HIGH PRECISE EFFECTIVE TEMPERATURES OF 182 MAIN SEQUENCE STARS

S.I. Belik, V.V. Kovtyukh, M.P. Yasinskaya

Odessa Astronomical Observatory, Odessa National University
T.G.Shevchenko Park, Odessa 65014 Ukraine,*val@deneb1.odessa.ua*

ABSTRACT. High precise temperatures ($\sigma = 10 - 15$ K) have been determined from line depth ratios for a set of 182 F-K field dwarfs of about solar metallicity (–0.5 < [Fe/H] < +0.4), based on high resolution (R=42 000), high S/N echelle spectra.

Key words: Stars: fundamental parameters; stars: effective temperatures; stars: dwarfs.

1. Introduction

The key to our analysis of the stellar spectra is the line-depth ratio technique, pioneered by Gray (1994) and successively improved by our group. This technique allows the determination of $T_{\rm eff}$ with an exceptional precision. It relies on the ratio of the central depths of two lines that have very different functional dependences on $T_{\rm eff}$. The method is independent of the interstellar reddening and only marginally dependent on individual characteristics of stars, such as rotation, microturbulence and metallicity.

Briefly, a set of 105 line ratio – $T_{\rm eff}$ relations was obtained in Kovtyukh et al. (2003), with the mean random error of a single calibration being 60–70 K (40–45 K in most cases and 90–95 K in the least accurate cases). The use of ∼70–100 calibrations per spectrum reduces the uncertainty to 5–7 K. These 105 relations use 92 lines, 45 with low (χ <2.77 eV) and 47 with high (χ >4.08 eV) excitation potentials, and have been calibrated with the 45 reference stars in common with Alonso et al. (1996), Blackwell & Lynas-Gray (1998) and di Benedetto (1998). The zero-point of the temperature scale was directly adjusted to the Sun ($T_{\rm eff}$=5777 K is adopted for the Sun), based on 11 solar reflection spectra taken with ELODIE, leading to an uncertainty in the zero-point of about 1 K. The application range for the calibrations is −0.5 <[Fe/H]< +0.4.

In the present study we add 182 new spectra to the sample, increasing the total number of dwarfs with precisely determined $T_{\rm eff}$ to 550.

2. Observations

The spectra used in this paper were extracted from the most recent version of the library of stellar spectra collected with the ELODIE echelle spectrograph at the Observatoire de Haute-Provence by Soubiran et al. (1998) and Prugniel & Soubiran (2001). The description of the instrument mounted on the 1.93 m telescope can be found in Baranne et al (1996).

The spectral range of the spectra is 4400–6800 ÅÅ and the resolution is R=42 000. The signal to noise ratio (S/N) of the spectra range from 40 to 680, with the large majority having S/N > 100. Spectrum extraction, wavelength calibration and radial velocity measurement were performed at the telescope with the on-line data reduction software while straightening of the orders, removing of cosmic ray hits, bad pixels and telluric lines were performed as described in Katz et al (1998). Further processing of the spectra (continuum placement, measuring equivalent widths, etc.) was carried out by us using the DECH20 software (Galazutdinov, 1992). Equivalent widths and depths R_λ of lines were measured manually by means of a Gaussian fitting. The Gaussian height was taken as a measure of the line depth. This method produces line depth values that agree with the parabola technique used by Gray (1994).

3. Results

In Table 1 for each star we report the mean $T_{\rm eff}$, the mean square deviation for each determination (σ), number of the calibrations used (N), and the standard error of the mean (σ(mean)). For comparison, we also provide $T_{\rm eff}$ as determined in Masana, Jordi and Ribas (2006). For the majority of stars we get an error which is smaller than 10 K.

Masana, Jordi and Ribas (2006) present a method to determine effective temperatures, angular semi-diameters and bolometric corrections for population I and II FGK type stars based on V and 2MASS IR pho-

Table 1: The computed $T_{\rm eff}$ for MS-stars.

