QFS 2016

International Conference on Quantum Fluids and Solids 2016

10–16 August 2016 • Prague • Czech Republic

BOOK OF ABSTRACTS

CONFERENCE PROGRAMME

QFS 2016

	Wed10th	Thu 11th	Fri 12th	Sat 13th	Sun 14th	Mon 15th	Tue 16th
8:00		Registration					
		Nambu Session	Richardson Session	Hall Session		Ginzburg Session	Matsubara Session
		Chair: Saunders	Chair: Pickett	Chair: Vinen		Chair: Bunkov	Chair: Tsubota
9:00		OPENING				Collin	
9:15			Haley	L'vov			Zwierlein
9:30		Eltsov				Kafanov	
9:45			Sasaki	Mukharski		Vavrek	Mou
10:00		Fukuyama				Souris	Matsumoto
10:15			Brewczyk	Barenghi		Qu	Berman
10:30		coffee	coffee	coffee		coffee	coffee
10:45							
		Maki Session	Tisza Session	Donnelly Session		Mulders Session	Fisher Session
		Chair: Kono	Chair: Krotscheck	Chair: Barenghi		Chair: Hakonen	Chair: Halperin
11:00		Wada	Chan	Vinen		Dmitriev	Serha
11:15		Gasparini		Golov			
11:30		Shirahama	Cheng	Tsuji		Parpia	Casey
11:45		Williams	Todoshchenko	Tsubota			
12:00		Matsushita	Polturak	Sergeev		Autti	CLOSING
12:15		Tagirov	Iwasa	Nemirovski		Nguyen	
12:30							
12:45							
13:00	Enss	lunch	lunch	lunch		lunch	
13:15							
13:30							
13:45	Vinen						
		Krupička Session	Kohn Session	Kopnin Session		Bajer Session	
		Chair: Skyba	Chair: Leiderer	Chair: Sauls		Chair: Sergeev	
14:00		Paschen	Moroshkin	Mizushima		Yong-il Shin	
14:15	coffee						
14:30		Bertaina	Shevtsov	Wiman		Fonda	
14:45	Pickett	Wolf		Godfrin		Sonin	
15:00		Stishov	Ikegami	Krotscheck		Galantucci	
15:15		Custers	Rees	Zimmerman		Proment	
15:30	Chan	Enss	Ghosh	Fomin		Hakonen	
15:45		Gordon	Salman	Khmelenko		Ancilotto	
16:00		coffee	coffee	coffee		coffee	
16:15							
16:30	Registra-	POSTERS	POSTERS	POSTERS		POSTERS	
17:00	tion						
18:00	Welcome				Confer-		
19:00	Party				ence	Concert	
20:00					Dinner		
21:00							

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Program Overview

WEDNESDAY 10 AUGUST

Tutorials			
13:00	T1	Christian Enss	Cryogenic techniques and low temperature properties of matter
13:45	T2	William Vinen	Bose condensation and superfluidity in liquid ^{4}He
14:30	Coffee		
14:45	T3	George Pickett	"Pure" superfluid ^{3}He, an introduction
15:30	T4	Moses Chan	The supersolid story
16:45	**Registration**		
18:00	**Welcome Party**		

THURSDAY 11 AUGUST

8:00			**Registration**
9:00			**Opening Ceremony**
Yoichiro Nambu Session			**Chair: John Saunders**
9:15	I1.1	Vladimir Eltsov	New faces of superfluid ^{3}He: Higgs bosons, Majorana fermions and Alice strings
10:00	I1.2	Hiroshi Fukuyama	A possible quantum-liquid-crystal phase in helium monolayers adsorbed on graphite
10:30		Coffee	
Kazumi Maki Session			**Chair: Kimitoshi Kono**
11:00	O1.1	Nobuo Wada	Huge Fermi liquid and non-fermi liquid heat capacities of 3He films formed in 3D nanopore
11:15	O1.2	Francis Gasparini	Theory for a multi-chamber superfluid Helmholtz resonator and superfluid fraction
11:30	O1.3	Keiya Shirahama	Gap-induced elasticity of atomically thin ^{4}He films
11:45	O1.4	Gary Williams	Third sound propagation with ^{4}He films adsorbed on 10nm multiwall carbon nanotubes
12:00	O1.5	Taku Matsushita	NMR for ^{3}He in the 1D state in nanochannels-possible Tomonaga-Luttinger liquid ^{3}He-
12:15	O1.6	Murat Tagirov	The study of ordered Al_2O_3 aerogel by magnetic resonance methods at low temperatures
12:30		Lunch	
Svatopluk Krupička Session			**Chair: Peter Skyba**
14:00	I1.3	Silke Paschen	Quantum criticality and novel phases in heavy fermion metals
14:30	O1.7	Gianluca Bertaina	One-dimensional liquid ^{4}He and hard-core systems: dynamical properties beyond Luttinger-Liquid theory
14:45	O1.8	Pierre-Etienne Wolf	Condensation of helium in a silica aerogel: a realization of the athermal Random Field Ising Model
15:00	O1.9	Sergei Stishov	Quantum degradation of the second order phase transition
15:15	O1.10	Jeroen Custers	Superconductivity and quantum critical behavior in the antiferromagnetically ordered heavy fermion compound Ce_3PtIn_{11}
15:30	O1.11	Christian Enss	Nuclear spin driven dynamics in non-equilibrium disordered quantum systems
15:45	O1.12	Eugene Gordon	Non-isothermal physico-chemical processes in superfluid Helium
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9:45	I2.2	Yutaka Sasaki	Visualizing textural domain walls in superfluid ^{3}He by magnetic resonance imaging
10:15	O2.1	Miroslaw Brewczyk	Thermal solitons in a quasi-1D Bose gas as revealed by studying static structure factor
10:30		Coffee	
Laszlo Tisza Session			**Chair: Eckhard Krotscheck**
11:00	I2.3	Moses Chan	Mass flow through thin solid helium samples
11:30	O2.2	Zhigang Cheng	Defect motions in quantum solids with spins
11:45	O2.3	Igor Todoshchenko	Waves on quantum surfaces
12:00	O2.4	Emil Polturak	Atomic force microscopy of solid He
12:15	O2.5	Izumi Iwasa	Nonlinear ultrasound propagation in solid ^{4}He due to pinning and unpinning of dislocations by ^{3}He
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14:30	I2.5	Oleksii Shevtsov	Electron bubbles and weyl fermions in chiral superfluid ^{3}He-A
15:00	O2.6	Hiroki Ikegami	Mobility of electrons on ^{3}He-^{4}He mixture
15:15	O2.7	David Rees	Stick-slip motion of a single electron chain on the surface of liquid helium
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	Henry Hall Session		**Chair: William Vinen**
9:00	I3.1	Victor L'vov	Statistics of quantum turbulence
9:45	I3.2	Yury Mukharsky	Quantum turbulence in ^{4}He studied using the SHREK facility
10:15	O3.1	Carlo F. Barenghi	Ultraquantum decay of strongly nonequilibrated BEC turbulence
10:30		Coffee	
	Russell Donnelly		**Chair: Carlo F. Barenghi**
11:00	O3.2	William Vinen	The decay of counterflow turbulence in superfluid ^{4}He
11:15	O3.3	Andrei Golov	Interplay between ultraquantum and quasiclassical turbulence in ^{4}He in the T=0 limit
11:30	O3.4	Yoshiyuki Tsuji	Lagrange trajectory of small particles in super fluid HeII
11:45	O3.5	Makoto Tsubota	Inhomogeneous quantum turbulence in a channel
12:00	O3.6	Yuri Sergeev	Quantum turbulence without energy cascade
12:15	O3.7	Sergey Nemirovski	Statistical signature of vortex filaments: dog or tail?
12:30		Lunch	
	Nikolai Kopnin Session		**Chair: James Sauls**
14:00	I3.3	Takeshi Mizushima	Topology, emergent Ising order, and spontaneous symmetry breaking in superfluid ^{3}He-B
14:30	O3.8	Joshua Wiman	Spontaneous helical order of Cooper pairs in liquid ^{3}He
14:45	O3.9	Henri Godfrin	Multi-particle excitations in superfluid ^{4}He investigated as a function of pressure
15:00	O3.10	Eckhard Krotscheck	Correlations in the low-density fermi gas: fermi-liquid state, dimerization, and BCS Pairing
15:15	O3.11	Andrew Zimmerman	Superfluid ^{3}He confined in nanoscale Pores
15:30	O3.12	Igor Fomin	Linear theory of orbital glass states of ^{3}He-A in aerogel
15:45	O3.13	Vladimir Khmelenko	Turbulence induced luminescence of nitrogen nanoclusters immersed in superfluid helium
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9:30	O4.1	Sergey Kafanov	Nanomechanical double clamped beam for probing quantum fluids
9:45	O4.2	František Vavrek	High Q-value quartz tuning fork in vacuum as a potential thermometer in millikelvin temperature range
10:00	O4.3	Fabien Souris	Dissipation mechanisms in a superfluid micromechanical resonator
10:15	O4.4	An Qu	Observation of metastable solid and superfluid helium-4 around 1 K
10:30		Coffee	
Norbert Mulders Session			**Chair: Pertti Hakonen**
11:00	I4.2	Vladimir Dmitriev	NMR studies of superfluid polar phase of ^{3}He
11:30	I4.3	Jeevak Parpia	The A-B transition for superfluid ^{3}He confined to a 1.08 micrometer tall geometry
12:00	O4.5	Samuli Autti	Experiments on topological defects in a Dirac superfluid
12:15	O4.6	Man Nguyen	Pressure dependence of the phase diagram of superfluid ^{3}He in the presence of anisotropic disorder
12:30		Lunch	
Konrad Bajer Session			**Chair: Yuri Sergeev**
14:00	I4.4	Yong-il Shin	Dynamics of half-quantum vortices in a spinor Bose-Einstein condensate
14:30	O4.7	Enrico Fonda	Quantized vortices following reconnections
14:45	O4.8	Edouard Sonin	Magnus force on vortex in superfluids without Galilean invariance: BEC in optical lattice
15:00	O4.9	Luca Galantucci	Vortex reconnections and rebounds in trapped Bose Einstein condensates
15:15	O4.10	Davide Proment	Evolution of a superfluid vortex filament tangle driven by the Gross-Pitaevskii equation
15:30	O4.11	Pertti Hakonen	Graphene resonators in studies of quantum fluids
15:45	O4.12	Francesco Ancilotto	Superfluid behavior of quasi-1D parahydrogen inside carbon nanotube
16:00		Coffee	
16:30	P4	Posters	

TUESDAY 16 AUGUST

Takeo Matsubara Session			**Chair: Makoto Tsubota**
9:00	I5.1	Martin Zwierlein	Solitons and spin-charge correlations in strongly interacting Fermi gases
9:45	O5.1	Chung-Yu Mou	Emergence of Metallic Quantum Solid Phases in a Rydberg-Dressed Fermi Gas
10:00	O5.2	Morio Matsumoto	Pseudogap phenomena near the BKT transition of a two-dimensional ultracold Fermi gas in the crossover region
10:15	O5.3	Oleg Berman	Towards high-temperature superfluidity of excitons in TMDC
10:30		Coffee	
Shaun Fisher Session			**Chair: William Halperin**
11:00	I5.2	Oleksandr Serha	Supercurrent in a room temperature Bose-Einstein magnon condensate
11:30	I5.3	Andrew Casey	SQUID detection of nano-electro-mechanical systems
12:00			**Closing Ceremony**

Abstracts

WEDNESDAY 10 AUGUST

T1

Cryogenic Techniques and Low Temperature Properties of Matter

Christian Enns

Heidelberg University, Germany

The most common method for producing temperatures well below one Kelvin is the $^3He/^4He$ dilution refrigerator. If equipped with a well-designed nuclear demagnetization stage such systems can reach temperatures in the low microkelvin range. We will discuss some basic aspects of these cooling techniques and will point out recent developments. In addition, methods to measure very low temperatures are presented, again with an emphasis on new techniques. Since the first liquefaction of helium many fascinating properties of matter at low temperatures have been discovered. A brief overview will be given, while highlighting a few specific examples.

T2

Bose condensation and superfluidity in liquid ^{4}He

William Vinen

University of Birmingham, UK

A description of the superfluid properties of liquid ^{4}He at temperatures below the lambda-transition (metastable frictionless flow, two-fluid effects, and the quantization of superfluid circulation) will be followed by an account of the way in which Bose condensation in a system of interacting particles can lead to such properties.

T3

“Pure” superfluid ^{3}He, an introduction.

George Pickett

Lancaster University, UK

At millikelvin temperatures the Fermionic ^{3}He atoms in liquid couple to form Cooper pairs to create superfluid ^{3}He. The Cooper pair has an angular moment of $\hbar$, in which the two component atoms orbit each other as a loosely-connected dimer. Since the angular momentum is odd, to preserve parity, the spin must also be odd, i.e. also $\hbar$. This gives the Cooper pairs a very rich structure allowing the existence of several phases with very different properties and provides a number of handles for probing the condensate especially by NMR and quasiparticle “optics”. An interesting regime is the very low temperature region, where the condensate is essentially “pure” giving rise to a number of interesting properties and with a wavefunction whose symmetry provides an interesting simulation of the metric of the universe, allowing “tabletop” cosmological experiments.

T4

The Supersolid Story

Moses Chan

Penn State University, USA

Torsional oscillator (TO) measurements of solid ^{4}He carried out twelve years ago found an abrupt drop in the resonant period (ΔP) below 0.2K, suggesting superfluid onset in the solid. However, subsequent studies indicate the ΔP is due to the stiffening of the solid. New TO studies free of stiffening effect placed an upper limit of superfluidity in solid of 5×10^{-6}. Interestingly this is not the last word in supersolidity. By means of a clever design, Hallock found evidence of superfluid-like mass flow through solid ^{4}He sandwiched between two superfluid reservoirs. Recent experiments at UMass, Alberta and Penn State on the nature of this mass flow will be discussed

THURSDAY 11 AUGUST

Yoichiro Nambu Session
Chair: John Saunders

(18.1.1921-5.7.2015)

Yoichiro Nambu was a Japanese-born American physicist, and a professor at the University of Chicago. Known for his contributions to the field of theoretical physics, he was awarded the Nobel Prize in Physics in 2008 for the discovery in 1960 of the mechanism of spontaneous broken symmetry in subatomic physics related to the strong interaction's chiral symmetry, the electroweak interaction and the Higgs mechanism.

I1.1

New faces of superfluid ^{3}He: Higgs bosons, Majorana fermions and Alice strings

Eltsov Vladimir

Department of Applied Physics, Aalto University, Finland

Topological superfluid ^{3}He possesses collective modes of the order parameter, which are analogous to Higgs boson of the Standard Model of particle physics, and fermionic excitations of Majorana, Weyl or Dirac character, which can live in bulk or as bound states at interfaces and order-parameter defects. We discuss new possibilities for studies of those states opened by recent advances in the experimental techniques. The developments include ultra-sensitive probes based on Bose-Einstein condensates of magnon quasiparticles and new superfluid phases engineered with nanostructured confinement. One example is the polar phase, where a long-time elusive half-quantum vortex has been discovered.

I1.2

Possible quantum-liquid-crystal phases in helium monolayers adsorbed on graphite

Hiroshi Fukuyama(1,2), S. Nakamura(2), M. Kamada(1), R. Nakamura(1) and T. Matsui(1)

1) Department of Physics, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

2) Cryogenic Research Center, The University of Tokyo, 2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan

Recently, physics of 2D helium adsorbed on graphite is attracting renewed interests and developing rapidly in two directions. One is the possible supersolidity in 2D ^{4}He and the other the quantum spin liquid (QSL) magnetism in 2D ^{3}He. We discuss that both the astonishing phenomena are associated with a new state of matter, the quantum liquid crystal (QLC), where possibly only the orientational symmetry is broken. The hypothesis was drawn from our latest heat capacity measurements on three different systems, i.e., ^{4}He/^{4}He/gr, ^{3}He/^{3}He/gr (S. Nakamura et al., arXiv:1406.4388v2) and ^{3}He/HD/HD/gr. In the last system, we found that a commensurate solid phase with quite different QSL properties from those of the already known QSL in the compressible^{3}He/^{3}He/gr QLC phase is stabilized essentially at a single density.

Kazumi Maki Session
Chair: Kimitoshi Kono

(27.1.1936-10.9.2008)

Kazumi Maki was a world-renowned physicist in the field of superconductivity. He was a USC College professor of physics and astronomy for 34 years and was amongst an elite group of Japanese physicists, who during the 20th century fostered the development of physics as a science in Japan. In later years, his research focused on unconventional superconductors which do not conform to traditional BCS theory.

O1.1

Huge Fermi liquid and non-Fermi liquid heat capacities of ^{3}He films formed in 3D nanopore

N. Wada(1), T. Matsushita(1), T. Nishida(1), Y. Tsuchiya(1), Y. Hara(1), M. Hieda(2)

1)Department of Physics, Nagoya University, Nagoya 464-8602, Japan
2)Col. of Lib. Arts & Sci., Tokyo Medical and Dental Univ., 2-8-30 Kounodai, Ichikawa, 272-0827, Japan

We measured heat capacity C of ^{3}He film formed in 3D nanopore whose pores 2.7nm in diameter are connected with the 3D period 5.5nm. A very thin ^{3}He film adsorbed on a ^{4}He layer preplated on nanopore wall shows the specific heat of the 3D Boltzmann gas to 26mK, the lowest temperature measured. With increasing the ^{3}He coverage, C approaches to linear in T at the low temperatures, suggesting the degenerate state of the 3D Fermi gas/liquid. The observed γ-value at a large ^{3}He coverage becomes much larger than that of the bulk ^{3}He liquid. At another thickness of the preplated ^{4}He layer, C/T becomes proportional to -log T that is a typical dependence of the non-Fermi liquid.

O1.2

Theory for a multi-chamber superfluid Helmholtz resonator and superfluid fraction+

Gasparini, F. M., Thomson, R. D.

Department of Physics, University at Buffalo, SUNY, Buffalo, NY 14260, USA

We report resonances in superleaks consisting of three chambers formed by direct bonding of Si wafers. A theory is presented for the resonances and compare with the experimental superfluid fraction. The theory follows that of Rayleigh for an open two–chamber gas Helmholtz resonator. One constructs a Lagrangian for the system and derives the equations of motion. The equation for the resonant frequency is sixth order. Solutions are obtained using the known dimensions of the resonators. This theory allows one to separate the superfluid fraction effects which are hydrodynamic in origin from effects which involve correlation-length coupling among films of different thickness. These correlation-length effects are described by a new kind of finite-size scaling [1].

[1] Stephen R. D. Thomson, Justin K. Perron and Francis M. Gasparini, submitted to Phys. Rev. B.

+Work supported by NSF, DMR-1101189; M. L. Rustgi Professorship Endowment.

O1.3

Gap-induced Elasticity of Atomically Thin ^{4}He Films

Shirahama Keiya(1), Takahashi Daisuke(2), Kogure Takayuki(1), Yoshimura Hitomi(1), Higashino Rama(1)

(1) Keio University, Department of Physics, Yokohama 223-8522, Japan
(2) Ashikaga Institute of Technology, Division of General Education, Ashikaga 326-8558, Japan

^{4}He films undergo a quantum phase transition from localized to superfluid states by increasing coverage n. We made torsional oscillator (TO) studies for films adsorbed on nanoporous glasses. A TO with localized films showed an apparent supersolid behavior, an increase in frequency f with a peak in Q-1. FEM analyses reveal that the behavior results from the stiffening of He films at low T. Q-1 and f are fitted well to a Debye-like activation with a distributed energy gap: The film elasticity is governed by gap between the localized and extended states, which decreases to zero as n approaches the critical coverage nc, and excitation over the gap. The elastic constant $K-1 = n2dG/dn$ that is estimated assuming that the He chemical potential G is at the middle of the gap agrees with $K-1$ obtained from FEM within an order of magnitude.

O1.4

Third sound propagation with ^{4}He films adsorbed on 10 nm multiwall carbon nanotubes

Emin Menachekanian, Vito Iaia, Mingyu Fan, Chaowei Hu, Ved Mittal, Raul Reyes, Wenxin Xie, and Gary A. Williams

University of California, Los Angeles, CA 90095, USA

Third sound propagation is studied for ^{4}He films adsorbed on multiwall carbon nanotubes with diameters of $10 \pm 1nm$. Strong layering effects are seen for film thicknesses between 3 and 6 atomic layers. Temperature sweeps at fixed thickness show a strong broadening of the KT transition and high attenuation at the onset, and results will be compared with the theory of Guyer and Machta for the KT transition on a cylinder.

O1.5

NMR for ^{3}He in the 1D state in nanochannels -possible Tomonaga-Luttinger liquid ^{3}He

Taku Matsushita(1), Ryosuke Shibatsuji(1), Kazunori Amaike(1), Mitsunori Hieda(1,2), Nobuo Wada(1)

1) Department of Physics, Graduate School of Science, Nagoya University, Nagoya 464-8602, Japan
2) College of Liberal Arts and Sciences, Tokyo Medical and Dental University, Ichikawa 272-0827, Japan

We have investigated ^{3}He adsorbed in 2.4nm 1D channels preplated with ^{4}He by pulsed NMR down to 70mK, where dilute ^{3}He crossovers to the 1D state below the temperature corresponding to the excitation Δ_{01} of azimuthal motion. Susceptibilities of ^{3}He suggest 1D crossover below 0.5K for dilute ^{3}He and 1D degenerate states for ^{3}He above 0.02 layers. For ^{3}He in the 1D state below 0.03 layers, the spin-spin relaxation times T_2 are proportional to 1/T below 0.12K. Since low-T T2 becomes constant at higher densities where the Fermi energy exceeds Δ_{01}, the low-T increase of T_2 is characteristic of the ^{3}He 1D state. The 1/T dependence is also that proposed for possible 1D Tomonaga-Luttinger liquid.

O1.6

The study of ordered Al_2O_3 aerogel by magnetic resonance methods at low temperatures

Tagirov Murat(1,2), Alakshin Egor(1), Klochkov Alex(1), Kuzmin Vyacheslav(1), Mamin Georgiy(1), Orlinskii Sergey(1), Rodionov Alex(1), Safiullin Kajum(1), Stanislavovas Andrey(1), Zakharov Mikhail(1)

(1) Kazan Federal University, Institute of Physics, 420008, Kremlevskaya 18 Kazan, Russia
(2) Institute of Perspective Research, TAS, 420111, L. Bulachnaya 36a Kazan, Russia

Samples of oriented Al_2O_3 aerogel are studied by the EPR and NMR techniques. At least two types of paramagnetic centers interacting with Al nuclei on the surface of aerogel are revealed. The X-ray irradiation forms induced paramagnetic centers, which interact with protons located on the surface of aerogel. The spin kinetics of ^{3}He in contact with oriented aerogels has been studied in the temperature range of 1.5 – 4.2 K. The significant difference in the relaxation times dependences on magnetic field and amount of ^{3}He in the NMR cell from the cases of previously studied net-like and powder SiO_2 aerogels has been observed. The model of magnetic relaxation process for ^{3}He nuclei is proposed.

Svatopluk Krupička Session
Chair: Peter Skyba

(8.1.1922-5.1.2014)

A leading personality of Czech solid state physics, Svatopluk Krupička's research was focused on magnetism of solid substances - especially the quantum mechanical description of ferrites and various magnetic oxides. His contribution to these studies opened a new chapter in condensed matter physics. He was a long-standing leader of the Union of Czechoslovak physicists, and after the velvet revolution, director of the Institute of Physics CAS, a co-organizer of this QFS 2016 Conference.

I1.3

Quantum criticality and novel phases in heavy fermion metals

Silke Paschen

Vienna University of Technology, Austria

Heavy fermion materials are prototype systems to study quantum criticality: the application of non-thermal control parameters such as magnetic field or pressure frequently induces a continuous phase transition at absolute zero in temperature. Quantum fluctuations emerging from such a "quantum critical point" (QCP) lead to exotic behaviour that cannot be accounted for by Landau Fermi liquid theory and is thus called non-Fermi liquid behaviour. Frequently, new phases, including unconventional superconductivity, form in the vicinity of a QCP. After an overview of the field I will present recent efforts to extend the temperature scale of such studies to ultralow temperatures using cooling by nuclear demagnetization.

O1.7

One-Dimensional Liquid ^{4}He and Hard-Core Systems: Dynamical Properties beyond Luttinger-Liquid Theory

Bertaina Gianluca(1), Motta Mario(2), Rossi Maurizio(3,4,5), Vitali Ettore(2), Galli Davide Emilio (1)

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(2) The College of William and Mary, Department of Physics, Williamsburg, Virginia 23187, USA
(3) Scuola Normale Superiore, Piazza dei Cavalieri 7, I-56126 Pisa, Italy
(4) International Center for Theoretical Physics (ICTP), Strada Costiera 11, I-34154 Trieste, Italy
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Low-energy properties of one-dimensional liquid ^{4}He can be described by Luttinger-liquid theory. By means of quantum Monte Carlo and analytic continuation techniques, we compute the density structure factor also at higher energies at zero temperature [1]. Such quantity reveals the evolution from a highly compressible liquid to a quasisolid regime, manifesting a pseudo-particle-hole continuum typical of fermionic systems. At high density, we observe a novel behavior that can be interpreted with the hard-rods model, whose dynamics we investigate. Our results are compatible with some predictions by nonlinear Luttinger-liquid theory.

