Universal aspects of quantum turbulence

16-20 Oct. 2017, Nice (France)

https://qt-nice-17.sciencesconf.org

Quantum turbulence is a non-equilibrium phenomenon observed in superfluid systems such as Helium II, Bose–Einstein condensates of alkali atoms and more exotic bosonic systems like exciton-polaritons and magnons. It involves processes with large spatial and temporal scale separations that combined with superfluidity gives rise to many interesting and novel physical problems, whose understanding is far from complete.

This workshop aims at gathering experimentalists working in different quantum fluid systems together with theoreticians expert in statistical mechanics, out-of-equilibrium systems, turbulence, and fluid mechanics. Cross-fertilisation between theoretical and experimental approaches on different quantum fluid systems will also be promoted, and novel experimental setups will be discussed. It is expected that this program will help to enlighten which aspects of quantum turbulence are universal.

Program

	Mon. 16	Tue. 17	Wed. 18	Thu. 19	Fri. 20
09:00					
09:30		Nicolas Pavloff	Antonio Picozzi		Nicolas Cherroret
10:00		Nicolas Pavloff	Antonio Picozzi	Pierre-Élie Larré	Jason Laurie
10:30		Coffee break	Coffee break	Coffee break	Coffee break
11:00		Claire Michel	Quentin Glorieux	Luca Galantucci	
11:30		Nick Parker	Robin Kaiser	Gabriele Ferrari	Stéphane Barland
12:00		Lunch	Lunch	Lunch	Lunch
13:00		Lunch	Lunch	Lunch	Lunch
13:30		Discussions	Discussions	Discussions	Discussions
14:00	Opening	Discussions	Discussions	Discussions	Discussions
14:30	Guido Boffetta	Alberto Amo	Marc Brachet	Kali Wilson	Vishwanath Shukla
15:00	Guido Boffetta	Alberto Amo	Marc Brachet	Francesco Marino	Patricio Clark Di Leoni
15:30	Discussions - Coffee break	Discussions - Coffee break	Discussions - Coffee break	Discussions - Coffee break	Closing
16:00	Discussions - Coffee break	Discussions - Coffee break	Discussions - Coffee break	Discussions - Coffee break	Closing
16:30	Martin Weitz	Simon Pigeon	Carlo Barenghi	Davide Proment	Closing
17:00	Hayder Salman	Guillaume Huyet	Alberto Villois	Laurent Chevillard	
18:00	Welcome drink				
19:00					
20:00			Dinner		
21:00			Dinner		
22:00					

Monday, October 16, 2017

TIME	EVENT	(+)
14:00 - 14:30	Opening	
14:30 - 15:30	Guido Boffetta - A brief review on two-dimensional turbulence	
15:30 - 16:30	Discussions - Coffee break	
16:30 - 17:00	Martin Weitz - Calorimetry and First-Order Coherence Measurements of a Bose-Einstein condensed photon gas	
17:00 - 17:30	Hayder Salman - Long-range Ordering of Vortex Excitations in a Two-Dimensional Superfluid Far From Equilibrium	
18:00 - 19:00	Welcome drink	

Tuesday, October 17, 2017

TIME	EVENT	(+)
09:30 - 10:30	Nicolas Pavloff - Non-linear structures in transcritical superfluid flows	
10:30 - 11:00	Coffee break	
11:00 - 11:30	Claire Michel - Experimental evidences of light superfluidity in a bulk nonlinear crystal	
11:30 - 12:00	Nick Parker - Vortices and turbulence in quantum ferrofluids	
12:00 - 13:30	Lunch	
13:30 - 14:30	Discussions	
14:30 - 15:30	Alberto Amo - Condensation, superfluidity and turbulence in polariton fluids	
15:30 - 16:30	Discussions - Coffee break	
16:30 - 17:00	Simon Pigeon - Vortex and domain propagation in resonantly supported superfluid of light	
17:00 - 17:30	Guillaume Huyet - TBA	

