Project Earth Science

ASTRONOMY

REVISED SECOND EDITION









By Geoff Holt and Nancy W. West

NSTA press
National Science Teachers Association

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Project Earth Science: Astronomy

Revised 2nd Edition

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Acknowledgments

Many people contributed to this revision of *Project Earth Science: Astronomy*, as others did to previous editions. This volume began as a collection of Activities and Readings for Project Earth Science (PES), a professional development program for middle school teachers, funded by the National Science Foundation. The Project Earth Science team consisted of middle school teacher leaders, college professors and scientists, and innovators in educational research. The Activities were written and adapted by this team, and have undergone many revisions as a result of using them in the classroom, and feedback provided by other teachers through in-service training.

The principal investigators on the original project were Iris R. Weiss, Diana Montgomery, Paul B. Hounshell, and Paul D. Fullagar. The teacher leaders were Kevin Barnard, Kathy Bobay, Pam Bookout, Betty Dean, Lynanne (Missy) Gabriel, Flo Gullickson, Michele Heath, Cameron Holbrook, Linda Hollingsworth, Geoff Holt, Kim Kelly, Laura Kolb, Karen Kozel, Kim Taylor, Dana White, Tammy Williams, and Lowell Zeigler. Significant contributions were made to the original publication by Kevin Barnard, Missy Gabriel, and Geoff Holt. The original manuscript was reviewed for scientific accuracy by Wayne Christiansen, professor of astronomy at the University of North Carolina at Chapel Hill. We would like to thank all who contributed to the previous editions of *Project Earth Science: Astronomy*. P. Sean Smith was author of the first edition, and part of the PES team.

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Introduction

Project Earth Science: Astronomy is part of a four-volume series of Earth science books. The remaining three are *Meteorology, Physical Oceanography*, and *Geology*. Each volume contains a collection of hands-on Activities developed for the middle and junior high school level, and a series of background Readings pertaining to the topic area.

Additions and Changes to Revised 2nd Edition

Activities and Readings have been rewritten to improve clarity and scientific currency, and to suggest additional teaching and learning strategies. The Resources section at the back of this book is almost entirely new. At the beginning of each Activity, there now is a Planner to quickly provide information about that Activity. Material specifically for students, and material specifically for teachers, is more clearly delineated. There are new sections for students within Activities titled What Can I Do? and Fast Fact. Additional new sections included for teachers are How Do We Know This?, Safety Alerts!, Connections, Differentiated Learning, and Assessment.

Within each Activity, there is a section for teachers titled Preconceptions containing a series of questions designed to help draw students into a discussion of the subject. These discussions should reveal students' preconceptions. A preconception is an opinion or view that a student might have prior to studying a particular topic. These opinions may not be accurate because the student does not have the correct information or does not understand that information. Asking students about their preconceptions at the outset of a new instructional topic can provide useful information about what students already know and what misinformation needs to be corrected for them to have a good understanding of the topic.

About *Project Earth Science: Astronomy*

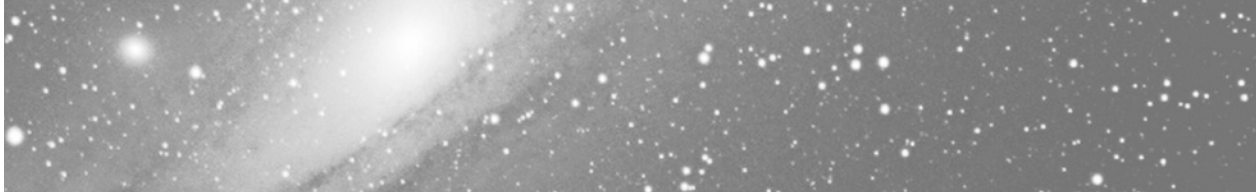
Project Earth Science: Astronomy is based on the concept of the uniqueness of Earth among all the planets in the solar system. Concepts and Activities were chosen that elaborate on this theme. This volume focuses on planetary astronomy and aims to give students a sense of viewing Earth from some point beyond the solar system. By placing Earth in the context of the solar system and viewing it as "just another planet," it is hoped that students will begin to grasp the unique aspects of the planet. Chief among these aspects is that Earth is the only planet in the solar system capable of sustaining life.

This book is divided into three sections: Activities, Readings, and Resources. The Activities in this volume are designed to be hands-on. In collecting and developing these Activities, we tried to use materials that are either readily available in the classroom or inexpensive to purchase.

Each Activity has a student section and a teacher guide. The student section has background information that briefly explains the concepts behind the Activity in non-technical terms. Following this is the procedure for the Activity and a set of questions to guide students as they draw conclusions.

The teacher versions of the Activities, titled Teachers' Guide to Activity X, contain a more detailed version of the background information given to students, and a summary of the important points that students should understand after completing the Activity.

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You will find the approximate time to allow for each Activity in the section titled Time Management. The Preparation and Procedure section describes the setup for the Activity and gives sources of materials. Extended Learning gives ideas for challenging students to extend their study of the topic. Use these ideas within the class period allotted for the Activity if time and enthusiasm allow. Interdisciplinary Study includes ideas for relating the concepts in the Activity to other science topics and to other disciplines such as language arts and social studies. The final section of the teachers' guide provides answers to the questions in the student section of the Activity, and discussions on Assessment.

The Activities are followed by a section of Readings for the teacher. One or more of these Readings are referred to in the guide to each Activity. The Readings provide both background information on the concepts underlying the Activities as well as supplementary information to enhance classroom discussions.

A guide to astronomy resources for students and teachers follows on page 163. Though not exhaustive, the guide should give teachers the means to explore this fascinating subject.

Creating Scientific Knowledge

Everyone has wondered if there is life elsewhere in the universe. Could those distant, tiny points of light seen in the night sky have orbiting planets that might also have intelligent life forms? What is it about planet Earth that makes life possible? Do any other planets in our solar system have the same or similar conditions? Do they have water or oxygen? Where are the other planets located in relation to Earth and the Sun?

