

Name: _____

Classification of Stellar Spectra

Introduction

In this activity you will learn about spectral types of stars. You will use spectra to find the peak wavelength, color, and temperature of real stars. You will also build a Hertzsprung-Russell Diagram.

Objectives

After completing this activity students will be able to:

- Use computer software (CLEA/VIREO) to display a stellar spectrum and identify the peak wavelength of the spectrum.
- Describe how the peak wavelength of a stellar spectrum is related to color of the star.
- Describe how the peak wavelength of a stellar spectrum is related to the temperature of the star.
- Describe the relationship between luminosity and temperature.
- Construct a H-R Diagram using Microsoft Excel and describe how temperature and luminosity are related to spectral type.

Definitions

Here are some helpful reminders of terms/symbols from lecture that we will be using today:

- λ – Greek letter lambda. Used as the symbol for wavelength.
- Å – Angstrom. A measurement of wavelength. Note – $1 \text{ Å} = 1 \times 10^{-10}$ meters.

Directions

How to Begin:

1. Double click on the “Vireo” icon on the start screen:
 - Go to File... Login and enter your names. You don't need to enter a table number.
 - Go to File... Run Exercise... Classification of Stellar Spectra
 - Go to Tools... Spectral Classification...
 - Go to File...Display...Comb. (Phot + Trace)
2. Load the first unknown spectrum which you will identify:
 - Go to File... Unknown Spectra... Program List...
 - Select “HD 27685” from the Program List
3. Change the wavelength (λ) range:
 - Go to File... Display... Spectral Range
 - Change minimum value to 3600Å and maximum value to 7400Å

4. Open an Excel spreadsheet to record values and to do calculations.

- Your spreadsheet should have the following columns:

	A	B	C	D
1	Star Name	Peak Wavelength	Temperature	Luminosity

PART A: Peak Wavelengths

After following the “How to Begin” instructions, have a look at your first spectrum. In the middle panel you will see a photograph of the spectrum that should look familiar from class. In the bottom panel you will see a trace or spectral line profile. Draw a sketch of what the line profile looks like:

- Record what you notice about the shape (ex. Is it a line or a curve? Does it have peaks? If so, how many?). Are there any other features you see in the spectrum?

After making notes on the shape of the first spectrum, it is time to record the peak wavelength. To measure the peak wavelength:

- Point the cursor at the peak and clicking the left mouse button.
- At the bottom of the window displayed, two numbers will be listed, “Cursor@: ____” and “Intensity: ____”. These are the measurements of the wavelength and relative intensity at the location selected by the cursor.
- The “Cursor@: ____” value is the peak wavelength. This is the value you will record in Table 1.

Record your peak wavelength for HD 27685. Then, using Step 2 from the “How to Begin” instructions, load and record the peak wavelengths for your remaining stars.

Table 1.

Star	Peak Wavelength (Å)
HD 27685	
HZ 948	
HD 5351	
HD 23511	
HD 66171	
BD +63 137	

Don't forget to record your values from Table 1 into your Excel spreadsheet.

- From Question 1 should have noticed there are “dips” in the curves. Thinking about the types of spectra you have learned about in class (continuous, emission, absorption), and looking at the photographed spectrum, what is the cause these features?
- Using a star of your choosing, explore the spectrum. Go to File...Spectral Line Table. Click on the deepest “dips” and record the element causing these features at different wavelengths in Table 2.

Star: _____

Table 2.

Wavelength (Å)	Element

PART B: Stellar Color

In class you have learned that wavelength, energy, and temperature are determining factors in what type of electromagnetic (EM) radiation is emitted from an object. The human body has a temperature of 98.6°. This means our bodies emit radiation in the infrared. However, our eyes are only able to see in the visible range of the EM spectrum, which is why we need night vision goggles to see the radiation we emit. The visible portion of the EM spectrum covers a measly 3000 Å out of the 1,000,000,000 Å range of the entire spectrum (gamma rays have wavelengths as short as ~0.1 Å and radio waves can be as long as a billion Å)! But that doesn't mean we still can't see noticeable differences in the world around us!

