

Extra! Extra! Read All About the Universe!

Barb Mattson (USRA/GSFC)

JHU Space Grant

July 8, 2013

Gallery Walk

Take a tour of the Cosmic Times posters



Gallery Walk '

- ' Start at one Cosmic Times poster station
 - Cosmic Times poster
 - 3 versions of the newsletter: early edition (7-8 grade), home edition (9-10 grade), late edition (11-12 grade, same readings as on posters)
- ' At each poster, use the chart paper to record the answers to the following two questions, as they relate to that issue of Cosmic Times
 - What big questions are facing scientists?
 - What answers have scientists just found?
- ' You will have 4 minutes at the first poster, and 2 minutes at each subsequent poster
- ' Return to first poster and prepare a 1-minute summary of all the responses (write it down!)

The year is 1919... '

- What's going on?
- What's going on in science?
- What is your view of the Universe?

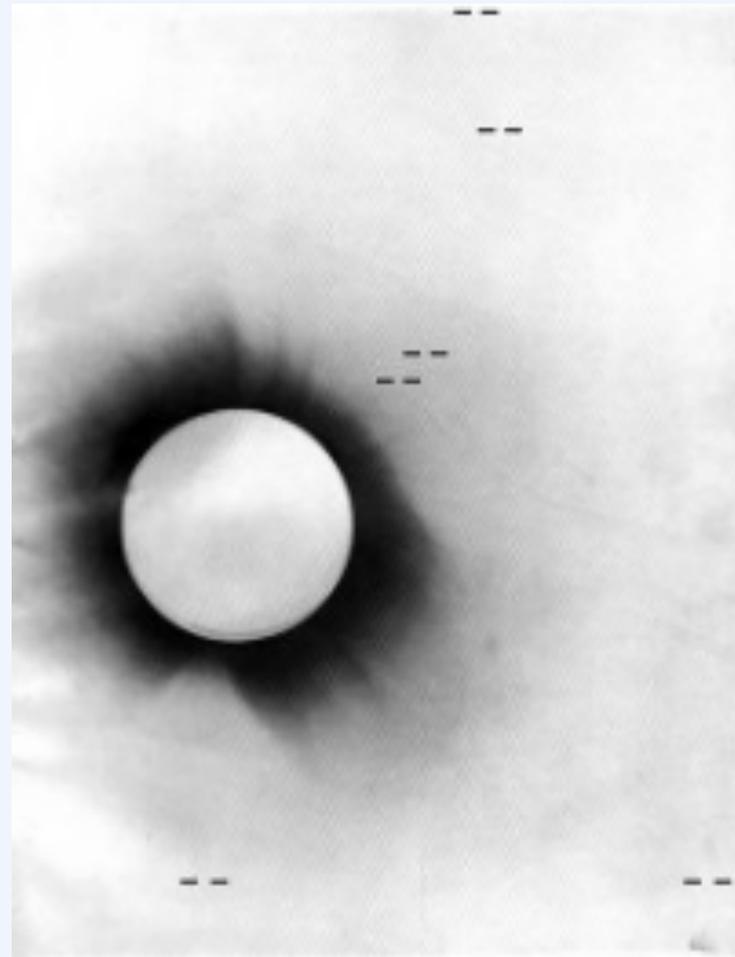
✦ Infinite

✦ Unchanging/static

✦ Ageless '

1919 – Einstein's Gravity

- ' What is Gravity?
 - ' Gravity is curved space-time.
 - Gravity bends light.
 - Amount of deflection ' differs from Newton's prediction. '
- 1919 Solar Eclipse verified Einstein's prediction.



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→ 1919 Solar Eclipse verified Einstein's prediction.

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

SUN'S GRAVITY BENDS STARLIGHT

Einstein's Theory Triumphs

"One of the greatest—perhaps the greatest—of achievements in the history of human thought" was what Sir Joseph Thomson, President of the Royal Society of London, called Dr. Albert Einstein's prediction, which was apparently verified during the total eclipse of the Sun May 29 last.

Sir Joseph made his pronouncement during a discussion of the results from observations of the solar eclipse at a joint meeting of the Royal Society and the Royal Astronomical Society in London on Thursday evening, November 6, before a large attendance of astronomers and physicists. The excitement in the air was almost palpable as it seemed generally accepted that the observations were decisive in verifying the prediction of Dr. Einstein, Professor of Physics at the University of Berlin and Director of the Kaiser Wilhelm Physical Institute.

The prediction

According to the gravitational principles enunciated by Sir Isaac Newton in his classic work *Optics* some two centuries ago, a ray of light from a distant star just grazing across the edge of a massive object should be bent by an amount that depends on the object's mass and thus its gravitational field. Newton thought of gravity as a force that pulls things toward an object: the bigger the object, the stronger the pull.

The most massive object in the vicinity of the Earth is the Sun. So according to Newtonian principles, a light ray from a distant star grazing the edge of the Sun should be attracted or bent by the Sun's gravity by an amount equal to 0.87 seconds of arc. To be sure, that angle is very small, about equivalent to a human hair at 75 feet; but it is actually measurable on today's astronomical photographic plates if adequate care is taken.

Dr. Einstein's general theory of relativity, however, conceives of gravitation as indistinguishable from inertia. The "force" of gravity one feels pressing one down into a chair is the same as the "force" one feels when pulled forward in an automobile when the driver brakes.

According to Dr. Einstein, gravity, like inertia, doesn't pull. Instead, a mass warps or curves space and time surrounding the object. The amount of curvature is proportional to the amount of mass. The curvature of space then curves the paths taken by rays of light.



