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Progress in Understanding Magnetic Reconnection in Laboratory and Space Astrophysical Plasmas[1]

MASAAKI YAMADA, Center for Magnetic Self-organization, PPPL, Princeton University, Princeton NJ 08543

Magnetic reconnection, a topological rearrangement of magnetic field lines, is a key for the self-organization processes in plasmas. It is seen in the evolution of solar flares, in the dynamics of the earth's magnetosphere, in the formation process of stars and in the self-organization of fusion research plasmas. During magnetic reconnection a conversion of magnetic energy to plasma kinetic energy occurs by way of acceleration or heating of plasma particles. This tutorial talk presents the fundamental physics of magnetic reconnection from a point of view of an experimentalist and reviews the recent significant progress made for laboratory and space plasmas with a special focus on two-fluid effects. A companion review of magnetic reconnection research is given from a theorist's point of view in this conference [1]. One of the most important questions is why reconnection occurs much faster than predicted by the classical MHD theory. In the past ten years, significant advances in understanding the physics of magnetic reconnection have been achieved through dedicated laboratory plasma experiments [2], observations from satellites [3], and numerical simulations [4]. Extensive theoretical and experimental work has revealed that two-fluid dynamics, the different behavior of ions and electrons, are important within the thin, critical layer where reconnection occurs, such as is seen in the magnetosphere2. Significant findings are: (1) The reconnection dynamics are determined both by local and global conditions, (2) The profiles of the reconnection layer and reconnection rate change drastically as the plasma's collisionality is reduced, (3) Hall MHD effects have been measured in both laboratory and space plasmas, with the key signature 'out-of-reconnection-plane' quadrupole field component cleary observed, (4) Electrostatic and electromagnetic fluctuations and their spatial profiles were measured in the reconnection layer of both laboratory and space plasmas with notable similarities, and (5) The reconnection rate increases significantly when the ratio of the electron mean free path to the scale length approaches unity, implying strong two fluid effects. A new scaling of reconnection resistivity with respect to this ratio was obtained from the laboratory results. The impact of the recent improved understanding on research on space-terrestrial plasmas will be discussed. (1) A. Bhattacharjee, this conference. Ann. Rev. Astrmy. & Astrph. V.42, 365 (2004), (2) M. Yamada, Earth Planets Space v.53, 539 (2001) and references there in, (3) F. Mozer et al., Phys. Rev. Lett 89, 15002-1 (2002), T. D. Phan, et al., Nature 404 (6780), 848 (2000), (4) J. Birn, J. F. Drake, et al., J. Geophysical Research-Space Physics 106 (A3), 3715 (2001)

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