Skygazing

a mini-course designed by

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Table of Contents

Abstract

My goal with this mini-course is to teach the students the basics of the nearby sky through hands-on demonstrations and projects. I focus on topics they can directly observe like the phases of the Moon, why the sky is blue, and what causes the seasons. One lesson involves "building" a model of the solar system using volunteers to represent each planet and the sun. The students will get an idea of the vast distances in space by noting how far away from each other they are as well as an idea of how the planets differ by holding objects of differing sizes. Other lessons teach them the evolutionary process of a star's life and the difficulty of maneuvering a rover on Mars.

All of the activities attempt to emphasize participation from the entire class. Whenever possible I encouraged the students to describe any personal observations they had made on the topic. I also dedicated five minutes at the beginning of each lesson to asking the students what they remembered from my last visit. I was always impressed by how much they absorbed!

Course Description

Introduction

I presented this mini-course to Chris Bell's first graders and Mihal Elman's third graders at Fall Creek Elementary in Ithaca, New York. Both classes joined together for one 90-minute session each week. I attempted to always teach to the third-grade level and the first graders had no problem keeping up. When I began, the students had already been studying the planets in our solar system and understood the Earth's motion in space. If they had not already discussed the Earth's rotation, I definitely would have started with a session on what causes night and day. Older students can still learn from these lessons but would benefit from more specifics (i.e. doing some of the math required for calculating the relative size of each of the planets in the 'Structure of our Solar System' lesson or explaining how an electron moves within an atom to create energy levels in the 'Why the Sky is Blue' lesson).

Each session covered a new topic relating to the solar system, but since the material was all very closely related there were always opportunities to reference earlier lessons. (For example, when learning how stars are formed, the students remembered that Jupiter could have formed a star if it were 80 times bigger as discussed when we constructed our model solar system.) The sessions complement each other but are independent so the order can be switched and any single lesson can be left out.

I visited the classroom seven times and we took a trip to Fuertes Observatory on the Cornell University campus. Excluding the activity at the observatory, I aimed for each lesson to involve discussion as a group followed by splitting up into smaller groups for a more hands-on activity. When there was enough time we reconvened as a group to go over what everyone had learned. The only lesson that did not involve separating into groups was the 'Reasons for the Seasons' lesson which also turned out to be the least effective.

Mini-Course Goals

The goal of the mini-course was to give the students an understanding of the workings of the solar system. The students learned about the formation, make-up, and placement of the planets, what causes the seasons and the phases of the Moon, current exploration missions on Mars, famous astronauts and how they live in space, and how stars are born and eventually die. By the end of the mini-course they had constructed a to-scale model of our solar system, visualized using props the Earthly and lunar motions giving rise to the seasons and the phases of the Moon, navigated a student Rover through a maze, written a postcard home describing their favorite place on Mars, and partaken in an astronaut meal.

General Suggestions

Having two classes (a total of 37 students) was definitely a challenge. Most activities would have benefited from a smaller number of students and some (as noted in the Procedures sections) activities required splitting up into two groups. The issues included not having enough time to answer everyone's questions and not finding a set up where everyone could get a good view. Although we were able to make it work, I would strongly suggest performing these activities with less than 20 students.

Given more visiting opportunities, I would have liked to cover additional topics like constellations, the Aurora, solar and lunar eclipses, extrasolar planets, comets, sunspots, and causes of weather.

Of course, I could not have done anything without the help and support of Chris and Mihal. Their presence and participation was invaluable since I had no experience at all with keeping the attention of 37 students under the age of eight for over an hour. I now know that a quick five-minute game of 'Simon Says' can recapture the attention of a fidgety audience. Their enthusiasm was contagious, and they were able to draw parallels between the ideas I brought up and topics the students had learned in class. I also appreciate the freedom they gave me to decide how I taught the topics we chose.

Graduate Student Biography

Whenever people ask me where I come from, I never know what to tell them. As you can imagine, my predicament is quite frustrating because the question comes up not only often, but also usually in casual encounters where pouring out your life story as an answer is highly inappropriate. These days I say I am from upstate New York since that is where I currently reside just off the Cornell University campus. Cornell's impressive astronomy department brought me here, and I am working to earn my doctorate by researching the dynamics of large galaxies beyond our Milky Way. My work takes me two or three times a year to a large radio telescope in the middle of the Puerto Rican jungle. I am happy in the small town of Ithaca for now, but even with the trusty companionship of my adoring bulldog Bella, I don't think I will survive many more of these icy cold winters.

Often home is where you were born which for me would be the bustling city of Indianapolis, but I lived there only for the first eighteen months of my life. I have played countless games of Go Fish, gorged myself on cupcakes for breakfast, and built lop-sided snowmen here, but these memories are of visits to see my sister and her three darling tykes and not of my own childhood.

I've spent most of my 24 years in the town of Norwalk, Connecticut with my mom and little brother so perhaps I should call home the place that plays backdrop to most of my memories. In Connecticut I experienced many of those important firsts: my first game-winning soccer goal, my first date, my first conversation with my little brother during which I realized he was not the enemy. My trips to visit for the holidays should feel like homecomings, but life has moved on without me there. My room has been filled with furniture I don't recognize and the dog that greets me at the door is not the one I remember from my childhood. The company of my mom and my brother makes me feel cozy and content but by those standards I could call anyplace "home" as long as they were there.

While I have fond connections with all of the places I have mentioned so far, none of them feel like home quite like the unique and almost indescribable city of Berkeley where I spent my undergraduate years at the University of California. For me this urban mix of strong ideals and utmost acceptance of all things weird is home. I met fascinating people everyday including a professor who had discovered 80% of the known planets outside of our solar system and a second grader who asked me why cornstarch felt so funny (by the way, Albert Einstein wrote an entire paper on the strange properties of cornstarch). I had been intrigued by physics and math before, but at Berkeley I first realized not only my love for astronomy but also my desire to share what I learned with others.

I think you should call home wherever it is you feel you belong and most likely this will be the place that speaks the most of who you are. While finding a home may take some time, I'd imagine, if you're lucky, you'll have more than one.

Session 1: Structure of Our Solar System

Learning Outcomes

Upon completion of this session, students will:

- Understand the relative sizes of the planets and the Sun.
- Understand the relative distances between the planets and the Sun.
- Learn a few key interesting facts about each planet.
- Have created their own mnemonic device for remembering the order of the planets.

Duration

Twenty-five minutes for introducing myself and for discussion followed by thirty-five minutes for building our model worked well. The students had lots of questions so I answered as many as possible for five minutes at the end of the session.

