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Preliminary report

INTERFERENCE FRINGES OF A CCD CAMERA

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SUMMARY: Very high interference disturbance has been noticed in a SBIG ST-6 CCD camera when applied in solar spectrophotometry. The interference fringes have been removed by tilting the plane of the CCD receiver with respect to the optical axis of the spectrograph Littrow lens.

1. INTRODUCTION

A long-term observation program of Fraunhofer spectral lines is in progress at Belgrade Observatory. The program was proposed by Arsenijević et al. (1987) and elaborated by Vince et al. (1988), Skuljan et al. (1992 a) and also in Skuljan et al. (1992 b) where the first results on equivalent widths of some spectral lines were presented.

The equatorial solar spectrograph (Kubičela 1975) was used as a photometric scanner (Arsenijević et al. 1988). The application of a CCD radiation receiver at the focal plane of spectrograph has been considered lately.

In many CCD cameras unwanted interference fringes appear disturbing the images of the observed objects as well as the background of the picture. Even if the fringes are negligible or completely absent in white light or in glass-filter defined wavelength intervals of observation, they may readily appear in monochromatic light in spectrophotometric applications. The observers usually try to obtain the same fringes pattern in the corresponding flat field image and to eliminate them through a proper flat-fielding procedure, e.g. Collados and Rodriguez (1993).

Here we present another approach to the fringes problem and its solution.

2. OUR APPROACH

In the absence of a proper CCD camera for spectrophotometry, a Santa Barbara Instrument Group ST-6 professional CCD imaging camera has been applied at the equatorial solar spectrograph of Belgrade Observatory. Besides some other acceptable properties of this camera (resolution, sensitivity, spectral and photometric response) and some available software, it yielded images heavily disturbed by the interference fringes (Figure 1a). Here a 0.2 nm portion of the solar spectrum around the Na I 568.26 nm Fraunhofer line is shown. Few other flaws (gray dots) appearing in Figure 1 are irrelevant for our further discussion.

The Belgrade spectrograph is a Littrow-type instrument arranged in the way that the entrance slit is placed in the plane of dispersion (being, of course, perpendicular to the same plane). In this case the angle of incidence, α in Figure 2 of the light falling at CCD surface which is perpendicular to the optical axis (CO) of the Littrow lens, (L), amounts to about 0.°6. Here the effect of an existing Barlow lens, not shown in Figure 2, has been taken into account.

