Danish-Sino Workshop on Strongly Interacting Cold Atomic Gases

December 1st to 5th 2014

Aarhus University

AARHUS UNIVERSITET

Sponsored by

DET FRIE FORSKNINGSRÅD

Schedule

Abstracts

List of participants

Compact timetable

Organizers

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Monday December 1st

Location: Aarhus Institute of Advanced Studies (AIAS) Main Auditorium

9.00-9.30
Welcome and introduction. History of the AIAS.

9.30-10.15
Artem Volosniev: *Analytical approach to strongly interacting trapped systems in one dimension*

10.15-10.30
Break

10.30-11.15
Xi-Wen Guan: *Wilson ratios in exactly solvable models of large spin cold atoms*

11.15-12.00
Jesper Levinsen: *Strong-coupling ansatz for the one-dimensional Fermi gas in a harmonic potential*

12.00-13.00
Lunch

Location: 1525-626 (Physics Department)

13.00-13.45
Klaus Mølmer: *Exciting physics with excited atoms*

13.45-14.30
Qi Zhou: *Shaping single-particle spectra of ultracold atoms for accessing novel quantum many-body phenomena*

14.30-15.00
Break

15.00-15.45
Manuel Valiente: *Low-energy behaviour of strongly-interacting bosons on a flat-banded lattice above the critical filling factor*

16.00-18.00
LAB TOURS Department of Physics and Astronomy

18.00
Dinner

Tuesday December 2nd

Location: 1525-626 (Physics Department)

9.00-9.45
Shizhong Zhang: *Transport Properties of Unitary Fermi Gases*

9.45-10.30
Wei Zhang: *Topological superradiance in a degenerate Fermi gas*

10.30-11.15
Break

11.15-12.00
Jacob Sherson: *Human quantum optimization and measurement bang-bang control*

12.00-13.00
Lunch

Location: 1525-626 (Physics Department)

13.00-13.45
Durga Bhaktvatsala Rao Dasari: *Generating many-body entanglement in long-range interacting systems by dissipation*

13.45-14.30
Mario Napolitano: *Non-destructive detection of the BEC phase-transition*

14.30-17.30
EXCURSION to Moesgaard Museum.

18.30
Dinner downtown (Restaurant Sechzehn)

Wednesday December 3rd

10.00-12.00
Transportation to Sandbjerg Estate. Bus leaves from Radisson Hotel at 10.00.

12.00-13.00
Arrival and lunch at Sandbjerg.

13.00-13.45
Peng Zhang: *Few-body problems in ultracold Bose-Fermi mixture and dipolar gas*

13.45-14.30
Georg Bruun: *Probing many-body physics with cold atoms – The Higgs boson and quantum hexatic order*

14.30-15.00
Break

15.00-15.45
Lan Yin: *Novel quantum phases of dipolar Fermi gases in optical lattices*

15.45-16.30
Jan Arlt: *Squeezing and entanglement in matter waves*

16.30-17.00
Break

17.00-17.45
Boyang Liu: *Higgs mode without Lorentz invariance*

18.00
Dinner

Thursday December 4th

9.00-9.45
Lars Johann Wacker: *^{39}K and ^{87}Rb dual Bose-Einstein condensates: Production and Experiments*

9.45-10.30
Zhenhua Yu: *Revealing the origin of super-Efimov states in the hyper spherical formalism*

10.30-11.15
Break

11.15-12.00
Dmitri Fedorov: *Three-body recombination in cold atomic gases*

12.00-13.00
Lunch

13.00-13.45
Xiong-Jun Liu: *Interacting Effects in the Presence of Induced Spin-Orbit Couplings and Gauge Fields for Cold Atoms*

13.45-14.30
Zheyu Shi: *Three-body problem with spin-orbit coupling*

14.30-15.00
Break

15.00-15.45
Wei Yi: *Three-component Fermi gas with spin-orbit coupling*

16.00-18.00
Poster session

18.00
Workshop Dinner

Friday December 5th

9.00-9.45
Zhigang Wu: *Coexistence of density wave and superfluid orders in a dipolar Fermi gas*

9.45-10.30
Andrew James Hilliard: *Spin dynamics and feedback with a quantum gas: Experiments from the BEC 'Lattice' laboratory at Aarhus University*

10.30-11.00
Break

11.00-11.45
David Petrosyan: *Long-range binding potentials between microwave-driven Rydberg atoms*

11.45-12.00
Closing remarks.

