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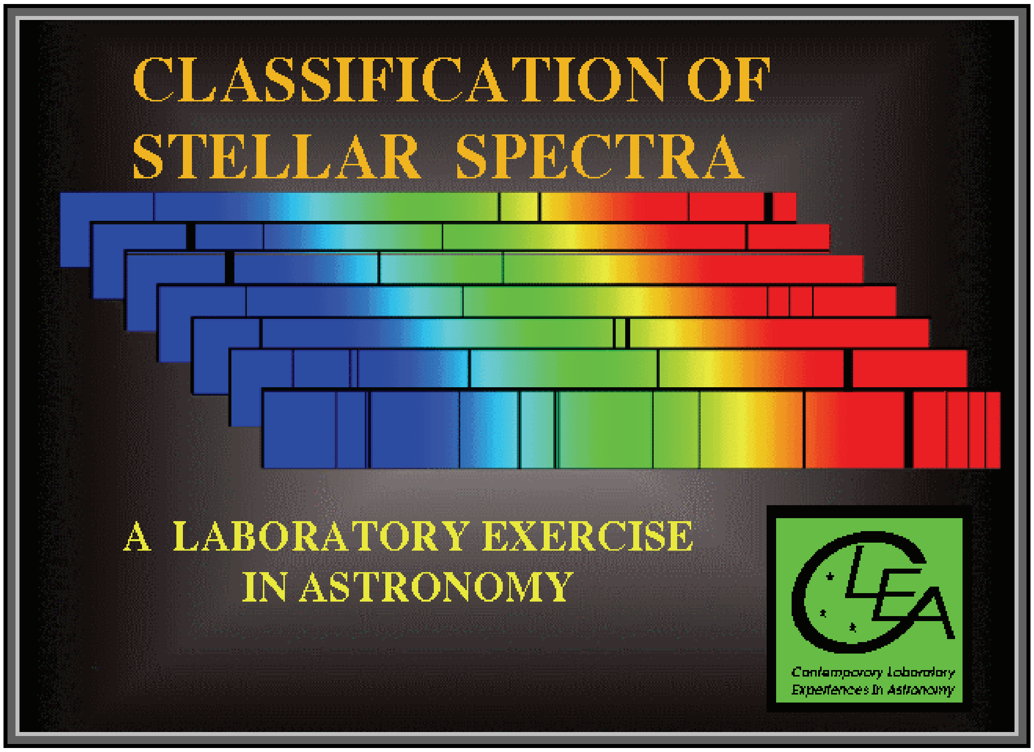
name

Stellar Spectra

(A CLEA Computer Exercise)



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You'll be using a virtual telescope on a computer to obtain your own telescope observations. You'll be taking spectra, analyzing them, and finally classifying them. The program outline and display details are relatively similar to the previous CLEA laboratory (same telescope console and control keys). The more commands you remember from the Photometry Lab the faster you will finish.

BUDGET YOUR TIME!

Each of Part I, II, and III should take you NO MORE THAN **HALF** AN HOUR.

You will need to work **solidly** or you will not finish this lab in time.

Preparation

Please come prepared to this Lab. Should you have missed doing the Pre-Lab, do it now and hand it in together with the rest of the Lab Report. Since there will not be enough time to do the Pre-Lab and the Lab you might have to complete your work at home. In that case copy your data onto a diskette (if you do not have one ask the instructor) and consult the Take-Home-Spectroscopy Lab for instructions of how to download the CLEA software onto you computer.

For reference here is one of the Figures from the Pre-Lab that will help you recognize and understand the spectra you will be seeing in this lab.

