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A model of non-Maxwellian electron distribution for the analysis of ECE in JET discharges

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Discrepancies between electron temperature measurements by Thomson Scattering (TS) and Electron Cyclotron Emission (ECE) have been often observed in high-temperature tokamak plasmas, in particular on TFTR [1], JET [2] and FTU [3]. Such observations, made on different machines, by different types of instruments, using different calibration methods, are too ubiquitous to be ascribed to instrumental effects; they rather call for explanations based on physics phenomena. The hypothesis that the discrepancy could be associated to non-Maxwellian bulk electron distributions has been put forward in the past [4,5] and appears as a plausible explanation in the case of a plasma heated by EC waves, as FTU [3]. For TFTR and JET, electron heating rather takes place because of the interaction of the electron distribution either with a fast ion tail driven by Neutral Beam Injection and/or Ion Cyclotron Resonance Heating, or by energetic alpha particles produced by fusion reactions in a D-T plasma. Two mechanisms are known to produce small bipolar distortions of the electron distribution in the presence of energetic ions: collisional relaxation [6] or Landau damping of Kinetic Alfvén Waves, as observed in the Magnetosheath [7,8].
Recent experiments performed in JET at high level of plasma heating, in preparation of, and during the D-T campaign have shown again TS-ECE discrepancies on an extensive database [9]. ECE is observed to be higher or lower than TS, depending on the plasma scenario. Moreover, ECE measured by a Martin-Puplett interferometer on a broad frequency range displays differences between 2nd and 3rd harmonics, which, at high temperatures (> 4 keV) and high densities are expected to yield the same radiation temperature. In order to perform a systematic analysis of this effect, a simple model of bipolar distortion of the electron distribution function has been developed, allowing analytic calculation of the EC emission and absorption coefficients. Extensive comparisons of the modelled ECE spectra at both the 2nd and the 3rd harmonic with experimental measurements provide a compelling confirmation of bulk electron distribution distortions around 1-2 times the electron thermal velocity and prove useful for a first level of analysis of this effect.

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