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Professional paper

A NEW COMPUTER SYSTEM FOR POLARIMETRIC MEASUREMENTS

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SUMMARY: A new computer-based system for polarimetric measurements has been developed at the Belgrade Observatory to replace the old analog-digital one. The system consists of a standard PC computer, expanded with a 12-bit AD/DA card, which is directly applied to the output signals from the photomultiplier and the position angle marker of the polarization analyzer. A special software package has been developed to support all the steps in the observing process. Finally the new system has been tested and compared with the old one, using a group of standard polarized stars.

INTRODUCTION

Polarimetric measurements of Be stars have been carried out at the Belgrade Observatory since 1974 with the 65-cm Zeiss refractor (Kubičela *et al*, 1976). The stellar polarimeter was modified in 1979 (Arsenijević *et al*, 1994) but only a partial analog-to-digital conversion has been implemented by introducing a special device (KRS 24-100) which converted the analog signals into the digital ones, and saved them onto an audio cassette. The data from the cassette could partially be processed (only the calculation of amplitudes and phases was performed) by an old-type computer (Wang). The rest of the reducing procedure was performed by another old-type computer (Spectrum) but the output data from the Wang had to be entered into the Spectrum, typing them manually. All the advantages of using the modern PC technique including the final result presentation and the analysis were simply unfeasible in such a scheme of the measuring procedure.

In order to overcome this problem we decided to replace the old measuring system and make it completely PC-compatible. Instead of the Wang-compatible digital cassette recorder (KRS) we used a simple PC XT computer which is capable to directly read the input signals via a standard AD/DA data acquisition card. Of course, a special software had to be developed to support this configuration. The software is intended to replace all the analog devices used with the old system (Servogor, XY plotter) as well as to store all the relevant measuring data onto a disk, for further processing. Once read into the computer, the measured data can easily be processed and presented by means of standard programming.

MEASURING SYSTEM

The old measuring system is illustrated in Figure 1. The light from a star passes through a rotating polaroid and reaches the photomultiplier. The signal from the photomultiplier, amplified by the Keithley model 410 Micro-microammeter, goes to the AD converter and the tape recorder (KRS 24-100, Mess System Technik) where it is integrated over a period of 4 seconds, converted into digital form and saved onto an audio tape. The polaroid rotates with a period of 60 seconds. During that time, the KRS makes exactly 15 values of the input signal and a cycle is finished. Another signal called the *mark signal* is generated by a special electric contact mounted on the polaroid axis to indicate the start of a new cycle. The KRS starts reading and saving the input data only when it detects an arbitrary starting mark signal selected by the observer. A typical measurement consists of several cycles (each having 60 seconds duration). The measured values of the input signal corresponding to the same phase of the rotating polaroid are then overlapped to form a unique sequence of 15 data sets called ***channels***. Of course, these are no physical channels. Each set is only to be related to the same 24° position angle interval of the polaroid during its rotating cycle.

