Publ. Astron. Obs. Belgrade No. 75 (2003), 63 - 66 *Contributed paper*

THE OBSERVED MnI 539.47 nm LINE PROFILES IN THE PRECEDING SUNSPOT OF THE NOAA 9563 ACTIVE REGION

I. VINCE[1], A. LUDMÁNY[2] and O. VINCE[1]
[1]*Astronomical Observatory, Volgina 7, 11160 Belgrade – 74, Serbia and Montenegro*
E–mail E-mail: ivince@aob.aob.bg.ac.yu

[2]*Heliophysical Observatory, P.B. 53, Debrecen, Hungary*
E–mail ludmany@tigris.klte.hu

Abstract. The spectra of the MnI 539.47 nm line of preceding sunspot of the NOAA 9563 active region and the quiet photosphere in the vicinity of this active region were observed. The observations were carried out with the horizontal solar spectrograph of Heliophysical Observatory in Debrecen on August 6, 2001. The profiles of the MnI 539.47 nm line in the quite photosphere, umbra and in four positions in penumbra, as well as their parameters (equivalent width (EW), central depth (CD) and full width at half maximum (FWHM)) are determined. Relative large increase (30–70%) of the MnI 539.47 nm line profile parameters from quiet photosphere to umbra is obtained. The MnI 539.47 nm line profile parameters observed in a sunspot exhibit an opposite behaviour to those observed in solar plages.

1. INTRODUCTION

It is a well established observational fact that the MnI 539.47 nm spectral line profile parameters, observed in the solar irradiance, vary about 2% with the solar activity cycle (Livingston, 1992). It has been shown theoretically that the MnI 539.47 nm line is very sensitive to the change of photospheric temperature (Erkapić and Vince 1995), but it is not enough for explanation of the amplitude of its cycle variation. These theoretical results were confirmed by observations (Vince and Vince, 2002) Recently, using multi-line and multi-species NLTE calculations, we have shown that the MnI 539.47 nm line is sensitive to the optical pumping of the uv1 MnI 279.48 nm line transition that overlaps with the MgII k (279.5 nm) line (Doyle et al., 2001), whose intensity is very enhanced in plage regions. Our observations of the MnI 539.47 nm line in plage regions (Vince et al., 2000) qualitatively support the results of these calculations. Therefore, it can be supposed that the variation of this line profile during the solar cycle is due to the temperature variation and variation of plage region coverage. However, besides the influences exerted by the variations of temperature and plage region coverage, for quantitative explanation of the MnI 539.47 nm line profile variation with the solar activity cycle it is necessary to examine the influence of the sunspots too. For this purpose we observe the spectrum of the preceding sunspot of active region NOAA 9563.

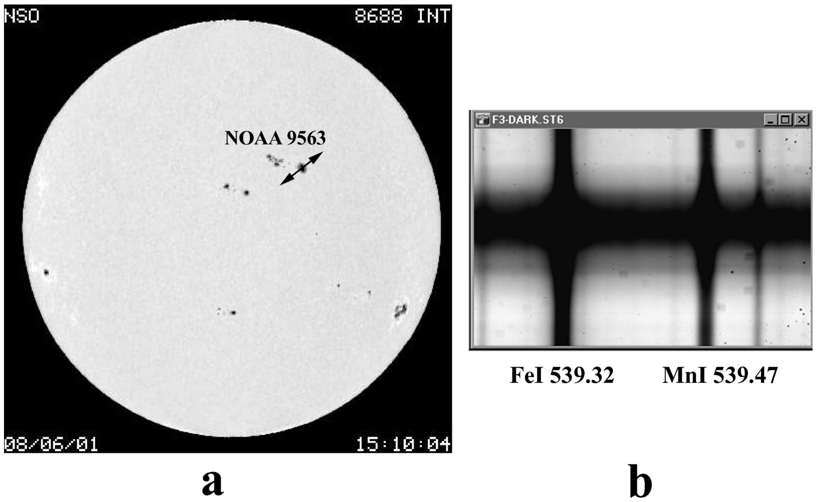

Figure 1: a) The white-light image of the sun on the 6th of August 2001 and the position of the observed sunspot with the slit orientation; b) The CCD image of the observed spectrum.

