Oscillations in a Sunspot Transition Region Observed with SOHO

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SUMER Data

- Ultraviolet spectroscopic data obtained with the SUMER spectrograph (cf. [4], [7]) aboard SOHO.
- Longest time series: August 29, 1996, $09^{\mathrm{h}}08^{\mathrm{m}}$ UT – $13^{\mathrm{h}}31^{\mathrm{m}}$ UT (4 h 23 min in two spectral lines).
- Continuous scans over the active region NOAA 7986 centered at $l_1 = -6\overset{\circ}{.}33$, $b_1 = -10\overset{\circ}{.}94$.
- C IV at 1548.1Å (profile shown in Figure 3, left) originates in the transition region at temperatures of about $7 \times 10^4 \ldots 1.3 \times 10^5$ K.
- Ne VIII at 770.41Å (profile shown in Figure 3, right) is emitted in the upper transition region at temperatures of about 6×10^5 K.

Supplementary Data

- Supplementary observations of the active region NOAA 7986:
  - EIT (a partly synchronous time series of 2 hours, example image Figure 1)
  - CDS experiment aboard SOHO, showing a bright EUV plume [1]
  - Magnetograms of the Solar Observatory Einsteinturm Potsdam (Figure 2).

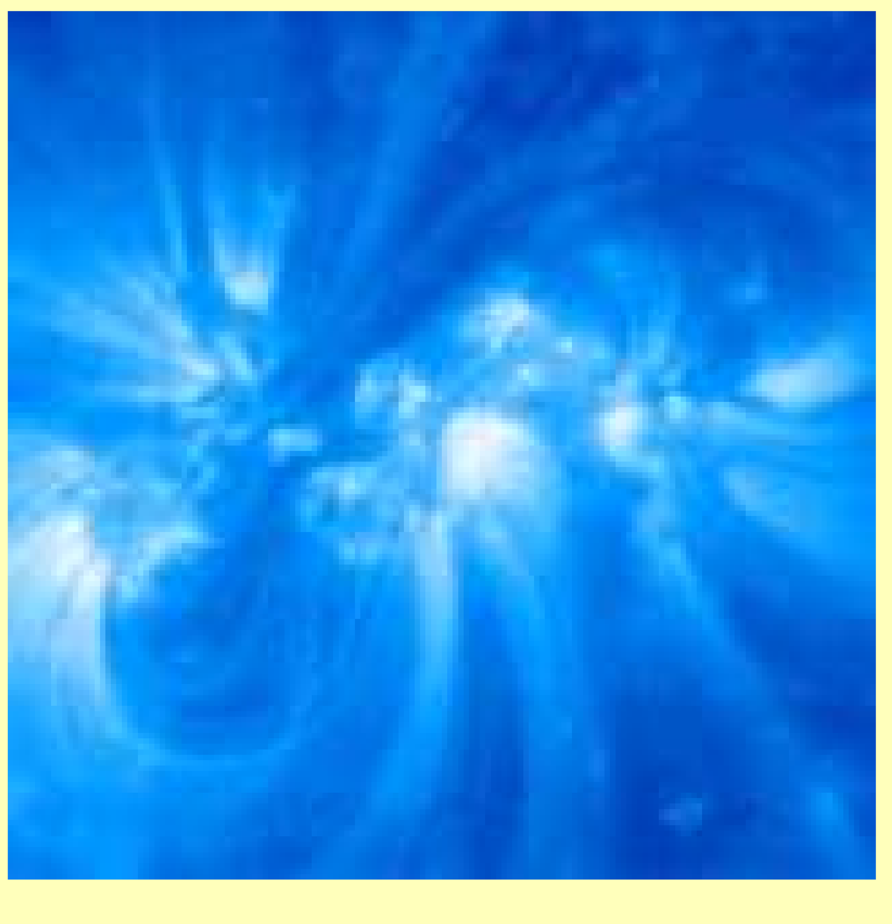

Figure 1: UV image of the Sun obtained by the SUMER EIT experiment at 09:00 UT on August 29, 1996 in the line FE IX/X at 171 Å which originates at temperatures of $\approx 1 \cdot 10^6$ K, well above the lines analysed here. This image is from the beginning of the parallel time series to the SUMER data.

