Helmholtz Alliance

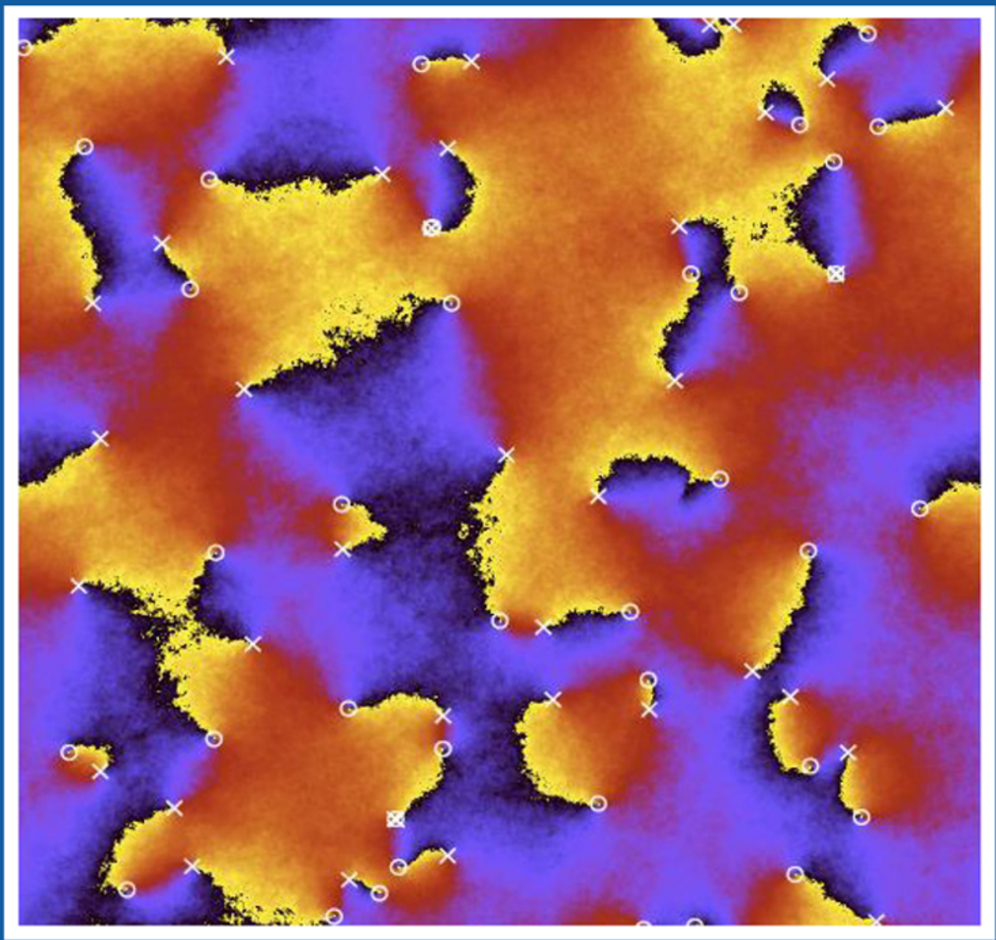
Extremes of Density and Temperature: Cosmic Matter in the Laboratory

ExtreMe Matter Institute EMMI

Relaxation, Turbulence, and Non-Equilibrium Dynamics of Matter Fields

— From Quantum Fluids to High-Energy Physics —

RETUNE



Programme

21 - 24 June 2012

GSI

HELMHOLTZ ASSOCIATION

Center for Quantum Dynamics

EMMI

Programme

Wednesday, 20 June 2012

19:00	*Welcome reception at the International Science Forum*	

Thursday, 21 June

09:00	*Opening*	
09:20	Joe Vinen (Birmingham)	An Introduction to Superfluidity and Quantum Turbulence
10:10	Carlo Barenghi (Newcastle)	Quantum Vortices and Their Reconnections
10:50	*Coffee/Tea*	
11:40	Makoto Tsubota (Osaka)	Quantum hydrodynamics and turbulence in Bose-Einstein Condensates
12:20	Gregory Falkovich (Rehovot)	Phase transitions in turbulence
13:00	*Lunch*	
14:30	Ulrich Heinz (Columbus)	"Perfect fluidity" in relativistic heavy-ion collisions
15:10	Elena Bratkovskaya (Frankfurt)	Off-shell dynamical approach for relativistic Heavy-Ion Collisions
15:50	*Coffee/Tea*	
16:30	Jean-Paul Blaizot (Saclay)	Thermalization of the quark-gluon plasma
17:10	Jürgen Berges (Heidelberg)	Turbulence and Bose Condensation: From the Early Universe to Cold Atoms
17:50	*Evening at free disposition*	

Friday, 22 June

09:00	Carlo Ewerz (EMMI)	The ExtreMe Matter Institute
09:20	Christof Wetterich (Heidelberg)	Prethermalization
10:10	Igor Tkachev (Moscow)	Turbulence in the Early Universe
10:50	*Coffee/Tea*	
11:40	Kerson Huang (Cambridge/Singapore)	A Superfluid Universe
12:20	Alberto Amo (Paris)	Superfluidity and hydrodynamic excitations in out of equilibrium polariton condensates
13:00	*Lunch*	
14:30	Johanna Stachel (Heidelberg)	The ALICE experiment at LHC (prelim.)
15:20	Brian Anderson (Tucson)	Two-dimensional quantum turbulence in Bose-Einstein condensates
16:00	Matthew Davis (Queensland)	Nonequilibrium Bose gases with c-fields
16:40	*Coffee/Tea*	
17:10	Andrei Golov (Manchester)	Turbulence in Superfluid ^{4}He in the $T = 0$ Limit
17:50	Michiel Wouters (Antwerpen)	c-field descriptions of nonequilibrium polariton condensates
18:30	*Dinner buffet and Posters*	

