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# DISCOVERY OF CIRCULAR POLARIZATION IN THE WHITE DWARF G99−37*

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ABSTRACT

The continuum radiation in a band from 3800 to 6000 Å from the DGp white dwarf G99−37 is found to have circular polarization of 0.63 ± 0.03 percent. The effect in this band does not appear to be time-variable, although variations of about 0.3 percent may be present in narrower-wavelength bands. The polarization drops from 0.98 percent in the ultraviolet to 0.44 percent in the blue and then rises gradually to a value around 0.8 percent in the red. A search for linear polarization did not show a definite effect, the measured value in a broad band being $p = 0.21 \pm 0.13$ percent.

A list is given of twenty-four other stars which have been observed for circular polarization with negative results.

Since the discovery of circular and linear polarization of the optical continuum radiation from the λ4135 white dwarf Grw+70°8247 (Kemp *et al.* 1970; Angel and Landstreet 1970*b*) a search for other circularly polarized white dwarfs has been in progress. This program recently led to the discovery of circular polarization in the DC star G195−19 (Angel and Landstreet 1971*a*, *b*; Kemp, Swedlund, and Wolstoncroft 1971). It is the purpose of this Letter to report that circular polarization has been detected in the λ4670p white dwarf G99−37 = GR 248 (Greenstein 1969), and to present a list of other stars which have been observed for circular polarization.

The observations contained in this Letter were made with the polarimeter described in Angel and Landstreet (1970*a*, *b*), mainly using the 82-inch and 107-inch telescopes of McDonald Observatory. All the measurements below have been corrected for night sky and instrumental efficiency. The errors quoted are the calculated standard deviations on the assumption that counting statistics are the only source of error.

After circular polarization was detected in the continuum radiation of G99−37, measurements were made in the band 3800–6000 Å on six different nights to determine whether the effect is variable. The measured values are listed in Table 1. It is seen that there is not a significant variation from one measurement to another, and none of the measured values differ by as much as 2 standard deviations from the mean unfiltered polarization of $V = 0.63 \pm 0.03$ percent. The sign of the polarization is opposite to that of Grw+70°8247 and G195−19, and is positive in Kemp's (1970) convention: to an observer facing the star, the *E*-vector in a fixed plane rotates counterclockwise. All observations in this paper are given with this convention.

The circular polarization was also measured through various glass filters to determine its general wavelength dependence. The individual measured values of the polarization and details of the filters used are given in Table 1. The mean wavelength dependence of the circular polarization is shown in Figure 1. In this figure, the horizontal error bars

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TABLE 1

MEASURED CIRCULAR POLARIZATION OF G99−37

| Mean Wavelength of Passband (Å) | Half-Power Points of Passband (Å) | Time of Measurement (J.D. 2440000+) | Measured Circular Polarization (%) | Filter* |
|---|---|---|---|---|
| 4900 | 3800, 5850 | 973.68 | 0.76±0.09 | None |
| | | 973.70 | 0.67±0.09 | |
| | | 976.62 | 0.67±0.06 | |
| | | 977.73 | 0.54±0.07 | |
| | | 978.71 | 0.68±0.07 | |
| | | 979.59 | 0.76±0.07 | |
| | | 980.59 | 0.63±0.07 | |
| 3550 | 3175, 3925 | 976.69 | 0.93±0.09 | Corning 7-54 |
| | | 979.69 | 1.04±0.10 | |
| 4300 | 3800, 4775 | 977.77 | 0.23±0.11 | Corning 5-59 |
| | | 979.65 | 0.55±0.11 | |
| | | 980.62 | 0.52±0.09 | |
| 4600 | 3775, 5400 | 978.60 | 0.49±0.07 | Corning 4-96 |
| 5850 | 5075, 6450 | 979.62 | 0.65±0.11 | Corning 3-70 |
| 6550 | 6000, 7000 | 976.79 | 0.97±0.11 | Chance OR-2 |
| | | 980.68 | 0.60±0.11 | |
| 7200 | 6675, 7600 | 978.66 | 0.69±0.19 | Corning 2-64 |

* All filters are standard thickness.