Wednesday, October 18, 2017

TIME	EVENT	(+)
09:30 - 10:30	Antonio Picozzi - Introduction to optical wave turbulence	
10:30 - 11:00	Coffee break	
11:00 - 11:30	Quentin Glorieux - TBA	
11:30 - 12:00	Robin Kaiser - Non-equilibrium precondensation of classical waves in two dimensions propagating through atomic vapors	
12:00 - 13:30	Lunch	
13:30 - 14:30	Discussions	
14:30 - 15:30	Marc Brachet - Quantum Turbulence and the Gross-Pitaevskii Equation	
15:30 - 16:30	Discussions - Coffee break	
16:30 - 17:00	Carlo Barenghi - Vinen turbulence in a trapped Bose-Einstein condensate	
17:00 - 17:30	Alberto Villois - Dynamics of Electron Bubbles in Superfluid Helium-4	
20:00 - 22:00	Dinner	

Thursday, October 19, 2017

TIME	EVENT	(+)
10:00 - 10:30	Pierre-Élie Larré - Many-body quantum phenomena in fluids of nonlinear light	
10:30 - 11:00	Coffee break	
11:00 - 11:30	Luca Galantucci - Quantum Vortex Reconnections and Rebounds in Trapped Bose Einstein Condensates	
11:30 - 12:00	Gabriele Ferrari - Vortex reconnections and rebounds in trapped atomic Bose–Einstein condensates	
12:00 - 13:30	Lunch	
13:30 - 14:30	Discussions	
14:30 - 15:00	Kali Wilson - Photon fluids in propagating geometries	
15:00 - 15:30	Francesco Marino - Evidence of a directed percolation phase-transition in a long-delayed optical system	
15:30 - 16:30	Discussions - Coffee break	
16:30 - 17:00	Davide Proment - Universal and nonuniversal aspects of vortex reconnections in superfluids	
17:00 - 17:30	Laurent Chevillard - Including the roton minimum in the dispersion of excitations: implications on the vortex reconnection phenomenon	

Friday, October 20, 2017

TIME	EVENT	(+)
09:30 - 10:00	Nicolas Cherroret - Novel perspectives from Anderson localization of matter waves	
10:00 - 10:30	Jason Laurie - Kelvin-wave turbulence theory for small-scale energy transfer in quantum turbulence	
10:30 - 11:00	Coffee break	
11:30 - 12:00	Stéphane Barland - Bistable and Addressable Localized Vortices in Semiconductor Lasers	
12:00 - 13:30	Lunch	
13:30 - 14:30	Discussions	
14:30 - 15:00	Vishwanath Shukla - Sticking Transition in a Minimal Model for the Collisions of Active Particles in Quantum Fluids	
15:00 - 15:30	Patricio Clark Di Leoni - Finite temperature effects in helical quantum turbulence	
15:30 - 17:00	Closing	

Condensation, superfluidity and turbulence in polariton fluids

Alberto Amo * [1]

[1] Laboratoire de Physique des Lasers, Atomes et Molecules (Phlam) – CNRS, Université de Lille – France

Polaritons in semiconductor microcavities provide an extraordinary platform to study the nonlinear properties of quantum fluids. The coupling of polaritons to light allows injecting the fluid with controlled density and velocity and, through the escape of photons out of the cavity, it ensures direct access to the properties of the polariton gas (phase, coherence, etc.). In this presentation we will review the fluid phenomena observations of the last decade, including condensation, superfluidity, vorticity and the emergence of turbulence [1]. We will pay particular attention to the out-of-equilibrium features arising from the short polariton lifetimes. [1] I. Carusotto and C. Ciuti, *Quantum fluids of light*, Rev. Mod. Phys. **85**, 299 (2013).

*Speaker

Vinen turbulence in a trapped Bose-Einstein condensate

Carlo Barenghi * [1]

[1] School of Mathematics, Statistics and Physics (NCL) – Newcastle upon Tyne NE1 7RU, United Kingdom

Experiments in superfluid helium have revealed the existence of two regimes of quantum turbulence: a "quasi-classical turbulence" regime (which shares important properties with ordinary turbulence, notably the Kolmogorov energy spectrum),
and a "Vinen turbulence" regime (more similar to a random flow). In this talk I shall report the numerical observation of Vinen turbulence in a typical harmonically-trapped condensate, and discuss the evidence of Vinen turbulence in other flows which appear to lack an energy cascade.

*Speaker

Bistable and Addressable Localized Vortices in Semiconductor Lasers

Stéphane Barland * [1]

[1] Institut de Physique de Nice, Université Côte d'Azur and CNRS – CNRS : UMR7010 – France

In presence of suitable nonlinearity and spatial coupling, optical devices can sustain solitary waves. When dissipation is taken into account, solitary waves are attractors of the dynamics and can therefore be nucleated by external perturbations which bring the system into the basin of attraction of the localized solution. In this contribution we will discuss the necessary conditions for the emergence of such optical localized states and their ability to carry phase defects. We illustrate this by showing the existence of mutually incoherent localized vortex beams in an experimental system based on coupled semiconductor lasers.