Herr Einstein in Berlin

actually arranged, but out of the 16 plates taken, only two showed as many as five stars each. Prof. Eddington was also unable to stay several more months to take check-photographs of the star field.

Sir Frank explained in detail the apparatus both expeditions had employed, the way the photographic plates were measured back at the Greenwich Observatory, the corrections that had to be made for various disturbing factors, and the methods by which comparison between the theoretical and observed positions had been made. He convinced the meeting that the results were definite and conclusive, and that deflection did take place. He also asserted that the measurements showed that the extent of the deflection was in close accord with the theoretical amount predicted by Dr. Einstein, as opposed to half of that amount, the amount that would follow if the principles of Newton were correct.

"After a careful study of the plates I am prepared to say that there can be no doubt that they confirm Einstein's prediction," Sir Frank declared. "A very definite result has been obtained that light is deflected in accordance with Einstein's law of gravitation."

"For the full effect that has been obtained, we must assume that gravity obeys the new law proposed by Einstein," added Prof. Eddington. "This is one of the most crucial tests between Newton's law and the proposed new law."

WHY A TOTAL SOLAR ECLIPSE?

According to predictions by both Sir Isaac Newton and Dr. Albert Einstein, a ray of light from a star nearly behind the Sun (as seen from Earth) will be deflected—bent toward the Sun—as it passes by the limb (edge) of the Sun. Such a deflection would make the star look slightly farther away from the edge of the Sun than it really is.

Dr. Einstein's theory of relativity, however, predicts that the amount of the deflection should be double that predicted by Newtonian mechanics. The maximum shift, for a star whose ray of light just grazes the limb of the Sun, would be 1.75 seconds of arc, twice the amount Newton predicted (0.87 arcsecond). The apparent positions of stars closer to the Sun's limb would be shifted more than those of stars farther away.

The more stars around the Sun during a solar

the Sun and the stars to be photographed at the same time.

Prof. Eddington himself decided to lead an expedition to the island of Principe, in the Gulf of Guinea close to the coast of West Africa, near the end of the path of totality (see map). He also convinced the Astronomer Royal—Sir Frank Dyson, Director of the Royal Observatory, Greenwich—to send another expedition elsewhere, to minimize the chances of clouds interfering with the observations. Led by Dr. Andrew Crommelin from the Royal Observatory, it set up instruments at Sobral in northern Brazil, near the beginning of the path of totality.

At each of these places, if the weather were propitious on the day of the eclipse, it would be possible to take during totality a set of photographs of

his astronomers the differences and Sir Isaac's May 29, as the Sun appears to us, a cluster of stars in the sky

able in the sky

l solar eclipse,

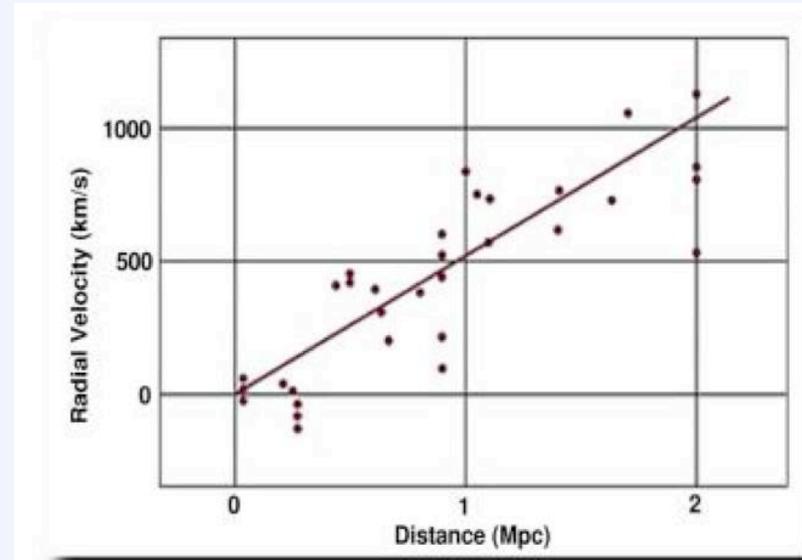
when the Moon blocks most of the Sun's blinding light. And by unusual good fortune, the total solar eclipse of 1919 took place right on May 29.

The amount by which starlight is deflected by the Sun is thus regarded by astronomers and physicists as one of the crucial tests in determining the validity of the Dr. Einstein's Theory of

was a deflection due to the Sun's presence. The effect of the predicted gravitational bending of the ray of light is to throw the apparent position of the star away from the Sun," said Sir Frank. If

1929 - Expanding Universe '

- Vesto Slipher showed the “nebulae” were red-shifted.
 - I.e. moving very fast away from us. '
- Hubble put together the redshifts with their distances.



Hubbles' Original Data

Universe is expanding!

1929 - Expanding Universe'

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Universe is Expanding

“Red Shift” is Proof of Einstein’s General Theory

Using the 100-inch Hooker Telescope at Mount Wilson Observatory, Dr. Edwin Powell Hubble has studied a variety of spiral nebulae and established that they are moving away from us at a rapid pace – strong evidence of an expanding universe. He has further determined that the speed of motion increases with greater distance.

Hubble and his colleague Milton Humason measured the radial velocities and distances of twenty-four of these nebulae. Because they are moving so quickly, their light waves are stretched out. This shifts their energy signals – as we detect them – toward the red end of the electromagnetic spectrum, a phenomenon known as “redshift.” The team noticed that dimmer, more distant objects have a larger redshift than objects closer to Earth. As reported in a recent paper, Hubble’s measurements led him to a useful velocity-distance relationship: redshifts increase in direct proportion to their distance from us.

