

Cosmology in the High School Classroom? Are you crazy?

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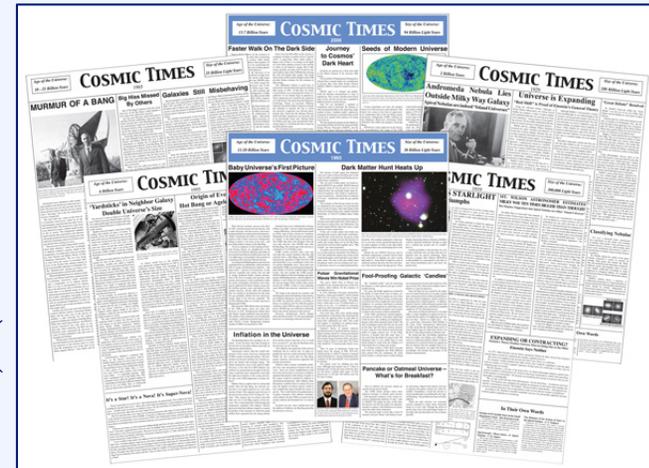
April 6, 2014

Outline

- What is Cosmic Times?
- A taste of Cosmic Times
 - 1955 – Big Bang versus Steady State
 - 1965 – Breaking the Stalemate
 - 1993 – Cosmology's End?
 - 2006 – Continuing Story
- Century Timeline

What is Cosmic Times? (

- Suite of curriculum support materials tracing our understanding of the expanding universe
- (Includes:
 - 6 posters resembling front page newspapers 1919 to 2006 (
 - 3 newsletter versions of (each poster, two at differentiated reading levels (
 - 4-5 lesson plans for each poster exploring fundamental science, social (context, and reading skills



You will receive the Cosmic Times posters and a DVD containing materials at the end of this workshop

Quick notes on 1929

- Edwin Hubble discovers:
 - Milky Way is but one of many galaxies
 - Universe is expanding

Age of the Universe:
2 Billion Years
COSMIC TIMES
Size of the Universe:
280 Million Light Years

1929

Andromeda Nebula Lies Outside Milky Way Galaxy

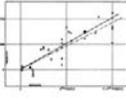
Spiral Nebulae are indeed "Island Universes"



Edwin Hubble found that the Andromeda nebula is an entire galaxy far beyond the Milky Way.

Universe is Expanding

"Red Shift" is Proof of Einstein's General Theory



Hubble's discovery that galaxies are moving away from us at a speed proportional to their distance is the first evidence of an expanding universe.

"Great Debate" Resolved

Hubble's discovery settles the "Great Debate" over the size of our own Milky Way Galaxy and the distance to, and nature of, spiral nebulae.

The Minds Atop Mount Wilson

The year 1929 was a landmark year for astronomy. It was the year that Edwin Hubble announced that the Andromeda Nebula is an entire galaxy far beyond the Milky Way. It was also the year that Hubble announced that the universe is expanding.

Fundamental science concepts: redshift, distance to galaxies, Cepheid variables (patterns in data)

1955 – Origin of the Universe

- Scientists debate: is the universe:
 - ageless and infinite?
 - finite, with hot “bang” beginning? (

Age of the Universe:
6 Billion Years
COSMIC TIMES
Size of the Universe:
4 Billion Light Years

'Yardsticks' in Neighbor Galaxy Double Universe's Size

The distance to the nearest galaxy, the Magellanic Clouds, has been estimated at 170,000 light years. This is a type of measuring yardstick that astronomers use to determine the size of the universe. The distance to the nearest galaxy, the Magellanic Clouds, has been estimated at 170,000 light years. This is a type of measuring yardstick that astronomers use to determine the size of the universe.

Origin of Everything: Hot Bang or Ageless Universe?

It will not be long before the origin of the universe will be a subject of debate. The origin of the universe will be a subject of debate. The origin of the universe will be a subject of debate.

Death of a Genius

Albert Einstein in 1955. The world has just lost its greatest scientific mind. Albert Einstein died in his sleep on April 18th from complications of a long-ago kidney ailment. He was 76 years old.

Hoyle Scoffs at "Big Bang" Universe Theory

British cosmologist Fred Hoyle has scoffed at the "big bang" theory. He has scoffed at the "big bang" theory. He has scoffed at the "big bang" theory.

Radio 'Ear' on the Universe Being Built

The MKA will be the first radio telescope to be built in the United States. It will be the first radio telescope to be built in the United States.

Gala...
Recent attempt
up a bit short, TV
NGC 3521 and 12
80 billion and 12
puzzle is why the
galaxies doesn't col
matter.
Baby Un

EXPA
Einstein's
1917. Albert Einstein and the Dutch astronomer Willem
theory of relativity could describe a black
it when it was annihilated.

Einstein Says Neither
...ing One or the Other

The further we look into the cosmos, the more we are puzzled by what physicists now wrestling with. Later researchers proposed a logical constant represents an...
...ing fudge
... real universe
...logical constant represents an...
...energy. That energy m...

Reading Strategies

Use one of the reading strategies to understand the CT article “Origin of Everything”

Reading Strategy: (Reciprocal Teaching (

- (Pair up
- (Both partners read the same paragraph (aloud or to yourselves)
- (One partner summarizes the paragraph for the other
- (The other partner “checks and perfects” – state what you agree with, question parts you don’t understand, add more information, connect ideas
- (Read the next paragraph and switch roles
- (Continue with each paragraph until you’ve read and understood the article

**Origin of Everything:
Hot Bang or Ageless Universe?**

Has the Universe always existed, or does it have a beginning, middle and an end? It's difficult to imagine a deeper mystery than this. However, this topic was recently discussed at the meeting of the National Academy of Sciences in Pasadena, California.

The case for an ageless, steady-state Universe was presented at the conference by astrophysicist Jesse L. Greenstein and physicist William A. Fowler of the California Institute of Technology. The steady-state theory says the Universe forever looks much like it does today; this "steady state" theory competes with the "evolutionary" theory of the Universe. The evolutionary theory claims an initial collection of hot particles exploded at the dawn of time. These particles formed all the Universe's hydrogen (and perhaps helium) in one gigantic event.

Both theories explain – in entirely different ways – the fact that the Universe is expanding. This expansion was first detected in 1914, when American astronomer Vesto Melvin Slipher surveyed some galaxies and noticed the light from all of them was "red-shifted." All light travels in waves. In the spectrum of visible light, red light has the longest wavelength. If an object (such as a galaxy) is giving off light and the object is moving away, that motion lengthens the wavelengths, causing the light to "red-shift." It's similar to how the sound of a retreating locomotive drops in pitch as it passes by you.

In the steady-state theory the expansion comes from the continuous bubbling up of the element hydrogen, from empty space at a rate of one particle every cubic meter every 300,000 years or so. This hydrogen eventually gathers and condenses into stars. Through nuclear fusions in their cores, stars make all the heavier elements (e.g. carbon, oxygen, silicon, iron, copper, etc.) from this hydrogen. As stars die, they scatter the heavier elements around the galaxies. These heavier elements mix with hydrogen, and new stars form with rocky planets around them – like our own Solar System. As evidence of that process, Greenstein and Fowler referred to the heavy-element-making red giant stars which can be seen today in our own galaxy.

An important point of the steady-state Universe is that it does change over time. Hoyle, the scientist who supports this theory, compares the deathless steady-state Universe to a river. It may appear unchanging, but there is plenty of movement and change under the surface. So, to borrow the old river saying, you can never step into the same Universe twice.

In contrast, there is the "evolutionary" theory of Russian-born American physicist George Gamow and his colleagues Ralph Alpher and Robert Herman. These scientists say the explosion and radioactive decay of a hot ball of neutrons at the birth of the Universe created all hydrogen and some helium. These elements formed as the blast expanded and cooled. The first stars were made of only this original hydrogen and helium. Those stars fused those original elements into new, heavier elements. These heavier elements were then scattered through the galaxies as the first stars died, and this led to the more complex mixtures of elements seen in stars now.

This evolutionary theory also explains why galaxies are moving away from each other: they are still in flight from the power of the initial blast. Newton's laws of motion help to explain this (an object in motion will remain in motion unless a force acts on it). There may be other direct evidence of the blast as well. Alpher and Herman have predicted that some faint left-over heat from that initial explosion may still exist in the form of stretched-out light waves called "microwaves" just a few degrees above absolute zero. However, no one has yet figured out a way to detect these left-over microwaves.

