Statistical error estimation of the WPIA method and its application for nonlinear EMIC-proton interactions

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Theoretical and simulation studies suggest that the EMIC waves with various frequency changes are generated through the nonlinear wave particle interaction with the energetic protons. The nonlinear EMIC emissions with are studied by the Arase satellite data analysis in the Earth’s inner magnetosphere. Wave-particle interaction analysis (WPIA) method which calculate the inner product between the electromagnetic fields and the particle velocities and their phase differences has been developed to show the direct evidence of the energy transfer between the plasma waves and particles. We apply the WPIA method for the EMIC rising tone emissions observed by Arase satellite on 11th Dec. 2017. We perform parametric analyses on the energy and pitch angle of the particles to identify the region causing the efficient energy transfer with the EMIC waves in the proton distribution function. We also show statistical errors which come from the ion particle detector (LEP-i). The errors from the counting statistics and the ambiguity of the looking direction of the ion detectors are estimated. We estimate the minimum integral time in the WPIA method with which we can neglect the counting statistics. The bootstrap method, one of the Monte-Carlo method, is employed to estimate the random sampling errors in the looking direction considering the azimuthal and elevation angle response obtained in laboratory experiments. We discuss significance of the energy transfer by calculating the confidence interval of the WPIA results.

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