[1] G. Bertaina et al., Phys. Rev. Lett. 116, 135302 (2016)

O1.8

Condensation of helium in a silica aerogel: a realization of the athermal Random Field Ising Model

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We experimentally study the condensation of ^{4}He in light silica aerogels to probe the effect of dilute disorder on a first order phase transition. Using light scattering to measure the fluid state on a local scale, we show that our system is well described by the, out-of-equilibrium, athermal, Random Field Ising Model (RFIM) introduced by Sethna et al (PRL 70, 3347, 1993). Specifically, we evidence the two phenomena predicted by this model.
i) A disorder driven critical point (Aubry et al, PRL 113, 085301, 2014)
ii) A microscopic Return Point Memory along minor hysteresis loops.
Our measurements are the first to demonstrate these two effects in a single physical system.

O1.9

Quantum degradation of the second order phase transition

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The specific heat, magnetization and thermal expansion of single crystals of antiferromagnetic insulator EuTe, were measured at temperatures down to 2 K and in magnetic fields up to 90 kOe. The heat capacity and thermal expansion coefficient reveal λ-type anomalies at the second order magnetic phase transition at low magnetic fields, evolving to simple jumps at high magnetic fields and low temperatures, well described in a fluctuation free mean-field theory. The experimental data and the corresponding analysis favor the quantum concept of effective increasing space dimensionality at low temperatures that suppresses a fluctuation divergence at a second order phase transition

O1.10

Superconductivity and Quantum Critical Behavior in the antiferromagnetically ordered Heavy Fermion Compound Ce_3PtIn_{11}

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Dimensionality plays a crucial role in the character of a magnetic quantum critical point (QCP). In order to understand how the physics is influenced when going from 3D to 2D Kondo structures the $Ce_nT_mIn_{3n+2m}$ (T = transition metal, n=1, 2,..; m = 0, 1,..) family offers an alternative to otherwise artificially grown lattices, with cubic $CeIn_3$ at the 3D and $CeCoIn_5$ as an example of the opposite (2D) end of the series.

Here we discuss results on single crystals of Ce_3PtIn_{11} located in between. At ambient pressure the compound undergoes two successive antiferromagnetic (AFM) transitions at $T_1 = 2.17K$ and $T_N = 2K$. Superconductivity emerges in the complex AFM state below T_c=0.32K. Both phenomena coexist in a wide range of the pressure – temperature phase diagrams. The critical pressure to reach the QCP ($T_N = 0$) equals $p_c \gg 1.3GPa$.

O1.11

Nuclear spin driven dynamics in non-equilibrium disordered quantum systems

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The investigation of non-equilibrium disordered quantum systems with novel experimental techniques have resulted in fundamentally new insights of their dynamics. In particular, the importance of nuclear spins as surprisingly active degrees of freedom at ultra-low temperatures has been revealed in recent measurements on amorphous solids. These new findings are of high relevance to many quantum devices, like quantum dots, qubits, SQUIDs, nano-mechanical systems and quantum limited amplifiers. We present the experimental evidence for a nuclear spin driven dynamics in non-equilibrium disordered quantum systems and discuss a possible theoretical framework for such a mechanism.

O1.12

Non-isothermal Physico-Chemical Processes in Superfluid Helium

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Our experiments show that the limiting heat flow, which spoiled the fast removal of heat from a hot body by the second sound waves, exists in nanoscale as well. Moreover, this limit is exceeded in practically any exothermic process between the particles introduced into He II. In particular the merging of small cold clusters of any metal leads to the molten clusters appearance. Because the coagulation occurs mainly in quasi-1D quantized vortices the thin nanowires with dense-packed structure are its product, the perfect microspheres with atomically smooth surface can be formed at high concentrations of metal. The noticeable overheating has been also observed in the atom-molecular processes.

P1.1

Phase diagram of a time-reversal symmetry-breaking state in d-wave superconducting films

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We report a theoretical study of the phase diagram of unconventional superconducting films. This study is motivated by a recent theoretical work on d-wave superconducting films, in which a novel ground state with broken time-reversal (BTR) symmetry was predicted. In this previous theory, the system is assumed to have a cylindrical Fermi surface. We report anisotropic Fermi surface effects on the phase transition from the conventional BCS state to the BTR state. We also discuss the possibility of the stripe phase in d-wave superconducting films.

P1.2

Development of Experiment for Direct Observation of Majorana Cone at Surface of Superfluid Helium Three B Phase

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Recently, the surface states of superfluid ^{3}He are very attractive topics in the contexts of "topological superfluids". In the scheme of topological superfluids, there is a gapless cone-like surface state in the bulk gap of a surface density of states (SDOS). We call such surface state Majorana cone. Recent transverse acoustic impedance measurements of superfluid ^{3}He B-phase revealed the SDOS. However, those measurements only suggested a shape of the total SDOS that is calculated by integration of all incident angle. In this work, we plan to detect Majorana cone directly by quantum Andreev reflection which should depend on the energy of SDOS at an angle of incident.

P1.3

Porous media research by ^{3}He NMR techniques

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Nuclear magnetic resonance (NMR) of ^{3}He is a developing method of obtaining information about structure and properties of the porous substrates. The NMR characteristics of normal liquid ^{3}He at temperatures above the Fermi degeneracy of this quantum liquid strongly depend on size of pore and magnetic properties of pore's surface where ^{3}He is located. The main reason for that is highly effective spin diffusion, which transfers the "magnetic state" of adsorbed ^{3}He nuclei to the liquid ones and so-called "fast exchange" process of interchange between adsorbed and liquid state ^{3}He nuclei. A summary on spin kinetics data of ^{3}He in various nano-porous media at temperatures 1.5 – 4.2K is reported.

P1.4

Quantum criticality in Kondo quantum dot coupled to helical edge states of interacting 2D topological insulators

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We theoretically realize a novel quantum phase transition (QPT) between the one-channel Kondo (1CK) and two-channel Kondo (2CK) fixed points in a quantum dot coupled to helical edge states of interacting 2D topological insulators, recently realized experimentally in InAs/GaSb bilayer. Combining perturative renormalization group with bosonization techniques, we extract critical properties of this quantum critical point (QCP). Our work offers the first example of theoretically accessible 1CK-2CK QCP in soild state systems, and sheds light on this long standing problem since 1990s' in Kondo dot embedded in conventional Luttinger wire due to its strong coupling nature.(NJP, 2015)

P1.5

Condensation energy as a function of doping for underdoped $\mathbf{YBa_2Cu_3O_{6+x}}$ cuprates

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We report the condensation energy, the critical thermodynamic magnetic field and the mass anisotropy for superconducting cuprates $YBa_2Cu_3O_{6+x}$, with x ranging from underdoping ($x = 0.55$) to optimally doped ($x = 0.9$). We apply the Layered Boson-Fermion model of superconductivity [1], to model layered superconductors such as cuprates. By minimizing the Helmholtz free energy of the system, two optimal parameters of the model are determined, which are the impenetrability of the planes and the paired fermion fraction. The obtained results reproduce the experimental results within a 10 % error range.
[1] P. Salas, M. Fortes, M. A. Solís and F. J. Sevilla, Physica C **524** 37 (2016).
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P1.6

Superfluid transitions of ^{4}He films under new dimensional and topological conditions of nanopores

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We have investigated various new superfluid(SF) transitions of the ^{4}He films formed in nanopores which have respective conditions of dimension and topology. The ^{4}He nanotubes formed in straight nanochannels show SF onset characteristic to 1D, due to thermal excitations of the 2π-phase windings. In 3D nanopore, even thin film shows a typical 3D SF transition, where the thermal wavelength is large compared to the period of 3D pore connection. For a thick film in the 3D pore, we observed a successive phase change from normal to the 2D degenerate state followed by the 3D SF transition, in a marginal 2-to-3 dimension where the wavelength is obviously shorter than the 3D period.

P1.7

Highly mobile metastable state of He solid layer on graphite: A glass formation by mechanical perturbation?

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Solid layers of helium on graphite surface is known to undergo a highly mobile state (HMS) once the solid layer is enforced to slip on the substrate. The HMS collapses to the original inert state with the life time extending over 10^4 sec. In this paper, we suggest that the HMS is a structural glass by showing the similarities between the present system and BEDT-TTF. The latter was recently uncovered to be an electronic glass if the cooling rate is rapid enough across the freezing temperature (Wigner crystal formation temperature). We then suggest that a novel behavior on the metastability of glass should be seen for He-4 case as the condensation fraction grows in the liquid overlayer.

P1.8

Universal non-linear I-V at an impurity quantum critical point

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Universal non-linear I-V at an interacting quantum critical point (QCP) is often out of reach theoretically. Here, however, we provide a striking example of analytically accessible QCP in a spinless quantum dot coupled to Ohmic resistive leads through a symmetrical double-barrier, realized in recent experiments. The transmission approaches unity (on resonance) with a weak backscattering at low temperature and applied bias when tuned exactly to the QCP. Drawing on the dynamical Coulomb blockade theory via bosonization and re-fermionization, we obtain analytically the full I-V curve, in excellent agreement with experiments.

P1.9

Optimized Jastrow correlations for a one dimensional periodic system

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Jastrow correlations are a powerful tool to describe properties of strongly correlated systems. Mostly these correlations are optimized within variational Monte Carlo (VMC) calculations, especially for electronic systems. On the other hand there are diagrammatic methods like Hyper Netted Chain (HNC) summations, which are very successfully in describing Helium fluids. A drawback, compared to VMC is the necessary approximation of elementary diagrams. This is compensated by the lower numerical demand, the parameter free optimization and the possibility to deal with excited states. The extension of the HNC-method (and also the Fermion version FHNC) to periodic systems, i.e. a inhomogeneous density with a certain period, is presented. Special emphasis is given to the numerical feasibility of the approach. It is shown that by exploiting the symmetry even realistic three dimensional problems can be treated. The result for a inhomogeneous but periodic one dimensional electron gas is presented. As starting point we use a sinusoidal density. With this approach we describe the transition from a regime where the local density approximation (LDA) is a good approximation to a regime where it fails. Finally an outlook is given to possible applications e.g. electrons in solids, Helium adsorbed on surfaces and metal-Mott insulator transition.

P1.10

Manifestation of Fermi edge singularity in co-tunnelling regime

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The Fermi edge singularity (FES) is a prominent manifestation of the Coulomb interaction. It could be observed in a controllable way by studying the transport through the quantum dot (QD), which is electrostatically coupled to the leads. In this paper we study how FES affects higher-order tunnelling processes (co-tunnelling). To study this problem we use the bosonic description of fermions, which naturally incorporates the Coulomb interaction. We report multifractional dependense of the current through QD on the energy of the level on QD and on the bias between the leads. The universal powers are determined by the scattering phases due to interaction with charge on the QD.

P1.11

The ^{3}He NMR as a probe for geological research

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There are various methods for studying geological samples, but for some of them traditional methods are not very suitable or not reliable. For instance, the integral porosity measurements for substrates with low porosity or so-called closed porous substrates demand new methods to be implemented. The ^{3}He NMR at temperatures in the range of 1.5K – 4.2K is developing method for such application. The NMR data of ^{3}He in pores of several model samples and geological specimens is reported, the models of nuclear magnetic relaxation is proposed and the value of integral porosity estimated. The inverse Laplace transform of the ^{3}He longitudinal magnetization recovery curve has been carried out and the distribution of the relaxation times T1 has been obtained.

P1.12

The dynamics of HD adsorbed on MCM-41: NMR studies

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Nuclear spin-spin and nuclear spin-lattice relaxation times of a monolayer of HD molecules adsorbed on MCM-41 were measured with pulsed NMR in the temperature range of $1.5 < T < 20K$. We observed two distinctly different thermally activated processes of the HD molecule motions in the MCM-41 sample. For $5 < T < 8.8K$, the molecule motions are characterized by a slow diffusion process, which is followed by a fast diffusion process for $8.9 < T < 12K$. The molecule motion is dominated by liquid-like behavior above 12 K. The NMR results are discussed with a simple model that describes cluster motion at low temperature and single molecule motion at high temperature.

P1.13

Quasiclassical Approach to a SODW state in URu_2Si_2

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A quasiclassical approach is employed to theoretically investigate a new state based on spin orbit density wave (SODW) order suggested as a potential mechanism for the hidden-order phase in the heavy fermion compound URu_2Si_2 by T. Das [1]. A formalism is set up using a Hamiltonian including spin-orbit coupling and a Fermi surface nesting condition postulated in the latter. Preliminary results show the gapped structure of the density of states induced by the SOC and FS topology even in the absence of off-diagonal interactions. This quasiclassical machinery can be used to derive spin-dependent transport in the SODW state in this system.

[1] T. Das, *Phys. Rev. B* **89**, 045135(2014).

P1.14

Cosmological and particle physics experiments in superfluids

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Owing the combined symmetries the symmetry-breaking phase transitions in the Universe and superfluid ^{3}He has a many similarities. The ^{3}He may play of the role of test tube for different theories of the Universe and particle physics. In this presentation we will discuss the multiverse scenario of the Universe development. In particularly, the A-B phase transition may be considered in a frame of multiverse and inflation theories. There will be discussed different types of elementary excitations, including Majorana, Higgs boson, magnon BEC ets.

P1.15

Ground state properties of quantum halo trimers and tetramers

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Recent research of weakly bound systems consisting of few particles will be presented, with special emphasis on the universality of quantum halo states - weakly bound systems with a radius extending well into the classically forbidden region. The focus of the study are clusters consisting of T↓, D↓, ^{3}He, ^{4}He and alkali atoms. The use of variational and diffusion Monte Carlo methods enabled very precise calculation of both size and binding energy of the trimers and tetramers. Using dimensionless measures of the binding energy and cluster size, studied clusters are compared to other known halos in different fields of physics. Furthermore, the structural properties of helium trimers are compared with recently published experimental results.

P1.16

Magnetization process, thermodynamics and magnetocaloric effect of the spin-1/2 XXZ Heisenberg cubooctahedron

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Magnetic properties of the spin-1/2 XXZ Heisenberg cubooctahedron are examined using exact numerical diagonalization as a function of the exchange anisotropy. While the Ising cubooctahedron exhibits in a low-temperature magnetization curve only one-third magnetization plateau, another four intermediate plateaux can be found in magnetization curve of the Heisenberg cubooctahedron for arbitrary but non-zero exchange anisotropy. The novel plateaux generally extend over a wider range of magnetic fields with the exchange anisotropy. The Heisenberg cubooctahedron exhibits in a vicinity of all magnetization jumps anomalous thermodynamic behavior accompanied with a giant magnetocaloric effect.

P1.17

Magneto-thermodynamic signatures of quantum critical points of the ferrimagnetic mixed-spin Heisenberg chains

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Thermodynamic properties of the ferrimagnetic mixed spin-(1/2,S) Heisenberg chains are examined using quantum Monte Carlo simulations. Zero-temperature magnetization curves involve two quantum critical points with magnetization cusps, which determine a breakdown of Lieb-Mattis ferrimagnetism and Luttinger spin liquid, respectively. Thermodynamic signatures of these quantum critical points are examined at finite temperatures. While the magnetization curve at non-zero temperatures is almost without any signature, other thermodynamic response functions (susceptibility, specific heat, entropy) provide a more clear evidence of quantum critical points through local maxima or minima, respectively.

P1.18

Theoretical and experimental study of properties of $HoFe_6Al_6$-H single crystals with a magnetic compensation point at temperatures near absolute zero

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Ferrimagnetic $HoFe_6Al_6$ (tetragonal $ThMn_{12}$-type crystal structure) has a compensation point for the Ho and Fe magnetic sublattices at temperatures near absolute zero. The influence of hydrogen addition on the magnetism of a $HoFe_6Al_6$ is studied. Hydrogenation increases the Fe sublattice magnetic moment from 10 to 10.45 μB as a result of volume expansion and thus, decompensates Fe and Ho sublattices. H-T phase diagrams and a full magnetization process of the $HoFe_6Al_6$Hx (x = 0; 1) single crystals are obtained theoretically by using a single-ion model for the crystal-electric-field interaction and a mean-field model for exchange interaction. Experimental study is carried out in fields up to 60 T.

P1.19

Comparison of Critical Current Scaling Behaviors in MgB2/SiC/Si thin films

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Scaling behaviors of critical current density Jc in MgB2 thin films are investigated on different films with thickness of 100nm, 50nm and 10nm based on comprehensive scaling formula. Experimental data are reduced and analyzed with the formula over a wide range of magnitudes. In 100nm and 50nm films single scaling function has been able to fit experimental Jc data oven ten orders of magnitudes with appropriate flux pinning parameters. On the other hand, for the 10nm film, we find different Jc dependences on temperature and magnetic field, suggesting anomalous or low dimensional superconductivity.

P1.20

PRESSURE EFFECT ON THE EINSTEIN-LIKE PHONON MODE IN SUPERCONDUCTING YB_6

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YB6 is known as a conventional type-II BCS superconductor, in which the strong coupling superconductivity with $2\Delta/k_BT_c \approx 4.1$ is mediated by the Einstein-like phonon mode of Y atoms located at $\hbar\omega E \approx 9$ meV. We have investigated the pressure effect on ωE by Raman scattering up to 14 GPa. A linear increase of this phonon mode energy with pressure yields a value of the isothermal Grüneisen coefficient $\gamma T = -\partial ln\omega E/\partial lnV = 3.85$. Moreover, the pressure effect on the electron-phonon interaction calculated from the McMillan-Allen-Dynes expression for the superconducting transition temperature was determined.

P1.21

PRESSURE DEPENDENCE OF THE UPPER AND THIRD CRITICAL FIELD IN SUPERCONDUCTING YB_6

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We present measurements of the superconducting critical temperature T_c, the upper critical field H_{c2} and the third critical field H_{c3} as a function of pressure in BCS superconductor YB_6 ($T_c = 7.5K$, $H_{c2}(0) = 280mT$ and $H_{c3}(0) = 450mT$) up to 3 GPa. The magnetic susceptibility and magnetoresistivity measurement down to 2 K have shown a negative pressure effect on Tc as well as on H_{c2} and H_{c3} with slopes $dlnT_c/dp = 6 \div 7$ %/GPa, $dlnH_{c2}/dp = -14$ %/GPa and $dlnH_{c3}/dp = -11\%/GPa$, respectively. The positive pressure effect on the coherence length, $d\xi(0)/dp = 2nm/GPa$, together with the zero pressure effect on the magnetic penetration depth, $d\lambda(0)/dp \approx 0$, imply that the Ginzburg-Landau parameter $\kappa(0) = \lambda(0)/\xi(0)$ decreases markedly with pressure, $d\kappa(0)/dp = -0.32/GPa$, and moves YB_6 to the type-I direction at $p_c \approx 10GPa$.

P1.21

Melting and ordering of electrons on helium in a confined geometry

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Low-dimensional electron systems exhibit the enhancement of electron correlations when confined to narrow channels. Here we investigate the influence of confinement on the ordering of a quasi-1D electron system on the surface of liquid helium. We find that at weak confinement the melting of the Wigner Solid (WS) is determined by 2D Kosterlitz- Thouless theory. By contrast, at stronger confinement the melting of the WS depends on the confinement strength, as well as electron density and temperature. As the electron row number N_y changes, varying commensurability results in a modulation of the WS order, even when N_y is surprisingly large, which is confirmed by Monte Carlo simulations.

P1.22

Computer simulation of quasi-1D electron system in parabolic confinement

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Electrons bound to the surface of liquid helium form a model system in which the physics of strongly correlated particles interacting via Coulomb potential can be investigated. Here we present molecular dynamic study of strongly correlated electrons in an external parabolic confinement. We analyze the diffusion coefficient as well as velocity autocorrelation function dependence on the commensurability of Wigner Solid (WS). We show that melting of q1D-WS depends on the confinement strength.

P1.23

Graphene-like microwave billiards: Van-Hove singularities (VHS) and Excited-State Quantum Phase Transitions (ESQPT).

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Superconducting 2D microwave resonators containing triangular lattices of metallic cylinders form photonic crystals, which enable to model finite-sized graphene flakes. High presision spectral measurements resolving all excitations are possible. We describe the spectra by an algebraic model, providing analytical solutions to the dispersion relations and density of states. At the VHS, whose energies correspond to an ESQPT, we find stable stripe-like states parallel to the zig-zag direction, simillar to the topological edge states, however these appear in the bulk. They are stable with respect to long range perturbations and noise, and appear also for irregular shapes of the boundaries.

P1.24

Localized excitations in 2D system of charged hard-core bosons

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Making use of an asymptotic analysis and continual approximation we constructed the phase diagram of localized excitations over a homogeneous ground state for the 2D system of charged hard-core bosons. It is shown that in the superfluid (SF) phase the excitations are the ferro- and antiferro- type vortices. Near the boundary between the SF and supersolid (SS) phases, the antiferro-type vortices in the SF phase begin to dominate, their inflation leads to a change of the homogeneous ground state from the SF to SS phase. In the SS phase the vortices are only possible at the half-filling (net charge-ordered phase), while at arbitrary filling the topological excitations like skyrmions exist.

P1.25

The ground state phase diagram of 2D spin-pseudospin system

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High-Tc cuprates show examples of the mutual coexistence and competition of the spin and charge ordering. We examine the 2D model system where one of the on-site copper valence triplet states ("pseudospin" S=1 states), or Cu2+, has a spin s=1/2 degree of freedom. Depending on the value of the on-site correlation, inter-site density-density interaction, the spin exchange integral and doping, the system shows different types of the ground state ordering. These include both the competition and coexistence of the spin and pseudo-spin ordering, for a strong and weak exchange coupling, respectively. We present the results of the analytical and numerical calculations.

P1.26

Nonlinear transport of the inhomogeneous Wigner crystal in a channel geometry

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Transport properties of an electronic Wigner crystal on the surface of helium-4 are investigated in a 10 and 5-μm-wide channel, which allows creating a controllable Wigner crystal inhomogeneity above a variety size of the gate area. This inhomogeneity significantly affects the Wigner-crystal-attributed transport phenomena, such as Bragg-Cherenkov scattering and sliding transition. In particular, when the density above the gate is much higher than in the rest of the channel, the density-altered area starts behaving as an "individual" Wigner crystal, which is revealed in observation of two subsequent sliding transitions. A simple model is proposed, which allows qualitative explanation of such behavior.

P1.27

Nanofluidic structures for the study of mesoscopic topological superfluidity

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The confinement of liquid helium-3 into nanofluidic structures of precisely defined geometry and surface conditions, enables the stabilization of specific phases (e.g. superfluid ^{3}He-A, ^{3}He-B or normal Fermi liquid). This opens the way to the sculpture of hybrid nanofluidic structures for the investigation of mesoscopic topological superfluidity. We present some designs, which exploit the ability to create clean junctions between phases. We propose methods for the study of thermal transport, targeted towards a study of the proximity effect in SNS junctions and the detection of predicted edge states in chiral superfluid ^{3}He-A.

P1.28

Self-generated oscillations of the electron density in a photo-excited electron gas on liquid helium

Nasyedkin Kostyantyn(1), Kono Kimitoshi(1,2,3)

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We study self-generated oscillations (SGO) of the electron density which emerge in the photo-excited electron gas on liquid helium under the zero-resistance state regime. We use the Corbino geometry sample cell with the outer ring electrode divided into 4 segments and record the ac transient current from each segment simultaneously. The cross-correlation analysis of the recorded data shows a phase shift between the current oscillations for different segments that implies the existence of the charge flow in an azimuthal direction. The charge flow changes its direction when a polarity of the magnetic field is changed and coincides with the direction of the edge magnetoplasmons propagation.

P1.29

Fluidity of domain walls in dilute ^{3}He–^{4}He mixture monolayer films ≈ Possible 1D Fermi fluid and 2D Dirac fermions in helium film on graphite ≈

Morishita Masashi, Umemoto Masatoshi

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To interpret the anomalous behaviors of measured heat capacity of dilute ^{3}He–^{4}He mixture monolayer films, fluidity of domain walls and possible behaviors as 1D Fermi fluid and 2D Dirac fermions of mobile ^{3}He atoms in the domain walls have been proposed. In particular, observed anomalous T2-behavior of heat capacity can be attributed to the linear dispersion of the Dirac fermions. Existence of critical velocity of superfluidity of ^{4}He film due to the Landau criterion has also been proposed. To obtain more precise and definite information about the behavior of ^{3}He atoms, heat capacity measurements with smaller amount of ^{3}He atoms are in progress, and these results will also be presented.

P1.30

Low temperature heat capacity of ^{4}He films on graphite

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Helium-4 films adsorbed on graphite surfaces provide an ideal 2D boson system. At some areal densities, possible supersolidity has been reported. However, their properties have not been clearly understood yet. Heat capacities of ^{4}He films have been measured at rather low temperatures between 1 and 80 mK and at areal densities between 2 and 24 nm^{-2}. Between 19 and 24 nm^{-2}, small but definite bumps have been observed below 20 mK, whose origin has not been understood yet. On the other hand, the measured heat capacity above 30 mK hardly change between 13 and 24 nm^{-2}, which suggests that the second atomic layer does not solidify at these areal densities, at least not into a commensurate solid.