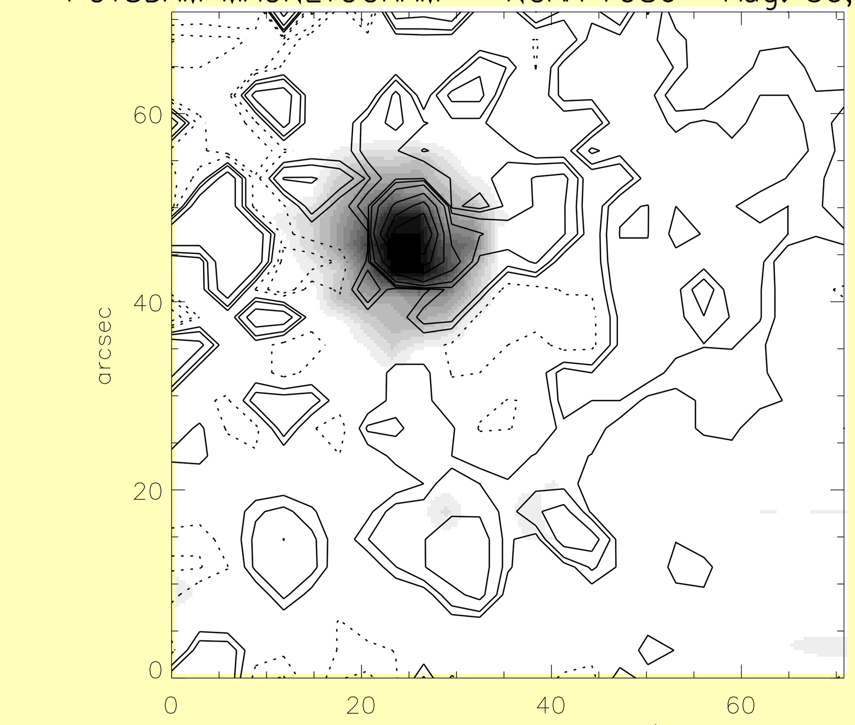

Figure 2: Magnetogram of the sunspot region NOAA 7986 obtained at the Solar Observatory Einsteinturm on August 30, 1996 in the line Fe I at 5250.3 Å. The shaded area represents the spot contours. North is up, East is to the left.

First Results

- This part of the work considers intensity variations.
- Investigation of the maximum intensity in the line center of both spectral lines above the umbra (6×6-pixel area).

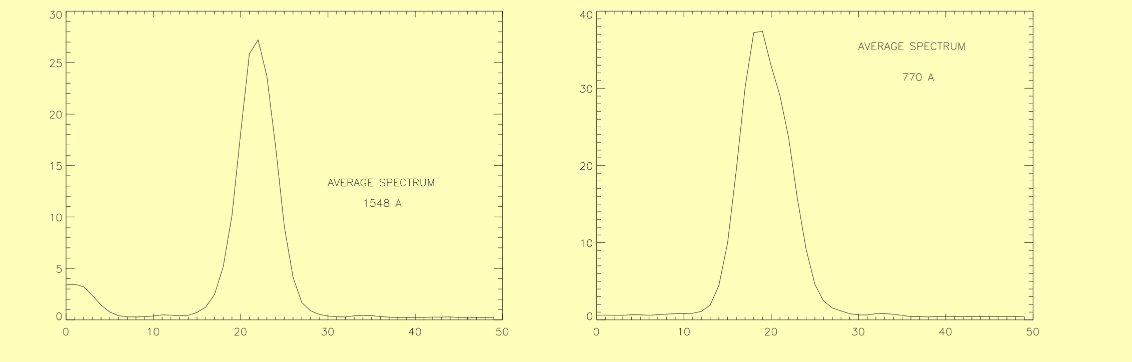

Figure 3: Average profile of the spectral line at 1548 Å (left) and 770 Å (right). Each profile is an average of 283 spectra in the umbra. The abscissa gives pixel coordinates with 50 pixels corresponding to 2.10 Å for 1548 Å and 1.05 Å for 770 Å, respectively; the ordinate gives count rates. Off the spectral line, the count rates are of the order of 1 on average.

- Usual flatfielding procedures not applied. Compensation for possible instrumental effects and exposure differences by subtraction of background extracted from an area off the spot and off the spectral line from each image (average background count rates of the order of one count in those areas; cf. Figure 3).
- Slit of $1'' \times 120''$, scan steps of $1\overset{''}{.}14$. Subsequent scans in same direction, shifted by half a step. Hence spectra regarding a specific position are not scanned in even temporal steps. For the analysis we used the program package "DES7" of Stefan Larsson (Stockholm Observatory), including a power routine for uneven temporal spacing.

