Secular variation of the magnetic field of 52 Her – precession?

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Abstract. The magnetic star 52 Her shows different variations of the magnetic field strength, which could not be attributed only to the rotation of the star.

The obviously present secular variation is explained on a trial basis by the precession of a gravitationally coupled binary system.

Since the detection of a magnetic field in the CP star 52 Her (HD 152107, A2p) by ***Babcock*** [1] in 1949 more than half a century has elapsed - a secular period, which led up to now to the compilation of 274 measuring values obtained from different observatories and authors.

The sporadic and lumpy distribution of observations demands sophisticated methods for the period analysis, taking in consideration "truncated waves". Nevertheless, a trend of a secular variation cannot be overlooked. Usually the magnetic field strength B_{eff} is positive and shows a large scatter, but in 1978 occurred a polarity reversal with a conspicuous negative peak [5, 7], which lasted only a year.

Thorough investigations of the instrumental polari-sation at the 2m telescope with Zeeman-analyzer in Tautenburg carried out by ***Oetken*** (Potsdam) and ***Bartl*** (Tautenburg) as well as the comparison with the quasi-simultaneous observation of the magnetic field of 53 Cam by ***Scholz*** (Potsdam) led to the exclusion of an instrumental artefact.

Taking the temporary polarity reversal real, the negative peak should reoccur any time in future, marking thus a secular period. Indeed, the search for periods by Fourier analysis yielded a period of 23.5 years; that means, the reoccurrence of the negative peak could be expected now.

As far as the observations were secured by photographic Zeeman-spectra, also the radial velocity values were reduced, the phasing of which showed a modulation bumping [8]. The radial velocity as well as the magnetic field strength vary by a period [12] of P_r = 3.8575 d caused by the rotation - or by the action of an orbiting companion.

The photographic Zeeman-spectra from Tautenburg (Germany) and Niznij Arkhyz (Russia) were measured on the *Modified Abbe-Comparator* [4] at the Astrophysical Observatory Potsdam and reduced by a special computer program (Gerth), which allows selection and statistics of special spectral lines relating to the prominent elements Fe, Cr, Ti, Si, Eu, Mn, H. The effective magnetic field (Stokes V) was determined by the *Zeeman*-shift of individual spectral lines assessing the gravity centre of the line profiles on an oscilloscope screen and taking into account the mean *Landé*-factor (*z*-value).

The short-time and the secular periods could be brought together assuming a close binary system with a magnetic main star and a companion of less mass, which perform a precessional motion by dissipatively synchronised rotation and revolution. The binary is a gravitationally coupled system of two rotationally flattened stars with tilted to each other axes of torque, angular momentum, and orbital plane, which oscillate (rotate) with five eigenfrequencies (rotation and procession of both stars, precession of the orbital plane).

Precession as an explanation for secular variations was first proposed by ***Gerth*** [5] and later discussed and justified by ***Gerth*** [6] and ***Lehmann*** [10,11].

The rotational period of 3.8575d as committed by ***Wolff*** and ***Preston*** [12] could be corroborated by Gerth [7, 8]. The secular variation of the magnetic field, however, should be confirmed by further observation. Unfortunately, the observation of 52 Her has been broken off in 1994 for thematic and personal reasons, thus truncating the last positive wave of observation.

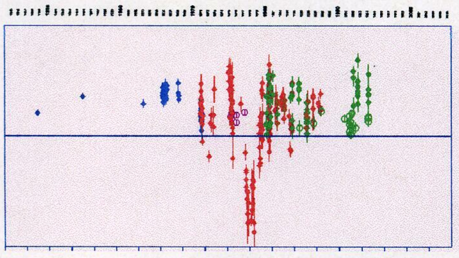

Fig. 1 Measurements of the magnetic field strength of 52 Her in time progression using the observations and measurements of different authors – see Reference 1 – 13.

Author	Reference	values-colour		photographic
1. Babcock (1958)	1	2		(else O)
2. Wolff, Preston (1978)	12	47		
3. Borra, Landstreet (1980)	2	6	O	photoelectric
4. Gerth (1990)	7	139		
5. Kolev, Tomov, Gerth (1992)	9	11		
6. Glagolevskij, Gerth et al. (1992)	9	38		
7. Bychkov, Elkin, Shtol (1992)	12	12	O	photoelectric
8. Glagolevskij, Gerth (suppl.)	-	16		
9. Bychkov, Shtol (suppl.)	-	3	O	photoelectric

(The magnetic scaling is given by the 2 first measurements from Babckock: 840 G and 1430 G.)

