OBSERVATIONS OF ALFVÉN WAVES SIMULTANEOUSLY IN Hα AND K

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Abstract. Simultaneous spectroheliograms of a quiet region at solar disk centre in Hα + 0.29 Å, Hα - 0.29 Å, K + 0.18 Å and K - 0.18 Å show much similarity in the asymmetries in the two lines. The fibrils are identical geometrically. Both lines show patterns of line-of-sight motions propagating along the fibrils. Close to the network, the velocity of propagation is of the order of 12 km s^{-1} towards or away from the network; further away the patterns propagate away from the network at velocities of the order of 75 km s^{-1}. The latter are interpreted as Alfvén waves, the former as due most likely to variations in longitudinal velocities along the fibrils.

1. INTRODUCTION

There is a long history of observations of Alfvén waves in Hα fibrils (McMath 1939, Sawyer, 1974). Henry Smith prepared (or at least had) a film at Sacramento Peak Observatory around 1958, demonstrating the phenomenon, though its identification as such is more recent (Giovanelli, 1975).

In 1975 we made further observations of Alfvén waves in chromospheric fibrils. The waves are detected by observing the propagation of transverse velocities along fibrils, which are aligned with the magnetic field. The transverse motions are observed via line asymmetries.

Although profile asymmetries in unblended lines are due only to Doppler shifts, differential motions along the line of sight make the interpretation of asymmetric profiles difficult (e.g. Beckers, 1962). Far more confidence can be placed in the results if those from two or more lines formed differently are in agreement. For observations of chromospheric fibrils, there are only two independent lines in which high-enough spatial resolution can be obtained, Hα and K. Therefore we undertook a study involving time-sequences of observations of a region near the centre of the disk using these lines, obtaining spectroheliograms simultaneously at Hα + 0.29 Å, Hα - 0.29 Å, K_{2R} and K_{2V}.

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2. OBSERVATIONS AND ANALYSIS

The observations were obtained with the Sacramento Peak tower telescope, spectroheliograms being obtained in the 9th order in Hα and the 15th in K with a 300 lines mm grating and a dispersion of 6.9 and 11.5 mm/Å at Hα and K respectively. Observations were obtained at two wavelengths in each line, pairs of fixed slits being placed in the plane of the spectrum to allow two symmetrically-spaced monochromatic slit images to be transmitted in each line. The orders were isolated by an appropriate red filter for Hα and by the use of a red-insensitive emulsion for K. Spectroheliograms were obtained, as usual, by scanning the solar image over the entrance slit and driving synchronously two cameras mounted on the same rigid frame, one for the pair of Hα spectroheliograms and one for the K. To avoid overlap, the width of the spectroheliograms had to be limited to less than the separation between the closer of the two pairs of slits.

With this arrangement it is possible to get fairly-well-balanced densities between the two spectroheliograms in the one line, but residual differences in the widths of the fixed slits do result inevitably in small, harmless, residual density differences. To ensure adequate densities a compromise was needed. The slit widths were as great as we dared use (exit slits 0.25 mm, corresponding to 36 mÅ at Hα and 22 mÅ at K, entrance slit 0.30 mm); and a new frame commenced every 20 s, resulting in good exposures in Hα and the brighter K features, but the big intensity variations across the solar surface in K_2 left the fainter features underexposed.

The wavelengths used in Hα were also based on a compromise giving an acceptably large separation, and hence width of spectroheliograms, but close enough to line centre to relate to the higher levels of the chromosphere. The fibrils are still evident at Hα ± 0.29 Å, as are the chromospheric granules; the main differences between images at line centre and at these wavelengths are due to Doppler shifts and to a relative reduction in intensity of the bright network features. In consequence we chose Hα ± 0.29 Å for this study. In K we used K ± 0.18 Å, which lie fairly close to the K_2 maxima.

A 42 min sequence was obtained on 15 May 1975, with seeing of good quality throughout. Auxiliary observations included white-light and Hα line centre (0.5 A pass-band) slit-jaw images simultaneous with the start of each scan.

The analysis has been qualitative. The velocities are shown by photographic subtractions of the spectroheliograms in one wing from those in the other, both for Hα and K. These were then placed side-by-side on the one frame, and a time-lapse film produced showing the two together. From this we can see whether similar motions are revealed in the two lines.

We have also used blink comparison of the original frames, subtractions, and photographic additions of the images in opposite wings which enable the individual fine-structures to be seen better without the disturbing influence of Doppler shifts.

The region studied is not far from disk centre, and appears to be typical of any quiet part of the disk. The system of fibrils at A (Figure 1a, b) is visible further from the network in Hα ± 0.29 Å than in K ± 0.18 Å. Blink comparison shows that the same individuals are present in the two lines, but the relative intensities vary irregularly from fibril to fibril and along their lengths. With occasional exceptions (e.g. B), fibrils brighter than average in Hα are brighter too in K; and similarly for structures darker than average. The shorter apparent lengths of the dark K fibrils may possible be due merely to inadequate exposure; for the bright fibrils, it seems more likely that they are due mainly to lower opacity in K than in Hα at the wavelengths used. Whatever the reason, there is a zone where fibrils obscure lower structures, and this is more extensive in Hα than in K.

Figure 1 also shows side-by-side the subtractions in Hα (1c) and K (1d). Where the fibrils appear in both lines, the asymmetries have identical shapes and signs, differing only in magnitude between the two lines.

