose fringes spacing can be dynamically tuned. In this poster we present the test set-up of the accordion lattice where the single beam pointing stability and the inter-fringe absolute position have been continuously characterized as a function of the accordion angle.

*Speaker

Ultracold atoms in strong disorder: towards the Anderson transition

Yukun Guo*[1]

[1]Laboratoire Charles Fabry – Institut d'Optique Graduate School, Université Paris-Saclay, Centre National de la Recherche Scientifique : UMR8501 – France

Abstract

Disorder lies at the heart of many fundamental phenomena in condensed matter systems, such as metal-insulator transition in amorphous electronic conductors, superfluidity in porous media, and possibly high-Tc superconductivity.
The celebrated Anderson localization (P. W. Anderson *Phys. Rev.* 109, 1492, 1958) is one of the most emblematic effect of the disorder. Indeed, it predicts that the disorder can completely freeze the motion of quantum particles, leading to a genuine metal-insulator transition. This intriguing effect results from the destructive quantum interferences between many scattering paths and is ubiquituous to wave physics. To date, Anderson localization has been observed with differents systems, for electronic or classical waves (Lagendijk et al. Phys. Today August 2009, for a recent review). However, despite extensive theoretical and experimental efforts over the past 50 years, the precise understanding of this localization effect remains an exciting but formidable task, both for experiment and theory.
Ultracold atomic systems offers new approaches to these issues. In particular, their great promises have been demonstrated in our group by two landmarks experiments: the first demonstrations of Anderson localization with matter waves (1D and 3D) and direct signature of coherence via the coherent backscattering signal. We are currently working on a new method that will allow us to investigate the localization-delocalization quantum phase transition (Anderson transition) that occurs in 3D, the "graal" of the domain.

*Speaker

Quantum simulation of dynamical gauge fields using ultracold atomic mixtures

Apoorva Hegde*[1], Alexander Mil[1], Torsten Zache[2], Andy Xia[1], Rohit Bhatt[1], Markus Oberthaler[1], Philipp Hauke[3], Jürgen Berges[2], and Fred Jendrzejewski[1]

[1]Kirchhoff-Institut für Physik, Heidelberg University – Germany
[2]Institut für Theoretische Physik, Heidelberg University – Germany
[3]INO-CNR BEC Center and Department of Physics, University of Trento – Italy

Abstract

Gauge theories form the fundamental building block of High Energy Physics. They are essential for the describing the interaction of elementary particles through gauge fields. We use a mixture of ultracold sodium and lithium atoms to engineer a building block for the quantum simulation of such dynamical gauge fields [1]. We associate the matter field with lithium atoms and the gauge field with sodium atoms. Local gauge invariance, which is of central importance when describing gauge theories is achieved in this experiment by interspecies spin changing collisions, which locally conserves angular momentum, thus enforcing the necessary constraint of Gauss' law. The building block further can be further extended to a 1D system using an optical lattice. [1]A. Mil, T. V. Zache, A. Hegde, A. Xia, R. P. Bhatt, M. K. Oberthaler, P. Hauke, J. Berges, and F. Jendrzejewski, https://doi.org/10.1126/science.aaz5312

*Speaker

Universal quantum computation and quantum error correction with ultracold atomic mixtures

Valentin Kasper*[1], Daniel González-Cuadra[1], Apoorva Hegde[2], Andy Xia[2], Alexandre Dauphin[1], Felix Huber[1], Eberhard Tiemann[3], Maciej Lewenstein[1], Fred Jendrzejewski[4], and Philipp Hauke[5]

[1]ICFO- The Institute of Photonic Sciences – Spain
[2]Universität Heidelberg – Germany
[3]Leibniz Universität Hannover – Germany
[4]Universität Heidelberg – Spain
[5]Università di Trento – Italy

Abstract

Quantum information platforms made great progress in the control of many-body entanglement and the implementation of quantum error correction, but it remains a challenge to realize both in the same setup. Here, we propose a mixture of two ultracold atomic species as a platform for universal quantum computation with long-range entangling gates, while providing a natural candidate for quantum error-correction. In this proposed setup, one atomic species realizes localized collective spins of tunable length, which form the fundamental unit of information. The second atomic species yields phononic excitations, which are used to entangle collective spins. Finally, we discuss a finite-dimensional version of the Gottesman-Kitaev-Preskill code to protect quantum information encoded in the collective spins, opening up the possibility to universal fault-tolerant quantum computation in ultracold atom systems.

*Speaker

Lieb-Liniger variational ansatz and one-dimensional dipolar gases

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[1]Laboratoire de Physique de l'ENS-Lyon, CNRS UMR5672 – École Normale Supérieure - Lyon, Centre National de la Recherche Scientifique - CNRS – 46, allée d'Italie F69007 Lyon, France, France

[2]Università degli Studi di Salerno Dipartimento di Fisica "E. R. Caianiello" – Via Giovanni Paolo II, 132, Stecca 9 I 84084 Fisciano (SA) - Italy, Italy

[3]CNR-IOM-DEMOCRITOS – Centro DEMOCRITOS - Istituto Officina dei Materiali CNR-IOM c/o Scuola Internazionale Superiore di Studi Avanzati (SISSA) Via Bonomea 265, 34136 Trieste ITALY, Italy

[4]Enrico Fermi - Dipartimento di Fisica – Dipartimento di Fisica "E. Fermi" - Largo Bruno Pontecorvo 3, 56127 Pisa, Italy

Abstract

We introduce a variational ansatz using the ground state wavefunction of the integrable Lieb-Liniger mode [1] as trial wavefunction. The expectation value of the potential energy is obtained from an approximation of the static structure factor of the Lieb-Liniger model introduced by Cherny and Brand[2]. We apply the variational ansatz to the calculation of the ground state energy of a quasi-one dimensional gas of dipolar bosons [3] as a function of density and tilt angle of the dipoles. We discuss the breathing modes of the dipolar gas.

E. H. Lieb and W. Liniger, Phys. Rev. **130**, 1605 (1963)

A. Y. Cherny and J. Brand, Phys. Rev. A **79**, 043607 (2009).

F. Deuretzbacher, J. C. Cremon, and S. M. Reimann, Phys. Rev. A **81**, 063616 (2010); **87**, 039903(E) (2013).

*Speaker

Probing the BCS-BEC crossover with persistent currents

Giovanni Pecci*[1], Piero Naldesi[2], Luigi Amico[3,4,5,6], and Anna Minguzzi[2]

[1]Laboratoire de Physique et Modélisation des Milieux Condensés (LPMMC) – Université Grenoble Alpes, CNRS : UMR5943 – France

[2]Laboratoire de Physique et Modélisation des Milieux Condensés (LPMMC) – Université Grenoble Alpes, CNRS : UMR5493 – France

[3]Università degli studi di Catania [Catania] – Piazza Università, 2 95131 Catania, Italy

[4]LANEF – LANEF – France

[5]Quantum research center – United Arab Emirates

[6]Center for Quantum Technology – Singapore

Abstract

We study the persistent current in a Fermi gas along with the BCS-BEC crossover. To this end, we consider an attractive degenerate gas confined in a ring-shaped potential in the presence of an artificial gauge field. Relying on exact results corroborated by numerical analysis, we study the energy levels of the system as a function of the applied artificial gauge field. We find a doubling of the periodicity of the ground-state energy as a function of the artificial gauge field and disappearance of the parity effect, indicating that persistent currents can be used to infer the formation of tightly-bound bosonic pairs.

*Speaker

Exact Results for the Boundary Energy of One-Dimensional Bosons

Zoran Ristivojevic*[1]

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Abstract

We study bosons in a one-dimensional hard-wall box potential. In the case of contact interaction, the system is exactly solvable by the Bethe ansatz, as first shown by Gaudin in 1971. Although contained in the exact solution, the boundary energy in the thermodynamic limit for this problem is only approximately calculated by Gaudin, who found the leading order result at weak repulsion. Here we derive an exact integral equation that enables one to calculate the boundary energy in the thermodynamic limit at an arbitrary interaction. We then solve such an equation and find the asymptotic results for the boundary energy at weak and strong interactions. The analytical results obtained from the Bethe ansatz are in agreement with the ones found by other complementary methods, including quantum Monte Carlo simulations. We study the universality of the boundary energy in the regime of a small gas parameter by making a comparison with the exact solution for the hard rod gas.

*Speaker

Characterization of a quantum gas microscope with a sub-wavelength resolution based on AC Stark shifts

Romain Veyron*[1], Vincent Mancois[1], Jean-Baptiste Gérent[1], Guillaume Baclet[1], Philippe Bouyer[1], and Simon Bernon[1]

[1]Laboratoire Photonique, Numérique et Nanosciences (L2PN) – Univ. Bordeaux - CNRS - Institut d'Optique Graduate School – France

Abstract

Quantum gas microscopes have become a major element for quantum simulations using ultra-cold atoms in optical lattices. Long-range order as anti-ferromagnetic correlations between lattice sites have been observed in far field optical lattices using density and spin resolved microscopy. Decreasing the lattice period would increase the interaction energies in those systems to enter deeply into quantum regimes.
Our group recently proposed a theoretical work (1) where the lattice period can be reduced by trapping atoms in close proximity (down to tens of nanometers) with a nano-structured surface generating sub-wavelength lattice potentials. At such a distance from the surface, the attractive Casimir-Polder force between the atoms and the surface needs to be compensated. The surface is engineered by a spatially varying field to doubly dress the ground state which forms a controllable trapping potential with a tunable trapping position.

