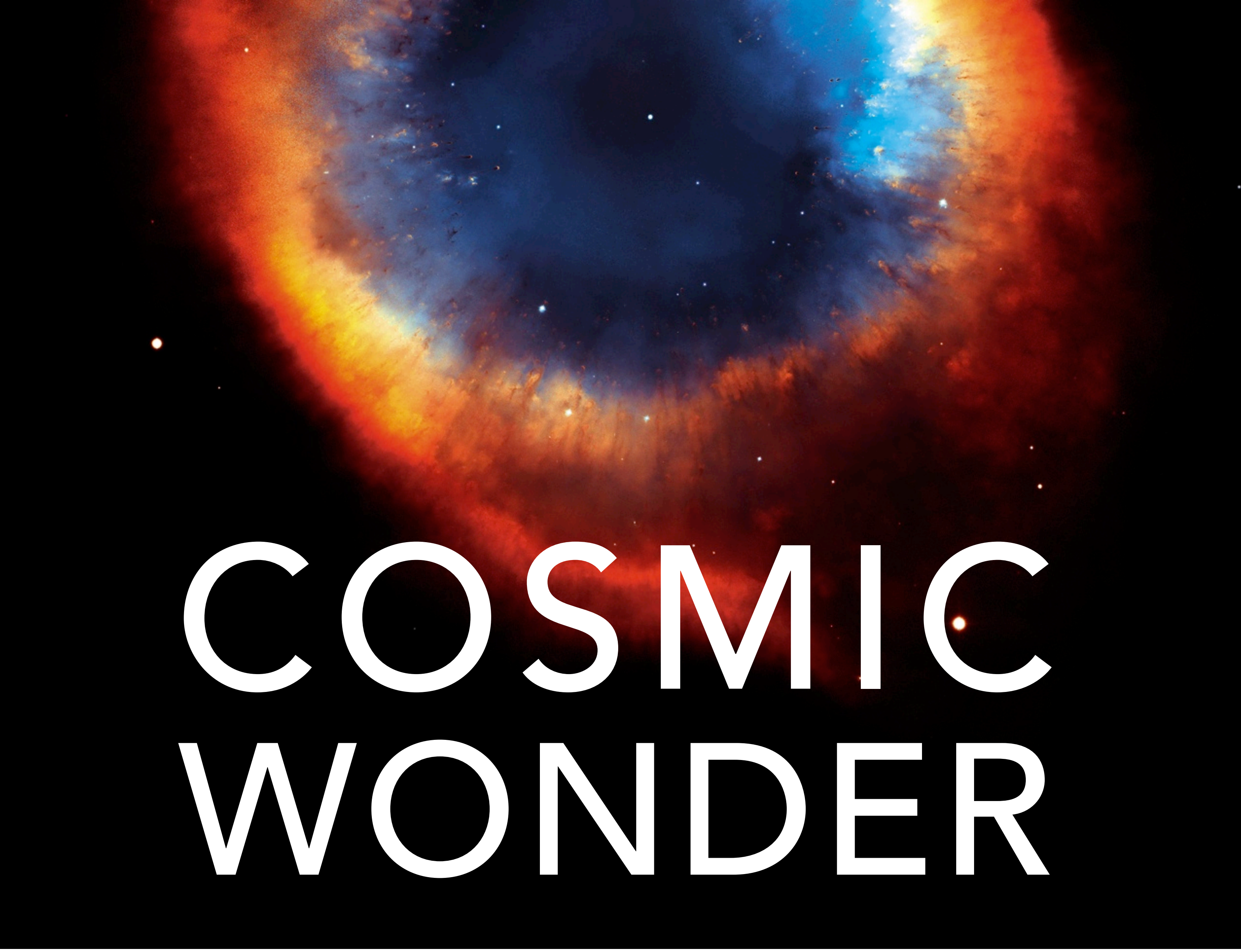


COSMIC WONDER

EDUCATOR GUIDE

ADLER PLANETARIUM

COSMIC WONDER
SHOW SUMMARY

Cosmic Wonder is a live show that showcases sophisticated images from Microsoft Research's innovative WorldWide Telescope. You will feel as if you are moving through the universe to view, up close, the most current images we have of neighboring nebulae, galaxies, and stars.

