ing at the surface of the primary star (0\textdegree68). Since \( R_1 \) is fixed by the known tem-
ture and luminosity, the only variable left is \( m_1 \), but the discrepancy is so large that
mass required for the primary would seem to be unrealistically large.

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REFERENCES


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EMISSION-LINE RATIOS IN THE SOLAR CORONA

A number of recent investigations seem to confirm Shklovsky’s suspicion that the red
\( \mathrm{Fe}^{x+} \lambda 6374 \) and green (\( \mathrm{Fe}^{x+} \lambda 5303 \)) emissions arise in different parts of the corona
lings 1961; Dollfus 1961; Rösch 1961; Billings and Lehman 1962; Jefferies, Pecker,
Thomas 1962; Seaton 1962). If this is true, then the observed green/red line-inten-
ratio is not a true measure of the ionization and cannot be used to determine the
tron kinetic temperature, \( T_e \). There seems to be general agreement that this, together
macroscopic motions, explains in part the well-known discrepancy between \( T_e \),
dermined by this method, and the ion kinetic temperature \( T_k \), determined from line
es.

We recently published the results of a detailed photometric study of coronal spectra
ained by Bernard Lyot and one of us (M.K.A.) at the 1952 total eclipse. The spectro-
s include the spectrum of a bright coronal condensation that was on the west limb
he time of the eclipse, and the emission of this condensation could be readily separ-
d from the emission of other coronal material in the line of sight by subtraction.
ther, the distribution of intensity across the condensation as measured in the con-
um and in a number of emission lines was consistent with the assumption that the
densation was symmetrical about an axis normal to the sun’s surface. By making this
sonable asumption, we were able to recover the electron density and the emission of
es as a function of distance \( \rho \) from this axis of symmetry by solving Abel’s equation
, Evans, and Orrall 1962; hereafter called “Paper I”). Visual study of the spectra
ngly suggests that both the electron-scattering continuum and the ionization were
est at the center of the condensation. Lines arising in ions of highest ionization
ential (class IV lines, such as \( \mathrm{Ca}^{x+} \lambda 5694 \)) were strongly concentrated to the center
he condensation, while lines arising in ions of lowest ionization potential (class I lines,
\( \mathrm{Fe}^{x+} \lambda 6374 \)) were completely missing at the center but strong at the edges.
es in the intermediate classes (II and III) showed increasing concentration to the
ter with increasing ionization potential. These observations were fully confirmed by
photometric analysis. According to theory, the ionization depends only on the elec-
temperature and not on the density. Thus the observations imply that the electron
ity and temperature (and hence pressure) were greatest along the axis of symmetry
he condensation and decreased outward.

since we have determined the emission of both the green and the red lines as functions
\( \rho \), we may use the ratio of these emissions to find the distribution of electron tempera-
across the condensation. An obvious self-consistency test of such an analysis would

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be to study ratios of additional observed lines to see whether they all yield the same temperature distribution. In order to avoid using uncertain abundance ratios, we shall consider only pairs of lines produced by the same chemical element. Further, to reduce uncertainties due to difficulties in the excitation theory, we shall consider only lines that arise in ground configurations and that have only two levels. That is, we shall confine our attention to lines from \( p \) and \( p^e \) ground configurations and avoid lines from \( p^g \) and \( p^2 \) configurations, which have five levels each. The excitation problem for \( p \) and \( p^e \) configurations is already complex, as the careful analysis by Pecker and Thomas (19...) shows; but the problem for the five-level configurations is even more difficult—particularly because many of the radiative transitions connecting these levels cannot be observed.

The green/red emission ratio, of course, fulfills these requirements. From among the well-identified coronal lines we find two additional ratios similar to the emission ratio \( \lambda 5303/\lambda 6374 \). These are \( \lambda 3601/\lambda 4232 \), and \( \lambda 4412/\lambda 5536 \). (These lines correspond

<table>
<thead>
<tr>
<th>( \rho ) (10^4 km)</th>
<th>( N_u(\rho) ) for ( \lambda 4232 ) (cm(^{-3}))</th>
<th>Emission Ratios</th>
<th>( \lambda 5303/\lambda 6374 )</th>
<th>( \lambda 3601/\lambda 4232 )</th>
<th>( \lambda 3601/\lambda 4232 )</th>
</tr>
</thead>
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<tr>
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<td>2</td>
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<td>3</td>
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<tr>
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<td>3</td>
<td>8</td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>1.9</td>
<td>5</td>
<td>4</td>
<td></td>
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</tr>
</tbody>
</table>

The line \( \lambda 5536 \) is visible on the plates but too faint to measure with sufficient accuracy to recover the emission. It is particularly difficult to measure it in the condensatic where it is superposed on the strong electron-scattering continuum. We have, therefore, simply measured the intensity, using a microphotometer slit large enough to integrate over the central core of the condensation. For consistency, we have remeasured \( \lambda 4412 \) using the same slit size. The resulting intensities (erg cm\(^{-2}\) sec\(^{-1}\) steradian\(^{-1}\)) are 12.7 for \( \lambda 4412 \), consistent with earlier measures, and 4.9 for \( \lambda 5536 \). The resulting intensity ratio \( \lambda 4412/\lambda 5536 \) is 2.6. This is probably a fair approximation to the emission ratio, since most of the \( \lambda 4412 \) emission comes from the center of the condensation and this is pro...
ably also true of λ 5536, considering the high ionization potential of A x (421 ev). (The line 5536 is so faint compared with the coronal continuum that it is impossible to verify his, however.) If anything, the observed intensity of λ 5536 is an upper limit.

