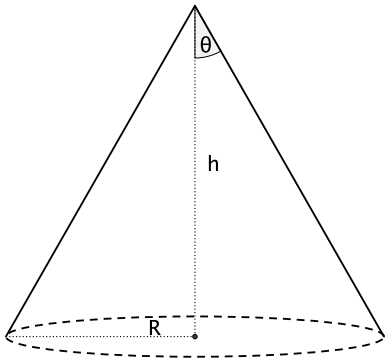
Herschel's Star Gages

In this activity you will use Herschel's "star-gage" method to determine the shape of a system of stars from within. You will also examine some potential problems with Herschel's method.

1. William Herschel attempted to map out the shape of the Milky Way star system using a method he called "star-gages." The star-gage method is based on two crucial assumptions. The first assumption is that Herschel's telescopes could penetrate to the boundaries of our stellar system. In this case, Herschel realized that, when he looked through his telescope, he was really viewing stars in a cone-shaped region of space. The apex angle θ of this cone (see the figure below) was just half of his telescope's "field of view" (which just depends on the telescope and eyepiece he was using). The height h would then be the distance from the telescope to the edge of the stellar system (beyond which, Herschel assumed, there were no more stars). The volume of the cone is given by $V = (1/3)\pi h^3 \tan^2\theta$. In the space below, write a sentence expressing the proportionality relation between the volume V of this cone and the height h.



2. Herschel's second assumption was that stars are distributed uniformly inside the boundaries of the stellar system. In this case the number of stars in any region of space should be directly proportional to the volume of that region. Use this fact, and your result above, to write a sentence describing the proportionality relation between the number of stars N seen in Herschel's telescope and the distance h to the edge of the stellar system.

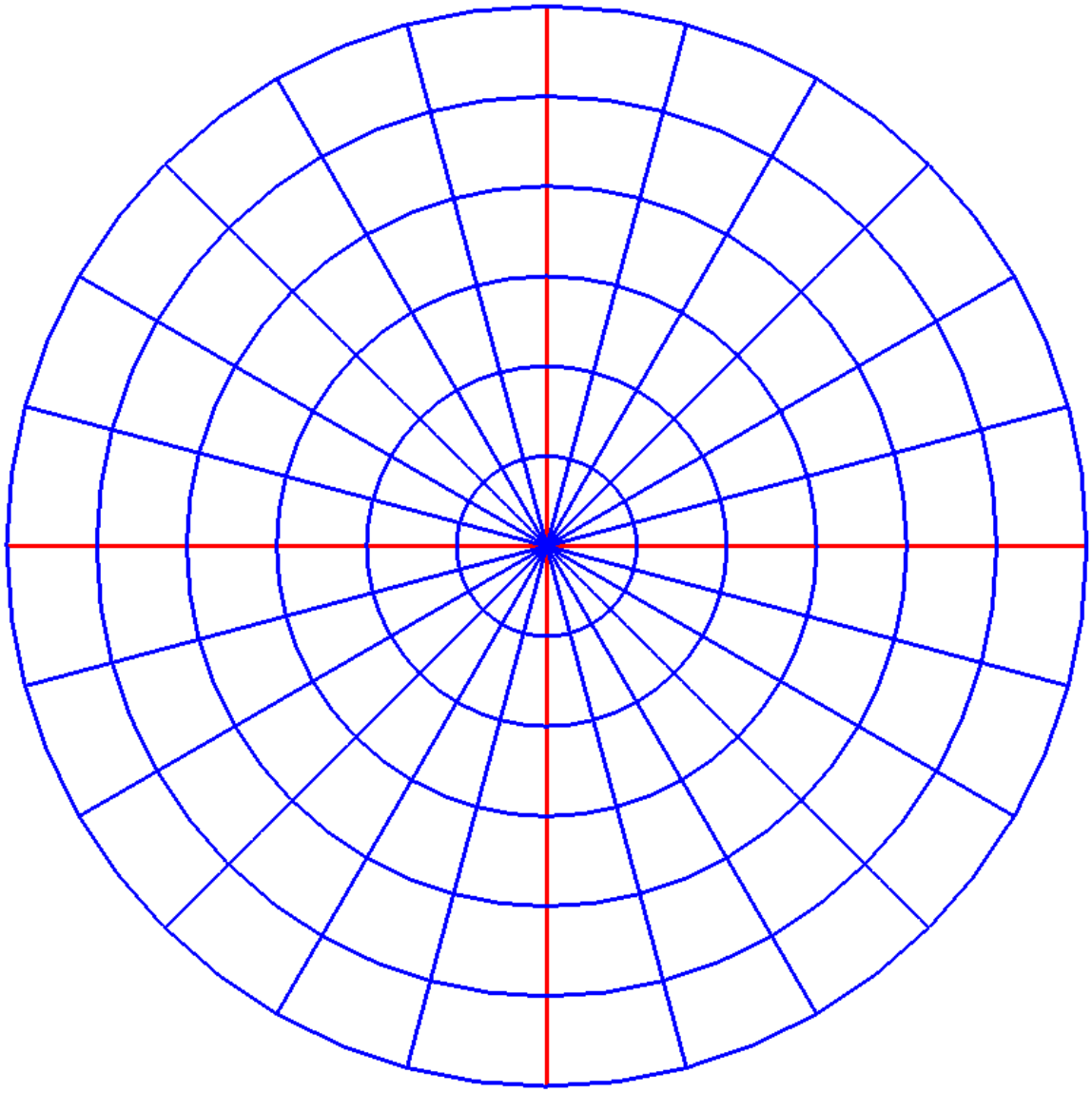
3. Herschel concluded that he could estimate the relative distance to the edge of the stellar system in a given direction by counting the number of stars he could see (through his telescope) in that direction and then taking the cube root of that number. Does this fit with your result above? Explain.

