Modern Solar Facilities – Advanced Solar Science, 161–164
F. Kneer, K. G. Puschmann, A. D. Wittmann (eds.)

High-resolution CN spectroscopy of small-scale solar magnetic features

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Abstract. High-resolution spectroscopic observations of small-scale magnetic elements in the solar photosphere were carried out in the spectral region 387.5–388.4 nm with the 1-m Swedish Solar Telescope (SST). This part of the spectrum covers not only the violet CN band-head, but also contains some lines of the CH molecule. The analysis of the line-core intensity contrasts of the CN and CH lines in bright points (BPs) yielded that on average the BPs appear brighter, thus providing a higher rms contrast, in the CN than in the CH lines in the same spectral band.

1 Observations

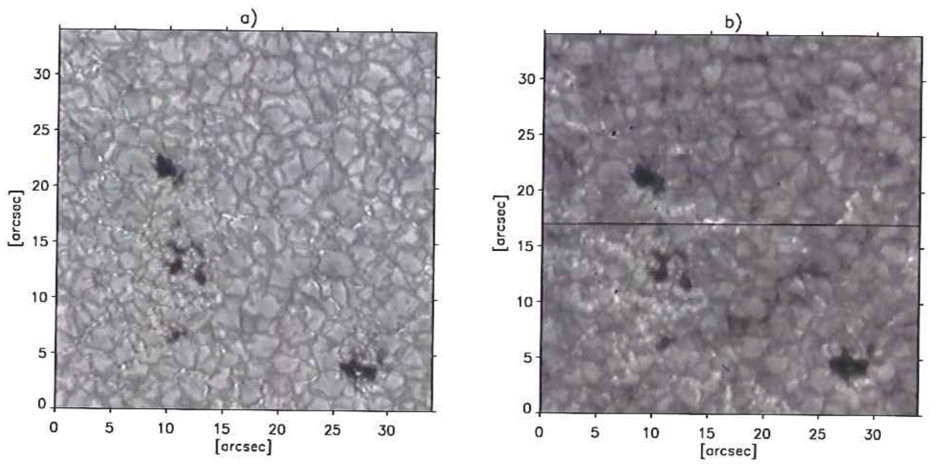

Figure 1. Active region NOAA0753 observed near μ=0.95. The left panel (a) shows a high resolution red "continuum" image (at λ =705.7 nm) restored with MFBD. The right panel (b) represents an example of a slit-jaw image taken in the violet CN band.

The spectroscopic dataset presented here was collected with the TRIPPEL (TRI-Port Polarimetric Echelle-Littrow) spectrograph (Kiselman et al. 2007) installed at the SST. It was used simultaneously with the tip-tilt and the adaptive optics (AO) system and has a slit width of 25 μm, which corresponds to about 0.11 arcsec in the image plane. We have used a narrow-band interference filter (CWL=387.9 nm, FWHM=0.7 nm with 60 % peak transmission) in front of the CCD camera as an order sorter. The light reflected by the slit box was used to obtain slit-jaw images in the violet CN band simultaneously with the spectra (e.g. Fig. 1 - right). The exposure time for spectra and slit-jaw images was 1.5 s. 10% of the total incoming sunlight were separated by a 90/10 grey beamsplitter in the light path before the spectrograph in order to obtain high resolution images in a red "continuum" window using a narrow-band interference filter centered at 705.7 nm with a FWHM of 0.7 nm. These images, collected with exposure times of 10 ms, are uncorrelated in time with the spectroscopic dataset and are processed by the Multi Frame Blind Deconvolution (MFBD) routine (Löfdahl 2002), thus providing almost diffraction limited quality (e.g. Fig. 1 - left). All employed CCD cameras were Kodak Megaplus 1.6, 10 bit with 1536×1024 pixels of 9 μm each.

We have observed on 14 April 2005 an active region NOAA0753 located near μ =0.95. Strong seeing variations and rotation of the FOV allowed us only to record few individual slit spectra, rather than full scans over some solar area. The analysed spectroscopic data were estimated to have 0.3 arcsec spatial resolution and a resolving power of 130 000.

