

## Physics 10293 Lab #8:

### The Outer Planets

#### Introduction

Today we will explore the motions in the sky of the outer planets that are easily visible to the naked eye: Mars, Jupiter and Saturn.

#### Step 1

Start by opening the Skyguide tab on the sidebar, then select the top option, "Student Exercises". Select "C: The Planets". This will open a list of exercises. Open "Exercise C1: The Inner Planets of the Solar System" and from here, exercise "Part 1: Orbits of the inner planets."

When one of the outer planets is directly on the opposite side of the Earth from the Sun, we call this opposition. During this time, the planet and the Earth are at their smallest distance from one another, and the planet is therefore at its brightest in our nighttime sky, high overhead at midnight.

The simulation "Part 1: Orbits of the inner planets" begins during September, 2009. Starting from this time and going forward, find the approximate dates of the next five oppositions of Mars. You may want to change the rate at which time flows to speed up this part of the lab. Remember, during opposition, you should be able to draw a straight line from the Sun, through the Earth, to Mars.

Opposition #1 date: \_\_\_\_\_

Opposition #2 date: \_\_\_\_\_

Opposition #3 date: \_\_\_\_\_

Opposition #4 date: \_\_\_\_\_

Opposition #5 date: \_\_\_\_\_

What is the approximate average interval, in years and months, between successive Martian oppositions? This is the Martian synodic (solar) period.

\_\_\_\_\_ years \_\_\_\_\_ months

## **Step 2**

You may have noticed that during Opposition #5, the Earth and Mars were much closer together than during earlier oppositions. Since Mars has an elliptical orbit, such close approaches will occur when Mars is near perihelion (the little notch marked in its orbit), its closest approach to the Sun.

In fact, the closest approach recently occurred on August 27, 2003. Set the date to this day to see where Mars was with respect to the Earth on that day.

Every time Mars has an opposition (especially back in August 2003), we are typically bombarded with messages about Mars being "huge" or "the size of the full moon" as if this is some sort of amazing record or incredible and unprecedented visual phenomenon, but actually, Mars doesn't look all that different at various oppositions. Its brightness and apparent size depend on the distance from Earth to Mars at the time of opposition.

Use the "Home" button to return to Fort Worth and set the date for the first opposition date recorded above. Set the time to 11pm, then use the "Find" sidebar to find Mars. Once you see Mars on your screen, hover your cursor over it to determine the distance from Earth (observer) to Mars.

Repeat this for each of the opposition dates we studied in Step 1 and record the information below (round off to three digits). Note that "au" for distance means "astronomical unit" which is the Earth-Sun distance, approximately 93 million miles.

Earth-Mars distance for Opp. #1: \_\_\_\_\_ au

Earth-Mars distance for Opp. #2: \_\_\_\_\_ au

Earth-Mars distance for Opp. #3: \_\_\_\_\_ au

Earth-Mars distance for Opp. #4: \_\_\_\_\_ au

Earth-Mars distance for Opp. #5: \_\_\_\_\_ au

Earth-Mars distance for Aug 27, 2003: \_\_\_\_\_ au

% difference between Aug 27 and other close opposition: \_\_\_\_\_

The 5th opposition represents a "typical" minimum opposition. The Earth-Mars opposition occurs near the Martian perigee about every 9th or 10th opposition. The August 27, 2003 opposition was heralded by many as something incredibly special, but in reality, it wasn't much different from an ordinary opposition near perigee.

On your worksheet, calculate the percentage difference in distance  $100 * (\text{difference}) / \text{closest distance}$ , which shows in percentage terms, this opposition wasn't much different than most other oppositions of this kind.

In order for Mars to truly appear to be "the size of the full moon" in the sky, its distance from Earth would have to be about 0.004 au, not 0.372 au!

### **Step 3**

For this part of the lab, we will go to another Skyguide exercise. Open the Skyguide tab on the sidebar, then at the top of that window, where it reads "Student Exercises >> C - The Planets >> C3 - Direct and Retrograde Motion of the Planets."

