CLASSROOM ACTIVITY

From Earth to the Galaxies

General Information

★ Level: secondary 1 to 5.

★ Students per group: individual exercise or in pairs.

★ How long: one 60-minute period.

★ Where: in class

★ When: before a visit to the Planetarium.

★ Type of activity: exploring math.

★ Key words: solar system — star — galaxy — circle — radius — diameter — circumference — speed — time — structure of the Universe — light year — scale factor.

★ Skills honed: measuring, calculating, converting units, using scale models.

Starting Point

How long would a ray of light take to travel the distance separating the Earth and Moon? To reach the Sun or Pluto? To zoom out to the closest star? To cross the Milky Way? To cross the Universe?

Preconceptions

It's very difficult to imagine the true dimensions of our solar system, our Galaxy or the Universe as a whole. Usually the dimensions that students envision are much smaller than the true dimensions of these different systems.

Basic Concepts

Contrary to popular belief, a light year (abbreviated as ly) is a measurement of **distance** rather than time. A light year equals the distance that a ray of light travels in one year, at a speed of 300,000 km/s. A light year therefore represents 300,000 km/s x 60 s/min x 60 min/h x 24 h/d x 365 d/y—in other words, nearly 10,000,000,000,000 km (ten trillion kilometres).

A light year is a useful unit of measurement for representing the very large distances we find in astronomy once we journey outside the solar system. For example, the star closest to our Sun, Alpha Centauri, is located more than 40,000,000,000,000 km from our star. It's much easier to write four light years (or 4 ly). Likewise, our Galaxy, the Milky Way, is 100,000 light years across. The same figure expressed in kilometres would contain 18 zeroes! A distance of 100,000 ly means that a ray of light would take 100,000 years to cross the Galaxy from one end to the other.

Even expressed in light years, the figures become enormous when we consider the distances between galaxies. For example, the galaxy neighbouring our Milky Way, the great Andromeda galaxy, is located nearly two and a half million light years away. Such a distance means that the light from Andromeda now hitting our eye has travelled for nearly two and a half million years before reaching us. So when we look at Andromeda, we see it as it was two and a half million years ago, which was even before the first humans walked on Earth!

If this seems illogical to you, the following example should clarify things. Imagine that you mail an Australian pen pal a photograph of your garden in the spring, but to save on postage, you send your letter by ship. Your letter takes two months to reach your friend. When she opens the envelope, she sees the photograph showing your garden as it was two months earlier when you first snapped the picture. In other words, she sees your garden as it looked two months before, and not as it looks when she actually receives your letter. If you're a good gardener, chances are the look of your garden has changed greatly in two months.

In astronomy, looking into the distance means looking into the past. When our telescopes focus on the light of galaxies located several billion light years from Earth, we see these galaxies as they were several billion years ago (hence early in their development). That's why we often speak of telescopes as time machines. Given these facts, light years are a very useful unit of measurement in astronomy.

Goals

Your students will discover how the Universe is organized into different hierarchical structures (Earth-Moon system, solar system, Milky Way, galaxy cluster) and calculate the dimensions of these structures and the objects they contain. Students will become familiar with the concepts of light year, scale factor and unit conversion.

Steps in the Activity

Preparations

Prepare enough copies of the student handout From Earth to the Galaxies.

IMPORTANT

Web browsers and other software often allow the user to view and print pdf documents at a reduced scale (usually to fit page margins). If this is the case, make sure to select "no scaling" in the dialogue box when printing, otherwise you might have to reprint the students' sheets.

To verify that you have selected the correct print format, measure the distance between the centre of the Earth and the centre of the Moon, at the bottom of page 1 of the students' copy, with a centimetre ruler. The distance should equal 15.2 centimetres.

Make sure to neither enlarge nor reduce the size of the copies you make for your students.

Discuss with students the following notions: the architecture of the Universe (Earth-Moon system, solar system, Milky Way, galaxy cluster), distances in the Universe, and light years. Suggest that they review these notions by completing the student handout.

Supplies

Each student (or student pair) requires:
- A copy of the student handout "From Earth to the Galaxies".
- A ruler graduated in millimetres.
- A calculator (optional).

Assignment

Distribute the handout and explain what students must do. Tell them how long they'll have to complete the questions. Remind them that they must measure the distances between the objects from centre to centre, except in the case of the diameter of the Milky Way and the diameter of the observable Universe, where arrows specify the distance to be measured. In this case, students must measure the distance between the tips of the arrows.

Wrap-up

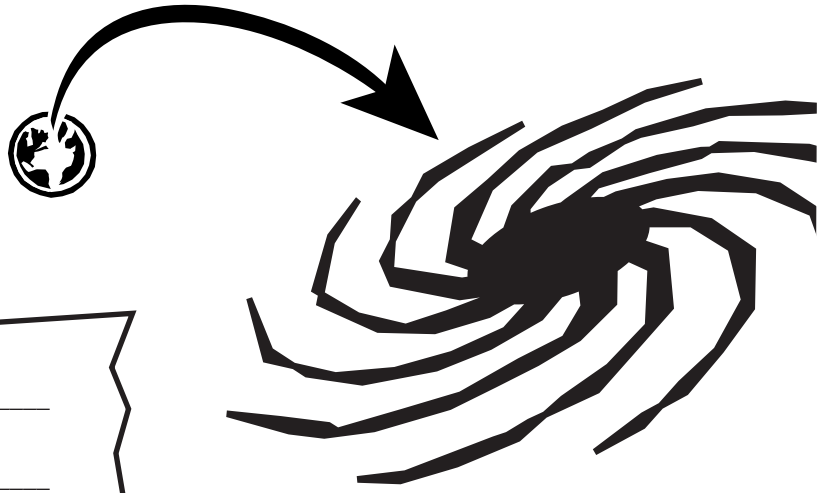
Discuss the following points with your students and have them share their answers and thoughts. Intercontinental telecommunications rely increasingly on geostationary satellites located 36,000 km above the Earth's surface. Radio waves, which also move at lightspeed, must therefore travel to the satellite and back to enable a phone conversation between two points on the planet. What delay does this cause in the conversation? Does this delay hinder conversation? What about a conversation between astronauts on the Moon and flight controllers on Earth? A manned mission to Mars is planned within the next 50 years. The minimum distance between Earth and Mars is 55 million km. What would the minimum delay be between sending a question from Earth and getting an answer back from the Martian colony?

By mid-2006, the U.S. space probes Voyager 1 and 2 were located respectively at over 14.7 and 11.9 billion km from Earth outside the solar system. No manmade object had ever travelled farther. They continue to explore space with their instruments and to send valuable scientific data to Earth using their radio transmitters. How long does the signal transmitted by the probes travel before reaching us on Earth?

Answers

- Communication delay with geostationary satellites (two-way transmission):
  (2 x 36,000 km) ÷ 300,000 km/s = 0.24 second. This delay doesn't hinder conversation.
- Earth-Moon communication delay (two-way):
  (2 x 380,000 km) ÷ 300,000 km/s = 2.53 seconds. With this delay, conversing becomes harder.
- Earth-Mars communication delay (two-way):
  (2 x 55,000,000 km) ÷ 300,000 km/s = 367 seconds or more than 6 minutes. Instead of con versing, you must simply "exchange information."
- Delay between sending a signal by Voyager 1 and 2 and receiving it on Earth (one-way only)
  Voyager 1: 14,700,000,000 km ÷ 300,000 km/s = 49,000 seconds or 13 hours 36 minutes.
  Voyager 2: 11,900,000,000 km ÷ 300,000 km/s = 39,667 seconds or 11 hours 1 minutes.

STUDENT HANDOUT



From Earth to the Galaxies

Name : _____

Group : _____ Date :_____

Do you know how fast light travels? Almost 300,000 km a second! Nothing in the Universe moves faster than light. Use this figure to answer the questions below. When measuring the distance between two bodies, make sure you measure from centre to centre. When arrows appear on a drawing, measure the distance between the tips of the arrows.

1. How many times could a ray of light circle the Earth in one second? Clues: the Earth's diameter is 12,756 km and pi = 3.1416.

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2. The constancy of the speed of light enables us to create units of length to measure very large distances in the Universe. For example, the light second is the distance that a ray of light travels in one second. How many kilometres does a light second equal?

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3. a) What's the distance in kilometres separating the Earth and Moon? (Use a ruler to measure the distance in centimetres between the Moon's centre and the Earth's centre on the drawing below. Then convert the distance into kilometres using the scale factor for the drawing.)
Scale: 1 cm = 25,000 km.

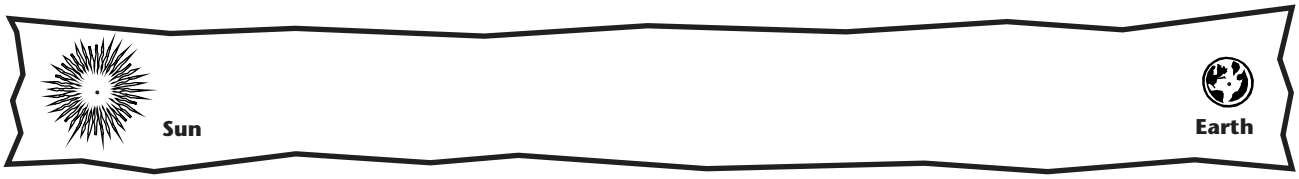
_____

_____

Earth **Moon**

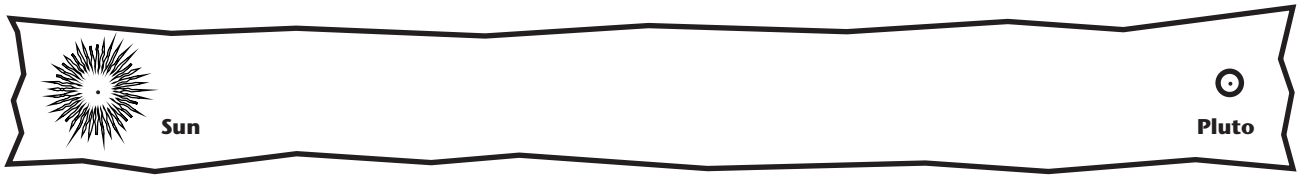
b) How many light seconds does the Earth-Moon distance equal?

4. a) What is the average distance between the Earth and Sun in kilometres?
Scale: 1 cm = 10,000,000 km.



b) How many light minutes does this distance equal?

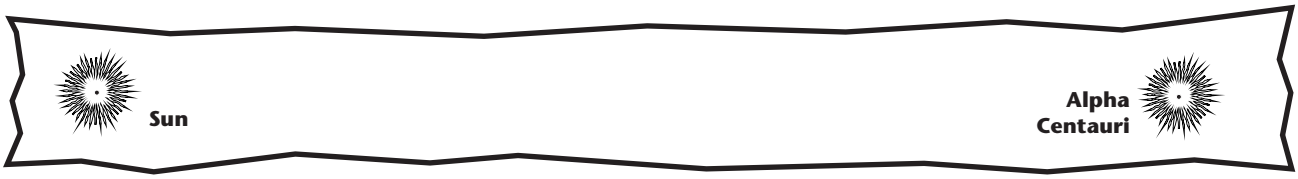
5. a) How many kilometres from the Sun is Pluto, the most distant planet?
Scale: 1 cm = 400,000,000 km.



b) How many light hours does this distance equal?

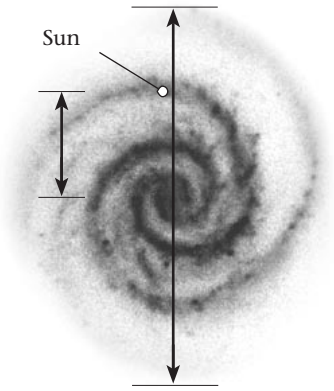
6. To measure distances beyond our solar system, we use the light year as a unit of length. One light year is the distance that a ray of light travels in one year. How many kilometres are in one light year?

7. a) Alpha Centauri is the closest star to our Sun. How far apart are these two stars in light years? Scale: 1 cm = 0.3 ly.



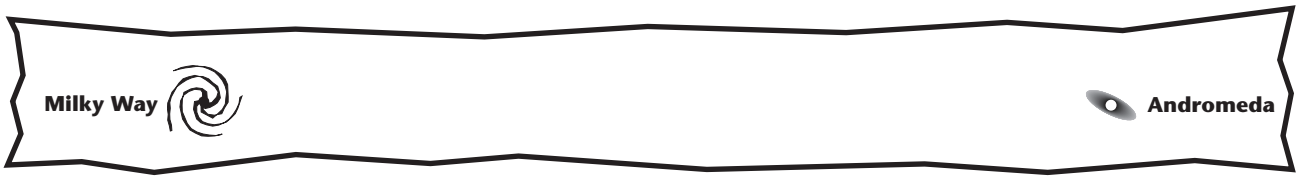
b) Express the same distance in kilometres.

8. a) The Sun is just one of the hundred of billions of stars populating our Galaxy, the Milky Way. What's the Milky Way's diameter in light years? (Use the ruler to measure the distance in centimetres between the tips of the arrows on the drawing below. Then convert the distance into light years by using the scale factor for the drawing.)
Scale: 1 cm = 20,000 ly.



b) What distance in light years separates the Sun from our Galaxy's centre?

9. Our Milky Way is part of a small group of about 40 galaxies called the Local Group. In this group, Andromeda is the galaxy most resembling the Milky Way. What distance in light years separates Andromeda's centre from the Milky Way's centre?
Scale: 1 cm = 200,000 ly.



10. The entire Universe harbours hundreds of billions of individual galaxies, each one containing hundreds of billions of stars. What's the estimated radius of the observable Universe?

Scale: 1 cm = 15,000,000,000 ly.