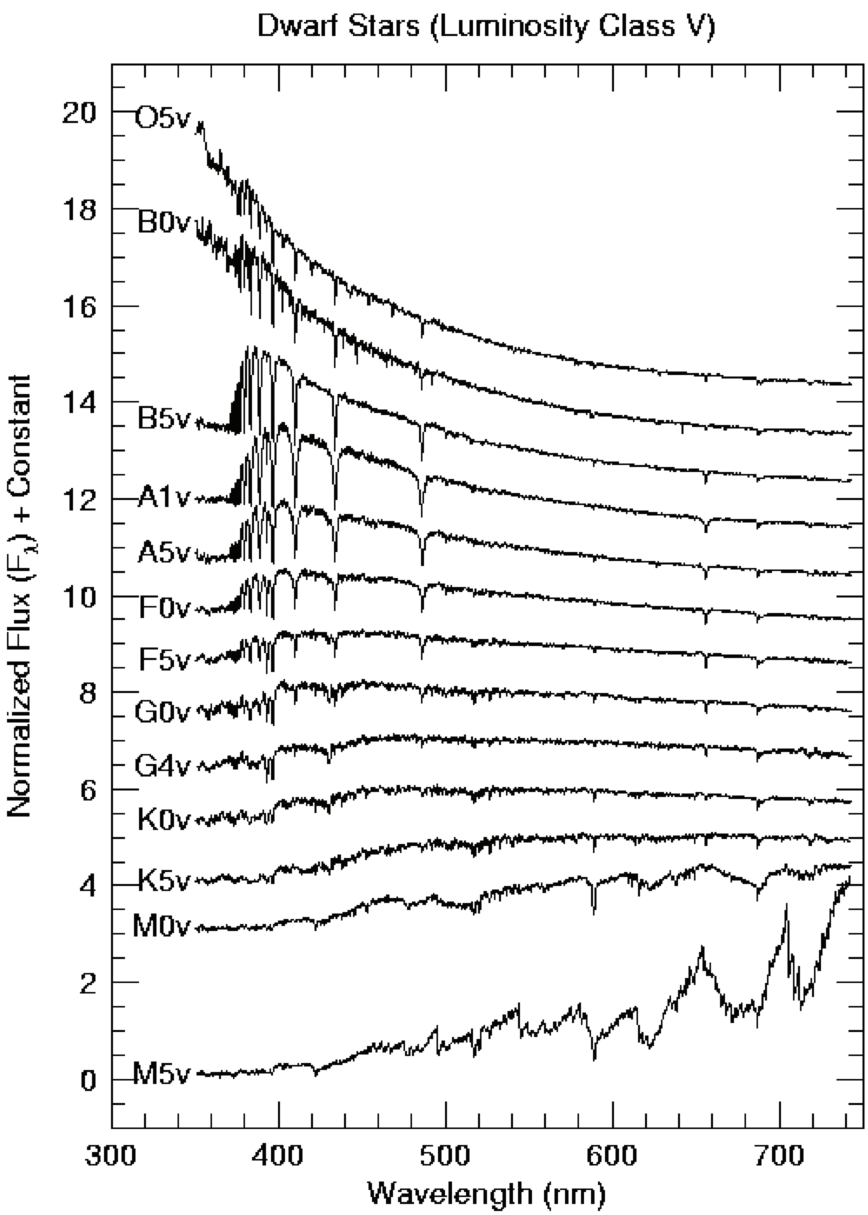

Image taken from http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit1/SpTypes/.

You will be asked in Part II to draw which part of the above spectrum you are analyzing in the lab. Use a RULER to draw two lines indicating the wavelength range of the spectra in the lab.

Part I — Obtaining Spectra using a Virtual Telescope

Budget your time – Part I should take you NO MORE THAN **HALF AN HOUR**.
If it takes longer you are either not working or doing something wrong.

1) Do the following

- Double click on Spectroscopy icon; log in. Click on **RUN** and select the **Take Spectra** choice.
- Go to the **Telescope** menu and click on **Request Time**. Select the **1m** or the **4m** telescope. If you get time, click on **Telescope** again and chose the **1m** or **4m** telescope. Repeat again later!!

  [In real life, large telescopes are highly oversubscribed. Therefore, if you were a professional astronomer, you would have to apply for time on a competitive basis. This is just to give you a feeling of what real astronomers have to deal with — this aspect has been included in the "Virtual Telescope" program. If you are "lucky," the program will grant you time, otherwise **re-apply** 15 minutes later. I know this is nasty — but who said these labs do not test your patience — and thank the producers of this program for not including "virtual clouds" in this program.]

- Click on **Dome** to open the dome. Turn on the tracking by clicking on **Tracking**. Click on the **Field** menu; select **Field 1**.
- Move the telescope with respect to the sky by using the directional controls, **N, E, S, W**. (The **SLEW RATE** moves telescope slew at different speeds).
- Click on **MONITOR** to switch between the **FINDER** and **INSTRUMENT** (the telescope). The red square tells you where your big telescope is pointing. Click again on **MONITOR.** In the **INSTRUMENT** mode you'll see the **CLOSE-UP** of the star field. The small slit will appear in the center of the field of view. Center the star within the slit.

  [All telescopes have a finder scope (the additional small telescope located at the side of big telescopes). The finder gives you a much larger field of view, so you can identify which part in the sky you are looking at.]

