Wednesday

09:00 – 09:45 Keynote Lecture

Speaker: Turitsyn, Sergei; Aston Institute of Photonic Technologies, UK.
Title: Optical wave turbulence in fibre lasers

09:45 – 10:05

Speak: Onorato, Miguel, Dipartimento di Fisica, Università di Torino
Title: Anomalous correlators in classical nonlinear dispersive wave systems

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10:05 – 10:25

Speaker: Navon, Nir; Yale University USA.
Title: Matter-wave turbulence in a quantum gas

10:25 – 10:45

Speaker: Picozzi, Antonio; University of Bourgogne Franche Comté, France.
Title: Disorder-induced acceleration of wave condensation in multimode optical fibers

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10:45 – 11:15

Tea/Coffee break

11:15 – 11:35

Speaker: Kuznetsov, Evgenii; LITP, Russia.
Title: Expansion of the strongly interacting superfluid Fermi gas:
symmetry and self-similar regimes

11:35 – 11:55

Speaker: Pandit, Rahul; Indian Institute of Science, Bangalore, India.
Title: The formation of compact objects at finite temperatures in a self-gravitating bosonic system

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11:55 – 12:15

Speaker: Nazarenko, Sergey; Universite Cote d'Azur - INPHYNI, France.
Title: Inverse cascades in BEC

12:15 – 12:35

Speaker: Musacchio, Stefano; University of Torino, Italy.

Title: Condensate in quasi-two-dimensional turbulence

12:35 – 14:00

Lunch @ Conference venue

14:00 – 14:20

Speaker: Pushkarev, Andrei; Skolkovo Institute of Science and Technology, Russia.
Title: Nonlinear Ocean Waves Generator and Fourier-Real Space Energy Pipelines

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14:20 – 14:40

Speaker: Krstulovic, Giorgio; Observatoire de la Côte d'Azur, UCA. France.
Title: How do trapped particles interact with and sample superfluid vortex excitations?

14:40 – 15:00

Speaker: Biferale, Luca; Dept. Physics and INFN University of Rome Tor Vergata, Italy.
Title: Recent results on rotating turbulence

15:00 – 15:10

Free time

15:10 – 15:55

Speaker: Pouquet, Annick; UCAR, USA.
Title: Dissipation, Intermittency and Anisotropy in Decaying Rotating Stratified Turbulence: A Case of Marginal Instability?

16:00 – 16:30

Tea/Coffee break

16:30 – 17:30 Special Lecture

Speaker: Brachet, Marc; ENS Paris, France.
Title: A journey from classical to quantum turbulence.

Wednesday

09:00 – 09:45 Keynote Lecture

Speaker:
Turitsyn, Sergei; Aston Institute of Photonic Technologies, UK.

Title: Optical wave turbulence in fibre lasers

Abstract:
Analyzing a large data base of high-resolution direct numerical simulations of decaying rotating stratified flows, one can show that anomalous mixing and dissipation, marked anisotropy, and strong intermittency are all observed simultaneously in an intermediate regime in which both waves and eddies interact efficiently nonlinearly. A critical behavior governed by the stratification occurs at Richardson numbers of order unity, close to the shear instability threshold, and with an accumulation of data points in its vicinity. This confirms the central dynamical role of strong large-scale intermittency in the vertical velocity, the temperature and their gradients in such turbulent flows.

09:45 – 10:05

Speak:
Onorato, Miguel; Dipartimento di Fisica, Università di Torino

Title: Anomalous correlators in classical nonlinear dispersive wave systems

Abstract :
We show that Hamiltonian nonlinear dispersive wave systems with cubic nonlinearity and random initial data develop, during their evolution, anomalous correlators. These are responsible for the appearance of "ghost" excitations, i.e. those characterized by negative frequencies, in addition to the positive ones predicted by the linear dispersion relation. We explain theoretically their existence by nonresonant wave-wave interactions, extending some concepts widely used in the Wave Turbulence Theory. Namely, by generalizing the classical Wick's decomposition to include the second-order anomalous correlator, we show that the latter is responsible for the presence of "ghost" excitations. We test our theory on the celebrated β-Fermi-Pasta-Ulam-Tsingou chain and show that numerically measured values of the anomalous correlators agrees, in the weakly nonlinear regime, with our analytical predictions. We also predict that similar phenomenon will occur in other nonlinear systems dominated by nonlinear interactions, including surface gravity waves.

10:05 – 10:25

Speaker:
Navon, Nir; Yale University USA.

Title:
Matter-wave turbulence in a quantum gas

Abstract:
The recent production of homogeneous Bose gases [1] has opened exciting possibilities to study far-from-equilibrium many-body dynamics in clean uniform quantum fluids. In this talk, I will present our study of the emergence of a turbulent cascade in a homogeneous Bose fluid forced out of equilibrium on a large scale using a spatially-uniform force [2]. In contrast to classical fluids where the dissipation scale is set by the viscosity of the fluid, the turbulent cascade of our quantum gas ends when the particles kinetic energy exceeds the laser-trap depth. This simple mechanism allows us to effectively tune the dissipation scale where particles (and energy) are lost. Using this new knob, we directly measure turbulent fluxes and observe in real time the propagation of the cascade front in momentum space [3]. Once the cascade front has reached the dissipation scale, a scale-invariant steady state is established over the entire inertial range.
[1] A. L. Gaunt et al., Phys. Rev. Lett. 110, 200406 (2013).
[2] N. Navon et al., Nature 539, 72 (2016).
[3] N. Navon et al., arXiv:1807.07564.

10:25 – 10:45

Speaker:
Picozzi, Antonio; University of Bourgogne Franche Comté, France.

Title: Disorder-induced acceleration of wave condensation in multimode optical fibers

Abstract:
Studies on wave turbulence revealed that random waves can exhibit a process of condensation. However, the observation of wave condensation in optics is hindered by the prohibitive large propagation lengths required to achieve the Rayleigh-Jeans thermalization. A phenomenon of spatial beam self-cleaning has been recently discovered in multimode optical fibers. Light propagation in multimode fibers is affected by a structural disorder of the material. We formulate a wave turbulence description of the random waves accounting for the impact of the disorder. The theory reveals that a conservative disorder introduces an effective dissipation in the system, which is shown to modify the regularization of wave resonances. We derive a discrete kinetic equation revealing that disorder accelerates the rate of thermalization and condensation by several order of magnitudes. Our experiments report the observation of light condensation: By decreasing the energy ('temperature') below a critical value, we observe a transition from the incoherent thermal Rayleigh-Jeans distribution to wave condensation featured by a macroscopic population of the fundamental mode of the trapping potential of the multimode fiber.

Reference: A. Fusaro, J. Garnier, K. Krupa, G. Millot, A. Picozzi, Dramatic acceleration of wave condensation mediated by disorder in multimode fibers, Phys. Rev. Lett. 122, 123902 (2019)

10:45 – 11:15

Tea/Coffee break

11:15 – 11:35

Speaker:
Kuznetsov, Evgenii; LITP, Russia.

Title: Expansion of the strongly interacting superfluid Fermi gas:
symmetry and self-similar regimes

Abstract:
We consider an expansion of the strongly interacting superfluid Fermi gas in the vacuum in the so-called unitary regime when the chemical potential $\mu \propto$ (\hbar^2)n $^{2/3}$/m where n is the density of the Bose-Einstein condensate of Cooper pairs of fermionic atoms. Such expansion can be described in the framework of the Gross-Pitaevskii equation (GPE) [1]. Because of the chemical potential dependence on the density $\sim n^{2/3}$ the GPE has additional symmetries resulting in existence of the virial theorem connected the mean size of the gas cloud and its Hamiltonian. It leads asymptotically at $t \to \infty$ to the ballistic expansion of the gas. We carefully study such asymptotics and reveal a perfect matching between the quasi-classical self-similar solution and the ballistic expansion of the non-interacting gas [2]. This matching is governed by the virial theorem derived in [3] utilizing the Talanov transformation [4] which was first obtained for the stationary self-focusing of light in the media with cubic nonlinearity due to the Kerr effect. In the quasi-classical limit the equations of motion coincide with 3D hydrodynamics for the perfect gas with $\gamma = 5/3$ which, as it was demonstrated by L.V. Ovsyannikov [5] and S.I. Anisimov and Yu.I. Lysikov [6], have additional symmetry. Just this symmetry provides one to find self-similar solution which describes, on the background of the gas expansion, the angular deformations of the gas shape in the framework of the Ermakov-Ray-Reid type system.
The work of E.K. was performed under support of the Russian Science Foundation (grant 19-72- 30028).

11:35 – 11:55

Speaker:
Pandit, Rahul; Indian Institute of Science, Bangalore, India.

Title: The formation of compact objects at finite temperatures in a self-gravitating bosonic system

Abstract:
Self-gravitating bosonic systems are consider to be strong candidates for dark-matter halos. We study the self-gravitating Bose-Einstein condensate in the three-dimensional (3D) Gross-Pitaevskii-Posson Equations (GPPE) by using a pseudospectral method. We carry out extensive direct numerical simulations (DNSs), with conserved mass, energy, and momentum (and 2/3 dealiasing), of the Fourier-truncated 3D GPPE to study the formation of finite-temperature compact objects in this system. In particular, the Fourier truncation allows us to explore the properties of compact object here at a finite temperature. We can also get the final states of the GPPE, in the large-time limit, by fine-tuning the temperature in the Stochastic Ginzburg-Landau-Poisson equation (SGLPE). We calculate the radius of the asymptotic compact object, for different values of short-range interaction between bosons, and its mass at both zero temperature and finite temperature. We show that suitable initial conditions can also lead to the formation of a rotating binary star in the GPPE.

This study has been carried out with Akhilesh Kumar Verma (IISc Bangalore) and Marc-Etienne Brachet (ENS Paris).

11:55 – 12:15

Speaker:
Nazarenko, Sergey; Universite Cote d'Azur - INPHYNI, France.

Title: Inverse cascades in BEC

Abstract:
Nonequilibrium Bose-Einstein condensation can be viewed as an inverse cascade of particles. We will discuss stationary and self-similar solutions of the wave turbulence kinetic equation and of the Gross-Pitaevskii model corresponding to the initial condensation stages and the steady states.

12:15 – 12:35

Speaker:
Musacchio, Stefano; University of Torino, Italy.

Title:
Condensate in quasi-two-dimensional turbulence

Abstract:
We investigate the process of formation of large-scale structures in a turbulent flow confined in a thin layer. By means of direct numerical simulations of the Navier-Stokes equations, forced at an intermediate scale, we obtain a split of the energy cascade in which one fraction of the input goes to small scales generating the three-dimensional direct cascade. The remaining energy flows to large scales producing the inverse cascade which eventually causes the formation of a quasi-two-dimensional condensed state at the largest horizontal scale. Our results show that the connection between the two actors of the split energy cascade in thin layers is tighter than what was established before: the small-scale three-dimensional turbulence acts as an effective viscosity and dissipates the large-scale energy thus providing a viscosity-independent mechanism for arresting the growth of the condensate. This scenario is supported by quantitative predictions of the saturation energy in the condensate.

12:35 – 14:00

Lunch @ Conference venue

14:00 – 14:20

Speaker:
Pushkarev, Andrei; Skolkovo Institute of Science and Technology, Russia.

Title: Nonlinear Ocean Waves Generator and Fourier-Real Space Energy Pipelines

Abstract:
We study deep water surface wind-driven waves in the wind direction bounded domains, through Hasselmann equation numerical simulation. The relevant example is wind waves excitation in marine straits, when the wind is directed across the strait.
It is shown that wave turbulence evolution can be split in time into two different physical regimes. The first regime consists in wind sea excitation for characteristic times equal to the ratio of the channel width to the characteristic spectral peak advection velocity. The second regime starts later in time, after significant enough wave energy accumulation at the down-wind boundary, and is associated with the opposite to the wind wave field advection.
We attract for the explanation of this purely nonlinear effect the concept of Real-Fourier spaces wave energy "pipelines", carrying the wave energy in opposite directions due to different advection velocity signs. Those "pipelines" are involved in nonlinear wave energy interchange with growing intensity, as the wave energy fills both of them. The wave system eventually reaches asymptotic stationary state in time, consisting of two co-existing states: the first, self-similar wave ensemble, propagating with the wind, and

the second, quasi-monochromatic waves, propagating almost orthogonal to the wind direction and tending to slant against the wind at the angle of 15 degrees closer to the wave turbulence origination shore line. That demonstrates, in particular, the fact of nonlinear wave generation against the wind. We propose to call this laser-like *N*onlinear *O*cean *W*aves *A*mplification mechanism by the acronym *NOWA*.
We should stress out that these results were obtained through the exact Hasselmann equation numerical solution. Any approximate nonlinear interaction models would distort the results dramatically.

14:20 – 14:40

Speaker:
Krstulovic, Giorgio; Observatoire de la Côte d'Azur, UCA. France.

Title: How do trapped particles interact with and sample superfluid vortex excitations?

Abstract:
Particles have been used for more than a decade to visualize and study the dynamics of quantum vortices in superfluid helium. In this work we study how the dynamics of a collection of particles set inside a vortex reflects the motion of the vortex. We use a minimal self-consistent model based on the Gross-Pitaevskii equation coupled with classical particle dynamics.
We find that each particle oscillates with a natural frequency proportional to the number of vortices attached to it. We then study the dynamics of an array of particles trapped in a quantum vortex and use particle trajectories to measure the frequency spectrum of the vortex excitations. Surprisingly, due to the discreetness of the array, the vortex excitations measured by the particles exhibits bands, gaps and Brillouin zones, analogous to the ones of electrons moving in crystals. We then establish a mathematical analogy where vortex excitations play the role of electrons and particles that of the potential barriers constituting the crystal. We find that the height of the effective potential barriers is proportional to the particle mass and the frequency of the incoming waves. We conclude that large-scale vortex excitations could be in principle directly measured by particles and novel physics could emerge from particle-vortex interaction.

14:40 – 15:00

Speaker:
Biferale, Luca; Dept. Physics and INFN University of Rome Tor Vergata, Italy.

Title: Recent results on rotating turbulence

Abstract:
We present recent numerical results on the transition from direct to split energy cascade at changing the aspect ratio and the rotation intensity. In particular we will discuss the limit of infinite vertical volume.

15:00 – 15:10

Free time

15:10 – 15:55

Speaker:
Pouquet, Annick; UCAR, USA.

Title:
Dissipation, Intermittency and Anisotropy in Decaying Rotating Stratified Turbulence: A Case of Marginal Instability?

Abstract:
Analyzing a large data base of high-resolution direct numerical simulations of decaying rotating stratified flows, one can show that anomalous mixing and dissipation, marked anisotropy, and strong intermittency are all observed simultaneously in an intermediate regime in which both waves and eddies interact efficiently nonlinearly. A critical behavior governed by the stratification occurs at Richardson numbers of order unity, close to the shear instability threshold, and with an accumulation of data points in its vicinity. This confirms the central dynamical role of strong large-scale intermittency in the vertical velocity, the temperature and their gradients in such turbulent flows.

16:00 – 16:30

Tea/Coffee break

16:30 – 17:30 Special Lecture

Speaker:
Brachet, Marc; ENS Paris, France.

Title:
A journey from classical to quantum turbulence.

Abstract:
In a first part, I will recall some results obtained in the early 80's on classical (Navier-Stokes/Euler equation) turbulence and the inviscid flow singularity problem. I will then illustrate the increase of available computing power during the last 35 years by showing up to date numerical results. I will end the classical part of my talk by showing how spectral truncation of the Euler equation allows the study of irreversible behaviors and bifurcations over a turbulent background.

The second part of my talk will start by a brief introduction to physical systems displaying regimes of quantum turbulence and standard models of superfluidity. The rest of the talk will concentrate on models based on the Gross-Pitaevskii equation (GPE, also called the non-linear Schrödinger equation). After introducing the Madelung transformation and vortex reconnection, I will show how spectral truncation of the GPE allows to consider some finite temperature effects. I will end the talk by showing some recent numerical results on quantum turbulence.
