September 2001 Number 18

Big Picture Science Newsletter

Science information for Montessori teachers of 6-15 year-olds

Big Picture Science News

This year, I've chosen astronomy as the subject for Big Picture Science Newsletter. The rest of this year's issues will address celestial objects, galaxies, and our solar system. The next issue will address stars and their life cycles.

I introduce the basic building blocks of matter and the four fundamental forces in this issue, but I am leaving the concept of force-carrying particles for those who are interested in this very abstract subject. See the resources on p. 7-8 if you or your students want to delve further.

Wishing you peace in your universe,

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Contents

The Early Universe

How can we help students imagine the unimaginable?

The first great lesson begins with the biggest bang of them all. All we can give students is an impression of the event. We can, however, make it an accurate impression of what is currently known about this ultimate beginning and the events that followed.

The first Great Lesson truly starts at the beginning – the beginning of time, that is. Teaching about the early universe is quite a challenge. It requires students to learn about many things that they can only imagine, not experience first hand. The lesson is much more than just the raw facts, however, as we explore the question, "Where did the universe come from?" There are **several levels of information** from which to choose and facts can be integrated with a story-telling approach.

We call the series of events at the beginning of the universe "the **Big Bang**", although some cosmologists say that "the **Big Stretch**" would be a better name. Names are hard to change, so I'll stick with the Big Bang, even though there is no explosion as we know it involved. We know about explosions of matter. The **Big Bang was an explosion of space**.

When we talk about the size of the universe, we are discussing the **visible** universe, that which we can detect. We do not know and cannot say anything about the time before the Big Bang or the space beyond the visible universe because we cannot detect anything from there (or even if there is a "there" there).

The amount of detail that students can use varies a great deal with their age level and ability to handle abstract material. In the description of the early universe and elementary particles, scientists use **very small and very large numbers**. This is quite a mathematical challenge for those not familiar with scientific notation, so don't be too concerned about absolute quantities for lessons to beginning students.

For advanced students, you can use the early universe as an opportunity to introduce scientific notation. For those advanced students who wish to study elementary particles, a subject that is most likely to interest middle school and beyond, I've included materials in the resources on page 7.

A timeline will help students get the overall picture of events. You can tailor your timeline to your students' interest level and ability to handle abstraction. I've included several levels of information starting on page 2.

Other abstractions that are part of this study include the **four fundamental forces**, of which we can experience only two, gravity and electromagnetism. Likewise, the fourth state of matter, the **plasma**, is something that isn't common in everyday experience, but is important for understanding of matter at the beginning and the stars that form from it later on. **Simulations** can be a valuable addition to study of the early universe. I have included a number of these on page 5.

Timeline of the Big Bang

The Big Bang can be described at several levels. Teachers will have to judge how much information is appropriate for their students. Below is a basic description of Big Bang events, followed by more advanced material and explanations in brackets. I am leaving out some of the background that needs to accompany the story, such as the structure of atoms, since that is easy to find in encyclopedias, etc. You will need to explain that although eras in Earth history are very long, some eras of the early universe were unimaginably short. You will find many different times listed for the events of the Big Bang, since the times are estimates derived from mathematical calculations, not something that can be measured. I have chosen times that are commonly used. Note that the Big Bang theory describes the expansion and cooling of the universe, not its absolute beginning. There is no explosion in scientists' explanations. Overall, the Big Bang theory is well established. I have included a controversial aspect of it, inflation, since this is an important idea now being tested by the MAP probe, which NASA launched last summer. (see p.4)

A Summary of the Big Bang

About 13 billion years ago, the universe came into existence. It started very small. **Time, space, and energy began**. The **space** quickly **expanded.** First it ballooned out at a fantastic rate (we call this **inflation**), then it continued to expand more slowly. The temperature was **astronomically hot** and matter as we know it could not exist at first. **Radiation** (rays of electromagnetic energy) made up most of the universe. The radiation was very high energy and so hot that it kept being changed to matter and back again. Still, **there was no light** because the universe was so dense. As the universe continued to **expand and cool, matter formed** and became the main thing in the universe. At first there were only parts of atoms. Later it was cool enough for atoms to form, and **then light shown** forth. This was about 300,000 years after the universe began. Later, the matter, which was **huge clouds of hydrogen and helium, clumped into galaxies** with their millions and billions of stars. As stars were formed and later collapsed and blew apart, the **other elements** that make up the matter we know **were formed**. Later galaxies were calmer, and in one of these, our Sun and its planets formed.