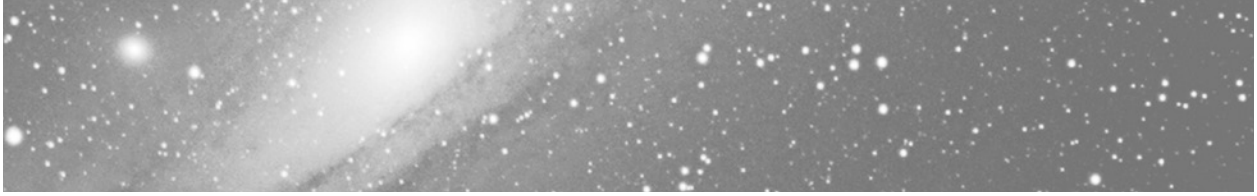
Ever since the dawn of the space age in 1957, space exploration has advanced our knowledge of the neighboring planets that share our Sun. Robot spacecraft have flown past each of the planets, and orbited Mercury, Venus, Mars, Jupiter, and Saturn. Robotic spacecraft have landed on Venus and Mars. For the first time, we can compare their geological and meteorological conditions with those of Earth. As scientists accumulate this new data, it also reveals how life, as we know it, is unique to Earth.

The space program has given us a snapshot of our own blue and white planet as photographed by journeying spaceships. Imagine what you would see if you could look at Earth from a point above the entire solar system. What would Earth look like, and how big would it be compared to the other planets? Does it spin and revolve like the others? Do the other planets have a moon like Earth's? Is the solar system crowded?

To answer these questions, we must first know where Earth is in relation to all the other planets. The Sun is at the center of the solar system with fast-orbiting Mercury in the first planet position. Venus is next, followed by Earth and Mars as you move out from the Sun. Moving still farther away are the giant planets—Jupiter, Saturn, Uranus, and Neptune.

Only when Earth is placed in the context of the solar system and considered as just another planet do its unique features come to light. NASA's Earth Science Program studies Earth as one global system. This is the perspective NASA has taken in studying every other planet. Now it is turning its attention back to our planet. Some of Earth's unique aspects have already been discovered using this approach. As NASA wrote, "If Earth were much smaller, it could not retain an atmosphere. If it were much closer to or much further from the Sun, the oceans would boil or freeze. If its orbit and axis of rotation did not fluctuate, the cyclical variations in climate that have spurred evolution would not exist."

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Getting Ready for Classroom Instruction

The Activities in this volume are designed to be hands-on. In developing them, we tried to use materials that are either readily available in the classroom or inexpensive to purchase. Note that many of the Activities also could be done as demonstrations.

Each Activity has two sections: a Student section and a Teachers' Guide. Each Student section begins with Background information to explain briefly, in nontechnical terms, what the Activity is about; the Objective states what students will learn. Then there is Vocabulary, which includes important astronomical terms students should know. This is followed by a list of the Materials needed and an estimate of the amount of Time that the Activity will take. Following this introduction is a step-by-step Procedure outline and a set of Questions and Conclusions to facilitate student understanding, encourage constructive thinking, and advance the drawing of scientific conclusions.

Each Student section concludes with additional activities for students in What Can I Do?

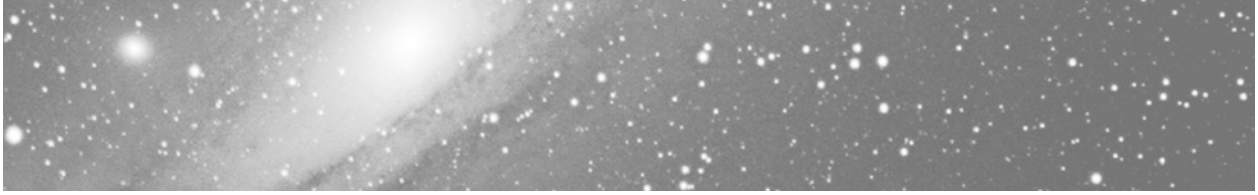
The Teachers' Guide contains What Is Happening?, a more thorough version of the background information given to students. The How Do We Know This? section explains techniques or research methods astronomers currently use to generate knowledge related to the Activity. This is followed by possible student Preconceptions, which can be used to initiate classroom discussions. Next comes a summary of What Students Need to Understand. Then Time Management discusses the estimated amount of time the Activity will take. Preparation and Procedure describes the setup for the Activity. Extended Learning challenges students to extend their study of each topic. Interdisciplinary Study relates the science in each Activity to other disciplines, such as language arts, history, and social sciences. Connections links astronomy to a similar process or concept in geology, meteorology, or physical oceanography. The final portion of each Teachers' Guide includes possibilities for Differentiated Learning, Answers to Student Questions, and suggestions for Assessment.

Although the scientific method often has been presented as a "cookbook" recipe—state the problem, gather information, form a hypothesis, perform experiments, record and analyze data, and state conclusions—students should be made aware that the scientific method provides an approach to understanding the world around us, an approach that is rarely so straightforward. For instance, many factors can influence experimental outcomes, measurement precision, and the reliability of results. Such variables must be taken into consideration throughout the course of an investigation.

As students work through the Activities in this volume, make them aware that experimental outcomes can vary and that repetition of trials is important for developing an accurate picture of concepts they are studying. By repeating experimental procedures, students can learn to distinguish between significant and insignificant variations in outcomes. Regardless of how carefully they conduct an experiment, they can never entirely eliminate error. As a matter of course, students should be encouraged to look for ways to eliminate sources of error. However, they also must be made aware of the inherent variation possible in all experimentation.

Finally, controlling variables is important in maintaining the integrity of an experiment. Misleading results and incorrect conclusions often can be traced to experimentation where important variables were not rigorously

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controlled. Teachers should encourage students to identify experimental controls and consider the relationships between the variables under study and the factors held under control.

Key Concepts

The Activities in this volume are organized under three broad astronomical concepts:

Key Concept I: Earth's position in the solar system
Key Concept II: Earth's unique properties
Key Concept III: Earth's characteristic phases and seasons

First, students investigate techniques that are used to measure distances and sizes of the magnitude found in the solar system. Using the information gained from these methods, students then place Earth in the solar system in relation to the rest of the planets. Second, students perform activities that stress the uniqueness of Earth. This section focuses on comparisons of Earth to other planets, particularly Venus and Mars. In the third section of the book, students are confronted with two areas of planetary astronomy about which many people have preconceptions: the reason for the phases of the Moon and the explanation of Earth's seasons.

We suggest organizing *Project Earth Science Activities* around these key concepts. To facilitate this approach, the conceptual outline for Astronomy is presented below, with the numbers of the Activities that pertain to each concept.