Activities

I introduced myself as this was my first trip to the classroom and explained briefly what astronomy is. After giving an example of a mnemonic device for remembering the order of the planets, the students came up with several of their own. We then constructed a (somewhat) to-scale model of the solar system using students to represent each planet. Each volunteer held both an object of a specific size to represent the planet's size relative to the others and a prop to help them remember one specific fact about the planet. As each "planet" was added to the model we went over some interesting facts.

Materials

- Round objects to represent planets: I used a stability (exercise) ball to represent Jupiter and scaled the rest of the planets' sizes to that. The objects I used are listed in an appendix but the scale can be changed. I would not recommend going any smaller, however, because at the scale I used Pluto was the size of a jellybean.

- Props for each planet: The props I used are listed below in the Background Information section but anything can be used to represent a fact you want the students to remember.
- A ruler: A ruler is needed to measure the spacing between each planet.

Background Information

The students had been studying the planets so they already knew a lot. However, since they had been broken into groups to study one planet per group, most knew only about their assigned planet. Thus I began this lesson assuming they already knew the basics of the solar system. More background information would probably be necessary for students who hadn't studied the solar system yet (i.e. the idea of the planets orbiting the Sun while rotating, what causes night and day, or how our solar system is a smaller part of our galaxy).

As we added each new planet to our model, I discussed some interesting facts about each planet (and the Sun) some of which are listed below. A great website for information on our solar system is http://nineplanets.org.

The Sun

The Sun is 5 billion years old and is a normal star (one of 100 billion in our galaxy). The Sun contains more than 99.8% of the mass in our solar system. The temperature at the core of the Sun is about 16 million degrees. The prop for the Sun was a light bulb since the Sun produces light.

Mercury

Mercury has no atmosphere so the nights are very cold (our atmosphere is like our blanket). On Mercury a day is longer than a year and you weigh less than you would on Earth. We don't know too much about this planet because we can't send spacecraft there (it gets cooked!). Mercury's prop was a pair of sunglasses because it is the closest planet to the Sun.

Venus

Venus rotates very slowly (there are about 243 Earth days in one Venus day). Venus is the third brightest object in the sky (after the Sun and the Moon) and is very hot because there are very thick clouds in the atmosphere (a runaway greenhouse effect). Venus' prop was a blanket to represent the thick clouds.

Earth

I asked the students what makes the Earth different from all of the other planets (us!). Twelve people have been to the Moon (the farthest humanity has ever traveled). The Earth's orbital period is 365 days and its rotational period is 24 hours. The temperature at the core of the Earth is hotter than the surface of the Sun. 71% of Earth's surface is covered with water. The prop for the Earth was a bottle of water because Earth is the only planet where liquid water can exist.

Mars

There is evidence of liquid water having existed on Mars in the past (erosion). Mars has a very thin atmosphere so the days are too hot and the nights are too cold for life. Mars is covered with craters and we have discovered meteorites on Earth that came from Mars. Spirit and Opportunity (the two Mars Rovers) were expected to last 2-3 months on Mars but have so far lasted 2 years and 2 months. The prop for Mars was a chair for the student to stand on because Mars has the highest mountain in the solar system (Olympus Mons).

Jupiter

Jupiter has no ground (just atmosphere) and has 63 known moons. Jupiter's size traps asteroids so they don't hit Earth which may be a big reason why we are here. Jupiter is the fourth brightest object in the sky and is more than twice as massive than all the other planets combined (Jupiter is 318 times the mass of the Earth. The prop for Jupiter was a flashlight with no batteries because if the planet were eighty times bigger it would have formed a star. (Planets and stars are formed the same way – from a collapsing gas cloud. If the cloud does not have enough mass, fusion cannot occur and the cloud will not become a star.)

Saturn

Saturn is the second largest planet and is the least dense (it is less dense than water!). Its rings are made up of rocks and dust (mostly water ice). The Cassini mission is currently studying Saturn and one of its moons, Titan. The prop for Saturn was a hula hoop to represent the planet's large rings.

Uranus

Uranus is tipped on its side (it's spin axis is nearly parallel to the ecliptic) most likely due to a collision in the planet's past. Uranus also has rings and was almost named George after King George III of England. (William Herschel, the discoverer of the planet, was British.) The prop for Uranus was a pillow so the student could lie on his/her side to represent the fact that Uranus is tipped.

Neptune

Neptune's orbit sometimes crosses Pluto's so that Neptune is the farthest planet from the Sun. Neptune's existence was predicted due to the movement of Uranus and is named after the God of the sea because it is blue. Neptune had a huge dark spot that suddenly disappeared for unknown reasons. The prop for Neptune was bangle bracelets since Neptune has rings also.

Pluto

Pluto has one moon (Charon) and seven moons in the solar system are larger than Pluto. Pluto is the only planet that hasn't been visited by spacecraft (although that will change with the New Horizons program). We don't really have a good idea of how large Pluto is. The prop for Pluto was a hat and scarf because it is (usually) the farthest planet from the Sun.

Procedures

1. Give the students a chance to share some of the information they know about the planets. Prompt them with questions if they don't come up with suggestions of their own.
2. Ask the students to list the planets in order of increasing distance from the Sun. Write the correct order on the board (Sun, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto) and give the students a mnemonic device for remembering their order (My Very Excellent Mother Just Sliced Us Nine Pizzas). Give the students a few minutes to discuss with a buddy, come up with their own version, and then share with the group.
3. Ask for volunteers to represent the Sun and each planet. Add planets one by one to the "model" discussing interesting facts about each planet as you go.

(The facts are listed above in the Background Information section.) Each volunteer should have a sphere to hold suggesting the size of the planet they are representing and a prop to help the students remember one fact about that planet. You can either measure out distances to each planet as you go or have the locations marked ahead of time with tape on the floor.

Suggestions

The props really helped the students hold on to at least one fact about each planet. When I asked the students on my next visit what they remembered from this lesson, most of what they came up with were facts based on the props.

The lesson could be made a little more challenging by going over the idea of ratios and showing some of the math that I used to determine the relative sizes of the planets to each other. Please note: the distances between each planet were to scale and the sizes of the planets were to scale but the two were not measured to the same scale. If I did everything to the same scale, either all of the planets would be too small to see or we would have to send the Pluto student to the next town!

I had planned to use a student as our ruler to measure out the distance to the next planet being added to the model. I thought we could measure the student's height and have him or her lie down to determine distances. We decided this might be too chaotic and awkward so we marked the distances using a ruler and tape before the class started.