Eras of the Big Bang

(Note: it is impossible to do even an approximate scale for this timeline. Estimated time spans are given occur at the end of each period. They are approximations from the mathematical equations of theoretical physics, like the descriptions of early events. The transitions of matter and energy are something like transitions in states of matter. We can say that quarks "froze" into protons and neutrons, for example, since there was no longer enough energy to drive the opposite reaction.)

1. **The vacuum era or Planck time**. The observable universe was only a tiny speck. In the first instant, energy, space, and time came into existence. Space expanded. All four fundamental forces acted as one – they were all unified. Time – miniscule

   [The Big Bang was not a huge explosion. It was a huge expansion of space. There was no great flash of light. It was incredibly hot and dense. The temperature (estimated to be 10^{32} degrees Kelvin – that's 1 followed by 32 zeros!) was so high that the "stuff" of the universe was only energy. This era is called Planck time after Max Planck, the physicist who theorized the events.]
2. **The era of inflation**. Space blew apart. The universe expanded at an enormous rate, tremendously faster than it is expanding today. Time – a tiny fraction of a second

   [Inflation helps explain the large-scale structure of the universe. During that fraction of the second, the universe grew more than a billion billion times, leaving tiny irregularities that later contributed to the bubble-like structure of galaxies. See MAP on p. 4.]
3. **The Grand Unified era – particle soup**. Gravity separated from the other forces, leaving the strong nuclear force, the weak nuclear force and electromagnetism united. The first building blocks of matter, elementary particles, formed. Time – much less than 1 second

   [The particles that condensed (quarks and leptons and their antiparticles) were easily converted from one to another at the high temperature, even though the universe had cooled 10,000 fold from the beginning. Matter and antimatter annihilated each other and were changed to high energy photons, but there was a slight excess of matter. This left a dense mix of particles and radiation.]

