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THE OPTICAL SPECTRAL LINE LIST OF RR TELESCOPII

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ABSTRACT

The symbiotic nova RR Telescopii has been observed with the 1.5 m telescope of the Cerro Tololo Inter-American Observatory (CTIO), using the 1.5 m bench-mounted echelle spectrograph in conjunction with a Tektronix CCD. It displays a rich emission-line spectrum, ranging in excitation from O I to [Ni VIII]. We present a list of 491 measured lines, with their suggested identifications, covering a wavelength range from 3430 to 9320 Å. Of these, only nine are unidentified, and 70 lines are cataloged that were not given in the original line list of Thackeray. Absolute line intensities are also given, which have been derived by comparing the high-resolution data with a flux-calibrated low-resolution spectrum taken with the Cassegrain spectrograph on the 1.0 m telescope at CTIO.

Subject headings: binaries: symbiotic — line: identification — stars: individual (RR Telescopii)

1. INTRODUCTION

Because of the great wealth of lines emitted by the symbiotic nova RR Telescopii since its outburst in 1944, it has been the subject of many extensive spectroscopic investigations (see, e.g., Aller et al. 1973). A symbiotic nova is one of a subclass of symbiotic stars, which are interacting binaries whose spectra indicate the presence of a late-type star and a hot companion (Mürset et al. 1991). The stellar components lie in a low-density extended nebular envelope caused by the cool giant's stellar wind, which is ionized by the hot star (Jordan, Mürset, & Werner 1994). This hot star can be thought of most likely as a white dwarf undergoing an outburst, similar to classical novae in that nuclear burning is ignited in a hydrogen-rich layer accreted on top of the stellar surface. However, the outbursts of symbiotic novae are not as sudden as those of classical novae and have a much longer duration, typically lasting decades, as is the case with RR Tel (Jordan et al. 1994). Thackeray (1977) has compiled the observations of RR Tel from its outburst in 1944 to the mid-1970s and contains most relevant references.

Recent interpretations of the nature of RR Tel indicate a very complex physical situation. Involved is a white dwarf, a Mira variable with a spectral type of around M5, a planetary nebula–like plasma, and an additional hot plasma that could be due to colliding winds from the two binary components (Feast et al. 1983; Penston et al. 1983; Mürset et al. 1991; Jordan et al. 1994; Heck & Manfroid 1985). The optical spectrum consists almost entirely of emission lines, and with increasing time, an emission spectrum has emerged that progresses to higher excitation, presumably caused by the evolution of the hot component to higher effective temperatures and smaller radii, which leads to the photoionization of the outer atmosphere of the giant (Kenyon et al. 1993). Thus, in addition to being a fascinating and complex astronomical object, RR Tel is also recognized as being an excellent source of emission lines that may be used to confirm theoretical predictions of wavelengths. Many emission lines, especially from high ionization stages of iron and nickel, have been identified for the first time in the optical spectrum of RR Tel (see, e.g., Raassen 1985).

In an attempt to probe the optical spectrum of RR Tel as deeply as possible, we have obtained high spectral resolution observations using the CCD detector with the bench-mounted echelle spectrograph (BME) on the 1.5 m telescope at the Cerro Tololo Inter-American Observatory (CTIO). These data have proved superior to existing optical spectra, which were recorded on photographic emulsion with limited spectral resolution and dynamic range (Aller et al. 1973; Thackeray 1977). Therefore, in this investigation, we are able to measure reliable emission-line intensities for much weaker features than was previously possible. The result is a detailed line list for the optical spectrum of RR Tel with identifications and intensities (where possible) of hitherto unidentified lines, and spectral lines of increasingly higher degrees of ionization.

2. OBSERVATIONS AND DATA REDUCTION

All the spectroscopic observations were obtained at the Cerro Tololo Inter-American Observatory in 1993 July. The 1.5 m BME and Tektronix 2048 CCD with a 200 μm fiber, 900 mm collimator, and 590 mm long camera were used in order to give us spectral data with a resolution of $\lambda/\Delta\lambda \simeq 25{,}000$ and signal-to-noise ratio (S/N) in the continuum of typically S/N $\simeq 20$ pixel^{-1}. Thus a high-resolution, high-S/N spectrum of RR Tel in the wavelength range 3430–9320 Å was obtained. This allowed a greater dynamic range than was the case in earlier observations and enabled us to measure reliable line intensities for much weaker features than was previously possible. Portions of our high-resolution data are shown in Figures 1 and 2.

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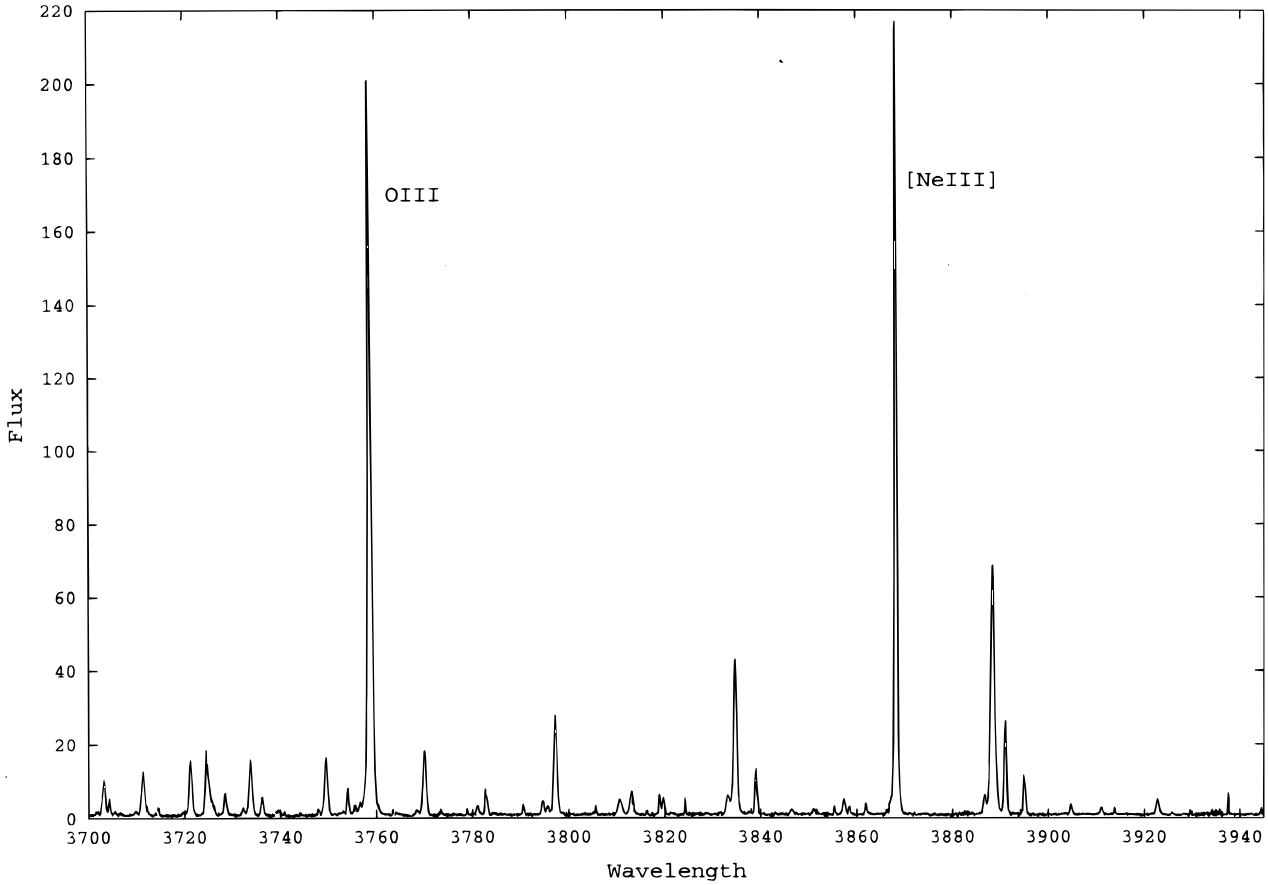

FIG. 1.—Flux-uncalibrated high-resolution optical spectrum of RR Tel in the wavelength range 3700–3945 Å, featuring the strong nebular lines of O III at 3759.80 Å and [Ne III] at 3868.74 Å.

In order to absolutely calibrate our data, it was necessary to obtain low-resolution spectra of RR Tel. The Cassegrain spectrograph and "2D-FRUTTI" on the 1.0 m telescope were used for this. However, this instrumental setup did not yield useful data for wavelengths beyond ~7000 Å, and hence no absolute line fluxes are available for the longer wavelengths. The low-resolution spectrum is shown in Figure 3. The accuracy of the flux calibration is estimated at 10%.

All CCD images were reduced using the Image Reduction and Analysis Facility version 2.3 implemented at the Queen's University Belfast Starlink node. Standard procedures were followed in the reduction of the images to one-dimensional spectra. The low-resolution spectra were optimally extracted and flux-calibrated using standards from CTIO lists. The densely packed echelle spectra were extracted using cosmic-ray rejection algorithms for sky regions only, as cosmic-ray hits in the spectra themselves could be confused with real emission features. Multiple high-resolution echelle images enabled us to median-filter the extracted spectra to subsequently eliminate cosmic rays. Once reduced to one-dimensional spectra, the data were input into the user-friendly spectrum-analysis program DIPSO (Howarth et al. 1996) for further analysis.

