Astron. Astrophys. 326, 218–220 (1997)

ASTRONOMY AND ASTROPHYSICS

Research Note

A new period for the magnetic white dwarf KPD 0253+5052

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Received 9 October 1996 / Accepted 7 February 1997

Abstract. We present phaseresolved circular polarization measurements of the rotating magnetic white dwarf KPD 0253+5052. A new and more accurate period of (3.79 ± 0.05) h for KPD 0253+5052 could be determined by measuring the broadband polarization in the Hβ and Hγ lines derived from medium resolution (about 5Å FWHM) spectropolarimetric data at different phases.

Key words: stars: individual: KPD 0253+5052 – stars: white dwarfs

1. Introduction

KPD 0253+5052 was detected during a survey for galactic-plane ultraviolet excess objects with an (U-B) color of about −1.0 by Downes & Margon (1983). They presented a medium resolution (15Å) optical spectrum, which shows distinct Zeeman split absorption lines of the Balmer series. The magnetic fieldstrength was determined to be (13.0 ± 0.7) MG. Later Achilleos & Wickramasinghe (1989) used this spectrum for their model spectrum calculations. They concluded that the optical spectrum of KPD 0253+5052 is well explained by a model with a magnetic dipole, which is offset in z-direction by 0.1−0.2 white dwarf radii, a dipole field strength of (12-14) MG, and a viewing angle of 20° ± 20°. Our phaseresolved spectropolarimetric data also point to a magnetic field geometry, which deviates from a centered dipole. Preliminary investigations favor an offset dipole with offsets not only along the dipole axis but also perpendicular to it. A detailed discussion of the determination of the field geometry by means of model spectra calculated with semiempirical and radiative transfer methods will be published in a forthcoming paper (Friedrich et al. 1997).

An effective temperature of (20000 ± 3000) K (Liebert et al. 1985) and 15000 K (Achilleos & Wickramasinghe 1989) was estimated from colors and model flux distributions, respectively.

KPD 0253+5052 was also investigated by means of white light polarimetry in the spectral range of 3200Å to 8600Å by Schmidt & Norsworthy (1991). Although the polarimetric variability could be confirmed by this observation, the poor sampling pattern led to several aliases in the power spectrum. Therefore only a relatively crude rotation period of (4.1 ± 0.5) h, derived from one night's data, was given.

2. Observation

From December 2 through 6, 1994 phaseresolved flux and circular polarization spectra were simultaneously taken at the Cassegrain focus of the 3.5m telescope of the German Spanish Astronomical Center with the "TWIN"-spectrograph and additionally implemented triple diaphragm and quarter wave plate. In this telescope configuration three double spectra are produced, one double spectrum for the object and two for simultaneous measurements of the sky background. The circular polarization spectrum is then calculated by the difference between the corresponding single spectra divided by their sum. The sum of the corresponding single spectra yields the flux spectrum. Intrinsic polarization of the optics was checked for by observing several early type SAO stars, which were assumed to be circularly unpolarized. All spectra were then correspondingly corrected. The grisms were selected such that the spectra cover the spectral ranges between 3700-5500 Å (blue channel) and 5700-7300 Å (red channel), respectively.

Since we were not interested in absolute fluxes, a flux standard (Feige 34) was observed only once during the observing run, in order to get the right continuum slopes.

3. Period analysis

The used sampling pattern of the phaseresolved observation was adjusted for the period of (4.1 ± 0.5) h derived by Schmidt & Norsworthy (1991) for KPD 0253+5052. Thus six circular po-

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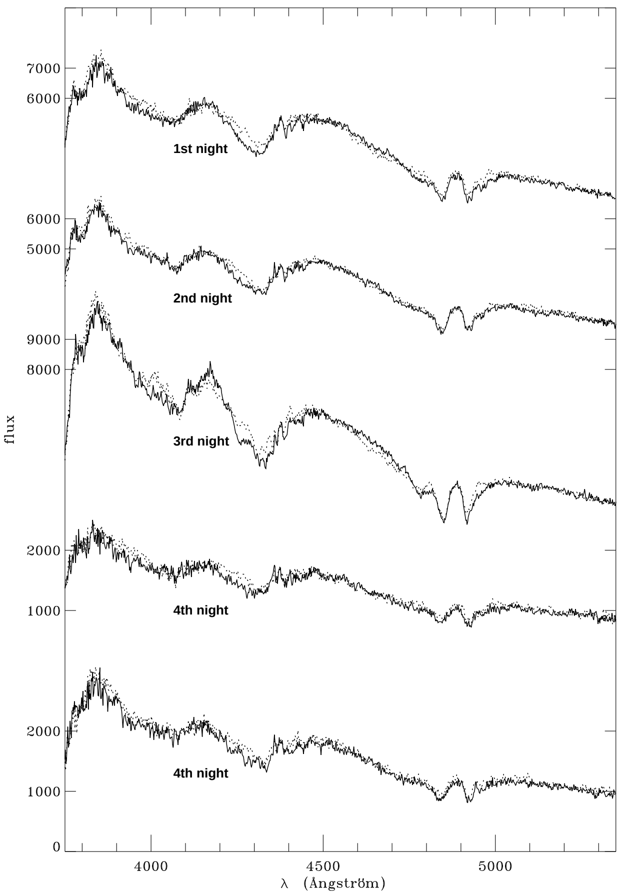

Fig. 1. Spectra for the clockwise and counterclockwise rotating E-vectors (solid, dotted) from different nights for "phase 6" according to the 4.1 h period. A phase shift between these spectra can easily be noticed. The two spectra of the 4th night were taken with half the exposure time used in the nights before. But the exposure and start times were chosen such that together they completely cover "phase 6".

