Astronomy 111 **Fall 2017**

Homework Assignment #6

(remember: no ragged edges; write on one side of page only; leave room for comments/corrections)

due in class Tue. 11/21

1. a) Estimate the central pressure inside a 1.5 $M_\odot$ neutron star whose radius is 15 km. Use the approximation of the hydrostatic equilibrium equation:

$$\frac{dP}{dR} = -g\rho \rightarrow P_{central} \sim g\rho R$$

where *g* is the gravitational acceleration at the surface, and ρ is the average density. Express your answer in *Pascals* (N/m^2). As a point of comparison, recall that the sea-level pressure on Earth is 10^5 Pascals.

b) Do the same for a 1.5 $M_\odot$ white dwarf whose radius is 10^4 km and compare.
c) Finally, do this for a 1.5 $M_\odot$ main sequence star whose radius is 1.5 $R_\odot$.

2. How is *synchrotron radiation* produced? What are the characteristics that distinguish it from thermal blackbody radiation?

3. Consider a 1$M_\odot$ **neutron star** with a radius of 15 km, rotating 100 times per second.
a) Calculate the gravitational acceleration, g, at the surface.
b) Calculate the centripetal acceleration at the equator, and compare with g.
c) How fast (in rotations per second) would the neutron star have to be rotating for the two accelerations to be equal? What do you think would happen then? (Then see #4, below for the white dwarf story.)

4. If a star rotates too rapidly, it will break apart. One way to think about this is to say that, in order to remain bound, the rotational speed of a particle on the surface of a star must be less than the circular orbital speed at that radius.
a) For a star of mass M, and radius R, write down the expressions for the rotational speed of a particle on the star's equator, and for the circular orbital speed. Now equate these speeds and solve for the relationship between P and R. Where have we seen this equation before?
b) Consider a **white dwarf** of mass 1 $M_\odot$ and R=10^4 km. What is the value of P you get from the equation in part a? This represents the *minimum possible period* that the white dwarf can have; if it rotated any faster, it would break up. How many rotations per second does this correspond to?
c) Could rotating white dwarfs explain all pulsars? If not, what else might you suggest?

5. The **tidal force** is a differential force: *dF/dr*, which the difference between the force at one distance and the force at another. If *dr* happens to correspond to, say, your height, then the tidal force is the difference in gravity felt by your head and by your feet. This amounts to a stretching force, since one end is pulled harder than the other end. Calculate the tidal force experienced by your body at the surface of a neutron star. Assume that the neutron star has a mass of 1.5 $M_\odot$ and a radius of 10 km. Assume that your mass is100 kg and that your *dr* (height) is 2 m when standing and 0.5 m when prone.

   a) What is the tidal force when you are standing?

   b) What is the tidal force when you are prone?

   c) Based on the above, what do you recommend for minimizing the tidal force?

   d) Compare the tidal **acceleration** you feel at the surface of that neutron star with what you feel at the surface of the earth., i.e., divide your answer in part a by your assumed 100-kg mass, and then divide that by $g_\oplus$ to calculate how many "g's" you feel on the neutron star. (You might be interested to know that the maximum limit for the human body, for a very brief duration, is 100 $g_\oplus$.)

Also:
Kutner Ch. 10: Problem 1

Kutner Ch. 11: Problems: 1, 7