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HBSでの偏光観測によるおうし座RV型星の長周期変動について

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Long-Term Periodic Variations in Polarization of RV Tauri Stars Observed with HBS

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ABSTRACT

The RV Tauri stars are semiregular variables whose light curves are characterized by alternate deep and shallow minima. On the basis of light curve the RV Tauri stars are divided into the RVa group and the RVb group. The RVb group is characterized by a long-term light variation superposed on pulsation period. The RVa group do not show such 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.

We newly made the spectropolarimetric observations of 4 bright RV Tauri stars, SS Gem, U Mon, CT Ori, and RV Tau, using 188cm reflector attached with the spectropolarimeter (HBS) at the Okayama Astrophysical Observatory of the National Astronomical Observatory in Japan. We determined intrinsic polarizations for these stars by removing interstellar polarizations and we obtained the following results about the wavelength dependence of intrinsic polarization.

1) There are three types of wavelength dependence of intrinsic polarization of SS Gem observed with HBS. These dependences seem to be due to the difference in phase of the formal period.
2) There are four types of wavelength dependence of intrinsic polarization of U Mon observed with HBS. These wavelength dependences seem to be due to the difference in phase of long-term light variation.
3) The wavelength dependence of CT Ori observed with HBS is the same as that observed with the multi-channel polarimeter (MCP). Therfore, the intrinsic polarization of CT Ori seems to be constant with time.
4) There are four types of wavelength dependence of intrinsic polarization of RV Tau observed with HBS. These wavelength dependences seem to be due to the difference in phase of long-term light variation, though this correlation between the wavelength dependence and the long-term phase observed with HBS is quite different from that observed with MCP.

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型が脈動周期に重なって長周期の光度変化を示すのに対して、RVa型はそのような長周期変化を示さない。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、岡山天体物理観測所の188cm反射望遠鏡に偏光分光測光装置（HBS）を取り付けて、明るい４個のおうし座RV型星の偏光分光観測を行った。そして、それぞれの星に対して星間偏光を差し引いて固有偏光を求め、固有偏光の波長依存性に関して次の結果を得た。

(1) HBSで求めたふたご座SS星の固有偏光の波長依存性には３つのタイプがある。それらは脈動変光の位相の違いによると思われる。
(2) HBSで求めたいっかくじゅう座U星の固有偏光の波長依存性には４つのタイプがある。それらは長周期光度変化の位相の違いによると思われる。
(3) HBSで求めたオリオン座CT星の固有偏光の波長依存性は、多色偏光測光装置（MCP）で求めた結果に等しい。したがって、オリオン座CT星の固有偏光は時間的に一定と思われる。

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(4) HBSで求めたおうし座座TV星の固有偏光の波長依存性には４つのタイプがある。それらは長周期光度変化の位相の違いによると思われる。ただし、MCPで求めた両者の相関関係とは異なっている。

Ⅰ. Introduction

The RV Tauri stars are semiregular variables which lie between the Cepheid and the Mira-type variables in the HR diagram. Their light curves are characterized by alternate 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.

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 curves, 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. The group B shows CH and CN bands near light minima 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 (1797)[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 radiation, 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) stars which left the AGB recently.

Their CDE's are thought to be formed as a result of mass loss at the final stage of the AGB phase (Jura (1986)[3]).

The author, together with Dr. 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 (hereafter referred to as MCP) attached to the 91cm reflector at the Dodaira Station of the National Astronomical Observatory. We obtained the intrinsic polarizations for all of the above 17 stars from the observed polarizations by removing the interstellar polarizations. The features of the intrinsic polarizations were reported in a series of papers by Yoshioka (Yoshioka (2000)[4], Yoshioka (2001)[5], Yoshioka (2002)[6], Yoshioka (2003)[7], and Yoshioka (2004)[8]).

We have been observing some of the above 17 RV Tauri stars with a spectropolarimeter, HBS (an abbreviation of "spectro-photo-polarimeter" in Japanese). The polarization observed already with HBS attached to the 91 reflector at the Dodaira Station of the National Astrophysical Oservatory in Japan (hereafter referred to as NAOJ) between 1998 March 10 and 2000 February 21 and attached to the 91cm reflector at the Okayama Astrophysical Observatory of NAOJ between 2001 April 19 and 2002 May 24 were reported by Yoshioka (2005)[9]. The intrinsic polarization above observed already with HBS were reported by Yoshioka (2007)[10]. We have newly observed some of the above 17 RV Tauri Stars with HBS. We report the observed and intrinsic polarizations observed newly with HBS in this paper.

Ⅱ. Observations

HBS measures linear polarization and flux in wavelength region between 400nm and 900nm. Its resolving power is in the range between 40 and 200. Although its resolving power is low, it can still measure the linear polarization of strong emission and absorption lines. The observational accuracy is estimated to be $[(p/50)^2+(0.05)^2]^{1/2}\%$, where p is the linear polarization degree in percent. The detailed description of HBS is described by Kawabata et al. (1999)[11].

The polarimetric observations with HBS reported in this paper were made between 2008 Nov 12 and 2009 Jan 19 at the Okayama Astrophysical Observatory of NAOJ. Reflector with 188m diameter was used .

Ⅲ. Results

In this paper, the intrinsic polarizations for four RV Tauri stars, SS Gem, U Mon, CT Ori, and RV Tau are reported. Data on these stars are listed in table 1. We obtained the intrinsic polarizations from the observed polarizations by removing the interstellar polarizations for each star. We adopted the empirical formula given by Whittet et al. (1992)[12] for a wavelength dependence of the degree of interstellar polarization p_{IS}, which is given as follows：

$$p_{IS}=p_{max}\cdot\exp[-K\ln^2(\lambda_{max}/\lambda)], \quad (1)$$

where p_{max} is the maximum degree of linear polar-

Table 1. Data on the RV Tauri Stars analyzed in this paper for Intrinsic Polarization. Periods are the formal period. The fifth column gives the classification in the General Catalogue of Variable Stars (Kholopov et al. 1985)[14]. The sixth column gives the classification on the basis of optical Spectra.

