**Stellar Populations** Name \_Sidney Sanders\_

The discussion question from last week asked (in part) what causes the drastic difference between the H-R diagram of the brightest stars in the sky and the H-R diagram of the closest stars. In this activity we are going to use a thought experiment using a conceptual model to explore this topic in more depth, as is frequently done in astronomy.

1) Picture a pit full of balls. A big pit. Like at Chuck E. Cheese, where you can actually dive into a pit full of plastic balls. This is the basis for the model we will use in this activity. Each ball will represent a region of space in which we find a single star of a given spectral type (e.g. A0, G2, etc). Note that the star itself is vanishingly small in this model; the ball represents a region of space surrounding the star. Now, just thinking of the balls in the pit, if you used larger balls to fill the pit, how does the number of larger balls compare to the number of smaller balls needed to fill the pit?

1a) The number of larger balls with be significantly smaller than the number of smaller balls that can fit in the same amount of space.

Now since each ball represents the region of space in which we find a single star of the given type, do larger or smaller balls represent rarer stars (i.e. rarer objects would have less of them in the pit)?

1b) the larger balls would represent the rarer stars. The number of balls is less than the number of smaller stars. Making their appearance of greater value.

Therefore, based on the above concepts if we can determine which spectral type of star is represented by what size of ball, then we can determine what spectral type is rare versus common in space.

To explore the topic in a more quantitative way, we may use the fact that the brightest star in the nighttime sky is apparent magnitude V= -1.46. This places a minimum distance on stars of various brightness, as a given absolute magnitude of star will have lower (brighter) apparent magnitudes the closer to the Sun the star is located. We can then use that distance information to mathematically construct the above model to allow us to understand the distribution of stellar types of differing absolute magnitudes (e.g. spectral types), and see what effect this has on the H-R diagram of the closest stars.

To see how this works, do the following:

(2) For the following table of stellar types, compute the minimum distance possible for each type of star based on the magnitude limit above (put another way: find the distance for which each star would have an apparent magnitude of -1.46). To do this you will need to use the distance modulus formula solved for distance, or

where m is the apparent magnitude, M is the absolute magnitude, and d is the distance.

\*NOTE: for some reason there is often confusion with this formula; ((m-M)/5) is the power in an exponent. Also: *make sure to enter at least 2 non-zero digits in each answer to avoid roundoff errors!*

(Table on next page)

|  |  |  |
| --- | --- | --- |
| Star type | Absolute magnitude | Minimum distance (parsecs) |
| O5 MS Star, Supergiant | -9.6 | 424.61956394 (pc) |
| B5 MS Star, red giant | -2.6 | 16.90440931 (pc) |
| A0 MS Star | 0.0 | 5.10504999 (pc) |
| G0 MS Star | +4.6 | 0.613762 (pc) |
| K0 MS Star | +5.6 | 0.38725764 (pc) |
| M5 MS Star/bright WD | +9.9 | 0.05345643 (pc) |

TIP: If you get a negative minimum distance something is wrong!

(3) What does this tell us about the number of stars of each type as compared to the other types? To answer this question we will turn to the model introduced above. Let us model the distribution in space of a given type of star as a box (or pit) full of balls, each ball containing a single star (of the given type) at its center. This results in an approximately uniform distribution of the selected type of star, with typical distances between stars of order the diameter of the ball. \**Note: as a reminder the distances between the stars (i.e. the ball diameters) are MUCH larger than the sizes of the stars themselves. So the balls represent not the sizes of the stars, but the volumes of space which contain a single star of the specified type.* Let us select a tennis ball (of radius 1.25 inches) to model the distribution of A0 stars. What is the scaling factor of this model? (See Week 1 for notes on computing scaling factors, etc.) Note that the minimum distance from the first table corresponds to the radius of the model ball.