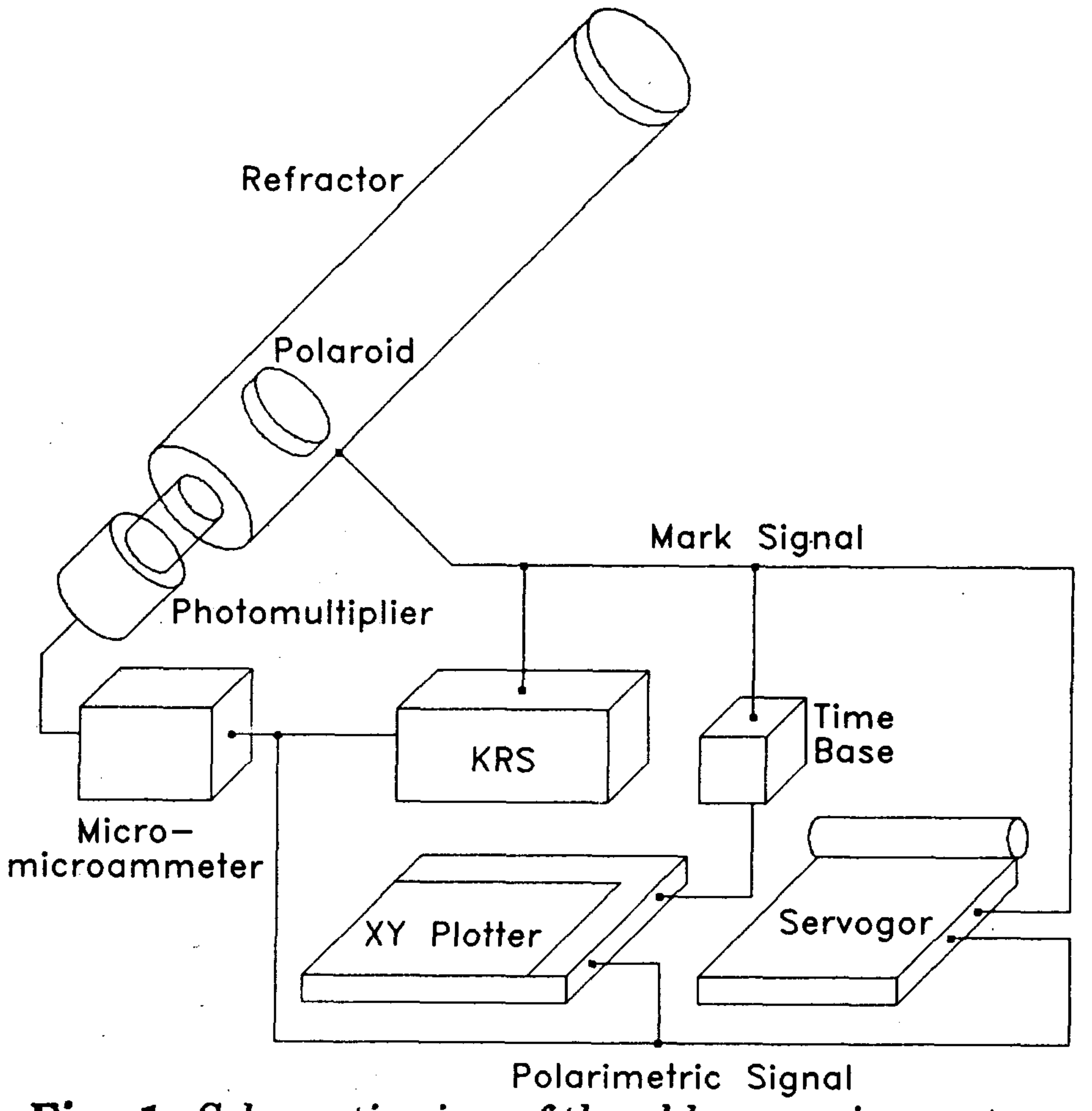

Fig. 1. Schematic view of the old measuring system.

The polarimetric signal is also transferred into two analog printing devices, in order to record the observation. The XY plotter (Philips XY Flat bed Recorder PM8120) gives the overlapped picture of all rotating cycles, while the Servogor gives the whole history of the measured signal. The time coordinate of the XY plotter is driven by the Philips Time-Base Generator.

The new measuring system is shown in Figure 2. The signals from the photomultiplier and from the position marker are both connected with the input port of the AD/DA card.

