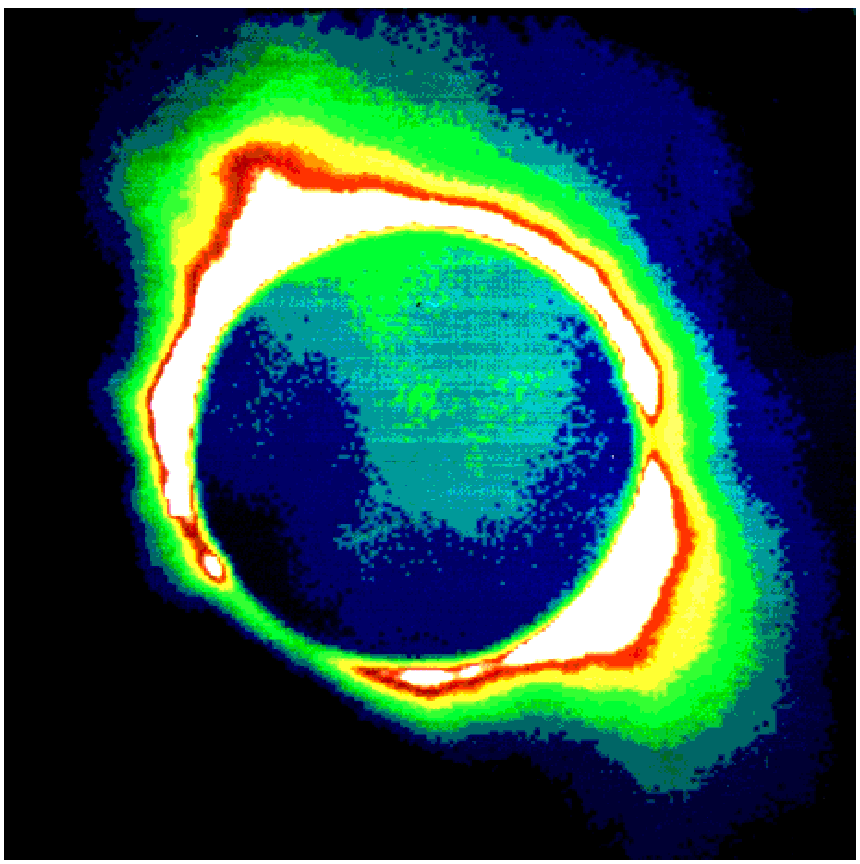
HANDS-ON UNIVERSE

HIGH SCHOOL SCIENCE AND MATH
IN THE CONTEXT OF ASTRONOMY
INVESTIGATIONS

Measuring Color



by Lawrence Hall of Science
University of California, Berkeley
Lawrence Berkeley National Laboratory
and TERC of Cambridge, Massachusetts

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HOU provides a visual and analytic way of exploring the universe.

Use HOU images from professional telescopes, along with HOU image processing software, to pursue investigations of astronomical objects, phenomena, and concepts. Opportunities available to HOU students can lead to accessing professional-grade telescopes via the World-Wide Web for observations as part of research projects such as searching for supernovae and asteroids.

- HOU has been developed and operated by staff at Lawrence Berkeley National Laboratory and Space Science Laboratories at the University of California at Berkeley, Californa, with generous support from the National Science Foundation (grant # ESI-9252915) and the US Department of Energy. The HOU curriculum was developed by TERC with contributions from the Berkeley staff and teachers. The educational center for HOU currently resides at Lawrence Hall of Science, University of California, Berkeley.

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Measuring Color

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HANDS-ON UNIVERSE™
Constants Sheet

Planetary Data:

Planet	Mass (kg)	Ave Radius (m)	Ave Orbital Radius(m)
Mercury	3.32×10^{23}	2.44×10^{6}	5.79×10^{10}
Venus	4.87×10^{24}	6.08×10^{6}	1.08×10^{11}
Earth	5.97×10^{24}	6.36×10^{6}	1.49×10^{11}
(Moon)	7.35×10^{22}	1.74×10^{6}	
Mars	6.42×10^{23}	3.40×10^{6}	2.28×10^{11}
Jupiter	1.90×10^{27}	6.80×10^{7}	7.78×10^{11}
Saturn	5.69×10^{26}	5.70×10^{7}	1.43×10^{12}
Uranus	8.69×10^{25}	2.51×10^{7}	2.87×10^{12}
Neptune	1.03×10^{26}	2.44×10^{6}	4.50×10^{12}
Pluto	1.30×10^{22}	1.50×10^{6}	5.90×10^{12}

Physical and Astronomical Constants:

Gravitational Constant = G = 6.673×10^{-11} N-m^2/kg^2
Speed of Light in a vacuum = c = 2.9979×10^{8} m/s
Earth-Sun Distance = Astronomical Unit = AU = 1.496×10^{11} m
Parsec = pc = 206265 AU = 3,26 ly = 3.09×10^{16} m
Light year = ly = 9.5×10^{-15} m
Mass of the Sun = 1.989×10^{30} kg
Luminosity of the Sun = 3.83×10^{26} W
Radius of the Sun = 6.96×10^{8} m

