おうし座RV型星のHBS（偏光分光測光装置）による偏光観測と その一般的な特徴

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Polarimetric Observations of the RV Tauri Stars with HBS (Hennko Bunnko Sokkosochi) and their General Features

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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が特徴の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、国立天文台の堂平観測観測所と岡山天体物理観測所の91cm反射望遠鏡に偏光分光装置（HBS）を取り付けて、明るい５個のおうし座RV型星の偏光分光観測を行った。そして次の結果を得た。

(1) ふたご座SS星といっかくじゅう座U星とおうし座RV星では、偏光度の波長依存性に時間変動が見られる。とくにふたご座SS星の時間変動は、この星には星周圏ダスト層がないとの、われわれのMCP観測から得られた結果を覆す。

(2) 上記の時間変動の多くには脈動の位相との相関が見られないが、長周期光度変化と相関がありそうな星がある。

(3) いっかくじゅう座U星のいくつかの観測では、その偏光度にいくつかの波長でピークが見られ、ピークの波長が放射の吸収帯に一致している。この結果を確認するために、さらなる観測を要する。

(4) おうし座RV星以外では、偏光位置角に波長依存性は見られない。おうし座RV星では、長周期光度変化の増光期に5500Å付近よりも短波長域で偏光位置角が波長とともに減少している。この波長依存性は、たて座R星の過去の偏光分光観測で観測されたものと似ている。

ABSTRACT

　The RV Tauri stars are semiregular variables whose light curves are characterized by alternate deep and shallow minima. On the basis of the 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 does not show such a long-term variation. On the basis of spectroscopic characteristics in 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 made the spectropolarimetric observations of 5 bright RV Tauri stars, using 91cm reflectors attached with the spectropolarimeter (HBS) at the Dodaira Station and the Okayama Astrophysical Observatory of the National Astronomical Observatory in Japan. We obtained the following results : (1) SS Gem, U Mon, and RV Tau show the time variation of the wavelength dependence of polarization. Especially, the time variation for SS Gem overrules the conclusion obtained by our observations with MCP that SS Gem does not have a circumstellar dust envelope ; (2) Many of the above variations do not correlate with the phase of pulsation, and for some stars the above variation may correlate with the phase of the long-term light variation ; (3) Some observations of U Mon show that the p values have several peaks and the wavelength of the peaks coincide with those of the dips in flux distributuions. Further observations are needed to confirm this result ; (4) Except for RV Tau, the observed θ values do not show a noticeable wavelength dependence. For RV Tau at the brightening phase of long-term light variation, the θ values with wavelength shorter than about 5500Å decrease with wavelength, whose dependence resembles that for R Sct obtained before by spectropolarimetrical observation.

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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 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 are reported in a series of papers by Yoshioka (Yoshioka (2000)[4], Yoshioka (2001)[5], Yoshioka (2002)[6], Yoshioka (2003)[7], and Yoshioka

(2004)[8]). General features are summarized as follows.

1) Both of the group A and the group B stars show various types of wavelength dependence of the degree of intrinsic polarization p_*. Some of p_* values take a maximum at an intermediate wavelength (hereafter referred to as the 凸 type dependence), and some of p_* values take a minimum at an intermediate wavelength (hereafter referred to as the 凹 type dependence). Some of p_* values increase with wavelength and some of p_* values decrease with wavelength. Some of the stars show different wavelength dependence at different phases. But, except for CT Ori, the group B star do not show the 凸 type dependence. On the other hand, the only C group star observed by us, V360 Cyg, does not show a noticeable wavelength dependence.

2) Generally speaking, the position angle of intrinsic polarization θ_* does not show a notable wavelength dependence. In case they show a wavelength dependence, there is a tendency that the p_* values also show a wavelength dependence.

2) The p_* values do not always take larger values at light minima. But there is a tendency that the p_* values take a maximum or a minimum values at primary light minima and that the p_* values show a wavelength dependence at primary light minima which is different from that at the other phase. They especially tend to decrease with wavelength at primary light minima.

We interpreted the above features as follows.

1) The intrinsic polarizations of the RV Tauri stars are caused by the scattering in CDE and the feature indicates that the intrinsic polarization changes according to a phase change in CDE. The time variation in the wavelength dependence of p_* values indicates the change in the size distribution of the grain of CDE. Especially, the 凹 type dependence indicates that there are two CDE's which have different grain size distributions, and that the p_* values have two peaks in the wavelength distribution and the p_* values have a minimum between the two peaks. The group B stars have a tendency to take the 凹 type dependence and, except CT Ori, most group B stars do not show the 凸 type dependence. Thus, the group B stars seem to have a tendency to have two CDE's with different gain size distributions. Concerning CT Ori, the only B group star which show the 凸 type dependence of p_* values, the formal period is rather large (135.5 days) and this star is not definitely classified as RV Tauri star in the General Catalogue of Variable Stars (Kholopov et al. (1985)[9]). Furthermore, according to Dawson (1979)[2], the mean CCD colors suggest that CT Ori is a giant star, and according to Momiyama (2003)[10], the spectra of CT Ori

indicate that this star is a subgiant or a dwarf star. Thus there is a possibility that none of the B group stars show the 凸 type dependence of p_* values, and that all the B type stars have more than two CDE's.

