Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1998 Volume VI: Selected Topics in Contemporary Astronomy and Space Science

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Where Are We in the Milky Way?

Curriculum Unit 98.06.09
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CONTENTS OF CURRICULUM UNIT

PHILOSOPHY

This unit is designed for students who attend an alternative high school program because they have had poor attendance and behavior problems, resulting in a lack of sufficient high school credits to graduate. These students have not had much success in school. Therefore, when a curriculum is created for them, several facts must be kept in mind. Realities, in terms of numbers and mathematics, are difficult for them to visualize, comprehend, and express in meaningful terms.

This curriculum was developed in collaboration with an English teacher. This unit will integrate two disciplines, English and Math and will be co-taught. The two teachers will introduce several mathematical and scientific concepts, making connections between and among science, math, history, and English. The approach will be interdisciplinary, supplemented by readings, films, and activities using the scientific method. Since classes at this high school are integrated (grades 9-12), we will team teach the class, seeking to improve student performance and skills at all levels.

The curriculum is designed so that each student in the class can feel at ease as s/he is motivated to learn more about where we are in relation to the Milky Way. Each student will play a special role in developing his or her talents with specific objectives in mind. As students are stimulated, our roles will reverse. They will become "teachers," and teachers will become the "learners." Students will guide and be guided through as series of group activities using a scientific approach.

Students' interest in astronomy and their understanding of the cosmic landscape will be stimulated by readings, both assigned and suggested. Students seem to be aware of what astronomy can offer to the human perspective, but are often unaware of the methods of science, including procedures and required rules. Hence, they look for "quick answers," seldom thinking or realizing that there is a process that leads toward a clearer understanding of the structure of the cosmic landscape.

Students will realize and understand that communication gaps develop as scientists become thirsty for knowledge about new frontiers. This gap leads people to all manner of unbelievable and unreliable sources for information-especially in new areas of inquiry. The media is an excellent example of misinformation and pseudoscience. By a rational, not an irrational or haphazard process, and through the interdisciplinary approach, students will be able to probe the cosmic landscape's many mysteries.

The main focus of this unit will be to determine where the earth is located in our solar system, and where the solar system is located in the Milky Way Galaxy. One of the many goals will be to give the students a sense of where they fit in this astronomical universe-a sense of location in the cosmic landscape, based on mathematical calculations

Students will compare the positions of the nine planets and sun, starting from earth, our home planet. When we consider sizes and distances in space, the goal will be to have students think "cosmically." As part of this mathematical comparison, students will review and practice the concept of scientific notation. The sheer size of the universe and the immense distance involved almost defy human understanding and experience. We live in a very thin layer on a small planet: our solar system comprises less than a speck in our Milky Way Galaxy, less than a grain of sand on an immense beach. Our solar system is almost invisible on the scale of our Milky Way Galaxy. Our galaxy is only a pinwheel of light in an enormous, expanding universe.

OVERVIEW OF THE MILKY WAY

On a dark cloudless night, you can see a faint band of light, stretched with stars and reaching across the sky. It was said that the ancient Hindus thought of this dim white glow as milk splitting the night sky; hence, they called these stars the Milky Way. Now, in the twentieth century we know that these stars, along with our Sun, form a huge, slowly revolving disk--our galaxy. The word "galaxy" itself comes from the ancient Greeks and their word for "milk,"--galactos. Thus, "Milky Way" is both the name of the band of light across a clear night sky and also the name of our galaxy.

Our earlier understanding of the Milky Way dates back to the 1800's Thomas Wright, an English astronomer, and Immanuel Kant, a German philosopher. Wright, by counting the number of stars visible in different directions, concluded that the solar system was near the center of a spherical cloud of stars rather than a flat disk, as had been suggested by Immanuel Kant. Because Wright thought the Milky Way was spherical, he thought the stars would lie in all directions of the night sky.

Today, it is inarguable that the basic shape of the Milky Way is a spiral flat disk. For instance, a budding astronomer can go outside on a clear night and see that there are vastly more stars in the direction of the Milky Way than there are stars in any other direction. If the Milky Way had a spherical shape, one would see about the same number of stars in every direction of the night sky. However, since it is a flat disk, one sees that stars are concentrated into the band which makes up the Milky Way. Kant further proposed that the Milky Way galaxy can be used to compare other existing galaxies. For example, it was assumed that every galaxy was shaped as a flat disk. In addition, the surface brightness of galaxies seemed fairly low, through observation of faint stars which appeared to have a relatively uniform lack of volume of light in the Milky Way.