Star	α_{1950}	δ_{1950}	Period (day)	Variable Star Class	Optical Group
SS Gem	$06^h05^m32^s$	$+22°37'48''$	89.3	RVa	B
U Mon	$07^h28^m21^s$	$-09°40'24''$	92.3	RVb	A_1
CT Ori	$06^h07^m07^s$	$+09°52'30''$	135.5	RV	B
RV Tau	$04^h43^m58^s$	$+26°05'12''$	78.7	RVb	A_1

ization which occurs at the wavelength λ_{max}; K is a linear function of λ_{max};

$$K = 0.01 + 1.66\lambda_{max}. \quad (2)$$

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

$$Q_* = Q - p_{max} \cdot \exp[-K \ln^2(\lambda_{max}/\lambda)] \cdot \cos\theta_{IS} \quad (3)$$

$$\text{and } U_* = U - p_{max} \cdot \exp[-K \ln^2(\lambda_{max}/\lambda)] \cdot \sin\theta_{IS}, \quad (4)$$

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

$$p_* = \sqrt{Q_*^2 + U_*^2} \quad (5)$$

$$\text{and } \theta_* = 0.5 \cdot \tan^{-1}(U_*/Q_*). \quad (6)$$

The p_{max}, λ_{max}, and θ_{IS} values for the above stars are determined by Yoshioka (2000)[4] and Yoshioka (2001)[5] on the basis of near-neighbor method described by Bastien (1985)[14]. The details of the results are as follows.

a) SS Gem

SS Gem belongs to the RVa group and to the group A_2, according to Dawson (1979)[2]. According to Preston et al. (1963)[1], SS Gem may be related to the group B, because it shows strong CN bands and weak Ca II lines. Even Dawson (1979)[2] described that the DDO colors indicates that SS Gem may be a member of the group B. Furthermore, Gonzalez, Lambert, and Giridhar (1997)[13] claimed that SS Gem should be reclassified as the group B, because its spectra show numerous C I lines in the spectrum.

SS Gem had been already observed 5 times with HBS on 1999 Feb 4/5, 2000 Jan 20/21, 2000 Jan 21/22, 2000 Feb 18/19, and 2000 Feb 21/22. The intrinsic polarizations for the above dates had been obtained by removing the following interstellar polarization for SS Gem: $\theta_{IS} = 171°$, $p_{max} = 2.81\%$, and $\lambda_{max} = 0.57\mu m$, which values were obtained by Yoshioka (2000)[4]. There is a possibility that SS Gem does not have an appreciable CDE, because the estimated interstellar polarization above described is close to the following values which are determined on the assumption that SS Gem does not have an intrinsic polarization and the observed polarization is the interstellar polarization: $\theta_{IS} = 1°$, $p_{max} = 2.96\%$, and $\lambda_{max} = 0.5\mu m$ (Yoshioka (2000)[4]).

SS Gem was newly observed with HBS on 2009 Jan 17/18. The observed polarization on this date is shown in figure 1. The top panel of this figure shows the flux distribution in arbitrary unit. The dips near 6800Å and 7600Å seem to be due to the absorptions of O_2 band of terrestrial atmosphere and the slight dip near 7200Å seems to be mainly due to water vapor of terrestrial atmosphere. The middle and the bottom panels of this figure shows the p and θ values, respectively. The Q and U values on 2009 Jan 17/18 are shown in figure 2. The top panel of this figure

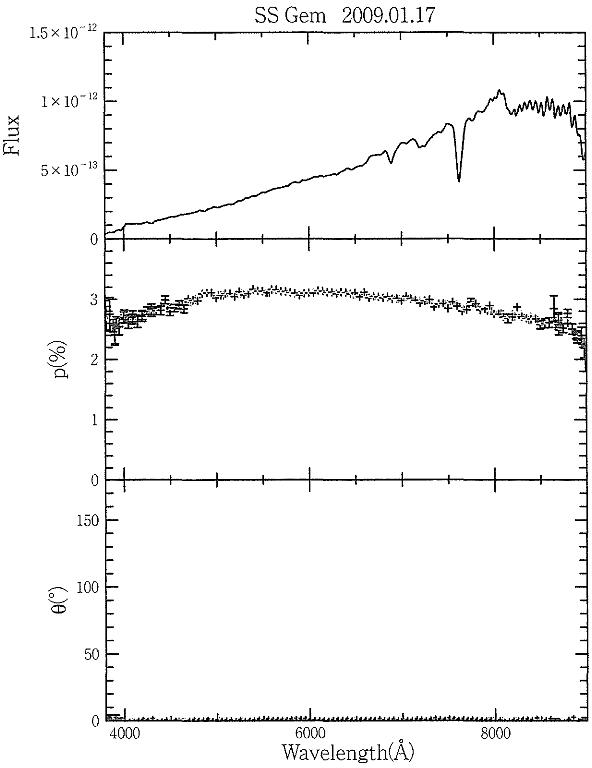

Fig 1. Wavelength dependence of the p and θ values of SS Gem on 2009 Jan 17/18.

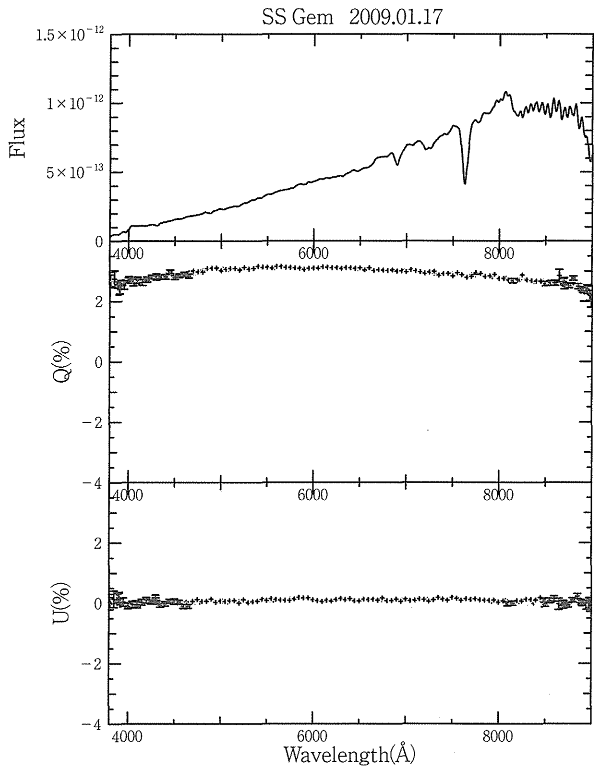

Fig 2. Wavelength dependence of the Q and U values of SS Gem on 2009 Jan 17/18.

