INTENSITY MEASUREMENTS IN THE WINGS OF THE NaD-LINES

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During the partial solar eclipse of 2nd October 1959, 8 spectrograms in the wavelength-regions 5170 Å and 5393 Å were obtained at the Einstein-tower in Potsdam. The limb-darkening and the center-limb variation in the wings of the NaD-lines and the Mg-triplet were investigated. The method used to eliminate the smearing by atmospheric scintillation and by the apparatus function was that proposed by A. Unsöld and initially applied by ten Bruggencate and coll. [1] and also by H. Scheffler [2].

The eclipse spectra comprise simultaneous exposures of the moon’s limb and the solar limb made with the aid of a special optical system; they refer to the second order of a 90 mm × 100 mm grating (600 ruling lines/mm) mounted in a Littrow-system with 12 m focal length. After the eclipse further plates were exposed in the sun’s center with two neutral glasses in front of the plates and a step-filter in front of the slit; these served for the construction of the characteristic curve, and for the calibration to the unit-intensity (solar center).

The effective instrumental profile (i.e. the combination of a Gaussian-curve determined by the air scintillation and of strong wings from the vertical apparatus function) was derived from the moon limb spectra. Corrections were applied to compensate for the photographic EBERHARD-effect. The scattering parameters σ of the Gaussian-curves of the four plates in the yellow region were: 1.2 ; 1.6 ; 1.8 ; 2.3. A corrected limb-darkening curve was determined with the help of these instrumental profiles. Our reductions show that the general limits of this method (caused by the uncertainty in defining the position of the true limb and by the limited accuracy of the photometry) do not permit the determination of the limb-darkening for cos θ < 0.04. For this region (i.e. for distances from the true limb smaller than the half-width of the instrumental profile) the results become uncertain. In the wings of the NaD-lines 10 points undisturbed by blends were measured for every wing and every line. As has already been shown by W. Mattig and E. H. Schröter [3] it is not advantageous to describe the intensity distribution in the wings of strong Fraunhofer-lines by the formula given by M. Minnaert [4], as has been done by other observers in recent years [5], [6], [7], since this involves approximations when comparing the observations with the
theory of Fraunhofer-lines. The above authors have therefore introduced a new relation which enables one to compare the observed parameters with the theory without the need for any additional assumptions. Our observations were reduced according to this new formula:

\[ \frac{i - \Delta i_i}{i_0} = 1 - x c_0 e^{-x \sec \theta}, \quad x = \frac{1}{\Delta \lambda^2}. \]

Fig. 1. — The limb-darkening from observations (AOP) and from the empirical solar models B"ohm-Vitense I and II.

Fig. 2a. — The center-limb-variation of the parameter \( c_0 \) ("wing-strength") from observations (AOP) and from the solar models B"ohm-Vitense I and II.

Fig. 2b. — The center-limb-variation of the parameter \( t \) ("mean selective optical depth") from the AOP observations and from the models.

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Here $c_0$ denotes the "wing-strength" and $i$ the mean selective optical depth. Taking logarithms, one obtains the linear relation:

$$\log \frac{1 - i + \Delta i_0}{x} = \log c_0 - \text{Mod.} \times t \times \sec \theta, \quad i_0 = 1.$$  

The smearing of the center-limb-variation in the wings by the instrumental profile was considered in the same manner as for the limb-darkening curve. The figures 1, 2a and 2b give the results of the observations in the yellow region of the spectrum. The comparison between our observations and the corresponding curves from the empirical solar models BöHM-VITENSE I and II [8] indicate that in all three cases corrections of these models are required in the sense I $\rightarrow$ II $\rightarrow$ AOP (Astrophysical Observatory Potsdam). Before carrying out quantitative computations of these corrections we shall first reduce the observations in the spectral region containing the Mg-triplet. These results will be published in detail elsewhere (see Mitteilungen des Astrophysikalischen Observatoriums Potsdam).

**Discussion**

**Pagel.** — While accepting in principle Schröter’s criticism of the derivation of darkening at the extreme limb from partial-eclipse or non-eclipse observations, I should like to point out that in my discussion the position of the limb is firmly anchored by the use of Kristenson’s measurements of the 1954 total eclipse. There is still the difficulty that Kristenson’s intensities are only relative and examination of the diagrams shows that there may be an uncertainty of $\pm 15\%$ in the absolute values. The effect of this on the temperature distribution is discussed in my paper.

**Schröter.** — A short remark in connection to Mr. Pagel’s paper about the limb darkening: our reductions show once more, that the determination of darkening at the extreme solar limb from material obtained during partial eclipses becomes remarkably uncertain for $\cos \theta < 0.06$ (see our slide). Therefore the results of Mr. Pagel’s investigation are based effectively only on Kristenson’s observations; there are only relative measurements, however.

**Pecker.** — The disagreement between your observations and the Böhm-Vitense models may come from the bad quality of the models, or from the possible non-LTE effects. Have you tried to use the "Schröter’s model"?

**Schröter.** — Of course, there are three possibilities, to explain the disagreement between our observations for the NaD-lines and Böhm-Vitense models (last slide): corrections of the models, inhomogeneities and non LTE-effects. But it is our opinion that it is not useful to decide between these possibilities, having observations only of one line type. It seems to be better to wait for the results of the reductions of the Mg-triplett lines and further observations. Then one may try to compare all these new observations with the known inhomogeneous models and to consider non LTE-effects.

**Elste.** — With respect to the energy measurements at the center of the disk at $\lambda$ 5000 Å by Labs and Sitnik, the effective temperatures of the model solar atmospheres of Böhm-Vitense has to be indeed about 2000 higher.
Schröter. — We have not tried to make quantitative computations for a solar model, neither have we considered inhomogeneities. But, of course, one may try to do this. The parameter $t$ gives further information about the deeper layers of the atmosphere. Comparing the measured limb-darkening with the center to limb variation of $t$ with the help of a homogeneous solar model, one is able to investigate inhomogeneities in the deeper layers, because of the quite different influence of those inhomogeneities on $t(0)$ and $J_{\lambda}(0, 0)$. But we think, that further observations are at present more important than such computations.

REFERENCES