3. LINE IDENTIFICATIONS

The velocity-corrected measurement of each line of our RR Tel spectrum is listed, in angstroms, in column (1) of Table 1. In column (5), the suggested identities of the major contributors to these lines are listed, where the ion is followed by the laboratory wavelength. A superscript at one of these wavelengths refers to a note at the end of the table.

Initially, the procedure for identifying the lines was to compare our measurements with the finding list of Moore (1945). Subsequently, these were revised using the more recent compilation by Corliss & Sugar (1979) and the Fe II line lists of Johansson (1977). At longer wavelengths, there was definite evidence of telluric lines and also night-sky emission lines. These were identified, using the recent work of Osterbrock et al. (1996), as OH and O_2 emission lines.

However, in order to obtain an accurate line list, we realize that a line identification due purely to wavelength coincidence is not sufficient. Thus the list of line identifications was compared with the spectra of other astrophysical objects, most importantly, that of η Carinae (Aller 1966), as this is a similar object. This was useful, as (1) it helped to identify hitherto unknown lines that were not listed in the aforementioned catalogs of line identifications, and (2) when similar lines were present in both spectra, it made the identification of such a line in RR Tel more secure.

The spectra of other gaseous nebulae were also compared with RR Tel's spectrum, using the same process as for η Car. The objects chosen for this comparison were the planetary nebulae NGC 6886 (Hyung, Keyes, & Aller 1995), IC 418 (Hyung, Aller, & Feibelman 1994a), IC 4997 (Hyung, Aller, & Feibelman 1994b), NGC 6572 (Hyung, Aller, & Feibelman 1994c), IC 2149 (Feibelman, Hyung, & Aller 1994), NGC 6567 (Hyung, Aller, & Feibelman 1993), NGC 7027

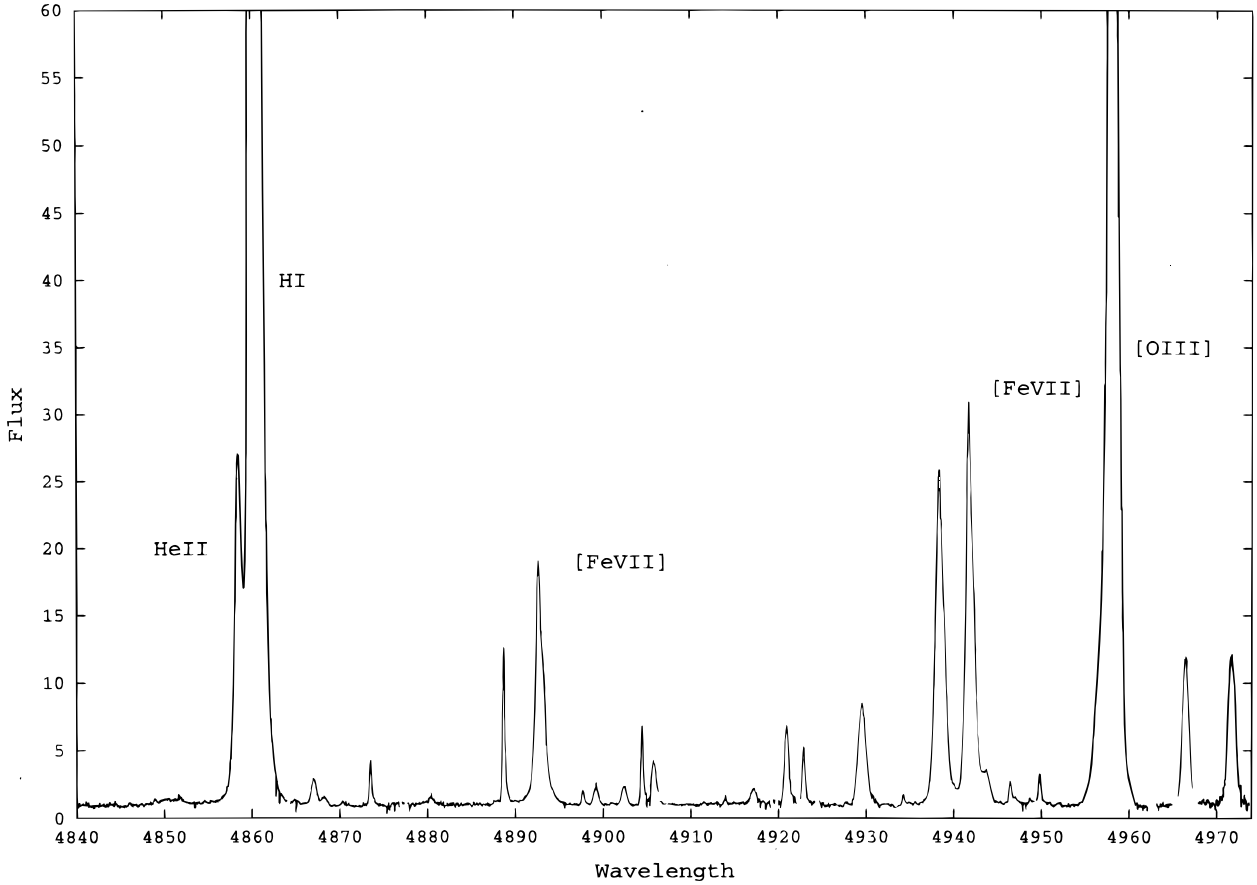

FIG. 2.—Flux-uncalibrated high-resolution optical spectrum of RR Tel in the wavelength range 4840–4974 Å, featuring lines of the highly ionized species [Fe VII] at 4893.90 Å and 4942.30 Å, as well as the strong Hβ line at 4861.33 Å.

(Aller & Keyes 1988), NGC 6302 (Aller & Czyzak 1978), and NGC 2440, NGC 6741, NGC 7009, NGC 7662, IC 2165, and IC 5217 (Wyse 1942), along with the H II region in the Orion Nebula (Osterbrock, Shaw, & Veilleux 1990; Osterbrock, Tran, & Vellieux 1992). In this case, when similar lines were found, it was very likely that the lines present in the planetary nebulae and H II regions were the same as those in RR Tel, as a consequence of its nebula-like extended envelope.

Other methods for ascertaining the accuracy of the line identifications existed. Initially, the identification was rejected if it was too far away from the measured wavelength, even if the feature was listed in the spectrum of η Car or other objects. As noted in § 2, the resolution of the instrument used to obtain the spectra was 25,000, equivalent to 0.14 Å at 3430 Å and 0.37 Å at 9320 Å. Therefore any line that differed from the measured wavelength by greater than 0.4 Å was generally discarded. The accuracy of the wavelength calibration was taken to be $\sim$0.03 Å at 3430 Å and $\sim$0.07 Å at 9320 Å. The velocity width of each line, Δv, in km s^{-1}, is listed in column (2) of Table 1, and this value serves as an indication of whether a line is resolved or not.

Any identification of a highly ionized species was treated with caution. The most abundant element found in the spectrum of RR Tel was iron, and the most ionized form was Fe VII. Thus it is improbable that a line from an ion with an ionization potential much greater than Fe^{+6} is present. For example, although the [S XIII] line at 3963.67 Å is a likely identification for the measurement at 3963.41 Å, its ionization potential is over 5 times that of Fe VII and has been omitted. However, RR Tel is known to show increasing degrees of ionization, and thus the [Ni VIII] line at 4446.20 Å is the probable identification of the line measured at 4446.37 Å even though its ionization potential is almost 30% greater than that of Fe VII.

After these methods were executed, in some cases it was still difficult to decide on a possible identification. Often, a line identification is more trustworthy if it is part of a multiplet where the other ionic transitions of that multiplet are also present. Conversely, if a line is the only observed component of a particular multiplet, its identification is questionable.

We made use of the Thackeray (1977) study in our work, although we note that many of his unresolved lines had become more easily identifiable, because of the increase in efficiency of detectors. An example of this is Thackeray's 4488.93 Å line, which he associated with both [Fe II] λ4488.75 and Fe II λ4489.19, although both iron lines are clearly resolved in the current RR Tel spectrum. However, it is still apparent that not all of the lines of this study are fully resolved. For example, the line at 3725.22 Å seems to be a blend of O II λ3725.30 and [O II] λ3726.00.

Twelve lines remain unidentified. Péquignot & Baluteau (1994) identified elements with $Z \geq 30$ in a nebula for the first time, but this did not prove to be helpful for RR Tel. In addition, there is no sign of TiO absorption as reported by Thackeray (1977).

