PUBLICATIONS
OF
DEBRECEN
HELIOPHYSICAL OBSERVATORY
OF THE
HUNGARIAN ACADEMY OF SCIENCES

**ПУБЛИКАЦИИ
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ГЕЛИОФИЗИЧЕСКОЙ ОБСЕРВАТОРИИ
ВЕНГЕРСКОЙ АКАДЕМИИ НАУК**

**A MAGYAR TUDOMÁNYOS AKADÉMIA
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NAPFIZIKAI OBSZERVATÓRIUMÁNAK
KÖZLEMÉNYEI**

Vol. 6 No. 1

DEBRECEN

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EDITOR: BÉLA KÁLMÁN
HEAD, HELIOPHYSICAL OBSERVATORY OF
THE HUNGARIAN ACADEMY OF SCIENCES
H-4010 D E B R E C E N
HUNGARY

ISSN 0209-7567

(Publ.Debrecen Obs., Volume 4, PAGES 1-40.)

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STUDY OF SPECTRAL LINE ASYMMETRY IN SUNSPOTS

LUDMÁNY A.

Abstract: *The previously found inverse line asymmetry is studied in sunspots near to the solar disc center.*

ИССЛЕДОВАНИЕ АСИММЕТРИИ СПЕКТРАЛЬНОЙ ЛИНИИ В СОЛНЕЧНЫХ ПЯТНАХ

ЛУДМАНЬ А.

Абстракт: *Исследуется раньше найденная инверсия асимметрии линии в солнечных пятнах вблизи центра солнечного диска.*

SPEKTRUMVONAL-ASZIMMETRIA VIZSGÁLATA NAPFOLTOKBAN

LUDMÁNY ANDRÁS

Összefoglalás: *Megvizsgáljuk a napkorong centrumához közeli napfoltok korábban talált negatív színképvonal-aszimmetriáját.*

INTRODUCTION

In a previous paper (Ludmány,1983, hereafter referred to as Paper I.) some observational facts have been published about the inversion of spectral line asymmetry in the majority of sunspots. The absence of the so-called "limb-effect" in sunspots (Beckers,1977) is in accordance with the theoretical assumptions about the inhibition of convection in magnetic fields - at least in the photospheric sense. However some other types of motion fields may exist in umbrae too, and the type of asymmetry of a spectral line may be an important characteristics of the motion, especially of inhomogeneities of velocity and intensity distributions, even without any shift of the line as a whole.

The present paper gives account of the investigation of the same problem on a more extended material, and in a somewhat more quantitative manner.

OBSERVATIONS AND THEIR REDUCTION

The most advantageous line for this purpose is the λ5714 Ti I , because it is magnetically insensitive, free of blends, and it has a favourable property: it is extremely weak in the quiet photosphere and fairly strengthened in umbrae, and so, the always problematic straylight has no influence to make systematic error, any tendency of photospheric origin cannot distort the result.

The observational material was of the same type as in Paper I. The photographic spectra were taken at the Main Astronomical Observatory of the Academy of Sciences of the Ukrainian SSR, in Kiev, Goloseevo. The instrument was the ACU-5 horizontal telescope, making a 16 cm diameter solar image on the 50 micron spectrograph slit. ORWO WO-3, and WP-3 plates were used with 2-24 sec exposure times. The position and size of the observed sunspots have been determined on the basis of the observational material of the Heliophysical Observatory of the Hungarian Academy of Sciences, Debrecen, which means the photospheric patrol observations with solar image of 11 cm diameter.

The spectrograph slit always crossed the center of the umbrae and the photospheric scanning was made with a slit height corresponding to 1", and by steps of 4.38 and 2.47 mÅ in the IV. and V. order respectively. The data were calibrated photometrically.

The most important action during the evaluations was the correction for the instrumental profile. It is quite obvious, that an asymmetrical transmission function (Fig. 1.) results an asymmetrical spectral line.

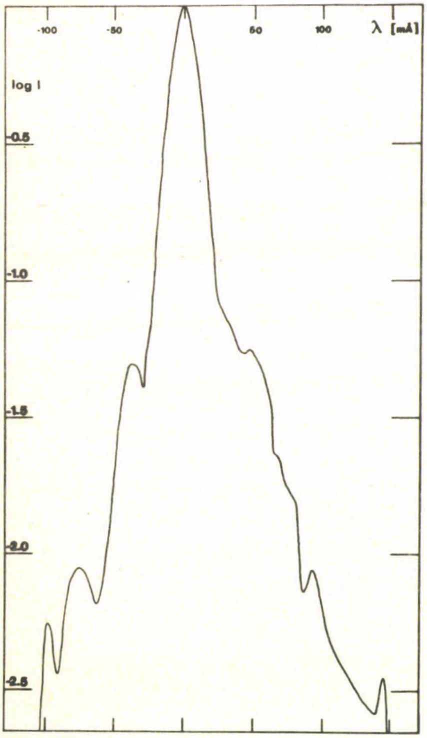

Fig.1. Instrumental profile of the ACU-5 teleskope (Kiev) in the fourth order.

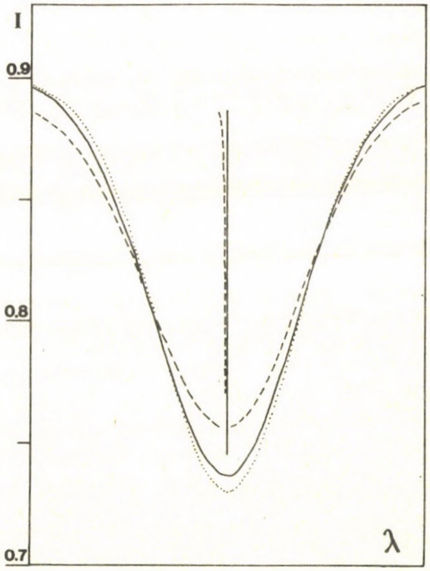

Fig.2. Gauss-profile (dotted line), resulting profile, after passage through the spectrograph (broken line), corrected profile (continuous line), the two latter with their bisectors.

To demonstrate this, an ideal Gauss-function was chosen as an entering line profile, and its convolution with the known instrumental profile was computed. The resulting curve with its bisector is plotted in Fig. 2. for the fourth order of the spectrograph. The distortion of the bisector is fairly remarkable, its upper part slightly declines to the left. In order to correct for this phenomenon, the deconvolution procedure described by Gurtovenko (1966) was carried out. This is an iteration method, and experience shows, that the first iterational step gives acceptable result, at least, as for the asymmetry, as is displayed in Fig. 2.

