Appendix C: Data

C.1: Unblended Solar Spectral Lines

Although there are a great many solar spectral lines (Moore, Minnaert and Houtgast list about 24000 lines[1]), most of them are blended with other nearby lines. To see clearly the profile of the line, especially in the wings, it is desirable to use unblended spectral lines. A scan of the Jungfraujoch Solar Atlas[2] was made by Rutten and van der Zalm[3] who identified 154 lines as being sufficiently unblended so that the profiles should be reliable. Inspection of these lines shows that some of them are noticeably blended and therefore should be rejected; this leaves 132 unblended solar lines. The profiles of these clean lines are shown in figure C-1.

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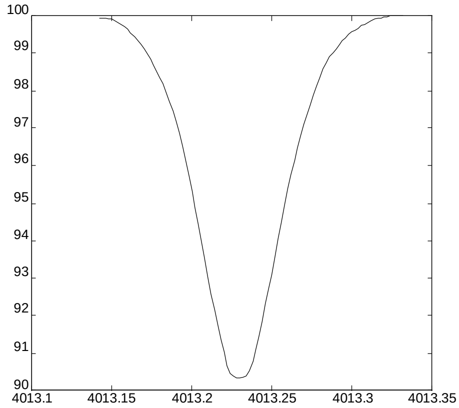
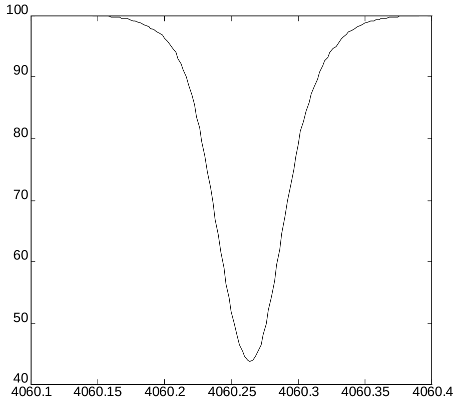
[1]Moore, C.E., Minnaert, M.G.J and Houtgast, J. "The Solar Spectrum 2935Å to 8770Å" *National Bureau of Standards Monograph* **61**, U.S. Government Printing Office, Washington (1966).

[2]Delbouille, L., Roland, G. and Neven, L. "Photometric Atlas of the Solar Spectrum from 3000Å to 10000Å" Institut d'Astrophysique, Liege (1973).

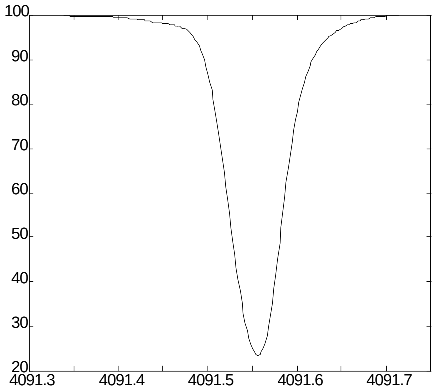
[3]Rutten, R.J and van der Zalm, E.B.J, "Revision of Solar Equivalent Widths, Fe I Oscillator Strengths and the Solar Iron Abundance", *Astronomy and Astrophysics Supplement Series* **55**, pg 143-161 (1984).



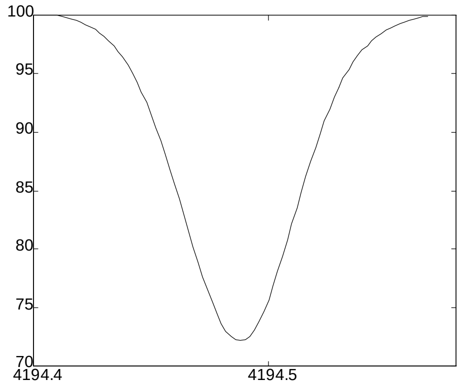
Ti I - 4013.232Å



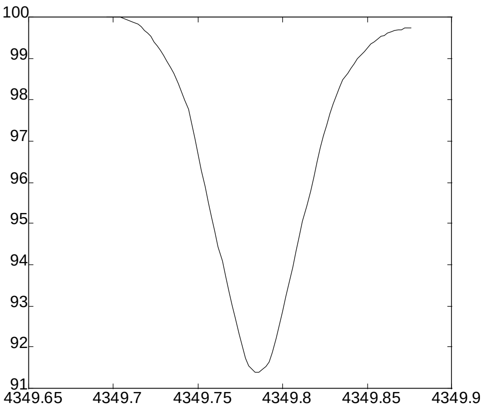
Ti I - 4060.266Å



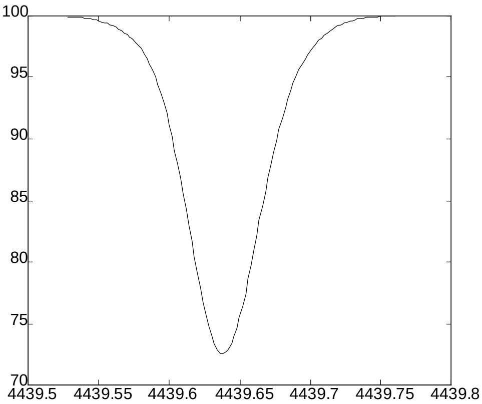
Fe I - 4091.556Å



Fe I - 4194.490Å

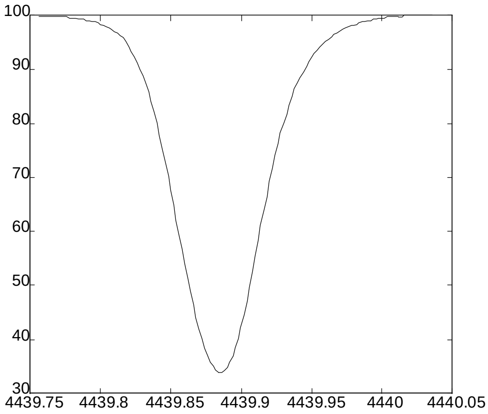


Ce II - 4349.787Å

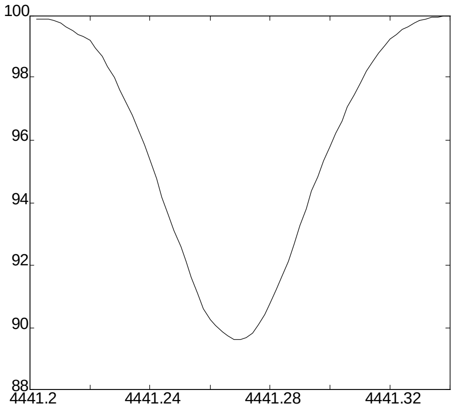


Fe I - 4439.639Å

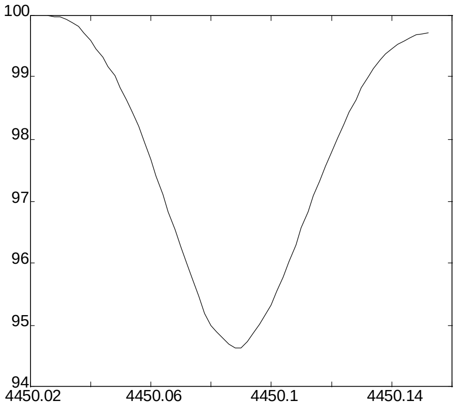
Figure C-1: Clean Solar Lines (continued on next page)



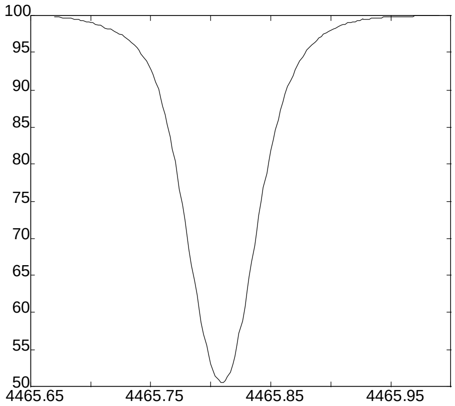
Fe I - 4439.887Å



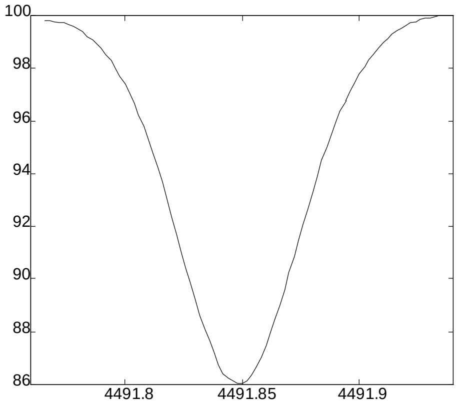
Ti I - 4441.271Å



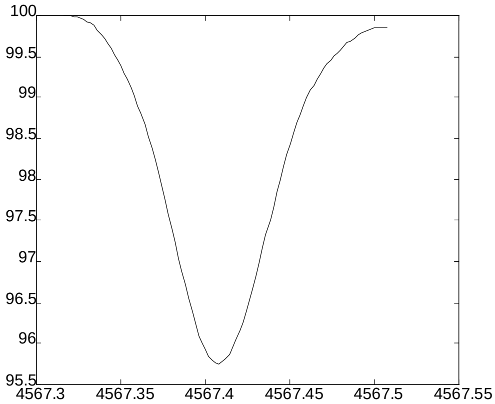
Ni I - 4450.091Å



Ti I - 4465.809Å

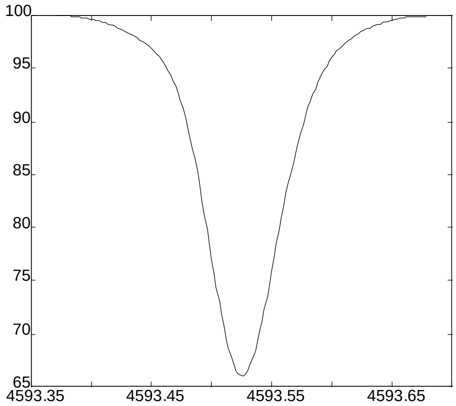


Cr I - 4491.850Å

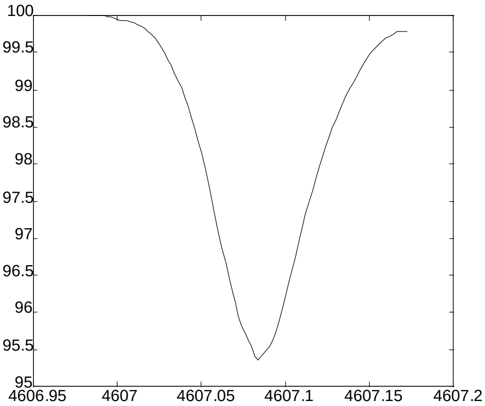


Ni I - 4567.410Å

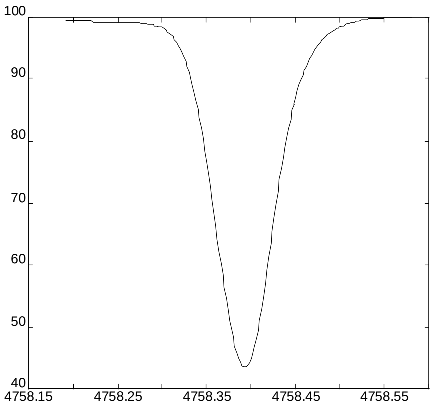
Figure C-1: Clean Solar Lines (continued on next page)



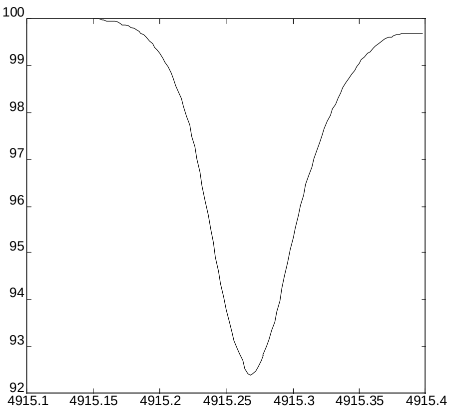
Fe I - 4593.528Å



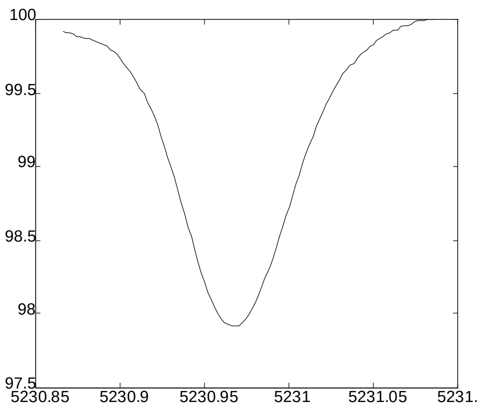
Fe I - 4607.087Å



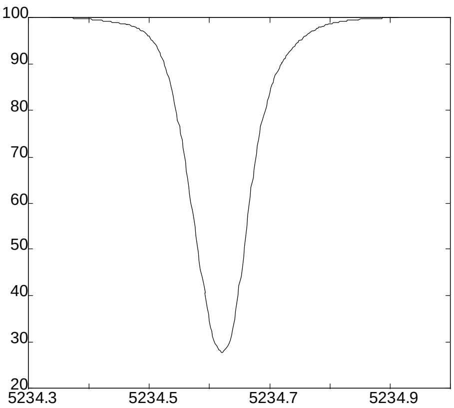
Ni I - 4758.420Å



Ti I - 4915.235

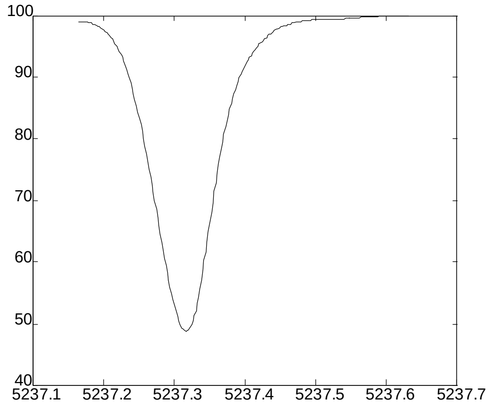


Ti I - 5230.970Å

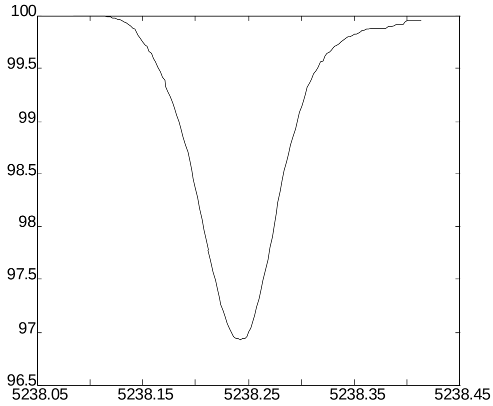


Fe II - 5234.622Å

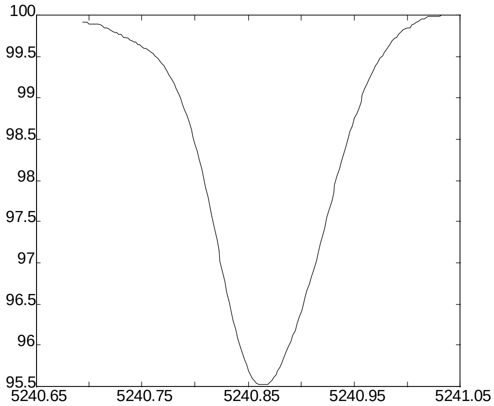
Figure C-1: Clean Solar Lines (continued)



