TV SPECTRUM SCANNER OF THE 6-METER TELESCOPE

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ABSTRACT: The television multichannel spectrophotometer of the BTA (SAO, USSR AS), used for accumulating and recording the spectra of faint astronomical objects, is described. The Soviet image detection system comprises a three-stage image tube (UM-92) optically coupled to a high sensitivity SIT TV tube. The system operates in a photon counting mode with digital definition of the centres of photoelectron events. The spectrophotometer operates on-line with a minicomputer which exercises control of the system and performs primary reductions of the data collected. Illustrations of scans obtained during observations are given.

INTRODUCTION

The problem of approaching the ideal photon detector exists in all large, ground based and space observational programs, and television systems operating in the photon counting mode, with direct image processing by computer, have been developed in many ways (Boksenberg, 1970; Robinson and Wampler, 1972; McGee et al., 1972; Blazit et al., 1975; Schectman and Hiltner, 1977; Cenalmor et al., 1978).

A television scanner for recording the spectra of faint objects with the BTA has been made at the SAO USSR Academy of Sciences. The primary aims in its design were high efficiency of detection and recording, together with adequate photometric accuracy. A description of some technical characteristics and properties of the scanner operating in the photon counting mode has been published by Balega et al. (1979a, 1979b). Currently the scanner is being used with the fast spectrograph (UAGS) at the prime focus of the BTA.

EQUIPMENT

In order to obtain a sufficiently high signal/noise ratio for the accurate recording of single photoelectron events, considerable amplifi-

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cation of the incident light is required. In our scanner, we use a three-stage image intensifier UM-92. The image appearing at the phosphor output, consisting of individual flashes which correspond to photoelectrons emitted by the first cathode, is optically coupled by a fast (f/2) objective lens to the photocathode of a SIT TV tube. The transmission efficiency overall is ≃ 2-3%. The use of a SIT tube as a 'light-signal' converter is determined by the following characteristics:

(1) high sensitivity and amplification.
(2) linearity over a large dynamic range (a change in luminosity by a factor of 10^3)
(3) satisfactory field purity.

The image and TV tubes are located in an enclosure surrounding the camera and filled with dry ice (Figure 1). The photocathode temperature is maintained at about 0°C to minimise the thermal photocathode current. Collection, accumulation and fast reduction of data are made with a minicomputer (Electronika-100I) or a microcomputer (Electronika-60). The information display and the digital magnetic tape recorder (external memory) are connected with the computer through a multiplexer. Block schematics of the whole system, the television unit and the digital part are shown in Figures 2, 3 and 4, respectively. In the data collection and reduction system the following operations are performed:
(a) determination of co-ordinates of centres of photoelectron events
(b) removal of ion events
(c) computer storage of data
(d) visual presentation of data in real time
(e) preliminary reduction of scans.

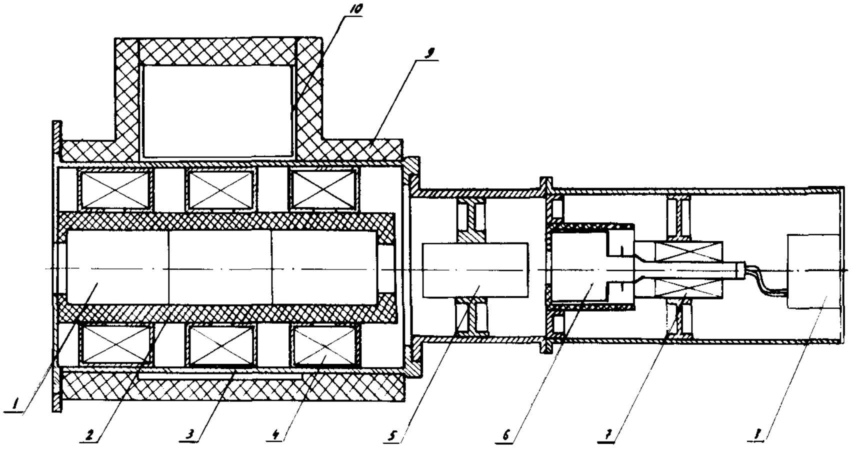

Figure 1. BTA Scanner camera: 1) image tube UM-92, 2) isolating case, 3) magnetic enclosure, 4) focusing coil, 5) transmission optics, 6) SIT tube, 7) focusing deflection system, 8) electronics boards, 9) heat insulation enclosure, 10) dry ice container.