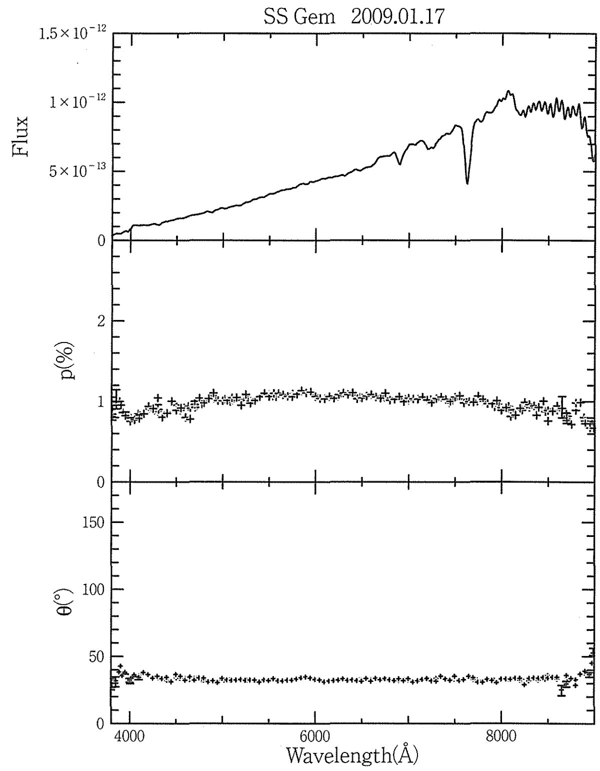

Fig 3. Wavelength dependence of the p_* and θ_* values of SS Gem on 2009 Jan 17/18.

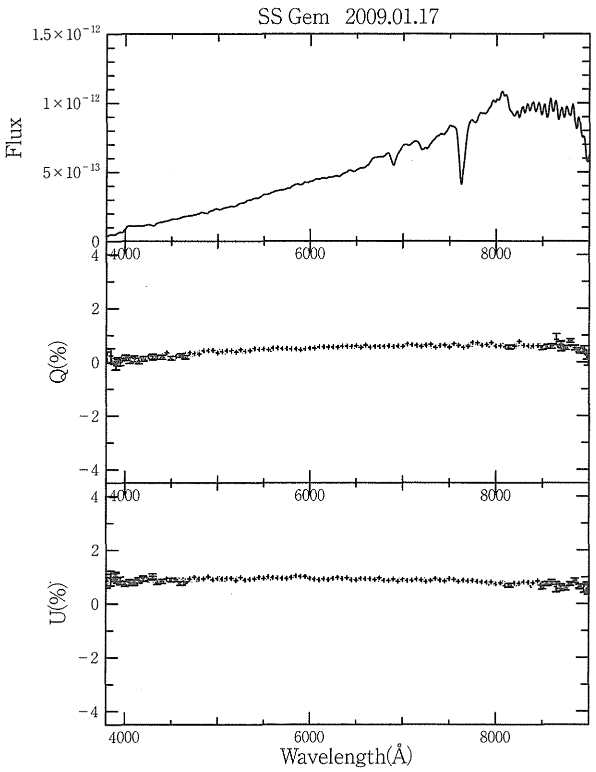

Fig 4. Wavelength dependence of the Q_* and U_* values of SS Gem on 2009 Jan 17/18.

shows the flux distribution, as in figure 1. The middle and the bottom panels of this figure shows the Q_* and U_* values, respectively.

The intrinsic polarization on 2009 Jan 17/18 are shown in figures 3 and 4. This intrinsic polarization is also obtained by removing the following interstellar polarization for SS Gem : $\theta_{IS}=171°$, $p_{max}=2.81\%$, and $\lambda_{max}=0.57\mu m$, which is the same that was used for removing the interstellar polarization for the observations before this date.

As is shown in figures 3 and 4, this observation reproduce the observations with HBS and MCP observed before this observation. For example, the observation with HBS on 2000 Jan 21/22 resembles this observation. The p_* values take values near 1% and they show slightly a wavelength dependence which takes a maximum at an intermediate wavelength (hereafter referred to as the 凸 type dependence). Most of the θ_* values are within the range from 30° to 40° and they decrease slightly with wavelength. Most of the Q_* values are slightly above 0%, and most of the U_* values are slightly below 1% and they do not show a noticeable wavelength dependence.

The intrinsic polarization on 2000 Feb 18/19 and on 1999 Feb 4/5 are shown in figures 5 and 6, respectively. As is shown in this figure, the p_* values decrease slightly with wavelength and the θ_* values increase

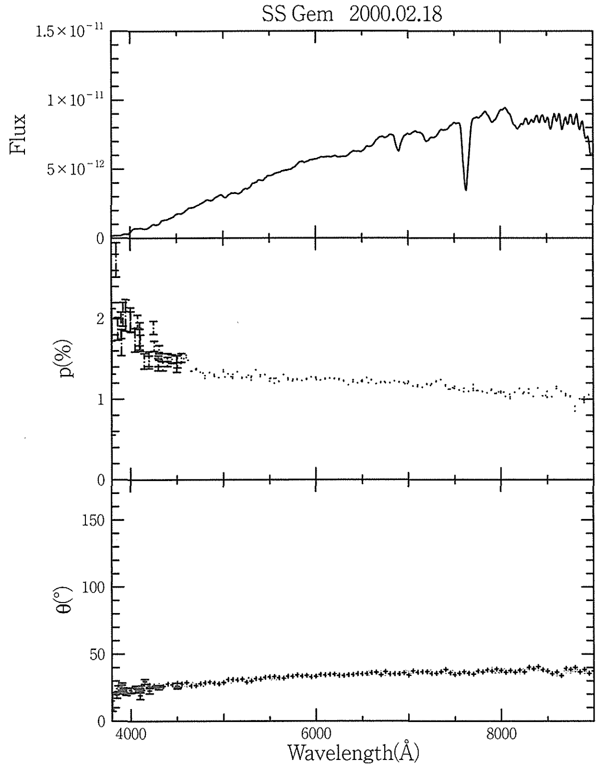

Fig 5. Wavelength dependence of the $p*$ and $\theta*$ values of SS Gem on 2000 Feb 18/19.

