Astronomy Exercise 5

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1. Color-magnitude diagram

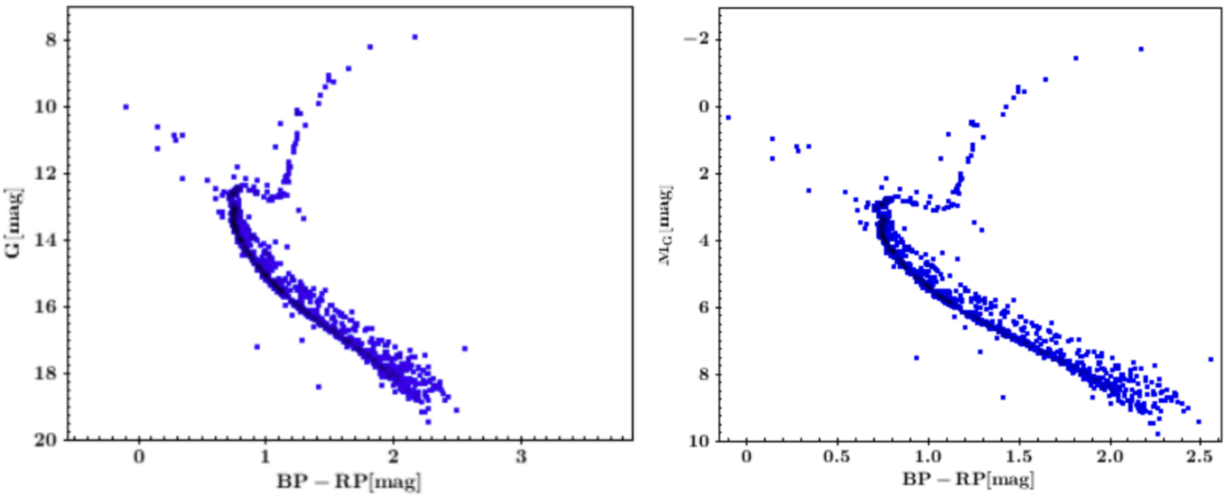


Figure 1: Sub-sample of the Gaia data release 3 (DR3) color-magnitude diagram (CMD) in apparent (left) and absolute (right) magnitudes. Each dot represents a star and they belong to a stellar cluster. Note: apparent magnitudes are denoted by G, G_{BP} and G_{RP} and absolute magnitudes denoted by M_G, $M_{G_{BP}}$ and $M_{G_{RP}}$.

a) Figure 1 (left) shows the color ($G_{BP} - G_{RP}$) on the x-axis and apparent magnitudes (G) on the y-axis of a group of stars in the Milky Way. The data is taken from a sub-sample of the Gaia data release 3 (DR3). Give a brief description of Photometry. Look up the Gaia mission and give the wavelength coverages of the G, G_{BP} and G_{RP} passbands.

From both diagrams we can identify a clear diagonal, which represents the main sequence. The stars in said main sequence are the ones which are in the phase of burning hydrogen. With the x-axis values we can determine or at least make assumptions about the color of the stars. With $BP - RP$ we can assume that stars to the left are more blueish and stars to the right of the x-axis are more reddish. Generally speaking stars that emmit blue light tend to be hotter than ones that emmit red light. With that in mind and taking a look at the y-axis we can further support that because we see that the blue stars seem to be brighter than the red ones. The wavelength coverage of G is about 330 to 1050 nanometers, the coverage of G_{BP} is the blue spectrum, which is around 450 to 495 and of G_{RP} it is the red spectrum, which is 620 to 750 nanometers.

b) A color-magnitude diagram (CMD) is a way to sort stars by brightness and temperature. What axis of the plot is a proxy for brightness? What direction of this axis represents increasing brightness? What axis of the plot is a proxy for temperature? What direction of this axis represents increasing temperature?

The y-axis of the plot is a proxy for brightness. This axis represents the magnitude of stars, which is a measure of their brightness. Moving upwards along the y-axis represents increasing brightness. Stars located higher on the CMD are generally brighter. The x-axis of the plot is a proxy for temperature. This axis represents a color index or spectral type, both of which provide information about the temperature of stars. Moving to the left along the x-axis represents increasing temperature. Bluer stars (with lower color indices or hotter spectral types) are found on the left side of the CMD, indicating higher temperatures.

c) On the left plot, label and describe the following components (stellar evolutionary stages): 1) main sequence, 2) main sequence turn-off, 3) horizontal branch, 4) blue stragglers, and 5) red giants.

