A&A 413, 285–291 (2004)
DOI: 10.1051/0004-6361:20034136

Astronomy
&
Astrophysics

A spectroscopic atlas of *o* Pegasi (A1 IV) $\lambda\lambda$3826–4882[⋆]

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Received 30 July 2003 / Accepted 5 September 2003

Abstract. We present a spectroscopic atlas of the sharp-lined, hot metallic-line star *o* Pegasi (A1 IV) based on spectrograms obtained with the long camera of the 1.22-m telescope of the Dominion Astrophysical Observatory using a Reticon detector. For $\lambda\lambda$3826–4882 the inverse dispersion is 2.4 Å mm^{-1} with a resolution of 0.072 Å. At the continuum the mean signal-to-noise ratio is 800. The wavelengths in the laboratory frame, the equivalent widths, and the identifications of the various spectral features are given. For studies of similar stars and for atomic physicists interested in improving atomic line parameters, this atlas should provide useful guidance. The stellar and synthetic spectra with their corresponding line identifications can be examined at `http://cdsweb.u-strasbg.fr/cgi-bin/qcat?/A+A/413/285`.

Key words. atlases – stars: early-type – stars: individual – *o* Pegasi – stars: chemically peculiar

1. Introduction

o Pegasi (43 Pegasi, HR 8641, HD 214994, BD +28° 4436, HIP 112051) is a sharp-lined and unreddened prototype of the hot metallic-line stars. Recently Adelman et al. (2003) found that its evolutionary track indicates that during its lifetime in the main sequence band when it was closer to the Zero Age Main Sequence, it was a Mercury-Manganese star. Its spectral type of A1 IV by Cowley et al. (1969) confirms both Osawa (1959) and Ljunggren & Oja (1961).

The spectroscopic material used for this atlas was analyzed by Adelman et al. (2003) who provide information on previous studies of the optical region for this star. It is assembled from a set of very high quality spectra obtained with a Reticon on a spectrograph with a known amount of scattered light which has been removed. By making widely available this spectrum in FITS and HTML formats and its measurements, we hope this material will be useful for other studies.

2. Observations and reductions

This spectral atlas of *o* Pegasi's spectrum $\lambda\lambda$3826–4882 is based on 2nd order exposures obtained with a Reticon detector and the IS96B image slicer with wavelength coverage of 67 Å at the long camera of the 1.22-m telescope of the Dominion Astrophysical Observatory (DAO) and with a resolution of 0.072 Å (two pixels) or a resolving power of 60 000. Its mean signal-to-noise (S/N) ratio is 800. The central wavelengths of the 19 spectrum sections between λ3860 and λ4850 were separated by 55 Å allowing a several Å overlap between adjacent sections. A central stop placed in the beam removed light in the same manner as the secondary mirror of the telescope. The exposures were flat fielded with those of an incandescent lamp placed in the coudé mirror train as viewed through a filter.

Reticon exposures were reduced to one-dimensional FITS files with the Program RET72 (Hill & Fisher 1986) utilizing the lamp exposures. Flat images were summed to create mean flat exposures. The arc and stellar exposures were then divided by the mean flat image.

We measured the arc files interactively using the relevant routine in the spectrophotometric reduction and analysis program REDUCE (Hill & Fisher 1986). An initial approximation to the dispersion characteristics of each DAO spectrograph were input. Then corrections, based on the agreement between the predicted and measured position of each line, were used to predict the position of each new line. When the corrections became sufficiently small, the remaining lines were measured automatically. Heliocentric radial velocity corrections

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[⋆] Full Table 2 is only available in electronic form at the CDS via anonymous ftp to `cdsarc.u-strasbg.fr (130.79.128.5)`, via `http://cdsweb.u-strasbg.fr/cgi-bin/qcat?/A+A/413/285` or in MS Excel format via `http://www.brandonu.ca/physics/gulliver/atlases.html`

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Table 1. *o* Pegasi spectrograms.

