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Intermittent Electron Acceleration by Magnetotail Reconnection

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Electron acceleration is pervasive in astrophysical and space plasmas. It is suggested that turbulence[1], shock[2] and magnetic reconnection[3] are efficient engines for energizing electrons. Magnetic reconnection can rapidly convert magnetic energy into plasma energy during the macroscopic topology changes of the magnetic field. It is commonly recognized that part of the converted energy goes to heat and accelerate electrons[4]. However, despite decades of intensive study, where and how are electrons being accelerated in reconnection remains an open question.

This Letter presents a comprehensive study of the electron acceleration from different mechanisms in the near-Earth magnetotail using the unique measurement capabilities of the Magnetospheric Multiscale (MMS) mission. We find that the average acceleration rates and occurrence rates of large acceleration tend to be higher in outflows with larger speeds (Figure 2). Betatron and Fermi accelerations are intensified near the neutral sheet, while the acceleration from $E_{||}$ is not only intensified in the neutral sheet, but also significant far from the neutral sheet, likely in the separatrix region. In contrast to previous studies suggesting that the acceleration and energy conversion predominantly occurs in the outflow region, we find that the acceleration rate near the X line is comparable to that in the outflow. One interesting finding is that electrons are intermittently accelerated in association with reconnection (Figure 2), suggesting that the near-Earth magnetotail activated by reconnection is in a turbulent state.

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References

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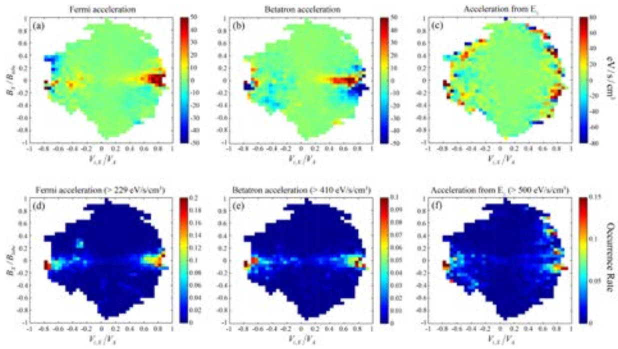

Figure 1. The average acceleration rates of (a) Fermi mechanism, (b) betatron mechanism, and (c) $E_{||}$ in $V_{i,X}$-B_X space. Panels (d)-(f) present the occurrence rate of rare large acceleration rate (the positive tail beyond the Gaussian distribution in Figure 2) of the (d) Fermi, (e) betatron, and (f) $E_{||}$ in $V_{i,X}$-B_X space. The bin size in each panel is 0.05×0.05. The bins with less than 100 data points have been removed to reduce statistical noises. The average value of each bin in panels (a), (b) and (c) is calculated by the boxplot average method.

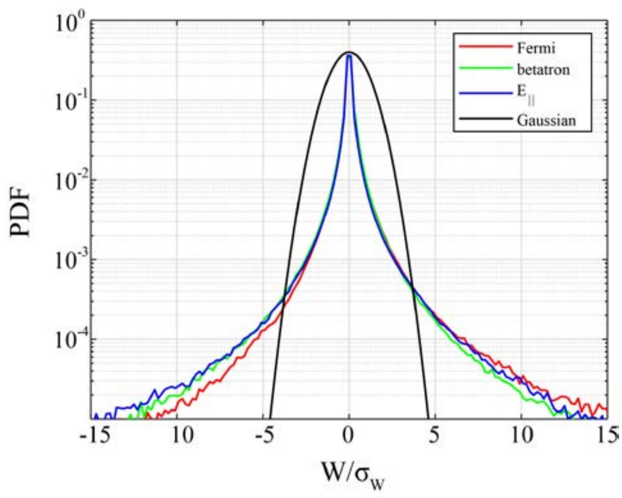

Figure 2. PDFs of the acceleration rates of the Fermi (red curve), betatron (green curve), and $E_{||}$ mechainisms (blue curve). The black curve represents the Gaussian distribution. The abscissa is normalized by the standard deviation of each PDF.