2. OBSERVATION, REDUCTION AND ANALYSIS

The observation of the MnI 539.47 nm line was carried out with the horizontal solar spectrograph of the Heliophysical Observatory in Debrecen. The diameter of the telescope primary lens is 53 cm. The spectrograph is a Czerny-Turner type. The grating has an area of 25x23 cm^2 with grating constant of 600 grooves/mm. For the detection of the solar spectrum we used an SBIG ST-6 CCD camera.

The observed data were obtained on August 6, 2001 for the preceding sunspot of activity region NOOA 9563. This region is located in the North-West part of the solar disc (see Fig. 1a). The spectrograph slit of 50 μm width was positioned as it is shown in this Figure by arrow. The observation was made in the fourth spectral order. The dispersion was about 0.8 pm/pixel. For isolating of the fourth spectral order we used the combination of two colored broadband glass filters: ZhS17 and SZhS23.

In Fig. 1b the observed CCD image of sunspot spectrum of the MnI 539.47 nm line and its vicinity (about 0.3 nm) can be seen. As the first step in data reduction the dark image is subtracted from the observed one. The fringing patterns are suppressed by tilting the CCD camera by about 5 degrees with respect to the incident light direction. Flat field correction is not performed, because we do not find yet any proper method to obtain a good flat field image.

Our goal is to analyze the changes of the line profiles from the quiet photosphere via penumbra to the umbra of the sunspot. For this purpose we divide the CCD spectrum along the spatial axis (axis perpendicular to the dispersion) into seven windows: one window covers the umbra, four - the penumbra and two - the quiet photosphere. The positions and approximative widths of these windows are presented on the photometric cross-section of the sunspot along the spectrograph entrance slit

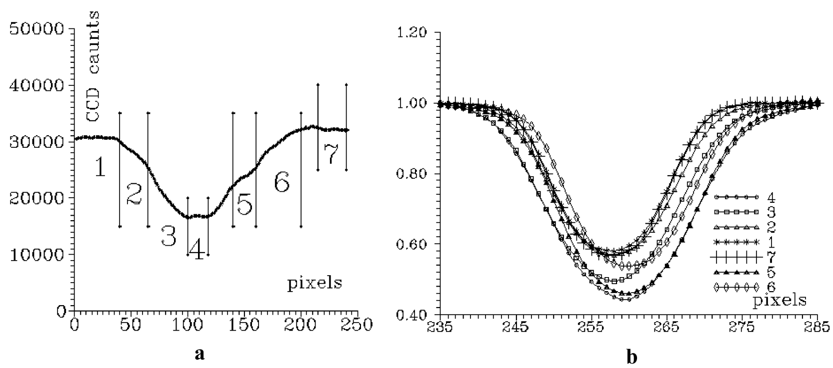

Figure 2: a) The relative intensity variation along the spectrograph slit; b) Profiles of the MnI 539.47 nm line for seven windows.

(Fig. 2a.). Windows 1 and 7 correspond to the quiet photosphere near the sunspot, 2 and 6 to the penumbra closer to the photosphere, 3 and 5 to the penumbra closer to umbra and, finally, 4 to the umbra itself.

The spectra from these windows are extracted by the ANALYST image processing program (Malkov, 1995). ANALYST gives an average one-dimensional spectrum from all cuts along the dispersion axis in a chosen window. These spectra are normalized to the local continuum and wavelength calibrated using the SPE program for one-dimensional processing and analysis of spectra (S. G. Sergeev). The final extracted profiles of the MnI 539.47 nm line for seven windows are presented in Fig. 2.b).

As one can see from Fig. 2.b) the profile of the MnI 539.47 nm line shows large changes from the quiet photosphere to the umbra of the sunspot. Using the SPE program we calculate the equivalent width (EW), full width at half maximum (FWHM) and the central depth (r) of these line profiles. In Fig. 3. the changes of these parameters against window position normalized to values from window 1 are presented. All these parameters increase from quiet photosphere to sunspot umbra. The full width at half maximum and the central depth increase by about 30%, and the equivalent width by about 70%.