2) The feature 2) indicates that generally CDE's do not change in a geometrical arrangement. Furthermore, it indicates that the wavelength dependence of θ_* values is caused by the variation in the size distribution of grain.

3) The feature 3) indicates that the variation of intrinsic polarization is caused by the variation in the radiation from the photosphere or by that the variation of CDE's is linked with the brightness variation.

We have been observing some of the above 17 RV Tauri stars with a spectropolarimeter, HBS (an abbreviation of "spectro-photo-polarimeter" in Japanese) in order to elucidate the right or wrong of the above interpretations. We report the results obtained so far 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 1998 March 10 and 2000 February 21 at the Dodaira Station of the National Astronomical Observatory in Japan (hereafter referred to as NAOJ) and between 2001 April 19 and 2002 May 24 at the Okayama Astrophysical Observatory of NAOJ. Reflectors with 91m diameter were used at both of the observatories.

Ⅲ．Results

In this paper, the results are reported for five RV Tauri stars, SS Gem, AC Her, U Mon, R Sct, and RV Tau. Data on these stars are listed in **table 1**. 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 CaⅡ 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 $(1997)^{12)}$ claimed that SS Gem should be reclassified as the group B, because its spectra show numerous C I lines in the spectrum.

SS Gem was observed 10 times with MCP. MCP measure linear polarizations simultaneously at eight wavelengths (at eight channels) of 0.36, 0.42, 0.455, 0.53, 0.64, 0.69, 0.76, and 0.88 μm. SS Gem does not show significant time variation at most wavelengths. The θ values at most channels are within the range from $-2°$ to $3°$ and they do not show a noticeable wavelength dependence. The p values at most channels are within the range from 2.7% to 3.1% and they do not show a noticeable wavelength dependence, though they sometimes show slightly the 凸 type dependence. On the other hand, the p values of the intrinsic polarization for the observations with small observational errors, which were obtained by removing the interstellar polarization, do not show a noticeable wavelength dependence or they decrease rather with wavelength. The interstellar polarizations were estimated on the basis of the near-neighbor

Table 1. Data on the RV Tauri Stars analyzed in this paper.
Periods are the formal period. The fifth column gives the classification in the General Catalogue of Variable Stars (Kholopov et al. 1985)[9]. The sixth column gives the classification on the basis of optical Spectra.

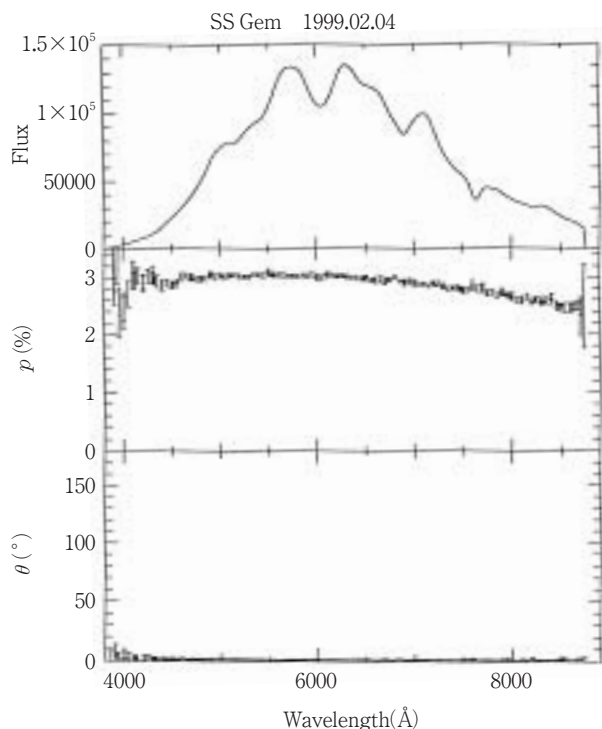| Star	α_{1950}	δ_{1950}	Period (day)	Variable Star	Optical Class Group
SS Gem	$06^h05^m32^s$	$+22°37'48''$	89.3	RVa	B
AC Her	$18^h29^m48^s$	$+21°51'30''$	75.5	RVa	B
U Mon	$07^h28^m21^s$	$-09°40'24''$	92.3	RVb	A_1
R Sct	$18^h44^m43^s$	$-05°45'36''$	140.2	RVa	A_1
RV Tau	$04^h43^m58^s$	$+26°05'12''$	78.7	RVb	A_1

