International Conference on magnetic fields in O, B and A stars
ASP Conference Series, Vol. No.305, 2003
L.A. Balona, H.F. Henrichs & R. Medupe, eds.

The Supergiant ν Cep an Externally Influenced Magnetic Star ?

Ewald Gerth

D-14471 Potsdam, Gontardstr 130, Germany.

Gerhard Scholz

Astrophysical Institute Potsdam, Germany.

Yurij V. Glagolevskij [1,2]

[1] *Special Astrophysical Observatory of Russian AS, Nizhnij Arkhyz 357147, Russia*
[2] *Isaac Newton Institute of Chile, SAO Branch*

Abstract. The supergiant ν Cep (HD 207260, A2Ia) was observed to have a remarkably large magnetic field strength of nearly +2000 G in 1978. Continued observations from 1975 to 1992 have yielded a magnetic period of 4.7 y and half this value for the radial velocity. The long period and the improbability that such a strong magnetic field can occur in a supergiant, suggests a model of a binary system with a magnetic companion which influences the main star indirectly by its external field.

1. Introduction

In a survey for magnetic stars carried out in Tautenburg from 1967 – 1980, the supergiant ν Cep (HD 207260, A2Ia) was observed, among others. In contrast to all expectations for the physics of supergiants - as outlined by Gerth (1988) - a strong magnetic field strength of $B_{\text{eff}} = +2000$ G was measured in 1978 by Scholz (1980, 1981) using the *Modified Abbe-Comparator* (Gerth et al. 1977) of the Astrophysical Observatory, Potsdam. The mainly photographic observations were continued in Zelenchuk and Rozhen by Gerth et al. (1991), confirming the earlier results and rendering a data set sufficient for a period search and the construction of a phase diagram.

2. Observational results and period analysis

The photographic Zeeman-spectra were reduced for the magnetic field and the radial velocity up to 1980. Later on only the magnetic field was measured, so that we miss now the *RV*-data. However, additional *RV*-data were obtained in the observation campaign 1975-1980. Fig. 1 shows the covering of magnetic and *RV*-data in the period 1975-1995.

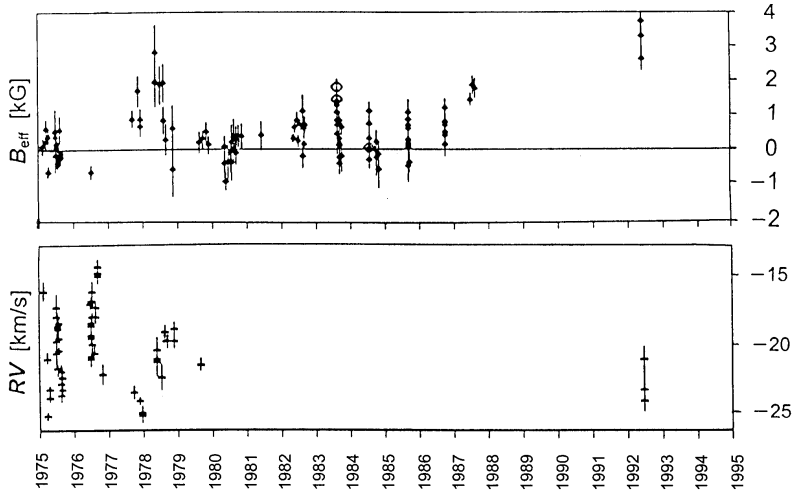

Figure 1. Observations of ν Cep from 1975 – 1995. Shown are photographic Zeeman spectra (dots) and photoelectric measurements (circles) from Tautenburg, Zelenchuk and Rozhen. The magnetic field strength is in kG and the radial velocity in km s^{-1}.

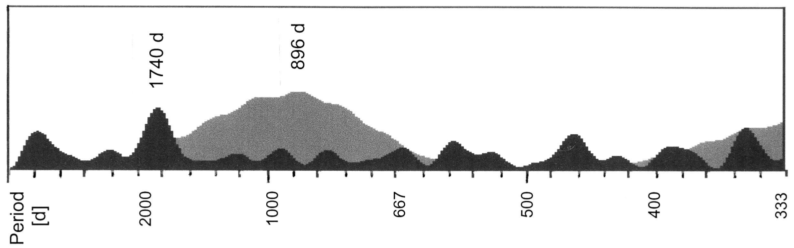

Figure 2. Period analysis of the data using a Fourier transform Black: magnetic field - 147 data points. Grey: radial velocity - 55 data points

Maximum:	Period	Amplitude
Magnetic field:	$P_{mag} = 1740$ d	$B = 555$ G
Radial velocity:	$P_{RV} = 896$ d	$v = 2.88$ km/s
Period relation:	$P_{mag} \;/\; P_{RV} = 1.94 \sim 2.$	

The observational data (Fig. 1) were subjected to a period analysis (Fig. 2). The power of the frequency zero is subtracted for the clear evidence of the fundamental frequency. The different widths of the power peaks is because of the observation periods, which are for the magnetic field data 13 y and for the radial velocity data 5 y. The results show a magnetic period of 4.7 y and a radial velocity period of 2.4 y, giving an approximately 2 : 1 ratio between the magnetic and the radial velocity periods (Scholz 1984). This behaviour is similar to that caused by tidal effects with two high tides running like waves around the star during the periastron approach of the companion in a binary system.

