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Derivation of the physical parameters for strong and weak flares from the H_α line

M.A. Semeida *, **M.G. Rashed**

Department of Solar and Space Research, National Research Institute of Astronomy and Geophysics, Helwan, Egypt

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Abstract The two flares of 19 and 30 July 1999 were observed in the H_α line using the multichannel flare spectrograph (MFS) at the Astronomical Institute in Ondřejov, Czech Republic. We use a modified cloud method to fit the H_α line profiles which avoids using the background profile. We obtain the four parameters of the two flares: the source function, the optical thickness at line center, the line-of-sight velocity and the Doppler width. The observed asymmetry profiles have been reproduced by the theoretical ones based on our model. A discussion is made about the results of strong and weak flares using the present method.

1. Introduction

Analysis of the H_α line profiles is a useful way for the determination of physical parameters in solar chromospheric structures. The method most frequently used, is known as the classical cloud model, which allows a simultaneous determination of four parameters: the source function, the optical thickness at line center, the line-of-sight velocity and the Doppler width. This method succeeds in inverting line profiles in chromospheric structures (Alissandrakis et al., 1990; Tsiropoula et al., 1993; Tsiropoula and Schmieder, 1997; Liu and Ding, 2001; Semeida, 2004; Semeida et al., 2005; Rashed, 2008). However, it is only effective for dark features on the disk, such as dark mottles of a chromospheric rosette region (e.g., Tsiropoula et al., 1993, 1999; Tsiropoula and Schmieder, 1997), superpenumbral fibrils and arch filament systems (e.g., Alissandrakis et al., 1990; Mein et al., 1996). The heights of these structures above the chromospheric base play a decisive role in shaping the observed profiles. The method of differential cloud models was proposed by Mein and Mein (1988), which takes into account the fluctuations of the chromospheric background in active regions and velocity shears inside the cloud, but it can only be applied to dark clouds in order to avoid singularities and eliminate spurious solutions. The method of multi-cloud model has been used to analyze the spectra of limb features, such as post-flare loops (e.g., Gu et al., 1997); however, this method may lead to meaningless solutions for the flare ribbons on the disk. In cases of bright features, the radiative and collisional damping effect may play an important role in the formation of the H_α line. Hence, the Voigt profile is more realistic than a Gaussian profile in the cloud model. Tsiropoula et al. (1999) approximated the Voigt

* Corresponding author.

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profile by the sum of a Doppler core and Lorentzian damping wings and considered the variation of the source function with optical thickness. In this method, the theoretical profiles have a singularity in Lorentzian damping wings (where the denominator equals zero) which causes a poor fit if assuming a constant source function. Some authors have investigated the variations of the source function with the opacity of the structures (Mein et al., 1996; Paletou, 1997), and the cloud model is extended to cases of non-constant source functions (Zhang et al., 1987; Mein et al., 1996; Tsiropoula et al., 1999). However, the adoption of a non-constant source function yields only little improvement in the case of a low opacity. Note also that the H_α source function is sensitive to larger macroscopic velocities of the order of a few tens of km s^{-1}, but this effect is less important for high electron densities where the collisional excitation plays a significant role (Heinzel et al., 1999). Here we still use a constant source function to analyze the line spectra. In this sense, the value of the source function that we obtain reflects a mean value averaged over a specific region.

Concerning solar flares, the most obvious signature of H_α line profiles is the red asymmetry, which has been interpreted as a consequence of downflows related to the chromospheric condensation (e.g., Ichimoto and Kurokawa, 1984; Canfield et al., 1987; Gan and Fang, 1990; Ding et al., 1995; Cauzzi et al., 1996). In this work we pay special attention to the origin of the line asymmetry and use a new method to analyze the H_α profiles in strong and weak flaring regions. This method avoids using a background profile which is usually hard to determine. Two-dimensional parameters are deduced, based on the 2D spectra of the flaring regions and the results are useful for a better understanding of the flare dynamics.

