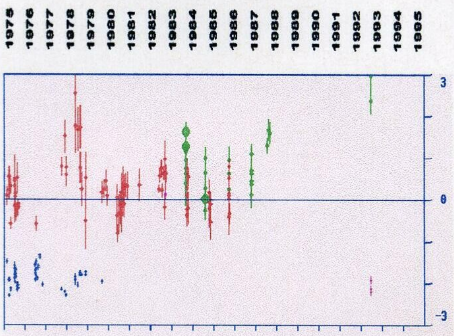
The supergiant νCep – an externally influenced magnetic star ?

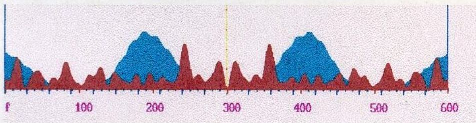


Observational data of νCep in time progression from 1975 to 1995 on photograhic Zeeman-spectra and photoelectric measurements O

1. red Magnetic field strength – observed in Tautenburg (Germany)
2. green – observed in Zelenchuk (SAO, Russia)
3. blue Radial velocity – observed in Tautenburg
4. violet – observed in Zelenchuk

The scaling for the magnetic field strength is kG and for the radial velocity 10 km/sec.

All measurements were carried out at the Astrophysical Observatory Potsdam using the Modified Abbe-Comparator [1] by G. Scholz and E. Gerth. The reducing programs were written by E. Gerth. The measuring method was the determination of the position and shift by the line profiles. The star was investigated for its magnetic behaviour. The reduction of the radial velocity values was performed only for the observation from 1975 to 1980, and 1992.



Period analysis of the observational data by Fourier transform

1. red magnetic field 147 data Frequency spacing: 0.00001 d^{-1} for 1 step
2. green radial velocity 55 data Periods: left –333 d centre ∞ right +333 d

Results: Main maximum of power spectrum	Period	Amplitude
1. Magnetic field:	$P_{mag} = 1740$ d	$B = 555$ G
2. Radial velocity:	$P_{RV} = 896$ d	$v = 2.88$ km/s

Both periods have the relation $P_{mag} / P_{RV} = 1.94 \sim 2$.

Comments: The different widths of the power peaks is because of the observation periods, which are – relating to the main covering – for the magnetic field data 13 a and for the radial velocity data 5 a. The amplitude B = 555 G is only a quarter of the high peak of 2000 Gauss, which results by overlaying of the maxima of several curves with coinciding phases.
The frequency spectrum is symmetrical with a linear definition region from negative to positive frequencies, which allows a significance test by the shift theorem of the Fourier transform. The power of the frequency zero is subtracted for the clear evidence of the fundamental frequency.

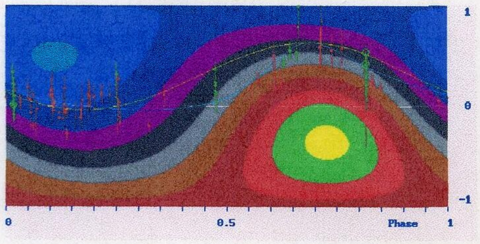
A model of νCep as a binary system

Assumptions:

1 The period P_{mag} =1740 d is taken as the orbital period of a companion.
2 The radial velocity variation is taken as the orbital and/or tidal motion.
3 A high eccentricity is possible and would explain the period ratio 2:1.
4 Adopted mass and radius of the main star: $M_* = 13\, M_\odot$ $R_* = 47\, R_\odot$

Conclusions:

1. A body revolving circularly around the has the orbital radius $r_* = 30\, R_*$
2. The revolving velocity of the orbiting body is 42 km/s .
3. With the RV-amplitude of 2.9 km/s is the relation of velocities 14.4 .
4. The velocity relation gives the mass of the companion $M_{comp} = 0.9\, M_\odot$



Magnetic modelling of the binary with external sources

Deposition of a magnetic dipole on the companion with the parameters:

Charge	r_{comp}/R_*	Longitude	Latitude (related to the main star)
1	30.12	250	1
−1	29.88	250	−1

Phase diagram of the observational data: Epoch: 2442413 JD Period: 1740 d

According to the MCD-method [10] the sources are topographically fixed to the main star, connecting rigidly rotation and phase.

The magnet is positioned in a distance of 30 stellar radii and tilted with its north pole to the main star, thus achieving an optimal fitting by $i = 41°$.

