Spontaneously generated temperature fluctuations in turbulent flows

Gaurav Prabhudesai[1], Stephane Perrard[1,2], François Pétrélis[1], Stephan Fauve[1]

[1] Laboratoire de Physique de l'École Normale Supérieure, CNRS, PSL Research University, Sorbonne Université, Université de Paris, F-75005 Paris, France
[2] Laboratoire PMMH, UMR 7636, ESPCI, Université PSL, 10 quai Saint Bernard, 75005 Paris
gaurav.prabhudesai@ens.fr

In the absence of external heat sources, temperature fluctuations can still be generated spontaneously in turbulent flows. In the incompressible limit, two mechanisms lead to the generation of spontaneous temperature fluctuations; viscous dissipation and adiabatic heating/cooling driven by incompressible pressure fluctuations [1]. The effect of adiabatic heating/cooling is usually neglected since it is proportional to the coefficient of thermal expansion of the fluid β which is usually small ($\beta \approx 2 \times 10^{-4}\ K^{-1}$ for water and $\approx 3 \times 10^{-3}\ K^{-1}$ for air).

We design an experiment to study these spontaneously generated temperature fluctuations in a closed von Kármán swirling flow of air at Mach number of order 10^{-3} and whose boundaries are maintained at a constant temperature. We observe intermittent peaks of low temperature (fig. 1) correlated with pressure drops within the flow and show that they are caused by vorticity filaments. The measured ratio of temperature to pressure fluctuation agrees with the prediction based on adiabatic cooling within vortex cores. Relying on this property, a model for vorticity filaments is presented that captures the spatial structure of its temperature field. This experimental study shows that although the Mach number of the flow is small, there exist regions within the flow where compressible effects cannot be discarded and locally dominate the effect of viscous dissipation.

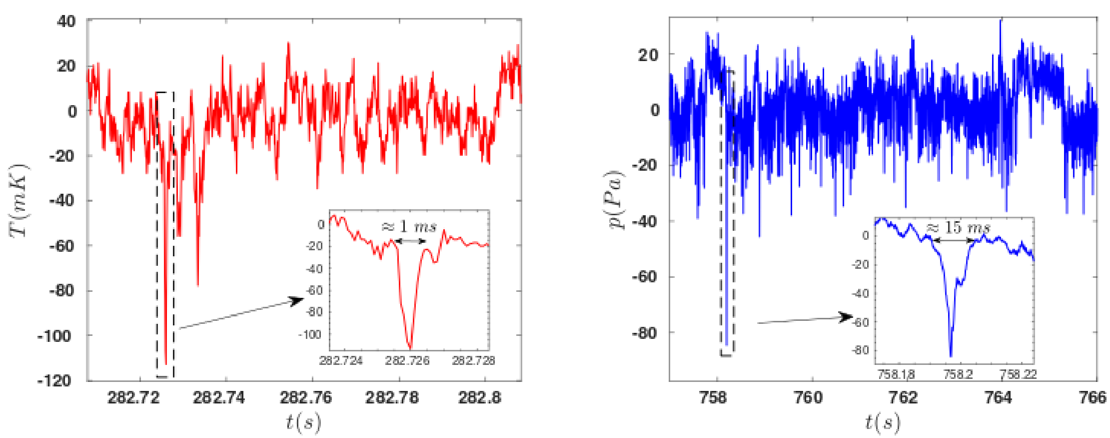

Figure 1. (a) Time series of temperature fluctuations measured in the bulk. (b) Time series of pressure fluctuations measured at the boundary. Inset figures show the zoom of one negative peak observed in temperature and pressure fluctuations.

References

1. BJ Bayly, CD Levermore, T Passot, *Physics of Fluids A: Fluid Dynamics*, **4**, 945–954, (1992)