BEYOND THE SOLAR SYSTEM

Expanding the Universe in the Classroom

A professional development resource for teachers

GUIDE TO THE DVD

The *Beyond the Solar System* DVD and accompanying resources were produced for NASA by the Universe Education Forum and the Science Media Group at the Harvard-Smithsonian Center for Astrophysics.

UNIVERSEFORUM

For related materials, professional development opportunities, or for additional copies, go to www.universeforum.org/btss

DVD OVERVIEW

All humans should participate in the pleasure of coming to know their universe better.

– Science for All Americans, Project 2061

Current news releases from NASA and research institutions like the Harvard-Smithsonian Center for Astrophysics are full of amazing discoveries about our universe—the detection of planetary systems orbiting other stars; new evidence for the ages of the oldest stars and galaxies; galaxy motions that indicate mysterious new dark forms of matter and energy fill all of space. These exciting developments deserve to be accessible to students, teachers and the public, who express great interest in astronomy and space science. Yet true comprehension of these findings requires a basic scientific understanding of the nature and history of our universe, a fascinating but potentially challenging topic that often gets scant attention in the demanding environment of today's science classroom. Indeed, most students leave high school having never explored the universe beyond the solar system.

Welcome to *Beyond the Solar System: Expanding the Universe in the Classroom*. The Science Education Department of the Harvard-Smithsonian Center for Astrophysics, in association with NASA, has produced this DVD to help teachers in grades 8-12 deepen their own and their students' understanding of the structure and evolution of the universe and the nature of science. The DVD combines scientific and educational research to provide a professional development resource for teachers that integrates science content with pedagogical content knowledge.

Why teach about the universe and the Big Bang?
The Big Bang scenario for the origin and evolution of our expanding universe is one of the most powerful ideas in all of astronomy and physical science, confirmed by a century of observational evidence and predicted by Einstein's theory of gravity, general relativity. Yet many of us—students and teachers alike—are not aware of the Big Bang as a compelling example of the connections between evidence, models and explanation in science. The Big Bang is more than "just a theory"—and as such, learning about it can help students better understand the nature of science.

The *National Science Education Standards* includes the topic of origin and evolution of the universe as part of the essential content of Earth and space science understanding. Yet providing concrete, inquiry-based experiences for students to learn these concepts can be a challenge for teachers. The *Beyond the Solar System* DVD has been designed to help teachers "expand the universe" in their classroom.

The DVD contains more than two hours of video, organized into two modular strands of material—science content, and teaching and learning resources. These

are intended to promote greater understanding of the scientific concepts through discussion and reflection, activities, and application of the ideas to teaching. Also included are lesson plans, student guides, assessments, content background articles, summaries of relevant standards, and web links to further resources. These instructional materials are provided on the DVD in PDF format and can be printed from a computer.

Using Beyond the Solar System

Beyond the Solar System can be used in a variety of learning situations. The DVD is designed for use by in-service and pre-service teachers, astronomy educators, professional development providers, high school and college students, and informal educators. The video and print material on the DVD is especially well suited for the following educational settings:

- In-service teacher professional development workshops
- Pre-service teacher education courses
- Distance learning/Telecourses
- High school and introductory college courses
- Astronomy and space science education resource collections
- Informal science learning programs in museums, planetariums, and community-based organizations

See page 16 of this guide for suggestions on how to plan a professional development experience using the *Beyond the Solar System* DVD.

DVD OUTLINE

Introduction (4:18)

SCIENCE CONTENT STRAND

Key Concepts:

- Our universe is made of galaxies (3:02)
- Galaxies are moving apart (2:04)
- Looking out into space is looking back in time (3:36)
- We can see light from the big bang (2:55)
- Our early universe was simple (3:10)
- Gravity formed structures in our universe (2:02)
- Einstein's model predicts the big bang (3:47)

Evidence:

About our universe...How do we know:

- What stars and galaxies are made of? (2:09)
- The distances to stars and galaxies? (2:04)
- The speed of galaxies? (2:10)
- The age of our universe? (3:12)

Researchers:

- Marcelo Gleiser–Big Questions (3:38)
- Hiranya Peiris–Big Bang (3:41)
- Kim McLeod–Black Holes (2:37)
- Robert Kirshner–Dark Energy (5:01)
- David Charbonneau–Other Solar Systems (4:59)

TEACHING AND LEARNING STRAND

Student Ideas:

- Introduction (4:23)
- Travis–Where are the stars? (3:33)
- Katrina–How far out do stars go? (4:38)
- Martin–What is a galaxy? (4:10)
- Gregory–How are galaxies arranged? (4:26)
- Zocrates and Friends–What was the big bang? (4:55)

Classrooms:

- Modeling the universe (12:24)
- The nature of models (8:16)
- Exploring with telescopes (9:26)
- Measuring with telescopes (9:12)
- Cosmic timeline (9:45)

Resources:

- Introductory materials (4 PDF documents)
- Curriculum materials (19 PDF documents)
- Visual resources (4 PDF documents; 4 video clips)
- Science education standards (3 PDF documents)
- Web resources

PATHWAYS THROUGH BEYOND THE SOLAR SYSTEM

The modular format of the material on this DVD provides for a wide variety of potential pathways through it. The following descriptions of the *Beyond the Solar System* segments may suggest different ways of approaching the content depending on whether you are interested in furthering your own science learning, facilitating a workshop with other educators on this topic, or applying the ideas and resources from this DVD to designing your own classroom learning experiences.

