A FIBER-OPTIC THREE-CHANNEL PHOTOMETER FOR SIMULTANEOUS UBVRI MEASUREMENTS - IMPROVED DESIGN AND NEW RESULTS

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A modern photometer designed for variable star observation should meet the following specifications: 1. Simultaneous measurements of object, comparison star and sky in order to allow compensation of changing atmospheric transparency and background radiation. 2. Simultaneous multicolor measurements of each channel yielding high efficiency and accurate colors. 3. Coverage of a large wavelength region (U-I) with high time resolution. A photometer, fitting these requirements has been designed at the Universitäts-Sternwarte München. In principle light from three sources in the focal plane of a telescope is guided through optical fibers to three spectrographs, each splitting the incoming signal into five wavelength regions. The resulting 15 output channels are linked to photon counting detectors. Their signals finally are processed in a microcomputer. The basic components are shown in Fig. 1. Details are given in the following:

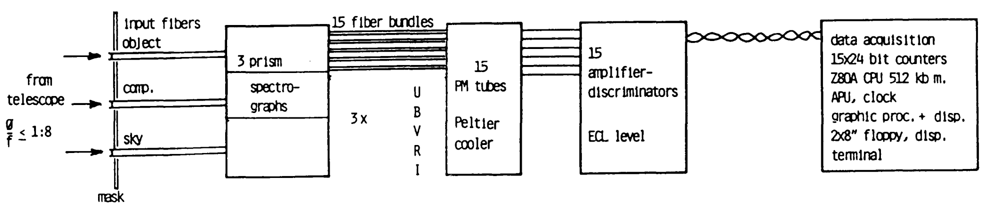

Fig. 1 Blockdiagram of the 15-channel photometer

1. FIBER INPUT

Each of the three input channels consists of a small diaphragm ($\phi \leq 1$ mm) which is projected by a lens system onto a quartz monofiber with $\bar{4}00\mu$ core diameter. The positions of the individual fibers are maintained by holes in an acrylic plate. This mask is prepared on the telescope itself just prior to observation. Star centering within the diaphragms is controlled by autoguiding a nearby offset star ($m \leq 16$ at 1 m Tel.) by means of a three-stage image tube and a Newicon TV camera.

J. B. Hearnshaw and P. L. Cottrell (eds.), Instrumentation and Research Programmes for Small Telescopes, 61–64.

https://doi.org/10.1017/S0074180900151022 Published online by Cambridge University Press

2. COLOR SEPARATION

The end faces of the input fibers form the entrance slit of three identical prism spectrographs each projecting a small spectrum onto a fiber array. Proper bundling and/or shaping of its individual elements yields the separation of several slightly overlapping wavelength regions. Thus different color systems can be realized. In the present photometer version the standard UBVRI filter characteristics were approximated.

3. DETECTOR UNIT

The 15 spectrograph output fibers are connected to a very close arrangement of 15 miniature photomultipliers (PM) cooled by Peltier elements. Integrated amplifier/discriminators convert the PM pulses to normalized ECL signals.

4. DATA ACQUISITION

Photo counting is performed by 15 24-bit counters controlled from a Z80A microcomputer system. Storage of data and/or programs is possible on a 512 kB RAM disk, two 8" floppy disks (1 MB each) or a 20 MB Winchester disk. On line light curves can be displayed on a graphic screen while communications are possible from a separate terminal with display and printer. The acquisition software allows to define all observing parameters via a menu and to perform statistical analysis of all channels. The normal range of integration times covers 1s to 25.4s. However special software with less sophisticated on-line facilities allows continuous time resolution down to 5 ms. A reduction program calculates the object intensities relative to a comparison star. For this purpose the observations of a program star have to be enclosed between two calibration measurements each taking about 10 min.

5. PERFORMANCE

From various observing runs at the ESO 1 m telescope and the Calar Alto 1.2 m telescope a lot of experience was obtained with the new photometer. Compared to a conventional photometer the new instrument has gained a considerable amount of efficiency. This is mainly due to the fact, that the available observing time can completely be used for each individual channel. Furthermore the measuring principle yields an enormous gain of efficiency since observations can be performed even through cloudy skies with variations of transparency up to 80%. Of further interest in this respect is the quantum efficiency of the individual channels. A comparison of count rates obtained with the ESO 1 m single channel photometer using a Quantacon detector and with

	single-ch. photometer	15-ch. photometer
U	340 cts/2s	220 cts/2s
B	1790	2830
V	5070	5560
R	6260	2750
I	7070	820

Table I

the new instrument is given in Table I for a star with $V=12^{m}.7$ (U-B=.7, B-V=.9). Higher count rates are measured in B and V while the lower signal in R and I is exclusively due to the lack of red-sensitive miniature photomultipliers. The accuracy of brightness determination amounts to 1-2% if errors due to photon statistics can be neglected.

6. FUTURE DEVELOPMENTS

Improvements of the present photometer device concern the following developments:
1) computer controlled positioning of the input fibers,
2) increased spectral resolution yielding up to 30 color channels,
3) improved fiber input optics with automatic flat field control,
4) automatic calibration and continuous test of PM stability during day time,
5) improved U and R, I response,
6) increased on-line facilities (EFT, on-line reduction, etc.).

DISCUSSION

Rucinski: How long does it take to generate the aperture plate?

Barwig: Mask preparation is quite simple since we only have to center the individual stars in an eyepiece while a drilling machine, attached to it, transfers the positions to an acrylic plate.

Garrison: That is a nice piece for engineering technology, but as a user I would worry about the flexibility of the system. For example, if I wanted to work to a fixed number of counts in U for red and blue stars, I would have trouble varying the relative integration times.

Barwig: For each channel the integration time can individually be set (or counts can be summed up afterwards).

Mochnacki: Why do you use three separate spectrographs?

Barwig: In order to avoid cross-talking due to stray light.

Ryan: How well do the transmission functions of the five passbands approximate standard UBVRI passbands?

Barwig: A special array of monofibers, which have been bundled or shaped properly, can match the standard system very closely.

Caton: Do you use 3 separate Fabry lenses or do you depend on the fibre optics to mix the star and sky signals?

Barwig: We depend on the fiber optics to mix the signals. The lenses are used to project the star image in the diaphragm onto the fibre entrance.