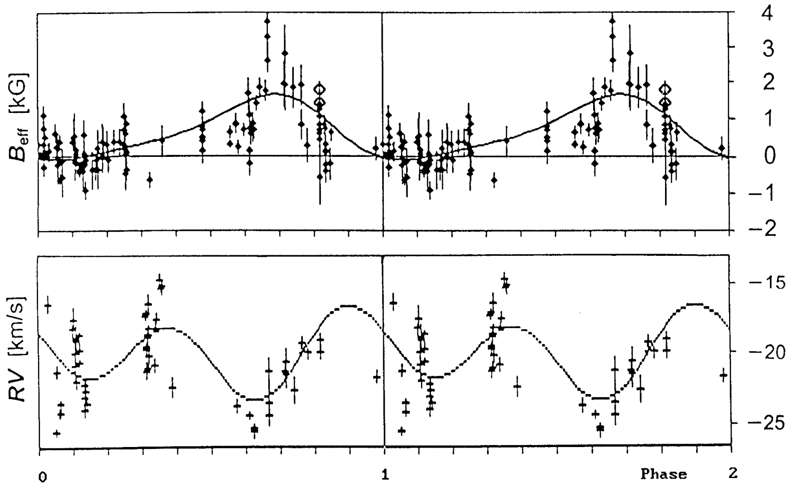

Figure 3. Fitting of the magnetic and the radial velocity data from Fig. 1 to the phase curves computed by the MCD-method of modelling. Top: Magnetic dipole on a companion by 3 R_* at periastron. Bottom: Radial velocity in phase of the magnetic field by $P = 1740$ d.

The magnetic field varies from -400 G to +2000 G in some years, rising slowly and decaying rapidly after maximum field strength. The clear long-term variation of the magnetic field cannot be attributed to rotation of the star, the period of which was estimated using $v \sin i = 38$ km s^{-1}, to be about 44 days (Scholz & Gerth, 1980, 1981), adopting a stellar radius of about 47 $R_\odot$.

3. A model of νCep as a binary system

A possible explanation for the secular variation could be: (i) dynamo action (Krause & Scholz 1986); (ii) pulsation; or (iii) precession (Gerth 1984). Objections can be raised against all these possibilities. Therefore, we propose another possibility: the influence of an external magnetic field located on a companion on the atmosphere of the supergiant primary (Fig. 4).

Calculations of a model of an orbiting magnetic star inducing a magnetic field on the surface of the primary star was performed using the MCD-method of Gerth & Glagolevskij (2001). The parameters of the model were adjusted for best fit to the observational data and phased with the period (Fig. 3).

For an optimal fit to the observational data by a binary model of ν Cep, the magnetic period, $P_{mag} = 1740$ d, is assumed to be the orbital period. The radial velocity variation with half of that period, namely $P_{RV} = 870$ d, can be understood as tidal motion in an orbit of high eccentricity and would explain the 2 : 1 period ratio. The adopted mass $M = 13\ M_\odot$ and the radius $R_* = 47$ $R_\odot$ of the primary were estimated from the $T_{\rm eff} - M_{bol}$ diagram.

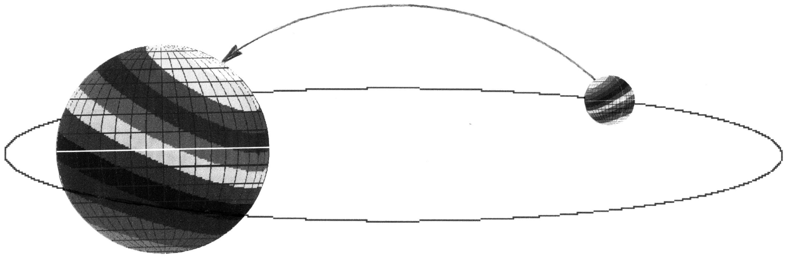

Figure 4. Scheme of the opposition of the main star and the companion

4. Conclusion

From celestial mechanics, some conclusions can be deduced for the secondary. For a circular orbit, the orbital radius is approximately $r_{orb} = 30\ R_*$. The orbital velocity of the secondary is 42 km s^{-1}. With the a RV amplitude of 2.9 km s^{-1}, the orbital velocity ratio is then 14.4, giving a mass of $M_{comp} = 0.9\ M_\odot$ for the secondary. On an elliptical orbit with an eccentricity of $\varepsilon = 0.9$, the periastron distance of the secondary from the main star can be as small as 3 R_* with an orbital inclination of $i = 41°$.

The calculation of an induced surface magnetic field from a source outside the star is performed using the method of the "magnetic charge distribution", which originally has been developed for the modelling of magnetic stars with topographically fixed surface field structures, but can be applied also to orbital motion. We do not assert that the magnetic field variations in ν Cep are necessarily due to the effect of a companion, but the possibility cannot be excluded.

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