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Bayesian Model Selection for Whistler Mode Chorus Sub-Packet Identification

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Whistler mode chorus is a powerful electromagnetic emission observed in the outer radiation belts of the Earth that is an important driver of the dynamics of energetic electrons through resonant wave-particle interactions. Chorus waves are characteristically quasi-coherent and are observed as bursts of wave power called chorus elements with frequencies in the VLF range that can change on time scales of the order of tens of wave periods. Chorus elements are further subdivided into sub-packets (or sub-elements) that are characterized by a peak in the wave amplitude. Sub-packet properties, such as duration and frequency sweep-rate, control the trapping time of resonant energetic electrons and thus the efficiency electron acceleration. Identifying the properties of whistler mode chorus algorithmically from multi-channel waveform data is a significant challenge, however knowing the statistical properties of chorus sub-packets is necessary for constructing realistic models of electron acceleration in the radiation belts.

In this study we apply Bayesian model selection techniques to waveform data from the Van Allen Probe mission. Using a handful of test-cases we construct an ensemble of empirical models for chorus sub-packets and calculate directly the probability of a given model to explain the data. The result of this model selection study revealed two things. First, that the most probable empirical model of sub-packet waveforms had an amplitude profile that was a hyperbolic secant. This suggested a new theory of whistler mode chorus using the Ginzburg-Landau equation which has chirped-soliton solutions. These chirped soliton solutions have a slightly different frequency chirp profile than the original empirical model that was tested. Incorporating these new theoretical sub-packet solutions into the model selection technique revealed that the theoretical model was more probable. This methodology is a powerful modern version of the scientific method that is relevant in a world with abundant data. Second, since the most probable model of a chorus sub-packet was the same for the sub-packets studied it means that we can use this model to automatically extract the sub-packets from wave-form data. This parameter extraction technique will lead to the construction of a database of sub-packet properties that can be used for the construction of realistic models of electron acceleration in the radiation belts.