12.00-13.00
Lunch

13.00
Departure from Sandbjerg.

Artem Volosniev

Department of Physics and Astronomy, Aarhus University

Title:
Analytical approach to strongly interacting trapped systems in one dimension

Abstract:
Since the early days of quantum mechanics one dimensional systems were used to develop our understanding of quantum theory and to construct mathematical and numerical techniques to answer physical problems in higher dimensions. Nowadays trapped quasi-one-dimensional few-body systems can be realized experimentally which drives a new wave of interest to few-body problems in one dimension.

In this talk I will show that strongly interacting one-dimensional trapped systems can be approached analytically if the pairwise interaction is of zero range and all particles have equal masses. If those conditions are fulfilled the particles to a large extent behave as spinless (spin-polarized) fermions. And since in one dimension a system of particles can always be ordered the wave function should be defined through the probabilities of different orderings in the system. During this talk I will present a newly developed method to determine these probabilities.

I will also show how this system can be mapped to an effective spin-chain model, e.g. XX model, with coupling constants that are position-dependent and determined by the trapping potential. This opens exciting possibilities for engineering stationary and dynamic quantum states with one dimensional set-ups of trapped strongly interacting particles by changing the shape of the trapping potential.

Xi-Wen Guan

Wuhan Institute of Phys. & Math., Chinese Academy of Sciences

Title:
Wilson ratios in exactly solvable models of large spin cold atoms

Abstract:
Interacting bosons and fermions with large spin mathematical symmetries greatly expand our understanding of many-body physics. In this talk, I will discuss recent theoretical and experimental developments of one-dimensional (1D) integrable quantum gases of multicomponent cold atoms with high spin symmetries. In particular, I will study universal low energy physics of 1D interacting bosons and fermions with large spins through the Luttinger parameters, Wilson ratios and Contact. We found that the usual Wilson ratio present an elegant parameter to characterize the spin fluctuations of Fermi liquids in all dimensions. In contrast, the second type of Wilson ratio enable one to characterize the particle number fluctuations in all quantum liquid phases of many-body systems. These universal ratios provide a deep understanding of quantum fluctuations and magnetism in interacting many-body systems of bosons and fermions with higher mathematical symmetries.

Jesper Levinsen

Aarhus Institute of Advanced Studies, Aarhus University

Title:
Strong-coupling ansatz for the one-dimensional Fermi gas in a harmonic potential

Abstract:
The one-dimensional (1D) Fermi gas with repulsive short-range interactions provides an important model of strong correlations and is often amenable to exact methods. However, in the presence of confinement, no exact solution is known for an arbitrary number of strongly interacting fermions. Here, we propose a novel ansatz for generating the lowest-energy wavefunctions of the repulsive 1D Fermi gas in a harmonic potential near the Tonks-Girardeau limit of infinite interactions. We specialize to the case of a single $\downarrow$ particle interacting with $N_\uparrow$ particles, where we may derive analytic forms of the approximate wavefunctions. Comparing with exact numerics, we show that the overlap between the wavefunctions from our ansatz and the exact ones in the ground-state manifold exceeds 0.9997 for $N_\uparrow \leq 8$. Moreover, the overlap for the ground-state wavefunction at strong repulsion extrapolates to ~ 0.9999 as $N_\uparrow \to \infty$. Thus, our ansatz is essentially indistinguishable from numerically exact results in both the few- and many-body limits.

