THE ASTROPHYSICAL JOURNAL, 177:235–244, 1972 October 1

ROCKET-ULTRAVIOLET SPECTRA OF SIX STARS IN PERSEUS

DONALD C. MORTON, EDWARD B. JENKINS, AND WILLIAM W. MACY
Princeton University Observatory
Received 1972 April 11

ABSTRACT

Spectra of the O and B stars ϵ, ζ, ξ, o, and 40 Per, and HD 24640 have been photographed between 1130 and 2300 Å with a pair of rocket-borne objective spectrographs. Photospheric lines of He II, C II, C III, C IV, N III, Ni IV, Si III, and Si IV and also possibly N V, O IV, Al II, and Al III have been identified in one or more of the stars. The interstellar Lα line was measured in ξ, o, and 40 Per, giving an average volume density of 1.7 ± 0.5 hydrogen atoms cm^{-3} in this direction. There appears to be an interstellar contribution to the C II λ1334.5 line in ζ Per, but otherwise the spectra are too noisy for conclusive detection of the usual ultraviolet interstellar lines of C II, N I, O I, and Si II. The C IV resonance doublet in ζ Per (B1 Ib) has a P Cygni profile with a shift of -900 km s^{-1} in the absorption line, though no such displacement was found in the Si IV pair. For ξ Per (O7.5) the resonance lines of N V, Si IV, and C IV all have P Cygni profiles with absorption shifts averaging -1840 km s^{-1}. Smaller velocities were measured for the absorption lines of C III λ1175.7 and N IV λ1718.5 which arise from excited levels.

I. INTRODUCTION

The Princeton rocket program of photographing far-ultraviolet spectra has been continued with NASA Aerobee 4.267 which was pointed toward stars in Perseus. As before, our purpose has been to study stellar absorption lines, circumstellar absorption and emission lines, and interstellar absorption lines. Except for hydrogen, the interstellar lines are expected to be very narrow, and hence require the maximum possible wavelength resolution. Consequently, we had a second flight of the objective spectrographs described by Morton *et al.* (1972, hereinafter MJMY). We used the same active control by rate-integrating gyros for fine stabilization and obtained a resolution comparable with the 0.5 and 0.6 Å achieved on ζ Oph and δ Sco with the earlier flight. In practice, however, weak features are difficult to recognize in our Perseus spectra because these stars are fainter and consequently the signal-to-noise ratio is lower. The spectra of ϵ and ζ Per already have been studied by Carruthers (1970, 1971) who recorded the region between 1000 and 1400 Å at 2 Å resolution with a windowless electronographic camera. He discovered the Lyman resonance absorption bands of interstellar H_2 in the spectrum of ξ Per. Low-resolution spectral scans of ϵ and ζ Per between 1150 and 4000 Å were obtained by Stecher (1970) to determine the interstellar extinction curve in this direction.

II. INSTRUMENTATION, FLIGHT DETAILS, AND DATA REDUCTION

The rocket was launched on 1970 December 2 at 7^h30^m UT from the White Sands Missile Range. The payload consisted of two objective spectrographs of the type originally flown by Morton and Spitzer (1966) and Morton (1967), but now with the important modifications outlined by MJMY. Fine stability on the targets was provided by a pair of rate-integrating gyros which actively controlled gas jets in the pointing system. The high-dispersion spectrograph, with a scale of 19 Å mm^{-1}, had a plane reflection grating of 3600 lines mm^{-1}, while the low-dispersion instrument with 68 Å mm^{-1} had a grating with only 1200 lines mm^{-1}. Lithium fluoride correctors in the Schmidt cameras gave wavelength coverage down to nearly 1100 Å.

The attitude control system was programmed to orient the rocket towards Perseus so that spectra of ξ, o, and 40 Per and HD 24640 were recorded near the center of the 10° diameter field of view, while ϵ and ζ Per were closer to the edges. There were simultaneous exposures by the two cameras on two adjacent targets separated by 6°1 in the dispersion direction. The cameras first photographed longer wavelengths for 70 s between altitudes of 111.3 and 164.3 km, and then shorter wavelengths for 150 s from 169.3 km up to the peak altitude of 174.2 km and down to 99.0 km. The rate gyro in yaw limited motions in the dispersion direction to $\pm 16''$, corresponding to 0.6 Å in the high-resolution spectrograph, while the rate gyro in pitch had a deliberate drift to widen the spectra perpendicular to the dispersion. Since we could tolerate much larger motions in roll, only the coarse stabilization was used about this axis. The combined motions in pitch and roll widened the spectra on the long exposures between 90 and 140 μ, and somewhat less on the short exposures.

