

Properties of stars: temperature, colour index and equivalent width of spectral lines

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ABSTRACT

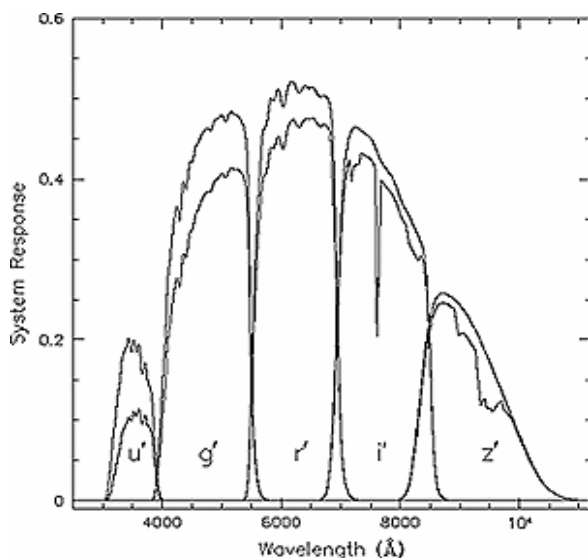
Stars can be distinguished by their colour, temperature and mass. These three features are closely linked to each other: the hotter the star is, the more the colour is towards blue, because it emits most of its energy at shorter wavelengths. We were able to build some diagrams which linked the colour and the temperature of some stars, in order to deduce the temperature of a larger amount of stars.

I. INTRODUCTION

With our research we wanted to achieve two goals:

1. Starting from a limited number of stars, we verified and analyzed the linear trend of the function in the color-temperature diagram and we have applied this relation to a large amount of stars to get easily their temperature.
2. Through the study of the spectrum of 10 stars at different temperatures we analyzed the trend of the equivalent width of the absorption lines H α and CaII K, as a function of temperature.

A color index is the difference between two magnitudes of the same star obtained with two different photometric filters. We used the *ugriz* filters that have characteristic wavelengths in the range of the visible light.

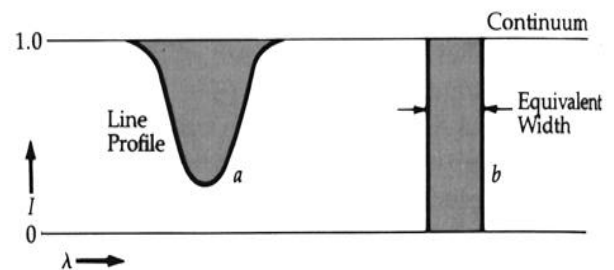


The equation of the colour - temperature diagram we are going to verify is:

$$y = Bx + A$$

where y is the color index and x is the reciprocal of the temperature ($1/T$).

The equivalent width (EW) is defined as the width of the rectangle whose height corresponds to the absorption of 100% of the radiation and whose area, namely the absorbed energy, is the same of the real spectral line.



Despite the name, the equivalent width does not give information about the width of the lines. A wide and shallow line or a narrow and deep line can represent the absorption of the same number of photons and therefore have the same equivalent width.

From the mathematical point of view:

$$EW = f / I_{\text{cont}}$$

where:

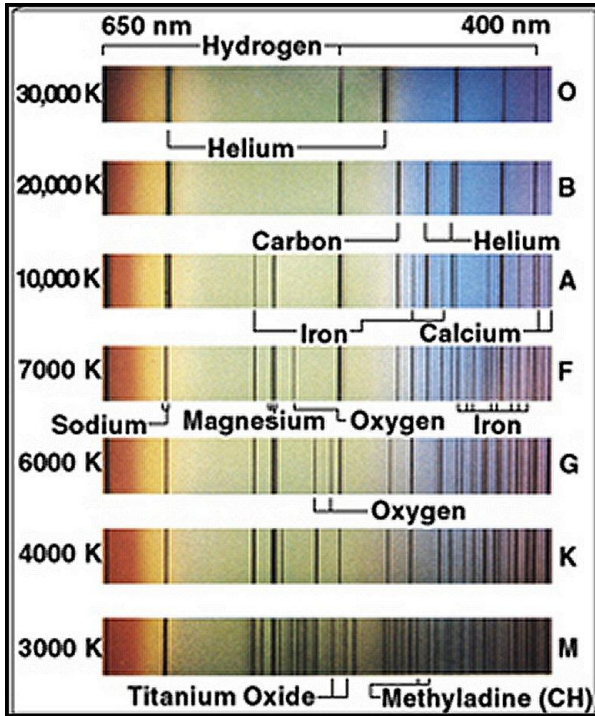
f is the absorption line flux ($\text{erg/cm}^2 \text{ s}$);