More evidence for the evolutionary Universe comes from Edwin Hubble's 1929 measurements of the speed of galaxies beyond our own. Hubble found that the farther away a galaxy is, the faster it appears to be moving away. This is exactly what would be expected if there was an ancient blast that started it all, and things have been moving away ever since.

The downside to an evolutionary Universe, of course, is that it doesn't end happily. There's no unlimited supply of hydrogen as in the steady-state theory. In the evolutionary Universe, the Universe might expand forever and will eventually run out of hydrogen; the stars eventually burn out, and the Universe cools down to a vast frozen graveyard of dead stars. Another possibility for the evolutionary Universe is that the gravity of all matter might eventually pull everything back together again in a gigantic collapse that rebounds, explodes, and starts the Universe all over – this is the endlessly exploding and collapsing Universe described by the late physicist Richard Tolman from CalTech.

Which theory is correct? Only more research with bigger and better telescopes will tell. •

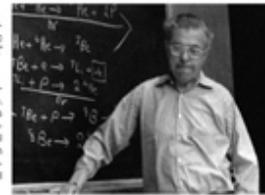
Hoyle Scoffs at "Big Bang" Universe Theory

British cosmologist Fred Hoyle has thrown down the gauntlet with regards to where and when all the Universe's elements were created. In a recent radio broadcast he criticized a competing theory, presented by Ukrainian-born American physicist George Gamow. He labeled Gamow's theory as a ridiculous "big bang."

Gamow's Evolutionary Theory of the Universe claims an initial stew of super-hot nuclear fusions of basic particles created all the hydrogen in the Universe in an explosive moment. The same blast caused space to expand. The ongoing expansion from that "big bang" is observed by astronomers today throughout cosmos.

Hoyle strongly disagrees with this theory. "It is an irrational process that cannot be described in scientific terms ... [not] challenged by an appeal to observation," he has written regarding Gamow's theory.

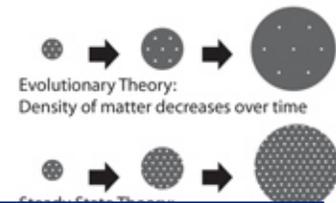
For one thing, the "big bang" requires something before the explosion. No one knows what that might be. If on the other hand, the Universe is eternal and stars are always being made and forever making heavier elements, as Hoyle suggests, there is no need for an initial explosion. Recent advances in nuclear physics seem to back Hoyle's "steady state" view, calling on the pressures and temperatures inside stars to manufacture all the heavy elements seen in the cosmos today. •



Fred Hoyle

Origin continued on bottom of page 4

Origin continued from page 3

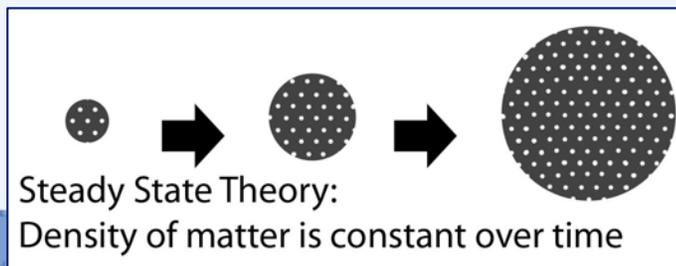


“Origin of Everything” article on pages 3-4
Do Paragraphs 2, 4, 5, 6, 7

Summarize the Article (

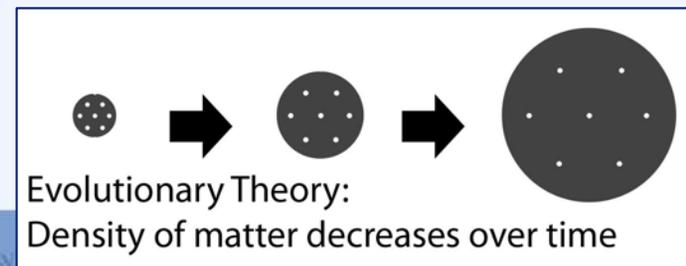
Steady State Universe

- (Unchanging situations need not be static
- (New matter can be created spontaneously as the universe expands (a few hundred atoms per year per galaxy)
- (The universe is constant in its overall density



Evolutionary Universe

- (Universe is expanding from a state of high density and pressure.
- (Hydrogen & Helium were formed as universe cooled.
- (There should be left over a background radiation with a temperature of ~ 5 Kelvin
- (Hoyle scoffed at this theory and coined the term "Big Bang"



The Evidence is Clear

Bowl of Evidence

Scientists sort through theories by examining evidence and making inferences

Steady State vs. Big Bang (

- Resolution of Steady State vs Big Bang won't come until the mid-to-late 1960s
- But as a competing theory, the Steady State provides the impetus to make observations to test the theories
- Note that this lesson can be adapted for **any** science topic where there are two (or more) competing theories

1955 – Origin of the Universe

- Scientists debate: is the universe:
 - ageless and infinite?
 - finite, with hot “bang” beginning?
- Both theories account for observations
- Deadlock!

Fundamental science concepts: nature of science, origin of the universe

Age of the Universe:
6 Billion Years

COSMIC TIMES

Size of the Universe:
4 Billion Light Years

'Yardsticks' in Neighbor Galaxy Double Universe's Size

The distance to the nearest galaxy beyond our own, the Magellanic Clouds, has been estimated to be 170 million light years. This is the distance to the nearest galaxy beyond our own, the Magellanic Clouds, has been estimated to be 170 million light years. This is the distance to the nearest galaxy beyond our own, the Magellanic Clouds, has been estimated to be 170 million light years.

Origin of Everything: Hot Bang or Ageless Universe?

It is still unclear to scientists whether the universe had a beginning or has always existed. The debate is between those who believe in a hot bang and those who believe in an ageless universe.

Death of a Genius

Albert Einstein's death in 1955 was a significant event in the history of science. His theory of relativity had revolutionized our understanding of the universe.

Hoyle Scoffs at 'Big Bang' Universe Theory

British cosmologist Fred Hoyle has scoffed at the 'big bang' theory of the origin of the universe. He believes in a steady state model where the universe has always existed.

Radio 'Ear' on the Universe Being Built

The Murchison Widefield Array (MWA) is a radio telescope array in Western Australia. It is designed to study the early universe and the formation of the first stars.

1965 – Breaking a Stalemate

- A hot “bang” should leave left-over heat
- Data and theory came together in 1965
 - Penzias and Wilson found a 3 K residual noise while making radio observations of the Milky Way
 - Peebles and Dicke (Princeton) had just calculated an estimate for the temperature of the residual background in the microwave region

Fundamental science concepts: spectra, electromagnetic spectrum, origin of the Universe

Age of the Universe:
10 - 25 Billion Years

COSMIC TIMES

1965

Size of the Universe:
25 Billion Light Years

MURMUR OF A BANG



One of the biggest surprises from the recent discovery of the Big Bang's faded thunder is how many other have been missed. Last year, Romanus Anisimov and his colleagues published a study that said the intense heat would now be between 1 and 10 degrees Kelvin. They even predicted searching for the signal in very temperate mountains near the Earth's surface in 1965. ...

Big Hiss Missed By Others

...the night astronomer of the new galaxy. ...

Galaxies Still Misbehaving

San Diego. Other researchers are finding some mismatches in galaxy evolution, and no one has offered a convincing explanation. ...

QUASARS: Express Trains To Netherworlds

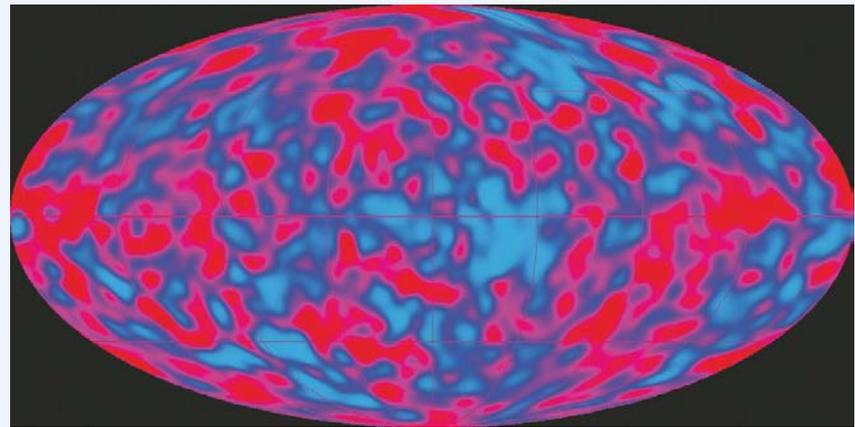
...the edge of the known universe. ...

