The Reynolds number dependencies of grid turbulence

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Because of the unique capabilities of the Variable Density Turbulence Tunnel, we are able to investigate nearly homogeneous and isotropic turbulence over a wide range of Reynolds numbers. The choice of pressurizable Sulfur Hexafluoride as a working gas makes it possible to reach extremely high Reynolds numbers without changing boundary conditions. In this talk, we focus on the question whether there is scaling in turbulence and how it changes with Reynolds number, as well as on the fundamental question of how fast turbulent energy decays once it has been produced.

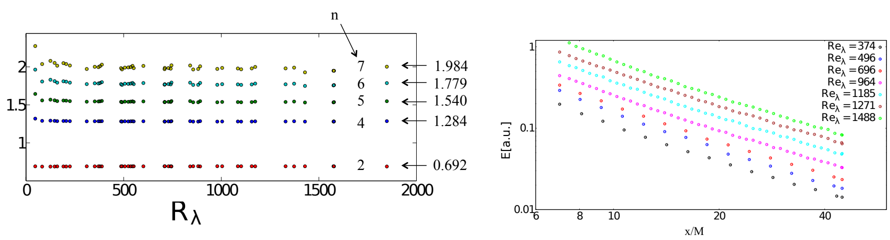
Scaling in turbulence

We study turbulence in the Variable Density Turbulence Tunnel, which is a pressurizable wind tunnel that generates highly turbulent, nearly isotropic and homogeneous flows. This is done using sulfur hexafluoride pressurized up to 15 bar as a working gas. This provides varying Taylor scale Reynolds numbers $\mathrm{Re} = u\lambda/\nu$ higher than those of any comparable experimental facility. Turbulence is produced by a classical grid of crossed bars and measured with NSTAPs, nano scale temperature anemometer probes developed at Princeton university[1].

It is believed that turbulence exhibits power-law scaling in certain statistical quantities. A famous example is the Kolmogorov's theory on the scaling of structure functions[2], followed by many refined theories in the following years. However, a distinct experimental or numerical verification in a strict sense is yet to be done. The Variable Density Turbulence Tunnel allows us to identify the scaling exponents of n-th order over a wide range of Reynolds number showcasing their universality and reproducibility.

Decay of turbulence

One of the unsolved problems in turbulence is the answer to the question of how fast turbulent energy decays in time. Common consensus is that the decay can be modeled with a power law function with an exponent between 1.1 and 1.4[3,4]. A more precise understanding of this decay exponent, especially concerning it's dependence on relevant parameters, is still lacking. There are some hints that this decay exponent might exhibit a Reynolds number dependence[5]. In the Variable Density Turbulence Tunnel we are able to change the Reynolds number independently of any boundary condition, making it possible to check systematically for a Reynolds number dependence.



(a) (b)

Figure 1: (a): The Reynolds number independence of the first few scaling exponents of the velocity differences structure functions. (b): The decay of turbulent kinetic energy for various Reynolds numbers with increasing distance from the grid. The data is staggered for better visibility.

[1] Bailey, S. C. C., Kunkel, G. J., Hultmark, M., Vallikivi, M., Hill, J. P., Meyer, K. A., Tsay, C., Arnold, C. B., Smits, A. J., J. Fluid Mech. 11, 160-179 (2010)
[2] Kolmogorov, A. N., Dokl. Akad. Nauk SSSR 30, 299-303 (1941)
[3] Krogstad, P., Davidson, P., J. Fluid. Mech 642, 373-394 (2010)
[4] Comte-Bellot, G., Corrsin, P., J. Fluid. Mech 25, 657-682 (1966)
[5] Kurian, T., Fransson, J. H. M., Fluid Dyn. Res. 41, 1-32 (2009)