Nonequilibrium phenomena in superfluid systems: atomic nuclei, liquid helium, ultracold gases, and neutron stars

Report of Contributions

Contribution ID: **1** Type: **not specified**

Welcome

Monday 12 May 2025 10:30 (15 minutes)

Presenter: VAN KOLCK, Ubirajara (ECT*, Trento)

Contribution ID: **2** Type: **not specified**

Introduction

Monday 12 May 2025 10:45 (30 minutes)

Author: MAGIERSKI, Piotr (Warsaw University of Technology)

Co-authors: HASKELL, Brynmor (Nicolaus Copernicus Astronomical Center); WLAZŁOWSKI, Gabriel (Warsaw University of Technology); ROATI, Giacomo (University of Florence, LENS)

Presenters: HASKELL, Brynmor (Nicolaus Copernicus Astronomical Center); WLAZŁOWSKI, Gabriel (Warsaw University of Technology); ROATI, Giacomo (University of Florence, LENS); MAGIERSKI, Piotr (Warsaw University of Technology)

Contribution ID: **3** Type: **not specified**

Microscopic Models of Induced Fission Dynamics

Monday 12 May 2025 11:45 (45 minutes)

Based on recent developments of time-dependent nuclear density functional theory (TD-DFT) and the time-dependent generator coordinate method (TD-GCM), significant advances in microscopic description of various aspects of induced fission dynamics have been reported. These include studies of the effect of fluctuations on fission observables, dynamics of neck formation and rupture, the energy dissipation mechanism and total kinetic energy distribution, fragment distributions and properties of fragments beyond scission. Finite-temperature effects have been considered in TD-DFT, while the TD-GCM has been generalized to include time-dependent generator states. With the coherent superposition of TD-DFT trajectories in the generalized TD-GCM, fission dynamics is described fully quantum mechanically in an approach that extends beyond the adiabatic approximation and includes quantum fluctuations.

Author: VRETENAR, Dario

Presenter: VRETENAR, Dario

Contribution ID: **4** Type: **not specified**

Determining Fission Fragment Spin Properties Using Projection Techniques

Monday 12 May 2025 12:30 (30 minutes)

Author: SCAMPS, Guillaume

Presenter: SCAMPS, Guillaume

Contribution ID: **5** Type: **not specified**

Fluctuation-induced couplings between superfluids and boundary solids

Monday 12 May 2025 13:00 (30 minutes)

This talk adresses the transport properties of superfluids like Helium II when taking into account the internal degrees of freedom of boundary solids. Indeed, superfluids have the special property of managing frictionless transport due to their absence of viscosity below a critical velocity. In such systems, the boundary solids are often described a simple boundary condition where the wavefunction of the fluid must be vanish. However this neglects that solids do have internal degrees of freedom which may couple with the excitation modes of the superfluid, leading to a friction at its boundaries even below the critical velocity. These fluctuation-induced effects, based on a retarded van der Waals interaction, have already been studied for solid-solid friction and more recently for room-temperature solid-liquid friction, leading to the discovery of exciting phenomena in the field of nanofluidics. Here, using a perturbative field theory, we explore these couplings at low temperature in the context of superfluids and determine what are the proper dynamical boundary conditions for the fluid. Thus, we investigate how mode couplings impact the exceptional transport properties of superfluids.

Author: COQUINOT, Baptiste (Institute of Science & Technology Austria (ISTA))

Presenter: COQUINOT, Baptiste (Institute of Science & Technology Austria (ISTA))

Contribution ID: **6** Type: **not specified**

Structure and Dynamics of Pairing Field in Unconventional Fermi Superfluids

Friday 16 May 2025 10:45 (30 minutes)

Author: TÜZEMEN, Buğra (Institute of Physics Polish Academy of Sciences)

Presenter: TÜZEMEN, Buğra (Institute of Physics Polish Academy of Sciences)

Contribution ID: **7** Type: **not specified**

Real-time non-equilibrium dissipative dynamic of strongly interacting many-fermion systems