Saturday, 23 June

09:00	Sergej Demokritov (Münster)	Ground state and excitations (vortices and sound waves) in a Bose-Einstein condensate of magnons
09:50	Jonathan Keeling (St. Andrews)	Condensation, superfluidity and lasing of coupled light-matter systems
10:30	Hiromitsu Takeuchi (Hiroshima)	Tachyon Condensation in Bose-Einstein Condensates
10:50	*Coffee/Tea*	
11:40	Vladimir Eltsov (Aalto)	Bose-Einstein condensation of magnons in superfluid ^{3}He-B and its applications to vortex studies
12:20	Sergey Nazarenko (Warwick)	Wave Turbulence in Bose-Einstein Condensates
13:00	*Lunch*	
14:30	Gora Shlyapnikov (Orsay)	Novel physics with polar molecules
15:20	Kenji Fukushima (Keio)	Instability in an expanding non-Abelian system
16:00	Anton Rebhan (Wien)	Nonabelian plasma instabilities
16:30	*Coffee/Tea*	
17:00	*Excursion*	
20:00	*Conference dinner*	

Sunday, 24 June

09:30	Vanderlei Bagnato (Sao Carlos)	Quantum turbulence in an atomic trapped superfluid: the observation of a power law in the kinetic energy spectrum
10:10	George Pickett (Lancaster)	*tba*
10:50	*Discussion Session*	
11:30	*Coffee/Tea*	
11:50	Boris Nowak (Heidelberg)	Nonthermal fixed points and superfluid turbulence
12:30	Jörg Schmiedmayer (Wien)	Relaxation in an Isolated Quantum System
13:10	*Lunch and Closing*	

Practical Information

The local participants will wear a green sticker on their name tag. They will answer any practical questions you may have.

Location

The conference hall is in the Internationales Wissenschaftsforum Heidelberg (IWH), situated in the old town of Heidelberg at the foot of the castle hill. The address is the following:

Internationales Wissenschaftsforum Heidelberg
Hauptstrasse 242
D-69117 Heidelberg

The public transport station that is closest is "S-Bahnhof Altstadt". It can be reached with the S-Bahn (lines S1 and S2) or the bus (line 33). Then it's a 3 minutes walk in direction of the city centre to reach the IWH.

The nearest parking opportunities are "Parkhaus 13" at the "Karlsplatz" (16 € per day) and "Parkhaus 12" at the "Kornmarkt" (12,- € per day). It is a 3-minute walk from there to the IWH.

For more information, please look up the local public transportation and German railway Internet pages:

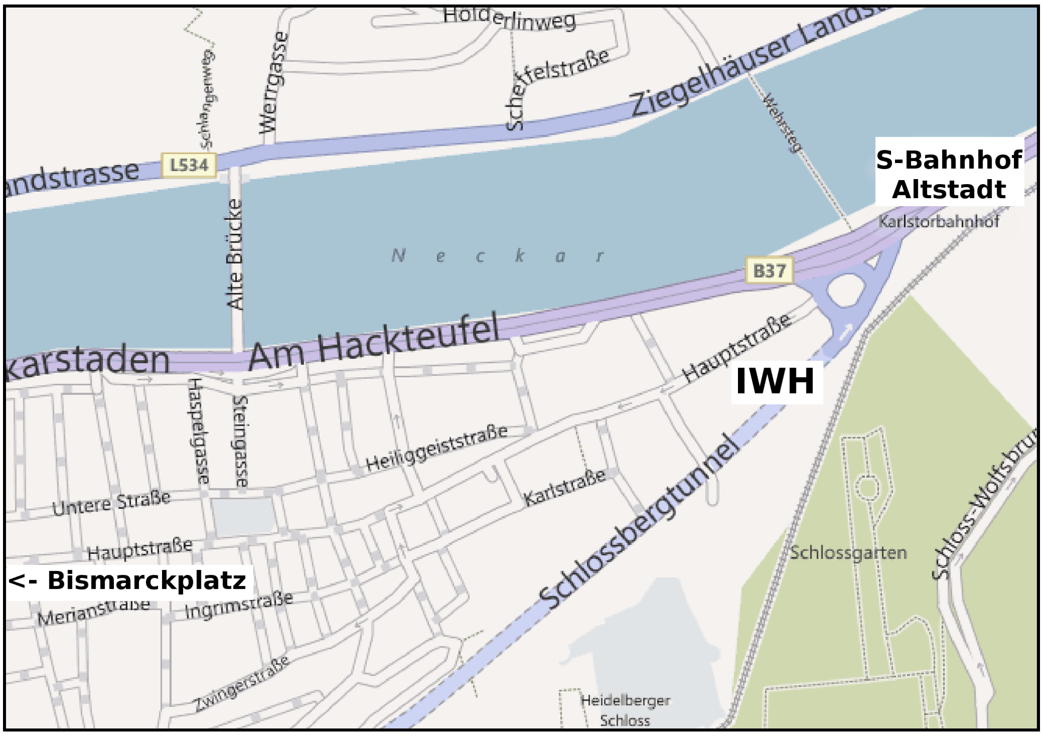
http://www.vrn.de
http://www.bahn.com

Transportation to and from Frankfurt airport can be found at:

http://www.transcontinental-group.com/en/frankfurt-airport-shuttles/
https://www.tls-heidelberg.de/en/

There is also map with many useful annotations at:

http://g.co/maps/jt46s



Internet

There is a wifi Internet access in the conference hall. Connect to WLAN 'UNI-WEBACCESS' and open your browser. It will automatically redirect to the login page.

login: iq3
password: 8x7du

The web-page of the conference is:

http://www.thphys.uni-heidelberg.de/ smp/RETUNE2012/index.php

It contains additional information about the conference. We will try to assemble the material of the conference and make it available on the web-page as well.

