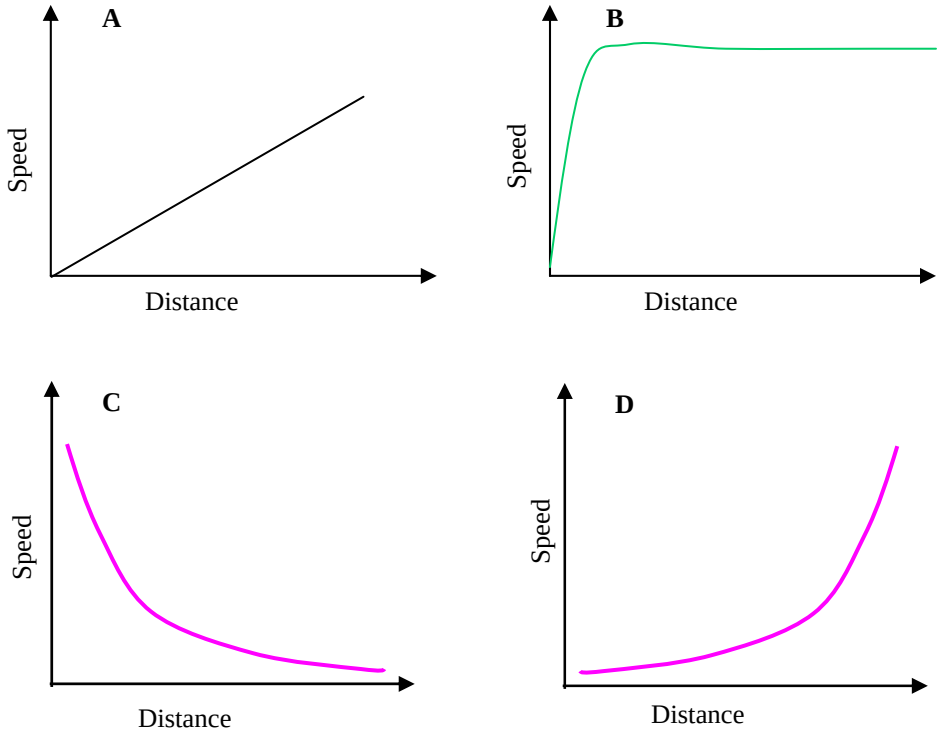
The stars, gas and dust in a galaxy rotate about the center of the galaxy. We would like to know exactly how to describe the rotation of all parts of the galaxy. In other words, we want to know if galaxies rotate like merry-go-rounds, or like planets orbit the Sun, or in some other way.

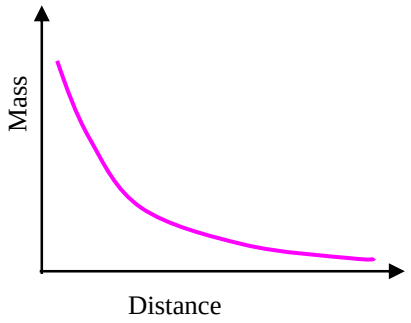
1. Below are four graphs that show speed versus distance from the center. Which of these graphs best represents how a plot would look for the speeds of points on a merry-go-round and which best represents how a plot would look for the speeds of the planets in our solar system?



2. Where is the majority of the mass in our solar system? (In what object?)

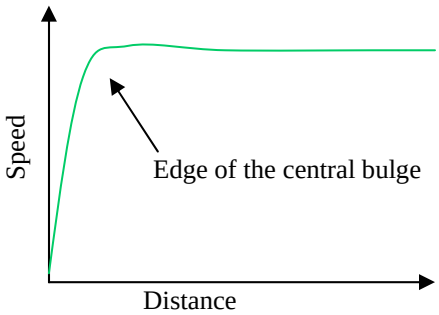
We know that the overwhelming majority of the mass of our solar system is in the Sun and that all the planets are gravitationally bound into orbits around the Sun. We also know that planets located closer to the Sun travel faster than planets further from the Sun. As a result, we find that the graph showing the rotational speed of the planets versus distance will look very similar to the graph showing the distribution of mass in the solar system. Namely that the amount of mass near the center of the solar system would be very high (due to the Sun) and as you move away the amount of mass found in any region gets smaller and smaller because the planets are separated by larger and larger distances.

