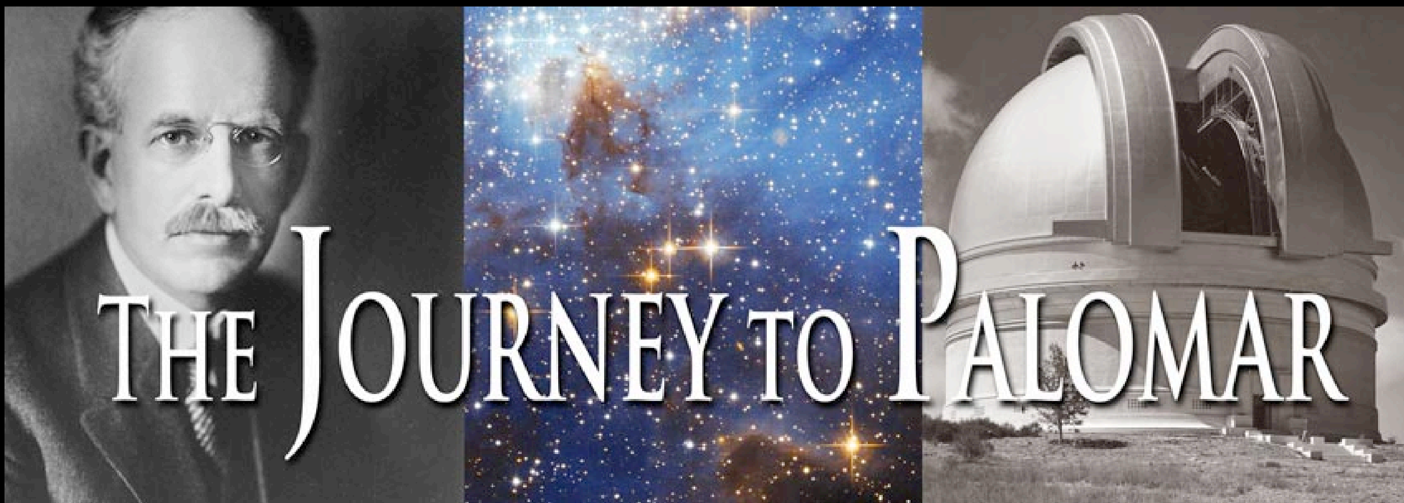

TEACHER GUIDE

For Teachers of Grades 6-12

PBS

OVERVIEW

The Journey to Palomar is an engaging story of the life and times of one of the most remarkable scientists of all time. When we read about the lives of such great thinkers as Galileo, Marie Curie, or Einstein, the focus is on their individual contributions to science. What is unique about George Ellery Hale is that he opened the door to solving some of the greatest mysteries of the cosmos not just through his own discoveries, but by paving the way for his fellow astronomers and future generations of scientists.

Most people, especially young people, are not aware that America led the world in space exploration long before NASA and the Moon landing. For nearly five decades, from the 1890s through the 1930s, Hale led the effort to build the four biggest telescopes in the world. The astronomers who used them throughout the 20th century made the greatest discoveries since Copernicus and Galileo. The science and technology that American astronomers and engineers pioneered led to the marvels we see today, like the amazing images from the Hubble Space Telescope.

Hale also changed the nature of astronomy, from a process of observing and describing objects in the heavens to a science rich in theories of how stars and galaxies evolved, and how the universe as a whole came into being. Hale established the “new” science of astrophysics, with the goal of determining not only *where* objects were in the sky, but *what* they were and whether they were changing over time.

The Journey to Palomar provides a lot of information to digest in a single sitting. Students need time to think about and process what they are seeing by talking with the teacher and other students. Even if the 90-minute timeframe of the film fits perfectly into a double science period, it is best to break it into several segments, followed by class discussion.

The Journey to Palomar Teacher Guide
was funded by

NORTHROP GRUMMAN
DEFINING THE FUTURE

http://www.northropgrumman.com/

Images courtesy of:
Astronomical: NASA/STSci
Historical: The Huntington Library, Art Collections & Botanical Gardens

Developed by Cary Sneider, Ph.D.
in collaboration with Mason Productions, Inc.
and The Astronomical Society of the Pacific

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Since the most common period length is 45 to 55 minutes, an ideal approach is to split the viewing into four segments followed by discussion. If you take this approach, be sure to record the program when it airs on broadcast television (or purchase the DVD) and review the following standards-based **lesson plans** designed to help your students get the most out of the film.

1st Class: Who Was George Ellery Hale and What Did He Do?
2nd Class: What Do Telescopes Do? Why Is Size Important?
3rd Class: How Has Our Understanding of the Universe Changed?
4th Class: How Did Hale's Personality and Illness Shape His Life?

As an educational experience, *The Journey to Palomar* can lead to an entire unit of study for middle or high school students, which is far richer than the 90-minute video itself. Standards-based **Unit Plans** on three major themes of the film are provided for structuring a sequence of activities that may last a week or longer. The first four ***lesson*** plans above give the students a chance to watch and discuss the program, while the three ***units*** give them a chance to explore in depth one or more of the themes introduced in the film. It is recommended that you complete all four lessons before starting one of the units, which can be presented in any order.

Unit 1. Understanding the Universe: The transformation of the science of astronomy from describing the motions and positions of objects in a universe that was thought to be unchanging, to learning about the physics and chemistry of stars in an evolving universe.

Unit 2. The Building of Large Telescopes: The essential relationship between engineering and science, the development of methods, machines, and materials at the cutting edge, and of course the design of the telescope itself.

Unit 3. Hale and Overcoming Illness: Interwoven throughout this epic tale of how the world's greatest observatories came into being is an account of the vision, passion, and charm of this remarkable person, as well as the tragedy of Hale's lifelong struggle with illness.

Each of the lessons and units have been developed to align with one or more educational standards listed in the 2008 update of the *Benchmarks for Science Literacy*, which may be found at: http://www.project2061.org/publications/bsl/online/. A chart showing major alignments (dark shading) and minor alignments (light shading) for each lesson and unit is shown on the next page.

Alignment with *Benchmarks for Science Literacy Online*	Lessons				Units		
By the end of the 8th grade, students should know that	1	2	3	4	1	2	3
The sun is a medium-sized star located near the edge of a disc-shaped galaxy of stars, part of which can be seen as a glowing band of light that spans the sky on a very clear night.							
The universe contains many billions of galaxies, and each galaxy contains many billions of stars. To the naked eye, even the closest of these galaxies is no more than a dim, fuzzy spot.							
The sun is many thousands of times closer to the earth than any other star. Light from the sun takes a few minutes to reach the earth, but light from the next nearest star takes a few years to arrive. The trip to that star would take the fastest rocket thousands of years.							
Some distant galaxies are so far away that their light takes several billion years to reach the earth. People on earth, therefore, see them as they were that long ago in the past.							
By the end of the 12th grade, students should know that							
The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements found on earth and behave according to the same physical principles.							
On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass.							
Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years.							
Eventually, some stars exploded, producing clouds containing heavy elements from which other stars and planets orbiting them could later condense. The process of star formation and destruction continues.							
Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and X-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle data and complicated computations to interpret them; space probes send back data and materials from remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed.							
Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe.							
Using the newly invented telescope to study the sky, Galileo made many discoveries that supported the ideas of Copernicus. It was Galileo who found the moons of Jupiter, sunspots, craters and mountains on the moon, and many more stars than were visible to the unaided eye.							
Ideas about what constitutes good mental health and proper treatment for abnormal mental states vary from one culture to another and from one time period to another.							
Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge provides a means of estimating what the behavior of things will be even before they are made. Moreover, science often suggests new kinds of behavior that had not even been imagined before, and so leads to new technologies.							

"FOR TEACHERS" SITE MAP

Introduction to "For Teachers" Website

- Overview

Alignment to Benchmarks for Science Literacy

Lesson Plans

- 1st Lesson: Who Was George Ellery Hale and What Did He Do?
- 2nd Lesson: What Do Telescopes Do? Why Is Size Important?
- 3rd Lesson: How Has Our Understanding of the Universe Changed?
- 4th Lesson: How Did Hale's Personality and Illness Shape His Life?
- Concept Maps: A Powerful Visual Aid for Learning

Unit Plans

- Unit 1. Understanding the Universe
  - Activity 1A. Diagnostic Quiz about the Sun and Stars
  - Activity 1B. Observing the Sun Safely
  - Activity 1C. Sun-Earth Viewer
  - Activity 1D. How Do We Know the Sun Is a Star?
  - Activity 1E. Distinguishing between Nebulae and Galaxies
  - Activity 1F. Structure and Evolution of the Universe
  - Further Resources for Learning about the Universe
- Unit 2. The Building of Large Telescopes
  - Activity 2A. Using a Telescope to View the Moon, Planets, and Stars
  - Activity 2B. How Do Telescopes Work?
  - Activity 2C. The Problem of "Seeing."
  - Activity 2D. Size Matters
  - Activity 2E. Telescopes of Tomorrow
  - Activity 2F. Science and Engineering
  - Further Resources for Learning about Telescopes
- Unit 3. Hale and Overcoming Illness
  - Activity 3A. Breaking the Silence
  - Activity 3B. The Science of Mental Illness

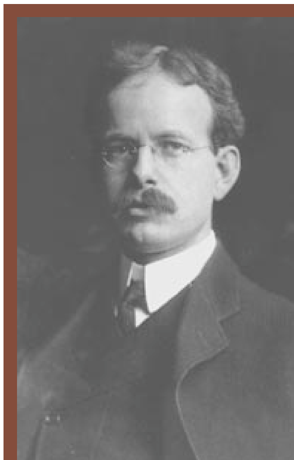
LESSON PLANS

Unlike a textbook, *The Journey to Palomar* is not easily split into chapters. The three themes of the film—Hale the person, the building of large telescopes, and understanding the universe—are interwoven. Following Hale's life and accomplishments is a more natural and engaging way of telling the story than it would be to separate the themes. However, in order for your students to take away the really important ideas in the film, the following lesson plans are structured to bring out these themes one at a time.

1st Class: Who Was George Ellery Hale and What Did He Do?
2nd Class: What Do Telescopes Do? Why Is Size Important?
3rd Class: How Has Our Understanding of the Universe Changed?
4th Class: How Did Hale's Personality and Illness Shape His Life?

Each lesson can fit in one 45- or 50-minute class period. Or two lessons could fit into a 90-minute block.

1st LESSON: WHO WAS GEORGE ELLERY HALE AND WHAT DID HE DO?


George Ellery Hale

The objective of Lesson One is to introduce students to the major themes of the story, with emphasis on the early influences in Hale's life. Start out with an overview to alert your students to what they are going to see and know why it's an important part of their learning. For example:

"You are about to see the first part of a film about a remarkable person: George Ellery Hale. The film is an excellent introduction to the science and technology of astronomy. Today I'd like you to focus on how one individual can transform a whole field of science.

"Have any of you heard of George Ellery Hale? What have you heard?

"We'll be watching the first fifteen minutes of this film. Afterwards I will ask some questions, so you might want to jot down notes on what you hear about who George Ellery Hale was, what he did, and how he affected the lives of other people."

Viewing. View the first 14 minutes of *The Journey to Palomar*. A good place to stop the film is after Yerkes Observatory finally opens. This section introduces all of the themes of the film—the influences on Hale's life, his passion for astronomy, his drive to build large telescopes and need to influence wealthy people, and his lifelong battle with a serious illness that today could quite possibly be diagnosed and successfully treated.

Think, Pair, Share. Before leading an all-class discussion, it's helpful for students to have two or three minutes to collect their thoughts by writing down their own answers to the questions. They can then share with one other student. This method, called "think, pair, share," can be used for each of the four lessons. It's usually best not to ask too many questions, so the students have time to think more deeply about the subject.

Questions: Here are four open-ended questions that might frame the discussion.

- What were the early influences on Hale as a young man?
- What questions about astronomy interested Hale?
- What did he discover about the Sun?
- What is Hale known for today?

Concept maps are a wonderful way to organize the discussion and keep track of the students' understanding of the film. Since it takes a little while to become fluent at creating concept maps, start by recording the students' ideas as a list on the board, and then demonstrate how to organize their ideas into a concept map.

Keep the first concept map simple. If possible, draw it on a large sheet of butcher paper, so that a new concept map can be added after each lesson. An illustration of a list and concept map that might emerge from the first lesson is shown on the next page.

Image courtesy of:
Special Collections Research Center,
University of Chicago Library

Discussion: Who was George Ellery Hale and what did he do?

What were the early influences on Hale as a young man?
"Growing up in Chicago."
"Charles Darwin's theory of evolution."
"His father was rich and built an observatory for him."

What questions about astronomy interested Hale?
"He wanted to know what the Sun was made of."
"He wanted to know if stars evolved like living things."

What did he discover about the Sun?
"He found out it had carbon in it."

What is Hale known for today?
"Building really big telescopes."

