SPACE AND TIME VARIATIONS OF THE SOLAR Na D LINE PROFILES

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(Received in final form 9 December, 1971)

Abstract. Preliminary results are presented of observations of the solar Na D lines obtained with high space and time resolution (2.4″ × 2.4″), (6 s). The following conclusions may be drawn.

(i) The line profiles vary strongly with space and time implying that time averaging over a long period and large area will not produce the 'true' profile.

(ii) The centre-limb increase in apparent Doppler width in the D lines is intrinsic. It is not due to space or time averaging.

(iii) The amplitude of the 300-s oscillation may range up to 1.5 km/s in the region of formation of the D lines. Large line asymmetries are associated with this motion. Observations which do not resolve this motion can not be considered adequate.

(iv) The variation of the D line profile caused by the 300-s oscillation may be described as follows: (a) The core is raised and lowered without change of shape. (b) The wings broaden as the central intensity rises and narrow as it falls. These variations are qualitatively explained by the scanning of the line formation region through the solar atmosphere.

(v) Doppler width values derived from pairs of D line profiles are strongly correlated with the motion of the element observed. Hotter elements move upward, cooler downward.

(vi) Indications of running waves have been found in the time variation of the core line bisectors.

The profile variations observed provide a framework in which various properties of the centre limb variation of these lines may be considered. In particular they show that any expectation of accuracy in profile coincidence above a certain value must be doomed by the intrinsic variability of the solar atmosphere.

1. Introduction

Up to the present time almost all observations of solar Fraunhofer line profiles have been 'averaged' in space and time, that is to say, have been obtained with long spectrograph slits over relatively long periods of observation.

In particular the Na D lines have never been photoelectrically observed with both high space and time resolution. Waddell's (1962) observations of the center-to-limb variation of these lines were obtained with a slit 30″ long and an observation period of about a minute. Figure 1 is a spectroheliogram taken in the center of Na D_1 by Sheeley (1969) with the slit used by Waddell superimposed. We see that such a slit is much larger than the characteristic size of the brightness inhomogeneities, which exist even in regions well away from active centers. Subsequent observers (Brault *et al.*, 1971) have used observation periods which are a significant fraction of a 300-s oscillation period. In general, the resulting profile is not characteristic of any element of the solar atmosphere at any time.

Solar Physics **24** (1972) 43–58.

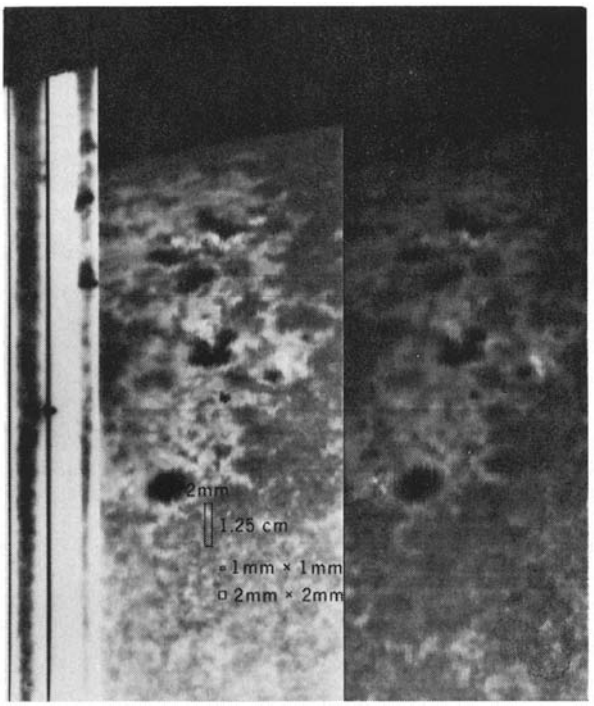

Fig. 1. Na D line spectroheliogram showing areas of disc observed with slits and image slicers.

This paper describes an effort to obtain a closer approximation to the true profiles of the D lines and their variation across the disk. Such data is essential for an adequate description of the solar atmosphere. The center-limb variation contains information on the mean physical properties of the line-forming region (Jefferies and Curtis, 1967; Wilson and Worrall, 1969). We may also use the line profiles to deduce whether or not the line source function is frequency dependent (Worrall, 1971). Accurate data is required for such analyses which demands that the distortion of the center-limb observations by space and time averaging be known.

In this paper we describe some of the effects of space and time averaging on the D line profiles. In order to do this we have to correct the profiles for velocity shifts. When we do this we find that the Doppler width of the corrected profiles is strongly correlated with the mean velocity of the solar element observed. Our high time resolution enables us to obtain information on the velocity field throughout the region of line formation by studying the variation of the line bisector. With low time resolution only the mean velocity may be studied. We have searched for evidence of variations in the line bisectors which might indicate the presence of propagating waves. In low time resolution studies such information is clearly lost.

2. The Observations

We made the observations at Kitt Peak National Observatory with the vertical