Exposure Number	Heliocentric Julian Date	Central Wavelength (Å)	Radial Velocity (km s^{-1})	S/N
W489311199	2 449 201.9173	3860	7.8 ± 0.5	500
W489413273	2 449 617.7520	3915	7.5 ± 0.3	450
W489413233	2 449 615.7298	3970	7.7 ± 0.3	900
W48915377	2 448 540.8790	4025	8.0 ± 0.2	580
W48927713	2 448 848.8472	4025	8.2 ± 0.2	530
WoPeg4025		4025		600
W48927744	2 448 849.8493	4080	7.6 ± 0.7	1000
W48915305	2 448 537.8588	4135	7.3 ± 0.2	370
W48915328	2 448 538.7153	4135	7.2 ± 0.3	560
WoPeg4135		4135		650
W48915333	2 448 538.8418	4190	7.7 ± 0.2	730
W48915337	2 448 538.9563	4245	7.7 ± 0.2	590
W48927803	2 448 851.8163	4245		650
W48915372	2 448 540.7629	4300	8.1 ± 0.3	700
W48915367	2 448 540.6606	4355	7.6 ± 0.6	500
W48915362	2 448 539.9318	4410	7.7 ± 0.3	650
W48915357	2 448 539.8269	4465	8.4 ± 0.3	1000
W48915353	2 448 539.7186	4520	7.7 ± 0.1	840
W48927770	2 448 849.8404	4575	7.9 ± 0.6	830
W48927775	2 448 850.9332	4630	7.3 ± 0.1	700
W48927632	2 448 845.8784	4685	7.4 ± 0.5	650
W48927602	2 448 844.9214	4740	8.7 ± 0.9	550
W48927809	2 448 851.9189	4795	7.3 ± 0.1	850
W48927843	2 448 852.8288	4795	7.5 ± 0.1	920
WoPeg4795		4795		800
W48927849	2 448 852.9263	4850	7.6 ± 0.6	800

were calculated with the program VSUN (Hill & Fisher 1986). Wavelength-calibrated spectra were produced with REDUCE using the arc files. The wavelength scale accuracy is better than 0.005 Å.

Table 1 lists the spectrograms with their exposure numbers, Heliocentric Julian Dates at the mid-points of their exposures, central wavelengths, the derived radial velocities and their associated errors, and an estimate of the S/N ratio. The S/N ratio of each section was estimated from the root-mean-square deviation for the continuum point intervals, usually smooth regions without lines close to the continuum, as part of the rectification process. The mean of these S/N ratios is about 800:1.

The radial velocity of each spectrum was measured using the program VCROSS (Hill & Fisher 1986) that cross-correlated the stellar with a synthetic spectrum calculated with the preliminary atmospheric parameters of $T_{\rm eff}$ = 9600 K, log g = 3.6, 0.2 dex times solar metallicity, a microturbulence of 1.7 km s^{-1} and a V sin i of 7 km s^{-1}, produced by the program SYNTHE (Kurucz & Avrett 1981). The cross-correlation function was fitted by a Gaussian, the centroid and FWHM of which were allowed to vary. A zero background slope of the Gaussian fit was an important restriction. The mean error of the radial velocities, as shown in Table 1, is 0.3 km s^{-1}. All spectra were shifted to rest wavelengths before further processing.

The stellar intensity files were rectified with REDUCE so that the continuum was calculated from locally averaged points. The rectification was completed by interpolating between the averaged data with Hermite spline functions, which always pass through the averaged continua at the selected wavelengths. The scattered light along the spectrum was assumed to be 3.5% of the continuum (Gulliver et al. 1996). The atlas and the published equivalent widths reflect this correction. This initial rectification was performed by the usual choosing of suitable continuum points by visual inspection. The resultant rectified spectrum served as the basis for the analysis of the spectrum reported in Adelman et al. (2003).

The final stellar parameters of *o* Pegasi were determined, as described in Adelman et al. (2003), by fitting the initial rectification version of the observed spectrum including an extracted Hγ profile plus the relative continuous fluxes from both the IUE UV and visible as tabulated by Adelman et al. (1989). The parameters found were $T_{\rm eff} = 9550 \pm 10$ K, log g = 3.75 ± 0.01, the individualized abundances of Adelman et al. (2003), a microturbulence of 1.3 ± 0.1 km s^{-1} and a V sin i of 6.6 ± 0.1 km s^{-1}. The parameter determination used synthetic spectra of the Hγ regions from ATLAS9 LTE plane parallel model atmospheres (Kurucz 1993) with Program SYNTHE (Kurucz & Avrett 1981) as well as the predicted fluxes with ATLAS9 for comparison with the observations. The $T_{\rm eff}$ and log g were determined by simultaneously fitting the continuous flux including both IUE UV and visible and the extracted Hγ profile using STELLAR (Hill et al. 1996; Hill et al. 2003). The Hγ profile was predominantly sensitive to log g and the shape of the continuous fluxes to $T_{\rm eff}$. V sin i was determined by fitting the spectrum from $\lambda\lambda$4450–4800 using STELLAR. The microturbulence was determined from the fine analysis of Adelman et al. (2003).

