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INVESTIGATIONS OF TYPICAL STELLAR SPECTRA WITH HIGH DISPERSION

I. TABLE OF LINES IN α CYGNI*

O. STRUVE AND P. SWINGS

ABSTRACT

This paper contains a new table of wave lengths of absorption lines in the spectrum of α Cygni between λ 3862 and λ 6590.

In recent papers on the spectra of stars surrounded by extended shells[1] a comparison of the line intensities to those of the classical supergiant of type A, α Cygni, has often been most useful for the discussion of dilution and excitation effects. A similar situation has arisen for stellar atmospheres which have an abnormal abundance of hydrogen.[2] It is also well known that the absorption spectra of novae near maximum are similar to α Cygni. The usefulness of a list of lines in α Cygni is thus unquestionable. A very helpful compilation of data for the stronger lines was published in 1938 by A. B. Wyse;[3] this table was based on the following sources:

Region λλ 2950–3299, unpublished measures by Wyse
Region λλ 3300–3912, Wright[4]
Region λλ 3913–4674, Morgan[5]
Region λλ 3913–4804, Baxandall[6]
Region λλ 4805–6600, Marshall[7]

In the region λλ 3226–3957 a new table of wave lengths was published by one of us[8] in 1939; this list was based upon spectrograms secured at the McDonald Observatory and shows more lines than were listed by Wright. In using Wyse's compilation in the violet and blue regions we sometimes felt the desirability of supplementing it with the fainter lines and of increasing the accuracy of some of the wave lengths. In the region λ >4800 the situation was quite unsatisfactory: a large part of the lines remained unidentified, and many of them are doubtful, in spite of the large intensities assigned to them by the measurer.

We have prepared a new table of wave lengths from λ 3862 to λ 6587, based on measurements of coudé spectrograms taken in August, 1940, at the McDonald Observatory.[9] Our dispersion is: 1.87 A/mm at λ 3935, 2.6 at λ 4000, 3.0 at λ 4360, 4.5 at λ 5000, and 12.2 at λ 6350. The lines are listed in Table 1; the identifications in parentheses either

* *Contributions from the McDonald Observatory, University of Texas*, No. 39.

[1] Struve and Roach, *Ap. J.*, **90**, 727, 1939 (17 Leporis); Struve and Swings, *Ap. J.*, **93**, 446, 1941 (Pleione); Greenstein, *Ap. J.*, **93**, 453, 1941 (Pleione).

[2] Greenstein, *Ap. J.*, **91**, 438, 1940 (υ Sagittarii).

[3] *Lick Obs. Bull.*, **18**, 129, 1938.

[4] *Lick Obs. Bull.*, **10**, 100, 1921.

[5] *Pub. Yerkes Obs.*, **7**, Part III, 40, 1935.

[6] *Catalogue of 470 of the Brighter Stars*, Solar Physics Committee, South Kensington, 1902.

[7] *Ap. J.*, **82**, 97, 1935.

[8] Struve, *Ap. J.*, **90**, 699, 1939.

[9] For a description of the coudé spectrograph, see *McDonald Contr.*, No. 1, p. 103, 1940.

