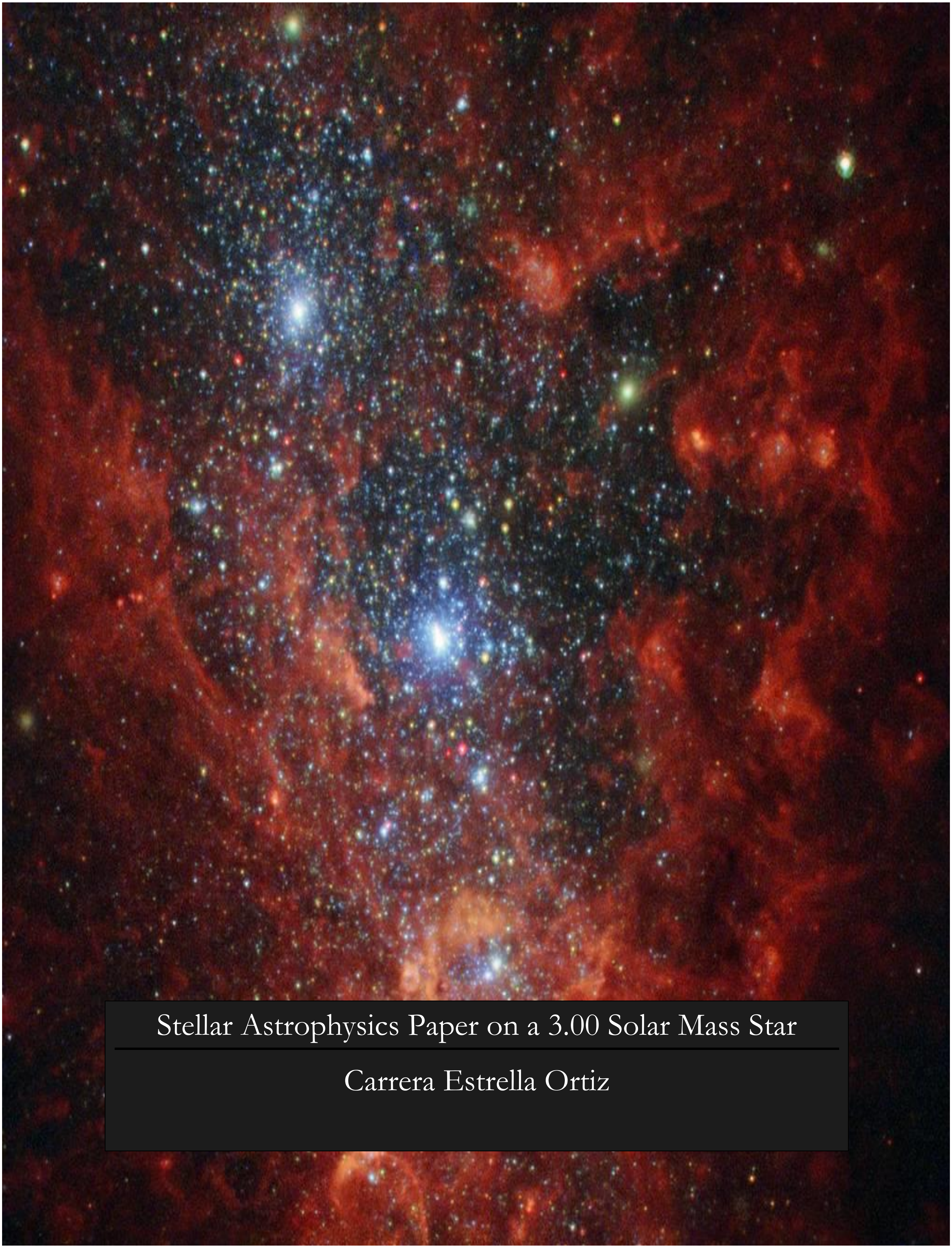


Stellar Astrophysics Paper on a 3.00 Solar Mass Star

Carrera Estrella Ortiz

I. INTRODUCTION

Here on Earth, we have intricate lives that are guided by even more intricate systems both inside of us and in the world we live. Throughout many years, humans have learned to survive and adapt using the resources available to them. Humanity has made great strides and great mistakes, though there have always been cultures that have looked up to the night sky and felt determined to understand the heavenly bodies that appear when the Sun rests out of view. Constellations have long provided direction for those lost or headed to a new destination of promise, from sailors to enslaved people searching for freedom. Ancient Mayans and Chinese cultures have long held rooted beliefs connected to the night sky, and what a bright sky they must have had the opportunity to gaze upon. Even now, you still may remember the first time you were able to make a wish on a "falling star", or the beauty of what it looked like to see the Milky Way for the first time if you've had such a chance where the light pollution does not disguise the Universe just outside of our atmosphere. Now, we are taking it upon ourselves to admire this beauty with a new perspective as our tool. Science and data are going to guide us into a star, where we shall understand the intricate systems that lie within the bright dots that illuminate the night, despite the vast distances of space between our home and these stars. From the center to the surface of a star, we will journey through a world of science and space.

II. PURPOSE

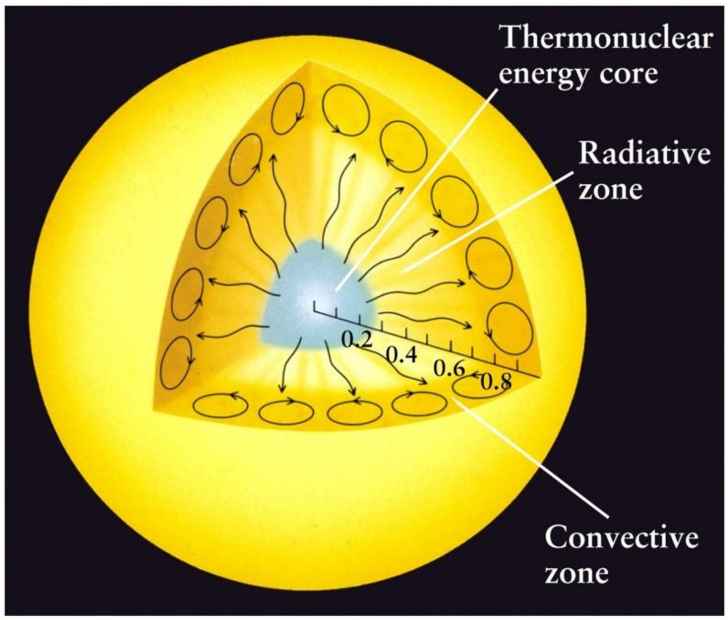
This paper is intended to characterize and discuss stellar interior and surface values of a 3.00 solar mass star that is on the main sequence. The paper here is reliant heavily on the provided data of both a 1.00 solar mass star that is critical for comparisons as well as the data for a 3.00 solar mass star. The data provided in an excel sheet includes a variety of information from surface and central conditions such as temperature, mass, luminosity, and radius. Additionally, there are 10 columns each with about 400 cells of data regarding the aforementioned characteristics and more at specific distances of the star's radius. The data will allow for definitions of the star's core, calculations regarding its stellar properties, and interpretations of the models created utilizing the data in relation to the star's behavior and internal reactions. After understanding its stellar interior, we can discuss characteristics that determine various facets of the main sequence lifetime of this 3.00 solar mass star. We are scientifically describing a typical 3.00 solar mass star in depth to understand its mechanisms and unique characteristics that could, and will, be used as a point of comparison for other known 3.00 solar mass stars.