Hubble’s initial analysis reveals that for every million parsecs of distance, the velocity of the spiral nebulae increases by approximately 300 miles per second, where one parsec is equal to 3.26 light years. He determined distances to the nebulae using Cepheid variables, stars with

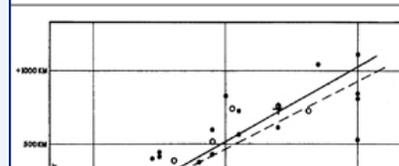
Although Hubble’s work presents a tremendous breakthrough in our understanding of the universe, one big question remains. How far out into the universe does his model hold? The 100-inch telescope can resolve Cepheids in only the nearest nebulae. In nebulae where Cepheids are barely visible, Hubble has identified the most luminous individual stars, some 50 to 100 times brighter than the Cepheids. He uses these luminous stars as standard candles for more distant objects.

But today’s telescopes, and the stars they see, will only take Hubble so far. To measure even greater distances, astronomers will need a larger telescope and new types of standard candles.

One new instrument may hold the key. Last year the Rockefeller Foundation agreed to provide the six million dollars needed to fund the construction of a new observatory with a 200-inch telescope. When completed, this telescope will hold four times the light-gathering power of the instrument Hubble currently uses.

Einstein’s General Theory Holds True

The past decade has been an exciting and challenging time in the development of scientific understanding of the universe, with theorists testing their ideas against the framework of Albert Einstein’s 1916 theory of general relativity. The theory establishes the universe as three dimensions of space and one of time. It proposes that gravity curves the fabric of space-time and the natural motions



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

Hubble's research led to this diagram, showing the general correlation between how far away a galaxy is and

the “cosmological constant,” designed specifically to avoid the implication of an expanding

1955 – Origin of the Universe

- Scientists debate: 'Is Universe ...'
 - ageless and infinite?
 - finite, with hot "bang" beginning?



Evolutionary Theory:
Density of matter decreases over time



Steady State Theory:
Density of matter is constant over time

Steady State vs. Big Bang

Steady State theory

- ' Fred Hoyle, Hermann Bondi and Thomas Gold see the movie *The Dead of Night*, in which the end of the story circles back to its beginning
- ' Unchanging situations need not be static
- ' New matter can be created spontaneously as the universe expands (a few hundred atoms per year per galaxy)
- ' Expansion of universe and creation of new matter balanced via a negative energy
- ' The universe is constant in its overall density

Evolutionary theory

- ' Starting from earlier work, George Gamow & Ralph Alpher worked out the conditions in the early universe
- ' Universe is expanding from a state of high density and pressure
- ' Hydrogen and 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"

1955 – Origin of the Universe

- Scientists debate:
Is 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

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?

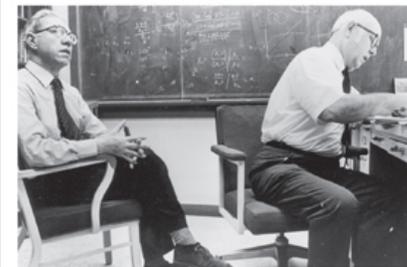
The case for an ageless, steady-state universe which forever looks much as it does today was presented at the conference by astrophysicists Jesse L. Greenstein and physicist William A. Fowler of the California Institute of Technology. The steady state theory rivals the “evolutionary” theory of the universe 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 drops 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

again in a 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.

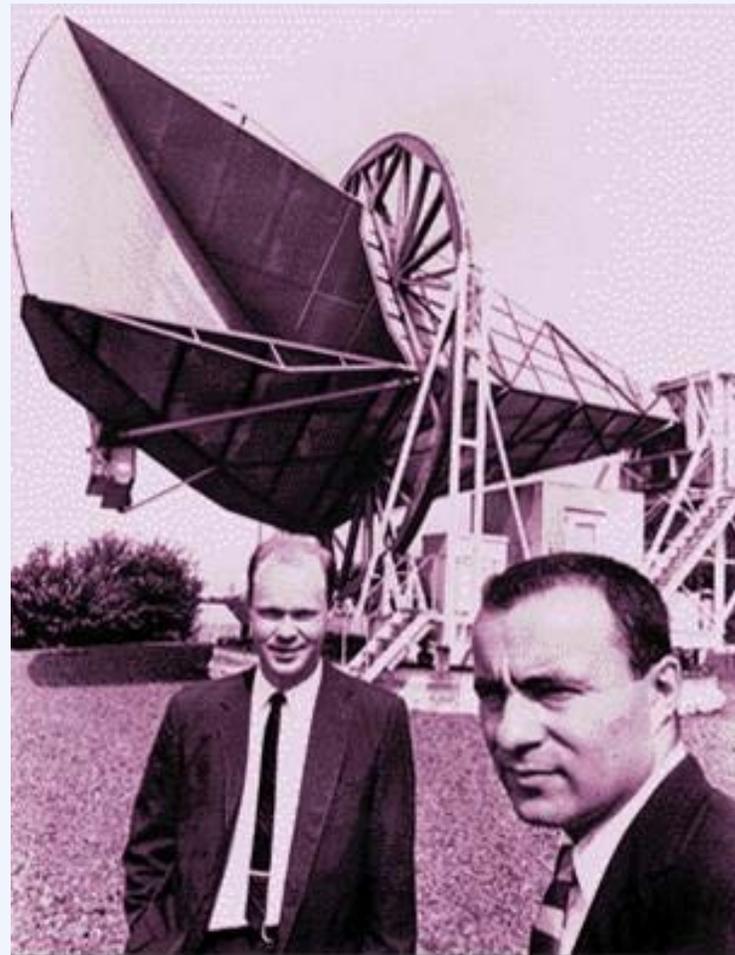
Hoyle Scoffs at “Big Bang” Universe Theory

evidence of that process, Greenstein and Fowler referred to the heavy-element-making red giant

a rival theory, championed by Ukrainian-born American physicist George Gamow, labeling it