I. While Earth's position relative to the Sun and other planets is always changing, its distance from the Sun is almost constant. To understand many features of Earth that make it unique and habitable, we need to know where Earth is in relation to the Sun and other planets. Several tools are available to learn where Earth is in the solar system. (Activities 1, 2, 3, 4, and 5)

II. Earth's position in the solar system is responsible for its unique properties. Among these properties is the fact that Earth is the only planet in the solar system that sustains life. (Activities 6, 7, 8, and 9)

III. Many preconceptions exist about Earth and its characteristics. Looking at Earth as "just another planet" can help correct these preconceptions. (Activities 10 and 11)

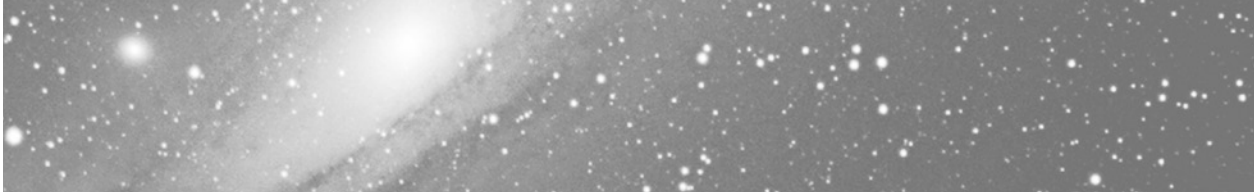
Project Earth Science: Astronomy and the *National Science Education Standards*

Effective science teaching within the middle-level age cluster integrates the two broadest groupings of scientific activity identified by the National Science Education Standards: (1) developing skills and abilities necessary to perform scientific inquiry, and (2) developing an understanding of the implications and applications of scientific inquiry. Within the context of these two broad groupings, the Standards identify specific categories of classroom activities that will encourage and enable students to integrate skills and abilities with understanding.

To facilitate this integration, a Standards organizational matrix for *Project Earth Science: Astronomy* appears in the front matter on pages xvi–xvii. The categories listed along the *x*-axis of the matrix, also listed below, correspond to the categories of performing and understanding scientific activity identified as appropriate by the Standards.

Subject and Content. Specifies the topic covered by an Activity.
Scientific Inquiry. Identifies the "process of science" (i.e., scientific reasoning, critical thinking, conducting investigations, formulating hypotheses) employed by an Activity.

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Unifying Concepts. Links an Activity's specific subject topic with "the big picture" of scientific ideas (i.e., how data collection techniques inform interpretation and analysis).
Technology. Establishes a connection between the natural and designed worlds.
Personal/Social Perspectives. Locates the specific astronomy topic covered by an Activity within a framework that relates directly to students' lives.
Historical Context. Portrays scientific endeavor as an ongoing human enterprise by linking an Activity's topic with the evolution of its underlying principle.

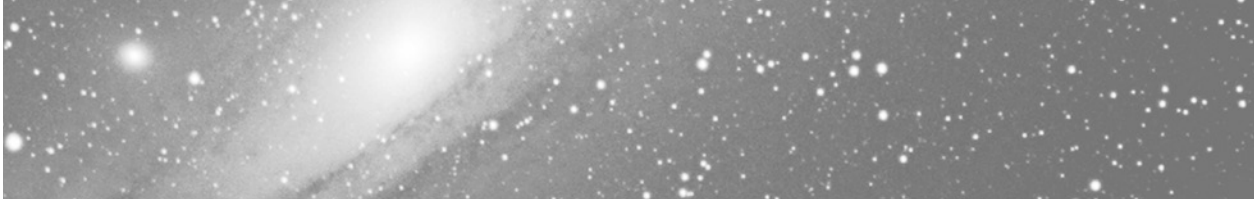
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Safety in the Classroom Practices

The teaching and learning of science today through hands-on, process, and inquiry-based activities make classroom and laboratory experiences effective. Addressing potential safety issues is critical to securing this success. Although total safety cannot be guaranteed, teachers can make science safer by adopting, implementing, and enforcing legal standards and best professional practices in the science classroom and laboratory. Safety in the Classroom Practices includes both basic safety practices and resources specific to the Project Earth Science series. It is designed to help teachers and students become aware of relevant standards and practices that will help make activities safer.

1. When working with glassware, meter sticks, wires, projectiles, or other solid hazards, students use appropriate personal protective equipment (PPE), including safety glasses or goggles, gloves, and aprons.
2. When working with hazardous liquids, indirectly vented chemical splash goggles, gloves, and aprons must be used.
3. Always review Material Safety Data Sheets (MSDSs) with students relative to safety precautions when working with hazardous chemicals.
4. Be careful to wipe up any spilled water on the floor quickly—slip and fall hazard.
5. Be careful when working with the hot plate and hot water—skin can be burned. Have students notify you immediately if someone is splashed with boiling water.
6. Be careful when working with a hot lamp—skin can be burned. Have students notify you immediately if someone is burned.
7. When working with lamps, keep away from water or other liquids—electrical shock hazard.
8. Handle glass thermometers with care so as not to drop or break them—broken glass is a sharp hazard.
9. Know the source of dirt used in an Activity and make sure the source is pesticide- and fungicide-free.
10. Use caution when working with sharp items such as scissors and floral or electrical wires, as they can cut or puncture skin.
11. Wash hands with soap and water upon completing the lab.
12. Use caution when working with pointed objects such as compasses or stakes—impalement hazards.
13. Make sure all trip and fall hazards are removed from the floor prior to darkening the room for an Activity.
14. Keep extension cords off the floor—trip and fall hazards.
15. Make sure that students never look directly at the Sun without appropriate eye protection—major eye hazard.
16. Never eat food or beverage that has been either brought into the lab or used in the lab—potential hazardous chemical contamination.
17. Make sure to abide by school and school district rules on using candy as a reward.
18. When heating liquids, use only heat-resistant glassware (Pyrex- or Kimax-type equipment). Remember that glass labware is never to be placed directly on heating surfaces. Hot containers are potential hazards.
19. When heating liquids on electrical equipment such as hot plates, use ground-fault-protected circuits (GFI).
20. Always remind students of heat and burn hazards when working with heat sources such as hot plates, heating water, and more.

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21. Select only markers with low volatile organic compounds (VOC). Some students may be allergic to VOC vapors.
22. Use only asbestos-free vermiculite. Vermiculite containing asbestos will expose students and teacher to this health hazard.
23. Teachers should always model appropriate techniques before requiring students to cut, puncture, or dissect.

