

The Galilean Moons of Jupiter

The year 2003 brought the discovery of 21 new satellites orbiting the planet Jupiter, bringing the total number to 61. Jupiter’s four largest moons, the Galilean satellites: Ganymede, Callisto, Io, and Europa, can be seen with a small telescope or a pair of binoculars. If you were to observe them every day for a couple of weeks and sketch their positions relative to Jupiter, you would be able to use the sketches to determine the orbit, and hence the orbital period, of each moon. Using the orbital information for the moons and Newton’s form of Kepler’s 3rd law, you will calculate the mass of the planet Jupiter.

Between January 7 and January 24, 1610, Galileo made such a series of sketches of Jupiter and its four largest moons (Figure 1). We have provided a computer-generated series of diagrams of Jupiter and its moons for this same time period, spaced exactly one day apart (Figure 2).

1. Sketch the path of each satellite by connecting the successive points for each of the satellites on Figure 2. Each path should be a smooth wave.
2. Measure the period of each satellite, in days, from the paths you sketched on Figure 2. Measure the diameter of each satellite’s orbit and convert this to km (Note: Jupiter’s diameter is 142 985 km).
3. Use the period and size of the orbit to determine the velocity of the satellite (Note: Circumference = πD).
4. Using Newton’s form of Kepler’s 3rd law, ($M = \frac{v^2 R}{G}$; where M is the mass, v is velocity, R is the *radius* (NOT diameter!), and the universal gravitational constant, $G = 6.67 \times 10^{-20} \text{ km}^3 \text{ kg}^{-1} \text{ s}^{-2}$) calculate the mass of Jupiter for each moon. Find the **average** Jupiter mass from the 4 values (accepted mass of Jupiter is $1.89878 \times 10^{27} \text{ kg}$).

Satellite name	Period (days)	Period (seconds)	Diameter of orbit (mm)	Diameter of orbit (km)	Circumference of orbit (km)	Velocity (km/s)	Mass of Jupiter
Io							
Europa							
Ganymede							
Callisto							

5. Look at Galileo’s sketches of Jupiter and its moons (Figure 1), which he made in Venice, Italy, between January 7 and January 24, 1610. Compare these to the computer-generated diagrams in Figure 2. On what two days in this period did Galileo not make a sketch?
6. Using Figure 2, predict what Jupiter and its moons looked like on January 25, 1610 at the same time that the other diagrams were made. Make a sketch of this and label the moons.

