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The Characteristics of Intrinsic Polarization for Four RV Tauri Stars

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４個のおうし座RV型星の固有偏光の特徴について

吉　岡　一　男

要　　旨

おうし座RV型星は，主極小と副極小を交互にくり返す光度変化に特徴がある半規則的な脈動変光星である．この変光星は，光度曲線をもとにRVa型とRVb型に細分類されており，RVb型が脈動周期の光度変化に重なって長周期の光度変化が見られるのに対して，RVa型にはそのような長周期変化は見られない．また，この変光星は可視域のスペクトルをもとに，酸素過剰なAグループと炭素過剰なB，Cグループに細分類されている．

われわれは，国立天文台堂平観測所の91cm反射望遠鏡を用いて，おうし座RV型星の多色偏光観測を行った．観測された17個の星の内，４個の星に対して星間偏光成分を取り除いて固有偏光成分を求めた．星間偏光成分は，near-neighbor法で決定された．われわれが得た星間偏光成分の偏光位置角は，他の観測者の得た値に近いが，われわれが得た星間偏光成分の偏光度のいくつかは，他の観測者の値と大きく異なる．われわれの得た値は，星間偏光に対してより根拠のある仮定に基づいているので，より信頼度が高い．

われわれの求めた固有偏光成分は，いっかくじゅう座U星を除き，星周圏ダストの幾何的配置が時間変動をしないことを示唆している．さらにわれわれの結果は，Aグループの星で観測された偏光度が中間の波長で極大値をとる傾向がある，というわれわれがすでに得ている結果を支持している．

ABSTRACT

The RV Tauri stars are semiregular variables whose light curves are characterized by alternate deep and shallow minima. On the basis of light curves the RV Tauri stars are divided into the RVa and the RVb groups. The RVa group is characterized by a relatively regular light curve, while the RVb group is characterized by a superimposition of a long-term variation. On the basis of spectroscopic characteristics in an optical region the RV Tauri stars are divided into the oxygen-rich group, the group A, and the carbon-rich group, the group B and the group C.

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We made the multicolor polarimetric observations of RV Tauri stars, using the 91cm reflector at the Dodaira Station of the National Astronomical Observatory. Among 17 stars observed we obtained the intrinsic polarizations of 4 stars by removing the interstellar polarizations. The interstellar polaizations were determined by the near-neighbor method. Our values for the position angle of interstellar polarization are close to those determined by other observers, while some of our values for the degree of interstellar polarization are noticeably differ from those determined by other observers. Our values seem to be more reliable, because our assumptions concerning the interstellar polarization are more founded.

The intrinsic polarizations determined by us suggest that except for U Mon the geometrical arrangement of circumstellar dust envelope do not change with time. Furthermore, our results confirm the tendency for the degree of observed polarization for the stars belonging to the group A to take a maximum at an intermediate wavelength, which were observed by us.

1. Introduction

The RV Tauri Stars are semiregular variables which lie between the Cepheids and the Mira-type variables in the HR diagram. Their light curves are characterized by alternative deep and shallow minima. The periods between two adjacent deep minima, which are called double periods or formal periods, range between 30 to 150 days. The RV Tauri stars have relatively regular periods, but the magnitudes of maxima and minima are not constant. Interchanges of minima sometimes occur, i. e., two deep or shallow minima occur in succession.

On the basis of light curves the RV Tauri stars are divided into 2 subgroups, RVa and RVb. The RVa group is characterized by a relatively regular light curve, and the interchanges of minima do not occur frequently. The RVb group is characterized by a rather irregular light curve, especially by a superposition of a long-term brightness variation.

On the basis of spectroscopic characteristics in an optical region Preston et al. (1963)[1] divided the RV Tauri stars into 3 subgroups, group A, group B, and group C. The group A generally shows anomalously strong TiO bands at light minima whose strength corresponds to early M-type supergiants, while intensities of metallic lines indicate the G or K-type. The group B shows spectra to which a definite spectral type cannot be assigned. The most distinctive characteristics is that near light minima CH and CN bands appear with considerable strength indicative of an enhanced carbon abundance. The group C shows all the characteristics of the group B except that the carbon features are weak or not present. Dawson (1979)[2] divided the group A into the group A_1 and A_2. The group A_1 shows TiO bands near light minima, while the group A_2 does not show TiO bands at any phase.

The RV Tauri stars show strong excess infrared radiations, which indicates that they are embedded in circumstellar dust envelopes (hereafter referred to as CDE). The RV Tauri stars are generally regarded as post-asymptotic giant branch (hereafter referred to as post-AGB) objects which left the AGB recently. Their CDE's are thougt to be formed as a result of mass loss at the final stage of the AGB phase (Jura (1986)[3]).

The author, togather with Dr. K. Saijo and Associated Prof. H. Sato, has made the multicolor polarimetric observations of 17 RV Tauri Stars between 1993 October 23 and 1998 October 29, using the multi-channel polarimeter attached to the 91cm reflector at the Dodaira Station of the National Astronomical Observatory. In this paper, we report the characteristics of intrinsic polarization for 4 RV Tauri stars, TW Cam, SS Gem, U Mon, and R Sct.

