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Editorial

Foreword

We started thinking about a dossier on coarsening because, although many excellent reviews exist, a collection of papers where the diverse manifestations of this phenomenon were gathered together and discussed at a relatively broad and basic level, addressing both theory and experiments, would have been useful.

Coarsening certainly plays an important role in physical sciences, where phenomena of phase ordering and phase separation are widespread [1–3]. But it is also relevant in biology, characterizing for instance the motion of birds flocks [4] or bacterial suspensions [5]; in social sciences, with several implications in finance and opinion making [6]; in chemistry [7], being a possible outcome of sustained reactions. Coarsening is also important for a wealth of applications in metallurgical and plastic productions, food [8] and drug preparations, construction industry and many other areas.

The pattern formation observed in driven systems [9] is also very often the outcome of a coarsening process, although many other dynamical features such as traveling waves and chaos, non-equilibrium stationary and oscillating states may be observed. In particular, coarsening has been recognized to be widespread in surface science where Ostwald ripening [10]—a phenomenon at the historical roots of coarsening studies—is observed.

In the very initial stage of this project, when trying to circumscribe this wide field, we felt the problem to delineate what coarsening should be meant to be. Apart from the obvious fact that coarsening refers to a situation where a certain spatial scale grows in time, its ubiquitous appearance in such different manifestations seems to make worthless any attempt to further refine its definition. Indeed coarsening is often accompanied by specific properties such as self-similarity and scaling, extremization of a Lyapunov functional, perpetual power-law growth and so on, but restricting its definition to the occurrence of these features is fruitlessly constricting. After all, we believe this vagueness could be a strong point that can be constructively exploited to bring together different topics, promoting interdisciplinarity and circulation of ideas among scientists working in different areas. It is in this spirit we have undertaken the project of this dossier.

Not only coarsening is a widespread and technologically important phenomenon, but it also represents possibly one of the most simple and paradigmatic examples of a non-equilibrium process, being sometimes considered as representative in some respect of a large class of phenomena where time-translational invariance lacks. Besides the interest in itself, a deep comprehension of coarsening is probably an unavoidable step towards the understanding of more complex non-equilibrium evolutions where aging is observed. An example is provided by the physics of glassy and frustrated systems where a long-lasting and still open debate exists regarding the nature of the equilibrium state, specifically if it ought to be similar to the structure emerging from the Parisi solution of the Sherrington–Kirkpatrick mean-field model [11], or if, instead, a simpler organization with only two symmetry-related states, as in a ferromagnet, should occur in finite-dimensional systems. It has been argued that such difference ought to be manifested in the dynamics after a quench [12], since in the latter case a coarsening phenomenon akin to the one observed in a standard magnetic system should be detected.

Despite the relevance of the whole subject, a reference theory for coarsening is not fully developed. Clearly, particular instances, mainly in one dimension or in some special limits, are amenable to exact analytic solutions or to controlled approximation schemes, but these are not yet available in general. At least in the cases where coarsening is accompanied by a dynamical scaling, in analogy with the corresponding equilibrium problems, such an invariance could be possibly enforced for the development of renormalization group techniques to attack the problem. However, for coarsening, this is nowadays only possible for the quite specific case of the growth of a critical phase [13]. This makes coarsening one of the fundamental problems deserving new analytical tools and ideas.

A common thread connects coarsening to many other fundamental issues of modern Physics. Among these, a deep relation exists with condensation phenomena. A clear manifestation occurs in magnetic systems where it can be shown [14] that, for a vector order parameter with $N \to \infty$ components, coarsening amounts to the building-up of a condensate akin to what is known in Bose–Einstein gases. In this case, the term *condensation* refers to the fact that the development of magnetization is obtained through the population of the zero wave-vector mode growing macroscopically. However the relations between condensation and coarsening are not restricted to that: condensation is also observed in stochastic particle

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systems.[1] Here, a finite fraction of some quantity conserved by the dynamics, usually referred to as mass, condenses into a small region of space [15–18]. A well-studied example is the zero-range process where unit masses hop between sites of a lattice. In this process, if the hopping rates decay sufficiently slowly and the total mass exceeds a critical value, then condensation occurs: in the stationary state, a macroscopic mass-fraction is contained in a single site [17,19]. Starting from random initial conditions, the condensate emerges through a coarsening process [20–22] where the excess mass accumulates on a number of putative condensing sites and coarsening is then determined by the exchange of particles between them until one prevails [21,22]. Similarly to what occurs in other coarsening systems, the timescale for condensation diverges with the system size and coarsening is perpetual if the thermodynamic limit is taken from the onset.

As it is clear from this short introduction, it is by far impossible to cover such an extended subject as coarsening in a single review. Therefore, in planning this volume, we tried at least to collect contributions that could address a varied and significative part of the possible instances. The dossier contains two contributions of general character on coarsening and pattern formation by L. Cugliandolo and by A.A. Nepomnyashchy, respectively. Four contributions focus on coarsening in specific contexts: surface science (P. Politi), granular systems (A. Baldassarri et al.), fluids (S.K. Das et al.), and active matter (G. Gonnella et al.). Finally, the contribution by F. Corberi faces the effects of disorder.

We are aware that a number of other topics that could have legitimately entered the volume are not contained here. However, the spirit of the collection is not an encyclopedic one, but rather aims at providing the reader with a broad and possibly simple and instructive introduction to the subject, referring to specialized publications for further in-depth readings. We hope it will be appreciated.

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[1] We warmly thank Martin Evans for providing us a brief account of this subject.