Astron. Astrophys. 352, 619–622 (1999)

ASTRONOMY AND ASTROPHYSICS

Polarization variability in magnetic white dwarfs GD 229 and G 240-72

A.V. Berdyugin[1,2,3] **and V. Piirola**[2]

[1] Astronomy Division, University of Oulu, Linnanmaa, PL 3000, 90401 Oulu, Finland (andrei@ukko.oulu.fi)
[2] Tuorla Observatory, University of Turku, Väisäläntie 20, 21500 Piikkiö, Finland
[3] Crimean Astrophysical Observatory, P.O. Nauchny, Crimea 334413, Ukraine

Received 10 September 1999 / Accepted 30 October 1999

Abstract. GD 229 and G 240-72 belong to the group of strongly polarized magnetic ($B \geq 10^8$) white dwarfs which do not show apparent polarization variability. New polarimetric observations obtained in November 1996 and 1997 at the Nordic Optical Telescope clearly confirmed a previously reported detection of long-term variations in polarization of GD 229 and have given for the first time an evidence of similar variations in G 240-72. As this variability can be seen only on the time scale of $\geq$ 10 years, the rotational periods of these objects must be about or longer than 100 years. Such an extremely slow rotation is probably a result of magnetic braking.

Key words: stars: magnetic fields – stars: rotation – stars: white dwarfs – stars: individual: GD 229 – stars: individual: G 240-72

1. Introduction

If the strength of magnetic field on a white dwarf surface is $\geq 10^7$G, the continuum radiation can be noticeably polarized. Such polarization can be detected and studied with conventional broad-band polarimetry. If the magnetic and rotational axes do not coincide (oblique rotator), stellar rotation gives rise to variations in the broad-band polarization. About one-fourth of magnetic white dwarfs have been observed to be polarimetric variables and about half of known objects have been intensively studied to search for the variability (Landstreet, 1992). Most of the variability periods range from several hours to several days. An unusually short period has been found recently in RE J0317-853 (725 sec – Barstow et al. 1995), while KUV 2316+123 has the longest known period – 17.86 days.

There is a group consisting of five magnetic white dwarfs, Grw+70 °8247, LP 790-29, G 240-72, G 227-35 and GD 229, in which no apparent polarization variations have been found on time scales from tens of minutes to more than ten years (West, 1989, Schmidt & Norsworthy, 1990). All these objects have a surface field strength of about a few hundred MegaGauss (MG) and show a large degree of polarization. The absence of variability can be explained either by co-alignment of the magnetic and rotational axes (symmetric rotator) or by a very long ($\geq$ 100 years) rotational period. The latter explanation could infer the ‘magnetic braking’ mechanism, resulting from magnetically driven transfer of the angular momentum of the progenitor star to a stellar wind during the giant stage and to an expanding envelope during the following stage of collapse. Theoretical considerations show that such braking may be very effective, slowing down the rotational velocity to zero (Pacini, 1970; Hardorp, 1974; Brecher & Chanmugam, 1978) However, given merely the fact of non-variability, it is not easy to choose between these two possibilities. On the other hand, detection of long-term variations over decades would support the hypotesis of very slow rotation.

The first polarization measurements for most of these objects have been made in the 1970s, while the latest observations which did not reveal variability were made in 1986-88 by West (1989). We present new polarization measurements of two white dwarfs belonging to the group of apparent non-variables: GD 229 and G 240-72.

2. Observations

Exploratory observations of GD 229 were made in 1994 with the UBVRI polarimeter (Piirola, 1973, 1988) attached to the 1.25 m telescope of the Crimean Astrophysical Observatory. These measurements revealed the difference in the magnitude of both circular and linear polarization and position angle in comparison with the data published in the past (Berdyugin, 1995). In November 1996 and 1997, we made new high S/N observations of GD 229 and G 240-72 using a similar polarimeter (Korhonen et al., 1984) at the 2.5 m Nordic Optical Telescope (NOT), La Palma. Both linear and circular polarization have been measured for GD 229 with superachromatic $\lambda/4$ plate as the polarization modulator, and only linear polarization for G 240-72 ($\lambda/2$ plate). The instrumental polarization was determined by observations of standard non-polarized stars. It was found to be of $\leq$ 0.05% in all passbands and, therefore, negligible for our study. In order to transform the observed polarization from the instrumental to the standard coordinate system, the highly polarized standard HD 204827 was observed. The scale and sign of the circular polarization was checked by observations of Grw+70°8247.

