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Radial Velocity and Magnetic Field Measurements of the A-type Supergiant ν Cep (HD 207260)

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On the basis of 55 Zeeman spectrograms obtained at Tautenburg in the years 1975–1979 the effective magnetic fields and the radial velocities of the supergiant ν Cep (HD 207260) were determined. For the effective magnetic field a slow variation occurring on a time scale of years was found. The spectrograms taken at the first time show only moderate effective magnetic field strengths of a few hundred Gauß, but in the year 1978 values of +2000 Gauß were detected.
The measured radial velocities show a longtime variability similar to that of the magnetic field as well as more rapid changes. A periodical variation of the radial velocity with a period of ~ 39.9 days, perhaps produced by the rotation of the star, is indicated. The Balmer absorption lines H_β, H_γ, and H_δ have different radial velocities refering to the presence of an expanding envelope. Moreover, there exist significant differences between the velocities of various elements respectively ions of 1–4 km/s.

Aus 55 von 1975 bis 1979 in Tautenburg erhaltenen Zeeman-Spektrogrammen wurden effektive Magnetfelder und Radialgeschwindigkeiten des Überriesen ν Cep (HD 207260) bestimmt. Für das effektive Magnetfeld wurde eine langsame Variation mit einer Zeitskala in der Größenordnung von Jahren gefunden. Die ersten Spektrogramme ergeben nur mittlere effektive Magnetfeldstärken von einigen 100 Gauß, doch 1978 wurden Werte von +2000 Gauß gefunden.
Die gemessenen Radialgeschwindigkeiten zeigen sowohl Langzeitvariabilität ähnlich dem Magnetfeld als auch schnellere Änderungen. Eine periodische Variation der Radialgeschwindigkeit mit einer Periode von ~ $39\overset{d}{.}9$, möglicherweise durch die Rotation des Sternes erzeugt, wurde aufgefunden. Die Balmer-Absorptionslinien H_β, H_γ und H_δ haben verschiedene Radialgeschwindigkeiten, was auf eine expandierende Hülle schließen läßt. Zwischen verschiedenen Elementen bzw. Ionen existieren deutliche Geschwindigkeitsunterschiede von 1–4 km/sec.

1. Introduction

During the last two decades, the supergiant ν Cep (HD 207260), A2 Ia, was included in numerous spectroscopic and photometric investigations. As far as we know the star has no significant photometric variability. In the David Dunlop Observatory photometric system of 285 stars ν Cep is used even as a standard star. The magnitude and colors given in the paper of Mc Clure (1976) are $m_v = 4.29$ mag. (Johnson and Morgan *UBV* system), $(B - V) = 0.52$ mag., and $(U - B) = 0.13$ mag. Many infrared photometric measurements are to be mentioned. According to Johnson (1967) the observed large infrared excess might be explainable as emission from a circumstellar shell. Additional evidence for the existence of an envelope is the presence of an emission component in the red wing of H_α as reported by Rosendhal (1973) and by Frandsen (1975).

The determination of radial velocities of a sample of early- and intermediate-type supergiants by Abt (1957) showed that all velocities are variable in a semiregular manner. For ν Cep radial velocities between −21 and −25 km/s were found during the observational epoch of one month. The values show four maxima so that Abt adopted a period of 7.6 days. Further radial velocity data, published by Abt and Biggs (1973), differ by about ±4 km/s for the individual observational series with a mean value of −21 km/s if three old spectrograms taken at July 1909, Nov. 1911, and Sept. 1912 are neglected. These old plates gave essentially smaller radial velocities, namely -6.1 ± 2.0, -9.8 ± 2.3, resp. -9.9 ± 0.7 km/s. However, periodical variations of the radial velocity in any time-scale are not to discern.

Polarimetric investigations of ν Cep were carried out by various authors. Circular polarization observations were made during the period Sept. 1972–Aug. 1973 by Stokes et al. (1974). ν Cep was found to be very probable circularly polarized. The amount (normalized Stokes parameter V) is about two times larger than the observational accuracy and the sence in the handeness was found to be of opposite sign in the "blue" and "red" spectral region. The existence of a small circular polarization in ν Cep has also been confirmed and improved by Avery et al. (1975) and Martin and Campbell (1976).