2. Observations and Reductions

The multi-channel polarimeter can measure linear polarizations simultaneously at 8 colors. These colors are indicated with the number of the channel in order of wavelength, whose effective wavelengths are 0.36, 0.42, 0.455, 0.53, 0.64, 0.69, 0.76, and 0.88μm, respectively. The construction and the operation of this polarimeter are described by Kikuchi (1988)[4]. An accuracy of better than 0.03% can be obtained for bright stars with this polarimeter.

Using this polarimeter, we observed the degree of linear polarization p and the position angle of polarization θ. We also obtained the normalized Stokes parameters Q and U, where there are following relations:

$$Q = p\ \cos 2\theta, \tag{1}$$

and $$U = p\ \sin 2\theta. \tag{2}$$

The program by Hirata (1993)[5] was used for the reduction of the raw date into the quantities of p, θ, Q, and U.

We obtained the intrinsic polarization from the observed polarization by removing the interstellar polarization. We adopted the empirical formula given by Whittet et al. (1992)[6] for a wavelength dependence of interstellar p_{IS}, which is given as follows:

$$p_{IS} = p_{max} \cdot \exp[-K\ \ln^2(\lambda_{max}/\lambda)], \tag{3}$$

where p_{max} is the maximum degree of linear polarization which occurs at the wavelength λ_{max} ; K is a linear function of λ_{max} ;

$$K = 0.01 + 1.66\lambda_{max}. \tag{4}$$

The narmalized Stokes parameters for the intrinsic polarization Q_* and U_* are calculated by the following equations:

$$Q_* = Q - p_{max} \cdot \exp[-K\ \ln^2(\lambda_{max}/\lambda)] \cdot \cos 2\theta_{IS}, \tag{5}$$

and $$U_* = U - p_{max} \cdot \exp[-K\ \ln^2(\lambda_{max}/\lambda)] \cdot \sin 2\theta_{IS}, \tag{6}$$

where Q and U are the observed quantities and θ_{IS} is the position angle of interstellar polarization. Then the intrinsic polarization p_* and θ_* are calculated by the following equations:

$$p_* = \sqrt{Q_*^2 + U_*^2}, \tag{7}$$

and $$\theta_* = 0.5 \cdot \tan^{-1} (U_*/Q_*). \tag{8}$$

The p_{max}, λ_{max}, and θ_{IS} values are determined on the basis of the near-neighbor method described by Bastien (1985)[7]. According to this method, the p_{IS} and θ_{IS} values for the star concerned are estimated in the following way.

A catalog of stars which are thought to have no intrinsic polarization is used. Using the catalog, we find the smallest circle, centered on the target star, which has more than 20 stars within it. Circles of radius 2°, 4°, 6, 8°, and 10° are considered. If less than 20 stars are found within a 10° circle, only those stars are used. The θ_{IS} value is then estimated by averaging the θ_{IS} values of the stars found above. The stars are weighted according to $1-r/r_C$, where r is the angular distance between the star and the target star, r_C is the radius of the circle mentioned above. To help in estimating the p_{IS} value due to interstellar clouds in front of the target star, the ratio $p/E(B-V)$ are calculated for the same stars, using the weights mentioned above. In obtaining $E(B-V)$ values, the value of $R=3.1$ are used. With a knowledge of $E(B-V)$ value due to foreground interstellar clouds for the target star, the p_{IS} value for the target star is estimated.

We used the interstellar polarization database (hereafter referred to as ISPOL database) compiled by Hirata (1999)[8] as the catalog of stars with no intrinsic polarization. The ISPOL database contains 13969 data for several wavelengths collected from 45 literatures. Using the ISPOL database, we estimated the θ_{IS} value for the target star according to the near-neighbor method. In case the θ_{IS} values of near-neighbor stars depend strongly on the position in the celestial sphere or on the distance, its dependence is taken into account in estimating the θ_{IS} value for the target star. We also estimated the p_{IS} value for the target star for several wavelengths according to the near-neighbor method, except for the parameter for the estimation. As mentioned above, $E(B-V)$ is adopted as the parameter in the near-neighbor method. However, many RV Tauri stars embedded in CDE. Thus, It seems that, for many RV Tauri stars, the observed $E(B-V)$ includes not only the interstellar component but also the circumstellar component. For example, DuPuy (1973)[9] found that the intrinsic colors corrected for interstellar reddening are redder than those for normal, stable supergiants, which he attributed to CDE. Therefore, we adopted a distance as the parameter, instead of $E(B-V)$. After estimating the p_{IS} values for several wavelengths, we determined simultaneously the p_{max} and λ_{max} values as the least-squares solution for the expression (3).

3. Results

Among the 17 RV Tauri stars observed by us, only for the 4 stars reported in this paper the interstellar polarizations have been determined by other observers. The position, subclass, and distance for the above 4 stars are given in table 1. The details of the results are as follows.

a) TW Cam

According to Preston et al. (1963)[1] TW Cam cannot be placed unambiguously in the group A. TW Cam was observed 5 times on 1993 Dec. 23/24, 1995 Jan. 15/

Table.1. Data on the RV Tauri Stars analyzed for Intrinsic Polarization. The second column gives the classification in the General Catalogue of Variable Stars (Kholopov et al. 1985)[17]. The third column gives the classification on the basis of optical spectra. Distances are taken from Dawson (1979)[2].