P1.31

Microfabrication of Multi-Slit Structures for Studies of Quasi-2 Dimensional Topological Superfluid ^{3}He

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2) University of Tokyo, Cryogenics Research Center, Japan

3) Keio University, Department of Applied Physics and Physico-Informatics, Japan

4) University of Tokyo, Department of Electrical Engineering and Information Systems

Superfluid ^{3}He has been attracting much interest as a topological superfluid. Confinement of ^{3}He into well-defined slit geometries enables us to perform ultrasound experiments of topological properties, such as edge-related surface collective (Higgs) modes, and flow experiments, such as phase slippage by half-quantum vortices. We report fabrication of multiple micro-slit structures through a thin Si layer of SOI chips, where the slit dimensions are 1μm×100μm×50μm, by semiconductor processing techniques including Reactive Ion Etchings. The method and result of our microfabrication and prospective experiments are discussed.

P1.32

Escape Rates of Surface-State Electrons on Liquid Helium Film

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3) Institute of Physics, Kazan Federal University, Kazan 420008, Russia

While the escape of electrons is proposed to be a readout mechanism of a quantum-bit on the basis of the ground and the first-excited surface-states of electrons on liquid He, we measured the escape rates of surface-state electrons on liquid helium film with a STM-like tip at around 1.5K. We use a microchannel device with upper and bottom electrodes to control the initial electron density ($\approx 10^8 cm^{-2}$) on the helium film surface, and the adjustable tip is placed above the surface with tens of μm distance. The electric field dependent escape rates are presented here, and methods for detecting different rates are also developed.

P1.33

Quantum Monte Carlo study of Mg-doped bulk helium-4

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Mg-doped helium droplets are believed to have an observable metastable state in which the alkali atoms remain separated by a considerable distance, thus forming so-called “atomic foam”. The exact nature of such a state is not well understood. We will describe our efforts to study the confinement-induced long-distance interaction between a pair of Mg atoms suspended in the superfluid.

P1.34

NMR study of interactions in ^{3}He-^{4}He mixture films on graphite.

A. Waterworth(1), J. Nyeki(1), B. Cowan(1), J. Saunders(1)

1) Department of Physics, Royal Holloway, University of London, UK

Layered ^{3}He-^{4}He fluid mixture films on graphite provide a model 2D Fermi system, which is tuned by changing either the ^{3}He or ^{4}He surface density. We report preliminary SQUID NMR measurements, at temperatures down to 250 μK, for ^{3}He on a three layer ^{4}He film. For ^{3}He coverages $1 \leq$ n3 ≤ 4 nm^{-2}, the data allow comparison with Fermi gas theory. At higher ^{3}He coverages (n3 ≥ 5.0 nm^{-2}) population of the first excited surface Andreev bound state leads to a more complex temperature dependent magnetization, arising from a change in structure of the ^{4}He fluid layer. The magnetization at low ^{3}He densities (n3 $\leq$ 1.0 nm^{-2}) will also be discussed, in terms of interactions mediated by the ^{4}He layer.

P1.35

Intertwined superfluid and density wave order in two dimensional ^{4}He

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Department of Physics, Royal Holloway, University of London, UK We review our

torsional oscillator measurements which find four distinct regimes of anomalous superfluid response in the second layer of ^{4}He adsorbed on graphite, over a coverage range near third layer promotion. Our identification of a new quantum phase is consistent with heat capacity measurements. Interestingly the most recent path-integral Monte Carlo simulations find no evidence for second layer commensurate solid. Our data identifies the new phase to be an unconventional emergent state in which superfluidity and solidity are quantum entangled. We also find the superfluid response persists up to third layer promotion at which the energy scale governing superfluid onset vanishes.

P1.36

^{4}He confined in narrow nanopores

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Path integral Monte Carlo (PIMC) and diffusion Monte Carlo calculations of ^{4}He confined in narrow nanopores are presented. Superfluid fraction and the one-body density matrix (OBDM) are obtained with the goal to determine the effective dimensions of ^{4}He in the nanopore.
The PIMC superfluid fraction and OBDM scale as a 1D Luttinger Liquid at extremely small liquid pore diameters only, where the liquid atoms form a 1D line at the center of the pore, while for larger pores, crossover to 2D behaviour is obtained [2]. The effects of disorder are estimated for selected nanopore sizes and densities.

1. L. Vranjes Markic and H. R. Glyde, Phys. Rev. B92, 064510 (2015)

P1.37

Coupling of the Wigner Crystal with Liquid Helium 4 under Sliding Condition

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A Wigner crystal (WC), a two-dimensional electron solid, trapped on liquid ^{4}He is coupled with surface excitations of the liquid. And it shows resonance modes called "coupled plasmon-ripplon (CPR) modes". We measured the frequency change of the CPR modes before and after the sliding of the WC occurs, which is induced by applying ac electric field by corbino electrodes. The resonance frequencies jump at the sliding point. This is due to drastic change of the coupling between the WC and liquid ^{4}He surface because the periodic dimples on liquid surface, which are placed just below WC electrons, disappears when the sliding occurs. We also discuss about the critical behavior.

P1.38

Effective mass calculations for a two-dimensional dipolar fermion gas

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We consider a two-dimensional spin-polarized system of atomic or molecular gas of dipolar fermions with dipole moments aligned in the perpendicular direction. We use the static structure factor information from quantum Monte Carlo simulations and from variational ground-state calculations to obtain effective (many-body) dipole-dipole interaction. We calculate the many-body effective mass of the system within the G0W approximation to the self-energy. The role played by density fluctuations in the calculated effective mass as a function of interaction strength is assessed.

P1.39
Quantum Phases of Spin-1 Bosons on the AB Chain

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Motivated by recent studies on optical lattices, we explore the one-dimensional structure of spin-1 bosons in an alternating lattice, assuming on-site Coulomb repulsion and antiferromagnetic interaction. We determine the quantum phases by calculations of ground-state energy via Density Matrix Renormalization Group. Results in the chemical potential in the thermodynamic limit give evidence of insulators in integer and semi-integer densities, and superfluid phases. We show the phase diagram for small quantum fluctuations considering spin-1 bosons as a function of the spin-dependent term, where important contributions of the exchange interaction in the evolution of insulator regions are found.

P1.40
Magnetic properties and magnetocaloric effect in $MnCo_{0.95}Cu_{0.05}Ge$ compound

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We studied the structure, magnetic and magnetocaloric (MC) properties of $MnCo_{0.95}Cu_{0.05}Ge$ alloy. A single phase of the Ni_2In-type hexagonal structure (space group P63/mmc) is proven to be formed in the final sample by X-ray powder diffraction pattern at room temperature. A second-order paramagnetic-ferromagnetic transition is observed at Curie temperature $T_C \approx 256$ K, accompanied by a large MC effect. Below T_C, the sample shows strong ferromagnetism, which is caused by the sub-lattice Mn-Mn ordering. The maximum value of magnetic entropy change is evaluated to be $13.64\,J\,kg^{-1}\,K^{-1}$ for a magnetic field change $\Delta H = 7$ T. The corresponding relative cooling power reaches $869\,J\,kg^{-1}$.

P1.41

Quantum Criticality, Quantized Massive Gauge Fields, and the Strange Metal in High-Tc Cuprates

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2) Graduate School of Pure and Applied Science, University of Tsukuba

Tacon et al.[1] have observed by means of resonant inelastic X-ray scattering that damped magnetic excitation are present inside the electron-hole spin-flip continuum(up to 300 meV) in doped high-Tc cuprates. Kanazawa[2, 3] has introduced quantized collective-massive gauge fields around the doped hole as collective modes, which contain effects of spin fluctuation, charge fluctuation, and phonon. In addition,Kanazawa[4 − 6] has proposed the mechanism of evolution of the Fermi arc with increasing of temperature and holo-doping in high Tc cuprates. It is seen that the evolution of the Fermi arc is much related to the restoration of the spontaneous symmetry breaking. In this study, we will discuss the relation among quantum criticality, the strange metal, and quantized massive gauge fields in high Tc cuprates.

[1]M. Le Tacon et al. Nat.Phys.7,725(2011)
[2]I. Kanazawa,Physica C 185-189,1703(1991)
[3]I. Kanazawa,J.Phys.A36,9371(2003)
[4]I. Kanazawa,J.Phys.Chem.Solids 66,1388(2005)
[5]I. Kanazawa,Physica C 470,S183(2010)
[6]I. Kanazawa,T.Sasaki,Phys.Scr.T165,014038(2015)

P1.42

QUANTUM EFFECTS IN HYDROGEN SORPTION BY MESOPOROUS MCM-41 MATERIAL

Maria.V. Khlystiuck, Alexander.V. Dolbin, Valentyn.B. Esel'son, Victor.G. Gavrilko, Nikolay.A. Vinnikov, Razet. M. Basnukaeva

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Studies of hydrogen absorption by porous silicate MCM-41 materials have shown that the processes of sorption and subsequent desorption of the H_2 molecules MCM-41 channels are several mechanisms that occur in different temperature ranges. At a temperature below 8 K, the diffusion coefficients H_2 weakly dependent on temperature, which corresponds to the change in the MCM-41 pores filling mechanism, from layer-by-layer filling to the capillary condensation of H_2 molecules. Obtained results were compared with experimental results for H_2 sorption by carbon nanotubes.

FRIDAY 12 AUGUST

Robert Richardson Session
Chair: George Pickett

(26.6.1937-19.2.2013)

Robert Coleman Richardson was an American experimental physicist whose area of research included sub-millikelvin temperature studies of helium-3. Richardson, along with David Lee and Douglas Osheroff, shared the 1996 Nobel Prize in Physics for their 1972 discovery of superfluid helium-3 in the Cornell University Laboratory of Atomic and Solid State Physics.

I2.1

Non-isothermal Physico-Chemical Processes in Superfluid Helium

Haley R. P.

Lancaster University

Coherent condensates appear as emergent phenomena in many systems, sharing the characteristic feature of an energy gap separating the lowest excitations from the condensate ground state. An object moving with high enough velocity that the excitation spectrum becomes gapless can create excitations at no energy cost and initiate the breakdown of the condensate. This limit is the well-known Landau velocity. For the neutral Fermionic superfluid ^{3}He-B in the T=0 limit, flow around an oscillating body displays a very clear critical velocity for the onset of dissipation. However, to our considerable surprise, we have found that for uniform linear motion there is no discontinuity whatsoever in the dissipation as the Landau critical velocity is passed and exceeded.

I2.2

Visualizing Textural Domain Walls in Superfluid ^{3}He by Magnetic Resonance Imaging

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2) Dept. of Applied Physics, Univ. of Fukui, Fukui, JAPAN.
3) LTM Center, Kyoto University, Kyoto, JAPAN.

A real space image of textural domain walls inside a single 100 micrometer thickness slab of superfluid ^{3}He-A was MRI-imaged. Straight lines, which appeared in between large domains of uniform textures, were textural domain walls (solitons) with particularly important feature. The observed NMR properties suggest that the domain wall has almost dipole-locked soliton structure inside the wall, which connects two regions of uniform $\mathbf{d} = \mathbf{l}$ texture with different chirality, namely $\mathbf{d}, \mathbf{l}$ and $-\mathbf{d}, -\mathbf{l}$. This soliton is accompanied with two surface chiral domain walls located back to back on both side of the slab surface. The surface chiral domain walls anchor the dipole-locked soliton in its place.

O2.1

Thermal solitons in a quasi-1D Bose gas as revealed by studying static structure factor

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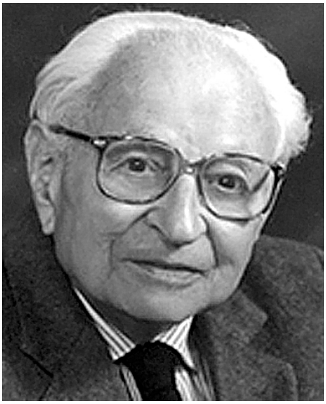
We study, within a framework of the classical fields approximation, the static structure factor of a weakly interacting Bose gas at thermal equilibrium. As in a recent experiment (R. Schley et al., Phys. Rev. Lett. 111, 055301 (2013)), we find that the thermal distribution of phonons in a three-dimensional Bose gas follows the Planck distribution. We find as well a disagreement between the Planck and phonon distributions in the case of elongated quasi-one-dimensional systems. We attribute this discrepancy to the the existence of spontaneous dark solitons (thermal solitons as reported in T. Karpiuk et al., Phys. Rev. Lett. 109, 205302 (2012)) in an elongated Bose gas at thermal equilibrium.

Laszlo Tisza Session
Chair: Eckhard Krotscheck



(7.7.1907 - 15.4.2009)

Laszlo Tisza, physics professor and expert in quantum mechanics and thermodynamics formulated the two-fluid theory of superfluid helium-4. His research areas included theoretical physics as well as the history and philosophy of science, specifically on the foundation of thermodynamics and quantum mechanics.

I2.3

Mass flow through thin solid helium samples*

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3) Penn State University, PA, USA; current address: Neel Insitut, France
4) Penn State University, PA, USA

We will report measurements of superfluid-like mass flow through solid helium samples sandwiched between two superfluid reservoirs as used sby Hallock at the Univ.of Mass.(PRL 100, 235301, 2008). Instead of a solid sample of 4 cm as employed by Hallock, our solid samples have thicknesses of 8, 50 and 1000 microns. Our measurements show interesting differences from that found at UMass, flow rate as a function of path length, temperature and pressure will be presented. Work supported by US NSF.

O2.2

Defect motions in quantum solids with spins

Cheng Zhi-Gang, Beamish John

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Defect motion in solid helium has uniquely quantum nature due to the large zero-point motion of helium atoms. Dislocations in solid ^{4}He are strongly pinned by ^{3}He impurities at low temperature but extremely mobile at high temperature, causing the shear modulus greatly reduced. ^{3}He has even larger zero-point motion than ^{4}He and extra nuclear spins, which may govern defect motion differently. We report shear modulus measurements of hcp solid ^{3}He to explore its dislocation motion. We observed the crossover between stiff and soft states due to ^{4}He impurities immobilizing dislocations as static pinning sites, as well as dissipation strongly depending on frequency. Both suggest the coupling between spin system and dislocation motion. We also observed extra softening at high temperature that does not exist for solid ^{4}He.

O2.3
WAVES ON QUANTUM SURFACES

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At an interface between two media, the 3D symmetry is broken which allows for the existence of exotic particles like Majorana fermions or anyons. A natural way to explore these surface excitations is to study surface resonances. In addition to usual capillary waves, helium at low temperatures supports phase waves, like waves of crystallization. By using a double resonance technique we have obtained the first evidence of the crystallization waves in ^{3}He at temperatures well below 0.5 mK. We also discuss the possibility of phase waves at the interface between two different superfluid phases of ^{3}He. This wave does not have usual material mass, and its inertia is due to spin supercurrents.

O2.4
Atomic force microscopy of solid He

Ori Scaly, Almog Danzig, and Emil Polturak,

Technion- Israel Inst. Of Technology, Department of Physics, Haifa 32000, Israel

Crystallites of solid He can move in relation to each other inside the solid. We detected such motion directly, using an in-situ acoustic sensor [1]. An interesting question is what physical mechanism would enable such motion. One possibility is a fluid monolayer at the interface, acting as lubricant. Another possibility is slip of crystal grains induced by gliding dislocations. To answer this question, we constructed a new sensor made of 1micron thick conducting wire loop embedded in the solid. Magnetic flux is applied through the loop. Motion of the wire induced by moving solid will produce a current which will be detected by a SQUID amplifier. The S/N of this apparatus should be 100 times higher than before[1]. We hope to detect the motion of the solid in real time.

1. E. Livne, et al., J. Low Temp. Phys. 180,185 (2015).

O2.5

Nonlinear ultrasound propagation in solid ^{4}He due to pinning and unpinning of dislocations by ^{3}He

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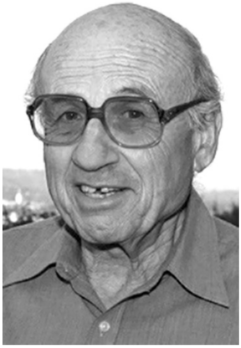
2) Serin Physics Laboratory, Rutgers University, New Jersey, USA

Ultrasound attenuation (α) and velocity (v) at 9.6MHz are measured in polycrystalline hcp ^{4}He. Ultrasound signal above 200mK is linear and understood in terms of resonant vibration of dislocation segments pinned at network nodes with average pinning length (4.5μm), much shorter than that from shear modulus (59μm). Dramatic changes in α and v are observed below 200mK. The changes are strongly dependent on temperature, nonlinear and hysteretic. These effects result from pinning and unpinning of dislocations by ^{3}He impurities (0.3ppm). The dislocation damping constant due to thermal phonons, the binding energy between dislocation and ^{3}He, and the stress-induced unpinning process are analysed.

Walter Kohn Session
Chair: Paul Leiderer



(9.3.1923 - 19.4.2016)

Walter Kohn was an Austrian-born American theoretical physicist and theoretical chemist. He was awarded, along with John Pople, the Nobel Prize for chemistry in 1998. The award recognized their contributions to the understanding of the electronic properties of materials. Kohn played the leading role in the development of density functional theory, which made it possible to incorporate quantum mechanical effects into electronic density calculations (rather than through its many-body wavefunction). This computational simplification led to many insights and has become an essential tool for studying electronic materials, as well as atomic and molecular structures.

I2.4
Electrohydrodynamic effects in superfluid ^{4}He

Petr Moroshkin

RIKEN Center for Emergent Matter Science, Japan

We inject large quantities of electrically charged impurity particles into superfluid ^{4}He that can influence the properties and the dynamics of the superfluid. Applied large static electric field induces the motion of the charged superfluid and perturbations of the liquid surface that can be captured by a fast video camera. We observe several electrohydrodynamic phenomena that so far had not been addressed in relation to superfluid helium: electroconvection, formation of bubbles, surface waves, quasistatic dimples and humps (Taylor cones), jet emission (electrospraying), as well as a shuttle motion of charged microparticles and their trapping at the free surface of the liquid.

I2.5
Electron bubbles and Weyl Fermions in chiral superfluid ^{3}He-A

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The A phase of ^{3}He is a chiral superfluid that spontaneously breaks parity and time-reversal symmetries. This was beautifully demonstrated by the observation of an anomalous Hall mobility of electron bubbles by the RIKEN group. We present the theory of the anomalous Hall effect for negative ions in superfluid ^{3}He-A, based on a full quantum mechanical treatment of multiple scattering of Bogoliubov quasiparticles by ions embedded in the chiral superfluid. Quantum interference leads to the transverse force on the ions. Our results are in quantitative agreement with the RIKEN experiments, providing a microscopic view of the underlying processes responsible for the anomalous Hall effect.

O2.6

Mobility of Electrons on ^{3}He-^{4}He Mixture

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2) Department of Physics, KAIST, Daejeon 305-701, Republic of Korea

Adsorbed ^{3}He atoms on a free surface of ^{3}He-^{4}He mixture liquid offer an ideal two-dimensional (2D) Fermi system with a tunable interaction between ^{3}He, showing 2D Fermi degeneracy and potentially superfluidity. To study properties of the 2D ^{3}He, we performed a first systematic measurement of mobility of electrons trapped on the free surface down to 10 mK by varying the concentration of ^{3}He from 0.5 to 6.1 %. We found that the mobility in the Wigner crystal regime is understood in terms of the viscosity of the bulk liquid at temperatures higher than about 100 mK and the specular reflection of ballistic ^{3}He quasiparticles below 100 mK. We discuss the influence of the 2D ^{3}He on the mobility.

O2.7

Stick-slip motion of a single electron chain on the surface of liquid helium

Rees David(1,2), Beysengulov Niyaz (2,3), Lin Juhn-Jong(1,2), Kono Kimitoshi (1,2,3)

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A quasi-1D electron crystal moving across the surface of liquid helium performs stick-slip motion (SSM) due to repeated coupling and decoupling with surface capillary waves (ripplons)[1]. The decoupling threshold force is larger when the electrons form well-defined rows, due to the enhancement of resonant ripplon scattering. Here we show that continuously reducing the number of electrons in the crystal therefore results in a modulation of the SSM as the number of rows changes. We find that the SSM persists even in the limit of the single electron chain. The influence of reduced dimensionality on the electron-ripplon coupling will be discussed.

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O2.8

Studying the shape and stability of multielectron bubbles in liquid helium under externally applied electrical fields

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Multielectron bubbles (MEBs) are charged cavities in liquid helium that provide a rich system to study the behavior of electrons on curved surfaces, and to investigate the properties of two dimensional electron layers at densities that have never been explored. In this talk, I will discuss a new strategy to trap MEBs for several seconds, which is a significant improvement over existing techniques. This has allowed us to study the effect of electric field on the shape and stability of the bubbles. Using time varying electric fields, it has been possible to excite their resonant modes, which suggest a new way of investigating these interesting objects.

O2.9

Mobility of Electron Bubbles in Superfluid Helium

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Using a density functional theory that accounts for the properties of surface tension and equation of state in superfluid Helium-4, we model the motion of a self-trapped electron within a cavity. Full 3D simulations are perfrormed to study the complex spatio-temporal dynamics. By studying the motion of the electron subject to an applied electric field of different strengths, the mobility of the electron bubble both within the bulk and for a bubble trapped on a quantised vortex is determined. We discuss our results in light of the recent proposals on the interpretation of measured electron mobilities in liquid Helium. Our results also provide an important tool in understanding the dynamics of electrons trapped on quantised vortices.

P2.1

Chiral magnetic effect in a two-band lattice model of Weyl semimetal

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Employing a two-band model of Weyl semimetal, the existence of the chiral magnetic effect (CME) is established within the linear-response theory. The crucial role played by the limiting procedure in deriving correct transport properties is clarified. Besides, in contrast to the prediction based on linearized effective models, the value of the CME coefficient in the uniform limit shows a nontrivial dependence on various model parameters. Furthermore, we show that the Weyl nodes are not required for the CME in a clean, infinite system. Similar to the anomalous Hall effect, the CME results directly from the Berry curvature of energy bands, even when there is no monopole source from the Weyl nodes.

P2.2

Behaviour of multielectron bubbles in liquid helium pressed against thin solid films

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A Multielectron bubble (MEB) is a cavity formed inside liquid helium with a layer of electrons confined to its inner surface. Here we describe an experiment to study the behaviour of MEBs pressed against a charge collection electrode, where the electrode was covered with thin films of different materials, comprising of both metals and dielectrics. Preliminary analysis of the experimental data suggests that MEBs lose their charge in a time scale of seconds when they are held against the thin film. We suspect that quantum tunnelling of electrons through the thin layer of helium between the MEB and the thin film plays the dominant role in determining the charge loss mechanism.

P2.3

Quantum Phase Transition in the Electron-Hole Liquid in the Coupled Quantum Wells

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Many-component electron-hole plasma is considered in the Coupled Quantum Wells (CQW). It is found that the homogeneous state of the plasma is unstable if the carrier concentration is sufficiently small. Instead, the electron-hole liquid drops appears. A homogeneous electron-hole liquid state is stable if the distance between the quantum wells L is small. However, as the distance L increases and reaches a certain critical value Lcr, the plasmon spectrum of the electron-hole liquid becomes unstable, what results in the appearance of the charge density waves of a finite amplitude in both quantum wells. An effective mass renormalization is considered, and the strong mass renormalization is found for the electron-hole liquid after the quantum phase transition occurs.

P2.4

A proposal for detecting edge current in px+ipy topological superfluid ^{3}He

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Superfluid ^{3}He is a natural candidate for studying topological superfluidity (TSF) as it is the only fully confirmed p-wave superfluid/superconductor in existence. It is especially powerful for such a purpose in the sense that it hosts different types of TSFs in a single material: from time reversal invariant TSF in bulk ^{3}He-B to time reversal broken $p + ip$ TSF in ^{3}He-A and polar phase can all be seen within it when properly configured. Despite such strengths in superfluid ^{3}He, no true topological signature has been established due to lack of realistic measurement scheme. We propose a method for detecting one of the topological signatures, i.e. the angular momentum generated by the edge current of two dimensional $p + ip$ ^{3}He-A. A micromechanical gyroscope is being developed for the measurement, and we report on our progress.

P2.5

An energy gap in the spectrum of atomic excitations ^{4}He system. Superfluidity.

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The procedure of the reduction of the N-particle wave function, describing the collective motion of the atoms in the quantum system of He4, to the binary wave function of neighboring atoms is proposed. Considering the helium atoms as quantum particles, we calculated their energy in the ground and first excited state.It is shown that state of atoms in the liquid He4 is characterized by the discrete energy spectrum resulting in formation of s- and p- zones corresponding to the ground and excited states of helium atoms, separated by energy gap of value $\approx$5-8 K. The existence of a gap in the energy spectrum of the atomic excitation in He4 system allows us to draw an analogy between the physical mechanisms of superfluidity and classical superconductivity.

P2.6

Observation of splitting and coalescence an with Multi electron bubbles

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When the two dimensional layer of electrons above the surface of liquid helium is taken beyond a critical density, multielectron bubbles (MEBs) are formed. These are spherical cavities in liquid helium which contain electrons bound within a nanometre distance from their inner surfaces. MEBs form a model system for probing properties of interacting electrons over curved surfaces, but have been subject to limited experimental investigation. The purpose of this paper is to report on new surprising observations with MEBs, particularly related to their splitting and coalescence. In the presence of a high electric field, MEBs could be split into many smaller bubbles, where the electrons were distributed unequally between the daughter bubbles. Coalescence of MEBs could also be observed, in spite of the bubbles being negatively charged. The coalescence could be seen in the bulk liquid, as well as when the MEBs were attached to a solid surface. Analysis of these experimental results reveals a new way of tuning the density of electrons in MEBs, which will be essential to observe new electronic phases in this novel system.