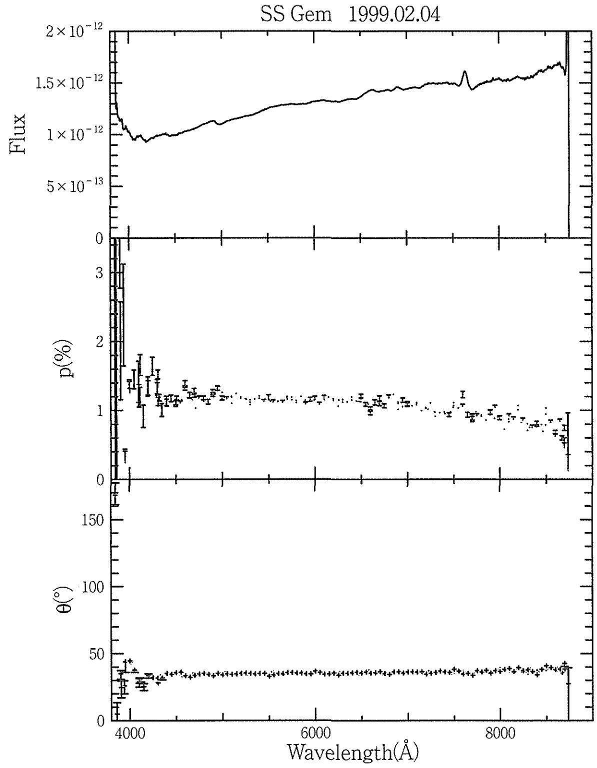

Fig 6. Wavelength dependence of the $p*$ and $\theta*$ values of SS Gem on 1999 Feb 4/5.

slightly with wavelength. On the other hand, the $p*$ values on 1999 Feb 4/5 are small, which are near 1%.

The above three types of observations with HBS observed before this observation were obtained at different phases. According to the visual light curves by the American Association of Variable Star Observers (hereafter referred to as AAVSO), the observations on 1999 Feb 4/5, 2000 Jan 18/19, and 2000 Feb 21/22 correspond to the phases from secondary light minimum to secondary light maximum, from secondary light maximum to primary light minimum, and near secondary light minimum, respectively. On the other hand, the observation on 2009 Jan 17/18 correspond to the phase from primary light maximum to secondary light minimum. These phase differ each other. Thus, the variation of intrinsic polarization seem to be due to the variation in phase.

b) U Mon

U Mon belongs to the RVb group and to the group A_1. U Mon was observed 13 times with HBS on 1998 Mar 10/11, 1999 Jan 4/5, 1999 Jan 7/8, 1999 Feb 1/2, 1999 Feb 6/7, 1999 Mar 1/2, 1999 Mar 3/4, 1999 Nov 29/30, 2000 Jan 21/22, 2001 Feb 21/22, 2001 Apr 19/20, 2001 Apr 22/23, and 2001 May 10/11. The intrinsic polarizations for the above dates were obtained by removing the following interstellar polarization: $\theta_{IS}=3°$, $p_{max}=0.77\%$, and $\lambda_{max}=0.5\mu m$, which values were obtained by Yoshioka (2000)[4].

U Mon was newly observed with HBS on 2009 Jan 14/15. The intrinsic polarization at this date are shown in figures 7 and 8. This intrinsic polarization is also obtained by removing the interstellar polarization which is the same that was used for removing the interstellar polarization for the observations before this date. As is shown in figure 7, The $p*$ values decrease slightly with wavelength from 1.2% to 0.8% and the $\theta*$ values do not show a noticeable wavelength dependence. Most of the $\theta*$ values are within the range from 10° to 20°. This type of wavelength dependence was not detected by the observations with HBS before this date.

The observation on 1999 Jan 4/5 is shown in figure 9, As is shown in this figure, the $p*$ values increase with wavelength from about 0.6% to about 1.4%. On the other hand, the $\theta*$ values do not show a noticeable wavelength dependence. Most of the values are within the range between 170° to 10°. This type of wavelength dependence often is seen in our MCP observations, especially at darkening phase. According to the visual light curve by AAVSO, the observation on 1999 Jan 4/5 corresponds to the phase near the secondary light maximum. The observation on 1999 Feb 1/2 is shown in figure 10. As is shown in this figure, the $p*$

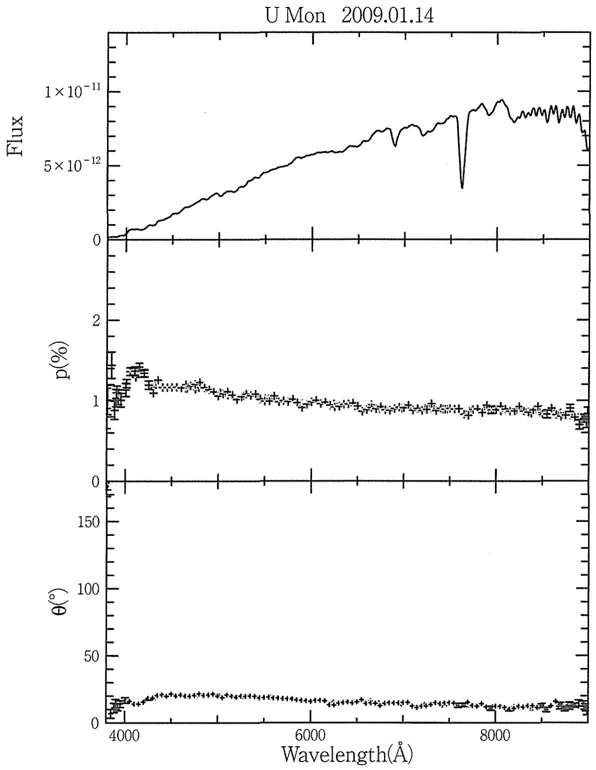

Fig 7. Wavelength dependence of the p_* and θ_* values of U Mon on 2009 Jan 14/15.

