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Long-period intensity oscillations of the quiet solar atmosphere from TRACE 1600 continuum observations

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Abstract. We have analysed a 6-hour long time sequence of ultraviolet (uv) images obtained on May 24, 2003 in 1600 Å continuum under high spatial and temporal resolutions from the *Transition Region and Coronal Explorer* (TRACE). We have selected 15 isolated bright points, 15 network elements and 15 quiet background regions from these images for detailed analysis. We derived the cumulative intensity values and the light curves of these features for the total duration of observations, and performed also a power spectrum analysis using the complete time series data. We found that the uv bright points, the uv network and the uv background regions exhibit long-period intensity oscillations namely, 5.5 hours, 4.6 hours and 3.4 hours respectively, in addition to the more familiar small scale intensity fluctuations. We suggest that these longer periods of oscillation might be related to solar atmospheric g-modes.

Key words. Waves – Sun: chromosphere – Sun: oscillations

1. Introduction

The gravity waves play an important role in studying the coupling of lower and upper solar atmospheric regions and are therefore of tremendous inter-disciplinary interest. The gravity waves in the Sun can be divided into two types, namely, (i) the internal gravity waves, may be confined to the solar interior, and (ii) the atmospheric gravity waves, which are related to the photosphere and chromosphere, and that may propagate beyond. In particular, the observation of the internal gravity mode oscillations of the Sun would provide a wealth of information about the energy-generating region, the solar core, which is poorly probed by the p-mode oscillations. For the atmospheric gravity mode oscillations, it has been suggested that the turbulent convection below the photosphere will generate the high order, non-radial g-mode oscillations (Stix 1970). There has been numerous theoretical studies on solar-atmospheric gravity waves by various groups (Whitaker 1963; Lighthill 1967; Stein 1967; Schmieder 1977) in the past. In Frazier (1968) ($k - \omega$) diagrams, the traces of gravity waves are suspected and Deubner (1974) has observed the generation of gravity waves by individual granules. Cram (1978) has investigated the evidence of low, but significant, power at frequencies relevant to gravity

Send offprint requests to: R. Kariyappa waves. He had also concluded from the studies of phase lag between successive layers, that there was an upward energy flux. In addition, Brown & Harrison (1980) have observed the indications of the possible existence of trapped gravity waves by analyzing the brightness fluctuations of the visible continuum. These atmospheric gravity waves, by-products of the granulation, are expected to be fairly common and may not be negligible in the energy balance of the lower chromosphere. Palle (1991) had discussed in great detail on various methods to search for solar gravity waves and mode of oscillations.

In recent years, an increasing amount of attention has been given to atmospheric gravity waves. Such waves are likely to be excited when convective down-flows in Sun's outer envelope penetrate into the underlying stably stratified, radiative layers. They are difficult to observe and this can be attributed to several reasons. As a result of strong radiative damping, the gravity waves cannot propagate in the photosphere (Schmieder 1977), and thus may not be observed in lines formed in this region. Further, as pointed out by Deubner (1981), the gravity waves were expected to be extremely difficult to observe because there are local, small-scale features requiring very high spatial resolution observations. Only high temporal and spatial resolutions data will reveal these gravity waves which are small-scale phenomena. Using wavenumber and frequency-resolved (k, f) phase-difference spectra and horizontal propagation diagram, Straus & Bonaccini (1997) have presented, observationally, the strongest evidence of gravity wave presence in the middle photosphere. There are also some observational investigations showing that there is a signature of atmospheric gravity waves at chromospheric level using time sequences of filtergrams and spectra obtained in Ca II H&K and Mg b_2 lines (Damé et al. 1984; Kneer & von Uexküll 1993; Kariyappa et al. 2006). Recently, Rutten & Krijger (2003) have also analysed ultraviolet (1700 Å) and white-light image sequences of internetwork regions from TRACE and shown that there is a signature of atmospheric gravity waves.

