Non-resonant acceleration of He^+ by EMIC waves observed by MMS in the magnetosphere

*Naritoshi Kitamura[1], Masahiro Kitahara[2], Masafumi Shoji[3], Yoshizumi Miyoshi[3], Yuto Katoh[2], Satoko Nakamura[4], Hiroshi Hasegawa[1], Yoshifumi Saito[1], Shoichiro Yokota[5], Barbara L Giles[6], Thomas Earle Moore[6], Daniel J Gershman[6,7], William R Paterson[6], Craig J Pollock[8], Christopher T Russell[9], Robert J Strangeway[9], Stephen A Fuselier[10,11], James L Burch[10]

1. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2. Department of Geophysics, Graduate school of Science, Tohoku University, 3. Institute for Space-Earth Environmental Research, Nagoya University, 4. Research Institute for Sustainable Humanosphere, Kyoto University, 5. Department of Earth and Space Science, Graduate School of Science, Osaka University, 6. NASA Goddard Space Flight Center, 7. University of Maryland, 8. Denali Scientific, 9. Institute of Geophysics and Planetary Physics, University of California, Los Angeles, 10. Southwest Research Institute, 11. University of Texas at San Antonio

Wave-particle interactions have been suggested to play a crucial role in particle acceleration in collisionless space plasmas in which the motion of charged particles is controlled by electromagnetic fields. Using an electromagnetic ion cyclotron (EMIC) wave event observed by MMS, we investigate energy transfer between He^+ and EMIC waves in detail. The four MMS (Magnetospheric Multiscale) spacecraft traversing the duskside magnetosphere measured electromagnetic ion cyclotron (EMIC) waves from ~10 to 13 UT on 1 September 2015. The burst ion data from Fast Plasma Investigation Dual Ion Spectrometer (FPI-DIS) with a time resolution of 150 ms are available around the two of the wave packets. Strongly phase bunched He^+ ions with energies of ~100 eV to ~2 keV were detected in the wave events. To directly detect energy exchange between ions and EMIC waves, we apply the Wave-Particle Interaction Analyzer (WPIA) method that is to calculate the dot product between the wave electric field ($\mathbf{E}_{wave}$) and ion current perpendicular to the background magnetic field ($\mathbf{j}$). A positive $\mathbf{j} \cdot \mathbf{E}_{wave}$ for the phase bunched He^+ near the beginning of the second wave event indicates that the He^+ was being accelerated by $\mathbf{E}_{wave}$. The observed pitch angle (slightly larger than 90 degrees) of He^+ is consistent with non-resonant interaction with the wave but is inconsistent with cyclotron resonance. The maximum energies for both of the event are consistent with simple test particle calculations in the wave using observed parameters. Although the separation of the spacecraft (~160 km) is smaller than the cyclotron radius of accelerated He^+ (~200-600 km) in the second wave event, significant differences in flux among the 4 spacecraft were observed when the flux of He^+ became large. This indicates that the non-resonantly accelerated He^+ is distributed fairly non-uniformly in the wave.

Keywords: EMIC waves, Non-resonant ion acceleration, MMS spacecraft, Heavy ion, Wave-particle interaction

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