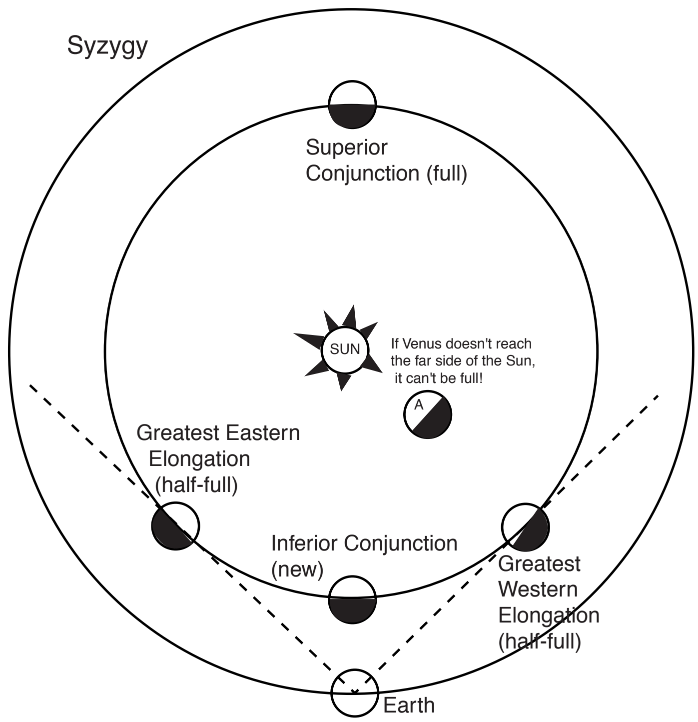
Variable Venus

Venus's thick cloud cover means that it doesn't show us any surface features. But its appearance *does* change, as seen from Earth. It goes through *phases*, when only part of the illuminated portion is visible from Earth. It also varies greatly in angular size, because of its varying distance from Earth.

Phases of Venus:
Galileo discovered that, like the Moon, Venus has *phases*, when at times only part of its sunlit half is visible from Earth, and at other times the entire sunlit half is visible. When Venus is in between Earth and the Sun, we see only a small portion of its sunlit half. In those times Venus is said to be *crescent*. Look at the images in the Venus section of Solar System Update. Which image shows a crescent Venus? ____. When Venus is to the side of the Sun, it appears approximately half-full. Which images show a Venus which is just more than half-full? ___and___. When Venus is on the far side of the Sun, we see its entire lit side, and Venus is "full". Which image shows a "full Venus"? ___



If Venus were circling the Earth at a distance closer than the Sun, then we would never see it "full". It would always be a crescent, even when it was farthest from Earth (position A in the diagram). Galileo used this argument to prove that Venus in fact orbits the Sun, not the Earth, and it was a very crucial argument for the Sun-centered hypothesis (the Copernican view). The points of ***SYZYGY*** for a planet inside the Earth's orbit (an *inferior* planet), are *inferior conjunction*, *superior conjunction*, *greatest Western elongation and greatest Eastern elongation*. An inferior planet never is at Opposition, where they are in the opposite direction as the Sun – only superior planets (like Jupiter) can do that. An inferior planet never can be more than 90 degrees from the sun. The maximum angle it can be is its *greatest elongation*.

Changing apparent size:
To a first approximation, Venus's orbit is a circle around the Sun, with an average distance (semimajor axis) of 0.72 AU. Using Solar System Update, what is its eccentricity? _____.
Since its eccentricity is small, its orbit is very close to a circle. Earth's average distance is _____ AU. What is its eccentricity? _____. So, Earth's maximum distance from the Sun is _____ AU, and its minimum distance is _____ AU. What is the minimum distance from Venus to the Earth? It would be when Venus and Earth are lined up on the same side of the Sun, *inferior conjunction* on the figure. On average that distance would be 1 AU – 0.72 AU = _____ AU. Some years, though, when Venus is at its farthest from the Sun, and Earth at its closest, the distance could be smaller. What would that smallest possible distance be? _____ AU. Now, what would the maximum distance from the Earth to Venus be? This would happen when Venus and Earth are in a line, but with the Sun in between (*superior conjunction* on the figure). The distance would then be 1.0 + 0.72

AU = 1.72 AU. But sometimes that happens when the Earth is at aphelion, so the maximum possible is _____ AU.

