Astronomy 134 Name/section:

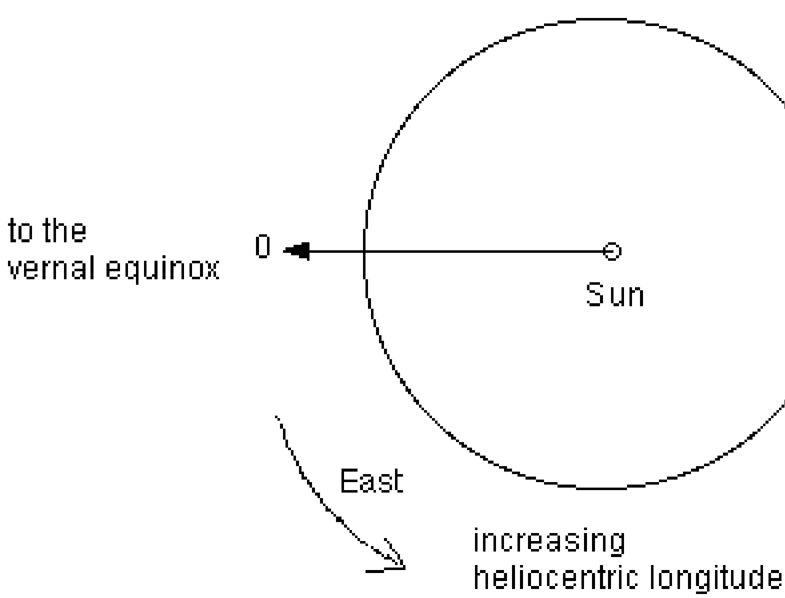
The Orbit of Mercury

Introduction

If you make a couple of simplifying assumptions: 1) Mercury orbits the Sun in the same plane as the Earth, and 2) the orbit of Mercury is a circle that is slightly off center from the Sun, then you can use some simple observations to graphically construct the orbit of Mercury and determine its orbital parameters to within an astonishing degree of accuracy! With a simple sextant (a device used for measuring angles in the sky) and enough time (you would have to observe for at least a year) you could easily make the observations of Mercury yourself. However, there is one other observing project you would have to undertake. You would also have to observe the Earth's motion against the background stars to determine its relative position with respect to the Sun throughout the year. With these two sets of observations, you could investigate Mercury's actual motion around the Sun.

Since you won't have time to make these observations yourself, we can use the predicted positions for the coming year which can be found in any astronomical almanac as well as many astronomy sky simulation programs (the values below were taken from the program Voyager). To make plotting easy, we will denote the Earth's position in heliocentric coordinates. Heliocentric coordinates are a spherical coordinate system centered on the Sun (helio-centric = Sun-centered). Heliocentric latitude is the angle above or below the ecliptic plane. Because the Earth's orbit defines the ecliptic plane, the heliocentric latitude of the Earth will always be 0 degrees! Heliocentric longitude is the angle around the ecliptic plane (like Earth longitude is the angle around the equator) with 0 degrees being set arbitrarily to the direction of the vernal equinox.

Figure 1. Heliocentric longitude



The positions of Mercury we are interested in are those positions when it appears most distant from the Sun. Since the angle from the Sun is called a planet's elongation, what we need are Mercury's maximum elongations. When the elongation is west of the Sun, Mercury will appear in the morning right before sunrise. When the elongation is east of the Sun, Mercury will appear in the evening sky right after sunset. When the elongation is a minimum (i.e. zero), Mercury will be directly in front of, or directly behind the Sun.

