ASTR 306 Homework #3 (Spring 2024)

1. Sky Background (15 points)

Imagine you are taking spectra of stars using a fiber-fed spectrograph with fibers that have an angular diameter projected on the sky of D (in arcseconds). Assume the typical seeing is about 1.2 arcsec FWHM, and in the red part of the spectrum the night sky has surface brightness of μ_R = 20.8 mag/arcsec^2. Plot the fraction of *total* light (star + sky) in the aperture that comes from a star of magnitude m_R=16 as a function of fiber diameter D, for $D = 0 - 5$ arcsec. Overplot similar curves for stars of magnitude m_R=17, 18, and 19. Why would using big fibers be good for doing spectroscopy? Why would they be bad? Why would small fibers be good? Why would they be bad? If the Sloan Digital Sky Survey used fibers with a 3 arcsecond diameter, what fraction of the total light in the SDSS fibers came from the star, for stars of m_R=16, 17, 18, 19?

Helpful hint: Remember in HW #2 you worked out the "aperture correction" needed to relate the aperture magnitude of a star (i.e., the amount of light within an aperture of size r) to its total magnitude. See your solutions or mine….

2. Spectroscopic setup (15 points)

Arriving at the observatory for my spectroscopic observing run, I find that the only grating I have available is a 300 line/mm grating blazed at 8000Å in the first order. But I want to observe in the blue from 3500Å to 5000Å.

- How could I best do this and what precautions should I take?
- At what angle will 4000Å light be found relative to the grating normal?
- What is the blaze angle of the grating?
- What camera focal length should I use to fit the spectrum on a CCD 20mm wide?
- If the 2 arcsecond wide slit projects to 66 microns on the detector, what is the spectral resolution (give it in terms of both $\Delta\lambda$ and R)?
- What is the velocity resolution (in km/s)?

For this problem, assume the grating surface is normal to light from the collimator (in other words, $\alpha = 0$).

3. Spectrograph design (15 points)

You are designing a spectrograph for a 5-meter diameter telescope working with a focal ratio of f/10. The collimator is 6 inches in diameter, and the spectrograph slit is 1 arcsec wide and projects to 30 microns (3pixels) on the detector. An astronomer asks you what spectral resolution they will have with a 1200 line/mm grating at a wavelength of 5000Å. What do you tell them? Explain any assumptions you need to make.

4. Observing Setup (5 points)

You are interested in studying the kinematics of elliptical galaxies by measuring the widths of absorption lines in their spectra. To get accurate velocity measurements, you want your spectra to have as good a velocity resolution as possible. You have two choices of observing setups:

Setup #1: Observe the width of the Calcium H & K lines ($\lambda = 3934\text{Å}, 3969\text{Å}$) using a blue-optimized grating that gives wavelength resolution of $\Delta\lambda = 1.3\text{Å}$

Setup #2: Observe the width of the Calcium triplet lines ($\lambda = 8498\text{Å}, 8542\text{Å}, 8662\text{Å}$) using a red-optimized grating that gives wavelength resolution of $\Delta\lambda = 2\text{Å}$

Which setup would you pick and why?

Aside from velocity resolution, are there other reasons to pick one setup over the other for observing elliptical galaxies? Explain.