Stochastic deformations of bubbles in turbulence

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Bubble deformation and fragmentation in turbulent flows play a major role in gas exchanges, being responsible, for instance, for up to 40% of the CO_2 transfer[1]. In turbulent flows, bubble fate is controlled by the ratio between inertial and capillary forces, namely the Weber number, We. Due to the inherent stochasticity of turbulent flows, however, the critical Weber number that separates breaking bubbles ($\mathrm{We}>\mathrm{We}_c$) from non breaking bubbles ($\mathrm{We}<\mathrm{We}_c$)[2] is only defined in a statistical sense, and it strongly depends on the observation time as reported by several authors[3,4]. To rationalize the definition of the critical Weber number, we perform direct numerical simulations of a single bubble in an homogeneous and isotropic turbulent flow, as illustrated in Figure 1a, and study the dynamics of bubble deformations. We decompose the bubble interface into the spherical harmonics base and follow the amplitude of every mode in time. An example is given on Figure 1b for the mode (2, 0) at two different Weber numbers. We quantify the evolution of the modes standard deviation and their correlation time as a function of We. We show that the modes amplitude can be described by a stochastic oscillator whose parameters depend on the flow statistics. We measure the probability density function of each mode, and deduce the probability that the deformations pass, in a given time window, a critical value for break-up. This procedure leads to a critical Weber which depends on the observation time.

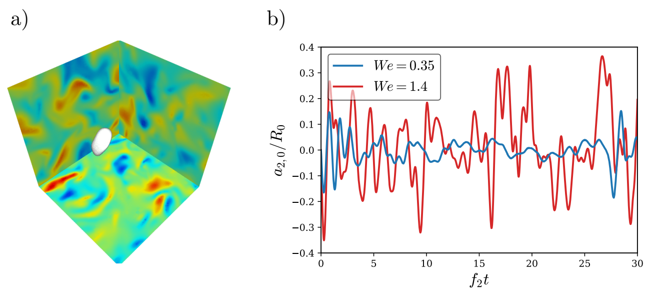

Figure 1: (a)Snapshot of a bubble (in white) in a turbulent flow at We = 1. Background planes represent each velocity component. (b) Amplitude of the mode (2, 0) of deformation, divided by the initial bubble radius R_0, as a function of the dimensionless time $f_2 t$, where f_2 is the mode 2 oscillation frequency, for two different Weber numbers at a Taylor Reynolds number of 55.

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