Table 1. Atomic lines found in ultracool dwarf synthetic spectrum from 10000 – 25000Å. The columns are priority of the line (Pr), wavelength in Å(λ (Å)), element name (Atom), residual flux in "ultracool dwarf" synthetic spectrum (UCD_ss), residual flux in "Arcturus-like" synthetic spectrum (Ar_ss), residual line intensity from hard copy of Arcturus atlas (Ar_At), residual line intensity from hard copy of Sunspot umbra atlas (Ss_At).

Pr	λ (Å)	Atom	UCD_ss	Ar_ss	Ar_At	Ss_At
	10003.086	Ti I	0.909	0.716	0.75	–
	10011.745	Ti I	0.928	0.756	0.77	–
	10032.099	*Ba I*	*0.887*	*1.000*	*0.97*	–
	10034.491	Ti I	0.855	0.739	0.63	–
	10048.826	Ti I	0.845	0.730	0.65	–
	10057.728	Ti I	0.867	0.659	0.65	–
	10059.904	Ti I	0.868	0.779	0.72	–
	10155.159	Fe I	0.917	0.790	0.67	–
	10167.463	Fe I	0.893	0.753	0.65	–
2	10340.880	Fe I	0.772	0.608	0.55	–
1	10343.820	Ca I	0.365	0.420	0.44	–
	10378.995	Fe I	0.904	0.747	0.68	–
3	10395.789	Fe I	0.650	0.566	0.50	–
1	10396.802	Ti I	0.384	0.441	0.35	–
	10471.272	*Ba I*	*0.936*	*1.000*	*0.99*	–
1	10496.114	Ti I	0.403	0.445	0.35	–
1	10584.633	Ti I	0.425	0.449	0.38	–
2	10607.718	Ti I	0.677	0.639	0.70	–
1	10661.623	Ti I	0.455	0.475	0.41	–
2	10677.047	Ti I	0.621	0.581	0.61	–
1	10726.391	Ti I	0.489	0.490	0.45	–
2	10732.864	Ti I	0.615	0.591	0.60	–
2	10746.440	Na I	0.783	0.840	0.94	–
	10749.293	Na I	0.880	0.749	1.00	–
2	10774.866	Ti I	0.652	0.622	0.63	–
2	10821.176	S I	0.696	0.451	0.85	–
	10827.896	Ti I	0.928	0.924	0.97	–
2	10834.848	Na I	0.757	0.732	0.84	–
	10847.634	Ti I	0.926	0.926	0.95	–
1	11019.848	K I	0.477	0.902	1.00	–
1	11022.653	K I	0.550	0.934	0.95	–
2	11119.798	Fe I	0.764	0.536	0.52	–
2	11251.116	Fe I	0.766	0.546	0.98	–
	11298.862	Fe I	0.837	0.609	0.55	–
	11303.052	*Ba I*	*0.488*	*0.977*	*1.00*	–
3	11374.081	Fe I	0.557	0.538	0.50	–
1	11381.454	Na I	0.094	0.416	0.35	–
1	11403.779	Na I	0.076	0.385	0.26	–
3	11422.323	Fe I	0.509	0.469	0.37	–
2	11439.127	Fe I	0.650	0.476	–	–
1	11593.591	Fe I	0.477	0.437	–	0.70
1	11607.575	Fe I	0.359	0.389	0.30	0.60
	11610.522	Cr I	0.899	0.557	0.52	0.70
1	11638.264	Fe I	0.395	0.411	0.33	~0.55
