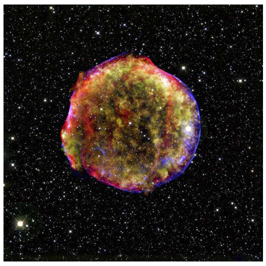
Astronomy 350 Fall 2011
Homework #2

Due in class: Friday, Sept. 9

1. *Supernova Archæology* As discussed in class, the great astronomer Tycho Brahe in the year 1572 discovered a "new star" which in fact a supernova, the explosion of a dying massive star. This was one of the closest supernova explosions in recorded history. This object is known as SN 1572 or Tycho's supernova, and long ago faded from view in visible light. But the supernova remains bright in X-rays, which were used to make the image at right, taken by the NASA's *Chandra* X-ray telescope in the year 2009.



chandra.harvard.edu/photo/2009/tycho/

   (a) [**5 points**]. The measured radius of the supernova is 8 parsec, where 1 parsec = 3.1×10^{13} km. The age of the supernova is just the time between the Tycho's discovery and the *Chandra* observation. Using these, find the speed at which the supernova is expanding, in km/sec. Comment on your answer. Also compare your answer to the speed of light, 3.0×10^5 km/s.

   (b) [**5 points**]. The X-rays coming from the supernova have wavelengths around $\lambda = 4 \times 10^{-10}$ m. Using this, find the present temperature of the supernova. How does this compare to the Sun's surface temperature of 6000 K and central temperature of 16 million K?

   (c) [**5 points**]. In parts (a) and (b), we have found present-day values for the speed and temperature of the supernova. In fact, the supernova debris is not in a vacuum, but rather the material from the explosion has continually been expanding and running into and sweeping up interstellar gas. Given this, do you expect that the speed from part (a) is higher or lower than the speed in the past? And do you expect the temperature from part (b) to be higher or lower than it was in the past?

2. *Newton's Laws and Snarky Science Fiction Criticism.* [**5 points**]. In a certain science fiction story written for youngsters, an accident causes an untethered astronaut to float away from his spaceship. Fortunately, he manages to return to safety to the ship by making swimming motions with his arms. What is wrong with this? What is the difference between swimming in water and "swimming' in space? In your explanation, be sure to be clear about which of Newton's laws are relevant.

3. *Newtonian Gravity and Acceleration.*

   (a) [**5 points**] An object undergoing constant acceleration a for a time interval Δt seconds has its velocity change by an amount $\Delta v = a\Delta t$. Near the surface of the Earth, the acceleration of gravity is constant and equal $g = 10$ m/s^2. Using this, find the time it take for an object, released from rest, to go from 0 to 60 mph; note that

$$1 \text{ mph} = 1\frac{\text{mile}}{\text{hour}} = 1\frac{\text{mile}}{\text{hour}} \times \frac{1.6 \text{ km}}{1 \text{ mile}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ hour}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 0.45 \text{ m/s} \quad (1)$$

Nowadays, a really good, expensive sportscar can go from 0 to 60mph on a level track in 3.5 seconds. Would it accelerate faster if it drove off the top of a tall building?

(b) [**5 points**] The Moon orbits the Earth at a distance of $r_{\text{Moon}} = 385,000$ km $\approx 60\text{R}_{\text{Earth}}$, that is, about at 60 Earth radii. Find the gravitational acceleration of an object at the Moon's distance from the Earth. How fast could an object with this acceleration go from 0 to 60 mph?

4. *Weighing Masses by Watching Orbits.*

(a) [**5 points**] By dropping ordinary household objects in ordinary households (and laboratories) we find the acceleration due to gravity at the Earth's surface is $g = 10$ m/s^2. Use this result, the radius of the earth $R = 6400$ km $= 6.4 \times 10^6$ m, and the laboratory value $G = 6.7 \times 10^{-11}$ $\frac{\text{m}^3}{\text{kg s}^2}$ to calculate the mass of the Earth.

Comment on how this method is similar to and different from the usual method of weighing an object (such as yourself!) on a scale.

(b) [**5 points**] Now imagine that the Earth is made of rocks, which have a density (mass per unit volume) $\rho_{\text{rock}} \approx 5000$ kg/m^3, that is, a cube 1m on a side of rock would have a mass of 5000 kg or about 5 tons. Calculate the volume of the Earth given it's measured radius, and use the density of rock to estimate the Earth's mass this way. How does this result compare with that of part (a)?

(c) [**5 points**] Now consider the motion of objects in the solar system. Imagine that we double the Sun's mass, but all orbits retain the same distances and shapes. Without doing a detailed calculation, use Newton's laws of motion and gravity to explain whether you expect the planets to move faster or slower than they do in the real Solar System?

(d) [**5 points**] As seen in the preview of Lecture 1, at the center of our Galaxy, we observe stars orbiting a central object which is invisible in some wavelengths. Explain (but you don't need to calculate–yet!) how we can use these orbits to determine the mass of the central object. Be clear about what data is needed (i.e., semi-major axis? period? orbital speed?).

(e) [**5 bonus points**] In galaxies, including our own, we can determine the orbit speeds of stars at various distances from the galaxy center. If we know the speed at a particular distance, this gives a measure of the mass *interior to* that distance (i.e., the mass "enclosed" by the star's orbit). Explain how we can use data on orbits at different distances to determine the mass distribution of a galaxy.