4. **The electroweak era**. At the beginning of this era, the strong force separated from the other two forces. The first building blocks of matter formed. At the end, electromagnetism and the weak force split. Since then, the four fundamental forces have been separate. Time - about 0.0001 second [First, quarks and leptons became separate particles that could not convert to one another. Then the strong force bound the quarks into protons and neutrons. No free quarks exist after this – they are "frozen" into larger particles. The temperature dropped another 100 billion times, but was still hotter than the Sun's surface. We can recreate the unification of the electromagnetic and weak forces in particle accelerators, but nothing that we think happened before that.]
5. **The era of nucleosynthesis**. The strong force coupled the protons and neutrons into the nuclei of atoms. Matter existed as a plasma. The temperature cooled to a billion degrees Kelvin. Time – 3 sec [The temperature was still too high to permit electrons to orbit atomic nuclei. Most of the matter was in the form of hydrogen nuclei – single protons. About a quarter of it became helium nuclei (2 protons and 2 neutrons). Small amounts of deuterium (hydrogen with one proton + one neutron) and helium-3 (with only one neutron) formed. A very tiny amount of the nuclei of the next heavier elements, lithium and beryllium formed. By the time these elements had formed, the temperature was too low to fuse the nuclei into any heavier elements. Elements such as carbon and oxygen came later, forged inside giant, dying stars. *The kinds and ratios of atoms that the Big Bang theory predicts are what we find if we look at a section of space where no stars have formed or at the oldest stars. This is important evidence for the theory*.]
6. **The era of coupled matter and radiation**. Matter was a plasma of particles. Light could not shine because the photons kept bouncing back and forth between the matter. The universe was still hot and dark. Time – until about 300,000 years
   [The universe was still so dense and hot that matter existed only as a plasma of charged particles, electrons and positively charged atomic nuclei. These interact strongly with photons, absorbing and emitting them. The photons were being stretched to longer wavelengths throughout this time.]
7. **The era of first light**. Matter and energy separated. It was cool enough for electrons to orbit atomic nuclei and the first atoms formed. Matter became hot gas instead of plasma. The first light shone throughout the universe. Time – about 300,000 years
   [The temperature had dropped to 3000° K. Photons streamed out between the atoms. The first light was in the visible range of wavelengths, but as space continued to expand, the wavelengths were stretched longer. *We can still see what is left of this first light as the cosmic microwave background radiation, important evidence for the Big Bang theory*.] (See p. 4)
8. **The cosmic Dark Ages**. During this time, great clouds of gases begin to condense into galaxies and stars. Time – from about 300,000-900,000 years
   [The background temperature dropped to about 20°K. The light from the Big Bang dissipated. Clouds of hydrogen molecules nearby absorbed the light the sparse new stars made. Although it was bright near individual stars, the universe as a whole was dark.] (See references for more details.)
9. **The bright era**. The many stars and galaxies illuminate the sky. Time - about 1 billion years to the present.
   [As many stars ignited and the galaxies grew, their ultraviolet light ionized the hydrogen around them and light shown once more. The galaxies are not evenly distributed. They have a foam-like structure – walls and bubbles of galaxies with voids in between. The first galaxies had supermassive black holes at the center. (Supermassive black holes have the mass of about a million suns.) As these black holes pulled in the stars around them, they released huge amounts of energy. A telescope is a time machine. When we look to the edge of the visible universe, we can see these early galaxies because of the enormous radiation from their black holes. They are called **quasars**. (That's short for quasi-stellar objects.) The background temperature of the universe is now about 3° K.]

Summary of events – matter and forces:

First particles →	Quarks and leptons (electrons) →	Neutrons and protons →	Nuclei of atoms →	Whole atoms
4 forces united	Gravity is separate 3 forces united	Strong force binds quarks	Strong force binds neutrons & protons	Electromagnetism binds electrons & nuclei

How do we know there was a Big Bang?

There are **four main lines of evidence for the Big Bang**. First, in the nineteenth century, an astronomer named Heinrich Olbers looked at the night sky and wondered why any of it was black. If the universe was infinitely old, then the light of the infinite stars should make the whole sky light. We call this idea "**Olber's paradox**.". Since the night sky is mainly black, he concluded that the **universe is not infinitely old**. It must have had a beginning.

In the late 1920's, a scientist named Edward Hubble discovered that **other galaxies are moving away** from us. He could tell this by looking at the spectrum of light coming from the galaxies. The lines that come from hydrogen were shifted in their position in the spectrum. We call this effect the red shift, because the lines moved toward the red end of the spectrum. This happens if the light and its observer are moving apart at high speed. In this case, it is space that is getting bigger and increasing the distance between the two. The data showed that the **farthest galaxies were moving away faster than the closer galaxies**. Scientists thought about what it would look like if time were reversed (like running a video backwards), and they knew that the **galaxies were once packed together**.