Star	Variable Star Class	Optical Group	α_{1950}	δ_{1950}	Distance (pc)
TW Cam	RVb	A_2	$04^h16^m33^s$	$+57°19.2'$	6160
SS Gem	RVa	A_2	$06^h05^m32^s$	$+22°37.8'$	1540
U Mon	RVb	A_1	$07^h28^m21^s$	$-09°40.4'$	580
R Sct	RVa	A_1	$18^h44^m43^s$	$-05°45.6'$	220

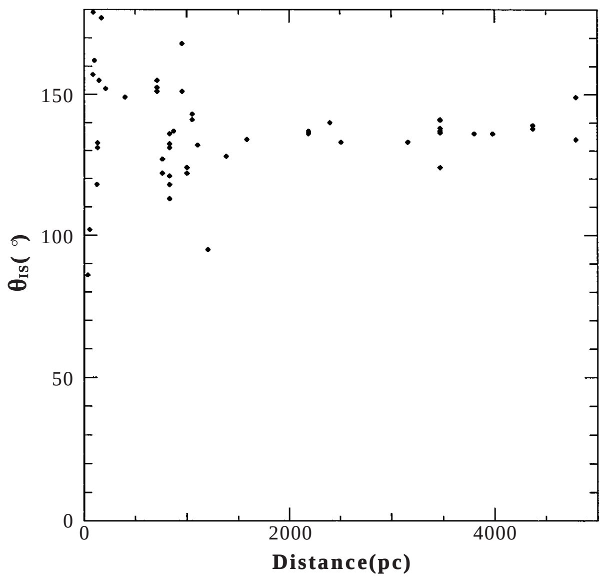

Fig.1. Dependence of the θ_{IS} values near TW Cam on distance. The scatter of θ_{IS} values becomes small for the stars with distance of more than 1250pc.

16, 1996 Oct. 29/30, 1996 Nov. 25/26, and 1996 Nov. 27/28.

We found 35 stars from the ISPOL database which are within a 6° circle centered on TW Cam. We selected 14 stars (20 data) for the estimation of the θ_{IS} value among the above 35 stars whose distances are larger than 1250pc. The value of 1250pc was adopted, because for the stars with distance of more than 1250pc the scatter of θ_{IS} values becomes small, as is shown in figure 1. The estimated value is; $\theta_{IS}=144°$. In this estimation, the dependences of θ_{IS} values on α_{1950} and distance were taken into account.

We selected 11 stars (11 data) for the estimation of p_{IS}(V) value whose distances are larger than 2000pc, where p_{IS}(V) means the p_{IS} value for V color. We also selected 4 stars (4 data) for the estimation of p_{IS}(G) value whose distances are larger than 2000pc, where p_{IS}(G) means the p_{IS} value for G color. The value of 2000pc was adopted, because for the stars with distance of more than 2000pc the dependence of p_{IS} values on distance differs from that for the stars within 2000pc. As is shown in figure 2, the p_{IS}(V) values within 2000pc increase with distance, while those for distance over 2000pc decrease with distance. The same holds for the p_{IS}(G) values. In the estimation of these values, these dependences were taken into account. In the estimation of the p_{IS}(V) value, HDE232947 was excluded because its p_{IS}(V) value differ markedly from those for the other stars. The estimated values are; $p_{IS}(V)=2.24\%$, and $p_{IS}(G)=2.03\%$. Assuming that $\lambda_{max}=$

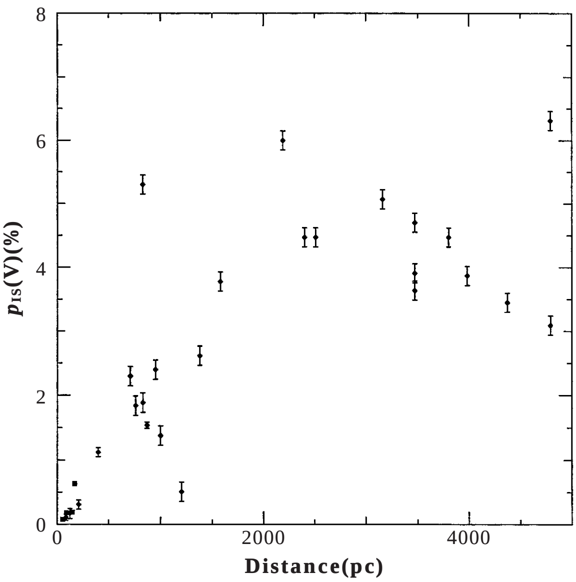

Fig. 2. Dependence of the p_{IS}(V) values near TW Cam on distance. The p_{IS}(V) values decrease with distance for the stars with distance of more than 2000 pc.

