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Dynamical shock: Theory and observations

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Collisionless shock waves in plasmas are usually considered as stationary nonlinear waves that cause irreversible changes of plasma state. However, in the very beginning of the collisionless shock physics it was observed experimentally (Morse et al., 1971) and in computer simulations (Biscamp and Welter, 1972) that quasiperpendicular shock behavior can be nonstationary. Later it was hypothesized that nonstationary dynamics is typical for high-Mach-number shocks. Now it is clear that there exist several types of nonstationary effects. Both computer simulation and experimental observations have shown different manifestations of shock front variability, which differ by dimensionality and strength. In general, temporal variations result in spatially inhomogeneous multidimensional shock front structure. Relatively weak effects will result in a “vibrating” shock front structure resembling that of a stationary shock with relatively small variations of the number of reflected ions and wave activity upstream of the shock, while strong effects may cause the shock front disruption and overturning. In this last case the shock front “disappears” and a “new” one is formed in the vicinity of the “old” front, this phenomenon is usually called a reformation. Another feature of quasiperpendicular shocks observed experimentally and in simulations is a phenomenon of front rippling, which is essentially multidimensional. The question whether rippling is always related to the shock front nonstationarity or it can exist in quasistationary shocks is still open. Several spacecraft programs, including multi-spacecraft missions like ISEE, AMPTE and Cluster provided an opportunity to measure spatial scales and characteristic times more carefully. This allowed observing unambiguous manifestations of shock front reformation and rippling. We discuss also the observational features of particle distributions associated with the shock front reformation.