



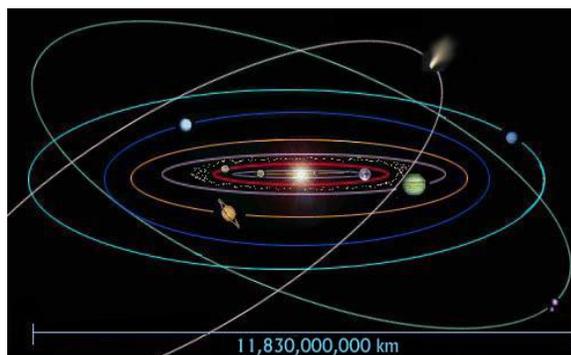
Solar System Scale Model

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| | | |
|--|---|---|
| <p>Target Audiences:</p> <ul style="list-style-type: none"> • Public science events • Youth groups • Science museums, planetaria • Astronomy clubs • Community events • Other Informal Science educational locations & events | <p>Activity Time: 15-20 minutes</p> <p>Age Group: 9-adult</p> |  |
| <p>Materials Needed:</p> <ul style="list-style-type: none"> • 2.5m diameter scaled Sun (e.g. balloon, whatever) • Scale models of the 8 planets, asteroids, Kuiper belt objects • 3 differently-scaled versions of Earth, including 1 that matches your scaled Earth • Toy car or other scale model example • Extra Earth marbles (<i>optional</i>) • Eclipse glasses (<i>optional</i>) • Printed satellite image of event location (<i>optional</i>) • Transparent overlay of scaled planet orbits (<i>optional</i>) | | |

Background:

The scale of our solar system is difficult to imagine when we are standing on what appears to be a large planet looking at an apparently small Sun. Pictures don't help much. Although we could print the planet sizes to scale, the paper would need to be way too large to show the scaled distances. Instead, to help you understand the sizes and distances of our solar system, we've created a scale model.



*Our Solar System, real imagery but **not** to scale*



Process:

1. **Ask your audience if they know what a scale model is.** A scale model is a representation or copy of something that is larger or smaller than the actual object but maintains the relative proportions.

The cars in the image on the right are all scale models that represent real cars. Each has been made to a different 'scale' or 'amount smaller' than a real car.



Show participants an actual toy car or other scale model example.



2. **Show the audience the balloon or your scaled Sun. Ask them what they think it is?** This is a good time to talk about the color of the Sun (white) and why it looks yellow or orange at sunrise/set (because the blue, green, & violet colors are filtered out by the thick atmosphere).
3. **In our model, the Sun has been scaled down to a 2.5m (8') balloon. How large would the scaled Earth be?** Show the audience the 3 model Earths and ask them to estimate which is the correct size for our balloon Sun. [23 mm blue marble] This would be a good time to mention that 1 million Earths would fit inside the Sun, and it would take 109 Earths strung across the disc of the Sun at the equator.
4. **Ask the participants how far away should the Earth marble be placed to be in scale with the Sun balloon.** Ask questions to make sure they understand the concept of scaling distance as well as size – if all proportions are kept, then distance scales just as size does. Thus something scaled down to half size would also be scaled to half the distance. Hand out some Earth marbles and have the audience stand as far away as they believe the scale Earth should be placed. Accept all answers. **Collect the Earth marbles!**



5. How could they figure out how far away to place their Earth marble?

If you have eclipse glasses, have participants put them on. If not, caution the participants that prolonged staring at the Sun can damage their eyes. Ask participants to hold one arm straight out and use the smallest piece of their hand they can to cover up the Sun – they should only glance up quickly or wait for sunset or thin clouds! What piece did they use? [*pinkie fingernail*] Now, have them hold up that same piece of their hand and try to cover up the Sun balloon. How far back would they have to walk to be able to cover the balloon with their little fingernail? Let them try to back up to figure it out... [*~270m*]



This works because in our scale model, all the proportions remain the same as the real Sun and Earth!

6. Show participants the rest of the model planets and ask them to identify each.

Remind them all the planets are to scale. This is a good time for discussion between the presenter and the participants on what they know about the planets and what questions they might have.

7. If you have one, show participants the satellite map of the area and the orbit overlays. Encourage discussion and questions.

8. If participants are still excited and engaged, explore the relative sizes of the nearest star, our galaxy, and the universe (as on the attached worksheets).



** Scale Model Worksheet **

1. The instructor will show you 3 model Earths to choose from. Which model Earth is the correct size/scale for our model 2.5m Sun?



A _____



B _____



C _____

2. How many Earths would fit inside the Sun? _____
3. The instructor will show you the scale model Earth and Moon. The real Moon is about 385,000 km from the Earth, about 30 times the Earth's diameter. How far away should the scale Moon be placed from the scale Earth? _____
4. The Sun is 150,000,000 km from the Earth. How far away should our scale Earth be placed from the balloon Sun?

Hint: you can figure this out with math:

$$\frac{\text{distance}}{150,000,000 \text{ km}} = \frac{2.5\text{m}}{23 \text{ mm}} \quad \text{so distance} = 270 \text{ meters}$$

Or, there's an easier way:

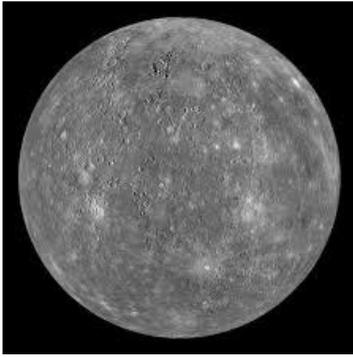
Hold your arm straight out, *glance* up at the Sun and use the smallest piece of your hand you can to cover up the Sun. What piece did you use?

Now, hold up that same piece of your hand and try to cover up the Sun balloon. How far back would you have to walk to be able to cover the balloon with your little fingernail?

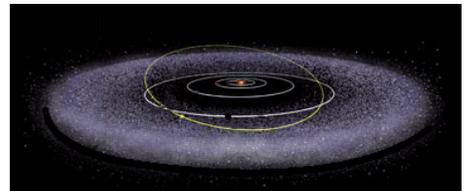
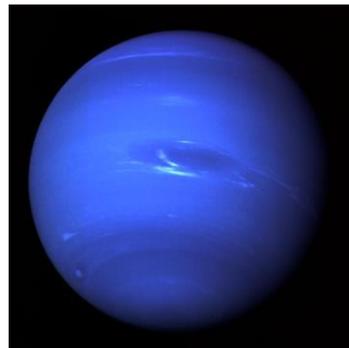


This works because in our scale model, all the proportions remain the same as the real Sun and Earth!

5. The instructor will show you the other scaled planets, the asteroid belt, and some Kuiper belt objects. Can you identify the other objects in our scale model?





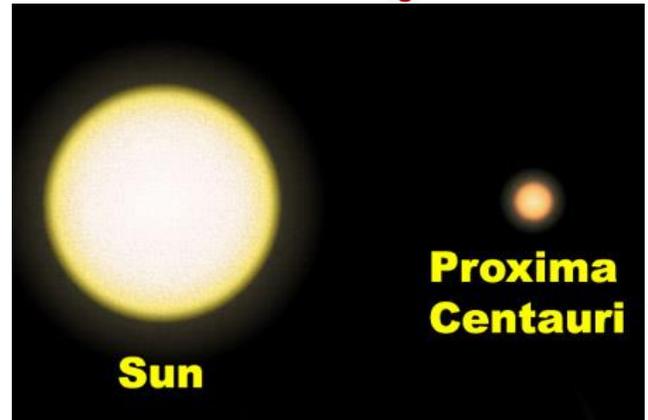




6. Here is a picture of our Sun compared with the nearest star, Proxima Centauri. On our scale, where the Sun is a 2.5m balloon, how large do you think Proxima Centauri would be, and how far away?

