Probing the solar plasma through ratio–ratio diagnostic technique – Ne V emission lines

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We present here Ne V line intensity ratios as a function of electron density (N_e) and temperature (T_e). These results are presented in the form of ratio–ratio diagrams, which should in principle allow both N_e and T_e to be deduced for the Ne V line emitting region, a non-isothermal and inhomogeneous solar plasma. We also discuss the importance of this investigation to analyse and interpret the spectral data from the coronal diagnostic spectrometer (CDS) on the spacecraft *SOHO* (solar and heliospheric observatory).

THE inference of plasma density (N_e), temperature (T_e) and their inhomogeneities through spectroscopic diagnostic techniques for solar ions, is a problem of universal importance for both laboratory and cosmic plasmas. Without the knowledge of these physical parameters, almost nothing can be said regarding the generation and transport of mass, momentum and energy. Various diagnostic techniques have been developed to deduce physical parameters such as N_e, T_e, differential emission measure, flows, and elemental abundances, making use of these spectra. This topic has been reviewed recently for solar plasmas in particular and astrophysical plasmas in general[1–3].

A fundamental property of hot solar plasmas is their inhomogeneity. The emergent intensities of spectral lines from optically thin plasmas are determined by integral along the line of sight through the plasma. The line-ratio diagnostics uses an observed line intensity ratio to determine density or temperature from theoretical density – or temperature-sensitive line-ratio curves, based on atomic model and taking account of physical processes for the line formation. As the solar atmosphere is highly structured and inhomogeneous, the line intensity ratios in general, depend both on N_e and T_e. We, therefore, investigate this problem from another

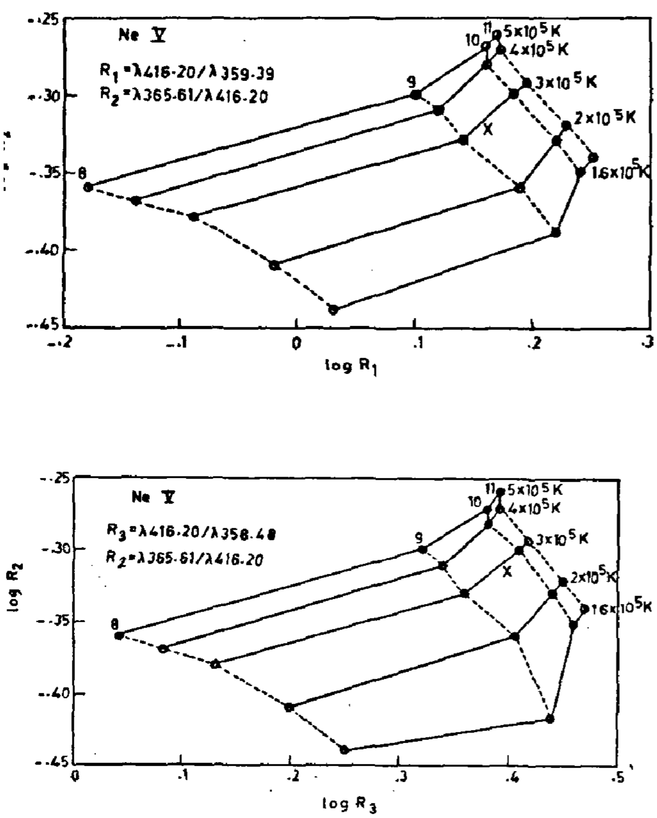

Figure 1. Plot of the theoretical Ne V log of emission line ratios $R_1 = 416.20/359.39$ against $R_2 = 365.61/416.20$ and $R_3 = 416.20/358.48$ against $R_2 = 365.61/416.20$ for a range of logarithmic electron temperature (log T_e = 5.2 – 5.7; T_e in K) and logarithmic electron densities (log N_e = 8–11; N_e in cm^{-3}). Points of constant T_e are connected by solid lines while those of constant N_e are joined by dashed lines.