HD	$T_{\rm eff}$ K	σ	N	σ (mean)	$T_{\rm eff}$ (Masana)	HD	$T_{\rm eff}$ K	σ	N	σ (mean)	$T_{\rm eff}$ (Masana)
000330	6042	49	68	5.9	5764	044966	6237	103	58	13.5	–
000739	6491	62	40	9.8	–	045654	6385	271	43	41.3	–
001461	5728	35	121	3.1	–	046871	6087	53	62	6.7	5992
001497	5859	72	112	6.8	5776	048410	5899	69	79	7.7	5946
001581	5954	62	65	7.7	–	048591	5784	201	52	27.9	–
001832	5799	107	107	10.4	5747	048684	5955	88	95	9.1	5907
002330	5991	78	91	8.2	6178	049932	6507	38	20	8.6	–
003229	6478	44	47	6.4	–	049933	6674	131	18	30.8	–
003268	6263	82	53	11.2	6221	050039	6332	73	45	10.8	6377
003801	6115	48	85	5.2	6259	059360	5908	129	52	17.8	5799
004813	6211	46	72	5.5	–	059468	5570	65	105	6.3	–
005600	6209	163	43	24.8	6454	059967	5781	63	100	6.3	–
007228	6150	165	34	28.3	6127	059984	6166	154	47	22.5	–
007476	6549	78	35	13.2	–	061421	6662	53	24	10.7	–
007570	6054	42	94	4.3	–	063077	6057	107	67	13.0	5814
008997	4655	282	48	40.7	–	064235	6325	185	36	30.8	–
009966	5844	81	107	7.9	5845	064606	5340	129	102	12.8	–
010126	5554	73	109	7.0	5539	065430	5227	64	111	6.1	5157
010132	5382	59	115	5.5	–	067230	6698	123	10	38.8	–
010556	6003	58	93	6.0	6073	067827	6081	66	92	6.9	5942
010647	6163	49	62	6.3	–	068168	5707	47	119	4.4	–
013555	6551	47	28	9.0	6509	068284	5901	127	64	15.9	5843
014214	6035	44	110	4.2	–	068380	6491	75	31	13.5	6739
014802	5960	74	99	7.4	–	069056	5594	60	111	5.7	5598
015632	5761	41	122	3.7	5728	070937	6291	322	15	83.0	6495
016673	6292	31	35	5.2	6224	070958	6639		1		6458
016895	6364	64	57	8.5	–	071595	6569	93	33	16.2	6679
019902	5595	51	119	4.7	5531	072659	5907	63	65	7.8	5998
020367	6022	46	112	4.3	6019	072945	6310	60	65	7.4	–
020807	5855	96	97	9.8	–	075880	5683	59	92	6.2	–
022556	6183	96	62	12.2	5954	075935	5434	40	111	3.8	–
023596	5931	74	100	7.4	–	076932	6089	139	55	18.7	–
025069	5119	96	97	9.7	–	078660	5684	66	92	6.9	5710
025444	5828	52	104	5.1	–	079126	5987	66	58	8.6	5885
025457	6374	96	16	24.0	6403	083870	5688	275	40	43.5	–
025825	5982	44	108	4.2	5974	085533	5659	68	109	6.5	5547
026756	5638	75	112	7.1	5642	089744	6253	70	73	8.2	6149
026767	5815	38	114	3.6	–	097503	4538	47	73	5.5	4496
026784	6190	80	31	14.3	6221	100563	6407	70	57	9.3	6489
027406	6013	86	48	12.5	–	101013	5262	74	100	7.4	–
027857	5750	58	91	6.1	5965	103432	5622	47	111	4.4	5608
028344	5947	28	110	2.7	5939	104956	6102	68	52	9.4	6112
028821	5650	89	90	9.4	5800	105113	5986	61	101	6.1	–
028992	5875	35	99	3.6	6021	105755	6173		1		5854
029419	6034	35	112	3.3	5987	107213	6194	76	49	10.9	6254
029587	5754	80	91	8.4	5722	108019	5973	110	80	12.3	5938
030376	5529	68	114	6.4	5519	108863	5181	94	110	9.0	–
030708	5740	55	123	4.9	5936	109098	5841	79	111	7.5	5828
032070	5611	89	89	9.5	5565	109247	5765	147	39	23.6	–
032963	5741	34	112	3.2	–	110223	6119	143	25	28.6	6163
033256	6572	42	19	9.5	–	111513	5796	54	111	5.1	–
033636	5935	74	53	10.1	5930	112914	4898	77	98	7.8	–
034445	5815	51	104	5.0	5867	114642	6453	73	22	15.5	–
034745	6109	77	57	10.2	6136	114762	6255	20	2	14.3	5919
037495	6650	47	4	23.3	–	115617	5509	74	108	7.1	–
038309	5776	253	53	34.8	–	115954	5818	68	106	6.6	5870
038393	6388	26	29	4.8	–	116091	5876	83	82	9.2	–
042548	6708	49	10	15.6	6661	117635	5239	65	87	7.0	–
043042	6514	75	25	15.1	–	118096	4305	105	76	12.1	–
043318	6340	46	55	6.2	–	120136	6337	78	27	15.0	–
043856	6227	50	43	7.6	6092	120510	6467	71	37	11.6	6372