A note about captioning: English subtitles are available for every video segment on the DVD, and can be activated by selecting the "Set Up" menu from the main menu screen.

SCIENCE CONTENT STRAND

Key Concepts, Evidence, and Researchers

What are the essential concepts needed to understand the structure and evolution of our universe? How can astronomers determine the features of stars and galaxies that are trillions of miles away? What big questions are scientists researching?

Viewers may use this strand of material to check or strengthen their own understanding of these concepts; to stimulate a science content-centered discussion among teachers or students; or to prompt questions for further investigation. The extensive print and web resources that accompany the DVD provide more in-depth content background.

Focus Questions

As you watch each of the short segments in the Science Content Strand, use the following questions to guide your thinking and discussion:

How is this explanation the same or different from your own understanding of this concept?

Are there any completely new terms or ideas that you would want more information about?

What questions do you have after viewing this segment?

What would your students need to know in order to make sense of these ideas?

Many of the Science Content Strand video clips use simple visual models and conceptual analogies to help illustrate scientific concepts. The Evidence segments use models to explain the thought processes that astronomers use to interpret observational evidence. Each of these models, like all models, has its strengths as well as its limitations. Thus, these clips can be used to prompt rich discussions about the interplay between models, evidence and explanation in science.

Key Concepts

This series of short video clips explains the conceptual chain of observations, evidence, and logical reasoning that support the standard Big Bang model for the origin and evolution of our universe.

- Our universe is made of galaxies (3:02)
- Galaxies are moving apart (2:04)
- Looking out into space is looking back in time (3:36)
- We can see light from the big bang (2:55)
- Our early universe was simple (3:10)
- Gravity formed structures in our universe (2:02)
- Einstein's model predicts the big bang (3:47)

Evidence

Without direct experience, how can we know what stars and galaxies are made of, or how old the universe is? This segment illustrates some of the practical and conceptual tools used by astronomers.

About our universe...How do we know:

- What stars and galaxies are made of? (2:09)
- The distances to stars and galaxies? (2:04)
- The speed of galaxies? (2:10)
- The age of our universe? (3:12)

Researchers

We have learned a lot about the structure and evolution of our universe, but many big questions are yet to be answered. These interviews with scientists highlight some of the fascinating space science research topics currently under investigation.

- Marcelo Gleiser–Big Questions (3:38)
- Hiranya Peiris–Big Bang (3:41)
- Kim McLeod–Black Holes (2:37)
- Robert Kirshner–Dark Energy (5:01)
- David Charbonneau–Other Solar Systems (4:59)

Relevant Resources

Before or after viewing the Science Content Strand, you may wish to read the following documents from the Resources section of the DVD:

Introductory Materials
Cosmology Frequently Asked Questions (CosmologyFAQs.pdf)
Big Bang Primer (BB_primer.pdf)

Curriculum Materials
Measuring Galaxies Teacher Background (Galaxies_background.pdf)

Visual Resources
Frontiers of Cosmology Presentation (Frontiers.pdf)
Cosmic Models Presentation (Cosmic_models.pdf)
NASA's Exploration of the Universe (NASA_missions.pdf)

TEACHING AND LEARNING STRAND

Student Ideas, Classrooms, and Resources

How can a teacher help students to truly understand the universe beyond the solar system? The Teaching and Learning Strand begins with one-on-one interviews that highlight common student ideas about the size, scale, structure, and age of the universe. These interviews give viewers the opportunity to confront their own mental models of the universe. Along with the Classroom footage and the instructional Resources, this strand gives teachers the tools they need to consider effective strategies for moving students from their initial ideas to more powerful ways of understanding offered by scientific ideas.

Student Ideas

What kinds of mental models of the universe do students bring to the classroom? These interviews illustrate common student ideas that can serve as barriers—or building blocks—to deeper conceptual understanding of our universe.

- Introduction (4:23)
- Travis–Where are the stars? (3:33)
- Katrina–How far out do stars go? (4:38)
- Martin–What is a galaxy? (4:10)
- Gregory–How are galaxies arranged? (4:26)
- Zocrates and Friends–What was the big bang? (4:55)

Focus Questions

As you listen to these students explain their models of the universe, think about whether you agree or disagree with their ideas. Where do the ideas student bring to the classroom come from? Where does your own knowledge about the universe beyond the solar system come from?

Are there student ideas that you find surprising?

What ideas can you identify that agree with scientists' conceptions?

What ideas and questions do you see that could serve to motivate future learning?

What ideas do you see—about astronomy and space science concepts or about the nature of science—that might be barriers to deeper understanding?

How might you help students "cross the bridge" from their initial ideas to those accepted by scientists?

Classrooms

These real classroom vignettes show students and teachers exploring the universe using *Beyond the Solar System* instructional materials. View them to reflect on your own strategies for supporting student thinking and learning.

- Modeling the universe (12:24)
- The nature of models (8:16)
- Exploring with telescopes (9:26)
- Measuring with telescopes (9:12)
- Cosmic timeline (9:45)

Focus Questions

Teachers may wish to print and review the lesson plans for these activities before viewing them in action. The video footage of these classrooms has been edited to give viewers a taste of how the *Beyond the Solar System* activities might be used, but they are not comprehensive. Consider the following questions as you view the classroom scenes:

What ideas and understandings are students exploring through this classroom activity?

