Using Thompson Scatter Radars to Probe Plasma Properties and Waves in the Geospace Environment

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1 Extended Abstract

Thomson Scatter Radars have successfully measured plasma parameters in the ionosphere for over sixty years, and advancements in technology and radar theory allow for a deeper understanding of plasma physics within the geospace environment. For example, it is common for ionospheric models and measurements to resolve the ion temperature by assuming that the ion velocity distribution is an isotropic-Maxwellian. However, in the presence of moderate to strong electric fields the ion velocity distribution in the weakly-ionized, magnetized F-region ionosphere distorts from a Maxwellian [1]. This is the result of ion-neutral collisions and Resonant Charge Exchange between O+ and O, which is the dominant ion-neutral collision type in this region. A consequence of the distortion of the ion velocity distribution is that the ion temperature becomes anisotropic, leading to larger ion temperatures perpendicular to the magnetic field than parallel. The collision cross-section between O+ and O is unknown, and different estimates of this interaction imply different temperature anisotropies. This uncertainty in collision cross-section makes it more convenient and common to assume a Maxwellian ion distribution when analyzing data, and therefore we obtain inaccurate ion temperatures. However, the O+-O collision cross-section, and thus the ion temperature anisotropy, can be resolved using data from high-latitude advanced Thomson Scatter Radars and a Monte-Carlo simulation to compute the ion velocity distributions for a wide range of collisional and plasma parameters [2].

This presentation will discuss research into the nature of O+-O collisions in the ionosphere, as well as current research into wave modes sensed by Thomson Scatter Radars. Fundamentally, the radars measure increased power returns when the Bragg scattering condition is met by some source of plasma density fluctuations in the ionosphere. Typically, wave modes of the plasma provide this source of structuring, and the radars measure strong power returns at the “ion line" which is associated with the ion-acoustic mode; the “gyro line" which is associated with the electrostatic whistler mode; and the “plasma line" that comes from the Langmuir mode. However, the existence of an ion-acoustic mode or electrostatic whistler mode is not guaranteed in the ionosphere. For temperature ratios of $T_e/T_i < 3.5$, there is no solution for roots of the dielectric function near the ion-acoustic frequency [3], and therefore no wave mode exists. In this presentation, a formalism is developed to explain non-resonant modes as occurring at frequencies where the dielectric function has a local minimum, as opposed to a root corresponding to a resonant wave mode. This is explained by analogy to a driven oscillator, where the initial conditions of a plasma will drive an oscillation at $\omega = kv$, and a minimum in the dielectric allows for a maximum in the amplitude of the oscillating electric field. With this formalism, the frequency of non-resonant “waves" can be numerically solved for as a function of basic plasma parameters. This allows predictions of when the ion line and gyro line are observable by Thomson Scatter Radars.

References

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