PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
103: 1176–1181, November 1991

LAMBDA PERSEI: AN UNUSUAL B9 IV STAR

ANNE B. UNDERHILL[1]

Department of Geophysics and Astronomy, University of British Columbia, Vancouver, BC V6T 1Z4, Canada

Received 1991 July 29, revised 1991 August 21

ABSTRACT

Spectrograms of λ Per obtained at 30 Å mm^{-1} in the red region show weak emission peaks in the core of the Hα absorption line. The *V/R* for the emission components changed from about 1.0 on 1990 October 28 UT to less than 1.0 on 1990 October 29 UT. The midpoints of absorption lines from He I, Si II, Fe II, and the midpoints of the Hα profile measured at residual intensities between 0.80 and 0.96 are shifted slightly shortward of the wavelengths suggested by the catalog radial velocities of λ Per and by the wavelength of the sharp central absorption core of Hα. It is plausible that the emission features originate in plage areas on the surface of λ Per and that the aspect of the plages presented to the observer changes as the star rotates. Plages imply the presence of surface magnetic fields.

Similar spectra were obtained for ζ Aql and κ And; these are stars having about the same spectral type as λ Per. The Hα line is entirely in absorption in these stars. The measured radial velocities for these stars are slightly more negative than the catalog values for these stars. The catalog radial velocities for all three stars depend heavily on the perceived wavelengths of Hβ, Hγ, and Hδ. The radial velocity of ζ Aql changed by a small amount during the 1990 observing season.

Key words: emission-line star-B star

1. Introduction

During a program to obtain 30 Å mm^{-1} spectra of Of stars in the red region, spectra of ζ Aquilae, κ Andromedae, and λ Persei were obtained to be used as standard spectra for minimizing the extraneous absorption lines due to O_2 and H_2O in the Earth's atmosphere. It was a surprise to find that in the case of λ Per emission components were present in the core of Hα. The purpose of this paper is to present these observations and to draw attention to the facts (1) that λ Per is a Be star and (2) that in October 1990 the *V/R* changed in about 24 hours from near equality to less than 1. It is unusual for Hα to be in emission in a B9-A0 main-sequence star. It is even more unusual for the *V/R* to change by a readily detected amount in 24 hours. The present observations may indicate that Hα-emitting plages occur on the surface of λ Per and that the configuration facing the observer changes as the star rotates.

Catalog information about ζ Aql, κ And, and λ Per is given in Table 1. The spectral type listed for λ Per in Table 1 is from the present spectrograms. The spectrum of λ Per, except for the emission at Hα, is very similar to the spectrum of κ And. That star is generally recognized to be a B9 IVn star (Hoffleit & Jaschek 1982). According to Jaschek, Conde & de Sierra (1964) λ Per is a B9 V star, ζ Aql has been classified as A0 V, B9.5 V, and B9 V, while types A0 IV and B8 V are reported for κ And. Gray & Garrison (1990) give A0 IIIn for λ Per and A0 V*a*nn for ζ Aql; they do not classify κ And. I prefer the type B9 for λ Per and κ And because the He I line at 6678.15 Å is present in each spectrum at about the same low intensity. This He I line is not evident in the spectrum of ζ Aql.

The radial velocities given in Table 1 are unweighted means of the results listed by Abt & Biggs (1972) from different observatories. They are based on photographic spectra obtained in the blue-violet region with a variety of spectrographs. No account has been taken of possible systematic differences between the radial velocities determined at the separate observatories.

Assuming that the catalog results are equivalent measurements of the same thing, the dispersions about the catalog results for λ Per, ζ Aql, and κ And indicate that the root-mean-square deviation of the mean value, σ, is ± 2.8, ± 3.6, and ± 6.3 km s^{-1}, respectively. The typical σ in a result from 5–7 lines on my spectra, determined from

TABLE 1
Catalogue Information

HD No.	HR No.	Name	Spectral Type	$v \sin i$[a] (km s^{-1})	Rad. Vel.[b] (km s^{-1})
25642	1261	λ Per	B9 IV	205	+ 4.6
177724	7235	ζ Aql	A0 V	345	−22.7
222439	8976	κ And	B9 IV	190	−10.8

[a] Fukuda 1982; Uesugi and Fukuda 1982.
[b] Using data from Abt and Biggs 1972.

