

History of Saturn Discoveries

Students use *History of Discovery* cards and interpretive skits to examine how scientists throughout history have explored Saturn. The lesson enables students to discern the multicultural nature of scientific inquiry and to see how the improvement of technology increases our ability to solve scientific mysteries.

The lesson also prepares students to create and interpret their own timelines spanning the years 1610 to 2010. The timelines depict scientists, technologies, and discoveries.

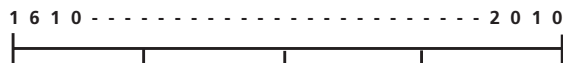
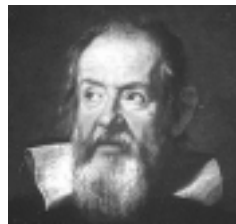
MEETS NATIONAL SCIENCE EDUCATION STANDARDS:

History and Nature of Science

- *Science as a human endeavor*
- *History of science*

Science and Technology

- *Understandings about science and technology*



PREREQUISITE SKILLS

- Measuring in centimeters
- Reading science content
- Recording key information
- Creating timelines

BACKGROUND INFORMATION

Background for Lesson Discussion, page 96

Questions, page 99

Answers in Appendix 1, page 225

35–50: Moons

56–63: The Cassini–Huygens Mission

EQUIPMENT, MATERIALS, AND TOOLS

For the teacher

- Photocopier (for transparencies & copies)
- Overhead projector
- Chalkboard, whiteboard, or easel with paper; chalk or markers
- 1-meter (or 2-meter) strip of adding-machine tape or butcher paper

For each of 10 student groups

- Chart paper (18" × 22"); markers

For each student

- 1-meter (or 2-meter) strip of adding-machine tape or butcher paper
- Markers
- Notebook paper; pencil

Materials to reproduce

Figures 1–14 are provided at the end of this lesson.

FIGURE	TRANSPARENCY	COPIES
1	1	
2–11		1 card per group
12		1 per group
13		1 per student
14		1 for teacher



Background for Lesson Discussion

History of discovery

(See *Procedures & Activities, Part II, Step 6*)

Here are some questions (*with answers*) to help students in interpreting the data they collect on their *History of Discovery* tables.

- What do you notice about technology over time?

Answer — The type of technology changed from small refracting telescopes to larger reflecting telescopes, then to spacecraft that flew by Saturn, and finally, to a spacecraft (Cassini–Huygens) that will orbit Saturn and tour the Saturn system.

- What do you notice about the dates of discoveries?

Answer — There were long periods of time between discoveries. More discoveries have been made in recent years.

- What do you notice about the discoveries as technology improves?

Answer — The discoveries are more numerous and more detailed as technology improves. Technology improved dramatically within the last century, so the discoveries increased dramatically as well.

Ancient astronomers

(See *Procedures & Activities, Part II, Step 3*)

Students may want to know more about ancient astronomers. Here is some background information: People in ancient cultures — as long as 5,000 years ago, according to the records they left us — followed the motions of the Sun, the Moon, stars, and planets. The earliest recorded observations of Saturn appear to have been made by astrologer-priests during the reign of King Esar-haddon of Assyria in about 700 B.C.

Early observers watched the sky for omens. They realized that while the stars generally traversed the night sky in unchanging patterns, there were some points of light that appeared to

wander across the starry background. In fact, the name given by early Greek astronomers to these points of light was “planetes,” which meant “wandering stars.”

People all over the world have given their own names to the Sun, the Moon, the stars, and the planets. The Greeks named one of the bright “planetes” after their god Cronos. The Romans considered Cronos to be the same as their god Saturn. Almost 1,500 years after the ancient Roman culture flourished, European astronomers explained the motions of the wandering lights in terms of a system with planets orbiting the Sun — a Solar System. European astronomers generally accepted the Roman names for the planets and selected Roman names for new celestial objects found with the aid of telescopes.

According to the National Science Education Standards, students should know that:

- People of all backgrounds — with diverse interests, talents, qualities, and motivations — engage in science and engineering. Some of these people work in teams and others work alone, but all communicate extensively with others.
- Throughout history, many scientific innovators have had difficulty breaking through accepted ideas of their times to reach conclusions that are now accepted as common knowledge.
- Technology drives science because it provides the means to gain access to outer space; collect and analyze samples; collect, measure, store, and compute data; and communicate information.
- Science drives technology because it provides principles for developing improved instrumentation and techniques and the means for addressing questions that demand more sophisticated instruments.



Lesson Plan

Part I: How Do We Know What We Know about the Planets?

- 1 Ask students: How do we know all that we know about the planets in our Solar System?
- 2 Record their responses on the chalkboard (or whiteboard or easel paper).

