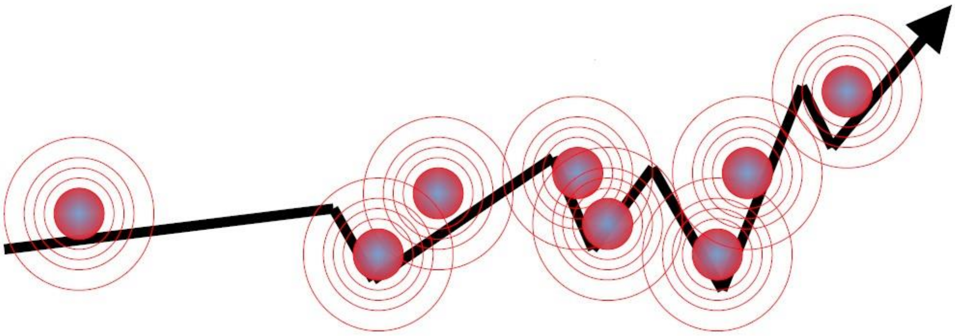
Polish-French (mini)Symposium: Development in the Physics of Ultracold Matter



July 1-2, 2021

Paris

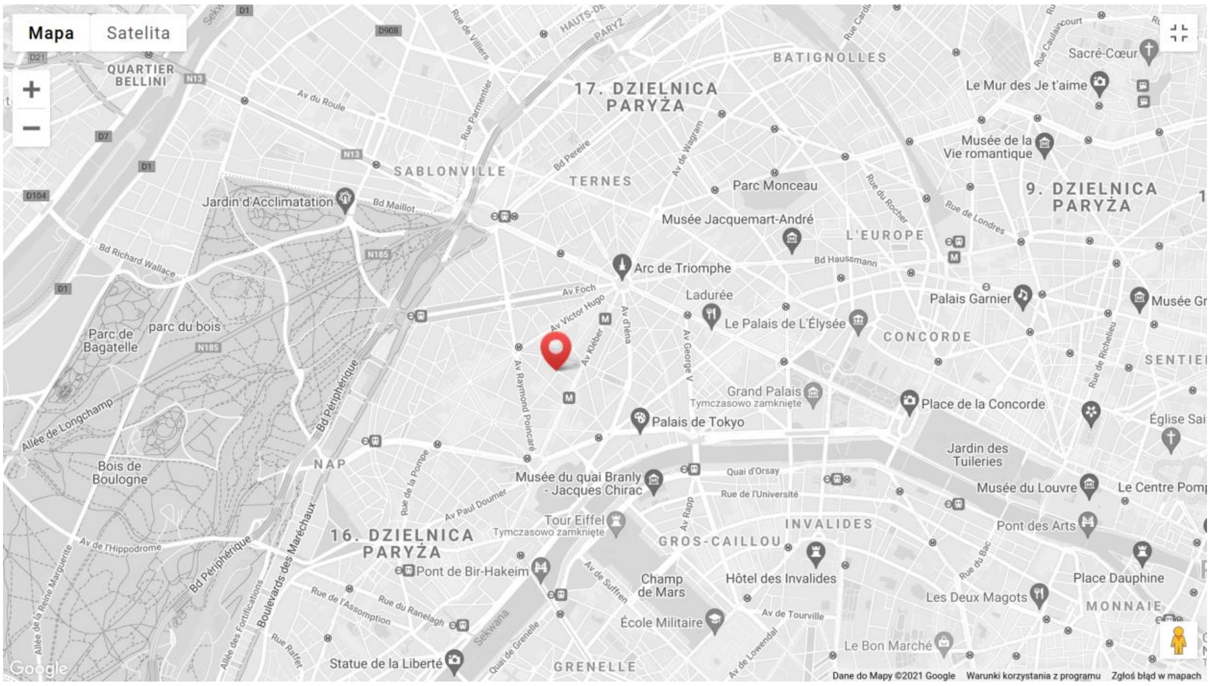
ACADEMIE POLONAISE DES SCIENCES
Centre Scientifique à Paris

