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Overview

Activity description

The **Hubble Deep Field Academy** is an online exploration that invites students to examine the Hubble Deep Field image and simulate the process used by astronomers to count, classify, and identify objects in the image. Students also estimate the objects' distances from Earth. This activity is modular so that all or part of it can be completed at the educator's discretion.

Grade levels / Target audience

Grades 6-8, Target Grade: 7

Subjects

- Astronomy
- Math

Concepts

- The size of the universe
- The number of galaxies in the universe
- Galaxies and galaxy types
- Characteristics of galaxies used for classification and identification

Prerequisites

Before completing this activity, students should:

- be able to read grade-level-appropriate material.
- be able to complete and interpret data tables.
- have a general knowledge or awareness of estimation and representative samples.
- understand that galaxies are composed of stars, gas, and dust bound together by gravity, and that our own Milky Way is just one example of a galaxy in the universe.

Process skills

- Estimating
- Classifying
- Predicting
- Interpreting
- Identifying patterns using scientific data
- Comparing and contrasting

Preparing for an Online Exploration

Before using the activity...

1. Preview the activity and decide if it meets your instructional needs and students' learning needs.
2. Read these Teaching Tips for a full understanding of the activity.
3. Work through the activity as your students would. As you go through the activity, pay attention to the following:
    - How will students navigate through the activity, and what difficulties may they encounter?
    - Can students complete the activity successfully?

- Can the activity or selected parts of the activity be completed within your allotted instructional schedule or time-frame?

4. Check out your computers:
   - Review the Computer Needs section.
   - Reserve a time to use the computer lab if necessary.
   - Bookmark the activity on the Web browser of each student computer.
5. Determine a strategy for organizing your students. Options include:
   - A whole-group/educator-directed approach using one computer.
   - A cooperative team approach in a computer lab, with each student in a group having specific responsibilities while working on the activity (such as “mouse user,” “note taker,” and “oral reader”).
   - A one-student-per-computer approach.
6. Think about how the activity aligns with other instructional materials that you already use, such as:
   - Curriculum guides
   - Textbooks
   - Videos
   - Posters
   - Lab guides

Preparation time

- Allow time to preview the activity, read these Teaching Tips, and review the Science Background section as necessary. The Science Background will provide content information relevant to the activity and will help you answer questions posed by students.
- Allow time to download, print, and make copies of the Hubble Academy Log (HAL) Workbook for students. The workbook contains the activity's questions and provides blank spaces for answers. Students fill in answers as they encounter

questions in the activity.

- Allow time to explore the additional references and links provided in the Grab Bag, identify follow-up activities as appropriate, and gather needed supplies.

Execution time

Educators should allow approximately 45-55 minutes for the Orientation section of the activity and approximately 45-55 minutes for each of the activity's four "Academy" levels. About 30-40 minutes should be allotted for students to complete the readings in the Deeper Views section. Depending on the length of a class, the needs of your students, and your instructional purpose, completion of the full activity could take between three and five class periods. Be aware that the number of computers connected to the Internet and the speed at which the computer systems can process images may significantly alter the time needed to complete this activity.

Field-test

Sections of this activity were tested at multiple sites. The final version of the complete activity was last field-tested in May 2008.

Last update

July 2015

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Education Standards

The **Hubble Deep Field Academy** includes the following sections: Orientation, Stellar Statistician, Cosmic Classifier, Distance Wizard, Deep Field Observer and Deeper Views. It is appropriate for students in middle school.

GRADE LEVEL: 6-8

TARGET GRADE: 7

Outcome 1:	
In the "Orientation" section, students will generate questions based on observations of the Hubble Deep Field image and compare their questions with astronomers' questions.	
National Science Education Standards	**Content Standard A: Science as Inquiry** As a result of activities in grades 5-8, all students should develop the abilities necessary to do scientific inquiry. • Identify questions that can be answered through scientific investigations.
NCTM Principles and Standards of School Mathematics	**Data Analysis and Probability** In grades 6-8, all students should formulate questions that can be addressed with data, and collect, organize, and display relevant data to answer them.

Outcome 2:	
In "Stellar Statistician," students will estimate the number of objects in the Hubble Deep Field and compare their estimates with astronomers' estimates.	
Common Core Mathematics Standards	**Mathematical Practice Standards for all Grades** CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them. CCSS.Math.Practice.MP4: Model with mathematics. **Grade 7** • CCSS.Math.Content.7.SP.A.2: Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions. For example, estimate the mean word length in a book by randomly sampling words from the book; predict the winner of a school election based on randomly sampled survey data. Gauge how far off the estimate or prediction might be.

National Science Education Standards	**Content Standard A: Science as Inquiry** As a result of activities in grades 5-8, all students should develop the abilities necessary to do scientific inquiry. • Use mathematics in all aspects of scientific inquiry.
AAAS Project 2061 Standards	**The Physical Setting: A. The Universe.** By the end of 8th grade, students should know that • 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. 4A/M1bc
Mathematics	**Number and Operations** In grades 6-8, all students should compute fluently and make reasonable estimates.

Outcome 3:	
In “Cosmic Classifier,” students will classify objects in the Hubble Deep Field, describe their characteristics, and use a table to display their data.	
Common Core Mathematics Standards	**Mathematical Practice Standards for all Grades** CCSS.Math.Practice.MP5: Use appropriate tools strategically. **Grade 6** CCSS.Math.Content.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by: describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
National Science Education Standards	**Content Standard A: Science as Inquiry** As a result of activities in grades 5-8, all students should develop the abilities necessary to do scientific inquiry. • Use appropriate tools and techniques to gather, analyze, and interpret data. • Use mathematics in all aspects of scientific inquiry.

Standards	**The Mathematical World: C. Shapes** By the end of 8th grade, students should know that • The graphic display of numbers may help to show patterns such as trends, varying rates of change, gaps, or clusters that are useful when making predictions about the phenomena being graphed. 9C/M4
Mathematics	**Data Analysis and Probability** In grades 6-8, all students should formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

Outcome 4:	
In "Distance Wizard," students will estimate the distances of objects in the Hubble Deep Field from Earth using the relationship between size, brightness, and distance.	
Common Core Mathematics Standards	**Mathematical Practice Standards for all Grades** CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them. CCSS.Math.Practice.MP4: Model with mathematics.

National Science Education Standards	**Content Standard A: Science as Inquiry** As a result of activities in grades 5-8, all students should develop the abilities necessary to do scientific inquiry. • Use mathematics in all aspects of scientific inquiry.
AAAS Project 2061 Standards	**The Physical Setting: A. The Universe** By the end of 8th grade, students should know that • The universe contains many billions of galaxies, and each galaxy contains many billions of stars. 4A/M1bc • Some distant galaxies are so far away that their light takes several billion years to reach the earth. 4A/M2de
Mathematics	**Number and Operations** In grades 6-8, all students should compute fluently and make reasonable estimates.

