



## **Ionospheric Scintillation at Low Frequencies: Broadband Spectra and Phase Measurements from Natural Radio Sources**

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Observations of strong natural radio sources such as Cassiopeia A taken using the Low Frequency Array (LOFAR) centred on the Netherlands, and the Kilpisjärvi Atmospheric Imaging Receiver Array (KAIRA) in arctic Finland, over the frequency range 10-250 MHz show almost continual ionospheric scintillation. Dynamic spectra of these observations show scintillation varying from weak to strong scattering and the effects of refraction due to large-scale structure in the ionosphere can also be visible. Recent efforts have also attempted to measure phase scintillation in addition to the regular intensity measurements, using simultaneous low-resolution all-sky imaging, to confirm when strong refraction is seen. Delay-Doppler spectra (the two-dimensional power spectrum of a dynamic spectrum) sometimes show an arc structure, similar to the “scintillation arcs” reported from observations of interstellar scintillation, which can be used to model parameters such as the distance to the scattering “scree” and the velocity of the scattering medium transverse to the line of sight. These two parameters are inherently linked in modelling which means that one needs to be known before the other can be established accurately. The dense core of the LOFAR array has been used to take temporal cross-correlations between station pairs to establish a picture of the velocity field in the ionosphere; with KAIRA other supporting instrumentation can be used to estimate ionospheric velocities in nearby regions. These velocities are used to attempt to establish the altitudes dominating scattering due to the ionosphere.