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TABLE 1

THE SPECTRUM OF α CYGNI IN THE REGION λλ 3862–6587

Wave Length	Int.	Identification
3862.66	10	*Si* II 2.59 (6)
3863.97	1	*Fe* II 3.95 (1)
3864.22	0	*Mo* I 4.11 (1000)
3865.60	3	*Cr* II 5.59 (75) *Fe* I 5.53 (600)
3866.60	0	*Cr* II 6.54 (7) *V* II 6.74 (60)
3867.55	1	*He* I 7.48 (15) (*Fe* I 7.22 (150))
3868.42	0	*Cr* II 8.27 (5)
3872.74	7	(*Fe* I 2.50 (300)) *Fe* II 2.76 (pr)
3878.65	8n	*Fe* I 8.58 (300) (*V* II 8.71 (300))
3882.24	1	(*Ni* II 1.92 (1))
3886.30	1	*Fe* I 6.28 (600)
3889.05	20	H_8 9.05 (60)
3891.90	1	*Fe* I 1.93 (100)
3892.21	0	*S* II 2.32 (35) *Cr* II 2.14 (4)
3896.15	2	*V* II 6.16 (60)
3897.97	0	*Fe* I 7.89 (100) *Fe* I 8.01 (80)
3899.03	2	*V* II 9.14 (200)
3899.72	1	*Fe* I 9.71 (500)
3900.54	10	*Ti* II 0.54 (50) *Al* II 0.68 (200)
3901.62	1	....
3902.91	2	*Fe* I 2.95 (500) *Mo* I 2.96 (1000)
3903.22	1	*V* II 3.26 (250)
3903.82	1	*Fe* I 3.90 (100)
3905.54	7	*Cr* II 5.64 (25) *Si* I 5.53 (15)
3906.04	7	*Fe* II 6.04 (5)
3906.82	0	(*Fe* I 6.48 (300))
3908.23	0	(*Fe* I 7.94 (100))
3911.36	1n	*Cr* II 1.32 (3)
3912.45	1	(*Ti* II 2.32 (pr))
3913.47	10	*Ti* II 3.46 (70)
3914.47	5	*Fe* II 4.48 (2) *V* II 4.33 (250)
3915.28	0	(*Ti* II 5.43 (pr)) *Cr* II 5.30 (pr)
3916.43	1	*V* II 6.41 (200)
3918.46	2	*Fe* I 8.65 (60) *Fe* II 8.51 (pr) *Fe* I 8.32 (20)
3920.67	2n	*C* II 0.68 (200)
3922.92	1	*Fe* I 2.91 (600)
3927.84	1	*Fe* I 7.92 (500)
3929.77	0	*V* II 9.73 (50)
3930.31	4	*Fe* I 0.31 (600)
3931.22	0	*Fe* I 1.12 (35)
3932.01	3	*Ti* II 2.02 (30)
3933.58 3933.87	20 15	*Ca* II 3.67 (600)
3935.04	1n	*Cr* II 5.18 (pr)
3935.98	3	*Fe* II 5.94 (6)
3936.79	1	*Cr* II 6.95 (1)
3937.64	0	(*Fe* I 7.33 (80))
3938.29	6	*Fe* II 8.29 (2)
3938.99	4	*Fe* II 8.97 (4)
3942.57	0	*Fe* I 2.44 (100)
3944.03	3	*Al* I 4.03 (2000)
3944.53	1	....
3945.21	4	*Cr* II 5.11 (1) *Fe* II 5.21 (pr) *Fe* I 5.13 (30)
3946.81	0	*Fe* I 7.00 (50)
3947.34	0	*O* I 7.33 (300) *O* I 7.51 (50) *Fe* I 7.53 (70)
3948.82	1	*Fe* I 8.78 (150)
3949.90	0	*Fe* I 9.96 (150)
3951.26	1	*Fe* I 1.17 (150)
3951.97	3	*V* II 1.97 (500)
3956.70	0	*Fe* I 6.68 (150)
3958.08	1	*Cr* II 8.07 (2) *Zr* II 8.22 (150)
3959.04	0	....
3960.85	1	*Fe* II 0.89 (3)
3961.57	3	*Al* I 1.53 (2000)
3962.68	1	....
3963.19	0	*Fe* I 3.11 (125) (*S* II 3.13 (10))
3963.75	0	*Cr* I 3.69 (300)
3964.58	2n	*He* I 4.73 (50) *Fe* I 4.52 (80)
3966.07	1	*Fe* I 6.07 (100)
3968.38 3968.65	20 15	*Ca* II 8.47 (500)
3969.59	1?	*Fe* I 9.26 (600) *Cr* I 9.75 (200)
3970.10	20	*H*ε 0.08 (80)
3972.88	1	....
3973.84	1	*V* II 3.64 (300)
3974.17	4	*Fe* II 4.16 (3)
3975.05	2	*Fe* II 5.03 (2)
3976.11	1	....
3976.52	0	*Cr* I 6.66 (300) *Fe* (I?) 6.61 (35)
3977.61	0	*V* II 7.74 (60) *Fe* I 7.75 (300)
3978.81	0	(*Cr* II 9.20 (pr))
3979.54	4	*Cr* II 9.51 (20)
3980.24	1	....
3981.51	0	(*Fe* I 1.77 (150)) *Fe* II 1.61 (pr)
3981.96	2n	*Ti* II 2.01 (3)
3982.61	1	*Y* II 2.59 (100)
3983.90	0	*Fe* I 3.96 (200) *Cr* I 3.91 (200)
3987.65	0	....
3988.22	0	....
3991.22	1	*Zr* II 1.13 (100) *Cr* I 1.12 (200)
3992.06	0	....

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TABLE 1—*Continued*

Wave Length	Int.	Identification
3997.09	1	*V* II 7.12 (200)
3998.84	0n	*Zr* II 8.97 (30) *S* II 8.79 (60)
4001.10	0	....
4002.11	3	*Fe* II 2.07 (2)
4002.53	2	*Fe* II 2.55 (3)
4002.82	0?	*V* II 2.94 (80)
4003.27	1	*Cr* II 3.33 (25)
4004.27	0	*Fe* II 4.15 (pr)
4005.20	1	*Fe* I 5.25 (250)
4005.69	4	*V* II 5.71 (800)
4007.11	0	*Fe* I 7.27 (80) *Cr* II 7.04 (pr)
4007.95	1	(*Fe* II 7.72 (pr) (*S* II 7.78 (5))
4009.27	1	*He* I 9.27 (10)
4011.54	1	....
4012.46	6	*Ti* II 2.39 (50) *Fe* II 2.47 (1) *Cr* II 2.50 (30)
4013.74	1	*Fe* I 3.82 (200) *Fe* I 3.79 (80)
4014.55	1	*Fe* I 4.53 (200) *Sc* II 4.49 (8)
4015.51	3	*Ni* II 5.48 (1)
4021.81	0	*Fe* I 1.87 (200)
4023.37	3	*V* II 3.39 (600)
4024.55	5	*Fe* II 4.55 (5)
4025.19	2	*Ti* II 5.14 (25)
4026.14	2n	*He* I 6.19 (5)
4026.45	1	*Al* II 6.5 (30)
4027.59	1	....
4028.36	5	*Ti* II 8.34 (80)
4029.30	1	(*Fe* I 9.64 (80))
4030.54	0	*Fe* I 0.49 (120) *Mn* I 0.75 (500) *Cr* II 0.28 (pr)
4031.42	2n	*Fe* II 1.46 (1)
4032.94	3	*Fe* II 2.95 (3) (*Mn* I 3.07 (400))
4034.30	1n	*Mn* I 4.49 (250)
4035.64	3	*V* II 5.63 (400)
4036.50	2	*V* II 6.78 (60)
4037.96	2n	*Cr* II 8.03 (25)
4039.61	0	*V* II 9.57 (20)
4044.01	2	*Fe* II 4.01 (pr)
4045.82	5	*Fe* I 5.81 (400)
4046.87	0	*Fe* II 6.81 (pr)
4047.67	0	....
4048.90	3	*Fe* II 8.83 (3) *Cr* II 9.14 (18)
4050.53	0	(*Zr* II 0.33 (10))
4051.89	3	*Cr* II 1.97 (12)
4053.75	3	*Ti* II 3.83 (8)
4054.00	3	*Cr* II 4.11 (8)
4054.92	1	*Fe* I 4.88 (25) *Fe* I 5.04 (40)
4055.63	1	....
4056.14	1	*Ti* II 6.21 (3) *Cr* II 6.07 (4)
4057.45	3	*Fe* II 7.46 (2)
4058.43	1	*Fe* I 8.23 (80) *Fe* I 8.76 (40)
4060.30	0	....
4063.65	3	*Fe* I 3.60 (400)
4064.42	1	*Ti* II 4.40 (2)
4065.06	0	*V* II 5.08 (100)
4067.05	5	*Ni* II 7.05 (30) *Cr* II 7.05 (pr)
4068.01	1	*Fe* I 7.98 (150)
4068.19	1	....
4068.73	0	....
4069.96	2	*Fe* II 9.88 (1)
4070.89	2	*Cr* II 0.90 (10)
4071.75	3	*Fe* I 1.74 (300)
4072.75	1	*Cr* II 2.56 (4)
4073.60	0	*Fe* II 3.45 (0) *Fe* I 3.77 (80)
4075.61	1	*Si* II 5.45 (2) *Cr* II 5.63 (pr)
4076.01	0	*Fe* II 5.95 (pr)
4076.86	2n	*Si* II 6.78 (1) *Fe* I 6.64 (80) *Fe* II 7.16 (3) *Cr* II 6.87 (3)
4077.68	4	*Sr* II 7.71 (500)
4079.79	0	*Fe* I 9.84 (80)
4082.23	1	*Fe* II 2.59 (1) *Cr* II 2.30 (10)
4083.12	0	....
4093.06	1	*Fe* II 3.24 (0)
4099.65	1	(*N* I 9.94 (150)) (*S* II 9.44 (8))
4101.75	20	*H*δ 4101.74 (100)
4109.92	1	*Fe* I 9.81 (120) *N* I 9.98 (1000)
4110.96	3	*Cr* II 1.01 (18)
4111.35	0	(*Cr* I 1.36 (20))
4111.77	2	*Fe* II 1.90 (1)
4113.18	0	*Cr* II 3.24 (5)
4118.27	0	*Fe* I 8.55 (200)
4119.51	1	*Fe* II 9.53 (pr)
4120.85	1	*He* I 0.81 (3)
4121.94	0	*Fe* I 1.81 (100)
4122.66	5	*Fe* II 2.64 (4)
4123.66	1	*Fe* I 3.74 (80)
4124.77	3	*Fe* II 4.79 (1)
4125.67	0	*Fe* I 5.62 (80) *Mn* II 5.86 (1)
4126.22	0	*Fe* I 6.19 (80)
4127.16	1	*Cr* II 7.08 (3)
4128.07	8	*Si* II 8.05 (8)
4128.79	3	*Fe* II 8.73 (3)
4129.51	0	....
4130.86	8	*Si* II 0.88 (10)
4131.85	0	*Fe* I 2.06 (300)
4132.36	1	*Cr* II 2.41 (7) *Mn* II 2.28 (1)
4133.20	0	*Fe* I 2.90 (100)
4134.59	0	*Fe* I 4.68 (150)