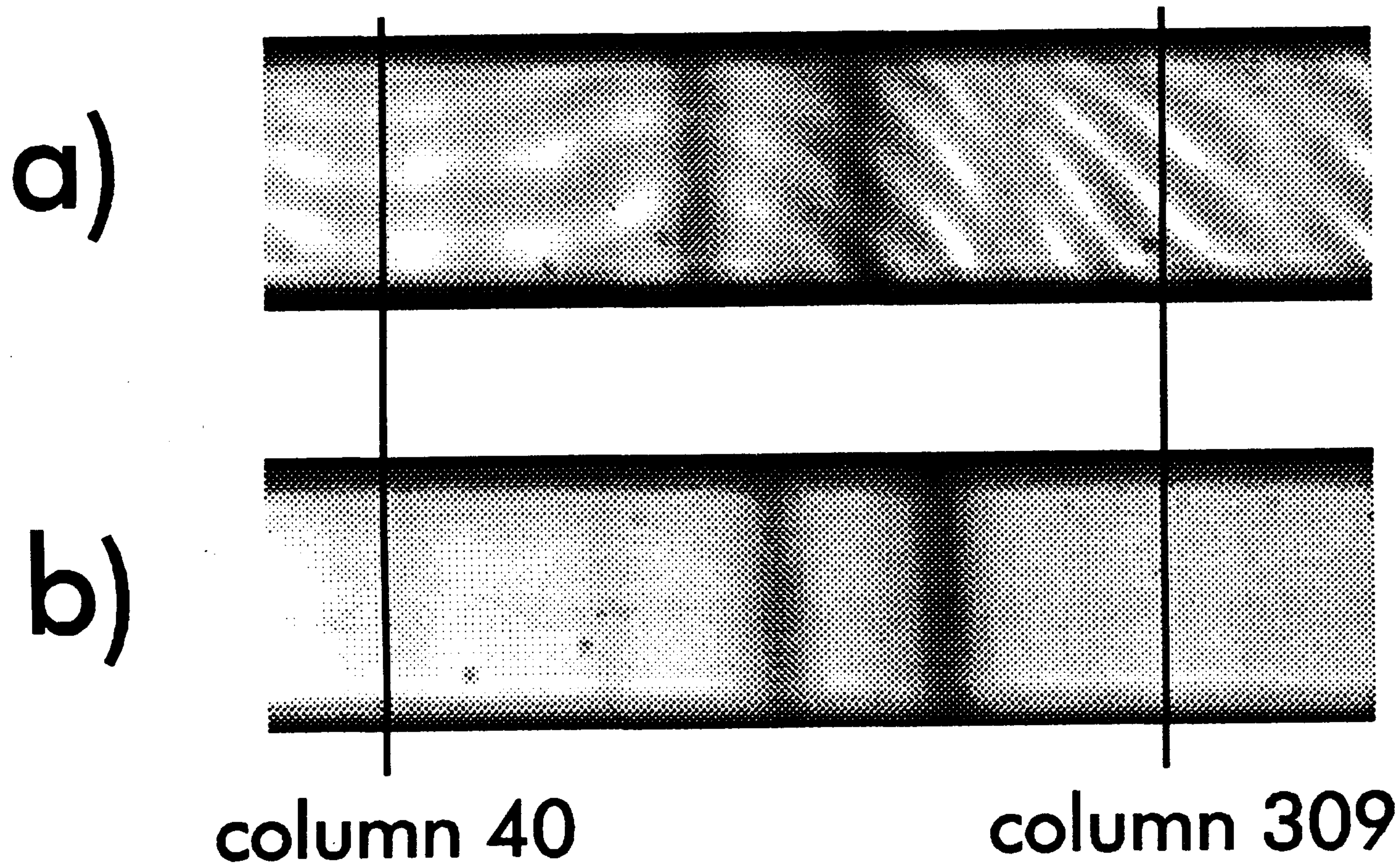

Fig. 1 Solar spectrum around Na I 568.26 nm spectral line taken with SBIG ST-6 CCD camera: a) in the original arrangement of the spectrograph, and b) with the spectrograph rearanged to remove the interferometric fringes. The windows comprize 80×375 pixels. The columns 40 and 309 along which the photometry has been done are pointed out.