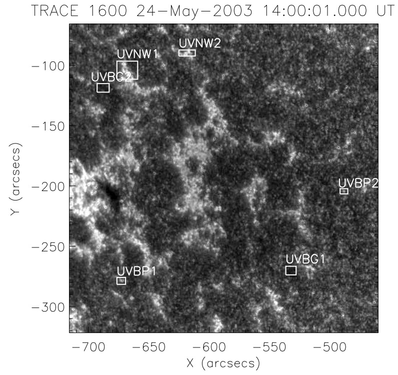

Fig. 1. One of the TRACE filtregrams obtained 2003 May 24 in the 1600 Å ultraviolet continuum, with indication of the boxes used to sample the different features, uv bright points (UVBP), uv network elements (UVNW), and uv background regions (UVBG).

In the present paper, we made an attempt to search for atmospheric g-modes in the lower choromosphere using long time sequences of intensity oscillations in a quiet region at the sites of uv bright points, uv network elements and uv background regions observed under high spatial, spectral and temporal resolutions in the ultraviolet at 1600 Å from the TRACE Space Mission. We present the first results of these analysis.

2. Observations and data analysis

We obtained a coordinated and simultaneous observations during May 18-24, 2003 with TRACE, SOHO/MDI and SOHO/CDS experiments. High spatial and temporal resolutions images have been obtained near the center of the solar disk covering both active and quiet regions. The solar rotation correction has been taken care during the observations. The TRACE observations are obtained in three wavelength regions: 1550 Å, 1600 Å and 1700 Å. In this paper, we have used only the observations obtained with TRACE on 2003 May 24 in the 1600 Å uv continuum. It is a 6-hour (14:00–20:00 UT) long time sequence of 617 images, taken every 35 seconds. These images have been analysed in IDL using SolarSoftWare (SSW). For this preliminary study, we have chosen 15 uv bright points (UVBP), 15 uv network elements (UVNW), and 15 uv background regions (UVBG) in a quiet region. We used square/rectangular boxes covering selected features to isolate them, as evidenced in Fig. 1. Then, we summed up all the pixel intensity values covered by each box and extracted the cumulative intensity of the chosen features for the entire 6-hour duration of the observations. The light curves of all UVBPs, UVNWs, and UVBGs have been derived and plotted as a function of time. We have then performed a power spectrum analysis on the time series data to determine the period of the intensity oscillations associated with these features.

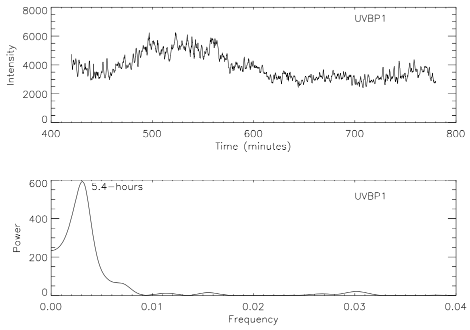

Fig. 2. *Upper panel:* An example of the light curve of an isolated 1600 Å continuum bright point (UVBP1) observed during 6 hours with TRACE. *Lower panel:* The power spectra of the light curve of that bright point (UVBP1).

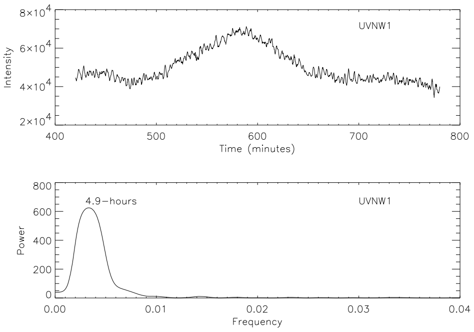

Fig. 3. *Upper panel:* Light curve of an isolated ultraviolet network element (UVNW1). *Lower panel:* Power spectra of that network element (UVNW1).