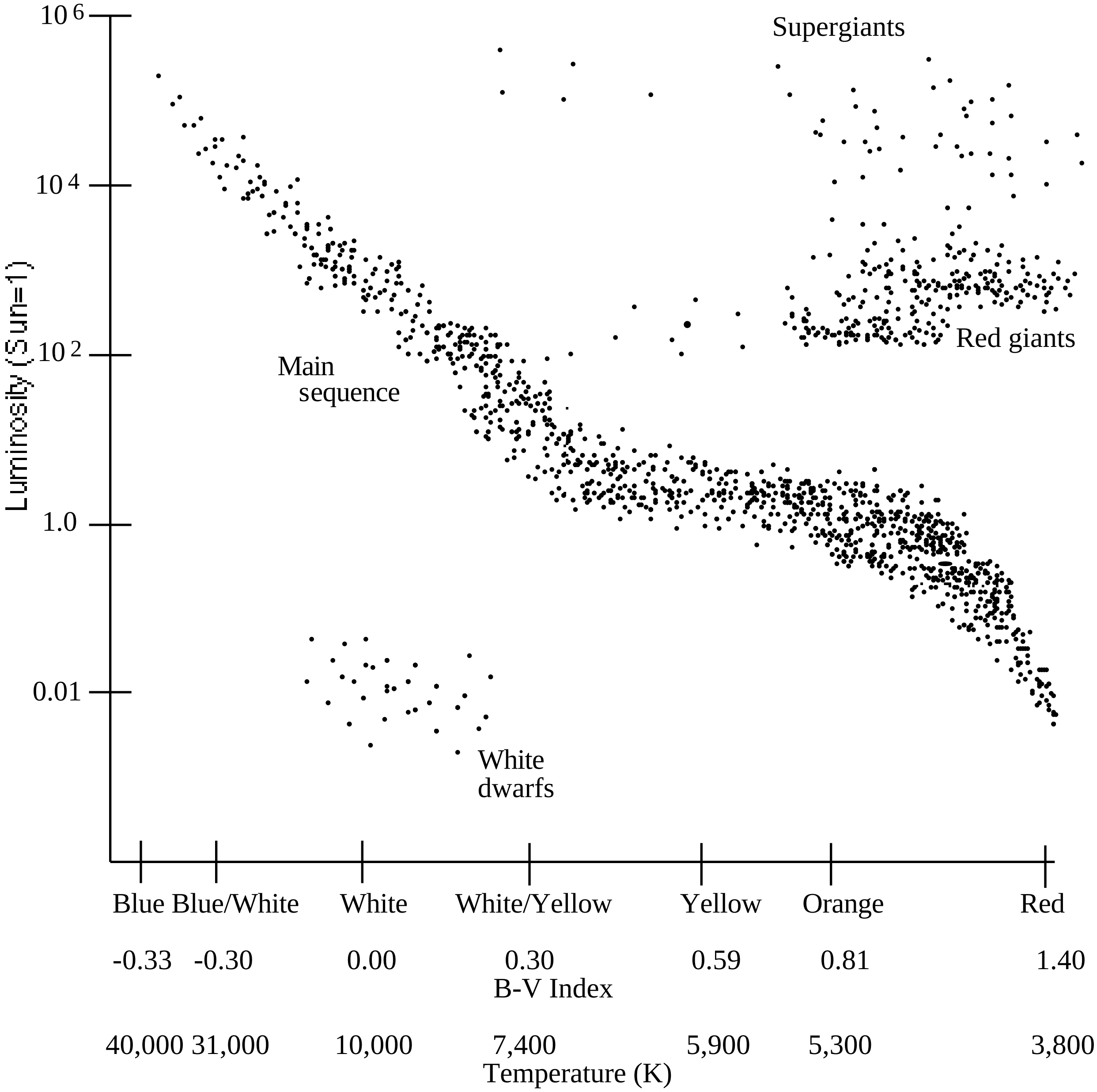
Brightness Conversion Table
Magnitudes to Brightness (W/m^2)

