The Nearest and Brightest Stars

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Introduction:

From a dark site we can see thousands of stars in the night sky, as well as one star, the Sun, during the day. However, the stars that we see are not representative of our celestial neighborhood. Most of our neighbors are too faint to be seen without the aid of a telescope. Some of them are so faint that it requires a telescope in space or special equipment to see them. Also, many of the stars that we do see are actually double and even multiple stars that need a telescope to separate them or are even too close for most telescopes to separate the two stars

Making Models:

In this representation of the nearest and brightest stars, we use marbles to approximate the colors of the stars. Unfortunately, it is sometimes difficult to get marble colors that are close to actual star colors—a limitation to this model. All of the marbles are the same size, while the actual stars range in size from sub-brown dwarfs (free-floating planets?) with masses a few times that of Jupiter and about the same size as Jupiter, to giants with masses 10 to 30 times the mass of the Sun and diameters over a thousand times that of the Sun. While we can approximate the colors of the stars, we clearly cannot model their sizes simultaneously!

Materials:

For our model, we use 1-inch (25 mm) marbles and two clear plastic containers to hold them. In addition, we use a plastic display tray to hold and to display the marbles with their representative star colors (see Figures 1 and 2). The total that you order for each color will depend on how the objects you use are packed (5s, dozens, etc.). We obtained marbles from: http://www.rainbowturtle.com/ and https://www.moonmarble.com/ You can use smaller marbles or other spheres or pony beads that can represent the range of star colors. Table 1 includes the marbles that we used.

Table 1: Colors and Numbers Needed

Color	Marble	Number	Color	Marble	Number
Blue	Crystal Dark Blue	6	Orange	Orange	47
Light Blue	Crystal Light Blue	51	Red	Opal/Solid Red	106
White	Opal/Solid White	36	Red-Brown	Crystal Quartz/Peach	2
Yellow-White	Lemon Yellow	14	Brown	Bald Eagle	14
Yellow	Opal/Solid Yellow	21	Dark Brown	Crystal Amber	3

Displaying the Stars:

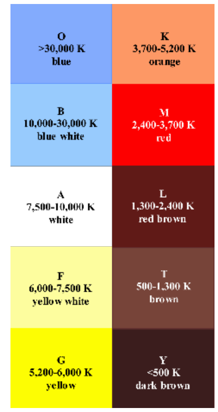
There are several ways that one can display the nearest and bright stars.

Lists of Stars: Table 3 (at the end of the activity) lists the 150 nearest stars. The stars are listed in order of their distances from the Earth. Obviously, the closest one is the Sun. Table 3 contains 107 star systems (including the Sun), with a total of 150 individual stars. There are a number of multiple star systems represented. Nineteen of the stars are known as of the beginning of 2018 to have planetary systems in orbit around them. There may be five other stars with planets, but these are yet to be confirmed. We have listed their names, visual magnitudes, ***absolute magnitudes***, ***luminosities*** relative to the Sun, distances in ***light-years***, temperatures, diameters, ***spectral types***, and number of planets (if they have any). Terms in bold italics are defined at the end of this activity. Table 4 (at the end of the activity) has the 149 brightest stars as we see them (visual magnitude) in the night sky. With the closest star, the Sun, this makes 150 stars. The columns are similar to those for Table 3. There are six stars common to both lists and these are shown in bold type. Seven of these stars, including the Sun, have known planetary systems. There is one other star with a possible planet, but this has yet to be confirmed.

Stars grouped by spectral type: One can also group the stars by their spectral types (Table 2). In this case, it becomes clearer that there is a difference between the nearest and brightest stars: most nearby stars are faint and cool while the brightest stars are generally brighter and hotter. It is clear that the *Nearest Stars* are dominated by the cooler (and smaller) stars while the *Brightest Stars* are dominated by hotter (larger) stars. Figure 1 shows this trend as represented by the marbles. Figure 2 gives the key to the marble representation of the star colors, temperatures, and classifications. Figures 3 and 4 represent this as a graph using marbles and Figure 5 shows this as a traditional graph. Figure 6 is the same as Figure 1, except for the use of pony beads. While not quite as visual, the cost of pony beads is about $10 while the marbles cost over $100. **Note:** star temperatures do not always exactly match spectral type as there are uncertainties in both, especially for faint objects.