SS Gem   1999.02.04

Fig.1 Wavelength dependence of the observed p and θ values of SS Gem on 1999 February 4/5.
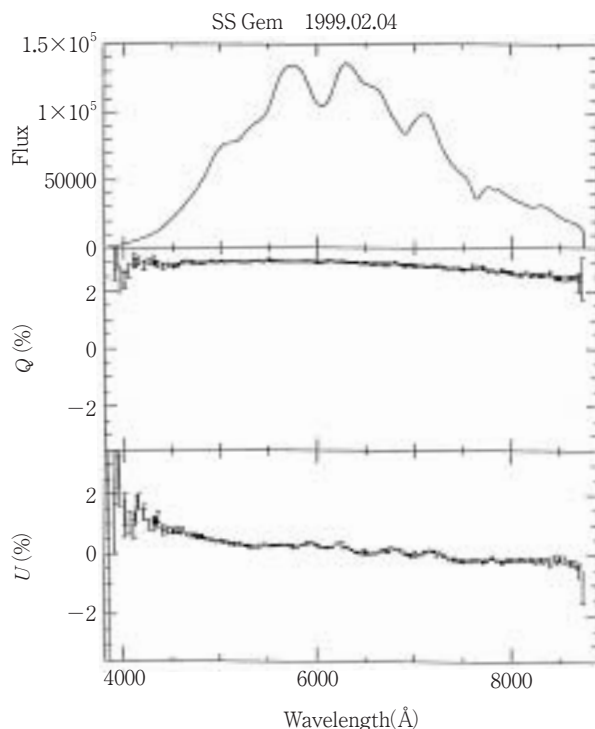
Fig.2 Wavelength dependence of the observed Q and U values of SS Gem on 1999 February 4/5.

method described by Bastien (1985)[13]. The estimated values are ; $\theta_{IS}=171°$, $p_{max}=2.81\%$, and $\lambda_{max}=0.57\mu m$, where θ_{IS} is the position angle of interstellar polarization and p_{max} is the maximum degree of linear polarization which occurs at the wavelength λ_{max}. 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]).

Five observations were made for SS Gem on 1999 February 4/5, 2000 January 20/21, 2000 January 21/22, 2000 February 18/19, and 2000 February 21/22.

The observation on 1999 February 4/5 is shown in **figure 1.** The top panel of this figure shows the flux distribution in arbitrary unit. The small dips near 5050Å and 5200Å seem to be mainly due to the absorptions of metallic lines such as Fe. On the other hand, 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 shorter side of the dip between 5800Å and 6300Å seems to be mainly due to the D lines of Na and the longer side seems to be mainly due to metallic lines such as Fe

and due to O_2 band of terrestrial atmosphere. As is shown in figure 1, most of our observations with HBS reproduce the observations with MCP, and the p values show slightly the 凸 type dependence. The observed values on 1999 February 4/5 of the normalized Stokes parameters Q and U are shown in **figure 2**. As is shown in the middle panel of this figure, the Q values also show slightly the 凸 type dependence, whose dependence is typical of our observations with HBS. As is shown in the bottom panel of figure 2, the U values show many maxima or minima and these maxima or minima seem to correspond to the dips of the flux distribution in figure 2. However, the U values on the other observations do not show these maxima or minima. According to a visual light curve by the American Association of Variable Star Observers (hereafter referred to as AAVSO), the observation on 1999 February 4/5 corresponds to the phase from the secondary light minimum to the secondary light maximum, which is different from those for the other observations. Thus, these maxima or minima may appear only at this phase. **Figure 3** shows the observation on 2000 February 18/19. As is shown in the middle panel of this figure, the p values decrease with wavelength. According to a visual light curve by AAVSO, the observation on 2000 February 18/19 corresponds to the phase from the secondary light maximum to the
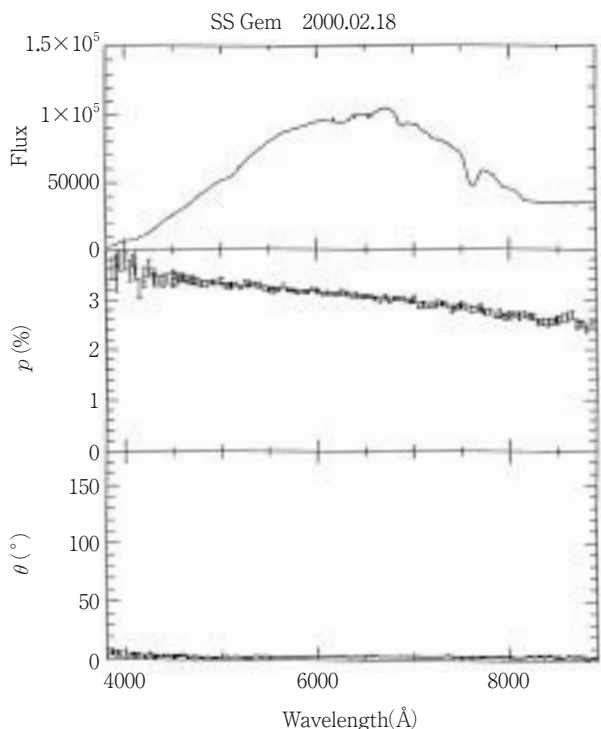
Fig.3 Wavelength dependence of the observed p and θ values of SS Gem on 2000 February 18/19.
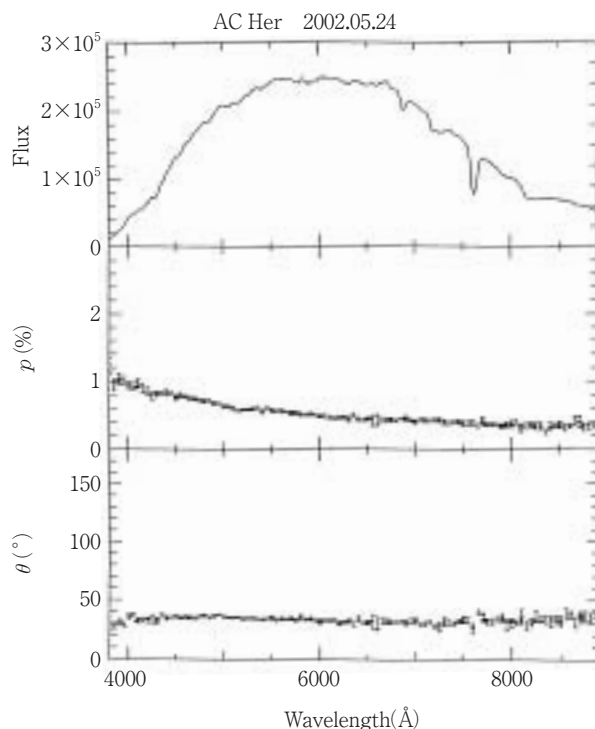
Fig.4 Wavelength dependence of the observed p and θ values of AC Her on 2002 May 24/25.