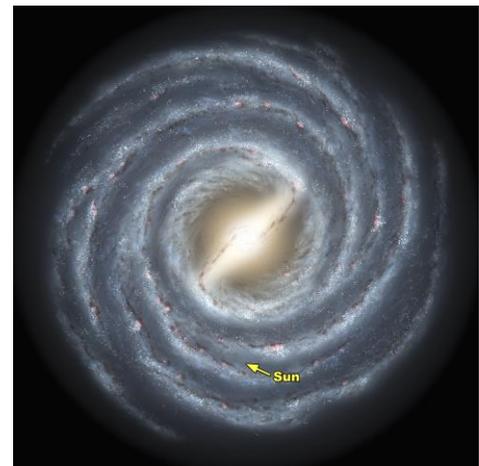
Scaled size of nearest star:

Scaled distance of nearest star:



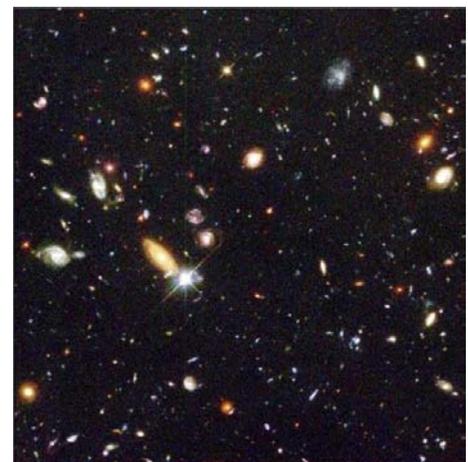
*Size to scale but **not** distance*

7. Here is a painting of our Milky Way galaxy, with the Sun marked. The galaxy is 100,000 light-years across. On our scale, where the Sun is a 2.5m balloon, how big would this galaxy be?



8. Our Milky Way is only one of billions and billions of galaxies. If our Milky Way were scaled to the size of a 250mm paper plate, how far away would the nearest (large) galaxy be?

Now, imagine billions and billions of paper plate galaxies!





Answers

1. The instructor will show you 3 model Earths to choose from. Which model Earth is the correct size/scale for our model 2.5m Sun?

C 23 mm marble (the smallest)



2. How many Earths would fit inside the Sun? *~1 million*
3. ...The real Moon is about 385,000 km from the Earth, about 30 times the Earth's diameter. How far away should the scale Moon be placed from the scale Earth? *~180mm or .7 m*
4. The Sun is 150,000,000 km from the Earth. How far away should our scale Earth be placed from the balloon Sun?
Your little fingernail would cover up the Sun, and you would need to walk back ~270m to cover the balloon with your little fingernail.
5. Planets on the worksheet, in order from left to right and top to bottom: *Mercury, Venus, Mars, asteroids, Jupiter, Saturn, Uranus, Neptune, Kuiper belt (includes Pluto)*
6. On our scale, how large do you think Proxima Centauri, the nearest star to our Sun, would be, and how far away? *Proxima Centauri to scale would be 361mm and it would be 72,000km (!!!) away*
7. The Milky Way Galaxy is 100,000 light-years across. So, *on our scale, the Milky Way Galaxy would extend about out to the orbit of Saturn.*
8. The Andromeda Galaxy, the closest large galaxy to the Milky Way, is about 2 million light-years away. If our Milky Way were scaled to the size of a 250mm paper plate, how far away would the nearest (large) galaxy be? *The plates would be about 5 meters apart. So, the stars are very far apart, but the galaxies are relatively close together!*



