# Cosmology in the High School Classroom? Are you crazy?

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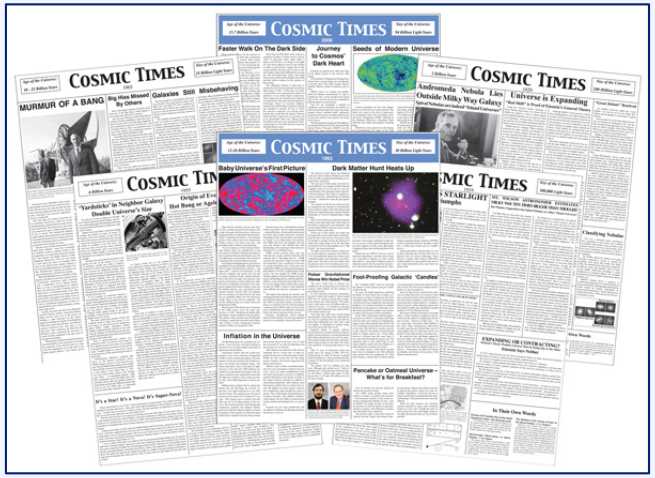
# Outline

- 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

Age of the Universe: Infinite

# COSMIC TIMES

1919

Size of the Universe: 300,000 Light Years

## SUN'S GRAVITY BENDS STARLIGHT
### Einstein's Theory Triumphs

## MT. WILSON ASTRONOMER ESTIMATES MILKY WAY TEN TIMES BIGGER THAN THOUGHT
But Disputes Suggestions that Spiral Nebulae are Other "Island Universes"

Age of the Universe: 10 - 25 Billion Years

# COSMIC TIMES

1965

Size of the Universe: 25 Billion Light Years

## MURMUR OF A BANG

## Big Hiss Missed By Others

## Galaxies Still Misbehaving

Age of the Universe: 2 Billion Years

# COSMIC TIMES

1929

Size of the Universe: 280 Million Light Years

## Andromeda Nebula Lies Outside Milky Way Galaxy

## Universe is Expanding
"Red Shift" is Proof of Einstein's General Theory

## "Great Debate" Resolved

Age of the Universe: 12-20 Billion Years

# COSMIC TIMES

1993

Size of the Universe: 30 Billion Light Years

## Baby Universe's First Picture

## Dark Matter Hunt Heats Up

Age of the Universe: 6 Billion Years

# COSMIC TIMES

1955

Size of the Universe: 4 Billion Light Years

## 'Yardsticks' in Neighbor Galaxy Double Universe's Size

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

## Death of a Genius

## Hoyle Scoffs at "Big Bang" Universe Theory

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

## Journey to Cosmos' Dark Heart

## Seeds of Modern Universe

## Biggest Mystery: What is Dark Energy?

## 'First Light' Wins Nobel

## Radio 'Ear' on the Universe Being Built

## Sorting Out the Dark Stuff

Size of the universe

Expanding universe

Nature of supernovae

# Quick notes on 1919

- The universe was believed to be:
  - 300,000 light years (size of Milky Way)
  - Static
  - Timeless
- Einstein's General Theory of Relativity (1916) revolutionized scientists' view of gravity
- Observations of the 1919 total solar eclipse supported Einstein's theory

*Age of the Universe: Infinite*

**COSMIC TIMES**

1919

*Size of the Universe: 300,000 Light Years*

**SUN'S GRAVITY BENDS STARLIGHT**

**Einstein's Theory Triumphs**

**MT. WILSON ASTRONOMER ESTIMATES MILKY WAY TEN TIMES BIGGER THAN THOUGHT**

**But Disputes Suggestions that Spiral Nebulae are Other "Island Universes"**

**EXPANDING OR CONTRACTING?**

**Einstein's Theory Predicts Universe Must be Doing One or the Other**

**Einstein Says Neither**

**In Their Own Words**

Fundamental science concepts: motions of the Earth, Moon & Sun, solar eclipse, gravity, curved space-time

# 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

1929

Size of the Universe: 280 Million Light Years

**Andromeda Nebula Lies Outside Milky Way Galaxy**

**Spiral Nebulae are indeed "Island Universes"**

**Universe is Expanding**

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

**"Great Debate" Resolved**

**Classifying Nebulae**

**The Minds Atop Mount Wilson**

**Athlete-Scholar Unveils the Future of the Universe**

**Former Mule-Team Driver and Janitor Helps Discover Expanding Universe**

**In Their Own Words**

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

1955

**'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 reading mile markers in space, of course. To properly divine the distance of stars and the scale of the universe first he had to discover that Nature has created more than one kind of mile marker, or yardstick, if you will. Until a few years ago, there was just one cosmic yardstick known to astronomers, and it was being used incorrectly. Oddly enough, it took the wartime blackouts in Los Angeles to begin setting things straight.

That first *universal* yardstick was discovered around the turn of the century. It is a type of pulsating, variable star called a Cepheid. Henrietta S. Leavitt of the Harvard Observatory was surveying the Magellanic Clouds, three *junior* galaxies outside of the Milky Way, when she noticed that brighter Cepheids pulsed slower than dimmer Cepheids. This was intriguing, since for all practical purposes the stars in the Magellanic Clouds can be considered the same distance from Earth. It suggested that those Cepheids were offering up a handy relationship between their real (not just apparent) luminosity and their pulsation rate.

If, for example, an astronomer observes a fast-pulsating Cepheid in our own Milky Way galaxy which appears dim from Earth, he can use Miss Leavitt's brightness/pulsation relationship to surmise that the star is actually very bright, just very distant. Likewise, a slowly pulsing Cepheid which appears bright *in our sky* is probably a relatively dim star that only appears bright because it's closer.

The same relationship seemed to hold with Cepheids found in dense star clusters, in our own Galaxy, as was discovered by astronomer Solon Bailey. Finally, astronomer, Harlow Shapley standardized the yardstick so he could map the distance of both fast-period and slow period Cepheids both inside and outside globular clusters in the Milky Way.

"Thus a period-luminosity relation was established which covered the whole range of the Cepheid variation and which was accepted as the period-luminosity relation for the next 30 years," recalled Baade in a speech at a recent award ceremony of the Astronomical Society of the Pacific.

