THE Mg II h & k LINES AS DIAGNOSTICS OF THE SOLAR CHROMOSPHERE

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ABSTRACT The Mg II resonance lines are used as a probe of the thermal structure of the solar chromosphere. Observations from the UVSP/SMM data base are discussed together with their calibration onto an absolute intensity scale. Theoretical line profiles match the observed ones well except for the k₃ self reversal, which is too deep in all theoretical profiles.

Keywords: Sun; Mg II h & k; chromosphere; radiation transfer

INTRODUCTION

Avrett and co-workers have done extensive numerical calculations with the PANDORA code to construct models of different components of the solar atmosphere (e.g. Vernazza et al. 1981 and the paper by Avrett & Loeser in these proceedings). Recently, the latest of these VAL models have been modified to include the effects of differential diffusion of hydrogen and helium atoms and ions on the energy balance of the chromosphere and transition region (Fontenla, Avrett, & Loeser 1990 and 1991). The upward diffusion of neutral hydrogen in the new models makes the artificial temperature plateau at 20 000 K obsolete. Due to lack of accurate diagnostics, uncertainties in temperature and density distributions are large at the lower boundary of the transition region. To further constrain the thermal structure of the models I compare observed line profiles of the Mg II h & k lines with theoretical profiles from the present VAL models.

Due to their large opacity the Mg II resonance lines provide excellent atmospheric diagnostics over a wide range of heights if sufficient observations with high spatial and spectral resolution are available. A modest number of such observations is available in the data base of the Ultraviolet Spectrometer and Polarimeter (UVSP) that flew on board the Solar Maximum Mission (SMM) spacecraft.

UVSP/SMM OBSERVATIONS

The secondary mirror of the UVSP instrument could be tilted to scan the solar surface pixel by pixel over a range of 256"×256", where the pixel size was determined by the field of view of the entrance slit of the spectrometer. The Mg II h & k lines at around 280 nm were observed with two different entrance slits (see Table). Slit number 20 was used to make atlas scans. Due to the large field of view ΔΩ, of this slit these scans contain little spatial information. They are useful here to obtain an absolute intensity calibration (see next Section).
Slit 12 was used to make both spectrograms (a wavelength scan from one specific pixel) and rastergrams (surface scans at one wavelength) in magnesium. Contiguous combinations of spectrogram and rastergram are of particular interest here. Provided the rastergram is taken at a wavelength near the core such sequences allow us to determine whether the spectrogram was taken from a plage or quiet-Sun region, network or cell-interior. Due to the low number of counts per pixel this determination is not always conclusive. Statistical variations in the count rate allow for about half the observed intensity variations.

**CALIBRATION**

To compare spectrograms with calculated line profiles the observed photon counts need to be calibrated onto an absolute intensity scale. Observations in this paper were calibrated by fitting a spectrogram obtained with the large aperture slit (20) onto a well-calibrated (better than 20%, courtesy of R. L. Kurucz) rocket spectrum. Calibrations over a large field of view have the advantage that they are largely independent of the exact location on the solar surface. When the calibration is established for slit 20 it can be converted to a calibration of the small aperture slit (12) since both slits use the same detector (number 5) and light path.

The measured intensity \( \bar{I}_{\lambda_0} \) (the average of the true intensity over viewing angle of the entrance slit S and width of the exit slit) at wavelength \( \lambda_0 \) is related to the number of photon counts \( \Phi \) at that wavelength by:

\[
\bar{I}_{\lambda_0} = C(\lambda_0; S)\Phi(\lambda_0; S)/t; \quad C \equiv \frac{hc}{(\lambda_0 A \Delta\Omega_S \Delta\lambda_0)},
\]

where \( A \) is the effective telescope area, \( t \) the gate time, \( \Delta\Omega_S \) the aperture of the entrance slit, and \( \Delta\lambda_0 \) is the width of the exit slit. We find \( C(280; 20) = 375 \) [erg cm\(^{-2}\) sr\(^{-1}\) nm\(^{-1}\)] (Experiment 21342). Using the different aperture and exit slit width of slit 12 we find \( C(280; 12) = 2.5 \times 10^3 \) [erg cm\(^{-2}\) sr\(^{-1}\) nm\(^{-1}\)].

**RADIATION TRANSFER MODELING**

Theoretical profiles from the given VAL model atmospheres were obtained with a Partial frequency Redistribution (PR) version (Uitenbroek 1989) of MULTI (Carlsson in these proceedings). Figure 1 shows the theoretical line profile from model C (thick line) together with the observed intensity from UVSP Experiment 22466 (thin line). From a contiguous rastergram (taken at 278.86 nm, as indicated by the vertical line) we determined that the spectrogram represents quiet-Sun cell interior with a possible network contribution. The theoretical profile (thick line) matches the observed one well apart from the central \( k_3 \) self reversal. Convolving the theoretical profile with a Gaussian of up to 6 km/s width, which is comparable to the instrumental broadening, does not improve the fit much. In all computations we have done so far the theoretical
k₃ minima are too deep compared with observed profiles, not only for model C but also in the of the hotter models VAL F and P.

Fig. 1: Theoretical profile from atmospheric model VAL C (thick line). Thin line is observed spectrogram (Experiment 22466) taken with slit 12. Vertical line marks wavelength of contiguous rastergram; µ is the cosine of viewing angle.

CONCLUSION

The current VAL models match the quiet–Sun MgII profiles well up to and just above the temperature minimum, judging from the fit of wings, k₁ minima and emission peaks. They do not reproduce the observed central absorption self reversal in the MgII resonance lines (the same holds true for the CaII resonance lines). Therefore, either the temperature structure at the top of the chromosphere has to be adjusted, or the theoretical line broadening has to be treated in a more sophisticated way. In the first case the transition temperature rise should occur at higher densities in “hot” elements, so that core line source function does not decrease as it does in very hot models. In the second case a more realistic representation of macroscopic velocity fields may be needed instead of the combination of micro- and macro turbulence that is used here.

REFERENCES

PART VII

Further Perspectives on Cool Stars
Figure 1 from “Lithium Dispersion of Halo Dwarfs” by C.P. Deliyannis and M.H. Pinsonneault.

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