

DESTINATION UNIVERSE

SCHOOL GROUP EXHIBIT GUIDE



DESTINATION UNIVERSE

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Highlights

Universal Quick Facts

- Age of Sun: about 5 billion years
- Age of Universe: 13.7 billion years
- Distance to Andromeda Galaxy (nearest major galaxy to Milky Way): 2.4 million light years
- Galaxies formed when the Universe was very young, and are the oldest structures around
- Light year: a distance of about 6 trillion miles
- Milky Way: size--100,000 light years across; number of stars—at least 200 billion
- Nearest star to Sun: Alpha Centauri/Proxima Centauri (triple star), 4.3 light years
- Speed of light: 186,300 miles per second
- Star colors: blue stars are the hottest, while red stars are the coolest
- Star sizes: the biggest stars burn fuel quickly and last only a million years or so, while the smallest stars last hundreds of billions of years
- Stars are born in nebulas, great clouds of gas and dust that can condense under gravity and form new solar systems
- Stars are powered by nuclear fusion of their cores caused by great pressures at their cores
- It is in the cores of stars and in supernova explosions that all elements heavier than hydrogen, helium, and lithium are formed



Websites to Visit

Hubble Site: www.hubblesite.org

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

The Web Nebula: nineplanets.org/twn/types.html

NASA/Goddard Space Flight Center Top Story:
www.gsfc.nasa.gov/topstory/archives2004.html

3-D Models of Surrounding Universe: www.anzwers.org/free/universe/virgo.html

National Optical Astronomy Observatory gallery: www.noao.edu/image_gallery/

Powers of 10: micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/



Pre- and Post-Visit Engaging Questions

Origins

Where do you think the Universe came from?

How do you think all the myths about the origins of the Universe came about?

If you made up a story about where the Universe came from, what would it be?

Can you imagine taking everything in the Universe and squishing it down to the size of a speck—or smaller? That's the way astronomers believe the Universe was when it started, at the instant of the Big Bang.

If the Big Bang was the beginning of our Universe, what was going on before it? Scientists don't know; it's a big mystery right now.

Stars

Which kind of star do you think lives longest: a giant, hot blue star, or a small, cool, red star? The giant star burns so much fuel, it may last only a million years, or less. The small star is very efficient; the smallest of them live so long—trillions of years—that so far none of them have run out of fuel!

Stars are like gigantic explosions—but they are so big that their gravity keeps them from exploding outward. They have so much fuel that they can go on burning for millions or billions of years.

What happens when a star runs out of fuel? It suddenly stops exploding, and its gravity makes it collapse.

When a star like our Sun runs out of fuel, it collapses into a white dwarf—a "dead" star about the size of the Earth.

When a bigger star runs out of fuel, it collapses into a neutron star or a black hole. A neutron star is the size of a big city, spins very fast (sometimes many times each second), and is so dense that a piece of it the size of a sugar cube would weigh hundreds of millions of tons!

A black hole collapses completely, with most of the material of the big star that died shrinking to a single point in space. Gravity is so strong in a black hole, that light doesn't escape it—that's why it's called a black hole.

Nebulae

What's the weather like out in space? Hmmm—just like Earth, it's sometimes clear, and sometimes cloudy!



A nebula is a cloud in space—but it's not made of water droplets like Earth clouds, and it's much, much bigger. In fact, nebula means cloud.

"Nebulae" (neb you lay) is plural for nebula (neb you luh). If you catch someone saying "nebulas," you can tell them that's not the right way to say it.

Do you know what nebulae are made of? Gas and dust.

Hydrogen and helium, gases that have been around since the beginning of the Universe, are the most common gases found in nebulae. Most other types of matter—like carbon, nitrogen, oxygen, iron, sulfur, and all that—exist in space because they have been "cooked up" inside stars.

Some nebulae are what's left over after stars have died and spread the material they made into space.

Some nebulae are making new stars inside: the gases and dust of the nebulae are coming together, by gravity, into stars and planetary systems.

Most of the material in your body, and in nature around you, including the Earth itself, was made inside stars that died billions of years ago, before our Solar System formed.

Galaxies

Do you know what a galaxy is? A great group of stars, dust, and gas, so big that it can take light tens of thousands or hundreds of thousands of years to cross!

Is our Sun part of a galaxy? What's its name? The Milky Way.

How big is the Milky Way? It's 100,000 light years across, shaped like a big spiral pinwheel, and contains at least 200 billion stars!

How many galaxies are there? Astronomers estimate there are between 50 billion and 100 billion galaxies in the visible universe—that is, that we can see and take pictures of with our telescopes.

What's the nearest big galaxy to the Milky Way? Andromeda, which is about 2.4 million light years away—it takes over 2 million years for light from Andromeda to reach us!

How far away is the farthest galaxy we have seen? The Hubble Space Telescope has taken pictures of galaxies that are about 13 billion light years away—it's taken most of the time our Universe has been around for their light to reach us!

Details and Background

Introduction

Welcome to Destination Universe—a journey from our Sun to the farthest reaches of the cosmos.

Along the way, you'll see where stars are born...how they die... meet nebulae of all kinds...and travel from our galaxy to countless galaxies beyond.

It's a very long trip—nearly 14 billion light years. Are you ready?



Origins Theater

For your reading enjoyment, below is a transcript of the dialog from the Origins Theater movie in Destination Universe. The dialog comes from interviews with Drs. E. C. Krupp and Marcelo Gleiser.

"The question as to where we come from is as old as time. Every culture that we have some record of has a story relating their origins.

"You start thinking, okay, I look around myself and I see the variety of nature; I see all the trees, the bugs, the people, animals, planets, stars... where, how, all this came to be, it's mind boggling, really.

"So the language of the myth had to bring fantastic stuff, like the creation of the world and of people, and animals, out of nothing or out of gods, into a language that people could relate to everyday things.

"When people are trying to figure out how all this got here, they look, in fact, to things around them that suggest origins. People, for example, see that chickens and ducks come from eggs. The egg is the source. So the egg become—at least in the Chinese myth of Pan Gu—a reasonable place to start.

"Out of that egg comes Pan Gu, only trouble is, he's got to make the world, the cosmos—whatever it is the Chinese thought was in fact life, the Universe and everything, and he has nothing to work with but himself.



"He basically disintegrated into the world. His skin became the land, his eyes became the sun and the moon, his blood became the waters of the rivers and oceans—they even say the vermin, the little critters that lived on top of him, became the people.



"There are stories as well that involve someone from up in the sky falling from the sky, through the sky. The Iroquois have this idea that there was a couple up in the clouds. The wife was pregnant with twins and when she told her husband she was going to have twins, he was very infuriated by that. A tree is pulled out from the ground in the upper world, and it opens up a hole in the sky. And somehow [he pushes] her through a hole in the cloud world, and she fell down to the world.

"And she winds up down on the surface of the Earth—the primordial waters of the Earth. There is no Earth; it's just fluid. Except there's a turtle swimming there, and she winds up on the back of the turtle. And out of the act, out of that circumstance, ultimately develops the establishment of the terrestrial world.

"And so when you look around, all the creation myths somehow explain the appearance, the emergence of the world,

out of the elements that exist in their vicinity: mud, water, trees.

"For the Egyptians, the Nile was absolutely key to their survival. So their creation myth had to do with something emerging from the waters of the Nile, the giver of life.

"Now in Egypt, Earth was in fact male—Geb. And the sky was female—Nut. In many different cultures, you find just the opposite the case. You find in fact, the sky is male. The



enveloping sky, in fact, raining fertility down on Mother Earth. And the reason for that reversal of what we're normally used to encountering in ancient traditional societies is the simple fact that most of the fertility in Egypt came from the Earth. Not from the sky—it hardly ever rains in Egypt!

"The best theory that we have at our disposal today tells us that approximately 13.7 billion years ago, the Universe began as an infinitesimal volume of energy and matter. A very hot, dense soup of primordial particles, the particles that make up the stuff we're made of. And this bubble of a Universe expanded in explosive fury, and then, as it's doing that, it cools.

"And as it cooled, structures started to be made. So first protons and neutrons were made, then you had electrons binding to that forming atoms. You had big clouds of hydrogen, which is the



lightest element, that would collapse and form the first galaxies and stars.

"And in one of those galaxies there was a small star that was formed about 5 billions years ago, which is our Sun, and from there, we have the Earth and the other planets of the solar system.

"The physical universe that begins in this extraordinarily bizarre Big Bang explosion, and then just keeps on going, and accelerates out perhaps to an infinite size—that's stranger than any myth I've ever read.

"Storytelling and science really are talking about the most fundamental things: How is it that things are they way they are, really. Not just human things, not on that scale, but on the grandest of scales. And that is talking about the formation of the universe and the nature of the gods. Well, science doesn't quite talk about the nature of the gods, but it sure as heck talks about the formation of the Universe, and the structure of the universe, and the fate of the universe, and those are stories that have concerned us for as long as we've been talking."

Stars

What is a Star?

