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Collisionless relaxation of downstream ion distribution at shocks: Theory, simulations, and observations

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It is well known from satellite observations of the magnetosphere and theory/models that incident ions are decelerated at the quasi-perpendicular shock front and start to gyrate just behind the ramp. The formed distribution is non-isotropic and non-gyrotropic. We show theoretically and confirm in 1D hybrid simulations that the downstream ion pressure becomes spatially periodic, which should cause accompanying spatially periodic oscillations of the magnetic field. Gradual gyrotropization of the ion distribution due to the collisionless gyrophase mixing results in smoothing out the pressure variations and decay of the magnetic oscillations. The origin of these oscillations is similar to the origin of the overshoot-undershoot structures in high-Mach number shocks. These magnetic oscillations are part of the front structure and are stationary in the shock front frame. They should be dustinguished from various waves generated downstream of the ramp due to various plasma instabilities or shock nonstationarity.