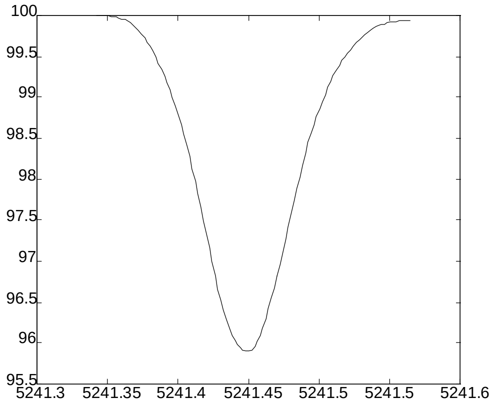
Cr II - 5237.316Å



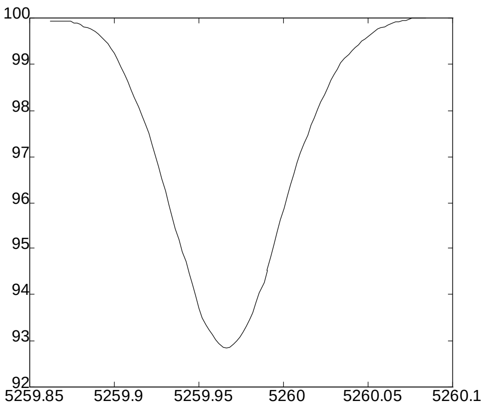
Fe I - 5238.243Å



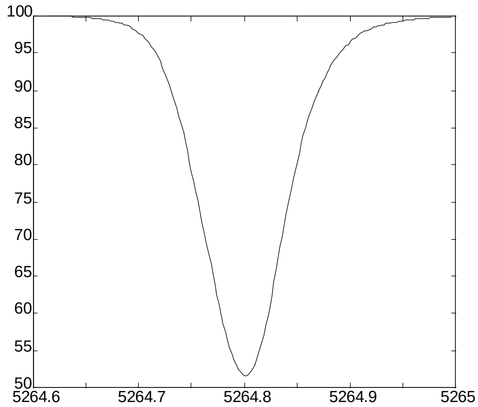
V I - 5240.870Å



Cr I - 5241.450Å

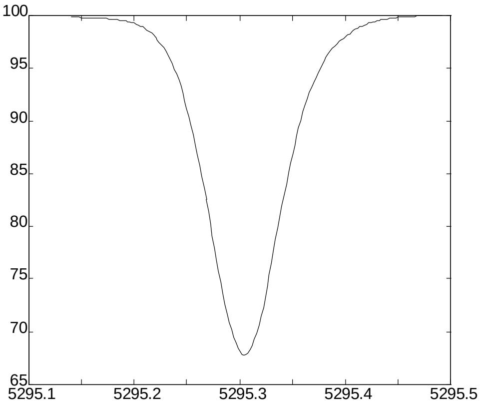


Ti I - 5259.968Å

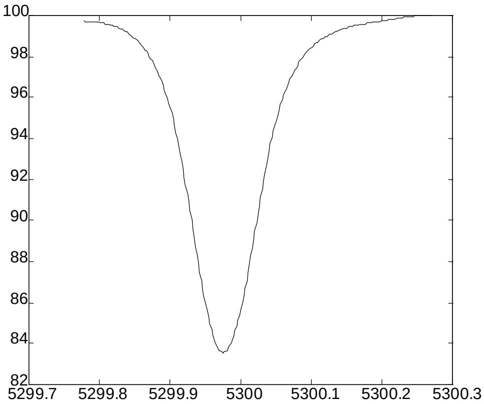


Fe II - 5264.802Å

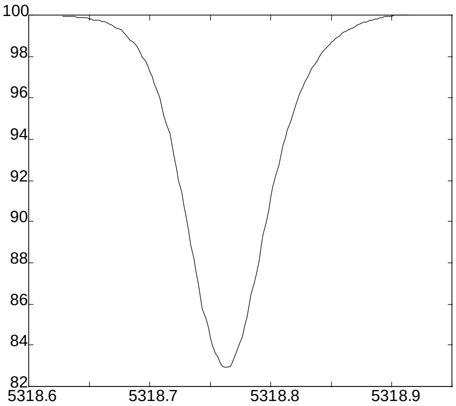
Figure C-1: Clean Solar Lines (continued)



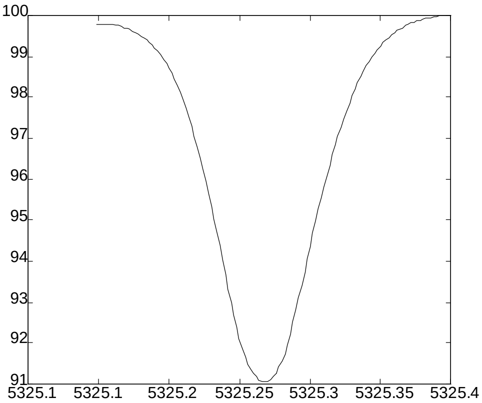
Fe I - 5295.306Å



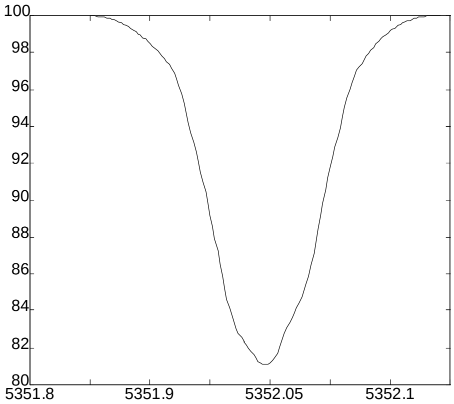
Ti I - 5299.978Å



Cr I - 5318.763Å



Co I - 5325.270Å



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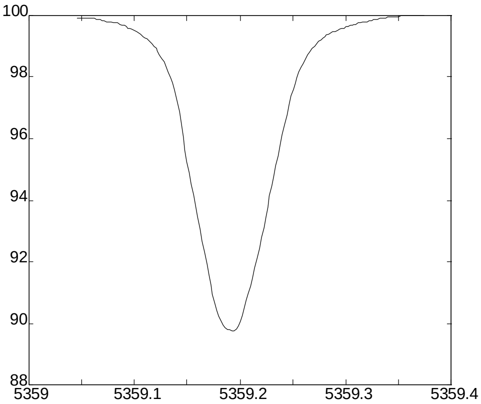
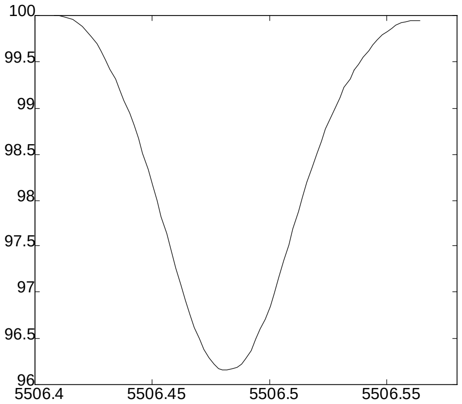
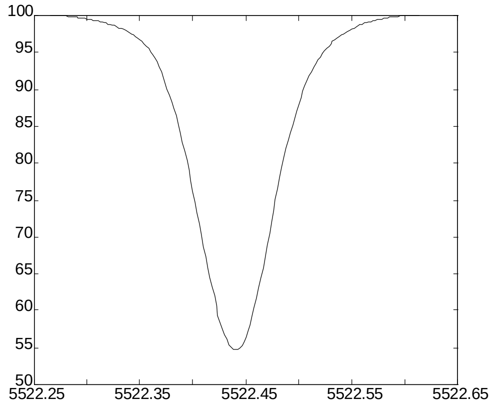


Co I - 5359.194Å

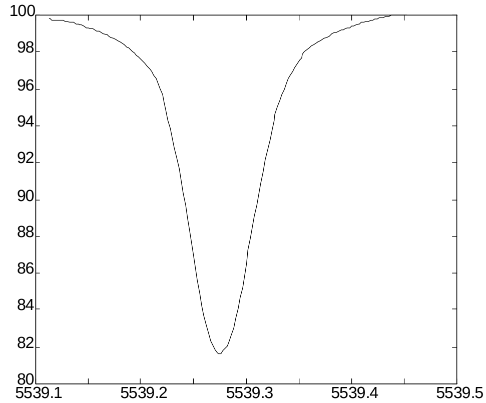
Figure C-1: Clean Solar Lines (continued)



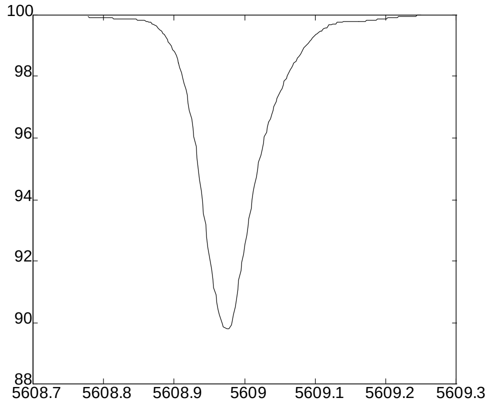
Mo I - 5506.485Å



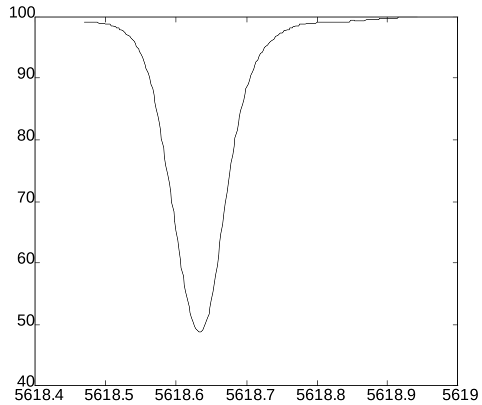
Fe I - 5522.442Å



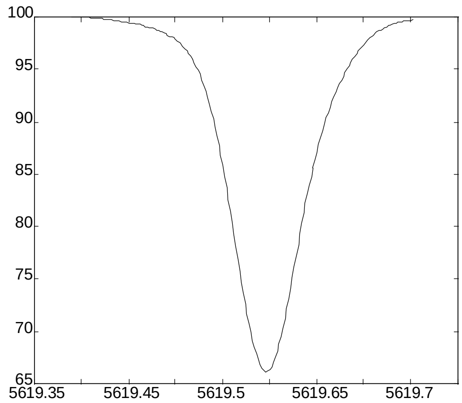
Fe I - 5539.278Å



Fe I - 5608.976Å

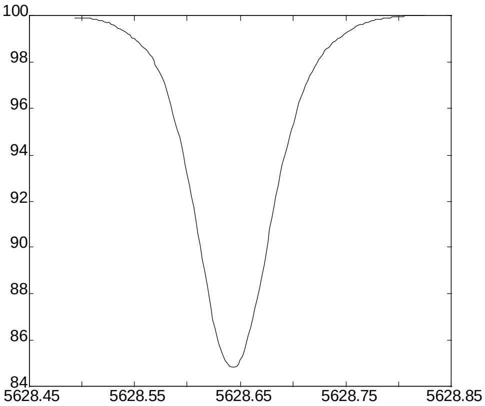


Fe I - 5618.634Å

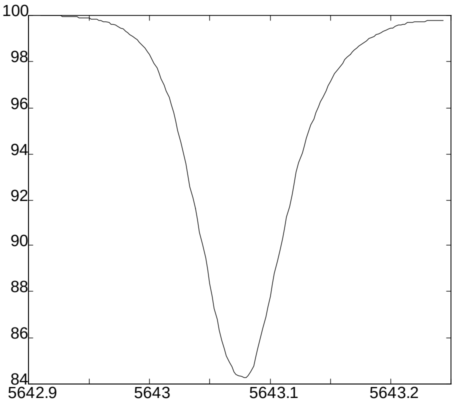


Fe I - 5619.597Å

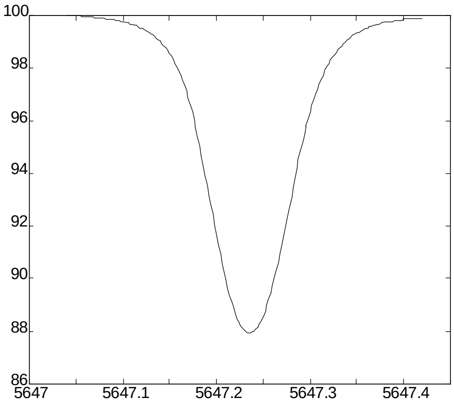
Figure C-1: Clean Solar Lines (continued)



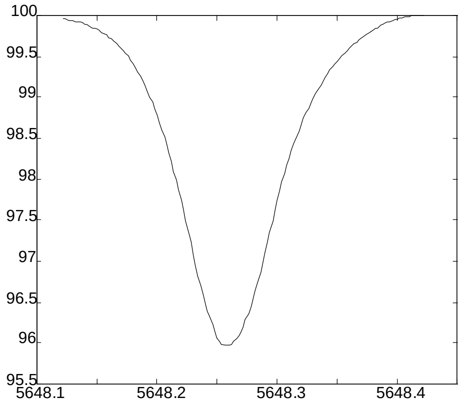
Cr I - 5628.643Å



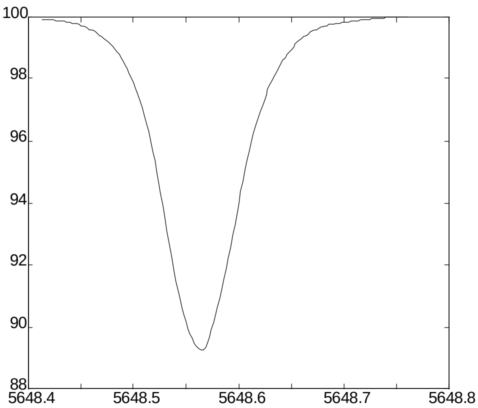
Ni I - 5643.078Å



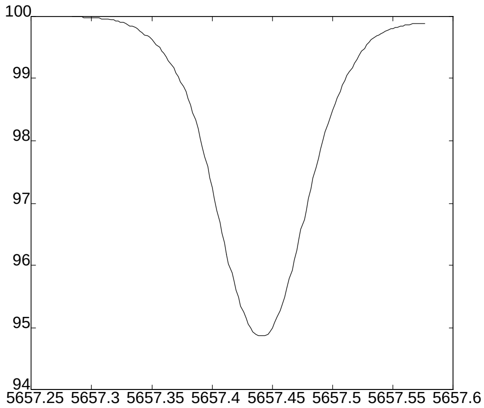
Co I - 5647.238Å



Cr I - 5648.262Å

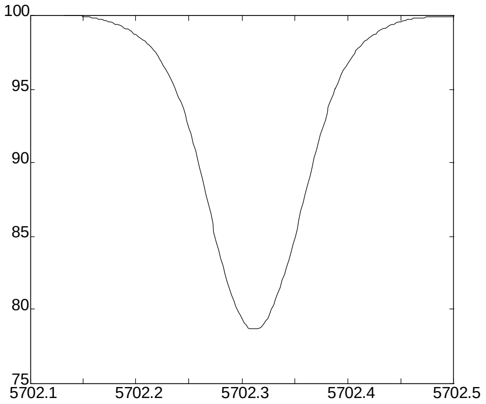


Ti I - 5648.565Å

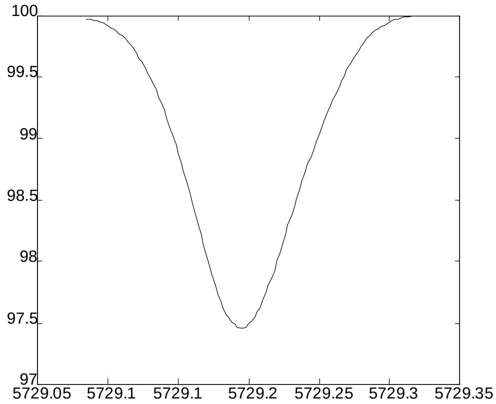


V I - 5657.443Å

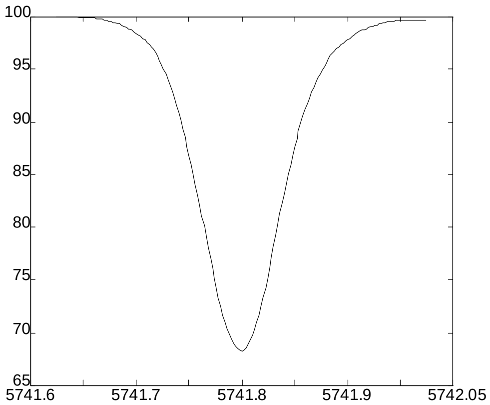
Figure C-1: Clean Solar Lines (continued)