*Speaker

A brief review on two-dimensional turbulence

Guido Boffetta * [1]

[1] University of Torino – Italy

In this talk I will review the main properties of two-dimensional turbulence. In particular the phenomenology of the double cascade, the statistics of the inverse energy cascade and the formation of the large scale condensate will be discussed on the basis of numerical simulations. The presence of a two-dimensional phenomenology in three-dimensional flows will also be discussed.

*Speaker

Quantum Turbulence and the Gross-Pitaevskii Equation

Marc Brachet * [1]

[1] Laboratoire de Physique Statistique de lÉNS (LPS) – École normale supérieure - Paris, Université Pierre et Marie Curie - Paris 6, Université Paris Diderot - Paris 7, Centre National de la Recherche Scientifique : UMR8550 – France

The talk will start by a brief introduction to physical systems displaying regimes of quantum turbulence. The status of several standard models of superfluidity will then be discussed. The rest of the talk will concentrate on models based on the Gross-Pitaevskii equation (GPE).

In classical turbulence helicity is known to deplete nonlinearity and can alter the evolution of turbulent flows. In quantum turbulence its role is not fully understood. The free decay of an helical quantum turbulent flow, studied by direct numerical simulations of the Gross-Pitaevskii equation at high spatial resolution, will be presented.

The evolution has remarkable similarities with classical flows, which go as far as displaying a dual transfer of incompressible kinetic energy and helicity to small scales. Spatiotemporal analysis indicates that both quantities are dissipated at small scales through nonlinear excitation of Kelvin waves and the subsequent emission of phonons. At the onset of the decay, the resulting turbulent flow displays polarized large scale structures and unpolarized patches of quiescence reminiscent of those observed in simulations of classical turbulence at very large Reynolds numbers.

*Speaker

Anderson localization of matter waves: mesoscopic and quantum boomerang effects

Nicolas Cherroret * [1]

[1] Laboratoire Kastler Brossel (LKB (Jussieu)) – École normale supérieure - Paris, Université Pierre et Marie Curie - Paris 6, Centre National de la Recherche Scientifique : UMR8552 – Case 74 - Tour 12, 4 place Jussieu, F-75252 Paris CEDEX 05, France

In the last decades, the field of atom optics has allowed for accurate experimental investigations of quantum transport with cold atoms. In this context, the physics of Anderson localization (AL) of interacting and non-interacting waves in disordered environments can today be finely studied, using tunable atomic matter waves in well controlled optical random potentials.

After briefly introducing the main concepts of atom optics in random optical potentials, I will address the problem of the out-of-equilibrium evolution of a non-interacting matter wave in a random potential. The discussion will be focused on two different dynamical scenarios where unexpected and somehow counter-intuitive manifestations of AL show up. The first scenario will be concerned with the spatial spreading of a narrow wave packet of zero mean velocity. AL then manifests itself as a "mesoscopic echo" effect in the density distribution, a phenomenon which has been first observed experimentally with cold atoms only recently. In the second scenario, I will consider the evolution of a wave packet to which a finite mean velocity has been impulsed. In this case, AL leads to a surprising "quantum boomerang" effect of the center of mass, signaling a retro-reflection of the wave packet in the random potential.

*Speaker

Including the roton minimum in the dispersion of excitations: implications on the vortex reconnection phenomenon.

Laurent Chevillard * [1]

[1] Laboratoire de Physique de lÉNS Lyon (Phys-ENS) – École Normale Supérieure - Lyon, Centre National de la Recherche Scientifique : UMR5672 – 46 allée dÍtalie 69007 Lyon, France

In order to participate in the elaboration of a phenomenology of quantum turbulence at scales smaller than typically the inter-vortex mean distance, we study theoretically and numerically the predictions of the Gross-Pitaeviskii when the roton minimum in included. This can be done while considering a non-local two-body interaction in this Hamiltonian picture. We calibrate the model with accepted measurements of the dispersion excitation spectrum of superfluid Helium, and study the implications on the vortex reconnection phenomenon as it is observed in numerical simulations. We furthermore determine, using methods developed in the context of classical turbulence, whether "small scales" are created after reconnection. This work is done in collaboration with Jason Reneuve and Julien Salort.