Send offprint requests to: A.V.Berdyugin (andrei@ukko.oulu.fi)

Table 1. Polarization of GD 229

Paper	Time of observations	Spectral region or $\lambda/\Delta\lambda$(Å)	P_l,%	θ, deg	P_c,%
Kemp et al. (1974)	18.12.73	4300/1000	2.8 ± 0.4	75.0 ± 8.0	
		5900/1200	4.4 ± 0.8	90.0 ± 5.0	
Landstreet & Angel (1974)	22.12.73	B	2.9 ± 0.1	78.4 ± 1.0	
		3180-4760			-1.0 ± 0.1
	06.11-	4760-6020			-0.6 ± 0.1
	08.11.73	6020-7460			-0.2 ± 0.2
Efimov (1981)	19.06-	B	2.8 ± 0.2	75.0 ± 1.0	
	28.07.74	V	4.3 ± 0.8	84.0 ± 5.0	
Angel et al. (1981)	24.05.76	B	2.7 ± 0.2	79.5 ± 2.4	
West (1989)	1986-88	U	1.6 ± 0.2	127.0 ± 4.0	-0.1 ± 0.4
		B	2.4 ± 0.1	98.0 ± 2.0	-0.1 ± 0.1
		V	4.4 ± 0.2	97.0 ± 1.0	0.4 ± 0.2
		R	4.8 ± 0.2	94.0 ± 1.0	0.4 ± 0.1
		I	3.5 ± 0.5	92.0 ± 2.0	0.1 ± 0.3
This paper	04.11.96	U	2.79 ± 0.06	102.8 ± 0.6	3.19 ± 0.02
		B	4.01 ± 0.07	113.9 ± 0.5	0.69 ± 0.04
		V	5.64 ± 0.09	115.4 ± 0.5	-0.37 ± 0.05
		R	7.68 ± 0.09	110.7 ± 0.3	-0.94 ± 0.04
		I	4.60 ± 0.30	109.0 ± 2.0	-0.08 ± 0.12

3. New and old polarization measurements

3.1. GD 229

In a search of the long-term variations West (1989), compared his linear polarization measurements with the first data published by Kemp et al. (1974). These first observations were not sufficienly accurate, and it was not possible to judge about variability by comparing the R band position angle obtained by Kemp et al. (1974) with the value obtained by West (87° ± 12° and 94.2° ± 1°, respectively). More accurate observations of GD 229 were published by Landstreet & Angel, 1974; Efimov, 1981; Angel et al., 1981) but these escaped from West's consideration. In Table 1, we present all broad-band polarization data available from the literature, including our latest measurements. One can see from this table that there is an obvious difference in position angle measured in the period 1973–1976 (Landstreet & Angel, 1974; Efimov, 1981; Angel et al., 1981) and that measured by West. The B band position angle has rotated from 80° to 98°, while the degree of polarization remained at approximately the same value (about 2.4% - 2.9%).

A comparison of our new data with that obtained by West (1989) shows further rotation of the position angle in all passbands by 15° - 20°, except for U band, where the position angle deviates from those observed in other wavelength bands at both epochs. The degree of polarization has increased in all passbands by factor of 1.5. There is also a remarkable change in the circular polarization, especially in the U band, to a much larger value of 3.2%, as compared to −0.1%. The sign of polarization has changed as well. The difference between our and West's data is depicted also in Fig. 1 as a wavelength dependence of circular polarization, linear polarization and position angle of linear polarization.