And thus, the journey begins.

III. CONTENT

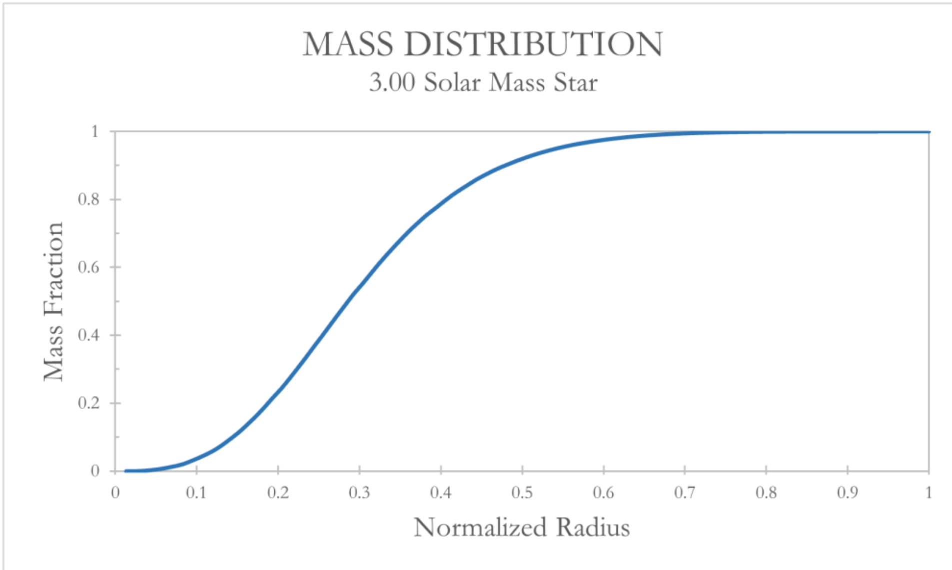
The most familiar to star to the inhabitants of our solar system is our Sun. To astronomers, the Sun provides us not only with life but a point of comparison that allows us to identify other stars in terms of solar units. For example, the closest star system to us is Alpha Centauri, a triple star system with the smallest star Proxima being the most near us. In this star system, Alpha Centauri A and B are notable not only for their relative proximity to our Sun, but also due to their similarities to the Sun. According to authors Kamper and Wesselink of a research paper titled *Alpha and Proxima Centauri*, the stars Alpha Centauri A and B have “1.10 and 0.91 solar masses, respectively.” [2], showcasing how our Sun is used as a reference point to describe the stars we are able to observe and study in the universe. Similarly, when describing the radius of stars, we also tend to comment in terms of solar radii. However, instead of discussing our nearby star system like Kamper and Wesselink, instead we will use a larger mass star. At 3.00 solar masses, or the mass of one million Earths, this star is three times more massive than a 1.00 solar mass star and unsurprisingly also surpasses the 1.00 solar mass star’s temperature and luminosity in terms of its surface characteristics. At a temperature of just over 15,000 K, the 3.00 solar mass star is about 2.73 times hotter than a 1.00 solar mass star. The 1.00 solar mass star is very similar to our Sun, with a slightly larger radius and dimmer luminosity. Compared to the 3.00 solar mass star, the larger star has a 1.56 times larger radius and an incredible luminosity of being 136 times greater than a 1.00 solar mass star. From these comparisons, we see that a 3.00 solar mass star is impressive in many aspects and becomes easier to imagine in a realistic manner.

To understand stars in a sense greater than massive amounts of intensely hot gas and plasma, it is important to understand its composition and interior structure. A star generates immense amounts of energy in two critical forms: thermal energy and gravitational energy. As shown by the image below of the Interior Structure [3], the thermal energy arises from the star's thermonuclear fusion occurring in the core of a star and transfers through means of either convection or radiation until it eventually radiates outward to us, consequently providing life on our planet.

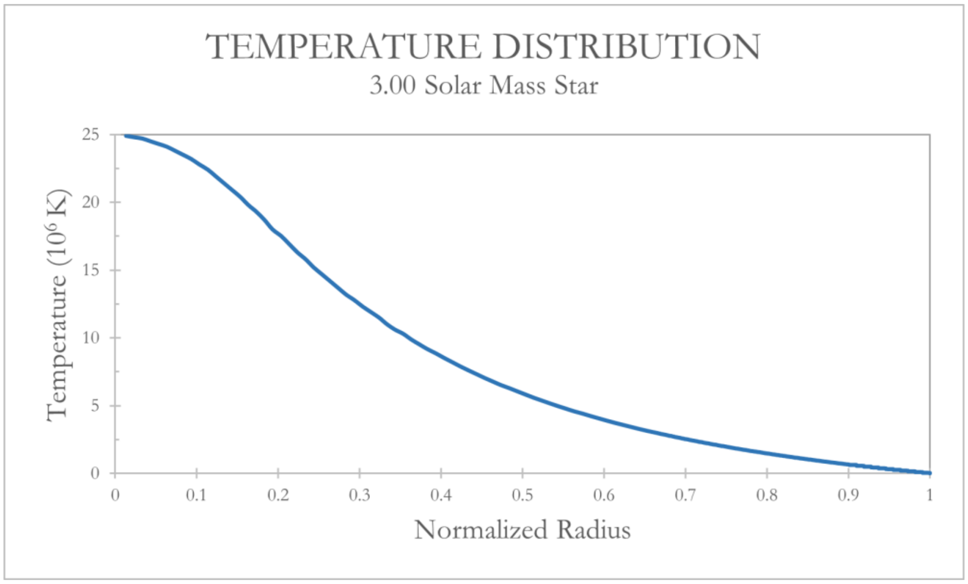


The gravitational energy is a consequence of the how much mass is contained within the star, and the magnitude of a star's gravitational energy increases as its mass increases. These two forms of energy are key to understanding the internal system of a star and how it maintains equilibrium as long as it possibly can before becoming more chaotic. Before further discussing this topic, the data can help us describe more internal characteristics specific to the 3.00 solar mass star.

