Astronomy 61 - Spectroscopy homework and lab - Due Wed., 2015 March 4

I'm making this due after the observing runs.

(1) In the lab, you'll reduce some data that I took with the MDM 2.4m telescope, modular spectrograph, and the 'templeton' CCD. Let's trace out how this was taken.

a) Go to the MDM observatory website,

http://mdm.kpno.noao.edu/index/MDM_Observatory.html

and find `instrumentation and filters` (in the left column), and from that page click through to `modspec`. You'll find labeled picture of the spectrograph hanging on the 2.4m telescope. Light comes in from the top, goes through a slit, then through a collimator lens, to the grating, and is dispersed upward and to the left to a camera lens (which in this case is simply a commercial camera) and the spectrum is imaged on the detector at the base of the blue can. The old manual for the spectrograph is linked from the mdm site, but it's very large – it's a scan of a paper copy – so I've included it in this package. No need to download it. The numbers in this problem are mostly from that manual.

b) The telescope's primary mirror is 2.4 meters in diameter, and the optical system is $f7.5$, which means that the focal length of the whole system (primary plus secondary) is 7.5 times the diameter of the primary. If you multiply these you'll find the focal length is 18 meters. The Templeton CCD has pixels that are 24 microns (a micron is 10^{-6} meter) across. Find the image scale for direct imaging in arcseconds per millimeter, and the number of arcseconds a pixel subtends when the CCD is used for direct imaging.

c) The collimator's focal length is 429 mm, so it's placed 429 mm below the slit. The lens that takes the dispersed light and forms an image at the detector is a 200 mm focal length Canon camera lens. How many times smaller is the image formed on the detector, compared to the image in the focal plane? [This is embarrassingly trivial to compute.] Notice that if the grating were replaced by a mirror, the spectrograph could be used as a *reducing camera*, which is useful for imaging a larger area of sky than a detector would otherwise see.

d Have a look at the little article by Francois Schweizer (1979, PASP, vol. 91, p. 149), included in this packet. Consider the case in which the grating has 600 lines per millimeter (his g is the inverse of this), and the collimator-camera angle is 31 degrees (his Φ). Modspec's reflection grating is designed to have the light come in on one side of the normal go out on the other – so that his angle β is negative. You want the center wavelength of your spectrum to be 600 nm, or 6000 Å, so that $\alpha - \beta = 31$ degrees when λ is 600 nm. You're working in first order $n = 1$. Figure out how far from the horizontal you need to tilt the grating for this to work. (I mean "horizontal" to be the plane perpendicular to the collimator axis; this plane is parallel to the ground when the telescope is parked looking up.)

e Note that once you're set up, α is fixed, but β varies with wavelength. Referring to Schweizer's article, ind $d\beta/d\lambda$ for the setup, and from this, compute the dispersion at the detector in terms of nanometers of wavelength per millimeter on the detector (recall that the focal length of the camera is 200 mm). Suppose the detector has 24 micron pixels. How many nm of wavelength does each pixel subtend?

f How many pixels on the spectrograph detector will a 1-arcsecond slit subtend, along the spatial axis? This follows easily from your answers to (a) and (b).

g Schweizer's article points out that there's a further demagnification factor due to the fact that the grating isn't the same the thing as a mirror. Using this, figure out how many detector pixels a 1-arcsec slit projects to along the dispersion axis. Convert this to a range of wavelengths, $\Delta\lambda$. How much of a doppler velocity shift does $\Delta\lambda$ correspond to at 600 nm?