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Impact of the rippling of a 2D perpendicular shock front on ion acceleration mechanisms: PIC and test particles simulations

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Both hybrid/full particle simulations and recent experimental results have clearly evidenced that the front of a supercritical quasi-perpendicular shock can be rippled. Recent two-dimensional simulations have focussed on two different types of shock front rippling: (1) one characterized by a small spatial scale along the front is supported by lower hybrid wave activity, (2) the other characterized by a large spatial scale along the front is supported by the emission of large amplitude nonlinear whistler waves. These two rippled shock fronts are observed self-consistently respectively when the static magnetic field is perpendicular to (so called "B0-OUT" case) or within (so called "B0-IN" case) the simulation plane. "B0-OUT" and "B0-IN" cases are respectively characterized by a small and large rippling scale along the shock front. On the other hand, several studies have been made on the reflection and energization of incoming ions with a shock but most have been restricted to a one dimensional shock profile only (no rippling effects). Herein, two-dimensional test particle simulations based on strictly perpendicular shock profiles produced in two-dimensional PIC simulations are performed in order to investigate the impact of the shock front ripples on incident ion (H^+) dynamics. The acceleration mechanisms and energy spectra of the test-ions (described by shell distributions with different initial kinetic energy) interacting with a rippled shock front are analyzed in detail. Both "B0-OUT" and "B0-IN" cases are considered separately; in each case, y-averaged (front rippling excluded) and non-averaged (front rippling included) profiles will be analyzed. Present results show that: (1) the incident ions suffer both shock drift acceleration (SDA) and shock surfing acceleration (SSA) mechanisms. Moreover, a striking feature is that SSA ions not only are identified at the ramp but also within the foot which confirms previous 1-D simulation results; (2) the percentage of SSA ions increases with initial kinetic energy, a feature which persists well with a rippled shock front; (3) furthermore, the ripples increase the leak of cross shock potential of the shock front (more directly transmitted- or DT- ions are produced); it strongly affects the relative percentage of the different identified classes of ions (SSA, SDA and DT ions), their average kinetic energy and their relative contribution to the resulting downstream energy spectra; (4) one key impact of the ripples is a strong diffusion of ions (in particular through the frontiers of their injection angle domains and in phase space) which leads to a mixing of the different ion classes. This diffusion increases with the size of the spatial scale of the front rippling; (5) through this diffusion, an ion belonging to a given category (SSA, SDA, or DT) in y-averaged case changes class in non-averaged case without one-to-one correspondence.