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Detecting the edges of Earth's ion foreshock using Magnetic Gauss's Law

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Various types of plasma waves play key roles in magnetospheric physics in contexts ranging from the magnetosphere and its boundary layers to planetary bow shocks and foreshocks. Due to limited available spacecraft measurements, the waves are often assumed to be plane waves that extend to infinity in all directions. A good example is the Earth's ion foreshock where intrinsically right-hand circularly polarized magnetosonic modes are generated by a fast ion beam. Many prior studies of these waves assume no variation of important physical quantities in the direction perpendicular to wave propagation. We show that Magnetic Gauss's Law implies that this assumption must be violated near the edge of the wave domain. The resulting false signature in the standard Magnetic Gauss's Law calculation of the wave vector orientation may be used to detect the domain edge. We demonstrate this new edge detection method in a simple wave model, a 2-D hybrid Vlasov simulation conducted using the Vlasiator code, and ARTEMIS spacecraft observations. In both the simulation and the spacecraft observations, this new signature is shown to correlate well with a determination of the foreshock edge based on the properties of the fast ion beam. As the plane wave assumption is widely used in space physics data analysis techniques such as minimum variance analysis, these results may stimulate a reexamination of this assumption in other magnetospheric physics contexts.

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