Assignment #6 – Motions of the Planets

Explaining the motions of the planets was the most difficult task ancient astronomers faced. Unlike the stars, which move smoothly across the sky, the planets’ motions are much more complex. They move relative to the background stars from day to day and week to week, and sometimes appear to stop, turn around and move in the opposite direction for a few weeks! This odd “backwards” motion is called Retrograde Motion, and explaining it was no easy feat!

PART A

Let’s try to figure out how the planets “normally” move across the sky. Start Stellarium. Change the Date & Time to June 15, 1998 at 7:00 AM. Zoom out and drag the horizon until the whole sky is centered on the screen. Turn off the Atmosphere, if it is on, and label the planets by opening the View window and putting a check mark next to Show Planets and Show Planet Markers in the Planets and Satellites section of the Sky sub-menu. Also, check the box next to Planets in the Labels and Markers section, and drag the slider next to Planets about halfway to the right. Close the View window. All the planets are visible in the sky at this moment, as you can see, along with the Sun and Moon (and also three of the largest Asteroids: Ceres, Pallas and Vesta!).

• What do you notice about how the Sun, Moon, Planets and Asteroids are arranged in the sky?

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• What is the name of this imaginary line across the sky? _____________________________

To check your answer, press the “,” (“comma”) key to display the Ecliptic in red.

Press the ALT and = keys at once to make one Sidereal Day pass. As you remember from class, a sidereal day is the amount of time it takes for any star (except the SUN!) to circle the sky once. A sidereal day is 23 hours, 56 minutes, or 4 minutes shorter than a 24-hour solar day.

Hold down the ALT and “=” keys and watch the planets move through the sky as the Sidereal Days pass. Notice that the planets do not stand still relative to the stars, but move, generally in one direction, as the days and weeks pass. Keep holding down “ALT =” and note the way the planets move.

• Which way do the planets (and the Sun and Moon and Asteroids) normally move across the sky from day-to-day (N to S, S to N, E to W or W to E)? ____________________________

This normal direction of movement is called Direct Motion. Keep letting the time pass. Every so often, something strange happens to one or another of the planets. It slows down, stops, then turns around and starts moving in the opposite direction for a few days or weeks! This strange backward motion is called Retrograde Motion.
• When the planets move in Retrograde motion, which way do they move (N to S, S to N, E to W or W to E)? ________________________

Let’s see if this strange motion happens to all the planets, and to the Sun & Moon. Keep holding down Alt = and watching each planet (and the Sun & Moon) travel across the background stars. Let at least a year or two go by, or at least two complete trips across the sky for each planet (until you come back to where you started twice). After you've watched each object carefully for a while, record in Table 1 a “yes” or “no” whether you ever see the object undergo retrograde motion.

<table>
<thead>
<tr>
<th>Object</th>
<th>Retrograde motion?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td></td>
</tr>
<tr>
<td>Moon</td>
<td></td>
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<tr>
<td>Mercury</td>
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<tr>
<td>Venus</td>
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<td>Mars</td>
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<td>Jupiter</td>
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<td>Saturn</td>
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<tr>
<td>Uranus</td>
<td></td>
</tr>
<tr>
<td>Neptune</td>
<td></td>
</tr>
</tbody>
</table>

• Which objects in Table 1 show no retrograde motion? _______________________________

PART B

Now let’s try to explain what causes retrograde motion. The Geocentric (Earth at the center of the Solar System) explanation for such motion required the use of epicycles. Epicycles, as the diagram below shows, are “orbits superimposed on orbits.” First proposed by Greek thinkers, epicycles were made popular by the astronomer Ptolemy in the 1st century. Ptolemy was able to explain almost all the planets motions by assuming that the Earth was at the center of the Solar System, and that each planet (except the Moon and Sun) moved in a circular epicycle that was itself centered on the planet’s circular orbit around the Earth (called the “deferent”).

![Diagram of Geocentric System](image)
• Assuming that the planet moves counterclockwise around the epicycle, and the epicycle itself moves counterclockwise around the deferent, **shade the part of the path along the epicycle in Figure 1** where the planet will exhibit retrograde motion.

