Python 1

Due: Friday, October 16th at 5 pm

For all answers with a numerical output: use scientific notation where appropriate. For all answers that require you to record the python command you used: copying and pasting from the terminal is fine.

1) **Lists:** Make a list in python of the Vmags of the five brightest stars from BrightStars.dat.
   a. *Write down the bash command you used to get the numbers for your list. Hint: To make it easier on yourself you can use something like the following command to only print a specific column to the screen:*
      `awk '{ print $column_number }'`
   b. *Print the list in python and copy the output down.*
   c. *Write down the python command to access the first element of the list. What is the first element of the list?*
   d. *Write down the python command to delete the last element of the list. What is the last element of the list?*
   e. *Write down the python command to append the first element of the list to end of the list.*
   f. *Write down the command that now resorts the list so that the brightest stars come first (smallest Vmags).*

2) **Dictionaries:** Make a dictionary where the keys are the five brightest stars' names (column 1 in BrightStars.dat) and the values are the stars' parallax (column 10 in BrightStars.dat).
   a. *Try using the same command as for lists to access the first element of your new dictionary. Copy the output you get here. Why do you think this doesn't work?*
   b. *Write down the python command you would use to add the new key 'Alpha Centauri' with the associated value of 754.81 to your dictionary.*
   c. *Write down the python command that prints all the values in your dictionary. Copy the output from this command. What TYPE of variable do you get from this command output?*

3) Arrays: First import numpy. Next, make an array out of your dictionary values from above using the following command: `np.array(dictionary.values).` You now have an array of parallax values.

   a. *Calculate the distance to each of the stars in the array. Use: distance (parsecs) = 1 / parallax (arcseconds). Be careful of units! Copy the python command you used to do this as well as the output (distance values in parsecs).*

   b. *Make a new array that is the distance to each star in parsecs (if you did not already do so above). Translate each distance from parsecs into light years. Copy the command you used to do this as well as the output (distance values in lyrs). Reminder: There are 3.26 lyr in a pc.*

   c. *Write down the python command you used to find the minimum distance in lyr from this array and write down the minimum distance itself. This is the distance to our closest neighbor, Alpha Centauri!*

4) Creating Data in Python: Let's make some fake data and make inferences about it. This may seem like a silly exercise, but making faking data to test your methods can be a very useful technique in science!

   a. *Make an evenly spaced array that goes from values 0.02 to 2.5. Print this array and copy the output here. What python command did you use to make the array?*

   b. *What is the length of this array? What python command did you use to find the length?*

   c. *How many values in this array are less than 0.1? What percent of the total does that represent? What python commands did you use to find this?*

   d. *What python command would you use to find the indices of the values between the minimum value of the array and the mean of the array? Try the command and copy the indices you get here.*

   e. *What is the python command you would use to find the values associated with those indices?*

f. *What is the python command you would use to find the index of the minimum value in the array (assuming the array is unsorted)?*

g. *What is the python command you would use to get the first 10 values of the array? Copy the output of this command.*

5) **Python as a Calculator Part 1:** The Schwarzschild radius is the radius within which no light can escape; any object with a radius smaller than it's Schwarzschild radius is a black hole. At the center of our Milky Way galaxy is a supermassive black hole called Sagittarius A*. We are going to calculate the Schwarzschild radius of this and other objects. The formula for the Schwarzschild radius is as follows: $r_s = \frac{2GM}{c^2}$, where c is the speed of light, G is the gravitational constant and M is the mass of the object. Make an array in python that contains the masses of Sag A* (4.31x10^6 solar masses), the sun (1 solar mass), and the mass of a neutron star (about 1.4 solar masses). The units for these should be the same since arrays are homogeneous!

   a. *Print the array you just created and copy the output here. What are the units on this array?*

   b. *Now in python, define variables for G and c in cgs units ("centimeters, grams, seconds"). Make a new array of the masses above with units of grams using the "operate and assign" technique. Write the python command you use to do this.*

   c. *Write the python command you used to find the Schwarzschild radii for these objects. What numbers do you get for the radii? What are the units on these radii (cgs units)?*

   d. *Now convert the above radii to units of solar radii using python. Record the answer that you get. Hint: If you were in cgs units above all you need to do is divide your answer by the radius of the sun in cm.*

   e. *Now convert these values to AU (1 AU is the distance from the earth to the Sun). Write down the answers that you get for the Schwarzschild radii in AU.*

   f. Sag A* has a mass of over a million solar masses within its Schwarzschild radius. *Compare the size of this Schwarzschild*

radius to the size of planetary orbits in the solar system. Would any planets be within this Schwarzschild radius?

    g. The radius of a neutron star is around 10 km. *How much larger is a neutron star than its Schwarzschild radius?*

6) **Python as a Calculator Part 2:** Make an array that contains the distances (in AU) from the sun of all the planets (plus Pluto!). Helpful numbers: Mercury 0.387 AU, Venus 0.723 AU, Earth 1 AU, Mars 1.524 AU, Jupiter 5.203 AU, Saturn 9.523 AU, Uranus 19.208 AU, Neptune 30.087 AU, Pluto 39.746 AU.

    a. *Use python to convert all the values in the array to distances in cm. Write down the output of this command.*

    b. Kepler's third law, which relates the orbital distance to orbital period is given as follows: $\frac{T^2}{a^3} \approx \frac{4\pi^2}{GM}$, where T is the period of the orbit, a is the semi-major axis (distance), G is the gravitational constant, and M is the mass of the sun. *Using G and M defined in cgs units, write down the python command you use to find the orbital period for all the planets. What are the orbital periods, and what are their units?*

    c. *Use python to calculate the orbital period in years for all the planets. Write down the answers you get. Hint: There are 3.154x10^7 seconds/year.*

    d. *Use python to calculate the "light travel time" in **hours** to all the planets based on the distances (in cm) from part a, and record the output here.*

CGS Units Cheat Sheet:

Gravitational constant (G) 6.68x10^-8 [cm^3 g^-1 s^-2]

Speed of light   (c) 3.0x10^10 [cm/s]

Astronomical unit   (AU) 1.496x10^13 [cm]

Parsec   (pc) 3.086x10^17 [cm]

Light year   (ly) 9.463x10^17 [cm]

Solar mass $(M_\odot)$ 1.99x10^33 [g]

Solar radius $(R_\odot)$ 6.96x10^10 [cm]