Clay Models of the Solar System

Larry Lebofsky
JWST/NIRCam Team,
Girl Scouts of Southern Arizona

Background:

Children and adults alike have difficulty comprehending the scale of the Solar System and the Earth-Moon system. This includes the relative diameters of the planets, their relative volumes, and their distances from the Sun. In this activity, updated from ones that were created by the Astronomical Society of the Pacific, we acknowledge the IAU's (International Astronomical Union) dynamically-defined Solar System with eight planets and, at the moment, five dwarf planets. For scientists who look at the "bigger picture" and include the physical properties of Solar System objects, Pluto, as well as several of the Solar System's moons, are worlds that have many of the characteristics of the eight planets as defined by the IAU–atmospheres, seasons, satellites, geologic activity, oceans/seas, etc. Also, the IAU's definition of "what is a planet," can also be questioned when one look at the over 3,700 (as of the writing of this activity) extra-solar planets, few of which are similar to the eight in our Solar System.

Modeling the Solar System:

What is critical with any model is to engage the participants—if at all possible, everyone should participate. A big part of any modeling needs to be a discussion about the types of models (mechanical, mathematical, computer-generated, etc.) and their limitations. This helps to identify and rectify misconceptions and helps to avoid creating new ones.

Model limitations: In this activity, we are only modeling the relative sizes of the planets, their volumes (and diameters). In the images below, we use about 2.5 pounds of modeling clay, which yields a 10-cm diameter Jupiter. On this scale, the 1-meter diameter Sun (a lot of clay) would be over 100 meters from the Earth and over 500 meters from Jupiter. Clearly, we cannot model distances or planetary orbits here. Also, we are not modeling the relative densities of the planets. Gas giant Jupiter, while 1300 times the volume of Earth is "only" 317 times the mass of the rocky Earth. Finally, as you can see from the images of the planets below, they are not red (the color of the clay we used), except for Mars.

Comparing the real Solar System to the Clay Model:

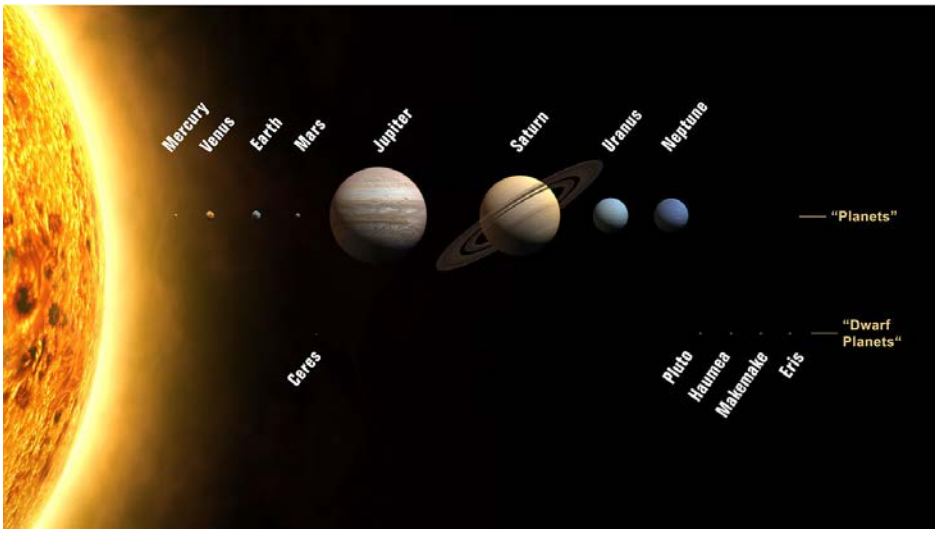


Figure 1: The relative sizes of the eight planets and 5 dwarf planets, IAU.

Figure 1 illustrates the sizes of the planets and dwarf planets Again, remember that, while the order is correct, the distances are not. For example, a 1-cm diameter Jupiter would be more than 50 meters away from the Sun and tiny Eris, the farthest dwarf planet, would be almost a kilometer away from the Sun! Also, the planets all orbit the Sun so they are essentially never lined up like this!

