

The Size of the Solar System

Overview

Questions: **My answers:**

- Become familiar with the scale of the planets vs. their distances.
- Get an overview of the solar system.

Introduction

It is easy to flip to the index of an astronomy textbook to discover that, say, the Sun lies 150 million kilometers away from Earth. It is far more difficult (if not impossible), however, to picture this distance in the human mind. In this exercise, we will learn to access the often unpalatable distances encountered in astronomy by simply scaling the huge distances to more recognizable, pedestrian numbers. So long as every distance within the system of interest is scaled by the same factor, we retain the meaningful information about *relative* distances between objects. This is exactly the same principle employed by map makers so that they can fit Texas, for example, onto a turnable page.

Constructing the Model

Table 1 gives current measurements for the actual sizes and orbital distances of the planets. For moons, the semi-major axis is the distance to the planet.

Table 1: Measured Astronomical Distances in Solar System (*KBO radii are not well known)

Object	Radius (km)	semi-major axis (km)
Sun	6.96×10^5	--
Mercury	2.44×10^3	5.83×10^7
Venus	6.05×10^3	1.08×10^8
Earth	6.38×10^3	1.50×10^8
Moon	1.74×10^3	3.84×10^5
Mars	3.40×10^3	2.27×10^8
Jupiter	7.14×10^4	7.78×10^8

Io	1.82×10^3	4.22×10^5
Ganymede	2.63×10^3	1.07×10^6
Saturn	6.03×10^4	1.43×10^9
Titan	2.58×10^3	1.22×10^6
Uranus	2.56×10^4	2.87×10^9
Neptune	2.43×10^4	4.50×10^9
Pluto	1.16×10^3	5.91×10^9
Charon	6.35×10^2	1.96×10^4
Quaoar*	5.84×10^2	6.49×10^9
Sedna*	7.45×10^2	7.51×10^{10}

As you can see, even when expressed in the one of the largest units (km) used to describe Earth-bound distances, the sizes of and distances to the planets require numbers raised to large powers of ten. In order to fully appreciate the relative sizes and distances within the solar system, it is necessary to scale these numbers down to values small enough so that we can "see" them in terms of more familiar distances. We can accomplish this by dividing every number in Table 1 by some constant **scale value**.

To determine the scale value you'll need to know how much space you have. Suppose the length of a hallway in the campus in meters is 10 meters. We can choose a scale factor, so that we can fit all the planets from the Sun to **Uranus** in this hallway. Then, the scale value can be obtained through the following procedure:

If 10 meters are assigned to 2.87×10^9 Km

Then the scale factor for distances from the Sun is: $1 \text{ meter} / 2.87 \times 10^8 \text{ Km}$

For the size of the planets, we can choose in our scaled model, the radius of the Sun to be 10 centimeters. Then, the scale value can be obtained through the following procedure:

If 10 centimeters are assigned to 6.96×10^5 Km

Then the scale factor for radii is: $1 \text{ centimeter} / 6.96 \times 10^4 \text{ Km}$

Use the scale factors to calculate the size of your object and the distance of the object from the Sun (round two decimal digits). Fill in these values in table 2. To make it easier to make the model, find the distance from the previous object to the current object. Again, record the distance in table 2.

As an example, below you will find the calculations for the first three rows:

Scaled radius of the Sun: $6.96 \times 10^5 \text{ Km} * (1 \text{ cm}/6.96 \times 10^4 \text{ Km}) = 10 \text{ cm}$

Scaled radius of Mercury: $2.44 \times 10^3 \text{ Km} * (1 \text{ cm}/6.96 \times 10^4 \text{ Km}) = 0.04 \text{ cm}$

Scaled Distance Mercury-Sun: $5.83 \times 10^7 \text{ Km} * (1 \text{ meter}/2.87 \times 10^8 \text{ Km}) = 0.20 \text{ m}$

Scaled radius of Venus: $6.05 \times 10^3 \text{ Km} * (1 \text{ cm}/6.96 \times 10^4 \text{ Km}) = 0.09 \text{ cm}$

Scaled Distance Venus-Sun: $1.08 \times 10^8 \text{ Km} * (1 \text{ meter}/2.87 \times 10^8 \text{ Km}) = 0.38 \text{ m}$

Scaled Distance Venus-Mercury: $(1.08 \times 10^8 \text{ Km} - 5.83 \times 10^7 \text{ Km}) * (1 \text{ meter}/2.87 \times 10^8 \text{ Km}) = 0.17 \text{ m}$

Object	Radius (cm)	Distance from Sun (m)	Distance from Previous (m)
Sun	10.00	0.0	0.0
Mercury	0.04	0.20	0.20
Venus	0.09	0.38	0.17
Earth	.09	.52	.15
Mars	.05	.79	.27
Jupiter	1.03	2.71	1.92
Saturn	.87	4.98	2.27
Uranus	.37	10	5.02

Neptune	.35	15.68	5.68
Pluto	.02	20.59	4.91
Quaoar	.01	22.61	2.02
Sedna	.01	261.67	239.06
Moons	Planet	Radius (cm)	Distance to planet (m)
Moon	Earth	.02	1.34×10^{-3}
Io	Jupiter	.03	1.47×10^{-3}
Ganymede	Jupiter	.04	3.73×10^{-3}
Titan	Saturn	.04	4.25×10^{-3}
Charon	Pluto	.01	6.83×10^{-5}

Using the information from table 2, draw a **scale** picture of your objects on plain white paper. If you have the Sun, you may need to tape some paper together. If your object is a **moon**, you should include your sketch on the same paper as the planet it orbits. Label the picture.

