Name ________________________ **Section**_________________

Partner(s)_____________________ **Date**_________________

TWINKLE, TWINKLE LITTLE STAR
HOW ASTRONOMERS KNOW WHAT YOU ARE

Since journeys to the stars are not possible at this time, astronomers use every source of information available to them to learn about our neighbors in the galaxy and beyond. This activity will introduce you to a very important technique - spectroscopy - and how it is used by astronomers.

Activity 1: Shedding Some Light on Spectroscopy

How do you suppose astronomers know what stars and the atmospheres of distant planets are made of?

View the white lights in the room with the diffraction glasses. What do you see?

BE CAREFUL OF THE EQUIPMENT. THE BULBS ARE VERY FRAGILE AND HIGH VOLTAGE IS MAINTAINED BY THE POWER SUPPLY.

The instrument you will be using is called a **spectroscope**. You look in the end without the screw. The screw controls the size of the slit that light will pass through. It should not be adjusted without instructions.

1. Turn on the power supply containing the hydrogen tube. Make sure the spectroscope is about 2-3 inches away from the tube. Look through the spectroscope and move the spectroscope left and right until the light in the center slit is very bright. You should be able to see a pattern of colored lines to the right and left of the bright center slit.

   Record the colors as you see them. Use colored pencils to draw the pattern in the chart below.

2. Turn off the power and carefully remove the hydrogen tube using the piece of sponge provided. The tube is spring loaded and you can remove it by grasping it and gently forcing the tube down until it clears one end of the apparatus and then pulling the tube out. Place the tube containing helium into the power supply. Turn the power on and record the line spectrum for helium.

3. Repeat the procedure in step 2 using the tubes containing mercury, neon, and nitrogen.

ELEMENT	LINE SPECTRUM
HYDROGEN	
HELIUM	
MERCURY	
NEON	
NITROGEN	

What did you notice that was the same about all samples?

What did you notice that was unique about each element?

As all matter, stars are composed of **atoms**. When an atom is excited by heat or electricity its electrons become excited and orbit the nucleus at a higher energy level (further away from the nucleus). The electrons will subsequently lose the energy and fall back to their original levels. The light energy released (due to the electron losing energy) is given off in a distinctive colored pattern called a **spectrum (pl. spectra)**. Each different atom or element has its own unique spectrum which can act like a fingerprint. Molecules also have spectra but because molecules are more complex, their patterns are often bands (like nitrogen) rather than thin lines.

Now for a Little Mystery!

4. Try to figure out what is in Tube X and Z . Repeat the procedure you did before using the tubes containing Elements X and Z. These tubes contain two of the five elements you tested previously.

ELEMENT X	
ELEMENT Z	

What is Element X?

Explain why you decided this.

What is Element Z?

Explain why you decided this.

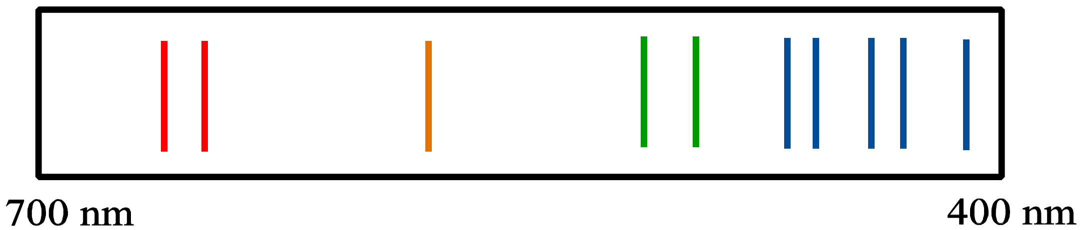
When an astronomer attaches a spectroscope to a telescope, he or she can record the spectrum of a star. The spectra of stars provide one basis for classifying stars. Stars have colors which you can notice if you let your eyes acclimate at night (red, orange, yellow, white, and blue). The major lines in a star's spectrum dictates the color. Stars of similar color share other characteristics that astronomers can use to predict the fate of stars.