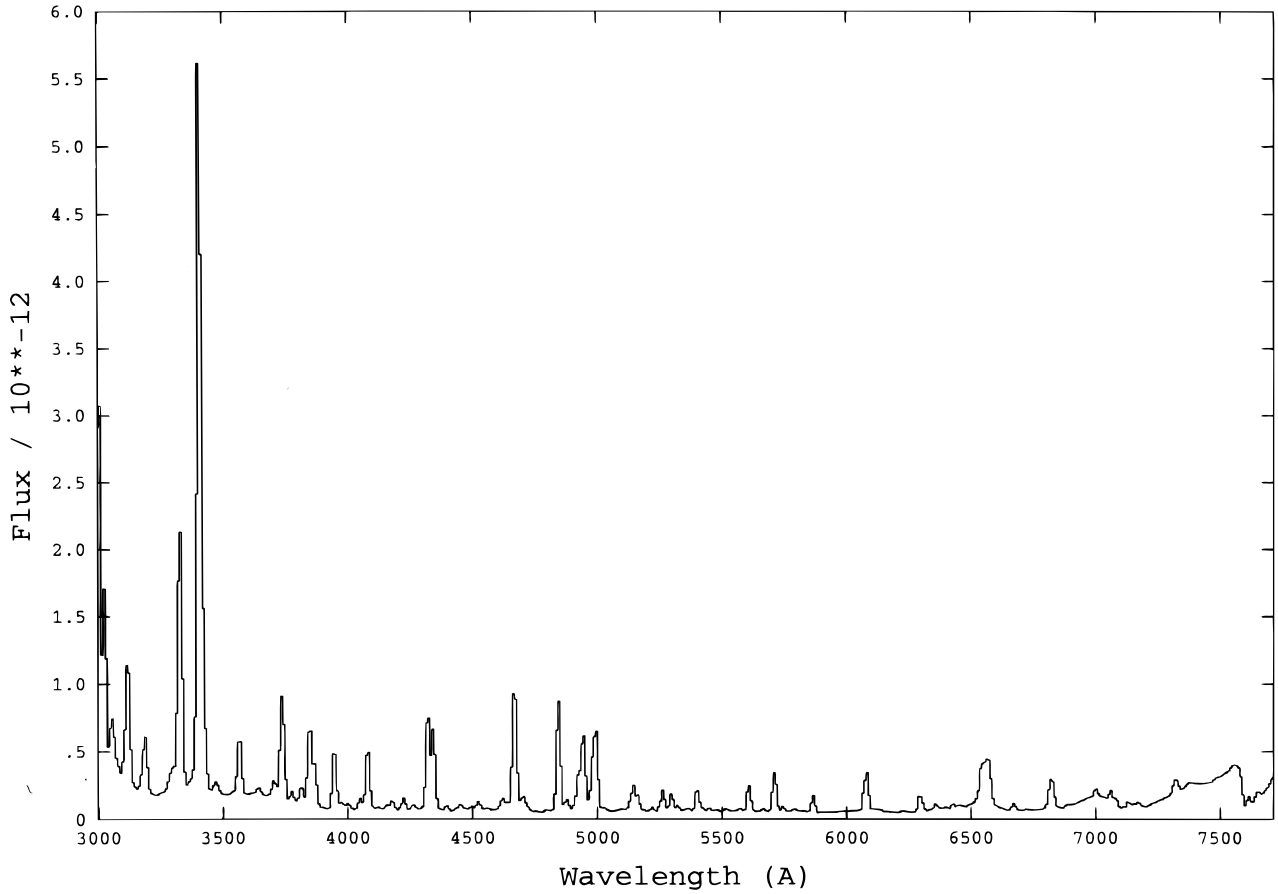

FIG. 3.—Flux-calibrated low-resolution optical spectrum of RR Tel. The flux is in units of 10^{-12} ergs cm^{-2} s^{-1}.

4. LINE INTENSITIES

The measured intensity of each line in ergs cm^{-2} s^{-1} is listed in column (3) of Table 1, while the value corrected for interstellar extinction is listed in column (4). These intensities were obtained by comparing the high- and low-resolution spectra. This was a formidable task because of the vast quantity of lines in the optical spectrum of RR Tel—in the low-resolution spectrum, most of the lines were not clearly resolved, leading to many blends. It therefore proved impossible to compare one particular line in the high-resolution spectrum with its counterpart in the low-resolution data, so, instead, the high-resolution data were degraded to the same quality as the low-resolution spectrum. A polynomial fit of the low-resolution data divided by the degraded high-resolution data was obtained, and the original high-resolution spectrum was multiplied by this fit. Thus a flux-calibrated, high-resolution spectrum was achieved. The error in each line intensity listed in Table 1 is estimated at less than 15%, except where indicated by the footnotes.

The line intensities were corrected for extinction using the coefficients listed in Cardelli, Clayton, & Mathis (1989) for the *UBVR* spectral regions. $E(B-V)$ for RR Tel is well quantified and taken to be equal to 0.08 (Jordan et al. 1994).

To the best of our knowledge, no other study of RR Tel exists that contains an absolutely calibrated line list of the optical spectrum. However, Aller et al. (1973) list line intensities relative to Hβ. Thus it was possible to carry out an approximate comparison between the intensity of RR Tel's lines in 1968 (Aller et al. 1973) and 1993, by scaling the line intensities in this study relative to Hβ. It was found that the strength of the lines for low-ionization species is decreasing, while the line intensities of species of higher degrees of ionization is increasing. For example, the line intensities of species such as He I, [O I], Fe II, and O III are decreasing while the intensity of [Fe V] lines is increasing. This is the expected result, as RR Tel's emission spectrum has been advancing toward higher excitation (Kenyon et al. 1993).

5. DISCUSSION

Out of the 491 lines measured in the optical spectrum of RR Tel, only 12 remain unidentified. The number of lines measured here but not listed in Thackeray (1977) is 70, including [Cu II] at 3806.34 Å, which was predicted by Thackeray to appear in RR Tel, because of its presence in the spectrum of η Car (Thackeray 1953).

Unfortunately, our spectra are not of a sufficiently high resolution to prove the existence of previously unobserved weak emission lines whose wavelengths have been theoretically predicted, such as the Fe XI transition, which was noted by Raassen (1985) to lie at a wavelength of 7891.8 Å.

Further observations of the RR Tel high-resolution spectrum are planned in 1996 July, using the University College London coudé echelle spectrograph on the 3.9 m Anglo-Australian Telescope (AAT). This should lead to both higher spectral resolution ($R = 50{,}000$) and higher S/N than the data presented here and will also allow us to obtain accurate absolutely calibrated data for the $\lambda > 7000$ Å

TABLE 1

OPTICAL LINE LIST OF RR TELESCOPII

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
3444.07	37	2.875	4.067	O III λ3444.10[b]	15
3475.73	12	0.033	0.047	Fe II λ3475.74	4
3487.22	95	0.397	0.562	Fe III λ3487.11	90
3488.90	74	0.499	0.706	Fe III λ3488.92[c]	60[d]
				Cr II λ3489.07[c]	135
3492.42	44	0.057[e]	0.081	[Fe VI] λ3492.10	4F
3494.64	15	0.062	0.087	Fe II λ3494.67	16
3502.16	89	0.331	0.468	[Fe II] λ3501.62	26F
				O IV λ3502.20	18
				Co II λ3501.72	2
3507.35	19	0.033[e]	0.046	Fe II λ3507.39[c]	16
				V II λ3507.53[c]	159
3555.99	45	0.219	0.310	[Fe VI] λ3555.60	4F
3574.17	53	0.092	0.130	[Fe VI] λ3573.86	9
				Ne II λ3574.23	9
3586.61	61	6.240	8.830	He I λ3587.05[c]	31
				[Fe VII] λ3587.20	3F
				[Co VI] λ3586.80	1F
3604.38	21	0.011[e]	0.015	Cr II λ3603.61[c]	13
				Cr II λ3603.80	13
3613.70	30	0.023[e]	0.033	He I λ3613.64[b]	6
3621.33	157	0.485	0.686	Fe II λ3621.27[c]	144
				Cr II λ3621.51[c]	98
				V II λ3621.20[a]	76
3626.94	21	0.016[e]	0.023	Fe II λ3637.17[c]	193
3634.24	25	0.048[e]	0.068	He I λ3634.37[c]	28
3658.58	9	0.006[e]	0.008	H I λ3658.64[b]	7
3659.41	25	0.011[e]	0.016	H I λ3659.42[b]	6
3660.30	29	0.016[e]	0.023	H I λ3660.28[b]	6
3661.15	27	0.018[e]	0.026	H I λ3661.11	6
3662.79	53	0.587	0.830	H I λ3662.26[b]	6
				[Fe VI] λ3662.50	4F
3664.69	40	0.075[e]	0.106	H I λ3664.68[b]	6
3666.15	37	0.080[e]	0.114	H I λ3666.10[b]	5
3667.74	42	0.096	0.136	H I λ3667.68[b]	5
3669.30	73	0.249	0.352	H I λ3669.46[b]	5
				[Ca VI] λ3669.10	1F
3671.47	42	0.119	0.168	H I λ3671.48[b]	5
3673.76	48	0.193	0.273	H I λ3673.76[c]	5
3676.41	51	0.252	0.356	H I λ3676.37[b]	4
3679.38	52	0.313	0.443	H I λ3679.36[b]	4
3682.87	55	0.373	0.528	H I λ3682.81[b]	4
3686.83	63	0.495	0.700	H I λ3686.83[b]	4
3691.61	52	0.291	0.412	H I λ3691.56[b]	4
3695.55	31	0.028[e]	0.039	O III λ3695.37	21
3697.16	58	0.473	0.669	H I λ3697.15[b]	3
3698.88	40[e]	0.049	0.070	O III λ3698.70	21
3702.26	26	0.040[e]	0.057	O V λ3702.00	16
3702.68	18	0.031[e]	0.043	O III λ3702.75[b]	14
3703.88	57	0.733	1.040	H I λ3703.85[c]	3
3705.02	32	0.186	0.263	He I λ3705.00[c]	25
3706.17	39	0.054[e]	0.077	Ti II λ3706.22	73
				Ca II λ3706.03	3
3707.27	30	0.024[e]	0.034	O III λ3707.24[b]	14
3710.48	50	0.061[e]	0.086	S III λ3710.42	1
3711.99	58	0.918	1.300	H I λ3711.97[c]	3
3715.15	25	0.101[e]	0.143	O III λ3715.08[b]	14
				Cr II λ3715.19[c]	20
				He II λ3715.27[b]	...
3721.88	52	1.100	1.560	H I λ3721.95[c]	3
				[S III] λ3721.70[b]	2F
3725.23	11	0.726[e]	1.030	O II λ3725.30	14
				[O III] λ3726.03[c]	1F
3729.17	48	0.372	0.526	[O II] λ3728.76[b]	1F
				O IV λ3729.03	6
3732.90	43	0.108	0.153	He I λ3732.86[b]	24
3734.41	57	1.160	1.640	H I λ3734.37[c]	3
3736.82	43	0.276	0.390	O IV λ3736.78[b]	6
				Ca II λ3736.90	3

