SIMULTANEOUS FIVE COLOR (UBVRI) POLARIMETRY OF EF ERI*

V. PIIROLA[1,2], A. REIZ[3], and G. V. COYNE[1]

[1]Vatican Observatory, Città del Vaticano

[2]on leave from University of Helsinki Observatory

[3]University Observatory, Copenhagen, Denmark

ABSTRACT. We present the first observations of the AM Her type object EF Eri where both the polarization and the photometric data are recorded simultaneously in five color bands (UBVRI). The position angle rotates strongly (~ 30°) vs. wavelength from U to I, probably due to Faraday rotation or due to fact that the polarized radiation seen in the different wavelength bands comes from different parts of the accretion region. The phase dependence of the position angle requires field and accretion geometry more complicated than a simple centered dipole and a second emitting region producing weaker intermediate pulses in the infrared seems to be present. We derive the value of the inclination of the system $i = 55° \pm 5°$, the colatitude of the active pole $\beta_1 = 38° \pm 5°$, and the second emitting region $\beta_2 = 115° \pm 5°$, both of which are nearly at the same longitude facing the main accretion stream.

1. INTRODUCTION

In order to establish the wavelength dependence of polarization and photometric variations over the orbital cycle (~ 81 min) in greater detail we have made simultaneous circular and linear polarimetry and photometry of EF Eri in five colours (UBVRI). Exactly simultaneous measurements in different colours are essential due to the short period and the rapid flarelike activity.

2. OBSERVATIONS

The observations were made on six nights during the period Nov. 15-21, 1984 with the Danish 1.5 m telescope at La Silla using a multichannel version of the double image chopping polarimeter (Piirola 1973, 1975; Korhonen, Piirola and Reiz, 1984). Circular and linear polarization were observed simultaneously on Nov. 19-21 and the linear polarization on the

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nights Nov. 15-19. The measurements in different colors were made simultaneously by using five photomultipliers and dichroic filters to split the light into five spectral regions. The resulting passbands are close to the standard UBVRI system, with effective wavelengths 0.36, 0.44, 0.53, 0.69, and 0.83 μm, respectively.

The average curves from our linear and circular polarimetry of EF Eri in Nov. 15-21 are presented in Figs. 1a-b. The data were combined into phase bins with phase zero corresponding to the narrow infrared minimum where the magnetic pole and the accretion column point closest to the observer. The individual observations showed little variation in the polarization curves from night to night. Averaging is thus appropriate in order to increase the signal-to-noise ratio. The linear polarization peaks in the visual and drops toward the ultraviolet and the infrared, the height of the pulse being about 1.5, 7.5, 10.8, 6.5, and 4.5 % in the UBVRI bands, respectively. The shape of the curves changes vs. wavelength and the linear polarization pulse becomes broader toward the infrared, the maximum being also shifted to a later phase ($\Delta\Phi$ = 0.04 from B to I). Two weaker pulses (~ 2.5 % and 1.5 %) are detected in the I band near the phases Φ = 0.25 and Φ = 0.85. The first one occurs ~ 0.35 phase before and the other ~ 0.25 phase after the main pulse. The circular polarization declines to zero in the I band at these weak pulses but remains positive in the other bands where the weak linear polarization pulses are only marginally seen. Contrary to the earlier observations in 1979-83 by Tapia (1979), Bailey et al. (1982), and Cropper (1985) the circular polarization shows a clear negative excursion lasting about $\Delta\Phi$ ~ 0.14 phase. This indicates that changes in the system geometry have occurred.

The position angle curves are given in Fig. 2. At the main pulse the angle is accurately determined and decreases nearly with a constant rate, except for the jump near the phase 0.62, most clearly seen in the B and the V band. The direction of the linear polarization is relatively well defined also outside the main pulse, especially in the R and I bands. After the main pulse the sense of rotation changes and the position angle increases during the phase interval 0.7 - 1.0. An extreme value is observed near the phase 1.0 = 0.0 after which the position angle decreases again until the discontinuity at phase 0.3 takes place.

3. RESULTS AND DISCUSSION

It is clear from the position angle curves (Fig. 2) that a simple dipole model cannot explain the polarization behaviour. If the model parameters are chosen so as to fit the slope of the position angle curve at the main pulse ($i = 55^{\circ}$, $\beta = 38^{\circ}$) the observed points will deviate from the computed curve outside the main pulse and a second maximum of the position angle values is observed near Φ = 0.9 where the model predicts a minimum. Also the discontinuity of the observed position angle curve at phase Φ = 0.3, most clearly seen in the R and I bands (Fig. 2) points to the possibility that a transition between two polarizing regions takes place and the second emitting region is responsible for the observed curve in the phase interval Φ = 0.8 - 0.3. Further support of this interpretation is found both from the linear and the circular polarization and the light curves.