In this show, you will experience how the wonder of discovery has connected humans across civilizations as you travel through time and space. During our journey, you will see how stars are born and die, travel to the very edge of the detectable universe, and come face-to-face with the evidence supporting one of the great space mysteries of our time - dark matter. See how we all have a role to play in the cycle of observing, wondering, and making discoveries.

We begin by flying over a number of impressive telescopes and sky observatories, including one that is centuries old. Civilizations throughout history have observed, wondered about, and explained astronomical events. One such event was a "guest star" recorded in 1054 in China, Europe and the Americas. Only relatively recently have we been able to confirm this event as a supernova star death by tracking the expansion of the resulting nebula.

The show also examines constellations. Cultures all over the world have created stories and myths explaining the patterns of stars we see in the sky. Although we now know that constellations themselves are not astronomical bodies, scientists rely on the 88 official constellations as a map of the sky. In the show, we zoom in on the Orion constellation - one of the best-known constellations in the night sky. We can use Hubble Space Telescope images from both visible and infrared light spectrums to observe star birth happening in this area of the sky.

The Hubble Space Telescope is only one of the tools throughout history that has allowed us to refine our understanding of the universe. A number of historical documents in the Adler's collection illustrate an evolving picture of what the universe is, from an Earth-centered model to one that shows stars on the surfaces of spheres. Today, the Hubble Extreme Deep Field image developed from the Hubble shows us 95% of cosmic history and gives us a glimpse as to just how big the universe is.

But many mysteries have yet to be fully explained. For example, our predictions of how fast galaxies should be able to spin without flying apart do not align with what we have actually been able to see. Mysterious dark matter may account for this. New tools have been developed that might help us discover where dark matter is, but much work needs to be done. Will you be the next one to help solve the mystery of dark matter?

Science Ideas in the Show

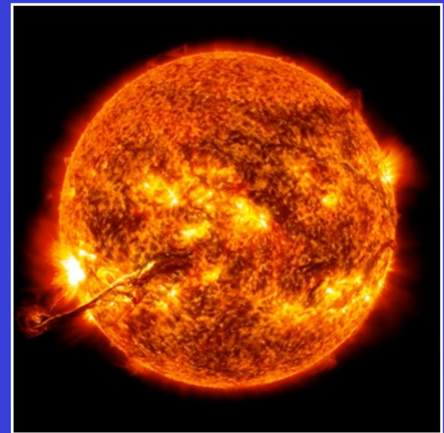
Star Life Cycles

Our Sun – like every star in the Universe – undergoes a life cycle that can stretch billions of years from birth to death. The state-of-the-art visualizations in *Cosmic Wonder* are only a glimpse of the dynamic life cycles of stars.

All stars are formed in nebulae, or clouds of gas and dust found scattered throughout galaxies. As the core of the new star forms, the amount of mass it contains determines the type of star it is. The Sun is considered a “main sequence” star. main sequence stars are at a point in their lifecycle where they will spend the most time. They make up about 90% of all known stars and have enough energy to last billions of years. Other stars, called supergiants, are much more massive and have a life cycle that only spans millions of year. red dwarf stars are much smaller and may last trillions of years.

Throughout their lifespan, stars create energy by converting hydrogen to helium through the process of nuclear fusion in their cores. This process of fusion generates energy and heat, which in turn produce pressure within the star that pushes outwards. The inward pull of gravity acts against this outer push, keeping the star’s size steady.

A star spends most of its life in this stable state where outward and inward forces are exactly balanced, but what happens next depends on how massive the star is. Our Sun will stay in its main sequence phase around 5 billion more years, for a total of about 10 billion year. When our Sun nears the end of its life, it will begin to run out of hydrogen fuel in its core. Fusion in the surrounding layers will tip the balance between gravity and pressure, and the Sun will expand to become a red giant.