I_{cont} is the intensity of the continuum ($\text{erg/cm}^2 \text{ s } \text{\AA}$);

from this we get:

$$[EW] = [\text{\AA}]$$

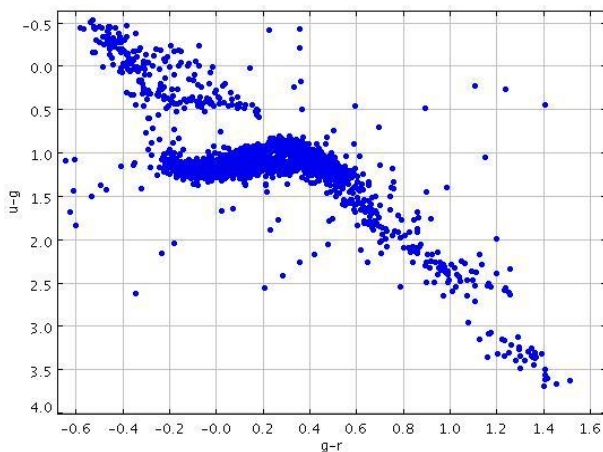
Experimentally we see how the absorption lines are different from one another depending on the temperature. Their behavior therefore is the following:



II. OBSERVATIONAL DATA

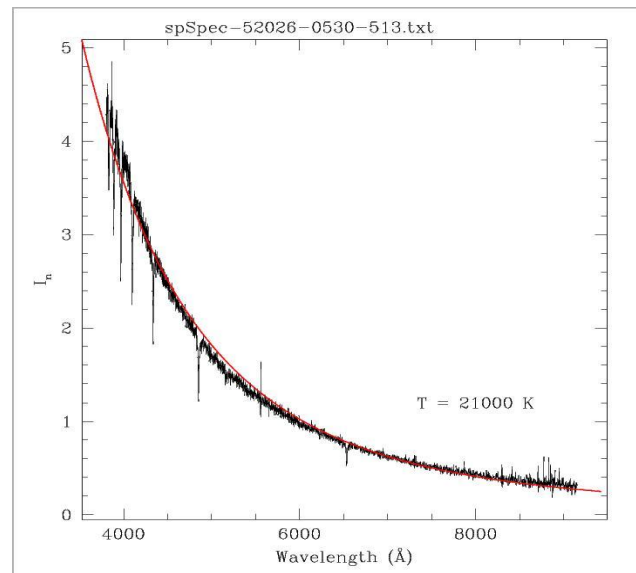
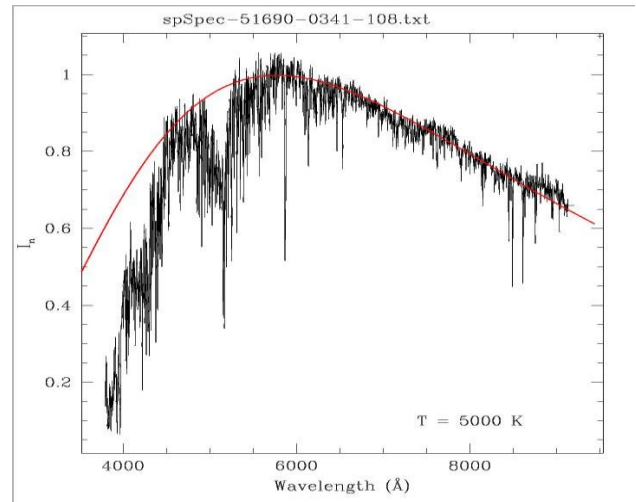
A sample of 5000 stars was taken from the archive of the Sloan Digital Sky Survey (www.sdss.org) with the respective information, including the magnitudes taken with the *ugriz* filters.

III. WORK DESCRIPTION



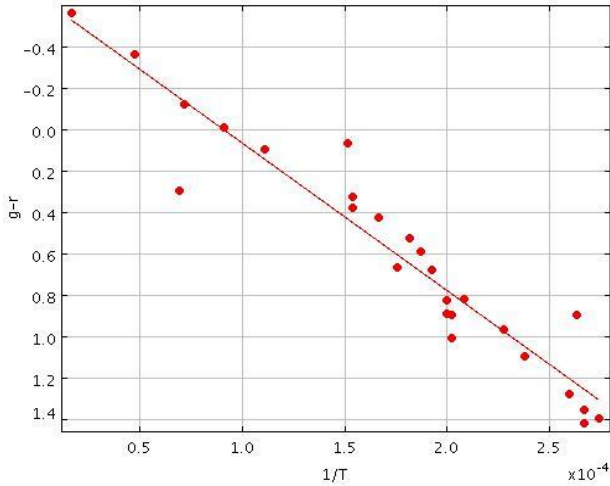
We obtained the *g-r* and *u-g* color indices by calculating the difference between the magnitudes of *g* and *r* (*g-r*) filters and between the magnitudes of the *u* and *g* (*u-g*) filters of all the 5000 stars. Then, we put these values in a plot to obtain a color-color diagram. We selected 26 stars out of the 5000, taken from different parts of the color-color diagram, so that the stars had different temperatures, and we extracted their spectra.

