PHYS-3301 Homework 11 Due 27 Nov 2013

This homework is due in the dropbox outside 2L26 by 11:59PM on the due date. If you wish to turn it in ahead of time, you may email a PDF or give a hardcopy to Dr. Frey.

1. **Doppler Broadening** *based on Barton 13.4*

   The sun emits a spectral line of wavelength λ. When we observe the sun, this line is broadened because some parts of the sun rotate toward the earth and some rotate away. What is the ratio of the difference in wavelengths observed from opposite points on the sun's equator to the line's emitted wavelength? The circumference of the solar equator is 4.4×10^6 km, and the sun's equator rotates once every 25 days. You may make any appropriate approximations and work to 2 significant figures.

2. **Fast Orbit**

   The star S-2 orbits the (presumed) black hole at the center of our galaxy with the highest known orbital speed of any astrophysical object. Consider a simplified model of its orbit as a perfect circle with a period of $T \approx 15$ yr and orbital speed of $u \approx 0.02c$. Also suppose that the earth is in the same plane as S-2's orbit at a distance much greater than the size of the orbit. S-2 emits a spectral line of frequency $\omega \approx 8 \times 10^{14}$ Hz; what is the difference of the observed frequency at earth to the emitted frequency as a function of emitted time t? Let $t = 0$ be the distance of closest approach between S-2 and earth. Give the formula first in terms of variables and then calculate numerical values. Work to 1 significant figure. You may safely assume that the earth's orbital speed around the sun and the sun's orbital speed around the center of the galaxy are negligible.

3. **Atmospheric Pressure**

   This isn't a terribly good approximation, but assume that the earth's atmosphere is made of a single type of molecule of mass m and has constant temperature T throughout. Using the Boltzmann factor, argue that the atmospheric density and pressure are exponential functions of height near the earth's surface. *Hint:* It *is* a good approximation to assume that the earth is flat and that the gravitational acceleration g is constant. *Another Hint:* Pressure is given by the integral $p = \int \rho g dy$ where y is height.