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DISCOVERY OF CIRCULARLY POLARIZED LIGHT FROM A WHITE DWARF*

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ABSTRACT

Strong circular polarization, 1–3 percent, has been discovered in visible light from the semi-DC "peculiar" white dwarf Grw+70°8247. This is the first such observation on any white dwarf, and is taken as indicating a strong magnetic field. From the theory of gray-body magnetoemissivity, to which the wavelength dependence of the circular polarization would appear to conform, one estimates a mean projected B field of 1×10^7 gauss.

This is to report the first detection of circularly polarized light from a white-dwarf star. The discovery follows a series of theoretical speculations regarding the properties of white dwarfs, including their probable rapid spin, and it culminates several months of fruitless search for direct evidence of strong magnetic fields in such stars (Angel and Landstreet 1970; Preston 1970). It is also the first known case of significant circular polarization in visible light from any star, apart from the polarization of narrow Zeeman-split lines in magnetic Ap stars and in sunspots (see also a forthcoming survey of circular polarization by Gehrels 1970).

The star in question is Grw+70°8247, visual magnitude 13.2. It is a unique, semi-DC type with very little spectral structure (Greenstein and Matthews 1957), having only a shallow (12% depth) unidentified band at λ4135 and two even weaker bands at λλ4475 and 3650.

We see a diffuse circular polarization, throughout the visible and near-ultraviolet spectrum and presumably extending into the infrared, of one sign and of magnitude 1–3 percent, generally increasing toward long wavelengths. The sign (sense) is such that, to an observer facing the star, the E-vector in a stationary plane rotates clockwise. The discovery was made on the 24-inch Pine Mountain telescope of the University of Oregon. A photoelastic polarization system was used which was adapted from laboratory magnetoemission experiments (Kemp, Swedlund, and Evans 1970). These measurements were then verified with more detail on a 36-inch telescope at Kitt Peak Observatory, by means of an equivalent system based on polarized photon counting (Angel and Landstreet 1970). We summarize the trend of the data in Figure 1. Within the time span and resolution involved, the polarization was at least approximately constant in time—certainly no changes in sign were seen. Precaution against spurious results arising in the apparatus, in both sets of measurements, was taken by making readings on miscellaneous

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comparison stars; these showed no circular polarization on the scale of the present data. A discrepancy of rather less than a factor of 2 between the Pine Mountain and Kitt Peak data in the visible may be accounted for by calibration errors and differing sky conditions. Two Pine Mountain observations, representing about 30-minute signal averages on the nights June 14 and June 26, agreed within 10 percent. However, systematic study of long-period variation (over hours, days, etc.) remains to be done. The vertical error bars in Figure 1 are estimates of systematic error. Short-time resolution, on the other hand, was limited purely by photon statistics: The measuring intervals required for a standard deviation σ of 10 percent in the measured fractional polarization were about 15 minutes and 5 minutes with the 24- and 36-inch telescopes, respectively; any more rapid, genuine variations are not yet detectable.

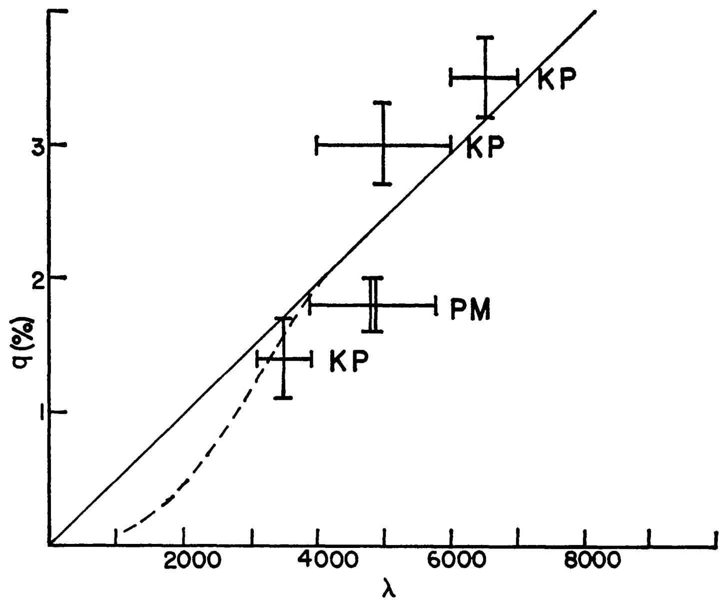

FIG. 1.—Circular polarization, in percent, of light from the white dwarf Grw+70°8247. The data PM refer to two measurements 12 days apart at Pine Mountain; these yielded the same result. The data KP (Kitt Peak) were taken on one occasion. Horizontal bars indicate the approximate wavelength passbands, set by the optical components and filters where used. *Straight diagonal line*, theoretical graybody $q(\lambda)$ for $B = 1.2 \times 10^7$ gauss. Dashed line suggests the possible effect of a plasma cutoff for $\lambda_p \simeq$ 3000 Å.