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
3740.15	88	0.165	0.233	He II λ3740.28	...
				[Fe VI] λ3740.20	5F
3741.52	15	0.026[e]	0.036	Fe II λ3741.56	15
				Ti II λ3741.63	72
3744.97	44	0.032[e]	0.045	O IV λ3744.73	6
3748.63	34	0.062[e]	0.088	Fe II λ3748.49[c]	154
				He II λ3748.66[b]	...
3750.19	58	1.200	1.700	H I λ3750.15[c]	2
3752.86	22	0.010[e]	0.014	N III λ3752.80	...
3753.74	73	0.065[e]	0.092	Ne II λ3753.83	38
3754.71	32	0.290	0.410	Cr II λ3754.59[c]	20
				O III λ3754.67[b]	2
				N III λ3754.62	4
3756.09	46	0.114	0.161	Fe V λ3755.70	-F
				He I λ3756.10	66
3757.31	63	0.210	0.297	O III λ3757.21[b]	2
3759.25	69	16.10	22.80	O III λ3759.87[b]	2
3769.16	59	0.114	0.161	Ni III λ3769.46[c]	4
				He II λ3769.13[b]	...
				He I λ3768.81	65
3770.64	57	1.300	1.840	H I λ3770.63[c]	2
				N III λ3771.08	4
3774.05	28	0.066[e]	0.093	O III λ3774.00[b]	2
				Fe II λ3774.16	29
3779.04	11	0.003[f]	0.005	S III λ3778.90	5
3779.56	18	0.037	0.053	Fe II λ3779.58	23
3781.72	47	0.131	0.185	He II λ3781.68[b]	5
3783.52	48	0.342	0.484	Fe II λ3783.35	14
				[Fe V] λ3783.22	3F
3791.27	34	0.097	0.137	O III λ3791.26[b]	2
3795.30	38	0.204	0.289	[Fe V] λ3794.94	3F
3796.31	39	0.147	0.208	He II λ3796.33	29
3797.94	58	1.860	2.630	H I λ3797.90[c]	2
3806.31	18	5.210	7.370	[Cu II] λ3806.34[c]	2F
3811.35	72	0.345	0.488	O III λ3810.96	2
				O VI λ3811.36	1
3813.72	60	0.428	0.605	He II λ3813.50[b]	4
				[Fe VI] λ3813.54	3F
3819.60	31	0.192	0.272	He I λ3819.61[b]	22
3820.39	47	0.227	0.321	[Fe V] λ3820.20	3F
3824.91	15	0.085	0.120	Fe II λ3824.91[c]	29
3833.98	74	0.391	0.553	He II λ3833.80[b]	4
				He I λ3833.57	62
3835.43	61	2.870	4.060	H I λ3835.39	2
				O V λ3834.42	1
3838.10	80	0.016[e]	0.022	Mg I λ3838.29[c]	3
				[Fe V] λ3838.10	1F
3838.90	30	0.013[e]	0.018	[Fe V] λ3838.90	3F
3839.71	39	0.573	0.811	[Fe V] λ3839.27	3F
3847.12	44	0.076	0.107	[Fe VI] λ3846.94	-F
				[Fe V] λ3846.72	-F
3851.78	46	0.076	0.107	[Fe V] λ3851.34	3F
3852.51	22	0.017[e]	0.025	[Fe II] λ3851.63[c]	9F
				V II λ3852.10[c]	3
				O II λ3852.45	...
3853.66	29	0.011[e]	0.015	Si II λ3853.66	1
3856.02	23	0.057	0.081	Si II λ3856.02[b]	1
3858.09	50	0.211	0.298	He II λ3858.07[b]	4
3859.16	34	0.080	0.113	[Ni IV] λ3858.90	-F
3862.60	30	0.097	0.137	Si II λ3862.59[b]	1
3867.30	2	0.263[e]	0.372	He I λ3867.48	20
3868.87	43	10.10	14.30	[Ne III] λ3868.74[b]	1F
3887.47	42	0.219[e]	0.310	He II λ3887.44	4
3889.06	70	4.870	6.890	Hζ λ3889.05[b]	2
3891.70	42	1.110	1.570	[Fe V] λ3891.80[b]	3F
3895.70	44	0.451	0.638	[Fe V] λ3895.70[b]	1F
3905.42	40	0.114	0.161	[Fe VI] λ3905.01	-F
				[Fe II] λ3905.62	8F
				Si I λ3905.53	3

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
3911.75	42	0.080	0.113	O II λ3911.96	17
3914.50	18	0.032	0.046	Fe II λ3914.48[b]	3
3923.48	50	0.206	0.291	He II λ3923.48[b]	4
3926.53	33	0.020	0.029	He I λ3926.53[b]	58
3930.27	12	0.018[e]	0.026	Fe II λ3930.31	3
3933.75	37	0.007[f]	0.009	Ca II λ3933.66	1
3936.45	83	0.006[f]	0.009	Fe II λ3935.94	173
				He I λ3935.91[b]	57
3938.29	16	0.095[e]	0.135	Fe II λ3938.29[b]	3
3945.18	17	0.030[e]	0.043	Fe II λ3945.21[b]	3
3957.05	48	0.032[e]	0.045	[Fe IV] λ3958.10	-F
				[Ni V] λ3956.90	-F
3961.59	31	0.031[e]	0.044	O III λ3961.59	17
3963.41	27	0.007[e]	0.009	...	...
3964.77	33	0.046[e]	0.065	He I λ3964.73[b]	5
3967.60	43	3.820	5.400	[Ne III] λ3967.51[b]	1F
				He II λ3968.43	3
3970.12	62	4.560	6.450	Hε λ3970.07	1
				Fe II λ3969.40[c]	3
3974.14	15	0.051[e]	0.073	Fe II λ3974.16[c]	29
3988.91	47.08	0.021[e]	0.030	N I λ3989.05	...
				Sc II λ3989.06	8
3990.63	56	0.016[e]	0.023	[Ni IV] λ3990.25	-F
3992.80	80	0.649	0.918	[Ni II] λ3993.15[b]	4F
3997.75	48	0.030	0.043	[Ca V] λ3997.28	2F
4001.79	76	0.388	0.521	Fe II λ4002.07[c]	29
4003.58	38	0.054	0.072	[Fe V] λ4003.21	1F
4009.21	29	0.018	0.024	He I λ4009.27[c]	55
4011.23	47	0.027	0.036	[Na V] λ4011.20	1F
4014.91	48	0.053	0.072	Fe II λ4015.20	142
				[Fe VI] λ4014.56	-F
4018.40	50	0.054	0.072	Fe II λ4018.49	13
4024.50	29	0.062[e]	0.083	Fe II λ4024.55	127
4025.58	44	0.235	0.316	He II λ4025.60	3
				He I λ4025.49	19
4026.22	37	0.362	0.486	He I λ4026.19[c]	18
4028.66	122	0.045[e]	0.060	Ti II λ4028.33[c]	87
4039.95	62	0.022[e]	0.029	N II λ4039.35	...
4057.52	20	0.004[e]	0.005	N IV λ4057.80	3
4068.65	46	0.446[e]	0.599	[S II] λ4068.60[c]	1F
4070.01	29	0.046[e]	0.062	C III λ4070.03[b]	16
				O II λ4069.90	10
				Fe II λ4070.03	22
4071.51	44	0.347[e]	0.466	[Fe V] λ4071.50	1F
				O II λ4072.16[b]	10
				[Ni IV] λ4071.80	...
4074.08	30	0.013[e]	0.017	O III λ4073.90[b]	23
4075.87	14	0.012[e]	0.016	O II λ4075.87	10
4076.41	57	0.157	0.211	[S II] λ4076.22[b]	1F
4084.32	70	0.034[e]	0.046	O II λ4084.66[b]	21
				[Fe II] λ4084.32	24F
4087.26	10	0.006[e]	0.008	O II λ4087.16[b]	48
				Fe II λ4087.27	28
				N II λ4087.35	37
4097.30	31	0.345[e]	0.464	N III λ4097.31[b]	1
4100.04	51	0.408[e]	0.548	He II λ4100.04[b]	3
4101.73	61	5.770	7.750	Hδ λ4101.74[c]	1
4103.22	46	0.260[e]	0.349	N II λ4103.37[c]	1
4114.52	32	0.091	0.122	[Fe II] λ4114.48	23F
4119.31	27	0.011[e]	0.015	O II λ4119.23[b]	20
				Fe II λ4119.53	21
4120.85	23	0.052[e]	0.070	He I λ4120.80	16
4122.63	15	0.045	0.060	Fe II λ4122.64[c]	28
				[K V] λ4122.60[b]	1F
4124.73	15	0.015[e]	0.020	Fe II λ4124.79	22
4128.05	15	0.020	0.027	Si II λ4128.05[c]	3
4128.65	15	0.015	0.021	Fe II λ4128.74[c]	27
4138.39	18	0.007[e]	0.010	Fe II λ4138.40	39