Part II: Connections to Saturn

- 1 Have the students form 10 groups. Have each group write answers to the following question on chart paper: What do you know to be true about Saturn?
- 2 Have the student groups post their charts and report out. Then ask the students: How do we know all that we know about Saturn? (“Knowing” could be the result of observing through sky-watching, telescopes, or space missions.) Record their answers on the chalkboard.
- 3 Display a transparency of *Sky Observation by Ancient Cultures* (Figure 1). Introduce the idea that Saturn was observed by ancient cultures as a wandering point of light in the night sky. Interpret the text in the figure, and ask the students to look at the drawings (the “sky pictures”) and determine which point of light is wandering in the pictures provided.

Additional material: See Appendix 3 for an illustration and accompanying table depicting Saturn’s position in the sky over the course of the Cassini mission. The illustration and table could be made into transparencies for display and discussion.

- 4 Tell students that they will receive information about different observers of Saturn — people or space missions. Give each of the 10 groups a copy of one *History of Discovery Card*

(Figures 2–11). You will need to cut the pages along the dashed lines, or in half, as each page has two cards printed on it. Give each group a copy of the *Interview Guide* (Figure 12). Tell the students to prepare an interview role-play by answering the questions on the *Interview Guide*. The students should read their group’s card and interpret the information, focusing on the people (or space mission), the technology, and the discoveries that resulted. The *Glossary* (Appendix 2) provides definitions of terms.

- 5 Ask the students to divide the work among group members to include the following roles: reader, interviewer, recorder, and actor who represents the scientist or space mission. To prepare for the role-play, the reader reads the card to the group. The group discusses how the actor will answer the interview questions and agrees on the responses. During the role-play, the interviewer asks the questions from the *Interview Guide*. The actor responds to the interview questions based on the group’s discussion of the answers. The recorder writes the answers on the *Interview Guide*.

Suggest that actors respond dramatically to the questions. As an option, the students might use props and/or costumes that fit the information on their card.

- 6 Give each student a copy of the *History of Discovery Table — for Students* (Figure 13). Have each group role-play their interview for the class in chronological order of their *History of Discovery Card*. While each group role-plays their interview, have the students take notes on their *History of Discovery Table*.

- 7 When all discoveries have been role-played and recorded, ask the students what they have learned about technological advancements and discoveries about Saturn. Discuss the relationship between scientific discovery and technology and how knowledge about Saturn has



changed over time as a result of technological advancements. Guide students to see that many kinds of people in different cultures have made and continue to make contributions to science and technology. (See *Background for Lesson Discussion*.)

Part III: Assessment

- 1 Post a 1-meter strip of adding-machine tape or butcher paper on the chalkboard. Measure and record dates from 1610 to 2010 on the strip of paper, as shown below. Explain that the 25-cm increments represent 100-year periods. Alternately, you might use a 2-meter strip having 50-cm increments.
- 2 Give each group a strip of paper that is 1 meter (or 2 meters) long. Instruct the students to use the data on their *History of Discovery Table* to create a timeline of technology advancements and discoveries about Saturn. The students' timelines should have three types of information: 1) date, 2) technology, and 3) major Saturn discoveries. You might have the students use different colors for each type of information.
- 3 Have each student interpret the timeline and compose a letter to Galileo on notebook paper telling him how scientific understanding of Saturn has evolved (and might yet evolve) since the time of his observations. Ask students to address these questions: What news would be most exciting to share with Galileo? What advances have been made in technology?

	1610	1710	1810	1910	2010
1-meter timeline		25 cm	50 cm	75 cm	100 cm
2-meter timeline		50 cm	100 cm	150 cm	200 cm

What additional discoveries were made due to these advances? What do we hope to learn by the year 2010, after the Cassini spacecraft has toured the Saturn system?

Assessment Criteria

1. *Figure 14 is a History of Discovery Table for the teacher that includes the correct location on the timeline for each of the Saturn explorers (scientist or spacecraft), plus a listing of discoveries and technologies.*
2. *Each student's timeline should have:*
 - *Years properly labeled and spaced.*
 - *Names, discoveries, and technologies properly placed and labeled.*
3. *Each student's letter to Galileo should contain an explanation about the relationship between improved technology and increased discoveries. The letter should also give one or more examples of specific discoveries and the technology used to make the discoveries.*

Part IV: Questions for Reflection

- What are the different categories of technologies that have been used to explore Saturn?
- What different cultures have been represented by the scientists who have made discoveries about Saturn?



Questions

These questions and their answers can be used to provide background for teachers or to explore prior knowledge and facilitate discussions with students. The answers are found in Appendix 1, starting on page 225.