4. To test Herschel's method, run the *Herschel's Star Gages* program. (DO NOT change any of the options!) The window shows the view through one of Herschel's telescopes. You can use the slider to point the telescope in any direction within a single common plane. Luckily for you, the program also displays the number of stars in the field, so you don't have to count them yourself like Herschel did. Let's try to use Herschel's method to map out the distribution of stars in this system. Start by using the program to complete the table below. [Note: let your instructor know if you need help finding the cube root function on your calculator.]

Position Angle	**Star Count**	**Length** ($= \sqrt[3]{\text{Star Count}}$)
0°		
15°		
30°		
45°		
60°		
75°		
90°		
105°		
120°		
135°		
150°		
165°		
180°		
195°		
210°		
225°		
240°		
255°		
270°		
285°		
300°		
315°		
330°		
345°		

5. For each position angle, plot the location of the edge of the stellar system on the polar grid below (the radial curves are spaced by one unit, the degree markings begin at zero toward the right, with increments of 15 degrees in the counterclockwise direction). Connect the points you plot to trace out the boundaries of the stellar system.

6. Describe the general shape of the stellar system (at least for directions along this particular plane). Where is the Sun located in this diagram? Would you say the Sun is near the center of this star system?



7. NOW select Show Plot of Star Gages from the Telescope Options menu. In the new window, click Plot Data Continuously. Now drag the angle slider around to fill in the plot. Do the results shown in the plot show the same shape as your diagram? Describe any significant differences.

8. Now select Show 3D View of Star Systems from the Telescope Options menu. This displays a window showing the stellar system as viewed from the outside. From the Star System Options menu in this new window, select Show All Stars in System and Show Cone for Telescope's Field of View. [Note: the star system shown in the simulation is NOT what Herschel found. This is just an example to show how Herschel's star-gages work.] How does the 3D view compare to the plot you constructed from your star gages? Describe any significant differences.

9. As you have seen, Herschel's star gage method works pretty well as long as his assumptions are valid, as they were for the artificial star system in the simulation. But what if they are not valid, what happens then? Let's start by examining what happens if we can't see all the way to the edge of the Milky Way. In the Telescope Options menu, select Limit Telescope Viewing Distance (and make sure the other two options are still selected). This pops up a new slider that sets the maximum distance to which we can see. Set this value to 15 stellar units. Move the Angle slider around slowly until you have plotted the star gages in all directions (these new points should be shown in blue on the plot). Does the resulting star gage plot match the previous star gage plot? Does it match the actual distribution of stars in this example system? Explain why or why not.

10. Where does the Sun appear to be located within the star system, according to this new star-gage plot? Is that where it is *really* located within this star system?

11. Clear the data from the Star Gage Plot. Now let's see what happens if the stars in our system are not distributed uniformly. In the System menu (Telescope View window) select Nonuniform 1. Look at the Star System window. What is different about this system, as compared to the previous one?

12. Reset the d_{max} value to 60 stellar units, and then construct the Star Gage Plot as before. Does your Star Gage Plot correctly represent the shape of the stellar system? If not, why not?

13. Later in his career, Herschel observed many tightly packed clusters of stars through his giant telescopes. The regions around these tightly packed clusters had relatively few stars. Does the existence of these star clusters call into question either of the assumptions on which Herschel's star-gages were based? If so, which assumption and why?

14. Herschel also found that any time he viewed the Milky Way through a telescope with a larger aperture he was always able to see more stars than with a smaller aperture telescope. In addition, there was always a hazy whiteness in the background. Does this result call into question either of the assumptions on which Herschel's star gages were based? If so, which assumption and why?

15. Herschel's star-gage data indicated that the Milky Way was a cylindrical disk (or "grindstone") of stars, with the diameter of the disk 4 to 5 times greater than its thickness. This disk had a large cleft in one side, and the Sun lay near the center of the disk. Based on your answers to the last two questions, how much confidence should be placed in Herschel's star gages?

16. As mentioned above, Herschel's star-gages indicated that the Sun lay near the center of the Milky Way system. Maybe that is because we really are at the center of the Milky Way system, but we have seen another possible explanation for this result. What is this explanation? If this explanation is correct, is the Milky Way bigger or smaller than Herschel thought?