High Resolution Time Series of Narrowband Ca II K Images in the Chromosphere

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Abstract. We have observed a region of quiet Sun near disk center with the Vacuum Tower Telescope (VTT) of the Kiepenheuer-Institut für Sonnenphysik at the Observatorio del Teide, Tenerife, Spain in April 2005 in several wavelengths. Observations were made at the Ca II K line at 393.3 nm, using a Lyot filter with a bandwidth of 30 pm FWHM, centered at the K\textsubscript{2ν} emission peak; at the H\textalpha line at 656.3 nm, using a Lyot filter (25 pm FWHM) centered at line core, and in the G-band (430.5 nm), using an interference filter (1 nm FWHM). We acquired a two-hour long sequence of images at a cadence of ten seconds and a spatial resolution of about 0.3″. We present our Ca observations of excellent spatial resolution which show morphological structures in internetwork regions similar in form, size and lifetime to those present in recent numerical models of the solar chromosphere.

1. Introduction

Modern 3D radiation hydrodynamic models of the chromosphere show a highly dynamic 2D morphological pattern for the temperature distribution at chromospheric heights of ∼ 800 km above τ = 1 and higher (Wedemeyer et al. 2004, hereafter W04). As already suggested by Carlsson & Stein (1995), the dynamical behaviour of chromospheric structures originates from upwards propagating waves that form shocks above the photosphere. Our observations are targeted at detecting these structures as well as measuring their dynamics.

2. Observations

The data presented here was taken at the German Vacuum Tower Telescope (VTT) at the Observatorio del Teide on Tenerife, Spain, on April 18, 2005 in the time span between 8:25–10:21 UT. We observed the quiet Sun near disk center in the Ca II K (3933 Å) line using a Lyot filter with a bandwidth of 0.3 Å FWHM (see Figure 1). The filter was centered at the K\textsubscript{2ν} emission peak of the line. The field of view extended over 48″×48″ with a pixelscale of 0′′.145/px. Simultaneously H\textalpha line core (6563 Å, 0.25 Å FWHM) as well as G-band (4305 Å, 10 Å FWHM) filtergrams were acquired. The Kiepenheuer Institute Adaptive Optics System (KAOS) was used to maintain a high spatial resolution despite an exposure time of two seconds for the Ca filtergrams. The simultaneously acquired G-band data was taken with an exposure time of 10 ms in form of speckle bursts that later on were used for speckle reconstruction. A stable network cell can be seen during the whole sequence, surrounded by a highly dynamic, weblike structure (Figure 4, top). The network structure coincides with G-band bright points (Figure 4, bottom), while the corresponding G-band image shows no bright small-scale structure in the internetwork regions of the calcium filtergram.

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3. Discussion

The observed small-scale structure in the internetwork regions is similar to the one of the model chromosphere of W04. For better comparison, we show a close-up of a non-magnetic region side-by-side to a temperature cut of Wedemeyer’s model at the geometrical height of 1000 km above optical depth unity (Figure 2). In both cases a bright/hot mesh-like structure with enclosed dark/cool regions can be seen. The spatial scales are of the order of the granulation pattern.

In order to verify the assumption that the observations indeed map the chromosphere, further analysis needs to be done. The pattern seen in the model looks suspiciously similar to that of reversed granulation (see Leenaarts & Wedemeyer-Böhm 2005, and references therein) but reversed granulation evolves much slower than the observed pattern presented here. Consequently, the investigation of characteristic pattern evolution timescales may give proof that the filtergrams do not show reversed granulation but the chromospheric pattern. We thus calculated the autocorrelation of the 2D pattern in the calcium filtergrams within subfields of the size of 1′′45 (Figure 3), fitted the function $AC(t) = \exp(-\frac{t}{\tau})$ to the autocorrelation function, and determined the timescale, $\tau$, for each subfield independently. The timescale $\tau$ represents the time after which the autocorrelation of the pattern decreased to a value of $1/e$. The resulting timescales are shown for all subfields in the left panel of Figure 3, revealing that the magnetic network is easily distinguishable from internetwork regions by its long lifetime. The histogram of the pattern evolution timescales (right panel of Figure 3) exhibits a large range of values from only 26 seconds to a few hundred seconds with a very prominent peak at $\sim 38$ seconds. The short timescales, including the values around the peak, are clearly due to internetwork regions, whereas the network exhibits longer timescales.
Figure 2. The close-up (left) of the internetwork region indicated in Figure 4 and a snapshot of the gas temperature (right) at the geometrical height of 1000 km above optical depth unity (Wedemeyer et al. 2004). Clearly, there are similarities in shape and size of the structures.

W04 state a pattern evolution time scale of 20–25 seconds for the temperature distribution in their non-magnetic model chromosphere as shown in Figure 2. When comparing their finding with the result presented here, one has to consider a number of effects that tend to increase the pattern evolution timescale (see Wedemeyer 2003). First of all, the lower spatial resolution of the observation smears out fluctuations, leading to a longer timescale. Moreover, W04 analyse the gas temperature at fixed geometrical heights, whereas the observed intensity is formed over a certain optical depth range along the line of sight. Considering these effects, the timescales derived from the observations presented here are already in reasonable agreement with the model chromosphere. How-
Figure 4. Sample of simultaneous filtergrams in the Ca channel (top) and the G-band channel (bottom). A network cell can be seen as well as the on average darker internetwork regions. The network structures coincide spatially with the bright points in the G-band image. The square in the upper panel marks the region shown in Figure 2.
ever, the important point is that the corresponding values for the reversed granulation present in the model by W04 are of the order of $\sim 70$ seconds (Wedemeyer 2003) which exceeds those found here.

Unfortunately, it is not clear yet how the temperature distribution at this height corresponds to filtergrams of the observed kind. Nevertheless, we feel that observations of high spatial and spectral resolution similar to those presented here give a diagnostic tool to understand the behaviour of the chromosphere and may be related to waves within this region.

4. Conclusions and Outlook

The observed pattern in the internetwork region is very similar to the small-scale structure exhibited in the temperature cuts at a height of 1000 km above $\tau = 1$ of recent non-magnetic chromosphere models both in morphology and evolution timescales. This indicates that the pattern we observe does not resemble reversed granulation, even though the spatial scales are similar, but indeed shows the small-scale structure of the low to middle solar chromosphere.

However, there remain questions regarding the processes involved in the formation of the Ca II K, emission peak, especially about its sensitivity to temperature variations at different heights. Therefore, care must be taken as to not misinterpret the results of the analysis of filtergrams of this kind. We intend to investigate the timescales of the network and internetwork regions as well as the underlying photospheric data in further detail. The magnetic small-scale structure in the G-band images and its correlation to the network in the calcium filtergrams will also be subject to deeper analysis.

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References