A Night-Time Model Solar System

Brewster LaMacchia

email: bwl@jovian.com

There are dozens of possible activities for constructing scale models of the solar system. They all generally have one goal: to give a sense of scale to the our solar system, both in the relative size as well as relative distances between planets.

However, I was looking for a model that would not only give a sense of scale, but could also help explain why the planets appear the way they do in the night sky. Also, the model had to be for use at night. Originally the idea was for a model that, along with a handout, could be explored on its own. Early experience showed this was not feasible, so the model now has a tour guide.

Given the huge variation in size of the planets and the sun, the model does not try and show them to scale. This shortcoming is more than offset by other advantages.

A good resource for more info about solar system models and planet positions is: `http://www.vendian.org/mncharity/dir3/solarsystem/`

Materials

I have tried a number of different ways of creating the planets used in the model, see the text following this list for a description of what worked. Apologies for using English units of measure, but if you walk into Home Depot and ask for a 2.43 meter long 2.5 x 5 cm piece of wood, you'll get a blank stare instead.

STAKES

10 eight foot long pressure treated 1x2s, cut to 6'-7' lengths (to keep the planets out of reach of small kids), with a 6" point on the end. Avoid pieces with knots in them, as they

will break when you pound them into the ground. Oak stakes (like those used for holding up plants) could also be used.

PLANETS

Transparent or translucent balls for planets and sun. (Having the balls scaled correctly in size was not a goal of this model.) The model currently uses a combination of the following:

- ping-pong balls
- yellow hard plastic ball with crinkle surface (this is the sun)
- super-balls (the ‘clear’ type)
- plastic spheres (from art supply store).
- Another possible source of round objects to be planets are lamp globes sold at lighting stores- the large outdoor ones tend to be made of plastic (avoid glass).

LIGHTS

3V (2 D cell) flashlight (for sun)

Light source for planets (6 sources total):

- AAA penlight flashlights
- Dual AA battery holders, switch, yellow LEDs, 220 Ω resistors, wire, heat shrink tubing
- Dual C cell battery holder, switch, 3V christmas light bulbs and sockets without shunts, rubber washers or grommets, wire, switch, heat shrink tubing

MISC.

Optional: 2” to 11/4” hose coupling (like that used for sump hoses) for mounting sun.

Mars Black acrylic paint (a very opaque black, has nothing to do with the planet Mars)

Fine magic marker pens if using ping-pong balls exclusively, otherwise a selection of transparent acrylic paint, and decent brushes for acrylic paint. You may need thin the paints to avoid brush strokes showing.

Clear coat spray on acrylic (spray on the planets once they’re done)

36” of 1/4 inch clear acrylic rod

About 6’ of self-adhesive velcro (black if you can get it)

Batteries (as needed) - watch for sales and stock up.

Signs for the stakes naming each object, 2 sets.

Clear packing tape, or other wide transparent tape.

Tools: Glue gun, knife, clear tape, staple gun with 1/4 or 3/8 staples, drill, saw, dremmel tool. If wiring up planets: low wattage soldering iron, solder, heat source for heat shrink tubing.

You will also either need software that can plot the positions of the planets on a 2D grid, or access to the web to use one of the many web based orrery programs (for example, see `http://www.fourmilab.ch/solar/solar.html`).

Estimated costs using the simplest approach: stakes $30, balls $10, flashlights $22, velcro $10, markers and black paint $10, acrylic rod $5. Replacement batteries as needed, a set for the model as described here ran about $15.

Construction detail

Don't be scared by the length of this section. Three different approaches were tried. All 3 are described here so they can serve as a starting point for implementing this with other materials that you may have available. Time to build it was 2 hours for the stakes, and 1 to 2 hours each for the planets, depending on the level of detail.