1	11689.976	Fe I	0.021	0.388	0.31	0.45
1	11690.220	K I	0.013	0.483	0.40bl	~0.48
1	11769.639	K I	0.061	0.601	0.70	0.65
1	11772.838	K I	0.004	0.468	0.42	~0.55
3	11780.543	Ti I	0.522	0.736	0.75	0.82
3	11783.267	Fe I	0.485	0.453	0.40	0.67
3	11797.179	Ti I	0.779	0.757	0.75	0.82
2	11828.185	Mg I	0.705	0.430	0.21	0.50
1	11882.847	Fe I	0.277	0.353	0.29	0.55
1	11884.085	Fe I	0.364	0.398	0.33	0.57
2	11892.878	Ti I	0.731	0.606	0.57	0.70
2	11949.542	Ti I	0.700	0.571	0.55	0.72
	11955.955	Ca I	0.878	0.620	0.85	0.82
1	11973.050	Fe I	0.225	0.334	0.28	–
1	11973.848	Ti I	0.498	0.574	0.53	~0.50
1	12432.273	K I	0.080	0.582	0.67	0.65
2	12484.618	Ti I	0.793	0.661	0.98	0.98
1	12522.134	K I	0.022	0.528	0.57	0.60
3	12526.081	K I	0.429	0.989	0.97	0.99
2	12556.999	Fe I	0.790	0.606	0.62	0.80
	12600.277	Ti I	0.862	0.748	0.75	0.80
	12671.092	Ti I	0.864	0.746	0.75	0.83
2	12679.144	Na I	0.656	0.589	0.66	0.65
2	12679.224	Na I	0.658	0.604	0.66	0.65
	12738.383	Ti I	0.914	0.726	0.75	0.75
	12816.046	Ca I	0.857	0.615	0.79	0.76
2	12821.672	Ti I	0.628	0.519	0.45	0.67
	12823.868	Ca I	0.889	0.671	0.83	0.78
2	12831.442	Ti I	0.645	0.527	0.50	0.70
2	12847.033	Ti I	0.621	0.512	0.50	0.70
2	12879.769	Fe I	0.740	0.571	0.55	0.75
1	12899.764	Mn I	0.468	0.444	0.22	0.57
	12975.912	Mn I	0.851	0.587	0.46	0.75
	13011.895	Ti I	0.852	0.729	0.75	0.77
	13077.263	Ti I	0.896	0.798	0.70	0.80
1	13123.410	Al I	0.433	0.390	0.21	0.45
1	13150.753	Al I	0.500	0.415	0.25	0.52
	13233.279	*Rb I*	*0.642*	*1.000*	*1.00*	*0.99*
	13281.485	Mn I	0.902	0.632	0.55	0.82
2	13293.795	Mn I	0.619	0.497	0.33	0.72
1	13318.944	Mn I	0.547	0.465	0.27	0.67
	13371.782	*Lu I*	*0.385*	*0.749*	*1.00*	–
	13377.794	K I	0.854	0.989	1.00	–
	13409.108	Ti I	0.716	0.583	0.97	1.00
	13600.372	Mn I	0.818	0.627	⊕	⊕
3	13626.696	Mn I	0.593	0.477	⊕	⊕
3	13642.930	Mn I	0.672	0.519	⊕	⊕
	13662.993	*Rb I*	*0.523*	*0.989*	⊕	⊕
	13688.911	Ti I	0.905	0.822	⊕	⊕
	13787.736	V I	0.832	0.746	⊕	⊕
3	13847.454	Mn I	0.725	0.558	⊕	⊕
3	13864.219	Mn I	0.625	0.492	⊕	⊕
3	13997.520	Mn I	0.663	0.509	⊕	⊕
	14040.849	V I	0.841	0.757	⊕	⊕