As previous stated we can see the 1) main sequence as the dark plotted diagonal in about the middle of the plot. The 2) main sequence turn-off is the point on the main sequence where stars begin to evolve away from the main sequence. That would around the area where the data points or stars begin to have a lower magnitude than 12.5 as these data points start to malform the diagonal. The 3) horizontal branch is a region populated by stars that have evolved off the main sequence, typically after exhausting their core hydrogen. Most of the stars with about a lower magnitude than 12.5 would be in that region as they are clearly not part of the main sequence. 4) Blue stragglers are stars that appear to be younger or more massive than their surroundings. Those are outliers deviating from the expected evolutionary track or the right branch of the stars with a lower magnitude than 12.5. 5) Red giants are evolved stars that have exhausted the hydrogen in their cores and expanded. They appear on the CMD as bright and reddish. Again stars on the top right branch that evolves to the right would be counted as red giants.

d) The right plot shows the same CMD as the left, but the apparent magnitudes have been converted to absolute magnitudes. Using the plot write down the apparent and absolute magnitudes of the main sequence turn-off points. Use the distance modulus formula to find the approximate distance to this stellar cluster.

The apparent magnitude of the MSTO as m_{MSTO} is as previous stated about 12.5 and the absolute magnitude as M_{MSTO} is around 2.5. The distance modulus formula is:

$$
\begin{aligned}
m - M &= 5log_{10}(\frac{d}{10}) \\
\frac{1}{5}(m - M) &= log_{10}(\frac{d}{10}) \\
10^{\frac{1}{5}(m-M)} &= \frac{d}{10} \\
d &= 10^{(\frac{1}{5}(m-M)+1)}
\end{aligned}
$$

Inserting the values no we get:

$$
\begin{aligned}
d &= 10^{(\frac{1}{5}(m-M)+1)} \\
&= 10^{(\frac{1}{5}(12.5-2.5)+1)} \\
&= 10^{(\frac{1}{5}(10)+1)} \\
&= 10^{(2+1)} \\
&= 10^3 \\
&= 1000
\end{aligned}
$$

The distance is about 1000 parsec.