Mag.	I	R	V	B	U	Bolometric
5.0	2.40×10^{-11}	1.65×10^{-11}	3.61×10^{-11}	9.24×10^{-11}	1.83×10^{-11}	2.40×10^{-10}
5.1	2.19×10^{-11}	1.51×10^{-11}	3.29×10^{-11}	8.43×10^{-11}	1.67×10^{-11}	2.19×10^{-10}
5.2	2.00×10^{-11}	1.37×10^{-11}	3.01×10^{-11}	7.69×10^{-11}	1.52×10^{-11}	2.00×10^{-10}
5.3	1.82×10^{-11}	1.25×10^{-11}	2.74×10^{-11}	7.02×10^{-11}	1.39×10^{-11}	1.82×10^{-10}
5.4	1.66×10^{-11}	1.14×10^{-11}	2.50×10^{-11}	6.40×10^{-11}	1.27×10^{-11}	1.66×10^{-10}
5.5	1.52×10^{-11}	1.04×10^{-11}	2.28×10^{-11}	5.84×10^{-11}	1.16×10^{-11}	1.52×10^{-10}
5.6	1.38×10^{-11}	9.52×10^{-12}	2.08×10^{-11}	5.33×10^{-11}	1.06×10^{-11}	1.38×10^{-10}
5.7	1.26×10^{-11}	8.69×10^{-12}	1.90×10^{-11}	4.86×10^{-11}	9.63×10^{-12}	1.26×10^{-10}
5.8	1.15×10^{-11}	7.92×10^{-12}	1.73×10^{-11}	4.44×10^{-11}	8.79×10^{-12}	1.15×10^{-10}
5.9	1.05×10^{-11}	7.23×10^{-12}	1.58×10^{-11}	4.05×10^{-11}	8.02×10^{-12}	1.05×10^{-10}
6.0	9.57×10^{-12}	6.60×10^{-12}	1.44×10^{-11}	3.69×10^{-11}	7.32×10^{-12}	9.57×10^{-11}
6.1	8.76×10^{-12}	6.02×10^{-12}	1.32×10^{-11}	3.37×10^{-11}	6.68×10^{-12}	8.76×10^{-11}
6.2	7.99×10^{-12}	5.49×10^{-12}	1.20×10^{-11}	3.07×10^{-11}	6.09×10^{-12}	7.99×10^{-11}
6.3	7.29×10^{-12}	5.01×10^{-12}	1.10×10^{-11}	2.80×10^{-11}	5.56×10^{-12}	7.29×10^{-11}
6.4	6.65×10^{-12}	4.57×10^{-12}	1.00×10^{-11}	2.56×10^{-11}	5.07×10^{-12}	6.65×10^{-11}
6.5	6.07×10^{-12}	4.17×10^{-12}	9.13×10^{-12}	2.33×10^{-11}	4.63×10^{-12}	6.07×10^{-11}
6.6	5.54×10^{-12}	3.81×10^{-12}	8.33×10^{-12}	2.13×10^{-11}	4.22×10^{-12}	5.54×10^{-11}
6.7	5.05×10^{-12}	3.47×10^{-12}	7.60×10^{-12}	1.94×10^{-11}	3.85×10^{-12}	5.05×10^{-11}
6.8	4.61×10^{-12}	3.17×10^{-12}	6.93×10^{-12}	1.77×10^{-11}	3.51×10^{-12}	4.61×10^{-11}
6.9	4.21×10^{-12}	2.89×10^{-12}	6.33×10^{-12}	1.61×10^{-11}	3.21×10^{-12}	4.21×10^{-11}
7.0	3.84×10^{-12}	2.64×10^{-12}	5.77×10^{-12}	1.47×10^{-11}	2.93×10^{-12}	3.84×10^{-11}
7.1	3.50×10^{-12}	2.41×10^{-12}	5.27×10^{-12}	1.34×10^{-11}	2.67×10^{-12}	3.50×10^{-11}
7.2	3.20×10^{-12}	2.20×10^{-12}	4.80×10^{-12}	1.23×10^{-11}	2.44×10^{-12}	3.20×10^{-11}
7.3	2.91×10^{-12}	2.00×10^{-12}	4.38×10^{-12}	1.12×10^{-11}	2.23×10^{-12}	2.91×10^{-11}
7.4	2.66×10^{-12}	1.83×10^{-12}	4.00×10^{-12}	1.02×10^{-11}	2.03×10^{-12}	2.66×10^{-11}
7.5	2.43×10^{-12}	1.67×10^{-12}	3.65×10^{-12}	9.29×10^{-12}	1.85×10^{-12}	2.43×10^{-11}
7.6	2.21×10^{-12}	1.52×10^{-12}	3.33×10^{-12}	8.48×10^{-12}	1.69×10^{-12}	2.21×10^{-11}
7.7	2.02×10^{-12}	1.39×10^{-12}	3.04×10^{-12}	7.38×10^{-12}	1.54×10^{-12}	2.02×10^{-11}
7.8	1.84×10^{-12}	1.27×10^{-12}	2.77×10^{-12}	7.06×10^{-12}	1.41×10^{-12}	1.84×10^{-11}
7.9	1.68×10^{-12}	1.16×10^{-12}	2.53×10^{-12}	6.44×10^{-12}	1.28×10^{-12}	1.68×10^{-11}

Brightness Conversion Table
Magnitudes to Brightness (W/m^2)

Mag.	I	R	V	B	U	Bolometric
8.0	1.51×10^{-12}	1.04×10^{-12}	2.28×10^{-12}	5.83×10^{-12}	1.16×10^{-12}	1.51×10^{-11}
8.1	1.38×10^{-12}	9.49×10^{-13}	2.08×10^{-12}	5.32×10^{-12}	1.06×10^{-12}	1.38×10^{-11}
8.2	1.26×10^{-12}	9.66×10^{-13}	1.90×10^{-12}	4.85×10^{-12}	9.66×10^{-13}	1.26×10^{-11}
8.3	1.15×10^{-12}	7.90×10^{-13}	1.73×10^{-12}	4.43×10^{-12}	8.81×10^{-13}	1.15×10^{-11}
8.4	1.05×10^{-12}	7.21×10^{-13}	1.58×10^{-12}	4.04×10^{-12}	8.04×10^{-13}	1.05×10^{-11}
8.5	9.55×10^{-13}	6.58×10^{-13}	1.44×10^{-12}	3.69×10^{-12}	7.34×10^{-13}	9.55×10^{-12}
8.6	8.71×10^{-13}	6.00×10^{-13}	1.32×10^{-12}	3.36×10^{-12}	6.69×10^{-13}	8.71×10^{-12}
8.7	7.95×10^{-13}	5.47×10^{-13}	1.20×10^{-12}	3.07×10^{-12}	6.11×10^{-13}	7.95×10^{-12}
8.8	7.25×10^{-13}	5.00×10^{-13}	1.10×10^{-12}	2.80×10^{-12}	5.57×10^{-13}	7.25×10^{-12}
8.9	6.62×10^{-13}	4.46×10^{-13}	9.99×10^{-13}	2.55×10^{-12}	5.08×10^{-13}	6.62×10^{-12}
9.0	6.04×10^{-13}	4.16×10^{-13}	9.12×10^{-13}	2.33×10^{-12}	4.64×10^{-13}	6.04×10^{-12}
9.1	5.51×10^{-13}	3.79×10^{-13}	8.32×10^{-13}	2.12×10^{-12}	4.23×10^{-13}	5.51×10^{-12}
9.2	5.03×10^{-13}	3.46×10^{-13}	7.59×10^{-13}	1.94×10^{-12}	3.86×10^{-13}	5.03×10^{-12}
9.3	4.59×10^{-13}	3.16×10^{-13}	6.93×10^{-13}	1.77×10^{-12}	3.52×10^{-13}	4.59×10^{-12}
9.4	4.18×10^{-13}	2.88×10^{-13}	6.32×10^{-13}	1.61×10^{-12}	3.21×10^{-13}	4.18×10^{-12}
9.5	3.82×10^{-13}	2.63×10^{-13}	5.77×10^{-13}	1.47×10^{-12}	2.93×10^{-13}	3.82×10^{-12}
9.6	3.48×10^{-13}	2.40×10^{-13}	5.26×10^{-13}	1.34×10^{-12}	2.68×10^{-13}	3.48×10^{-12}
9.7	3.18×10^{-13}	2.19×10^{-13}	4.80×10^{-13}	1.22×10^{-12}	2.44×10^{-13}	3.18×10^{-12}
9.8	2.90×10^{-13}	2.00×10^{-13}	4.38×10^{-13}	1.12×10^{-12}	2.23×10^{-13}	2.90×10^{-12}
9.9	2.65×10^{-13}	1.82×10^{-13}	4.00×10^{-13}	1.02×10^{-12}	2.03×10^{-13}	2.65×10^{-12}
10.0	2.41×10^{-13}	1.66×10^{-13}	3.65×10^{-13}	9.30×10^{-13}	1.85×10^{-13}	2.41×10^{-12}