Pr	λ (Å)	Atom	UCD_ss	Ar_ss	Ar_At	Ss_At
	14253.141	V I	0.848	0.765	⊕	⊕
	14270.253	Ca I	0.850	0.531	⊕	⊕
	14308.700	Fe I	0.852	0.551	⊕	⊕
	14423.053	V I	0.875	0.807	⊕	⊕
	14752.870	*Rb I*	*0.368*	*0.968*	⊕	⊕
2	14767.484	Na I	0.786	0.706	⊕	⊕
2	14779.732	Na I	0.706	0.615	0.99	0.57bl
	14999.917	*Ba I*	*0.435*	*0.952*	*1.00*	*0.95*
2	15024.992	Mg I	0.780	0.399	0.24	0.49
	15040.246	Mg I	0.815	0.412	0.24	0.55
	15057.099	Ca I	0.829	0.895	0.97	0.77
2	15077.291	Fe I	0.771	0.545	0.98	0.79
1	15163.067	K I	0.254	0.534	0.67	0.67
1	15163.067	K I	0.254	0.534	0.67	0.67
1	15168.376	K I	0.280	0.572	0.70	0.72
	15288.938	*Rb I*	*0.501*	*0.993*	*1.00*	*0.85*
	15289.966	*Rb I*	*0.299*	*0.940*	*1.00*	*0.90*
2	15334.847	Ti I	0.618	0.436	0.45	0.60
	15490.339	Fe I	0.858	0.642	0.64	1.00
2	15543.756	Ti I	0.628	0.451	0.47	0.65
	15602.842	Ti I	0.867	0.646	0.73	0.72
	15698.979	Ti I	0.855	0.699	0.70	0.75
2	15715.573	Ti I	0.629	0.446	0.50	0.67
	15836.788	Ti I	0.851	0.710	0.73	0.85
2	16136.823	Ca I	0.795	0.474	0.76	0.70
2	16150.763	Ca I	0.695	0.427	0.68	0.67
	16155.236	Ca I	0.829	0.496	0.80	0.80
2	16157.364	Ca I	0.674	0.416	0.67	0.62
2	16197.075	Ca I	0.635	0.398	0.55	0.56
	16204.087	Ca I	0.825	0.494	0.85	–
2	16388.857	Na I	0.771	0.770	0.95	0.87
	16454.533	Si I	0.868	0.585	0.98	0.93
2	16718.957	Al I	0.678	0.398	0.55	0.45bl
2	16750.564	Al I	0.626	0.380	0.27	0.50
2	17108.662	Mg I	0.799	0.403	0.27	0.47
	17123.809	*Y I*	*0.581*	*0.699*	*0.99*	*0.96*
	17422.836	*Y I*	*0.537*	*0.631*	*1.00*	*0.90*
	17663.289	*Y I*	*0.526*	*0.625*	*0.95*	*0.98*
	17903.229	*Y I*	*0.489*	*0.559*	*1.00*	–
	18049.807	*Y I*	*0.473*	*0.557*	*1.00*	–
	18115.295	*Y I*	*0.458*	*0.533*	*1.00*	–
	18181.758	*Y I*	*0.450*	*0.539*	–	–
	18234.975	*Lu I*	*0.377*	*0.732*	*1.00*	–
	18293.682	*Y I*	*0.523*	*0.641*	⊕	⊕
1	18465.312	Na I	0.333	0.402	⊕	⊕
1	18465.312	Na I	0.333	0.402	⊕	⊕
1	18465.484	Na I	0.337	0.410	⊕	⊕
3	18856.646	Fe I	0.770	0.458	⊕	⊕
	18987.010	Fe I	0.830	0.495	⊕	⊕
	19046.178	Ca I	0.828	0.555	⊕	⊕
1	19309.223	Ca I	0.144	0.326	⊕	⊕
1	19452.982	Ca I	0.125	0.311	∼0.20	–
1	19505.738	Ca I	0.142	0.337	0.22	∼0.30
	19728.117	*Y I*	*0.601*	*0.726*	*0.99*	*0.95*