The most popular tool for the examination of asymmetry is the above mentioned bisector method. However, this is, after all, a slightly subjectiv indicator, and therfore some attempts are known to make it more quantitative. One of them uses the following formulae (Kostyk et al.,1976):

$$\Delta = \frac{\mu_3}{\mu_2^{\frac{3}{2}}}$$

$$\mu_i = \int (\lambda-\lambda_i)[1-r(\lambda)]\, d\lambda$$

$$\lambda_c = \frac{\int \lambda[1-r(\lambda)]\, d\lambda}{\int [1-r(\lambda)]\, d\lambda}$$

Here μ_i is the i-th central momentum, λ_c is the position of the line center, and Δ is the measure of asymmetry.

OBSERVATIONAL RESULTS

The sunspot observations taken in the $\Delta\Theta<30°$ ($\cos\Theta>0.87$) surrounding of the solar disc centre were collected. After photometry some profiles obviously suffering from any defects were omitted. For the photometric calibration the photoelectric sunspot spectrum of Wöhl et al.(1970) was used.

The resulting material consists of 44 profiles. The whole material seems to show the same property, as that of the Paper I, namely a clear tendency to have an inverse asymmetry, although there are some positively asymmetric and any undefined examples. Instead of plotting all of the profiles, let the Fig. 3. show the above defined Δ asymmetry plotted versus sunspot area.

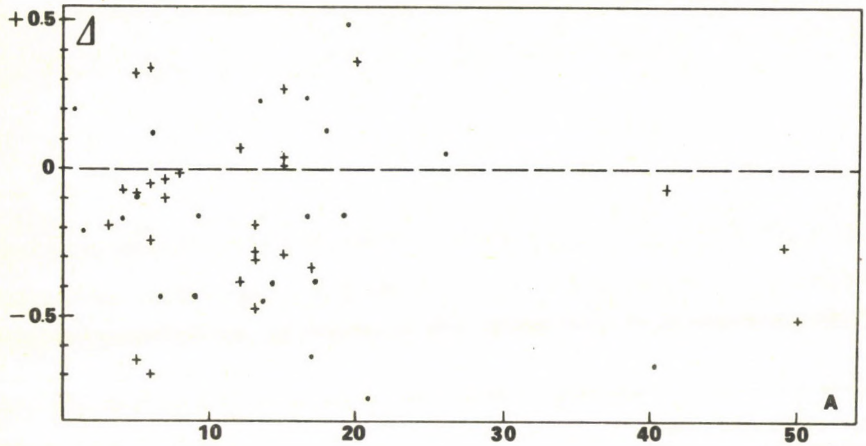

Fig.3. Asymmetry of the Ti I 5714Å line in sunspots versus sunspot area.

Crosses mark the data measured for the present work, and those of the Paper I (reduced to sunspots with $\Theta \leq 30°$) are shown by dots.

The important feature of this figure is, that the distributions of the two materials (of Paper I and the present one) are rather near to each other, the distributions of the negative-positive declinations are: 12-5 in Paper I, 20-7 in the later evaluated material, and so, 73% of all profiles have negative asymmetries. From the point of view of interpretation it is not less important, that not all bisectors decline to the left. As for the area dependence it does not seem to have any clear tendency as was the case in Paper I too.

This line has been already applied by Beckers for line shift measurements (Beckers, 1977) and turbulence determination (Beckers, 1976) in sunspots. In this latter paper two concrete line profiles are published, one of them is that of the λ5714 Ti I line. Closer inspection of these figures reveals that both of these profiles have negative asymmetry, so it appears, that the fact of asymmetry exists, and it should be accounted for.

ACKNOWLEDGEMENTS

I am deeply indebted to E.A. Gurtovenko for his continuous attention and help in this work, and my sincere thanks are due to S.I.Gandzha for many helps in instrumental problems.

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TWO-COMPONENT MODELLING OF SUNSPOT SPECTRAL LINE PROFILES

LUDMÁNY A.

Abstract: *A two-component model is discussed as a possible interpretation of the negative asymmetry of spectral line λ5714 Ti I in sunspots.*

ДВУХКОМПОНЕНТНОЕ МОДЕЛИРОВАНИЕ ПРОФИЛЕЙ СПЕКТРАЛЬНОЙ ЛИНИИ В СОЛНЕЧНЫХ ПЯТНАХ

ЛУДМАНЬ А.

Абстракт: *Обсуждается двухкомпонентный модель в качестве возможной интерпретации отрицательной асимметрии спектралной линии λ5714 Ti I в солнечных пятнах.*

SPEKTRUMVONAL-PROFILOK KÉTKOMPONENSÜ MODELLEZÉSE NAP-FOLTOKBAN

LUDMÁNY ANDRÁS

Összefoglalás: *Megvizsgáljuk a kétkomponensü modellt, mint a λ5714 Ti I semleges titánvonal napfoltbeli negatív aszimmetriájának lehetséges interpretációját.*

INTRODUCTION

There are two complementary directions in the study of the dynamics of the solar photosphere. It is possible to investigate the physical parameters down to the smallest, technically possible details (microscopic approach), on the other hand, one can investigate macroscopic characteristics globally on an extended statistical mass. If a model of a macroscopic feature is built up from the microscopic parameters and processes, it should be in accordance with the observed macroscopic phenomenon. If we observe the behaviour of the photospheric spectral lines, and their shifts or shapes without spatial resolution, many individual details are averaged. The first quantitative attempt to explain the center-limb variations of spectral lines was made by E.H. Schröter, 1957, by averaging two different components, this was the two-stream model. Serious development was achieved by using refined parameters and realistic geometry, a detailed overview is given by D. Dravins, 1982.

As for the sunspots, it has been assumed for a long time, that the ordinary convection is inhibited inside them. Nevertheless, there are both of observational and theoretical reasons to regard the umbral structure being inhomogeneous. So, it seems to be reasonable to study, to what extent can we account for a special global feature with the known local parameters.

OBSERVATIONAL FINDINGS ABOUT UMBRAL INHOMOGENEITIES

I want to give a possible interpretation of the asymmetry of line profiles in sunspots published earlier, see Ludmány 1983 and Ludmány 1986, hereafter referred to as Paper I and Paper II. The main points of these papers are: the bisectors of the majority of line profiles in sunspot umbrae do not show the ordinary "C"-shape of the photospheric bisectors, (positive asymmetry), but they are rather inverted, about 70% of them show negative asymmetry. One cannot recognize any significant area dependence of this phenomenon.

There are observations in the literature supporting this statement, as e.g. those of Teplitskaya and Turova,1985, Makita and Kawakami,1986, and as an interesting matter, the close inspection of the figures in the paper of Beckers,1976 results the same conclusion.

Referring to the above mentioned modellings, it seems to be reasonable to make a trial with the two-component sunspot model. There have been reports for a long time about bright elements in umbrae, they are to be seen even in drawings made in the last century. The modern observational tools have made possible many refinements of the characteristics of these phenomena, named "bright umbral dots", but the available data are rather different. The Table I displays the more important measurements of bright dots.