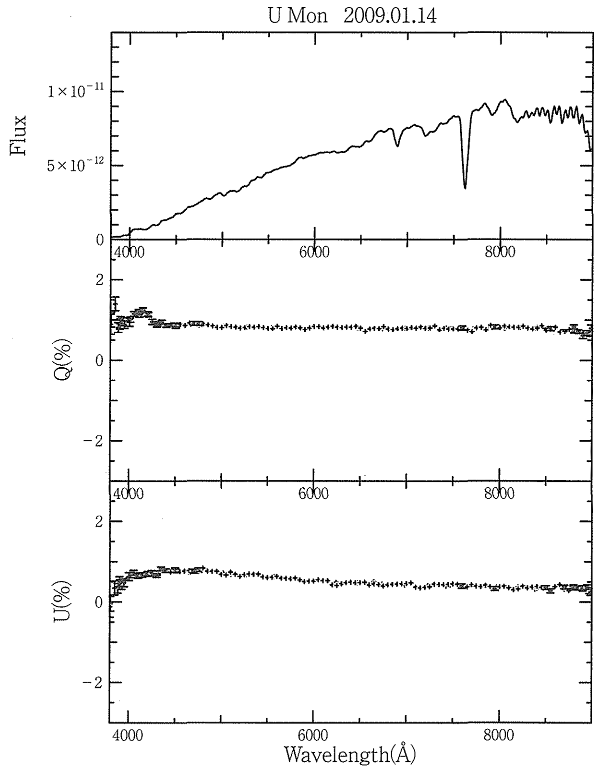

Fig 8. Wavelength dependence of the Q_* and U_* values of U Mon on 2009 Jan 14/15.

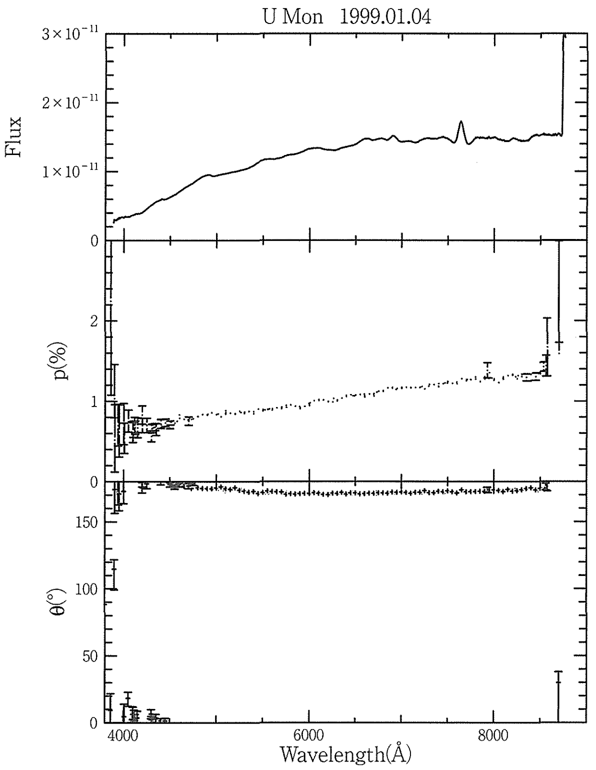

Fig 9. Wavelength dependence of the p_* and θ_* values of U Mon on 1999 Jan 4/5.

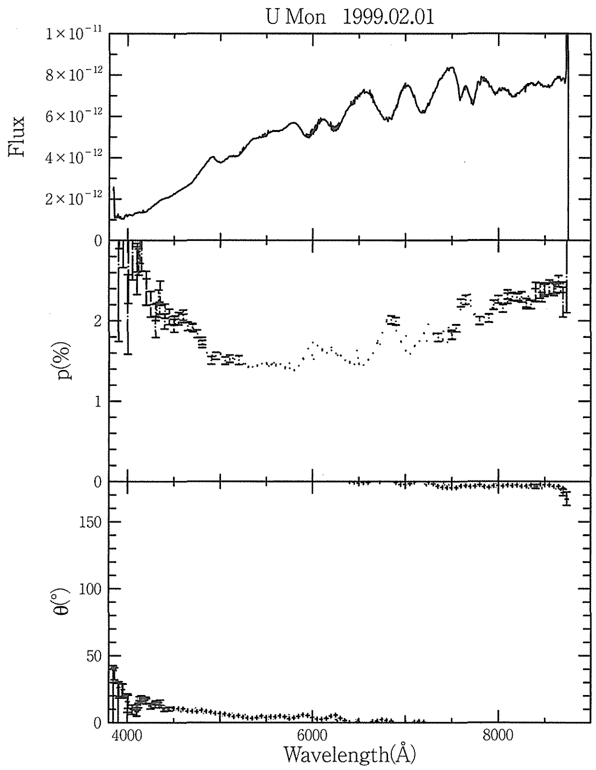

Fig 10. Wavelength dependence of the p_* and θ_* values of U Mon on 1999 Feb 1/2.

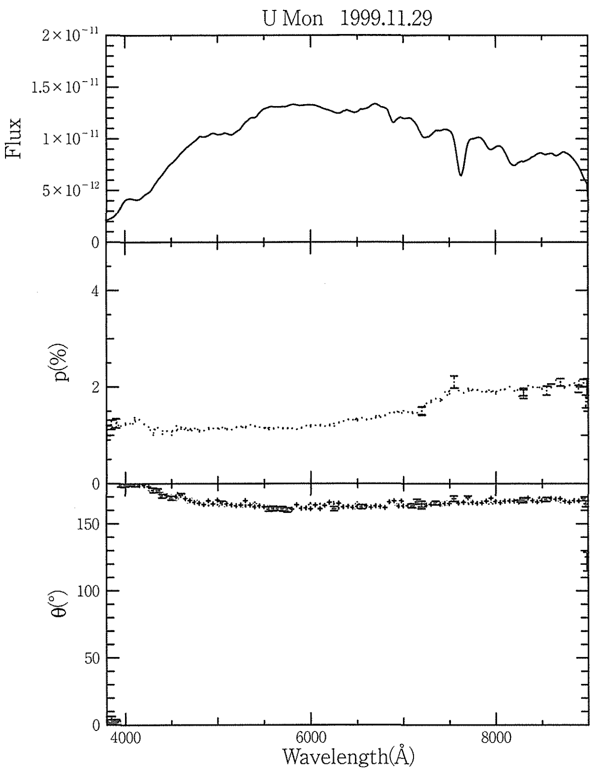

Fig 11. Wavelength dependence of the p_* and θ_* values of U Mon on 1999 Nov 29/30.