2. Observations and data reduction

The newly rebuilt multichannel flare spectrograph (MFS) at Ondřejov Observatory (Kotrč et al., 1992) was used to take a time series of H_α line spectra of a flare in the active region NOAA 8636 located at N21 E58 on 19 July 1999. The observing time is from 08:16:30 UT to 10:56:00 UT and according to the Solar Geophysical Data, the flare began at 08:19:00 UT and ended at 10:58:00 UT, reaching its maximum at 08:35:00 UT, and it was an event with H_α importance 2N and soft X-ray class M5.8. Also, the H_α flare spectra of 30 July, 1999 taken during the time interval from 08 h:51 m:00 s UT to 08 h:52 m:30 s UT in the active region NOAA 8651 located at N24 E44. According to the Solar Geophysical Data this flare starts at 08 h:47 m:00 s UT, ended at 09 h:06 m:00 s UT, reaching its maximum at 08 h:52 m:00 s UT and it was an event with H_α importance SN and soft X-ray class C5.4. The output from the ordinary video cameras is a TV image with a rectangular frame, the ratio of the sizes being 4.0:3.0. The system of observation works with the frequency of 25 pictures/s, and each picture has horizontal lines. Chips of CCD cameras are usually ½″ in diagonal (6.4 × 4.8 mm) or 1/3″ (4.8 × 3.6 mm) with various numbers of the chip pixels. After we digitized and processed spectra we corrected it by getting the dispersion curve and calibrated it by getting a very good calibration curve for all of H_α line spectra of our studied flare. Then we reduced it by subtracting the undisturbed profile near the flaring region to get the H_α line profile spectra.

3. Method of spectral analysis

The classical cloud model adopts a mean profile over the quiet chromosphere as the background profile. However, for flares it is not feasible because of the large fluctuations in the active-region background. Here we use a technique avoiding the use of a background profile (Liu and Ding, 2001; Semeida, 2004, 2008; Semeida et al., 2005).

In the Cloud model, the line intensity is given by

$$I(\Delta\lambda) = I_o(\Delta\lambda)e^{-\tau(\Delta\lambda)} + S_o[1 - e^{-\tau(\Delta\lambda)}], \quad (1)$$

where the source function S_o is assumed to be constant and frequency independent, $I_o(\Delta\lambda)$ is the background intensity and $\tau(\Delta\lambda)$ is the optical thickness which is expressed as follows:

$$\tau(\Delta\lambda) = \tau_o H(a, x) \quad (2)$$

where $H(a, x)$ is the Voigt profile and given by

$$H(a, x) = a/\pi \int_{-\infty}^{+\infty} \frac{e^{-y^2}}{a^2 + (x - y)^2} dy \quad (3)$$

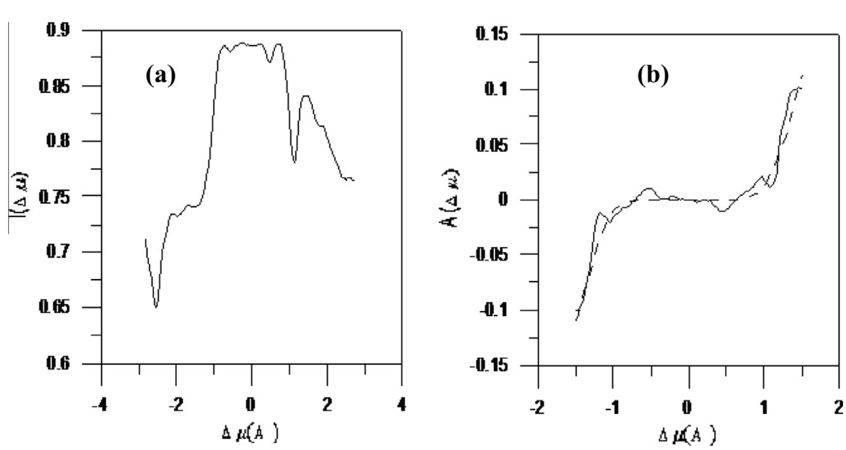

Figure 1 Strong flare (July 19, 1999). (a) Atypical H_α line profile with asymmetry in the flaring region at time 08:36:35 UT. (b) Comparison between the asymmetry profile observed (solid line) and the fitted one (dotted line). The intensity is normalized to the continuum near the H_α line.