All of the students were really eager to volunteer and it was hard to choose just one when all forty hands shot up. Luckily the teachers had popsicle sticks with all of their names so we could draw names from a jar.

Session 2: Reasons for the Seasons

Learning Outcomes

Upon completion of this session, students will:

- Understand the combined motions of the Earth and Sun that cause the seasons.
- Correct the common misconception that seasons are caused by differing distances between the Sun and the Earth at different times of the year.
- Learn that the north pole of the Earth always points towards the star Polaris.

Duration

The demonstration only took 20 minutes to set up and then discuss. I stretched out the lesson by allowing the students to ask questions about any astronomy topic after they had bored of the seasons discussion. However, the students got really antsy after 30 minutes of sitting and listening to me talk.

Activities

Demonstrate the reasons for the seasons by setting up an Earth-Sun system with a lamp and a globe. Investigate how much sunlight hits the Earth at different positions in its orbit around the Sun.

Materials

- Aluminum foil or something shiny to represent a star.
- A globe.
- Rope or string to mark the Earth's orbit.
- A lamp to represent the Sun.
- 4 pieces of paper with "December", "March", "June", and "September" written on them.

Background Information

There is a general misconception that the seasons are caused by the fact that the Earth is sometimes closer or farther from the Sun. Many people believe that in the winter we are farther from the Sun and in the summer we are closer. This is simply not true! The Earth's orbit is not a perfect circle, but the change in temperature due to differing Earth-Sun distances is too small to cause seasons of any kind. The seasons are a consequence of the Earth's tilt. The Earth orbits the Sun in a plane and rotates about its own axis while orbiting. The Earth's axis of rotation is not perpendicular to its orbital plane (called the ecliptic) and is instead tilted from the vertical by 23.5 degrees. During the summer in the northern hemisphere the northern half of the Earth is tilted toward the Sun so the sunlight is more direct. The days are also longer so the Sun has more time to warm the ground. During the winter in the northern hemisphere the northern half of the Earth is tilted away from the Sun so the sunlight is less direct. The days are also shorter so the Sun has less time to warm the ground.

Procedures

1. Set up the lamp in the middle of the room and tell the students it represents the Sun. Mark out the Earth's orbit around the lamp using rope or string (I used a hula hoop).
2. Ask a volunteer to crumble up the aluminum foil and tape it high on a far wall. Tell them this will represent Polaris and that the Earth's north pole always points towards this star.
3. Hold the globe with the north pole facing Polaris and stand along the rope tracing out the Earth's orbit. Keep the pole facing Polaris as you walk around in the orbit in a counter clockwise direction.
4. Put a sticker on your location and a location in the opposite hemisphere to use as examples when discussing what parts of the globe are undergoing what seasons at different positions in the orbit.
5. Ask the students where the globe should have to go to have the north pole pointing towards Polaris AND the southern hemisphere pointing towards the Sun. Label that December.
6. Ask the students where the globe should have to go to have the north pole pointing towards Polaris AND the northern hemisphere pointing towards the Sun. Label that June.

7. Ask the students where the March and September labels should go. (Looking towards Polaris, March is on the left and September is on the right.
8. Explain how during the summer sunlight is more direct and the Sun has longer to warm the ground. (I used the examples of sitting by a fire and cooking in a microwave. If you want to get warmed by a fire, you would stand in front of it rather than lie down with your feet pointing toward it so that more of your body gets direct heat. If you want to warm your food, you cook it longer to make it hotter.
9. Ask the students what would happen if the Earth were not tilted (answer: we wouldn't have seasons, days would be 12 hours and nights would be 12 hours).

Suggestions

This session was the least effective of all the lessons. There were few opportunities for students to volunteer and too much of the lesson lacked hands-on activity. I wanted to bring in a heat lamp so that I could stand it up right and then tilt it to show them the difference in heat reaching their hands, but the heat lamp made a terrible noise when tilted (perhaps it's a safety mechanism!). The difference in temperature from a tilted versus non-tilted light bulb was too subtle for them to notice.

I originally had one of the students hold the globe and carry it around in its orbit, but the task was too awkward for the student. Keeping the north pole pointed in the right direction and walking slowly around the hula hoop proved to be too confusing. I asked one of the teachers to do it while I explained what was happening.

Session 3: Mars Rovers

Learning Outcomes

Upon completion of this session, students will:

- Recognize some points of interest on Mars.
- Learn the latest discoveries made by the two Rovers on Mars (Spirit and Opportunity).
- Understand some of the specifics involved in getting a Rover to the planet Mars.
- Understand the difficulties in communicating with the Rovers and the importance of being clear with directions.

Duration

I gave a fifteen-minute presentation during which I only allowed a few questions. Then we split into two groups (one for drawing postcards and one for playing the maze game) and gave the students twenty minutes to do each activity. This time frame was quite rushed and ten extra minutes for each activity would have been very helpful.

Activities

I gave a presentation explaining the basics of Mars and the Rovers. First I showed an animation of a Rover launching and then landing on Mars. I acquired the video from Diane Bollen who is in charge of Mars outreach here at Cornell. I then showed a quick slide show of ten or so points of interest on Mars. Then we split into two groups. While one group colored blank postcards, the other group pretended to be NASA scientists directing a student Rover through a maze of desks and chairs.

Materials

- Rover launch and descent animation video.
- Slide show of ten or so points of interest on Mars and information on the latest findings from Spirit and Opportunity.
- Blank postcards (one for each student) and markers or crayons.

- A blindfold.
- A chalkboard or white board for writing out instructions.

Background Information

The goal of this lesson was to teach the students about some of the recent information discovered by the two Rovers on Mars. We watched an animation of a Rover launch and landing. I explained the events as they took place in the video. Soon after launch the rockets are ejected because once their fuel is used up they are no longer needed. The shuttle containing the Rover is forced to spin at first because spinning objects are easier to point at a specific target. Once the Rover approaches Mars, a cord is ejected to carry this angular momentum away and stop the spinning. As the Rover travels through the Martian atmosphere a heat shield is necessary but is then no longer important after the Rover is slowed by a parachute. Safety balloons are also inflated all around the Rover's pod to keep it safe during its series of bounces once hitting the surface. The Rover is able to tell whether or not it is upside down once landing and the pod turns over before opening like a flower to reveal the Rover. Lots of tests were done to practice the Rover's decent from out of its pod because crashing at that point would be a shame! Two of the most important tools on the Rover are the panoramic camera on top (the camera is the eyes of the Rover) and the RAT (Rock Abrasion Tool) which drills into rocks to determine what they are made of.

I also showed photographs of some points of interest to give the students a larger picture of the planet. The pictures included a shot of what most of the landscape consists of (a dry, windblown red desert), Vastitas Borealis (a large crater near the north polar cap with ice inside), the northern and souther poles, the Happy Face and Lowell craters, the Face on Mars, Olympus Mons (the highest mountain in the solar system), Vallis Marineris or Mariner Valley (the "Grand Canyon of Mars" which stretches as long as the United States), a place where lots of hematite was found (evidence that water once existed on Mars in liquid form), blueberries (smooth and spherical rocks found all over Mars containing hematite), a shot of the pod from which Opportunity emerged (taken by Opportunity of course), the two moons Phobos and Deimos, and a shot of the Earth as seen from Mars. Most of the pictures came from the NASA website on Mars (http://mars.jpl.nasa.gov). Pictures of large areas (like the poles or Olympus Mons) came from the Mars Global Surveyor a satellite in orbit around Mars, and close up pictures (like the blueberries or locations of hematite) came from the Mars Exploration Rovers.

Procedures

1. Explain briefly what the Rovers are and what they have learned about Mars so far. (They have found evidence that water must have existed on Mars in liquid form in the past. That evidence is a mineral called hematite that is formed when liquid water is present.) Emphasize things the students will see in the video.
2. Show the animation of a Rover launch and landing. Explain key moments.
3. Show a slide show of cool Mars pictures. Make the last slide a collage of many different photos and leave that slide up so they can view it during the next part of the activity.
4. Divide the students into two groups. (If you have less than twenty students, one group would be okay.) Bring one group to a different room.
5. Each student in the group that stays in the original room with the slide show should receive a blank postcard. Tell them to pretend they are a Rover writing home to their family and friends about their favorite place on Mars. They are free to draw, color, and write as they wish. They can use the final powerpoint slide for reference.
6. The other group of students will construct a Rover maze and lead a student Rover through it. Ask for a volunteer to be the Rover and send him or her out of the room so they cannot hear or see. (Giving them a book to read keeps them out of trouble!)
7. With the remaining students, construct a maze of desks and chairs. Tell the students they have a certain number of commands (5 or so, depending on the size of the maze) to get their Rover through the maze to an agreed upon destination (we called our final destination "the carpet of dreams"). Explain that they can only say backward/forward/left/right and a number of steps (specifying full steps or half steps is okay too). Write down the commands

they decide on. The best way to do this is to have someone (not blindfolded) be directed through the maze.

8. Call the student Rover back in and blindfold him or her. One at a time have a representative from the group read the instructions aloud. The reader should not be looking at the Rover so he or she cannot adapt his or her instructions to what the Rover is doing.
9. Count how many times the Rover bumps into something. Most likely the practice student Rover and the blindfolded student Rover will have different sized steps and so the directions won't work for the blindfolded Rover.
10. Explain to the students the difficulties involved with having to send commands to the Rovers with a time delay. An issue that came up with one of the Rovers was that the scientists wanted it to go forward for 100 steps or so. The command was sent, but one of the wheels got stuck at around step 15 so the Rover kept turning and turning its wheels in the same spot until one wheel was almost completely buried. It took days of maneuvering to free the wheel! Emphasize that controlling the Rovers is much harder than a simple remote control.

Suggestions

The Rover maze can be as competitive or as noncompetitive as you want it to be. We could have kept score of how many times the Rovers bumped into things and whether or not they reached their final destination. If we had more time, running through the Rover maze with a second student Rover would have been helpful.

While one teacher helped me with the Rover maze, the other stayed with the students coloring their postcards. He collected questions the students had about the presentation and the Rovers in general so that I could answer them when we reconvened as a group.

Session 4: Moon Phases

Learning Outcomes

Upon completion of this session, students will:

- Know what causes the phases of the Moon.
- Correct the misconception that the phases of the Moon are caused by the Moon being in the shadow of the Earth.
- Understand the progression between different Moon phases and the process of waxing and waning.
- Know what the Moon looked like on their birthday and what day of the current month will have a similar looking Moon.

Duration

We had ten minutes of introductory discussion before we split into two groups. Twenty minutes for each group to perform the moon phases activity worked well, but then we ran out of time for the birthday moon activity. An extra ten minutes for the birthday moons would have been enough.

Activities

We discussed first what the students already knew about the Moon and I explained in very general terms that the phases were caused by the relative positions of the Earth, Moon and Sun. I hung up a poster of the current month with the picture of what the Moon would look like on each day to aid the discussion. We then split into two groups. One group was read a story while the other participated in a moon phases activity which involved using a lamp and Styrofoam balls in a dark room to visualize the phases of the Moon.

Materials

- Large poster of the current month with a picture of the Moon on each day. (You can get this from www.stardate.org/nightsky/moon)
- One moon phases worksheet per student (as described below, plus markers).

- One 3-4 inch Styrofoam ball on a stick (like the long toothpicks used for making shish kabobs) for each student.
- A bright lamp.
- A laminated card for each student with their name and a picture of what the Moon looked like on their birthday. (You can get a picture of the Moon on any day since 1990 until 2020 from the following website: http://liftoff.msfc.nasa.gov/academy/universe/MOON.HTML)

Background Information

Moon Phases

New Moon (The Moon is between the Sun and the Earth, so we only see the side of the Moon that is shadowed. Thus from Earth the Moon seems to disappear.)

Waxing Crescent (The Moon rotates from being a New moon toward 1st quarter and looks like a backwards "C".)

First Quarter (The right half of the side of the Moon facing the Earth is lit.)

Waxing Gibbous (The Moon rotates from being in 1st quarter to a Full Moon.)

Full Moon (The Earth is between the Moon and the Sun, so we see one side of the Moon being entirely lit.)

Waning Gibbous (The Moon rotates from being a Full Moon toward last quarter.)

Last Quarter (The left half of the side of the Moon facing the Earth is lit.)

Waning Crescent (The Moon rotates from being in last quarter to being a New Moon and looks like a "C".)

Solar and Lunar Eclipses

Solar eclipses can only occur during a New Moon. The Moon is between the Sun and the Earth during a New Moon but the three bodies are not always lined up (i.e. the Moon is higher in the sky than the Sun). Occasionally the Earth, Moon, and Sun do align so that the Sun's light is blocked by the Moon passing directly in front of the Sun, and this is called a solar eclipse.

Lunar eclipses can only occur during a Full Moon. The Earth is between the Moon and the Sun during a Full Moon but again the three bodies are not always lined up. When the

Earth, Moon, and Sun are aligned, the Sun's light is blocked from reaching the Moon by the Earth's passing between them, and this is called a lunar eclipse.

Information for Worksheet

New Moon (Students hold balls in front of their faces between themselves and the lamp.)

First Quarter (Students hold balls over the shoulder of the person to their left so their right shoulders face the lamp.)

Full Moon (Students hold balls high above their heads opposite the lamp so their backs face the lamp.)

Last Quarter (Students hold balls over the shoulder of the person to their right so their left shoulders face the lamp.)

Procedures

1. Ask the students what they know about the Moon and to give examples of what the Moon looks like (i.e. a banana, a ball).
2. Hang up a poster of the current month with pictures of what the Moon will look like each night. Point out that the changes in the Moon are not random but a progression from waxing to waning and back again.
3. Explain that the Moon shines by reflecting sunlight and looks different to us here on Earth depending on how much of the Moon's surface is being lit up. Mention the names of the main phases of the Moon and point out when solar and lunar eclipses occur.
4. Break the students up into groups small enough to sit comfortably around a lamp with enough room to draw.
5. While the others read a story (perhaps a book on space or even the Moon!), ask the students participating in the activity to sit around a lamp in a dark room. (Low light is ideal so that the students can see shadows but still have enough light to draw by.)
6. Give each student a Moon Phase worksheet and a Styrofoam ball on a stick.
7. Explain that the lamp represents the Sun, the ball represents the Moon, and their head represents the Earth. Mention that their nose could be the town where their school is located.

8. Ask the students to hold the Styrofoam ball first directly between themselves and the lamp, then over the shoulder of the person to their left, next opposite the lamp, and finally over the shoulder of the person to their right.
9. In each of the four positions, explain what the phase of the Moon is called and what the students should be seeing. Allow time for the students to draw what they see on their worksheets (they can either color in the part of the Moon that is illuminated or the part that is shaded). Encourage them to watch the shadows grow and shrink as they move the ball slowly from one position to the next.
10. Once everyone has completed the moon phases activity, bring the groups together to discuss what they saw. Ask for volunteers to describe what the different phases looked like and to point them out on the large Moon calendar.
11. Pass out the laminated card with each student's name and a picture of what the Moon looked like on his or her birthday. Give each student a chance to match the picture on their card with a picture on the calendar to determine what day of the current month will have a moon most like their birthday moon.

Suggestions

If given more time, I would have done a demonstration with a student before beginning the activity. Ask a volunteer to stand near the lamp in a dark room and point out how all, some, or none of his or her face can be illuminated as he or she walks around the lamp. Repeat a couple of times so that everyone gets a chance to see.

When the students place themselves between the ball and the lamp, make sure they hold the ball high enough so that their heads don't block the light from the Sun. The Earth, Moon, and Sun do sometimes line up so that the Moon's light is blocked (a lunar eclipse) but normally the Moon is fully illuminated here in the full moon phase.

The light in the room and having enough room to move the balls around are key so putting some effort into making sure the set up works is worthwhile. The Birthday Moons exercise is a good addition to the main activity, but can be essential if the classroom set up does not work well enough for the students to see the proper illumination patters on their balls. We performed the activity near a large window with the shades drawn and only spots close to the window made viewing difficult so that is where I sat.

If there are enough instructors and the room was large enough, instead of breaking up into groups and allowing only one group to perform the activity at a time, each group could gather around different lamps in the same darkened room and perform the activity at once.

Session 5: Astronauts and Life in Space

Learning Outcomes

Upon completion of this session, students will:

- Have learned about famous astronauts and benchmarks in the space travel program.
- Will understand how astronauts eat, sleep, exercise, play instruments, go to the bathroom, bathe, and dress in space.
- Will have had their own space meal snack.

Duration

We spent forty-five minutes working through my powerpoint presentation on famous astronauts and life in space. The students had lots of questions and comments to share as usual and since we were not pressed for time I allowed them. Then we had fifteen minutes for a snack at the end.

Activities

I put together a powerpoint presentation (about 30 slides) featuring famous astronauts and pictures of astronauts at work in space. We discussed the accomplishments of the famous astronauts and how they do normal everyday activities in space. We concluded with the types of food astronauts eat and had our own space meal.

Materials

- Powerpoint presentation: More details are in the Background Information section.
- Tortillas (one for each student)
- Fruit roll-ups (or some kind of dried fruit)
- Tang (enough for everyone to have a glass)

Background Information

Most of this lesson consisted of a presentation and answering questions the students had about living in space. In the first half of the presentation I showed pictures of famous astronauts and mentioned some of their accomplishments. I began by asking the class who was the first living creature to orbit the Earth in space (answer: Laika a Russian dog who showed that a living being could survive being launched into orbit in 1957). The astronauts/cosmonauts I mentioned were: Yuri Gagarin (first person to go into space and orbit the Earth in 1961, called a cosmonaut because he's Russian), John Glenn (first American to orbit the Earth in 1962, also became the oldest person to ever go into space when he was 77 during a space flight in 1998), Valentina Tereshkova (first woman in space in 1963, and also the first civilian in space), Neil Armstrong (first person on Moon in July 1969, total time in space: 8 days, 14 hours and 10 minutes), Buzz Aldrin (second person to walk on Moon – he was right behind Neil Armstrong on the Apollo 11 mission, was also a jet fighter pilot in the US Airforce), Guy Bluford (first African-American in space on the Challenger Mission in 1983, total time in space: 28 days, 16 hours, and 33 minutes), Sally Ride (first American woman in space in 1983, writes childrens books on space travel, the Moon, and Mars), Mae Jemison (first African-American woman in space in 1992, attended Cornell Medical School), Sergei Krikalev (cosmonaut, has spent the longest time in space: 803 days, 9 hours and 39 minutes – that's over 2 years!), and Dennis Tito (the first paying space "tourist", paid for his own ticket to space and spent 7 days, 22 hours and 4 minutes there in 2001).

The remainder of my presentation showed pictures of astronauts in space and we discussed how they are able to do things that we consider ordinary here on Earth but that are made difficult by the lack of gravity.

How do they breathe?

Ask the students what we breathe in (oxygen) and what we exhale (carbon dioxide). Astronauts get oxygen to breathe by mechanically splitting water into hydrogen and oxygen (what plants usually do here on Earth during photosynthesis). The water is recycled from moisture collected in the air from their sweat and exhalations. Carbon dioxide is also filtered out.

How do they sleep?

Ask the students what would happen if they were to lie down in their bed with no gravity. Astronauts need to be tied down while they sleep so that they don't float around and bump into things.

How do they exercise?

Astronauts need to exercise at least 2.5 hours a day because they don't use their muscles like we do by simply walking and raising our arms due to the lack of gravity. They also need to be strapped down if they are going to use a treadmill.

How do they talk to their families?

Astronauts can send voice recordings or e-mails to a satellite which then conveys the information to Kennedy Space Center. The scientists there then distribute the messages to their families.

How do they hear sound?

Explain to the students that sound needs air to travel and that when you make sounds with your mouth, those sounds make the air between your mouth and their ears vibrate. In space since there is no air, sounds cannot be heard. However, there is air inside the shuttle so they can hear sounds inside the shuttle (I showed pictures of astronauts playing instruments).

How do they go to the bathroom?

Ask the students what would happen if they sat down or stood in front of the toilet with no gravity. Astronauts need leg restraints to keep them from floating away while going to the bathroom. They also use toilets that have strong suction to keep waste from floating away.

How do they bathe?

Astronauts use sponges to soap themselves up and then to rinse off in plastic cylinders resembling showers. They then have to wipe down the walls of the cylinder to collect the water that has floated away.

How do they do laundry?

On the shuttle an astronaut will have a change of clothes for each day, but in the Space Station they change their clothes once every 10 days. Once they are finished with an outfit, they put it in with the trash which then gets sent back to Earth (these trash shuttles called Progress burn up in the Earth's atmosphere). Astronauts have special launch suits (which are always orange) that contain air tanks and other instruments to help them if something goes wrong during launch. They also have EVA (extravehicular activity) suits that are white and are worn when doing work outside of the shuttle. These suits have communication equipment inside as well as diapers (since they can spend up to 8 hours outside of the shuttle). One regular days, astronauts just wear their normal clothes.

How do they eat?

Astronauts have to be careful about what they eat in space. Ask the students why hot food might be dangerous (a hot particle could float away and burn someone). Ask the students why bread might be dangerous (crumbs can get in someone's eye or throat or in the machinery). So astronauts eat tortillas instead of bread. Explain that most of the food is dehydrated. Some does not need to be rehydrated (like dried fruit or jerky). Food that is rehydrated is usually done so by using a water gun to shoot water into a plastic bag containing the food.

For a list of all of the people who have been in space see: http://en.wikipedia.org/wiki/List_of_astronauts_by_name. For information on living in space, NASA has a great site: http://spaceflight.nasa.gov/living/index.html.

Procedures

1. Give the powerpoint presentation or slide show. Answer questions as they come up.
2. Distribute tortillas and fruit roll-ups. Let the students watch you mix the Tang so they understand it starts as a powder. Pass out the Tang.

Suggestions

To save time we did not put the Tang into individual plastic bags and add water. We just mixed it in a large bowl and poured each student a cup.

Having each student return to their desk to eat their snack helped with the chaos factor!

I originally had planned making "dehydrated ice cream" (the kind that starts as a powder and you add milk). The stuff I found had to be frozen before serving and was not very tasty so I left this part out of the meal. I did have a hunk of real dehydrated ice cream (the kind you get from science museum gift shops) and we broke off little pieces for the students to try. If I had more time I would have looked into a way of making ice cream (even if it wasn't frozen). The students were very happy with the rest of the food though.

Session 6: Blue Sky

Learning Outcomes

Upon completion of this session, students will:

- Understand there are different forms of light (i.e. ultraviolet, infrared, optical)
- Have viewed spectra of 4 different elements through handheld grisms
- Have acted out the role the Earth's atmosphere plays in transmitting sunlight
- Be able to explain why the sky is blue and why sunsets are red

Duration

First we spent ten minutes on an introductory discussion. Since the classroom did not get dark enough to view the element gas tubes, we then took four to five students at a time into the coat closet (where it was dark). Each group spent around five minutes viewing the gas tubes through the grisms so forty-five minutes were needed to give everyone a turn. After splitting up, we regrouped for more discussion for an additional ten minutes. We did not have time for a final activity (as mentioned in the Suggestions section below).

Activities

As a group we discussed the different kinds of light that make up the electromagnetic spectrum and the idea that each object has its own spectrum. I also explained what they would be looking at before viewing the gas tubes through the handheld grisms. Each gas tube contained a different element and each element has its own unique spectrum. After everyone had a turn to view the gas tubes, we discussed as a group what they had seen. We then acted out the path of a sun's light ray through the Earth's atmosphere to understand why the sky appears blue during the day and red at sunset.

Materials

- Handheld grisms (one for each student)
- Three or four gas tubes each containing a different element (see Suggestions section for advice on how to locate these)

- A poster of the electromagnetic spectrum (instructive but not necessary)

Background Information

Light is both a particle and a wave (an concept which is fittingly called the "particle-wave duality") and in this lesson we focus on the wave nature of light. The wavelength of the light wave determines what kind of light you have. The entire range of wavelengths is called the electromagnetic spectrum and is broken up into different kinds of light. At the highest frequencies (and thus the shortest wavelengths) are gamma rays, followed by x-rays, ultraviolet light, optical light, infrared light, and then microwaves and radio waves (with the lowest frequencies and thus the highest wavelengths). A gamma ray is very high-energy light that can be produced in many astronomical sources. X-rays are the same rays used in doctor's offices to look at our bones. Ultraviolet light is the harmful light that comes from the Sun and can lead to sunburns, and optical light is the range of wavelengths of light that we can see with our eyes. Infrared light is emitted by heat sources and is what people see when they use night vision goggles.

Some objects have continuous spectra meaning they emit light at all wavelengths (but some much more than others). For instance, the Sun has a continuous spectrum over the optical range of the electromagnetic spectrum that peaks in the yellow (i.e. emits more yellow light than any other color). Other objects have line spectra meaning they emit only at very specific wavelengths. Every element has its own unique line spectra so when we look at an astronomical object, we can tell what elements the object is made of based on what spectra we see coming from the object. The gas tubes used in this lesson each contain one single element (i.e. hydrogen, helium, or neon) and will thus emit different spectra.

A grism is a prism with a special grating (in other words, slotted lines). As light travels through the grism, different wavelengths are treated differently. Thus the grism separates the light coming from the light tubes into different colors so the students can observe what colors make up the spectrum of a particular element.