The principal stars we observed are listed in table 1. These five stars, as well as several fainter ones, were obtained on all four exposures, but only those spectra with quoted wavelength ranges were strong enough for a detailed analysis. The basic data on spectral types, magnitudes, colors, and distances were taken from Lesh (1968), who adopted Johnson's (1963) intrinsic colors. Conti and Alschuler (1972) have classified ξ Per as O7.5 I and estimated $M_V = -5.0$. Harris (1956) included ϵ Per in the I Persei aggregate associated with α Per and all the other stars in the table with the II Persei aggregate associated with ζ Per. Blaauw (1961) believes ξ Per is a runaway star from II Persei and lies about 80 pc beyond the rest of the stars so that 400 pc might be a better estimate of its distance. According to the Bright Star Catalog (Hoffleit 1964), o and 40 Per are spectroscopic binaries while ϵ Per has two spectra visible, and both ϵ and ξ Per have variable radial velocity.

The Kodak far-ultraviolet film type 101-01 used on this flight was developed for 6 min in D19 at 68° F. An intensity calibration made near 1400 Å on a strip from the same batch was adopted for the whole range since MJMY found that the H and D curve for this film essentially was independent of wavelength. As before, we assumed that the film had no reciprocity failure. The spectra were scanned by the Sacramento Peak densitometer using a rectangular spot 10 μ × 20 μ with the narrower dimension in the dispersion direction. The digital output was converted to relative intensities in order to plot the curves in figures 1 and 2.

Wavelengths were derived as described by MJMY. Preliminary values were obtained from the known parameters of the spectrographs along with preflight calibration exposures on stars and mercury spectra. Then a constant wavelength shift was applied

TABLE 1

STARS OBSERVED IN PERSEUS

Star	Spectrum	V	$B-V$	$E(B-V)$	Distance (pc)	Exposure	Wavelength Ranges: High Dispersion (Å)	Wavelength Ranges: Low Dispersion (Å)
ϵ Per......	B0.5 III	2.90	−0.18	0.10	302	2	1465–1580	1455–1905
ζ Per......	B1 Ib	2.87	+0.11	0.30	322	1	...	1310–2295
						2	1200–1475	1150–1660
ξ Per.....	O7.5	4.03	+0.01	0.33	322 (400)*	2	1300–1565	1130–2070
o Per......	B1 III	3.79	+0.06	0.32	322	2	...	1145–1505
40 Per....	B1 IV	4.96	−0.02	0.24	322	2	...	1180–1930
HD 24640	B1.5 V	5.48	−0.05	0.20	322	2	...	1180–1930

* ξ Per is a runaway star which probably lies 80 pc beyond the rest of the group.

