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Identifying Scales in the Ionospheric Structure through Scintillation Events

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In the polar regions, ionospheric electron density structures are known to develop as a result of plasma instabilities driven by currents and pressure gradients. These plasma structures are typically investigated through in-situ observations using instruments aboard spacecraft and rockets. In addition, measurements recorded by ground-based GNSS receivers provide valuable indirect data about the impact of ionospheric irregularities on the propagation of radio wave emitted by satellites.

At high latitudes, the Canadian High Arctic Ionospheric Network (CHAIN) records fluctuations in the amplitude of radio signals from GNSS satellites, which are then analyzed to determine the characteristic length scales of the ionospheric plasma through which radio waves propagate. Probability distributions of these fluctuations are constructed for various fixed frequency ranges. The distributions are found to be well-described by the Castaing function, which was introduced in fluid dynamics to describe the distribution of velocity fluctuations in two-dimensional neutral fluid turbulence.

Our analysis reveals that the scale parameter of the Castaing distribution decreases as the frequency of amplitude fluctuations increases, meaning that only high-frequency amplitude fluctuations conform to Gaussian statistics. For some scintillation event cases, a Gaussian distribution is observed at frequency scales where the signal power density level falls below the instrumental noise level. The results of our study suggest that the radio wave propagation occurred through an ionospheric layer with a weak electron density gradient, yet abundant in small-scale electron density structures. These results also suggest that a thermal plasma equilibrium is reached only when small scales dominate the interaction processes in the plasma.