Table 1 lists the diameters, volumes, and masses of the planets and dwarf planets, relative to the Earth and as illustrated in the clay model the percent of the total volume of all of these objects

Planet/Dwarf	Diameter Earth =1	Volume Earth = 1	Mass Earth =1	Actual Volume (%)	Model Volume (%)	Model Ratio
Mercury	0.383	0.0562	0.0553	0.00254	0.00256	1.0079
Venus	0.950	0.857	0.815	0.0388	0.04	1.0303
Earth	1.000	1.000	1.000	0.0453	0.0456	1.0060
Mars	0.532	0.151	0.107	0.00682	0.00688	1.0084
Jupiter	10.97	1321	317.83	59.848	60.0	1.0025
Saturn	9.14	764	95.159	34.586	34.433	0.9956
Uranus	3.98	63.1	14.536	2.858	2.852	0.9980
Neptune	3.86	57.7	17.147	2.615	2.620	1.0019
Total				**100.0**	**100.0**	
Ceres	0.075	0.0004	0.00015	0.000018	Not Modeled	
Pluto	0.182	0.0060	0.0022	0.000276	Not Modeled	
Haumea	0.10	0.0014	0.0007	0.000063	Not Modeled	
Makemake	0.11	0.0015	0.0007	0.000071	Not Modeled	
Eris	0.182	0.0060	0.0028	0.000276	Not Modeled	
Moon	0.273	0.0203	0.0123		Not Modeled	

Therefore, Jupiter makes up 60% of the total volume of the planets, followed by Saturn at about 35%. The Earth makes up only 0.05% of the combined volume of all the planets!

For comparison, from the *Earth/Moon Comparisons* activity, the volume of the Earth is 49.5 times the volume of the Moon (the Earth is 98% of the mass of the Earth-Moon system). However, the Sun is by far the largest object in the Solar System, making up 99.8% of the volume of the entire Solar System!

With this model, we cannot also model the distances of the planets from the Sun. Distances are very large in comparison to the sizes (diameters) of the Sun and planets. The distance from the Earth to the Sun is about 107 times the diameter of the Sun and the average distance to Pluto is nearly 40 times that! In this activity we are able to model the relative sizes (diameters and volumes) of the planets but not their relative distances.

A Clay Model of the Planets of the Solar System:

Other clay models of the planets include Pluto as they were created prior to Pluto's reclassification as a dwarf planet. However, in those models, Pluto is, as can be seen in Table 1, about 1/350,000 of the original ball of clay**. Realistically, one cannot easily make a ball of clay that small. For that reason, we have designed our model to include only the eight planets and have left off Pluto and the other dwarf planets.** If you had 10 or 20 pounds of clay, you might be able to include the dwarf planets! Because the dwarf planets are so small including them does not change the volume percentages of the eight planets at the level shown in Table 1. For example, Mercury's volume percentage goes from 0.00254355% to 0.000254356% of the total of all the planets with and without the dwarf planets, respectively. While this model is not a "perfect" representation of the relative volumes of the planets, it is not too bad! Looking at Table 1, Venus is "off" the most. Could you refine the model to make the Venus model closer to the actual value?

Procedure:
Draw eight circles in a line on a piece of paper to represent the eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. You may try to draw the circles to represent your estimates of their sizes. Put the names of the planets under your circles. Some of the steps for this activity are illustrated on the last page.