Seaton (1962) has made a new study of the coronal ionization equilibrium based on recent theoretical and laboratory determinations of the necessary cross-sections. He points out that his results are not much different from the earlier ones of Allen and Elwert. Using his results, one may compute the relative abundance of the two stages of ionization that give rise to the two lines involved in each of the emission ratios. That is, one may compute Fe xiv/Fe x, Ni xvi/Ni xii, and A xiv/A x as functions of electron temperature. These quantities must be multiplied by a factor in order to obtain the corresponding emission ratio. This factor will be determined by the excitation process. In their studies of the green/red ratio, Edlén (1942), Elwert (1952), and Waldmeier (1952) all assumed that the upper level was populated only by collisions from the ground level. For this process, the factor is independent of the density and is so insensitive to temperature that they are able to write for the emission ratio: λ 5303/λ 6374 = 2.40 (Fe xiv/Fe x). Assuming the same excitation process, we find, for the nickel and argon emission ratios, λ 3601/λ 4332 = 2.35 (Ni xvi/Ni xii) and λ 4412/λ 5536 = 2.51 (A xiv/A x).

Using the above formulae and Seaton's (1962) general expression for the ionization, one readily derives the following formulae for the logarithm of the emission ratios:

\[
\log \frac{\lambda 5303}{\lambda 6374} = 10.104 + 4 \log \frac{t}{T} - \frac{6.211}{t},
\]

\[
\log \frac{\lambda 3601}{\lambda 4332} = 8.585 + 4 \log \frac{t}{T} - \frac{8.145}{t},
\]

\[
\log \frac{\lambda 4412}{\lambda 5536} = 7.921 + 4 \log \frac{t}{T} - \frac{11.739}{t}.
\]

Here \( t = 10^{-6} T_e \) (° K), and logarithms are to the base 10. These expressions are displayed graphically in Figure 1, where, for comparison, we have also plotted Elwert's (1952) results for the λ 5303/λ 6374 ratio.

We may now use Figure 1 to see what electron temperatures are implied by our observed emission ratios. The argon emission ratio indicates that in the central core of the condensation the temperature is \( 1.45 \times 10^6 \) ° K. The nickel emission ratio implies that the entire condensation is at a uniform temperature of \( 1.0 \times 10^6 \) ° K, while the iron emission ratio implies that, except for the central core, the temperature is everywhere between 0.65 and 0.70 \( \times 10^6 \) ° K.

It is difficult to see how errors in photometry or in the solution for the emission could account for these discrepancies (except possibly near \( \rho = 0 \), where the solution of Abel's equation is uncertain). One would have to change the observed ratios by orders of magnitude to derive a common temperature distribution from the three ratios. Further, our assumption of axial symmetry is not critical. If one assumed, instead, that the condensation was uniform in the line of sight but varied with position angle, the discrepancy would remain.

Pecker and Thomas (1962) have made a more detailed study of the excitation of the red and green coronal lines in which they included the effect of coronal self-emission from excited configurations. They conclude: "The coronal self-emission might be reasonably expected to introduce a factor 2 or so change in the green/red ratio computed without including the self-emission; the effect can never exceed a factor 10." This is clearly too small to make an important change in the derived temperature. No comparable study has been made for the nickel and argon ratios, but, since the same configurations are involved, they might be expected to show the same behavior. Thus it seems unlikely that the discrepancy can be blamed on the theory of excitation.
But probably the most serious difficulty is that all three ratios predict temperatures too low to account for the observed yellow-line (\( \lambda 5694 \)) emission, and, as Seaton points out, it is practically impossible to produce both Fe \( \text{x} \) and Ca \( \text{xv} \) in the same volume of space if the present ionization theory is correct.

In summary, then, we find that, although qualitatively one may explain the spectrum by assuming that the temperature and density are greatest at the center and decrease outward, no smooth variation of temperature across the condensation will predict simultaneously the three emission ratios and the observed yellow line. If these contradictions are to be explained by temperature gradients within the condensation, then the gradients must be too steep to be resolved by our observations. There may be imbedded within the condensation small, unresolved, low-temperature structures such as those proposed by Jefferies et al. (1962) to explain the coronal Fe \( \text{x} \) emission. If so, then our values for the emission are very coarse averages that merely indicate the trend of temperature variation, and the interpretation of their ratios will be doubtful. But as we have no other evidence for a fine structure in this condensation, it seems to us rather ad hoc to assume it.

It is a pleasure to thank J. T. Jefferies and R. N. Thomas for their comments on the results of this note.

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