In such sub-wavelength lattices, one needs to overcome the diffraction limit to image in-situ the lattice sites. In this work, we present the experimental characterization of a sub-wavelength resolution method applicable to quantum gas microscopes. The test setup consists in imaging ultra-cold atoms in a crossed dipole trap by dressing the excited state with a spatially varying AC Stark shift. The latter is generated by quasi co-propagating laser beams forming an optical lattice with a lattice spacing of 8 μm . Fast absorption imaging in less than 10 μs and full widths at half maximum down to 100 nm has been achieved so far. By changing the laser beam geometry to counter propagating beams, a resolution smaller by a factor of 10 can be expected.
(1) M. Bellouvet et al., Phys. Rev. A 98, 023429 (2018).

*Speaker

Stability of optomechanical self-structured phases and dissipative solitons of cold atoms with optical feedback

Giuseppe Baio*[1], Gordon R. M. Robb[1], Alison M. Yao[1], Gian Luca Oppo[1], and Thorsten Ackemann[1]

[1]University of Strathclyde – United Kingdom

Abstract

We study the transverse self-structuring of a cloud of cold thermal atoms with effective atomic interactions provided by a coherent driving beam retro-reflected by means of a single mirror. The resulting self-structuring due to optomechanical forces is much richer than expected for an effective nonlinear Kerr medium, displaying hexagonal, stripe and honeycomb structures depending on the interaction strength, parametrized by the linear susceptibility. In the stripe phase the system recovers inversion symmetry. Phase domains are described in the framework of real Ginzburg-Landau amplitude equations. Moreover, the subcriticality of the new hexagonal phase allows the existence of a feedback soliton effectively functioning as a self-sustained dark atomic trap.

*Speaker

Quench Spectroscopy: Low-energy excitations from real-time dynamics

Tommaso Comparin*[1], Fabio Mezzacapo[1], and Tommaso Roscilde[1]

[1]Laboratoire de Physique de lÉNS Lyon – École Normale Supérieure - Lyon, Centre National de la Recherche Scientifique : UMR5672, Université Claude Bernard Lyon 1, Université de Lyon – France

Abstract

The low-energy excitations on top of the ground state, often described in terms of quasiparticles, are an essential property of quantum many-body systems. A key quantity related to these excitations is the Dynamical Structure Factor, which is experimentally accessible both in condensed matter systems (e.g. via inelastic neutron scattering) and in ultracold atomic gases (via Bragg spectroscopy).

Quench spectroscopy is an alternative approach to characterize low-energy excitations, which is rather based on the dynamics after a quench. After preparing an out-of-equilibrium state, one should follow its unitary dynamics and extract information about low-energy excitations by looking at the time dependence of relevant observables - typically correlation functions. This protocol is specially suitable to ultracold-atomic experiments, where quenches and the study of dynamics are among the most common tasks.

We explore the theoretical validity of the quench spectroscopy approach in one- and two-dimensional lattice systems, employing several numerical methods to simulate quantum dynamics. We focus on the case of quantum spin models, for which Linear Spin Wave Theory provides a well-established benchmark, where quasiparticles appear as sharp spectral features. Deviations from this theory, which are in principle accessible via quench spectroscopy, may open interesting directions in connection with current studies of magnetic condensed-matter systems.

*Speaker

Supersonic Rotation of a Superfluid: A Long-Lived Dynamical Ring

Yanliang Guo*[1], Romain Dubessy[2], Mathieu De Goër De Herve[2], Avinash Kumar[2], Thomas Badr[2], Aurélien Perrin[2], Laurant Longchambon[2], and Hélène Perrin[2]

[1]Laboratoire de Physique des Lasers – Université Paris-Nord - Paris XIII – France
[2]Laboratoire de Physique des Lasers – Université Paris-Nord - Paris XIII – France

Abstract

We present the experimental realization of a long-lived superfluid flow of a quantum gas rotating in an anharmonic potential, sustained by its own angular momentum. The gas is set into motion by rotating an elliptical deformation of the trap. An evaporation selective in angular momentum yields an acceleration of rotation until the density vanishes at the trap center, resulting in a dynamical ring with 350 angular momentum per particle. The density profile of the ring corresponds to the one of a quasi two-dimensional superfluid, with a linear velocity reaching Mach 18 and a rotation lasting more than a minute. In this poster, we have demonstrated the first experimental realization of a superfluid dynamical ring, an important step towards the observation of a giant vortex.

*Speaker

Inelastic collision dynamics of a single cold ion immersed in a Bose-Einstein condensate

Thomas Dieterle[1], Moritz Berngruber[1], Christian Hölzl[1], Robert Löw[1], Krzysztof Jachymski*[2], Tilman Pfau[1], and Florian Meinert[1]

[1]5. Physikalisches Institut [Stuttgart] – Germany
[2]University of Warsaw – Poland

Abstract

We study inelastic collisional dynamics of a single cold ion in a Bose-Einstein condensate. The experiment reveals rapid ion-atom-atom three-body recombination leading to formation of weakly bound molecular ions followed by secondary two-body molecule-atom collisions quenching the rovibrational states towards deeper binding energies. In contrast to previous studies exploiting hybrid ion traps, here an effectively field-free environment is utilized, and a low-energy ionic impurity is created directly from the atomic ensemble. Energy-resolved field-dissociation technique allows to trace the relaxation dynamics of the recombination products. The experiment is interpreted by a stochastic simulation based on Langevin capture dynamics and a three-body calculation of the inelastic collision cross sections.

*Speaker

Elementary excitations in superfluid Fermi gases

Hadrien Kurkjian*[1], Serghei Klimin[1], Jacques Tempere[1], Yvan Castin[2], and Senne Van Loon[1]

[1]Universiteit Antwerpen – Belgium

[2]LKB – Ecole Normale Supérieure de Paris - ENS Paris – France

Abstract

I will discuss the excitation spectrum of an ultracold gas of paired fermions in its superfluid phase. There remains important open questions on this fundamental subject of many-body quantum physics, and cold atom experiments have now the capacity to answer them. Like in other superfluids, the lowest-energy excitations are phonons: collective modes of density fluctuations. But unlike most superfluids, the phonon dispersion may become subsonic in a Fermi gas, which has important consequences on the interaction mechanisms between phonons, and thus on the system's dissipative properties.

At higher energy, I will show that another collective branch, related to excitations of the order-parameter amplitude, exists inside the continuum of fermionic pair-breaking excitations. The observability and dispersion relation of this branch (sometimes called "Higgs" branch) is still controversial in the theoretical literature while several experimental results are available. I will explain that to distinguish clearly the collective mode contribution from the continuum, one should perform an analytic continuation of the order-parameter Green's function through the branch cut associated to the continuum. Near the transition temperature, those two collective branches (phonons and Higgs modes) disappear in favor of a single pairing collective mode with quadratic dispersion, acting as a precursor of the phase transition.

Finally, in these paired systems, there exists a gapped spectrum of fermionic quasiparticles. I will explain how to described this fermionic branch beyond the mean-field approximation by viewing the quasiparticles as a polaronic impurities embedded in a sea of phonons.

*Speaker

Interaction potentials and ultracold scattering cross sections for the 7Li+-7Li ion-atom system

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Abstract

Experimental research on ion-atom interactions in dilute, trapped gas systems at ultracold temperatures is rapidly evolving towards detailed probes of the quantum dynamics of the resulting products. One of the main goals is to thermalize an atomic ion within the ultracold atomic gas. Despite continuous progress regarding the precise control of the trapped ion motion, reaching the ultra-low relative energy regime (E/kB $\approx$ 1μK or lower) for ion-atom collisions is still challenging experimentally. At these energies, quantum effects emerge as only few partial waves contribute to the collision. Due to ion heating as a result of interactions and trap imperfections in dynamical trapping, it is experimentally advantageous to investigate the full quantum regime at the highest possible temperatures. We therefore focus this study on the scattering properties of 7Li+-7Li as this is a light system, with isotopic abundance, for going toward the quantum regime. We calculate the isotope independent Li+-Li potential energy curves for the electronic ground and first excited states – X2Σ+g and A2Σ+u respectively. Scattering phase shifts and total scattering cross section for the 7Li+-7Li collision are calculated with emphasis on the ultra-low energy domain down to the s-wave regime. The effect of physically motivated alterations on the calculated potential energy curves is used to determine the bound of accuracy of the low-energy scattering parameters for the ion-atom system. Accurate large scattering lengths with their bounds are determined. The computed scattering length for the A2Σ+u state, au = 1325 a0, is positive and has well-constrained bounds. For the X2Σ+g state, the scattering length, ag = 20465 a0 has a large magnitude, and it is sensitive to the restrained change of the potential, due to the presence of a vibrational state in the vicinity of the dissociation limit. Study of 7Li+-7Li is published recently in Phys. Rev. A 101, 052702 (2020).