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
4144.12 ……	60	0.288	0.387	He I λ4143.76[c]	53
				[Fe V] λ4144.40	-F
4146.05 ……	9	0.011[e]	0.014	Cr II λ4145.77[c]	162
				O II λ4146.09[b]	106
4146.59 ……	17	0.008[e]	0.010	[Fe II] λ4146.65	21F
				S II λ4146.94	65
4147.27 ……	13	0.007[e]	0.009	Fe II λ4147.26[c]	141
				Ni II λ4147.30[c]	…
4152.42 ……	39	0.051	0.069	[Co II] λ4152.59[c]	-F
				[Fe II] λ4152.78	…
				[Fe IV] λ4152.50	…
				C III λ4152.43	21
4163.39 ……	89	0.017[e]	0.023	[O III] λ4163.21	…
				[K V] λ4163.30[b]	1F
				Ti II λ4163.64	105
4165.67 ……	9	0.002[e]	0.003	[Cu II] λ4165.79	1F
4168.93 ……	32	0.007[e]	0.009	He I λ4168.97[b]	52
4173.44 ……	16	0.086	0.116	Fe II λ4173.45[c]	27
4177.20 ……	22	0.075	0.101	[Fe II] λ4177.21	21F
4177.64 ……	19	0.051	0.068	Fe II λ4177.70[c]	21
4178.85 ……	17	0.156	0.210	Fe II λ4178.86[c]	28
				[Fe II] λ4178.95	23F
4181.20 ……	39	0.104	0.140	[Fe V] λ4181.30[b]	1F
4186.86 ……	34	0.022	0.029	C III λ4187.05[b]	18
4187.82 ……	13	0.004[e]	0.005	[Ti II] λ4187.46	20F
4189.73 ……	37	0.017[e]	0.023	O II λ4189.77[b]	36
				S II λ4189.71	44
4192.02 ……	13	0.002[f]	0.003	Ni II λ4192.07[c]	10
4195.78 ……	80	0.035	0.047	N III λ4195.70[b]	6
4198.93 ……	57	0.743	0.998	Fe II λ4199.09[c]	141
				Cr II λ4199.02	180
4199.83 ……	55	0.217	0.292	He II λ4199.83[b]	3
4201.18 ……	24	0.037[e]	0.050	[Ni II] λ4201.19[c]	3F
4201.86 ……	29	0.014	0.019	[Ni II] λ4201.74	3F
4206.65 ……	36	0.043	0.058	[Fe IV] λ4206.30	-F
4209.03 ……	38	0.045	0.061	Cr II λ4209.02	162
4211.10 ……	24	0.023	0.031	[Fe II] λ4211.10	23F
4216.07 ……	14	0.005[e]	0.007	[Fe IV] λ4217.10	-F
4227.66 ……	83	0.086[e]	0.115	[Fe V] λ4227.74[b]	2F
4231.56 ……	19	0.007[e]	0.009	[Fe II] λ4231.56	21F
				Ne II λ4231.60	52
				V II λ4231.17	25
4232.23 ……	22	0.010	0.013	V II λ4232.07	225
4233.15 ……	18	0.143	0.192	Fe II λ4233.17[c]	27
4238.45 ……	88	0.086	0.116	Cr II λ4238.69	17
4243.96 ……	19	0.342	0.460	[Fe II] λ4243.98[c]	21F
4244.80 ……	20	0.144	0.194	[Fe II] λ4244.81	21F
4247.25 ……	74	0.725	0.974	C III λ4247.56	11
				Sc II λ4246.83	7
4251.45 ……	28	0.010[e]	0.013	[Fe II] λ4251.49	23F
4257.26 ……	27	0.066[e]	0.089	S II λ4257.42	66
				V II λ4257.02	200
4258.13 ……	18	0.045	0.061	Fe II λ4258.16[b]	28
4267.19 ……	51	0.020	0.027	C II λ4267.27[b]	6
4273.31 ……	16	0.017	0.023	Fe II λ4273.32	27
4276.84 ……	26	0.381	0.512	[Fe II] λ4276.83[b]	21F
				Fe II λ4276.81	…
4278.12 ……	15	0.017[e]	0.023	Fe II λ4278.13[b]	32
4287.32 ……	13	2.250	3.020	[Fe II] λ4287.40[b]	7F
4290.15 ……	11	0.005[e]	0.007	Ti II λ4290.22	41
4294.11 ……	28	0.010[e]	0.014	[Ni II] λ4294.11	4F
				[Fe V] λ4294.18	-F
				Ti II λ4294.09	20
4296.55 ……	16	0.113	0.152	Fe II λ4296.57[c]	28
4303.16 ……	16	0.065	0.087	Fe II λ4303.66[c]	27
				O II λ4303.82[b]	54
4305.89 ……	19	0.062	0.084	[Fe II] λ4305.90	21F
4312.82 ……	17	0.006[e]	0.007	Ti II λ4312.85[b]	41
4314.25 ……	16	0.031	0.042	Fe II λ4314.29	32

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
4319.53	18	0.157	0.211	[Fe II] λ4319.62[c]	21F
				O II λ4319.63[b]	2
4326.28	22	0.023	0.031	[Ni II] λ4326.28[c]	3F
4332.62	173	0.049	0.066	O II λ4332.76[b]	65
				S III λ4332.71	4
4338.77	63	0.548	0.736	He II λ4338.67[b]	3
4340.52	64	7.890	10.60	Hγ λ4340.47[c]	1
4343.91	64	0.032	0.043	Ti II λ4344.29	20
				Mn II λ4343.99	6
4346.82	19	0.050	0.065	[Fe II] λ4346.85	21F
4349.39	23	0.006[e]	0.008	O II λ4349.43[b]	2
4351.67	16	0.104	0.140	Fe II λ4351.76[b]	27
4352.70	21	0.125	0.168	[Fe II] λ4352.78	21F
4358.35	19	0.095	0.128	[Fe II] λ4358.37	21F
4359.31	18	0.274	0.368	[Fe II] λ4359.34[c]	7F
4363.32	40	9.210	12.40	[O III] λ4363.21[b]	3F
4368.25	14	0.006[e]	0.007	Fe II λ4363.26	...
4369.39	16	0.025	0.033	Fe II λ4369.40[c]	28
4370.70	23	0.003[e]	0.004	Fe II λ4371.10	4
				V II λ4370.63	...
4371.62	24	0.005[e]	0.006	O II λ4371.65	76
				C II λ4371.59	45
4372.43	20	0.076	0.102	[Fe II] λ4372.43[c]	21F
4379.12	39	0.023	0.031	N III λ4379.09[b]	17
4382.67	19	0.029	0.039	[Fe II] λ4382.75	6F
4384.22	14	0.031	0.041	Fe II λ4384.33	32
4385.27	15	0.050	0.067	Fe II λ4385.38[c]	27
4387.93	31	0.081	0.109	He I λ4387.93[b]	51
4395.01	17	0.021	0.028	Ti II λ4395.03	19
4398.05	85	0.057	0.077	Ne II λ4397.94	56
4399.77	16	0.005[e]	0.007	Ti II λ4399.77	51
4413.74	16	0.190	0.255	[Fe II] λ4413.78[c]	7F
				Fe II λ4413.60	32
4414.90	15	0.023[e]	0.031	[Fe II] λ4414.78[b]	6F
				O II λ4414.91[b]	5
4416.20	18	0.306	0.411	[Fe II] λ4416.27[c]	6F
4416.72	22	0.101	0.136	Fe II λ4416.82	27
4425.62	160	0.236[f]	0.317	[Fe V] λ4426.34	-F
4429.20	18	0.008[e]	0.011	V II λ4429.11	13
4432.44	19	0.022	0.030	[Fe II] λ4432.45[c]	6F
4437.57	25	0.013	0.018	He I λ4437.55[b]	50
4443.82	10	0.008	0.011	Ti II λ4443.80	19
4446.37	65	0.034	0.046	Fe II λ4446.25[c]	187
				[Ni VIII] λ4446.20	1F
4448.12	19	0.005[e]	0.006	O II λ4448.21[b]	35
4450.43	9	0.003[e]	0.005	Ti II λ4450.49	19
4452.03	17	0.116	0.156	[Fe II] λ4452.11[c]	7F
4454.68	34	0.040	0.054	Zr II λ4454.80	40
4457.79	17	0.149	0.200	[Fe II] λ4457.95[c]	6F
4461.51	28	0.008[e]	0.010	[Mn IV] λ4461.70	2F
				Fe II λ4461.43	26
4465.44	22	0.005[e]	0.006	O II λ4465.40[b]	94
				N II λ4465.54	21
4468.49	20	0.023	0.031	Ti II λ4468.48	31
4471.55	37	0.660	0.887	He I λ4471.48	14
4472.91	16	0.025[e]	0.034	Fe II λ4472.92[c]	37
4474.90	18	0.066	0.088	[Fe II] λ4474.91[c]	7F
				[Co VII] λ4475.00	2F
4479.17	42	0.059	0.079	[Fe II] λ4479.10	-F
4481.26	34	0.007[e]	0.010	Mg II λ4481.13[b]	4
				[Mn IV] λ4481.00	2F
4485.17	13	0.006[e]	0.007	...	...
4488.66	19	0.059	0.079	[Fe II] λ4488.75[c]	6F
4489.07	16	0.109	0.146	Fe II λ4489.19	37
4491.34	15	0.119	0.160	Fe II λ4491.40[c]	37
4492.61	19	0.039	0.053	[Fe II] λ4492.64	6F
4498.79	66	0.110	0.148	Ne II λ4498.94	64
4501.25	18	0.010	0.014	Ti II λ4501.27	31
4508.28	16	0.061	0.082	Fe II λ4508.26[c]	222