SUPERNOVAE LEAVE BEHIND COSMIC X-RAY GENERATORS

...two years after discovering that the universe is made of X-rays, astronomers are starting to propose direct evidence with greater accuracy. ...

1993 – Cosmology's End? (

- By the mid-90s, cosmologists thought that they had only to “fill in the details”



- Remaining questions:
 - Will the expansion continue forever, or will universe eventually collapse back on itself?
 - What is the mass-density of the universe (which would answer the above)?

Brief diversion ...

- Things may not be what they seem
- When we see odd behavior, we look (more carefully at what's going on (

Not the End of Cosmology (

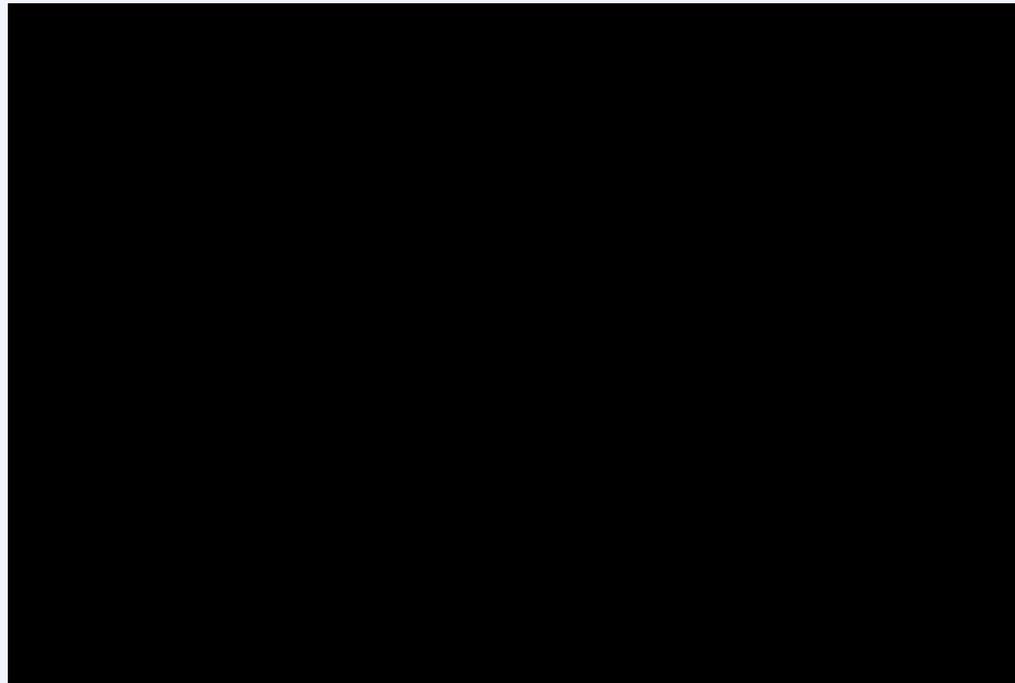
In 1997... (

- (Gravity is the longest-reaching force according to physics
- (So, the expansion of the universe should be slowing down...
- (By observing supernovae in distant galaxies, researchers determine that the expansion is **speeding up** ')



Cosmologists get **very** excited!

History of the Universe's Expansion (



Video clip from DVD *Beyond the Solar System: Expanding the Universe in the Classroom*, produced for NASA by the Harvard-Smithsonian Center for Astrophysics. © Smithsonian Institution

2006 – Cosmologists are busy

- Dark energy is well-established, having been detected in many ways
- Still, the nature of dark energy is largely a mystery
- Stay tuned to this continuing science story...

Fundamental science concepts: expanding universe, distances in the universe, supernovae, gravity

Age of the Universe:
13.7 Billion Years

COSMIC TIMES

2006

Size of the Universe:
94 Billion Light Years

Faster Walk On The Dark Side

There is thick evidence for the existence of dark energy, a peculiar energy that is boosting the expansion of the cosmos. Dark energy accounts for almost three-quarters of the universe. It appears to be accelerating the distance between galaxies and working against gravity, but its nature is still unknown.

The new evidence is the discovery of an effect dark energy has on photons of light from the earliest universe. This recent light began moving across the universe just 380,000 years after the Big Bang, and its initial energy has been shifted into the microwave part of the energy spectrum in the 13 billion years since.

The new observation, background CMB radiation. The detection of an effect on the CMB called Integrated Sachs-Wolfe (ISW) confirms the dark energy but an additional reflection on those photons.

ISW was named after Brian Kurt Sachs and Arthur Michael Wolfe, who first developed it in 1967. But its influence on the CMB was only verified by an international collaboration of researchers, including Harvard's Clifford C. Colla and Robert Critchfield (University of Pennsylvania) Charles Thorn's NASA WMAP team, and a collaboration of astronomers from the Sloan Digital Sky Survey and the Institute of Astrophysics at Paris.

This confirmation leads to new effects on light together a massive source of data on the large-scale structure of the universe and will help light the way for new observations. This new light observations have visible light, in x-ray, radio and microwave wavelengths.

Journey to Cosmos' Dark Heart

Scientists are gearing up to shed some light on the darkest mystery in the universe: dark energy.

NASA's Alpha Centauri Department of Energy has selected three concept studies for consideration to become their first Dark Energy Mission (DEM). DEM is slated to launch as early as 2011.

DEM's goal is to observe and double-check the distance measurements to Type Ia supernovae. This is to help reveal critical clues to how fast the universe has expanded at different points in cosmic history.

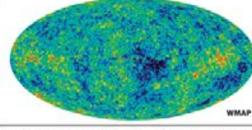
Type Ia's are considered a standard or comparison yardstick to determine the distance to other astronomical objects. By observing a large number of these "standard candles" of supernovae in galaxies far and near, researchers hope to find out just how quickly these galaxies are flying away from us.

The three proposed concept studies are: SuperNova Acceleration Probe (SNAP), the Advanced Dark Energy Physics Telescope (ADEPT), and the Dark Energy Space Telescope (DESTINY). Each would look at the supernovae in a different way.

SNAP would use a 1.6-meter optical-infrared telescope with a CCD charge-coupled device light detector that is free of optical artifacts, with a billion pixels. SNAP's detector has an area of 1.6 square meters. It would be able to see about 10,000 Type Ia supernovae in each year over a wide range of distances—about 100 times more supernovae than are now detected each year.

ADEPT would use a 1.6-meter near-infrared telescope to detect 10,000 Type Ia supernovae over two years. It would spend an additional year observing, in detail, 1,000 square degrees of sky. This would gather new findings on changes in the large-scale distribution of matter in the cosmos over the Big Bang. Both phases of DESTINY's mission would monitor the variability of similar ground-based observations by a factor of about 10.

Seeds of Modern Universe



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Biggest Mystery: What is Dark Energy?

The farther we look into the universe, the more puzzled we get. That's the expansion of the universe and predictions regarding that the universe has the problem of dark energy. This unknown force causes the universe to expand, and it is a profound mystery.

There are several theories being proposed to explain dark energy, but for now, nothing clear has been very far to do. The key will be to create a new generation of scientific instruments to search deeper into the cosmos.

In the recent the only way to talk about dark energy is to say what we know it does. It causes more space, new space, pushing galaxies farther apart and making the entire universe expand at an increasing rate. In the 1990s showed us that accelerating expansion in the 1990s showed us that accelerating expansion.

Initially, there was one big hint that dark energy existed from before measurements found evidence of it. Now other than the great Albert Einstein had theorized an "anti-gravity" effect, which he called the "cosmological constant," scientists today of general relativity to make a work with the universe that has been observed.

and constant an expanding fabric factor, without any connection to the real universe.

Latest research predicted that the statistical content represents an underlying background energy. This energy might cause some kind of pressure on the cosmos. Unfortunately, the theory predicts that the energy might be in 100 orders of magnitude stronger than dark energy appears to be.

Another strong candidate for dark energy is something called quintessence. The word is the same as the ancient Greek term for a mysterious fifth element—beyond earth, air, fire and water—which was used to describe the ether. In the cosmological context, the modern theory of quintessence holds that it is some kind of energy field that pushes particles apart. It is called the energy field that is called quintessence, which is thought that dark energy has only been in the universe for the last 5 billion years, so in effect it is new.

Scientists would like to learn much more about dark energy's impact on the universe to do this.

'First Light' Wins Nobel



As the 2006 Nobel Prize in Physics, it was presented for their 1992 discovery about the cosmic microwave background (CMB) in light from the beginning of the universe as we see it today.

