## §15. Identification of Low-Pressure Vortices

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Developing identification and extraction schemes of fluid motions is quite significant in order to investigate complex plasma behaviors by means of numerical simulation. Among various fluid motions, a *vortex* may be one of the most important one. For example, a vortex can twist magnetic field lines, to cause magnetic reconnections. However, in spite of great endeavor by many researchers for past two or three decades, we have not reached to consensus about how to define a vortex yet. Although many methods such as streamlines, $Q$- and $\Delta$-definitions have been developed to identify vortices, they have as much insufficiency as their advantages. (Consult with Kida and Miura[2] and references therein to see an overview on this topic, including the methods referred above.)

Aiming at providing an objective definition of vortices, we have developed a method named the Sectional-Pressure-Minimum and Swirl (SPMS) method.[1, 2, 3] The SPMS method identifies a)central axes of swirling motions with sectional minimum of pressure and b)swirling regions around these central axes. The outline of this method is as follows. For simplicity, we restrict ourselves to a three-dimensional, incompressible and neutral fluid. First, we investigate the three real eigenvalues of the pressure hessian $\partial^2 p/\partial x_i \partial x_j$ on each of grid points of a numerical simulation where $p$ is the pressure of a fluid. Having two positive eigenvalues of the pressure hessian means existence of a sectional minimum of the pressure on the plane normal to the eigenvector associated with the third (the smallest) eigenvalue. By choosing the sectional minima of the pressure which are located sufficiently close to the grid points and imposing a swirling condition[2, 3] on them, candidates of central axes of low-pressure vortices are prepared. Then, we the have central axes by connecting these candidates. Since the swirling condition is expressed by a negative discriminant, $D < 0$, of the two-dimensional velocity-gradient tensor which is obtained by projecting flow field on the planes of the sectional-pressure-minima, swirling regions of these low-pressure vortices are given by the area with negative $D$.

The SPMS method is applied to the simulation of a homogeneous and isotropic turbulence with number of grid points $N^3 = 128^3$. In Fig. 1, swirling axes of low-pressure vortices and swirling regions are presented. Since the whole swirling regions occupy more than 40% of the entire volume and look space-filling, only some typical swirling regions are presented in Fig. 1. By investigating spans of each of swirling vortices, it was found that typical span of cross sections of swirling vortices is about eight times of the Kolmogorov length scale.

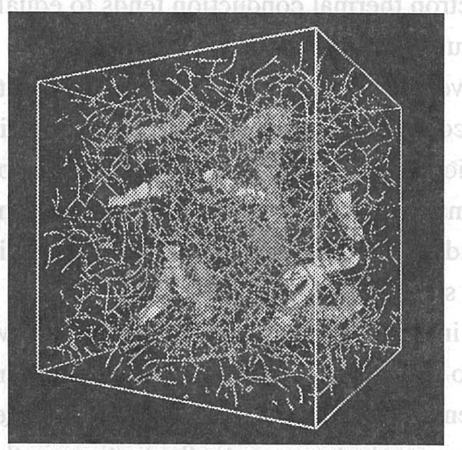

Figure 1: Central axis and swirling regions of homogeneous and isotropic turbulence

# References


[1] H. Miura and S. Kida: J. Phys. Soc. Jpn. **66** (1997) 1331.

[2] S. Kida and H. Miura, to appear in Eur. J. Fluid Mech.B.

[3] S. Kida and H. Miura: to appear in J. Phys. Soc. Jpn.