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Final Project Report

For our final project, we experimentally tested Kepler's Third Law, which relates the orbital period of a planet **T** to the length of its semimajor axis *a* under the proportionality $\mathbf{T}^2 \propto a^3$. To do this, we used data from the NASA Exoplanet Archive, which contains data collected from over 30,000 observations of exoplanets. Primarily utilizing primarily the numpy and matplotlib libraries, we created an experimental graph of a selected group of observations, determined the deviation of observed values from those predicted by Kepler's Third Law, and generated a constant of proportionality based on experimental values to re-derive the complete model equation. It is worth noting that the project's original premise was to examine trends in the spectral types of stars near Earth. However, we were forced to modify that idea because the database with appropriate data – SIMBAD – proved incompatible with analysis in Python using the skills at our disposal. As such, the project being presented now was adopted as an equal albeit different alternative.

Our data set had to be narrowed down from the 30,000 observations collected in the archive. To avoid outlying values, we limited the period to one Earth year, and further reduced the dataset by restricting the distance of objects from Earth to be within 100 pc of Earth, which also improves the reliability of the data. With both parameters applied, the data set was reduced to 1,903 targets. We downloaded the period and orbital semimajor axis data of these targets onto a .CSV file which was then uploaded to a folder in Jupyter Notebook. In a separate python file in the same Jupyter notebook folder we created a scatter plot with a fitted curve and error bars for each of the 1,903 data points. The scipy.optimize.curve_fit function returned a constant value k as sol[0] relating $\mathbf{T}^2$ to a^3, generating the equation $\mathbf{T}^2 = ka^3$.

The graph shows that the relationship between **T** and a is a ⅔ power ratio in keeping with Kepler's Third Law. The vermillion orange dots represent each data point and the vertical blue lines represent the error for each data point. The fitted curve represents the direct graph of $\mathbf{T} = k * a^{2/3}$ where k is experimentally equal to ~0.02 $\frac{AU^3}{day^2}$. Such a proof validates not only Kepler's Third Law, but the entire body of work founded on it in various industries, including predictions of the motion of Solar System planets and calculated flight paths of rockets and satellites going to the Moon and beyond the Solar System.

Throughout the project, the data collection and analysis process went smoothly. The NASA Exoplanet Archive is cohesive and user-friendly; the table allowed for simple parameter creation and was very easy to download and extract data. However, generating the graph was a struggle. The first issue was creating the error bars, due to having to extract the semimajor axis error from a function without calling the function in matplotlib.pyplot.errorbar. We resolved this by organizing the modelvallist(period) function's output with a numpy array and calling the array. The second major issue was creating the curve fit line and finding *k.* This was resolved by allowing the function to find k from the ideal outcomes (a y = ⅔x proportionality) and semi-major axis data.

In conclusion, this project was very helpful in interpreting the topics learned in this class in a real-world context. It is incredibly helpful in mimicking the code that will likely serve us well in our futures as aspiring researchers.