SFB/TRANSREGIO 49

FRANKFURT-KAISERSLAUTERN-MAINZ

CONDENSED MATTER SYSTEMS WITH VARIABLE MANY-BODY INTERACTIONS

SUMMER SCHOOL 2012

LOW-DIMENSIONAL QUANTUM MANY-BODY SYSTEMS

JOHANN WOLFGANG GOETHE UNIVERSITÄT FRANKFURT AM MAIN

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Table of Contents

CONTACT INFORMATION:

COLLEGE FOR THE ADVANCEMENT OF POSTGRADUATE EDUCATION

---

http://www.tr49.de

Executive Manager:
Priv.-Doz. Dr. Axel Pelster
Physics Department, Technische Universität Kaiserslautern, Germany
Phone +49 (0) 631 205 2270
axel.pelster@physik.uni-kl.de
College Coordinator:
Prof. Dr. Sebastian Eggert
Physics Department, Technische Universität Kaiserslautern, Germany
Phone +49 (0) 631 205 2375
eggert@physik.uni-kl.de

Introduction

Summer School 2012

sponsored by

Collaborative Research Center SFB/TR49

Condensed matter with strong many-body interactions is characterized by unusual, at times novel collective behaviour, which cannot be understood by the properties of its individual constituents. These strongly correlated systems normally show a high degree of complexity resulting from the interplay of several degrees of freedom (charge, spin and angular momentum) and their coupling to the ion lattice.

Within the framework of the Collaborative Research Center SFB/TR49 **Condensed Matter Systems with Variable Many-Body Interactions**, which is funded since 2007 by the German Research Foundation (DFG), the collective behaviour of interacting many-body systems is investigated on a broad phenomenological context. The topics embrace cooperative phenomena such as the Mott metal-insulator transition, superconducting/superfluid phases with strong interactions or Bose-Einstein condensation under various and sometimes extreme conditions. Besides the properties of the ground state, excitations and exchange processes, also containing dynamical aspects of correlations and coherence, are investigated in the SFB/TR49.

Further information about the Collaborative Research Center SFB/TR49 is available at its homepage

http://www.tr49.de

College for the Advancement of Postgraduate Education in the SFB/TR49

The researchers of the SFB/TR49 strive for two principle goals: The production of internationally first-class research results and the education of qualified experts and scientists of many-body interactions in condensed matter physics, both of which are equally important responsibilities towards society. It is a universally accepted truth that these two areas, research and postgraduate education, go hand in hand. Success in one area also requires excellence in the other and vice versa.

The College for the Advancement of Postgraduate Education is an integrated graduate school with the primary intention of improving and furthering the education of young researchers affiliated with the research projects of the Transregio. The College keeps high academic standards and strives for an optimal graduation time of three years for PhD candidates. To this end, the College will provide training opportunities, guidance, and a pleasant networking environment in order to assist the research progress of doctoral students towards graduation without delays. The College assists members in acquiring a variety of other skills that are expected from doctoral candidates on their way to becoming a self-reliant researcher, who not only excels in science, but is also ready to fill the position of a leading, responsible and independent scientist as demanded in all parts of society. The College offers many customized and transregional training opportunities, such as workshops, seminars, soft skill courses, lecture series, exchanges, books, excursions, information services, and - last but not least - personal career development and guidance.

Further information about the College for the Advancement of Postgraduate Education is available at its homepage

http://lucky.physik.uni-kl.de/~tr49/mgk

Summer School 2012
Low-Dimensional Quantum Many-Body Systems

Building on the success of various educational activities within the College for the Advancement of Postgraduate Studies, we now organize for the first time an international summer school which is geared towards specific topics in methods and research for students. The summer school is open for international registration and the lectures will be given by invited experts. The topic of the first summer school 2012 is **Low-Dimensional Quantum Many-Body Systems**, which contains many research fields of the SFB/TR49 and is, therefore, of central importance.

Low-dimensional many-body quantum systems reveal peculiar properties as quantum effects are enhanced in less than three spatial dimensions. Both experimental and theoretical experts will provide overview and introductory talks on various selected special topics. Particular emphasis will be devoted to a detailed discussion of the Tonks-Girardeau gas in 1d and the Berezinski-Kosterlitz-Thouless phase transition in 2d. Furthermore, the recent realization of the low-dimensional Anderson localization of ultracold atoms in both laser speckle disorder potential and incommensurate optical lattices will also be discussed. Finally, we also address the delicate evolution from BCS to Bose superfluidity in two dimensions both without and with spin-orbit and Zeeman fields.

Scientific Organization:

Priv.-Doz. Dr. Axel Pelster
Technische Universität Kaiserslautern
Germany
Phone +49 (0) 631 205 2270
Email *axel.pelster@physik.uni-kl.de*

Dr. Andreas Kreisel
University of Florida
United States of America
Phone +1 (352) 392 8756
Email *kreisel@itp.uni-frankfurt.de*

Prof. Dr. Sebastian Eggert
Technische Universität Kaiserslautern
Germany
Phone +49 (0) 631 205 2375
Email *eggert@physik.uni-kl.de*

Venue:

Hotel Deutscher Hof
Südallee 25
54290 Trier
Germany

Phone: +49 (0) 651 9778 0
Fax: +49 (0) 651 9778 400
Email: *info@hotel-deutscher-hof.de*
Internet: *http://www.hotel-deutscher-hof.de/default.asp?site=1&lang=en*

Registration

at the Conference Room, Thursday (18.00—19.00)

WLAN

consult hotel reception

Program

Trier Summer School 2012

Low-Dimensional Quantum Many-Body Systems

Thursday, August 16

until 18:00	***Arrivals, Registration***
19:00	***Dinner***
after dinner	***Socializing, Discussions***

Friday, August 17

until 8:30	***Breakfast***
9:00-9:15	**Opening**
9:15-10:45	**David Thouless (Seattle – United States of America):** Why are lower dimensions interesting?
10:45-11:15	***Coffee Break***
11:15-12:45	**Manfred Mark (Innsbruck – Austria):** Tunable quantum gases in one-dimensional confinement: Introduction
12:45-14:00	***Lunch***
14:00-15:30	**Manfred Mark (Innsbruck – Austria):** Tunable quantum gases in one-dimensional confinement: Tonks- and Super-Tonks-Girardeau Gases

15:30-16:00	***Coffee Break***
16:00-17:00	**Poster Flash Presentations**
19:00	***Dinner***
after dinner	**Poster Session I**

Saturday, August 18

until 8:30	***Breakfast***
9:00-10:30	**Gregory Astrakharchik (Barcelona – Spain):** Tonks-Girardeau and Super Tonks-Girardeau Gases
10:30-11:00	***Coffee break***
11:00-12:30	**David Thouless (Seattle – United States of America):** Berezinski-Kosterlitz-Thouless Transitions: Early Developments in the Theory
12:30-14:00	***Lunch***
14:00-15:30	**Gregory Astrakharchik (Barcelona – Spain):** Dipolar and Coulomb One-Dimensional Gases
15:30-16:00	***Coffee break***
16:00-17:30	**Poster Session II**
19:00	***Dinner***
after dinner	***Socializing, Discussions***

Sunday, August 19

until 8:30	***Breakfast***
9:00-10:30	**David Thouless (Seattle – United States of America):**
	Berezinski-Kosterlitz-Thouless Transitions:
	Scaling Theory, Surface Roughening, and Other Developments
10:30-11:00	***Coffee break***
11:00-12:30	**Laurent Sanchez-Palencia (Paris – France):**
	Speckle Disorder, Incommensurate Lattices, and Anderson Localization in One Dimension
12:30-14:00	***Lunch***
14:00-18:00	***Excursion***
19:00	***Dinner***
after dinner	***Socializing, Discussions***

