CORONAL LINE PHOTOMETER

MILAN MINAROVJECH and MILAN RYBANSKÝ

Astronomical Institute, Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Czechoslovakia

(Received 20 August, 1991; in revised form 29 December, 1991)

Abstract. A new photoelectric photometer to determine intensities of the spectral lines of the solar corona is described. The measurements cover the range from 400 nm to 900 nm with a time resolution up to 0.04 s. Starting from 1 January, 1991 the new photometer is used for patrol observations of the green (λ530.3 nm) and the red (λ637.4 nm) coronal lines at the coronal station Lomnický Štít.

1. Introduction

Long-term patrol observations of the emission coronal line intensities permit the quantification of the solar coronal activity at all heliographical latitudes. Apart from these, coronal measurements enable us to obtain a physical measure of the solar activity level. These reasons probably led d'Azambuja (1947) to publish such observations. The intensity data of the main coronal lines from the world network of Observatories have been published in *Quarterly Bulletin on Solar Activity* over the years 1947–1989. Sacramento Peak coronal data in graphical form are published in *Solar Geophysical Data – Prompt Report* since 1977. The values from all coronal stations, homogenized to the Lomnický Peak photometric scale, are available from the authors and are continuously published in *Contributions of the Astronomical Observatory Skalnaté Pleso*. The 1971–1985 data have been published already (Rybanský, Rušin, and Dzifčáková, 1990; and references given therein). The coronal index of solar activity over the period 1964–1987, derived from the green line homogenized intensity has been published already (Rybanský, Rušin, and Dzifčáková, 1990). Monthly means of the coronal index (CI) together with the amplitude of daily values are shown in Figure 1.

The second problem is connected with the spectral analysis of different coronal features, i.e., coronal condensations. Such features have lifetimes from several hours to several solar rotations. A record of the green coronal line with its surrounding is shown in Figure 2.

The third problem is also of considerable astrophysical interest, but with features of very short lifetime, i.e., oscillations (all parameters of the coronal line should be observed), coronal mass ejections etc. The time resolution needed for such a study is 1 s. Figure 3 shows the total intensity variation of the green line obtained with a new photometer.

This paper describes this new photoelectric coronal photometer, which is a contribution to solar coronal research in the direction discussed above. Experimental problems of coronal observations, construction of the photometer and the first results are described in the next sections.

Solar Physics **139:** 1–6, 1992.

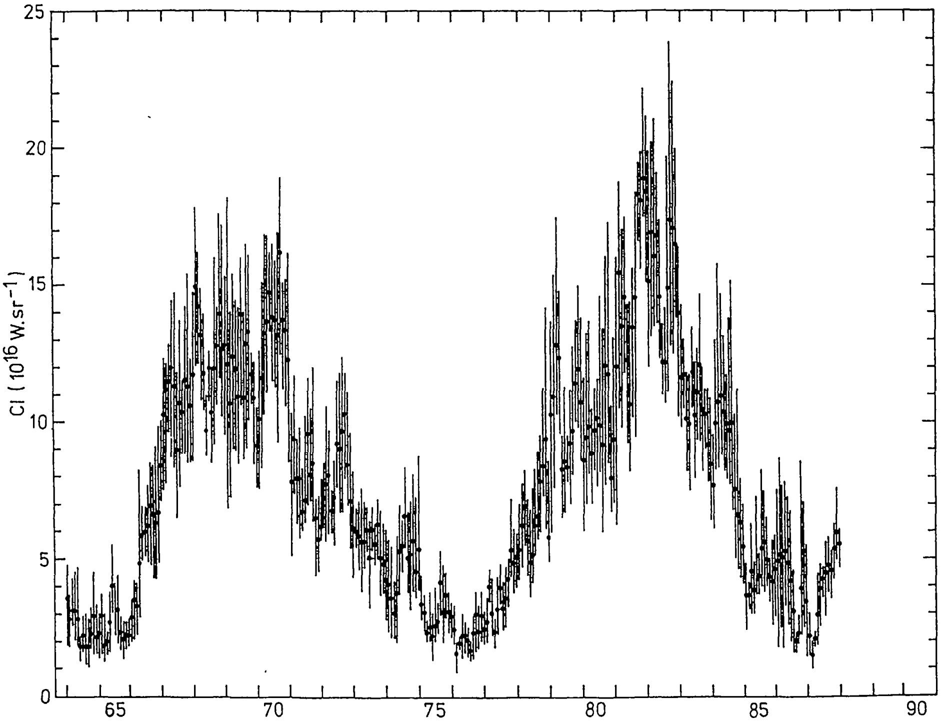

Fig. 1. Coronal index of solar activity (monthly means and extreme daily values at a given month) derived from the 530.3 nm line intensity in the years 1964–1987.

