Direct evidence of energy exchange between EMIC waves and ions observed by the MMS spacecraft at the off-equator magnetosphere

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Wave particle interactions, which cause particle acceleration and pitch-angle scattering, are a fundamental energy exchange process in collisionless space plasma. The four MMS (Magnetospheric Multiscale) spacecraft traversing the duskside magnetosphere measured electromagnetic ion cyclotron (EMIC) waves around 3.6, 8.7, and -5.2 R_E in X, Y, and Z GSM from ~12:18 to 12:22 UT on 1 September 2015. In this period, the burst ion data (150 ms resolution) are available, and cold ions (below 300 eV) are detected due to a large magnitude of the electric field drift by the wave electric fields under weak background magnetic fields (~22-40 nT). Since the frequency of the EMIC waves were lower than ~1/5 of the proton gyro frequency, perpendicular electric fields were derived from the cross product of the negative cold ion velocity and the magnetic field. Using these data, we investigate energy exchange between EMIC waves and ions. Thirty second averages of the dot product of the perpendicular components of the wave electric fields (0.05-0.1 Hz) and ion resonant currents reached -0.2 pW/m^3 in the energy range of 14-30 keV in the pitch angle range from 33.75 to 67.5 degrees near the beginning of the wave (~12:18:30 UT). The negative value in this pitch angle range indicates that the perpendicular energy of ions was being transferred to the EMIC waves propagating toward higher latitudes at the MMS location. This initial result indicates that EMIC wave growth due to wave particle interactions can occur far from the equator, although it has been thought that the source region of EMIC waves is near the equator.