Monday, August 20

until 8:30	***Breakfast***
9:00-10:30	**Laurent Sanchez-Palencia (Paris – France):**
	Anderson Localization in Two- and Three-Dimensional Anisotropic Disorder
10:30-11:00	***Coffee break***
11:00-12:30	**Carlos Sa de Melo (Atlanta – USA):**
	Ultra-cold fermions in the flatland: evolution from BCS to Bose superfluidity in two-dimensions without spin-orbit or Zeeman fields

12:30-14:00	***Lunch***
14:00-15:30	**Laurent Sanchez-Palencia (Paris – France):** Disorder and Interactions in Quantum Gases
15:30-16:00	***Coffee break***
16:00-17:30	**Carlos Sa de Melo (Atlanta – USA):** Ultra-cold fermions in the flatland: evolution from BCS to Bose superfluidity in two-dimensions with spin-orbit and Zeeman fields
17:30-17:45	**Closing**
19:00	***Dinner***
after dinner	***Socializing, Discussions***

Tuesday, August 21

until 9:00	***Breakfast***
after Breakfast	***Departure***

Abstracts of Invited Talks

Lieb-Liniger, Tonks-Girardeau and Super Tonks-Girardeau Gases

Gregory E. Astrakharchik

Departament de Fisica i Enginyeria Nuclear, Campus Nord B4,
Universitat Politecnica de Catalunya, E-08034 Barcelona, Spain
E-mail: astrakharchik@mail.ru

An overview of models describing one-dimensional Bose gases in different physical regimes is presented. Short-range interactions are modeled by a delta-function contact potential (Lieb-Liniger Hamiltonian). This many-body problem is exactly solvable by Bethe *ansatz* method which provides an exact value of the ground-state energy. Depending on the density and the value of s-wave scattering length, the system experiences a crossover from a weakly correlated (mean-field Gross-Pitaevskii) regime to a strongly correlated (Tonks-Girardeau) regime.

In the limit of an infinite strength of the coupling constant (Tonks-Girardeau gas), the wave function of strongly repulsive bosons can be mapped to the wave function of an ideal Fermi gas (Girardeau mapping). The energy and local properties are the same in both systems while non-local quantities (momentum distribution, etc.) are different.

A regime with even stronger correlations (super Tonks-Girardeau gas) can be reached by rapidly crossing the confinement-induced Olshanii resonance, realizing a metastable gas-like state of bosons interacting with large attractive coupling constant. This regime is characterized by an equation of state similar to that of hard-rod gas. A harmonically trapped system possesses a larger breathing mode compared to Tonks-Girardeau gas.

Dipolar and Coulomb One-Dimensional Gases

Gregory E. Astrakharchik

Departament de Fisica i Enginyeria Nuclear, Campus Nord B4,
Universitat Politecnica de Catalunya, E-08034 Barcelona, Spain
E-mail: astrakharchik@mail.ru

Repulsive dipolar and Coulomb gases are considered in one-dimensional geometry. Many-body wave function vanishes when two particles meet each other. This permits to use Girardeau mapping between the wave function of bosons and fermions interacting with the same potential. In the case of dipolar interaction the low-lying excitations are phonons and the long-range properties of the correlation functions are described by Luttinger liquid theory. In the limit of large density a quasi-crystal is formed. In the case of Coulomb gas the low-lying excitations are plasmons. The regime of a Wigner quasi-crystal corresponds to low density. In both dipolar and Coulomb gases there is a crossover between Tonks-Girardeau gas and a quasi-crystal regime as the density or interaction strength are changed.

Tunable Quantum Gases in One-Dimensional Confinement: Introduction

Manfred Mark and **Hanns-Christoph Nägerl**

Institute for Experimental Physics, Universität Innsbruck, Austria
E-mail: christoph.naegerl@uibk.ac.at

Ultracold atomic gases are ideal for investigating the properties of low-dimensional quantum many-body systems as all the relevant parameters can be well controlled and unwanted external perturbations can be kept at a minimum. In particular, the strength of the interparticle interaction can be tuned near scattering resonances, near so-called confinement-induced resonances. I will introduce the basic experimental techniques how to prepare, control, and detect specific many-body states for an ensemble of ultracold bosons in one-dimensional geometry. In particular, I will discuss scattering and possible loss processes that occur in confined dimensions.

Tunable Quantum Gases in One-Dimensional Confinement: Tonks- and Super-Tonks-Girardeau Gases

Manfred Mark and Hanns-Christoph Nägerl

Institute for Experimental Physics, Universität Innsbruck, Austria
E-mail: christoph.naegerl@uibk.ac.at

For atoms in one-dimensional geometry, the strongly-interacting limits of the Tonks-Girardeau and super-Tonks-Girardeau gases can be realized near scattering resonances. I will discuss the experimental signatures of these states and ask the question what will be the effect of an additional lattice potential along the longitudinal direction. I will give an outlook on ongoing and future work with atoms in one-dimensional geometry, in particular in view of new imaging capabilities, in view of introducing defects and disorder in a controlled way, and the possibility to realize interactions that are long-range.

Ultra-cold fermions in the flatland: evolution from BCS to Bose superfluidity in two-dimensions without spin-orbit or Zeeman fields

Carlos A. R. Sa de Melo

School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332, USA
E-mail: carlos.sademelo@physics.gatech.edu

I discuss the evolution from BCS to Bose superfluidity for ultracold fermions in two-dimensions with s-wave pairing, where the effective interaction can be experimentally tuned. The evolution from BCS to Bose superfluidity exhibits a crossover at zero temperature and close to the critical temperature for superfluidity. The transition between the normal and the superfluid phase is of the BKT type, with the emergence of vortex-antivortex pairs, and a possible phase transition into a square vortex-anti-vortex lattice may occur at lower temperatures. At zero temperature, I describe a few spectroscopic quantities such as excitation spectrum and momentum distribution, and some thermodynamic properties including pressure and compressibility. Lastly, I emphasize the possibility of realizing such phases experimentally in two-dimensional traps of ultracold Fermi atoms.

References

[1] R. D. Duncan and C. A. R. Sá de Melo, Phys. Rev. B **62**, 9675 (2000)
[2] S. S. Botelho and C. A. R. Sá de Melo, arXiv:cond-mat/0409357
[3] S. S. Botelho and C. A. R. Sá de Melo, J. Low Temp. Phys. **140**, 409 (2005)
[4] S. S. Botelho and C. A. R. Sá de Melo, Phys. Rev. Lett. **96**, 040404 (2006)

Ultra-cold fermions in the flatland: evolution from BCS to Bose superfluidity in two-dimensions with spin-orbit and Zeeman fields

Carlos A. R. Sa de Melo

School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332, USA
E-mail: carlos.sademelo@physics.gatech.edu

I discuss the evolution from BCS to Bose superfluidity for ultracold fermions in two-dimensions and in the presence of simultaneous spin-orbit and Zeeman fields. I emphasize the possibility of realizing such phases experimentally in two-dimensional traps of ultracold Fermi atoms. In such two-dimensional systems, several quantum phase transitions may occur by varying interactions, spin-orbit or Zeeman fields leading to topological phase transitions between various superfluid phases. I describe spectroscopic quantities such as excitation spectrum, momentum distribution, spectral function and density of states and, in addition, I construct topological invariants for each of the superfluid phases. Lastly, I analyze several thermodynamic properties to characterize different superfluid phases including pressure, compressibility, induced polarization, and spin susceptibility.

