A COMMENT ON THE NRL SOLAR LYMAN-ALPHA RESULTS

J. T. JEFFERIES AND R. N. THOMAS
Boulder Laboratories, National Bureau of Standards
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ABSTRACT

Supplementary comments are made on the Morton-Widing analysis of the NRL Ly-a observations; they serve to bring into sharper focus its relation to current attempts at analysis of self-reversed emission cores of collision-dominated lines for gradients of $T_e$, for chromospheric structure, and for differential structure between quiet sun and plage, sunspot and flare regions.

The successful efforts of Tousey and Purcell (1960) to obtain Ly-a observations of such resolution that current theoretical work may be applied to their interpretation in terms of detailed chromospheric structure are most impressive. We are gratified that Morton and Widing have been able to interpret these observations with our first-approximation theory (Jefferies and Thomas, the “Source-Function” series), on the basis of a two-level atom representation, with constant rate parameters through the region of core formation. As a supplement to their analysis, we should like to emphasize the following points, which tie their particular results into the over-all pattern of theoretical investigations of this type of line, whose source function is collision-dominated, and their application to empirical investigation of solar chromospheric structure.

1. The Ly-a results bear out strongly the point we have tried to emphasize in discussing the depth variation of the line source function for these collision-dominated lines, namely, the extreme sensitivity of the properties of the emission core—ratio of central to peak intensities and separation of the peaks—to the temperature structure of the atmospheric region where the core is formed. Indeed, the Morton-Widing discussion of Ly-a is very similar to our discussion of Ca$^+\text{H}$ and K with respect to this point (Jefferies and Thomas 1960).

The same effect is also brought out graphically in the differential results between quiet regions and plages, with the observed decrease in the ratio of peak to central intensity as the peak separation decreases. The effect corresponds to an outward movement (on an optical depth scale) of the region of significant $T_e$ increase (cf. Tables 2-4 of our Ca$^+$ discussion). The same empirical effect over “non-quiet” solar regions is found in Ca$^+$ by E. v. P. Smith (1960) and Mohler (1960).

2. The analysis has used our first-approximation attempt to include the effect of a gradient in electron temperature through a single exponential term in optical depth. This representation seems presently adequate for describing peak separations and peak-to-central intensity ratio; but for a large enough rise in $T_e$, the representation fixes these two parameters of the line essentially only by the position of the $T_e$ rise and not its amplitude. Morton and Widing’s result that the simple theory fails to predict the contour beyond the peak suggests that a more elaborate representation for $T_e$ ($\tau_0$) is necessary; because the predicted decrease is too great, a representation with a smaller temperature gradient is suggested. As they have remarked, preliminary calculations by all of us bear out this conjecture. It is significant in this connection that the empirical chromospheric model found by Thomas and Athay (1960) would indeed give a much smaller rate of decrease in $T_e$ with increasing optical depth than the exponential representation; for it shows a rise in $T_e$ from $\sim 9000^\circ$ to $\sim 2 \times 10^4$ (possibly to $\sim 4 \times 10^4$; Athay and Johnson 1960) over the region where $\tau_0$(Ly-a) decreases from $\sim 10^6$ to $\sim 10^8-10^9$. Thus, just as for Ca $\Pi$ and soon, we hope, for Mg $\Pi$, the Ly-a data appear good enough to require refinement of the simple representations we have been using to outline the physical effects.
It is probably also necessary now to re-treat the problem numerically, allowing rate parameters to vary through the atmosphere. Morton and Widing have emphasized the uncertainties arising from the choice of constant values for these parameters entering the analysis.

3. Finally, we would draw attention to the physical implication of the results on plage versus quiet areas. We have already emphasized the identity in differential behavior between quiet and disturbed areas, found for Ca$^+$ and Ly-$\alpha$. Each suggests an outward movement of the region of significant $T_\infty$ gradient, on a $\tau_0$ scale. Also, because of the increased amplitude of the emission core over the disturbed area, we require an increased value either of $T_\infty$ or of $n_e$. We have at various times in the past suggested that an increased density might be more effective than increased temperature in producing the observed behavior of Balmer lines in disturbed regions, both through increasing the effect of collisions on $S_L$ for H$\alpha$ and for moving upward the effective place of origin of H$\alpha$ relative to the Lyman lines. Morton and Widing find in their analysis little evidence for an increased $\Delta \lambda \alpha$ in the disturbed over the quiet area; indeed, what evidence there is favors the contrary. Thus we suggest that these results form one more link in the chain of evidence pointing to a change in both the location of $T_\infty$ increase and the absolute value of $n_e$, as the empirical structure to be associated with the presence of plages, sunspots, and flares in their outer atmospheric manifestations as opposed to a simple increase in $T_\infty$.

REFERENCES

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———. 1960a, ibid., 131, 429.
———. 1960b, ibid., p. 695.