2) Obtain Spectra

- Pick a star; make sure the star is in the center of the slit. Click on **Take Reading**. A screen with a plot now appears. Click on **Start/Resume Count**. A Spectrum will then appear. For bright stars this will be relatively fast. Click on **Stop Count** when S/N is 100, or more. Repeat for two more stars. Write the <u>magnitude</u> into Table 1. Click on **Save**; insert saved file name into table 1.
- Repeat this for all stars in Table 1. [To type in RA and Dec of each star click on **Set Coordinates.]**
- **If you think this takes too long, cut the integration time by using a LARGER telescope.** With the 4m telescope this part can be done very rapidly, but the 1m is not that bad either.

Table 1: Taking Spectra

Star	Tel	RA	Dec	saved file name	Apparent Magnitude	Spectral Type	Luminosity Class	Absolute Magnitude	Distance Modulus	Distance
						--- Add this later ---				
1	0.4	Any star								
2		Any star								
3		Any star								
4		6 22 56	31 44 2							
5		6 7 44	34 43 58							
6		6 5 13	30 18 25							
7		6 21 54	31 33 7							
8		6 2 37	31 37 54							
9		6 11 25	31 54 7							
10		6 17 13	34 10 59							
11		6 18 34	34 54 54							
12		6 8 18	31 27 47							
13		6 22 3	31 21 6							
14		6 2 57	31 29 45							
15		6 23 42	32 14 21							

If you think this takes too long, cut the integration time by using a LARGER telescope.

Do NOT wait around – BUDGET HALF AN HOUR ON THIS PART – No more than that!

Part II — Classifying Stellar Spectra with CLEA Program

Budget your time – Part II should take you **NO MORE THAN HALF AN HOUR**.
If it takes longer you are either not working or doing something wrong.

1) Changing to the Classification Window

- Click on **Return** to go to the previous window; then **RUN** followed by **CLASSIFY SPECTRA**
- Click on **LOAD**, chose **UNKNOWN SPECTRUM**, and select **PROGRAM LIST**. From the list of stars highlight the first one, HD124320, and click OK. The spectrum of HD 124320 is then displayed in the center panel of the classification screen.
- Again, click **LOAD** but chose the **ATLAS OF STANDARD SPECTRA** option. In the newly opened window click on **MAIN SEQUENCE** followed by **OK**. Thirteen comparison spectra are now displayed in a separate window, but you can only see 4 at one time. You'll see all remaining spectra if you drag down the scrollbar.
- The classification screen shows three panels — the center panel displays the spectrum of an unknown star (in this case of HD124320), and the top and bottom panels show the spectra of standard stars. Initially O5 is in the top and B0 in the bottom panel — if you click **DOWN** in the **CLASSIFICATION WINDOW**, B0 will be put into the top and B6 into the bottom panel, another down will put B6 in the top and A0 into the bottom panel.
- Look at the spectra. The range in wavelength is ____
- Consult Figure 1. Take a pen and draw two vertical lines illustrating that range.
- Now compare the spectra in the main sequence spectra of the thirteen comparison stars (click on the scrollbar in the **main sequence window**) to the spectra in Figure 1. Comment on how the slope of the black body spectra in that wavelength range changes with spectral type.

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- For which of the stars does the black body spectrum peak in that wavelength range? ___________
- What is the average surface temperature of that star? _____________________________________
- Click on **CONFIGURATION**, chose **DISPLAY,** then **Gray Scale**. Look at the spectra. Decide of whether you want to use the gray-scale or the intensity trace spectra (to return to the intensity trace click **DISPLAY** then **Intensity Trace).** Explain your choice.

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2) Doing it: Classifying the Spectra