Talks

An Introduction to Superfluidity and Quantum Turbulence

William (Joe) Vinen

School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, United Kingdom

Superfluids, formed in the liquid phases of the isotopes of helium and in very cold gases, are characterised by the presence of a coherent particle field, associated with Bose or BCS condensation, the behaviour of which is described in weakly interacting systems by a non-linear Schrodinger equation. As a result there are interesting links with other systems. Simple superfluids display two-fluid effects, a normal fluid coexisting with a superfluid component. Flow of the superfluid component is constrained by the phase coherence of the particle field, so that only irrotational flow is possible, with a quantized circulation and quantized vortex filaments. The quantised vortex filaments allow forms of turbulence in the superfluid component. Some of these forms have features that are similar to those encountered in classical viscous fluids; others are quite different, allowing, for example, turbulence in a fluid in which there is no viscous dissipation or in which either both fluids or two co-existing superfluids are involved.

Quantum Vortices and Their Reconnections

Carlo Barenghi

School of Mathematics and Statistics, Newcastle University, Herschel Building, Newcastle upon Tyne NE1 7RU, United Kingdom

In superfluid helium and atomic Bose-Einstein condensates, any rotational motion is strongly affected by quantum mechanical constrains; the vorticity, which in ordinary fluids is a smooth, continuous field, takes the form of discrete vortex filaments. I shall describe recent results in the study of vortex reconnections and turbulence, paying particular attention to the comparison between quantum and ordinary turbulence, and finite temperature effects in atomic condensates.

Quantum hydrodynamics and turbulence in Bose-Einstein Condensates

Makoto Tsubota

Department of Physics, Osaka City University, Sugimoto 3-3-138, Sumiyoshi-ku 558-8585, Japan

Quantum hydrodynamics and turbulence have been studied in the field of superfluid helium, while it is currently studied in atomic Bose-Einstein condensates (BECs). A general introduction to this issue and a brief review of the basic concepts are followed by the recent developments in these topics. We will discuss quantum turbulence in two-component BECs, and spin turbulence in spinor BECs etc.

Phase transitions in turbulence

Gregory Falkovich

Weizmann Institute of Science, Rehovot, Israel

We consider states far from thermal equilibrium within the Gross-Pitaevsky model. We focus on the inverse cascade at low wavenumbers/momenta, which feeds the condensate. We show that the condensate growth leads to a series of phase transitions accompanied by the change of symmetries.

"Perfect fluidity" in relativistic heavy-ion collisions

Ulrich Heinz

Physics Department, The Ohio State University, 191 West Woodruff Avenue, OH 43210-1117, Columbus, USA

The Quark-Gluon Plasma QGP created in heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) has been called a "perfect liquid". It exhibits the collective dynamic behaviour of a fluid with almost vanishing viscosity. Theory places lower limits on the shear and bulk viscosities of any real (i.e. not super-)fluid, and the QGP shear viscosity appears to be close to that limit. Recent progress on the modeling side of heavy-ion collision dynamics has put the quantitative determination of the QGP shear viscosity from experimentally measaured hadron spectra and anisotropic flow coefficients within reach. I will present new limits on the kinematic shear viscosity of QGP extracted from VISHNU, a hydrodynamic code that couples a viscous fluid description of the dense QGP phase with a microscopic Boltzmann cascade for the dilute late hadron resonance gas stage, in comparison with elliptic and triangular flow data from RHIC and LHC. As will be discussed, event-by-event fluctuations of the initial shape and density distribution in the QGP fireball and the resulting anisotropic flow play a crucial role in this extraction.

Off-shell dynamical approach for relativistic HIC

Elena Bratkovskaya

Institute für Theoretische Physik and Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe University, Ruth-Moufang-Str. 1, 60438 Frankfurt am Main, Germany

We present a conceptually novel approach - derived from Kadanoff-Baym equations in phase-space representation - for the dynamical description of the strongly interacting Quark-Gluon-Plasma (sQGP) including a dynamical hadronization scheme, i.e. the Parton-Hadron-String Dynamics (PHSD) transport approach which has been successfully applied for the description of heavy-ion collisions from lower FAIR to LHC energies. The PHSD model reproduces a large variety of observables (e.g. as quark-number scaling of elliptic flow, transverse mass and rapidity spectra of charged hadrons, dilepton spectra, collective flow coefficients etc.) which are associated with the observation of a sQGP. This transport model provides a solid tool to study the new stage of matter (sQGP) from a microscopic point of view incorporating the information from lattice QCD calculations in equilibrium.