Stars are huge balls of hotly burning hydrogen that form when a cloud of gas and dust falls together under gravity.

When we look at all the stars in our sky, we see them at different stages of their lives. Some are old, some are young—but none last forever.

The lifetime of a star depends on its size. Big stars burn short and fast, small stars burn long and slow.

Throughout its life, a star balances two powerful forces. The tendency of gravity to make a star collapse is opposed by the outward push of radiation from the internal burning of fuel.

Death comes when a star runs out of fuel. It's the crushing end of a star's lifelong battle to maintain its size.



Fact: Stars are usually born in clusters, and often with a companion or two. Star clusters tend to drift apart over time.

Fact: Nuclear reactions are a star's source of energy. Even a small star burns millions of tons of fuel per second.

Stellarium

The Stellarium a 3-D model of 243 stars within 35 light years of the Sun. Our Sun is in the center. At this scale, a similar model of our entire Milky Way Galaxy would be about the size of Oakland's Lake Merritt: about a mile across.

Press a button to see where a star is located:

- Can you find a single yellow star at the center? Our Sun—you are here
- Can you see a triple star near the Sun? Alpha Centauri—the closest stars to the Sun
- Can you discover a faint red star near the Sun? Barnard's Star—a red dwarf
- Can you find a bright orange star? Pollux—the closest giant star to the Sun
- Can you locate another star like the Sun? Tau Ceti—a single yellow star

- Can you spot a bright blue star with a white dwarf companion? Sirius—the brightest star in the night sky

It Takes All Types

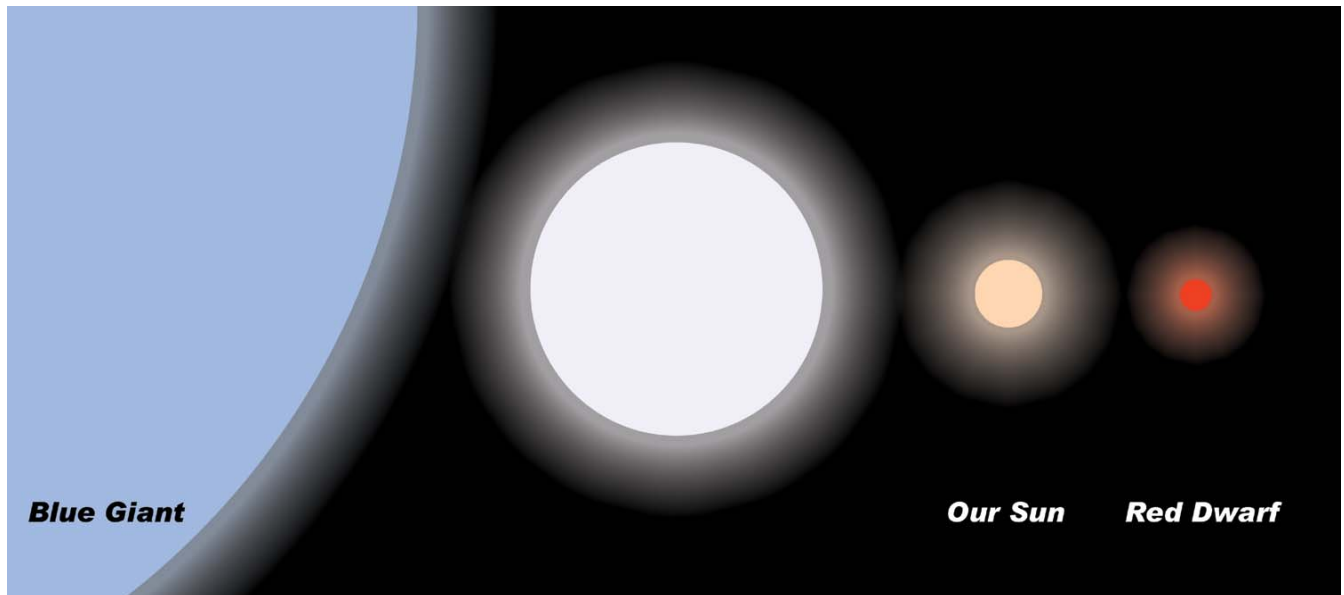
There are many different types of stars. Here are some examples of “Main Sequence” stars—that is, stars that are in their normal life span (before they exhaust their fuel and become red giants, white dwarfs, neutron stars, or black holes).

Red Dwarf: Smaller and cooler than our Sun. The longest-lived stars, because they burn hydrogen so slowly. No red dwarf has run out of fuel since the Universe began—and none will for perhaps 500 billion years or more. Example: Barnard’s Star.

White/Yellow: Our Sun is one. Expected to live about 10 billion years. (The Sun is just middle-aged—don’t worry!) Example: Alpha Centauri.

White: Bigger and hotter than our Sun, and shorter lived. Will burn up all its hydrogen in less than a billion years. Example: Sirius.

Blue Supergiant: The hottest stars, 50 to 100 times our Sun’s size. Will burn out in a few million years. Example: Rigel.



What if the Sun Were Bigger or Smaller?

The Sun is an example of a star seen up close. From Earth, the Sun appears to be about half the size of the average person’s “pinky” held at arm’s length.

Stars with less gas (or less “mass”) than our Sun are smaller and cooler. They burn their hydrogen slower and more efficiently than bigger stars, and live longer—the “economy cars” of the stars. They may appear yellow, orange, or red, red being the smallest and coolest of the hydrogen burning stars. If our Sun were one of these “red dwarf” stars, it would appear in our skies about ten times smaller and over a thousand times fainter!

Stars with more mass than the Sun are larger, hotter, and burn fuel quickly, like gas-guzzling SUVs. If the biggest of these giant blue stars were to take the Sun’s place, it would appear ten times larger and 8000 brighter!

Table of Star Properties—selected stars

Example	Size (diameter, compared to Sun)	Color	Temperature (on surface, in degrees Celsius)	Brightness (compared to Sun)
Barnard’s Star (red dwarf)	1/10	Red	3000	5/10000
The Sun	1	White/Yellow	5700	1
Vega	3	White	9000	60
Rigel (blue supergiant)	84	Blue/White	10000	40,000
Betelgeuse (red giant)	390	Red	3000	8,500

Star Temperature

Everything we know about stars, we know from observing their light. We know how hot or cool they are, for example. Visible light breaks down into a spectrum of different colors—the colors of the rainbow. Light on the blue end of the spectrum has more energy than light on the red end. So we know that blue stars are hotter than red stars.

Interactive

Here’s how astronomers measure the temperatures of stars:

1. Push the button to turn on the light bulb, which is to your left.
2. Move the slider to make the bulb hotter or cooler.
3. As you move the slider, look at the screen on the right. What color—or colors—of light do you see? How do they change?

What’s going on:

The bulb is shining through two filters—red and blue. The red filter lets only red light through. The blue filter lets only blue light through.

The hotter the bulb, the bluer the light. You can see that on the screen. And it's the same with stars: the hotter the star, the bluer the light.

When faintest, and coolest, the filament appears red-orange because it shines more of those colors than the other. As you heat up the filament, it begins to shine more and more of the higher-energy colors—yellow, green, and blue. At a certain temperature the “hotter” colors rise to the same brightness as the oranges and reds, and we experience the mixture as “white” light. If you could make the filament really hot, blue light would start to outshine the other colors and the white would become blue-tinted. However, this filament would probably melt before it got that hot....

The Life of A Star



A Star is Born

Hot clouds of hydrogen gas and dust in space are the birthplaces of stars. Where the gases condense they become hotter and denser. When the gases become hot enough, the process of nuclear fusion is sparked, where the nuclei of hydrogen are smashed together and “fuse” into helium nuclei, releasing some energy in the process.

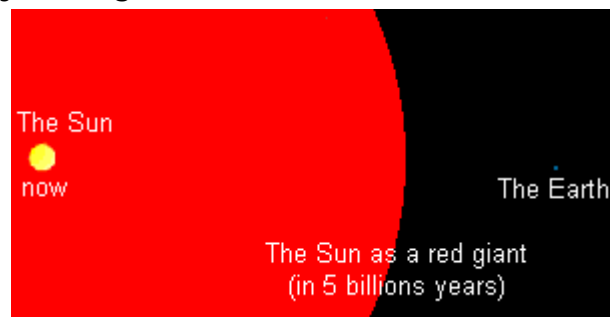
The center of the cloud now burns hot and bright: a star is born. The outer regions of the cloud may condense to form a system of planets, as in our Solar System.

Death Stars

The core of a star is like a giant hydrogen bomb—a continual explosion that keeps the star from collapsing under its own gravity. For most of the star's life it exists in a stable equilibrium between the two forces—like a game of tug o' war where both teams are equally strong. When a star runs out of fuel, what happens can be like a tug o' war where one team suddenly lets go of the rope. Think what happens to the other team!

Red Giant

A star like the Sun will run out of hydrogen after about 10 billion years.



When it begins to collapse, pressure at the core grows and the temperature increases, causing the star's outer shell to inflate and cool into a giant reddish bubble.