Venue

Polish Academy of Sciences

Scientific Center in Paris

74, rue Lauriston – 75116 Paris



Access:

- M° (line 1): Charles de Gaulle Etoile, (line 9): Iéna or (line 2): Victor-Hugo
- Bus (line 30): Boissière or (line 63): Iéna

PROGRAM

	Thursday, 1st July 2021			Friday, 2nd July 2021
11:30 - 11:50	**Coffee**			**4th Session (Rzążewski)**
11:50 - 12:00	Opening		09:30 - 10:15	Dominique Delande
	1st Session (Pawłowski)		10:15 - 11:00	Jakub Zakrzewski
12:00 - 12:30	Kazimierz Rzążewski		11:00 - 11:30	**Coffee**
12:30 - 13:00	Alice Sinatra			**5th Session (Deuar)**
13:00 - 13:30	Krzysztof Sacha		11:30 - 12:00	Bruno Laburthe-Tolra
13:30 - 15:00	**Lunch**		12:00 - 12:30	Anna Minguzzi
	2nd Session (Sacha)		12:30 - 13:00	Krzysztof Pawłowski
15:00 - 15:30	Dmitry Petrov		13:30 - 15:00	**Lunch**
15:30 - 16:00	Piotr Deuar			**6th session (Sinatra)**
16:00 - 16:30	Felix Werner		15:00 - 15:30	Mariusz Gajda
16:30 - 17:00	**Coffee**		15:30 - 16:00	Mirosław Brewczyk
	3rd Session (Minguzzi)		16:00 - 16:30	Hadrien Kurkjian
17:00 - 17:30	Yvan Castin		16:30 - 17:00	Emilia Witkowska
17:30 - 18:00	Tomasz Karpiuk		17:00 - 17:05	Closing
18:00 - 18:30	Giuliano Orso			
18:30 - 19:30	**mini Poster Session**			

1st July 2021

11:30 Coffee Break / Reception

11:50 Opening

12:00 - 13:30 1st Session (chairman Krzysztof Pawłowski)

Kazimierz Rzążewski “*Fluctuations of Bose-Einstein condensate”*

Alice Sinatra *“Nuclear spin-squeezing by continuous measurement”*

Krzysztof Sacha “*Time Crystal Phenomena”*

13:30 - 15:00 Lunch

15:00 - 16:30 2nd Session (chairman Krzysztof Sacha)

Dmitry Petrov “*Higher-order effective interactions for bosons near a two-body zero crossing”*

Piotr Deuar “*Scalable full quantum dynamics of dissipative Bose-Hubbard systems and multi-time correlations”*

Felix Werner *“High-order diagrammatic expansion around BCS: Polarized superfluid phase of the attractive Hubbard model“*

16:30 - 17:00 Coffee break

17:00 - 18:30 3rd Session (chairman Anna Minguzzi)

Yvan Castin "*Une quasi-particule massive dans un gaz de phonons / A massive quasiparticle in a phonon gas”*

Tomasz Karpiuk “*Disruption of a Bose-Fermi droplet by an artificial black hole”*

Giuliano Orso *“Effects of disorder in interacting quantum systems: from two-body Anderson transitions to disorder quenches”*

18:30 - 19:30 Mini Poster Session

Youcef Baamara “*Scaling laws for the sensitivity enhancement of non-Gaussian spin states”*

Filip Gampel “*Continuous observation of a few-body quantum system”*

Piotr Grochowski *“Many-body molecule formation at a domain wall in a one-dimensional strongly interacting ultracold Fermi gas”*

Jakub Kopyciński *”Solitons and phonons in 1D. Beyond the limit of weak interactions”*

Maciej Kruk *“Fock State Sampling Method for BEC Fluctuations”*

Maciej Łebek “*Repulsive dynamics of strongly attractive one-dimensional quantum gases”*

Tanausú Hernández “*Spin squeezing for several spin-orbit coupled fermions in an optical lattice”*

2nd July 2021

9:30 - 11:00 4th Session chairman Rzążewski

Jakub Zakrzewski "*Many body localization without disorder*"

Dominique Delande "*The Quantum Boomerang Effect*"

