

Comment on “Shear-induced quench of long-range correlations in a liquid mixture”

José M. Ortiz de Zárate and Jan V. Sengers

Institute for Physical Science and Technology, University of Maryland, College Park, Maryland 20742, USA

(Received 1 August 2005; published 6 January 2006)

Recently, Wada [Phys. Rev. E **69**, 031202 (2004)] presented an analysis of the long-range nature of concentration fluctuations in a binary liquid mixture subjected to a concentration gradient in a uniform shear flow as a function of the wave number k of the fluctuations. Specifically, he argued that the presence of a uniform shear causes the intensity of the concentration fluctuations to crossover from the well-known k^{-4} dependence at large wave numbers to a $k^{-4/3}$ dependence for small wave numbers. The purpose of this comment is to point out that the wave-number dependence of the concentration fluctuations to be expected in realistic experimental conditions will be affected by gravity and finite-size effects.

DOI: [10.1103/PhysRevE.73.013201](https://doi.org/10.1103/PhysRevE.73.013201)

PACS number(s): 66.10.-x, 05.20.Jj, 05.40.-a, 78.35.+c

In a recent publication Wada [1] considered nonequilibrium fluctuations in a liquid mixture subjected simultaneously to a concentration gradient and uniform shear flow. He derived an expression for the spatial Fourier transform $C_{cc}(\mathbf{k})$ of the equal-time autocorrelation of the concentration fluctuations as a function of the wave vector \mathbf{k} , a quantity accessible by light-scattering or shadowgraph experiments. It has been well established both theoretically and experimentally that for sufficiently large wave numbers k the intensity of nonequilibrium fluctuations in a liquid subjected to stationary temperature and/or concentration gradients varies as k^{-4} [2,3]. The effect is largest for wave vectors \mathbf{k} perpendicular to the gradient. Wada argues that the presence of shear flow causes a crossover of the intensity of the concentration fluctuations to a $k^{-4/3}$ dependence for small wave numbers, see Fig. 2 and Eqs. (46) and (47) in [1]. He then shows that for usual liquid mixtures the $k^{-4/3}$ dependence will occur at wave numbers smaller than $k_c \approx 10^3 \text{ cm}^{-1}$, corresponding to fluctuations with typical wavelengths of some tenths of a millimeter.

In his analysis Wada neglects any possible buoyancy effects due to gravity. Moreover, in practice one can only induce a stationary shear flow by putting a liquid layer of finite thickness between two moving parallel plates. Hence, for a complete theory of nonequilibrium fluctuations one must also include the effect of the presence of the boundaries on the fluctuating fields not considered by Wada. It has been shown that finite-size effects dramatically affect the nonequilibrium enhancement of the fluctuations for wave numbers $k \approx 1/L$, where L is the height of the fluid layer [4,5], that are comparable to the wave numbers where Wada predicts a $k^{-4/3}$

dependence. For instance, in a liquid layer subjected to a stationary temperature gradient, the intensity of the temperature fluctuations will initially increase with decreasing wave number as k^{-4} , then go through a maximum and then decrease as k^2 for small wave numbers due to the requirement for the temperature fluctuations to vanish at perfectly conducting walls, independent of the boundary conditions adopted for the velocity fluctuations [5]. Shadowgraph experiments have confirmed that the nonequilibrium enhancement of the temperature fluctuations vanishes at small wave numbers [6].

Finite-size effects on concentration fluctuations in liquid mixtures subjected to stationary gradients have also been investigated [7]. Due to the different nature of the boundary conditions for the concentration fluctuations (impermeable walls) one must expect a crossover from a k^{-4} dependence of the intensity of the concentration fluctuations to a finite non-zero value in the $k \rightarrow 0$ limit, an effect qualitatively similar to that of gravity [8]. In any case, the quenching of nonequilibrium fluctuations due to gravity or finite-size effects is stronger than the prediction of Wada.

We conclude that for the interpretation of actual experimental data one cannot neglect gravity and finite-size effects. Although there may be some initial crossover from a k^{-4} to a $k^{-4/3}$ behavior, researchers who plan to investigate concentration fluctuations in a liquid mixture subjected to a stationary concentration gradient in the presence of shear flow should expect to observe a wave-number dependence of the intensity of the concentration fluctuations that at small wave numbers will be significantly affected by gravity and finite-size effects.

[1] H. Wada, Phys. Rev. E **69**, 031202 (2004).

[2] T. R. Kirkpatrick, E. G. D. Cohen, and J. R. Dorfman, Phys. Rev. A **26**, 995 (1982)

[3] B. M. Law and J. C. Nieuwoudt, Phys. Rev. A **40**, 3880 (1989).

[4] L. Torner and J. M. Rubí, Phys. Rev. A **44**, 1077 (1991).

[5] J. M. Ortiz de Zárate and J. V. Sengers, Physica A **300**, 25

(2001); Phys. Rev. E **66**, 036305 (2002).

[6] M. Wu, G. Ahlers, and D. S. Cannell, Phys. Rev. Lett. **75**, 1743 (1995).

[7] J. M. Ortiz de Zárate, F. Peluso, and J. V. Sengers, Eur. Phys. J. E **15**, 319 (2004).

[8] A. Vailati and M. Giglio, Phys. Rev. Lett. **77**, 1484 (1996).