values show several humps and dips, and the humps exist at the wavelength of the dips of the flux. These humps and dips are also seen for the θ_* values. This type of wavelength dependence is also seen on some other observations. This type of dependence does not correlate with the phase. For example, according to the visual light curve by AAVSO, the observation on 1999 Feb 1/2 corresponds to the phase near the primary light minimum, while the other observations with this wavelength dependence also shows the other type of wavelength dependence. The observation on 1999 Nov 29/30 is shown in figure 11. As is shown in this figure, the p_* values in the wavelength range shorter than about 6500Å are lower than those longer than about 7500Å by about 0.8%, and increase from about 6500Å to about 7500Å. On the other hand, the θ_* values do not show a noticeable wavelength dependence. The phase on 1999 Nov 29/30 corresponds to that between the secondary light minimum and the secondary light maximum. The similar wavelength dependence also is seen for the observation on 2000 Jan 21/22, while the phase of this observation corresponds to that between the secondary light maximum and the primary light minimum. Thus, this wavelength dependence either does not correlate with the phase of the formal period. The newly detected wavelength dependence, i. e., the dependence in figure 7 was observed during the phase between the secondary light maximum and the primary light minimum, whose phase is similar to that of 2000 Jan 21/22.

On the other hand, the phases of long-term light variation for different types of wavelength dependence differ one another. For example, the observation on 1999 Jan 4/5 corresponds to the phase slightly after light minimum and the observation on 1999 Feb 1/2 corresponds to brightening phase. The observation on 1999 Nov 29/30 corresponds to the phase slightly before the light maximum, while the latest observation on 2009 Jan 14/15 corresponds to the phase slightly after light maximum or darkening phase. Therefore, the wavelength dependence may correlate with the phase of the long-term light variation.

c) CT Ori

CT Ori belongs to the group B. According to the General Catalogue of Variable Stars (Kholopov et al. (1985)[14]), this star is not definitely classified as RV Tauri stars. Actually, according to Dawson (1979)[2], the mean DDO colors suggest CT Ori is a giant, and the formal period of this star is rather large (135.5days). On the other hand, according to the abundance analysis by Gonzalez et al. (1997)[13], CT Ori shows the experienced fractionation process that has preferentially depleted their atmospheres of elements with high condensation temperatures, which is typical for the group B.

CT Ori was observed with MCP 8 times on 1994 Oct 19-20, 1994 Dec 21/22, 1994 Dec 24/25, 1995 Jan 19/20, 1995 Feb 16/17, 1995 Dec 12/13, 1996 Nov 25/26, and 1997 Feb 26/27.

This star was observed for the first time with HBS on 2009 Jan 19/20. According to the visual light curve by AAVSO, the observation on this date seems to correspond to the phase slightly before the primary light minimum, though it is ambiguous due to the lack in the data of photometric observation. The intrinsic polarizations for this dates were obtained by removing the following interstellar polarization : $\theta_{IS} = 176°$, $p_{max} = 0.73\%$, and $\lambda_{max} = 0.5\mu m$, which values were obtained by Yoshioka (2000)[7]. The intrinsic polarization correspond to the phase near the primary light maximum and to that slightly before the secondary light minimum. U Mon at this date are shown in figure 12. As is shown in this figure, the observational uncertainty is large. But, except for both ends, the p_* values show the 凸 type wavelength dependence and the θ_* values are near 150°. This type of wavelength dependence also were shown by the observations with MCP with relatively high observational accuracy. In particular, the θ_* values with middle channels

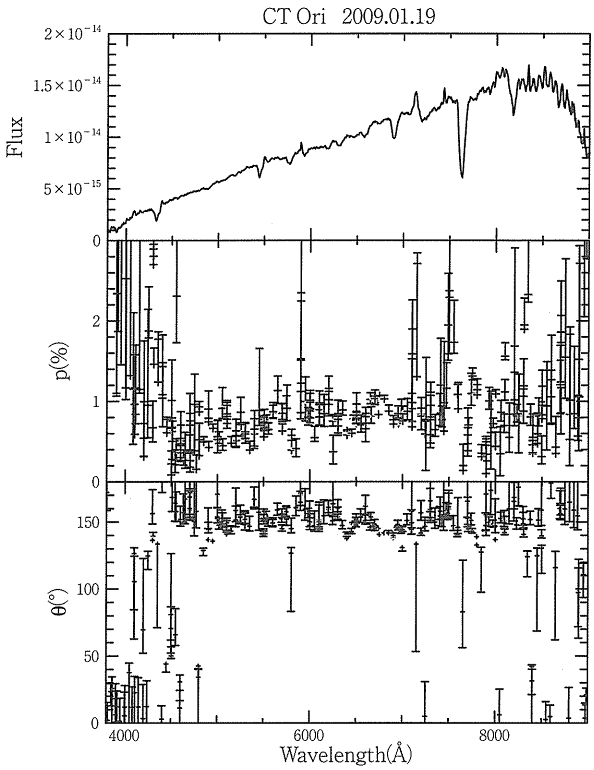

Fig 12. Wavelength dependence of the p_* and θ_* values of CT Ori on 2009 Nov 19/20.

