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An astronomical polarimeter

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Abstract. A polarimeter for the study of astronomical objects has been developed and calibrated. Observations of several objects have been made. The polarimeter covers the spectral range from 3150 Å to 8500 Å in standard *N, U, B, V, R, I* bands. Alternatively, narrow band filters between 3150 Å and 8500 Å can also be used. The instrument is capable of measuring polarizations down to 0.03 % with an error of 0.03 % for objects of fifth magnitude on a 1-m telescope. The instrument has a microprocessor-controlled data acquisition system with on-line processing capabilities. In addition to affecting polarization measurements, the instrument can also be used as a photometer.

Keywords : instrumentation—polarimetry

1. Introduction

Polarization studies of astronomical objects are important in the investigations of certain physical parameters such as size and distribution of grains, magnetic field, *etc.* It will be interesting to observe the polarization of several objects like T Tauri stars, Seyfert galaxies, quasars, BL Lac objects, late type stars, stars behind Bok globules, etc. However, one should note that the degree of polarization of astronomical objects is very small (typically 1 %) except in the case of objects like the BL Lacs (typically 10 %). Hence it is important that the errors in measurements should be small. With a view to measuring a very small degree of polarization and also since there is no astronomical polarimeter in the country, we have developed a sensitive polarimeter which can measure polarization down to 0.03 % with an error of 0.03 % (for fifth magnitude star on a 1-m telescope). The details of the instrument are discussed here.

2. The polarimeter

The polarimeter works on rapid modulation principle which is achieved by the rotation of halfwave retarder. All the photons collected by telescope are used to minimize the error due to photon statistics (Frecker & Serkowski 1976). The instrument is microprocessor-controlled, and Stokes' parameters are obtained on line with the help of a data-acquisition-cum-processing system. This has proved very useful in planning observations during the night and in increasing the effective use of telescope time.

The optical layout (figure 1) of the polarimeter consists of a rotating halfwave retarder, a similar fixed halfwave retarder, a set of filters (*N*, *U*, *B*, *V*, *R* and *I* bands), a neutral-density filter, a Wollaston prism, and a detecting system. Both the halfwave retarders are superachromatic (Pancharatnam 1955) and the retardance does not deviate more than 3° from 180° in the entire spectral range of 3100 Å to 11000 Å. The first halfwave retarder is rotated at a frequency of 10.41 Hz which results in the modulation of the polarized component of the radiation at 41.64 Hz (Frecker & Serkowski 1976). This fast rotation is essential to minimize the atmospheric scintillation effects. The first halfwave retarder in addition to changing retardance also changes the position angle of the optical axis which is wavelength dependent. This effect is totally eliminated by the use of a second halfwave retarder which is identical to the first one but is fixed (Serkowski 1947a). At present, provision for *N*, *U*, *B*, *V*, *R* and *I* filters with respective central wavelengths 3150, 3600, 4400, 5500, 7000 and 8000 Å has been made. However, other filters including narrow-band filters at any wavelength within 3150 Å to 8000 Å can also be used. As the filters are situated after the rotating halfwave retarder, narrow band interference filters can also be used without increasing the instrumental polarization.

With this instrument, observations of objects from 5 to 14 mag can be carried out with a 1-m telescope. For brighter objects a neutral density filter has to be used to protect the photomultiplier tubes from being damaged owing to excess photon flux. The beam is split using a Wollaston prism analyser. The choice of Wollaston prism is made as it gives the best separation angle between the two beams and has good transmission in the wavelength region of 3150 Å to 8500 Å. Both the beams are detected using a set of GaAs sensitized photomultiplier tubes. These photomultiplier tubes have a flat response from 3150 Å to 8500 Å and cover the important *I* band. The tubes are cooled to dry ice temperature to achieve low dark counts and are used in photon counting mode. The signal is integrated using coherent integration technique. The entire instrument is controlled by a Z-80 based microprocessor. The data are analysed for Stokes' parameters and results are obtained on line. For efficient operation, peripherals like Teletype, tape recorder and a CRT terminal are used.

3. Calibration and testing

The polarimeter has been calibrated in the laboratory for 100% polarization using a Glan prism. For 0% polarization and for other values, standard stars with known degree of polarization and position angle have been used. These observations

