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Three-dimensional magnetic reconnection: laboratory experiments and in situ measurements in the magnetosphere

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Magnetic reconnection is one of key issues in many fundamental plasma processes, such as solar flare, coronal mass ejections, magnetospheric substorm, as well as in the long-pulse steady state operation of magnetically confined fusion devices. The majority of current reconnection models are based on the Harris current sheet geometry and its development, with/without a guide field along the transparent direction. In fact a line should be structurally unstable if the magnetic flied vanishes at every point of the line. Under any small perturbation this line will break into null pairs, between them the magnetic field becomes finite. Thus magnetic reconnection is intrinsically a three-dimensional (3D) process [1].

In general, except for the case on a closed field line, 3D magnetic reconnection occurs on separatrices of a null, or the separator connecting magnetic null pairs. Recent analyses of in-situ observations by the Cluster mission show the presence of both single nulls and collections of nulls located in the current sheet of the Earth's magnetosphere [2]. Plasma waves and the particle dynamics in the magnetic null are very important to understand the three-dimensional (3D) magnetic reconnection process. A small plasma device, which named PPT device (abbreviated form of PKU Plasma Test device), has setup recently to study the dynamics of 3D magnetic null [3].

PKU Plasma Test device (PPT), are shown in this paper. PPT has a cylindrical vacuum chamber with φ50 cm×100 cm, and a pair of Helmholtz coils which can generate cylindrical or cusp magnetic geometry with magnitude from 0 to 2000 Gauss. Plasma was generated by a helicon source and the typical density is about 10^{13} cm^{-3} for the Argon plasma. Some Langmuir probes, magnetic probes, and one high-speed camera (10^6 frames per second) are setup to diagnostics. It's shown that the mode structures of rotational plasmas are typically as: the poloidal wavenumber k_p=1-10 (as shown in Figure 1), and the rotation frequency is about several kHz. Magnetic fluctuations exist during the plasma rotation processes with both cylindrical and cusp magnetic geometries, respectively. These preliminary results show that the plasma rotations might be related to some interesting electromagnetic processes.

Here we will report some recent results on 3D reconnection in the PPT device, such as the waves along the spines and the fan surfaces, as well as the particle dynamics around it. Furthermore, some wave modes around 3D nulls detected by in situ measurements in the magnetosphere will be reviewed. These results will be helpful to increasing our understanding of magnetic nulls and 3D reconnection.

References
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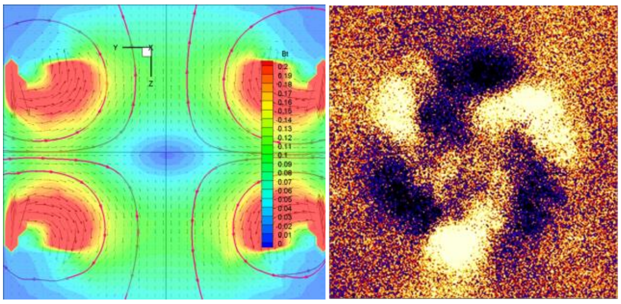

Figure 1. The geometry of a B-type magnetic null in the PPT device (left) and the plasma wave (k_p=3) in the fan surface of the B null (right).