Unfortunately, Shapley's yardstick had flaws, as the famous astronomer Edwin Hubble began to discover more than 20 years ago. Doctor Hubble began studying the starlight from globular clusters in the Andromeda nebula, a sister galaxy of the Milky Way, in 1931. For some reason those clusters were burning more dimly – 1.5 magnitudes dimmer – than their counterparts here in the Milky Way. This mismatch meant either the globular clusters in Andromeda are basically different animals than those in our own Milky Way, or Andromeda must be further than originally calculated.



*The telescope that confirmed the scale of the cosmos. Mount Palomar's 200-inch Hale Telescope was completed in 1948.*

As chance would have it, the solution came during the wartime blackouts of 1943 in California. Doctor Baade took advantage of the darkened skies and the power of the 100-inch Hooker telescope at the Mount Wilson Observatory near Los Angeles to re-examine Andromeda's globular clusters. Using special red-sensitive photographic plates Dr. Baade discovered two populations of stars: redder, fainter "Type II" stars near Andromeda's center and in its outlying halo (the same arrangement as in the Milky Way) and bluer, brighter "Type I" variable stars located in the outer spiral arms as well as in abundance in the Magellanic Clouds. So, Dr. Baade realized that there must be two populations of Cepheids – three Type I Cepheids more common in the disk of a galaxy and three Type II Cepheids more common in the globular clusters.

Each type of Cepheid, it turns out, has a different way of encoding its actual brightness into its pulsing light. It was as if the measuring stick for one type of Cepheid was measured in feet, i.e., a good old American yardstick, and the other was in cubits. The problem was Shapley had treated them both as regular 36-inch yardsticks.

". . . [U]nknowingly Shapley had made a fatal step when he linked the cluster-type variables to the type II Cepheids through the type II Cepheids in globular clusters and that in reality were are dealing with two different period-luminosity relations," explained Dr. Baade.

Recently at Mount Palomar, Baade and his computer assistant Henrietta Swope confirmed that both types of Cepheids are very different stellar animals. After recalibrating his measuring sticks, Dr. Baade startled his peers in 1952 at the Rome meeting of the International Astronomical Union by announcing that Andromeda was not 800,000 light-years away, as Hubble thought, but 1.8 million light-years distant. Likewise, with the two measuring sticks sorted out, the universe we knew in 1929 to be one billion light-years wide has now doubled in two billion light-years across.

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

It's difficult to imagine a deeper mystery than the one being addressed recently at the meeting of the National Academy of Sciences in Pasadena, California: Is the universe eternal or does it have a beginning, middle and an end?

The case for an ageless, steady-state universe which forever looks much as it does today was presented at the conference by astrophysicists Jesse L. Greenstein and physicist William A. Fowler of the California Institute of Technology. The steady state theory rivals the "evolutionary" theory of the universe which calls on an initial brew of hot particles exploding at the dawn of time and making all the universe's hydrogen and perhaps helium on one fell swoop.

Both theories explain – in entirely different ways – the inescapable fact that the universe is expanding. This cosmic expansion was first detected in 1914, when American astronomer Vesto Melvin Slipher surveyed some galaxies and noticed the light from most of them was "red-shifted." This is essentially the broadening and reddening of the visible light waves caused by the retreat of the galaxies. It's the electromagnetic equivalent of how the wail of a retreating locomotive slopes in tone as it passes by a train watcher's ear.

In the steady-state theory the expansion comes from the continuous bubbling up of the most basic 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 which, through nuclear fusions in their cores, manufacture all the heavier elements. As stars age and die, they disperse the heavier elements around the galaxies, giving rise to new stars 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 Galaxy.

An important aspect of the steady-state is that it's anything but static, as the champions of this theory British cosmologist Fred Hoyle likes to point out. Hoyle compares the deathless 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.

Then, on the other hand, there is the sense-what-less rosy "evolutionary" theory of Russian-born American physicist George Gamow and his colleagues Ralph Alpher and Robert Herman. These scientists call on the explosion and decay of a hot ball of neutrons at the birth of the universe to create all the hydrogen and some helium. These elements froze out as the blast expanded and cooled. The first stars were made of only these original elements and fused them into new, heavier elements. These, then, were dispersed through the galaxies as the first stars died, and led to the less pure mixtures of elements seen in stars now.

This evolutionary theory also accounts for the retreating galaxies. They are all still in flight from the power of the initial blast. There may be other direct evidence of the blast as well. Alpher and Herman have predicted that some faint residual heat from that initial explosion may still be glowing dimly in the form of stretched-out light waves called "microwaves" just a few degrees above absolute zero. As yet, however, no one has devised a way to detect this theoretical remnant heat.

More accessible evidence for the evolutionary universe comes from Edwin Hubble's 1929 measurements of the velocities of galaxies beyond our own, which built on Slipher's earlier discoveries. Hubble found that the more distant in space a galaxy is, and therefore the closer in time to the original explosion, the faster they appear to be moving away from us. This is exactly what would be expected if there was an ancient blast that started it all and things have been slowing down ever since.

The downside to an evolutionary universe, of course, is that it doesn't end happily. There's no limitless fount of hydrogen as in the steady-state theory. The universe has finite resources. So it might expand forever as all the stars burn out and the universe cools down to a vast, frigid stellar graveyard. Or the gravity of all matter might eventually pull everything back together again in an gigantic collapse that rebounds and starts the universe all over – the endlessly exploding and collapsing universe described by the late Caltech physicist Richard Tolman.

Which theory will prevail? Only more research with bigger and better telescopes will tell.



*Fred Hoyle and William Fowler in Fowler's office in the W.K. Kellogg Lab at Caltech.*

**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 panned a rival theory, championed by Ukrainian-born American physicist George Gamow, labeling it a ridiculous "Big bang."

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

Hoyle is having none of it. "It is an irrational process that cannot be described in scientific terms . . . [nor] 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.

**Death of a Genius**



*Albert Einstein in 1950.*

The world has just lost its greatest scientific mind. Albert Einstein died in his sleep on April 18th from complications of a lingering gall bladder infection. He was 76. There is no doubt that this rumpled, white-haired, pipe-smoking professor peered deeper into the nature of the universe than any other man. In death he joins a select few – such as Newton, Copernicus, Archimedes and Pythagoras – as a giant in science whose genius changed the course of history.