Epicycles work fine, but Copernicus threw them in doubt when he came up with his Heliocentric theory, postulating that the **Sun** was at the center of the Solar System. Then, when Galileo provided the proof that he was right, epicycles were officially thrown out for good. The heliocentric theory provided a better explanation of retrograde motion. To understand it, let’s look more closely at Mars’ retrograde motion.

Change the **Date & Time** to **October 1, 2007**. Turn the **Ground** off (use the **G** key). **Search** for the star **Tejat** to select and center it on screen. Turn the **constellation names and lines** on by pressing **C** and **V**. **Zoom in** until the **Field of View (FOV)** is about 30°. Click on the **Switch Between Equatorial and Azimuthal Mount** button on the bottom toolbar until the little telescope icon is lit up. This makes the Ecliptic plane horizontal. West is to your right, and East to your left. You should see **Mars** just to the West of Tejat, which is selected and surrounded by the rotating crosshairs onscreen.

• What constellation is Tejat in? ____________________________

Now press **L** five or six times to let time pass quickly. You should see Mars moving across the background stars in direct motion, from West to East. Mars will eventually slow down, stop direct motion, reverse direction and begin retrograde motion. **Stop time** (you may have to step forwards or backwards a few times) and find the exact day when Mars begins its retrograde motion.

• What day does Mars come to a stop and begin retrograde motion? __________________

Continue running time forward and watch as Mars stops **retrograde** motion and resumes **direct** motion. Again, you may have to step back and forth in time to find the exact day.

• What day does Mars resume direct motion? _______________________

• How long is Mars in retrograde motion? __________________________

**PART C**

Let’s try to understand retrograde motion by seeing what’s happening from high above the Solar System. Make sure the **Ground** and **Atmosphere** are off. Use the **Search Window** to find and center **Solar System Observer**. Then press **CTRL-G** to go there. Then **Find** and center the **Sun**. **Zoom in** until the **FOV** is about 1°. Open the **View** window (use the menu or press **F4**) and, in the **Sky** sub-menu, put check marks next to **Show Planets**, **Show Planet Markers** and **Show Planet Orbits**. Also put a check mark next to **Planets** in the **Labels and Markers** section and drag the **slider** next to **Planets** all the way to the right. Close the **View** window.

Change the **Date & Time** back to **October 1, 2007** (the time doesn’t matter). Now **zoom in or out** until **Jupiter’s orbit** just fills the screen.

You are looking down at the orbits of most of the Solar System on **October 1, 2007** – the same day you started looking at Mars for the previous section. The positions of **Mercury**, **Venus**, and the four largest asteroids (**Ceres, Pallas, Vesta & Juno**), and perhaps a comet, are also labeled, but just ignore them.
Tape a blank piece of paper along the bottom edge of your computer screen. Hold a ruler up to the screen and use it to mark a straight line from Earth to Mars down to the edge of the screen. Make sure the ruler extends all the way to the edge of the screen, and make a dot on the piece of paper where the ruler hits it. Label this dot with the date (10/1).

Press the = key five times to let five days pass. Use the ruler again to make to make a second dot. Label this one with new date (10/6). Continue making dots on the paper until February 20, 2008. If the dots start piling up on each other, you may have to mark some dots to the side to make them all visible.

When you are done, examine the dots you printed on the paper, with the dates marked. Remember, the spot where each line hits the paper indicates where Mars would appear that day against the distant stars from our point of view here on Earth. Call that spot “Mars' apparent position.” Look at the spot carefully from day to day to determine how it moves from our point of view here on Earth. Compare the pattern of dots to the dates when Retrograde Motion began and ended, that you measured earlier. This should help you understand why retrograde motion occurs.

• Describe how Mars' Apparent Position moves across the sky before, during and after retrograde motion starts. Remember, we determined earlier when Retrograde motion begins and ends.

• In your own words, then, explain what causes retrograde motion

• Why do the Sun and Moon not show any retrograde motion?

So retrograde motion has to do with the geometry of the planets’ positions, and the relative speeds of the planets in their orbits. Like most things in science, what at first looks like a complicated, confusing idea turns out to be fairly simple, and easily understandable!
Write a conclusion explaining what you learned in this exercise.

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PLEASE ATTACH YOUR “DOTS” PAGE TO YOUR ASSIGNMENT WRITE-UP