1. Two stars appear to have the same brightness, but one star is three times more distant than the other. How much more luminous is the more distant star?

Apparent brightness of an object with a given luminosity is inversely proportional to distance squared:

\[ \text{brightness} = \frac{L}{4\pi d^2} \]

Therefore the luminosity that can be inferred for an object is directly proportional to the distance to that object squared:

\[ L = \text{brightness} \cdot 4\pi d^2 \]

If two objects have the same brightness, but one is three times more distant, then the more distant object must be 9 times more luminous.

2. The double star system Albireo has one yellow star and one blue star. What do we know about the relative temperatures of these stars based on their observed colors? What do we know about their relative sizes? Please briefly explain your answers.

Yellow light is longer wavelength than blue light. We know that the wavelength at which a star emits most of its light is inversely proportional to the temperature of the star:

\[ \lambda_{\text{max}} \propto \frac{1}{T} \]

(This is what we practiced with the blackbody worksheets completed when John was leading the class.) So the yellow (longer wavelength) light is emitted by the cooler star.

The colors tell us directly about the relative temperatures of these stars, but they don’t tell us about the relative sizes of the stars. We would need to also know the relative luminosities of the two stars to infer their relative sizes.

3. To know some properties of a star, you must first know its distance. For other properties, knowledge of distance is not necessary. For each of the following properties, please place them into one of those two categories: size, temperature, color, chemical composition. Briefly state your reason for each.

   i. size: We **do need to know the distance** to a star to measure its physical size. If
we measure its angular size (which is very difficult in the best case scenario), then we need the distance to convert an angular size into a physical size. Alternatively, we can calculate the radius of a star from its luminosity and temperature:

\[ L = \text{flux} \cdot \text{SA} = \sigma T^4 4\pi R^2 \]

\[ R = \left( \frac{L}{4\pi \sigma} \right)^{1/2} \frac{1}{T^2} \]

and we need to know the distance to a star to calculate its luminosity.

ii. temperature: **Distance doesn’t need to be known.** Temperature can be estimated directly from a star’s color, or its spectrum.

iii. color: **Distance doesn’t need to be known.** The color can be directly observed for a star from images.

iv. chemical composition: **Distance doesn’t need to be known** to infer the chemical composition of a star. It is measured directly from a star’s spectrum, which bears the fingerprints of the elements present in that star’s atmosphere. The pattern of fingerprints does not depend on distance (although the pattern might be blue or redshifted with distance).

4. **Sirius, the brightest star in the sky, has a parallax of 0.379 arcsec. What is its distance in parsecs? In light years?**

   From lecture notes:

   \[ d[pc] = \frac{1}{p[arc \text{ sec}]} \]

   The distance to Sirius is thus 2.6 parsecs. 1 parsec ~ 3.26 light years, so the distance to Sirius is ~6.5 light years.

5. **How can an astronomer look at the HR diagram of a star cluster and estimate its age?**

   The HR diagram is a clock for the age of star clusters. We can look at the HR diagram to see which are the bluest stars burning on the main sequence. The bluest stars correspond to the most massive stars that are still burning hydrogen on the main sequence. (More massive stars burn faster, hotter and bluer on the main sequence; less massive stars burn slower, cooler, and redder). Measuring the most massive stars that still burn H on the main sequence is a clock, because we know that the cluster needs to be old enough so that all of the **more massive stars have already burned up all of their Hydrogen and left the main sequence.**
6. When the Sun becomes a white dwarf with a radius of $\sim 10^4$ km, what will be its luminosity when it is a temperature of $10^8$ K? of $10^6$ K? Express your answer in units of Solar luminosities.

[I emailed the students suggesting that they use $10^6$ and $10^4$ instead of these higher numbers. My mistake. They can/will get full credit for using either set. I did this calculation super fast and by hand... could be off.]

$$L = \text{flux} \cdot SA = \sigma T^4 4\pi R^2$$

$$\sigma = \text{Stefan Boltzmann constant} = 5.67 \times 10^{-8} \text{ W/(m}^2 \text{ K}^4)$$

Convert the white dwarf radius into meters: $10^4$ km = $10^7$ m, and plug numbers into the above equation.

$10^6$ K: $L \sim 7 \times 10^{31}$ W. The Sun’s luminosity is $\sim 4 \times 10^{26}$, so this hot white dwarf is about 100,000 times the luminosity of the Sun.

$10^4$ K: $L \sim 7 \times 10^{24}$ W. The Sun’s luminosity is $\sim 4 \times 10^{26}$, so this hot white dwarf is about 1/100 times the luminosity of the Sun.

7. Our galaxy has about 50,000 stars of average mass (0.5 Solar masses) for every main-sequence star of 20 Solar masses. But one 20 Solar mass star is about 10,000 times more luminous than the Sun and one 0.5 Solar mass star is only 0.08 times as luminous as the Sun.

a. How much more luminous is a single massive star than the total luminosity of the 50,000 less massive stars?

50,000 of the 0.5 Solar mass stars emit $50,000 \times 0.08$ Solar luminosities = 4,000 Solar luminosities. But one 20 Solar mass star emits 10,000 Solar luminosities, making that single star 2.5 times more luminous than 50,000 of the low mass stars!

b. How much mass is in 0.5 Solar-mass stars compared to 20 Solar-mass stars?

50,000 stars of 0.5 Solar masses have a total of 25,000 Solar masses, which is about 1,000 times more mass than is contained in a single 20 Solar mass star.

c. Which stars - lower mass or higher mass - contain more of our galaxy’s mass and which produce more of the galaxy’s light?

Low mass stars in galaxies contribute by far most of the stellar mass of a galaxy. However, the rare and very high mass stars contribute most of the light.
8. Go to: www.galaxyzoo.org. Click on "Story" and read. Be sure to read until the end, so that you learn what dataset you will be looking at. Then go back to the home page. Click on "Science" and read. For your classifications to be recorded as part of the project: Sign up for account. Then log into your account. Click on “Classify” and click on the blue “Help” button to get an idea of how to classify. The classify at least 20 galaxies. Write a few sentences about your experience classifying the galaxies.

This is really a “participation counts” question.