# Visions of the Universe

# Four Centuries of Discovery

Exhibit Script

### Note

This exhibit is presented on six double-sided panels. The content consists of twelve sides that are presented left to right along the front sides of the panels first (sides one to six) and then along the back sides of the panels (sides seven to twelve). Hence, side one and side twelve are back to back on panel one.

## Panel 1 – Front – Side 1

### *Visions of the Universe*

**Four Centuries of Discovery**

[image]

Telescopes have transformed not only our views of the universe, but also our understanding of the planets, stars, and galaxies within it.

In 1609, Galileo improved the recently invented spyglass, pointed it toward the heavens, and gave birth to modern astronomy. Over the years, telescopes advanced, grew larger, and moved from backyard, to mountaintop, to space. Astronomers peered ever deeper into the cosmos, producing both startling discoveries and stunning images.

Our visions of the universe reveal knowledge of its contents, as well as inspire awe and wonder at its beauty.

[image]

Images:
Top: Galileo demonstrating his telescope to his patrons; painting by G. Bertini
Bottom: Jupiter's Great Red Spot and its four largest moons – Io, Europa, Ganymede, and Callisto; composite image from the Galileo Mission, 1996

# Panel 2 – Front – Side 2

## *Exploring the Moon*

**The Moon is an ancient world, with countless craters, barren plains, and no atmosphere**

Our Moon is a familiar, yet strange world. As the brightest object at night, it is an obvious first choice for exploration with telescopes, photography, and space missions. The Moon has a gray geography of plains, mountains, and craters that one astronaut described as “magnificent desolation.”

**Mountains on the Moon (1610)**
Examining the Moon through an early telescope, Galileo spies bright peaks and long shadows that indicate rough, mountainous terrain.
[image]
Drawings of the Moon, Galileo

**Mapping the Moon (1651)**
Giovanni Riccioli and Francesco Grimaldi create a detailed map of the Moon and establish many of the names of lunar features still in use today.
[image]
Map of the Moon, G. Riccioli and F. Grimaldi

**Astronomy and Photography (1840)**
The invention of photography provides an accurate way to record what is seen through a telescope.
[image]
Heliotype print of the Moon, W. de la Rue

**Far Side of the Moon (1959)**
Space missions allow us, for the first time in history, to see the heavily cratered far side of the Moon.
[image]
Moon, Galileo Mission

**Human Exploration (1969)**
NASA’s Apollo missions succeed in landing men on the Moon and making limited explorations of its surface.
[image]
Astronaut James Irwin with the lunar lander and rover, Apollo 15

[image]
Background:
Full Moon, Kitt Peak National Observatory, 2002

# Panel 3 – Front – Side 3

## *Storms on the Sun*

**The Sun's atmosphere is filled with high-energy magnetic fields and explosive outbursts**

The Sun appears generally calm in visible light. In ultraviolet light and x-rays, however, the Sun is a fierce landscape of magnetic loops and million degree gas. Violent eruptions can trigger huge outbursts of material that stream across space. This stormy activity increases and decreases over an eleven-year solar cycle.

**Spots on the Sun (1610)**
Using telescopes, several astronomers observe that the Sun shows a changing pattern of spots.
[image]
Drawing of Sunspots over a month, C. Scheiner

**Corona and Outburst (1860)**
During the total eclipse of 1860, several observers record that the Sun's corona features a large, stormy outburst.
[image]
Drawing of the total solar eclipse of 1860, G. Tempel

**Magnetic Nature of Sunspots (1908)**
George Ellery Hale uncovers that sunspots are regions of intense magnetic fields – over a thousand times stronger than Earth's magnetic field.
[image]
Sunspot group, Mount Wilson Solar Observatory

**The High-Energy Sun (1970s)**
Astronomers use telescopes in space to observe the high-energy activity of the Sun, including this giant magnetic loop prominence.
[image]
Ultraviolet image of the Sun, Skylab

**Solar Weather (1990s)**
Space missions monitor the Sun and can follow the progression from sunspot, to magnetic explosion, to coronal outburst.
[image] Sunspot
[image] Explosion
[image] Outburst – The red disk obscures the Sun so the outburst can be seen.
Sun in visible and ultraviolet light, Solar and Heliospheric Observatory

[image]
Background:

Stormy Sun imaged in ultraviolet light, Solar and Heliospheric Observatory, 2000

# Panel 4 – Front – Side 4

## *Journey to Mars*

**Mars, the most explored planet beyond Earth, is a red, rocky, cold, dry, and dusty world**

Mars has sparked our imagination, even when we could not see its features clearly. Speculations of Martian civilizations have given way to detailed knowledge from spacecraft and robotic explorers. The most important discovery is the evidence for water, a necessary ingredient if life on Mars were ever to have existed.