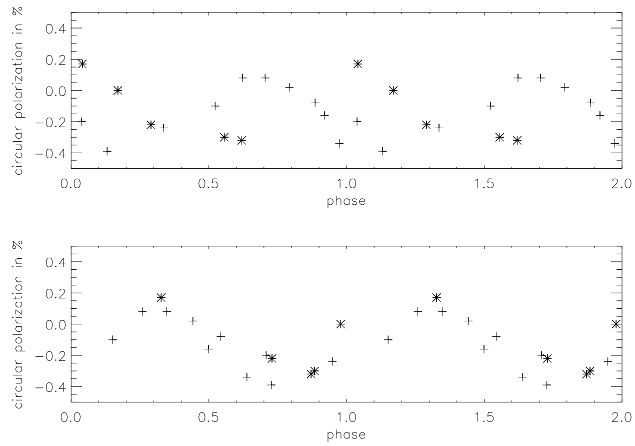

Fig. 2. White light polarimetric data (Schmidt & Norsworthy 1991) of KPD 0253+5052 folded with a period of 4.1 h (top) and 3.79 h (bottom). $*$ symbols are observations which were not used by Schmidt & Norsworthy in their period determination.

larization spectra were always taken at the same phase points within each 4.1 h period. The starting time of "phase 1" was arbitrarily chosen. About 1.5 periods could be observed every night. In Fig. 1 spectra for the clockwise and counterclockwise rotating E-vectors from different nights for "phase 6" according to the 4.1 h period are shown. Phase deviations within the 4 nights of our observing run can be noticed, which correspond to a temporal phase shift and imply a slightly different period for KPD 0253+5052. The period estimation of Schmidt & Norsworthy (1991) is based on data of one night only. But if all their data are folded with the period of 4.1 h it can be seen (Fig. 2) that the measurements obtained during their other observing runs are not consistent with this period, either.

In order to improve the period estimation we simulated broad band circular polarization measurements for Hβ (4500-5060 Å) and Hγ (4170-4480 Å) from our spectropolarimetric data. Data of all four nights were used, despite the bad signal-to-noise of the fourth night, due to a shorter exposure time. In a first approach, the temporal behavior of the mean circular polarization measured for Hβ and Hγ, respectively, was analyzed by fitting a linear trend plus a sinusodial oscillation to the data. Furthermore we also analyzed the time series of one distinct Hβ Zeeman component (4840 Å), which can be fairly seen in all spectra.

The mean circular polarimetric Hγ time series can be well modelled by a sinusoidal oscillation with a period of (3.79 ± 0.05) h which is significantly lower than the former period estimation of Schmidt & Norsworthy (1991). Fig. 3 shows the used range of trial periods and the corresponding χ^2-values for the Hγ line. The strong fluctuations are due to the large observational gaps. The minimum value of the χ^2 envelope yields the χ^2-value of 34.3 (51 d.o.f). The corresponding Hβ time series yields a best period of (3.78 ± 0.12) h with a χ^2-value of 65.8 (51 d.o.f.). If the data are folded with the newly derived period of 3.79 h (Fig. 4) no phase shifts occur during the observations. From the Hβ Zeeman component a period of (3.79 ± 0.02) h is derived, in good agreement with period values from the circular polarization. The corresponding large χ^2-value of this period estimation of 110.1 might be due to phase dependent diminishing of this Zeeman component and a possible confusion with other nearby Zeeman components.

As it can be seen in Fig. 4 there is a phase shift between the folded mean circular polarization data of Hβ and Hγ of about 0.4. The negative polarization maximum of Hγ nearly coincides with the minimum of the Hβ pulse profile. The reason might be that the blue side of the Hγ line is already influenced by the σ^+ components of Hδ, whereas the σ^+ components of Hγ do not interfere with Hβ in the magnetic field strength range considered here.

A mean circular polarization for the whole covered spectral range was also determined. It shows a sinusoidal oscillation around a mean value of about -0.5%, slightly more negative than the data of Schmidt & Norsworthy, but in phase with the older data. The deviation in the mean values of the two observations could be caused by the different wavelengths ranges.