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
4509.50	51	0.101	0.136	[Fe II] λ4509.61	6F
4510.99	44	0.034	0.045	N III λ4510.92[b]	3
				[K IV] λ4510.93	2F
4514.88	15	0.040	0.054	[Fe II] λ4514.90	6F
				N III λ4514.89	3
				Ne III λ4514.86	...
4515.31	16	0.189	0.254	Fe II λ4515.19[c]	20
4516.82	45	0.082	0.110	Cr II λ4516.56	191
4520.16	17	0.147	0.198	Fe II λ4520.23[c]	37
4522.56	16	0.082	0.110	Fe II λ4522.63[c]	38
4528.38	19	0.014	0.019	[Fe II] λ4528.39	6F
4532.98	19	0.006[e]	0.008	[Fe II] λ4533.00[c]	6F
4534.14	16	0.053	0.071	Fe II λ4534.17[c]	37
				N III λ4534.57[b]	3
				Ti II λ4533.97	50
4541.00	17	0.057[e]	0.077	N II λ4541.35[b]	...
				O II λ4541.31[b]	...
4541.62	53	1.050	1.410	Fe II λ4541.52[c]	38
				He II λ4541.59[b]	2
4544.93	16	0.003[e]	0.004	N III λ4544.80[b]	12
				Ti II λ4545.14	30
				Cr II λ4544.70	16
4549.44	17	0.147	0.198	Fe II λ4549.47[c]	38
				Ti II λ4549.62	82
4555.84	16	0.176	0.237	Fe II λ4555.89[c]	37
				Cr II λ4555.02	44
4558.60	15	0.007	0.009	Cr II λ4558.66	44
4571.09	19	0.149	0.200	Mg I λ4571.10[c]	1
				Cr II λ4571.24	16
4576.33	16	0.075	0.101	Fe II λ4576.33[c]	38
4581.11	26	0.007[e]	0.009	Fe II λ4581.12	...
				[Cr II] λ4581.18	3F
4582.82	16	0.062	0.083	Fe II λ4582.84	37
4583.82	18	0.223	0.300	Fe II λ4583.83[c]	38
4590.99	27	0.010	0.013	O II λ4590.97[b]	15
4593.75	12	0.003[e]	0.004	C II λ4593.47	...
4596.15	80	0.022[e]	0.030	O II λ4596.17[b]	15
				Fe III λ4596.09	...
				[Ni III] λ4596.80	-F
4603.71	55	0.052	0.070	N V λ4603.83	1
4606.41	46	0.056	0.075	V II λ4606.59	45
4607.26	40	0.031	0.041	[Fe II] λ4607.13[b]	3F
4613.74	54	0.029	0.039	O II λ4613.67[b]	92
				N II λ4613.87[b]	5
				S III λ4613.47	10
4618.83	11	0.003[e]	0.004	Cr II λ4618.83[c]	44
				C II λ4618.85	50
4620.50	16	0.037	0.050	Fe II λ4620.51[b]	38
4623.16	45	0.021	0.029	[Co II] λ4623.10	-F
4625.47	45	0.095	0.127	[Ar V] λ4625.54[b]	2F
				Fe II λ4625.55	219
4627.99	28	0.008[e]	0.011	Fe II λ4627.86	54
				Ne II λ4627.85	73
4629.29	17	0.195	0.262	Fe II λ4629.34[c]	37
4632.08	40	0.121	0.163	Fe II λ4631.90	219
				[Fe II] λ4632.27	5F
4634.09	32	0.370	0.497	N III λ4634.16[b]	2
4639.64	19	0.061	0.082	[Fe II] λ4639.68[c]	4F
4640.63	32	0.800	1.080	N III λ4640.64[b]	2
4641.85	41	0.160	0.215	N III λ4641.90[b]	2
				O II λ4641.81[b]	1
4647.38	34	0.087	0.116	C III λ4647.46[b]	1
				[Cr V] λ4647.50	3F
4649.12	30	0.039	0.053	O II λ4649.14[b]	1
4650.23	25	0.024	0.033	C III λ4650.16[b]	1
4650.82	24	0.011[e]	0.014	O II λ4650.84[b]	1
4651.97	60	0.065[e]	0.087	Fe II λ4652.28	219
				[Co VII] λ4652.20	1F
4654.40	42	0.018	0.024	Si IV λ4654.14	7

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
4657.04	27	0.193[e]	0.259	Fe II λ4656.97	43
4658.36	46	0.421	0.566	[Fe III] λ4658.10[b]	3F
				C IV λ46658.64[b]	8
4661.66	32	0.010	0.014	O II λ4661.64[b]	1
4663.69	12	0.012	0.015	Fe II λ4663.70	44
				Fe III λ4663.78	52
4664.41	17	0.021	0.029	[Fe II] λ4664.45[c]	4F
				Fe II λ4664.49	...
4665.60	42	0.016[e]	0.022	Fe II λ4665.80	26
				[Fe II] λ4665.65	4F
				Si III λ4665.87	13
4666.72	16	0.053	0.071	Fe II λ4666.75[b]	37
				[Fe III] λ4667.00	3F
4669.79	77	0.079	0.105	O II λ4669.53[b]	83
				Fe II λ4670.17	25
				[Fe III] λ4669.60	3F
4676.09	42	0.016[e]	0.022	O II λ4676.23[b]	1
4680.07	67	0.016[e]	0.022	...	...
4682.13	14	0.020[f]	0.027	Cu II λ4681.99	4
4685.75	57	16.90	22.70	He II λ4685.68[b]	1
4690.30	17	0.018	0.025	Cr IV λ4690.28	...
4696.38	90	0.051[e]	0.069	O II λ4696.36[b]	1
4698.80	58	0.511	0.687	[Fe VII] λ4699.00	2F
4701.77	44	0.135	0.181	[Fe III] λ4701.62[b]	3F
4707.12	27	0.004[e]	0.006	N IV λ4707.31	...
4711.47	72	0.052[e]	0.070	[Ar IV] λ4711.39[b]	1F
4713.10	31	0.182	0.245	He I λ4713.14[c]	12
4714.23	46	0.589	0.792	[Ne IV] λ4714.28[b]	1F
4724.23	46	0.564	0.758	[Ne IV] λ4724.15[b]	1F
				Fe II λ4724.07	17
4725.68	50	0.403	0.542	[Ne IV] λ4725.62[b]	1F
4728.05	18	0.147	0.198	[Fe II] λ4728.07[c]	4F
				Mn II λ4727.90	5
4731.43	16	0.049	0.066	Fe II λ4731.44[c]	43
4734.14	41	0.053	0.071	[Fe III] λ4733.93[b]	3F
4740.31	67	0.248	0.333	[Ar IV] λ4740.10[b]	1F
4745.43	12	0.004[e]	0.005	[Fe II] λ4745.49[c]	20F
4747.21	20	0.006[e]	0.007	[Co II] λ4747.20	-F
4754.99	41	0.062	0.083	[Fe III] λ4754.70[b]	3F
				S II λ4755.12	...
4769.68	44	0.062	0.083	[Fe III] λ4769.60[b]	3F
4772.04	15	0.008	0.010	[Fe II] λ4772.07[c]	4F
4774.72	20	0.077	0.104	[Fe II] λ4774.74[c]	20F
4777.92	43	0.031	0.041	[Fe III] λ4777.88[b]	3F
4788.55	42	0.018	0.024	[Cr V] λ4788.50	3F
				N II λ4788.13	20
4798.24	16	0.026	0.035	[Fe II] λ4792.28	...
				O IV λ4798.25	9
4805.47	14	0.009	0.012	Ti II λ4805.11	...
				Cr II λ4805.18	92
4814.53	18	0.261	0.351	[Fe II] λ4814.55[c]	20F
4824.10	16	0.013	0.018	Cr II λ4824.13[c]	30
				S II λ4824.07	52
				O IV λ4823.93	9
4825.67	17	0.005[e]	0.007	Fe II λ4825.71	30
4833.06	28	0.005[e]	0.007	Fe II λ4833.21	30
4846.93	16	0.003[e]	0.004	Fe II λ4846.92	...
4849.83	22	0.004[e]	0.005	Ne II λ4849.40	71
4852.66	39	0.007[e]	0.009	[Fe II] λ4852.73[c]	20F
4859.45	80	1.380	1.850	He II λ4859.32[b]	2
4861.41	67	18.60	25.00	Hβ λ4861.33[c]	1
4867.95	42	0.062	0.083	[Fe IV] λ4868.00	-F
				[Fe II] λ4867.73	...
4869.10	40	0.014[e]	0.019	Fe II λ4868.82	30
4871.25	28	0.007[e]	0.010	O II λ4871.58[b]	57
				Fe II λ4871.27	25
				[V II] λ4871.43	8F
4874.41	19	0.053	0.071	[Fe II] λ4874.49[c]	20F
4881.29	46	0.014[e]	0.019	[Fe III] λ4881.00[b]	2F