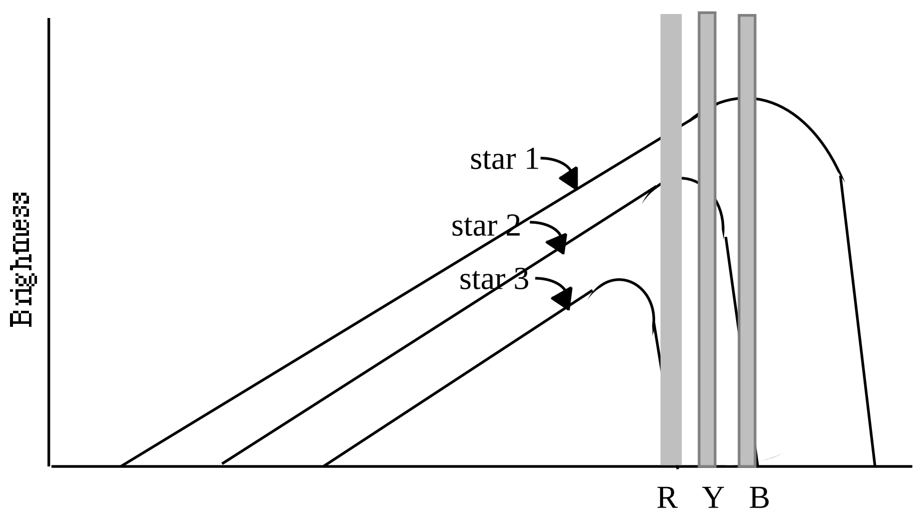
Hertzsprung-Russell Diagram



DISCUSSION SHEET
MEASURING THE COLOR OF STARS

Filters are used on telescopes to determine the brightness of an object in a specific color. One use of this information is to estimate the color of stars. Astronomers generally use a set of standard filters, meaning that the color of light each filter lets through is very well known. This is so one observer can compare data with another observer.

To determine the color of a star, a combination of filters that will show a sharp distinction between stars must be used. The diagram shows plots of brightness versus color for three stars. Vertical boxes are drawn to show the approximate position of red, yellow and blue filters. Astronomers generally use the yellow and blue filters to measure the color of stars because the difference of light through these filters changes significantly for different stars.



The naming convention for filters is relatively simple: the blue filter is called B, the red filter is called R, but the yellow filter is called V. This is because yellow is in the center of the visible color spectrum. To determine the color of a star using filters, the B filter is used to measure the amount of blue light coming from the star and the V filter is used to measure the amount of yellow light. These two values are used to get the *B–V index* of the star:

B–V index = (magnitude through B) – (magnitude through V)

The B–V index uses magnitudes, which are units astronomers use to quantify brightness. For more detail see the *Magnitude Scale Discussion Sheet*, and *Supplementary Activities 12, 13 & 14* in the Measuring Brightness module. For the *Measuring the Color of Stars with Images Unit* in this module you just need to know some simple tips about the magnitude scale. For converting magnitude to brightness use the Brightness Conversion Table at the front of this module.

Quick Tips for Using the Magnitude Scale

Magnitude Tip #1: The magnitude scale is an inverse scale, meaning that brighter stars have lower magnitudes than dim stars. One tip to remembering this is to think about replacing the word “magnitude” with “class”. One might expect a first class star to be brighter than a second class star, just as a first magnitude star is brighter than a second magnitude star.

Magnitude Tip #2: The magnitude scale is not linear. This means the change in brightness from one magnitude level to the next is not constant. In the magnitude scale, each level is 2.5 times brighter than the adjacent level. A magnitude 1 star is 2.5 times brighter than a magnitude 2 star and 6.25 (2.5 x 2.5) times brighter than a magnitude 3 star. This leads to some trickier mathematics; see *Supplementary Activity 13: Magnitude Calculations* in the Measuring Brightness module.

Magnitude Tip #3: The magnitude associated with a given brightness depends on which filter is being used. The conversion table for magnitudes to brightness in Watts/meter^2 has separate columns for each filter. Be careful to make sure you are looking in the correct column for the data you are seeking.

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SUPPLEMENTARY ACTIVITY 24

OBSERVING COLORS

Activity I: Using a Prism or Diffraction Grating

- Project a ray of light at an angle through a prism or diffraction grating so that the light emerges in a rainbow colored beam (called a spectrum).

1. Draw the spectrum on a piece of paper and save this with your class notes. Label each color with the first letter in the name of the color.

