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New Observations of Solar Wind Dissipation across Earth's Bow Shock

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Early solar wind (SW) observations showed ion distributions in the vicinity of Earth's bow shock included a secondary beam that was interpreted as SW ions reflected off the bow shock. The current theory of SW thermalization involves instabilities driven by the relative motion of the reflected ions and SW. We present new observations of ions measured by 3D plasma instruments flown on Cluster and Double Star satellites. Macroscopic results show the SW flow speed generally remains super-Alfvénic in the downstream region (magnetosheath) of the bow shock. Moreover, heat flux is also measured in the magnetosheath (MS) indicating ion distributions are not in thermal equilibrium. The Boltzmann H function shows it abruptly decreases at the magnetic ramp and remains finite in the MS. The time variation dH/dt shows that the largest departure from equilibrium occurs only in the narrow region of the magnetic ramp (one data point, 4s) and fluctuates about zero in the MS. Particles observed in front of the bow shock (secondary beam) have energies nearly the same as MS particles and show energy dispersion with higher energies extending further out consistent with MS particles gyrating across the magnetic ramp. Velocity space distributions show these particles consist of single or multiple beams in narrow energy and pitch-angle ranges that can abruptly brighten and spread. Moreover, we find the SW beam can penetrate into the MS with the beam temperature increasing only slightly, from $\sim$3.5 eV to 5 eV. These observations do not agree with current bow shock models requiring a new interpretation of how the SW energy is dissipated.