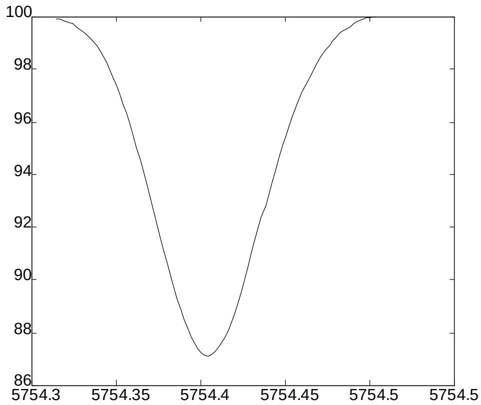
Cr I - 5702.314Å



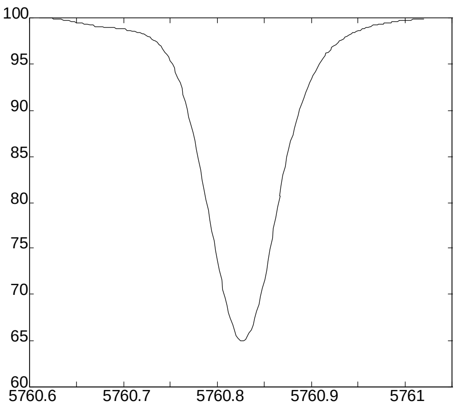
Cr I - 5729.198Å



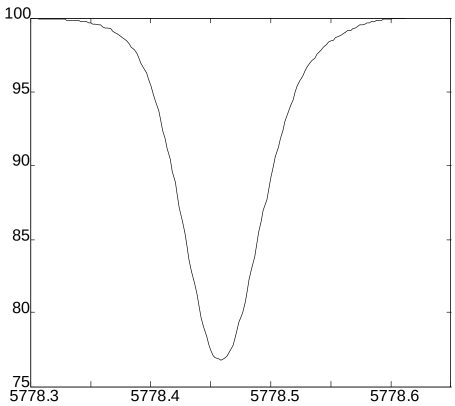
Fe I - 5741.851Å



Fe I - 5754.406Å

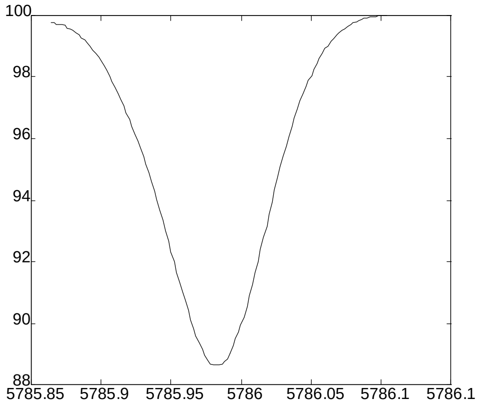


Ni I - 5760.829Å

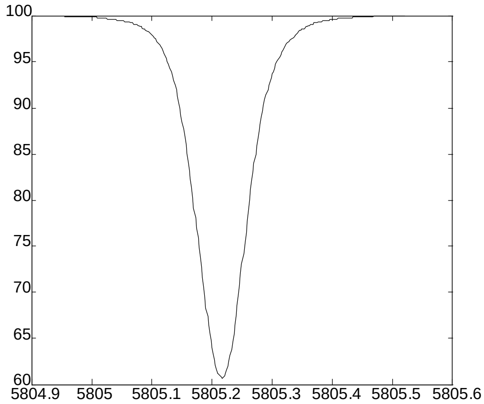


Fe I - 5778.461Å

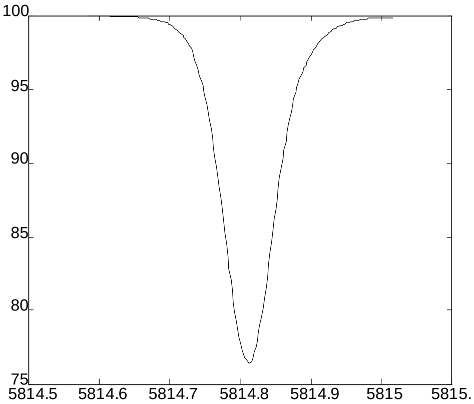
Figure C-1: Clean Solar Lines (continued)



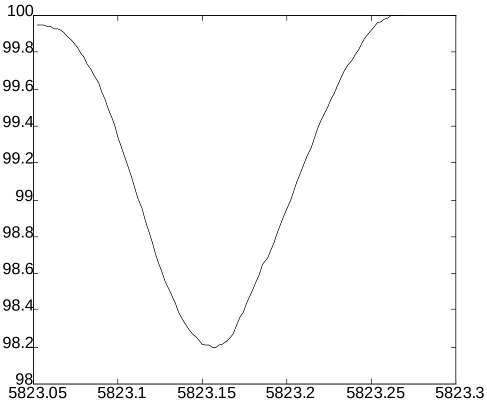
Ti I - 5785.984Å



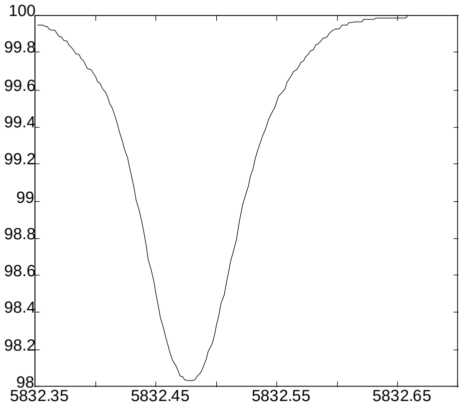
Ni I - 5805.218Å



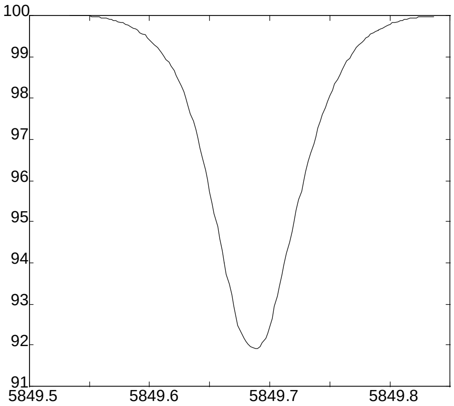
Fe I - 5814.814Å



Fe II - 5823.158Å

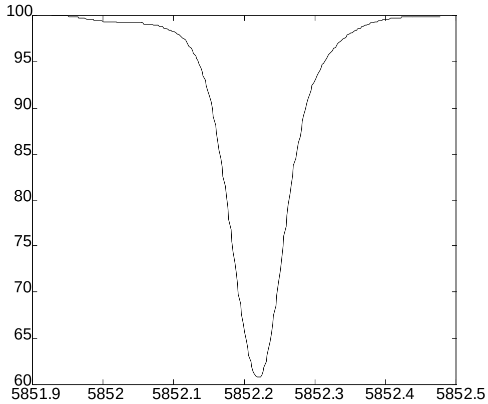


Ti I - 5832.480Å

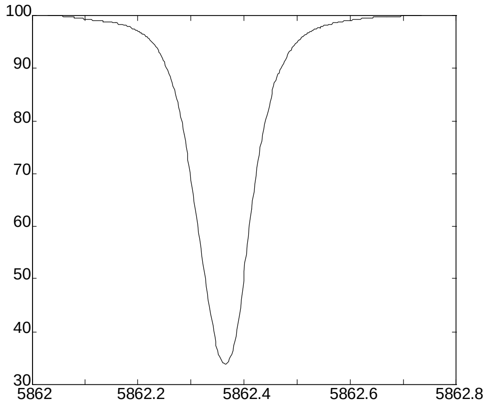


Fe I - 5849.687Å

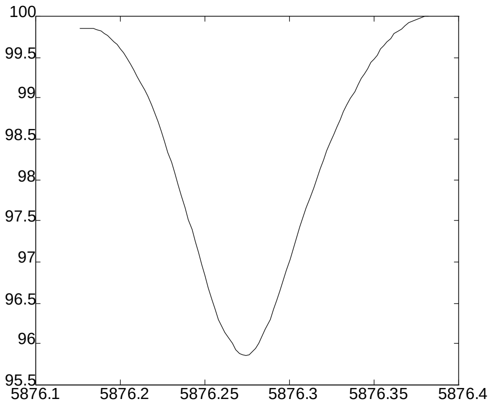
Figure C-1: Clean Solar Lines (continued)



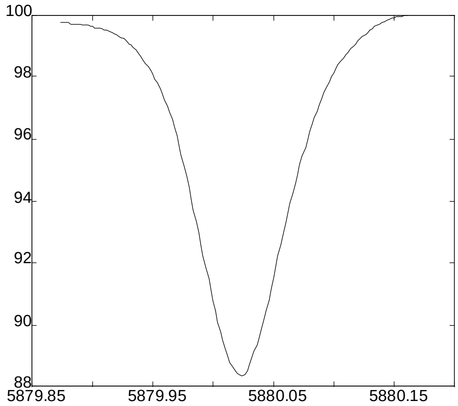
Fe I - 5852.219Å



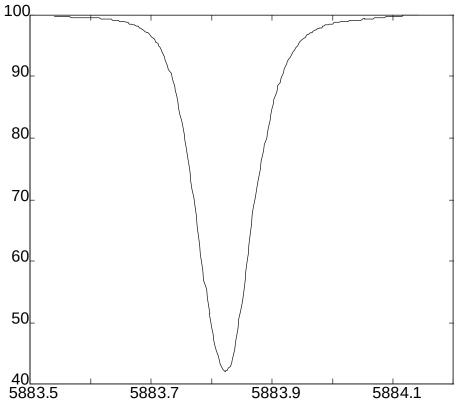
Fe I - 5862.364Å



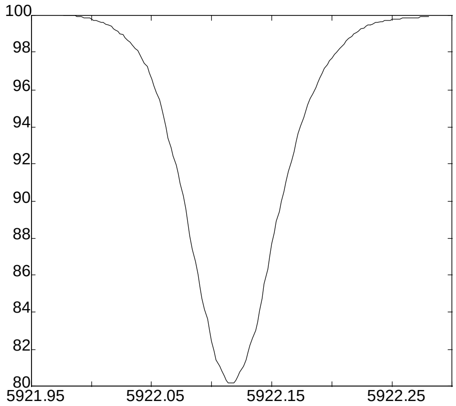
Fe I - 5876.276Å



Fe I - 5880.025Å

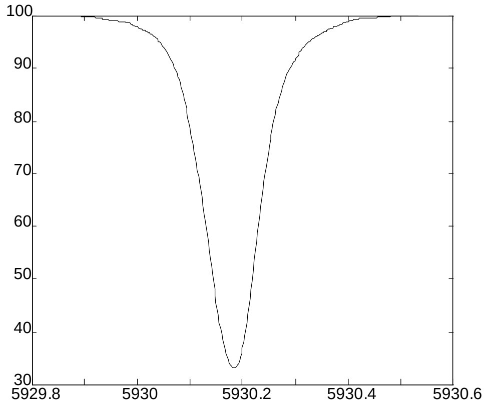


Fe I - 5883.823Å

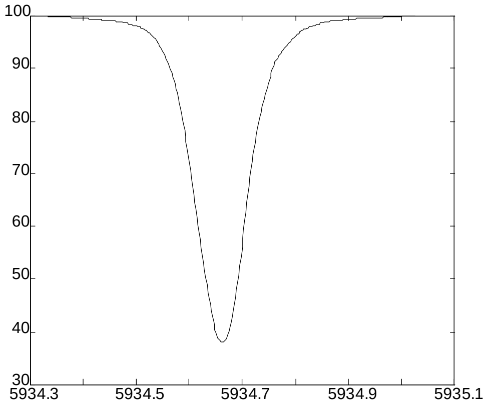


Ti I - 5922.119Å

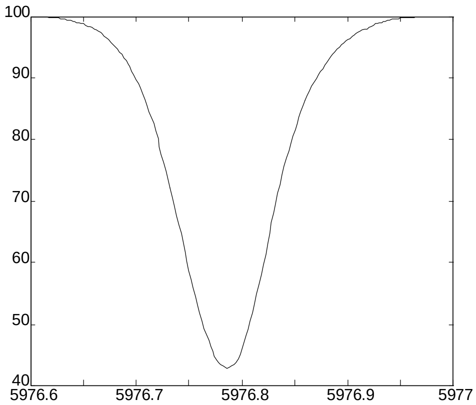
Figure C-1: Clean Solar Lines (continued)



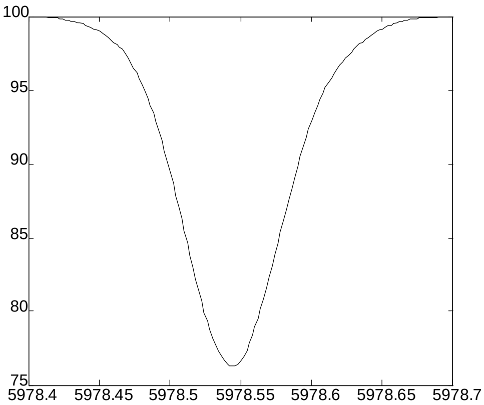
Fe I - 5930.182Å



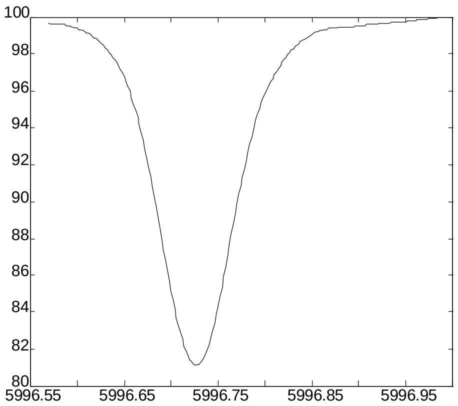
Fe I - 5934.662Å



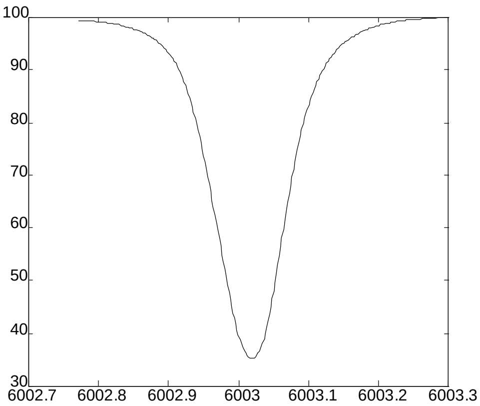
Fe I - 5976.786Å



Ti I - 5978.546Å

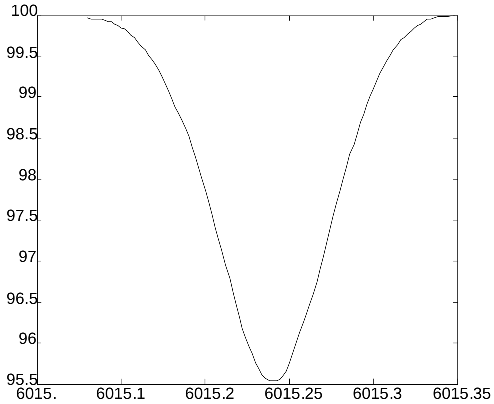


Ni I - 5996.729Å

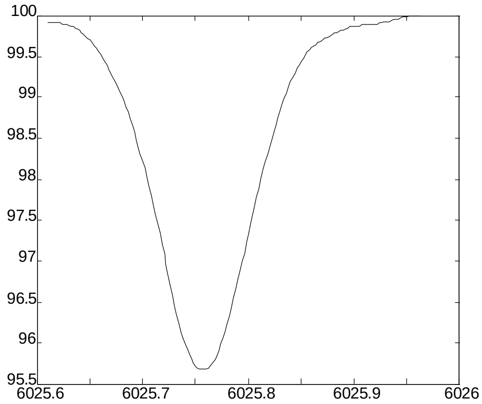


Fe I - 6003.017Å

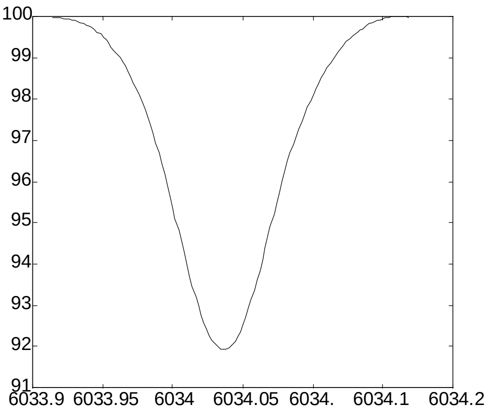
Figure C-1: Clean Solar Lines (continued)



