

Name: _____

Date: _____

Section: _____

Astron 104 Laboratory #2

Planetary Motion and the Night Sky

Chapter 5

Introduction

Modern astronomers have many tools to explore the solar system: large telescopes to provide detailed images, spacecraft orbiting other planets, even roving science labs on the surface of Mars. But the basic layout of the planets and structure of the solar system can be inferred simply by watching the motions of the planets through the night sky over weeks, months, and years. In this lab, we'll infer the structure of the solar system based on simple observations you can make with the naked eye.

Learning Objectives

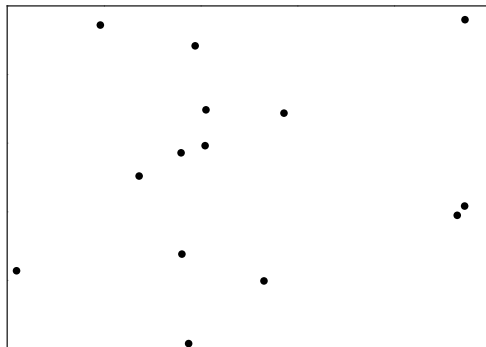
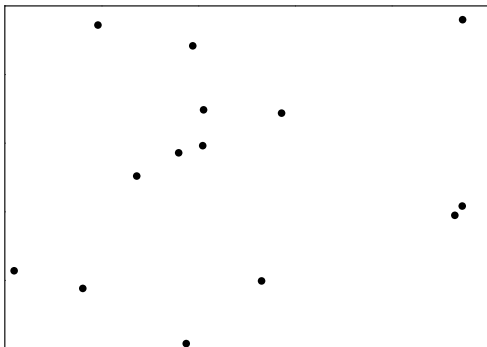
At the Completion of this lab, you should be able to:

1. describe how we can distinguish solar system planets from stars using observations
2. explain the evidence that planet orbits are coplanar
3. apply observational evidence to determine the orbital direction of planets
4. relate observed retrograde motion of planets to Earth's own orbital motion
5. use naked-eye observations to determine the order of planets from the Sun

Observing the Night Sky [20 pts total]

The illustrations on the next page show a section of the night sky on two different dates, 3 months apart. These illustrations are negative images — the black dots represent bright points of light, and the white space is the dark night sky.

Let's start off by playing ancient astronomer. Can you find any shapes or pattern in the points of light? Feel free to draw your own; there's no correct answer here! You can describe what you see in the space below the images. [5 pts]



A pattern of stars on the night sky is called an *asterism*. The familiar Big Dipper in the northern sky is one example. Asterisms made the night familiar to ancient astronomers, but also aided them in noticing changes. Look at the asterisms you found in the images above and describe anything that seems to change. [5 pts]

Some points of light seem to move through the constant pattern of the asterisms. Our modern word *planet* comes from the Greek word for *wandering*.

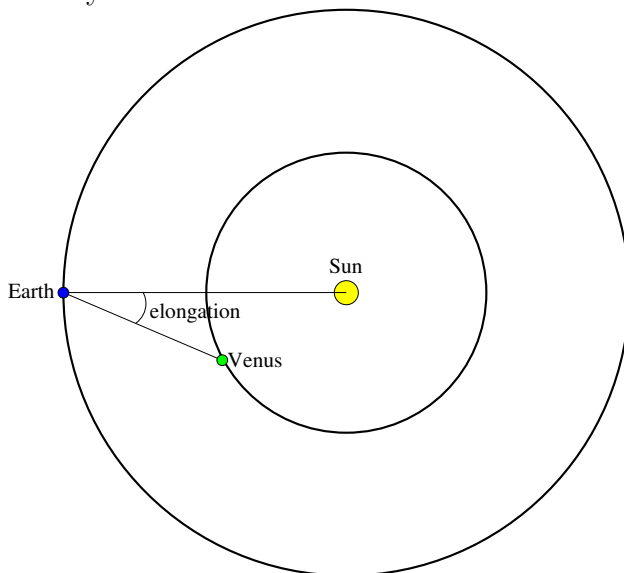
In the series of night sky illustrations shown above there is one planet. Circle the planet in each image. [5 pts]

How are you able to distinguish planet from the stars? [5 pts]

Ordering the Planets [35 pts total]

Planets orbiting farther from the Sun than Earth does are known as *superior* planets, while those orbiting closer to the Sun are known as *inferior* planets. Naked-eye observations can tell us which are which.

Diagram 1 at the end of the lab shows the Sun and the orbits of Venus (inner), Earth (shown as a dot), and Mars (outer) to scale. The *elongation* of a planet is the angle between the Sun and the planet in the sky as seen below:



A cartoon showing how elongation is defined

Place Venus somewhere along its orbit in Diagram 1 and indicate the elongation at this point in the orbit. [5 pts]

The *greatest elongation*, as its name implies, is the point where a planet's elongation reaches its maximum value. Draw Venus at its points of greatest elongation. Why are there two points? [5 pts]

Measure using a protractor the angle of greatest elongation for Venus. [5 pts]

Mercury is never seen farther from the Sun than 28° . Is Mercury closer or farther from the Sun than Venus? Briefly explain your reasoning, and draw Mercury's orbit on Diagram 1. [5 pts]

Mars is a superior planet. What is the largest possible angle between the Sun and Mars as measured from Earth? **[5 pts]**

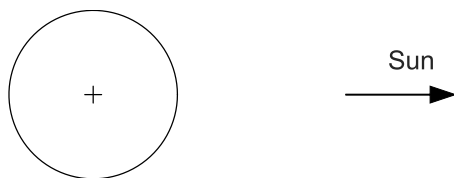
Opposition is when a planet is in the opposite direction as the Sun from Earth. Draw Mars at opposition in Diagram 1 (end of the lab). **[5 pts]**

How can we use observations of greatest elongation and opposition to determine if a planet is inferior or superior? **[5 pts]**

Modeling Orbital Motion **[55 pts total]**

Our model for the motions of planets in our solar system must match our observations of their movements in the night sky. Let's investigate the *heliocentric* model of the solar system, where the Sun is at the center and the planets orbit the Sun.

Earth rotates around its axis, and Sun appears to rise in the east. If you look down on the North Pole, which way is the Earth spinning, clockwise or counter-clockwise? Use the illustration below to describe and sketch your reasoning. **[5 pts]**



We can represent the orbits of the planets as circles (in reality they are all slightly elliptical, but only very slightly). Diagram 2 at the end of the lab shows the Sun and the orbits of Earth (inner), Mars (middle), and Jupiter (outer) to scale. We are looking down on the North Pole of the Earth from outside the solar system.

Earth orbits the Sun in the same direction that Earth rotates. Draw an arrow along Earth's orbit in Diagram 2 to indicate this direction. **[5 pts]**

Earth completes one orbit around the Sun in 12 months. Since a circle has 360° , how many degrees around its orbit does Earth move in every month? **[5 pts]**

Use a protractor to measure angles and mark the position of Earth in 1 month, 2 months, and 3 months from the moment shown in the diagram. Label the four positions 0, 1, 2, and 3. What fraction of its complete orbit does Earth travel in 3 months (from position 0 to position 3)? Does this match your diagram? **[5 pts]**

The outer edge of the paper represents the directions of distant stars — the asterisms that the planets appear to move through as we view them in the night sky from Earth. Use a ruler to draw a straight line from Earth at the starting position (position 0) through Mars to the edge of the page. This is the location of Mars among the stars at Earth's position 0. **[5 pts]**

Mars makes one orbit around the Sun in 1.88 years. How many degrees around its orbit does Mars move in 1 month? Show your work. **[5 pts]**

Mars travels around the Sun in the same direction as the Earth. Use a protractor to measure angles and mark the position of Mars in 1 month, 2 months, and 3 months from the moment shown in the diagram. Make sure you label each with the appropriate number. How many degrees does Mars travel around its orbit in 3 months' time? **[5 pts]**

For each position, 1 through 3, draw lines from Earth through Mars and to the distant stars. Does Mars move in the correct direction through the stars? (Does it match your star map observations from earlier?) **[5 pts]**

Jupiter is the next planet out and it takes about 12 years to orbit the Sun once. How many degrees around its orbit does Jupiter move in 1 month? Show your work. [5 pts]

For Jupiter, mark its position along its orbit for each of the next 3 months. How did you know which direction it should go? Explain briefly. [5 pts]

Retrograde Motion [20 pts total]

As you have seen, the planets appear to march steadily across the background stars as seen from Earth. But ancient astronomers, watching the sky night after night, noticed that occasionally the planets stop, reverse course, and wander back in the opposite direction across the sky! This is known as *apparent retrograde motion*.

