# SUPERFLUIDITY (SYSF)

Jointly organized by
Dynamics and Statistical Physics (DY)
Low Temperature Physics (TT)

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## OVERVIEW OF INVITED TALKS AND SESSIONS

(lecture room HSZ 04)

### Invited Talks

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| SYSF 1.1 | Mon | 09:45 | (HSZ 04) | **Rotons and superfluidity**, Sebastien Balibar |
| SYSF 1.2 | Mon | 10:15 | (HSZ 04) | **Disorder determined phase of the p-wave superfluid 3He**, Igor Fomin |
| SYSF 1.3 | Mon | 10:45 | (HSZ 04) | **From superfluids to vacuum of relativistic quantum fields**, Grigory Volovik |
| SYSF 2.1 | Mon | 11:30 | (HSZ 04) | **High-Temperature Superfluidity in an Ultracold Fermi Gas**, Martin Zwierlein, Jamil Abo-Shaeer, André Schirotzek, Christian Schunck, Wolfgang Ketterle |
| SYSF 2.2 | Mon | 12:00 | (HSZ 04) | **Superfluid regimes in strongly interacting Fermi gases**, Gora Shlyapnikov |
| SYSF 2.3 | Mon | 12:30 | (HSZ 04) | **Bose–Einstein Condensation in a Disorder Potential**, Robert Graham |

### Sessions

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| SYSF 1 | **Superfluidity 1** | Mon 09:45–11:15 | HSZ 04 | SYSF 1.1–1.3 |
| SYSF 2 | **Superfluidity 2** | Mon 11:30–13:00 | HSZ 04 | SYSF 2.1–2.3 |

# Sessions

**– Invited Talks –**

## SYSF 1 Superfluidity 1

Time: Monday 09:45–11:15 Room: HSZ 04

### Invited Talk

SYSF 1.1 Mon 09:45 HSZ 04

**Rotons and superfluidity** — •Sebastien Balibar — Laboratoire de Physique Statistique, Ecole Normale Superieure, 75231 Paris cedex 05, France

Fritz London understood that quantum mechanics shows up at the macroscopic level, and proposed in 1938 that superfluidity was a consequence of Bose-Einstein condensation. However, Lev Landau could not believe in London's ideas; instead, he introduced quasiparticles to explain the thermodynamics of superfluid 4He and its critical velocity. One of these quasiparticles was his famous "roton" which he considered as an elementary vortex. In 1946, London criticized Landau's "theory based on the shaky grounds of imaginary rotons". Despite their rather strong disagreement, Landau was awarded the London prize in 1960. Today, we know that London and Landau had both found part of the truth: BEC takes place in superfluid 4He, and rotons exist.

In my early experiments on quantum evaporation, I found direct evidence for the existence of rotons which play the role of photons in the photoelectric effect. But rotons are now considered as particular phonons which are nearly soft, due to the local order of superfluid 4He. In our recent studies of nucleation, rotons show their importance again: by using acoustic techniques, we have extended the study of liquid 4He up to very high pressures where the liquid state is very dense and metastable. We now wish to demonstrate that, at high density, the vanishing of the roton gap destroys superfluidity and triggers an instability towards the crystalline state.

### Invited Talk

SYSF 1.2 Mon 10:15 HSZ 04

**Disorder determined phase of the p-wave superfluid 3He** — •Igor Fomin — P. L. Kapitza Institute for Physical Problems, Kosygina 2, 119334 Moscow, Russia

For p-wave Cooper pairing several superfluid phases can exist. Two pases - ABM and BW are realized in the superfluid 3He. The order parameters of both phases are minima of the conventional Ginzburg and Landau free energy, obtained as a regular expansion in powers of the order parameter. Introduction of impurities in a form of high porosity aerogels in the superfluid 3He changes expression for its free energy. Singular terms appear in this expression. The singular terms dominate in a near vicinity of the transition temperature. As a result new phase can appear at cooling of liquid 3He from the normal phase in the superfluid. The order parameter of the new quasi-isotropic, or "robust" phase is found and suggested as a candidate for the experimentally observed A-like phase. Some properties of the suggested phase are discussed.

### Invited Talk

SYSF 1.3 Mon 10:45 HSZ 04

**From superfluids to vacuum of relativistic quantum fields** — •Grigory Volovik — Low Temperature Laboratory, Helsinki University of Technology, P.O.Box 2200, FIN-02015 HUT, Finland — Landau Institute for Theoretical Physics, 119334 Moscow, Russia

The phenomenon of emergent physical laws, which is manifested in most of the condensed-matter systems, is becoming the paradigm of the modern physics. We hope that this phenomenon can be also applicable to the high energy physics and gravity. The encouraging fact comes from universal properties of the ground states of quantum liquids, which play the role of the quantum vacua in particle physics. The role of matter is played by the fermion zero modes and by the bosonic collective modes of the liquid. There are only two basic universality classes of quantum vacua, which support the topologically stable gapless (massless) fermions. The more common class contains the vacua whose fermionic excitations live in the vicinity of the Fermi surface. Fermionic excitations in vacua belonging to the second class live near Fermi points – points in momentum space where the energy of excitation is zero. Near Fermi points, excitations behave as relativistic massless Weyl fermions, while the bosonic collective modes interacting with them simulate the gauge and gravitational fields. In this universality class the gauge fields, chiral fermions, Lorentz invariance, gravity, relativistic spin, and other features of Standard Model gradually emerge. The condensed-matter vacua demonstrate the possible solution of the cosmological problem: the huge contribution of zero point energy of quantum fields is cancelled without any fine tuning by microscopic degrees of freedom above the Planck cut-off.

## SYSF 2 Superfluidity 2

Time: Monday 11:30–13:00 Room: HSZ 04

### Invited Talk

SYSF 2.1 Mon 11:30 HSZ 04

**High-Temperature Superfluidity in an Ultracold Fermi Gas** — •Martin Zwierlein, Jamil Abo-Shaeer, André Schirotzek, Christian Schunck, and Wolfgang Ketterle — Department of Physics, MIT-Harvard Center for Ultracold Atoms, and Research Laboratory of Electronics, MIT, 77 Massachusetts Avenue, Cambridge, MA 02139, USA

Quantum degenerate atomic Fermi gases provide a remarkable opportunity to study strongly interacting Fermions. In contrast to other Fermi systems, such as superconductors, neutron stars or the quark-gluon plasma of the early Universe, these gases have low densities and their interactions can be precisely controlled over an enormous range. Our recent observation of vortex lattices in a rotating Fermi gas provides definitive evidence for superfluidity in these systems. Scaled to the density of electrons in a solid, this new form of superfluidity would occur already above room temperature.

### Invited Talk

SYSF 2.2 Mon 12:00 HSZ 04

**Superfluid regimes in strongly interacting Fermi gases** — •Gora Shlyapnikov — LPTMS, Universite Paris Sud, Bat. 100, 91405 Orsay Cedex, France

I will give an overview of recent studies of strongly interacting (two-component) Fermi gases and first focus on the regime of weakly bound dimers formed at a positive scattering length for the interspecies interaction. They represent novel composite bosons which exhibit the features of Fermi statistics at short interdimer distances. In particular, the Pauli exclusion principle for identical fermions provides a strong suppression of relaxation of these dimers to deep bound states and makes them remarkably stable, which pawes a way to their Bose-Einstein condensation (BEC). I then analyze mixtures of heavy and light fermionic atoms and address the problem of superfluidity in these systems. In the unitarity limit, where the amplitude of interaction between heavy and light fermions is tending to infinity, I will show how one can map this system onto the system of long-range interacting heavy bosons and treat a superfluid transition as BEC of such bosons.

### Invited Talk

SYSF 2.3 Mon 12:30 HSZ 04

**Bose–Einstein Condensation in a Disorder Potential** — •Robert Graham — Fachbereich Physik, Universität Duisburg-Essen

Modern experimentation with ultracold atoms in traps has revived the interest in the old but not completely solved problem of 'dirty bosons'. The problem is experimentally relevant for miniaturization of BECs on chips and can also be studied by tayloring disorder potentials via laser speckle fields. Theoretically it is intriguing because of the competition of localization and interaction, of Anderson localization and the elusive Bose-glass phase, and of disorder and superfluidity. The talk reviews recent theoretical work on this problem in our group, placing it in the context of some of the earlier work in this area.