Yerkes Observatory
under construction c1895

Concept Map Summarizing Ideas from Lesson 1

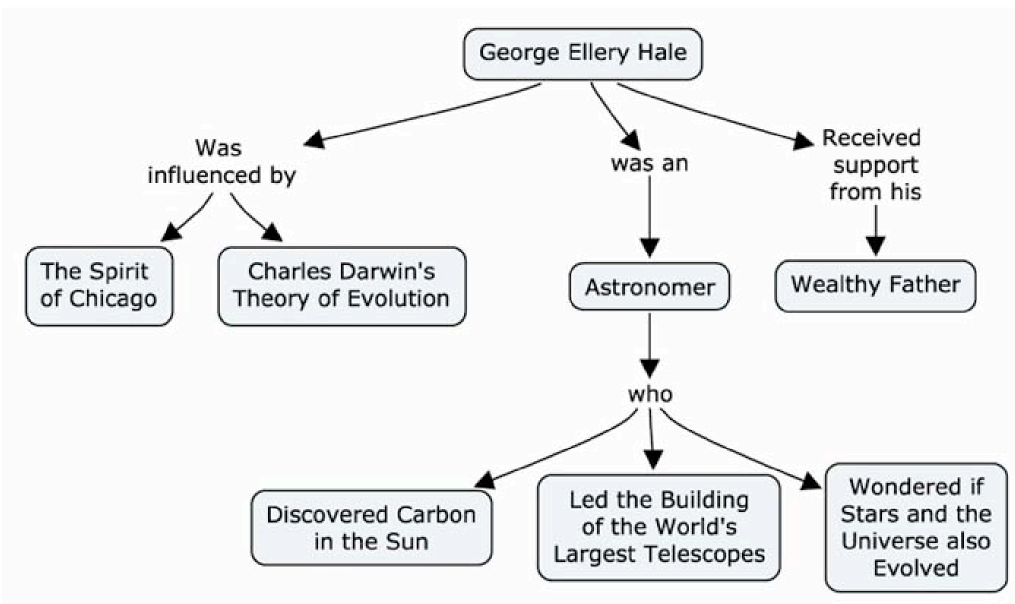


Image courtesy of:
The Huntington Library,
Art Collections & Botanical Gardens

2nd LESSON: WHAT DO TELESCOPES DO? WHY IS SIZE IMPORTANT?

Yerkes *refractor* displayed at the Columbian Exposition, 1893

A reasonable objective for Lesson Two is to communicate how telescope size is measured, and why bigger telescopes are better than smaller ones.

How Size Is Measured. It may seem odd for a telescope that weighs hundreds of tons and is twenty or thirty feet in length to be measured in inches. However, to an astronomer that is not so strange, since a telescope's performance depends primarily on the diameter of its lens or main mirror. The 40" telescope at Yerkes Observatory has a lens that is forty inches in diameter. The 100" Hooker Telescope on Mount Wilson has a main mirror that is one hundred inches in diameter. (The difference between telescopes using lenses and mirrors is discussed in **Unit 2: The Building of Large Telescopes**.)

Size Matters. Most people believe that larger telescopes simply magnify more, or make things appear closer. While that is not wrong, these are not the major advantages of larger telescopes. The important advantages of larger telescopes are that: 1) They collect more light, so it is possible to see fainter objects; and 2) They can reveal finer details. This is called "resolving power."

Viewing. Have the students view the next 30 minutes of the film. A good time to stop is just after the 100" Hooker telescope section is finished, and Hale views "first light" around midnight and sees that the image of a star is perfect (approximately 43 minutes from the beginning of film).

Think, Pair, Share. As in lesson one, ask your students to write down their answers to open-ended questions, then share with another student before participating in an all-class discussion. Since your students are now familiar with the procedure, this discussion should take less time. Invite the students to jot down their responses to the following questions by drawing concept maps if they wish.

Questions:

- Why did Hale need big telescopes?
- Why was it necessary for Hale to get help from rich people?
- What are the two most important parts of a big telescope?
- What are two different kinds of telescopes in the film?
- What kind of telescope is at Yerkes Observatory?
- What kind of telescope is at Mount Wilson Observatory?

Yerkes 40-inch *lens*

On the next page is a summary of possible responses to these questions and how they might be mapped. This time, as you map, point out that a concept map consists of: 1) Major concepts in boxes; 2) connected by words or phrases to show how the concepts are connected. Ideas usually flow from the top to the bottom of the page.

Summarize the lesson by describing the two types of telescopes and explaining the major advantages of larger telescopes.

Images courtesy of:
Special Collections Research Center,
University of Chicago Library

Discussion: What do telescopes do? Why is size important?

Why did Hale need big telescopes?
"So he could see stars that are far away and very dim."
"To see what things look like in detail."

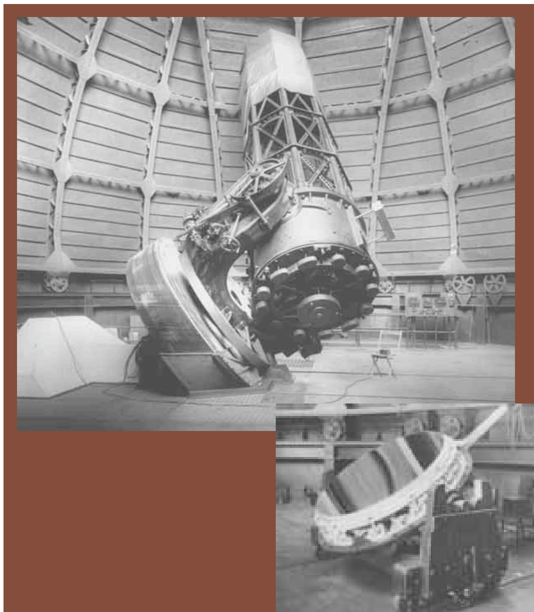
Why was it necessary for Hale to get help from rich people?
"Big telescopes cost a lot of money—millions!"
"Top experts are needed to make telescopes, and they are probably paid a lot."

What are the two most important parts of a big telescope?
"The lens or mirror, and the mounting."

What are two different kinds of telescopes in the film?
"Refractors use lenses and reflectors uses mirrors."

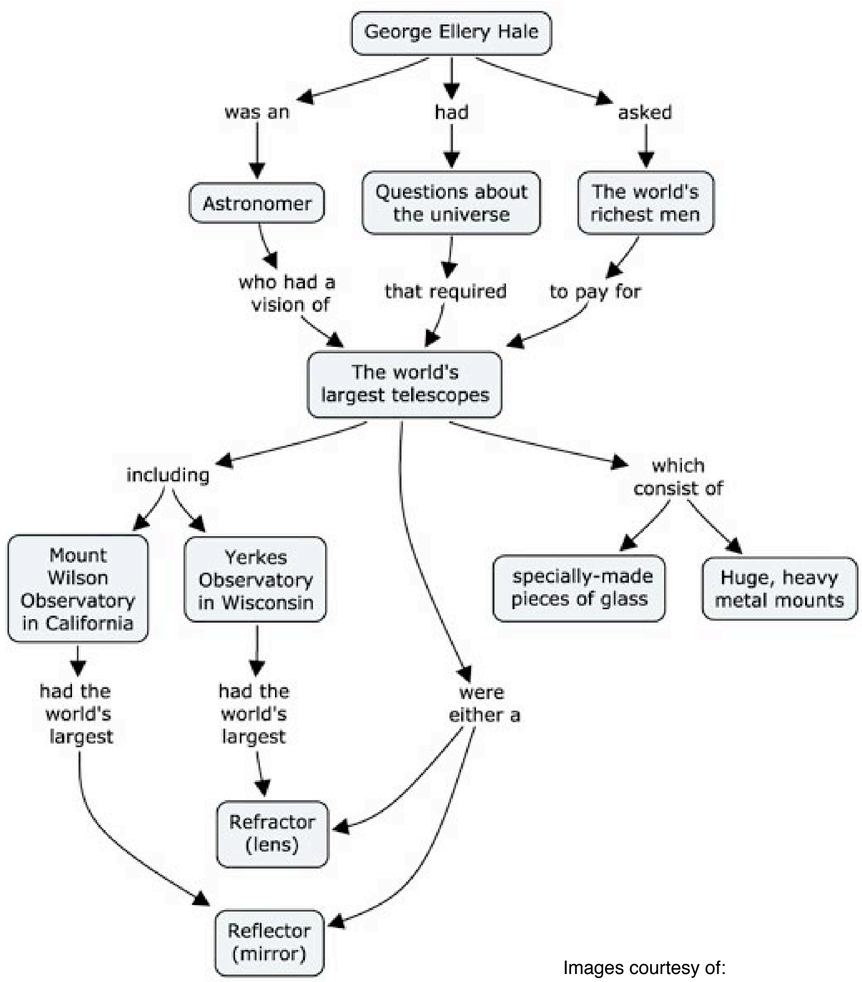
What kind of telescope is at Yerkes?
"The biggest *refractor* in the world."

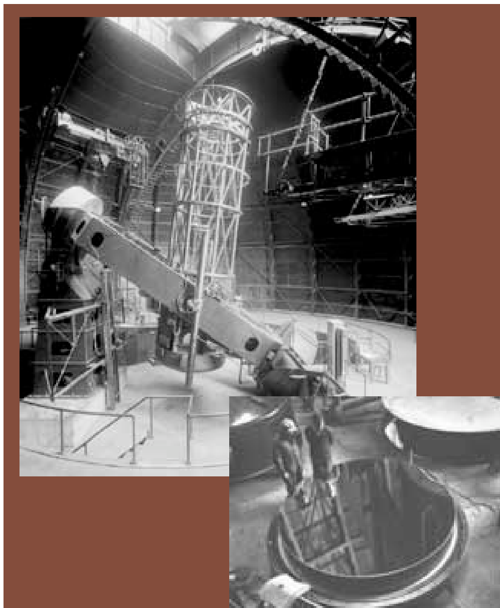
What kinds of telescopes are at Mount Wilson?
"The biggest *reflectors* in the world (at that time.)"



Mount Wilson 60-inch *reflector* and 60-inch *mirror*

Concept Map Summarizing Ideas from Lesson 2





Mount Wilson 100-inch *reflector* and 100-inch *mirror*

Images courtesy of:
The Huntington Library,
Art Collections & Botanical Gardens

3rd LESSON: HOW HAS OUR UNDERSTANDING OF THE UNIVERSE CHANGED?

The objective of Lesson Three is for the students to understand the important changes that Hale brought about in the science of astronomy. He implemented two major changes.

The Goals of Astronomers. Prior to Hale's day astronomers were primarily interested in positions and motions of astronomical objects. Hale thought it was possible to find out the true nature of stars and whether the universe as a whole evolved over time.

The Tools of Astronomers. The advantages of large telescopes had been recognized long before Hale's day, but few expected that telescopes larger than 40 inches in diameter would perform better than smaller telescopes given the distortions due to Earth's atmosphere. Hale was also one of the first to recognize that laboratories are needed for astronomy—to compare stellar spectra with spectra of known substances on Earth.

Viewing. Have the students view the next 30 minutes of the film. This portion of the film concerns the tremendous effort to construct the 200" telescope now on Palomar Mountain, which for decades was the largest telescope in the world. This section also tells about the most important discoveries made with Hale's telescopes, including Hubble's discovery that the "nebulae" are in fact distant galaxies like our own Milky Way, and the "expanding universe." These discoveries led to the "Big Bang" theory, which answered the questions that Hale had raised decades earlier about the evolution of the entire universe.

A good time to stop the film is at Hale's death, while his masterpiece—the 200" telescope—is being completed atop Palomar Mountain (approximately 73 minutes from the beginning of film).

Ladling molten glass for the
Palomar 200-inch telescope mirror

Edwin Hubble using the
Mount Wilson 100-inch telescope

Concept Maps. By now the students should be more familiar with how to construct concept maps. Instruct them to first jot down the answers to the following questions, and then work with a partner to apply their ideas to construct a concept map that illustrates the answers to these questions. If possible give each pair of students a large sheet of butcher paper and colored markers to draw their concept maps. Plan to share them the following day.

Questions: What questions have been answered, thanks to Hale's telescopes about…

- The Sun?
- The Stars?
- Nebulae?
- The Universe?

Walk around the room as students create their concept maps so that you can coach teams of students in how best to create their concept maps.

Images courtesy of:
The Huntington Library,
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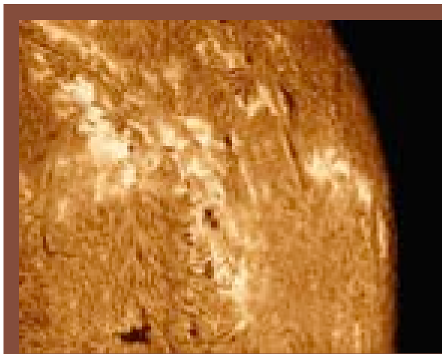
Discussion: How has our understanding of the universe changed?

What have you learned, either from the film or previously, about:



Our nearest star, the Sun

The Sun? “The Sun is a star. It’s bright because it’s very close to Earth.”
“There are dark spots on the Sun.”
“The Sun has a magnetic field.”
“The Sun is made of hydrogen, helium, carbon, and some other things.”

