Astrophysics Problem Set #7

Due Friday, October 23 at 4pm

ASSUMED READING: Before starting this homework, read R&P Chapter 6 (focus on sections 1 and 5) and Chapter 13 Sections 1 and 2.

1. Explain why the inverse square law of light relating flux, luminosity, and distance

   $$F = \frac{L}{4\pi d^2}$$

   has this relationship, where F is flux, L is luminosity, and d is distance from the light source. In essence, I am asking for a brief "proof" that given the definitions of flux and luminosity you have already worked on, that for light streaming away in all directions from a light source (so not like a laser, but light a star), that this equation must be the relationship between flux and luminosity. **NOTE:** See the last problem set solutions if you had trouble with the definitions of flux and luminosity.

2. For what astronomical purposes would one use a telescope having a long focal length and a large f ratio? **HINT:** In writing up your answer, you may want to describe the properties of images generated by such a telescope compared to a low f ratio telescope.

3. Some questions about the *Hubble Space Telescope.*
   - **a.** What is the theoretical angular resolution of the *Hubble Space Telescope* (objective diameter of D = 2.4 m) at λ = 2000 nm (infrared)?
   - **b.** Considering this answer, why would it ever be advantageous to observe in the infrared with the Hubble Space Telescope versus using the Keck telescopes (objective diameter 10.0 m) in Hawaii?

4. "Background-limited" means the flux from the star is not the major source of error since there is more flux from the night sky entering the detector (and as such, it dominates the uncertainty in the counts). Specifically explain how you would detect a star that is contributing only 1% of the flux compared to that of the night sky is to the CCD detector at the pixels the star is hitting.

5. **[R&P 6.3 clarified]** With the D = 2.4 m telescope at the MDM observatory, we can obtain a spectrum of a particular star with signal-to-noise ratio S/N = 100 in t = 20 min when the atmospheric seeing is average ($\theta = 1''.0$). How long would it take me to take the same data with the Keck Telescope (D = 10.0 m) with excellent seeing ($\theta = 0''.4$)? You can assume since we are using a big telescope, our target is faint objects and we are operating in the "background-limited" regime. You can also assume that if the parameter was not stated as changed here, it is the same between the two telescopes (*e.g.* - You can assume the same atmospheric transparency, quantum efficiency, etc.).

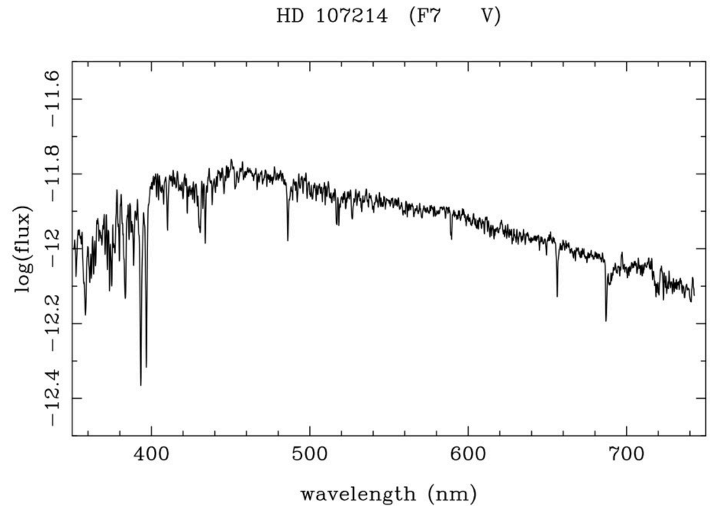
6. **[R&P 6.4 Variant]** A CCD detector is mounted at the focus of the SMARTS Consortium f/10.7 reflecting telescope with a D = 1.00 m mirror on Cerro Tololo, a mountain in Chile. The CCD chip contains 4064×4064 pixels, with each square pixel being 15μm on a side.
   a. What is the area (in square arcseconds) of the sky that is imaged on a single pixel?
   b. What is the area (in square arcminutes) of the sky that is imaged on the entire chip? Would the image of the full Moon fit into the chip? **[NOTE:** The Moon's angular diameter is about 0.5˚.]
   c. How many separate exposures would be required to cover the entire celestial sphere? **HINT:** Determine the surface area of the sky in square degrees by noting that $\Sigma = 4\pi(radians)^2$ is the surface area of the sky in steradians (1 steradian = 1 square radian).

7. **[R&P 6.5 Tweaked]** Suppose that you want to see stars that are as faint as possible in the ***background-limited*** case. The Astronomy Fairy gives you a choice: either she can increase the quantum efficiency of your retina from q = 0.1 to q = 1, or she can double the maximum pupil size of your eye while guaranteeing diffraction-limited angular resolution. *Clearly explain what effect each of the Astronomy Fairy's options has on your lower limiting flux, F_λ.* Which of these choices would produce a lower F_λ? Explain your choice.

8. Why is there a limit to the distances that we can determine the parallax? What benefit would there be to placing a satellite in orbit around Jupiter to make parallax measurements?

9. Let's consider some observations of a single star, HD 107214, selected somewhat at random by your professor from a paper by Jacoby, Hunter, and Christian (1984).[1]

a. To the right is the low-resolution spectrum for HD 107214 from Jacoby, Hunter, and Christian's paper [**NOTE:** Ignore the vertical flux units in the spectra, they are not in units we have discussed in class.] Estimate the surface temperature of this star, clearly explaining the technique you used.



b. More recently the parallax of this star was measured by the Hipparcos satellite to be 11.88±1.38 milliarcseconds, estimate the star's distance (including uncertainty). **NOTE:** To properly deal with uncertainty, you will have to compute the distance in the case of both the upper and lower limit of the parallax angle as well as the optimal estimate for the parallax angle.

c. What else would you need to know about this star to determine its radius?

[1] "A Library of Stellar Spectra",Jacoby, George H., Hunter, Deidre A., Christian, Carol A. 1984, Astrophysical Journal Supplement Series, **56**, 257.