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Particle acceleration during interactions between transient ion foreshock phenomena and Earth's bow shock

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Foreshocks are regions upstream of supercritical astrophysical shock waves that are in communication with the shock via suprathermal charged particles that have been energized and reflected by the shock and are counter-streaming into the incident plasma. These regions form upstream of the quasi-parallel region of the shock, in which the angle between the magnetic field in the incident plasma and the shock normal direction is less than $\sim$40 deg. The relative drift between the reflected suprathermal particles and the incident bulk flow is a source of free energy, which is capable of producing a variety of kinetic plasma instabilities and enhanced wave activity. Simulations and observations of Earth's and other planetary foreshocks have shown that large-scale transient phenomena can also develop due to nonlinear processes and interactions between foreshock particles and discontinuities in the incident solar wind. Several of these transient ion foreshock phenomena (TIFP), such as short large-amplitude magnetic structures (SLAMS), hot flow anomalies (HFAs), and foreshock bubbles (FBs), can result in the development of nonlinear wave activity and additional shocks upstream of the main bow shock. We present in situ observations, made by NASA's THEMIS mission, of ion and electron distributions from within and without SLAMS, HFAs, and FBs, examining the particle heating and acceleration taking place within those TIFP. The observations are compared to theoretical expectations for shock-drift acceleration, Fermi acceleration, and energy diffusion via wave-particle interactions. Our preliminary results show that SLAMS, HFAs, and FBs can be ideal particle accelerators. Finally, we develop an understanding for the upper energy limits for ion and electron acceleration in each of these TIFP at Earth's bow shock and use this to investigate how TIFP may accelerate particles at other astrophysical shocks, such as planetary and astrospherical bow shocks, shocks in stellar winds, and supernova shocks.