Pr	λ (Å)	Atom	UCD_ss	Ar_ss	Ar_At	Ss_At
1	19776.771	Ca I	0.074	0.306	0.16	0.30
1	19853.092	Ca I	0.516	0.428	0.45	0.50
1	19862.191	Ca I	0.162	0.345	0.25	∼0.35
1	19917.195	Ca I	0.280	0.417	0.45	0.65
1	19933.729	Ca I	0.555	0.443	0.45	0.65
2	19961.832	Ca I	0.638	0.477	∼0.60	–
	20170.207	*Y I*	*0.647*	*0.778*	*1.00*	*1.00*
	20831.520	*Y I*	*0.624*	*0.747*	*1.00*	*0.95*
	20879.256	*Y I*	*0.678*	*0.812*	*0.97*	*0.90*
2	21163.756	Al I	0.794	0.497	0.45	0.65
	21260.449	*Y I*	*0.526*	*0.617*	*0.96*	*1.00*
	21574.170	*Y I*	*0.605*	*0.733*	*1.00*	*0.95*
	21730.506	Sc I	0.821	0.904	0.95	0.98
1	21782.926	Ti I	0.532	0.467	0.50	0.70
	21812.055	Sc I	0.802	0.896	0.95	0.93
2	21897.377	Ti I	0.583	0.493	0.55	0.72
2	22004.494	Ti I	0.671	0.551	0.66	0.80
1	22052.141	Sc I	0.493	0.579	0.75	0.65
1	22056.426	Na I	0.342	0.469	0.50	0.50
1	22065.232	Sc I	0.544	0.635	0.83	0.75
1	22083.662	Na I	0.383	0.487	0.56	0.60
1	22211.229	Ti I	0.650	0.537	0.63	0.80
1	22232.838	Ti I	0.628	0.521	0.61	0.76
2	22266.729	Sc I	0.648	0.756	0.90	0.85
1	22274.012	Ti I	0.654	0.540	0.64	0.75
3	22310.617	Ti I	0.682	0.613	0.75	0.80
	22311.588	*Ba I*	*0.475*	*0.980*	*0.98*	*0.96*
2	22394.670	Sc I	0.587	0.686	0.89	0.81
2	22443.904	Ti I	0.773	0.657	0.77	0.85
	22543.826	*Y I*	*0.538*	*0.647*	*1.00*	*0.97*
	22656.963	Sc I	0.844	0.919	0.97	0.90
2	22963.336	Ti I	0.675	0.547	0.65	0.75
2	22986.250	Sc I	0.605	0.697	0.89	0.87
	23204.070	*Y I*	*0.686*	*0.826*	*1.00*	*0.96*
	23253.688	*Ba I*	*0.467*	*0.966*	*0.98*	*0.98*
1	23348.424	Na I	0.563	0.548	0.60bl	0.64
1	23378.945	Na I	0.516	0.535	–	0.60
1	23379.137	Na I	0.513	0.525	∼0.60	0.60
2	23404.758	Sc I	0.646	0.755	0.90	0.95
2	23441.471	Ti I	0.702	0.572	0.60bl	0.70
2	23719.029	Ti I	0.736	0.595	–	0.98
	23809.379	Sc I	0.694	0.801	0.96	0.95
	23990.445	*Y I*	*0.554*	*0.675*	*1.00*	–
	24074.787	Sc I	0.734	0.839	0.93	0.87
	24170.594	*Lu I*	*0.190*	*0.630*	*0.97*	*0.95*
2	24281.809	Ti I	0.788	0.611	1.00	0.70

