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ASTRONOMY AND ASTROPHYSICS

Research Note

Variations of the Ap star HD 208217*

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Abstract. We present a new determination of the rotation period of the Ap star HD 208217 based on photometric and magnetic measurements. The variations of this star are remarkable by the strong anharmonicity of its lightcurves in all colours as well as by the double wave of its mean magnetic field modulus variations.

Key words: stars: chemically peculiar – stars: individual: HD 208217 – stars: rotation

1. Introduction

HD 208217 = CpD $-62°6281$ (spectral type A0pSrEuCr) is known to present large photometric variations. On the basis of 15 observations carried out in the $uvby$ system with the 50cm Danish telescope, in September 1981, at the ESO La Silla Observatory, Manfroid & Renson (1983) reported a peak-to-peak amplitude of 0.14 magnitude in the Strömgren c_1 index, largely due to strong variations in the v band. These authors determined the rotation period as $8\overset{\mathrm{d}}{.}35 \pm 0\overset{\mathrm{d}}{.}10$. The $uvby$ data have been reanalyzed by Mathys & Manfroid (1985), who noted a strong anharmonicity of the v lightcurve, the amplitudes of the first two harmonics being approximately equal, respectively 0.0318 and 0.0271 mag.

In 1993 one of us (GM) discovered the presence of magnetically resolved lines in the spectrum of HD 208217 and started observing the variations of the mean magnetic field modulus (for a presentation of the technique, see Mathys (1990)). A rather large Doppler broadening and the presence of blends in the spectra affected the accuracy of the measurements, thus preventing clearcut conclusions to be derived from the magnetic variations. It was obvious, however, that the period initially deduced from the photometric data did not fit well the magnetic observations. A further observational effort was needed.

2. Observations and period analysis

Additional photometry was carried out in December 1993, again in the $uvby$ system, with the SAT telescope of La Silla. 14 points were obtained over an interval of one month. The homogenized data are given in Table 1.

The period search is performed by looking for the best fit of a mathematical model to the observational data. The fitting function is a cosine wave and its first harmonic:

$$m(t) = A_s + \sum_{i=1}^{I} B_i \cos\left(\frac{2\pi i\,(t-t_0)}{P} + \phi_i\right) \quad (1)$$

where m is the magnitude, P the fundamental period, I the total number of harmonics, t the time and t_0 the origin of time. Subscript s designates the distinct photometric data sets which, in all generality, may differ because of minor instrumental changes (only affecting the zero points), the use of different comparison stars, or the absence of the latter. The least-squares fit and the uncertainties of the estimated parameters are computed by the general method described by Press et al (1992).

The use of this period-searching algorithm has two advantages. Firstly, Eq. (1) is known to be a very good approximation for most well-studied Ap stars; higher-order harmonics, if at all present, are of small amplitudes (see, e.g., Mathys & Manfroid 1985, Manfroid & Renson 1994). Secondly, the zero-point differences between the Danish and SAT photometric systems are automatically adjusted by the procedure for each trial period. This is of little concern for large data sets with homogeneous phase coverage, where the zero-point shifts can be calculated from simple averages. With only a small observational material at our disposal, it becomes a big asset since the zero points of peculiar stars cannot be accurately estimated from regular standard-star transformations.

Because of the 12-year gap separating both sets of observations, an unambiguous determination of the period proves to

* based on observations made at the European Southern Observatory (La Silla, Chile; ESO programmes Nos. 53.7-028, 54.E-0416 and 55.E-0751)

Table 1. Differential photometry of HD 208217. The comparison star is HD 207964=HR 8352. The data are homogenized, so the average level is zero in each band and each photometric system.

HJD−2 400 000	u	v	b	y
44862.5474	0.0091	0.0414	0.0085	-0.0076
44863.5586	0.0015	-0.0096	-0.0006	0.0023
44863.8146	0.0016	-0.0189	-0.0019	0.0029
44866.5477	0.0009	-0.0045	-0.0007	0.0005
44870.6652	0.0090	0.0533	0.0142	-0.0055
44871.5594	0.0049	0.0168	0.0038	0.0003
44871.7600	0.0039	0.0028	0.0004	-0.0028
44872.5846	-0.0081	-0.0314	0.0001	0.0073
44873.5960	-0.0049	-0.0204	-0.0020	0.0072
44873.7575	-0.0025	-0.0177	0.0016	0.0039
44875.7504	-0.0023	-0.0271	-0.0071	0.0034
44876.5677	-0.0112	-0.0312	-0.0139	0.0005
44876.7451	-0.0009	-0.0256	-0.0125	0.0003
44877.5540	0.0001	0.0136	-0.0007	-0.0023
44878.5608	0.0070	0.0564	0.0141	-0.0080
49324.5261	-0.0015	-0.0058	-0.0027	-0.0028
49324.5373	0.0010	-0.0033	0.0028	0.0045
49325.5210	-0.0106	-0.0164	-0.0109	-0.0097
49325.5385	-0.0107	-0.0162	-0.0056	-0.0035
49326.5313	-0.0060	-0.0359	-0.0126	0.0045
49347.5355	0.0078	0.0002	-0.0001	-0.0024
49347.5663	0.0058	0.0030	0.0061	0.0067
49348.5351	-0.0065	-0.0311	-0.0026	0.0102
49349.5355	-0.0016	-0.0121	0.0020	0.0049
49350.5554	0.0071	0.0004	0.0028	0.0035
49351.5358	-0.0043	-0.0287	-0.0079	0.0037
49351.5602	-0.0027	-0.0312	-0.0099	0.0017
49352.5376	-0.0101	-0.0240	-0.0096	0.0022
49353.5360	0.0033	0.0237	0.0051	-0.0040