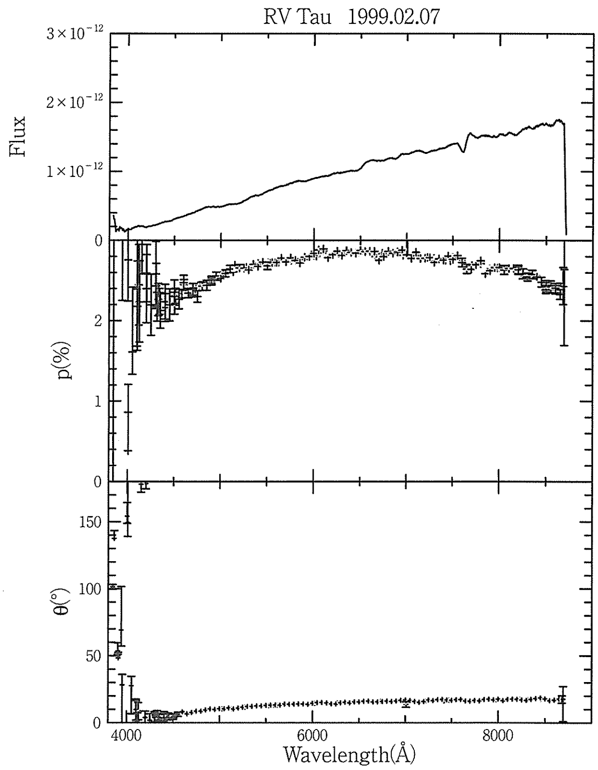

Fig 13. Wavelength dependence of the p_* and θ_* values of RV Tau on 1999 Feb 7/8.

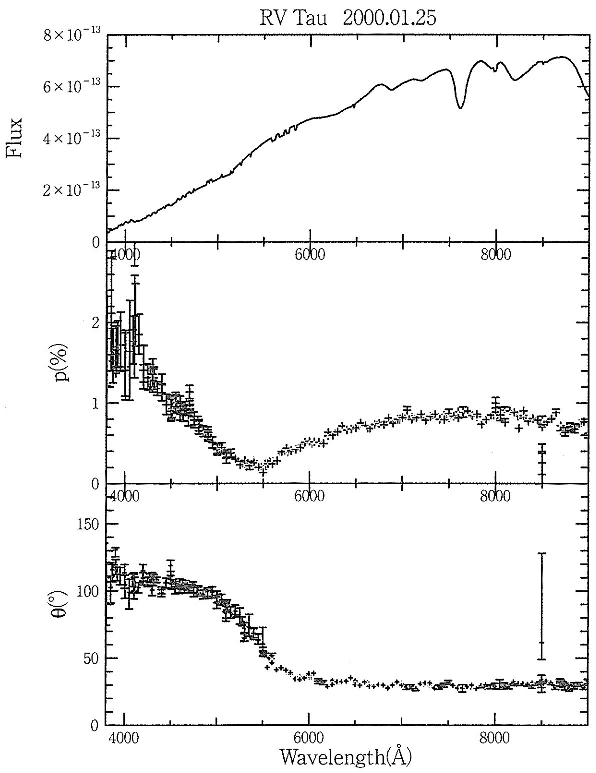

Fig 14. Wavelength dependence of the p_* and θ_* values of RV Tau on 2000 Jan 25/26.

are nearly constant with phase about 150°. Therefore, the observation on 2009 Jan 19/20 indicates that the intrinsic polarization of CT Ori is constant with time.

d) RV Tau

RV Tau belongs to the RVb group and to the group A_1. Six observations with HBS were made for RV Tau on 1999 Jan 5/6, 1999 Feb 7/8, 1999 Nov 28/29, 1999 Nov 30/Dec 1, 2000 Jan 23/24, and 2000 Jan 25/26. The intrinsic polarizations for the above dates were obtained by removing the following interstellar polarization : $\theta_{IS}=63°$, $p_{max}=0.45\%$, and $\lambda_{max}=0.5\mu m$, which values were obtained by Yoshioka (2001)[5].

The intrinsic polarizations obtained above have values within the range of those obtained with MPC.

The observations with HBS show three types of wavelength dependence. The first type is shown in figure 13, which was observed on 1999 Feb 7/8. As is shown in this figure, the p_* values show the 凸 type dependence, while the θ_* values do not show a noticeable wavelength dependence and they are in the range between 10° and 20°. The second type is shown in figure 14, which was observed on 2000 Jan 25/26. This figure shows that the p_* values with wavelength shorter than about 5500Å decrease with wavelength and those with wavelength longer than about 5500Å show slightly the 凸 type dependence. This figure also

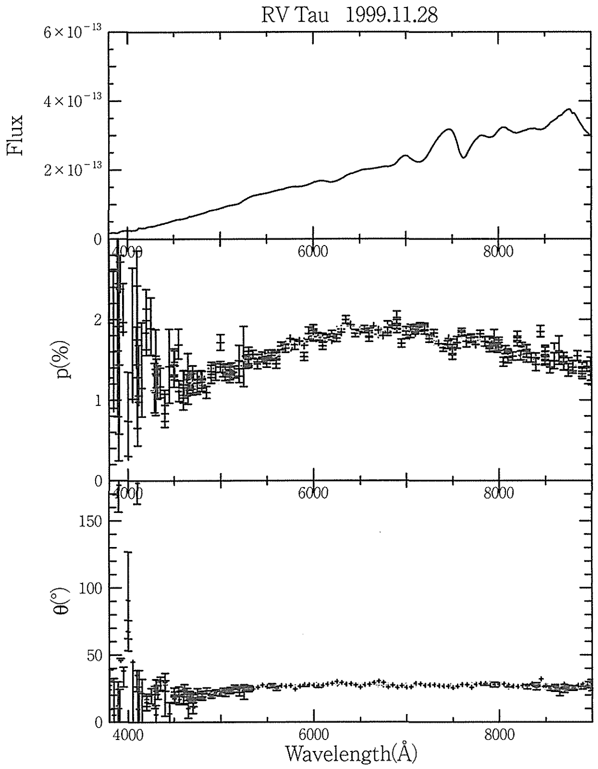

Fig 15. Wavelength dependence of the p_* and θ_* values of RV Tau on 1999 Nov 28/29.