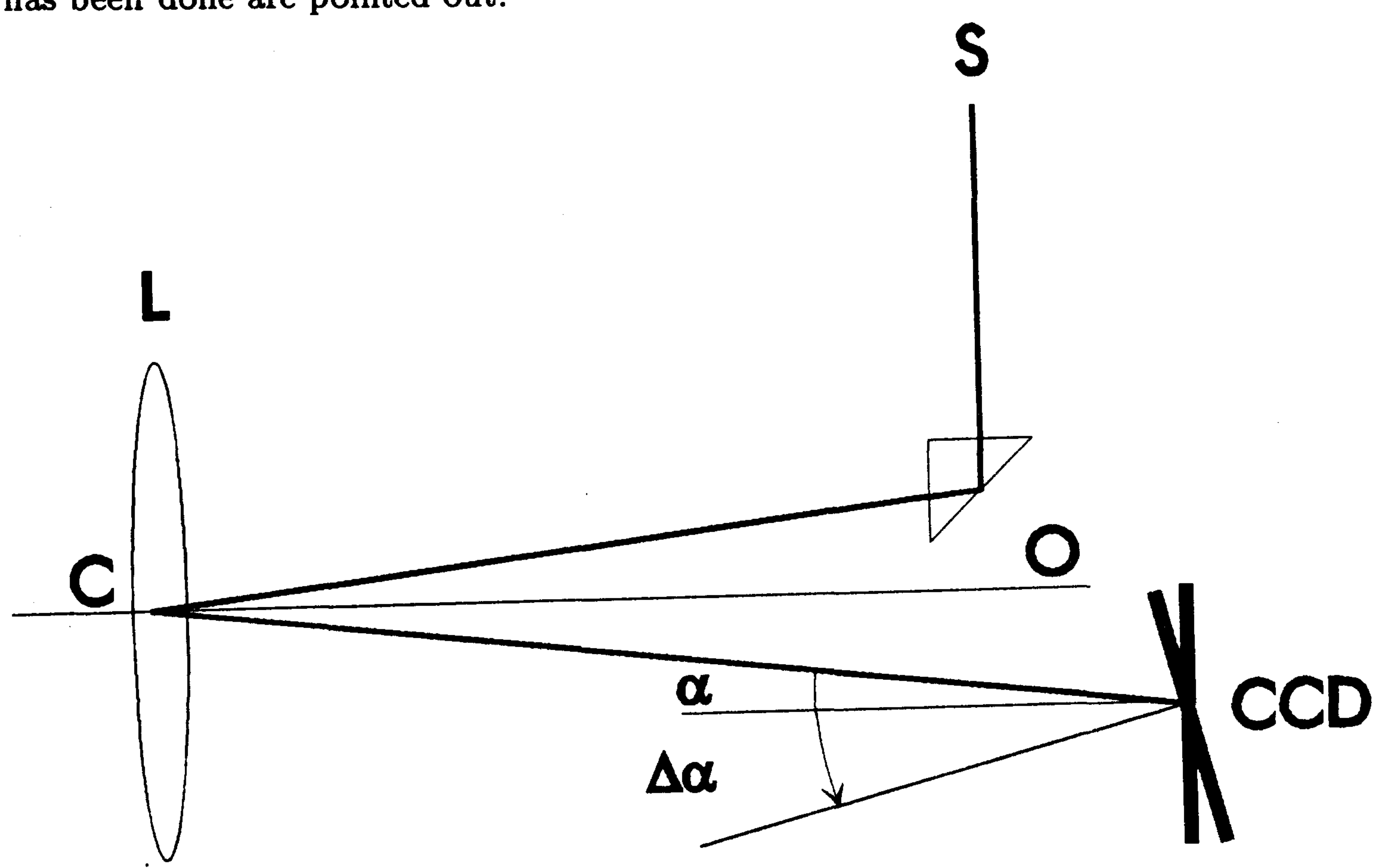

Fig. 2 Simplified lay-out of the spectrograph. S – entrance slit, L – Littrow lens, CO – its optical axis, CCD – radiation receiver in its normal and rotated positions.

Expecting that the conditions favouring the interference in front of the CCD chip could be broken off by increasing α we rotated the chip around an axis perpendicular to the dispersion plane for an additional angle $\Delta\alpha$. Indeed, when $\Delta\alpha$ amounted to 2^o the contrast of the interference fringes considerably decreased. Further, when $\Delta\alpha = 4.6^\circ$ was applied, the fringes completely disappeared (Figure 1b).

In the new situation the spectral dispersion and the focusing accuracy as well as the CCD receiver efficiency have been changed. The total incident angle at the CCD $(\alpha + \Delta\alpha)$ amounted to $5^\circ\!.2$. Let the spectral dispersion, expressed in nm/mm in CCD position perpendicular to the optical axis (CO), be D. Now, it has changed to $D\sec(\alpha + \Delta\alpha)$. The focusing error at the extreme parts of the 8.6 mm long CCD chip, introduced by the angle $\alpha + \Delta\alpha$, amounts to less than $\pm$ 0.4 mm with respect to the center of the chip. It is hardly detectable in the maximal F:50 Littrow light beam, and in our regular beam of integrated Sun light amounting to about F:100 it is negligible. Also, a non-zero incidence angle of the radiation reaching the CCD surface causes a lower illumination of the pixel area in proportion with $\cos(\alpha + \Delta\alpha)$. However, in our case this effect, amounting to less than 0.5%, is negligible.

The absence of interference patterns in Figure 1b has been checked photometrically. In spite of a slight shift of the spectral lines between Figures 1a and 1b, caused by necessary manipulation of the instrument, the photometric profiles have been done along the same pixel columns, No. 40 and No 309, in both spectra. One of this positions (40) covers some low-contrast fringes and the other (309) crosses the pattern of a quite high contrast. The scanning was performed between pixel rows 30 and 60 yielding 31 measured data along each scan. This is the region of the image where we usually measure the spectral lines. The results are shown in Figures 3 and 4.