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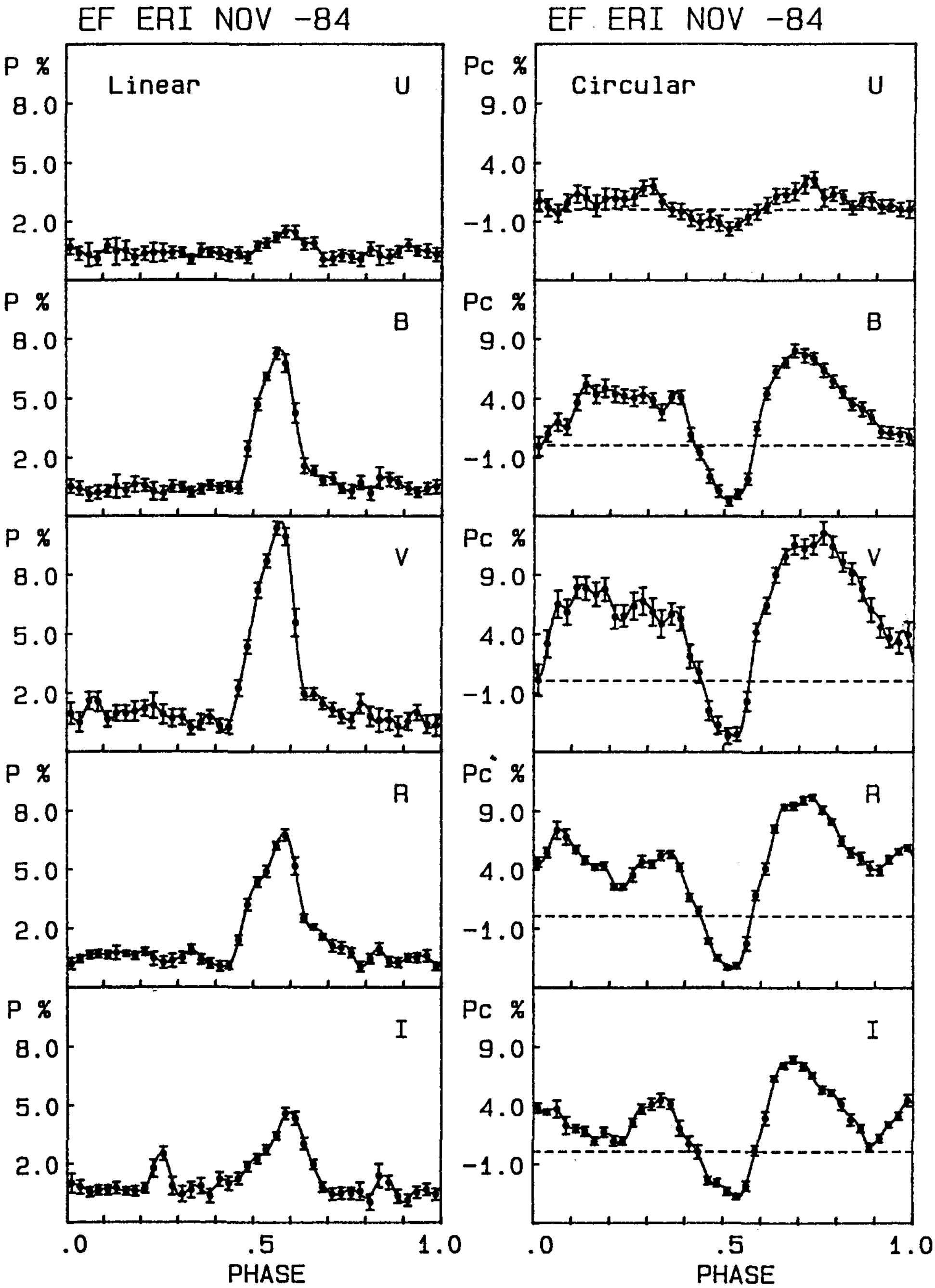

Fig. 1. Simultaneous five color (UBVRI) linear and circular polarimetry of EF Eri during the interval Nov. 15-21, 1984.