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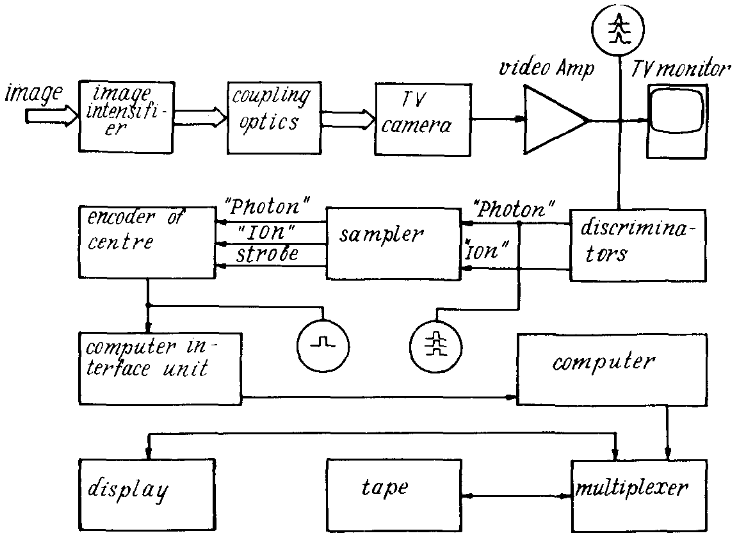

Figure 2. Block schematic of the scanner

OPERATION OF THE SYSTEM

The charge pattern, which is the analogue of the image projected on the image tube photocathode, appears on the target of the TV tube. This pattern is scanned with the reading electronic beam, using a high-

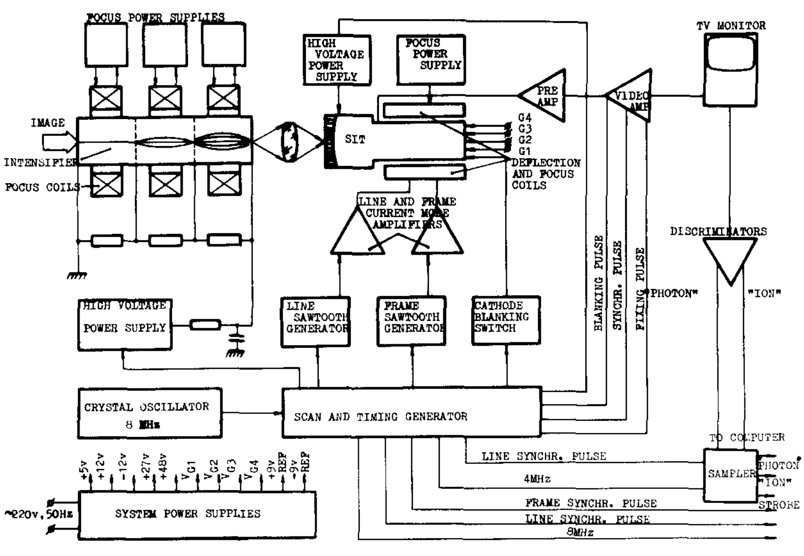

Figure 3. Television camera control system

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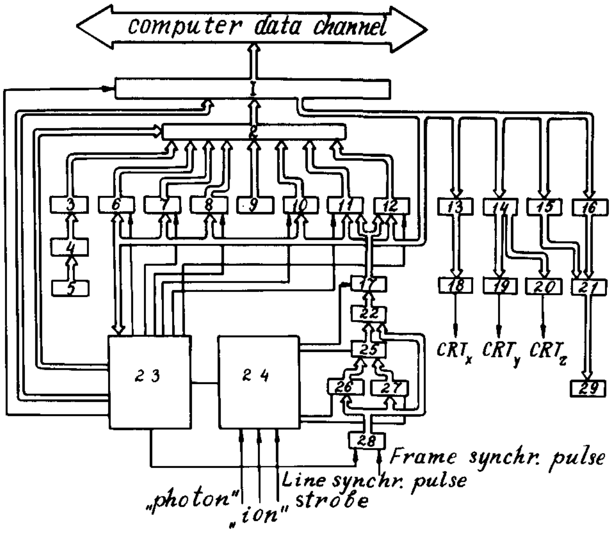