primary light minimum. However, the observation on 2000 February 21/22 which was made at nearly the same phase as that on 2000 February 18/19 do not show such a wavelength dependence and the p values show slightly the 凸 type dependence. Thus, the variation in the wavelength dependence is not due to the variation in phase. We need to do further observations in order to confirm the above wavelength dependence.

b）AC Her

AC Her belongs to the RVa group and to the group B. AC Her was observed 11 times with MCP. According to these observations, the observed polarization of AC Her shows the time variation with the formal period of 75.5days and there is a tendency for the observed p values to show the 凹 type dependence, which dependence becomes prominent near light minimum (Yoshioka (1997)[14]). Other observers also observed the time variation. Especially, Henson et al. (1985)[15] and Nook et al. (1990)[16] detected the time variation with the formal period. Yoshioka (2001)[5] detected also the variation of the observed polarization with about the orbital period of 1194days which was found by Winckel et al. (1998)[17].

Five observations were made for AC Her on 2001 April 22/23, 2001 May 10/11, 2001 May 12/13, 2002 May 23/24, and 2002 May 24/25.

The observation on 2002 May 24/25 is shown in **figure 4**, which is typical of our observations with HBS. As is shown in this figure, the observed values are within the range of those values observed with MCP. As is shown in figure 4, the p values decrease with wavelength, especially in the wavelength region which is shorter than about 6000Å. The Q and U values also decrease slightly with wavelength. These wavelength dependences are typical of our observations with HBS. According to the visual light curve by AAVSO, the observation on 2002 May 24/25 corresponds to the phase near the primary light maximum. On the other hand, the observation on 2001 April 22/23 which shows the above wavelength dependences corresponds to the phase shortly before the primary light minimum. Thus, our HBS observations indicate that the above wavelength dependence exists irrespective of the phase of light curve. Our MCP observations are not inconsistent with the above indication, because for the observations with MCP which show the 凸 type dependence the observational errors of p values in the longer wavelength are rather large.

As is shown in figure 4, the θ values do not show a noticeable wavelength dependence, which is observed on the other observations with HBS. On the other hand, the θ values observed with MCP often increase with the decrease of wavelength in the wavelength
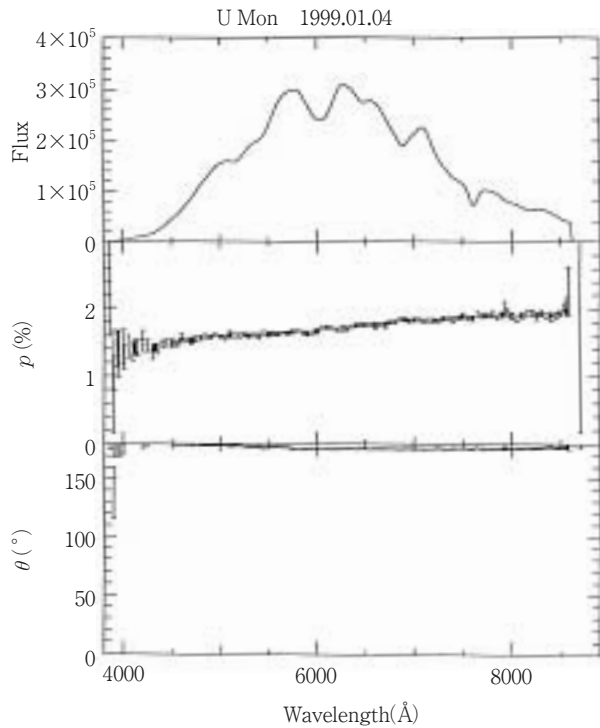
Fig.5 Wavelength dependence of the observed p and θ values of U Mon on 1999 January 4/5.

Fig.6 Wavelength dependence of the observed p and θ values of U Mon on 1999 February 1/2.

range which is shorter than about 5500Å. The reason of the above difference between the observations with HBS and those with MCP is not yet understood.

c) U Mon

U Mon belongs to the RVb group and to the group A_1. U Mon was observed 20 times with MCP. According to these observations, the observed p values sometimes show slightly the 凸 type dependence, while the observed θ values do not show a noticeable wavelength dependence. The observed polarization shows the time variation with the formal period. Moreover, the observed polarization also shows the long-term variation with the period which is close to the long-term brightness period of 2475days (Percy et al. (1991)[18]).