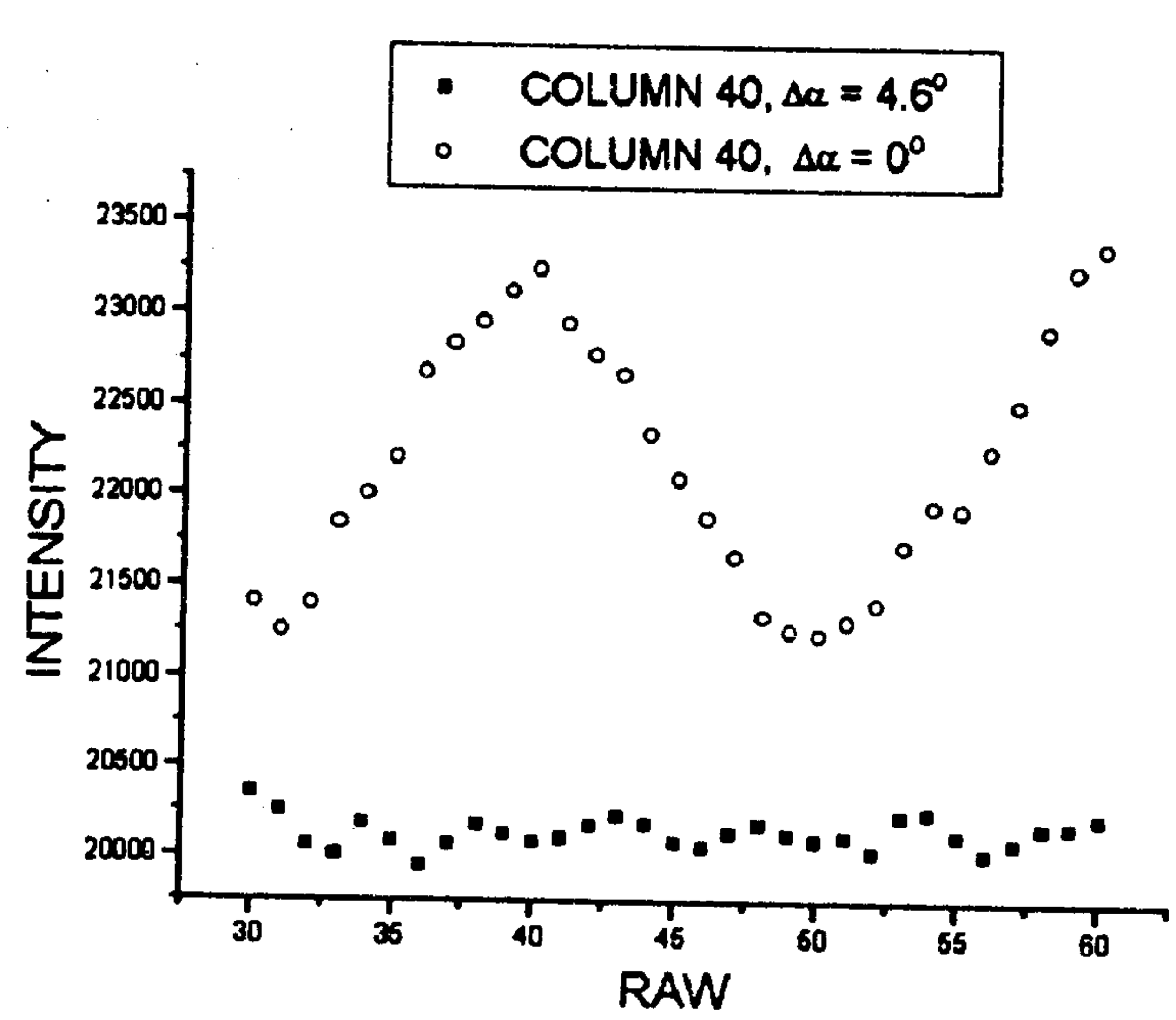

Fig. 3 Photometric profile along the 40-th column of pixels between rows 30 and 60 in normal position of CCD chip ($\Delta\alpha$=0) and in its rotated position ($\Delta\alpha$=$4^\circ\!.6$). Intensity is expressed in instrumental units. Note the absence of any large sine-wave disturbance in the rotated case.