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TABLE 1—*Continued*

Wave Length	Int.	Identification
4137.66	0	....
4138.10	1	(*Fe* II 8.21 (pr))
4139.65	0	....
4140.35	0	*Mn* II 0.19 (5)
4142.30	0	*S* II 2.29 (150)
4143.41	1	*Fe* I 3.42 (200)
4143.80	2	*He* I 3.76 (15); *Fe* I 3.87 (400)
4145.21	1	*S* II 5.10 (250)
4145.81	2	*Cr* II 5.77 (25)
4146.43	0	*Cr* II 46.45 (1)
4147.84	0	*Fe* I 7.67 (200)
4149.19	1	*Fe* I 9.37 (100); *Zr* II 9.20 (100)
4150.38	1	(*Fe* I 0.26 (50))
4154.25	0	*Fe* I 4.50 (100); *Cr* II 4.29 (pr)
4159.53	0	(*Al* II 9.45 (4); *Al* II 9.72 (6))
4160.57	1	(*Al* II 0.24 (12))
4161.53	2n	*Cr* II 1.05 (2); *Cr* II 1.27 (pr); *Ti* II 1.54 (30); *Cr* II 1.56 (pr)
4162.76	1	*S* II 2.70 (600)
4163.63	5	*Ti* II 3.65 (150)
4167.20	0	*Mg* I 7.39 (6)
4170.04	1	(*Fe* II 9.98 (pr))
4171.00	1	*Fe* I 0.91 (80); *Cr* II 0.86 (1)
4171.86	4	*Ti* II 1.90 (70)
4172.55	1	*Fe* I 2.75 (60); *Cr* II 2.60 (2)
4173.45	8	*Fe* II 3.45 (8)
4174.31	0	*Ti* II 4.09 (12)
4175.65	1n	*Fe* I 5.64 (100)
4176.38	1	*Fe* I 6.57 (100)
4177.67	6	(*Fe* I 7.60 (100); *Y* II 7.55 (50); *Fe* II 7.70 (pr))
4178.85	8	*Fe* II 8.85 (8)
4179.15	0	*Cr* II 9.43 (12)
4183.40	1	*V* II 3.43 (250)
4184.36	1	*Ti* II 4.33 (20)
4186.99	1	*Fe* I 7.04 (250)
4187.86	2	*Fe* I 7.80 (200)
4190.20	0	*Ti* II 0.24 (5)
4191.99	0	*Ni* II 2.02 (1)
4195.40	1	*Fe* I 5.34 (150); *Fe* I 5.62 (25)
4198.21	0	*Si* II 8.25 (3); *Fe* I 8.31 (250)
4199.08	0	*Fe* I 9.10 (300)
4200.56	0	(*Ti* II 0.40 (pr))
4202.11	1	*Fe* I 2.03 (400); *V* II 2.34 (150)
4205.33	1n	*V* II 5.09 (250); *Fe* II 5.48 (pr)
4206.45	0n	*Mn* II 6.43 (2)
4207.33	0	*Cr* II 7.35 (4)
4214.63	0	....
4215.49	3	*Sr* II 5.52 (400)
4219.34	0	*Fe* I 9.36 (250)
4222.08	0	*Fe* I 2.22 (200)
4224.76	3	*Cr* II 4.85 (20)
4226.76	1	*Ca* I 6.73 (500); *Al* II 6.81 (35)
4227.40	2	*Fe* I 7.43 (300); *Al* II 7.50 (30); *Al* II 7.41 (8)
4227.97	0	*Al* II 7.98 (20)
4231.19	0?	*S* II 0.98 (35)
4233.17	12	*Fe* II 3.17 (11)
4234.59	0	(*V* II 4.55 (40))
4235.92	1	*Fe* I 5.94 (300)
4238.74	1	*Fe* I 8.82 (200)
4240.81	0	*Al* II 0.75 (15)
4241.51	0	(*Cl* II 1.38 (60))
4242.38	7	*Cr* II 2.38 (30)
4243.69	1	....
4244.20	1	*Mn* II 4.25 (1)
4244.81	1	*Ni* II 4.81 (1)
4245.57	0	*Fe* I 5.26 (80)
4246.80	6	*Sc* II 6.83 (500)
4248.02	0	*Mn* II 7.95 (1); *Fe* I 8.23 (150)
4249.72	0	*Fe* I 0.13 (250)
4250.89	1	*Fe* I 0.79 (400)
4251.73	1	*Mn* II 1.77 (2)
4252.64	3	*Cr* II 2.62 (10)
4253.50	0	*Cl* II 3.51 (75)
4254.37	2	*Cr* I 4.35 (5000)
4255.20	0	....
4257.26	1	*S* II 7.42 (30)
4258.19	4	*Fe* II 8.15 (3)
4259.12	2n	*Mn* II 9.26 (2)
4260.42	2	*Fe* I 0.48 (400)
4261.41	0	....
4261.94	5	*Cr* II 1.92 (20)
4263.20	1	....
4264.01	0	*Fe* II 3.89 (1)
4267.07	1	*C* II 7.02 (350); *C* II 7.27 (500); *Fe* I 6.97 (70)
4269.22	2	*Cr* II 9.28 (10)
4271.06	1	*Fe* I 1.16 (400)
4271.77	2	*Fe* I 1.76 (1000)
4273.36	5	*Fe* II 3.32 (3)
4274.77	1n	*Cr* I 4.80 (4000)
4275.56	4	*Cr* II 5.57 (30)
4276.92	0	....
4278.20	3	*Fe* II 8.13 (1); *Cr* II 8.10 (1)
4279.16	0	*V* II 8.89 (60); *Cr* II 9.00 (pr); *Mo* II 9.02 (100)
4282.57	1	*Mn* II 2.50 (3); *Fe* I 2.41 (600); *S* II 2.63 (30)
4284.22	3	*Cr* II 4.21 (20)