References

[1] L. Han and C. A. R. Sá de Melo, Phys. Rev A **85**, 011606(R) (2012)
[2] K. Seo, L. Han and C. A. R. Sá de Melo, Phys. Rev. A **85**, 033601 (2012)
[3] K. Seo, L. Han and C. A. R. Sá de Melo, Phys. Rev. Lett. **109** (in press)
[4] L. Han and C. A. R. Sá de Melo, arXiv:1206.4984

Ultracold Quantum Gases in Controlled Disorder

Laurent Sanchez-Palencia

Laboratoire Charles Fabry, Institut d'Optique – CNRS – Univ Paris sud 11,
2 avenue Augustin Fresnel, F-91127 Palaiseau, France
E-mail: lsp@institutoptique.fr

The physics of disordered systems is attracting a growing interest within the field of ultracold quantum gases [1-3]. On one hand, ultracold atoms represent a formidable testbed for theory, providing well-controlled systems where almost all parameters are known *ab initio* and tunable, hence realizing so-called *quantum simulators*. Following this idea in the context of disordered systems, landmark results have been reported within the very last years, for instance direct observation of Anderson localization of matter waves in one [4,5] and three dimensions [6-7], as well as studies of the complex interplay of disorder and interactions [8-10]. On the other hand, ultracold atoms can introduce new ingredients in microscopic models that can modify usual pictures, for instance due to inhomogeneous trapping [11] or peculiar disorder correlations [12-17].

In this series of lectures, recent progress and open questions within the field of disordered quantum gases will be reviewed, from both theoretical and experimental perspectives. The first lecture will be devoted to an overview of standard techniques to realize controlled disorder for ultracold atoms [18,19], and of one-dimensional Anderson localization in speckle potentials [4,12-14,20] and bi-chromatic optical lattices [5,19]. The second lecture will discuss how Anderson localization extends to higher-dimensional geometries [15,21,22], where the physical picture is significantly more involved. Particular attention will be paid to the case of anisotropic three-dimensional speckle potentials [6,7,16,23]. The last lecture will finally introduce superfluid-insulator transitions in disordered, interacting Bose gases [24,25], many-body localization [26,27], and current experimental developments.

References

[1] L. Sanchez-Palencia and M. Lewenstein, *Disordered quantum gases under control*, Nat. Phys. **6**, 87 (2010).
[2] L. Fallani, C. Fort, and M. Inguscio, *Bose-Einstein condensates in disordered potentials*, Adv. At. Mol. Opt. Phys. **56**, 119 (2008).
[3] Boris Shapiro, *Cold atoms in the presence of disorder*, J. Phys. A: Math. Theor. **45**, 143001 (2012).
[4] J. Billy *et al.*, *Direct observation of Anderson localization of matter-waves in a controlled disorder*, Nature **453**, 891§ (2008).
[5] G. Roati *et al.*, *Anderson localization of a non-interacting Bose-Einstein condensate*, Nature **453**, 895 (2008).
[6] S.S. Kondov, W.R. McGehee, J.J. Zirbel, and B. DeMarco, *Three-dimensional Anderson localization of ultracold fermionic matter*, Science **334**, 66 (2011).

[7] F. Jendrzejewski *et al.*, *Three-dimensional localization of ultracold atoms in an optical disordered potential*, Nat. Phys. **8**, 398 (2012).

[8] L. Fallani *et al.*, *Ultracold atoms in a disordered crystal of light: Towards a Bose glass*, Phys. Rev. Lett. **98**, 130404 (2007).

[9] M. White *et al.*, *Strongly interacting bosons in a disordered optical lattice*, Phys. Rev. Lett. **102**, 055301 (2009).

[10] M. Pasienski, D. McKay, M. White, and B. DeMarco, *A disordered insulator in an optical lattice*, Nat. Phys. **6**, 677 (2010).

[11] L. Pezzé and L. Sanchez-Palencia, *Localized and extended states in a disordered trap*, Phys. Rev. Lett. **106**, 040601 (2011).

[12] L. Sanchez-Palencia *et al.*, *Anderson localization of expanding Bose-Einstein condensates in random potentials*, Phys. Rev. Lett. **98**, 210401 (2007).

[13] E. Gurevich and O. Kenneth, *Lyapunov exponent for the laser speckle potential: A weak disorder expansion*, Phys. Rev. A **79**, 063617 (2009).

[14] P. Lugan *et al.*, *One-dimensional Anderson localization in certain correlated random potentials*, Phys. Rev. A **80**, 023605 (2009).

[15] R.C. Kuhn, O. Sigwarth, C. Miniatura, D. Delande, and C. A. Müller, *Coherent matter wave transport in speckle potentials*, New J. Phys. **9**, 161 (2007).

[16] M. Piraud, L. Pezzé, and L. Sanchez-Palencia, *Matter wave transport and Anderson localization in anisotropic three-dimensional disorder*, Europhys. Lett. i*n press* (2012); arXiv:1112.2859.

[17] M. Piraud, A. Aspect, and L. Sanchez-Palencia, *Anderson localization of matter waves in tailored disordered potentials*, Phys. Rev. A **85**, 063611 (2012).

[18] D. Clément *et al.*, *Experimental study of the transport of coherent interacting matter-waves in a 1D random potential induced by laser speckle*, New J. Phys. **8**, 165 (2006).

[19] G. Modugno, *Anderson localization in Bose-Einstein condensates*, Rep. Prog. Phys **73**, 102401 (2010).

[20] M. Piraud *et al.*, *Localization of a matter wave packet in a disordered potential*, Phys. Rev. A **83**, 031603(R) (2011),

[21] S.E. Skipetrov *et al.*, *Anderson localization of a Bose-Einstein condensate in a 3D random potential*, Phys. Rev. Lett. **100**, 165301 (2008).

[22] A. Yedjour and B. van Tiggelen, *Diffusion and localization of cold atoms in 3D optical speckle*, Eur. Phys. J. D **59**, 249 (2010).

[23] P. Wölfle and R.N. Bhatt, *Electron localization in anisotropic systems*, Phys. Rev. B **30**, 3542 (1984).

[24] T. Giamarchi and H.J. Schulz, *Anderson localization and interactions in one-dimensional metals*, Phys. Rev. B **37**, 325 (1988).

[25] M.P.A. Fisher, P.B. Weichman, G. Grinstein, and D.S. Fisher, *Boson localization and the superfluid-insulator transition*, Phys. Rev. B **40**, 546 (1989).

[26] P. Lugan *et al.*, *Anderson localization of Bogolyubov quasiparticles in interacting Bose-Einstein condensates*, Phys. Rev. Lett. **99**, 180402 (2007).

[27] I.L. Aleiner *et al.*, *A finite-temperature phase transition for disordered weakly interacting bosons in one dimension*, Nat. Phys. **6**, 900 (2010).

Why are lower dimensions interesting?

D. J. Thouless

Univ. of Washington, Box 351560, Seattle, WA 98195, U.S.A.

E-mail: thouless@u.washington.edu

Two early, frequently quoted, papers on one-dimensional systems are Ising's paper on a chain of classical spins in one dimension [1], and Bethe's paper on a chain of quantum spins [2]. Ising's argument was simple, Bethe's subtle, but Onsager's solution of the two-dimensional Ising model combined features of both [3]. Sceptics thought that low-dimensional systems were uninteresting, because real materials live in a three-dimensional world. Singular behavior of the specific heat and related quantities was a feature of much earlier experimental results which had often been ignored. Around 1960 both experimenters, using careful analysis of measurements, and theorists, analysing high temperature and low field expansions of simple models, turned to a serious empirical study of the neighborhoods of critical points. It emerged that there was a limited number of universality classes, each with characteristic values of the critical exponents. Gas-liquid critical points share a universality class with the three-dimensional Ising model. The exponents for the two dimensional Ising model were found for adsorbates on suitable substrates, and experimental results are close to calculated values. A sample with rectangular faces behaves two-dimensionally when the temperature is such that the correlation length is long compared with the thickness, but short compared with the width and breadth. Another reason is that most electronic devices made in the past fifty years are based on transistors in which the electrons are trapped on a plane interface.