3. Results and discussion

There were indications of the existence of long-period oscillations in chromospheric bright points and network elements from previous CaII H-line observations (Kariyappa et al. 2006). But, since it was only a 35-minute duration time sequence, it was difficult to investigate long period oscillations. In order to confirm the existence of these long-period oscillations in the low chromosphere, at the level of the temperature minimum where the 1600 Å uv continuum is formed, in this paper we analysed a long time sequence of 6-hour and derived typical intensity time series for uv bright points (UVBPs), uv network (UVNWs) and uv background regions (UVBGs). An example of such time series is shown in Fig. 2 for one of the UVBPs (UVBP1). The time series shows small fluctuations in the intensity values. But, in addition, there is an indication of a longer period. To determine the period of these intensity oscillations, we have performed a power spectrum analysis. The power spectra of UVBP1 is shown in Fig. 2 also. One can clearly see from it the existence of a significant and prominent peak around 5.4 hours. And, on average, for the 15 uv bright points analysed, the period is around 5.5 hours. Similarly, we show qthe time series and power spectra for a uv network element (UVNW1) in Fig. 3. As we can see from its power spectra, it exhibits a period of intensity oscillations around 4.9 hours; and, on average, for the 15 network elements, it is around 4.6 hours. In Fig. 4, we present the time series and power spectra of one of the background region (UVBG1). We found that the average period of intensity oscillations associated to the background regions is around 3.4 hours. To verify that it was not linked to this specific set of data, we have also performed the power spectrum analysis on several uv bright points and uv network elements of May 22, 2003 to compare with the May 24, 2003 observations. We found that both data sets show the same dominating period associated with uv bright points (around 5.5 hours) and uv network elements (4.6 hours), and with comparable amplitudes. These long-period oscillations suggests high-order atmospheric gravity waves, proba-

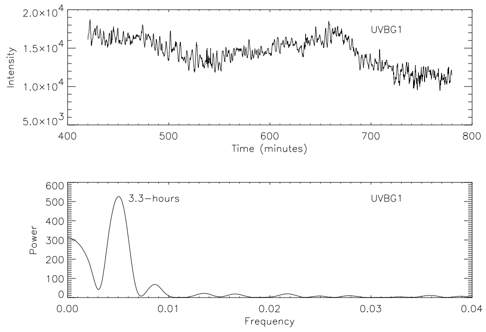

Fig. 4. *Upper panel:* Light curve of a background region (UVBG1). *Lower panel:* Power spectra of that background region (UVBG1).

bly excited by turbulent stresses in the convection zone.

4. Conclusions

We can summarise the main results derived from the analysis of the 1600 Å continuum observations as follows: uv bright points, uv network elements and uv background regions exhibit long-period oscillations of significant amplitude in addition to the small amplitude fluctuations of the classical 3–5 minutes oscillations. From a power spectrum analysis we showed that bright points are associated with oscillations periods of 5.5 hours and network elements with periods 4.6 hours, whereas the background regions show periods of 3.4 hours. The reasons for the existence of different periods for these different features are still to be investigated. We can argue, though, that the long-period of oscillations associated with the bright points or network elements are probably related to g-mode oscillations in the low chromosphere region where the 1600 Å continuum is formed. These results confirm the earlier findings that there is a signature of gravity waves in the chromosphere (and transition region) derived from the analysis of time sequence of filtergrams and spectra obtained in Ca II H&K, Mg b_2 lines and from TRACE observations (Damé et al. 1984; Kneer & von Uexküll 1993; Rutten & Krijger 2003; Kariyappa et al. 2006). In a subsequent paper (Damé & Kariyappa 2010), we analyse the simultaneous 1550 Å filtergrams sequence partly formed in the transition region (C IV lines content) to evidence waves propagation. We expect that the atmospheric gravity waves can exist in the stable, stratified photosphere and chromosphere, where convective overshoot is a natural mechanism to excite them. For these atmospheric gravity waves no model has yet been proposed supporting the current observational constraints.

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