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Identification of 3D Vortex structure using Cluster satellite magnetic field data

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Identifying vortices are the key to understand the turbulence in plasma shear layers. Vortices are often viewed as “the sinews and muscles of turbulence” (Kuchermann 1965) and there still have no effective vortex identification method due to the lack of accepted mathematical definitions. Here we refer to the term ‘vortex’ a ‘vortex core’ that is the regions of Galilean invariance (for details please see Jeong Hussain 1995). Unfortunately, no single definition of a vortex is currently universally accepted, despite the fact that many space observations claims they detected the “vortices” like Kelvin-Helmholtz vortices and many space physicists continue to discuss the space plasma physics in terms of vortices. Using the four Cluster satellite magnetic field data, we obtain the rate distortion tensor of magnetic fields and try to identify the 3D vortex structure using various vortex identification methods. The first criterion is Δ-criterion that defines vortices as "regions in which the eigenvalues of ∇ B are complex and the streamline pattern is spiraling or closed. The second criterion is the λ_2-criterion that looks for a pressure minimum. The third and fourth criterions requires the existence of vortex core lines that is the Galilean invariance inside the four Cluster tetrahedral mesh. Near the dusk side of magnetopause, we have identified 105 “vortex structures” using the Cluster magnetic field data. The direction of the vortex core lines varies from -0° to 180° to z-axis, which strongly suggests the structures are “3D” ones that should be the source or symptom of turbulence. Using these methods we may analyze the plasma turbulent layer more clearly.