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ASTRON 98

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Final Project Report

For my final project, I sought to find the relationship between star surface gravity and star mass. I figured that more massive stars would, in theory, have high surface gravities based on Newton's universal law of gravitation $g = \frac{GM}{R^2}$ (where g would be representative of the surface gravity of the star, G the gravitational constant, M the star mass, and R the radius of the star). To do this, I used data from NASA's Exoplanet Archive, which provides numerous data points for different metrics relating to exoplanets across the universe. To find a relationship, I used Numpy and MatplotLib to graph the raw data and utilized SciPy to attempt to fit the curve to an equation resembling Newton's universal law of gravitation.

This project was not what I had originally sought out to complete. My project proposal initially was to find a relationship between the mass of exoplanets and their orbital eccentricity as thai was something being explored in my physics class at the time. However, after completing the initial steps of the project I found it hard to find an accurate and consistent relation between the two factors, causing me to pivot to the project I have now.

The initial steps in my project included importing a csv file downloaded from NASA's exoplanet archive, which provided a table of 35131 rows × 8 columns. When importing the csv file, I found that my data had many "bad" rows, which I had to remedy with a skiprows command. This was a lot of data, and the scatter plot of the data included many outliers and, overall did not seem to exemplify much useful information (Figure 1). To remedy this issue, I filtered the data to a specific collection, focusing on star masses between 0 and 1.4 solar masses and star surface gravities between 3 and 5.5 $log_{10} \frac{cm}{s^2}$. This created a plot that focused on the greater portion of the data and showed a relation that looked promising (Figure 2).

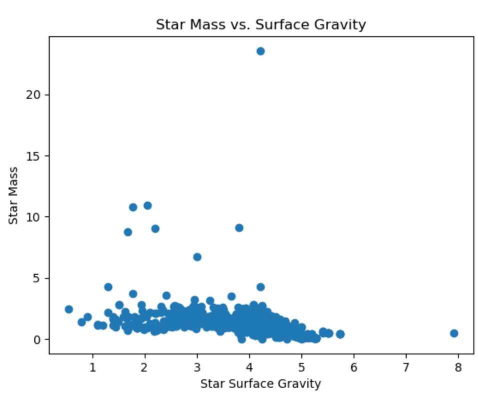

Figure 1

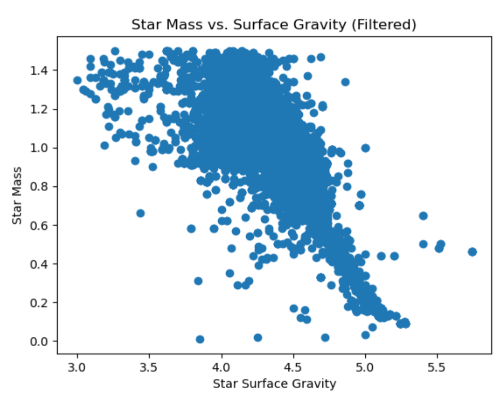

Figure 2

The next step was ot focus on the curve fitting. I initially tried to do this by using the equation $g = \frac{GM}{R^2}$ where I would try and find values of R that were appropriate for my data; however, I found the radii of stars was too variable of a factor to fit to and later switched to an approach focusing on fitting the data to values of density that were appropriate as density is less varied between stars and more dependent on star type. I was able to combine the equation for Newton's universal law of gravitation with the equation for a star's mass $M = \frac{4}{3}\pi R^3 \rho$. This is just the $M = \rho V$ equation where V is the volume, R represents the star's radius, and ρ is the density of the star. This allowed me to get the relation $S = \frac{GM}{(\frac{3M}{4\rho\pi})^{2/3}}$ or $S = \frac{GM^{1/3}(4\rho\pi)^{2/3}}{3^{2/3}}$ where S is the star surface gravity. The curve fitting process did not go as planned at first I thought this was due to the inconsistency of units in my data. To troubleshoot this problem, I tried to standardize all of the units to what my data provided: this meant "delogging" my star surface gravity values with the command ydata_unlogged = 10**stsur_grav and also putting all units into kg/cm^2 like what was represented in the data. Through research, I concluded that an appropriate value for density would lie somewhere between 2.842×10^{-4} and 1.989×10^{-3} $\frac{kg}{cm^3}$ (representing stars with 0.2 solar masses and 1.4 solar masses respectively). By going through with this process, I was able to finally get a density value that seemed to accurately represent my data: 0.00162457 $\frac{kg}{cm^3}$. However, my curve fitting still did not accurately represent the data in a way that proved useful (Figure 3). At first I thought this may be at least slightly fixed by limiting the y-values to those between 0 and 200000. I did this using a plt.ylim(0, 200000) command, but this instead highlighted the problem to do with my graph. My graph ended up have many outliers in the lower end of my star mass values (Figure 4). I hypothesize this was due to the fact that the density value my curve fitting predicted corresponded closer to values toward the higher end of the the star masses, hence the curve fitting more withing the higher data values.

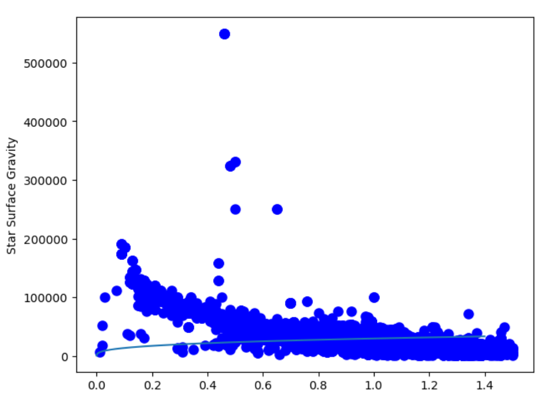

Figure 3

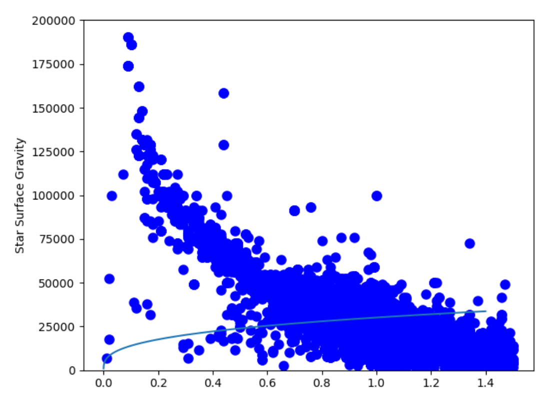

Figure 4

Unfortunately, my curve fitting process did not produce a helpful result. If I had more time to complete this project I would look into more sources on what appropriate curve fitting procedures would be for this given dataset. I would try to see if my issues were possibly caused by lighter stars having a different density proportionally to their mass. Maybe this was due to a wide variety of star types being presented and their densities being related to their star type. I would try filtering the data by star type and seeing if a correlation exists there. Ultimately, spending more time on this project would allow me to explore question like these and get tot the bottom of why my result wasn't exactly what I had thought initially.

Overall, this project, while unsuccessful, ultimately taught me a lot about real-world applications of the topic learned in this class and exposed me to the applicability of tools like these to physics. I hope that these skills will remain helpful as I go forward in my time in the Astronomy department.