The Stars? “The stars are distant Suns.”
“Stars have life cycles. They are born, they ‘live’ and they ‘die.’”
“Some stars change their brightness.”
“Stars make up our Milky Way, as well as other, more distant galaxies.”

Nebulae? “Some nebulae are clouds of gas and dust in our own Milky Way galaxy.”
“Some of what used to be called ‘nebulae’ turned out to be other ‘island universes,’ or what we now call galaxies.”

The Universe? “The universe is expanding.”
“The universe can be measured by finding distances to the furthest galaxies.”

One Possible Concept Map Summarizing Ideas from Lesson 3

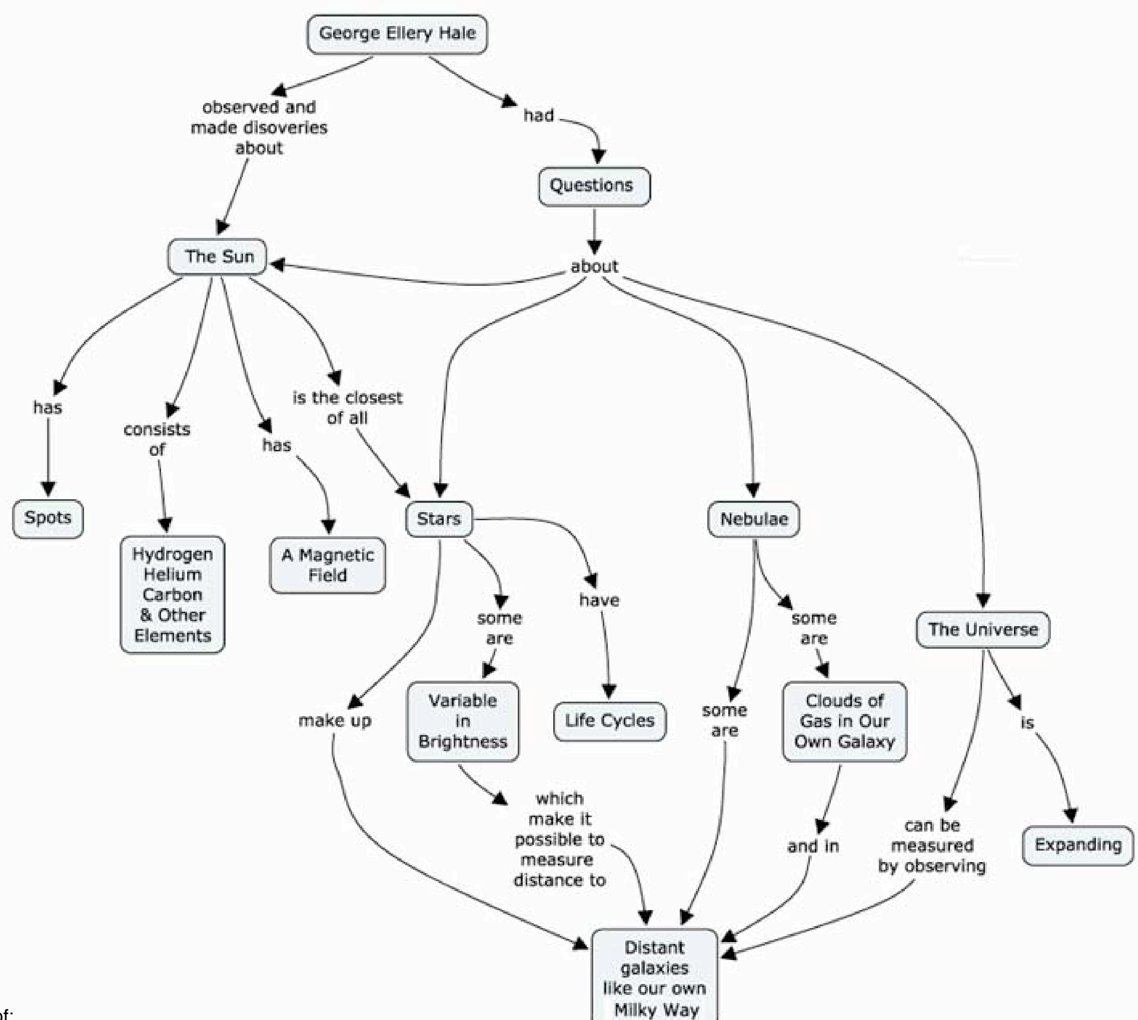
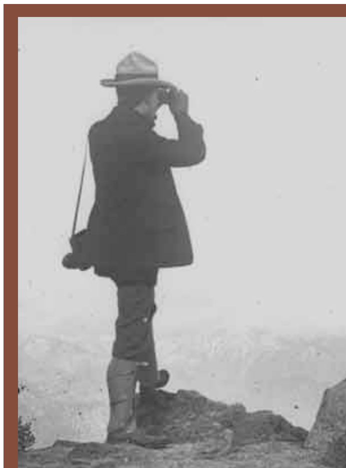


Image courtesy of:
The Carnegie Observatories

4th LESSON: HOW DID HALE'S PERSONALITY AND ILLNESS SHAPE HIS LIFE?

Spend the first few minutes of class having the students share their concept maps from the previous day with the rest of the class. Ask the students to notice what different people emphasized as most important. Then watch the rest of the film and discuss it.



Hale on Mount Wilson

A primary objective for Lesson 4 is for the students to express their own ideas about serious illness, and to realize that some of the world's most remarkable people have had to overcome serious mental and physical conditions. Exactly what Hale's condition was by today's standards remains a question that is debated by scholars, since the symptoms that are described in his known records could be interpreted as physical, mental, or a combination of both. The emphasis should be on understanding how different types of afflictions affect people and how people with great mental and/or physical challenges overcome them to make great contributions to humanity. Following are other examples:

- **John Nash**, who revolutionized economics with his investigations of game theory, had schizophrenia. More at: http://www.pbs.org/wgbh/amex/nash/filmmore/fd.html
- **Stephen Hawking**, a brilliant astrophysicist continues to make discoveries although he has has Lou Gehrig's disease. More at: http://www.pbs.org/wgbh/aso/databank/entries/bphawk.html
- **Ludwig van Beethoven** was one of the greatest composers of all time. He was deaf most of his adult life and struggled with deep depression. More at: http://www.pbs.org/wnet/gperf/education/beethoven.html

Key elements of Hale, the person, are:

Hale studying the Sun

Hale's Passion: He was not just *interested* in astronomy, he was ***passionate*** about solving some of the greatest mysteries of the universe—how stars and galaxies evolve, how the universe came into being.

Hale's Personality: Just about everyone liked George Ellery Hale. It is very possible that he would not have accomplished what he did if it were not for his charming personality.

Hale's Illness: It is not known for certain whether Hale's problems were mental, physical or a combination of both, but it is clear that his condition was terribly painful and debilitating for him. Nonetheless, the fact that he was such a forward-looking thinker and was able to contribute so much to the world, achieving goals that were thought by some to be impossible, suggests that perhaps his condition shaped his ideas and his life.

Viewing. Students watch the last fifteen minutes of the film, which recounts some of the remarkable achievements of Hale's life—the completion of the 200" Hale Telescope, its role in the discovery of Quasars, the most energetic and distant objects in the universe, the establishment of Caltech and the National Research Council, and a complete transformation of how we view ourselves in the universe.

Concept Maps. For this final lesson you may want to have each student create their own concept map of Hale, the Person, as a homework assignment. Start with the following questions:

Questions:

- How would you describe Hale's interest in astronomy?
- What was Hale's personality like?
- What were some of the symptoms of Hale's illness?
- Has watching the film changed any of your prior ideas about the challenges of illness?

Images courtesy of:
The Huntington Library,
Art Collections & Botanical Gardens

Discussion: How did Hale's personality and illness shape his life?

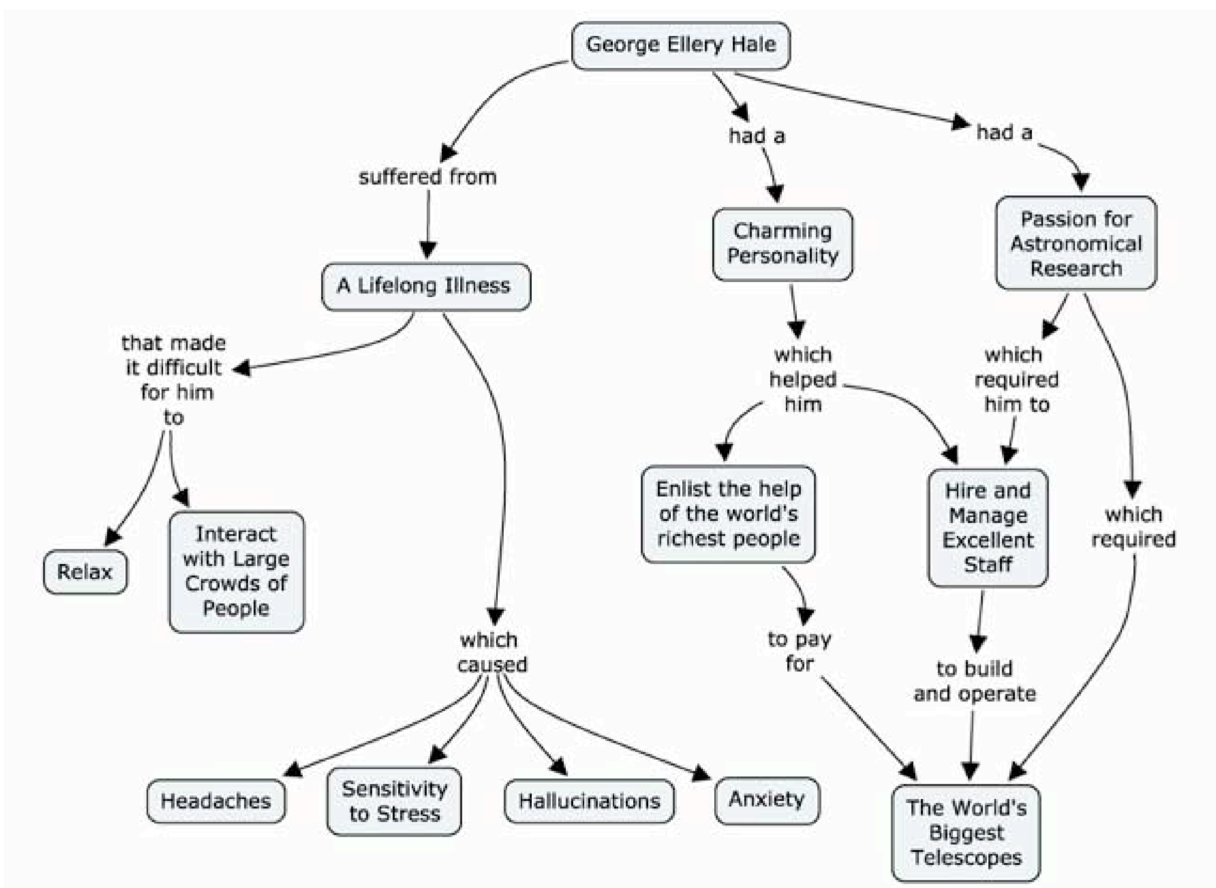
How would you describe Hale's interest in astronomy?
"He was passionate about finding out if the stars and universe evolve."
"His passion drove him to lead the building of very large telescopes."
"He hired the best astronomers for his observatories.

What was Hale's personality like?
"Just about everybody liked him."
"He was able to talk extremely rich people into donating their money for science."
"His personality helped him supervise the astronomers."

What were the symptoms of Hale's illness?
"He had headaches, anxiety, hallucinations, and he was very sensitive to stress."
"He had a hard time relaxing and did not like large crowds of people."

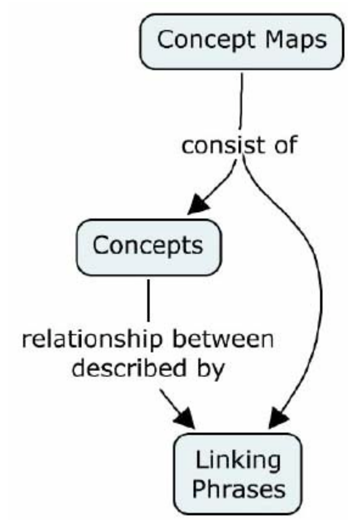
How was your understanding of overcoming illness changed from watching the film?
Answers will vary.

One Possible Concept Map Summarizing Ideas from Lesson 4



Assessment. To assess students' understanding of *The Journey to Palomar* and accompanying lessons, have each student create a concept map of the most important ideas in the film.

CONCEPT MAPS: A POWERFUL VISUAL AID FOR LEARNING



Concept maps provide an alternative way for your students to organize their ideas and show what they have learned from the film. Concept maps are composed of concepts connected by lines that explain how the concepts are related. Two concepts linked by a phrase form a proposition or statement. An example is shown at right. The structure of a concept map—not only the number of concepts, but also the variety of ways they are connected— indicates how deeply the creator of the map understands the topic.

