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Metastability in the Zero-Range Process

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1. Introduction

The zero-range process (ZRP) [1] is a simple lattice-based model for driven diffusive systems. For certain choices of parameters, the model exhibits a condensation transition (analogous to Bose-Einstein condensation) where a macroscopic proportion of particles accumulate on a single site [2]. Condensation is well-known in colloidal and granular systems [3] and also occurs in a variety of other contexts [4], including socio-economics, biology, and networks. Furthermore, the ZRP can be mapped to well-studied exclusion processes which describe the single-file diffusion of interacting particles. Condensation in the ZRP corresponds to phase separation in the exclusion process [5].

2. Metastability

Our recent studies of the ZRP [6] reveal the existence of a metastable state before the onset of coarsening. Specifically, we consider a model in which the diffusive current out of a particle cluster decreases with cluster size. At densities slightly larger than the critical condensation density, the diffusion rate into small clusters is less than the outgoing rate. Hence an initially homogeneous system with no large clusters can stay in a metastable "supersaturated" state for a long time. Eventually, fluctuations lead to the appearance of a large stable cluster; such clusters then grow and coalesce, finally leading to a single condensate.

Inspired by nucleation theory, we are able to estimate the critical cluster size and the mean nucleation time for a condensate. This complements previous work on late-stage cluster coarsening [7,8] as well as giving a possible analytical description of "traffic jam" formation [9].

In this poster we present the results of [6] together with new simulation data and further discussion of theoretical approaches to the metastable state.

3. Conclusion

The ZRP is an important paradigm for driven diffusive systems. It shows interesting physically-relevant behaviour but is sufficiently simple that one can analytically describe the evolution of an initial state through the successive stages of metastability, coarsening and condensation. We discuss various aspects of this model, with particular focus on the metastable stage.

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