3. CONCLUSION

The observed increase of the EW, FWHM and r of the MnI 539.47 nm line profile from the quiet photosphere to the sunspot umbra in the preceding spot of the active region NOAA 9563 is larger than the decrease of these parameters in plage regions (see, e.g., Vince et al, 2000). As the long-term observations show anticorrelation between the variation of the MnI 539.47 nm line parameters in solar irradiance spectrum and Wolf's sunspot number, it could be concluded that due to the larger area covered by plages and their higher intensity the influence of plages on the MnI 539.47 nm line profile is dominant. To confirm this conjecture further spectral observations of different types of sunspots and plages at different heliocentric angles are needed. Our ultimate goal is to combine the MnI 539.47 nm spectral line in different solar fea-

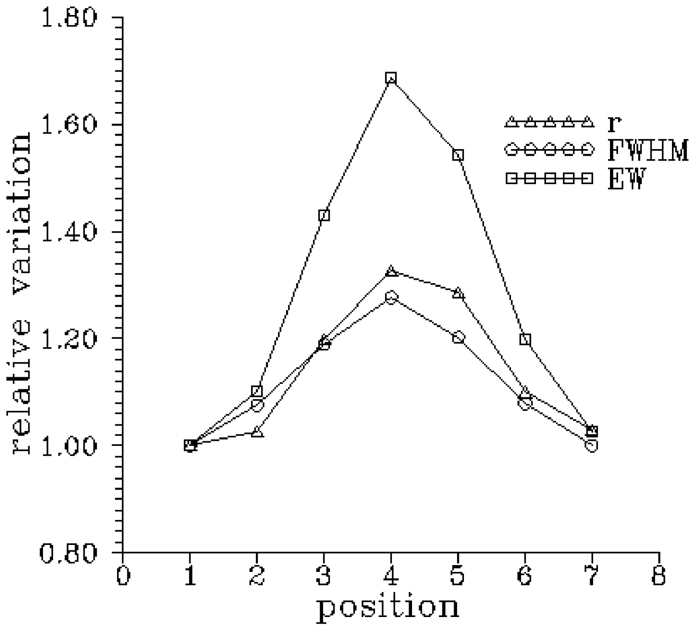

Figure 3: Variation of EW, FWHM and r along the slit position.

tures and simulate the observed activity cycle variation of this line in solar irradiance spectrum.

Acknowledgments. Ministry of Science, Technology and Development of the Republic of Serbia (Contract No.1951) supported our work. One of the authors (I.Vince) acknowledges the support of the "Arany János Közalapítvány".

References

Doyle, J.G., Jevremović, D., Short, C.I., Haushildt, P.H., Livingston, W. and Vince, I.: 2001, *Astron. Astrophys.*, **369**, L13-L16.

Livingston, W.: 1992, *in Proceedings of Workshop on the Solar Electromagnetic Radiation Study for Solar Cycle 22* (ed. R. F. Donnelly), U.S. Department of Commerce, 11-19.

Erkapić, S. and Vince, I.: 1995, *Publ. Astron. Obs. Belgrade* **49**, 159-162.

Malkov, S.: 1995, private communication

Sergeev, S.G.: private communication

Vince, I. Gopasyuk, O., Gopasyuk, S. and Vince, O.: 2000, *Contributed papers of XX Summer School and International Symposium on the Physics of Ionized Gases* (eds. Z. Lj. Petrović, M. M. Kuraica, N. Bibić and G. Malović), 507-510.

Vince, O. and Vince, I.: 2002, *Proceedings of the Regional Meeting on Solar Physics "Solar Researches in the South-Eastern European Countries: Present and Perspectives"* (eds. G. Maris and M. Messerotti), Éditions de l'Académie Roumaine, 143-146. (preprint)

Vitas, N., Vince, O. and Vince, I.: 2002, *Proceedings of the Regional Meeting on Solar Physics "Solar Researches in the South-Eastern European Countries: Present and Perspectives"* (eds. G. Maris and M. Messerotti), Éditions de l'Académie Roumaine, 147-151. (preprint)