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Relation between temperature and equivalent width in stellar spectra

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Abstract. We studied the spectra of 50 stars in order to measure the equivalent width (EqW) of three absorption lines (MgI, CaK, and Hα) and to determine the stellar surface temperature. We analyzed these data by plotting them in a graph.

1. Introduction

Stars are classified in different classes (O, B, A, F, G, K, and M) depending on the absorption lines in their spectra. In fact, a stellar spectrum contains absorption lines superimposed on a bright continuum spectrum because the radiation coming from the inner hot layers of the star passes through its cooler atmosphere. The absorption lines, at specific wavelengths, correspond to the different chemical elements. A lot of information about stars can be obtained by the spectral analysis, such as the temperature and composition of the atmosphere. We analyzed the spectra of 50 stars obtaining their temperature, and the equivalent width (EqW) of the Hα, CaK, and MgI lines. Our aim was to study the relation between temperature and EqW.

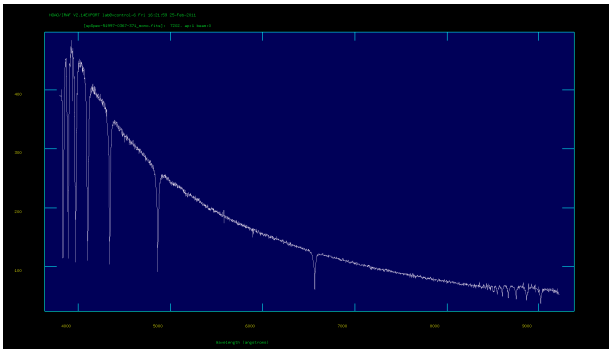

Fig. 1. Example of star spectrum where are visible the absorption lines.

2. Observational Data

We used 50 spectra downloaded from the public archive of the Sloan Digital Sky Survey (SDSS), which is a multi-filter imaging and spectroscopic survey using a dedicated 2.5-m wide-angle optical telescope at the Apache Point Observatory in New Mexico, United States.

3. Work description

In order to analyze the stellar spectra, we used the program IRAF (Image Reduction and Analysis Facility). Our first step was to measure the strength of the following spectral lines: Hα 6563 Å, CaK 3994 Å, and the MgI triplet 5169, 5174, and 5185 Å. The EqW is a measure of the strength of a spectral line. It is obtained by the ratio between the area of the line and the mean intensity of the continuum and it is measured in Å. It corresponds to the area of a rectangle with height equal to the continuum intensity and width equal to EqW.

We plotted the star spectrum by using IRAF and we identified each line by its wavelength. We measured the EqW by selecting the extremes of the absorption line and the program gave us the value as it is shown in Figure 3. At the beginning we had to:

- identify the absorption lines;
- recognize the average trend of the continuum;
- avoid taking the noise as a real absorption line;
- correctly manage the Mg triplet lines.

After that, we measured the EqW of the three absorption lines we wanted to study in the spectra of 50 stars.

Our second task was to estimate the stellar surface temperature. It can be obtained by comparing the stellar spectrum with different Planck curves in order to

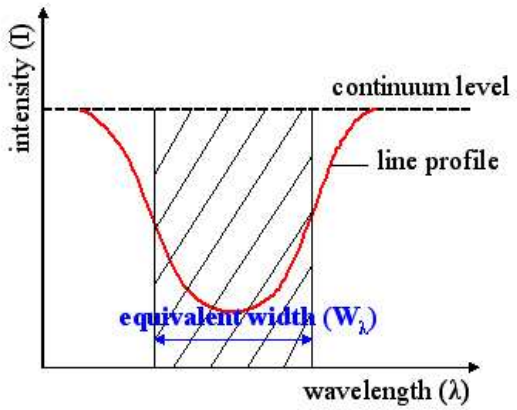

Fig. 2. Definition of equivalent width (EqW).

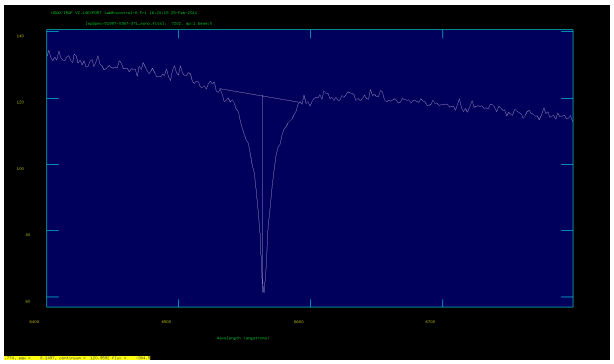

Fig. 3. Measurement of the EqW.

find the best fit. First of all, it was necessary to normalize each spectrum dividing its intensity by the average value at 5500 Å. This step was performed with IRAF. We imported in TOPCAT the normalized spectrum of every star. The file had two columns containing the values of wavelengths versus the normalized intensity.

We added a third column with the values calculated with the Planck formula:

$$B(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1} erg\, cm^{-3} s^{-1}\,.$$

Finally, we compared Planck functions of different temperatures with each normalized spectrum to find which one best fitted the observational data. In this way, we could estimate the surface temperature of each star.

Star	Hα	MgI	CaK	Temp
359	3.0619	1.9361	4.1538	8200
354	3.6682	0.9352	4.2199	7200
376	5.3558	0.482	2.5248	8200
394	7.2009	0.5439	2.8301	8500
249	2.3298	4.7906	13.4643	5900
336	1.776	17.7412	10.9787	3700
177	5.9089	3.0132	1.9839	15000
384	0.9973	10.4127	11.4679	4000
456	5.6037	1.2424	6.1368	7900
186	9.4123	0.2992	13.1835	19000
304	1.8155	6.8328	9.6957	5500
372	8.9406	0.1053	0.7179	13400
626	1.8406	10.057	7.1497	3650
53	2.6942	0.308	0.2735	40000
344	2.4588	7.6999	9.225	6200
158	5.6102	1.3561	3.5472	8200
380	7.8779	1.1923	6.4471	8300
55	2.7169	1.6001	1.1931	24000
168	0.7917	5.2902	0.6077	5500
86	4.2811	1.7285	1.9967	8100
397	5.1529	0.142	0.2071	32000
336	4.1334	2.1584	4.2648	8200
476	0.8235	9.5701	10.8895	4000
62	5.7181	0.6104	2.3796	9000
137	1.0728	7.0005	7.0947	4000
156	0.8588	8.1279	7.1872	4300
145	1.0518	6.7176	10.8595	4500
224	1.2243	10.5444	13.0317	4000
272	3.3576	2.4689	10.3778	6000
20	6.7547	1.0706	2.5972	7000
461	6.0099	0.8986	2.8028	8500
4	6.65	1.4018	5.008	8000
307	2.4157	5.2729	5.3514	6200
609	1.9629	7.265	8.5807	4900
593	14.7136	4.7784	1.4659	110000
152	5.8382	0.8064	1.7931	10000
204	9.618	1.1159	2.597	20000
19	14.6104	1.9292	1.5238	10000
393	14.2057	0.5352	0.2	9500
202	4.3555	0.8101	2.2181	8500
400	2.4656	5.3171	12.525	5500
434	2.9359	5.9551		4900
46	2.9406	4.4861	11.7843	6500
5	2.0827	8.8934		4100
615	1.3017		9.6384	4300
316	2.1029	6.0157	14.5466	4300
545	2.2587		0.095	100000
175	3.983		0.135	35000
371	8.5596	0.3127	0.6545	14500
196	0.0989		0.1314	35000

We reported all the data (temperature and EqW of the three absorption lines) on a table, and we used TOPCAT to plot the EqW (on the y-axis) versus the temperature in logarithmic scale (on the x-axis). We obtained three plots, one for each element, Hα, MgI, and CaK, respectively. As shown in Fig. 4, the plots appear to define three different and almost continuous functions. There are only a few outliers probably due to peculiar stars or measurement errors.