For additional safety regulations and best professional practices, go to

NSTA: Safety in the Science Classroom: *www.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf*

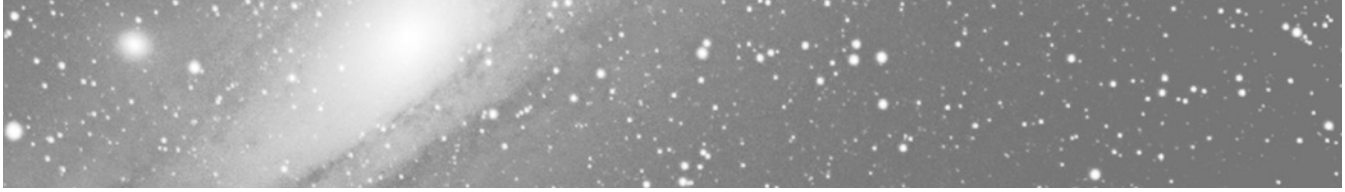
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Standards Organizational Matrix

Activity	Subject Matter and Content	Scientific Inquiry	Unifying Concepts and Processes
Activity 1 Measuring the Moon Indirectly	Indirect measurement of solar system objects	Understanding how to measure large distances	Use of mathematics in astronomy
Activity 2 Light Year as Distance	Concept of light year as a unit of distance	Expressing large distances in astronomy	Measurement of large distances
Activity 3 Solar System Scale	A scale model of size and distance in the solar system	Determining scale in the solar system	Measurements and models
Activity 4 The Speed of Light	Light has a finite speed	Understanding the consequences of light having a finite speed	Effect of finite speed of light on observation of distant objects
Activity 5 How Far to the Star?	Parallax (indirect measurement)	Measuring large distances using parallax	Relationship between explanation and evidence
Activity 6 The Formation of the Solar System	Solar nebula theory	Modeling accretion	Evidence and models
Activity 7 Habitable Zone	Distance and light	Investigating conditions necessary for life on a planet	Interactions among variable conditions within a system
Activity 8 The Greenhouse Effect	Nature and behavior of light	Modeling the heat-trapping effect of greenhouse gases	Relationship between explanation and evidence
Activity 9 Creature Feature	Compare Earth to Mars and Venus	Comparing possible life conditions on Venus and Mars to Earth	Relationship of life forms to physical environment
Activity 10 Reasons for the Seasons	Earth's seasons	Investigating the causes of Earth's seasons	Relationship of Earth's orbit and tilt of axis
Activity 11 Phases of the Moon	Moon's phases	Modeling the causes of the Moon's phases	Effects of the Moon's orbit around Earth and solar illumination

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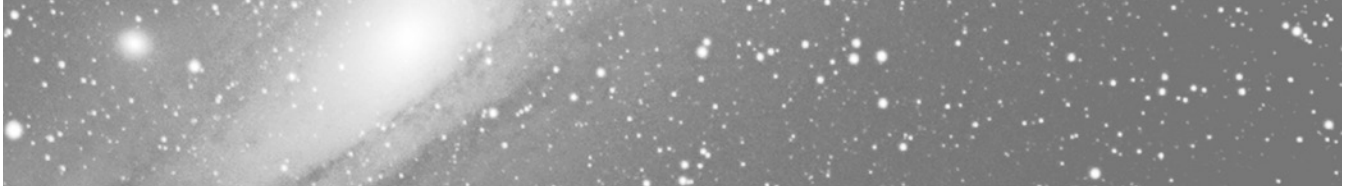
Technology	Personal/Social Perspectives	Historical Context	Key Concept
Technology of measuring devices		Cross-staffs used by ancient peoples for navigation	I
Communicating over large distances			I
		Copernicus developed a scale model of the solar system	I
Finite speed of light and all forms of electromagnetic radiation	The challenges of observing distant objects		I
Technology of measuring devices		Parallax predicted by ancient Greeks	I
		Examining theories of solar system formation	II
Measuring temperatures and distances	Evaluating the conditions for life as we know it		II
	Climate change		II
Technology to measure environmental conditions	Adaptation to extreme environments		II
Use of photocell and multimeter			III
	Evaluating preconceptions about Moon phases		III

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Activities at a Glance

Activity	Pages	Subject and Content	Objective	Materials
Activity 1 Measuring the Moon Indirectly	1–9	Indirect measurement of solar system objects	Learn how angular diameter can be used to measure the true diameter of the Moon.	Each group of students will need: paper plate, metric ruler, metric tape measure, index card, scissors, safety glasses or goggles
Activity 2 Light Year as Distance	11–18	Concept of light year as a unit of distance	Develop an understanding of the concept of a unit known as the "light year."	Each group of students will need: watch with second hand or a stop-watch, metric tape measure (30 m or more works best), calculator (helpful but not essential), safety glasses or goggles
Activity 3 Solar System Scale	21–29	A scale model of size and distance in the solar system	Build a scale model of the solar system.	Each group of students will need: trundle wheel, masking tape, eight stakes, eight index cards, sharp pencil, one ball (23.2 cm diameter), drawing compass (optional), solar viewing glasses for each student (optional)
Activity 4 The Speed of Light	31–36	Light has a finite speed	Understand the consequences of light having a finite speed.	Each student will need: a piece of candy or other treat
Activity 5 How Far to the Star?	39–48	Parallax (indirect measurement)	Investigate the factors affecting parallax.	Each group of students will need: construction paper (or manila folder), pencil, metric ruler, chalkboard or large sheets of A1 paper (594 mm x 841 mm), chalk or markers, scissors (if manila folders are used), tape (if manila folders are used), single-hole punch
Activity 6 The Formation of the Solar System	51–58	Solar nebula theory	Observe a model of how the solar system would have originated according to the solar nebula theory.	The class will need: one bag of vermiculite, containers of water placed centrally in the room, 100 mL graduated cylinder, 1,000 mL beaker or comparable container for overhead demonstration Each group of students will need: one stirring rod, one bucket (11 L) for student exercise, basin for collecting used water, 15 mL of vermiculite, indirectly vented chemical splash goggles and apron

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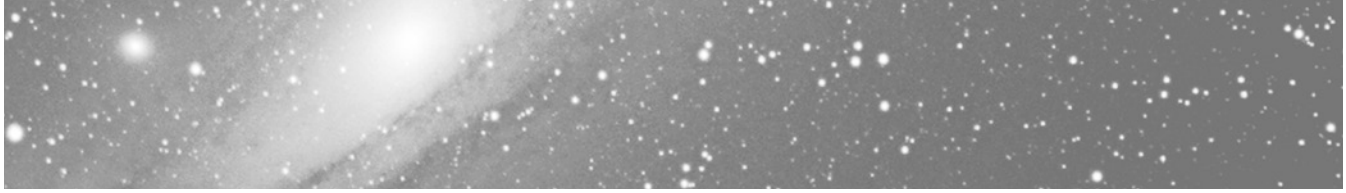