- In the **CLASSIFICATION WINDOW** press **DOWN** or **UP** buttons. This will put different standard stars into the top and bottom panel. Identify the spectral class of the star that most closely resembles the unknown star. For HD124320 this will be somewhere between A0 and A5.
- Click on the button labeled **DIFFERENCE** in the classification window. The bottom panel then shows the difference between the intensity of the comparison spectrum at the top and the unknown spectrum in the center. Page through the comparison spectra (using the **DOWN** or **UP** buttons) until this difference is minimized. You'll find that the difference spectrum between HD124320 and A0 is closer to a straight line than with A5. Thus HD124320 is an A2 star
- Click on **LOAD** and chose **SPECTRAL LINE TABLE**. This opens the **Spectral Line Identification** Window. You should now have three open windows. Move them around so that you see the **CLASSIFICATION WINDOW.**
- **DOUBLE CLICK** on any line in the **CLASSIFICATION WINDOW**. This causes a red vertical line to appear in the classification window, at the corresponding wavelength position. The measured wavelength is displayed in the bottom of the **CLASSIFICATION WINDOW** – and if the line is identified, two dashed red lines will frame the name and wavelength of that line in the **SPECTRAL LINE IDENTIFICATION WINDOW**. Identify some of the main spectral lines write this into Table 2 under "List Basic Spectral Features."
- Repeat those points for the remaining 10 stars in Table 2. Classify to the nearest 1/10 of a spectral type (*i.e.*, G2, not just G). Also identify the main spectral features. Once you have done two stars you'll find that you can do the rest of the stars relatively fast.

Table 2: Classifying the Spectra of Main Sequence Stars

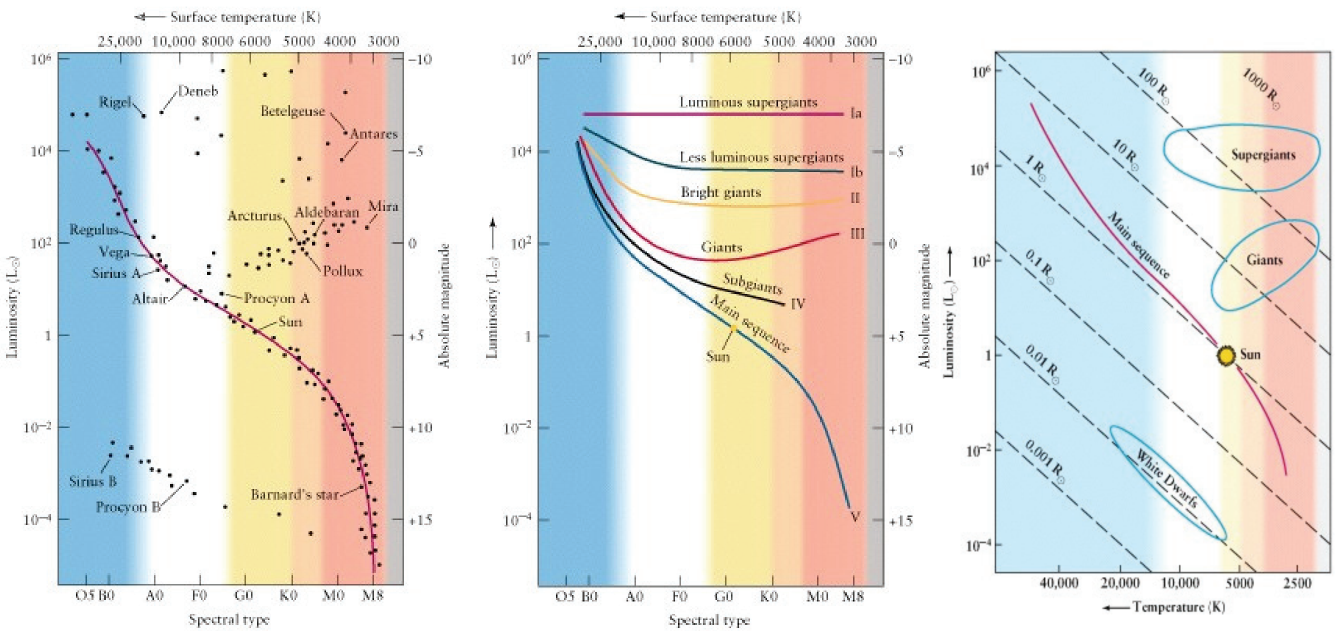
	Name	Spectral Type	List Basic Spectral Features	Absolute Magnitude (add later)
	HD124320	A2	Strong Balmer Lines: H_δ, H_ε	
1	HD 24189			
2	HD 240344			
3	BD+63 137			
4	HD 66171			
5	HD 35215			
6	Feige 41			
7	HD 242935			
8	HD 5351			
9	SAO 81292			
10	HD 27685			

Part III —Spectra of Stars from Table 1

Budget your time – Part III should take you **NO MORE THAN HALF AN HOUR.**
If it takes longer you are either not working or doing something wrong.

- Click on **LOAD,** chose **Unknown Spectrum**, then select **Saved Spectra**. From the list of stars highlight the first one (these are the spectra you took in **Part I),** and click **OK**. Classify that star. Write the **spectral types** into Table 1.

