Revolution of Jupiter's Moons

Introduction

Much scientific investigation involves inference, the use of observational evidence to infer the true nature of a system under study. For example, we observe a hole chewed in a bag of flower and see tiny tooth marks on the paper. From this evidence, we infer the presence of a rodent. In this lab, we will use scientific inference, observational data coupled with Newton's laws of motion, to infer the mass of the planet Jupiter.

In 1543 Copernicus hypothesized that the planets revolve in circular orbits around the Sun. Not much later, Tycho Brahe carefully observed the location of the planets over a period of 20 years using a sextant and compass. These observations were used by his student, Johannes Kepler, to deduce three empirical mathematical laws governing the motions of the planets in the solar system.

Kepler's Third Law relates the the semi-major axis of a planet's orbit (its average distance from the Sun) to its orbital period (how long it takes to get all the way around). Isaac Newton later demonstrated that all of Kepler's laws are natural consequences of a few basic laws of nature. While Kepler was only talking about the solar system, Newton's generalization applies to any two orbiting bodies.

$$a^3 = \frac{G(M+m)}{4\pi^2} P^2$$

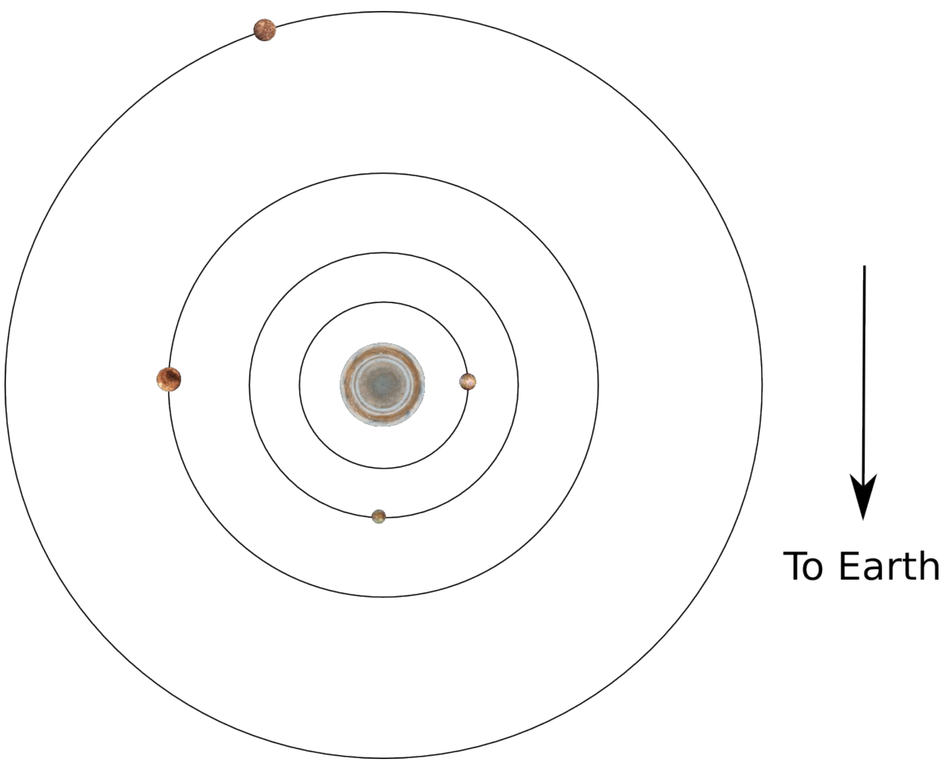
In the equation above, *a* is the semi-major axis of the orbit, *P* is the orbital period, and *M* and *m* are the masses of the orbiting bodies. With Newton's modification, we have a way to infer mass by observing the orbital dynamics of a system. In part one of this lab series, we will explore how the above relationship applies to Jupiter and its moons.

Part 1: The Jovian System

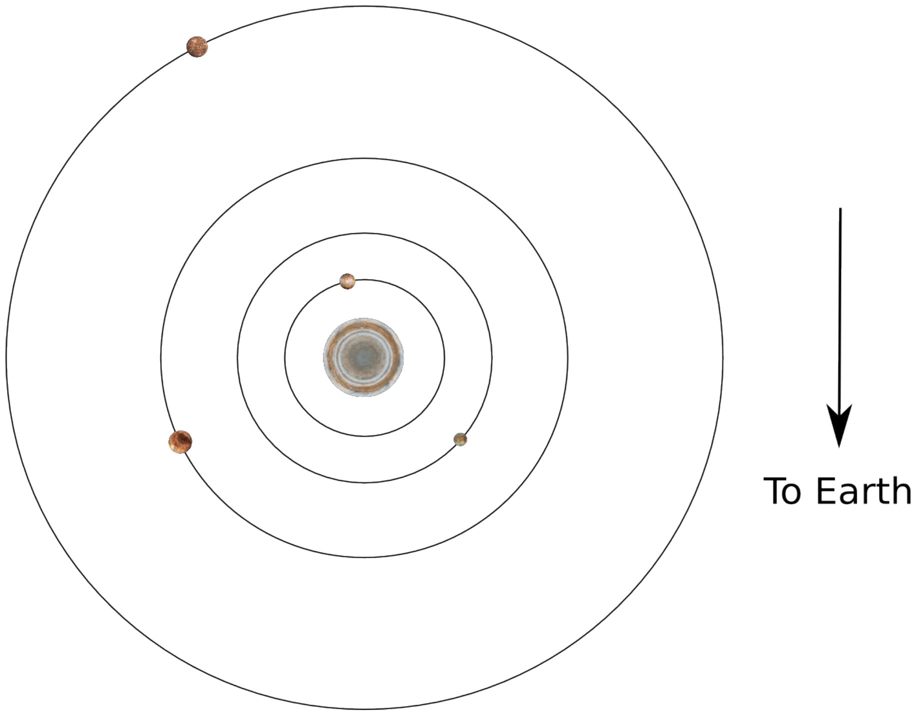
We will begin by developing an understanding of the motions of Jupiter's moons as observed from the Earth.

