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Applying Linear and Nonlinear E Region Plasma Instability Theories to High Latitude Observations.

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Extended Abstract

Meter-scale plasma echoes from the E region come under a number of "Types" that have been associated with their spectral width and Doppler shifts. These in turn have been attributed to differences in viewing directions and to the strength of the turbulence [1,2]. The Doppler shift of the most powerful spectra maximizes at a speed close to the ion-acoustic speed of the medium, where the growth rate is zero. The spectrum is narrower and saturates at the ion-acoustic speed in directions for which the plasma is linearly unstable. In other directions the spectrum broadens, the spectral power goes down, and the Doppler shift becomes systematically smaller as the direction of observation is increasingly close to being perpendicular to the electron ExB drift, where there is no linear growth. Intriguing exceptions to the rule are found with spectra found in directions perpendicular to the magnetic field but that are much narrower than the average and have Doppler shifts that are either much slower or much faster than the more common spectra associated with unstable directions (Types 3 and 4). Finally, slower echoes are seen in directions that deviate so much from the magnetic field direction that they should not exist according to linear theory [3].

The past decade has seen the advent of many new theoretical ideas/studies, the development of powerful numerical simulations and new observation techniques relying increasingly often on interferometry. As a result we are now starting to make sense of what seemed at first to be a real zoo of irregularities devoid of any real kind of connections. To start with, the most common so-called Type 1 and 2 spectra can now be understood through the nonlinear evolution of classic Farley-Buneman modified two-stream structures. The key process in the non-linear evolution is a rotation in the electric field inside growing structures [4]. The perturbed field evolves in such a way as to make the net field inside the structures go down, which slows down the growth until the net field becomes too small for growth. At that point the structures nevertheless continue to evolve, owing to their nonlocal character along the magnetic field, which forces them to develop a monotonically increasing aspect angle. This creates not just decay but electron heating as well. It is also responsible for the presence of structures with aspect angles greater (and sometimes far greater) than expected from linear theory. Going back to directions perpendicular to the magnetic field: the structures retain a basic two-dimensional character while being elongated along the electric field direction. Although growth is limited to a range of angles centered on the electron drift direction, one can observe them from any angle including from the long edges of the structures, where there is nothing but decay. The mysterious narrow spectra that had been labeled as Types 3 and 4 in the past are now also being sorted out, now that there is strong evidence for the slow narrow echoes to be coming from the D region between 90 and 100 km altitudes, while the narrow fast echoes come from the very top of the unstable layer [5]. Since the spectra are narrow, they first of all have to be associated with small growth rates and weak turbulence. The low altitude narrow spectra are associated with weakly growing modes affected by the effect of electron temperature modulations inside growing waves [6]. This decreases the instability threshold but diffusion still remains strong and the waves do not grow fast. The high altitude narrow echoes come from the fact that the relative ion-electron drift simply becomes too small near the top of the layer for structures to grow fast. At that point, the waves move at the ion-acoustic speed in the ion frame of reference, but the ion motion is such that the structures are seen by stationary ground observers to be moving at very near the ExB drift.

References

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