Scale of Model Solar System

Metric Units

Scale: Earth 23 mm = 12,800 km

Approximately 150,000,000:1

| <i>Object</i> | <i>Scaled Diameter</i> | <i>Scaled Distance from Sun</i> | <i>Actual Diameter</i> | <i>Distance in AU</i> | <i>Actual Distance from Sun</i> |
|-------------------------------------|------------------------|---------------------------------|--------------------------|-----------------------|-----------------------------------|
| Sun | 2.5 m | -- | 1,392,000 km | -- | -- |
| Mercury | 8.7 mm | 105 m | 4,900 km | .4 AU | 58 million km |
| Venus | 21.8 mm | 195 m | 12,100 km | .7 AU | 108 million km |
| Earth | 23 mm | 270 m | 12,800 km | 1.0 AU | 150 million km |
| Moon | 6 mm | .7 m from Earth | 3,500 km | | 385,000 km from Earth |
| Mars | 12.2 mm | 412 m | 6,800 km | 1.5 AU | 228 million km |
| Asteroids | dust | 540 - 945 m | Dust to 950 km | 2-3.5 AU | 300-525 million km |
| Jupiter | 250 mm | 1.4 km | 140,000 km | 5.2 AU | 780 million km |
| Saturn | 210 mm | 2.6 km | 116,000 km | 9.6 AU | 1500 million km |
| Rings | 450 mm | -- | ~280,000 km ¹ | | |
| Uranus | 91 mm | 5.2 km | 51,000 km | 19 AU | 2900 million km |
| Neptune | 89 mm | 8.1 km | 50,000 km | 30 AU | 4500 million km |
| Kuiper belt (incl Pluto) | Salt to pebbles | 8-15 km | <1200 km | 30-50 AU | 4.5–7.4 billion km |
| Proxima Centauri² | 361 mm | 72,000 km | 200,000 km | 268,000 AU | 4.3 light-years (>40 trillion km) |

An AU is the average distance between the Sun and the Earth, ~150 million km.

At this scale, 1 AU = 270 m = ~1/4 km = ~355 paces.

A light-year is a unit of distance, equal to the distance light travels in a year. This is just under 10 trillion kilometers.

Actual distances and diameters have been rounded.

¹ A-F rings

² Closest star other than our Sun



Scale of Model Solar System

US Units

Scale: .9" = 8000 mi

Approximately 150,000,000:1

| Object | Scaled Diameter | Scaled Distance from Sun | ~Actual Diameter | Distance in AU | ~Actual Distance from Sun |
|--------------------------------------|-----------------|--------------------------|-------------------------|----------------|-----------------------------------|
| Sun | 8' | -- | 865,000 mi | -- | -- |
| Mercury | .3" | 333' | 3,000 mi | .39 AU | 36 million mi |
| Venus | .8" | 616' | 7,500 mi | .72 AU | 67 million mi |
| Earth | .9" | 856' | 8,000 mi | 1.0 AU | 93 million mi |
| Moon | ¼" | 27" from Earth | 2,200 mi | | 239,000 mi from Earth |
| Mars | ½" | 1350' (¼ mi) | 4,200 mi | 1.5 AU | 142 million mi |
| Asteroids | Dust | 1800' -3100' | Dust to 590 mi | 2-3.5 AU | 186-326 million mi |
| Jupiter | 10" | 4451' (.9 mi) | 86,900 mi | 5.2 AU | 484 million mi |
| Saturn | 8" | 1.6 mi | 72,400 mi | 9.5 AU | 890 million mi |
| Rings | 20" | | 175,000 mi ³ | | |
| Uranus | 3.6" | 3.2 mi | 32,600 mi | 19 AU | 1.8 million mi |
| Neptune | 3.5" | 5 mi | 30,600 mi | 30 AU | 2.8 million mi |
| Kuiper belt (incl Pluto) | Salt to pebbles | 5-8 mi | <=750 mi | 30-50 AU | 2.8 – 4.6 billion mi |
| Proxima Centauri ⁴ | 14" | 44,000 mi | 123,600 mi | 268,000 AU | 4.3 light-years (~25 trillion mi) |

An AU is the average distance between the Sun and Earth, about 93 million miles.

At our scale, 1 AU = 887' = 296 yards = .17 mi = ~355 paces

A light-year is a unit of distance, equal to the distance light travels in a year. This is about 6 trillion miles.