Moons

35. How many moons does Saturn have?
36. Who discovered all these moons?
37. How did the moons get their names?
38. Are Saturn's moons like Earth's Moon?
39. Why does Saturn have so many moons, but Earth has only one?
40. Are Saturn's moons in the rings? Do the moons collide with the ring particles?
41. What is the difference between a moon and a ring particle?
42. What's gravity like on Saturn's moons? Could we walk there?
43. Are there volcanoes on any of Saturn's moons?
44. How cold are Saturn's moons?
45. Do any of Saturn's moons have an atmosphere? Could we breathe it?
46. Is there water on Titan?
47. Is there life on Titan?
48. What is the weather like on Titan?
49. Cassini carries a probe that is going to Titan and not Saturn or any other moons. Why Titan?
50. Will there be a mission that takes humans to Titan in the near future?

The Cassini-Huygens Mission

56. Why are we sending a spacecraft and not people to Saturn?
57. What will the Cassini robot do?
58. What spacecraft have been to Saturn? How have we gathered information about Saturn up until now?
59. What will Cassini learn that we do not already know from Voyager and Hubble Space Telescope data?
60. Why care about the Cassini mission?
61. Why is NASA's mission to Saturn called Cassini?
62. How much does the Cassini mission cost? Who pays for it?
63. How long does it take to plan and carry out a mission like Cassini?





Materials

Figure 1 **Sky Observation by Ancient Cultures (2 pages)**

Figures 2-11 **History of Discovery Cards**

Figure 12 **Interview Guide**

Figure 13 **History of Discovery Table — for Students (2 pages)**

Figure 14 **History of Discovery Table — for Teacher**





Sky Observation by Ancient Cultures

LESSON

4

Figure 1
(1 of 2)

These “sky pictures” show the constellation Leo — notice that a point of light moves through the constellation. The pictures are separated in time by approximately one month. The wandering light is the planet Saturn.

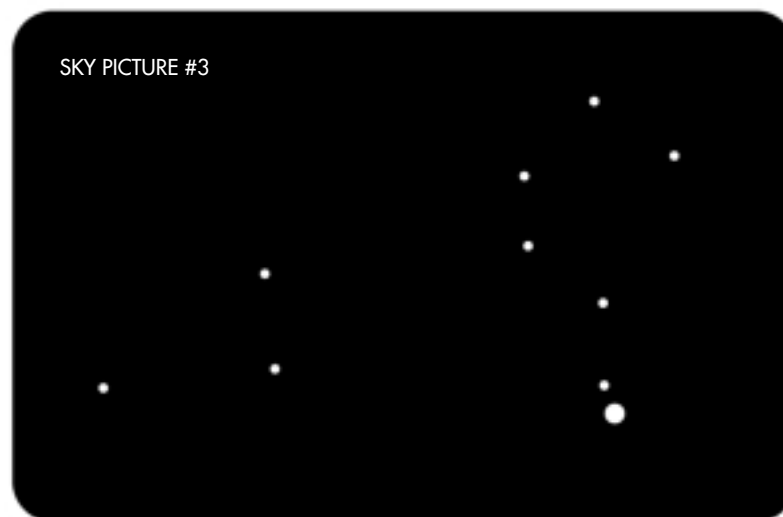
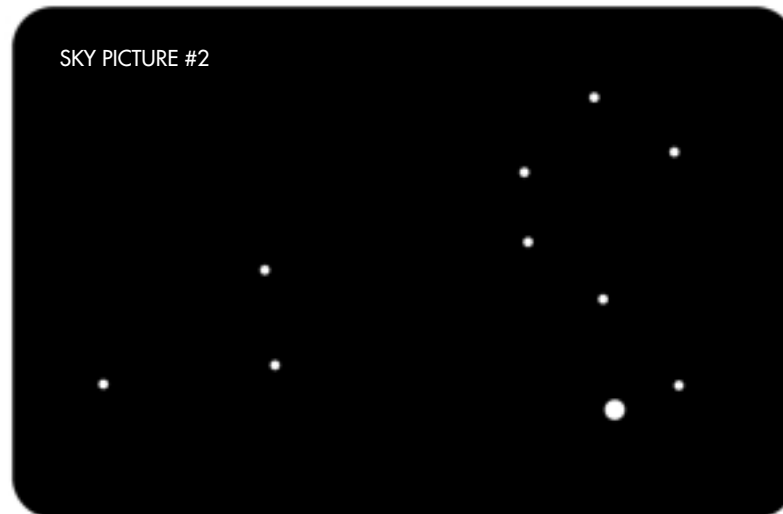
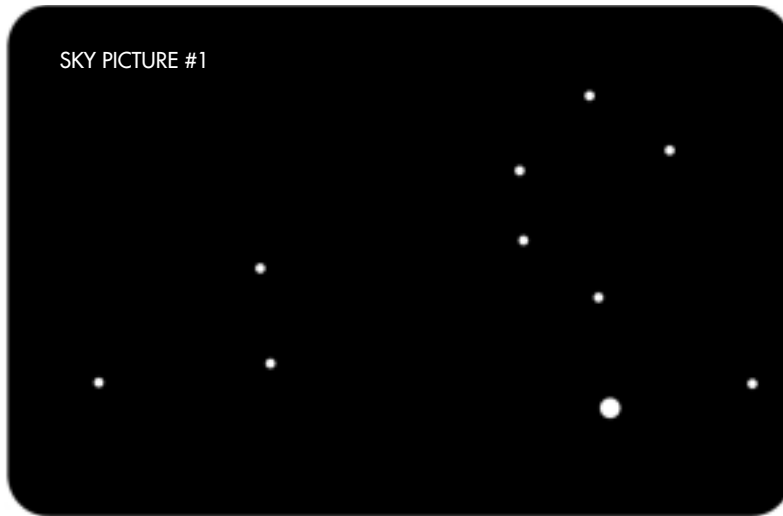