Wright's inconclusive argument was further redefined toward the end of the 18th century by an English astronomer named Sir William Herschel. Herschel incorrectly concluded that the Sun was the center of the Milky Way. Herschel did not have a method to measure distances to the stars, so he could not determine the Milky Way's size; Therefore, it is known that he was led astray because he did not know that dust clouds mask out distant stars and prevent us from seeing our galaxy's actual shape and size.

The size of the Milky Way was first measured in the early 1900's by a Dutch astronomer, Jacobus C. Kapteyn and the American astronomer, Harlow Shapley. Kapteyn used Herschel's method and added his own data, strengthened by his knowledge of distance to nearby stars. Kapteyn measured the distance to nearby stars by a scientific method called stellar parallax, or a change in an object's apparent position caused by a change in the observer's position. A familiar example is easy to demonstrate. Even a novice astronomer can hold his or her hand motionless at arm's length and close one eye to observe what seems to be a shift in the position of his or her finger. Repeating this exercise, now closing the other eye, causes the finger to appear to move against the background, although, in reality, his or her eyes have the changed the viewing position, and the finger has remained stationery.

This at-home demonstration helps us understand how parallax gives us the ability to see things three dimensionally. When we look at something, each eye sends a slightly different image to the brain, which then processes the pictures to determine the object's distance. To observe stellar parallax, astronomers take advantage of the Earth's motion around the Sun. They observe a star and carefully measure its position against background stars. They then wait six months--until the Earth has moved to the other side of its orbit--and make a second measurement. As a result, the star's position has changed, observed in comparison with the background stars. The angular distance that a star's apparent position changes depends on its distance from us. Although the change is larger for nearby stars than it is for more distant stars, the angular distance is extremely small for all stars. In fact the distance is so insignificant that that it is measured, not in degrees, but fractional degrees called "arc seconds."

A star's parallax (p) is defined as related to half of the degrees of angle created when the star changes position. Using that definition for parallax (p), the star's distance, (d) can be calculated using 1 / p, if we measure (p) in arc seconds, and (d), not in kilometer or light years, but in a new unit called "parsecs". This word comes from a combination of "parallax" and "arc seconds." There are 3,600 arc seconds in one degree.

Kapteyn's method of parallax, unlike Herschel's, was thus able to reasonably determine preliminary dimensions of the Milky Way. In total, the thickness of the Milky Way was found to equal 2,000 parsecs and have a diameter of 10,000 parsecs. However, almost immediately after Kapteyn's publication of his model of the Milky Way, an American astronomer, Harlow Shapley, published a model in strong opposition. Shapley argued that the Milky Way was larger than what Kapteyn had calculated and that the Sun was not near the center, but about two-thirds of the way out in the flat disk. Shapley defended his theory from a unique study of globular star clusters--dense groupings of up to a million stars.

Globular clusters have so many stars that they are very luminous and can be seen from great distances across the galaxy and beyond. Many of the clusters lie above the flat disk, so a clear view of them is quite apparent. At the time, Shapley knew that the evidence to support his model would be found by mapping the distribution of globular clusters. This would provide a more accurate representation of the Milky Way that had ever been achieved. To make up this map, Shapley needed to know the distances of the globular clusters from the sun. He could measure these distances by observing variable stars, those that change in brightness. Measurements were determined using the Standard Candle Method to calculate the distances to variable stars called "Cepheids."

Shapley took pictures of stars and compared their true brightness (B) to find the distances to those stars. Once again, even a novice astronomer can look at an object of known brightness and estimate its distance from how bright it appears. For example, while driving at night, one's life depends on making distance estimates of the lights of oncoming cars. The Standard Candle Method is just a more refined method to determine distance.

Hence, Shapley found globular clusters ranging 30,000 ly away. He also found other clusters further away which had a variety of angular sizes (physical shapes). Drawing his conclusions from the globular clusters, Shapley determined the shape of the Milky Way. But Shapley overestimated the Milky Way's diameter, and proposed that its size was approximately three times greater than was formerly accepted.

Shapley was able to determine the distance to the closest globular clusters. Shapley measured angular diameters of globular clusters of known distance, thus obtaining their true diameters. Assuming a statistical average for the true diameter of the clusters, he was able to then obtain distances estimated for the remote ones from their observed angular diameters.