11:00 - 11:30 Coffee break

11:30 - 13:00 5th session (chairman Piotr Deuar)

Bruno Laburthe-Tolra "*Measuring the growth of correlations in an array of dipolar particles*"

Anna Minguzzi "*Josephson effect(s) for strongly correlated gases in one dimension*"

Krzysztof Pawłowski "*LL-GPE and Quantum Droplets in 1D*"

13:30 - 15:00 Lunch

15:00 - 17:00 6th Session (chairman Alice Sinatra) - hybrid

Mariusz Gajda "*Coherent collisions of two Bose-Bose droplets*" (online)

Mirosław Brewczyk "*Berezinskii-Kosterlitz-Thouless phase induced by dissipating quasisolitons*" (online)

Hadrien Kurkjian "*Collective modes as precursors of the phase transition in superfluid Fermi gases*"

Emilia WItkowska "*Criticality-enhanced quantum sensing with spin-1 condensates*"

Abstracts

Talks (chronological order)

1st session, Thursday 12:00-13:30

Kazimierz Rzążewski, Centrum Fizyki Teoretycznej PAN, Warszawa

"*Fluctuations of Bose-Einstein condensate"*

1st session, Thursday 12:00

Particle fluctuations of a number of condensed atoms is one of fundamental problems of quantum gases physics. In the last two years it is not only a theoretical, but also the experimental problem. I will review nearly a quarter century of our own efforts. I will explain our new method of the Fock states sampling.

Alice Sinatra, Laboratoire Kastler Brossel, UPMC, Paris

"Nuclear spin-squeezing by continuous measurement"

1st session, Thursday 12:30

The nuclear spin of helium-3 is very well isolated from the environment and has coherence times measured to be hundreds of hours. We propose a method to manipulate at the quantum level the collective nuclear spin of a helium gas in a cell at room temperature, by means of a continuous quantum non demolition measurement. A discharge is temporarily switched-on in the gas which populates the metastable state of helium. The nuclear collective spin then slightly hybridizes with the collective spin of metastable atoms thanks to metastability exchange collisions. The metastable atoms interact with light in an optical cavity, and the field leaking out from the cavity is continuously measured. Nuclear spin squeezing provides a metrological gain for nuclear-spin based sensors such as miniaturized magnetometers and gyrometers whose sensitivity will ultimately reach the limits imposed by quantum mechanics. It also opens up fascinating perspectives on the possibility of creating and maintaining a macroscopic quantum state over very long periods of time.

[1] A. Serafin, Y. Castin, M. Fadel, P. Treutlein, A. Sinatra, "Etude théorique de la compression de spin nucléaire par mesure quantique non destructive en continu" / "Nuclear spin squeezing by continuous quantum non-demolition measurement: a theoretical study", Comptes Redus Physique Tome 22, pp. 1-35 (2021) (Open access https://comptes-rendus.academie-sciences.fr/physique/articles/10.5802/crphys.71/)

[2] A. Serafin, M. Fadel, P. Treutlein, A. Sinatra, “Nuclear spin squeezing in Helium-3 by continuous quantum non-demolition measurement", to appear in} Phys. Rev. Lett. , Available on the archive HAL https://hal.archives-ouvertes.fr/hal-03058456

Krzysztof Sacha, Uniwersytet Jagielloński, Kraków

“*Time Crystal Phenomena*”

1st session, Thursday 13:00

Time crystals are quantum many-body systems which due to interactions between particles can spontaneously self-organize in time and start moving periodically. It will be shown that such a phenomenon can be observed in closed periodically driven systems. It will be also presented that condensed matter phenomena, like Anderson or many-body localization, topological phases or Mott-insulating phase, can be realized in crystalline structures in time.

2nd Session, Thursday 15:00-16:30

Dmitry Petrov, LPTMS, Universite Paris-sud XI, Paris

"*Higher-order effective interactions for bosons near a two-body zero crossing"*

2nd Session, Thursday 15:00

We develop the perturbation theory for bosons interacting via a weak two-body potential V, attractive and repulsive parts of which cancel each other. We find that the leading nonpairwise contribution to the energy emerges in the third order in V and represents an effective three-body interaction, the sign of which in most cases (although not in general) is anticorrelated with the sign of the long-range tail of V . We calculate the leading two-body and three-body interaction corrections for tilted dipoles in quasi-low-dimensional geometries.