Time	Vocabulary	Key Concepts	Margin Features
50 minutes or less	Indirect measurement, Angular diameter, Similar triangles	I	Safety Alert!, Fast Fact, What Can I Do?, Connections
50 minutes or less	Light year	I	Fast Fact, What Can I Do?, Connections
More than 50 minutes but less than 100 minutes	Scale model, Scaling factor	I	Fast Fact, Safety Alert!, What Can I Do?, Connections
Less than 50 minutes	Radio wave, Speed of light, Speed of sound	I	What Can I Do?, Fast Fact, Safety Alert!, Connections
50 minutes	Direct measurement, Indirect measurement, Parallax effect, Baseline	I	Fast Fact, Safety Alert!
Less than 50 minutes	Solar nebula theory, Nebula, Protostar, Protosun	II	Safety Alert!, Fast Fact, Connections

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Activity	Pages	Subject and Content	Objective	Materials
Activity 7 Habitable Zone	61–68	Distance and light	Investigate the relationship between distance from a light source and temperature, and apply this relationship to understand why life in the solar system has been found only on Earth.	Each group of students will need: four Celsius thermometers (nonmercury); meter stick, a lamp with a 75-watt bulb, a clamp, and a stand; safety glasses or goggles for each student
Activity 8 The Greenhouse Effect	71–80	Nature and behavior of light	Observe and investigate a model of how light and the atmosphere interact to make Earth suitable for life.	The class will need: one large bag of potting soil, one box of plastic wrap, graph paper for each student Each group of students will need: two large disposable plastic cups, dirt to fill each cup (use commercial potting soil free of pesticide or fungicide), something to prop up thermometers (e.g., a slightly smaller cup or stack of books), one rubber band, two Celsius thermometers (nonmercury), hole punch
Activity 9 Creature Feature	83–90	Compare Earth to Mars and Venus	Consider some of the characteristics of Venus and Mars that make the planets uninhabitable for life as we know it.	Each group of students will need: construction paper (at least three different colors), scissors, glue, aluminum foil, straws, toothpicks, paper cups, transparent tape, floral wire
Activity 10 Reasons for the Seasons	93–103	Earth's seasons	Understand why Earth has seasons.	The class will need: one or two globes mounted so that the axis of rotation is tilted to 23.5° from vertical, a bright light source (lamp with at least a 75-watt bulb and without a shade), (optional) photocell such as a mini panel solar cell, (optional) multimeter or voltmeter
Activity 11 Phases of the Moon	105–116	Moon's phases	Understand the cause of the Moon's phases.	For Part 1, the class will need: one bright lamp (at least 75-watt) without shade, one extension cord, one Ping-Pong ball for each student (an option is polystyrene balls), safety glasses or goggles for each student For Part 2, each pair of students will need: cardboard, 15-cm diameter Styrofoam ball, pencil, black paint suitable for Styrofoam, safety glasses or goggles for each student

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Time	Vocabulary	Key Concepts	Margin Features
50 minutes or less	Habitable zone	II	Fast Fact, Safety Alert!, Connections, Resources
50 minutes	Greenhouse effect, Radiant heat, Infrared light	II	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resource
50 minutes		II	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resources
50 minutes	Orbit, Ellipse, Axis, Rotation axis	III	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resources
100 minutes (50 minutes per part)	Phases of the Moon	III	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resources

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Activity 7 Planner

Activity 7 Summary

Students measure temperature over time at different distances from a lamp. They also guess the distance that will give them a target temperature, and then interpolate the distance from their graphed data. Finally, they test their interpolated distance.

Activity	Subject and Content	Objective	Materials
Habitable Zone	Distance and light	Investigate the relationship between distance from a light source and temperature, and apply this relationship to understand why life in the solar system has been found only on Earth.	Each group of students will need: four Celsius thermometers (non-mercury); meter stick; a lamp with a 75-watt bulb, a clamp, and a stand; safety glasses or goggles for each student

Time	Vocabulary	Key Concept	Margin Features
50 minutes or less	Habitable zone	II: Earth's unique properties	Fast Fact, Safety Alert!, Connections, Resources

Scientific Inquiry	Unifying Concepts and Processes	Technology	Personal/Social Perspectives
Investigating conditions necessary for life on a planet	Interactions among variable conditions within a system	Measuring temperatures and distances	Evaluating the conditions for life as we know it

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Habitable Zone

Activity 7

How Distance and Temperature Are Related

Background

Earth is the only planet we know of in the solar system that supports life. Although Earth's neighboring planets may be considered to be in the **habitable zone**, neither Venus nor Mars have been found to be habitable. One of them is far too hot and the other is far too cold. Mars has practically no oxygen in the atmosphere, and most of the water is tied up in polar ice caps and permafrost. On Venus, the temperature stays around 460°C. The highest confirmed temperature ever recorded on Earth was 56.7°C in Death Valley, California, on July 10, 1913. If Earth were either closer or farther away, life as we know it never would have evolved.

In this Activity, you will investigate the way distance from a light source affects temperature—one of the many reasons why Earth is "just right" in its ability to support life.

Vocabulary

Habitable zone: A narrow range of distances from a star in which conditions are suitable to sustain life as we know it.

Fast Fact

Although Thomas Edison often is credited with inventing the lightbulb, Frederick de Moleyns was granted the first patent for a lightbulb in England in 1841. Edison's first U.S. patent was not filed until 1878.

Objective

Investigate the relationship between distance from a light source and temperature, and apply this relationship to understand why life in the solar system has been found only on Earth.

SCILINKS® THE WORLD'S A CLICK AWAY

Topic: the Earth or clement zone

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Materials

Each group of students will need

- four Celsius thermometers (nonmercury)
- meter stick
- a lamp with a 75-watt bulb, a clamp, and a stand
- safety glasses or goggles for each student

Time

50 minutes or less

Procedure

1. In this Activity, you will find where on the meter stick a thermometer should be placed so that the temperature it measures matches a target temperature that your teacher specifies before the experiment begins.
2. After putting on eye protection, place the meter stick on a table. Place the lamp at the end of the meter stick so that light is aimed down along the meter stick as shown in **Figure 7.1**.