From there, click on exercise "1: Direct motion." Run time forward several seconds so that you can watch the "direct" motion of the planets. If you let the time go for longer than that, you will notice Jupiter beginning a retrograde loop. Most of the time, planets tend to travel at a roughly uniform speed along the ecliptic toward the East. That means if we map the planets against the background stars, they will seem to move a tiny bit further east each day.

Now click on exercise "2: Retrograde motion".

Right-click on Jupiter and select "Local Path" from this menu.

Run time forward until you see Jupiter complete a retrograde loop, a short time interval where it seems to reverse course and go opposite of its normal easterly motion along the ecliptic. We're going to try to understand this motion a little better.

It is easier to see and draw the retrograde motion for Mars, so we are going to make a couple of adjustments to the exercise.

- Right-click Jupiter again and unselect "Local Path"

- Open the Find sidebar. Uncheck Jupiter and Saturn, then check Mars.

- One retrograde loop of Mars will occur starting in early 2012, so let's set the time in the simulation to November 1, 2011 at 11:00 AM.

- Set the time flow rate to 10 sidereal days.

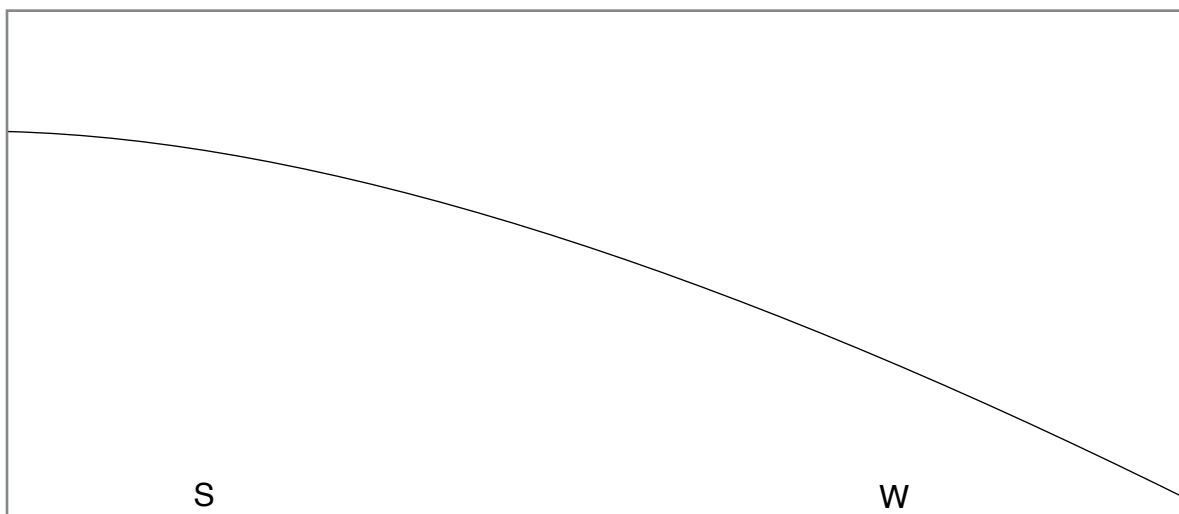
- Right-click Mars and turn on "Local Path." You may want to zoom in a little bit to make it easier to select Mars (see box below and use the "S" and "W" labels for zoom reference).

- On the TOP menu bar, open Options and "Orbit / Path Options..."

- In this dialog box, do the following:
  - Set the program to mark every 3 steps
  - Uncheck "Show date/time"

- Step time forward **MANUALLY** (one click per 10 days, otherwise, it will go way too fast for you to follow) enough times until you reach July 27, 2012.

- Below, make a sketch of this retrograde loop of Mars, marking every 30 days (every 3 steps) with a small dot and the date (month/day). The green ecliptic line has already been drawn for you for reference.



Now go back to "C - The Planets" in the title part of the skyguide sidebar.

Next, click on "C1 - The Inner Planets of the Solar System" and from there, click on exercise "1: Orbits of inner planets."