It is remarkable, that there is a significant scatter among the data in both of intensity and size measurements. This can be the consequence of instrumental or atmospheric circumstances, but there is another important feature: the variability of the umbral dot pattern. As for example Parfinenko 1981 points out, the size, or the for us especially important "filling factor" of bright dots may vary from spot to spot. There are even rare examples with no bright dots (in pictures of high quality). The observers generally agree in stating, that the more intense and bigger dots tend to occur at the border of the umbra, the smaller and less intense dots are placed at its center. These can explain some deviations between the different reports. However, this gives less chance to the model-making too, because the spot spectroscopy differs from the photospheric case, where the observer can be always sure, that a spectrograph slit of realistic height covers a statistically homogeneous mass of granules. In sunspots fairly different situations may occur.

There is a spectroscopic evidence too for the two-component sunspot model, even without high spatial resolution (see e.g. Makita,1963, Obridko,1968), namely, the coexistence of lines with different excitation temperatures, a part of them

Table I. Umbral dot data

Designations: UD - umbral dot, $*$ - dark component, $\odot$ - photosphere

Publ	intensity ($I_{UD}/I_{\odot}$)	size	filling factor	velocity
Makita,1963	~1		0.1	
Beckers, Schröter,1968	0.129(blue) 0.134(red) ~1(corrected)	420 km corrected: 150-200 km		
Krat et al., 1972	0.3-0.4	rather variable		
Kneer,1973	0.22 ($\overset{?}{\to}$1) $I_*/I_{\odot}$=0.13			3.0±0.5 km/s
Hejna,1977		1".6		
Loughhead et al.,1979		0".4-0".5 (distance: 0".9-1".3)	(0.07-0.24) (derived)	
Bumba, Suda,1980		density: 1".2-1".4		
Abdussamatov, 1980	<0.35 $I_*/I_{\odot}$<0.07		0.1±0.05	
Adjabshirzadeh, Koutchmy,1980	1	0".2-1" mainly 0".5		
Koutchmy, Adjabshirzadeh, 1981	1	33-200 km		
Parfinenko,1981	0.69 →1 at the P-U border	rather variable		
Adjabshirzadeh, Koutchmy,1983		0".225	0.05	

formed in hotter gas then the rest. This is of great importance from our point of view, because two states of different strengths of the same line can exist at the same time in inhomogeneous umbrae.

A theoretical assumption should be mentioned too. Parker (1979) argues, that the development of sunspots is observed to be progressing by coalescence of smaller spots (as is proven by many observations made in Debrecen too), and he suggests, that the flux ropes may keep their identity after the coalescence, they constitute a loose conglomerate under the surface. The domains between the flux ropes would be nearly field-free. If this is the case, then favourable conditions would be present for the so-called overstable oscillations: the emerging hot cells of gas would cool down at the surface by radiation, rather then by spreading as in the photosphere, and then they would submerge. So, the bright points would be the manifestations of these lifting cells at the surface. The observations do not contradict to this picture.

So, by synthetic line profile modelling we can check, which set of the above parameters proves to be real, reflecting the negative asymmetry.

SYNTHETIC LINE PROFILES

There are a number of one-component sunspot models, considering the spot umbra as a homogeneous phenomenon. However, as is mentioned above, many lines are strengthened differently at the temperatures of the two umbral components, as is the case with the 5714Å Ti I line, which is very faint in the photosphere and considerably strengthens at umbral temperatures. In such cases, it seems to be more realistic to synthetize the line from two lines formed under different conditions.

There are also two-component sunspot models, as that of Adjabshirzadeh and Koutchmy,1983 and Obridko (see in Obridko 1985). In our case the main problem is the high sensitivity of the Ti I line. To demonstrate this, the Fig.1. displays a sector from the Fig.10. of the paper of Stellmacher and Wiehr, 1970, in a somewhat altered form and scale, showing the computed profiles of this line on the basis of different sunspot models (unmarked curves).

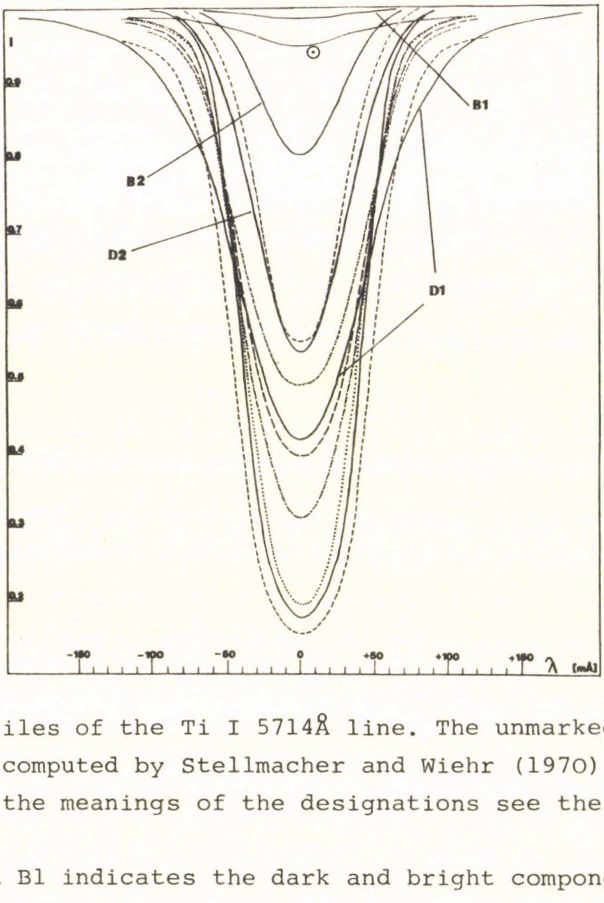

Fig.1. Profiles of the Ti I 5714Å line. The unmarked curves are computed by Stellmacher and Wiehr (1970). For the meanings of the designations see the text.

D1 and B1 indicates the dark and bright components respectively, computed with the two-component model of Adjabshirzadeh and Koutchmy,1983, with $v_{microturb}$= 1.3 km/s taken from Beckers,1976. The variability of the line is fairly remarkable.

There is an interesting circumstance. For the sake of comparison, Fig.1. indicates the profile formed in the photosphere taken from Delbouille et al.,1973, and marked with circle and dot. The different authors generally agree in stating, that the brightest dots are somewhat less, or nearly as intense as the average photosphere. Only a few publications report brighter dots rarely seen. So, the Bl profile appears to be too weak. It is expected to be somewhat stronger, then the photospheric line. It is possible, that the above bright point model describes actually just the most intense dots.

