Why Study the Sky?
A Supplement to the Study of Astronomy

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Academic Setting

This unit will be used at Jefferson Middle School in Albuquerque, New Mexico. I am designing the unit with my eighth grade special education (gifted) students in mind. These students will be enrolled in my Earth Science class as part of their gifted program (they are also typically enrolled in one or two other gifted classes). The typical class size averages fifteen students.

Jefferson is ethnically and socioeconomically diverse. It has a student population that is about fifty percent Anglo and forty percent Hispanic. Close to ten percent of the students are of "other" ethnic backgrounds. Around thirty percent of the students participate in the free lunch program. About forty percent of the students have been identified as LEP (limited English proficiency). We serve a diverse area that includes university professors' homes, less wealthy (but well-established) areas such as Martineztown, and several homeless shelters. My school has a surprisingly high percentage of students qualifying for gifted programs – more than fifteen percent of the school population. These gifted students are less diverse that the school population as a whole. The gifted students tend to be, on average, from higher socioeconomic groups, are slightly less often members of minority groups, and tend to be fluent in English.

Context and Background

Astronomy has always been important to people. Reverence for astronomical phenomenon cuts across many cultures. Evidence of this is seen by looking at the symbols people choose to represent themselves and their ideals on national flags. Approximately half of all national flags include astronomical symbols: constellations, stars, the sun, moon, cosmological symbols, and even, in the case of Cambodia, an astronomical observatory (Sagan 50).

At one point in the United States, astronomy was considered an integral part of the study of science or "natural philosophy." It was taught alongside other areas of science. However, between 1895 and 1910 there was a 90% decline in the number of entering college freshman who had studied astronomy. By 1930, only .06 percent of high school students were studying astronomy (Reed 12). Colleges dropped astronomy as a requirement for admittance, and high school science teaching focused mainly on biology, chemistry, and physics.

The renewed impetus for science education (and, incidentally, gifted education) in the wake of Sputnik's launch helped revive astronomy. Nevertheless, it remains uncommon in the typical high schooler's curriculum. In Albuquerque, where students are required to take at least two science classes, the geology/astronomy course is typically overlooked. This seems a shame. The growth of technology has made astronomy, one of the most ancient of the sciences, one of the most dynamic sciences of today (Moore 9). It would seem to be a branch of science that lends itself to interdisciplinary study – involving mathematics, history, physics, even philosophy. It is an ideal way for students to engage their minds in ways both critical and imaginative.

The Albuquerque Public Schools' middle school science curriculum consists of a year each of life science (basic biology), physical science, and earth science. It is in earth science (in eighth grade at my school), where students have their brief chance to study some astronomy. *Glencoe Earth Science*, my students' current textbook, consists of twenty-four chapters. One sixth of these chapters are devoted to astronomy. The chapters cover what one might expect – space exploration, the "sun-earth-moon" system, the solar system, and stars and galaxies. Middle school students have only a brief opportunity to learn about and become excited about astronomy.

As a teacher, I feel it is my responsibility to meet state standards relating to astronomy. But, I'm also responsible for providing my gifted special education students a "gifted" curriculum – one that is differentiated from the regular education class in terms of its environment, its content, the education process, and student's products. When I look at my student's textbook and the associated activities it suggests, it seems woefully inadequate for what I need – a curriculum that offers gifted children an interesting, relevant, and appropriately challenging group of activities and material. If my curriculum merely replicates what goes on in the regular education classroom, it becomes elitist - rather than, as I believe gifted education ought to be – necessary. So, I need a specialized astronomy curriculum for my students.

My students have high expectations for what they are asked to study. Believe it or not, many insist on knowing how what they are studying is relevant to their lives. It is easy for them to grasp the reasons for learning about the weather, geology, and even (to a lesser degree, given our location) oceanography – all essential parts of the Earth Science curriculum. However, it is more difficult for them to see the point of studying the fourth branch of the curriculum, astronomy. Other than, perhaps, the sun and the moon, they don't see how things in space will affect their comfort, future college options, or other economic prospects. (Do they realize that all the elements heavier than helium that they are made of, and interact with, come from stars – mainly supernovae (Trefil 79)?). Of course, they don't all feel this way. Many, if not most, of my students do have a natural curiosity about the universe and its different objects and phenomenon. Still, I do have my share of "Why do we have to study this?" and "How is this supposed to help me?" questions. These are questions to which I frankly don't have good responses – both because of my own lack of astronomy training and because I haven't thought about them enough myself. So, that's the point of this unit. I'd like to develop a framework for understanding why people in the past have studied astronomy and what we can learn about their learning. I'd like to supplement my own knowledge and help to make the curriculum more interesting, challenging, and relevant. I'd also like to examine reasons for continued study of the sky and how it might benefit my students or society today.

This curriculum "unit" is not designed to be a complete unit on astronomy. My narrative is not designed to give teachers a firm grounding in the science of astronomy, but may give them ideas to show why people study, and have studied, the sky. The unit includes a review of some of the early astronomers. I view my lesson plan ideas as supplements to a well rounded, high level, astronomy unit – not as a sufficient unit on its own.

Why study the sky? In order to answer this question, it will be useful to look at why people in the past have studied it, what have they learned, and how has the study of astronomy affected them and us. The broad topics I will look at are astrology, measurement of time, astronomy in ancient cultures, important early astronomers, asteroid impacts, and the search for extraterrestrial life.

Astrology

A typo? No - I realize that astrology is rarely spoken of in a science class unless it is used to debunk pseudoscience. However, I think students should know what astrology is and how it has influenced people. Today, many newspapers carry horoscopes (far more often than astronomy columns) and many people are not immune to their spell. I hope astrology will not seem mysterious and appealing to my students, but since it is so appealing to many people, they may as well know the roots and rationale for it. In addition, astrology has a long association with astronomy, as many early astronomers were followers or practitioners of astrology.

Astrology first originated in the third millennium BC in Mesopotamia. It became more fully developed in the Greek civilization of the Hellenistic period (Britannica, Vol. 1, 654). It is not surprising that ancient people realized that what happened in the sky unquestionably did affect their future. The changing seasons, flooding rivers, oscillations between rain and drought were all reflected in the changing positions of the sun and stars. It is also not surprising that ancient people assumed that celestial phenomenon could influence one's life not just directly though weather, climate, and agriculture, but indirectly as well (Moy). Astrologers came to believe that the location of the planets and other celestial objects at the time and location of one’s birth profoundly influence the future. They further believe that they can make accurate predictions on a variety of aspects of one’s life (Bourguignon). Typically the astrologer will emphasize coincidences and advise or predict things that are so vague, and of such a general nature, that they will apply to almost anyone.

Astrology was once required for serious medical studies. Hippocrates is supposed to have said, "A physician without a knowledge of astrology has no right to call himself a physician." (Reed 75) Long ago, a doctor would help a patient by constructing an astrological "chart," which indicated the location of things in the heavens at the time of the illness’ onset. This chart was to assist in both diagnosis and treatment of the patient.

Within the realm of science, astrology is regarded as a "relic of the past – irrational and totally without foundation." (Moore 26). There are many reasons for doubting astrology. For example, when people speak of a particular planet being "in" a constellation, we understand better than the ancients did that the planets are close to us and that the stars extremely far away – how could they influence us? And even within a constellation, individual stars are as far apart from each other. The constellations themselves are artificial constructs – why is Leo "masculine" while Pisces is "watery"? Our names for the signs of the Zodiac would be very different if we had adopted the Chinese or Egyptian system instead of Ptolemy’s (Moore 26). Studies of the lives of people born on the same day in the same hospital will find people of very different temperaments, talents, and convictions. This is further evidence of the pseudoscientific nature of astrology. Finally, skepticism is warranted when different astrologers make wildly different predictions. In studies where different astrologers are given nothing but the location and time of birth of subjects, they can not agree on the subject’s future or character (Sagan 50).

The remnants of the importance of astrology/astronomy can even be seen in some of the words and expressions we use today. Take *by Jove*, an appeal for assistance from Jupiter (Jove) or, *mazel tov* - meaning good luck in Yiddish it comes from the Hebrew meaning "may your planetary influences be favorable." (Reed 81). Some more examples: *disaster* comes from the Greek "bad star," *influenza* comes from Italian, meaning of astral "influence", or consider the word *consider* – from the Greek meaning "with the planets" (Sagan 49).

Time Measurement

One of the most significant aspects of how astronomy affects us is though our understanding of time. One of the most ancient of observations is the changing shadow made by the "moving" sun. The shadow will move from the west to the north to the east during the day. The clockwise movement of our (non-digital) clocks is reminiscent of this shadow movement (Reed 96). Many students will not know that the A.M. and P.M. refers to "ante meridiem" and "post meridiem" – "meridiem" or meridian being an imaginary line from a point north on the horizon through the overhead zenith point, and down to a point on the south horizon. Our local apparent noon (not necessarily 12 noon on a clock) is the time when shadows made by the sun are their shortest – the sun being then on the meridian. Our afternoon is the time when the sun is past the meridian or as we say "P.M." (Reed 96).

The days of the week also have their names rooted in astronomy. Most students will realize this about Sunday and Monday (moon-day), and perhaps if they think about it, Saturday (Saturn). However, they may not realize the origins of the other days. It’s easier to appreciate if one knows some Spanish, as many of my students do. Tuesday in Spanish is Martes, honoring Mars (a god of war). In English, Tuesday comes from Tiw, the Nordic god of war. Friday, in Spanish is Viernes relating to Venus the goddess of beauty. The English word Friday is derived from Freya’s day – Freya being the Nordic goddess of beauty (Reed 150).

The English and Spanish days for Wednesday and Thursday are reversed. Wednesday in Spanish is Miercoles, honoring Mercury. Thursday in Spanish is Jueves referring to Jupiter. The English Wednesday comes from Woden’s day – Woden being the Nordic equivalent of Jupiter. The English Thursday is derived from Thor’s day, the Nordic counterpart of Mercury. The ordering of the days within the week also comes from astronomy – that of ancient Egypt (Reed 151).

Since days pass quickly, further time measures are required. Astronomy comes to the rescue again. Our month or "moonth" is based on the waxing and waning cycle of the moon over 29.5 days (Reed, 97). The earliest known calendars are all based on the lunar month. But, how calendars evolved into what people around the world use today is interesting and appropriate information for students.

The Islamic calendar contains months of either 29 or 30 days. The Islamic calendar will vary between 354 and 355 days per year – compared to the seasonal calendar of 365.25 days per year. This means that the Islamic New Year and the holy month of Ramadan move backward through the year – cycling every 32.5 years. Also of astronomical significance in Islam is the determination of the time and direction (toward Mecca) of prayers. Although not relating to astronomy, the Islamic calendar began on July 16, 622 – the date on which Mohammed fled from Mecca to Medina to avoid assassination. The "A.H." designation assigned to an Islamic year refers to "Ab Hejira" meaning "from the flight" (Reed 98).

The Jewish calendar has elements that are both seasonal and lunar. The first day of the Jewish month begins at sunset on the day of the new moon (relating to the book of Genesis). Like the Islamic calendar, the Jewish calendar alternates months of 29 and 30 days (according to the lunar cycle). Unlike the Islamic calendar, the Jewish calendar makes a seasonal correction by adding a month per year in seven of every nineteen years (Reed 99).

The ancient Chinese lunar calendar (dating back to 2357 BC) also made similar seasonal corrections by adding months when necessary. The Chinese lunar calendar was last reformed in 104 BC. New Year's Day was fixed to begin on the day of the first new moon after the sun entered Aquarius – no earlier than January 21 and no later than February 20. Today, the sun is actually in Capricorn during this time, due to the procession of the earth's axis over time (Reed 99). (This procession seems like it would be a further complication for the astrologers.)

The Maya used one of the most complicated calendar systems - before 1000 AD. What we know of the Mayan calendar comes from books called codices – most of which (all but three) were destroyed by the Spanish conquistadors. The Mayans actually had three different calendar systems running simultaneously – none of which were based on the seasonal year. One, the "sacred count," was based on a 260 day counting system. A second system was an accumulative count based on the number of days since the creation of the universe (or their understanding of the date of creation). The third, highly accurate system was the Venus calendar. It was based on the knowledge that Venus was visible in their western sky as an evening star for 250 days and is visible in the east as a morning star for 236 days. This calendar also took into account the number of days that Venus was lost in the sun's glare (Reed 106).

The Mayans were very sophisticated astronomers. The Dresden lunar tables show that they could, using their base 20 number system, predict lunar eclipses (Aveni 105). Mayan astronomy rivals our own in computing the accuracy of the average lunar month. Astronomers of Palenque (southeastern Mexico) in eighth century AD combined a cycle of 43 months of 30 days and 38 months of 29 days. The average Palenque month is 29.530864 days long (although there is no reason to believe they measured to the third or more decimal place). The Copán (further south) mixed 79 months of 30 days with 70 months of 29 days. The average Copán month is 29.530201 days long. Modern astronomy computes the average length of the moon's phases as 29.530589 days (Aveni 104). The Mayans used their astronomy for many purposes including scheduling attacks, human sacrifices, marriages, and accession to the throne (Aveni 102).

Julius Caesar introduced the solar calendar to the West in what we now call 46 BC. Like the ancient Egyptian calendar, it too had 365 ¼ days per year. In order to get the "Julian" calendar started properly, its first year in use had 445 days. It is known as the "year of confusion." The Julian calendar did not take into account that a solar year is not exactly 365 ¼ days long – it's really 11 minutes and 14 seconds longer than this. Because of this small error, by the year 1582 spring had moved forward from its intended date by 10 days (Reed 102).

Ten days is a big deal especially if you're concerned about the accuracy of Easter and other holy days as were the Roman Catholics. In fact, the Copernican revolution, which confounded the church (see *Galileo* below), was prompted by the church's efforts to use an accurate calendar to help maintain social and political order (Moy). Anyway, a new reform of the calendar was needed, and in 1582, Pope Gregory XIII initiated it. He dropped ten days from October of this year, making the equinox come back to its appropriate date. The Pope also instituted the policy of having extra days during leap years. However, his reforms were not perfect. An error of one day will accrue in 3000 years (Reed 102), - assuming an asteroid hasn't wiped us out by then making the point moot (see "Earth Impacts" below).

All the Roman Catholic countries quickly adopted the "Gregorian" calendar. However, the Julian calendar continued to be used by Great Britain and its colonies until 1752. In September of 1752, the second day was followed by the fourteenth. This was met with mobs and riots in some places since people "lost" eleven days and had to pay their monthly bills with less weekly earnings (Reed 103).

Astronomy in Ancient Cultures

The field of "archeoastronomy" tries to reconstruct the history of the formation of astronomical knowledge and the methods of its adaptation by culture. It is a field wherein the sciences and the humanities can cooperate. The sciences can speak of archeology and astronomy and the humanities can speak of the culture that lived among the ruins and gazed at the stars (Raevsky). Archeoastronomy has shown its relevance in the study of the Anasazi of the southwestern US. At Chaco Canyon in New Mexico, there is a kiva (a circular religious room) that is built to allow a shaft of light to illuminate a niche – but this only occurs on the summer solstice (around June 21). This same kiva has 28 higher niches, possibly indicating the number of days it takes the moon to finish a complete cycle (Sagan 47).

At another Anasazi site, called Holly House, at Hovenweep (Utah), further astronomical ruins can be seen. Three portholes pierce the western wall of a tower. Two are oriented to let in light from the setting solstice sun, while the other is oriented to let in light from the equinox sunset. It is thought that tracking the light on the opposing wall would allow the planning of events including planting and harvesting (Malville 42). Malville's book *Prehistoric Astronomy in the Southwest* documents other aspects of Anasazi archeoastronomy, should teachers be interested in this topic. Another North American research topic for students or teachers is the astronomically oriented "medicine wheel," some of which date back 2000 years (Moore 19).

On the southern plain of England is a group of huge stones (dragged from 135 miles away) arranged in a circle. Known as Stonehenge, it is one of the best-known archeological/astronomical ruins. Its first incarnation was begun in 2750 BC. The stones are positioned so that the observer in the middle can see the sun in the stones' gateway on the first day of summer. Other alignments of the sun and moon could be observed through different archways. It is thought that people gathered at Stonehenge to worship their gods of the sun, the moon, and nature (Aveni 25).

Many other cultures have other astronomically significant aspects. For example, the 8500-year-old Ishango bone, found between the present countries of Uganda and Zaire, has notches indicating it may have been a lunar calendar (Aveni 93). Many indigenous societies in Africa (and elsewhere) are able to predict rainfall patterns by looking at the moon. They have learned that by looking at the tilt of the points of the moon's crescent relative to the horizon, they can forecast the wet and dry seasons (Aveni 96). Other interesting astronomically significant things that students or teachers may wish to investigate include the navigational abilities of Oceanic peoples, the astronomical traditions of China and India, and the famous Peruvian Nazca lines of the Inca.

Some Important Early Astronomers

Aristotle

Aristotle was/is one of the most influential of the Greek philosophers. He lived from 384 BC to 322. Among his many works are three experimental proofs that relate to astronomy. First, he noted that a sphere is "the shape that a body naturally assumes when all parts of it tend toward the center" – a primitive statement of gravity. Second, he noted that the stars appear to change in height above or below the horizon according to the observer's position on Earth. This was only to be expected if Earth was spherical. Thirdly, he proposed that because Earth's shadow on the moon during an eclipse is spherical, Earth must also be spherical (Moore 21).

Aristarchus of Samos

Another Greek astronomer, Aristarchus of Samos, lived from 310 BC to 230. One of his claims to fame was that he found a logical way of measuring the distance to the sun (although he was off because he couldn't make his measurements accurately enough). His main claim to fame is that he deduced that Earth orbited the sun, rather than - as was assumed at the time - Earth being the center of the universe. His views found few supporters, and the view that everything revolved around Earth held for more than a thousand years (Moore 23).

Ptolemy

Claudius Ptolemaeus of Alexandria's nickname is "The Prince of Astronomers." He is usually referred to simply as Ptolemy. He was born around 120 AD and died in 180. What we know of his work comes mainly through the book commonly known as *Almagest*, which served as a guide for Arabic and European astronomers until about the beginning of the 17th century (Britannica, Vol. 1, 287). Ptolemy is known for making the first good map of the world – many of its features are easily recognized today. In terms of astronomy, he revised Hipparchus' (another Greek astronomer) star charts. His proofs of a spherical earth include the observations that the stars don't rise at the same time in all places, that eclipses are observed at different times in different places, that some stars are not visible in all northern or southern locations, and that a voyaging ship's hull disappeared before it's mast (Trefil 29).

Most importantly, Ptolemy developed the "Ptolemaic System" that said the Earth was the center of the universe. This system put forward the idea that around the earth revolved, in perfect circular orbits, the moon, Mercury, Venus, the sun, and then Mars, Jupiter, and Saturn (all in this order in terms of distance from Earth). The area beyond Saturn was understood by Ptolemy to be a sphere of motionless stars. To account for the periodic apparent retrograde motion of some of the planets (i.e. at times Mars' orbit appears to go backwards), Ptolemy came up with the idea of the epicycle. In other words, he thought that the planets moved in perfect circles and that the centers of these circles moved in a perfect circle around Earth (Moore 24-25).

Copernicus

Nicolaus Copernicus lived from 1473 to 1543. He was first exposed to astronomy by the required study of astrology in his medical education (Reed 75). From about 1512, Polish churchman Copernicus developed a planetary system in which the planets moved around a sun which was located near the center of the universe. He developed his ideas while working on calendar reform for a church council (Britannica vol. 16, 761). In other words, the church itself brought on the Copernican Revolution! In 1540 when he was 67, he sent his manuscript, *On the Revolutions of the Celestial Spheres*, to the printer. Printing was a slow process back then, and it is said that he died upon receiving a copy of the book - three years later. His book contained a disclaimer that noted that the work was intended a mental game rather than a statement of reality. It is thought that this statement was put in the book not by Copernicus, but by his proofreader in an effort to keep the book from being banned by the church (Trefil 38).

Copernicus' work is so significant, that it is often called the "Copernican Revolution". His work is significant for several reasons (one of which is not simplicity, since his models still relied on epicycles to explain some orbits). First, his system did not require the elaborate series of crystalline spheres to hold the planets and stars in their orbits that Ptolemy's did. Second, the universe's size grew immensely with Copernicus' assumptions. In Ptolemy's system, the stars were thought to lie just beyond Saturn. In Copernicus' system, the stars must be extremely far away, since they remained stationary while Earth moved. A third area of significance concerned gravity. Aristotle taught that all things fell towards the center of the universe – but Copernicus said that the sun was the (near) center of the universe. So, a new explanation of falling bodies was needed (which eventually led to the Newtonian concept of universal gravitation) (Britannica, Vol. 16, 761).

Tycho Brahe

Danish nobleman Tycho Brahe was born in 1546 and died in 1601. He is an interesting character. Tycho's wealthy but childless uncle got his brother to promise to give him a baby boy to raise. When Tycho's mother gave birth to Tycho and his twin brother, the uncle was given Tycho's twin, as promised. Unfortunately, the twin died, leaving Tycho's uncle feeling cheated. So, Tycho's uncle kidnapped him and raised him (Trefil 43). (Another bit of Tycho trivia – he had a duel when he was twenty in which part of his nose was cut off. He repaired his nose with a mixture of gold, silver, and wax, which he used for the rest of his life (Moore 36)). While growing up, Tycho was impressed by an eclipse in 1560. He was especially impressed with the fact that celestial events such as the eclipse could be predicted. This led him towards the study of astronomy instead of law. In fact, Tycho's tutor was asked to make sure that he didn't study astronomy, so Tycho had to hide his books and instruments under his blankets (Trefil 43).

It was an unpredictable celestial event that especially captured Tycho's attention. In 1572, Tycho saw a star where none had previously been observed. The star was so bright it could by seen in daylight (it was a supernova). His studies of the star, reported in *De Nova Stella*, showed that the star was located beyond the realm of fixed stars (Britannica, vol. 2, 460). His work on this helped to make him a noted astronomer and brought on the attention of royalty.

The Danish King Frederick II, impressed with his subject, gave Tycho title to an island on which to make an observatory. While there, Tycho did a comprehensive study of the solar system and charted accurate positions of 777 fixed stars. He did all this before the invention of the telescope (Britannica, vol. 2, 459). Tycho never doubted that the sun moved around Earth (Moore 44). He was obsessed with accuracy and used massive (up to 40 foot) instruments to aid in his measurements. He built part of his observatory underground to shield it from wind vibrations. He even took into account the shrinkage and expansion of the brass in his instruments due to temperature fluctuations (Trefil 43).

Part of the reason that Tycho strived for such measurement accuracy was his belief in astrology. He once predicted that a 1566 eclipse of the moon foretold the death of the Sultan of Turkey (the Sultan did die – a bit before the eclipse) (Moore 36). Tycho wrote that "astrology is really more reliable than one would think" – if the known positions of the stars were properly improved (Sagan 64). Part of the goal of his work was to make astrology a more exact science by precisely charting the locations of stars and planets.

Tycho liked the power he had at his island observatory. He ran into some conflicts with Frederick II's successor over things like whether Tycho had the right to throw people into his island's dungeon. He ended up leaving Denmark for Prague. It was there that he hired an assistant, Johannes Kepler (see below). In 1601 in Prague, he went to a dinner party which included many nobles. He drank much Bohemian beer and felt it rude to leave the table to relieve himself. As Kepler wrote at the time, "he held back his water beyond the demands of courtesy." (Koestler 120). His injured bladder, or possibly bladder stones, led to an infection which killed him eleven days later (Trefil 47). On his deathbed, he bequeathed his celestial observations to Kepler, pleading: "Let me not seem to have lived in vain…let me not seem to have lived in vain." (Sagan 60). He wanted Kepler to use his data to better build his own Tychonic system, not the Copernican system (Koestler 121). This is did not happen, but Tycho's data was critical for Kepler's work, and Kepler's work was important for Newton.

Kepler

Austrian Johannes Kepler (1571-1630) is another one of the more interesting early astronomers. Although it is not what he is usually known for, he wrote one of the first pieces of science fiction, *Somnium* (The Dream). The novel concerned a voyage to the moon – a moon with an atmosphere, oceans, and beings who constructed the moon's "hollows" (the craters recently observed by Galileo with his new telescope). But the story also included elements of science as it was known in his time. The story included references to extreme cold and breathing difficulties during the flight, and zones of zero gravity (although he didn't use this word). In the book, he even supposed that the sun and the moon caused high tides (Koestler 248). He came close to understanding gravity, calling it a magnetic force.

Somnium, which was worked on over many years, was used as evidence that Kepler's 74 year old mother was a witch. Kepler raced to her defense and did save her – even inspiring the Duke of Württemberg to forbid witch trials on such slender evidence (several witches were burned at the stake each year in Kepler's hometown) (Sagan 67). Kepler's father was "at risk for hanging" for some unknown crime (Koestler 22) and it has been written that there was a psychopathic streak running through the family (Koestler 23).

Prematurely born, Kepler was sickly as a child and throughout much of his (often-miserable) life. Among his complaints were stomach and gall bladder problems, rashes and boils, and most disadvantageous for an astronomer, myopia and double vision (Koestler, 24). His family wandered a lot, which slowed his schooling, but he made it into seminary school at the age of thirteen and then later to the university to study theology. The university recommended him for a teaching position in math and astronomy. They may have felt he would make a better professor than a priest or perhaps the university was trying to get rid of him because of his Calvinist views and public defense of Copernicus (Koestler 33-34).

Kepler was interested in astronomy (having witnessed a comet and eclipse as a child) and he was interested in astrology. Kepler was so interested in astrology that he went to the effort of calculating the time of his conception (May 16, 1571 at 4:37 A.M.) (Koestler 17). He once wrote:

> No man should hold it to be incredible / that out of the astrologer’s foolishness and blasphemies / some useful and sacred knowledge may come / that out of the unclean slime / may come a little snail…that in the evil-smelling dung / a busy hen may find a decent corn / nay, a pearl or a golden corn / if she but searches and scratches long enough (Koestler 41).

Much of Kepler’s work was designed to help him perfect astrology and he was financially supported through parts of his life my making astrological charts for patrons. At the end of his life, he was court astrologer to the Duke of Wallenstein (Koestler 39).

Kepler met Tycho when he was 29 and Tycho was 53. The two were opposites in many ways and apparently quarreled often (Koestler 109). Kepler was eventually assigned to work on Mars’ orbit, one of the difficult planets because of its occasional backward (from our perspective) motion. Kepler boasted that he could solve the problem of Mars in eight days – but it ended up taking him eight years (Koestler 110). Tycho died about eighteen months after their initial meeting. Kepler was able to take control of Tycho’s precious and precise data. Tycho’s records were instrumental in helping Kepler develop his laws.

Before working with Tycho, Kepler had come to believe in a model of the universe that included musical harmonies and the Pythagorean solids. During one of his lectures, Kepler realized that the circles inscribed and circumscribed about an equilateral triangle had the same ratios as Jupiter and Saturn’s orbits (Koestler 45). After some work, he came up with the idea that all the planets’ orbits could be fitted onto spheres inscribed and circumscribed about the five Pythagorean or Platonic solids (see lesson plan). The Pythagorean solids, with their special properties had mystical appeal to the Greeks and apparently to Kepler as well. His musical harmonies, or "music of the spheres," corresponded to the speed of the planets as they orbited the sun (Trefil 51). At the time, Kepler was sure he had found the truth. His misguided belief in the five solids idea stayed with him, in a modified version, throughout his life (Koestler 48).

Now that Kepler had Tycho’s data, which he believed to be accurate, he had to work out a system that fit the facts. He struggled mightily. After much work he was left with what he said was a "single cartful of dung" - that being an oval shape (Sagan 62). He finally convinced himself, after laborious calculations, that the orbits of the planets were not perfect circles, but ellipses. In the sixteenth chapter of one of his books regarding this discovery, he wrote: "If thou, dear reader, art bored with this wearisome method of calculation, take pity on me who had to go through at least seventy repetitions of it…" (Trefil 47).

Kepler’s work eventually led to three laws of planetary motion (see lessons). Kepler’s first law states that a planet moves around the sun in an ellipse with the Sun at one of the ellipse’s two foci. His second law states that a planet sweeps out equal areas in equal time periods (picture the area a line connecting the sun and a planet would cover as the planet moved in its orbit), or that a planet moves faster when it’s closer to the sun. Kepler’s third law, or harmonic law, made the connection between the distance of a planet from the sun and the amount of time it takes to orbit the sun – the further the distance from the sun, the longer a planet’s orbit took (Sagan 62-63). If my descriptions are inadequate, please see the web site on Kepler’s Laws listed in the teacher reference section. Although Kepler worked with the mathematics of planets, his laws, of course, apply to any orbiting mass including moons, satellites, spacecraft, and even stars orbiting other stars.

Kepler did not call his laws "laws." He did not realize his observations would become the foundations of modern cosmology (Koestler 223). Kepler was a product of his time and did not have the understanding of gravity or the mathematical tool of calculus that helped Newton see the worth of Kepler’s writings. Kepler once wrote that "Copernicus did not know how rich he was " and the same could be said of Kepler – he didn’t realize how much he achieved (Koestler 223). His self written epitaph states: "I measured the skies, now the shadows I measure. Sky-bound was the mind, Earth-bound the body rests." (Sagan 62).

Galileo

Galileo Galilei was born in Pisa in1564 and died in 1642. Galileo is mentioned in most middle school earth science books and has an established reputation in the public’s mind. Unfortunately, as is sometimes thought, he did not invent the telescope, thermometer, or build the first pendulum clock. He was not the first person to discover sunspots. He did not drop weights from the leaning tower of Pisa. The Inquisition did not torture him, nor was he imprisoned in a dungeon (Koestler 172). He *is* however, responsible for the foundations of mechanics, or dynamics, the science of falling bodies.

As a student, Galileo did notice that a lamp swinging on the end of a cord had the same period no matter if the swing was long or short. He may have later even designed (not built) a pendulum clock (Moore 49). He was an experimenter and a tinker (rightly famous for things I won't discuss here), but he had a keen interest in astronomy. He gave public lectures on the supernova of 1604. In Venice in 1609, he heard of the telescope, something that would alter the course of his life.

After seeing the telescope, he quickly devised an improved way of making lenses. He soon made his own refracting telescope that magnified 32 times (Trefil 49). He was not the first person to look at the night sky with a telescope, or even to draw the moon as seen from a telescope, but he is surely the first person to take such advantage of it. Writing in Italian (rather than in Latin), he was able to publish and publicize his observations effectively. He was able to inform others about the moon's mountains and craters, the phases of Venus, four of Jupiter's moons (which he called "Medicean stars" in honor of the Grand Duke of Tuscany, a former pupil and future employer) (Britannica vol. 19, 640)), spots on the sun (which others had noted as well), and of vastly more stars in the sky (Trefil 52).

It was seeing Venus' phases that must have removed any lingering doubt that he was correct in holding the Copernican view that the planets revolved around the sun (Moore 52). Galileo believed that the planets revolved around the sun in perfect circles, even adopting the epicycle explanation to account for variations in orbits. Although he occasionally corresponded with Kepler, and was familiar with his work, he never did believe that the planets moved in elliptical orbits (Koestler 201).

In 1616, Galileo was warned by church authorities that "the doctrine that the Sun is the centre of the world and immovable is false and absurd, formally heretical and contrary to Scripture" (Moore 52). It's not that the church didn't like science or astronomy. Solar observatories were common in churches. The church had relied on astronomers for centuries for helping to accurately establish the date of Easter (Broad). Galileo was a religious man, and his disagreements with the church centered more on who had authority to make decisions (Reed 169-170). Were decisions to be made on reason informed by observation? Alternatively, were they to be made by the authority of tradition within a conservative religious framework? Galileo believed that he had little to worry about, because as a voracious social climber (Moy), he had powerful friends - one of whom was Cardinal Barberini (the future Pope Urban VIII) (Moore 52).

In 1632, Galileo published his *Dialogue on the Great World Systems* (Copernican and Ptolemaic). In it he makes his points via a dialog with three fictitious people, one of whom is Simplicio (Italian for "fool"), who defends the traditional Ptolemaic church view using Barberini's (who is now the Pope) favorite arguments (Trefil 53). This book was well received in Europe, except in Rome. Galileo was summoned to Rome by the Inquisition in 1633 (when he was 70) and was convicted of "suspicion of heresy." He was sentenced to house arrest in his villa near Florence where he continued working, even after going blind (Britannica vol.19, 641). Upon his death in 1642, the Pope refused to allow a monument to be erected over his tomb (Moore 53). It was not until 1992 that Pope John Paul II acknowledged that the church had erred in condemning him (Broad).

Newton

Englishman Isaac Newton was born in the year of Galileo's death, 1642. He died in 1727. Astrology has a place in Newton's life as it has with other astronomers. When Newton was 20, he picked up a book on astrology "out of curiosity to see what was in it." He was ignorant of some of the book's trigonometry, and quickly endeavored to learn geometry (reading Euclid). In two years, he had invented differential calculus (Sagan 68).

Newton's main concern in life was religion. He produced more written work on religious subjects than on the science for which he is remembered (Reed 180). Newton is remembered as the founder of the modern science of physics. His scientific work is vast and will not be reviewed here. He did recognize that what happened in the apple orchard was the same as what happened in space – uniting the previously separate fields of astronomy and mechanics (Trefil 54-55). He showed there was one force of gravity – his concept of universal gravitation (which he arrived at using Kepler's work, although he didn't acknowledge it in his book *Principia*) (Sagan 69). Using the calculus he developed, he was able to work out the orbits of the planets and show that they matched Kepler's laws (and Tycho's data) (Trefil 56). As Newton says in a letter to Robert Hooke, "If I have seen further it is only because I have stood on the shoulders of giants." (Kaplan 185). Incidentally, Newton was also the first person to build a reflecting telescope (Moore 72).

Earth Impacts

Aside from the sun's role in photosynthesis, astronomy does have direct bearing on our survival. Just ask the dinosaurs. Evidence suggests they were wiped out by an asteroid impact 65 million years ago (Hartman). Until recently, it was thought there were about 2000 "doomsday asteroids" (those greater than a kilometer in diameter) near Earth's orbit. New samplings of the sky indicate that there may only be 700 large asteroids that come within five million miles of Earth (a close call). Astronomer David Rabinowitz is encouraged by the lower number, but says it is no reason to stop worrying. He notes, "It doesn't matter much whether the interval [until impact] is a little longer. The point is, this is something that could wipe us out and *could happen any time."* (emphasis my own) (Petit).

NASA has a ten-year goal of finding at least 90 percent of the asteroids large enough to cause a global catastrophe. There are several asteroid hunting programs at the present time (see teacher references for web sites). One is project LINEAR (Lincoln Near Earth Asteroid Research Project) at MIT's Lincoln Laboratory that uses Air Force tracking telescopes located at White Sands, New Mexico. Another asteroid-watching program is called NEAR (Near-Earth Asteroid Tracking) which is run by NASA using Hawaiian telescopes (Maran 121). The Minor Planet Center in Cambridge, Massachusetts, operated by the Smithsonian Institution, acts as a worldwide clearinghouse of asteroid data. When all the large asteroids are believed to be spotted, astronomers can focus on smaller asteroids – those less than a kilometer in size that could still devastate a city, state, or small nation (Petit).

What if we do find an asteroid or comet headed our way? Astronomer Donald Yoemans of NASA notes that right now "we don't really have a plan." (Petit). It is presumed that any such asteroid will be many cycles of its orbit away from hitting the planet, giving many years for us to prepare. Rather than blow up an asteroid, which would send many pieces towards us, a better plan would be to use a missile to nudge it off its path (Maran 120).

It is often said that a meteorite has never killed anyone. However, as John S. Lewis points out in his book *Comet and Asteroid Impact Hazards on a Populated Planet*, a more accurate statement would be that "nobody has ever been killed by a meteorite in the presence of a physician and a meteoriticist." He documents more than 150 reports of damage, injury, death, and near misses collected from Latin, Greek, Chinese (some of the best records were kept in China), French, German, English, and other sources. Statistical averages compiled by the American Institute of Aeronautics and Astronautics in 1995 show a projected time-averaged fatality rate of 3000 people per year due to impacts (Lewis 13). Lewis' own calculations over a smaller time frame (100 years), using Monte Carlo simulations, found an average fatality rate of 250 people per year. In the simulation, most centuries had fewer fatalities than this, while a few had many more (Lewis xiv).

SETI

The Search for Extraterrestrial Intelligence (SETI) is sure to be of interest to middle school students brought up on science fiction. Many researchers believe that there are intelligent beings outside our solar system, and SETI is the quest that searches for evidence. There are ten billion suns similar to ours in the Milky Way, and over one hundred billion other galaxies are within the range of our telescopes (Maran 231). This gives the SETI people lots of hope and opportunity.

In 1961, astronomer Frank Drake tried to organize all the unknowns in the search for extraterrestrial intelligence into one equation (see references for web links). Its idea is to estimate the number of civilizations in our galaxy that are using radio waves now. In considering the Drake equation, pessimists might view the answer as one (we're alone in the Milky Way) while optimists like Carl Sagan might view the answer as closer to a million (Maran 233).

There are several ongoing current SETI searches. One is Project Phoenix, a successor to the NASA SETI program that was stopped in 1993. Project Phoenix uses radio telescopes to search the microwave radiation coming from individual stars. Microwaves are searched because there is less natural static at these wavelengths and because hydrogen gas gives off a signal in the microwave range. It is thought that other civilizations might take advantage of this fact by sending out signals near to hydrogen's. Other SETI programs include projects BETA (Billion-Channel Extraterrestrial Assay) and META (Mega-Channel Extraterrestrial Assay) (both sponsored by the Planetary Society) and The Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations (nicknamed SERENDIP). One part of SERENDIP is the SETI@home project that lets home computers help by analyzing SETI data. All the major SETI programs have their own web sites which link with the SETI Institute's site or the Planetary Society's web page (see teacher references) (Maran 238).

Even if we don't find evidence of intelligent life, is it possible that humans could spread their own intelligence throughout the galaxy? This at least might be interesting for students to think about. An astrophysicist at Los Alamos National Laboratory, Eric Jones, believes that the practical maximum velocity of spaceships is about ten percent of light's speed. Traveling to our nearest star would take 40 years at this speed. Jones believes that large star ships will eventually be built and go on long one-way journeys through our galaxy. Jones assumes that such ships will reach inhabitable planets and colonize them. He then assumes that each colonized world will itself send out a new colonization ship after 1000 years on their planet. Using this multiplier effect, Jones believes that humans can populate the entire Milky Way within 50 million years. This is long on a human scale, but not long on nature's scale of time – dinosaurs became extinct just 65 million years ago (Easterbrook 689-690).

Awe-stronomy

Have I answered my question? Is the sky worth studying? If I were a gifted middle school student, would I come away from this material thinking that astronomy is an interesting, important, and worthwhile subject? Perhaps not – middle school students are harsh critics. But, from this teacher's perspective, incorporating much of this material and lessons into a unit on astronomy will make for a richer experience than it otherwise would have been.

Astronomy does have value in showing us some truth about our environment. It has value both for capturing student's imagination and for disciplining their thinking as they learn and do the science. I think that perhaps astronomy's greatest value is that the universe can inspire awe in students (and teachers). We are, after all, a part of the universe, a part that perceives itself. Astronomy can assist us in looking at ourselves from a different perspective. It can lead us to ask questions like, "Are we alone in the universe?" "What is the nature of my universe?" and "What is my place in the universe?" - questions which may help us to lead more ethical, more meaningful lives. As Galileo wrote, "Philosophy is written in this grand book, the Universe, which stands continually open to our gaze. But it cannot be understood unless one first learns to comprehend the language and interpret the characters in which it is written" (Reed 65).

Implementation

New Mexico State Science Content Standards for grades 5-8 are taken from the State Department of Education web site at (http://sde.state.nm.us). I have referenced the standards by number for brevity.

Lesson: Survey of Earth Science Topics

Main New Mexico standards addressed: 15-A-2

This survey would be done at the beginning of the year. I will ask students what they think are the most interesting and/or important Earth Science topics to study. I further will ask them why they think New Mexico wants them to study these topics and why they themselves want to (or don't want to) study them. They will also be required to ask two adults why they should be required to study each of the four branches of earth science: geology, oceanography, meteorology, and astronomy. We will discuss results in class and I will collect and review the surveys.

Lesson: Astronomy/Astronomer quotes.

Main New Mexico standards addressed: 15-A-1

Each day throughout the year, I will present my students with a (hopefully) thought provoking quote. Some of these will be quotes by astronomers and about astronomy. This will be ongoing throughout the school year. This will familiarize students with some famous astronomers' names and some astronomical ideas. See teacher references for quote books.

Lesson: The Five Pythagorean Solids

Main New Mexico standards addressed: 2-C-2, 6-A-1

Students are asked to find and assemble as many different "regular polyhedron" as they can. Students will be building with "Zaks," which are plastic building blocks that come in a variety of polygon shapes. They are designed to rotate while they are connected, allowing for a variety of shapes and angles to be formed. All of the Pythagorean solids can be made from Zaks. I'm sure that the solids could be built or demonstrated in other ways too.

A regular polyhedron is a three-dimensional figure, with no holes, whose faces are all regular polygons. (A regular polygon has the same number of equal sides – triangle, square, cube, pentagon, etc...). It turns out that there are exactly five regular polyhedrons – also called the five Pythagorean solids. The five regular solids are the tetrahedron (4 equilateral triangles), the cube (6 squares), the octahedron (8 equilateral triangles), the dodecahedron (12 pentagons), and the icosahedron (20 equilateral triangles). All of these can be inscribed into a sphere so that all the vertices of the solid can touch the sphere. These can all also be circumscribed around a sphere so that the center of each face is touching the sphere.

Students will initially be told of Leonhard Euler and Descartes' observation that:

$V - E + F = 2$

Where V is the number of vertices (a cube having 8), E is the number of edges (a cube having 12), and F is the number of faces (a cube having 6) (Sagan, 1980).

As students work, I will give them hints to further their progress. For my students who are interested, I will show them a mathematical proof that there are only five regular solids (as seen in appendix two of Sagan's *Cosmos*). After the class has built the five regular solid shapes, they will be kept on display in the classroom. This activity will be done immediately before the beginning of our astronomy unit – the word astronomy will not be used in conjunction with this lesson, but will instead be presented to the students as just another one of the strange things that I have them do. It will make sense to students later in the context of learning about Kepler and his *certainty* that the five solids fit the planets' orbits (see narrative and see Sagan's *Cosmos* page 58 for a good diagram of Kepler's scheme).

Lesson: What's Astrology?

Main New Mexico standards addressed: 6-C-1, 15-A-1

Astrology is a topic that is rarely, if ever, addressed in a science class. I figure that since so many Americans believe in astrology, it would be a good idea for my students to at least have a basic understanding of what it is. It seemed that as I grew up, astrology was never discussed and this made it more mysterious and intriguing than it ought to have been to some of the people I knew. We will try to have a class discussion about what kids know and believe about astrology, and try to examine why so many people believe (or at least pay attention to) it. During this discussion, I will relay the basics of astrology (see narrative). This is also relevant because many of the early astronomers, for example Kepler, were devoted to astrology.

I'm not sure what students think about astrology. If there are some students who think there is something to it, I may do a lab having students see if they can pick their own horoscope out from a list of predictions that have had the astrological signs whited out.

Lesson: Astronomy and the Measurement of Time.

Main New Mexico standards addressed: 2-B-1, 5-B-1, 15-A-1

As a short homework problem, students will be asked to calculate how many lunar months there are in a year. They will then be asked to come up with their own idea of how to make a calendar that uses only lunar months and explain its advantages and disadvantages. As an additional short homework problem, I will ask students to calculate how long the average Mayan month was, using the monthly information from Palenque and Copán (see narrative).

In class, we will discuss their ideas and I'll let them know how different calendar systems work and how the Gregorian system has evolved. I'll also let them know how the days of the week are related to astronomy (see narrative).

Lesson: Astronomy in Ancient Cultures

Main New Mexico standards addressed: 2-B-1, 5-C, 15-A-1

Lecture on examples from the narrative of how some of the different ancient cultures used astronomical information (see narrative).

Lesson: The History of Astronomy (the abbreviated version)

Main New Mexico standards addressed: 2-B-2, 5-C, 6-G-1, 6-G-2, 6-G-3

In class, I will lecture on some historical aspects of astronomy. I will include information about why astronomy has been important to some cultures and information on some noteworthy astronomers (Aristarchus of Samos, Ptolemy, Copernicus, Galileo, and Kepler). I will try to include a sense of their characters, foibles, major work, and how their work changed (or didn't change) people's perception of reality (see narrative). I will break up this information into sections over several days.

Lesson: Kepler's Laws

Main New Mexico standards addressed: 1-A-1, 2-B-2, 8-B-4, 13-A-1

Students will make ellipses in two ways. They will take advantage of the fact that the sum of the ellipse's distances from two fixed points is constant. First, students will stick two pins through a paper into cardboard. A loop of string can be set around the pins. Moving a pencil along the inside of the loop of string, while keeping the string taut, will draw an ellipse. Another way to make an ellipse begins with a circle of paper. Ask students to put a dot anywhere on the circle, except the center. Have students fold the edge of the paper circle to the dot, then crease and unfold. Repeat this process many times for different parts of the circle – always folding the edge to the dot. The creases will end up tracing out an ellipse (Gardner 175-176).

Students will read *Aphelion Away!*, taken from the Science@NASA site (see references) which makes the point that because Earth's orbit is an ellipse, the sun's distance from the earth changes. It is furthest from the earth in July (receiving less sunlight) and closest to the earth in January. It also notes that (according to Kepler's Laws), Earth is moving slower in July, so the Northern summer is longer than the Southern summer by two to three days. The article also explains why the overall Earth is warmer in July compared to January despite its being further away! (The Northern Hemisphere has more landmass, which both heats up and cools off faster than the Southern Hemisphere with its greater water area.) Incidentally, this lesson goes incredibly well with "Modeling the Reasons for the Seasons," activity B-10, in *The Universe at your Fingertips – An Astronomy Activity and Resource Notebook*. This activity has students measure (from a photo) and graph the sun's distance from Earth over a year.

For a homework assignment, or as a short library computer activity, students will be asked to check out the NASA Observatorium web site, which provides an interactive demonstration of each of Kepler's Laws (see teacher references).

Lesson: On the Path of Discovery

Main New Mexico standards addressed: 1-B-2, 12-C-2

As described in *Craters: A Multi-Science Approach to Cratering and Impacts*, the "On the Path of Discovery" activity gives students data on Iridium abundance in different strata for different sites around the world. It has students analyze the data similarly to how Luis Alvarez did in his development of the killer asteroid hypothesis for the extinction of the dinosaurs.

Lesson: What are the Chances?

Main New Mexico standards addressed: 1-A-1, 1-B-1, 2-B-2, 9-A-6, 16-A-1

As described in *Craters: A Multi-Science Approach to Cratering and Impacts,* The "What are the Chances?" activity lists many of the larger asteroids along with their size, speed, and the probability of impact, according to both the work of Gene Shoemaker and Ernst Julius Opik. Students are asked to examine and analyze the data. Included is a nifty graph that will let students compare the energy and expected incidence of occurrence for various diameter bolide impacts.

Lesson: National Geographic Video - *Asteroids: Deadly Impact*

Main New Mexico standards addressed: 1-B-2, 9-A-6, 12-C-2, 16-A-1, 16-B-1

Among the topics this video focuses on are Gene Shoemaker’s career as a pioneer in Planetary Impact theory, comet Shoemaker-Levy’s crash into Jupiter, and speculation about future earth impacts. This will be shown after students have studied the solar system - including craters and impact probability.

Lesson: Apocalypse Now

Main New Mexico standards addressed: 5-B-5, 6-C-1, 16-A-1, 16-B-1

Students will read the *Discover* article "Twenty Ways the World Could End Suddenly" for homework. They will be given an evaluation sheet that will ask them to rank the twenty scenarios on the basis of *likelihood* (1 = likely event, 4 inconceivable event), human *ability to avert or prepare* for the disaster (1 = humans have control, 4 = humans have no control), *novelty* (1 = I’ve never heard of this idea before, 4 = I’m sure nearly everyone has heard of this idea before), and *fear factor* (1 = this kept me awake all night, 4 = this is silly). We will have a class discussion on the article’s ideas.

Lesson: Half-day field trip to the Lodestar Astronomy Center

Main New Mexico standards addressed: 5-B-5, 13-A-1

The Lodestar Astronomy Center has interactive astronomy exhibits, "Virtual Voyages" (a simulation dealing with the interception of a comet), and a planetarium. See teacher reference section for info on the Lodestar Astronomy Center.

Lesson: Awesome Astronomy

Main New Mexico standards addressed: 5-B-5, 6-F-1

Students will conduct Internet research on current topics in Astronomy such as: quasars, MACHOS, gamma ray bursts, dark matter, supernovae, black holes, the accelerating expansion of the universe, or other self selected astronomy topics. They will take notes on what they learn, and share the most interesting facts with classmates the next day. They will primarily use NASA Internet sites (see teacher references).