According to the Nobel Prize, "These two scientists also marked the beginning of modern cosmology as a physical science."

Using data from the satellite Cosmic Background Explorer (COBE), a team led by Mather and Boslward found the details of how the universe has cooled. They measured the spectrum of light from the background and found that it matched predictions from the Big Bang theory perfectly. They also found the tiny variations in the CMB that are the seeds of galaxies and other structures in the universe. It was difficult to account for the present structure of the universe, say cosmologists. Later experiments reflected the COBE data, but the best of the discovery comes from the mission.

Sorting Out The Dark Stuff

Dark matter is the universe's "missing mass." It does not appear to interact with normal matter, other than to tug on it with gravity. Dark matter was first proposed in the 1930s by astronomers who discovered that the amount of visible matter known to exist in galaxies wasn't enough to account for the measured gravitational effects. Dark matter is estimated to make up about a third of all particles that interact gravitationally with both stars and light.

Dark energy is on the other hand, is a strange animal. It reveals itself only by slowing everything down. This peculiar energy is thought to account for about 70 percent of the universe's energy content.

The more abundant matter in the universe—dark matter—tugs on both stars and light. It makes up just 23 percent of the universe. This is dwarfed by the most plentiful energy of all, dark energy, which is 73 percent of the universe. While both are mysterious, both have been detected.

Adopt SNAP, DESTINY



Scientists are gearing up to shed some light on the darkest mystery in the universe: dark energy.

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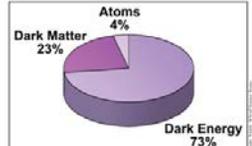
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Atoms 4%

Dark Matter 23%

Dark Energy 73%



What you would see if the universe's content includes 4% atoms, including billions of stars and planets, that make up only 4% of the universe. The rest is dark matter, and dark energy. Dark matter is a mysterious substance that makes up 23% of the universe, composed of "dark energy." Dark matter is a mysterious substance that makes up 23% of the universe, composed of "dark energy." Dark matter is a mysterious substance that makes up 23% of the universe, composed of "dark energy."

Age of the Universe: 13.7 Billion Years

Size of the Universe: 94 Billion Light Years

It is now 2014...

- What is our view of the universe? (
 - Finite
 - Changing
 - 13.7 billion years old

Century Timeline

Compare the Cosmic Times timeline with events in:

- * Other Science
- * Arts/Entertainment/Culture
- * World History/Politics

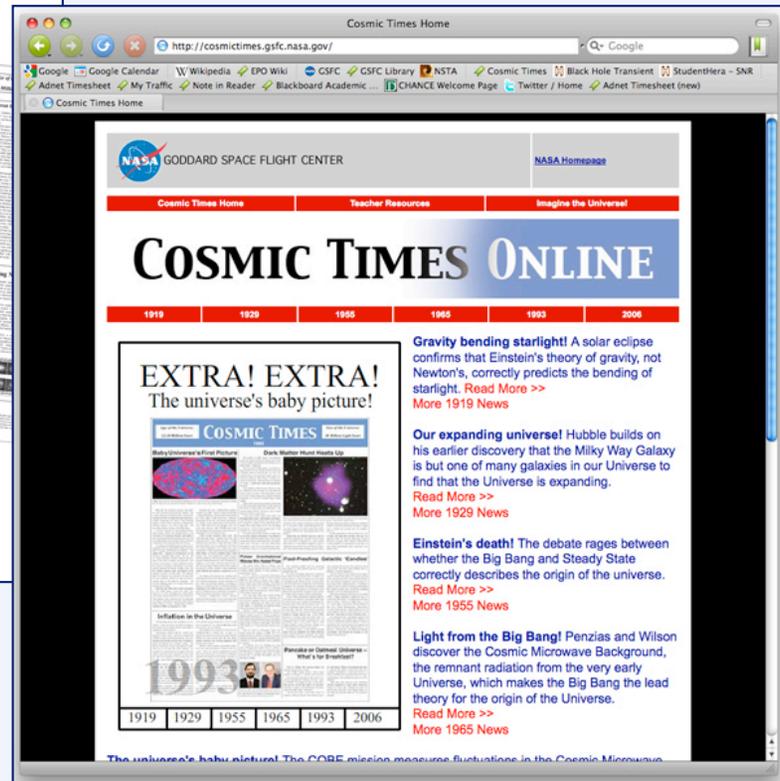
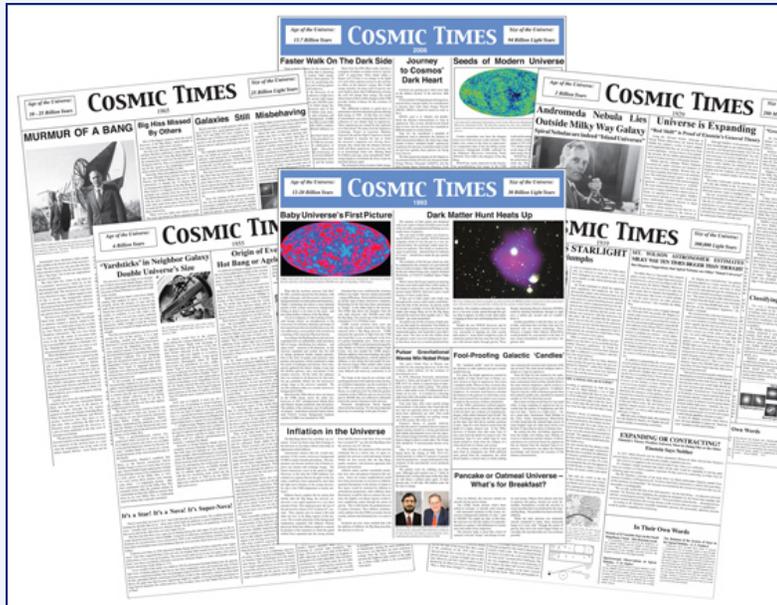
Opportunities for cross-disciplinary collaboration

Cosmic Times Timeline (

- (1912 - Henrietta Leavitt determines Cepheid Period-Luminosity relationship
- 1916 - Einstein's Theory of Gravity
- 1929 - Hubble's Law
- 1934 - "Super-nova" identified by Baade & Zwicky
- 1949 - Alpher & Gamow discuss nucleosynthesis
- 1952 - Baade recalibrates Cepheid P-L relationship
- 1965 - Penzias & Wilson discover CMB
- 1970 - Vera Rubin makes case for Dark Matter
- 1981 - Guth proposes Cosmic Inflation
- 1993 - COBE measures anisotropies in CMB
- 1998 - Dark Energy discovered
- 2003 - WMAP refines anisotropies in CMB

Cosmic Times (

Posters, Newsletters, Teacher's Resources, Lessons & Online-Edition all on our website: <http://cosmictimes.gsfc.nasa.gov/>



MURMUR OF A BANG

Andromeda Nebula Lies Outside Milky Way Galaxy

Spiral Nebulae are indeed "Island Universes"

SUN'S GRAVITY BENDS STARS

Einstein's Theory Triumphs

Radio 'Ear' on the Universe Being Built

Seeds of Modern Universe



Galaxies Still Misbehaving

Recent attempts to weigh galaxies still come up a bit short. Two spiral galaxies under study, NGC 3521 and NGC 972, have weighed in at 80 billion and 12 billion suns, respectively. The puzzle is why the amount of starlight from these galaxies doesn't add up to such huge amounts of matter.

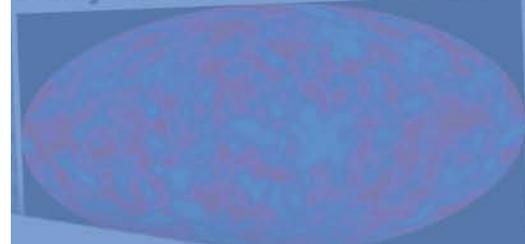
Dark Matter Hunt Heats Up

The mystery of dark matter just deepened with a new report of about 20 trillion suns-worth of invisible, unexplained stuff hiding out in a galaxy.

Classifying Nebulae

For over a thousand years, astronomers debated on the nature and evolution of faint clouds of gas and dust in the universe. However, until recently, there were insufficient observations to settle the matter.

Baby Universe's First Picture



'Yardsticks' in Neighbor Galaxy Double Universe's Size

The universe is twice as large as we thought says Caltech astronomer Walter Baade, who has now employed the giant 200-inch glass reflecting telescope at Mount Palomar to confirm the scale of the cosmos.