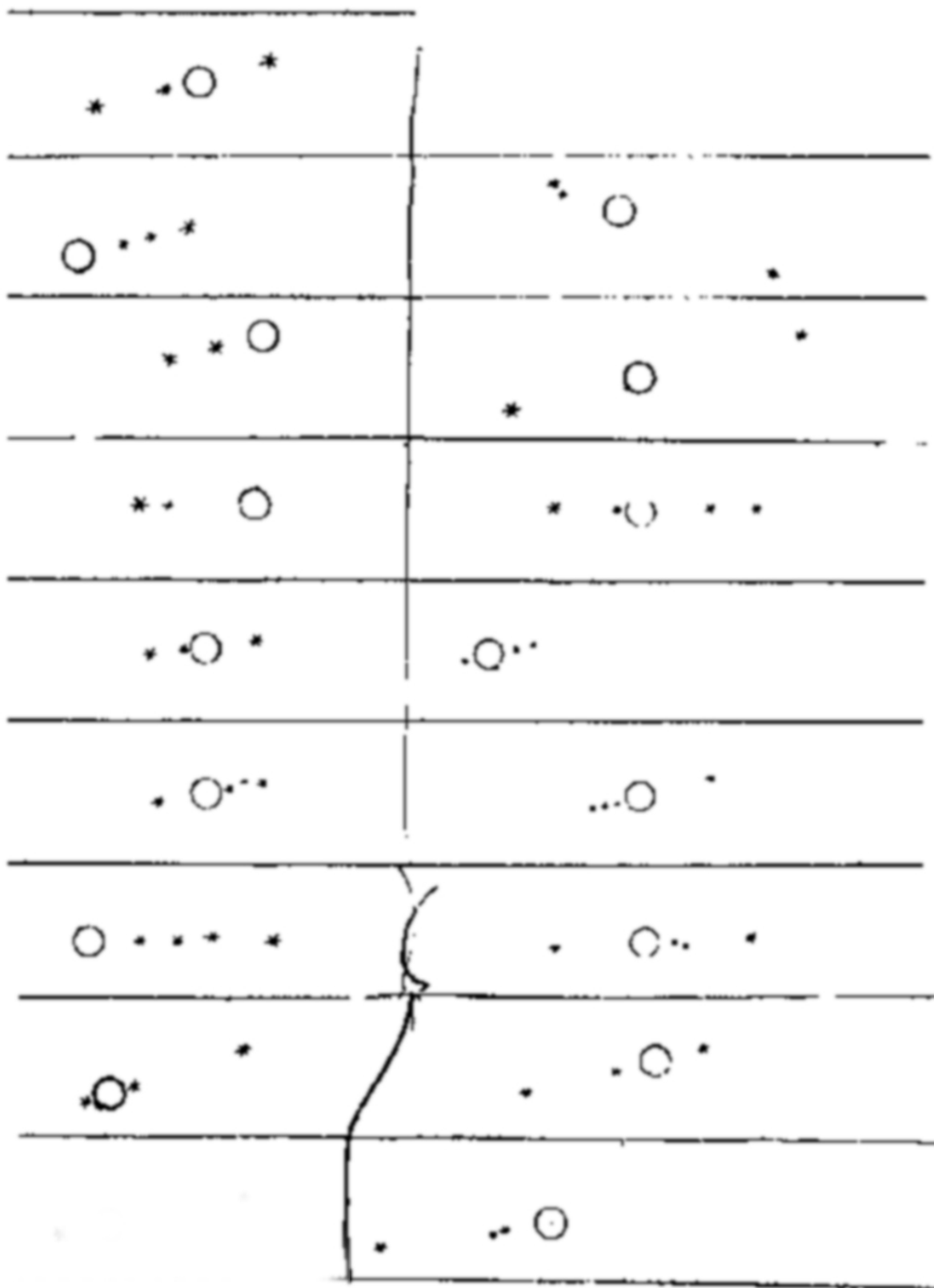


Figure 1: seventeen of Galileo's sketches of Jupiter and its moons, made on 17 nights between January 7 and January 24, 1610. The sketch on the top left was made on January 7, and the sketch on the bottom right was made on January 24. No sketch was drawn for two nights during this time period.

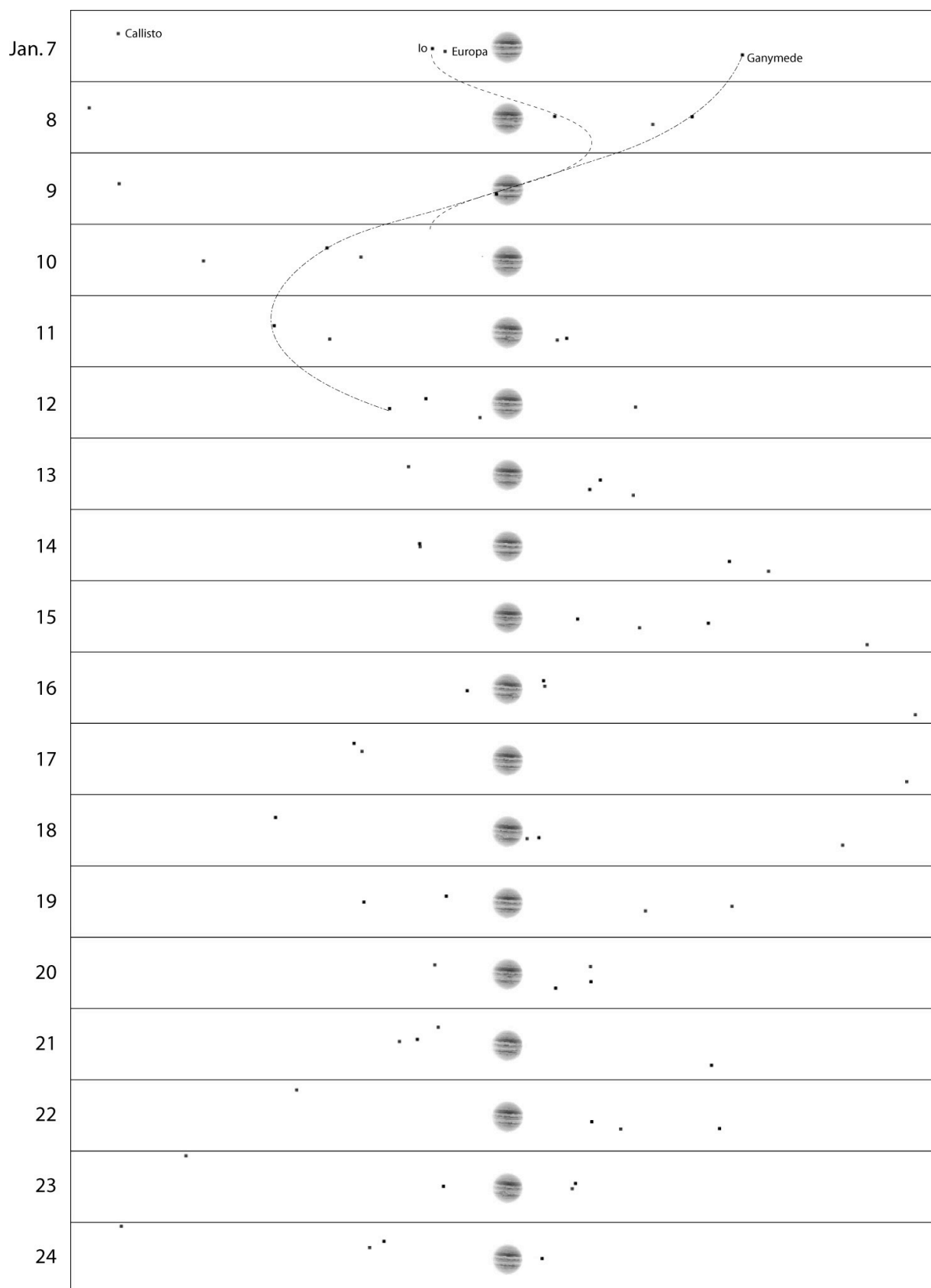


Figure 2: Starry Night prediction of Jupiter and its four largest moons as they appeared each evening, from Venice, on January 7-24, 1610. The beginnings of the curves for the moons Ganymede and Io are drawn to assist in identifying the moons throughout the orbit.