Measuring the magnetic field in CP stars using multiline approach

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We have developed a new code for measuring magnetic fields of stars by mean of calculation on the basic of fast transformation of the Fourier cross-correlation function from spectra with reciprocal circular polarization. To test the code, spectra of stars with previously measured magnetic field were used. In some cases, discrepancies between the field strength obtained by Babcock's classical technique and with the help of our code can be seen.

Introduction

The algorithm of magnetic field measurement with the use of cross-correlation function is suggested in the paper by Donati et al (1997). The procedure has received the name LSD and its successfully employed for measuring magnetic field of Sun and different-type stars.

We have make an attempt to implement the correlation method of magnetic field measurement in CP stars by way of computing the cross-correlation function of polarized components of the Zeeman spectra. As a simplifying supposition we assumed the magnetic field to have the same effect on all the lines used.

Since the value of Lande factors of spectral lines differs only sligtly, and the use spectral range is not higher than 1500 A, such a simplification can be considered to be quite possible.

Besides it is believed that: 1) the spectral line profiles in different polarizations are equal and differ but the value of the shift in consequence of the affect of the external magnetic field, 2) the level of the continuum is drown accurately. In this case the peak of the cross-correlation function must indicate to the value of the shift of all the lines used. Further, by using Babcock's usual formula , one can find magnetic field.

Results of testing the code.

To calculate the cross-correlation function we have written a code using the algorithm of fast Fourier transformation (Press at al., 1992). For analyzing the possibilities of application the method, we used the spectra with different characteristics: with narrow and wide lines, with strong and weak magnetic fields. Filtering of the spectrum is produced by the line depths. Application of mathematical mask is possible.

To test the code, the spectra obtained with the Main stellar spectrograph of the 6m telescope with the Zeeman analyzer were used. The first step of the processing was performed in the standard manner (Kudryavtsev, 2000).

Further our code was used to calculate the cross-correlation function. The field strength was determined by the shifts of its peaks. We have investigated the degree the shape of the correlation function depends on the line profile and came to a conclusion that the approximation of the peaks is best performed by a Gauss function.

Table 1.
Results of magnetic star measurements by classical and correlation technique.

Star	Bclassic	Bcorrel
HD 18078	950 +- 50 G	1030 +- 30 G
HD 293764	3860 220	2541 30
HD 110066	-130 28	-87 10
52 Her	520 60	460 20

For the analysis we selected 4 stars with magnetic fields of different magnitude and 2 null stars. All the spectrum were measured by the classical technique, i.e. by measuring individual lines (Kudryavtsev, 2000) and than by correlation method by our code. Results of determinations are listed in Table 1.

We can see good agreement of the measurements made by both techniques in stars with no field and with weak field. In the case of star HDE 293764 with a strong magnetic field considerable differences arose.

With a week magnetic field the cross-correlation function has a very symmetric shape and, as a consequence, the value of the shift is measured with a very high accuracy. When the field is strong, the line profiles in different polarizations considerably differ, have a complete structure, that is why the simplification we have developed as to their identity proves to be incorrect.

The accuracy of measurements is essentially affected by the choice of the method of approximation of correlation function. Although the approximation of the peaks was performed by the Gauss function, in some cases the approximation should be executed by function different from gaussian, which is determined in the Fig.1 (left).

The linear interpolation (on the right in the Fig.1) allows the shape of the correlation function to be improved and to measure the field with a higher accuracy. The portion of the spectrum of the star HD 18078 is presented in the Fig.2. In the case of very narrow lines the cross-correlation function is very symmetric and the shift can be measure with a high accuracy (Fig.3).