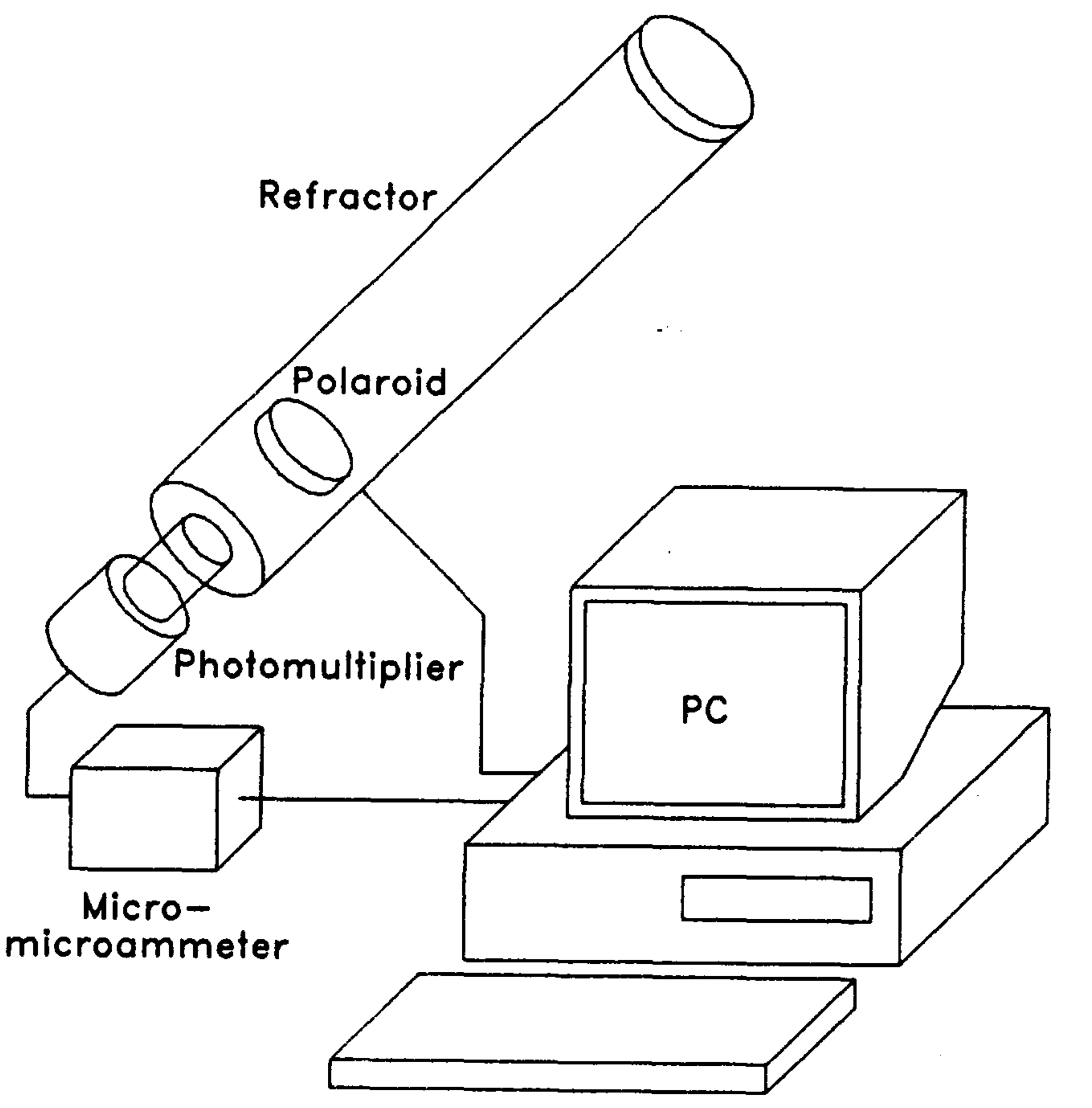

Fig. 2. Schematic view of the new measuring system.

The AD/DA card used in this work is relatively cheap and simple, but still good enough for precise professional measurements. It contains 16 independent analog-to-digital channels. Each channel can take an input signal ranged from 0 V to +10 V (unipolar operation) or from −10 V to +10 V (bipolar operation). The AD converter is driven by the corresponding software. It takes 60 μs to build each bit of the resulting value. A total time of less than 1 ms is necessary to convert any value in the input range into a 12-bit integer value (0–4095 in decimal representation).

We used the input channel 0 for the signal from the photomultiplier and the input channel 7 for the mark signal. The computer reads both input signals simultaneously and builds the corresponding sets of 15 input values during each rotating cycle of the polaroid. The integration of the input signal is performed by the same software. The computer reads the signal every few milliseconds and takes an average over a period of 4 seconds. The data are simultaneously displayed on the screen and saved onto the disk for further analysis.

SUPPORTING SOFTWARE

A special software is developed to support the whole measuring procedure, replacing all the devices used with the old system. The typical view of the main working panel of the program is shown in Figure 3. The screen is separated into several windows, each having its own function.

Two head windows hold the title, the date and the time of the observation. Corresponding Julian Date is also displayed. Both mean time and sidereal time are shown, updating properly every second. Under the head windows there are four working windows.

