INVESTIGATION OF THE LARGE PRECEDING SPOT OF AR 2779 FROM SMM DATA

M. Siarkowski[1], J. Jakimiec[2], J. Staude[3]

[1]Space Research Center, Polish Academy of Sciences, Wroclaw, Poland

[2]Astronomical Institute, Wroclaw University, Wroclaw, Poland

[3]Central Institute for Astrophysics, Solar Observatory "Einsteinturm", Potsdam, GDR

ABSTRACT. Complex data from the SMM spacecraft (UVSP and XRP/FCS) have been used to investigate the structure and dynamics of the large p spot of the active region NOAA 2779 from November 1980. The data comprise spectroheliograms in the continuum at 3096 Å and in H Ly-α, in C IV 1548 Å, and in 6 soft X-ray lines, velocity maps in the C IV line, and ground-based vector magnetograms for comparison. The spot shows an inhomogeneous structure characterized by a light bridge. In comparison with the darkest photospheric umbral cores the light bridge is bright in the photosphere and the transition region, but darker in the chromosphere. In the transition region we found upward motions above the umbra, but downward motions in the light bridge. Compared to the spot's surroundings the Ly-α emission is stronger above the umbra up to a factor of 3, but its spatial distribution is more inhomogeneous than the photospheric emission. A loop connecting two umbrae of opposite polarity is also bright in Ly-α, but also in X-rays. From the FCS data coronal temperatures of 1.8×10^6, 2.25×10^6, and 3.3×10^6 K have been derived for the umbra, penumbra, and the loop, respectively. The umbral data are compatible with the emissions predicted by the "Wroclaw-Ondřejov sunspot model".

ИССЛЕДОВАНИЕ БОЛЬШОГО ВЕДУЩЕГО ПЯТНА СД 548/1980, НАБЛЮДАЕМОЕ НА БОРТУ СПУТНИКА "SMM": Комплексные наблюдательные данные, полученные на борту спутника "SMM" (на приборах UVSP и XRP), были использованы для исследования структуры и динамики большого ведущего пятна в активной области СД 548/1980 (NOAA 2779) с 7 ого до 11 ого ноября 1980 г. Данные состоят из спектрогелиограмм в непрерывном спектре при 3096 Å, в линиях H Ly-α, C IV 1548 Å и в 6 линиях мягкого рентгеновского диапазона, кроме этого из карт скоростей в линии C IV и

наземных измерений вектора магнитного поля для сравнения. Пятно имеет неоднородную структуру со световым мостом. В сравнении с самыми темными ядрами фотосферной тени световой мост - яркое явление в фотосфере и в переходном слое, но темное в хромосфере. Было установлено, что в переходном слое над тенью плазма движется в верх, но в световом мосте вниз. В сравнении с окрестностью пятна излучение Ly-α в тени сильнее до множителя 3, но его пространственное рапределение менее однородно чем фотосферное излучение. Петля, соединяющая две тени с противоположными полярностями, яркая в Ly-α и в рентгеновском излучении. По данным XRP были получены значения корональной температуры 1.8 x 10^6K в тени, 2.25 x 10^6K в полутени и 3.3 x 10^6K в петле. Наблюдательные данные в тени согласованы с излучением, предсказанным "Вроцлав-Ондржейовской моделю солнечного пятна".