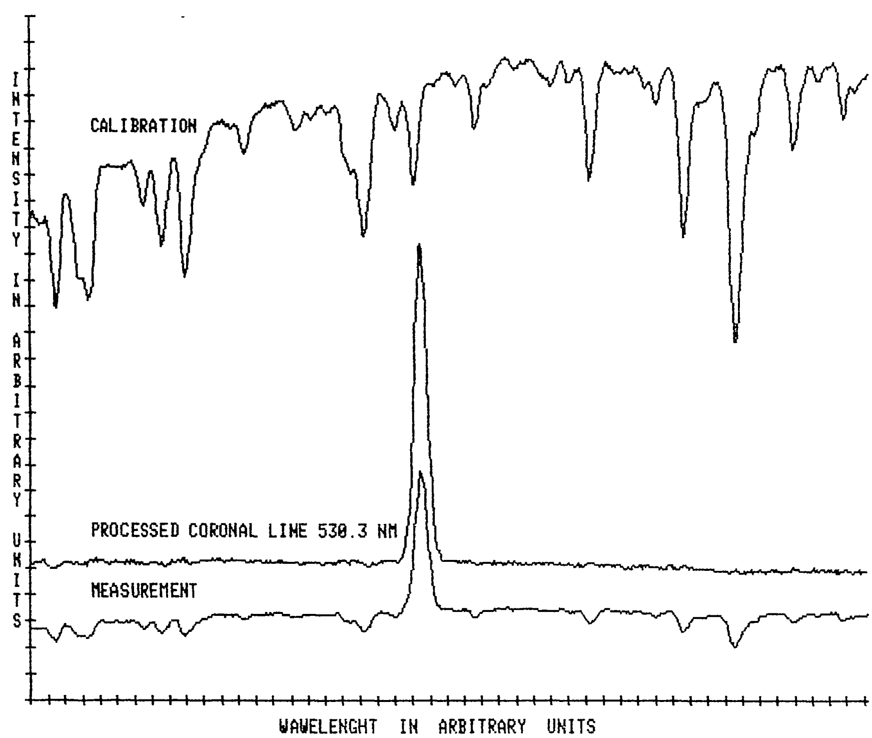

Fig. 2. Tracing of the 530.3 nm spectral region on October 17, 1990 at P.A. 340°. Calibration, measurement and resulting emission, averaged 100 ×.

