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Area of expertise

Two paradigms of streak formation in turbulent flows

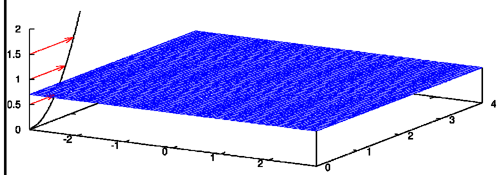

Fig.1

Streaks are elongated regions where the instantaneous velocity is below average. A visualisation plane parallel to the wall (Fig.1) with areas of small velocity painted black is shown in Fig.2. Streaks are very important in turbulence. But why are they there? One thing is well established: areas of smaller velocity appear because there are wall-normal motions transporting slow-moving near-wall fluid away from the wall. This is called a lift-up mechanism. But why do these areas have a pattern?

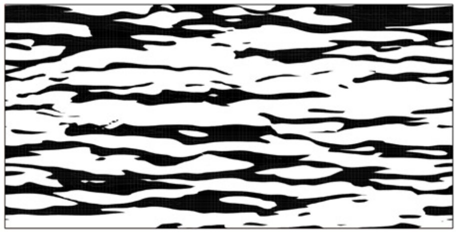

Fig.2

The answer that have been accepted for a long time was that the streaks have a pattern because the wall-normal motions have a pattern. Imagine, for example, a row of alternatively-rotating longitudinal vortices above a near-wall region of slow-moving fluid (Fig.3). On one side of the vortex the fluid moves up, and on the other it moves down, thus forming alternating elongated stripes of upward and downward motions. The upward motions carry up the slow-moving fluid, and when it crosses the visualisation plane (Fig.4) streaks become visible.

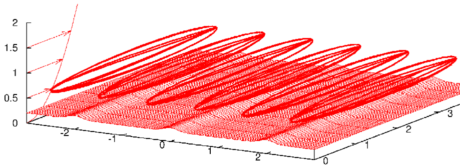

Fig.3

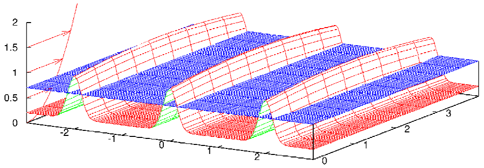

Fig.4

There is a conceptually different explanation. Consider the case when the wall-normal velocity has no pattern at all. Such upward motions alone will lead to patches in the visualisation plane having no pattern (Fig.5). Shear will then tilt the peaks, shifting the picture in the visualisation plane, but not adding any pattern (Fig.6). Then diffusion will smear this in wall-normal direction, and streaks will become visible (Fig. 7). Here, the pattern of streaks is dictated by the pattern-forming properties of combined lift-up, shear, and diffusion. The wall-normal motions might have no pattern at all.

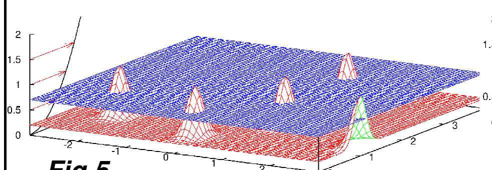

Fig.5

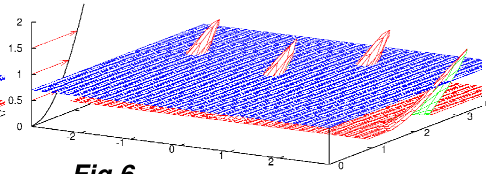

Fig.6

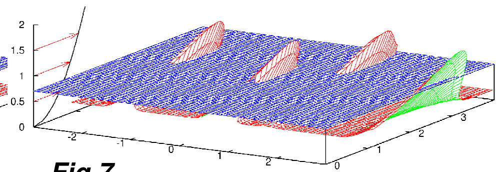

Fig.7

Careful numerical experiments supported the new paradigm. Since the pattern-forming mechanism is linear, within the new paradigm predictions can be made on the basis of the linearised Navier-Stokes equations. Fig.8 shows the plot of predicted vs. actual values of the streak spacing for a large variety of conditions. The theory was further confirmed by predicting the structure of the flow on a spanwise oscillating wall in drug-reduction regime. This result is described in a separate leaflet.

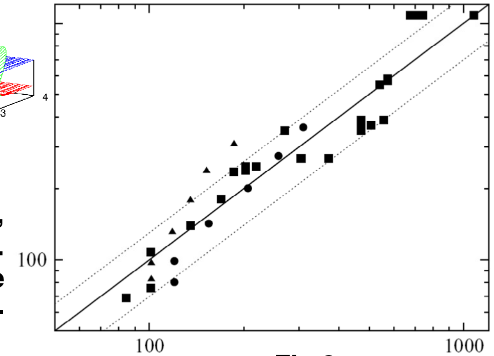

Fig.8

More information: Chernyshenko S.I. & Baig M.F. The mechanism of streak formation in near-wall turbulence, J. Fluid Mech., 2005, Vol:544, 99-131