Baade's discovery hasn't come from simply finding mile markers in space, of course. Properly divine the distance of stars in the universe first he had to discover that there has created more than one kind of yardstick.

Biggest Mystery: What is Dark Energy?

The further we look into the cosmos, the more puzzled we are. That's the experience of cosmologists now wrestling with the unknown.

cal constant an annoying fudge factor with any connection to the real universe. Later researchers proposed a cosmological constant represents an unknown energy. That energy n... the cosm...

EXPANDING OR CONTRACTING? Einstein's Theory Predicts Universe Must be Doing One or the Other

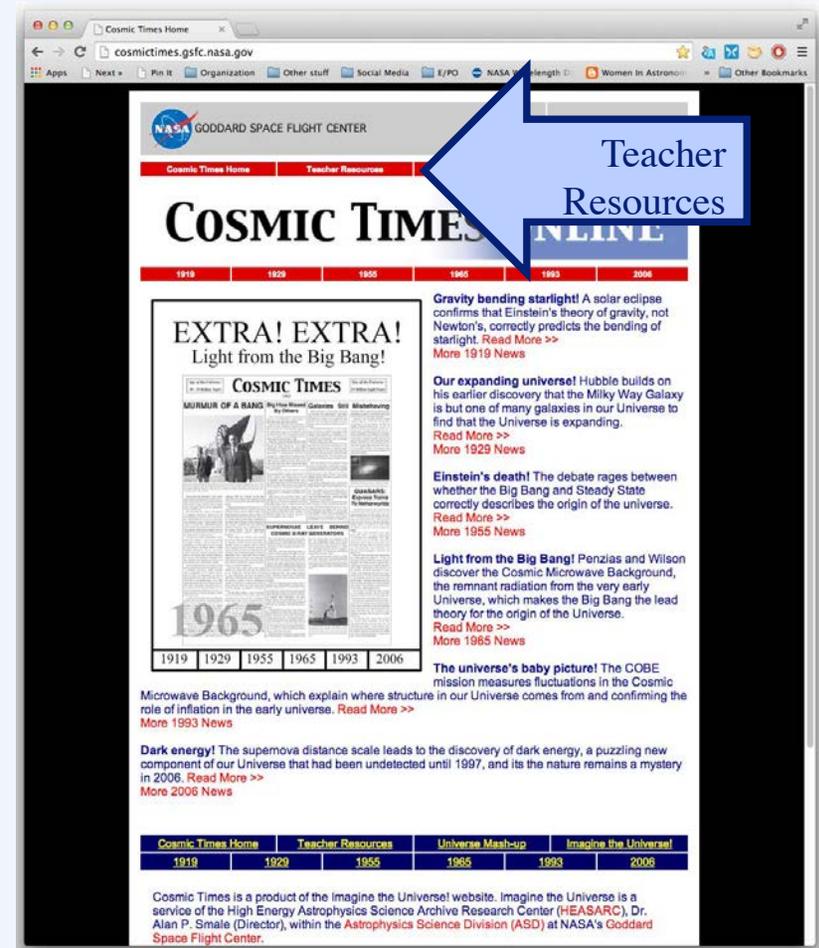
Einstein Says Neither

In 1917, Albert Einstein and the Dutch astronomer Willem de Sitter showed that his theory of relativity could describe a universe that was either expanding or contracting. It was not until 1929 that Edwin Hubble discovered that the universe was indeed expanding.

Classroom Resources: (

A Brief Tour (

- A variety of tools are available to help you navigate Cosmic Times and find the right resources for your classroom



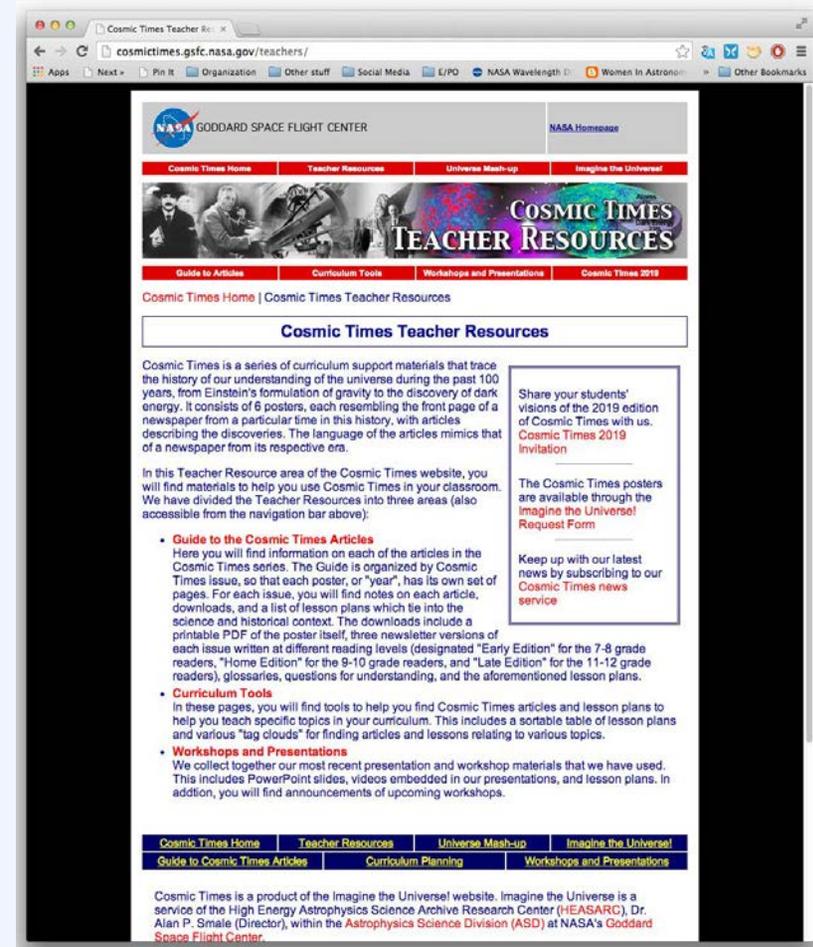
The screenshot shows the Cosmic Times Online website interface. At the top, there is a navigation bar with the NASA logo and 'GODDARD SPACE FLIGHT CENTER'. Below this, there are two main tabs: 'Cosmic Times Home' and 'Teacher Resources'. The 'Teacher Resources' tab is highlighted with a blue arrow pointing to it from the right. The main content area features a large headline 'EXTRA! EXTRA! Light from the Big Bang!' and a central image of a newspaper page from 1965. To the right of the image, there are several news snippets with 'Read More >>' links. At the bottom, there is a table with columns for years (1919, 1929, 1955, 1965, 1993, 2006) and a footer with contact information for the High Energy Astrophysics Science Archive Research Center (HEASARC).

Cosmic Times Home	Teacher Resources	Universe Mash-up	Imagine the Universe!		
1919	1929	1955	1965	1993	2006

Classroom Resources: (

A Brief Tour (

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The screenshot shows the Cosmic Times Teacher Resources website. The page features a navigation bar with links for "Cosmic Times Home", "Teacher Resources", "Universe Mash-up", and "Imagine the Universe!". Below the navigation bar is a large banner for "COSMIC TIMES TEACHER RESOURCES" with a sub-navigation bar for "Guide to Articles", "Curriculum Tools", "Workshops and Presentations", and "Cosmic Times 2019". The main content area is titled "Cosmic Times Teacher Resources" and contains a detailed introduction to the series, a list of resources, and a sidebar with a "Share your students' visions of the 2019 edition of Cosmic Times with us. Cosmic Times 2019 Invitation" form. The footer includes a table with links to "Cosmic Times Home", "Teacher Resources", "Universe Mash-up", "Imagine the Universe!", "Guide to Cosmic Times Articles", "Curriculum Planning", and "Workshops and Presentations".

Cosmic Times is a series of curriculum support materials that trace the history of our understanding of the universe during the past 100 years, from Einstein's formulation of gravity to the discovery of dark energy. It consists of 6 posters, each resembling the front page of a newspaper from a particular time in this history, with articles describing the discoveries. The language of the articles mimics that of a newspaper from its respective era.