[1] Guest Observer at the Dominion Astrophysical Observatory.

the spread in the radial velocities from individual lines and from measurements of the midpoint of the Hα absorption profile at residual intensities between 0.80 and 0.96, is ± 4.4 km s^{-1}. For purposes of discussion I shall conclude that the radial velocities from my spectra differ from the catalog values only if the difference is more than ± 7 km s^{-1} from the mean result from all catalogs.

Because of its rapid rotation and weak absorption lines, except for Hα, ζ Aql is a good star to use as a standard star for minimizing the telluric absorption in the red spectral region of O stars. The stars κ And and λ Per are not recommended as standard stars because their absorption lines are rather strong and are only moderately broadened by rotation. Furthermore, emission components occurred in Hα in October 1990 in the case of λ Per.

2. The Observations

Spectrograms were obtained with the Cassegrain spectrograph of the 1.83-m telescope at the Dominion Astrophysical Observatory using a 30-mm long, liquid-nitrogen-cooled EG&G RL1872F/30 Reticon with a diode size of 15 μm. The dispersion is 30 Å mm^{-1} and the spectra extend from about 6190 Å to about 7070 Å. A Cd-Ne comparison spectrum was used, comparison spectra being obtained before and after each stellar spectrogram while the telescope was pointing at the star. This procedure was followed in order to average out any possible shifts due to flexure of the spectrograph. Sufficient dark exposures and flat-field exposures were obtained to remove instrumental effects using the procedures developed at the University of British Columbia.

Information about the present spectrograms is given in Table 2. The nominal signal-to-noise ratio per pixel for each spectrogram is listed in the fifth column of Table 2. No cosmic-ray spikes or other such blemishes were noticed on the spectra. Each pixel corresponds to 0.477 Å; the effective resolution element is about 2.5–3.0 pixels. An image slicer was used in the focal plane of the telescope to optimize the throughput. The spectra were put on a relative absolute energy scale using the relative absolute spectrophotometry of ζ Aql and κ And listed by Breger (1976).

The absorption lines formed by O_2 and H_2O in the Earth's atmosphere were minimized for all three stars by dividing through by the pattern of telluric lines found after using a cubic spline piecewise fit to the continuum and Si II and Hα absorption-line profiles of ζ Aql. In this way the disturbing effects of the O_2 and H_2O lines, particularly those in the neighborhood of Hα, are greatly reduced.

Spectra of ζ Aql in which the absorption features due to telluric lines are minimized were obtained by dividing

TABLE 2
The Observations

Star	U.T. Date	B.J.D. − 2440000.	Exposure[a] (s)	S/N Ratio	Rad. Vel.[b] (km s^{-1})	σ (km s^{-1})	n[c]
λ Per	28 Oct 90	8192.9057	1200	982	− 8.2	12.2	7
	28 Oct 90	8192.9196	1200	1050	− 0.9	9.4	7
	29 Oct 90	8193.8779	720	881	−16.2	11.5	7
	29 Oct 90	8193.8862	720	910	− 3.9	14.5	7
ζ Aql[d]	02 Aug 90	8105.7259	300	665	−46.2	6.3	5
	03 Aug 90	8106.7197	240	956	−44.7	15.1	5
	04 Aug 90	8107.7107	240	959	−46.2	12.5	5
	05 Aug 90	8108.7601	240	1180	−23.0	24.0	5
	27 Sep 90	8161.6155	240	664	−25.8	8.9	5
	29 Sep 90	8162.6137	240	920	−14.2	8.3	5
	30 Sep 90	8164.6057	180	674	−20.3	4.7	5
κ And	29 Oct 90	8193.6112	960	854	−20.0	12.1	6
	29 Oct 90	8193.6220	900	907	−27.5	5.6	6

[a]For one spectrogram.
[b]The midpoints of Si II λλ6347,6371 at half depth together with the midpoint of Hα measured at three depths were used for ζ Aql. The midpoints at half depth of Fe II λλ6239,6248 and of He I λ6678 were measured for λ Per in addition to the Si II lines and Hα at two depths. In the case of κ And, the Fe II, Si II, and He I lines were measured as well as Hα at only one depth. The adopted wavelengths are listed in Table 3. The listed radial velocity is an unweighted mean of the results from all lines measured.
[c]The number of lines measured on the spectrogram.
[d]Three spectrograms of similar exposure time were obtained in quick succession each night. The B.J.D., exposure time, and S/N for the middle exposure are listed. The three spectrograms were added to provide one high S/N spectrogram for use to minimize telluric lines. This spectrogram was measured for radial velocity.