In the 1970s, Dr. Joseph Novak and his research group at Cornell University in New York pioneered concept mapping as a way to "view" a student's knowledge on a topic and easily compare one student's views to others'. As an assessment tool concept mapping has some advantages over traditional testing.

- When used as an assessment tool, concept maps have the potential to show not only what the students have learned, but also the relationships that they perceive among ideas.
- Concept mapping is non-linear. Students can lead the teacher along their own pathways, offering insight into how they think about the subject, revealing correct ideas, possible misconceptions, and possibly new and unexpected ways of thinking and reasoning.
- Drawing a concept map is a creative process, and therefore more likely than tests to engage students' enthusiasm and draw on their best thinking.
- Concept maps are less constraining that most test questions. For example, students can be asked to: "Create a concept map to show what you've learned about George Ellery Hale." Such a task allows students to reveal everything they've learned on the topic, and not be constrained by specific questions.

Students need to be introduced to concept mapping before it can be used as an assessment tool. A number of methods, cited in the list of resources below, can be found on the Internet. Novak and Gowin provide a detailed how-to on introducing concept mapping to various grade levels in Learning How to Learn (1984).

An excellent software tool for creating concept maps, or introducing your students to creating their own concept maps, can be downloaded from the web, free of charge, at the following website: http://cmap.ihmc.us/.

Acknowledgements: Thanks to Joseph D. Novak for developing Concept Mapping as a tool in science education and to James Gorman for researching this section.

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https://www.cu.edu/academicaffairs/assessment/assessment_toolbox/documents/CncptMpAssessSTANFORD_001.pdf

UNIT PLANS

The Journey to Palomar can be used as an excellent introduction to in-depth study of a number of topics in the science curriculum. In this section of the Teacher Guide you will find suggestions for teaching the following units:

Unit 1. Understanding the Universe: Hale's great contribution was to transform the science of astronomy from describing the characteristics and positions of objects in the sky, to learning about the structure and evolution of the universe and everything in it. This unit suggests additional lessons on the following topics:

- The Sun and stars
- Nebulae and galaxies
- The structure and evolution of the universe

Unit 2. The Building of Large Telescopes: *The Journey to Palomar* is not just about science; it's also about the essential relationship between engineering and science, about the development of methods, machines, and materials at engineering's cutting edge, and of course the design of the telescope itself. This unit suggests additional lessons on the following topics:

- Outdoor telescope viewing
- Viewing telescopic images online
- How telescopes work
- Why bigger telescopes are better
- The effects of atmospheric distortion
- Telescopes of the future
- How science and engineering support each other

Unit 3. Hale and Overcoming Illness: Interwoven throughout this epic tale of how the world's greatest observatories came into being is an account of the vision, passion, and charm of this remarkable person, as well as the tragedy of Hale's lifelong struggle with serious illness. This unit suggests additional lessons on the following topics:

- Breaking the silence about mental illness
- The science of mental illness

The Journey to Palomar was inspired by author Ronald Florence's book *The Perfect Machine: Building the Palomar Telescope* (Harper Collins). The book is an excellent resource for a broader understanding of the challenges of building the giant telescopes featured in *The Journey to Palomar*, as well as the science they were used for.

UNIT 1. UNDERSTANDING THE UNIVERSE

Hale transformed the science of astronomy from describing the motions and positions of objects in a universe that was thought to be unchanging, to learning about the physics and chemistry of stars in an evolving universe. His legacy is therefore even greater than the magnificent telescope on Palomar Mountain. It includes the remarkable astronomical discoveries of the 20th century, from Quasars to the Big Bang, and the amazing sights brought home to us by the Hubble Space Telescope—and giant telescopes yet to come.

Hale's legacy to science education is the very exciting and dynamic field of astronomy that we have to share with our students. However, educational researchers have found that successfully sharing these insights is no simple matter. Even college undergraduates have many misconceptions about astronomy that are very difficult to change. Consequently, the first activity is a diagnostic quiz so that you can use to find out what your students already know, and the misconceptions that they may hold, about the Sun and stars, nebulae and galaxies, and the universe as a whole. The other activities provide ideas for engaging your students in learning more about this exciting field, and hopefully shedding some of their misconceptions.

The goals of Unit 1 are for students to:

- Explain that the Sun is the closest star to Earth.
- Describe some of the characteristics of the Sun, including sunspots.
- Give evidence that the Sun is a star.
- Distinguish between nebulae and galaxies.
- Learn some initial ideas about the large-scale structure of the universe, its origin, and subsequent evolution.

George Ellery Hale was a solar astronomer. He wrote, *"Let us begin with the Sun. Its prime interest and importance, as the source of the light and heat on which we all depend, would be sufficient reason for its special consideration. But equally significant is the fact that the Sun is the only one of all the stars which lies near enough to the earth to be studied in detail ... if we wish to know what a star really is we must approach it closely, and this is possible only in the case of the Sun."*

George Ellery Hale, Ten Years Work of a Mountain Observatory, 1915

For the first 15 years, Mount Wilson Observatory was called 'Mount Wilson Solar Observatory.'

Activity 1A. Diagnostic Quiz about the Sun and Stars

George Ellery Hale realized that the easiest way to study stars was to start with the one in our own backyard—the Sun. Although the idea that the Sun is a star is presented in virtually all elementary school textbooks, the lesson is lost on many students, and few pick up that information before reaching college. Neil Comins (2001), an astronomy professor from the University of Maine, offers some examples of misconceptions that he has encountered over the years:

> "The Sun is a unique object, not a star."
> "The Sun/stars will last forever."
> "The Sun shines by burning gas or from molten lava."
> "The Sun doesn't rotate."
> "The Sun is solid."
> "There are many stars in the solar system."
> "Stars really twinkle."
> "Polaris, the North Star, is the brightest star in the sky."
> "A shooting star is actually a star falling through the sky."
> "All stars are yellow."

Lori Agan (2004) interviewed college students and found similar misconceptions plus a few others, such as "Stars are smaller than planets." When asking students about stars, one student brought up the subject of galaxies:

Researcher: "What is the galaxy? You said the Sun's going to affect the galaxy."

Student: "Right. I don't know specifically, but I would imagine that the galaxy is like a division of what we know as the universe like cells are a division of an organism."

Not only are many college students' ideas about stars and galaxies primitive, their understanding of the origins of the universe is even more limited. Slater, Prather and Offerdahl (2003) asked students about the Big Bang theory. Since the Big Bang is a widely accepted theory of the origin of both space and matter in the universe, they were surprised to find that although nearly all undergraduates had heard of the Big Bang (94%), approximately 25% of those thought it was a theory describing the creation of stars, planetary systems, solar systems, or Earth. And although more than half of the students who had heard of the Big Bang understood it was a theory of the creation of the universe, a large majority of them (80%) thought it was an explosion in pre-existing matter. Only two students (1% of the sample) correctly said it was an explosion from nothing.

A good way to launch a unit on the Sun and stars is to find out what your own students think by asking the same questions that these researchers asked their students. Following is a list of open-ended questions drawn from these studies that you can use as a quiz. An answer key with responses that are consistent with the understanding of modern astronomers is at right:

QUIZ QUESTIONS	CORRECT RESPONSES
What is a star?	A large spherical (ball-shaped) body of hot gases that produces its own light.
How do stars shine?	Nuclear reactions (hydrogen fusion) deep inside the star produce huge amounts of energy that eventually escape in the form of electromagnetic waves (heat and light for lower level students).
What is the difference between a star and a planet?	A star produces its own light, while a planet can only be seen by reflecting light from a nearby star. Planets are too small to shine like stars.
Where do stars come from/how are they formed?	Stars are "born" when material in huge clouds of gas and dust "clump" together and continue to attract more material due to gravitational attraction until it becomes large enough to ignite nuclear reactions deep inside the star.
Do stars change over time?	Yes. Stars "evolve" as they gradually burn their nuclear fuel, sometimes growing in size, throwing off shells of hot gases, and either cooling down, or if they are large to begin with, "dying" in a huge explosion.
Is there anything left after a star stops shining?	Yes. The fate of a star depends on its mass. A very massive star may explode or become a black hole. A less massive star may become a very dense neutron star, or just a cool dark body called a black dwarf.
How do stars differ from one another?	They differ in color, size, mass, composition, age, and whether or not they are surrounded by a system of planets.
What's the nearest star to the Earth?	The Sun
What galaxy is the Sun in?	The Milky Way
If the Sun were the size of a basketball (a little less than 10 inches in diameter) what object would you use to represent the size of the Earth?	The Sun's diameter is about 100 times Earth's diameter. So the correct answer is an object that is about one tenth of an inch in diameter.
What is a galaxy?	A galaxy is an "island universe," or a collection of a billion to a trillion stars, often in a pinwheel shape, but sometimes shaped like the Goodyear Blimp or irregular in shape.
What is a nebula, and how is it different from a galaxy?	The Big Bang is a theory of how all matter, energy, time and space came into existence. It is supported by several strong lines of evidence.
What does the Big Bang Theory attempt to explain?	The Big Bang is a theory of how all matter, energy, time and space came into existence. It is supported by several strong lines of evidence.

The most useful way to analyze the data from your class will be to do an "item analysis." That is, list the number of "right," "partially right" and "wrong" answers to each question in a table to determine which ideas will need the greatest amount of attention.

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Activity 1B. Observing the Sun Safely

This activity is adapted from "Observing the Sun Safely" by Professor John R. Percy, Universe at Your Fingertips, San Francisco: Astronomical Society of the Pacific, 1995.

A. SAFETY NOTE: ***Before doing this activity, warn the students to never look directly at the Sun—with or without a telescope or binoculars, as it can cause serious permanent damage to their eyesight.***

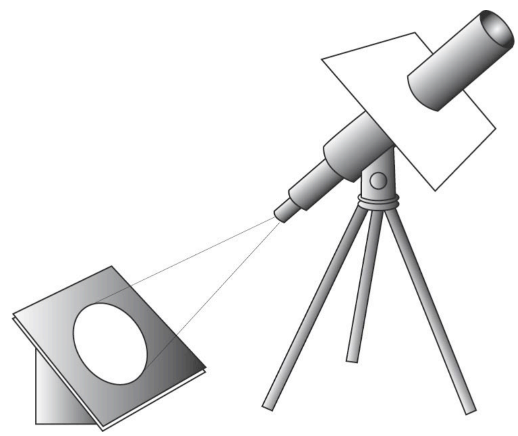
B. Telescope or Binocular Projection

One of the sources of misconceptions may be that students rarely learn about astronomy by starting with observations of the sky. Consequently, they may not connect what they learn in books with the real Sun, Moon, and stars. To avoid this problem, start by having your students observe the Sun in the sky safely, as described below.

The best way to safely see a sharp image of the Sun is to use a small telescope or binoculars. The lens should be no larger than 2" in diameter or the light will be too intense. (A larger telescope can be used if a sheet of cardboard with a 2" hole is placed over the front of the telescope to block out most of the Sun's light.)

Hold a sheet of stiff cardboard or foamcore over the end of the telescope and trace the circular outline. Cut out the circle and fit the cardboard over the end of the telescope. If using binoculars cut out just one hole, so that just one side of the binoculars is used to make a small telescope.

Prop up a sheet of white cardboard or foamcore on the ground. Point the telescope towards the Sun by observing the shadow of the telescope on the cardboard. (Do not sight along the telescope tube!) When a bright spot of light appears on the cardboard use the focus knob on the telescope to form a sharp image of the Sun.

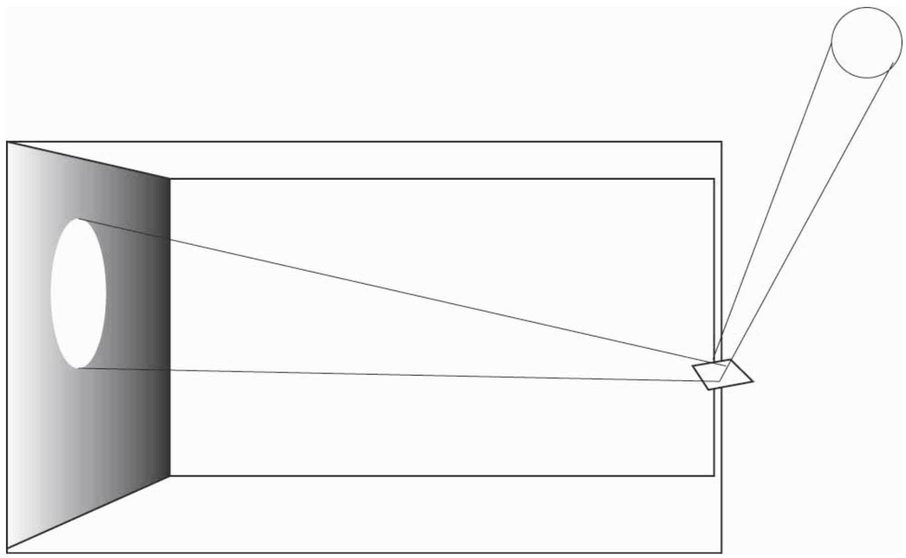


You may be lucky enough to observe dark areas on the Sun, called "Sunspots." If so, you can trace the outline of the Sun and mark the positions of the Sunspots. Observe a day or two later and you will probably see that the Sunspots have moved due to the rotation of the Sun on its axis.