P2.7

The electrical activity of He II with relative motion of normal and superfluid components

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The theory is proposed that explains the experiments [1–3] where an electric potential difference in the relative motion of the superfluid and normal components of superfluid helium (He II) was observed. The theory is based on the fact that in the presence of relative motion quantized vortex rings (QVR), contained in the normal component, have an anisotropic distribution function. This anisotropy and electrical properties of QVR leads to dipole moment density emergence in He II, which creates an electrical potential difference.

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P2.8

Measurement of drag of bubbles in liquid helium at high Reynolds numbers

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Multielectron bubbles are micron sized cavities inside liquid helium with electrons localized on the inner surface. Recent experiments on MEBs using a Paul trap showed that they can be trapped for few hundred milliseconds and the properties could be measured in non-destructive manner. Using a new and improved technique, we were able to study MEBs of sizes up to 100 microns. Since MEBs are charged bubbles, their motion can be controlled by electric fields compared to the gas bubbles in other liquids which is governed by gravity. This salient feature of MEBs allowed us to measure the drag of MEBs as a function of Reynolds number by analysing the trajectories. Due to the low viscosity and surface tension of helium compared to other liquids, the measurements could be performed at Morton Numbers that have never been explored. We also show that how the shape of a single MEB evolves from spherical to ellipsoidal as their speeds vary.

P2.9
NMR Studies of Superfluid Polar Phase of ^{3}He

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We report results of NMR experiments in superfluid polar phase of ^{3}He. This phase is not realized in bulk ^{3}He, but can be stabilized in ^{3}He confined in a new type of aerogel (nafen) which strands are nearly parallel to one another. In our experiments the polar phase was observed in all used samples of nafen with porosities from 98% down to 77%. It was found that the region of existence of this phase essentially depends on nafen porosity, pressure and on ^{4}He coverage of the nafen strands. NMR properties of the polar phase and influence of spin supercurrents on the spin dynamics were investigated. Possible future experiments will be also discussed in the talk.

P2.10
The Quantum Phenomena of Magnonics.

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The spin supercurrent and magnon BEC was observed in many magnetically ordered materials like Superfluid phases of ^{3}He-A and ^{3}He-B, antiferromagnets with Suhl-Nakamura interaction, YIG films ets. The different quantum phenomena were observed: Josephson effect, Goldstone modes, quantum vortex, critical current, phase slippage ets. In this presentation we will discuss the resent progress in these investigations.

P2.11

Working parameters of a Paul Trap to study charged bubbles in liquid helium

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In a recent experiment, we have used a linear Paul trap to hold and study multi-electron bubbles (MEBs) in liquid helium. MEBs have a charge-to-mass ratio (between 10^{-4} to 10^{-2} C/kg) which is several orders of magnitude smaller than ions (between 10^{6} to 10^{8} C/kg) typically studied in traditional ion traps. In addition, MEBs experience significant drag force while moving through the liquid. As a result, the experimental parameters, such as applied voltages and electric field frequencies, for stable trapping of MEBs are very different from those used in traditional ion trap experiments. The purpose of this paper is to model the motion of MEBs inside a linear Paul trap in liquid helium, determine the range of working parameters of the trap, and compare the results with experiments.

P2.12

The Flow Resistance of the Oscillating Tuning Fork Immersed in Superfluid Helium

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The result on the motion of He II excited by a tuning fork are analyzed. It is shown that before attaining certain threshold values by a parameter, with the structure of the Reynolds number, the normal and superfluid components move independently. In this case the force and the drag coefficient are completely determined by the motion of the normal component. When the parameter exceeds the threshold value which is critical for velocity the turbulent flow regime begins to work. This regime at a temperature below that for the transition to a superfluid state is attributed to the formation of quantized vortices. The motion of helium at a temperature above the transition point is discussed.

P2.13

The damping and drag coefficient of quartz tuning fork in superfluid solutions ^{3}He - ^{4}He

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The influence of ^{3}He impurity on the damping and drag coefficient of the oscillating tuning fork in superfluid solutions 5 and 15% of ^{3}He are presented. The measurements were performed at temperature range 0.5 - 4 K and the exciting voltage from 1 mVpp to 500 Vpp. The carried measurements allowed constructing the temperature dependences of the damping coefficient for measured ^{3}He concentrations, which have agreement with similar measurements for vibrating sphere. The calculation of the contributions of the viscosity, first and second sounds of the temperature dependence of the dissipation of the vibrations of the tuning fork has been performed.

P2.14

Coupling between first sound and second sound in dilute ^{3}He – superfluid ^{4}He mixtures

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Bulk superfluid helium supports two sound modes: first sound is an ordinary pressure wave, while second sound is a temperature wave, unique to superfluid systems. The sound modes do not usually exist independently, but pressure variations are accompanied by variations in temperature, and vice versa. We studied the coupling between first and second sound in dilute ^{3}He - superfluid ^{4}He mixtures, around 2 K, at saturated vapor pressure, using a quartz tuning fork oscillator. Second sound coupled to first sound creates anomalies in the resonance response of the fork, which disappear only at very specific temperatures and concentrations, where two factors governing the coupling cancel each other.

P2.15

Exploding and Imaging Bubbles in Superfluid Helium

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An electron bubble in liquid Helium-4 under saturated vapour pressure becomes hydrodynamically unstable at a pressure more negative than-1.9 bars, which can be easily achieved with focused sound waves. Here, we report on imaging the cavitation of an electron bubble at 30000 frames per second, which reveals that the bubbles can grow to as large as 1 mm within 2 ms of the cavitation event. As revealed from our numerical simulations, the inertia of the bubble wall during cavitation plays an important role in determining its maximum size. The dependence on temperature and static pressure within the experimental chamber will also be discussed.

P2.16

NANO-SIZE INHOMOGENEITY SUBSTRATE ANALYSIS USING SURFACE ELECTRONS OVER SUPERFLUID HELIUM FILM

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The quality of the substrate is a crucial in building of a quantum system. The surface electrons (SEs) over helium film with thickness d on substrate can be a good tool to analyze the surface. The mobility of SEs is limited by interactions with the helium atoms in gas, with ripplons and by surface roughness: $m^{-1} = m_c^{-1} + m_{im}^{-1}$ (m_c and m_{im} are mobilities of SE for ideal and real substrate). The variation potential from substrate is

$$\delta v \approx -Q_d \frac{e^2}{4\pi\epsilon_0 Z} \frac{\pi\xi}{A} \left(\frac{A}{Z}\right)^{1/2} e^{-\frac{2\pi Z}{A}} \tag{0.1}$$

(Z is distance of SE from the substrate, ξ and A are effective amplitude and period of inhomogeneities). At $A \approx z \approx d \approx 10^{-5}$ cm (z is distance from liquid helium surface) $\delta V \approx 10^{-3}K$ and at $z \approx d \approx A/2$ the $\delta V \approx 1K$ that leads to decreasing SEs conductivity. We suppose the activation energy can be applied instead of value δV. Here we propose innovation method providing a uniformity of d by accurate horizon of the cell and using electro-mechanic driver with plunger to adjust the liquid level.

P2.17

POLARON TRANSPORT ANOMALITIES OF SURFACE ELECTRONS OVER STRUCTURED SUBSTRATE COVERED BY HELIUM FILM

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The electron polaron can be formed over liquid He in gas phase using surface electrons (SE). Polaron has a low mobility and this may be used for monitoring the transition between kinetic and hydrodynamic regime. Polaron is considered to be a possible candidate for a quantum bit. Autolocalization of SE significantly depends on the structure and quality of substrate. The polaron formation at various helium film thicknesses covering the structured silicon substrate with a regular system of micropores is investigated in temperature range 1.6 – 2.4 K. It is found that the polaron formation temperature depends on substrate structure.

P2.18

Formation and plasma modes of multi-chain electron system over liquid helium

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We simulate the electron system over liquid helium in presence of confinement potential acting in the plane of electron layer. The transformation of electron crystal into multi-chain system is observed along with final formation into zigzag and single-chain configurations. Both longitudinal and transversal plasma oscillations of formed zigzag electron system are considered theoretically. One of the longitudinal oscillation modes is acoustic whereas other one is optical. Two transversal branches of oscillations are optical. We compare the dispersion laws of plasma modes with those in a single chain of electrons. The results obtained can be used in experimental efforts to identify the configuration of low-dimensional electron system over helium in presence of confinement potential.

P2.19

Some applications of a framework comprising E_F-incorporated equations for Δ_0 and T_c and the corresponding number equations

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Augmenting the conventionally employed framework of BCS-BEC crossover physicse.g., [1−3] via inclusion of the equation for Tc and the corresponding number equation, replacing the BCS equations for Δ_0 and T_c by the generalized BCS equations when dealing with non-elemental superconductors (SCs), and curtailing the limits of the number equations to avoid complex-valued solutions when EF $k_B\theta_D$ (k_B=Boltzmann constant; θ_D=Debye temperature), we draw attention to recent work that dealt with (1) crossover physics without appeal to scattering length theory,[4] (2) the long-standing puzzle posed by $SrTiO_3$,[5] (3) an explanation of hitherto unexplained features of La_2CuO_4,[6] and (4) heavy-fermion SCs.[7]

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P2.20

On the role of Fermi energy in determining properties of superconductors

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Supplementing the E_F-incorporated equations for Δ0 and T_c,1 which were recently employed to deal with SrTiO3, La2CuO4, and heavy-fermion superconductors (SCs), by similar equations for the critical current density j_0, we present new equations for the j_0 of elemental and composite SCs that depend solely on their following properties: E_F, Debye temperature, gram-atomic volume, Sommerfeld constant, and a dimensionless construct where m* is the effective mass of superconducting electrons and P_0 their critical momentum. Calling attention to the recent treatment of several SCs in such a framework,[2] we present here an explanation of the $\{T_c, j_0\}$ data on NbN films reported by Semenov et al.[3]

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P2.21

Correlation between the components of resistance tensor in disordered Nd_2-xCexCuO_4+δ as a manifestation of anisotropic pairing symmetry.

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The $\rho xx(B)$ and $\rho xy(B)$ of the electron-doped compounds $Nd_2 - xCexCuO_4 + \delta$ in under doped (x = 0.14) and optimally doped (x=0.15) regions near antiferromagnetic (AF)-superconducting (SC) phase transition and with varying degrees of disorder (δ) were investigated. In the under doped region where the coexistence of the long-range AF fluctuations and SC occurs the scaling relationship $\rho xy(B) \approx \rho xx^{\beta}(B)$ gives $\beta = 0.8$–1.55 can be connected both with a displaying of anisotropic s - or d - wave pairing symmetry and with a pinning due to an essential degree of disorder. The value $\beta \approx 1$ in optimally doped region points out on the evidence of the d - wave pairing symmetry.

P2.22

Helical Majorana fermions in dx2–y2 + idxy-wave topological superconductivity of doped correlated quantum spin Hall insulators

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We propose a novel route for realizing Majorana fermions in 2D spin-singlet topological superconducting state in doped correlated quantum spin Hall insulator, relevant for adatom-doped graphene. Via a renormalized mean-field approach, the system exhibits time-reversal symmetry breaking dx2−y2 + idxy-wave superconductivity near half-filling. Surprisingly, at large spin-orbit coupling, the system undergoes a topological phase transition to a new topological phase protected by a pseudospin Chern number. Two pairs of counterpropagating helical Majorana modes per edge, instead of two chiral propagating edge modes in the d + id′ superconductors, are realized.

P2.23

Superfluid-like Responses in Rotating Solid Helium

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The influence of DC rotation to a torsional oscillator (TO) cannot be clearly understood within the framework of elastic stiffening of solid helium since no effect is observed in the shear modulus measurements. In this study, we re-investigated the rotation effect on solid helium by using a rigid double-torus TO. Although new rigid TO experiments failed to reproduce the substantial DC rotation effect, an extremely small suppression of a frequency-independent period drop as small as 1.8 ppm was observed with rotation speed of 4rad/s. The signal is distinguishable from the frequency-dependent elastic contribution in various aspects. To elucidate its origin, several possibilities will be discussed.

P2.24

Friction in solid ^{4}He, classical and quantum

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“Macroscopic quantum friction” describes an irreversible exchange of quantized excitations between two bodies in relative motion. In usual materials and at high temperatures, quantum friction is negligible compared with classical friction, namely plastic deformation of the interface. In contrast, in solid He the measured classical friction is many orders of magnitude lower[1]. This opens the way to detect quantum friction, which in solid He is mediated by irreversible exchange of phonons[2]. While the phonon mechanism of quantum friction seems understood, it is the unusually low classical friction in solid He which remains a puzzle. This low friction alludes to some mass transport mechanisms unique to solid He, which at low temperatures allows plastic deformation with little or no dissipation.

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P2.25

Plastic Flow of Solid ^{3}He at Low Temperatures.

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Plastic flow of solid ^{3}He through a porous membrane frozen in the crystal is observed in the temperature range 0.1 - 1.0 K. It was found that the temperature dependence of the flow velocity has two characteristic regions - at temperatures above $\approx$ 0.2 K, the velocity decreases exponentially with lowering temperature, which corresponds to the thermally activated process, and at low temperatures the velocity is independent on T, which indicates the quantum mechanism of mass transfer. The experimental results can be explained within the vacancy model under special conditions or within the model of the motion of dislocations in the Peierls potential relief.

P2.26

PRESSURE GRADIENTS AND MAGNETIC RELAXATION IN QUENCHED
HCP ^{3}He-^{4}He CRYSTALS

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The samples of hcp solid mixture (1.0% ^{3}He in ^{4}He) are studied by pulse NMR technique. Samples are grown by blocked capillary method under different growth rates (about 8, 2, and 0.08 mK/s). NMR technique is used for phase identification by measurements of diffusion coefficient D, spin-lattice and spin-spin relaxation times (T_1 and T_2) at temperatures of 1.3 – 2.0 K and pressures of 34 – 36 bar. Along with D and T_1,T_2 for the hcp phase, we simultaneously observed the D and T_1, T_2 typical for liquid for growth rates 8 and 2 mK/s. That means liquid-like inclusions are formed in solid hcp matrix during fast crystallization. It has been established, that in the quenched samples there is continuous pressure relaxation due to local pressure gradients in the samples. It is also shown that the slower growth rate corresponds to smaller size of liquid droplets. Finally, the transition of the liquid droplets to some new state is observed.

P2.27

Influence of non-stoichiometry on the frustrated honeycomb system $Li_3Ni_2SbO_6$

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4) Southern Federal University, Chemistry Faculty, 344090 Rostov-on-Don, Russia

In this work we present the results of the investigation of new quasi two-dimensional (2D) honeycomb-lattice compound $Li_3Ni_2SbO_6$ and non-stoichiometric $Li_0, 8Ni_0, 6Sb_0, 4O_2$. The magnetization and NMR data reveal the change of the sign of magnetic interactions and suppressing of the magnetic correlations at low temperatures with doping. We assume the crossover to the cluster spin glass state in $Li_0, 8Ni_0, 6Sb_0, 4O_2$ instead of the antiferromagnetic transition in $Li_3Ni_2SbO_6$. Also from NMR data we conclude that the vacancies in the lithium subsystem rise the lithium mobility at high temperatures.

P2.28

Polarizability of methane cryodeposits

Drobyshev Andrey(1), Sokolov Dmytryy(2), Aldiyarov Abdurakhman(3), Shinbayeva Aynura(3)

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Experimental studies of the effect of methane deposition temperature on the value of the polarizability of the resulting thin films are reported. The values of the coefficients of refraction and density of the methane, which was obtained during the same experiment, allows to determine the polarizability of the methane molecules in the solid phase. These calculations were performed using the Lorentz-Lorenz equation by analogy to the calculations of the polarizability of carbon dioxide carried out in [1]. Measurements in the vicinity of the phase transition temperature T = 20.4 K in the range 14–32 K were carried out, meaning, the samples were investigated in two different states of the rotational subsystem of the crystal lattice of methane [2].

[1] M. Domingo, R. Luna, M.A. Satorre, C. Santonja, C. Millán, J. of Low Temp. Phys. 181, 1 (2015).

[2] A. J. Nijman A. J. Berlinsky, Phys. Rev. Lett. 38, 408 (1977).

P2.29

A Model of Glassy Phase for HCP ^{4}He Crystals

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A model of close-packed polytype with the structure of chaotic stacking faults is applied to interpret anomalous thermodynamic properties of disordered glassy phase in solid HCP ^{4}He [1]. The temperature dependences of solid ^{4}He free energy, pressure and heat capacity have been calculated. The HCP-based polytype is a crystal with perfect ordering along the plates, but atomically disordered in perpendicular direction. Such a crystal structure can be reduced to an anisotropic elastic medium with specific dispersion law. The theoretic results are compared with corresponding experimental data known from literature. The quantitative agreement between theory and experiment has been found and discussed. The developed polytype model can be applied to interpret the evolution of the ^{4}He lattice defect structure under external pressure at variation of the temperature.

[1] T.N. Antsygina, M.I. Poltavskaya, K.A. Chishko, Low Temp. Phys., 41, 743 (2015).

P2.30

IR-spectrometric studies of the spin-nuclear conversion in the vicinity of α- β- transition temperature of methane

A. Aldiyarov, A. Drobyshev, E. Koshikov, V. Kurnosov, A. Shinbayeva, D. Sokolov

Kazakh National University, 050071, al-Faraby av. 71, Almaty, Kazakhstan

The features of the solid methane properties are determined largely due to the nuclear spin relaxation processes and their influence on the rotational and translational subsystems of the methane crystal lattice. This most clearly affects the vibrational spectra of methane in the range of translational and librational vibration. This article presents results of the studies of the effect of condensation temperature of methane on the IR-spectra of the resulting thin films. In contrast to the rather large number of studies of equilibrium solid methane samples, we consider the results obtained directly in the course of samples' cryocondensation. Measurements in the vicinity of the phase transition temperature T = 20.4 K in the range from 14–32 K were carried out.

P2.31

Investigation of electric response in standing wave of first and second sound

Tymofiy Chagovets

Institute of Physics of the Czech Academy of Sciences

We report an experimental investigation of the electric response of superfluid helium that arises in an acoustic resonator in the presence of a first sound standing wave. Previous experiments showed a strong correlation between the resonance frequency of the electric response and the frequency of the second sound resonance. In recent experiments we observed the appearance of an potential difference on electrostatic probe whose resonance frequency is corresponded to the frequency of the first sound resonance in the experimental range of temperature (1.75 - 2.15K). It was found that the amplitude of the electric potential, ΔU, in resonance is proportional to the amplitude of the pressure oscillations in the first sound wave. Possible reasons of the electric response onset induced by first and sound will be discussed.

P2.32

Solid helium study using elasticity-sensitive torsional oscillator under DC rotation

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1) Keio University, Department of Physics, Yokohama 223-8522

2) Ashikaga Institute of Technology, Department of General Education, Ashikaga 326-8558

3) University of Tokyo, Cryogenic Research Center, Bunkyo-ku 113-0032

4) RIKEN, Low Temperature Phys. Lab., Wako-shi 351-0198

Recent elastic measurement of solid ^{4}He under DC rotation shows the insensitiveness of its elasticity to DC angular velocity, while the same rotation condition makes the characteristic period change in solid-packed torsional oscillator (TO) experiments. This contradiction must be due to the difference of the AC velocity; TO method is done within 10-100 times larger AC velocity than the elasticity measurements. To study the solid property under DC rotation in large AC velocity, we employ a "floating core" TO (Reppy, JLTP2012) that is sensitive to the elasticity of solid. This should reveal whether the "fast" elastic response affects to the change in period of TO under rotation or not.

P2.33

The spectroscopy of collective modes in unconventional superconductors and superfluids

Brusov Peter(1), Filatova Tatiana(2)

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(2) Financial University, Financial manegement faculty, Moscow 49 Leningradsky Prospekt, Moscow, Russia, 125993, GSP-3

We study the collective properties of unconventional superconductors and superfluids. We consider superfluid phases of ^{3}He within path integral technique and calculated the complete collective mode spectrum in different phases of superfluid ^{3}He. After the discovery of collective modes in unconventional superconductors (USC), their study becomes very important. Collective modes (CM) in HTSC exhibit themselves in many experiments: ultrasound attenuation (UA) and microwave absorption (MWA), neutron scattering, photoemission and Raman scattering, etc. The contribution of collective modes to UA and MWA may be substantial. We consider two-dimensional and three-dimensional models of p- and d-pairing for superconductors built by the path integration technique. Within these models we calculate the collective excitations in different unconventional superconductors [high temperature superconductors (HTSC), heavy fermion superconductors (HFSC), etc.] under p- and d-pairing. We consider both bulk and 2D systems. Some recent ideas concerning realization in HTSC of the mixtures of different states are investigated. Obtained results could be used for interpretation of the sound attenuation and microwave absorption data as well as for identifcation of the type of pairing and order parameter in unconventional superconductors. They allow us to distinguish pure d-wave state from the mixture of two d-wave states in HTSC. We create new direction in unconventional superconductors and superfluids: "The spectroscopy of collective modes".

P2.34

Superfluid ^{3}He-B in the vicinity of a boundary

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(1) Financial University, Applied Mathematics faculty, Moscow
(2)Financial University, Financial management faculty, Moscow 49 Leningradsky Prospekt, Moscow, Russia, 125993, GSP-3.

We have analyzed transverse sound experiments in superfluid ^{3}He -B, where some peaks in the transverse sound absorption have been observed. Our analysis of existing experimental data leads us to a conclusion that the deformed B phase is realized near the boundary. This implies that the influence of the wall or, speaking in general, of any confined geometry does not lead to the existence of a new phase near the boundary, but the wall deforms the order parameter of the B phase and this deformation leads to some important consequences.

P2.35

Magnetism based on rotational tunneling of protons in ice

Yen, Fei (1)

1) Institute of Solid State Physics, Chinese Academy of Sciences, Hefei 230031 P. R. China

The magnetization M(T) of ice exhibits an anomalous peak near 60 K and becomes positive near 48-72 K when subjected to external magnetic fields of 2 kOe or less. The field dependent magnetization M(H) exhibits an added hysteretic loop that is superimposed with the diamagnetic signal at low fields in the same temperature range. We conjecture that application of an external magnetic field induces concerted rotational tunneling of protons in groups of six in selective hexamers which create an internal magnetic field component that counters the internal magnetic field created by the electrons. Rotational tunneling of the protons appears to be correlated to the volume of ice which exhibits a minimum near 60 K. The slight discrepancies in M(T) and M(H) suggest that coupling exists between the two magnetic subsystems.

P2.36

Electron Transport on ^{3}He - ^{4}He mixture

Kitak Kim

KAIST, republic of Korea

P2.37

Notes on the Vollhardt "invariant" and phase transition in the helical itinerant magnet MnSi

Stishov, Petrova

Institute for High Pressure Physics of Russian Academy of Sciences,Troitsk, Moscow , Russia

In this paper we argue that rounded "hills" or "valleys" demonstrated by the heat capacity, thermal expansion coefficient, and elastic module are indications of a smeared second order phase transition, which is flattened and spread out by the application of a magnetic field. As a result, some of the curves which display a temperature dependence of the corresponding quantities cross almost at a single point. Thus, the Vollhardt crossing point should not be identified with any specific energy scale. The smeared phase transition in MnSi preceding the helical first order transition most probably corresponds to the planar ferromagnetic ordering, with a small or negligible correlation between planes. At lower temperatures, the system of ferromagnetic planes becomes correlated, acquiring a helical twist.

P2.38

Fermi liquid theory applied to a film on an oscillating substrate

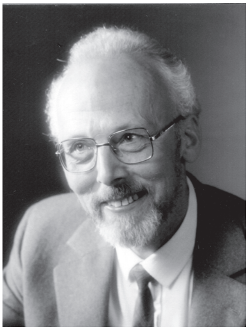
Kuorelahti(1), Tuorila(1) and Thuneberg(1)

1) University of Oulu, Theoretical Physics, Pentti Kaiteran katu 1, 90014 Oulu, Finland

We consider a film of a normal-state Fermi liquid on a planar substrate. Landau's Fermi liquid theory is applied to calculate the linear response of the film to transverse oscillation of the substrate. The response consists of a collective transverse zero sound mode, as well as incoherent quasiparticle excitations of the degenerate fermions. We calculate numerically the acoustic impedance of the film under a wide range of conditions relevant to normal state helium-3 at millikelvin temperatures. Some cases of known experiments are studied but most of the parameter range has not yet been tested experimentally.

SATURDAY 13 AUGUST

Henry Hall Session
Chair: William Vinen



(28.9.1928 - 4.12.2015)

Henry Edgar Hall FRS was one of the leading low temperature physicists of his generation in the United Kingdom. He contributed crucially to the experimental verification of the existence and importance of quantized vortex lines in superfluid ^{4}He and to an understanding of their dynamical behaviour. He designed and built the first working dilution refrigerator in the UK. In doing so, he made major contributions to our understanding of superfluidity in liquid ^{3}He.