2. Observations and Reductions

The 55 plates were obtained with Zeeman analyzer at the Coudé focus of the 2 m-telescope at Tautenburg by a group of colleagues. The spectrograms have a reciprocal linear dispersion of 7.9 Å/mm with the exception of one which has a value of 5.9 Å/mm (observational date *J. D.* 2442975.504). Because the best efficiency of the quarter-wave plate of the analyzer is near to λ 4250 Å all spectrograms were made in the blue-violet spectral region ranging from about $\lambda\lambda$ 4000—4600 Å. The width of the slit was equivalent to 0.12 Å. The spectrograms were measured on the oscilloscope display machine described by GERTH et al. (1977). The radial velocities and the effective magnetic field strengths were determined by using a code written by one of us (E. G.; details of the computing codes will be published in Publ. Astrophys. Obs. Potsdam).

Table 1 represents the measured radial velocities and effective magnetic field strengths. Data of observations and the number of the measured lines are tabulated, too. On account of a defect of one analyzer used 1976 it is not possible to calculate the effective magnetic field strengths in this observational period. Tabulated radial velocities as well as the magnetic fields correspond to the mean of all measured lines. The accuracy (r.m.s.) of a given radial velocity value is about ±0.4 km/s and that of the magnetic field strength about ±250 Gauß.

Table 1. Journal of observations

J. D. 2400000+	*RV* (km/s)	B_{eff} (Gauß)	*n* (lines)
1975			
42467.268	-16.39 ± 0.58	+ 99 ± 234	31
42501.649	+25.55 ± 0.28	+ 616 ± 254	38
42503.652	+21.27 ± 0.33	+ 247 ± 246	39
42521.524	-24.15 ± 0.26	- 625 ± 148	56
42524.548	-23.61 ± 0.26	+ 367 ± 190	58
42589.549	-18.31 ± 0.39	+ 360 ± 166	45
42594.535	-17.49 ± 0.77	+ 493 ± 511	25
42596.529	-20.83 ± 1.13	- 171 ± 452	25
42598.500	-19.91 ± 1.01	+ 549 ± 630	34
42599.533	-20.11 ± 0.28	- 171 ± 191	51
42602.549	-18.88 ± 0.35	+ 162 ± 257	48
42603.504	-19.00 ± 0.92	+ 83 ± 301	33
42604.567	-22.02 ± 0.34	- 163 ± 111	51
42623.532	-19.69 ± 0.28	- 232 ± 85	49
42623.555	-20.56 ± 0.22	- 421 ± 142	55
42624.538	-18.72 ± 0.21	- 377 ± 150	50
42645.566	-22.80 ± 0.35	- 148 ± 64	50
42646.458	-23.98 ± 0.47	+ 575 ± 400	37
42646.500	-23.09 ± 0.32	- 251 ± 124	51
42653.542	-22.66 ± 0.65	- 199 ± 212	28
42654.432	-23.49 ± 0.29	- 115 ± 107	53
1976			
42953.549	-17.36 ± 0.29		66
42955.546	-17.21 ± 0.27		71
42956.558	-19.54 ± 0.27		67
42958.545	-21.35 ± 0.33		70
42959.550	-19.79 ± 0.32		70
42962.545	-18.96 ± 0.38		69
42963.479	-18.59 ± 0.36		67
42966.515	-21.09 ± 0.27		65
42967.484	-20.28 ± 0.37		65
42969.503	-16.38 ± 0.54		30
42972.539	-18.32 ± 0.33		55
42975.504		- 643 ± 200	34
42998.569	-20.97 ± 0.37		54
42999.542	-20.79 ± 0.28		61
43005.454	-18.14 ± 0.41		59
43007.509	-17.49 ± 0.30		58
43029.417	-14.75 ± 0.43		44
43034.475	-15.35 ± 0.28		56
43036.597	-15.19 ± 0.52		48
43084.259	-22.49 ± 0.64		39
1977			
43411.332	-23.85 ± 0.41	+ 879 ± 239	39
43472.226	-24.47 ± 0.25	+1685 ± 437	37
43497.260	-25.66 ± 0.27	+ 664 ± 310	53
43498.395	-25.33 ± 0.33	+ 870 ± 282	55
1978			
43655.563	-21.24 ± 0.43	+1966 ± 624	42
43657.565	-20.58 ± 0.90	+1934 ± 692	30
43658.565	-21.50 ± 0.91	+2828 ± 803	29
43700.567	-22.65 ± 0.82	+1871 ± 570	38
43741.626	-19.42 ± 0.60	+ 839 ± 401	35
43742.583	-20.00 ± 0.37	+1924 ± 565	47
43768.429	-20.07 ± 0.27	+ 282 ± 450	50
43832.244	-20.02 ± 0.36	+ 593 ± 661	43
43833.278	-19.10 ± 0.35	- 559 ± 741	35
1979			
44118.577	-21.77 ± 0.33	+ 194 ± 290	59