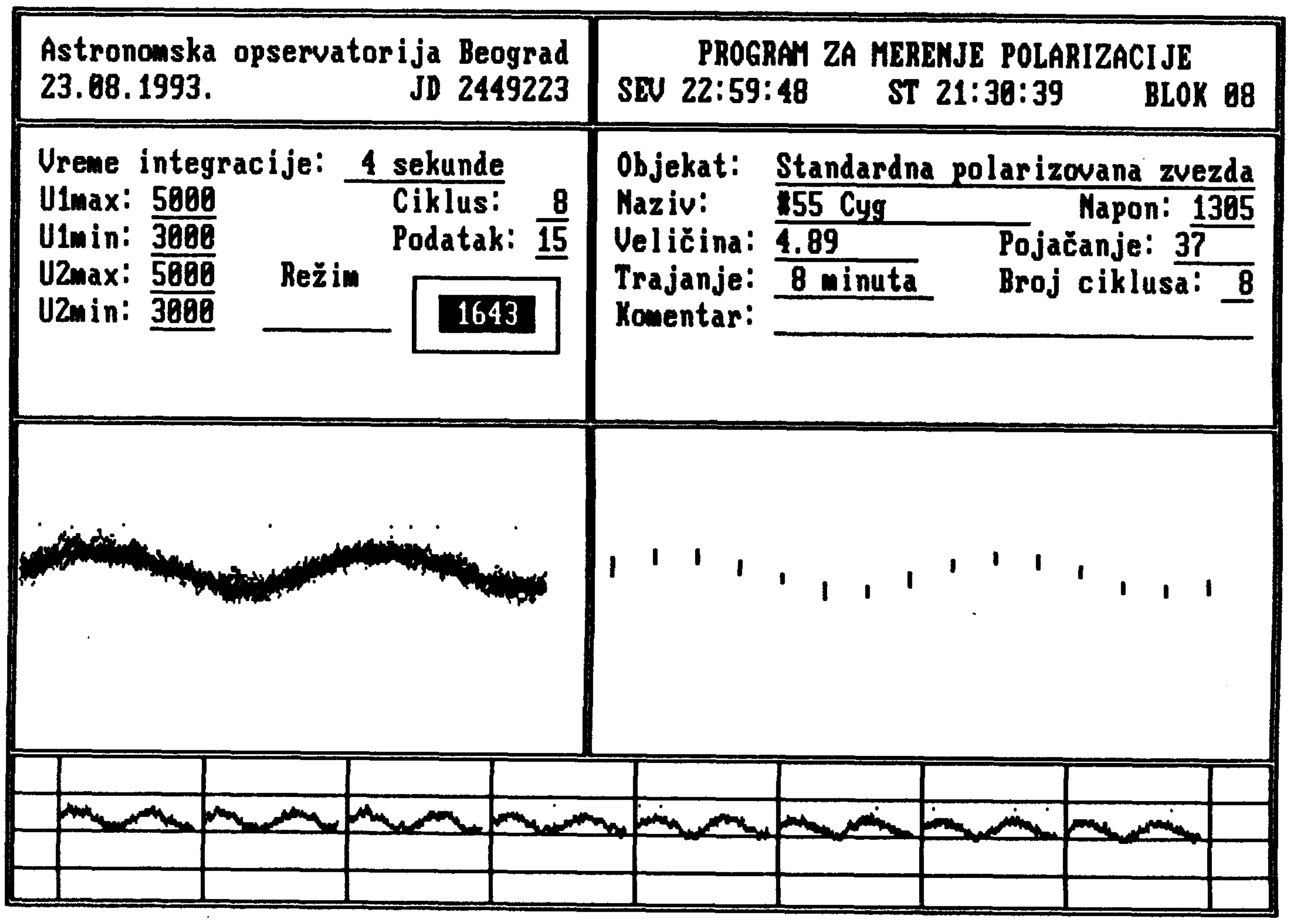

Fig. 3. The main working panel of the program supporting the observing process.

The two upper working windows hold all the necessary data concerning the measuring and the data presenting process (the type and the name of the object being measured, its magnitude, corresponding amplification, number of cycles, period of integration, and so on). Each data item can be changed, retyping it from the keyboard. Only when the observer is fully satisfied with the contents of these two windows, he may start the measuring process.

Two lower working windows hold the graphic presentation of the signal being measured. Real time values are plotted on the left window, while the integrated values (averaged values over the period of 4 seconds) are plotted on the right window. In both windows the horizontal axis shows the time from 0 to 60 seconds (one rotating cycle of the polaroid). Each cycle starts from point 0, overlapping the previous ones. Both windows have the same vertical axis showing the signal level in mV. The full scale of 0–5000 can be changed by retyping the values U1min and U1max.