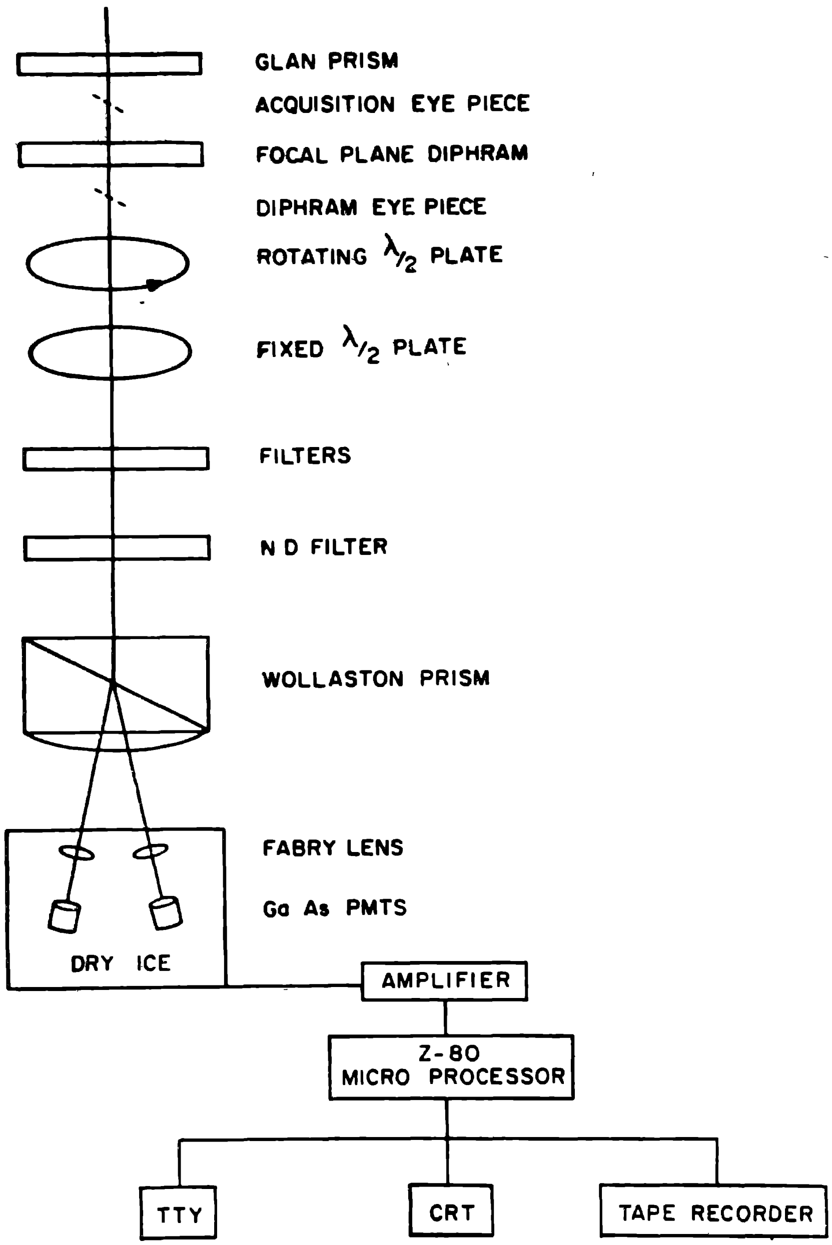

Figure 1. A block diagram of the polarimeter.

were made on the 1-m telescope at Naini Tal in 1983 May and at Kavalur in 1984 November. The results are given in table 1.

4. Observations

Preliminary observations with the polarimeter have already been carried out at Naini Tal and Kavalur. The objects include Seyfert galaxies, T Tauri stars, late type stars, R Aquarii, *etc*. These investigations will be published later. As an illustration, the results obtained for R Aquarii, an M 7e type star, are shown in figure 2.

Table 1. Results of calibration

Star	m_v	Type	P_u	θ_u	P_B	θ_B	P_V	θ_V	P_R	θ_R	P_I	θ_I	Remarks
9 Gem	6.2	B 3Ia	2.66%	164*	2.96	167	2.99	166	2.99	156	2.57	160	1984 Dec. 19–20
			±0.07		±0.04		±0.02		±0.04		±0.03		1-m telescope
			2.58	169	3.04	173	3.11	169	2.93	168			Kavalpur[1]
χ Her	4.6	F 9V	0.02		0.04		0.01		0.03		0.01		1984 Jun. 2–3
			±0.11		±0.04		±0.03		±0.04		±0.03		1-m telescope
							0.012*						Naini Tal[2]
							±0.009						

Note : (a) 9 Gem is a standard star with some degree of polarization.
(b) χ Her is a standard star with 0% polarization, hence measurement of angle is not possible.

*Values are available without filter.

[1]Coyne & Gehrels (1966).

[2]Serkowski (1974b).

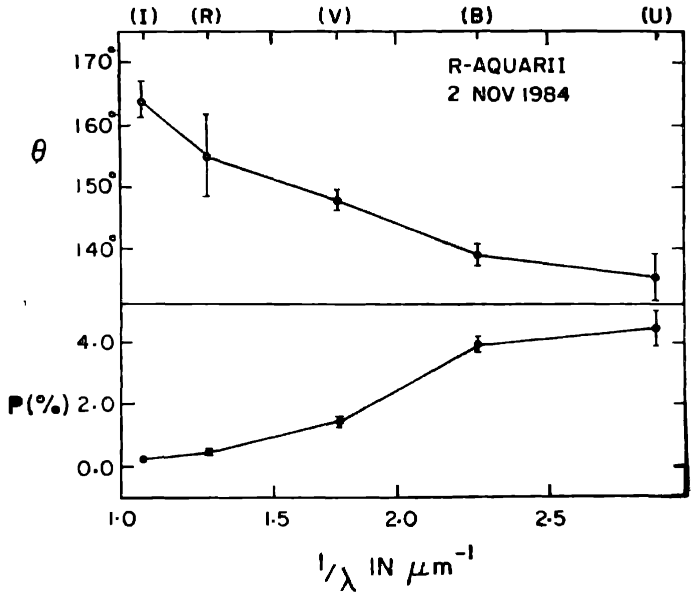

Figure 2. Wavelength dependence of percentage polarization (P) and position angle (θ). The position angle is measured positive from celestial north to east.

The wavelength dependence of polarization and position angle are clearly seen. The detailed discussion of the results will be published separately.

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