THE ASTROPHYSICAL JOURNAL, 283:L75–L77, 1984 August 15

TIME-RESOLVED SPECTRAL OBSERVATIONS OF SPICULE VELOCITIES AT SEVERAL HEIGHTS

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Received 1984 May 8; accepted 1984 May 18

ABSTRACT

The vacuum telescope of the National Solar Observatory, Sacramento Peak was used to obtain Hα spectral observations of spicules. A set of spectra corresponding to five slit positions above the solar limb were recorded every 8 s in order to study the temporal variation of spicules at several heights with high space and time resolution. The short time interval (< 2 s) between exposures at each height is a new feature of these observations. A typical flow event in a spicule was found to last 10–15 minutes. During this period the velocity did not reverse sign. The temporal behavior of the velocity at different heights in a spicule appeared to show a high correlation, with a time lag less than 7 s, implying signal propagation speeds greater than 300 km s^{-1}. Finally, no significant variation of spicule velocity with height in the chromosphere was noticed.

Subject headings: Sun: atmospheric motions — Sun: chromosphere

I. INTRODUCTION

Spicules on the solar limb were observed with the vacuum tower telescope of the National Solar Observatory, Sacramento Peak in the autumn of 1982. The object of the experiment was to obtain simultaneous information at several heights on the temporal variation of spicule velocities. Preliminary findings are reported in this *Letter*. A more detailed investigation will appear in a forthcoming publication.

At present very few time-resolved observations of spicule velocities exist. The most detailed ones are those of Pasachoff, Noyes, and Beckers (1968). However, these were taken before the construction of the vacuum telescope. We considered it worthwhile to make new observations taking advantage not only of the much higher spatial resolution afforded by the vacuum telescope, but also the short scanning time possible through the use of a CCD array. A unique feature of these observations is that they provide for the first time almost simultaneous spectral information at several heights above the solar limb.

II. METHOD OF OBSERVATION

Hα spectra were taken on 1982 October 3 with the echelle spectrograph and recorded on a 100 × 100 CCD array. A straight slit was used tangential to the limb, thus oriented almost perpendicular to the spicules. Each set of spectra corresponding to five parallel slit positions 1″ apart was recorded in approximately 8 s. The size of the region scanned was 18″ × 5″. The dispersion was 8 mm $Å^{-1}$, and the slit width was 200 μm which corresponds to a spatial resolution of 0″.7. Seeing during the course of the experiment remained better than 2″.

The reduction procedure consisted of first filtering the line profile to reduce noise and then locating the line centers (positions where the line intensity has a maximum). Line-of-sight velocities were computed from Doppler shifts.

III. RESULTS AND DISCUSSION

Figures 1*a*–1*e* show spacetime contour plots of line-of-sight velocities at various (increasing) heights in the chromosphere. There appear to be two regions, one centered around 10 Mm and another centered around 13 Mm of comparatively strong flows which we identify as spicules. Figures 2*a*–2*b* show the temporal variation of velocity at two different heights (slit positions) of a typical event near 10 Mm and 13 Mm, respectively, as measured along the slit. Figure 3 shows the distribution of spicular velocities at different slit positions or heights.

From Figure 1 we see that the typical flow event consists of an initial rapid stage in which the absolute velocity increases with time, followed by a gradual stage with comparatively little temporal variation and an eventual velocity decrease in magnitude. The time scale of a typical event appears to be about 10–15 minutes. During this period the velocity does not appear to reverse signs. The fine time resolution allows one to discern small amplitude fluctuations with periods around 2–3 minutes as seen in Figure 2. This point will be discussed in more detail in a subsequent publication where other sets of observations will also be considered.

Temporal plots of velocity at two different heights show good correlation. From an analysis of several sets of data, it was found that the correlation coefficient was always greater

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[2]Operated by the Association of Universities for Research in Astronomy, Inc. under contract AST 78-17292 with the National Science Foundation.