STAKES

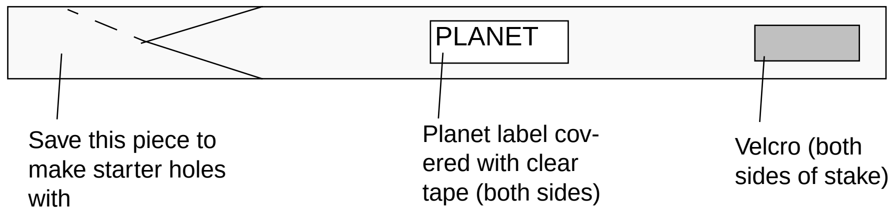
The stakes were cut such that when pounded into the ground, the planets would be out of easy reach of most 6th graders. Cut a 6 to 8 inch taper on the stakes to make pounding them into the ground easier. A 3lb mallet was used for pounding. Winters present a special problem - the stakes are not strong enough to be pounded into frozen ground. Use a small crowbar, or a small stake (made from scrap) to make a "starter" hole.

About 1/2 inch from the top attach a 4" piece of velcro to each side of the stake. Add a staple to the top and bottom of the velcro to "enhance" its self-adhesiveness. The stakes are aligned perpendicular to the sun stake, put velcro on each side so you don't have to care which side faces the sun. I put the "cloth" side of the velcro on the stakes and the "hook" side of the velcro on the flashlights.

A little above the middle attach the name tags to the stake using the clear packing tape. I copied the tags onto 60 lb cover stock so that it would hold up better.

At some point in time I expect to be faced with a star party on an asphalt 'field'. My only thought is to use cinder blocks and a piece of pipe attached to them to stick the stakes into, but 10 blocks is a lot to lug around. However, it would also solve the winter time frozen ground problem.

Detail of stake construction



SUN

The sun is a ball that might have been intended for use as a pet toy, as it has a bell inside of it. It had an interesting texture that loosely resembles magnified views of the sun's surface. The ball is about 3" in size.

A larger flashlight was used to make it bright, but the ball sat too low in the flashlight. A 2" to 11/4" hose coupling happen to exactly fit over the flashlight, the ball was glued to the other end. It also allows the flashlight to be used normally by slipping the coupling off.

Place a 4" piece of velcro on the flashlight. Add some hot melt to make sure the velcro stays stuck down with repeated use.

The 2 D cell flashlight seems to get about 5 hours from one set of batteries.

PLANET - PENLIGHT AND PING PONG BALL APPROACH

This was the first type of planet I tried, and the easiest to construct. The only problem is the penlight batteries only last about 2 hours, and I suspect the bulbs have a short life as they're 2.5V bulbs being run at 3 V to make them look bright. One package of replacement bulbs indicated a 15 hour bulb life. The expense of a lot of AAA batteries can add up. I've migrated to other planet types, except for the earth, where I find the penlight based approach easy to hold while orbiting the sun in the tour.

Only the naked eye visible planets are illuminated.

To mount a planet to the flashlight: Drill a small hole in a ping-pong ball. Place the hole on the line that divides the ball in half - you'll want this line to end up being on the terminator as it does show through. Cut the hole large enough to stick the end of the penlight into the ball about 1/4".

If the penlight has a focused lens type bulb, you will need to diffuse the light. I used fingers cut from a surgical glove taped over the end of the flashlight. Once you're happy with the light, use the hot melt to secure the ball to the flashlight. As a bonus, the glove finger prevents the bulb from getting glued in place, so it can be removed when it burns out.

Paint one-half of the ping-pong ball black using an opaque black paint. Pick the side that has the lettering on it to blacken, and use enough coats to completely blacken the back side.

On the sunlit side (i.e., the side that looks lit up when you turn on the flashlight), draw in planetary features using thin magic markers or the acrylic paints. I think magic markers work better, as the paints tended to have visible stroke lines. Do not over-color the balls. Use the web to find pictures of the planets, or an astronomy book. Watch out for pictures that have been color enhanced or are false color pictures.