The process in this exploration is the same one involved in flame tests for identifying chemical elements in solutions. The distinctive color or spectrum that results when an element is put in a flame can be used to identify that element. The colors you see in fireworks or sparklers are generated in the same manner. Neon signs or lights are another example. The colors in the signs can be changed by adding other gases.

Sun of a...?

Let's see if you can identify the major elements that occur in the Sun from a spectrum.

1. On the strip below is an *over-simplified* spectrum of the Sun. Your instructor will place a version on the overhead in color. Refer to the spectra you recorded for the five elements. Match the lines by color and position and identify the elements in the Sun.



According to the spectrum the Sun contains ____________ and _______________.

2. Explain how you made the choices.

One of the two major elements, helium, was first discovered from unidentified lines in the solar spectrum before it was isolated on Earth. In fact the name helium comes from name Helios, ancient god of the Sun. The actual solar spectrum is much more complicated than the one shown above.

Activity 2: **the Spectra of Stars**

You have had a chance to see how astronomers gather data about the composition of stars. Unfortunately, the spectra of stars is much more complicated than the spectra of individual elements. Stars can contain as many as 92 elements, each with characteristic spectral lines. Some of the elements also form ions, which have different characteristic spectral lines depending the ion's charge from their element. In addition, the temperature of a star will make the lines of some elements more prominent. Temperature also influences what ions are present too. However, all is not lost! Astronomers can still sort out which elements are present.

The overall appearance of a star's spectrum can give us more than just a star's composition. The spectrum can indicate the surface temperature of the star, and how far away the star is (along with magnitude data). Stars are classified by their overall spectra into classes, O-B-A-F-G-K-M. Their classes corresponds to their color and temperature.

Spectral Class	Color	Some Characteristic Features found in the Spectra	Typical Temperature Range (Kelvin)
O	blue	He^+, weak H	greater than 25,000
B	bluish-white	He, strong H	11,000 - 25,000
A	white	very strong H	7500 - 11,000
F	yellowish-white	moderate H, metals- moderate Ca^+	6000 - 7500
G	yellow	strong Ca^+, weak H	5000 - 6000
K	orange	metals strong and CH, CN appear	3500 - 5000
M	red	Na, molecules strong especially TiO	less than 3500

Astronomers have found that stars may have similar characteristic lines but have more subtle differences in their spectra. The stellar classification scheme accounts for these by dividing each class into ten categories. A number from 0 to 9 is added to the letter (A0, A1, A2,..., A9). The hottest star for each letter is the zero; the coolest is the 9.

What color are the coolest stars?

What color are the hottest stars?

Our Sun is a yellow star with a surface temperature of about 5800K. What spectral class do you think our Sun falls into? It the hot or the cool end of the class? Why?

Classifying a Star...or Stars Really Have Class!

Astronomers classify a star by comparing its spectrum to a set of standards. You will use computer-generated spectra to classify stars today.

1. Obtain a set of standard spectra (2 sheets - 4 pages) and a set of 8 unknowns (brown envelope). Compare each unknown with the standard spectra and determine its classification (for example: A5, F8, K3). You have to be careful. Some spectra will be between two standards. In this case you must estimate what its number should be.

2. Record the unknown star number and your classification in the data table provided.

Determining a Star's Distance From Earth (When a Ruler Just Won't Do)

Once you have the spectral class of a star you are on your way to determining how far away it is from the Earth. There a few variables we need to deal with first.

As a distant car approaches you at night, what do you notice about the headlights?

Why do you think this happens?

Astronomers have discovered that stars in the same spectral class are similar in brightness, or **magnitude**. Unfortunately stars are at varying distances from us and this changes how bright they appear to us, just as car headlights vary in brightness depending on how close they are. To handle this problem, astronomers have defined two properties for stars.