Monday 12 May 2025 16:30 (45 minutes)

Author: BULGAC, Aurel

Presenter: BULGAC, Aurel

Contribution ID: **8** Type: **not specified**

When polarons discover their statistics in two dimensions

Tuesday 13 May 2025 09:15 (45 minutes)

I will present recent results on two-dimensional systems: 2D polarized Fermi gases evolving from the polaronic limit to an FFLO instability and 2D mixtures of fermions and bosons. In the latter case I will discuss the fate of Fermi polarons obeying Bose statistics when their concentration gets finite.

Author: PIERI, Pierbiagio (University of Bologna & Istituto Nazionale di Fisica Nucleare)

Presenter: PIERI, Pierbiagio (University of Bologna & Istituto Nazionale di Fisica Nucleare)

Contribution ID: **9** Type: **not specified**

Box-trapped fermions out of equilibrium: emergence of sound, driven polarons and Fermi's golden rule

Wednesday 14 May 2025 14:45 (45 minutes)

The realization of homogeneous quantum gases trapped in optical boxes has been a milestone in quantum simulation [1]. These textbook systems are proving to be powerful playground to study out of equilibrium physics in clean settings. I will present some of our recent works on driven uniform Fermi systems: the strong-drive spectroscopy of Fermi polarons [2], the measurement of the Lindhard response [3], and the observation of the emergence and breakdown of Fermi's golden rule in a driven universal Fermi gas.
[1] N. Navon, R.P. Smith, Z. Hadzibabic, Nature Phys. 17, 1334 (2021)
[2] F.J. Vivanco et al., Nature Phys. 21, 564 (2025)
[3] S. Huang et al., Phys. Rev. X 15, 011074 (2025)
[4] J. Chen et al., arXiv:2502.14867 (2025)

Author: NAVON, Nir

Presenter: NAVON, Nir

Contribution ID: **10** Type: **not specified**

A single superconducting vortex on a leash: thermodynamics and applications

Tuesday 13 May 2025 10:45 (30 minutes)

We introduce the Single Vortex Box (SVB) –a nanodevice that allows to treat a single superconducting vortex as a macroscopic, yet quantized, "particle"that can be created and annihilated on demand using electrical current pulses[1]. By applying fast, nanosecond-resolving switching thermometry [2], we measure the temperature rise and the subsequent thermal relaxation resulting from the expulsion of just a single magnetic vortex from the aluminum SVB. Our experiment provides a calorimetric estimation of the energy dissipated in a superconductor due to a single moving vortex –a fundamentally important measurement that has never been accomplished before due to the lack of appropriate tools. Our pioneering demonstration is also a pivotal step towards the development of the vortex-based electronics including memory cells, superconducting diodes, logic elements, and heat valves. We raise a fundamental question: does the vortex dissipate energy as it moves across the superconducting strip, or is dissipation triggered only when the vortex is annihilated?

[1] M. Foltyn, K. Norowski, A. Savin, M. Zgirski, Quantum thermodynamics with a single superconducting vortex, Science Advances 10, eado4032 (2024).
[2] M. Zgirski, M. Foltyn, A. Savin, A. Naumov, K. Norowski, Heat Hunting in a Freezer: Direct Measurement of Quasiparticle Diffusion in Superconducting Nanowire, Phys. Rev. Applied 14, 044024 (2020)

Author: ZGIRSKI, Maciej (Institute of Physics, PAN)

Presenter: ZGIRSKI, Maciej (Institute of Physics, PAN)

Contribution ID: **11** Type: **not specified**

Vortex dynamics in strongly-interacting atomic Fermi superfluids: from few to many

Tuesday 13 May 2025 11:45 (45 minutes)