Conclusion

We have written a code and tested it, which showed that it can be applied to measuring magnetic field of stars by correlation method. There is a certain disagreement between our results and the results, obtained by traditional method, from measuring individual lines. To a considerable degree, this is associated with the inaccuracy of

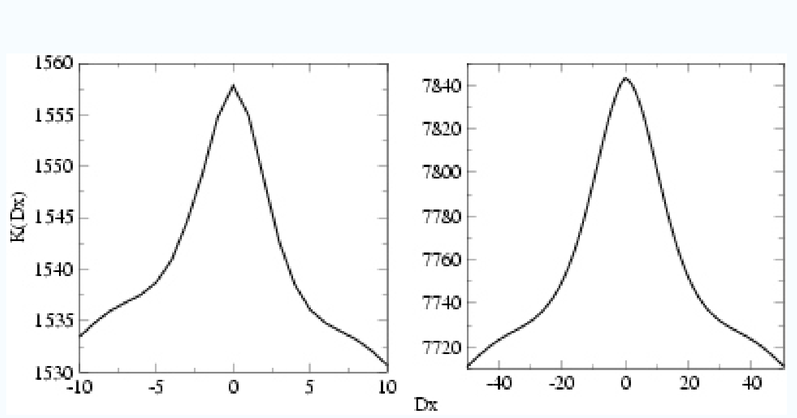

Fig.1 Cross-correlation function for weak field star.

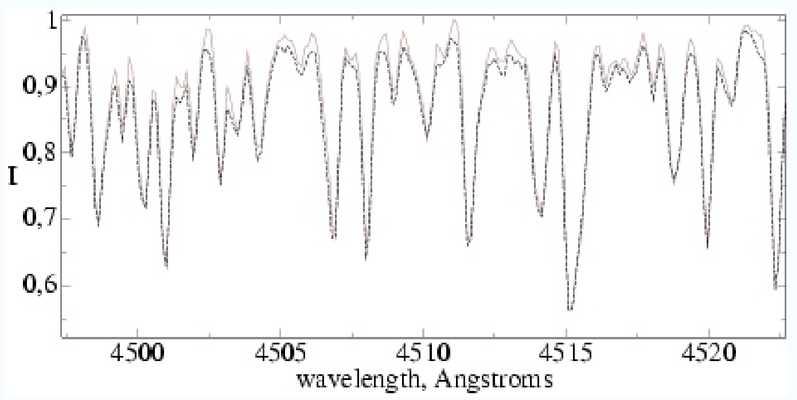

Fig.2 Portion of the spectrum of the star HD 18078

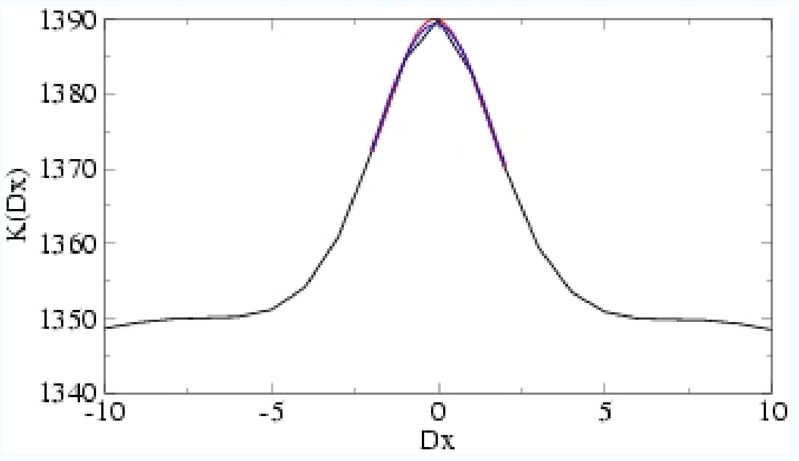

Fig.3 Cross-correlation function for o Uma

approximation of the peak by the cross-correlation function. It was shown that the use of the Gauss function is not always justified, sometimes it is useful to employ other functions (for instance, Lorentz function).

Besides there exist physical causes giving rise to such differences. In the classical method of measurements the weighted mean by the Lande factors line shift is measured, in using the cross-correlation the weighting take place by their intensity as well.
To remove the contribution of noises it is necessary to use masks.

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