These stellar parameters were used in turn in the program, STELLAR, to generate the synthetic spectrum that was convolved with a digitally sampled instrumental profile with a FWHM of 0.072 Å. The final rectification points for the atlas of *o* Pegasi were then chosen by a novel technique that involves the selection of suitable intervals from the synthetic spectrum of *o* Pegasi. From this synthetic spectrum rectification points can be selected that need not be actual continuum points. A trial choice of suitable rectification points is based upon any wavelength interval for which the synthetic spectrum is roughly smooth and there is good agreement with the observed spectrum. Obviously, good stellar parameters are a necessity. In effect this is an iterative process in which trial points are modified or rejected if there is not good agreement between the synthetic and observed spectrum. The process is complicated by poorly known atomic data for some lines which produce discrepant line strengths and positions in the synthetic spectrum. For any suitable rectification point, an intensity level is established from the synthetic spectrum and the observed spectrum is normalized at that value.

This technique can be used for any star that has well defined stellar parameters. It is particularly useful for rectification across broad hydrogen wings, for late type stars in which

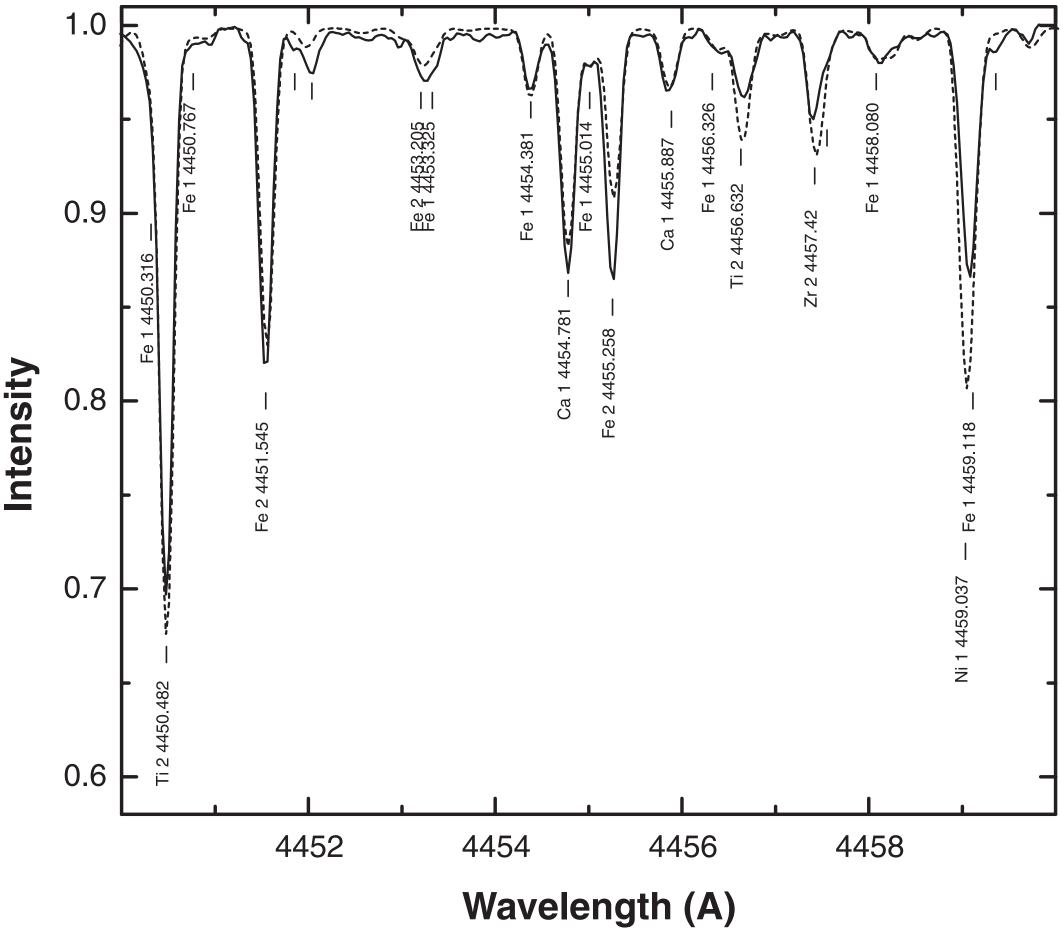

Fig. 1. $\lambda\lambda$4450–4460 section of the *o* Pegasi Atlas (solid line) and the synthetic spectrum (dashed line).

true continuum may be entirely absent and, as in this case, the appending of sections of spectra to produce a single monolithic spectrum. To facilitate the seamless combination of the sections there were at least two common rectification points over each several Å overlap.

3. Atlas

The final monolithic spectrum is displayed at the URL `http://www.brandonu.ca/physics/gulliver/atlases.html`. The JAVA tool provided there allows the display and comparison, in any combination, of the observed and synthetic spectra and their respective line identifications. Unrectified and rectified sections of the *o* Pegasi spectrum, and the complete rectified spectrum, are also available as FITS format files from the first author (AFG) and the CDS. Copies of the line identifications are also available.