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TABLE 1—*Continued*

Wave Length	Int.	Identification	Wave Length	Int.	Identification
4285.44	0	*Fe* I 5.44 (125)	4359.75	0n	(*Cr* I 9.63 (200)) *Zr* II 9.74 (8))
4286.21	1	*Fe* II 6.31 (1)	4361.28	2	*Fe* II 1.25 (2)
4287.84	2	*Ti* II 7.88 (30)	4362.15	2	*Ni* II 2.10 (1)
4289.17	1	....	4363.08	1	*Cr* II 2.93(3)
4290.23	5	*Ti* II 0.23 (60) (*Cr* I 9.72 (3000))	4365.06	0	*Mn* II 5.29 (1)
4291.31	0	*Fe* I 1.47 (125)	4366.13	0	*Fe* II 6.16 (tr)
4291.98	0	(*Mn* II 2.25 (0))	4367.63	2	*Ti* II 7.66 (25)
4294.10	7	*Ti* II 4.12 (60)	4368.38	1	*Fe* II 8.26 (1) *O* I 8.30 (1000)
4296.60	7	*Fe* II 6.58 (6)	4369.42	3	*Fe* II 9.40 (2)
4297.71	0	(*Fe* I 8.04 (100))	4370.82	0	(*Zr* II 0.95 (7))
4299.24	1	*Fe* I 9.24 (500)	4373.34	0	*Fe* I 3.57 (50)
4300.05	8	*Ti* II 0.05 (100)	4374.51	2	*Sc* II 4.46 (25) *Ti* II 4.82 (35)
4301.03	0	*V* II 1.18 (40)	4379.81	0	*Mn* II 9.74 (1)
4301.92	4	*Ti* II 1.93 (50)	4383.55	5	*Fe* I 3.55 (1000)
4303.20	9	*Fe* II 3.17 (15)	4384.41	6	*Mg* II 4.64 (8) *Fe* II 4.33 (pr)
4304.47	1	....	4385.38	8	*Fe* II 5.38 (7)
4305.56	1	*Fe* I 5.45 (100) *Sr* II 5.45 (40) *Sc* II 5.71 (20)	4386.72	2	*Ti* II 6.85 (80)
4306.92	1	*Al* II 7.16 (20)	4388.02	1	*He* I 7.93 (30) *Fe* I 7.90 (150)
4307.91	4	*Ti* II 7.90 (100) *Fe* I 7.91 (1000)	4388.43	0	*Fe* I 8.41 (125)
4309.28	0	*Fe* I 9.38 (125)	4389.39	0	*Fe* II 9.40 (1)
4309.95	0	....	4390.47	3	*Mg* II 0.58 (10)
4312.90	5	*Ti* II 2.87 (100) *Fe* II 3.03 (1)	4392.00	0	*S* II 1.84 (30)
4314.22	4	*Fe* II 4.29 (4) *Sc* II 4.08 (150)	4392.66	0	....
4315.01	4	*Ti* II 4.98 (20) *Fe* I 5.09 (500)	4394.05	2	*Ti* II 4.07 (15)
4315.98	0	....	4395.02	7	*Ti* II 5.04 (150)
4316.77	1	*Ti* II 6.80 (35)	4395.86	1	*Ti* II 5.84 (30)
4318.25	0	*Fe* II 8.22 (0)	4396.77	0	....
4319.76	1	*Fe* II 9.72 (1)	4398.36	1	*Ti* II 8.31 (10)
4320.85	3	*Ti* II 0.96 (40) *Sc* II 0.74 (40)	4399.78	4	*Ti* II 9.77 (100)
4322.36	1	....	4400.37	1	*Sc* II 0.35 (30)
4325.05	1	*Sc* II 5.01 (40)	4401.30	0	*Fe* I 1.30 (60)
4325.72	3	*Fe* I 5.76 (1000)	4402.93	2	*Fe* II 2.87 (2)
4326.70	1	*Mn* II 6.76 (3)	4404.70	3	*Fe* I 4.75 (1000)
4330.56	1	*Ti* II 0.71 (30)	4405.91	0	....
4336.48	0	*Cl* II 6.26 (45)	4406.87	0	....
4337.96	4	*Ti* II 7.92 (125)	4409.48	1	*Ti* II 9.22 (8) *Ti* II 9.52 (10)
4338.94	1	(*Fe* II 8.70 (pr))	4411.09	2	*Ti* II 1.08 (100)
4340.44	20	$H\gamma$ 0.46 (200)	4413.54	2	*Fe* II 3.60 (0)
4342.51	0	*Fe* II 2.36 (0)	4415.00	2	*Fe* I 5.12 (600)
4343.26	1	....	4415.59	2	*Sc* II 5.56 (25)
4344.17	2n	*Ti* II 4.29 (50) *Cr* I 4.51 (400)	4416.82	6	*Fe* II 6.82 (7)
4347.23	0	*Al* II 7.22 (8) *Al* II 7.32 (6)	4417.72	4	*Ti* II 7.72 (80)
4350.91	0	*Ti* II 0.83 (30)	4418.35	1	*Ti* II 8.34 (20)
4351.78	10	*Fe* II 1.76 (9) (*Mg* I 1.91 (15))	4419.68	1	*Mn* II 9.78 (2) (*Fe* III 9.60 (10))
4352.77	0	*Fe* I 2.74 (300)	4421.71	1	*Ti* II 1.95 (35)
4354.33	1	*Fe* II 4.36 (2)	4423.58	0	(*Ti* II 3.27 (pr))
4356.53	0	(*Al* II 6.71 (7))	4427.15	0	*Fe* I 7.31 (500)
4357.59	2	*Fe* II 7.57 (4)	4427.91	1n	*Mg* II 7.99 (7) *Ti* II 7.92 (pr)
4358.50	0	*Fe* I 8.50 (70)	4431.66	0	*Fe* II 1.63 (1)
			4434.04	2	*Mg* II 3.99 (8)
			4436.66	0	*Mg* II 6.48 (5)
			4438.01	0	....

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TABLE 1—*Continued*

Wave Length	Int.	Identification
4441.79	0	*Ti* II 1.72 (pr)
4443.81	7	*Ti* II 3.80 (125)
4445.82	0	....
4446.41	0	*Fe* II 6.25 (1)
4448.00	0	*Al* II 7.8 (15) *Fe* I 7.72 (200)
4449.56	1	*Fe* II 9.66 (1)
4450.49	4	*Ti* II 0.49 (50)
4451.54	3	*Fe* II 1.54 (4)
4452.38	0	....
4453.27	1n	*V* II 3.35 (30)
4454.23	0	*Fe* I 4.38 (200)
4455.28	3	*Fe* II 5.26 (3)
4456.60	0	*Ti* II 6.65 (10)
4461.58	3	*Fe* I 1.65 (300)
4462.59	0	....
4464.46	2	*Ti* II 4.46 (40) *V* II 4.32 (40)
4466.84	0	*Fe* I 6.55 (500)
4468.50	5	*Ti* II 8.50 (150)
4469.17	0	*Ti* II 9.16 (1) *Fe* I 9.38 (200)
4469.88	0	....
4470.83	1	*Ti* II 0.86 (25)
4471.55	2	*He* I 1.48 (100) *He* I 1.68 (7)
4472.94	3	*Fe* II 2.92 (2)
4474.35	0	*Fe* II 4.19 (0)
4481.26	16	*Mg* II 1.33 (100)
4482.92	0	(*Ti* II 2.44 (pr))
4483.64	0	*S* II 3.42 (100) *S* II 3.63 (50)
4487.39	1	....
4488.36	3	*Ti* II 8.32 (125)
4489.23	5	*Fe* II 9.18 (4)
4490.28	0	....
4491.42	6	*Fe* II 1.40 (5)
4493.42	0	*Fe* II 3.58 (1) *Ti* II 3.53 (8)
4495.77	0	*Fe* II 5.52 (pr)
4499.72	0	*Fe* II 9.71 (0)
4501.29	5	*Ti* II 1.27 (100)
4507.14	1	*Fe* II 7.19 (0) *Cr* II 7.19 (pr)
4508.28	7	*Fe* II 8.28 (8)
4510.40	0	*Mn* II 0.21 (3)
4511.57	0	(*Cr* II 1.82 (pr))
4515.36	7	*Fe* II 5.34 (7)
4516.85	0	(*Cr* II 6.56 (pr))
4518.21	1n	....
4520.21	6	*Fe* II 0.22 (7)
4522.64	7	*Fe* II 2.63 (9)
4524.92	0n	*Ti* II 4.73 (10) *Fe* I 5.15 (100) *S* II 4.95 (150)
4526.32	0	*Fe* II 6.58 (pr)
4528.59	0	*Fe* I 8.62 (600) *V* II 8.51 (300)
4529.40	1	*Ti* II 9.46 (40)

