Large deviation analysis of systems far from equilibrium

(Proposal for a strategic interdisciplinary studentship.)

1. Supervisors : Dr. Robert Jack (Physics), Prof. Peter Mörters and Dr. Johannes Zimmer (both Mathematics)

2. Title: Large deviation analysis of systems far from equilibrium

3. Project objective(s):

- Mathematical analysis of the hydrodynamic limit of particle systems with large deviation techniques.
- To combine expertise within in the faculty so as to facilitate research in out-of-equilibrium statistical mechanics (Rob Jack), large deviation techniques (Peter Mörters) and applications in the theory of upscaling (Johannes Zimmer).

4. Project description:

Large deviation principles play a central role in statistical physics, as a rigorous route towards defining and calculating free energies and entropies in equilibrium systems. More recently, large deviations have been used to study the dynamics of stochastic physical systems, for example in understanding glassy dynamics [1], or the flow of current through simple lattice models [2].

This area offers an opportunity to exploit expertise from mathematics to gain physical insight. Our main aim is to develop methods for characterising certain non-equilibrium states that are defined by constraints on the dynamical properties of physical systems. For example, in a system where the typical (equilibrium) state has no average current, we might analyse rare trajectories where these currents are finite. Ensembles of such trajectories often feature complex emergent structures that we aim to characterise [3].

Specifically, we will concentrate on the hydrodynamic limit of simple particle systems. We will employ constraints either on the current flowing through the system (non-equilibrium), or on constraints on the total amount of activity taking place in the system (relevant for slow/glassy dynamics). Exploiting the hydrodynamic limit in which exact and universal results may be obtained [4], we aim to understand emergent structure within these systems, including the existence of non-equilibrium free energies and possible long-ranged (power law) correlations in particle positions.

These results will have potential application in physical theories of non-equilibrium and of glassy systems, including new insights into the role of hydrodynamic modes for correlations near the glass transition [5].

5. Collaboration information: It is planned to appoint a student working towards a degree in mathematics.

References

[1] L. O. Hedges, R. L. Jack, J. P. Garrahan and D. Chandler, Science **323**, 1309 (2009).

[2] L. Bertini *et al.*, Phys. Rev. Lett. **94**, 030601 (2005).

[3] T. Bodineau and B. Derrida, Phys. Rev. Lett. **92**, 180601 (2004).

[4] S. Adams, N. Dirr, M. Peletier and J. Zimmer, Commun. Math. Phys., to appear.

[5] L. Berthier *et al.*, Science **310**, 1797 (2005).