Isaac Newton Institute for Mathematical Sciences

The Nature of High Reynolds Number Turbulence

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Turbulence holds a unique place in the field of classical mechanics. Despite the fact that the governing equations have been known since 1845, there is still surprisingly little we can predict with relative certainty. Of course, this is more than a little inconvenient, as turbulence is all around us. For example, it controls the drag on cars, aeroplanes and bridges, and dictates the weather through its influence on large-scale atmospheric and oceanic flows. The liquid core of the earth is turbulent, and it is this turbulence which maintains the terrestrial magnetic field against the natural forces of decay. Even solar flares are a manifestation of turbulence, since they are triggered by vigorous motion on the surface of the sun.

From a physical point of view turbulence may be regarded as an evolving velocity field which is spatially complex and chaotic in both space and time. Despite this complexity, it is observed that turbulence exhibits many near-universal features, particularly at high Reynolds numbers. In many ways this is surprising, and we still do not understand what lies behind this universality. The early ideas developed by Richardson, Taylor, Prandtl and Kolmogorov are still highly influential in our thinking, yet the status of these ideas is, perhaps, little more than plausible conjecture.

However there is, perhaps, room for cautious optimism. This positive view arises in part from the recent spectacular advances in the numerical simulation of turbulence. For the first time in the history of turbulence the simulations are good enough to probe the fundamental structure of high Reynolds number turbulence. This has the great advantage of allowing us to see directly the structure of the velocity field, and to interrogate its statistical properties, rather than having to rely on indirect measurements for this information.

Of course, numerical simulations are not, in themselves, sufficient to unlock the mysteries of turbulence. They provide only raw material which, in the absence of a theoretical construct, has little nutritive value. So it is crucial that those performing the computations engage in debate with the broader community. It is also important to confront the simulations with experimental data, as every simulation involves some form of compromise. It is fortunate, therefore, that in parallel with the computations, the quality of the experimental data is becoming increasingly high.

So the next few years promise to be an interesting time as classical phenomenological theories are put to the test and as mathematicians and scientists argue about the significance of the new computational and experimental data. The goal of this programme is to bring together leading experts from across the world to debate these fundamental questions.

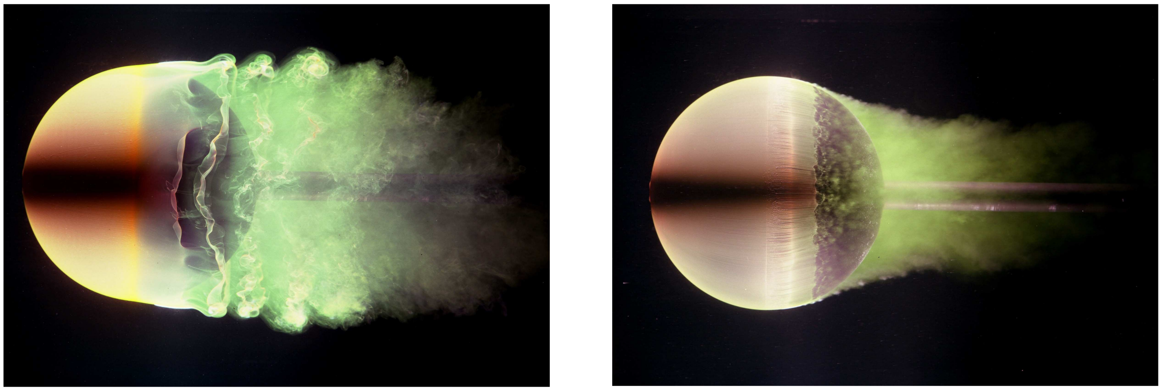

Figure caption: Flow past a sphere at two slightly different Reynolds numbers: (a) Re = 2×10^4, and (b) Re = 5×10^5. Note how much the turbulence has changed. [Photograph by H. Werle of ONERA, courtesy of J. Delery.]