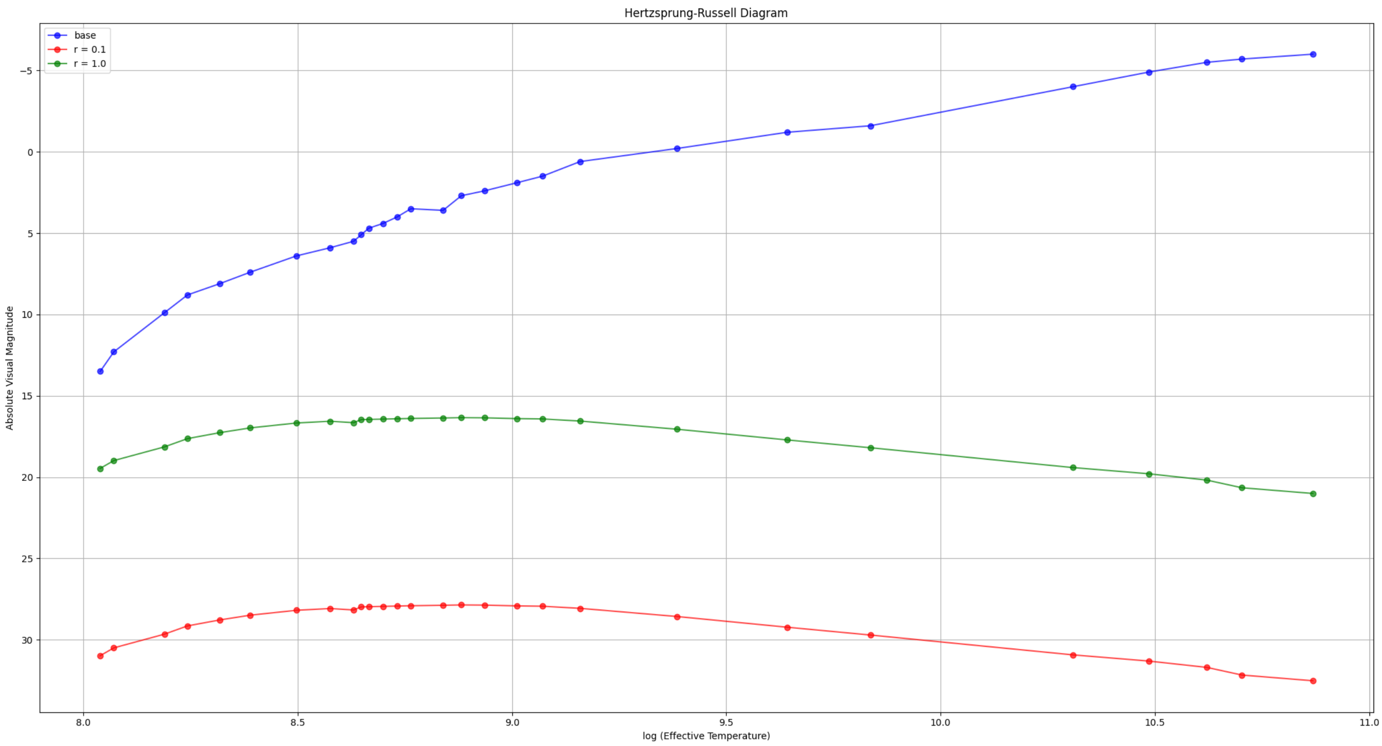
2. Hertzsprung-Russell diagram

The table shows the effective temperature (T_{eff}), the absolute magnitude in the band V (M_V), and the bolometric correction (BC) for a group of stars.

a) Using the data from the table below, plot the Hertzsprung-Russell diagram for the main-sequence stars in terms of M_V versus $log(T_{eff})$.

b) Plot in the same diagram the curve that describes the stars with radii $R = 0.1$, 1.0 and $10.0R_{\circ}$. You can use that $L = 4\pi R^2\sigma T_{eff}^4$; $M_V + BC = M_{bol\circ} - 2.5log(\frac{L}{L_\circ})$ where $M_{bol\circ} = +4.74$ to derive the equation for the curve.

S.N	T_{eff}	M_V	BC	S.N	T_{eff}	M_V	BC
1	52500	-6.0	-4.751	15	6400	3.5	-0.14
2	44500	-5.7	-4.40	16	6200	4.0	-0.16
3	41000	-5.5	-3.93	17	6000	4.4	-0.18
4	35800	-4.9	-3.54	18	5800	4.7	-0.20
5	30000	-4.0	-3.16	19	5700	5.1	-0.21
6	18700	-1.6	-1.94	20	5600	5.5	-0.40
7	15400	-1.2	-1.46	21	5300	5.9	-0.31
8	11900	-0.2	-0.80	22	4900	6.4	-0.42
9	9500	0.6	-0.30	23	4400	7.4	-0.72
10	8700	1.5	-0.17	24	4100	8.1	-1.01
11	8200	1.9	-0.15	25	3800	8.8	-1.38
12	7600	2.4	-0.10	26	3600	9.9	-1.89
13	7200	2.7	-0.09	27	3200	12.3	-2.73
14	6900	3.6	-0.11	28	3100	13.5	-3.21



3. Stellar classification

Figure 2. presents the relative line strengths, for different elements and molecules, for different types of stars. This can be used to classify stars into different stellar types, depending on which elements cause absorption features in the stellar spectrum.