The polarization here is a very wide-band effect. This indeed made detection feasible with telescopes of modest size, since photons from a large spectral region are collected simultaneously. The polarization data are mean values over a segment of the spectrum (*horizontal bars* in Fig. 1) set, in the Pine Mountain case, by response limits of the optics and photomultiplier alone; in the Kitt Peak work, color filters were used also, and the overall range was extended. A semiquantitative picture of the spectral polarization $q(\lambda)$ was thus obtained.

If the physical origin of the effect is indeed magnetic, we can attribute the wavelength-dependent polarization to the monotonic "graybody" magnetoemission which has been predicted theoretically (Kemp 1970) and demonstrated in the laboratory (Kemp *et al.* 1970). The first-order magnetoemission along the B field is then given by $q(\omega) = -\Omega/\omega = -\lambda\Omega/(2\pi c)$, where $\Omega = eB/(2m)$ is the Larmor frequency. Applying this to the data of Figure 1 yields $B = (1.2 \pm 0.3) \times 10^7$ gauss—an enormous field by most standards! This must be, of course, the projection along the observer's direction of an actual stellar field B_0, of poloidal geometry for example, inclined at some angle—B_0 being still larger.

No explanation other than the gray-body magnetoemission is at hand to account for the gross features of these observations; however, even the crude data carry some suggestion of departure from the simple linearity $q \propto \lambda$. Two complications are in fact expected (Kemp *et al.* 1970). One is a "spectroscopic" term due to the λ4135 band, superimposed on the gray-body term and proportional to the spectral derivative of the λ4135 band shape. The band being quite shallow and narrow, this effect would scarcely affect $q(\lambda)$ under the resolution shown. Second, there is reason to expect a falloff more rapid than λ^{+1} at short λ, i.e., at $\lambda < \lambda_p$, where $\omega_p = 2\pi c/\lambda_p$ is the plasma frequency. This follows from a thermal-equilibrium model for the magnetoemissivity, and it is speculation to apply this literally to surface conditions on a white dwarf. Still, the temptation was overwhelming to sketch in such a deviation, and we have done so in Figure 1 (*dashed line*). The indicated plasma frequency would pertain to an electron density of order 10^{21} cm^{-3}. Extensions of the data (by the use of large telescopes) into both the middle-ultraviolet and infrared are scheduled, to investigate the truth of the λ^{+1} dependence with a possible plasma correction (which might well be shifted from the location in Fig. 1.)

A comment is in order on the spectrum of Grw+70°8247, which, as noted, consists only of two or three vestigial absorption bands. A B-field of 10^7 gauss would displace the central (π) components of Hγ and Hδ by the quadratic Zeeman effect (Preston 1970), to just about the locations of the observed λλ4135 and 3650 features. Whether or not this particular assignment is correct, it is clear that a field of such magnitude would have a profound effect on any stellar spectrum.

The search for magnetic white dwarfs until now had centered on the DA types (having H-lines), with essentially null results. The quest is now shifted toward the DC and some "peculiar" types, based on the premise of diffuse or gray-body magnetic polarization. That Grw+70°8274 is a singular case would be surprising. We can at this time add only a null result on one DC star, G126−27—in which no time-averaged circular polarization as large as 0.2 percent is seen (Swedlund 1970). But the accuracy and scope of the survey can be much extended.

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REFERENCES

Angel, J. R. P., and Landstreet, J. D. 1970, *Ap. J.* (*Letters*), **160**, L147.
Gehrels, T. 1970, *A.J.* (in press).
Greenstein, J. L., and Matthews, M. S. 1957, *Ap. J.*, **126**, 14.
Kemp, J. C. 1970, *Ap. J.*, **162** (in press).
Kemp, J. C., Swedlund, J. B., and Evans, B. D. 1970, *Phys. Rev. Letters*, **24**, 1211.
Preston, G. W. 1970, *Ap. J.* (*Letters*), **160**, L143.
Swedlund, J. B. 1970, unpublished.