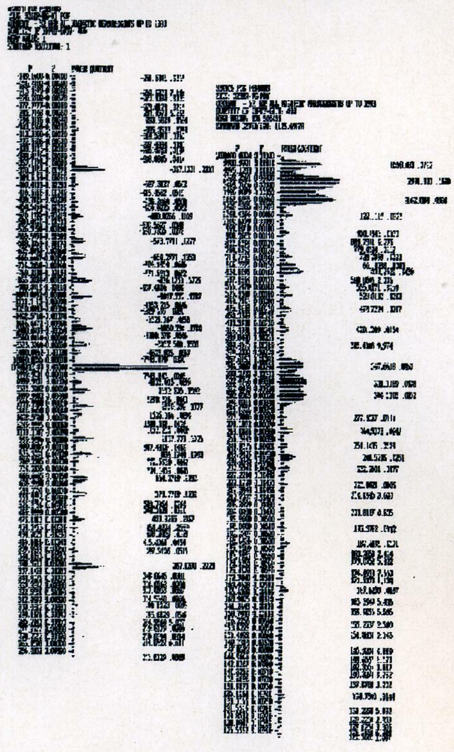

Fig. 2. Period analysis of the data set of 274 measuring data of different authors using the Fourier transform of non-equidistant data spacing. We demonstrate here the shifting of the WINDOW spectrum to the DATA spectrum, which marks significantly by repetition of the annual peaks three basic frequencies with the coordinated periods:

$$P_1 = 8599\ d \quad P_2 = 2991\ d \quad P_3 = 1662\ d$$

Explanation: The algorithm of the program calculates the complex frequency spectrum in the definition region of the Fourier integral from –∞ to +∞. The Fourier-transformed complex data are used for the transformation of multiplication, convolution and correlation in the frequency space, and – after operational processing – inversion into the original space. Especially important is the shift theorem, which marks the repetition of special features caused by multiplicatively overlayed functions to the original data. The WINDOW-function is the overlay of the time-spacing of the data. Its frequency spectrum from negative to positive frequencies is symmetrical to the frequency zero – with the observationally caused peaks of the year, the month, and the day – and other observational groupings. Another multiplicative overlay is the error distribution of the observational data, thus enabling the weighing by data quality.
The program calculates and prints out for each peak the frequency (or as here: the period) and the complex frequency (or as here: the power) by quadratic interpolation of three neighboring values.

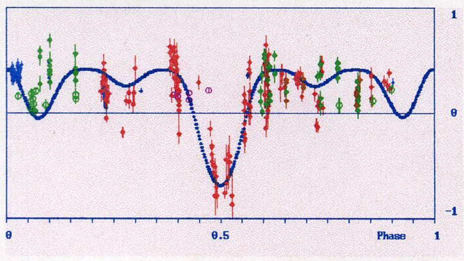

Fig. 3. Arrangement of the 274 observational data in a phase diagram centred to the negative peak in 1978 with the period P = 8800d and comparison to the averaged curve constructed by the 3 periods resulting from the period analysis.

For the phasing of the observational data the derived basic period of 8599 d has been changed a bit to 8800 d in order to put the early values from Babcock in concordance with the late measurements. Anyway, the very hard scatter of the values allows a broad variability of the periods taken from the analysis.

The 3 conspicuous periods of the analysis were used for the construction of the phase curve, centring all 3 cos-curves and reducing the upper part of the curves by a trigonometric function. This is the projection which could be expected by the view onto the southern hemisphere of the star.

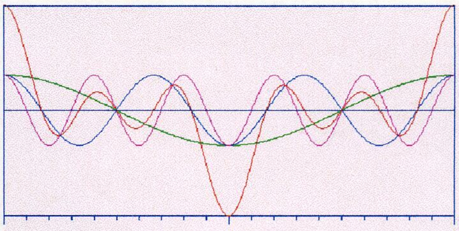

Fig. 4. Demonstration of the superposition of 3 oscillations with equal frequency spacing and equal amplitudes.

	frequency	period	function
1.	0.5	2	$y = \cos(\pi x)$
2.	1.5	0.6667	$y = \cos(3\pi x)$
3.	2.5	0.3333	$y = \cos(5\pi x)$

The red curve corresponds well to the averaged curve in Fig. 3.
The curve has only to be shifted upward and the upper part depressed because of the projection looking at the under part of the star.

