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Auroral Beading and Magnetospheric ULF Waves

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In plasma environments such as Earth's magnetosphere ultra-low frequency (ULF) Alfvén waves, field line resonances (FLRs) manifest as standing waves along geomagnetic field lines. This study demonstrates a strong correlation between FLRs and azimuthally periodic enhancements in auroral emissions known as Auroral Beads, which form along pre-existing discrete arcs. We report the development of periodic spirals and vortices in these arcs, which precede auroral breakup and substorm onset. Furthermore, we establish a connection between these ULF waves and STEVE (Strong Thermal Emission Velocity Enhancement), a recently discovered sub-auroral optical phenomenon characterized by a whitish-purple emission narrow in latitude and extending east-west, typically following substorm onset. A case study of an auroral beading and breakup event is presented, which is followed by a sub-auroral STEVE emission 40 minutes later. We identify ULF modulation of STEVE emissions at 10-25 mHz, attributing this to poloidal mode FLRs with large azimuthal wave numbers (m) that are typically associated with wave-particle coupling and instability. To investigate these phenomena, we employ a combination of REGO and THEMIS optical all-sky images and ground-based SuperDARN high-frequency radar measurements. This instrumentation allows us to examine the ionospheric ULF waves modulating the optical emissions. Additionally, we explore the role of wave-particle coupling based on test-particle simulation and measurements from the Van Allen Probes RBSP-A spacecraft, which traversed the inner magnetosphere a few hours of magnetic local time eastward of the beading/STEVE location. It is shown that the combined use of observational data and modeling is critical to our understanding of magnetosphere-ionosphere coupling processes and their impact on auroral dynamics, offering new insights into the complex interplay between ULF waves, auroral beads, and STEVE phenomena in near-Earth space plasma environments.

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