VÝSKUM VEĽKEJ VEDÚCEJ ŠKVRNY SD 548/1980, POZOROVANEJ Z DRUŽICE "SMM". Štruktúra a dynamika veľkej vedúcej škvrny v aktívnej oblasti SD 548/1980 (NOAA 2779) bola študovaná od 7. do 11. októbra 1980 na základe súhrnných pozorovacích údajov, získaných prístrojmi UVSP a XRP/FCS na družici "SMM". Spracované boli nasledovné údaje: spektroheliogramy v spojitom spektre v okolí vlnovej dĺžky 3096 Å, v čiare vodíka Ly-alfa, v čiare CIV 1548 Å, v 6-tich čiarach mäkkého röntgenového žiarenia, okrem toho rýchlostné mapy pre čiaru C IV a mapy vektora magnetického poľa, ktoré boli merané pozemskými prístrojmi. Študovaná škvrna mala nerovnorodú štruktúru, vyznačovala sa jasným mostom. Most vo fotosfére a v prechodnej vrstve bol jasnejší ako najtmavšie jadrá umbry, ale v chromosfére bol tmavší. V prechodnej vrstve nad umbrou bol nameraný pohyb smerom hore, nad jasným mostom bol zistený pohyb smerom dolu. Emisia v Ly-alfa bola nad umbrou trikrát vyššia ako hladina emisie v okolí škvrny. Priestorové rozdelenie emisie v Ly-alfa bolo výrazne nehomogénnejšie nad umbrou ako nad okolitou fotosférou. Dve umbry opačných polarít boli prepojené magnetickou slučnou, ktorú bolo možné pozorovať tak v Ly-alfa ako aj v röntgenovom žiarení. Koronálne teploty pre umbru 1.8 x 10^6 ^oK, penumbru 2.25 x 10^6 ^oK a slučku 3.3 x 10^6 ^oK boli vypočítané z FCS údajov. Namerané hodnoty pre umbru sú v zhode s emisiou predpovedanou "Wroclavsko-Ondřejovským modelom".

1. INTRODUCTION

In order to improve our knowledge of the structure and dynamics of sunspots, more complete sets of observed data should be analysed. Such data should be obtained simultaneously from an individual sunspot at as much different wavelengths as possible. Only in this way we could cover a large range of heights in the solar atmosphere, moreover, we could avoid the uncertainties arising from a mixture of data from different sunspots or from different phases of the development of a single spot.

For the present work complex data from the Solar Maximum Mission (SMM) spacecraft and ground-based stations have been used to investigate the large p-spot in the active region NOAA 2779 (Hale 17255, USSR Solar data 548/1980)

from November 7 to 11 (CPM), 1980. Flares in this active region have been studied in several earlier papers, e.g. at the limb on Nov. 6 and 7 (Švestka, 1983, 1984), on Nov. 8 (Doyle et al., 1985), Nov. 10 (Siarkowski et al., 1985), and close to the disk center on Nov. 12 (Mac Neice et al., 1985). Complex data from the region on Nov. 7 are also shown in a paper by Athay et al. (1982). In the following sections we shall give a survey on the available data and discuss some preliminary results from our analysis. A more detailed report is planned to be published in a subsequent paper.

2. OBSERVATIONS

From the SMM satellite we have used the following data: The Ultraviolet Spectrometer and Polarimeter (UVSP; Woodgate et al., 1980) was applied to sample the intensity in the continuum at 3096 Å, in the CIV line at 1548 Å, and in H Ly-α at 1216 Å. The sampled area (pixel) was 3" x 3", requiring an integration time of 0.063 s per pixel. The split widths were 30 mÅ at 3096 Å and in either wing of the CIV line where the two slits were separated, at their centers, by 294 mÅ. In Ly-α a slit with a width of 300 mÅ covered a greated part of the line core. Large rasters with 80 x 80 pixels have been used for the present analysis. The rasters at 3096 Å and 1548 Å have been recorded simultaneously, while the scanning in Ly-α was obtained separately. Ly-α scans exist for Nov. 10 and 11, scans in CIV and at 3096 Å for every day from Nov. 7 to 11. In addition to the intensity maps also Dopplergrams have been obtained from the difference of intensities in the CIV line wings (see Athay et al., 1982).

The Flat Crystal Spectrometer (FCS) of the Soft X-Ray Polychromator (XRP; Acton et al., 1980) on SMM produced monochromatic rasters in 7 channels every 0.256 s at different wavelengths between 1.4 Å and 22.4 Å and in the white light. The six X-ray channels correspond to resonance lines of different ions (O VIII, Ne IX, Mg XI, Si XIII, S XV, Fe XXV) which are emitted at temperatures between 1.5 x 10^6 K and 5 x 10^7 K. In active regions without flares mainly the O VIII, Ne IX, and Mg XI lines can be used to derive emission measures and temperatures; these lines have peak formation temperatures of 3 x 10^6, 4 x 10^6, and 7 x 10^6 K, respectively. Pixel spacings of 10" and grids of 42 x 42 pixels have been obtained. Because the XRP made scans with a collimated field of about 14" FWHM, a deconvolution has been applied to the observed data.

The described SMM data provide useful information from a large range of heights in the solar atmosphere: UVSP intensity maps were obtained from the photosphere (3096 Å), the upper chromosphere (Ly-α ; 2 x 10^4K), and the transition region (C IV; 10^5K; including also Doppler velocities with $|v| \lesssim 30$ km s^{-1}, while the XRP/FCS rasters show emissions formed in the corona. These data were completed by photospheric vector magnetograms from the Marshall Space Flight Center and H_α filtergrams from the Debrecen Heliophysical Observatory.

3. RESULTS

Without going into the details of the data analysis some interesting results will be shortly summarized here. The large p-spot was characterized by two umbrae within one penumbra, the umbrae being separated from each other by a photospheric light bridge. After coalignment of the different data sets, taking into account the differences in observing time, the sunspot structure could be studied at the different height levels. For example, Figure 1 shows the UVSP maps for the photospheric continuum and the Ly-α line intensity, both obtained on Nov. 10 with a time distance of 7.5 hours. Figure 2 shows the rasters of continuum, C IV line wing intensity, and Doppler velocity.

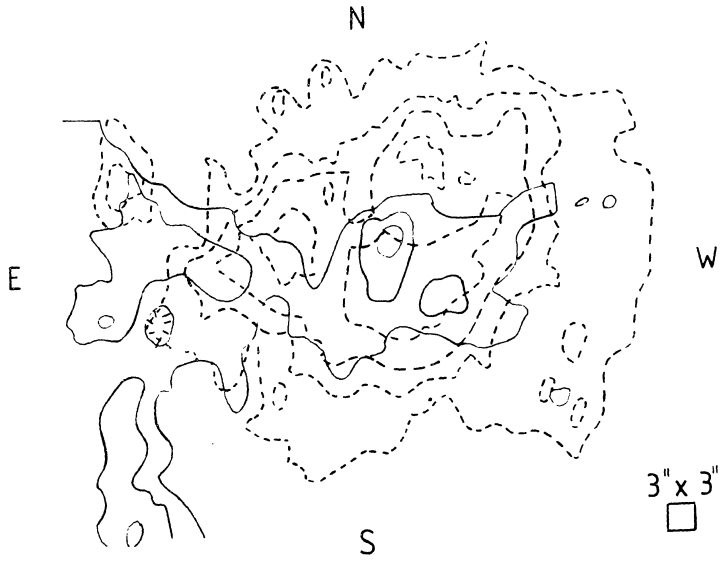

Fig. 1: UVSP contour plots of photospheric intensity at 3096 Å (dashed curves: contrast levels of 0.10, 0.25, 0.40, and 0.55 relative to the average intensity in the quiet surroundings) and of the Ly-α core intensity (full curves: contrast levels of 2.0, 2.5, and 3.0).
These maps from the large p-spot of AR 2779 were obtained on Nov. 10, at 07:51 UT (continuum) and at 15:27 UT (Ly-α).

Compared with the spot's surroundings, the Ly-α emission is stronger above the umbrae up to a factor of 3 in agreement with earlier results (Basri et al., 1979; Kneer et al., 1981; Lites and Skumanich, 1982); however, its spatial distribution is more inhomogeneous than that at photospheric level. The intensity in the C IV line wings is reduced above the umbra, but not in

