Dynamic phase transitions in stochastic clustering under confinement

Giulia Janzen[1], and Carlos Mejía-Monasterio[2],

[1] Theory of Polymers and Soft Matter, Department of Applied Physics, Eindhoven University of Technology.

[2] School of Agricultural, Food and Biosystems Engineering, Polytechnic University of Madrid.

When a system of interacting particles is driven out of equilibrium, macroscopic long range correlations emerge even if the interactions are local. An instance exhibiting such behaviour is that of a stochastic lattice gas of interacting particles in which one of the particles is subject to a external field. This Biased Particle (BP) produces changes at the microstructure of the medium (the other particles) that depend on the strength of the external field F and on the density ρ of the medium itself. Bath particles accumulate in front of the BP, creating jamming. This produces a frictional force that compensates the dragging force applied on the probe. As a consequence of the equilibrium between these forces, in the steady state the BP reaches a terminal drift velocity V . In the limit of small field ($F < 1$), the system reaches a viscous regime in which the terminal velocity depends linearly on the field: $V = F/\xi$, with ξ the friction coefficient. Behind the BP, a depleted region appears, with a medium density that approaches the equilibrium density as a long-range power law $\sim x^{3/2}$, meaning that the medium remembers the passage of the BP on large spatial and temporal scales. In confined geometries, these long-range correlations induce a superdiffusive growth of the BP fluctuations [1, 2, 3]. Moreover, when two BPs exist, they interact forming a stable pair that moves together as dragging force is minimised [4, 5].

Here we study the stochastic dynamics of many BPs driven out of equilibrium by an external force and moving in a dense quiescent bath through narrow channels. As the number of these BPs increases, a transition from a mixed phase to a collective pattern of dense clusters and dilute phases sets in, similar to mobility induced phase separation observed for active particles. Clustering is mediated by the interaction with the bath and follows from a stochastic aggregation-fragmentation process. We show that the phase separation persists as confinement stabilises the thermal fluctuations, leading to large and long lived clusters that facilitate the formation of clogs. When the clogs are formed the BPs exhibit a dynamic phase transition from superdiffusion to single-file and entrain the whole system into an anomalous slow dynamics. As a result, dynamics exhibit negative differential mobility.

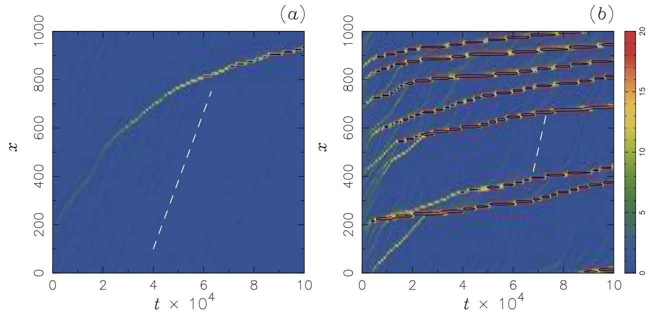

Fig. 1. Formation of clusters at *a*) low and *b*) high density of intruders in a long but narrow channel. Dashed lines indicate intruders evaporating between clusters.

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