Table 2: Stars Listed by Spectral Type

Spectral Type	Approximate Temperature Range	Color	Number Nearest Stars	Number Brightest Stars
O	>30,000K	Blue	0	6
B	10,000K-30,000K	Blue-White	3	48
A	7,500K-10,000K	White	4	32
F	6,000-7,500K	Yellow-White	2	12
G	5,200K-6,000K	Yellow	7	14
K	3,700K-5,200K	Orange	18	29
M	2,400K-3,700K	Red	97	9
L	1,300K-2,400K	Red-Brown	2	
T	500K-1,300K	Brown	14	
Y	<500K	Dark Brown	3	



Figures 1 to 4: The Nearest Stars and the Brightest Stars, Represented by Marbles

Fig. 1: The jar on the left represents the nearest stars and the jar on the right the brightest stars.

Fig. 2: Marble color coding

Fig. 3: Nearest stars

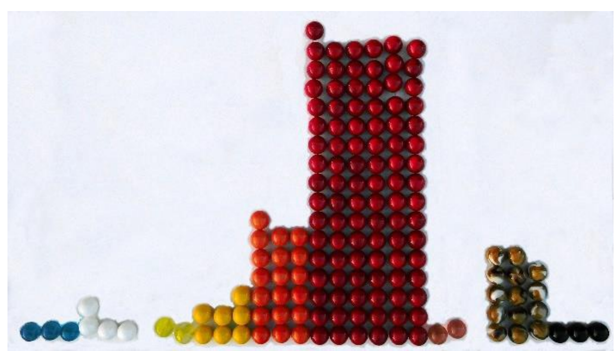


Fig. 4: Brightest Stars

Figure 5

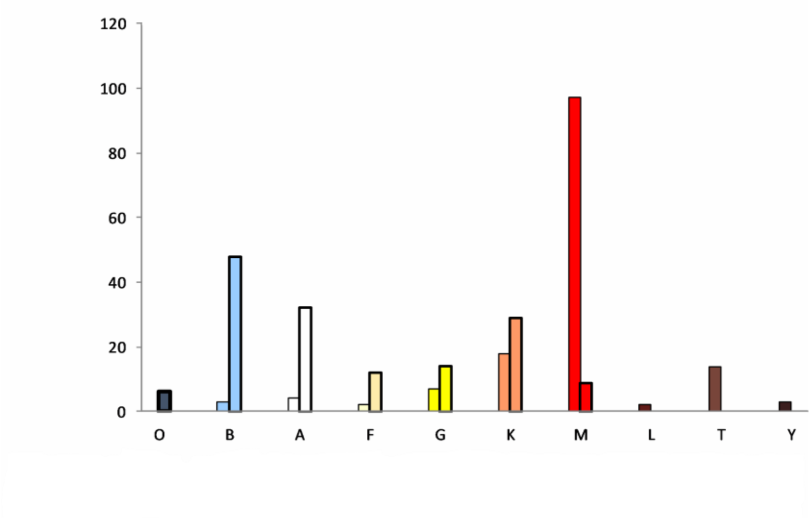


Fig. 5: Number of stars in each spectral/color range

Figure 6

Fig. 6: The Container on the left represents the nearest stars and the container on the right the brightest stars. This is the same as Figure 1, except with pony beads.