Actual distances have been rounded

³ A-F rings

⁴ Closest star other than our Sun



**** Going Further ****

1. Actually place the planets at their scaled distances

The scale model to Neptune would cover about 8 km (5 miles). We have done this several times – placing the various planets in local stores, libraries, schools, whatever. We had student teams create their own planet plus a display of information about that planet. We provided rubber stamps and pads at each planet display. People were given *Visit the Planets* cards with a square for each planet to be rubber-stamped when they visited it. Those with their cards completely filled out were offered a prize (solar poster, lenticular, etc.)

2. Draw the planet orbits on a satellite map of the area

We have also printed off satellite images of the area where we were setting up the scale model. Then on the map we drew the orbits of the various planets, with the Sun in the center at our location. People very much enjoyed looking at the maps!

3. Place the Earth at its scaled distance from the model Sun and observe it through a telescope

If a telescope or monocular or binoculars are available, place your scale Earth on top of something like a roof or antenna that is about 270 m (887') away from your model Sun. Point out the location to the kids (after they estimate where they think the model Earth ought to be) and let them look at the Earth through the telescope. You'll need a tripod for the scope.



Other Scale Model Resources

NASA Wavelength:

- The Earth as a Peppercorn: <http://nasawavelength.org/resource/nw-000-000-003-036/>
- Toilet Paper Solar System: <http://nasawavelength.org/resource/nw-000-000-003-035/>
- Solar Pizza Scale Model: <http://nasawavelength.org/resource/nw-000-000-003-142/>

- The Scale of Things: <http://nasawavelength.org/resource/nw-000-000-002-432/>
- Solar System Scale and Size: <http://nasawavelength.org/resource/nw-000-000-003-546/>
- The Incredible Two-Inch Universe: <http://nasawavelength.org/resource/nw-000-000-002-909/>
- Earth, Earth's Moon and Mars Balloons: <http://nasawavelength.org/resource/nw-000-000-003-545/>
- Trip to the Sun: <http://nasawavelength.org/resource/nw-000-000-003-320/>
- The Sun: <http://nasawavelength.org/resource/nw-000-000-002-713/>
- Where are We in the Solar System?: <http://nasawavelength.org/resource/nw-000-000-003-204/>
- How Big is the Sun? Exploring the Size and Scale of the Sun, Earth and Moon: <http://nasawavelength.org/resource/nw-000-000-003-261/>
- Solar System in My Neighborhood: <http://nasawavelength.org/resource/nw-000-000-003-194/>
- Distance to the Moon: <http://nasawavelength.org/resource/nw-000-000-001-838/>
- How Far Away is Saturn?: <http://nasawavelength.org/resource/nw-000-000-002-376/>
- Model the Sun and Earth: <http://nasawavelength.org/resource/nw-000-000-003-959/>
- The Size of the Sun: <http://nasawavelength.org/resource/nw-000-000-002-683/>
- Amazing – Saturn is So Far, Far Away!: <http://nasawavelength.org/resource/nw-000-000-002-375/>
- Earth's Bright Neighbor: <http://nasawavelength.org/resource/nw-000-000-003-980/>
- Play Dough Planets: <http://nasawavelength.org/resource/nw-000-000-002-107/>
- Modeling the Universe: <http://nasawavelength.org/resource/nw-000-000-001-530/>
- The Size of Things: <http://nasawavelength.org/resource/nw-000-000-002-433/>

Web Resources:

- 16 Pictures Will Make You Re-Evaluate Your Entire Existence: <http://www.buzzfeed.com/daves4/the-universe-is-scary#.wewveyYKB>
- How Small is planet earth! Renaud Mragry: <https://www.youtube.com/watch?v=sflszMEQ6jI>
- Astronomy Activity: Pocket Solar System: <https://www.youtube.com/watch?v=tTMuvtLLv4k&authuser=0>
- Earth in True Perspective: http://www.babamail.com/View.aspx?MemberId=835852&emailid=12288&source=mobile_share
- This Video Takes Place At Lightspeed: http://digg.com/video/this-video-takes-place-at-lightspeed?utm_source=digg&utm_medium=email
- The Next 209 Seconds Will Blow Your Mind: <http://www.iflscience.com/space/how-big-our-place-universe>