The model computations, mentioned in the introduction, describe the line formation under circumstances of the solar granular geometry (larger emerging intense granules, smaller intergranular lanes). There may be granular structures having a bright cell filling factor smaller then the solar case. Gray (1980) for example reports negative asymmetry at the lines of Arcturus, which is thought to have such a geometry. As for the filling factor of bright umbral dots, the different investigations give fairly similar data. The cited work of Adjabshirzadeh and Koutchmy,1983, gives 0.05, and most of the papers conclude, that it is between 0.05 and 0.1 or perhaps it is slightly larger. However, as is mentioned by Parfinenko (1981), it appeared in a few cases, that the evaluated bright dots are just the tops of somewhat larger and less intense areas, becoming appreciable on overexposed observations.

Fig.2. shows the resulting profile computed from the Dl and Bl displayed in Fig.1. with the following parameters: $I_{dot}/I_{dark}=11$, F=0.05 and 0.1 (Adjabshirzadeh, Koutchmy,1983) and $\Delta\lambda_{dot} = -60$ mÅ (that means v=3 km/s, Kneer,1973). The main conclusions are: the shifted component cannot distort such a wide line, and the strength and weigth of the brighter component is too small, as was pointed out by Obridko,1983. It is remarkable also in Fig.1., that the dark line component is very wide, perhaps, the value of $v_{microturb}$ is not as great for both components.

We can ask another question. Is it possible at all to explain the line asymmetries in sunspots by using a two-component model, and what are the necessary values of the above parameters?

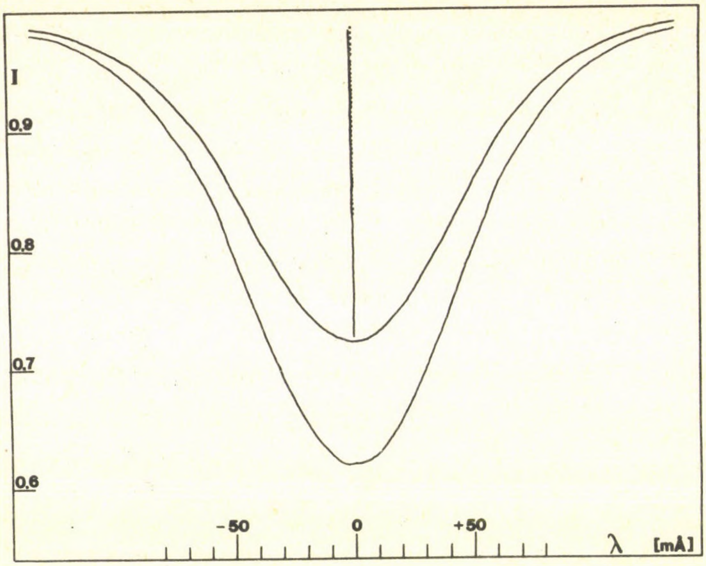

Fig.2. Resulting profiles of D1 and B1 at F=0.05 (lower curve), and F=0.1 (upper curve) with the bisector of the latter. A straight line is represented by dots.

As is mentioned above, there are observational hints, that the brighter regions are not limited to the brightest dots, comparable with the photosphere, but they are likely more extended and less bright mainly at the centre of the umbra. If so, they can form stronger lines being able to contribute significantly to the resulting profile. The concrete line computations are impossible without available model of such faintly bright regions. The above examples show, that rather different lines are formed in different temperatures, and further, the brightness and the filling factor of the brighter regions may vary from spot to spot. Perhaps, we can consider the umbra as a mosaic consisting of a dark, and a variety of brighter regions. This could explain the variability of the Ti line.

Therefore, Gauss-curves were chosen, which could have been considered to be realistic simulations in comparison with the other available theoretical profiles. In Fig.1. D2 and B2 mean imaginary "dark" and "bright" profiles respectively. The D2 is close to the broken curve (computed by Stellmacher and Wiehr,1970, Wittmann-Schröter model), the B2 is stronger, than the quiet line, expected in regions fainter than the quiet photosphere.

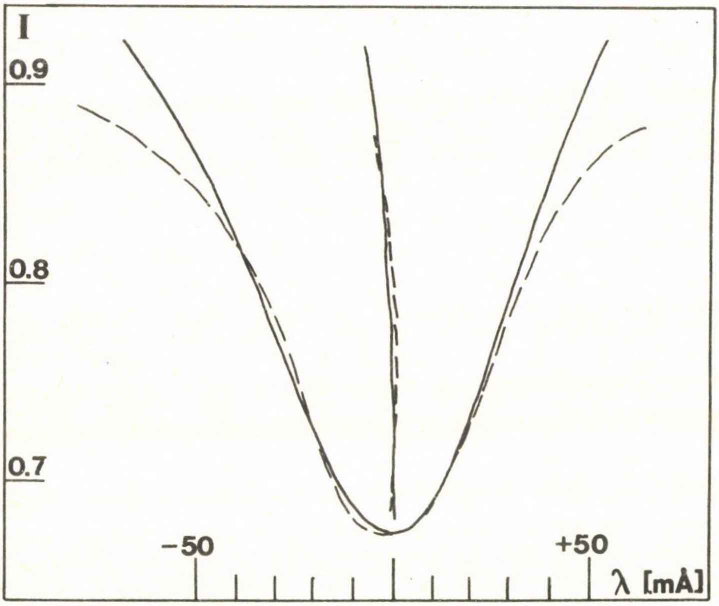

Fig.3. Two-component simulation of an asymmetric line.

Fig.3. shows a two-component simulation (continuous line) in comparison with an observed line profile published earlier (broken line, Ludmány,1983). The adopted parameters are: bright/dark intensity ratio: $I_B/I_D=3$, filling factor: F=0.3, shift of the bright component: $\Delta\lambda_B$=60 mÅ (v=3 km/s). This synthetic line possess a fairly similar bisector to the observed one, showing negative asymmetry.

CONCLUSION

Many numerical simulations were performed with different parameters. The experiences show, that if we want to achieve real profiles having the observed bisectors, constructed from two lines of plausible width and depth, then the possible values of the above parameters are limited. For the velocity a value of v=3 km/s or more, but at least 2 km/s is required. The asymmetry is very sensitive to the filling factor, which has to be more than 0.1, mainly 0.3-0.4. The I_B/I_D ratio may be greater, than 3, but not too much, because the bright line component would get presumably too weak in a too bright region.

Positive asymmetry can be also simulated by using the above parameters, and much greater filling factors, for instance F=0.7 causes an appreciable revearsal.

Beckers (1977) used the same Ti I line to measure the so-called limb-effect in sunspots and he did not found any significant line shift. He fitted a gaussian to the bottom of the line and determined the position of its minimum. He gives a value of 30 m/s for the standard deviation of his measurements corresponding to 0.6 mÅ. The minimum position of the simulated line indicated in Fig.3. shows a shift of 1 mÅ, slightly greater, than the above uncertainty, but they are nearly of the same order, and an effect like this appears to be at the frontier of detectability with the above method.