From their directions and derived distances, Shapley mapped out three-dimensional distribution in space of 93 globular clusters. He found the clusters formed a spheroidal system. The center of that spheroidal system was s point in the middle of the Milky Way and a distance of some 25000 to 30,000 ly. Shapley then made a correct assumption that the system of globular clusters is centered in the center of the galaxy. The sun lies far from the galactic center, the main disk of the galaxy probably extends a nearly equal distance beyond the sun and comprised a gigantic system, which is at least 100,000 ly across. Today the center of the galactic nucleus is estimated to be 8,000 pc from the sun.

Over the last 50 years, astronomers have revised and improved Shapley's model of the Milky Way. Given that the Milky Way is a flat disk and that other disk galaxies have spiral arms, astronomers have generally concluded that the Milk Way consists of several parts: It is a flat disk that is about 25 kilo parsecs in diameter. It has a halo that surrounds the disk, much as a bun surrounds a hamburger. There is a bulge where the central parts of the disk thicken. Within the disk, numerous bright young stars cluster into spiral arms that wind outward from near the center. Our Solar System lies between two arms about 8.5 kiloparsecs from the center. The orbits of the planets are tilted by about sixty degrees in respect to the galaxy's disk. This tilt is the reason why the band of the Milky Way on the sky is tipped with respect to the elliptical path that the sun follows.

SIZE AND DISTANCE IN SPACE

The sun is 30,000 light years from the center of the Milky Way. What does this mean? Not much, if we do not understand what a light year is.

Measuring a distance in terms of time may at first sound peculiar, but we do it often in everyday life. We say, for example, that New Haven is a two-hour drive from New York, or our house is a five-minute walk from the library. Expressing a distance in this fashion implies that we have a standard velocity. Astronomers, in fact, use a velocity standard: the speed of light in empty space is a constant and equals 299,792,458 meters per second (approximately 186,000 miles per second). Moving at this constant and universal speed, light in one year travels a distance defined by astronomers as one light year (ly), a total of 9.5 trillion kilometers. A light-year is a measure of distance. It is the distance light travels in one year at the rate of 186,000 miles per second.

Alpha Centauri, the nearest star, is about four light-years away. Only about forty of the stars in the sky are within sixteen light-years of the earth. The brightest star, Sirius, is nine light-years away. Betelgeuse, one of the largest known stars, is 270 light-years away. Students looking into space at night are now looking at how far they can see. We should not lose sight of how truly immense such distances are. For example, if we were to count off the miles in a light-year, one every second-it would take us about 185,000 years.

We can now use the light-year for setting the scale of the Milky Way Galaxy. In light-years, our galaxy is about 80,000 light-years across, with the sun orbiting roughly 30,000 light years from the center. Within the Milky Way disk, stars are separated by a few light-years.

Astronomical Constants

Astronomical Unit Au = 1.495978707 x 1013 cm
Parsec = 206265 Au

3.262 ly

3.263 x 1018 cm

Light Year Ly = 9.4605 x 1017 cm
6.324 x 104 Au

P (pi) = 3.14159265 or 3 1/7

Formulas

Circumference (C) of a circle, diameter (D), and radius, R (R =1/2 D)

’ = C
D

C= ’ D

C= 2’R

The area of a circle, using R and D:

A= ’ R2

A= ’ D2
4

The surface area of a sphere of radius, R is:

A= 4’ R2

Distance Formula:

D= RT

D = Rate
T

THE SOLAR SYSTEM

Our solar system is made up of the sun and all the bodies that travel around the sun. Nine planets, including the earth, move around the sun in orbit. Some planets have one or more satellites, rings, along with smaller debris, including asteroids, comets, meteorites, and dust. Our solar system is dominated by one body-the sun, and not the earth. The sun is a typical star, a great sphere of luminous gas, making it impossible for the earth to get but so close.

The sun and its nine planets form the solar system. But smaller bodies, satellites (moons) orbit the planets and asteroids and comets orbit the sun. If the paths the planets follow around the sun were visible, we would see that the solar system is like a huge set of elliptical rings, centered approximately on the sun and extending about four-billion miles outward to Pluto's orbit. It is hard to imagine such immense distances measured in miles. In fact, it is as foolish to use miles to measure the size of the solar system as it is to use inches to measure the distance between New York and China. Whenever possible, one should use units of measure appropriate to the scale of what one seeks to measure.