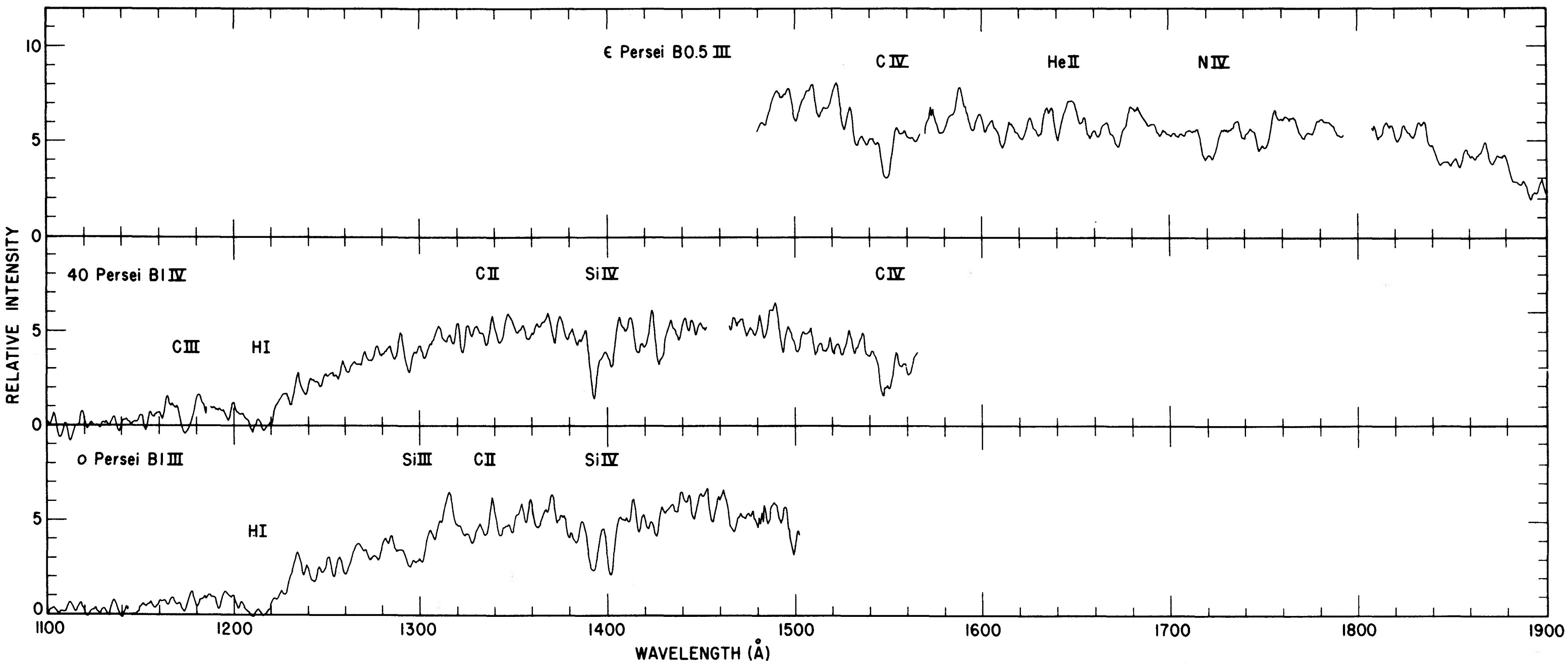

FIG. 1.—Spectra of ϵ, 40, and o Per obtained with the lower-resolution camera. The intensities in figs. 1 and 2 have been drawn proportional to the observed signals for 40, o, ζ, and ξ Per and proportional to 1/10 the signal for ϵ Per to indicate the relative accuracies. The decrease in intensities shortward of 1300 Å is due to absorption by the lithium-fluoride Schmidt corrector.

