Coherent structures and turbulence in two-dimensional hydrodynamics

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Project Outline and Objectives

The phenomenon of "condensation" in two-dimensional turbulence [1] is a very striking example of the self-organisation of large scale coherence from small scale fluctuations. The process works via the so-called inverse cascade mechanism whereby energy injected into a two-dimensional fluid by a small scale stochastic force is transferred to large scales by nonlinear coupling between different scales of motion in the Navier Stokes equations. When this inverse cascade reaches the size of the system the energy carried by the inverse cascade accumulates at the largest scales and subsequently self-organises to form large scale coherent vortices.

Recent theoretical work by Chertkov, Kolokolov and Lebedev has suggested that there are universal aspects of these large scale structures [3] and of the interactions between the large scale coherent flow and the small scale fluctuations [2]. Universal in this context means that there are structural features of the coherent vortices which are independent of the boundary conditions and independent of the details of the small scale forcing and dissipation. In this project we will study the extent to which these theoretical predictions are borne out by numerical evidence collected from pseudo-spectral simulations of the condensation process.

Required Background and Methodology

This project requires and interest in fluid dynamics and statistical physics. The student will not be required to do the simulations but an interest in numerical simulation of nonlinear PDEs would be helpful. The student will be expected to analyse the considerable amount of data generated by my code so a reasonable familiarity with data analysis in C and MatLab will be required.

Research Outcomes

The aim of the project is to verify numerically the structure of the zero modes of the vorticity evolution operator suggested in [3] to be responsible to the structure of the large scale coherent structure and to try to observe the so-called collinear anomaly for small scale vorticity fluctuations in the presence of a large scale coherent structure as outlined in [2]. Convincing demonstration of either or both of these predictions is likely to lead to a publication.

PhD prospects

This project is probably only suitable for MSc since I am not aware of any suitable co-supervisors for a PhD project on this topic outside of mathematics.

References

[1] M. Chertkov, C Connaughton, I. Kolokolov, and V. Lebedev. Dynamics of energy condensation in two–dimensional turbulence. *Phys. Rev. Lett.*, 99:084501, 2007.

[2] M. Chertkov, I. Kolokolov, and V. Lebedev. Strong effect of weak diffusion on scalar turbulence at large scales. *Phys. Fluids*, 19:101703, 2007.

[3] M. Chertkov, I. Kolokolov, and V. Lebedev. Universal velocity profile for coherent vortices in two–dimensional turbulence. *Phys. Rev. E*, 81:015302(R), 2010.