*Speaker

Controlling 3-body collisions of ultracold dipolar molecules using an electric field

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Abstract

Ultracold dipolar molecules are excellent candidates for engineering quantum applications [1] and cold, controlled chemistry [2]. Therefore, a lot of effort is devoted nowadays to produce ground state ultracold molecules in high densities. One of the main goals is also to produce quantum degenerate gases such as Bose-Einstein condensates or degenerate Fermi gases. Unfortunately, high losses of molecules occur. Therefore, one has to shield them against those losses. In this poster, we will focus on the control of 3-body collisions using an external static electric field, as it was proposed for a shielding of 2-body collisions [3,4] recently observed in an experiment [5]. We will describe the hyperspherical formalism used and present preliminary results. The goal is to create a long-range potential barrier at the same value of the electric field than for the 2-body shielding. More investigations will tell us whether the 3-body loss rate coefficients will be suppressed using this method.

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*Speaker

Mercury optical lattice clock with a 2D magneto-optical trap

Manuel Andia*[1], Changlei Guo[1], Valentin Cambier[1], James Calvert[1], Luigi De Sarlo[1], Sébastien Bize[1], Etienne Cantin[1,2], Dan Xu[1], Mads Tonnes[1], Paul-Eric Pottie[1], Hector Alvarez Martinez[1], Christian Ørtoft Bærentsen[1], Rodolphe Le Targat[1], Yannick Foucault[1], Bruno Ximenez Rodrigues Alves[1], William Moreno[1], Jérôme Lodewyck[1], Olivier Lopez[2], Anne Amy-Klein[2], Nicolas Quintin[2,3], Moustafa Abdel Hafiz[4], Alexander Kuhl[4], Sebastian Koke[4], Thomas Waterholter[4], Gesine Grosche[4], Nils Huntemann[4], Richard Lange[4], Burghard Lipphardt[4], and Ekkehard Peik[4]

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Abstract

We present recent developments of our 199Hg optical lattice clock at LNE-SYRTE. These include the development and optimisation of a two-dimensional magneto-optical trap (2D-MOT), a specificity of our Mercury clock, to increase the stability of the clock. Our resulting stability is below 10-15 at 1s (estimated based on the measurement of transition probabilities and the line shape). We also implemented a novel scheme allowing for accurate control of the magic frequency, thereby enabling control of lattice light shifts to the level of 10-18 or better. Together with increased reliability of the experiment, these improvements allowed us to participate relevantly in several international comparison campaigns, notably at long distance via optical fibre links. Our Mercury clock is particularly interesting in this context, as it contributes to the diversity of known transition frequency ratios between different atomic species, which are notably key to fundamental investigations: studying putative variations of fundamental constants, searching for dark matter...

*Speaker

Molecular gas spectroscopy in hollow core fibers for atomic cooling using Telecom laser systems

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Abstract

Addressing various transitions and atomic species in Atomic Molecular Optics (AMO) laboratories has become widely popular. Answering the need for compact and versatile single laser systems is thus of primary importance. The LP2N has developed a strong research expertise on inertial sensors with in particular the development of a bi-species gravimeter operating in 0g environment and allowing to test the weak equivalence principle. In our group, we are developing a fully fibered laser architecture for potassium cooling. It answers one long-term need for studying two-dimensional physics near nanostructured surfaces with both bosonic rubidium and fermionic potassium [1].

Also, in order to improve clocks and inertial sensors and open up new range of applications, it is essential to make the laser sources used for atom cooling exempt of free space optics, known to reduce long-term stability and portability. Usually, with the exception of the atomic cell, most of the laser architectures used are fully fibered. In parallel of this laser development we are currently benchmarking various hollow-core fibers in partnership with the XLIM.

We have already shown experimentally that lasers in the Telecom frequency range (1530 to 1560 nm) can be locked by modulation transfer spectroscopy on molecular vapours trapped in closed hollow-core fibers. The stability we can achieve with our scheme meets the requirements for atom cooling and allow for a robust and agile laser source with a relative uncertainty of few 10–11 and a bandwidth of 100kHz. We are currently aiming at the possibility to change the laser frequency with speed that meet the requirements of coherent control in AMO experiments.

*Speaker

Progress towards the development of a cold-atom inertial measurement unit for onboard applications

Jeanne Bernard*[1,2], Isadora Perrin , Yannick Bidel[2], Malo Cadoret[1,2], Nassim Zahzam[2], Alexandre Bresson[2], and Cédric Blanchard[2]

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Abstract

Light-pulse atom interferometers (AIs) use short pulses of light to split, deflect, and recombine
cold atoms used as a matter-wave source. Since their inception, they have proven to be extremely
sensitive and accurate gravito-inertial sensors measuring gravity [1], gravity gradients [2], and
rotations [3]. AIs appear now as promising candidates to compete with classical sensors used for geodesy, geophysics, or inertial navigation.
Today, only these classical relative sensors are available for onboard applications. This is a major drawback since such sensors require calibrations to correct for their drift. AI-based sensors on the contrary exhibit an inherent long-term stability and accuracy. Most of cold-atom AI experiments are performed in the laboratory environment, but their assets have led to
perform measurements outside the laboratory [4]. Moreover, cold-atom-based gravity sensors have started to be commercialized, targeting out-of-the laboratory applications. In this context,
the development of a cold-atom inertial measurement unit for onboard applications is particularly
attractive.
Our experimental setup consists presently of a vertical AI accelerometer and a horizontal AI accelerometer, our goal being to build a full inertial measurement unit with a single cold-atom
sensor measuring alternatively each inertial component of acceleration and rotation (instead of
having 6 independant sensors). Finally we aim to hybridize these AI sensors with classical ones,
combining the advantages of both technologies (for example the filling of the measurement dead
times is done using the classical accelerometers).
The aim of the present paper is to present our project, and in particular a new method

*Speaker

THz-wave Electrometry Based on Lightshift Measurements with Cold Trapped HD+ Ions

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Abstract

SI-traceable calibration of the amplitudes and phases of the electric field components of a THz-wave in a Cartesian laboratory frame may be performed by comparing the the lightshifts of HD+ two-photon rovibrational transitions with the molecular ion theory predictions.

*Speaker

to measure accelerations in a close-to-zero velocity regime [5]. We demonstrate a technique that allows the degeneracy between the two Raman transitions +-hbarkeff to be lifted by using
a frequency chirp on the Raman lasers. Applying this technique, we realize a Mach-Zehnder atom interferometer hybridized with a force balanced accelerometer. We achieve a short-term
sensitivity of 3.2 x 10ˆ-5 m.sˆ-2/sqrt(Hz) [5] and study the possible bias induced by this method.
This technique could be used for multiaxis inertial sensors, tiltmeters, or atom interferometry in
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Simulation of the GBAR experiment (Gravitational Behaviour of Antihydrogen at Rest)

Olivier Rousselle*[1], Serge Reynaud[1], Pierre Cladé[1], Saïda Guellati-Khélifa[1], and Romain Guérout[1]

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Abstract

One of the main questions of fundamental physics is the action of gravity on antimatter. We present here the simulation of the last part of the experiment GBAR at CERN, i.e. the measurement of the free fall acceleration of ultra-cold antihydrogen atoms in the gravitational field of Earth. A precision of the measurement beyond the % level is confirmed by taking into account the experimental design.

*Speaker

Fluids of light in atomic vapor

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Abstract

Since its discovery in 1995, Bose-Einstein Condensation (BEC) is a powerful object for quantum experiments. Its coherence offers a lot of possibilities for measuring quantum phenomena. Even though BEC is well studied with ultra-cold atoms cloud, an analogy for classical waves propagating in a non-linear medium can be established and condensation of classical waves has been predicted.
Our experiment is based on the use of an atomic vapor as a non-linear medium. By heating a Rubidium cell, we create a nonlinear medium with adjustable non-linearity. By modifying properties of the incident laser beam (shape, size, frequency, etc.) we are able to study a wide range of phenomena.
After the observation of pre-condensation of classical waves in this system, we turned to a study of fluids of light. We already could study in this system the creation of dispersive shockwaves as well as vortices interactions.

*Speaker

Nonlinear quantum optics with Rydberg atoms in an optical cavity

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Abstract

We present an experimental platform that combines an ultracold rubidium ensemble with a medium-finesse cavity to shape and control interactions between optical photons. Those photon-photon interactions are obtained by probing the atomic cloud in a ladder electromagnetically induced transparency (EIT) scheme to map Rydberg excitations onto photons. In this context, the optical response of the medium is very sensitive to the number of excitations propagating through the cavity due to a blockade phenomenon caused by the strong dipolar interactions between Rydberg atoms.

The inhomogeneous broadening of the Rydberg linewidth is a crucial parameter that set the transparency and the size of the blockade volume. We recently managed to reduce this broadening below 100 kHz by mean of degenerate Raman sideband cooling to reach a temperature of 1 μK. At this temperature, the Doppler contribution is negligible and it becomes possible to probe the ensemble directly inside the dipole trap as the differential light shift is significantly reduced.

Currently, we observe strong anti-bunching at zero delay for the 100S Rydberg state with a thousand atoms trapped in a Gaussian rms radius of 6 μm within a blockade sphere, corresponding to a regime where only one photon at a time can be transmitted by the resonator. This result, associated with the level of transmission in EIT, demonstrates that we have created strong photon-photon interactions with low loss.