Finally, there is a separate bottom window holding the real time signal shown in continuous time scale (without overlapping). Maximum of 8 cycles can be plotted separately. The vertical axis of this window also shows the signal level in mV, and is scalable by retyping the variables U2min and U2max.

The measuring process has two modes of operation. In the asynchronous mode, the input signal is read and plotted on the screen regardless of the mark signal. This means, the measurement will start immediately after pressing the start key, whether the mark signal is reached or not. Using this mode, the observer can properly rescale the signal axes of the graphic windows, and check the quality of the signal. In the synchronous mode, the computer waits for the mark signal and starts the measuring only when the mark is reached. The observer can control the duration of the measurement (the number of cycles), or he can break the process at any time, should something go wrong.

Once the measuring process is completed, the data can be saved onto the disk for further analysis.

RESULTS OF MEASUREMENTS

After the installation of the new measuring system, polarimetric measurements have been carried out simultaneously, using both systems. This allowed us to make a comparison of the two measuring systems. Several standard stars with well-defined polarization (the only exception is a program star μ Cep) were observed. The results of these observati-

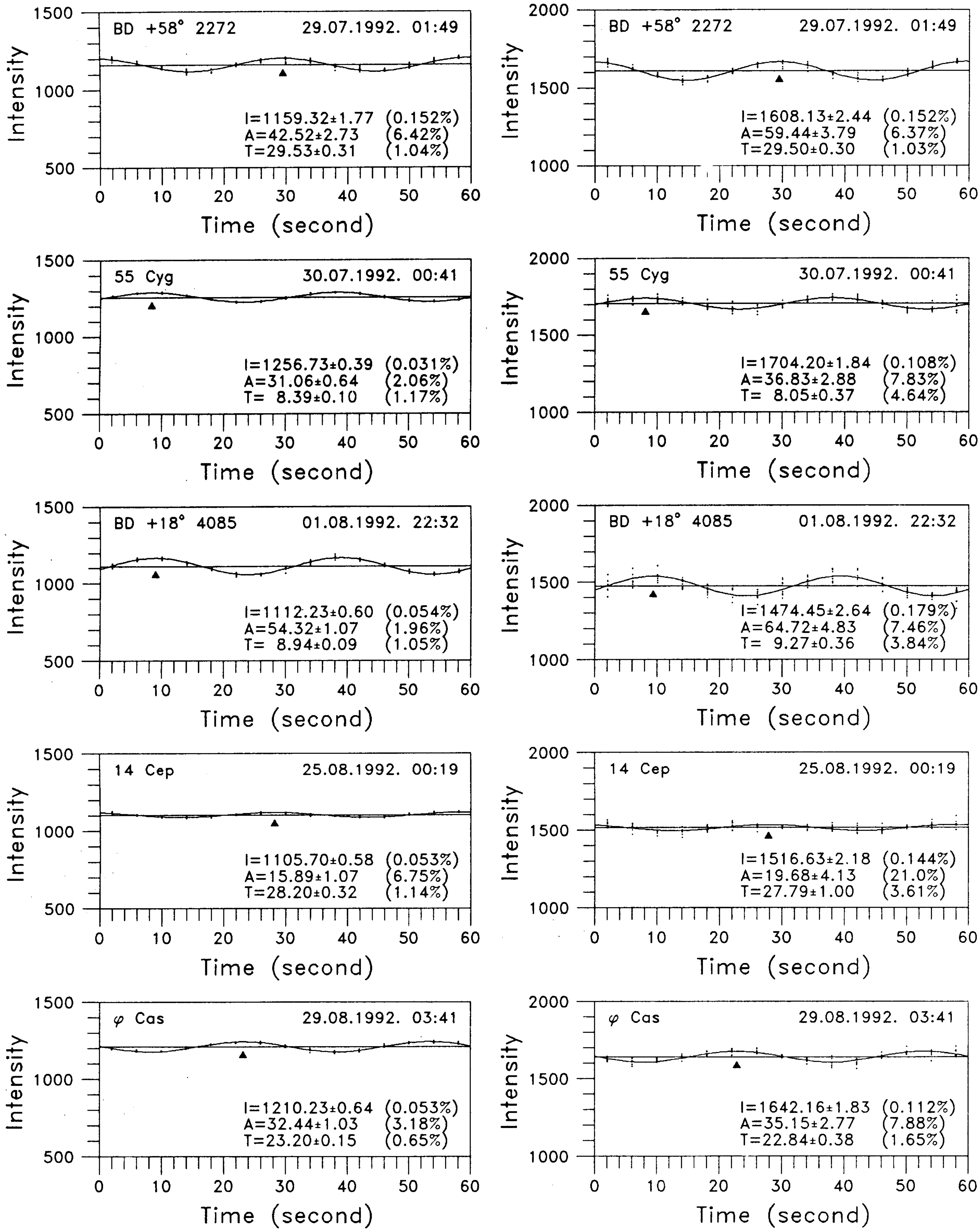

Fig. 4. Results of observations of some polarized stars performed with the old system (a) and with the new system (b) before introducing the R-C low-pass filter.

ons are shown in Figures 4 and 5 arranged in two columns, corresponding to the observations made with the old measuring system (a) and with the new one (b). The polarimetric data integrated over the period of 4 seconds are plotted as a function of time during the rotating period of the polaroid. Each star has been measured for 8 minutes (8 cycles). Therefore we have exactly 8 points in each of 15 groups (or channels) forming 15 "vertical bars".

