Lab 1 - Intro to Astronomy

Introduction

The goal of this lab was to calculate the mass of Jupiter using the orbital period and distance of one of its moons. From the Newton's version of Kepler's third law, we can relate the orbital period and orbital radius using the following equation:

$$T^2 = \frac{4\pi^2}{GM} R^3$$

- T is the orbital period
- R is the orbital radius
- M is the combined mass of the planet and the orbiting mass (we can ignore the mass of the moon due to its small mass compared to Jupiter)
- G is the gravitational constant

Now, in actuality the calculated constant ($\frac{4\pi^2}{GM}$) may differ between different moons due to a variety of factors.

In this lab, we will plot the orbital period and orbital radius of Jupiter's moons and use the slope of the line to calculate the mass of Jupiter.

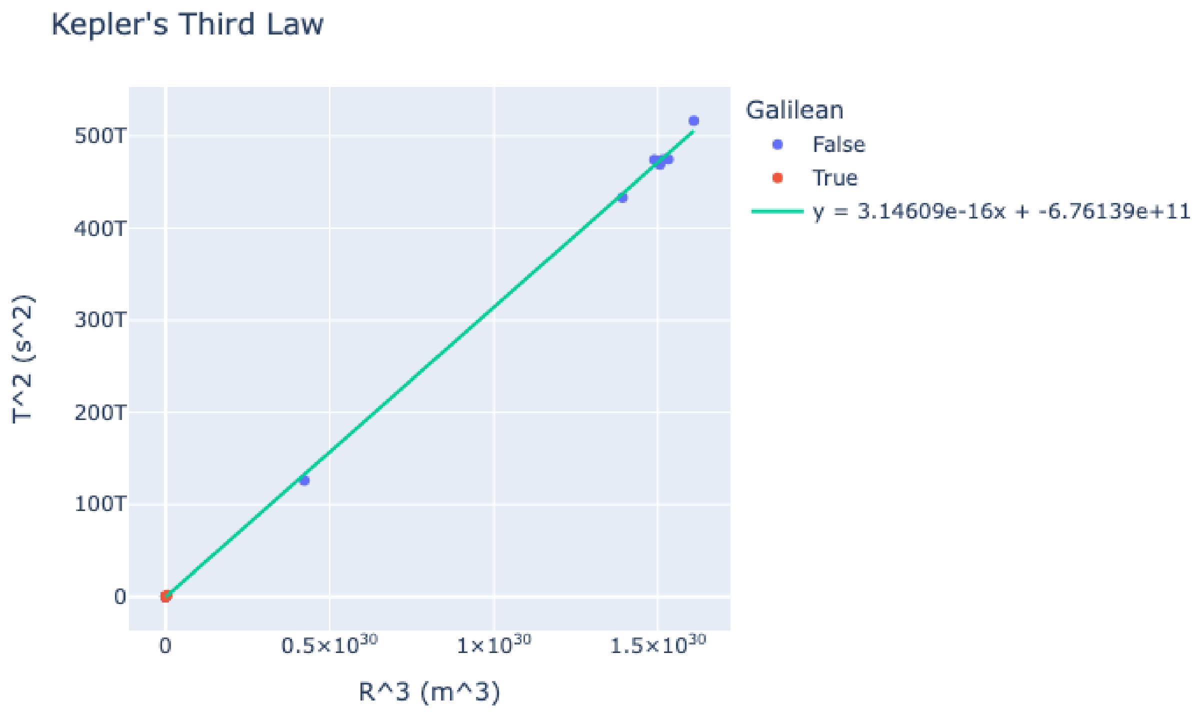
Data

After collecting data on the orbital period and orbital radius of Jupiter's moons (https://www.britannica.com/topic/moons-of-Jupiter-2236909), I prepared a python script to format it and do the calculations. Check my github repository for the code (https://github.com/mattraghu/Spring2024/tree/main/Astronomy/Labs/Lab1).