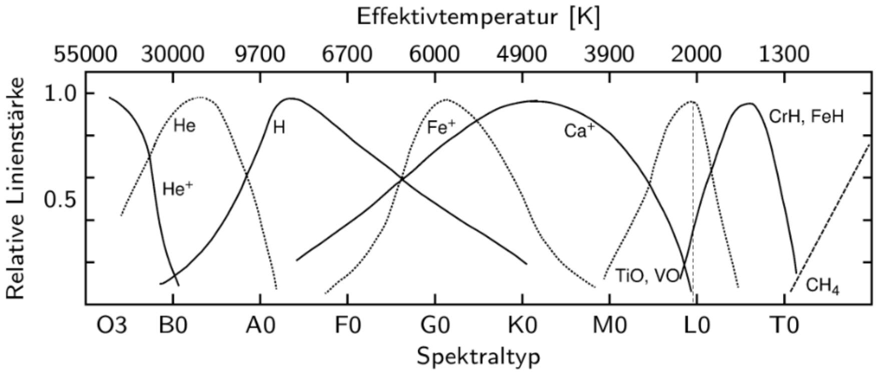


Figure 2: Diagram shows the relative absorption line strength in dependence of the stellar spectral type.

a) To get an idea of which energies different elements absorb, have a look at the Frauenhofer lines and write down the elements and their line energies that could help you classify the spectra shown in part (b) of this question.

B0:
- He: 0.9
- He^{+}: 0.1
- H: 0.1

A0:
- H: 0.8
- He: 0.3

F0:
- Ca^{+}: 0.4
- Fe^{+}: 0.2
- H: 0.7

G0:
- Ca^{+}: 0.6
- Fe^{+}: 0.95
- H: 0.4

K0:
- Ca^{+}: 1.0
- Fe^{+}: 0.5
- H: 0.3

M0:
- Ca^{+}: 0.8
- TiO, VO: 0.2

L0:
- TiO, VO: 0.95
- CrH, FeH: 0.4

T0:
- CrH, FeH: 0.3

b) Figure 3 shows the spectra of 5 different stars. Use the information from part (a) to estimate the spectral type of each star and state the reasons for you choosing this type. It is sufficient to mention the letter connected with the spectral class (O, B, A, F, G, K, M), while sub-classes do not need to be estimated.

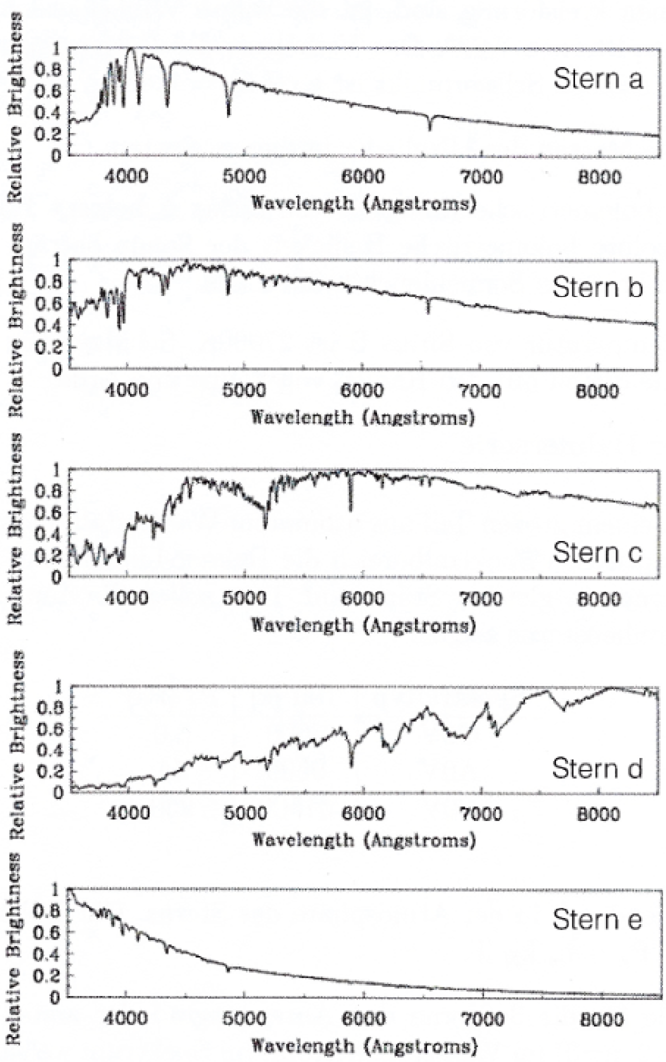


Figure 3: Stellar spectra in the optical wavelength regime for 5 different stars.