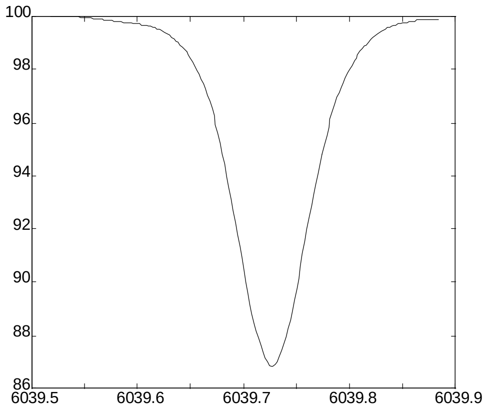
Fe I - 6015.242Å



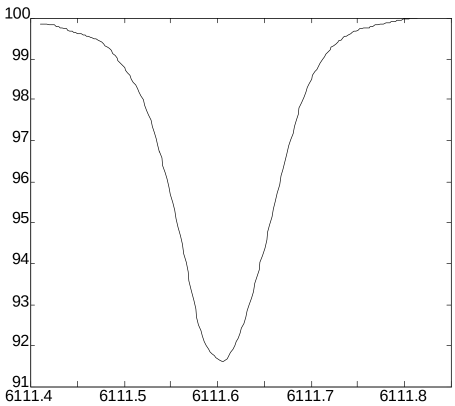
Ni I - 6025.760Å



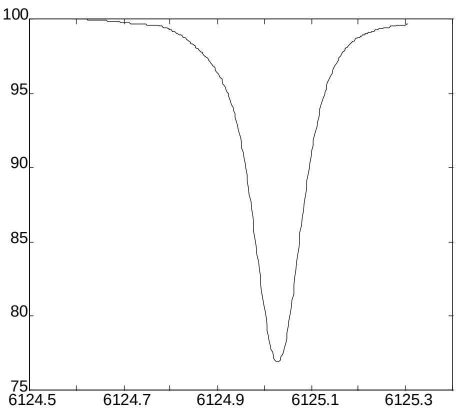
Fe I - 6034.037Å



V I - 6039.729Å

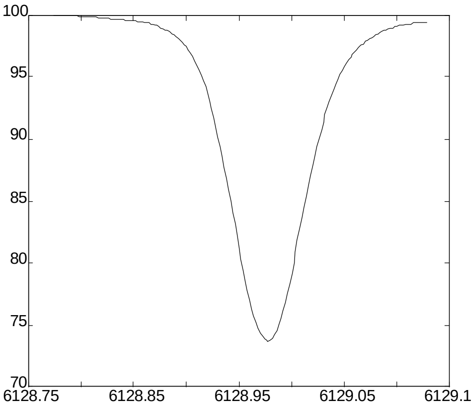


V I - 6111.658Å

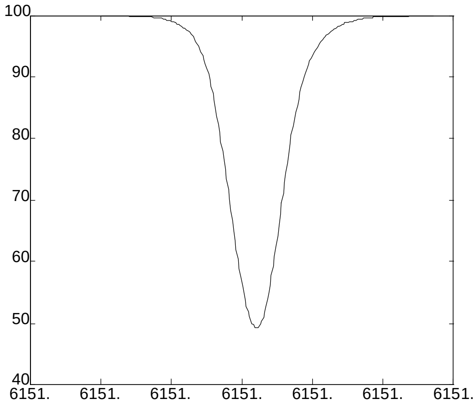


Si I - 6125.029Å

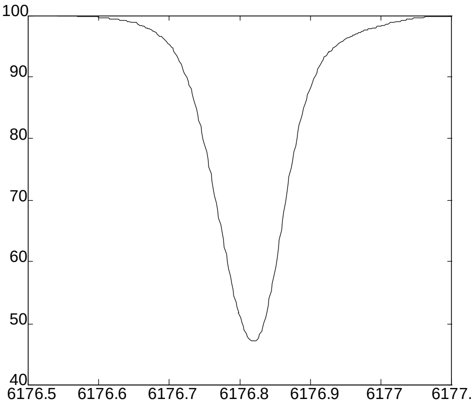
Figure C-1: Clean Solar Lines (continued)



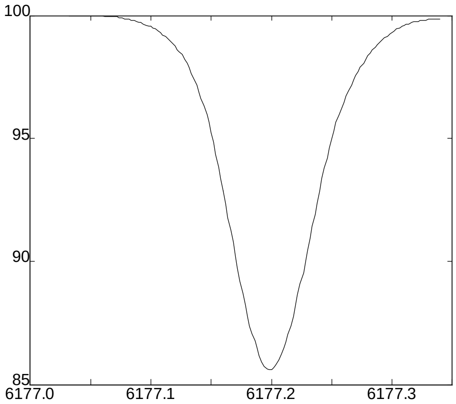
Ni I - 6128.979Å



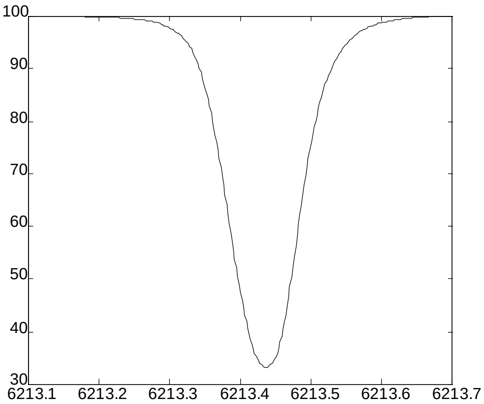
Fe I - 6151.622Å



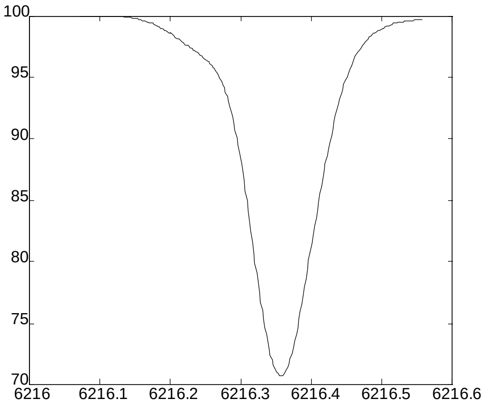
Ni I - 6176.818Å



Ni I - 6177.249Å

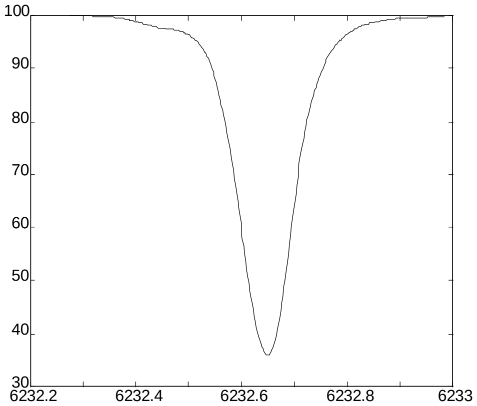


Fe I - 6213.436Å

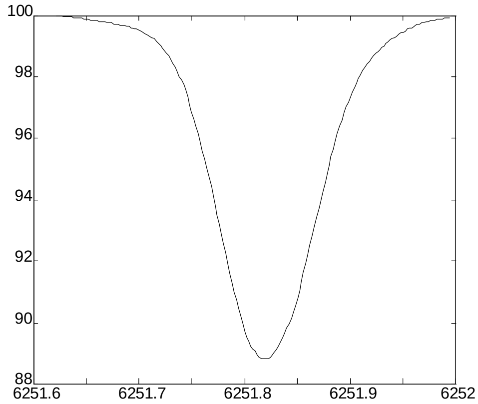


V I - 6216.360Å

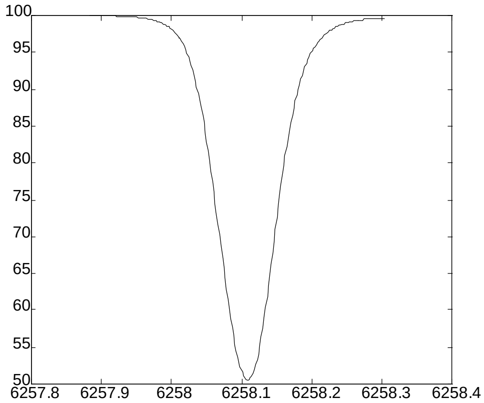
Figure C-1: Clean Solar Lines (continued)



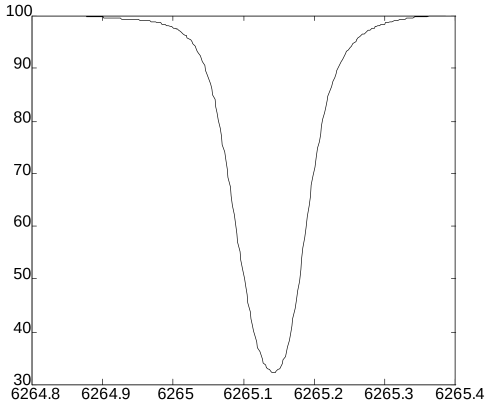
Fe I - 6232.647Å



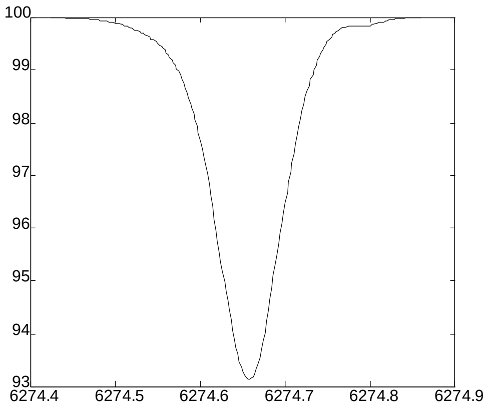
V I - 6251.823Å



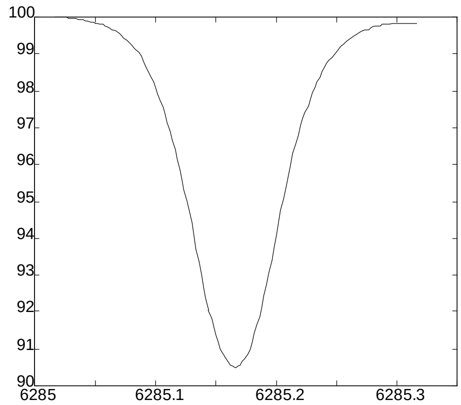
Ti I - 6258.110Å



Fe I - 6265.139Å

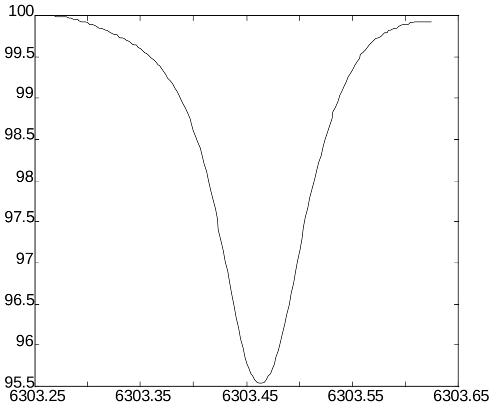


V I - 6274.658Å

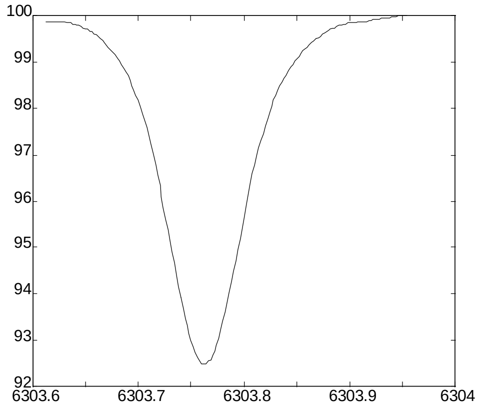


V I - 6285.168Å

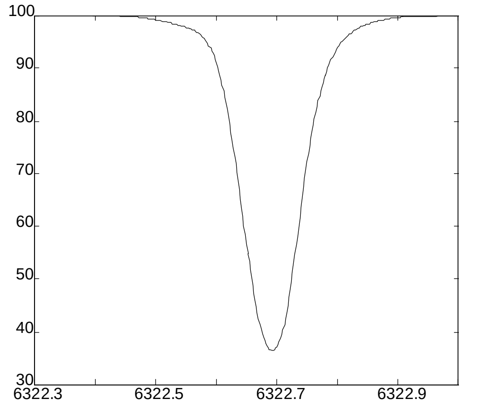
Figure C-1: Clean Solar Lines (continued)



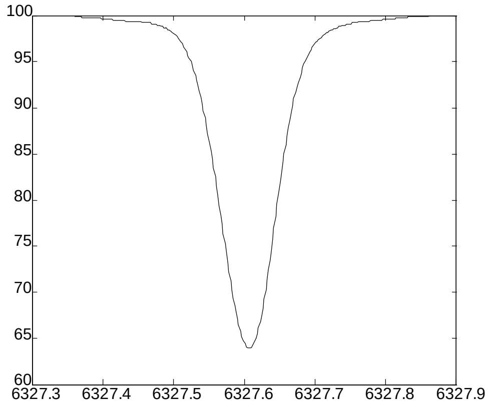
Fe I - 6303.466Å



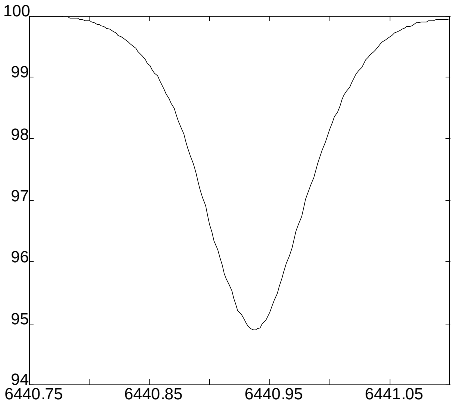
Ti I - 6303.765Å



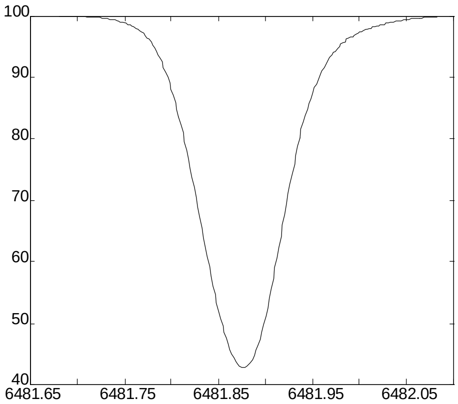
Fe I - 6322.693Å



Ni I - 6327.608Å

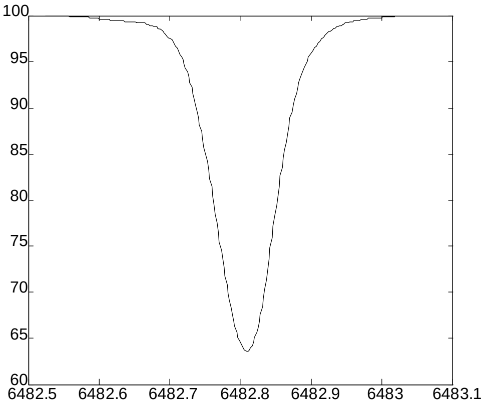


Mn I - 6440.937Å

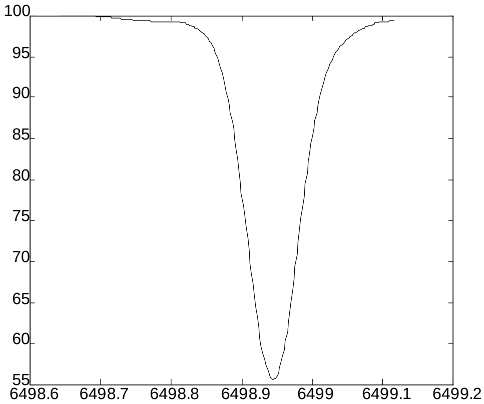


Fe I - 6481.877Å

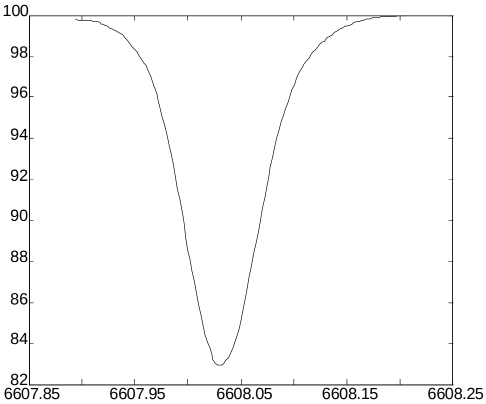
Figure C-1: Clean Solar Lines (continued)