For the purpose of illustrating the nature of the atlas, Figs. 1 and 2 show two adjacent 10 Å pieces, $\lambda\lambda$4450–4460 and $\lambda\lambda$4460–4470 of the section centered at 4465 Å of the *o* Pegasi atlas, which includes 19 such sections. Although the majority of the line identifications for this section are reproduced in the figures, multiple possible identifications of a given feature are not included to avoid overcrowding. The Java tool mentioned above gives a more accurate impression of the quality of the *o* Pegasi atlas.

Figures 1 and 2 also include the final synthetic spectrum produced by STELLAR as described above. The differences between the observed and synthetic spectra are striking, clearly illustrating the deficiencies in the atomic line parameters. This atlas and others can be used to improve these values.

4. Line identifications

We employed the program VLINE (Hill & Fisher 1986) to measure for each line the equivalent width, the central wavelength, the line depth, and the full width at half maximum of the fitted profile, which was taken to be a Gaussian for metal lines except for some He I lines which were Lorentzian profiles. Our rotational velocity estimate based on non-blended lines near Mg II λ4481 was 6 km s^{-1}. In measuring the spectrum, we used the fixed width profile feature for weak lines and to deconvolve blended lines requiring that their widths correspond to our derived rotational velocity estimate.

To begin the line identification process, we identified the cleanest lines in the spectrum which are minimally affected by noise and by blending components. These can often be found by examining stellar line identification lists of stars of similar temperature, previous studies of *o* Pegasi, or working with standard references. As not all atomic wavelength studies have equally well-determined wavelengths, we preferred to use those whose values are consistent with modern