be impossible, with dozens of equally likely candidates spread over a rather broad interval centered at $8\overset{\mathrm{d}}{.}6$ (see Fig. 1 for the periodogram relative to the b data set).

A few additional measurements of the star have been secured in September 1993 at the ESO 1 m telescope in a special narrow-band filter having the same central wavelength as Strömgren b. No comparison star was measured and the overall accuracy of the "all-sky" measurements cannot be compared to that achieved in the other data sets. Nevertheless they proved to be valuable in constraining the range of possible periods to about half a dozen candidates (see Fig. 2).

Lifting the remaining ambiguity was made possible by the analysis of the variations of the mean magnetic field modulus (Mathys et al. 1996). 31 magnetic mesurements were secured over two years. The resulting periodogram obtained with the same method as for the photometric data is shown on Fig. 3.

By combining the photometric and magnetic results, the most likely period appears to be P = $8\overset{\mathrm{d}}{.}44475(\pm 0\overset{\mathrm{d}}{.}00011)$. The next candidate is P = $8\overset{\mathrm{d}}{.}42880(\pm 0\overset{\mathrm{d}}{.}00011)$ which, although less probable, cannot be totally excluded.

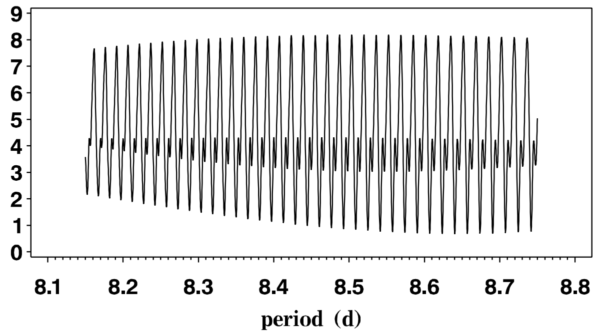

Fig. 1. Periodogram of the Strömgren b data; in this, and the next two figures, the quantity in ordinate is the *reduced* χ^2 of the fit by a cosine wave and its first harmonic

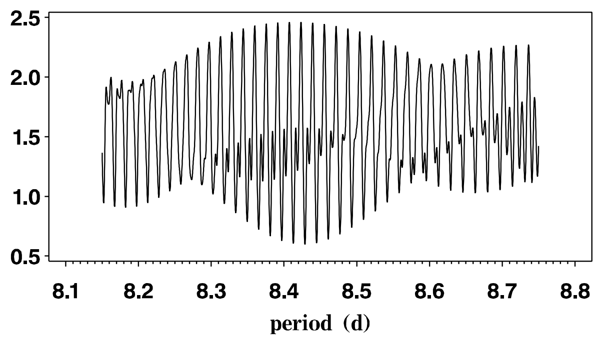

Fig. 2. Periodogram of the Strömgren b data together with the narrow-band data

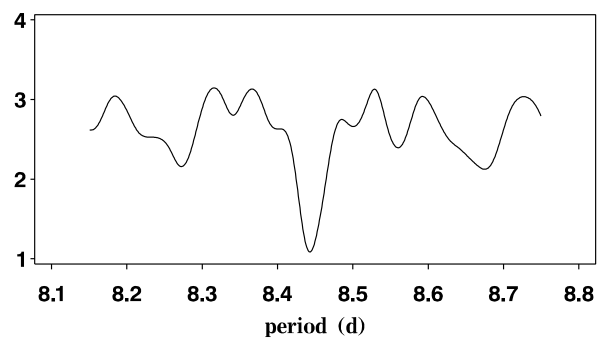

Fig. 3. Periodogram of the magnetic data

The $uvby$ lightcurves obtained with the newly determined period are shown in Fig. 4. The coefficients of the cosine-wave decomposition are given in Table 1. The origin of time is t_0 = 2 447 000.0.

HD 208217 is characterized by strongly anharmonic light curves. The amplitude of the first harmonic is practically equal to that of the fundamental wave in each band. A search for higher-order harmonics hints at a marginally significant second-order wave in the v band only (and in the indices m_1 and c_1). Third-order harmonics are totally negligible.