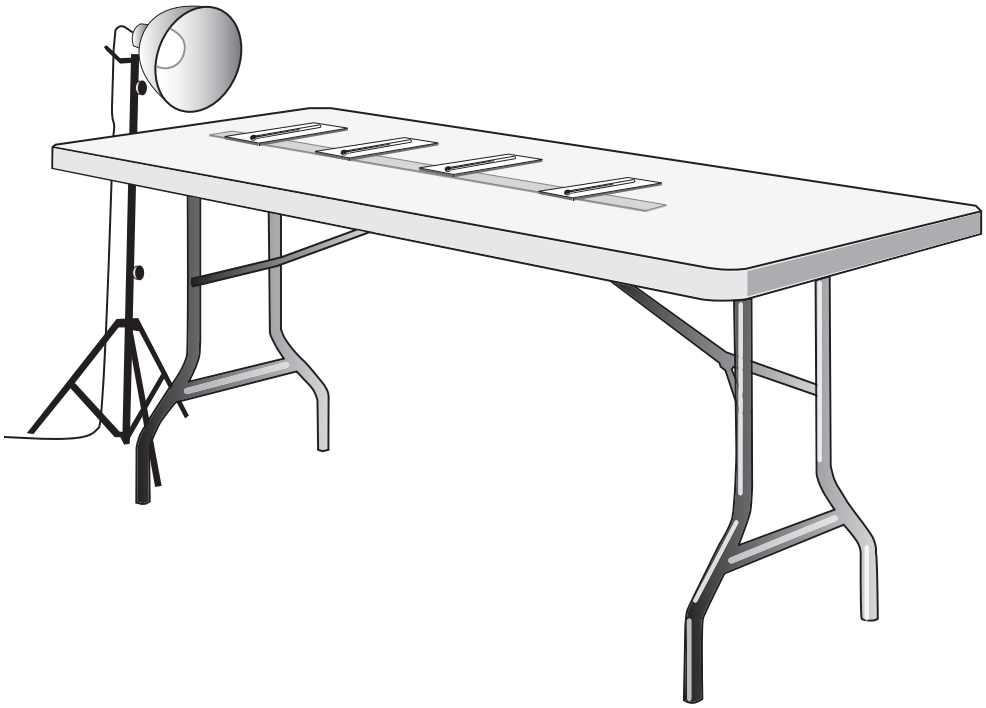


Figure 7.1
Four thermometers arranged along a meter stick at varying distances from a lamp

SAFETY ALERT

1. Safety glasses or goggles are required for this Activity.

2. Be careful when working with a hot lamp—skin can be burned. Notify your teacher immediately if someone is burned.

3. Handle glass thermometers with care so as not to drop or break them—broken glass is a sharp hazard.

4. When working with lamps, keep away from water or other liquids—electrical shock hazard.

3. Place the thermometers down flat on the meter stick in positions where you think one of them will have a temperature that will match the target temperature. Each thermometer represents a possible distance for Earth from the Sun. Be sure that the bulb of each thermometer is on the meter stick. Record the distance of each thermometer from the end of the meter stick that is next to the lamp in the data table in **BLM 7.1**.
4. Record the starting temperatures for each thermometer in the data table (**BLM 7.1**). Turn on the lamp and record temperatures for each thermometer every 3 min. until no temperature change is seen in any thermometer. Caution: The lamp and reflector will become hot.
5. If none of the final temperatures are the same as the target temperature, graph your results, plotting temperature versus distance. Then try to predict at what distance you should place thermometers when you repeat step 4 so that one of the final temperatures matches the target temperature. If necessary, continue repeating steps 3 and 4 until one of the thermometers reaches the target temperature.

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Questions and Conclusions

1. What happened to the temperatures when the light was turned on?
2. How difficult was it to find the position on the meter stick where the final temperature matched the target temperature? Why was this so?
3. How does distance from a source of light (the Sun, for example) affect temperature?
4. How would the temperatures on the gaseous planets (all the planets beyond Mars) compare to the temperatures on Mercury, Venus, Earth, and Mars (the terrestrial planets)?
5. What are some other factors besides distance from the Sun that determine the average temperature of the planet?
6. Based on your observations, do you think we could still live on Earth if the planet moved very much toward or away from the Sun? Why?
7. If Mars or Venus were somehow moved so they were now the same distance from the Sun as Earth, do you think we could live on either of them? Why or why not?

Fast Fact

In the northern hemisphere, the Sun is closer to Earth in the winter than it is in the summer.

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Data Table								
Trial	Thermometer	Distance to Thermometer	Temperature (°C)					
			Start	3 min.	6 min.	9 min.	12 min.	15 min.
1	1							
	2							
	3							
	4							
2	1							
	2							
	3							
	4							
3	1							
	2							
	3							
	4							

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Habitable Zone

How Distance and Temperature Are Related

What Is Happening?

The fact that Earth is the only planet in the solar system that we know supports life is a consequence primarily of its distance from the Sun. If Earth were only 2% of its present distance farther away from the Sun, it would be like Mars—a permanent "ice age" wasteland with a carbon dioxide atmosphere and most of its water tied up in polar ice caps. If Earth were only 5% closer to the Sun, it would be most like Venus, a planet many astronomers have described as a "hellish place." The surface temperature on Venus is about 460°C. Earth's distance from the Sun is just right, and practically no other distance will do. It has only recently been determined that the range of distances from the Sun in which Earth's conditions could have formed is very small compared to the scale of the solar system. Because of this narrow range (or habitable zone), Earth's atmosphere is the only one in the solar system that will allow water to exist in all three states simultaneously—solid, liquid, and gas.

Earth's distance from the Sun has allowed life to flourish here because of one of the properties of light: As the distance from a light source increases, the intensity of the light decreases. That is why in a room with only one light, it

How Do We Know This?

How do we know a planet's surface temperature?

In the case of some planets, we have made direct measurements by sending instruments to the surface of Venus and Mars, and into the atmosphere of Jupiter. With other planets, we can calculate a planet's surface temperature without a probe landing there by measuring how much heat the planet is radiating. This is accomplished by measuring the planet's brightness in the infrared part of the spectrum. With some planets, such as Jupiter, Saturn, Uranus, and Neptune, known as "gas giants," astronomers have selected an arbitrary level in the atmosphere to compare to the rocky planets' surface temperatures. Astronomers chose the level in each gas giant's atmosphere where the air pressure would be equal to Earth's air pressure at the surface. So, the "surface temperature" listed for those planets reflects our understanding of each planet's temperature at that depth in the planet's atmosphere.