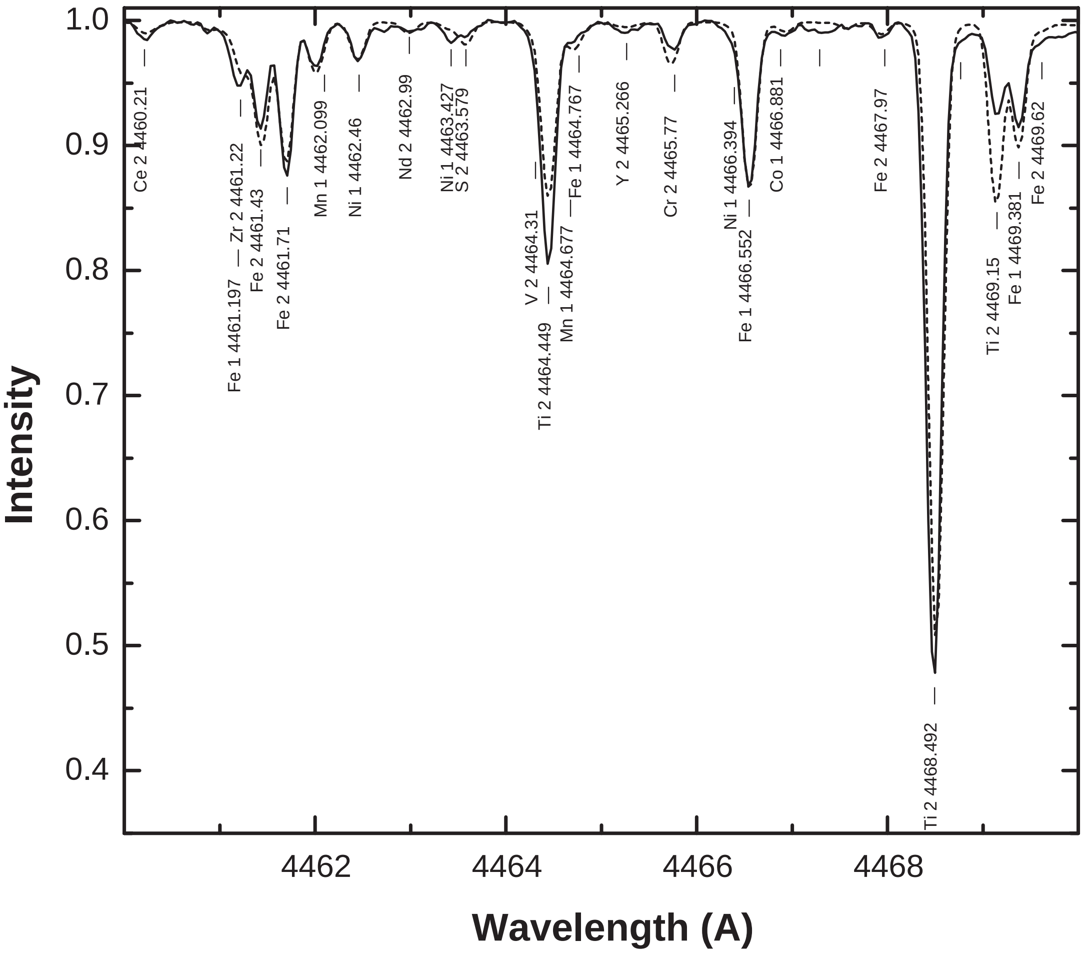

Fig. 2. $\lambda\lambda$4460–4470 section of the *o* Pegasi Atlas (solid line) and the synthetic spectrum (dashed line).

interferometric determinations for Fe I and Fe II. Stellar lines were first identified with the general references A Multiplet Table of Astrophysical Interest by Moore (1945), Wavelengths and Transition Probabilities for Atoms and Atomic Ions, Part 1 by Reader & Corliss (1980), and selected references from the bibliography of Adelman & Snijders (1974) whose most recent update is Adelman (2001). We used line identifications by Adelman and his associates for other stars which they have analyzed using DAO spectrograms in previous papers of this series.

A sample of the line identifications is presented in Table 2 for the $\lambda\lambda$4450–4470 section. The full identifications are available elsewhere as noted previously. To identify as well as possible the lines in the spectrum of *o* Pegasi after the elemental abundances of *o* Pegasi were initially determined, a synthetic spectrum was calculated using Program SYNTHE (Kurucz & Avrett 1981) with the adopted model atmosphere, solar abundances, the atomic data of Kurucz & Bell (1995), the instrumental profile of the long camera of the DAO coudé spectrograph, and the other parameters initially found for *o* Pegasi by Adelman et al. (2003). It was a good, but not perfect match. A list of lines which contributed significantly to the spectrum was made and used to help identify particularly the unidentified features. The major changes were the identification of Co II lines and some additional Fe II and Ni II lines as described in Adelman et al. (2003). The synthesized spectrum which is provided with this atlas was calculated after these additional clean lines which were found to be present were used to improve the derived abundances while those lines which were initially used and found to be blended were removed.