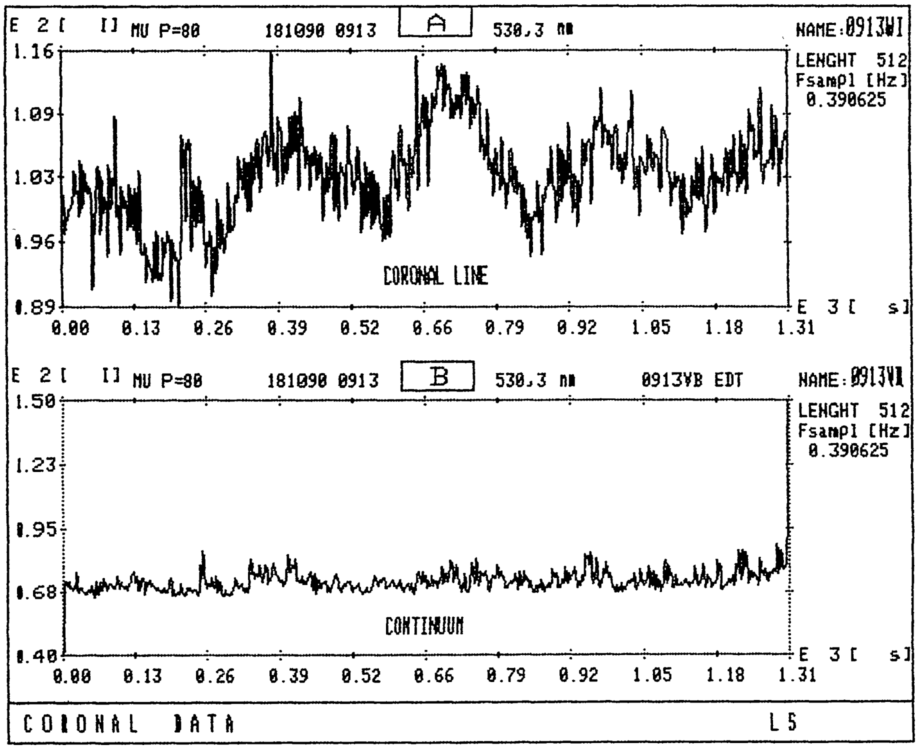

Fig. 3. The green line intensity variations (A) and the background (B). Taken on October 18, 1990 at P.A. 80°; t = 1310 s.

2. Experimental Problems of Coronal Observations

Scattered light of the solar disc in the Earth's atmosphere and in the telescope is the basic obstacle that must be removed. The ratio between the lower part of the solar coronal brightness and solar disc brightness varies from 5×10^{-4} (in the most intensive spectral lines) to 10^{-6} in the continuum. To this useful signal the scattered light is added, which may very quickly vary because of scintillation, so that only differential methods of measurements may provide reliable results.

Several different photoelectric spectrophotometers are used in astronomical observations. However, to make a photoelectric photometer for coronal lines is a problem. Up to now only one coronal line photometer is working, which was described by Fisher (1973) and Smartt (1982). Firstly, it is necessary to take into account that a very low light level is measured (photographic exposures are about 5–10 s with a very sensitive emulsion, 1000 ASA) immediately above the solar limb. The selection of a detector is critical: it should be something between a photodiode and a photomultiplier. The photocell has low sensitivity. A useful signal at normal temperatures is below the noise level. An integration reduces the time resolution. The same is valid for a CCD detector. Using a photodiode or a CCD with an amplifier requires the cooling of the detector. The use of a photomultiplier is risky because an increase of scintillations could occur and lead to its destruction. The measurements of coronal intensities at Sacramento Peak Observatory are for this reason made 240″ above the solar limb instead of 40″ generally used following the accepted convention. However, the most active phenomena which could influence the whole corona have their place very close to the chromosphere. When the height above the solar limb increases, the efficiency of studying active phenomena decreases.

A TV camera with an image amplifier is the detector in our photometer. A strong increase of the light on the detector causes its saturation, but no destruction occurs.

3. Description of the Coronal Photometer

The coronal photometer consists of the following parts:

- a modified SIT vidicon TV camera, type ITV 11–22,
- an electronic measuring module,
- a 16-bit processing computer, type M3T 320.

Pictures of the coronal spectra using the TV camera with regulated sensitivity are recorded from a spectrograph output. Selected fields of video signal on the output of the TV camera are marked out with two pairs of movable cursors. The voltage course of the video signal from the TV camera output, which belong to the cursor's selected sections, are integrated. Within each pair of cursors the integrals of the dark current, the observed spectral line and the continuum are measured. The nonlinearity of the full measuring system has been tested, and is less than 0.5%. The data from a selected number of lines of the TV frame are processed in real time in the electronic module and converted using an A/D converter to eight digital bits. The measured light intensities of selected spectral fields are simultaneously displayed together with a picture of the observed spectra and cursors on the TV monitor screen, as is shown in Figure 4. The