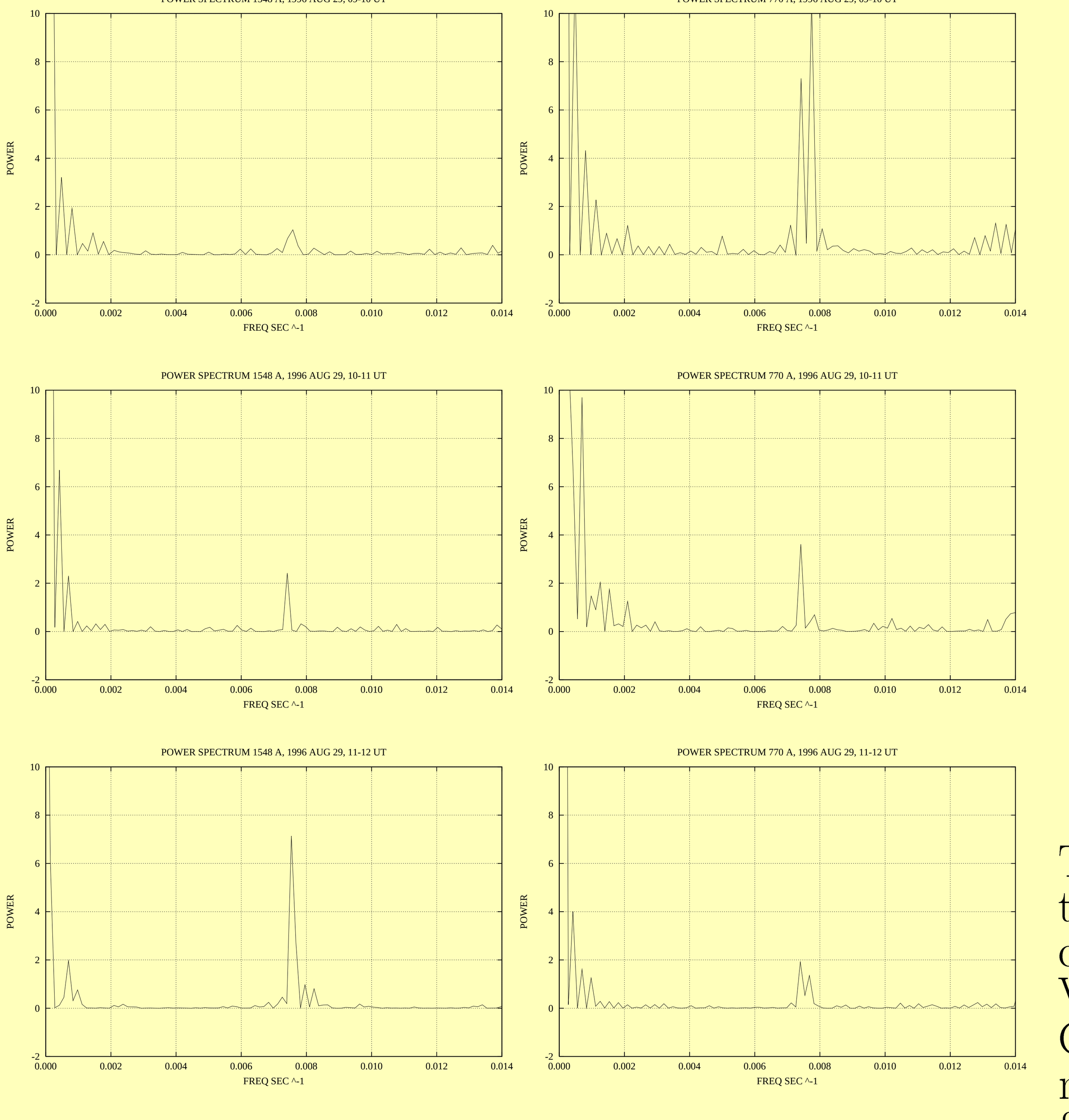

Figure 4: Power spectra derived for intensity variations from the SUMER spectra of August 29, 1996
– for the time intervals 09:08–10:00, 10:00–11:00, and 11:00–12:00 UT
– for the peak intensity
– in the spectral lines 1548 Å (transition region; left column), and
– 770 Å (upper transition region; right column).

- Intensity oscillations in the 2-minute range (7.5 to 8 mHz; 130 to 125 s) appear in both spectral lines. Figure 4 shows the power of the intensity oscillations for the intervals 09:08–10, 10–11, and 11–12 UT:
  - in the 1548 Å line the power increases by a factor of 7, while the line intensity increases by 35%;
  - in the 770 Å line the power decreases by a factor of 5, while the intensity decreases by 25%.
- The sunspot magnetic field has a relatively complex north polarity, with some weak south polarity in the immediate vicinity as well as to the east of the scanned region.

Conclusions

- A preliminary data analysis indicates intensity oscillations in the 2.2-minute-range (very close to 8 mHz) in both analysed spectral lines.
- The power spectra derived for 1-hour intervals show a slow temporal increase of oscillatory power in the C IV line, but a decrease in the Ne VIII line (Figure 4).
- The chromosphere-corona transition region (CCTR) above the sunspot region participates in the oscillation of the sunspot atmosphere. The presence of intensity oscillations hints at the non-adiabatic character of the waves.
- The changes of relative intensity oscillations **and** the mean intensities in opposite directions in the two lines could result from a cooling of the emitting and oscillating volume in the CCTR.

Previous Work

- Oscillations of velocity and partly of intensity with resonance peaks in the 2…3 minute period band have been discovered in the CCTR above sunspots by means of the UVSP instrument aboard the SMM spacecraft ([2], [3], [6]). These oscillations appear as a continuation of chromospheric umbral oscillations.
- The CCTR oscillations have been interpreted as a signature of the resonant transmission of the umbral atmosphere for magneto-atmospheric waves ([5], [8]).
- The lack of significant power in intensity oscillations in some data sets of Gurman et al. [2] on one hand, and their presence in other data on the other hand, has been explained by the different behaviour of the waves, appearing sometimes as adiabatic, in other cases as almost isothermal oscillations, respectively [5], [8]).

Future Work

- Investigation of velocity variations.
- Investigation of phase relations between the intensity oscillations in three different lines as well as between intensity and velocity oscillations.
- Comparison to the magnetic field structure as derived from magnetograms (Figure 2) and EIT images (Figure 1) of the parallel time series.

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