each continuum-rectified spectrum of ζ Aql for all spectra obtained in August 1990 by the mean spectrum of ζ Aql on 1990 August 2 represented by a continuous line which is fitted to the continuum and to the profiles of the absorption lines due to Si II and Hα. The mean spectrum for 1990 September 27 was used in the case of the September 1990 spectra to minimize the telluric absorption lines. Appropriate shifts and multiplying factors were found by trial and error so as to optimize the cancellation of the telluric absorption lines in each spectrogram. Sections of the final rectified corrected spectra of λ Per (top and middle) and κ And (bottom) are shown in Figure 1. The wavelength scales have been corrected for the shifts due to the motion of the Earth and for the radial velocities of the stars. The spectrum of ζ Aql is shown in Figure 2. In Figure 3, rectified spectra of λ Per (top and middle) and of κ And (bottom) in the region of the Si II lines are shown.

All of the telluric-line corrected spectra were measured for radial velocity with the results given in the last three columns of Table 2. The effective central time of each three-spectrum mean ζ Aql spectrogram is taken to be that of the middle exposure of the three spectra which were added. The value of σ listed in the second-to-last column characterizes the uncertainty of a result from one line. It is calculated from the spread of the results from the individual lines measured on each spectrogram assuming that with the adopted wavelengths, Table 3, the measurements are of the same thing and that the deviations are distributed according to the normal error law. The standard deviation of the mean result from each spectrogram is $\sigma (n-1)^{-0.5}$. The unexpectedly large value of σ for ζ Aql on 1990 August 3, 4, and 5 may be caused by the fact that in August one of the analog-to-digital converters of the Reticon electronics was behaving in an erratic manner.

3. Discussion

Comparison of the radial velocities given in Tables 1 and 2 shows that in 1990 the radial velocities of λ Per, ζ Aql, and κ And were slightly more negative than the results obtained from photographic, blue-violet spectra. The early results depend chiefly on the perceived displacements of the absorption cores of Hβ, Hγ, and Hδ. The radial velocity of ζ Aql appears to have varied through a small range during the 1990 observing season. The results obtained in August 1990 are suspicious because of the irregular behavior of the Reticon electronics noted above. This behavior generated a ripple which was minimized by smoothing over eight pixels. There are too few observations of λ Per and κ And to determine whether or not their radial velocities are changing.

Small emission components in the core of Hα of λ Per can be seen in Figure 1. The relative intensities of the *V* and *R* components changed in 24 hours. No previous record of the presence of emission components at Hα in the spectrum of λ Per could be found. The high *S/N* ratio (about 900) of the present spectra allows us to detect weak emission features. Such features are not present for κ And (Fig. 1) nor for ζ Aql (Fig. 2). The spectra of λ Per and κ And are very similar; this may be seen from Figure 3 which shows the profiles of the weak Si II lines for both stars. The profile of Si II λ6371 is visible also on the left-hand side of the spectra shown in Figure 1. The shallow profile due to He I λ6678 can be detected in Figure 1. This line is not present in the spectrum of ζ Aql (Fig. 2).

The sharp Hα absorption cores in the spectra of λ Per were measured for radial velocity as were the emission peaks. On 1990 October 28 the displacement of the core was $+2.5$ km s^{-1} while on 1990 October 29 it was -2.3 km s^{-1}. On 1990 October 28 the centers of the *V* and *R* emission components were displaced by -124.2 km s^{-1} and 140.0 km s^{-1}, respectively, while on 1990 October 29 these displacements were -107.8 km s^{-1} and 135.2 km s^{-1}. The emission components and the sharp core between them have not shifted as a unit between October 28 and 29. Rather, it appears that we are seeing emission from plagelike areas on the surface of the star and that the configuration of the plages changed as the star rotated.

If it is supposed that the radius of the photosphere of λ Per is 2 $R_\odot$ and that the minimum equatorial speed of rotation is 205 km s^{-1} (Table 1), the period is less than about 0.49 day. It is plausible that in 24 hours a different aspect of plage areas on the surface of λ Per will be seen. This will account for the changes observed in the weak Hα emission features. It is less plausible that the weak emission features seen for λ Per and their changes originate in an external equatorial disk such as is often postulated for Be stars. The presence of plages on the surface of λ Per suggests that magnetic fields are present on the surface of λ Per.