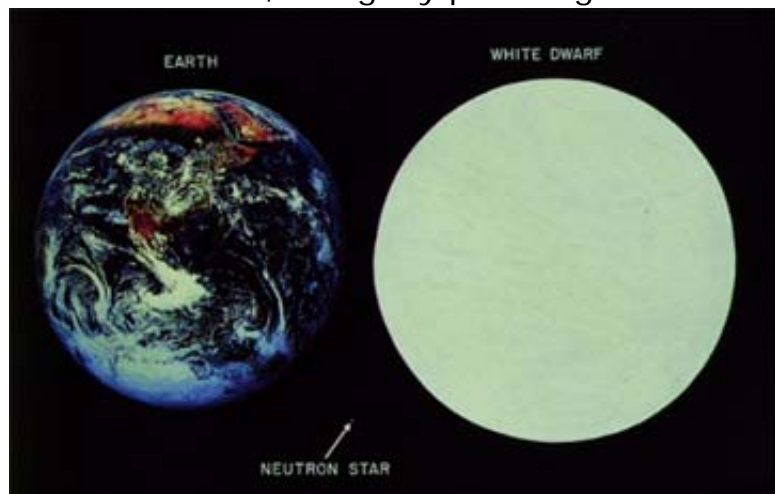
This "red giant" phase is the star's last chance to be noticed by its neighbors, like a flare set off by a sinking ship. As the shell of gas inflates, it becomes much, much brighter.

The bright red star "Betelgeuse" in Orion is a red giant. Betelgeuse is so large that if it were placed where the Sun is, the orbits of all the planets out to Mars would be inside of it!

Eventually, the outer shell of gas is blown off into space, forming an expanding bubble of gas called a "planetary nebula"—so called because of its spherical, planet-like appearance. The Ring Nebula, in Lyra, is a planetary nebula.

White Dwarf

The core of the dying Sun-sized star continues to collapse, becoming smaller, denser, and hotter—and fainter, too, because of its shrinking size. When it shrinks to about the size of the Earth, its tightly packed gases—mostly carbon—stop the collapse. This "white dwarf" star will cool down and grow fainter over time. Though Earth-sized, a white dwarf can contain as much mass as the Sun!



Neutron Star

Stars larger than the Sun are more temperamental when they exhaust their fuel. The hefty collapse crushes the gases at its core to enormous pressures that ignite a supernova—an awesome explosion that blasts much of the star's material violently into space as a ragged, tormented cloud—a nebula called a "supernova remnant."

The collapse of the massive star's core does not stop at the white-dwarf stage. Gravity continues to squeeze until the core is only a few miles across and the core's electrons and atomic nuclei are crushed together to form neutrons. "Neutron stars" are mind-bending objects: the mass of almost two Suns packed into a sphere a few miles across. If the entire human race was brought together and smashed down in the same way, humanity would be about the size of a sugar cube....



Black Hole

The death-collapse of the most massive stars doesn't even stop at the neutron star level. Nothing can stop the collapse, and the mass of two or more Suns retreats into a single point in space called a "singularity."

Though the star seemingly has disappeared, its mass and gravity remain. Close up to the singularity, gravity is so strong that light itself cannot escape—something Harry Houdini might have respected from a distance! This area of no escape would appear as an absolutely black zone, which gives this object its name: "black hole."

Nebulae

Nebulae are clouds of gas and dust in space. They come in different shapes, sizes, and colors, and have different stories to tell. But whether it's a planetary nebula or a supernova remnant, or a vast star-forming cloud, all nebulae play a role in the life cycle of the stars.



Types of Nebulae

Planetary Nebulae

Planetary nebulae have nothing to do with planets! Their round, planet-like shape earned them the name long ago when telescopes weren't very powerful.

These celestial bubbles are formed when a medium sized star (like the Sun) blows away its outer shell at the end of its life. They can appear as smoky rings or soapy bubbles, and are lit

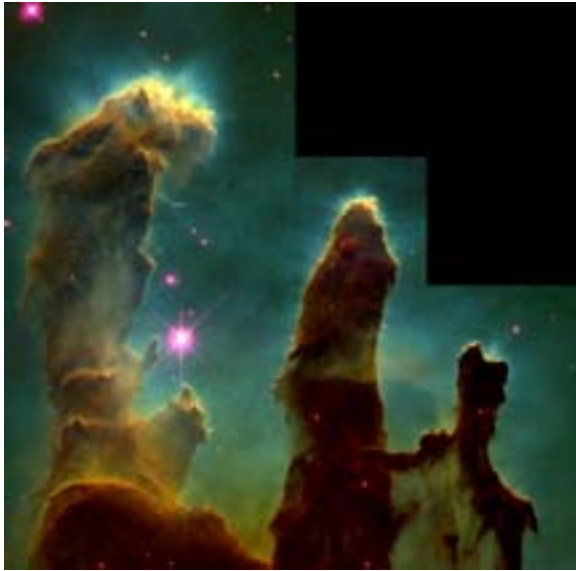
Fact: Planetary nebulae don't last very long before dissipating: only a few thousand years.

Fact: Planetary nebulae are not much bigger than a light-year in size—much larger than our Solar System, but small when compared to most of the other structures in the Universe.

up in dazzling colors by ultraviolet light shining from the dead star's remnant core—a white dwarf star.

Supernova Remnants

When a massive star explodes as a supernova, it violently blasts off most of its material into space in a raggedy, expanding cloud called a "supernova remnant." Like planetary nebulae, these expanding clouds don't get very large--only a few light years, at most—before dissipating into darkness.



Nurseries

Nebulae give birth to stars. Star-forming nebulae can be hundreds of light years across. Within them, swirls of gas and dust condense, spinning faster and faster as they grow more compact.

At the centers of these vortexes the gases get hotter and denser until they reach a critical point where the nuclear fusion process is sparked and a new star lights up. A star-forming nebula can produce dozens or even hundreds of stars in a cluster.

Fact: The famous Pleiades star cluster, also known as the Seven Sisters, is a young cluster of new stars that haven't yet split up on their own courses.

Emission Nebula

A nebula whose gases are "energized" by ultraviolet light from nearby stars is called an "emission nebula," and shines by its own light. Emission nebulae can be spectacularly colorful as different gases emit light in their own specific colors. The same thing goes on inside every neon light.

Reflection Nebula

Some nebulae do not shine with their own light, but instead reflect the light of nearby stars. Dust in these "reflection nebulae" reflects light in much the same way that a cloud on Earth reflects the Sun's light.

If the dust lies between us and a source of light (like a star or an emission nebula), we see a dark obscuring cloud instead, either partially or

completely blocking the light. This is sometimes called an “absorption nebula,” but it’s really just the “flipside” of a reflection nebula.

Colors of Nebulae

Light

Light is produced when an atom is temporarily energized by some source of energy, and then releases the energy again in the form of light. The amount of energy the atom releases determines the color of the light: blue light has more energy than red light.

An atom can release its energy in steps, like a child jumping down a staircase. Each step produces light whose color depends on the amount of energy released (just as the more steps a child jumps over, the louder the sound!). One way to tell what types of gases a nebula is made of is by looking at its color.

Nebula Gas

In space, a nebula is usually made of many different gases mixed together, so you can’t always tell what’s in it just by looking at its color. The only way to be sure is to look at its spectrum—and that’s what astronomers do, for each and every nebula.

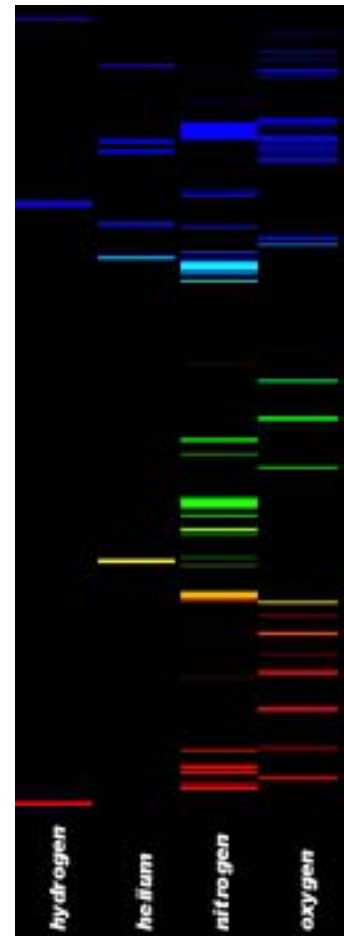
Gas Light

The tubes behind the glass are each filled with a different type of gas. When you turn on a tube, the gas atoms are energized by electricity and glow. Turn on each gas tube to see the color of its light. Look at the pictures of emission nebulae and see if you can tell the main type of gas in each. [Flip the thing] to see if you are right.

Fingerprinting the Luminous Suspects

There is more information in the light of these gases than simply their color. Look at the light through the diffraction grating—a film that splits up the different colors of light. What do you see? Try all of the different gases. What do you notice when you compare them?

