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Eun-Hwa Kim And J.R. Johnson

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Comment on "Mode Conversion of Waves in the Ion-Cyclotron Frequency Range in Magnetospheric Plasmas"

Eun-Hwa Kim* and Jay R. Johnson†

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Recently, Kazakov and Fülöp [1] studied mode conversion (MC) at the ion-ion hybrid (IIH) resonance in planetary magnetospheric plasmas by simplifying the dispersion relation of the fast wave (FW) modes to describe a cutoff-resonance (CR) pair near the IIH resonance, which can be reduced to a Budden problem. They suggested that when the IIH resonance frequency (ω_S) approaches the crossover frequency (ω_{cr}), and the parallel wavenumber ($k_\parallel$) is close to the critical wavenumber $k_\parallel^*(\omega_S = \omega_{cr})$, MC can be efficient for arbitrary heavy ion density ratios. In this Comment, we argue that (a) the FW dispersion relation cannot be simplified to the CR pair especially near ω_{cr} because in many parameter regimes there is a cutoff-resonance-cutoff (CRC) triplet that completely changes the wave absorption; and (b) the maximum MC efficiency does not always occur near $k_\parallel \approx k_\parallel^*$.

The importance of the CRC triplet at the location x^* where $\omega_S \approx \omega_{cr}$ is readily seen from the FW dispersion relation shown in Eq. (3) of Ref. [1]. There are obviously right-hand (RH) and left-hand (LH) cutoffs located at $n_\parallel^2 = \epsilon(\omega_R, x_R)$ and $n_\parallel^2 = \epsilon_L(\omega_L, x_L)$, which occur on either side of the IIH resonance $n_\parallel^2 = \epsilon_S(\omega_S, x_S)$. To illustrate the relative separation of the cutoffs and resonance depending on $k_\parallel$ and ω, we present in Figure 1a a reconstruction of Figure 3 from Ref. [1] including both the LH and RH (not shown in [1]) cutoffs. From this figure, it is obvious that near $\omega_S \sim \omega_{cr}$ the CRC triplet is important because the both cutoffs are very close to the resonance location.

To illustrate the importance of the CRC triplet vs the CR pair when solving the differential equation associated with the dispersion relation, we plot the perpendicular refractive index ($n_\perp$) as a function of Earths radial distance in Figure 1(b) for $k_\parallel/k_\parallel^* = [0.285, 0.93]$. For $k_\parallel/k_\parallel^* = 0.285$, it is apparent that there is no RH-cutoff within the spatial domain. In this case the topology is well described by a CR pair and a Budden solution is appropriate. In contrast, when $k_\parallel/k_\parallel^* = 0.93$, the RH-

* Princeton Plasma Physics Laboratory, Princeton University; ehkim@pppl.gov

† Princeton Plasma Physics Laboratory, Princeton University; jrj@pppl.gov

cutoff is located close to the resonance and the Budden approach is not appropriate, and it is necessary to describe the CRC triplet [2, 3].

Kim et al. [3] have previously evaluated absorption coefficients at the IIH resonances for variable concentrations of sodium and azimuthal and field-aligned wave numbers. They clearly showed that the FW dispersion relations at Mercury have the CRC triplet structures. Moreover, the maximum MC coefficient at Mercury increases up to 100% as the result of interference between incoming and reflected waves from RH cutoff near the IIH resonance. The maximum absorption occurs at $(m_z,\ N_{Na}/N_e,\ \omega_S/\omega_{ci}) =$ (1, 0.12, 0.2), (2, 0.25, 0.4), and (3, 0.45, 0.6), respectively, where m_z is field-aligned wave harmonic number. Under these conditions, $k_\parallel/k_\parallel^*$ are 0.5, 0.69, and 0.78, respectively, and thus $k_\parallel/k_\parallel^* < 1$ rather than $k_\parallel/k_\parallel^* \approx 1$ at Mercury.

In conclusion, we have confirmed that (a) the FW absorption at the IIH resonance is affected by not only the Budden tunneling parameter, but also on interference between the incoming and reflected waves in the CRC triplet, and (b) the maximum MC efficiency occurs over a wide range of $k_\parallel/k_\parallel^*$ and ω_S/ω_{cr} in planetary magnetospheres. Therefore, the approach presented in [1] cannot be generally used to estimate heavy ions densities in the planetary magnetospheres.

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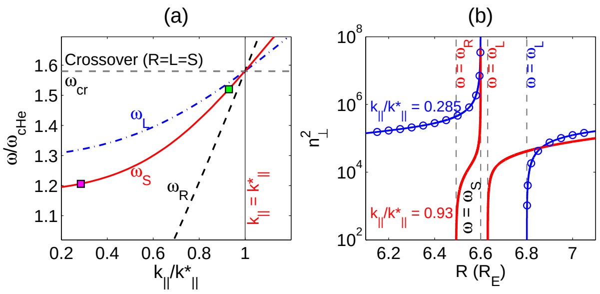

FIG. 1. Normalized IIH resonance (ω_S), LH- (ω_L), and RH-cutoff (ω_R) frequencies as a function of $k_\parallel$ at Earth. Here, $B_0(R = 6.6R_E) \approx$ 108nT, $N_e = 10\text{cm}^{-3}$, and $N_H/N_e : N_{He}/N_e =$ 9 : 1; (b) The perpendicular refractive index ($n_\perp$) of FW at Earth magnetosphere for $k_\parallel/k_\parallel^* = 0.285$ (blue-circled), and 0.93 (red), as marked in magenta and green squares in Figure 1a, respectively. The magnetic field at magnetic equator is assumed, such as $B_0(R) = 3.1 \times 10^{-5}(R/R_E)^{-3}$T.

[1] Y. O. Kazakov and T. Fülöp, Phys. Rev. Lett. **111**, 125002 (2013).

[2] C. F. F. Karney, F. W. Perkins, and Y.-C. Sun, Phys. Rev. Lett. **42**, 1621 (1979).

[3] E.-H. Kim, J. R. Johnson, and K.-D. Lee, Geophys. Res. Lett. **38**, L16111 (2011).

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Information Services
Princeton Plasma Physics Laboratory
P.O. Box 451
Princeton, NJ 08543

Phone: 609-243-2245
Fax: 609-243-2751
e-mail: pppl_info@pppl.gov
Internet Address: http://www.pppl.gov