In cine projection we have been able to distinguish two types of behaviour. (i) Very close to the network (C, Figure 1), there may be a slow propagation of asymmetries at velocities of the order of 12 km s^{-1} either towards or away from the network. (ii) Further away, there is a much faster propagation mainly away from the network at velocities of the order of 75 km s^{-1}. Both these types of behaviour occur in both lines, though the contrast in K is much lower in (ii), where the fibrils are also much fainter than in Hα. Giovanelli (1975) has already described the phenomenon (ii) in Hα, interpreting it as a propagation of Alfvén waves mainly outwards from the network. We can now confirm that it is observed in K. The same phenomenon is thus found in the only two types of line in which fibrils are visible.

It is not successful to present still photographs of velocitygrams showing the propagation of Alfvén waves in fibrils; this can be done adequately only with cinefilms (a film of this type was shown at the Symposium).

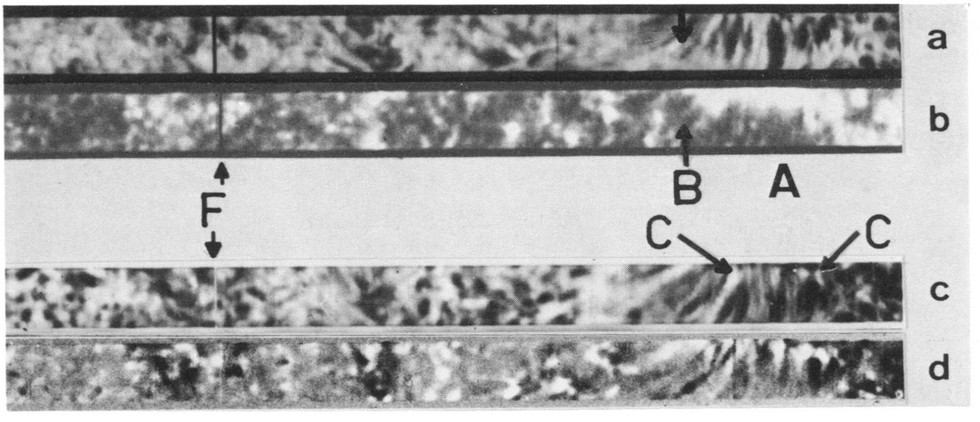

Fig. 1. (a, b) Spectroheliograms derived by adding (a) the Hα ± 0.29 Å and (b) the K_{2R} and K_{2V} images. (c, d) Corresponding subtractions in (c) Hα and (d) K; features darker than average are receding.

4. DISCUSSION

Where the fast waves occur, the fibrils and magnetic field are mainly horizontal, and the observed displacements are transverse. We have no doubt that the waves involved are of the Alfvén type. However these observations add nothing quantitatively to our knowledge of the amplitudes involved or the power carried, which remain as described by Giovanelli (1975).

The slower (12 km s^{-1}) propagation of asymmetries, either towards or away from the network when very close to it, seems to be explained most readily by changes in the well-known longitudinal oscillations inside magnetic elements and tubes of force. Since the fibrils are nearly vertical close to the network, motions along them have strong line-of-sight components when observed near disk-centre. On the contrary, transverse motions have only small line-of-sight components, so that the displacement velocities in an Alfvén wave very close to the network footpoint are of reduced amplitude.

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DISCUSSION

SPRUIT: What is the basis for your conclusion that transversal tube waves cannot be excited by granulation?

GIOVANELLI: This comes from considering the effects of hydrodynamic forces of granule motions in displacing fluxtubes. In turn this depends on the depth of a granule. I have estimated the corresponding increase in magnetic energy in such a tube, supposed to be vertical where the granule horizontal motion reverses. This gives the equilibrium displacement δ at the surface for a given granule and tube model. δ depends on whether the internal gas pressure is small in comparison with the magnetic pressure, as expected. If this is so, Spruit's 1974 convection zone model and a typical tube diameter at the surface imply that δ is $\lesssim 25$ km even for a depth of 2000 km to the level where the horizontal motion reverses. For bigger surface diameters, δ is even less. Unless the granule depth is much greater or the model data are inappropriate, granulation would seem unable to generate the transverse velocities required. The situation could be different if the tube diameter is effectively constant with depth, but this seems unlikely.

MOUSCHOVIAS: (1) Do you observe any mass transported in the direction in which the waves propagate? (2) Can you put any limits on the mass transport?

GIOVANELLI: (1) I do not know of any investigation aimed specifically at measuring gas flow along effectively horizontal fibrils. (2) Not from observations. I would expect any systematic flow towards or away from the network to be small in the fibrils. On the other hand, I would expect large-amplitude longitudinal waves to be present.

IONSON: Have you determined the spectral power function for these "Alfvén waves"?

GIOVANELLI: No. I suspect that it would be extremely difficult.

ROBERTS: I was very interested in your comment that the observed waves could be connected with the magnetic canopy. Could it be that you are seeing surface waves propagating along the canopy, i.e. along an interface between a magnetic field and a field-free atmosphere? At such an interface, a surface wave with phase speed of the order of the sound speed is possible. But this is probably too slow to agree with the speeds you quote.

GIOVANELLI: The Hα fibrils are higher than the canopy base, and it seems unlikely that the waves observed are purely surface waves. The observed speeds, typically 70 km s^{-1}, are much greater than the sound speed, which is unlikely to reach 10 km s^{-1}.