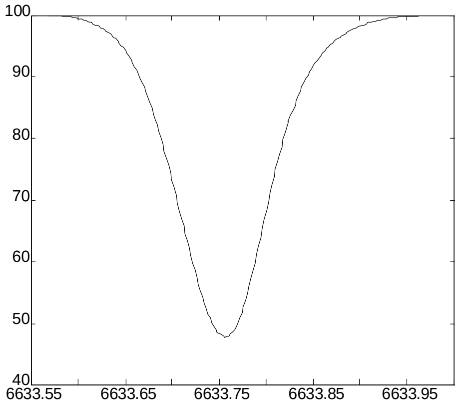
Ni I - 6482.808Å



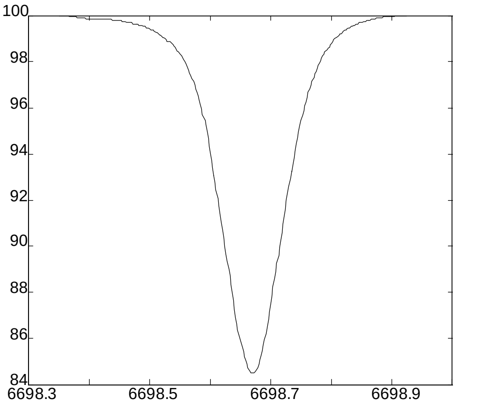
Fe I - 6498.946Å



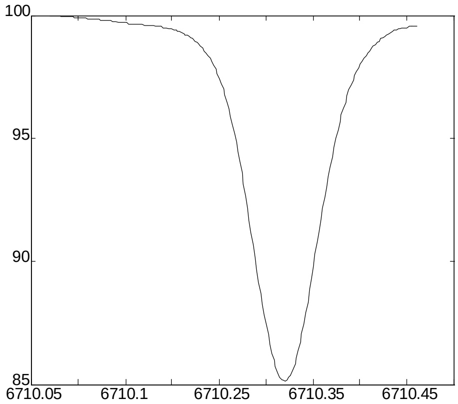
Fe I - 6608.031Å



Fe I - 6633.755Å

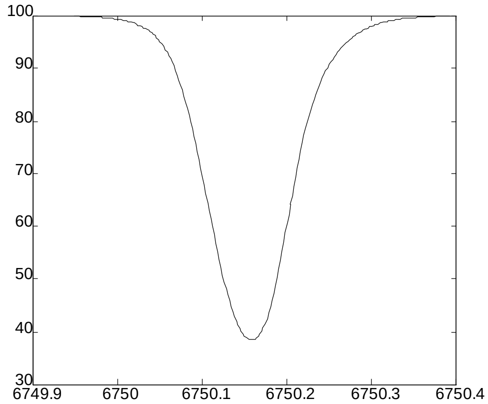


Al I - 6698.671Å

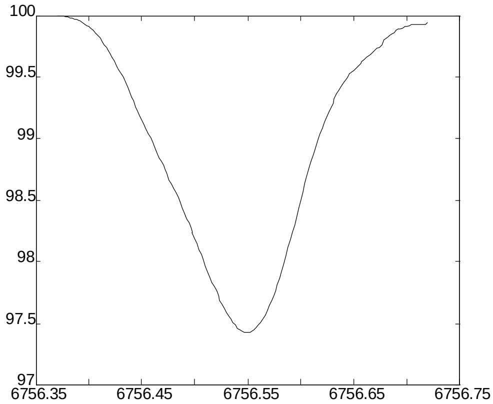


Fe I - 6710.322Å

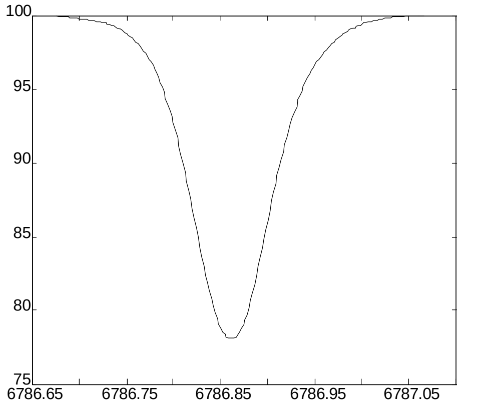
Figure C-1: Clean Solar Lines (continued)



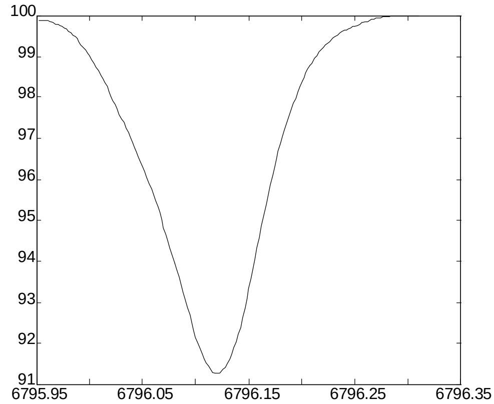
Fe I - 6750.158Å



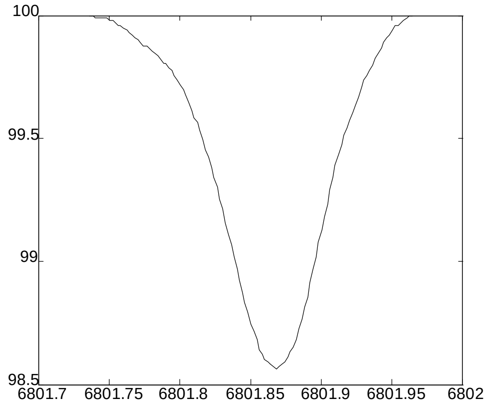
Fe I - 6756.547Å



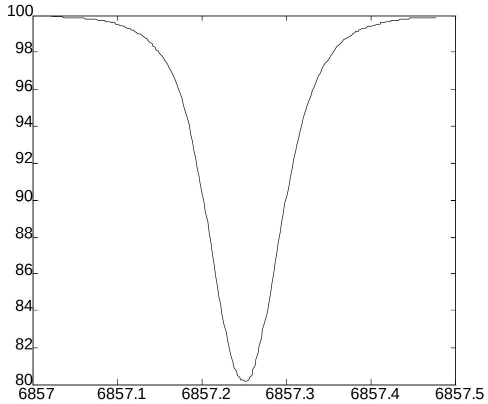
Fe I - 6786.863Å



Fe I - 6796.120Å

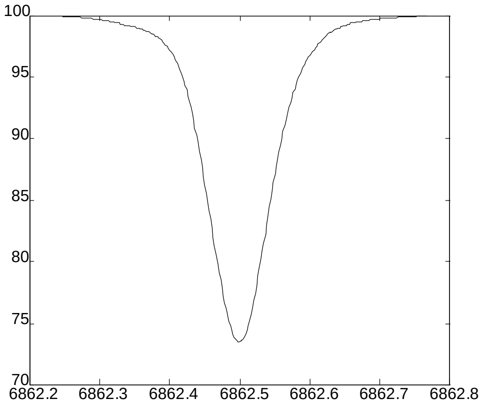


Fe I - 6801.869Å

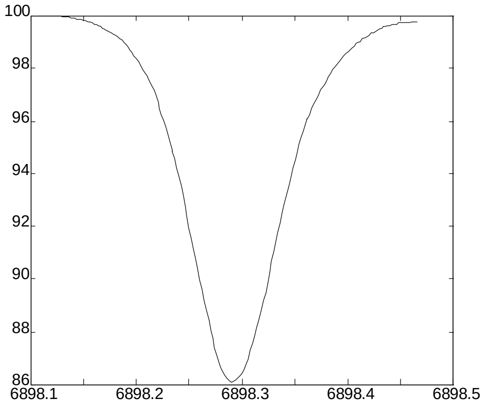


Fe I - 6857.252Å

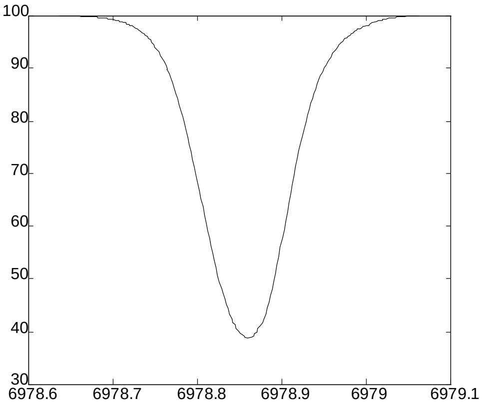
Figure C-1: Clean Solar Lines (continued)



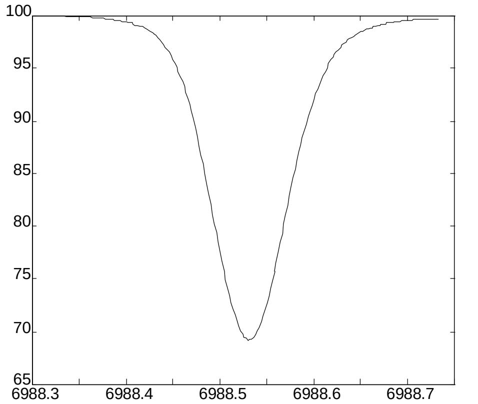
Fe I - 6862.499Å



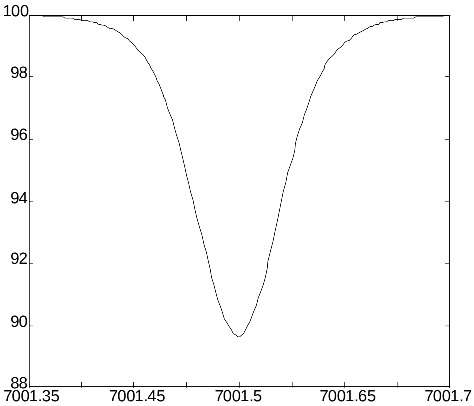
Fe I - 6898.294Å



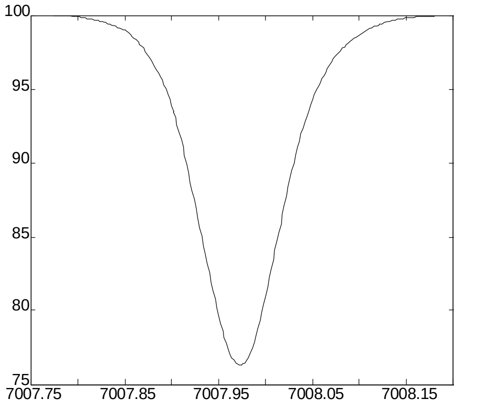
Fe I - 6978.859Å



Fe I - 6988.531Å

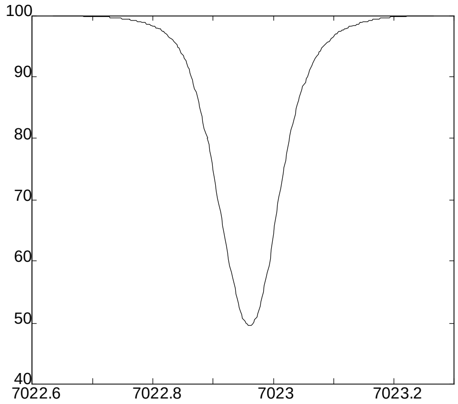


Ni I - 7001.549Å

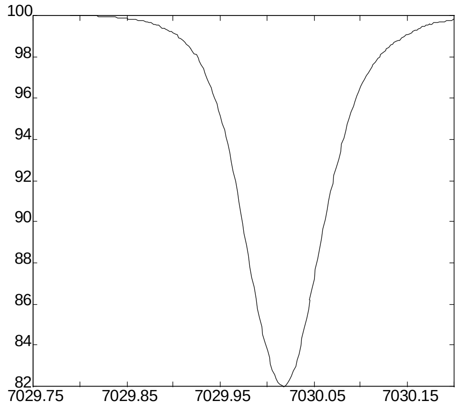


Fe I - 7007.973Å

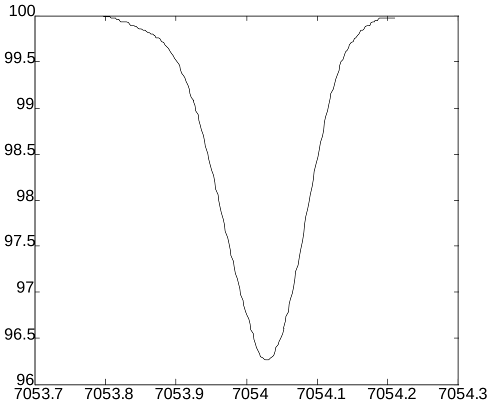
Figure C-1: Clean Solar Lines (continued)