TABLE 3

Adopted Wavelengths

Spectrum	Wavelength (Å)	Spectrum	Wavelength (Å)
Fe II	6239.36	Si II	6371.36
Fe II	6247.56	Hα	6562.82
Si II	6347.10	He I	6678.15

I am grateful to Nadine Dinshaw for assistance with the observing and to the Dominion Astrophysical Observatory for a generous award of observing time. This research has been supported by the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

Abt, H. A., & Biggs, E. S. 1972, Bibliography of Stellar Radial Velocities (New York, Latham Process Corp.)

Breger, M. 1976, ApJS, 32, 7

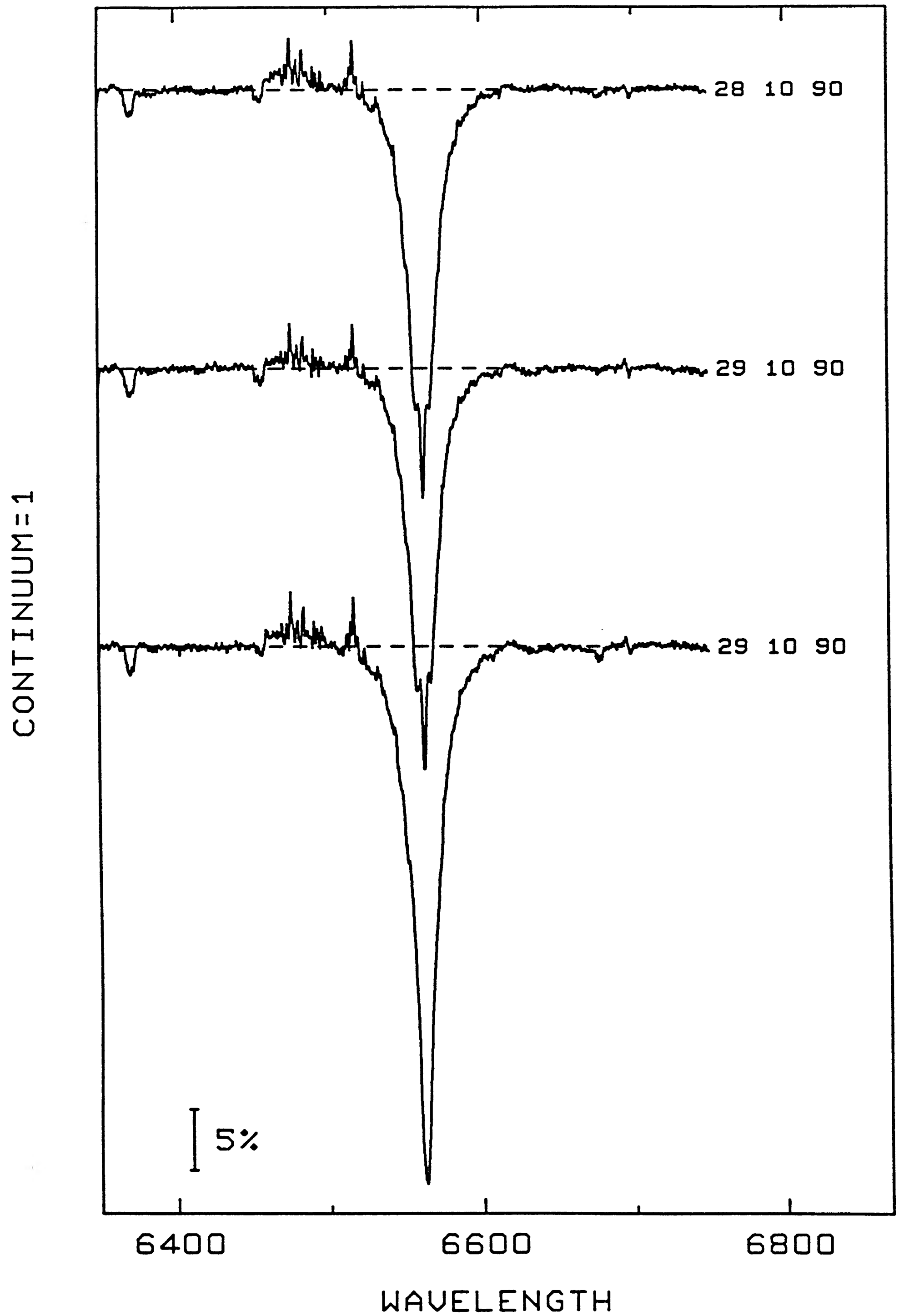

FIG. 1–Spectra of λ Per (top and middle) and κ And (bottom) in the Hα region on 1990 October 28 and 29 and on 1990 October 29, respectively. The telluric lines have been minimized. However, it was impossible to completely cancel the water-vapor lines shortward of Hα because the cancellation had to be attempted using a telluric spectrum from a spectrogram of ζ Aql obtained with a slightly different setting of the spectrograph and on another night.