The above discussion may seem to be arbitrary on account of the artificial profiles, but these are eventually not less probable than the others indicated in Fig.1. These simulations are obviously not adequate to study the fine structure of the profile in detail, and perhaps, the photographic spectra are also not really suitable for such purposes. But the asymmetry is a relative measure after all, and its tendency may be revealed also in such a simple way.

We may conclude, that the two (or more?) components can play a role in the picture. It is obvious , that they have to be taken into account for realistic line profile computations. If we assume, that the bright regions are more extended and partly less intense than the currently perceivable brightest dots, and they have significant velocities upwards, then they can contribute appreciably to the profile asymmetries. However, the necessary parameters occasionally appear to be exaggerated (especially the increasing F values), indicating, that this mechanism alone probably cannot be responsible for all asymmetry features.

AN ADDITIONAL NOTE

We received the paper of Makita and Kawagami (1986) during the preparations of this work. They report the same observational result (using the Fe I 6301.5Å line) as mentioned before, but instead of the inhomogeneities they analyse the effect of the outward velocity gradient on the asymmetry.

ACKNOWLEDGEMENT

I am greatly indebted to R.I. Kostyk, who computed for me the D1 and B1 profiles displayed in Fig.1.

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STUDY OF SOLAR Hα-LINE PROFILES BY MEANS OF FILTERGRAMS

BARANYI T.

Abstract: *The shape of the Hα-profile has been determined in 15 points of a solar active region on the basis of monochromatic images. A short overview is given about the developed version of the procedure published earlier.*

ИССЛЕДОВАНИЕ СОЛНЕЧНЫХ Hα ПРОФИЛЕЙ С ПОМОЩЬЮ ФИЛЬТЕРГРАММ

БАРАНИ Т.

Абстракт: *Определяется профиль линии Hα в 15 точках солнечной активной области на основе монохроматических снимков. Кратко обозреваем исправленный вариант раньше опубликованного метода.*

SZOLÁRIS Hα-VONALPROFILOK VIZSGÁLATA FILTERGRAMOK SEGITSÉGÉVEL

BARANYI TÜNDE

Összefoglalás: *Egy szoláris aktiv vidék 15 pontjában meghatároztuk a Hα vonalprofil alakját monokromatikus felvételek alapján. Röviden áttekintjük a korábban közölt eljárás továbbfejlesztett változatát is.*

INTRODUCTION

In a previous publication (Paper I: Baranyi, Ludmány, 1983) we discussed the necessity of the two-dimensional spectroscopy and a concrete possibility, which we held realizable by means of the birefringent filter of our observatory. That work could give an account just about the first attempts. This paper describes the theoretical and practical work having been done since then, and gives the Hα line profile in 15 arbitrarily chosen points of an active region. The more accurate determination of the filter transmission functions is described in Baranyi 1985, these are used here.

A very similar work was published not long before the Paper I (Caccin et al.,1983). They reconstruct the profiles of the spectral lines by means of photographs made by a birefringent filter, but they use a universal filter and another mathematical procedure (Caccin B., Roberti G.,1979, Caccin et al., 1984). Birefringent filters were used by LaBonte (1977), Tang (1983), Bray (1983) and Loughhead (1983). The spatial possibilities of gaining spectral informations may be improved also by spectrographs in different ways (Deslandres 1910, Grossmann-Doerth and von Uexküll 1971, Mein and Blondel 1972, Kussofsky and Pålsgård 1973, Martin et al. 1974, Mein 1977, Wülser 1984).

THE MATHEMATICAL BASIS OF THE METHOD

Let $\varphi_i(\lambda)$ denote the transmission function of the filter centered at λ_i wavelength, and let $H\alpha(\lambda)$ be the intensity distribution coming from a chosen point of the Sun, then the emerging intensity at the given point of the monochromatic image equals to

$$I_i = \int_{\lambda_1}^{\lambda_2} H\alpha(\lambda)\cdot\varphi_i(\lambda)\, d\lambda \qquad (1)$$

where $[\lambda_1, \lambda_2]$ is the range of transmission of the filter. For the best $\phi(\lambda)$ approximation of the $H\alpha(\lambda)$ it holds:

$$M = \int_{\lambda_1}^{\lambda_2} [H\alpha(\lambda)-\phi(\lambda)]\, d\lambda \rightarrow \min$$

The $\phi(\lambda)$ is expressed by the linear combination of $\varphi_i(\lambda)$-s:

$$\phi(\lambda) = \sum_{i=0}^{n} a_i \cdot \varphi_i(\lambda) \qquad (2)$$

where a_i are the solutions of the following system of equations:

$$\sum_{i=0}^{n} a_i \cdot \int_{\lambda_1}^{\lambda_2} \varphi_i(\lambda)\cdot\varphi_k(\lambda)\, d\lambda = \int_{\lambda_1}^{\lambda_2} H\alpha(\lambda)\cdot\varphi_k(\lambda)\, d\lambda \qquad (3)$$

$$k=0,\ldots,n$$

The approximation can be improved further, if we take into account, that certain distortions of $\phi(\lambda)$ are determined by the special shapes of the $\varphi_i(\lambda)$ functions. This can be reduced by using the $\sum b_i \cdot \varphi_i(\lambda)$ representation of the constant unity function. So, the improved approximation is:

$$\varphi(\lambda) = \frac{\sum a_i \cdot \varphi_i(\lambda)}{\sum b_i \cdot \varphi_i(\lambda)} \qquad (4)$$

Fig.1.a. displays the (2) representation of the Hα profile of the quiet chromosphere, 1.b. shows the $\sum b_i \cdot \varphi_i(\lambda)$ representation of the constant unity function, and 1.c. displays the Hα profile of the quiet chromosphere improved by (4).

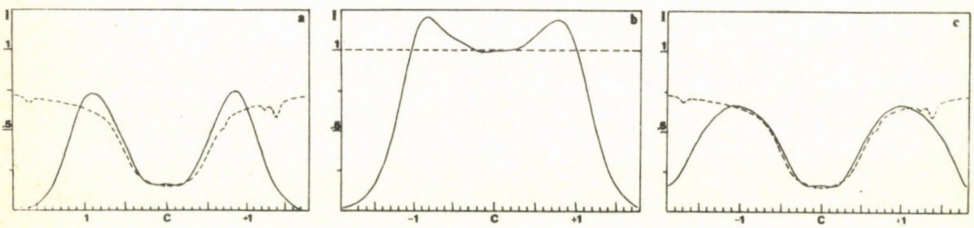


Fig.1. Functions to be represented (broken lines), and their approximations (continuous lines).