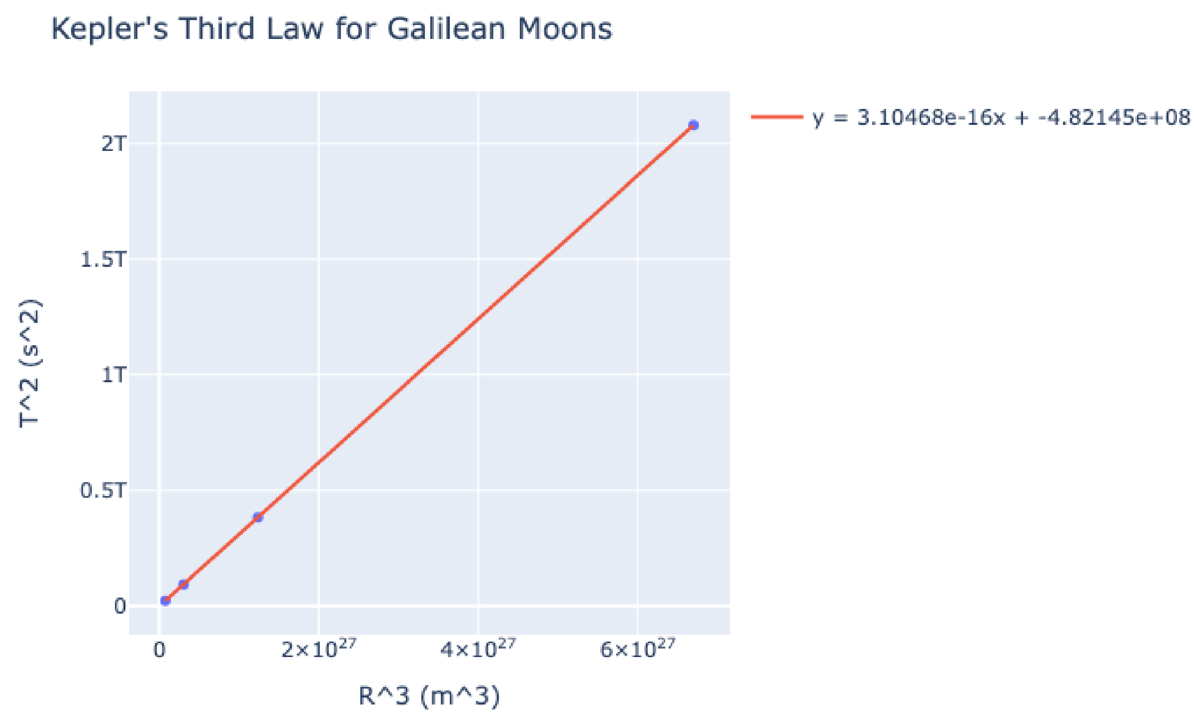
Name	Orbital Perioc	Radius (km)	Distance fron	Galilean	Orbital Perioc	Radius (m)	Distance fron	R (m)	R3	T2
Metis	0.3	21.5	128000	False	25920	21500	128000000	128021500	2.098208945	671846400
Adrastea	0.3	8.2	129000	False	25920	8200	129000000	129008200	2.1470983946	671846400
Amalthea	0.5	83.5	181400	False	43200	83500	181400000	181483500	5.9773878818	1866240000
Thebe	0.68	49.3	221900	False	58752	49300	221900000	221949300	1.0933553615	3451797504
Io	1.77	1821.6	421800	True	152928	1821600	421800000	423621600	7.6021124363	23386973184
Europa	3.55	1560.8	671100	True	306720	1560800	671100000	672660800	3.043605487	94077158400
Ganymede	7.16	2631.2	1070400	True	618624	2631200	1070400000	1073031200	1.2354837845	38269565337
Callisto	16.69	2410.3	1882700	True	1442016	2410300	1882700000	1885110300	6.699004955	20794101442
Themisto	130	4	7507000	False	11232000	4000	7507000000	7507004000	4.230580291	12615782400
Leda	240.9	10	11165000	False	20813760	10000	11165000000	11165010000	1.3918016568	43321260533
S/2018 J2	252	3	11419700	False	21772800	3000	11419700000	11419703000	1.489239090	47405481984
Himalia	250.6	85	11461000	False	21651840	85000	11461000000	11461085000	1.505487660	46880217538
Ersa	252	3	11483000	False	21772800	3000	11483000000	11483003000	1.514141402	47405481984
Pandia	252.1	3	11525000	False	21781440	3000	11525000000	11525003000	1.5308165235	47443112847
S/2011 J3	263	3	11716800	False	22723200	3000	11716800000	11716803000	1.608523402	51634381824

Plots

All Moons



Galilean Moons



Jupiter's Mass

All Moons

$m = 3.146086440304132e - 16$

$$
\begin{aligned}
M &= \frac{4\pi^2}{Gm} \\
&= \frac{4\pi^2}{6.67430e-11 \cdot 3.146086440304132e-16} \\
&= 1.88011e+27kg
\end{aligned}
$$

Galilean Moons

$m = 3.104676779596539e - 16$

$$
\begin{aligned}
M &= \frac{4\pi^2}{Gm} \\
&= \frac{4\pi^2}{6.67430e-11 \cdot 3.104676779596539e-16} \\
&= 1.90519e+27
\end{aligned}
$$

Conclusion

Compared to the actual mass of Jupiter (1.8982e+27 kg) (https://nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html) the calculated mass is very close. (For all the moons the percent error was -.953% and for the Galilean moons the percent error was .368%)

It goes to show how powerful Kepler's laws are and how they can be used to calculate the mass of celestial bodies. Of course, it is also important to be aware of the limitations of the model as real life factors can affect the results.