Reference:
J. Levinsen, P. Massignan, G. M. Bruun, and M. M. Parish, arxiv:1408.7096

Klaus Mølmer

Department of Physics and Astronomy, Aarhus University

Title:
Exciting physics with excited atoms

Abstract:
When two nearby atoms are excited from their ground states to Rydberg excited states with large dipole moments, their pairwise interaction is significantly increased. This provides an on/off controllable coupling with promising applications for controlled many-body dynamics, entanglement generation and quantum information processing. In small atomic ensembles, the interactions simultaneously couple all the atoms and may thus enable a highly non-linear quantum control of the collective many-body state of the system. The presentation will present the basic physical interaction mechanisms and it will present examples of recent theoretical proposals and experimental demonstrations of the rich physics of interacting Rydberg atoms.

Qi Zhou

Chinese University of Hong Kong

Title:
Shaping single-particle spectra of ultracold atoms for accessing novel quantum many-body phenomena

Abstract:
In this talk, I will discuss how to make use of current advancements in ultracold atom experiments for producing unconventional single-particle spectra, which significantly enhance correlation effects in the system, so that a variety of novel quantum many-body phenomena that are difficult to access in other systems naturally emerge. As a few examples, I will discuss an algebraic quantum liquid in two dimensions, and topologically nontrivial band structures in shaken optical lattices.

Manuel Valiente

Heriot-Watt University, Edinburgh, UK and IFA, AU

Title:
Low-energy behaviour of strongly-interacting bosons on a flat-banded lattice above the critical filling factor

Abstract:
Bosons interacting repulsively on a lattice with a flat lowest band energy dispersion may, at sufficiently small filling factors, enter into a Wigner-crystal-like phase. This phase is a consequence of the dispersionless nature of the system, which in turn implies the occurrence of single-particle localised eigenstates. We investigate one of these systems - the sawtooth lattice - filled with strongly repulsive bosons at filling factors infinitesimally above the critical point where the crystal phase is no longer the ground state. We find, the the hard-core limit, that the crystal retains its structure in all but one of its cells, where it is broken. The broken cell corresponds to an exotic kind of repulsively bound state, which becomes delocalised. We investigate the excitation spectrum of the system analytically and find that the bound state behaves as a single particle hopping on an effective lattice with reduced periodicity, and is therefore gapless. Thus, the addition of a single particle to a flat-banded system at critical filling is found to be enough to make kinetic behaviour manifest.

Shizhong Zhang

Department of Physics, The University of Hong Kong

Title:
Transport Properties of Unitary Fermi Gases

Abstract:
Recent experiments have started to probe various transport properties of unitary Fermi gases and revealed many intriguing phenomena. For example, it was shown that scaling invariance at unitarity implies that bulk viscosity vansihses while the shear viscosity entropy ratio approaches a quantum limit. Similar quantum limits exist for longitudinal and transverse spin diffusions. Other dc-transport measurements of conductivity etc. have been conducted as well. In this talk, I will discuss some recent advances in this direction and concentrate on two transport measurements, spin diffusion and dc-conducitivity. I will try to draw some implications of these measurements regarding the nature of unitary Fermi gases and indicate some possible new phenomena that could be uncovered in future experiments.

Wei Zhang

Renmin University

Title:
Topological superradiance in a degenerate Fermi gas

Abstract:
We predict the existence of a topological superradiant state in a two-component degenerate Fermi gas in a cavity. The superradiant light generation in the transversely driven cavity mode induces a cavity-assisted spin-orbit coupling in the system and opens a bulk gap at half-filling. This mechanism can simultaneously drive a topological phase transition in the system, yielding a topological superradiant phase. We map out the steady-state phase diagram of the system in the presence of an effective Zeeman field, and identify a critical quadracritical point beyond which the topological and the conventional superraidiant phase boundaries separate. We also propose to detect the topological phase transitions based on the unique signatures in the momentum-space density distribution.