This method can be used quite generally, the accuracy of the resulting spectra, the observable range of wavelength and the spectral resolving power are determined exclusively by the qualities of the filter.

THE OBSERVATIONAL MATERIAL

The used series of observations, consisting of 21 filtergrams, has been completed on 22-th of July 1984 between 8:14:40 and 8:15:00 UT at the Heliophysical Observatory, Debrecen, with the large coronograph and Halle-filter between -1Å and +1Å by 0.1Å steps. Fig.2.a. shows the view of the active region in the photosphere, and Fig.2.b. in the Hα line center.

The temperature of the filter was 44.6 C°, its bandwidth 1/2Å, the band of transmission is tunable to ±1Å. The smallest unity of the tuning scale is 20mÅ, the accuracy of the temperature scale is 0.2 C°. The contrast element was switched on. The following analytical form was used to describe the filter transmission functions:

$$\varphi_i(\lambda) = A \cdot \prod_{i=1}^{m} \cos^2\left[\pi \frac{d_i(\varepsilon-\omega)}{\lambda-\Delta\lambda_i}\right] =$$

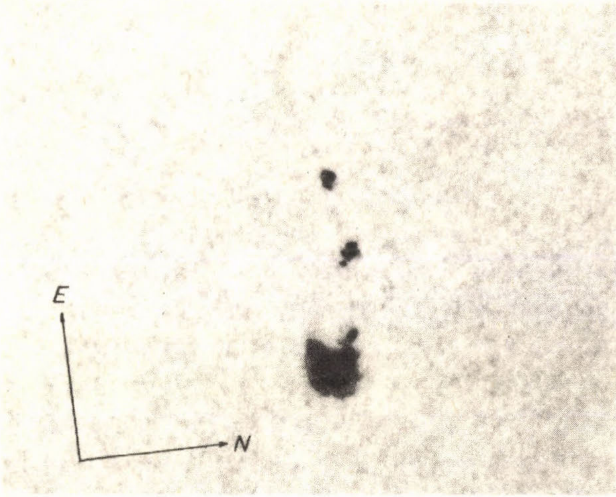
$$= 0.186 \cdot \cos^2\left[\pi \frac{6336 \cdot 6562.77}{\lambda-\Delta\lambda_i}\right] \cdot \cos^4\left[\pi \frac{3168 \cdot 6562.77}{\lambda-\Delta\lambda_i}\right] \cdot \cos^2\left[\pi \frac{1584 \cdot 6562.81}{\lambda}\right] \cdot$$

$$\cdot \cos^2\left[\pi \frac{792 \cdot 6562.81}{\lambda}\right] \cdot \cos^2\left[\pi \frac{396 \cdot 6562.81}{\lambda}\right] \cdot \cos^2\left[\pi \frac{198 \cdot 6562.81}{\lambda}\right] \qquad (5)$$

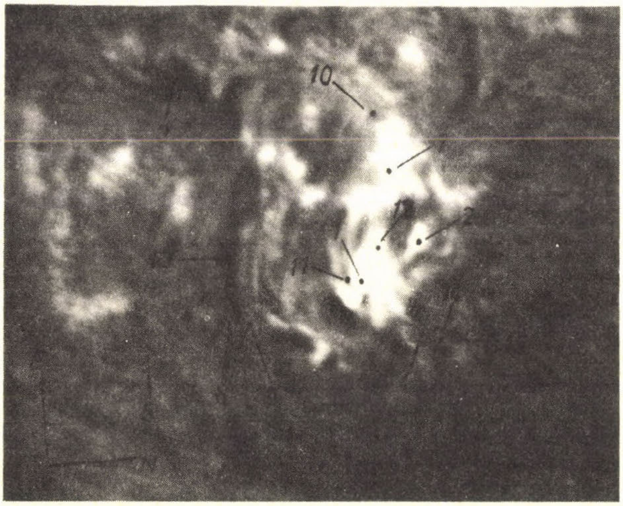
This formula fits well to the measured transmission functions. The $\Delta\lambda_i$ parameters express the tuning, the shift of the transmission functions of the filter elements.

The observations were taken with an Olympus camera, making automatic exposures and passing the film. The completion of the whole series lasted 20 seconds by manual tuning of the filter. As the shape of the calibration curve principally depends on the exposure time, and the exposure varies in automatic functioning, the calibration curve was inspected between 1/8 - 1/125 sec, and it is proven to be insensitive to the exposure in this range.

Since all pictures were taken with different, unknown exposures, the intensity data of the different photos were matched together in such a way, that the average background intensity of the quiet chromosphere was measured in every



a.)



b.)

Fig.2. The views of the studied active region in the photosphere (figure a., observed by Gerlei O.), and observed in the centre of the Hα line (figure b.). The evaluated points are indicated by numbers.

photo . The measureable datum of the chosen point is the following quantity:

$$C_i = \frac{\int H\alpha(\lambda)\cdot\varphi_i(\lambda)\, d\lambda}{\int H\alpha_0(\lambda)\cdot\varphi_i(\lambda)\, d\lambda} \qquad (6)$$

where the $H\alpha_0(\lambda)$ is the line profile of the average chromospheric background. This quantity will be named as "integral contrast" throughout this paper.

The photometric measurements were carried out with Zeiss G III. Schnellphotometer, having a micrometer of 0.01 mm accuracy in x-direction. Another 0.01 mm micrometer has been added in y-direction for this work. The 2x2 mm size of the photometer slit corresponded to a 1"x1" area of the solar surface.

It is nearly impossible to guide the large coronograph without disturbance during the whole series, therefore the big sunspot, well visible in all pictures, was used for the determination of position. Further, it was utilized, that the picture does not rotate in 20 seconds. So, if we put the zero point of the coordinate system to the centre of the sunspot, and we direct the x-axis parallel to the edge of the film, then the x,y coordinates will be the same in every pictures for all the points to be measured. The estimated positional accuracy is the half of the slit-with.

EXPERIENCES OF TEST-FUNCTIONS

The method should be tested for the applied filter and observing procedure, in order to determine the accuracy of spectral informations. Some typical profiles were drawn arbitrarily on the basis of spectra published elsewhere, and they were compared to their approximations made with this method. The integration was made between 6560.91Å and 6564.71Å, the quiet $H\alpha_0(\lambda)$ profile was taken from the spectrum atlas of Beckers et al. 1976. See Fig.3.

