

**SIERRA COLLEGE OBSERVATIONAL ASTRONOMY  
LABORATORY EXERCISE**

**Lab N11: The Hertzsprung-Russell Diagram**

**NAME**

**GROUP**

**OBJECTIVE:**

- Learn about the HR diagram.
- Learn about B-V colors.
- Learn how to apply the distance modulus.

**INTRODUCTION:**

In Lab N03, we learned about how bright stars look in the sky, which is called the visual or *apparent magnitude* ( $m$ ). A star's *absolute magnitude* ( $M$ ) is different—it is a measure of how powerful a star is, and specifically indicates how bright a star would look to us if it were at a distance of 10 parsecs. (A *parsec* is a unit of distance equal to 3.26 light years.) The *distance modulus* is the difference between an object's apparent magnitude and absolute magnitude ( $=m-M$ ).

**Thinking about the distance modulus**

Suppose a star had a distance modulus of zero. That means its apparent magnitude is the same as how bright it would look if it were at 10 pc. Therefore, the star must be at 10 pc from us. Stars that are farther than 10 pc have fainter apparent magnitudes (and fainter apparent magnitudes are larger numbers). Therefore their distance modulus would be larger than zero. A star closer than 10 pc would have a negative distance modulus.

A star's apparent magnitude ( $m$ ), absolute magnitude ( $M$ ), and distance ( $d$ , in parsecs) are related by Equation 1:

**Equation 1**

$$d = 10 \times 10^{(m-M)/5}$$

When measuring the brightness of a star, astronomers will insert a filter into the telescope to select a specific *wavelength band* to be included in the measurement. So instead of simply measuring the star's magnitude, the astronomer may measure the magnitude in the blue wavelength range ( $m_B$ ), red wavelength range ( $m_R$ ), or at the center of the visual range ( $m_V$ ).

Once the magnitudes have been measured at different bands, the *color index* of a star can be measured by simply subtracting one magnitude from another. We will be using the B-V color index (i.e.,  $m_B - m_V$ ).

The B-V color index is a way of measuring color. Very hot (blue) stars have a negative B-V color, while cool (red) stars have a positive B-V color. Astronomers have assigned seven *spectral classes*—OBAFGKM—to stars, ranging from hot stars to cold stars.

Each spectral class is divided into subclasses, ranging from zero to nine—zero indicating warmest, nine indicating coolest. For examples, a G3 star is warmer than a G8 star; an F0 star is hotter than a F2 star, and a K9 star is warmer than an M3 star. See the summary about spectral classes in Table A.

**Table A: Stellar colors**

Spectral Class	B-V	Temperature	Color
O5	-0.35	> 30,000 K	Blue
B0	-0.31	10,000-30,000 K	Blue
B5	-0.16		
A0	0.00	7500-10,000 K	Blue-White
A5	0.13		
F0	0.27	6000-7500 K	White
F5	0.42		
G0	0.58	5200-6000 K	Yellow
G5	0.70		
K0	0.89	3700-5200 K	Orange
K5	1.18		
M0	1.45	2400-3700 K	Red
M5	1.63		

Stars also fall into different *luminosity classes*—broad categories describing their power outputs.

**Table B: Luminosity classes**

Ia-b	Supergiants
II	Bright giants
III	Giants
IV	Subgiants
V	Main sequence (dwarfs)
VI	Subdwarfs
VII	White dwarfs (not always used)

Combining a star's spectral class and its luminosity class results in a star's *spectral type*, such as B7II, or G2V.

*Hertzsprung-Russell (HR) diagrams* are plots of B-V color index (or spectral type or temperature) on the horizontal axis, and the power output (often expressed in absolute magnitudes) on the vertical axis. HR diagrams are of critical value in stellar astronomy. Through these diagrams, we can understand the nature of stars—their births, lives, and deaths.

**PROCEDURE I: Assembling an HR diagram**

<b>Table C: Main sequence star photometric data</b>						
Star #	B-V	$M_v$		Star #	B-V	$M_v$
#1	0.16	1.8		#21	-0.27	-2.7
#2	0.99	6.5		#22	1.68	11.0
#3	0.26	2.8		#23	1.55	9.6
#4	1.32	7.8		#24	1.24	7.8
#5	0.41	3.4		#25	1.38	8.2
#6	1.42	8.6		#26	1.54	10.3
#7	0.78	5.5		#27	-0.15	-0.8
#8	1.60	11.3		#28	1.49	9.3
#9	1.63	10.7		#29	0.70	5.0
#10	0.60	4.4		#30	1.36	8.5
#11	1.05	6.7		#31	1.20	7.3
#12	1.45	9.0		#32	0.84	5.4
#13	1.58	10.7		#33	0.00	0.7
#14	1.65	11.7		#34	0.68	4.7
#15	0.50	4.2		#35	1.60	10.0
#16	1.11	6.5		#36	0.90	5.9
#17	0.48	3.5		#37	0.95	6.1
#18	-0.31	-4.8		#38	0.07	1.4
#19	1.66	10.6		#39	-0.35	-5.8
#20	1.48	9.7		#40	1.13	7.2