Piotr Deuar, Instytut Fizyki PAN, Warszawa

"*Scalable full quantum dynamics of dissipative Bose-Hubbard systems and multi-time correlations"*

2nd Session, Thursday 15:30

Methods for numerically simulating large driven-dissipative quantum systems are of increasing importance due to ongoing experimental progress in a number of platforms such as polariton condensates, nanopillars, photonic lattices, or transmon qubits. We demonstrate the positive-P method known otherwise from quantum optics to be ideal for this purpose across a wide range of parameters, focusing on the archetypal driven-dissipative Bose-Hubbard model. For example, full quantum dynamics of a nonuniform 256x256 lattice of sites is demonstrated. Accessible parameters include those where interactions and dissipation are significant, occupations low and common semiclassical approximations can break down. Antibunching or strong two-particle interference such as in the anomalous photon blockade can be simulated. The presence of dissipation alleviates instabilities in the positive-P method that were known to occur for closed systems, allowing the simulation of full quantum dynamics up to and including the steady state. In the accessible regime, numerical effort scales linearly with the number of sites, quadratically with the precision, and doesn't care about symmetry or its lack. We also find that the regions of applicability of the positive-P, and truncated Wigner approaches are mutually complementary. Together these approaches cover the majority of parameter space in the dissipative Bose-Hubbard model. The positive-P approach also provides a simple and physically intuitive way to calculate many unequal time correlations, allowing their investigation in a non-perturbative and scalable way.

Felix Werner, École Normale Supérieure, Paris

"High-order diagrammatic expansion around BCS: Polarized superfluid phase of the attractive Hubbard model"

2nd Session, Thursday 16:00

In contrast to conventional QMC methods, expansions of intensive quantities in series of connected Feynman diagrams can be formulated directly in the thermodynamic limit. Over the last decade, diagrammatic Monte Carlo algorithms made it possible to reach large expansion orders and to obtain state-of-the-art results of various key models of interacting fermions, mostly in the normal phase. We obtained first results inside a superfluid/superducting phase, namely the s-wave superfluid phase of attractive Hubbard model in 3D [1]. Spontaneous symmetry breaking is realized by expanding around a BCS Hamiltonian. All diagrams up to order ~12 are summed thanks to the connected determinant algorithm [2] with anomalous propagators. Working on the BCS side of the strongly correlated regime, we observe convergence of the expansion, and benchmark the results against determinant diagrammatic Monte Carlo [3]. In presence of a polarizing Zeeman field (where unbiased benchmarks are unavailable due to the sign problem) we observe a first-order superfluid-to-normal phase transition, and a thermally activated polarization of the superconducting phase. We also discuss the large-order behavior of the expansion and its relation to Goldstone and instanton singularities.

[1] G. Spada, R. Rossi, F. Simkovic, R. Garioud, M. Ferrero, K. Van Houcke, F. Werner, arXiv:2103.12038

[2] R. Rossi, PRL 119, 045701 (2017)

[3] E. Burovski, N. Prokof'ev, B. Svistunov, M. Troyer, PRL 96, 160402 (2006)

3rd Session, Thursday 17:00-18:30

Yvan Castin, École Normale Supérieure, Paris

"*Une quasi-particule massive dans un gaz de phonons / A massive quasiparticle in a phonon gas”*

Nous considérons en dimension 3 un superfluide homogène de très basse température présentant deux types d'excitations, (i) des phonons acoustiques sans bande interdite de relation de dispersion linéaire à faible nombre d'onde, et (ii) des quasi-particules gamma à bande interdite de relation de dispersion quadratique (massive) au voisinage de ses extréma. Des travaux récents [Nicolis et Penco (2018), Castin, Sinatra et Kurkjian (2017, 2019)], prolongeant l'étude historique de Landau et Khalatnikov sur l'interaction phonon-roton dans l'hélium 4 liquide, ont déterminé explicitement l'amplitude de diffusion d'un phonon thermique sur une quasi-particule au repos à l'ordre dominant en température. Nous généralisons ce calcul au cas d'une quasi-particule de vitesse de groupe subsonique arbitraire, avec une construction rigoureuse de la matrice S entre états asymptotiques exacts, tenant compte de l'interaction incessante phonon-phonon et phonon-gamma, qui habille le phonon et la quasi-particule incidents ou émergents de phonons virtuels ; ceci apporte un éclairage physique nouveau sur les diagrammes de Feynman de la diffusion phonon-gamma. Dans tout le domaine de l'espace des paramètres (nombre d'onde, force des interactions, etc) où la quasi-particule gamma est énergétiquement stable vis-à-vis de l'émission de phonons de vecteurs d'onde arbitraires, nous pouvons dès lors caractériser le mouvement erratique qu'elle effectue dans le superfluide à la suite de ses collisions incessantes avec les phonons thermiques, au travers de la force moyenne subie et des coefficients de diffusion en impulsion longitudinal et transverse intervenant dans une équation de Fokker-Planck puis, aux temps longs où la quasi-particule s'est thermalisée, du coefficient de diffusion spatiale.

English version: We consider in dimension 3 a very low temperature homogeneous superfluid exhibiting two types of excitations, (i) gapless acoustic phonons of linear dispersion relation at low wavenumber, and (ii) gapped gamma quasiparticles of quadratic (massive) dispersion relation in the vicinity of its extrema. Recent work [Nicolis and Penco (2018), Castin, Sinatra, and Kurkjian (2017, 2019)], extending the historical study of Landau and Khalatnikov on the phonon-roton interaction in liquid helium-4, has explicitly determined the scattering amplitude of a thermal phonon on a quasiparticle at rest at the temperature leading order. We generalize this calculation to the case of a quasiparticle of arbitrary subsonic group velocity, with a rigorous construction of the S-matrix between exact asymptotic states, taking into account the incessant phonon-phonon and phonon-gamma interaction, which dresses up the incident or emerging phonon and quasiparticle with virtual phonons; this sheds new physical light on the Feynman diagrams of phonon-gamma scattering. In the whole parameter space (wave number, interaction strength, etc.) where the gamma quasiparticle is energetically stable with respect to the emission of phonons of arbitrary wave vectors, we can then characterize the erratic motion it performs in the superfluid as a result of its incessant collisions with the thermal phonons, through the average force and the longitudinal and transverse diffusion coefficients involved in a Fokker-Planck equation, and then, at long times when the quasiparticle has thermalized, through the spatial diffusion coefficient.

Tomasz Karpiuk, Uniwersytet w Białymstoku

"*Disruption of a Bose-Fermi droplet by an artificial black hole"*

3rd Session, Thursday 17:30

We study the evolution of a binary system consisting of an artificial black hole and a white dwarf. We implement the quantum hydrodynamic equations and carry out numerical simulations. As a model of a white dwarf star we consider a zero temperature droplet of attractively interacting degenerate atomic bosons and spin-polarized atomic fermions. Such mixtures are investigated experimentally nowadays.

Giuliano Orso, Paris Diderot University

"Effects of disorder in interacting quantum systems: from two-body Anderson transitions to disorder quenches"

3rd Session, Thursday 18:00

In this talk I review our recent numerical work on the field of disordered systems in the presence of interactions. I first discuss the problem of the mobility edge for a system of two interacting particles, tracing out the complete phase diagram in the space of energy, interaction and disorder. Next, we use the Gross-Pitaevskii equation to simulate a recent experiment, studying the relaxation dynamics of a three-dimensional Bose-Einstein condensate after switching on or off a disorder potential generated by a laser speckle.

2nd July 2021

4th session, Friday 9:30 - 11:00

Dominique Delande, Laboratoire Kastler-Brossel, CNRS, Sorbonne Université, Ecole Normale Supérieure, Collège de France, Paris

"*The Quantum Boomerang Effect*"

4th session, Friday 9:00

When a wavepacket is launched with a finite velocity in free space, it follows a ballistic motion, both in classical and quantum mechanics. In the presence of a disordered potential, the generic classical behavior, described by the Boltzman equation, is a random walk whose characteristic length is the mean free path. The center of mass of the classical "wavepacket" first drifts ballistically in the direction of the initial velocity, slows down and ends up at long time displaced by one mean free path. The quantum dynamics is drastically different: the center of mass first drifts ballistically, but rapidly performs a U-turn and slowly returns to its initial position. I will describe this "Quantum Boomerang" effect both numerically and analytically in dimension 1, discuss the importance of symmetry properties and show that it is partially destroyed by weak particle interactions.

Jakub Zakrzewski, Uniwersytet Jagielloński, Kraków

"*Many body localization without disorder*"

4th session, Friday 10:15

I will discuss recent experimental and theoretical studies of non-ergodic dynamics and localization in tilted one-dimensional systems such as e.g. fermions in tilted optical lattices.

5th session, Friday 11:30 - 13:00

Bruno Laburthe-Tolra, Universite Paris 13, Villetaneuse, Paris

"*Measuring the growth of correlations in an array of dipolar particles"*

5th session, Friday 11:30

We investigated the spin dynamics and quantum thermalization of a macroscopic ensemble of S = 3 spins initially prepared in a pure coherent spin state. The experiment uses a unit-filled array of 10 thousand chromium atoms in a three dimensional optical lattice. Atoms interact at long distance under the effect of magnetic dipole-dipole interactions, realizing the spin-3 XXZ Heisenberg model with long-range couplings. We investigated the build-up of quantum correlations in this many-body system. For this, we measured collective properties such as the total population in the seven different Zeeman states or the collective spin length. We also found that the measurement of magnetization fluctuations and of the covariance between the measured populations in different Zeeman states provide direct quantitative estimates for two-body correlations.

Anna Minguzzi, LPMMC, Grenoble

"Josephson effect(s) for strongly correlated gases in one dimension"

5th session, Friday 12:00

We study Josephson oscillations of two strongly correlated one-dimensional bosonic clouds separated by a localized barrier. Using a quantum-Langevin approach and the exact Tonks-Girardeau solution in the impenetrable-boson limit, we determine the dynamical evolution of the particle-number imbalance, displaying an effective damping of the Josephson oscillations which depends on barrier height, interaction strength and temperature. We show that the damping originates from the quantum and thermal fluctuations intrinsically present in the strongly correlated gas. Thanks to the density-phase duality of the model, the same results apply to particle-current oscillations in a one-dimensional ring where a weak barrier couples different angular momentum states. In the latter case, depending on interaction strength and temperature, we identify various dynamical regimes where the current oscillates, is self-trapped or decays with time and involve phase slips of thermal or quantum nature.

Krzysztof Pawłowski, Centrum Fizyki Teoretycznej PAN

"LL-GPE and Quantum Droplets in 1D"

5th session, Friday 12:30

Describing the properties of a strongly interacting quantum many-body system poses a serious challenge. I will discuss an approximation, called here LLGPE, useful to study a 1D gas in the regime of any interaction strength. The LLGPE is a generalization of the Gross-Pitaevskii equation that may be deduced from a hydrodynamical description. I show that the linearization of LLGPE leads to dispersion relations of the elementary excitations that stay in good agreement with the exact results of the Lieb-Liniger model, for any strength of the contact interactions. I will briefly discuss the solitonic solutions of LLGPE and their correspondence to the so-called type II excitations. In the second part of my talk, I will move to LLGPE with the dipolar interactions included. In this case, one finds solutions resembling the quantum droplets, even though the celebrated Lee-Huang-Yang term is not applicable in the discussed cases. I will discuss the origin and properties of the quantum droplets and preliminary results concerning their dynamics and excitations.