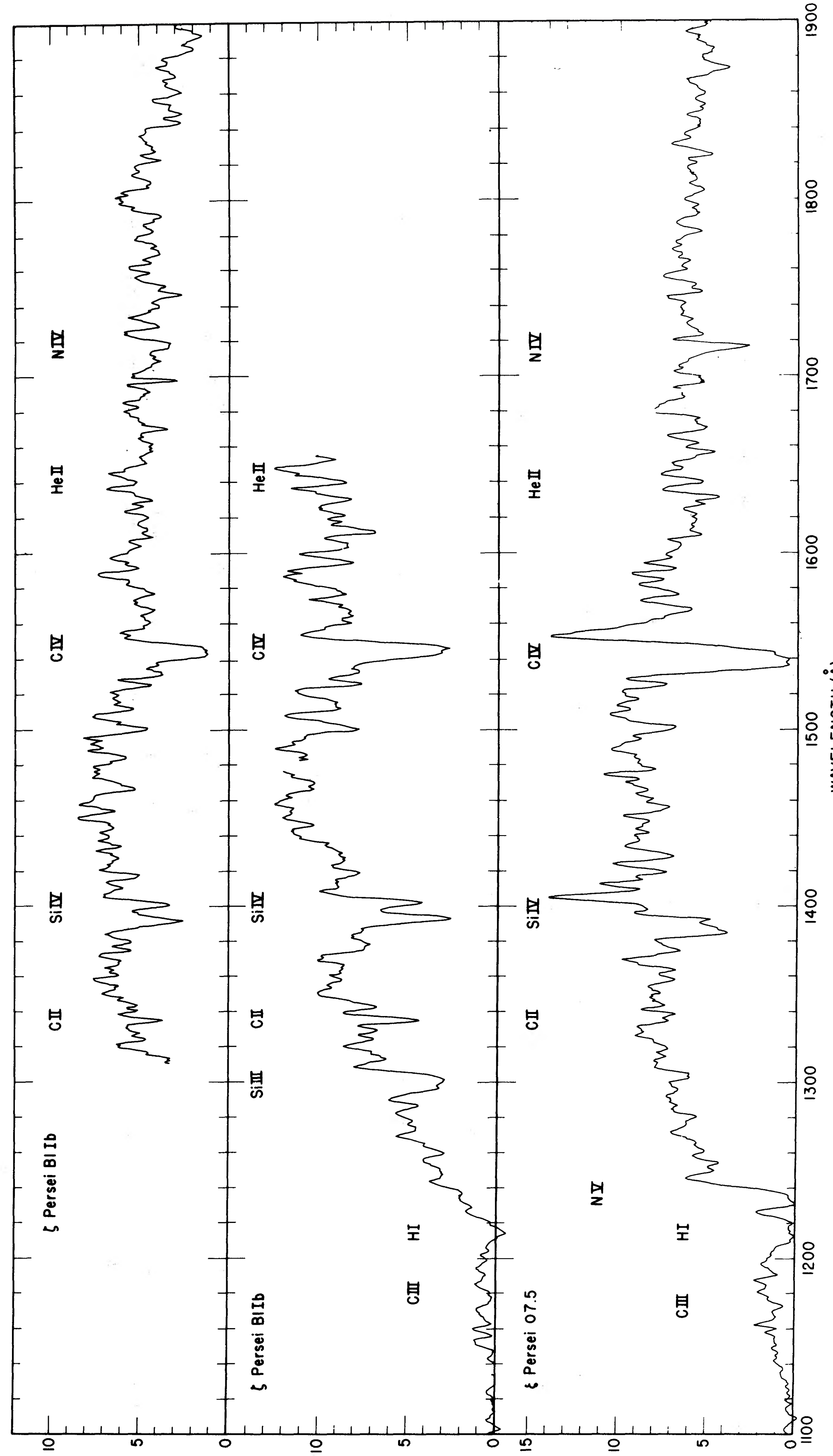

FIG. 2.—Spectra ζ and ξ Per obtained with the lower-resolution camera. The top spectrum of ζ Per was obtained in 70 s, and all the others in 150 s

TABLE 2

OBSERVED WAVELENGTHS IN PERSEUS SPECTRA

40 Per B0.5 V	o Per B1 III	ζ Per B1 Ib		ξ Per O7		Ion	UV Mult. No.	Laboratory Wavelength
Low λ(Å)	Low λ(Å)	High λ(Å)	Low λ(Å)	High λ(Å)	Low λ(Å)			λ(Å)
					1160.0			
1174.8	1173.9				1172.8	C III	4	1175.7(6)
	1180.9							
					1184.2	N III	20	1183.03,1184.54
	1192.5				1191.2			
1197.6								
	1203.0							
1214.0	1213.5	1218.8	1214.4		1215.6	H I	1	1215.67(2)
	1228.0							
1231.3						C IV	11.14	1230.05,1230.51
1238.7	1238.3				1231.0	N V	1	1238.82
	1243.5				1236.0	N V	1	1242.80
					1246.0	N V	1	1238.82,1242.80
1247.3	1248.5					C III	9	1247.38
					1250.2			
	1254.5				1254.5			
1261.7	1261.0	1259.4	1259.8		1261.3	Si II?	4	1260.42
	1274.0							
	1278.3				1280.7			
1286.7	1288.0		1286.5					
1294.5	1298		1299.5			Si III	4	1294.54-1303.32(6)
1302.8		1302.8			1303.7	O I?	2	1302.17
	1308.3					C III	11.44	1308.73
1314.0			1313.1			Si III	10	1312.59
					1315.0			
1318.3					1320.0			
1323.5			1324.2			C II	11	1323.9(4)
1328.4	1328.5		1328.6			Si III	48	1328.81
1336.2	1335.3	1334.7	1335.2	1334.9	1335.0	C II	1	1334.53
		1336.0				C II	1	1335.69(2)
				1338.7	1338.7	O IV	K	1338.60
1343.4	1343.5	1343.0	1343.0	1343.2	1343.7	Si III	39	1342.2(7)
						O IV	K	1343.00,1343.51
	1350.0							
1353.2			1353.4					
1358.5	1357.2				1358.2			
	1363.4			1363.0	1363.6	Si III	38	1364.3(6)
1372.4								
	1374.2		1374.8		1375.0			
1379.2	1380.0		1379.0					
1384.5	1383.6							
1393.5	1393.0	1393.1	1392.4	1385.0	1384.8	Si IV	1	1393.76
1402.5	1402.2	1402.7	1401.3	1393.1	1392.3	Si IV	1	1402.77
				1395.9	1396.2	Si IV	1	1393.76
				1404.9	1405.2	Si IV	1	1407.77
1409.7				1409.9	1409.5			
				1412.7	1412.5			
1416.9				1415.5	1415.4			
	1417.3	1417.4	1417.8			Si III	9	1417.24
1420.3								
	1422.2							
				1420.5	1419.5			
				1423.5	1423.8			
1428.6	1426.4			1429.8	1428.7	C III	11.52	1427.8(3)
			1434.0					
1438.4	1437.3							
1444.0								
1447.7	1446.6		1445.8					
1452.3								
1457.4	1456.8		1454.5	1454.5	1456.3			