<b>Table D: Giant star photometric data</b>						
Star #	B-V	$M_v$		Star #	B-V	$M_v$
#41	1.89	-5.7		#50	1.71	-6.0
#42	1.40	-0.2		#51	1.70	-0.2
#43	-0.25	-6.4		#52	1.03	0.5
#44	0.85	0.8		#53	0.69	-5.9
#45	1.62	-0.9		#54	1.08	-6.1
#46	1.21	-0.1		#55	1.16	0.6
#47	0.26	-6.0		#56	1.41	-5.5
#48	1.60	-0.4		#57	0.66	1.1
#49	0.00	-6.1		#58	1.85	-0.8

<b>Table E: White dwarf star photometric data</b>						
Star #	B-V	$M_v$		Star #	B-V	$M_v$
#59	0.01	11.0		#61	0.22	11.8
#60	0.51	12.2		#62	0.42	11.7

1. Table A gives the B-V color for the boundaries between spectral types—B0, A0, F0, G0, K0, and M0. Indicate and label those boundaries on the bottom of the HR diagram on Figure 1.
2. Table C gives the B-V colors, and absolute magnitudes ( $M$ ) for a set of main sequence stars. (Since the absolute magnitude data is from V-band data, it is also called  $M_v$  data.) Plot the stars on Figure 1. Number each point you plot!

3. Draw a smooth, curving line through your points to indicate the main sequence. (Do not “connect-the-dots” with a zig-zag line!). Label it “Main Sequence (V).”
4. Table D gives the B-V colors, and absolute magnitudes (M) for a set of giant stars. Plot the stars on Figure 1. Number each point you plot!
5. You should see two new groupings of stars. Draw a smooth, curving line through your points on the upper group to indicate the supergiants. (Do not “connect-the-dots” with a zig-zag line!). Label it “Supergiants (I).”
6. Draw a smooth, curving line through your points on the lower group to indicate the giants. (Do not “connect-the-dots” with a zig-zag line!). Label it “Giants (III).”
7. Table E gives the B-V colors, and absolute magnitudes (M) for a set of white dwarfs. Plot the stars on Figure 1. Number each point you plot!
8. Draw a smooth, curving line through your new points. (Do not “connect-the-dots” with a zig-zag line!). Label it “White Dwarfs (VII).”

**VOCABULARY:**

**Apparent magnitude (m)**  
**Absolute magnitude (M)**  
**Distance modulus (m-M)**  
**Parsec**  
**Wavelength band**  
**Luminosity classes**

**B-V color index**  
**Spectral classes**  
**Spectral classes**  
**Luminosity classes**  
**Spectral type**  
**HR Diagram**

**QUESTIONS/ANALYSIS:**

- 1) Given the data in Table F, plot the stars on your HR diagram, label them by name, and estimate their complete spectral type.

<b>Table F: Stellar photometric data</b>			
Star #	B-V	M <sub>v</sub>	Spectral Type
Betelgeuse	1.85	-5.85	
The Sun	0.63	4.83	
Arcturus	1.23	-0.30	
Polaris	0.60	-3.60	
Pollux	1.00	1.08	
Vega	0.00	0.58	

- 2) Given the data in Table G and your HR diagram (Figure 1), determine each star's absolute magnitude. Calculate each star's distance modulus, then using equation 1, distance in parsecs.

<b>Table G: Stellar apparent magnitudes</b>				
Star	$m_v$	Spectral Type	Distance modulus	Distance (pc)
A	6.0	M0 V		
B	6.0	M0 III		
C	6.0	M0 I		
D	16.2	F0 VII		

- 3) By how many magnitudes is a K5 I star more luminous than a K5 V star? How many times more luminous is this?  
(Hint: you may wish to review magnitude scale information given in Labs N03 and N04.)
- 4) Suppose you were looking at two stars, both at the same distance, but while star A is a G5 I, star B is a G5 III. How would they look different to you in a telescope? Be specific.  
(Hint: stars are so far away, they all look like pinpoints, so the answer is not how "big" the stars look.)
- 5) Suppose you were looking at two stars. Star A is an A0 I, while star B is a K0 I. How would they look different to you in a telescope?  
(Hint: stars are so far away, they all look like pinpoints, so the answer is not how "big" the stars look.)
- 6) Sirius is an A0 V star. It has a tiny white dwarf star orbiting around it, that has essentially the same B-V color index. How many magnitudes brighter, and how many times more luminous, is Sirius than its tiny companion star?  
(Hint: you may wish to review magnitude scale information given in Labs N03 and N04.)

Figure 1: Hertzsprung Diagram