6th Session, Friday 15:00 - 17:00

Mariusz Gajda, Instytut Fizyki PAN, Warszawa

“Coherent collisions of two Bose-Bose droplets”

6th Session, Friday 15:00

I will discuss coherent dynamics of two interacting Bose-Bose droplets. Their relative motion can be understood in terms of the evolution of zero-energy modes recovering symmetries spontaneously broken by the mean field solution. A phase-dependent interaction potential and Josephson-junction-like equations are introduced to explain the observed behaviour. I will show that the evolution of the droplets is a macroscopic manifestation of the hidden dynamics of their phases.

Mirosław Brewczyk, Uniwersytet w Białymstoku

"Berezinskii-Kosterlitz-Thouless phase induced by dissipating quasisolitons”

6th Session, Friday 15:30

We theoretically study the sound propagation in a two-dimensional weakly interacting uniform Bose gas. Using the classical fields approximation we analyze in detail the properties of density waves generated both in a weak and strong perturbation regimes. While in the former case density excitations can be described in terms of hydrodynamic or collisionless sound, the strong disturbance of the system results in a qualitatively different response. We identify observed structures as quasisolitons and uncover their internal complexity for strong perturbation case. For this regime quasisolitons break into vortex pairs as time progresses, eventually reaching an equilibrium state. We find this state, characterized by only fluctuating in time averaged number of pairs of opposite charge vortices and by appearance of a quasi-long-range order, as the Berezinskii–Kosterlitz–Thouless (BKT) phase.

Hadrien Kurkjian, CNRS, Laboratoire de Physique Théorique, Touluse

"*Collective modes as precursors of the phase transition in superfluid Fermi gases"*

6th Session, Friday 16:00

I will discuss the collective excitation spectrum of a superfluid Fermi gases at and around the critical temperature. In this regime, the response of the system to a driving pairing field is dominated by a collective mode with a quadratic dispersion. Still visible above Tc, this mode acts as a precursor of the phase transition. It evolves from a relaxation mode (of pure imaginary frequency) to a propagating mode as a function of the interaction strength, and it can be observed by coupling the gas to a reservoir of Cooper pairs.

Emilia WItkowska, Instytut Fizyki PAN, Warszawa

"Criticality-enhanced quantum sensing with spin-1 condensates"

6th Session, Friday 16:30

We theoretically investigate estimation of the control parameter in a spin-1 Bose-Einstein condensate near quantum phase transitions in a transverse magnetic field with a fixed macroscopic magnetization [1, 2]. We quantify sensitivity by quantum and classical Fisher information. For these different metrics, we find the same, beyond-standard-quantum-limit (SQL) scaling with atom number near critical points, and SQL scaling away from critical points [1,2]. In the particular case of antiferromagnetic condensates, the system exhibits the first- and second-order phase transition depending on the value of magnetization. We exploit both types of system criticality as a resource in the precise estimation of control parameter value. We demonstrate supersensitivity and show that the precision scales with the number of atoms up to N^4 around critically [1].

In addition, we study the precision based on the error-propagation formula providing the simple-to-measure signal which coincides with its scaling with the quantum Fisher information. We find that both depletion of the mF=0 Zeeman sub-level and transverse magnetization provide signals of sufficient quality to saturate the sensitivity scaling. To explore the effect of experimental imperfections, we study the scaling around criticality at nonzero temperature and with nonzero detection noise. Our results suggest the feasibility of sub-SQL sensing in spin-1 condensates with current experimental capabilities.

[1] Safoura S. Mirkhalaf, Emilia Witkowska, and Luca Lepori, *Supersensitive quantum sensor based on criticality in an antiferromagnetic spinor condensate*, Phys. Rev. A 101, 043609 (2020)

[2] Safoura S. Mirkhalaf, Daniel Benedicto Orenes, Morgan W. Mitchell, and Emilia Witkowska, *Criticality-enhanced quantum sensing in ferromagnetic Bose-Einstein condensates: Role of readout measurement and detection noise*, Phys. Rev. A 103, 023317 (2021)

Posters

Poster session, Thursday, around 18:30

Youcef Baamara, Laboratoire Kastler Brossel

“Scaling laws for the sensitivity enhancement of non-Gaussian spin states”

We identify the large-N scaling of the quantum gain offered by over-squeezed spin states, that are accessible by one-axis-twisting, as a function of the preparation time. We further determine how the scaling is modified by relevant decoherence processes and predict a discontinuous change of the quantum gain at a critical preparation time that depends on the noise. Our analytical results for arbitrary N provide recipes for optimal and feasible implementations of quantum enhancements with non-Gaussian spin states in existing atomic experiments, well beyond the reach of spin squeezing.

