Experimental Investigation of the Emergence of Chaos in the Dynamics of Current Sheets and Flux Ropes

Walter Gekelman, Tim De Haas, Bart Van Compernolle,S. Vincena[1]
[1]*Department of Physics University of California, Los Angeles, 1000 Veteran Avenue, 90095, USA*

The solar corona is populated with thousands of magnetic flux ropes at any one time. In a laboratory experiment ropes immersed in a uniform magnetoplasma are observed to twist about themselves, writhe about each other and rotate about a central axis. They are kink unstable and smash into one another as they move. Flux ropes are also generated when a sheet of current tears into magnetic islands. Both cases are investigated. Full three dimensional magnetic field and flows are measured at thousands of time steps. Each collision results in magnetic field line reconnection and the generation of a quasi-seperatrix layer (QSL). Three dimensional magnetic field lines are computed by conditionally averaging the data using correlation techniques. The vector potential is calculated from the 3D current and the plasma potential is evaluated everywhere in the volume allowing the determination of the total electric field $\vec{E} = -\nabla\phi - \frac{\partial \vec{A}}{\partial t}$ and the plasma resisitivity $\eta(\vec{r},t)$. This are compared to the location of the QSL. The permutation entropy is calculated from time series of the magnetic field or flow data and used to calculate the Jensen Shannon complexity map. The location of data on this map indicates if the magnetic fields are stochastic, or chaotic. The complexity is a function of space and time. Other types of chaotic dynamical models such as the Lorentz, Gissinger and Henon process also fall on the map and can give a clue to the nature of the flux rope turbulence. The entropy and complexity change in space and time which reflects the change and possibly type of chaos associated with the ropes. The maps give insight as to the type of chaos (deterministic chaos, fractional diffusion , Levi flights..) and underlying dynamical process. The power spectra of much of the magnetic and flow data is exponential and Lorentzian structures in the time domain are embedded in them. Other quantities such as the Hurst exponent are evaluated for both magnetic fields and plasma flow.