3. Magnetic Field

The measurements of the Zeeman spectrograms yield the longitudinal magnetic field componente B_{eff}. Now, B_{eff} can be determined either by the mean value of the individual displacements of the lines of a spectrogram or by the inclination of the straight line which represents the relation between the wavelength difference $\Delta\lambda/\lambda^2$ between the lines in the right- and lefthand polarized spectrum and the effective Landé factor $g_{eff} = z$. In consequence of the small number of lines measurable in the spectrograms of ν Cep as well as of the large scattering in the line displacements for a constant z-value the determination of the inclination of the straight line for a single spectrogram is very uncertain. Therefore, a value of B_{eff} given in Table 1 is a weighted mean derived from the line shifts. The weight corresponds to the deviation of the individual values from a normal distribution. In Fig. 1 these effective magnetic field strengths are represented as a function of time. A hint at a periodic behaviour with a period of about 4 years and a maximum of the magnetic field of +2000 Gauß at the beginning of the year 1978 is to be seen. The reality of the existence of such a large longitudinal magnetic field at the beginning of 1978 has also been confirmed by the following procedure. For the six spectrograms which show the large positive field the average of the measured line shifts $\Delta\lambda$ of a spectral line was plotted in the $\Delta\lambda/\lambda^2$-z-diagram, in each case in which a spectral line exists at least in two spectrograms (in consequence of the use of a mean calculated from a summarizing of n plates the scattering of the points in the $\Delta\lambda/\lambda^2$-z-diagram is diminished in compliance with a factor $1/\sqrt{n}$). Fig. 2 represents this diagram; an average magnetic field of $+2300 \pm 425$ Gauß is clear indicated.

The existence of strong longitudinal magnetic fields in Ap stars has been placed beyond dispute since 1946 (1947), by the observation of the longitudinal Zeeman effect in the spectra of such stars. The periodical variation of the effective magnetic field B_{eff} observed for many Ap stars is most frequently interpreted by the rotation of the star. Accordingly, the question arises, if it is possible to explain the magnetic behaviour of ν Cep in the same way.

The equatorial rotational velocity v of ν Cep can be estimated from the parameters T_{eff} and M_{bol}. Corresponding to these values — $\log T_{eff} = 3.95$ and $M_{bol} = -6.51$ mag. published by BURKI (1978) — the radius would be 35 $R_\odot$ so that the magnetic period of about 4 years, ~1400 days, would yield an equatorial rotational velocity of 1.2 km/s. According to ROSENDHAL (1970) the measured $v \cdot \sin i$ value is 38 km/s. Even with the concession of a large uncertainty of both values it seems improbable to assume that the large magnetic period reflects the rotation of the star. Vice verca, the slow variation of the detected magnetic field is probably produced by a physical process in the atmosphere of ν Cep and not the consequence of different visibility of the magnetic field caused by the rotation of the star only.

4. Radial Velocities

The radial velocities show a rather complex behaviour. Fig. 3 represents the values of Table 1. The shape is similar to that of the magnetic field, but a large scattering is conspicuous in each observational epoch. A search for a period in the radial velocities during 1975 and 1976 by the method of LAFLER and KINMAN yields a faint hint at a period near 39.9 days. Take into account the longtime variation of the radial velocities, in Fig. 4 the deviations from the mean radial velocity curve was drawn assuming the period of 39.9 days. Wether rotation or pulsation is the reason for this obviously periodical variation cannot be decided with certainty, though the succeded estimations seem to speak more in favour of the rotation.

The equatorial rotational velocity v, the period P, and the stellar radius R are related by $v = \frac{50.6 \cdot R}{P}$, if R, v, and P are expressed in solar radii, km/s, and days, respectively. Because ν Cep is viewed at unknown inclination i,