The immediate outpouring of tributes to the German-born scientist begins to convey his place in history. President Eisenhower said "No other man contributed so much to the vast expansion of 20th century knowledge." Moshe Sharett, the Prime Minister of Israel observed "The world has lost its foremost genius." There were even eulogies behind the Iron Curtain. Pravda described him as "A great transformer of natural science."

The true nature of Einstein's achievements are better known to his colleagues and scientific progeny, who still labor to understand, test and apply his theories. There is his revolutionary rethinking of light as not just waves but particles. Then his theory of special relativity, which set speed limit within the universe at that of light. Or his most famous equation $E = mc^2$, which dissolved the wall between matter and energy. Finally, we have his space-time bending theory of gravitation. Taken together, Einstein's ideas are the basis of all modern physics.

For the non-physicist, however, Einstein's genius is a given, but largely a mystery. The man on the street knows that such things as television and the hydrogen bomb are the results of his work, but we scarcely grasps how it is so. We are, it seems, rather like the nurse at Einstein's deathbed, who failed to grasp the great man's final words, uttered in German. She did not speak German. Most of us do not speak physics. Instead, we sense the importance of the man indirectly and gaze like children at a parade, as his life and his genius passes before us.

**It's a Star! It's a Nova! It's Super-Nova!**

There's more than one sort of "new" star in the heavens, say astronomers. The evidence has been building for decades that novae – those stars which light up suddenly to great brightness, then fade away – actually come in at least two distinct classes. On one hand there are pedestrian, Clark Kent-like novae and on the other there are truly Super-Novae.

The first clue that there were super-novae lurking among the stars came 35 years ago by the recently deceased astronomer Edwin Hubble. Using his revolutionary method for measuring *celestial* distances, he calculated that a nova observed in 1885 in the Andromeda Galaxy actually must have been about one hundred times more luminous than any nova recently observed in our own Milky Way Galaxy.

Fourteen years later, in 1934, physicists Walter Baade and Fritz Zwicky coined the term "super-nova" when they suggested these were not only far brighter than normal novae, but rare, once-in-a-millennium, events in any given galaxy. The most recent super-nova in our own galaxy, they speculated, were those recorded by Germanic astronomer Johannes Kepler in 1604, and another seen by Danish astronomer Tycho Brahe in 1572.

A new wrinkle to the matter was added in 1941 by astronomer Rudolph Minkowski. He split the light from 18 distant galactic super-novae into their component colors and found that nine of those spectrums contained no telltale lines for hydrogen (Type I) and five did (Type II). The possible reason for this, speculates British cosmologist Fred Hoyle, is that in the superlative violence of their death throes, the giant stars that become supernovae might be capable of fusing hydrogen and helium to forge heavier elements like carbon and iron. They are then, truly, not only Super, but Nova-fide Stars of Steel.

**Radio 'Ear' on the Universe Being Built**



*Jodrell Bank's Mark I radio telescope under construction.*

Construction continues for what will be Earth's largest steerable radio antenna for listening to celestial radio broadcasts. The huge, 250-foot-wide metal dish of the Mark 1 radio telescope at Jodrell Bank in England is designed to be a fully adjustable. This will allow astronomers to explore the entire sky for radio transmissions – something they cannot do today. It will also be able to investigate the recently discovered 1420.4 Megahertz radio emissions thought to be coming from hydrogen gas at the center of the Milky Way.

The MK1 will replace the 218-foot parabolic aerial antennae, also at Jodrell Bank. That pioneering aerial uses tall poles and wire mesh to reflect and concentrate radio waves to a single point. Though the current set up allows astronomers some leeway – they can tilt the 150-foot-high central receiver pole somewhat to cover a little more sky – it relies heavily on the spinning of Earth in its orbit to change its view of the heavens.

Despite that limitation, the eight-year-old parabolic aerial antenna has led to some important discoveries which many that made the case for building the Mark 1, according to its designer Dr. Bernard Lovell of the University of Manchester. Among the most startling and discoveries was that there are radio emissions coming from the Great Andromeda Nebula and that the brightest radio emitter in the night sky is from a little nebula in the constellation Cassiopeia.

# 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

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 one 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 ... [nor] 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 from page 3

age, die, and explode, 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 all 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. ♦

Evolutionary Theory:
Density of matter decreases over time

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

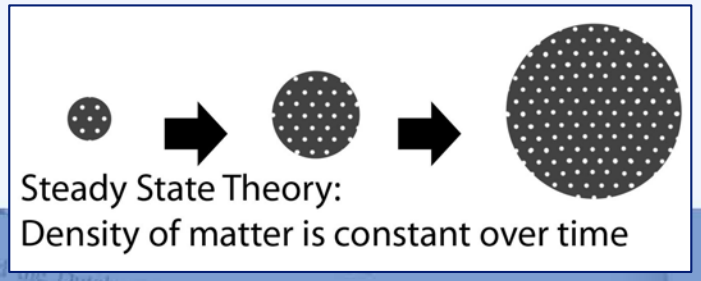
# Summarize the Article (

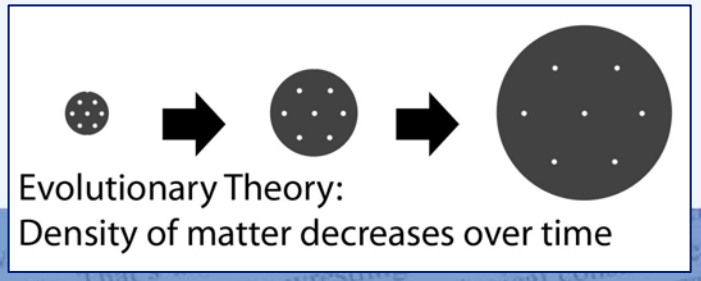
## Steady State Universe

- ( 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!

Age of the Universe: 6 Billion Years

COSMIC TIMES

1955

Size of the Universe: 4 Billion Light Years

'Yardsticks' in Neighbor Galaxy Double Universe's Size

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It's a Star! It's a Nova! It's Super-Nova!