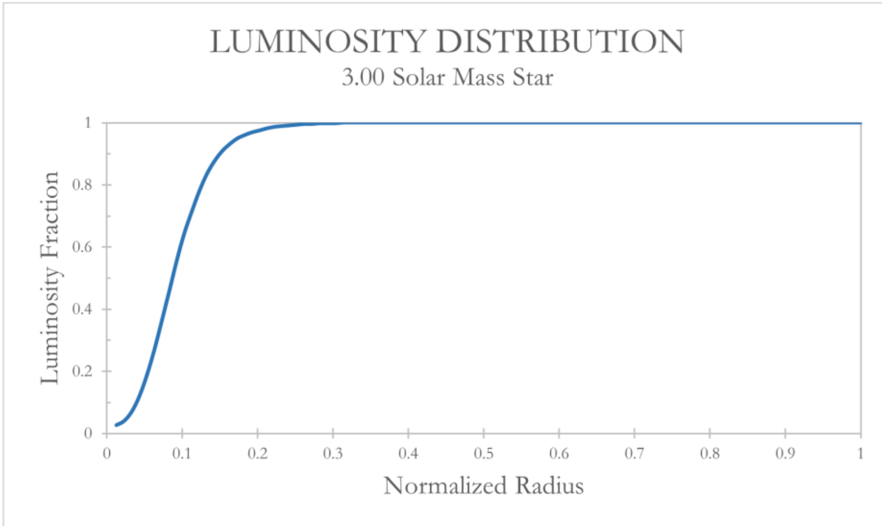
Using the data for this star, we can visualize important characteristics that largely define a star in terms of its normalized radius to understand how these aspects change from the star's center to its surface.



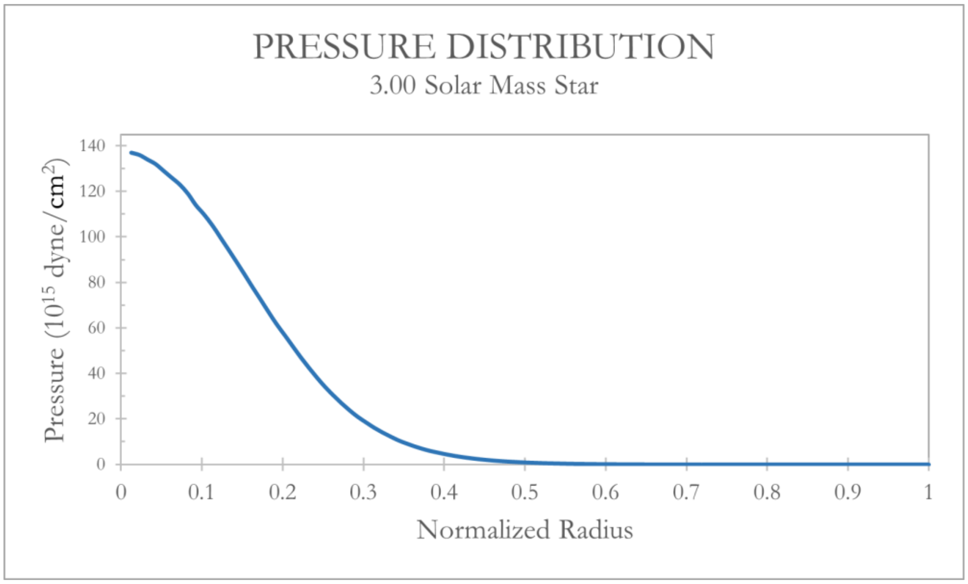
This stellar model is a representation of the mass distribution of a 3 solar mass star graphing the fraction of the star's mass against its normalized radius from its center to the surface. A star, especially one on the main sequence of its life, is dominated by thermonuclear reactions that are fusing hydrogen into helium. Though this topic will be discussed more in depth later on, it is important to note this now in order to understand why this graph depicts the majority of the mass in the stellar interior belonging to when we are in the 30-70% range of our stellar radius. The star's heat and pressure are causing nuclear reactions to form where hydrogen is being fused into Helium. There is a hydrogen fusing core in the center of the star surrounded by an envelope of helium that has yet to precipitate to create its own core of fusion. Because helium is a heavier element, approximately 4 times the mass of Hydrogen, there is a larger mass distribution closer to these heavier elements, though the star still has an extremely large amount of hydrogen at this point that is not a negligible portion of its mass. The dense core of thermonuclear reactions within the star is a large component of the stellar mass, and therefore the mass distribution is more centralized with some expansion due to the different densities of elements created in the fusion reactions.



The stellar model of temperature distribution illustrates a decrease in temperature by the millions of Kelvin as the radius expands to the surface. This is due to heat being generated through the thermonuclear fusion reactions happening in the core of the star as it fuses hydrogen to helium. This heat initially travels outward through convective zones and eventually reaches through the surface as it radiates outward, some escaping into the cold dark space surrounding the star. The intense heat of the core reaching about 25 million Kelvin at its peak temperature is what allows the star to produce helium and as we will understand later, profoundly impacts its classification as well as its most prominent spectroscopic details.



The graph displays the star's luminosity fraction compared to a normalized radius of the 3 solar mass star. Starting from the center of the star, the graph is increasing its luminosity until we are at about the first 20% of its radius, where the total luminosity in the star is finally produced. Knowing that the energy in a star is created from the fusion reactions in the core, it is logical that the graph depicts the 3 solar mass star's luminosity growing where the fusion reactions are occurring. As the heat transfers throughout the star and into the Universe, as well as providing energy into the reactions within the star, the luminosity is also growing throughout the star until it has been fully produced and is finally just passing through the layers. It can be expected that with more massive stars at higher temperatures, the rate of reactions within the star’s thermonuclear core increase, intensifying the star’s luminosity. Where the luminosity is produced is essential in determining a clear region for the core of the star without physically being able to access the stellar interior at our current level of scientific knowledge, tools, and resources.



