DYNAMICS OF Hα SPICULES ACCORDING TO SPECTRAL OBSERVATIONS AT VARIOUS HEIGHTS OF THE SOLAR CHROMOSPHERE

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Abstract. Almost simultaneous height sequences of 69 spicules in the Hα line have been studied. The spectra are obtained at six heights during 6 s on the east side of the solar disk with the 53-cm Lyot coronagraph of Abastumani Astrophysical Observatory.

Radial velocities $V_r$, total intensities or equivalent widths $W$, full widths at half maximum of intensity (FWHM) at all heights are determined (about 300 profiles of the Hα line). It is found that:

1. Absolute values of radial velocities increase linearly with the height (see Equation (1));
2. Variation of the sign of the radial velocity along single spicules was never observed.

These results combined with the findings on the spicules radial velocities and shifts obtained earlier (Kulidzanishvili and Nikolsky, 1978; Nikolsky and Platova, 1970) led us to the conclusion that the 5-min tangential oscillations of spicules involve the entire spicule at once.

The intensity height scales for single spicules and for the chromosphere ‘in toto’ are determined; they turned out to be $2.5 \times 10^3$ km and $1.9 \times 10^3$ km respectively (see Equations (2) and (3)).

The dependence curve of the Hα line half-widths $\Delta \lambda$ on the height $h$ is drawn. The Hα line half-width for those spicule groups which are traced at all heights (10 spicules) decreases with the height (Figure 4); for the majority (~60 spicules) it remains essentially constant. Non-thermal 'turbulent' velocities $V_t$ in Hα spicules are defined. A mean value of the 'turbulent' velocity $V_t$ at $T = 6000^\circ$ appeared to be 20–30 km s$^{-1}$.

The hydrogen concentration in the spicules at 5000 km is $6 \times 10^{11}$ cm$^{-3}$.

1. Introduction

Simultaneous observations of spicules at various heights are of significant importance to understand the structure and dynamics of the solar chromosphere. One of the tasks of such observations is to investigate the height dependence of the radial velocity $V_r$ in spicules. The results obtained by various authors significantly differ from each other. For instance, Mouradian (1965) has found that the Doppler shift decreases along the spicule, while Michard (1959), Beckers (1966), Beckers et al. (1966) have found an increase of radial velocities with height. Nikolsky and Sazanov (1966), Pasachoff et al. (1968) have pointed to the absence or a weak dependence of $V_r$ on the height.

Controversy between the results of various authors is not mainly due to synchronous, but to extended-in-time observations at different heights. Therefore we obtained the Hα spectrograms of the spicules quasi-synchronously (during 6 s at the heights within 5000 km–9500 km), in striving for an unambiguous solution of the problem.
2. Observational Technique

Observations of spicules at various heights simultaneously are related to certain instrumental difficulties being surmounted in different ways by different authors. Pasachoff et al. (1968) took the spicules spectra simultaneously, but only at two heights by parting the beam of light; Nikolskaya (1967, 1977a, b) photographed the spicules at several heights, but the time intervals between the frames were rather large.

We have tried to photograph spicules at several heights in as short a time as possible and we have attempted to determine the heights accurately at most. A special device was placed in front of the spectrograph slit involving some modification of the line-shifter described by Nikolsky (1970). The difference consists in the fact that the middle glass block is made wide, 45 mm (the slit height is 60 mm) and in that it can turn discretely at small angles relative to the outside glass blocks. The outside glass blocks are turned to a certain angle and they are fixed; they serve for controlling the concentricity of the solar limb and slit.

Pressing the button the observer plugs in the film rewinding and the pitch selector which turns the middle glass block at a certain angle. At releasing the button the camera shutter falls into step. One exposure, for taking the spicules at one height including the film rewinding and the turning of the middle glass block, lasts a second. The whole cycle can be repeated continuously for various heights.

The observational material was obtained by the author with the 53 cm coronagraph of Abustumani Astrophysical Observatory. From many height sequences of Hα spicules spectra taken on different days the best set, obtained on May 25, 1978, was chosen for analysis. The curved slit of the spectrograph 0.04 mm wide was concentric to the east limb. That part of the solar limb taken through passing of the middle wide glass block and used for treating corresponds to a 40° arc of the solar limb.

The set consists of Hα spectrograms of spicules at six heights. They are displayed in Figure 1 together with the heights determined by the formula given in (Nikolsky, 1970). The accuracy is not worse than ±0'.5. The isopanchromatic film 180 ASA was used. For absolute calibration the spectrum of the solar disk center was used. The films were developed in Kodak D-19. Time of development – 8 min at 20 °C. The dispersion of the spectrogram is 0.96 Å mm⁻¹ in the second order, the scale – 16 arc sec per mm in the Coude focus. The exposure time is 0.2 s. The resolution on each photograph is about 1 arc sec.

3. Measurements

The Hα spectra sequence selected for analysis begins at a height of 5000 km above the photosphere. At this height 69 spicules were chosen which were traced in the second and third frames. In the fourth one (height 7300 km) the number of the spicules identified reduced to 66 and in the last frames (heights 8800 km and