7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Frequency Chirping of Electromagnetic Ion Cyclotron Waves in Earth's Magnetosphere

Xin Tao[1], Zeyu An[1], Fulvio Zonca[2,3], and Liu Chen[3,2]

[1] Department of Geophysics and Planetary Sciences, University of Science and Technology of China, Hefei, China

[2] Center for Nonlinear Plasma Science and C.R. ENEA Frascati, C.P. 65, 00044 Frascati, Italy

[3] Institute of Fusion Theory and Simulation, School of Physics, Zhejiang University, Hangzhou, China

e-mail: xtao@ustc.edu.cn

Frequency chirping, a rapid change in frequency over time, has been observed in several wave modes in Earth's magnetosphere and laboratory plasmas. In the magnetosphere, examples of frequency chirping waves include whistler mode chorus waves, electromagnetic ion cyclotron (EMIC) waves, magnetosonic waves, and electron cyclotron harmonic waves. Similarly, in fusion plasmas, Alfven modes have been observed to exhibit frequency chirping on different time scales. These chirping waves generally consist of discrete packets that are narrowband and quasi-coherent. Interaction with these chirping modes often results in the rapid transport of energetic particles in phase space, affecting space weather or deteriorating particle confinement in fusion devices. Therefore, there is significant research interest in understanding the physical mechanism of frequency chirping in both communities of space and laboratory plasmas.

In this work, we focus on the frequency chirping of EMIC waves in the magnetosphere, which has been studied only preliminarily. The only theoretical model (Omura *et al.*, 2010) of EMIC wave chirping we know of is based on nonlinear wave-particle interactions, which produces a chirping rate proportional to EMIC wave amplitude. Here, we propose a new model of EMIC wave chirping based on nonlinear wave-particle interaction theories of EMIC waves and the principle of the recently proposed “Trap-Release-Amplify” (TaRA) model (Tao, Zonca and Chen, 2021) of whistler mode chorus waves. Our new model relates the chirping rate of EMIC waves not only to wave amplitude via nonlinear wave-particle interactions but also to the background magnetic field inhomogeneity for the first time, providing a more comprehensive understanding of the underlying mechanisms of EMIC wave chirping. Additionally, we provide a direct quantitative comparison between theoretical chirping rates and observations. The comparison shows good agreement, suggesting the validity of our new model and that the same underlying principle of chirping mechanisms exists between EMIC waves and chorus waves. Our results, therefore, not only improve the understanding of the chirping of EMIC waves but also open new perspectives for further investigating the chirping mechanism of other wave modes in both space and laboratory plasmas.

References:

Omura, Y. *et al.* (2010) ‘Theory and observation of electromagnetic ion cyclotron triggered emissions in the magnetosphere, *Journal of Geophysical Research: Space Physics*, 115(A7). Available at: https://doi.org/10.1029/2010JA015300.

Tao, X., Zonca, F. and Chen, L. (2021) ‘A “Trap-Release-Amplify” Model of Chorus Waves’, *Journal of Geophysical Research: Space Physics*, 126(9). Available at: https://doi.org/10.1029/2021JA029585.