1965 - Breaking the Stalemate

- ' A hot “bang” should leave left-over heat
- ' Data and theory came together in 1965
 - Penzias and Wilson found ' a mysterious 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. '



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MURMUR OF A BANG



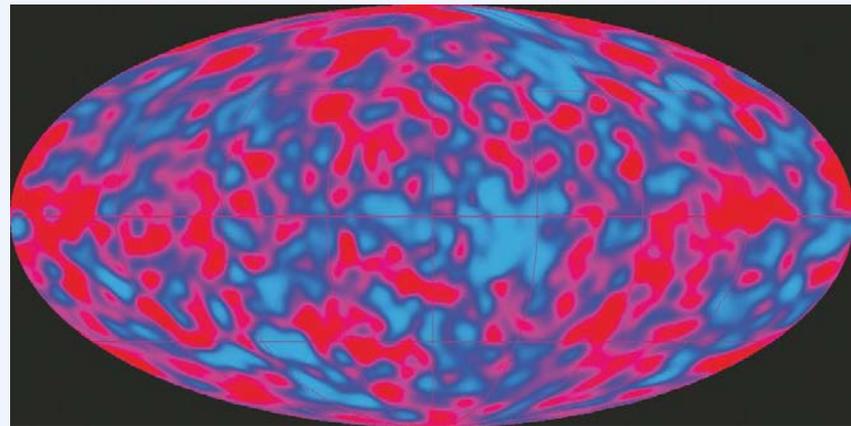
Robert Wilson (left) and Arno Penzias stand in front of their horn reflector antenna in Holmdel, New Jersey. They discovered a radiation signal that matches that expected by theorists who proposed that the universe began with a hot explosion called the “big bang”. This discovery was made by accident as they tried to track down the source of unwanted noise in their receiver.

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

The faint radio hiss comes in the form of 7.3-centimeter microwaves, which lie on the spectrum between visible light and radio waves, including George Gamow, Ralph Alpher and Robert Herman had argued in the late 1940s for the existence of a background radiation.

1993 - Cosmology's End?

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

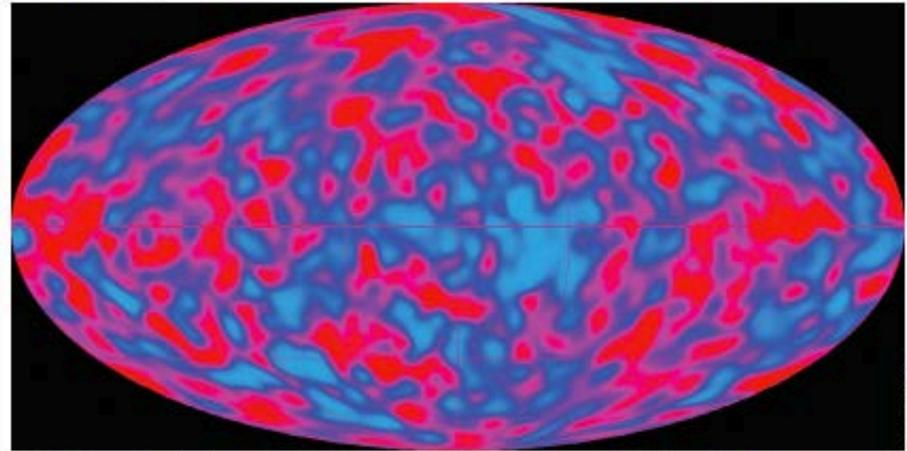


- Remaining questions:
 - Will the expansion continue forever, or will Universe eventually collapse back on itself?
 - What is the mass-density of the Universe (which would answer the above)?

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Baby Universe's First Picture



COBE's map of the sky, showing minute fluctuations in the cosmic microwave background. Astronomers estimate that this map shows the background radiation 300,000 years after the Big Bang. (NASA image)

What did the newborn universe look like? In 1965, scientists peered into the distance with a radio telescope, and discovered a microwave background that was rather plain and featureless. Today's technology has drawn a more detailed picture of this cosmic microwave background, telling us there's a lot more to the story...and providing further evidence of the Big Bang. "If you're religious, it's like looking at God," said George Smoot, an astrophysicist at the University of California, Berkeley and leader of the research team that unveiled the discovery. He was addressing a room packed with scientists at

Scientists have now confirmed the existence of these very slight – but now clearly measurable – energy differences. Smoot and his team created an all-sky map of these microwave variations, illustrating for the first time these anisotropies, or “lumps”, in the oldest light in the universe. The COBE data shows the afterglow from the very early universe, only 300,000 years after the Big Bang. The current age of the universe is estimated at 12 to 20 billion years.

COBE excited scientists three years ago with data that exactly matched what they had expected from a Big Bang universe. COBE detected the light from the CMB, as predicted, in the form of a uniform glow. These data were collected by COBE's main instrument designed by John Mather of NASA's Goddard Space Flight Center, who also headed the COBE project.

Fundamental science concepts: origin of the Universe

Cosmology's End?