That being the case, venturing into a stellar interior could give us more insight into the way in which every massive and brilliant star is fighting a war between pressure and gravity. Gravity, a function of math and distance, increases at close ranges and heavier masses. A 3.00 solar mass star such as this with a mass larger than our Sun and a million times more massive than Earth has immense gravity. This self-gravity at every layer of the star weighs down heavily at the core, similarly to a diver in the ocean, as explained by J. Zirker in Journey from the Center of the Sun, where he states that "the pressure at any depth must support the weight of water above that depth or else the ocean would collapse upon itself." (Zirker, 36). [4] So in this, as a large amount of mass is pressing down on the core, there is also where outward thermal pressure from the nuclear reactions is needed the most to allow the star to continue its long-lasting life. As the graph depicts, the center of the radius of our 3.00 solar mass star has the largest amount of pressure at almost 140 x 10^{15} dynes per centimeter squared. As the extent of the thermonuclear reactions decrease as we travel outside of the star's core and closer to the star's surface, there is less pressure from the star.

From these stellar models, there is a pattern that the ongoings located in the star's core are crucial in the star's key characteristics. To clearly separate the core of the star from its outer layers, we find where the data shows the luminosity's mass fraction at 99% and compare that to the normalized radius of the star. From interpreting the graph, it was mentioned that around 20% of the star's radius, the star's total luminosity was produced due to the core's thermonuclear reactions. This aligns with the finding that 99% of the luminosity in the 3.00 solar mass star is produced at the 0.24315 fraction of the star's radius. As the data is given in centimeters, the core radius is 2.70 x 10^{10} cm, or 270,000 km in a more manageable number. In the core of the star, the energy transport is radiative as shown by the data. With a definite radius defined for the Core and a knowledge of the star's radius as given in terms of solar units, allowing for a simple calculation, a ratio of each volume can be easily obtained using the volume for a sphere: $V = 4\pi r\char`^3$ in order to determine how much of the star's volume is determined by the core.

$$V_{core} = 4\pi(R_{core})^3 = 4\pi(270{,}000\ km)^3 = 7.8732\ x\ 10^{16}\ \pi\ = 7.90\ x\ 10^{16}\pi\ km^3$$

$$\begin{aligned} V_{total} &= 4\pi(R_{total})^3 = 4\pi(1.596101 * R_{Sun}) = 4\pi(1.596101 * 6.957\ x\ 10^5 km)^3 \\ &= 4\pi(1.110407466\ x\ 10^6\ km)^3 = 5.476550674\ x\ 10^{18}\pi\ km^3 \\ &= 5.50\ x\ 10^{18}\pi\ km^3 \end{aligned}$$

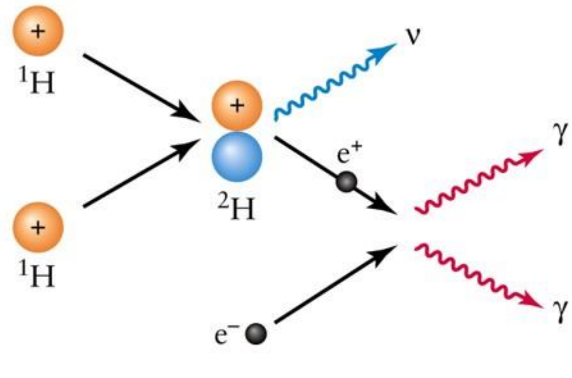
$$Ratio\ of\ Core\ Volume\ to\ Total\ Volume:$$

$$\frac{V_{core}}{V_{total}} = \frac{7.90x10^{16}\pi\ km^3}{5.50\ x\ 10^{18}\pi\ km^3} = 1.43636\ x\ 10^{-2} = 0.014$$

From the work applied here, we see that the ratio is largely skewed to the total volume of the star and that the core provides less than 2% of the star's total volume despite providing such a large percentage of the luminosity and other stellar characteristics for the star.

With the volume and its ratios found, naturally the mass of the star and its core are waiting to have their turn. The star's total mass is known, both in solar units and easily calculated in kilograms as the Sun's value of mass is 1.99×10^{30} kilograms. This value multiplied by 3.00 informs us that the star's mass is 5.97 x 1030 kilograms. From our set of data, the datum point of our core's radius also corresponds to the datum point of the core's mass fraction. Thus, the mass fraction is 0.365 times that of the total mass of our star. Converting the mass fraction, we find that the core's mass is 1.095 solar masses, or 2.8×10^{30} kilograms. By taking a simple fraction between the core's mass and the star's total volume, we find that the core is 36.5% of the star's total mass. This truly outlines the impressiveness of the stellar density inside of its core, how many atoms there must be at such high speeds and how many reactions are taking place within this star in order to have such a high mass content and yet contained in such a small radius relative to the entire star that the volume is such a small percentage of the star.

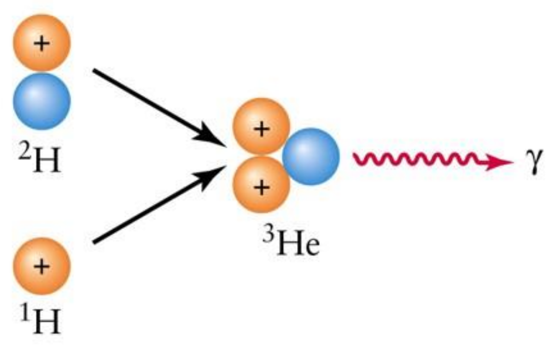
To detail these reactions taking place inside the core, we must understand what reactions are taking place. Thermonuclear reactions must obey many laws of conservation involving mass, energy, electric charge, nucleons, and leptons. The proton-proton chain is the largest contributor of the nuclear reactions that are fusing hydrogen into helium and occur in 3 steps.



a Step 1

[5]

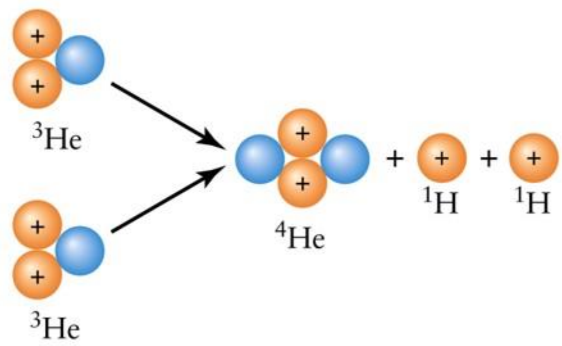
During step one, the stellar interior is full of colliding hydrogen atoms with a single proton. At high temperatures, translating to high speeds for the atoms, these collisions are causing fusion reactions to occur as binding energy is released with each fusion reaction, generating heat and energy for the star. Eventually, two fast-paced hydrogen atoms collide and create deuterium, and in the process releases a neutrino, causing some energy loss in the star. Additionally, the lost positive charge is balanced through the emission of a positron, which in the sea of particles, meets an electron and annihilates, releasing two gamma rays. This step is required to occur twice in order for helium to be produced.