Fukuda, I. 1982, PASP, 94, 271

Gray, R. O., & Garrison, R. F. 1990, ApJS, 65, 581

Hoffleit, D., & Jaschek, C. 1982, The Bright Star Catalogue (New Haven, Yale Univ. Obs.)

Jaschek, C., Conde, A., & de Sierra, A. C. 1964, Pub. Astr. Obs. Nat. Univ. de la Plata, 28, No. 2

Uesugi, A., & Fukuda, I. 1982, Revised Catalogue of Stellar Rotational Velocities (Kyoto, Dept. Astronomy, Kyoto Univ.)

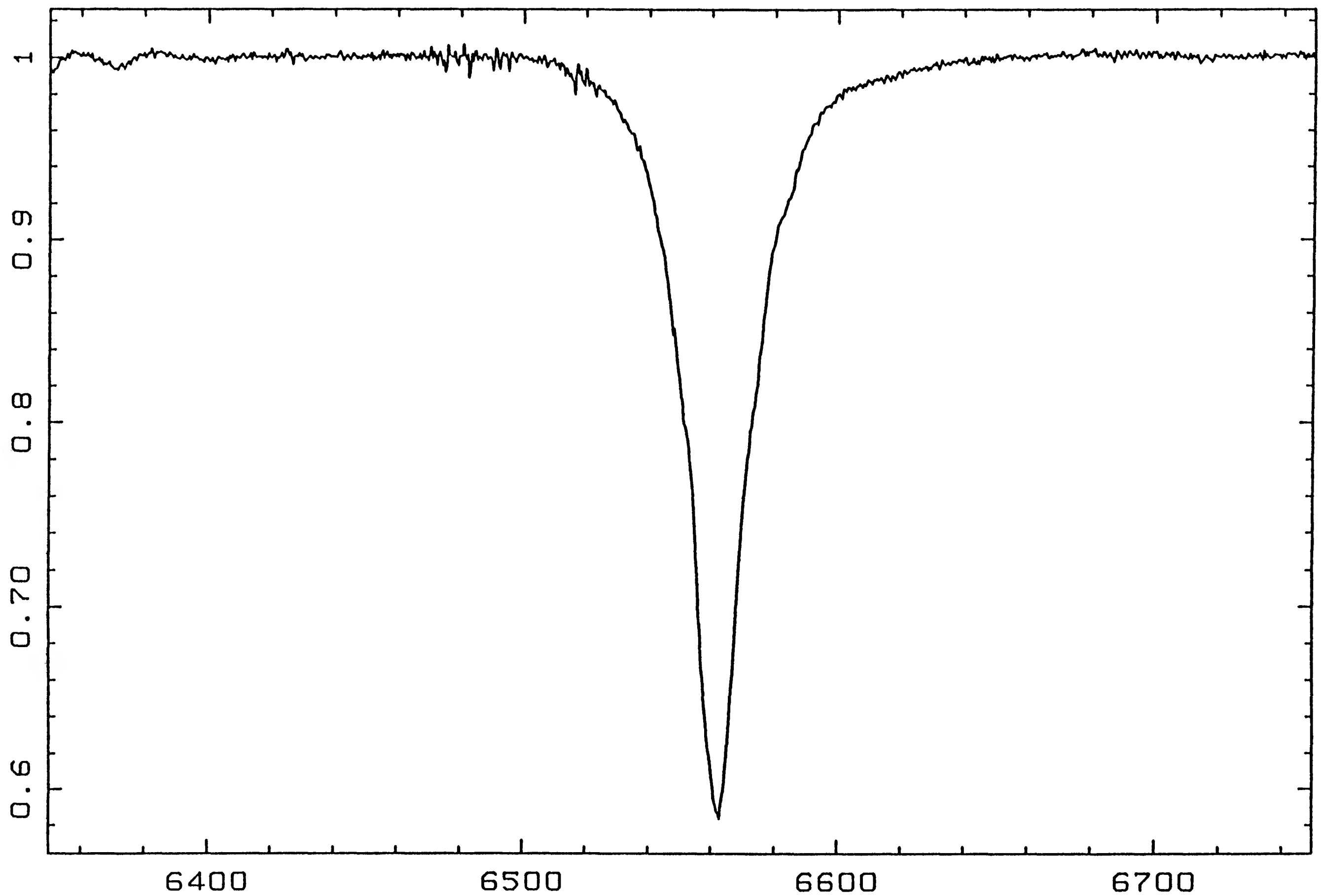

FIG. 2–The telluric-line corrected and rectified spectrum of ζ Aql in the region of Hα.