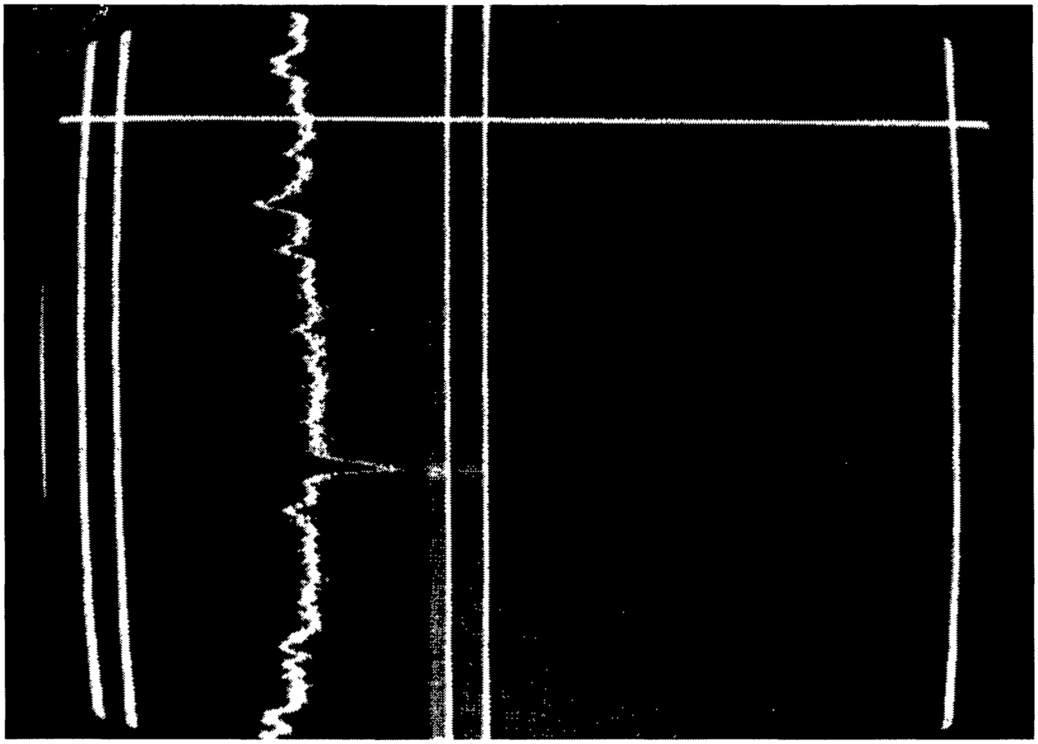

Fig. 4. Display on the monitor during the green-line intensity measurements (see details in text).

direction of the TV frame lines is across the direction of the spectral dispersion. The first pair of cursors, located in a dark area of the picture, defines the field where the dark signal current is measured. The second pair of cursors, located on the recorded picture of the spectra, defines the area where the spectral line intensities are measured.

The unprocessed values of measured and digitized signal are displayed for each line through points shown by the displayed curve. The cursors on the margin of the picture show the limited range values of the measured data. The cursor, located in the direction of the TV frame lines, defines the number of transmitted digitized data from the TV frame to the processing computer. The data from the output of the electronic module are transmitted in real time to the processing computer using an optical cable.

Depending on the type of observation, the measured dark current, the calibration signal obtained from the center of the solar disk in the same spectral region, and the data from the observed section of the coronal spectra usually consisting of 2×512 byte for each TV frame are processed by the computer. Furthermore, the header parameters of the coronal emission line and the intensity of the continuum are obtained.

The measurement can be performed in the spectral range 400–900 nm. A time resolution of 40 milliseconds is given by the frame frequency of the TV camera. Depending on the selected number of averaged measurements, the final data are obtained with 16 values. The effective time of measurement is 0.64 s.

4. The First Results

The new photometer has been tested since July 1, 1990. From January 1, 1991 routine measurements of green and red coronal line intensities have been made. However, it was impossible to carry out a measurement at 40″ above the solar limb because of very frequent saturation of the photometer. A new height of measurement has been chosen experimentally: 55″ above the solar limb. Similarly, the course of the green and red coronal line intensities was extrapolated from the observed height towards 40″.

For the green line we found:

$$I' = 1.39I \qquad \text{for } I < 36 \tag{1}$$

and

$$I' = 49 + (I - 35)^{1.14} \qquad \text{for } I \geq 36 \,. \tag{9}$$

For the red line λ637.4 nm:

$$I' = 1.53I \qquad \text{for all } I \,. \tag{3}$$

I' denotes intensity at the height 40″, I at the observed height 55″.

The unit is the equivalent width in 10^{-16} m or 10^{-6} Å of the adjacent continuum spectrum of the solar disc center at the same wavelength.

To guarantee the continuity with the preceding routine data set, the I' will be further published.

References

d'Azambuja, L.: 1947, *Quart. Bull. on Solar Activity*, No. 77.
Fisher, R. R.: 1973, Sacramento Peak Obs., AFCRL–TR–73–0696, No. 205.
Rybanský, M., Rušin, V., and Dzifčáková, E.: 1990, *Bull. Astron. Inst. Czech.* **41**, 79.
Smartt, R. N.: 1982, *SPIE*, Vol. 331, Instrumentation in Astronomy IV, p. 442.