References

[1] E. Ising, Z. Phys. **31**, 253 (1925)
[2] H. A. Bethe, Z. Phys. **71**, 205 (1931)
[3] L. Onsager, Phys. Rev. **65**, 117 (1944)

Theory of BKT transitions: early work

D. J. Thouless

Univ. of Washington, Box 351560, Seattle, WA 98195, U.S.A.

E-mail: thouless@u.washington.edu

The idea that topological defects might drive phase transitions in superfluids or solids goes back more than sixty years. My first reintroduction to this idea came in 1969 when Anderson asked me about the one-dimensional Ising model with a $1/r^2$ interaction between spins, which had come up in his work on the Kondo effect. This problem could be represented in terms of an interaction between domain walls that depended logarithmically on the distance between them. My eventual answer was that this should lead to an odd sort of phase transition in which the energy was a continuous function of temperature, but the magnetization jumped from a nonzero value to zero at the transition [1]. A rigorous version of this result was obtained by Fröhlich and Spencer [2]. Two years later Kosterlitz and I realized that the logarithmic interaction between positive and negative vortices in thin liquid helium films led to a transition between a superfluid film with nonzero superfluid density and no free vortices, and a normal film with free, unpaired vortices [3], which would lead to dissipation proportional to the shear rate of the fluid. We soon learned that Berezinskii [4] had anticipated our discovery by a year or so. We attempted to build a scaling theory of such transitions, which was achieved by Kosterlitz in 1974, when he was at Cornell University [5]. Again, Fröhlich and Spencer [6] obtained a rigorous version of this theory.

References

[1] D. J. Thouless, Phys. Rev. **187**, 732 (1969)
[2] J. Fröhlich and T. Spencer, Commun. Math. Phys. **84**, 87 (1982)
[3] J. M. Kosterlitz and D. J. Thouless, J. Phys. C **5**, L125 (1972)
[4] V. L. Berezinskii, Zh. Eksp. Teor. Fiz. **61**, 1144 (1971)
[5] J. M. Kosterlitz, J. Phys. C **7**, 1046 (1974)
[6] J. Fröhlich and T. Spencer, Phys. Rev. Lett. **46**,1006 (1981)

Theory of BKT transitions: later developments

D. J. Thouless

Univ. of Washington, Box 351560, Seattle, WA 98195, U.S.A.

E-mail: thouless@u.washington.edu

Phase transitions in two dimensions driven by thermal excitation of topological defects, such as the superfluid transition in helium films, proved to be theoretically tractable. They also promised to have a striking experimental signature, an abrupt change in superfluid density, whose magnitude was proportional to the transition temperature, with no adjustable constants [1,2]. Such an effect had been seen, but its unexpected appearance led the experimenters to reanalyze their data, and the effect disappeared. Careful work to detect such an effect was undertaken by Bishop and Reppy [3], who oscillated a Mylar film with a liquid helium coating, and measured how much normal fluid moved with the substrate, and how much superfluid was left behind. The theoretical work of Ambegaokar et al [4] was vital for interpreting these measurements in terms of an abrupt change in superfluid density at the “continuous phase transition”.

We had written about some other applications of the theory in two dimensions, including melting, the planar spin model of magnetism, and a classical atomic gas to plasma transition. At about the same time as the theory was shown to be relevant to real systems, it was found by Halperin and Nelson [5] that the melting transition is not a single transition, but goes by two stages, losing first rigidity and then losing crystalline order. We argued that there would not be such a transition in superconductors, but Beasley et al. showed why we were wrong [7]. In 1976 Chui and Weeks [6] found that the roughening of a facet of a three-dimensional crystal was a phase transition in the same class as the superfluid to normal transition in a helium film. This was a surprise, because the obvious representation of the facet free energy does not make this apparent, and a further change of variables is required to show it.

References

[1] D. R. Nelson and J. M. Kosterlitz, Phys. Rev. Lett. **39**,1201 (1977)
[2] J. V. Jose *et al.*, Phys. Rev. B **16**, 1217 (1977)
[3] D. J. Bishop and J. D. Reppy, Phys. Rev. Lett. **40**,1727 (1978)
[4] V. Ambegaokar *et al.*, Phys. Rev. Lett. **40**,783 (1978)
[5] V. I. Halperin and D. R. Nelson, Phys. Rev. Lett. **41**,121 (1978)
[6] S. T. Chui and J. D. Weeks, Phys. Rev. B **14**, 4978 (1976)
[7] M. R. Beasley *et al.*, Phys. Rev. Lett. **42**,1165 (1979)

Abstracts
of Posters

Evolution of Bose-Einstein Condensates in a Gravitational Cavity

Javed Akram[1] and **Axel Pelster[2]**

[1]Fachbereich Physik, Freie Universität Berlin, Germany
[2] Fachbereich Physik, Technische Universität Kaiserslautern, Germany
E-mail: jvdakramqau@gmail.com

We investigate both the static and dynamic properties of weakly interacting Bose-Einstein condensates (BEC) in an one-dimensional gravitational cavity. There the effect of gravity is compensated by an exponentially decaying potential, which is created by the total internal reflection of an incident laser beam from the surface of a dielectric serving as a mirror for the atoms. By solving the underlying Gross-Pitaevskii equation with a variational Gaussian condensate wave function, we derive a coupled set of differential equations for the width and the height of the condensate. By considering small deflections around the respective equilibrium positions, we determine the collective excitations of the BEC. Furthermore, we analyze how the BEC cloud expands ballistically due to gravity after switching off the evanescent laser field.

Non-equilibrium dynamics in the 1-D Bose-Hubbard model

Felix Andraschko

Fachbereich Physik, Technische Universität Kaiserslautern, Germany
E-mail: felix.andraschko@googlemail.com

We study the spreading of local impurities inserted into Bose-Hubbard chains in the ground state or following a quantum quench. By considering different interaction strengths, we draw a connection between the weakly interacting regime, in which the dynamics are dominated by free boson-like behaviour, and the large-U regime, in which the impurities can be well described by a model of free fermionic quasiparticles. Making use of the Lieb-Robinson bound, we are able to perform numerical simulations in the thermodynamic limit using a Lightcone Renormalization algorithm based on corner transfer matrices.

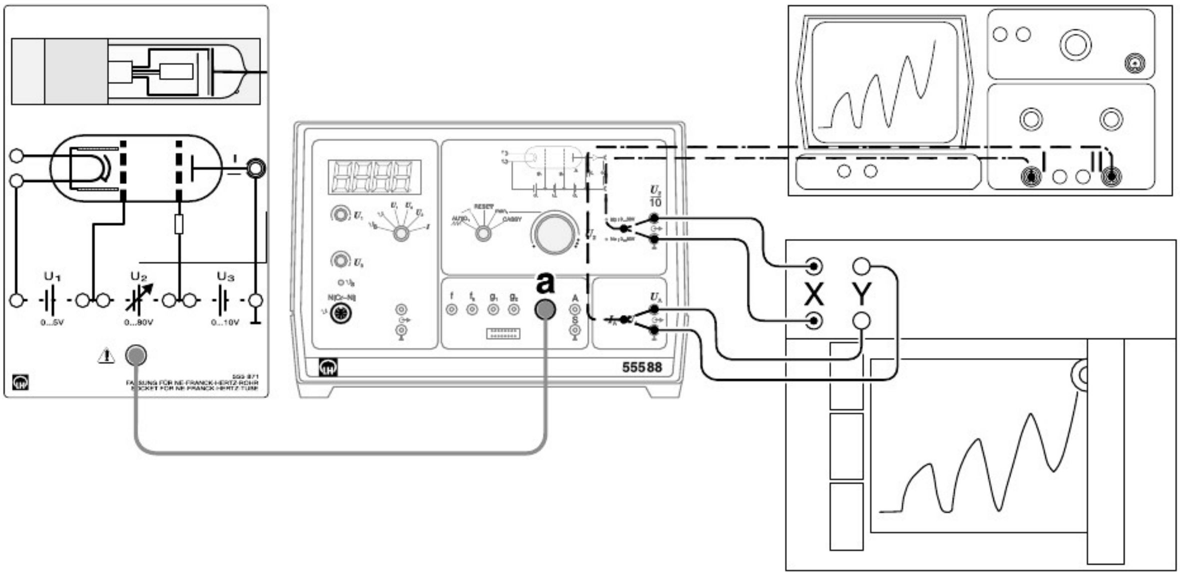
Frank-Hertz Experiment with Neon

Ahmad Ata Atiyha

Bethlehem University, West Bank, Palestine
E-mail: aatiyha@bethlehem.edu

Atomic spectra are not the only means of investigating the presence of discrete energy levels within atoms. In 1914, James Frank and Gustav Hertz performed an important experiment which supported Bohr's quantum theory of the atom (Nobel Prize 1926). They provided the same evidence as the investigation of line spectra. The experiment of Frank and Hertz shows clearly that the energy of the atom is quantized and that an atom can have energies of certain well-defined values. This experiment provides direct proof for the truth of the concepts of quantum theory.