- Below is a typical snapshot of Jupiter and its moons. Use the picture to answer **Questions 1 and 2** in your answer packet.
- Compare your answer with your partner group and come to a consensus on the answer. Share your answers with the class.

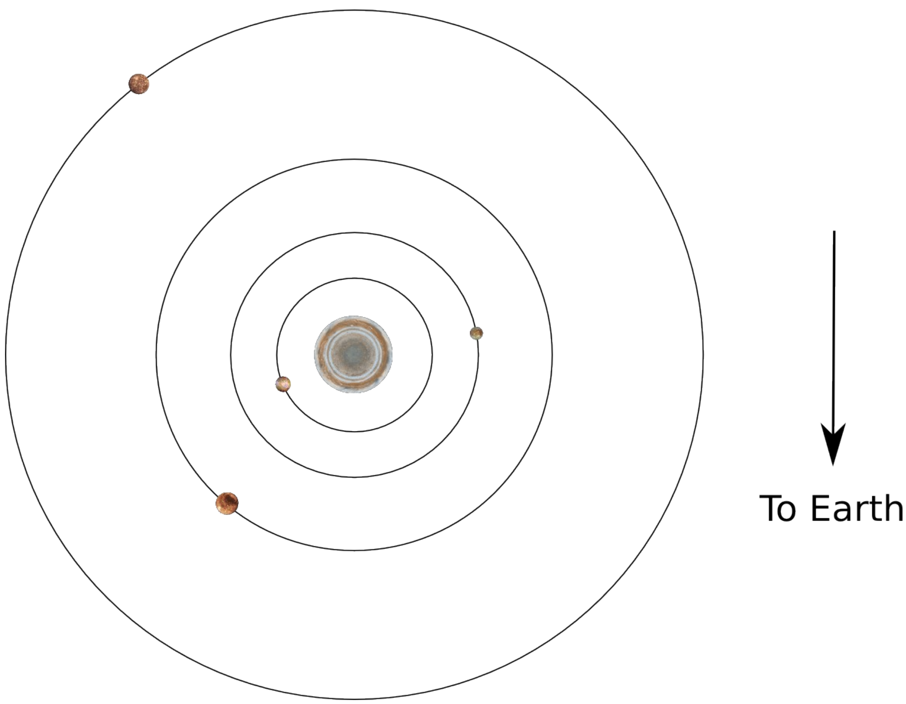
- Below are three snapshots of the of the Jovian system as viewed from above Jupiter's north pole. In the space provided in your answer packet, sketch the system as it would be seen from Earth.



Snapshot 1



Snapshot 2



Snapshot 3

- The snapshots above were taken **12 hours apart** from each other. Use this information to answer **Question 4.**
- On the lab web page, **http://phys.stthomas.edu/MoonsOfJupiter/** click the Jupiter Simulations Link and watch the video there. Answer **Questions 5 and 6**. Share your answers with the class

<u>Part 2:</u> Develop an Observing Plan

Now, we will explore the connection between images of the Jovian system and Newton's version of Kepler's Third Law.

- In your answer packet, answer **Part 2 Questions 1 and 2**. Share your results with the class.

- On the lab web page, choose the **Circular Motion** link. Watch the demo after choosing each of the options under the 'Image' menu. Answer **Questions 3 and 4**.

- **Observing Restrictions!**
  - Jupiter is currently only observable for 3 hours per night.
  - You have been awarded 15 images total.
  - Weather in Minnesota favors plans requiring a small number of consecutive nights.

- The **Circular Motion** plot on the web page displays a continuous line. You will not have continuous observations but snapshots at several discrete points in time. You must use what you know about the orbital period of each of Jupiter's moons (from Part 1) and your observing restrictions (above) to decide how to best distribute your observations in time. Answer **Questions 5 through 9**.

- Discuss your parameters from **Question 9** with the class and come to a class consensus on your observing plan.