Creating an H-R Diagram: One can also plot the luminosity of the stars (relative to the Sun) on the Y-axis and the temperature on the X-axis. This creates a ***Hertzprung-Russell diagram*** (***H-R diagram***). Only a few of the nearest stars are more luminous than the Sun and only a few are hotter than the Sun. This is shown in Figures 7 and 8, coded by color. What is most striking about the H-R diagrams is how the other stars compare with our Sun. Many of us are taught that the Sun is a "typical" or "average" star. As can be seen in Figures 7 and 8, the Sun is not typical of either the brightest stars or the nearest stars!

Figures 7 and 8

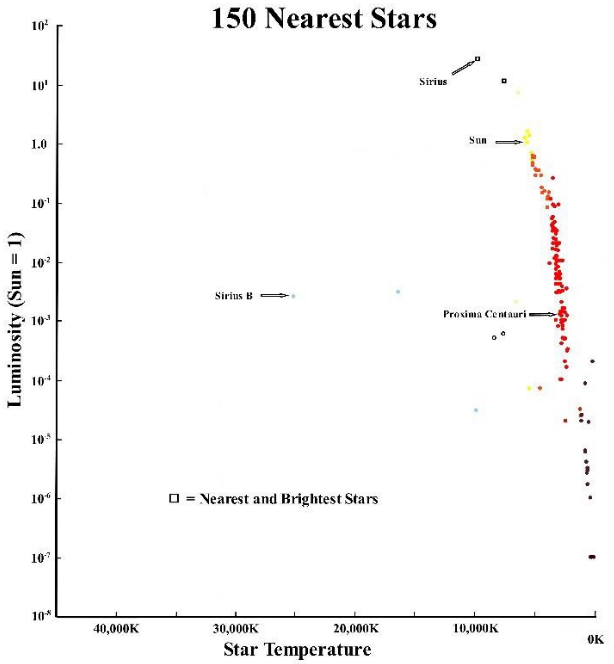


Fig. 7: H-R diagram for nearest stars.

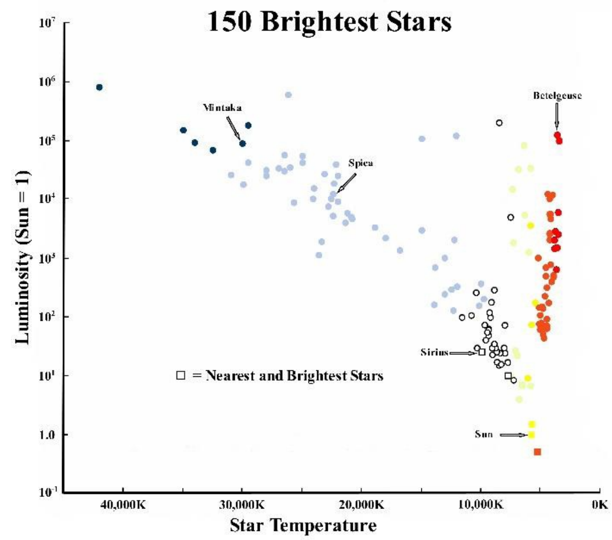


Fig. 8: H-R diagram for brightest stars.

Do not judge a star by its color:
If you carefully look at the stars in Tables 3 and 4, you will note that the classifications and the colors/temperatures of the stars do not match perfectly. Temperatures may be uncertain by a few hundred degrees and spectral classifications are based on spectral lines, not the colors of the stars.

You can also see that, for example, a red or blue star in the Nearest list is much fainter than a red or blue star in the Brightest list. In the Nearest list, we find very small and faint red dwarf stars, stars that may only be 10% or 15% of the diameter (and mass) of the Sun, while, in the Brightest list, we find stars such as Betelgeuse, which are near the end of their lives and have evolved into red giants or supergiants. In contrast, the Brightest blue stars are many times more massive than the Sun, while the blue stars in the Nearest list have evolved beyond the red giant stage, no longer support nuclear reactions, and are now cooling off.