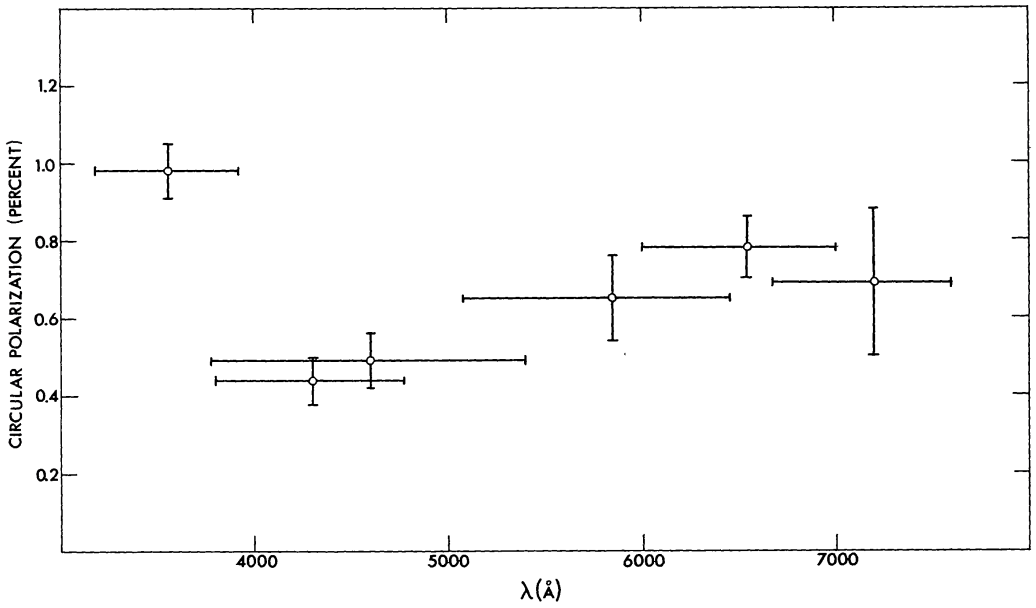


FIG. 1.—Mean circular polarization of G99−37 as a function of wavelength. Horizontal bars give the half-power points of the sensitivity curves; vertical bars show the standard deviations resulting from counting statistics.

show the width between half-power points on the folded filter-photocathode sensitivity curves; the effects of atmospheric extinction have been included. The average circular polarization is about 5 times weaker than that of Grw+70°8247, but the dependence on wavelength in the two stars is quite different. In G99−37 the polarization is at a minimum in blue light, while in Grw+70°8247 it is at a maximum (Angel and Landstreet 1970*b*). Both show sharp variation below 4000 Å and slow variation above this wavelength. It may be significant that the polarization of both stars and of G195−19 all show extrema in blue light.

Examination of the data in Table 1 shows that suspiciously large variations in the polarization measured in the blue (5-59 filter) and orange (OR-2 filter) are present. Although the measurements are not sufficiently precise for it to be clear whether the variations are significant, there may be variations of ∼0.2–0.3 percent present in the data on a time scale of days. Even though these possible variations do not seem to appear significantly in the unfiltered data, it is suggestive that the smallest unfiltered polarization was measured on the same night when the anomalously low blue polarization was obtained. The possibility of time variation is particularly significant in view of the periodic variability of the polarization of G195−19 reported in the accompanying Letter (Angel and Landstreet 1971*b*).

The unfiltered circular-polarization data obtained at J.D. 2440976.62 were printed out every 6 seconds for approximately 1 hour. These data have been Fourier-analyzed for all periods between 12 seconds and 2 hours to determine if short-period variations in the polarization are present. The resulting power spectrum was not significantly