The dynamics of quantized vortices underlies many phenomena of different quantum systems, from superconductors to neutron stars, and represent a particularly hard problem to tackle in fermionic systems. In this talk I will report a series of experiments on vortex dynamics in strongly-interacting Fermi superfluids, highly controllable systems where the dynamic of vortices can be studied in a bottom-up approach. Thanks to a micron-scale control over the external potential acting of the superfluid, we can arrange arbitrary configurations of vortices. We create on-demand vortex dipoles, namely a vortex-antivortex pair, representing the minimal configuration to study vortex motion and dissipative dynamics. By tracking the motion of a single vortex-dipole we measure the transverse and longitudinal mutual friction components characterizing the motion of vortices at finite temperature. Then, by adding a second vortex-dipole we engineer controlled dipole-dipole collision and unveil the interaction of vortices with sound excitations in the superfluid. Finally, we create an ordered structure of many vortices of the same charge by merging two counterflowing concentric superfluids, and we study the stability of such a vortex necklace. For large number of vortices, the symmetry is broken by vortex pairing in small clusters, occurring with a growth rate that follows the same scaling of the classical Kelvin-Helmholtz instability, characterizing the merging of counterflowing fluids.

Author: DEL PACE, Giulia (University of Florence)

Presenter: DEL PACE, Giulia (University of Florence)

Contribution ID: **12** Type: **not specified**

Quantum vortices leave a macroscopic signature in the thermal background

Tuesday 13 May 2025 12:30 (30 minutes)

Author: GALANTUCCI, Luca (Istituto per le Applicazioni del Calcolo, Consiglio Nazionale delle Ricerche (IAC-CNR))

Presenter: GALANTUCCI, Luca (Istituto per le Applicazioni del Calcolo, Consiglio Nazionale delle Ricerche (IAC-CNR))

Contribution ID: **13** Type: **not specified**

Strongly dissipative vortex dynamics in the holographic superfluid

Tuesday 13 May 2025 13:00 (30 minutes)

Holography or gauge/gravity duality provides a novel description of a strongly coupled superfluid via a gravitational theory in a higher-dimensional curved space-time with a black hole. Vortex dynamics in the holographic superfluid exhibits strong dissipation in the range of real-world superfluids. The talk gives an overview of various aspects of dissipative vortex dynamics and quantum turbulence in 2 and 3 dimensions, based on numerical real-time simulations of the holographic superfluid.

Author: EWERZ, Carlo (EMMI, GSI Helmholtzzentrum für Schwerionenforschung)

Presenter: EWERZ, Carlo (EMMI, GSI Helmholtzzentrum für Schwerionenforschung)

Contribution ID: **14** Type: **not specified**

Fermion pairs and loners under the microscope

Tuesday 13 May 2025 14:45 (45 minutes)

Author: ZWIERLEIN, Martin (MIT)

Presenter: ZWIERLEIN, Martin (MIT)

Contribution ID: **15** Type: **not specified**

Inertial effects in superfluid vortex dynamics

Tuesday 13 May 2025 15:30 (30 minutes)

Author: RICHAUD, Andrea (Universitat Politècnica de Catalunya)

Presenter: RICHAUD, Andrea (Universitat Politècnica de Catalunya)

Contribution ID: **16** Type: **not specified**

Learning about Neutron Star Interiors

Wednesday 14 May 2025 09:15 (45 minutes)

Neutron stars are compact celestial objects that offer the unique opportunity to explore matter and its interactions under conditions that cannot be reproduced elsewhere in the Universe. Their extreme gravitational, rotational and magnetic energy reservoirs fuel their diverse emission properties, which are visible across the electromagnetic waveband as well as the gravitational wave window. However, accurately measuring global neutron-star properties such as mass, radius, and moment of inertia poses significant challenges. Probing internal characteristics such as the crustal composition or superfluid physics is even more complex. In this talk, I will provide an overview of the various methods we use to measure global and small-scale neutron star characteristics and their underlying assumptions. I will discuss where astrophysicists employ independent methods and adopt multimessenger approaches to gather complementary data from observable phenomena. I will specifically highlight where observations provide insights into the nature of superfluid and superconducting phases of matter, setting the stage for further related discussions during this workshop.

