THE INFLUENCE OF MAGNETIC FIELDS ON THE ANALYSIS OF SUNSPOT STRUCTURE

by

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I. INTRODUCTION

In attempting to derive the physical conditions in sunspot umbrae by the analysis of equivalent widths or line profiles, the influence of the magnetic field on line formation, and consequently on the results obtained, has not been clearly shown. Several workers have considered the problem but are not in complete agreement as to the magnitude of this effect (see p. 138 in Bray and Loughhead 1964 and p. 85 in Zwaan 1965). The intent of this study was to quantitatively investigate with a somewhat more rigorous theoretical study the error that has been made by neglecting magnetic line formation. In order to accomplish this, I felt that a new semi-empirical umbral model was needed which achieved better agreement with the published continuum data than was possible with the predictions of existing models. By improving the reliability of the model using continuum measurements, one can be certain that the results obtained regarding the influence of the magnetic field are not made suspect by the physical conditions of the model.

Reviews of the physical conditions in sunspots have been made by Bray and Loughhead (1964) and Zwaan (1965) which roughly indicate hydrostatic pressures and a scaling down of the photospheric temperature distribution. Zwaan (1965) has derived one of the better umbral radiation models of the past few years, while more recently Mattig (1969) has obtained a nearly isothermal umbral model based primarily on a suspected limb brightening which only he has verified observationally. A different type of study of the physical conditions in sunspots in which no continuum radiation field is predicted are the magnetohydrostatic models by Deinzer (1965), Yun (1968), and Dicke (1970).

In outlining the major points of this study, Section II describes the method by which the umbral model was obtained and the criterion used in establishing the validity of the model. Further confirmation for the validity of the model is provided in Section III. The method for calculating curves of growth and the method by which the Zeeman broadening was included in the computations is described in Section IV. The analysis and discussion of the line data is presented in Section V and the conclusions are presented in the final section.

II. THE UMBRAL MODEL

The model computations were made for a given temperature distribution, logarithm of the effective gravity, and chemical composition using a computational scheme due to Elste (1968). The digital computer program I used was written by Elste and Evans (1969). Hydrostatic equilibrium, neglecting magnetic and turbulent pressure, was assumed in the pressure model computation while the ionization equilibrium included contributions from hydrogen and nine element groups. Several elements with similar ionization potentials were considered together by adding their abundances and using the ionization potential and partition functions of the most abundant element in the group. Helium ionization, molecular formation, and the formation of negative ions were not included. Utilizing graphs given by Aller (1963), the assumption of no molecular hydrogen formation was found to be valid in the deeper layers of the umbral atmosphere, but deviated somewhat in the outer layers where the number of hydrogen molecules becomes a fairly large fraction of the total hydrogen content. However this increase was not believed to produce an important effect on the computations. The sources of continuous absorption included were bound-free and free-free transitions in H, H^-, H_2^+, and the most abundant metals (Elste 1968). (For further details see Appendix A.)

In the derivation of the umbral model, temperature distributions of other authors (Zwaan 1965, Mattig 1969) were reviewed in order to examine the predicted continuum intensity ratios (spot to photosphere) as a function of wavelength for an LTE continuum formation mechanism. In checking the predicted values with available observational data, certain modifications seemed in order. In this investigation, the temperature distribution in the photosphere