- If you look at an Hertzsprung-Russell diagram you will notice that especially the red stars many have very different luminosities. For example, as seen below, the M0 star could be on the main sequence, or it could be a giant or even a supergiant star.



These three images are taken from the book "Universe" by Freedman and Kaufmann

How much more luminous is the M0 supergiant than the M0 main sequence star? ____________

How much bigger is the M0 supergiant than the M0 main sequence star? __________________

- Click on **LOAD** and then on **Atlas of Standard Spectra** option. In the newly opened window do not click on **Main Sequence**, rather, click on **Spectral Type** and load the luminosity class that is *closest* to the best spectral type. Luminosity classes of that spectral type are being loaded into the comparison spectra windows. Repeat the same procedure as before, but differentiate between the Luminosity classes. Write the **luminosity class** into Table 1. Repeat for all stars.

Which of the stars in Table 1 are super giants? (List their star numbers) __________________

Which of the stars in Table 1 are giants? ____

Which of the stars are main sequence stars? ______________________________________

Part IV — Absolute Magnitudes and Distances

Can be done at Home

1) Absolute Magnitudes

Determine the **absolute** magnitudes for stars in Table 1 and Table 2. Use Appendix 2; differentiate between dwarfs, giants, and super giants. You may need to interpolate (approximate values are fine). Write answers into Tables 1 and 2.

2) Distances

From the "distance modulus" [the difference between apparent and absolute magnitude] calculate the distance. Write into Table 1. You already did this in the photometry lab. Write into Table 1.

The distance in parsecs is: $d = 10^{\left(\frac{m_V - M_V + 5}{5}\right)}$ (this means ten to the power of $\frac{m_V - M_V + 5}{5}$)

Explain in words why the difference between apparent and absolute magnitude gives a distance.

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3) Questions

Are those stars within our Galaxy? Explain. [Hint: How big is our Galaxy?]

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Are all stars in the same cluster? Explain.

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If your luminosity class is wrong, how would this affect the distance determination?

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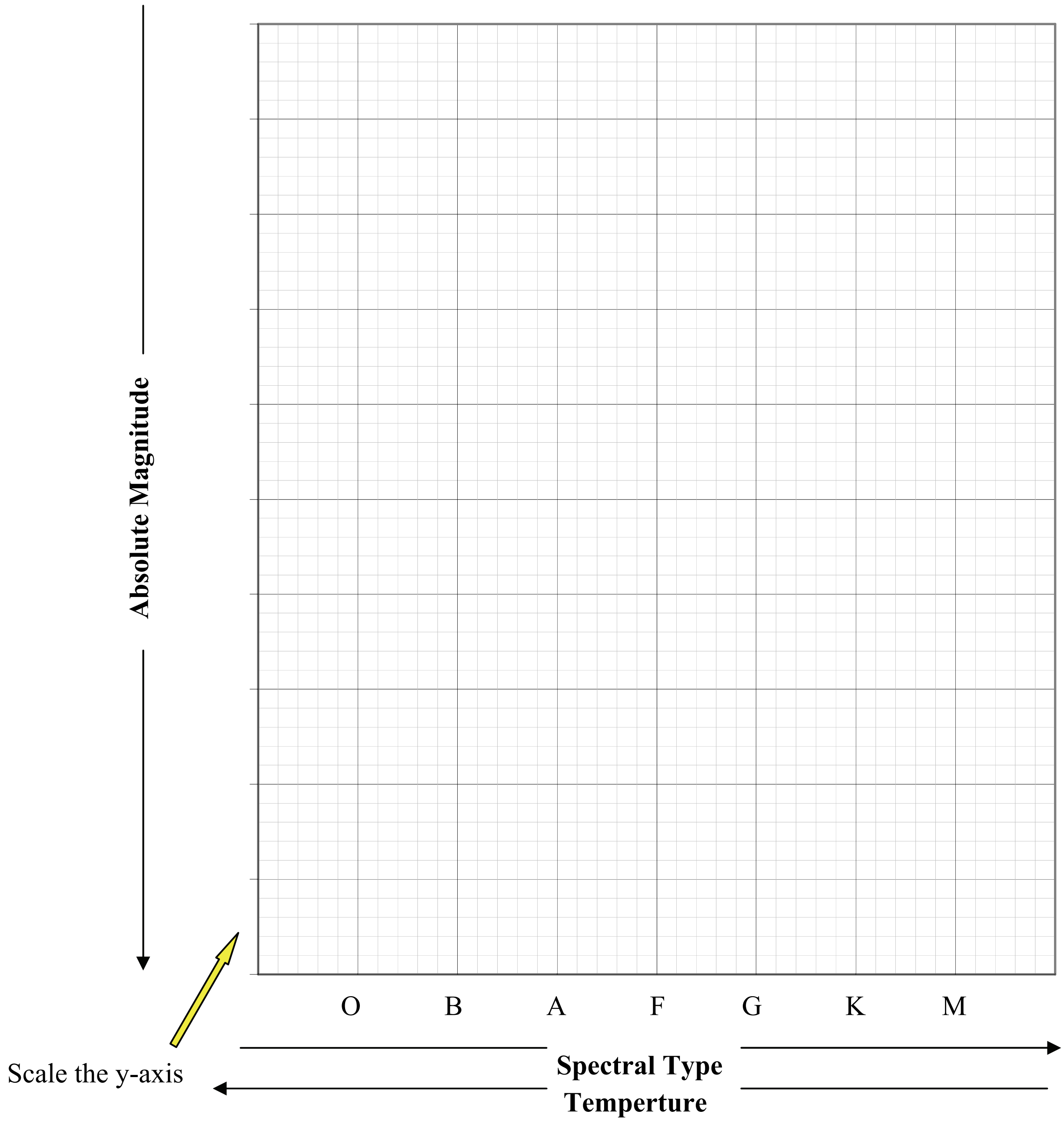
4) Plot the data from Table 1 AND Table 2.