(3) Scaling factor (inches per parsec): 0.24509803

(4) To compare the distribution of different types of stars, we first need to determine the proper size of balls to use in our model for each type. Fill in the data (from #2) for the minimum distance for each stellar type on the table on the next page, then using the scale factor from #3, compute the size (radius) of ball that should be used to model the distribution of each type of star. [See the notes from week one to review how to compute a distance in a scale model using a scaling factor.] *Again, make sure to enter at least 2 non-zero digits in each answer!*

|  |  |  |
| --- | --- | --- |
| Star Type | Minimum Distance (parsec) | Ball radius (inches) |
| O5 MS Star, Supergiant | 424.61956394 (pc) | 104.07341862 (in) |
| B5 MS Star, red giant | 16.90440931 (pc) | 4.14323742 (in) |
| A0 MS Star | 5.10504999 (pc) | 1.25123769 (in) |
| G0 MS Star | 0.613762 (pc) | 0.15043185 (in) |
| K0 MS Star | 0.38725764 (pc) | 0.09491608 (in) |
| M5 MS Star/bright WD | 0.05345643 (pc) | 0.01310206 (in) |

TIP: if you did NOT get a ball radius of 1.25 inches for the A0 star type, something is wrong;

recheck your work.

(5) To investigate the relative numbers of various types of stars, we want to take a measure of how many stars of each type are within a given distance of the Sun and therefore within a set, fixed volume of space. In the ball analogy this is equivalent to asking how many balls we would need to fill a given space (such as a box or the ball-pits in various child play areas).

An approximate way to calculate the number of balls that will fit into a box would be to take the volume of the box and divide by the volume of the ball. So let us take a box 2 feet (24 inches) on a side. First, what amount of space does this represent? To answer this, use the scale factor to compute how many parsecs 2 feet (24 inches) represents.

(5a) Represented 'box' size in space 5.88235272 parsecs

Then find the volume of the box (volume = size3)

(5b) Represented 'box' volume in space 203.5416013 parsecs3

(6) Now, to find how many stars of each type are found in that volume of space, we return to the

model and ask how many balls are needed to fill the box. To find this, first we compute the volume of the box.

(6a) Actual box volume (in inches3) 203.5416013 inches3

Next, compute the volume of the ball used to represent the spacing of each star type (fill in the table below). Recall that the volume of a sphere is calculated as V = (4/3) \* pi \* r3

Finally, divide the box volume by the ball volume to approximate the number of balls which would fit in the box for each type of star (fill in the table below as 6b).

*Again, make sure to enter at least 2 non-zero digits in each answer!*

|  |  |  |  |
| --- | --- | --- | --- |
| Star Type | Ball Radius (inches) | Ball Volume (inches3) | Number of balls in box |
| O5 MS Star, Supergiant | 104.0734 (in) | 4721802.7188 (in^3) | 0.0000431 (balls) |
| B5 MS Star, red giant | 4.1432 (in) | 297.9177 (in^3) | 0.6832 (balls) |
| A0 MS Star | 1.2512 (in) | 8.2048 (in^3) | 24.8076 (balls) |
| G0 MS Star | 0.1504 (in) | 0.0145 (in^3) | 14037.3518 (balls) |
| K0 MS Star | 0.0949 (in) | 0.0036 (in^3) | 56539.3336 (balls) |
| M5 MS Star, bright WD | 0.0131 (in) | 0.000009 (in^3) | 22615733.4778(balls) |

(7) The number of balls in the box for each type of star in the table above is the model representation of the number of stars of each type contained within a 'box' of space the size of which you computed above. Note that the 'box' of space is the same size for all star types, so what you have computed is effectively an inventory of this 'box' of space. Based on this, what is the most common type of star?

(7) The most common type of star is: M5 MS Star, bright WD

(8) How many stars in total (of these types) do we find in the 'box' of space?

(8) Total number of stars is: 22615733.4778

(9) Based on this, we also can compare how common differing types of stars are with respect to each other. For example how many A0 stars are there per B5 star? To answer this fill in the following statement:

(9) There are 36.3108 A0 stars per single B5 star.

(10) In this project we are assuming that one star of each type is at the minimum distance,

therefore, plotting the 'brightest' stars in the sky on an H-R diagram would have one star appear

at the location of each type of star listed. However, the H-R diagram of the 100 nearest stars

will appear considerably different. To find the 100 nearest stars, we could think of doing the

same process as we did above, but using a smaller and smaller box until the total number of

balls across all types summed to 100. What type of stars would we expect to find in our list of

the nearest 100, and where do they fall on the H-R diagram?

(10a) Type of stars: A0 MS Star?

(10b) Where do they fall on the H-R diagram: Upper Left?

(11) Finally, returning to the discussion board question: What does the difference in the H-R diagram of the brightest stars versus the H-R diagram of the nearest stars tell us about the relative distances (and therefore rarity) of intrinsically bright stars as compared to intrinsically faint stars?

(11) I’m not sure…