In this Teacher Resource area of the Cosmic Times website, you will find materials to help you use Cosmic Times in your classroom. We have divided the Teacher Resources into three areas (also accessible from the navigation bar above):

- **Guide to the Cosmic Times Articles**
Here you will find information on each of the articles in the Cosmic Times series. The Guide is organized by Cosmic Times issue, so that each poster, or "year", has its own set of pages. For each issue, you will find notes on each article, downloads, and a list of lesson plans which tie into the science and historical context. The downloads include a printable PDF of the poster itself, three newsletter versions of each issue written at different reading levels (designated "Early Edition" for the 7-8 grade readers, "Home Edition" for the 9-10 grade readers, and "Late Edition" for the 11-12 grade readers), glossaries, questions for understanding, and the aforementioned lesson plans.
- **Curriculum Tools**
In these pages, you will find tools to help you find Cosmic Times articles and lesson plans to help you teach specific topics in your curriculum. This includes a sortable table of lesson plans and various "tag clouds" for finding articles and lessons relating to various topics.
- **Workshops and Presentations**
We collect together our most recent presentation and workshop materials that we have used. This includes PowerPoint slides, videos embedded in our presentations, and lesson plans. In addition, you will find announcements of upcoming workshops.

Share your students' visions of the 2019 edition of Cosmic Times with us. Cosmic Times 2019 Invitation

The Cosmic Times posters are available through the Imagine the Universe! Request Form

Keep up with our latest news by subscribing to our Cosmic Times news service

Cosmic Times Home	Teacher Resources	Universe Mash-up	Imagine the Universe!
Guide to Cosmic Times Articles	Curriculum Planning	Workshops and Presentations	

Cosmic Times is a product of the Imagine the Universe! website. Imagine the Universe! is a service of the High Energy Astrophysics Science Archive Research Center (HEASARC), Dr. Alan P. Smale (Director), within the Astrophysics Science Division (ASD) at NASA's Goddard Space Flight Center.

Classroom Resources: (

Guide to the Articles (



The screenshot shows the Cosmic Times Teacher Resources page on the NASA website. The page features a navigation bar with links for 'Cosmic Times Home', 'Teacher Resources', 'Universe Mash-up', and 'Imagine the Universe!'. Below the navigation bar is a banner for 'COSMIC TIMES TEACHER RESOURCES' with sub-links for 'Guide to Articles', 'Curriculum Tools', 'Workshops and Presentations', and 'Cosmic Times 2019'. The main content area is titled 'Cosmic Times Teacher Resources' and contains an introductory paragraph, a list of resources, and a footer. A blue arrow points to the 'Guide to the Articles' link in the navigation bar.

Cosmic Times Teacher Resources

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Share your students' visions of the 2019 edition of Cosmic Times with us.
[Cosmic Times 2019 Invitation](#)

The Cosmic Times posters
[View the posters](#)

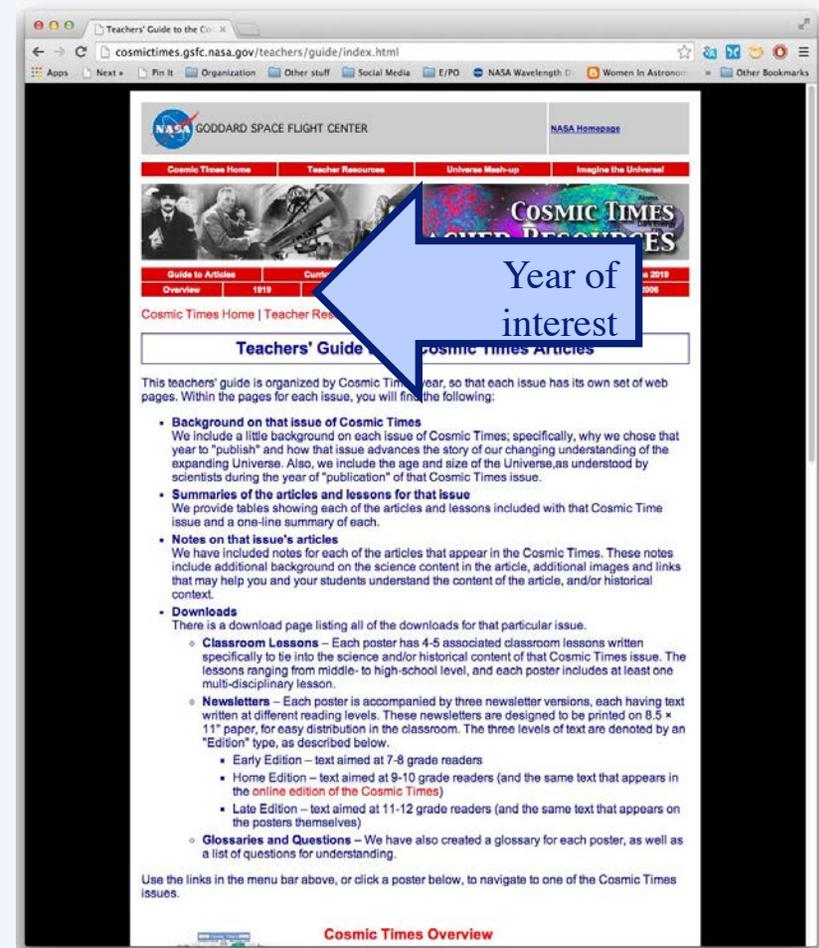
Service
[View the service](#)

Footer:
Cosmic Times is a product of the Imagine the Universe! website. Imagine the Universe! is a service of the High Energy Astrophysics Science Archive Research Center (HEASARC), Dr. Alan P. Smale (Director), within the Astrophysics Science Division (ASD) at NASA's Goddard Space Flight Center.

Classroom Resources: (

Guide to the Articles (

- (Here you will find further information organized by year/issue of Cosmic Times



The screenshot shows the NASA Cosmic Times Teachers' Guide website. The page is titled "Teachers' Guide to the Cosmic Times" and is organized by year/issue. A blue arrow points to the "Year of interest" dropdown menu, which is currently set to "2019". The page content includes a "Background on that issue of Cosmic Times" section, "Summaries of the articles and lessons for that issue", "Notes on that issue's articles", and "Downloads". The "Downloads" section lists "Classroom Lessons", "Newsletters", and "Glossaries and Questions".

Teachers' Guide to the Cosmic Times

This teachers' guide is organized by Cosmic Times year, so that each issue has its own set of web pages. Within the pages for each issue, you will find the following:

- **Background on that issue of Cosmic Times**
We include a little background on each issue of Cosmic Times; specifically, why we chose that year to "publish" and how that issue advances the story of our changing understanding of the expanding Universe. Also, we include the age and size of the Universe, as understood by scientists during the year of "publication" of that Cosmic Times issue.
- **Summaries of the articles and lessons for that issue**
We provide tables showing each of the articles and lessons included with that Cosmic Time issue and a one-line summary of each.
- **Notes on that issue's articles**
We have included notes for each of the articles that appear in the Cosmic Times. These notes include additional background on the science content in the article, additional images and links that may help you and your students understand the content of the article, and/or historical context.
- **Downloads**
There is a download page listing all of the downloads for that particular issue.
 - **Classroom Lessons** – Each poster has 4-5 associated classroom lessons written specifically to tie into the science and/or historical content of that Cosmic Times issue. The lessons range from middle- to high-school level, and each poster includes at least one multi-disciplinary lesson.
 - **Newsletters** – Each poster is accompanied by three newsletter versions, each having text written at different reading levels. These newsletters are designed to be printed on 8.5 × 11" paper, for easy distribution in the classroom. The three levels of text are denoted by an "Edition" type, as described below.
 - **Early Edition** – text aimed at 7-8 grade readers
 - **Home Edition** – text aimed at 9-10 grade readers (and the same text that appears in the [online edition of the Cosmic Times](#))
 - **Late Edition** – text aimed at 11-12 grade readers (and the same text that appears on the posters themselves)
 - **Glossaries and Questions** – We have also created a glossary for each poster, as well as a list of questions for understanding.

Use the links in the menu bar above, or click a poster below, to navigate to one of the Cosmic Times issues.

