SPACE AND TIME VARIATIONS OF K17699
SOLAR LINE PROFILE

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Abstract. The temporal and spatial behaviour of the K17699 line profile is investigated. In particular we have measured the asymmetries of the line profile at several residual intensities using the bisector method. We find, in the bisector of the mean line profile, similar shapes as those obtained before for different positions on the solar disk. However the strong variations of the bisector found with time and geometry of input aperture, warns us against the use of the mean or integrated profiles (either in time or space). Moreover, we find an anticorrelation between the asymmetry in the line profile at different residual intensities and the shift, found as the distance to a terrestrial line, for any position observed on the solar disk. No limb effect for this line is found, within errors.

1. Introduction

Non-resolved velocity fields produce asymmetries in absorption line profiles. In the solar photosphere it is believed that they are the consequence of the space average over the granulation velocity field (Voigt, 1956; Schröter, 1957) although alternative or complementary mechanisms have been proposed (see Dravins, 1982, for a recent review).

The line K17699 has been used recently in whole disk measurements of the solar oscillations with a resonant scattering technique (e.g. Brookes et al., 1978). Their asymmetries have been studied by Snider (1972) and Gasanalisade (1979) although with a poor time resolution. The purpose of this paper is to study the behaviour of the line profile looking for space and time variations.

2. Observations and Reduction

The observations were made during two periods: May–June 1978 and September–October 1980, in the solar station of the Göttingen University at Locarno using the 45 cm Gregory-Coudé reflector. Details of the equipment are given by Wiehr et al. (1980).

A spectral region containing the K17699 solar line and the terrestrial O2 7697 was photoelectrically scanned using a stepping motor (1 step = 0.72 mÅ). At the same time another photomultiplier was recording the nearby continuum. In order to avoid transparency fluctuations the ratio between the two detector signals was taken. Every scan consisted of two measurements over the region (first towards the blue then back)
recording their sum on magnetic tape. The duration of this procedure was 53 s per scan. The observational sets were done at the disk center with different apertures consisting of holes in a mirror placed in front of the spectrograph slit and at several positions on the north part of the solar rotation axis. The census of the observations is given in Table I.

<table>
<thead>
<tr>
<th>Observation series</th>
<th>Position ( (\mu = \cos \theta) )</th>
<th>Aperture</th>
<th>Date of observation</th>
<th>Number of scans measured</th>
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<tbody>
<tr>
<td>0</td>
<td>Integral light</td>
<td></td>
<td>1 Oct., 1980</td>
<td>26</td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>40(^{a})</td>
<td>26 Sept., 1980</td>
<td>53</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>40(^{a})</td>
<td>5 Oct., 1980</td>
<td>61</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>8(^{\prime})</td>
<td>6 June, 1978</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
<td>8(^{\prime})</td>
<td>16 Sept., 1980</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>1.0</td>
<td>4(^{\prime})</td>
<td>28 May, 1978</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
<td>4(^{\prime})</td>
<td>5 Oct., 1980</td>
<td>125</td>
</tr>
<tr>
<td>7</td>
<td>0.8</td>
<td>4(^{\prime})</td>
<td>29 May, 1978</td>
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<td>0.8</td>
<td>4(^{\prime})</td>
<td>24 Sept., 1980</td>
<td>61</td>
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<td>4(^{\prime})</td>
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<tr>
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<tr>
<td>11</td>
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<tr>
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<tr>
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<tr>
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<td>0.3</td>
<td>4(^{\prime})</td>
<td>1 Oct., 1980</td>
<td>61</td>
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<tr>
<td>15</td>
<td>0.2</td>
<td>4(^{\prime})</td>
<td>1 June, 1978</td>
<td>59</td>
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</table>

\(^{a}\) In these scans the effective aperture was the exit slit of the spectrograph.

The solar region under investigation was displayed on a TV monitor via a Ca\(^{+}\) K filter. We carefully avoided observations in or close to active regions.

For the full disk measurements the light was collected by a small coelostat system with 5 mirrors onto the spectrograph slit. Since the diameter of the mirrors was small and this system did not have appropriate tracking we believe that vignetting could happen while taking these spectra.

To determine the wavelength distance between the terrestrial and solar lines we have searched for the apparent minimum of each line and then we fitted different vertical parabola. We tried different numbers of points around the apparent minimum (80–200 for the solar line and 60–130 for the terrestrial one), and the minimum of the parabola which best fitted the data (in the least-squares sense) was taken.

The continuum intensity was measured in 3 segments free of weak lines giving a r.m.s. fluctuation of 1.5\% on average. After a parabolic smoothing (over 5 points) we measured the asymmetry of the lines using the bisector method as the positions of the midpoints which have equal residual intensities referred to the minimum of the fitted parabola as zero-reference.

Measurements of the spectrograph instrumental profile were done using a He–Ne laser. The profile was symmetric within 0.2 mÅ. Using this profile we proceeded to
Fig. 1. Mean bisectors corresponding to the different observational sets. Typical errors are of 30 m s\(^{-1}\).
restore the spectra by the optimum filter method, and then recalculated the minima and
the asymmetries. The results found were equal, within errors, to the ones found without
the restauration process.

3. Variations of the Asymmetries with the Position on the Disk

In Figure 1, the bisectors corresponding to an average of all scans at different positions
on the solar disk are displayed. Typical errors are of 30 m s\(^{-1}\). The terrestrial line shows
asymmetries less than 40 m s\(^{-1}\) (: 1 mÅ) except near the continuum, probably due to
a blend.

