§ 26. Intermittency and Field Structure in MHD and NS Turbulence

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In the MHD and Navier-Stokes turbulence the energy is supplied at large scales of motion and transferred to smaller scales due to the hydrodynamic and/or resistive instability. The nonlinear interaction among wavevector components of the magnetic and velocity fields generates an organized structure in the fields with various size which often reaches macroscopic scale. The motion of the fluids and plasmas of various scales interacts each other, so that when the scale of the motion decreases, the fluctuation of the fields becomes stronger and the statistics deviates from the Gaussian, the intermittency. It is believed that after many times of cascade step towards smaller size the motion of the field forgets the memory at large scales and the statistical isotropy is recovered. However, it is expected that when there exists strong interaction among the small and large scales of motion through the organized structure the local isotropy of the fields is not be recovered. The spatial structure of the fields has so far been studied by graphical visualization, but shape and size depend critically on the threshold value at which the fields are visualized. The field structure with high amplitudes of the fields appears also in the long tail of the probability density function (PDF) and the high order moments of the velocity and magnetic increment with a separation r.

We have studied the structure functions of the longitudinal and transverse velocity increments defined by $\delta u(\boldsymbol{r}) = (\boldsymbol{u}(\boldsymbol{x}+\boldsymbol{r}) - \boldsymbol{u}(\boldsymbol{x}))\cdot \boldsymbol{r}/r$ and $\delta \boldsymbol{v}(\boldsymbol{r}) = (\boldsymbol{u}(\boldsymbol{x}+\boldsymbol{r}) - \boldsymbol{u}(\boldsymbol{x}))\cdot(1-\boldsymbol{rr}/r)$, respectively. The scaling behavior of the structure functions in the inertial range for the NS turbulence and decay of the anisotropy with decrease of scales were studied. The structure function is defined as

$$S_{p,q}(\boldsymbol{r}) = \langle |\delta u(\boldsymbol{r})|^p |\delta \boldsymbol{v}(\boldsymbol{r})|^q \rangle \tag{1}$$

which depends on the direction $\boldsymbol{r}$. The steady NS turbulence was maintained by adding a random isotropic force at low wavenumbers. The structure function $S_{p,q}(\boldsymbol{r})$ was computed and expanded in terms of the spherical harmonics as

$$S_{p,q}(\boldsymbol{r}) = \sum_{l,m} S_{p,q}^{l,m}(r) Y_{lm}(\theta,\phi). \tag{2}$$

The scaling exponent of the expansion coefficient $S_{p,q}^{l,m}(r)$ was measured. When the field is exactly isotropic, the coefficients other than the isotropic part $S_{p,q}^{0,0}(r)$ vanish, but in reality, there is a residual anisotropy in the field. We have computed the anisotropic expansion coefficients and compared the rate of decay. It was found that the isotorpic coefficients $S_{2m,0}^{0,0}(r)$ and $S_{0,2n}^{0,0}(r)$ have the scaling range with the finite width as expected. The scaling exponent is defined by $S_{2m,0}^{0,0}(r) \propto r^{\zeta_{p,q}^{0,0}}$. We observed that $\zeta_{2m,0}^{0,0}$ is larger than $\zeta_{0,2m}^{0,0}$ for $2m > 4$. This means that the transverse velocity increment has fluctuations stronger than the longitudinal ones, which is consistent with the existence of strong vortex tubes in turbulence.

As for the anisotropic components, the coefficients $S_{2k,0}^{l,m}$ and $S_{0,2k}^{l,m}$ decay more slowly than the case of the isotropic ones when $2m$ becomes large. Moreover the decay rate of $S_{0,2k}^{l,m}$ is smaller than that of $S_{2k,0}^{l,m}$.

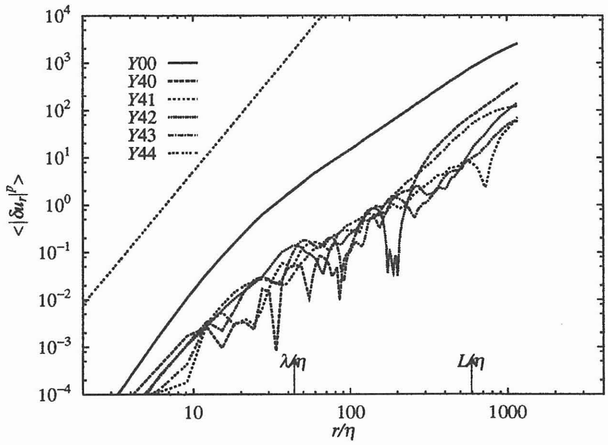

Fig.1 Decay of the isotropic component $S_{8,0}^{0,0}(r)$ and anisotropic component $S_{8,0}^{4,m}(r)$ for the longitudinal structure function at the eighth order. $R_\lambda = 460$.

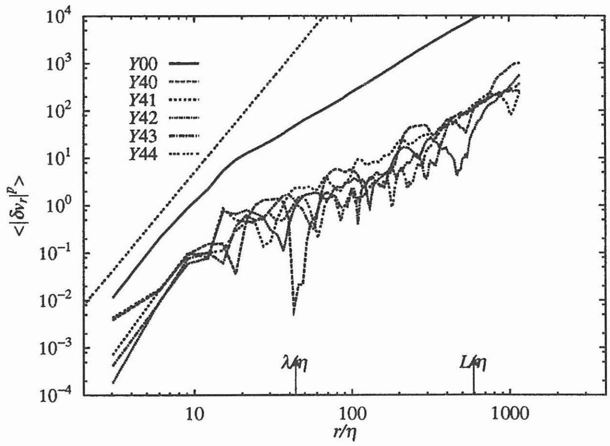

Fig.2 Decay of the isotropic component $S_{0,8}^{0,0}(r)$ and anisotropic component $S_{0,8}^{4,m}(r)$ for the transverse structure function at the eighth order. $R_\lambda = 460$.

Reference

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2) Arad, I., L'vov, V. S., and Procaccia, I., Phys. Rev., **59**, (1999) 6753.