Cosmic Times Overview

Classroom Resources: (

Guide to the Articles (

- (Here you will find further information organized by year/issue of Cosmic Times

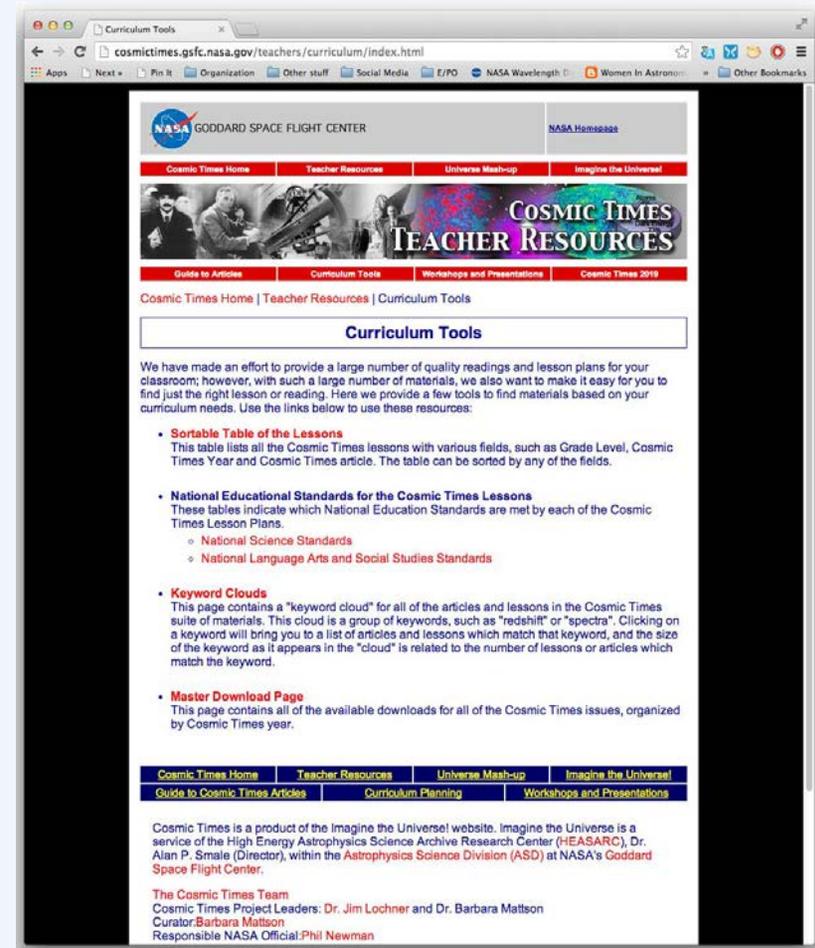
- Downloads
 - Poster
 - Newsletters
 - Glossary
 - Questions for understanding
- Additional information (about each article (
- Classroom lesson plans

The screenshot shows the NASA Cosmic Times Teacher Resources website for the year 1919. The page is titled "1919 Cosmic Times" and features a navigation menu with links to "Cosmic Times Home", "Teacher Resources", "Universe Mash-up", and "Imagine the Universe!". Below the navigation menu is a banner for "COSMIC TIMES TEACHER RESOURCES" with a sub-menu for "Guide to Articles", "Curriculum Tools", "Workshops and Presentations", and "Cosmic Times 2018". The main content area includes a "1919 Cosmic Times" section with a description of the first edition of the Cosmic Times, a list of available resources (Download 1919 poster, newsletters, and glossary; Teacher's Guide to the 1919 articles; 1919 Lessons), and a "Request Form" for posters. Below this is a "1919 Article Overview" section with a table of articles.

Article	Thread	Summary
Sun's Gravity Bends Starlight	Expanding Universe	Observations of stars near the Sun during the eclipse of 1919 show that the starlight bends just as predicted by General Relativity.
Sidebar: Why a Total Eclipse?	--	Describes why observers needed a solar eclipse to make observations of starlight bending around the Sun.
Mount Wilson Astronomer Estimates Milky Way Ten Times Bigger Than Thought	Size of the Universe	Astronomer Harlow Shapely finds that the Milky Way is 10 times bigger than previous measurements, using the period-luminosity relationship for Cepheid variables as discovered by Henrietta Leavitt.
Expanding or Contracting?	Expanding Universe	Einstein's theory of General Relativity predicts that the Universe cannot be static – it must be expanding or contracting. Einstein adds the "Cosmological Constant" to keep the Universe static.
In Their Own Words	--	Snippets of papers published by other astronomers during this time. The snippets highlight the Cepheid period-luminosity relationship, redshift of galaxies, and the nature of spiral nebulae.

Classroom Resources: (Curriculum Tools (

- (Here you will find tools to help you find the right lessons and articles for your curriculum needs



The screenshot shows a web browser window displaying the 'Curriculum Tools' page from the Cosmic Times Teacher Resources website. The page is titled 'Curriculum Tools' and is part of the 'Cosmic Times Teacher Resources' section. It features a navigation bar with links to 'Cosmic Times Home', 'Teacher Resources', 'Universe Mash-up', and 'Imagine the Universe!'. Below the navigation bar is a banner for 'COSMIC TIMES TEACHER RESOURCES' with a sub-menu for 'Guide to Articles', 'Curriculum Tools', 'Workshops and Presentations', and 'Cosmic Times 2019'. The main content area is titled 'Curriculum Tools' and contains a list of resources:

- Sortable Table of the Lessons**: This table lists all the Cosmic Times lessons with various fields, such as Grade Level, Cosmic Times Year and Cosmic Times article. The table can be sorted by any of the fields.
- National Educational Standards for the Cosmic Times Lessons**: These tables indicate which National Education Standards are met by each of the Cosmic Times Lesson Plans.
 - National Science Standards
 - National Language Arts and Social Studies Standards
- Keyword Clouds**: This page contains a "keyword cloud" for all of the articles and lessons in the Cosmic Times suite of materials. This cloud is a group of keywords, such as "redshift" or "spectra". Clicking on a keyword will bring you to a list of articles and lessons which match that keyword, and the size of the keyword as it appears in the "cloud" is related to the number of lessons or articles which match the keyword.
- Master Download Page**: This page contains all of the available downloads for all of the Cosmic Times issues, organized by Cosmic Times year.

At the bottom of the page, there is a footer section with a navigation bar and contact information for the Cosmic Times Team, including project leaders Dr. Jim Lochner and Dr. Barbara Mattson, and the responsible NASA official, Phil Newman.

Classroom Resources: (Curriculum Tools (

- (Here you will find tools to help you find the right lessons and articles for your curriculum needs
 - Sortable list of lessons

Cosmic Times Lesson Plans

The table below lists all the Cosmic Times lessons. "Year" and "Article" indicate which Cosmic Times issue and article(s) the lesson goes with. Some lessons may be used for both middle school (MS) and high school (HS) classes. The lesson titles are linked to descriptions and downloads of the lessons.

Clicking on a column heading will sort the table alphabetically according to that column. Clicking the same column again will reverse the order.

Year	Lesson Title	Summary	Level	Article	Discipline
All/Any	Cosmic Times Jigsaw	Students work in teams to see the big picture of about how scientists have come to know what they do about the Universe using articles from the Cosmic Times posters.	MS,HS	All	Multidisciplinary
All/Any	Cosmic Times Gallery Walk	Students spend a few minutes at each Cosmic Times poster to answer an open-ended question about the information on that poster.	MS,HS	All	Multidisciplinary
2006	Tools of the Trade	Students explore the telescopes and technologies that will shape our understanding of the Universe in the coming years.	HS	Journey to Cosmos' Dark Heart	Physics, Astronomy
2006	Century Timeline	Students create a timeline of world events from 1905 through 2006, the years encompassed by the Cosmic Times posters, to get a sense of the history surrounding the discoveries over the past century.	MS,HS	All	Multidisciplinary
2006	Things Are Not What They Seem	Students explore a discrepant event by designing experiments to test what makes a "come back can" return or UV beads change color.	MS,HS	Sorting Out the Dark Stuff	Physics, Astronomy
2006	Measuring Dark Energy	Students simulate an experiment in which the discovery of dark energy can be made by plotting modern supernova distances on a Hubble Diagram.	HS	Faster Walk on the Dark Side	Physics, Astronomy

Classroom Resources: (Curriculum Tools (

- (Here you will find tools to help you find the right lessons and articles for your curriculum needs
 - Sortable list of lessons
 - National Education Standards for each lesson

The screenshot shows the 'Cosmic Times Teacher Resources' page. It features a navigation bar with links to 'Cosmic Times Home', 'Teacher Resources', 'Universe Mash-up', and 'Imagine the Universe!'. Below the navigation is a banner for 'COSMIC TIMES TEACHER RESOURCES' with sub-links for 'Guide to Articles', 'Curriculum Tools', 'Workshops and Presentations', and 'Cosmic Times 2019'. The main content area is titled 'Cosmic Times Lesson Plans National Science Educational Standards'. It includes a table showing the alignment of lesson plans with National Science Education Standards (NS-5-8.1 through NS-9-12.7). The table is titled '1919 Lesson Plans' and lists lessons such as 'Einstein and His Times', 'Eclipses and Moon Phases', 'Two Versions of Gravity: Newton and Einstein', and 'Einstein's Gravity'.

