Does ν Cep indicate a non-axisymmetric dynamo?

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Abstract

According to observations of Scholz and Gerth the supergiant ν Cep has a magnetic field with a maximum field strength up to 2500 Gauss. This field shows a period of about 5 years. It is unplausible that this magnetic field is a relic since ν Cep was formed by expansion of a B-star. We claim here that ν Cep represents a dynamo exciting a magnetic field which in the average strongly deviates from symmetry about the rotation axis.

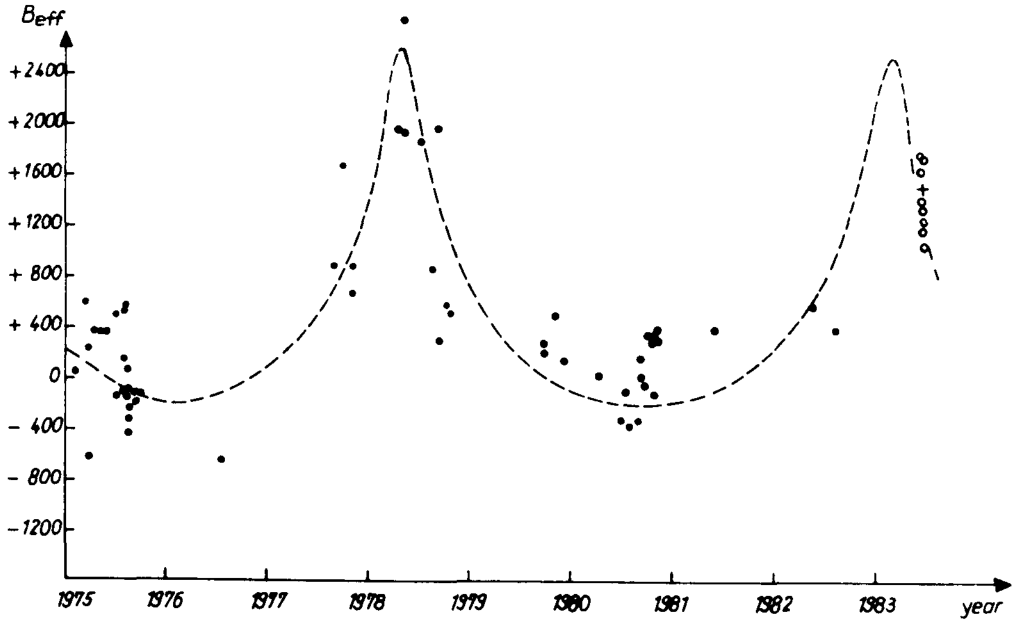
We know for some cosmical objects with certainty that their magnetic fields are dynamo excited: that are some planets (Earth, Jupiter, Saturn) and the Sun. The average magnetic fields of this objects are mainly axisymmetric with respect to the axis of rotation. Deviations from this symmetry are secondary effects.

Theoretical considerations show that under certain circumstance those magnetic fields are most easily excited which have no symmetry with respect to the axis of rotation. This is the case for α^2-dynamos with sufficiently strong anisotropy, which is due either to the influence of rotation (Rüdiger, 1978, 1980) or to the radial stratification (Rädler 1980, 1985). Dynamo models of that kind excite fields where the leading term is a dipol with its moment lying in the equatorial plane.

All magnetic stars possess highly non-axisymmetric fields. But they cannot, at present, used as examples for non-axisymmetric mean-field dynamos since the question whether these fields are relics or excited by dynamo action is still open. For a clarification the supergiant ν Cep could be a suitable case as we know that a short time ago it was in quite a different evolutionary state, probably an early B-star. That is why ν Cep is worth a closer analysis.

The supergiant ν Cep is of spectral type A2Ia. It is assumed that it is an evolved B-star with radius $R \approx 90\ R_\odot$. A magnetic field was first found by Scholz and Gerth (1980, 1981), meanwhile, this field shows a period of about 5 years (Scholz, Gerth, Glagolevskij and Romanjuk

C. R. Cowley et al (eds.), Upper Main Sequence Stars with Anomalous Abundances, 51–54.



Magnetic field of ν Cep from measurements at Tautenburg (•), Selentschuk (o) and with the magnetograph of Selentschuk (+).

(1984)). It has a maximum value of about 2500 Gauss, the minimum is rather flat and seemed to be negativ of about -300 Gauss. What is the origin of this magnetic field?

It is generally assumed that a supergiant like ν Cep was formed by expansion of a B-star, say a star of about 6 $R_{\odot}$, i.e. it was enlarged by a factor 15. In case the present magnetic field is the relic of that of the main sequence B-star we find by extrapolation that this star had a field of at least some 10^5 Gauss strength. But this contradicts our knowledge about B-stars. Consequently, the possibility of a relic is rather unplausible, the magnetic field must be formed in a later evolutionary state.

If the magnetic field is formed in a later state the only possibility is that it is excited by a working dynamo. The period of 5y opens the possibility of an oscillatory dynamo.

From the Sun and the solar type stars we know periods of activity cycles down to about 7 years, i.e. periods of the magnetic field down to 14 years. The period of ν Cep, five years, is rather short. That is the more of importance since the period to some extend increases with the thickness of the convective layer (skin effect). Consequently, we would expect a much larger period for the supergiant ν Cep than for the (rather small) solar type stars.

Another argument against an oscillatory dynamo is the high degree of anharmonicity which the observed curve of B_{eff} shows. We know from the Sun and the (periodic) solar type stars that activity cycles do not so much differ.

So we have good reasons for excluding the possibility of a working oscillatory dynamo.

The most plausible explanation, which is now left, is that the 5 year period of the magnetic field is the period of rotation and the magnetic field strongly deviates from the symmetry with respect to the rotational axis. This view of the matter is supported by the following argumentation.

If we, as above, assume that ν Cep was formed by expansion of a B-star by a factor 15, and assume, in addition, a rotational period of this B-star of, say, 2 days, we find by taking into account the conservation of angular momentum a rotational period for ν Cep of about 500 days, i.e. about 1 1/2 years.

But mass loss is ubiquitous among highly luminous OBA stars. Therefore, even if the mass loss rate is unknown for ν Cep, the assumption of conservation of angular momentum is unlikely to be a correct one. For the increase of the rotational period up to about 5 years, mass loss in the presence of a magnetic field can presumably explain the braking of the rotational velocity. Thus ν Cep is well fitting in the picture we have from magnetic stars. Also the strongly anharmonic time variation of B_{eff}, one extrema narrow, the other one broad, is a typical behaviour of such stars like α_2CVn, 53 Cam and others.

So we have good reasons to assume that ν Cep is a realisation of a non-axisymmetric mean-field dynamo. Following this idea we have to conclude that ν Cep has an extended convection zone. This does not contradict the generally accepted view. In addition, a statement concerning the structure of the convection is possible:
It is well known that dynamos with remarkable differential rotation preferably excite fields showing symmetry with respect to the axis of rotation. Hence we have to conclude that ν Cep has a convection of such a structure, which does not cause differential rotation. This is possible for convection where the turnover time is large compared

with the rotational period (Rüdiger 1983, Hathaway 1984). Hence, according to our view, the supergiant ν Cep shows a convection with long living large cells.

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