I3.1
Statistics of quantum turbulence

Victor S. L'vov and Anna Pomyalov

Dept. of Chemical Physics, Weizmann Institute of Science, Rehovot 17600, Israel

Based on the current understanding of statistics of quantum turbulence in ^{4}He and ^{3}He as well as on the results of its ongoing analytical, numerical and experimental studies, we discuss the following problems in the large-scale, space-homogeneous, steady-state turbulence: Energy spectra of the normal and superfluid velocity components; Cross-correlation function of the normal and superfluid velocities; Energy dissipation by mutual friction and viscosity; Energy exchange between the normal and superfluid components; High-order statistics and intermittency effects. The statistical properties will be discussed for different types of turbulent flows: coflow of ^{4}He; flow of ^{3}He-B with laminar normal fluid; pure superflow and counterflow of ^{4}He.

I3.2
Quantum turbulence in ^{4}He studied using the SHREK facility

Yury Mukharsky(5), C. Baudet(1,2), M. Bon Mardion(3,4), P. Bonnay(3,4), F. Chillà(6), L. Chevillard(6), F. Daviaud(5), P. Diribarne(3,4), B. Dubrulle(5), D. Faranda(5), B. Gallet(5), M. Gibert (7,8), A. Girard(3,4), J.M. Poncet(3,4), J.-P. Moro(9), P.-E. Roche(7,8), B. Rousset(3,4), E. Rusaouën(7,8), J. Salort(6), E-W. Saw(5), S. Nazarenko(10), A. Golov(11)(SHREK collaboration)

SHREK collaboration
1. Univ. Grenoble Alpes, LEGI, Grenoble, France
2. CNRS, LEGI, Grenoble, France
3. Univ. Grenoble Alpes, INAC-SBT, Grenoble, France
4. CEA, INAC-SBT, Grenoble, France
5. SPEC, CEA-CNRS, Universite Paris-Saclay
6. Laboratoire de Physique de l'ÉNS de Lyon, CNRS/Université Lyon, Lyon, France
7. Univ. Grenoble Alpes, Institut NEEL, Grenoble, France
8. CNRS, Institut NEEL, Grenoble, France
9. CEA, DEN-DANS-DM2S-STMF-LIEFT, Grenoble, France
10. Warwick Uniwersity, Inst. of Mathematics, UK
11. Manchester University, School of Physics and Astronomy, UK.

We will present recent results from SHREK collaboration. Different sensors were used to characterize the turbulence: hot wire anemometer, Pitot tubes, flexible cantilever anemometer and second-sound absorption. The Pitot tubes have new design which allows for potentially wider frequency range. I will also present a novel noise-reduction method of spectral averaging. The method allows to average down to zero almost all sources of sensor and preamplifier noise, including thermal noise.

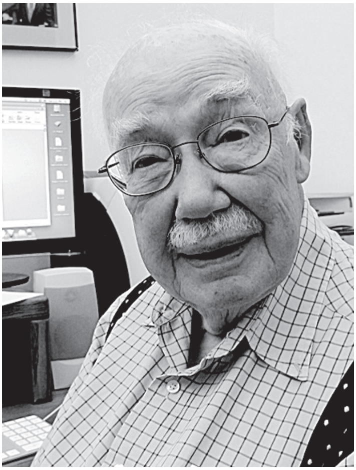
O3.1
Ultraquantum decay of strongly nonequilibrated BEC turbulence

G.W. Stagg, N.G. Parker, and C.F. Barenghi

School of Mathematics and Statistics and Joint Quantum Centre Durham-Newcastle, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom

Following Berloff and Svistunov (2002) we study the emergence of a macroscopically coherent condensate from the cooling of a thermal gas of weakly-interacting bosons. Starting from a uniformy occupied highly nonequilibrated condition, we track the growth of the low k modes which feature a tangle of quantised vortex lines. Analysis of vortex line density, incompressible energy spectrum and correlation function suggests that the tangle is a random flow without large scale structures similar to the ultraquantum turbulence of Walmsley and Golov (2008) and the counterflow turbulence first observed by Vinen.

Russell Donnelly Session
Chair: Carlo Barenghi



(16.4.1930 - 13.6.2015)

An internationally recognized authority in the field of low-temperature physics, Donnelly directed the Cryogenic Helium Turbulence Laboratory at the University of Oregon. Here Russ launched an intense period of research on superfluid flow and some of the exotic features of helium II, such as rotons and quantized vortex rings. He was a champion of outreach being the principal science consultant for a documentary "Absolute Zero".

O3.2

The decay of counterflow turbulence in superfluid ^{4}He

J. Gao(1,2), W. Guo(1.2), V.S. L'vov(3), A. Pomyalov(3), L. Skrbek(4), E. Varga(4), W.F. Vinen(5)

1) National High Magnetic Field Laboratory, 1800 East Paul Dirac Drive, Tallahassee, Florida 32310, USA.
2) Florida State University, Mechanical Engineering Department, Tallahassee, Florida 32310, USA.
3) Weizmann Institute of Science, Department of Chemical Physics, Rehovat 76100, Israel.
4) Charles University, Faculty of Mathematics and Physics, Ke Karlova 3, 121 16 Prague, Czech Republic.
5) University of Birmingham, School of Physics and Astronomy, Birmingham B15 2TT, UK.

Experiments, based on the attenuation of second sound and on the visualization of normal-fluid flow with metastable He2 excimer molecules, are reported, showing that the form of the decay of thermal counterflow turbulence in superfluid ^{4}He after a heat current is switched off depends on whether in the steady state there is turbulence in the normal fluid: in the absence of such turbulence, the decays follows that expected from Vinen's phenomenological equations; in the presence of such turbulence, the decay has the more complicated form that is usually observed. A simple theory is presented that accounts, semi-quantitatively, for this more complicated form.

O3.3

Interplay between ultraquantum and quasiclassical turbulence in ^{4}He in the T=0 limit

P. M. Walmsley, A. I. Golov

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We investigated free decay of the density, L(t), of tangled quantized vortices generated by negative ions in superfluid ^{4}He at T 0.2 K. By varying the current of ions and duration of their injection, we could control the initial energy of large-scale flow in the superfluid. Hence, either pure ultraquantum 'Vinen' (uncorrelated tangles decaying as $L \approx t^{-1}$) or pure quasiclassical (structured tangles decaying as $L \approx t^{-3/2}$) turbulence could be created, as well as a mixture of the two, in which the former decay law L(t) converts into the latter after a delay. The polarization (ratio of lengths of the structured and random components) of the tangle in its ultimate state is estimated.

O3.4

Lagrange trajectory of small particles in super fluid HeII

Wataru Kubo and Yoshiyuki Tsuji

Nagoya University, Department of Energy Engineering and Science, Nagoya city Japan 464-8603

Small tracer parties in HeII are visualized and their motions are analyzed. The particles are made of solid hydrogen whose diameter is an order of micron. In a counter flow, changing the heat flux and bath temperature, Lagrange velocity and accelerations are computed by analyzing the visualized images through PTV technique. We studied how the particle sizes affect the statistics of particle motions. The probability density functions of acceleration shows nearly stretched exponential shape. But the tail part is significantly affected by the particle sizes. These are similar characteristics in classical turbulence. We compared the detail of them and discuss their property.

O3.5

Inhomogeneous quantum turbulence in a channel

Makoto Tsubota, Satoshi Yui, Shinichi Ikawa

Department of Physics, Osaka City University, Osaka 558-8585, Japan

We discuss the numerical simulation of inhomogeneous quantum turbulence in a square channel. The recent visualization experiments revealed inhomogeneous flow profile in a channel. We discuss three topics. One is inhomogeneous structure and dynamics of vortices in thermal counterflow[1]. The second is superfluid boundary layer in pure normal flow, where we found the logarithmic velocity profile of superfluid velocity [2]. The last is coflow turbulence. The simulation finds a novel behavior that vortices are dragged into an attractor by the mutual friction [3].

[1] S. Yui, M. Tsubota, Phys. Rev. B91, 174504(2015).
[2] S. Yui, K. Fujimoto, M. Tsubota, Phys. Rev. B92, 224513(2015).
[3] S. Ikawa, M. Tsubota, Phys. Rev. B93, 184508 (2016).

O3.6

Quantum turbulence without energy cascade

Yuri A. Sergeev(1), Carlo F. Barenghi(2), Andrew W. Baggaley(2)

1) Newcastle University, Joint Quantum Centre (JQC) Durham-Newcastle and School of Mechanical and Systems Engineering, Newcastle upon Tyne NE1 7RU, United Kingdom
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Earlier the existence has been established of two regimes of quantum turbulence: the quasiclassical regime associated, at hydrodynamic scales, with the Richardson cascade and the Kolmogorov energy spectrum, and the ultraquantum (Vinen) regime without the classical energy spectrum and cascade. This raises the question whether Vinen turbulence is a new form of disorder, or there are mechanisms which prevent the development of the classical cascade and the Kolmogorov spectrum. We argue that the latter is the solution of this important puzzle.

O3.7

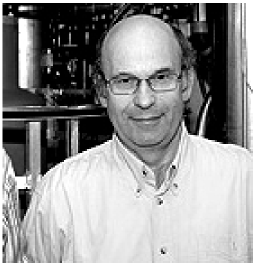
Statistical signature of vortex filaments: dog or tail?

Serggey Nemirovskii

Institute of Thermophysics, Lavrentyev ave, 1, 630090, Novosibirsk, Russia

The title of talk coincides with the title of the paragraph in famous book on classical turbulence by U. Frisch. In this paragraph the author discussed the role of statistical dynamics of vortex filaments in theory of turbulence and put the above question. In other words, whether the main properties of turbulence (cascade, scaling laws) are the sequence of the vortex line dynamics or the latter have only marginal signature. The goal of my talk is to discuss which elements of vortex dynamics would lead to main ingredients of theory of turbulence. We discuss an exchange of energy between different scales, the possible origin of Kolmogorov type spectra and the decay of quantum turbulence.

Nikolai Kopnin Session
Chair: James Sauls



(17.5.1946 - 20.10.2013)

Nikolai Borisovich Kopnin was a Russian physicist specializing in superconductivity and superfluidity, particularly non-equilibrium and non-stationary phenomena. One of the forces acting on quantum vortices in superfluids and superconductors is known as the "Kopnin force" after him. In 1991, by extending his theory concerning this force to chiral superfluids, he predicted the existence of fermionic bound states, quasiparticles now known as Majorana fermions, and that it may be possible to observe them in topological superfluids and superconductors.

I3.3

Topology, emergent Ising order, and spontaneous symmetry breaking in superfluid ^{3}He-B

Takeshi Mizushima

Department of Materials Engineering Science, Osaka University, Toyonaka, Osaka 560-8531, Japan

Superfluid ^{3}He serves as a rich repository of topological quantum phenomena, and the marriage of the prototypical topological superfluid with nanofabrication techniques brings about a rich variety of spontaneous symmetry breaking, such as a variety of Nambu-Goldstone modes and Higgs modes. In this talk, I review the recent progress on understanding the nontrivial topological structure and symmetry breaking of superfluid ^{3}He. This includes the emergence of Majorana fermions, their quantum mass acquisition at the topological critical point, and new bosonic modes bound to the surface. A key ingredient to understand these novel phenomena is the emergence of the Ising order. I show that the emergent Ising order spontaneously forms the domain wall by increasing a magnetic field across the topological critical point.

O3.8

Spontaneous helical order of Cooper pairs in liquid ^{3}He

Wiman Joshua(1), Sauls J. A.(1)

1) Northwestern University, Department of Physics & Astronomy

Confined liquid ^{3}He is predicted to have superfluid phases which spontaneously break the translational symmetry of their confining geometry. We predict a superfluid phase with helical order that is energetically stable within narrow cylindrical channels near Tc and at both high and low pressures. This helical order is manifest in the supercurrent, which traces out a double-helix. Using a strong-coupling Ginzburg-Landau (GL) theory that accurately reproduces the bulk phase diagram, we present the phase diagram, including 5 other superfluid phases, as a function of temperature, pressure, channel radius, and surface conditions. We also discuss the transverse NMR signatures of this phase.

O3.9

Multi-particle excitations in superfluid ^{4}He investigated as a function of pressure

Beauvois K.(1, 2, 3), Campbell C. E.(4), Dawidowski J.(5), Fåk B.(1, 6, 7), Godfrin H.(2, 3), Krotscheck E.(8, 9), Lauter H.-J.(10), Lichtenegger T.(8, 9), Ollivier J.(1), Sultan A.(2, 3, 7)

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2) Univ. Grenoble Alpes, Inst NEEL, F-38000 Grenoble, France

3) CNRS, Inst NEEL, F-38042 Grenoble, France

4) School of Physics and Astronomy, Univ. of Minnesota, Minneapolis MN 55455, USA

5) Comisión Nacional de Energía Atómica and CONICET, Argentina

6) Univ. Grenoble Alpes, INAC-SPSMS, F-38000 Grenoble, France

7) CEA, INAC-SPSMS, F-38000 Grenoble, France

8) Department of Physics, University at Buffalo, SUNY Buffalo NY 14260, USA

9) Institute for Theoretical Physics, Johannes Kepler University, A4040 Linz, Austria

10) Spallation Neutron Source, ORNL, Oak Ridge, Tennessee 37831, USA

The dynamic structure function S(q,E) of superfluid ^{4}He has been measured at very low temperatures for pressures up to 10 bars, in the multi-excitation regime. The neutron scattering measurements were performed at the Institut Laue-Langevin on the time-of-flight spectrometer IN5. Our measurements at saturated vapour pressure [1] display a very rich landscape of multi-excitations, including a “ghost phonon” and other remarkable features which are found to depend on pressure in agreement with the Dynamic Many-Body theory [2].

[1] K. Beauvois et al., arXiv:1605.02638v1, to be published.

[2] C. E. Campbell, E. Krotscheck, and T. Lichtenegger, Phys. Rev. B 91, 184510 (2015).

O3.10

Correlations in the low-density Fermi gas:Fermi-Liquid state, Dimerization, and BCS Pairing

Fan, H.-H.(1, 2), Krotscheck E.(1, 2), Zillich, R. E.(2)

(1) Department of Physics, University at Buffalo, SUNY Buffalo NY 14260, USA

(2) Institute for Theoretical Physics, Johannes Kepler University, A4040 Linz, Austria

We present ground state calculations for low-density Fermi gases the optimized Fermi-Hypernetted Chain integral equation method which provides, in the density regimes of interest, an accuracy better than one percent. As a function of density and/or coupling strength we encounter an instability of the normal state of the system which is characterized by a divergence of the scattering length indicating phonon-exchange driven dimerization. We then study, in the stable regime, the superfluid gap and its dependence on the density and the interaction strength. The most important finite-range corrections are a direct manifestation of the many-body nature of the system.

O3.11

Search for New States of Superfluid ^{3}He in Nanoscale Pores and Silica Aerogel

Zimmerman, A.M., Nguyen, M.D., Halperin, W.P.

Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208, USA

Recent theoretical work on the phase diagram of superfluid ^{3}He confined in long pores of 200nm diameter has predicted a vastly altered phase diagram, with the possibility of stabilizing the polar phase as well as a number of A-like and B-like phases.1 In order to investigate this experimentally, we have obtained 50% porosity samples of anodic alumina with 200nm co-aligned pores with lengths of 100μm. We report the results of NMR measurements of the phase diagram of superfluid ^{3}He in these samples. This work was supported by the National Science Foundation, DMR-1103625.

[1.] J. J. Wiman et al., Phys. Rev. B 92, 144515 (2015)

O3.12

Linear theory of orbital glass states of ^{3}He-A in aerogel

Fomin Igor

P.L. Kapitza Institute for Physical Problems, Russian Academy of Science, Kosygina 2, 119334 Moscow, Russia

Spacial variation of the orbital part of the order parameter of ^{3}He-A in aerogel is represented as a random walk of the unit vector l in a field of random anisotropy produced by the strands of aerogel. For a range of distances, where variation of l is small in comparison with its absolute value, correlation function of directions of l(r) is expressed in terms of the correlation function of the random anisotropy field. With simplifying assumptions about this correlation function a spatial dependence of the average variation l^2 is found analytically for isotropic aerogel and for different types of its anisotropy. Average projections of l on the axes of anisotropy are presented. Numerical estimations of characteristic length of disruption of the long-range order and of the critical anisotropy for restoration of this order are made and compared with experiment and with previous estimations.

O3.13

Turbulence induced luminescence of nitrogen nanoclusters immersed in superfluid helium

Khmelenko Vladimir(1), Meraki Adil(1), McColgan Patrick(1), Boltnev Roman (2), Lee David(1)

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2) Branch of Talroze Institute for Energy Problems of Chemical Physics, Russian Academy of Sciences, 142432, Russia

We studied thermoluminescence of ensembles of molecular nitrogen nanoclusters, containing stabilized atoms, immersed in liquid helium. We found that the intensity of thermoluminescence follows the heat conductivity function for turbulent He II. The decay of thermoluminescence at constant temperature follows a hyperbolic law. These results provide evidence for vortex induced chemical reactions for nitrogen atoms in superfluid helium leading to the appearance of luminescence in ensembles of nitrogen nanoclusters. The intensity of thermoluminescence depended strongly on the size of nanoclusters. Thermoluminescence was also observed in normal helium but via a different mechanism.

P3.1

Boundary effects in quantum turbulence at ultra low temperatures

Mäkinen Jere(1), Eltsov Vladimir(1), Silaev Mihail(2)

1) Aalto University, Department of Applied Physics, FI-00076 AALTO, Finland
2) KTH-Royal Institute of Technology, Department of Theoretical Physics and Center for Quantum Materials, Stockholm, SE-10691, Sweden

We have observed turbulent and laminar motion in superfluid ^{3}He-B after spin-down to rest at temperatures below 0.25 T_c. During the initial turbulent period the effective kinematic viscosity is strongly suppressed in a polarized vortex tangle as a result of cylindrical symmetry of the container and weak transfer of angular momentum to walls. After that we measure hours-long laminar decay of the precessing vortex cluster. The extrapolation of the decay rate to zero temperature reveals pressure-independent finite dissipation. We attribute it to a new dissipation mechanism where Kelvin waves are excited by vortex friction at the surfaces of the container and lose their energy in bulk.

P3.2

Dynamics of quantized vortices before reconnection at finite temperature

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The goal of this paper is to investigate the dynamics of quantized vortex loops, just before the reconnection at finite temperature. Modeling is performed on the base of vortex filament method. It was discovered that the initial position of vortices and the temperature strongly affect the dependence on time of the minimum distance $\delta(t)$ between tips of two vortex loops. However, this relationship takes a universal square-root form $\delta(t) = [(k/2\pi) * (t * -t)]^{1/2}$ at distances smaller than the distances, satisfying the Schwarz reconnection criterion, when the nonlocal contribution to the Biot–Savart equation becomes about equal to the local contribution. In the "universal" stage, the nearest parts of vortices form a pyramid-like structure with angles which neither depend on the initial configuration nor on temperature.

P3.3

Theory of adiabatic fountain resonance with superfluid ^{4}He

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The theory of "adiabatic fountain resonance" with superfluid ^{4}He is clarified. In this geometry a film region between two silicon wafers glued at their outer edge opens up to a central region with a free surface. We find that the resonance in this system is not a Helmholtz resonance as claimed by Gasparini and co-workers, but in fact is a 4th sound resonance. It occurs at relatively low frequency because the thin silicon wafers flex appreciably from the pressure oscillations of the sound wave. We raise questions about the "giant proximity effect" claimed to have been observed with this resonance.

P3.4

Mechanical momentum transfer in wall-bounded superfluid turbulence

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Unlike classical turbulence, the dissipation of energy and mechanical momentum in quantum turbulence is governed by different mechanisms. We show, using an analogy of the classical Reynolds stress, that the transfer of mechanical momentum to the wall is caused by the presence of a quantum vortex tangle, giving rise to an effective "momentum" viscosity with the temperature dependence different from the effective viscosity for the energy dissipation. We also show that the notion of vortex-tension force can be understood as the gradient of the Reynolds stress, determined by the new effective "momentum" viscosity.

P3.5

Some recent results from the one-fluid model of He II

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Heat transport in He II has several special features related to the relative presence of phonons and rotons, the laminar or turbulent flow and the relation between phonon mean-free path and the diameter of the container. We propose an application of the one-fluid model of He II able to describe the transition between these three different regimes (Landau, ballistic and Gorter-Mellinck regime). The previous regimes appear in the refrigeration of heat-producing systems. As a particular illustration, we consider counterflow refrigeration of an array of cylindrical heat-producing systems between two parallel plates.

P3.6

Diffusion of Quantum Vortices

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Symmetry breaking and the formation of topological defects through the Kibble-Zurek mechanism at the transition of ^{3}He to its superfluid phase is perhaps the best experimental analogy to the series of symmetry-breaking phase transitions in the early universe. In the Grenoble-Lancaster experiment [Nature 382.6589 (1996): 332-334] a region of superfluid ^{3}He is thermalised by a neutron capture event, then quenched through the superfluid phase transition by the surrounding fluid. This forms a localised area of quantised vorticity which spreads into the surrounding fluid. We simulate the spread of a region of quantised vortices with the point vortex model and the Gross-Pitaevskii equation in 2D.

P3.7

Investigation of Saturation Effects on Turbulence Decay by a Confined Geometry

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The study of growth and decay of gird turbulence is standard in classical fluids, and has been pursued in quantum turbulence on small channels. We generate turbulence by pulling a grid through a much larger channel in superfluid ^{4}He. Turbulent intensity, ω, is measured using second sound. Supposedly ω decays by either $\approx t^{-11/10}$ or $\approx t^{-17/14}$ when energy containing eddies are growing. If eddies saturate at the channel size, it decays as $\omega \approx t^{-3/2}$. Rates of decay and saturation are examined by a phase amplitude locked system.

M. R. Smith, R. J. Donnelly, N. Goldenfeld, and W. F. Vinen, Phys. Rev. Lett. 71, 2583 (1993).; S. R. Stalp, L. Skrbek, and R. J. Donnelly, Phys. Rev. Lett. 82, 4831 (1999)

P3.8

Visualization of a vortex tangle using a quasiparticle camera in superfluid ^{3}He-B

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We present our measurements on visualising a vortex tangle created by a vibrating wire in superfluid ^{3}He-B. Measurements were carried at low temperatures where the normal component of the superfluid comprises ballistic quasiparticles. We illuminate the tangle by a quasiparticle beam and detect its presence via the 'shadows' cast by the Andreev scattering of incident quasiparticles by the vortices. The 'shadows' are measured by a 5x5 detector made from 25 miniature quartz tuning forks. Our measurements and numerical simulations show that the profile of quasiparticle beam is independent on the emitted beam power and that produced tangle is non-isotropic with respect to the motion of the wire.

P3.9

Formation of Quantum Turbulence Produced by Vibrating Wire in Superfluid ^{4}He

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We report the formation of turbulence produced by a vibrating wire in superfluid ^{4}He, by studying vortex emissions with a ring size larger than 38 μm in diameter as a function of generation power of vortex lines. An emission rate of vortex rings from the turbulence remains low until the beginning of high-rate emissions, suggesting that a portion of vortex lines produced by the wire is provided to the formation of a vortex tangle until an equilibrium is established. The formation time and the emission rate after the formation are proportional to $\epsilon^{-1.2}$ and ϵ^2, respectively, where ϵ is the generation power. These dependences may emerge from quantum turbulence with constant energy flux.

P3.10

Study of particle motion in He II counterflow across a wide heat flux range

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Some discrepancy exists in the results of He II counterflow experiments obtained using PIV when compared with those obtained using PTV. It is suggested that this is due to differing applied heat flux ranges. An earlier PTV experiment in our lab attempted to test this model but the applied heat flux did not actually overlap with any PIV experiments. We report a PTV study of solid D2 particle motion in counterflow, and the heat flux range overlaps that of all previous visualization studies. The observed particle velocity distribution transitions from a two-peak structure to a single peak centered at 0.5vn as the heat flux is increased. The temperature dependence of this transition is examined.

P3.11

Statistical measurement of counterflow turbulence in superfluid helium-4 using He_2* tracer-line tracking technique

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A high precision flow visualization technique based on the tracking of thin lines of He_2* molecular tracers has been developed in our lab. We have applied this technique in the study of steady-state counterflow turbulence in superfluid helium-4. Besides mapping out the velocity profile in the flow channel, we can also determine turbulence statistics such as the velocity distribution functions and the structure functions based on the analysis of tracer-line mages. We report how these statistics vary with temperature and heat flux. We also discuss our on-going development of an advanced tracer-line image processing method.

P3.12

Turbulent ^{4}He flows generated by an oscillating grid and visualized by particle tracking

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The dynamics of micron-sized solid deuterium particles is studied experimentally in turbulent flows of both He I and He II by visualization. Turbulence in both phases is mechanically generated by a grid, consisting of equally spaced circular holes, oscillating at frequencies up to 3 Hz. We find that, in He II, at length scales larger than the mean intervortex distance, particle velocity statistical distributions closely resemble those obtained in viscous He I. Our results reinforce the idea that turbulent flows of He II mimic viscous flows, at large enough length scales.

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P3.13

The decay of thermal counterflow turbulence in superfluid ^{4}He from small heat currents

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Quantum turbulence is easily generated in superfluid ^{4}He in the presence of a thermally-generated counterflow of the two fluids. For small heat fluxes the turbulence is present only in the superfluid component and takes the form of a random tangle of quantized vortex lines. When the heat flux is removed the vortex line density, L, decays according to the equation $dL/dt = -(X_2\kappa/2\pi)L^2$, where κ is the quantum of circulation and X_2 is a dimensionless function of temperature. New experimental measurements of X_2 are presented, together with new values of this parameter derived from computer simulations. Both are compared with values derived from a theory due to Vinen and Niemela.