C. Window Sill Reflection

Make a cardboard mask for a small mirror by punching a half-inch hole in the middle. Tape it over the mirror. On a sunny day, close all of the blinds in the classroom and place the mirror with the mask on the window sill, so that it catches direct sunlight and reflects it onto an opposite wall. If the wall is not light in color, use a large sheet of white cardboard, film screen, or other large white surface on which to project an image of the Sun.

The image will be somewhat blurry, but if there are sunspots they may show up by this method. The small spot on the mirror acts as a "pinhole," or small hole, through which all of the Sun's rays must pass. By tracing rays of light from the Sun, as in the illustration, you can see how it forms an image.



Safe Solar Projection with a Mirror on the Window Sill

D. Closure

Provide an opportunity for your students to describe what they observed. Then discuss the answers that they gave on the diagnostic quiz. Encourage differences of opinion and discussion rather than giving out the "right answers," but be sure to return to these questions at the end of the unit.

Activity 1C. Sun-Earth Viewer

http://sunearth.gsfc.nasa.gov/sunearthday/media_viewer/flash.html

One of the most beautiful and informative websites about astronomy is the Sun-Earth Viewer, developed by NASA's Sun-Earth Forum. Arrange for your students to spend at least one class period exploring this Flash application. They will find:

- A series of images of the Sun, taken in different colors of light, updated daily.
- A dozen colorful illustrations, including cut-away views of the Sun, with short narratives on topics such as: the Sun's interior, the Sun's effects on Earth, the 11-year solar cycle, how the Sun affects Earth's magnetosphere, the aurora, electromagnetic spectrum, and Earth's ionosphere.
- Colorful simulations of solar phenomena, including Coronal Mass Ejections and the Aurora.
- Interviews with solar astronomers.

This image of the Sun in Extreme Ultraviolet light was taken by the SOHO Satellite. It is one of many images displayed on the Earth-Sun Viewer website. The website allows users to magnify any part of the image, and scan to see different parts of the image in detail.

The Earth-Sun viewer provides many opportunities for your students to unravel some of their misconceptions about the Sun. However, it will still be necessary to address each misconception explicitly.

Image courtesy of:
NASA / SOHO

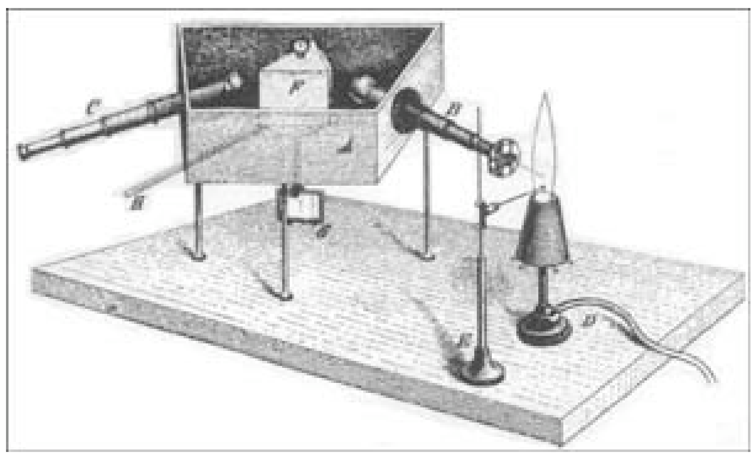
Activity 1D. Spectra: How Do We Know the Sun Is a Star?

(The following historical background is adapted from “Teaching Astronomy Through History: The Complementary Roles of Science and Engineering,” by Cary Sneider and Varda Bar, History of Philosophy and Science Education Conference, Calgary, Canada, June 2007.)

Since the ancient Greek philosophers, there has been speculation that the Sun is a star and the stars are all distant suns. However, it was not until the invention of spectroscopy that this idea was confirmed. During the 18th century Newton found that sunlight could be dispersed into various colors, but his equipment did not permit sufficient dispersion to observe emission lines in sunlight. Improvements led to the interesting discovery of dark lines in the solar spectrum by the English chemist William Hyde Wollaston in 1802, and a decade later by Joseph von Fraunhofer. While there was a lot of interest in this discovery, no one fully understood its significance until half a century later.

The mystery of the Fraunhofer lines was eventually solved with the help of Robert Wilhelm Bunsen, who invented the Bunsen burner. Today we take for granted the simple Bunsen burner—a standard piece of equipment in every high school and college chemistry lab. Its advantage is that it produces a very clean flame, so that if a sample of a chemical is placed into the flame you can see its spectrum, rather than the spectrum of the material that is burning. The advantage of the Bunsen burner for astronomy was realized when scientists from two different fields met to discuss common interests. Robert Wilhelm Bunsen was already an accomplished chemist when he met Gustav Kirchhoff, a young Prussian physicist, whom Bunsen credited with solving the Fraunhoffer mystery. In 1859 he wrote:

“At present Kirchhoff and I are engaged in a common work which doesn’t let us sleep ... Kirchhoff has made a wonderful, entirely unexpected discovery in finding the cause of the dark lines in the solar spectrum .... thus a means has been found to determine the composition of the Sun and fixed stars with the same accuracy as we determine sulfuric acid, chlorine, etc., with our chemical reagents.”



The Bunsen-Kirchoff Spectroscope from “Chemical Analysis by Observation of Spectra, Gustav Kirchoff and Robert Bunsen, Annalen der Physik und der Chemie (Poggendorff), Vol. 110 (1860), pp. 161-189 (dated Heidelberg, 1860)

George Ellery Hale built on these ideas by observing the same spectral lines of carbon in the Sun as those produced by burning a sample of carbon in his laboratory. The discovery of the same elements in the Sun as in the stars finally convinced astronomers that the Sun is indeed a star. Hale also discovered that the Sun has a magnetic field.

Observing Spectra in the Classroom

Flame Test. Many high school chemistry labs are equipped with Bunsen burners and simple materials for conducting a "flame test"—a means of identifying chemical reagents by observing the colors they produce when held in a Bunsen burner flame. This is the same procedure developed by Bunsen and Kirchoff, with the addition of a spectroscope, to compare spectra observed in the lab with those of the stars.

Spectrum Tubes. Many high school physics laboratories stock several spectrum tubes filled with various gases and a power supply to ionize the gas so that it glows. Common gases are hydrogen, helium, mercury vapor, and neon, but others are available. Turning on the power supply immediately shows that the gases glow in different colors. Observing with inexpensive diffraction gratings reveals the bright emission lines characteristic of these gases. A common activity is to show the students several tubes, have them record the colors they see, then show an "unknown star." Based on their earlier observations the students can identify a hot glowing gas in the star.

Several companies sell classroom kits for performing flame tests and observing the results with a spectroscope. Most of the same companies also sell spectrum tubes and power supplies. These companies include:

Carolina Biological <www.carolina.com>

Boreal Laboratories http://sciencekit.com

Sargent-Welch < http://sargentwelch.ca/>

Instructional Materials

GEMS Invisible Universe Guide

http://www.lhsgems.org/gemsInvUniv.html

The Lawrence Hall of Science, in collaboration with NASA's "Swift" mission to study gamma-ray bursts, has produced an activity guide dedicated to deepening student understanding of the electromagnetic spectrum. This guide is part of LHS's "Great Explorations in Math and Science" series. Recommended for teachers of Grades 6-8.

Spectroscopy Online

There are many online resources about spectroscopy. Some of the best available at the time of this writing are:

MiniSpectroscopy

http://mo-www.harvard.edu/Java/MiniSpectroscopy.html

This software displays a sample spectrum simultaneously with a graphical (intensity vs. wavelength) view. Students draw or redraw the graph using the computer mouse, and the corresponding "spectroscope view" appears or changes immediately as they draw, changing just as changes are made in the graph, giving students a kinesthetic connection between making the graph and viewing the spectrum.

Imagine the Universe

< http://imagine.gsfc.nasa.gov/>

This NASA website offers activities and information for students ages 14 and up and for anyone interested in learning about our universe. Activities include "What is Your Cosmic Connection to the Elements?" and multi-media resources. Recommended for teachers and students Grades 7-12 and general audiences.

Chandra X-ray Observatory Classroom Activities

< http://chandra.harvard.edu/edu/formal/index.html>

This section of Chandra's website contains classroom-ready activities about the electromagnetic spectrum and the objects observed by the Chandra x-ray telescope. Recommended for teachers of Grades 7-12.

Amazing Space

< http://amazing-space.stsci.edu/>

This website contains online explorations and classroom resources based on the greatest discoveries from NASA's Hubble Space Telescope. Recommended for students and teachers of Grades 3-12 and general audiences.

Starbase

http://www.ph.surrey.ac.uk/astrophysics/files/spectroscopy.html

This informative website provides a well-organized and detailed overview of stellar spectroscopy.

Project Lite

http://lite.bu.edu/

"Project LITE: Light Inquiry Through Experiments" is a software, curriculum, and materials development project that allows the user to explore physical aspects of the electromagnetic spectrum, particularly the emission and absorption of light.

Universe in the Classroom

http://www.astrosociety.org/uitc

This quarterly electronic newsletter for teachers includes an informative article with hands on activities to help teachers bring the subject right into the classroom along with additional links for digging deeper into the subject. Of particular interest might be issue number 68, http://www.astrosociety.org/education/publications/tnl/68/solar.html *Our Solar Connection: A Themed Set of Activities for Grades 5-12* by Dr. Wil van der Veen.

Activity 1E. Distinguishing between Nebulae and Galaxies


ANDROMEDA GALAXY

Hale did not make the great discovery that separated nebulae and galaxies. That discovery was made by an astronomer he hired, Edwin Hubble, and his assistant, Milton Humason, using the great Hooker 100-inch telescope at Mount Wilson. Hubble tackled the problem of the nebulae. At the time, any cloudy object seen in the night sky with telescopes was referred to as a *nebula* (plural *nebulae*). These objects were not clouds in Earth's atmosphere since they never changed their shape or position in the sky, but their true nature was unknown. Some were irregular in shape, some appeared spherical, and others had various spiral shapes.

Hubble turned the great telescope on the largest of these spiral nebulae in the constellation Andromeda, where he saw—for the first time—that it was composed of tiny stars. However, he could not tell how far away it was until he took a series of photographs through the telescope. By comparing photos taken at different times he was able to determine that some of the stars varied in brightness. The types of stars that he identified were known to vary with a period that was related to their brightness. By taking many more photographs, he was able to determine the periods of many of these stars. By comparing the maximum brightness of these stars with nearby stars that had the same period (whose distance could be measured by a different method) he determined that the spiral cloud in Andromeda was a million light years away. This confirmed that the universe was many times larger than had previously been thought, and filled with many different kinds of nebulae.

Hubble made his discovery in 1923 and published the result in 1929. In brief, he found that nebulae with spiral shapes were all huge collections of stars, like our own Milky Way. Astronomers at that time called them "island universes." Today we call them *galaxies*. Other cloud-like objects that were not composed of distant collections of stars, but were relatively nearby in our own galaxy, retained the name *nebulae*.

In 1952, Walter Baade, using the 200-inch telescope on Palomar Mountain, found that there are two different types of variable stars, which led to the conclusion that the galaxies are twice as far away as Hubble had thought. Our nearest "neighbor" in intergalactic space, the great galaxy in Andromeda, is actually two million light years from us, which means it takes two million years for the light from Andromeda to arrive on Earth. If a star were to explode in Andromeda today, we wouldn't know about it for two million years!


CRAB NEBULA

Classifying Nebulae and Galaxies

The following activity is based in part on "Galaxy Sorting" by Sally Stephens, *The Universe at Your Fingertips, A Project ASTRO Resource Notebook*, San Francisco: Astronomical Society of the Pacific, 2000.

To simulate the state of astronomy at the beginning of the 20th Century, print out images of a dozen galaxies and a dozen nebulae from a source such as http://nasaimages.org/. Print them in color if at all possible (though black and white is okay too). You may want to laminate the images or put them into plastic page protectors so you can use them again. A nice collection of galaxies is available for download at: http://161.58.115.79/education/astro/act5/gal_sort.html

Images courtesy of:
Andromeda: Dave Jurasevich
Crab Nebula: The Carnegie Observatories

Tape or pin the images around the walls of your classroom and number each image, but do not indicate its name or information about it. Create an "identification key" for later use with the number of each object and short descriptions from the website where you obtained the images.

Tell the students that the images around the room have all been taken by various telescopes and their job is to see what they can learn from the images by classifying them according to their appearance. Provide several magnifying lenses so that students can look at the images up-close.

