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Preliminary report

INSTRUMENTAL PROFILE OF THE DEBRECEN SOLAR SPECTROGRAPH

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SUMMARY: The solar spectrograph of the Heliophysical Observatory at Debrecen, Hungary, was investigated to determine its instrumental profile. The measurements were made by using a HeNe laser beam. The widths and asymmetries of the profiles decrease toward higher spectral orders, the most advantageous orders being the third and the fourth ones. To eliminate the broadening of solar lines on account of the instrumental profile, the straightforward iteration method of Gurtovenko has been applied. The efficiency of the method is demonstrated by the simulation of the broadened and corrected spectral line profiles.

Key words. Instrumentation: spectrographs – Methods: miscellaneous – Techniques: spectroscopic

1. THE INSTRUMENT AND MEASUREMENTS

The large coronograph of the Debrecen Observatory was designed in the 1950's, and a series of 9 such instruments were manufactured in the LOMO factory, Leningrad (Gnevyshev et al. 1967), and distributed in the states of the former Soviet Union, Poland and Hungary. This instrument is equipped with a large spectrograph of Czerny-Turner type. Most important parameters of the assembly: the objective has a diameter of 53 cm, its primary focal length is 8 m with a possibility to be enlarged by an auxiliary optics to a 12 m effective focal length. The spectrograph has a focal length of 8 m. Its grating is manufactured on a 25 × 23 cm glass plate containing 600 grooves per millimeter. The profiles of the grooves are optimized for the third spectral order.

The instrumental profile measurements are generally based on a light source providing a monochromatic feature which can be considered as having a negligible linewidth (with respect to the profile to be measured). Usually two kinds of sources use, a low-pressure glass tube (containing e.g. krypton gas) stimulated by a high frequency source excited from outside, or a gas laser. The former tool usually provides a fine narrow line with no interference problem, but it is usually fairly weak which makes the measurement difficult. The helium-neon gas laser provides the strong red line of NeI (λ = 6328.173 Å) but it has a disagrable feature: even the slightest amount of scattered light results in a fairly intense interference pattern on the detecting surface due to the highly coherent laser waves.

In the present work, the red line of a HeNe laser was used as a monochromatic light source. To eliminate the interference pattern mentioned, a matt plate was placed before the entrance slit and was kept in permanent motion during the exposures so that this diffuse medium blurred all sporadic interference fringes, and additionally ensured a reasonably uniform illumination of the collimator mirror. The detection was carried out by an SBIG-ST6 CCD camera.