Another important piece of evidence is the **cosmic microwave background radiation**. This was discovered in 1964 by researchers who were trying to use microwaves for communications. They found that there was a faint background "noise" of microwaves at a certain frequency, no matter which way they aimed their antenna. Later, astronomers launched a space probe called COBE (Cosmic Background Explorer) which imaged the cosmic microwave background radiation. The fact that this radiation exists says that **light rays shown throughout whole universe at once** a long time ago. One astronomer called these microwaves "the universe's baby picture". Astronomers recently launched another probe called MAP to study the cosmic microwave background radiation in greater detail. (see below)

The last major line of evidence is the chemical elements that are found in starless regions of space. They are hydrogen, deuterium (hydrogen with a neutron in its nucleus), helium, and traces of lithium. These **elements and their proportions are what the Big Bang theory predicts**, from the properties of neutrons and protons. Neutrons can decay into protons (along with electrons and other particles), but the reverse can happen only at extremely high energy levels. If neutrons and protons were initially equal, and many of the neutrons changed to protons, then the resulting mix would yield the ratios of hydrogen and helium we see today. Furthermore, **the oldest stars have fewer heavy elements than later stars**.

Exploring with MAP – the Microwave Anisotropy Probe

Last June, NASA launched the MAP spacecraft. It will make more detailed measurements of the cosmic microwave background than any other instrument so far. Astronomers want this data because they believe that it will either confirm or refute the concept of inflation. It will help them decide which of their current theories is the most useful for describing the early universe, or it will send them back to the drawing board to construct a different theory.

You can follow the MAP mission on NASA's website, http://map.gsfc.nasa.gov/m_mm.html
The "universe" tab on the first page leads to information about theories of the early universe.

What is a .....?

Kelvin scale – a scale used to measure temperature. Zero degrees Kelvin is absolute zero, the temperature at which molecules and atoms stop moving. This is the lowest temperature possible. To convert degrees Kelvin to degrees Celsius, subtract 273 degrees. Water boils at 373°K.

Plasma – a state of matter possible only at very high temperatures in which one or more electrons are stripped from their atoms. The atomic nuclei and free electrons form a dense, gas-like mixture. Plasmas are formed from gases, but unlike them, plasmas conduct electricity. Plasmas make up the most of the visible matter in the universe, including stars. Gases can become plasmas when they are subject to extremely high heat or electrical discharges. On Earth, tiny amounts of plasma are formed in lightening strikes. They quickly return to gases after the lightening passes. There are also small amounts of plasmas in fluorescent light bulbs.

Simulations to help students think about the early universe

While there are no direct hands-on activities that concern the early universe, there are demonstrations and simulations that can help students think about these mind-boggling events. Here are some to try.

The expansion of space and inflation – You need a large toy balloon with a light color. Before your demonstration, blow up the balloon and use a Sharpie-type pen to make a number of spots that are about 1½ inches apart on it. Deflate the balloon. Show the children the spots and have them measure the spaces between them. Then blow up the balloon. As you begin to blow, put one big breath into it so that it pops out quickly to a larger size. Then blow slowly and steadily so that it expands more slowly. When the balloon is blown up, have the students measure the distance between the spots. Ask them if the spots moved. (No, only the material between the spots expanded.)

Red shift, the Doppler Effect – (Taken from the Exploratorium Science Snackbook) While you would have a hard time showing red shift with light, you can easily show Doppler shift with sound. You need a noise-maker such as an electric buzzer, battery operated. You can buy these at Radio Shack. Place the buzzer and its battery in a container with about 4 feet of sturdy cord attached. A tennis ball that has been split halfway open works well. You can tape up the slit after you have filled it and leave two wire ends hanging out so that you can connect and disconnect the circuit. Turn on the buzzer and swing the ball around in a large circle. You should be able to hear the rising and falling frequency as the sound waves are compressed and stretched. (Make sure you try this without students first and provide a safe area to swing the ball without hitting anything.) Explain that when light waves are stretched, they get redder and when they are compressed, they get bluer. Astronomers can tell from the shift in light waves from a star or galaxy whether gravity is pulling it closer or it is being carried farther away by the expansion of space.

Quarks and the strong force – You can model the properties of the strong force and the structure of nucleons (protons and neutrons) with Styrofoam balls and a large rubber band. You will need three Styrofoam balls about 1½ inches in diameter. Pass the rubber band around the middle of each ball and use string or heavy thread to tie the rubber band together between the three balls. You will end up with three balls drawn together at the center. Explain that this is like the strong force holding quarks in protons and neutrons. The strong force acts over a very short distance. If a quark moves away a little bit, the strong force gets stronger. There is a point past which the strong force can act. Imagine what it would be like if you pulled one of the balls so far that the rubber band broke.