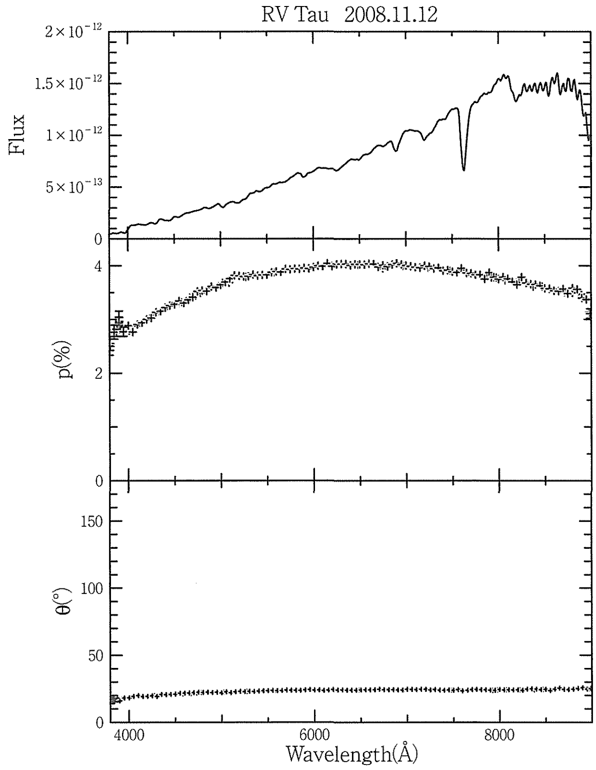

Fig 16. Wavelength dependence of the p_* and θ_* values of RV Tau on 2008 Nov 12/13.

shows that the θ_* values with wavelength shorter than about 5500Å decrease with wavelength from about 110° to about 30°, which dependence resembles that for R Sct observed by Landstreet and Angel (1977)[16]. The third type is shown in figure 15, which was observed on 1999 Nov 28/29. As is shown in this figure, the wavelength dependence for this date seems to indicate the transition from the first type to the second type. According to the visual light curve by AAVSO, these types do not correlate with the phase of the formal period. This difference seems to correlate with the phase of the long-term brightness variation. The long-term phase from 1999 Jan 5/6 to 1999 Feb 7/8 is a darkening one, while that from 2000 Jan 23/24 to 2000 Jan 25/26 is a brightening one. On the other hand, the long-term phase from 1999 Nov 28/29 to 1999 Nov 30/December 1 is a minimum one.

However, this correlation between the wavelength dependence and the long-term phase observed with HBS is quite different from that observed with MCP. According to the observations with MPC, the p_* values decrease with wavelength when they were observed during darkening phase of long-term light variation, and the p_* values show the 凸 type dependence at other phases.

RV Tau was newly observed with HBS on 2008 Nov 12/13 and 2009 Jan 15/16. The intrinsic polarization at these dates are shown in figures 16 and 17. These intrinsic polarization are also obtained by removing the interstellar polarization which is the same that was used for removing the interstellar polarization for the observations before this date. As are shown in these figures, the p_* values show the 凸 type wavelength dependence and the θ_* values do not show a noticeable wavelength dependence. Most of the θ_* values are within the range from 10° to 30°. This type of wavelength dependence is the same as that was observed with HBS from 1999 Jan 5/6 to 1999 Feb 7/8, though the p_* values are larger than those on 1999 Jan and 5/6 to 1999 Feb 7/8 by about 1%. According to the visual light curve by AAVSO, the observation on 2008 Nov 12/13 corresponds to the brightening phase from the primary light minimum to the primary light maximum, and the observation on 2009 Jan 15/16 corresponds to the phase slightly before the primary light minimum. Both observations correspond to phase of long-term light variation of the immediately after light maximum. These new observations also indicate that the wavelength dependence correlate with the phase of the long-term brightness variation.

This correlation is consistent also with the observations with MCP. The variations of Q_* and U_* with the phase of long-term light variation observed with MCP are similar qualitatively to those observed with HBS.

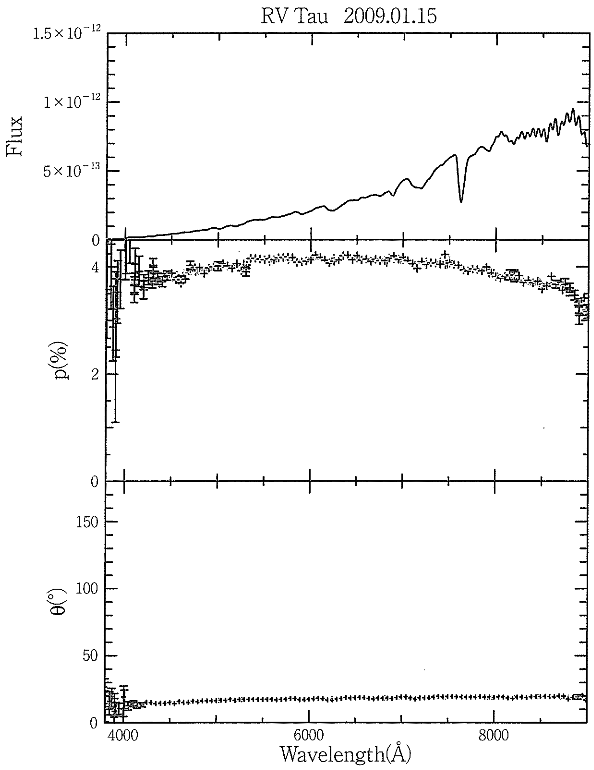

Fig 17. Wavelength dependence of the p_* and θ_* values of RV Tau on 2009 Jan 15/16.

Ⅳ. Summary

We newly made the spectropolarimetric observations with HBS for the bright RV Tauri stars, SS Gem, U Mon, CT Ori, and RV Tau, and obtained the intrinsic polarization by removing the interstellar polarization. We obtained the following information on the wavelength dependence

1) There are three types of wavelength dependence of intrinsic polarization of SS Gem observed with HBS. These dependences seem to be due to the difference in phase of the formal period.
2) There are four types of wavelength dependence of intrinsic polarization of U Mon observed with HBS. These dependences do not correlate with the phase of formal period. These types of dependence were observed at different phases of long-term light variation. Therefore, these wavelength dependences seem to be due to the difference in phase of long-term light variation.
3) Except for both ends of wavelength where the observational uncertainty is large, the p_* values of CT Ori show the 凸 type wavelength dependence and the θ_* values are near 150°. This type of wavelength dependence also were shown by the observations with MCP. Therfore, it seems that the intrinsic polarization of CT Ori is constant with time.
4) There are four types of wavelength dependence of intrinsic polarization of RV Tau observed with HBS. These dependences do not correlate with the phase of formal period. These types of dependence were observed at different phases of long-term light variation. Therefore, these wavelength dependences seem to be due to the difference in phase of long-term light variation. This correlation is consistent also with the observations with MCP.

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