Radio 'Ear' on the Universe Being Built

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

# 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

Age of the Universe: 10 - 25 Billion Years

COSMIC TIMES

1965

Size of the Universe: 25 Billion Light Years

MURMUR OF A BANG

Big Hiss Missed By Others

Galaxies Still Misbehaving

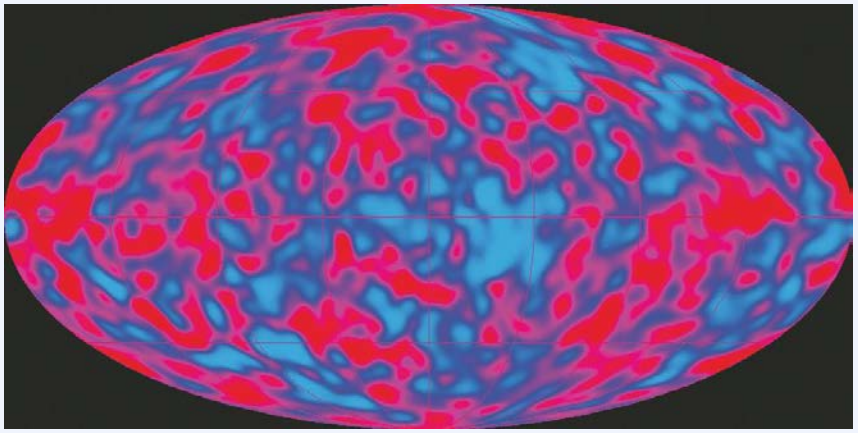
QUASARS: Express Trains To Netherworlds

SUPERNOVAE LEAVE BEHIND COSMIC X-RAY GENERATORS

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

# 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…

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**

**Journey to Cosmos' Dark Heart**

**Seeds of Modern Universe**

Atoms 4%
Dark Matter 23%
Dark Energy 73%

**Biggest Mystery: What is Dark Energy?**

Adept SNAP-L Destiny

**'First Light' Wins Nobel**

**Sorting Out the Dark Stuff**

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

# 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

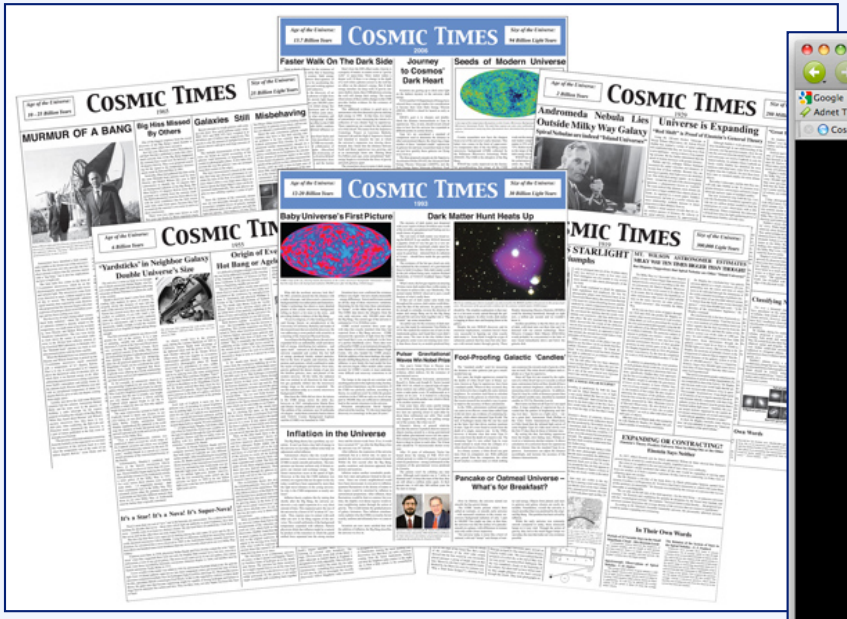
Opportunities for cross-disciplinary collaboration

# 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 Univ
SUN'S GRAVITY BENDS STARL
Einstein's Theory Triumphs
Radio 'Ear' on the Universe Being Built
Seeds of Modern Universe
Galaxies Still Mis
Dark Matter Hunt Heats Up
'Yardsticks' in Neighbor Galaxy
Double Universe's Size
Classifying Nebulae
Baby Universe's First Picture
EXPANDING OR CONTRACTING?
Einstein's Theory Predicts Universe Must be Doing One or the Other
Einstein Says Neither
Biggest Mystery:
What is Dark Energy?

# 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

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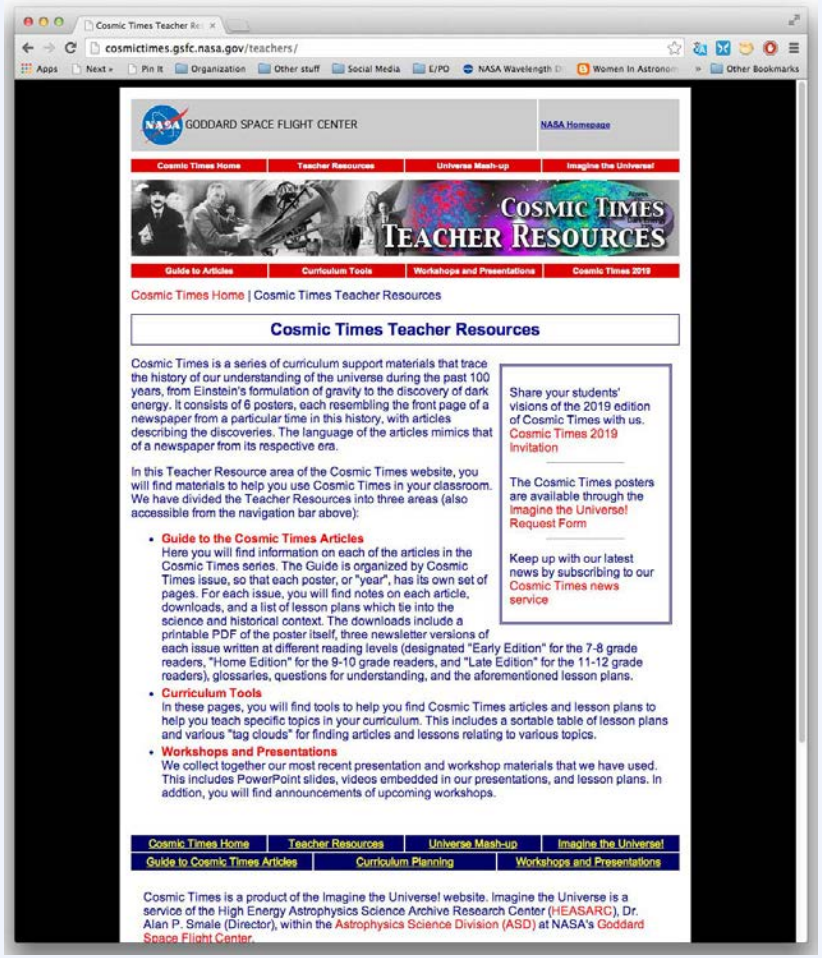