Your challenge:
The changing distance from Venus means that its angular size as seen from Earth will vary considerably. When it is at its closest, its angular size is much larger than when it is at is farthest. What is the ratio of the farthest possible distance to closest possible distance? ___________

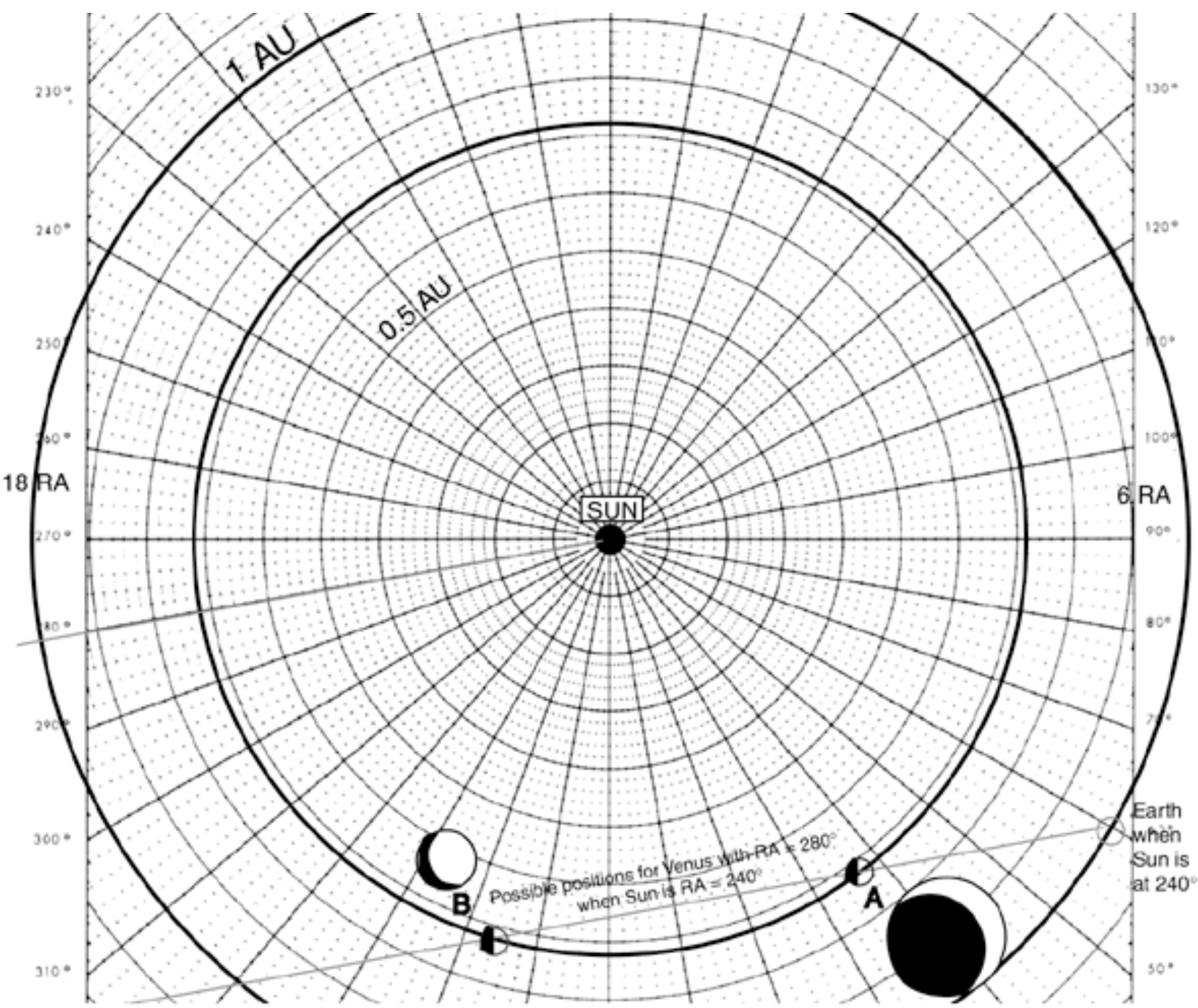
Use an online program such as Solar System Live (http://fourmilab.to/solar/) to determine Venus's distance from Earth for one half of the cycle, from minimum distance to maximum distance (or from max to min). (For 2002, the minimum distance was late in the year; the maximum distance is in the summer of 2003). Start at the day you find the minimum distance, and then check once a month till you get to the maximum distance. What is the minimum distance you find? ________. The maximum? ________. Write down the RA of Venus and the Sun, then change those values from Hours and Minutes to degrees. Recall that the RA in degrees = 15 (H + M/60). Calculate the last column, the *elongation*: the angular separation of Venus from the Sun, as the Right Ascension, of Venus – the Right Ascension of the Sun, in degrees. When is it greatest? ___________

