

## Particle simulations on electron acceleration at Quasi-Perpendicular Shocks

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We found efficient production of non-thermal electrons up to  $\gamma \sim 20$  in results of three-dimensional full kinetic simulations of quasi-perpendicular shocks. The seed acceleration occurs in large-amplitude electromagnetic wave excited in the most front region of the shock foot. A small portion of electrons keeps staying in the foot region due to the scattering by the large-amplitude electromagnetic wave, and these electrons can get energy from the motional electric field in the shock rest frame. Since the large-amplitude electromagnetic wave is only possible in 3-D simulations, no electron acceleration is observed in previous 1-D and 2-D simulations. After the seed acceleration, these electrons can be further accelerated at the shock ramp region by the shock drift acceleration. The acceleration process occurs during the steepen phase of the self-reformation, and the acceleration efficiency depends on the phase of the shock self-reformation. In contrast to the standard Fermi acceleration at quasi-parallel shocks, the electron acceleration process at quasi-perpendicular shocks is much quicker (order of the ion cyclotron period); however, electrons cannot experience effective acceleration again and again so that there would be an energy limitation of the acceleration. In this presentation, we will discuss the energy limit of electron acceleration at quasi-perpendicular shocks by using simulation results obtained from the K computer.

Keywords: shock acceleration, particle simulation