Revisiting Taylor's Hypothesis for Homogeneous Turbulent Shear Flow

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Taylor's hypothesis of frozen flow has frequently been used to convert temporal experimental measurements into a spatial domain[1]. Thus Taylor's hypothesis, also know as frozen turbulence hypothesis, can be used to infer time dependencies from the spatial description of the turbulence. Its validity is of crucial importance for experimental studies and theoretical investigations.

Direct numerical simulations of homogeneous turbulent shear flow with a constant shear rate $S = \partial U/\partial y$ are performed and analyzed using a scale-dependent, wavelet-based approach. Taylor's Hypothesis is revisited by consideration of the correlation of the Eulerian acceleration with the convective acceleration. As stated by Pinsky et al.[2], "The hypothesis states that the velocity fluctuations at a certain point of the turbulence are caused mainly by advection, and the full (Lagrangian) accelerations of a fluid parcel turn out to be zero. In other words, the complete compensation of temporal (local) and inertial accelerations takes place." Fig. 1 shows the joint probability distribution functions (pdfs) of the the Eulerian and convective accelerations and at large scales (left) and small scales (right) of the turbulent motion. The two accelerations only show a strong anti-correlation at small scales, but not so at large scales. Additionally, the angle between the two accelerations is evaluated (not shown here) and again anti-correlation is observed at small scales, but not at larger scales of the turbulent motion. Hence, Taylor's hypothesis applies to the small scale motion in homogenerous turbulent shear flow, but it does not hold at larger scales, which is in agreement with Tennekes[3].

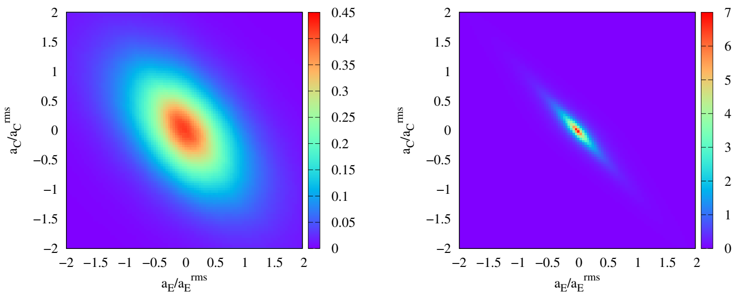

Figure 1: Joint probability distribution functions (pdfs) of the the Eulerian acceleration and the convective acceleration at large scales (left) and small scales (right) of the turbulent motion.

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[1] Taylor, *Proc. R. Soc. Lond.* **164**, 476 (1938).
[2] Pinsky et al., *Phys. Fluids* **12**, 3195 (2000).
[3] Tennekes, *J. Fluid Mech.* **67**, 561 (1975).