

Astronomy 2115

Fall 2023

Homework #6

Due Thursday, Oct 24 in class

For full credit you must write your solutions neatly and include all work. Do not forget the units.

- 1) How do astronomers conclude that vast quantities of dark matter surround our Galaxy? How is this dark matter distributed in space?
- 2) What is the winding dilemma? What does it tell us about the nature of the spiral arms?
- 3) The disk of the Galaxy is about 50 kpc in diameter and 600 pc thick. (a) Find the volume of the disk in cubic parsecs. (b) Find the volume (in cubic parsecs) of a sphere 300 pc in radius centered on the sun. (c) If supernovae occur randomly throughout the Galaxy, what is the probability that a given supernova will occur within 300 pc of the Sun? If there are about 3 supernovae/century in our Galaxy, how often, on average, should we expect to see one within 300 pc?
- 4) Sketch the rotation curve you would obtain if the Galaxy were rotating like a rigid body.
- 5) The mass of our Galaxy inside the Sun's orbit is calculated from the radius of the Sun's orbit and its orbital speed. By how much would this estimate be in error if the calculated distance to the galactic center were off by 10%? By how much would this estimate be in error if the calculated orbital velocity was off by 10%? Explain.
- 6) A gas cloud located in the spiral arm of a distant galaxy is observed to have an orbital velocity of 400 km/s. If the cloud is 20 kpc from the center of the galaxy and is moving in a circular orbit, find (a) the orbital period of the cloud and (b) the mass of the galaxy contained within the cloud's orbit.
- 7) Suppose an X-ray binary is found in which the visible star is a $12 M_{\odot}$ red giant, the orbital period is 3.65 days, and the semimajor axis is 0.12 AU. Show whether the companion likely to be a neutron star or a black hole.
- 8). A cosmic ray (an electron or nucleus moving at speeds close to the speed of light) travels across the Milky Way at a speed of 0.98 times the speed of light. If the Milky Way is 30,000 pc across, how long does this journey take in our (essentially stationary) frame of reference and the cosmic ray's frame of reference, in years?
9. The mass of the Interstellar Medium of the Galaxy is currently about $5.5 \times 10^9 M_{\odot}$.

Every year, on average, about $2 M_{\odot}$ of gas are turned into stars, so we say the star

formation rate is $2 M_{\odot} \text{ yr}^{-1}$. (a) At this rate, how long will it take to convert all of the

remaining Interstellar Medium into stars, in billions of years? (b) If the age of the Galaxy's disk is 10 billion years, does your answer indicate that we are near the beginning or the end of the disk's star formation lifetime? (c) Some fraction of the mass turned into stars is returned to the Interstellar Medium by winds from stars, Planetary Nebulae, and supernovae. Will this lengthen or shorten the time you found in (a), and why?

10. Which is more likely to have a blue color, a spiral galaxy or an elliptical galaxy? Explain why.

11. What is the Hubble law? How can it be used to determine distances?

12. What observations suggest that present day galaxies formed from smaller assemblages of matter?

13. The average radial velocity of galaxies in the Hercules cluster is 10,800 km/s. (a) using $H_0 = 73 \text{ km/s/Mpc}$, find the distance to the Hercules cluster in Mpc. (b) How would your answer to (a) differ if the Hubble constant had a smaller value?

14. In the spectrum of the galaxy NGC 4839, the K line of singly ionized calcium has a measured wavelength of 403.2 nm. (a) What is the redshift of this galaxy? (b) Determine the distance to this galaxy in Mpc using $H_0 = 73 \text{ km/s/Mpc}$.