2. Create a mnemonic (a phrase with each word starting with the first letter of each color in order) for the colors of the spectrum.(**R**ed, **O**range, **Y**ellow, **G**reen, **B**lue, **V**iolet)

Activity II: Using Color Filters

• Look around your classroom through the red, yellow and blue filters provided by your teacher. Notice how a colored filter can change the appearance of various colored objects.

3. Which color looks darkest through the red filter?

4. Which color looks brightest through the blue filter?

5. Describe in words what the filter is doing to light of different colors?

• Look at the same image using two different palettes. **Open** the image *btarg1* and select *blue.pal*. Then **Open** the image *btarg1* again and select *red.pal*

• Move the windows so you have two images side by side, one with a blue star and one with a red star. *Please note: you have just instructed the software to color these stars, this is not necessarily related to the true color of the stars.*

6. For each image, decide which filter makes the star appear brightest, medium, and dimmest.

7. Suppose a red filter is used on the telescope when observing a very blue star. Would the image appear brighter or dimmer or the same as when no filter is used at all?

8. Suppose a blue filter is used on the telescope when observing a very blue star. Would the image appear brighter or dimmer or the same as when no filter is used at all?

• For the next color challenge you will work in groups of four. One pair in the group will have a colored piece of paper. The other pair, the observers, must estimate the color of the paper by looking at it through various filters. The observers may not see the paper directly until after they have estimated its color. After one pair has a turn at observing, switch roles. For each observing team:

9. What was the predicted color of the paper?

10. What is the actual color of the paper?

11. Describe your technique and logic in predicting the color of the paper.

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SUPPLEMENTARY ACTIVITY 25
OBSERVING COLOR AND TEMPERATURE

A star's color is a direct effect of the temperature at its surface. To understand this look at an incandescent light controlled by a rheostat. As the setting of the rheostat changes, thus changing the current to the light bulb and therefore the temperature of the light bulb filament, note how the color of the bulb is affected.

1. List the different colors you see in the light as you change the rheostat.

2. What color is the light when the rheostat is on high?

3. What color is the light at a middle setting?

4. What color is the light at the lowest setting?

5. At what setting do you think the light bulb is coolest?

6. At what setting do you think the light bulb is hottest?

7. What color would you expect a very hot star appear to be?

8. Would a very hot star have a high or low B-V index? (See the *Measuring the Color of Stars Discussion Sheet* for an explanation of the B-V index.)

9. What color would you expect a relatively cool star appear to be?

10. Would a cool star have a high or low B-V index?

11. Imagine you could double or even quadruple your distance away from a star. What would happen to the star's:

A. Apparent brightness?

B. Luminosity?

C. Color?

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MEASURING THE COLOR OF STARS WITH IMAGES UNIT

In this activity you will determine the color of stars that have been observed with the Leuschner telescope. There are four different stars with two images of each, one using a blue filter (B) and one using a yellow or visible filter (V). These stars will be referred to as your target stars. For each target star there is also a standard star that was observed at nearly the same time so you can assume the observing conditions are the same. Given the known apparent brightness of the standard stars, you can calibrate the target stars to determine their apparent brightness. This procedure is explained in further detail in the *Photometry Techniques Unit* in the Measuring Brightness module..

target star in B	target star in V	standard star in B	standard star in V
Btarg1	*Vtarg1*	*Bstan1*	*Vstan1*
Btarg2	*Vtarg2*	*Bstan2*	*Vstan2*
Btarg3	*Vtarg3*	*Bstan3*	*Vstan3*
Btarg4	*Vtarg4*	*Bstan4*	*Vstan4*

standard star	apparent magnitude
Bstan1	8.0
Vstan1	7.0
Bstan2	9.2
Vstan2	7.2
Bstan3	7.8
Vstan3	7.5
Bstan4	7.0
Vstan4	7.0

Perform the following procedure to get the apparent brightness of each target star through each filter. Record all of your data in the table provided.

1. Use **Auto-Aperture** to get the Counts for each of the stars. (In most cases the target or standard star is the only star in the image; if not, it is clearly the brightest star in the image.)
2. Use the Brightness Conversion Table to get the apparent brightness of each standard star.
3. Calibrate each target star using the fact:

ratio of Counts = ratio of apparent brightness of the target and standard stars

These ratios are equal because the two stars were observed at nearly the same time by the same equipment, so presumably under the same observing conditions.

Note: There is one exception you must account for. The exposure time for *Bstan2* is three times longer than the exposure time for *Btarg2*. This means the telescope collected three times more light from the standard star than it would if the exposure time had been the same as the target star's. You must correct for this in your ratio. You can find the exposure time for any image yourself by selecting **Image Info** under **Data Tools**. Scroll down about a page or more and find "exp. time." The time is given in seconds.

4. Use the Brightness Conversion Table to find the apparent magnitude of each target star. Find the closest magnitude that corresponds to your value for apparent brightness.
5. Calculate the B–V index for each target star.
6. Use the Table on page 14 to approximate the color and temperature of each target star. If your B–V index falls between two values in the table, estimate the answer.

	Star1	Star2	Star3	Star4
1. Counts of Btarg				
Counts of Bstan				
Counts of Vtarg				
Counts of Vstan				
2. Apparent Brightness of Bstan				
Apparent Brightness of Vstan				
3. Apparent Brightness of Btarg				
Apparent Brightness of Vtarg				
4. Apparent Mag of Btarg				
Apparent Mag of Vtarg				
5. B–V Index of Target				
6. Color and Temperature of Target				

Table : B–V index, Temperature and Color Data for Familiar Examples for Main Sequence Stars

B–V Index	Surface Temperature (K)	Color	Familiar Examples
-0.31	21,000	Blue	Spica
-0.17	13,500	White-Blue	Regulus
0.00	10,000	White	Sirius, Vega
0.16	8,100	Yellow-White	Altair
0.45	6,500	Yellow	Procyon
0.57	6,000	Orange	Sun
1.24	3,300	Red-Orange	Kapteyn's Star
1.61	2,600	Red	Barnard's Star

HANDS-ON UNIVERSE™
DISCUSSION SHEET

THE HR DIAGRAM

In the early 1900's two astronomers were working independently on the classification of stars and came up with very similar results. A Danish astronomer, Ejnar Hertzsprung, plotted stars according to their absolute magnitudes and spectral classes. An American astronomer, Henry Norris Russell, created a plot of luminosity vs. temperature for many stars. Their investigations were seen as roughly equivalent, and the Hertzsprung-Russell (HR) diagram is a result of their findings.