Jacob Sherson

Department of Physics and Astronomy, Aarhus University

Title:
Human quantum optimization and measurement bang-bang control

Abstract:
Optimal control has in the past decade been applied to an increasing number of quantum processes involving dynamics of individual and many particles. In the vast majority of these cases the control landscape has been benign, showing predominantly global maxima, and making optimization using local gradient methods extremely successful. At scienceathome.org we compare the speed of convergence of standard optimizational methods such as the Krotov algorithm with the speed of human players solving the time dependent Schrdinger equation using an online graphical interface. We demonstrate that for a class of problems related to a quantum computation architecture using ultracold atom in optical lattices the players consistently outperform the algorithms at finding decent fidelity solutions. We furthermore find that a hybrid optimizational scheme involving algorithmic optimization based on player solutions severely outcompetes the bare algorithms in reaching the optimal values. An understanding of the players intelligent adaptation to particular quantum challenges might lead to new and more efficient global optimization algorithms.

In the second part of my talk, I will discuss the possibility of extending complete bang-bang quantum state engineering to cases in which two non-commuting Hamiltonians cannot be found. Specifically, we explore complete controllability using a sequence of non-destructive probing of ultra-cold atoms in optical lattices and intrinsic many-body time evolution. As an application, we demonstrate quantum state preparation of e.g. Schrödinger cat states using appropriately timed projective measurements.

Durga Bhaktvatsala Rao Dasari

Department of Physics and Astronomy, Aarhus University

Title:
Generating many-body entanglement in long-range interacting systems by dissipation

Abstract:
Originally inhomogeneities, decoherence and decay of the atomic systems were minimized in quantum computing proposals so that their effects would not disturb the ideal unitary evolution of the system. Recent works, however, suggest a quite opposite strategy where inhomogeneities are created on purpose and the system is driven on resonance with short lived states such that it dephases and decays to robust steady states [1]. By suitable use of the interactions, these states can be selected, e.g., as entangled states or states encoding the outcome of a quantum computation [2,3]. We investigate the coherent effects induced by dissipation and decoherence in neutral atom based quantum computing proposals [4], for creating robust entangled states and long distance gates.

[1] B. Kraus, H. P. Büchler, S. Diehl, A. Kantian, A. Micheli, and P. Zoller, Phys. Rev. A **78**, 042307 (2008).
[2] D. D. Bhaktavatsala Rao and K. Mølmer, Phys. Rev. Lett. **111**, 033606 (2013).
[3] D. D. Bhaktavatsala Rao and K. Mølmer, arXiv:1407.1228.
[4] M. Saffman, T. G. Walker, and K. Mølmer, Rev. Mod. Phys. **82**, 2313 (2010).

Mario Napolitano

Department of Physics and Astronomy, Aarhus University

Title:
Non-destructive detection of the BEC phase-transition

Abstract:
The experimental detection of phase-transitions is a very common and interesting topic in ultra-cold matter research. Although the realization of Bose-Einstein condensates is nowadays a very widespread experimental technique, there are questions about its formation that are not yet fully understood.

In our experiment we use dispersing probing techniques to investigate in a single-shot experiment the formation of a ^{87}Rb condensate, and compare the results with more traditional time-of-flight (TOF) measurements. We study both irreversible (evaporation) and irreversible (adiabatic change of the trapping potential) BEC transitions.

The dispersive, non-destructive probe is able to estimate the sample phase-space-density during several cycles from uncondensed to condensed phases, in agreement with the TOF results.

Peng Zhang

Renmin University

Title:
Few-body problems in ultracold Bose-Fermi mixture and dipolar gas

Abstract:
In this talk we introduce two of our recent works on few-body problems in ultra cold gases.
(I) Calibration of Interaction Energy between Bose and Fermi Superfluids. (arXiv: 1409.0282). In this job we study the interaction energy in a mixture of Bose and Fermi superfluids realized in recent cold atom experiment. On the Bose-Einstein-condensate (BEC) side of a Feshbach resonance between fermionic atoms, this interaction energy can be directly related to the scattering length between a bosonic atom and a dimer composed of fermions. We calculate the atom-dimer scattering length from a three-body analysis with both a zero-range model and a separable model including the van der Waals length scale, and we find significant deviation from the result given by a mean-field approach. We also find that the multiple scattering between atom and dimer can account for such a deviation. Our results provide a calibration to the mean-field interaction energy, which can be verified by measuring the shift of collective oscillation frequency.
(II) Effect of short-range interaction for collision of ultracold dipoles (arXiv: 1410.0545). In this job we consider the scattering of two ultracold polarized dipoles with both a short-range interaction (SRI) and a weak dipole-dipole interaction (DDI) which is far away from a shape-resonance. In previous works the scattering amplitude is usually calculated via 1st-order Born approximation. Our results show that significant derivation from this approximation can arise in some cases. In these cases the SRI can significantly modify the dipole-dipole scattering amplitude, even if the scattering amplitude for the SRI alone is negligibly smaller than the dipolar length of the DDI. We further obtain approximate analytical expressions for the inter-dipole scattering amplitude.