b Step 2

[5]

During the second step of the process, available deuterium and a proton collide to form a rare and unstable form of helium containing two protons and one neutron, while also releasing a gamma ray in the process. This step, similar to step one, also occurs twice.



c Step 3

[5]

During the final step of the proton-proton chain, a stable helium-4 atom with two protons and two neutrons is most commonly created through the collision of 2 of the helium atoms from the previous step, releasing two protons as a side result of the process. All in all, six hydrogens were required as an input to the process, though two were released as an output, meaning the change of mass is equivalent to four hydrogen atoms in the process of making helium within the star.

The CNO cycle tends to be more dominant in stars that have a slightly higher mass than a 1.00 solar mass star. The CNO cycle is a much lengthier process in which carbon initially fuses with a proton to form nitrogen and release a gamma ray due to a positron annihilation. The unstable nitrogen previously formed decays into a carbon atom, releasing other tiny particles along with it. Eventually, after many more transformations, a stable atom of nitrogen is converted and collides with a proton to form oxygen, thus resetting the cycle of decay and transformation until a nitrogen atom with seven protons and eight neutrons combines with a proton to then transform into a carbon atom and a stable helium atom.

Though this is not the only form of the CNO cycle, and not as in depth as it may be described elsewhere, it is the most common form of the CNO cycle producing helium through thermonuclear reactions.

From the lecture notes of Dr. Sowell on fusion reactions[6], we can utilize formulas in order to determine the energy per gram per second of each reaction in the star's core and take the ratio of these energy rates in order to get an understanding of the most common reactions within the 3.00 solar mass star's core due to it being a crucial aspect of the star's life. The formula for energy per gram per second of the PP chain is as follows:

$$\varepsilon_{pp} = C_{pp} * \rho * X^2 * \left(\frac{10^6}{T}\right)^{\frac{2}{3}} * e\hat{}(-33.8\left(\frac{10^6}{T}\right)^{\frac{1}{3}}, where\ C_{pp} = 2.5\ x\ 10^6$$

To simplify due to all variables and core conditions being located in a spreadsheet, I will instead relay the calculated value from the excel sheet as the formula is provided. Note, the same will occur for the CNO cycle. The CNO energy generation rate formula is as follows:

$$\varepsilon_{CNO} = C_{CNO} * \rho * X * X_{CNO} * \left(\frac{10^6}{T}\right)^{\frac{2}{3}} * e^{-152.3\left(\frac{10^6}{T}\right)^{\frac{1}{3}}}$$

$$, where\ Ccno = 9.5\ x\ 10^{28}\ and\ XCNO = Z/3$$

The energy generation rate for the proton-proton chain is 56.3 energy per gram per second in the star's core, whereas the CNO reactions release about 2.1 x 10^4 energy per gram per second. The ratio of these reactions is 373 CNO reactions for every PP reaction in the star's core. Using the energy rates graph [7] below and applying from the datum that the core's temperature is about 25 million Kelvin, these rates and ratios seem to fall within reason for the 3.00 solar mass star.

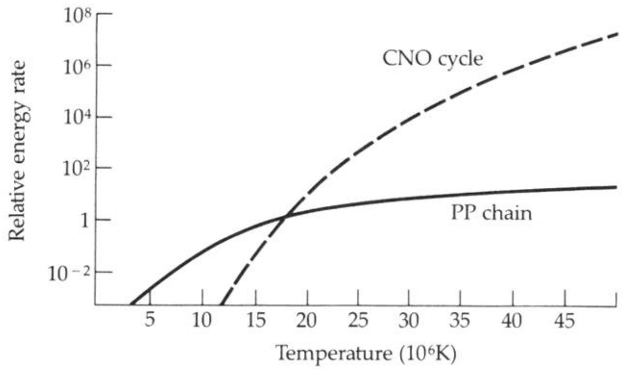


Figure 16–2 Energy-generation rates. The rates for the PP chain and CNO cycle are compared as a function of temperature for Population I stars. Note the crossover at about 18 million K.

With there being an abundance of these reactions per second, astronomers are interested in knowing the amount of hydrogen in kilograms that are involved in the numerous amounts of reactions taking place. If 100% of the surface luminosity is generated by the PPI chain, the number of necessary reactions per second would be determined by the surface luminosity divided by the energy generation rate. Knowing that the 3.00 solar mass is stated to have a luminosity 116.596101 times that of the Sun, and the Sun's luminosity is 3.846 x 10^{26}, the surface luminosity of the 3.00 solar mass star is 4.48 x 10^{28} J/s. Converting the 26.732 MeV to J, and performing the calculation as stated:

$$\frac{4.48\ x\ 10^{28}\frac{J}{s}}{4.28\ x\ 10^{-12}J} = 1.05\ x\ 10^{40}\ reactions/second$$

Knowing that the PPI chain involves a net total of 4 hydrogen, we multiply 4 and the speed of light squared by the atomic mass of hydrogen, subtract that energy by the energy produced, and then divide by the c2 constant in order to find the mass in kilograms of hydrogen in each reaction. Then, to compute the amount of hydrogen in kilograms is converted to energy per second, we simply multiply the values of how many reactions per second are within the star by the amount of hydrogen in each reaction.

$$\frac{4m_H c^2 - energy\ produced}{c^2} = hydrogen\ (kg)/reaction$$

$$\frac{4(1.008u)c^2 - 26.37MeV(\frac{c^2}{931.5MeV})}{c^2} = 4.00369\ kg\ of\ H/reaction$$

$$1.05\ x\ 10^{40}\frac{reactions}{second} * 4.00369\ \frac{kg\ of\ H}{reaction} = 4.204\ x\ 10^{40}\frac{kg\ of\ H}{s}$$

In the star's core, if the surface luminosity were entirely produced by the PPI chain, the star would produce 4.204 x 10^{40} kilograms of hydrogen per second.