Author: GRABER, Vanessa (Royal Holloway, University of London)

Presenter: GRABER, Vanessa (Royal Holloway, University of London)

Contribution ID: **17** Type: **not specified**

Restless neutron stars: timing noise and pulsar glitches

Wednesday 14 May 2025 10:00 (45 minutes)

Superfluidity impacts the dynamics of rotating neutron stars. The presence of superfluids in neutron stars is an important ingredient in models of pulsar glitches, oscillation modes, cooling of old pulsars and, possibly, even timing noise. I will discuss how simulations of quantised vortices can help us to understand how superfluid momentum is transported in neutron stars, and their relevance for the astrophysical phenomena of pulsar glitches and timing noise.

Author: ANTONELLI, Marco (CNRS / LPC Caen)

Presenter: ANTONELLI, Marco (CNRS / LPC Caen)

Contribution ID: **18** Type: **not specified**

Energy dissipation in the superfluid interior of neutron stars

Wednesday 14 May 2025 10:45 (30 minutes)

Author: Dr PĘCAK, Daniel (Institute of Physics, Polish Academy of Sciences)

Presenter: Dr PĘCAK, Daniel (Institute of Physics, Polish Academy of Sciences)

Contribution ID: **19** Type: **not specified**

Rotating dipolar supersolids: from synchronous motion to neutron-star type glitches

Wednesday 14 May 2025 11:45 (45 minutes)

Author: POLI, Elena (Innsbruck University)

Presenter: POLI, Elena (Innsbruck University)

Contribution ID: **20** Type: **not specified**

Superfluid fraction in the inner crust of neutron stars

Wednesday 14 May 2025 12:30 (30 minutes)

In the inner crust of neutron stars, exotic nuclear clusters are probably arranged in a periodic lattice, and surrounded by a superfluid gas of unbound neutrons. The superfluid component of the crust is involved in some of the mechanisms to explain pulsar glitches. But, for the comparison with observations, one needs to know the neutron superfluid fraction. In order to compute it, the crucial point is the evaluation of the so-called "entrainment", that is a non-dissipative force between the superfluid component and the lattice. Attempts to compute it have been done in the context of band theory without explicitly including superfluidity [1], leading to values of the superfluid fraction too small to explain observed Vela glitches [2][3]. However, the validity of this approximation in the neutron star crust has been questioned [4][5]. Moreover, there is a strong tension between these band theory calculations and what one obtains in the formalism of superfluid hydrodynamics [6]. In order to solve this issue, we analyzed the inner crust of neutron stars within the Hartree-Fock-Bogoliubov framework, in the lasagna [7] and spaghetti [8] phase. Recently, we also extended our formalism to the 3D crystal case. In order to well describe the interplay between band structure and superfluidity, periodicity of the lattice has been taken into account using Bloch boundary conditions. By introducing a stationary relative flow between clusters and the surrounding neutron gas, we computed the actual neutron superfluid fraction. Our results are significantly larger than previous ones obtained in normal band theory. Also, we found the analytical explanation why the obtained entrainment is in reality much weaker than in normal band theory calculations.
[1] N. Chamel, Phys. Rev. C 85, 035801 (2012).
[2] N. Andersson, K. Glampedakis, W. C. G. Ho, and C. M. Espinoza, Phys. Rev. Lett. 109, 241103 (2012).
[3] N. Chamel, Phys. Rev. Lett. 110, 011101 (2013).
[4] G. Watanabe and C.J. Pethick, Phys. Rev. Lett. 119, 062701 (2017).
[5] Y. Minami and G. Watanabe, Phys. Rev. Res. 4, 033141 (2022).
[6] N. Martin and M. Urban, Phys. Rev. C 94, 065801 (2016).
[7] G. Almirante and M. Urban, Phys. Rev. C 109, 045805 (2024).
[8] G. Almirante and M. Urban, Phys. Rev. C 110, 065802 (2024).

