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Mechanism for irreversible dissipation at collisionless shocks: Nonlinear ion acoustic instability

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Comparison of electrostatic waves observed by Cassini at the bow shocks of Saturn and Earth revealed that the most dominant wave power has the same frequency range, and the waves have very similar waveforms at both planets. This comparison led us to identify the dominant wave component at both bow shocks to be nonlinear ion acoustic waves. To understand the role of the instability that generate the waves, we carried out particle simulations, and found that the nonlinear ion acoustic instability can increase the temperature of electrons, and produce flat-topped electron distributions which have been observed to be characteristic to the shock transition and downstream magnetosheath at Earth [Feldman et al. (1982)]. The increase in the electron temperature is proportional to the relative drift between electrons and ions in our simulation, and hence is expected to increase with the cross-shock electrostatic potential, and consequently with the solar wind flow energy, a result that has been observationally established [Thomsen et al. (1987); Hull et al. (2000)]. The nonlinear ion acoustic instability, therefore, appears to be the dominant mechanism for irreversible dissipation across collisionless bow shocks.