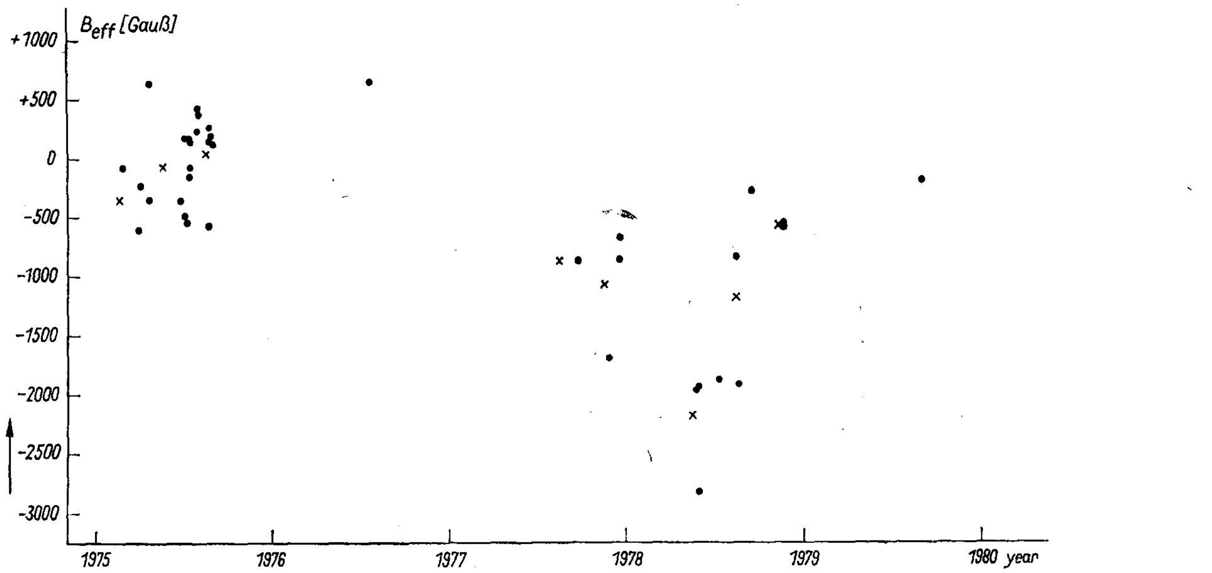

Fig. 1. Effective magnetic field in progress of time. Crosses denote mean values of three month.
(In consequence of an artifact of the measuring process the polarity of the magnetic values must be contrary to the present data of Fig. 1)

the observed value of $v \cdot \sin i = 38$ km/s gives for $\sin i = 90°$ the lowest limit of the period, 46 days. Compared to it, a pulsational period can be estimated from the value Q published by BURKI (1978). Corresponding to BURKI log Q is -1.368; with a density of $\varrho/\varrho_\odot \sim 7.5 \cdot 10^{-5}$ for ν Cep the fundamental radial pulsational period is about 4.9 days. Shorttime velocity variations are indicated, but to be shure, further observations are necessary. Our observational material is inadequate in many aspects so that no secure conclusion can drawn in this respect.

Radial velocity differences for lines of neutral and ionized elements in supergiants have been derived by various authors, e.g. ADAMS and MCCORMACK (1935) already, GROTH (1972), and AYDIN (1972). Our measurements of ν Cep confirm this effect. A detailed study of differential velocities for various elements, various ions of the same element and even for lines of the same element but belonging to different multiplets has been made. In Table 2 the differential velocity displacements are given. The radial velocities of ions of the elements Fe II, Cr II, and Ti II show clear differences; a dependence on the time cannot be found, because these differences may be represented by a normal distribution as confirmed by the χ^2-test. For iron the radial velocities between the ion and the neutral element yield very distinct differences between 1975 and 1976.