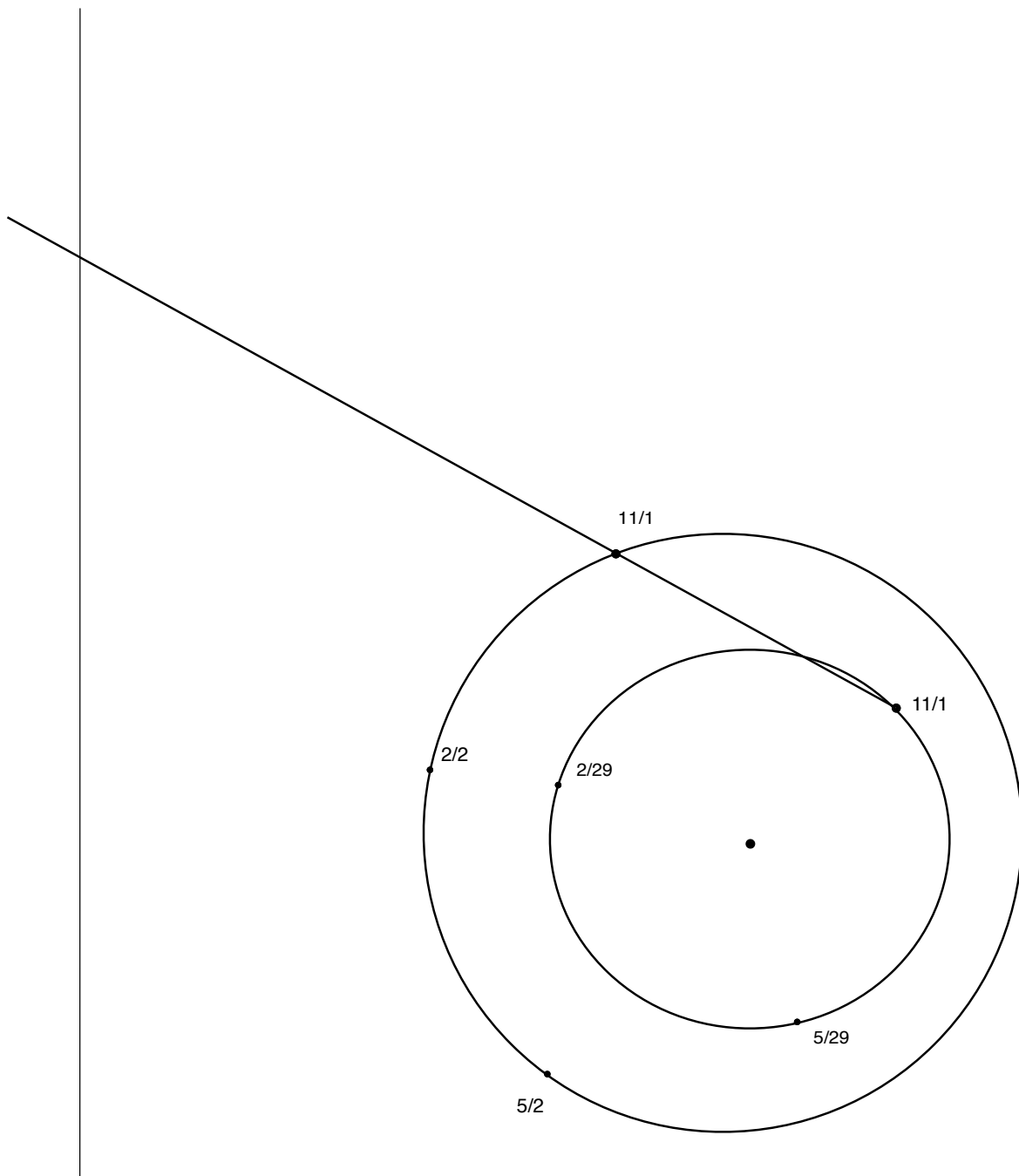
We're going to focus first on the orbit and motion of Mars, so zoom in until Mars' orbit nearly fills the screen, keeping the Sun near the center as best you can.