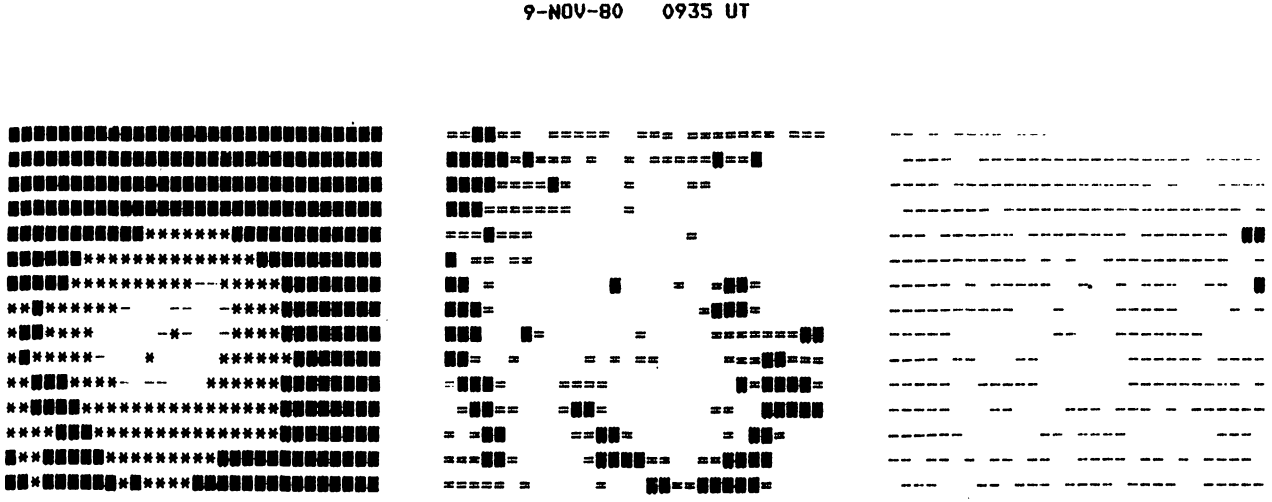

Fig. 2: UVSP rasters of intensity at 3096 Å (for Nov. 10 idential with Fig. 1), in the C IV line wings, and Dopplerogram in C IV (from left to right, respectively), obtained on Nov. 9 and 10. Two pixels have been averaged in vertical (N-S) direction. Dark pixels correspond to strong emission in the intensity rasters. White (empty) pixels mean upward motion, minus (-) signs mean downward motion (redshift) in the Dopplergram.

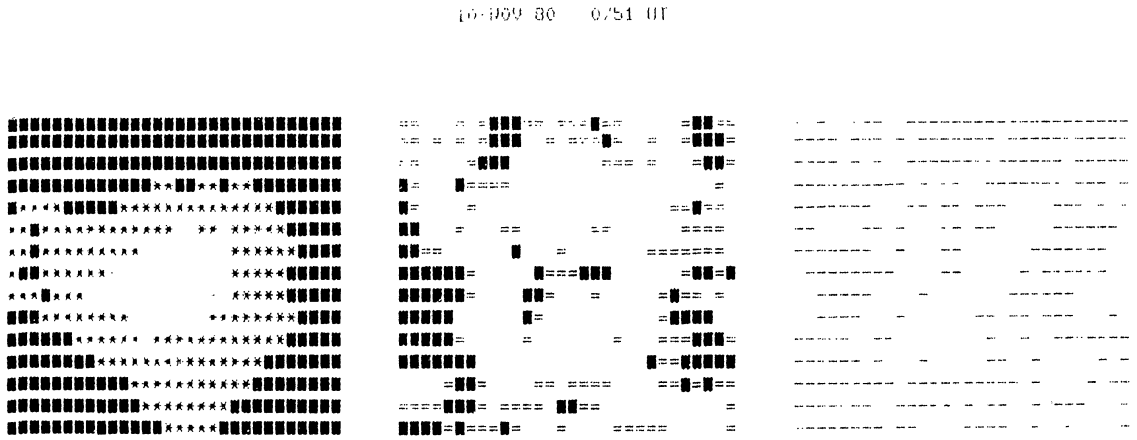

Fig. 2: UVSP rasters of intensity at 3096 Å (for Nov. 10 idential with Fig. 1), in the C IV line wings, and Dopplerogram in C IV (from left to right, respectively), obtained on Nov. 9 and 10. Two pixels have been averaged in vertical (N-S) direction. Dark pixels correspond to strong emission in the intensity rasters. White (empty) pixels mean upward motion, minus (-) signs mean downward motion (redshift) in the Dopplergram.

the light bridge. The intensity decrease is partially caused by a decrease of the Doppler width over umbrae, but even if this effect is eliminated there remains a reduction in intensity. In comparison with the darkest umbral cores at photospheric level the light bridge is bright in the photosphere, in H_α, and in the transition region, but obviously darker in Ly-α.

Observations of mass motions in the umbral transition region so far show some contradictions: Lites (1980) and Mein et al. (1982) found upward velocities of 20 km s^{-1}, Nicolas et al. (1982) measured downdrafts of the same size beside a much stronger downward motion of nearly 90 km s^{-1} (the UVSP cannot measure such high velocities), and Athay et al. (1982) obtained smaller velocities in both directions with a preponderance of downdrafts resembling the inverse Evershed effect in the chromosphere. Our p-spot clearly shows a tendency to small upward motion of a few km s^{-1} in the umbral transition region, but small downward motion in the light bridge every day from Nov. 7 to 11 (see Table 1).

