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Turbulence in buoyancy-driven bubbly flows

Vikash Pandey[1,2], Dhrubaditya Mitra[2], Prasad Perlekar[1]
[1] Theory Physics Group, TIFR Hyderabad, India, [2] AlbaNova Univ. Center, NORDITA, Sweden.
e-mail (speaker): perlekar@tifrh.res.in

Rising bubbles in water show fascinating dynamics, even a single bubble may not rise vertically upward in still water as was already noted by Leonardo da Vinci. The dynamics of many rising bubbles, as you usually see in a glass of champagne or in a fish tank, show a kaleidoscope of behavior. Although bubbly flows are important in many industrial and natural processes, e.g., aeration and boiling, accurate measurements of velocity fluctuations of such flows have been possible only recently.

What is the flow generated when a fluid is stirred by a dilute suspension of bubbles as they rise due to buoyancy? Expectedly, the bubbles stir the fluid and generate a chaotic flow. This chaotic flow, often called pseudo-turbulence, has been recently studied extensively using experiments, theory, and computer simulations [1-4]. The general belief is that such bubbly flows are very different from usual turbulent flows, that are described by a theory originally formulated by A.N. Kolmogorov in 1941 [5].

Our recent results radically change this picture [6]. We present state-of-the-art numerical simulations and analysis to show that, contrary to the general belief, the bubbly flows possess characteristics of both Kolmogorov-like turbulence at large scales and signatures of pseudo-turbulence at small scales [6]. The two regimes are clearly observed when the viscosity of the fluid is sufficiently small, or the bubbles rise fast enough. We have extended the range of parameters explored even in the cutting-edge experiments but not beyond what we believe is experimentally accessible.

References

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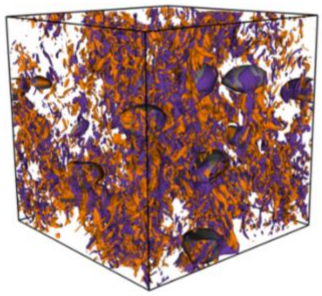

Figure 1: The iso-contour plot of the z-component of the vorticity in a turbulent bubbly flow. We show the contour corresponding to positive (negative) values in purple and orange respectively. The bubbles are represented using grey contours.