Figure 2. Elongation directions

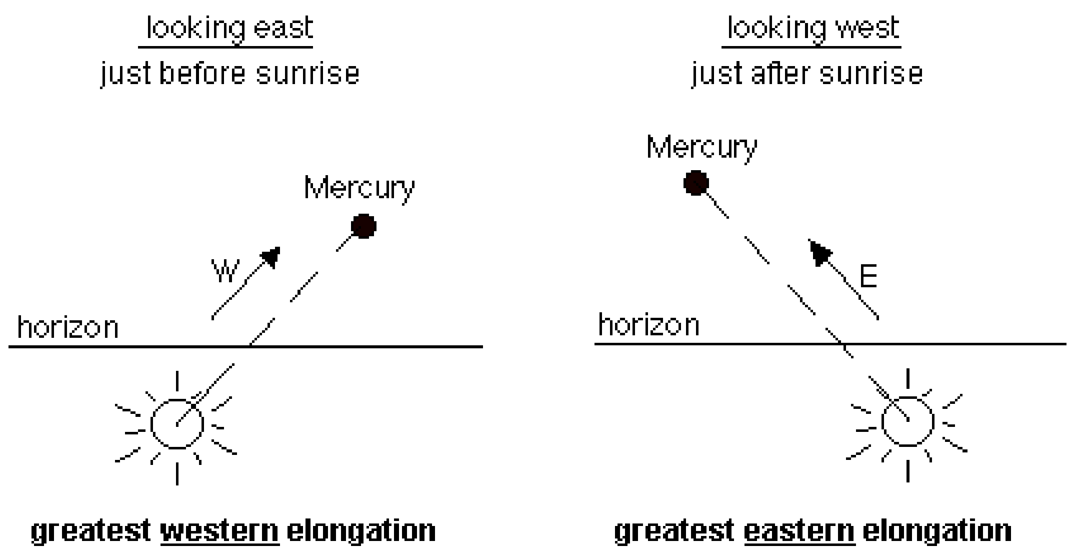


Figure 3 (on the following page) shows Mercury's elongations from a heliocentric viewpoint.

Construct Mercury's orbit

1. Draw a circle to represent the Earth's orbit in the middle of a sheet of tracing paper. Set 1 A.U. = 10 cm.

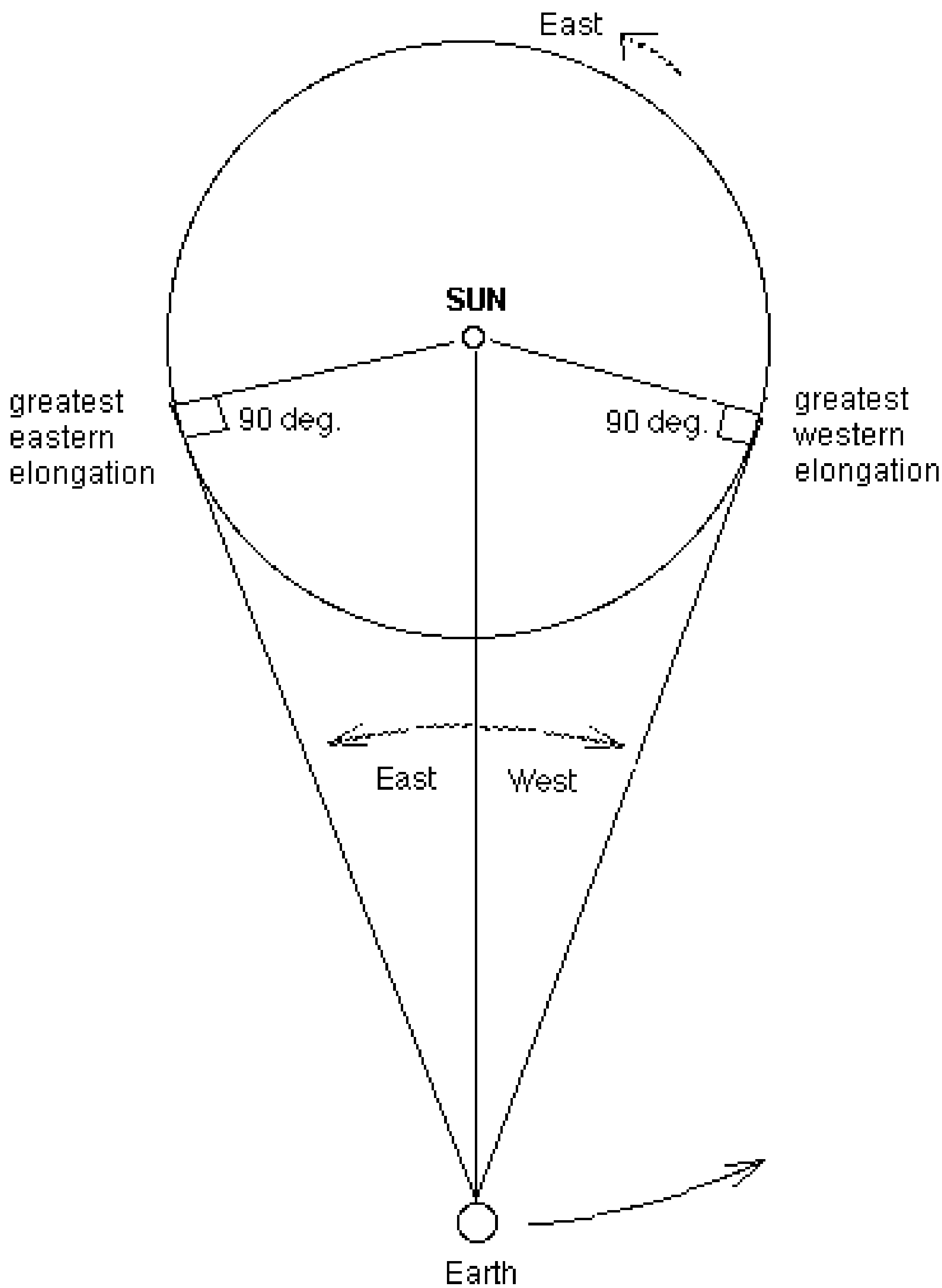
2. To approximate the eccentricity of the Earth's orbit (0.0167), offset the Sun 0.17 cm from the center of the circle you just drew. Label the Sun with a small circle with a dot in the center of it.

