Experimental investigation of turbulent superstructures in canonical boundary layers along flat plates with zero pressure gradient

Turbulent flows along a flat plate with zero pressure gradients (ZPG) have been investigated in great detail in the last several decades due to the vast scientific and technological interest for this type of canonical flow. Of particular focus in the last two decades has been large-scale coherent motions called superstructures. These superstructures appear as meandering high- and low-momentum flow motions within the log-law region. A remarkable feature of these structures is that they can extend up to several boundary layer thicknesses (δ) in the streamwise direction. In addition, they strongly meander in the spanwise direction and it has been shown that they can carry a relatively large portion of the turbulent kinetic energy, especially at large Reynolds numbers. These highly ordered coherent fluid motions are very important as the complex turbulent exchange phenomena can be explained qualitatively taking the presence and interaction of these structures into account. However several questions arise, namely, if a family of turbulent superstructures exists or if the turbulent superstructures observed in experiments are a superposition of individual large scale structures or if different superstructures exist depending on the intensity of the structures. Therefore, a canonical turbulent boundary layer flow along a flat plate with zero pressure gradient (ZPG) will be investigated at Reynolds numbers up to Re_θ = 100,000 in the Atmospheric Wind tunnel Munich (AWM). Furthermore, the Trisonic Wind tunnel Munich (TWM) will be used to study the effect of Mach number on superstructures in a ZPG turbulent boundary layer between 0.3 < Mach < 3.0. High resolution 2D and 3D PIV/PTV measurement techniques the size, shape and organization of the turbulent superstructures, their dynamics and mutual interaction and near their interaction with low-speed streaks near the wall and the surrounding flow field will be examined.

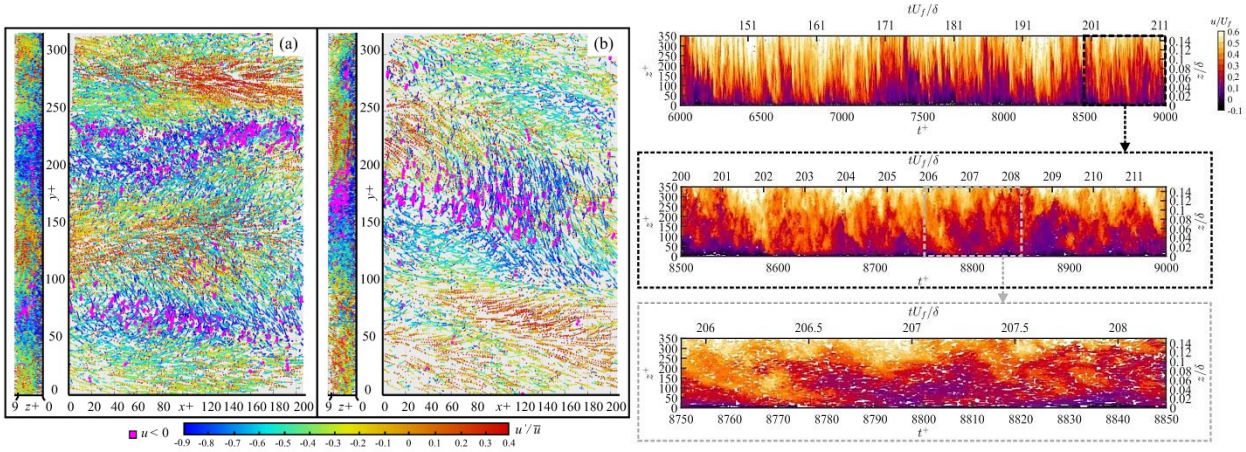

Figure: (left) Near-wall streaky coherent motions measured with 3D time-resolved PTV. (right) Time record of coherent structure layers in near-wall and log-law regions measured with 2D time-resolved PTV.

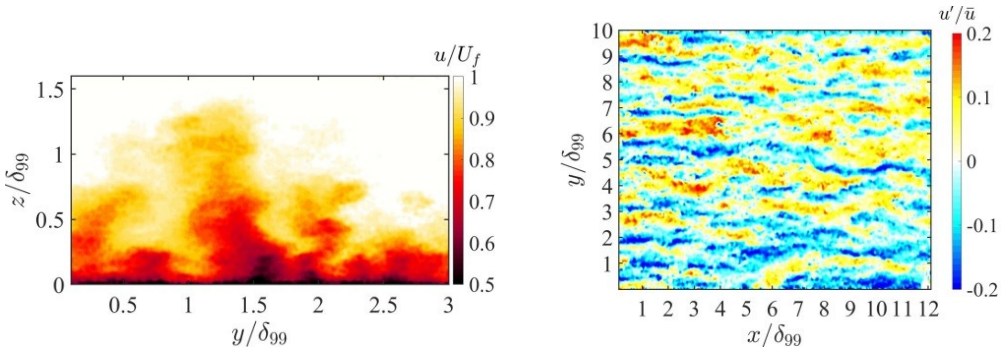

Figure: (left) Cross-stream view of superstructures in a ZPG turbulent boundary layer at Mach = 0.3. (right) Meandering high- and low-momentum superstructures in log-law layer at Mach = 2.0.