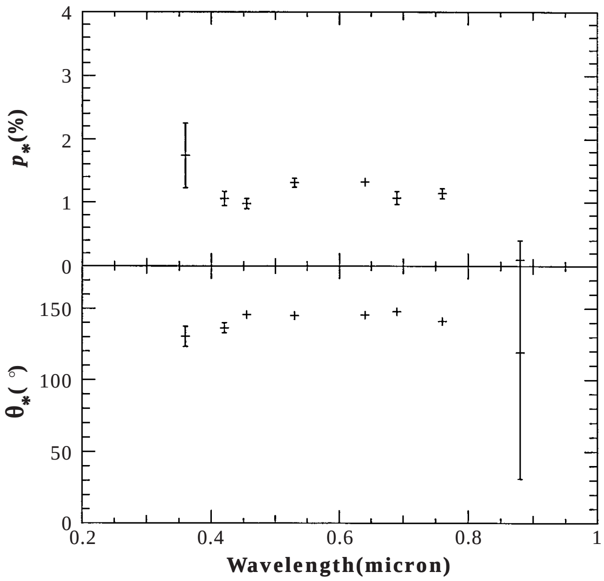

Fig. 3. Wavelength dependence of the p_* and θ_* values of TW Cam on 1993 December 23/24. The p_* values show a slight 凸 type dependence.

0.52μm, we determined that p_{max}=2.15% as the least-squares solution, where the above λ_{max} value were taken from the results by Nook et al. (1990)[10]. We prescribed the λ_{max} value, because the least-squares solution gives unrealistic values for p_{max} and λ_{max} when not only p_{max} but also λ_{max} is taken as a free parameter. In the determination of p_{max} and λ_{max} values, the p_{IS}(B) values were excluded because the p_{IS}(B) values are much larger than the p_{IS}(V) and p_{IS}(G) values for the stars with distance of more than 2000pc.

Nook et al. (1990)[10] determined that $\theta_{IS}=135.8°\pm4.0°$, $p_{max}=2.97\pm1.00$%, and λ_{max} =0.52μm by the near-neighbor method. Their θ_{IS} value is relatively close to our value. On the other hand, their p_{max} value is rather larger than our value, which seems to reflect our regard to the decrease of p_{IS} values with distance.

We obtained the intrinsic polarization by removing the interstellar polarization of our values. As is shown in figure 3, the data with small observational error show a tendency for the p_* values to take a maximum at an intermediate wavelength (hereafter referred to as the 凸 type dependence). Some data observed at other dates show a tendency for the p_* values to take a minimum at an intermediate wavelength (hereafter referred to as the 凹 type dependence). However, these data have large observational errors, thus the above 凹 type dependence is doubtful. Many θ_* values are within the range from 130° to 150° and show neither wavelength dependence nor time dependence.

b) SS Gem

According to Preston et al. (1963)[1], SS Gem may be related to the group B, because it show strong CN bands and weak Ca II lines. Dawson (1979)[2] also described that the DDO colors indicate that SS Gem may be a member of the group B. Furthermore, Gonzalez, Lambert, and Giridhar (1997)[11] claimed that SS Gem should be reclassified as the group B based on the numerous C I lines in its spectrum. SS Gem was observed 10 times on 1993 Nevember 27/28, 1993 December 23/24, 1994 February 2/3, 1994 February 19/20, 1994 December 21/22, 1995 January 18/19, 1995 March 21/22, 1996 February 2/3, 1996 October 27/28, and 1997 January 28/29.

We found 49 stars from the ISPOL database which are within a 4° circle centered on SS Gem. We selected 31 stars (86 data) for the estimation of the θ_{IS} value among the above 49 stars whose distances are within the range from 600 pc to 2200pc. The above range of distance was adopted, because for the stars within the above range the θ_{IS} and p_{IS} values do not depend on the distance, as are shown in figures 4 and 5, respectively. The estimated value is; $\theta_{IS}=171°$.

We selected 13 stars (16 data), 31 stars (48 data), and 8 stars (22 data) for the estimations of $p_{IS}(B)$, $p_{IS}(V)$, and $p_{IS}(G)$ values, respectively, whose distances also are within the range from 600pc to 2200pc. The estimated values are; $p_{IS}(B)=2.66$ %, $p_{IS}(V)=2.64\%$, and $p_{IS}(G)=2.95\%$. We determined that $p_{max}=2.81\%$ and $\lambda_{max}=0.57\mu m$ as the least-squares solution.

Nook et al. (1990)[10] determined that $\theta_{IS}=170°\pm10°$, $p_{max}=2.25\pm1.00\%$, and $\lambda_{max}=0.54\pm0.04\mu m$ by the near-neighbor method. Their θ_{IS} value almost coincides with our value. On the other hand, their p_{max} value is rather smaller than our value, which may reflect that the p_{IS} values within the range of the above distance are larger than those without the range. Their λ_{max} value is slightly smaller than our value, though the difference is within the determination error.

We also determined the interstellar polarization on the assumption that SS Gem does not have an intrinsic polarization and the observed polarization is the interstellar polarization. We obtained the following results as the least-squares solution; $\theta_{IS}=1°\pm2°$, $p_{max}=2.96\pm0.3\%$, and $\lambda_{max}=0.56\pm0.14\mu m$, where the errors represent the range of the values determined from the data on individual nights. These values are fairly close to our values determined by the near-neighbor method, which may suggest the above assumption.

We obtained the intrinsic polarization by removing the interstellar polarization of our values. As is shown in figure 6, the data with small observational error show neither wavelength dependence nor time dependence. Many p_* values are within the range from 0.8% to 1.1%, and many θ_* values are within the range from 30° to 40°.

