Particle-in-cell simulation of rising-tone magnetosonic waves

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Magnetosonic waves are a common electromagnetic emission in the Earth's inner magnetosphere. These waves, also known as equatorial noises, propagate nearly perpendicular to the background magnetic field and have a frequency range from the local proton gyrofrequency up to the lower hybrid frequency. Satellite observations have shown that the wave power is usually confined within a few degrees from the geomagnetic equator both inside and outside the plasmasphere. Recently, a considerable amount of literature has grown around the topics of magnetosonic waves due to their potential roles in both accelerating and scattering radiation belt electrons. It has been shown that the waves can accelerate radiation belt electrons through Landau resonance and the timescale can be on the order of one day, suggesting the importance of magnetosonic waves in the electron dynamics of the radiation belt.

Recent observations[1] have reported that magnetosonic waves can exhibit rising-tone structures in the frequency-time spectrogram. However, the generation mechanism has not been identified yet. In this study[2], we investigate the generation of rising-tone magnetosonic waves in the terrestrial magnetosphere using 1D PIC simulations, in which the plasma consists of three components: cool electrons, cool protons and ring distribution protons. We find that the magnetosonic waves excited by the ring distribution protons can form a rising-tone structure with frequency of the structure ranging from about $0.5\Omega_{lh}$ to nearly Ω_{lh}, where Ω_{lh} is the lower hybrid frequency. It is further demonstrated that the rising frequency of magnetosonic waves can be accounted for by the scattering of ring distribution protons. Moreover, the rising-tone timescale obtained by PIC simulations are compared with the satellite observation. Our findings provide some new insights to understand the nonlinear evolution of plasma waves in the Earth's magnetosphere.

References
[1] Boardsen, S. A., et al. (2014), Van Allen Probe observations of periodic rising frequencies of the fast magnetosonic mode, Geophys. Res. Lett., 41, 8161–8168, doi:10.1002/2014GL062020.
[2] Sun, J., Chen, L., Wang, X., Boardsen, S., Lin, Y., & Xia, Z. (2020). Particle-in-cell simulation of rising-tone magnetosonic waves. Geophysical Research Letters, 47, e2020GL089671.https://doi.org/10.1029/2020GL089671

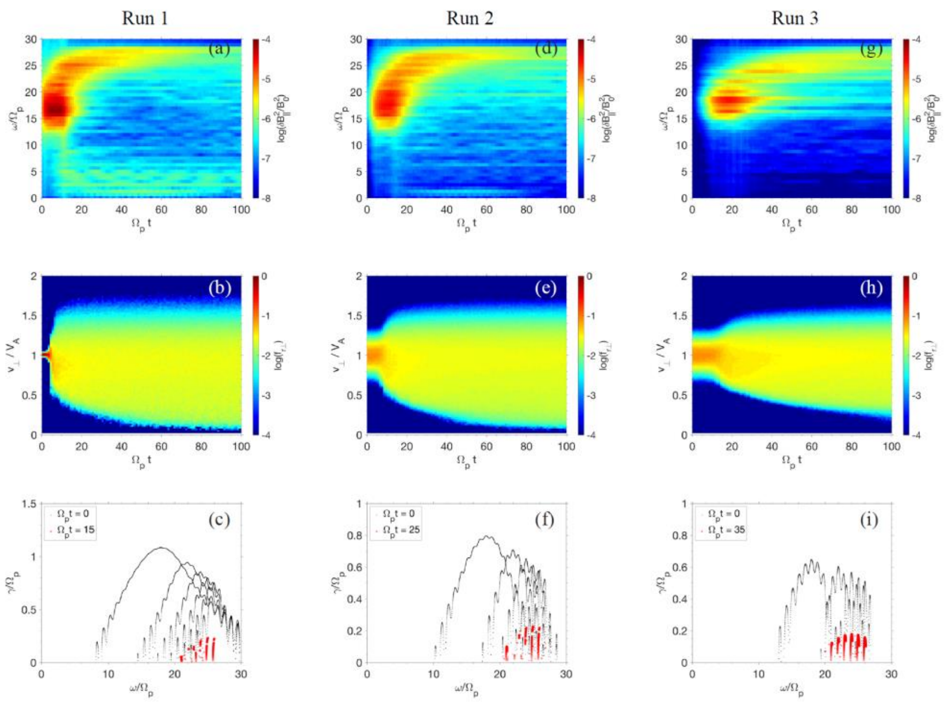

Figure 1. (a) Power spectral density of $\delta B_{\parallel}/B_0$ as a function of normalized frequency and time for PIC Run 1 with n_r = 2.5%n_0 and v_{rt} = 0.01V_A.. (b) The temporal evolution of the perpendicular velocity distributions of ring protons $fr\perp$. (c) The linear growth rate as a function of the frequency for different moments. Similar to (a-c) but (d-f) for PIC Run 2 with n_r = 2.5% n_0 and v_{rt} = 0.1V_A, and (g-i) for PIC Run 3 with n_r = 1% n_0 and v_{rt} = 0.1V_A.