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Magnetic reconnection and particle acceleration in solar atmosphere

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In this talk I will review the recent studies on magnetic reconnection and particle acceleration in the solar atmosphere.
Magnetic reconnection and particle acceleration are universal and fundamental processes in astrophysical, space and laboratory plasmas, and hence comparative study is important. In the solar atmosphere, one can observe the temporal evolution of global magnetic topology in detail. On the other hand, it is difficult to obtain the information of the distribution function of particles, because in-situ measurements are not available. From the view point of plasma parameters, the solar atmosphere is characterized by the rapid changes of plasma parameters as a function of height because of strong gravitational stratification. The corona, sun's outer atmosphere, is fully ionized and almost collisionless plasma. Bothe the ion inertial length and ion Larmour radius is of the order of 1m, whereas the global scale of the phenomena is more than 10000km. Therefore the scale gap is more than 7 orders of magnitude even within the magnetohydrodynamic regime. In the lower atmosphere, namely the photosphere and chromosphere, the ionization fraction is very low because the temperature is 10000K or less. Furthermore, because of the high density the plasma is fully collisional (mean free path much smaller than the scale of phenomena).
Recent multi-wavelength observations has revealed that magnetic reconnection occurs throughout the solar atmosphere. In particular, observations from Hinode satellite found a lot of dynamic and explosive phenomena driven by fast magnetic reconnection occurring in the solar chromosphere. Since the chromosphere is fully collisional, it is unlikely that fast reconnection is accommodated by the kinetic effects (such as wave-particle interaction), as is often considered for collisionless reconnection. However, since the chromospheric is weakly ionized, Hall effect and/or ambipolar diffusion may play a role. Our numerical simulations suggest that, in chromospheric plasma where ambipolar diffusion dominates resistive and Hall terms, a thin current sheet is produced by ambipolar diffusion. Then resistive tearing instability occurs in the thin current sheet, which eventually leads to the formation of plasmods and intermittent fast reconnection.
Non-thermal electrons are often observed as hard X-ray emission associated with magnetic reconnection in the active region corona. However, no hard X-ray emission has been detected in the reconnection events in the solar quiet region, where magnetic field is weaker (1-10G) than that in the active region (~100G). On the other hand, non-thermal electrons with similar energy (>100 keV) are often observed associated with magnetic reconnection in the magnetosphere of the Earth, where magnetic field is many order of magnitude smaller that that of active and quiet solar corona.
In order to examine which plasma parameter regulate the electron acceleration, we have compared the observed plasma parameters in reconnection events in solar active region, solar quiet region, Earth's magnetosphere and solar wind. It is found that the difference of electron acceleration efficiency cannot be explained by the difference in magnetic field strength, electric field strength nor electric potential. Rather, it is consistent with Alfven velocity (ratio of cyclotron to plasma frequency) or product of electric field and Larmour radius. Implication of this result of acceleration theory will be discussed.