The control of this Rydberg polariton state will thereby enable us to perform several quantum optics experiments with the deterministic generation of non-Gaussian states or the creation of a two-photon phase gate.

*Speaker

Accurate measurement of the Casimir-Polder interactions

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Abstract

For two decades, the number of cold atom experiments increases exponentially. In parallel, the physic of nanotechnologies enables us to explore sufficiently small scales, so the Casimir-Polder interactions between an atom and a surface become a dominant effect.
Here, we propose a unique experimental setup, which rely on a slow beam of metastable Argon atoms. Starting from a MOT, we push the trapped atoms at tunable velocities in the range of 10 to 150 m/s. The atoms pass then through a transmission nanograting (100 nm or 200 nm pitch). Therefore, the matter waves are diffracted. We use an MCP/DLD detector to detect the diffracted atoms.

The de Broglie wavelength being of the order of magnitude of the nm, which is very interesting in order to interact with nanostructures. Consequently, when the atoms are passing through the nanograting, they interact with the intern surfaces of the nanograting. Thus, the Casimir-Polder interactions affects the diffracted pattern by enlarging the diffraction envelop. The measure of this enlargement give access to the Van der Waals interaction coefficient.Using a 200nm pitch nanograting, the atoms experiment the interaction potential at distances from the surface in the range of 20 to 60nm, this give us access to the retarded van der Waals potential.
This original experimental setup makes possible to do an accurate measurement of the Casimir-Polder interactions, it is to say about 1% errors.

*Speaker

Cavity QED with Bose-Einstein Condensates in a running wave resonator

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Abstract

1. Scientific context

Recently self-emergence phenomena, like glassiness and crystallization, have been extensively studied using pumped condensed atomic sampled, coupled to a high finesse optical resonator [1]. So far these experiments have been realized in standing wave cavities, which impose the resonator geometry to the lattice being formed by the atoms and the light scattered into the cavity modes. Adopting degenerate multimode cavities opens new horizons to study order emergence effects, where compliant lattices between atoms and light can show a dynamical evolution [2]; crystal defects and frustration could be studied with such a system.

2. Results and perspectives

The results are so far related to the charging of the dipole trap formed in the intracavity radiation field at 1560 nm. The improvement on the frequency and power locking of this radiation to the cavity has permitted us to make a new series of experiments that rely on the ability of turning the magnetic field off rapidly without disturbing the cavity. Thanks to this, we have implemented a true molasses and demonstrated a seven-fold increase in the in-trap number of atoms by using a gray molasses technique utilizing hyperfine dark and bright states arising through twophoton Raman transitions [3]. Atoms at deeper potentials need to be addressed by a further red-detuned cooler from the F = 2 to F' = 3 transition of 87Rb D2 line, since the dipole trap creates a large differential Stark shift between ground and exited states. We have observed that the gray molasses technique still works at this far detuned condition and that more atoms can be loaded into the trap by modifying the frequency of the Raman beams appropriately. On the other hand, the waist of the trapped center in the cloud of atoms gets reduced, indicating lower temperatures than the ones achieved by ordinary techniques. This is a great advantage for creating large samples of ultracold atoms fast and efficiently, as shown for the process of creating all-optical BECs in microgravity [4].

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*Speaker

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Ground-state coherence vs orientation: competing mechanisms for light-induced magnetic self-organization in cold atoms

Guillaume Labeyrie*[1], Robin Kaiser*[1], Josh Walker*[2], Gordon Robb[2], Gian Luca Oppo[2], and Thorsten Ackemann*[2]

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Abstract

We investigated the interplay between two mechanisms for magnetic self-organization in a cloud of cold atoms subjected to a retro-reflected laser beam. The transition between two different phases, one linked to a spontaneous spatial modulation of the $\Delta m = 2 ground-state coherence and the other to that of the magnetic orientation (sp$

*Speaker

Unraveling two-photon entanglement via the squeezing spectrum of light traveling through nanofiber-coupled atoms

Jakob Hinney[1], Adarsh Prasad[1], Sahand Mahmoodian[2], Klemens Hammerer[2], Arno Rauschenbeutel[1,3], Philipp Schneeweiss[1,3], Jürgen Volz[1,3], and Maximilian Schemmer[*3]

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Abstract

We observe that a weak guided light field transmitted through an ensemble of atoms coupled to an optical nanofiber exhibits quadrature squeezing. From the measured squeezing spectrum we gain direct access to the phase and amplitude of the energy-time entangled part of the two-photon wavefunction which arises from the strongly correlated transport of photons through the ensemble. For small atomic ensembles we observe a spectrum close to the lineshape of the atomic transition, while sidebands are observed for sufficiently large ensembles, in agreement with our theoretical predictions. Furthermore, we vary the detuning of the probe light with respect to the atomic resonance and infer the phase of the entangled two-photon wavefunction. From the amplitude and the phase of the spectrum, we reconstruct the real- and imaginary part of the time-domain wavefunction. Our characterization of the entangled two-photon component constitutes a diagnostic tool for quantum optics devices.

*Speaker

Unraveling two-photon entanglement via the squeezing spectrum of light traveling through nanofiber-coupled atoms

Jakob Hinney[1], Adarsh Prasad[1], Sahand Mahmoodian[2], Klemens Hammerer[2], Arno Rauschenbeutel[1,3], Philipp Schneeweiss[1,3], Jürgen Volz[1,3], and Maximilian Schemmer*[3]

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Abstract

We observe that a weak guided light field transmitted through an ensemble of atoms coupled to an optical nanofiber exhibits quadrature squeezing. From the measured squeezing spectrum we gain direct access to the phase and amplitude of the energy-time entangled part of the two-photon wavefunction which arises from the strongly correlated transport of photons through the ensemble. For small atomic ensembles we observe a spectrum close to the lineshape of the atomic transition, while sidebands are observed for sufficiently large ensembles, in agreement with our theoretical predictions. Furthermore, we vary the detuning of the probe light with respect to the atomic resonance and infer the phase of the entangled two-photon wavefunction. From the amplitude and the phase of the spectrum, we reconstruct the real- and imaginary part of the time-domain wavefunction. Our characterization of the entangled two-photon component constitutes a diagnostic tool for quantum optics devices.

*Speaker

Collective Dissipative Molecule Formation in a Cavity

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Abstract

Ultracold atoms and molecules that are coupled to a cavity can exhibit collective effects, such as polariton formation or superradiance. Here, we propose a mechanism to harness these collective and dissipative effects in order to realize high-yield molecular formation from ultracold atoms. We consider a setup where atom pairs trapped inside a lattice are continuously photoassociated by a laser. The excited state molecules are coupled to a lossy cavity that induces collective decay into the molecular ground state. We consider a weak driving regime, in which both cavity mode and molecular excited states can be adiabatically eliminated. Using the systems symmetries, we simulate large numbers of atom pairs, and find that the molecular yield can be increased simply by increasing the number of atoms. For realistic experimental setups with polar and nonpolar molecules, we show that our method based on collective dissipation can compete with state-of-the-art association schemes.

*Speaker

CoOL Me 2020

Cold-atom On-Line Meeting

Nov. 16-18, 2020

online (9-18 Paris time)

POSTER SESSION 2

Beyond-Luttinger-liquid thermodynamics of a one-dimensional Bose gas with repulsive contact interactions

Giulia De Rosi*[1,2], Pietro Massignan[3], Maciej Lewenstein[4,5], and Grigori E. Astrakharchik[1]

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Abstract

We present a thorough study of the thermodynamics of a one-dimensional repulsive Bose gas, focusing in particular on corrections beyond the Luttinger-liquid description. We compute the chemical potential, pressure, and contact as a function of temperature and gas parameter with an exact thermal Bethe ansatz. In addition, we provide interpretations of the main features in the analytically tractable regimes, based on a variety of approaches (Bogoliubov, hard core, Sommerfeld, and virial). The beyond-Luttinger-liquid thermodynamic effects are found to be nonmonotonic as a function of gas parameter. Such behavior is explained in terms of nonlinear dispersion and "negative excluded volume" effects, for weak and strong repulsion, respectively, responsible for the opposite sign corrections in the thermal next-to-leading term of the thermodynamic quantities at low temperatures. Our predictions can be applied to other systems including super Tonks-Girardeau gases, dipolar and Rydberg atoms, helium, quantum liquid droplets in bosonic mixtures, and impurities in a quantum bath.

*Speaker

Certifying the adiabatic preparation of ultracold lattice bosons in the vicinity of the Mott transition.

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Abstract

We present a joint experimental and theoretical analysis to assess the adiabatic experimental preparation of ultracold bosons in optical lattices aimed at simulating the three-dimensional Bose-Hubbard model. Thermometry of lattice gases is realized from the superfluid to the Mott regime by combining the measurement of three-dimensional momentum-space densities with ab-initio quantum Monte Carlo (QMC) calculations of the same quantity. The measured temperatures are in agreement with isentropic lines reconstructed via QMC for the experimental parameters of interest, with a conserved entropy per particle of S/N= 0.8(1)kB. In addition, the Fisher information associated with this thermometry method shows that the latter is most accurate in the critical regime close to the Mott transition, as confirmed in the experiment. These results prove that equilibrium states of the Bose-Hubbard model – including those in the quantum-critical regime above the Mott transition – can be adiabatically prepared in cold-atom apparatus.