TABLE 2 (CONTINUED)

ε Per B0.5 V High λ(Å)	ε Per B0.5 V Low λ(Å)	40 Per B0.5 V Low λ(Å)	ο Per B1 III Low λ(Å)	ζ Per B1 Ib Low λ(Å)	ξ Per O7 High λ(Å)	ξ Per O7 Low λ(Å)	Ion	UV Mult. No.	Laboratory Wavelength λ(Å)
1467.6	1466.5	1466.2	1467.8	1467.5		1466.4			
					1472.5	1472.2			
1473.8		1475.0							
1477.8	1478.0	1479.1			1478.8	1478.1	C III	12.04	1478.0(3)
1483.9	1484.5	1484.5	1486.5	1485.0					
1494.2	1493.1	1494.1	1493.1						
1501.4	1501.2	1501.8	1499.9	1500.6	1502.6	1501.4	Si III	36	1501.3(6)
1512.5	1513.0	1511.7		1512.4	1512.3	1512.0			
1517.0	1517.0	1516.5				1517.4			
		1521.0							
1526.1	1526.4	1525.7		1525.9	1526.7	1525.5	Si II?	2	1526.72
1532.3	1533.2	1532.2		1532.4			C III	11.65	1531.85
							Si IV	24	1533.22
							Si II?	2	1533.44
1539.0	1538.3	1539.5							
1543.5	1543.2								
1548.0	1548.8	1547.5					C IV	1	1548.20
1550.8		1550.8		1544.5	1540.8	1540.3	C IV	1	1550.77
				1552.8	1554.0	1552.7	C IV	1	1549.1(2)
1556.4	1556.5								
		1561.3							
1564.5	1564.7								
1568.9						1567.8			
1575.5									
1578.0	1578.5			1577.5		1577.5			
						1584.8			
						1591.3	C III	11.58	1591.48
	1595.0			1593.8					
	1601.8								
				1604.1					
	1610.8			1611.5		1610.3			
	1621.2			1620.7					
	1629.8			1630.2		1631.0			
	1640.2			1640.2		1640.1	He II	12	1640.4(3)
						1647.8			
	1652.5			1652.0					
	1657.3					1656.5			
	1661.8					1661.7			
				1670.7		1670.5	Al II?	2	1670.81
	1672.0						Si IV	27	1672.61
						1676.1			
	1718.5			1718.1		1717.0	N IV	7	1718.55
						1720.7	N IV	7	1718.55
	1722.3								
				1729.4					
	1739.0								
	1747.2			1746.7		1747.8	N III	19	1747.86
	1750.3			1751.4		1751.8	N III	19	1751.24,1751.75
				1759.3			C II?	10	1760.6(3)
	1770.5			1770.5					
	1775.0								
						1781.6			
				1790.9					
						1805.2			
				1809.3					
	1820.7			1822.4					
						1825.5			
	1828.3								
				1843.5			Si III	20	1842.55
				1848.5					
	1854.0						Al III?	1	1854.72,1862.78
				1860.8					
	1871.5					1874.0			
	1885.0			1884.5					
	1891.8			1891.7					
						1935.5			
						2025.5			