The pattern of different colors you see in a gas’ light—its “spectrum”—is as unique to that gas as a fingerprint is to a person. If you know the spectral



“code” of a gas, you can identify it even from millions of light years away. All you have to do is separate the colors with a diffraction grating and look at the spectrum!

Red and Blue (Nebula in a Bottle)

Some nebulae are blue. Some are dark and reddish. But not because of the gas inside them. It’s because of the way their dust particles scatter light.

Interactive

In front of you are three tubes filled with a gel that acts like nebula dust. Slide them all down.

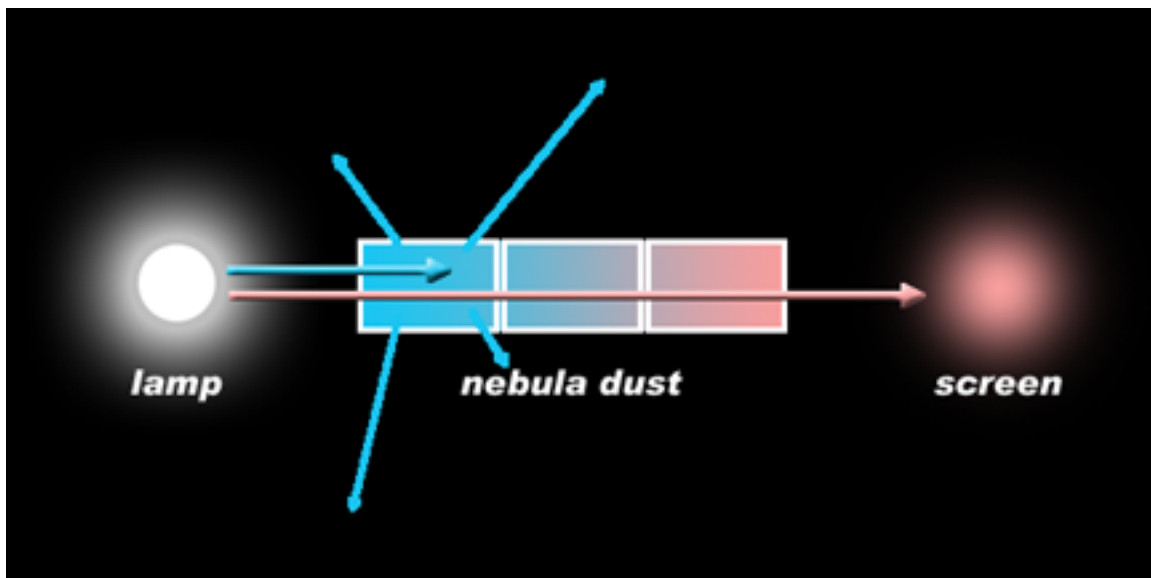
The projector on the far left shines white light, like starlight, onto the screen on the far right.

Push the tubes up into the light, one at a time. The tubes will look sort of blue at the end closest to the light. At the other end, farthest from the light, they’ll look orangey-red.

The light on the screen gets redder as you add more tubes—like starlight shining through a nebula.

That’s because the blue wavelengths of light hit particles in the gel and bounce away, while the red wavelengths pass on through to the screen.

The same thing happens when starlight hits nebula dust—the blue light bounces away as it moves through the dust.



Fact: Starlight that passes through dust clouds before reaching us, if not completely blocked, appears reddened too.

Fact: Earth's sky is blue for the same reason that a reflection nebula is, though in this case it's air molecules that are reflecting the Sun's blue light in all directions. A sunset appears reddish because it has to pass through a lot of Earth's atmosphere before reaching our eyes, and much of its blue light has been scattered away. Dust in the atmosphere, from a volcanic eruption or a windstorm, can make sunsets even redder than usual.

Fact: When light bounces off of a cloud of particles, like dust grains, the light is scattered about in all directions. This "fuzzy" type of reflection is called "scattering."

Galaxies

Introduction



Island Universes

When astronomers first looked at galaxies through telescopes, they thought they were clouds of gas and dust, and called them nebulae. As telescopes grew larger, so did our appreciation of the size and distance of the galaxies. When we learned these objects were made of countless hordes of stars, the galaxies came to be thought of as "island universes."

Star Clouds

Galaxies are huge clouds containing hundreds of billions of stars, dust, and gas and stretching tens or hundreds of thousands of light years from one side to the other. They formed around 13 billion years ago, when our Universe was very young.

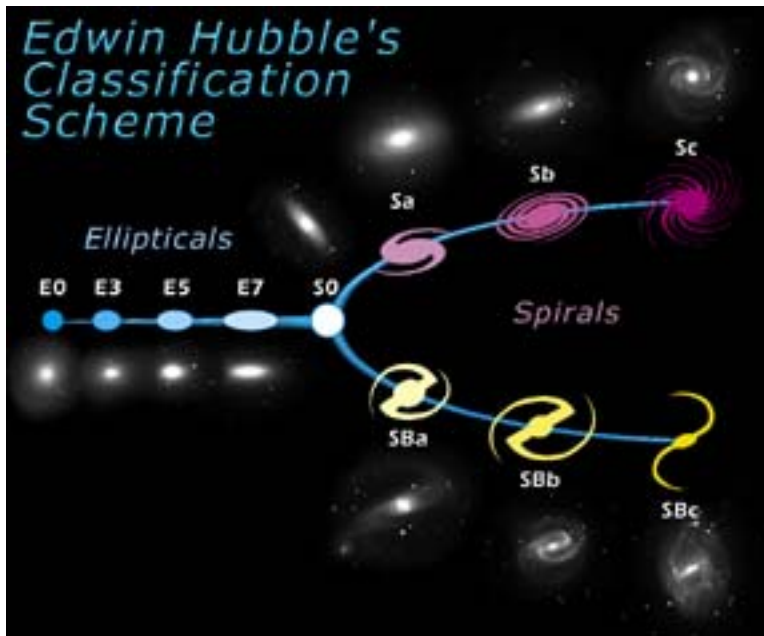
Milky Way

Galaxies come in a variety of shapes and sizes. Our galaxy, the Milky Way, is a spiral galaxy, with a bulge at the center surrounded by a flat disk containing spiraling "arms" of stars, gas, and dust. The Milky Way contains perhaps 200 billion stars and is 100,000 light years from edge to edge.

Galaxy Hunter!

Familiar Shapes

We sort galaxies by their shapes. As well as “spiral” galaxies like the Milky Way, there are “elliptical” and “irregular” galaxies. Ellipticals can appear oval to nearly circular, and can range in sizes from the enormous “giant ellipticals” to relatively tiny “dwarf ellipticals.” Irregulars are random, chaotic masses of stars with no regular shape, and are usually dwarfs.



Rich Variety

Just like people, galaxies have very different characters. Some are laced with great clouds of gas and dust, while others appear relatively dust-free. Some are alive with the hustle and bustle of new star formation, while others are more like retirement communities, filled only with old stars. Some are going through violent activity, spewing out great jets of gas, magnetism, and radio waves. Others are

quiet.

Galaxy Collider

Neighboring galaxies attract each other by gravity. Over time, this powerful force can change the shapes of nearby galaxies. When two galaxies collide head-on, they can be violently distorted or even merge together.

Our Milky Way galaxy is destined to collide with the Andromeda galaxy—in about five billion years.

Fact: Even when galaxies collide head on and appear as if all heck has broken loose, the individual stars themselves do not tend to collide. In fact, new star formation can be accelerated in a galaxy that has been disturbed by colliding with another.

Fact: A galaxy collision is slow, taking place over as much as one or two billion years.

Universe Calendar

History of the Universe

How old is the Universe? When did the Sun form? Where do humans fit in?

Think of it this way: shrink the entire history of the Universe down to one year, with the Big Bang on January 1. All of human existence—from the first Homo Sapiens to today—happens in the final two minutes of the last day of the year.

You can puzzle it out for yourself! Here is a table showing the events of the evolution of the Universe when compressed into one calendar year.

Event	Years Ago	Calendar Date
Big Bang	13.7 billion	January 1 st
First Galaxies Form	13 billion	January 19 th
Universe Continues to Develop	13 billion-4.5 billion	Winter, Spring, and most of Summer
The Sun and Solar System Form	4.5 billion	September 3 rd
The First Life Appears on Earth	4 billion	September 16 th
First dinosaurs appear	248 million	December 25 th
Dinosaurs become extinct	65 million	December 30 th , 6:26 AM
Life on Earth continues to evolve	40 million-200,000	December 31 st , 11:52 PM
All of human existence so far	200,000-present	December 31 st , 11:58 PM

Extra Feature: Bigger than Galaxies

Galaxy groups

Galaxies are very social! They stick together, by gravity, in groups of different sizes. The Milky Way belongs to a small club: a group containing 39 galaxies, including the large Andromeda and Pinwheel spiral galaxies, as well as a host of smaller “dwarfs.” This “Local Group” is about 10 million light years across.

Galaxy clusters

Our Local Group lies on the outskirts of a much bigger cluster of galaxies, the “Virgo Cluster.” The Virgo Cluster dominates our corner of the Universe, containing 150 large galaxies and over 1000 smaller ones. It is believed that our Local Group is being pulled toward the center of the Virgo Cluster, 45 million light years away.

