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NEW MEASUREMENTS OF CIRCULAR POLARIZATION AND AN EPHEMERIS FOR THE VARIABLE WHITE DWARF G195–19

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ABSTRACT

Observations of the white dwarf G195–19 made for over a year show that the periodic variation in circular polarization continues with constant frequency and amplitude; an accurate value for the period, 1.3309 ± 0.0004 days, is obtained. While the variation in blue-green light is sinusoidal, extensive measurements in red light show an asymmetric curve, reaching a minimum about 6 hours earlier than in the blue-green.

I. INTRODUCTION

The white dwarf G195–19 is the only object known with periodically variable circular polarization. The initial observations made over a period of 2 weeks (Angel and Landstreet 1971, hereafter Paper I) showed sinusoidal variation in blue-green light from 0 to 0.5 percent with a period of 32 hours. A few measurements in red light showed a stronger polarization, variable between 0.5 and 1 percent. In this paper we report the results of observation continued for over a year, with the aim of obtaining an accurate ephemeris and better data in the red.

II. OBSERVATIONS

The new data were obtained at the 50-inch and 84-inch (127- and 213-cm) telescopes of Kitt Peak National Observatory (1971 March and 1972 January), at the 82-inch and 107-inch (208- and 272-cm) telescopes of McDonald Observatory (1971 March and November), and at the 48-inch (122-cm) telescope of the University of Western Ontario (1970 April). The polarimeter described by Angel and Landstreet (1970) or the modified version with gallium arsenide phototubes (Landstreet and Angel 1972) was used to make all measurements. The data were reduced in the same way as in Paper I. A total of 82 new observations of typically one-half-hour duration was obtained in various colors on 17 separate nights.

In the blue-green band, defined by a Corning 4-96 filter with half-power points at 3800–5400 Å, the 32-hour periodic fluctuations are found to continue steadily over the entire period of observation. Independent fitting of the new data gives the same period and amplitude as was originally found. There are a sufficient number of data points over the total period of observation so that a unique, accurate period can be assigned which brings them all into phase. The same procedure was followed as previously (Paper I) to make a least-squares fit to a periodic function of the form

$$V(t) = V_0 + V_1 \sin(\omega t + \phi)$$

for all the original and new data, 64 data points in all. The best-fit values are

$$V_0 = -0.231 \text{ percent};\ V_1 = 0.241 \text{ percent},$$

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and a period of 1.3309 days. The phase is such that the polarization is strongest at JD 2,440,979.071. These parameters give the minimum value of χ^2 equal to 76, indicating that the data are rather well fitted by the sinusoidal wave. This is also apparent in the plot of all the data superposed at the best-fit period (fig. 1a). A χ^2 of 60 would be expected if the real variation were perfectly sinusoidal and the errors only due to random counting statistics. If not due to chance (a 7 percent probability), the slightly higher value can easily be explained by small systematic errors in data taken on five telescopes with changing instrumentation. If, making some allowance for the possibility of systematic errors, we require that acceptable fits have $\chi^2 < 100$, then the range of possible frequencies is from 1.3305 to 1.3313. No other periods in the range 0.5–5 days give an acceptable fit.

Except for the most recent data taken this year, the red data were taken in a band from 6000 to 7000 Å (half-power points) with either S-20 phototubes and a Chance OR-2 sharp-cut filter or with gallium arsenide phototubes, a Corning 2-63 glass filter, and a liquid filter of dilute copper sulfate. All the points in this band, superposed with the same period and phase as the blue-green data, are shown in figure 1*b*. The average polarization is a factor 2 stronger than in the blue-green band, and there is clearly a periodic variation, although the maxima and minima do not correspond with those in the blue-green. Furthermore, the variation is not well fitted by a smooth sinusoidal variation. In the region of phase from 0.2 to 0.3, several points lie significantly lower than would be expected from a smooth wave, and the scatter of measurements on different nights is greater than expected from counting statistics.