Table 1

Mean velocity above the spot umbra and central meridian distance of the spot (sign "-" denotes blueshift)

data	time (UT)	v (km s^{-1})	CMD
7 Nov 1980	0119	- 0.1 $\pm$ 4.0	W53
7 Nov	1852	- 1.7 6.7	W42
8 Nov	0613	- 1.3 3.2	W 36
8 Nov	1712	- 2.0 4.5	W 30
9 Nov	0927	- 3.3 4.4	W22
9 Nov	2331	- 1.4 4.5	W14
10 Nov	0743	- 1.6 2.3	W10
11 Nov	1525	- 0.6 3.6	E07

From the FCS data of Nov. 9 an average coronal temperature of $T = (1.79 + 0.28/-0.14) \times 10^6$ K has been obtained for the umbra from 4 pixels. For comparison we derived $T = (2.25 + 0.30/-0.22) \times 10^6$ K from 9 pixels in the penumbra and $T = (3.3 \pm 0.3) \times 10^6$ K in a loop connecting opposite magnetic polarities at the eastern limb of the p-spot; the loop is also bright in Ly-α (see Figure 1). The intensitites measured at different height levels of the umbral atmosphere are compatible with the emissions predicted by the 'Wroclaw-Ondřejov sunspot model' (Staude et al., 1983, 1984).

ACKNOWLEDGEMENTS

The authors would like to thank Drs. R.D. Bentley and Richard A. Shine for placing at disposal the SMM data, Mona J. Hagyard for MSFC vector magnetograms, and Lorant Dezső and Béla Kálmán for H_α filtergram from the Debrecen

observatory, together with helpful comments from all of these colleaugues. Stimulating discussions with colleagues in the Wroclaw observatory, especially with Barbara and Janusz Sylwester, are gratefully acknowledged.

REFERENCES

Acton, L.W., and 23 co-authors: 1980, Solar Phys. 65, 53.
Athey, R.G., Gurman, J.B., Henze, W., Shine, R.A.: 1982, Astrophys. J. 261, 684.
Basri, G.S., Linsky, J.L., Bartoe, J.-D.F., Brueckner, G., Van Hoosier, M.E.: 1979, Astrophys. J. 230, 924.
Doyle, J.G., Byrne, P.B., Dennis, B.R., Emslie, A.G., Poland, A.I., Simnett, G.M.: 1985, Solar Phys. 98, 141.
Kneer, F., Scharmer, G., Matting,,W., Wyller, A., Artzner, G., Lemeire, P., Vial, J.C.: 1981, Solar Phys. 69, 289.
Lites, B.W.: 1980, Solar Phys. 68, 327.
Lites, B.W., Skumanich, A.: 1982, Astrophys. J. Suppl. 49, 293.
MacNeice, P., Pallavicini, R., Mason, H.E., Simnett, G.M., Antonucci, E., Shine, R.A., Rust, D.M., Jordan, C., Dennis, B.R.: 1985, Solar Phys. 99, 167.
Mein, P., Simon, G., Vial, J.C., Shine, R.A.: 1982, Astron. Astrophys. 111, 136.
Nicolas, K.R., Kjeldseth-Moe, O., Bartoe, J.-D.F., Brueckner, G.E.: 1982, Solar Phys. 81, 253.
Siarkowski, M., Jakimiec, J., Sylwester, B., Sylwester, J., Bentley, R.D., Shine, R.A.: 1985, Porc. SMA Workshop, Irkutsk (in press).
Staude, J., Fürstenberg, F., Hildebrandt, J., Krüger, A., Jakimiec, J., Obridko, V.N., Siarkowski, M., Sylwester, B., Sylwester, J.: 1983, Acta Astron. 33, 441; 1984, Astron. Zh. 61, 956.
Švestka, Z.: 1983, Soace Sci. Rev. 35, 259.
Švestka, Z.: 1984, Solar Phys. 94, 171.

DISCUSSION

G.B. Gelfreikh
Higher values of coronal temperature above the penumbra obtained in your analysis are consistent with a higher temperature at the periphery of sunspots in radio data. I've reported yesterday.

J. Staude
Yes, I agree.