In the present experiment, the method of Frank and Hertz will be applied to Neon. In this experiment, the energy loss of free electrons through inelastic scattering from neon atoms is investigated. Most probably the excitation occurs from the ground state to the ten 3p states, which are 18.4 eV and 19.0 eV above the ground state.



Two Particle Pair Distribution Function of Trapped Quantum Gases

Renu Bala[1], Niranjan Myneni[1 *], J.Bosse[2] and K. N. Pathak[1]

[1]Centre for Advanced Study in Physics, Panjab University, Chandigarh, India
[2] Institute for Theoretical Physics, Freie University, Berlin, Germany
E-mail: pathak@pu.ac.in

We obtain the expression for two particle pair distribution function for weakly interacting quantum gases using a variant of quantum BBGKY equation. The expression is valid for all temperatures for Fermi gas and above condensation temperature for Bose gas. Below the condensation temperature, expression for Bose gas is also obtained but it is lengthy. Some numerical results will be presented for one and two particle distribution function.

---

* Student visitor from University of Hyderabad, India.

Emergence of Alternative Crossover Routes In BCS-BEC Crossover

Raka Dasgupta

S.N. Bose National Centre for Basic Sciences, Kolkata, India
E-mail: dasguptaraka@gmail.com

We investigate the BCS-BEC crossover picture taking into account the additional scattering between the Cooper pairs and the newly formed bosons near the resonance, which essentially is a three-body process. We show that it leads to alternative crossover routes, and brings out interesting properties of the crossover phenomenon. Most noteworthy of them is the nonreversibility of the process. If the two-body interaction is attractive, starting from a stable Bose-Einstein condensate (BEC) state, crossover to BCS can be achieved; but if the BCS state is the starting point, instead of a stable BEC region, what the system crosses over to is a metastable condensed state.

References

[1] R. Dasgupta, Phys. Rev. A **82**, 063607 (2010)

Mean-Field Theory for Extended Bose-Hubbard Model with Hard-Core Bosons

Nicolas Gheeraert[1], Shai Chester [2], S. Eggert[3] , and A. Pelster[3]

[1]Institute of Theoretical Physics, University of Edinburgh, UK
[2]Physics Department, Columbia University, USA
[3]Fachbereich Physik, Technische Universität Kaiserslautern, Germany
E-mail: axel.pelster@physik.uni-kl.de

In this work we solve the extended Bose-Hubbard Model with hard-core bosons within mean-field theory for both a quadratic and triangular lattice. To this end the nearest neighbor terms involving both interaction and hopping are factorized into a mean field and an operator [1]. In this way, we obtain a natural divison of the lattice into sublattices, yielding a much simpler two- or three-site mean-field Hamiltonian for the quadratic and triangular lattice, respectively. An additional on-site hard-core interaction allows each site to be occupied by at most one boson, thus the two- or three-site mean-field Hamiltonian reduces to a 4x4- or 8x8-matrix. The resulting energy eigenvalues have to be extremized with respect to the order parameters, which represent the condensate density and the average number of particles for each of the sublattices. As a result we obtain a mean-field phase diagram, which consists of a Mott insulator phase, a density wave phase, a superfluid phase and, for the triangular lattice, also of a supersolid phase. Furthermore, we determine whether the respective transition lines in the phase diagram are of first or second order. Finally, we follow Ref. [2] and investigate how quantum corrections affect the mean-field results within a field-theoretic motivated variational approach, thus reducing the errors in comparison with quantum Monte Carlo simulations [3].

References

[1] J. M. Kurdestany, R. V. Pai, and R. Pandit, *Ann. Phys. (Berlin)* **524**, 234 (2012)
[2] F. E. A. dos Santos and A. Pelster, *Phys. Rev. A* **79**, 013614 (2009)
[3] X.-F. Zhang, R. Dillenschneider, Y. Yu, and S. Eggert, *Phys. Rev. B* **84**, 174515 (2011)

Numerical Solutions of Gross-Pitaevskii equation for a disordered Bose condensed gas

Tama Khellil[1], Antun Balaž[2], and Axel Pelster[3]

[1]Physics Department, Freie Universität Berlin, Germany
[2] SCL, Institute of Physics Belgrade, University of Belgrade, Serbia
[3] Physics Department, Technische Universität Kaiserslautern, Germany
E-mail: khellil@zedat.fu-berlin.de

We present a numerical study of a Bose-condensed gas in a harmonic trapping potential and a Gaussian-distributed disorder potential in one dimension at zero temperature. The underlying Gross-Pitaevskii equation for the condensate wave function represents a nonlinear, partial differential equation and is difficult to solve exactly. Using a computer program [1] that solves the time-independent Gross-Pitaevskii equation in one space dimension in a harmonic trap using the imaginary-time propagation, we are able to obtain its numerical solution for each realization of the disorder potential. Performing disorder ensemble averages we have access to both the condensate density and to the density of disconnected local mini-condensates in the respective minima of the disorder potential [2]. Our study is performed for different values of the disorder strength and the correlation length of the disorder, so that we can study the influence of both of them on the numerical solutions. For small disorder strengths we reproduce the seminal results of Huang and Meng for a Bogoliubov theory of dirty bosons [3,4].

References

[1] D. Vudragović, I. Vidanović, A. Balaž, P. Muruganandam, and S. Adikari, Comput. Phys. Commun. **183**, 2021 (2012)
[2] R. Graham and A. Pelster, Int. J. Bif. Chaos **19**, 2745 (2009)
[3] G. M. Falco, A. Pelster, and R. Graham, Phys. Rev. **75**, 063619 (2007)
[4] G. M. Falco, A. Pelster, and R. Graham, Phys. Rev. **76**, 013624 (2007)

Rare gas clusters at ultra low energies

Olga P. Klimenko and **E.A. Kolganova**

University «Dubna» and BLTP, JINR, 141980 Dubna, Moscow region, Russia

E-mail: klimenko@theor.jinr.ru

Investigations of the rare gas clusters are of a great interest for various branches of physical chemistry and molecular physics. For instance, investigations of ^{4}He dimers and trimers is an important step towards understanding the properties of liquid helium droplets and the superfluidity in ^{4}He films, see, e.g., the papers [1, 2]. Great interest in the properties of clusters containing several atoms is born by the tremendous activity in the research on the Bose-Einstein condensation in ultracold gases, see, e.g., the papers [3, 4]. The quantum few-body problem is important for investigating physical processes at practically all possible length and energy scales. The present work is devoted to studying Neon and Helium dimers by numerical solution of the Shrödinger equation. The TTY [5], TT [6] and AVZ5 [7] potentials are used as atom-atom interaction models. The dimers binding energies, scattering length and effective range for ^{20}Ne and ^{4}He are calculated.