Procedures

1. Gather the students as a group and ask them to offer examples of different types of light (i.e. ultraviolet, infrared, microwaves, optical light).
2. Explain how light is a wave and different wavelengths mean different kinds of light. Go over the entire electromagnetic spectrum using a poster as an aide if you have one.
3. Since the students will probably understand the concept of optical light but may have a problem comprehending the idea that there are types of light we can't "see", elaborate on the example of ultraviolet light. Explain that the Earth's atmosphere protects us from harmful UV light and that astronauts need space suits to provide air but also to block UV light since they are no longer protected by the atmosphere. Ask the students if they are worried about getting a sunburn from the lights in the classroom. Explain that you can get burned by UV light (from the Sun) but not by optical light (from the lights in the classroom) since they are different types of light.
4. Explain the idea of a spectrum and that each element has its own unique spectrum. Mention that astronomers can determine what stars and galaxies are made of by looking at their spectra.
5. Depending on the size and light level of the classroom, break the class up into groups of as many students as can easily view one of the gas tubes. While the remaining students have free time, help one group at a time view the gas tubes. Instruct the students to hold the grisms about 6 to 8 inches from their eyes and to look to the side of the gas tube (not directly at it) through the grism. Ask them what colors are brightest and what colors are missing from each of the different spectra.
6. Gather together as a group and explain what the Earth's atmosphere is made of (if you think they might know, ask the students what elements they think are in the atmosphere). Explain that different colors of optical light (i.e. red versus blue) have different wavelengths and thus behave differently in the Earth's atmosphere.

7. Ask for three volunteers to represent molecules in the Earth's atmosphere. Stagger them in a zigzag so everyone can see.
8. Ask for a volunteer to represent a red light wave. Gently guide the red light student through the maze set up by the atmospheric "molecules" to demonstrate that red light travels through the atmosphere mostly unimpeded.
9. Ask for a volunteer to represent a blue light wave. Gently bump the blue light student into all of the atmospheric "molecules" to demonstrate that blue light bounces repeatedly off of molecules in the atmosphere.
10. Explain that the sky appears blue because we are seeing the blue light reflected off of the particles in the Earth's atmosphere. For similar reasons, sunsets appear red. The sun's light has to travel through the most atmosphere when the sun is at the horizon so the only light that makes it through to our eyes is red light.

Suggestions

The materials for this lesson may be difficult to find. Any introductory physics class in a university setting should have a stockroom with supplies used for demonstrations during lectures (which is where I found the gas tubes and grisms). I would suggest contacting an outreach office in a physics department to gain access to the supplies in this stockroom. (At Cornell University the physics outreach office website is: http://www.ccmr.cornell.edu/education/)

I had planned another activity to drive home the point that sunsets appear red but the sky appears blue due to different positions of the Sun in relation to the Earth's atmosphere, but we ran out of time. For this activity, fill a clear pan (a large, flat tupperware works well) with water and shine a flashlight through it. Have the class note the lack of color. Add powdered milk (or a bit of liquid milk works too) to the water. Now the flashlight beam should appear blue when viewed from the side and red when viewed from the end of the pan opposite the flashlight. This behavior mimics the effect the Earth's atmosphere (i.e. the powdered milk) has on sunlight (i.e. the flashlight).

Session 7: Stellar Life Cycles

Learning Outcomes

Upon completion of this session, students will:

- Understand that stars are not ageless objects but evolve over time.
- Know the main stages of a star's life.
- Be able to point out what different stages of a star's life look like.

Duration

The duration for this activity is very flexible depending on how many questions the students are allowed to ask. Allotting ten minutes for an introductory discussion, fifteen minutes for the activity, and twenty minutes for a concluding discussion worked well.

Activities

I described briefly (in approximately ten minutes) the stages of a star's life and emphasized key points that I thought would help the students identify the life stage with its appropriate picture. We then broke the students up into groups and gave them each a set of identical laminated pictures of stars at different stages of their evolution. I asked the students to discuss amongst their group what order they thought the pictures should go in (from the birth of a star to the death of a star). We then reconvened for 20 minutes to go over the correct answer and discuss why groups had chosen the orders that they did.

Materials

- Five sets of pictures of seven main stages of a star's life (the number of sets you need depends on how many students you have – each student does not need to have his or her own picture, but I found it helped)

Background Information

A star is not an ageless object but instead evolves. Seven of the main life stages are detailed below. Images for each stage were found by performing a Google Image search.

Protostar

Stars are born from clouds of collapsing gas. Usually a large cloud (called a nebula) begins to collapse in several different spots which each become stars. The collapsing gas which will eventually be a star is called a protostar. A good picture to use of the protostar stage is the stellar nursery called the Eagle Nebula.

Protoplanetary Disk & Stellar System Formation

The collapsing cloud of gas also rotates and begins to form a disk of material around its middle. This disk of material eventually clumps together to form planets. A good picture to use of the protoplanetary disk and stellar system formation stage is the Orion Nebula.

Young Star

Once the cloud has collapsed enough for the star to begin burning its fuel (and thus emit light) and has formed its planets (if it is going to have any) the star is very hot and blue in its youngest stage. A good picture to use of the young star stage is the cluster of young stars called the Pleiades.

Middle-aged, Normal Star

The majority of a star's life is spent in the hydrogen-burning phase. Our sun has been burning hydrogen for nearly 5 billion years and will continue to do so for 5 billion more until it runs out of hydrogen to burn. These stars are considered "normal". A good picture to use of the middle-aged star stage is the Sun.

Red Giant Star

Once a star runs out of hydrogen to burn it will move on to heavier fuel (after hydrogen comes helium). The more massive a star is to begin with, the heavier the elements it can burn through. When the Sun ceases to burn hydrogen it will puff out its outer layers to become what is called a "red giant" because it is redder in color and much larger in radius. A good picture to use of the red giant star stage is the star Betelgeuse (pronounced Beetlejuice).

Dying Star

When a star can no longer burn through to any heavier elements there is no radiation pressure (i.e. pressure from the light being emitted) to fight against the force of gravity pulling the star inward. Thus the star will collapse under its own weight without any support. The outer layers of the star collapse much faster onto a compact core and bounce off that core in a spectacular explosion. This explosion is called a supernova and the material that is thrown off can be seen expanding outward from the leftover core of the star for millions of years. A good picture to use of the dying star stage is Supernova 1987A (named for the year in which it was discovered).

