§15. Emission Measure of a Solar Flare in Non Equilibrium Ionization

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We have studied the time evolution of BCS spectra of He - like S XV, Ca XIX and Fe XXV ions observed by the Yohkoh satellite for a solar flare on 6th September 1992[1]. Electron temperatures are derived through a fit of synthetic spectra to the observed S XV, Ca XIX and Fe XXV spectra using new evaluated atomic data. The ion density ratios derived from the spectra without assuming ionization equilibrium show a time - dependent non equilibrium ionization. The shift from equilibrium values indicates an ionizing plasma. For the first time the emission measures are derived from the spectra without assuming ionization equilibrium and solar abundances.

Usually the emission measure is derived based on an assumption of ionization equilibrium. We have used a new method without assumption of the ionization equilibrium. This method gives a larger emission measure for Fe ions than that assuming ionization equilibrium.

The observed line intensity I_w is written as,

$$I_w = \varepsilon_w n(\text{He-like ion}) n_e V/(4\pi r^2)$$
$$= \varepsilon_w (n(\text{He-like ion})/n(Z)) (n(Z)/n(H)) \times (n(H)/ne) n_e^2 V/(4\pi r^2) \quad (1)$$
$$= \varepsilon w (n(\text{He-like ion})/n(H)) (n(H)/n_e) \times n_e^2 V/(4\pi r^2) \quad (2)$$

where ε_w is the emissivity of the line w, n_e electron density, n(Z) and n(H) are the densities of the element of Z and hydrogen, V the volume where the line is emitted and r is the distance from the earth to the Sun. Usually the emission measure n_e^2V is derived assuming ionization equilibrium for n(He-like ion)/n(Z) and element abundance for n(Z)/n(H) to be the solar abundance from Eq.(1). But we have derived the emission measure from Eq.(2) using the ion abundance n(He-like ion)/ n(H) derived from the intensity ratio I_w/I_c where I_c is the intensity of the continuum.

The derived emission measures (EM) from two different spectra of Fe and Ca are shown in Fig. 1. The values of EM(Ca) and EM(Fe) agree well with each other in all the phases including the rising phase. When ionization equilibrium is assumed, the derived $[EM(Fe)]_{eq}$ from Eq.(1) is generally smaller than $[EM(Ca)]_{eq}$ and $[EM(S)]_{eq}$ by more than a factor of two. This is evidence for non equilibrium ionization in solar flares. In Fig. 1, the emission measure $[EM]_{eq}$ derived from the line intensity assuming the ionization equilibrium are also plotted for Fe, Ca and S. After the maximum phase the electron temperatures from three different spectra are the almost the same in our case. Therefore we think the main emission region is the same for Fe, Ca and S spectra after the maximum phase.

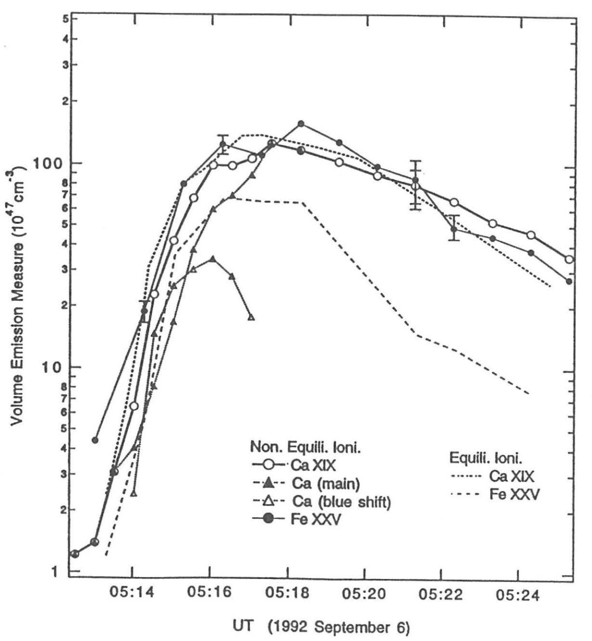

Fig.1 The time evolution of the emission measures. Solid and dotted lines with symbols are those obtained without assuming the ionization equilibrium, whereas the dashed and dot-dashed lines without symbols are those obtained using the ionization equilibrium

1). T. Kato et al, accepted in Ap. J. (1997)