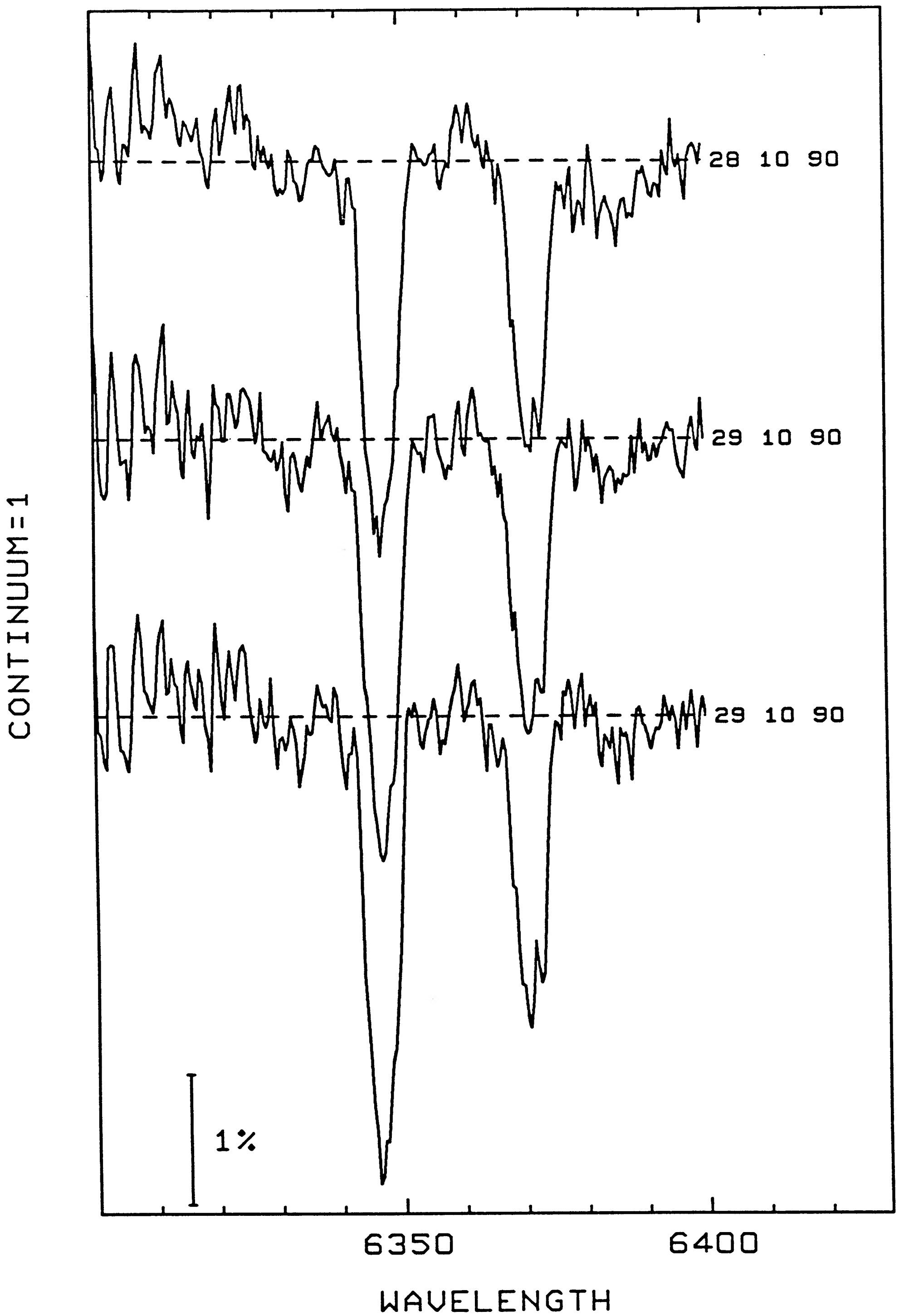

FIG. 3–The spectrum of λ Per (top and middle) and of κ And (bottom) in the region of the Si II lines on 1990 October 28 and 29 and October 29, respectively.