End Stage

The contents of the core of the star that is left behind after a supernova occurs depends on how massive the star was at the beginning of its life. Low-mass stars like our Sun eventually become what is called a white dwarf (a dead star made of mostly electrons that no longer produces light). Intermediate-mass stars eventually become neutron stars (a dead star made of mostly neutrons that also no longer produces light). The most massive stars become black holes, stars whose gravity is so strong that not even light can fight its way out. A good picture to use of the end stage is drawings of Cygnus X-I (a black hole).

My students were particularly interested in black holes so I spent some extra time explaining these objects. There are a few ways we can detect black holes even if light cannot escape from them to be observed by our telescopes. One way is watching the motions of other stars. For example, at the center of our galaxy the stars are moving rapidly and appear to be orbiting an invisible object. Astronomers believe the unseen object pulling on these stars and causing them to orbit is a black hole. Another way to observe a black hole is to look for very high-energy x-ray jets that form as material falls into a black hole. When material is added to a black hole it does not fall straight in but rather spirals inward in a disk that forms around the black hole. The material in this disk emits x-rays before entering the black hole to be lost forever and those x-rays can be detected by our telescopes. The gravity around a black hole is so strong that strange things happen to infalling material. If you were to watch your friend fall into a black hole he or she would appear to be stretched and to be redder in color.

Procedures

1. Explain to the entire class the progression of a typical star's life from birth to death. Emphasize points that will help them connect the stage of life you describe with what they will see in the pictures later.
2. Break the students up into groups of seven and pass out one set of pictures to each group. Ask the students to discuss within their groups what order they think the pictures should go in.
3. Once all the groups have come to a decision, reconvene and hang up their results. Before revealing the correct order, discuss why different groups made the choices that they did.
4. Discuss the correct order and explain again what is happening at each stage. Discuss where the Sun fits in as a normal star in the middle of its life.

Suggestions

To avoid fighting over the pictures, we broke the students up into groups of seven so that each student in a group had his or her own picture. Before we split up, one of the teachers made a rule that no one was allowed to touch anyone else's picture. This rule helped a great deal because otherwise there would have been a lot of struggling over pictures. This rule also allowed each student to feel like he or she had the final say in deciding where his or her particular picture went in the line up.

Session 8: Trip to Fuertes Observatory

Learning Outcomes

Upon completion of this session, students will:

- Have visited an observatory and learned the basics of how the optics work.
- Have viewed solar flares through the telescope.

Duration

Including a short ten-minute introduction to the observatory, we spent two and a half hours there as the students took turns viewing the sun. The day was overcast so we often had to wait for clouds to pass before we could begin viewing again which added time.

Activities

While a group of eight students at a time gathered around the telescope to wait their turn to view the solar flares and ask questions about how the telescope works, the others ate lunch and ran around on the lawn outside. I also brought models of asteroids to discuss with the students while they waited.

Materials

- An observatory to visit
- Props to entertain those who are waiting their turn to look through the telescope (i.e. books, posters, asteroid models, etc)

Background Information

There are two main types of telescopes: reflectors and refractors. In a reflecting telescope, the incident light from a distant star or galaxy hits a mirror and is then reflected (i.e. bounces back) into a detector. In a refracting telescope, the incident light passes through a lens and is focused before reaching a detector.

Procedures

1. Give a brief introduction to the history of the telescope and explain how the telescope works. (Questions to answer: Is it a reflector or a refractor? What kind of celestial objects does it look at?)
2. Bring in no more than eight students at a time to gather around the telescope while the others play outside. Allow each student to take turns viewing the sun and the solar flares. While the others wait explain again how the telescope works (point out where the mirrors/lenses are), answer questions, and use whatever props you have brought to pass the time.

Suggestions

We decided a trip to the observatory during the day rather than at night would not only be easier but also more fun for the students. While they were very eager to look at the solar flares, the telescope could not hold their interest for long. I think for them viewing the solar flares was just as exciting as viewing a planet or a star at night. Going during the day also allowed the students to run around outside and thus be entertained while others were inside using the telescope.

We were lucky enough to have only a few clouds and so did not have trouble with weather. I brought an indoor activity, however, because rain had been in the forecast. I brought about 30 color pictures of different objects in space and planned on asking the students to guess what was in the picture. Some were obvious (like the Moon or the Earth or a galaxy), some were very unobvious (like a black hole or a close-up of the surface of Mercury), and some were pictures the students had already seen in my other visits (like pictures of the Space Station from my astronaut presentation and pictures of Mars).

Resource Materials

http://nineplanets.org

http://mars.jpl.nasa.gov

www.stardate.org/nightsky/moon

http://liftoff.msfc.nasa.gov/academy/universe/MOON.HTML

http://en.wikipedia.org/wiki/List_of_astronauts_by_name

http://spaceflight.nasa.gov/living.index.html

http://www.ccmr.cornell.edu/education

www.google.com

http://www.astro.cornell.edu/facilities/fuertes

Appendix I: Planet Calculations

Planet Calculations

Name	Size (km)	Dist to Sun (km)	Dist to Earth (km)	Time from Earth for light
Sun	1.39e6	0	1.50e8	8 min
Mercury	4.88e3	5.79e7	9.21e7	5 min
Venus	1.21e4	1.08e8	4.20e7	2 min
Earth	1.28e4	1.50e8	0	0
Mars	6.79e3	2.28e8	7.8e7	4 min
Jupiter	1.43e5	7.78e8	6.28e8	35 min
Saturn	1.21e5	1.43e9	1.28e9	1.2 hrs
Uranus	5.11e4	2.87e9	2.72e9	2.5 hrs
Neptune	4.95e4	4.50e9	4.35e9	4 hrs
Pluto	2.27e3	5.91e9	5.76e9	5.3 hrs

NOTE
I calculated "distance to Earth" assuming the planets were as close as possible. I also calculated the "time from Earth for light" assuming the same.

Appendix II: Solar System Model

Name	Diameter of Sphere	Suggested Object	How far to stand (from Sun)
Sun	5.35 m		0
Mercury	1.9 cm	Large marble	½ ft
Venus	4.7 cm	Tennis ball	1 ft
Earth	4.9 cm	Tennis ball	1.3 ft
Mars	2.6 cm	Large marble	2 ft
Jupiter	55 cm	Stability ball	6.7 ft
Saturn	46.6 cm	Large bouncy ball	12.4 ft
Uranus	19.7 cm	Soccer ball	25 ft
Neptune	19.1 cm	Soccer ball	39 ft
Pluto	0.87 cm	Jelly bean	51 ft