Superclusters—clusters of galaxy clusters

The Local Group and the Virgo Cluster are part of the Coma-Virgo Supercluster, an association of groups and clusters containing about 2000 galaxies and filling a region about 200 million light years across.

Filaments, Sheets, and Walls—networks of superclusters

As we look farther into space, a clearer picture of our Universe is coming into view. Superclusters form vast networks that resemble a crazy spattering of spaghetti strewn through space, with enormous, apparently empty voids separating the strands.

What's the biggest thing we have seen? It depends on what you consider a "thing" to be. Superclusters—clusters of galaxy clusters—appear to be strung together into filaments and sheet-like shapes, some of these several hundred million light years across. In 2003, a "structure" 1.37 billion light years across was announced—though it's not known whether this actually is a "thing," or just looks that way....

Within our current ability to see and count galaxies, it is estimated that there are between 50 and 100 billion of them.

Even on a Clear Day, You Can't See Forever

Recently, the Hubble Space Telescope took a picture of some galaxies believed to be 13 billion light years away. Considering that the Universe is about 13.7 billion years old, we view these galaxies as they were when the Universe was very young indeed!

Universal Fun

Kaleidoscope

Sit down below and look up on high! Turn the wheel and watch images of the cosmos "kaleid" (yes, my spell checker complained about that word). As you peer up at perplexing heavenly sights, do you get the chilling impression that you are at the specimen end of a microscope, with the great denizens of the Universe at large squinting down at you....



Black Hole

Q: What is a Black Hole?

A: A black hole is what's left when a really big star dies. Gravity there is so strong, not even light can escape. So it looks black.

Q: Could you travel through a black hole?

A: Not as far as we know. Gravity would stretch you long and thin as you went in. At the center, you would be crushed to nothing.

Q: What is a wormhole?

A: A wormhole is a theoretical shortcut through the fabric of the Universe. Some people have suggested that we could enter and leave them via black holes.

But don't buy that ticket yet! No one has ever found a wormhole.

Q: Where would you end up if you could travel by black hole?

A: Some people think you could pass through a black hole into another universe. Even if you could find out about life in a parallel universe, you'd never get the story back to your friends in this one!

Cruising Through the Universe

The Universe is a very big place, and there's an awful lot to see. So you'd better get moving fast.

After departing the Solar System, you pass stars, nebulae, and star clusters. Soon, you leave our Milky Way Galaxy far behind, then our Local Group of galaxies.

Even the huge Virgo Supercluster shrinks in the rearview mirror as you head out into really deep space, 13 billion light years away. Have a great trip!



Speed of light

Light moves fast: 186,300 miles each second. At that speed, you could get from London to New York in a few hundredths of a second, to the Moon in little more than a second, or to the Sun in only 8 minutes! Pluto is a 5-hour light-flight away.

Beyond our Solar System, the speed of light becomes less attractive to would-be space-trekkers: even the nearest star to our Sun would take over 4 years to reach!

As you walk along the gallery, the objects you see are at increasingly greater distances and sizes. With each step, you may stop to ponder how fantastically far from home you virtually stand.

Here is a quick-look list of the distances to the objects shown in this gallery:

- Stars in the Milky Way—20,000 light years

- Shell of Gas—20,000 light years
- Helix Nebula—650 light years
- Keyhole Nebula—9,000 light years
- Andromeda Galaxy—2.4 million light years
- Two Spiral Galaxies—114 million light years
- Hubble Ultradeep Field—from 2 to 13 billion light years

Extra Feature: Measuring Cosmic Distances

This article is an in-depth description of how astronomers measure the vast distances in space. These details are not included in Destination Universe, but you may find some of the information useful.

Getting a clear picture of the Universe we live in means knowing how big it is—and though the cosmic distances we know today are nearly beyond comprehension, it's easy to take the knowledge for granted.

But measuring these great distances is not straightforward. Astronomers have spent centuries coming up with clever ways to measure the distances to objects in the Universe, from the nearest stars to the most distant galaxies. Here is a description of some of the “measuring sticks” in the astronomer’s desk drawer:

Measuring Stick: Parallax

Good for measuring distances out to 100 light years.

Hold your finger up at arm’s length in front of the stars in the wall panel. Now shut each eye in turn: left eye, right eye....

Do you notice your finger shifting to the left and to the right against the background of stars?

The visual shifting of something near against something far is called “parallax.”

We can observe—and measure—parallax in nearby stars when we take pictures of them six months apart. A six-month delay takes us to opposite sides of the Earth’s orbit around the Sun. It puts the greatest distance between the two pictures—equivalent to the left- and right-eye views of our experiment. With a bit of math, we can tell how far the shifting stars are.

But parallax will only tell us the distance to the stars closest to us.

Measuring Stick: Cepheid Variables

Good for measuring distances out to 10 million light years.



Measuring the distances to far away objects would be easier if we had some kind of ruler. A standard star at a known distance would be ideal.

Once we've located our standard star, we can search for others. If we come across an identical star that's fainter, we know that it must be farther away.

About a century ago, a special type of star was discovered: a "Cepheid variable." Variable stars change in brightness in a rhythmic pattern, and Cepheid variables were found to pulsate with periods that depended on their size, and in turn their actual brightness. So, wherever astronomers could find a Cepheid-type variable star they could measure its period of pulsation to determine its actual brightness. Then by comparing that actual brightness to how bright it appeared, they could calculate the star's distance.

It was with Cepheid variable stars, in 1923, that the distance to the Andromeda galaxy was found to be far greater than originally thought, elevating its status as a "spiral nebula" to a new type of object: a galaxy. Today, the distance to the Andromeda galaxy is known to be about 2 million light years.

Measuring Stick: Planetary Nebulae

Good for measuring distances out to: 100 million light years.

At greater distances, seeing individual stars in galaxies becomes more and more difficult as they become fainter and blend together.

Distances to galaxies as far away as the Virgo Cluster—which is about 45 million light years away—can be measured using planetary nebulae as measuring sticks. When a planetary nebula absorbs ultraviolet light emitted by the white dwarf at its center, its gases glow in very particular colors of light—especially a certain color of green that is easy to spot with telescopes even at this great distance. The brightness of the light we see tells us the distance to that nebula and the galaxy it is in.

Measuring Stick: Type 1A Supernovas

Good for measuring distances out to the edge of the visible universe (about 13 billion light years).

One type of supernova occurs when a very large star runs out of fuel and explodes. The brightness of this type of supernova varies greatly and depends on how big the exploding star is.

Another type of supernova—type "1A"—happens when a white dwarf star, pulling gas off of a nearby companion star, reaches a critical threshold of mass and can no longer hold up against its own gravity. It collapses in about a second's time and explodes in a brilliant flash. The useful thing

about type 1a supernovas is that they are all about the same brightness, so measuring how bright they appear tells us how far away they are—even if it's in a galaxy ten billion light years away!

Measuring Stick: Gravitational Lenses

Good for measuring distances out to the edge of the visible universe (about 13 billion light years).

At the edge of the visible Universe we observe the most distant galaxies. They are so far away, and their light has taken so long to reach us, that we see them as they were when the Universe was still very young.

In some cases, a very large object, like a huge galaxy or galaxy cluster, stands between the distant galaxy and us. The gravity of the intervening object bends the rays of light of the more distant galaxy, creating multiple images of it. This phenomenon is called a "gravitational lens." Astronomers are using the behavior of the multiple images of the distant galaxies to measure distances as great as 13 billion light years.

Measuring Stick: Red Shift

Ever been caught speeding by a Highway Patrol officer with a radar gun? Ever wonder how they nabbed you?

A radar gun emits a beam of radio waves at a certain frequency that bounces off of an object and back to the radar unit. Ordinarily, the reflected beam has the same frequency as the emitted beam, but if the target is moving toward or away from the radar gun, the frequency changes. Sound waves do the same thing, something you know about if you've listened to the horn of a car or train change in pitch as it passes you, going from approaching to receding.

Visible light also shifts if the light source is moving toward or away from us: its light becomes "redder" if the object is moving away.

In 1929, when this phenomenon, known as the "red shift," was being used to measure how fast galaxies are moving toward or away from us, an awesome discovery was made: most galaxies are moving away from us. Furthermore, the farther away a galaxy is, the faster it is moving away! The Universe, it seemed, was expanding!

The expansion of the Universe and the red shift this causes in the light of galaxies gives us a handy tool for measuring the greatest cosmic distances. The redder the light, the farther away the galaxy!

Because of the uniform expansion the Universe seems to be engaged in, with the speed a distant galaxy traveling away from us being greater the



more distant it is, the “red shift” in a galaxies light can be used to measure its present distance from us.

Powers of Ten

Where do you fit in the Universe?

How big are you compared to the Universe? How far is the edge of space? Find out here!

Zoom out, frame by frame, from you at the Space and Science Center ... to the edge of the known Universe. When you're done, you can zoom back in again.