Returning to the star's luminosity, it is first important to note that apparent magnitudes and absolute magnitudes are important to measure the relative brightness of stars as well. Apparent magnitudes are how bright a star looks to us from Earth, whereas absolute or visual magnitudes measure how bright each star looks as if it were at a common distance of typically 10 parsecs. Counterintuitively, brighter stars have a more negative magnitude. Using 4.75 mag as the absolute magnitude of the 1.00 solar mass star and applying the knowledge of each star's luminosity, we can solve for the absolute magnitude of the 3.00 solar mass star.

$$m_1 - m_2 = 2.5\log\left(\frac{L_2}{L_1}\right)$$

$$M_{1.00} - M_{3.00} = 2.5\log\left(\frac{L_{3.00}}{L_{1.00}}\right)$$

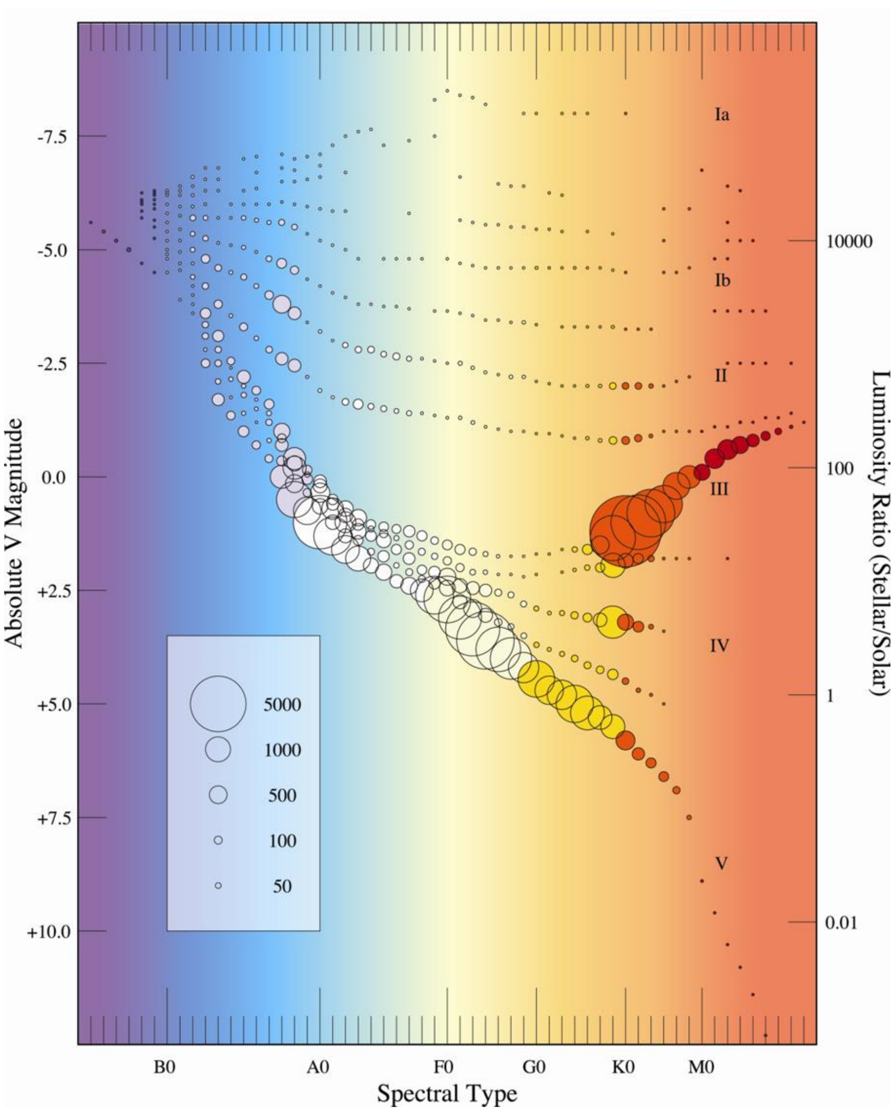
$$4.75 - M_{3.00} = 2.5\log\left(\frac{116.57999L_{Sun}}{0.86071L_{Sun}}\right)$$

$$M_{3.00} = 4.75 - 2.5\log(171.2623437)$$

$$M_{3.00} = 4.75 - 2.5(2.233661883)$$

$$M_{3.00} = 4.75 - 5.584154707 = \mathbf{-0.83\ mag}$$

The 3.00 solar mass star is calculated to have an absolute magnitude of -0.83 mags, making it brighter than the 1.00 solar mass star. Knowing the absolute magnitude of the star also helps to find where the star is located on the HR diagram, which is an important tool in classifying stars. Pictured below is Dr. Sowell's HR diagram pictured beautifully and in a comprehensible manner, making the ease of reference for the HR diagram easier. [8]

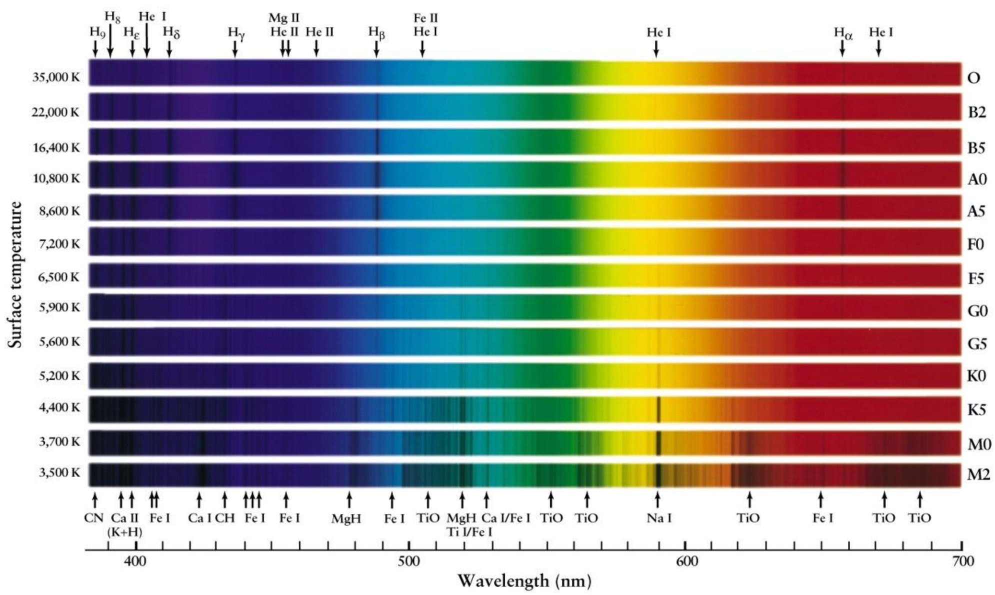


The Hertzsprung-Russell diagram, more commonly referred to as the HR diagram, displays an incredible amount of information about the stars plotted on the diagram. In this diagram, luminosity increases on the positive y-axis while temperature decreases on the x-axis pointing left. Additionally, there is a classification system also applied to the HR diagram that is typically noted on the bottom x-axis, as well as information about stars implied by certain areas of the graph such as its stage in life, mass, and radius. It is due to the Stefan-Boltzmann Law that there exists so much information that can be found out about the star simply by analyzing its placement on the HR diagram. The Stefan-Boltzmann Law provides a formular relating luminosity to other stellar aspects mathematically in the form of:

$$L = 4\pi\sigma R^2 T^4.$$

This formula is commonly used as a ratio of two stars described in solar units to solve for certain aspects of a star. From a diagram that will be included further along, there are many outlined indicators of the radius increasing as luminosity increases and temperature decreases as a star maintains hydrostatic equilibrium. There are many other additional formulas involving magnitudes and elements in spectroscopy and photometry that allow for astronomers to find the results of where a star should be placed on the HR diagram through different means.

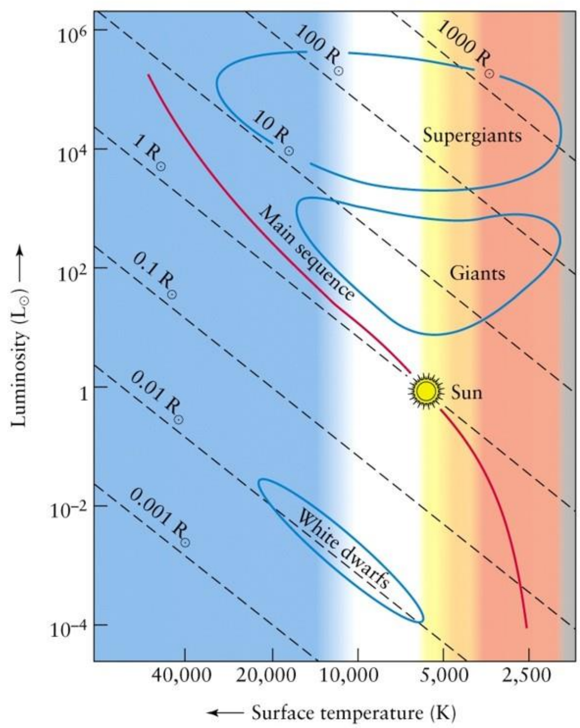
Returning to the classification system on the HR diagram, known as the Harvard classification system, was bolstered by many astronomers throughout the years, with significant contributions from Annie Jump Cannon who consolidated it and created the main group of OBAFGKM stars – each letter in its own class with a special phrase to help remember it: “Oh Be A Fine Girl – Kiss Me!”. [9] The O stars are the hottest, while the M stars are the coolest stars. The 3.00 mass star, at around 15,000 K, solely based off temperature given the temperature range from the Encyclopedia Britannica, this star would likely be a B star as B stars "typically range from 10,000 K to 25,000 K and are also bluish white but show neutral helium lines." [10] With this temperature-based assumption of stellar classification and location on the HR diagram as a main sequence star, the 3.00 solar mass star is an extremely luminous. Assuming it had the same composition as the Sun, we would look at its spectral type [11] using the image below and compare the spectral types to describe the features in the optical spectrum. Do to being a relatively average size and temperature for a B star, we shall assume it is about a B5 V classification and then look at the spectral type figure.



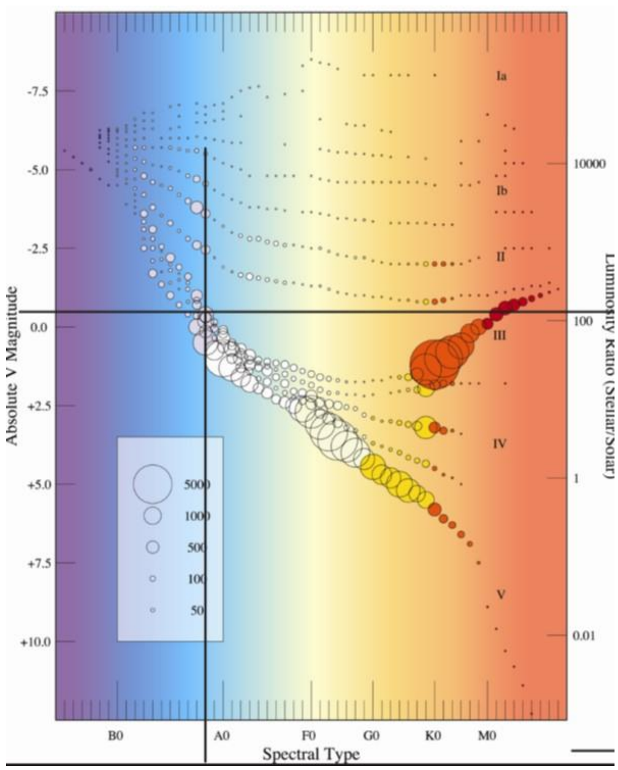
With this in view, there are moderately strong H-alpha and H-beta lines, as well as other ionized hydrogen lines such as H-delta and H-gamma. For its spectral type, the He I lines are very weak, though this is due to it being a cooler B star as higher temperatures meet the needs of high ionization energies, and instead the star has stronger H lines as already mentioned. To be expected, there are no metals present in this star as those are associated with the coolest stars, typically classified as M stars, that allow for molecular bonds to form.

Though a G2 V star is not labeled in the above examples of different spectral types, that is our Sun's classification with its own notable spectral lines present!

Though temperature is an important aspect in determining spectral types, it is not the most precise reflection of a star if other factors such as mass, luminosity, and absolute magnitude are not considered. From the figure below [12], we can see just how many factors of a star can be inferenced from its position on the HR diagram.