# Classroom Resources: ( Guide to the Articles (

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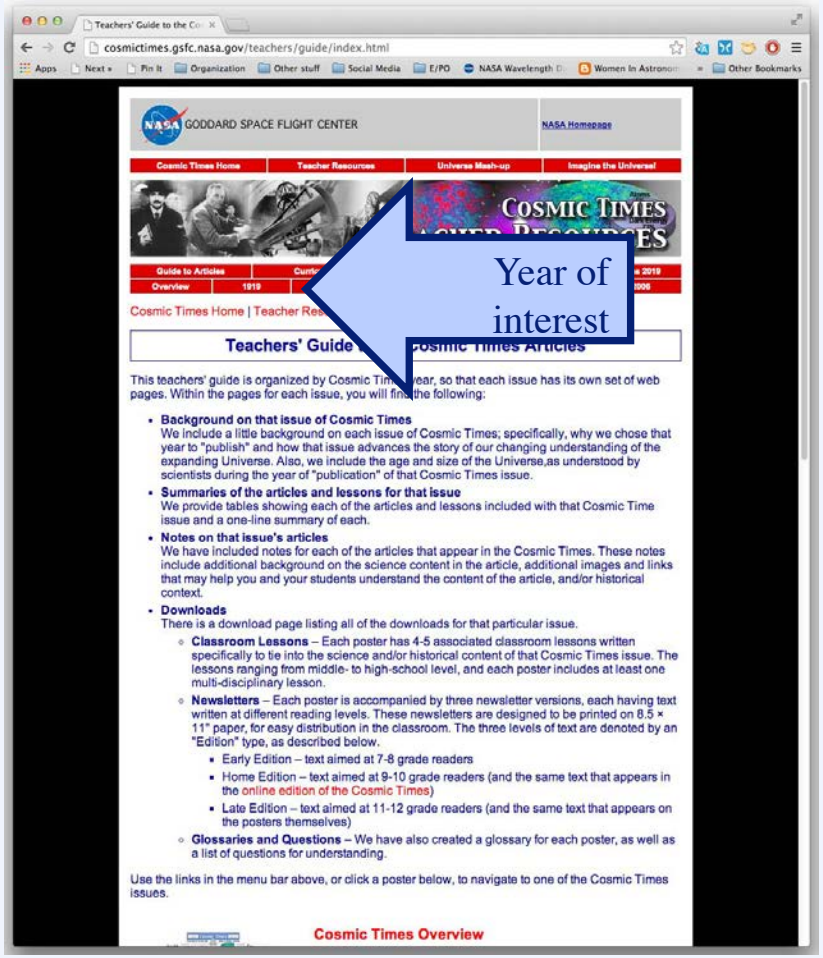
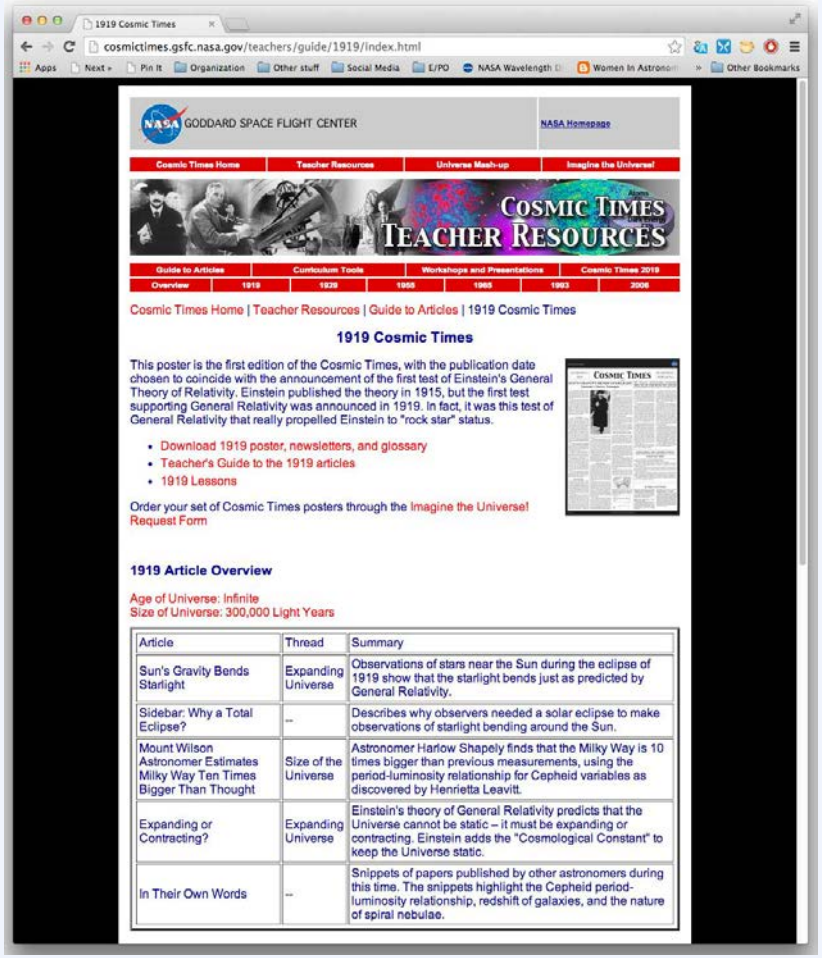
- ( Here you will find further information organized by year/issue of Cosmic Times