Although their ratio stays more or less constant, the amplitudes B_1 and B_2 change dramatically with wavelength, with

Table 2. Parameters of the least-squares fits for the photometric and magnetic variations of HD 208217. The error on each parameter is indicated in parentheses. σ is the scatter around the least-squares fit. r is the total range of the analytical model. Units are magnitude and Gauss.

	B_1	B_2	ϕ_1	ϕ_2	σ	r
u	0.0057 (0.0019)	0.0047 (0.0018)	3.89 (0.33)	2.72 (0.37)	0.0038	0.0167
v	0.0314 (0.0014)	0.0273 (0.0013)	3.58 (0.04)	2.36 (0.05)	0.0028	0.0920
b	0.0077 (0.0012)	0.0072 (0.0011)	4.14 (0.14)	2.20 (0.15)	0.0025	0.0261
y	0.0049 (0.0014)	0.0041 (0.0013)	6.25 (0.23)	5.83 (0.32)	0.0030	0.0155
$b-y$	0.0110 (0.0009)	0.0110 (0.0009)	3.75 (0.08)	2.38 (0.08)	0.0016	0.0363
m_1	0.0153 (0.0016)	0.0092 (0.0016)	3.18 (0.08)	2.45 (0.17)	0.0034	0.0412
c_1	0.0513 (0.0021)	0.0431 (0.0020)	0.33 (0.04)	5.49 (0.05)	0.0045	0.1480
$< H >$	379.8 (162.4)	484.6 (146.3)	5.80 (0.42)	1.50 (0.22)	341.1	1510.2

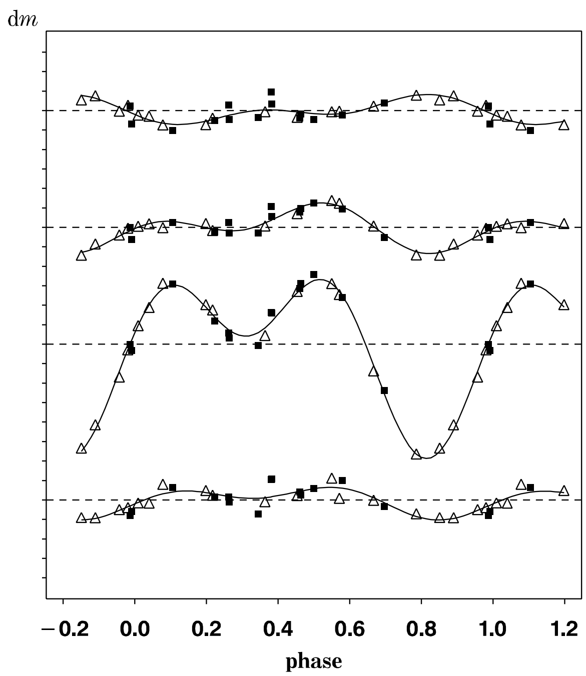

Fig. 4. Lightcurves in $uvby$ (bottom to top) plotted with the period $8^{\mathrm{d}}.44475$; ticks on the ordinates are separated by 0.01 mag; *open triangles* represent the Danish telescope 1981 data; *filled squares* are the SAT 1993 observations

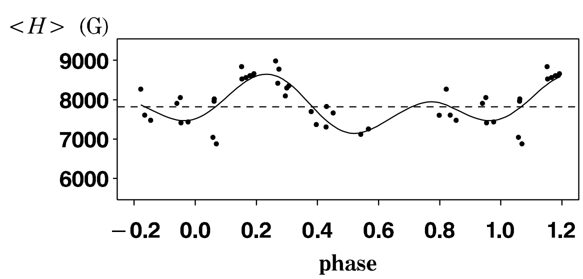

Fig. 5. Phase diagram of the mean magnetic field modulus with the period $8^{\mathrm{d}}.44475$

a sharp maximum in the v band and a reversal between the b and y bands. The phases of the various components are more consistent and the double-wave pattern is recognizable in every band.

The phase diagram of the mean magnetic field modulus, with a two-wave fit superimposed, is shown on Fig. 5. The coefficients of the fit are given in the last line of Table 1. While the presence of a first harmonic in the magnetic variations is now well established, the observational errors do not allow to conclude on possible higher-order terms.

3. Conclusions

The combination of photometric and magnetic observations of the star HD 208217 allowed the derivation of its rotational period as $P = 8^{\mathrm{d}}.44475(\pm 0^{\mathrm{d}}.00011)$. The optical lightcurves and the magnetic modulus variations appear to be highly anharmonic and the photometric amplitudes are strongly wavelength dependent. It is interesting to note that HD 208217 is the only star known to present a double-wave structure in the magnetic field modulus variations (Mathys et al. 1996). All this suggests a rather uncommon atmospheric structure and shows the need for additional magnetic observations.

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