Georg Bruun

Department of Physics and Astronomy, Aarhus University

Title:
Probing many-body physics with cold atoms - The Higgs boson and quantum hexatic order

Abstract:
In this talk, I describe how cold atoms can be used to test two phenomena which play a key role in our description of quantum many-body physics.

The first is the Higgs mode, which plays a fundamental role for our understanding of both low and high energy physics, giving elementary particles their mass and leading to collective modes in condensed matter and nuclear systems. The Higgs mode has been observed in a limited number of table-top systems, where it however is characterised by a short lifetime due to decay into a continuum of modes. A major goal which has remained elusive so far, is therefore to realise a long-lived Higgs mode in a controllable system. Here, we show how an undamped Higgs mode can be observed unambiguously in a Fermi gas in a two-dimensional trap, close to a quantum phase transition between a normal and a superfluid phase. The second phenomena is the hexatic phase, which is a phase in between a liquid and a crystal. We show how such a phase can be realised in the quantum regime for the first time, using a two-dimensional gas of dipolar molecules. We derive approximate phase diagrams using a pair of Lindemann criteria, suitably adapted to deal with effects of thermal fluctuations in two dimensions. The hexatic phase is predicted to survive down to very low temperatures.

Lan Yin

Peking University

Title:
Novel quantum phases of dipolar Fermi gases in optical lattices

Abstract:
Ultracold quatum gases with electric and magnetic dipole moments have been realized in experiments. The complexity of dipole-dipole interaction offers opportunities to create novel quantum phases in these systems. In this talk, I will discuss some of these phases in dipolar Fermi gases in optical lattices. Under a rotating DC electric or magnetic fields, a chiral p-wave superfluid phase can be generated in a square optical lattice [1]. In a cubic optical lattice, the supersolid phase my appear as the result of competition between CDW and superluid phases [2]. Fractional Chern states can also be created in optical lattices with topological notrivial bands at fractional fillings [3].

[1] B. Liu and L. Yin, Phys. Rev. A 86, 031603(R) (2012).
[2] T.-S. Zeng and L. Yin, Phys. Rev. B 89, 174511 (2014).
[3] T.-S. Zeng and L. Yin, arXiv:1410.3724.

Jan Arlt

Department of Physics and Astronomy, Aarhus University

Title:
Squeezing and entanglement in matter waves

Abstract:
Recent experiments have demonstrated the production of squeezing and entanglement in neutral atoms using various techniques. I will show how spin dynamics can be used to create such non-classical ensembles and how their properties can be measured. In particular I will present a criterion for estimating the amount of entanglement and show that Dicke-like states containing at least 28-particle entanglement can be observed. Moreover I will show how the Quantum-Zeno paradox can be employed to conduct an interaction free measurement in these systems.