Thirteen observations were made for U Mon on 1998 March 10/11, 1999 January 4/5, 1999 January 7/8, 1999 February 1/2, 1999 February 6/7, 1999 March1/2,and1999 March 3/4, 1999 November 29/30, 2000 January 21/22, 2001 February 21/22, 2001 April 19/20, 2001 April 22/23, and 2001 May 10/11.

The observation on 1999 January 4/5 is shown in **figure 5**, which is typical of our observations with HBS. As is shown in this figure, the observed values are within the range of those values observed with MCP. As is shown in this figure, the p values increase with wavelength and the Q values slightly increase
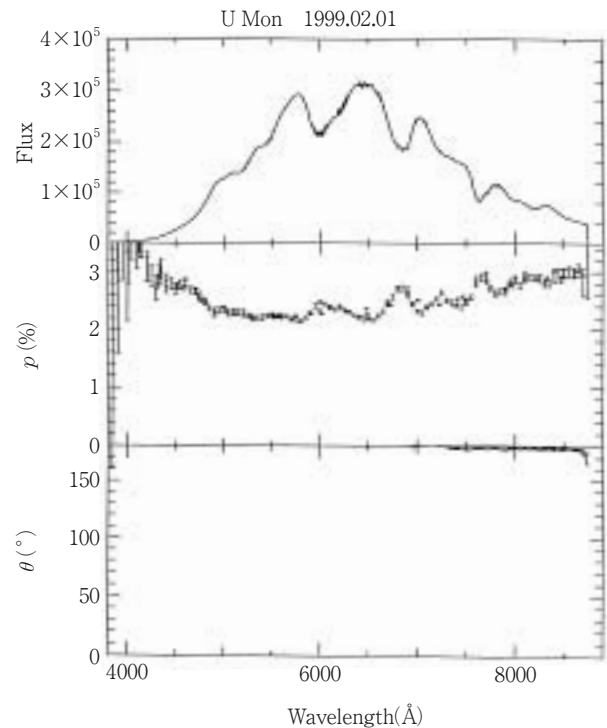
with wavelength. This wavelength dependence often is seen in our MCP observations, especially at darkening phase. According to the visual light curve by AAVSO, the observation on 1999 January 4/5 corresponds to the phase near the secondary light maximum. The observation on 1999 February 1/2 is shown in **figure 6** and **7**. As is shown in figure 6, the p values show several humps and dips, and the humps exist at the wavelength of the dips of the flux. As is shown in **figure 7**, these humps and dips are also seen for the Q and U values. This wavelength dependence is also seen on some other observations. This dependence does not correlate with the phase. For example, according to the visual light curve by AAVSO, the observation on 1999 February 1/2 corresponds to the phase near the primary light minimum, while the observations with this wavelength dependence correspond to the phase near the primary light maximum and to that slightly before the secondary light minimum. U Mon also shows another wavelength dependence. The observation on 1999 November 29/30 is shown in **figure 8**. As is shon in figure 8, the p values in the wavelength range shorter than about 6500Å are lower than those longer than about 7500Å by about 0.8%, and the p values increase from about 6500Å to about 7500Å. The phase on 1999 November 29/30 corresponds to that between the secondary light minimum and the secondary light maximum. The

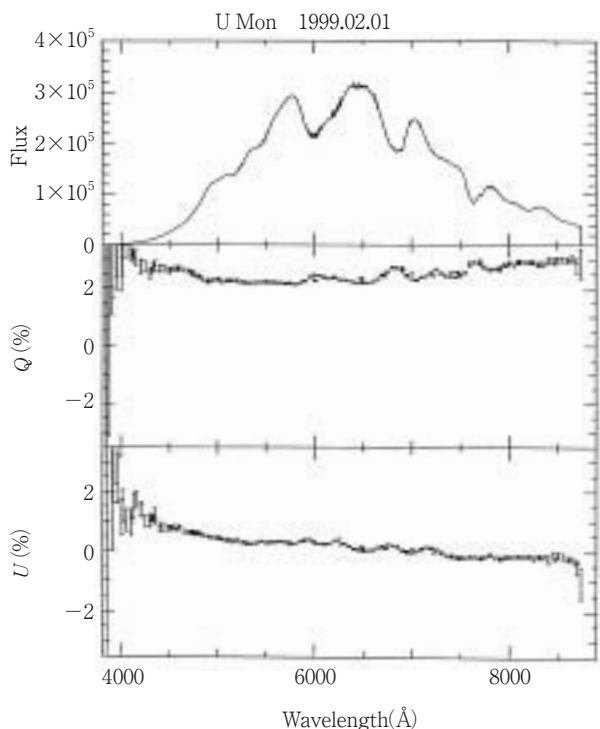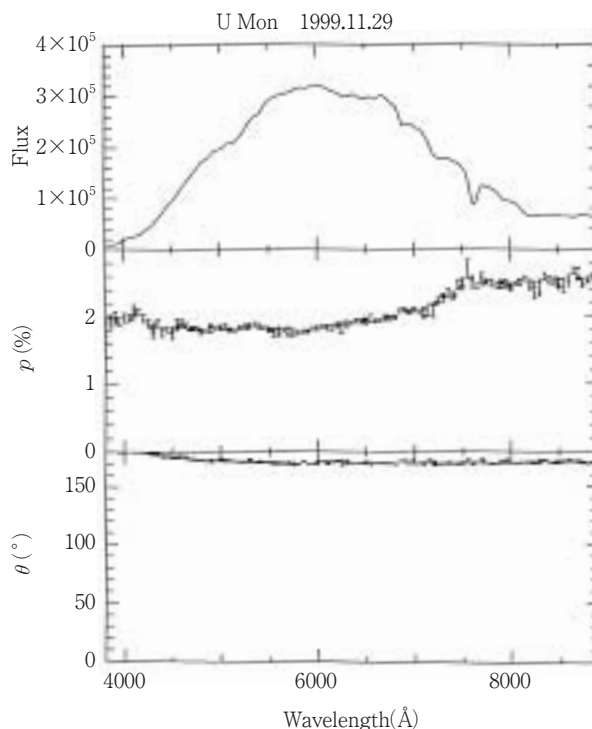**Fig.7** Wavelength dependence of the observed Q and U values of U Mon on 1999 February 1/2.