TABLE 2

STARS OBSERVED FOR CIRCULAR POLARIZATION*

| Star Name | EG or GR No.† | *V* | Spectrum | Date of Observation (J.D. 2440000+) | Measured Circular Polarization (percent) |
|---|---|---|---|---|---|
| LTT 17144=G218−8... | 245 | 14.1 | DC | 973.58 | +0.10 ±0.08 |
| F7=BPM 70331..... | 267 | 14.5 | DC | 896.67 | +0.08 ±0.11 |
| R548..... | 10 | 14.10v | DA | 973.61 | −0.05 ±0.09 |
| W219..... | 24 | 15.20 | λ4670 | 973.65 | −0.06 ±0.10 |
| 40 Eri B..... | 33 | 9.52 | DA | 977.70 | +0.04 ±0.05 |
| LB 1320=G83−10..... | 169 | 15.7 | DC | 972.65 | −0.03 ±0.11 |
| G175−34B..... | 180 | 12.45 | DC | 925.56 | +0.12 ±0.13 |
| G39−27..... | 40 | 15.94 | DC | 972.69 | +0.21 ±0.15 |
| G191−B2B..... | 247 | 11.5 | DA wk | 923.63 | +0.023±0.037 |
| GD 84..... ... | 215 | 15.5 | DC | 973.79 | +0.03 ±0.10 |
| GD 85..... | 216 | 14.5 | DBs | 972.72 | +0.07 ±0.10 |
| G107−70..... | 52 | 15.67 | DC | 973.77 | +0.03 ±0.10 |
| U Gem..... | ... | 8.8–13.8 | SS Cyg | 973.73 | −0.04 ±0.09 |
| Z Cam..... | ... | 10.2–13.4 | SS Cyg | 973.81 | −0.07 ±0.09 |
| G47−18..... | 182 | 15.18 | λ4670p | 972.76 | −0.04 ±0.08 |
| G195−42..... | 251 | 15.3 | DC | 973.83 | +0.09 ±0.10 |
| G42−33..... | 252 | 15.37 | DC | 972.80 | −0.02 ±0.11 |
| G44−32..... | 72 | 16.55v | DC | 973.88 | −0.05 ±0.12 |
| L971−14=G10−11.... | 78 | 15.30 | DC? | 973.92 | +0.05 ±0.17 |
| F46..... | 81 | 13.24 | DO-B | 972.93 | +0.07 ±0.05 |
| LB 2539=GD 323..... | 235 | 14.5 | DBp | 972.90 | +0.06 ±0.09 |
| Ton 202..... | 109 | 15.68 | DC‡ | 972.97 | −0.17 ±0.17 |
| GD 190..... | 193 | 14.72 | DBs | 973.01 | +0.14 ±0.10 |
| LTT 16151=G187−15.. | 262 | 15.5 | DC | 896.65 | −0.06 ±0.10 |

* Eight stars observed earlier with negative results are given in Angel and Landstreet (1970*b*).

† Eggen and Greenstein (1965*a*, *b*, 1967); Greenstein (1969, 1970).

‡ Recently identified as a QSO (Greenstein and Oke 1970).

different from a noise spectrum. The amplitude of a sinusoidal polarization wave which would give a power-spectrum peak of the same height as the largest peak observed is 0.18 percent. A periodic polarization wave with an amplitude 50 percent greater than this and a period in the range considered would almost certainly be detected. It therefore appears that if the circular polarization of G99−37 varies, the variation does not have an amplitude greater than about 0.2 percent on any time scale from 12 seconds to about 15 days.

G99−37 was also observed on J.D. 2440977.63 in the band 3800–6000 Å for linear polarization. The polarization, if present, is small, the measured value being $p_x = p \cos\theta = +0.14 \pm 0.09$ and $p_y = p \sin\theta = +0.17 \pm 0.10$. The ratio of linear to circular polarization appears to be $\lesssim 0.3$ in both G99−37 and G195−19 (Angel and Landstreet 1971*b*), in contrast to the case of Grw+70°8247 where this ratio is $\sim 1$ in the blue. This suggests that circular polarization is the primary effect in stars of this type, and that the occurrence of linear polarization is secondary.

An unwidened spectrum of G99−37 was obtained at 200 Å $mm^{-1}$ using the Meinel image-tube spectrograph on the 107-inch telescope. The features observed by Greenstein —a shallow line at 4300 Å and broad shallow absorption bands at 4400 and 4700 Å—are present on our plate. Greenstein's identification of the latter features as the Swan bands of $C_2$ is confirmed by our detection of a further band at λ5170, which coincides exactly with the next (0–0, 1–1, 2–2) Swan band. No other features are clearly present to beyond 6500 Å.

A large number of other stars have been observed for circular polarization. These are mostly white dwarfs of various spectral types, including the light-variable white dwarfs R548 (Lasker and Hesser 1971) and G44−32 (Lasker and Hesser 1969), but two SS Cygni stars have been included. The data which have not previously been published are presented in Table 2. These data have not yet been Fourier-analyzed.

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