Large scale fluctuations in hydrodynamics turbulence

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Turbulent flows in three dimensions of space involve a direct cascade of energy from a large scale l_0 to a much smaller Kolmogorov length scale η. In the limit of large Reynolds number, the statistical properties of the inertial range $1 \ll kl_0 \ll l_0/\eta$ have been well studied, starting from the analytical predictions given by Kolmogorov in 1941, and much refined since then. However, the dynamics of large scales ($kl_0 \ll 1$) have been much less studied experimentally, in particular in the absence of large scale forcing such as rotation or stratification. Several analytical predictions for the mean wavenumber energy spectrum $E(k)$ at small wavenumber k have been proposed over the years, in particular by Saffman with $E(k) \propto k^2$ [1] and by Batchelor with $E(k) \propto k^4$ [2]. Up to date, both the Saffman and Batchelor spectra lack direct experimental evidence.

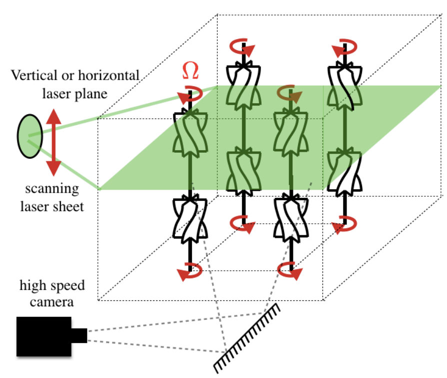

Figure 1. Sketch of the experimental set up. A tank of 15 x 15 x 15cm is forced with 8 chiral helices, setting an integral length scale $l_0 \approx 6$ mm significantly smaller than the system size.

We designed an experiment to study these large scale velocity fluctuations. Using 8 chiral helices as forcing elements (see figure), we achieve a significant scale separation between the forcing scale and the experiment size allowing us to investigate the large scale statistics. We use index matching technique to obtain full optical access in the tank, in order to measure the velocity field in the bulk. Using an upgraded 3D scanning PIV technique, we measure the three dimensional two point velocity correlation function. We report the observation of the Saffman spectrum over a wide range of Reynolds numbers studied in the experiment. Our observation would imply a thermalization of the large scale fluctuations in a turbulent flow. These experimental results show that the large scale fluctuations may be described by equilibrium statistical mechanics, contrary to the direct cascade of energy.

Références

1. G. K. Batchelor & I. Proudman, The large-scale structure of homogenous turbulence, *Phil. Trans. Royal Soc.*, (1956)
2. P. G. Saffman, The large-scale structure of homogeneous turbulence, *Journal of Fluid Mechanics* (1967)