Direct observation of collisionless energy transfer from MHD wave to ions via Landau and transit-time damping in laboratory plasma

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In collisionless space and astrophysical plasmas, Landau and transit-time damping are essential processes for energy transfer [1]. The energy transfer from wave to particle occurs in collisionless laboratory plasma through the interaction between particle and wave, associated with the deformation of ion velocity space from Maxwell-Boltzmann distribution [2]. We present the direct observation of mass-dependent collisionless energy transfer via Landau and transit-time damping in a laboratory plasma. Figure 1(a) shows ion velocity distribution measured by fast charge exchange spectroscopy with a time resolution less than ion-ion collision time. The deformation of ion velocity space from Maxwell-Boltzmann distribution is clearly observed at 0.1ms after the onset of magnetohydrodynamics (MHD) burst. The Landau and transit-time damping are confirmed by the bipolar velocity-space signature of the ion velocity distribution function, as seen in Figure 1(b). The excellent agreement between the decrease of resonant phase velocity evaluated from the bipolar velocity-space signature and the wave's phase velocity, estimated from the chirping down burst frequency of the MHD oscillations measured with the plasma displacement, is clear evidence for the Landau damping.

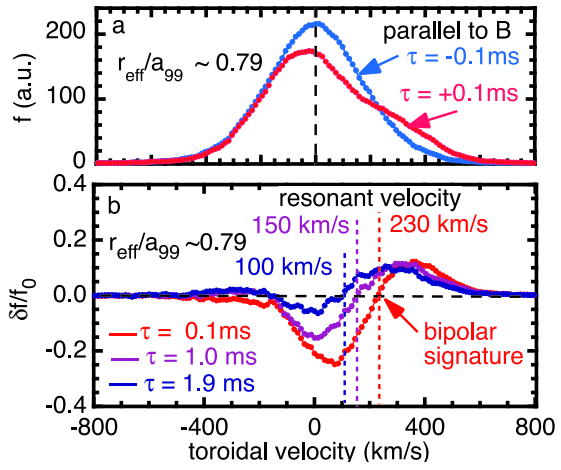

Fig.1 (a) Distribution function of ion velocity at 0.1 ms before (blue circles) and after (red circles) the onset of MHD burst, (b) the difference of velocity distribution function between 0.1 ms before and 0.1ms (red circles), 1.0 ms (purple circles), 1.9 ms (dark blue circles) after the onset of MHD burst.

Reference

[1] C. Chen, et. al, Nat. Commun. 10, 740 (2019).

[2] K.Ida et. al., Commun. Phys. 5, 228 (2022).