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
4889.60	18	0.166	0.233	[Fe II] λ4889.63[c]	4F
4893.66	65	0.846	1.140	[Fe VII] λ4893.90[b]	2F
4898.60	20	0.017	0.022	V II λ4898.64	...
4900.07	35	0.039	0.052	[Fe IV] λ4900.05	-F
4901.96	30	0.005[e]	0.006	Cr II λ4901.65[c]	...
4903.27	38	0.044	0.059	[Fe IV] λ4903.50	-F
4905.33	19	0.086	0.116	[Fe II] λ4905.35[c]	20F
4906.66	38	0.091	0.123	[Fe IV] λ4906.70[b]	-F
4914.84	14	0.006	0.007	N I λ4914.94	9
4918.04	43	0.038	0.051	Fe III λ4918.00[b]	...
				[Fe IV] λ4918.10	-F
4921.95	33	0.141	0.189	He I λ4921.93[b]	48
4923.91	21	0.068	0.092	Fe II λ4923.92[c]	42
4930.53	60	0.349	0.469	[O III] λ4931.00[b]	1F
				[Fe III] λ4930.50	1F
				[Fe III] λ4930.70	1F
4935.14	20	0.009[e]	0.011	N I λ4935.03	9
4939.29	69	1.120	1.510	[Ca VII] λ4940.30	1F
4942.71	61	1.160	1.560	[Fe VII] λ4942.30[b]	2F
4947.38	320	0.021	0.028	[Fe II] λ4947.38[c]	20F
				V II λ4947.58	197
				[Cr II] λ4947.17	15F
4949.68	32	0.009	0.012	Fe II λ4950.42	...
4950.73	20	0.035	0.047	[Fe II] λ4950.74[c]	20F
4952.87	29	0.005	0.007	Cr II λ4952.78	...
4959.07	59	6.500	8.740	[O III] λ4958.91[b]	1F
4967.34	50	0.378	0.508	[Fe VI] λ4967.14	2F
4972.62	60	0.457[e]	0.614	[Fe VI] λ4972.47[b]	2F
5460.74	79	0.065[e]	0.081	Fe III λ5460.81	68
5485.39	47	0.021[e]	0.026	[Fe VI] λ5485.70[b]	1F
5495.42	14	0.014[e]	0.017	[Fe II] λ5495.82	17F
5496.06	31	0.013[e]	0.016	[Fe II] λ5495.82[c]	...
				Si II λ5496.24	...
5527.35	21	0.019	0.024	[Fe II] λ5527.33[c]	17F
5534.88	19	0.016	0.021	[Fe II] λ5534.86[c]	55
5586.31	77	0.041[e]	0.051	[Ca VI] λ5586.31	2F
5592.23	57	0.023[e]	0.028	O III λ5592.37[b]	5
5618.66	75	0.336	0.419	[Cr II] λ5618.90	1F
5631.35	78	0.052	0.065	[Fe VI] λ5631.07[b]	1F
				[Ca VI] λ5631.40	2F
5677.14	60	0.030	0.037	[Fe VI] λ5676.95[b]	1F
5684.56	26	0.004[e]	0.005	Sc II λ5684.19	29
5686.58	54	0.008[e]	0.009	N II λ5686.21	3
5688.42	35	0.005[e]	0.007	Fe II λ5688.23	...
				Si II λ5688.86	...
5711.30	33	0.007[e]	0.009	[Ni II] λ5711.46	14F
5720.88	58	0.383	0.478	[Ni VI] λ5720.10	...
				[Fe VII] λ5720.90[b]	1F
5722.10	44	0.401	0.500	Fe II λ5722.56	58
5747.03	44	0.010[e]	0.012	[Fe II] λ5746.96[c]	17F
5754.86	41	0.033	0.041	[N II] λ5754.80[c]	3F
5875.79	41	0.180	0.225	He I λ5875.65[c]	11
				[Fe VI] λ5875.75	-F
5932.08	48	0.010	0.012	Fe II λ5932.05	47
5991.28	24	0.007[e]	0.009	Fe II λ5991.38	46
6004.85	33	0.008[e]	0.011	He II λ6004.80[b]	
6036.89	48	0.011[e]	0.015	He II λ6036.70[b]	8
6086.94	59	1.090[e]	1.360	[Ca V] λ6086.37[b]	1F
				V II λ6086.93	125
6101.89	48	0.008[e]	0.010	[K IV] λ6101.83[b]	1F
6182.23	22	0.006[e]	0.008	...	...
6300.28	17	0.134	0.158	[O I] λ6300.32[b]	1F
6301.44	11	0.070	0.083	...	...
6310.57	40	0.020[e]	0.024	[S III] λ6310.20[c]	3F
				He II λ6310.80[b]	7
6312.32	50	0.067	0.080	[S III] λ6312.06[b]	3F
6317.90	33	0.011[e]	0.013	Fe II λ6318.00	...
6347.09	53	0.011[e]	0.013	Si II λ6347.09[b]	2
				N II λ6347.10	46

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
6363.81	16	0.049	0.058	[O I] λ6363.88[b]	1F
6364.98	14	0.029	0.034	N II λ6364.90	...
6371.42	25	0.013[e]	0.016	Si II λ6371.36[b]	2
6383.71	23	0.014	0.017	Fe II λ6383.75	...
6385.41	21	0.012	0.014	Fe II λ6385.47	...
6406.45	156	0.027[e]	0.032	He II λ6406.30[b]	7
				Fe II λ6407.30	74
6416.88	23	0.010[e]	0.012	Fe II λ6416.91	74
6432.64	12	0.016	0.019	Fe II λ6432.65	40
6435.13	52	0.071	0.084	[Ar IV] λ6435.10[b]	1F
6456.35	17	0.019	0.022	Fe II λ6456.38	74
6506.24	13	0.007[e]	0.008	Fe II λ6506.33	...
6526.85	65	0.020[e]	0.024	[N II] λ6527.40	1F
				[Si I] λ6526.85	1F
6534.30	14	0.003	0.004	...	...
6560.25	117	0.770[e]	0.960	He II λ6560.10[b]	2
6563.06	70	[g]		Hα λ6562.82[b]	1
6583.91	83	0.106	0.125	[N II] λ6583.39[b]	1F
6626.57	39	0.012[e]	0.014	Fe II λ6627.28	210
6666.85	22	0.010[e]	0.012	[Ni II] λ6666.78[c]	2F
				O II λ6666.94	85
6678.16	20	0.086	0.101	He I λ6678.15[b]	46
6683.34	83	0.044	0.052	He II λ6683.23[b]	7
6792.69	35	0.014[e]	0.016	[Fe IV] λ6791.9	-F
6809.31	16	0.007[e]	0.008	[Fe II] λ6809.21	31F
6823.36	210	0.149	0.176	Fe II λ6823.09	...
6830.26	243	0.327	0.386	O V λ6830.00	12
				[Fe II] λ6830.06	32F
6835.82	15	0.057	0.067	N II λ6836.20	54
6890.71	16	...	...	He II λ6890.88[b]	7
6941.10	25	...	...	[Ni I] λ6941.63	2F
6997.58	53	...	...	[Fe IV] λ6996.80	-F
7005.87	54	...	...	[Ar V] λ7005.70[b]	1F
7065.34	42	...	...	He I λ7065.19[b]	10
7136.05	62	...	...	[Ar III] λ7135.80[c]	1F
7155.15	21	...	...	[Fe II] λ7155.14	14F
7171.42	121	...	...	[Ar IV] λ7170.40[b]	2F
				[Fe II] λ7171.98	14F
7177.62	61	...	...	He II λ7177.50[b]	6
7277.74	23	...	...	V II λ7277.17	...
7281.32	40	...	...	He I λ7281.35[b]	45
7301.91	26	...	...	Fe II λ7301.57	72
7317.69	18	...	...	S II λ7317.63	18
7320.21	71	...	...	[O II] λ7319.90[b]	2F
7330.67	56	...	...	[O II] λ7330.70[b]	2F
				Mn II λ7330.54	4
7342.25	16	...	...	Fe II λ7342.42	...
7377.87	19	...	...	[Ni II] λ7377.90	2F
7409.52	28	...	...	Fe II λ7409.03	...
7411.62	32	...	...	[Ni II] λ7411.57[b]	2F
				[V II] λ7411.90	4F
7413.78	30	...	...	[Ni II] λ7413.33	2F
				OH λ7413.75	...
7452.49	33	...	...	[Fe II] λ7452.50[b]	14F
7592.77	79	...	...	He II λ7592.74[b]	6
7711.47	30	...	...	Fe II λ7711.44	73
7713.98	20	...	...	...	...
7795.59	17	...	...	...	...
7822.89	13	...	...	...	...
7854.91	23	...	...	S II λ7855.523	...
7917.74	30	...	...	[Ti II] λ7916.25	6F
7966.14	15	...	...	S II λ7967.43	12
				Fe II λ7967.79	...
8027.38	14	...	...	OH λ8028.17	...
8061.03	41	...	...	[Ti II] λ8060.16	6F
				Fe II λ8060.16	...
8063.69	34	...	...	Fe II λ8062.98	...
				Fe II λ8064.27	...