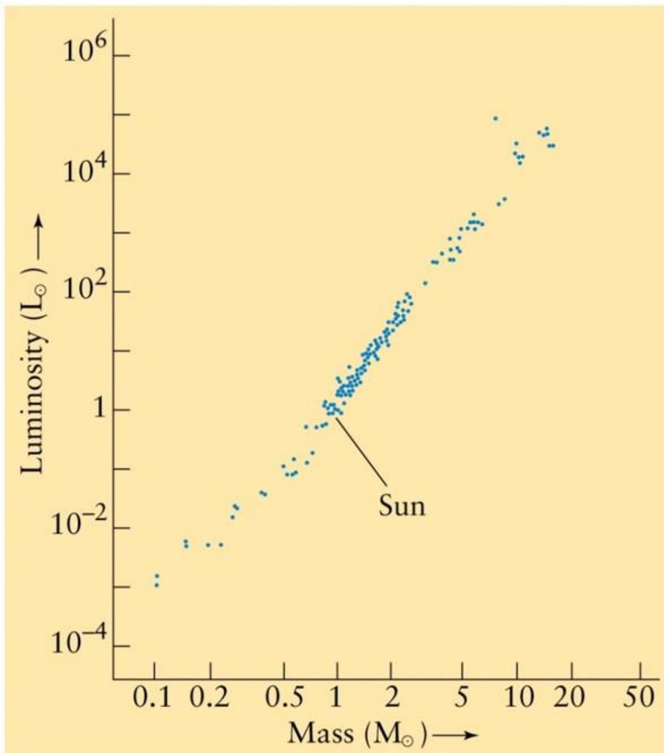


Yet, the best diagram to use for determining the stellar classification of the 3.00 solar mass star is the HR diagram first shown in this paper, but noticing the many different elements can also help to ensure that the star is located in the right position on the diagram. By comparing from the absolute magnitude calculated earlier of -0.83 mags and the luminosity being slightly above 110 times that of the Sun, and the help of some electronic tools (pen and ruler), the HR diagram has helped to deduce that the more likely stellar classification of the 3.00 solar mass star is not too far off as a B8 V. As we can see, this position on the diagram is more accurate as it reflects its temperature, absolute magnitude, mass, radius, and luminosity more true to character when comparing this graph to the previously shown HR diagrams that showcase more of the inferenced elements based off spectroscopy and photometry.



[8*]

This star, being on the main sequence as shown on the HR diagram, has a predictable evolutionary path which can be noticed by the patterns of the stars that are not on the main sequence. The question then arises, how long is this star's main sequence lifetime? Before performing the necessary calculations to answer this question, it is important to note that a star with more mass produces more energy at faster rates than lower mass stars. Therefore, a relationship exists between mass and luminosity, and there is an indication of an inverse relationship between a star's main sequence lifetime and its mass. The mass-luminosity relationship visually can be represented as a diagram, where luminosity is proportional to its mass in solar units to the fourth power. As expected, we can see that on this diagram [13] where a 3.00 solar mass star closely lines up with the luminosity around 10^2 which approximately reflects its luminosity of almost 120 times that of the Sun. To find out how to calculate its main sequence lifetime, we still need more mathematical relationships.



[13]

In terms of energy, thanks to Einstein we are aware of the equation that energy is equal to mass times the speed of light squared ($E = MC^2$). Due to the speed of light being a universal constant, we can simplify the equation for energy being proportional to mass. We can simplify these into a nuclear time scale, where we set tau (the lifetime) equal to the energy divided by the rate at which the energy is being used as fuel. In terms of stars, this is its energy divided by luminosity. Substituting the previous mathematical relationships and multiplying it by the Sun's main sequence lifetime of 10×10^9 years, the results are:

$$\tau = (10\ x\ 10^9\ years) * (\frac{\Delta E}{L})$$

$$where\ \Delta E\ is\ proportional\ to\ M, and\ L\ is\ proptional\ to\ M^4, the\ expression\ is\ as\ follows:$$

$$\tau = (10\ x\ 10^9 years) * \left(\frac{M}{M^4}\right) = \left(\frac{10\ x\ 10^9 years}{M^3}\right), where\ M\ is\ in\ solar\ units$$

$$\tau_{3.00} = \left(\frac{10\ x\ 10^9 years}{3^3}\right) = \left(\frac{10\ x\ 10^9 years}{27}\right) = 370\ x\ 10^6\ years$$

From the simplified form of the timescale, we can calculate that the main sequence lifetime for a 3.00 solar mass star is 370 million years, long outlasting us.

And yet, it is not the only star out there. In our Universe, there is a true and real blue 3.00 solar mass B8 V star named Alpha Sagittarii, or Rukbat, with characteristics similar to those mentioned here. The mass and classification are the main identical aspects, but the other characteristics are not incredibly different. Located in the constellation Sagittarius approximately 55 parsecs away, according to the Universe Guide's website [14], Rukbat has most recently been stated to have a radius 2.05 times larger than the Sun and a luminosity almost 130 times greater than our Sun. These are larger values than expected for a 3.00 solar mass as in this paper we have discussed a 3.00 solar mass star (like Rukbat) having a radius of about 1.6 times that of our Sun rather than over double it. Additionally, the luminosity datum point for the general 3.00 star discussed in this paper was 116 times that of the Sun, which is a smaller value than Rukbat is characterized to have according to the Universe Guide. Despite the luminosity difference, Rukbat is still characterized to have a smaller absolute magnitude of 0.23 mags, though it is still visible to the naked eye. The temperature is the only thing not found from the Universe Guide's website and instead is utilized from the datum point from The Sky Live's website [15] given as about 11,500 K, which is a lower temperature than expected, likely to help the star maintain its hydrostatic equilibrium. With how similar these two stars are, the span of Rukbat's life and its characteristics throughout should not be significantly different from the life that the 3.00 solar mass star was described to have. Operating from the same principles and having such similar descriptions, Rukbat still has many more reactions before it evolves into its next stage off the main sequence.

IV. CONCLUSION

In the end, this star is not near likely to ending up as something as exciting as a black hole or allow us to view a supernova in our time, but it is still a relatively impressive star. Larger and brighter than our Sun in almost all aspects, this star is an insight into the intricate mechanisms that every star is experiencing. Despite humanity, even across multiple generations, not living long enough to witness its birth or its death, we have still studied as much of the science as possible to predict its evolution. There is something magical about learning about the star's knowing that the atoms in our body, the blood in our veins, could never have existed had these stars in the universe never existed. Describing and characterizing a star and the science behind at expert level is simply a gateway into astronomy, a field where its students have such a drive of curiosity, and immense tasks against time to face against. Though this paper has come to its conclusion, your journey into astrophysics does not have to end here, and may the stars guide you into finding new knowledge.

V. CITATIONS

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