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CREATING STARS

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1. CODE SUMMARY

To be able to construct stars, we had to work with the 4 first order differential equations learned in lecture. These included the Pressure, Mass, Temperature, and Luminosity equations. These ODEs could not be solved analytically. We used the Runge-Kutta code built in class to solve our equations. The Runge-Kutta code (rkproject1.py) was modified to solve four differential equations.

Once this step was done, we needed to write a code that would build our Sun using the Runge-Kutta code. Here we needed to define many equations to be able to calculate the ODEs. We thought it would be efficient to create a python file that housed all the constants and equations including the ODEs. We started to implement functions into our code. These included Density, Luminosity, Mass, Pressure and Temperature and other functions such as kappa and epsilon. We quickly failed in executing this plan, and so initially we worked with all of our equations defined as functions, and the constants inside of the python file called "build_the_sun.py". The objective was to plot Radius vs; Pressure, Temperature, Luminosity and Mass.

Our code had many errors at the beginning which we resolved by testing and debugging our code step by step. The initial condition values are incredibly sensitive. The slightest change in a value can result in many errors. To combat this we implemented a error detection statement. If any values such as 'NaN' (not a number) were detected during the Runge-Kutta calculations the whole process would stop and we would know to adjust our initial conditions. Once properly adjusted, the code would run and output meaningful plots.

We kept all the initial conditions of the sun, and only tweaked the central temperature. The goal was to find the right initial conditions that would plot a 1 M_{Sun} star. Once this step was finished (after many days of trial and failing!) we moved on to plot 20 random stars on the H-R diagram. As we had already started to extract data from MESA, we used the mass compositions, central temperature and pressure and the radius to see how closely we could get using our code to the MESA generated stars. We threw in all these initial conditions and calculated the effective temperature and luminosity of the star. Initially we thought we could solve the optical depth integral inside our code, and find the radius where this integral was approximately 1. We could then extract the temperature of the star at this very specific and it would be our effective temperature. In theory this is a novel idea, however executing it was extremely problematic. After multiple failed attempts and some help from our peers, we found the equation to calculate the effective temperature and used it on all our 20 star models. Using the "build_multiple_stars.py" file, we created 20 stars and data files with only the luminosity and effective temperature. Then using "hr-d.py", we plotted these stars.

2. SUN

Below is our result for modelling the Sun. This is a rough approximation, using much simpler code compared to MESA. There are boundary conditions that must be met in order for these plots to be a good model of the Sun. The temperature and pressure must go to 0 as we reach the surface. Luminosity and mass must go to the Sun's luminosity and mass as we reach the surface of the Sun. By observing this plot we can see that there are obvious errors, the luminosity goes to 1.4 solar luminosity and the mass goes to 0.91 solar mass. The temperature goes very close to 0, it reaches a value of 0.01.

We knew it would be difficult to get a perfect model of the Sun, this is what MESA set out to do and spent many hours and many people working on it. Our code is a much simpler approach to modelling stars so it is reasonable to have some error in the final values. As long as we have a reasonably close answer to the actual values of the Sun then we have achieved what we set out to do. The code will now produce rough models of stars when passed other initial values. We can now attempt to replicate a simple HR diagram.

