Collisionless plasma transport in the presence of open stochastic magnetic field lines

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The collisionless plasma transport in open stochastic magnetic fields has been studied for understanding the mechanisms of the thermal quench in tokamak disruption using a global gyrokinetic simulation code GTS. Previous studies have mostly focused on the dynamics of the passing electrons along the open magnetic field lines during the thermal quench. However, we found that a significant amount of the electrons can be trapped in the device due to the magnetic mirror effect and positive electrostatic potential produced in stochastic layer, although the magnetic field lines are open to the wall. A high-resolution vacuum field analysis of the stochastic layer provides rich information regarding the 3-D magnetic topology for understanding the characteristics of the plasma transport in such systems. In this study, we present a comprehensive picture of the relation between both parallel and perpendicular plasma dynamics and the 3-D topology of the stochastic layer, which is essential to understand thermal quench physics. It was found that the consistent coupling of electron and ion dynamics through the ambipolar electric fields plays a critical role in determining the electron thermal energy transport. The 3-D ambipolar potential builds up in the stochastic layer to keep the quasi-neutrality of the plasma during the thermal quench. The ambipolar potential produces the ExB vortices that mix the plasma across the magnetic field lines. The ExB mixing helps the high-energy trapped electrons to exit to the wall through the favorable open magnetic field lines. As a result, the electron temperature decreases steadily within the time scale of milliseconds.