Table 1 (Continued)

HD	T_{eff} K	σ	N	σ (mean)	T_{eff} (Masana)	HD/BD	T_{eff} K	σ	N	σ (mean)	T_{eff} (Masana)
120567	5184	89	111	8.4	–	174457	5831	99	116	9.2	5875
122518	5893	85	96	8.7	5919	175806	6047	100	84	10.9	6150
122727	5702	80	111	7.6	5699	180945	6474	85	21	18.5	6374
124115	6472	116	5	51.9	6458	181096	6126	158	32	27.9	–
124425	6441	58	3	33.3	6435	182274	6427	163	19	37.4	6330
125706	5849	86	92	9.0	5793	186226	6305	125	54	16.9	–
128429	6569	108	9	36.0	6388	189259	6726	76	11	22.9	6768
129171	5860	63	107	6.1	5893	190360	5564	47	116	4.4	–
134044	6164	48	77	5.5	6545	190437	6121	100	59	13.1	–
140209	5742	75	112	7.1	–	191533	6251	45	60	5.8	–
140901	5553	55	107	5.4	–	197967	6322	70	71	8.4	6176
140913	5902	58	93	6.0	5951	198023	6551	131	19	30.1	6567
142860	6334	88	30	16.0	–	198343	4555	204	24	41.6	–
147887	5833	141	80	15.8	5946	201191	4334	44	62	5.6	–
148049	6105	105	64	13.1	6058	203608	6235	96	32	17.1	–
150177	6171	89	2	63.1	6107	209458	6098	39	97	4.0	6051
157881	4146	165	6	67.6	–	211976	6376	81	61	10.3	6493
160693	6075	2	2	1.3	5788	211998	5599	205	49	29.2	–
161797	5602	56	112	5.2	–	215648	6291	68	46	10.1	–
163714	6021	84	66	10.4	–	216435	5921	39	107	3.8	–
165670	6355	52	40	8.2	–	217107	5585	54	119	5.0	–
165908	6098	21	2	14.7	–	218059	6352	79	43	12.0	6342
166073	6380	117	36	19.4	6399	219420	6267	44	65	5.4	–
166183	6283	116	43	17.7	6317	220221	4892	46	89	4.8	–
167407	5957	89	91	9.3	5988	222368	6270	59	76	6.7	–
168151	6652	69	15	17.7	–	283704	5499	49	121	4.4	–
170291	6311	86	49	12.3	6299	+11 9332	5230	40	100	4.0	–
170579	6280	171	43	26.0	6346	+26 2461	6014	149	38	24.3	–
171888	6167	70	81	7.8	6207	+52 2815	4325	134	33	23.3	–
171951	6124	66	72	7.8	–	SUN	5777	31	100	3.1	–
172675	6295	82	38	13.4	–						