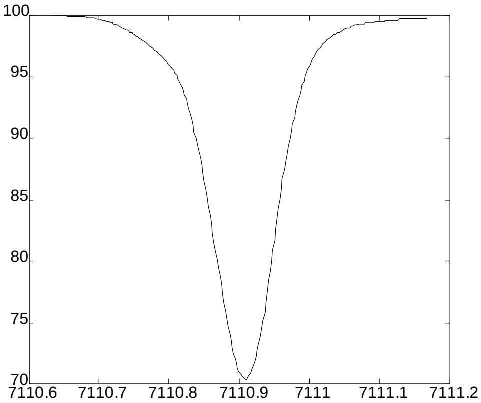
Fe I - 7022.961Å



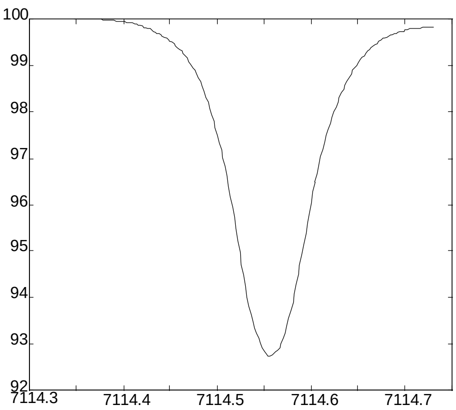
Ni I - 7030.019Å



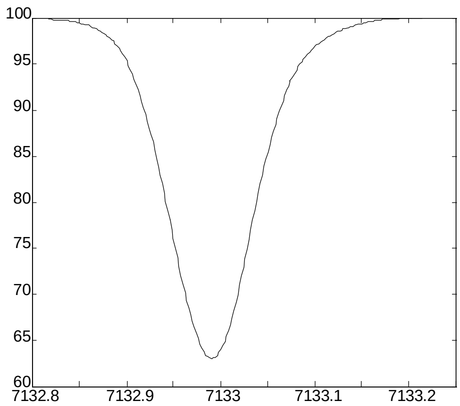
Co I - 7054.028Å



Ni I - 7110.909Å

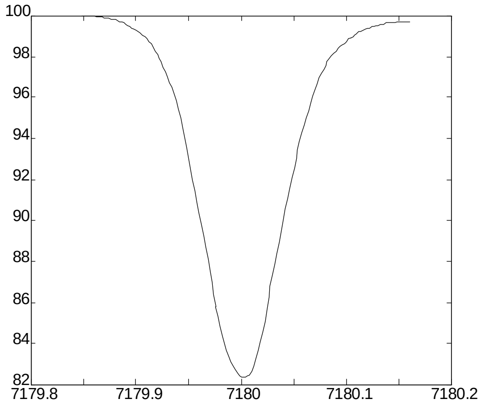


Fe I - 7114.557Å

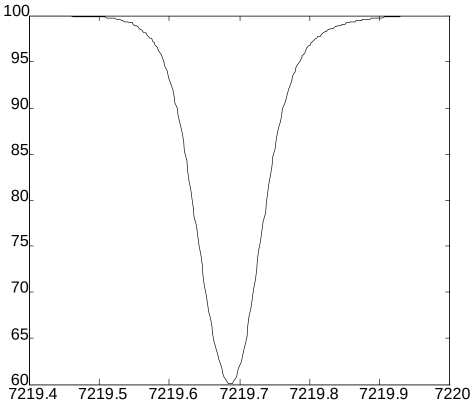


Fe I - 7132.992Å

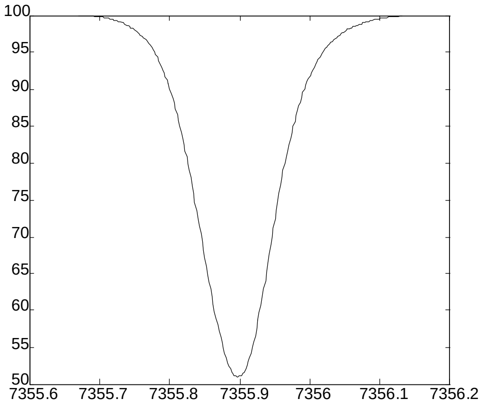
Figure C-1: Clean Solar Lines (continued)



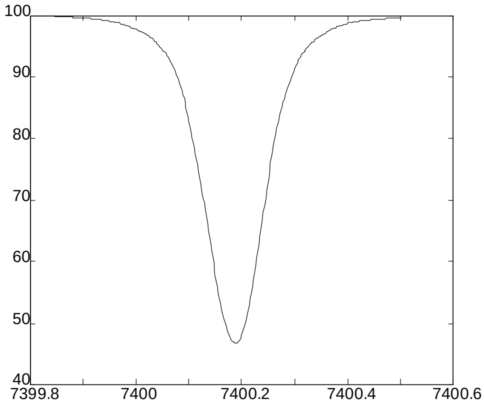
Fe I - 7180.000Å



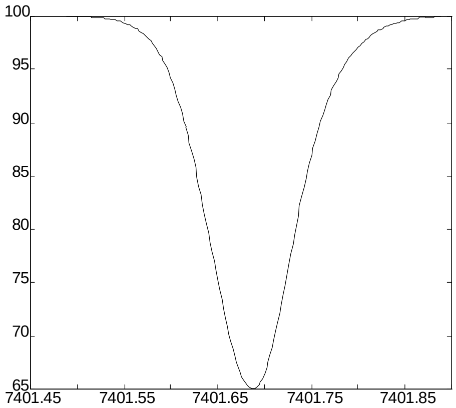
Fe I - 7219.688Å



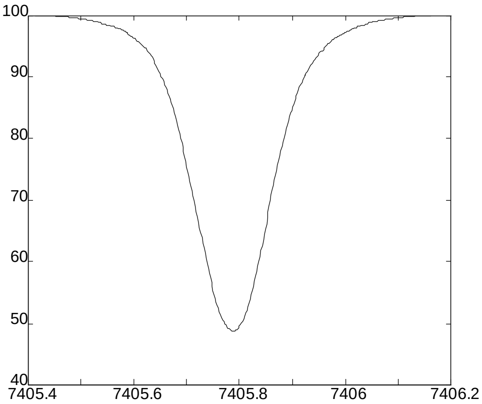
Cr I - 7355.898Å



Cr I - 7400.188Å

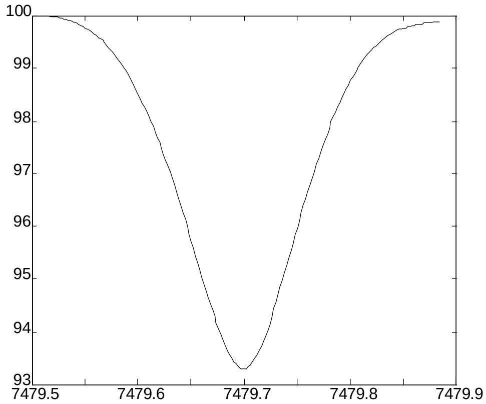


Fe I - 7401.689Å

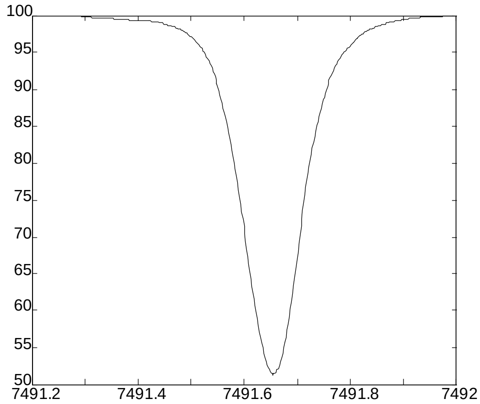


Si I - 7405.788Å

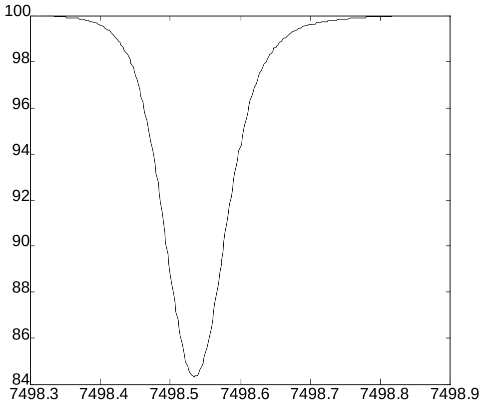
Figure C-1: Clean Solar Lines (continued)



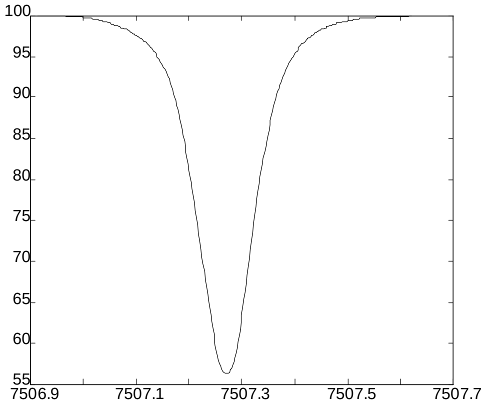
Fe II - 7479.700Å



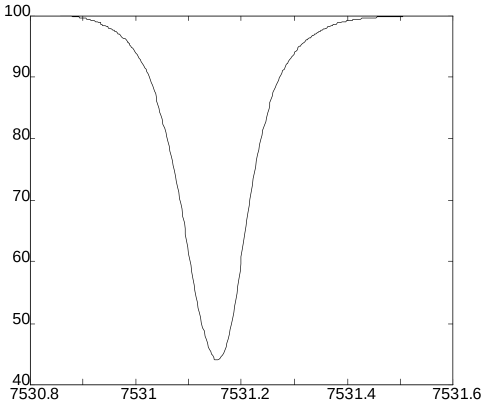
Fe I - 7491.655Å



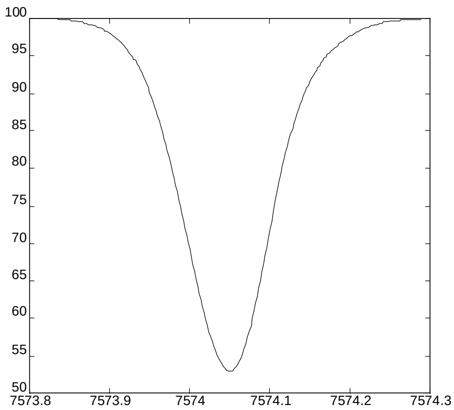
Fe I - 7498.535Å



Fe I - 7507.271Å

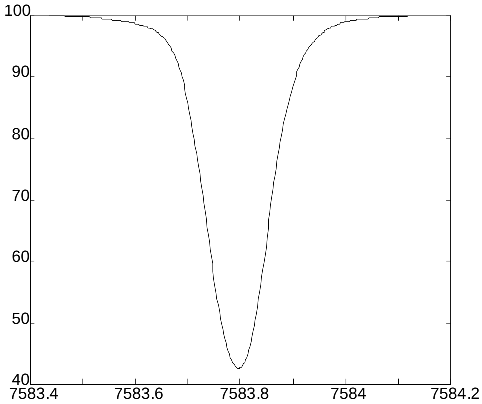


Fe I - 7531.153Å

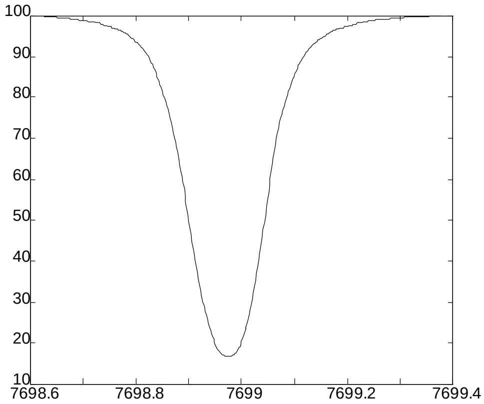


Ni I - 7574.048Å

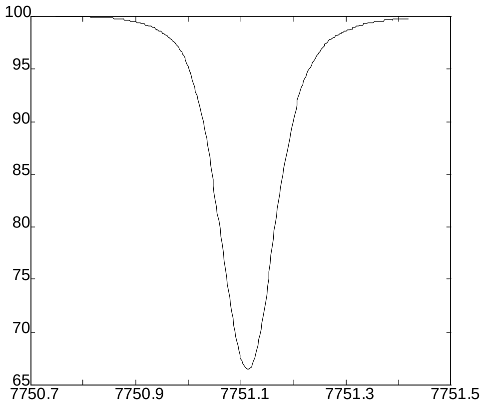
Figure C-1: Clean Solar Lines (continued)



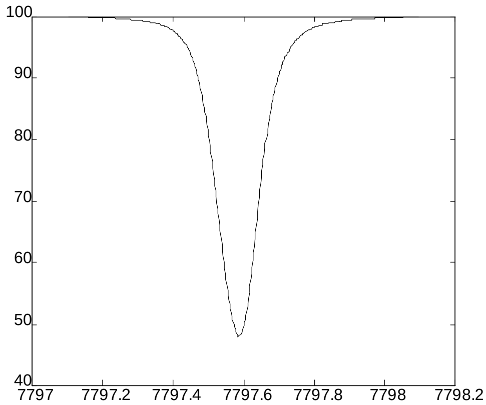
Fe I - 7583.797Å



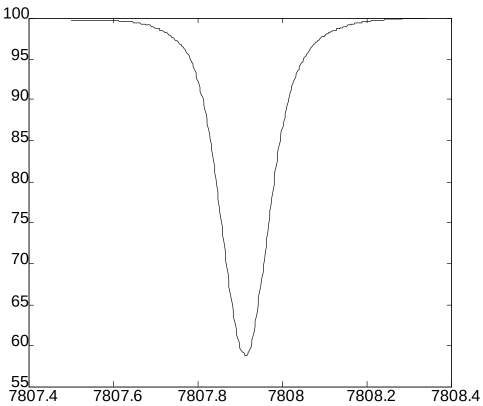
K I - 7698.974Å



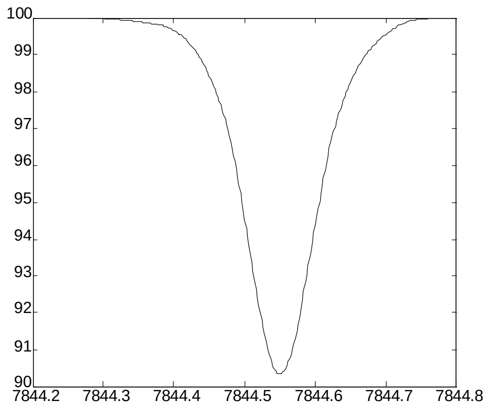
Fe I - 7751.114Å



Ni I - 7797.587Å



Fe I - 7807.913Å



Fe I - 7844.552Å

Figure C-1: Clean Solar Lines (continued)

The number of clean lines for each element and ionisation state is shown in table C-1.

Table C-1: Number of Lines per Element

Element	I	II
Al	1	-
Ce	-	1
Co	5	-
Cr	9	1
Fe	65	4
K	1	-
Mn	1	-
Mo	1	-
Ni	18	-
Si	2	-
Ti	15	-
V	8	-

Details on the transitions involved are shown in table C-2. The sources of the *gf*-values are:

a - Astrophysical *gf*-value determined in this work.

BIX - Blackwell, D.E., Petford, A.D., Shallis, M.J. and Simmons, G.J. "Precision Measurement of Relative Oscillator Strengths - IX. Measures of Fe I Transitions from Levels a^5P_{1-3} (2.18 - 2.28 eV), a^3P_2 (2.28 eV), $a^3P_{0,1}$ (2.49 - 2.42 eV), $z^7D^o_{1-5}$ (2.48 - 2.40 eV) and a^3H_{4-6} (2.45 - 2.40 eV)" *Monthly Notices of the Royal Astronomical Society* **199**, pg 43-51 (1982).

BTiII - Blackwell, D.E., Menon, S.L.R., Petford, A.D. and Shallis, M.J. "Precision Measurement of Relative Oscillator Strengths for Ti I - II. Transitions from Levels a^5F_{1-4} (0.81 - 0.84 eV), a^1D_2 (0.90 eV) and a^3P_{0-2} (1.05 - 1.07 eV)" *Monthly Notices of the Royal Astronomical Society* **201**, pg 611-617 (1982).

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KP - Kurucz, R.L. and Peytremann, E. "A Table of Semiempirical gf Values" (in three parts) *Smithsonian Astrophysical Observatory Special Report* **362**, Smithsonian Institution Astrophysical Observatory, Cambridge (1975).

LWS - Lennard, W.N., Whaling, W. and Scalo, J.M. "Ni I Transition Probabilities and the Solar Nickel Abundance" *The Astrophysical Journal* **197**, pg 517-526 (1975).

MOR - Milford, P.N., O'Mara, B.J. and Ross, J.E. "Measurement of Relative Intensities of Fe I Lines of Astrophysical Interest" *Journal of Quantitative Spectroscopy and Radiation Transfer* **41**, pg 433-438 (1989).

MRW - May, M., Richter, J. and Wichelmann, J. "Experimental Oscillator Strengths of Weak Fe I Lines" *Astonomy and Astrophysics Supplement Series* **18**, pg 405-426 (1974).

WBW - Wolnik, S.J., Berthel, R.O. and Wares, G.W. "Measurement of Oscillator Strengths for Fe I and Fe II" *The Astrophysical Journal* **166**, pg L31-L33 (1971).