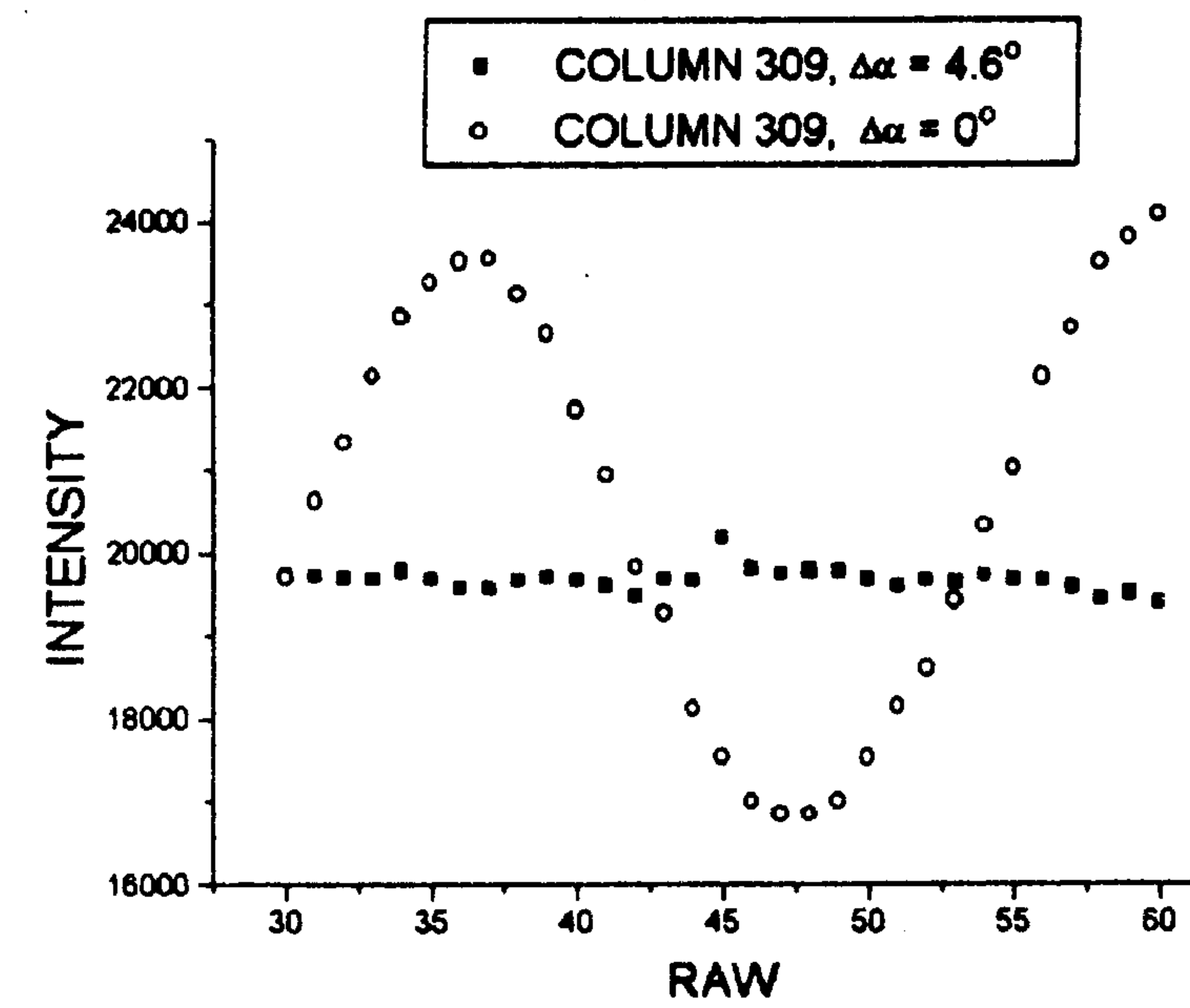

Fig. 4 Same as Fig.3 but for the 309-th column.

One can easily see that high-amplitude interference signal in $\Delta\alpha = 0$ ° in both Figures is not recognizable in $\Delta\alpha = 4^\circ\!.6$ cases. The interference pattern is lost below the noise level in the last curves where standard deviation amount to $\pm$85.7 instrumental intensity units or $\pm$ 0.43 % of the spectral continuum level and $\pm$ 137.6 intensity units or $\pm$ 0.70% of the continuum for the 40th and 309th columns, respectively. At this point it has to be noticed that in our procedure no flat-fielding has been done. Were the flat field applied, one could expect a somewhat lower noise level - but certainly with no qualitative consequences on the present results.

3. CONCLUSION

The interference fringes originating near the surface of the CCD chip have been successfully removed by increasing the light incidence angle. It is to be expected that this procedure can be applied in all other similar cases. Somewhat lower efficiency of the receiver caused by its inclined position may usualy be neglected, and the corresponding increase of the spectral dispersion has to be taken into account. Certain loss of spectral resolution due to focusing errors at the ends of the CCD chip must remain below the desired limit. This may impose a limit on the CCD inclination angle.

However, in some cases rotation of the receiver around an axis lying in the spectral dispersion plane can be considered as equally suitable.

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ИНТЕРФЕРЕНЦИОНИ ПРСТЕНОВИ ЈЕДНЕ CCD КАМЕРЕ

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Претходно саопштење

Приликом примене једне SBIG ST-6 CCD камере у Сунчевој спектрофотометрији примећени су јаки интерференциони прстенови на спектрограмима. Ови поремећаји уклоњени су променом нагиба равни CCD пријемника у односу на оптичку осу Литровљевог сочива спектрографа.