Tunneling and mode conversion of waves in the ion cyclotron frequency range in the planetary magnetospheres

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Observational studies indicate, in addition to protons, the presence of several ion species, e.g., He\(^+\) at Earth’s, Na\(^+\) at the Mercury’s, S\(^{2+}\) and O\(^+\) at Jupiter’s environments [1]. Narrow-band linearly polarized ultra-low frequency (ULF) waves \((f \simeq 1 \, \text{Hz})\), having a resonant structure and a peak frequency between the cyclotron frequency of protons and heavy ions, have been detected in the magnetospheres of Earth and Mercury. Such wave events have been suggested to be driven by linear mode conversion (MC) of the fast magnetosonic waves (FW) at the ion-ion hybrid (IIH) resonances. Since the resonant frequency is linked to the plasma composition, solving the inverse problem allows one to estimate the concentration of the heavy ions from the measured frequency spectra.

Planetary magnetic fields are intrinsically radially inhomogeneous that leads to the appearance of the \(L\)-cutoff layer accompanying the IIH resonance to the low magnetic field side. In this work we prove that waves with a low parallel wave number \(k_\parallel\) can not tunnel through the cutoff-resonance layer, and thus can not be detected by the satellite. On the contrary, we evaluate conditions under which an efficient tunneling and MC can occur in magnetospheric plasmas [2]. For such conditions, the resonant MC frequency is close, but somewhat below, the crossover frequency. Finally, we discuss how these results can be applied to the interpretation of experimental observations.

References