Homework #7

ASTR 1020

Introductory Astronomy II: Stars & Galaxies *(John Bally)*

Due Tuesday, 7 April 2009

NAME:______________________ Student ID: ______________________

A] Stages of Star Formation.

1. **The volume of interstellar gas from which our Sun and Solar System formed**.

Astronomers have determined that stars form from "dense" molecular cloud cores in Giant Molecular Clouds (GMCs). Typical densities of observed cores in GMCs are about n(H) ~ 10^4 atoms of hydrogen in each cm^{-3} . The mass M, contained within a spherical volume of radius R is given by $M = (4/3)\pi r^3 n(H) m_H$ (here we assume that the cloud core consists entirely of atoms of hydrogen, H). If the mass of the Solar System is about the mass of the Sun, M(Solar System) = 2 x 10^{33} grams, what was the radius of the cloud core from which the Solar system and Sun formed? (Note: The most massive planet, Jupiter, has only about 0.001 times the mass of the Sun… thus, to about 1% precision, nearly all of the mass in the Solar System is in the Sun.)

2. Describe, using a combination of sketches and words, how the gravitational collapse of a cloud core (such as the one above) leads to the birth of a star, and possibly a planetary system. How long does each major stage take (in hundreds of thousands, or millions of years)?

B] Structure of the Milky Way Galaxy:

Sketch the major constituents of our Milky Way galaxy. Give approximate dimensions (in light years or Parsecs) for each component and describe what types of stars or gas each is made from.

C] Rotation Curves and the Mass of the Milky Way.

1. Measurements of the motion of our Solar System with respect to distant galaxies and quasars have shown that we orbit the center of our Galaxy with a speed of about V = 250 km / second. Astronomers have also found that the center of our Galaxy is located at a distance of 8.5 kilo-parsecs from us. Thus, the distance between the Sun and the Galactic center is 8.5 x 10^3 pc. A parsec (1 pc) contains 3.086 x 10^{18} cm. Calculate the circumference of the Sun's orbit about the Galactic center (hint: $C = 2 \pi R$ where R is the radius of the Sun's orbit, here assumed to be circular).

2. How long is a "Galactic year" (e.g. the time it takes for our Solar System to make one round trip around the Galaxy)? Hint: The time it takes to travel a distance $C = 2 \pi R$ at velocity V is given by $t = C/V$ where t is in seconds if C is in cm and V is in cm/sec.

3. Use Newton's Law to estimate the mass of our Galaxy interior to the Sun's orbit about the center of the Milky Way. Hint: The orbital speed of a body in circular motion in the gravitational field of an object of mass M is given by $V_{orbit} = (GM/R)^{1/2}$ where $G = 6.78 \times 10^{-8}$ is Newton's gravitational constant in c.g.s units, M is the mass about which the object is orbiting, and R is the radius of the orbit. Express the mass of the Milky Way galaxy in grams (the c.g.s unit of mass) AND in terms of the mass of our Sun (= $2.\times 10^{33}$ grams).

4. As we will see during the next weeks of lecture, the orbital speeds of stars about the centers of their own galaxies is approximately constant. In other words, the orbital speed does NOT decrease with distance form the centers of galaxies. This is VERY different from the orbital speeds of planets which decrease a $R^{-1/2}$ with increasing distance, R, from their parent stars. What does this imply about the amount of mass enclosed within the orbits or stars in a galaxy? Hint: consider a star that is 100 pc, then 1,000 pc, and finally 10,000 pc from the center of a galaxy. What can you conclude about the mass enclosed in each orbit if the orbit speed is the same for each distance from the galactic center?

D. Supernovae , Stellar Corpses. Densities and escape speeds.

1.) What is the difference between a Type I and a Type II supernova?

2.) A typical white dwarf has a radius of R = 10,000 km and mass comparable to the Sun ($M_{Sun} = 2 \times 10^{33}$ grams). Calculate the average density (density = Mass / Volume). Give your answer in grams per cubic centimeter. Recall that the volume of a sphere is Volume = $(4/3)\,\pi\, R^3$.

3.) Calculate the escape speed from the surface ($V_{esc} = [2\,GM / R]^{0.5}$). Give your answer in km/sec.

4.) A typical neutron star has a mass of about 1.0 M_{Sun} and a radius of 10 kilometers. Calculate the average density (density = Mass / Volume). Give your answer in grams per cubic centimeter.

5.) Calculate the escape speed from the surface ($V_{esc} = [2\,GM / R]^{0.5}$). Give your answer in km/sec.

6.) The Sun has a radius of 7×10^{10} cm. Calculate the average density. Give your answer in grams per cubic centimeter.

7.) Calculate the escape speed from the surface of the Sun. Give your answer in km/sec.

8.) How do the above escape speeds compare to the escape speed from the Earth's surface?