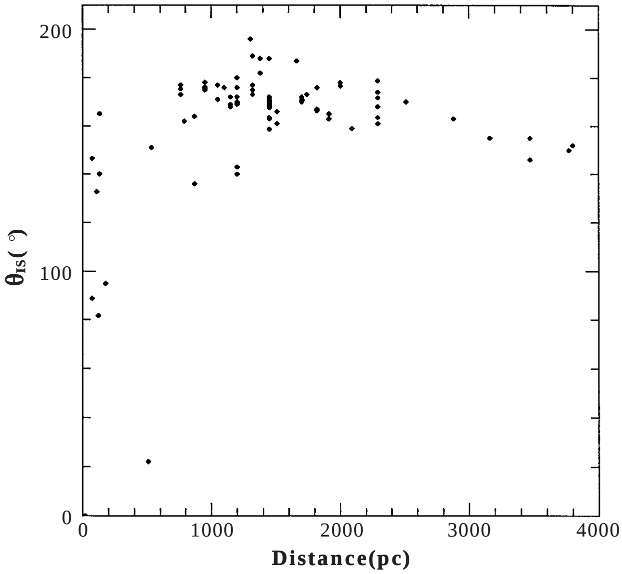

Fig.4. Dependence of the θ_{IS} values near SS Gem on distance. The θ_{IS} values do not depend on distance for the stars within the range from 600pc to 2200pc.

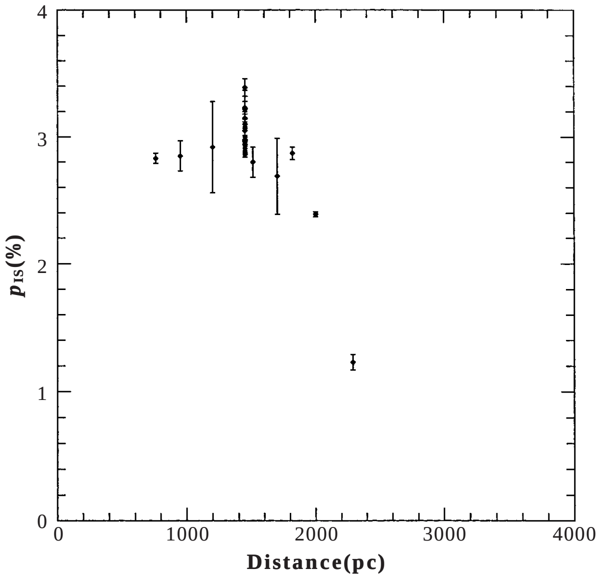

Fig.5. Dependence of the $p_{IS}(G)$ values near SS Gem on distance. The $p_{IS}(G)$ values do not depend on distance for the stars within the range from 600pc to 2200pc.

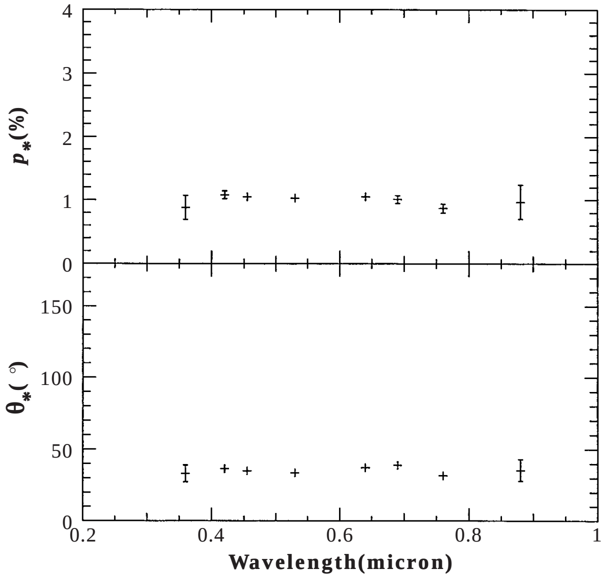

Fig.6. Wavelength dependence of the p_* and θ_* values of SS Gem on 1993 November 27/28. The p_* and θ_* values do not depend on wavelength.

c) U Mon

U Mon was observed 20 times on 1993 October 27/28, 1993 November 27/28, 1993 December 25/26, 1994 February 2/3, 1994 February 23/24, 1994 March 31/April 1, 1994 April 4/5, 1994 December 24/25, 1995 January 15/16, 1995 March 20/21, 1995 December 8/9, 1995 December 12/13, 1996 January 31/February 1, 1996 February 3/4, 1996 February 27/28, 1996 November 25/26, 1997 January 27/28, 1997 December 10/11, 1997 December 11/12, and 1998 February 10/11.

We found 47 stars (58 data) which are within a 6° circle centered on U Mon. Among these stars, the θ_{IS} values have been observed for 42 stars (53 data). We estimated the θ_{IS} value for U Mon from these 53 data. The estimated value is; $\theta_{IS}=3°$. In this estimation, the dependences of θ_{IS} values on α_{1950} and δ_{1950} were taken into account.