Tell the students to classify the images into two or more categories, and to indicate their scheme by naming each category and indicating the numbers of images that belong in each category.

When the students have finished inspecting all the images and created their categories, have one student write his or her scheme on the board, and list the numbers of objects that correspond to each category. Ask if other students have a similar scheme, and ask them to describe any small differences. Then ask if another student has a very different scheme and put that up on the board as well. It is likely that the students will arrive at a small number of different categories.

Lead a discussion about what the students think these objects might be, and why there may be similarities and differences. Then, summarize the story about Edwin Hubble's discovery of the differences between galaxies and nebulae and use one or more of the schemes that the students devised to indicate that they have already sorted them into the two categories—distant galaxies and nearby nebulae.

Finally, explain that ***galaxies*** contain billions of stars, including the Milky Way Galaxy in which we live. Hubble categorized the images of galaxies that he took with the large telescope at Mount Wilson by their appearance. His system of categories is still used today. One of the schemes that the students developed may be similar to the following one developed by Hubble:

1) Elliptical galaxies, with no spiral structure
2) Spiral galaxies, with arms that spiral out from the center
3) Irregular galaxies, which are oddly-shaped, neither elliptical nor spiral

A diagram of Hubble's classification scheme can be found at the following website:

http://csep10.phys.utk.edu/astr162/lect/galaxies/hubble.html

Explain that nebulae are clouds of gas and dust that are mostly the remains of exploded stars. One type of nebula that might be confusing to some is called "planetary nebulae." They were given that name because they appeared round, like planets, in very early telescopes. However, they are not planets at all, but much larger clouds of gas and dust produced when a massive star exploded.

Navigating the Milky Way

If you've ever wondered how to navigate your way home to "The Alpha Quadrant" should you become lost within our home galaxy, you and your students will appreciate the following slide show from the Chandra satellite project. It is a very clear description of galactic coordinates, using Earth's latitude and longitude lines as examples.

http://chandra.harvard.edu/xray_astro/navigation.html

Activity 1F. Structure and Evolution of the Universe

One of the most difficult concepts to teach is the large-scale structure and evolution of the universe. Happily there is a website where a great number of accessible, accurate, and engaging educational materials are available. You will find these materials at The Universe Forum, produced for NASA by the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and available on the web at:

http://www.cfa.harvard.edu/seuforum/

On the home page you will find four guided "Explorations." These are beautifully illustrated and simply written descriptions of four big ideas about the universe as a whole:

- Our Place in Space
- The Big Bang
- Black Holes
- Dark Energy

Clicking on "Educational Resources" will bring you to a portal with these excellent resources for exploring the universe:

Beyond the Solar System: Expanding the Universe in the Classroom

http://www.universeforum.org/btss/

How can teachers and students explore some of the biggest questions about our place in space and time? This professional development DVD is filled with video, print, and online resources for educators of students and adults alike. Recommended for Grades 8-12.

The Incredible Two-Inch Universe (pdf)

http://chandra.harvard.edu/resources/podcasts/2inch/podcasts.xml

Explore the universe by shrinking the cosmic scale in four steps, zooming out from the realm of the Earth to the realm of the galaxies. Recommended for students, teachers, informal audiences, and the general public.

Frequently Asked Cosmic Questions

http://www.universeforum.org/questions/

Does the universe have an edge, beyond which there is nothing? How do we know there really was a Big Bang? Find answers to frequently asked questions about the structure and evolution of the universe here. Recommended for teachers and students Grades 7-12, and general audiences.

Cosmic Questions Educators' Guide (pdf)

http://cfa-www.harvard.edu/seuforum/learningresources.htm

This 74-page booklet, created to accompany the national traveling exhibition "Cosmic Questions: Our Place in Space and Time," contains eight activities for understanding key astronomical concepts. "Cosmic Survey," "Modeling the Universe," "Learning about Light," "Multi-wavelength Astronomy," "The Expanding Universe," and "Is There Life Out There?" are among the activities included. Recommended for teachers of Grades 7-12. Download from:

How Big Is Our Universe? Booklet (website with downloadable pdf)

http://www.universeforum.org/howfar/index.html

Using beautiful photographs and straight-forward methods and ideas, this website takes readers out of our solar system, into the realm of the stars, the galaxies, and finally the vast panorama of the observable universe. You can also download and print a pdf version of these explorations. Recommended for Grades 5-12 and general audiences.

Black Hole Interactive

http://www.universeforum.org/bh_popup_spacetimelab.htm

Ever since Einstein, we've been exploring a universe in which space can stretch and time can slow down. This interactive animation lets you visualize how space and time are distorted around a massive object like a black hole. Recommended for general audiences.

Further Resources for Learning About the Universe

The following resources about astronomy and astronomy education on the Web were assembled by Andrew Fraknoi, Astronomy Professor at Foothill College and former Executive Director of the Astronomical Society of the Pacific.

1. Engaging Articles

An Ancient Universe (for teachers; on how we know the age of the universe is much longer than creationists claim; with B. Partridge, G. Greenstein, and J. Percy): http://education.aas.org/publications/ancientuniverse.html
(an earlier version, with classroom activities can be found at: http://www.astrosociety.org/education/publications/tnl/56/index.html)

Astronomy Education in U.S. (a general review of the many arenas where it takes place): www.astrosociety.org/education/resources/useduc.html

Astronomy Textbooks, Used Book Chains, and Big Macs: A Perspective (in *Astronomy Education Review*): http://aer.noao.edu/cgi-bin/article.pl?id=152

Dealing with Astrology, UFOs, and Faces on Other Worlds: A Guide to Addressing Astronomical Pseudoscience in the Classroom (in *Astronomy Education Review*): http://aer.noao.edu/cgi-bin/article.pl?id=70

Enrollments in Astronomy 101 Courses: An Update (in *Astronomy Education Review*): http://aer.noao.edu/cgi-bin/article.pl?id=12

How Fast Are You Moving When You Are Sitting Still? (the motions of the Earth for teachers): http://www.astrosociety.org/education/publications/tnl/71/howfast.html

Insights from a Survey of Astronomy Instructors in Community and Other Teaching-Oriented Colleges in the United States (in *Astronomy Education Review*): http://aer.noao.edu/cgi-bin/article.pl?id=89

Light as a Cosmic Time Machine (brief introduction for the general public): http://www.pbs.org/seeinginthedark/astronomy-topics/light-as-a-cosmic-time-machine.html

Lives of the Stars (a brief introduction for the general public): http://www.pbs.org/seeinginthedark/astronomy-topics/lives-of-stars.html

Mars (a brief introduction for the general public): http://www.pbs.org/seeinginthedark/astronomy-topics/mars.html

"Music of the Spheres" in Education: Using Astronomically Inspired Music (in *Astronomy Education Review*): http://aer.noao.edu/cgi-bin/article.pl?id=193

So You Want to Start a Project ASTRO Site (Q & A on program where astronomers adopt a classroom): www.astrosociety.org/education/astro/about/astrofaq.html

Steps and Missteps toward an Emerging Profession (Education and Outreach in Astronomy): http://www.astrosociety.org/pubs/mercury/34_05/epo.pdf

Teaching Astronomy with Science Fiction (in *Astronomy Education Review)*: http://aer.noao.edu/cgi-bin/article.pl?id=33

Teaching What a Planet Is: A Roundtable on the Educational Implications of the New Definition of a Planet (in *Astronomy Educat. Review)*: http://aer.noao.edu/cgi-bin/article.pl?id=207

What's a Planet and Why Is Pluto Not in the Planet Club Anymore (brief introduction): http://www.pbs.org/seeinginthedark/astronomy-topics/planets-and-pluto.html

Your Astrology Defense Kit (a skeptical article to help educators respond to astrological claims): www.astrosociety.org/education/astro/act3/astrology3.html#defense

2. Educational Activities

A Flag for Your Planet (Family Activity): http://www.astrosociety.org/education/publications/tnl/66/flag3.html

Family Heroes: Should Uncle Fred be in the Sky? (thinking about constellations)]:
http://www-tc.pbs.org/seeinginthedark/pdfs/family_heros.pdf

Finding Your Way to Mars, Pennsylvania: An Astronomy and Geography Activity:
http://www.pbs.org/seeinginthedark/pdfs/geography_astronomy_activity.pdf

Picture an Astronomer Activity: www.astrosociety.org/education/astro/act1/astronomer.html

Sky Heroes: Reinventing the Constellations (for classrooms):
http://www.pbs.org/seeinginthedark/pdfs/Sky_Heroes.pdf

Starry Lives, Starry Skies: Observing Different Stages in Stellar Evolution:
http://www-tc.pbs.org/seeinginthedark/pdfs/starry_lives_starry_skies.pdf

Surfing the Solar System Web-based Quiz Game: www.astrosociety.org/education/surf.html

Testing Astrology Activities: http://www.astrosociety.org/education/astro/act3/astrology.html

3. Resource Guides

Astronomical Pseudo-science: A Skeptic's Resource List (astrology, UFO's, creationist cosmology, etc.):
www.astrosociety.org/education/resources/pseudobib.html

Astronomy and the Arts (poetry, music, and art):
http://www.pbs.org/seeinginthedark/resources-links/astronomy-and-the-arts.html

Astronomy Classroom Activities on the Web: An Annotated Topical Guide (for K-12 teachers):
www.astrosociety.org/education/activities/astroacts.html

Astronomy and Poetry: http://aer.noao.edu/cgi-bin/article.pl?id=10

Environmental Issues & Astronomy (light pollution, observatory sites, frequency spectrum allocation, etc.):
www.astrosociety.org/education/resources/environment.html

Exchanging Messages with Extraterrestrial Civilizations: www.astrosociety.org/education/family/resources/seti.html

The Astronomy of Many Cultures: http://www.astrosociety.org/education/resources/multi.html

Science Fiction with Good Astronomy (a topical listing and brief review):
www.astrosociety.org/education/resources/scifi.html

SETI (The Search for Extra-Terrestrial Intelligence): A Basic Reading List:
http://www.seti.org/publications/bibliography.php

Websites on College Astronomy Teaching (teaching strategies, resources, labs, demos, etc.):
www.astrosociety.org/education/resources/educsites.html

Women in Astronomy Bibliography (general references and specific readings for 36 women astronomers):
www.astrosociety.org/education/resources/womenast_bib.html

UNIT 2. THE BUILDING OF LARGE TELESCOPES

The Journey to Palomar is a good introduction to large telescopes, but the "Wow!" factor comes when students actually look through a real telescope at mountains and craters on the moon, or at a star-like object and see it "close-up" as a planet—a ball in space. It should, therefore, be an important part of every student's experience to look through telescopes at the moons of Jupiter, the rings of Saturn, and the mountains and craters of our own Moon, and to learn about the discoveries of Galileo. There are also a few specific ideas that students should learn *about* telescopes.

Hale's first telescopes were *refractors*, telescopes that work by bending, or refracting, light using large glass lenses. Since light must pass through the lens in a refractor, the quality of the glass must be perfect. It is difficult to achieve that quality with very large lenses. *Reflectors* work by reflecting the light from mirrors with curved surfaces. A concave mirror can accomplish the same thing as a lens—to form the image of an object in great detail. Larger telescopes form brighter images with more detail.

In both kinds of telescopes an eyepiece can be used like a magnifying glass, to magnify the image formed by the main lens or mirror. Today, instead of an eyepiece, astronomers usually attach more sensitive detectors. A digital camera called a CCD or a spectroscope can be used to reveal, in fine detail, the colors that make up the images. Spectroscopes do this with a prism or diffraction grating (glass or mirror with many finely-ruled lines). See the resource list at the end of this unit for a list of remotely operated telescopes that your students can use to take their own pictures of celestial objects.

The goals of Unit 2 are for students to:

- Be able to use a telescope to focus on the Moon, planets, and other objects.
- Draw a sketch to show the differences between refractors and reflectors.
- Use lenses to demonstrate how telescopes work.
- Explain the problem of "seeing," or "atmospheric distortion."
- Explain that larger telescopes collect more light and reveal finer details than smaller telescopes.

Activity 2A. Using a Telescope to View the Moon, Planets and Stars
Activity 2B. How Do Telescopes Work?
Activity 2C. The Problem of "Seeing."
Activity 2D. Size Matters
Activity 2E. Telescopes of Tomorrow
Activity 2F. Science and Engineering
Further Resources for Learning about Telescopes

Activity 2A. Using a Telescope to View the Moon, Planets and Stars

Start the unit by explaining the important role played by telescopes in the history of astronomy. For thousands of years people observed the planets "wander" among the stars, but had no idea that the solid Earth beneath their feet was one of those planets. Then when telescopes were invented, and it was apparent that the Moon and planets were in fact huge balls of matter in space, the idea that Earth could be one of those balls was seriously considered.

