Astronomy 101 Lab: Retrograde Motion

If you own a laptop, please bring it to class. You will submit your answers on Cobra using a Word document provided on the website listed below. The Stellarium shortcuts you used in the first lab are on the inside cover of your lab packet and on the website.

If you are using your own computer, be sure it is set for the Central Time Zone. Check the video links on Cobra to make sure your Mac or PC have the correct settings.

Pre-lab Assignment: In class, we've talked about retrograde motion and how it was explained using both Earth-centered (geocentric) and Sun-centered (heliocentric) models of the Solar System. In this lab, you will study the retrograde motion of the planet Mars as it would have been observed by the ancients. Answer the following questions before coming to lab.

A) Define the term "retrograde motion." Is this a diurnal motion or an annual motion?

B) When a planet is moving retrograde, is it moving eastward or westward relative to the background stars?

C) Ptolemy used a geocentric model with epicycles to explain retrograde motion. Describe how using a planet moving on an epicycle could explain retrograde motion.

D) Copernicus explained retrograde motion in the heliocentric model. Why does Mars undergo retrograde motion in this model?
**Introduction:** Retrograde motion is the apparent backward motion of the planets against the background stars. As you watch the planets move in the sky, you'll find that whereas they always rise in the east and set in the west, over the course of the year, they generally travel in the same direction as the Sun, from west to east. However, relative to those background stars, there are times when the planets appear to stop, change their direction for a short while, stop again, and then resume their normal course through the sky. When the planet has reversed its normal direction, we say that it is in retrograde.

In this project, you will use the Stellarium program to watch the retrograde motion of several of the planets, in particular the retrograde motion of the planet Mars.

The Stellarium shortcuts you used in the first lab are on the inside cover of your lab packet and at this URL. [http://natsci.parkland.edu/ast/101/shortcuts2.pdf](http://natsci.parkland.edu/ast/101/shortcuts2.pdf)

Start by opening Stellarium. Exit full-screen mode, remove the atmosphere, the cardinal directions, and remove the simulated ground. You are now able to see the entire night sky without any interference. To keep the view relatively stable, we need to switch the view from an azimuthal mount to an equatorial mount. Click the button seen here and to the right of the Saturn button or you can type "Ctrl+M" ("Command+M" for Macs). When it is in equatorial mode, the button is lit.

A. Retrograde motion of the inner planets: We'll start by determining how many of the visible planets undergo retrograde motion. Start by selecting the Sun. If you can't find it, open the search window. Center on the Sun by typing the space bar.

Since Mercury and Venus are closer to the Sun than Earth, they never stray far from the Sun in the sky. From the "play" position, increase the time flow six times. Let the time run forward for approximately two years. Carefully watch the direction that the Sun moves relative to the stars to see the direction that planets normally move. See if Mercury and/or Venus reverse direction, undergoing retrograde motion.

You will submit your answers on Cobra. The answer sheets at either URL below have the tables you need to complete.


1A. Does Mercury show retrograde motion?  
1B. Does Venus show retrograde motion?

2. Explain why Mercury and Venus should or should not show retrograde motion in a heliocentric system.

Set the date back to today's date. You can do this quickly by typing "8" or clicking the button between "play" and "fast forward". Since the retrograde motion of Mars was already mentioned in the introduction, we will wait to observe this until later in the lab. For now, check the remaining planets visible to the naked eye: Jupiter and Saturn.

B. Retrograde motion of the outer planets: Find and center on Jupiter. You may set the time flow in one of two ways: either increase the time flow seven times from the "play" position, or hold down the "[l]" key to move the time forward one solar week. Run time forward for two years. Watch carefully to see if Jupiter undergoes retrograde motion. Follow the same procedure for Saturn.

3A. Does Jupiter undergo retrograde motion?  
3B. Does Saturn undergo retrograde motion?
For the rest of the lab, we will take a detailed look at the retrograde motion of Mars. *Make sure your location is Champaign or Urbana. Turn on the constellation boundaries and turn on the constellation labels.*

**C. Retrograde motion of Mars:** Set the date to 2020 June 29 (2020-06-29). Find and center on Mars. You will find Mars in the constellation Pisces. Use the arrow keys on the keyboard to move the sky until the constellation Pisces is centered in the field of view. Make sure Mars is still selected.

Increase the time flow the same way you did before. When you advance time, Capricornus will remain centered in your field of view and you can watch Mars move through the background stars. Note that there will be two points where Mars seems to stop and change direction. These are called the *stationary points*. Run time forward until about 2021-02-01. Stop the time flow.

Now that you have seen it once, you will have an easier time completing the table. Reset the date to 2020-06-29. Change the time to noon. Make sure Mars is selected so you can readily see the distance and apparent diameter from Earth. Stellarium also displays a lot of information you don’t need. Open the Configuration window and select the Information tab. *Uncheck every box for the “Displayed fields” except: Right ascension/Declination (of date), Altitude/Azimuth, Size, and Distance.*

Note that Mars’s apparent diameter is less than a degree (°) and less than an arcminute (‘). The motion of Mars will be easier to track by activating planet trails. Turn them on by typing *"Shift+T"*. You can erase the planet trails by typing the shortcut again.

4. Confirm that the right ascension (RA) (rounded to the nearest minute), the distance (from Earth not the Sun) (rounded to two decimal places), and the apparent diameter in arcseconds (rounded to one decimal place) you see in Stellarium for this date are already recorded in the table on the answer sheet.

5. Increase the date by seven solar days. Record the right ascension rounded to the nearest minute in the table on the answer sheet. For example, 15h43m37s would round to 15h44m. Record the distance from Earth rounded to two decimal places, and the diameter in arcseconds in the table. Repeat this procedure until you’ve finished the table.

6. Before going further, take a screenshot of the trail made by Mars on Stellarium. On Windows, open Snipping Tool. You can do this by pressing the Windows key, then type “Snip”. You have a few options to capture the full screen, or a clip of only Stellarium. Make sure your clip shows the retrograde loop of Mars. Save the screenshot to your computer. On a Mac, press "Command+Shift+3". This will automatically save the image to your desktop. Check the image before going further and make sure it shows the trail of Mars through the celestial sphere.

Consult your table and the screenshot to answer the following questions.

7A-B. Mars reaches its stationary points (as defined above) on approximately what dates? These must be more than one month apart.

8. Based on your answer to Question 7, how long does Mars's retrograde period last?

9. On what date is Mars exactly half-way through its retrograde period?
Set the date to what you answered in Question 9. Set the time to local midnight (01:00:00 in CDT, 0:00:00 in CST). It may help to turn on the ground, the cardinal directions, and the meridian for the next question.

10. In terms of the cardinal directions, where is Mars located in the sky when it is in the middle of its retrograde period?

11. Based on the table, on what date is Mars closest to the Earth?

12. Mars has the largest apparent diameter on what date?

Consult the figure on the right for the next two questions.

13. Based on the last three questions and the position of the Sun at the time you used, what planetary configuration is Mars in?

Mars’s average distance from the Sun is 1.52 AU and Earth’s average distance from the Sun is 1 AU. Use this information to answer the last two questions.

14A. How far is Mars from Earth at conjunction?
14B. How far is Mars from Earth at opposition?

The apparent sizes of objects are inversely proportional to their distances. If you took an object and moved it twice as far away, it would appear to be half of its original apparent size. Move it to three times its original distance and it will appear to be one-third its original size.

15. Determine how many times larger Mars would appear at opposition than at conjunction by dividing the conjunction distance by the opposition distance.

Submit your answer sheet and your screenshot of the planet trail of Mars to the dropbox on Cobra.