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Shock Acceleration of Electrons: The Role of Mach Number and Shock Surface Fluctuations

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Energetic electrons are a common feature of interplanetary shocks and planetary bow shocks, and they are invoked as a key component of models of nonthermal radio emission, such as solar radio bursts and radio emission in the outer heliosphere. A simulation study is carried out of electron acceleration for quasi-perpendicular shocks, typical of the shocks in the solar wind. Two and three-dimensional self-consistent hybrid simulations of quasi-perpendicular shocks provide the electric and magnetic fields in which test particle electrons are followed. A range of different Mach numbers and shock normal angles are investigated. When the Mach number is low, the results agree with theory assuming magnetic moment conserving reflection, with electron energy gains of a factor only 2 to 3. For high Mach numbers, i.e. super-critical, the shock front has a dynamic rippled character. In this case the electrons can suffer scattering in the ion-scale turbulence within the shock layer, producing higher energy gains and some modification of the loss-cone distribution functions predicted by magnetic moment conservation. In addition, acceleration to high energies is present over a wider range of shock normal angles. Distribution functions for reflected and transmitted electrons are computed based on initial upstream kappa distributions similar to the solar wind electron distribution, allowing quantitative comparisons with observations. In addition, the impact of upstream turbulence on the structure of low Mach number shocks is examined, in order to investigate whether such shocks can also produce efficient acceleration due to additional electron scattering.