**An Indistinct Planet (1659)**
Christiaan Huygens' early drawings of Mars show only fuzzy dark patches and perhaps a hint at the presence of a polar ice cap.
[image]
Drawings of Mars, C. Huygens

**Mars Imagined (1878)**
The detailed markings of Giovanni Schiaparelli's maps of Mars inspire ideas of canals built by a Martian civilization. Neither the canals nor the fine markings were real.
[image]
Map of Mars, G. Schiaparelli

**Surface Features (1965)**
The Mariner missions obtain the first close-up images of Mars and revolutionize our view of its surface .
[image]
[image]
[image]
[image]
Features on Mars, Mariner 9
Left to right: Craters, volcanoes, sand dunes, and channels

**Landing on Mars (1976)**
The twin Viking Landers are the first successful Mars surface missions and begin our onsite investigations of its rock-strewn landscape.
[image]
Mars surface with scrapings made by the Viking 2 Lander to retrieve soil samples

**Water on Mars (2008)**
While ancient river structures provide evidence of water on Mars long ago, the Phoenix Lander finds present-day water in ice below the surface.

[image]
Ancient river delta on Mars, Mars Global Surveyor

[image]
Background:
Mars Global Mosaic, Viking Orbiters, 1980

# Panel 5 – Front – Side 5

## *Majestic Rings of Saturn*

**Saturn's rings are composed of thousands of ringlets made of millions of icy particles**

In the 1600s, understanding Saturn's rings was difficult because they seemed to disappear when seen edge-on. Today, space missions have explored the ring system in exquisite detail. The other giant planets – Jupiter, Uranus, and Neptune – have only a few dark rings. We do not yet know why Saturn alone has such abundant, bright rings.

**A Ring Around Saturn (1659)**
By studying the varying appearance of Saturn over many years, Christiaan Huygens figures out that it is surrounded by a tilted, flat ring.
[image]
Drawing of Saturn's ring orientation throughout its orbit, C. Huygens

**A Gap in the Ring (1676)**
Giovanni Cassini discovers an empty gap in Saturn's ring, indicating that it must be multiple rings.
[image]
Drawing of Saturn with gap in ring, G. Cassini

**Ring Particles (1895)**
James Keeler and William Campbell observe motions within the rings and show that they are composed of a vast number of individual icy particles.
[image]
Saturn, Yerkes Observatory

**Ringlets (1980)**
As the Voyager missions fly by Saturn, they reveal that clumping and clustering of the ring particles have formed thousands of ringlets.
[image]
Rings of Saturn, Voyager 2

**Ring System Portrait (2006)**

With Saturn eclipsing the Sun, the Cassini Orbiter captures a backlit view that shows the full extent of the ring system, including the faint and dusty outer rings.
[image]
Backlit view of Saturn's rings, Cassini-Huygens Mission

[image]
Background:
Saturn, Hubble Space Telescope, 1999

# Panel 6 – Front – Side 6

## *The Nature of Comets*

**A comet's spectacular appearance begins with a small, icy object orbiting the Sun**

For most of history, the seemingly random appearances of comets have been interpreted as bad omens from the heavens. However, as we learned to predict and understand comets, their visits became opportunities to enjoy their beauty and to study their structure. That structure starts in a tiny, icy nucleus just a few miles across and extends to two tails that can stretch for millions of miles across interplanetary space.

**Beyond the Moon (1577)**
Observing the Great Comet of 1577, Tycho Brahe estimates its distance and shows it to be at least four times farther than the Moon.
[image]
Woodcut of the Great Comet of 1577, J. Daschitzsky

**Comets Become Predictable (1758)**
The comet predicted by Edmund Halley returns, proving that comets have understandable, though often highly stretched, orbits around the Sun.
[image]
Orbits of Comet Halley and the planets from Mars to Neptune

**Sun-swept Dust Tail (1901)**
Karl Schwarzschild calculates that the curved, yellowish dust tail of a comet is swept back by light from the Sun pushing on the dust-sized particles.
[image]
Great Comet of 1882, South African Astronomical Observatory

**Wind-swept Ion Tail (1951)**
Ludwig Biermann explains how the straight, bluish ion tail of a comet is swept back by the solar wind – a stream of charged particles flowing away from the Sun.
[image]
Comet Hale-Bopp, K. Hartnett

**Dirty Snowball (1986)**
As the Giotto spacecraft flies past Comet Halley, it finds a several-mile-wide, dark, potato-shaped nucleus of ice and rock that is emitting jets of icy and dusty particles.
[image]
Nucleus of Comet Halley, Giotto Mission

[image]
Background:
Comet NEAT, WIYN Telescope, 2004

# Panel 6 – Back – Side 7

## *Secrets of Starlight*

**Other stars are similar to our Sun, but they have a variety of colors, temperatures, and sizes**

Our Sun is just one of a hundred billion stars in our Milky Way Galaxy. We see stars as just points of light, but careful analysis of starlight reveals their characteristics. Stars may differ greatly in brightness, size, and age, but all are powered by nuclear fusion. Stars can be found alone, in pairs, or grouped into vast clusters.

**Many, Many Stars (1610)**
Using a telescope, Galileo finds an “almost inconceivable number” of new stars, including more than 500 in the constellation of Orion.
[image]
[image]
Left: Star chart of the belt and sword of Orion, Galileo; Right: Image of the belt and sword of Orion, K. Geary

**Binary Stars (1803)**
After observing close pairs of stars for twenty-five years, William Herschel proves that some stars orbit around each other, and are called binary stars.
[image]
Diagram of the orbit of one star (star B) around another (star A) in a binary pair, W. Herschel

**Distances to Stars (1838)**
Friedrich Bessel is the first to measure the distance to a faraway star, 61 Cygni, showing it to be more than six hundred thousand times farther than the Sun.
[image]
Star chart of the constellation Cygnus, J. Bode

**Traits of Stars Depend on Mass (1910s)**

Astronomers study star clusters and deduce that, for most stars, the mass of the star determines its color, size, brightness, and surface temperature.
[image]
Star cluster in Hercules, Dominion Astrophysical Observatory

**Lifetimes of Stars (1930s)**
Physicists figure out that nuclear fusion will power our Sun for about 10 billion years, while supergiant stars will shine for less than 50 million years.
[image]
Orion Constellation, T. Nordgren

[image]
Background:
Pleiades Star Cluster, Palomar Observatory, 1986

# Panel 5 – Back – Side 8

## *Star Birth in Orion*

**The Orion Nebula is a majestic interstellar gas cloud where stars are born**

The Orion Nebula is a bright fuzzy patch in the sky that may have been observed as early as 1610. However, it was not until 1864 that astronomers could prove that the nebula is a giant cloud of glowing gas. We now know that the nebula is the fiery birthplace of not only thousands of stars, but also of planetary systems in orbit around those stars.

**Orion Nebula and Trapezium Stars (1659)**
Christiaan Huygens' drawing of the fuzzy region in Orion, containing three of the four Trapezium stars at its center, makes the nebula widely known.
[image]
Drawing of Trapezium region, C. Huygens

**Astrophotography (1880)**
Henry Draper takes the first photographs of the Orion Nebula, paving the way for later astronomers to record faint details of all nebulae.
[image]
Trapezium region photograph, H. Draper

**Stellar Birthplace (1940s)**
Astronomers learn how stars form within interstellar clouds and conclude that bright nebulae like Orion contain newborn stars.
[image]
Orion Nebula photograph, ©1928 UC Regents/Lick Observatory

**Thousands of Stars (1995)**

Studies using infrared light to see deeper into the nebula reveal several thousand stars, each only a few million years old.
[image]
Trapezium region in infrared light, European Southern Observatory

**Planetary Disks (1995)**
These dark disks are planetary systems forming around newborn stars in the Orion Nebula.
[image]
Protoplanetary disks seen edge-on, Hubble Space Telescope

[image]
Background:
Orion Nebula, Hubble Space Telescope, 2006

# Panel 4 – Back – Side 9

## *Stellar Explosions*

**Some stars die in bright and powerful explosions that scatter their remains across interstellar space**

Stars live for millions to billions of years, and most fade away relatively quietly. A rare few, however, suffer catastrophic collapse and blow themselves apart in violent supernova explosions. The matter in these stars is blasted across space at millions of miles per hour, creating glowing nebulae called supernova remnants.

**A New Brightest Star (1604)**
A new star that outshines all others in the night sky suddenly appears and then slowly fades away over the next year.
[image]
Engraving of constellation of Ophiuchus, J. Kepler

**Supernova in Andromeda (1885)**
A nova, or new star, in the center of the Andromeda Nebula is later recognized to be incredibly bright and defines a new category called supernovae.
[image]
Drawing of supernova location in Andromeda, A. Common

**Stars Explode (1930s & 1940s)**
Astronomers show that a supernova is the explosion of a star that ejects its matter across interstellar space.
[image]
Radio wave observation of supernova remnant Cassiopeia A, Very Large Array

**Supernova 1987A (1987)**
The nearest observed supernova since the invention of the telescope provides decades of detailed study for astronomers.
[image]
[image]
Supernova 1987A before and after the explosion, D. Malin

