Homework2, due Tuesday, 29 October at 1:00pm

Instructions: Please write your answers clearly on a separate sheet of paper. You may turn in the assignment at the beginnning of class, by email (gherczeg1@gmail.com) as a **single pdf document**, with any code at the end of the assignment. If handcopy, staple all sheets together. Show all work. No late homework will be accepted. This homework is worth 1.5 homeworks

0. Reading Pre-View: Onno Pols, Chapters 3-4, Interior structures, equations of state, and polytropes

1. Redo homework 1 (16 pts). I am guessing that your plots are not very good. Remake your plots! Make sure that they look good.

2. Make your own HR diagram (20 pts). *Gaia*-DR2 is the arguably the most perfect dataset humans have ever produced. In this problem, you will create your own HR diagram. You will nedd to save this file for the next question. A file with Gaia data of stas within 100pc is located at: https://kiaa.pku.edu.cn/~gherczeg/stellar

a: Plot an HR diagram, with $B_P - R_P$ on the x-axis and the absolute G magnitude on the y-axis. Hint: look up what a heat map is.

b: Label important locations on the plot.

c: Describe the uncertainties and how they affect your HR diagram.

3. HR Diagrams and Gaia (50 pts). HR diagrams and color-magnitude diagrams are the foundation for understanding stellar evolution. Gaia is now revolutionizing galactic stellar astronomy. This question asks you to use commonly-used resources to get data, and then plot and interpret diagrams. Turn in all python code written for this question.

a: Find membership lists for the following open clusters: pleiades, Hyades, and NGC 752. Write the ciations for each cluster.

b: Download the Gaia astrometry and photometry for these sources, either at the Gaia website or using vizier or Topcat. How many of these objects are members? Describe your logic.

c: Plot the color-magnitude diagrams for the members of each cluster. Mark the locations of at least 6 types of stars on the HR diagram (it's ok if that region is not populated in your membership list). How are those stars generating energy?

d: What differences do you see between these clusters? What causes those differences? What else do you see in the cluster HR diagram?

e: Compare these clusters to the field stars.

4. Introduction to Blackbodies (20 pts): The blackbody curve and emissivities are an essential part of stellar astronomy.

a: Write down the planck function in terms of wavelength.

b: Derive Wien's law.

c: Describe Wien's law in your own words, without equations.

d: Earth behaves as a blackbody. The absorption of solar radiation is balanced by the thermal emision from Earth. Using this face, the luminosity of the sun, and the distanc to the Sun, compute the expected surface temperature of Earth. Assume that clouds reflect 40% of the incident solar flux back into space, so only 60% is absorbed.

5. Introduction to Stellar Structure and Hydrostatic Equilibrium (35 pts): Consider the density inside a star to follow:

$$\rho(r) = \rho_c \left[1 - \left(\frac{r}{R_*}\right)^2\right] \tag{1}$$

where ρ_c is the central density. Boundary conditions at the stellar surface are set to 0, i.e., $P(R_*) = T(R_* = 0)$.

a: Find an expression for the central density in terms of R_* and M_*.

b: Use hydrostatic equilibrium and the boundary conditions to find pressure as a function of radius. Your answer will be in the form of $P(r) = P_c \times$ (polynomialinr/R?). What is P_c in terms of M_* and R_*? Express P_c numerically with M_* and R_* in solar units.

c: Assuming an ideal gas, compute the central temperature in this model:

i: Considering the composition to be pure ionized H

ii: Considering the composition to be pure ionized He

d: Verify that the virial theorem is satisfied and write down an explicit expression for the potential energy Ω

6. Introductory definitions (9 pts): Define the following terms in your own words. Use equations where appropriate, but also always include a physical description in words.

(a) ideal gas

(b) virial theorem

(c) blackbody

(d) energy transport by convection

(e) Kelvin-Helmholz timescale

(f) HR diagram

(g) Jeans mass

(h) stellar effective temperature

(i) hydrostatic equilibrium