A NEW POLARIMETER FOR STELLAR POLARISATION MEASUREMENT

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ABSTRACT. A polarimeter for the measurement of Stokes' parameters for stellar and quasi stellar objects in specific wavelength regions has been reported. The variable retardation and dispersive property of a small angle Babinet Compensator has been exploited for such measurement. The theoretical basis of the method is given in detail.

1. INTRODUCTION

Multi element detector arrays like CCD, IPCS, IDS, etc., have given a new dimension to astronomical instrumentation. CCDs with high quantum efficiency, low read out noise and small pixel size (~10-15μ) have become available. Such CCDs are finding their place at the detector end in many astronomical instruments. These have been successfully used in polarimeters enabling many spectral and spatial elements to be observed simultaneously. The Babinet Compensator has been known as a sensitive device for measurement of small phase changes in polarised light. It has been shown that with suitable precautions[1] the minimum detectable phase change[2] may be made as low as 2π milli radian. CCDs coupled to a Babinet Compensator-polariser combination in a specified manner can provide a convenient means of measuring four Stokes' parameters separately in very narrow wavelength intervals simultaneously for a considerably large wavelength range.

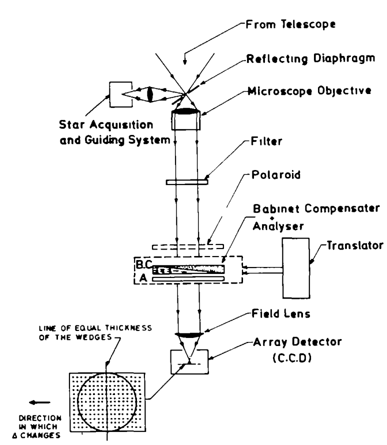

Fig.1. OPTICAL ARRANGEMENT OF THE POLARIMETER

2. THEORY

Fig. 1 shows the optical set up for the polarimeter. When a babinet Compensator having a small wedge angle is placed in the path of a polarised collimated beam followed by an

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analyser, a varying phase retardation is introduced between the E & O components of the wave along one diameter of the beam. But a constant phase difference remains along the perpendicular direction parallel to the line of equal thickness of the wedges. If this beam of light is imaged with a suitable field lens to a detector array in such a way that, say the columns of the detector coincide with the direction of constant phase, then the change in intensity of the beam in the perpendicular direction due to the difference in phase change introduced by the wedges can be obtained from the corresponding column average. The value of phase change introduced by the compensator along any column at a distance χ from the line of equal thickness of the wedge is given by

$$\Delta = \delta_1 - \delta_2 = \frac{2\pi}{\lambda}(n_e - n_o)\, 2\chi \tan\alpha \qquad (1)$$

where n_e and n_o are the extraordinary and ordinary refractive indices of wedge material and α is the wedge angle. If further $I_{\lambda up} + I_{\lambda P}$ Q_λ, U_λ, and V_λ are the Stokes' parameters of the incident beam of wavelength λ then modulation of the intensity at any point in the perpendicular direction for this wavelength can be obtained by the Muller matrix product of the corresponding elements.

If λ_1 to λ_2 is the range of wavelength getting transmitted through the filter and this wavelength range is divided into n small intervals, then the total intensity at any point will be the summation for all wavelengths.

$$I_m = \frac{1}{2}\left[\sum_{n=1}^{n} I_{\lambda_n up} + \sum_{n=1}^{n}\left(I_{\lambda_n P} + U_{\lambda_n}\cos\Delta + V_{\lambda_n}\sin\Delta\right)\right] \qquad (2)$$

I_m is the intensity which is measured from the column average. A quantity over all average intensity per pixel can be defined for the purpose of normalisation from equation (2) by taking an average over a large number of cycles of Δ i.e. integration over the values 0 to $2K\pi$.

For the spectral response of the detector and filter and other components proper weighting factors can be introduced and the equation (2) can be written in expanded form as

$$\begin{aligned}(I_{m,\Delta}) = I_{uptot} &+ a_1 I_{\lambda_1 P} + a_1 U_{\lambda_1}\cos\Delta_{\lambda_1} + a_1 V_{\lambda_1}\sin\Delta_{\lambda_1}\\ &+ a_2 I_{\lambda_2 P} + a_2 U_{\lambda_2}\cos\Delta_{\lambda_n} + a_2 V_{\lambda_2}\sin\Delta_{\lambda_2}\\ &+ - - - - - - -\\ &+ a_n I_{\lambda_n P} + a_n U_{\lambda_n}\cos\Delta_{\lambda_n} + a_n V_{\lambda_n}\sin\Delta_{\lambda_n}\end{aligned} \qquad (3)$$

One needs to do at least (3n+1) measurements of $(I_{m,\Delta})$ and the corresponding (3n+1) equations so obtained can be solved to give I_λ, U_λ, V_λ and Q_λ.

3. REMARKS

1. Approach is simple with no movement required for any component during observation

2. Simultaneously it can give all four Stokes' parameters for a reasonably large wavelength range.

3. Correction for defects in the optical polarising elements can be done in the reduction process.

REFERENCES

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2. Jerrard, H.G. *J. Opt. Soc. Am.* 39, pp 1031, (1949)