**Multiwavelength Studies (2004)**
NASA's Great Observatories study the visible, infrared, and x-ray emissions from the gaseous remnant of the 1604 supernova 400 years after its observed explosion.
[image]
Visible Light
Hubble Space Telescope and CTIO
[image]
Infrared Light
Spitzer Space Telescope
[image]
X-rays
Chandra X-ray Observatory

[image]
Background:
Crab Nebula supernova remnant, Hubble Space Telescope, 2005

# Panel 3 – Back – Side 10

## *Galaxies Revealed*

**Galaxies are gigantic swarms of billions of stars with vast clouds of gas and dust**

Until a century ago, we knew of only one galaxy – our Milky Way Galaxy. Though galaxies are enormous, they are at immense distances from us, and astronomers need huge telescopes to see them clearly. We now estimate there are perhaps a hundred billion galaxies in the universe in a variety of sizes and shapes.

**Deep Sky Catalog (1774)**
While searching for comets, Charles Messier compiles a catalog of faint fuzzy objects in the sky.
[image]
Charcoal drawing of Andromeda Nebula, C. Messier

**Spiral Nebulae (1845)**
Using his giant telescope, William Parsons resolves a fuzzy nebula to reveal a pinwheel-shaped pattern.
[image]

Drawing of the nebula that would later be known as the Whirlpool Galaxy, W. Parsons

**The Great Debate (1920)**
Astronomers Harlow Shapley and Heber Curtis debate whether the nebulae are part of our Milky Way Galaxy or are “island universes” unto themselves.
[image]
Andromeda Galaxy, Yerkes Observatory

**Galaxy Shapes (1936)**
Edwin Hubble, who showed that many nebulae are really galaxies, is also the first to classify galaxy shapes into groups.
[image] Spiral
[image] Barred Spiral
[image] Lenticular
[image] Elliptical
[image] Irregular
Images from the Hubble Space Telescope

[image]
Background:
Spiral galaxy Messier 101, Hubble Space Telescope, 2006

# Panel 2 – Back – Side 11

## *Discovering the Universe*

**The universe is everything – from planets, to stars, to galaxies, and beyond**

Four centuries ago, the night sky was thought to hold only five planets, and astronomers were not yet sure whether Earth or the Sun was at the center. Since then, we have measured distances to stars, mapped out the structure of our Milky Way Galaxy, and uncovered galaxies strewn through the cosmos.

**Laws of Planetary Orbits (1609)**
Johannes Kepler’s laws of planet motions improve planet predictions and help to convince astronomers that the Sun is at the center of the solar system.
[image]
Orbits of the planets, from Mercury to Saturn

**Stars of the Milky Way (1785)**
William and Caroline Herschel count stars across the sky to create a map of the apparent shape of our Milky Way.
[image]
Drawing of Milky Way, W. Herschel

**Other Galaxies (1925)**
After detecting variable stars in the Andromeda Nebula, Edwin Hubble calculates that it is far beyond the Milky Way, and is really the Andromeda Galaxy.
[image]
[image]
Top: Photographic negative of discovery of a variable star (noted VAR!) in Andromeda, Observatories of the Carnegie Institution of Washington
Bottom: Andromeda Galaxy, Warner and Swasey Observatory

**Web of Galaxies (1986)**
Three-dimensional maps of galaxy positions show that they are not randomly distributed, but instead lie along interconnected lines that resemble a cosmic web.
[image]
3-D plot of galaxy positions in the Sloan Digital Sky Survey, looking outward from the Milky Way (white dot)

**Galaxies Across Space (1996)**
A series of amazingly detailed images from the Hubble Space Telescope reveal galaxies stretching throughout the known universe.
[image]
Hubble Ultra Deep Field, Hubble Space Telescope

[image]
Background:
Milky Way panorama, A. Mellinger, 2000

# Panel 1 – Back – Side 12

## *Future Visions*

Since Galileo, astronomy has seen vast changes. Telescopes are now controlled by computers, observe in many wavelengths of light, and are launched into space.

Yet knowledge remains the ultimate goal. Our observations help answer age-old questions and also inspire new questions about the universe.

How will our universe evolve, and does it have an end?

How do collections of stars, gas, and dust develop into spectacular galaxies?

When did stars first light up the universe?

Are there any Earth-like planets around other stars, and do they harbor life?

Many amazing discoveries and incredible visions await future astronomers.

[image] 
Spiral galaxy NGC 1309, Hubble Space Telescope

[image] 
Star forming region NGC 3603, Hubble Space Telescope

[image] 
Background:
Illustration of an extrasolar planet around a red dwarf star, G. Bacon

**Visions of the Universe: Four Centuries of Discovery** is presented by the Space Telescope Science Institute, American Library Association, and Smithsonian Astrophysical Observatory, through funding from the National Aeronautics and Space Administration.