*Speaker

Finite temperature effects in helical quantum turbulence

Patricio Clark Di Leoni * [1]

[1] Istituto Nazionale di Fisica Nucleare, Sezione di Roma Tor Vergata (INFN, Sezione di Roma Tor Vergata) – Via della Ricerca Scientifica, 1 00133 – Roma, Italy

We perform a study on the evolution of helical quantum turbulence at different temperatures. We show how for temperatures close to the critical the fluid can act as a very viscous classical flow with the decay of the incompressible kinetic energy and the helicity becoming exponential. The transition from this behaviour to the one observed at zero temperature is smooth as a function of temperture. The presence of thermal effects can inhibit the development of a proper turbulent cascade. We provide a anzats for the viscosity that scales linearly with temperature.

*Speaker

Vortex reconnections and rebounds in trapped atomic Bose–Einstein condensates

Gabriele Ferrari * [1,2]

[1] Istituto Nazionale di Ottica - Consiglio Nazionale delle Ricerche (INO-CNR) – via Sommarive 14, 38123 Povo-Trento, Italy
[2] Dipartimento di Fisica, Università di Trento (Uni Trento) – via Sommarive 14, 38123 Povo, Italy, Italy

Quantized vortex interaction mechanisms in atomic condensates have been widely studied in rotating systems, with the self organization of alike vortices into a regular Abrikosov lattice, and also in flat quasi-2D systems, where vortex and antivortices coexist and affect their mutual dynamics. In both these kinds of systems vortices align (or anti align) along a single preferential direction. This is given by the rotation axis in the first case or by the confined direction in the second one. The interaction mechanism among vortices is hence mainly restricted to a 2D problem. We study the interaction mechanisms between vortices in an axially symmetric, elongated BEC. In such a geometry vortices tend to align in a radial plane and can therefore assume any orientation in such plane. Due to the asymmetric confinement the associated phase pattern varies substantially in a region not larger than the transverse Thomas Fermi radius, therefore initially far away vortices orbit around the center of the BEC unaffected by the presence of the other until they approach and start interacting, changing their relative velocity and their relative orientation. Depending on the approaching configuration the two vortices might bounce or reconnect. We combine experimental observations of real-time vortex dynamics and Gross-Pitaevskii simulations and provide a clear picture of 3D interaction mechanism between vortex filaments [1].

Serafini et al., PRX 7, 021031 (2017)

*Speaker

Quantum Vortex Reconnections and Rebounds in Trapped Bose Einstein Condensates

Luca Galantucci * [1], Simone Serafini [2], Elena Iseni [2], Tom Bienaimé [2], Russell Bisset [2], Franco Dalfovo [2], Giacomo Lamporesi [2], Gabriele Ferrari [2], Carlo F. Barenghi [1]

[1] Newcastle University – United Kingdom
[2] INO-CNR BEC Center – Italy

Interactions and reconnections of coherent filamentary structures play a fundamental role in several distinct physical systems: plasmas, nematic liquid crystals, polymer and macromolecules physics (including DNA), optical beams, classical and quantum fluids. In particular, in fluids (both classical and quantum) vortex reconnections enhance fine-scale mixing, redistribute energy amongst lengthcales triggering a Kolmogorov turbulent energy cascade and are responsible for helicity transfers from large (links and knots) to small (coils and twists) scales.

More in detail, in quantum fluids the interacting filaments are isolated effectively one-dimensional vortex lines to which the singular vorticity field is confined. This discrete nature of quantum vortices makes quantum fluids an ideal setting for studying reconnections being the latter isolated dramatic events, strongly localised in space and time and, hence, conceptually and practically easier to study.

Previous studies of vortex reconnections in quantum fluids have been performed in homogeneous systems, focusing on geometric features of reconnecting events and kinetic energy redistribution processes transforming incompressible kinetic energy in acoustic modes. Recently, employing a knot theory toolkit developed in topological fluid dynamics, several studies have analysed the impact of reconnections on the helicity of the flow, investigating whether the latter is conserved in these inviscid systems where reconnections are allowed as a result of quantum pressure effects. In this work, we numerically investigate two-vortex interactions in three-dimensional elongated trapped BECs in the zero temperature limit. Via numerical simulations employing the mean-field Gross-Pitaevskii model, we have discovered that new forms of vortex interactions are supported in this confined and inhomogeneous geometry. Besides conventional reconnections already predicted and observed in homogeneous quantum fluids, we have identified novel double reconnections, ejections and bounce regimes.