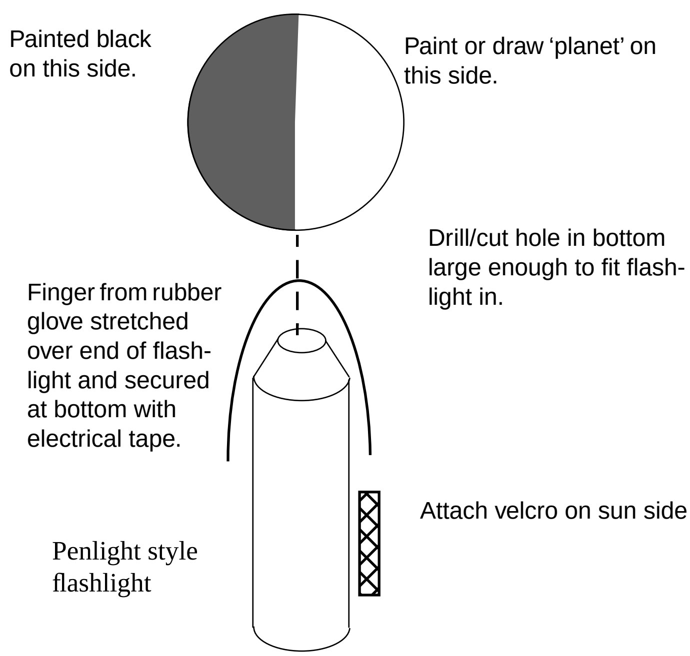
Attach a piece of velcro to the middle of the flashlight, align it such that the dark side of the planet faces away from the sun when the rod is stuck to the velcro on the stake.

To make life easier, use orange ping-pong balls for Mars and Saturn.

For Saturn's rings, I used a coffee can lid with the edges cut off. Some writing was visible on the lid so a bit of sandpapering was called for. A hole the size of the ball was cut in the center of the lid, and the Saturn ping pong ball was glued in at 3 spots, 2 on the dark side - though I suggest attaching the rings before painting.

Venus has no readily visible features, but I did draw a light pencil cloud pattern and then erased it to smudge it out to give it bit of depth.

Ping-Pong Ball Planet details



LED ILLUMINATED PLANETS

This was an idea to get around the battery life problem of the AAA penlights. I used a yellow LED as the illumination source, powered by two AA batteries. Don't forget the current limiting resistor, a value of around 220Ω should be fine. Lower values will produce a brighter light, but at corresponding decreases in battery life.

The LED was used in conjunction with the superball. A hole large enough to insert the LED was drilled in the ball, and the LED glued in place. The resistor was tied to one side of the LED, and then the battery wires attached to the other end of the resistor and the other end of the LED. (LEDs are polarized, they will light only when connected in one way. If it doesn't light, swap the battery wires.)

Before attaching the wires, heat shrink was slid over the wires. Once the connections were soldered, the heat shrink tubing was slid over it, and heat applied to shrink it. The super ball was mounted on the end of a 5" piece of the acrylic rod, with the alignment such that the LED was in the middle of what would become the back side.

The back side was painted black, and some surface features painted on the front.

The effect is very nice (calling it realistic might be a stretch), as the LED projects light strongest face on, which gives a more natural lighting effect than achieved with the incandescent bulbs. On the downside, LEDs aren't that bright, and the monochromatic light will hide any coloring. For Mercury, this is not a big deal.

I do not suggest the LED approach.

CHRISTMAS LIGHTS WITH PING-PONG BALLS

Looking to cut costs (the AAA batteries needed for the penlights never seem to be on sale for less than larger sized ones), I hit upon the idea of using a string of miniature christmas lights and C sized batteries. The 35-50 light sets use bulbs that work well off of 3V.

However, sets sold today have the "if one burns out, they all stay lit" feature, which is done by putting a shunt in parallel with the filament. This would cut down on battery life. The day was saved when I found battery operated light sets. 15 bulbs and a battery holder for $3.99 (and 50% off at the end of the season - of course finding them out of season may be a bit of a problem, but if 1998 was any indication, Xmas merchandise will be available around Memorial Day). The battery operated light sets' bulbs don't have shunts.