TABLE 1—*Continued*

Wavelength (Å) (1)	Δv (km s^{-1}) (2)	Intensity (10^{12} ergs cm^{-2} s^{-1}) Measured (3)	Corrected[a] (4)	Identification (5)	Multiplet Number (6)
8237.01	45	...	...	H I λ8236.90[b]	6
				Fe II λ8237.14	...
8269.33	16	...	...	...	...
8400.65	15	...	...	[Cr II] λ8400.89	19F
8431.72	26	...	...	C V λ8432.20	...
8467.10	33	...	...	H I λ8467.26[b]	10
8468.60	20	...	...	Fe II λ8469.20	...
8490.04	22	...	...	[V II] λ8490.44	17F
8502.68	80	...	...	H I λ8502.65[b]	10
8579.38	81	...	...	[V II] λ8579.15	11F
8590.18	45	...	...	...	...
8598.32	7	...	...	H I λ8598.39[b]	9
8616.82	21	...	...	[Fe II] λ8616.96[b]	13F
8693.29	19	...	...	O_2 λ8693.22	...
8750.52	44	...	...	H I λ8750.48[b]	9
8769.50	12	...	...	OH λ8769.14	...
8780.01	14	...	...	Fe II λ8780.16	...
8828.74	14	...	...	Fe II λ8827.76	...
8862.92	39	...	...	H I λ8862.79[b]	9
8921.27	18	...	...	...	...
8926.68	32	...	...	Fe II λ8926.65	...
9014.68	40	...	...	H I λ9014.91[b]	9
9063.25	60	...	...	He I λ9063.40	77
9069.37	46	...	...	[S III] λ9069.40[b]	1F
9203.28	16	...	...	Fe II λ9203.13	...
9229.06	37	...	...	H I λ9229.02[b]	8

[a] Measured intensities corrected for interstellar extinction using $E(B-V) = 0.08$ (see text for details).
[b] Observed in the spectrum of a gaseous nebula (see § 3 for details).
[c] Observed in the spectrum of η Car (see § 3 for details).
[d] In the cases in which more than one identification is listed for a given line, the first is taken to be the primary contributor to the blend.
[e] The estimated error in the line intensity is between 15% and 40%.
[f] The estimated error in the line intensity is greater than 40%.
[g] The line was saturated in the high-resolution spectrum.

region, in contrast to the present paper. In the future, we intend to use our high-resolution optical (CTIO and AAT) observations to undertake a detailed analysis of the emitting regions of the RR Tel system and to investigate changes in the physical conditions between the 1993 and 1996 observations. This work will benefit from our recent diagnostic calculations for many species observed in the optical wavelength range, including S II (Keenan et al. 1996), O I (Keenan et al. 1995), Fe III (Keenan et al. 1993), and Fe VII (Keenan & Norrington 1991). Many of the diagnostically important emission lines that arise from these species are intrinsically weak and will only be reliably detected in the high spectral resolution and high-S/N observations mentioned here. We also intend to compare our optical observations with near-simultaneous high-resolution spectra from the *International Ultraviolet Explorer* satellite, which have been obtained for the CTIO observations and are planned for the AAT data, noting that a meaningful comparison of UV and optical line fluxes will therefore be possible, greatly increasing their diagnostic potential. For example, the O III and Fe VII optical lines provide useful temperature diagnostics, but when combined with O III λλ1661, 1667 and Fe VII λ2015, respectively, they also provide excellent density diagnostics (Keenan & Aggarwal 1987; Keenan & Norrington 1991).

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REFERENCES

Aller, L. H. 1966, Proc. Natl. Acad. Sci., 55, 671
Aller, L. H., & Czyzak, S. J. 1978, Proc. Natl. Acad. Sci., 75, 1
Aller, L. H., & Keyes, C. D. 1988, Proc. Natl. Acad. Sci., 85, 2417
Aller, L. H., Polidan, R. S., Rhodes, E. J., & Wares, G. W. 1973, Ap&SS, 20, 93
Cardelli, J. A., Clayton, G. C., & Mathis, J. C. 1989, ApJ, 345, 245
Corliss, C., & Sugar, J. 1979, J. Phys. Chem. Ref. Data, 8, 1
Feast, M. W., Whitelock, P. A., Catchpole, R. M., Roberts, G., & Carter, B. S. 1983, MNRAS, 202, 951
Feibelman, W. A., Hyung, S., & Aller, L. H. 1994, ApJ, 426, 653
Heck, A., & Manfroid, J. 1985, A&A, 142, 341
Howarth, I. D., Murray, J., Mills, D., & Berry, D. S. 1996, DIPSO (V3.4)—A Friendly Spectrum Analysis Program (Starlink User Note 50.20) (Chilton, UK: Rutherford Appleton Lab.)
Hyung, S., Aller, L. H., & Feibelman, W. A. 1993, PASP, 105, 1279
———. 1994a, PASP, 106, 745
———. 1994b, ApJS, 93, 465
———. 1994c, MNRAS, 269, 975

Hyung, S., Keyes, C. D., & Aller, L. H. 1995, MNRAS, 272, 49
Johansson, S. 1977, Phys. Scr., 15, 183
Jordan, S., Mürset, U., & Werner, K. 1994, A&A, 283, 475
Keenan, F. P., & Aggarwal, K. M. 1987, ApJ, 319, 403
Keenan, F. P., Aller, L. H., Bell, K. L., Hyung, S., McKenna, F. C., & Ramsbottom, C. A. 1996, MNRAS, 281, 1073
Keenan, F. P., Aller, L. H., Hyung, S., & Brown, P. J. F. 1995, PASP, 107, 148
Keenan, F. P., Aller, L. H., Hyung, S., Conlon, E. S., & Warren, G. A. 1993, ApJ, 410, 430
Keenan, F. P., & Norrington, P. H. 1991, ApJ, 368, 486
Kenyon, S. J., Mikołajewska, J., Mikołajewski, M., Polidan, R. S., & Slovak, M. H. 1993, AJ, 106, 1573
Moore, C. E. 1945, A Multiplet Table of Astrophysical Interest (rev. ed.; Princeton: Princeton Univ. Obs.)
Mürset, U., Nussbaumer, H., Schmid, H. M., & Vogel, M. 1991, A&A, 248, 458
Osterbrock, D. E., Fulbright, J. P., Martel, A. R., Keane, M. J., Trager, S. C., & Basri, G. 1996, PASP, 108, 2770
Osterbrock, D. E., Shaw, R. A., & Veilleux, S. 1990, ApJ, 352, 561
Osterbrock, D. E., Tran, H. D., & Veilleux, S. 1992, ApJ, 389, 305
Penston, M. V., et al. 1983, MNRAS, 202, 833
Péquignot, D., & Baluteau, J.-P. 1994, A&A, 283, 593 (erratum 289, 659)
Raassen, A. J. J. 1985, ApJ, 292, 696
Thackeray, A. D. 1953, MNRAS, 113, 211
———. 1977, MmRAS, 83, 1
Wyse, A. B. 1942, ApJ, 95, 356