The main experiences with the applied filter are:

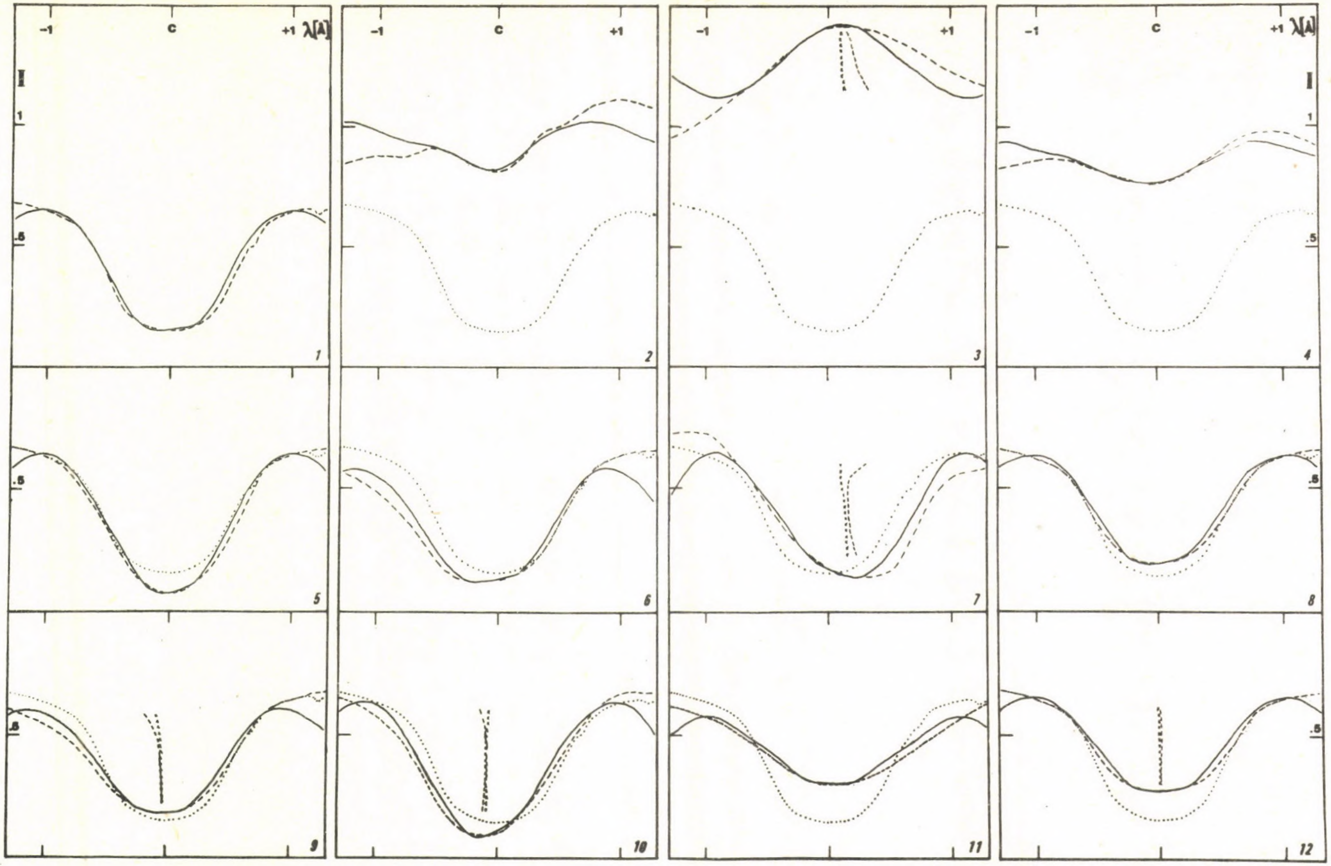


Fig.3. Test-functions with bisectors (broken lines), and their approximations (continuous lines) with bisectors (crosses). Dotted lines mark the quiet Hα profile.

1.) The approximation cannot be improved arbitrarily. It is the best in that case, when the 17 positions between -0.8Å and +0.8Å by 0.1Å steps are used. The use of the ±0.9Å and ±1Å positions does not improve the result because of the secondary maxima.

2.) The represented profiles differ at most with a value of 0.01 from the original profiles in the range -0.3Å,+0.2Å, and so, the representation is quite reliable here.

3.) Although only the filter positions between -0.8Å and +0.8Å were used, the constructed profile well approaches the original distribution between -1Å and +1Å.

4.) The special shape of the filter functions explains, that the local maxima at -1Å and +1Å are equal. Therefore, the more asymmetric is the true line profile, the bigger is the error of the approximation outside the central region mentioned in 2.). This error is generally 0.02-0.05. The maximum of the difference may reach 0.08-0.12 between ±0.8Å and ±1Å in very asymmetric cases (Fig.3./2,3,7).

5.) The bisectors of the represented and true profiles coincided only in nearly symmetric cases (Fig.3./1,5,8,12). In more asymmetric cases the position of the bisector can be estimated with an accuracy of 0.05Å, or of 0.1Å in marginal cases (Fig.3./7). (In a few cases the bisector of the test function is displayed with broken line, and that of the representation is marked with crosses.) The difference between the true profile and its representation can be determined as a function of λ with ±0.01 accuracy in the groups of profiles of identical position of bisector, and so it can be taken into account as a correction. This correction eliminates the tendency, that the representations tend to be narrower then the true profiles.

6.) Since the (6) integral contrast is the measurable quantity, it is worth studying, what is its connection with the $H\alpha(\lambda)/H\alpha_0(\lambda)$ intensity ratio. Two examples are displayed in Fig.4., where the continuous line and the crosses show the integral contrast and the true intensity ratio respectively in dependence of the filter position (these are the 10. and 12. test functions). It is remarkable, that the filter flattens the intensity ratio function, because of the wide transmission band, and the satellite maxima. The application of the mathematical procedure is therefore not only possibile but even unavoidable.

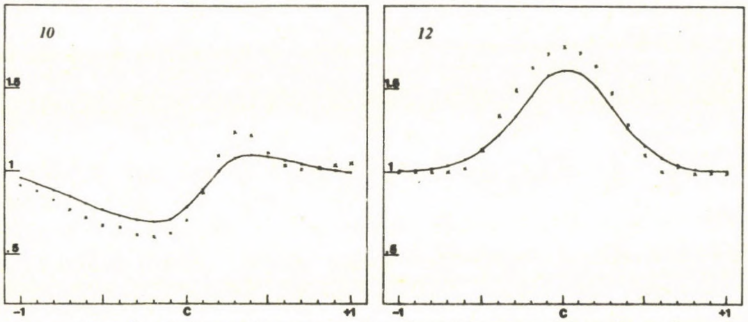


Fig.4. Integral contrasts (continuous lines) and the true intensity ratios (crosses).

7.) The values of integral contrast constitute a smooth curve in dependence of filter position, and so do the (1) I_i values, the total intensities transmitted by the filter.