Wave Length	Int.	Identification
4534.04	7	*Ti* II 3.97 (150) *Fe* II 4.17 (2) *Mg* II 4.26 (4)
4539.68	0	*Cr* II 9.62 (2)
4541.48	4	*Fe* II 1.52 (4)
4544.03	0	*Ti* II 4.01 (20)
4546.35	0	(*Cr* I 5.96 (200))
4547.38	0	(*Ni* II 7.15 (5))
4549.50	15	*Fe* II 9.47 (10) *Ti* II 9.63 (200) *Fe* II 9.21 (4)
4551.62	0	....
4553.44	0	....
4553.98	1	*Ba* II 4.04 (1000) (*Zr* II 3.97 (12))
4554.97	4	*Cr* II 5.02 (20)
4555.89	6	*Fe* II 5.89 (8)
4556.91	0	....
4558.66	6	*Cr* II 8.66 (100)
4560.48	0	....
4563.79	5	*Ti* II 3.77 (200)
4564.54	1	*V* II 4.59 (200)
4565.77	2	*Cr* II 5.78 (10)
4567.15	1	....
4568.21	0	*Ti* II 8.31 (8)
4571.98	5	*Ti* II 1.98 (300)
4574.63	0	(*Fe* I 4.72 (12) *Zr* II 4.50 (2))
4576.36	4	*Fe* II 6.33 (4)
4577.75	1	*Fe* II 7.78 (pr) (*O* I 7.66 (30))
4579.34	1	*Fe* II 9.52 (1)
4580.14	2n	*Fe* II 0.05 (1) (*Ti* II 0.46 (5) *Cr* I 0.06 (300))
4581.71	0	*Fe* I 1.52 (60)
4582.81	4	*Fe* II 2.83 (3)
4583.89	9	*Fe* II 3.83 (11)
4585.69	1	*Al* II 5.82 (40)
4588.21	5	*Cr* II 8.22 (75)
4589.98	3	*Ti* II 9.95 (100) *Cr* II 9.89 (3)
4591.20	0	*Cr* II 1.39 (tr)
4592.09	4	*Cr* II 2.09 (20)
4593.94	0	....
4595.99	3	*Fe* II 5.68 (pr) *A* I 6.10 (1000)
4598.52	1	*Fe* II 8.53 (1)
4600.05	0	*V* II 0.15 (150)
4601.42	0	*Fe* II 1.34 (pr) *Cl* I 1.00 (20)
4616.67	4	*Cr* II 6.64 (18)
4618.82	6	*Cr* II 8.83 (35)
4620.51	4	*Fe* II 0.51 (3)
4621.57	1	*Cr* II 1.41 (pr)
4622.83	1n	....
4625.32	0	*Fe* II 5.55 (tr) *Fe* I 5.05 (100)
4626.02	1	*Fe* II 5.91 (1)

