Investigation of the dynamics of chromosphere and photosphere from spectra obtained by parallel observations using SUMER on SOHO and the VTT on Tenerife

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Abstract. This is a preliminary report about parallel observations of chromospheric and photospheric spectra in the ultraviolet and visible spectral regions using SUMER on SOHO and the VTT on Tenerife performed begin of September 1996. The aim is to search for relations of vertical velocity patterns in the upper photosphere and chromosphere in the solar disk center. In addition temporal changes in these parts of the solar atmosphere are investigated.

1. Introduction

Investigations of small-scale vertical velocity patterns and spectral line shapes have given some insight into the dynamics of the photosphere, mainly into the deepest parts. E.g. Nesis et al. (1992) interpreted the enhanced line broadening in the intergranulation as a turbulence effect.

Several further spectral analyses were performed to determine, whether the physical and structural changes characterizing the low photosphere take also place in the upper one (Espagnet et al. (1995), Kučera, Rybák and Wöhl (1995)).

The aim of the present project is to perform similar analyses from spectral data obtained simultaneously over a large part of the solar atmosphere.

2. Observations

2.1. Instruments

The Vacuum Tower Telescope (VTT) at Izaña, Tenerife, (Schröter, Soltau and Wiehr, 1985) is very suitable for high resolution spectroscopy in the visible. Its Echelle spectrograph allows to obtain simultaneous spectra in several wavelength regions with a maximum difference of 2000 Å. The spectra are registered by cooled slow-scan CCD cameras with 1024 by 1024 pixels and applying a 16 bit A/D conversion. When using a binning of 4 in wavelength (giving a wavelength coverage of about 8 mÅ at 6000 Å) and 2 in the spatial direction (giving a spatial coverage of 0.17 arcseconds), the S/N obtainable for exposure times of 0.2 seconds is about 500. Quite often spatial structures of smaller than one arcsecond can be resolved within these spectra.

SUMER - Solar Ultraviolet Measurements of Emitted Radiation - onboard the SOHO spacecraft (SOlar Heliospheric Observatory) provides high resolution spectral images in the far and extreme ultraviolet (Wilhelm et al., 1995). Spectra in the wavelength range 450 Å to 1610 Å are recorded by a two-dimensional microchannel plate detector. The possible spatial resolution is of the order of 1 arcsec, and the spectral resolution is 40 mÅ per pixel in first order (20 mÅ in second order).

2.2. Spectral lines

While all spectral lines taken by the VTT are absorption lines, those taken by SUMER are emission lines. We have aimed in covering a wide range in formation heights in the photosphere and chromosphere; the full range of the chromosphere is covered by spectral lines of set 1, the lower chromosphere is covered by spectral lines of set 2. A census of all spectral lines used is given in Table 1. With SUMER the daily measurements were either performed using lines of set 1 or set 2 simultaneously, while at the VTT all the spectral recordings were taken in the lines listed simultaneously.

Table 1. Spectral lines used

wavelength [Å]	identification	formation temperature / height	instrument	remark
1025.400	H, Ly_β	20000 [K]	SUMER	set 1
1027.430	O I	< 10000 [K]	SUMER	set 1
1036.337	C II	30000 [K]	SUMER	set 1
1037.018	C II	30000 [K]	SUMER	set 1
1037.613	O VI	300000 [K]	SUMER	set 1
1304.372	Si II	17000 [K]	SUMER	set 2
1304.858	O I	< 10000 [K]	SUMER	set 2
1306.029	O I	< 10000 [K]	SUMER	set 2
1315.918	C I	< 10000 [K]	SUMER	set 2
1316.542	S I	< 10000 [K]	SUMER	set 2
1317.221	Ni II	60000 [K]	SUMER	set 2
1318.998	N I	< 10000 [K]	SUMER	set 2
5434.543	Fe I	560 [km]	VTT	nonsplit
5576.099	Fe I	310 [km]	VTT	nonsplit
6301.508	Fe I	340 [km]	VTT	g_{eff}=1.667
6302.499	Fe I	250 [km]	VTT	g_{eff}=2.500
6494.994	Fe I	500 [km]	VTT	g_{eff}=1.025

2.3. Observing procedures

Since it is not a trivial task to have the spectrograph slits of SUMER and the VTT coaligned to about one arcsecond and keep this coalignment for several hours, it was decided to scan areas of the solar disk center with both instruments. The length of the usable spectrograph slit at the VTT is about 80 arcseconds, while it was selected for SUMER 120 and 24 arcseconds, respectively. The spectrograph slits were in both instruments aligned in the solar north-south direction having the disk center in the middle of each slit length. The scanning was from solar east to west with the VTT and in both directions with SUMER. The scanning stepwidth selected with the VTT was 0.4 arcseconds and that for SUMER 1.14 arcseconds and 0.76 arcseconds, respectively. The width of the areas scanned were $\pm$ 4 arcseconds with the VTT. They varied between $\pm$ 18.24 arcseconds (long slit), $\pm$ 3.8 arcseconds (short slit) and $\pm$ 0 arcseconds (no scanning) with SUMER. This corresponds to a large area scanning, a small area scanning and in the final phase 1d measurements with data collection in the burst mode into RAM. The duration of the different scans were 495 seconds, 165 seconds and 55 seconds, respectively, for SUMER. The measurement period was down to 15 seconds for SUMER without scanning. The complete area scanning at the VTT took 100 seconds (20 times 5 seconds) for each cycle.