Boyang Liu

Tsinghua University

Title:
Higgs mode without Lorentz invariance

Abstract:
The fate of the Higgs amplitude mode without Lorentz invariance is investigated. Specifically, we employ the BEC-BCS crossover system to manifestly stduy the variation of the Higgs mode. The time-dependent Ginzburg-Landau theory shows that this system can be smoothly tuned away from the Lorentz invariant point. We calculated the response functions of the phase and amplitude fluctuations and find that at the extreme BCS limit the Higgs mode is indistinguishable from the Goldstone mode due to the strong damping by the fermion quasi-particles. As one goes away from the extreme BCS limit the damping effect is weaker and the peaks of Higgs and Goldstone mode are well separated. There is a clear signal of the Higgs mode. However, if we move further to approach the unitarity the Higgs mode peak gradually vanishes since the Lorentz invariance is lost. The spectral functions only show one gapless Bogoliubov mode. We also studied the case of Coulomb gas. In the presence of the U(1) gauge field, the Goldstone mode is gapped. The Higgs mode can not decay to this low energy excitations. The signal of Higgs mode becomes much clearer.

Lars Johann Wacker

Department of Physics and Astronomy, Aarhus University

Title:
^{39}K and ^{87}Rb dual Bose-Einstein condensates: Production and Experiments

Abstract:
Bose-Einstein condensates (BECs) offer highly controllable experimental systems and have proven to be an ideal testing ground for exploring effects from different fields such as nuclear, many-body or solid state physics.

The effective interaction of ultracold atoms can be described through their scattering length. By addressing magnetic Feshbach resonances this parameter can be tuned by several orders of magnitude, leading to an extraordinary degree of control. Varying the magnetic field hence also determines whether atoms are mutually attractive or repulsive.

This controllability leads to a wide range of applications. Combining this feature with optical trapping allows us to produce ^{39}K BECs. Beside its intraspecies Feshbach resonances, ^{39}K allows for tuning of its interaction with ^{87}Rb via interspecies resonances.

Based on such an interspecies resonance we have produced the first ^{39}K and ^{87}Rb dual BECs. This novel system opens up for many different research directions. We have been able to use the interspecies resonance to control the miscible/immiscible phase transition of the condensates.

The possibility of adjusting the scattering lengths furthermore allows studies of the Efimov effect, where three identical bosons interact resulting in an infinite number of bound states described by a universal scaling factor. This state was originally considered in the context of three identical bosons in nuclear systems, but has more recently been observed in a system of cold atoms. Within our current work we investigate Efimov physics in a two species system, which provides insights beyond the original picture of three identical bosons.

Zhenhua Yu

Tsinghua University

Title:
Revealing the origin of super-Efimov states in the hyper spherical formalism

Abstract:
Quantum effects can give rise to exotic Borromean three-body bound states when any two bodies can not bind. An outstanding example is the Efimov states for certain three-body systems with resonant s-wave interactions in three dimensions. Recently a field theoretical calculation predicted a new kind of universal three-body bound states for three identical fermions with resonant p-wave interactions in two dimensions. These states were called "super-Efimov" due to their binding energies $E_n = E_* \exp(-2e^{\pi n/s_0+\theta})$. The scaling $s_0 = 4/3$ was found to be universal while E_* and θ are the three-body parameters. However the quest to understand the origin of universality of these new states by elementary quantum mechanics has not been met. Here we use the hyperspherical formalism and show that the origin of the "super-Efimov" states is due to an emergent effective potential $-1/4\rho^2 - (s_0^2 + 1/4)/\rho^2 \ln^2(\rho)$ at large hyperradius ρ. Moreover, our numerical calculation indicates that the three-body parameters E_* and θ are also universal for pairwise interparticle potentials with a van der Waals tail.

Dmitri Fedorov

Department of Physics and Astronomy, Aarhus University

Title:
Three-body recombination in cold atomic gases

Abstract:
Three-body recombination process in cold atomic gases exhibits certain universal properties - often referred to as Efimov physics - which can be described within a model-independent theory using only few of the low-energy parameters of the inter-atomic interactions. In this contribution we shall focus on recombination into deep dimers and discuss the interplay between the universal and non-universal properties of the recombination rates, particularly in the systems of atoms with different masses

Xiong-Jun Liu

International Center for Quantum Materials, Peking University

Title:
Interacting Effects in the Presence of Induced Spin-Orbit Couplings and Gauge Fields for Cold Atoms

Abstract:
Generation of spin orbit coupling and gauge fields for ultracold atoms has attracted considerable attention for it opens important new opportunities in the study of exotic topological phases and novel many-body physics with clean and controllable platforms. In this talk I will discuss the interacting effects in the presence of induced spin-orbit couplings and gauge fields for cold atoms. The talk is arranged in three parts, corresponding to the systems in the presence of 1D spin-orbit coupling, 2D spin-orbit coupling, and induced magnetic field, respectively. The novel physics we discuss include the many-body dynamics in a spin-orbit coupled Bose-Einstein condensate, topological superfluid phases for cold fermions with 1D and 2D spin-orbit couplings, and chiral spin liquid phases in the presence of induced magnetic field.

Zheyu Shi

Tsinghua University

Title:
Three-body problem with spin-orbit coupling

Abstract:
In this talk I will talk about how synthetic spin-orbit (SO) coupling can strongly affect three-body physics in ultracold atomic gases. We consider a system which consists of three fermionic atoms, including two spinless heavy atoms and one spin-1/2 light atom subjected to an isotropic SO coupling. We find that SO coupling can induce universal three-body bound states with negative s-wave scattering length at a smaller mass ratio, where no trimer bound state can exist if in the absence of SO coupling. The energies of these trimers are independent of high-energy cutoff, and therefore they are universal ones. Moreover, the resulting atom-dimer resonance can be effectively controlled by SO coupling strength.

Wei Yi

University of Science and Technology of China, Easy Campus

Title:
Three-component Fermi gas with spin-orbit coupling

Abstract:
We will discuss various interesting aspects of a three-component Fermi gas under spin-orbit coupling. More specifically, we consider a system where a third fermionic spin species is added to a non-interacting two-component Fermi gas with spin-orbit coupling, which interact spin-selectively with the two-component Fermi gas. We show that spin-orbit coupling and the spin-slective interaction can give rise to highly non-trivial few-body correlations. In particular, under the synthetic spin-orbit coupling that has recently been realized experimentally, the two-body state of the system intrinsincally acquires a non-zero center-of-mass momentum, which would lead to a new type of Fulde-Ferrell pairing in spin-orbit coupled Fermi systems. Whereas under a Rashba spin-orbit coupling, a universal trimer state can be stabilized over a wide parameter region. This trimer state can even emerge in the absence of any dimers, leading to the so-called universal Borromean binding. These findings have interesting implicaitons for the corresponding many-body systems such as 6Li-40K-40K or 40K-40K-40K mixtures, where novel many-body phases with exotic corrleations may be found.

Zhigang Wu

Department of Physics and Astronomy, Aarhus University

Title:
Coexistence of density wave and superfluid orders in a dipolar Fermi gas

Abstract:
We study a two-dimensional spin-polarized Fermi gas with electric dipoles aligned by an external electric field. This system is known to exhibit three stable zero temperature phases, namely the normal Fermi liquid, the p-wave superfluid and the density wave phase. We investigate the possibility of a new phase in which the density wave order and the superfluid order coexist. We find that the system in the density wave phase becomes unstable towards pairing as the tilting angle of the dipoles increases and the dipolar interaction becomes more attractive. Importantly, the resulting superfluid order does not destroy the density wave order. We discuss possible experimental methods by which such a coexistence can be detected.

Andrew James Hilliard

Department of Physics and Astronomy, Aarhus University

Title:
Spin dynamics and feedback with a quantum gas: Experiments from the BEC 'Lattice' laboratory at Aarhus University

Abstract:
In this talk, I will report on two topics we pursue in the BEC 'Lattice laboratory at Aarhus University.

The first topic is spin dynamics in a 2D quantum gas: Through spin-changing collisions, two clouds with opposite spin orientations are spontaneously created in a Bose-Einstein condensate held in an optical lattice. After ballistic expansion, both clouds acquire ring-shaped density distributions with superimposed angular density modulations. The measured density distributions depend on the applied magnetic field and are well explained by a simple Bogoliubov model. The two clouds are anti-correlated in momentum space, paving the way towards the creation of an atom source with non-local Einstein-Podolsky-Rosen entanglement.

The second part of the talk covers current work on the preparation of ultra-cold thermal clouds of a fixed atom number by dispersive imaging and feedback. Typically, the atom number in an ultra-cold thermal cloud is limited by technical fluctuations, leading to a scatter in population of $\pm 10\%$. I will outline our method to reduce these fluctuations by a factor of 1000, and discuss current and future experiments made possible through this unprecedented ultra-cold atom source.

David Petrosyan

AIAS-AU, DK & IESL-FORTH, GR

Title:
Long-range binding potentials between microwave-driven Rydberg atoms

Abstract:
Atoms in high-lying Rydberg states strongly interact with each other via long-range dipole-dipole and van der Waals potentials. In combination with coherent laser and microwave field manipulations of the atomic internal states, these interactions constitute the basis for many quantum information processing schemes. Furthermore, cold atoms excited to Rydberg states represent a convenient platform to simulate and study few- and many-body physics.

The most basic few-body phenomenon is the formation of a bound pair of particles. I will present a mechanism to obtain long-range binding potentials between Rydberg atoms interacting with each other via attractive and repulsive van der Waals potentials and driven by a microwave field. I will then show that the Rydberg-dimer states can be selectively and coherently populated from the two-atom ground state using destructive quantum interference to cancel excitation of a single-atom Rydberg state. A suitably excited Rydberg-dimer state can be used to realize a two-qubit interaction gate which is not susceptible to mechanical forces between the atoms and is therefore immune to motional decoherence.

List of participants

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MON 1/12

9-12 AIAS AUD.
- 9.00-9.30 Intro + AIAS history
- 9.30-10.15 1 talk
  - A. Volosniev
- 10.15-10.30 break
- 10.30-12.00 2 talks
  - X.-W. Guan
  - J. Levinsen

12.00-13.00 Lunch

13-16 1525-626
- 13.00-14.30 2 talks
  - K. Mølmer
  - Q. Zhou
- 14.30-15.00 break
- 15.00-15.45 1 talk
  - M. Valiente
- 15.45-16.00 break

16-18 IFA LAB TOURS

18 DINNER

TUES 2/12

9-12 1525-626
- 9.00-10.30 2 talks
  - S. Zhang
  - W. Zhang
- 10.30-11.15 break
- 11.15-12.00 1 talk
  - J. Sherson

12.00-13.00 Lunch

13-15 1525-626
- 13.00-14.30 2 talks
  - D. Dasari
  - M. Napolitano

14.30-17.30 EXCURSION

Moesgaard Museum Transportation by bus from IFA..

Transportation by bus back to Radisson Hotel.

18.30 DINNER

WED 3/12

10.00-12.00 Transportation to Sandbjerg Estate Pickup for at Radisson Hotel

12.00-13.00 Lunch

13-19 Sandbjerg
- 13.00-14.30 2 talks
  - P. Zhang
  - G. Bruun
- 14.30-15.00 Break
- 15.00-16.30 2 talks
  - L. Yin
  - J. Arlt
- 16.30-17.00 Break
- 17.00-17.45 1 talk
  - B. Liu

18 DINNER

THURS 4/12

9-12 Sandbjerg
- 9.00-10.30 2 talks
  - L. Wacker
  - Z. Yu
- 10.30-11.15 break
- 11.15-12.00 1 talk
  - D. Fedorov

12.00-13.00 Lunch

13-16 Sandbjerg
- 13.00-14.30 2 talks
  - X.-J. Liu
  - Z. Shi
- 14.30-15.00 break
- 15.00-15.45 1 talk
  - W. Yi

16.00-18.00 Poster session

18 DINNER

FRI 5/12

9-12 Sandbjerg
- 9.00-10.30 2 talks
  - Z. Wu
  - A. Hilliard
- 10.30-11.00 break
- 11.15-11.45 1 talk
  - D. Petrosyan
- 11.45-12.00 Closing remarks

12.00-13.00 Lunch

13.00 Departure from Sandbjerg Estate

Bus transportation to Fredericia train station and to IFA has been arranged.