The string was cut up into individual (Venus, Mars) or pairs of bulbs (for Jupiter and Saturn, to make them brighter). A hole was drilled in the back of a ping-pong ball (don't forget to keep the seam on the terminator). A rubber washer was glued over the hole to hold the bulb in place.

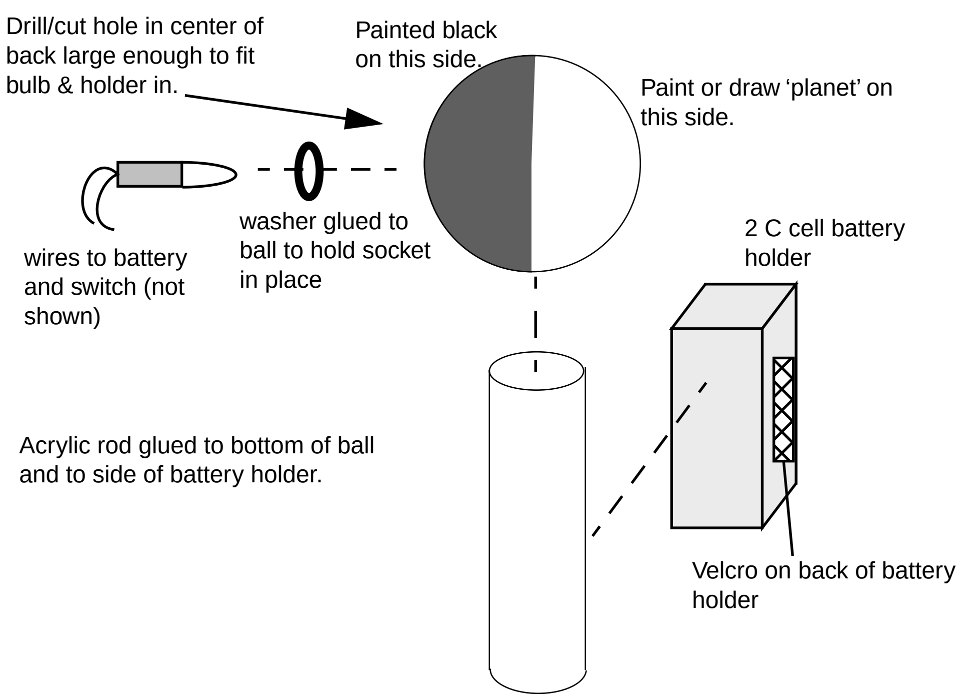
A 5" piece of rod was glued (hot melt) to the bottom of the ball, and it in turn glued to the side of the two C cell sized battery holder. A small switch was wired into one side of the battery, and the lights wired in. Everything was held down with hot melt. Attach velcro to the back of the battery holders.

Make sure you orient the whole thing such that the dark side faces away from the Sun when you velcro the assembly to the stakes.

An interesting effect was achieved by smearing a very thin layer of hot melt over the bulbs in a kind of crinkle pattern. This made the light appear somewhat diffuse, but also created brighter and dimmer areas that looked a bit more “natural,” except maybe for Venus, which in visible light rarely has much detail.

The back half of the ping-pong ball was painted black, and the “surface” features painted on the front, or you could draw them in with marker. See the prior section on using the penlights to see how to make Saturn’s rings.

Ping-Pong Ball Planet using Xmas lights details



LIGHTS WITH CLEAR SPHERES

This is the currently favored approach, though I only did this for Jupiter and Saturn to create larger size spheres to allow more detail to be shown. The main reason is cost, ping-pong balls are cheap (about $5/dozen), where as a single 2” sphere cost about $4. I was able to find them at an art supply store in the architectural materials section (Charrette, they have several stores in the Boston area. They also had the clear acrylic rod, paints, etc.). They are sold as hemispheres, and have a small nub in the middle that has to be filed off.

Holes for two bulbs were drilled in the back hemisphere, and then rubber washers attached to hold the light bulbs in place. A piece of foil was glued to the inside, and the outside painted black. (Pushing the sockets all the way in would be nicer as the wires could be hidden, but then the problem of replacing them comes into play.)