Figure 1
(2 of 2)

Astronomers frequently use “negative” images of star fields for detailed studies because black stars and other celestial objects on a white background are easier to see. At night, “negative” star charts are often easier to use with a flashlight.

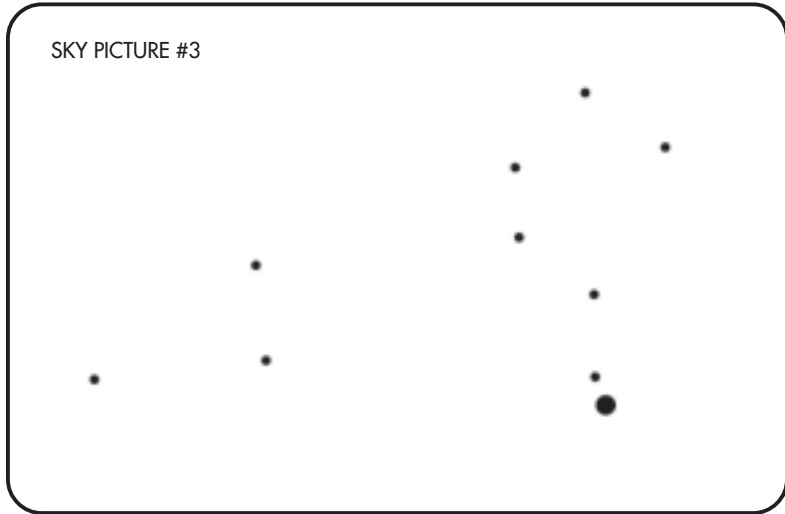
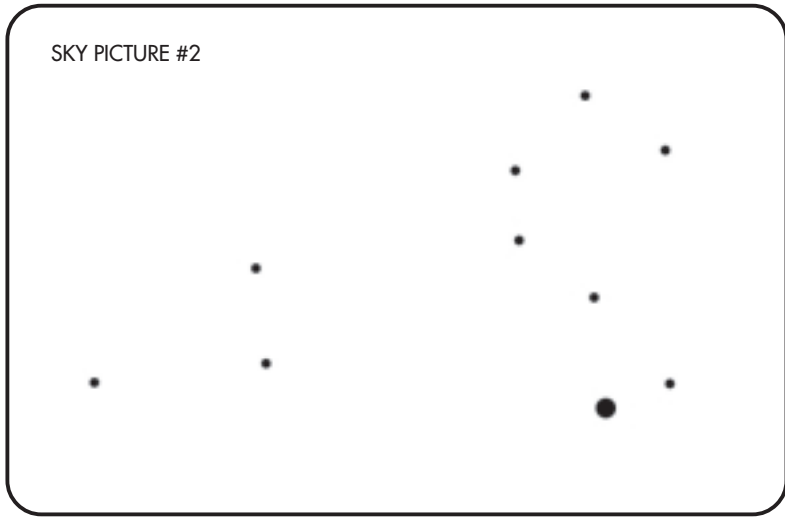
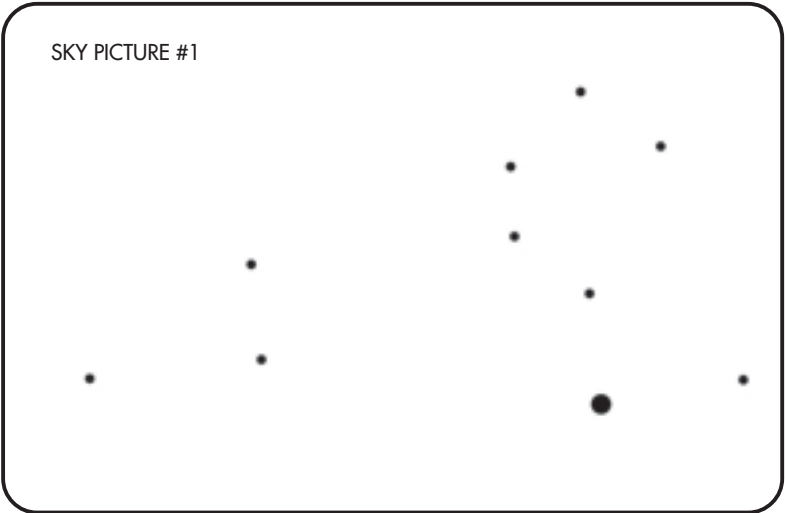
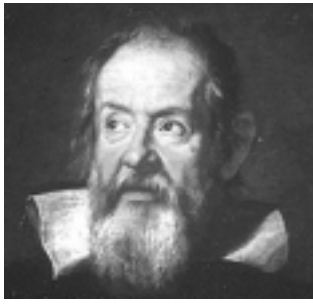


Figure 2

History of
Discovery
Card

Galileo Galilei 1610

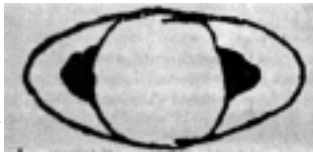
Italian astronomer (1564–1642)



Istituto e Museo di Storia della Scienza



Le Opera di Galileo Galilei Edizione Nazionale



In 1610, Galileo Galilei observed Saturn through a refractor telescope, which used lenses a few inches across to magnify distant objects by 20 to 30 times. He observed Saturn to be “triple,” thinking that he was seeing two “lesser stars” (moons) or companions to the planet, or perhaps they were two bulges that were features of the main body. In the fall of 1612 he observed Saturn again and to his surprise he found the planet to be perfectly round! In 1616, he found that Saturn’s “companions” had reappeared and grown, and he made a drawing that today would be readily interpreted as Saturn and its ring system. Galileo died never knowing that he’d been the first to observe Saturn’s rings.

(Middle) Galileo’s 1610 drawing of Saturn. His telescope was unable to resolve the ring shape and he thought he was seeing three objects.

(Left) Galileo’s 1616 drawing of Saturn. He was able to discern the ring shape but thought it was attached to the planet.

Figure 3

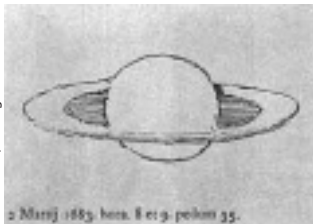
History of
Discovery
Card

Christiaan Huygens 1655

Dutch astronomer (1629–1695)



Huygensmuseum Hofwijck



The Museum, Le Hague
2 Marsj. 1685. hocc. 8 et 9. peim 35.

In March 1655, at age 26, Christiaan Huygens viewed Saturn through a more powerful telescope than Galileo’s. Huygens’ skill at crafting lenses allowed his instrument to magnify objects about 50 times. Huygens’ observations and his study of other astronomers’ observations led him to determine that Saturn had a flat ring encircling its equator, and unlike Galileo, he could see that the ring did not touch the planet. Huygens discovered Saturn’s largest moon, which would be named Titan 200 years later. He observed that the moon orbited Saturn every 16 days. Its orbit was well beyond the extent of the ring, but like the ring, it was in the plane of Saturn’s equator. He recognized that the disappearance of Saturn’s “companions,” which Galileo had observed in 1612, occurred whenever Saturn’s thin ring appeared edge-on to Earth observers. This event occurs about every 15 years because, like the Earth, Saturn’s north–south axis is tilted. This tilt causes our view of Saturn’s rings to change as the planet travels in its 30-year orbit around the Sun. The Huygens probe to Titan, built by the European Space Agency, is named after Christiaan Huygens.

(Bottom) Huygens’ drawing of Saturn, 1683.





Figure 4

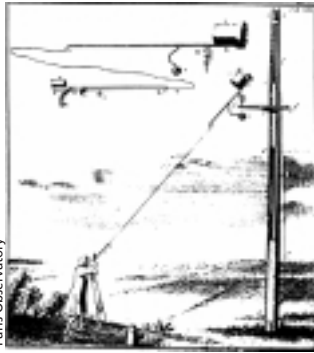
History of
Discovery
Card

Jean-Dominique Cassini 1675

*Italian–French astronomer
(1625–1712)*



Paris Observatory



Paris Observatory

In the late 17th century, Jean-Dominique Cassini studied Saturn from the Paris Observatory using a series of refracting telescopes. Cassini's largest telescope was 136 feet long, dwarfing Galileo's 4-foot telescope and allowing him to see far greater detail. In 1675, Cassini discovered that Saturn's "solid" ring had a gap in it that divided it into two separate rings. Today this gap is called the Cassini Division. The ring outside the division is the A ring, while the brighter ring within is the B ring. No one yet knew what the rings were made of, how thick they were, or whether they were permanent features around Saturn. Cassini also discovered four moons of Saturn (the moons weren't named until later): Iapetus (1671), Rhea (1672), and Tethys and Dione (1684). Other moons would not be discovered until over a century later. Cassini is the astronomer for whom NASA's Cassini mission to Saturn is named.

(Left) Many astronomers of Cassini's time used tubeless telescopes. A framework structure or a rope, as shown here, was used to align the eyepiece with the objective lens.

Figure 5

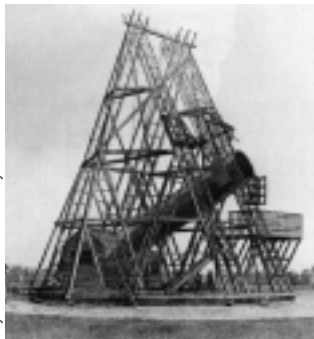
History of
Discovery
Card

William Herschel 1781

German–British astronomer (1738–1822)



Yerkes Observatory



Royal Astronomical Society

In 1781, William Herschel discovered the planet Uranus beyond the orbit of Saturn, ending Saturn's long reign as the most-distant planet. The discovery also effectively doubled the size of the Solar System because Uranus is twice as far away from the Sun as is Saturn. In 1789, Herschel discovered the sixth and seventh moons of Saturn, which would later be named Mimas and Enceladus. Herschel was among the first to use a reflecting telescope, which used mirrors instead of lenses to focus the light



Royal Astronomical Society

coming from distant objects. He constructed and used a telescope with a 48-inch mirror that weighed a ton and was housed in a tube 40 feet long. The telescope was located in his backyard in Bath, England. To reach the eyepiece, he climbed a scaffolding that rose 50 feet into the air! Herschel was often assisted by his sister Caroline, who was also an accomplished astronomer.

(Above) Caroline Herschel.

(Left) Herschel's 40-foot-long reflector telescope in Bath, England.





Figure 6

History of
Discovery
Card

James Keeler 1895

American astronomer (1857–1900)



Mary Lea Shane Archives, Lick Observatory

In 1888, James Keeler observed Saturn with the telescope at the Lick Observatory in California. On the first night the observatory began operating, Keeler saw a narrow, dark gap close to the outer edge of Saturn's A ring. This gap is now called the Encke Gap (the astronomer Johann Encke received the credit, though he could not quite resolve the gap in detail when he observed it in 1837). In 1895, Keeler observed Saturn's rings using a telescope at the Allegheny Observatory in Pennsylvania. Connected to the telescope was a spectrograph, which analyzed the light reflected from the rings. The light he saw indicated that the innermost parts of the rings were moving around Saturn faster than the outermost parts. This offered experimental evidence that the rings were not a solid disk, but instead made up of individual particles moving like tiny moons around Saturn.



Mary Lea Shane Archives, Lick Observatory

(Left) An 1888 engraving of the 36-inch refractor used by Keeler at the Lick Observatory.

Figure 7

History of
Discovery
Card

Gerard Kuiper 1944

Dutch–American astronomer (1905–1973)



Yerkes Observatory

In 1944, Gerard Kuiper [KOY-per] discovered Titan's atmosphere using a spectrograph attached to a reflector telescope at McDonald Observatory in Texas. Unlike Keeler's spectrograph, Kuiper's spectrograph detected infrared light (that is, infrared radiation, often called heat) instead of visible light. Kuiper was particularly interested in finding out if any of the moons orbiting around other planets in the Solar System had atmospheres. He studied the infrared light reflected off the 10 largest moons, and in 1944 he reported that Titan, the largest moon of Saturn, was the only one having an atmosphere that could be easily detected. Astronomers observed the sky only in visible light until



McDonald Observatory

the 1930s, when the first radio-wavelength observations were made. Today, we view the Universe across the entire electromagnetic spectrum, in radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma ray.

(Left) This is the 82-inch reflector telescope at McDonald Observatory that Kuiper used for his observations.



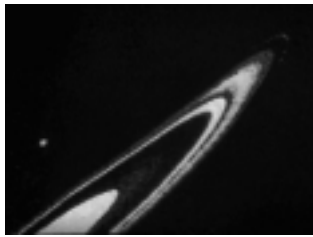


Figure 8

History of
Discovery
Card

Pioneer 11 1979

U.S. spacecraft



NASA's small robotic observer passed within 22,000 km of Saturn's cloudtops in September 1979, providing the first close-up images of the Saturn system. Pioneer 11 took pictures of Saturn's poles and clouds, detected heat generated deep from within Saturn, made the first measurements of Saturn's magnetic field, confirmed the E ring (suggested in 1967 by scientists studying Earth-based telescope images), discovered the F ring just outside the A ring, and made a possible detection of the G ring (a faint, narrow ring just beyond the F ring). Pioneer 11's view of Saturn was about 50,000 times closer than any Earth-based telescope could see. Pioneer 11 represented a new way for astronomers to explore the planets. Rather than scientists building their own telescopes and working individually to make new discoveries from observatories on Earth, a team of people — scientists, engineers, and different kinds of specialists working together — built a robot having various instruments and sent it into space to send back images and other kinds of data.

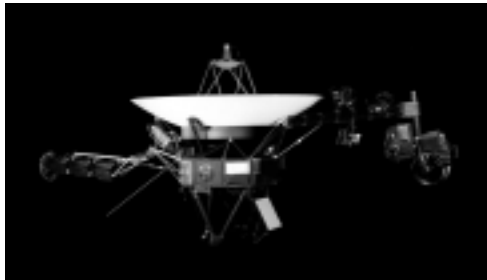
(Left) A portion of Saturn's rings observed by Pioneer 11.

Figure 9

History of
Discovery
Card

Voyager 1 & 2 1980–1981

U.S. spacecraft



Twin NASA spacecraft made extensive flyby studies of Saturn — in November 1980, Voyager 1 passed within 125,000 km of Saturn's cloudtops, and in August 1981, Voyager 2 passed within 101,000 km. The Voyager missions sent back tens of thousands of color images of the Saturn system. They measured high wind speeds along Saturn's equator, provided close-up pictures of several known moons, and discovered

that Titan's atmosphere is very thick and made mostly of nitrogen. The Voyagers also discovered several small moons: Telesto, Calypso, Pan, Atlas, Prometheus, and Pandora. Voyager cameras showed us that Saturn's rings are actually made up of thousands of tiny "ringlets," and that strange spoke-like structures hover above the B ring. The spacecraft confirmed the existence of both the innermost D ring as well as the outer G ring that had been tentatively identified by Pioneer 11. By observing the way radio waves and visible light pass through the rings, scientists inferred from Voyager data that ring particles range in size from nearly invisible dust to icebergs the size of houses.

(Bottom) A Voyager close-up image of Saturn's rings.





Figure 10

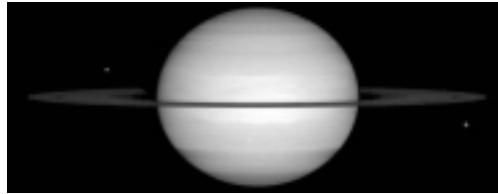
History of
Discovery
Card

Hubble Space Telescope 1995

U.S. orbiting observatory



IMAX, Smithsonian, Lockheed



NASA launched the Earth-orbiting Hubble Space Telescope (HST) in 1990 from Space Shuttle Discovery. HST's main mirror is 2.4 meters across, and the entire telescope is about the size of a school bus. HST observes in visible, ultraviolet, and infrared light. It is not significantly closer to the planets and stars than are telescopes on the ground, but its views of the Universe are undistorted by Earth's atmosphere. HST orbits the planet every 90 minutes from about 600 km (370 miles) above the surface. Astronauts can visit it every few years to upgrade the instruments. HST has provided views of cloud eruptions in Saturn's atmosphere, monitored the thickness and density of the faint, outermost E ring, and searched for new Saturn moons during times when the rings appear edge-on to Earth observers. HST has also made infrared images of Titan's surface that helped to show where the Cassini mission would land its Huygens probe.

(Top) Deploying the HST on April 25, 1990, from the Space Shuttle.

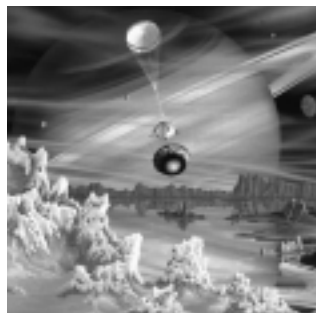
(Bottom) A nearly edge-on view of Saturn's rings taken by the Wide-Field and Planetary Camera aboard HST.

Figure 11

History of
Discovery
Card

Cassini-Huygens 2004-2008

U.S. spacecraft and European probe



Cassini-Huygens was launched in 1997 and will arrive at Saturn in 2004. During a 4-year tour of the Saturn system, the spacecraft will study the majestic planet, its extraordinary rings, and its moons. The Cassini orbiter carries six instruments to "see" in four kinds of "light" (visible, infrared, ultraviolet, and radio), as well as instruments for measuring dust particles, charged particles, and magnetic fields. The Huygens probe will parachute through Titan's atmosphere and land on the surface, taking more than 1,000 images of Titan's clouds and surface. No human has ever seen the sights that will be captured by the Huygens probe — will there be lakes, oceans, mountains, and craters? Compared with the instruments aboard the Voyagers or the Hubble Space Telescope, the Cassini orbiter instruments can observe in much finer detail. Cassini will have 4 full years to study the Saturn system instead of just a few days as did the Pioneer 11 and Voyager flyby missions. Cassini will fly within about 20,000 km of Saturn's cloudtops, and as close as 1,000 km to some of the moons.

(Top) Cassini-Huygens in the assembly bay at JPL.

(Left) Artist's concept of the Huygens probe landing on Titan.





Figure 12
(1 of 2)

Interview Guide

Names of Interview Team Members:

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Interview questions to be role-played:

1. What is your name and where do you come from? or What is the name of the space mission that you represent?

2. What year do you represent?

3. What was the most exciting thing about your work?



Figure 13
(1 of 2)

History of Discovery Table — for Students

Year	Scientist or Spacecraft	Discoveries	Technologies



Figure 13
(2 of 2)

Year	Scientist or Spacecraft	Discoveries	Technologies



Figure 14

History of Discovery Table — for Teachers (1 of 2)

Year	Scientist or Spacecraft	Location from Start of Timeline		Discoveries	Technologies
		1-m Timeline	2-m Timeline		
1610	Galileo Galilei (b. Italy)	0 cm	0 cm	<ul style="list-style-type: none"> • Saw “bulges” on either side of Saturn that resembled ears or handles. 	<ul style="list-style-type: none"> • Used a 20- to 30-power handheld refractor telescope.
1655	Christiaan Huygens (b. Netherlands)	11.3 cm	22.5 cm	<ul style="list-style-type: none"> • Suggested that Galileo’s “bulges” were the two sides of a detached, flat ring encircling Saturn. • Discovered Titan, Saturn’s largest moon. 	<ul style="list-style-type: none"> • Used a more powerful telescope (50-power) than Galileo’s.
1676	Jean-Dominique Cassini (b. Italy as Gian Domenico Cassini; moved to France)	16.5 cm	33.0 cm	<ul style="list-style-type: none"> • Saw a gap (Cassini Division) in the ring that Huygens saw, dividing the ring into the A and B rings. • Discovered the moons Iapetus, Rhea, Tethys, Dione. 	<ul style="list-style-type: none"> • Used very long refracting telescopes at the Paris Observatory.
1789	William Herschel (b. Germany; moved to England)	44.8 cm	89.5 cm	<ul style="list-style-type: none"> • Discovered the moons Mimas and Enceladus. 	<ul style="list-style-type: none"> • Used a 48-inch reflector telescope in England.
1895	James Keeler (b. United States)	68.8 cm	137.5 cm	<ul style="list-style-type: none"> • Saw a narrow gap in the outermost portion of the A ring (the feature was later named the Encke Gap). • Showed that rings are not solid disks. 	<ul style="list-style-type: none"> • Used a 36-inch refractor at Lick Observatory, California (gap in A ring). • Used a 13-inch refractor with spectrograph at Allegheny Observatory (rings not solid).
1944	Gerard Kuiper (b. Netherlands; moved to U.S.)	71.3 cm	142.5 cm	<ul style="list-style-type: none"> • Discovered that Titan has an atmosphere. 	<ul style="list-style-type: none"> • Used 82-inch reflector with an infrared spectrograph at McDonald Observatory.
1979	Pioneer 11 (U.S./NASA)	92.3 cm	184.5 cm	<ul style="list-style-type: none"> • First close-up images of Saturn; detected planet’s magnetic field; found F ring; tentative find of G ring. 	<ul style="list-style-type: none"> • Flyby space mission; camera and other instruments.



Figure 14

History of Discovery Table — for Teachers (2 of 2)

Year	Scientist or Spacecraft	Location from Start of Timeline		Discoveries	Technologies
		1-m Timeline	2-m Timeline		
1980– 1981	Voyager 1 and 2 (U.S./NASA)	92.5– 92.8 cm	185.0– 185.5 cm	<ul style="list-style-type: none"> • Images of Saturn, moons, rings, and “ringlets.” • Discovered moons Telesto and Calypso; moon Pan “clearing” Encke Gap; moon Atlas “guarding” edge of A ring; moons Prometheus and Pandora “shepherding” the braided F ring. • Imaged the E ring. • Found high winds on Saturn at the equator. • Found Titan’s atmosphere to be very thick and mostly nitrogen. • Saw spoke-like structures on B ring. Confirmed D and G rings. Data showed sizes of ring particles. 	<ul style="list-style-type: none"> • Two flyby missions; cameras and other instruments.
1995	Hubble Space Telescope (U.S./NASA)	96.3 cm	192.5 cm	<ul style="list-style-type: none"> • Provided view of cirrus-like clouds erupting in Saturn’s atmosphere; imaged edge-on view of rings in 1995. • Imaged Titan’s features to show Huygens probe landing site. 	<ul style="list-style-type: none"> • Earth-orbiting telescope; operates above atmosphere.
2004– 2008	Cassini–Huygens (U.S./NASA; European Space Agency probe)	98.5– 99.5 cm	197.0– 199.0 cm	<ul style="list-style-type: none"> • Discoveries: to be made. • Study Saturn, rings, moons. • Four-year tour. • Huygens probe to Titan. 	<ul style="list-style-type: none"> • Highly sophisticated spacecraft; many instruments.