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TABLE 1—*Continued*

Wave Length	Int.	Identification	Wave Length	Int.	Identification
4627.01	0	*Fe* II 6.78 (pr)	5030.77	1–0	*Fe* II 0.74 (3)
4629.34	9	*Fe* II 9.34 (7)	5035.76	1	*Fe* II 5.77 (3)
4631.52	1	(*Fe* II 1.89 (0))	5036.92	0–1	*Fe* II 6.92 (K2)*
4632.48	1	....	5040.91	4	*Si* II 1.13 (8)
4634.08	5	*Cr* II 4.11 (25)	5042.18	0	(*Fe* II 2.20 (pr))
4635.29	4	*Fe* II 5.33 (5)	5056.12	6	*Si* II 6.17 (10)
4636.36	0	*Ti* II 6.34 (4)	5061.60	1	*Fe* II 1.79 (1n)
4638.01	1	*Fe* I 8.02 (80)	5063.48	0–1	*Fe* II 3.43 (pr)
4640.66	0	*Fe* II 0.84 (0) (*Al* II 0.38 (18) *Al* II 0.36 (20))	5075.78	1–0	*Fe* II 5.83 (1n)
4657.04	4	*Fe* II 6.97 (1) *Ti* II 7.21 (18)	5093.58	1	*Fe* II 3.47 (1n) *Fe* II 3.65 (1n)
4663.01	1	*Al* II 3.05 (50) *Ti* II 2.76 (pr)	5097.25	1	*Fe* II 7.37 (1n) *Cr* II 7.29 (7)
4663.73	2	*Fe* II 3.70 (0)	5100.74	3	*Fe* II 0.84 (4) *Fe* II 0.70 (2)
4665.63	0	*Fe* II 5.80 (pr)	5127.91	0–1	*Fe* II 7.87 (1)
4666.77	3	*Fe* II 6.75 (2)	5129.11	1–0	*Ti* II 9.15 (30)
4668.48	0	(*Fe* I 8.14 (125)) *S* II 8.58 (50)	5136.71	0–1	*Fe* II 6.79 (tr) *Fe* II 6.81 (pr)
4670.16	2	*Fe* II 0.17 (0) *Sc* II 0.40 (300)	5146.21	1	*Fe* II 5.87 (0n) *Fe* II 6.12 (pr) *O* I 6.06 (70)
4708.62	0–1	*Ti* II 8.66 (20) *Fe* (II?) 8.97 (3)	5147.31	0	*Fe* II 7.09 (K2)
4731.46	6	*Fe* II 1.44 (3)	5149.57	1	*Fe* II 9.54 (3n)
4734.04	0–1	*Fe* (II?) 4.09 (3)	5150.89	0–1	*Fe* II 0.93 (pr)
4739.57	1–0	*Mg* II 9.59 (5)	5153.41	0–1	*Cr* II 3.49 (15) *Na* I 3.64 (600)
4755.86	0	(*Mn* II 5.73 (0))	5154.16	1	*Ti* II 4.08 (15)
4780.01	2	*Ti* II 9.95 (100) (*Fe* II 0.07 (pr))	5160.82	1–0	*Fe* II 0.82 (1)
4805.09	2	*Ti* II 5.10 (125)	5167.35	1–2	*Mg* I 7.34 (100) *Fe* I 7.49 (700)
4812.37	1	*Cr* II 2.35 (25)	5168.97	8	*Fe* II 9.03 (12)
4824.14	8	*Cr* II 4.13 (75)	5172.72	3	*Mg* I 2.70 (200) (*Fe* II 3.00 (0))
4836.16	2	*Cr* II 6.22 (25)	5183.62	4	*Mg* I 3.62 (500)
4848.28	7	*Cr* II 8.24 (60)	5185.87	2	*Ti* II 5.90 (35)
4855.94	1	*Cr* II 6.19 (20)	5188.75	3	*Ti* II 8.70 (100)
4861.29	15	*H*β 1.33 (500)	5197.57	7	*Fe* II 7.57 (6)
4864.34	3	*Cr* II 4.32 (50)	5216.84	2	*Fe* II 6.93 (3)
4865.85	1–0	*Ti* II 5.62 (3) *Fe* II 6.25 (pr)	5226.60	2	*Ti* II 6.55 (50)
4871.57	1–0	*Fe* II 1.61 (pr) *Fe* I 1.32 (200)	5227.14	1	*Fe* (II?) 7.0 (K15) *Fe* I 7.19 (400)
4874.10	0	*Ti* II 4.02 (3)	5227.59	2	(*Ti* II 7.89 (pr))
4876.40	7	*Cr* II 6.41 (50)	5232.62	1	*Fe* I 2.94 (800) *Cr* II 2.50 (15)
4883.57	0–1	*Y* II 3.69 (200)	5234.66	7	*Fe* II 4.62 (7)
4884.60	2	*Cr* II 4.57 (10)	5237.32	4	*Cr* II 7.34 (75)
4911.16	1	*Ti* II 1.18 (100)	5237.88	1	*Fe* II 8.00 (1)
4923.92	10	*Fe* II 3.92 (12)	5247.94	1	*Fe* II 8.03 (2)
4957.54	1	*Fe* I 7.61 (300)	5251.16	1	*Fe* II 1.31 (2)
4984.55	1–0	*Fe* II 4.56 (1)	5254.94	3	(*Fe* II 4.92 (pr))
4993.38	1	*Fe* II 3.35 (1)	5256.97	1	*Fe* II 6.89 (K1)
5001.95	3	(*Fe* II 1.89 (pr))	5260.42	3	*Fe* II 0.33 (5nn)
5004.03	2n	*Fe* II 4.26 (3n)	5262.22	1	*Ti* II 2.10 (3)
5005.60	0	(*Ti* II 5.17 (pr) *N* II 5.14 (500))	5264.28	1	*Fe* II 4.23 (1n) *Mg* II 4.14 (5)
5015.90	1	*He* I 5.67 (100) *Fe* II 5.77 (0)	5264.87	3	*Fe* II 4.80 (2)
5018.44	10	*Fe* II 8.43 (12)	5272.52	2	*Fe* II 2.41 (2)

* Capital K refers to the intensities in King's list of iron lines in the visual region (*Ap. J.*, **87**, 109, 1938).