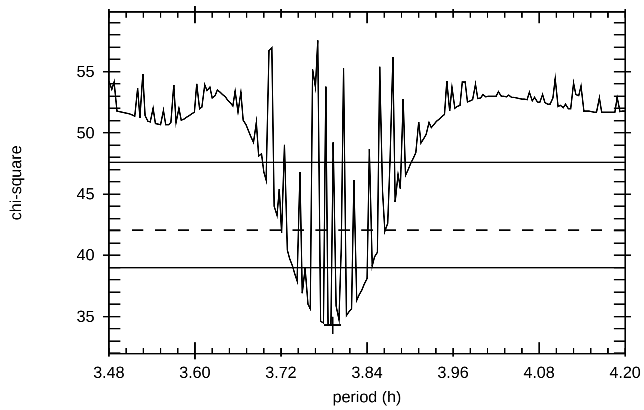

Fig. 3. χ^2 values of the sinusoidal fits for different trial periods of the mean circular polarization of the Hγ line. The solid and dashed lines are the 99%, 90%, and 68% confidence levels (top to bottom), respectively.

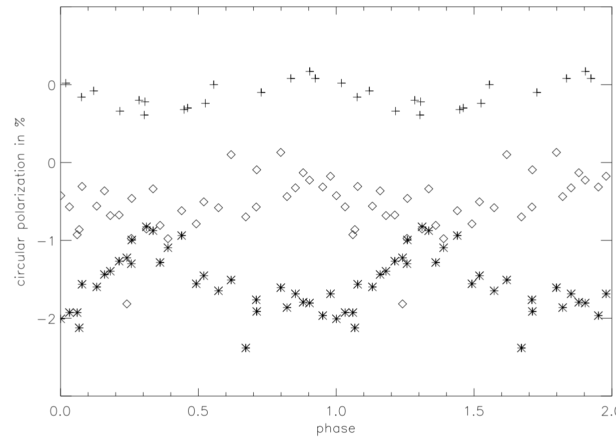

Fig. 4. White light polarimetric data (Schmidt & Norsworthy 1991, top) and simulated broadband polarimetric data (this observation) at the positions of the Hβ and Hγ lines (middle and bottom, respectively) of KPD 0253+5052 folded with a period of 3.79 h. Phase 0 corresponds to the epoch given by Schmidt & Norsworthy.

A period search using common techniques such as epoch folding or Fourier analysis is strongly biased due to the large observational gaps, and cannot be used to get individual period estimates, therefore. But besides many aliases caused by harmonics due to the exposure time of 41 min for an individual spectrum a peak was found at a period of 3.8 h in the χ^2-distribution of the epoch folding.

4. Discussion

By means of fitting a linear trend together with a sinusoidal oscillation a new and more accurate period of (3.79 ± 0.05) h was derived for KPD 0253+5052. This period is significantly (6σ) shorter than the older value of 4.1 h derived by Schmidt & Norsworthy (1991) and the error is reduced by a factor of 10.

Rotating magnetic white dwarf stars offer the possibility to determine all parameters describing the magnetic field geometry, like inclination of the magnetic field axis, field strength and deviations from the dipole geometry. As all spectra are modulated according to the rotation period, a erroneous rotation period will result in wrong phase shifts — in this case a whole period in about two days.

Since the investigation of period distributions among magnetic white dwarfs of Schmidt & Norsworthy (1991) hardly any progress has been made. At that time nine magnetic white dwarfs were known spinning with periods up to 18 days and five being polarimetrically constant. The latter were given periods longer than 100 years since all show highly polarized continua and variations should be easily detectable. From the observation of main sequence stars together with conservation of angular momentum much shorter rotation periods for white dwarfs would be expected. Transferring magnetically angular momentum to the interstellar medium could be an explanation for the slow rotation of white dwarfs. Thus a relationship between the magnetic field strength and the period should exist in the sense that a stronger field corresponds to a longer period.

Meanwhile some new stars can be added to the sample. Two of them, RE J0317-853 (Barstow et al. 1995) and HE 1211-1707 (Reimers et al. 1996) are spinning with periods lower than 100 minutes. In addition RE J0317-853, with 725s the fastest rotating magnetic white dwarf known so far, has a dipole field strength of 340 MG, and HE 1211-1707 one of 80 MG, suggesting that there is no correlation between period and magnetic field strength.

As more and more spectropolarimetric data become available there seems to be some indication that deviations from a pure dipole magnetic field geometry are common among magnetic white dwarfs. About a quarter of all magnetic white dwarfs show multipole or offcentered dipole field geometries. According to Putney & Jordan (1995) this is in agreement with the magnetic field geometries found for Ap stars under the assumption that the field structure is conserved during stellar evolution. There are also a few magnetic Ap stars with very long periods of hundreds of days and more (Catalano & Renson 1984). Together with a similar space density of Ap and magnetic white dwarf stars (e.g. Angel et al. 1981) this is speaking in favor of Ap stars being the progenitors of magnetic white dwarfs.

Acknowledgements. We thank the staff members of the Calar Alto Observatory for their assistance during the observation and the Deutsche Forschungsgemeinschaft for financial support. S.F. acknowledges a post doctoral grant from the Deutsche Forschungsgemeinschaft.

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