Author: ALMIRANTE, Giorgio (IJCLab)

Presenter: ALMIRANTE, Giorgio (IJCLab)

Contribution ID: **21** Type: **not specified**

Superfluid hydrodynamics in neutron stars

Wednesday 14 May 2025 13:00 (30 minutes)

Author: ALLARD, Valentin (Warsaw University of Technology)

Presenter: ALLARD, Valentin (Warsaw University of Technology)

Contribution ID: **22** Type: **not specified**

Sound and Doppler effect in Supersolids

Tuesday 13 May 2025 10:00 (45 minutes)

Author: Dr RECATI, Alessio (INO-CNR BEC Center)

Presenter: Dr RECATI, Alessio (INO-CNR BEC Center)

Contribution ID: **23** Type: **not specified**

Exploring the role of impurities on the supercurrent stability in atomic superfluid rings

Wednesday 14 May 2025 15:30 (30 minutes)

Persistent currents are long-lived metastable states characterized by quantized circulation, denoted by the winding number w. The main topic of this talk is the investigation of the stability of these supercurrents in the presence of impurities and throughout the BEC-BCS crossover. For this purpose, we solve the Gross-Pitaevskii equation in the BEC regime and employ a time-dependent density functional theory for the unitary Fermi gas (UFG) and BCS limits. Our results show that when the initial winding number w0 exceeds a critical value, the supercurrent becomes unstable and w, as well as the flow energy or current, decays over time. The dissipation mechanism associated with vortex generation is present across all interaction regimes; however, in the BEC limit, it is the sole mechanism responsible for the decay of the persistent current. In contrast, in the UFG and BCS regimes, an additional dissipation channel emerges—the pair-breaking mechanism —which reduces the superfluid fraction and thus the current stability. Notably, vortex emission in the BCS regime is accompanied by Cooper pair breaking that extends beyond the vortex core. This pair-breaking process prevents the imprinting of a persistent current with a winding number above a threshold, whose value decreases as the system approaches the BCS regime. Furthermore, we explore how the number and distribution of impurities affect the critical winding number and the dissipation of flow energy. We find that in the BEC limit, the critical winding number increases with impurity density, whereas near the BCS regime, it is constrained by the pair-breaking threshold regardless of impurity characteristics.

Author: XHANI, Klejdja (Politecnico di Torino, Dipartimento Scienza Applicata e Tecnologia)

Presenter: XHANI, Klejdja (Politecnico di Torino, Dipartimento Scienza Applicata e Tecnologia)

Contribution ID: **24** Type: **not specified**

Exploring Turbulence and Interference with Cold Atoms

Thursday 15 May 2025 09:15 (45 minutes)

In this talk I will discuss some results related to turbulence and interference motivated by cold-atom experiments here at WSU.

Author: FORBES, Michael (Washington State University)

Presenter: FORBES, Michael (Washington State University)

Contribution ID: **25** Type: **not specified**

Transition to rotating quantum turbulence

Thursday 15 May 2025 10:00 (45 minutes)

Author: GIBERT, Mathieu (Institut Néel CNRS)

Presenter: GIBERT, Mathieu (Institut Néel CNRS)

Contribution ID: **26** Type: **not specified**

Modelling Superfluid Dynamics in Neutron Stars in 2D and 3D

Thursday 15 May 2025 10:45 (30 minutes)