3. H-R DIAGRAM

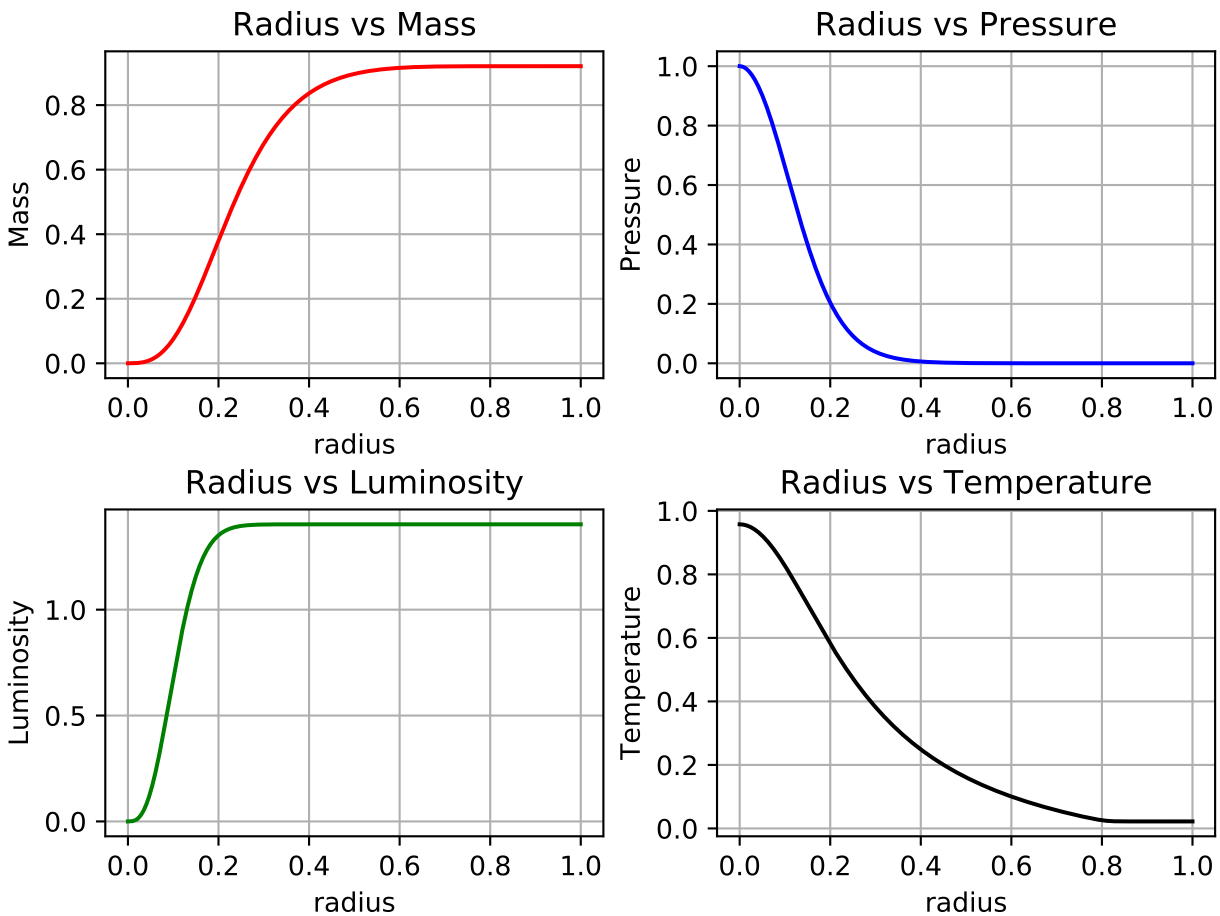

Figure 1. Our acquired plots, modelling the Sun.

In order to compare our model to the industry standard, we submitted the mass and metallicity of 20 different stars to MESA through their online interface. Since our model corresponds to the zero-age main sequence point for the star, we had to compare our results with the data we received back from MESA at that same point. Unfortunately, MESA does not provide a straightforward method of locating which of the thousands of models they provide, coincide with that point. As a result, we had to plot the luminosity of the star over its lifetime to estimate the age of the star when it joins the main sequence, and then locate the model that corresponds to that age among the thousands in the compiled history file. Once all the models had been located, we were able to write a code that extracts the luminosity and effective temperature for each of these models from the stars' history files to create a Hertzsprung-Russell diagram that could then be plotted alongside our own calculated luminosities and effective temperatures. While this method was tedious and inaccurate, it was sufficient for providing a general comparison to our models.

Due to time constraints and the difficulty finding the zero-age main sequence points for each of the MESA models, we ended up working backwards, creating our own models after we had received the MESA data. We wanted to compare our data with theirs by using the values for the composition, temperature, pressure, and radius from the MESA models as our inputs for our own code, which could only be done after we had all of the MESA data back. Once all of that data had been input into our code and we had saved our results in text files, we created a new code to extract that data from the text files to plot against the MESA models. While the luminosity vs. effective temperature plot using logarithmic scales showed that both sets of stars followed a linear trend, as we would expect on a H-R Diagram, our models show a much wider and colder range of temperatures, as well as luminosity values several orders of magnitude greater than those calculated by MESA.