The scale of each image is ten times larger than the last one. See how quickly that takes you out into deep space.

Star Dust

The Big Bang created a universe containing just three elements: hydrogen, helium, and lithium. The other elements came later, when burning stars fused the lighter atomic nuclei into bigger, heavier nuclei.

Carbon, for instance, is made in large stars—and in smaller ones near the end of their life cycle. Large stars can fuse atomic nuclei for elements as heavy as iron. Heavier elements such as gold and uranium are made when big stars explode.

The heavier elements forged by dying stars are smeared thinly through space, mixing with the hydrogen of star-forming nebulae. It was in such a nebula that our Solar System and the Earth were formed, and you along with it!

You are made of stardust.

And in five or so billion years, our Sun will die and spread the material of our Solar System—including us—back into the cosmos, returning us to where we came from.

Image Captions

Exhibit Entrance

Helix Nebula (spinning in the entry portal bubble). Will our Sun look like this one day? The Helix Nebula is the closest example of a planetary nebula created at the end of the life of a Sun-like star. The outer gasses of the star expelled into space appear from our vantage point as if we are looking down a helix. The remnant central stellar core, destined to become a white dwarf star, glows in light so energetic it causes the previously expelled gas to fluoresce. The Helix Nebula lies about 650 light-years away towards the constellation of Aquarius and spans about 2.5 light-years. (Caption adapted from Astronomy Picture of the Day.)



Spiral galaxy NGC 3370: Amid a backdrop of far-off galaxies, the majestic dusty spiral, NGC 3370, looms in the foreground in this NASA Hubble Space Telescope image. Recent observations show intricate spiral arm structure spotted with hot areas of new star formation. This galaxy is in the constellation Leo, at a distance from us of about 100 million light years. (Caption adapted from Hubblesite.org, Hubble Space Telescope.)



Pleiades star cluster: Perhaps the most famous star cluster in the sky, the Pleiades can be seen without binoculars from even the depths of a light-polluted city. Also known as the Seven Sisters and M45, the Pleiades is one of the brightest and closest open clusters. The Pleiades contains over 3000 stars, is about 400 light years away, and only 13 light years across. Quite evident in the photograph are the blue reflection nebulae that surround the brighter cluster stars. Low mass, faint, brown dwarfs have also been found in the Pleiades. (Caption from Astronomy Picture of the Day.)



Nebula RCW 49: Stars and planets appear to be under construction in



dusty nebula RCW 49. Hot stars are well on their way to clearing out the nebula's central regions. Also, more than 300 newborn stars are seen here strewn throughout the cosmic dust clouds and filaments. Infrared data indicate the likely presence of protoplanetary discs around some of the infant suns, among the faintest and farthest potential planet-forming discs ever observed. Such exciting results give further support to the idea that planet-forming discs are a natural part of a star's evolution. A mere 14,000 light-years away

toward the constellation Centaurus, the industrious RCW 49 is about 350 light-years across. (Caption from Astronomy Picture of the Day.)

Exhibit Introduction

Pillars of Creation, in the Eagle Nebula: Newborn stars are forming in the



Eagle Nebula. This image, taken with the Hubble Space Telescope in 1995, shows evaporating gaseous globules (EGGs) emerging from pillars of molecular hydrogen gas and dust. The giant pillars are light years in length and are so dense that interior gas contracts gravitationally to form stars. At each pillars' end, the intense radiation of bright young stars causes low-density material to boil away, leaving stellar nurseries of dense EGGs exposed. The Eagle Nebula, associated with the open star cluster M16, lies about 7000 light years

away. (Caption from Astronomy Picture of the Day.)

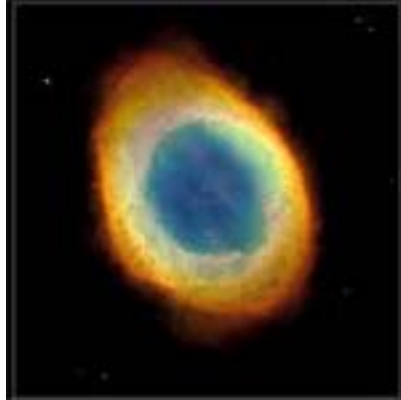
Crab Nebula supernova remnant: The Crab Nebula, filled with mysterious



filaments, is the result of a star that was seen to explode on July 4th, 1054 AD. This spectacular supernova explosion was recorded by Chinese, Japanese, and (quite probably) Anasazi astronomers. The filaments are mysterious because they appear to have less mass than expelled in the original supernova and higher speed than expected from a free explosion. In the nebula's very center lies a pulsar: a neutron star rotating, in this case, 30 times a second. The Crab Nebula is in the constellation Taurus, at a distance

from us of about 6,500 light years. (Caption adapted from Astronomy Picture of the Day.)

Ring Nebula: Except for the rings of Saturn, the Ring Nebula (M57) is probably the most famous celestial band. This planetary nebula's simple, graceful appearance is thought to be due to perspective -- our view from planet Earth looking straight into what is actually a barrel-shaped cloud of gas shrugged off by a dying central star. Hot blue gas near the energizing central star gives way to progressively cooler green and yellow gas at greater distances with the coolest red gas along the outer boundary. Dark, elongated structures can also be seen near the nebula's edge. The Ring Nebula is about one light-year across and 2,000 light-years away in the



northern constellation Lyra. (Caption adapted from Astronomy Picture of the Day.)

Distant Galaxies, Hubble Ultra-deep Field: Galaxies, galaxies everywhere—as far as NASA's Hubble Space Telescope can see. This view of nearly 10,000 galaxies is the deepest visible-light image of the cosmos. Called the Hubble Ultra Deep Field, this galaxy-studded view represents a "deep" core sample of the Universe, cutting across billions of light-years. The snapshot includes galaxies of various ages, sizes, shapes, and colors. The smallest, reddest galaxies, about 100, may be among the most distant known, existing when the universe was just 800 million years old. The nearest galaxies—the larger, brighter, well-defined spirals and ellipticals—



thrived about 1 billion years ago, when the cosmos was 13 billion years old. (Caption adapted from Hubblesite.org, Hubble Space Telescope.)

What is a Star?

Globular star cluster NGC 6397 (image inside the bubble dome): In our neck of the galaxy stars are too far apart to be in danger of colliding, but in the dense cores of globular star clusters star collisions may be relatively common. In fact, researchers have evidence that the closely spaced blue stars near the center of this image taken by the orbiting Hubble Space Telescope were formed when stars directly collided. Pictured is the central region of NGC 6397, a globular cluster about 6,000 light-years distant, whose stars all formed at about the same time. NGC 6397's massive stars

have long since evolved off the main sequence, exhausting their central supplies of nuclear fuel. This should leave the cluster with only old low mass



stars; faint red main sequence stars and brighter blue and red giants. However, spectroscopic data show that some of these stars, descriptively dubbed blue stragglers, are clearly main sequence stars which are too blue and too massive to still be there. Suggestively the stragglers appear to be two and occasionally three times as massive as the lower mass cluster stars otherwise present, supporting evidence for their formation from two and even three star collisions. (Caption adapted from Astronomy Picture of the Day.)

Globular star cluster M80: If our Sun were part of M80, the night sky



would glow like a jewel box of bright stars. M80 is one of about 250 globular clusters that survive in our Galaxy. Most of the stars in M80 are older and redder than our Sun, but some enigmatic stars appear to be bluer and younger. These unusual stars are known as blue stragglers, and by analyzing pictures like this, astronomers have been able to find the largest population of blue stragglers yet. As blue stragglers are now thought to be due to stars coalescing, the collision and capture rate at the dense center of M80 must be

very high. (Caption adapted from Astronomy Picture of the Day.)

Giant galactic nebula NGC 3603: NGC 3603 is the largest region of



glowing gas in our Milky Way galaxy. Spanning over 20 light years across, the giant emission nebula is home to a massive star cluster, thick dust pillars, and a star about to explode. The young star cluster near the center heats the region's mostly hydrogen gas. Many stars in the cluster are estimated to be about one million years old, much less than the five billion-year age of our Sun. NGC 3603 lies approximately 20,000 light years away toward the constellation of Carina.

(Caption adapted from Astronomy Picture of the Day.)

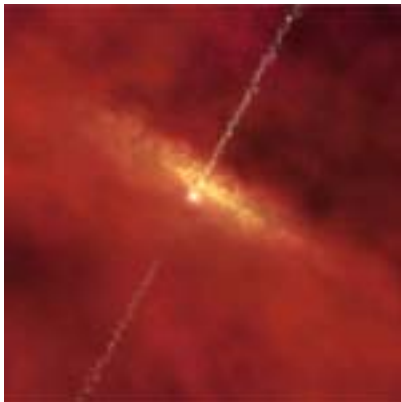
Ultraviolet image of the Sun: This image of the active Sun from the Solar and Heliospheric Observatory (SOHO) was made using ultraviolet light emitted by ionized Helium atoms in the Solar chromosphere. Helium was

first discovered in the Sun in 1868, its name fittingly derived from the Greek word Helios, meaning Sun. Almost 27 years later Helium was finally discovered on Earth. Helium is now known to be the second most abundant element (after Hydrogen) in the Universe. (Caption adapted from Astronomy Picture of the Day.)