Among the above 47 stars, the $p_{IS}(V)$ values have been observed for 33 stars (37 data). We estimated the $p_{IS}(V)$ value for U Mon from these 37 data. The estimated value is; $p_{IS}(V)=0.71\%$. In this estimation, the dependence of $p_{IS}(V)$ values on α_{1950}, δ_{1950}, and distance were taken into account. Among the above 47 stars, the $p_{IS}(G)$ values have been observed for one star (2 data). We estimated the $p_{IS}(G)$ value for U Mon from these 2 data. The estimated value is; $p_{IS}(G)=0.82\%$. Assuming that $\lambda_{max}=0.50\mu m$, we determined that $p_{max}=0.77\%$ as the least-squares solution, where the λ_{max} value were taken from the results by Serkowski (1970)[12]. We prescribed the λ_{max} value, because the least-squares solution gives unrealistic values for p_{max} and λ_{max} when not only p_{max} but also λ_{max} is taken as a free parameter. In the determination of p_{max} and λ_{max} values, the p_{IS}(B) values were excluded because the p_{IS}(B) values are noticeably smaller than the p_{IS}(V) and p_{IS}(G) values.

Serkowski (1970)[12] determined that $\theta_{IS}=10°$, $p_{max}=1.85\%$, and $\lambda_{max}=0.50\mu$m. His θ_{IS} value is relatively close to our value. On the other hand, his p_{max} value is larger than our value by more than a factor of 2. As is exemplified in figure 7, the scatter of p_{IS} values is large and the accuracy of our determination is low. However, Serkowski (1970)[12] determined his values on the assumption that the interstellar polarization in the B band is the same as in the V band and that its value is equal to the average of the observed polarization in the above two bands. His assumption seems to be unreliable, thus his p_{max} value also seems to be unreliable. In fact, as is shown in figure 7, his p_{max} value is larger than the maximum p_{IS}(V) values for the stars within 4000pc.

We obtained the intrinsic polarization by removing the interstellar polarization of our values. According to Yoshioka (1998)[13], the observed Q and U values show a long-term time variation with the period which is close to those of the long-term time variations of brightness and radial velocity. The average θ_* and p_* values also show long-term time variations, but they do not show a conspicuous time variation in the wavelength dependence. The θ_* values do not show a conspicuous wavelength dependence. The p_* values do not show a conspicuous wavelength dependence, too, though they sometimes show a marginal 凸 type dependence, as is shown in figure 8.

d) R Sct

R Sct is unique, because it has a long pulsation period (144 days) as a RV Tauri star and it shows an erratic light curve and sometimes shows a deep minimum. According to Buchler et al. (1995)[14], the irregular pulsations of this star are described by a chaotic dynamics with an embedding dimension of 4. R Sct was observed 3 times on 1993 November 24/25, 1994 February 21/22, and 1996 April 4/5.

We found 26 stars from the ISPOL database which are within a 6° circle centered on R Sct. We selected 4 stars (5 data) for the estimation of the θ_{IS} value among the above 26 stars which satisfy the following conditions; $d \leqq 1000$pc, $18^h33^m \leqq \alpha_{1950} \leqq 19^h$, and $\delta_{1950} \geqq -10°$. The above ranges were adopted, because the scatter of data becomes discernibly smaller by narrowing the ranges, as are shown in figures 9 and 10. We also excluded the data whose θ_{IS} values are larger than 100°. The estimated value is; $\theta_{IS}=59°$. In this estimation, the dependences of θ_{IS} values on δ_{1950} and distance were taken into account.

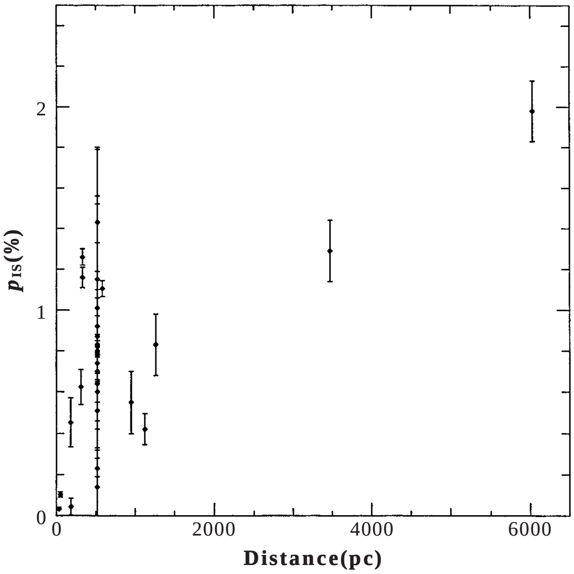

Fig. 7. Dependence of the p_{IS}(V) values near U Mon on distance. The scatter of the p_{IS}(V) values is large for the stars within 2000pc.

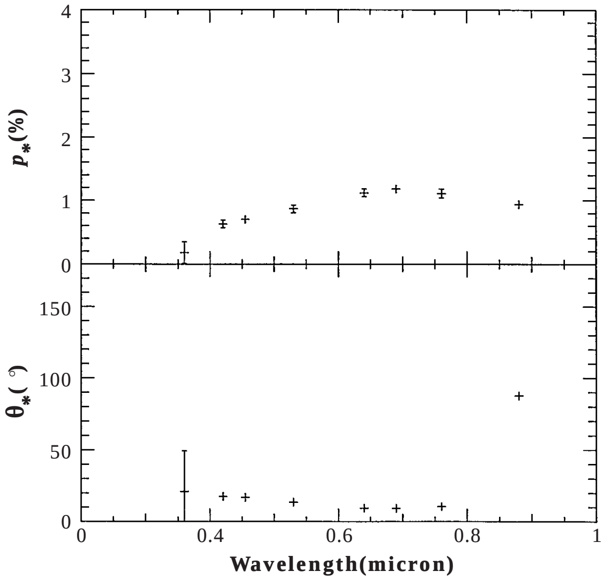

Fig. 8. Wavelength dependence of the p_* and θ_* values of U Mon. on 1998 February 10/11. The p_* values show a marginal 凸 type dependence.

