A SYSTEMS APPROACH TO WALL TURBULENCE

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The potential impact of control of turbulence near walls, particularly in the context of the energy expenditure and emissions associated with overcoming turbulent skin friction, is well known. At the level of fundamental understanding, the ability to effect practical control in applications such as commercial air vehicles would imply a significant advance in understanding of the dynamics and scaling of turbulence. In recent work, we have described an approach to understanding the scaling behavior of wall turbulence based on a gain analysis of the resolvent formulation of the Navier-Stokes equations. The picture at each wavenumber/frequency combination is essentially that of linear dynamics of wavelike fluctuations around the turbulent mean velocity profile associated with the selective response of the resolvent, forced by nonlinear triadic interactions from other wavenumbers and frequencies. This formulation permits the treatment of wall-bounded turbulent flow using the elegant theoretical tools of systems theory, revealing information about how the system behaves as a whole, inclusive of the nonlinearity, but in tractable and compact form. In this talk, I will outline the underlying resolvent analysis and give examples of its post- and pre-dictive power with respect to observations of real wall turbulence, including scaling behavior of velocity fluctuations, coherent vortical structure and strategies for control.

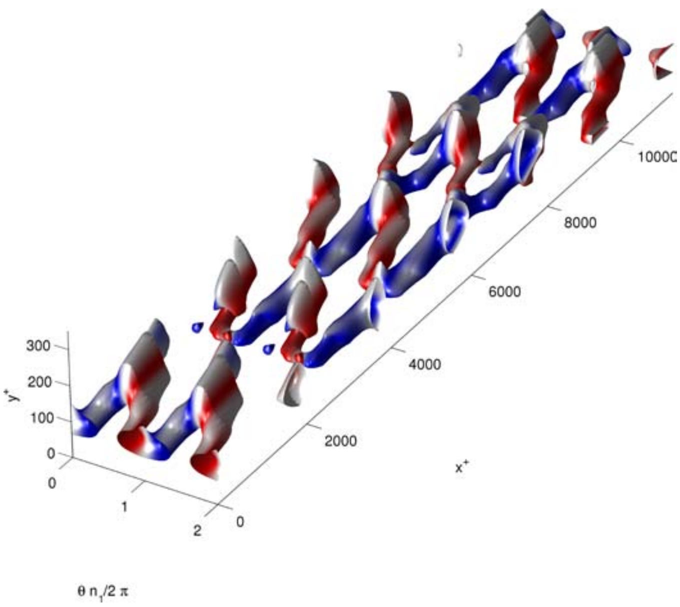

Figure 1. Isosurfaces of swirling strength colored by wall normal vorticity for a combination of two velocity response modes from the resolvent analysis of [1] and mean shear reveal a structure reminiscent of hairpin vortex packets.

References

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