1. Roll the entire ball of clay into a long cylinder (hot dog shape; see Fig. 2, Step 1)
    - Cut the clay into 10 equal parts
    - Combine 6 parts together into a ball and put this on the circle labeled Jupiter
    - Combine 3 parts together into a ball and put this on the circle labeled Saturn
2. Roll the last piece of clay into a cylinder
    - Cut the clay into 10 equal parts
    - Combine 4 parts together with the ball representing Saturn, making a new ball
    - Combine 2 parts together into a ball and put this on the circle labeled Uranus
    - Combine 2 parts together into a ball and put this on the circle labeled Neptune
3. Roll the last 2 pieces of clay into a cylinder
    - Cut the clay into 10 equal parts
    - Combine 2 parts together with the ball representing Saturn, making a new ball
    - Combine 4 parts together with the ball representing Uranus, making a new ball
    - Combine 3 parts together with the ball representing Neptune, making a new ball
4. Roll the last piece of clay into a cylinder (see Fig. 2, Step 4)
    - Cut the clay into 10 equal parts
    - Combine 2 parts together into a ball and put this on the circle representing Venus
    - Combine 2 parts together into a ball and put this on the circle representing Earth
    - Combine 1 part together with the ball representing Saturn, making a new ball
    - Combine 2 parts together with the ball representing Uranus, making a new ball
    - Combine 1 part together with the ball representing Neptune, making a new ball
5. Roll the last 2 pieces of clay into a cylinder
    - Cut the clay into 10 equal parts
    - Combine 1 part together with the ball representing Earth, making a new ball
    - Roll 1 part into a ball and put this on the circle representing Mars
    - Combine 3 parts together with the ball representing Saturn, making a new ball
    - Combine 3 parts together with the ball representing Uranus, making a new ball
6. Roll the last 2 pieces of clay into a cylinder
    - Cut the clay into 10 equal parts
    - Combine 3 parts together into a ball and put this on the circle representing Mercury
    - Combine 2 parts together with the ball representing Earth, making a new ball
    - Combine 3 parts together with the ball representing Mars, making a new ball
7. Roll the last 2 pieces of clay into a cylinder (see Fig. 2, Step 7)
    - Cut the clay into 10 equal parts
    - Combine 1 part together with the ball representing Mercury, making a new ball
    - Combine 3 part together with the ball representing Mars, making a new ball
    - Combine 6 parts together with the ball representing Saturn, making a new ball

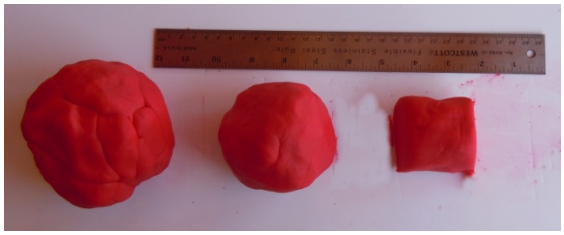
Your Estimates:
How close in size were your circles compared to the sizes (the volumes) of the balls?

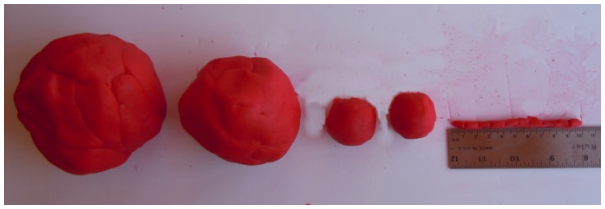
Did you notice a trend? The inner four planets, the rocky planets, are all much smaller than the outer gas giant planets.

Worlds in Comparison:
Jupiter makes up 60% of the volume of the planets, followed by Saturn at about 35%. The Earth makes up only 0.05% of the combined volume all of the planets! However, the Sun is by far the largest object in the Solar System, making up 99.8% of the volume of the entire Solar System!

While we have modeled the sizes (volumes) of the planets, we have not modeled the distance between the planets. The distances are very large in comparison to the sizes of the Sun and planets. The distance from the Earth to the Sun is about 107 times the diameter of the Sun and the average distance to Pluto is nearly 40 times that! In this activity we are able to model the relative sizes of the planets but not their relative distances.


Step 1: Cylinder in10 pieces


Step 1: Jupiter, Saturn and 1 pieces


Step 4: Four planets and cylinder


Step 4: Six Planets and 2 pieces


Step 7: Eight Planets

Figure 2: Several steps in the creation of the eight planets