This is a reconstruction of the original function using only the 3 main frequencies as a trigonometric series in the inverse Fourier transform. If we use all values of the frequency spectrum (see Fig. 2), then the entire original function is reconstructed. The original function is smoothed if the frequency spectrum is reduced by a limiting function (normal distribution or cut off by a rectangle function).

Short-periodic variations – rotation

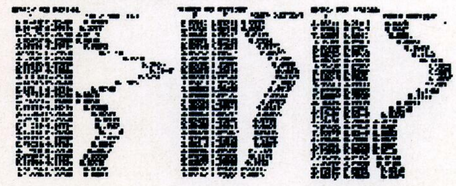

Fig. 5. Periodograms in the frequency region of the rotational period P = 3.8575 d

a) Magnetic data of Wolff and Preston [12] 3.8575 d
b) Magnetic data of Tautenburg, Nizhnij Arkhyz, Rozhen 3.85652 d
c) Radial velocity data of Tautenburg 3.85640 d

The analysis of period used by ours establishes the period 3.8575 d on the data basis of Preston and Wolff [12] but shows for the Tautenburg-data [7, 8] a slight deviation, which is because of the longer time basis. The mean value of the magnetic and the radial velocity data of P=8565 d can be regarded as an averaged period.

The phase curve of the magnetic values can be reconstructed by the coefficients of the Fourier-transform in the inverse procedure. This curve, however, is overlaid to the secular variation. The arrangement of the dots in a phase diagram by the rotation period is not convincing because of the fluttering among the different mean levels of the secular variation, producing a chaotic scatter of dots.

Only the subtraction of the secular curve makes the arrangement of dots similar to a functional dependence. The averages curve in Fig.3 could be used for this purpose. This function should be determined very correctly, for a residual deviation would leave an appreciable scatter of dots.

A good way to show the rotation phase curve while maintaining the whole values of the dots is the selection of those parts of the sequence where the secular variation is minimal has been proposed by *Glagolevskij*: using only the magnetic data of the long positive plateau. The scatter of dots is suppressed by a sliding average, which relates to the rotation period and clears the phase relation of the mean value.

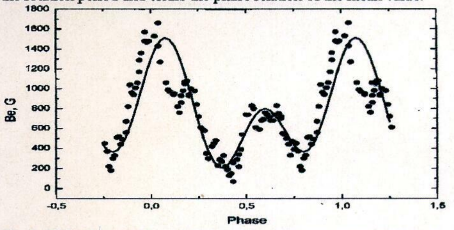

Fig. 6. Slidingly over 10 neighbouring dots averaged magnetic values and levelled phase curve with the rotation period P = 3.8575 d [12].

Mapping and modelling of the of the magnetic field

Mapping and modelling of the of the magnetic field structure of a star relates to the topographically fixed features on the surface, which become detectable only by the rotation. By the authors a special procedure of modelling has been developed [see other posters of Gerth&Glagolevskij], that allows the calculation of the surface distribution of the magnetic field assuming virtual magnetic field sources inside the star. The parameters to the virtual magnetic sources are those of a quadrupole.

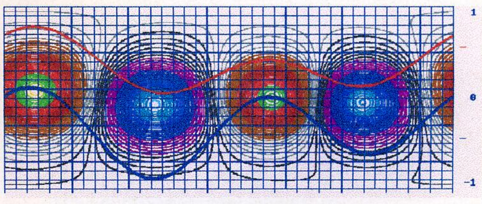

Fig. 7. Mercator-map with iso-magnetic lines of the quadrupole structure and drawn in rotational phase curves for $i = 40°$ and $i = 130°$. The scaling of the magnetic field is 2000 G from 0 to 1.

The magnetic structure derived for the quadrupole model after Fig. 6. for the northern hemisphere holds also for the southern hemisphere. The course of the curve is similar but moved to the negative region. In the course of the secular variation the rotational phase curve is moving up and down but lasts the longest time in the northern hemisphere. Thus, the scatter of the measuring values in Fig. 1 and Fig 3. has also its physical reason, but the set of observational values of the magnetic field of 52 Her is not scooped out by this.

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