to each flight spectrum to determine the numbers in table 2 which gave the best agreements with the laboratory wavelengths of a few lines with reliable identifications. In all cases the shifts amounted to 1.7 Å or less except for 4.4 Å needed to bring the low-dispersion long exposure of ζ Per into coincidence with the others. The lines used to fix the wavelength scales were primarily C II λ1335.3, Si IV λλ1393.8, 1402.8, and He II λ1640.4 with some weight also given to C III λ1247.4 and N IV λ1718.6 when available. We avoided the resonance lines of Si IV for ζ and ξ Per since they can have wavelength shifts due to expanding shells in such stars. These displacements also are possible in the lines we did use, but the small corrections applied to wavelengths obtained without adopting any line identifications show that any such shifts cannot be large. Furthermore, it is unlikely that the lines of He II, C III, or N IV which arise from highly excited states would have the same shift as the C II resonance line. Unfortunately the interstellar Lα line was too weak and broad on any of the exposures to be used as a primary wavelength standard, but the resulting estimates for its wavelength provided useful checks. Most of the wavelengths quoted in table 2 should be correct to ±1 Å, though there could be larger errors at the extremities of the spectra. The table lists only the lines that are clearly visible in each spectrum. The figures show that many other lines also must be present, though not as easily distinguishable from the noise. We have omitted HD 24640 from the table because the only definitely discernible lines were at 1217, 1394, and 1402 Å.

III. LINE IDENTIFICATIONS

In the right-hand columns of table 2 we have listed probable identifications of many of the lines observed in the Perseus spectra. The laboratory wavelengths were taken from Moore (1950, 1965) or Kelly (1968). Further spectroscopic data on most of these lines have been quoted by MJMY in a similar table for δ Sco and ζ Oph.

a) *Telluric Lines*

Since the zenith distance of the Perseus stars was only 20°.5, we did not expect much telluric contamination of the spectra. There is no evidence for the O_2 absorption at 1244.5 Å which was detected in the δ Sco spectrum.

b) *Interstellar Lines*

The interstellar Lα line is a major feature in all the low-resolution spectra of table 1 except ϵ Per which does not extend to 1216 Å. Table 3 lists column densities N_H and equivalent widths W_λ derived from the three spectra strong enough for reliable measurements. As in the paper by MJMY, we did not derive N_H from the equivalent width of the Lα profile, but instead we determined what value of N_H best seemed to cancel the observed absorption after it was multiplied by exp $[+\tau(\lambda, N_H)]$. This more accurate method avoids the need to estimate a continuum height in the vicinity of the line. The relatively large uncertainties quoted in table 3 are due mainly to the poor

TABLE 3

INTERSTELLAR HYDROGEN DENSITIES

Star	Type	N_H (10^{20} atoms cm^{-2})	n_H (atoms cm^{-3})	$W_\lambda(L\alpha)$ (Å)
ξ Per............	O7.5	20 ± 5	1.6 ± 0.4	33
o Per............	B1 III	17 ± 7	1.7 ± 0.7	30
40 Per...........	B1 IV	17 ± 7	1.7 ± 0.7	30

signal-to-noise ratio in the spectra. To facilitate comparison with the measurements of other investigators we also have listed the Lα equivalent widths which correspond to the N_H values. Our determination of N_H to ξ Per agrees well with the measurement by Savage and Jenkins (1972) of $20(+8, -6) \times 10^{20}$ atoms cm^{-2} from the low-resolution scans by OAO-2. On the other hand, Carruthers (1970) reported $W_\lambda(L\alpha) = 15 \pm 3$ Å for ξ Per with a corresponding $N_H = 4.2(+1.9, -1.5) \times 10^{20}$ atoms cm^{-2}. The column densities listed in table 3 represent averages over distances of 322 pc to o and 40 Per and 400 pc to ξ Per (see table 1). The corresponding volume densities n_H are slightly larger than the 1.1 atoms cm^{-3} found in the direction of ζ Per by Savage and Jenkins, and significantly greater than their measurement of 0.33 atoms cm^{-3} toward ϵ Per. It is noteworthy that the mean density of hydrogen in the direction of ζ, ξ, o, and 40 Per is somewhat higher than the average of 0.6 atoms cm^{-3} found by the OAO survey of stars roughly 300 pc from the Sun. This suggests that the II Persei association has a local enrichment of gas similar to the one found in the northern part of the Scorpio-Centaurus association (II Scorpii) by Jenkins, Morton, and Matilsky (1969) and Savage and Jenkins (1972).