You can further model protons and neutrons if you have 6 balls. Paint three one color (red for example) and three a second color (green for example). Fasten two red and one green together. Fasten the remaining three together as well. The red symbolizes an up quark and the green, a down quark. (Explain that physicists needed words to label different kinds of quarks, so quarks have strange names that do not describe their properties.) The "particle" with two up quarks and one down quark is a proton. A neutron has one up quark and two down quarks. The up quark has a charge of +2/3 and the down quark has a charge of -1/3. (Yes, quarks are weird – they have fractional charge.) The neutron ends up with zero charge and the proton with a +1 charge. You can label the quarks with their charge and have students discover the total charge on protons and neutrons or which is a proton and which is a neutron.

The cosmic structure of galaxies – You need a pan of water, dish detergent, and a jar or flask. Fill the container with soapy water, place your hand over the opening, and invert the container. Spread your fingers apart just a little bit so that the solution leaks out in spurts and bubbles enter the container. When the solution is gone, you should have a container full of large bubbles. In the universe, the galaxies and other celestial objects are mainly on the walls of a huge bubble-like structure. One of the main structures is called the Great Wall of Galaxies. In between there are regions of space that have little matter.

How space could be finite, but boundless – You can model a two dimensional space that curves back on itself with a Mobius strip. First make a ring by taping together the ends of a strip of paper. Show students that there is an outside and inside surface. Then make a Mobius strip (see an encyclopedia if you need instructions) from similar strip of paper and challenge students to draw a line along the whole outside. This is a model of a closed, two dimensional space. It's a little tough to jump to a closed three-dimensional space, but a fun stimulus for thought.

The Four Fundamental Forces

A force is something that changes the shape, size, or motion of an object. It can be defined as a push or a pull. We can't see a force, but we can see the result of a force – a change in matter. Forces are what hold together the physical structure of the universe. All the forces in the universe can be classified as one of four fundamental kinds. Here is a summary of the properties of the four fundamental forces.

Name of force	Distance it acts	Relative strength	Other properties
Gravity	Infinite – obeys the inverse square law	Extremely weak Only a tiny fraction of the strong force.	Gravitational attraction is a property of matter. It is directly proportional to mass. It is the least understood force. It holds planets, moons, stars, and galaxies together.
Electromagnetism	Infinite – obeys the inverse square law	About $1/100^{th}$ (1%) of the strong force	This force can be attractive or repulsive. It acts only on charged particles. It binds electrons to the nucleus of atoms and binds atoms into molecules.
Strong force (also called strong nuclear interaction)	Tiny – diameter of an atomic nucleus; 1/100,000 of an atom's diameter	The strongest force, but only strong at very short distances	The strong force holds quarks together in protons and neutrons and binds the atom's nucleus. Within limits, it gets stronger if the particles start to move apart. Since it is only about 100 times as strong as electromagnetism, the largest stable atomic nucleus has less than 100 protons.
Weak force (also called weak nuclear interaction)	Smallest – 1/100 the diameter of an atomic nucleus	Weak, a small fraction of the strong force, but much stronger than gravity	This is the only force that effects neutrinos. It acts in beta decay and other types of radioactive decay in which neutrinos are involved. It plays a role in the fusion reactions that power the Sun and in radioactivity that heats the Earth's core.

The Standard Model of Elementary Particles

Particle physics can quickly become overwhelming. This material is for upper elementary and higher. Below is a diagram that shows the particles we find in ordinary matter. The symbols for each particle are given in square brackets. (For more information, see the Particle Adventure website and books on p.7.)