- Stop time from flowing. It is too distracting.
- Open the Find sidebar and uncheck the boxes to the left and right of Venus and Mercury.
- Set the date to the beginning of our drawing of the retrograde loop: November 2, 2011 at 11:00 AM.
- On the diagram on the next page, draw dots at the approximate location of Earth and Mars every 30 days. For each pair of dots, draw a line from the Earth, through Mars, that ends near the left hand side of the page near the vertical reference line, like the example shown for the first date. The first, fifth and ninth locations of Earth and Mars have been drawn for your reference, along with their respective dates.
- Where each of your Earth-Mars lines crosses the reference line, write a small number, starting with 1.
- Draw a line through the endpoints of your lines, and you should see the motion of Mars go through the same loop that you drew previously.

This is the reason that planets undergo retrograde loops, a process that confused skywatchers for centuries until Renaissance astronomers put forth a model for the solar system with the planets orbiting the Sun at the center.

For more background into this scientific revolution, we will use some of the other exercises in the Skyguide.

Use the diagram on the next page of Earth's orbit and Mars' orbit to track the retrograde motion of Mars.



#### **Step 4**

In the Skyguide sidebar, return to "Student Exercises" and select "B - Solar System." Work your way through exercises B1 through B4 and answer the associated questions below.

#### **Retrograde Motion**

When Mars is in the middle of its retrograde loop in Exercise "1: Retrograde motion", what is the date?

\_\_\_\_\_

Based on your answers in step 1, is Mars closer to opposition or superior conjunction (lined up on opposite side of the Sun)?

\_\_\_\_\_

#### **The Geocentric Model**

According to the Ptolemaic geocentric model of the solar system, a planet's orbital path around the Earth is called a...?

\_\_\_\_\_

In this model, the retrograde loop is caused by the planet's turning on the smaller circular path called a ...?

\_\_\_\_\_

Notice that in this model, when Mars is undergoing a retrograde loop, it is closest to Earth and therefore brightest, which matches the observations they were able to make at that time.

#### **Inferior and Superior Planets**

Use a diagram and a sentence or two to explain why Mercury and Venus are never visible at midnight.

From **Exercise B2: Planetary Orbits and Configurations:**

What is Mercury's sidereal period? \_\_\_\_\_ days

What is Mercury's synodic period? \_\_\_\_\_ days

Jupiter's synodic period: \_\_\_\_\_ years

Jupiter's sidereal period: \_\_\_\_\_ years

From **Exercise B3: Johannes Kepler and Ellptical Orbits:**

Mars' perihelion distance: \_\_\_\_\_ au

Mars' aphelion distance: \_\_\_\_\_ au

Major axis of Mars' orbit: \_\_\_\_\_ au

Does Mercury move faster when it is  
closer to perihelion or aphelion? \_\_\_\_\_

From **Exercise B4: Galileo Strengthens the Heliocentric Model:**

Use a diagram to help explain why, in the geocentric model,  
the phase of Venus should never be full or gibbous.



What is the phase of Venus in exercise 1? \_\_\_\_\_

The simulation in exercise 2 shows the angular size of Venus changing as it goes through a 584-day cycle of phases. Remember, the angular size tool is on the top left (the down arrow next to the hand allows you to change tools).

What is the angular diameter of Venus (in arcseconds) when it is showing the following phases:

Full: \_\_\_\_\_

Half lit (at maximum elongation): \_\_\_\_\_

New: \_\_\_\_\_

This variation in size is precisely what the heliocentric model suggested would happen and also contradicted the geocentric model.

Briefly explain why Galileo's observation of the moons orbiting the planet Jupiter went against the geocentric model.

## **Essay**

On your own paper, think back on the labs you did this semester and answer the following questions about the eight regular labs we did this semester, which were...

- 1 - Using the real in-class celestial spheres.
- 2 - Introduction to Starry Night, motion of Sun/Moon
- 3 - Using Starry Night to learn about and predict eclipses
- 4 - Starry Night Exercises I: Coordinates, Sun and Moon
- 5 - Starry Night Exercises II: Phases of the Moon, Eclipses
- 6 - Starry Night: The Orbit and Motion of Mercury
- 7 - Starry Night: The Orbit and Motion of Venus
- 8 - Starry Night: The Outer Planets

Which regular lab (not supplemental lab) was most enjoyable for you and why?

Which regular lab was least enjoyable for you and why?

Which regular lab did you learn the most from that would potentially help you on the final exam in lecture? Explain.

Which regular lab did you learn the least from? Explain.