PHOTOPOLARIMETRY OF SOME MIRA-TYPE STARS

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ABSTRACT. The variations of the polarization parameters of three Mira–type stars V CrB, S CrB, T Her in the UBVRI bands are presented.

Key words: Stars: late-type: miras; stars: individual: V CrB, S CrB, T Her.

1. Introduction

An existence of dusty circumstellar envelopes is a wide-spread phenomenon. Such envelopes have been detected at R CrB-type stars, red giants and supergiants, T Tau-type stars, hot non-periodic Algol-type stars, IR sources etc.

Visible appearance of the dust existence varies from the existence of great IR excesses and absorption lines to photometric and polarimetric peculiarities. The physics of dusty circumstellar envelopes is a subject for special study.

In spite of the quite a few data on the miras polarimetry and spectropolarimetry one should note its inhomogenity and fragmentary. Rather detailed information has been obtained for only small number of miras. Besides, most observations has been made at bright stage of stars due to brightness deficiency.

However, observations at the minimum and nearby to the co-called Eruption Point (EP) at the phase 0.8 (Fischer, 1968) are of special interest. That is a reason why at the Crimean Astrophysical Observatory (CrAO) in 1987 have been started the photopolarimetric observations of a sample single miras representing various spectral types and types of variability to study their polarimetric characteristics in minima and nearby to EP.

In this note we present some data of photopolarimetry of mira-type stars T Her (M-type), V CrB (C-type) and S CrB (M-type) based on the observations at CrAO. Everywhere the elements from the GCVS (Kholopov, 1985) were used to calculate the phases of light variations.

2. Observations and data reduction

All our photopolarimetric observations of miras were carried out at CrAO from May, 1987 till June, 1988 with the 125 cm telescope using the computer controlled UBVRI Double Image Chopping Photopolarimeter, developed by V. Piirola (1988).

The instrument provides measurements of the intensity and polarization simultaneously in UBVRI bands centered at 0.36, 0.44, 0.53, 0.69, and 0.83μ, respectively.

The instrumental polarization in each color, determined from the observations of unpolarized standard stars, was usually very small ($< 0.2\%$). The calibration of the position angle was made observing stars with well known large interstellar polarization (Serkowski,1974; Coyne et al.,1974, Hsu & Breger, 1982). The duration of observation varied from 15 min till one hour depending on the brightness of the star and sky conditions.

3. T Her

The star belongs to the most numerous class M-type miras. Only communication about the polarimetric observations of the star has been published in 1967 (Zappala, 1967). No polarization has been found. New observations of this star were carried out at the CrAO from May 11, 1987 till August 22, 1988.

Comparison star was SAO 66729 (V=7.42, B-V=0.98, U-B=0.87, V-R=0.73, V-I=1.31).

No correction for interstellar polarization was applied since the star is located at high galactic latitude (b=+58°).

The period of pulsation of this star is one of shortest. It allowed us to monitor the polarimetric and photometric variations in the course of four adjacent cycles of pulsation (practically at all phases in one cycle and in some part of three adjacent cycles.