On SUMER the spectra were taken using 6 spectral windows of 25 pixels width on the detector. At the VTT the spectra were taken using four CCD cameras simultaneously.

During all the daily observing times the solar rotation correction was applied at both instruments to keep the scanning over physically the same solar disk center region selected at the start time of the SUMER observations.

Slit-jaw videos were taken on S-VHS cassettes at the VTT during most of the parallel observing time in the central emission of the Ca II K line, during a fraction of the time videos were also also taken in H_α and in white light. These video images were taken with two different scalings around the center of the slit to cover either about 100 by 100 arcseconds (adapted to the usefull slit length at the VTT) or about 150 by 150 arcseconds (to adapt to the longer slit of SUMER). The comparison of the video images with raster scans from the SUMER data allows to check the coalignment of the instruments.

Since the parallel observations at the VTT started often only shortly after local sunrise, about one or two hours after starting a new determination of the solar disk center was performed. This reduces shifts by differential refraction for the limbs used for the disk center determination and avoids possible shifts by differential bending between the main telescope and its guiding telescope. After the new disk center positions were determined (that takes about one minute) the scanning continued on the physical old areas - taking into account their westward displacements caused by the solar rotation.

2.4. Observing period

The parallel observations were performed during nearly 20 hours from September 3 until September 9, 1996, mainly between 7 and 14 UT. There were about 1.1 hours of simultaneous observations with very good seeing at the VTT on September 7, 8:00 until 9:10 UT. Some hours of parallel observing time were not used due to bad weather at Izaña.

3. Reductions

3.1. VTT data

From the slit-jaw videos taken at the VTT appropriate frames were grabbed for a checking of the coalignment with SUMER. In Figure 1 an example is given. In Figure 1 also an example of our preliminary reduced VTT spectra is given. Intensity variations of several percent caused by the granules and the intergranulation in the continuum and line shifts by velocity fields (wiggly lines) hopefully still can be seen in this reproduction.

Figure 1 : Slit-jaw image in Ca II K from September 9, 1996 at 8:26:58 UT (left, the vertical line is the spectrograph entrance slit, the horizontal line is from a wire determining the lower end of the spectrum region) showing the same solar area as in the raster scan of Fig.2 (left); along with a corrected VTT spectrum of the 6494 Å region form another observing run of September 7, 1996 (right). The wavelength range is 2.01 Å, the spatial range is 77 arcseconds.

3.2. SUMER data

Some raster images were obtained for the checking of the levels of the count rates within the different spectral lines and the coalignment verification. An example is given in Figure 2, where also two spectral regions of line set 1 are given.

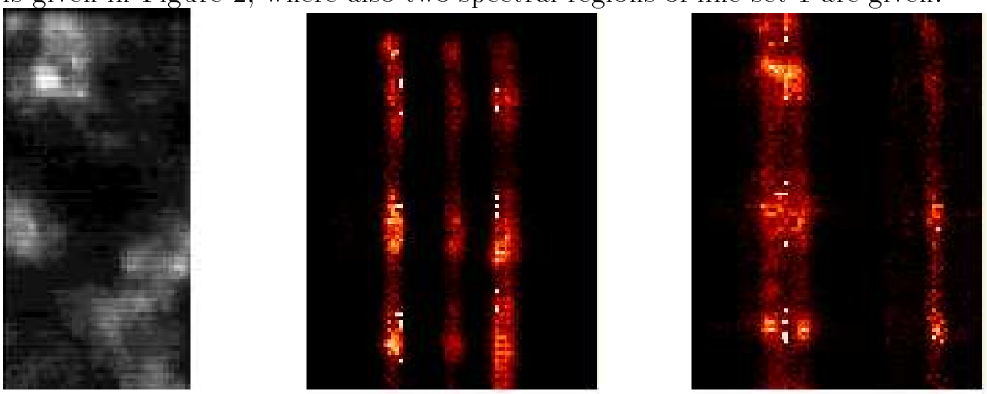

Figure 2 : An example of a SUMER raster scan in Ly$_\beta$ (left) taken September 9, 1996, 9:01 UT; size about 100 by 38 arcseconds (the same solar area as in Fig.1, left). Spectra of C II and O VI lines 1036 - 1038 Å(middle) and Ly$_\beta$ and O I 1027 Å(right) from the same observing run.

4. Discussion and conclusions

The VTT spectra will be processed using the procedures described by Kučera, Rybák and Wöhl (1995). For the SUMER spectra most of the data sets are still on their way from the space flight center to the data center in Germany.

From the preliminary investigation of the data it is obvious, that the aim of overlapping areas for the parallel observations in the disk center is very good fullfilled. The VTT spectra show the well known velocity patterns of solar origin and this should also be the case in the SUMER spectra. Whether any relations between the velocity patterns can be found must be subject to a more detailed analysis.

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