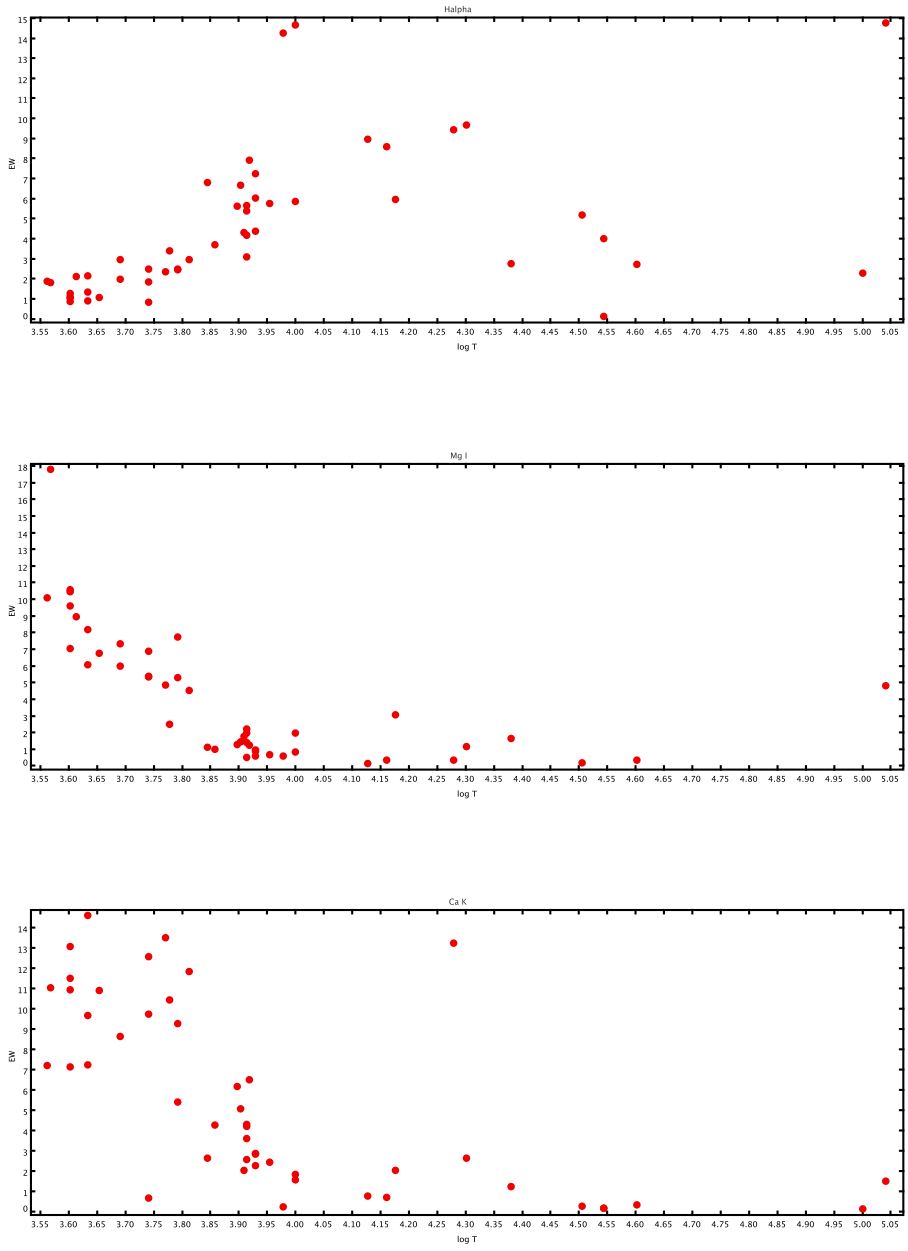

Fig. 4. From top to bottom: EqW of each sample star versus its temperature, for Hα, Mg I and CaK, respectively.

4. Results

According to the literature, there is a relation between the absorption lines and the surface temperature of a star on which the spectral classification is based. We obtained three plots showing a trend whose maximum is at different temperatures.