Astronomy 100 Name(s):

Exercise 9: A model of nearby space and how to detect life there

By looking at an apparently flat background of stars at night or at a star chart printed on a page, we often forget about the three-dimensional nature of the universe.

In this exercise, you will construct (with welding rods and Styrofoam balls) a model of nearby space including 50 or so of the nearest stars. Of course, you will need information on where to place the stars accurately; you will need a **coordinate system** to specify the position of an object in space.

Astronomers use the **right ascension** (RA) to determine the position along the celestial equator of an object (think of it as sort of a space longitude). By tradition, the RA is measured counterclockwise in units of hours and minutes, starting at 0 hours and coming back, after one full circle, to 24 hours. To determine the angle above or below the celestial equator you will need the **declination** (think of this as a space latitude). The declination runs from -90° (celestial south pole) to +90° (celestial north pole). Both of these coordinates are laminated to the metal pole bases.

In addition, the stars have been colored according to their **spectral classes**; **blue** balls represent O, B and A type stars; **yellow** represent F and G type; **orange** represents K type and **red** represents M type. Finally, there are **red giants** as well as **white dwarf** stars (they have a "d" in the star type).

A. Select a *base*. We'll start with the bases with labels printed in **black**. Note the coordinates and note the name and stellar spectral type of the star. The Sun is set up as an example.

B. Using the spectral type, select the appropriate *Styrofoam ball* (or balls connected by *toothpicks*, if you've selected a multiple star system). Remember, size is a factor, too.

C. Using a scale of 5 centimeters = 1 light year, spindle the ball(s) on a *welding rod*. Place the base at the appropriate RA and then adjust the distance and the ball's height to achieve the correct distance and declination (you have to do these two together, so a lot of fiddling will be required).

D. Repeat steps A to C for the remaining bases.

Questions:

1. Given that the Milky Way (the galaxy in which these stars reside) is thought to be shaped as **flattened disk**, is this evident from the model (in other words, do the stars bunch up along the celestial equator)? What does this imply about the true **thickness** of our galaxy?

2. Given that the Milky Way is also thought to be a **spiral-armed galaxy**, is there any evidence of these "arms" in the model (in other words, do the model's stars seem to define an "arm")? What does this imply about the true **width** of our spiral arms?

3. How long would it take a message (radio, TV or any other EM wavelength) to reach the **furthest** star on this model **and** return to us? What year would the message needed to have left earth in order for a reply to reach us today (2003)?

4. The text makes a claim on page 190 that half of the nearby stars are in binary systems. Check the model and calculate the percentage of stars in **multiple-star systems**. For this calculation you will need to count stars (even ones in multiple-star systems) separately.

5. How many Sun-like stars (remember, even if it's in the same spectral class as the Sun, it **can't** be part of a multiple-star system — except under certain circumstances!) are there on this model? What percentage of all the stars in the model are Sun-like?

6. The nearest 25 star systems could be contained in a sphere of about how many light years' radius? What is the volume of this sphere (in cubic light-years)? Calculate the **stellar density** in stars per cubic light year.

The black-lettered labels represent the nearest 25 star systems; the red-lettered labels represent the *next* 25 nearest star systems. Set up the red-lettered base star systems.

7. The next nearest 25 star systems extended the model outward by about how many *more* light years? How much more volume of space (in cubic light-years) does this extra spherical shell occupy? Calculate the **stellar density** in stars per cubic light year of this spherical shell.

8. Comparing the stellar densities in questions 6 and 7, what conclusion can you draw about the Sun and its position inside the Milky Way galaxy; for instance, does the Sun seem to occupy a relatively **less** densely or **more** densely populated patch of space?

9. Is the answer to question 7 confirmation that **the Local Bubble** exists? Look up the size of the Local Bubble on the Web. Would you expect to see the Local Bubble on this model?

The **Voyager 1 probe**, after it completed its "grand tour" of the planets in 1989, was programmed to leave the solar system with whatever fuel it had left on board. This, and the gravitational assists from the planets, increased its speed to 39000 miles per hour, the fastest speed ever achieved by a human-built vehicle. That speed is equal to 5.77×10^{-5} light-years/year (remember that light year is a *distance*).

10. How long (in years) will Voyager 1 take in reaching Proxima Centauri?

11. How long (in years) will Voyager 1 take in reaching the edge of the model? To put this in perspective, ice ages on Earth seem to occur (in the Quaternary Period, anyway) roughly every 100,000 years. **How many ice ages** will have occurred by the time Voyager 1 reaches the edge of the model?

12. **Fusion drives** seem to be the best bet for achieving higher interstellar speeds. Why *aren't* the **solar sail** and **magnetic particle propulsion** systems being considered for interstellar drives?

13. Even with a fusion drive, there will "only" be a one hundred fold increase in the **efficiency** of the propulsion; in other words, the fusion drive's top speed will be one hundred times **faster** than what Voyager 1 is doing today. How long will it take a fusion-drive powered vehicle to reach Proxima Centauri? For the forseeable future, will humans be able to travel across interstellar distances?

Horrible fates

14. A star with the mass of Sirius A (16 solar masses) can end its "life" by undergoing a **supernova**. How long before the lethal front of x-rays and cosmic rays the supernova generates overwhelms the Earth?

15. If that weren't bad enough, the **matter shock front** of the supernova, consisting of the newly-created elements the supernova made, is ejected at an average of 10,000 km/s. How long before this lethal wash of ionized particles sweeps over the Earth? If we somehow survive the first wave in question 14, would there be sufficient time to develop a way to leave our planet for safer parts of the galaxy?