Experimental Study of Two-fluid Effects on Magnetic Reconnection in a Laboratory Plasma with Variable Collisionality

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This paper describes the recent findings on two-fluid effects on magnetic reconnection in the MRX (Magnetic Reconnection Experiment) with variable collisionality. The MRX device was upgraded last year to accommodate wide range of collisionality regime. As our experimental operation regime has moved from the collisional to the collision-free, two-fluid effects have become more evident. It is observed that the 2-D profile of the neutral sheet is significantly changed from the rectangular of the familiar Sweet-Parker type to the double wedge shape as the collisionality is reduced and the reconnection rate increases. The recent evolution of our experimental research from the magnetohydrodynamics (MHD) to the two-fluid analysis is presented to illuminate the physics of the Hall MHD in a collision-free reconnection layer. In particular, a clear experimental verification of an out-of-plane quadrupole field, a characteristic signature of the Hall MHD, has been made in the MRX neutral sheet, where the sheet width is comparable to the ion skin depth. It is important to note that the Hall effects, which occur due to 2-D laminar flows of electrons in the reconnection plane, is observed together with the presence of low and high frequency magnetic turbulence which has often 3-D structures. This observation in MRX has a striking similarity to magnetospheric measurements of reconnection region, in which the quadrupole component has also been detected together with magnetic fluctuations. This work is supported by DOE, NSF and NASA.