Figure 4. Block schematic of digital system of the scanner: 1) Channel distribution interface, 2) Output multiplexer, 3) Vector, 4) Encoder, 5) Keyboard, 6) Readout register, 7) Record register, 8) Modifier register, 9) Switch register, 10) Instruction register, 11) Pseudocentre address register, 12) Centre address register, 13) X-number register, 14) y,z number register, 15) Indication register No. 1, 16) Indication register No. 2, 17) Buffer register No. 3, 18) D/A (x), 19) D/A (y), 20) D/A (z), 21) Decoding circuit, 22) Adder, 23) Input-output control circuit, 24) Centre location encoder logics, 25) Commutator, 26) Buffer register No. 1, 27) Buffer register No. 2, 28) Line counter, 29) Numerical indicators.

stability electromagnetic scanning system. Scanning is performed at a line frequency of 15625 Hz and a frame frequency of 30.5 Hz on 512 lines. The size of the raster on the image tube photocathode is 15 x $15mm^2$. The signal target current is amplified by a low noise preamplifier (pass band 30 Hz - 7.3 MHz) and the noise current reduced to an input of 2nA. The videosignal formed is supplied to the videocontrol device where electronic flashes can be observed and mono- and multielectronic events can be discriminated. This closed cycle, with synchronous visualization, simplifies optical and electronic focusing and adjustment of the system as a whole.

For spectrophotometry of point objects a comparatively small part of the photocathode is used (two parallel spectra are projected on the photocathode image tube: the spectrum of the object and that of the sky background). Sampling of the working signal on the television raster and its further reduction are fulfilled in two sampling bands, located along the frame. It is possible to regulate the sampling bandwidths and the delay relative to the beginning of the line. Here the information is contained in two bands of $0.5 \times 15mm^2$. When making observations, the spectra investigated are projected on the image tube photocathode so that the direction of dispersion is perpendicular to the direction of the SIT line scan and the portions of the bands sampled and displayed on the monitor are those containing the spectra.

The use of the minimum working field on the TV raster reduces the number of noise events recorded. During the sampling times, the discrimination system determines in the videosignal on each line the presence or absence of a monoelectron event and changes correspondingly the output to either logical "1" or "0". Thus, during the period of scanning of one frame one gets 2 x 500 signals corresponding to the number of working lines i.e. channels (12 channels in each frame are reserved for return and blanking of the reading beam). In a similar manner, the discrimination system can detect the presence of multielectron events. The diameter of individual photoelectron events on the image tube is on the average $\simeq$3-4 channels, which exceeds the size of the resolution element of the SIT. Therefore, to improve spatial resolution, the event should be attributed to only one element of memory, i.e. the centroid. Thus, in the digital system of the scanner, photon events are registered with equal weights (independent of amplitude) and the centres of events are encoded; amplifier noise, parasitic signals and ion events are removed by the discriminators. The mode of operation, the storage time, the delay etc. are set from the display and the information being stored is shown on the display in real time. To increase the efficiency of observations with the scanner, a TV autoguider was installed at the slit of the UAGS spectrograph giving a field of $15 \times 15mm^2$ (130×130 arcsec^2 for the BTA). An I-SIT tube is used in the camera of the TV autoguider and with good seeing it provides accurate guiding on stars up to 19-20 mag at the 6-m telescope with continuous scanning.

WORKING CHARACTERISTICS

(1) The positional stability of the scanner has been investigated in the laboratory and in real observational conditions at the BTA. Emission lines of a comparison spectrum (Ar, He, Ne) were taken as reference points. The measurements showed that the positional instability was ±10μm, giving an accuracy for radial velocity measurements of $\simeq$ ±45km/s (at reciprocal linear dispersion 100 Å/mm); (2) The width of the instrumental profile of the system is $\sim$40μm ($\simeq$4Å at reciprocal linear dispersion 100 Å/mm); (3) The dynamic range is within $\sim$30 to 8000 photoel./channel. hr; (4) Dark noise of the system is $\simeq$80 photo-el./s cm^2; (5) The capacity of single channels is not limited in practice ($\simeq 10^6$ events per channel); (6) The quantum efficiency of the scanner at λ=4800 Å is $\simeq$5%. In a comparatively short time the system accurately records weak lines of the night sky (Fig. 5); (7) Reciprocal linear dispersions used are 50, 100, 200 Å/mm; (8) The operating spectral range is 3700 - 8000 Å.