<table>
<tr><td colspan="2">Hadrons are made of quarks - the strong force acts on them.</td><td colspan="2">Leptons are not made of quarks and therefore not effected by the strong force.</td></tr>
<tr><td colspan="2">Baryons are the hadrons made of three quarks.</td><td rowspan="3">Electrons have a mass of about 1/1800 of the proton and carry a negative (-) charge. They are fundamental – not made of anything smaller. [e^-]</td><td rowspan="3">Neutrinos have little or no mass and no charge. They hardly interact with ordinary matter. The Sun sends a constant stream of neutrinos to and through the Earth. [v, the Greek letter nu]</td></tr>
<tr><td colspan="2">Nucleons are the baryons that occur in the nuclei of atoms of ordinary matter.</td></tr>
<tr><td>Neutrons (two down quarks and one up quark) have no charge. They have slightly more mass than protons. [n^o]</td><td>Protons (two up quarks and one down quark) have a positive (+) charge. [p+]</td></tr>
</table>

Resources for studying the early universe

Dewey decimal numbers – the universe (520, 523.1), particle physics (539.7)

LE = lower elementary; UE = upper elementary; MS = middle school; HS = high school

Books for students

Asimov, Isaac. 1995. ***The Birth of Our Universe***. Gareth Stevens, Inc. ISBN 0-8368-1192-5. This updated version of Asimov's original work has a good basic explanation of the Big Bang and several useful size comparisons, such as the distance to the farthest quasars if the Milky Way were a foot across. LE-UE

Couper, Heather and Nigel Henbest. 1997. ***Big Bang: The Story of the Universe***. DK Publishing. ISBN 0-7894-1484-8. I include this book because you are likely to find it in libraries. The illustrations are useful, but there are many inaccuracies in the information. Its "facts" about the beginning of the Big Bang and inflation have inaccuracies. See below for a new DK book on the Big Bang. UE-MS

Kallen, Stuart A. 1997. ***Exploring the Origins of the Universe***. (Secrets of Space series) Twenty-first Century Books. ISBN 0-8050-4478-7. This book covers the history of people's ideas about the universe and its origin, but is weak on the Big Bang itself. UE-MS

Simon, Seymour. 1998. ***The Universe***. Morrow Junior Books. ISBN 0-688-15301-1. This book has many photographs and drawings to illustrate its solid introduction to the universe. It includes good information on quasars. LE-UE

Stwertka, Albert. 1995. ***The World of Atoms and Quarks***. Twenty-first Century Books. ISBN 0-8050-3533-8. This includes good information on the four fundamental forces and the Standard Model of elementary particles. UE-MS

The Universe. 1998. (Time-Life Student Library) ISBN 0-7835-1354-2. This is a well-done, well-illustrated reference for UE-HS.

Wells, Robert E. 1995. ***What's Smaller than a Pygmy Shrew?*** Albert Whitman & Co. ISBN 0-8075-8837-7. This little book is a great introduction to elementary particles. Although primarily for LE, some UE would likely learn from it as well. See also by Wells, ***Is a Blue Whale the Biggest Thing There Is?*** Albert Whitman & Co. ISBN 0-8075-3655-5. It introduces the sizes of stars, galaxies, and the universe.

Books and magazine article – References and adult background

Clark, Stuart. 1995. ***Stars and Atoms: From the Big Bang to the Solar System***. Oxford University Press. ISBN 0-19-521087-5. This book has good diagrams of the four forces splitting off and of the particles during the Big Bang. MS-adult

Cowen, R. **"Light's Debut: Good Morning Starshine!"** Science News Magazine, Vol. 160, No. 6, Aug. 11, 2001. This article describes the cosmic dark ages and their end. There is a color diagram. MS-adult.

Croswell, Ken. 1999. ***Magnificent Universe***. Simon & Schuster. ISBN 0-684-84594-6. This is a gorgeous, large format hardback with beautiful illustrations. It has a valuable chapter on the universe, as well as chapters on planets, stars, and galaxies. LE for illustrations, UE-adult

Dickenson, Terence. 1999. ***The Universe and Beyond***. 3rd edition. Firefly Books. ISBN 1-55209-377-8. This includes a good overview diagram of the universe's structure. It is heaver on text than some, but the writing is well-done and interesting. HS-adult.