Table 2. Sensitivity of first priority lines to temperature, gravity and metallicity. The columns are wavelength in Å(λ (Å)), name of element (Atom), central line intensity in the 2000/5.0/0.0 synthetic spectrum (LD), temperature sensitivity in % ($\Delta r_\nu^{(\mathrm{Teff})}$), log g sensitivity in % ($\Delta r_\nu^{(\log\,\mathrm{g})}$), metallicity sensitivity in % ($\Delta r_\nu^{([\mathrm{M/H}])}$).

λ (Å)	Atom	LD	$\Delta r_\nu^{(\mathrm{Teff})}$	$\Delta r_\nu^{(\log\,\mathrm{g})}$	$\Delta r_\nu^{([\mathrm{M/H}])}$
10343.820	Ca I	0.172	-1.22	-6.86	19.49
10396.802	Ti I	0.115	4.27	-2.01	-19.01
10496.114	Ti I	0.125	4.24	-2.08	-18.65
10584.633	Ti I	0.138	4.06	-2.18	-18.21
10661.623	Ti I	0.155	3.56	-2.33	-17.85
10726.391	Ti I	0.176	3.02	-2.50	-17.36
11019.848	K I	0.423	-4.75	-26.12	55.45
11022.653	K I	0.489	-4.11	-25.90	48.95
11381.454	Na I	0.039	5.94	-8.27	27.39
11403.779	Na I	0.030	6.98	-7.64	23.92
11593.591	Fe I	0.186	3.70	-3.38	25.00
11607.575	Fe I	0.119	5.42	-3.17	22.44
11638.264	Fe I	0.136	5.22	-3.23	23.51
11689.976	Fe I	0.135	5.12	-3.04	23.01
11690.220	K I	0.013	14.39	-7.58	18.94
11769.639	K I	0.027	11.44	-7.75	22.51
11772.838	K I	0.011	15.74	-6.48	19.44
11882.847	Fe I	0.094	6.08	-2.99	19.55
11884.085	Fe I	0.139	4.96	-3.02	22.66
11973.050	Fe I	0.078	6.43	-3.21	17.74
11973.848	Fe I	0.462	0.02	-3.98	-2.38
12432.273	K I	0.032	9.18	-10.13	29.43
12522.134	K I	0.025	10.08	-9.68	25.00
12899.764	Mn I	0.219	3.10	-4.05	24.90
13123.410	Al I	0.319	-4.76	-5.51	16.89
13150.753	Al I	0.370	-2.73	-6.24	19.58
13318.944	Mn I	0.299	2.17	-4.71	26.03
15163.067	K I	0.449	-1.32	-12.69	39.75
15163.067	K I	0.188	-0.05	-7.47	29.71
15168.376	K I	0.208	-0.58	-8.22	31.19
18465.312	Na I	0.575	-2.66	-11.25	22.02
18465.312	Na I	0.353	-2.69	-7.12	20.91
18465.484	Na I	0.376	-2.68	-8.02	20.94
19309.223	Ca I	0.091	2.76	—	4.85
19452.982	Ca I	0.078	3.08	-7.82	3.85
19505.738	Ca I	0.100	2.60	-7.69	5.39
19776.771	Ca I	0.073	3.03	-7.71	3.44
19853.092	Ca I	0.506	-3.16	-5.64	13.11
19862.191	Ca I	0.107	2.54	-7.51	5.54
19917.195	Ca I	0.196	1.43	-7.56	12.57
19933.729	Ca I	0.537	-1.81	-6.34	14.41
21782.926	Ti I	0.479	-1.46	-4.14	0.17
22052.141	Sc I	0.374	2.22	-8.95	29.38
22056.426	Na I	0.311	-0.77	-5.17	17.47
22065.232	Sc I	0.424	1.91	-9.68	30.26
22083.662	Na I	0.356	-2.50	-5.42	17.85
22211.229	Ti I	0.589	-0.93	-6.59	6.50
22232.838	Ti I	0.569	-0.88	-6.01	5.41
22274.012	Ti I	0.594	-0.91	-6.65	6.64
23348.424	Na I	0.564	-2.73	-7.47	16.79
23379.137	Na I	0.526	-3.71	-7.71	16.45

Atomic lines in infrared spectra for ultracool dwarfs
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Description for tables.

Our results are shown in two tables. Table 1 contains all identified lines with central intensities deeper than 0.8 of residual flux using “ultracool dwarf model” identifications. Table 2 investigates the sensitivity of priority 1 lines identified in Table 1 to tempereture, gravity and metallicity.

In the first column of Table 1 we estimate the priority of lines for measurement of atomic data.
a) Priority 1 indicates that atomic line is deeper than 0.6 in the 2000/5.0/0.0 synthetic spectrum. Also we include as first priority three lines of Ti (22211.229, 22232.838, 22274.012Å) which are shallower than 0.6. They are located far from strong atomic and molecular lines and thus are good for identification purposes in the spectra of ultracool dwarfs.
b) Priority 2 indicates that the residual flux of an atomic line is between 0.8 – 0.6.
c) Priority 3 indicates that the atomic line is located in the wing of a nearby stronger line or in a wavelength region with strong telluric absorption.

