The consequences of density inhomogeneities on solar radio burst wave emissions due to electron beams

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Type III radio bursts are observed during solar flares. They are thought to be caused by electron beams propagating in the solar corona [Reid and Ratcliffe, 2014]. Magnetic reconnection is a possible accelerator of the electron beams since it generates unstable distribution functions as well as and density inhomogeneities [Muñoz and Büchner, 2018]. The properties of radio emissions by electron beams in such environment are, however, still poorly understood. We capture the non-linear kinetic plasma processes of radio emissions in such plasmas by numerical simulations utilizing the fully kinetic Particle-In-Cell (PIC) code ACRONYM [Kilian et al, 2012]. Our model takes into account unstable electron velocity distribution functions (EVDFs) as they are supposed to be created by the magnetic reconnection. These EVDFs allow two distinct mechanisms of radio wave emissions: plasma emissions due to wave-wave interactions and so-called electron cyclotron maser emissions (ECME) due to wave-particle interactions [Melrose, 2008].

Our most important finding is that the number of harmonics of Langmuir waves increases due to the density inhomogeneities caused by reconnection (see Figure 1, top panel). The harmonics are generated by the interaction of beam-generated Langmuir waves and their harmonics. In addition we also found evidence for the emissions of transverse harmonic electromagnetic waves due to a coalescence of beam-generated and fundamental Langmuir waves with a vanishing wavevector. We investigate the consequences of the reconnection-related density inhomogeneities on the conversion process of the free energy of the electron beams to electrostatic and electromagnetic waves and the frequency shift. Our findings explain the observation of Langmuir waves and their harmonics in solar radio bursts and the observed frequency shifts in these emissions. Harmonics of electron cyclotron waves caused by perpendicular gradients in the beam EVDFs are observed (see Figure 1, bottom panel).

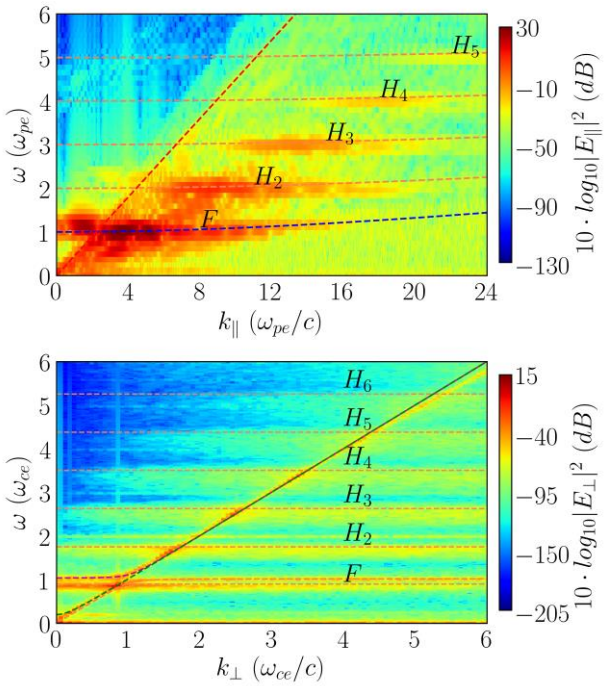

Figure 1: Fundamental and harmonics of Langmuir waves (top) and electron cyclotron waves (bottom).

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