This graph at right is produced by gathering the light from all the matter throughout the galaxy over ***all wavelengths*** in the electromagnetic spectrum. It shows how much mass is located at different distances in the galaxy based on the light coming from that matter.



At right is a graph showing the rotational speed for objects thought a galaxy versus the distance from the center of the galaxy to those objects.

3. Provide a detailed description of how the rotational speed of the galaxy changes (if at all) as you move away from the center of the galaxy.



4. Based on the rotation curve above, would you say that the mass of a galaxy is distributed with the overwhelming majority of mass located in the center? If not, explain how the galaxy's mass would be distributed.

5. Is your answer to question 4 consistent with the mass distribution graph shown above that comes from the light we observe from matter in the galaxy? (Do they agree?) If not, which of the two descriptions of the mass distribution of the galaxy do you believe is more correct? Why?

6. The graph showing the distance from the center of the galaxy versus the total amount of light emitted at all wavelengths implies that mass is distributed such that
    a. like our solar system, with the overwhelming majority of the mass located at the center
    b. the overwhelming majority of the mass is located only in the outermost parts
    c. little mass in the center of the galaxy, with the rest of the mass distributed evenly throughout the rest of the galaxy
    d. little mass in the center, with a slowly increasing amount of mass as you move outward
    e. little mass in the center, with the overwhelming majority of the mass about halfway out from the center and very little mass in the outermost parts

7. The rotation curve of a galaxy indicates that the speed of things in the galaxy varies in the following way
    a. things near the center of the galaxy go fastest with the speeds of things decreasing steadily from the center outward
    b. things near the center of the galaxy go slowest with the speeds of things increasing rapidly from the center to the outermost parts
    c. things near the center of the galaxy go slowest with the speeds of things increasing rapidly, but becoming constant within a small distance from the center, so that all things throughout the rest of the galaxy have nearly the same speed.
    d. things near the center of the galaxy move slowest with the speeds of things steadily increasing from the center outward
    e. things near the center of the galaxy move slowest with the speeds of things increasing rapidly until they reach a maximum speed about halfway out, then speeds decrease as you move further outward

8. The interpretation of the rotation curve of a galaxy is that the mass in a galaxy is distributed such that
    a. like our solar system, with the overwhelming majority of the mass located at the center
    b. the overwhelming majority of the mass is located only in the outermost parts
    c. little mass in the center of the galaxy, with the rest of the mass distributed evenly throughout the rest of the galaxy
    d. little mass in the center, with a slowly increasing amount of mass as you move outward
    e. little mass in the center, with the overwhelming majority of the mass about halfway out from the center and very little mass in the outermost parts

9. The interpretation for the distribution of mass in the galaxy is different depending on whether you consider how mass is arranged based on the light we receive or the rotational speeds we measure. Which of the following ideas do you think best resolves this conflict?
    a. We should consider only the information from light curves because gravity doesn't work in galaxies like it does in the rest of the universe, which leads to an incorrect interpretation from the rotation curve.
    b. We should consider only the information from the rotation curves because dust may be blocking the light coming from things in galaxies so that the light curve does not accurately trace the mass.
    c. We should consider the information from the rotation curve which suggests that there is matter distributed uniformly throughout a galaxy. This matter has normal gravitational interactions with matter we can observe and causes all the things in a galaxy beyond the center to move with about the same speed. The information from the light curve implies that this matter has not been observed using light.
    d. We should consider only the information from the light curve because there is an extremely large black hole in the centers of galaxies pulling things into the center causing things to only move slowly when they get near the black hole.

Scientists now believe that about 90% of all the mass in a galaxy has not been observed at any wavelength. This matter is distributed uniformly throughout the galaxy, including the halo. We call this matter "dark matter".

10. Using the information above, check your answers to questions 8 and 9.