Photos: NASA

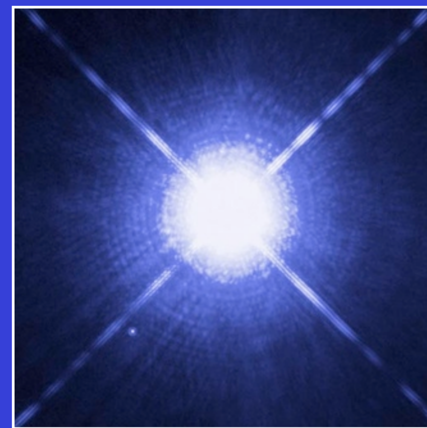
Later in the red giant phase, the Sun will convert the helium that has built up in its core into other, heavier elements. This will generate even more energy and more pressure, pushing the Sun's material outwards. Eventually the outer layers of the Sun will escape into space leaving the core of the star exposed. When this happens, fusion in the Sun will stop. Its leftover core, called a white dwarf, will continue to glow because of residual heat, but eventually this glow will fade away.

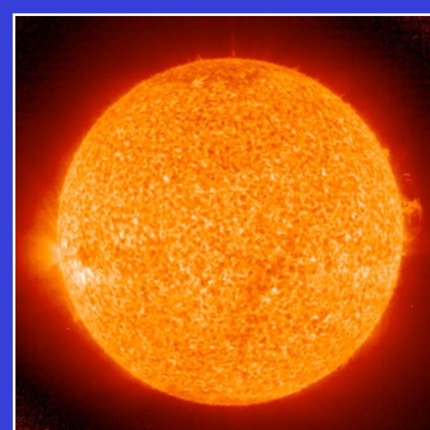
Many white dwarfs simply fade out of sight as they cool down. However, some white dwarfs in systems with multiple stars may pull in hydrogen from a neighboring star, building up a layer of new potential "fuel." If the layer gets thick enough, it can ignite suddenly and create an explosion that is known as a nova.

Stars that are more than 8 times the mass of the Sun do not form white dwarfs. Instead, their heavy core consisting of iron will implode, causing a "core-collapse" supernova like the one witnessed in 1054 AD.

After a supernova, the size of the core that remains determines what happens next. Stellar cores from supernovae explosions that are between 1.4 and 3 times the mass of the Sun may form very small and massive neutron stars. You might recall from *Cosmic Wonder* that neutron star material the size of a penny would be heavier than all the buildings in Chicago. Stellar cores over 3 times the mass of the Sun might have enough mass to form a black hole. But most novae and supernovae explosions simply give off gas and dust that might form into a new nebula, restarting the cycle of star life.

Learn more at: http://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve/





Photos: NASA

Constellations

Constellations have played a very important role for humans, from navigation tools to planting practices. Although many cultures have created their own mythology around different constellations in the sky, the official constellations that are used today are derived from the 48 ancient Greek constellations defined by Ptolemy (c. 90 AD - c. 168 AD).

Misconception alert: While constellations appear to look the same from wherever we might be on Earth, it is important to remember that they only look the way they do because of our perspective on the planet Earth. While the stars in the constellations look like they are arrayed on a flat surface, some stars in each constellation are much closer to us than others. If we were to travel to another part of the galaxy, we would see a completely different configuration of the same stars.

Although they are not actual objects in the sky, constellations are still an extremely useful tool for astronomers to use as reference points. Similar to state and country boundaries on a map, the boundaries of constellations are something we have constructed so we can talk about different areas of the sky with more clarity and accuracy.

Credit: Starry Night

Dark Matter

Cosmic Wonder introduces one of the most exciting discoveries of recent science, dark matter, which we now theorize makes up about 25% of the Universe. Dark matter is not named "dark matter" because it is literally black or just hard to see – it is called dark matter because it does not emit or reflect any light on the electromagnetic spectrum. We have instruments to detect light emissions from parts of the electromagnetic spectrum we cannot see, such as Gamma rays or X-rays, but dark matter does not interact with the electromagnetic spectrum so we cannot detect it directly.