Life of a Star

Jets from a Forming Star (illustration): This illustration shows a star in the process of forming from a rotating, collapsing cloud of gas and dust, sending out two polar plumes of gas spewed out and funneled away by the forming star's powerful magnetic field.



Eta Carina: Eta Carina may be about to explode. But no one knows when – it may be next year, it may be one million years from now. Eta Carina's mass—about 100 times greater than our Sun—makes it an excellent candidate for a full blown supernova. Historical records do show that about 150 years ago Eta Carina underwent an unusual outburst that made it one of the brightest stars in the southern sky. Clearly visible in the image are two distinct lobes, a hot central region, and strange radial streaks. The lobes are filled with lanes of gas and dust that absorb the blue and ultraviolet light emitted near the center. The streaks remain unexplained.

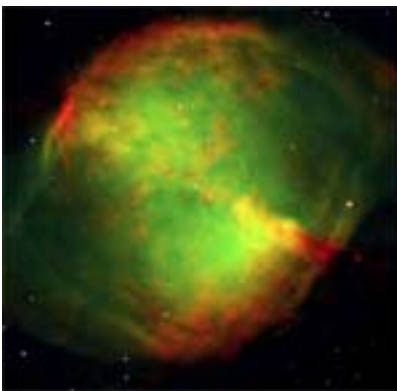


Star cluster M 29: An open cluster of stars, within our Milky Way Galaxy. M 29 is about 4,000 light years away in the direction of the constellation Cygnus.



Nebulae Intro

Dumbbell Nebula, M27 (image inside bubble dome): While searching the skies above 18th century France for comets, astronomer Charles Messier diligently recorded this object as number 27 on his list of things that are definitely not comets. So what is it? Well, 21st century astronomers would classify it as a planetary nebula ... but it's not a planet either, even though it may appear round and planet-like in a small telescope. Messier 27 (M27) is now known to be an excellent example of a gaseous emission nebula created as a Sun-like star runs out of nuclear fuel in its core. The nebula forms as the star's outer layers are expelled into space. The visible glow is generated as atoms are excited by the dying star's intense but invisible ultraviolet light. Known by the popular name Dumbbell Nebula, the beautifully symmetric interstellar gas cloud is about 1,200 light-years away in the constellation Vulpecula. (Adapted from Astronomy Picture of the Day.)



Orion Nebula: The Great Nebula in Orion can be found in the night sky just below and to the left of the easily identifiable belt of three stars in the popular constellation Orion. This nebula is one of the closest stellar nurseries, where young stars are being formed even now. Clumps of gas (mostly hydrogen and helium) and dust in the nebula are squeezed together by their own gravity until they collapse and form stars. Some stars we can see here, partially obscured by the nebula, are only about 100,000 years old—just babies compared to the 5 billion years of our Sun.



(Caption adapted from Astronomy Picture of the Day.)

Dumbbell Nebula, M27: See above caption for image in bubble dome.

Spirograph Nebula: What is creating the strange texture of IC 418?



Dubbed the Spirograph Nebula for its resemblance to drawings from a cyclical drawing tool, planetary nebula IC 418 shows patterns that are not well understood. Perhaps they are related to chaotic winds from the variable central star, which changes brightness unpredictably in just a few hours. By contrast, evidence indicates that only a few million years ago, IC 418 was probably a well-understood star similar to our Sun. Only a few thousand years ago, IC 418 was probably a common red giant star. Since running out of

nuclear fuel, though, the outer envelope has begun expanding outward leaving a hot remnant core destined to become a white-dwarf star, visible in the image center. The light from the central core excites surrounding atoms in the nebula causing them to glow. IC 418 lies about 2,000 light-years away and spans 0.3 light-years across. (Adapted from Astronomy Picture of the Day.)

Colors of Nebulae

Tarantula Nebula: The Tarantula Nebula is more than 1,000 light-years across—a giant emission nebula within our neighboring galaxy the Large Magellanic Cloud.



Inside this cosmic arachnid lies a central young cluster of massive stars, cataloged as R136, whose intense radiation and strong winds have helped energize the nebular glow and shape the spidery filaments. In this image, other young star clusters can be seen still within the nebula's grasp. Also notable among the denizens of the Tarantula zone are several dark clouds invading the nebula's outer limits as well as the dense cluster of stars

NGC 2100 at the extreme left edge of the picture. The small but expanding remnant of supernova 1987a, the closest supernova in modern history, lies just off the lower right corner of the field. The image covers an area on the sky about the size of the full moon in the southern constellation Dorado.

(Caption adapted from Astronomy Picture of the Day.)

Eagle Nebula: From afar, the whole thing looks like an Eagle. A closer look of the Eagle Nebula, however, shows that the bright region is actually a window into the center of a larger dark shell of dust. Through this window, a

brightly lit workshop appears where a whole open cluster of stars is being



formed. In this cavity tall pillars and round globules of dark dust and cold molecular gas remain where stars are still forming. Already visible are several young bright blue stars whose light and winds are burning away and pushing back the remaining filaments and walls of gas and dust. The Eagle emission nebula lies about 6,500 light years away, spans about 20 light-years, and is visible with binoculars toward the constellation of Serpens. (Adapted from Astronomy Picture of the Day.)

Planetary nebula Abell 39 (pale blue soap bubble): Planetary nebula



Abell 39, now six light-years across, was once a Sun-like star's outer atmosphere expelled thousands of years ago. Observations indicate that Abell 39 contains only about half of the oxygen found in the Sun, an intriguing but not surprising confirmation of the chemical differences between stars. The reason why the central star is slightly off center by 0.1 light-years is currently unknown. Abell 39 lies about 7,000 light years away. (Caption adapted from Astronomy Picture of the Day.)

SN 1987A: Glittering stars and wisps of gas create a breathtaking



backdrop for the self-destruction of a massive star, called supernova 1987A, in the Large Magellanic Cloud, a nearby galaxy. Astronomers in the Southern hemisphere witnessed the brilliant explosion of this star on Feb. 23, 1987. Shown in this NASA Hubble Space Telescope image, the supernova remnant, surrounded by inner and outer rings of material, is set in a forest of ethereal, diffuse clouds of gas. The supernova remnant and the Large Magellanic Cloud are about 160,000 light years away. (Caption adapted from

Astronomy Picture of the Day.)

Red and Blue

NGC 1999: A dusty bright nebula contrasts dramatically with a dusty dark nebula. The nebula, cataloged as NGC 1999, is a reflection nebula, which

shines by reflecting light from a nearby star. Unlike emission nebulae, whose



reddish glow comes from excited atoms of gas, reflection nebulae have a bluish cast as their interstellar dust grains preferentially reflect blue starlight. While perhaps the most famous reflection nebulae surround the bright young stars of the Pleiades star cluster, NGC 1999's stellar illumination is provided by the embedded variable star V380 Orionis, seen here just left of center. Extending right of center, the ominous dark nebula is actually a condensation of cold molecular gas and dust so thick and dense that it blocks

light. From our perspective it lies in front of the bright nebula, silhouetted against the ghostly nebular glow. New stars will likely form within the dark cloud, called a Bok globule, as self-gravity continues to compress its dense gas and dust. Reflection nebula NGC 1999 lies about 1,500 light-years away in the constellation Orion, just south of Orion's well known emission nebula, M42. (Caption adapted from Astronomy Picture of the Day.)

Star Forming Region in the Large Magellanic Cloud, N11B: Massive



stars, abrasive winds, mountains of dust, and energetic light sculpt one of the largest and most picturesque regions of star formation in the Local Group of Galaxies. Known as N11, the region is within the Large Magellanic Cloud (LMC), a small irregular galaxy

neighboring the Milky Way. The image highlights N11B, part of the nebula that spans about 100 light years and is particularly active. Studying the stars in N11B has shown that it actually houses three successive generations of star formation. Compact globules of dark dust housing emerging young stars are also visible on the upper right. The LMC is about 160,000 light years away. (Caption adapted from Astronomy Picture of the Day.)

Galaxies—What is a Galaxy?

Spiral Galaxy M66 (image inside the bubble dome): Why isn't spiral galaxy M66 symmetric? Usually density waves of gas, dust, and newly formed stars circle a spiral galaxy's center and create a nearly symmetric galaxy. The differences between M66's spiral arms and the apparent

displacement of its nucleus are all likely caused by the tidal gravitational pull



of nearby galaxy neighbor M65. Spiral galaxy M66 spans about 100,000 light years, lies about 35 million light years away, and is the largest galaxy in a group including M65 and NGC 3628 known as the Leo Triplet. Like many spiral galaxies, the long and intricate dust lanes of M66 are seen intertwined with the bright stars and nebulas that light up the spiral arms. (Caption adapted from Astronomy Picture of the Day.)