Lesson: the Drake Equation

Main New Mexico standards addressed: 5-B-1, 6-C-1

I will show and describe the Drake equation to students. We will discuss some of the assumptions that go into assigning values to the variables. The assumptions are briefly discussed in *Astronomy for Dummies* and more extensively at the *Sky and Telescope* web site listed in the teacher references. I will ask students to visit the Drake equation calculator web site (see teacher references) and input their own values to see what they get.

Lesson: Message to the Stars

Main New Mexico standards addressed: 1-A-1, 14-C-1

Students will work in groups to design a message (content and form) that they think is best suited for sending or beaming into space. After this is done and shared, I'll let them know about the information included in the Voyager probe and the Arecibo Interstellar Message (Sagan 287-290). This would also be a good time to tell students about Eric Jones' ideas for human population of the galaxy (see narrative).

Lesson: Journey to Mars –Part I

Main New Mexico standards addressed: 13-D-1

Students will read one of five articles from the March 2000 edition of

Scientific American that focuses on a manned mission to Mars. Each student will read his or her own article silently for 15-20 minutes. Then students will meet with other students who have not read their particular article and share the main ideas. Each student will record the main ideas of each article.

Lesson: Journey to Mars – Part II

Main New Mexico standards addressed: 13-D-1

I will show the Scientific American Frontiers video *Journey to Mars*. This video features Bob Zubrin, one of the main authors from their previous day's work. I will have a question sheet to accompany the film. Highlights of the film include making rocket fuel on Mars, using virtual reality to train for space missions, growing food and purifying waste water in space, combating muscle deterioration, and weightless training on the "vomit comet" airplane.

Lesson: Resolved: Astronomy should be removed from the middle school science curriculum.

Main New Mexico standards addressed: 15-A-2

This debate will feature half the class arguing that astronomy should be removed from the middle school science curriculum – giving reasons for their positions and alternative curricular ideas. The other half of the class will argue that astronomy is a vital part of the middle school science curriculum and state reasons why it should be kept.

Documentation

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Trefil, James, S. *Space Time Infinity*. New York: Pantheon Books. Washington: Smithsonian Books, 1985.

Teacher Resources

Books and Magazine Articles

Begley, Sharon. "Science of the Sacred". *Newsweek*. 28 Nov. 1994: 56. An interesting read for the teacher (and maybe student?).

Economist. "The Outward Urge". 31 Dec. 1999: 95-96.

Another good reading for teacher and student. Discusses the history of how science has extended the frontiers of human understanding.

Fripp, Jon. *Speaking of Science: Notable Quotes on Science, Engineering,* *and the Environment*. Eagle Rock, VA: LLH Technology Publishing, 2000.

Kaplan, Rob. *Science Says: A collection of Quotations on the History, Meaning, and Practice of Science*. New York: W. H. Freeman and Company, 2000.

Powell, Corey S.; Martindale, Diane "Twenty Ways the World Could End Suddenly". *Discover,* Oct. 2000: 50.

Sagan, Carl: Murmurs of Earth: The Voyager Interstellar Record.

A 1978 account of the work and decisions leading to the information contained in Voyager.

Teacher Curriculum Guides

Franknoi, Andrew. *The Universe at your Fingertips – An Astronomy Activity and Resource Notebook.* Project ASTRO. The Astronomical Society of the Pacific, 1995.

Two inches thick – full of lessons aimed mainly at grades 4-9. Includes a grade level chart for activities, background articles, reproducible lessons, resource lists, and more. This is great for generating ideas.

Hartman, William K., Cain Joe. *Craters: A Multi-Science Approach to Cratering and Impacts*. National Science Teachers Association, 1995.

Filled with 20 activities on craters and impacts that integrate key science skills. Includes a CD of crater images from Earth, other planets, and especially the moon. Some activities would work well for regular education middle school science classes and some are more suited for high school. Includes some high powered activities on the Alvarez theory for the extinction of the dinosaurs.

Smith, Sean P. *Project Earth Science: Astronomy*. Arlington, Virginia. National Science Teachers Association. 1998.

Aimed at 7th-9th graders. Includes 11 activities and 14 readings. Great for someone just starting to teach astronomy.

Wright, Russell G. *Asteroid!: An Event-Based Science Module*. Innovative Learning Publications. 1996.

Contains copies of lots of brief newspaper articles, interviews with science professionals, student interviews, data tables. This is designed to be used as a simulation activity, but parts could be used independently.

Internet Web Sites

Aphelion Away! (A student reading referred to in the Kepler's Laws lesson). http://science.nasa.gov/headlines/y2001/ast03jul_1.htm.

Drake Equation Information. The SETI institute has a nice presentation of the Drake equation: http://www.seti-inst.edu/science/drake-bg. They also have an interactive Drake equation calculator (just input your own values) at: http://www.seti-inst.edu/science/drake-calc.html. The Sky & Telescope magazine site has a section dedicated to giving reasonable estimates (and justifications for these estimates) for the variables of the Drake equation. It was updated in 2001. Go to: http://www.skypub.com/news/special/9812seti_aliens.html

Harvard's site about the search for extra-solar planets (with related links): cfa-www.harvard.edu/planets.

The Lincoln Near Earth Asteroid Research (LINEAR) project: www.ll.mit.edu/LINEAR.

NASA's main site for astronomy information. This site has links to lessons and other worthy astronomical sites, it's a great starting point for student and teacher research: http://science.nasa.gov/Astronomy.htm. Or try NASA's Spacelink site: http://spacelink.nasa.gov/index.html which will let you do extensive searches of the NASA sites.

NASA's Near-Earth Asteroid Tracking (NEAT) project: http://neat.jpl.nasa.gov/.

NASA Observatorium – Kepler's Laws orbital simulators (referred to in the Kepler's Laws lesson plan): http://observe.ivv.nasa.gov/nasa/education/reference/orbits/orbit_sim.html.

Planetary Society's Web page: www.seti.planetary.org.

Potentially Hazardous Asteroids list maintained by the Minor Planet Center: cfa-www.harvard.edu/iau/lists/Dangerous.html.

SETI@home project: www.setiathome.ssl.berkeley.edu.

Spaceguard Foundation – a private organization dedicated to saving Earth from killer asteroids: http://spaceguard.ias.rm.cnr.it/SGF/.

Video Resources

Asteroids: Deadly Impact. National Geographic Video. Videocassette. NGT, Inc., 1997. 60 minutes.

Among the topics this video focuses on are Gene Shoemaker's career as a pioneer on planetary impact theory, comet Shoemaker-Levy's crash into Jupiter, and speculation about future earth impacts.

Scientific American Frontiers: Season IX: *Journey to Mars.* PBS Video. 55 minutes.

Highlights of the film include: making rocket fuel on Mars, using virtual reality to train for space missions, growing food and purifying waste water in space, combating muscle deterioration, and weightless training on the "vomit comet" airplane.

Field Trip Resources

The Lodestar Astronomy Center has interactive astronomy exhibits, "Virtual Voyages" a simulation dealing with the interception of a comet, and a planetarium. It is located at the New Mexico Museum of Natural History & Science at 1801 Mountain Rd. NW in Albuquerque. The telephone number is 841-5955.