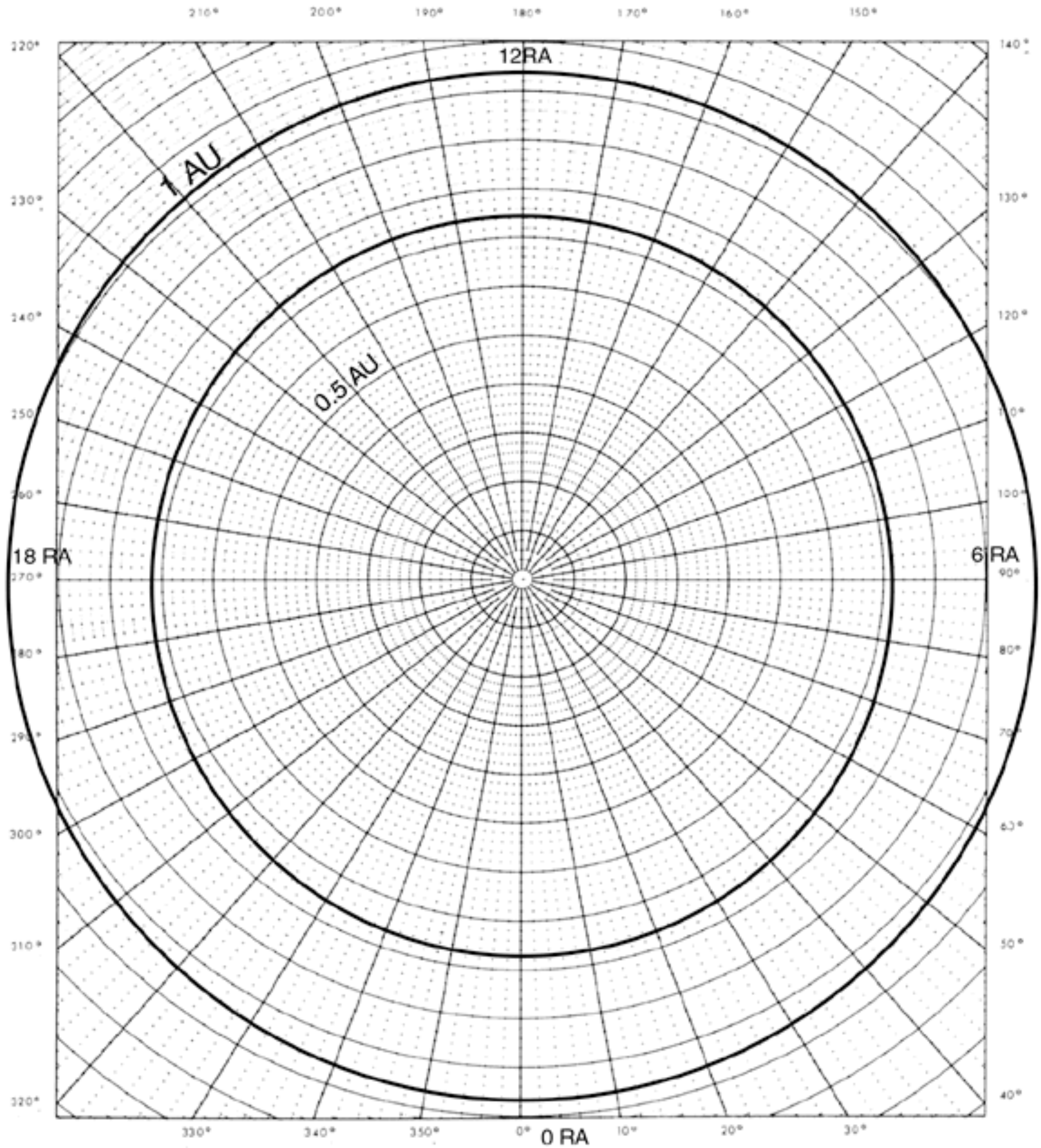
Date (one per month)	**Distance of Venus from Earth (AU)**	**Right Ascension of Venus (H:M)**	**(degrees)**	**Right Ascension of Sun (H:M)**	**(degrees)**	**Earth-Sun-Venus angle (degrees)**