For those lines not in Moore (1945), letters are used in place of multiplet numbers to indicate the other sources: C = Catalan et al. (1964), D = Dworetsky (1971), G = Guthrie (1985), H = Hudlt et al. (1982), I = Iglesias et al. (1988) for V II and Iglesias & Velasco (1964) for Mn II, J = Johansson (1978), K = Kiess (1951), Kiess (1953), KX = Kurucz & Bell (1995), L = Litzen (2002), MCS = Meggers et al. (1975), N = Nilsson et al. (1991), and P = Pettersson (1983). Some multiplet numbers are from Moore (1965) for Si II and from Moore (1993) for C I and O I.

In Table 2 the far left column contains the letters B and R, standing for blue and red, which are guides to the range of lines whose wings are at least somewhat blended together. For example in Fig. 1, the features corresponding to N I 4214.804 and Fe I 4216.1838 are labelled B and R, respectively, because they are blended with the shortward and longward wings of the Sr II 4215.524, Fe I 4215.4777 blend. The remaining columns are the laboratory wavelength in Å (the stellar wavelength as corrected for the stellar radial velocity of each spectrum), the equivalent width (W_λ) in mÅ, the line depth as a fraction of the

Table 2. Line measurements of *o* Pegasi ($\lambda\lambda$4450–4460 Region).

	Laboratory λ(Å)	W_λ (mÅ)	Depth	Width (Å)	Identification(s)
B	4214.773	4.5	0.008	0.60	N I(5)4214.804(9)
	4215.444	64.6	0.117	0.52	Sr II(1)4215.524(300r), Fe I(419)4215.4777(2)
R	4215.965	5.6	0.013	0.49	Fe I(3)4216.1838(8)
B	4450.270	4.8	0.025	0.18	Fe I(476)4450.3156((3)), (Ni I(236)4450.301((2))
R	4450.478	55.2	0.304	0.17	Ti II(19)4450.4821(230)
	4450.808	2.0	0.011	0.18	Fe I(972)4450.7669(p)
	4451.542	32.6	0.184	0.17	Fe II(J)4451.545(4)
B	4451.852	1.5	0.008	0.18	
R	4452.036	4.1	0.022	0.18	
B	4453.193	3.2	0.017	0.18	Fe II(KX)4453.205(p)
R	4453.323	3.4	0.018	0.18	V II(199)4453.342(50), Fe I(555)4453.325(2)
	4454.386	5.2	0.027	0.18	Fe I(350)4454.3810(5)
B	4454.777	23.1	0.127	0.17	Ca I(4)4454.781(20), Zr II(40)4454.80(10)
	4455.025	2.7	0.014	0.18	Mn I(28)4455.012(5), Fe I(974)4455.014((2))
R	4455.255	22.9	0.134	0.16	Fe II(J)4455.258(3)
	4455.861	5.9	0.031	0.18	Mn I(28)4455.821(6), Ca I(4)4455.887(40), Fe II(140)4455.846(p)
B	4456.423	2.1	0.011	0.18	Fe I(516)4456.3257((1))
R	4456.667	7.0	0.037	0.18	Ti II(113)4456.632(8), (Ca I(4)4456.612(10)), (Fe I(973)4456.629(p))
B	4457.411	8.7	0.046	0.18	Zr II(79)4457.42(8), Ti I(113)4457.428(40)
R	4457.591	1.1	0.006	0.18	(Mn I(28)4457.553(20))
	4458.130	3.5	0.019	0.18	Fe I(492)4458.0802((3))
B	4459.077	27.5	0.132	0.20	Ni I(86)4459.037(20), Fe I(68)4459.1176(10)
R	4459.360	1.9	0.010	0.18	
	4460.224	2.6	0.013	0.18	Ce II(2)4460.21(2400)
B	4461.200	11.2	0.050	0.21	Fe I(471)4461.1967((2)), Zr II(67)4461.22(10)
	4461.431	14.3	0.085	0.16	Fe II(26)4461.43(p)
R	4461.698	22.1	0.125	0.17	Fe I(2)4461.6528(8), Fe II(D)4461.71(p)
	4462.003	7.0	0.036	0.18	Mn I(28)4462.099(20)
	4462.455	5.9	0.031	0.18	Ni I(86)4462.460(10)
	4463.009	1.6	0.008	0.18	Nd II(50)4462.99(740)
B	4463.422	2.7	0.014	0.18	Ni I(102)4463.427((3)), (CeII(20)4463.41(420))
R	4463.598	1.7	0.009	0.18	S II(43)4463.579(20)
B	4464.304	3.2	0.017	0.18	V II(199)4464.310(50)
	4464.447	34.3	0.193	0.17	Ti II(40)4464.4486(92)
R	4464.711	3.1	0.016	0.18	Mn I(22)4464.677(8), Fe I(472)4464.7665((2))
	4465.256	1.9	0.010	0.18	Y II(81)4465.266(212)
	4465.751	4.2	0.022	0.18	Cr II(191)4465.77(4)
B	4466.428	3.1	0.016	0.18	Ni I(168)4466.394((3))
R	4466.555	22.6	0.128	0.17	Fe I(350)4466.5518(12)
	4466.895	2.0	0.010	0.18	(Co I(150)4466.881(10))
	4467.291	1.3	0.007	0.18	
	4467.940	1.0	0.005	0.18	Fe II(D)4467.97(p)
B	4468.487	102.2	0.523	0.18	Ti II(31)4468.4924(1540)
R	4468.768	1.3	0.007	0.18	
B	4469.149	12.0	0.067	0.17	Ti II(18)4469.1500(16)
R	4469.374	13.2	0.076	0.16	Fe I(830)4469.381(3n)
	4469.588	1.4	0.007	0.18	(Co I(150)4469.547(15)), Fe II(G)4469.62(p)

