ASTRONOMY 121 - Fall 2023
Homework Assignment #1
DUE by Monday, October 2, 2023
900 points

Download *HW1.zip*; by unzipping it, the directory "HW1" will be created.

1. Effective wavelengths [50 points]

Using Eq. 3 in the provided paper by Fukugita et al. (1996), calculate the effective wavelength of the following provided filters: U, B, V, R, I, J, H, and K. The filters are in the directory "./HW1/filters/". Make a table with the filter names and the effective wavelengths.

2. Vega-to-AB corrections [50 points]

Using the provided spectra of the star Vega (./HW1/templates/vega.dat), spectral class A0, derive the Vega-to-AB corrections in the following provided filters: U, B, V, R, I, J, H, and K. The Vega-to-AB correction is the magnitudes of the Vega star in the AB system. Compile a table with these Vega-to-AB corrections (you can add a third column to the table constructed in Problem #1).

3. Rest-frame absolute magnitudes and colors [200 points]

For all the provided stellar templates (sampling the full range of spectral types and luminosity class; Pickles 1998), calculate, numerically, the absolute magnitude in the U-band (M_U), in the B-band (M_B), and in the V-band (M_V) in the AB magnitude system. The Pickles' templates are in:
./HW1/templates/pickles_stars/ascii_norm/
Within this directory, you will also find the file *README*. As the name of the file encourages, read it carefully. The file *Table.dat* provides the filename of each template, and the corresponding spectral type, luminosity class, and effective temperature at the surface. Complete the file Table.dat by adding 5 new columns, namely M_U, M_B, M_V, $U-B \equiv M_U$-M_B, and $B-V \equiv M_B$-M_V.

4. H-R Diagram [200 points]

With the information calculated above and the information in *Table.dat*, construct the H-R diagram. Make two versions of the H-R diagram: 1) $y = M_V$ (with bright top and faint bottom) vs $x = \log(T_{eff}[K])$ (with hot left and cold right); 2) $y = M_V$ (with bright top and faint bottom) vs $B-V$ (with blue, i.e., smaller color, left and red, i.e., larger color, right). In both version, plot with different colors each different luminosity class, and also over-plot the location of the Sun (spectral type G5 V).

5. Color-Color Diagram [200 points]

Plot $y = U - B$ (with blue, i.e., smaller color, top and red, i.e., larger color, bottom) vs $x = B - V$ (with blue, i.e., smaller color, left and red, i.e., larger color, right); connect the different points belonging to the same luminosity class and color code the individual stars as a function of temperature (I would recommend the color coding being as a function of $\log(T)$). Calculate $U - B$ and $B - V$ colors also for a perfect blackbody with different temperatures from $T_{\rm eff} = 2200$ K to $T_{\rm eff} = 100,000$ K (I recommend sampling this range uniformly in logarithmic space), and over-plot them, color coding them as a function of temperature of the blackbody (again, $\log(T)$). Do you notice any trend? Describe and discuss your findings.

6. Bolometric Corrections [150 points]

Using the Pickles (1998) models of stars, derive the bolometric corrections of the U-band, the V-band, and K-band, in the AB system, for all different spectral types. Plot $y = BC_{\rm AB}(U) = m_{\rm U} - m_{\rm Bol}$ vs surface temperature $x = \log(T_{eff}[K])$, color coding differently the different luminosity classes. Repeat this figure, once showing $y = BC_{\rm AB}(V) = m_{\rm V} - m_{\rm Bol}$, and a third figure showing $y = BC_{\rm AB}(K) = m_{\rm K} - m_{\rm Bol}$.

7. Distance modulus [50 points]

The naked eye can see only stars brighter than m_V=6. Assuming that no bolometric correction is required for the Sun, how far away could it be seen by the eye if its absolute magnitude M_V=4.83?.

TIPS:

1. Download the files "HW1.tar.gz" and unpack it by typing:
   >gunzip HW1.tar.gz
   >tar -xvf HW1.tar

2. First, read the first couple of pages of "HoggEtal2002.pdf" for a detailed definition of magnitudes and the practical formulas to derive them (and relative magnitude systems, i.e., Vega versus AB) in addition to what covered in class. You can also quickly read the other paper (Fukugita et al. 1998) regarding the AB system. Make sure you read the README file in each directory.

3. You should solve each problem (except #7) numerically, i.e., you will need to write a code for each problem to make the calculations (mostly solving integrals numerically) and to make electronic digital figures (best format is PNG or PDF). You can use whatever language you want for the coding, but I would strongly recommend Python.

4. Do not hesitate to reach out to me for any questions you may have!