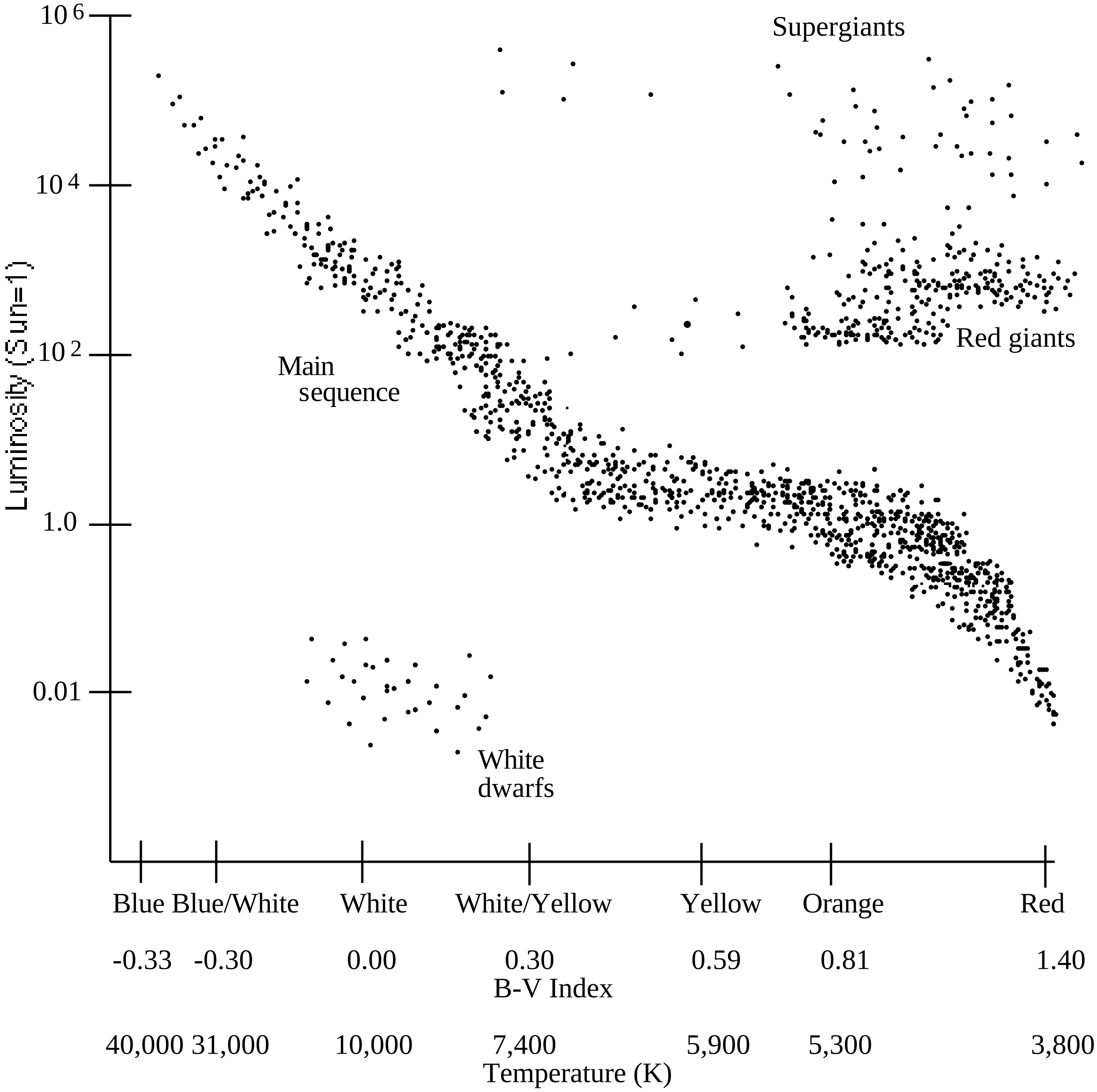
The HR diagram included at the end of this Discussion Sheet is called a general HR diagram because it is based on stars of all different types from many different regions of the sky. The objective is to show the distribution of various types of stars and their relative quantities. To create a general HR diagram, many stars are observed at a given time, their luminosity and temperature are determined and those values are plotted. The HR diagram can be thought of as a snapshot plot of these stars at one time. A star's position on the HR diagram is determined by its luminosity and temperature at the time of observation. Since HR diagrams of many different stars, in many different regions, observed at many different times all yield similar distributions, it can be assumed that the general HR diagram describes an average distribution of stars. More specific HR diagrams of a single star cluster are used to determine factors about that cluster such as the type of stars in the cluster and the distance or age of the cluster.

When examining a general HR diagram, notice that the stars are clumped into several groups. The broad line of stars extending from the upper left-hand corner to the lower right is called the main sequence. Most stars on a general HR diagram are on the main sequence because this line represents the luminosity and temperature that exists for most of a star's life. When a star begins to fuse hydrogen in its core, it assumes its place on the main sequence and stays at that position until its hydrogen fuel runs out and it evolves into a later stage of its life. The main sequence lifetime of a star is generally upwards of 90% of its total lifetime. The temperature, and accordingly the color, of a star during its main sequence period are primarily determined by its mass. High mass stars are very hot so they are blue, while low mass stars are cool and red.