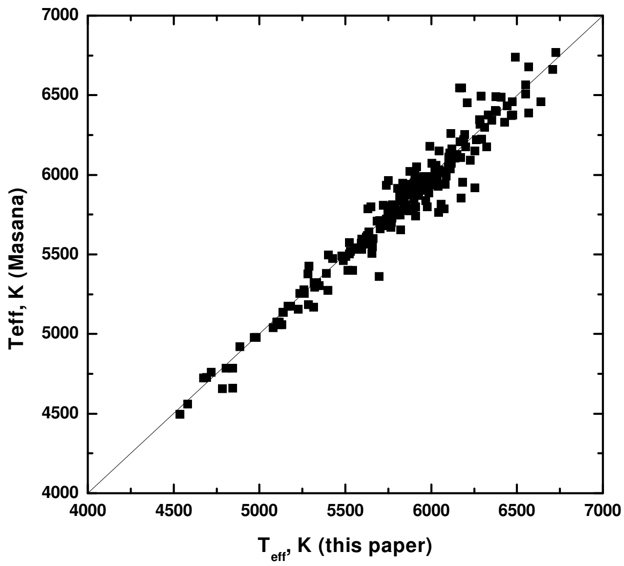

Figure 1: Comparison of our $T_{\rm eff}$ with estimates from Masana, Jordi and Ribas (2006).

tometry. Accurate calibration is accomplished by using a sample of solar analogues, whose average temperature is assumed to be equal to the solar effective temperature of 5777 K. By taking into account all possible sources of error they estimate associated uncertainties to better than 1 angular semi-diameter for unreddened stars. They determined $T_{\rm eff}$, angular semi-diameters, radii and bolometric corrections in the V and K bands for the 10 999 FGK stars.

Table 1 contains our final $T_{\rm eff}$ determinations for 182 MS stars. As one can see from Table 1, for the majority of stars we get an error which is smaller than 10 K. The consistency of the results derived from the ratios of lines representing different elements is very reassuring. It shows that our 105 calibrations are essentially independent of micro-turbulence, LTE departures, abundances, rotation and other individual properties of stars.

The temperatures of Masana, Jordi and Ribas (2006) are in a good agreement with our estimates – see Fig. 1.

4. Conclusion

The high-precision temperatures were derived for a set of 182 dwarfs, which may serve as temperature standards in the 4000–6750 K range. These temperatures are precise to within 10–35 K for the major fraction of the sample.

Acknowledgements. This work is based on spectra collected with the 1.93-m telescope of the OHP (France). Dr. C. Soubiran is acknowledged for help with spectral material.

References

Alonso A., Arribas S., Martínez-Roger C.: 1996, *A&ASS*, **117**, 227.

Baranne A., Queloz, D., Mayor, M., et al.: 1996, *A&ASS*, **119**, 373.

Blackwell D.E. & Lynas–Gray A.E. 1998, *A&ASS*, **129**, 505.

di Benedetto G.P.: 1998, *A&A*, **339**, 858.

Galazutdinov G.A.: 1992, *Prepr. SAO RAS*, **92**, 28.

Gray D.: 1994, *PASP* **106**, 1248.

Katz D., Soubiran C., Cayrel R., Adda M., Cautain R.: 1998, *A&A*, **338**, 151.

Kovtyukh, V.V., Soubiran, C., Belik, S.I., Gorlova N.I.: 2003, *A&A*, **411**, 559.

Masana E., Jordi C., Ribas I.: 2006, *A&A*, **450**, 735.

Moultaka J., Ilovaisky S. A., Prugniel P., Soubiran C.: 2004, *PASP*, **116**, 693.

Prugniel P. & Soubiran C.: 2001, *A&A*, **369**, 1048.

Soubiran C., Katz D., Cayrel R.: 1998, *A&AS*, **133**, 221.