The front hemisphere was lightly sanded on the outside, then painted white on the inside to diffuse the light, and then the cloud design painted on the outside. Leave ‘gaps’ in the cloud to create a 3D effect (artistic license being applied to make up for lack of artistic ability to paint an accurate planet). I gave up trying to make the terminator look “fuzzy.”

Glue the two halves together (Elmers glue works well), and once dried mount the whole thing on a 5” piece of rod mounted to the battery holder, as described previously. **Make sure you orient the whole thing such that the dark side faces away from the Sun when you velcro the assembly to the stakes.**

The two bulbs get wired in parallel (they’re that way they are in the battery operated set, where as strings that run on 110VAC are wired in series). Attach velcro to the back of the battery holders.

For Saturn’s rings, a plastic CD jewel case cut into a circle was used, as it is the right size for a 2” planet size. The plastic won’t hold paint unless you sand if first. Using a dremmel tool with a variety of attachments, you can make rings that really don’t need paint. Don’t forget to paint the planet’s shadow on the rings.

THE UNLIT ONES

Use 5” pieces of the clear rod to mount ping-pong balls for Uranus, Neptune, and Pluto. Paint half of the ball black - since they’re not lit, the seam is not a problem. Attach a piece of velcro to the rod, align it such that the dark side of the planet faces away from the sun when the rod is stuck to the velcro on the stake.

Pluto is anyone’s guess for appearance, but if you picked Triton as your model, it would be as good as guess as any. Since Uranus, Neptune, and Pluto aren’t lit, and the model is intended for use at night, don’t kill yourself on them.

For an interesting effect, thin the paint and apply it to the ball. Then lightly roll the ball on a coarse piece of paper towel that has a dimple pattern to remove spots of paint. Repeat as needed over different areas of the ball with different colors. Tricks like this are a good way to make up for lack of artistic capability, which certainly applies to me.

ODD & ENDS

Bring spare batteries and bulbs, and a spare planet and stake if you really want to be prepared.

Set it up

If you have a tough time with spatial relationships, practice laying this out until you feel comfortable with the process. Absolute accuracy is not important.

Get a printout of the current planet position (see the sample on the next page).You'll want two, one for the inner planets and the other for the outer planets. The distances from the Sun to the planets, on a scale of 1cm = 1 million km (1 inch = 1.6 million miles, or 1AU = 4.84 feet), is as follows:

TABLE 1. Model distances, orbital periods

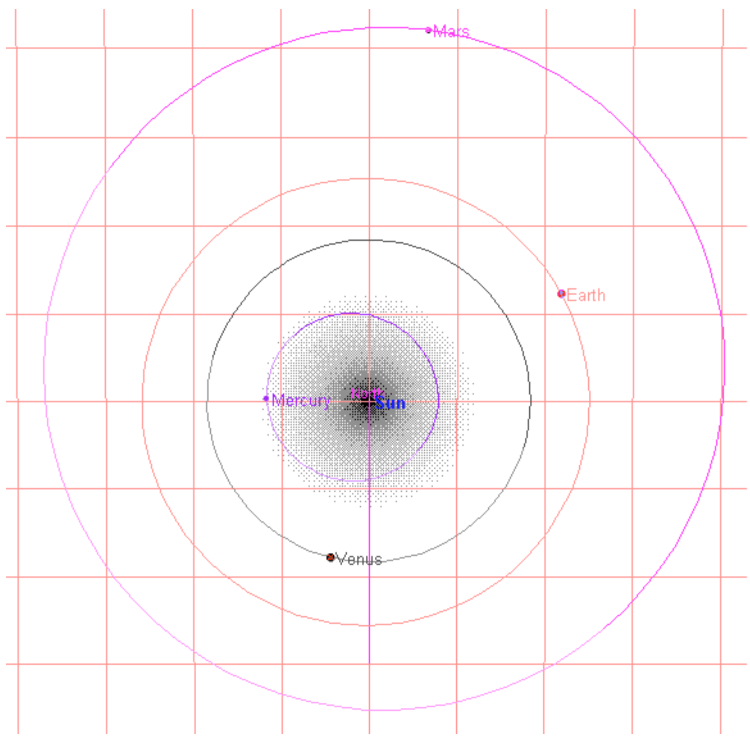
Planet	Dist from sun (10^6 km)	Dist from sun (10^6 mi)	Model dist. (feet)	orb. period (years)
Mercury	58	36	2	.24
Venus	108	68	3.5	.62
Earth	150	93	5	1
Mars	230	140	7.5	1.88
Jupiter	780	490	26	11.9
Saturn	1,400	890	47	29.5
Uranus	2,900	1,800	94	84
Neptune	4,500	2,800	148	165
Pluto	5,900	3,700	190	248

