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Magnetospheric radio and plasma wave emissions: Quasilinear analysis of Juno spacecraft data

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The magnetospheres of magnetized planets such as the Earth, Jupiter, and Saturn, are known as prodigious sources of radio and plasma wave emissions. Among these the most powerful source of radio emission is the giant planet Jupiter. The contemporary Juno mission is part of NASA's New Frontiers Program, and it is a Jupiter exploration mission. Its unique polar orbit makes it possible to investigate and characterize Jupiter's polar magnetosphere and its aurora. Juno spacecraft is continuing to detect the strong radio wave emission as well as other types of plasma waves such as the whistler waves and upper-hybrid waves. Juno also measures energetic particles and other physical quantities such as the density and magnetic field intensity. These measurements thus provide an unprecedented opportunity to understand the physical processes that leas to these radio and plasma wave emissions. The self-consistent quasilinear plasma kinetic theory is a useful tool that may be employed to replicate, and thus help understand, the essential characteristics of the electrons and the electromagnetic waves measured by the Juno space probe. Such an endeavor reveals the nature of wave emission and saturation mechanisms, and thus not only helps understand the fundamental processes taking place in the Jovian magnetospheric environment, but also enhances the scientific return of NASA's space mission. This presentation will overview some recent progresses made in this context. Findings from this study can easily be extended to other similar environment such as the Earth's magnetosphere and the associated radio (Auroral Kilometric Radiation) and plasma waves, as well as solar and astrophysical environments.

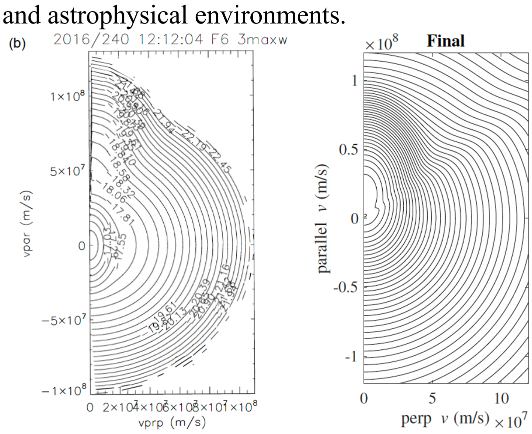

Figure 1. [Left] Observed electron phase-space distribution showing the field-aligned beam and a relaxed loss-cone. [Right] The relaxed (saturated) state of electron beam-plus-loss-cone electron distribution function computed from quasilinear theory.

In Ref. [1] the Juno data for Hectometric (HOM) emission was analyzed and modeled with quasilinear theory. As a demonstration of the analysis, the side-by-side comparison of the observed electron phase space distribution and theoretically-computed relaxed state of electron distribution is displayed in Figure 1. The comparison of observed waves and theoretically computed dynamic spectra associated with the loss cone-induced HOM emission and the field-aligned electron beam-induced whistler waves is shown in Figure 2.

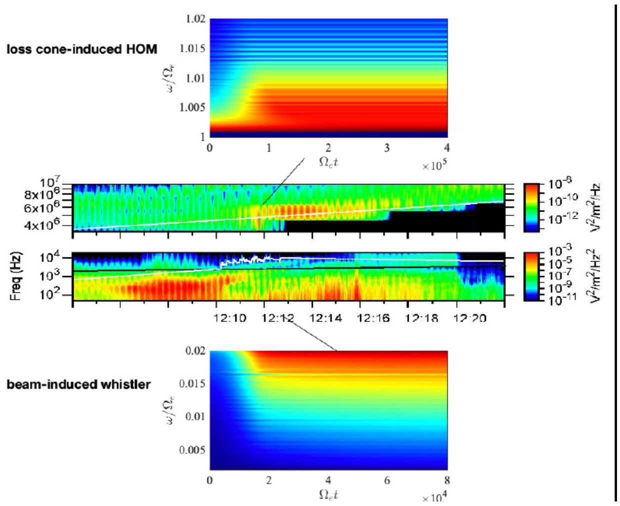

Figure 2. Comparison of observed wave spectra (middle) and theoretically calculated loss-cone-induced HOM emission (top) and the beam-induced whistler wave emission (bottom).

In the presentation other examples of Juno Wave instrument and particle (largely based on the JADE instrument) data as well as the theoretical replication based on the rigorous application of self-consistent wave and particle quasilinear analysis will be overviewed. This includes a recent work on the broadband kilometric (bKOM) emission source region [2].

[1] P. H. Yoon, J. D. Menietti, F. Allegrini, *et al.* (2025), *J. Geophys. Res.*, *130*, e2024JA033241.
[2] P. H. Yoon, J. D. Menietti, F. Allegrini, *et al.* (2025), Quasilinear wave-particle analysis in the source region of Jovian kilometric radio emission, *J. Geophys. Res.*, submitted for publication.