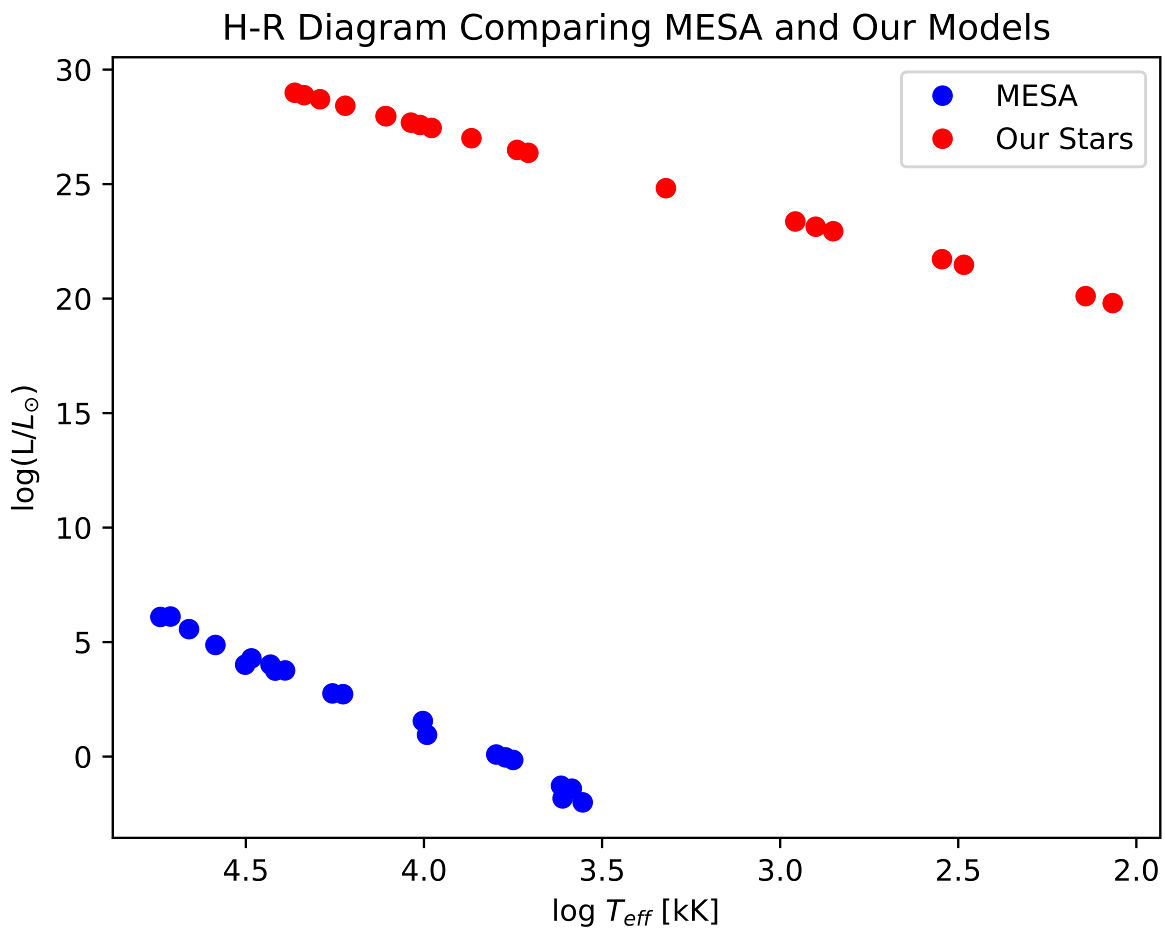

Figure 2. A Hertzsprung-Russell Diagram comparing the values for our star models and the ones calculated by MESA.

REFERENCES

[1]Fields, C. E., & Timmes, F. X. (2015-). MESA-Web. Retrieved from *http://mesa-web.asu.edu*

[2]NASA, (n.d.). Retrieved March 5, 2019, *https://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html*

[3]Basu, S. (n.d.). The Sun. Retrieved March 5, 2019, from *http://www.astro.uwo.ca/ basu/teach/ast020/notes/sun.pdf*