Thermalization of the quark-gluon plasma

Jean-Paul Blaizot

IphT, Sarclay, France

Turbulence and Bose Condensation: From the Early Universe to Cold Atoms

Jügen Berges

Institute for Theoretical Physics, Heidelberg University, Philosophenweg 16, 69120 Heidelberg, Germany

The ExtreMe Matter Institute

Carlo Ewerz

ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, D-64291 Darmstadt, Germany

Prethermalization

Christof Wetterich

Inst. Theoretical Physics, University of Heidelberg, Philosophenweg 16, 69120, Heidelberg, Germany

Turbulence in the Early Universe

Igor Tkachev

INR, Moscow, Russia

Universe reheating after Inflation will be discussed, with the emphasis on Turbulence and associated phenomena.

A Superfluid Universe

Kerson Huang

MIT/Institute of Advanced Studes, Nanyang Technological University, 60 Nanyang View #02-18, Nanyang, USA/Singapore 639673

Particle physics tells us that the vacuum is a dynamic medium possibly filled with complex scalar fields. Condensed matter physics tells us that a complex scalar field, whatever its origin, serves as order parameter for superfluidity. Considering the implication of all this on a cosmic scale, one comes to the conclusion that the universe may be a superfluid. We describe the emergence of such a superfluidity during the big bang, in terms of a mathematical initial-value problem based on Einstein's equation. This is made possible by using the Halpern-Huang scalar potential, which is asymptotically free. The solution shows that the universe expands with accelerating rate, with an equivalent cosmological constant that decays in time according to a power law, and this gives dark energy without the usual fine-tuning problem. The dynamics of quantized vorticity allows the growth and decay of a superfluid vortex tangle (quantum turbulence), in which vortex reconnections can create all the matter present in the universe. The inflation era is the lifetime of quantum turbulence, according to this model. As for the present universe, the energy density of the superfluid is dark energy, and deviation of the superfluid from uniformity, due to the prescence of galaxies, is observed as dark matter, through gravitational lensing. Vortices surviving from the Planck era had core diameters growing from Planck length to the order of 108 light years. These giant vortex cores could explain the galactic voids now observed. Vortex reconnections generate two opposite jets of energy, which could explain cosmic jets. A collapsing rotating black hole in the superfluid would be covered with "hair" in the form of vortex filaments, which could explain the "non-thermal filaments" seen near the center of the Milky Way.

Superfluidity and hydrodynamic excitations in out of equilibrium polariton condensates

Alberto Amo

Laboratoire de Photonique et Nanostructures, CNRS, Route de Nozay, 91460 Marcoussis, France

Exciton-polaritons are composite bosons arising from the strong coupling between quantum well excitons and photons confined in a semiconductor microcavity. They can be easily created by optical excitation and form extended bosonic condensates at relatively high temperatures (10-300 K). Their mixed matter-light nature provides polaritons with unprecedented properties: from their exciton component they inherit strong particle interactions giving rise to a number of non-linear phenomena, while their partly photonic origin gives rise to a very low mass (10-5 the free electron mass) and a short lifetime (a few picoseconds) due to the continuous escape of photons out of the microcavity. For this reason, polariton condensates present strong out-of-equilibrium features, their steady state being determined by the interplay between optical pumping, relaxation and decay. Here we will show experiments on the transition from a superfluid phase to shockwaves, vortex and soliton formation when a polariton condensate encounters a potential barrier in its flowpath at different Mach numbers. We will show that these phenomena present novel features arising from the out-of-equilibrium nature of polaritons, allowing the study of driven-dissipative quantum hydrodynamic phenomena not accessible in other kind of bosonic condensates.

The ALICE experiment at LHC (prelim.)

Johanna Stachel

Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, Heidelberg, Germany

Two-dimensional quantum turbulence in Bose-Einstein condensates

Brian Anderson

College of Optical Sciences, University of Arizona, 1630 E University Blvd, AZ 85750, Tucson, USA

The experimental and theoretical tools of atomic-gas Bose-Einstein condensates (BECs) are enabling rapid development of an understanding of two-dimensional quantum turbulence (2DQT) in compressible superfluids. For example, using highly oblate BECs, numerous experimental methods can be used to generate disordered distributions of quantized vortices that can be associated with 2DQT, and new vortex detection and manipulation techniques are emerging. In conjunction with this experimental progress, analytical and numerical efforts are uncovering new aspects regarding the vortices involved in 2DQT, from their dynamics to their relationships with energy spectra. This talk will focus on the physics of quantized vortices in 2DQT, particularly with respect to the common goals of experimental, numerical, and analytical efforts with condensates. We will give an overview of our recent findings on these topics, and will emphasize current and upcoming experimental capabilities regarding 2DQT and vortex studies in BECs. With such research, we hope to discover new insights into the broad topics of superfluid turbulence and vortex dynamics.

Nonequilibrium Bose gases with c-fields

Matthew Davis

School of Mathematics and Physics, University of Queensland, St Lucia, Queensland 4072, Australia

The mean-field Gross-Pitaevskii equation has proven to be an excellent description of many experiments involving the dynamics of Bose-Einstein condensates. However, different theoretical formalisms can result in a similar equation of motion for a classical field that can be applied to degenerate Bose gases at finite temperatures near the critical point, and even the quantum dynamics near zero temperature. In this talk we will provide an introduction to these c-field techniques for Bose gases, and briefly describe nonequilibrium applications. These include the dynamics of condensate formation, and the determination of the superfluid fraction at finite temperature, as well as the dynamics of an engineered quantum phase transition in a two-component Bose gas at zero temperature.