How does the activity support student thinking and learning?

What strategies is the teacher using to support student learning?

In what ways does the activity integrate science content and science process understanding?

What examples can you find of students expressing details about their ideas and beliefs?

What questions would you want to ask the teacher in this classroom?

Resources

This section of the DVD contains an extensive collection of PDF-format classroom instructional materials, extra DVD-Video clips, and web links. The PDF documents and web links in the Resources section can be accessed from a computer via the on-screen menu of the DVD, using Apple's DVD@ccess technology. Instructions for setting up DVD@ccess on either Windows or

Macintosh computers can be found by clicking "Help" on the Resources menu screen. Alternatively, you may access these PDF documents and web links directly from the BTSS_DVD disc icon as it appears on your computer.

INTRODUCTORY MATERIALS (4 PDF documents)

The documents in this section are:

- **Guide to Beyond the Solar System** (BtSS_guide.pdf) (This document)
- **Beyond the Solar System Cover Insert** (BtSS_DVD_insert.pdf) (4-page full color DVD insert)
- **Frequently Asked Questions** (CosmologyFAQs.pdf)
  An article with answers to frequently asked questions about the Big Bang and other topics in cosmology.
- **Big Bang Primer** (BB_primer.pdf)
  A chart outlining what we DO and DON'T know about the early universe based on evidence, along with a list of common conceptual difficulties and resources from the DVD that are related to these ideas.

CURRICULUM MATERIALS (19 PDF documents)

This section contains a unique set of standards-based classroom activities and assessments that have been tried and tested in classrooms nationwide. You can view several of the activities in action in the Classrooms section of the *Beyond the Solar System* DVD. The activities present a vision of teaching and learning about the origin and evolution of the universe as articulated by the *National Science Education Standards*' Content Standard D, and the AAAS *Benchmarks for Science Literacy*, for grades 6-8 and 9-12. The sequence of classroom activities is:

- **Modeling the Universe**
  "Modeling the Universe" is an assessment activity that allows you and your students to see what they know and understand about Earth's place in the solar system and universe. Used both before and after a unit of astronomy instruction, it can make student learning visible in a compelling way. It can also be used to begin discussion about the nature of scientific models. The "Birdseed Galaxy" presentation can then be used to help students visualize a true-scale model of the solar system compared to the vast distances between stars in our galaxy.

PDF documents supporting the "Modeling the Universe" activity:

Modeling the Universe Teacher Guide (MTU_teacher.pdf)

Modeling the Universe Student Guide (MTU_student.pdf)

Birdseed Galaxy Model (BirdseedGalaxy.pdf)

- **Exploring with Telescopes**
  These *Beyond the Solar System* activities guide you through using the MicroObservatory network of automated telescopes that can be operated by your students via the Internet. Read the "Intro to MicroObservatory Telescopes" first to find out how your students can pursue authentic astronomical investigations by posing questions, gathering and analyzing observational data, and interpreting their own results as they explore the universe.

  The "Portrait of the Universe" activity gets students using the telescopes to take images of a variety of objects, then analyzing their images to ask and answer questions about the Moon, planets, stars, nebulae, and galaxies. The "Measuring Size from Images" activity provides the key to being able to quantitatively measure sizes and distances using the telescopes, and helps to inform an understanding of size and scale in the universe.

PDF documents supporting the "Exploring with Telescopes" activities:

Intro to MicroObservatory Telescopes (mObs_intro.pdf)

Portrait of the Universe Teacher Guide (Portrait_teacher.pdf)

Portrait of the Universe Student Guide (Portrait_student.pdf)

Measuring Size from Images Guide (Measuring_size.pdf)

Portrait Activity Images (Portrait_images.pdf)

Telescope Observation Log Sheet (Telescope_log.pdf)

- **Measuring Galaxies with Telescopes**
  How big and how old is the universe? This culminating telescope investigation for high school students has them first taking images of galaxies near and far; then measuring and calculating their distances; then predicting how they might expect galaxies to be moving based on various models of gravity; and then comparing their results with the galaxy velocity measurements in a NASA database. From this data, students explore the concept of an expanding universe and can actually determine an estimate for the age of our universe!

PDF documents supporting the "Measuring Galaxies" activity:

Measuring Galaxies Teacher Background (Galaxies_background.pdf)

Measuring Galaxies Teacher Guide (Galaxies_teacher.pdf)

Measuring Galaxies Student Guide (Galaxies_student.pdf)

Galaxy Activity Images (Galaxy_images.pdf)

- **Cosmic Timeline of the Universe**
  This image sorting assessment activity stimulates a discussion about what students know and don't know about the relative ages of objects in the universe, and about how those ages can be determined. By physically manipulating objects and images of items new and old, students represent their own mental models of change through time.

PDF documents supporting the "Cosmic Timeline" activity:

Cosmic Timeline Teacher Guide (Timeline_teacher.pdf)

Cosmic Timeline Student Guide (Timeline_student.pdf)

Cosmic Timeline Images (Timeline_images.pdf)

- **Beyond the Solar System Assessments**
  These assessments have been designed to help you diagnose strengths and weaknesses in students' conceptual understanding of the middle and high school science standards that relate to the topic of origin and evolution of the universe. Professional development providers can use them with teachers as they check their own understanding and their awareness of the students' level of understanding.