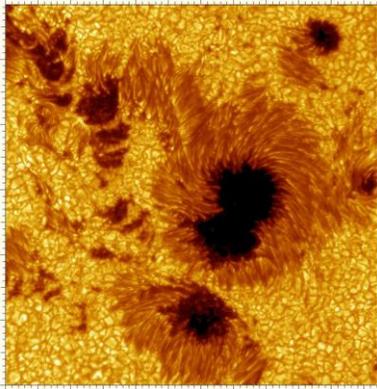


Developer's Notes for Solar System Scale Model

Scaled Sun – 2.5 m (8') diameter. Cost: few dollars to many hundreds

Note: the Sun is white (not yellow or orange, which is a misconception). See <http://solar-center.stanford.edu/SID/activities/GreenSun.html>

An inexpensive ($\$ < 10$), one-dimensional Sun can be cut out of a plastic paint tarp or butcher paper. If you are working with young children, have them dip their hands in paint and make hand prints on the Sun. They could be shown imagery of sunspots, discuss them, and imagine their prints represent sunspots.



Weather balloons ($\$25$ - $\$75$) do give an impressive 3-D look. But since they are designed to explode at high altitudes, they are quite fragile for use around children.



Vinyl balloons can be custom-made by companies who make advertising balloons ($\$300$ - $\$400$). Straps can be added for anchoring. It is possible to paint sunspots on the vinyl (we had a sunspot researcher here at Stanford paint our spots). The vinyl balloon was not too hard to carry around in a suitcase and easily inflatable by a hair dryer.



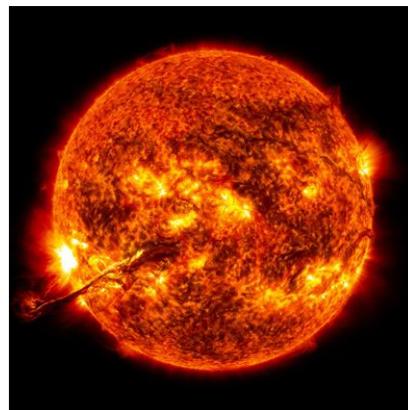
Stanford Solar Center's custom-made vinyl balloon Sun



Image by Mike Reid

Vinyl balloon manufacturers are now able to use imagery from NASA's STEREO twin spacecraft to produce printed vinyl balloons. This increases the cost significantly (\$800-\$1000). The balloon to the left was produced for Mike Reid, using imagery from NASA's STEREO twin spacecraft.

Another option is to have a 2.5 m (8') diameter flat image of the Sun produced on vinyl paper similar to that used for scientific posters. Add grommets for hanging. The poster is less costly (\$300-\$400) than the vinyl balloon, and more colorful (though less impressive than the 3D). The poster Sun is easy to fold and carry around. Outstanding solar imagery is produced by the AIA instrument aboard NASA's Solar Dynamics Observatory. <http://sdo.gsfc.nasa.gov/data/>





Earth globes to compare your Sun to. Cost: a few dollars

You'll need 3 example Earths of different sizes to ask your audience which might be the correct scale for your 2.5 m (8') Sun. You could use an inflatable beach ball/Earth globe as the largest, 300 mm (12) is good, inexpensive and available on the net. For the medium size, perhaps use the small stress-reliever globes, also available on the net. For the tiniest, you will need one of the Earth marbles that will also represent the Earth in your scale model. More info on that below.



