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The DUCHESS Mission: Quantifying Ducted Chorus Waves' Contribution to Radiation Belt Dynamics

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Whistler-mode chorus waves are critical in accelerating and precipitating the seed population of radiation belt electrons. In the Earth's magnetosphere, these waves can propagate either ducted or non-ducted along magnetic field lines. As non-ducted waves propagate away from their generation region near the equator, their obliquity increases, followed by significant wave damping via suprathermal electrons. This restricts the wave spatial (latitudinal) extent and confines intense waves near the equator. Under wave ducting, on the other hand, the damping can be minimized to allow chorus waves propagate to middle latitudes and often reach the ionosphere. These ducted whistlers at middle latitudes are far more efficient at resonantly interacting with relativistic electrons and should therefore be an essential ingredient in any radiation belt model. Due to a lack of observations, however, ducted whistlers still have not been characterized quantitatively in terms of occurrence rates as a function of local plasma parameters, geomagnetic activity, location, and their effects on particles.

From a polar-orbiting vantage point, DUCHESS (DUcted CHorus Electron Scattering Satellite, a pending 6U CubeSat mission at LEO) will fill this observational gap with direct measurements of ducted chorus (in the 0.5-5 kHz range) and of the inferred equatorial chorus rates based on locally measured precipitating-to-trapped electron flux ratios in the 100-300 keV range. Equipped with a flight-proven energetic particle detector and a high-heritage Search Coil Magnetometer (SCM), DUCHESS can directly measure ducted whistlers in-situ and 100-300 keV electron precipitation spectra as a proxy of remote, equatorial whistlers. This way, DUCHESS can determine the occurrence rate of ducted whistlers interacting with radiation belt electrons, without the mapping uncertainties befuddling conjunctions on separate (ionospheric and equatorial) spacecraft. This is DUCHESS' primary science objective, which drives the mission design and can be accomplished by a six-month minimum mission. By studying the probability of ducted propagation during radiation belt traversals, DUCHESS will also statistically determine the relative abundance of ducting as a function of location and conditions (geomagnetic activity, wave frequency), providing the much-needed observational constraints for inclusion of ducting in radiation belt models.

In this presentation, we will introduce the science background, targeted objectives, and proposed technical approach for DUCHESS. We will also outline how DUCHESS' first-of-a-kind simultaneous observations of chorus waves along with pitch-angle resolved energetic electron spectra can help address other open questions in Earth's radiation belts, thus revolutionizing our understanding and modeling of the radiation belt dynamics.

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