Fig.8 Wavelength dependence of the observed p and θ values of U Mon on 1999 November 29/30.

similar wavelength dependence also is seen for the observation on 2000 January 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. This wavelength dependence was observed during brightening period of the long-term light variation. Thus, this dependence may correlate with the phase of the long-term light variation.

d） R Sct

R Sct belongs to the RVa group and to the group A_1. R Sct was observed 3 times with MCP. According to these observations, the observed p and θ values show neither a noticeable time variation nor a noticeable wavelength dependence.

R Sct was observed only one time on 2001 May 13/14. This observation is shown in **figure 9**. As is shown in figure 9, the p values decrease with wavelength by about 0.5％, while the θ values do not show a noticeable wavelength dependence. The Q values decrease with wavelength by about 0.25％, while the U values do not show a noticeable wavelength dependence. These values are within the range of those values with MCP, but the wavelength dependence for HBS is different from that for MCP. The p and Q values observed with MCP rather
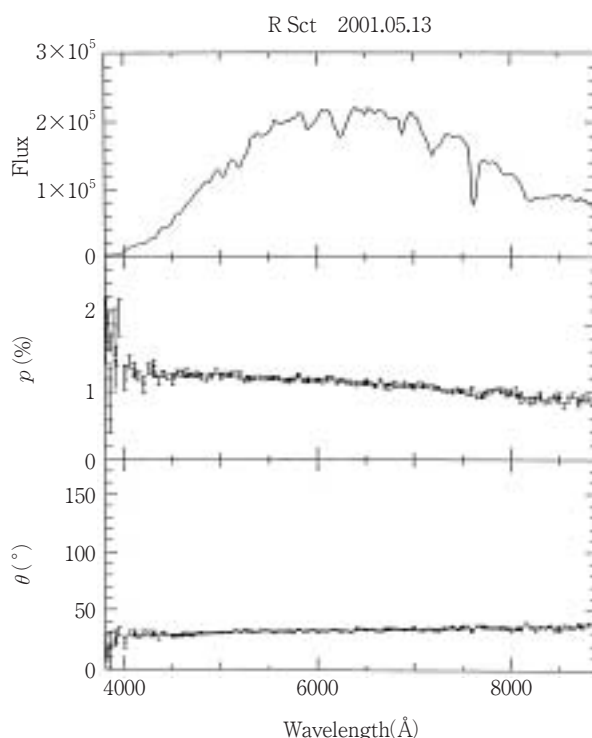

Fig.9 Wavelength dependence of the observed p and θ values of R Sct on 2001 May 13/14.

increase slightly with wavelength than decrease with wavelength. According to the visual light curve by AAVSO, the observation on 2001 May 13/14
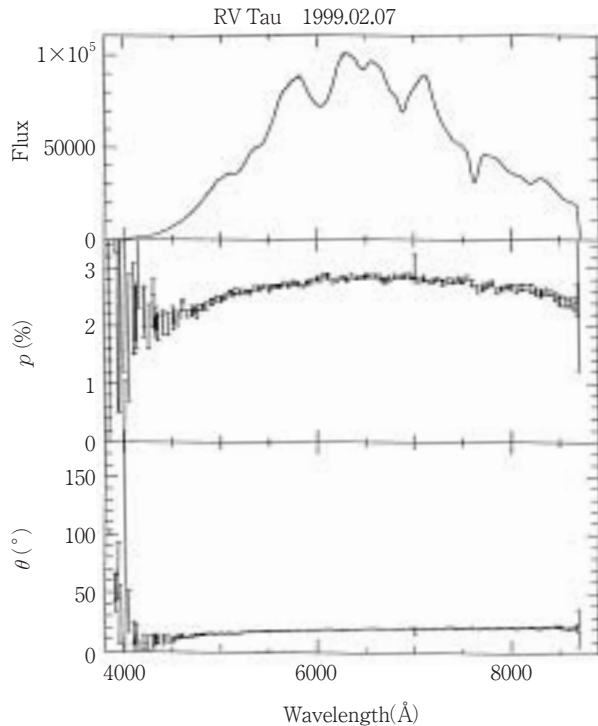
RV Tau 1999.02.07

Fig.10 Wavelength dependence of the observed p and θ values of RV Tau on 1999 February 7/8.