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TABLE 1—*Continued*

Wave Length	Int.	Identification
5275.01	2	*Fe* II 4.98 (0); *O* I 5.08 (50); *Cr* II 4.99 (20)
5276.05	6	*Fe* II 5.99 (7)
5280.14	1	*Cr* II 9.92 (15); *Cr* II 0.08 (10)
5284.18	4	*Fe* II 4.09 (3)
5291.72	2	*Fe* II 1.75 (2nn)
5298.75	0–1	*O* I 9.00 (70)
5306.11	1	*Cr* II 5.85 (25); *Fe* II 6.23 (0n)
5308.42	1	*Cr* II 8.44 (20)
5310.74	1	*Cr* II 0.70 (12)
5313.55	2	*Cr* II 3.59 (25)
5316.71	8	*Fe* II 6.61 (8); *Fe* II 6.78 (4)
5318.72	1	*Cr* II 8.41 (4)
5325.56	3	*Fe* II 5.56 (2)
5334.90	3	*Cr* II 4.88 (40)
5336.85	1	*Ti* II 6.81 (30)
5337.80	2	*Cr* II 7.79 (12); *Fe* II 7.71 (0)
5339.53	2	(*Fe* II 0.07 (pr))
5346.62	0	*Fe* II 6.56 (K1); *Cr* II 6.54 (5)
5362.88	6	*Fe* II 2.86 (5)
5387.01	1	*Fe* II 7.14 (2nn)
5393.79	0–1	*Fe* II 3.56 (pr)
5396.02	1	*Fe* II 5.86 (1nn)
5401.99	1	*Fe* II 2.11 (2nn)
5414.35	1n	*Fe* II 4.09 (2)
5425.32	2	*Fe* II 5.27 (2)
5427.86	1	*Fe* II 7.82 (3)
5430.04	2	*Fe* I 9.70 (500); *Cr* II 0.41 (pr)
5433.00	3	*Fe* II 2.98 (pr); *S* II 2.83 (600)
5435.22	0	*O* I 5.16 (70)
5467.04	1–0	*Fe* II 6.95 (3)
5478.40	2	*Cr* II 8.35 (15)
5482.38	1	*Fe* II 2.40 (2)
5487.63	1	....
5493.85	1–0	*Fe* II 3.87 (1)
5502.24	1–0	*Cr* II 2.05 (12)
5503.29	0–1	*Cr* II 3.18 (8); *Fe* II 3.40 (1)
5506.24	2	*Fe* II 6.27 (3nn)
5508.69	0–1	*Cr* II 8.60 (8)
5510.80	1–0	*Cr* II 0.68 (7)
5512.42	0–1	*O* I 2.70 (70h)
5534.86	5	*Fe* II 4.86 (4)
5586.78	0	*Fe* I 6.76 (400)
5780.41†	1	....
5875.59	3	*He* I 5.62 (1000)
5957.90‡	3	*Si* II 7.61 (5)
5978.96	3	*Si* II 8.97 (7)
5991.11‡	2	*Fe* II 1.38 (K10)
6084.18	0	*Fe* II 4.11 (K5)
6147.84	3	*Fe* II 7.73 (2)
6149.23	3	*Fe* II 9.24 (2)
6155.99	1	*O* I 5.99 (150)
6156.74	1–2	*O* I 6.78 (300)
6158.14	2	*O* I 8.20 (1000)
6175.14	1	*Fe* II 5.16 (1)
6230.91	0	*Fe* I 0.73 (60)
6238.36	3	*Fe* II 8.37 (1)
6239.97	1	*Fe* II 9.95 (K2)
6247.53	5	*Fe* II 7.56 (3)
6252.51	0	*Fe* I 2.56 (60)
6305.26	1–0	*Fe* II 5.32 (1)
6317.58	1	*Fe* (II?) 7.40 (K3)
6331.96	1	*Fe* II 1.97 (1n)
6347.10	10	*Si* II 7.10 (10)
6371.31	8	*Si* II 1.36 (8)
6383.74	0	*Fe* II 3.75 (K5)
6416.90	3	*Fe* II 6.90 (1)
6432.89	1	*Fe* II 2.65 (K8)
6442.90	0	*Fe* II 2.97 (K6)
6456.38	4	*Fe* II 6.38 (3); *O* I 6.07 (500)
6469.8†	2	(*Fe* II 9.58 (pr))
6472.9†	1	....
6475.8†	3	....
6482.1	2	*Fe* II 2.20 (1)
6516.1	2	*Fe* II 6.05 (K20)
6545.9	1	*Mg* II 5.80 (10)
6550.1†	1	....
6562.2§	10A	*H*α 2.82 (2000)
6563.5‖	2E	
6586.7	1–0	*Fe* II 6.69 (K5)

† Stellar character not certain.

‡ Blended by atmospheric line; but stellar component certain. There may be faint lines of *Fe* II at λλ 6491.3, 6493.0, and 6517.0; but they are blended with atmospheric lines. The interstellar lines D_1 and D_2 have not been included in the table.

§ Extending from λ 6561.3 to λ 6563.0.

‖ Extending from λ 6563.0 to λ 6564.2.

are doubtful or represent minor contributions. The mean errors of the wave lengths depend on the character of the line and on the region and may be readily estimated from Table 1. In H and K the stellar and interstellar components appear separated, whereas the observed D lines seem to be chiefly interstellar.[10]

[10] Merrill, Sanford, Wilson, and Burwell, *Ap. J.*, **86**, 278, 1937.

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In the region $\lambda < 4700$ a Process emulsion was used. Because of the excellent quality of the spectrograms, many lines could be added to Morgan's table, and the vast majority of his fainter lines, not included in Wyse's list, have been verified. In the region $\lambda > 4700$ an Agfa Super-Pan Press emulsion was used, and relatively fewer lines were measured. Our present list in the visual region differs considerably from Marshall's, and the identifications are now as complete as in the blue and violet parts of the spectrum. In several parts of the visual region, weak stellar lines may have been masked by atmospheric features. On the whole, very few lines remain unidentified.

The laboratory wave lengths and intensities were taken from the *M.I.T. Wave Length Tables*, except for *Fe* II (Dobbie), *V* II (Meggers and Moore), *Si* II, *Mn* II, *Cr* II, and *Ni* II (mostly Moore, *Multiplet Table* and unpublished material). The laboratory intensity scales are sometimes unsatisfactory with regard to uniformity. A photometric survey is planned which would replace our estimates of stellar intensities by equivalent widths.

The variations in radial velocity[11] and in color[12] have occasionally led to the suggestion[13] that α Cygni may be a variable star of the β Cephei type. The period, if there is any, seems[13] to be of the order of 0.2 day. A very sensitive criterion should be the profile of $H\alpha$, which pictures the physical state of the atmosphere. It is known that bright $H\alpha$ exhibits large variations in intensity, the period of which may be several months, although a short period was not considered impossible.[14] In order to test the possibility of a very short period, six coudé spectrograms were taken during the night of August 4, 1940. They are excellent in the visual region and cover an interval of 0.25 day. There is no indication of a change in the profile of the complex line $H\alpha$.

We are greatly indebted to Mrs. Moore-Sitterly for her unpublished wave-length tables of various elements.

McDonald Observatory
and
Yerkes Observatory
June 1941

[11] Paddock, *Lick Obs. Bull.*, **17**, 99, 1935.

[12] Greaves, Davidson, and Martin, *Pub. Royal Obs.* (Greenwich), 1932, p. 54; Güssow and Guthnick, *Klein. Veröff.* (Berlin-Babelsberg), No. 8, 1930, star No. 419.

[13] C. and S. Gaposchkin, *Variable Stars*, p. 177, 1938.

[14] Struve and Roach, *Ap. J.*, **78**, 302, 1933.

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