The key ingredients driving the observed two–vortex dynamics are the anti–parallel preferred (energy-conserving) alignment of the two vortices and the impact of density gradients driving the vortex motion. This last factor is peculiar to non-homogeneous trapped BECs, determining hence different reconnection dynamics with respect to homogeneous BECs.
These numerically predicted vortex interaction regimes are confirmed by our experimental observations. The latter have been performed elaborating an innovative real-time imaging technique capable of visualizing simultaneously the temporal evolution of the average position and orientation of the vortex lines. This technique has allowed to investigate quantum vortex reconnections

*Speaker

to unprecedented resolution, allowing an unambiguous identification of the novel reconnection regimes.

Non-equilibrium precondensation of classical waves in two dimensions propagating through atomic vapors

Robin Kaiser * [1]

[1] Institut Non Linéaire de Nice Sophia-Antipolis (INLN) – Université Nice Sophia Antipolis [UNS], CNRS : UMR7335, Université Nice Sophia Antipolis (UNS) – 1361 route des Lucioles Sophia Antipolis 06560 Valbonne, France

The nonlinear Schŕodinger equation, used to describe the dynamics of quantum fluids, is known to be valid not only for massive particles, but also for the propagation of light in a nonlinear medium, predicting condensation of classical waves. Here we report on the initial evolution of random waves with Gaussian statistics using atomic vapors as an efficient two dimensional nonlinear medium. Experimental and theoretical analysis of near field images reveal a phenomenon of nonequilibrium precondensation, characterized by a fast relaxation towards a precondensate fraction of up to 75%. Such precondensation is in contrast to complete thermalization to the Rayleigh-Jeans equilibrium distribution, requiring prohibitive long interaction lengths.

*Speaker

Many-body quantum phenomena in fluids of nonlinear light

Pierre-Élie Larré * [1]

[1] Laboratoire Kastler-Brossel (LKB) – Université Pierre-et-Marie-Curie – 4, place Jussieu - 75252 Paris Cedex 05, France

In the presence of a significant optical nonlinearity, a beam of light may behave as a quantum fluid of interacting photons: One speaks of "quantum fluid of light." The ease of access to observables in these photonic systems make them especially promising for quantum simulation. An optical platform that presently attracts a growing interest within the community of quantum fluids of light consists in a paraxial beam of quasimonochromatic light propagating in a nonlinear optical medium. To begin with, I will review a general many-body quantum theory of light propagation in such a configuration. As a first application of this formalism, we will then see that a frictionless flow of superfluid light may be revealed from the dramatic cancellation of the optomechanical deformation of an elastic solid immersed into a nonlinear liquid or vapor. In a third part, I will present an in-progress pump-and-probe experiment of integrated silicon photonics aiming to extract the Bogoliubov dispersion relation of a fluid of light from the measurement of the probe's dephasing in a nonlinear channel waveguide. Fourthly, I will show that the propagating geometry constitutes a simple platform to investigate the dynamics of many-body quantum systems projected out of equilibrium after an interaction quench, including phenomena like the light-cone effect and prethermalization. A recent extension accounting for the presence of some disorder potential generated through cross-phase modulation in a nonlinear optical fiber will be sketched out. Before concluding, a mechanism of thermalization and evaporative cooling allowing a Bose-Einstein condensation of a quantum fluid of light will be presented.

*Speaker

Kelvin-wave turbulence theory for small-scale energy transfer in quantum turbulence

Jason Laurie * [1]

[1] Aston University – Aston Triangle, Birmingham, B4 7ET, UK, United Kingdom

We present an overview of recent results regarding Kelvin-wave turbulence as a mechanism for
small-scale energy transport in superuid helium and Bose-Einstein condensates. We

outline the latest theoretical formalism using wave turbulence theory for predicting the power-law

behaviour of energy exchanges between a statistical ensemble of weakly interacting Kelvin-waves

on a single quantized vortex line. Furthermore, we will discuss the controversy around the locality

of interaction, and explain why nonlocal interactions lead to a four-wave turbulent description.

Finally, we present the most recent numerical simulations using the Biot-Savart and Gross-Pitaevskii
equations that both indicate nonlocality of the six-wave process.