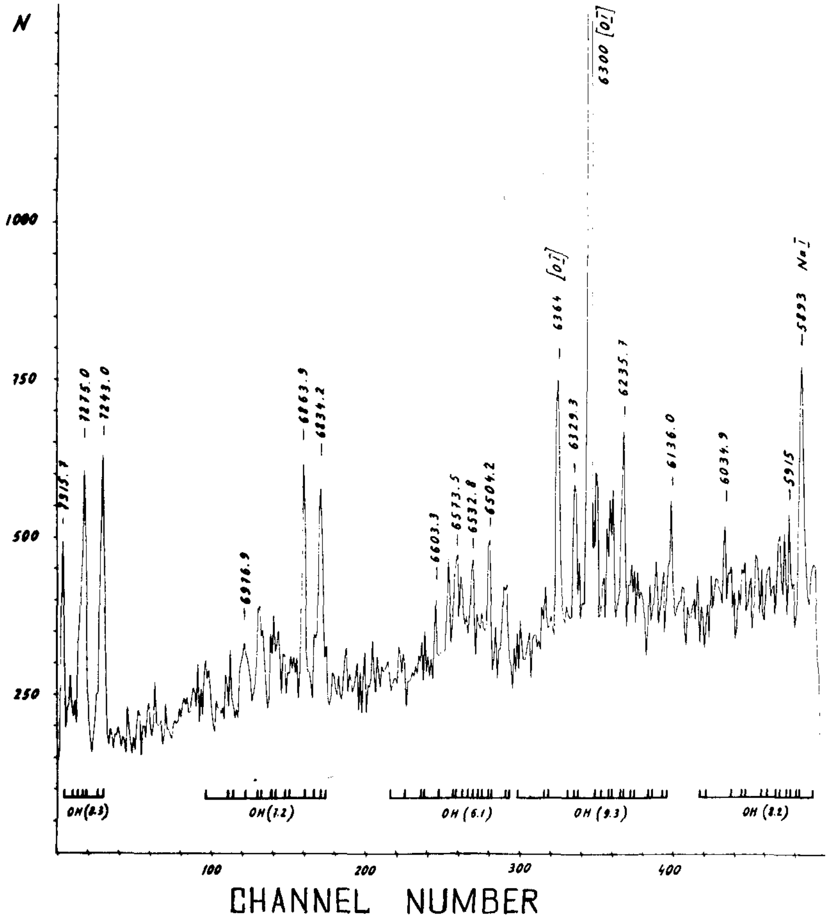

Figure 5. Fragment of night sky scan. Reciprocal linear dispersion 100A/mm; integration time 13min; slit 0.2mm (2"5).

DIGITAL REDUCTION OF THE SCANNER SPECTRA

We use standard processing which includes:
(a) arithmetic operations with two spectra (for example, summation for improving signal/noise ratio, subtraction to search for variability, subtraction of the sky background etc.);
(b) correction for non-uniformity in sensitivity and spectral sensitivity of the channels;
(c) construction of the dispersion curve from the comparison spectrum records and determination of the wavelength scale;
(d) preliminary smoothing and filtering of noise.

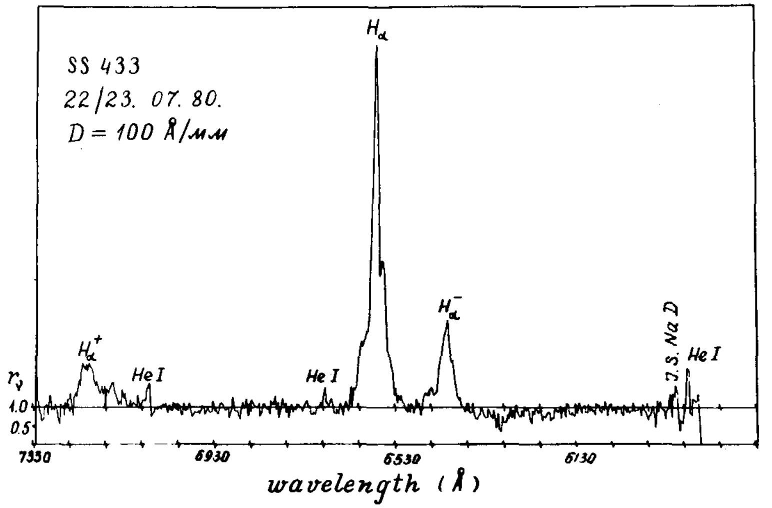

Figure 6. Fragment of spectrum of SS 433 obtained at the BTA, 5800-7300 A. Dispersion 100A/mm; slit 0.1mm; integration time 10min.

As an example of the spectra we obtain with this scanner which has been in use at the BTA since 1977, the spectrum of SS 433 at a dispersion of 100 Å/mm is shown in Figure 6.

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