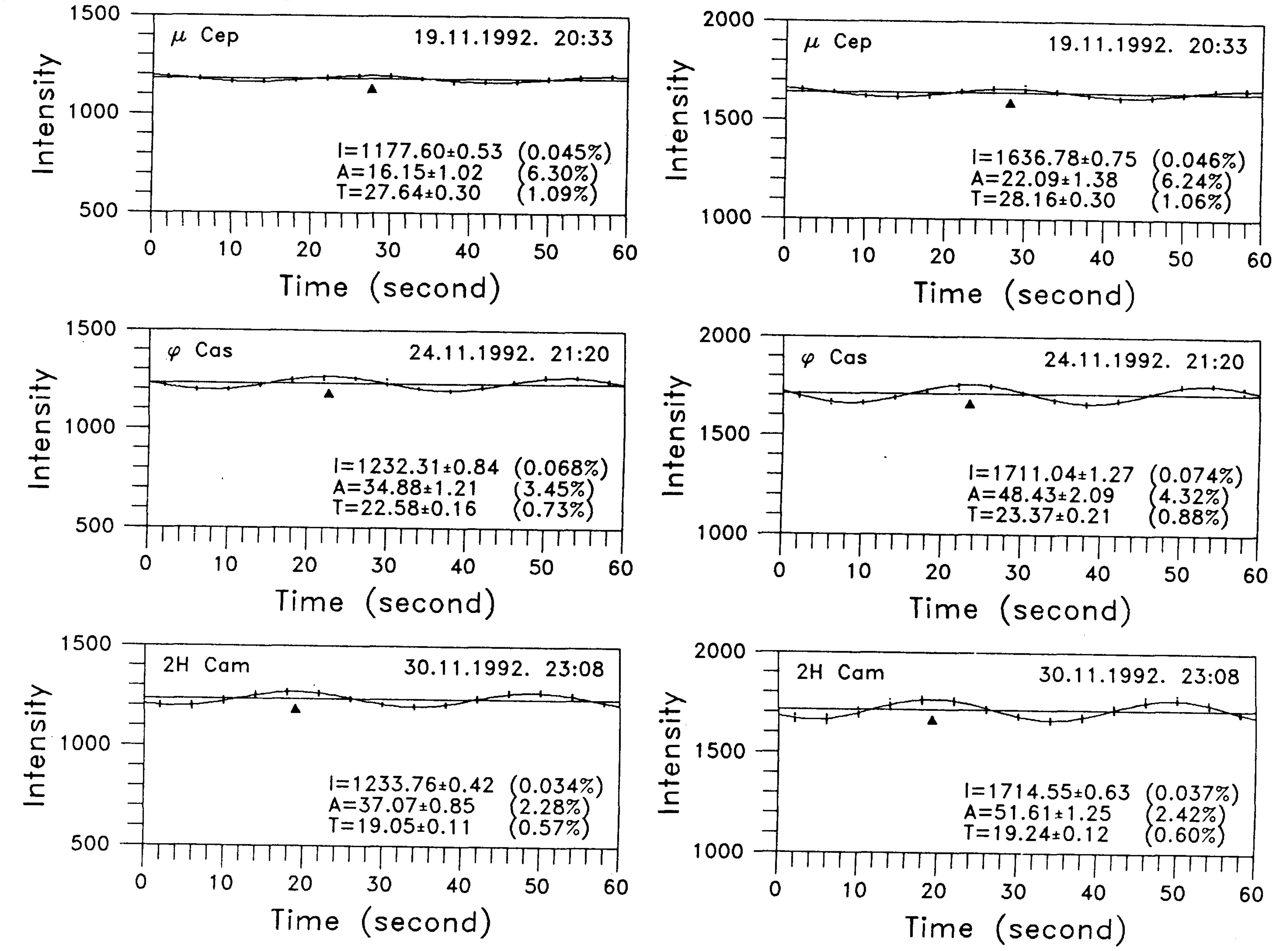

Fig. 5. Results of observations of some polarized stars performed with the old system (a) and with the new system (b) after introducing the R-C low-pass filter.

A cosine-wave fit $y = I + A\cos\omega(t - T)$ through the measured points is drawn, where I is the mean level of the signal, A is the amplitude, ω is the rotating frequency ($\omega = 2\pi/P$, $P = 30$ s) and T is the time instant corresponding to zero phase of the cosine function. At that moment, the position angle of the rotating polaroid is identical to the position angle of the polarized stellar light, and a maximum of the intensity is attained.

The values of the parameters I, A and T, together with their r.m.s. errors are presented on each graph. The relative error is shown in brackets. The mean level I is also shown as a straight line, while the time T of zero phase is indicated by a triangle marker.

The comparison of the two measuring systems can be easily done by comparing any graph from the right column with the corresponding graph in the left column. Each pair of graphs corresponds to the same star observed at the same time.

During the first several observations the new AD converter was fed with the signal taken from the Keithley Micro-microammeter output. The signal-to-noise ratio turned out to be rather low (see the scattering of the measured points in Figure 4b, as well as the corresponding numerical values of r.m.s. errors). To remove this problem, a T-type R-C low-pass filter ($R_1 = 56$ kΩ, $C = 4.7$ μF, $R_2 = 28$ kΩ) with the time-constant amounting to about 0.4 s (gradually rejecting frequencies above approximately 1 Hz) has been introduced between the Micro-microammeter and the AD converter. The result is seen in Figure 5b where the corresponding r.m.s. errors are smaller and comparable to the errors of the old measuring system. This level of the errors has been found acceptable.

Similar R-C low-pass filters precede the inputs of the two parallel analog channels of the polarimeter, the time-continuous recorder Servogor and the time-periodic XY Philips recorder. The third parallel AD channel, KRS 24-100, has a selectable amount of averaging (integrating) the signal from the Micromicroammeter.

