Generation of Kappa-like electron velocity distribution function by Whistler and Langmuir mode wave spectra

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Charged particles in magnetized plasma environment such as the solar wind or planetary magnetosphere pervasively feature non-thermal energetic (tail) population. Such a feature has been modeled by the so-called Olbert-Vasyliunas Kappa distribution since the 1970s, which is a purely empirical model. However, since the trail-blazing work by Tsallis in the late 1980s, the space plasma community has adopted the Tsallis non-extensive statistical theory as a fundamental explanation for the Kappa model. Such an effort, which began in the early 2000s, was led by, among others, Leubner, Livadiotis, Lazar, and others. While the non-extensive statistical framework provides a conceptual foundation for the Kappa distribution, it is true that the physical mechanisms that undergird the notion of non-extensive nature of a statistical system are not widely available. One of them is the asymptotic theory of Langmuir turbulence by Yoon, proposed in a series papers published in mid 2010s. According to this theory, the long-time steady-state Langmuir turbulence spectrum is commensurate only with the electron Kappa distribution and no other velocity distribution functions. While such a theory represents one of the few physical mechanisms that actually leads to the formation of Kappa distribution, the theory assumes an unmagnetized plasma. Space and laboratory plasmas are usually immersed in the background of ambient magnetic field. The extension of Yoon's asymptotic weak turbulence theory to magnetized plasmas is yet to be done. Instead, for magnetized plasmas, a number of approaches are taken in the literature to explain the formation of Kappa distribution. These models usually assume a background of wave spectrum, with which, one solves the quasilinear kinetic equation in order to obtain a Kappa-like solution for the particle distribution function - see, for instance, the paper by Ma and Summers (1998), or Kim et al. (2016). The present paper also takes a similar approach, but in the present model, the quasilinear kinetic equation that includes the effects of spontaneously-emitted wave fluctuations are also included. By adopting such a model, it is demonstrated that a steady-state Kappa-like electron velocity distribution function in magnetized plasma emerges when the electrons are immersed in the background permeated by a constant magnetic field plus the spectra of whistler-mode and Langmuir-wave fluctuations. It can be shown that steady-state solution of the quasilinear Fokker-Planck equation leads to a Kappa-like model with an exponential cutoff factor. Such a model is equivalent to the recently proposed regularized Kappa distribution by Scherer et al (2018). While Scherer et al.'s motivation was to put forth a mathematical model to avoid the divergence of higher-order velocity moments in Kappa model, such a model is a natural consequence of the present theory.