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Editorial

Nonequilibrium Phenomena in Confined Systems

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Confined systems exhibit a large variety of nonequilibrium phenomena. In this special issue, we have collected a limited number of papers that were presented during the XXV Sitges Conference on Statistical Mechanics, devoted to "Nonequilibrium phenomena in confined systems". The conference took place in Barcelona from the 6th until the 10th of June 2016 (http://www.ffn.ub.es/~sitges25/), was organized by G. Franzese, I. Latella, D. Reguera, and J.M. Rubi, and gathered more than 60 international scientists in the areas of physics, chemistry, and biology working on confined systems in topics like: Diffusion and entropic transport in confined systems; Ion and polymer translocation; Phase transitions and chemical reactions in confined media; Forces induced by fluctuations in confined systems and Casimir effect; Confined active matter; Macromolecular crowding; and Energy conversion in confinement.

In the first contribution to this special issue [1], by P. Malgaretti, I. Pagonabarraga and J.M. Rubi, the authors focus on how local forces in heterogeneous media modify Brownian motion and lead to deviations in the Gaussian probability distribution of displacements typical of thermal motion. Their results can be used to detect local forces and to characterize relevant properties of the host medium.

Crowding is another source of heterogeneous local forces. In their contribution, P.M. Blanco, M. Via, J.L. Garcés, S. Madurga, and F. Mas analyze protein diffusion in crowded media [2]. They use dextran macromolecules as obstacles and propose a model based on effective radii accounting for macromolecular compression induced by crowding. They adopt a Brownian dynamics computational model to calculate the diffusion coefficient and the anomalous diffusion exponent. They compare their results with experiments, emphasizing the effects of varying volume fraction and hydrodynamic interactions.

The search for the origin of life motivates the study performed by D. Niether and S. Wiegand [3] about the accumulation process of formamide in hydrothermal pores. The authors consider a heuristic approach and show that the combination of thermophoresis and convection in hydrothermal pores leads to an accumulation of formamide that depends on the geometry of the system and ambient conditions. A sufficiently high concentration of formamide could allow the synthesis of prebiotic molecules.

Smaller bio-pores are considered by M. Aguilella-Arzo, M. Queralt-Martín, M.-L. Lopez, and A. Alcaraz that in their contribution [4] address fluctuation-driven transport of ions in nanopores. The authors study the bacterial channel OmpF under conditions similar to those met in vivo. They use a three-dimensional structure-based theoretical approach to shed light on the conditions to observe the actual transport of ions against their concentration gradient.

Active matter is another biologically-relevant subject, and is the focus of the contribution by A. Geiseler, P. Hänggi, and F. Marchesoni [5]. The authors consider the taxis of artificial swimmers—a purely stochastic effect associated with a non-uniform activation of the particles' self-propulsion. With numerical and analytical techniques, they study how such swimmers respond to a spatio-temporally modulated activating medium.

A stochastic process is also at the base of the Feynman–Smoluchowski ratchet introduced and solved by V. Holubec, A. Ryabov, M.H. Yaghoubi, M. Varga, A. Khodaee, M.E. Foulaadvand and P. Chvosta in their contribution [6]. Using a generalization of the Fick–Jacobs theory, they demonstrate a connection between the ratchet effect emerging in the model and the rotations of the probability current of particles. In addition, the direction of the particles' mean velocity is explained using a simple discrete analogue of the model.

A comparison between biological and inorganic confinement is provided in the contribution by G. Camisasca, M. De Marzio, M. Rovere, and P. Gallo [7]. The authors perform numerical simulations in two situations: water confined in a hydrophilic pore that mimics an MCM-41 (inorganic) environment, and water at interface with a protein. They address the slow dynamics and structural changes of supercooled water under these confinements and compare how the α-relaxation changes with respect to bulk water.

The simulations of J. Martí, C. Calero, and G. Franzese instead focus only on water under inorganic confinement [8]. They analyze the structure and dynamics of water at the interface of different carbon-based materials, including armchair carbon nanotubes and a variety of graphene sheets (flat and with corrugation). They show that the diffusion of water confined between parallel walls depends on the plate distance in a non-monotonic way and is related to the water structuring, crystallization, re-melting, and evaporation for decreasing inter-plate distance.

Structural, thermal, and dynamical behaviors of ionic liquids confined in silica ionogels are analyzed by neutron scattering in the experiments of S. Mitra, C. Cerclier, Q. Berrod, F. Ferdeghini, R. de Oliveira-Silva, P. Judeinstein, J. le Bideau, and J.-M. Zanotti. In their contribution [9], the authors discuss various dynamic parameters and the detailed nature of phase transitions at time- and length-scales smaller than those of earlier experiments with different techniques. In particular, their results explain the good ionic conductivity of ionogels.

A kinetic theory of a confined quasi-two-dimensional gas of hard spheres is presented in the contribution by J.J. Brey, V. Buzón, M.I. García de Soria, and P. Maynar [10]. In this paper, a model formulated for granular gases is reviewed, and a Boltzmann kinetic equation for elastic hard spheres is introduced in order to obtain a detailed description of the dynamics of the system.

Another inorganic system which is particularly interesting is one made of a few confined colloids. I.A. Martínez, C. Devailly, A. Petrosyan, and S. Ciliberto discuss energy transfer between colloids via critical interactions [11]. By considering two beads that are trapped by two optical tweezers whose distance is periodically modulated, they report a temperature-controlled synchronization of the particles in a binary mixture close to the critical point of the demixing transition.

Noise can also induce coherence at the level of electron spins. B. Spagnolo, C. Guarcello, L. Magazzù, A. Carollo, D. Persano Adorno, and D. Valenti investigate nonlinear relaxation phenomena in various metastable condensed matter systems [12]: phase dynamics in Josephson junctions, electron spin relaxation in an n-type GaAs bulk driven by a fluctuating electric field, and stabilization of quantum metastable states by dissipation. They provide detailed discussion on the relevance of noise-enhanced stability, stochastic resonant activation, and the noise-induced coherence of electron spin in these systems.

With the organization of the Conference, we aimed to provide a unique opportunity to exchange points of view, to promote contacts and new collaborations among researchers working on different inter-disciplinary areas, and to create a forum for debate that could help to answer the open questions related to the novel effects induced by confinement. This issue is the natural continuation of the interchange of ideas that started during the Conference sessions. We hope that this small selection of contributions will trigger further investigation and discussion among their readers.

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