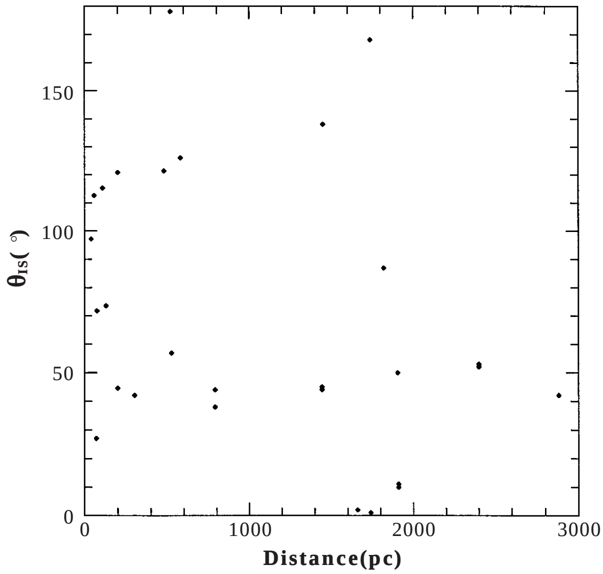

Fig. 9. Dependence of the θ_{IS} values near R Sct on distance. All the data are plotted.

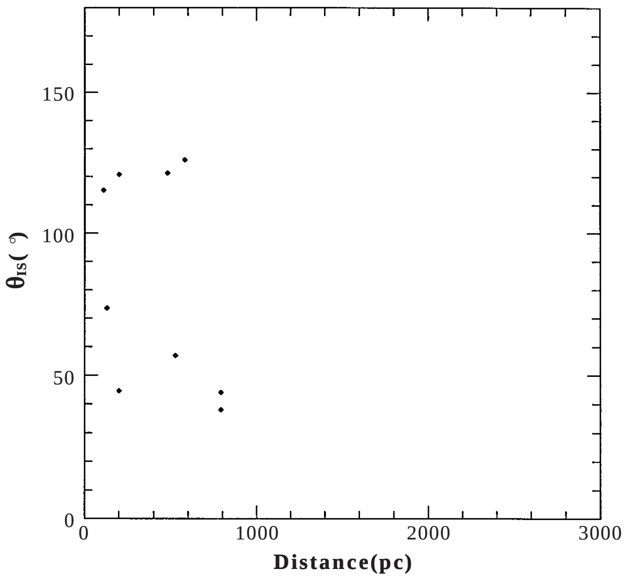

Fig. 10. Dependence of the θ_{IS} values near R Sct on distance. The data are polotted which satisfy the following conditions; $d \leqq 1000$pc, $18^h33^m \leqq \alpha_{1950} \leqq 19^h$, and $\delta_{1950} \geqq -10°$.

Among the above 26 stars, we selected 8 stars (8 data) and 2 stars (2 data) for the estimations of p_{IS}(B) and p_{IS}(V), respectively, which also satisfy the above conditions except for that for θ_{IS} values. The estimated values are; $p_{IS}(B)=0.44\%$ and $p_{IS}(V)=0.46\%$. In these estimations, the dependence of p_{IS}(B) values on distance was taken into account. We determined that $p_{max}=0.46\%$ and $\lambda_{max}=0.55$ μm as the least-squares solution.

Serkowski (1970)[12] determined that $\theta_{IS}=32°$, $p_{max}=1.15\%$, and $\lambda_{max}=0.50\mu$m. His θ_{IS} value is rather smaller than our value, and his p_{max} value is larger than our value by a factor of 2.5. The scatters of θ_{IS} and p_{max} values are large and the accuracy of our determination is low. Howerver, Serkowski (1970)[12] determined his values on the same assumption as that for U Mon, thus the accuracy of his determination seems to be low. In fact, as is shown in figure 11, his p_{max} value is apparently too high. Shakhovskoi (1964)[15] determined that $\theta_{IS}=53.6°$ and $p=0.64\%$. The detector of his observations was an antimony-cesium photocathode without filters. He determined the θ_{IS} value by averaging of observed θ values for 7 early-type stars within a 5° circle centered on R Sct. According to him, there is a linear relationship between observed Q and U values. He attributed this relationship to a variation of intrinsic p values, with the intrinsic θ values remaining constant. He determined the interstellar p value by finding the point of intersection in the QU plane of the regression line for the above relationship and the line with the inclination of $2\theta_{IS}$ passing through the origin. His asumption seems to be more reliable than that by Serkowski (1970)[12], thus his values seem to be more reliable than those by Serkowski (1970)[12]. Our θ_{IS} and p_{IS} values are more close to those by Shakhovskoi (1964)[15] than those by Serkowski (1970)[12], though the p value by Shakhovskoi (1964)[15] is larger than our p_{IS} value by a factor of 1.4.

