

A SEARCH FOR OPTICAL CIRCULAR POLARIZATION IN WHITE DWARFS AND LATE-TYPE STARS WITH CIRCUMSTELLAR SHELLS

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Received 1972 December 4; revised 1973 January 4

ABSTRACT

A search for broad-band optical circular polarization in the light from white dwarfs has been carried out for 15 stars previously observed for luminosity variations. The data for three of the observed dwarfs—EG 11, EG 55, and EG 165—suggest the presence of circular polarization, if a 2σ effect is used as the criterion for a positive result.

We have also searched for broad band optical circular polarization in six late-type stars which exhibit intrinsic plane polarization and large infrared excess. If the same criteria as for the white dwarfs were used, only Z Eri showed an effect.

Subject headings: circumstellar shells — polarization — white-dwarf stars

I. INTRODUCTION: WHITE DWARFS

The existence of strong stellar magnetic fields is suggested by the discovery of broad-band optical circular polarization in the four white dwarfs Grw+70°8247, G99—37, G99—47, and G195—19 (Kemp *et al.* 1970; Angel and Landstreet 1970*a, b*, 1971, 1972; Landstreet and Angel 1971). Of the four known luminosity-variable white dwarfs (Hesser and Lasker 1971), three have been observed earlier for optical circular polarization, with negative results (Angel and Landstreet 1970*b*; Landstreet and Angel 1971). A search for such continuum circular polarization in the optical radiation from 15 additional white dwarfs previously observed for luminosity variations (Hesser and Lasker 1971) is reported here.

II. EXPERIMENTAL

The observations were made with the Cerro Tololo Inter-American Observatory 36-inch (91-cm) telescope, 1972 November 6–9, and 1972 November 14–18. The circular polarimeter, employing a Pockels cell, EMI 9502S (S-11) photomultipliers, and a Wollaston prism, is a two-channel instrument, similar in design to that previously described by Angel and Landstreet (1970*a*).¹ The wavelength bandpass used for the search was centered at 4900 Å with a full width at half-maximum of approximately 800 Å, defined by a 0139 Heliotek interference filter and the photomultiplier response.

The instrument was carefully tested for systematic effects, including conversion of incident off-axis linearly polarized light to elliptically polarized light because of a small residual natural birefringence of the Pockels cell crystal (KD*P) (the so-called linear-to-circular conversion [LCC] effect), instrumental electronic asymmetries (measured circular polarization of unpolarized incident radiation), and depolarization of incident circularly polarized light. The polarized incident radiation was ob-

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‡ Operated by the Association of Universities for Research in Astronomy, Inc. under contract with the National Science Foundation.

¹ The circular polarimeter will be described in detail in a forthcoming publication.

tained by inserting Polaroid linear and circular polarizers in the light beam while observing a bright star. The LCC could at times be reduced to less than ~ 1 percent by Pockels cell alignment, with typical LCC factors during the observation period being 2–3 percent. In a test of the reduction of the LCC by 90° instrument rotation, observations were made of VY CMa, a red star known to have large (14.3 percent) linear polarization (Dyck *et al.* 1971). From measurements of the ratios of the counting rates in the two channels at Pockels cell voltages corresponding to retardations 0 and π , and at two instrument positions separated by 45° , it is possible to measure the linear polarization of the incident radiation. The value determined for VY CMa was (15.5 ± 0.7) percent, in agreement with Dyck *et al.* (1971). The apparent circular polarization was 0.4 percent without instrument rotation; however, this was reduced to less than 0.03 percent by comparing data obtained at two positions of the instrument, separated by 90° . The typical depolarization factor in each channel was ~ 10 percent and the typical instrumental asymmetry was 0.07 percent. As a further check on the instrument operation the circular polarization of the optical radiation from Grw+70°8247 was measured using the University of Michigan 52-inch (132-cm) telescope, 1972 October 27. The polarization was determined to be (2.85 ± 0.24) percent, in agreement with previously reported results (Kemp *et al.* 1970; Angel and Landstreet 1970a; Angel, Landstreet, and Oke 1972).

III. DATA: WHITE DWARFS

Observation times of particular white dwarfs were chosen so as to obtain statistical errors of ≤ 0.1 percent. Measured corrections for the intensity and polarization of the night sky have been included. The measured linear polarization of the sky at 90° from the Moon (the Moon was up during the second observation period) was ~ 47 percent, decreasing to less than 3 percent at approximately 20° from the Moon. The intensity contribution from the moonlit sky was as large as 5–10 percent of that from the star for positions close to the Moon. The effect of correcting for the sky was to increase the experimental error by less than 5 percent. Since the total integration times were divided into several equal-length periods (runs), we were able to monitor statistical fluctuations in the data. These were consistent with Poisson statistics, with