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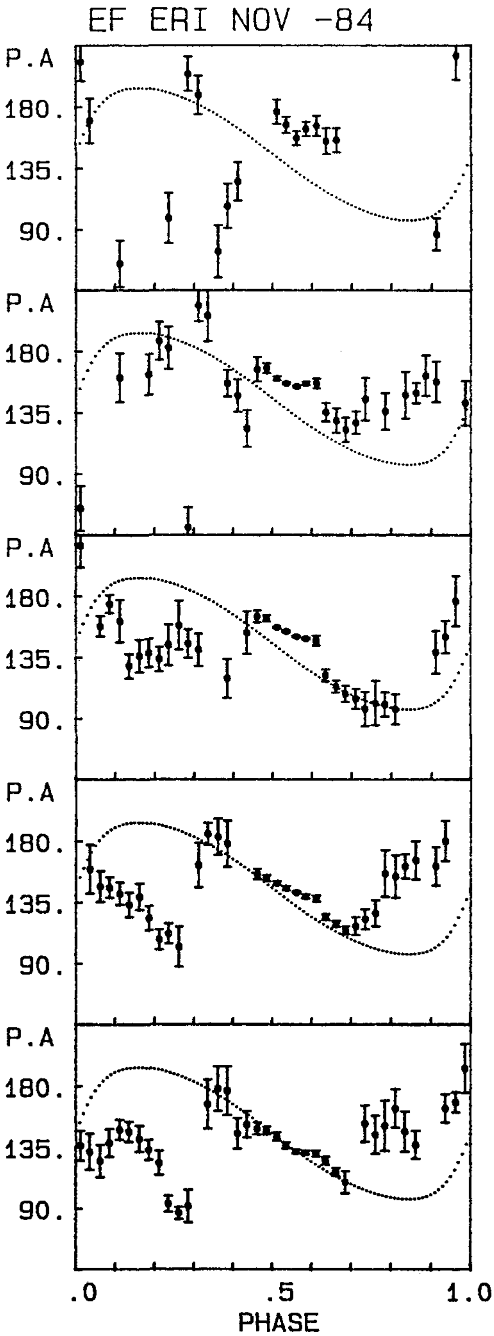

Fig. 2. The dependence of the position angle on orbital phase for the linear polarization observations of EF Eri given in Fig. 1. The dotted line gives a dipole model fit for the value of the inclination $i = 55^{o}$ and the magnetic colatitude $\beta = 38^{o}$. The deviations of the observed curve from the model fit indicate that the simple dipole model is not valid in the case of EF Eri and a second emitting region is responsible for the observed polarization in the phase interval 0.8-0.3.

The weaker linear polarization pulses observed in the I band at the phases Φ = 0.85 and Φ = 0.25 (Fig. 1a) coincide with the appearance and the disappearance of the second emitting region and are thus naturally explained. At the limb crossings the field is perpendicular to the line of sight and a linear polarization pulse is observed. The circular polarization drops to zero in the UBV bands at the phase Φ = 0.0 = 1.0 (Fig. 1b) where the accretion column above the active pole points closest to the observer and the polarization decreases due to cyclotron beaming effects and self absorption in the column. The radiation from the second emitting region, however, keeps the circular polarization positive in the R and I bands near phase Φ = 0.0 and a peak is observed instead of a minimum. Similarly, the increase of the brightness of the object in the phase interval Φ = 0.8 - 0.3 (maximum near Φ = 0.05) at the long wavelengths is explained. The radiation from the second emitting region is much redder than that coming from the active pole, i.e. the brightening around phase Φ = 0.0 is not seen at all in the blue light curve, it is weak in the V band but very strong in the red and the infrared where the absolute maximum brightness of the object is observed near the phase Φ = 0.05. The red colour indicates a lower field strength at the second emitting region than in the active pole, where the polarized radiation peaks in the V band (Figs. 1a-b).

The position angle curves at the main pulse show a strong rotation (~ 30°) of the observed position angle vs. wavelength from U to I band. One explanation is that radiation seen at different wavelengths comes from different parts of the accretion region. Another possible mechanism is Faraday rotation of the plane of polarization, which is proportional to the square of the wavelength. The linear dependence of the rotation angle, $\theta_{\lambda} - \theta_{R}$, on λ^2 gives support to Faraday rotation as the mechanism responsible. We also point out that the zero-crossings of circular polarization occur very nearly at the same phase in each color which would not necessarily be the case if the radiation in different bands comes from significantly different parts of the accretion region. We will discuss elsewhere the observations and the possible interpretations in more detail.

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REFERENCES

Bailey, J., Hough, J.H., Axon, D.J., Gatley, I., Lee, T.J., Szkody, P., Stokes, G., and Berriman, G.: 1982, Mon. Not. R. astr. Soc. 199, 801
Cropper, M.: 1985, Mon. Not. R. astr. Soc. 212, 709
Korhonen, T., Piirola, V., and Reiz, A.: The ESO Messenger, December 1984
Piirola, V.: 1973, Astron. Astrophys. 27, 385
Piirola, V.: 1975, Ann. Acad. Sci. Fennicae AVI, No. 418
Tapia, S.: 1979, IAU Circular No. 3327

https://doi.org/10.1017/S0252921100104865 Published online by Cambridge University Press