Book Review

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Ortíz de Zárate, J., Sengers, J.V., Hydrodynamic Fluctuations in Fluids and Fluid Mixtures

The book gives a very clear presentation about hydrodynamic fluctuations in fluid and fluid mixtures. The nature of these fluctuations around non-equilibrium states is surprisingly different from their equilibrium behaviour. In equilibrium, density and temperature fluctuations are correlated over a distance of the order of the size of the molecules, if one is not close to a critical point or line. Away from equilibrium, new terms appear which have algebraic long ranged tails.

The authors discuss the various misconceptions along the road to the present understanding in a very thorough and entertaining way. In particular the microscopic picture proposed by Bogoliubov (1946, 1962) is incorrect. It was based on the view that the fluid away from equilibrium would proceed to equilibrium in two distinct stages: first a kinetic stage with a time scale of the order of intermolecular collisions, after which local equilibrium is established; second the macroscopic hydrodynamic stage. Implicit in this assumption is that the long range contributions described in this book do not exist.

Local equilibrium is the proper assumption to understand non-fluctuating hydrodynamic behaviour. It is clearly not correct, however, to use local equilibrium for the correlation functions of the temperature and the densities. As the authors explain, one should add fluctuating contributions to the dissipative fluxes and assume that the fluctuation-dissipation theorems remain valid at the local values of the temperature and densities in non-equilibrium states. This simple assumption of local equilibrium for the fluctuating contributions to the dissipative fluxes leads to the long range contributions in the correlation functions of the temperature and the densities, derived and discussed in this book. The first introductory chapter gives a good overview of these matters.
The second chapter introduces non-equilibrium thermodynamics without fluctuations. It prepares the reader to construct equilibrium and non-equilibrium solutions around which the analysis of the fluctuations is done. As a first step towards this goal, fluctuations around equilibrium and their short range nature are discussed in the third chapter. In the same chapter two sources of the long range contributions in non-equilibrium states are identified. The first is that the strength of the noise contributions depends for instance on the temperature, which varies through the system. The second are mode-coupling contributions.

In the fourth chapter, fluctuations are studied for a one-component system in a temperature gradient, referred to as the Rayleigh-Bénard problem. Boundary effects are ignored. As everywhere in the book the governing equations are systematically linearized in the fluctuating contributions. Appropriate approximations are made and the structure factor calculated. It is found that the resulting Brillouin peaks have different heights. In the equal time correlation function a long-range contribution proportional to the square of the temperature gradient appears. In the direction normal to the temperature gradient this contribution is proportional to the inverse of the fourth power of the wave vector. Similar behaviour is found in the fifth chapter for mixtures.

Chapters six and seven discuss confinement effects. For free boundaries this is reasonably straightforward. For the more realistic rigid boundaries this requires considerably more, partly numerical, work. An important result is that the behaviour of the long range contribution is proportional to the square of the component of the wave vector normal to the temperature gradient up to a magnitude comparable to the inverse thickness of the fluid layer, above which it becomes proportional to the inverse of the fourth power of the wave vector. An analysis of the real space behaviour is given which shows the long range nature of these contributions and their dependence on the thickness of the fluid layer.

Chapter eight treats the behaviour of the fluctuations when one approaches the Rayleigh-Bénard instability. The authors compare their exact solution with the results of the most unstable mode approximation and the Swift-Hohenberg model and conclude that the most unstable mode approximation is much better.

The analysis in the fifth chapter is extended in the ninth chapter for binary mixtures to include the effects due to confinement. The tenth chapter discusses experimental results. In particular light scattering and shadowgraphy are treated in detail clarifying the experimental consequences of the theoretical results. This is a very appropriate and useful chapter. In a final chapter the authors consider a number of problems which are also very interesting: one-
component fluids under shear; a liquid-vapour interface with a temperature gradient along the surface; nematic liquid crystals and a reaction diffusion system. This is material enough to write another book about.

The book is an impressive contribution to the understanding of fluctuations in non-equilibrium systems. The authors are unbelievably thorough. The equations are explained in detail. Solutions are given. Where needed numerical solutions are presented. Approximate solutions are compared with the numerical solutions. The available literature is discussed and results compared. The experimental verification of the results is discussed in some detail. It is a great book.

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