After its hydrogen fuel is depleted, a star contracts and begins to fuse helium in its core. This can occur rapidly or gradually depending on the mass of the star, but in either case it causes the star to expand to a greater radius than that of the main sequence star. During the expansion the star cools considerably. A low mass star that was a yellow or orange main sequence star evolves to a red giant during this expansion period. It is red because it is cool, and it is a giant because it has such a large radius. Similarly, a high mass blue or white main sequence star evolves into a yellow or orange supergiant.

A red giant will undergo yet another phase of evolution where it sheds its outer layers leaving a very dense core of carbon. The outer layers drift off to become what is called a planetary nebula, which is a ring of burning hydrogen that looks like a smoke ring. The dense core is called a white dwarf. It is white because it is very hot, but a dwarf because it has a very small radius. In fact, a white dwarf can have the mass of the sun packed into an object about the size of the Earth. A white dwarf does not have enough mass to initiate carbon burning to produce more energy so it will slowly grow cooler and fade away.

A Typical HR Diagram for a Large Population of Stars



HANDS-ON UNIVERSE™
SUPPLEMENTARY ACTIVITY 26
CLASSIFICATION AND PLOTTING

1. Collect data from your classmates, family and neighbors on their age and pulse rate and plot this data on a set of axes. Is there any correspondence between these two characteristics

2. Gather data from your classmates and create a plot of height versus number of siblings. Is there any correspondence between these two characteristics?

3. Consider the following pairs of characteristics and predict whether or not there would typically be a correspondence between them:

A. Height and shoe size.

B. Age and eye color.

C. The temperature of a star and its color.

D. The apparent brightness of an object and its distance away.

E. The luminosity of a star and its color.

4. Collect more data on people's age and height. Try to get a good distribution of ages. You may want to pool data with others of your classmates. Create a plot with height on the vertical axis and age on the horizontal axis.

5. Describe in words the relationship found between people's age and height.

HANDS-ON UNIVERSE™
SUPPLEMENTARY ACTIVITY 27
CREATING AN HR DIAGRAM

The Table on pages 21–22 contains the luminosity and color data for 48 stars. Use the HR Diagram axes on page 20 to plot the data and create your own HR Diagram. Be careful to notice that the scale of the plot is not linear. You will need to calculate the B – V index for each star.

$$B - V = m_b - m_v = \text{(magnitude using the B filter)} - \text{(magnitude using the V filter)}$$

1. Describe any trends or patterns that appear in your plot.

2. Lightly circle the regions on the diagram that you would distinguish as isolated groups or clusters. How many different regions do you find?

3. Label each region on your diagram indicating its average color and whether it has high or low luminosity.

4. Based on your HR Diagram:

A. Which stars are hot?

B. Which stars are cool?

C. Which stars are large in radius?

D. Which stars are small in radius?

5. Use the position of each of your star regions on the HR Diagram to determine the type of star in that region; i.e., main sequence, red giant, supergiant, or white dwarf.