2 Results

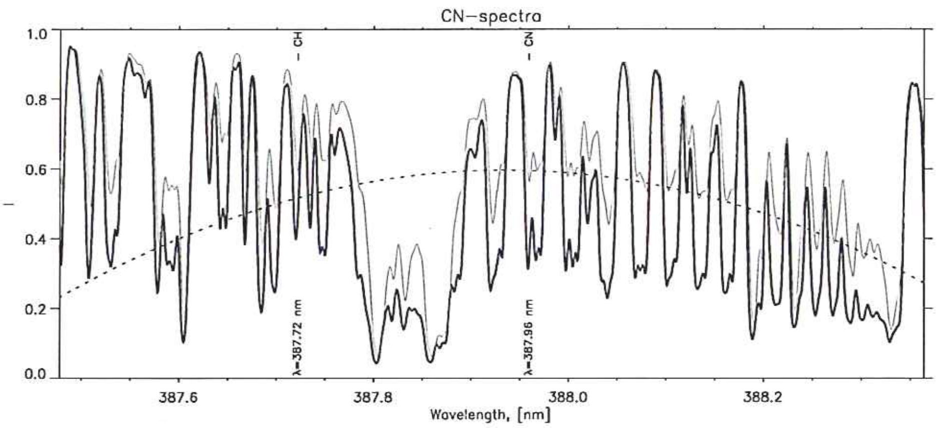

Figure 2. Example of the observed CN spectrum of a BP (grey line) near μ=0.95 and of the quiet Sun (black line). The filter curve (dashed line) as obtained in the data reduction is also shown.

In Fig. 2 a sample of observed CN spectra is shown. There are individual CH lines among the forest of CN lines in the observed wavelength band. In a BP (grey line) the spectrum shows a considerably reduced absorption in spectral lines of CN and CH as compared to that in a quiet Sun area. We have defined the contrast of intensity I_λ as $C_\lambda = I_\lambda / < I_\lambda >_{qs} -1$, where $< I_\lambda >_{qs}$ means the intensity averaged over a quiet Sun area in the immediate vicinity of the observed active region. In the present analysis we measured:

- the line-core intensities I_{CH} of a CH line at 387.72 nm and I_{CN} of a CN line at 387.96 nm (marked in Fig. 2),