In general there are blueward shifts except for the 1978 observations near the limb.
In the positions, on the solar disc, where we have measurements in the two observing
periods, some differences are detected but an interpretation as real long-term variation
as reported by Livingston and Hollweger (1982) for whole disk measurements is still
speculative.

The bisectors of the disk center have a great similarity with the ones observed by
Gasanalisisade (1979) except in that we do not observe the kink toward the red at 70\%
residual intensity. This kink was predicted by Dravins et al. (1981, see their Figures 6a
and 7) for strong resonance lines in this wavelength region taking into account the
granular velocity field only. Near the limb the agreement with Gasanalisisade (1979) is
good. All qualitative effects seen at disk center remain in integrated light with the
amplitude somewhat reduced.

4. The Limb Effect

The variation of the mean distance between the lines, corrected by rotation and orbital
motion of the Earth, along the position on the solar disk is the so-called limb effect. From
our data we do not find any significant effect, within errors, as can be expected taking
into account the spectral region we are dealing with and the height of formation of the
line. This behaviour is the same as the one reported by Snider (1972). A bump of
200 m s\(^{-1}\) was detected between positions \(\mu = 0.8\) and \(\mu = 0.7\) which we interpret as
the supergranulation velocity field which we cannot average. In accordance with these
results we do not find any significant difference between integral light and disk center
values.

5. Time Variation

The variation of the bisectors with time for different positions on the solar disk is shown
in Figure 2. As one can see their shape and position change greatly confirming the
apparent erratic behaviour reported by Snider (1970).

There can be seen that the bisector looks very different for distinct apertures and
positions; for instance the scans measured at \(\mu = 1.0\), with the exit slit of the spectro-
graph as the effective aperture (observation series 1 and 2) show a very much less erratic
behaviour than the others, probably due to the fact that they have been measured
without a hole-mirror and so have a different distribution of the intensities.
Fig. 2. Some examples of line variations of the line bisectors showing different behaviour. Time interval 53 s.
To check this time variation we have used a direct FFT power spectrum analysis of the asymmetries at different residual intensities. As most of them showed a significant peak around 5 min (see Figure 3a), we have tried to correlate this temporal behaviour with the 5 min velocity oscillation measured by the distance between the solar and terrestrial lines.

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Fig. 3. These plots refer to the scans made at $\mu = 1.0$ and $L = 40^\circ$ without hole mirror, (observation series number 1). (a) Power spectra of the distance between solar and terrestrial lines, (corrected by Earth rotation in every scan) showing the 5 min peak. (b) Cross-correlation function of the distance between lines and asymmetries of the solar one at different intensities: (1) at 40%; (2) at 60%; (3) at 80%; (4) at 90% of the continuum intensity. Dotted lines correspond to the significance levels of 99 and 95% of the null test.
The cross-correlation function was found between the different series of asymmetries and the velocity determinations. An example is shown in Figure 3b. We set the levels of significance of 95% and 99% of a null test and the result is that there is significant anticorrelation, at 0 lag, in most of the cases; only in the observation series numbers 2, 11, and 13, (see Table I) the correlation failed at those significance levels, but in those cases the 5 min oscillation was buried in noise. Similar calculations were done using the distance between the apparent minima of the lines to check if the correlation was an artifact of the parabola fits, obtaining the same result.

This anticorrelation means that when the solar line is shifted to the red due to material motions the profile of the line shows a blueward asymmetry. A similar effect was found by Roddier (1967) in the resonance line Sr\textsubscript{1}4607 showing a change from asymmetric to symmetric profiles.

Slaughter and Wilson (1972) have reported a correlation between the residual intensity at the bottom of the line profile and the 5 min oscillation for the Na D lines. To check that, we have done power spectra of such intensity and found no significant power at any frequency.

6. Conclusions

The asymmetries of the K\textsubscript{1}7699 Å solar line varies with the position on the disk, time and field of view. Looking at the time behaviour of the bisectors of the spectral line, we conclude that the shape of the mean profile can change considerably depending on the time interval used to measure (Higgs, 1962). The geometrical configuration of the aperture used to observe does affect the observed profile as well.

The most important finding is the anticorrelation found between the asymmetries measured at different residual intensities and the photospheric oscillations (mainly by 5 min). Such effects were proposed by Eriksson and Maltby (1967), Kostik and Orlova (1972), Barylko (1978), and Cram \textit{et al.} (1979). This relation was not detected by Koch \textit{et al.} (1979) for 4 lines and Kostik and Orlova (1974, 1977) for 11 iron lines. However we think that our line is more adequate to look for this correlation, for 3 main reasons:

(a) the line is formed higher in the photosphere and is therefore freer of convective motions;

(b) the granulation contrast is smaller in the red part of the spectrum (Wittman, 1978);

(c) the amplitude of the acoustic waves increases with height.

It is also interesting to note that Altrock and Keil (1977) found in some regions correlations between velocity and intensity fluctuations in the Mg4571 line formed near the temperature minimum. Staiger (1982) has measured the phase difference between intensity and velocity oscillation for this Mg b line. His results differ from the normally accepted value of 90° for the 5 min oscillation. As our samples are 53 s time averages we cannot exclude this influence in our measurements.

The full disk observations taken were not long enough to draw any conclusion. Although the profile seems to be asymmetric we cannot find any significant time variations. Observations of this kind will be of interest in the light of the use of this line in resonance scattering spectrometry.
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References