Spiral galaxy M83: M83 is one of the closest and brightest spiral galaxies



in the sky. Visible with binoculars in the constellation Hydra, majestic spiral arms have prompted its nickname as the Southern Pinwheel. Although discovered 250 years ago, only much later was it appreciated that M83 was not a nearby gas cloud, but a barred spiral galaxy much like our own Milky Way Galaxy. M83 is a prominent member of a group of galaxies that includes Centaurus A and NGC 5253, all of which lie about 15 million light years away. To date, six supernova explosions have been recorded in M83. An intriguing double ring has been discovered at the

center of M83. (Caption adapted from Astronomy Picture of the Day.)

Ring-shaped spiral galaxy AM 0644-741: How could a galaxy become



shaped like a ring? The rim of this galaxy is an immense ring-like structure 150,000 light years in diameter composed of newly formed, extremely bright, massive stars. That galaxy, AM 0644-741, is known as a ring galaxy and was caused by an immense galaxy collision. When galaxies collide, they pass through each other, their individual stars rarely coming into contact. The ring-like shape is the result of the gravitational disruption caused by a small intruder galaxy passing through a large one. When this happens, interstellar gas

and dust become condensed, causing a wave of star formation to move out from the impact point like a ripple across the surface of a pond. The intruder galaxy has since moved out of the picture. Ring galaxy AM 0644-741 lies about 300 million light years away. (Caption adapted from Astronomy Picture of the Day.)

Infrared image of Milky Way galaxy: You might expect that being a



resident of the Milky Way Galaxy, we Earthlings would be afforded the most splendid, front-row, VIP box seat view of our home spiral of stars. But the adage, "You can't see the forest for the trees," is no less true in the galactic sense. A galaxy is more than a group of stars: it

also contains all of the clouds of gas and dust that the stars form from. The spiral arms of the Milky Way form a murky barrier blocking visible light, and hiding the stars of the galaxy from view. But take a look with infrared eyes, and you will see much more. Infrared light is not as hampered by the absorbing effects of dust as visible light is; infrared emissions from stars and nebulae can pass straight through, providing a hidden image that we can sleuth out with infrared sensitive cameras. This picture is a mosaic of the sky in infrared, featuring the edge-on view of our spiral Milky Way galaxy.

Galaxy Hunter

Andromeda Galaxy: Andromeda is the nearest major galaxy to our own Milky Way Galaxy, about 2.3 million light years away in the constellation Andromeda. Our Galaxy is thought to look much like Andromeda. The diffuse light from Andromeda is caused by the hundreds of billions of stars that compose it. The several distinct stars that surround Andromeda's image are actually stars in our Galaxy that are well in front of the background object. (Caption adapted from Astronomy Picture of the Day.)



HCG 87: Posing for this cosmic family photo are the galaxies of HCG 87, about four hundred million light-years distant toward the constellation Capricorn. The large edge-on spiral, the fuzzy elliptical galaxy, and the spiral near the top are identified members of the group, while the small spiral galaxy in the middle is likely a more distant background galaxy. While not exactly locked in a group hug, the HCG 87 galaxies are interacting gravitationally, influencing their fellow group members' structure and



evolution. (Caption adapted from Astronomy Picture of the Day.)

Virgo Cluster of Galaxies: The Virgo Cluster of Galaxies is the closest cluster of galaxies to our Milky Way. The Virgo Cluster is so close that it spans more than 5 degrees on the sky—about 10 times the angle made by a full Moon. It contains over 100 galaxies of many types, including spiral, elliptical, and irregular galaxies. The Virgo Cluster is so massive that it is noticeably pulling our galaxy toward it. (Caption adapted from Astronomy Picture of the Day.)



Day.)

Galaxy Collider

Two galaxies collide: In NGC 1275, one galaxy is slicing through another. The disk of the dusty spiral galaxy near the image center is cutting through a large elliptical galaxy. Galaxies can change significantly during a collision like this, with gravitational tides distorting each galaxy and gas clouds being compressed and lighting up with new star formation. Galaxy collisions occur in slow motion to the human eye, with a single pass taking as much as 100 million years. NGC 1275 is a member of the Perseus cluster of galaxies that lies about 230 million light-years away toward the constellation of Perseus.



Each galaxy is about 50,000 light years across. (Caption adapted from Astronomy Picture of the Day.)

Stephan's Quintet: What are four closely grouped galaxies doing in this image? The grouping composes a majority of the large galaxies in Stephan's Quintet, with the fifth prominent galaxy located off the image to the lower right. Three of these four galaxies show nearly the same red shift, indicating that they reside at the same distance from us. These three galaxies are in the midst a titanic collision, each ripping the others apart with gravitational tidal forces. The large bluish spiral below and left of center is a foreground galaxy much closer than the others and hence not involved in the cosmic



battle. Most of Stephan's Quintet lies about 300 million light-years away towards the constellation of Pegasus. (Caption adapted from Astronomy Picture of the Day.)

Kaleidoscope

Cat's Eyes Nebula: Three thousand light-years away, a dying star throws off shells of glowing gas. This image reveals the Cat's Eye Nebula to be one of the most complex planetary nebulae known. In fact, the features seen in the Cat's Eye are so complex that astronomers suspect the bright central object may actually be a binary star system. (Caption adapted from Astronomy Picture of the Day.)



Whirlpool Galaxy: The Whirlpool Galaxy is a classic spiral galaxy. Only 30 million light years distant and fully 60 thousand light years across, the Whirlpool is one of the brightest and most picturesque galaxies in the sky. Anyone with a good pair of binoculars can see this Whirlpool toward the constellation of Canes Venatici.



Eagle Nebula: See the Pillars of Creation caption in the exhibit introduction.

Egg Nebula: The dramatic and mysterious-looking object revealed in this Hubble Space Telescope image is known as the Egg Nebula. It is an aging star about 3,000 light years away, entering its planetary nebula phase of evolution. Surrounded by an expanding cloud of gas and dust, a dense cocoon of dust (seen as the dark band running diagonally across the center) encloses the star itself and blocks it from direct view. The searchlight appearance is created as light from the star shines more easily through the thinner parts of the cocoon. Dust particles in the expanding cloud scatter and reflect the starlight making the beams visible. (Caption adapted from Astronomy Picture of the Day.)



Cruising Through the Universe

Stars in the Milky Way—NGC 3603: See caption for NGC 3603 in "What is a Star?"

Shell of gas blown off by a dying star: This image is Hubble's latest view of an expanding halo of light around a distant star, named V838 Monocerotis. The illumination of interstellar dust comes from the red supergiant star at the middle of the image, which gave off a flashbulb-like pulse of light two years ago. V838 Mon is located about 20,000 light-years away from Earth in the direction of the constellation Monoceros (the Unicorn), placing the star at the outer edge of our Milky Way galaxy. (Caption adapted from Hubblesite.org, Hubble Space Telescope.)



Helix Nebula: See caption in Exhibit Introduction.

Keyhole Nebula: The dark dusty Keyhole Nebula gets its name from its unusual shape. The Keyhole Nebula is a smaller region superposed on the larger Eta Carina Nebula. These nebulae were created by the dying star Eta Carina, which is prone to violent outbursts during its final centuries. Noted and discussed as early as 1840 when a spectacular explosion became visible, the Eta Carina system now appears to be undergoing an unusual period of change. An emission nebula that contains much dust, the Keyhole Nebula is roughly 9,000 light years distant.



Andromeda Galaxy, or M 31: See caption in Galaxy Hunter.

Two spiral galaxies, NGC 2207 and IC 2163: In the direction of the constellation Canis Major, about 114 million light years away, two spiral galaxies pass by each other in a near-collision like majestic ships in the night. Billions of years from now, only one of these two galaxies will remain. Until then, spiral galaxies NGC 2207 and IC 2163 will slowly pull each other apart, creating tides of matter, sheets of shocked gas, lanes of dark dust, bursts of star formation, and streams of cast-away stars. Astronomers predict that NGC 2207, the larger galaxy on the left, will eventually incorporate IC 2163, the smaller galaxy on the right. In the most recent encounter that peaked



40 million years ago, the smaller galaxy is swinging around counter-clockwise, and is now slightly behind the larger galaxy. The space between stars is so vast that when galaxies collide, the stars in them usually do not collide. (Caption adapted from Hubblesite.org, Hubble Space Telescope and Astronomy Picture of the Day.)

Hubble Ultradeep Field: What did the first galaxies look like? To help answer this question, the Hubble Space Telescope has just finished taking the Hubble Ultra Deep Field (HUDF), the deepest image of the universe ever taken in visible light. The HUDF shows a sampling of the oldest galaxies ever seen, galaxies that formed just after the dark ages, 13 billion years ago, when the Universe was only 5 percent of its present age. Staring nearly three months at the same spot, the HUDF is four times more sensitive, in some colors, than the original Hubble Deep Field. Astronomers the world over will likely



study the HUDF for years to come to better understand how stars and galaxies formed in the early universe. (Caption adapted from Astronomy Picture of the Day.)