Outcome 5:	
In "Deep Field Observer," students will demonstrate their knowledge of galaxy properties and characteristics by answering questions.	
National Science Education Standards	**Content Standard A: Science as Inquiry** As a result of activities in grades 5-8, all students should develop the abilities necessary to do scientific inquiry • Use appropriate tools and techniques to gather, analyze, and interpret data.
Standards	**The Physical Setting: A. The Universe** By the end of 8th grade, students should know that • The universe contains many billions of galaxies, and each galaxy contains many billions of stars. 4A/M1bc • Some distant galaxies are so far away that their light takes several billion years to reach the earth. 4A/M2de

Outcome 6:	
In "Deeper Views," students will read and comprehend informational text independently and proficiently.	
Standards	**Range of Reading and Level of Text Complexity** CCSS.ELA-Literacy.CCRA.R.10: Read and comprehend complex literary and informational texts independently and proficiently.

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Computer Needs: Software and Hardware

Web browser

This activity was designed for use with standard compliant browsers. This includes:

- Internet Explorer 8 and later, on Windows
- Safari on Macintosh
- Chrome
- Firefox

Although this activity may not format properly on non-compliant browsers (including Internet Explorer 5.01 and earlier versions, Internet Explorer for the Macintosh, and Netscape 4.0 and earlier), all content should be available. This activity has not been tested with any other browsers.

Plug-ins

If you wish to use all of the interactive graphics and features, you will need the Adobe Flash Player plug-in. However, the majority of the activity does not require plug-ins. Download the Adobe Flash Player plug-in.

Hardware requirements

You will need an Internet-connected computer capable of running one of the following Web browsers: Firefox, Chrome, Safari, or Internet Explorer 8, or later.

PC Hardware Requirements:	
CPU	Any
Main Memory	Operating system basic requirements (typically 4GB)
Operating System	Windows 7, 8, or later
Display	Color required: Minimum 256 colors Color recommended: 16K colors or better Resolution: Configured for 1024x768, or larger
Printer	Required to print 8-page Hubble Academy Log ("HAL") Workbook for each student
Disk Space	Enough space for installation of a browser

Mac Hardware Requirements:	
CPU	Any
Main Memory	Operating system basic requirements (typically 4GB)
Operating System	Mac OS X, or later
Display	Color required: Minimum 256 colors Color recommended: 16K colors or better Resolution: Configured for 1024x768, or larger
Printer	Required to print 8-page Hubble Academy Log ("HAL") Workbook for each student
Disk Space	Enough space for installation of a browser

Operating systems

- Any operating system that can support Firefox, Chrome, Safari, or Internet Explorer 8, or later. This includes Windows 7 and 8 and Macintosh OS X, or later.
- Most Unix systems

How to configure the browser

- Set your display to 1024x768 pixels, or better.
- Maximize the browser window to fill the screen.
- Configure the browser to hide the Location Toolbar and Personal Toolbar. This can be done from the “View” menu item.

- Make sure JavaScript is enabled. Because browsers update frequently, a handy website to visit is enable-javascript.com, which compiles up-to-date methods for enabling JavaScript in different browsers. Alternatively, a Google or Bing search for the following search phrases will lead you to directions on how to enable JavaScript in the browser you are using:
    - "firefox enable javascript"
    - "safari enable javascript"
    - "IE enable javascript"

Troubleshooting

For many problems, try clearing the browser's cache. To clear the cache in Firefox:

1. Go to the *History* menu item.
2. Select *Clear Recent History*. Select the *Cache* checkbox.
3. In *Time Range To Clear*, select *Everything*.
4. Click on *Clear Now*.
5. Try the activity again. Some pages may need to be reloaded.

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Lesson Plan

Purpose

The purpose of the **Hubble Deep Field Academy** activity is to provide students with a first-hand experience in using the same process used by scientists when studying and classifying objects in the universe. Students have the opportunity to ask and answer their own questions about a previously unknown region of space and compare their questions to the ones posed by astronomers. Students also examine and classify celestial objects based upon observed properties such as color and shape. The scientific process is reinforced when students compare their results with astronomers' results and learn that often scientists do not always agree or get the same results. They, however, must be able to support their results with evidence.

Learning outcomes

Students will…

- generate questions based on observations of the Hubble Deep Field image and compare their questions with astronomers' questions.
- estimate the number of objects in the Hubble Deep Field and compare their estimate with astronomers' estimates..
- classify objects in the Hubble Deep Field, describe their characteristics, and use a table to display their data.
- estimate the distances of objects in the Hubble Deep Field from Earth using the relationship between size, brightness, and distance.
- demonstrate their knowledge of galaxy properties and characteristics by answering questions.
- read and comprehend informational text independently and proficiently.

Prerequisites

Before completing this activity, students should:

- be able to read grade-level-appropriate material.
- be able to complete and interpret data tables.
- have a general knowledge or awareness of estimation and representative samples.
- understand that galaxies are composed of stars, gas, and dust bound together by gravity, and that our own Milky Way is just one example of a galaxy in the universe.

New Vocabulary

ASTRONOMY

The study of the universe and the celestial bodies that reside in it, including their composition, history, location, and motion.

ASTRONOMER

A scientist who studies the universe and the celestial bodies residing in it, including their composition, history, location, and motion. A scientist who studies celestial objects using visible light is called an optical astronomer, while one who studies celestial objects in radio wavelengths is called a radio astronomer.

BIG BANG

A broadly accepted theory for the origin and evolution of our universe. The theory states that the observable universe started roughly 15 billion years ago from an extremely dense and extraordinarily hot "bang."

BIG DIPPER

A grouping of the seven brightest stars of the constellation Ursa Major, or the Great Bear. The outline of these stars resembles a large ladle or dipper. It is frequently used to aid in navigation at night, but it also assists in finding other stars and galaxies.

CLASSIFICATION

The act or process of dividing into groups according to certain criteria.

DEEP FIELD

A very deep picture or view of the universe that is a long, cumulative exposure of the sky. It allows scientists to see thousands of galaxies that they otherwise would not be able to see. Studying these galaxies – some that may have formed within 1 billion years of the Big Bang – in a wide variety of shapes and colors has provided important clues to understanding the evolution of the universe.

ELLIPTICAL GALAXY

A galaxy that is shaped like an ellipse – a special kind of elongated circle. Elliptical galaxies typically contain less dust and gas and rotate much more slowly than spiral galaxies. The largest elliptical galaxies are comprised of trillions of stars.

ESTIMATION

An approximation that may be incomplete or uncertain, and often only provable by direct and precise calculation or scientific experimentation.

GALAXY

A collection of stars, gas, and dust bound together by gravity. The smallest galaxies may contain only a few hundred thousand stars, while the largest galaxies have thousands of billions of stars. The Milky Way galaxy contains our solar system.

HUBBLE SPACE TELESCOPE (HST)

One of the earliest, largest, and most versatile space telescopes ever launched by NASA. The HST's orbit outside the distortion of Earth's atmosphere allows it to take extremely sharp images with almost no background light. One of NASA's Great Observatories, the telescope has proven to be vital for research by astronomers since its launch in 1990.

HYPOTHESIS

An assumption or interpretation of a situation or condition that is based on previous work and knowledge. It is typically made in order to guide experimentation intended to support or refute the hypothesis. Often in scientific investigations the hypothesis is considered to be an educated guess.

IRREGULAR GALAXY

A galaxy that does not have any regular or set shape. Irregular galaxies usually vary greatly in size, and are the least common type of galaxy.

LIGHT-YEAR

The distance light travels in one year at a speed of 300,000 km/sec, which is about 9.5 trillion km.

MATHEMATICAL OPERATION

An action or procedure that produces a new value from one or more input values. Addition, subtraction, multiplication, and division are typically considered to be the four basic mathematical operations.

MILKY WAY GALAXY

The Milky Way, a spiral galaxy, is the home of Earth. The Milky Way contains more than 100 billion stars and has a diameter of 100,000 light-years.

ORBIT

The path followed by a celestial object moving in a gravitational field. For example, the planets travel around the Sun because the Sun's gravitational field keeps them in their paths.

REPRESENTATIVE SAMPLING

A statistical sampling that includes individuals that comprise a large group, but it can fairly and accurately portray the various members and differences and similarities within the group without actually portraying those characteristics for every single member. The sampling process may involve selecting members at random, at fixed intervals, grouped by a certain time period, or any variety of other methods.

SPIRAL GALAXY

A galaxy that is shaped like a flat disk with a bulge in the center and long, spiral arms that swing out from the center and rotate around it like a pinwheel. Spiral galaxies usually contain large amounts of dust and gas, and the stars in the galaxy-- like the Sun in the Milky Way-- rotate around the center of the galaxy.

STAR

A huge ball of gas held together by gravity. The central core of a star is extremely hot and produces energy. Some of this energy is released as visible light, which makes the star glow. Stars come in different sizes, colors, and temperatures. Our Sun, the center of our solar system, is a yellow star of average temperature and size.

STATISTIC

A numerical fact or piece of data typically taken as part of a larger collection that is studied and used by statisticians.

STATISTICIAN

An individual who studies the collection, classification, analysis, and interpretation of numerical facts or data, and who, by use of mathematical theories of probability, imposes order and regularity on certain aspects of those facts or data.

TELESCOPE

An instrument used to observe distant objects by collecting and focusing their electromagnetic radiation. Telescopes are usually designed to collect light in a specific wavelength range. Examples include optical telescopes that observe visible light and radio telescopes that detect radio waves.

UNIVERSE

Refers to the sum total of all physical matter and energy that exists, including, but not limited to, the planets, stars, galaxies, and all the other objects and contents of intergalactic space.

Teaching Tips

General misconceptions

Students may think that:

- most galaxies are easily viewed with the naked eye.
- all galaxies are the same.
- galaxies are composed of material that is different from stars.
- galaxies are static, remaining unchanged with time.
- you can judge the distance of a galaxy based on its size.
- there is nothing between galaxies.
- the Magellanic Clouds are composed only of space dust.
- the universe is only a few thousand years old.
- we can see all the stars in the universe when we look into the sky at night.
- the Big Bang, the birth of the universe, was an explosion into pre-existing space.

Note: For a list of additional misconceptions and the facts to dispel them, see Myths vs. realities: Galaxies on Amazing Space.

Preparation time

- Allow time to preview the activity, read these Teaching Tips, and review the Science Background section as necessary. The Science Background will provide content information relevant to the activity and will help you answer questions posed by students.
- Allow time to download, print, and make copies of the Hubble Academy Log (HAL) Workbook for students. The workbook contains the activity's questions and provides blank spaces for answers. Students fill in answers as they encounter questions in the activity.
- Allow time to explore the additional references and links provided in the Grab Bag, identify follow-up activities as appropriate, and gather needed supplies.

Execution time

Educators should allow approximately 45-55 minutes for the Orientation section of the activity and approximately 45-55 minutes for each of the activity's four "Academy" levels. About 30-40 minutes should be allotted for students to complete the readings in the Deeper Views section. Depending on the length of a class, the needs of your students, and your instructional purpose, completion of the full activity could take between three and five class periods. Be aware that the number of computers connected to the Internet and the speed at which the computer systems can process images may significantly alter the time needed to complete this activity.

Physical layout of room

You may decide to have students work individually or in small groups of two or three. To maximize learning, no more than three students should share a computer at a time.

Adaptations can be made to accommodate a classroom that has one computer with Internet access (See One-computer Classrooms below). Suggestions include leading a whole-class activity and discussion by connecting the computer to a projector or monitor.

Materials

- Computers with Internet access for as many students as possible. See Computer Needs, One-computer Classrooms, and Classrooms without Computers.
- A printout of the eight-page Hubble Academy Log (HAL) Workbook for each student. The HAL contains activity questions and blank spaces for student responses. Students answer the HAL questions as they complete the **Hubble Deep Field Academy** activity.

Procedure / Directions

The **Hubble Deep Field Academy** consists of the following sections or levels:

ORIENTATION

Students are introduced to the concepts that will be addressed throughout the activity. To get them thinking as scientists, students are required to write questions that they want to have answered about the objects in the Hubble Deep Field image. Students then compare their questions to the questions astronomers have asked, thus forming an initial understanding of some of the principal purposes behind the Hubble Deep Field studies.

STELLAR STATISTICIAN

Students practice estimation skills as they begin to explore the Hubble Deep Field image. Students first estimate the number of objects in the image. They then use representative sampling techniques to refine their estimates. Finally, students use their estimates to calculate the total number of galaxies in the Hubble Deep Field image and the universe.

COSMIC CLASSIFIER

Students classify 15 objects, based on color and shape, from one camera view (A, B, or C) of the Hubble Deep Field image. They then compare their results to astronomers' results.

DISTANCE WIZARD

Students acquire first-hand experience with the challenge of determining the distances of celestial objects from Earth. Students attempt to arrange six celestial objects in the Hubble Deep Field image according to their distances from Earth, based on visual observations. Students then compare their results with astronomers' results and explain the discrepancies between their responses and those of the astronomers.

DEEP FIELD OBSERVER

Students review the concepts presented in the previous activity sections, and demonstrate their knowledge of galaxy properties and characteristics by answering questions. Students use a clickable galaxy icon to review information from the previous activity sections as they answer questions in the HAL. Students then view an "oddball" object from the Hubble Deep Field image that has been difficult for astronomers to classify. Students apply information acquired throughout the activity to determine what the object is. Finally, students compare their interpretation of the "oddball" objects to astronomers' interpretations.

DEEPER VIEWS

This section of the activity contains readings about other deep-space surveys that followed the Hubble Deep Field. Some surveys were carried out by Hubble alone, and others were a joint venture, providing multiwavelength coverage of portions of the sky.

BEFORE USING THE ACTIVITY...

1. Preview the activity and decide if it meets your instructional needs and students' learning needs.
2. Read these Teaching Tips for a full understanding of the activity.
3. Work through the activity as your students would. As you go through the activity, pay attention to the following:
    - How will students navigate through the activity and what difficulties may they encounter?
    - Can students complete the activity successfully?

- Can the activity or selected parts of the activity be completed within your allotted instructional schedule or timeframe?

4. Check out your computers:
   - Review the Computer Needs section.
   - Reserve a time to use the computer lab, if necessary.
   - Bookmark the activity on the Web browser of each student computer.
5. Determine a strategy for organizing your students. Options include:
   - A whole-group/educator-directed approach using one computer.
   - A cooperative team approach in a computer lab, with each student in a group having specific responsibilities while working on the activity (such as “mouse user,” “note taker,” and “oral reader”).
   - A one-student-per-computer approach.
6. Think about how the activity aligns with other instructional materials that you already use, such as:
   - Curriculum guides
   - Textbooks
   - Videos
   - Posters
   - Lab guides

PREPARING STUDENTS FOR THE ACTIVITY...

1. Give students a pre-assessment to determine their computer experience and/or their background knowledge of galaxies.
2. Use the Myths vs. realities: Galaxies to identify student misconceptions about galaxies.
3. Share the activity’s outcomes and vocabulary with students.
4. Use a large monitor, projector, or transparencies to provide an overview of the

activity for students and to demonstrate how to navigate it.

5. Use the Orientation section of the activity to introduce the activity and prepare students for what they will encounter in the other sections.
6. Organize students in such a way that more experienced computer users are matched up with less experienced ones.
7. Consider using one of the suggested activities in the Evaluation / Assessment section to measure student learning.
8. Consider using one of the suggested activities in the Follow-up / Interdisciplinary activities section to provide students with additional exploration or research opportunities.
9. Consider using the print-ready worksheets (What Does a Million Look Like?) available for download in the Grab Bag and in the Follow-up / Interdisciplinary activities section if students need additional practice working with or understanding extraordinarily large sizes and numbers.

WHILE STUDENTS ARE DOING THE ACTIVITY...

1. Help students navigate through the activity as necessary.
2. Provide options for students who finish the activity early:
    - Have students review the activity to define key vocabulary words.
    - Have students visit related websites to conduct additional research.
    - Have students complete some type of assessment activity. Suggested assessment activities can be found in the Evaluation / Assessment section.

Evaluation / Assessment

The Hubble Academy Log and the "Deep Field Observer" activity can be used as assessment activities to measure student learning. Other suggestions include the following:

- Have students prepare written reports, oral reports, or other types of presentations based on what they learned while completing the activity.
- Ask students to create a list of potential real-world applications for which they would use certain skills from the activity, such as: (1) estimating, (2) representative sampling, (3) classifying and identifying objects, and (4) determining distances.
- Have students explore the Amazing Space "Galaxy Trading Cards" and sort them according to galaxy type.
- Have students use the Amazing Space Graphic Organizer, "Comparison of spiral, elliptical and irregular galaxies" as a guide to finding and classifying additional galaxies in the HDF image.
- Have students identify and classify additional galaxies using the HUDF image/zoom feature.

Follow-up / Interdisciplinary activities

This activity presents an opportunity for students to visualize the size of very large numbers. Since this can be challenging for students, it is beneficial to provide additional practice and understanding in this area. The additional practice also can support interdisciplinary connections, in this case, mathematics. The following activities, developed by educator Kirk Fitch of Montgomery County, Md., directly address this need and are available as downloadable PDFs below:

- "What Does a Million Look Like?"

- "999,999 Cans of Soda on the Wall?"
- "How Many's a Million? Billion? Trillion?"

Other suggested activities include the following:

SCIENCE:

Students can learn more about galaxies and galaxy types by:

- Completing the Amazing Space Online Exploration, "Galaxies Galore, Games and More"
- Conducting additional research and completing the student version of the Amazing Space Graphic Organizer, "Comparison of spiral, elliptical and irregular galaxies"

MATH:

Students can investigate the topic of probability:

- Ask students why a coin is used to decide who will kick off first in a football game. Have students demonstrate, by using a coin, why this is a probability problem.
- Use a set of dice to find the probability of rolling a chosen number between 2 and 12. Have the students experiment by rolling the dice a set number of times and looking at the distribution of the rolls.
- Look for examples in life where counting and probability are apparent – this could include the likelihood of finding the matching sock from a pile of socks to finding two of the same marshmallow shapes in a bowl of cereal.

ART:

Have students draw pictures of galaxies and compare them to Hubble galaxy images.

Teaching Tips

ENGLISH LANGUAGE ARTS:

Have students write a science fiction story that incorporates the different shapes of the galaxies or some aspect of a particular galaxy type.

One-computer classrooms

It is recommended that educators use a projector or large monitor connected to a computer in order to display the activity. To facilitate a more organized and predictable large-group presentation, and avoid last-minute glitches, bookmark the activity or pages you wish to use and/or save selected activity screens for offline viewing. This will eliminate the inconvenience of unexpectedly losing Internet connectivity.

In addition, students may use the classroom computer and complete the **Hubble Deep Field Academy** as a learning station activity.

Classrooms without computers or Internet access

Several strategies are available to educators working in environments without access to computers or the Internet. If your classroom is not equipped with a computer and/or an Internet connection, try one of the following:

- If you have a computer with Internet access and a printer in the school library or at home, you can…
    - download and print copies of the Hubble Ultra Deep Field lithograph from Amazing Space. Lithograph copies can be used to create your own version of the **Hubble Deep Field Academy** activity.
    - print the information provided in the Science Background, which can be used as content reading for students.

  - check the Grab Bag for a variety of other educational resources and links that can be used to create your own activity, as reading material for students, or as information sources for student research.

- If your school has a computer lab, students may be able to complete the activity in the computer lab, either individually or in small groups.
- If you have a classroom computer but no Internet connection, some software programs and Web browsers provide offline access to Web pages. These programs allow you to save Web pages to a local hard drive. You can then open the downloaded Web pages locally and view them as if you are online.
- Students may have computers with Internet access at home. If so, consider assigning the **Hubble Deep Field Academy** as a homework or extra-credit assignment.

Homeschoolers

This activity is easily followed without additional support if the prerequisites are met. Parents can preview the activity and examine these Teaching Tips ahead of time. More information for homeschooling parents can be found at:

- American Homeschool Association
- Yahoo Homeschooling Groups
- The Home School Learning Network
- Griffith, Mary. (March 1999). The Homeschooling Handbook, 2nd edition. Three Rivers Press: New York.

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Science Background

The following information provides additional background about the Hubble Deep Field. It also can be used as an information source for student research projects, or to support review activities and group discussions.

1. What is a deep field?

In astronomy, a deep field is a long-exposure observation taken to view very faint objects. Light is collected over a long period of time, so the detectors have a chance to gather as much light as possible. Objects can be very far away and appear faint to us due to the vast distances over which the light must travel. Objects can also lie close to us and be faint because they don't give off much light. So "deep" doesn't necessarily mean far. In the case of the Hubble Deep Fields, deep does imply far away since the images were taken in locally empty areas.

2. What is the Hubble Deep Field?

The Hubble Deep Field project was inspired by some of the first deep images to return from the Hubble Space Telescope after the 1993 servicing mission. These images showed that the distant universe contained galaxies in a bewildering variety of shapes and sizes. Some had the familiar elliptical and spiral shapes seen among local large galaxies, but there was an unusual abundance of peculiar shapes as well. Few astronomers had expected to see this diversity presented in such amazing detail.

Impressed by these results, a special advisory committee convened by Robert Williams, then director of the Space Telescope Science Institute (STScI), recommended that he use his annual director's discretionary time to take the deepest optical picture of the universe. The idea was to aim Hubble at a single piece of the northern sky for 150 consecutive orbits over 10 days in December of 1995. Images from the Hubble Deep

Teaching Tips

Field project were made available to astronomers around the world shortly after completion of the observation.

In 1996, the Hubble Deep Field (later named the HDF-North) was the "deepest-ever" view of the universe, revealing a few thousand never-before-seen galaxies. The varieties of galaxy shapes and colors, as well as how they change with distance away from us, are important clues to understanding the development of galaxies in the universe.

Hubble took a second deep look in the southern hemisphere in October of 1998. The HDF-South was a scientific check to see if a similar result would be obtained in a different region of the sky. Each of the Hubble Deep Fields shows thousands of galaxies in an area of the sky that is as small as the size of President Roosevelt's eye on a dime held at arm's length.

Such deep images of the distant universe are likely to be one of the enduring legacies of the Hubble Space Telescope.

3. Why do we say the HDFs are looking back in time?

When we look out into space, we are also looking back in time. The speed of light is very fast, but space is very, very large. The result is that light takes significant time to cross space.

Light from the Sun takes eight minutes to reach Earth. The light we see today from the next nearest star was emitted over four years ago. Light from the nearest large galaxy, Andromeda, takes over 2 million years to reach us. That means that we see Andromeda as it appeared more than 2 million years ago!

The light from galaxies billions of light-years away has taken billions of years to reach us, and we see them as they were billions of years ago. Hence, observations of distant

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galaxies show us what the universe looked like at an earlier time in its history. By studying the properties of galaxies at different distances, and thus different epochs, we can map the changing development of galaxies in the universe!

4. What are some questions astronomers are trying to answer by studying the Hubble Deep Field?

The HDFs contain some of the faintest galaxies we've ever been able to see over a large range of distances. Since seemingly "empty" spots were chosen, most of the galaxies in the Deep Fields lay billions of light-years away. The images show that the distant universe contains galaxies in a bewildering variety of shapes and sizes. Some have the familiar elliptical and spiral shapes seen among galaxies today, but there are many peculiar shapes as well. Few astronomers had expected to see this diversity presented in such amazing detail. Besides the classical elliptical and spiral galaxies, the variety of other galaxy shapes and colors are important clues to understanding the evolution of the universe.

The HDFs are important because they can help answer such questions as:

- **How many galaxies are there in the universe?**
  The Hubble Deep Field has been used to count galaxies ten times as faint as the deepest existing ground-based optical observations and nearly twice as faint as the deepest existing Hubble images (at that time).
- **How were galaxies assembled?**
  Detailed studies of the ages and chemical compositions of stars in our own galaxy suggest that it has led a relatively quiet existence, forming stars at a moderate rate for the last 10 billion years. Other spiral galaxies seem to have similar histories. If this is the typical evolution for spiral galaxies, then predictions can be made for what they should have looked like at half their present age --

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including their size, color, and abundance. The images of distant galaxies from the Hubble Deep Fields can be used to check these predictions for spiral galaxy assembly.

On the other hand, nearby elliptical galaxies generally appear to be very old and to have stopped forming stars long ago. Astronomers have debated about when such galaxies formed and whether they formed through the collapse of a single large cloud of gas or through collisions of many smaller galaxies or proto-galaxies. The Hubble Deep Field, along with other deep Hubble images, provides a snapshot through time, which can be used to search for distant elliptical galaxies or primeval galaxies that might later evolve into elliptical galaxies. Thanks to images like the HDF, astronomers in the 1990s concluded that collisions play a dominant role in elliptical galaxy formation.

- **How did large-scale structure develop in the universe?**
  The Hubble Deep Field has been used to perform statistical studies of the distribution of galaxies on the sky. These studies provide an essential test of models for the development of structures (like clusters and superclusters of galaxies) in the universe. The Hubble Deep Fields extended such studies to fainter limits.
- **Is the universe open or closed?**
  The distribution of galaxies in the Hubble Deep Field images yields clues to the ultimate fate of the universe. Einstein's theory of general relativity includes the idea that space may be curved. A closed universe would have positive curvature like a sphere, while an open universe would have negative curvature like a saddle. In addition, while an open universe would continue to expand forever, a closed universe could halt the expansion and collapse in upon itself. The Hubble

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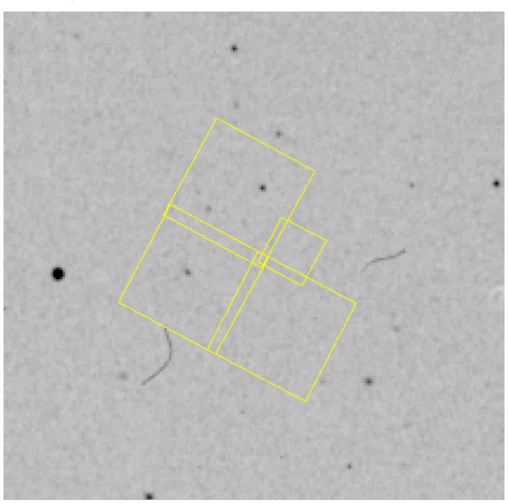
Deep Field results are compared to models that predict how the universe should look if it is open or closed.

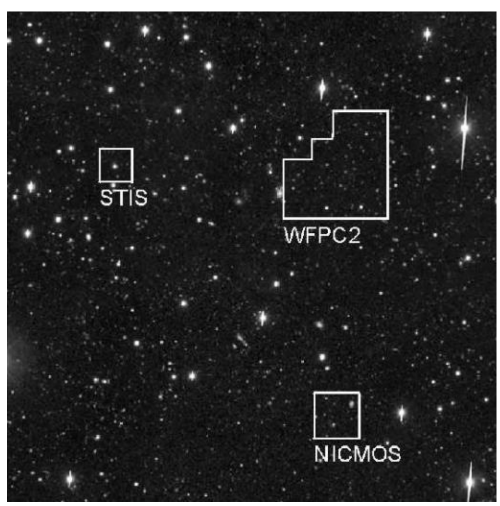
5. How was the area covered by the Hubble Deep Fields selected?

Each of the Hubble Deep Fields represents a "carefully selected random spot on the sky." To allow the Hubble Space Telescope to peer deeply into the sky, astronomers selected a special region of Hubble's orbit where Hubble can view the sky without being blocked by the Earth or experiencing interference from the Sun or Moon. These regions are known as the Northern and Southern Continuous Viewing Zones. The field also had to be far away from the plane of our own galaxy, to avoid being cluttered with objects in our galaxy. Finally, the field needed to have nearby guide stars, used to keep Hubble pointed at the field. These criteria led to the selection of a spot of sky near the handle of the Big Dipper in the Northern Hemisphere and a spot of the sky in the constellation Tucana in the Southern Hemisphere.

The positions of the HDF-N and HDF-S are shown in the images below.



Hubble Deep Field-North



Hubble Deep Field-South

Representing narrow "keyhole" views across the universe, the Hubble Deep Field images cover specks of sky 1/30th the diameter of the full Moon. This view is so narrow, that just a few foreground stars in our Milky Way galaxy are visible, and they are vastly outnumbered by the menagerie of far more distant galaxies. Some galaxies are incredibly faint, less than one-billionth the brightness of the faintest object the human eye can see. Though the fields are very small samples of the sky, they are considered representative of the typical distribution of galaxies in space because the universe has shown to have statistically similar properties in all directions.

6. How long did it take the Hubble Space Telescope to obtain the HDF-N image?

The HDF-N image was assembled from 276 separate exposures with the Wide Field and Planetary Camera 2, taken over 10 consecutive days between December 18 and 28, 1995.

7. What is a galaxy?

A galaxy is a massive system of millions to trillions of stars, along with dust and gas, all held together by their mutual gravity. Galaxies come in different sizes, shapes, and colors. Our Sun, along with our planet Earth, is located in a spiral galaxy named the Milky Way.

Galaxies can be placed into three main classes:

- **Elliptical Galaxy** - A galaxy having an oval or nearly spherical shape. Some are more elongated than others. They are composed mostly of old stars and contain very little gas and dust. The smallest elliptical galaxies (called "dwarf ellipticals") are probably the most common type of galaxy in the nearby universe.
- **Spiral Galaxy** - A galaxy made up of a pancake-shaped disk with spiral (pinwheel-shaped) arms, a bulge of stars near its center, and a spherical halo of

stars surrounding both the disk and bulge. The sizes of the disk and bulge vary. The galaxy is composed of a mixture of old and young stars as well as gas and dust. The spiral arms are sites of active star formation. The majority of large galaxies in the nearby universe are spirals.

- **Irregular Galaxy** - A galaxy whose shape does not show a regular pattern, neither elliptical nor spiral. Irregulars contain both young and old stars and are often rich in gas and dust. These galaxies often have active regions of star formation. Sometimes the irregular shape of these galaxies results from interactions or collisions between galaxies. Observations such as the Hubble Deep Fields show that irregular galaxies were more common in the distant universe.

8. How far away are the galaxies seen in the Hubble Deep Field-North image?

The nearest galaxies seen in the Hubble Deep Field are about 1 billion light-years away. The farthest are estimated to be about 11 billion light-years away.

9. How do astronomers measure the distances to galaxies?

Astronomers generally cannot measure the distance to a galaxy directly. Instead, they use what is called the "distance ladder," in which known nearby distances are used to accurately estimate much larger distances. For example, the distance from Earth to the Sun is well known, and using that distance (and other observations), we can determine distances to nearby stars. By using the properties of various types of stars, we can then get estimates of distances to nearby galaxies.

One important type of luminous star is called a "Cepheid variable." The brightness of these stars is variable and the period of that variation has been accurately related to the luminosity, or intrinsic energy output. By comparing how bright a Cepheid variable star appears with its intrinsic luminosity, scientists can determine how far away it is, and, by association, the distance to the host galaxy.

For distant galaxies, astronomers can use supernovae, stellar explosions that are incredibly bright. One special class of supernovae has a well-known peak intrinsic luminosity and is thus suitable for accurate distance measurements. Astronomers measure the brightness of a supernova for months to years following the explosion to determine the pattern as it fades, called the “light curve.” The light curve helps us identify the class of supernova, as well as its peak brightness. For suitable supernovae, one can again compare apparent brightness to intrinsic luminosity and determine distance. Supernovae can be seen out to a distance of a few billion light-years.

The most distant galaxies have their distances estimated by cosmological redshift. Cosmological redshift is the stretching of light due to the expansion of the universe. It is called “redshift” because red is the longest wavelength of the visible-light spectrum. The more distant the galaxy, the longer its light has been travelling across expanding space, and the greater the cosmological redshift. Measuring how much the light from a distant galaxy has been redshifted gives us a measure of its distance.

These methods are a few of the many possible ones that are collectively called the distance ladder. It is a ladder because astronomers rely upon the measurements of closer galaxies to Earth in order to calibrate the accuracy of distant galaxy measurements. Hence, you must establish the nearby measures before you can trust the faraway measures. Each rung of the ladder must be climbed carefully to reach the most distant parts of the universe.

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10. Why do astronomers conduct surveys?

Surveys are an important tool for astronomers. When they examine a section of the sky, astronomers observe a sample of a particular type of celestial object, whether it be stars, galaxies, or supernovae. The characteristics of that sample of objects are studied to measure and predict properties of similar objects throughout the universe.

11. How "deep" can these surveys eventually go? Is there a limit?

When the first Hubble Deep Field was done in 1995, astronomers saw galaxies out to about 11 billion light-years away. Each subsequent deep-field survey extended that reach by a few hundred million light-years. Thanks to these surveys, astronomers have been able to study galaxies as they were less than 1 billion years after the Big Bang.

The universe is 13.8 billion years old, so one cannot look further back in time than that. In addition, the light astronomers on Earth receive from stars and galaxies gets progressively redder with distance (due to cosmological redshift, see question 10 above). Infrared observatories of the future (like the James Webb Space Telescope) will allow astronomers to view faint galaxies whose light has been stretched beyond Hubble's observing capabilities. As our observatory technology improves, so will our understanding of the early universe.

12. The Hubble Deep Field opened new cosmic territory for exploration. What other deep-sky surveys did Hubble participate in?

Astronomers have used Hubble's sharp "eye" in several explorations of the distant universe. The original Hubble Deep Fields were done in both the northern and southern sky during the mid-1990s. In 2003-2004, the Hubble Ultra Deep Field (HUDF) took advantage of a newly installed camera to look even deeper into the cosmos. An infrared follow-up to the HUDF took place in 2009, and an ultraviolet extension was released in 2014.