Neutron stars are the collapsed cores of massive stars that have undergone a supernova explosion. They are the densest known astrophysical objects, with a mass typically 1.4 times that of the Sun compressed into a radius of approximately 10 km. Deep within the star, where the density exceeds the nuclear equilibrium density, neutrons become superfluid and protons become superconducting. As a result, the star's rotation and magnetic flux become are quantised into extremely thin vortices and fluxtubes respectively. These vortices pin to nuclear lattice sites or defects in the star' s crust. When the star's rotation rate slows down, the vortices move outward to conserve angular momentum. At the same time, these vortices unpin and self-reorganise to release the stored angular momentum in catastrophic discrete events known as rotational glitches which are observed as an instantaneous increase in the observed rotation rate of pulsars. A complete theory of the micro and macroscale superfluid dynamics to explain this phenomenon does not yet exist and current theoretical models are hampered by an incomplete understanding of the interactions between superfluid vortices, fluxtubes and crustal nuclei. For this talk, I will be concentrating on some of our recent results in two-dimensionally modelling the vortex dynamics in a neutron-star using the point vortex model. The current focus of this work is to explore the behaviour of a lattice of vortices within a grid of pinning sites by statistically studying their collective unpinning behaviour as it undergoes linear spin down.

Author: JACOB THOMAS, Julie (Newcastle University)

Presenter: JACOB THOMAS, Julie (Newcastle University)

Contribution ID: **27** Type: **not specified**

Surprising vortex dynamics in superfluid 3He: Strong pinning, vortex sheets and wave turbulence

Thursday 15 May 2025 11:45 (45 minutes)

Fermionic p-wave superfluid 3He is known to host various kinds of quantized vortices, including half-, single- and double-quantum. Regular motion of such vortices through the fluid is well understood: It is governed by the mutual friction, which originates in interaction of vortex-core-bound fermions with bulk quasiparticles. I present three examples of less usual vortex dynamics observed experimentally: 1) In the polar phase of superfluid 3He, containing nodal line in the energy spectrum, vortices are easily pinned in the confining matrix of solid nanostrands, used to stabilize the polar phase. This may provide the best laboratory model for vortices in a neutron star interacting with the crust. 2) Dynamically driven transition from vortex lines to vortex sheets in the A phase, where moving vortex structures create synthetic electromagnetic field for Bogoliubov quasiparticles, which are Weyl fermions in the A phase. 3) Development of Kelvin waves (KWs) and KW-turbulence on vortices in the B phase, where the gap in the energy spectrum allows suppression of bulk quasiparticles and mutual friction at the lowest temperatures. KWs are believed to be an essential energy transfer mechanism in the ultra-low-temperature quantum turbulence. In a Fermi superfluid, KWs additionally interact with the core-bound states, overheating them.

Author: ELTSOV, Vladimir (Aalto University)

Presenter: ELTSOV, Vladimir (Aalto University)

Contribution ID: **28** Type: **not specified**

Observation of distinct dynamical scalings in turbulent Bose-Einstein condensates

Thursday 15 May 2025 12:30 (30 minutes)

Author: MADEIRA, Lucas (ECT*)

Presenter: MADEIRA, Lucas (ECT*)

Contribution ID: **29** Type: **not specified**

Kelvin-Helmholtz Instability in atomic Fermi superfluids: short and long term dynamics

Thursday 15 May 2025 13:00 (30 minutes)

Author: HERNANDEZ RAJKOV, Diego (LENS)

Presenter: HERNANDEZ RAJKOV, Diego (LENS)

Contribution ID: **30** Type: **not specified**

Laboratory neutron star analogues in the two-dimensional vacuum of superfluid 3He

Thursday 15 May 2025 14:45 (45 minutes)

Author: AUTTI, Samuli (Lancaster University)

Presenter: AUTTI, Samuli (Lancaster University)

Contribution ID: **31** Type: **not specified**

Vortex Avalanches in Neutron Stars

Thursday 15 May 2025 15:30 (30 minutes)

Rotational glitches can result from the angular momentum exchange between the curst and neutron star interiors. We study the dynamics of about 600 quantum vortices in a spinning-down two-dimensional neutron superfluid using the Gross–Pitaevskii model. For the first time, we find convincing spatial-temporal evidence of avalanching behaviour with about 10-20 vortices in each event resulting from vortex depinning and collective motion, during glitches and their post-evolutions. In the later stage, vortices continue to depin and circulate around the vorticity void in a similar manner to that seen in previous point-vortex simulations. We also demonstrate the exponential and power-law distributions in the avalanche waiting time and size under a controllable setup. Lastly, we comment on the challenge of extrapolating these results to conditions in real neutron stars, which contain many orders of magnitude more vortices.

