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Direct detection of ion pitch angle scattering by plasma waves in space plasma

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Energy exchange between charged particles and plasma waves have been supposed to contribute to loss and energization of plasmas in the magnetosphere. Especially, electromagnetic ion cyclotron (EMIC) waves can cause acceleration and scattering of ions in a wide energy range. It has been suggested theoretically that when energy is transferred from ions to EMIC waves, the pitch angle of ions decreases and ions precipitate into the Earth's ionosphere. The energy transfer between the plasma waves and ions can be evaluated by calculating the inner product of the wave electric field vector and the ion velocity vector using wave-particle interaction analysis (WPIA). We have expanded the WPIA method to directly detect the pitch angle scattering of protons by EMIC waves. On June 21, 2021, the Arase satellite successfully observed intense EMIC waves by PWE/EFD and MGF and deformation of the pitch angle distribution of ions by LEP-i simultaneously. We applied the WPIA analysis and detected the pitch angle scattering and the energy exchange. Significant Lorentz force works to decrease pitch angles of ions. At the same time, several protons increase their energy with increasing their pitch angles. These are the first direct evidence of the pitch angle scattering between EMIC waves and protons in the space plasma. We compare the WPIA results with the theoretical diffusion curve in the velocity distribution function. We also discuss what parameters contribute to the saturation and decay of EMIC wave amplitudes.