Turbulence in Superfluid 4He in the T=0 Limit

Andrei Golov

School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK

In superfluid 4He, vorticity is confined to atomically-thin cores of quantized vortex lines. In a laminar flow, vortex lines preserve their identity (no reconnections). In contrast, a tangle of vortex lines in a turbulent flow is subject to frequent reconnections that randomize the tangle, allow its topology to relax and feed the cascade of energy towards larger wavenumbers. At low temperatures, the dissipative lengthscales are as small as several nanometers; turbulence can hence span a huge range of lengthscales. At temperatures $T = 1K$, the energy cascade reaches quantum lengthscales at which the discrete nature of vorticity is important; here small vortex rings and Kelvin waves on individual vortex lines become key players. Different dynamics are expected for tangles of different structures and energy spectra that can be created by different means of driving turbulence. Recent experimental advances will be reviewed. Our means of driving turbulence included: rotational acceleration (either one-off or AC) of a cube-shaped container, coalescence of a beam of vortex rings, electrostatic forcing of a vortex tangle through negative ions trapped on vortex cores. Detection of turbulence was achieved through probing the density of vortex lines by micron-size charged vortex rings and monitoring the transport of trapped ions, sensitive to vortex reconnections and fluctuations of flow velocity. The following observations will be presented and discussed: the dynamics and free decay of turbulence with either classical (dominated by the large-scale flow) or quantum (dominated by the tension of quantized vortex lines) energy spectra, transition from laminar to turbulent flow for either a cloud of polarized vortex rings or an array of rectilinear vortex lines in rotation, fine structure (Kelvin waves and small vortex rings) of a vortex tangle at quantum lengthscale.

c-field descriptions of nonequilibrium polariton condensates

Michiel Wouters

Universiteit Antwerpen, Universiteitsplein 1, 2610 Antwerpen (Wilrijk), Belgium

Ground state and excitations (vortices and sound waves) in a Bose-Einstein condensate of magnons

Sergej Demokritov

Institute for Applied Physics, University Münster, Corrensstr. 2-4, 48149 Münster, Germany

Condensation, superfluidity and lasing of coupled light-matter systems

Jonathan Keeling

School of Physics and Astronomy, University of St Andrews, St Andrews Fife KY16 9SS, St Andrews, United Kingdom

The great experimental progress in realising and studying polariton condensates has made it possible to now study experimentally a number of fundamental questions about the relation between lasing, condensation, coherence and superfluidity. In my talk, I will discuss the consequences of finite particle lifetime on several of these questions. In particular I will discuss how pattern formation in a non-equilibrium condensate is strongly affected by finite particle lifetime [1]. I will also address aspects of superfluidity [2], reviewing the results that have been seen so far, and proposing an alternate approach to clearly define the superfluid properties of a polariton condensate. As the polariton system is intrinsically two dimensional, I will also discuss how the power law correlations expected in two dimensions are modified by finite particle lifetime and finite size [3].

[1]J. Keeling and N. G. Berloff, Phys. Rev. Lett 100, 250401 (2008); M. O. Borgh, G. Franchetti, J. Keeling, and N. G. Berloff, Phys. Rev. B, in press (2012)

[2] J. Keeling, Phys. Rev. Lett. 107 080402 (2011)

[3] G. Roumpos et al, Proc. Nat. Acad. Sci 109, 6467 (2012); J. Keeling, M. H. Szymanska, and P. B Littlewood, p 293 in Optical Generation and Control of Quantum Coherence in Semiconductor Nanostructures, eds. by G. Slavcheva and P. Roussignol (2010)

Tachyon Condensation in Bose-Einstein Condensates

Hiromitsu Takeuchi

Hiroshima University, Hiroshima, Japan

Brane cosmology proposes that the Big Bang occurs when a pair of a brane and an anti-brane annihilate each other on collision. A phase transition accompanied with a spontaneous symmetry breaking occurs and consequently formations of lower- dimensional topological defects, e.g. cosmic strings, are inevitable. Such a phase transition is triggered by the so-called "tachyon condensation", where the existence of the tachyon is a consequence of the instability of the system. Here we show that the tachyon condensation by a pair annihilation of a brane and an anti-brane can be prepared in a laboratory experiment of atomic Bose-Einstein condensates. In this system, formations of vortices from domain-wall annihilations in three dimensions are understood as kink formations in a two-dimensional phase ordering dynamics. This study provides insights into how the presence of the extra dimensions influences to a phase transition confined in a restricted space embedded in higher dimensions.

Bose-Einstein condensation of magnons in superfluid 3He-B and its applications to vortex studies.

Vladimir Eltsov

O.V. Lounasmaa Laboratory, Aalto University, PO BOX 15100, 00076 AALTO, Finland

In superfluid 3He-B traps for magnon excitations can be formed by the order-parameter texture and the applied profile of the static magnetic field. At temperatures around 0.2Tc and below one can pump magnons to the trap using NMR techniques to create macroscopic occupation of the ground or of a selected excited level. Such magnons form Bose-Einstein condensates as demonstrated by the long-lived coherent spin precession after switching off the pumping. The orbital texture is flexible and as the magnon occupation number increases the profile of the trap gradually changes from harmonic to a square well, with walls almost impenetrable to magnons. This is the first experimental example of Bose-Einstein condensation in a box. At the lowest temperatures the lifetime of the magnon condensates reaches minutes. They become a very sensitive probe for properties of superfluid 3He. We will give examples of using the condensates for studies of quantized vortices in 3He-B, including structure of the vortex cores and vortex dynamics in the zero-temperature limit.