We know that dark matter is there because it does have mass and so interacts gravitationally with objects around it. Gravity is the force of attraction between all objects that have mass and it acts between objects in space. Gravity holds together the orbits of planets and their moons, solar systems, and galaxies themselves.

Misconception alert: Your students may say that there is no gravity in space. This misconception is based on images of astronauts and other objects "floating" in outer space. Although it seems like gravity does not exist in space because we experience weightlessness, that phenomenon occurs because astronauts are in a constant freefall as they orbit the Earth.

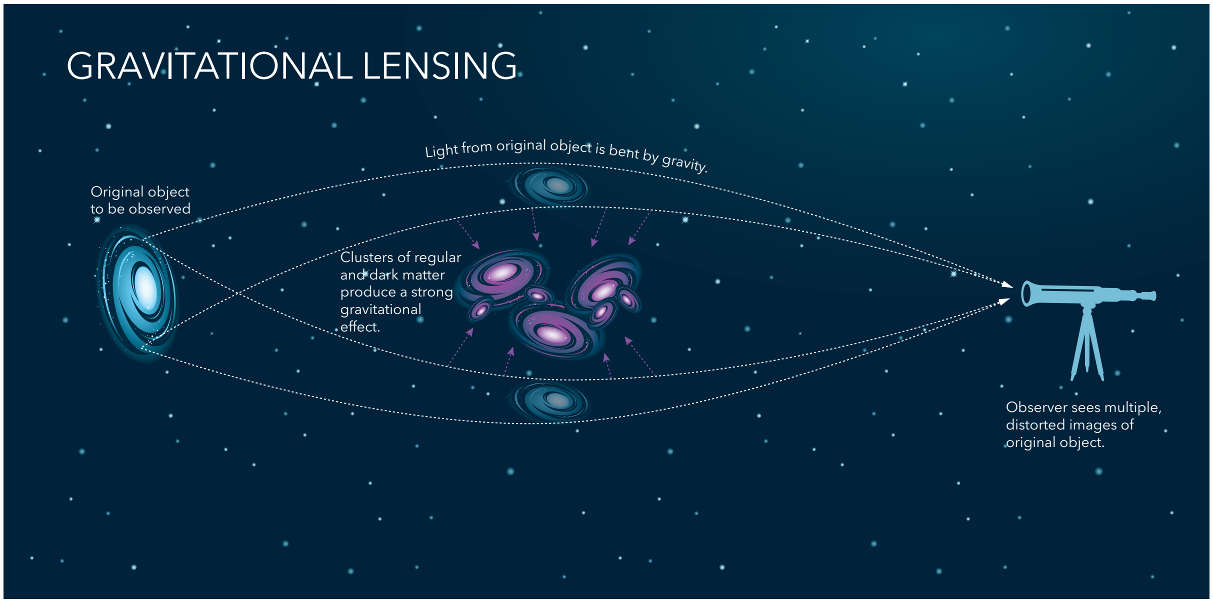
We can use gravity to make predictions about the Universe. Neptune was discovered because the actual orbits of other planets did not match up with their predicted orbits. Scientists calculated that there must be another planet with gravity affecting the orbits and predicted where that planet would be. Their calculations were confirmed with the discovery of Neptune.

Scientists used this same process of observation and prediction to discover the existence of dark matter. They discovered that the amount of mass needed to keep a galaxy together was much more than what they actually observed in galaxies. Even in clusters of galaxies, we simply could not detect enough "stuff" in the cluster to hold the cluster together. There had to be something else adding to the gravity of the galaxies. These observations and measurements are evidence of galaxies being surrounded by a halo of dark matter.

Although we do not know exactly what dark matter is, scientists have developed a number of theories. This area of research should yield some amazing discoveries in the next few years.