Table C-2: Clean Solar Lines

λ (Å)	Ion	RMT	Lower	E_L (cm^{-1})	Upper	E_U (cm^{-1})	log(*gf*)	source
4013.232	Ti I	186	$z^5F^o_3$	16961.42	g^3F_2	41871.87	-0.41	KP
4060.266	Ti I	80	a^3P_1	8482.437	$x^3P^o_2$	33114.49	-0.58	KP
4091.556	Fe I	357	b^3P_1	22946.860	$w^3D^o_1$	47271.999	-2.12	MRW
4194.490	Fe I	274	a^3G_4	21999.167	$x^5G^o_4$	45833.24	-2.48	KP
4349.787	Ce II	59	$b^4H^o_{5½}$	0.00	$z^2H_{5½}$	27183.807	-0.42	KP
4439.639	Fe I	515	a^1G_4	24574.690	$x^3F^o_3$	47092.776	-3.31	KP
4439.887	Fe I	116	a^3P_2	18378.215	$z^5S^o_2$	40895.022	-2.84	MRW
4441.271	Ti I	160	a^3G_3	15108.153	$v^3G^o_4$	37617.93	-0.76	KP
4450.091	Ni I	178	$z^3G^o_3$	31786.210	g^3F_3	54251.353	-1.77	LWS
4465.809	Ti I	146	a^5P_2	14028.47	$y^5P^o_3$	36414.58	-0.163	BTiIV
4491.850	Cr I	83	a^3P_2	24093.16	$w^5D^o_2$	46349.50	-1.97	KP
4567.410	Ni I	102	$z^5G^o_3$	28578.046	f^3F_4	50466.172	-2.64	KP
4593.528	Fe I	971	$z^3F^o_3$	31805.097	f^5P_2	53568.72	-2.06	MRW
4607.087	Fe I	724	a^1P_1	27543.00	$v^3D^o_2$	49242.68	-2.86	KP
4758.420	Ni I	193	$z^1F^o_3$	31031.042	f^3F_2	52040.568	-1.84	KP
4915.235	Ti I	157	a^3G_5	15220.400	$y^3H^o_5$	35559.662	-1.019	BTiIV
5230.970	Ti I	215	b^3P_1	18061.54	$w^3P^o_1$	37173.03	-1.07	KP
5234.622	Fe II	49	$a^4G_{3½}$	25981.65	$z^4F^o_{2½}$	45079.91	-2.31	KP
5237.316	Cr II	43	$b^4F_{4½}$	32854.46	$z^4F^o_{4½}$	51943.04	-1.32	KP
5238.243	Fe I	962	$z^3F^o_2$	32134.014	e^5G_3	51219.059	-2.86	KP
5240.870	V I	131	$b^2H_{5½}$	19145.13	$x^2H^o_{5½}$	38220.63	0.11	KP
5241.450	Cr I	59	a^5P_1	21856.94	$x^5P^o_1$	40930.31	-2.13	a
5259.968	Ti I	298	$z^1D^o_2$	22081.15	e^1F_3	41087.31	-0.13	KP
5264.802	Fe II	48	$a^4G_{2½}$	26055.40	$z^4D^o_{1½}$	45044.21	-3.51	KP
5295.306	Fe I	1146	$z^5G^o_3$	35611.649	e^5H_3	54491.08	-1.69	MRW
5299.978	Ti I	74	a^3P_1	8492.437	$x^3D^o_1$	27355.065	-2.83	KP

Table C-2: Clean Solar Lines (continued)

λ (Å)	Ion	RMT	Lower	E_L (cm^{-1})	Upper	E_U (cm^{-1})	log(*gf*)	source
5318.763	Cr I	225	$y^7P^o_2$	27728.87	f^7D_2	46524.84	-0.74	KP
5325.270	Co I	192	$y^4G^o_{5½}$	32430.59	$e^4G_{5½}$	51203.75	0.24	KP
5352.048	Co I	172	$z^4G^o_{5½}$	28845.22	$f^4F_{4½}$	47524.47	0.06	C
5359.194	Co I	194	$y^4F^o_{3½}$	33466.87	$e^4H_{4½}$	52121.21	0.21	KP
5506.485	Mo I	4	a^5S_2	10768.33	$z^5P^o_3$	28923.66	-0.05	KP
5522.442	Fe I	1108	$z^3P^o_2$	33946.965	g^5D_2	52049.82	-1.55	MRW
5539.278	Fe I	871	b^3D_3	29371.86	1^o_2	47419.72	-2.66	MRW
5608.976	Fe I	1108	$z^3P^o_2$	33946.965	g^5D_3	51770.577	-1.73	KP
5618.634	Fe I	1107	$z^3P^o_2$	33946.965	e^3D_2	51739.964	-1.38	MRW
5619.597	Fe I	1161	$z^3G^o_5$	35379.237	f^5G_6	53169.21	-1.70	MRW
5628.643	Cr I	203	b^3G_3	27597.22	$z^3H^o_4$	45358.63	-1.13	KP
5643.078	Ni I	259	$z^1G^o_4$	33590.159	f^3F_3	51306.085	-1.33	KP
5647.238	Co I	112	$a^2P_{1½}$	18389.57	$y^2D^o_{2½}$	36092.44	-1.56	C
5648.262	Cr I	239	$z^5F^o_2$	30858.82	f^5D_2	48558.57	-0.77	KP
5648.565	Ti I	269	$z^3D^o_3$	20126.072	e^3F_4	37824.69	-0.51	KP
5657.443	V I	37	$a^4D_{2½}$	8578.52	$y^4D^o_{1½}$	26249.48	-1.03	KP
5702.314	Cr I	203	b^3G_5	27816.88	$z^3H^o_6$	45348.73	-0.90	KP
5729.198	Cr I	257	b^3D_3	31009.00	$x^3P^o_2$	48458.67	-1.13	KP
5741.851	Fe I	1086	$y^5F^o_3$	34328.775	e^3D_2	51739.964	-1.73	MRW
5754.406	Fe I	866	b^3D_3	29371.86	$u^5D^o_3$	46745.03	-2.70	MRW
5760.829	Ni I	231	$y^3F^o_3$	33112.368	f^3F_4	50466.172	-0.97	KP
5778.461	Fe I	209	b^3F_3	20874.521	$y^3D^o_3$	38175.382	-3.475	MOR
5785.984	Ti I	309	$y^5G^o_5$	26772.98	f^5H_6	44051.37	0.63	KP
5805.218	Ni I	234	$y^3F^o_2$	33610.916	e^1F_3	50832.039	-0.62	KP
5814.814	Fe I	1086	$y^5F^o_2$	34547.235	e^3D_2	51739.964	-1.97	MRW
5823.158	Fe II	164	$c^2F_{3½}$	44915.07	$z^2G^o_{4½}$	62083.17	-3.15	KP
5832.480	Ti I	309	$y^5G^o_6$	26910.69	f^5H_6	44051.37	-0.57	KP

Table C-2: Clean Solar Lines (continued)

λ (Å)	Ion	RMT	Lower	E_L (cm^{-1})	Upper	E_U (cm^{-1})	log(*gf*)	source
5849.687	Fe I	922	b^1G_4	29798.96	$x^3F^o_4$	46889.207	-2.932	MOR
5852.219	Fe I	1178	$y^3F^o_4$	36686.204	f^5G_4	53769.020	-1.213	MOR
5862.364	Fe I	1180	$y^3F^o_4$	36686.204	e^3G_5	53739.488	-0.60	KP
5876.276	Fe I	1084	$y^5F^o_1$	34692.172	f^5F_2	51705.052	-3.38	KP
5880.025	Fe I	1201	$y^5P^o_3$	36766.988	f^5G_4	53769.020	-1.94	MRW
5883.823	Fe I	982	$z^3D^o_1$	31937.350	e^3F_2	48928.423	-1.36	MRW
5922.119	Ti I	72	a^3P_0	8436.630	$y^3D^o_1$	25317.842	-1.466	BTiII
5930.182	Fe I	1180	$y^3F^o_2$	37521.186	e^3G_3	54379.44	-0.23	WBW
5934.662	Fe I	982	$z^3D^o_2$	31686.377	e^3F_3	48531.896	-1.17	MRW
5976.786	Fe I	959	$z^3F^o_3$	31805.097	e^3F_3	48531.896	-1.219	MOR
5978.546	Ti I	154	a^3G_3	15108.153	$z^3H^o_4$	31830.016	-0.496	BTiIV
5996.729	Ni I	249	$y^3D^o_2$	34163.294	e^3F_2	50834.435	-2.20	KP
6003.017	Fe I	959	$z^3F^o_4$	31307.272	e^3F_4	47960.973	-1.12	WBW
6015.242	Fe I	63	a^5P_1	17927.411	$y^5F^o_2$	34547.235	-4.57	KP
6025.760	Ni I	251	$y^3D^o_2$	34163.294	f^1D_2	50754.137	-1.19	KP
6035.037	Fe I	1142	$z^5G^o_5$	34782.448	g^5D_4	51350.505	-2.45	KP
6039.729	V I	34	$a^4D_{2½}$	8578.52	$z^4P^o_{2½}$	25130.96	-0.68	KP
6111.658	V I	34	$a^4D_{½}$	8412.94	$z^4P^o_{½}$	24770.62	-0.78	KP
6125.029	Si I	30	$3d^3D^o_1$	45276.20	$5f^3D_2$	61597.90	-0.93	KP
6128.979	Ni I	42	b^1D_2	13521.352	$z^5F^o_3$	29832.810	-3.33	DK
6151.622	Fe I	62	a^5P_3	17550.210	$y^5D^o_2$	33801.595	-3.331	MOR
6176.818	Ni I	228	$y^3F^o_4$	32973.414	e^3G_5	49158.529	-0.53	LWS
6177.249	Ni I	58	a^1S_0	14728.847	$z^3D^o_1$	30912.838	-4.24	KP
6213.436	Fe I	62	a^5P_1	17927.411	$y^5D^o_1$	34017.127	-2.75	KP
6216.360	V I	19	$a^6D_{2½}$	2220.13	$z^6D^o_{3½}$	18302.27	-1.45	KP
6232.647	Fe I	816	$z^5P^o_2$	29469.033	e^5D_1	45509.155	-1.57	KP
6251.823	V I	19	$a^6D_{3½}$	2311.37	$z^6D^o_{3½}$	18302.27	-1.32	KP

Table C-2: Clean Solar Lines (continued)

λ (Å)	Ion	RMT	Lower	E_L (cm^{-1})	Upper	E_U (cm^{-1})	log(*gf*)	source
6258.110	Ti I	104	b^3F_3	11639.820	$y^3G^o_4$	27614.693	-0.355	BTiIV
6265.139	Fe I	62	a^5P_3	17550.210	$y^5D^o_3$	33507.144	-2.550	BIX
6274.658	V I	19	$a^6D_{1½}$	2153.20	$z^6D^o_{½}$	18085.82	-1.69	KP
6285.168	V I	19	$a^6D_{2½}$	2220.13	$z^6D^o_{1½}$	18126.27	-1.50	KP
6303.466	Fe I	1140	$z^5G^o_6$	34843.980	e^5G_5	50703.912	-2.61	a
6303.765	Ti I	104	b^3F_3	11639.820	$y^3G^o_3$	27499.033	-1.566	BTiIV
6322.693	Fe I	207	b^3F_3	20874.521	$y^3F^o_4$	36686.204	-2.42	KP
6327.608	Ni I	44	b^1D_2	13521.352	$z^3F^o_3$	29320.782	-3.15	LWS
6440.937	Mn I	39	$b^4D_{2½}$	30419.61	$z^4D^o_{2½}$	45940.93	-1.36	KP
6481.877	Fe I	109	a^3P_2	18378.215	$y^5D^o_2$	33801.595	-2.984	BIX
6482.807	Ni I	66	a^3P_2	15609.861	$z^1F^o_3$	31031.042	-2.63	LWS
6498.946	Fe I	13	a^5F_3	7728.071	$z^7F^o_3$	23110.948	-4.687	Bwk
6608.031	Fe I	109	a^3P_2	18378.215	$y^5D^o_3$	33507.144	-4.03	MRW
6633.755	Fe I	1197	$y^5P^o_3$	36766.998	e^5P_3	51837.279	-0.78	MRW
6698.671	Al I	5	$4^2S_{½}$	25347.69	$5^2P^o_{½}$	40271.98	-1.90	a
6710.322	Fe I	34	a^3F_4	11979.260	$z^5F^o_5$	26874.562	-5.40	KP
6750.158	Fe I	111	a^3P_1	19552.493	$z^3P^o_1$	34362.890	-2.80	KP
6756.547	Fe I	1120	b^1D_2	34636.82	$w^3F^o_2$	49433.18	-2.621	BIX
6786.863	Fe I	1052	$y^5D^o_2$	33801.595	e^3F_3	48531.896	-2.07	MRW
6796.120	Fe I	1007	c^3F_3	33412.78	$v^5F^o_3$	48122.97	-2.28	KP
6801.869	Fe I	34	a^3F_2	12968.573	$z^5F^o_1$	27666.362	-5.47	KP
6857.252	Fe I	1006	c^3F_4	32873.68	$z^1G^o_4$	47452.770	-2.15	MRW
6862.499	Fe I	1191	$y^5P^o_3$	36766.998	e^7G_4	51334.94	-1.57	MRW
6898.284	Fe I	1078	$y^5F^o_4$	34039.540	e^3F_3	48531.896	-2.054	MOR
6978.859	Fe I	111	a^3P_0	20037.86	$z^3P^o_1$	34362.890	-2.500	BIX
6988.531	Fe I	167	a^3H_6	19390.197	$y^5F^o_5$	33695.418	-3.66	MRW

Table C-2: Clean Solar Lines (continued)

λ (Å)	Ion	RMT	Lower	E_L (cm^{-1})	Upper	E_U (cm^{-1})	log(*gf*)	source
7001.549	Ni I	64	a^3P_2	15609.861	$z^3D^o_2$	29888.505	-3.66	LWS
7007.973	Fe I	1078	$y^5F^o_5$	33695.418	e^3F_4	47960.973	-2.06	MRW
7022.961	Fe I	1051	$y^5D^o_2$	33801.595	e^5F_2	48036.667	-1.25	MRW
7030.019	Ni I	126	$z^3P^o_2$	28569.210	e^3D_2	42790.027	-1.59	KP
7054.028	Co I	140	$b^2D_{2½}$	21920.09	$y^2D^o_{2½}$	36092.44	-1.53	C
7110.909	Ni I	64	a^3P_2	15609.861	$z^3D^o_3$	29668.918	-2.55	KP
7114.557	Fe I	267	a^3G_5	21715.770	$z^3G^o_4$	35767.591	-3.68	KP
7132.992	Fe I	1002	c^3F_4	32873.68	$x^3F^o_4$	46889.207	-1.520	MOR
7180.000	Fe I	33	a^3F_4	11976.260	$z^5D^o_4$	25900.002	-4.76	KP
7219.688	Fe I	1001	c^3F_4	32873.68	$u^5D^o_4$	46720.85	-1.19	KP
7355.898	Cr I	93	$z^7P^o_2$	23305.01	e^7S_3	36895.72	-0.11	KP
7400.188	Cr I	93	$z^7P^o_3$	23386.35	e^7S_3	36895.73	0.03	KP
7401.689	Fe I	1004	c^3F_2	33765.33	$w^3D^o_1$	47272.095	-1.43	KP
7405.788	Si I	23	$3d^3D^o_1$	45276.20	$4f^3F_2$	58775.44	0.40	KP
7479.700	Fe II	72	$b^4D_{2½}$	31387.98	$z^4F^o_{3½}$	44753.82	-3.67	KP
7491.655	Fe I	1077	$y^5F^o_1$	34692.172	e^5F_2	48036.667	-0.98	KP
7498.535	Fe I	1001	c^3F_3	33412.78	$u^5D^o_3$	46745.03	-1.94	KP
7507.271	Fe I	1137	$z^5G^o_3$	35611.649	e^3F_2	48928.423	-1.89	KP
7531.153	Fe I	1137	$z^5G^o_4$	35257.345	e^3F_3	48531.896	-1.38	KP
7574.048	Ni I	156	$z^3D^o_1$	30912.838	e^3D_1	44112.192	-0.30	KP
7583.797	Ni I	402	b^3G_3	338.805	$y^3F^o_2$	37521.186	-2.06	KP
7698.974	K I	1	$4^2S_{½}$	0.0	$4^2P^o_{½}$	12985.17	-0.16	KP
7751.114	Fe I	1304	$x^5F^o_5$	40257.367	h^5D_4	53155.13	-1.84	KP
7797.587	Ni I	201	$z^1D^o_2$	31441.665	e^1D_2	44262.619	-0.03	KP
7807.913	Fe I	1303	$x^5F^o_5$	40257.367	g^5F_5	53061.28	-1.49	KP
7844.552	Fe I	1250	$y^3D^o_1$	38995.764	e^3D_2	51739.964	-2.88	KP