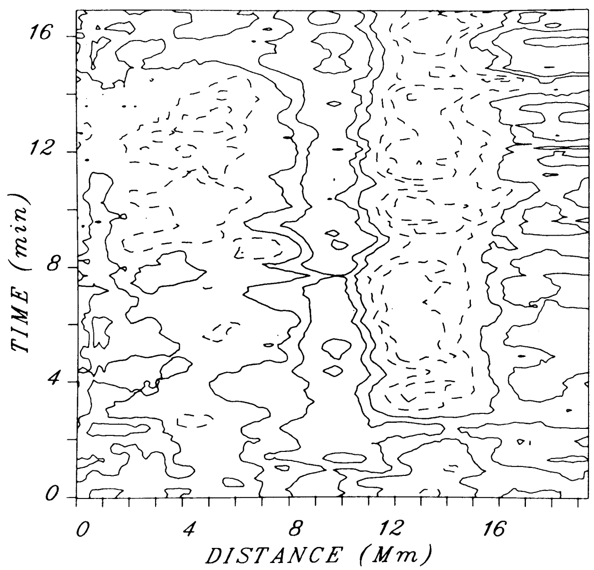

FIG. 1*a*

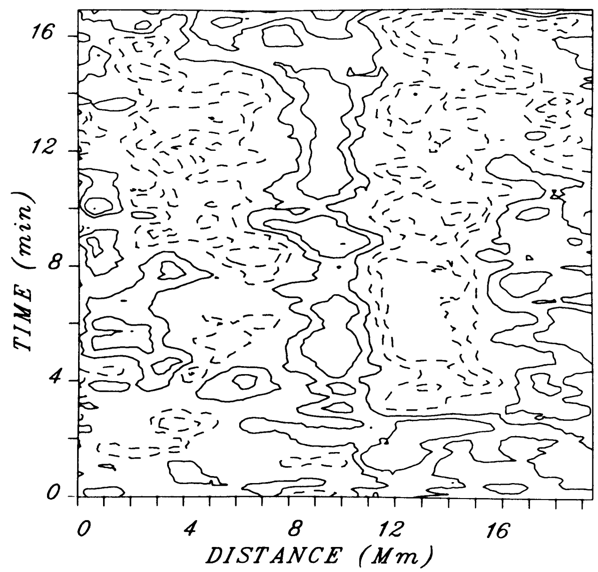

FIG. 1*b*

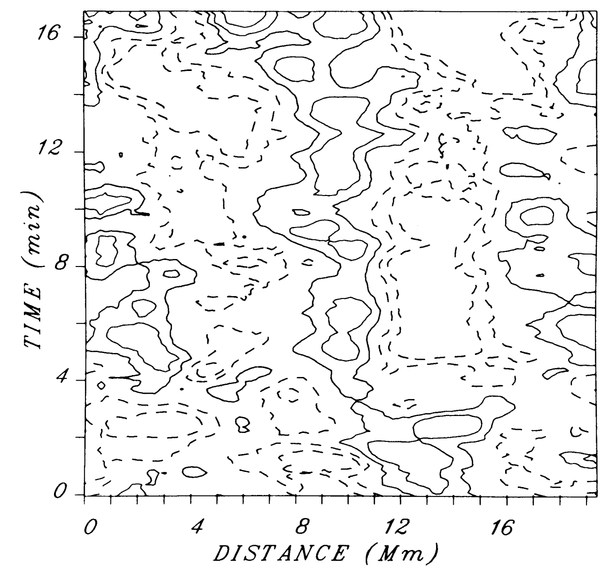

FIG. 1*c*

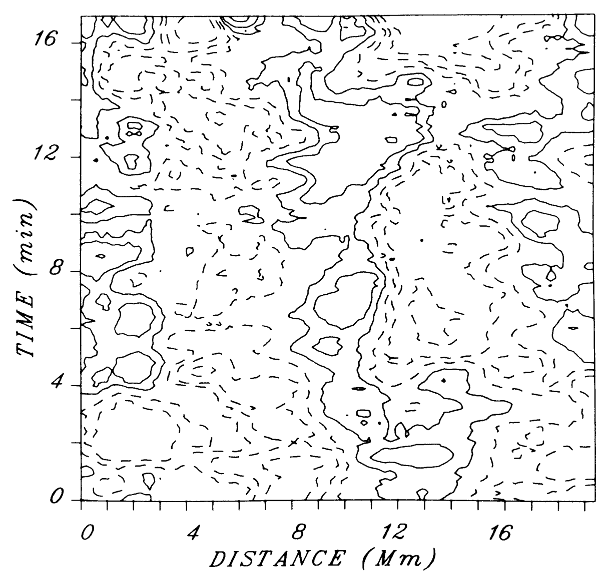

FIG. 1*d*

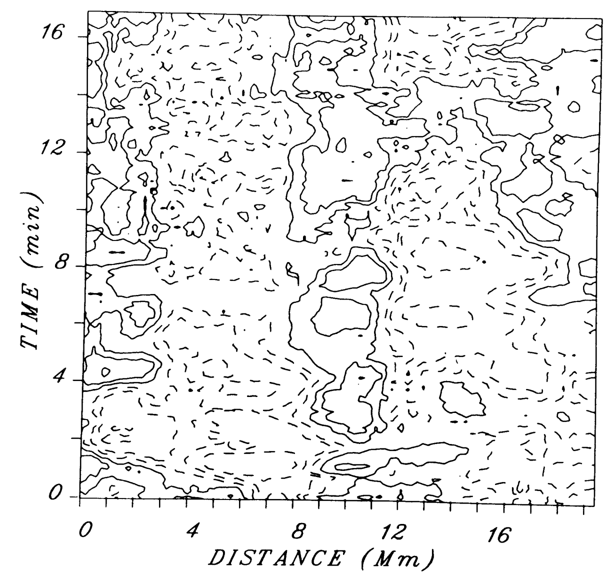

FIG. 1*e*

FIG. 1.—Contour plots of the velocity at various spacetime points are shown in (*a*)–(*e*) which correspond to slit positions 1–5, respectively (in order of increasing height in the chromosphere). Distances are measured along the slit (with respect to one end of the slit). The solid (broken) lines denote approaching (receding) line-of-sight velocities. The absolute magnitudes of the contour levels are 1, 2.5, and 5 km s^{-1}.