Gravitational Lensing

We do not know what dark matter is, but we can directly image the effects its gravity has on light and thus find places where it exists. Gravitational lensing helps us see where there might be pockets of dark matter. With extremely massive objects, light bends around them so objects behind might actually look like they are to the top, bottom, or the side of the massive object in the middle *(see diagram below).*



Credit: Adler Planetarium

Strong gravitational lensing occurs when we see multiple copies of galaxies, such as in the diagram. When we see images from telescopes that have replicated images around a cluster of galaxies, we can infer that there is a large amount of dark matter where the images are centered. However, it is quite rare to see this effect. Most of the dark matter we have detected is through weak gravitational lensing, which produces much smaller distortions and requires us to analyze the average shapes of galaxies in an area of sky for variations.

Learn more at http://ed.ted.com/lessons/patricia-burchat-sheds-light-on-dark-matter#watch

Telescopes

Telescopes play a leading role in Cosmic Wonder. Although we are driven by an innate curiosity to learn about the cosmos, it is only with the continuous development of observational tools that we can make new discoveries.

In 1609, Galileo Galilei became the first recorded person to use a telescope to study the night sky. Galileo's telescope used a simple lens system that required telescopes to get longer, and lenses to get bigger, if you wanted to see objects that were fainter because they were further away. However, at a certain size these telescopes were too big to function properly because the lenses were only supported at the outer edges and eventually would sag. Issac Newton invented the first reflecting telescope in 1671. Reflecting telescopes allowed us to decrease the length of the telescope while still being able to see fainter objects in the sky.

Misconception alert: Galileo Galilei did not invent the telescope. It was invented in the Netherlands a few years before he was the first to use it to study the night sky.

Rapid developments in telescopes have enabled us to understand more and more of the Universe. During the 18th and 19th centuries, astronomers developed the ability to calculate stellar distances using telescopes. The invention of the spectroscope allowed astronomers, for the first time, to determine the chemical composition and motion of objects in space. Telescope development continues today.

In 1990, NASA and the European Space Agency launched the Hubble Space Telescope. Hubble orbits high above the atmosphere of the Earth and is able to see the Universe more clearly, without blurring that is caused by the atmosphere. Many telescopes and satellites detect different ranges of energy on the electromagnetic spectrum. The electromagnetic spectrum defines the wavelengths and frequencies of light energy. While we only can see light in the visible portion of the spectrum, telescopes can now detect energy from every portion of the electromagnetic spectrum, allowing us to see new phenomena in space, such as remnants from the Big Bang that we couldn't detect otherwise.

Cosmic Wonder uses images from the WorldWide Telescope (WWT) to immerse you in the cosmos. Developed by Microsoft Research, and with support from NASA, WWT is a computer-based visualization program that aggregates information from all of the world's best ground and space-based telescopes. As well as being a useful tool for researchers to visualize telescope data, WWT is also available for download for personal and educational use from www.worldwidetelescope.org. In the application, you are able to take guided tours of space delivered by world-class astronomers or explore on your own.

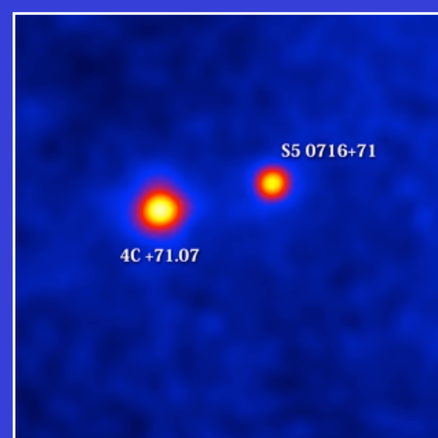
Pre and Post Activities
New Explorers

These activities assume students have little or no prior knowledge about space science and are designed as introductions to some of the driving concepts in *Cosmic Wonder*. They can also be done as stand-alone activities or as the introduction to a longer curriculum.

Stars: Are you just starting to explore space? A good place to start is by learning more about stars, especially our Sun. Check out NASA's *Sun As A Star: Science Learning Activities for Afterschool* for introductory activities about the Sun, other stars, and the different ways we have of learning about them. Visit http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Sun_As_a_Star_Educator_Guide.html to view the activities.

Detecting Galaxies: We are finding that galaxies formed much earlier in the Universe then what we once thought. With *The Most Distant Galaxies*, you can try your hand at estimating how many galaxies there are in the Hubble Deep Field image and learn how scientists classify galaxies. Go to http://www.spaceupdate.com/activities_su.html#as04 and then choose "distant galaxies" from the pull down activities tab.

Help galaxy scientists: Become a galaxy classification expert by going to www.galaxyzoo.org and contribute to real science going on right now!



Photos: NASA

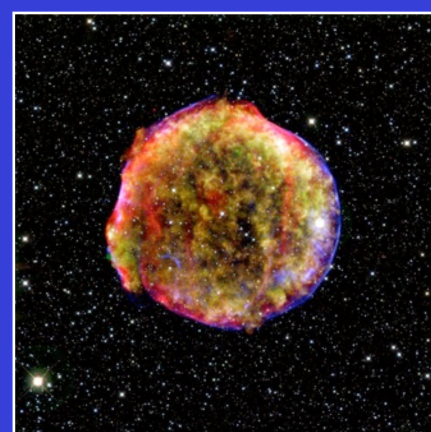
Experienced Explorers

These activities build on ideas in the show that are fairly concrete and/or familiar to students from popular science. Students need to know that stars give off light, as well as how to interpret evidence from multiple sources.

Black Holes: We can't see them, but we think they're there... Black holes fascinate us and we are continually trying to create new ways of detecting them. NASA's Goddard Space Flight Center's developed a series of activities around *Big Explosions, and Strong Gravity* including a way to model the orbits of stars around black holes. http://bigexplosions.gsfc.nasa.gov/activities/black_holes.html

Supernovae: A supernova is the ultimate explosion! It releases tons of stellar energy, can lead to the creation of brand new stars, and even briefly outshines galaxies. Explore these "big explosions" in Goddard Space Flight Center activity, Supernova Explosions by learning about the different types of stars and which ones are capable of supernova explosions. http://bigexplosions.gsfc.nasa.gov/activities/supernova_demos.html

Our Changing Understanding of the Universe: Science is constantly changing due to more advanced technology that enables us to make new observations and discoveries. NASA's Goddard Space Flight Center developed *Cosmic Times* (http://cosmictimes.gsfc.nasa.gov/ to track highlights in space science across the decades.



Photos: NASA

Expert Explorers

These activities tackle more abstract topics in space science and require students to work with ideas and data that they might not be able to directly replicate.

Space-based Telescopes and the Electromagnetic Spectrum: With the development of more sophisticated telescopes, we are continually expanding what we will be able to observe in space. Much of our current - and future - knowledge is dependent on telescopes in orbit around the Earth that detect types of energy in the electromagnetic spectrum beyond visible light. NASA has developed a series of activities called Space-Based Astronomy to discover what the electromagnetic spectrum is and how we can use different parts of the electromagnetic spectrum to view different parts of the sky. http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Space.Based.Astronomy.html

Dark Matter: Dark matter is one of the newest mysteries about space. Check out Goddard Space Flight Center's *Cosmic Times* to track highlights in space science across the decades. *What's the Matter*, from 1965, showcases some of the leading evidence regarding dark matter. Over this two-day activity students are put in the shoes of scientists faced with a set of data that conflicts with observations. Will the students make the same inferences about dark matter? http://cosmictimes.gsfc.nasa.gov/teachers/guide/1965/lessons.html#jeopardy

Photos: NASA

Standards Addressed

Next Generation Science Standards

Combined with classroom curriculum, a visit to *Cosmic Wonder* can help your students meet the following standards by introducing the listed Disciplinary Core Ideas and Crosscutting Concepts.