EVALUATION OF THE MEASURED DATA

The error of the measurements consists of two parts: one is the local error (positional and photometric), the other is the background error originating in the smallness of the coverable chromospheric area and the uneven illumination.

The measured integral contrast functions were smoothed according to point 7.), and the resulting values were multiplied by the computed value of $\int H\alpha_0(\lambda)\cdot\varphi_i(\lambda)d\lambda$. In principle, this results the I_i values necessary to the (3) system of equations. However, these I_i values do not satisfy the other requirement of smoothness, mentioned in 7.). As a consequence, the received linear combination has an oscillating character. Many efforts have been made to exlude this instability of the (3) system by smoothing the I_i series. I tried to derive the requirement of smoothness from the analytical form of the filter transmission function. After the possible transformations, the I_i values should have been the points of a trigonometric polinom in dependence of the filter position, but unfortunately, the result turned out to be not satisfactory. Attempts were made with common smoothing procedures, and polinom fitting. The best result was achieved by twofold application of smoothing splines, and the evaluation of measurements was so performed. This results a small distortion, but checks made with the test functions showed, that it can be neglected. The smoothing requires the observations outside the ±0.8Å range also.

The Fig.5. shows the Hα profiles in the points denoted in Fig.2. The results of linear combinations are drawn with broken lines, for comparison, the quiet $H\alpha_0$ profile is drawn with dotted lines. The continuous lines show the resulting profiles after corrections, following from the experiences of the test function representations. This means a small widening of the profiles, and the biggest value of correction is 0.05 on the intensity scale. This smoothing is quite acceptable, because of the spectral resolving power of 0.3Å.

DISCUSSION

Let us summarize a few remarks by inspecting the Fig.5. The 1.,2.,7.,12. points are in plages, the increases of the central emerging intensity (r_c) of their profiles are between 0.07 (12. point) and 0.12 (1. point), these values are rather reliable according to the numerical tests. Their bisectors have similar characters. We saw in the numerical examples, that if a bisector had been shifted, or distorted, this was reflected by the bisector of the reconstructed profile, although the degree of the shift and the distortion was decreased, but the tendency was not altered. The 3., 8., and 13. points are placed in filaments, their central emerging intensities descend by 0.03 (13. point) and 0.05 (3. point) below that of the quiet profile, the 3. line shows a slight

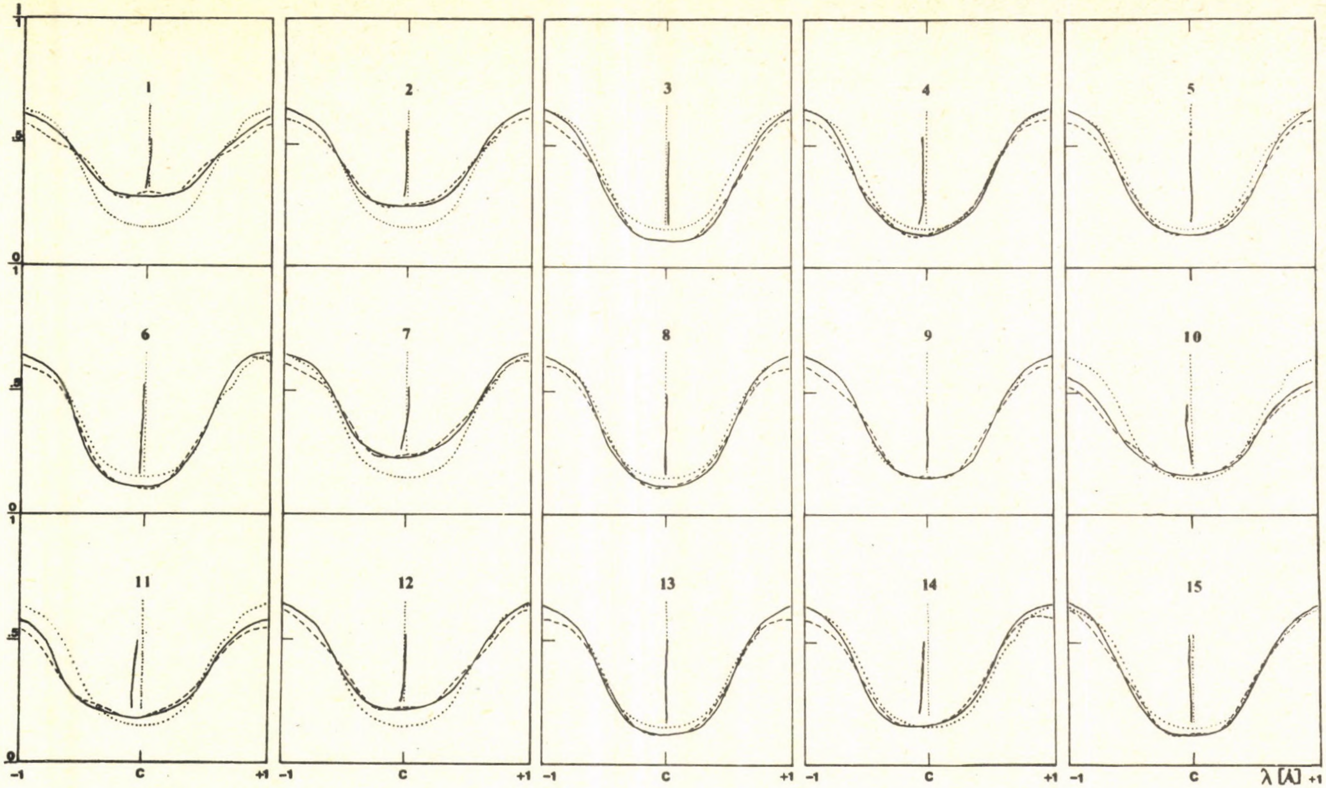


Fig.5. Hα line profiles in the points numbered in Fig.2.b. Profiles without correction are indicated by broken lines, after correction by continuous lines. The quiet Hα profile is displayed by dotted lines. The continuous bisectors belong to the continuous profiles, in comparison with the straight median lines (plotted with dots).

redshift. The 4.,5.,6.,15. points are in fibrils, the changes of their central emerging intensities are between -0.02 (2.) and -0.05 (6.). The 14. point is placed between two fibrils. Its r_c equals to that of the quiet line, but its blueshift is unambiguous. The 9. point is an arbitrarily chosen "quiet" locus. The 10. and 11. points have fairly similar profiles, the former is above a small spot, the latter belongs to a fibril, connected with the large spot, this fibril is visible up to the ±1Å photos. This line centres are more intense than the quiet line centre, but at the wings the darker spot and the fibril are visible.

The above examples show, that fairly similar line profiles are formed in the features of the same character in the active region. The presented method seems to be suitable (perhaps with further refinements) to supply data, which serve as an observational basis for modelling of chromospheric formations.

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