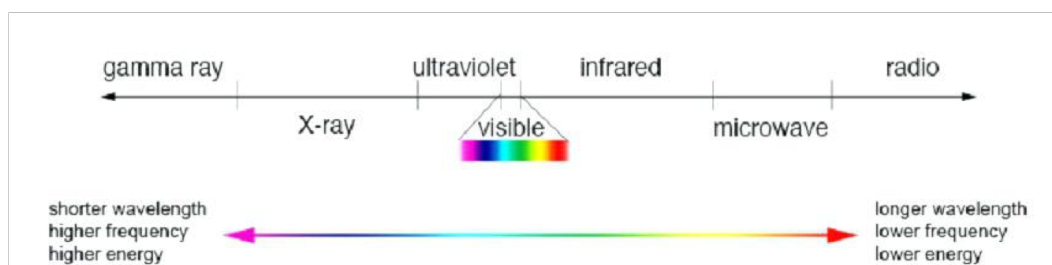
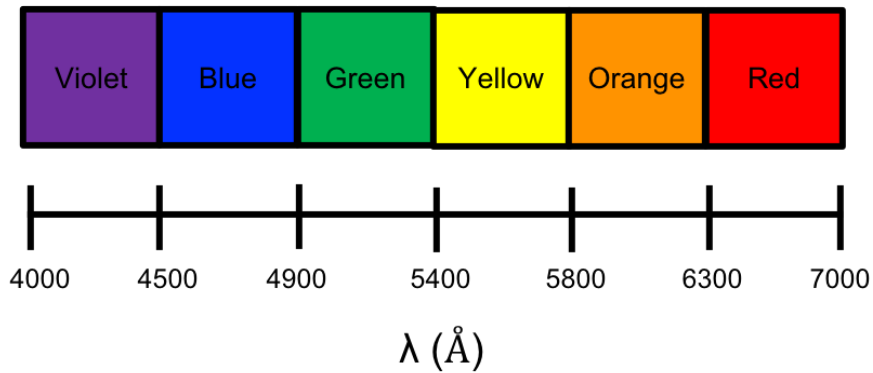


Image: <http://www.original-fish.com/>

Looking at the visible portion of the electromagnetic spectrum, we see that different colors are associated with the following wavelengths:



We established in Part A that different stars have different peak wavelengths. Since we know visible light depends on wavelength, we can assume these peak wavelengths cause stars to have different colors. The Sun is yellow. The stars Rigel and Betelgeuse in the constellation Orion are blue and red, respectively. Using the peak wavelengths from Table 1, determine the colors of your stars.

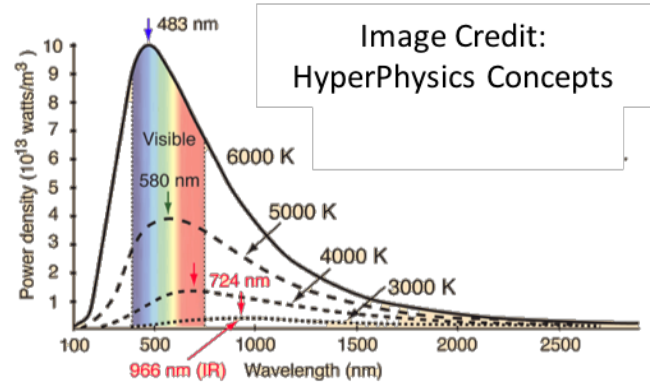
Table 3.

Star	Color
HD 27685	
HZ 948	
HD 5351	
HD 23511	
HD 66171	
BD +63 137	

1. How are wavelength and color related (ex. the shorter the wavelength the “_____” the color)?
2. The Sun looks yellowish-white to our eyes. However, its peak wavelength is $\sim 5000 \text{ \AA}$, which corresponds to what color?
3. So, if the Sun peaks at $\sim 5000 \text{ \AA}$, why does it appear yellowish-white in the sky? (Hint. Think back to elementary school art class and color mixing...)

PART C: Wien's Law

A blackbody is a perfect absorber and emitter of electromagnetic radiation. Blackbody radiation has a very distinct peaked and smooth curve. While stellar spectra are not perfectly smooth, they can be approximated as blackbodies. Using Wien's law, the peak wavelength of this curve can be used to calculate temperature. Using Equation 1, you will calculate the temperatures for each of your stars.



$$\lambda_{\text{peak}} = \frac{2.9 \times 10^7}{T} \quad (1)$$

Using basic algebra, we can rearrange Equation 1 to solve for temperature:

$$T = \frac{2.9 \times 10^7}{\lambda_{\text{peak}}} \quad (2)$$

It is now time to get temperatures. In your Excel worksheet, use the peak wavelengths and Equation 2 to calculate the temperatures of each of your stars.

Table 4.

Star	Temperature
HD 27685	
HZ 948	
HD 5351	
HD 23511	
HD 66171	
BD +63 137	

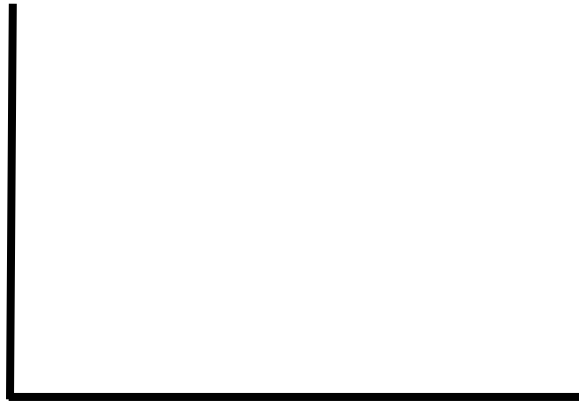
Don't forget to record your temperature values from Excel spreadsheet into this table

1. How are peak wavelength and temperature related?

PART D: Build H-R Diagram

As discussed in your lecture, the Hertzsprung-Russell diagram is very useful for showing the relationship between the luminosity and temperature of stars on the Main Sequence. It is also useful for seeing how luminosity and temperature change as the star ends its time as a Main Sequence star and goes off to do other things, like be a Red Giant or White Dwarf.

