Thermal Nonequilibrium Fluctuations in Fluids at Mesoscopic Length Scales

J.M. Ortiz de Zarate
Facultad de Ciencias Fisicas, Depto. de Fisica Aplicada 1, Universidad Complutense, Madrid, Spain

J.V. Sengers [C, S]
Institute for Physical Science and Technology and Department of Chemical Engineering, University of Maryland, College Park, MD, U.S.A.

When a fluid layer is subjected to a temperature gradient, while still maintained in a quiescent nonequilibrium state without thermal convection, mesoscopic temperature fluctuations develop due to a coupling of the temperature fluctuations with the transverse-momentum fluctuations through the temperature gradient [1]. In a liquid mixture, also nonequilibrium concentration fluctuations develop due to a coupling with the transverse-momentum fluctuations through the concentration gradient induced by the Soret effect [2]. It has been well established that the intensity of such nonequilibrium fluctuations will be inversely proportional to the fourth power of the wave number of the fluctuations [3].

In the present paper we shall elucidate how the dependence of these thermal nonequilibrium fluctuations on the wave number is affected by gravity and by the boundary conditions resulting from the finite height of the fluid layer. We consider fluid layers with both negative and positive values of the Rayleigh number. Gravity causes the intensity of the nonequilibrium fluctuations to saturate at smaller wave numbers while the boundary effects eventually cause the nonequilibrium fluctuations to vanish with the square of the wave number for extremely small wave numbers. The resulting nonequilibrium structure factor exhibits a maximum at an intermediate value of the wave number [4]. This maximum is present at both negative and positive values of the Rayleigh number, becomes very pronounced for positive Rayleigh numbers and diverges as one approaches the critical value of the Rayleigh number associated with an incipient convective instability. Comparisons with available experimental information will be discussed.

The research at the University of Maryland is supported by the Office of Basic Energy Sciences of the U.S. Department of Energy under Grant No. DE-FG-02-95ER14509.

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