TABLE 1
WHITE DWARFS OBSERVED FOR CIRCULAR POLARIZATION

EG No.	Spectrum	<i>V</i>	Date Observed (JD 2441600+)	Measured Mean Circular Polarization
5	DG	12.36	30	$-(0.32 \pm 0.69) \times 10^{-3}$
11	DAs	12.84	36, 37, 38	$-(2.30 \pm 0.57) \times 10^{-3}$
19	DA	12.65	38	$-(1.65 \pm 0.97) \times 10^{-3}$
20	DA	12.25	37	$+(1.23 \pm 0.93) \times 10^{-3}$
21a	DA	11.2	28	$-(0.59 \pm 0.72) \times 10^{-3}$
22	DAs	14.0	37	$+(1.28 \pm 1.08) \times 10^{-3}$
41	$\lambda 4670$	14.10	36	$+(0.49 \pm 1.08) \times 10^{-3}$
54	DF	12.98	30	$-(0.16 \pm 0.80) \times 10^{-3}$
55	...	13.66	37, 38	$+(4.0 \pm 1.0) \times 10^{-3}$
62	DA, Fs?	12.0	28	$+(0.14 \pm 0.54) \times 10^{-3}$
70	DAn	12.97	36	$+(1.76 \pm 1.06) \times 10^{-3}$
82	$\lambda 4670$	11.44	30	$-(0.11 \pm 0.99) \times 10^{-3}$
142	(DA)	13.50	31	$+(0.81 \pm 1.00) \times 10^{-3}$
158	DOd	11.50	29	$-(0.42 \pm 0.72) \times 10^{-3}$
165	(DAs)	13.05	30	$-(1.70 \pm 0.73) \times 10^{-3}$

the exception of EG 55 where it was necessary to reject one of the eight runs because its polarization differed from the mean polarization by 6σ .

The results of the measurements are shown in table 1. The indicated error is 1 standard deviation, and has been calculated on the assumption that the data obey Poisson statistics. The sign convention is that of Kemp *et al.* (1970). Using a 2σ effect as the criterion for a positive result, it can be seen that in all but the three cases EG 11, EG 55, and EG 165 no circular polarization has been observed. We point out, however, that for EG 55 inclusion of the rejected run (see above) reduces the 4σ effect to 2.6σ and, moreover, if the error is then calculated directly from the rms spread in the seven separate runs, the polarization differs from zero by less than 2σ . The time limitations arising from using the 36-inch telescope prohibited either a measurement on these stars at two instrument positions separated by 90° , or a measurement of the linear polarization. Thus systematic effects arising from LCC have not been eliminated as contributing to the observed results. However, for the four white dwarfs which were previously discovered to have circular polarization, the linear polarization is weaker than the circular polarization. If such is the case for the three dwarfs reported here, this source of systematic error is negligible. In conclusion, the data suggest the presence of circular polarization at about the 0.2 percent level and strongly warrant further observations of these objects.

IV. INTRODUCTION: LATE-TYPE STARS

A detailed study by Dyck *et al.* (1971) has established a relation between the intrinsic optical plane polarization and the amount of infrared excess in the radiation from approximately 60 cool stars. The results obtained are consistent with the presence of circumstellar envelopes. The wavelength dependence of linear polarization and correlations between linear and circular polarization in such objects can provide information about the particles and their behavior in the atmospheres of these stars.

V. DATA: LATE-TYPE STARS

Six stars were observed with the Cerro Tololo Inter-American Observatory 36-inch telescope, 1972 November 18–20, using the circular polarimeter described in § II. The results of the observations are presented in table 2. The quoted errors are 1 standard deviation. The sign criterion is that of Kemp *et al.* (1970).

Using a 2σ criterion, the only positive result obtained was for Z Eri. An apparent circular polarization arising from linear-to-circular conversion of the reported 0.9 percent linearly polarized radiation (Dyck *et al.* 1971) is too small with the instrument used here (LCC factor ~ 3 percent) to account for the observed result. Further observations of Z Eri are planned. To date, circular polarization in late-type stars

TABLE 2
INFRARED STARS OBSERVED FOR CIRCULAR POLARIZATION

Name	<i>V</i>	Date Observed (JD 2441600+)	Measured Mean Circular Polarization
α Cet	8.7	41	$+(0.05 \pm 0.48) \times 10^{-3}$
Z Eri	6.4	41	$+(1.09 \pm 0.44) \times 10^{-3}$
R Lep	6.0	40	$+(0.37 \pm 0.36) \times 10^{-3}$
W Ori	5.6	40	$+(0.66 \pm 0.36) \times 10^{-3}$
α^1 CMa	3.8	40	$-(0.49 \pm 0.36) \times 10^{-3}$
VY CMa	7.5	40, 41	$+(0.01 \pm 0.30) \times 10^{-3}$

has been observed in VY CMa (0.4 percent at $1\ \mu$, <0.5 percent with a V filter) by Gehrels (1972) and in NML Cyg (maximum, 0.6 percent at $1.7\ \mu$) and VY CMa by Serkowski (1973). Gehrels's null results in the visible are in agreement with ours.

We acknowledge the cooperation, advice, and help of Professor W. A. Hiltner of the University of Michigan Astronomy Department. Klaus Czuia of CTIO was a major help with the observations and data reduction. James Ionson and Garth Gerber were of considerable help with the instrument construction and testing. The CTIO staff provided major electronics and logistical support. This work was supported by a Rackham grant and funds from the Office of the Vice-President for Research at the University of Michigan.

Note added in proof.—It has recently come to our attention that J. R. P. Angel and P. G. Martin have submitted a paper in which they describe observation of circular polarizations of between 0.04 and 0.35 percent at $0.84\ \mu$ in the infrared stars NML Tau, CIT 6, IRC 10322, and CIT 11. These stars have characteristics similar to VY CMa and NML Cyg.

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