Wave Turbulence in BEC

Sergey Nazarenko

Mathematics Institute, University of Warwick, Gibbet Hill road, CV4 7AL, Coventry, UK

I will present a description of BEC turbulence in different regimes: an inverse cascade in weak wave turbulence followed by strong turbulence of anihilating vortices followed by an acoustic turbulence stage. I will discuss a kinetic model for condensate interacting with thermalised gas. I will talk about differences between the 2D and the 3D cases. I will draw attention to the links between the wave wave turbulence and BKT transition.

Novel physics with polar molecules

Gora Shlyapnikov

Université Paris-Sud XI, Orsay, France

Instability in an expanding non-Abelian system

Kenji Fukushima

Department of Physics, Keio University, 3-14-1 Hiyoshi, Kohoku-ku,
Yokohama-shi, Kanagawa 223-8522, Japan

At extremely high energy the real-time dynamics in the non-Abelian gauge theory can be approximated by classical evolution with small fluctuations. In such a system instabilities develop contributing to the pressures. I will summarize the systematic investigations of those instabilities in the expanding geometry.

Nonabelian plasma instabilities

Anton Rebhan

Institute for Theoretical Physics, Vienna University of Technology, Wiedner
Hauptstr. 8-10, A-1040 Wien, Austria

I discuss the evolution of plasma instabilities in a nonabelian plasma with momentum anisotropy in the regime where Boltzmann-Vlasov equations are applicable but where chromomagnetic fields have grown nonperturbatively large such that an energy cascade from low to high momentum modes develops. Numerical results are presented for the cases of a stationary anisotropy as well as for a system undergoing longitudinal expansion as in the early stages of heavy-ion collisions.

Quantum turbulence in an atomic trapped superfluid: the observation of a power law in the kinetic energy spectrum

Vanderlei S. Bagnato

IFSC, Univeristy of Sao Paulo, Av. Trabalhador Sao Carlense, 400, Sao Carlos - SP, Brazil

We analyze the spectrum of kinetic energy of a turbulent sample of trapped Rb atoms forming a quantum fluid. Turbulence is produced by an oscillatory field as described in previous work. The analysis is performed to identify the inertial range of momentum and associated with the appearance of the power law dependence of the type $k^{-\delta}$. We found that for a turbulent cloud of atomic superfluid, $E(k) \sim k^{-3}$. Comparison with the Kolmogorov $-5/3$ power law is performed. Details of the experiment are presented. Finally, arguments are discussed concerning the importance of the phenomenon of quantum turbulence and the existence of scaling law for the understanding of the phenomenon of turbulence in general. Support from FAPESP, CNPq and CAPES

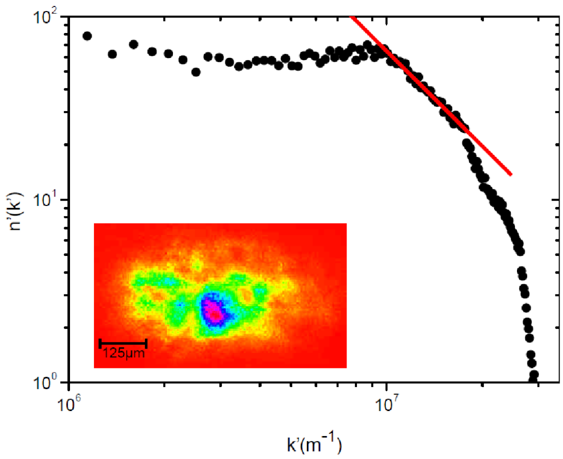


Figure 1: figure showing the momentum distribution and the presence of the power law behavior in $n(k)$

Nonthermal fixed points and superfluid turbulence

Boris Nowak

Institut für Theoretische Physik , Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany

Many-body systems far away from thermal equilibrium can show a much wider range of characteristics than equilibrium systems. Among the wealth of possible non-equilibrium many- body configurations most interesting candidates are those which show universal behavior. We present a selection of such phenomena in ultracold Bose gases, characterized by specific power-laws in space and time. These are closely related to the presence and turbulent dynamics of (quasi-)topological defects in the Bose field, which generically appear far from equilibrium. Examples include interaction quenches in 1D, condensate perturbations in 2D and rapid evaporative cooling in 3D.

Relaxation in an Isolated Quantum System

Jörg Schmiedmayer

Vienna Center for Quantum Science and Technology, TU-Wien, Stadionallee 2, Wien, Austria

Posters

Macroscopic quantum tunneling in BECs

Lincoln Carr

Center for Quantum Dynamics, University of Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We study the quantum tunneling dynamics of many-body entangled solitons composed of ultracold bosonic gases in 1D optical lattices. A bright soliton, confined by a potential barrier, is allowed to tunnel out of confinement by reducing the barrier width and for varying strengths of attractive interactions. Simulation of the Bose Hubbard Hamiltonian is performed with time-evolving block decimation. We find the characteristic $1/e$ time for the escape of the soliton, substantially different from the mean field prediction, and address how many-body effects like quantum fluctuations, entanglement, and nonlocal correlations affect macroscopic quantum tunneling; number fluctuations and second order correlations are suggested as experimental signatures. We find that while the escape time scales exponentially in the interactions, the time at which both the von Neumann entanglement entropy and the slope of number fluctuations is maximized scale only linearly.