The resulting yellow phase curve appears sinusoidal-like and has a too broad maximum, which does not correspond to the narrow peak of the observational data. Considering the possibility of an eccentric orbit this problem can be overcome. Therefore, the longitude scaling is transformed by the focally centred ellipse

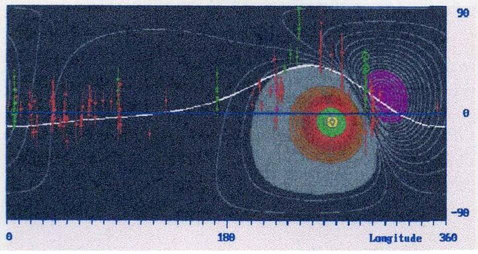
$r = C_1/(1 - \epsilon \cos(\varphi + C_2)$ r orbital radius ϵ eccentricity C_1, C_2 constants ,

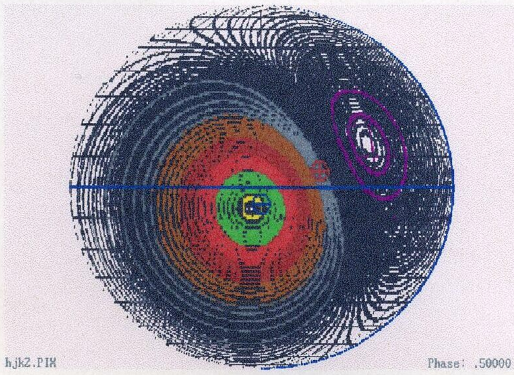
yielding the blue phase curve. The degree of approximation is limited, of course.

Mapping of the polar region in periastron distance

A possibility to show the magnetic face of the star is the modelling by a narrower circular orbit at the periastron distance from the focus. The apastron side is thus not represented well. However, the flexibility of the method allows a rather good fitting. Below: The map is constructed with $\epsilon = 0.9$ and $r_{comp} = 3.0\, R_*$. Right: Globe.

	Charge	r_{comp}/R_*	Longitude	Latitude
Parameters:	1	3.2	290	5
	−1	2.8	270	−5





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In a searching programme for magnetic stars carried out in Tautenburg (Germany) in the years 1967-1980 among others the supergiant νCep (HD 207260, A2Ia) was observed. In contrast to all expectations for the physics of a supergiant [3] a surprisingly strong magnetic field strength of B_{eff} = 2000 G was measured in 1978 by Scholz [8, 9] on the *Modified Abbe-Comparator* [1] of the Astrophysical Observatory Potsdam. The mainly photographic observations were continued in Zelenchuk (SAO Nizhnij Arkhyz, Russia) [4], confirming the earlier results and rendering a sufficient data set for the search of periods and the representation in a phase diagram.

The magnetic field varies from −400 G to +2000 G in a period of 4.7 [8] years with a slow ascending part and a rapid decay after the maximum. The secular variation of the magnetic field could not be attributed to the rotation of the star. The rotational period can be estimated to about 55 days [8, 9], suggesting the radius of the star to be 47 $R_\odot$ and the value of $v\sin i$ by 44 km/s. For the magnetic field strength a period of 4.7a and for the radial velocity a period of and 2.4 a was found, indicating a ratio of approximately the 2 : 1 between the magnetic and the radial velocity variations [10]. This reminds of tidal effects – similar to such ones as described by Gerth and Scholz for the star ET And [4]. The amplitude of the radial velocity of nearly 3 km/s was in [8] suspected to be caused by a binary motion.

The explanation for the secular variation could be:

1. action of a dynamo, [7]
2. pulsation, [4]
3. precession. [2]

Against all these possibilities objections could be raised. Therefore, we advance here a further possibility: the influence of an external magnet located on a companion onto the atmosphere of the main star.

A companion would be required also for the precession model. In this case, however, the phase curve of the magnetic field should be more harmonic, but it looks rather like the radial velocity curve of a spectroscopic binary system with a high orbital eccentricity.

The construction of a magnetic field distribution from a source outside the star can easily be performed using the method of the *"Magnetic Charge Distribution"* [6], which has been developed for the modelling of magnetic stars with a topographically on the surface fixed magnetic field structure. An external magnet requires the separation of map and phase, which is not programmed yet. The formal computation of a circularly orbiting companion, however, gives a rather good fitting to the observational facts.

We do not assert that the external magnet of νCep is the last conclusion, but the real existence of such a constellation in a binary system is imaginable and shows, moreover, the high flexibility of the MCD-method [6] of modelling magnetic stars.