*Speaker

Evidence of a directed percolation phase-transition in a long-delayed optical system

Francesco Marino * [1]

[1] CNR-Istituto Nazionale di Ottica (INO-CNR) – Italy

Directed percolation (DP) is one of the paradigmatic models of non-equilibrium phase transitions and has been applied to
a wide variety of physical systems.
The gravity-driven penetration of fluids through a porous medium, non-equilibrium models related to epidemic spread-
ing and the transition from laminar to turbulent flows are well-known examples of this universality class. Recent experiments in fluids have provided the first clear evidence of DP critical behavior, and sparkled renewed attention for this non-equilibrium phenomenon, so far only associated to spatio-temporal dynamics.

In this talk, I will show that a stochastic, long-delayed bistable laser– a system without explicit spatial degrees of freedom– undergoes a genuine active-to-absorbing critical phase transition, belonging to the (DP) universality class.
While the system is indeed purely temporal, "effective" spatial degrees of freedom emerge from the inherent,
multiple timescales induced by the long-delay dynamics. These results estabish a strong equivalence between long-delayed and spatially extended systems and opens a new avenue for studying critical phenomena in long-delayed setups.

*Speaker

Experimental evidences of light superfluidity in a bulk nonlinear crystal

Claire Michel * [1]

[1] Institut de Physique de Nice (INPHYNI) – CNRS : UMR7010, Université Nice Sophia Antipolis [UNS] – Parc Valrose 06108 NICE CEDEX 2, France

We report a direct experimental detection of the frictional-superfluid transition in the flow of a fluid of light past a weakly perturbing localized obstacle in a bulk nonlinear crystal. In our cavityless all-optical system, we extract on the one hand a direct optical analog of the drag force experienced by the obstacle and measure on the other hand the associated obstacle displacement. We observe a superfluid regime characterized by a suppression of long-range radiation from the obstacle, which is, as expected, associated to the cancellation of the drag force and the absence of displacement of the obstacle.

*Speaker

Vortices and turbulence in quantum ferrofluids

Nick Parker * [1]

[1] Newcastle University – United Kingdom

The experimental achievement of superfluid Bose gases composed of atoms with large magnetic dipole moments has realized the quantum ferrofluids, a form of fluid which combines the extraordinary properties of superfluidity and ferrofluidity. The presence of both short-range, isotropic atomic interactions and long-range anisotropic interactions enriches the properties of the fluid, while the coupling to magnetic fields opens new routes to control it. We will show how quantum vortices become modified in this system, including the occurrence of elliptical cores, density ripples and anisotropic vortex-vortex interactions. We will also discuss the behaviour of turbulence in quantum ferrofluids, showing how the dipolar interactions drive the polarization of the turbulence into columnar or stratified configurations depending on the sign of the dipolar interactions.

*Speaker

Non-linear structures in transcritical superfluid flows

Nicolas Pavloff * [1]

[1] Laboratoire de Physique Théorique et Modèles Statistiques (LPTMS) – CNRS : UMR8626, Université Paris XI - Paris Sud – Bâtiment 100 Université Paris-Sud Centre Scientifique d'Orsay 15 rue Georges Clémenceau 91405 Orsay cedex, France

I will review some of the non-linear structures generated by the uniform motion of a heavy obstacle in a superfluid: solitons, dispersive shock waves, oblique solitons, vortices...

*Speaker

Introduction to optical wave turbulence

Antonio Picozzi *† [1]

[1] Laboratoire Interdisciplinaire Carnot de Bourgogne (ICB) – UMR 6303 CNRS-Université de Bourgogne Franche-Comté, BP 47870, F-21078 Dijon Cedex – France

We will review different formalisms describing the dynamics of random nonlinear optical waves: The wave turbulence kinetic equation describing, e.g., thermalization and wave condensation; the Vlasov formalism describing large scale collective incoherent structures in analogy with long-range gravitational effects; the weak Langmuir turbulence formalism describing, e.g., spectral incoherent solitons, as well as shock and collapse spectral singularities. We will also discuss recent works related to the spontaneous emergence of strong phase-correlations leading to incoherent FPU recurrences that violate the H-theorem of entropy growth. We will present an unexpected phenomenon of thermalization that is not constrained by energy and momentum conservation and which is characterized by an equilibrium with zero inverse temperatures.