The C II lines at 1334.53 and 1335.67 Å appear to be resolved in the high-dispersion spectrum of ζ Per with the short-wavelength component stronger, even though it has the smaller gf-value. Similar patterns were found in the spectra of δ Sco and ζ Oph. Since the stronger component is formed by absorption from the ground state, we believe the enhancement over the expected photospheric line ratios is due to interstellar C II. Jenkins (1972) has estimated the stellar contribution and derived the interstellar column density for ionized carbon. The C II line in ξ Per should be almost entirely interstellar, but no column density has been calculated because the high- and low-dispersion scans disagree in equivalent width, probably as a result of the noise in the spectra. The noise in the high-dispersion spectrum of ζ Per also prevented us from identifying with certainty the expected interstellar lines of O I and Si II. Interstellar absorption probably does contribute to lines at 1260 and 1300 Å in the low-dispersion spectra, but the resolution does not permit us to decide how much blending there is with other lines.

c) *Stellar Lines*

The weaker signals and somewhat lower resolution of the Perseus spectra have prevented us from quoting as detailed a set of identifications as MJMY found for δ Sco. However, lines of He II, C II, C III, C IV, N III, N IV, Si III, and Si IV almost certainly are present in one or more of the spectra described here, and lines of N V, O IV, Al II, and Al III also are probable. Some of these lines definitely originate in the stellar photospheres, while others show negative velocity shifts and P Cygni profiles characteristic of the expanding shells that have been found associated with hot supergiants (Morton 1969).

i) *HD 24640*, B1.5 V

In this weak spectrum the only clearly identifiable features are the interstellar Lα line and the Si IV resonance doublet, which shows no evidence for a wavelength displacement.

ii) *40 Persei*, B1 IV

For this star we apparently have resolved the C IV resonance doublet, even with the low-dispersion camera. The Si IV pair also is present, but the absence of the weaker component of the N V doublet suggests that the line at 1238.7 Å must be due primarily to some other ion. There are no velocity shifts within the uncertainties of our wavelengths.

iii) *o Persei*, B1 III

The Si IV resonance doublet definitely is present, but the N V pair is less certain because the intensity ratio is reversed. There is no evidence for any displaced lines.

iv) *ϵ Persei*, B0.5 III

The high-dispersion spectrograph resolved the C IV doublet. Again the wavelengths agree with the laboratory values with no evidence for an expanding shell.

v) *ζ Persei*, B1 Ib

The C IV resonance doublet has a P Cygni profile with weak emission slightly longward of the laboratory wavelength and strong absorption displaced shortward by 4.6 Å or -900 km sec^{-1}. However, no such shift appears in the Si IV pair unless there is an error in the wavelength scale derived from the assumption that an interstellar line contributes to C II λ1334.5 with no large velocity shift. The adopted scale also is consistent with no shift in the N IV and He II absorptions from relatively high excited levels. The short-wavelength ends of the ζ Per spectra are too weak for a definite check on the presence of N V. Usually O and B supergiants have similar velocity displacements for N V, Si IV, and C IV, but in the spectrum of ζ Oph (O9.5 V) described by MJMY Si IV was unshifted while C IV was shifted by -900 km s^{-1} and N V possibly by -400 km s^{-1}. The stars ζ Per and ζ Oph appear to be intermediate between the main-sequence B stars such as δ Sco (B0 V), which have no detected line shifts, and the hotter bright giants and supergiants such as δ Ori (O9.5 II), ϵ Ori (B0 Ia), and ζ Ori (O9.5 Ib) in which the C IV, Si IV, and N V resonance absorption lines are all displaced by about -1500 km sec^{-1}.

