Exploiting coherent and incoherent scatter to understand magnetospheric substorms

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The ISR technique is based on the weak Bragg scatter from ion-acoustic fluctuations matching the radar k-vector. The technique calls for high power large aperture UHF systems. ISRs are thus very sensitive to ion-acoustic turbulence, which can enhance the backscattered power by >3 orders of magnitude (referred to as Naturally Enhanced Ion-Acoustic Lines, or NEIALs) and create exotic morphologies in both the ion-line and plasma-line spectra [1]. These features, and their relation to bulk properties of the surrounding medium, provide clues as to the mechanism of destabilization. But the term 'NEIAL' is a phenomenological designation, and multiple mechanisms may be at play. However, when combined with high-resolution measurements of aurora, and our extensive knowledge of auroral physics, a rich framework emerges for identifying and quantifying magnetospheric drivers, and understanding their role in geospace system dynamics.

This paper applies this data fusion framework to the study of magnetospheric substorms. Our observational evidence focuses on the Poker Flat ISR (PFISR) facility, where pulse-by-pulse steering can resolve NEIAL power spectra as a function of range, frequency, and magnetic aspect angle at rapid cadence, as well as enabling the construction of four-dimensional (space-time) views of the thermal ionospheric plasma [2]. In one event, NEIALs at the poleward boundary of a substorm expansion were found to be correlated with a region of inertial Alfven waves (IAWs) extending >500 km [Figure 1]. In another case, a secondary onset and aurorally breakup occurred fully within the PFISR volume. The event is characterized by auroral forms retreating rapidly in altitude (also assume related to IAWs) and the formation of flat-topped ion-acoustic spectra and splitting plasma lines, thought to be associated with cavitating Langmuir turbulence [3]. The forthcoming EISCAT-3D facility will be able to probe this physics with considerably higher space-time resolution.

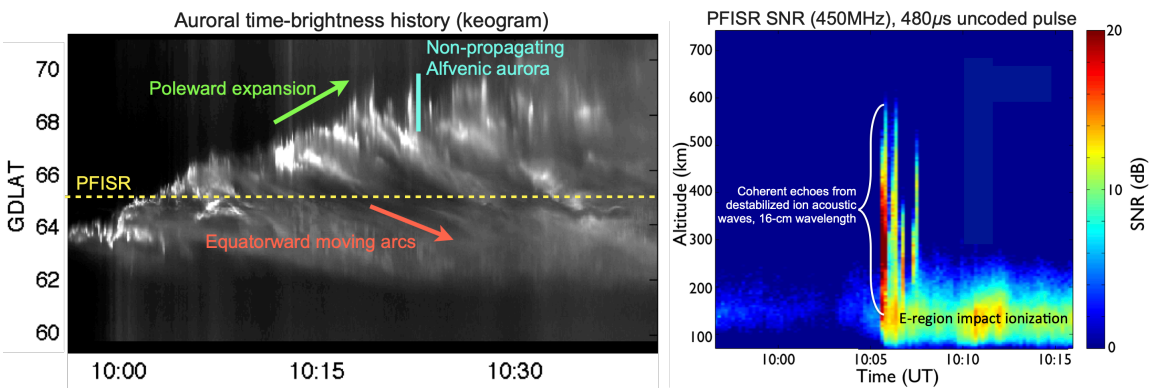

Figure 1. Left: Auroral keogram (north-south brightness cut) showing the poleward expansion of a substorm through the PFISR location. Three distinct auroral motions are observed. Right: Zenith observations of SNR by the PFISR facility. The broad enhancements at the leading edge of the substorm expansion are coherent scatter by destabilized ion-acoustic waves.

References

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