Start by placing the Sun stake into the middle of the area you'll be using. If Jupiter or Saturn are visible, pick one, and starting at the Sun, pace off the distance to it, walking in the direction of the planet's position in the sky. Actually, if you're setting this up and the star party will last for an hour or two, you should put the stake in about 15 degrees or so to the West of the planet's current position, that way the actual planet doesn't appear too far off from the stake as the night progresses. You now have a reference line to orient the rest of the planets with. This procedure also works if you can see the constellation that Uranus, Neptune, or Pluto is in. The small angular error incurred by starting at the Sun (instead of the Earth) when pacing out the distance is minor.

If Mars or Venus are the only ones visible, you will need to modify the procedure. Make your best guess about Earth' s position relative to the Sun (i.e., assuming it's early evening, place the Earth such that when you look to the West from the Earth stake, your Sun stake is about where the Sun set on the horizon. Then place the planet by walking out from the Earth stake, and then repace the distance walking out from the Sun. Reposition the Earth stake as needed to line things up after adjusting the planet position. Or, if you know about where the Sun went down, move the Earth 15 degrees clockwise around the Sun for every hour after Sun set.

Using your planet and the Sun as the reference points, lay out the other planets using the positions previously printed. The stakes should be oriented parallel to the Sun's surface. Once all the stakes are in place, and the positioning verified, attach the planets. Turn things on once the event starts.

FIGURE 1. Example Solar System map from chart software



OTHER OBJECTS

At the scale of the model, distances to some other objects:

Heliopause (boundary of the solar wind with the interstellar wind), using 150 AU as the average distance to the front (bow shock) side: 726 feet.

Alpha Centauri: 4.5 light years or 285,000 AU: 1.4 million feet, or 261 miles.

Center of the Milky Way: 27,700 light years (1.8 billion AU): 1.6 million miles (6.5 times the earth moon distance)

Andromeda Galaxy: 2.5 million light years (158 billion AU): 30 million miles. (about to the orbit of Venus)

The tour - Show Time!

Try to make sure star party attendees know about the model, and that tours will be given every 10-15 minutes to small (dozen to fifteen) groups of people. Encourage people to walk to the different planets on their own as well. Here are some things to do outside of the tour:

- If the area is dark enough to make planet locations non-obvious, give a small prize to the first student to find Pluto.
- Encourage “races” out to Pluto among groups of students.
- Students will ask “where’s planet so and so.” Make them go walk out to the stakes to find out.
- Ask them to go to Neptune, and stand so that they face away from the Sun (so it’s midnight), and what planets do they see?

There are all sorts of activities that can be done - see any of the papers about scale model solar systems for some suggestions. What you should try and do are things that take advantage of the spatial relationships of the model. Here are some ideas. It doesn’t hurt to know basic planetary facts - sizes, length of day, length of year type stuff. Throw them in as needed to drive home the concept that the universe is full of wonder and that *nowhere else are things “just like here on Earth.*”

GET THEM INVOLVED

While this has been written up as a bunch of facts, don’t just spout them off. Ask (almost) EVERYTHING as a question. I’ve had 6th graders who have just covered astronomy answer most of the questions!