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

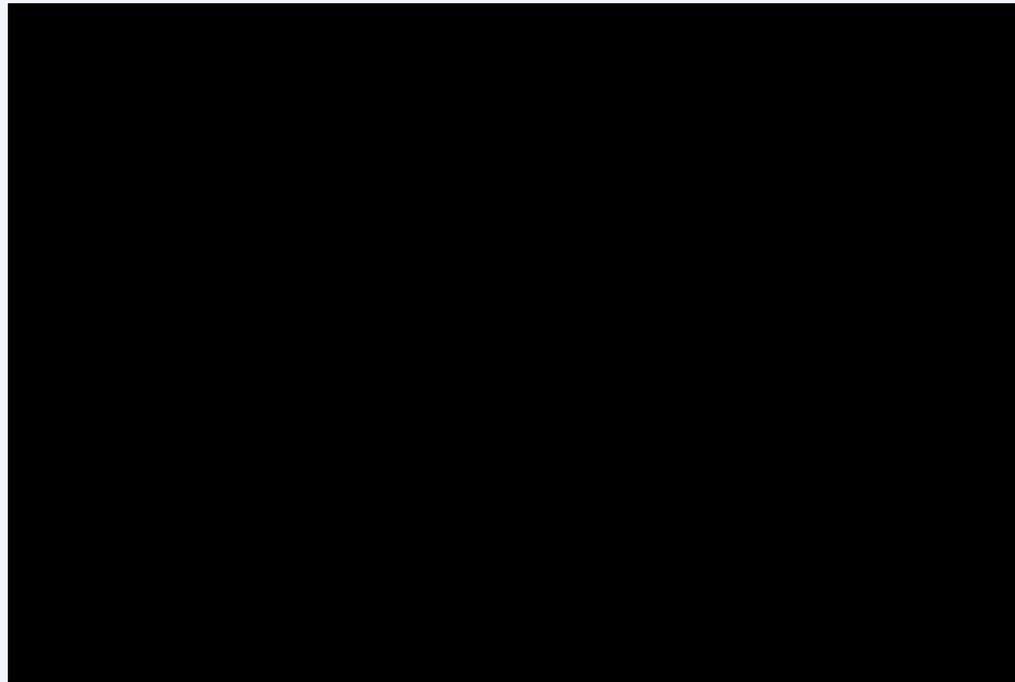
2006 – Cosmologists are busy

- ' In 1997, cosmologists were surprised (to say the least)
 - 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** (
- ' Now, 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...



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

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Faster Walk On The Dark Side

There is fresh evidence for the existence of dark energy, a peculiar entity that is hastening the expansion of the cosmos. Dark energy amazingly comprises almost three-quarters of the universe. It appears to be accelerating the distances between galaxies and working against gravity, but its nature is still unknown.

Here's how the ISW effect works. Gravity is a property of matter, so matter exists in "gravity wells" in space-time. More matter makes a deeper well. If there is no change in the depth of a well while a photon crosses it, the well has no effect on the photon's energy. But if dark energy stretches out deep wells of gravity into

Sorting Out the Dark Stuff

There's some good news and bad news about the cosmos. The bad news is that the normal matter which makes up humans, the Earth and Sun - and everything else we can detect - accounts for just 4 percent of the known universe! The good news is that our tiny little portion of the universe is beginning to get a handle on what makes up the rest of it.

The more abundant matter in the universe - dark matter - doesn't rule either. It makes up just 23 percent of the universe. This is dwarfed by the most prominent entity of all - dark energy, which is 73 percent of the universe. While both are mysterious, and both have been dubbed "dark" because they can't be directly sensed, they are very different beasts.

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 their measured gravitational effects. Dark matter is currently thought to be a kind of cold particle that interacts extremely weakly with both atoms and light.

Dark energy, on the other hand, is a stranger animal. It reveals itself only by flinging everything else apart. This peculiar energy is right now creating more space out of nothing and pushing everything in the universe further apart at a faster rate. And that's good news too, if you like privacy.



Supernovae, like the one in the lower left portion of this distant galaxy, were used to determine that the universe's expansion rate is accelerating, leading scientists to propose the existence of dark energy.

found mystery.

There are several theories being proposed to explain dark energy. So far, however, testing these ideas has been very hard to do. The key will be to create a new generation of scientific instruments to search deeper into the cosmos.

At the moment the only way to talk about dark energy is to say what we know it does. It creates more space, new space, pushing galaxies further apart and making the entire universe larger at an increasing clip. Some measurements of distant supernovae in the late 1990s showed us this startling phenomena.

Ironically, there was one big hint that dark energy existed even before astronomers found

kind of pressure on the cosmos. Unfortunately, the theory predicts that the energy ought to be 120 orders of magnitude stronger than dark energy appears to be.

Another strong contender 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 acted in the Moon and stars. Unlike the cosmological constant, the modern theory of quintessence holds that it is some kind of energy field that pushes particles apart. It states that the energy is variable and that it can lessen in strength as it travels through space and time. This concept fits the data available, which sug-

aster rate. Starting about some unexplained "dark" overwhelm the force of gravity art.

ose to name it dark energy, with dark matter, which is problem in cosmology. energy is, that's anybody's file there are at least a half e seem very close to an

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

The year is 2013... '

- What's going on?
- What's going on in science?
- What is your view of the Universe?

