EUROPEAN MECHANICS SOCIETY

Colloquium Final Report

N. 620 – Extreme dissipation and intermittency in turbulence

Dates and location: **17/05/2021 - 19/05/2021, Delft, The Netherlands**

Chairperson **Gerrit Elsinga**

Co-Chairperson **Julian Hunt**

Conference fees

- registration fee **0.0 €**

What other funding was obtained? **-**

What were the participants offered? **-**

Number of members of Euromech (reduced registration fee) **73**

Number of non-members of Euromech (full registration fee) **2**

Applicants (members)

- Farid Aligolzadeh
- Ryo Araki
- Amaury Barral
- Tim Berk
- Kovid Bhatt
- Luca Biferale
- Wouter BOS
- Clément Bret
- Dhawal Buaria
- Tom Buchwald
- Michele Buzzicotti
- Adam Cheminet
- Laurent Chevillard
- Guillaume Costa
- Jeffrey Cuzzi
- Predrag Cvitanovic
- Simon Delcamp
- Miguel Diaz-Lopez
- Berengere Dubrulle
- Ian Eames
- Gerrit Elsinga
- Edith Falgarone
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- Pierre Hily-Blant
- David Hosking
- Julian Hunt
- Juan Ignacio Polanco
- Takashi Ishihara
- Javier Jimenez
- Robert Kerr
- Rich Kerswell
- Eliezer Kit
- Giorgio Krstulovic
- Elyas Larkermani
- Andrew Lehmann
- Pierre Lesaffre
- Alex Liberzon
- Moritz Linkmann
- Jinyuan Liu
- Tian Ma
- Nicolás Müller
- Sugan Murugan
- Sergey Nazarenko
- Rui Ni
- Matteo Novara
- Kosuke Osawa
- Miguel Pérez
- Jason Picardo
- Alain Pumir
- Thibaud Richard
- Samriddhi Sankar Ray
- Daniel Schanz
- Andreas Schröder
- Vishwanath Shukla
- Shiyong Tan
- Guilherme Tegoni Goedert
- Yoshiyuki Tsuji
- Valentina Valori
- Alberto Vela-Martin
- Dario Vincenzi
- Michael Wilczek
- Tong WU
- P.K Yeung
- Xinxian Zhang

Applicants (non members)

- Shiyong Tan
- Yoshiyuki Tsuji

Scientific Report

Extreme viscous dissipation rates and the associated extreme strain rates are critical in many industrial, environmental and astrophysical processes dominated by small-scale turbulence. For example, dissipation extremes can lead to local flame extinction and pollutant formation, affect the chemistry of molecular clouds, are sites for droplet collision and growth in clouds and enhance the intermittency of the scalar dissipation rate. Extreme dissipation also sets the smallest scale in a turbulent flow, thereby posing resolution requirements for experiments and numerical simulations, which is especially relevant for those aiming to study the mentioned small-scale processes.

Despite its importance, there is no suitable theory to explain the Reynolds number scaling of the dissipation extremes. Any successful new theory will need to properly account for the intermittency and the development of turbulent flow structures at high Reynolds numbers. However, connecting the recent understanding of turbulent flow structure with the prediction of dissipation extrema in real industrial, environmental and astrophysical applications remains a significant challenge and opportunity.

This colloquium brought together scientists from different disciplines (fluid mechanics, turbulence, applied mathematics, atmospheric sciences and astrophysics) to discuss the key questions confronting the field.

Keynote lectures were presented by:
- Luca Biferale (Tor Vergata, Rome), who reported on the insights gained from turbulence simulations where a feedback on the local vorticity is implemented
- Bérengère Dubrulle (U Paris-Saclay, CNRS), who presented results from experimental and numerical investigations of potential blow-up events in turbulent flow
- Takashi Ishihara (Okayama University), who discussed large-scale shear layer structures in high-Reynolds number turbulence
- Eliezer Kit (Tel Aviv University), who presented atmospheric measurements of intermittency and burst of extremely high dissipation
- Alain Pumir (ENS de Lyon, CNRS), who showed the extreme enstrophy and dissipation events observed in Direct Numerical Simulations and their Reynolds number dependence
- P.K Yeung (Georgia Tech), who discussed recent advances in high-resolution high-Reynolds number simulations and their relevance to the investigation of extreme events

Furthermore, a total of 29 contributed talks were presented. The themes emerging from these talks and the discussions are summarized as follows.

Observations of extreme events
Results were presented from direct numerical simulations as well as laboratory experiments. They revealed that the Reynolds number scaling of the extreme events cannot be predicted from classical arguments, i.e. Kolmogorov theory. A theory to explain the observations is currently lacking. The multi-fractal model may provide (upper) bounds, but not yet the actual scaling. Furthermore, the present observations cover a limited Reynolds number range and it would be of important interest to extend them to higher Reynolds numbers, especially in light of the reported large-scale influences (see below). The dynamics of extreme events were also discussed, which is relevant to their stability and the development of potential singularities. Several talks have, therefore, considered extreme events and intermittency from the perspective of singularities and the irreversibility of turbulence, where Lagrangian and Eulerian viewpoints have been combined.

The flow cases considered in the different talks included homogenous isotropic turbulence, MHD turbulence, wall-bounded turbulence, superfluids and buoyancy driven flows. In MHD, extreme dissipation originates from multiple sources and their relative importance was examined. The implications of extreme events for particle motions, clustering and collisions were also discussed.

Large-scale influences

The fact that extreme events do not follow classical scaling suggests that they may be influenced by large scales. Several talks discussed the mechanisms of collective vortex organization, the importance of non-local triads and the clustering of intense dissipation into large-scale structures, such as for example large-scale shear layers. Examples of large-scale (or larger-scale) clustering of intense dissipation events were given from direct numerical simulations, atmospheric observations (so-called bursting phenomena) and cosmic observations of molecular clouds. Such spatial clustering of very intense small-scale motions is considered to have important implications for dissipation scaling as well as particle dispersion. A model based on the organization of intense dissipation in large-scale shear layers was proposed, which could capture the observed anomalous scaling of extreme dissipation. Furthermore, the analysis of weak solutions of the Navier-Stokes equations provided further insight in the origins of the low-dimensional accumulation of dissipation (clustering).

Numerical experiments and control

Computer simulations allow modification, or removal, of the different terms in the governing equations. Results from these numerical experiments provide guidance to the design of turbulence control strategies and give insight in the significance of these terms in the cascade process and in the development of intermittency. Similarly, the methods developed to explore causality in turbulent flows make local changes to the flow and examine their effect. This is a relatively new and promising development.

Overall the colloquium was successful in bringing the communities together and provided fruitful discussions on the progress in the field as well as on the open issues. The organizers would like to thank EUROMECH for their support.

Number of participants from each country

Country	Participants
Netherlands	1
United States	1
Japan	1
Other	72
Total	**75**

Please send this report in electronic form to the Secretary General of EUROMECH, within one month after your Colloquium.