We obtained the intrinsic polarization by removing the interstellar polarization of our values. The p_* values show neither a conspicuous time dependence nor a conspicuous wavelength dependence. Most of their values are within the range from 0.7% to 0.9%, though the values on 1993 November 24/25 are slightly larger than those on 1996 April 4/5 by about 0.1%. Some of the data show a slight increase with wavelength as is exemplified in figure 12. The θ_* values show neither a conspicuous time dependence nor a conspicuous wavelength dependence. Most of their values are within range from 20° to 30°, as is also exemplified in figure 12. Contrary to the above results, the θ_* values obtained from the interstellar polarization by Serkowski (1970)[12] show a noticeable wavelength dependence (Yoshioka (1995)[16]).

3. Discussion

We obtained the intrinsic polarization for 4 stars, for which the intersteller

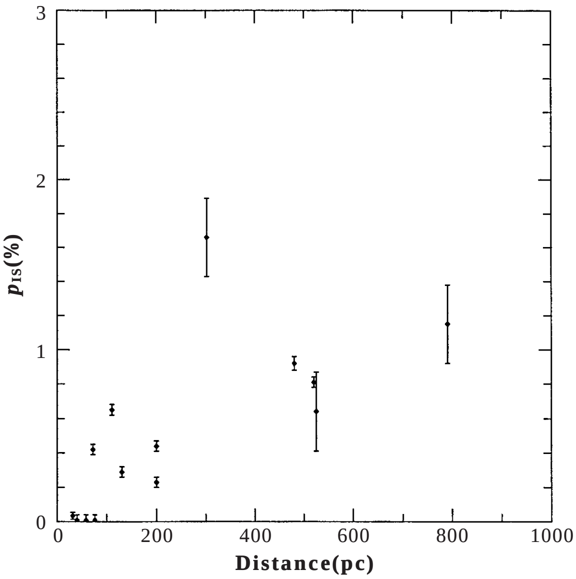

Fig.11. Dependence of the p_{IS}(B) values near R Sct on distance. All the data within 1000pc are plotted. This figure shows that the p_{max} value by Serkowski (1970)[12] is too high for the star with distance of 220pc.

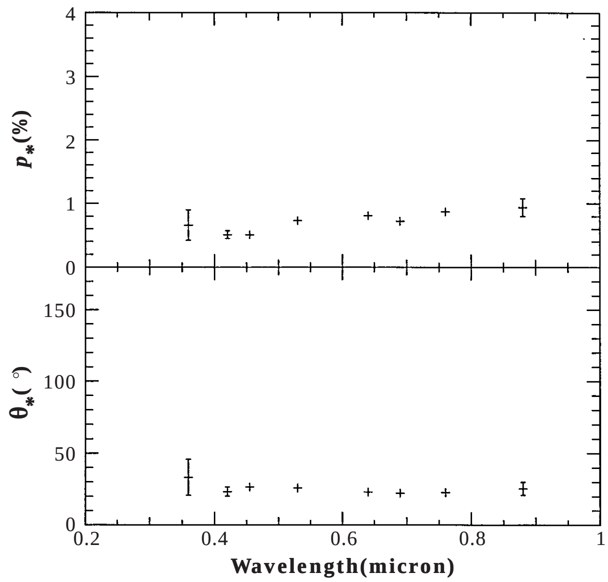

Fig.12. Wavelength dependence of the p_* and θ_* values of R Sct on 1996 April 4/5. The p_* values increase slightly with wavelength.

polarization had been determined by other observers. Generally speaking, our θ_{IS} values which were determined by the near-neighbor method from the ISPOL database are close to those determined by other observers, while in some cases our p_{max} values differ markedly from those by other observers. Thus, our θ_{IS} values seem to be reliable. As the numbers of data are relatively large and the scatters are relatively small for TW Cam and SS Gem, our p_{max} values for these stars seem to be reliable. The differences between our p_{max} values for these stars and those by Nook et al. (1990)[10] seem to be mainly due to the parameter used to estimate p_{max} values. As mentioned above, our selection of the parameter is more grounded than that by Nook et al. (1990)[10], so our p_{max} values seem to be more reliable. As the number of data are small and the scatters are large for U Mon and R Sct, the accuracy of our p_{max} values for these stars seem to be low. Nevertheless, as mentioned above, our p_{max} values seem to be more reliable than those by Serkowski (1970)[12].

Except for U Mon, our θ_* values do not show neither a noticeable time variation nor a noticeable wavelength dependence. The average of our θ_* values for U Mon show the time variation, but they do not show a noticeable wavelength dependence.

Except for U Mon, our p_* values do not show a conspicuous time variation. The average of our p_* values for U Mon show the time variation.

These results suggest that except for U Mon the geometrical arrangements of CDE of these stars do not change with time. For U Mon, the geometrical arrangement of CDE seem to change with the short-term and the long-term brightness variation. For TW Cam and R Sct the definite conclusion concerning the time variation cannot be drawn, because the observational errors are large and/or the observations were made at about the same magnitudes.

Our p_* values do not show a conspicuous wavelength dependence or show a slight 凸 type dependence. This result confirms the tendency for the observed p values of the stars belonging to the group A to show a 凸 type dependence.

The analysis are being made for the remaining 13 stars which include the stars belonging to the RVb group and to the group B and the group C.

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