continuum height, the line width (FWHM) in Å, and the identified atomic lines which cause the observed feature. The stellar and the laboratory wavelengths should be close, but blending and errors can produce discrepancies. Possible identifications are given in parentheses and brackets indicate that an identified line may be contributing to two measured stellar features.

The following discussion indicates which atomic species were found in the observed spectral range of *o* Pegasi. A Multiplet Table of Astrophysical Interest by Moore (1945) was the primary source of line identifications. When other references were used which substantially replaced or supplemented this source they are given immediately after the species name. In general species not identified are not discussed.

1. H I – The Balmer lines are present.

2. He I – The strongest and medium strength He I lines in the region studied are present.

3. C I – Moore (1993) – The stronger lines of multiplet 6 are cleanly present while the weaker members are blended. One line of multiplet 5 is also cleanly present.

4. C II – Moore (1993) – One line of multiplet 6 is unblended while the other is blended.

5. O I – Moore (1993) – Lines of multiplets 3 and 5 are present.

6. Mg I – Lines of multiplets 3, 11, 14, 15, and 17 are cleanly present while that of multiplet 16 is blended.

7. Mg II – Lines of multiplets 4, 5, 9, 10, and 18 are present.

8. Al I – The two lines of multiplet 1 are present.

9. Al II – λ4663.054, multiplet 2, is present and λ3900.680, multiplet 1, is probably part of a blend.

10. Si I – Moore (1967) – λ3905.523, multiplet 3, the strongest line in the observed region is present.

11. Si II – Moore (1965) – Lines of multiplets 1, 3, 3.01, 7.05, 7.06, 7.26, and 20 are present.

12. S I – The three lines of multiplet 2 are present.

13. S II – Pettersson (1983) – All lines with intensities $\geq$20 are present as is one intensity 19 line and probably a few other weaker lines.

14. Ca I – Lines of multiplets 2, 4, 5, 6, 23, 25, 37, and 51 are present.

15. Ca II – The H and K lines of multiplet 1 are present.

16. Sc II – Lines of intensity $\geq$8 of multiplets 7, 8, 14, and 24 are present as well as a few weaker lines with intensities of 2 or more.

17. Ti I – Almost all lines with intensities $\geq$60 are present as are many with intensities between 35 and 55.

18. Ti II – Litzen (2002) – All lines with intensities $\geq$64 are present as are many with intensities between 6 and 64 and some lines from Hudlt et al. (1982) and from Moore (1945).

19. V I – The ultimate line λ4379.24 probably corresponds to a 1.8 mÅ feature.

20. V II – Iglesias et al. (1988) – Almost all lines with intensities $\geq$20 are present as are a few weaker lines. A few lines only from Moore (1945) are retained.

21. Cr I – Kiess (1953) – Almost all lines with intensities $\geq$100 are present along with many with intensities between 75 and 100. A few weaker lines are marked as possible identifications.