Author: LIU, Gary (Newcastle University)

Presenter: LIU, Gary (Newcastle University)

Contribution ID: **32** Type: **not specified**

Vortices in Immiscible Mixtures of Bose Einstein Condensates

Friday 16 May 2025 10:15 (30 minutes)

Immiscible superfluid mixtures have been shown to display a wider variety of exotic dynamics than their single component counterparts. Here we consider the mean-field vortex solutions and their stability within a two-component Bose-Einstein condensate in the immiscible limit. We begin by systematically study the dynamics of a binary immiscible Bose-Einstein condensate in two dimensions, where a small bubble of the second component is used to "stir"the first component. We rigorously map out the critical velocity for vortex shedding as a function of the size of the bubble, in analogy to the critical velocity of a laser spoon. Observing that the dynamics of the system depend on the initial size and velocity of the bubble, we then show that a dimensionless parameter with the same form as the Weber number (a dimensionless parameter that characterizes the flow of a multiphase classical fluid) accurately predicts the resulting bubble fragmentation.

Author: DORAN, Ryan (Newcastle University)

Presenter: DORAN, Ryan (Newcastle University)

Contribution ID: **33** Type: **not specified**

Instability dynamics in immiscible binary Bose-Einstein condensates under constant forces

Friday 16 May 2025 09:45 (30 minutes)

Considering the initially immiscible configuration of homogeneous binary Bose-Einstein condensates confined in a two-dimensional circular box, I will report the results of some investigations we have carried out considering the emergence of Rayleigh-Taylor (RT) and Kelvin-Helmholtz (KH) instabilities.

Author: TOMIO, LAURO (Instituto de Física Teórica, UNESP)

Presenter: TOMIO, LAURO (Instituto de Física Teórica, UNESP)

Contribution ID: **34** Type: **not specified**

Electrodynamics of vortices in quasi-two-dimensional scalar Bose-Einstein condensates

Monday 12 May 2025 14:45 (30 minutes)

Author: SHIN, Seongho (University of Luxembourg)

Presenter: SHIN, Seongho (University of Luxembourg)

Contribution ID: **35** Type: **not specified**

Stabilizing Solitonic Dynamics of Ultracold Gases in the BCS-BEC crossover

Friday 16 May 2025 09:15 (30 minutes)

We develop a time dependent effective theory based on the PLDA theory [1] for the ground state behaviour of the order parameter of fermions in the BCS-BEC crossover. Our approach is computationally efficient and paves the way to compare with elaborated experimental implementations. With our time dependent theory we study the stability of dark soliton [2,3] solutions at T=0 across the BCS-BEC crossover. We discuss how one can stabilize density fluctuations arising due to nonlinear mismatch while seeding the soliton and extend the lifetime of the soliton profile. We analyze possible escenarios relevant for the implementation with ultracold fermions using Spatial Light Modulators (SLM) and Digital Micromirror Devices (DMD). Our dynamical treatment can be extended to include additional corrections as with mPLDA theory[4,5] and finite temperature. This work is partially supported by the grant UNAM-DGAPA-PAPIIT:IN118823, as well as by grants from NVIDIA and utilized NVIDIA RTX 6000 Ada.

[1] S. Simonucci and G. C. Strinati, Phys. Rev.B 89, 054511 (2014)
[2] A. Cetoli, J. Brand, R. G. Scott, F. Dalfovo, and L. P. Pitaevskii, Phys. Rev. A 88, 043639 (2013)
[3] M. D. Reichl and E. J. Mueller, Phys. Rev. A 95, 053637 (2017)
[4] L. Pisani ,V. Piselli, and G. C. Strinati, Phys. Rev B 108, 214503 (2023)
[5] L. Pisani ,V. Piselli, and G. C. Strinati, Phys. Rev. B 108, 214504 (2023)