vi) *ξ Persei*, O7.5

In this star we found P Cygni profiles with both emission and absorption for N V λλ1238.8, 1242.8; Si IV λλ1393.8, 1402.8; C IV λλ1548.2, 1550.8; and N IV λ1718.6, but only a displaced absorption line for C III λ1175.7. As shown in table 4, the N V, Si IV, and C IV absorptions from the ground state average -1840 km s^{-1} toward the observer while the C III and N IV absorptions from excited levels have much smaller velocities. The longward displacements of the emission lines probably result from distortions caused by the absorptions superposed on the broad emission profiles. Longward of the Si IV lines there is some evidence for a second emission pair at 1412.5 and 1423.8 Å. Their separation is close to the 9.0 Å expected for Si IV, but the displacement

TABLE 4

P CYGNI LINES IN THE LOW-DISPERSION SPECTRUM OF ξ PERSEI

Ion	E.P. (eV)	λ_{lab} (Å)	λ_{obs} (this paper) (Å)	$\lambda_o - \lambda_l$ (Å)	Velocity (km s^{-1})	λ_{obs} (Carruthers) (Å)
C III absorption.......	6.50	1175.7	1172.8	−2.9	−500	1169
C III emission.........	...	...	...	...	...	1180
N V absorption........	0	1238.8	1231.0	−7.8	−1890	...
N V absorption........	0	1242.8	1236.0	−6.8	−1640	1230
N V emission..........	...	1242.8	1246.0	+3.2	...	1242
Si IV absorption.......	0	1393.8	1384.8	−9.0	−1940	...
Si IV absorption.......	0	1402.8	1392.3	−9.5	−2030	...
Si IV emission.........	...	1393.8	1396.2	+2.4	...	...
Si IV emission.........	...	1402.8	1405.2	+2.4	...	...
C IV absorption.......	0	1549.1	1540.3	−8.8	−1700	...
C IV emission.........	...	1550.8	1552.7	+1.9	...	...
N IV absorption.......	16.20	1718.6	1717.0	−1.6	−280	...
N IV emission.........	...	1718.6	1720.7	+2.1	...	...

would imply accretion of matter at $+4300$ km s^{-1} which is more than 5 times the escape velocity. Therefore, these lines must be due to other transitions or to the continuum showing between strong absorption features. In the case of N IV, the larger shift for the emission suggests that there may be some error in the wavelength scale near the end of the spectrum, though elsewhere the good agreement for H I λ1215.7, C II λ1334.5, and He II λ1640.4 indicates that the scale must be reliable within ± 1 Å for this star.

In the region around Lα where our low-resolution spectrum overlaps with that of Carruthers (1970, 1971), we confirm his observations of an N V emission line and shifted absorption lines due to both N V and C III. Carruthers also found a C III emission component which could be lost in the noise of our spectrum. Neither spectrum shows any evidence for a Si III λ1206.5 absorption which has been found shifted in other hot supergiants. Unfortunately, as shown by the last column in table 4, we do not reproduce Carruthers's wavelength measurements so that we have used only our numbers to estimate the absorption-line velocities. He noted a possible confusion of a N IV triplet at 1169 Å with the shifted C III multiplet, but the excitation of 51.8 eV required for the N IV absorption means that it should not be a strong line.

The velocities we have found for the N V, Si IV, and C IV resonance absorption lines in ξ Per are very similar to the average displacement of -1840 km s^{-1} measured for these lines in the spectrum of the O5f star ζ Pup by Morton, Jenkins, and Brooks (1969). However, in the O5f star, the shifts for C III and N IV were somewhat greater at -1860 and -780 km s^{-1}, respectively, and He II also had a P Cygni profile with the absorption component shifted by -350 km s^{-1}.

The flight of Aerobee 4.267 was sponsored by the National Aeronautics and Space Administration through contract NSr-31-001-901 with Princeton University and through launch support provided by the Sounding Rocket Branch of the Goddard Space Flight Center. We are grateful to Mr. James Plascyk of the Perkin Elmer Corporation who supervised the preparation of the spectrographs and Mr. William Harter of Princeton who assisted at White Sands. We also wish to thank the Sacramento Peak Observatory for the opportunity to use their digital densitometer.

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