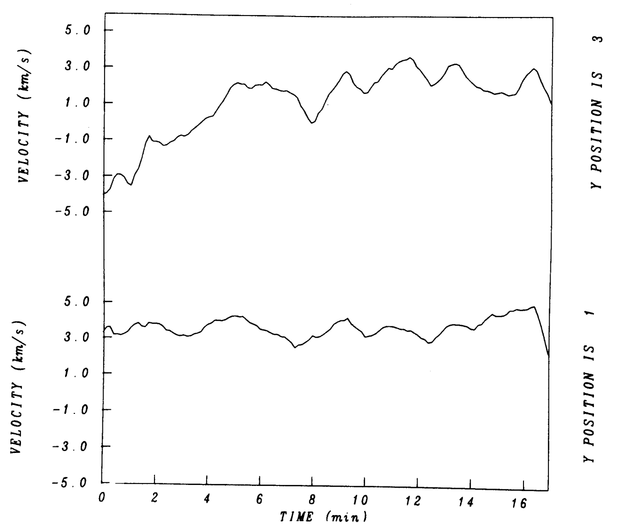

FIG. 2*a*

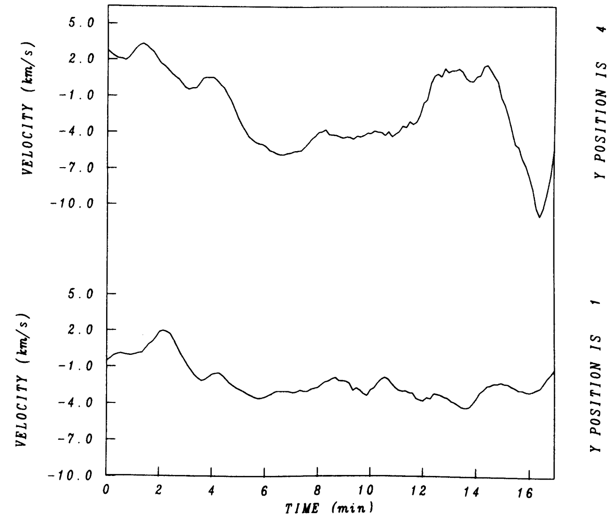

FIG. 2*b*

FIG. 2.—The time variation of spicule velocity at two heights is shown in (*a*) and (*b*) for typical events from the region near 10 Mm and 13 Mm, respectively.

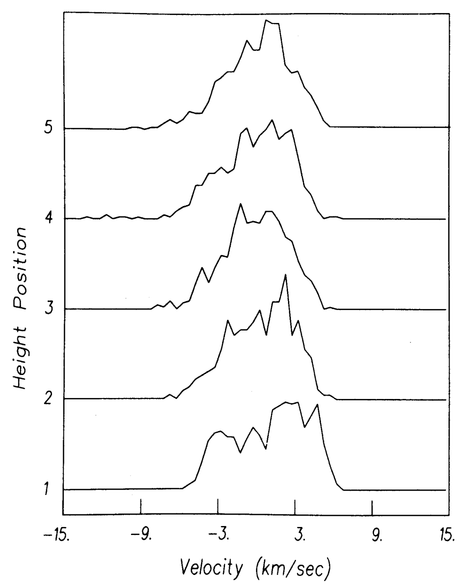

FIG. 3.—Histograms of spicular velocities are shown for each of the five slit positions. Positions 1, 2, 3, 4, and 5 are, respectively, 1″, 2″, 3″, 4″, and 5″ above the limb. Histograms were computed by measuring the maximum (positive or negative) flow for all of the easily identified spicules along the slit at each time step. The histograms show how the maximum spicular velocities are distributed at each height. Note that the change with height is small.

than 0.5, and the maximum time lag was less than 7 s. This implies signal propagation speeds v_p greater than 300 km s^{-1}, for a height separation of 3″. Such a value is more than an order of magnitude greater than the sound speed ($\sim$ 10 km s^{-1}) as well as the spicule velocity ($\sim$ 20 km s^{-1} after projection effects are taken into account). This result tends to argue against a purely hydrodynamical model for spicules. On the other hand, an Alfvén wave could propagate with speeds $\sim v_p$, if one assumes a particle density 10^{11} cm^{-3} and a magnetic field strength of 40 gauss. Thus an MHD mechanism is still possible. Pasachoff, Noyes, and Beckers (1968) give a lower limit of 90 km s^{-1} for v_p, which is still an order of magnitude greater than the sound speed.

An attempt to detect whether spicule velocities show a systematic trend with height indicates a possible weak dependence as can be seen from Figure 3. This is consistent with the findings of Pasachoff, Noyes, and Beckers (1968) and Nikolskii and Sasanov (1966).

This work was done when one of us (S. S. H.) was a visitor at the National Solar Observatory, Sacramento Peak. He would like to thank Dr. J. B. Zirker for his hospitality and the Indian National Science Academy and COSTED for travel support.

We would like to thank H. A. Mauter and P. Wiborg for their help and painstaking efforts during the observations.

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