Axes for HR Diagram

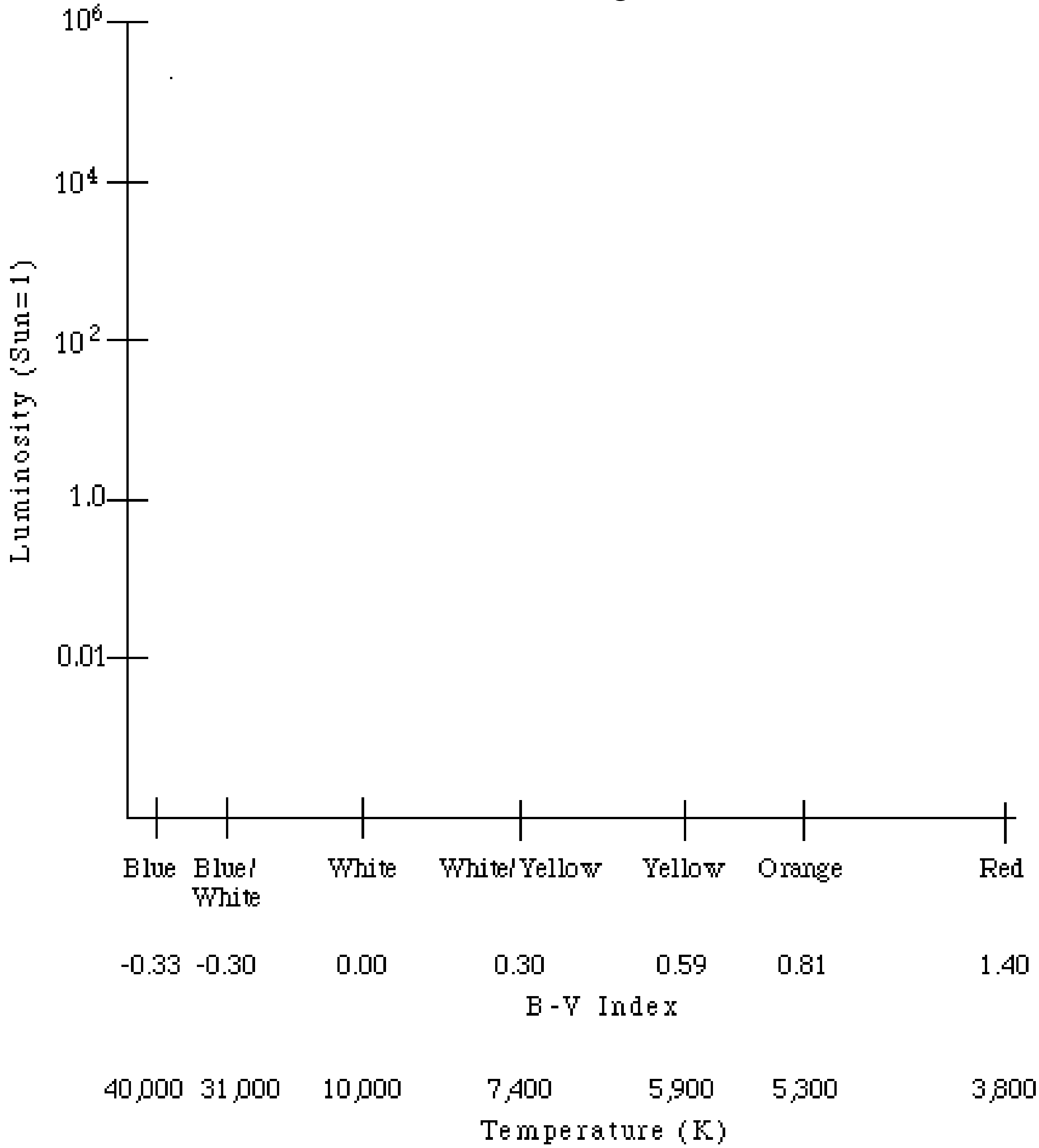


Table of Luminosity, Apparent Magnitude with a Blue Filter, and Apparent Magnitude with a Visible Filter for a Random Sample of Stars

Luminosity (Sun=1)	m_b	m_v	B–V Index	Type Star
42000.0	11.1	11.5	. . . . .	. . . .
98.0	8.2	8.2	. . . . .	. . . .
12000.0	15.6	15.8	. . . . .	. . . .
8.0	2.3	2.0	. . . . .	. . . .
1.2	0.5	-0.1	. . . . .	. . . .
0.02	14.2	12.7	. . . . .	. . . .
320.0	8.9	9.0	. . . . .	. . . .
780.0	7.8	8.0	. . . . .	. . . .
12.0	9.3	9.2	. . . . .	. . . .
7.5	8.4	8.2	. . . . .	. . . .
3.1	9.2	8.6	. . . . .	. . . .
2.2	6.0	5.3	. . . . .	. . . .
9000.0	12.3	12.6	. . . . .	. . . .
0.01	13.0	13.2	. . . . .	. . . .
2.9	12.6	12.2	. . . . .	. . . .
9200.0	8.6	7.7	. . . . .	. . . .
0.8	7.4	6.6	. . . . .	. . . .
0.7	8.8	7.9	. . . . .	. . . .
300.0	9.8	9.9	. . . . .	. . . .
8000.0	7.0	6.2	. . . . .	. . . .
5000.0	5.8	4.8	. . . . .	. . . .
110.0	9.1	9.2	. . . . .	. . . .
44000.0	11.3	11.7	. . . . .	. . . .

Luminosity (Sun=1)	m_b	m_v	B–V Index	Type Star
88.0	7.2	7.2	. . . . .	. . . .
14000.0	13.8	14.1	. . . . .	. . . .
8.9	5.3	5.0	. . . . .	. . . .
1.8	8.6	8.0	. . . . .	. . . .
0.5	11.3	10.4	. . . . .	. . . .
0.04	13.6	12.2	. . . . .	. . . .
820.0	8.9	9.1	. . . . .	. . . .
720.0	8.4	8.5	. . . . .	. . . .
15.0	6.3	6.2	. . . . .	. . . .
7.8	12.4	12.2	. . . . .	. . . .
3.1	14.2	13.6	. . . . .	. . . .
2.1	5.8	5.1	. . . . .	. . . .
6000.0	14.3	14.5	. . . . .	. . . .
0.03	13.0	13.2	. . . . .	. . . .
4.9	12.6	12.2	. . . . .	. . . .
433.0	7.2	7.3	. . . . .	. . . .
0.6	7.4	6.7	. . . . .	. . . .
0.4	14.6	13.8	. . . . .	. . . .
0.7	9.8	9.0	. . . . .	. . . .
700.0	9.8	9.9	. . . . .	. . . .
5000.0	12.9	12.0	. . . . .	. . . .
1.8	5.7	5.1	. . . . .	. . . .
210.0	9.1	9.1	. . . . .	. . . .
0.03	12.4	12.5	. . . . .	. . . .
0.2	9.9	8.9	. . . .	

HANDS-ON UNIVERSE™

USING THE HR DIAGRAM UNIT

This unit uses the data obtained for Stars1-4 in the *Measuring the Color of Stars with Images Unit*. You will also need to refer to the HR diagram in the *Using The HR Diagram Discussion Sheet.*

1. What are the possible positions on the HR diagram for each target star?

2. Assume target stars 1 and 3 are both main sequence stars.

- **A**. Use the HR diagram to estimate the luminosity of each star.
- **B**. Recall the apparent brightness measured in step 2 of *Measuring the Color of Stars with Images Unit* for each of these stars
- **C**. Use this information to get a ratio of distances for these stars.

3. Repeat step 2 assuming target Star1 is a white dwarf and target Star3 is a red giant.

Date: ______________ Name: _____________________

Answer Sheet

Using the HR Diagram Unit

1. Possible position on the HR diagram of

Star1:

Star2:

Star3:

Star4:

2A. Estimated luminosity of

Star1:

Star3:

2B. Apparent brightness of

Star1:

Star3:

2C. Distance ratio of Star1 to Star3:

3A. Estimated luminosity of

Star1:

Star3:

3B. Apparent brightness of

Star1:

Star3:

3C. Distance ratio of Star1 to Star3:

