The Universality of The Universe

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Overview

This unit is designed to add enrichment to a 10th grade honors chemistry course. I teach gifted students and try to show application of coursework to the world and other areas of science. It is especially important to show these students some of the many science specialties. Cosmology, as such, is not part of any chemistry curriculum or for that matter any standard high school science curriculum. Rather than teach this material as an individual unit I have designed course material and activities to enhance several standard units of a chemistry course.

When students learn how to use numbers in scientific notation, I will introduce them to some real numbers associated with the universe. Again these numbers will be used when students learn dimensional analysis. When I teach atomic structure I also teach nuclear chemistry and discuss binding energy and nuclear energy. A natural example of these is the formation and death of stars and the formation of planets such as earth. The next unit focuses on electron configuration and quantum mechanics. As part of this unit we study light spectra. An extension of this unit will involve the analysis of light from space. The conclusion of the unit on the structure of the atom will be a discussion of String theory and the most fundamental particles of matter will be related to the Big Bang theory.

Rationale

Besides the work being done at the molecular level in Biology, recent developments in science have been in the area of furthering our understanding of the cosmos. This work is the result of many years of data collection, improved instrumentation, improved computing powers and a belief that there was a unifying principle that could unite and explain the seemly complex and diverse scientific phenomena at the basic level of an atom and at the immense level of the Universe. The recent photographs from Mars captured public and student interest and again raised interest in outer space, both as an area of fascination and as controversy for the money spent.

Recently on PBS two of the most brilliant minds in physics- Brian Greene and Stephen Hawking- have created TV series, which explain the Universe and String Theory. These shows sparked an interest in both students and the public. As educators we need to be able to discuss these topics with our students and help the shows be more accessible. Students will naturally demand that their science courses be current. The availability of these shows provides a rich teaching resource and brings these fine scientists to the students. It is not often that students can see and listen to such erudite professors explain their work with a passion and with a simplicity that is understandable to a 10^{th} grader. The TV shows are also able to animate difficult concepts and use photographs and other actual artifacts to demonstrate both how the data was obtained and the implications. Both these men have also written books for the mass market. Again students are able to read the writings of these scientists and realize the value of any scientist who can communicate at a non-technical level. The books have diagrams and photographs which are more sophisticated than any high school text.

The science curriculum in the Pittsburgh Public Schools expects that most students will complete the required three units of science with Biology in 9^{th} grade, Chemistry in 10^{th} grade and Physics in 11^{th} grade. Earth and Space science is offered in some schools, as an alternative, for the students who have weaker math backgrounds. Students with a strong science interest may then take a second level course in Biology, Chemistry and Physics in 12^{th} grade. These are offered as AP courses with very specific objectives. With these curriculum choices, able science students are not exposed to any study of cosmology and have no knowledge of this field. As a chemistry teacher of the more advanced classes I would like to integrate some of the ideas of cosmology so that students have a broader knowledge base, as well as an appreciation of how that knowledge was obtained. Rather than teach a separate unit on cosmology I would like to integrate topics into the regular Chemistry curriculum and show the interconnection of the different sciences.

Contrary to how we teach science, it is not neatly compartmentalized. Modern Biology is described by the behavior of molecules and by the transfer of electrical impulses, requiring both an understanding of physics and chemistry. To understand the universe a study of physics and chemistry is required. A further understanding of the beginning of the universe helps us to understand the composition of matter so that we can better manipulate atoms to manufacture materials to provide more efficient computing power or to build designer drugs and genes to combat illness. The National Science Education Standards, as developed by the National Academy of Sciences, promotes the idea that conceptual and procedural schemes unify science disciplines and provide students with powerful ideas to help them understand the natural world. If there is a unifying theory then it too must encompass all areas of science so science can no longer be considered to be several mutually exclusive sub-categories. It is important that students see this interconnection.

Like many scientific journeys, the road to our understanding of the cosmos involved the imagination and the belief that there was a simple explanation, which could explain everything in the universe. It also required scientists to see the connection between a discovery in one area of science and the area in which they were studying. Another standard promoted by the National Academy of Science is that students understand that science is a human endeavor with knowledge evolving over time and almost always built on earlier knowledge. Following the historical process of the development of these ideas, helps students to appreciate the contribution of each scientist and that the sum forms a mighty whole. The development of our ideas about the universe was that, the rules that describe the universe around us should also apply to how matter behaves on earth and how it behaves at a very fundamental level.   This belief in a simple explanation has often led to some great intuitive concepts being proposed and later validated by experimentation when the technology advanced. This model of a mind seeking simplicity and reasoning on a broad level is another view of how a scientist thinks. Einstein and Dirac's ideas are wonderful examples for students to appreciate.

Outer space has been the stuff of science fiction for many years and the Star Wars series and movies have captured the imagination of students. Intermingled with the fiction is sometimes real science or science sounding theories. Students are often curious from their readings and will ask about dark matter, the missing mass, neutrinos, etc. I find that I am not always able to answer these questions and do not prove to be as good an example of a rounded science teacher as I would like. Putting together this unit also allows me to increase my own knowledge and better answer these questions. Once I add some of the material to my course I will be opening myself up to questions outside of what I have chosen to discuss. Again I will be vulnerable and need to have an understanding beyond what I present in this unit.

How cosmology will fit in my Chemistry 1 course**.**

The first topic in Chemistry 1 is to learn to express very big and very small numbers in scientific notation and to carry out mathematical operations with these. To add meaning to the math I would like to use many real numbers from cosmology. To improve their handling of large numbers I would ask students to compare some of these numbers and develop an idea of ratios and percentages. Students will also become familiar with the meaning of billion and trillion, which are often used in non-scientific literature. The first unit also involves learning to convert units. Again I would like to use some constants associated with cosmology, such as the speed of light, for some of the problems.

Atomic structure is the third unit of the Chemistry 1 course. A historical development of the structure of the atom is presented. For a standard Chemistry I course, the smallest particles identified are protons, electrons and neutrons. As part of this unit students also study nuclear reactions and binding energy of the nucleus. The energy from the sun and the creation of the different elements would be an appropriate integration in this unit.

The following unit is electron configuration. Students are introduced to the electro-magnetic waves, wavelengths, frequency and energy of a photon. Students learn that the emission spectra of light from energized atoms is a way of identifying elements. Students examine the flame spectra produced when various substances are burned. Examination of the light received from space provides evidence to support the Big Bang Hypothesis. The same analysis that is used in the chemistry lab is also used to identify the elements of matter floating in space. The light received also is shifted to red wavelengths and through the Doppler effect, proves that the universe is expanding. This analysis of light methodology is applicable to both matter on earth and also for matter many billions of miles away.

To understand the distribution of electrons in an atom, quantum mechanics is studied. A limited explanation is possible as the math involved is more sophisticated than is appropriate for 10^{th} grade. At the end of this unit students should be aware that protons and neutrons are not the smallest sub-atomic particles. I would like to introduce the concept of string theory and all the other sub-atomic particles. To tie it all together, I would want to discuss the Big Bang theory and show how this needs to be consistent with our understanding of the composition of matter. From this I would like students to see how endeavors in one area of science further understanding in other areas.

As the material is integrated into the standard units of the chemistry course students will work extra problems or answer questions specific to that topic. By the time we reach string theory students will be struggling to follow all the material. It is always difficult to explain what we cannot visualize. It is also difficult to visualize that which we have never seen and looks like nothing that we have ever seen. Metaphor and language break down at this point. As a culminating activity I would like students to assess some of the different representations of string theory and critically rate them.

Objectives

Primarily I would like students to understand that knowledge of matter implies an understanding of how matter was first formed and hence how the universe began. Although our planet may be one of the only planets that supports life as we know it, the universe however far away is composed of the same atoms and that we ourselves are composed of ancient stars. This is a wonderful opportunity for students to see how universal is the concept of an atom and its sub-particles and that it is not limited to a 10^{th} grade chemistry class. (PPS science standard 1 & 2)

Students will be able to describe how stars are formed and die by using nuclear reactions and determining the energy produced for such interactions. Students will also be able to describe how elements were formed and relate to the graph of binding energy per nucleon versus atomic number. Students will be able to describe how scientists know that these elements are in the universe through the light that we receive from stars. Furthermore students will understand that we see light from the initial Big Bang and that from this light we can determine the age of the universe. (PPS content standard 2)

Other objectives under science standard 2 are that students will be able to describe the sub particles of matter including quarks, bosons and force particles and realize that scientists propose an even smaller basic fundamental particle – a string. Students then will be able to relate the initial seconds of the Big Bang and String Theory.

Students will be able to cite examples of how science advances through building on previous experiments and theories, as well as examples where an intuitive leap and belief in a simple explanation produced breakthroughs and a new way of thinking. (PPS science standard 1)

Students will be able to handle very large and small numbers and be able to make comparisons and use ratios to determine relative size. Students should be able to use some of the standard constants of nature and express them in everyday units or make comparisons to further understand the "size" of these constants. Students will be able to use dimensional analysis to solve problems and convert units (PPS math standard 2)

Students will be able to read scientific explanations from a variety of sources and evaluate them for their clarity and ease of understanding. Students will write an original story, which uses the words associated with string theory as metaphors. (Communication standards 2 & 3)

Strategies

The first unit of my Chemistry 1 course is to teach students to handle very large and very small numbers. I start this unit with a wonderful 10-minute video developed by Roy Eames. This video takes a couple picnicking in Chicago and successively expands the point of view by a power of ten as the camera moves away from the couple. The expansion goes out to the extent of the size of the universe. The camera then zooms back down to the couple and decreases the point of view by a power of ten until a proton is reached. This is understood, at the time of the video, to be the limit of how small we can break down matter. Students are fascinated by this video, but typically I just use it as an introduction, to the need of scientists to describe very large and very small measurements. Now that I have completed this seminar, I can discuss its content better and update the information provided. It was made in the 1950's. In fact it is a wonderful introduction to cosmology and now I wish to integrate it into the upcoming units.

One of the points made by the narrator is that both the world of outer space and the world of the atom have periods of complexity and periods of vast emptiness at their particular level. This begins the idea that there is a commonality between the universe and the basic unit of matter. It also shows that as you change your viewpoint you see different relationships, so that even as we notice areas of greater density and areas of lower density, the universe is in fact uniform.

Students often are weak at handling numbers in scientific notation. They can tell me how to add and subtract exponents algebraically but if asked to carry out operations of adding, subtracting, multiplying or dividing with numbers written in scientific notation, they struggle. A graphing calculator will give them answers but the students are unable to look at two numbers in scientific notation and estimate an approximate answer to the correct power of ten. This means that they are unable to eyeball two numbers and have a sense of how much smaller or larger one number is compared to the other. Generally I just make up random numbers for students to manipulate or express in scientific notation. I will now use the many measurements that I have encountered during this cosmology course, in my worksheets. Many books written for a lay audience use billion and trillion and I would want to ensure that students were familiar with these expressions, especially since these are ambiguous terms and differ in meaning in the US compared to Europe. Students will also be asked to compare quantities and find out how much bigger or smaller two measurements are. For example they could compare the size of the nucleus of an atom to the size of the atom, or the size of the earth to the solar system.

The next unit in Chemistry 1 is to make sure that students can use the metric system and interchange between units. They are asked to use the prefixes for very small measurements but I will also ask them to be more familiar with the larger prefixes such as mega- and giga-. As part of this unit students are introduced to dimensional analysis. Determining the speed of light in miles per second; calculating the distance traveled by a light in a year; using a Plank length to find Plank time: all these calculations use dimensional analysis but again help students determine the relative magnitude of certain common measurements. Students also use dimensional analysis as a problem-solving tool to aid them in reading and setting up problems, without being overwhelmed. Traditionally I have used pharmacy problems to help students develop their dimensional analysis skills but would now use more problems around cosmology.

Then students use their dimensional analysis skills to solve density problems. I would like to add to the standard problems, finding the density of a nucleus, finding the density of an atom, finding the density of the earth, finding the density of a star, finding the density of a black hole, and finding the average density of the universe etc. This should further emphasize the alternating areas of high density and low density found in the universe and in an atom.

The next unit is an introduction to energy and its role in determining the direction of change. I also check for understanding of the electromagnetic attractive force and reinforce its meaning and the circumstances that mean that it is stronger or weaker. Since I want to discuss all four forces, I will also include the gravitational force and compare and contrast it with the electromagnetic force.

In discussing the gravitational force I will describe how pleasing it was to Newton that the force that described the action between matter on earth also accounted for the movement of the planets around the sun.

Now the students are ready to start chemistry. I start with a historical development of the atom and then discuss the composition of the nucleus and isotopes. From this we look at what types of nuclei are most likely to be stable and realize that the ratio of neutrons to protons is critical. Students learn that there is an interaction between the neutron and proton that is strong enough to overcome the powerful repulsive force between two protons. This would be the appropriate time to introduce the strong force and its role in keeping the nucleus together. This would be compared to the electromagnetic force. When we look at the "belt of stability" we discuss what happens to nuclei created that do not fit within this narrow set of stable combinations. At this point the conversion from proton to neutron can be discussed. The positron is then introduced, along with the concept of the antimatter. Students are always fascinated by antimatter and the potential for destruction if the earth were to come in contact with sufficient antimatter. I have learned in this seminar that this is unlikely, but that at the beginning of the universe both antimatter and matter were present and that it is only due to a slight in-balance in the favor of matter that there is indeed a universe. We will discuss particle accelerators and how the positron was discovered. Symmetry tells us that there will be antimatter particles for all the particles. As students write nuclear equations they will realize that antimatter is part of nuclear decay and does exist. The inter-conversion between protons and neutrons also involves the weak force and we will discuss it as the last force type.

From this we discuss binding energy and students calculate it for several atoms and find the binding energy per nucleon. Students learn to use Einstein's famous $E=mc^2$, which they have seen emblazoned on many a T-Shirt. Through calculations they see that a very small mass loss produces large amounts of energy. We look at binding energy per nucleon quantity against mass number and students see that the nucleus becomes more stable as the mass number increases until iron-58 is reached. After this point larger nuclei become less stable. This graph explains why larger atoms undergo nuclear fission and smaller atoms undergo nuclear fusion. Students then calculate the energy produced in nuclear reactions and compare fusion and fission. Students will also calculate the energy produced when a neutron decays to form a proton and an electron and see that this is energetically favorable due to the small mass differential in favor of the neutron between the two particles.

I would then want to use the energy from the sun as an example of fusion and then use the life of a star to better illustrate how we get the elements. Nucleosynthesis describes the formation of matter from the early formation of hydrogen and helium nuclei. It is how stars are formed and how sometimes planets are formed. A star starts out as hot gas of primarily hydrogen and a small amount of helium. When the fast moving hot protons collide there is sometimes sufficient energy for a neutron to form and through the strong force stay with the proton and form a deuterium nucleus. The strong force must be sufficiently strong enough to overcome the repulsion between the two nuclei. This balance between the electrostatic force and the strong force is critical to the formation of earth. If the strong force had been any stronger, then protons would have combined and we would have no hydrogen to fuel the stars or form water. Any weaker, then no other element than hydrogen would have formed. This deuterium atom again can combine with another hydrogen atom and form a helium-3 isotope. The combination of two of these isotopes then forms a helium-4 stable isotope. This is an example of nuclear fusion. Incredibly hot temperatures are needed for this process to occur, but even greater amounts of energy are produced. So a star or our sun glows with the enormous energy that is being produced. When a big star's central hydrogen has all been converted into helium the core is pulled inwards, squeezing it hotter until the helium itself can react. This will only occur in very massive stars where gravity is so powerful that the temperature will reach to a billion degrees. The helium will combine to form carbon-12 and then by a chain of transmutations into progressively heavier nuclei: oxygen, neon, sodium, silicon etc. Finally iron-58 is formed and is the most tightly bound and stable nucleus. Energy must be added before any other element can form. Now there is an in-balance for the star and gravity has the upper hand and the core implodes to form a neutron star. This process produces enough energy to blow off the outer layers of the star and debris containing oxygen, carbon and the other heavy elements are mixed in with the hot hydrogen gas. The mix of these lighter elements in space match the mix found on earth. The intense heat produced in the blast also allows for the endothermic process of forming elements of atomic number greater than 26 right up to uranium at 92.

The carbon, oxygen and iron atoms in the Solar System are fossils from the dusty cloud from which it formed about 4.5 billion years ago: they were made from heavy stars that had already expelled processed debris by that time. These elements represented only two percent of the mass: hydrogen and helium were still the major atoms. Heavier atoms are over-represented on Earth, because hydrogen and helium are volatile gases that escaped from all the inner planets. In contrast, the giant planet Jupiter, is like the sun primarily hydrogen and helium. It was formed from the cooler outer part of the disc that surrounded the newly formed Sun and its own gravity was enough to retain these lightweight atoms.

After developing an understanding for the nucleus of the atom, the next unit looks at how the electron behaves. We first look at electromagnetic radiation and the students become familiar with using wavelength and frequency. The idea of a quantum of light is introduced and calculations involving Plank's constant are used to compare different forms of electromagnetic radiation in terms of energy and wavelength and frequency. The remaining key concepts of quantum theory: uncertainty principle and wave/particle duality, are introduced. Once we have covered orbitals and possible energy levels for atoms, students observe the flames of various elements burning and learn that emission spectra are a fingerprint of an element. Furthering the theme that what applies in the lab also applies to the universe, we will examine the spectra from the sun and realize how we have determined its composition. Enhancement for this unit will include a discussion of the red shift and its implication, as well as the fact that examining this light allows us to determine the mixture of helium and hydrogen in the universe. Light from the big bang is just reaching us and has been shifted so much that it is now in the microwave range of energy and shows a spectrum consistent with a black body of temperature 2.6 K. This represents the last remnant of energy remaining from the Big Bang and gives the average temperature of the universe. Typically the rest of the unit involves writing electron configurations for atoms.

Before leaving a detailed examination of the atom I usually discuss quarks and string theory. I would like to expand on this more. Students will be given a list of all the particles and discuss how some of these particles have been found and how others are postulated to give the theory a symmetry. We will then discuss the Big Bang, as a means of understanding how matter evolved and hence its composition.

The universe began as a piece of very high energy of the size of a Plank length. Only quantum mechanics applied. Space itself began to expand. The first use of this energy was to form photons and photons with such high energy that they broke up to form particles/ antiparticle pairs. As energy dissipated and the temperature fell, particles gained mass and a mixture of particles developed. The weak force can cause an anti-particle to become the particle. With infrequent interactions such as these, the balance shifted to more particles than antiparticles and matter became possible. At this point the universe was light with a sprinkling of baryonic particles. Now quarks combined to form neutrons and protons. There was still sufficient energy though for protons to form neutrons and positrons or neutrons to form protons and electrons. With further expansion and cooling the only decay possible was that of the neutron and so electrons were also formed. Energy was low enough that neutrons and protons combine to form nuclei. After one hundred seconds, the universe contained protons and helium nuclei in the ratio of seven to one, together with tiny amounts of deuterium and lithium. The formation of the other elements would have been discussed earlier.

At the Big Bang there was only one force particle and it broke up into the four basic particles within a few seconds of the Big Bang. Particle accelerators have been able to produce the boson or the integration of the weak and strong force. Gravity and the theory of relativity remained incompatible with this quantum model and so scientists have proposed String theory to unify the two. The string, a vibrating, multi-dimensional string is proposed to be the fundamental particle and variations on the frequency of vibration creates the different particles of matter. Students should understand that this is the most current explanation but that we have no experimental evidence to explain this. Mathematics has given us some clues. This would end the first quarter of the course.

Classroom Activities

As mentioned above much of this unit is integrated into a current curriculum, just with more emphasis on numbers and facts about cosmology. A series of questions/problems that will be added are included in the appendix.

Some of the other instructional activities include:
The students will view the Ray Eames "Powers of Ten" video as an introduction to using scientific notation and as a means to show the continuum from atom to universe and some similar patterns as well. Students will be asked to write a response to this video. They will also read the opening chapter to Bill Bryson's "A Short History of Nearly Everything." This book was written by a popular travel writer who had always been fascinated by science and made a three year commitment to reading and interviewing scientists so that he would better understand the developments. His overview is well written in language readily understood by a lay audience. He makes good use of comparisons to convey the relationships between different measurements. Students will also be asked to develop a few comparisons of their own.

Students will be required to read several extracts throughout the unit. During the unit on atomic theory and quantum mechanics, the students will read the second chapter, "Snow White and the Particularly little People," from "Once Upon a Universe" by Robert Gilmore. This chapter describes energy levels, uncertainty principle, forces, particles in an atom and binding energy. Students will be asked to describe which analogy was the most effective and give their reasons.

Students will also read chapter 4 from “Just Six Numbers” by Martin Rees. This chapter discusses the strength of the strong force and the implications if its value were to be any larger or smaller. Rees also emphasizes that the mix of chemicals on earth is due to processes which occurred many billions of years earlier and have been traveling space for a long time. This particular selection provides an excellent description of the relationship between mass and energy. Students will be asked to answer a series of questions to check that they have grasped the significance and incredible strength of the strong force. Rees writes beautifully and makes his knowledge very accessible. He is a leading researcher who used to be The Director of Cambridge University’s famous Institute of Astronomy and England’s Astronomer Royal.

Stephen Hawking describes light spectra, the Doppler effect and the interpretation of light gathered from telescopes, in the companion book to the PBS show, “Stephen Hawking’s Universe,” and in “The Universe in a Nutshell.” The former gives written descriptions and the video animates these more, whereas the latter has some very slick graphics. These two examples will be the focus of a class discussion when students will try to explain in their own words what they have understood. We will also discuss the different forms of explanations in the readings. Students will keep these as references and possible sources for their project.

Students will also be required to read the first chapter of Brian Greene’s “The Elegant Universe.” This will be read at the conclusion of electronic configuration and quantum mechanics so that students will understand that although quantum mechanics explained behavior of electrons and other small particles, it was not a good explanation for the macro- world of the universe. Before reading the chapter they will view the introduction to the video “The Elegant Universe.” This is very high tech and gives previews to the Show, as does chapter one for the book. From this chapter students will be given a list of all the sub-atomic particles, the four forces and their particles. The students will be asked to find definitions for the list of words found in the appendix. Then to have the students feel more comfortable with all these names and the many theories, they will be asked to write a story, using a selection of the words as analogies to illustrate the meaning of the words. Many times words from science become part of everyday language. Being scientifically literate will enrich anyone’s writing. An example of such writing is a story written by Woody Allen in the New Yorker(July 28, 2003). This example does not use the words to reflect their meaning, but is a clever story using such words as quarks, bosons, etc. Writing this analogy forces the students to understand these words better.

Students will read another chapter from “Once Upon A Universe”. The chapter entitled ‘Waking Beauty’, explains the Big Bang theory and how the smallest particles combined to form the universe. Students will be asked to sketch this development based on a time line.

As a final exercise the students will view the last show from the PBS “The Elegant Universe” based on Brian Greene’s book and narrated by Brian Greene. This last segment explains strings and the M-theory and finally branes and ends with the latest theories about how the Big Bang was created. It also explains how multiverses have been proposed as a means to explain the weakness of the gravity force. The graphics, the analogies and the demonstrations are extremely clever.

As a final project students will be asked to pick one concept from a list and find two explanations of this concept. These explanations could be verbal, illustrations, analogies or scenes from videos. Students will be asked to explain the concept in their own words and then evaluate the effectiveness of the two explanations in making a difficult concept clear. Through our classwork they will have been exposed to several examples already, but they will be encouraged to seek other sources for themselves. Students will write an essay critiquing the sources that they found and will also present their work to the class so that all can participate and also hopefully see other examples of clever explanations.

Annotated Bibliography/ Resources

Asczel, Amir. *God's Equation: Einstein, Relativity, and the Expanding Universe.* MJF Books. New York. 1999. A historical development of the ideas in cosmology, the people who championed them and the research which supported the ideas.

Bodanis, David. *$E= mc^2$: A biography of the most famous equation.* Walker and Company. New York. 2000. The last chapter gives a good explanation of nuclear reactions in the universe.

Bryson, Bill. *A Short History of Nearly Everything*. Broadway Books. New York. 2003. An overview of science written for a lay audience. Very readable with many good analogies and interesting historical information, especially about the scientists.

Ferris, Timothy. *The Whole Shebang.* A description of the Big Bang and other cosmological material.

Filikin, David. *Stephen Hawking's Universe: The cosmos explained*. Perseus Books. 1997. The companion to the PBS series of the same name. Good illustrations and historical development.
DVD. *Stephen Hawking's Universe: The cosmos explained.* An excellent show explaining the universe. Also a web site supports this DVD with excellent teacher guides. www.pbs.org./wnet/hawking

Gilmore, Robert. *Once Upon A Universe: Not-so- Grimm Tales of Cosmology.* Springer –Verlag New York. 2003
This uses a fairy tale format to describe topics in cosmology. Many excellent analogies are used and the explanations very thorough. In particular the big bang is very well done.

Greene, Brian. *The Elegant Universe.* First Vintage Books. 2000
An excellent description of string theory and the conflicts of physics, which lead to this theory.

www.pbs.org.elegantuniverse: This web site contains background information to the PBS show about this book. There is a glossary of terms and written descriptions of some of the material explained in the show. The shows themselves can also be played on the computer so that students may access the shows without buying the DVD.

Hawking, Stephen. *The Universe in a Nutshell*. Bantum Books 2001.
A description of string theory, supergravity etc. The photographs and illustrations are fabulous.

Hogan, Craig. *The little Book of the Big Bang: A Cosmic Primer*
Springer –Verlag New York. 1998.
This book provides some excellent summary charts comparing matter, eras of the universe and the basic particles. The explanation of the Big Bang is thorough but written simply enough that an able high school student could understand.

Morning, Gary F. *The Complete Idiot's Guide to: Theories of the Universe.* Alpha Books. 2002. A basic definitions and descriptions to start a beginner. Other sources give better examples and richer descriptions.

Rees, Martin. *Before The Beginning: Our Universe and Others*. Perseus Books. New York. 1998. A very readable description of recent thinking in cosmology with arguments for a multiverse. He also talks about the personalities behind the discoveries.

Rees, Martin. *Just Six Numbers: The Deep Forces That Shape the Universe.*
Basic books. 2000.
This well written text, easily understood by the lay audience, uses a series of numbers whose values control and determine the Universe, as we know it. It is an interesting approach and covers the essentials with the description of each number and the implications of variations to their value.

Silk, Joseph. *A Short History of the Universe*. W.H. Freeman Co. 1997.
Comprehensive and more current than Stephen Weinberg's.

Smoot, George and Davidson, Keay. *Wrinkles in Time.* Avon Books. New York 1993. Not only a good description of the major ideas of cosmology but authors give more explanation of the collection of data and its implications.

Weinberg, Stephen. *Dreams of a Final Theory.* Vintage Books. 1992. Describes the grand quest for a final theory which will unify both the quantum world and also explain gravity.

Weinberg, Stephen. *The First Three Minutes*. Basic Books. 1977. A little out of date but still well written.

Videos for Classroom.

The Films of Charles and Ray Eames. Volume1: Powers of Ten. Pyramid Home Video.

The Elegant Universe. NOVA. WGBH Boston Video.

ACTIVITIES:

1. The following is a list of sample problems that would be added to existing worksheets to give greater emphasis to measurements relating to the study of the universe.

Students should be able to look and find the following to write in scientific notation.

mass of the earth is 5.8×10^{27} grams
radius of the earth is 6.4×10^{6} m
mass of the sun 334,672 x earth's mass
radius of solar system 6×10^{12} cm
radius of a nucleus 5×10^{-3} pm
radius of an atom 100 pm
mass of an average nucleus
mass of proton 1.67252×10^{-24} g
mass of electron 9.1095×10^{-28} g
mass of neutron 1.67495×10^{-24} g
distance of sun to earth 149,600 km
age of earth 4.5 billion years old
radius of Milky Way
distance of earth to Jupiter 778, 330 km
distance of earth to Neptune 4,497,070 km
speed of light 3×10^{8} m/sec
number of planets in the universe 10 billion trillion trillion
number of galaxies 140 billion

Write the above using prefixes more suitable to the size of the measurement.

Performing operations using numbers written in scientific notation.

Determine the volume of an atom, a nucleus, the space included in the milky way
Find the ratio of the radius of a nucleus to that of an atom.
Find the ratio of the radius of the sun to the orbit of the earth around the sun.
Find the ratio of the mass of an electron compared to that of a proton

Using dimensional Analysis
find the speed of light in miles per hour
find the distance traveled in one light year
if voyager travels at 35,000 mph, how long would it take to travel form earth to Neptune ?
If a nucleus is the size of a tennis ball how far away are the electrons ?
If the earth is the size of a pea, how far away is the sun ?

Density problems to add to that unit:
find the density of a nucleus
find the density of an atom
find the density of earth
find the density of the sun
the universe comprises 2 atoms of matter per m3, what % of the volume of the universe is matter ?
find the density of a black hole.

PROJECT 1.

Many times words from science become incorporated into common usage. For example ' The new regulation created entropy within the organization .' You are to write a one and a half to two-page story using 14 of the following words in a non-science context. You are to incorporate the words so that they loosely have their true meaning in other words are forming an analogy. You are not trying to create a hokey way to give the scientific definitions of these words. You are also to give the scientific definition of every word in the list before beginning.

Grading Criteria: words defined correctly 10 pts.
words used correctly to reflect their meaning 20 pts.
creative story. interesting 10 pts.
grammatically correct and well organized 10 pts.

WORD LIST.

uncertainty principle quantum strings/ string theory
photon duality of nature quarks and types TOE
spin & rules around spin neutrino wavelength fusion
fission nuclear forces antimatter weak force gluon boson
frequency multiple dimensions

PROJECT II

You are to find two sources of explanation for the topic that you are assigned. You are to evaluate these two sources in their effectiveness to explain the topic. You are to be specific with your reasons and give example. You must also use your own words to describe what you understand about your topic. If possible include a copy of the material and the source. If it is on video please describe. You will be presenting your sources and giving your critique to the class.

Your topic will come from one of the following:

Big Bang String Theory Nuleosynthesis Microwave Background

Uncertainty Principle Red-Shift a brane expanding universe

parallel universes multiple dimensions dark matter black holes

Appendix A: Content Standards for the Pittsburgh Public Schools.

The following standards are addressed in this unit.

Reading , Writing, Speaking and Listening.

2. All students read and use a variety of methods to make sense of various complex texts.
3. All students respond orally and in writing to information and ideas gained by reading narrative and informational texts and use the ideas to make decisions and solve problems.
4. All students write for a variety of purposes, including to narrate, inform and persuade.

Science and Technology

1. All students explain how scientific principles of chemical, physical and biological phenomena have developed and relate them to real-world situations
2. All students demonstrate knowledge of basic concepts and principles of physical, chemical, biological and earth sciences.
4. All students explain the relationship among science, technology and society.
5. All students construct and evaluate scientific and technological systems using models and to explain or predict results.

Mathematics.

1. All students use numbers, number systems, and equivalent forms (including numbers, words, objects and graphics) to represent theoretical and practical situations.
2. All students compute, measure and estimate to solve theoretical and practical problems.
3. All students evaluate, infer and draw appropriate conclusions from charts, tables and graphs, showing relationships between data and real-world situations.