Benchmarks for Science Literacy (AAAS 1993) strongly recommends that students compare the appearance of stars and planets through telescopes or binoculars. By the time they leave middle school students should observe mountains and craters on the Moon and compare telescopic views of the stars and planets: "When a modest telescope or pair of binoculars is used instead of the naked eyes, stars only look brighter—and more of them can be seen. The brighter planets, however, clearly are disks." (*Benchmarks*, 1993, page 62)

Before organizing an evening star gazing class, it is important to provide practice in using telescopes or binoculars during the day. Have your students use telescopes or binoculars to focus on something in the distance with writing, so they will clearly understand what it means to be *in focus*.

It is best to have several small telescopes or binoculars so that all of the students can practice pointing and focusing, rather than one large telescope for the class. In fact, it will be easier for students to focus inexpensive low-power telescopes than more expensive high-power telescopes.

Once they are able to use a telescope or binoculars to look at familiar objects during the daytime, your students will be ready to look at the moon. While moon views are best in the evening after the Sun has set, mountains and craters can even be seen when the moon is visible during the day. **Caution your students never to point their instruments at the Sun, or they could severely and permanently damage their eyes.**

Once your students are comfortable using a telescope to observe the moon, they will be ready to compare stars and planets as suggested by *Benchmarks*. Tips for conducting "star parties," in which students and parents can be invited to use these instruments in the evening, can be found on the web at: http://161.58.115.79/education/astro/astropubs/htm_events.html

References

Benchmarks for Science Literacy (1993). Project 2061, American Association for the Advancement of Science. New York, Oxford: Oxford University Press, 1993.

Activity 2B. How Do Telescopes Work?

Students can see how refracting and reflecting telescopes work at the website of the *Journey to Palomar* project: http://www.journeytopalomar.org. They can also learn more about Hale's giant telescopes, view 3D models of them and take a virtual tour inside the domes at the Mount Wilson and Palomar Observatories.

Numerous descriptions of refractors and reflectors can be found on the web. One of the best is: http://science.howstuffworks.com/telescope.htm

Another is from the Naperville Astronomical Association at: http://www.stargazing.net/naa/scope2.htm

However, the best way for students to learn how telescopes work is through activities with lenses. There are a number to choose from, but the set of activities that best illustrate the role of the large "objective" lens and the smaller "eyepiece" is called *More Than Magnifiers.* Sources for the teacher's guide and classroom kit are listed below.

The Teacher Guide, *More Than Magnifiers*, is available from the Lawrence Hall of Science at the following web address: http://lawrencehallofscience.stores.yahoo.net/morthanmag.html

From the website: In this ingenious unit, students use the same two lenses in different ways to create optical instruments, and in so doing find out how lenses are used in magnifiers, simple cameras, telescopes, and slide projectors. They learn that lenses have certain measurable properties that can help determine which lenses are best for specific purposes. This guide brings into practical "focus" important understandings related to physics, optics, and light, and makes a great connection to the GEMS guides *Color Analyzers* and *Microscopic Explorations*.

A kit that accompanies the unit is available from Carolina Biological at the following web address: http://www.carolina.com/product/114801.do

A classroom set of materials is also referenced in Module 3 of the Hands On Optics project: http://www.hands-on-optics.org/resources/

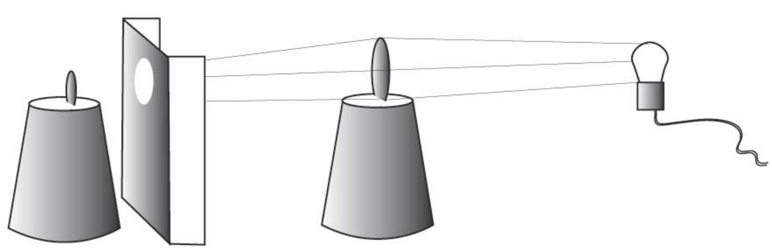
If you do not have the time or funds to purchase the complete set of activities, but you have some lenses in the storeroom, you can do some of the key activities as follows:

1. Measure the focal length of your lenses by forming an image of a bright, distant object on a piece of paper. The distance from the lens to the image is the focal length. (Usually larger lenses have longer focal lengths, but that is not always the case.) Lenses with the longest focal lengths will be the "objective" lenses and those with a shorter focal length will be the "eyepieces."

2. Mount the lenses on an optical bench, on balls of clay, or on upside-down paper cups as shown in the illustration below.

4. Darken the classroom as much as possible. Turn on one bare light bulb and turn off all other lights.

5. Hand out the mounted objective lenses to small groups of students along with a blank sheet of white paper. Demonstrate how to fold the paper so it stands up as a "projection screen."



6. Demonstrate how to move the objective lens towards and away from the paper to form a sharp image of the light bulb on the paper screen. Your students will notice that the image is upside-down.

8. Now hand out the mounted eyepiece lenses. Demonstrate how to place the eyepiece close to the screen so as to magnify the image of the light bulb.

9. Have one student look through the eyepiece at the image. While he or she is looking, have another student pull the screen out of the way. The student looking through the eyepiece will see a focused telescopic image of the light bulb.

10. **Debrief** by asking questions and having the students reflect on the activity:

    “What does the objective lens do?” (It forms an image on the screen—just like a camera forms an image on a piece of film, or a digital image array)

    “What does the eyepiece do?” (It magnifies the image so it is easier to see.)

    “How might the image be different if the lens were bigger?” (It would be brighter, and if the focal length were longer, the image would also be bigger and show more detail.)

Activity 2C. The Problem of "Seeing."

While Hale was pushing for bigger and bigger telescopes, a legitimate objection was that distortions caused by moving air would blur the images, so that a bigger telescope might be no better than a smaller one. The sites at Mount Wilson and Palomar were carefully chosen for their smooth, stable atmospheric conditions, but Hale took a huge gamble in building such monumental telescopes without any guarantees that they would work, especially at Mount Wilson.

The common term for distortions of the atmosphere is "twinkling." Stars twinkle because the light from a star passes through the atmosphere, which is always changing, forming oddly distorted "lenses." This happens because a change in temperature slightly changes the density of the air, which changes the air's index of refraction (the amount it bends light).

The twinkling is much more obvious through a telescope, which magnifies the distortions as it does the images. The term used by astronomers is "seeing." If the "seeing" is excellent, the air is very still and images do not shimmer. If "seeing" is poor, the images seem to move a little in the eyepiece and alternately get fuzzy and clear.

"Seeing" in the night sky. The best way to observe the effects of "seeing" is with real telescopes in the night sky. Have your students look at stars near the horizon, where the starlight must pass through a lot of the atmosphere. The "seeing" will be very poor. On the other hand, "seeing" will be better when looking at star images overhead because the starlight passes through much less of the atmosphere.

"Seeing" in the classroom. A hair dryer is a useful tool for demonstrating "seeing" in the classroom. Whether the students are using lenses mounted in cups, as in the previous activity, or real telescopes during the day, blowing a blast of hot air in front of the lens will make the image appear to shimmer.

Debrief by asking the students:

> "How do poor 'seeing' conditions change the view?" (The image gets blurry and seems to shimmer.)
>
> "Why do you think that happens?" (Moving air and changes of temperature distort the air, making it act like a changing lens.)
>
> "Why might people have doubted that bigger telescopes would really be better? (If the telescope magnified the effect of poor "seeing," the bigger telescopes would have been a huge waste of funds. Luckily that didn't happen.)
>
> "What did Hale do to reduce the effects of 'seeing'?" (He put the telescopes on mountain tops, away from cities, and in places where the air was as still as possible.)

You might conclude by pointing out that even though Hale was right in that huge telescopes did see more detail than smaller telescopes, they were somewhat limited by "seeing" conditions. The Hubble Space Telescope, which orbits well above the atmosphere, has a diameter of only 94.5 inches, but it can detect much greater detail than even the giant Hale Telescope on Palomar Mountain.

Activity 2D. Size Matters

When it comes to telescopes, size really does matter. The huge telescopes pioneered by George Ellery Hale revealed details never seen before, such as the individual stars in the Andromeda Galaxy, now known to be two million light years away.

There are two ways to share this insight with your students—during a dark-sky evening with a variety of telescopes or online.

Dark Sky Observing. Astronomy is a very popular hobby, and there are literally hundreds of astronomy clubs throughout the world. Most of these clubs include stargazing as one of their club activities and most amateur astronomers are hospitable to teachers and their students.

To find a club near you that is enthusiastic about sharing their time and telescopes, go to the NASA Night Sky Network home page -- http://nightsky.jpl.nasa.gov -- and click on the "Find Clubs in the USA" button. If you can't find one near you, try the Astronomical League. The Astronomical League is the major national organization of amateur astronomy clubs. The home page can be found at: http://www.astroleague.org/. Check out their website and click on "Societies" for a listing of member clubs by state. When you find the club nearest you, click on their website to find out when they are holding "star parties." These are generally evenings in a location remote from brightly-lit areas, where amateurs can bring their telescopes for an evening of serious observing. Contact the Club President in advance, and ask if it would be possible for your students to look at the same galaxy through a variety of different telescopes, so that the students can see what a difference diameter makes in the brightness and detail of an image.

However, warn your students that the galaxies they see will not appear as spectacularly as in the images they see online, because when viewing an image visually, the eye only "collects" light for a fraction of a second. Images, on the other hand, are taken with timed exposures of many minutes, so they are able to gather light longer and see much fainter features that appear much brighter.

Online Observing. The easiest way to see what a difference size makes is to compare images taken by amateur astronomers using small telescopes with images taken by professional astronomers using large telescopes. For example, one good object for the comparison is M51, the Whirlpool nebula. Amateur images of this object can be found on several web pages including: http://seds.org/Messier/more/m051_m3.html

Then, switch to the Hubble Space Telescope images of the Whirlpool nebula and you'll find that Hubble has taken an amazingly detailed image of just the center of the Whirlpool Galaxy—which usually comes out just as a bright blob in amateur images. Be sure to download the short video that zooms in on the center of the galaxy. You'll find the Hubble download page of the Whirlpool Galaxy at: http://hubblesite.org/newscenter/archive/releases/2001/10/

Activity 2E. Telescopes of Tomorrow

Nearly every important discovery made with Hale's telescopes was a surprise, either because it was entirely unexpected or was even more astonishing than anticipated. It took insightful science and creative engineering to accomplish these remarkable achievements, which set the stage for the next generation of giant American telescopes.

Looking to the future, there are three giant telescopes now on the drawing boards of space engineers. Each telescope will have unique designs:

- **The James Webb Space Telescope** will be located one million miles from Earth, with 18 hexagonal mirrors.
- **The Giant Magellan Telescope**, located in Chile, will have seven 20-foot mirrors working together.
- **The Thirty-meter Telescope** will have 492 smaller hexagonal mirrors, forming a 100-foot primary mirror.

When they are completed, all three telescopes will function together as a team to:

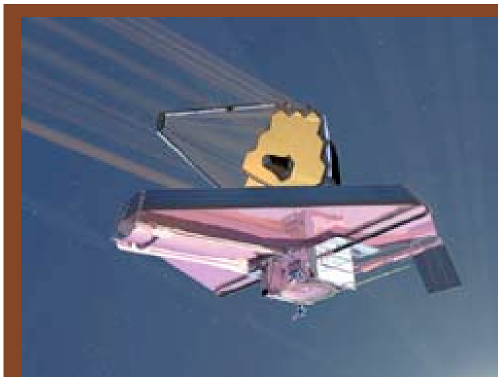
- Search for the first galaxies that formed after the Big Bang.
- Determine how galaxies evolved.
- Observe the formation of stars and planetary systems.
- Look for evidence of life on planets orbiting other stars.

Astronomers are very excited about continuing Hale's quest and uncovering new questions and discoveries that will change our view of the cosmos.

The home video DVD of *The Journey to Palomar* includes three DVD "extras," under the title *In Hale's Shadow*, which feature these three giant telescopes, each a direct descendant of the telescopes at Mount Wilson and Palomar. Your students will also be able to view these vignettes as part of a NASA student webcast. When viewing the webcast, they will hear more from the astronomers featured in the vignettes, who will answer questions from students like themselves. The webcast will be archived so it can be accessed from the pbs.org website.

The James Webb Space Telescope

When NASA's Hubble Space Telescope ends its useful life, it will be replaced by the James Webb Space Telescope (JWST), which will be named in honor of the NASA Administrator who led America's expeditions to the Moon and prepared to explore the outer planets of our solar system. The main mirror of the Webb telescope will be about 21 feet in diameter, two-and-a-half times the diameter of the Hubble's mirror, and it will be made out of beryllium, the lightest weight metal known. This telescope will be launched in 2013. At the Webb Telescope's website -- http://www.jwst.nasa.gov/public.html -- you can:



James Webb Space Telescope

- See how the telescope will fit into the rocket for launch into space
- See how the telescope will deploy in space
- Manipulate a computer model of the telescope
- Enjoy games that will explain how the telescope works
- Make your own paper model of the James Webb Space Telescope
- Explore links to other websites to learn more about infrared astronomy and JWST

The James Webb Space Telescope will be able to "see" in infrared light so that it can look at objects much closer to the time of the Big Bang, when the first galaxies were in their infancy. It will also be able to look *inside* dust clouds where stars and planetary systems are forming today.