The Herzsprung Russel Diagram



a) Draw the data from **Table 1** **AND** **Table 2** into the above plot.
b) **Highlight** the main sequence, giants and supergiants.
c) **Circle** all stars that are **not** main sequence stars, giants or supergiants.
d) What are those circled stars? Is there something strange going on?

Appendix 1 — Luminosity, Temperature & Radii of Main Sequence Stars

Spectral Type	M_V	B-V	T [K]	R/Rs	L/Ls	M/Ms
O5	-5.8	-0.32	40000	17.8	501000	40
B0	-4.1	-0.30	28000	7.4	20000	18
B5	-1.1	-0.16	15000	3.8	790	6.4
A0	+0.7	+0.00	9900	2.5	79	3.2
A5	+2.0	+0.15	8500	1.7	20	2.1
F0	+2.6	+0.30	7400	1.4	6.3	1.7
F5	+3.4	+0.45	6600	1.2	2.5	1.3
G0	+4.4	+0.60	6000	1.04	1.3	1.1
G5	+5.1	+0.65	5500	0.93	0.8	0.9
K0	+5.9	+0.81	4900	0.85	0.4	0.8
K5	+7.3	+1.18	4100	0.74	0.2	0.7
M0	+9.0	+1.39	3500	0.63	0.1	0.5
M5	+11.8	+1.69	3000	0.32	0.01	0.2
M8	+16.0	+2.00	2400	0.14	0.001	0.1

Appendix 2 — Magnitudes of Different Luminosity Classes

Luminosity Class → → →			Main Sequence V	Giants III	Supergiant s I
Spectral Type	B-V	T [K]	M_V		
O5	-0.32	40000	-5.8		
B0	-0.30	28000	-4.1		-6.4
B5	-0.16	15000	-1.1		
A0	+0.00	9900	+0.7		-6.2
A5	+0.15	8500	+2.0		
F0	+0.30	7400	+2.6		-6
F5	+0.45	6600	+3.4		
G0	+0.60	6000	+4.4	+1.1	-6
G5	+0.65	5500	+5.1	+0.7	-6
K0	+0.81	4900	+5.9	+0.5	-5
K5	+1.18	4100	+7.3	-0.2	-5
M0	+1.39	3500	+9.0	-0.4	-5
M5	+1.69	3000	+11.8	-0.8	
M8	+2.00	2400	+16.0		

Lab Report

For Extra Credit do the Spectral-Classification-Extra-Credit-Lab

Objective of the Lab.

Summarize the main parts of this lab

What did you learn about how astronomers do real research?

Critically comment on the usefulness of Stellar Spectral Classification. What information (list stellar properties) do we obtain about stars when analyzing their spectra? What information do we NOT obtain from stellar spectra?

The x-scale of the HRD can be determined via photometry and via spectroscopy. Under which conditions would you prefer which method? [Hint: First list the advantages and disadvantages of each method, then give at least one example of when you'd prefer each of spectroscopy and photometry.]