References

[1] S. Grebenev, J.P. Toennies, and A.F Vilesov, Science **279**, 2083 (1998)
[2] K.K. Lehman and G. Scoles, Science 279, 2065 (1998)
[3] F. Dalfovo, S. Giorgini, L.P. Pitaevskii, and S. Stringari, Rev. Mod. Phys. **71**, 463 (1999).
[4] T. Köhler, T. Gasenzer, P.S. Julienne, and K. Burnett, Phys. Rev. Lett. **91**, 230 401 (2003).
[5] K.T. Tang, J.P. Toennies, C.L. Yiu, Phys. Rev. Lett. **74**,1546 (1995)
[6] K.T. Tang, J.P. Toennies, J. Chem. Phys. **118**, 4976 (2003)
[7] S.M. Cybulski, R.R. Toczyłowski, J.Chem.Phys. **111**, 10520 (1999)

Two-Particle Resonances in Open Systems

Arkadiusz Kuros

Physics Department, Jan Kochanowski University, Kielce, Poland
E-mail: akuros@ujk.edu.pl

We consider a quasi one-dimensional system composed of two Coulombically interacting electrons confined in a Gaussian trap. Apart from bound states, such a system exhibits resonances that are related to the ionization process. We determine the resonance widths and energies within the framework of the complex-coordinate rotation method. We investigate the effect of the control parameters on the binding properties of the two-particle system.

Quantum Monte Carlo Simulations in Low-Dimensional Many-Body Systems

Denis Morath and Sebastian Eggert

Physics Department, Technische Universität Kaiserslautern, Germany
E-mail: dmorath@physik.uni-kl.de

We are investigating the Hubbard-chain using Stochastic Series Expansion as well as analytical methods like bosonization. Here we present results for the density distribution of the 1D-Hubbard-model in a box and in a harmonic trap. This system is particularly interesting since it can be realized by ultra cold atoms in an optical lattice. In contrast to other numerical methods like DMRG it is possible to calculate the density distribution at finite temperatures. This way we can study the temperature dependence of the density distribution and predict below which temperatures it will be possible to resolve $2k_F$- and $4k_F$-oscillations experimentally. We were able to describe these oscillations in the density distribution by a bosonization approach.

Dipolar Bose-Einstein Condensates in Weak Anisotropic Disorder Potentials

B. Nikolic[1], A. Balaz[1], and A. Pelster[2]

[1]SCL, Institute of Physics, Pregrevica 118, Belgrade, Serbia
[2]Physics Department, Technische Universität Kaiserslautern, Germany
E-mail: branko@ipb.ac.rs

Here we examine in detail the properties of a homogeneous dipolar Bose-Einstein condensate in an anisotropic random potential with Lorentzian correlation at zero temperature. To this end we solve perturbatively the Gross-Pitaevskii equation up to second order in the random potential and obtain analytical results for the disorder ensemble averages of both the condensate and the superfluid depletion, the equation of state, and the sound velocity. For a pure contact interaction and a vanishing correlation length we reproduce the seminal results of Huang and Meng, which were originally derived within a Bogoliubov theory around a disorder averaged background field [1]. For dipolar interaction and isotropic Lorentzian disorder we obtain results which are qualitatively similar to the case of an isotropic Gaussian-correlated disorder [2]. In case of a general anisotropic Lorentzian correlated disorder all these quantities show characteristic anisotropies which arise from the formation of fragmented dipolar condensates in the minima of the anisotropic disorder potential.

References

[1] K. Huang and H. F. Meng, *Phys. Rev. Lett.* **69**, 644 (1992)
[2] C. Krumnow and A. Pelster, *Phys. Rev. A* **84**, 021608(R) (2011)

Stability analysis for Bose-Einstein condensates under parametric resonance

W. Cairncross[1] and A. Pelster[2]

[1]*Institut für Theoretische Physik, Freie Universität Berlin, Germany*
[2]*Physics Department, Technische Universität Kaiserslautern, Germany*
E-mail: axel.pelster@physik.uni-kl.de

We conduct a stability analysis for Bose-Einstein condensates (BECs) in a harmonic trap under parametric excitation by periodic modulation of the s-wave scattering length. We are motivated by the classical system of a parametrically driven pendulum, wherein an originally unstable equilibrium may be stabilized by parametric excitation. Following Ref. [1], we obtain equations of motion for the radial and axial widths of the condensate using a Gaussian variational ansatz for the Gross-Pitaevskii condensate wave function. Linearizing about the equilibrium positions, we obtain a system of coupled Mathieu equations, the stability of which has been studied extensively [2,3]. We carry out an analytic stability analysis for the Mathieu equations, and compare with numerical results for the nonlinear equations of motion. We find qualitative agreement between the Mathieu analytics and nonlinear numerics, and conclude that the previously unstable equilibrium of a BEC might be stabilized by parametric excitation.

References

[1] I. Vidanovic, A. Balaz, H. Al-Jibbouri, and A. Pelster, Physical Review A **84**, 013618 (2011)
[2] J. Slane and S. Tragesser, Nonlinear Dynamics and Systems Theory **11**, 183 (2011)
[3] J. Hansen, Archive of Applied Mechanics **55,** 463 (1985)

Beyond the Hubbard model: best effective single dressed band description of interacting atoms in optical lattices

Ulf Bissbort, Jan Pohlmann, Frank Deuretzbacher, and Walter Hofstetter

Institut für Theoretische Physik, Goethe Universität Frankfurt a.M., Germany
E-mail: janpohlmann@lepo.de

We construct the effective lowest-band Bose-Hubbard model incorporating interaction-induced on-site correlations. The model is based on ladder operators for local correlated states, which deviate from the usual Wannier creation and annihilation operators, allowing for a systematic construction of the most appropriate single-band low-energy description in form of the extended Bose-Hubbard model. A formulation of this model in terms of ladder operators not only naturally contains the previously found effective multi-body interactions, but also contains multi-body induced single particle tunneling, pair tunneling and nearest-neighbor interaction processes of higher orders. An alternative description of the same model can be formulated in terms of occupation-dependent Bose-Hubbard parameters. These multi-particle effects can be enhanced using Feshbach resonances, leading to corrections which are well within experimental reach and of significance to the phase diagram of ultracold bosonic atoms in an optical lattice. We analyze the energy reduction mechanism of interacting atoms on a local lattice site and show that this cannot be explained only by a spatial broadening of Wannier orbitals on a single particle level, which neglects correlations.

Momentum-dependent pseudogaps in the half-filled two-dimensional Hubbard model

Daniel Rost[1], E.V. Gorelik[1], F. Assad[2], and N. Blümer[1]

[1]*Institute of Physics, Johannes Gutenberg University Mainz, Germany*
[2] *Institute of Theoretical Physics and Astrophysics, University of Würzburg, Germany*
E-mail: rostda@uni-mainz.de

We compute unbiased spectral functions of the two-dimensional Hubbard model by extrapolating Green functions, obtained from determinantal quantum Monte Carlo simulations, to the thermodynamic and continuous time limits. Our results clearly resolve the pseudogap at weak to intermediate coupling, originating from a momentum selective opening of the charge gap. A characteristic pseudogap temperature T*, determined consistently from the spectra and from the momentum dependence of the imaginary-time Green functions, is found to match the dynamical mean-field critical temperature, below which antiferromagnetic fluctuations become dominant. Our results identify a regime where pseudogap physics is within reach of experiments with cold fermions in optical lattices.

Influence of spatially inhomogeneous atomic interactions on the dynamics of Bose-Einstein condensates in optical lattices

Golam Ali Sekh

Scientific Computing Laboratory, Institute of Physics Belgrade,
University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia
E-mail: skgolamali@ipb.ac.rs

We study dynamics of bright solitons in Bose-Einstein condensates under the influence of nonlinear impurity potential [1]. We use the effective potential approach from Ref. [2] to investigate interplay of optical lattices and nonlinear impurities in controlling the dynamics of bright solitons. We show that, similar to optical lattices, the nonlinear potential can also be used to move the solitons into or away from the impurity region. Finally, we examine a possibility for the existence of stable fundamental gap solitons by making use of the inverted Vakhitov-Kolokolov criterion [3].