1. Draw a H-R diagram. Label the following things: Luminosity, temperature, Main Sequence, Red Giants, White Dwarfs. (Hint – make sure your axes are going the correct direction!) Have TA verify your work before moving forward.



TA's okay! _____

In addition to luminosity being related to temperature, it is also related to spectral type. In 1901, Annie Jump Cannon created the "OBAFGKM" spectral sequence, where O-type stars are the hottest and M-type stars are the coolest. The spectral types have the following temperature ranges: **O**: >30,000 K, **B**: 10,000 - 30,000 K, **A**: 7,500 - 10,000 K, **F**: 6,000 - 7,500 K, **G**: 5,200 - 6,000 K, **K**: 3,700 - 5,200K, **M**: < 3,700 K.

In order to make your H-R diagram, you need to calculate the luminosity of your stars. The luminosity of a blackbody can be calculated using the Stefan-Boltzmann equation where L is luminosity, A is area, and T is temperature:

$$L = 5.67 \times 10^{-8} * 4\pi R^2 * T^4 \quad (3)$$

Where $4\pi R^2$ is the area of the star (R=radius) and T is the temperature. However, since we do not know the area of our stars, we will simplify the equation:

$$L \propto T^4 \quad (4)$$

With this information and your previous calculations, you are now ready to make your own H-R diagram and determine the spectral type of your stars.

The wavelength range of the program we are using does not go far enough into the ultraviolet to include O, B, and A-type stars. Additionally, it does not go far enough into the infrared to include M-type stars. Add the following stars to your Excel worksheet and calculate their temperatures.

Star	Peak Wavelength (Å)
Rigel	2395
Mu Columbae	880
Proxima Centauri	9533
Alnilam	1055
HD 21389	2980

In your Excel spreadsheet, use your calculated temperatures and Equation 4 to approximate the luminosity of each of your stars. After completing your calculation, you will have a column with luminosity values and a column with temperature values. Use Excel's graphing abilities to plot these two columns to make your H-R diagram. **Select the luminosity and temperature columns → Click on 'Insert' tab → Click on 'Recommended Charts' and select 'Scatter'.**

You may notice that your plot looks a bit...funny. Some advice on how to fix that:

- Click on your plot and then click on 'Chart Design' Tab (upper left).
- Need to label axes. Click on 'Add Chart Element'. Select 'Axis Titles'. Select both 'Primary Horizontal' and 'Primary Vertical'. This will create textboxes next to each axis. Label them appropriately.
- Click on the y-axis of your plot. Click on 'Add Chart Element'. Select 'Axes' and then 'More Axis Options'. A menu will show up on the right-hand side of the spreadsheet. Click on the picture of three bars and then expand the 'Axis Options' menu. Look at your Luminosity values and change the minimum and maximum bounds to match the luminosity range. At the bottom of the Axis Options menu there is a box labeled 'Logarithmic Scale'. Click it.
- Click on the x-axis of your plot. The 'Axis Options' menu will still be open. Look at your temperature values and change the minimum and maximum values to match your calculations. Remember the temperature axis is backwards, so click the 'Values in Reverse Order' to fix this.

After your diagram is complete, show it to your TA before moving on.

TA's okay! _____

- Each star in your list belongs to one of the “OBAFGKM” spectral types. Looking at your H-R diagram, fill in the spectral type for each of your stars in Table 5.

Note. We found the peak wavelengths by eye which causes error. You may find stars that are just above the temperature boundary of a spectral class. If the difference is less than 200K, put it in the spectral class below – ex. If $T=7700$: classify as F-type even though it just crosses over into A-type.

Table 5.

Star	Spectral Type
HD 27685	
HZ 948	
HD 5351	
HD 23511	
HD 66171	
BD +63 137	
Rigel	
Mu Columbae	
Proxima Centauri	
Alnilam	
HD 21389	

PART E: Final Thoughts

- Say two G-type stars have the same temperature but different luminosities, what is a physical reason that could cause this to occur? (Hint – Look at Equation 3)
- Looking at your hand-drawn H-R diagram, what happens to the temperature of a star as it moves from the Main Sequence to the Red Giant phase?