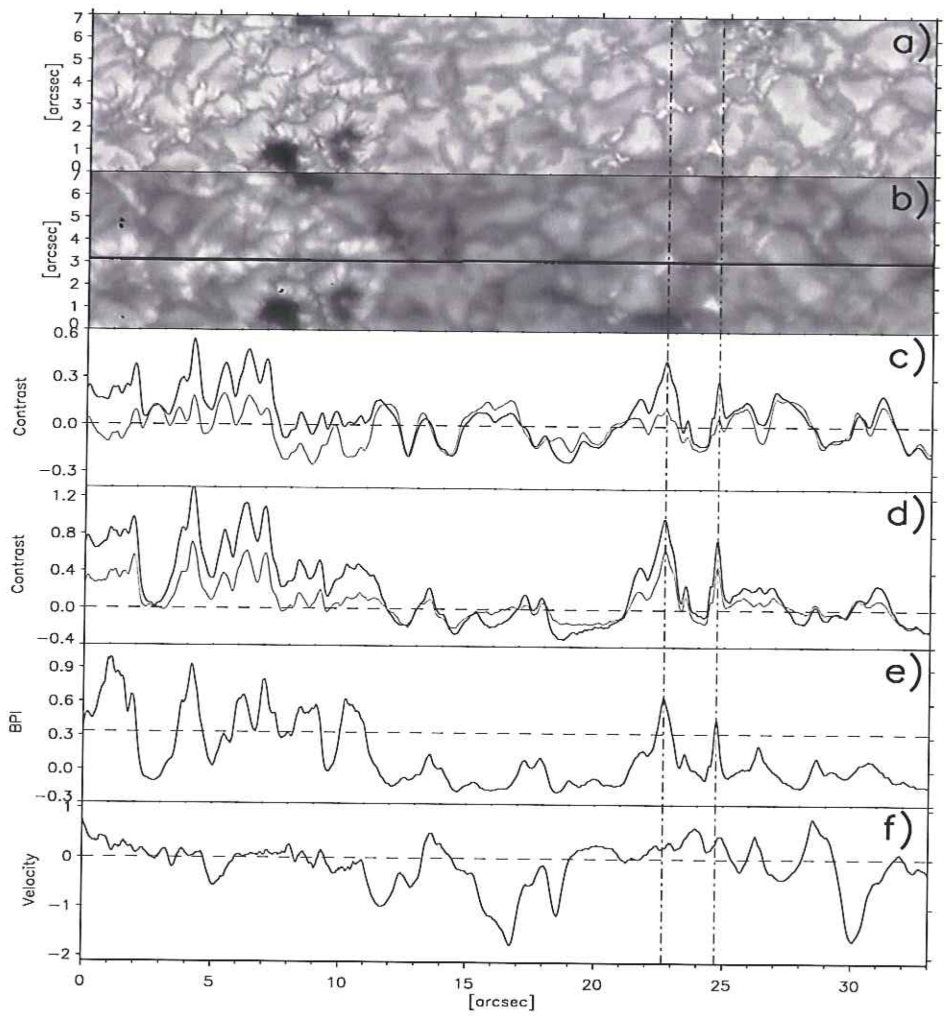

Figure 3. Spectroscopic data observed in the active region NOAA0753 at μ=0.95 on 14 April 2005 at 14:56 (UT) : a) High-resolution red "continuum" image; b) slit-jaw image; c) integrated and continuum intensity contrasts $C\,(I_{int})$ - black, $C\,(I_{cont})$ - grey; d) line-core intensity contrasts $C\,(I_{CN})$ - black, $C\,(I_{CH})$ - grey; e) Bright Point Index; f) velocity measurements v_{CN} in $[km/s]$. The horizontal black line in b) marks the position of the slit. All the images as well as the spatial domain of the spectrum were coaligned by cross correlation.

- 'quasi'-continuum brightness I_{cont}, averaging it over wavelength positions in the spectra which are the least affected by absorption,

- integrated intensities I_{int}, calculated by integration over λ of the whole obtained spectral domain multiplied with the prefilter profile,

- the LOS velocities, v_{CN}, which were computed from measured Doppler shifts in the CN line at λ_{CN}=387.73 nm with a relative accuracy of around 60 m/s. Upflows were assigned negative velocities and downflows positive.

In order to determine the positions of bright small-scale magnetic features and automatically distinguish them from the non-magnetic bright features the Bright Point Index (BPI) was calculated (Langhans et al. 2004). Here we use line-core intensities of the Fe I line at 387.80 nm and of a CN line at 387.73 nm. A threshold of BPI=0.33 is used to separate magnetic bright features from the non-magnetic ones.

In Fig. 3 we present one example of a calibrated spectroscopic dataset. BPs, as the rule, have a high value of the BPI>0.33, enhanced continuum contrast $C(I_{cont})$ >0 and have a compact shape. Also the integrated intensity always has a higher contrast than the continuum, i.e. $C(I_{int}) > C(I_{cont})$. The line-core contrast in such structures is always as $C(I_{CN}) > C(I_{CH})$. In many photospheric structures showing low BPI, like granules and many intergranular lanes, assumed to be non-magnetic in nature, the continuum and line-core intensities tend to show $C(I_{int}) < C(I_{cont})$ and $C(I_{CN}) < C(I_{CH})$. The latter is probably caused by the difference in temperature sensitivity of the molecules. Basically all magnetic brightenings are located in the intergranular downflow area. Many observed BPs show a reduced vertical velocity surrounded by downflows (e.g. at 22.7 arcsec in Fig. 3).

3 Conclusions

Considering all 25 individual imaging positions of the slit we estimate that in BPs the ratio of contrasts in CN line cores to those in CH line cores lies in a range between 1.4 and 5.4 with a mean value around 2, i.e CN lines on average show twice the contrast as the CH lines in the same wavelength band. This is in line with the imaging observations by Zakharov et al. (2005).

Acknowledgements. We are grateful to the SST technical staff and G. Scharmer for help with the instrumentation. The SST is operated by the Royal Swedish Academy of Sciences at the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

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Zakharov, V., Gandorfer, A., Solanki, S. K., & Löfdahl, M. G. 2005, A&A, 437, L43