But Hubble also has partnered with other observatories to study this distant territory. These surveys, including the Great Observatories Origins Deep Survey (GOODS), help astronomers view the history of galaxies and the universe in many wavelengths, including X-rays. Hubble is also working with other observatories on the Frontier Fields program. The Frontier Fields project is doing deep surveys around giant clusters of galaxies. These clusters are massive enough to produce gravitational lensing, and that lensing boost helps Hubble see a bit farther into the universe than it otherwise could.

13. What is the Hubble Deep Field-South (HDF-S)?

The HDF-S, taken in 1998, was a second look at a different region of the sky, located in the Southern Hemisphere. It is in the constellation Tucana, near the south celestial pole and complements the original Hubble Deep Field (HDF-N), taken in late 1995. Taking a second deep field helps astronomers confirm that the HDF-N sample of distant galaxies is representative, and that it is not unusual in some way. The two HDFs are, in fact, consistent with the astronomical principle that the universe should look statistically the same in any direction we look.

14. What is the Hubble Ultra Deep Field (HUDF)?

The HUDF, observed between September 2003 and January 2004, represents the deepest portrait of the visible universe ever achieved by humankind. It is actually two separate images taken in visible light by Hubble's Advanced Camera for Surveys (ACS) and in infrared light by the Near Infrared Camera and Multi-object Spectrometer (NICMOS). Both images reveal galaxies that are too faint to be seen by ground-based telescopes, or even in Hubble's previous deep fields. Within the images, astronomers have searched for the most distant galaxies ever observed, some over 12 billion light-years away. Because the light from such galaxies has taken over 12 billion years to travel across space, we see these galaxies as they were, only about 1 billion years after the big bang. A key question for HUDF astronomers is how galaxies develop from this very early time.

15. What is the Hubble Ultra Deep Field 2009 (HUDF09)?

The HUDF09 represents the deepest image of the universe ever taken in near-infrared light. The faintest and reddest objects in the image are galaxies or proto-galaxies as they existed about 600 million years after the Big Bang. The image was taken in the same region as the Hubble Ultra Deep Field (HUDF) by Hubble's infrared-wavelength detectors in Wide Field Camera 3 (installed during the 2009 servicing mission). The image shows an even deeper view into the universe than previous deep fields, because the light from very distant galaxies is stretched out of the ultraviolet and visible regions of the spectrum into near-infrared wavelengths by the expansion of the universe.

16. What is the Hubble eXtreme Deep Field (XDF)?

The XDF is a small portion of the original HUDF created in 2004. It was assembled by combining 10 years of NASA Hubble Space Telescope photographs taken of a patch of sky at the center of the original Hubble Ultra Deep Field. The XDF contains about 5,500 galaxies and can be considered a 2012 update to the HUDF09.

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17. What is the Great Observatories Origins Deep Survey (GOODS)?

The purpose of the GOODS survey is to study the distribution and development of galaxies across several wavelength regions, from X-rays to infrared light. The survey involved three of NASA's great observatories: the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory, as well as ground-based telescopes. The telescopes observed two representative spots in the sky, one in the Northern Hemisphere and the other in the Southern Hemisphere, revealing over 50,000 galaxies. Astronomers have identified more than 2,000 of them as infant galaxies, observed when the universe was less than about 2 billion years old. By combining light from all three of NASA's Great Observatories with data from ground-based telescopes, astronomers are working to build a coherent picture of galaxy evolution. The survey observations were taken in 2002-2003.

18. What is the Cosmic Evolution Survey (COSMOS)?

The purpose of COSMOS is to look at how the large-scale structure of the universe evolved by tracing the evolution of galaxies, star formation, active galactic nuclei, and dark matter. The survey covered a large portion of the sky near the ecliptic, so that many ground-based telescopes could contribute to the data set. Telescopes that observe light from radio waves through X-rays contributed to the survey, with Hubble and the Subaru Telescope making major contributions. Hubble observed more than 2,000 spiral galaxies with the Advanced Camera for Surveys. The survey's results show that so-called barred-spiral galaxies were far less plentiful over the last 7 billion years than they are today in the local universe. The study's results confirm the idea that bars are a sign of galaxies reaching full maturity as the "formative years" end. The observations were taken between fall 2003 and spring 2005.

19. What is the All-wavelength Extended Groth Strip International Survey (AEGIS)?

The purpose of AEGIS is to study the physical properties and evolutionary processes of the universe when it was about half its current age (about 7 billion years ago). The AEGIS program consists of data from major space and ground-based telescopes and spans the electromagnetic spectrum from radio waves to X-rays. Hubble's Advanced Camera for Surveys observed a narrow strip of sky near the Big Dipper. These images from more than 500 separate observations taken between June 2004 and March 2005, reveal a wealth of galaxies at many stages of their evolution through cosmic time.

A wide diversity of galaxies can be seen throughout the images. Some are beautiful spirals or massive elliptical galaxies, like those seen in the nearby universe, but others look like random assemblages of material, the leftovers from violent mergers of young galaxies. While Hubble spied tens of thousands of galaxies — many of them odd and chaotic — other telescopes observing at non-visible wavelengths and over wider areas have pinpointed more extreme and exotic objects, including supermassive black holes and energetic starburst galaxies.

The panorama image, created by weaving together 63 separate Hubble pointings, shows a snowstorm of galaxies that does not appear evenly spread out. Some galaxies seem to be grouped together. Others are scattered through space. This uneven distribution of galaxies traces the underlying concentration of matter in the universe, which astronomers often call the "cosmic web." Most of the matter comprising this web-like distribution is dark, so astronomers use the visible galaxies to trace its structure.

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Words from a scientist

by Ray Lucas

The Hubble Deep Field Academy exemplifies the work that astronomers face today in attempting to understand how galaxies have formed and evolved over the history of the universe. When faced with objects we do not fully understand, we try to classify them based on their observable traits. We first have to discern which traits are the most important ones to be measured or counted, and second, we have to decide what procedures we will follow in using our classification system. Sometimes the most important characteristics or methods are also the easiest to see or use, but sometimes nature is more subtle, and sometimes we find that our ways of studying a problem are unwieldy, or somehow unsuitable. Sometimes even our fundamental assumptions about a problem are challenged, and we find that different questions need to be asked.

This is an exercise in which students can participate by identifying galaxies' observable traits to use for classification and then attempting to identify relationships and patterns among the traits. Once such patterns and relationships are established, the questions of why they exist and their significance can be addressed, and tests can be designed to probe for more answers. Just as scientists find in their own everyday work, students will see that the answers are not always easy or clear and that some amount of interpretation is always required. Perhaps even entirely new ways of looking at data may be required in order to reach plausible answers to questions.

This exercise helps students learn about the value of graphically representing data as a means of identifying trends, as well as the importance of sharing scientific results with peers. Although the lesson is designed for use in middle school science classes, it is hoped that these exercises will serve as a springboard that helps the student embark on a lifetime of learning in any field of study. After all, even the oldest professional scientist is still a student of nature!

