Temporal evolution of mottles observed in Hα

Z. Funda Bostancı and Nurol Al Erdoğan  

1Istanbul University, Faculty of Science, Department of Astronomy & Space Sciences, 34119 University-Istanbul, Turkey

Abstract. In April 2002, Hα observations of the solar chromosphere with high spatial and spectral resolution were obtained with the ‘Göttingen Fabry-Perot Spectrometer’ mounted in the Vacuum Tower Telescope (VTT) at the Observatorio del Teide/Tenerife. In this work, we analyze a short time sequence of a quiet region with chains of mottles. Some physical parameters of dark mottles are determined by using Beckers’ cloud model which takes the source function, the Doppler width, and the velocity to be constant within the cloud along the line of sight. Here, we present the results of our study.

1. Introduction

Two dimensional Hα observations of network regions on the solar disk center with high spatial resolution show dark elongated structures, the so-called ‘dark mottles’. These structures usually form two groups, which are called chains of mottles or rosettes (Beckers, 1963). In a chain, mottles point in the same direction while rosettes have a more or less circular shape with a bright center, which is surrounded by a number of mottles aligned radially outwards (Tziotziou et al. 2003).

Beckers’ cloud model (Beckers 1964) is widely used for the determination of physical quantities of mottles such as the line-of-sight velocity, the source function, the optical depth, and Doppler width (Tsiropoula et al. 1994; Lee et al. 2000; Tziotziou et al. 2003; Al et al. 2004; Bostancı 2005). Here, we applied this model to a short time series of a two-dimensional field of view which includes chains of mottles.

2. Observations & Data Analysis

The observation of a network region near disk center was done in Hα using the ‘Göttingen Fabry-Perot Spectrometer’ mounted in the Vacuum Tower Telescope (VTT) at the Observatorio del Teide/Tenerife (Bendlin & Volkmer 1995; Koschinsky et al. 2001). Two-dimensional broad-band and narrow-band images were taken simultaneously at 18 wavelength positions by scanning through Hα. The wavelength settings of two consecutive positions differed by 125 mÅ and the time interval between two consecutive scans was 49 s. The broad-band images were restored by spectral ratio (von der Lühe 1984) and speckle masking (Weigelt 1977) methods while the narrow-band images were reconstructed by using a method given by Keller & von der Lühe (1992). The Hα line profile for
Figure 1. A short time sequence of the entire FOV (30′.3 × 20′.5) at +0.650 Å (first column) and −0.650 Å (second column) from the Hα line center with corresponding Doppler and intensity images (third and fourth column, respectively). The time cadence is 49 s.

each pixel of the field of view was produced from intensity values of narrow-band images belonging to 18 wavelength positions.

3. Cloud Model

The observed contrast profiles were matched with theoretical contrast profiles by using the cloud model (Beckers 1964). This model assumes the source function, the Doppler width, and the LOS velocity to be constant within the cloud along the line of sight. The contrast profile is given by

\[ C(\lambda) = \frac{I(\lambda) - I_0(\lambda)}{I_0(\lambda)} = \left( \frac{S}{I_0(\lambda)} - 1 \right) \left( 1 - e^{-\tau(\lambda)} \right) \]  

where \( I_0(\lambda) \) is the reference profile emitted by the background. \( S \) denotes the source function and \( \tau(\lambda) \) the optical thickness. The wavelength dependence of the optical thickness is given by

\[ \tau(\lambda) = \tau_0 \exp \left[ - \left( \frac{\lambda - \lambda_c(1 - v_{\text{LOS}}/c)}{\Delta \lambda_D} \right)^2 \right] \]  

where \( \tau_0 \) is the optical depth at the line center, \( \lambda_c(v_{\text{LOS}}/c) \) the shift due to the velocity \( v_{\text{LOS}} \) and \( \lambda_c \) the line center wavelength.
Figure 2. Short time sequences of velocity, Doppler width, source function, and optical depth for the region marked by the white frame in Figure 1 (corresponding to the size of 21\arcsec 3 × 8\arcsec 1). Time proceeds row by row from top to bottom with a cadence of 49 s. In the velocity images, blue and red colours indicate upward and downward motion, respectively.
4. Results

In this study, we found the average thickness of the mottles to be 0.7′′ ranging between 0.3′′ and 1.1′′ and the average length to be 9.8′′ ranging between 6.7′′ and 13.4′′. Their lifetime is close to 10 minutes. Their inclination appears more horizontal than vertical with respect to the solar surface, while their orientation slightly changes in some frames. Sometimes nearby mottles seem to merge forming a single structure or they split in two parts. Their shape and length clearly change from frame to frame as can be seen in Figure 1.

The optical depth at the line center varies from 0 to 4 with a mean value of 1.7 which is in agreement with the mean value found by Lee et al. (2000). The center parts of the structures under investigation show higher values, while their boundaries correspond to lower ones. The source function varies between 0 and 0.15. For this parameter we found a mean value of 0.08, which is below the values found by other authors (Tziotziou et al. 2003; Lee et al. 2000). The highest values occur close to the footpoints of the mottles. The Doppler width ranges between 0 and 0.88 Å with a mean value of 0.52 Å. Lee et al. (2000) found a mean value of 0.55 Å for this parameter. The velocity takes values between −25 and 25 km/s indicating the presence of both downward and upward motion as seen in some frames of our time series (see Figure 2). During our observation, the footpoints of dark mottles mostly showed red-shift while their upper parts showed both blue and red shift. The dominant motion is an upflow with a mean value of 1.64 km/s.

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