*Speaker

Topological Mott transition in a Weyl-Hubbard model with dynamical mean-field theory

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Abstract

Weyl semimetals are three-dimensional, topologically protected, gapless states which show exotic phenomena such as Fermi arc surface states or negative magnetoresistance. It is an open question whether interparticle interactions can turn the topological semimetal into a topological nontrivial Mott insulating phases. We investigate an experimentally motivated model for cold atoms in optical lattices with the main focus on interaction effects and topological properties by means of dynamical mean-field theory (DMFT). We characterize topological phases by numerically evaluating the Chern number via the Ishsikawa-Matsuyama formula for interacting phases. Within our studies, we do not find a Mott insulating phase which exhibits a nontrivial Chern number. For a deeper understanding of the Weyl-semimetal-to-Mott-insulator topological phase transition, we evaluate the topological properties of quasiparticle bands as well as so-called blind bands. Our study is complementary to recent studies of Weyl semimetals with DMFT.

*Speaker

Observation of the algebraic localization-delocalization transition in a one-dimensional disordered potential with a bias force

Lucas Lavoine*[1], Thomas Bourdel[2], Guillaume Berthet[3], Amaudric Boisse[4], Mithilesh Kumar Parit[5], and A. Brolis[5]

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Abstract

One-dimensional (1D) Anderson localization phenomena are strongly affected by a bias force or equivalently a voltage in electronic systems. We experimentally study this case, launching a noninteracting 39K Bose-Einsteincondensate in a 1D disordered potential induced by a far-off-resonance laser speckle, while controlling a bias force. In agreement with theoretical predictions, we observe a transition between algebraic localization and delocalization as a function of our control parameter that is the relative strength of the disorder against the bias force. We also demonstrate that the transition is intrinsically energy independent and that the initial velocity of the wave packet only plays a role through an effective disorder strength due to the correlation of the disorder.

*Speaker

Absorption spectroscopy and atom number measurement of subwavelength volumes of cold atoms

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Abstract

I will present a variation on the usual absorption imaging applied to large atomic clouds. This technique resembles tomography, where the atomic density is scanned with a subwavelength precision thanks to a phase shifted standing wave light-shift and a combination of microwave and optical transitions [1].
At each iteration of the "tomography", the volume of atoms imaged is hundreds of nanometers thick, introducing diffraction. The medium is also dense and requires a saturated probe. We therefore question the application of Beer Lambert formula to measure absolute number of atoms and to test it, compare coupled dipoles simulations to a basic atom number calibration as well as a spectroscopic measurement on the subwavelength slices of atoms.
Doubly dressed states for near-field trapping and subwavelength lattice structuring. M.Bellouvet, C.Busquet, J.Zhang, P.Lalanne, P.Bouyer, and S.Bernon. Phys. Rev. A 98, 023429 – Published 31 August 2018

*Speaker

Chaos-assisted long range hopping for quantum simulation

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Abstract

The quantum tunneling effect usually first evokes the textbook case of a classically forbidden
crossing of a potential barrier. However this phenomenon can be far richer in quantum systems
whose classical counterpart exhibits dynamics that can be both chaotic or regular depending on the initial conditions. Indeed, in the phase space of such systems, regular orbits form stable
islands, that can be seen as potential well, surrounded by a chaotic sea of unstable orbits (see
Fig. 1). The tunneling oscillations between two neigbouring regular islands is then generically
mediated by a state delocalized in the chaotic sea. This leads to sharp resonances in the tunneling oscillation frequencies, a phenomenon known as chaos-assisted tunneling [1].

From an experimental point of view, this rich physics can be simulated using driven optical
lattices. We recently demonstrated [2] in collaboration with a team of experimentalist, the first

*Speaker

explicit observation of such tunneling resonances in a quantum system. In this work we show that the very same mechanism actually generates long-range hopping across distant sites of the driven lattice, and we propose procedures for their experimental observation. These results open the way to a new regime of tunability for quantum simulations, making possible to simulate classes of systems that are difficult to address by other means.

[1] S. Tomsovic and D. Ullmo, Phys. Rev. E 50, 145 (1994)

M. Arnal, G. Chatelain, M. Martinez, N. Dupont, O. Giraud, D. Ullmo, B. Georgeot, G. Lemari, J. Billy, and D. Gury-Odelin, Science Advances 6 (2020).

Supersolid Stripe Crystal from Finite-Range Interactions on a Lattice

Guido Masella*[1], Adriano Angelone[2,3], Fabio Mezzacapo[4], Tao Ying[5], Marcello Dalmonte[2,3], Guido Pupillo[1], and Nikolay Prokof'ev[1,6]

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Abstract

Strong, long-range interactions present a unique challenge for the theoretical investigation of quantum many-body lattice models, due to the generation of large numbers of competing states at low energy.

Here, we investigate a class of extended bosonic Hubbard models with off-site terms interpolating between short and infinite range, thus allowing for an exact numerical solution for all interaction strengths and of direct interest for experiments with cold Rydberg-dressed atoms in an optical lattice.

We predict a novel type of stripe crystal at strong coupling. Most interestingly, for intermediate interaction strengths we demonstrate that the stripes can turn superfluid, thus leading to a self-assembled array of quasi-one- dimensional superfluids (superstripes). [1]

Furthermore, by means of simulated temperature quenches we are able to explore the out-of-equilibrium states whose excess energy with respect to the ground state is within the energy window typically accessed in cold atom experiments. [2]

G. Masella, A. Angelone, F. Mezzacapo, G. Pupillo, and N. V. Prokof'ev,Supersolid Stripe Crystal from Finite-Range Interactions on a Lattice, Phys. Rev. Lett. 123, 045301 (2019).

A. Angelone, T. Ying, F. Mezzacapo, G. Masella, M. Dalmonte, and G. Pupillo, Nonequilibrium Scenarios in Cluster-Forming Quantum Lattice Models, Phys. Rev. A 101, 063603 (2020).

*Speaker

Constructing U(1) gauge symmetry in electronic circuits

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Abstract

Classical electronic circuits have proven powerful to study several topological lattice structures (Ningyuan et al., PRX 5, 2015; Imhof et al., Nat. Phys. 14, 2019). Here, we study electronic circuits that can be described by a lattice Hamiltonian with local U(1) symmetry experimentally and explore the extent to which a classical physical simulator in the form of an electronic circuit might be useful as a stepping stone for lattice gauge theories like SU(2).

*Speaker

Towards ColdAtom Experiments in Chinese Space Station

Xuzong Chen[1], Hui Li[1], Jiacheng Yu[1], Bo Fan[1], Wei Xiong[1], Yin Zhang[1], Xiaolong Yuan[1], Shifeng Yang[1], Jingxin Sun[1], Qi Huang1, Ren Liao[1], Jupeng Zhao[1], Libo Liang[1], Qingpei Zheng[1], Xiaoji Zhou[1], Bing Wang[1], Diejun Chen[1], Liang Liu[2], Weibiao Chen[2], Muming Liu[3], Baolong Lu[4], Shuyu Zhou[2]

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Abstract

The presentation introduce coming Cold Atom Experiments in Chinese Space Station. Chinese space station is due to launch in 2021, and the science module II is due to launch in 2022 with an Cold Atom Physics Rack (CAPR). The purpose for the cold atom physics rack is to achieve picokelvins ultra low temperature and implement four challenging experiments based on CAPR in first three years, and about 10 experiments is planned in next seven years, the mission for the experiments is focused on quantum simulation.

There are three advantages for the quantum gas in space: (1) ultralow temperature: 10^{-12} K (pK) three order lower than on the earth (nK), (2) longer observation time (20s), three order longer than on the earth (20ms), (3) space uniform, no gravity gradient potential.

Four fundamental physics experiments based on quantum gas will be implemented in the Chinese space station in first three years:
(1) Quantum Magnetism, (2) Exotic material; (3) Acoustic black hole; (4) Efimov effect.

The polarized Fermi-Hubbard superfluid at large order

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Abstract

Using the connected determinant Monte Carlo algorithm, we have obtained first results in the superfluid phase of the attractive Fermi-Hubbard model, which is a simple model describing optical lattice experiments. Expanding around the BCS Hamiltonian, we sum up all diagrams up to large order and we observe that the series is convergent even in the strongly correlated regime. We discuss the relation between the large-order behavior and singularities as a function of the expansion parameter. We benchmark our results against determinant diagrammatic Monte Carlo in the unpolarized regime and we explore the previously inaccessible polarized regime, where we observe the first order phase transition which was observed experimentally in the continuum.

*Speaker

Hanbury-Brown and Twiss bunching of phonons and of the quantum depletion in a strongly-interacting Bose gas

Hugo Cayla[1], Salvatore Butera[2], Cécile Carcy[3], Antoine Ténart*[4], Gaétan Hercé[1], Marco Mancini[5], Alain Aspect[1], Iacopo Carusotto[6], and David Clément[1]

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Abstract

We report the realisation of a Hanbury-Brown and Twiss (HBT)-like experiment with a gas of strongly interacting bosons at low temperatures. The regime of large interactions and low temperatures is reached in a three-dimensional optical lattice and atom-atom correlations are extracted from the detection of individual metastable Helium atoms after a long free-fall. We observe a HBT bunching in the non-condensed fraction of the gas whose properties strongly deviate from the HBT signals expected for non-interacting bosons. In addition, we show that the measured correlations reflect the peculiar quantum statistics of atoms belonging to the quantum depletion and of the Bogoliubov phonons,i.e., of collective excitations of the many-body quantum state. Our results demonstrate that atom-atom correlations provide information about the quantum state of strongly-interacting particles, extending the interest of HBT-like experiments beyond the case of non-interacting particles.

*Speaker

Vortex Reconnections across the BEC-BCS Crossover

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Abstract

We study the dynamics of a reconnection of two vortex lines in the superfluid Fermi gas across the BEC-BCS crossover. To this end we use the fully microscopic method based on Time-Dependent Density Functional Theory (TDDFT), extended to superfluid systems. We find that close to the reconnection point relative distance scales algebraically with the exponent close to 1/2 independently of the system details, as was predicted for Bose-Einstein Condensates both by semiclassical models and numerical simulations. We extend this analysis to the superfluid gas of ultracold fermions and find that the scaling result applies also to these systems.

*Speaker

Synthetic Flux Attachment

Gerard Valenti-Rojas*[1], Niclas Westerberg[2], and Patrik Ohberg[1]

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Abstract

Flux attachment is a mechanism by which charged particles capture magnetic flux quanta and form composite entities. As a consequence of flux dressing, these composites may acquire fractional quantum numbers (e.g. electric charge) and statistics. This phenomenon is directly associated to the emergence of a Chern-Simons gauge field.
Although charge-neutral systems do not couple to vector potentials, geometric (Berry) phases induced in ultracold neutral atoms allow emulating the behavior of charged particles in electromagnetic fields. Nowadays, these phases can be engineered in Bose-Einstein condensates by means of laser coupling.
We describe how a suitable interaction of this light-matter system generates an effective singular nonlinear gauge potential. Such a field is a function of matter density and performs a laser-tuned version of flux attachment. We derive bottom-up the macroscopics (i.e. emergence) of an Abelian Chern-Simons theory from a microscopic, weakly-interacting system of bosons. We find that the effective description of the condensate is that of a fractional quantum Hall fluid where anyonic flux-charge vortices are formed. Finally, we outline the implementation of the current scheme and its implications as a quantum simulation of a gauge theory in 2+1D that uses a single atomic species only.

*Speaker

Dynamics of Optomechanical Droplets in a Bose-Einstein Condensate

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Abstract

We investigate the existence and behaviour of stable optomechanical droplets formed when a Bose-Einstein condensate (BEC) interacts with an optical field in the presence of a feedback mirror. We investigate the dynamics of the droplets, and show that they can undergo motion with uniform velocity or uniform acceleration. The coupling between BEC density and the optical field means that monitoring the optical field transmitted by the feedback mirror could provide a means of continuously and non-destructively monitoring the motion of the BEC.

*Speaker

Loschmidt echo singularities as dynamical signatures of strongly localized phases

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Abstract

Quantum localization (single-body or many-body) comes with the emergence of local conserved quantities — whose conservation is precisely at the heart of the absence of transport through the system.

In the case of fermionic systems and S=1/2 spin models, such conserved quantities take the form of effective two-level systems, called l-bits. While their existence is the defining feature of localized phases, their direct experimental observation remains elusive. Here we show that strongly localized l-bits bear a dramatic universal signature, accessible to state-of-the-art quantum simulators, in the form of periodic cusp singularities in the Loschmidt echo following a quantum quench from a Néel/charge-density-wave state. Such singularities are perfectly captured by a simple model of Rabi oscillations of an ensemble of independent two-level systems, which also reproduces the short-time behavior of the entanglement entropy and the imbalance dynamics. In the case of interacting localized phases, the dynamics at longer times shows {red} a sharp crossover to a faster decay of the Loschmidt echo singularities}, offering an experimentally accessible signature of the interactions between l-bits.

*Speaker

Self-oscillating atomic clouds in Magneto-Optical Traps

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Abstract

The aim of our research is to study self-oscillating, large ultracold atomic clouds in a Rubidium-87 Magneto-Optical Trap. By tuning the confinement forces in particular ways it is possible for the atoms to enter the self-oscillatory regime. We call the self-oscillatory regime the unstable regime, and the regime, where we observe that the atoms do not move - the stable regime.

The research aims at addressing three questions:

(1) What are the necessary experimental parameters for entering the unstable regime?

(2) What happens in the unstable regime?

(3) What can be said about the structures in the unstable clouds?

*Speaker

Strong correlations in lossy one-dimensional quantum gases: from the quantum Zeno effect to the generalized Gibbs ensemble

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Abstract

We consider two-body losses in bosonic gases trapped in one-dimensional optical lattices. The system is initialized in a Mott insulator with one particle per site and at time t = 0 begins to evolve under the simultaneous action of coherent dynamics and two-body losses. By exploiting the separation of time scales typical of a system in the many-body quantum Zeno regime, and
establishing a connection with the theory of the time-dependent generalized Gibbs ensemble, we are able to provide an accurate description of the dynamics of the system, and to show that its long-time behaviour deviates significantly from mean-field analyses. The possibility of observing our predictions in an experiment with 174 Yb in a metastable state is discussed.

*Speaker

Spreading of Correlations and Entanglement in the Long-Range Transverse Ising Chain

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Abstract

The dramatic effect of long-range interactions on the dynamics of quantum matter has attracted significant experimental and theoretical attention in recent years. In contrast with short-range interacting lattice models, where the spreading of correlations is limited by the well-known Lieb-Robinson bounds, sufficiently long-range interactions lead to the instantaneous propagation of information and the breakdown of the notion of causality, consistent with the absence of known Lieb-Robinson bounds. In the intermediate (quasi-local) regime between these two limits, the existence of some form of causality is strongly debated and remains a crucial outstanding problem.

In this work, we address this question by studying the out-of-equilibrium dynamics of the one-dimensional transverse Ising model with algebraic long-range exchange coupling. We employ a state of the art tensor-network approach, complemented by analytic calculations and consider various experimentally accessible quantities, like correlation functions, local magnetization, and Rényi entropies.

Our results demonstrate the emergence of a weak form of causality in the quasi-local regime of long-range spin models, characterized by fundamentally non-universal scaling laws which allows us to reconcile contrasting observations in the existing literature.

We further demonstrate that the scaling of quantum entanglement, by contrast, takes on a universal form with a well-defined entanglement edge which propagates ballistically for all interaction ranges we consider. We corroborate our numerical results with a novel analytical method which confirms this surprising finding, and explain it in terms of a quasi-particle picture.

These results provide new insight as to how information and correlations propagate in quantum matter and we expect that they will motivate rapid experimental investigation of our predictions and stimulate further theoretical work studying these effects in other long-range models.

*Speaker

Multi-spin cat state in small arrays of large dipolar spins

Youssef Trifa*[1] and Tommaso Roscilde[2]

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[2]Laboratoire de Physique - ENS Lyon – École Normale Supérieure - Lyon, Université Claude Bernard Lyon 1, Centre National de la Recherche Scientifique : UMR5672 – France

Abstract

We unveil theoretically the robust non-equilibrium formation of Schrödinger's cat states in systems of large spins coupled via a dipolar XXZ Hamiltonian. Two spins of length S with appropriately tuned quadratic Zeeman fields realise the paradigmatic one-axis twisting (OAT) Hamiltonian, leading to the formation of a cat state for an arbitrary value of S at a well defined time (independent of the value of S). Remarkably, tuning the Zeeman field away from the value realising the OAT dynamics only leads to a small perturbation of the cat state, due to the fact that the sector at maximum total magnetisation is weakly coupled to the other sectors of the Hilbert space. In particular the effect of the Zeeman field is weaker the larger the spin S. A similar robustness is also observed when coupling together several spins arranged in a chain - we observe the formation of cat states with up to 5 spins. The robustness of cat states is the result of weak ergodicity breaking in the non-equilibrium dynamics of the XXZ dipolar Hamiltonian, due to the existence of "quantum scars" in the spectrum. Our results are relevant for future experiments on small arrays of magnetic atoms (Cr, Er and Dy).

*Speaker

Optical Shielding of Destructive Chemical Reactions between Ultracold Ground-State NaRb Molecules

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Abstract

We propose a method to suppress the chemical reactions between ultracold bosonic ground-state ^{23}Na^{87}Rb molecules based on optical shielding. By applying a laser with a frequency blue-detuned from the transition between the lowest rovibrational level of the electronic ground state X^1Σ^+(v_X=0,j_X=0), and the long-lived excited level b^3Π^0(v_b=0,j_b=1), the long-range dipole-dipole interaction between the colliding molecules can be engineered, leading to a dramatic suppression of reactive and photoinduced inelastic collisions, for both linear and circular laser polarizations. We demonstrate that the spontaneous emission from b^3Π^0(v_b=0,j_b=1) does not deteriorate the shielding process. This opens the possibility for a strong increase of the lifetime of cold molecule traps and for an efficient evaporative cooling. We also anticipate that the proposed mechanism is valid for alkali-metal diatomics with sufficiently large dipole-dipole interactions.

*Speaker

Parity-dependent charge exchange in LiBa+ experiment

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Abstract

The precise control at the single quantum level of ultracold collisions is one of the most challenging goal of researches on ultracold gases. Collisions between cold and trapped atoms and ions have the practical advantage to provide the possibility to observe the reactants and products with long trapping lifetimes. Over the past few years various achievements [1–5] have been obtained in investigating a single ion immersed within an ultracold neutral atomic bath, to explore various processes like radiative or non-radiative charge exchange, spin flip, non-radiative quenching, radiative molecular formation ...

The experimental setup of the Freiburg group involves polarized 6 Li(2s) atoms in the —F = 1/2, m F = 1/2, m I = 1, m S = –1/2 > level, colliding with a long-lived 138Ba+ ion in the excited metastable states (5d 2 D 5/2,3/2). Non-radiative charge exchange (NRCE), fine structure quenching (FSQ) process and non-radiative quenching (NRQ) are probed in the experiment.

We have developed several theoretical models of increasing complexity in order to identify the main interactions at play during these processes: a semi-classical Landau-Zener (LZ) model, a few-channel quantum scattering (FCQS) model with spin orbital couplings, and a multi-channel quantum scattering (MCQS) model considering spin-orbit couplings and rotational couplings. In the absence of rotational couplings, the FCQS model predicts that NRCE always dominates the dynamics of the collision, in contrast experimental measurements. The MCQS model is found necessary to qulaitatively reflect the experimental findings. The calculated energy-dependent reaction rate approaches the Langevin prediction, while we also predict the presence of a shape resonance around 1 millikelvin. The dependence of the results with the temperature of the 138Ba+ ion, not precislely in the experiment, will be discussed.

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*Speaker

Electron Electric Dipole Moment in matrix

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Abstract

Electric Dipole Moments (EDMs) of electrons, neutrons or nuclei are sensitive probes for new physics beyond the Standard Model of particle physics. We will preent the projet Electric Dipole Moment with atoms and molecules in Matrix, where we propose to measure the electron EDM using embedded particles in a cryogenic solid matrix of rare gas or hydrogen. Matrices offer unprecedented sample sizes while maintaining many characteristics of an atomic physics experiment, such as manipulation by lasers. An EDM experiment on atoms and molecules in inert gas matrices has the potential to reach a statistical sensitivity in the order of 10ˆ{-36} e.cm; a value several orders of magnitude beyond that of any other proposed technique. In a strong collaboration between experimental (LAC, ISMO) and theoretical (CIMAP) groups, we seek to perform a detailed investigation using metal atoms (Cs typically) in argon and parahydrogen matrices in view of a first proof of principle EDM measurement.

*Speaker

Circulating pulse cavity enhancement as a method for extreme momentum transfer atom interferometry

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Abstract

Large scale atom interferometers promise unrivaled strain sensitivity to midband gravitational waves, and will probe a new parameter space in the search for ultra-light scalar dark matter. These atom interferometers require a momentum separation above 10ˆ4 hbar k between interferometer arms in order to reach the target sensitivity. Prohibitively high optical intensity and wavefront flatness requirements have thus far limited the maximum achievable momentum splitting. We propose here a scheme for optical cavity enhanced atom interferometry, using circulating, spatially resolved pulses, and intracavity frequency modulation to overcome these limitations and reach 10ˆ4 hbar k momentum separation. We present parameters suitable for the experimental realization of 10ˆ4 hbar k splitting in a 1 km interferometer using the 698 nm clock transition in 87Sr and describe performance enhancements. Although technically challenging to implement, the laser and cloud requirements are within the reach of upcoming cold-atom based interferometers. Our scheme satisfies the most challenging requirements of these sensors and paves the way for the next generation of high sensitivity, large momentum transfer atom interferometers.

*Speaker

Bragg pulses shaping in an atomic interferometer

Charlie Leprince*[1], Alexandre Dareau*[1], Quentin Marolleau[1], Victor Gondret[1], Ziyad Amodjee[1], Marc Cheneau[1], Denis Boiron*[1], and Christoph Westbrook[1]

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Abstract

Our team aims at testing Bell inequalities with momentum-entangled atoms using metastable Helium. Pairs of momentum-entangled atoms are generated by applying a moving optical lattice onto a Bose-Einstein condensate [1] and then sent into a four-mode atomic interferometer [2], consisting of two consecutive Bragg pulses playing the role of a deflector (mirror) and a 50:50 beam splitter. The entangled atom pairs emitted in four different momentum modes are mixed in two independent sub-interferometers, that we call Alice and Bob. A thorough test of Bell inequalities requires to have a good control over the phases and reflectivities of the "atom optics" forming the interferometer. This can be achieved by properly tuning the parameters of the Bragg beams (intensity, duration, temporal shape). We will present the numerical simulations we made in order to shape the Bragg deflector and splitter considering our criteria and constraints. We used the most satisfying Bragg pulses we found as inputs of a Bell simulation in order to check whether the Bell correlator, which depends on joint detection probabilities at the output of the interferometer and oscillates as a function of the relative phase between Alice and Bob, would be measurable with a good contrast. We find that sinc-shaped Bragg deflector and splitters would best achieve a phase control without decreasing the contrast of the Bell correlator, thus making it possible to measure a Bell parameter S greater than 2 according to quantum theory.

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*Speaker

Shelving spectroscopy of the strontium intercombination line.

Isam Manai[1], Anaïs Molineri[2], Clémence Fréjaville[2], Clément Duval[1], Pierre Bataille[1], Romaric Journet[2], Fabrice Wiotte[1], Bruno Laburthe-Tolra[1], Etienne Maréchal[1], Marc Cheneau[2], and Martin Robert-De-Saint-Vincent*[1]

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[2]Laboratoire Charles Fabry – Institut d'Optique Graduate School, Université Paris-Saclay, Centre National de la Recherche Scientifique : UMR8501 – France

Abstract

We present a spectroscopy scheme for the 7-kHz-wide 689-nm intercombination line of strontium [1]. We rely on shelving detection, where electrons are first excited to a metastable state by the spectroscopy laser before their state is probed using the broad transition at 461 nm. This enhances dramatically the signal strength as compared to direct saturated fluorescence [2] or absorption [3] spectroscopy of the narrow line. This enhanced signal eliminates the need for high strontium density or flux, thereby increasing the lifetime of the atomic source.

Our scheme is comparable to thermal-beam calcium clocks, that gained more than one order of magnitude in precision when implementing shelving detection [4, 5]. Since lower velocities from strontium ovens allow similar interrogation times on shorter path lengths, we do not make use of a Ramsey interferometry setup. Consequently, the shelving spectroscopy is applicable both to directed atomic beams and hot vapor cells with isotropic atomic velocities. We describe its implementation in both of these settings, with similar fractional instability 2 10ˆ-12 at 1 s limited by technical noise, about one order of magnitude above our estimate of shot noise limitations given our parameters. Our work thus illustrates the robustness and exibility of a scheme that can be very easily implemented in the reference cells or ovens of most existing

strontium experiments, and may find applications for low-complexity optical clocks.

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*Speaker

Light-mediated strong coupling between a mechanical oscillator and atomic spins 1 meter apart

Manel Bosch Aguilera*[1], Gian-Luca Schmid* , Thomas Karg , Chun Tat Ngai , Maryse Ernzer , Baptiste Gouraud , and Philipp Treutlein

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Abstract

Strong coupling between quantum systems is an essential prerequisite for many intriguing quantum mechanical phenomena and for their application in quantum technology. Achieving strong coupling typically relies on short-range forces like the Coulomb force or on high-quality electromagnetic resonator structures in which the systems are placed like an optical cavity. This restricts the range of the coupling to small distances.

In our experiment, we use a free-space laser beam to generate strong coherent coupling between the spin of an atomic ensemble and a nanomechanical membrane over a macroscopic distance of one meter in a room-temperature environment [1]. We have shown that this coupling is very flexible and tunable: depending on the relative phase between the interactions, we achieve an effective Hamiltonian interaction or a dissipative interaction between the spins and the mechanical oscillator. This allowed us to observe normal mode splitting, coherent energy exchange oscillations, parametric gain interactions and dissipative coupling of the systems [1].

Our approach to engineer coherent long-distance interactions with light makes it possible to couple physically very different systems in a modular way, opening up a range of new opportunities for quantum control in hybrid quantum networks [2]. By using a mechanical oscillator and an atomic spin ensemble, we are able to couple a macroscopic object to a well controlled microscopic quantum system. Such a hybrid quantum system opens up many opportunities for quantum sensing and signal transduction and fundamental studies of non-classicality [3].