Objective

Investigate the relationship between distance from a light source and temperature, and apply this relationship to understand why life in the solar system has been found only on Earth.

Key Concept

II: Earth's unique properties

Materials

Each group of students will need

- four Celsius thermometers (nonmercury)
- meter stick
- a lamp with a 75-watt bulb, a clamp, and a stand
- safety glasses or goggles for each student

Time

50 minutes or less

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becomes increasingly difficult to read a book as you move farther away from the source. The intensity of the light decreases with the square of the distance from the source. This means that if you move twice as far away from the source, the intensity of the light will be only one-fourth of what it was. Earth is placed in such a way that it gets just the right intensity of light to allow its unique atmosphere to exist.

This Activity is designed to show students that distance from a light source will affect temperature and that the range of distances in which a specific temperature can exist is relatively small.

Preconceptions

Ask students, "Have you ever seen people or animals use light as a source of heat?" Students might provide interesting examples—heat lamps in bathrooms, chicken brooders, or cats sitting under a lamp, for instance. Then ask, "How does it feel as you get closer to the bulb? How does it feel if you get too close to the bulb?"

What Students Need to Understand

- The intensity of light decreases as you move away from the source.
- As the intensity of light decreases, the temperature resulting from that light will also decrease.
- The temperature on a planet is primarily a consequence of the planet's distance from the Sun. But, there are other factors as well.
- The range of distances from the Sun in which life can exist is very narrow.

Time Management

Including setup and cleanup, this Activity will take 50 minutes or less. Therefore, students could have another task to do between temperature readings. For example, they could be completing an assignment on planetary comparisons that emphasizes the uniqueness of Earth.

Preparation and Procedure

Prior to the class, assemble all the materials in a central location. Make sure that all lamps are working and that none of the thermometers is broken.

Prior to the class period, set up an apparatus and place one thermometer somewhere near the middle of the meter stick. Turn the light on and allow it to remain on until the temperature on the thermometer no longer rises. Let this temperature be the "target temperature" mentioned in the student instructions.

SAFETY ALERT

1. Safety glasses or goggles are required for this Activity.

2. Be careful when working with a hot lamp—skin can be burned. Notify your teacher immediately if someone is burned.

3. Handle glass thermometers with care so as not to drop and/or break them—broken glass is a sharp hazard.

4. When working with lamps, keep away from water or other liquids—electrical shock hazard.

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Students will try to determine where on the meter stick to place a thermometer so that its temperature matches the target temperature.

Be sure that thermometers are calibrated. Also, be sure that room temperature does not change much between the time the target temperature is determined and the time this Activity is done. If the room temperature changes too much, the target temperature may actually be below room temperature, making this Activity impossible. For additional information, refer to Reading 8: Global Warming, and Reading 9: The Water Cycle.

Extended Learning

- Some students may want to further investigate the relationship between intensity and distance from a light source. This can be done easily in a room with a single light source and a light meter. It provides an excellent opportunity for students to use graphing skills, plotting distance versus light intensity.
- There are other factors that determine a planet's surface temperature besides light intensity—in particular, the atmosphere. The atmosphere affects temperature through a phenomenon known as the greenhouse effect. In addition to extensive literature on this topic, there are activities that demonstrate it quite well, such as Activity 8: The Greenhouse Effect.
- Astronomers have found hundreds of planets that orbit other stars beyond our solar system. Students may want to investigate discovered planets that are believed to be in the star's habitable zone.

Interdisciplinary Study

Many astronauts have tried to describe what Earth looks like from space and their reactions to the sight. Their accounts provide us with a unique perspective on our planet. The descriptions highlight Earth's beautiful and fragile nature. Some of these accounts can be found at the following websites:
www.spacequotations.com/
www.brainyquote.com/quotes/type/type_astronaut.html
www.solarviews.com/eng/earthsp.htm

- Have students read these accounts and react to them in small group or class discussions. What do these descriptions make students realize about Earth that they did not realize before?
- Have students discuss the uniqueness and fragility of Earth in groups after studying Reading 7: Earth as a System; Reading 9: The Water Cycle; and Reading 11: The Coming Climate Crisis?

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Connections

Geologists who study ice ages discuss the effect of changes in the shape of Earth's orbit on the extent of glaciation. The orbit's eccentricity cycles between being more circular and more elliptical on about a 100,000-year scale. This is one component of Milankovitch cycles, named for the engineer and mathematician who first described them. Have students learn about the geologic evidence for these cycles in eccentricity.

Resources

www.spacequotations.com/

www.brainyquote.com/quotes/type/type_astronaut.html

www.solarviews.com/eng/earthsp.htm

Differentiated Learning

Ask students in advanced math classes to graph their data on a graphing calculator. They can then find the best-fit line for their data, determine the sweet spot to match your target temperature, and check their mathematically derived answer experimentally.

Answers to Student Questions

1. All the temperatures rose, but those closer to the light source rose by a greater amount and more rapidly.
2. Answers will depend on students. It may be difficult to find the position since the range of distances from the light source that accompanies the target temperature is small.
3. As distance increases, radiant energy decreases.
4. Since the gaseous planets are farther away, their temperatures should be lower than the temperatures of the inner planets.
5. The atmosphere; the amount of liquid water. For example, Earth's atmosphere helps keep a lot of heat in, and the ocean currents moderate temperatures all over the planet.
6. No. A very small change in the distance from the Sun leads to very drastic changes in conditions on Earth, most notably in temperature.
7. Answers will vary. There is quite a bit of evidence that neither planet would be habitable even if it were in the position of Earth. Evidence from the geologic record suggests that Earth took billions of years to evolve life-sustaining conditions.

Assessment

- While students are making their measurements, monitor them and help them troubleshoot problems by asking open-ended questions (e.g., "Is there another way to do that?" "Describe to me what you've done. Where have you had trouble? What do you think you could do about it?").
- For a summative assessment, you could grade answers to questions. You could also have students demonstrate their graphing and understanding by giving them another set of data and asking them to show you how to find the distance for a target temperature.

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Activity 8 Planner

Activity 8 Summary

Students measure the temperature in two soil-filled cups sitting in the Sun for about 50 minutes. One cup is uncovered; the other has a clear plastic cover. Students then graph and compare the data from the two cups.

