ASTR 337: Homework 4

Due Date/Time: Beginning of class (7 pm), Wednesday, October 2nd 2019

Problems

1. From Chromey: 6.1 ("Describe the kind of motion an altazimuth mount must…")

2. Comparing the quality of astronomical observing sites:
   a. An average night of seeing at the 16-inch Smith telescope is roughly 2.5 arcseconds at V-band. Calculate the Fried parameter ($r_{0\lambda}$) of the observatory site. Then, using $r_{0\lambda}$, calculate the Strehl ratio of a seeing-limited image from the Smith telescope.
   b. An average night of seeing at the 8-meter Gemini South telescope in Chile is roughly 0.7 arcseconds at V-band. Calculate the Fried parameter and the corresponding Strehl ratio of a seeing-limited image from Gemini.
   c. How do your answers for (a) and (b) compare for the two sites? What factors might contribute to any differences?
   d. Let's say we have a *truly extraordinary* night of 0.3 arcsecond seeing at Amherst College. How does the diffraction limit at V-band for our 11-in telescopes compare to the seeing in this scenario? What would this mean for our images/telescope performance?

3. From Birney: On a given night, we measure the seeing to be 1.5 arcseconds for a star at a zenith distance of 30º. What would be the expected seeing at a zenith distance of 70º?

4. Verifying the plate scale of the Amherst Telescopes: a DS9 + Python exercise.
   Submit M13 images, all created tables/lists, & Jupyter Notebook code via Moodle. Please use your assigned star name on your notebook submission.
   a. Install the free SAOImage DS9 image viewer on your own computer.
   (Available for Windows/Mac/Linux: http://ds9.si.edu/site/Download.html)

   b. Navigate a web browser to the STScI Digitized Sky Survey (DSS):
   https://archive.stsci.edu/cgi-bin/dss_form
   and download an optical FITS image of the Hercules Globular Cluster, M13. Use a field of view (angular size) of 40 arcmin × 40 arcmin. Include a copy of the DSS image with your assignment (screenshot JPG, PNG, GIF, etc. are fine).

   c. Make a table of the 10 brightest objects (by V magnitude) in your DSS image from the Hubble Guide Star Catalog (GSC 2.3), and overplot their positions on the image. This is easy with DS9:

`Analysis Menu` (*not* button) `> Catalogs > Optical > GSC 2.3`

d. Filter the list of stars to include only the brightest ones: In Filter input box in catalog tool, enter
`$Vmag>10.0 && $Vmag<12.0`
...and hit “Filter”. This will plot a number of regions on your FITS image. Adjust the thresholds if needed to get approximately 10 bright stars plotted on the image of M13 in DS9 (make sure there are at least 10 within the image boundaries).

e. From the catalog tool window, click “File” > “Export” > “Tab-Separated-Value” to save your star list. It is now ready to import into pandas (recall that reading in tab delimited data requires the `delimiter='\t'` argument).

f. Import the data into pandas, and measure the separations between **at least three** pairs of stars using their RA and Dec coordinates. Use a Python module of astronomy tools called *astropy* to measure separations between the pairs of coordinates. Here is your first chance to import and use a new Python module on your own! You can read how to use it here: http://docs.astropy.org/en/stable/coordinates/matchsep.html
* Record which pairs of stars you measured, and their separations in <u>arcseconds</u>.

g. From the class Github page, download the Amherst Telescope FITS file for M13 and open it in DS9. Select a scale in DS9 and adjust scale parameters accordingly to view the major features and locate the same bright stars you identified in the DSS image in Step (d). In the DS9 “Zoom” menu, you may need to invert the X and/or Y axis of the image to match the North up, East left orientation of the DSS image. Also include a screenshot of this image with your assignment, with the pairs of stars circled.

h. Using the <u>same</u> three pairs of the stars you used in Step (f), use Python to measure the plate scale in arcseconds/pixel of the M13 image from the Amherst 11” Telescope. You will probably find it easiest to display the image in DS9, then use its features to measure the pixel position of each star (this can be done by creating a circular region around the star, using `Region -> Centroid` from the menu, then double clicking the region to bring up a coordinate window). Save those x/y coordinates into a file, and then calculate the pixel separations between each pair, $r = \sqrt{(\Delta x^2 + \Delta y^2)}$, in your Jupyter notebook.

i. For each pair of stars, divide the separation in arcseconds you measured from the DSS image by the number of pixels you measured in the Amherst image to find the pixel scale of our CCD camera. Create a final table including the following for each pair of stars measured: Stars chosen, RA, Dec, x-position, y-position, separation in pixels from the Amherst image, separation in arcseconds from the DSS image, and estimated pixel scale.

j. What is the average of pixel scales you measured? Calculate the percent error of your average pixel scale from the "accepted value" of 0.643"/px for the Amherst CCD camera. What might be some sources of error in your measured pixel scales?

Pre-Lab Reading and Questions for Week 5

Reading

Please read the following sections in Chromey:

- 7.1 (*Isolated Atoms*) through 7.4 (*Photoconductors*)
- 8.1 (*Detectors*) and 8.2 (*CCDs*)

Questions

1. Define what is meant by an "electron-hole pair". How is this pair created?
2. What is a semiconductor? Why are semiconductors often doped (i.e. modified with impurities), and why might that be beneficial when creating an astronomical detector?
3. (a) In your own words, describe the properties of (1) signal and (2) noise, and (3) discuss the utility of measuring the signal-to-noise ratio.
   (b) In an astronomical image, which components (stars, background, etc) illustrate each of these quantities?
4. What is taking place in the plot shown in Figure 8.2? What kind of measurements might we take to create a plot like this?
5. Why is an analog-to-digital converter necessary?
6. Pick the three terms from the list in the **second** bullet of the Summary on page 267 with which you are *least familiar* and define them in your own words.

NOTES ON RIGHT ASCENSION AND DECLINATION:

RA $= \alpha$ is measured in units of **time** (h, m, s), and sometimes in units of angle of rotation ($^\circ$,$'$, $''$).

DEC $= \delta$ is measured in units of **arc** ($^\circ$,$'$, $''$).

Along the celestial equator, $24^h = 360^\circ$. Note that 1^s of time $= 15\ \cos(\delta)\ ''$ of arc, so it is important to specify the units of time to one more decimal place than the units of arc for comparable accuracy.

When making **calculations** (addition, subtraction, etc.) with α, δ it is much easier to convert the sexigesimal values for α, δ to decimal hours or degrees, respectively. For example: $15^h16^m01.90^s = 15.26719^h = 229.00792^\circ$. But remember that degrees of RA have different arc lengths depending on DEC: A15° wedge in RA at DEC$= 0^\circ$ (the celestial equator) covers 15° of arc, but at DEC$= 45^\circ$ it covers only $15 * cos(45) = 10.6^\circ$ of arc (how much does it cover at the NCP?).

When taking **trigonometric functions** in Python $(sin(\alpha), cos(\delta))$ you **must** convert both α, δ to decimal *radians*. For example: $15^h16^m01.90^s = 229.00792^\circ = 3.99694$ radians.