Table 2. Linear polarization of G 240-72

Paper	Time	Band	P_l,%	θ, deg
Angel et al. (1974)	21.12.73	B	1.49 ± 0.08	47.5 ± 1.5
West (1989)	1986-88	U	1.3 ± 0.4	58.0 ± 8.0
		B	1.2 ± 0.2	49.0 ± 4.0
		V	1.3 ± 0.1	45.0 ± 2.0
		R	0.7 ± 0.1	43.0 ± 5.0
		I	0.6 ± 0.1	37.0 ± 6.0
This paper	28.11.97	U	0.79 ± 0.15	14.0 ± 6.0
		B	1.40 ± 0.11	37.0 ± 2.0
		V	1.86 ± 0.12	35.0 ± 2.0
		R	0.73 ± 0.07	21.0 ± 5.0
		I	0.47 ± 0.11	31.0 ± 9.0

3.2. G 240-72

All available broadband linear polarization data are presented in Table 2. As is seen, B band position angle obtained by Angel et al., (1974) and that obtained by West are virtually identical within the errors of determination (47.5° ± 1.5° vs. 49° ± 4°). However, the new value, which we measured in 1997, is 37° ± 2°. The systematic decrease of position angle in comparison with the West's data is clearly seen in all passbands, although only in B and V bands the observational accuracy is good enough to make a definite judgement. The degree of polarization remained within the errors at the same value in U, B, R and I bands, but there is some indication of probable increase in V band (1.3% ± 0.1% vs. 1.9% ± 0.1%).

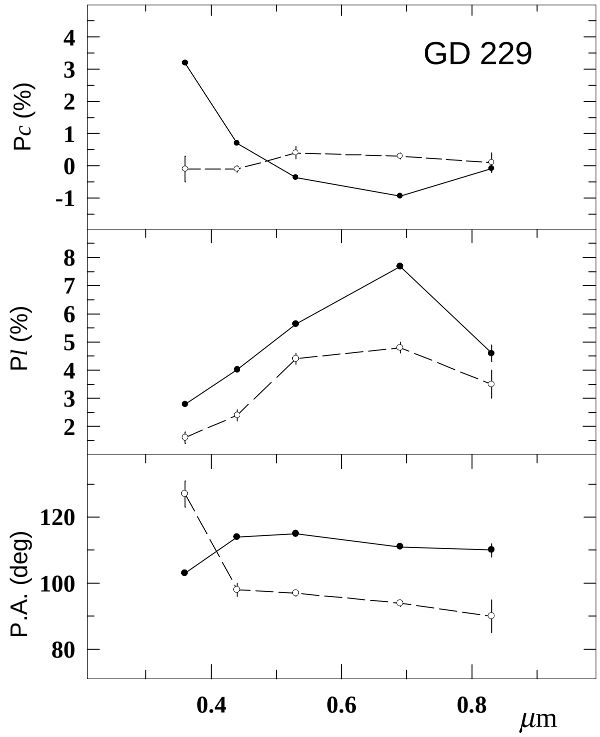

Fig. 1. Circular polarization, linear polarization, and position angle of linear polarization of GD 229 plotted against the effective wavelengths of the UBVRI passbands (0.36, 0.44, 0.53, 0.69 and 0.83 μm). Vertical bars are 2σ errors. Our measurements are shown by filled circles connected with solid lines, West's measurements - by open circles and dashed lines.

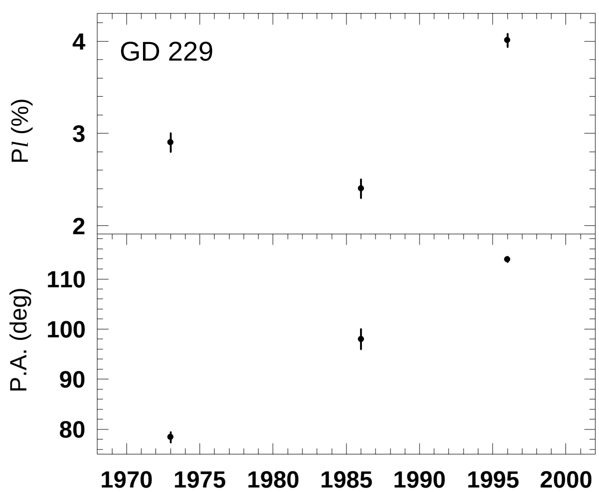

Fig. 2. Variations of the linear polarization and position angle of GD 229 in B band from December 1973 to November 1996. Vertical bars are 2σ errors.