RV Tau 2000.01.25

Fig.11 Wavelength dependence of the observed p and θ values of RV Tau on 2000 January 25/26.

corresponds to the phase slightly before the primary light maximum. The phases for the three observation with MCP are different from that with HBS and they are darkening phases. Thus, this difference in wavelength dependence may correlate with the phases.

According to Landstreet and Angel (1977)[19], who observed R Sct spectropolarimetrically with resolution between 20Å and 40Å at the phase of 0.46, the p values have a slight peak near 6000Å and for the wavelength lower than about 5500Å the θ values decrease with wavelength from about 80° to lower than 40°. These wavelength dependences, especially that for the θ values, is not seen for our HBS and MCP observations.

e ） RV Tau

RV Tau belongs to the RVb group and to the group A₁. RV Tau was observed 19 times with MCP. According to these observations, the observed polarization shows the conspicuous long-term variation with the period which is close to the long-term brightness period of 1224days, though the time variation with the formal period is not conspicuous (Yoshioka (1998)[20]). The data points in the QU plane turn clockwise round a trajectory which is nearly described as circle of radius of about 2.5%. The wavelength dependence of p values varies according
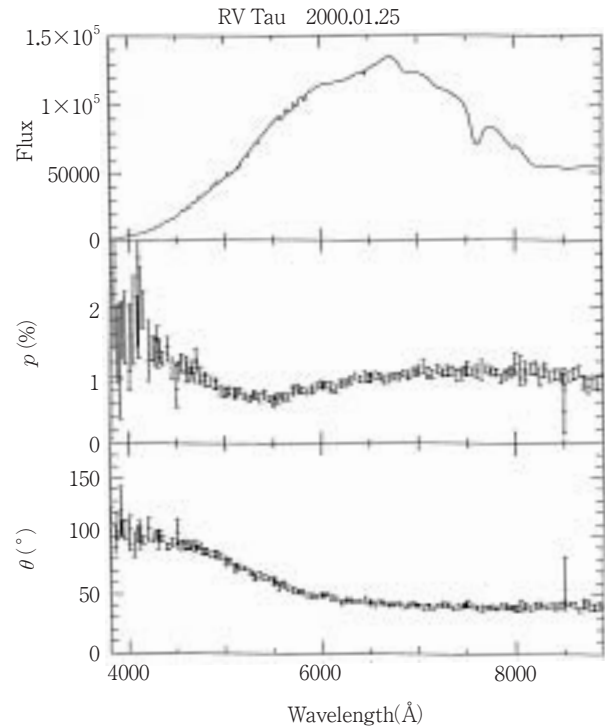
to the position in the QU plane. The p values decrease with wavelength, when the Q values are positive and the U values are negative. This term corresponds to the phase in the long-term brightness variation during darkening or slightly before minimum. The p values do not show such a wavelength dependence during the other term. Six observations were made for RV Tau on 1999 January 5/6, 1999 Februay 7/8, 1999 November 28/29, 1999 November 30/December 1, 2000 January 23/24, and 2000 January 25/26. The observed values are within the range of those values with MCP.

The observation on 1999 February 7/8 is shown in **figure 10**. 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. According to the visual light curve by AAVSO, the observation on this day corresponds to the phase slightly before the secondary light maximum. The observations from 1999 January 5/6 to 1999 February 7/8 show a similar wavelength dependence, where various phases are included. On the other hand, the observations from 2000 January 23/24 to 2000 January 25/26 show the wavelength dependence different from the above one, as is shown in **figure 11**. 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 shows that the θ values
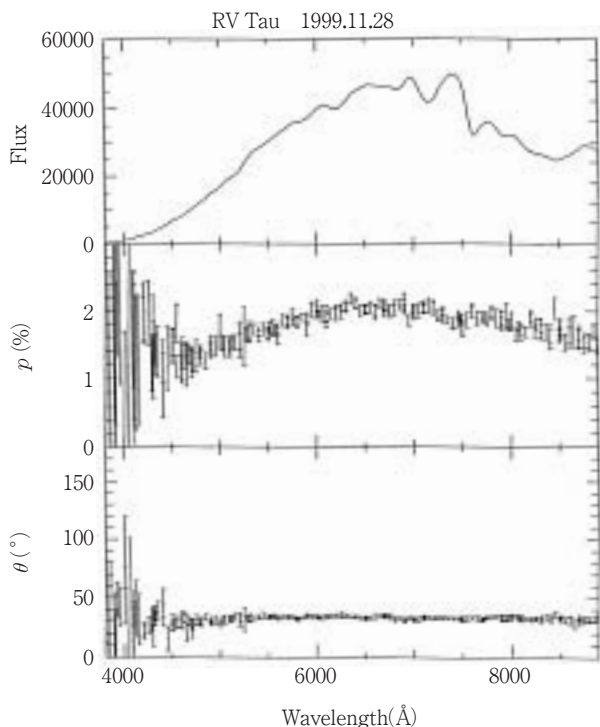
Fig.12 Wavelength dependence of the observed p and θ values of RV Tau on 1999 November 28/29.

with wavelength shorter than about 5500Å decrease with wavelength from about $100°$ to about $40°$, which dependence resembles that for R Sct observed by Landstreet and Angel (1977)[19]. The observation of figure 10 corresponds to the phase near the secondary light maximum. This phase is similar to that for figure 11. Thus, the difference in wavelength dependence 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 January 5/6 to 1999 February 7/8 is a darkening one, while that from 2000 January 23/24 to 2000 January 25/26 is a brightening one. On the other hand, the long-term phase from 1999 November 28/29 to 1999 November 30/December 1 is a minimum one and the wavelength dependence for this phase seems to indicate the transition from that for darkening phase to that for brightening phase, as is shown in **figure 12**. However, the correlation between the wavelength dependence and the long-term phase observed with HBS is quite different from that observed with MCP, which is above described.