Author: CABALLERO-BENITEZ, Santiago Francisco (Universidad Nacional Autónoma de México)

Presenter: CABALLERO-BENITEZ, Santiago Francisco (Universidad Nacional Autónoma de México)

Contribution ID: **36** Type: **not specified**

Implementations on local quantum friction

We propose three distinct schemes for implementing local \textit{quantum friction} (QF) within the Hartree-Fock-Bogoliubov (HFB) approximation to efficiently dissipate energy in fermionic many-body systems. The first scheme introduces a local current-dependent potential in the Hamiltonian, the second incorporates an external pairing potential that conserves particle number, and the third employs a pairing potential that does not. Combining these potentials optimizes the cooling process. Unlike traditional methods that modify the density matrix, local quantum friction directly influences the unitary evolution of wavefunctions, making it particularly suitable for cooling fermionic many-body systems while preserving orthogonality. By integrating these frictional potentials into time evolution, our approach accelerates convergence to ground states compared to conventional stationary methods. We also explore applications to spin-imbalanced systems, demonstrating the versatility of this framework.

Author: ALBA-ARROYO, Jose Ernesto (Warsaw University of Technology)

Presenter: ALBA-ARROYO, Jose Ernesto (Warsaw University of Technology)

Session Classification: POSTER SESSION

Contribution ID: **37** Type: **not specified**

A single superconducting vortex on a leash: thermodynamics and applications

Author: ZGIRSKI, Maciej (Institute of Physics, PAN)

Presenter: ZGIRSKI, Maciej (Institute of Physics, PAN)

Session Classification: POSTER SESSION

Contribution ID: **38** Type: **not specified**

Shapiro steps in strongly-interacting Fermi gases

Josephson junctions represent a powerful tool to probe macroscopic phase coherence in different systems. They are also fundamental for atomtronics circuits, thanks to their well defined current-chemical potential and current-phase. In our experimental system, we create atomic Josephson junctions using Fermi superfluids of lithium-6, realized by coupling two quasi-two-dimensional atomic clouds with a tunneling barrier. By moving the tunneling barrier across the junction while modulating the position at a given frequency, we are able to inject an alternate current. Then, measuring the chemical potential imbalance developed across the junction after a few modulation periods, we can study the dynamics resulting in the system. Our experimental results show that the AC driving of the barrier introduces a step-like behavior in the current-chemical potential curve, with a number of plateaus at a chemical potential value that is an integer multiple of the driving frequency [1]. This behavior is the analog of Shapiro steps observed in superconducting Josephson junctions illuminated by an external electromagnetic field [2]. We studied the AC response for a molecular BEC and a unitary Fermi gas junction, finding that in both cases the plateaus in the current-chemical potential characteristic coincides with the emission of a well-defined number of vortices, suggesting that the stabilization of the current in the plateaus is operated by phase slippage processes.
[1] V. Singh et al., Phys. Rev. Lett. (2024).
[2] S. Shapiro, Phys. Rev. Lett. 11(2) p. 80 (1963).

Author: FROMETA FERNANDEZ, Marcia (Istituto Nazionale di Ottica, CNR-INO)

Presenter: FROMETA FERNANDEZ, Marcia (Istituto Nazionale di Ottica, CNR-INO)

Session Classification: POSTER SESSION

Contribution ID: **39** Type: **not specified**

Towards general-purpose simulation platform for superfluid fermions

Author: WLAZŁOWSKI, Gabriel (Warsaw University of Technology)

Presenter: WLAZŁOWSKI, Gabriel (Warsaw University of Technology)

Session Classification: POSTER SESSION

Contribution ID: **40** Type: **not specified**

Anomalous Doppler effect in superfluid and supersolid atomic gases

Author: ZAWIŚLAK, Tomasz (University of Trento, Pitaevskii BEC Center)

Presenter: ZAWIŚLAK, Tomasz (University of Trento, Pitaevskii BEC Center)

Session Classification: POSTER SESSION