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Measurement of zero-frequency fluctuations generated by coupling between Alfvén modes in the JET tokamak

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We report on the first direct measurement of three-wave coupling between Alfvén modes and a zero-frequency fluctuation in a magnetically-confined plasma. Alfvén eigenmodes can be destabilized by energetic particles generated by auxiliary heating schemes, or by fusion-born alpha particles in a burning plasma. Alfvén eigenmodes have traditionally been regarded as detrimental to plasma confinement because they can give rise to strong transport of the energetic particles [Heidbrink PoP 2020]. Recent theoretical advances [Chen PRL 2012, Qiu Pop 2016] and numerical simulations [Biancalani PPCF 2021, Mazzi Nat Phys 2022] have suggested that unstable Alfvén eigenmodes can have a stabilizing effect on the background turbulence by generating zero-frequency zonal flows. To date, the coupling of a zonal-flow component to the Alfvén eigenmodes lacks experimental demonstration, and is the object of this presentation. In the experiment in the JET tokamak, a trace minority of 3He ions accelerated to MeV energies by means of Ion Cyclotron Resonant Frequency (ICRF) waves are shown to destabilize core localized Alfvén modes. Most of the heating is ultimately absorbed by the thermal electrons as the 3He ions slow down and hence high electron temperature is obtained. Despite negligible collisional heating transferred from the 3He to the thermal ions, the thermal ion temperature is shown to increase and equalize the electron temperature when Alfvén modes are observed. Bicoherence analysis of the Doppler backscattered signal shows that Alfvén modes of frequency inside the toroidally induced gap (and its harmonics) exhibit nonlinear three-wave coupling interactions with a zero-frequency fluctuation that is consistent with a zonal mode. The increase in the deep core-ion temperature and reduced power balance ion heat diffusivity suggests a stabilizing effect of the turbulence by a zero-frequency zonal mode generated by the Alfvén eigenmode. We will show how the coupling between Alfvén and a zero-frequency zonal mode is reproduced by direct nonlinear gyrokinetic simulations using the CGYRO code.