We normalized the spectra so that in every spectrum the intensity is 1 at wavelength $\lambda=6000\text{\AA}$. By applying to every spectrum Planck's law and changing every time the temperature value until we found the best fitting to the observed spectrum, we estimated the approximate surface temperature of the stars.



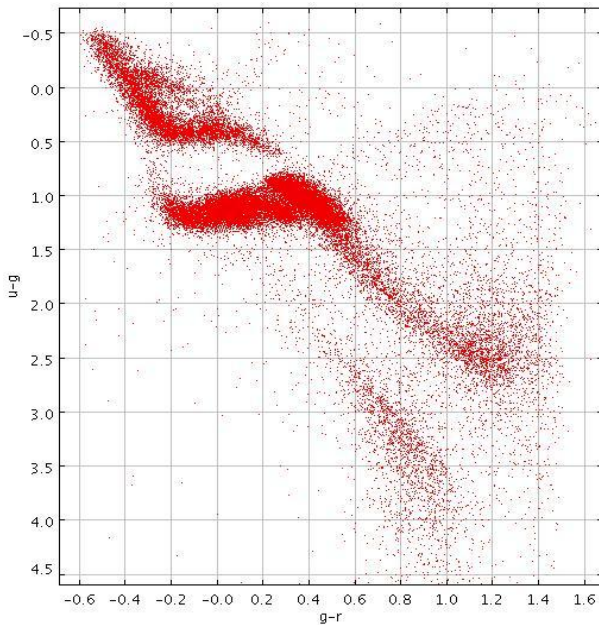
In these plot the black curve is the actual spectrum of the star, while the red one is Planck's law. After finding the temperature of these 26 stars, we built 4 plots putting on the x-axis the reciprocal of the stellar temperature ($1/T$) and on the y-axis a different color index for every plot (*g-r*; *u-g*; *r-i*; *g-i*). In this way we verified that the color index is inversely proportional to the temperature.

In these plots the trend of the data can be easily fitted with a straight line.



The straight line which best fits the above data, is given by the following equation:

$$g - r = -0,647 + (7151/T)$$

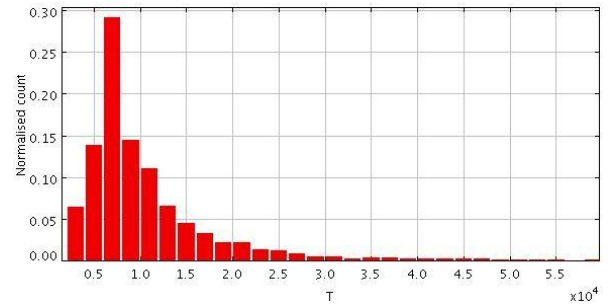


Then, we extracted from the same archive, a list of 100000 stars and we built a new color-color plot (u-g vs. g-r).

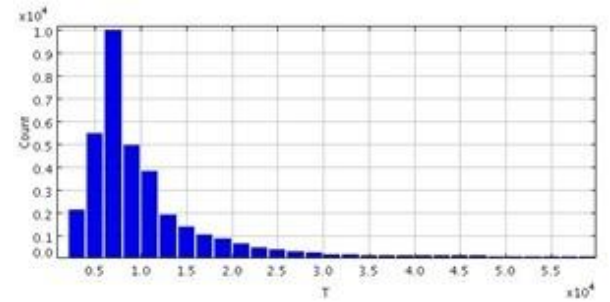
We applied the color index–temperature relation first to the 5000 and after to the 100000 stars. By means of the known color indices, we obtained the temperature of the stars and we created histograms plotting on the x-axis the temperature just found for the 5000 and 100000 stars, and in the y-axis the number of stars calculated in fixed intervals of temperature.

We can see that in the interval between 5000 K and 15000 K there is the highest amount of stars.

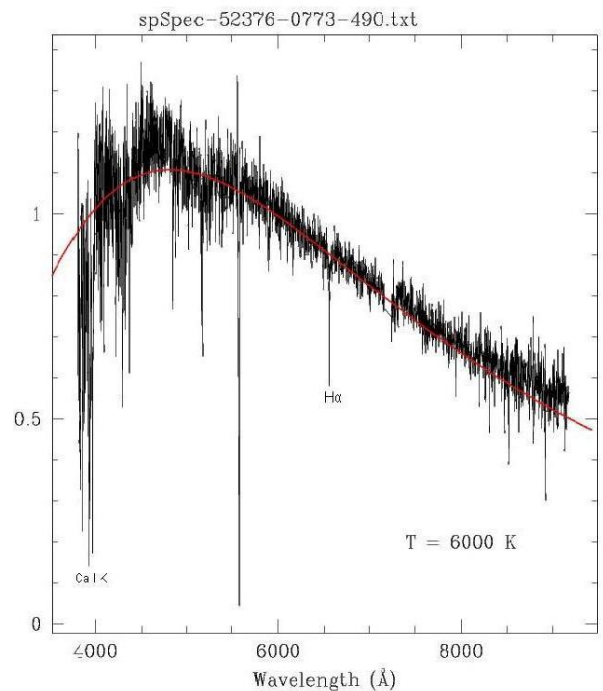
Histogram of the 5000 stars:

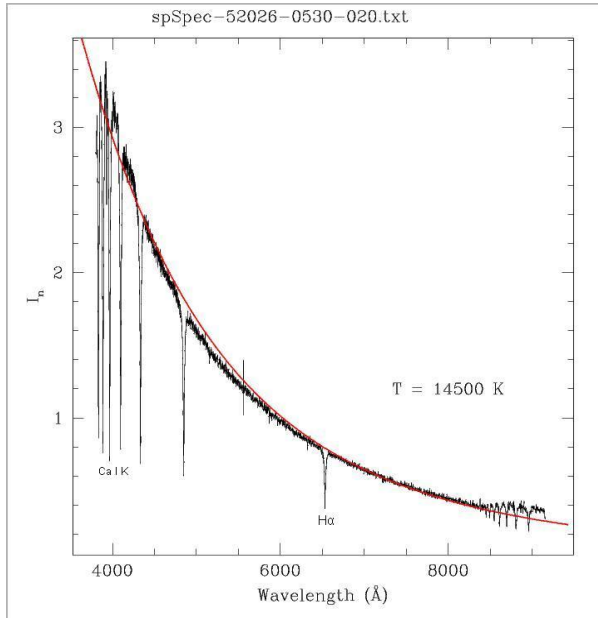


Histogram of the 100000 stars:

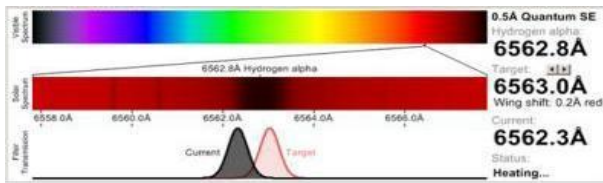


In order to study the equivalent width of the spectral lines in connection with the temperature, we considered the spectra of 10 stars at different temperatures: 3650K, 3850K, 4400K, 5200K, 6000K, 6500K, 9000K, 14500K, 21000K, 60000K.

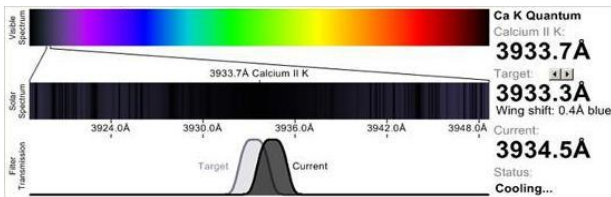




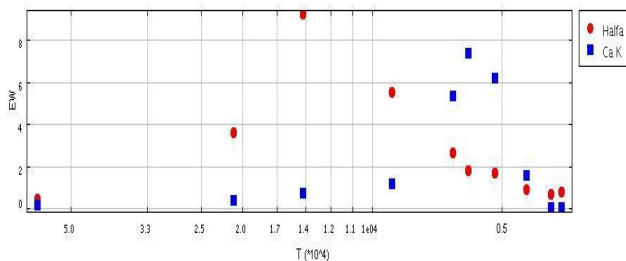
We measured the absorption lines corresponding to H α (at 6563 Å):



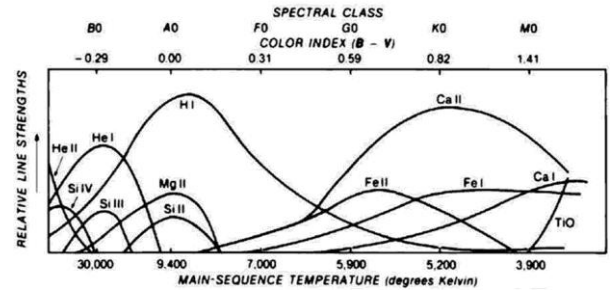
and Ca II K (at 3934 Å):



We calculated the equivalent width using the program IRAF. Furthermore we compared EW with T, in a logarithmic scale, so we found the following graph:



A peak of Ca K is well visible around 5000 K, while a peak of H is approximately at 11000 K, so we verified the expected behavior of spectral lines typical of these elements as shown in the following figure:



IV. RESULTS

In the first part of the work, we verified that there is a linear relation between the color of the stars and the reciprocal of their temperature. In the second part, we verified the expected behavior of spectral lines typical of H and Ca II K.