Homework #8, Astro 1

Due November 29th, 2019

1. (U11-21.27) **Box 21-2 in U11 & Box 21-1 in U10** A spaceship flies from Earth to a distant star at a constant speed. Upon arrival, a clock on board the spaceship shows a total elapsed time of 8 years for the trip. An identical clock on Earth shows that the total elapsed time for the trip was 10 years. What was the speed of the spaceship relative to Earth?

2. (U11-21.30) **Box 21-2 in U11 & Box 21-1 in U10** An astronaut flies from Earth to a distant star at 80% the speed of light. As measured by the astronaut, the one-way trip takes 15 years. (a) How long does the trip take as measured by an observer on Earth? (b) What is the distance from Earth to the star (in light-years) as measured by an Earth observer? As measured by the astronaut?

3. (U11-21.60) **Box 21-3 in U11 & Box 21-2 in U10** What is the Schwarzschild radius of a black hole whose mass is that of (a) Earth, (b) the Sun, (c) the supermassive black hole in NGC 2461 (Section 21-7 in U11 & Section 21-5 in U10)? In each case, also calculate what the density would be if the matter were spread uniformly throughout the volume of the event horizon.

4. (U11-21.63) **Box 21-3 in U11 & Box 21-2 in U10** Prove that the density of matter needed to produce a black hole is inversely proportional to the square of the mass of the hole. If you wanted to make a black hole from matter compressed to the density of water (1000 kg/m^3), how much mass would you need?

5. (U11-22.26) 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 20,000 pc 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.

6. (U11-22.41) **Box 21-2 in U11 & Box 21-1 in U10** The stars S0-2 and S0-19 orbit Sagittarius A* with orbital periods of 14.5 and 37.3 years, respectively. (a) Assuming that the supermassive black hole in Sagittarius A* has a mass of 4.1×10^6 $M_\odot$, determine the semimajor axes of the orbits of these two stars. Give your answers in AU. (b) Calculate the angular size of each orbit's semimajor axis as seen from Earth. (See Section 22-1 for the distance from Earth to the center of the galaxy.) Explain why extremely high-resolution infrared images are required to observe the motions of these stars.

7. (U11-22.46) 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 volume of the galaxy, what is the probability that a given supernova will occur within 300 pc of the Sun? If there are about three supernovae each century in our galaxy, how often, on average, should we expect to see one within 300 pc of the Sun?

8. (U11-22.47) **Box 19-2** An RR Lyrae star whose peak luminosity is 100 $L_\odot$ is in a globular cluster. At its peak luminosity, this star appears from Earth to be only 1.47×10^{-18} as bright as the Sun. Determine the distance to this globular cluster (a) in AU and (b) in parsecs.