Continue adding new positions for Mars and Earth in Diagram 2 until you have reached at least 9 months from the starting point. What fraction of its orbit has Earth traced out in 9 months? How many degrees is this? [5 pts]

What fraction of its orbit has Mars traced out in 9 months? [5 pts]

At each time point, draw the line from Earth through Mars to the distant stars. Does Mars continue to move steadily in the same direction across the sky? How can you tell when it changes direction? [5 pts]

Explain what actual motions cause the apparent retrograde motion of Mars when viewed against the background of distant stars? [5 pts]

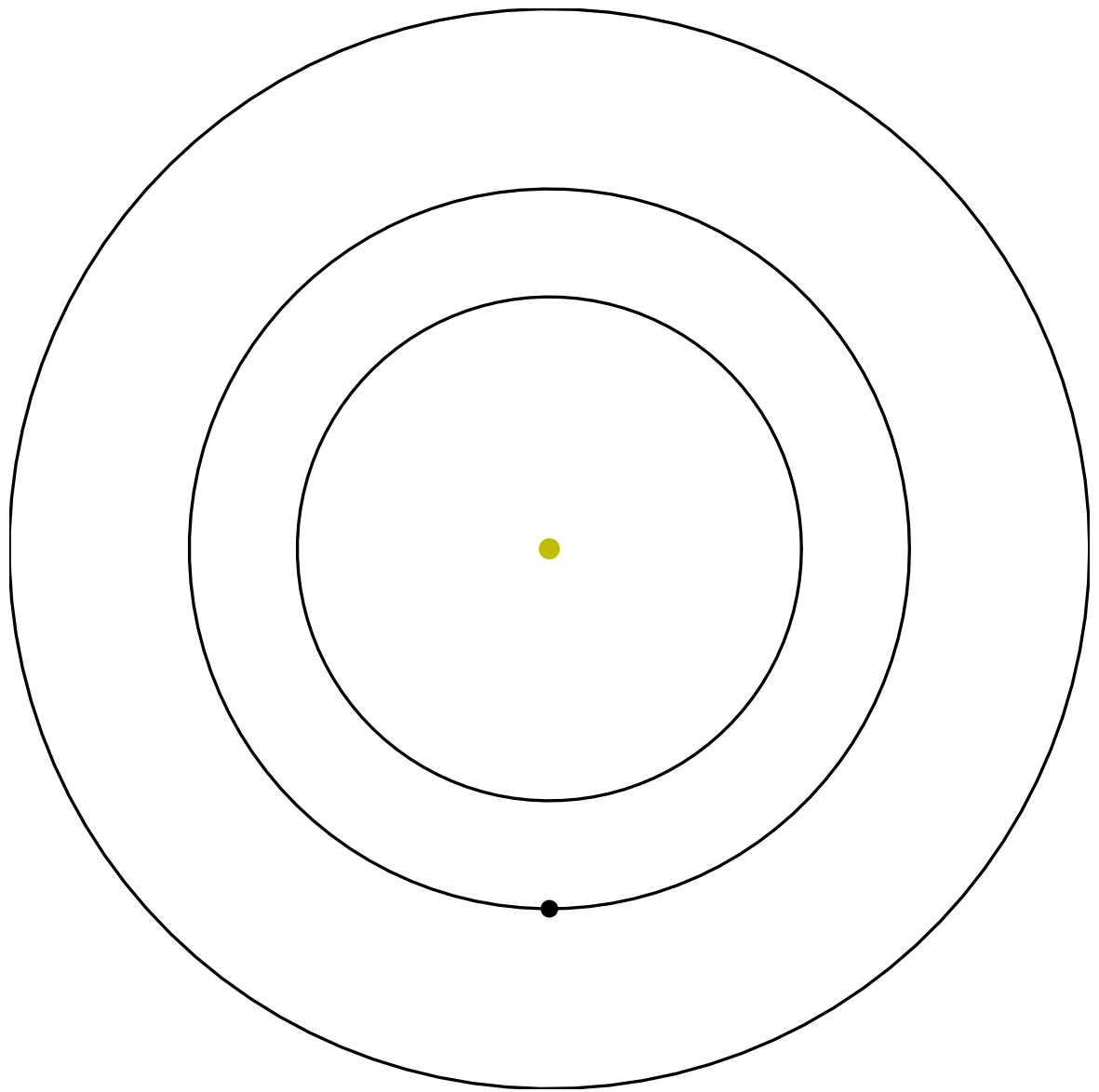


Diagram 1: Venus/Earth/Mars orbits

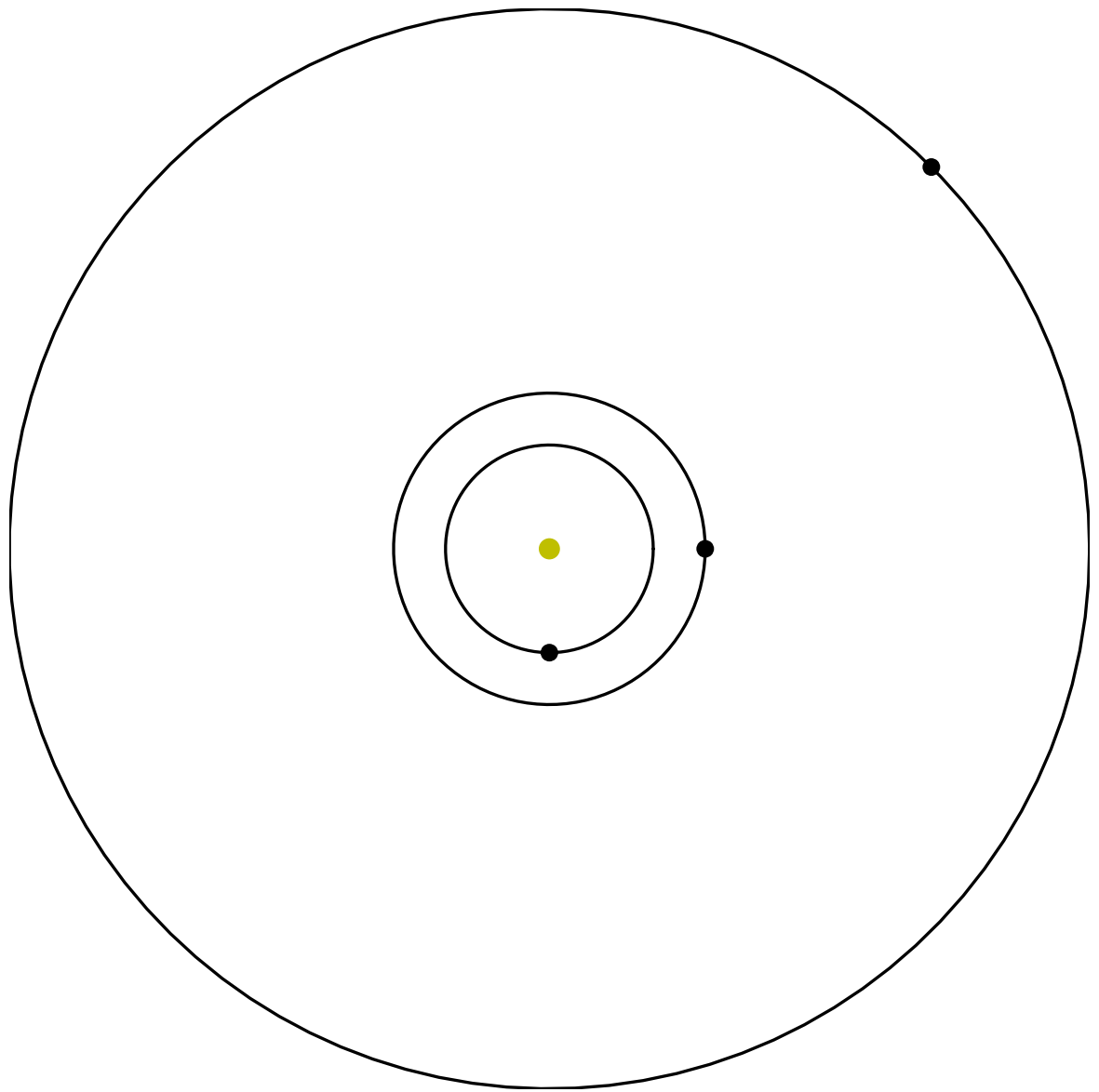


Diagram 2: Earth/Mars/Jupiter orbits