The first property is **absolute magnitude (M)** which is how bright a star would appear if it was at a fixed distance away from the Earth[1]. *This is a calculated value and removes distance as a concern when we compare stars.* The only thing that affects absolute magnitude is the natural intensity of the star. Some stars are "low beam" while others are "high beam". More importantly, it turns out that most stars in the same spectral class have the same absolute magnitude! That means that we can determine the absolute magnitude of any star as long as we have the spectral class and a graph relating the two. The graph is called the H-R diagram (for Hertzsprung and Russell who discovered it) and is shown in FIGURE 1.

The second property is **apparent magnitude (m)**. Apparent magnitude is how bright a star actually appears from Earth and *it does depend on distance.* Because of the way the magnitude scale is set up, the brightest stars will have large negative magnitude values while dim stars will have large positive values. The closer a star is, the more negative its apparent magnitude will be. Examples of the absolute and apparent magnitudes of some common celestial objects are shown in the table below.

---

[1]Distance used by astronomers is 3.1×10^{14} km or 10 parsecs (1 parsec = 3.1×10^{13} km; the abbreviation for parsec is pc)

Object	Apparent Magnitude (m)	Absolute Magnitude (M)	Distance from Earth	Spectral Class
Sun	-26.8	+4.8	1 AU*	G2
Full Moon	-12.7	itty bitty	2.6×10^{-3} AU	--
Venus (at brightest)	-4.6	itty bitty	0.27 AU	--
Mars and Jupiter	-2.5	itty bitty	0.5 and 4.2 AU	--
Sirius A (brightest star, other than Sun)	-1.5	+1.4	2.6 pc	A1
Rigel (in Orion)	+ 0.1	-6.6	237 pc	B8
Deneb (in Cygnus)	+ 1.3	-6.9	991 pc	A2
Polaris (in Ursa Minor)	+ 2.1-+8.8 (variable star)	-4.4	132 pc	F8
faintest stars observable with naked eye	+ 5-6			

Suppose a star has an apparent magnitude of +1.4. What would happen to its apparent magnitude if the star could be moved closer to Earth? farther away?

What would happen to a star's absolute magnitude if it was moved closer or further away from Earth?

Now, how does all this magnitude business help us to determine a star's distance? Remember that apparent magnitude depends on distance but absolute magnitude does not. The difference between apparent and absolute magnitude, called the **distance modulus** (m-M), can be directly related to the distance of the star from Earth. This relationship is shown in the graph in FIGURE 2[2].

Going the Distance...

1. Use FIGURE 1 to determine the absolute magnitude (M) of each of your unknowns. Record the M values in the data table.

2. Find the apparent magnitude (m) for each of your unknown stars from the data table below.

Unknown	m	Unknown	m	Unknown	m
1	9.19	11	14.42	21	9.10
2	14.11	12	9.00	22	9.34
3	8.44	13	12.85	23	14.73
4	9.88	14	9.60	24	9.13
5	12.61	15	13.18	25	13.95
6	9.27	16	8.17	26	12.33
7	13.61	17	11.37	27	11.00
8	7.80	18	8.76	28	13.35
9	10.45	19	11.66	29	9.43
10	11.96	20	10.22	30	10.70

3. Determine the distance modulus for each star by subtracting the absolute magnitude from the apparent magnitude {m-M} and record the value in the data table.

4. Use FIGURE 2 to determine how far away each star is based on its distance modulus (m-M value). The distance is measured in parsecs (pc).

[2]The equation used to generate FIGURE 2 is: $m-M = 5 \log d - 5$, where d is the distance in parsecs.

DATA TABLE

Unknown #	Spectral Class	Absolute Magnitude (M)	Apparent Magnitude (m)	Distance Modulus (m-M)	Distance in Parsecs

Are all your stars close or far apart (consider astronomical distances)? Explain.

Compare your results to another group in the class.

Figure1 - Absolute Magnitude against Stellar Spectral Class

Figure 2 - Distance Modulus against Distance in parsecs