POLARIZATION MEASUREMENTS OF SOME Be STARS

I. Vince
J. Arsenijević
S. Marković-Krstjanin
S. Jankov
Lj. Skuljan
Astronomical Observatory, Volgina 7
11050 Belgrade, YUGOSLAVIA
Received: 7 November 1994

I. INTRODUCTION

In about 50% of all Be stars the intrinsic polarization has been statistically established. The intrinsic character of this polarization has been revealed primarily by the time dependent variations. The time intervals involved are very diverse. There are short-term dependent variations within minutes, hours or days, as well as long-term ones, when months, years or even decades come in question. So far the nature of polarization changes and the insufficient quantity of observational data do not allow any definitive conclusion of the physical envelope, structure and geometry.

The long-term polarization variations, for years to decades, have been examined in a very limited number of stars. The same is true for the connection of the polarization parameters with photometric quantities such as the brightness of a star or hydrogen emission. Having in mind the importance of polarization data of Be stars, on one side, and the ability to observe in a very long series with the same telescope available at Belgrade Astronomical Observatory on the other, a program of studying long-term optical polarization changes of some selected bright stars was set up in 1974. The aim of this work was to obtain reliable long-term data on polarization changes in the V spectral region and to examine the possible connections of these changes with different activity phases of Be stars— principally with the shell phases. In this paper we present the observational data of Be stars α And, γ Cas and 88 Her for the period 1974 - 1992 and κ Dra for the period 1979 - 1992.

The long-term changes in the intrinsic polarization percentage are evident in all stars. It seems that these changes have a cyclic character with the cycles lasting several years. The amplitudes of the polarization percentage variations are not higher than a half of the percent. The changes of the position angles are within an interval of about 30° or smaller.

II. OBSERVATIONS

Polarimetric observations at Belgrade Astronomical Observatory from 1974 till 1992 were carried out with the 65 cm Zeiss refractor and the stellar polarimeter (Kubičela et al. 1976) which was modified in 1979 to enable one to obtain digital magnetic records suitable for further computer processing. The measurements were done in the V spectral region. Integration of the raw polarimetric signal was done in 4-second intervals. The angular velocity of the analyzer was one turn per minute. In most cases under "one measurement" we mean up to eight one-minute polarimetric sine-
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wave signals phase-averaged. The typical standard deviation of one eight-minute individual measurement is 0.07% for Stokes parameters Q and U.

The measurements were always done when the sky polarization and brightness were low. In the case of the only faint star, 88 Her, the observations with a sky signal higher than an adopted value have been rejected in the course of the numerical reduction. During the whole interval of observation the instrumental system was carefully checked. Stars of zero-polarization (17 stars) and non-zero polarization standards (11 stars) were observed in the usual way in order to determine the telescope system. The instrumental polarization was always very close to zero. The complete revision of the system constants was carried out for the observations till 1990 with all standard stars. The consequences of this revision are small changes in the system constants and calculated polarization parameters published before 1990.

The interstellar components were estimated for three stars. For the star κ Dra the procedure of evaluating the interstellar component is thoroughly described in the paper Arsenijević et al. (1986). The estimation of the interstellar component in the direction of 88 Her is described by Arsenijević et al. (1987). For the star γ Cas we used Clarke's (1990) values who analyzed the data of several authors. The interstellar parameters of ω And have been estimated by some authors but we did not use any of these data, instead we preferred to first analyze the stars in the field around ω And and then make our own estimation. So, in this paper, we present the observed polarization data. It is convenient that the interstellar component of ω And polarization is, very probably, small and without influence on the global picture of polarization itself and its variation too.

III. ω And (HD 217675, B6IIIe, v sin i = 260 km/s)

The long-term changes in both polarization parameters are noticeable. In Figure 1-a one can see three periods of high annual mean values of polarization percentage, namely during the years 1975, 1983 and 1991, with eight years between them. Two periods of lower polarization percentage are also well seen during 1977-79 and 1984-85. The highest annual mean value was reached in the year 1975 (0.54%) and the smallest one in the year 1977 (0.14%). It is very possible that the same or smaller polarization percentage value might be reached during 1985, which is unfortunately, presented only with three measurement values.

In Figure 1-b the position angle data show three maxima: in 1976, 1983 and 1988. During 1976 the position angles were in the interval around the value 124°, in the year 1983 around 97° and in 1988 around 92°. The smallest values of position angles were reached at the ends of periods preceding the new polarization percentage rising phases.