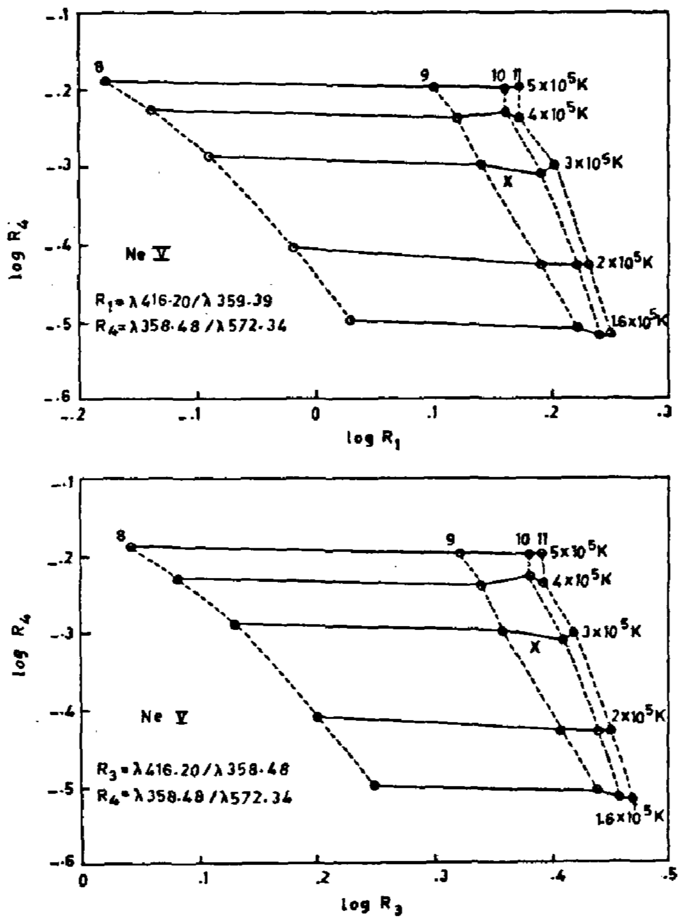

Figure 2. Plot similar to Figure 1 but with $R_1 = 416.20/359.39$ against $R_4 = 358.48/572.34$ and $R_3 = 416.20/358.48$ against $R_4 = 358.48/572.34$.

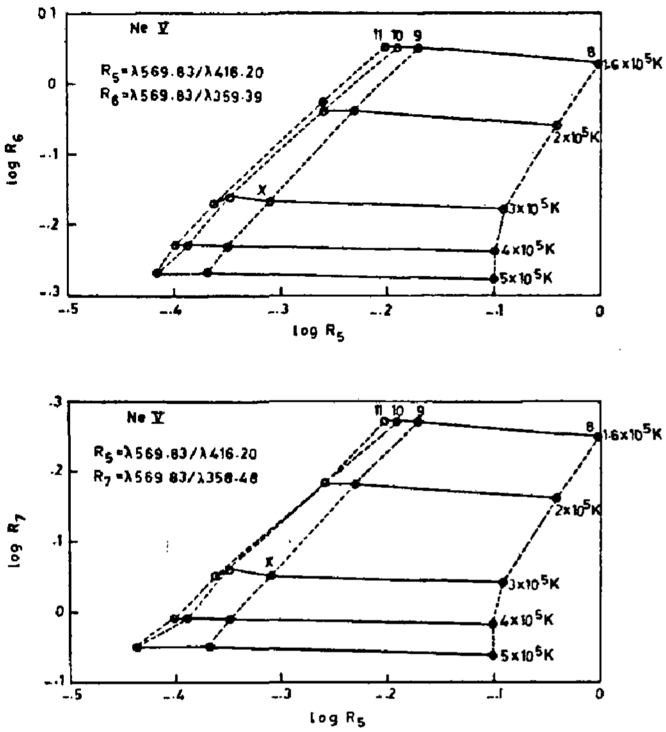

Figure 3. Plot similar to Figure 1 but with $R_5 = 569.83/416.20$ against $R_6 = 569.83/359.39$ and $R_5 = 569.83/416.20$ against $R_7 = 569.83/358.48$.

viewpoint. We plot ratio–ratio diagrams for a grid of ($\log N_e$, $\log T_e$) values appropriate to the line formation. Using this approach, it is possible to simultaneously determine N_e and T_e from the measured/computed values of line intensity ratios. This diagnostic technique seems to be more realistic, given the adequate pairs of line intensity ratios observed from space[4,5].

The Ne V solar ion has its maximum ionic concentration at 2.8×10^5 K as per the ionization equilibrium calculations[6]. The photospheric abundance of neon relative to hydrogen is 3.5×10^{-5} (ref. 7). We have carried out an extensive computation of Ne V line emissivities over a relevant density and temperature range. Under solar conditions, these ratios are usually sensitive to variations in both the electron density and temperature. Hence in principle they should only be used to determine N_e or T_e when the other plasma parameter has been independently estimated. In Figures 1–3 we plot several ratio–ratio diagrams, such as $\log R_1$ vs $\log R_2$, $\log R_3$ vs $\log R_2$ and so on, for a suitably chosen grid of ($\log N_e$, $\log T_e$) values appropriate to the solar transition region. Using these figures it is possible to simultaneously determine both the electron density and temperature from the measured/computed values of the line intensity ratios. The physical processes involved and atomic data used in the present investigation are the same as described in a previous paper[8].

Table 1. Ne V electron densities and temperatures from ratio–ratio diagrams (cf. Figures 1–3)

Ratio–ratio	N_e (cm^{-3})	T_e (K)
R_1–R_2	2.5×10^9	2.9×10^5
R_3–R_2	3.4×10^9	2.9×10^5
R_1–R_4	2.0×10^9	2.9×10^5
R_3–R_4	2.7×10^9	2.8×10^5
R_5–R_6	1.1×10^9	2.8×10^5
R_5–R_7	1.9×10^9	2.8×10^5

In view of the non-availability of measured line intensities, we have computed theoretical line intensities, making use of a schematic spherically symmetric model atmosphere[9]. This exercise has been done only to ascertain the applicability of this technique to deduce N_e and T_e. The theoretical line intensity ratios thus obtained are: $\log R_1 = 0.16$, $\log R_2 = -0.32$, $\log R_3 = 0.39$, $\log R_4 = -0.32$, $\log R_5 = -0.31$, $\log R_6 = -0.15$ and $\log R_7 = 0.07$. The derived N_e and T_e from the different sets of ratio–ratio diagrams are presented in Table 1.

It should, however, be worthwhile to point out here that this diagnostic technique can be successfully applied to realistic cases, given the adequate observation. Such observation is expected shortly from the CDS instrument on SOHO. This technique may also be of great advantage to laboratory plasma diagnostics.

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