PDF assessment documents:

Multiple Choice Assessment Teacher Version (BtSS_assess_teacher.pdf)

Multiple Choice Assessment Student Version (BtSS_assess_student.pdf)

Open-Ended Assessment Questionairre (BtSS_questionnaire.pdf)

VISUAL RESOURCES (4 DVD-Video clips; 4 PDF documents)

This section contains four extra video visualizations of astronomical concepts, a PDF document with annotations of those four video animations, and three PDF documents that can assist teachers in presenting information about current astronomy research.

Use your DVD player to view these four visualizations:

- **Take a trip through space and time** (1:25)
  Follow the imaginary path of a photon's 14 billion year journey from the time of the Big Bang to its rendezvous with NASA's WMAP space probe.

- **Fly through the universe** (2:03)
  Take an imaginary journey from the Earth to the stars, and out of our Milky Way galaxy.

- **Cosmic Evolution** (1:21)
  View our changing and evolving universe, from the first few moments of the Big Bang to the formation of galaxies.

- **Take a deep look into our universe** (1:50)
  Zoom from the familiar night sky to the furthest galaxies seen by the Hubble Space Telescope.

Use your computer to access these PDF reference and presentation documents:

- **Guide to the Animations** (Animations.pdf)
  These annotations provide context and narration for the four video animations in this section of the DVD.

- **Frontiers of Cosmology Presentation** (Frontiers.pdf)
  This presentation provides a "real image" overview of today's astronomical and cosmological frontiers.

- **Cosmic Models Presentation** (Cosmic_models.pdf)
  This presentation helps explain the current scientific model for the origin and evolution of the universe in the context of the history and nature of science.

- **NASA's Explorations of the Universe** (NASA_missions.pdf)
  An overview of the current and future space science missions NASA is using to investigate the nature of the universe.

SCIENCE EDUCATION STANDARDS (3 PDF documents)

These three documents outline some of the key science standards that pertain to the *Beyond the Solar System* curriculum materials:

- **Summary of Universe Standards** (Summary_standards.pdf)
  This document summarizes the K-12 space science and astronomy content standards, drawn from both the NRC *National Science Education Standards* and the AAAS *Benchmarks for Science Literacy*.

- **Universe Teaching and Learning** (Universe_teaching.pdf)
  This reference document is intended to help teachers make decisions about instruction and assessment. It summarizes the learning goals for student understanding of the origin and evolution of the universe, and the education research that is relevant to those goals.

- **Models Teaching and Learning** (Models_teaching.pdf)
  The science content from *Beyond the Solar System* can be used to help

students understand the role of models, evidence and explanation in science. This document summarizes the learning goals for this topic and the relevant education research on student learning.

WEB RESOURCES (4 DVD@ccess links)

These four primary web sites directly support the content of the *Beyond the Solar System* DVD. In order to access these links from the Web Resources on-screen menu, you will need to enable the DVD@ccess program on your computer.

- **Beyond the Solar System Home**
  http://www.universeforum.org/btss/
  Check this web site for updates to *Beyond the Solar System,* opportunities for professional development, and links to further resources.

- **NASA-Smithsonian Universe Forum**
  http://www.universeforum.org/
  The home site of the producers of *Beyond the Solar System* contains science background information, resources for teaching and learning about the structure and evolution of the universe, and links to NASA's Universe Exploration missions.

- **NASA Exploring the Universe**
  http://www.nasa.gov/vision/universe/starsgalaxies/
  Find out how NASA is exploring the universe beyond the solar system.

- **NASA Deep Space Missions**
  http://www.nasa.gov/missions/deepspace/
  Learn about the current and future missions NASA is using to study the nature of the universe.

ADDITIONAL WEB RESOURCES

NASA-Smithsonian Universe Forum
http://www.universeforum.org/

Beyond the Solar System
http://www.universeforum.org/btss/

MicroObservatory Guest Observer Portal
http://www.microobservatory.org/

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

Modeling the Universe
http://www.universeforum.org/mtu/

Harvard-Smithsonian Center for Astrophysics
http://cfa-www.harvard.edu/

From the Ground Up! Online Telescope Curriculum
http://www.cfa.harvard.edu/webscope/

NASA RESOURCES

Universe Exploration

Beyond Einstein Research Program
http://universe.nasa.gov/

Wilkinson Microwave Anisotropy Probe
http://wmap.gsfc.nasa.gov/

Hubble Space Telescope
http://www.hubblesite.org/

Chandra X-ray Telescope
http://chandra.harvard.edu/

Spitzer Infrared Space Telescope
http://www.spitzer.caltech.edu/

Universe Missions
http://science.hq.nasa.gov/missions/universe.html

Space Science Education Resource Directory
http://teachspacescience.org

NASA's Night Sky Network of Amateur Astronomy Clubs
http://nightsky.jpl.nasa.gov

Imagine the Universe!
http://imagine.gsfc.nasa.gov

Astronomy Picture of the Day
http://antwrp.gsfc.nasa.gov

USING BEYOND THE SOLAR SYSTEM FOR PROFESSIONAL DEVELOPMENT

The *Beyond the Solar System* DVD provides a modular set of science and pedagogical content resources that can be flexibly used to design professional development programs for teachers who wish to engage their students in exploring the universe beyond the solar system. The following template provides one possible learning cycle that facilitators may wish to use as they design professional development sessions using the *Beyond the Solar System* materials.

1. Select a topical focus

Either before or at the beginning of a session, facilitators can work with participants to identify a particular area of interest for teachers to investigate. The beginning of a *Beyond the Solar System* session should start with a discussion in which participants turn the focus topic into essential questions worth investigating. An example of such a question might be: *What are some key ideas about the universe beyond the solar system that I want my students to understand?*

Here is a list of potential focus topics:

- Assessing student ideas about the universe
- Supporting student inquiry
- Interpreting astronomical images
- Size and scale in the universe
- Galaxies
- The Big Bang
- Gravity's role in the universe
- Change over time in the universe
- Models, evidence, and explanation in science

2. Explore *Beyond the Solar System* content

Immerse participants in their own exploration of science content through one of the *Beyond the Solar System* activities. This will help the group make connections between the session focus and classroom practice. Consider using the following questions to guide discussion and reflection as participants complete the activity:

What questions came up in your group as you were working?

What content were you learning (or re-learning) as you worked with the materials?

When investigating this content, what would you expect students to know and be able to do?

What are some ways in which this activity is related to the origin and evolution of the universe content standards, or the science as inquiry standards?

3. View *Beyond the Solar System* video material

Now participants are ready to view the video segments. Depending on whether participants are focusing on their own science learning or classroom practice, you may wish to pre-select a relevant set of segments. Provide participants with the Focus Questions from the Science Content and Teaching and Learning Strand descriptions earlier in this guide to help them record their observations and reflections as they view the video segments. You can also choose to have different groups view different strands of material and then share their observations later.

4. Reflect and make connections

Ask participants to write for five minutes, reflecting on what they observed in the video material and posing questions that arose for them as they watched. Then have small groups share their reflections and identify common themes and questions. Reconvene the groups so that each can share and explain their major findings.

Depending upon the expertise of the facilitator and the particular session focus, this discussion may prompt a more in-depth discussion of some aspect of *Beyond the Solar System* science content, or of ways that the video and *Beyond the Solar System* activities might relate to the participants' classroom experiences.

5. Extend and evaluate

Questions raised during the reflection stage can lead to more topics to investigate in a follow-up session, or questions that participants can pursue in their classrooms. Ask teachers to write down personal responses to the following prompts:

Key insights from today's session that I will take with me back to my classroom:

Science topics or questions I wish to know more about:

Issues related to teaching and learning about the universe that I wish to address in my classroom:

Encourage participants to order their own copy of the *Beyond the Solar System* DVD at our web site:

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

At this site, teachers will also be able to find updates to the *Beyond the Solar System* resources, and join an online discussion. Distribute the Evaluation on page 19 of this guide to assess the effectiveness of your session and to identify ideas for your next workshop.

SESSION EVALUATION

1. How would you rate the following aspects of this *Beyond the Solar System* workshop?

	Excellent	Very Good	Good	Fair	Poor
Session goals were clear and appropriate					
Organization and content of session					
Enhancement of your own understanding of the universe beyond the solar system					
Opportunities to learn strategies and activities for promoting student learning					
Beyond the Solar System (BtSS) classroom activity Activity explored:					
BtSS Video reflections: Science Content Strand Segments viewed:					
BtSS Video reflections: Teaching and Learning Segments viewed:					
Relevance/applicability to your classroom					
Presenters' facilitation skills					
Resources/Materials presented during session					
Other (describe):					

2. In which part of the workshop did you feel you learned the most? What key insight(s) did you gain?

3. Which aspects of the workshop were least effective, and why?

4. Explain how you might use some part(s) of today's experience in your classroom.

5. Other comments, recommendations for improving this workshop or a follow-up:

IMAGE AND ANIMATION CREDITS

The astronomical images and animations contained within this DVD are used with permission.

Home:
Hoag's Object, R. Lucas (STScI/AURA), Hubble Heritage Team, NASA
Hubble Space Telescope, NASA

Introduction:
Solstice sunrise at Stonehenge, Copyright © 2005 of Kev & Fee Warner of MercuryMoon.co.uk
Chinese star map, photo by Kevin Burke, artifact courtesy of the National Academy of Sciences
Orion and zoom into night sky, NASA, G. Bacon and Z. Levay (STScI)
Milky Way illustration, Christian Goldbach, Index to Constellations, 1799. Image courtesy Linda Hall Library of Science, Engineering and Technology
Milky Way photo, © Axel Mellinger, Institut für Physik
Spacewalk, courtesy NASA, Challenger STS-41C
Gemini Observatory, Gemini Observatory/AURA
Fly through the solar system, Susan Friedman/What's Up in the Universe
Zoom out from solar system, Science Media Group, Data from Milky Way Series Digital Universe, Hayden Planetarium, American Museum of Natural History, permission granted by Brian Abbott (no modifications were made to the data)
Milky Way galaxy, Ken Eward/National Geographic Image Collection
30 Doradus nebula , N. Walborn (STScI), R. Barbá (La Plata Observatory) and NASA
Crab Nebula supernova remnant, NASA, ESA, J. Hester, A. Loll (ASU); D. De Martin (Skyfactory)
Hodge 301 in the Tarantula Nebula, Hubble Heritage Team (AURA/STScI/NASA)
Barred spiral galaxy NGC 1300, NASA, ESA, and The Hubble Heritage Team (STScI/AURA)
NGC 3603, Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (Univ. Washington), You-Hua Chu (Univ. Illinois Urbana-Champaign), and NASA
Expanding galaxies animation, Dana Berry, SkyWorks Digital, Inc.
Clouds over observatory, Science Media Group
Centaurus A galaxy, © European Southern Observatory
Resources icon, Laurent Baumann

Key Concepts: Our universe is made of galaxies:
Milky Way over telescope, Gemini Observatory, Peter Michaud & Kirk Pu'uohau-Pummill
Fly through the solar system, Susan Friedman/What's Up in the Universe; Science Media Group
Zoom out of the Milky Way, Science Media Group, Data from Milky Way Series Digital Universe, Hayden Planetarium, American Museum of Natural History, permission granted by Brian Abbott (no modifications were made to the data)
Milky Way galaxy, Ken Eward/National Geographic Image Collection
Sun, SOHO (ESA & NASA)
Galaxy fly-through, 2dF Galaxy Redshift Survey/Swinburne Centre for Astrophysics and Supercomputing
Stephan's Quintet, Gemini Observatory Image/Travis Rector, University of Alaska Anchorage
Stephan's Quintet, NASA, J. English (U. Manitoba), S. Hunsberger, S. Zonak, J. Charlton, S. Gallagher (PSU), and L. Frattare (STScI)
Spiral galaxy M 101, NASA

Centaurus A galaxy, © European Southern Observatory
Warped Spiral Galaxy ESO 510-13, Hubble Heritage Team (STScI/AURA), C. Conselice (U. Wisconsin/STScI) et al., NASA
NGC 4676 The Mice, NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA
HCG 87, Gemini Observatory/GMOS - South Commissioning Team
Abell 2218, NASA, N. Benitez (JHU), T. Broadhurst (Racah Institute of Physics/The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
Hoag's Object, NASA and The Hubble Heritage Team (STScI/AURA)
Abell 1689, NASA, N. Benitez (JHU), T. Broadhurst (Racah Institute of Physics/The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA

Key Concepts: Galaxies are moving apart
Gemini telescope animation, Gemini Observatory/AURA
M51 Whirlpool Galaxy, NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA)
Stephan's Quintet, Gemini Observatory Image/Travis Rector, University of Alaska Anchorage
NGC 3370 Galaxy, NASA, The Hubble Heritage Team and A. Riess (STScI)
Edge-on spiral galaxy, T. Rector (U. Alaska Anchorage), Gemini Observatory, AURA, NSF
Gemini Deep Field, Gemini Observatory/Isobel Hook and the GMOS System Verification Team
Edwin Hubble at telescope, The Huntington Library, San Marino, California
Spiral galaxy M 101, NASA
Spiral galaxy M74, NASA, ESA and the GMOS Commissioning Team (Gemini Observatory)
Spiral galaxy NGC 3949, NASA, ESA and The Hubble Heritage Team (STScI/AURA), S. Smartt (The Queen's University of Belfast)
Hoag's Object, NASA and The Hubble Heritage Team (STScI/AURA)
Barred Spiral Galaxy NGC 1365, FORS Team, 8.2-meter VLT Antu, ESO
Spiral Galaxy 3310, NASA and The Hubble Heritage Team (STScI/AURA); G.R. Meurer and T.M. Heckman (JHU), C. Leitherer, J. Harris and D. Calzetti (STScI), and M. Sirianni (JHU)
Spiral galaxy NGC 4414, W. Freedman (Carnigie Obs.), L. Frattare (STScI) et al., & the Hubble Heritage Team (AURA/ STScI/ NASA)
Andromeda Galaxy, GALEX Team, Caltech, NASA
Edwin Hubble with pipe, Observatories of the Carnegie Institute of Washington
Cosmic Microwave Background, The Boomerang Collaboration

Key Concepts: Looking out into space is looking back in time
Zoom in to Hubble Ultra Deep Field, NASA, G. Bacon and Z. Levay (STScI)
Laboratory, Science Media Group
Beam of light animation, Science Media Group
Earthrise, Apollo 8 Crew, NASA
Earth, NASA Goddard Space Flight Center
Moon, Harvard-Smithsonian Center for Astrophysics
Astronaut on the Moon, Apollo 17 Crew, NASA
Mission Control, Courtesy NASA
Sun, SOHO (ESA & NASA)

Ocean sunset, Science Media Group
Hubble Ultra Deep Field, S. Beckwith & the HUDF Working Group (STScI), HST, ESA, NASA
Pan across Hubble Ultra Deep Field, NASA and G. Bacon (STScI)

Key Concepts: We can see light from the big bang
Hubble Ultra Deep Field, S. Beckwith & the HUDF Working Group (STScI), HST, ESA, NASA
Pan across Hubble Ultra Deep Field, NASA and G. Bacon (STScI)
Zoom in to Hubble Ultra Deep Field, NASA, G. Bacon and Z. Levay (STScI)
Spectrum, Science Media Group
Earth, NASA Goddard Space Flight Center
Penzias and Wilson, Copyright © 2004 Pearson Education, publishing as Addison Wesley
COBE, NASA/GSFC
Cosmic microwave background, NASA/GSFC
Clouds over observatory, Science Media Group
Earth in space, Science Media Group