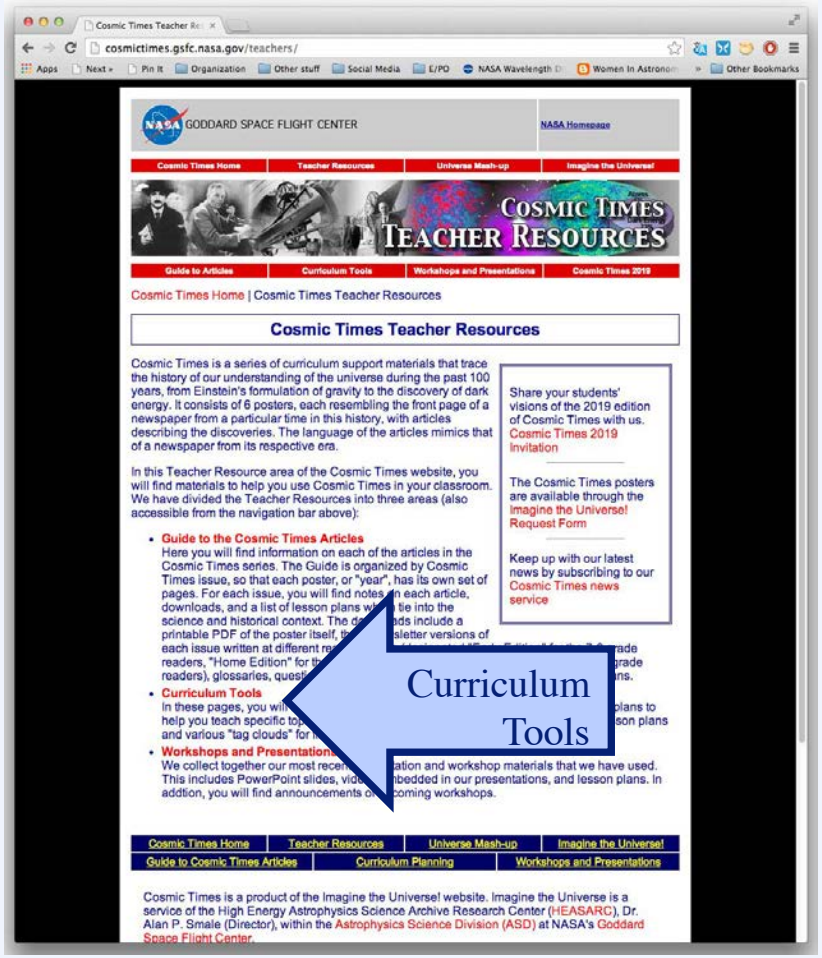


# Classroom Resources: ( Guide to the Articles (

- ( 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



# Classroom Resources: ( Curriculum Tools (



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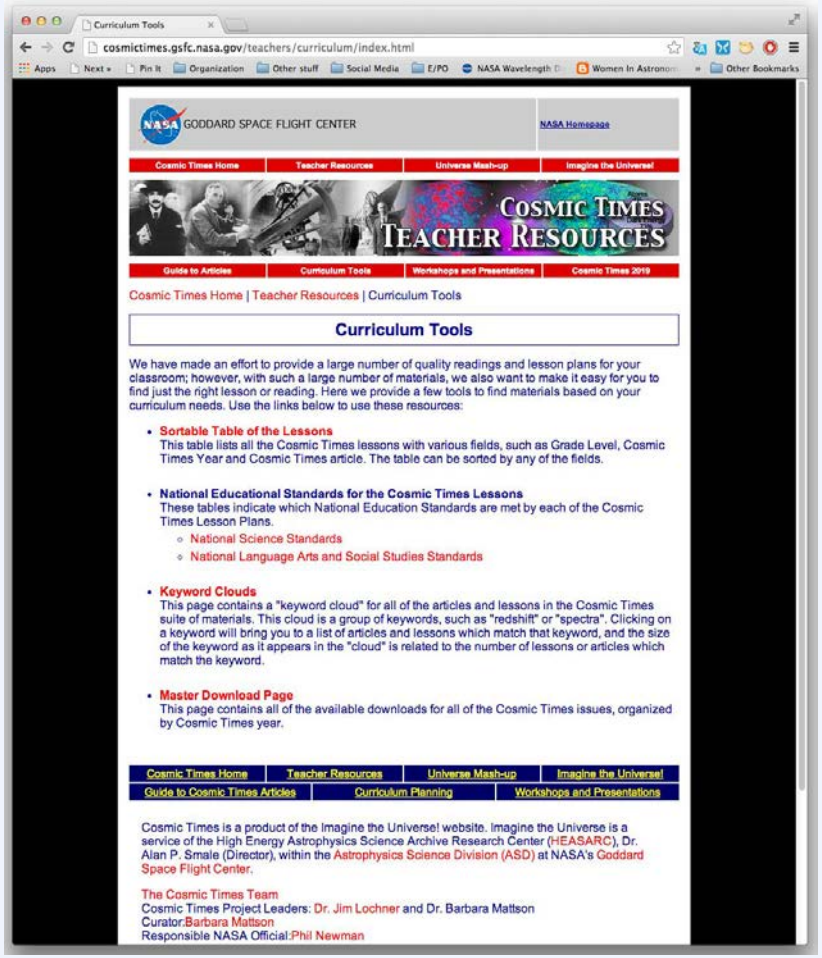

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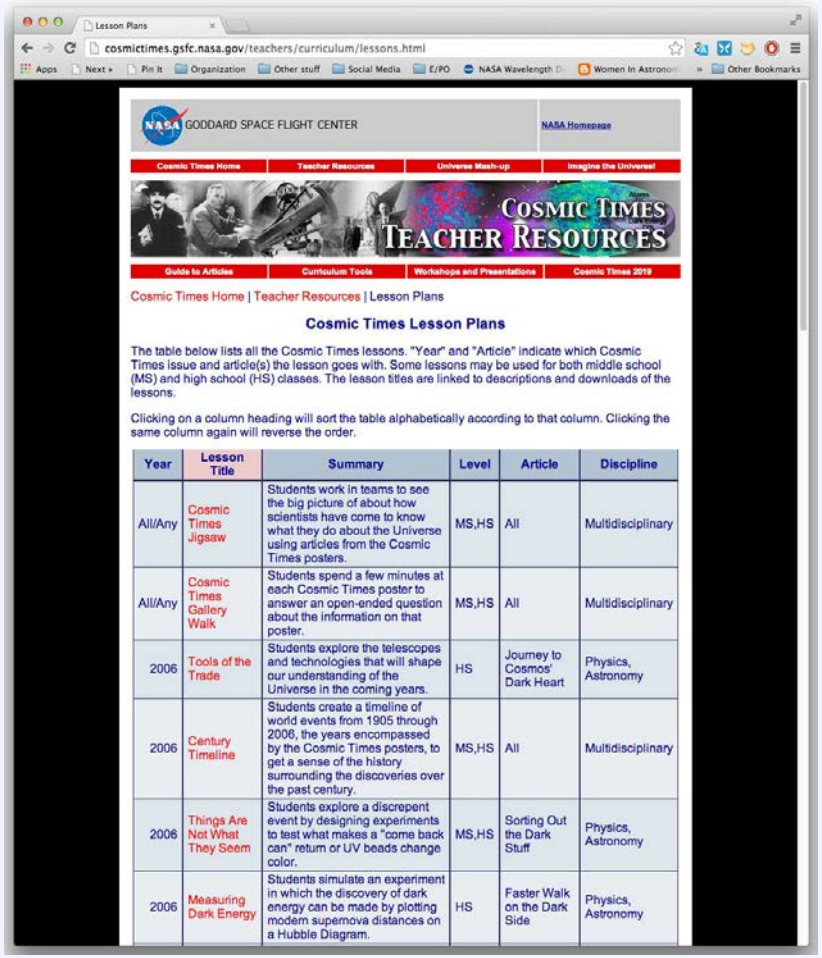
  - Sortable list of lessons




| 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 discrepent 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 (

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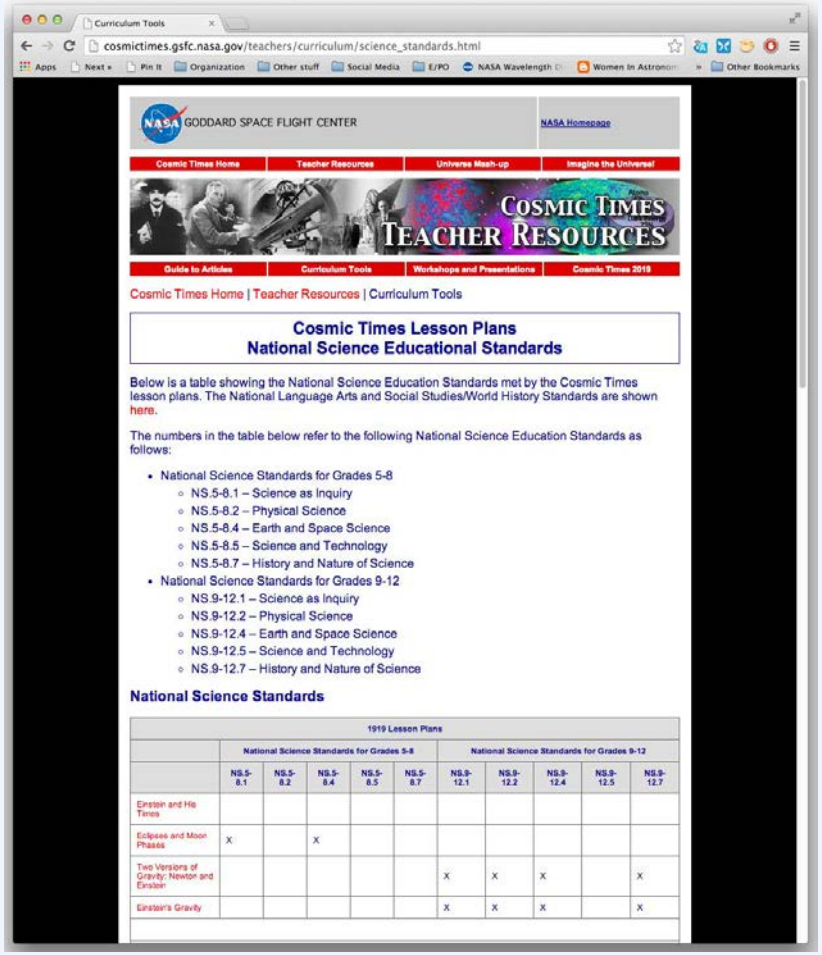
  - Sortable list of lessons
  - National Education Standards for each lesson



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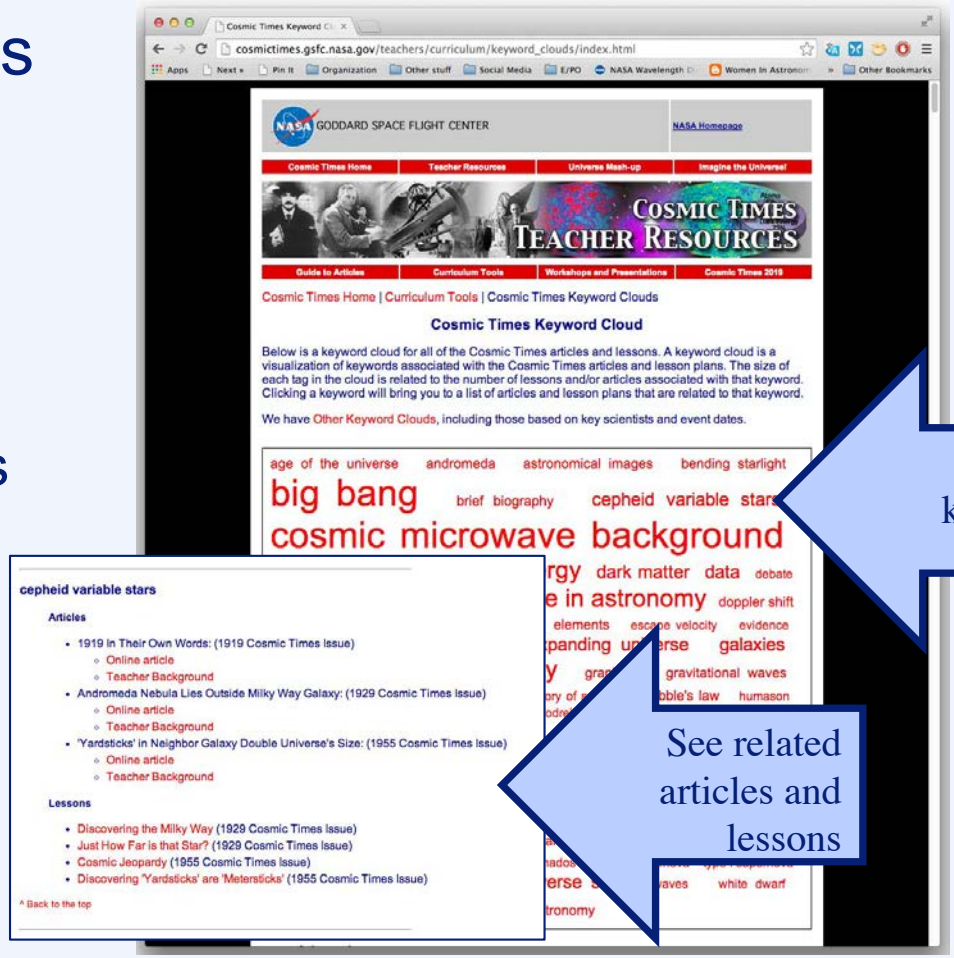

# Classroom Resources: ( Curriculum Tools (

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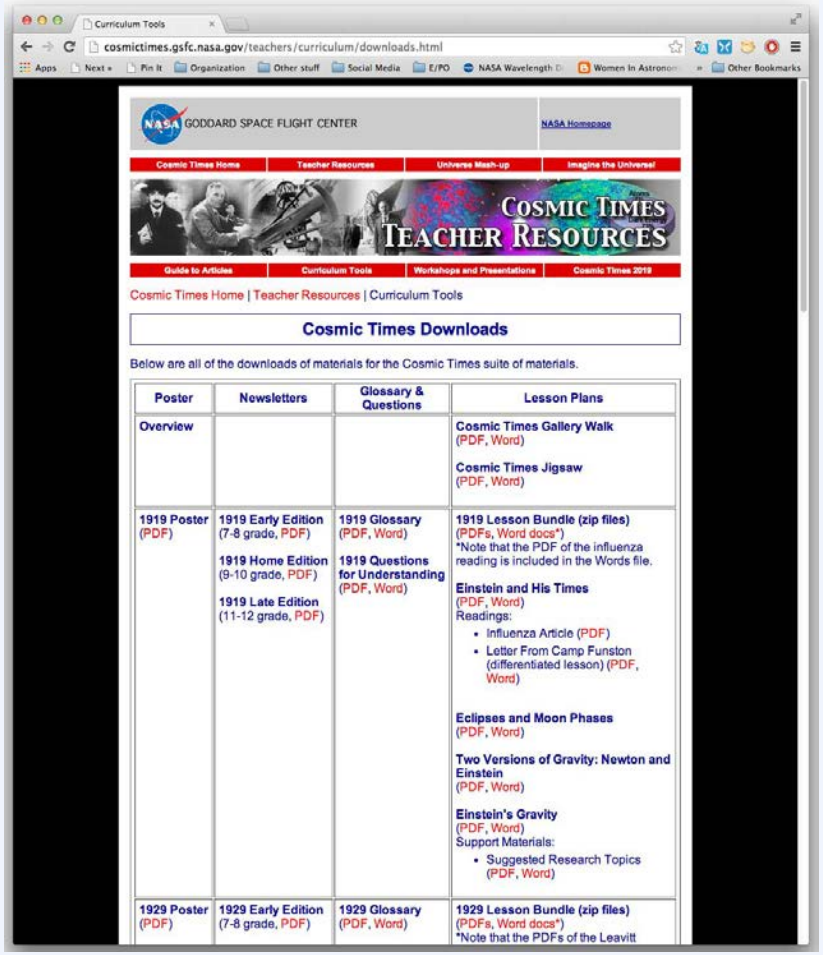
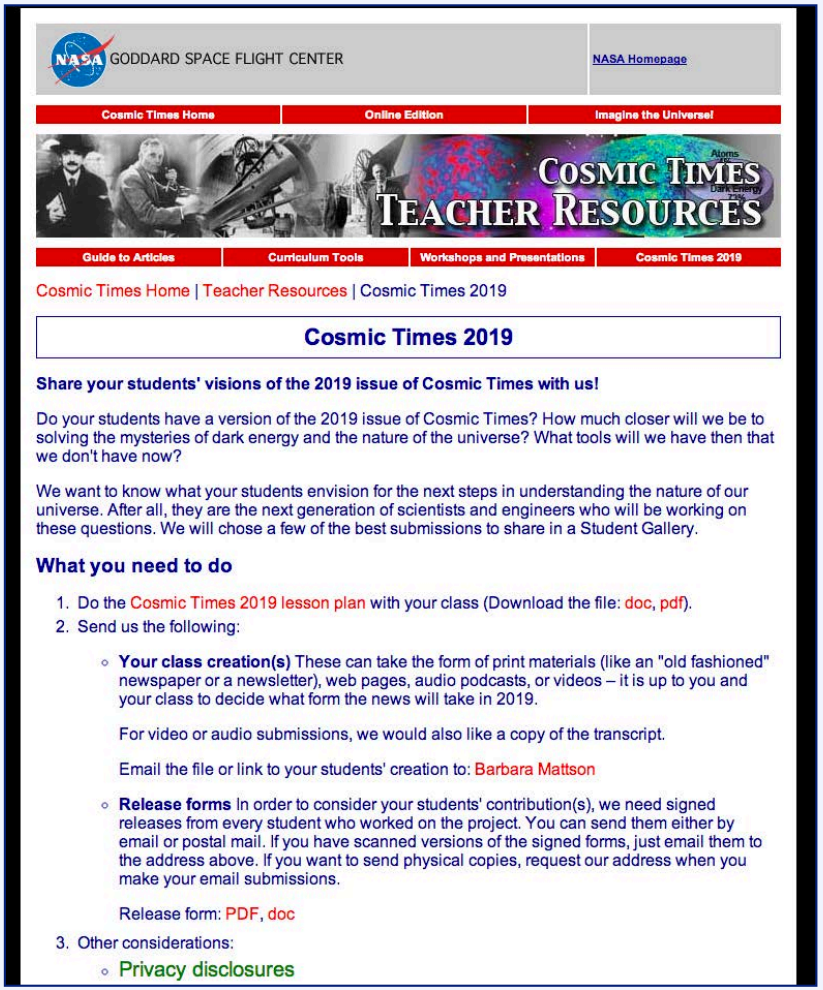
  - Master download page



# 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



GODDARD SPACE FLIGHT CENTER | NASA Homepage

Cosmic Times Home | Online Edition | Imagine the Universe!

COSMIC TIMES TEACHER RESOURCES

Guide to Articles | Curriculum Tools | Workshops and Presentations | Cosmic Times 2019

Cosmic Times Home | Teacher Resources | Cosmic Times 2019

**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 (

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