3. Using a blue pencil, draw the major axis of the Earth's orbit and label it. Note that the major axis of any planet's orbit must pass through the Sun (since Kepler determined that the Sun is at one focus of the ellipse). Thus, your major axis should pass through the Sun and the center of your original circle representing the Earth's orbit.

4. Label the point of perihelion on the Earth's orbit. This will occur on Jan. 4 (in 2004) at a heliocentric longitude of 103.7 degrees.

5. When looking down on the solar system from positions north of the ecliptic plane, east is always counterclockwise. Draw arrows around the Earth's orbit to indicate which way is east and which way is west.

Figure 3. The maximum elongations of Mercury- heliocentric perspective.



6. Draw a line from the Sun out through the Earth's orbit in the direction of heliocentric longitude 0 degrees. Label it 0 degrees. Remember, this is the direction to the vernal equinox (a point in the constellation Pisces where the ecliptic crosses the celestial equator). Remember that heliocentric longitude increases to the east (counterclockwise).

7. Where is the Earth on the day of the vernal equinox? Label this point on the Earth's orbit March 21. On the vernal equinox, we see the Sun in the direction of the vernal equinox in the sky.

Now you will need to plot the maximum elongations of Mercury on the appropriate days. The predicted elongations and heliocentric longitude of the Earth on those dates is given in Table 1 and Table 2 below.

8. Plot and label (with the date) the position of the Earth for each of the dates below.

9. To help measure the elongations, draw a line from the Earth to the Sun on each of those dates.

Table I. Orbital positions of the Earth (in heliocentric longitude) 2003/2004 on the dates of Mercury's maximum elongations.

Date of maximum elongation	**Heliocentric longitude of Earth**
August 14, 2003	322 degrees
September 27, 2003	4
December 9, 2003	77
January 17, 2004	117
March 29, 2004	189
May 14, 2004	234
July 27, 2004	305

Table II. Mercury's greatest elongations in 2003/2004.

Date of maximum elongation	**Mercury's elongation**
August 14, 2003	27.4 degrees EAST
September 27, 2003	17.9 degrees WEST
December 9, 2003	20.9 degrees EAST
January 17, 2004	23.9 degrees WEST
March 29, 2004	18.8 degrees EAST
May 14, 2004	26.0 degrees WEST
July 27, 2004	27.1 degrees EAST

10. With a red pencil, draw in the exact elongations of Mercury on the appropriate dates. On the days of maximum western elongation, you should see Mercury to the right of the Sun (see figures 2 and 3) and on days of maximum eastern elongation, you should see Mercury to the left of the Sun.

11. The polygonal figure delineated around the Sun by the red lines you just drew shows you the boundaries of Mercury's orbit! To construct the orbit, use the polar coordinate paper provided, or your compass, to draw Mercury's orbit as a circle which should just touch all of your red lines. (You may be a little off on some of the lines, but if you are off on very many, or by more than a tiny bit, it probably means you have made an error somewhere.) Label this circle "Mercury's orbit".

12. As accurately as possible, measure the distance (in cm) between the center of Mercury's orbit and the Sun.

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13. Use a blue pencil to draw and label the major axis of Mercury's orbit.

14. Measure the semi-major axis of Mercury's orbit (i.e. half the major axis). Convert this number to astronomical units. (Remember, 10 cm = 1 A.U.)

semi-major axis (in A.U.s) =

15. You now have all the information you need to compute the eccentricity of Mercury's orbit!

$$\text{eccentricity} = \frac{\text{dist. of Sun from the center of Mercury's orbit}}{\text{semi-major axis of Mercury's orbit}} =$$

16. Label the point of perihelion of Mercury's orbit.

17. What is the heliocentric longitude of Mercury's perihelion?

18. What is Mercury's distance from the Sun (in A.U.s) when it is at perihelion?

19. What is Mercury's distance from the Sun (in A.U.s) when it is at aphelion?

20. What will be the distance between the Earth and Mercury on Jan. 17, 2004?

21. Where was Mercury on the days that greatest elongations were measured on the Earth? Label these points on Mercury's orbit with the appropriate dates.

22. Estimate, as accurately as you can, Mercury's orbital period.

For comparison (i.e. do not edit your answers above!!!!) here are some of the actual parameters of Mercury's orbit:

semi-major axis: .387 A.U.
eccentricity: .206
perihelion distance: .307 A.U.
aphelion distance: .467 A.U.