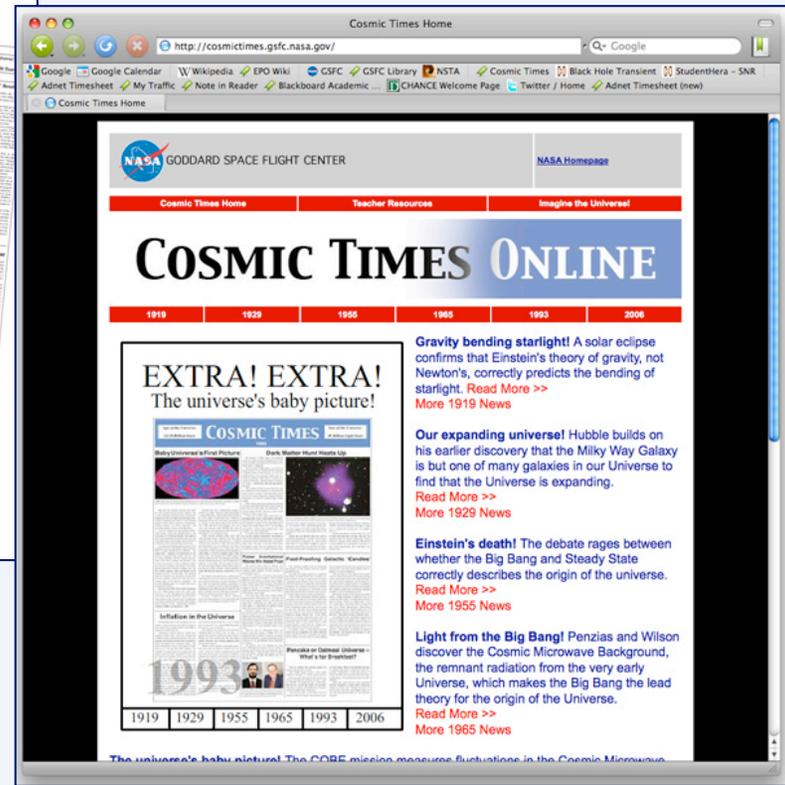
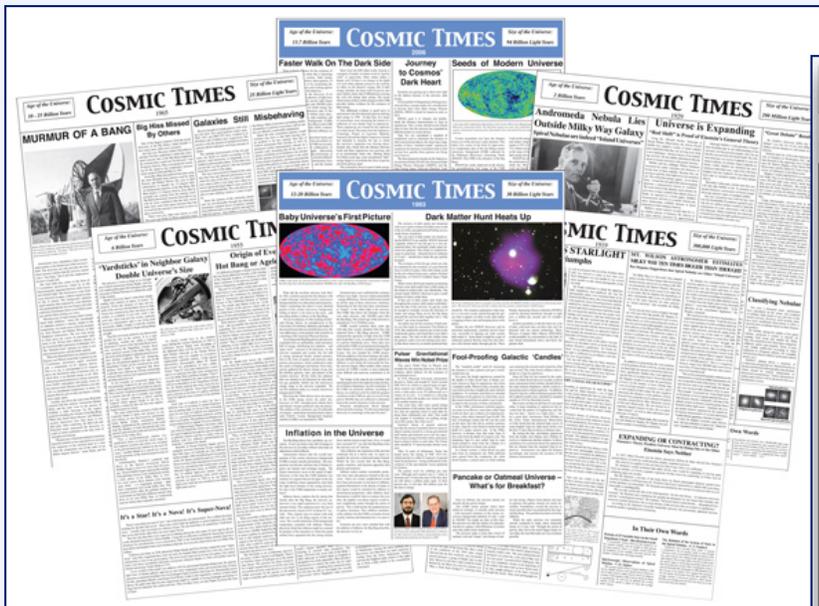
✦ Finite

✦ Changing

✦ 13.7 Billion Years Old

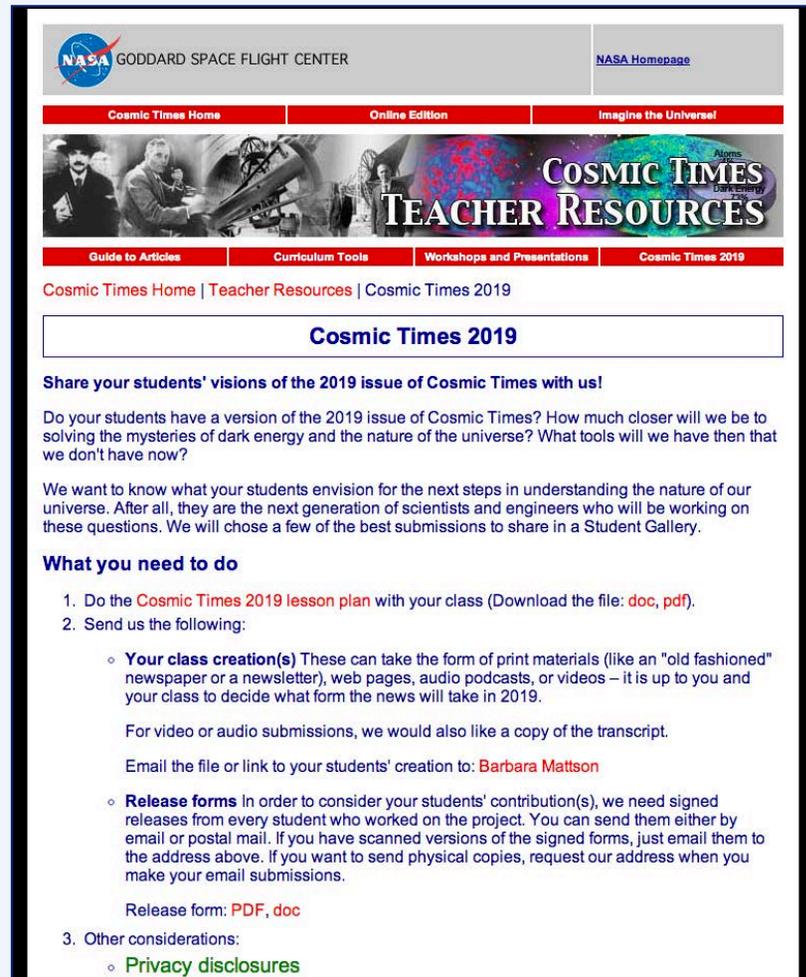
Cosmic Times'

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



2019 Cosmic Times '19

- ' In our “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:
 - o **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](#)

- o **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:
 - o **Privacy disclosures**

Universe Mash-up '

New project-based lesson plan and materials where students create a media mash-up related to Cosmic Times themes

NASA GODDARD SPACE FLIGHT CENTER

NASA Homepage

Cosmic Times Home Teacher Resources Universe Mash-up Imagine the Universe!

COSMIC TIMES ONLINE

Media Archive Frequently Asked Questions In the Classroom

Media Archive

Accretion Disk

URL: http://nsf.gov/news/mmg/mmg_disp.cfm?med_id=66143

Description: An artist's conception of the accretion disk in the binary star system WZ Sge.

Media Available: This page contains an image showing an artist's impression of an accreting white dwarf star.

Keywords: accretion disk, white dwarf, type 1a supernova, image



Animation of the Effects of Dark Energy

URL: <http://www.nasaimages.org/luna/servlet/detail/nasaNAS-22-22-127998-236204>

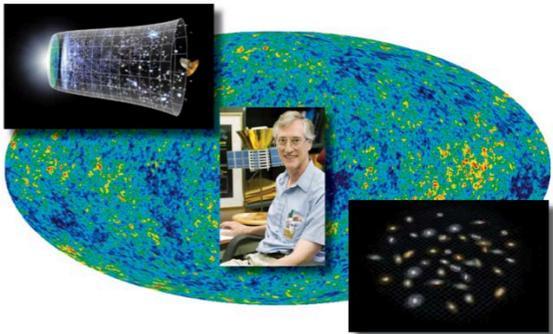
Description: MPEG This animation shows the expansion history of the Universe by modeling the Universe as a two-dimensional grid of galaxies. The Big Bang, shown as a flash of light, is immediately followed by rapid expansion of the Universe. This expansion then slows down because of the gravitational attraction of the matter in the Universe. As the Universe expands, the repulsive effects of dark energy become important, causing the expansion to accelerate. For



NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

Universe Mash-Ups

Cosmology 101 Through Video Mash-up Projects



Curriculum support materials by:

Gerri Cvetic, NBCT
Chesapeake High School
Pasadena, MD

Dr. Barbara Mattson
NASA/GSFC
Greenbelt, MD

These materials were created under NASA's Education and Public Outreach

Universe Mash-up '

Sample mash-up created by our summer intern, Faith Tucker '

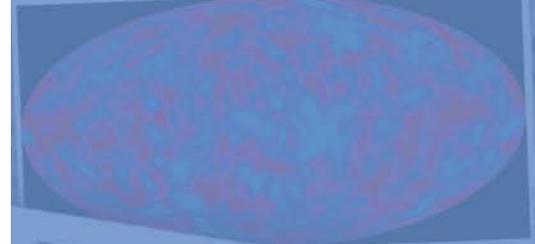


MURMUR OF A BANG

Andromeda Nebula Lies Outside Milky Way Galaxy

Spiral Nebulae are indeed "Island Universes"

Baby Universe's First Picture



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

Einstein Says Neither

SUN'S GRAVITY BENDS STARS

Einstein's Theory Triumphs

Radio 'Ear' on the Universe Being Built

Seeds of Modern Universe

Dark Matter Hunt Heats Up

'Yardsticks' in Neighbor Galaxy Double Universe's Size

Biggest Mystery: What is Dark Energy?

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



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.

actly as arranged, but out of only two showed as many as Prof. Eddington was also more months to take the star field.

Sir Frank explained that both expeditions had photographic plates were taken at the observatory.

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, consisting of aerial uses tall poles to support and concentrate radio waves from thousands of miles away.

perhaps the greatest history of astronomy in London, which

San Diego, Cal. has yet offered. About the watchers in

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 simple yard markers in space, of course. Properly divine the distance of stars is the universe first he had to discover. He has created more than one kind of

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.

Some of the dark matter was found using satellite. ROSAT detected dark matter in a very unusual way. It appears to be

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, consisting of aerial uses tall poles to support and concentrate radio waves from thousands of miles away.

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Sir Frank explained that both expeditions had photographic plates were taken at the observatory.

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

cal constant an annoying fudge any connection to the real universe. Later researchers proposed a logical constant represents an unknown energy. That energy is the cosmos

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.

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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

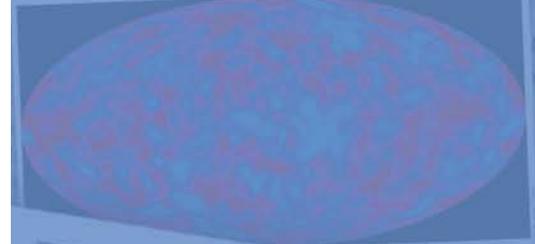
MURMUR OF A BANG

Andromeda Nebula Lies Outside Milky Way Galaxy

Spiral Nebulae are indeed "Island Universes"

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.

Baby Universe's First Picture



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...