Decide which end of the hallway to start at. Tape the picture of the Sun to the wall. Then measure from the wall and place Mercury on the wall at the appropriate distance. Then measure from Mercury to Venus and tape Venus to the wall. Continue until all planet pictures up to Uranus, along with their moons, are taped to the wall.

Now with Neptune, Pluto, Quaoar and Sedna figure out how many times longer the hallway would have to be to fit those objects in using this scale (i.e. it would have to be 1.5 times longer, twice as long, 10 times longer...) Note that distance on the picture and tape the pictures to the wall opposite the Sun.

Observations from the Model

1. Look at the pictures of the planets, and at table 2. Are all the pictures the right size? Can you tell the difference between Jupiter and Neptune from the pictures? How about Neptune and Uranus? Can you tell the difference between Earth and Mars? Explain your answers.

From the diagram the picture of Jupiter is a little bit bigger than Neptune but not overly big. Now for Neptune/Uranus and Earth/Mars they look to be about the same but that is because their mass are almost equal to each other.

2. How does the spacing of the terrestrial planets compare to the spacing of the Jovians?

The terrestrial planets are closely spaced orbits and are closer to the sun. The Jovians are widely spaced orbits but are further away from the sun.

3. How does the spacing of the KBOs compare to the spacing of the Jovians and Terrestrials?

The KBO (Kuiper belt object) is approximately 7.48×10^2 meters from sun, so saying that it is much further away from both Jovians and terrestrial.

4. Look at the Earth and Moon. Is the Moon relatively close to or far from Earth?

The distance between the moon and earth is 1.34×10^{-3} so the diagram does illustrate the distance between the two.

5. Look at the other planets with moons. Which one has the farthest moon from the planet? Which one is the closest? Is there a big difference?

From my calculation I show that the Charon to Pluto is closer and Titan to Saturn is the farthest away. There is a very small difference between all four moons.

6. Are there any problems with this model? How would you solve those problems? What would be the problems with the new model?

The Calculation that I got was difficult to match up on the diagram. Some planets seemed to be off a few inches on the model. So after recalculating the equation, I found that everything seemed to match up. Having more space would have possibly helped.

Stand at the position of Earth and hold a ruler at arms length. Close one eye and measure the size the Sun appears to be. Enter this into table 3. Stand at the position of Mercury and Saturn and measure the size again. Enter these values into table 3. Calculate the ratio of the size of the Sun at that planet to the size of the Sun at Earth.

Table 3: Sun Size		
Standing at	Apparent Size	Compared to Earth
Earth	3,959	0
Mercury	1,516	2,443
Saturn	36,184	32,225

Radius in miles

Questions

Show your work and explain your answers for full credit.

- The largest asteroid is Ceres, which is an average of 4.50×10^2 Km in radius and 4.14×10^8 km from the Sun on average. How big would its picture be (in sensible units)? Where would it be placed in the model (both from the Sun and from the "previous object".) Why was the radius specified as an average?

Average radius= .01cm / from the sun=1.44m / previous object= .65m between Mars and Jupiter. Ranges in size and does not keep its same mass

2. Human space vehicles like the space shuttle or International Space Station generally orbit around 250 km above the Earth's surface. How far would that be from the sketch of the Earth? It takes a few hours to get into orbit, and about 3.5 days to get to the moon. What does this tell you about the planned program to send humans to Mars? $2.5\text{km} = 2.5 \times 10^5$

$2.5 \times 10^5 - 1.50 \times 10^8 \times (1/2.87 \times 10^8) = .52\text{m}$ It would take twice as long to Mars than to the moon.

3. Solar power is a great way to power a spacecraft in orbit around Earth. Would it also be useful around Mercury and Saturn? Explain.

Solar power would be useful for both planets but Mercury would have greater power from it than would Saturn because it is closer to the sun where the solar power is getting its energy. Mercury .20 Saturn 4.98 from sun.

4. The nearest star is alpha centauri, 4.3 light-years away. Where would you have to go to post its picture? $4.3 \text{ light-years to } 4.07 \times 10^{13} \text{ km}$

$1 \text{ light-year} = 9.46 \times 10^{12}$ Distance from the sun: 141,811.85m
 $(4.07 \times 10^{13} \text{ km} \times 1/2.87 \times 10^8)$

5. Alpha Centauri is actually a multiple star system, but one of the stars is nearly identical to the Sun. If you included a picture of a planet the size of Earth with your picture of alpha Centauri, would you be able to see your picture of the other planet while standing at the picture of Earth (assuming you had a clear line of sight: no trees, buildings, or Earth in the way)?

No the size of the sun is bigger than the mass of the earth. So with that Alpha Centauri is the largest star including the sun so there would be no chance of seeing the other planets on the other side.

6. Summarize the observations you can make about the solar system from this model.

Minimizing the size of the solar system does take a lot of time to reach numbers than can be built on a house wall but with the excitement afterwards, the capability to research and design a part of the solar system that has never been touched by us humans excites me the most. I have learned much more than I thought about the solar system and how it is a gentle piece of art that orbits a big star (sun). Knowing the mass of each planet and distance between each planet all depends on its orbit around the sun.

Questions: My Answers: