X-RAY LINES FROM Mg VIII AND Si X IONS AND THEIR DIAGNOSTIC USE

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ABSTRACT. The solar X-ray emission lines from Mg VIII and Si X ions have been studied. The variation of theoretical line intensity ratio I(λ 75.03)/I(λ 74.86) from Mg VIII and I(λ 50.69)/I(λ 50.52) from Si X as a function of electron density is found to be good density monitors of the emitting regions of solar plasma. The computed values of line intensity from these ions based on Kopp and Orrall model have been used to derive electron density of the quiet Sun and coronal holes. The electron densities of 10^9 cm^{-3} and 4.6 x 10^8 cm^{-3} are estimated at the electron temperatures of 8 x 10^5 K and 1.6 x 10^6K for the quiet Sun whereas the respective values of 5.4 x 10^8 cm^{-3} and 1.7 x 10^8 cm^{-3} are obtained for the coronal holes. The line intensity ratios studied here are independent of temperature variation and are therefore excellent candidates for electron density diagnostics. However, observational data with improved spectral resolution is needed for using X-ray line pairs studied for their diagnostic use.

INTRODUCTION

Ions in the boron sequence have rich emission line spectra in the X- and EUV region. Observations of the relative strengths of EUV lines from these ions especially Mg VIII and Si X have been extensively used to probe the solar plasma (Elwert and Raju 1975; Flower and Nussbaumer 1975a,b; Vernazza and Mason 1978; Dwivedi and Raju 1980; Saha and Trefftz 1983; Dwivedi 1988). However, little attention has been paid so far to use X-ray lines from these ions for electron density diagnostics of solar and astrophysical plasmas mainly due to lack of observational data. Recently Brown et al. (1986) have studied the electron density diagnostics in the 10-100 Å interval for a solar flare with considerable emphasis on line intensity ratios from helium-like ions. In the present investigation X-ray lines from Mg VIII and Si X have been considered for electron density diagnostics of cosmic plasmas. According to the ionization equilibrium calculations of Jordan (1969), Mg VIII has maximum relative ion abundance at 8 x 10^5 K and Si X at 1.6 x 10^6 K. Because of its maximum relative ion abundance around 8 x 10^5 K, lines emitted from Mg VIII ion are most suitable to probe chromosphere-corona transition region and coronal holes.

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METHOD

If the computed line intensity ratio is found to vary with electron density, one finds it useful for density diagnostics. Moreover, the observed line intensity ratio should fall well within the density-sensitive portion of the curve in order to reliably determine the electron density. However, the observed lines with calibrated intensities have to be distinctly free from any ambiguity with regard to the blending, masking or other observational problems. Therefore, one finds very few observed lines with calibrated intensities to exploit them for density determinations. One of the other possible ways to look at the problem is to use a model atmosphere to compute the corresponding line intensities to find out the theoretical values of N_e. Such a study is also useful in identifying close lines arising from different ions prevalent in the atmosphere and provides first hand information to predict lines with observable intensity, which have hitherto not been observed, for future observations. This study also acts as a test or constraint on the model atmosphere when compared with the observational data. We have, therefore, used a model atmosphere of Kopp and Orrall (1976) for the quiet Sun and coronal holes to estimate the line intensities in order to use them for density determinations. The necessary steady state equilibrium equations for various levels accounting for different physical processes as well as the atomic data used have been described by Dwivedi and Raju (1980).

RESULTS AND DISCUSSION

Density sensitivity of line intensity ratios considered in this study arises because of the existence of the metastable levels.

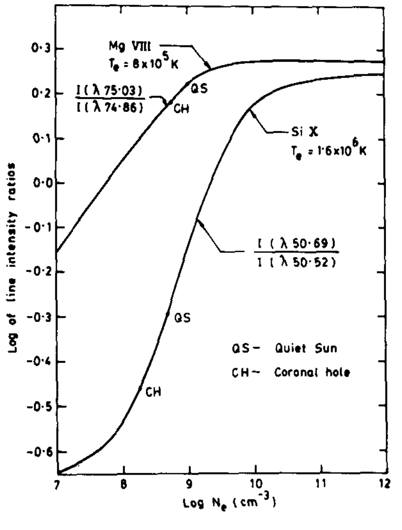

FIG.1. Electron density dependence of Mg VIII and Si X density-sensitive X-ray line intensity ratios. Dots correspond to the computed intensity ratios based on the model atmosphere of Kopp and Orrall (1976).