References:

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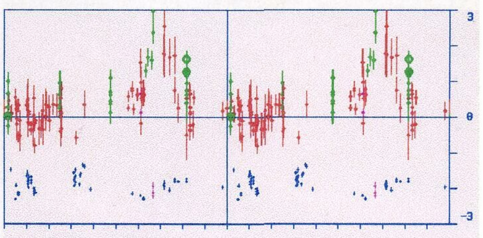
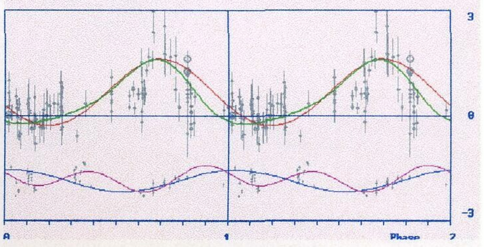
Double phase representation of the observations
Epoch: 24444213 JD Period: 1740 d = 4.76 a





Fitting of the data of the magnetic Field strength and the radial velocity

(The scaling for the magnetic field strength is kG and for the radial velocity 10 km/sec - see figure above left)

Magnetic dipole on a companion on a circular orbit in a distance of

1. red 30 stellar radii and an inclination of the axis to the main star by 13°. The phase curve shows a sinusoidal form because of the large distance.
2. green: 3 stellar radii, inclination to the main star by 75° and to the equator by 27°. The phase curve deviates from the sinusoidal form, improving the fitting.

Radial velocity representation in phase of the magnetic field by the period of 1740 d

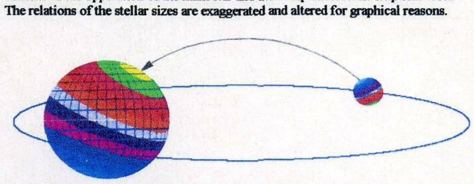
3. blue: Period relation 1:1 − possible but no good fitting of two lumps of data. The amplitude of 2.9 km/s is used for the velocity relation 14.4.
4. violet: Period relation 2:1 − optimal fitting according to the Fourier analysis. The curve exhibits a slight deviation from the sinusoidal form because of a row of odd numbers of overwaves, supporting the basic wave.

Comments:

1. The calculation of the phase curves on the binary model represents well the limits of the variation regions of the magnetic field strength and the radial velocity.
2. The magnetic variation with a slim peak cannot be represented by the revolution of the companion on a circular orbit.
3. The magnetic curve form would be explained accounting for a large eccentricity.
4. The nearby circular orbit of 3 stellar radii shows the "magnetic face" of the star only in the moment of periastron.
5. Considering an eccentric elliptical orbit we assume that the fitting could be made complete. However, this is a matter of future programming.
6. The period relation of the magnetic to the radial velocity variations of 2:1 cannot be overlooked but seems not to correspond to the orbital motion with 1:1.
7. The period relation of 2:1 would be explained by the action of tidal waves, which are excited by the periodically approaching companion in a highly eccentric orbit.

The constellation of a binary system νCep

Scheme of the opposition of the main star and the companion on an elliptical orbit. The relations of the stellar sizes are exaggerated and altered for graphical reasons.

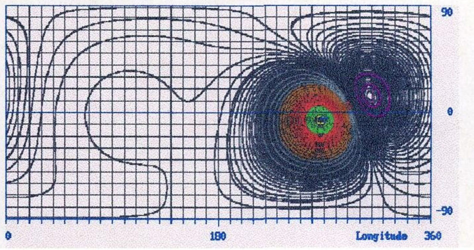


The magnetic dipole is tilted towards the main star penetrating it by a magnetic field. The tilting of the companion to the main star could be preserved by precession. The negative pole of the companion influences a positive pole on the opposite star. The magnetic lines of force connecting the two stellar bodies are arcs of a circle.

Conclusions and objections

1. C: The magnetic field on the main star is not topographically fixed on the surface. The pole structures slide over the surface in opposition to the companion.
   O: The magnetic field migrating over the surface and penetrating the electrically conducting body of the main star provokes a braking force after Lenz's law. By this way the angular momentum of the orbit accelerates the rotation of the main star in a long-lasting process in direction to synchronisation.
2. C: A high eccentricity of the orbit is required for the narrow peak in the magnetic phase curve and for the period relation of 2:1 of the magnetic and radial velocity variations leading to the excitation of tides in the main star [4].
   O: The periastron approach is the phase of the strongest interaction between main star and companion with exchange of angular momentum and influence of the outer magnetic field and gravitational forces. The latter is responsible for tidal bulges on two opposite sides of the main star.
   The stellar body of the main star alters the course of the penetrating field lines and has a screening effect on the apastron side of the surface.
3. C: From the relation of the orbital velocity to the amplitude of the radial velocity the mass of the companion is derived of nearly 1 solar mass. This would be a normal star like the sun, which could produce its magnetism by – maybe – the dynamo mechanism [7].
   O: The companion cannot be observed directly because of the vicinity of an overwhelmingly bright main star.
   Thus the companion of νCep remains in the underground of hypothesis.

Below: Magnetic map of the star νCep in periastron approach on a circular orbit.
Centre above: Globe to the map with the two influenced opposite poles



International Conference on ***Magnetic Fields*** in O, B and A Stars, Mmabatho, South Africa, 27 November – 1 December, 2002