Atomic lines without an assigned priority might be relevant in the analysis of ultracool dwarf spectra, but they are predicted to be weak in the synthetic spectrum.

The second column shows the wavelength of the line in Å in air . These values were taken from VALD. We check that wavelengths from Arcturus and Sunspot umbra atlases identification files are in a good agreement with VALD. The wavelengths of a few lines differ from VALD values by less than 0.1Å in the region 10000 – 20000 Å and by less than 0.3Å beyond 20000 Å.

The third column shows the atomic identifications of the line.

Columns 4 – 7 show the linedepths of identified lines. Column 4 – the residual flux in the line obtained from the “ultracool dwarf” synthetic spectrum; column 5 – from the ”Arcturus-like” synthetic spectrum; column 6 – measured from the hard copy of Arcturus atlas depth of identified atomic lines; column 7 – the same as column 6 for the hard copy of the Sunspot umbra atlas. As was mentioned above we used the hard copy versions of the Arcturus and Sunspot umbra atlases to measure linedepths. The accuracy of our line depth measurements from the hardcopy atlases is ∼0.01 – 0.02 for the Arcturus atlas (column 6) and ∼0.02 – 0.03 for the Sunspot umbra atlas (column 7). We note that linedepth information given in columns 6 and 7 is only used to check the presence of a line in the observed spectra. Thus we do not need high accuracy linedepth measurements for the observable spectra of the Sunspot umbra and Arcturus.

We note that the data in the Sunspot umbra atlas provide a spectrum from 11600Å, rather than 10000Å where our figures and tables start from. Some lines are labelled (see column 7) by the symbol ”∼” which means that part of the line in the hard copy of the atlas is obscured by a gap in the data and the value given in the table is for the visible part of the line. In columns 6 and 7 there are also some lines with ”bl” suffices. This means that these lines are blended with stronger nearby lines.

There are two regions with strong telluric absorption (marked in columns 6 and 7 by $\bigoplus$): 13600–14770Å and 18260–19450Å , regions between the J and H, and H and K photometric bands. Lines identified from VALD in these regions are difficult to observe in ground based observations but can be used in probable future space observations of ultracool dwarfs.

Finally we note, that in Table 1 we italicise atomic lines of Rb, Y, Ba and Lu, identified only using theoretical computations. Although these lines are not seen in the observations of Arcturus and Sunspot umbra, they are strong in synthetic spectrum computed for the 2000/5.0/0.0 model atmosphere, and therefore also likely to be strong below 2000 K.

In Table 2 we show only lines which were marked in Table 1 as first priority lines. The first column are wavelengths in Å; the second column are names of elements. In the third column we give the central line intensity for the “ultracool dwarf” (2000/5.0/0.0) spectrum. We compute some synthetic spectra for ultracool objects varying parameters of $T_{\rm eff}$, log g and metallicity to show the sensitivity of the central intensities of identified lines to these parameters. For our computations we chose the minimal step in model atmospheres grid: $\Delta T_{\rm eff}$ = 100 K, Δlog g = 0.5, Δ[M/H]=-0.5. In columns 4 – 6 we show the difference of central intensity (in %) computations with “new” models from central intensity computations for our “ultracool dwarf model”. Negative values in columns 4 – 6 indicate that a line is stronger in the new model relative to the reference model 2000/5.0/0.0.

Column 4 shows the dependence of residual fluxes on effective temperature. For comparison a 2100/5.0/0.0 synthetic spectrum was used. One can see that only a few lines show strong temperature dependence for $\Delta T_{\rm eff}$ =100 K. The NextGen 2000/4.5/0.0 model was used with 2000/5.0/0.0 to test gravity sensitivity. The dependence for Δ(log g)=0.5 is also relatively weak for most lines and is shown in column 5. Δ[M/H]=0.5 from computations using NextGen model atmospheres 2000/5.0/-0.5 and 2000/5.0/0.0 is shown in column 6. The metallicity dependence is relatively high for all lines. Thus Table 2 indicates that relatively small variations of model atmosphere parameters will not seriously affect our line selection and prioritisation.