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Corrigendum to "Wave–particle resonance condition test for ion-kinetic waves in the solar wind" published in Ann. Geophys., 34, 393–398, 2016

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A correction of the wave–particle resonance parameter study in our recent publication is reported. The wave–particle resonance parameter for the electron cyclotron resonance was erroneously estimated. Unfortunately, the correction invalidates a major conclusion of the paper, that the ion-kinetic sideband waves in the solar wind most closely satisfy the electron cyclotron resonance condition. Correct analysis suggests the condition for the electron Landau resonance is most favorably met, rather than the proton or electron cyclotron resonances.

The resonance parameters are defined as

$$\zeta^{(m)} = \frac{\omega - m\Omega_s}{k_\parallel v_{\mathrm{th}}}. \quad (1)$$

An index of $m = 0$ indicates the Landau resonance, and that of $m = \pm 1$ the cyclotron resonance. ω is the wave frequency, Ω_s the cyclotron frequency of species s, $k_\parallel$ the parallel component of the wavevector with respect to the mean magnetic field, and v_{th} the thermal speed of the particles.

In our original work, we erroneously used the proton cyclotron frequency instead of the electron cyclotron frequency in our calculation of the electron cyclotron resonance. The resonance parameters for the other resonance types, viz. proton Landau, proton cyclotron, and electron Landau resonances, were properly estimated. However, Figs. 3 and 4 in our original work are affected by this error and are updated here to reflect the correct assessment of the electron cyclotron resonance condition. In the revised Fig. 3 (we use the same figure numbers here as in the original publication for consistency), the resonance parameters are now recomputed separately for the protons and the electrons, and are plotted as a function of the wavenumbers (normalized to the ion inertial length). In contrast to the result presented in the original paper, the corrected parameter for the electron cyclotron resonance (the bottom panel) exhibits markedly large deviations from unity. In reality, none of the observations satisfy this resonance condition, consistent with the fact that the measured frequencies are around the proton cyclotron frequency in the plasma rest frame, and thus have a large offset to the electron cyclotron frequency by a factor of 1836. Protons can resonate with the waves both in the Landau and the cyclotron senses, since some of the observed waves satisfy the condition $\zeta_{\mathrm{L(p)}} \sim 1$ or $\zeta_{\mathrm{C(p)}} \sim 1$ (see the first and the second panels, respectively). However, the largest proportion of the wave observations now satisfy the electron Landau resonance condition, $\zeta_{\mathrm{L(e)}} \sim 1$ (third panel).

The histograms of the Landau and cyclotron resonance parameters are displayed in the corrected Fig. 4 for the protons (top 2 panels) and the electrons (bottom 2 panels), confirming that the electron Landau resonance is most favored, followed

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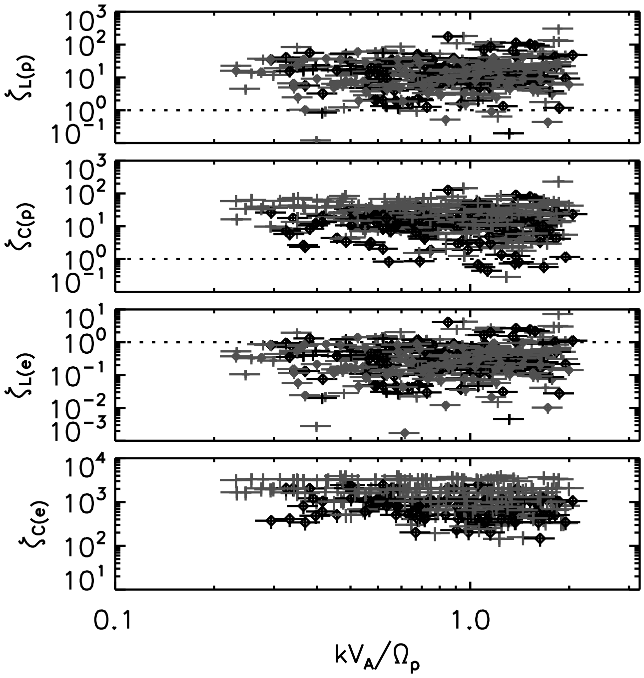

Figure 3. Landau resonance parameter with protons $\zeta_{\mathrm{L(p)}}$, cyclotron resonance parameter with protons $\zeta_{\mathrm{C(p)}}$, Landau resonance parameter with electrons $\zeta_{\mathrm{L(e)}}$, and cyclotron resonance parameter with electrons $\zeta_{\mathrm{C(e)}}$ for discrete waves in the solar wind observed by Cluster spacecraft (Perschke et al., 2014). Gray data points indicate the plasma condition of low beta (below unity), and black data points high beta.

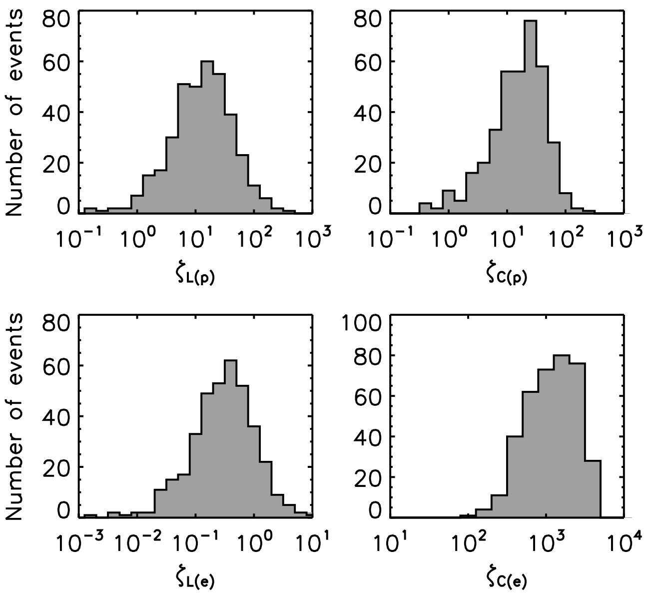

Figure 4. Histograms of proton Landau resonance parameter $\zeta_{\mathrm{L(p)}}$ (top left), proton cyclotron resonance parameter $\zeta_{\mathrm{C(p)}}$ (top right), electron Landau resonance parameter $\zeta_{\mathrm{L(e)}}$ (bottom left), and electron cyclotron resonance parameter $\zeta_{\mathrm{C(e)}}$ (bottom right).

by the proton Landau and cyclotron resonances. In contrast, the electron cyclotron resonance is not likely occurring because of the large offset in the frequencies to that of the electron cyclotron, yielding a result of $\zeta_{\mathrm{C(e)}} \sim 10^3$.

Our modified conclusion is that the ion-kinetic sideband waves in the solar wind can be in Landau resonance with the electrons although the frequencies are only of the order of proton cyclotron frequency. The reason for this is that the sideband waves have large propagation angles, being nearly perpendicular to the mean magnetic field, and the parallel components of the wave vector are sufficiently small. The correction of the resonance test indicates that the electron cyclotron resonance is not likely occurring on the ion kinetic scales, in contrast to our earlier conclusion. The electron Landau interaction is the most likely scenario for the dissipation mechanism on the ion kinetic scales, and our work also shows support for the occurrence of the proton Landau and cyclotron resonances (even though statistically not very significant).

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