Advanced Activity:
On the circular (polar) graph paper, the inner heavy circle is Venus's orbit at 0.72 AU and the outer heavy circle is Earth's orbit (1.0 AU). Here comes the hard part. Put Earth on its circle at the location so that the SUN appears to be at the Right Ascension on your data table. (So, if the Right Ascension of the Sun is 240°, put the Earth on the circle at 60°). Place one Earth for each line on the table. Now, for at least 4 times (near inferior conjunction, near superior conjunction, greatest elongation, and at least one other time, place Venus at the proper place on its circle so that its distance from Earth is correct. NOTE: Venus will NOT be on the longitude that corresponds to its Right Ascension, since we didn't make Earth the center of the graph. Instead, the line from Earth to Venus will be **parallel to** the line from the center of the graph to that Right Ascension. If

that line intersects the Venus orbit in two places, use the distance of Venus to help you tell which location is correct. Now, sketch what Venus should look like as seen from Earth for these locations. Show its correct relative size!

The image below shows a sample of how your results would look. The gray circle is the position that the Earth would be in if the Sun is at a RA of 240°. Now, let's suppose that Venus is at an RA of 280°. We would not put Venus on its circle at position 280°. If you did that, the line from Earth to Venus would not go to a star with RA of 280°. Remember, the stars are VERY far away!. To locate Venus, first draw a line from the SUN (in the center) to the direction 280° (shown as a gray line). Now draw a line parallel to that one, but starting at the Earth (lower, longer gray line). You notice that it intersects the circle which is Venus's orbit in two places. One is very near the Earth (about 0.45 AU) and one is farther (about 1 AU). (To get the distance, measure against the radial distance scale — each heavier circle is 0.1 AU apart). How would each Venus look? The Venus at position A would be very large, and would be a crescent, since only a little bit of the lighted side is visible from Earth. The Venus at position B would be half the size, since it is twice as far away. But, it would be over half full, since over half of the lighted side is facing the Earth. Now, try the plots for the real data in your data table on the blank polar plot on page 4.




210°
200°
190°
180°
170°
160°
150°
220°
140°
12RA
1 AU
230°
130°
240°
120°
0.5 AU
18 RA
270°
6 RA
90°
80°
300°
60°
310°
50°
320°
40°
330°
340°
350°
0°
0 RA
10°
20°
30°