Nonequilibrium Bose gases with c-fields

Matthew Davis

School of Mathematics and Physics, University of Queensland, St Lucia, Queensland 4072, Australia

The mean-field Gross-Pitaevskii equation has proven to be an excellent description of many experiments involving the dynamics of Bose-Einstein condensates. However, different theoretical formalisms can result in a similar equation of motion for a classical field that can be applied to degenerate Bose gases at finite

temperatures near the critical point, and even the quantum dynamics near zero temperature. In this talk we will provide an introduction to these c-field techniques for Bose gases, and briefly describe nonequilibrium applications. These include the dynamics of condensate formation, and the determination of the superfluid fraction at finite temperature, as well as the dynamics of an engineered quantum phase transition in a two-component Bose gas at zero temperature.

Emergence of pair-coherence in many-body quenches

Uwe R. Fischer

Department of Physics and Astronomy, Seoul National University, #56-512 Gwanak_599, Gwanak-ro, Gwanak-gu, South Korea

We investigate the dynamical mode population statistics and associated first- and second-order coherence of an interacting bosonic two-mode model when the pair-exchange coupling is quenched from negative to positive values. It is shown that for moderately rapid second-order transitions, a new pair-coherent phase emerges on the positive coupling side, which is not single-particle fragmented as the em ground-state density matrix would prescribe it to be.

Sound waves in non-stationary media

Armen Hayrapetyan

Physikalisches Institut, Universität Heidelberg, Im Neunheimer Feld 226, 69120 Heidelberg, Germany

The propagation of sound through a spatially homogeneous but non-stationary medium is investigated within the framework of fluid dynamics. For a non-vortical fluid, especially, a generalized wave equation is derived for the (scalar) potential of the fluid velocity distribution in dependence of the equilibrium mass density of the fluid and the sound wave velocity. A solution of this equation for a finite transition period in terms of the hypergeometric function is determined for a phenomenologically realistic, sigmoidal change of the mass density and sound wave velocity. Using this solution, it is shown that the energy flux of the sound wave is not conserved but increases always for the propagation through a non-stationary medium, independent of whether the equilibrium mass density is increased or decreased. It is found, moreover, that this amplification of the transmitted wave arises from an energy exchange with the medium and that its flux is equal to the (total) flux of the incident and reflected wave. An interpretation of the reflected wave as a propagation of sound backward in time is given in close analogy to Feynman and Stueckelberg for the propagation of anti-particles. The reflection and transmission coefficients of sound propagating through a non-stationary medium is analyzed in more detail for hypersonic waves with transition periods between 15-200 ps as well as the transformation of infrasound waves in non-stationary oceans.

Thermalization induced by chaotic behavior in classical Yang-Mills dynamics with the initial condition of color-glass condensate

Hideaki Iida

Department of Physics, Kyoto University, Kitashirakawa Oiwakecho, Kyoto 606-8502, Japan

Possible thermalization mechanism in heavy-ion collisions is explored in classical Yang-Mills (CYM) theory with the initial condition of color-glass condensate with noise varied. We calculate the Lyapunov exponents and show that even a tiny noise triggers instability of the system and then a chaotic behavior sets in as described by the positive Lyapunov exponents, or Kolmogorov-Sinai (K-S) entropy, which would take a saturate value after a characteristic time dependent on the ratio of strengths of the noise to the back ground coherent fields. Thus

we see that the entropy production is achieved in CYM theory with a realistic initial condition of relativistic heavy-ion collisions.

Chiral Superfluidity of the Quark-Gluon Plasma

Tigran Kalaydzhyan

DESY-Hamburg, Deutsches Elektronen-Synchrotron (DESY), Notkestrasse 85, 22607 Hamburg, Germany

We argue that the strongly coupled quark-gluon plasma can be considered as a chiral superfluid. The "normal" component of the fluid is the thermalized matter in common sense, while the "superfluid" part consists of long wavelength (chiral) fermionic states moving independently. We use several non-perturbative techniques to demonstrate that. First, we analyze the fermionic spectrum in the deconfinement phase ($T_c < T < 2\ T_c$) using lattice (overlap) fermions and observe a gap between near-zero modes and the bulk of the spectrum. Second, we use the bosonization procedure with a finite cut-off and obtain a dynamical axion-like field out of the chiral fermionic modes within QCD. Third, we use relativistic hydrodynamics for macroscopic description of the effective theory obtained after the bosonization. Finally, solving the hydrodynamic equations in gradient expansion, we find that in presence of external electromagnetic fields the motion of the "superfluid" component gives rise to the chiral magnetic, chiral electric and dipole wave effects. Latter two effects are specific for a two-component fluid, which provides us with crucial experimental tests of the model.

Functional RG flow for Burgers' equation

Steven Mathey

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The stochastic Burgers' equation is studied as a toy model for Navier-Stokes turbulence. Starting from the "quantum" effective action we derive renormalisation flow equations for the viscosity and the correlation functions. We investigate the different fixed points.

Anomalous scaling in the random-force-driven Burgers equation: A Monte Carlo study

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The random-force-driven Burgers equation appears in a variety of contexts ranging from cosmology, condensed matter and statistical physics to traffic flow. However, its origins are in the field of hydrodynamic turbulence where it was conceived as a simple model for the Navier-Stokes equations. Indeed, the clear physical picture of Burgers equation makes it a useful tool for testing new analytical and numerical methods for real-world turbulence. Here, we present a new approach to determine numerically the statistical behavior of small-scale structures in hydrodynamic turbulence. Starting from the functional integral representation of the random-force-driven Burgers equation we show that Monte Carlo simulations allow us to determine the anomalous scaling of high-order moments of velocity differences. Given the general applicability of Monte Carlo methods, this opens up the possibility to address also other systems relevant to turbulence within this framework.

