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A SINGLE-CELL PHOTOPOLARIMETER

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ABSTRACT

A simple, single-cell photopolarimeter has been developed for use at the cassegrain focus of the 102 cm Ritchey-Chretien reflector at Kavalur. The design and performance of the instrument are discussed.

Key Words: polarimeter-stellar polarimetry

1. Introduction

In astronomy, polarimetric observations have been employed in studies of the nature of planetary surfaces, interstellar and circumstellar dust, magnetic field in celestial bodies, etc. Depending on the aim of investigations, information about the state of polarization is required to be determined.

The state of polarization is completely defined by four Stokes parameters, I,Q,U,V (Clarke and Grainger 1971). Observationally, one generally measures two quantities, degree of polarization p, and position angle, θ. These quantities are related to the Stokes parameters as follows:

$$p = \frac{(Q^2 + U^2 + V^2)^{1/2}}{I} \qquad (1)$$

and

$$\theta = \frac{1}{2} \arctan (U/Q). \qquad (2)$$

The position angle, θ, is always measured with respect to the meridian, increasing from north towards east.

A polarimeter basically requires an analyzer which allows radiation of only one state of polarization to pass through whose intensity is measured with a suitable detector. In photoelectric detecting arrangements, the fluctuations in the measured intensities due to scintillations are reduced by chopping the incident light at a known frequency. Devices like rotating half-wave plate, pockels cell, photo-elastic modulator, etc., are used for this purpose. For highly polarized sources, chopping may be avoided, otherwise chopping at a frequency, preferably, greater than 10 Hz is necessary.

The scope of the present paper is limited to the description of a photopolarimeter

developed for use at the cassegrain focus of the 102 cm telescope at Kavalur

2 Instrument

A schematic lay-out of the instrument, in its present form, is shown in Figure 1 The first element is a polariod sheet which is rotated manually in steps of 5° This is followed, in succession, by a diaphragm slide, a filter slide, a Lyot type depolarizer, and photomultiplier tube assembly. The diaphragm slide carries four apertures of different sizes, and the filter slide can accommodate five filters It is desirable to use a depolarizer before the photomultiplier tube since the photocathodes are usually sensitive to the plane of vibration of the incident light

Uncooled 1P21 and dry-ice cooled EMI 9558 B photomultipliers serve as the photon detectors Both dc recording as well as photon counting methods have been used for measuring the intensity of light

