Astronomy 16 – Modern Astrophysics
Fall 2014
Week 7

Questions for the week:

1. What is the equilibrium temperature of an object heated by Sunlight and re-radiating thermal energy, that's 1 AU from the Sun? (Carried over from two weeks ago.)

   By the end of the week, you will be able to answer this question. Actually, you can already…you might want to start thinking about it.

Topics:

   Nuclear reactions: CNO cycle, triple-alpha
   Heat transport
   (Virial theorem)
   Spectral classification of stars
   Luminosity classes
   The Hertzsprung-Russell diagram (HRD)
   The magnitude system, include the color index

Reading:

   For some of Tuesday's class, we'll be finishing the stellar structure material, so I've left some of the reading and topics/questions from last week that are relevant.

   Read sec. 15.4, which summarizes the individual stellar structure equations (and discusses neutrino observations that

observationally confirm our understanding of what's going on at the center of the Sun). Read the Appendix too. It's short, and shows you how to calculate the time it takes a photon produced at the Sun's center to make it to the Sun's surface.

Finally, you can review the Virial Theorem from the very end of Ch. 3. It is relevant when we consider the conversion of gravitational energy to heat and light in a contracting star. (We may put off discussion of this, again.)

After spending a little time on each of the above topics, we'll move on to the surfaces of stars and observable properties of stars. To prepare for that, please read all of Ch. 14 (it's short), starting by skimming 14.1, which is about HSEQ and should be a review for all of you. Then move on to spectral classification (sec. 4.2), which was a revolutionary development in early 20th Century astronomy (and is basically an application of the Boltzmann plus Saha equations – think back to our Wednesday night discussion of the temperature-dependence of the level population of neutral hydrogen with its electron in the n=2 state. Then read about luminosity classes (sec. 14.3), which are an application of line broadening. And then in sec. 14.4, read about the Hertzprung-Russell diagram, which is the way we organize our understanding of stellar astrophysics and stellar evolution.

We will next move on to Ch. 13 (material to be discussed the second half of Thursday's class). You've already read 13.1 (parallax) and the first part of 13.2 (inverse square law). You can review this material and then start reading new material at the bottom of p. 310 (the magnitude system) and continue on through the end of sec. 13.4 (p. 321). We'll read the end of Ch. 13 (about binary stars) for the following week.

Important concepts and related facts to keep in mind as you re-read, and make sure you can answer while/after you've done the reading. We will discuss all of these in class this week.

From last week:

Take a careful look at the nuclear reaction chains (Figs. 15.5, 15.6). Make sure you understand what each symbol means. Is there any net production or destruction of C, N, or O in the CNO cycle?

Why should the CNO cycle operate in higher mass stars (while the p-p chain operates in lower mass stars)?

What's the "triple alpha" process? Why does it require even higher pressure than even the CNO cycle?

When you look at the stellar structure equations (p. 369), where is all this information about nuclear physics hidden?

Looking at the radiation transport equations on p. 369, note that I asked you only to skim the relevant sections. But you should be able to describe in words what convection is (what physical processes are going on in a convecting fluid) and you should think about why convection naturally starts when radiation can't efficiently transport heat. Try to analyze why a boiling pot of water on the stove transports heat from the bottom to the top of the water by convection. Don't forget to think about what sort of wavelength the light has that's generated from the heat at the bottom of the pot. And it might help to know that water is very

good at absorbing infrared light. It has a large cross section in the infrared.

When you look at the radiation transport equation, can you draw parallels to Ohm's law? What plays the role of the voltage difference? What plays the role of the current? Of the resistance?

Finally – about the virial theorem – consider a gravitating system in equilibrium ("virialized") that consists only of the Earth and a small satellite in a circular orbit. To raise the satellite to a higher orbit, work must be done against gravity (you want to move it higher up in the gravitational potential well). But, if you look at Kepler's third law, you see that larger orbits have smaller velocities, so the satellite in its new, higher orbit will have less kinetic energy than it originally did. So maybe we can get to the higher orbit "for free" by simply converting KE to PE without having to fire the satellite's rockets and expend additional energy. What does the virial theorem tell us about this? What fraction of the work against PE will the change in KE do for us?

New for this week:

Once again, can you explain the physics behind the trends of hydrogen Balmer absorption line strength vs. stellar surface temperature based on basic LTE physics?

Can you explain the physics behind the luminosity class designation? All else being equal, will a star with a bigger radius have broader or narrower absorption lines in its spectrum?

Looking at the HR diagram (HRD), how can you figure out the radius of a star that's plotted on it? Where in the HRD are the super-giants? And where are the smallest stars (white dwarfs)?

What information, aside from the measured flux, do you need to figure out the apparent magnitude of a star? What about the absolute magnitude? Do you see how the distance modulus (eq. 13.22) is really just an expression of the inverse square law?

The color index, such as B – V, is really the ratio function for the Planck function problem on the last homework. Can you explain how the *difference* between two measured magnitudes in two different filters corresponds to the *ratio* of the Planck function evaluated at two different wavelengths?