Kappa distribution and active regions at the sun: probing with microwave gyroresonant radiation

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A true distribution of tenuous astrophysical plasmas often deviates from the classical Maxwellian one. The reasons for such deviations can be several fold: sporadic energy releases resulting in acceleration of charged particles, long relaxation times due to infrequent binary collisions, important role of far interactions by means of plasma waves and MHD turbulence etc. [1]. In particular, the time intervals between the energy release episodes can be shorter than needed for the plasma to fully relax towards a Maxwellian; in such cases the Maxwellian distribution will never be established, so another distribution will play a role of a quasi-stationary distribution. It is known that under certain conditions, a so-called kappa-distribution plays a role of this quasi-stationary distribution. Detecting the deviation of the true distribution of the plasma from the Maxwellian one is fundamentally important, but difficult to perform given that for many observations the Maxwellian distribution is hard to distinguish from the kappa distribution with a reasonably large index, say kappa=10. Interestingly, in case of plasma with the kappa distribution, the microwave gyroresonance emission with its large optical depth is extraordinarily sensitive to the kappa index value, because the optically thick emission is highly sensitive to small variations at the tail of the distribution. To demonstrate the power of the method, we consider microwave emission from a 3D model [2] of active region and demonstrate that its brightness changes measurably with the kappa index up to kappa = 50 at least. In our study we adopt an AR thermal model to reproduce the optically thin EUV data on average, but allow a kappa distribution with unknown index rather than the Maxwellian distribution. We vary the kappa index and compute the radio brightness maps from the same 3D model using theory developed in [3]. These synthetic maps are convolved with the point spread function of a given radio interferometer and compared with the observed radio brightness maps. The synthetic radio brightness increases rapidly as the kappa index decreases, which allows, perhaps, the ever most stringent constraints on the kappa-indices consistent with the data. We found that the allowable kappa indices are well above the value around 15 and the best consistent with values of 25-30 or above. We discuss implications of this finding and potential ways to further constraint the kappa distribution shape in the solar plasma.

[l] G.D. Fleishman, I.N. Toptygin, Cosmic Electrodynami **ISBN: 978-1-4614-578**, 712 (2013).

[2] G.M. Nita, et al., ApJ **799**, 236 (2015).

[3] G.D. Fleishman, A. Kuznetsov, ApJ **781**, 77 (2014).