

## MMS spacecraft observation of electron-scale foreshock waves

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Formation of the foreshock region is unique to collisionless plasmas in that the plasma is disturbed even upstream of the shock wave. Various spacecraft observations in situ in the foreshock region ahead of the Earth bow shock have revealed that the shock-reflected, backstreaming ions are the likely source of the disturbance in the foreshock region, particularly through the right-hand ion beam instability producing the right-hand polarized, nearly parallel-propagating whistler waves. The advent of the four MMS spacecraft offers us now an opportunity of studying the foreshock waves on spatial scales of about 10 km, down to nearly the gyro-radius or the inertial length of electrons. A foreshock encounter on 30 November 2015 is studied in detail using the dispersion analysis tool for the multi-spacecraft data. The dispersion branch of the whistler mode continues from the ion-kinetic scale (on the length scale of about 100 km) to the electron-kinetic scale. This result indicates that foreshock turbulence develops by exciting a series of the whistler mode at various wavelengths.

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