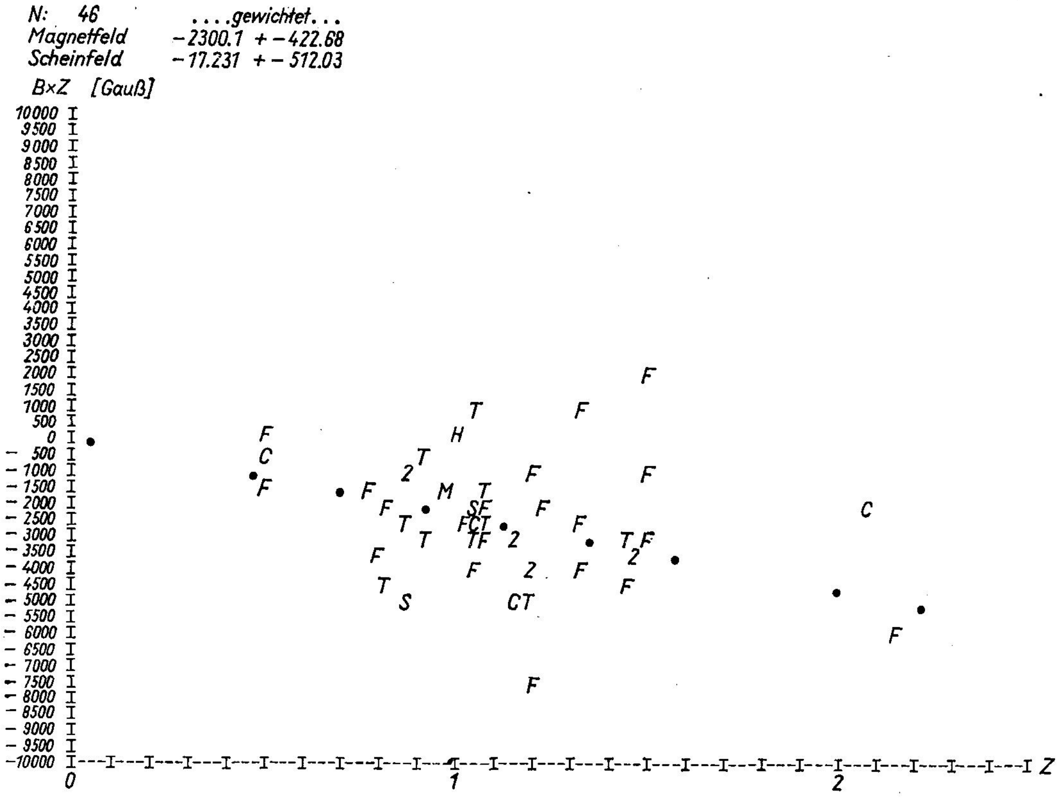

Fig. 2. $B \cdot z$ — z-diagram for the six spectrograms with the large magnetic field. In case that a line is present in two spectrograms at least, the mean displacement of the line is plotted. Symbols are initial letters of the elements, dots are the result after a calculus of observations. (see also legend of Fig. 1!)

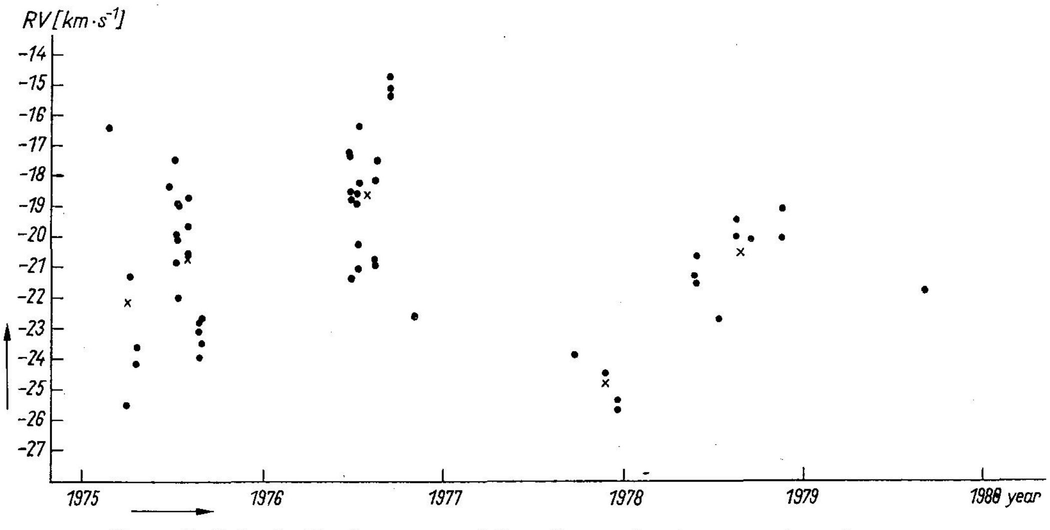

Fig. 3. Radial velocities in progress of time. Crosses denote mean values of a group.