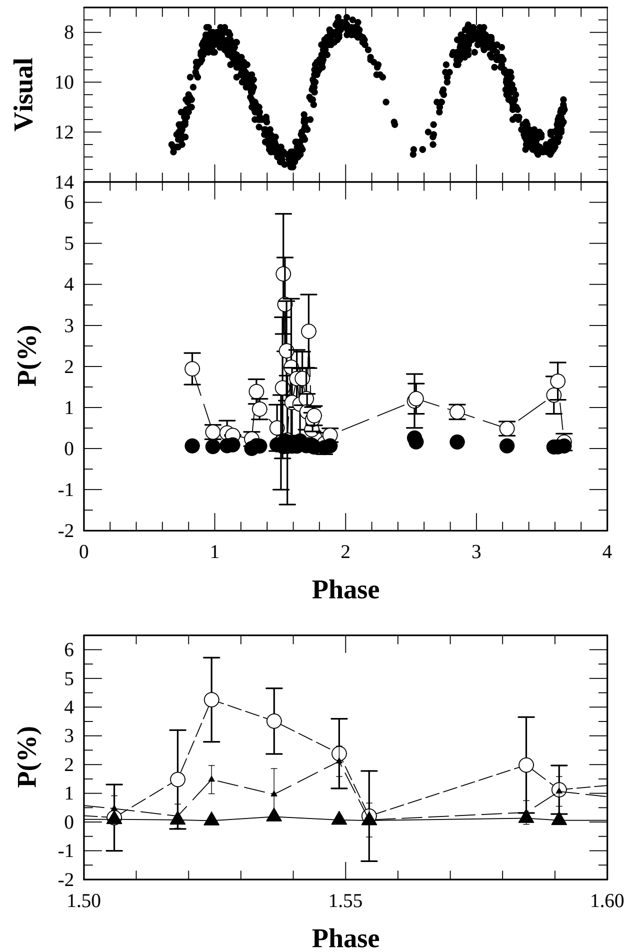

Figure 1: Variations of polarization degree P% (middle and bottom panels) with the phase of light variations in visual band from AAVSO (top panel) for T Her.

The visual light curve from the data of AAVSO is shown in Fig. 1 (upper panel).

In the figure an abscissa shows the phase of light variations and number of cycle calculated from the moment of previous light maximum. The light minimum is at the phase 1.6. A middle panel shows the variations of the degree of polarization P(%) only for two bands: U (open circles) and B (filled circles). The polarization in V,R and I bands is close to zero and does not depicted in the figure to avoid the overlap of the points. It is seen that the polarization is small everywhere except the phase interval between 1.5 and 1.6 which corresponds to the light minimum. In more details the variations of the polarization in this phase interval are shown in lower panel for three bands: U (open circles), B (filled circles) and R (filled triangles). It is seen that in this phase interval the degree of polarization has maximum and rises up to 4% in U-band.

Wavelength dependencies of T Her for some phases are shown in Fig. 2.

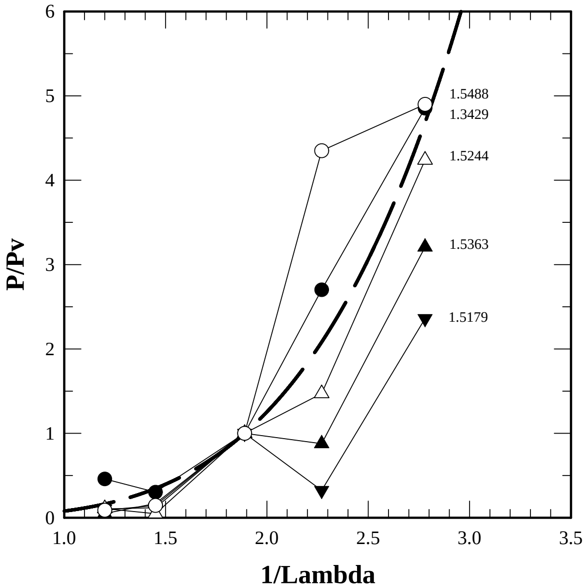

Figure 2: Wavelength dependencies of polarization P of T Her normalized to the degree of polarization P_v in V band. Numbers nearby to the curves indicate the phase of light variations. Thick dashed line corre-

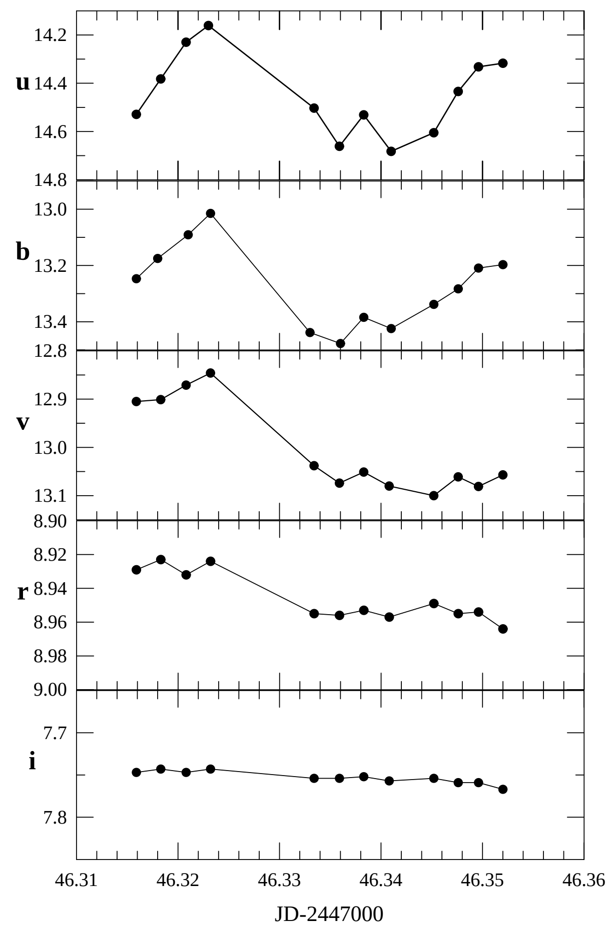

Figure 3: Intraday variations of the brightness of T Her in ubvri bands (instrumental system) on September 7, 1987 (JD 2447046).

It is seen that the shape of these dependencies tends to the the curve of Rayleigh scattering (thick dashed line) as the star approaches to its light minimum. The most prominent maximum of the degree of polarization in U band is also located in this narrow phase interval at the very bottom of the light minimum. So, it seems that the polarization is in fact produced by the scattering the radiation of the star on small dust particles in its circumstellar envelope.

It is well known that late-type stars are unstable on various time scales. In contrast to the longtime variability of miras much less is known about their intraday variations. Fig. 3 shows the brightness variations of T Her during one of night (September 7, 1987) when one can see the different kind of variations.

It is well seen that the maximum amplitude of brightness variations was in U band (about 0.5^m) and decreased toward red light where the amplitude of brightness variations in I band was less than 0.1^m. The time scale of variation was about one hour.

According to the classification by Strelkova (1956) T Her belongs to the II type of light variability, which is characterized by the shortwave colors variations in opposite sense with respect to the brightness variations, i.e. in the phase of minimum the star became bluer due to the decreasing of the TiO absorption bands with the decreasing the stellar temperature. This is well seen in Fig. 4 where we show the colors variations in four adjacent cycles of pulsation.

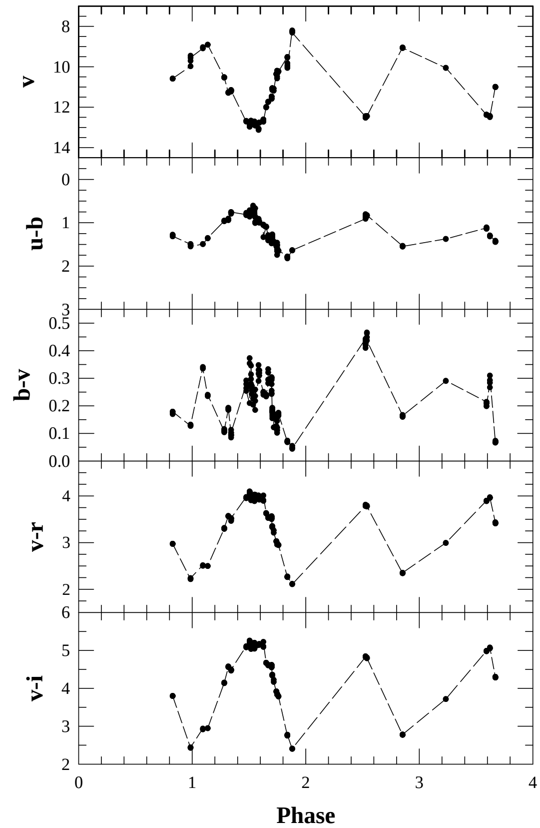

Figure 4: Variations of brightness v and colors u-b, b-v, v-r, v-i of T Her in instrumental system with phase.

4. S CrB

The star belongs to the M-class. Previous polarimetric measurements, made by several authors in 1966 – 1970, revealed rather large and variable polarization. It was found that the degree of polarization increased when the brightness of the star goes toward its light minimum. New photopolarimetric observations of the star was made at CrAO from May 12, 1987 till August 11, 1988. The comparison star was SAO 64617 for which we estimated V=6.86, B-V=0.95, U-B=1.01, V-R=0.75, V-I=1.28. Our results are shown in Figs. 5,6,7.

As it is seen in Fig. 5, the broad polarization maximum, mostly prominant in U-band, locates in the broad light minimum. The position angle of polarization changed in the large interval of angles without any obvious dependence on phase.

The wavelength dependence of polarization is typical for miras, with large scattering in ultraviolet (Fig. 6).

The shortwave color indices changed in accord with the variation of brightness (Fig. 7).

It allows us to place this star into group I by the Strelkova's (1956) classification.

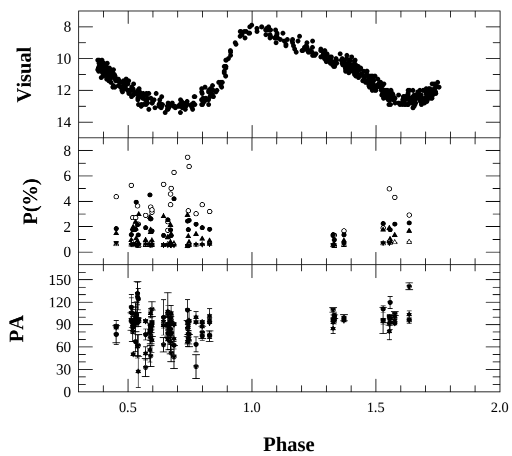

Figure 5: The variations of brightness in visual light from AAVSO (top panel), degree of polarization P(%) (middle panel) and position angle PA (degrees) (bottom panel) of S CrB in U (open circles), B (filled circles), V (filled triangles) and R (open triangles) bands with the phase of the light variations in two adjacent cycles.

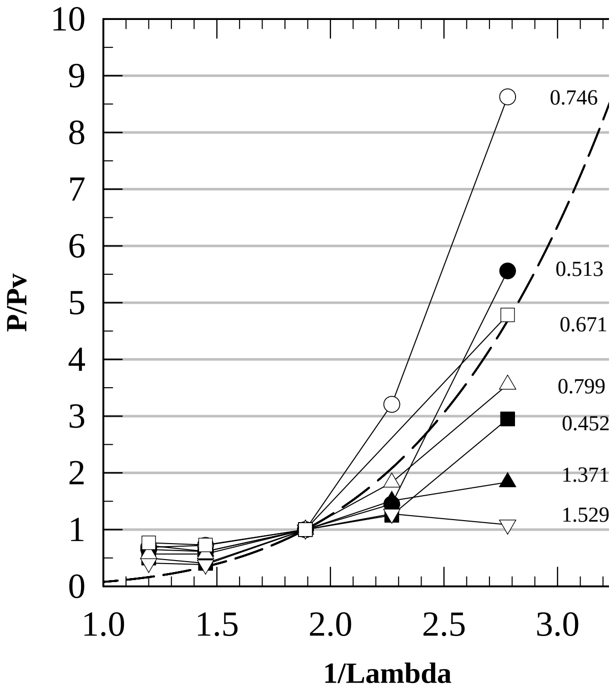

Figure 6: Same as Fig. 2, for S CrB.

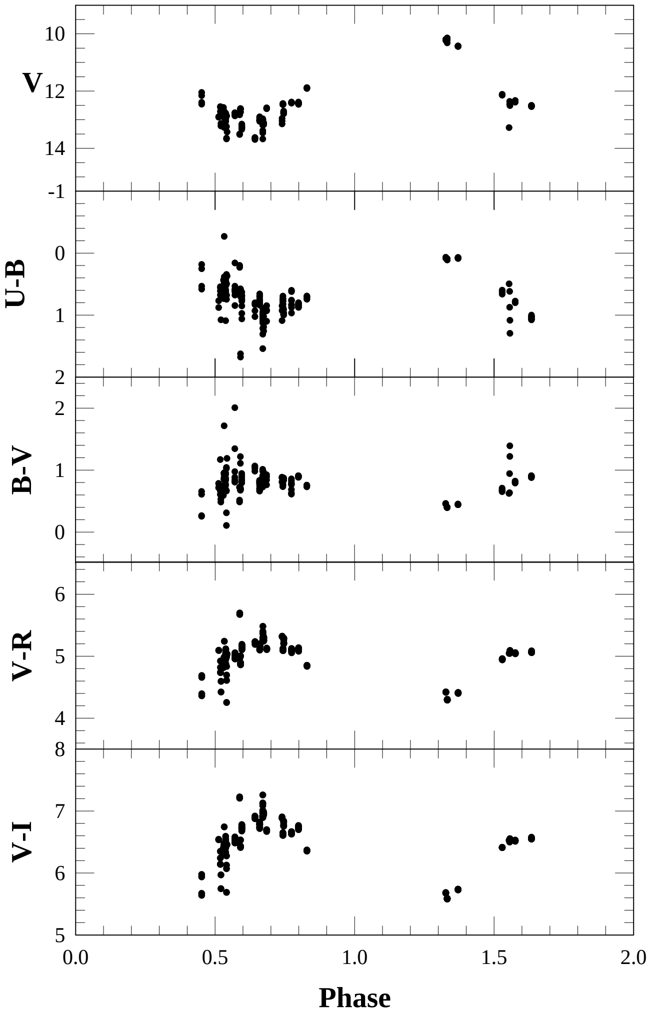

Figure 7: Same as Fig. 4 for S CrB but in standard Johnson system.

5. V CrB

The star belongs to C-class. Previous polarimetr observations of the star made by different observe encompass the wavelength from the blue region to 2, The variation of polarization parameters with time ar wavelength was revealed inthe sence the star faded o. the degree of polarization increased. Our observations were carried out from June 5,1987 till June 20, 1988. No correction for interstellar polarization was applied since the star is at high galactic latitude (b=51°. The detailed analysis of polarimetric study of V CrB had been published by Efimov (1995). Here we pay attention to some features. Beside of rise the polarization at the brightness minimum it is seen from Fig.8 that rather large (up to 5%) degree of polarization in B-band was observed at the maximum, in contrast to the polarization in other bands. It is seen also that the polarization plane has a continuous rotation in the course of pulsation cycle (Fig. 8, bottom panel).

Wavelength dependencies of the degree of polarization in different phases show that the polarization rises toward shortwaves more fast then it may be expected from the Rayleigh scattering (Fig. 9).

It is interesting that behaviour of position plane of polarization is quite different for two extreme stage of the star: in phase of minimum the orientation of the position angle in all bands is the same. However, the position angles of polarization in the maximum of brightness turns from visual and red to ultraviolet by 90° (Fig. 10). Till now no reasonable explanation was

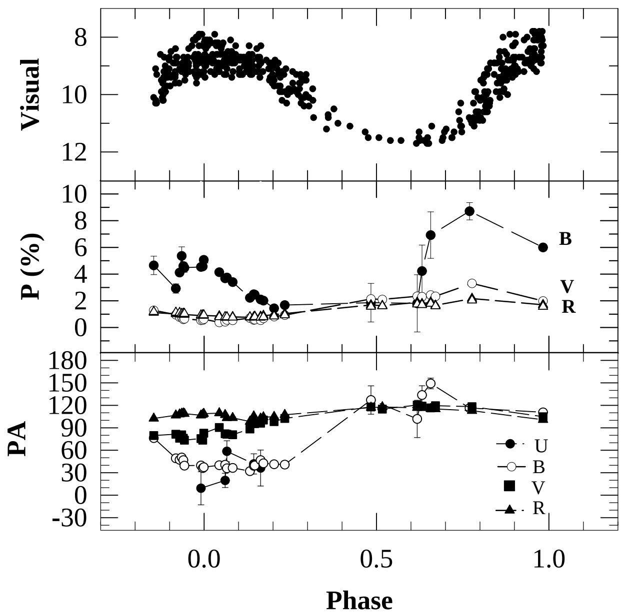

Figure 8: Same as Fig. 5 for V CrB.

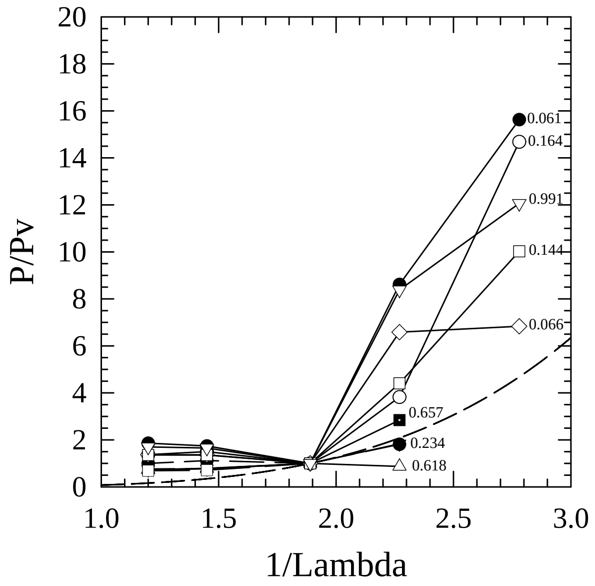

Figure 9: Same as Fig. 2 for V CrB.

