Tracking dissipative structures from PIV measurements: a new criterion to detect singularities in experimental flows

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A well known experimental fact is that the energy dissipation rate of turbulent flows remains constant in the limit of vanishing viscosity [1], a phenomenon referred to as the dissipation anomaly . In the late 40's, Onsager [2] suggested to connect this observation to the appearance of singularities in solutions to the Navier-Stokes equations, the existence of which was postulated by Leray in 1934 [3]. Since then, mathematicians have failed to prove rigorously such a conjecture [4]. From a physicist point of view, most attempted detection of singularities have been done via numerical simulations. They are, however, strongly limited by the resolution and the computing time. Part of these limitations are relaxed when performing experiments with turbulent flows. Indeed, in a well-designed experiment, one can reach fairly easily large Reynolds numbers and monitor the velocity field for time long enough (minutes to hours) to accumulate enough statistics for reliable data analysis. In the past, exploration about the dissipative anomaly and potential singularities of Navier-Stokes equations has been limited by the data instrumentation, since only global (torque), or local measurements in space (hot wire) or in time (photography) were available. With the advent of modern Particle Image Velocimetry, measurements of the velocity fields over the decimetric to millimetric size range are now available, at frequencies from 1Hz to 1kHz, providing data comparable with outputs of large eddy simulations. In this presentation, we discuss the Duchon-Robert energy balance equation [5] to infer a singularity criterion based on energy dissipation through scales. From this criterion, we derive a PIV-based method to detect potential singularities in experimental flows.

References

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