22. Cr II – Kiess (1951) – Almost all lines of intensity $\geq$4 are present as well as some with intensities between 1 and 3. Some lines from Dworetsky (1971) supplement this source.

23. Mn I – Catalan et al. (1964) – All lines with intensities $\geq$2000 are present as well as most with intensities $\geq$500 and a few with intensities $\geq$200.

24. Mn II – Iglesias & Velasco (1964) – Almost all lines with intensities greater than 40 are present as well as most with intensities between 20 and 40.

25. Fe I – Most lines with intensities $\geq$1 are found along with many with intensities in parentheses and some formerly predicted lines from Nave et al. (1994). The wavelengths when available are from Nave et al. (1994).

26. Fe II – Johansson (1978) – Many lines from Dworetsky (1971) and Guthrie (1985) are present. All lines from Johansson's Table I with intensities $\geq$3 and some intensity 1 and 2 lines are present except close to the core of Hβ. All lines from his Table II are present. As noted by Adelman (1987) many predicted Fe II lines in Moore (1945) are present.

27. Fe III – Glad (1956) – Only λ4419.599, the strongest line and λ4431.015, one of the next strongest lines, of multiplet 4 are found.

28. Co I – Lines with intensities $\geq$30 are present along with many of intensities 20 and 25.

29. Co II – Kurucz & Bell (1995) – The synthetic spectrum of *o* Pegasi with the initial Co abundance from the Co I lines shows that several Co II lines are present.

30. Ni I – Most lines of intensity $\geq$7 are present. Many with intensities of 2 to 6 are present.

31. Ni II – Lines of multiplets 9, 10, 11, 12, and 13 are present as well as some not included in Moore (1945) according to the synthetic spectral calculations.

32. Zn I – The three lines of multiplet 1 are present.

33. Cd I – There are features close to the position of two lines of multiplet 2 λ4799.918 and λ4678.160. In other stars of similar temperature both yield very large overabundances and so are marked only as possible identifications. The former might be due to instead to a Ca II line.

34. Sr II – The two strong lines of multiplet 1 are present as well the two lines of multiplet 3, one of which is blended.

35. Y II – Nilsson et al. (1991) – All lines with intensities $\geq$165 are present as well as many with intensities between 43 and 164.

36. Zr II – Almost all lines with intensities $\geq$3 are present as well as many intensity 1 and 2 lines.

37. Ba II – Lines of multiplets 1, 3, and 4 are present, some of which are blended.

38. La II – Meggers et al. (1975) – Many lines are present with intensities $\geq$1100.

39. Ce II – Meggers et al. (1975) – Many lines are present with intensities $\geq$860 along with a few weaker ones.

40. Nd II – Meggers et al. (1975) – Of the five strongest lines, 3 are clearly present and 2 are parts of blends.

41. Eu II – Meggers et al. (1975) – Several of the strongest lines are present.

42. Gd II – Meggers et al. (1975) – Of the five strongest lines, two are clearly present, two are blended, and one is absent. Gd II is regarded as being weakly present.

43. Tb II – Meggers et al. (1975) – Only the strongest line in the observed region, λ3948.73, is a probable identification of a 3.1 mÅ feature.

44. Dy II – Meggers et al. (1975) – Of the strongest three lines in the region present, one is cleanly identified and the other two are blended. This species is regarded as having lines which are weakly present.

45. Ho II – Meggers et al. (1975) – The strongest line in the observed region, λ4045.44, might be blended with Co I(41)λ4045.386, but was not marked as a definite identification in the line list.

46. Er II – Meggers et al. (1975) – The strongest line in the observed region, λ3906.31, might contribute to a 4.8 mÅ feature.

47. Tm II – Meggers et al. (1975) – The strongest line in the observed region, λ3848.02, might contribute to a 1.8 mÅ feature along with a weak Y II line.

48. Yb II – Meggers et al. (1975) – The strongest line in the region observed, λ4180.81, might be the identification of a 2.0 mÅ feature.

Acknowledgements. AFG and SJA thank Dr. James E. Hesser, Director of the Dominion Astrophysical Observatory for the observing time. This research was supported in part by grants from the National Sciences and Engineering Research Council of Canada and The Citadel Foundation.

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