In Figures 9 to 11, we illustrate the size difference among some of the stars that we might be familiar with. In Figure 9 are Mintaka (O-star, about 16.5), Spica (B-star), Sirius (A-star), the Sun (G-star), and Proxima Centauri (M-star). In Figure 10 we have shrunk the scale down to show Betelgeuse (M-star, supergiant) and Mintaka! In Figure 11 are the Sun and Sirius B (“white” dwarf). There are several things to note here: 1. Betelgeuse is about 1,000 times the diameter of the Sun but is about 12 times the mass of the Sun. 2. At the other extreme, Sirius B (which was once a B-star and then a red giant) is about the diameter of the Earth with a mass about the same as the Sun!

Figures 9 to 11: Relative Star Sizes

Fig. 9: Right to left—Mintaka. Spica, Sirius, Sun, and Proxima Centauri

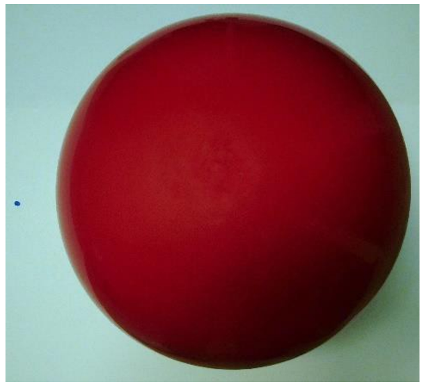


Fig. 10: Right to left—Betelgeuse and Mintaka

Fig. 11: Right to left—the Sun and Sirius B

Terminology:

Light-year: A light-year is the distance light travels in one year, 9.46 x 10^{12} kilometers.

Arcsecond: An arcsecond is an angular measurement equal to 1/60 of an arcminute and 1/3600 of a degree. Since the Moon is about one-half of a degree (30 arcminutes), an arcsecond is 1/1800 the width of the Moon.

Parsec: A parsec (parallax-second) is a unit of distance equal to 3.26 light-years. From 3.26 light-years away, the Earth would have a maximum separation of 1 arcsecond from the Sun. As viewed from the Earth, a star 3.26 light-years away would appear to move back and forth by 1 arcsecond (each way) relative to distant stars because of the motion of the Earth in its orbit around the Sun.

Luminosity: In astronomy, the total amount of energy emitted by a star, galaxy, etc. For stars, the luminosity is usually given relative to the Sun (Sun = 1).

Absolute Magnitude: In order to compare the relative magnitudes (brightnesses) of stars, astronomers use the term absolute magnitude: how bright a star would look from a distance of 10 parsecs (32.6 light-years). Magnitudes and absolute magnitudes are usually given at visual wavelengths.

Spectral Type: A good explanation of the currently used spectral classification system is given at: http://en.wikipedia.org/wiki/Stellar_classification . Briefly, stars are classified by their temperature (hottest to coldest): O, B, A, F, G, K, M, L, T, Y, a number (0 to 9, hotter to cooler) that further subdivides the temperature, and a Roman numeral that subdivides the stars into hypergiants, supergiants, ***main sequence***, etc. and the several classes of dwarfs. Technically, all main-sequence stars, including the Sun, are dwarfs!

Hertzsprung–Russell diagram: The Hertzsprung–Russell diagram (H-R diagram) is a graph of stars showing the relationship between their luminosities and their temperatures (spectral types). A little caution is needed here. You may see variations on the way the H-R diagram is plotted. The Y-axis may be plotted as luminosity relative to the Sun or as absolute magnitude. The X-axis may be plotted as spectral type or temperature (with color tossed in).

Main Sequence: The band of stars on the H-R diagram where stars reside as they fuse hydrogen to helium. Once they exhaust the hydrogen in their cores, stars will evolve off the Main Sequence and become red giants or supergiants. Stars up to about 8 times the mass of the Sun will collapse and become “white dwarfs” once fusion ceases. Larger stars will become supernovas and become neutron stars or black holes.

Figures 12 and 13: Two Representations of the Hertzsprung-Russell Diagram