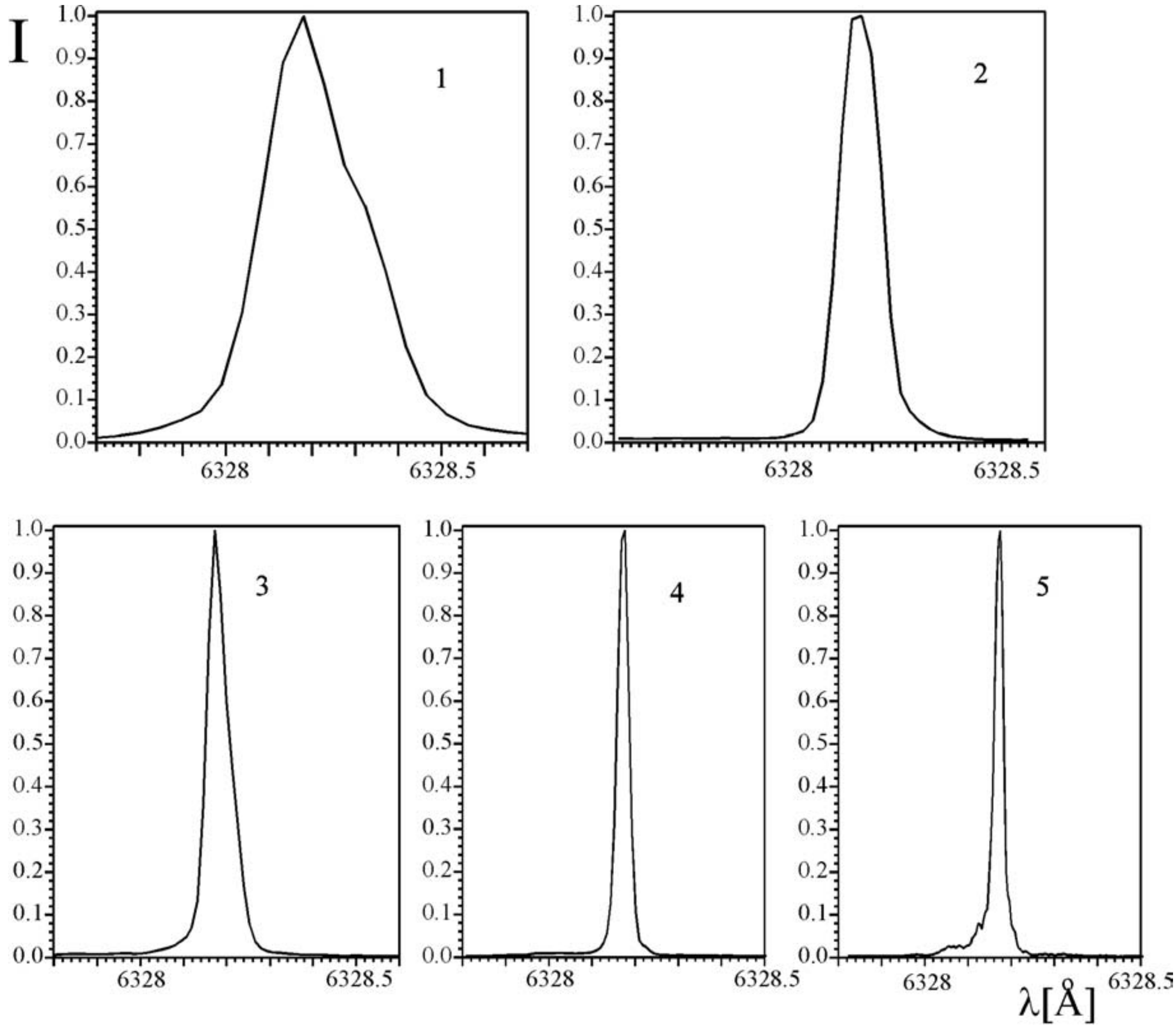

Fig. 1. *Instrumental profiles of the spectrograph in the first to fifth orders.*

The instrumental profile is affected by the width of the spectrograph entrance slit. From a former experience, a width of 50μm was selected. All measurements were carried out with this value, and it will be adopted in all further observations.

2. SHAPES OF THE INSTRUMENTAL PROFILES

The measured contours of the spectrograph instrumental functions in the first to fifth spectral orders are plotted in the Fig. 1. The widths of the profiles decrease as the spectral order is increased.

The full widths at half maximum (FWHM) of the instumental profiles decrease toward higher spectral orders. The obtained FWHM values are presented in Table 1.

Table 1. The measured FWHM values.

order	FWHM (mÅ)
1.	258,3
2.	108,7
3.	58,9
4.	32,2
5.	23,6

It is obvious from the above figures and table, that the first order is of no use for high resolution spectral line profile analysis because of the broad instrumental contour. Furthermore, the fifth order is also useless, in spite of the narrow profile and high dispersion, because the grating is positioned to almost grazing incidence ensuing a substantial intensity loss, and because the wings of this profile are asymmetric. Therefore, the performance of the spectrograph will be demonstrated in the second, third and fourth orders.

3. THE METHOD OF CORRECTION

As is well known, the instrumental function $h(\lambda)$ affects the input line profile $f(\lambda)$ in such a way that one detects a smeared output profile $(g\lambda)$.

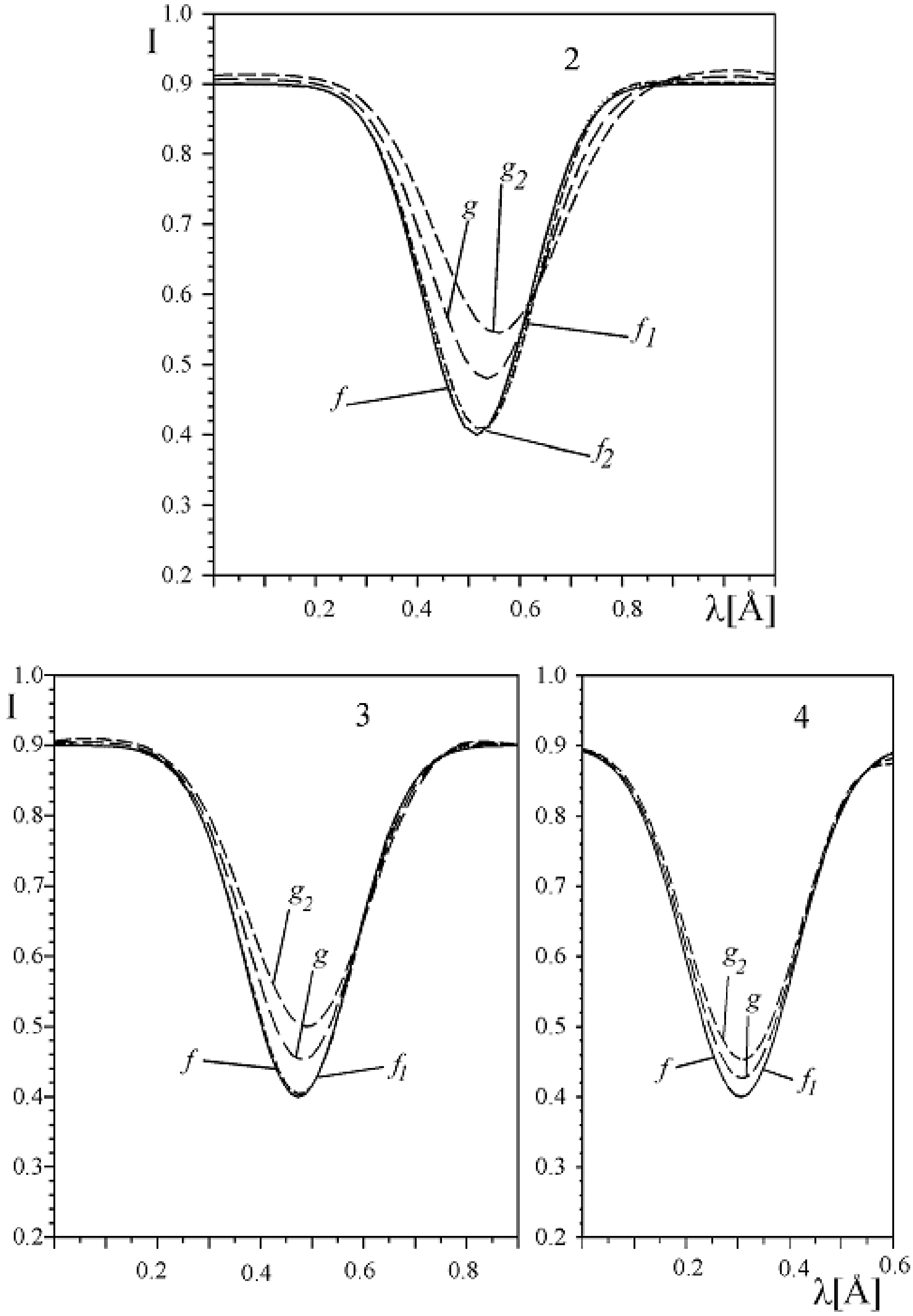

Fig. 2. *Corrected profiles in the second to fourth spectral orders according to Gurtovenko's method. Continuous line indicated by f: original solar line (arbitrary gaussian similar to a solar line), g: observed profile (smeared by the instrument), g_2: twice smeared profile, f_1 and f_2: first and second approximations.*

The observed contour can be expressed as a convolution of the true and instrumental profiles:

$$g(\lambda) = \int f(\lambda - x)h(x)dx.$$

As the function $f(\lambda)$ (the solar line) cannot be determined explicitely from this equation, some of the numerical evaluation methods should be applied. A widely used method is based on a Fourier transform procedure. Instead, we used a fairly straightforward iteration procedure which was described by Gurtovenko (1966). The procedure is referred to as the "method of doubled smearing". The idea is based on the assumption that, in a first approximation, the deviation of the true profile ($f(\lambda)$) and the measured (smeared) profile ($g(\lambda)$) is nearly equal to the difference between the once and twice smeared profiles.

Thus, for the first approximation of $f(\lambda)$, denoted $f_1(\lambda)$, we assume:

$$f_1(\lambda) - g(\lambda) = g(\lambda) - \int g(\lambda - x)h(x)dx.$$

Here the instrumental function is normalized; $\int h(\lambda)d\lambda = 1$. If the $h(\lambda)$ is narrow enough, this first step gives a satisfactory result, i.e. $f_1(\lambda) \cong f(\lambda)$, if this is not the case, then further steps can be made by the iteration formula:

$$f_n(\lambda) = f_{n-1}(\lambda) + g(\lambda) - \int f_{n-1}(\lambda - x)h(x)dx.$$

The effect of the above procedure can be demonstrated in the following way (see Fig. 2) A simple Gaussian curve which is comparable to an ordinary photospheric line (f) is taken, then smeared by the measured instrumental profile (g), and two iteration steps are carried out to reconstruct the original profile. As can be expected, the effect of the instrumental smearing decreases with increasing order because of the diminishing half width. It is also worth mentioning that the asymmetry of instrumental origin can be observed on the smeared profile (mainly in the second order) but the above procedure also helps eliminating it.

4. CONCLUSION

Figs. 1 and 2 demonstrate that the most advantageous spectral orders of the Debrecen spectrograph are the third and fourth ones. The first order provides a too broad and asymmetric profile which does not allow precise observations. The correction procedure provides satisfactory reconstruction in the second order, but the most precise measurements are possible in the third and fourth orders. These data and method will be used in all future spectral observations carried out in Debrecen. As a further advancement we hope to complete the present data with measurements at other wavelengths, or possibly by a different approach as a check.

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ИНСТРУМЕНТАЛНИ ПРОФИЛ СУНЧЕВОГ СПЕКТРОГРАФА У ДЕБРЕЦЕНУ

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Претходно саопштење

Одредили смо инструментални профил сунчевог спектрографа Хелиофизичке опсерваторије у Дебрецену (Мађарска). Мерења смо вршили користећи HeNe ласерски сноп. Ширина и асиметрија профила опадају са повишењем спектралног реда и најпогоднији су трећи и четврти ред. За одстрањивање ширења сунчевих линија услед утицаја инструменталног профила примењен је један итерациони поступак који је увео Гуртовенко. Ефикасност поступка је приказана помоћу симулације ширења и корекције профила спектралних линија.