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Figure 1 shows the variation of the intensity ratios of X-ray lines from Mg VIII and Si X ions as a function of electron density. The values of temperature indicated in this figure are those at which the relative ion abundances of the elements are reported to be the maximum. In order to study the temperature dependence of line intensity ratios, we have carried out the computation at two different temperatures on either side of the temperature at which the relative ion abundance of the element is maximum. We find that the line intensity ratios discussed here are rather insensitive of temperature variation.

The intensity ratio of the $(\frac{3}{2} - \frac{5}{2})$ and $(\frac{1}{2} - \frac{3}{2})$ lines of the multiplet $(2s^2\ 2p\ {}^2P^o - 2s^2\ 3d\ {}^2D)$ is an electron density diagnostic. The $(\frac{3}{2} - \frac{5}{2})$ transition is usually blended with the $(\frac{3}{2} - \frac{3}{2})$ transition. X-ray line pair $\lambda 75.03 - \lambda 74.86$ from Mg VIII seems to be an excellent candidate for electron density diagnostic for the quiet Sun and coronal holes. Similarly the X-ray line pair $\lambda\ 50.69 - \lambda 50.52$ from Si X could be equally useful for probing the solar plasma. The X-ray lines from Mg VIII and Si X corresponding to the $(\frac{3}{2} - \frac{1}{2})$ of $(2s^2\ 2p\ {}^2P^o - 2s^2\ 3s\ {}^2S)$ transition have observable intensity and could also be useful for diagnostic studies. Unfortunately, there are not many observed X-ray lines from these ions with calibrated intensities suitable for density determinations. In order to determine the electron density from the quiet Sun and coronal hole regions, the computed line intensities based on Kopp and Orrall model have been used. The line intensity ratios thus obtained are shown by dots in Figure 1 for the quiet Sun and coronal holes. The electron density thus derived are listed in Table 1 using X-ray lines from Mg VIII and Si X ions which seem to be quite reasonable and await observational support by future solar missions. We have also listed the line intensity ratios based on the model atmosphere of Elzner (1976) for the quiet Sun for the sake of comparison. Some of the observed lines by Malinovsky and Heroux (1973) are also indicated. Computed line intensities using models are meant only to assert the potentiality of the line intensity ratios studied here for density diagnostics. However, the variation of the line intensity ratio as a function of electron density is independent of any model parameters and could be used to derive electron density from observed values of line fluxes that future missions might provide.

CONCLUSION

The X-ray lines from Mg VIII and Si X are exellent candidates for probing cosmic plasmas. A model atmosphere of Sun has been used to ensure the utility of the line intensity ratios for diagnostic studies. Notwithstanding the derived electron densities being model dependent, the line intensity ratio curves as a function of electron density are independent of any model parameters-elemental abundances and relative ion abundances etc. It is, therefore, concluded that the X-ray lines studied could potentially be used as density indicators

TABLE 1. Computed line intensity ratios and derived electron densities using Kopp and Orrall model

Line ratio	Quiet Sun		Coronal hole	
	Intensity ratio	N_e (cm^{-3})	Intensity ratio	N_e (cm^{-3})
		Mg VIII-ion		
I(λ75.03) / I(λ74.86)	1.67	10^9	1.52	5.4×10^8
	1.56	6.8×10^8		
	1.47*	4.6×10^8		
I(λ82.82) / I(λ74.86)	0.53	10^9	0.51	5.8×10^8
	0.52+	6.3×10^8		
		Si X-ion		
I(λ50.69) / I(λ50.52)	0.50	4.6×10^8	0.34	1.7×10^8
	0.37+	2.2×10^8		
I(λ55.01) / I(λ50.52)	0.32	4.6×10^8	0.29	1.5×10^8
	0.30+	2.7×10^8		

+Computed line intensity ratio using Elzner model (1976)
*Observed line intensity ratio from Malinovsky and Heroux (1973).

of the solar and astrophysical plasmas. None the less, the observational data with improved spectral resolution is awaited by future solar missions in order to use these lines for density diagnostics in a realistic fashion.

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