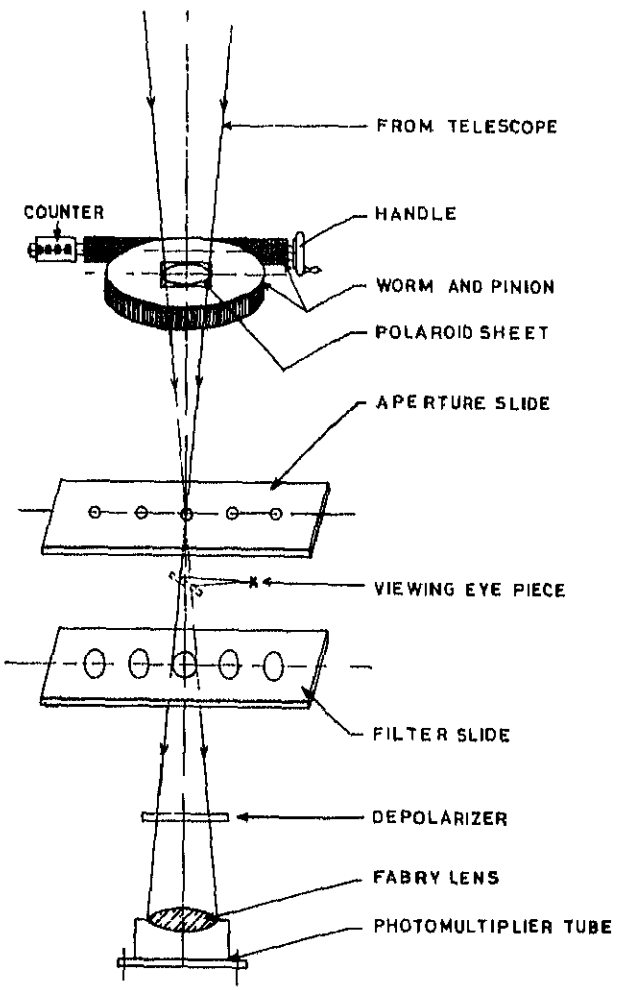

Fig 1 Layout of the Polarimeter

Polarization observations with this instrument consist in measuring the intensity at each position of the polariod in the sequence 0°-90°-180°-270°-360°-45°-135°-225°-315°-360° (0)°, where the numbers represent the angles by which the polariod is turned from some arbitrary initial position whose orientation from the celestial north is determined separately

From these intensity values one calculates the following quantities.

$$\frac{Q}{I}=\frac{1}{p_0}\cdot\frac{(I_0+I_{180})-(I_{90}+I_{270})}{(I_0+I_{180})+(I_{90}+I_{270})}, \quad (3)$$

$$\frac{U}{I}=\frac{1}{p_0}\cdot\frac{(I_{45}+I_{225})-(I_{135}+I_{315})}{(I_{45}+I_{225})+(I_{135}+I_{315})}, \quad (4)$$

where (I_0 ... I_{315}) represent the intensities at the subscribed positions of the polaroid, and p_0 is the efficiency factor of the polariod sheet

Ideally, $P_0 = 1$, but, in practice, its value is determined by actual experiments. The extent of departure from ideality is wavelength dependent and the experiments are repeated at different wavelengths.

Substituting eqs.(3), (4), and V=O (for measurements of linear polarization only) in eqs. (1) and (2) the values of p and θ can be determined.

3. Performance

The results of observations of some standard polarized stars (Hsu and Breger 1982) are shown in Table 1. The errors were estimated from the scatter of observational points, by using standard procedure. The position angles were measured in arbitrary reference systems, and are not presented in the table.

The accuracy of polarimetric observations depends on several factors, notable among them being the sky condition. A single-cell polarimeter, without the chopping facility, is particularly susceptible to such sources of error. Large errors in some observations reported here seem to have arisen, largely, due to bad sky conditions.

The accuracy of polarimetric measurements also depends on the brightness of the star. Observations of R CrB (in its diminishing phase, $m \sim 10^m$) and Nova Vulpecula (September 1984) show results which are consistent with others' observations (Coyne and Shawl 1973, for R CrB). If the star is highly polarized but faint, the accuracy of measurements is expected to be of the same order as that when the star is bright but less polarized.

TABLE 1

Observations of Standard Stars

HD	Star name	α_{1985}			δ_{1985}			Spectral type	m_v	Standard value P ± ε %	Observed value P ± ε %
		h	m	s	°	′	″				
80558	HR 3708	9	18	12.5	-51	29	49	B7Iab	5.91	3.32 ± 0.02	3.35 ± 0.32
147084	σSCo	16	19	43.8	-24	08	05	A5II	4.54	4.46 ± 0.03	4.30 ± 1.12
160529	-33° 12361	17	40	59.6	-33	29	52	A2Ia	6.67	7.31 ± 0.02	5.70 ± 1.96 (V)
187929	ηAql	19	51	42.4	+0	57	57	F6-G2Ib	3.5-4.3	1.76 ± 0.03	1.57 ± 0.183 (B) 1.97 ± 0.47 (V)

V : V - Filter
B : B - Filter

To conclude, this instrument is quite suitable for polarimetric observations not requiring accuracies in the second place of decimal. On trial runs with 102 cm telescope, it has been found possible to observe 10^{th} magnitude objects under photometric sky conditions.

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