§7. Nonlocal Nature of the Energy Transfer to Magnetic Fields in Magnetohydrodynamic Turbulence

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Orthonormal divergence-free wavelet analysis of energy transfer from velocity field to magnetic field due to some isolated vortices is carried out.

Distribution of scale-to-scale wavelet nonlinear energy transfer

$$N_{jk} := -\int \boldsymbol{u}_j \cdot (\boldsymbol{u} \cdot \nabla)\boldsymbol{u}_k d^3\vec{x}$$

is shown in Fig.1. Since N_{jk} satisfies the balance condition $N_{jk} = -N_{kj}$, the graph is odd with respect to the line $j = k$. If N_{jk} has positive value at (j, k), it implies that energy is transferred from $E_j^{(u)}$ to $E_k^{(u)}$ by N_{jk}. Since positive peaks are aligned at $k = j + 1$, the following two characteristics are concluded: (1) energy is transferred from larger scales to smaller ones, and (2) the dominant nonlinear transfers are local. Although the flow is not fully developed turbulent state but has only several large rolling-up vortices, this tendency is quite similar to that of fully developed three dimensional turbulent flow[1)].

Energy transfer between the velocity and magnetic fields by magnetic induction

$$L_{jk} = \int \boldsymbol{u}_j \cdot (\nabla \times \boldsymbol{B}_k) \times \boldsymbol{B} d^3\vec{x}$$

is shown in Fig. 2. It is remarkable that, irrespective of the scale of magnetic field, transfer to the magnetic energy is induced by the large scale wavelet modes of the velocity field. This result directly shows that the induction of magnetic field is dominated by large scale flow structures. Especially for the smaller scales of magnetic field, this result implies that the inductive energy transfer is dominated by non-local interactions. It should be remarked that $\boldsymbol{u}_2$, the mode that most intensively excites the magnetic field does not agree with the peak of the kinetic energy spectrum $E_1^{(u)}$.

Scale-location-to-Scale-location wavelet energy transfer from velocity to magnetic fields is analyzed. The magnetic field excitation occurs around the coherent vortical structures. In Fig.3 cone representation visualization of wavelet transfer is shown[2)].

1). K. Kishida et al., PRL **83**, 5487 (1999).

2). K. Araki and H. Miura, "Concentration of active nonlinear energy transfer in rolling-up vortices", ICTAM 2008.

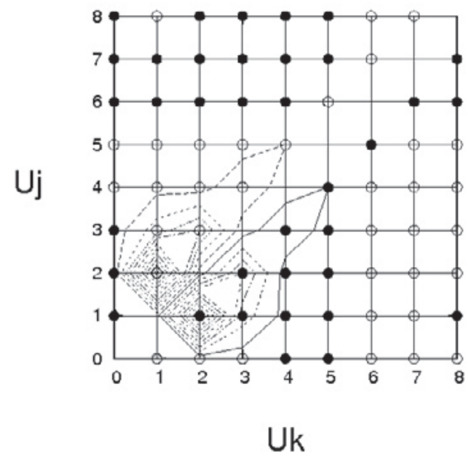

Fig.1 Wavelet spectra of nonlinear kinetic energy transfer N_{jk}.

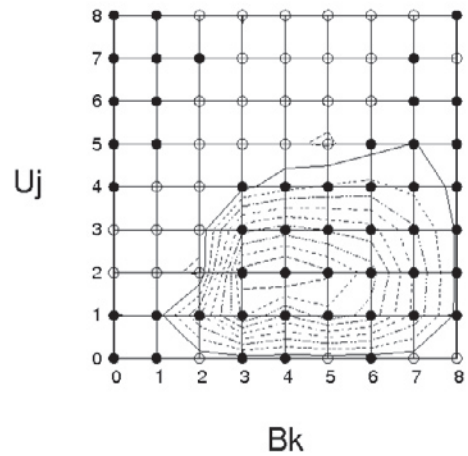

Fig.2 Wavelet spectra of nonlinear kinetic energy transfer N_{jk}.

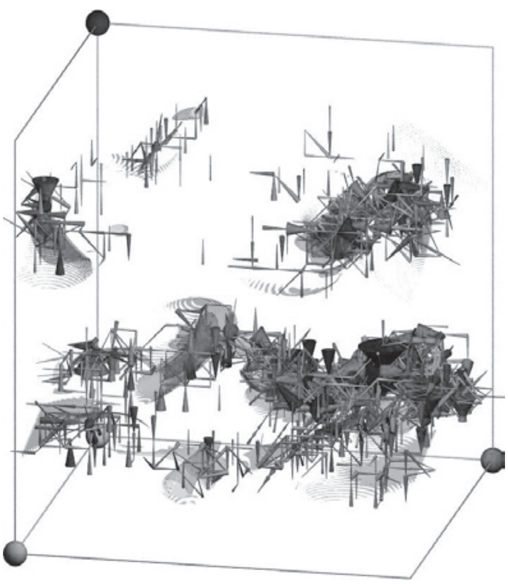

Fig.3 Spatial structure of magnetic field excitation.