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Preface

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Dissipative structures in matter out of equilibrium: from chemistry, photonics and biology, the legacy of Ilya Prigogine (part 1)

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The idea of this theme issue emerged during the *XIV international Workshop on Instabilities and Non-equilibrium Structures*, which took place on 4–7 December 2017 in Valparaiso, Chile. This workshop, organized by the University of Chile and the Pontificia Universidad Catolica de Valparaiso, was dedicated to the memory of Ilya Prigogine, who stimulated the development of research in the areas of nonlinear physics, non-equilibrium thermodynamics and statistical mechanics in South America, especially in Chile. There are two reasons to pay tribute to Ilya Prigogine in 2017. This year corresponds both to the centenary of his birth and to the 50th anniversary of his *theory of dissipative structures*. It was indeed in 1967, on the occasion of an important scientific meeting, that for the first time he explained this concept. The resounding progress he reported has been described as marking *the end of the tyranny of equilibrium* in thermodynamics. He not only increased our knowledge of the fundamental laws governing the evolution of matter but also announced future advances that he foresaw. The future of 1967 is our present of 2017. We now have a deeper

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understanding of the behaviour of matter at equilibrium and out of equilibrium; we have answered questions that were still mysterious at the time; other questions unsuspected or neglected in 1967, have appeared and taken the foreground. We have witnessed the growing importance of mathematical and computer modelling in the study of natural phenomena and society.

This theme issue is intended to provide an overview by experts working in dissipative structures, ranging from experimentalists to theoreticians, mathematicians and engineers. Dissipative structures have been observed in all areas of nonlinear science in chemistry, biology, ecology, optics and physics. This theme issue contains two volumes.

The first volume is focused on the theory of dissipative structures. The second volume is concentrated on the applications of dissipative structures in nonlinear sciences. The first volume features an introductory article discussing the physics of dissipative structures authored by René Lefever [1]. The second paper by Thomas Erneux [2] reviews how the search for sustained chemical oscillations became a priority for Prigogine and his coworkers by the end of the 1960s. The paper explains mathematically why early two-variable models failed to provide bounded solutions and supports the conclusion that the Brusselator is the first minimal model describing the onset of chemical oscillations in a way fully compatible with thermodynamics and the mass action law. Dissipative structures are not necessarily periodic in space or in time. They can also be aperiodic in time and localized in space. Specifically, they consist of isolated or randomly distributed spots surrounded by uniform regions. They correspond to the spatial and/or temporal confinement of energy, chemical concentration, light or biomass density. The formation of localized structures often called cavity solitons or dissipative solitons is a universal feature of self-organized non-equilibrium systems and is a common occurrence in many fields of nonlinear science. The paper by Nail Akhmediev *et al.* [3] discusses the formation of localized structures and extreme events in optical devices. A challenging direction for further analysis of three-dimensional dissipative structures in the form of light bullets for optical resonators is discussed by the Nikolay Rosanov group [4]. The effect of a delayed feedback on the dynamics of light bullets is analysed by Alexander Pimenov *et al*. [5] for a mode-locked semiconductor laser. Dissipative optical solitons in parity-time-symmetric potentials have been investigated in the paper by Boris Malomed and colleagues [6] and by Li Pengfei *et al*. [7]. The analysis of optical Kerr frequency comb generation using whispering gallery mode cavities is reviewed by Balakireva & Chembo [8] emphasizing another aspect of dissipative structures. In particular, they analyse potential applications in relation to optical Kerr frequency comb generation. Optical frequency combs are expected to have industrial applications such as the generation of ultra-stable lightwave and microwave signals for aerospace engineering, optical communication networks and microwave photonic systems. Next, the paper by Vladimir Zykov [9] presents a review of spiral wave formation in excitable media. Leon Brenig [10] reports on the reduction of nonlinear dynamical systems to canonical forms. Finally, Albert Goldbeter [11] presents an overview of dissipative structures in the biological sciences. This review focuses on various nonlinear phenomena, such as bistability, time-oscillations, spatial patterns and waves in biological systems.

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