Lagrangian Quantum Turbulence

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Kadanoff-Baym Approach to Thermalization

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We propose quantum field theoretical approach to thermalization of gluonic matter in heavy ion collision at RHIC and LHC. This approach is represented by Kadanoff-Baym equation. In this presentation, we estimate time scale of mode instability due to quantum collision term in non-expanding system.

Nonthermal fixed points and superfluid turbulence

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Turbulence in an ultracold Bose gas, in one, two and three spatial dimensions, is investigated analytically and numerically. A special focus is set on the infrared regime of large-scale excitations following universal power-law distributions distinctly different from those of commonly known weak wave-turbulence phenomena. It is explained, how the infrared power laws can be understood from the statistics of vortices as well as from an analytic field-theoretic approach based on the 2PI effective action. Possible ways to experimentally study strong turbulence phenomena with ultracold atomic gases are outlined.

What we understand from heavy-ion reactions

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Recently, nuclear multifragmentation has attracted great interest due to its similarity to the collapse and explosion of massive stars. By this reason, the importance of isotopic effects in nuclear multifragmentation are related to astrophysical processes such as supernova simulations and neutron star models. It was shown that the N/Z dependence of nuclear fragmentation at relativistic energies predicts modifications in liquid drop parameters of nuclear matter [1] and [2]. Modifications for symmetry energy coefficients of nuclear matter at freeze-out density are investigated on the basis of the Statistical Multifragmentation Model (SMM). In order to compare our predictions with MSU experimental data we consider the

fragmentation of the projectiles ^{124}Sn and ^{112}Sn which were also used for the MSU experiments [3] and [4], and of the projectiles ^{124}Sn, ^{124}La and ^{107}Sn used for the ALADIN experiments [1]. Comparing our results with the experimental data, it is confirmed that a significant reduction of the symmetry term coefficient is found necessary to reproduce the experimental data.

[1] R. Ogul, A.S. Botvina et al., Phys. Rev. C 83, (2011) 024608.
[2] R. Ogul, U. Atav, F. Bulut, N. Buyukcizmeci, M. Erdogan, H. Imal, A.S. Botvina and I. N. Mishustin, J. Phys. G: Nucl. Part. Phys. f 36, 115106 (2009).
[3] C.B. Das, S. Das Gupta, W. Lynch, A. Mekjian and B. Tsang, Phys. Rep. f 406, 1 (2005).
[4] T.X. Liu, et al., Phys. Rev. f C 69, 014603 (2004)

Many-body resonant tunneling in the Wannier system

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We study the spectral properties of a many-body two-band Wannier-Stark system modelled by a two-band Bose-Hubbard Hamiltonian. The crossover between regular and quantum chaotic resonant tunneling is shown to appear and it is characterized in terms of parameters of the system. By parametric-time evolution of eigenstates, it is shown that two statistically independent energy spectra present a remarkable difference in their espective diffusion processes through the resonant regime. Finally, as main result we propose a method to prepare of Mott-insulator-like states in the first excited band by controlled quantum sweeps across a cascade of single Landau-Zener events.

Generalized Boltzmann equation in ultrasoft region

Daisuke Satow

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We derive a kinetic equation for quark excitations with an ultrasoft momentum, g^2T, from the Kadanoff-Baym equation in QCD at extremely high T in the linear response regime, where g is the coupling constant and T is temperature of the equilibrium state [1]. We show that this equation is equivalent to the self-consistent equation in the resummed perturbation theory at equilibrium used in the analysis of the quark spectrum with the ultrasoft momentum [2]. Furthermore, we derive the equation that determines the n-point function with external lines for a pair of quarks and $(n-2)$ gluons with ultrasoft momenta, using the gauge symmetry.

[1] D. Satow and Y. Hidaka, arXiv:1204.6532 [hep-ph].
[2] Y. Hidaka, D. Satow and T. Kunihiro, Nucl. Phys. A 876, 93 (2012)

Dynamical view of the Schwinger mechanism

Naoto Tanji

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Particle production via the Schwinger mechanism has been studied as a mechanism of matter formation in the context of heavy-ion collisions. I will describe particle pair creation in a strong electric field focusing on its real-time dynamics.

The time evolution of the momentum distributions of created particles will be presented, which show collective motion of plasma oscillation due to the back reaction from the created particles. This plasma oscillation shows damping because of interference between matter fields. I will also discuss the particle production in a boost-invariantly expanding electric field which spans between two charged plates receding from each other at the speed of light.

Parity Violation in Hydrogen and Squeezing

Martin Trappe

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We discuss the propagation of hydrogen atoms in static electric and magnetic fields in a longitudinal atomic beam spin echo (lABSE) Interferometer. The atoms acquire geometric (Berry) phases that exhibit a manifestation of parity-(P-)violation effects arising from electroweak Z-boson exchange between electron and nucleus. We provide analytical as well as numerical calculations of the behaviour of the metastable n=2 states of hydrogen. We are able to systematically search for Berry phases with tailored properties. Besides maximizing P-violating geometric phases emerging for the respective states we also find the possibility to modify their decay rates, nearly at the order of a percent, solely through P-conserving geometric phases. We also investigate possibilities to enhance the precision of the interferometry experiment using squeezed many-particle states instead of single atoms.

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