An Overview of Transient Ion Foreshock Phenomena and their Impacts on Earth's Magnetosphere

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Ion and electron foreshocks form upstream of the quasi-parallel portion of bow shocks in space plasmas. A significant fraction of incident particles can be accelerated and reflected at a bow shock, resulting in their counter-streaming along field lines and interacting with the incident plasma. Earth's bow shock provides a natural laboratory to study the complex interactions between the incident solar wind and the counter-streaming foreshock populations and compare in situ observations to global simulations of the system. Such simulations and observations have revealed the ion foreshock to be a complex environment characterized by strong wave activity and suprathermal particles and punctuated frequently by large-scale transient disturbances, which we refer to here as transient ion foreshock phenomena (TIFP). A veritable "zoo" of TIFP have been identified, including strong large-amplitude magnetic structures, foreshock cations and cavities, hot flow anomalies, and the recently discovered foreshock bubbles, and several of these features have also been observed at other planetary systems in the heliosphere. As observed at Earth, these TIFP often involve significant pressure variations compared to the pristine upstream solar wind, and it has been established that these pressure variations can penetrate through the magnetosheath resulting in significant magnetopause deformations. Here, we provide an overview of the latest understanding of various TIFP, including how they form, their unique and common characteristics, and the latest estimates of their occurrence rates. We discuss the difficulty in distinguishing between different types of TIFP using single-point satellite observations and stress the importance of multi-point analysis for TIFP identification. We next outline the latest results showing how TIFP impact Earth's magnetosphere. Due to their frequency, we argue that TIFP are an important mode of energy transfer from the solar wind into Earth's magnetosphere. We finish with a brief discussion of outstanding questions concerning TIFP and the importance of the ion foreshock for driving activity in Earth's magnetosphere.