Activity	Subject and Content	Objective	Materials
The Greenhouse Effect	Nature and behavior of light	Observe and investigate a model of how light and the atmosphere interact to make Earth suitable for life.	The class will need: one large bag of potting soil, one box of plastic wrap, graph paper for each student, safety glasses or goggles for each student Each group of students will need: two large disposable plastic cups, dirt to fill each cup (use commercial potting soil free of pesticide or fungicide), something to prop up thermometers (e.g., a sightly smaller cup or stack of books), one rubber band, two Celsius thermometers (nonmercury), hole punch

Time	Vocabulary	Key Concept	Margin Features
50 minutes	Greenhouse effect, Radiant heat, Infrared light	II: Earth's unique properties	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resource

Scientific Inquiry	Unifying Concepts and Processes	Personal/Social Perspectives
Modeling the heat-trapping effect of greenhouse gases	Relationship between explanation and evidence	Climate change

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The Goldilocks Effect: Earth Is Just Right

Reading 5

So far, scientists have found that Earth is the only planet in the solar system capable of sustaining life as we know it—that is, complex, multicellular life-forms similar to human beings.

The Goldilocks Principle refers to a planet such as Earth that is "just right" for sustaining human life. The popular term, Goldilocks Principle, or Effect, comes from the traditional folk tale, "The Story of the Three Bears" (or "Goldilocks and the Three Bears"), first published in Britain in the 1830s. The idea of something being "just right" comes from this story, in which Goldilocks finds three bowls of porridge, one that is too hot, another too cold, and a third that is just right. And so it goes for three chairs, one too big, the next too small, and the other just right. Then, being tired, Goldilocks finds three beds, one is too hard, the next is too soft, and the final is just right.

The idea of "just right" has come to mean something that is in the middle, between two extremes, like Goldilocks' bowls of porridge, chairs, and beds.

In terms of astronomy, the Goldilocks Principle refers to planets that are Earth-like and thus habitable by complex, multicellular life-forms such as humans. The scientific term is the habitable zone (HZ) (**Figure R5.1**). This generally refers to the distance a planet (such as Earth) is from the star (such as our Sun), where a planet can maintain liquid water on its surface.

For example, the two planets closest to Earth in the solar system are Venus and Mars. Both have many similarities to Earth but neither has been found to support life.

Venus is the second planet from the Sun in our solar system (Mercury is the closest), and Earth's neighbor. Venus is similar to Earth in size and composition, but its atmosphere is quite different. Venus's thick atmosphere, composed mostly of carbon dioxide, and total cloud cover trap in the heat, making Venus the hottest planet in the solar system. The surface of the planet is so hot—nearly 500°C—that any water that might have existed would have been completely vaporized.

Mars, the fourth planet from the Sun, Earth's neighbor on the other side, has some similarities to Earth and to Venus (see Activity 9: Comparing Earth to Mars and Venus). Like Venus, most of Mars's atmosphere is made up of carbon dioxide, with trace amounts of methane and water. Mars is known as the Red Planet because of the iron oxide in its atmosphere, but that atmosphere is so thin, it cannot protect the planet's surface and trap

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heat with its greenhouse gases. As a result, the surface temperature of Mars is very cold, as low as –90°C.

Earth remains the "just right" planet because of its distance from the Sun, and its atmosphere that traps and retains the right amount of heat to allow liquid water to exist. These are some of the reasons Earth is just right to sustain human life.

The concept of the HZ leads inevitably to the question of other life in the universe. There are a great many planetary systems in the Milky Way galaxy, and odds are good that some of these planets will be in the HZ. Such Goldilocks planets may have conditions similar to Earth with the proper atmosphere, liquid water, and habitable temperatures.

Planets outside our solar system are known as extrasolar planets, or exoplanets. Scientists have already identified hundreds of exoplanets. Astronomers are tirelessly searching for Earth-like planets. Perhaps there is life on other Goldilocks planets.

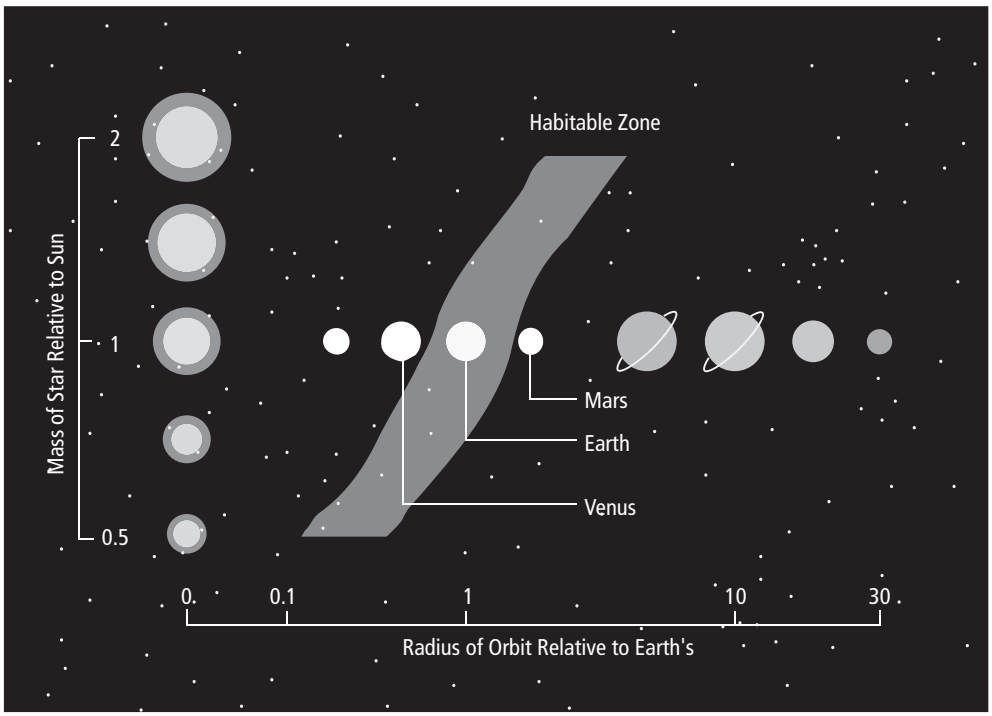


Figure R5.1
This graphic shows the relationship of the mass (and luminosity) of a star to the distance of the star's habitable zone.

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