Disciplinary Core Ideas

ESS1.A: The Universe and its Stars

The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1)

PS2.B: Types of Interactions

Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the Sun. (MS-PS2-4)

Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). (MS-PS2-5)

ESS1.A: The Universe and Its Stars

Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2)

ESS1.B: Earth and the Solar System

The solar system consists of the Sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2), (MS-ESS1-3)

The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (MS-ESS1-2)

ESS1.A: The Universe and Its Stars

The star called the Sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1)

The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2), (HS-ESS1-3)

Crosscutting Concepts

Scale, Proportion, and Quantity
Natural objects exist from the very small to the immensely large. (5-ESS1-1)
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-3), (MS-ESS1-4)

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-1)

Interdependence of Science, Engineering, and Technology
Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. (MS-ESS1-3)

Connections to Nature of Science
Scientific Knowledge Assumes an Order and Consistency in Natural Systems
Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-ESS1-1), (MS-ESS1-2)

Illinois State Science Standards

Cosmic Wonder can help your students meet these Illinois State Science Standards.

Middle School

12.F.2c Identify easily recognizable star patterns (e.g., the Big Dipper, constellations).

12.F.3c Compare and contrast the sun as a star with other objects in the Milky Way Galaxy (e.g., nebulae, dust clouds, stars, black holes).

13.B.3b Identify important contributions to science and technology that have been made by individuals and groups from various cultures.

High School

12.F.4a Explain theories, past and present, for changes observed in the universe.

12.F.4b Describe and compare the chemical and physical characteristics of galaxies and objects within galaxies (e.g., pulsars, nebulae, black holes, dark matter, stars).

12.F.5a Compare the processes involved in the life cycle of stars (e.g., gravitational collapse, thermonuclear fusion, nova) and evaluate the supporting evidence.

12.F.5b Describe the size and age of the universe and evaluate the supporting evidence (e.g., red-shift, Hubble's constant).

Glossary of Terms

Constellation: A grouping of stars that have been given a name for identification purposes. The International Astronomical Union recognizes 88 official constellations.

Dark Matter: A substance that makes up approximately 25% of the universe and does not emit light energy, but does interact with the gravitational field of visible objects. Dark matter was inferred as a result of observations that galaxies did not contain enough visible mass to be held together. Today, we can pinpoint the location of dark matter using techniques such as gravitational lensing.

Electromagnetic Spectrum: The range of electromagnetic radiation that includes gamma rays, X-rays, ultra violet light, visible light, infrared, microwaves, and radio waves.

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

Gravitational Lensing: The phenomenon of light bending around extremely massive objects, such as black holes and galaxy clusters, resulting in distorted images. Gravitational lensing lets us “see” things we cannot see directly, such as dark matter and black holes.

Gravity (Gravitational Force): The attractive force between all masses in the universe. All objects that have mass possess a gravitational force that attracts all other masses. The more massive the object, the stronger the gravitational force. The closer objects are to each other, the stronger the gravitational attraction.

Infrared Light: A range of the Electromagnetic Spectrum that has lower energy than visible light. Using tools that "see" in infrared allows us to detect objects that we otherwise could not.

Nebula: A cloud of gas and dust, enriched by previous generations of stars. Some nebula are formed directly from the remnants of the collapse of a star.

Neutron Star: The remains of a large, massive star that is extremely small and dense after a supernova explosion.

Pulsar: A neutron star that "pulses", or emits a beam of electromagnetic radiation with each rotation.

Supernova: A stellar explosion. Supernova can form from either the explosion of a massive star or a white dwarf that undergoes runaway nuclear fusion. Supernova explosions are extremely luminous and can temporarily outshine a galaxy. The outer layers are blasted out in an expanding cloud.

Ultraviolet Light: A range of the Electromagnetic Spectrum that has higher energy than visible light. Using tools that "see" in ultraviolet allows us to detect objects that we otherwise could not.

White Dwarf: The hot, compact remains of a low-mass star like our Sun that has exhausted its sources of fuel for thermonuclear fusion. White dwarf stars are generally about the size of the Earth.