Image courtesy of:
NASA / James Webb Space Telescope

Your students may have heard of "infrared goggles," sometimes used by soldiers to see the enemy at night; but it is not likely that they understand how such goggles work. An excellent activity that communicates the way that "false color" can be used to make invisible things visible is called "Red Hot, Blue Hot: Mapping the Invisible Universe," developed for a family science program, From the Ground Up. In the activity your students will map warm and cold areas on a cookie sheet in a way that is analogous to how the James Webb Space Telescope will create images in infrared light. You can download the activity guide at: http://www.astrosociety.org/afgu/.

The Giant Magellan Telescope

The Giant Magellan Telescope (GMT) will be located on a 9,000-foot peak in Chile to take advantage of the excellent "seeing" there in the smooth, dry air. It is scheduled for completion around 2017. The GMT will be a reflecting telescope but, unlike Hale's telescopes, the GMT's mirror will be composed of seven individual mirrors that will function as one giant mirror, *80 feet in diameter*. Each individual mirror segment will be three feet wider in diameter than the Palomar's 200-inch mirror. Computers will rapidly adjust the shape of the individual mirror segments to correct for blurriness due to changes in the Earth's atmosphere. This technique is called "Adaptive Optics." It will allow the GMT to see details ten times finer than the Hubble Space Telescope, and it will have enough light-gathering power to see a candle on the surface of the Moon. Your students can learn more about the GMT at its website: http://www.gmto.org/.

Giant Magellan Telescope

Thirty-meter Telescope

The Thirty-meter Telescope

The giant Thirty-meter Telescope (TMT) will be located on a high mountaintop in Hawaii or Chile, and will use the same adaptive optics technique as the GMT. However, it will have an even larger mirror. 492 segments will form a mirror surface 30 meters--or about *100 feet*--in diameter! Your students can learn more about the TMT at its website: http://www.tmt.org/.

Images, by Todd Mason, courtesy of:
GMT: The Carnegie Observatories
TMT: The TMT Observatory Corporation

Activity 2F. Science and Engineering

One of the major themes of *The Journey to Palomar* is the amazing engineering that went into the construction of the world's largest telescopes. Some of the most powerful images in the film relate to the development of new technologies, such as the construction of moveable floors, the dangerous job of pouring huge glass discs, grinding and polishing glass to an accuracy of two millionths of an inch, and inventing bearings made of a film of oil.

Despite these remarkable achievements in engineering, without being explicit about the relationship between science and engineering, students may miss an important point: science and engineering are mutually supportive. One cannot survive without the other. To better understand this relationship, ask your students to research the following topics:

1. **The Stages of Human Civilization.** Ask your students to find out how anthropologists and other social scientists have classified the various stages of human civilization. It is likely that they will find in their social studies textbooks or on the web that human civilization started with the Old Stone Age, followed by the New Stone Age, the Bronze Age, the Iron Age, and so on, up to the Industrial Age and the Information Age. When the students bring back this information ask them to discuss why they think these ages are named for changes in the prevalent technology of the period, rather than the prevalent science of the period.

2. **How Science Drives Engineering.** Ask the students to look up the history of some early inventions: the steam engine, light bulb, gramophone, etc. To what extent were these driven by science? To what extent were they driven by people simply trying out different methods and materials to solve a problem? How about earlier inventions, such as fire and agriculture? To what extent were these driven by science?

3. **How Engineering Drives Science.** Ask the students to look up recent scientific discoveries, such as the human genome or planets around other stars. What technologies had to be invented to make these discoveries possible?

4. **Can Science and Engineering Survive Without Each Other?** After the above experiences, ask the students to discuss whether they think science or engineering could get along without the other today. What would fields that depend on both—such as medicine—be like without science? without engineering?

Further Resources for Learning about Telescopes

Hands-On Universe

http://www.handsonuniverse.org/

Hands-On Universe™ (HOU) is an educational program that enables students to investigate the Universe while applying tools and concepts from science, math, and technology. Using the Internet, HOU participants around the world request observations from an automated telescope, download images from a large image archive, and analyze them with the aid of user-friendly image processing software.

MicroObservatory Online Telescopes

http://mo-www.harvard.edu/MicroObservatory/

MicroObservatory is a network of five automated telescopes that can be controlled over the Internet. Users of MicroObservatory are responsible for taking their own images by pointing and focusing the telescopes, selecting exposure times, filters, and other parameters. The educational value lies not just in the image returned by the telescope, but in the satisfaction and practical understanding that comes from mastering a powerful scientific tool. Observations can be set up in advance and run automatically.

Optical Powers: Telescopes and Imaging

http://sunra.lbl.gov/%7Evhoette/Explorations/OpticalPowers/0-op-title.html

Optical Powers is a curriculum and workshop that engages students in scientific thinking and analysis of images that leads to an understanding of the technology of telescopes, optical systems, and imaging cameras. The purpose of the program is to enable teachers with only minimal experience in this area to guide their students efficiently through the maze of variables that go into producing useful images while maintaining a foundation in understanding the science involved.

SLOOH Online Observatory

http://reference.aol.com/space/telescope

Slooh.com observes the universe every night, weather permitting. Starting at about 2PM ET every day, users can view different objects through the two Slooh telescopes, which are located on Mount Teide in the Canary Islands off the West African coast.

Bradford Robotic Telescope

http://www.Telescope.org

This 14-inch Schmidt-Cassegrain telescope, located in Tenerife, Canary Islands, can be directed online to take images of the sky, anywhere from the north celestial pole to 52 degrees south latitude. Receive your pictures back in days or weeks as1,056 x 1,027-pixel color or black-and-white JPEGs. Cost is free to educators.

Astronomy Picture of the Day

http://antwrp.gsfc.nasa.gov/apod/

NASA's Astronomy Picture of the Day website contains images and links to exciting astronomical discoveries and observations. It also includes a searchable directory and glossary of astronomical phenomena.

Astronomy Village: Investigating the Universe

http://www.cotf.edu/av1/main.html

Astronomy Village®: Investigating the Universe™ transports students to a virtual observatory community -- an "astronomy village" – where they take part in a variety of scientific investigations. This exciting multimedia program supplements high school science curricula as a culminating activity to astronomy instruction. Ten investigations cover a broad cross-section of current research in astronomy.

National Optical Astronomy Observatory (NOAO)

http://www.noao.edu/education/

The NOAO Educational Outreach Program was established to make the science and scientists of NOAO more accessible to the K-12 and college-level communities. This website includes links to information about opportunities and resources for teachers and students.

UNIT 3. HALE AND OVERCOMING ILLNESS

Interwoven throughout this epic tale of how the world's greatest observatories came into being is an account of the vision, passion, and charm of this remarkable person, as well as the tragedy of Hale's lifelong struggle with illness.

Hale's medical records have yet to be located and reviewed by experts. Exactly what Hale's condition was by today's standards remains a question that is debated by scholars, since the symptoms that are described in his known records could be interpreted as physical, mental, or a combination of both. The emphasis should be on understanding how different types of afflictions affect people and how people with great mental and/or physical challenges overcome them to make great contributions to humanity. Following are other examples:

- **John Nash**, who revolutionized economics with his investigations of game theory, had schizophrenia. More at: http://www.pbs.org/wgbh/amex/nash/filmmore/fd.html

- **Stephen Hawking**, a brilliant astrophysicist continues to make discoveries although he has has Lou Gehrig's disease. More at: http://www.pbs.org/wgbh/aso/databank/entries/bphawk.html

- **Ludwig van Beethoven** was one of the greatest composers of all time. He was deaf most of his adult life and struggled with deep depression. More at: http://www.pbs.org/wnet/gperf/education/beethoven.html

Mental illness is poorly understood by the vast majority of Americans and is rarely taught in schools. *The Journey to Palomar* is an excellent opportunity to initiate a unit on this important topic. Some of the reasons why it is so important to include mental illness as a school topic are summarized in Mental Health: A Report of the Surgeon General, http://www.surgeongeneral.gov/library/mentalhealth/chapter1 as follows:

> In the 1950s, the public viewed mental illness as a stigmatized condition and displayed an unscientific understanding of mental illness. Survey respondents typically were not able to identify individuals as "mentally ill" when presented with vignettes of individuals who would have been said to be mentally ill according to the professional standards of the day. The public was not particularly skilled at distinguishing mental illness from ordinary unhappiness and worry and tended to see only extreme forms of behavior—namely psychosis—as mental illness. Mental illness carried great social stigma, especially linked with fear of unpredictable and violent behavior (Star, 1952, 1955; Gurin et al., 1960; Veroff et al., 1981).
>
> By 1996, a modern survey revealed that Americans had achieved greater scientific understanding of mental illness. But the increases in knowledge did not defuse social stigma (Phelan et al., 1997). The public learned to define mental illness and to distinguish it from ordinary worry and unhappiness. It expanded its definition of mental illness to encompass anxiety, depression, and other mental disorders. The public attributed mental illness to a mix of biological abnormalities and vulnerabilities to social and psychological stress (Link et al., in press). Yet, in comparison with the 1950s, the public's perception of mental illness more frequently incorporated violent behavior (Phelan et al., 1997). This was primarily true among those who defined mental illness to include psychosis (a view held by about one-third of the entire sample). Thirty-one percent of this group mentioned violence in its descriptions of mental illness, in comparison with 13 percent in the 1950s. In other words, the perception of people with psychosis as being dangerous is stronger today than in the past (Phelan et al., 1997).
>
> The 1996 survey also probed how perceptions of those with mental illness varied by diagnosis. The public was more likely to consider an individual with schizophrenia as having mental illness than an individual with depression. All of them were distinguished reasonably well from a worried and unhappy individual who did not meet professional criteria for a mental disorder. The desire for social distance was consistent with this hierarchy (Link et al., in press).
>
> Why is stigma so strong despite better public understanding of mental illness? The answer appears to be fear of violence: people with mental illness, especially those with psychosis, are perceived to be more violent than in the past (Phelan et al., 1997).

In contrast to the wealth of material available for teaching about the universe and about telescopes, very little is available for the middle and high school level about mental illness. However, there are two notable curriculum materials, either of which would provide an excellent basis for a unit on mental health as part of a science and/or health program. These are briefly described below.

Activity 3A. Breaking the Silence
Activity 3B. The Science of Mental Illness

<u>Activity 3A</u>. Breaking the Silence

Breaking the Silence: Lesson Plans, Games, and Posters Created to Break the Silence about Mental Health in our Schools is described at the following website: http://www.btslessonplans.org/

The rationale for this program is described on the website as follows:

> People keep quiet about mental illness. They don't talk about their brother who hears voices, their mother who stays in bed with depression, or the counting rituals they themselves do before they can leave their house. So our children become hidden victims. Afraid to speak about their illness, or unable to recognize the symptoms, they may deteriorate for years before getting treatment.
>
> BREAKING THE SILENCE was developed for NAMI (National Alliance for the Mentally Ill) as part of their "Campaign to End Discrimination" to end this cycle of ignorance and shame. NAMI is a non-profit, grass-roots organization of families and friends, with more than 1,000 chapters nationwide, dedicated to eradicating mental illnesses and improving the quality of life of all those affected by these diseases.

Thanks to funding from the American Psychiatric Foundation, teachers can obtain a BTS Tool Kit free of charge by registering at the website.

Activity 3B. The Science of Mental Illness

The Science of Mental Illness: NIH Curriculum Supplement for Middle School, is described at the following website: http://science-education.nih.gov/customers.nsf/MSMental.

Through this teacher's guide, students gain insight into the biological basis of mental illnesses and how scientific evidence and research can help us understand its causes and lead to treatments and, ultimately, cures. The guide includes the following lessons:

1. The Brain: Control Central	The brain is the organ that controls feelings, behaviors, and thoughts, and changes in the brain's activity result in long- or short-term changes to these.
2. What's Wrong?	Mental illnesses such as depression are diseases of the brain.
3. Mental Illness: Could It Happen to Me?	Though everyone is at risk, factors such as genetics, environment, and social influences determine a person's propensity to develop a mental illness.
4. Treatment Works!	Medications and psychotherapies are among the effective treatments for most mental illnesses.
5. In Their Own Words	Mental illnesses affect many aspects of a person's life, but they can be treated so that the individual can function effectively.
6. You're the Expert Now	Learning the facts about mental illness can dispel misconceptions.

The NIH Curriculum Supplements combine cutting-edge science research discoveries from the National Institutes of Health, one of the world's foremost medical research centers, with interactive instructional materials. Each supplement is a teacher's guide to two weeks' of lessons on science and human health. All of the books in the series are:

- FREE to Science Teachers and School Administrators
- Consistent with National Science Education Standards
- Targets grades K-12
- Incorporates real scientific data

For more educational resources, visit PBS Teachers (http://www.pbsteachers.org).

The Astronomical Society of the Pacific (ASP) is the lead partner for the development of the teacher guide for* The Journey to Palomar. *The ASP is a recognized leader in the field of astronomy education, and with a strong network of formal and informal educators that they serve through a variety of programs.

http://www.astrosociety.org/education.html