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*Speaker

Cavity-Enhanced Microscope for Cold Atoms

Tigrane Cantat-Moltrecht*[1], Jean-Philippe Brantut[1], and Nick Sauerwein[1]

[1]LQG - Laboratory for Quantum Gases, EPFL, Lausanne – Switzerland

Abstract

We are setting up a novel type of atom microscope, consisting of an ultra-cold Fermi gas of Lithium 6 atoms in a high-finesse cavity, combined with high-numerical-aperture optics (0.37). This combined system will allow to trap the atoms in a micro-tweezer at 780nm inside the near-concentric cavity mode, as well as to control spatially and temporally the atom-cavity coupling by lightshifting the 2P state with a tightly focused beam at 460nm addressing the 2P to 4D transition of Li6. Controlling this coupling will also allow to tune the cavity-mediated interactions between atoms temporally and spatially, paving the way for novel schemes of quantum simulation of random all-to-all interactions between fermions.

Currently, this optical system has been assembled, characterized, and placed inside the UHV chamber. A MOT cloud of Li6 can be imaged inside the cavity by two-color fluoresence at 671nm and 460nm and we are working towards trapping the atoms inside the 780nm micro-tweezer. I will summarize the important ideas and technical developments behind the design, present the current status of our experiment and the next steps towards a working "cavity-microscope".

*Speaker

Storage and release of light in subradiant excitations of a dense atomic cloud

Igor Ferrier-Barbut*[1]

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Abstract

The description of the interaction between a single two-level atom and radiation is well established and underpins several milestones of modern physics. The response of the system is characterized by a resonance frequency and a decay rate. This picture is modified when considering more than one emitter. Light-induced interactions modify dramatically the response of the ensemble and the behavior of the system becomes collective. Several phenomena arising from collective effects have been observed in atomic systems, in particular subradiance was recently observed in a dilute cloud of cold atoms. Engineering subradiant states has drawn an increasing attention recently. For instance, the opportunity to store an excitation in an atomic medium for a long time has inspired proposals to use subradiance for quantum memories, and the sensitivity of subradiant states to external fields could be a promising route for quantum metrology. I report here on the study of subradiant collective decay in a dense ensemble of cold 87Rb atoms. Thanks to the high densities reached in our clouds, we explore for the first time collective effects in this strongly interacting regime where the interatomic distances are much smaller than the probing wavelength. We observe a subradiant decay and investigate its dependence on the cloud parameters, observing scalings that reveal long-range interactions. Moreover, we implement an experimental procedure that allows to release the excitation stored in these long-lived modes in a directional pulse of light. This technique is a first step for the realization of devices for light storing and quantum memories based on subradiance.

*Speaker

Narrow-line spectroscopy to cool strontium atoms

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Abstract

My Ph.D. consists of the construction of a new-generation quantum gas microscope experiment for strontium gases. Thanks to this experiment, we will study two dimensional systems with both long- and short-range interactions. By setting the system out of equilibrium with a sudden change of the interaction strength (quantum quench), we will characterize both the relaxation dynamics and the final state through the measurement of two-point correlation functions. Recently we developed in partnership with the Laboratoire de Physique des Lasers (Université Paris 13 - France) a new shelving spectroscopy scheme for the Sr 689-nm intercombination line. Relying on electron shelving, it is very robust, easy to implement, and increases dramatically the signal strength as compared to direct saturated absorption spectroscopy of this line. This considerably decreases the need for high strontium density or flux, increasing the lifetime of the atomic source.

*Speaker

Abstract for Poster presentation

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Abstract

Intensity correlations and light scattered by a cold atomic cloud
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Université Côte d'Azur, CNRS, INPHYNI, France

The measurement of coherence properties of light is important to characterize the source itself, the emission processes, or the light-matter interaction when one studies for example the light scattered by atoms or molecules. This measurement is usually done with interferometric technique, corresponding to the measurement of the electric field correlation. However, since the work of Glauber, it is well known that if one aims at fully characterizing the coherence properties of a light source, one needs to measure the correlation functions at all orders. Going one step further, one gets the second-order temporal correlation function, also called temporal intensity correlation function.

In this work, we study the intensity correlations of light scattered by a cold atomic cloud illuminated by laser beams. This is done on a cold atom experiment that have already shown nonlinear single atom scattering properties, such as Mollow triplets [1]. The goal is now to detect and characterize non-classical cooperative behavior in the light-matter interaction, that have been predicted by theory [2]. However, such effects are small and the experiment needs to be improved.

In this poster, I will present the general experimental setup used to measure the first and second-order correlation functions, as well as the key ingredients to be able to observe those new quantum correlations.

Keywords: Cold Atoms, Nonlinear optics, light-matter interaction

References:

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Quantum effects in the cooperative scattering of light atomic clouds, L. Pucci *et al.*, Phys. Rev. A **95**, 053625 (2017).

*Speaker

Imaging and Localizing Individual Atoms Interfaced with a Nanophotonic Waveguide

Yijian Meng[1], Christian Liedl[1], Sebastian Pucher[1], Arno Rauschenbeutel[1], and Philipp Schneeweiss[*1]

[1]HU Berlin – Germany

Abstract

Single particle-resolved fluorescence imaging is an enabling technology in cold-atom physics. However, so far, this technique has not been available for nanophotonic atom-light interfaces. Here, we image single atoms that are trapped and optically interfaced using an optical nanofiber. Near-resonant light is scattered off the atoms and imaged while counteracting heating mechanisms via degenerate Raman cooling. We detect trapped atoms within 150 ms and record image sequences of given atoms. Building on our technique, we perform two experiments which are conditioned on the number and position of the nanofiber-trapped atoms. We measure the transmission of nanofiber-guided resonant light and verify its exponential scaling in the few-atom limit, in accordance with Beer-Lambert's law. Moreover, depending on the interatomic distance, we observe interference of the fields that two simultaneously trapped atoms emit into the nanofiber. The demonstrated technique enables postselection and possible feedback schemes and thereby opens the road toward a new generation of experiments in quantum nanophotonics.

[*]Speaker

Towards Quantum Simulation of Light-Matter Interfaces with Strontium Atoms in Optical Lattices

Annie Jihyun Park*[1], Jan Trautmann[1], Valentin Klüsener[1], Neven Šantić[1], André Heinz[1], Eva Casotti[1], Florian Wallner[1], Yilong Yang[1], Dimitrios Tsevas[1], Immanuel Bloch[1,2], and Sebastian Blatt[1]

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[2]Ludwig Maximilian University [Munich] – Germany

Abstract

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully emulated strongly correlated condensed matter systems. With the recent development of quantum gas microscopes, these quantum simulators can now control such systems with single-site resolution. Within the same time period, atomic clocks have also started to take advantage of optical lattices by trapping alkaline-earth-metal atoms such as Sr, and interrogating them with precision and accuracy at the 10e-18 level. Here, we report on progress towards a new quantum simulator that combines quantum gas microscopy with optical lattice clock technology. We have developed in-vacuum buildup cavities with large mode volumes that will be used to overcome the limits to system sizes in quantum gas microscopes. To benchmark the size and homogeneity of the lattice created by these cavities, we image their intensity profile by loading ultracold strontium atoms in the lattice and inducing local atom loss. By combining the buildup cavity with our recently demonstrated state-dependent lattices for the clock states, we aim to emulate strongly-coupled light-matter-interfaces in parameter regimes that are unattainable in real photonic systems.

*Speaker

Cold Atom Online Meeting 2020

	Monday	Tuesday	Wednesday
	8:50-9:00: Opening remarks		
9:00 - 10:00	**Rydberg atoms*** S. Whitlock (Strasbourg, F) D. Barredo (Palaiseau, F)	**Metrology*** T. Mehlstäubler (Braunschweig, D) R. Geiger (Paris, F)	**Atom-light interactions*** J. Simonet (Hamburg, D) W. Guérin (Nice, F)
10:00 - 10:30	Discussion room*	Discussion room*	Discussion room*
10:30 - 11:00	**Coffee break**	**Coffee break**	**Coffee break**
11:00 - 12:00	**Magnetic atoms*** L. Chomaz (Innsbruck, A) J. Schachenmayer (Strasbourg, F)	**Entanglement & correlations*** B. Vermesch (Grenoble, F) P. Preiss (Heidelberg, D)	**Cold atoms in cavities*** J.-P. Brantut (Lausanne, CH) M. Z. Huang (Paris, F)
12:00 - 12:30	Discussion room*	Discussion room*	Discussion room*
12:30 - 14:00	**Lunch break**	**Lunch break**	**Lunch break**
14:00 - 15:00	**Poster session (1h30) on BigBlueButton**	**Chaos and Integrability*** J. Billy (Toulouse, F) J. Dubail (Nancy, F)	**Poster session (1h30) on BigBlueButton**
15:00 - 15:30		Discussion room*	
15:30 - 16:00	**Coffee break**	**Coffee break**	**Coffee break**
16:00 - 17:00	**Cold molecules*** K.-K. Ni (Cambridge, US) M. Lepers (Dijon, F)	**Quantum-tech industry session*** Philippe Bouyer (Muquans, F) Thomas Monz (Alpine Quantum Technologies, A) Mark Saffman (ColdQuanta, US) Adrien Signoles (Pasqal, F)	**Topological phases*** M. Aidelsburger (Munich, D) S. Nascimbene (Paris, F)
17:00 - 17:30	Discussion room*	Discussion room*	Discussion room*
			17:30-17:45: Closing remarks

* **Zoom web-conference** (registered participants have received the link via e-mail)