Three shell phases have occurred during the period of our observations. The periods of higher polarization percentages and position angles correspond approximately to the periods of the shell episodes. The polarization data on ω And during the interval of 18 years speaks about a very active period of the star's life, but we also noticed a tendency for some global attenuation of its activity.

IV. γ Cas (HD 5394, B0 IV, v sin i = 230 km/s)

The polarization percentages for γ Cas have a general decreasing trend during the whole period of observation, going from the annual mean value of 0.90% in the year 1974 to the value 0.45% in 1992, which is easily seen in the Figure 2a. But, three small "short-lived" (about 2 - 3 years) increases are present: the first one starting probably in
FIGURE 1. (a) Observed intrinsic polarization percentage and (b) polarization position angle of the star o And in the V spectral region during 1974 - 1992 (dots). Annual mean values are denoted by triangles connected by full line.
FIGURE 2. (a) Observed intrinsic polarization percentage and (b) polarization position angle of the star γ Cas in the V spectral region during 1974 - 1992 (dots). Annual mean values are denoted by triangles connected by full line.
1977 and well seen at the beginning of 1978; the second in 1985; and the last one in the year 1991, with the amplitudes of the variations smaller than 0.3%. It might be that the general decreasing trend of polarization percentage, having a very long-term character, started in 1934 and lasted until now, with some smaller disturbances.

The position angle of the star γ Cas presented in the Figure 2b changes in the interval between 106° and 118° if we exclude the value measured in 1976 as a single measurement during this year.

The visual brightness of γ Cas in the interval of time 1974 - 1989 has a general increasing trend according to Telting et al. (1993). This means that the polarization percentage and visual brightness are anti-correlated. A discussion of Hα equivalent widths data and polarization percentage for the period of time 1974 - 1985 are presented by Arsenijević et al. (1990).

V. 88 Her (HD 162732, B6-7IV-Ve, \( v \sin i = 300 \text{ km/s} \))

In Figure 3a two phases of high polarization percentage in the star 88 Her are seen. During the first period (1979 - 1982) the annual mean value of the percentage reached 0.51%. During the second period (1989 -1991) polarization percentage was a little higher, 0.64%. Two phases with the small percentage were in the periods 1975 - 1978 and 1984 - 1986 with the values 0.14% and 0.24%, respectively. The amplitudes of the changes in polarization percentage are under 0.5%.

The position angle observations presented in Figure 3b shows variations between 85° and 52° during the years 1974 - 1975. After that period position angle is smaller than 70°.

For the period 1974 - 1979 the correlation of the polarization percentage and Hα emission peak intensities have been found as well as the anti-correlation of the percentage and visual brightness (Arsenijević et al. 1987).

One Be shell phase of 88 Her that started during the year 1976 is very well documented by published data. According to our polarimetric data there was another shell phase that started maybe in the year 1988 but we have not yet seen the published data.

VI. κ Dra (HD 109387, B7IIIpe, \( v \sin i = 205 \text{ km/s} \))

Polarimetric data presented in Figure 4a covers the period of 14 years when the polarization percentage changes from 0.15% in 1980 to 0.54% in 1985. The position angle in Figure 4b changes from 7.8° in 1980 to 28.4° in 1986 (maximum). After 1986 both polarization parameters decrease till 1991.

The photometric data of the star carried out at Hvar Observatory (private communication) confirm anti-correlation of the polarization percentage and visual brightness of the star. The daily mean value of the intrinsic optical polarization in percent obtained from 1979, exhibits a close correlation with the equivalent width of the Hα spectral line (Arsenijević et al. 1993).

VII. CONCLUSIONS

The intrinsic visual polarization percentage for all four stars is smaller than 1%.

Long-term variations in both intrinsic polarization parameters occur in all four observed stars.

The amplitude of the polarization percentage changes are not higher than 0.5%.
FIGURE 3. (a) Observed intrinsic polarization percentage and (b) polarization position angle of the star 88 Her in the V spectral region during 1974 - 1992 (dots). Annual mean values are denoted by triangles connected by full line.
FIGURE 4. (a) Observed intrinsic polarization percentage and (b) polarization position angle of the star κ Dra in the V spectral region during 1979 - 1992 (dots). Annual mean values are denoted by triangles connected by full line.
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The amplitude of the position angle changes are less than 30°.

The anti-correlation between polarization percentage and visual brightness was always noticed when data existed, but for our period of observations and sample of stars this fact is only partly documented in some periods.

The correlation between polarization percentage and Hα emission strength is firmly confirmed for some of our program stars. More data are needed for the final conclusion.

VIII. REFERENCES