	National Science Standards for Grades 5-8					National Science Standards for Grades 9-12				
	NS-5-8.1	NS-5-8.2	NS-5-8.4	NS-5-8.5	NS-5-8.7	NS-9-12.1	NS-9-12.2	NS-9-12.4	NS-9-12.5	NS-9-12.7
Einstein and His Times										
Eclipses and Moon Phases	X		X							
Two Versions of Gravity: Newton and Einstein						X	X	X		X
Einstein's Gravity						X	X	X		X

Classroom Resources: (Curriculum Tools (

- (Here you will find tools to help you find the right lessons and articles for your curriculum needs

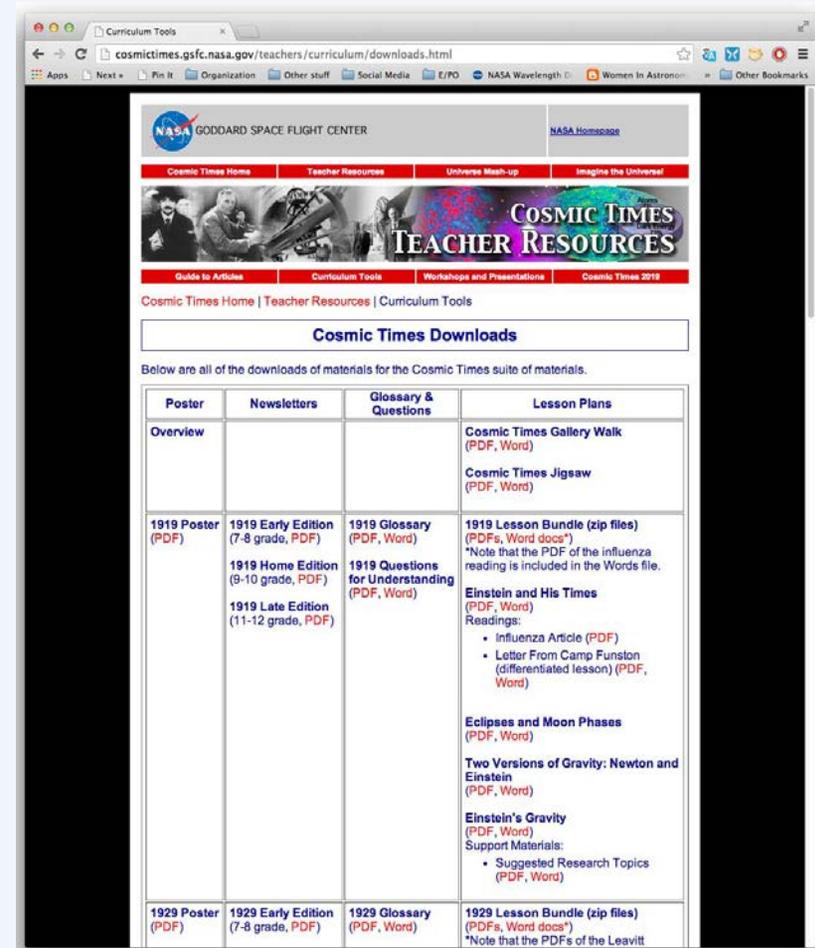
- Sortable list of lessons
- National Education Standards for each lesson
- Keyword clouds

The screenshot displays the Cosmic Times Keyword Clouds website. At the top, there's a NASA logo and the text 'GODDARD SPACE FLIGHT CENTER'. Below that, there are navigation tabs: 'Cosmic Times Home', 'Teacher Resources', 'Universe Mash-up', and 'Imagine the Universe!'. The main heading is 'Cosmic Times Keyword Cloud'. Below this, there's a paragraph explaining that the cloud is a visualization of keywords associated with Cosmic Times articles and lesson plans. The size of each tag is related to the number of lessons and/or articles associated with that keyword. A callout box on the right points to the cloud with the text 'Click a keyword'. Another callout box on the left points to a list of articles and lessons related to 'cepheid variable stars' with the text 'See related articles and lessons'. The list includes articles like '1919 In Their Own Words' and 'Andromeda Nebula Lies Outside Milky Way Galaxy', and lessons like 'Discovering the Milky Way' and 'Just How Far is that Star?'.

Classroom Resources: (Curriculum Tools (

- (Here you will find tools to help you find the right lessons and articles for your curriculum needs

- Sortable list of lessons
- National Education Standards for each lesson
- Keyword clouds
- Master download page



The screenshot shows a web browser window displaying the Cosmic Times Teacher Resources page. The page features a navigation bar with links to Cosmic Times Home, Teacher Resources, Universe Mash-up, and Imagine the Universe!. Below the navigation bar is a banner for Cosmic Times Teacher Resources. The main content area is titled "Cosmic Times Downloads" and lists various materials for download. The materials are organized into a table with four columns: Poster, Newsletters, Glossary & Questions, and Lesson Plans. The table lists materials for 1919 and 1929, including posters, newsletters, glossaries, and lesson bundles.

Poster	Newsletters	Glossary & Questions	Lesson Plans
Overview			Cosmic Times Gallery Walk (PDF, Word) Cosmic Times Jigsaw (PDF, Word)
1919 Poster (PDF)	1919 Early Edition (7-8 grade, PDF) 1919 Home Edition (9-10 grade, PDF) 1919 Late Edition (11-12 grade, PDF)	1919 Glossary (PDF, Word) 1919 Questions for Understanding (PDF, Word)	1919 Lesson Bundle (zip files) (PDFs, Word docs) *Note that the PDF of the influenza reading is included in the Words file. Einstein and His Times (PDF, Word) Readings: <ul style="list-style-type: none">Influenza Article (PDF)Letter From Camp Funston (differentiated lesson) (PDF, Word) Eclipses and Moon Phases (PDF, Word) Two Versions of Gravity: Newton and Einstein (PDF, Word) Einstein's Gravity (PDF, Word) Support Materials: <ul style="list-style-type: none">Suggested Research Topics (PDF, Word)
1929 Poster (PDF)	1929 Early Edition (7-8 grade, PDF)	1929 Glossary (PDF, Word)	1929 Lesson Bundle (zip files) (PDFs, Word docs) *Note that the PDFs of the Leavitt

2019 Cosmic Times (

- (In the capstone lesson plan, students are asked to look to the future
- (Students speculate what we will know on the 100th anniversary of the Cosmic Times, what technology we will have, and what questions are still unanswered
- (We're inviting submissions for a possible "student gallery" of 2019 Cosmic Times creations
- (See the website for more

The screenshot shows the NASA Cosmic Times 2019 Teacher Resources website. At the top, there is a NASA logo and the text "GODDARD SPACE FLIGHT CENTER" and "NASA Homepage". Below this is a navigation bar with three red buttons: "Cosmic Times Home", "Online Edition", and "Imagine the Universe". The main content area features a large banner with the text "COSMIC TIMES 2019" and "TEACHER RESOURCES" over a background image of scientists and a telescope. Below the banner is another navigation bar with four red buttons: "Guide to Articles", "Curriculum Tools", "Workshops and Presentations", and "Cosmic Times 2019". The main text area contains the following information:

Cosmic Times 2019

Share your students' visions of the 2019 issue of Cosmic Times with us!

Do your students have a version of the 2019 issue of Cosmic Times? How much closer will we be to solving the mysteries of dark energy and the nature of the universe? What tools will we have then that we don't have now?

We want to know what your students envision for the next steps in understanding the nature of our universe. After all, they are the next generation of scientists and engineers who will be working on these questions. We will chose a few of the best submissions to share in a Student Gallery.

What you need to do

1. Do the [Cosmic Times 2019 lesson plan](#) with your class (Download the file: [doc](#), [pdf](#)).
2. Send us the following:
 - **Your class creation(s)** These can take the form of print materials (like an "old fashioned" newspaper or a newsletter), web pages, audio podcasts, or videos – it is up to you and your class to decide what form the news will take in 2019.For video or audio submissions, we would also like a copy of the transcript.
- Email the file or link to your students' creation to: [Barbara Mattson](#)
- **Release forms** In order to consider your students' contribution(s), we need signed releases from every student who worked on the project. You can send them either by email or postal mail. If you have scanned versions of the signed forms, just email them to the address above. If you want to send physical copies, request our address when you make your email submissions.
- Release form: [PDF](#), [doc](#)

- 3. Other considerations:
- [Privacy disclosures](#)

Cosmic Times (

Posters, Newsletters, Teacher's Resources, Lessons & Online-Edition all on our website: <http://cosmictimes.gsfc.nasa.gov/>