Ⅳ．Summary

We made the spectropolarimetric observations with HBS for the bright RV Tauri stars, SS Gem, AC Her, U Mon, R Sct, and RV Tau, and obtained the following results.

1）The observed values are within the range of those values observed with MCP.

2）The observed p values for SS Gem show the variation in the wavelength dependence, which indicates that SS Gem has CDE. The p values show two types of wavelength dependence, which do not correlate with the phase of light curve. SS Gem at the phase from a secondary light minimum to a secondary light maximum shows several humps and dips in the distribution of U value over wavelength. The observed p values for AC Her decrease with wavelength, especially in the region shorter than about 6000Å, which dependence exsits irrespective of the phase of light curve. This wavelength dependence is not inconsistent with the 凹 type dependence which is often observed with MCP.

3）The observed p values for U Mon show three types of wavelength dependence, which do not correlate with the phase of formal period. For one type, the p values, together with the Q and U values, show several humps and dips and the humps exist at the wavelength of dips in the flux distribution. For another type, the p values in the wavelength range shorter than about 6500Å are lower than those longer than about 7500Å, which dependence may correlate with the phase of the long-term light variation.

4）The observed p values for R Sct decrease with wavelength, which dependence had not been observed with our MCP observations and may correlate with the phase of formal period.

5）The observed p values for RV Tau show three types of wavelength dependence, which seem to correlate with the phase of long-term wavelength dependence, though the correlation observed with HBS is quite different from that observed with MCP.

6）Except for RV Tau, the observed θ values do not show a noticeable wavelength dependence. For RV Tau at the brightening phase of long-term light variation, the θ values with wavelength shorter than about 5500Å decrease with wavelength, which dependence resembles that for R Sct observed by Landstreet and Angel (1977)[19].

Further observations are necessary to elucidate the above wavelength dependence. We are now obtaining the intrinsic polarization from the observed polarization for the above stars by removing interstellar polarizations.

References

1) Preston, G.W., Krzeminski, W., Smak, J., and Williams, J. A. 1963, *The Astrophysical Journal*, Vol.137, 401.

2) Dawson, D. 1979, *The Astrophysical Journal, Supple.*, Vol.41, 97.

3) Jura, M. 1986, *The Astrophysical Journal*, Vol.309, 732.

4) Yoshioka, K. 2000, *Journal of the University of the Air*, No.18, 133.

5) Yoshioka, K. 2001, *Journal of the University of the Air*, No.19, 95.

6) Yoshioka, K. 2002, *Journal of the University of the Air*, No.20, 95.

7) Yoshioka, K. 2003, *Journal of the University of the Air*, No.21, 237.

8) Yoshioka, K. 2004, *Journal of the University of the Air*, No.22, 111.

9) Kholpov, P.P., Samus, N.N., Erolov, M.S., Goranskij, V.P., Gorynya, N.A., Kukarkina, N.P., Kurochkin, N.E., Medvedeva, G.I., Perova, N.B., and Shugarov, S.Yu. 1985, General Catalogue of Variable Stars, 4th ed. (Nauka Publishing House, Moscow).

10) Momiyama, T. in his master's thesis.

11) Kawabata, Koji S., Okazaki, A,. Akitaya, H., Hirakata, N., Hirata, R., Ikeda, Y., Kondoh, M., Masuda, S., and Seki, M. 1999, *Publications of the Astronomical Society of the Pacific*, Vol.111, 898.

12) Gonzalez, G., Lambert, D.L., and Giridhar, S. 1997, *The Astrophysical Journal*, Vol.481, 452.

13) Bastien, P. 1985, *The Astrophysical Journal, Supple.*, Vol.59, 277.

14) Yoshioka, K. 1997, *Journal of the University of the Air*, No.15, 71.

15) Henson, C.D. Kemp, J.C., and Kraus, D.J. 1985, *Publications of the Astronomical Society of the Pacific*, Vol.98,1192.

16) Nook, M.A., Cardelli, J.A., and Nordsieck, N. 1990, *The Astronomical Journal*, Vol.100, 2004

17) Winckel, H.V., Waelkens, C., Waters, L.B.F.M., Molster, F.J., Udry, S., and Bakker, E.J. 1998, *Astronomy and Astrophysics*, Vol.336, L.17.

18) Percy, J.R., Sasselov, D.D., Alfred, A., and Scott, G. 1991, *The Astrophysical Journal*, Vol.375, 691.

19) Landstreet, J.D., and Angel, J.R.P. 1977, *The Astrophysical Journal*, Vol.211, 825.

20) Yoshioka, K. 1998, *Journal of the University of the Air*, No.16, 211.