EXPLAIN THE MODEL

Cover just the basics - that 1” = 1.6 million miles, that the Sun would be less than an inch in size, Jupiter a small dot, and the Earth a grain of sand at that scale. The distances between the planets ARE to scale. Earth is 93 million miles, or about 5 feet. Light takes 8 minutes to cover that distance (walking from the Sun to Earth at the scale of the model, you’re traveling 100 times the speed of light). North is ‘up’.

GET EVERYONE ORIENTED

Have everyone get near the Earth, and get one student volunteer to be the leader. Ask them to pretend their head is the Earth, and to stand such that it is noon on *“Mount Nose”* (see Activity 4 *“Earth, Moon and Stars” Teachers Guide*, Lawrence Hall of Science, Univ. CA Berkley if you’re not familiar with *Mount Nose*.)

Now ask the leader to make one Earth day go by (spin counter clockwise). Unvelcro the Earth, and ask them to make it be 3 months, then 6 months (where are they now?) and then 9 months later. (walk in an orbit, counterclockwise). They should spin as they walk, but since they just ate dinner, spinning 365 times is probably not a good idea.

Mercury would go around a little over 4 times, and Venus about 1.5 times during that Earth year.

GROUP EFFORT

Ask everybody to stand so that it’s noon (and close to the earth stake). Now ask them to stand so that it’s 6PM - where is the sun? (setting in the West, or right eye). Look out at the stakes - whatever planets are visible, they should see in the sky over the stakes. This is what you mean when you say everything is oriented in the correct position.

Now ask everyone to stand so it’s midnight (you may want to stand in front of the crowd). Where is the sun? What planets will never be visible at midnight? Ask the volunteer to walk in a circle around the sun at Venus’ orbit to drive the concept home.

Compare that to Mars (ask the volunteer to make a martian year go buy) or the outer planets.

Next make it 6AM (the kids just got to stay up all night). Where is the Sun rising? (in the East, their left eye). Point out any planets visible in the AM. If it was 6 months later, we would see different planets. We would see things differently if it was a few years later. *Try and dispel the "what planet is visible in what month of the year?" problem*.

The re-union tour

This next section contains more factoids that can be used to extend the tour. Give the audience a chance to ask questions, usually you can use that to lead into something else on the tour. Don't be bummed if some people wander off...

Maybe obvious, be don't try and do ALL of these things with each group you give a tour to. It's too much!

WHY GALILEO'S TELESCOPE HELPED PROVE PLANETS DON'T ORBIT THE EARTH

With everyone facing the sun, make Venus (or Mercury) orbit once, making sure you hold it such that the unlit side always faces away from the Sun. What does the planet appear like? (phases of the moon) But if it really went around the earth, all the phases are in the wrong place - the way it looks can only work if the planet goes around the Sun.

ODDITIES OF THE SOLAR SYSTEM

At some point people either ask or I work in some factoids about the planets. For example, after finishing the *Mount Nose*/Earth "day" exercise, ask the volunteer to demonstrate a day on Venus (they should rotate the opposite direction - clockwise). A Venusian (sidereal) day is 244.3 earth days long, a year (orbital period) is 224 days.

Ask the volunteer what Uranus would be like to demonstrate. I don't make the volunteer demonstrate, though if I'm pretty sure no dogs have been by, I'll roll a few times across the ground to demonstrate Uranus' odd rotation. Right now Uranus' south pole is pointing towards the sun, in 2007 the sun will be over the equator, in 2028 the north pole will be pointing at the sun (it's orbital period is 84 years, a day is 17 hours, 14 minutes).

Pluto also rotates on its side. Uranus is tipped about 98°, whereas Pluto is tipped 122° (Venus is 177°, basically 'upside' down, hence it's retrograde rotation description). Pluto's orbit is tipped 17° to the ecliptic (most people won't know what that is, but you can demonstrate). At the scale of the model, Pluto could be 30' up in the air! Pluto crossed over the orbit of Neptune on Jan 14, 1999, once again becoming the '9th' planet from the sun. Pluto's 247.7 year orbit is in a 3:2 resonance with Neptune's 164.8 year orbit, so they will never collide.

Speaking of resonances, Mercury's 88 day orbit is in a 3:2 resonance with its 58.6 (earth day) long day - this is from tidal effects from the Sun.

