EUROPEAN MECHANICS SOCIETY

Scientific Report
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Colloquium No.565..... Scientific Report

One of the earliest research topics in fluid dynamics, dating back to the 19th century, is still open: how does the flow of liquid or gas in a pipe, between two plates or above one plate transition to turbulence? How can one predict or characterize the resulting dramatic increase in drag, and perhaps even control it? Those flows share one property in common: linear stability theory does not help in predicting the route from laminar to turbulent. This problem lies at the crossroads between hydrodynamics, chaos theory, stastistical physics, and current research relies on cutting-edge experimental and numerical techniques.
An increasingly large and active international community interested in this topic has emerged since the last meeting on the subject held in Bristol (United Kingdom) in 2004. The goal of the present colloquium was to gather both experienced and younger experts in the field, in order to present and discuss the latest developments in the discipline.
84 participants from more than 17 countries, representing at least 29 nationalities, were present over these full 4 days, including 71 presentations of 20 minutes each, no distinction being made between key-note and younger speakers, as well as a poster session. Most leading scientists in the field were present, which made fruitful discussions possible all along the colloquium. The event benefited greatly from the presence of a few important names from other related fields of nonlinear sciences.
The facilities of IESC Cargèse, coupled with the great location, pleasant atmosphere and dinners in town also helped in creating a friendly and cooperative feeling within this emerging community.
The schedule of the colloquium was organised following a number of topics, some of them (Non-Newtonian aspects of transition, Astrophysical Flows) original within the discipline itself. A special attention was paid during the elaboration of the program to bridging these different scientific approaches together rather than questioning their compatibility. New methodologies (flow visualization techniques, simulation using parallel computing, new algorithms for data processing) were discussed throughout the talks rather than as a special topic.
Major recurring topics and questions discussed over the whole week:

1) Spatiotemporal aspects of the transition near its onset.
Extensive experimental data obtained by B. Hof and coworkers in pipe flow have made it clear that the determination of the onset of transition requires statistical approaches. There is a wide interest, motivated in the two introductory talks by Y. Pomeau and N. Goldenfeld, in whether the onset of transition can be described as a critical phenomenon, whether it falls into the universality class of directed percolation and why this assumption makes sense by analogy with phase transition or ecology models. More experimental campaigns are needed and the question is not closed yet. Many talks examined the mechanisms at play in the dynamics of localized structures (puffs, spots, stripes) in the spatio-temporally intermittent regimes, with a recent emphasis on the contribution of large-scale motions (talks of Schlatter, Wesfreid, Couliou). Experimental and numerical techniques in this field have recently reached the exciting point where quantitative cross-comparison is now possible.

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2) Description of the transition process from a dynamical systems point of view. Theoretical ideas formulated by Waleffe, Mullin, Eckhardt, Kerswell, Cvitanovic and coworkers more than 15 years ago have begun now to gain quantitative support from well-resolved numerical data. Current efforts from many teams aim at extracting numerically and experimentally recurrent structures, i.e. exact yet unstable solutions of the phase space such as fixed points, periodic orbits and at mapping out the infinite-dimensional phase space. Bifurcation diagrams have highlighted the role of boundary crisis in the formation of the chaotic saddle in phase space, which supports locally transient turbulence in physical space. The notion of edge manifold, dividing phase space into several basins of attraction appears as established. New promising emerging directions concern the reduction of symmetries and the ongoing extension of these ideas to localized turbulence regimes (closing talk of M. Avila).

3) Emergence of localization. Given the experimental and numerical evidence for localized turbulence near its onset, various new numerical techniques (bifurcation analysis, edge tracking, asymptotics, windowing…) are being developed in order to identify correspondingly localized solutions of the governing Navier-Stokes equations.

4) Modelisation of subcritical transition. Low-order modeling strategies were proposed to account for the spatiotemporal aspects of subcritical transition. Along recent models by D. Barkley, P. Manneville and others, new ideas from synchronization theory and pattern formation will hopefully lead to new developments.

5) Non-newtonian transition. Two full sessions covered the recent developments in the case of non-Newtonian rheologies such as polymer flows, shear-thinning fluids, particle suspensions and extensions towards elastic turbulence. Unexpectedly, the concept of edge state is central in explaining drag reduction mechanisms (talk of M. Graham).

6) Astrophysical applications. There are several suggestions that turbulence in Keplerian discs can be explained by subcritical transition theories in close analogy with the purely hydrodynamical context (talk of F. Rincon). There were discussions about the relevance of academical geometries such as Taylor-Couette flows for this problem.

7) Control of subcritical transition. Despite huge industrial interest, nonlinear control strategies for subcritical flows are only emerging. The team of B. Hof has demonstrated that forced full relaminarisation of pipe flow is experimentally possible using carefully designed obstacles, which opens up interesting possibilities for severe drag reduction.

Many questions obviously remain open but the overall feeling of this growing community is optimistic. Thanks to the presence of most prominent actors, the novelty of most presented results, the pleasant location (including excellent organizational facilities and time for informal discussions), as well as the fine food and great weather, the colloquium was considered a total success. Several experienced participants called it during their talk “the best meeting ever on the subject”. It is expected that many new ties will have consolidated within the community during this week, resulting in further progress within this cross-disciplinary discipline.