Key Concepts: Our early universe was simple
Crab Nebula (menu icon), NASA, ESA, J. Hester, A. Loll (ASU); Davide De Martin (Skyfactory)
Zoom from Earth, Science Media Group
Periodic Table of Elements, Science Media Group
Abell 1689, NASA, N. Benitez (JHU), T. Broadhurst (Racah Institute of Physics/The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
Cecilia Payne, Courtesy Harvard University Archives
Sun animation, SOHO (ESA & NASA)
Large Magellanic Cloud, NASA and the Hubble Heritage Team (STScI)
Bethe and chalkboard, Cornell University Photo Archive
Cosmic Microwave Background, The Boomerang Collaboration
Stars in NGC 6397, NASA and the Hubble Heritage Team (STScI/AURA), A. Cool (SFSU)
Supernova 1987A, P. Challis (CfA)
Kepler supernova remnant composite, NASA, ESA, R. Sankrit and W. Blair (Johns Hopkins University)
Crab Nebula composite, X-ray: NASA/CXC/ASU/J. Hester et al.; Optical: NASA/HST/ASU/J. Hester et al.; Radio: VLA/NRAO
Cygnus loop supernova remnant, Jeff Hester (Arizona State University) and NASA
Crab Nebula supernova remnant, Palomar Observatory
Jupiter, NASA/JPL/University of Arizona
Earth, NASA Goddard Space Flight Center
Clouds, Science Media Group
Laguna Beach, Science Media Group

Key Concepts: Gravity formed structures in our universe
Hodge 301 in the Tarantula Nebula, Hubble Heritage Team (AURA/STScI/NASA)
Playing catch, Science Media Group
Milky Way animation, Science Media Group
Barred spiral galaxy NGC 1300, NASA, ESA, and The Hubble Heritage Team (STScI/AURA)
NGC 3603, Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (Univ. Washington), You-Hua Chu (Univ.

Illinois Urbana-Champaign), and NASA
Saturn, NASA/JPL/Space Science Institute
Cosmic Microwave Background, NASA/WMAP Science Team
Cosmic evolution animation, NASA/WMAP Science Team
Zoom out from solar system, Science Media Group, Data from Milky Way Series Digital Universe, Hayden Planetarium, American Museum of Natural History, permission granted by Brian Abbott (no modifications were made to the data)
30 Doradus nebula, N. Walborn (STScI), R. Barbá (La Plata Observatory) and NASA
Supernova animation, NASA and A. Hobart (CXO)
Crab Nebula supernova remnant, NASA, ESA, J. Hester, A. Loll (ASU); D. De Martin (Skyfactory)

Key Concepts: Einstein's model predicted the big bang:
Big Bang animation, Dana Berry, SkyWorks Digital, Inc.
Einstein, Hebrew University of Jerusalem, represented by the Roger Richman Agency
Chalkboard, Science Media Group
Gemini Observatory, Gemini Observatory/AURA
Ultra-deep field galaxies, NASA, ESA, S. Beckwith (STScI) and the HUDF Team
Spacetime animation, Science Media Group
Cosmic microwave background, NASA/WMAP Science Team
Spiral galaxy NGC 4414, W. Freedman (Carnigie Obs.), L. Frattare (STScI) et al., & the Hubble Heritage Team (AURA/STScI/NASA)
Spectrum, Smithsonian Astrophysical Observatory
Sun animation, SOHO (ESA & NASA)
Ocean, Science Media Group

Evidence: What's it made of?
Inside the Eagle Nebula (menu icon), T. A. Rector & B. A. Wolpa, NOAO, AURA
Earth in space, Science Media Group, Milky Way data courtesy Axel Mellinger
Astronaut on the Moon, Apollo 17 Crew, NASA
Mars rover animation, NASA/JPL-Caltech
Milky Way pan, Science Media Group, Milky Way data courtesy Axel Mellinger
Lens flare, Science Media Group
Prism, Science Media Group
Spectrum, Smithsonian Astrophysical Observatory
Star field, © Scott Tucker, www.darksky.com
Element spectra, Smithsonian Astrophysical Observatory, Science Media Group
Spiral galaxy NGC 4414, W. Freedman (Carnigie Obs.), L. Frattare (STScI) et al., & the Hubble Heritage Team (AURA/STScI/NASA)
30 Doradus Nebula, N. Walborn (STScI), R. Barbá (La Plata Observatory) and NASA
Herbig-Haro 46/47, NASA/JPL-Caltech/A. Noriega-Crespo (SSC/Caltech)

Evidence: How far?
Students in Harvard Square, Science Media Group
HCG 87, Gemini Observatory/GMOS - South Commissioning Team
Leo star field, © T. Credner & S. Kohle, AlltheSky.com
Light bulbs, Science Media Group
Andromeda Galaxy, P. Challis (CfA), Palomar Observatory

Evidence: How fast?
Galaxies NGC 2207 and IC 2163, Debra Meloy Elmegreen (Vassar College) et al., & the Hubble Heritage Team (AURA/STScI/NASA)
Spiral galaxy M 101, NASA
Spiral galaxy NGC 3314, NASA and the Hubble Hertiage Team (STScI/AURA)
UGC 10214, NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA
NGC 4676 The Mice, NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA
Barred spiral galaxy NGC 613, M. Neeser (Univ.-Sternwarte München), P. Barthel (Kapteyn Astron. Institute), H. Heyer, H. Boffin (ESO), ESO
Spectra and spectral lines, Smithsonian Astrophysical Observatory
Hydrogen gas tube, Science Media Group
Earth, Science Media Group
M31 galaxy, P. Challis (CfA), Palomar Observatory
Hubble Ultra Deep Field, S. Beckwith & the HUDF Working Group (STScI), HST, ESA, NASA

Evidence: How old?
NGC 6093 (menu icon), The Hubble Heritage Team (STScI/NASA)
Hubble Ultra Deep Field, S. Beckwith & the HUDF Working Group (STScI), HST, ESA, NASA
Universe expansion animation, Dana Berry, SkyWorks Digital, Inc.
Marathon runners, Science Media Group
Galaxy cluster HCG 87, Gemini Observatory/GMOS - South Commissioning Team
Centaurus A galaxy, NASA/JPL-Caltech/J. Keene (SSC/Caltech)
Barred spiral galaxy NGC 1300, NASA, ESA, and The Hubble Heritage Team (STScI/AURA)
NGC 6745, NASA and The Hubble Heritage Team (STScI/AURA)

Researchers: Big Questions (Marcelo Gleiser)
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Very Large Array, NRAO / AUI / NSF
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Eskimo Nebula, NASA, Andrew Fruchter and the ERO Team [Sylvia Baggett (STScI), Richard Hook (ST-ECF), Zoltan Levay (STScI)]

Researchers: Big Bang (Hiranya Peiris)
Cosmic microwave background, NASA/WMAP Science Team
Content of our universe, Smithsonian Astrophysical Observatory
Cosmic evolution animation, NASA/WMAP Science Team

Researchers: Black Holes (Kim McLeod)
Andromeda Galaxy, GALEX Team, Caltech, NASA
M51 center, NASA and The Hubble Heritage Team (STScI/AURA), courtesy K. McLeod
Hubble Space Telescope, STS-103, STScI, ESA, NASA]
Quasar 3C 273, NASA and J. Bahcall (IAS), courtesy K. McLeod

Zoom in to a black hole, Suzaku, NASA/GSFC, Dana Berry
Quasar 3C 273, NASA, A. Martel (JHU), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA), courtesy K. McLeod

Researchers: Dark Energy (Robert Kirshner)
Hubble Ultra Deep Field, S. Beckwith & the HUDF Working Group (STScI), HST, ESA, NASA
Supernova 1987A, The Hubble Heritage Team (AURA/STScI/NASA)
Young Robert Kirshner, R. Kirshner
Pan across night sky, Science Media Group
Supernova 1994D, High-Z Supernova Search Team, HST, NASA
Distant supernovae (before and after), NASA and S. Riess (STScI)
Abell 2218 galaxy cluster, NASA, N. Benitez (JHU), T. Broadhurst (Racah Institute of Physics/The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
X-ray view of hot gas around Abell 2125 galaxy cluster, NASA/CXC/UMass/Q.D.Wang et al.

Researchers: Other Solar Systems (David Charbonneau)
Planetary system animation, NASA/JPL-Caltech/T. Pyle (SSC)
Planetary system transit, ESA and NASA
Extrasolar planetary system, NASA/JPL-Caltech/T. Pyle (SSC)
Extrasolar planet with star, NASA/JPL-Caltech/R. Hurt (SSC)
Planetary system illustration, NASA/JPL-Caltech/T. Pyle (SSC)
Illustration of Jupiter-like planet, Greg Bacon (STScI), NASA

Students: Where are the stars?
Earth, NASA Goddard Space Flight Center
Space Shuttle, NASA
Pluto, Eliot Young (SwRI) et al., NASA
Stars, G. De Marchi (STScI and Univ. of Florence, Italy) and F. Paresce (STScI)/NASA, ESA

Students: What is a galaxy?
Earth, NASA Goddard Space Flight Center
Space Shuttle, NASA
Pluto, Eliot Young (SwRI) et al., NASA
Stars, G. De Marchi (STScI and Univ. of Florence, Italy) and F. Paresce (STScI)/NASA, ESA

Students: How are galaxies arranged?
Earth in space, Science Media Group
Milky Way, Ken Eward/National Geographic Society Image Collection
Universe fly through, 2dF Galaxy Redshift Survey/Swinburne Centre for Astrophysics and Supercomputing

Students: What was the big bang?
Hubble Ultra Deep Field, S. Beckwith & the HUDF Working Group (STScI), HST, ESA, NASA

Resources: Scientific Visualizations
Take a trip through space and time, NASA/WMAP Science Team
Fly through the universe, Susan Friedman/What's Up in the Universe; Science Media Group; Ken Eward/National Geographic Society Image Collection; 2dF Galaxy Redshift Survey/Swinburne Centre

for Astrophysics and Supercomputing
Cosmic Evolution, Chandra X-ray Center/A. Hobart
Take a deep look into our universe: NASA, ESA, and G. Bacon (STScI); NASA, ESA, F. Summers, Z. Levay, L. Frattare, B. Mobasher, A. Koekemoer and the HUDF Team (STScI)

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BEYOND THE SOLAR SYSTEM
Expanding the Universe in the Classroom

This DVD is produced for NASA by the Universe Education Forum and the Science Media Group at the Harvard-Smithsonian Center for Astrophysics.

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