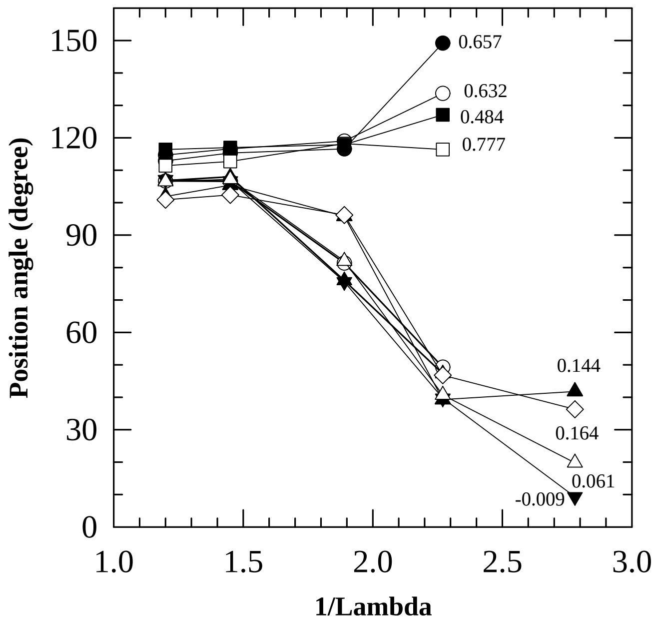

Figure 10: Same as Fig. 2 for V CrB but for position angle.

suggested.

The results of observations of V CrB may be summarized as follow:

1. There are two different state of polarization. One state is observed at the phase of minimum and characterized by the practically constant orientation of the polarization plane along the spectrum. The other one with strong wavelength dependence of the position angle of polarization is typical for phase of maximum.

2. When star goes from maximum to minimum the degree of polarization increases and the position angle of polarization rotates.

3. The fast increase of the polarization occured at the phase nearby to 0.6.

6. Discussion

From the study of the polarization variations at o Ceti it was found that its degree of polarization in UV at the phase 0.8 has a rapid increase at the factor two and then falls down. This rise of polarization occured at the EP in the light curve described by Fischer (1968). This is also the time of the minimum of the U-B color (Serkowski, 1971) and the appearance of hydrogen emission lines. It was suggested that at this point starts the process of fast generation of small (less then 0.05μ) dust particles.

As the distance from the EP increases the size of the particles increases to 0.1μ or more (Materne, 1976) just before the new EP (Shawl, 1975b). However, until now we cannot distinguish between very small dust and gas atoms or molecules, since both give rise to Rayleigh-like scattering.

Three classes of models basing on asymmetry of physical or/and geometrical conditions have been proposed to explain the polarimetric features of miras:

1. Asymmetric distribution of circumstellar silicate dust with ferromagnetic inclusion (Shakhovskoj, 1963; Serkovski, 1971; Shawl, 1975a, 1975b).

2. Photospheric asymmetry, convective cells (Harrington, 1969; Schwarzschild, 1975).

3. Alignment of dust particles by magnetic field (Donn et al., 1966,1968; Kruszewski, 1971; Dolginov and Mitrofanov, 1977).

The best agreement with observations has a combined model by Marcondes-Machado (1987), suggesting that:

1) dust consists of the silicate particles with ferromagnetic inclusions;

2) size of particles changes with the distance from the star;

3) there is the alignment of particles by the stellar magnetic field;

4) the geometry of magnetic field transforms with the distance from the star from dipole near to the stellar surface to the helix one;

5) the radiation at different spectral regions is generated at different distances from the star;

6) the dust condensation to certain final size occurs at the distance from the star from 3 to 10 stellar radii.

Physical characteristics of miras are strongly changed in the course of the pulsation cycle. Change of temperature exerts influence on the such physical properties of dust particles as their size, shape and composition which are connected with the optical properties of dust particles. It is clear that the change of these properties at the time of dust formation will change the properties of radiation passed through the dusty envelope. In particular, one may expect the specific changes of the colors and polarization parameters.

These variations will be most significant during the process of the dust formation as it takes place at R CrB-type stars. These changes may be used as the diagnostic tool for the property of circumstellar dust (Grinin, 1988; Efimov, 1988a, 1988b).

7. Conclusion

The comparison of our observations with the data from literature allow to conclude that cycle-to-cycle variations of polarization parameters of optical radiation may occure for stars of the same spectral class. The fast increase the polarization may take place not only at phase 0.8 but at other phases at the minimum brightness of star. There are some evidence on the possible intraday variations of brightness of some miras. To study the process of dust formation one need to estimate the effect of the absorption lines on the the observed photometric behaviour of miras and discriminate between the scattering on dust and gas. The tools to detect and study the dust around stars are the IR radiarion, the comparison of changing the degree of polarization and color indices with variation of brightness. The corresponding data may be obtained from the potopolarimetric monitoring of miras at the stage of dust formation.

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