Filip Gampel, Instytut Fizyki PAN

“Continuous observation of a few-body quantum system”

We study the influence of frequent observation on the temporal evolution of a single or several quantum particles. To this end we introduce a model of detectors on a grid measuring position and momentum. Using the Monte Carlo wavefuntion (MCWF) method allows us to develop a framework to predict single possible trajectories of the particle(s).

Tanausú Hernández, Instytut Fizyki PAN

“Spin squeezing for several spin-orbit coupled fermions in an optical lattice”

We investigate the dynamical formation of spin squeezing in the system composed of several ultra-cold fermions in a one-dimensional optical lattice from the initial spin coherent state. As the basic Fermi Hubbard model is unable to generate spin squeezing, we include the spin-orbit coupling to induce the production of spin-squeezed states. The corresponding Fermi-Hubbard Hamiltonian is analyzed in the transformed frame to obtain a relevant spin model which explains squeezing generation. An exact numerical analysis of the model for a small number of lattice sites was performed in different scenarios to probe the influence of spin-orbit coupling. Since we are working with a small number of particles, a special focus on boundary conditions was necessary to obtain accurate results. Finally, we show how the squeezing generation can be understood with the help of the OAT model under a certain regime of parameters.

Piotr Grochowski, Centrum Fizyki Teoretycznej PAN

"Many-body molecule formation at a domain wall in a one-dimensional strongly interacting ultracold Fermi gas"

We analyze how the presence of the bound state on top of strong inter component contact repulsion affects the dynamics of a two-component ultracold Fermi gas confined in a one-dimensional harmonic trap. By performing full many-body numerical calculations, we retrieve dynamics of an initially phase separated state that has been utilized to excite the spin-dipole mode in experimental settings. We observe an appearance of pairing correlations at the domain wall, heralding the onset of a molecular fraction at the interlayer between the components. We find that such a mechanism can be responsible for the stabilization of the phase separation.

Jakub Kopyciński, Centrum Fizyki Teoretycznej PAN

"Solitons and phonons in 1D. Beyond the limit of weak interactions"

The usefulness of the widely-known Gross-Pitaevskii equation (GPE) falls down as soon as gas enters the strongly repulsive interaction regime. In this regime, one can still invoke hydrodynamics combined with the exact solution of the Lieb-Liniger (LL) model. This approach results in the modification of the GPE, which we call LLGPE. We put our main focus on the LLGPE and study type-I and type-II excitations within this model. We use the linearization to obtain the dyspersion relation of type-I excitaions. The phononic spectra turn out to be consistent with the LL model for a wider range of interactions than GPE. We also find out the dark soliton energies have a qualitative agreement with type-II excitation energies. We point out there is no many-body approach we can compare to as they are either highly model-dependent or unsuitable in the strongly interacting case. We argue the LLGPE has a broader range of applicability than the GPE with a constraint of slowly varying density.

Maciej Kruk, Instytut Fizyki PAN

"Fock State Sampling Method for BEC Fluctuations"

I will present the details of our new method for sampling statistical ensembles of Bose gases, and our results for 1D harmonic and ring traps.

Maciej Łebek, Centrum Fizyki Teoretycznej PAN

“Repulsive dynamics of strongly attractive one-dimensional quantum gases”

We analyze the dynamics of one-dimensional quantum gases with strongly attractive contact interactions. We specify a class of initial states where attractive forces effectively act as strongly repulsive ones during the time evolution. Our findings extend the theoretical results connected with super-Tonks-Girardeau gas to highly non-equilibrium dynamics. The mechanism is illustrated on the prototypical problem of the domain stability in two-component Fermi gas. We discuss non-local interactions and analyze the universality of the presented results.