Passive scalar spectra in turbulent suspensions of bubbles

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While the scaling of the velocity spectra in bubble-induced turbulence is well established in the current literature[1], the passive scalar spectrum behaviour has not been deeply investigated. We use Direct Numerical Simulations (DNS) of bubbly flows transporting passive scalars at different Schmidt (Sc) numbers that the scalar spectra show a transition from a $k^{-5/3}$ to a k^{-3} scaling with the wavenumber k, in contrast with those of single-phase isotropic turbulence. In addition, the scalar spectrum shows an even steeper scaling at high wavenumbers for the cases with a mean scalar gradient in the horizontal direction. This transitional length is comparable to or below the bubble diameter and decreases with the molecular diffusivity of the scalar in the liquid phase. Using the equations for the scalar spectral budget, we find that the mean scalar gradient produces the scalar fluctuations at length scales above the bubble diameter, contrary to the velocity fluctuations and that the scalar transfer term scales as k^{-1}, confirming the hypothesis proposed in a recent experimental work[2]. Finally, we calculate the bubble suspension's convective scalar diffusivity that differs based on the direction of the mean scalar gradient depending on the gas volume fraction and molecular diffusivity in the liquid.
A more detailed description of the results can be found in our work[3].

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[1] Risso, *Ann. Rev. Fluid Mech.* **50**, (2018).

[2] Dung et al., *J. Fluid Mech*. **958**, A5 (2023).

[3] Hidman et al., https://arxiv.org/abs/2211.06293

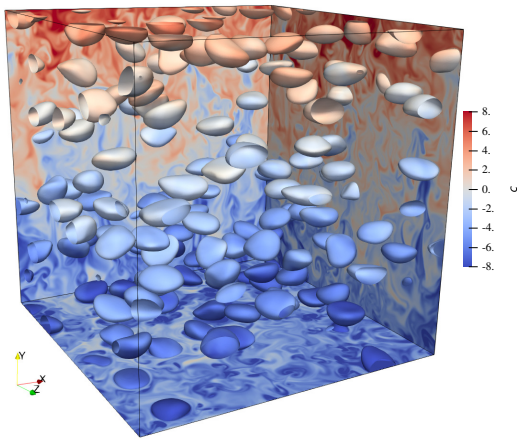

Figure 1: Instantaneous snapshot of the total scalar field at Sc=7 for a suspension at 5% of volume fraction.