4. Discussion

We can say now that polarization of GD 229 is definetely variable on the time scale of about 10 years. In the B band, over the last 20 years, the degree of polarization has increased from 2.8% to 4.0%, while the position angle has rotated from 80° to 114° (see Fig. 2). If the observed polarization variations are due to the slow rotation, the rotational period of GD 229 can be about 80–100 years. Repeating observations in the next 10–15 years will allow us to make a more accurate estimation.

We can also conclude that there is an evidence of long-term polarization variations in G 240-72. Such variations, however, are seen only on time-scales of more than 20 years. This suggests a rotational period which is at least two times longer than in GD 229. Along with the magnetic field strength, the total amount of mass loss is another important factor determining braking efficiency (e.g. Pacini, 1970). As the surface field strength in both white dwarfs is of $\geq 10^8$G (well above the 10^6G limit required for effective braking), the slower rotation of G 240-72 is probably resulted from smaller mass loss on the stage of formation in comparison with GD 229.

5. Conclusions

Our observations show that the magnetic white dwarf GD 229 which was considered for many years as the canonical magnetic white dwarf with non-variable polarization, actually is a long-term polarization variable. Since the most probable explanation of this phenomenon is a very slow rotation, we consider our results as an observational evidence of magnetic braking effect in highly magnetic single white dwarfs.

However, the details of how this mechanism works are not clear yet. A steady mass loss at the time of formation in presence of a strong magnetic field could bring the degenerate star to a nearly complete standstill (see Pacini 1970; Brecher & Chanmugam, 1978). It assumes that rotating and nonrotating (or very slow rotating) magnetic white dwarfs are formed under very different conditions of mass loss. Alternativelly, rotators could have been spun up by mass transfer from the undetected companions. An extremely fast rotating and highly massive RE J0317-853 can be even the end product of a double-degenerate merger (Barstow et al. 1995). The apparent absence of rotators with the periods in a range of ∼100 days - ∼100 years among the magnetic white dwarfs (see Schmidt & Norsworthy, 1990) is another unexplained phenomenon. Whether it is the effect of the observational selection or natural outcome from the braking process is to be determined.

Acknowledgements. Nordic Optical Telescope is operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway and Sweden, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofisica de Canarias. This research was partly supported by grant from the Centre for International Mobility (CIMO), Finland.

References

Angel J. R. P., Borra E. F. & Landstreet J. D., 1981, A&A Suppl, 45, 457
Angel J. R. P., Hintzen P., Strittmatter P. A., & Martin P. G. 1974, ApJ Lett,190, L71
Barstow M. A., Jordan S., O'Donoghue D., Burleigh M. R., Napiwotzki R. & Harrop-Allin M. K. 1995, MNRAS, 277, 971
Berdyugin A. V., 1995, Astron. Let., 21, 695
Brecher K. & Chanmugam G., 1978, ApJ., 221, 969

Efimov Yu. S., 1981, Izv. Krym. Astrophys. Obs., 63, 118
Hardorp J., 1974, A&A, 32, 133
Kemp J. C., Coyne G. V., Swedlund J. B. & Wolstencroff R. D., 1974, ApJ Lett, 189, L79
Korhonen T., Piirola V. & Reiz A., 1984, ESO Messenger, No 38
Landstreet J. D., 1992, A&A Rewiew, 4, 35
Landstreet J. D. & Angel J. R. P., 1974, ApJ Lett, 190, L25
Pacini F., 1970, Mem. Soc. Astron. Ital, 41, 445
Piirola, V., 1973, A&A 27, 383
Piirola, V., 1988, in Polarized Radiation of Circumstellar origin, eds. G.V. Coyne et al. (Tucson, Univ. of Arizona Press), 735
Schmidt G. D. & Norsworthy J. E., 1990, ApJ, 366, 270
West S. C., 1989, ApJ, 345, 511