References

[1] G. A. Sekh, Phys. Lett. A **376**, 1740 (2012)
[2] D. Anderson Phys. Rev. A **27**, 3135 (1983)
[3] E. A. Ostrovskaya and Y. S. Kivshar, Opt. Exp. **12**, 19 (2004)

Quantum phases of a spin 1/2 chain under competing influence of Dzyaloshinskii-Moriya (DM) interaction, exchange anisotropy and magnetic field

Daniel Sellmann and Sebastian Eggert

Physics Department, Universität Kaiserslautern, Germany
E-mail: sellmann@physik.uni-kl.de

We study a one-dimensional spin 1/2 chain under the joint influence of Dzyaloshinskii-Moriya (DM) interactions, symmetric exchange anisotropy and magnetic field perpendicular to the DM vector using Density Matrix Renormalization Group (DMRG). For weak DM interactions, the system can be treated perturbatively by field theoretical methods, i.e. bosonization and pertubative renormalization group. At zero temperature, the phase diagram is supposed to contain three phases:

(i) antiferromagnet with Neel vector in the plane spanned by the DM vector and the magnetic field;
(ii) dimerized antiferromagnet with Neel vector perpendicular to both the DM vector and the magnetic field;
(iii) gapless Luttinger liquid.

In particular the emergence of dimerization and neel order - typically competing phases - in one phase is somewhat peculiar and therefore of special interest. In a first step, these findings are to be confirmed numerically and in a second step we want to investigate the phase diagram beyond weak couplings.

The irreversibity and stability of quantum system in terms of classical limit-tricky for the situation mixed with chaos and regular

Wenjun Shi

Department of Physics and Electrical Engineering, Ningde Normal University, China
E-mail: shi_wenjun@yahoo.com

Recently the community of quantum chaos is developing a new idea to find the fingerprint of classical chaotic and regular dynamics in quantum mechanics, and the key point is to disturb the Hamiltonian rather than to disturb the initial state just done in the classical world. The manifestation of this idea is to use the internal product of quantum states with two different Hamiltonians (perturbative and non-perturbative) in terms of the same initial quantum state, thus we can study the decay behaviors of the modular of internal product with time increased. The research tool was firstly introduced by Peres with the name Loschmidt echo and becomes a very hot field as the breakthrough on 2001 for the discovery of exponential decay using classical Lyapunov exponent to characterize in terms of classical limit for strong chaos. Besides the community of quantum chaos, the Loschmidt echo is equivalent to fidelity in the research field of quantum information having the tight connection with decoherence and also can be applied to the stability of cold atoms. In this poster, I put the focus on the classical limit with mixed-type phase space which is quite tricky now for the scientific community. Using the famous model kick rotator, we consider particularly for two special situations having very few knowledge here, one is the decay law of edge of chaos and the other is the variation of decay law from weak chaos to strong chaos in terms of chaotic sea. We will report some general regular patterns that we find using numerical simulation and theoretical analysis. The variation of decay laws corresponding to different time scales and stretched exponential decay could be taken a general situation for the mixed-type systems. Here we put forward a theory of statistical property of classical action that could give some explanation partly, but actually some physical mechanisms are still unknown, so we also make some comments of other group's works which are maybe useful to improve our work in the future.

Quantum spin-dimer-systems in two dimensions and the magneto-caloric effect

Dominik Straßel and **Sebastian Eggert**

Physics Department, Universität Kaiserslautern, Germany
E-mail: strassel@rhrk.uni-kl.de

We are interested in coupled spin-dimer-systems in two dimensions on a square-lattice and on a honey-comb-lattice, which are modeled by a Heisenberg-model including a Zeemann-term. We consider the magneto-caloric effect for these systems in order to extract the T-B-phase-diagram, to get a clear identification of all phases, and to gain an understanding of the mechanism behind the magneto-caloric effect. The phase transition is identified by an extrema in the magneto-caloric effect which signals a maximum of the entropy. The magneto-caloric effect is widely used by experimentalists so we can compare with experiments and with analytic results. For these systems we start to analyze the size and temperature behavior of coupled dimer-systems, for a constant inter-dimer-coupling strength.

Strong renormalization of the Fermi-surface topology close to the Mott transition

Luca F. Tocchio

Department of Physics, Universität Frankfurt, Germany
E-mail: tocchio@th.physik.uni-frankfurt.de

The underlying Fermi surface is a key concept for strongly-interacting electron models and has been introduced to generalize the usual notion of the Fermi surface to generic (superconducting or insulating) systems. By using improved correlated wave functions that contain backflow and Jastrow terms, we examine the two-dimensional t-t' Hubbard model and find a non-trivial renormalization of the topology of the underlying Fermi surface close to the Mott insulator. Moreover, we observe a sharp crossover region, which arises from the metal-insulator transition, from a weakly interacting metal at small coupling to a resonating valence-bond superconductor at intermediate coupling. A violation of the Luttinger theorem is detected at low hole dopings. Possible instabilities to phase separation are also discussed.

High-Resolution Probing and Manipulation of Strongly Interacting One-Dimensional Quantum Gases

Andreas Vogler

Physics Department, Technische Universität Kaiserslautern, Germany
E-mail: vogler@physik.uni-kl.de

Our work focuses on the experimental investigation and manipulation of the spatial density-profiles of few one-dimensional tubes of ultracold bosons. In our experiment, we are employing a tightly focussed electron-beam, which ionizes atoms of an atomic cloud by electron-impact ionization. The produced ions are then extracted by means of electrostatic optics and detected. This allows us to probe atomic density distributions with high temporal and spatial resolution. Furthermore, the electron-beam is a versatile tool to manipulate the atomic ensemble. It allows for heating or cooling as well as a precise reduction of the atom-number. These features are employed to prepare a tailored BEC, which is subsequently loaded into a deep two-dimensional blue-detuned optical lattice. This confines the gas into tens of individual one-dimensional quantum-gases with interaction strengths varying from weak (quasi-condensate) to strong (Tonks-Girardeau). By applying an inverse Abel-Transformation, we are able to extract high-precision density-profiles of effective one-dimensional quantum-gases with different interaction-strengths. These profiles allow for a detailed comparison with theory e.g. the exact zero-temperature Lieb-Liniger model as well as the Yang-Yang model for finite temperatures. Further experiments will aim at the preparation of non-equilibrium and quenched states and the investigation of their thermalization properties.

Quantum Phase Diagram of Bosons with Modulated Scattering Length in Optical Lattices

T. Wang[1], F.E.A. dos Santos[2], V. Bagnato[2] , and A. Pelster[3]

[1]Harbin Institute of Technology, Harbin, China
[2] Institute de Fisica de Sao Calos, Sao Calos, Brazil
[3]Fachbereich Physik, Technische Universität Kaiserslautern, Germany
E-mail: tauwaang@gmail.com

We study a homogeneous system of spinless bosons in a cubic optical lattice of arbitrary dimension, where the s-wave scattering length is periodically modulated with some amplitude and frequency in the vicinity of a Feshbach resonance [1]. To this end we follow Ref. [2] and perform a similar analysis as for shaken lattices in order to map the driven system for large enough frequencies to an effective time-independent one. Subsequently, we calculate the transition line between the Mott insulator and the superfluid phase both within a Landau theory extended for the driven system [2,3] and within a mean-field theory for the effective time-independent system [4]. Although the respective results deviate from each other, they coincide for a large particle number per site.