Small marbles for small planets. Cost: a few dollars

To avoid loss, and the temptation for kids to play with the planets, we put each marble in a small, clear plastic box. These are purchased at TAP Plastics™.

| | | |
|--------------------------------|---|--|
| <p>Mercury</p> | <p>~8 mm marble (1/3").</p> <p>Grey would be best, but only brown and dark red seem to be available. You might paint one the correct color.</p> |  |
| <p>Venus</p> | <p>~22 mm marble (3/4").</p> <p>We couldn't find any marble the appropriate color, so we purchased a clear marble and painted it.</p> |  |
| <p>Earth & Moon</p> | <p>23mm Earth (.9") 6 mm Moon (1/4") – clear marble</p> <p>Gorgeous Earth marbles (23 mm; .9") are available on the web, made from recycled glass and using 6 colors. Continents are clear, rivers and mountains are visible. Our favorite Earth marbles come from Shasta Visions™. Having these exquisite Earths to show audiences really excites them. These marbles often disappear, so plan to have extras on hand. Note – the Earth marbles come in several sizes. For this scale, make sure you get the 23 mm ones.</p> |   |



| | | |
|-----------------------------------|--|--|
| <p>Mars</p> | <p>~12 mm (1/2")</p> <p>On the net, look for the Fabricas Selectas™ Mars Marble Set. The little marbles are perfect (you won't need the shooter). Use paint to add the ice caps.</p> |  |
| <p>Asteroid belt</p> | <p>You need black dust for this. Embossing powder, grit for grinding telescope mirrors, or any black powder you can find should work. In a pinch, use dirt. If you wish, find a small pebble to represent Ceres.</p> |  |
| <p>Kuiper belt objects</p> | <p>We used a collection of small clear marbles and multi-sized little white beads, collected in a plastic box. Explain to the audience that the little marbles represented Pluto, Eris, Makemake, and Haumea. The smaller beads represent the rest of the KBOs. This is a good time to talk about why Pluto is no longer a planet.</p> |   |

Jupiter and Saturn – Cost: inflatable beach balls, or plastic mirrors and Styrofoam™ hemispheres

The easiest and least expensive way to produce Jupiter and Saturn is to buy inflatable beach balls of the right sizes and colors, 250 mm and 210 mm (10", 8"). Cut Saturn's rings out of poster board. Cut a hole in the center exactly large enough for your beach ball. Then paint the inner 25 mm or so black and color the outside to resemble Saturn's rings. If necessary, you can tape the poster board rings to the ball.



A more professional solution is to use mirrors, Smoothfoam™ (like Styrofoam™), and plastic. Purchase a 450 mm x 280 mm (18" x 11") piece of plastic mirror from TAP Plastic™ for Saturn, and a



400 mm x 280 mm (16" x 11") mirror for Jupiter. Use a Softfoam™ (similar to Styrofoam™) hemisphere of 250 mm (10") for Jupiter and 200 mm (8") for Saturn, (both available on the web). Paint the hemispheres to look like the respective planets. The planets can be glued to the mirrors with Elmer's™ white glue. The mirrors can be placed on plastic book/sign stands for viewing (also from TAP). Expect people, especially children, to want to touch these planets.



Jupiter glued to a mirror

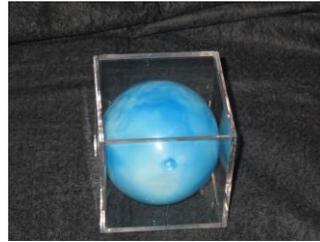
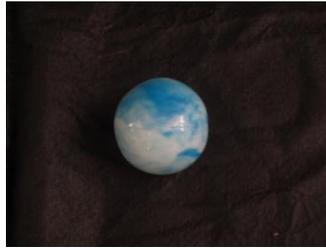
For Saturn's rings, have TAP™ cut a semicircle "doughnut": 450 mm (16" in diameter, rings 76 mm (3") wide, 250 mm (10") semicircle cut out in center. The rings can be painted and covered with sparkles to simulate ice. For support on the mirror, have TAP™ cut 2 clear plastic square rods of 12mm x 12mm x 76 mm (½" x ½" x 3"). Glue these to the mirror, then glue Saturn's rings to the rods. The glue is acrylic cement. TAP can provide it.



Examples of Jupiter & Saturn glued to mirrors

Uranus and Neptune – inexpensive dog balls

PetsMart™ has dog balls that are about the right size and colors for Uranus and Neptune. The balls fit well into plastic baseball display boxes available from TAP Plastic™.



Family Portrait – small planets