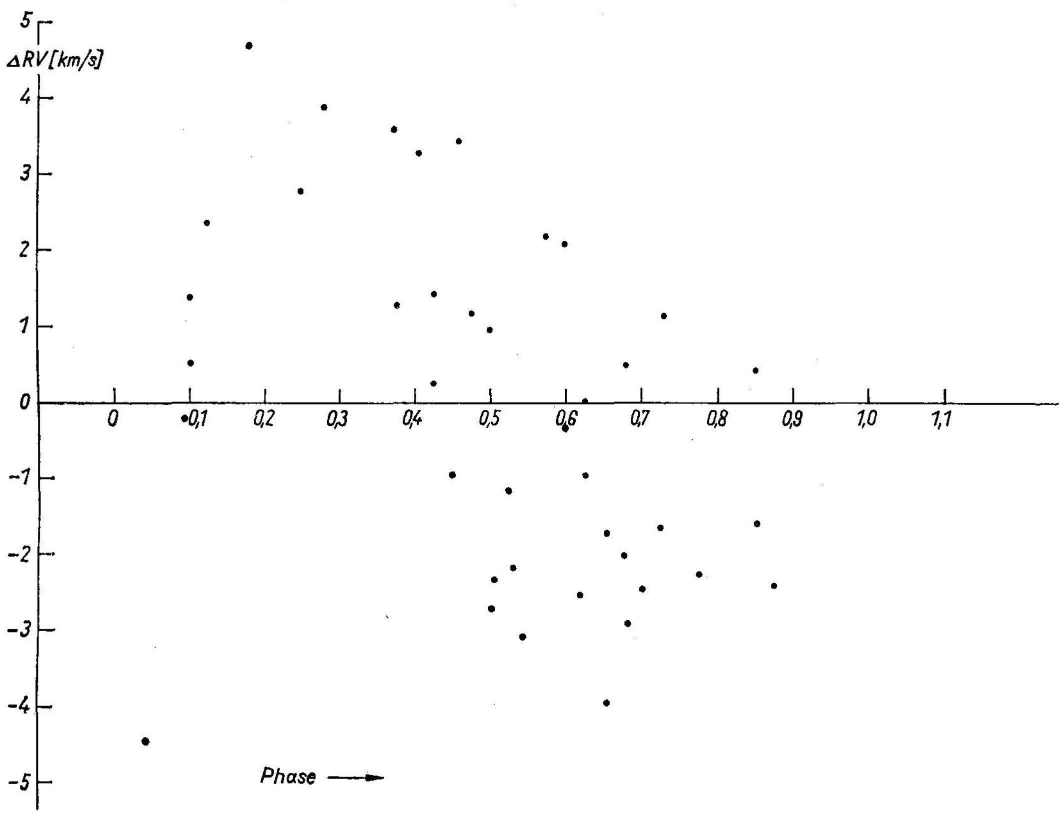

Fig. 4. Radial velocity differences during the years 1975 and 1976. Period is 39.9 days.

Table 2

Differences (*Element*)	*RV* (km/s)	*Element*	*RV* (km/s)
FeII — CrII	-1.15 ± 0.24	FeII	-20.36
FeII — TiII	-0.54 ± 0.20	H_β	-25.42
$(\mathrm{FeII} - \mathrm{FeI})_{1975}$	-3.32 ± 0.81	H_γ	-22.81
$(\mathrm{FeII} - \mathrm{FeI})_{1976}$	-0.82 ± 0.49	H_δ	-16.77

As already mentioned in ν Cep H_α has a P Cygni profile (Rosendhal, Frandsen). OB supergiants often show P Cygni profiles at H_α, H_β, and other strong lines indicating an expanding envelope of the atmosphere. The absorption cores of the Balmer lines show different radial velocities, suggesting an increase of expansional velocity with distance from the surface of the star, e.g. Hutchings (1968). Such velocity variations of H_β, H_γ, and H_δ were also found for νCep. The values obtained in Table 2 are means of each hydrogen line of all spectrograms. Since the lines H_β and H_δ lay at the borders of the spectral region of our plates the measuring error is comparatively large, i.e. 5—7 km/s in comparison to 3—4 km/s for a metallic line so that details concerning a dependence on time cannot be given.

5. Discussion

Concerning the discordant radial velocities of ~ —18 to ~ —25 km/s during observational time the question arises if ν Cep may be a spectroscopic binary. But, a determination of the orbital elements was not attempted because of the poorly determined shape of the velocity curve. Shorttime velocity variations superposed to the longtime variations are present; a period of ~ 39.9 or 44 days derived from the observations of 1975 and 1976 is indicated. The occurrence of two equally well determined periods is caused by the fact that a separate treatment of the data of 1975 resp. 1976 gives a period of 41.8 days in each case, but with a phase shift between both years. Unfortunately, the number of the observations per year is too small so that this result can be quite accidental.

The magnetic field of ν Cep is probably of other origin than that of the magnetic Ap stars. Arguments in favour of a rigid-rotator generally assumed for Ap stars cannot be found. On the contrary the existence of a magnetic field in ν Cep is probably produced by a physical process perhaps in connection with a possible companion of this star. At present many questions are open, p.e. the reality of the displacement indicated between the extreme values of the radial velocity and magnetic field.

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