References

[1] S.E. Pollack, D. Dries, R.G. Hulet, K.M.F. Magalhaes, E.A.L. Henn, E.R.F. Ramos, M.A. Caracanhas, V.S. Bagnato, Phys. Rev. A **81**, 053628 (2010)
[2] A. Eckardt, C. Weiss, and M. Holthaus, Phys. Rev. Lett. **95**, 260404 (2005)
[3] F.E.A. dos Santos and A. Pelster, Phys. Rev. A **79**, 013614 (2009)
[4] A. Rapp, X. Deng, and L. Santos, *arXiv:1207.0641*

List
of Participants

1. Javed Akram
   Physics Department
   Freie Universität Berlin
   Germany
   `jvdakramqau@gmail.com`

2. Felix Andraschko
   Physics Department
   Technische Universität Kaiserslautern
   Germany
   `felix.andraschko@googlemail.com`

3. Gregory Astrakharchik
   Departament de Fisica i Enginyeria Nuclear
   Universitat Politecnica de Catalunya
   Barcelona
   Spain
   `astrakharchik@mail.ru`

4. Ahmad Ata Atiyha
   Physics Department
   Bethlehem University
   West Bank
   Palestine
   `aatiyha@bethlehem.edu`

5. Renu Bala
   Physics Department
   Panjab University
   Chandigarh
   India
   `renu28feb@gmail.com`

6. Shai Chester
   Physics Department
   Columbia University
   New York
   USA
   `iahs81@gmail.com`

7. Raka Dasgupta
   Department of Theoretical Sciences
   S.N. Bose National Centre for Basic Sciences
   Kolkata
   India
   `dasguptaraka@gmail.com`

8. Sebastian Eggert
   Physics Department
   Technische Universität Kaiserslautern
   Germany
   `eggert@physik.uni-kl.de`

9. Benjamin Gänger
   Physics Department
   Technische Universität Kaiserslautern
   Germany
   `gaenger@physik.uni-kl.de`

10. Nicolas Gheeraert
    Institute for Theoretical Physics
    University of Edinburgh
    United Kingdom
    `n.gheeraert@free.fr`

11. Tama Khellil
    Physics Department
    Freie Universität Berlin
    Germany
    `khellil@zedat.fu-berlin.de`

12. Olga Klimenko
    Bogoliubov Laboratory of Theoretical Physics
    Joint Institute for Nuclear Research
    Dubna
    Russia
    `olechka2410@bk.ru`

13. Jan Krieg
    Physics Department
    Universität Frankfurt
    Germany
    `jan.krieg@online.de`

14. Arkadiusz Kuros
    Physics Department
    Jan Kochanowski University
    Kielce
    Poland
    `akuros@ujk.edu.pl`

15. Martin Laux
    Physics Department
    Technische Universität Kaiserslautern
    Germany
    `laux@rhrk.uni-kl.de`

16. Moitri Maiti
    Physics Department
    Technische Universität Kaiserslautern
    Germany
    `maiti@physik.uni-kl.de`

17. Manfred Mark
    Institute for Experimental Physics
    Universität Innsbruck
    Austria
    `manfred.mark@uibk.ac.at`

18. Denis Morath
Physics Department
Technische Universität Kaiserslautern
Germany
`dmorath@physik.uni-kl.de`

19. Niranjan Myneni
Physics Department
Panjab University
Chandigarh
India
`niranjanmyneni2004@gmail.com`

20. Branko Nikolic
Institute of Physics
University of Belgrade
Serbia
`branko@ipb.ac.rs`

21. Axel Pelster
Physics Department
Technische Universität Kaiserslautern
Germany
`axel.pelster@physik.uni-kl.de`

22. Jan Pohlmann
Physics Department
Universität Frankfurt
Germany
`pohlmann@itp.uni-frankfurt.de`

23. Daniel Rost
Physics Department
Universität Mainz
Germany
`rostda@uni-mainz.de`

24. Carlos Sa de Melo
School of Physics
Georgia Institute of Technology
Atlanta
United States of America
`carlos.sademelo@physics.gatech.edu`

25. Laurent Sanchez-Palencia
Institut d'Optique
Centre National de la Recherche Scientifique
Paris
France
`lsp@institutoptique.fr`

26. Marek Schiffer
Physics Department
Freie Universität Berlin
Germany
`marek.schiffer@gmx.de`

27. Golam Ali Sekh
Institute of Physics
University of Belgrade
Serbia
`skgolamali@ipb.ac.rs`

28. Daniel Sellmann
Physics Department
Technische Universität Kaiserslautern
Germany
`sellmann@physik.uni-kl.de`

29. Wenjun Shi
Department of Physics and Electrical Engineering
Ningde Normal University
China
`shi_wenjun@yahoo.com`

30. Dominik Straßel
Physics Department
Technische Universität Kaiserslautern
Germany
`strassel@rhrk.uni-kl.de`

31. David Thouless
Physics Department
University of Washington
Seattle
United States of America
thouless@phys.washington.edu

32. Luca Tocchio
Physics Department
Universität Frankfurt
Germany
`tocchio@itp.uni-frankfurt.de`

33. Andreas Vogler
Physics Department
Technische Universität Kaiserslautern
Germany
`vogler@physik.uni-kl.de`

34. Tao Wang
Physics Department
Technische Universität Kaiserslautern
Germany
`tauwaang@gmail.com`

Notes

time	**Friday**	**time**	**Saturday**	**time**	**Sunday**	**time**	**Monday**
until 8:30	Breakfast	until 8:30	Breakfast	until 8:30	Breakfast	until 8:30	Breakfast
9:00-9:15	Opening						
9:15-10:45	**David Thouless** *Why are lower dimensions interesting?*	9:00-10:30	**Gregory Astrakharchik** *Tonks-Girardeau and Super Tonks-Girardeau Gases*	9:00-10:30	**David Thouless** *Berezinski-Kosterlitz-Thouless Transitions: Scaling Theory, Surface Roughening, and Other Developments*	9:00-10:30	**Laurent Sanchez-Palencia** *Anderson Localization in Two- and Three-Dimensional Anisotropic Disorder*
10:45-11:15	Coffee Break	10:30-11:00	Coffee Break	10:30-11:00	Coffee Break	10:30-11:00	Coffee Break
11:15-12:45	**Manfred Mark** *Tunable quantum gases in 1-dimensional confinement: Introduction*	11:00-12:30	**David Thouless** *Berezinski-Kosterlitz-Thouless Transitions: Early Developments in the Theory*	11:00-12:30	**Laurent Sanchez-Palencia** *Speckle Disorder, Incommensurate Lattices, and Anderson Localization in One Dimension*	11:00-12:30	**Carlos Sa de Melo** *Ultra-cold fermions in the flatland: evolution from BCS to Bose superfluidity in two-dimensions without spin-orbit or Zeeman fields*
12:45-14:00	Lunch	12:30-14:00	Lunch	12:30-13:30	Lunch	12:30-14:00	Lunch
14:00-15:30	**Manfred Mark** *Tunable quantum gases in 1-dimensional confinement: Tonks- and Super-Tonks-Girardeau Gases*	14:00-15:30	**Gregory Astrakharchik** *Dipolar and Coulomb One-Dimensional Gases*	14:00-18:00	Excursion	14:00-15:30	**Laurent Sanchez-Palencia** *Disorder and Interactions in Quantum Gases*
15:30-16:00	Coffee Break	15:30-16:00	Coffee Break			15:30-16:00	Coffee Break
16:00-17:00	Poster Flash Presentations	16:00-17:30	Poster Session II			16:00-17:30	**Carlos Sa de Melo** *Ultra-cold fermions in the flatland: evolution from BCS to Bose superfluidity in two-dimensions with spin-orbit and Zeeman fields*
19:00	Dinner	19:00	Dinner	19:00	Dinner	19:00	Dinner
after dinner	Poster Session I	after dinner	Socializing, Discussions	after dinner	Socializing, Discussions	after dinner	Socializing, Discussions