*Speaker

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Vortex and domain propagation in resonantly supported superfluid of light

Simon Pigeon * [1,2]

[1] Queen's University of Belfast (QUB) – University Road Belfast, BT7 1NN, Northern Ireland, United Kingdom

[2] Laboratoire Kastler Brossel (LKB (Jussieu)) – Université Pierre et Marie Curie (UPMC) - Paris VI, CNRS : UMR8552, École normale supérieure [ENS] - Paris – Case 74 - Tour 12, 4 place Jussieu, F-75252 Paris CEDEX 05, France

Light evolving within a non-linear medium has been shown to behave as a superfluid. In polariton semiconductor microcavity, the dissipation acting on the light-matter fluid can be optically compensate with quasi resonant laser field. However, this support impact significantly the properties of the fluid. I will present how this impact can be revealed through the study of vortex and domain dynamics.

*Speaker

Universal and nonuniversal aspects of vortex reconnections in superfluids

Davide Proment * [1], Alberto Villois [1], Giorgio Krstulovic [2]

[1] School of Mathematics, University of East Anglia, Norwich Research Park (UEA) – Norwich NR4 7TJ, United Kingdom

[2] Université de la Côte d'Azur, OCA, CNRS, Lagrange (OCA) – Observatoire de la Cote d'Azur – Boîte Postale 4229, 06304 Nice Cedex 4, France

Insight into vortex reconnections in superfluids is presented, making use of analytical results and numerical simulations of the Gross-Pitaevskii model. Universal aspects of the reconnection process are investigated by considering different initial vortex configurations and making use of a recently developed tracking algorithm to reconstruct the vortex filaments. We show that during a reconnection event the vortex lines approach and separate always according to the time scaling $\delta \sim$ tˆ(1/2) with prefactors that depend on the vortex configuration. We also investigate the behavior of curvature and torsion close to the reconnection point, demonstrating analytically that the curvature can exhibit a self-similar behavior that might be broken by the development of shocklike structures in the torsion.

*Speaker

Anatomy of Vortex annihilation and vortex reconnection

Sergio Rica * [1]

[1] Universidad Adolfo Ibanez (UAI) – Avd Diagonal Las Torres 2640, Chile

In this talk I will discuss, by an asymptotic technique the spatiotemporal dynamics of the process of vortex annihilation in the frame of the Nonlinear Schrodinger Equation. This work is in collaboration with Itamar Procaccia and Yves Pomeau.

*Speaker

Long-range Ordering of Vortex Excitations in a Two-Dimensional Superfluid Far From Equilibrium

Hayder Salman * [1], Davide Maestrini

[1] University of East Anglia – United Kingdom

We study the relaxation of a 2D ultracold Bose-gas from a nonequilibrium initial state consisting of vortices and antivortices in experimentally realizable square and rectangular traps that have been realized experimentally. We focus on how quantized vortices can form clusters of like signed vortices. Such clustering can be understood in terms of negative temperature states of a vortex gas. Using a mean field approximation for the vortex gas, we show that, within the negative temperature regime, an order parameter emerges that is related to the formation of long range correlations between vortices. It turns out that the order parameter corresponds to the streamfunction of the 2D flow field that is governed by a Boltzmann-Poisson equation. It is, therefore, associated with the emergence of a mean rotational hydrodynamic flow with a non-zero coarse-grained vorticity field. Solutions of the Boltzmann-Poisson equation in a square domain reveal that maximum entropy states of the vortex gas correspond to a large-scale monopole flow field. A striking feature of this mean flow is the spontaneous acquisition of angular momentum by a superfluid flow with a neutral vortex charge. These mean-field predictions are verified through direct simulations of a point vortex gas and 2D simulations of the Gross-Pitaevskii equation. An approach is also developed that permits detailed quantitative comparisons between the entropy and energy associated with the emergent mean flow fields and the predictions of the Boltzmann-Poisson equation.

*Speaker

Sticking Transition in a Minimal Model for the Collisions of Active Particles in Quantum Fluids

Vishwanath Shukla *† [1], Marc Brachet [2], Rahul Pandit [3]

[1] Service de Physique de l'Etat Condensé, CEA Saclay (SPEC, CEA-Saclay) – CEA-DRF-IRAMIS – Bat. 772, Orme des Merisiers, CEA Saclay, F-91191, GIf sur Yvette, France
[2] Laboratoire de Physique Statistique de lÉNS (LPS) – École normale supérieure - Paris, Université Pierre et Marie Curie - Paris 6, Université Paris Diderot - Paris 7, Centre National de la Recherche Scientifique : UMR8550 – France
[3] Department of Physics, Indian Institute of Science, Bangalore (IISc Bangalore) – India

Particles of low velocity, travelling without dissipation in a superfluid, can interact and emit sound when they collide. We propose a minimal model in which the equations of motion of the particles, including a short-range repulsive force, are self-consistently coupled with the Gross-Pitaevskii equation. We use this model to demonstrate the existence of an effective superfluid-mediated attractive interaction between the particles; and we study numerically the collisional dynamics of particles as a function of their incident kinetic energy and the length-scale of the repulsive force. We find a transition from almost elastic to completely inelastic (sticking) collisions as the parameters are tuned. We find that aggregation and clustering result from this sticking transition in multi-particle systems.

*Speaker
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Dynamics of Electron Bubbles in Superfluid Helium-4

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The study of the motion of an electron bubble in a superfluid is presented. The electron bubble dynamics is studied in the adiabatic approximation using the Gross-Pitaevskii equation to model the superfluid wave-function and a Schŕodinger equation to model the electron wave-function. This model allows us to recover the key dynamics of the ion-vortex interactions that arise and the subsequent ion-vortex complexes that can form. We determine the vortex-nucleation limited mobility of the ion to recover values in reasonable agreement with measured data. Moreover, considering the scenario of an ion trapped on the core of a vortex line, we investigate how small and large amplitude Kelvin waves and solitary waves affect the drift velocity of the ion. In particular, we have identified that Hasimoto soliton-bubble complexes propagating along the vortex can arise.

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Calorimetry and First-Order Coherence Measurements of a Bose-Einstein condensed photon gas

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Bose-Einstein condensation has been observed with cold atomic gases, exciton-polaritons, and more recently with photons in a dye-filled optical microcavity [1]. I will here describe recent measurements of our Bonn group determining the heat capacity and other calometric quantities of a two-dimensional photon gas in the regime around the Bose-Einstein phase transition. Moreover, the transversal coherence of the optical quantum gas has been characterized in detail.

The photon Bose-Einstein condensate is generated in a wavelength-sized optical cavity, where the small mirror spacing imprints a low-frequency cutoff with a spectrum of photon energies restricted to well above the thermal energy [2,3]. Thermal equilibrium is achieved by repeated absorption re- emission processes on the dye molecules. To determine calorimetric properties of the optical quantum gas, we analyze spectra of the dye microcavity emission at different levels of the phase space density, from which we first determine the internal energy per photon, and after differentiation with respect to the ratio of temperature and critical temperature the heat capacity can be determined. At the phase transition, the observed specific heat shows a cusp-like singularity, illustrating critical behavior, analogous to the -transition of liquid helium [4]. From the optical spectra we have also determined the entropy per photon of the trapped photon gas. More recently, see also work by the Nyman group [5], the transverse coherence of the two-dimensional photon gas was determined interferometrically both below and above the condensation threshold, showing the expected increase over the full sample size above the threshold. Far below the condensation threshold, we for the first time in an optical quantum gas observe the genuine thermal de Broglie wavelength [6].

See, e.g.: Novel superfluids, Vol. 1, K. H. Bennemann and J. B. Ketterson (eds.) (Oxford University Press, Oxford, 2013).

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*Speaker

Photon fluids in propagating geometries

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Over the past decade, photon fluids, have emerged as an experimental platform for studies of superfluidity and many-body physics. In a photon fluid in a propagating geometry, a laser beam propagates through an intensity dependent nonlinear medium, such that the photons in the beam act as a gas of weakly interacting particles. As such the behaviour and dynamics of the transverse electric field show many similarities to that of a weakly interacting gas of atoms, where the transverse electric field plays the role of the order parameter, and the propagation direction maps to time. Photon fluids have two distinct advantages: first technological simplicity, and second they allow for measurement of both the phase and amplitude of the order parameter. I will give an overview of recent experiments underway in the Extreme Light Lab at Heriot-Watt University including vortex nucleation in a nonlocal superfluid, synthetic magnetism and artificial gauge fields in rotating photon fluids, rotating black holes, and most recently, investigations of the dynamics of droplets of light that have angular momentum.

*Speaker

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