P3.14

Observation of Axial Flow and Vortex Produced by Cryogenic Motor in Superfluid ^{4}He

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We report a superfluid flow induced by a cryogenic motor immersed in superfluid ^{4}He. We mounted a motor with rotor blades at the bottom of a transparent cylinder to observe the free surface of ^{4}He superfluid. We find that the rotating blades induces a parabolic meniscus of superfluid ^{4}He, producing axial superfluid flow in the cylinder. Secondly, we mounted the motor in a cylindrical box with a small hole at the center of the top and a narrow channel at the bottom, to produce a suction superfluid flow through the small hole. In this setup, we have successfully produced a funnel-shaped vortex in superfluid ^{4}He.

P3.15

Novel dynamics of vortices in coflow quantum turbulence: vortices trapped on an attractor

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We perform a numerical simulation of the dynamics of quantized vortices produced by coflow in a square channel using the vortex filament model. Unlike the situation in thermal counterflow, where the superfluid velocity vs and normal-fluid velocity vn flow in opposite directions, in coflow, vs and vn flow in the same direction. Quantum turbulence in thermal counterflow has been long studied theoretically and experimentally, and its various features have been revealed. In recent years, an experiment on quantum turbulence in coflow has been performed to observe different features of thermal counterflow [1]. By supposing that vs is uniform and vn takes the Hagen-Poiseuille profile, we calculate the coflow turbulence [2]. Vortices preferentially accumulate on the surface of a cylinder for vs=vn by mutual friction; namely, the coflow turbulence has an attractor. As the vortices become dense on the attractor, they spread toward its interior by their repulsive interaction. Then, the superfluid velocity profile induced by the vortices gradually mimics the normal-fluid velocity profile. This is an indication of velocity matching, which is an important feature of coflow turbulence.

[1] E.Varga, S.Babuin, and L.Skrbek, Physics of Fluids 27, 065101 (2015).
[2] Shinichi Ikawa and Makoto Tsubota, Phys. Rev. B 93, 184508 (2016).

P3.16

Transition to turbulence and streamwise inhomogeneity of counterflowing He4.

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We report preliminary results of the complementary experimental and numerical studies of the streamwise vortex lines density (VLD) distribution in counterflowing He4. The experiment is set up in a long square channel with VLD and local temperature measured in three streamwise locations. In the steady state we observe nearly streamwise-homogeneous VLD. Experimental second sound data as well as numerical data (vortex filament method in a long planar channel starting with seeding vortices localized in multiple locations) show that the initial build up pattern of VLD displays complex features depending on the position in the channel, but the tangle properties appear uniform along the channel.

P3.17

Logarithmic velocity profile of wall-bounded quantum turbulence in superfluid ^{4}He

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In the filed of hydrodynamics, the logarithmic velocity profile has been studied as one of the most important statistical law near a solid surface. However, it has been unknown whether or not quantum turbulence exhibits the similar law. This study shows that the logarithmic velocity profile appears in wall-bounded quantum turbulence [1]. We performed the numerical simulation of quantum turbulence between the two parallel plates by using the vortex filament model. We investigated the configuration and dynamics of the inhomogeneous vortex tangle to find the characteristic behavior of the logarithmic velocity profile.

[1] S. Yui, K. Fujimoto, and M. Tsubota, Phys. Rev. B 92, 224513 (2015)

P3.18

Small-scale universality of particle dynamics in turbulent flows of He II

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The flow-induced motions of small particles suspended in He II are investigated experimentally, by visualization, above 1 K. We show that the statistically described particle dynamics does not depend on the type of imposed two-fluid flow, at scales smaller than the average distance between quantized vortices. Regardless of the mechanically or thermally driven nature of the large-scale flow, the tails of the observed particle velocity distributions display the same power-law shape. This property of quantum turbulence can be seen as analogous to the small-scale universality reported to occur in classical turbulent flows of viscous fluids. We acknowledge the support of GAČR 16-00580S.

P3.19

Coupled dynamics for superfluid He4 in the channel.

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We present the results for the coupled dynamics of normal and superfluid components of the superfluid He4 in the channel. We consider the case of the counterflow turbulence with laminar normal component. In particular, we calculated profiles of the normal velocity, the mutual friction and the vortex line density, as well as other flow properties and compared them to the case when the dynamic of the normal component is “frozen”. We have found that the coupling between the normal and superfluid components leads to a flattening of the normal velocity profile, increasingly more pronounced with temperature as the mutual friction, and therefore coupling, become stronger. The commonly measured flow properties also change when the coupling between two components is taken into account.

P3.20

Motion of negative ions along quantized vortices in superfluid ^{4}He

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We have measured the mobility and limiting terminal velocity of electron bubbles sliding along vortex lines in superfluid ^{4}He for a broad range of temperatures (0.1 - 1 K). This allows dissipative processes at small length scales to be probed, which can include drag exerted by an excess density of excitations in the vicinity of the vortex core; the scattering and generation of Kelvin waves; and condensation of ^{3}He impurity atoms onto vortex cores. We have also used this technique to probe the dynamics of agitated vortex arrays and the corresponding timescales for relaxation back towards a rectilinear array, providing new insight into the decay of quantum turbulence at short length scales.

P3.21

Heat Transfer Peculiarities in ^{3}He-^{4}He Mixtures in Cylindrical Geometry

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Using the system of hydrodynamics equations for superfluid mixtures the problem of temperature and concentration distribution in cylindrical geometry is solved. Temperature excitations are caused by an oscillating heat source situated inside of the cylinder. The obtained solution may serve for better understanding of heat transfer in experiments dealing with oscillating tuning fork.

P3.22

Spin-density fluctuations and exchange in normal-liquid ^{3}He

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We investigate the dynamics of spin- and density waves of a strongly-correlated, normal-liquid fermions at absolute zero in two and three dimensions and compare our results with neutron scattering measurements of the dynamic structure function in liquid ^{3}He. We calculate both the density- and the spin-density response function at a comparable level of accuracy. Inclusion of intermediate double-pair states turns out to be essential obtain the energy of both the density and the paramagnon mode; the resulting dynamic structure function shows excellent agreement with experiments.

P3.23

Roton states in liquid He4

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Realization of the nanoparticles rotational degrees of freedom in a melt leads to an increase in entropy and may causes spontaneous rotation of the nanoparticles. Rotation of the nanoparticles can also stabilize the phase composition of the particles and their size [1,2]. In the case of liquid He4 such particles can be formed as non-equilibrium parts of the crystalline phase (near the melting curve) or a cluster of normal component in the superfluid phase, the stability of which is supported by the spontaneous rotation of the nanoparticles. The kinetic and thermodynamic parameters of the rotonic states of the nanoparticles in a liquid helium are determined.

[1.] A.I. Karasevskii, Phil. Mag. 95, 1717 (2015).
[2.] A.I. Karasevskii, Metallofiz. Noveishie Tekhnol., 38, 141 (2016) (in Russian).

P3.24

Circulation and Vortices in Rotating Superfluid Helium 4 Confined in a Ring

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We investigated the circulation and quantum vortices in a rotating superfluid ^{4}He confined in a ring. A torsional oscillator with a torus cavity and a superleak separation was used to produce and to detect a standing wave of second sound in circumferential direction. It is known that the second sound velocity is decreased in the presence of vortices due to the mutual friction (Miller et al., PRB, 17 1035 (1978)). We observed a hysteresis in second sound velocity versus rotation angular velocity from 0 to 2.5 rad/s. This implies vortices are (meta-)stable even at zero angular velocity for a couple of days. An analogy to type-II superconductors and a stability of vortices are discussed.

P3.25

Theoretical analysis for mobility of ions below a free surface of ^{3}He-B

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At a surface of the superfluid ^{3}He-B, Majorana fermions emerge as the surface bound state. Observation of the surface bound state was attempted via mobility of ions below a free surface [1]. Although the observed mobility is suppressed than that in the bulk B-phase at low temperatures, it is independent of the trapped depth which is shorter than the coherence length. Then, it has not been clear whether the experiment could observe the surface bound state. In this presentation, I will show that the mobility of ions below a free surface, at which quasiparticles are specularly reflected, does not so much depend on the depth within the coherence length. Therefore, I conclude that the experiment observed the ideal surface bound state with linear dispersion.

[1] H. Ikegami et al., J. Phys. Soc. Jpn. 82, 124607 (2013).

P3.26

Search for spatially-modulated phases in confined superfluid ^{3}He

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Superfluidity in ^{3}He arises via p-wave pairing, and the rich order parameter structure allows for multiple superfluid phases. It is predicted that confinement to a slab of thickness of order 10 coherence lengths will, near the A-B transition, trigger the spontaneous appearance of domain walls between regions of superfluid B phase with different orientation, creating a spatially-modulated (striped) phase. Our NMR measurements on a 1.1 um slab of ^{3}He at low pressure disagree both with the NMR signatures of single-domain B phase, and a periodic stripe phase. However they can be explained by a spatially-modulated phase with domain structure supporting unequal amounts of different domains.

P3.27

Suppression of Tc and gap of superfluid ^{3}He by confinement in a 200 nm slab geometry

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The order parameter of superfluid helium-3 confined in a cavity with height comparable to the coherence length is dominated by surface pair-breaking. We describe an accurate determination of the suppression of the superfluid transition temperature, Tc, in an engineered nanofluidic 200 nm slab at various pressures. The results are compared to the predictions of quasi-classical theory. We start from a solid ^{3}He film on the surfaces, and then tune the surface pair-breaking by pre-plating them with a solid ^{4}He film and eventually with a superfluid ^{4}He film. Small volumes of bulk ^{3}He at opposite ends of the cavity mark the unsuppressed Tc and rule out discrepancies due to temperature gradients.

P3.28

Microwaves radiation by roton streams in superfluid helium

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The process of two rotons annihilation into two microwave photon is considered in present work. The possibility of such process follows from an analysis of the two roton Raman scattering experiments in the superfluid helium [1]. In the Rybalko's experiments generation of microwaves in the disk dielectric resonator was observed with a frequency of 180 GHz [2]. It is equal to the energy of the roton gap. Microwave were excited by a heat flows, which were created by the Kapitsa guns. The explanation of this generation is possible through the processes of two bound rotons annihilation.

[1] C A Murray 1975 J. Phys. C: Solid State Phys. 8 L90

[2] Rybalko A.S. arxiv.org/pdf/0811.2114

P3.29

Thermal boundary resistance between simple objects and liquid ^{3}He

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The thermal boundary resistance (R) between materials and liquid helium is crucial in the cooling of materials into the microkelvin regime, yet not fully understood. We have designed a set-up to measure R between a simple metallic object (wire or foil) and liquid ^{3}He. The metal is cooled in a ^{3}He immersion cell, precooled with a copper nuclear demagnetisation cryostat. The temperature of the metal is determined by a SQUID based current sensing noise thermometer. Measurements on a 25 micron diameter gold wire found a crossover to very weak temperature dependence of R below 3 mK. Follow-up experiments on a 7 micron gold foil will also be reported to search for potential size effects.

P3.30

Intrinsic precession of the spin of Bogoliubov-quasiparticles at the inhomogeneously-distorted B-phase of the superfluid ^{3}He.

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Bogoliubov-Nambu Hamiltonian has two energy levels separated by the gap. The levels are two-fold degenerate due to the spin. Adiabatic change of quasiparticle position at k-space produces non-Abelian gauge potential, which is a generalization of Berry-connection for the case of degenerate levels. For the distorted B-phase Berry-connection is found. We assume that the adiabatic force is produced by inhomogenuity of the order parameter. Resulting effective magnetic field acting on the spin degree of freedom is directed perpendicular to the quasiparticle momentum and the force. The influence of intrinsic precession of quasiparticles possibly can be observed at NMR experiments as a reduction of a signal from the regions with large enough gradients.

P3.31

Observation of a new superfluid phase for ^{3}He embedded in "nematically ordered" aerogel

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Theory predicts that nanoscale confinement and anisotropic disorder profoundly change the stability of the pairing in superfluid ^{3}He, and can lead to novel phases. A torsion pendulum is used to study ^{3}He confined in an extremely anisotropic, nematically ordered aerogel with $\approx$ 10 nm thick alumina strands, spaced $\approx$ 100 nm apart aligned with the pendulum axis. A measurement of the pendulum's period yields the fraction of the fluid that is decoupled from the container and is related to the superfluid fraction. We observe kinks when superfluid fraction is plotted versus temperature, corresponding to phase transitions at various pressures. We find a new superfluid phase that is not seen in bulk ^{3}He. Drawing on theoretical work we argue that at low pressure, this new phase is the Polar Phase.

P3.32

Cavitation bubbles in liquid ^{4}He close to the λ-transition

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We report direct optical observation of cavitation bubbles in liquid helium, both in classical viscous He I and in superfluid He II close to the λ-transition. Heterogenous cavitation occurs due to the fast flowing liquid past the oscillating body – a quartz tuning fork of resonant frequency of 4 kHz. A cluster of small bubbles is observed and it changes rapidly size and position with time. At first look, there is no difference between He I and He II, but a few differences were observed: i) achieving cavitation is easier in He I; ii) the bubbles can last longer than one camera frame in He I. We acknowledge the support of Charles University Grant Agency under grant GAUK 1968214.

P3.33

Emergence of Non-Axisymmetric Vortex in Chiral P-Wave Superconductor

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We study strong-coupling effect upon an isolated vortex in the two-dimensional chiral p-wave superconductor. We solved the Eilenberger equation for the quasiclassical Green's functions and the Éliashberg equation with single mode Einstein boson self-consistently. We calculate the free-energy of the obtained vortices, and found that there is a non-axisymmetric vortex, which is possibly more stable than the axisymmetric circular vortex.

P3.34

Effects of a magnetic field on vortex states in superfluid ^{3}He-B

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Superfluid ^{3}He-B possesses three locally stable vortex structures known as a normal-core vortex (o-vortex), an A-phase-core vortex (v-vortex), and a double-core vortex (d-vortex). In this work, we study the effects of a magnetic field on these vortex structures by solving the two-dimensional Ginzburg-Landau equation. We find that the energetic stability of the v-vortex and d-vortex states exhibits nontrivial dependance on the magnitude of the magnetic field as well as its direction, while the o-vortex has the highest free energy among three vortices for any situations we analyzed.

P3.35

Dramatic effect of superfluidity on the collapse of He4 vapor bubbles

Qu An, Trimeche Azer, Jacquier Philippe, Grucker Jules

Laboratoire Kastler Brossel, ENS-PSL Research University, CNRS, UPMC-Sorbonne-Universités, Collége de France, 24 rue Lhomond, 75005 Paris, France

The lifetime of cavitation bubbles produced by an acoustic wave focused in liquid helium-4 is investigated. This lifetime is found to be different by orders of magnitude depending on whether the liquid is superfluid or not. We show that if the liquid is in the superfluid state, the bubble lifetime is well explained by a purely mechanical model, corresponding to the so-called Rayleigh regime. In the normal state, the Rayleigh-Plesset regime applies, in which heat diffusion plays a crucial role and dramatically increases the bubble lifetime.

P3.36

Turbulent Transition in Superfluid ^{4}He Oscillatory Flows

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3) Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Mlynsk á dolina F1, 842 48, Bratislava, Slovak Republic

We discuss recent investigations into the transition to turbulence in oscillatory flows of superfluid ^{4}He. We studied the in-line forces acting on a quartz tuning fork with a 6.5 kHz fundamental and a 40 kHz flexural resonant mode in the temperature range 10 mK to 2.17 K. By extending the accessible range of velocities with respect to previous works, we have observed more than one distinct hydrodynamic critical velocity at low temperatures. We discuss the significance of these critical velocities, focusing on the behaviour of pure superfluid at very low temperatures. In the two-fluid regime, we were able to determine the vortex line density generated by the fork from the attenuation of second sound. We present results which characterize quantitatively the formation of classical and quantum turbulence and we show that both can arise separately.

P3.37

Transition to turbulence in He II due to a double paddle oscillator

David Schmoranzer(1), Martin James Jackson(1), Elisa Zemma(2) and Javier Luzuriaga(2)

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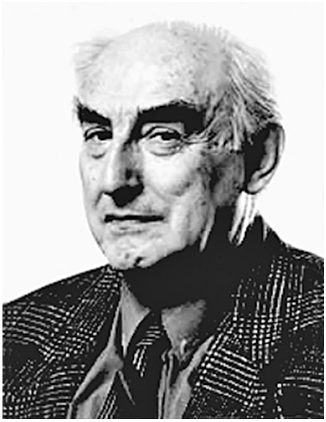
2) Centro Atomico Bariloche, Avda. E.Bustillo, S. C. de Bariloche, Rio Negro, Argentina

We present results on the transition to turbulence in isotopically pure superfluid ^{4}He due to an oscillating double-paddle structure, investigated in the temperature range from 20 mK (pure superfluid) to 1100 mK (two-fluid regime). The double-paddle displays a high-Q resonance which is strongly non-linear even at very low drives in He II as well as in vacuum. Critical velocities for the onset of non-linear drag force are clearly identified and compared to other experimental results on oscillators in He II such as tuning forks or vibrating grids. The utility of the micromachined double-paddle as a new type of quantum turbulence generator/detector for very low temperatures is discussed.

MONDAY 15 AUGUST

Vitaly Ginzburg Session
Chair: Yuri Bunkov



(4.10.1916 - 8.11.2009)

Vitaly Lazarevich Ginzburg, Russian physicist and astrophysicist, was awarded the Nobel Prize for Physics in 2003 for his pioneering work on superconductivity. He shared the award with Alexey A. Abrikosov of Russia and Anthony J. Leggett of Great Britain. Ginzburg was also noted for his work on the theories of radio wave propagation and the origin of cosmic rays.

I4.1

Nanomechanical beams for sub-coherence length studies in superfluid ^{3}He

Eddy Collin (speaker), R. Gazizulin, O. Maillet, A. Fefferman

Institut Néel/CNRS and Université Grenoble Alpes, 38042 Grenoble, France

Mechanical probes such as vibrating wires and forks are neat devices for the studies of quantum fluids. The coherence length of superfluid ^{3}He is of the order of 100 nm, a lengthscale which is easily attained today using clean room fabrication: it is thus possible now to probe this scale using dedicated nano-electro-mechanical systems (NEMS). We present low temperature properties of these devices, both linear and non-linear, and introduce measuring techniques. In particular, the parametric amplification scheme is extremely useful for over-damped systems. We discuss preliminary fluid dynamics measurements using NEMS of cross dimensions about 100 nm, and lengths up to 300 microns.

O4.1

Nanomechanical double clamped beam for probing quantum fluids.

Bradley D.I., George R., Haley R.P., Kafanov S., Pashkin Yu.A., Pickett G.R., Poole M., Prance J.R., Schanen R., Sarsby M., Tsepelin V., Wilcox T.

Lancaster University, Department of Physics, Lancaster LA1 4YB, United Kingdom

Vibrating wires and quartz tuning forks are well known and developed tools to probe the properties of normal and superfluid helium. They enable the study of helium properties in the frequency range from DC to about 300 kHz. We have developed a fabrication method for nanoelectromechanical systems (NEMS), that permits the creation of aluminium doubly clamped suspended nanowires with cross-sectional dimensions of 100nm x 100nm. This size is comparable to the superfluid helium-4 penetration depth, and opens up investigation of the properties of quantum fluids on a shorter length scale. The extremely broad range of available lengths of nanowires, from $0.5\mu m$ up to $500\mu m$, provides the possibility to cover the frequency range from tens of kHz up to hundreds of MHz. We present novel results probing gaseous, normal fluid and superfluid helium-4 using these vibrating nanowires. The observed behaviour of the nanowires immersed in helium-4 can be explained with a hydrodynamic damping in the framework of the two fluid model.

O4.2

High Q-value quartz tuning fork in vacuum as a potential thermometer in millikelvin temperature range

Člove\v{c}ko Marcel, Kupka Martin, Skyba Peter, Vavrek František

Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, 04001 Košice, Slovakia

The results of a newly developed pulse-demodulation (P-D) technique introduced to measure high Q-value quartz tuning forks (QTF) in vacuum and millikelvin (mK) temperature range are presented. By applying P-D technique with extremely low excitation energy ($\approx$ fJ) to a standard 32 kHz QTF, we were able to measure the resonance frequency of fork's decay signal with resolution better than 10 μHz. We've found a continuous and reproducible temperature dependence of the fork's resonance frequency in mK range. Observed dependence suggests a potential application for the QTFs to be used as thermometers in mK range. We also discuss the physical origin of the observed phenomenon.

O4.3

Dissipation mechanisms in a superfluid micromechanical resonator

Fabien Souris(1), Xavier Rojas(2), John Davis(1)

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2) Royal Holloway, University of London, Department of Physics, Egham, Surrey, United Kingdom

There has been significant interest in micro and nanomechanical systems as quantum resources, and recently it has been realized that superfluid ^{4}He is among the most promising candidates for studying mechanics in the quantum regime. Here we performed a careful analysis of the dissipation mechanisms in our microfabricated superfluid mechanical resonator. We show that despite already reaching a quality factor up to 900,000, it has the potential to reach quality factors as high as 108 at 100 mK. Coupled to a microwave resonator this architecture would be in an ideal position to harness mechanical quantum effects and study the effect of confinement on superfluid ^{3}He.

O4.4

Observation of metastable solid and superfluid helium-4 around 1 K

An Qu, A. Trimeche, J. Dupont-roc, J. Grucker, Ph. Jacquier

Laboratoire Kastler Brossel, Paris, France

In 2012, using an optical interferomertric method, we have successfully observed the metastable solid helium at the pressure 5bar below the melting pressure. This year, with the same technique, the homogeneous cavitation density of superfluid helium at T=0.96 K is measured and found to be $\rho cav = 0.1338 \pm 0.0002 g * cm^{-3}$. A well established equation of state for liquid helium at negative pressures converts this to the cavitation pressure $P_{cav} = -5.1 \pm 0.1 bar$. This cavitation pressure is consistent with a model taking into account the presence of quantized vortices, but disagrees with previously published experimental values of P_{cav} .

Norbert Mulders Session
Chair: Pertti Hakonen

(31.3.1959 - 30.3.2015)

Norbert Mulders had many research interests, at the core of which was understanding phenomena in quantum fluids and solids at temperatures near absolute zero. He perfected the technique of making silica aerogel, a fibrous solid that is only four times heavier than air, to study the properties of quantum fluids in disordered media. His experiments revealed spectacular new phenomena that raised tremendous interest in the low temperature physics community.

I4.2

NMR studies of superfluid polar phase of superfluid ^{3}He

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2) Moscow Institute of Physics and Technology, 141700 Dolgoprudny, Russia

We report results of NMR experiments in superfluid polar phase of 3He. This phase is not realized in bulk ^{3}He, but can be stabilized in ^{3}He confined in a new type of aerogel (nafen) which strands are nearly parallel to one another. In our experiments the polar phase was observed in all used samples of nafen with porosities from 98% down to 77%. It was found that the region of existence of this phase essentially depends on nafen porosity, pressure and on ^{4}He coverage of the nafen strands. NMR properties of the polar phase and influence of spin supercurrents on the spin dynamics were investigated. Possible future experiments will be also discussed in the talk.

I4.3

The A-B transition for superfluid ^{3}He confined to a 1.08 micrometer tall geometry

Zhelev, N. (1), Abhilash, T.S.(1), Smith, E.N.(1), Bennett, R.G.(1), Rojas, X.(2), Saunders, J. (2), and Parpia, J.M. (1)*

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2) Department of Physics, Royal Holloway University of London, Egham, TW20 0EX Surrey, United Kingdom

Motivated by recent experimental and theoretical work, we confine superfluid ^{3}He to a 1.08 micron thick nanofluidic cavity incorporated into the head of a torsion pendulum. For measurements between 0.1 and 5.6 bar we observe that the A phase is always interspersed between the B phase and the normal state and the superfluid fraction of the A phase is always greater than that of the B phase which is bulk-like. The dissipation is greater in the B phase than the A phase contrary to bulk behavior. Despite clean surfaces that do not pin the phase boundary, the non-monotonic supercooling of the A phase is seen to be much smaller than in the bulk. Our experiment did not observe the presence of the striped phase, likely due to bowing of the cell cavity at pressure.

O4.5

Experiments on Topological Defects in a Dirac Superfluid

Autti(1), Etlsov(1), Heikkinen(1), Volovik(1), Zavjalov(1), Yudin(2), Dmitriev(2)

1) Low Temperature Laboratory, Aalto University, Finland
2) P.L. Kapitza Institute for Physical Problems RAS

Topological quantum matter systems support topological objects in the order-parameter field and exotic quasiparticles with universal properties among systems of the same class. We study with NMR spectroscopy linear objects (vortices) in the polar phase of superfluid ^{3}He, a triplet superfluid with a Dirac nodal line. The single- and half-quantum vortices are created by rotation, and spin vortices by NMR excitation. All types of vortices can be also created by the Kibble-Zurek mechanism. We demonstrate the Aharonov-Bohm effect for spin waves and discuss the role of disorder. In future this Dirac superfluid allows studies of flat-band fermions and of the fermion condensation in vortex cores.

O4.6

Pressure Dependence of the Phase Diagram of Superfluid ^{3}He in the Presence of Anisotropic Disorder

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1) Northwestern University, Department of Physics and Astronomy, Evanston, IL 60208, USA

In previous work, we have observed dramatic changes in the phase diagram of superfluid ^{3}He in the presence of anisotropic quasiparticle scattering from negatively strained silica aerogel.[1,2] We have discovered a B-like superfluid phase more stable than the A-phase in a magnetic field, marked by a tricritical point and a strain-dependent critical magnetic field. In addition, a strain-driven textural transition appears in the B-like phase at low temperatures. Here we report the pressure dependence of these phenomena from our NMR measurements. This work was supported by the National Science Foundation, DMR-1103625

[1.] JIA Li et al, PRL 112, 115303 (2014)
[2.] JIA Li et al, PRL 114, 105302 (2015)

Konrad Bajer Session
Chair: Yuri Sergeev

(13.10.1956 - 29.9.2014)

Konrad gained his degree in Physics from the University of Warsaw in 1980, and was awarded his PhD in Fluid Dynamics at DAMTP, Cambridge in 1989. His research interests were in magnetohydrodynamics and vortex dynamics in classical and quantum systems; also in problems of gasification, in which he played a coordinating role at the University of Warsaw. Konrad was instrumental in the formation of the European High-Performance Infrastructures in Turbulence (EuHIT) consortium and was passionate about scientific outreach and helped found the Copernicus Science Centre in Warsaw.

I4.4

Dynamics of half-quantum vortices in a spinor Bose-Einstein condensate

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1) Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea

2) Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, Korea

Quantum vortices with half the quantum circulation, known as half-quantum vortices (HQVs), have been observed in various spinor superfluid systems recently. In this presentation, we describe our recent experimental studies of HQV dynamics in a spin-1 antiferromagnetic Bose-Einstein condensate, where we observe the spontaneous dissociation of a singly charged vortex into a pair of HQVs and the collisional dynamics of HQV pairs, revealing the short range interactions arising from their ferromagnetic cores. Additionally, we investigate the relaxation dynamics of turbulent superflow containing many HQVs to find that spin waves are generated by the collisional motions of the HQVs.

O4.7

Quantized vortices following reconnections

Fonda Enrico(1), Sreenivasan Katepalli R.(2), Lathrop Daniel P.(3)

1) New York University, Physics Department, New York , New York 10012, USA

2) New York University, Departments of Physics and Mechanical Engineering and the Courant Institute of Mathematical Sciences, New York , New York 10012, USA

3) University of Maryland, Department of Physics, Department of Geology, Institute for Research in Electronics and Applied Physics, and Center for Nanophysics and Advanced Materials, College Park, Maryland 20742, USA

We visualized quantized vortex reconnections in superfluid ^{4}He using sub-micron frozen air tracers. Compared to previous work, the fluid was almost at rest leading to fewer, straighter, slower-moving vortices. This condition allowed us to observe the propagation of Kelvin waves and to characterize the influence of the inter-vortex angle on the evolution of the recoiling vortices. The agreement of the experimental data to the analytical and numerical models suggests that the dynamics of the reconnection of long straight vortices on the scale of these experiments can be described by the self-similar solutions of the local induction approximation or Biot-Savart equations.

O4.8

Magnus force on vortex in superfluids without Galilean invariance: BEC in optical lattice

Sonin, E.B.

Racah Institute of Physics, Hebrew University of Jerusalem, Givat Ram, Jerusalem 91904, Israel

Broken Galilean invariance suppresses the transverse Magnus force on a vortex as demonstrated by well-known examples of superfluids without Galilean invariance: the Josephson-junction array and impure superconductors. Another example of a superfluid without Galilean invariance is BEC in optical lattices, where up to now vortex dynamics is in early stages of investigation and usually uses the Bose-Hubbard model. This report addresses the general case of a superfluid in a periodic potential based on the Bloch band theory and the momentum balance. The continuous approximation restores translational invariance broken by the periodic potential, but the theory is not Galilean invariant. Noether's theorem provides the conservation law for quasimomentum, while the balance for true momentum is derived from the equations of motion. The calculations of the transverse forces on the vortex, the Magnus and the Lorentz forces, require in general the analysis of the balance of true momentum. While the developed theory yields the same Lorentz force, which was known before, a new expression for the Magnus force was obtained. The theory demonstrates how a small Magnus force emerges if the particle-hole symmetry is broken. The theory was applied to the Bose-Hubbard model close to the phase transition "superfluid-Mott insulator". There is an area in the phase diagram, where the Magnus force has an inverse sign with respect to that expected from the sign of velocity circulation. The present theory predicts the Magnus force much weaker than obtained in previous estimations, which did not check momentum balance.

O4.9

Vortex reconnections and rebounds in trapped Bose Einstein condensates

L. Galantucci(1), S. Serafini(2), F. Dalfovo(2), G. Lamporesi(2), G. Ferrari(2), C. F. Barenghi(1)

(1) Joint Quantum Centre and School of Mathematics and Statistics, Newcastle University
(2) INO-CNR BEC Center and Dipartimento di Fisica, Universita' di Trento

We perform a numerical study of two-vortex interactions in trapped elongated Bose-Einstein condensates in the T=0 limit. We observe different vortex interactions regimes depending on the vortex orientations and their relative velocity: unperturbed orbiting, bounce dynamics, single and double reconnection events. The key ingredients driving the dynamics are the anti-parallel preferred alignment of the vortices and the impact of density gradients. The results are confirmed by ongoing experiments in Trento performed employing a real-time imaging technique [1].

[1] Serafini et al., Phys. Rev. Lett., 115, 170402 (2015)

O4.10

Evolution of a superfluid vortex filament tangle driven by the Gross-Pitaevskii equation

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1) University of East Anglia, School of Mathematics, Norwich Research Park, Norwich, NR4 7TJ, United Kingdom
2) Université de la Côte d'Azur, CNRS, Observatoire de la Côte d'Azur, Laboratoire J.L. Lagrange, UMR7293, B.P. 4229, 06304 Nice Cedex 4, France

We study the evolution of a vortex filament tangle driven by the Gross-Pitaevskii equation using a recently developed vortex-tracking algorithm. We observe the Vinen's decay law for the vortex line density with a coefficient that is in quantitative agreement with the values measured in Helium II. We investigate the properties of the tangle, showing that linked rings may appear and that local curvature and torsion distributions exhibit large fluctuations and self-similar dynamics. We obtain the temporal evolution of the Kelvin wave spectrum providing evidence of the development of a weak-wave turbulence cascade. Ongoing investigations on reconnections may also be presented. (arXiv:1605.00567)

O4.11

Graphene resonators in studies of quantum fluids

J.-P. Kaikkonen, A. Savin, A. Laitinen, I. Todoshchenko, and P.J. Hakonen

Low Temperature Laboratory, Department of Applied Physics, Aalto University, 00076 AALTO, Finland

Suspended graphene and carbon nanotube devices are among the most precise mass, force and charge sensors. We are utilizing these ultrasensitive devices in investigations of atomic layers and bulk superfluid phases of ^{3}He and ^{4}He. In our first experiments we have investigated thin superfluid ^{4}He layers on top of graphene resonators. Shifts of resonance frequency as well as changes in the resonance structure are found. For reference, we have studied fully superfluid-immersed graphene resonators. In these experiments, we have also investigated dynamic behavior of two gold MEMS resonators coupled non-linearly via graphene. Internal resonances in this coupled system are observed.

O4.12

Superfluid behavior of quasi-1D parahydrogen inside carbon nanotube

Rossi Maurizio(1), Ancilotto Francesco(2)

(1) Scuola Normale Superiore di Pisa, Pisa (Italy)
(2) Dipartimento di Fisica dell' Universita' di Padova, Padova (Italy)

We study, by using Quantum Monte Carlo simulations at T=0, para-hydrogen (pH2) confined in carbon nanotubes (CNT) of different radii. The radial density profiles show solid-like concentric shells and eventually a central column, which can be considered an effective 1D fluid whose properties are well described by the Tomonaga-Luttinger theory. For the central column in a (10,10) CNT, we found an ample density range in which the Luttinger liquid is a superfluid stable against a weak disordered external potential, as the one expected in real CNT's. Our results suggest that pH2 in CNTs could be a practical realization of the long sought-after, elusive superfluid phase of para-hydrogen.

P4.1

Nanomechanical Resonators in Superfluid Helium-4

Bradley D. I.(1), Haley R. P.(1), Kafanov S(1), Pashkin Yu. A.(1), Pickett G. R.(1), Poole M.(1), Sarsby M.(1), Tsepelin V.(1), Wilcox T.(1)

1) Department of Physics, Lancaster University, Lancaster, LA1 4YB, UK

We have successfully probed the properties of helium-4 using a doubly clamped nanomechanical beam for temperatures from the superfluid transition at 2.2K down to 1.5K at saturated vapour pressure. The beam used was 100nm wide, 100nm thick and 15μm long, with a resonance frequency of 8.6MHz and Q-factor of roughly 21000. Observations of resonance frequency shift and damping match well to predictions derived using hydrodynamic contributions from the two fluid model, confirming that the variations seen are due to changes in the fluid properties. The resonances of the beam are observed to be linear at low measurement powers, becoming Duffing-like for measurement powers above 0.1pW.

P4.2

Spontaneous annihilation of topological defects in ^{3}He-A near T$_c$

Kasai Jun(1), Okamoto Yohei(1), Nishioka Keishi(1), Takagi Takeo(2), and Sasaki Yutaka(1)

1) Dept. of Physics, Kyoto University, Kyoto, Japan.
2) Dept. of Applied Physics, University of Fukui, Fukui, Japan.
3) LTM Center, Kyoto University, Kyoto, Japan

We have succeeded in stabilizing a number of textural domain walls inside a single 100 micrometer thickness slab of superfluid ^{3}He-A. A real space distribution of those topological defects is observed by our MRI measurements. The locations and the shapes of topological defects remain the same as far as they are kept quietly in a deep A phase. However, we found that the topological defects move and annihilate spontaneously at temperature very near Tc. During the annealing process there appears a spontaneous change in NMR spectra, which can be interpreted as spontaneous heat generation. However the relation between annihilation and heat generation is not clear at this moment.

P4.3

Demagnetisation of Solid ^{3}He on Aerogel to Study Quasiparticle-Free Superfluid

Bradley D. I.(1), Fisher S. N.(1), Guenault A. M.(1), Haley R. P.(1), Halperin W. P.(2), Pickett G. R.(1), Shen Y.(2), Tsepelin V.(1), Vonka J.(1), Zimmerman A.(2), and Zmeev D. E.(1)

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2) Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208, USA

We describe an experimental setup to study both solid and superfluid ^{3}He at ultra-low temperatures. A layer of solid ^{3}He formed on the surface of a large aerogel sample submersed in superfluid ^{3}He will be cooled down to below 100μK in a double nuclear demagnetisation process. NMR on the solid ^{3}He will be used to search for the possible magnetic phase transition. Additionally, within the aerogel sample there is a cavity to create superfluid completely insulated from all parasitic heat flows. Here we intend to study the Bose-Einstein condensate of magnons in the state virtually free of quasiparticle excitations. In this contribution we report the progress made in these experiments.

P4.4

Added mass of He II in experiments with oscillating quarts tuning fork

I. Gritsenko, K. Klokol, S. Sokolov, and G. Sheshyn

ILTPE - B.Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine

Using the method of quartz tuning fork the temperature and pressure dependences of resonance frequency of the tuning fork, for T = 0.1 – 1.5 K and P = 1 – 24.8 atm, were measured and the amount of He II entrained by vibrating prong of the fork (added mass) was determined in the laminar flow regime. Quartz tuning forks with different resonance frequencies 6.65 kHz, 8.46 kHz, 12.1 kHz, 25.0 kHz, 33.6 kHz were studied. It was found that at T 1 K added mass per unit length of the fork prong and added mass coefficient depends on frequency. In addition we checked that, at T = 365 mK, the added mass changes with pressure according to the density change of He II with pressure.

P4.5

Strong Coupling Effects and Shear Viscosity in an Ultracold Fermi Gas

Daichi Kagamihara, Yoji Ohashi

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We theoretically investigate the shear viscosity η, as well as the entropy density s, in the normal state of an ultracold Fermi gas. Including pairing fluctuations within the framework of a T-matrix approximation, we calculate these quantities in the BCS-BEC crossover region. We evaluate the ratio η /s, to assess the lower bound of this ratio, conjectured by Kovtun, Son, Starinets (KSS). In the crossover region, this ratio is found to decrease with increasing the interaction strength, to become very close to the KSS bound slightly in the BEC side at the superfluid phase transition temperature.

P4.6

Competition of Triangular and Square Vortex-Lattice in Two-Component Bose-Einstein Condensates

Toshiaki Kanai, Makoto Tsubota

Department of Physics, Osaka City University, Japan

Quantum vortex-lattice formulation in two-component BECs has been studied theoretically[1] and experimentally[2]. In two-component BECs, there are some behaviour which do not appear in one-component BEC. Change of structure of quantum vortex-lattice is one of the most clear behaviours. The structure of vortex-lattice is triangle, square, vortex-sheet et al[1], and depend on some parameters. We study numerically the competition of triangular and square vortex-lattice around the boundary of triangular lattice phase and square lattice phase. Around the boundary , because of the competition, the relaxation time will get longer. So, we pay attention to the relaxation time.

[1]K.Kasamatsu, M.Tsubota, and M.Ueda, Phys. Rev. Lett. 91, 150406 (2003)
[2]V.Schweikhard et al, Phys. Rev. Lett. 93, 210403 (2004)

P4.7

A novel multi-frequency lock-in technique to probe superfluid helium-4 using quartz tuning forks.

Bradley D.I., Haley R.P., Kafanov S., Noble M.T., Pickett G.R., Tsepelin V., Vonka J., Wilcox T.

Lancaster University, Faculty of Science and Technology, Department of Physics, Lancaster, LA1 4YB, UK

We report on a novel new technique to measure the resonance of linear oscillators by exciting and measuring the response over many frequencies simultaneously. By using a multi-frequency lock-in analyser we can measure the resonance curve much quicker than by using a conventional single frequency lock-in amplifier technique. We use multi-frequency lock-in and a standard Standford Research Systems SR830 Lockin Amplifier to measure the frequency response of two 25μm wide quartz tuning forks and show that both instruments yield identical results. We further confirm this by measuring the resonance frequency and width of the forks over temperatures between 4.2K and 1.5K.

P4.8

Development of Low Temperature Amplifier and Small RF-Coil: Search for New Phase of ^{3}He in Very Confined Geometry

Obara(1), Hirata(1), Okazaki(1), Yano(1), Ishikawa(1), Kashiwaya(2), Koyanagi(2), Kashiwaya(2)

1) Department of Physics, Osaka City University, JAPAN
2) AIST

Although ^{3}He in very confined geometry have been attracted the academic interests for decads, the experimental evidence of the new phases in such geometry are not very clear because of the experimental difficulties. We will show the possibile breakthrough technique to detect the very small NMR signals from the ^{3}He nuclear-spins in such a confined geometry. Our amplifier consists of three-stage ePHEMT devices, which have the high-gain, high-input-impedance and the low output impedance in several MHz range at 4 K. We are also developing the microfabricated RF-coil so as to detect the NMR signals from thin-thread-shaped sample. We will show and discuss the basic properties of our system.

P4.9

Direct spectroscopic study of bubbles containing electrons in excited states: a feasibility study

Pal Anustuv, Morrill Drew, Ghosh Ambarish

1) Indian Institute of Science, Dr. A Ghosh, Dept. of Physics, Bangalore, India
2) Brown University, Dept. of Physics, Rhode Island, USA
3) Indian Institute of Science, Dept. of CeNSE, Bangalore, India

An electron injected into liquid helium self assembles into a nanometre sized cavity, called the electron bubble. The electron can exist in various energy states, which can be investigated through direct optical absorption. This has been experimentally observed by exciting the electron from the ground (1s) state to excited states by several groups in the past. Here, we present a feasibility study of probing the excited state bubbles with direct optical absorption, which in principle can provide valuable insight into this interesting system. In particular, we propose using a high power laser to drive the ground state bubbles to the excited (1p) state and subsequently measure direct infrared absorption of the 1p bubbles. We will discuss the experimental design, in particular the challenges in detecting such small effects.

P4.10

Magneto-electric and Dielectric Effect Measurement Technique at very Low Temperatures

J.S. Xia(1), L. Yin(1), N.S. Sullivan(1), V.S. Zapf(2), and A. Paduan-Filho(3)

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2) National High Magnetic Field Laboratory, Los Alamos National Laboratory, Los Alamos, NM 87545, USA
3) Instituo de Fisica, University de Sao Paulo, Sao Paulo, 05315-970 SP, Brazil

We report the design and operation of a device for studying the magneto-electric, dielectric effect, and resistance at very low temperatures (below 10 mK). The unique advantage is the sample is directly immersed in cold liquid ^{3}He, which is cooled with a large (25 M2) surface area silver sinter heat exchange connected to a nuclear stage magnetization refrigerator. An AC coil is added outside of the sample, so that the capacitance, resistance and DC and AC effects can be measured simultaneously. The details and performance of the device are discussed, and a few of the measurements are demonstrated.

P4.11

Microwave source based on SINIS Junction

Masuda Shumpei, Tan Kuan Yen, Partanen Matti, Lake Russell, Govenius Joonas, Möttönen Mikko

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Superconducting circuits provide a promising platform for quantum technological applications. In this context, microwave photons in superconducting resonators and waveguides are routinely used as information and energy carriers between different components of the circuit. We demonstrate an engineered microwave photon source driven by voltage-controlled quantum tunneling of electrons through superconductor-insulator-normal metal junctions. We observe the direct conversion of the electronic energy into microwave photons by measuring the energy spectrum of the created microwave radiation. This device enables electrical control of the photonic state as well as the output power emitted from the resonator, thus functioning as an on-demand photon source that can readily be integrated into quantum circuits.

P4.12

Sub-superfluid 3-He coherence length cross-section SiNN (Silicon Nitride – Niobium) wires.

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We report on the room temperature characterization of ultrafine composite wires formed of high stress Silicon Nitride onto which a film of superconducting Nb was evaporated. The wires' cross section (50 nm square) is less than the coherence length of superfluid ^{3}He. We describe the fabrication details of the wires, together with room temperature characterization of the resonant frequency and Q of the wires with and without the additional Nb layer. Further we will describe the so-called "self oscillation regime" where these devices execute harmonic motion when illuminated with intense laser light. We observe stable limit-cycle behavior with an amplitude of roughly one-eighth of the impinging laser wavelength, and characterize entrainment of this motion with inertial forcing. Such parametric drive implemented with double-frequency driving force may enable these devices to be operated in the viscous as well as ballistic regimes in norml and superfluid ^{3}He.

P4.13

The influence of high magnetic field on resonant characteristics of high Q-value quartz tuning fork in vacuum in milikelvin temperature range

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We have extensively studied the influence of high magnetic field (up to 8 Tesla) on vacuum resonant characteristics of a commercially available 32 kHz quartz tuning fork in millikelvin temperature range. High magnetic field applied perpendicularly to both the direction of oscillations and piezoelectric current generates additional force acting on oscillating electric dipoles inside quartz. This additional force (as a possible source of de-coherence) effectively stiffens the quartz crystal manifested by the rise of resonance frequency and simultaneously decreases its electrical conductivity which leads to additional dissipation. We discuss a physical origin of the observed phenomenon.

P4.14

Observation of high-order transitions in a superconducting qubit coupled to coplanar waveguide cavity

Yu-Cheng Chang, Ze-Yan Chen, Jyh-Yang Wang, Teik-Hui Lee, Teik-Hui Lee, Myrron A. Aguila, Joshoua Esmenda and Chii-Dong Chen

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Coherent interaction between a superconducting transmon quantum bit and an on-chip superconducting cavity is studied. The transmon consists of a SQUID whose transition frequency between the two lowest levels of the transmon can be tuned continuously by the applied external magnetic flux threading the SQUID loop. As this level spacing is tuned to close to the resonance frequency of the Nb superconducting cavity, the Rabi-splitting feature emerges, indicating a coherence coupling between the qubit and the cavity. In addition, the higher-order transitions involving 2nd and 3rd excitation levels and multiple photons are observed, but there are no sign of qubit-cavity coupling.

P4.15

Inductively Coupled Superconducting Quantum Interference Device Transduction of Nanoelectromechanical Systems at Low Temperatures

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We present work on high Q Nanoelectromechanical systems (NEMS) at millikelvin temperatures, transduced via a Superconducting Quantum Interference Device (SQUID) in low magnetic fields (200mT). In this technique, the NEMS is inductively coupled to the SQUID, mounted far from the magnet, allowing flexibility in magnetic field without affecting SQUID behaviour. A SiN dobly clamped beam (300μm x 250nm x 100nm), has been characterised from 3K to 21mK, observing thermally driven motion. We observe tuneable feedback effects between the SQUID and the NEMS, resulting in self-sustained oscillations with stability greater than 8ppb.

P4.16

Head-on collision of xenon atoms against superfluid 4-helium droplets.

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We study the head-on collision of a heliophilic xenon atom with a superfluid helium droplet made of 1000 atoms. At variance with previous findings for a heliophobic cesium atom of similar atomic weight, it is found that the xenon atom has to hit the droplet with a large kinetic energy to get across it without being captured. When this happens the xenon impurity does not emerge as a bare atom; instead, due to its heliophilic character, it carries away some helium atoms whose number depends on the collision energy.

P4.17

Dissipative superfluidity and mesoscale confinement

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Pressure driven flow of a superfluid inside a narrow channel can be maintained by the nucleation of vortices and their resulting motion across the flow lines. The maximum velocity of the superfluid is set by a nucleation rate which crucially depends on the microscopic details of the vortex cores and flow profile. Within the kinetic vortex theory, we have determined the critical superfluid velocity inside mesoscale constrictions and obtain agreement with experimental results for superfluid helium-4 in nanopores. In the small pore limit, when the ratio of pore radius to correlation length is of order unity, we find a drastic suppression of the superfluid velocity due to a reduction in the energy barrier of flow reducing excitations.

P4.18

Measurement of the complex permittivity of liquid He-4 in millimeters wave range by "whispering gallery" mode resonator

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We report an experimental study of electrical properties of liquid helium 4 in temperature range 1.2-3 K. The complex permittivity of He4 was determined using a "whispering gallery" resonator. Using the resonant perturbation method the complex permittivity of liquid He4 is extracted. Our result is consistent with theoretical and experimental works by other authors. We also discuss effect of doubling of the "whispering gallery" modes propagating in the cavity.

P4.19

Adiabatic melting experiment: status and prospects.

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We describe our ongoing experiment, aiming to cool saturated helium mixtures to ultra-low temperatures, into tens of microKelvins regime. Previously we demonstrated physical principle of cooling at temperatures well below of superfluid transition of concentrated phase, pure ^{3}He (JLTP,81, p.725 (2007)). We describe improvements made to protect system from irreversibility appearing owing to higher temperature surroundings, and to practical realization of the method. Results of testing different systems at low temperatures are presented and discussed.

P4.20

Momentum distribution of liquid ^{4}He across the normal-superfluid transition

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We have carried out a study of the momentum distribution of liquid ^{4}He across the normal-superfluid transition temperature using the path integral Monte Carlo method. The momentum distribution and one-body density function have been accurately calculated in a range of temperatures which crosses the critical point. Our results show that a kink in the momentum distribution is present only in the superfluid region and disappears when crossing the transition temperature, in a behavior currently unexplained by theory. This kink appears in the range of momentum corresponding to the roton excitation , whose dynamic structure factor peak amplitude is already known to drop when the fluid becomes normal.

P4.21

Measurements of ion motion and trapping in solid helium using a planar injector

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A novel type of planar ion injector, with carbon nanotubes embedded into a conducting surface, is constructed. When in contact with solid helium, depending on the polarity of electric field at the surface, either positive or negative ions can be injected. We studied the motion of ions in a single crystal of hcp ^{4}He, grown inside a diode, one plate of which had such an injector. Step-like and pulsed injection of ions of both signs were employed. The measured time-dependent records of current, arriving at the second electrode, allowed to quantify the temperature dependences of ion mobilities, rates of trapping by dislocations and lifetimes of trapped states.

P4.22

Compact 1K Rotating Cryostat for Helium 4 Experiment

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For studies of novel phenomena of superfluid helium 4 in a nanoscale confinement, we constructed a compact, inexpensive and easily-operated 1K rotating cryostat in Keio University. A rotating system consists of a dewar, a cryostat insert and all the electronic instruments fixed tight on two round tables. The system is rotated by a servo motor underneath the dewar. Using a computer in a laboratory frame, one can control the rotation and collect data from the rotating instruments via Wi-Fi. The maximum rotation angular velocity is 6 rad/s, which is greater than typical critical angular velocities of superfluid helium 4. The performance of the rotating system and the cryostat will be shown.

P4.23

Fast coherent control of Bose-Einstein condensates without unwanted excitations

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Various control schemes of the dynamical evolution of quantum systems have been proposed. The control schemes rely on coherence and interference effects embedded in the quantum dynamics of the system, and vary in efficiency, generality of application, and sensitivity to perturbations. Adiabatic dynamics of a quantum system is useful when external field-generated variation of the Hamiltonian is used to manipulate the system's evolution. However, an adiabatic process must be carried out very slowly. In such slow processes, decoherence caused by the interaction with environment can degrade the fidelity of the control. Recognition of this restriction has led to the development of control protocols, which we call assisted adiabatic transformations or shortcut to adiabaticity. In this talk, we show fast controls of Bose-Einstein condensates using the fast-forward protocol.

P4.24

Ground state energy for a Lieb-Liniger gas within a multi-rods structure: Variational Monte Carlo vs Mean-Field calculations

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We use the Variational Monte Carlo (VMC) method to calculate the groun state energy of an interacting Bose gas constrained by an one-dimensional periodic multi-rods structure created by applying an external Kronig-Penney potential. Our variational results are compared with those we previously obtained using the Mean-Field approximation [1] where we analytically solve the Gross-Pitaevskii equation. In the limit of zero external potential, we recover the well-known Lieb-Liniger gas, which becomes the Tonks gas for strong interactions. In this case we compare our variational results with those obtained originally by Lieb and Liniger [2], as well as with those calculated by means of the Diffusion Monte Carlo (DMC) method [3]. Only in the region of high density and weak interaction, Mean-Field results are equal to DMC results and better than the variational ones.

[1] O.A. Rodríguez and M.A. Solís, "Ground state of a Lieb-Liniger gas within multi-rods solving analytically the Gross-Pitaevskii equation", work in process.
[2] E.H. Lieb and W. Liniger, PR **130**, 1605 (1963).
[3] G.E. Astrakharchik and S. Giorgini, PRA **68**, 031602 (2003).

We thanks partial support from grants CONACyT 221030 and PAPIIT IN107616.

P4.25

Quantum-limited heat conduction over macroscopic distances

Tan, Kuan Yen(1) Partanen, Matti(1) Govenius, Joonas(1) Lake, Russell E.(1) Mäkelä, Miika K.(1) Tanttu, Tuomo(1) Möttönen, Mikko(1).

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We present experimental observations of quantum-limited heat conduction over macroscopic distances extending to a metre. We achieved this improvement of four orders of magnitude in the distance by utilizing microwave photons travelling in superconducting transmission lines. This suggests that quantum-limited heat conduction has no fundamental distance cutoff.
This work establishes the integration of normal-metal components into the framework of circuit quantum electrodynamics, which provides a basis for the superconducting quantum computer. In particular, our results facilitate remote cooling of nanoelectronic devices using faraway in situ-tunable heat sinks.

P4.26

Zero-temperature properties of a strongly-interacting superfluid Fermi gas in the BCS-BEC crossover region

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We theoretically investigate physical properties and strong-coupling effects in the BCS-BEC crossover regime of a superfluid Fermi gas at T=0. Within the framework of an extended T-matrix approximation, we evaluate various quantities, such as the compressibility, chemical potential, sound velocity, as well as the Tan's contact. The calculated compressibility and chemical potential are shown to agree well with the recent experiments on a ^{6}Li superfluid Fermi gas in the crossover region. We also discuss how superfluid fluctuations affect these quantities at T=0. Our results would be useful for the understanding of quantum many-body effects in a strongly interacting Fermi superfluid.

P4.27

Single-particle properties of a strongly interacting Bose-Fermi mixture
above the BEC phase transition temperature

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We theoretically investigate normal state properties of a Bose-Fermi mixture with a strong attractive interaction between Fermi and Bose atoms. We extend the ordinary T-matrix approximation (TMA) with respect to Bose-Fermi pairing fluctuations, to include the Hugenholtz-Pines' relation for all Bose Green's functions appearing in TMA self-energy diagrams. This extension is shown to be essentially important to correctly describe physical properties of the Bose-Fermi mixture, especially near the BEC instability. Using this improved TMA, we clarify how the formation of composite fermions affects Bose and Fermi single-particle excitation spectra, over the entire interaction strength.

P4.28

Strong coupling effects on specific heat of a Fermi gas with a p-wave interaction

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Including pairing fluctuations within a strong-coupling theory, we theoretically investigate strong coupling effects on the specific heat at constant volume CV of a Fermi gas with a p-wave interaction above the superfluid transition temperature T_c. We show thatCV is sensitive to the formation and the dissociation of preformed p-wave Cooper pairs. From the temperature dependence of CV, we determine a characteristic temperature, below which p-wave pairing fluctuations are remarkable. Since the appearance of preformed Cooper pairs is a precursor of the superfluid phase transition, the measurement of CV would be useful to estimate how the current experiment is close to T_c.

P4.29

One-dimensional soft particles with zero scattering length: from the Tonks-Girardeau gas to a high-density compressible fluid.

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We study the equation of state and the dynamical structure factor of zero-temperature bosons interacting via a soft-shoulder potential in pure 1D, by using quantum Monte Carlo and analytic continuation techniques. The interaction is tuned to zero scattering length, which, in the limit of low density, corresponds to the Tonks-Girardeau limit and maps to the Ideal Fermi gas. By increasing the density, the system becomes relatively more compressible, albeit manifesting features typical of a precursor of a cluster phase. Our findings should be relevant for dressed Rydberg gases.

P4.30

Higgs mode in a trapped superfluid Fermi gas

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In quantum many-body systems with spontaneous breaking of a continuous symmetry, Higgs modes emerge as collective amplitude oscillations of order parameters. Recently, Higgs modes have been observed in superconductors and for in Bose gases in optical lattices. But, it has not yet been observed in Fermi gases. In this study, we use the time-dependent Bogoliubov-de Gennes equations to investigate Higgs amplitude oscillations of the superfluid order parameter in a trapped Fermi gas induced by a sudden changes of the s-wave scattering length. In particular, we discuss how the frequency and damping of the Higgs mode changes as one goes from BCS regime to BEC regime.

P4.31

Platform for ultra-low temperature transport measurements on low-dimensional electron systems

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We present work on cooling a two-dimensional electron gas (2DEG) in a GaAs-AlGaAs quantum well to ultra-low temperature. We cool the 2DEG via Ohmic contacts thermalised to blocks of silver sinter in a ^{3}He immersion cell mounted on a nuclear demagnetisation cryostat. The electron temperature is measured with a noise thermometer coupled via an additional Ohmic contact. We derive a thermal model that links the temperatures of 2DEG and noise thermometer with heat flow in the cell, and confirm this model experimentally. So far we have cooled 2DEG below 3 mK, under a measured $\approx 30\,fW$ heat leak. Improved electrical filters should reduce these values and take the 2DEG into the microkelvin regime.

P4.32

Magnetic resonance study of high-density atomic hydrogen and tritium stabilized in solid tritium matrices below 1K

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We report on a magnetic resonance study of high-density atomic hydrogen and tritium stabilized in a pure T_2 and $T_2 : H_2$ matrices below 1K. Average concentrations of T atoms exceeding $1.5 \times 10^{20} cm^{-3}$ were obtained while storing thin (50-500nm) tritium films at temperature 150mK. The record-high concentration of H atoms, $9 \times 10^{19} cm^{-3}$, was reached by storing $T_2 : H_2$ mixtures where a fraction of T atoms becomes converted into H due to the isotopic exchange reaction $T + H_2 = TH + H$. The maximum concentrations of H and T atoms were limited by their recombination which occurred in an explosive manner while the threshold concentrations were found to be dependent both on the film thickness and storage temperature.

P4.33

Elastic measurements of TLSs in amorphous silicon at mK temperatures

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The low temperature properties of glass are distinct from those of crystals due to the presence of poorly understood low-energy excitations. These are usually thought to be atoms tunneling between nearby equilibria, forming tunneling two level systems (TLSs). Elastic measurements on amorphous silicon films deposited with e-beam evaporation suggest that this material contains a variable density of TLSs that decreases as the growth temperature increases from room temperature to 400 ^{o}C. We present measurements of the elastic properties of these films down to 10 mK and an analysis in the framework of the standard tunneling model.

P4.34

Influence of ^{4}He coverage on resonance properties of quartz tuning fork immersed in liquid ^{3}He

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Nowadays quartz tuning forks are commonly used for temperature measurements in experiments with liquid (normal or superfluid) ^{3}He. In most of the experiments pure ^{3}He is used, but in some of them small amount of ^{4}He is added in order to cover surfaces by a few monolayers of ^{4}He. We report measurements of influence of different ^{4}He coverages on the fork resonance properties at different pressures. We have found that presence of even small paramagnetic ^{3}He may essentially change the temperature calibration especially at high pressures.

P4.35

Surface states and Bose-Einstein condensation

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We show that an energy gap in the particle energy of an infinite 3D Bose gas not only increases the BEC critical temperature and gives the exponential behavior of the specific heat near to $T = 0$ but when we generalize to include any dimension d we find a finite BEC critical temperature even at $d = 0$. Although an energy gap in the boson energy for a gas inside a infinite box has not been found even for an interacting gas [1], when surface states are created inside the box introducing an appropriated external potential, an energy gap appears between the ground and the first excited states of the particle energy spectrum. Here we report the critical temperature, the condensed fraction, the internal energy and the specific heat for a d-dimensional Bose gas with a generalized dispersion relation plus an energy gap, i.e., $\varepsilon = \varepsilon_0$ for $k = 0$ and $\varepsilon = \varepsilon_0 + \Delta + c_s k^s$, for $k > 0$, where $\hbar k$ is the particle momentum, ε_0 the lowest particle energy, c_s a constant with dimension of energy multiplied by a length to the power $s > 0$. Thermodynamic properties are ε_0 independent since this is just a reference energy. For $\Delta = 0$ we recover the results reported in Ref. [2].

[1] N.M. Hugenholtz and D. Pines, Phys. Rev. **116**, 489 (1959).
[2] V. C. Aguilera-Navarro, M. de Llano y M. A. Solís, Eur. J. Phys. **20**, 177 (1999).

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P4.36

Investigation of exotic spin phases in the one-dimensional spin-1/2 quantum magnet LiCuSbO4 by high-field NMR spectroscopy

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We will report our recent results of high-field NMR studies of the quantum magnet LiCuSbO4 (LCSO) that presents an excellent model system of a one-dimensional spin-1/2 quantum magnet with frustrated exchange interactions. Such networks are predicted to exhibit a plethora of novel ground states beyond classical ferro- or anti-ferromagnetic phases. In LCSO the absence of a long-range magnetic order down to sub-Kelvin temperatures is suggestive of the realization of a quantum spin liquid state. Our NMR measurements in strong magnetic fields up to 16 Tesla reveal clear indications for the occurrence of a long-sought field-induced nematic phase close to the saturation field.

P4.37

High-field magnetic resonance spectroscopy on kagome Swedenborgites
$YBaCo_3MO_7$(M=Al, Fe)

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We performed a combined experimental study of magnetic properties of the Swedenborgite type single crystals of $YBaCo_3AlO_7$ and $YBaCo_3FeO_7$ with high field ESR and high field NMR spectroscopy. In title compounds the magnetic lattice can be described as a stacking of kagome layers, where unconventional ground states such as a spin liquid state can be expected due to the strong geometrical frustration. The experimental results show the occurrence of short-range quasi static electron spin correlations at T* = 22 K for $YBaCo_3AlO_7$ and T*= 50K for $YBaCo_3FeO_7$ but not a long-range antiferromagnetic order. We compare our results with AC and DC susceptibility measurements and discuss a possible competition between a spin glass-like state due to intrinsic structural disorder and a spin liquid state arising from strong magnetic frustration in this materials.

P4.38

Dynamic nuclear polarization and control of 29-Si nuclear spins in As doped Si

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We report on experiments of dynamic nuclear polarization (DNP) of donor and 29Si nuclear spins in natural silicon. We demonstrate very high polarization of 29Si nuclei which are strongly coupled to donor electrons. By utilizing the methods of DNP it is possible to select spin ensembles based on the strength of 29Si superhyperfine interaction with the donor electron. The ensembles can be further manipulated with NMR. The samples were studied in strong magnetic field of 4.6 T and temperatures below 1 K, in which conditions the donor electron spins are fully polarized.

P4.39

Crystalization of ^{4}He in Aerogel via Mass Flow from Surrounding Solid ^{4}He

Ryuji Nomura

Tokyo Institue of Technology

TUESDAY 16 AUGUST

Takeo Matsubara Session
Chair: Makoto Tsubota

(3.4.1921 - 15.12.2014)

Takeo Matsubara was a Japanese physicist. He proposed a method of statistical mechanics related to Green's function (many-body theory), by applying quantum field theory techniques to statistical physics. He graduated from Osaka Imperial University, and worked as full professor in Hokkaido University, Kyoto University, and Okayama University of Science. He was the winner of the Nishina Memorial Prize in 1961, and was director of the Physical Society of Japan.

I5.1

Solitons and spin-charge correlations in strongly interacting Fermi gases

Martin Zwierlein

Massachusetts Institute of Technology, Cambridge, USA

Ultracold atomic Fermi gases near Feshbach resonances or in optical lattices realize paradigmatic, strongly interacting forms of fermionic matter. Topological excitations and spin-charge correlations can be directly imaged in real time. In resonant fermionic superfluids, we observe the cascade of solitonic excitations following a pi phase imprint. A planar soliton decays, via the snake instability, into vortex rings and long-lived solitonic vortices. For fermions in optical lattices, realizing the Fermi-Hubbard model, we detect charge and antiferromagnetic spin correlations with single-site resolution. At low fillings, the Pauli and correlation hole is directly revealed. In the Mott insulating state, we observe strong doublon-hole correlations, which should play an important role for transport.

O5.1

Emergence of Metallic Quantum Solid Phases in a Rydberg-Dressed Fermi Gas

Chung-Yu Mou

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We examine possible low-temperature phases of a repulsively Rydberg-dressed Fermi gas in a three-dimensional free space. It is shown that the collective density excitations develop a roton minimum, which is softened at a wavevector smaller than the Fermi wavevector when the particle density is above a critical value. The mean field calculation shows that unlike the insulating charge density waves states often observed in conventional condensed matters, a self-assembled metallic density wave state emerges at low temperatures. In particular, the density wave state supports a Fermi surface and a body-center-cubic crystal order at the same time with the estimated critical temperature being about one-tenth of the non-interacting Fermi energy. Our results suggest the emergency of a fermionic quantum solid that should be observable in current experimental setup.

O5.2

Pseudogap phenomena near the BKT transition of a two-dimensional ultracold Fermi gas in the crossover region

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We investigate a 2D Fermi gas near the Berezinskii-Kosterlitz-Thouless (BKT) transition. Within the framework of a self-consistent T-matrix approximation, we clarify how strong 2D pairing fluctuations cause pseudogap phenomena in the low temperature region where the BKT transition has recently been observed in a 6Li Fermi gas [Ries et al., PRL 114, 230401 (2015), and Murthy et al., PRL 115, 010401 (2015)]. We also discuss how these pairing fluctuations lead to bosonic characters of this system in this regime. Since the BKT transition has recently become a realistic hot topic in cold Fermi gas physics, our results would be useful for the understanding of this unconventional Fermi superfluid.

O5.3

Towards high-temperature superfluidity of excitons in TMDC

Berman Oleg(1,2), Kezerashvili Roman(1,2)

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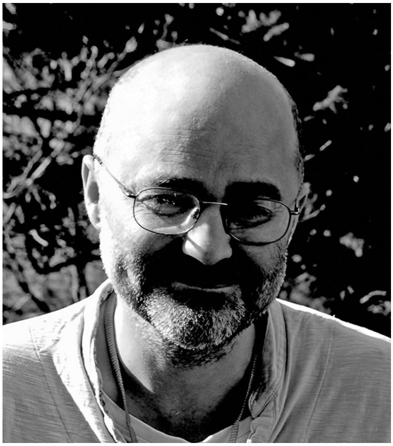
Two-dimensional dipolar excitons, formed by electrons and holes, spatially separated in two parallel transition metal dichalcogenide (TMDC) atomically thin layers, form superfluid at temperatures below the critical one. The effective masses of A and B dipolar excitons, collective excitations spectrum, sound velocity and critical temperature Tc for superfluidity were obtained for various TMDC bilayers. Tc for two-component exciton system in a TMDC bilayer is about one order of magnitude higher than Tc for any one-component exciton system, because for a two-component system Tc depends on the reduced mass of A and B excitons, which is always smaller than the individual mass of A or B exciton.

Shaun Fisher Session
Chair: William Halperin



(8.6.1967 - 4.1.2015)

Apart from a period working at CNRS in Grenoble, Shaun was with Lancaster's Department of Physics for the whole of his academic career. Shaun was a consummate experimental physicist and already as a graduate student he was devising experimental techniques which have since been taken up around the world. He will be best remembered for his discovery of quantum turbulence in superfluid helium-3 at microkelvin temperatures (previously thought impossible) and his subsequent studies of quantum turbulence in general. He was also a key part of the team which demonstrated the analogue of cosmic string formation in superfluid helium-3.

I5.2

Supercurrent in a room temperature Bose-Einstein magnon condensate

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A supercurrent of magnons is detected by Brillouin light scattering spectroscopy in a magnon Bose-Einstein condensate (BEC) prepared in a room temperature $Y_3Fe_5O_{12}$ magnetic film. The local laser heating induces a frequency shift between different parts of the BEC and leads to an increasing phase gradient in the condensate. As a result, a phase-gradient-induced current – a magnon supercurrent – flowing out of the focal spot, is excited. This efflux reduces the BEC density in the probing point but it does not alter the dynamics of gaseous magnons.

I5.3

SQUID detection of Nano-electro-mechanical systems

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2) Lancaster University, Physics Department, UK

Nano-electro-mechanical systems at low temperatures can form elements of ultra-sensitive detection schemes. The integration of such devices into quantum fluids experiments provides a potential route for studying surface modes and properties of confined superfluids. In this work we investigate how the properties of a NEMs beam are modified by coupling to the input circuit of a remote SQUID, a configuration compatible with ultra-low temperatures. Here modification of the SQUID bias conditions and the magnetic field applied to the NEMs beam effect the strength and sign of the coupling to the SQUID. We demonstrate that the beam can be driven into a stable state of self-sustained oscillations.

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Appendix

Information on Public Transportation and Directions to Conference Locations

The public transport system in Prague is operated by Dopravní podnik hlavního města Prahy (DPP) http://www.dpp.cz/en/ and consists of a dense and extensive network of underground metro lines, trams and buses. A useful Journey Planner can be found at the following link: http://spojeni.dpp.cz/ConnForm.aspx?cl=E5

The Conference will be held at the Clarion Congress hotel, which is near the metro station ”Vysočanská ”

From Vaclav Havel Airport to Clarion Congress Hotel (Conference Venue)

Bus 119 to ”Nadrazi Veleslavin” → metro line A to ”Mustek” → metro ”B” to ”Vysočanská”

or

Bus 100 to ”Zlicin” → metro ”B” to ”Vysočanská”

The tutorials will be held at the Faculty of Mathematics and Physics Troja Campus, which is near the Bus Station ”Kuchyňka”

Vaclav Havel Airport to Troja Campus (Tutorial Venue)

Bus 119 to ”Nadrazi Veleslavin” → metro line A to ”Muzeum” then metro line C in the direction of Letňany to ” Nádraží Holešovice” Bus 201 (towards Bakovská) to Kuchyňka.

Hotel Clarion to Troja Campus (Tutorial Venue)

Bus 177 (going to Poliklinika Mazurská) or 136 (going to Vozovna Kobylisy) from Vysočanská metro station to Střížkov metro station then bus 201 to Kuchyňka

or

Metro line B (Yellow Line) towards Zličín from Vysočanská to Florenc, Metro Line C (Red Line towards Letňany) to Nádraží Holešovice, Bus 201 to Kuchyňka

Concert
Concert, Betlémská kaple (Bethlehem chapel) http://www.bethlehemchapel.eu/en/, Metro Station ‘Národní třída’

Czech Phrase list

Phrases		
English	Czech	Phonetic
Yes	Ano	Ah-no
No	Ne	Neh
Good morning	Dobré ráno	Do-breh rah-no
Hello, goodbye	Ahoj, čau	Ahoy, chow
Good Day	Dobrý den	Dobree dehn
Good evening	Dobrý večer	Dobree veh-chehr
Good-bye(formal)	Nasheldanou	Nah-shle-dah-noh
Good night	Dobrou noc	Do-broh nots
Nice to meet you	Těší mě	Tye-shee Mye
How are you ?(formal)	Jak se máte ?	Yak seh mah-te
How are you ?	Jak se máš ?	Yak seh mahsh
I am well	Mám se dobře	Mahm seh do-breh
Do you speak English ?	Mluvíte anglicky ?	Mloo-veeteh ahngleetskee
I do not speak Czech	Nemluvím česky	Neh-mloo-veem cheskee
I do not understand	Nerozumím	Neh-rozoo-meem
I am sorry	Promiňte	Pro-min-tey
Excuse me	S dovolenim	S dovo-len-eem
Thank you	Děkuju	Dyeh-kooyoo
Please, You are welcome	Prosím	Pro-seem
What is it ?	Co je to ?	Tso yeh toh
How much is it ?	Koli to stojí ?	Koleek toh stoyee
Bill, please	Zaplatíme	Za-pla-teem
Bon appetit	Dobrou chuť	Do-broh kuhtye
Cheers	Nazdraví	Nah-zdrah-vee
Do you have ...	Máte....	Mah-teh
Chicken	Kuře	Koorzyeh
Steak	Biftek	Beef-tehk
Fish	Ryby	Ree-bee
Cheese	Sýr	Seer
Bread	Chléb	Khlehb
Beer	Pivo	Pee-vo
Wine	Víno	Vee-no
Water	Voda	Vo-dah
Where is the ..	Kde je ... ?	Gdeh je ...
Restaurant	Restaurace	Rehs-tau-rahtseh
Restroom	Toaleta	Toh-ah-lehta
Shop	Obchod	Ob-khod
Street	Ulice	Oo-leetseh
Police	Policie	Poleetsee-eh
Hospital	Nemocnice	Neh-mots-nitseh
Train station	Nádraží	Nah-drazhyee
Airport	Letiště	Leh-teesh-tyeh
Help!	Pomoc	Po-mots
One beer, please	Jedno pivo prosím	yedno pee-vo pro-seem

Common Czech Notices
Muzi / Pani = Gent's Room
Zeny /Damy = Lady's Room
Ukončete výstup a nástup, dveře se zavírají! = Stop getting off or getting on, the doors are closing! (Prague subway announcement)
Příští zastávka: Náměstí Republiky = Next stop: Náměstí Republiky
Mimo provoz = Out of Order
Otevřený = Open
Zavřeno = Closed
Vchod / vstup = Entrance
Východ / Výstup = Exit
Nebezpečí / Pozor = Danger/Beware
Vstup zakázán = No Tresspassing
Kouření zakázáno = No Smoking
Výtah = Elevator

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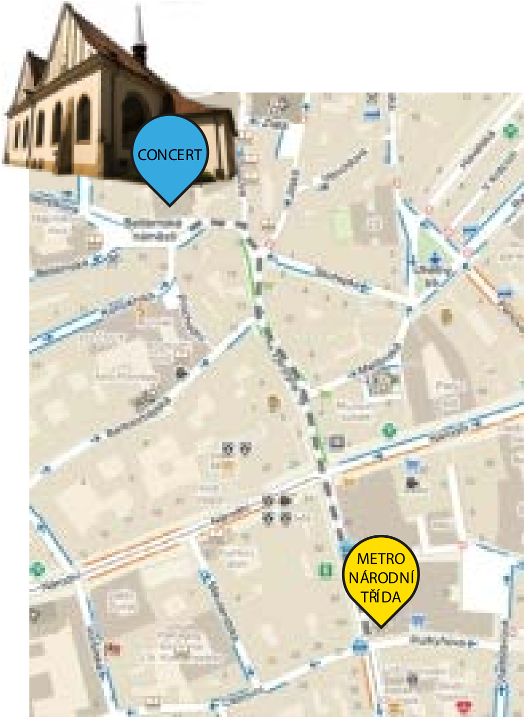
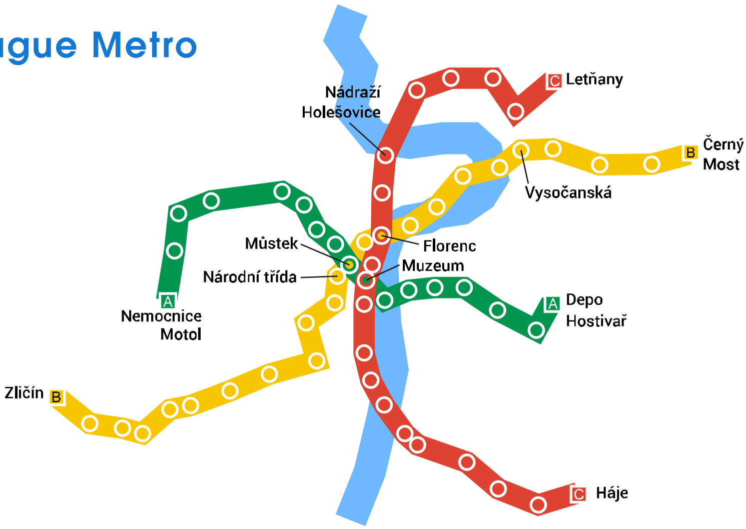


Directions to the concert

Please take the yellow Metro line (Line B) to Národní Třída and then follow the marked path towards Betlémská kaple located at Betlémské náměstí. The return trip is also easiest using Metro Line B.

Prague Metro



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