Effects of electron density, multiple ionization a photoionization on the ionization equilibrium the kappa-distribution in the solar corona and plasma diagnostics

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The physical conditions in the transition region and solar corona can lead to formation of non-Maxwellian kappa-distributions. The shape of the electron distribution changes individual ionization, recombination, as well as collisional excitation rates, and consequently line intensities. This allow us to diagnose non-Maxwellian distributions from spectral observations. Ionization equilibrium in the coronal conditions with low electron densities is usually approximated to be independent of electron density, as it is assumed that the ionization and recombination from the ground levels dominate. However, the metastable levels can have significant populations, leading to density-dependent effects in ionization equilibrium. Similarly, electron impact multiple ionization is commonly neglected, which again is not necessarily true for distribution with the enhanced high-energy tail.

We analyzed how these effects affect the ionization equilibria for kappa-distributions. We have found that density effects on the ionization equilibrium are lower for the kappa-distributions with low kappa then for the Maxwellian one. The photoionization behaves similarly with kappa. The increase of the ionization rates for the strongly non-Maxwellian distributions leads to the suppression of the photoionization effects. Reversely, effect of double ionization on the ionization equilibrium is stronger for low values of kappa. However, density dependent dielectronic recombination shifts the ionization peaks to lower temperature similarly for the all of kappa and Maxwellian distributions.

These improvements were included into the new version of KAPPA package (software and database) providing fast calculations of synthetic spectra for kappa-distributions for different kappa > 1.7, temperatures, and electron densities. Synthetic spectra calculate with improved KAPPA package enable us to diagnose electron distribution from EUV spectra of flares, active regions or quiet Sun.