HISTORY

Uranus was discovered by William Herschel on March 13, 1781. It had actually been ‘discovered’ on at least 17 occasions before by astronomers - it took Herschel’s better telescope and observing technique to realize that it was a planet and not a star. It was the first case of ‘extending’ the size of the universe (solar system), and had a profound impact on the thinking of the time. At magnitude 5.9, it borders on naked eye visibility from a dark location.

Neptune was the first planet to have its position predicted, which once again was a “first” for the scientific method. Galileo gets credit for scientific method- instead of accepting a statement simply because someone says so, he devised experiments to test hypothesis. While he didn’t drop the rock and feather, he did prove that the mass of an object does not affect the rate at which it falls. Interestingly enough, Galileo observed Neptune in December 1612, and again in January 1613 while looking at Jupiter. However, he did not realize it was a planet - probably a good thing, as suggesting that there were more planets probably would have gotten him in more trouble.

It wasn’t until 234 years later in 1846, that Johann Gall actually spotted Neptune very close to its predicted position. Urbain Jean Leverrier (a Frenchman) had provided the calculation - though an Englishman, John Couch Adams, had also made the same prediction and published it at the same time, thus starting a debate about who should be considered the discoverer.

The motion tour

This last segment talks about motions. You can lead into by asking people how fast they think they’re moving right now. I’ve provided the numbers (rounded off) on a variety of scales. It can be fun to let people guess...

EARTH ROTATION

Assuming a latitude of 45°, and an equatorial radius of 6400 km, the motion is 835 km/hr (620 mi/hr). At the equator it’s 1670 km/hr (1000 mi/hr).

EARTH’S ORBIT AROUND THE SUN

The mean radius is 150 x 10^6 km, or 93 x 10^6 miles. This works out to be:

2.6 x 10^6 km/day (1.6 x 10^6 mi/day) or
110,000 km/hr (67,000 mi/hr) or
30 km/sec (19 mi/sec)

ORBIT AROUND THE CENTER OF THE GALAXY

Assuming the radius is 27,700 light years (8.5 kpc), and the orbital period is 240 million years (note: actually, the speed and radius are the known quantities, the orbital period is what is calculated).

7 billion km/year (4 billion miles/year) or
19 x 10^6 km/day (12 x 10^6 mi/day) or

800,000 km/hr (490,000 mi/hr) or
220 km/sec (135 mi/sec)

This motion is in the direction of Deneb (in Cygnus). There is also a relative motion to nearby stars (think of a merry-go-round horse bobbing up and down as it goes around) of about 20 km/sec (12 mi/sec) in the direction of the Lyra/Hercules border.

Try and indicate these directions in the sky (or pointing down into the ground if needed).

Pick a sentence that you say, and follow it with “we moved 1000 miles in the time it took me to say that” to help make the numbers seem real.

THE GALAXY RELATIVE TO THE COSMIC MICROWAVE BACKGROUND

There is also some motion with in the Local Group (the Milky Way and Andromeda galaxies are closing at about 20 mi/sec). That motion is swamped by the motion (of the Local Group) towards the “Great Attractor” at about 600 km/sec (375 mi/sec), which is in the general direction of Centaurus.

Other Suggestions

Others have made suggestions for even more things to do with this model. I’ve kept them separate so that I can give proper credit.

MITCHELL CHARITY

[Ed. note: Mitchell maintains the solar system model meta-page described earlier]

I wonder of “cold lights” might be of use. I've seen them sold inexpensively at 4th-of-July gatherings, both as stubby green tubes (say 1x10cm), often worn hanging from one's neck, and as long thin colored tubes (say 1/2 x 100cm) which can be curved into loops.

Aside from serving as markers, they make a person's night-time appearance much more dramatic, and add some festivity.

One might explain why a dim sun *must* be used. Else eyes hurt, grass toasted, etc. A camera flash might emphasize the point, at the expense of night vision. And this leads into an explanation of why the planets have been painted half-dark.

# # #