Editorial

Topical issue on Multi-scale phenomena in complex flows and flowing matter

New research topics related to the statistical and dynamical properties of matter flowing in simple and complex flows have emerged in the recent years at the crossroads among industrial processes, biotech applications, fundamental physics, engineering and Earth sciences. Depending on the microscopic interactions, a sample of molecules or mesoscopic particles can flow like a simple Newtonian fluid, deform elastically like a solid, or behave with a complex rheology and strong non-equilibrium properties. When the internal constituents are active, as for biological entities, complicate collective motions can be observed. Sometimes these *particles* undergo breakup or coalescence processes, whose occurrence strongly depends on the flow statistics.

In many realistic applications, the large scale advecting flow has chaotic spatial and temporal fluctuations, sometimes over a wide range of scales/frequencies as in the case of fully developed turbulent flows. As a result, flowing matter often exhibits a tight coupling between small-scale fluctuations and large-scale flow structures, urging for a unifying view at both Lagrangian and Eulerian levels.

Flows of interest can be at the nano-, micro- or macro-scales, and need different theoretical, numerical and experimental approaches. The interplay of the dynamical and other related processes taking place at the different scales remains, for many problems, elusive and challenging.

This topical issue of the *European Physical Journal E* brings together a cross-section of research advances and activities, highlighting the diversity of basic and applied interests in flowing matter across the scales. It is the result of a widespread activity in Europe and beyond, involving communities from physics, bio-physics, mechanical engineering and applied mathematics.

Several papers discuss peculiar aspects of complex flowing behaviour at changing the characteristic lengthscales of the system, in particular focusing on thermal fluctuations, nanoscale heterogeneities and structural transition [1–5]. The discrete nature of the dispersed phase is investigated in terms of Lagrangian structures at micro/meso-scale (*e.g.* colliding particles, polymers, active matter, micro-swimmers) by several authors [6–11]. Few contributions focus on classical problems related to non-linear systems or the turbulent behaviour of Newtonian fluids, but focusing on new observables or novel approaches to anomalous scaling: these include the discussion of dissipated energy in diffusive systems [12], turbulence under rotation or with strong helical properties [13–16], with waves [17], or with modified non-linear interactions [18,19].

The papers in this issue showcase examples of active mutual scientific fertilization across different disciplines and approaches. Among these, the application of techniques inherited from statistical mechanics, both in analyzing large-scale dynamics of chaotic systems, as well as mesoscale statistics of glass-forming liquids, but also energy-landscape analysis of mechanical deformation and the study of flowing properties in jammed systems, just to name a few. The ultimate goal of this compilation is to further stimulate the interaction across the boundaries between fundamental and applied research, and among scientists of different areas, leading to the emergence of new challenging directions, bold concepts, and exciting developments.

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