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Grab Bag

Downloadable activity documents

PRINT-READY WORKSHEETS

- What Does a Million Look Like?
- 999,999 Cans of Soda on the Wall?
- How Many's a Million? Billion? Trillion?

Web resources

One of the unique features of using the Internet is the ability to move quickly and easily to other links of related topics. If you find an appropriate related link, don't forget to bookmark it for future use. These related links can play an important role in enhancing your lesson. They can provide the latest information on astronomy or more information for a research topic. They also can be used to introduce, reinforce, or extend a concept or topic. Sample Web resources from the Space Telescope Science Institute and others are listed below.

WEB RESOURCES FROM THE SPACE TELESCOPE SCIENCE INSTITUTE (STSCI):

Amazing Space

An award-winning website that includes a comprehensive collection of standards-based science education materials. Materials and activities are organized by topic and type.

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HubbleSite

Contains news releases of Hubble's science and remarkable discoveries, illustrated facts about the telescope and its instruments, and gorgeous pictures of stars, planets, galaxies, nebulae, and more.

James Webb Space Telescope

Contains news releases and information about the James Webb Space Telescope, which will use infrared sensing technology to look into the farthest reaches of the universe.

Inbox Astronomy

Get the latest astronomy news and pictures delivered directly to your e-mail account.

Frontier Fields: Pushing the Limits of the Hubble Space Telescope

A Wordpress blog that follows the science of the ongoing Frontier Fields project.

HubbleSite News Release Archive: Galaxy

HubbleSite News Release Archive: Survey

SELECT HUBBLESITE NEWS STORIES:

- Barred Spiral Galaxies Are Latecomers to the Universe. In a landmark study of more than 2,000 spiral galaxies from the largest galaxy census conducted by NASA's Hubble Space Telescope, astronomers found that so-called barred-spiral galaxies were far less plentiful 7 billion years ago than they are today in the local universe.
- Findings From Hubble Deep Field Hone in on Distant Galaxies. News Release Number: STScI-1996-24. Includes an article on the Hubble Deep Field project and images.

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- Hubble's Deepest View of the Universe Unveils Bewildering Galaxies Across Billions of Light Years. Includes an article on the Hubble Deep Field image and what scientists hope to learn from it. Also includes images and videos.
- Hubble's Deepest View Ever of the Universe Unveils Earliest Galaxies. This is the release for the Hubble Ultra Deep Field – a deeper view of the universe than was achieved by the HDFs.
- Hubble's Deepest View of Universe Unveils Never-Before-Seen Galaxies. A near-infrared image of the Hubble Ultra Deep Field reveals even more distant galaxies than the visible-light HUDF.
- Hubble Discovers 67 New Gravitationally Lensed Galaxies in the Distant Universe. The COSMOS project used observations from several observatories including Hubble, the Spitzer Space Telescope, the XMM-Newton spacecraft, the Chandra X-ray Observatory, the Very Large Telescope, and the Subaru Telescope to survey a single 1.6-square-degree field of sky (nine times the area of the full Moon). As a result, astronomers discovered 67 new gravitationally lensed galaxies.
- Hubble Goes to the eXtreme to Assemble Farthest Ever View of the Universe. Astronomers have assembled a new, improved portrait of mankind's deepest-ever view of the universe. Called the eXtreme Deep Field, or XDF, the photo was assembled by combining 10 years of NASA Hubble Space Telescope photographs taken of a patch of sky at the center of the original Hubble Ultra Deep Field.

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- Hubble Pans Across Heavens to Harvest 50,000 Evolving Galaxies. Several hundred images taken with NASA's Hubble Space Telescope have been woven together into a rich tapestry of at least 50,000 galaxies. The Hubble view is yielding new clues about the universe's youth, from its "pre-teen" years to young adulthood.
- NASA's Hubble Finds Most Distant Galaxy Candidate Ever Seen in Universe. Includes an article highlighting some of the changes to Hubble and deep explorations since the Hubble Deep Field image. Includes images and videos.
- The Secret Lives of Galaxies Unveiled in Deep Survey. Two of NASA's Great Observatories, bolstered by the largest ground-based telescopes around the world, are beginning to harvest new clues to the origin and evolution of the universe's largest building blocks, galaxies. Called the Great Observatories Origins Deep Survey (GOODS), astronomers are studying galaxy formation and evolution over a wide range of distances and ages.
- The Universe "Down Under" is the Latest Target for Hubble's Latest Deep-View. The observation, called the Hubble Deep Field-South, doubles the number of far-flung galaxies available to astronomers for deciphering the history of the universe.

OTHER WEB RESOURCES:

Below you will find links to additional information that comes from sources other than STScI. Some of the resources are quite in-depth, and it is easy to get lost. It is suggested that you bookmark this page before you examine each source. That way, should you get lost, you can use the bookmark to return to this page. Since other parties run the sites listed below, there is no way of guaranteeing their stability. You

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may occasionally find a site "under construction," or you may find that a site is completely gone. There is no way to control such situations because the sites are out of our control. This page is only a fraction of the information available on the Web.

If you do not find what you are looking for here, GO FIND IT!

- **Article:** The Hubble Deep Field: The Most Important Image Ever Taken. What was the significance of the Hubble Deep Field image? Why does it matter to astronomers? This article gives one man's opinion of the image.
- **Article:** Hubble's Deepest View of Universe Unveils Never-Before-Seen Galaxies. An article on the Hubble Ultra Deep Field images.
- **Online book:** A Meeting With the Universe: Science Discoveries from the Space Program. This online book chronicles space exploration and the new vistas opening to humankind through space telescopes and advanced imaging techniques. One section addresses the different classifications of galaxies.
- **Website:** NASA Education. A website for educators that includes many electronic resources, as well as a search engine to find NASA education materials.
- **Web page:** NASA Educator Resource Centers. A list, by state, of contacts for acquiring NASA materials.
- **Website:** NASA. Updated daily; provides links to all NASA-related information, resources, and centers.
- **Website:** NASA Wavelength Digital Library. A convenient way to find NASA education resources related to earth and space science.

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- **Website:** NASA's Great Observatories. Information about NASA's Great Observatories, including the Hubble Space Telescope, the Compton Gamma Ray Observatory, the Chandra X-Ray Observatory, and the Spitzer Space Telescope.
- **Website:** NASA's Imagine the Universe! . A service of the High Energy Astrophysics Science Archive Research Center (HEASARC) at NASA/GSFC, designed for students ages 14 and up. This site has resources and activities for all things having to do with astronomy, along with a section just for teachers.
- **Web pages:** Near-Infrared Galaxy Morphology Atlas. An in-depth discussion regarding the classification of galaxies from the California Institute of Technology.
- **Web pages:** Science@NASA: Galaxies. A brief explanation of galaxies and types of galaxies.
- **Web pages:** What is a Galaxy? An explanation of characteristics and types of galaxies.

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