CONCLUSION

A new computer-based system for polarimetric measurements at the Belgrade Observatory including the appropriate software has been developed, installed and tested using a group of standard polarized stars. After introducing a R-C low-pass filter at the input of the AD converter, the errors of the observed data are found to be comparable to those obtained by the old system.

The whole observing procedure is greatly improved. All the data concerning the measurement are automatically stored into the computer memory and may be directly accessible to any other software, eliminating the problem of incompatibility previously existing. The problem of identification does not exist any more, because the computer program stores all the necessary information (the name and the type of the object) together with the measured data. In addition, the information about the time, the date, the amplification etc. is also stored with the measured data. Moreover, the observer can add his own comment to complete the information. The whole process of observation is faster and much more comfortable. Finally, the errors caused by the human factor are minimized.

Standard AD/DA cards in conjunction with a personal computer could also successfully be used in other observing programs to replace most of old measuring techniques.

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НОВИ КОМПЈУТЕРСКИ СИСТЕМ ЗА ПОЛАРИМЕТРИЈСКА МЕРЕЊА

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Стручни рад

Развијен је нови компјутерски систем за полариметријска мерења на Опсерваторији у Београду, као замена за стари аналогно-дигитални. Систем се састоји од стандардног PC рачунара, допуњеног једном 12-битном AD/DA картицом, која је непосредно везана на излазне сигнале из фотомултипликатора и маркера положајног угла поларизационог анализатора. Развијен је посебан компјутерски програм за подршку свих фаза у процесу посматрања. Коначно, нови систем је тестиран и упоређен са старим, користећи скуп стандардних поларизованих звезда.