An experimental study on particle-pair dispersion in bubble-induced turbulence

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Bubble-induced turbulence (BIT) plays an important role in mixing, transport and collision of small particles in many natural and industrial applications. Most of our knowledge about the physics of BIT, comes from Eulerian measurements[1], having statistics at fixed points with respect to some reference frame. In recent years, Lagrangian measurements following the motion of individual fluid tracers have become possible in bubbly flows[2]. A crucial component of the Lagrangian description of BIT is the relative pair dispersion, based on the relative separation $r(t) = \|\mathbf{x}_2(t) - \mathbf{x}_1(t)\|$ of two fluid particles at respective positions $\mathbf{x}_1(t)$ and $\mathbf{x}_2(t)$ at time t. The present work is aimed to address this topic. Here, we report the first experimental study of particle-pair dispersion in BIT for varying initial separations. To this end, 3-dimensional Lagrangian particle tracking measurements[3] are carried out in an octagonal bubble column in which the flow is generated by a homogeneously distributed bubble swarm (Fig. 1a) rising in water. The results (Fig. 1b) show that the relative dispersion follows the classical ballistic regime at short times. After this, the dispersion transitions to another regime whose behaviour seems to depend on the initial separation. We are currently obtaining improved data to explore and understand in more detail the relative dispersion behaviour at intermediate and long times.

(a) (b)

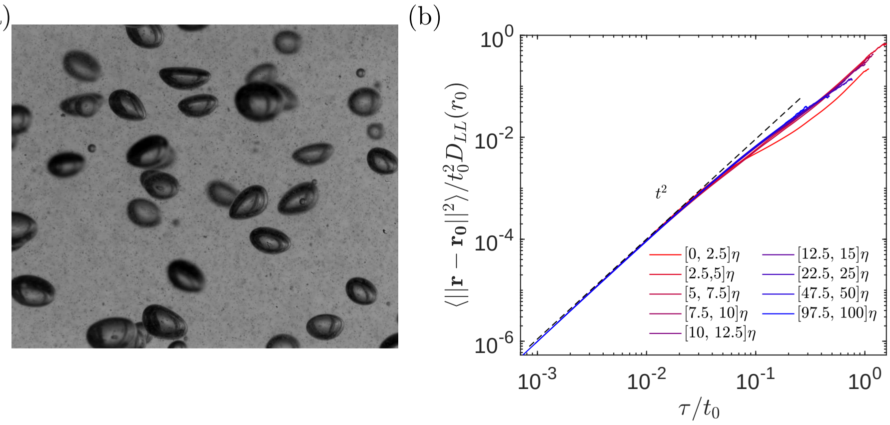

Figure 1: (a) Sample shadowgraphy images from our experiment. (b) Relative pair separation $\langle\|\mathbf{r} - \mathbf{r}_0\|^2\rangle$ for various initial separations $r_0 = 0$–2.5η, 2.5–5η, ..., 97.5–100η. Here, η is the estimated Kolmogorov scale and D_{LL} is the longitudinal second-order structure function.

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[1] Ma et al., *J. Fluid Mech.* **936**, A42 (2022).
[2] Sommer et al., *Miner. Eng.* **124**, 116–122 (2018).
[3] Tan et al., *Exp. Fluids* **61**, 47 (2020).