SUN'S GRAVITY BENDS STARS

Einstein's Theory Triumphs

perhaps the greatest history of... London, which...

Radio 'Ear' on the Universe Being Built

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, consisting of aerial uses tall poles...

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...

'Yardsticks' in Neighbor Galaxy

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.

Double Universe's Size

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

Biggest Mystery: What is Dark Energy?

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

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



Classifying Nebulae

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

Teacher Resources'

NASA GODDARD SPACE FLIGHT CENTER [NASA Homepage](#)

[Cosmic Times Home](#) [Online Edition](#) [Imagine the Universe!](#)

COSMIC TIMES TEACHER RESOURCES Atoms Dark Energy

[Guide to Articles](#) [Curriculum Tools](#) [Workshops and Presentations](#)

[Cosmic Times Home](#) | [Cosmic Times Teacher Resources](#)

Cosmic Times Teacher Resources

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.

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](#)

Follow us on Twitter
[@NASACosmicTimes](#)

Guide to the Articles '1929 Cosmic Times

The screenshot shows a web browser window with the URL cosmictimes.gsfc.nasa.gov/teachers/guide/1929/index.html. The page header includes the NASA logo and "GODDARD SPACE FLIGHT CENTER" with a link to the "NASA Homepage". Below the header are three red navigation buttons: "Cosmic Times Home", "Online Edition", and "Imagine the Universe!". A large banner image features the text "COSMIC TIMES TEACHER RESOURCES" over a collage of historical astronomical images and a colorful galaxy map. Below the banner is a table with three columns: "Guide to Articles", "Curriculum Tools", and "Workshops and Presentations". The "Guide to Articles" column has sub-links for the years 1919, 1929, 1955, and 1965. The "Workshops and Presentations" column has sub-links for 1993 and 2006. A breadcrumb trail reads: [Cosmic Times Home](#) | [Teacher Resources](#) | [Guide to Articles](#) | [1929 Cosmic Times](#). The main heading is "1929 Cosmic Times". The text below explains that this poster is the second edition of the Cosmic Times, published to coincide with Hubble's discovery of an expanding universe, contrary to Einstein's static universe model. A list of links includes: "Download 1929 poster, newsletters, and glossary", "Teacher's Guide to the 1929 articles", and "1929 Lessons". A thumbnail image of the 1929 Cosmic Times poster is shown on the right. At the bottom, there is a link to "Order your set of Cosmic Times posters through the Imagine the Universe! Request Form" and a section titled "1929 Article Overview".

NASA 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	
1919	1929	1955	1965	1993	2006

[Cosmic Times Home](#) | [Teacher Resources](#) | [Guide to Articles](#) | [1929 Cosmic Times](#)

1929 Cosmic Times

This poster is the second edition of the Cosmic Times, with the publication date chosen to coincide with the announcement of Hubble's results which found that the Universe was expanding. These results were contrary to Einstein's assumption of a static Universe. In addition, in order to show that the galaxies were all moving away from us, Hubble first showed that there *were* other galaxies outside the Milky Way.

- [Download 1929 poster, newsletters, and glossary](#)
- [Teacher's Guide to the 1929 articles](#)
- [1929 Lessons](#)

Order your set of Cosmic Times posters through the [Imagine the Universe! Request Form](#)



1929 Article Overview

Keyword Clouds'

Cosmic Times Keyword Clouds

NASA GODDARD SPACE FLIGHT CENTER [NASA Homepage](#)

[Cosmic Times Home](#) [Online Edition](#) [Imagine the Universe!](#)

COSMIC TIMES TEACHER RESOURCES Atoms Dark Energy

[Guide to Articles](#) [Curriculum Tools](#) [Workshops and Presentations](#)

[Cosmic Times Home](#) | [Curriculum Tools](#) | [Cosmic Times Keyword Clouds](#)

Cosmic Times Keyword Cloud

Below is a keyword cloud for all of the Cosmic Times articles and lessons. A keyword cloud is a visualization of keywords associated with the Cosmic Times articles and lesson plans. The size of each tag in the cloud is related to the number of lessons and/or articles associated with that keyword. Clicking a keyword will bring you to a list of articles and lesson plans that are related to that keyword.

We have [Other Keyword Clouds](#), including those based on key scientists and event dates.

age of the universe andromeda astronomical images bending starlight
big bang brief biography cepheid variable stars
cosmic microwave background
cosmology crab nebula **dark energy** dark matter data debate

Master Download Page

The screenshot shows a web browser window with the URL cosmictimes.gsfc.nasa.gov/teachers/curriculum/downloads.html. The page header includes the NASA logo and 'GODDARD SPACE FLIGHT CENTER'. Below the header are navigation links: 'Cosmic Times Home', 'Online Edition', and 'Imagine the Universe!'. A central banner features the text 'COSMIC TIMES TEACHER RESOURCES' with images of scientists and a telescope. Below the banner are more navigation links: 'Guide to Articles', 'Curriculum Tools', and 'Workshops and Presentations'. The main content area is titled 'Cosmic Times Downloads' and contains the following text: 'Below are all of the downloads of materials for the Cosmic Times suite of materials.'

Poster	Newsletters	Glossary & Questions	Lesson Plans
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)	<p>1919 Lesson Bundle (zip files) (PDFs, Word docs*) *Note that the PDF of the influenza reading is included in the Words file.</p> <p>Einstein and His Times (PDF, Word) Readings:</p> <ul style="list-style-type: none"> • Influenza Article (PDF) • Letter From Camp Funston (differentiated lesson) (PDF, Word)