Filkin, David. 1997. ***Stephen Hawking's Universe: The Cosmos Explained***. Basic Books. ISBN 0-465-08199-1. This book is based on the PBS series. See page 154-155 for a diagram of the early universe. These pages – "The story as far…" – have a good Big Bang summary. MS-adult.

Gribbin, John. 1998. ***Almost Everyone's Guide to Science: The Universe, Life, and Everything***. Yale Nota Bene. ISBN 0-300-08460-9. This is a good guide to the scientific method and to science content. For adult background. See the footnote on p.210 for a perspective on the Big Bang.

(Continued on page 8)

Lidsey, James E. 2000. ***The Bigger Bang***. Cambridge University Press. ISBN 0-521-58289-X. This has good background information for the general reader, covering the basic physics and events. HS-adult.

Spence, Pam (general editor). 1998. ***The Universe Revealed***. Cambridge University Press. ISBN 0-521-64239-6. This has a diagram of the early universe that shows the particles. Illustrations for LE. UE-adult.

Tyson, Neil de Grasse, Charles Liu, and Robert Irion. 2000. ***One Universe: At Home in the Cosmos***. Joseph Henry Press. ISBN 0-309-06488-0. This beautiful, large format hardback is organized around the themes of motion, matter, energy, and frontiers of cosmology. It is a great help with background information on particles and forces, as well as the early universe. LE for illustrations, UE-adult

Forthcoming books and other resources

These books are soon-to-be published.

Morgan, Jennifer. 2002. ***Born with a Bang: The Universe Tells Our Cosmic Story***.

Parsons, Paul. 2001. ***The Big Bang: The Beginning of the Universe***. DK Publishing.

Swimme, Brian. 2001. ***The Unfolding Universe***. ISBN 1-56331-842-3.

I have not seen this book, but the reviews looked interesting:

Kook, Professor Ima. 2000. ***The Big Bang Theory: The Bang that Created Our Universe***. (As Dreamed by Itsy #3) ISBN 1-892298066. A little girl dreams about the Big Bang. LE

Internet sites

http://www.damtp.cam.ac.uk/user/gr/public/bb_home.html
Cambridge Cosmology: The Hot Big Bang – the history of our universe and galaxies sections are good. There is an animation available in the section on galaxy clusters that shows the location and magnification of the Hubble deep-field image (a picture of distant space with many galaxies).

http://www.pbs.org/deepspace/timeline/
Mysteries of Deep Space Timeline from PBS – events of the Big Bang

http://map.gsfc.nasa.gov/m_mm.html
NASA's site about the MAP (Microwave Anisotrophy Probe) mission; click the universe tab for Big Bang information

http://imagine.gsfc.nasa.gov/docs/features/exhibit/map_exhibit.html
NASA's Imagine the Universe for middle school (Their elementary site, Star Child, is very watered down) – the MAP probe and the structure of the early universe. See the link to Introduction to Cosmic Background Radiation for a basic tutorial. Follow the links to Imagine Science and FAQs for more information about the universe in general, as well as quasars and galaxies.

http://csep10.phys.utk.edu/astr162/lect/cosmology/hotbb.html
The Hot Big Bang from University of Tennesee

http://cfa-www.harvard.edu/seuforum/explore/bigbang/bigbang.htm
Introduction to the Big Bang from the Smithsonian Institute and Harvard; see the briefing room for basic information.

http://www.particleadventure.org
Particle Adventure - This is a basic tutorial on elementary particles, good for middle school and up.

http://www.sciam.com/specialissues/0398cosmos/0398peebles.html
This is an update of an article that first appeared in Scientific American in Oct. 1994. It is entitled "The Evolution of the Universe".