In order to investigate this variation with higher statistical accuracy, data were taken at Kitt Peak on four successive nights (covering all phases of the star) with a broad band in the red and infrared for maximum counting rate. The gallium arsenide

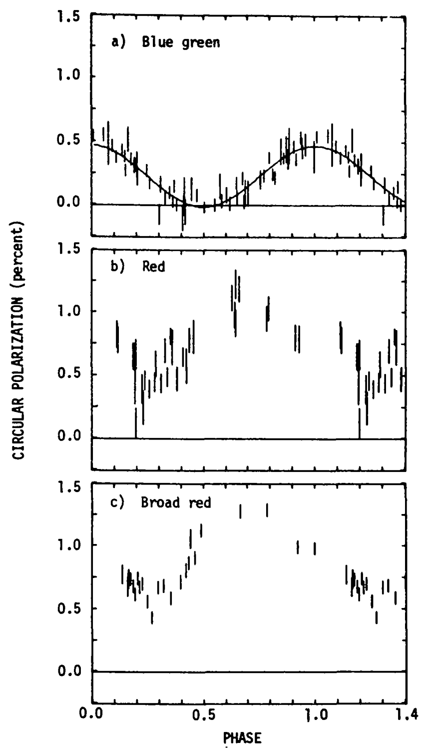

FIG. 1.—Circular polarization measurements of G195–19 superposed with period 1.3309 days and phase = 0 at JD 2,440,979.071 in the wavebands (*a*) 3800–5400 Å, (*b*) 6000–7000 Å, and (*c*) 6000–8800 Å. The data points are shown by vertical lines extending 1 standard deviation above and below the measured value.

phototubes and Chance OR-2 red glass filter were used, giving a sharply defined band between 6000 and 8800 Å. The resulting measurements are plotted in figure 1*c*. It will be seen that the polarization varies in much the same way as in the narrower red band, although the average value (0.9 percent) is slightly larger. The variation does not appear to be sinusoidal and shows a sharp rise from phase 0.4 to 0.6. However, there is no sharp structure at phase 0.2.

III. DISCUSSION

The obvious explanation suggested after the initial discovery of periodically variable circular polarization was in terms of a rotating star with a strong, oblique magnetic field. The fact that the periodicity is found to be stable and phasable over a year adds weight to this interpretation, which we adopt in the following discussion.

An interesting feature of the new data is the clear asymmetry of the polarization variation, shown directly by the broad-red data and by the offset in peak polarization in the different color bands. This requires that there is no plane of symmetry through the rotation axis of the star. An example of a field configuration satisfying this condition is that due to an off-center dipole whose axis does not pass through the rotation axis.

The new data confirm that at different phases of the period the wavelength dependence of circular polarization V is quite different. At phase 0.25 the increase with wavelength is slight, from about 0.15 percent in the blue-green to 0.4 percent in the red, while at phase 0.6 the rise is from around zero in the blue-green to 1.2 percent in the broad-red band. As has already been pointed out in Paper I, this would be explained if the relative strength of a polarization at different wavelengths varies with field strength. Such a behavior must occur in very strong fields where the cyclotron and observed frequencies are comparable. Alternatively, the effect could be caused by changes in composition over the surface of the star, as is seen in magnetic A stars.

The ephemeris given above is of sufficient accuracy that all types of observation from the last year or so can be assigned a phase with good accuracy. The fractional error in the period $\Delta P/P = 0.0003$, corresponding to an error in phase of ± 0.07 per year. The three spectrophotometric observations reported by Greenstein, Gunn, and Kristian (1971) do not show marked variations from one to another, although a change of 0.06 mag in the V-band region is noted. Since there is some evidence for variable composition, it is possible that clearly identifiable features may appear at some phase if observations were spread throughout the cycle. In general, the photographic spectra of this star show a completely featureless continuum, and the image-tube spectrum reported in Paper I shows no spectral features up to 6000 Å at phase 0.65. However, an indication that there may be features at phase 0.77 (JD 2,441,010.710) comes from a plate obtained by E. A. Spiegel, J. C. Theys, and J. Toomre with the Carnegie image-tube spectrograph at the 84-inch telescope of Kitt Peak National Observatory. This shows two broad, shallow bands, one ~60 Å wide, centered at 5870 Å, and the other 30 Å wide at 5754 Å.

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