C.2: Abundances of the Elements

Table C-3: Solar Abundances of the Elements[4]

Atomic Number	Element	Abundance	Error
1	H	12.00	-
2	He	10.99	0.035
3	Li	1.16	0.1
4	Be	1.15	0.10
5	B	2.6	0.3
6	C	8.56	0.04
7	N	8.05	0.04
8	O	8.93	0.035
9	F	4.56	0.3
10	Ne	8.09	0.10
11	Na	6.33	0.03
12	Mg	7.58	0.05
13	Al	6.47	0.07
14	Si	7.55	0.05
15	P	5.45	0.04
16	S	7.21	0.06
17	Cl	5.5	0.3
18	Ar	6.56	0.10
19	K	5.12	0.13
20	Ca	6.36	0.02
21	Sc	3.10	0.09
22	Ti	4.99	0.02
23	V	4.00	0.02
24	Cr	5.67	0.03
25	Mn	5.39	0.03
26	Fe	7.67	0.03
27	Co	4.92	0.04
28	Ni	6.25	0.04
29	Cu	4.21	0.04
30	Zn	4.60	0.08
31	Ga	2.88	0.10
32	Ge	3.41	0.14
37	Rb	2.60	0.15
38	Sr	2.90	0.06
39	Y	2.24	0.03
40	Zr	2.60	0.03
41	Nb	1.42	0.06
42	Mo	1.92	0.05
44	Ru	1.84	0.07
45	Rh	1.12	0.12
46	Pd	1.69	0.04
47	Ag	0.95	0.25
48	Cd	1.86	0.15
49	In	1.66	0.15
50	Sn	2.0	0.3
51	Sb	1.0	0.3
56	Ba	2.13	0.05
57	La	1.22	0.09
58	Ce	1.55	0.20
59	Pr	0.71	0.08
60	Nd	1.50	0.06
62	Sm	1.00	0.08
63	Eu	0.51	0.08
64	Gd	1.12	0.04
65	Tb	-0.1	0.3
66	Dy	1.1	0.15
67	Ho	0.26	0.16
68	Er	0.93	0.06
69	Tm	0.00	0.15
70	Yb	1.08	0.15
71	Lu	0.76	0.30
72	Hf	0.88	0.08
74	W	1.11	0.15
76	Os	1.45	0.10
77	Ir	1.35	0.10
78	Pt	1.8	0.3
79	Au	1.01	0.15
81	Tl	0.9	0.2
82	Pb	1.85	0.05
90	Th	0.12	0.06
92	U	<-0.47	-

[4]Anders, E. and Grevesse, N. "Abundances of the Elements: Meteoric and Solar" *Geochimica et Cosmochimica Acta* **53**, pg 197-214 (1989).

C.3: Model Atmospheres

The model atmosphere used in this work, the Holweger-Müller model atmosphere[5] is shown in table C-4. (This atmosphere is also referred to as HOLMUL, HOLMU and other similar abbreviations.)

Table C-4: The Holweger-Müller Model Atmosphere

$\log(\tau_{5000Å})$	Height (km)	Temp. (°K)	$\log(P_g)$	$\log(P_e)$	$\log(\kappa_{5000Å})$	$\log(\rho)$
-4.50	662	4267	2.5405	-1.4583	-2.6045	-8.8955
-4.40	641	4286	2.6337	-1.3692	-2.5380	-8.8042
-4.30	622	4306	2.7164	-1.2894	-2.4778	-8.7235
-4.20	604	4326	2.7924	-1.2159	-2.4217	-8.6496
-4.10	587	4347	2.8637	-1.1465	-2.3686	-8.5804
-4.00	571	4368	2.9315	-1.0803	-2.3175	-8.5146
-3.90	556	4390	2.9967	-1.0162	-2.2680	-8.4516
-3.80	541	4413	3.0600	-0.9536	-2.2198	-8.3906
-3.70	526	4435	3.1218	-0.8927	-2.1721	-8.3310
-3.60	512	4455	3.1824	-0.8335	-2.1248	-8.2723
-3.50	498	4475	3.2419	-0.7753	-2.0780	-8.2148
-3.40	483	4493	3.3007	-0.7183	-2.0313	-8.1577
-3.30	469	4511	3.3588	-0.6621	-1.9850	-8.1013
-3.20	455	4530	3.4164	-0.6061	-1.9390	-8.0456
-3.10	441	4551	3.4736	-0.5500	-1.8934	-7.9904
-3.00	427	4572	3.5304	-0.4942	-1.8479	-7.9356
-2.90	413	4592	3.5870	-0.4390	-1.8024	-7.8809
-2.80	399	4610	3.6433	-0.3848	-1.7568	-7.8263
-2.70	385	4627	3.6993	-0.3311	-1.7112	-7.7719
-2.60	371	4644	3.7552	-0.2777	-1.6657	-7.7176
-2.50	357	4662	3.8109	-0.2242	-1.6204	-7.6635
-2.40	343	4682	3.8665	-0.1702	-1.5753	-7.6098
-2.30	329	4704	3.9220	-0.1157	-1.5303	-7.5563
-2.20	315	4728	3.9775	-0.0607	-1.4854	-7.5030
-2.10	301	4754	4.0329	-0.0052	-1.4406	-7.4500

[5]Holweger, H. and Müller, E.A. "The Photospheric Barium Spectrum: Solar Abundance and Collision Broadening of Ba II Lines By Hydrogen" *Solar Physics* **39**, pg 19-30 (1974).

Table C-4: The Holweger-Müller Model Atmosphere (continued)

$\log(\tau_{5000Å})$	Height (km)	Temp. (°K)	$\log(P_g)$	$\log(P_e)$	$\log(\kappa_{5000Å})$	$\log(\rho)$
-2.00	287	4782	4.0884	0.0510	-1.3958	-7.3971
-1.90	272	4812	4.1437	0.1077	-1.3511	-7.3445
-1.80	258	4844	4.1991	0.1650	-1.3063	-7.2920
-1.70	244	4880	4.2545	0.2236	-1.2616	-7.2398
-1.60	229	4917	4.3098	0.2825	-1.2167	-7.1878
-1.50	214	4959	4.3651	0.3429	-1.1719	-7.1362
-1.40	199	5005	4.4204	0.4048	-1.1269	-7.0849
-1.30	184	5056	4.4756	0.4684	-1.0816	-7.0341
-1.20	169	5113	4.5308	0.5342	-1.0358	-6.9837
-1.10	154	5174	4.5858	0.6018	-0.9892	-6.9339
-1.00	139	5236	4.6405	0.6703	-0.9416	-6.8844
-0.90	123	5296	4.6949	0.7386	-0.8930	-6.8349
-0.80	108	5357	4.7489	0.8079	-0.8434	-6.7859
-0.70	92	5431	4.8023	0.8838	-0.7906	-6.7385
-0.60	77	5527	4.8547	0.9722	-0.7311	-6.6937
-0.50	62	5654	4.9050	1.0817	-0.6582	-6.6532
-0.40	47	5804	4.9521	1.2121	-0.5690	-6.6175
-0.30	34	5963	4.9949	1.3551	-0.4678	-6.5865
-0.20	21	6133	5.0333	1.5100	-0.3558	-6.5603
-0.10	10	6327	5.0671	1.6843	-0.2284	-6.5401
0.00	0	6533	5.0974	1.8652	-0.0950	-6.5248
0.10	-9	6714	5.1221	2.0212	0.0212	-6.5110
0.20	-18	6898	5.1458	2.1744	0.1359	-6.4992
0.30	-26	7129	5.1671	2.3554	0.2716	-6.4924
0.40	-33	7396	5.1855	2.5513	0.4196	-6.4903
0.50	-39	7672	5.2013	2.7408	0.5651	-6.4909
0.60	-45	7927	5.2153	2.9056	0.6943	-6.4918
0.70	-51	8139	5.2284	3.0364	0.7994	-6.4908
0.80	-57	8315	5.2412	3.1414	0.8857	-6.4879
0.90	-63	8444	5.2543	3.2179	0.9496	-6.4821
1.00	-69	8526	5.2685	3.2683	0.9923	-6.4724
1.10	-77	8610	5.2843	3.3198	1.0360	-6.4613
1.20	-85	8700	5.3014	3.3742	1.0826	-6.4491

Another commonly used model atmosphere is the Harvard-Smithsonian Reference Atmosphere (HSRA).[6] A recent solar model atmosphere is given by Edvardsson *et al*.[7]

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[6]Gingerich, O., Noyes, R.W., Kalkofen, W. and Cuny, Y. “The Harvard-Smithsonian Reference Atmosphere” *Solar Physics* **18**, pg 347-365 (1971).

C.4: Wavelength Shifts of Solar Lines

The data on wavelength shifts of solar spectral lines (from Dravins *et al.*[8]) and depths of formation (from Stathopoulou and Alissandrakis[9]) used to determine the variation of vertical flow velocity with height in the photosphere in chapter 7 are shown in table C-5. All of the lines are Fe I lines.

Table C-5: Wavelength Shifts of Solar Lines

Wavelength (Å)	Redshift (mÅ)	Depth ($\log \tau_{5000\text{Å}}$)	Height (km)	Velocity (kms^{-1})
5717.8379	3.7	-1.85	265	0.442
5731.7666	5.0	-1.82	261	0.375
5753.1287	7.4	-2.36	337	0.251
5775.0849	5.4	-1.83	262	0.356
5852.2222	4.8	-1.09	152	0.390
5862.3651	11.7	-2.23	319	0.038
5927.7919	5.6	-1.14	160	0.353
5929.6802	13.5	-1.09	152	-0.046
5956.6997	7.4	-1.87	268	0.264
6007.9556	5.1	-1.84	263	0.382
6027.0562	6.0	-1.90	272	0.338
6065.4921	10.1	-3.78	538	0.137
6173.3433	8.9	-2.21	316	0.204
6200.3204	6.6	-2.42	346	0.317

[7]Edvardsson, B., Andersen, J., Gustafsson, B., Lambert, D.L., Nissen, P.E. and Tomkin, J. "The Chemical Evolution of the Galactic Disk 1. Analysis and Results" *Astronomy and Astrophysics* **275**, pg 101-152 (1993).

[8]Dravins, D., Lindegren, L. and Nordlund, Å. "Solar Granulation: Influence of Convection on Spectral Line Asymmetries and Wavelength Shifts" *Astronomy and Astrophysics* **96**, pg 345-364 (1981).

[9]Stathopoulou, M. and Alissandrakis, C.E. "A Study of the Asymmetry of Fe I Lines in the Solar Spectrum" *Astronomy and Astrophysics* **274**, pg 555-562 (1993).

Table C-5: Wavelength Shifts of Solar Lines (continued)

Wavelength (Å)	Redshift (mÅ)	Depth ($\log \tau_{5000Å}$)	Height (km)	Velocity (kms^{-1})
6213.4375	8.6	-2.59	370	0.221
6219.2886	9.2	-2.88	410	0.193
6232.6493	10.2	-2.47	353	0.155
6240.6516	6.5	-1.66	237	0.324
6246.3271	9.9	-3.34	474	0.161
6265.1412	10.0	-2.76	393	0.158
6270.2322	9.9	-1.81	259	0.163
6280.6240	7.7	-2.22	318	0.269
6297.8013	9.3	-2.45	350	0.193
6301.5091	10.8	-3.36	477	0.122
6315.8164	7.3	-1.19	167	0.290
6322.6936	3.7	-2.47	353	0.461
6335.3378	9.7	-3.15	448	0.177
6336.8328	10.1	-3.12	444	0.158
6380.7483	7.4	-1.59	227	0.288
6411.6586	11.8	-3.49	496	0.084
6430.8538	9.8	-3.76	535	0.179
6494.9910	10.3	-4.22	607	0.161
6593.8798	8.8	-2.73	388	0.236
6609.1189	8.6	-2.03	291	0.246
6677.9958	6.6	-3.79	539	0.340
6750.1597	10.0	-2.42	346	0.192
6828.5976	7.8	-1.72	246	0.294
6843.6606	12.2	-1.85	265	0.102

C.5: Centre-to-Limb Variations of Equivalent Width

The centre-to-limb variations of equivalent width of a number of lines observed by Kostic[10] are shown in table C-6.

Table C-6: Equivalent Width CLV

		Equivalent width (mÅ) at μ =						
λ (Å)	Elem.	1.00	0.80	0.60	0.50	0.44	0.30	0.28
4389	Fe	71.7	-	-	80.8	-	86.2	-
4445	Fe	38.8	-	-	48.1	-	55.3	-
5225	Fe	71.0	-	-	78.4	-	81.8	-
5247	Fe	65.8	-	-	73.7	-	78.3	-
5250	Fe	64.9	-	-	75.1	-	79.5	-
6093	Fe	33.0	31.9	31.4	-	30.8	-	30.7
6157	Fe	59.9	56.0	58.1	-	59.0	-	59.8
6176	Ni	64.0	63.6	61.7	-	63.4	-	-
6186	Ni	31.9	31.6	31.7	-	32.5	-	-
6204	Ni	21.9	22.7	22.9	-	23.8	-	-
6380	Fe	49.1	48.8	51.0	-	50.8	-	50.6
6419	Fe	89.0	85.3	83.1	-	82.2	-	80.1
6635	Ni	23.8	23.8	25.0	-	25.5	-	-
6713	Fe	21.5	22.8	21.9	-	22.9	-	21.9
6786	Fe	23.1	23.7	25.0	-	25.1	-	26.6
6820	Fe	41.6	42.7	42.2	-	42.6	-	41.4
7727	Ni	96.8	95.5	95.2	-	93.2	-	-

[10] Kostic, R.I. "Damping Constant and Turbulence in the Solar Atmosphere" *Solar Physics* **78**, pg 39-57 (1982).

C.6: Monochromator Calibration

The relative spectral response of the monochromator system described in Appendix B is shown in table C-7.

Table C-7: Spectral Response of Monochromator

Wavelength (Å)	Photons per unit detector response
3000	4.62
3100	7.71
3200	11.09
3300	15.20
3400	18.73
3500	20.85
3600	18.25
3700	15.57
3800	10.75
3900	9.29
4000	7.59
4100	5.79
4200	4.35
4300	3.11
4400	2.18
4500	1.61
4600	1.31
4700	1.14
4800	1.05
4900	1.00
5000	1.00
5100	1.02

Wavelength (Å)	Photons per unit detector response
5200	1.06
5300	1.12
5400	1.19
5500	1.27
5600	1.38
5700	1.61
5800	1.74
5900	1.74
6000	1.70
6100	1.85
6200	2.01
6300	2.21
6400	2.40
6500	2.61
6600	2.81
6700	3.01
6800	3.17
6900	3.34
7000	3.52
7100	3.71
7200	3.88
7300	4.09