The earth's radius makes a convenient unit scale for measuring the size of the other planets. The earth's distance from the sun makes another acceptable unit for measuring the scale of the solar system.

The astronomical unit, abbreviated, AU, is the unit of measuring the distance from the planets. The distance from earth to the sun is about ninety-three trillion miles (150 million kilometers). Using AU to measure the scale of the solar system, Mercury turns out to be 0.4 AU from the sun, while Pluto is about 40 AU.

The solar system is the limit of our exploration of the universe with space craft. But telescopes, such as the Hubble, have extended our view far beyond the solar system to reveal that the Earth is one of many planets orbiting the Sun, and the Sun is but one of a vast swarm of stars orbiting the center of our galaxy, the Milky Way.

THE SUN

The Sun is really a star. It is a huge body of hot, glowing gases. Compared to other stars, the Sun is average in size. The Sun appears to us as a huge luminous disk because the Earth is the third planet closest to it. If we were several light years away, the Sun would appear as a small paint of light. The Sun is 30,000 light years (ly) from the center of the Milky Way. Many facts have been discovered about the Sun by studying it during solar eclipses. A solar eclipse occurs when the moon moves between the Sun and the Earth. In this position, the moon blocks the path of the Sun's light and casts a shadow on Earth.

In order for us to clearly understand our position in the solar system there are important facts we must keep in mind about the Sun. Its distance from the Earth is 93 million miles. It takes the sun's light 8 minutes and 20 seconds to reach Earth. The diameter of the Sun is about 864,000 miles and its rotation speed is 29km/sec, which equals to one complete revolution every 25 days.

Aristrachus, who lived in Samos (an island in the Mediterranean), estimated the relative size and distances between the Earth, Moon, and Sun. His calculations gave us a sense of their proportionate size and their relative distances from Earth. For example, by comparing the size of the Earth's shadow on the Moon during a lunar eclipse to the size of the Moon's disk, Aristrachus determined that the Moon's diameter was about one third the diameter of the Earth.

Aristarchus also calculated that the Sun is approximately 20 times farther from the Earth than is the Moon. These findings were determined by measuring the angle between the Sun and Moon when the Moon was exactly half lit. We now know the figures were inaccurate.

The Sun's rotation rate can be determined from the differences in the Doppler shifts. The Doppler method confirms that the Sun rotates faster at low latitudes than at high latitudes. At a latitude of seventy-five degrees the rotation period is about 33 days, and its direction of rotation is from West to East like the orbital revolution of the planets. It is possible for different parts of the Sun to rotate at different rates because of its gaseous composition, as opposed to the solid mass and slower speed of the terrestrial planets.

EARTH

In our look at the Milky Way, then the solar system, we can see just how involved we are with circles and things which are circular. We think in mathematical terms-circumference, radius, diameter, and Pi, which enable us to gain an understanding of circular objects.

CONCLUSION

At the conclusion of this unit, students will gain a better understanding of their place in the Milky Way. From a mathematical perspective and through interdisciplinary study, they will practice and demonstrate skills in the following:

- Problem solving activities
- Giving oral demonstrations, presentations
- Writing reports
- Creating art projects
- Building vocabulary through defining, usage, and practice
- Making graphs to show relative distances
- Using mathematical formulas
- Using scientific tables
- Taking several quizzes
- Developing and responding to questions for thought/discussion

Finally, each student will first evaluate his/her own performance and identify what he/she has learned or discovered. Then he/she will evaluate the class itself, responding in writing to several open-ended questions to determine what worked and what didn't work for students in this class. This information will be used to guide future planning and continued development of this unit.

VOCABULARY

1. Interstellar cloud: A cloud of gas and dust between the stars. These clouds may be many light years in diameter.

2. Interstellar matter: Matter in the form of gas or dust in the space between stars.

3. Light-year: A unit of distance equal to the distance light travels in one year. (ly, abbreviation). Ly = 1013 or about six trillion miles.

4. Mass: A measure of the amount of material an object contains.

5. Nebula: A cloud in interstellar space.

6. Orbit: The circular path planets take around a center, as the path the earth takes around the sun.

7. Planet: Any of the nine largest bodies revolving around the sun or orbiting the sun.

8. Solar Nebula: The rotating disk of gas and dust from which the sun and planets formed.

ASTRONOMERS

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1. Nicholas Copernicus: Developed a new model of the solar system. Known for making the earth an astronomical body bringing a kind of unity to the universe.
2. Erastosthenes: Concluded a technique for measuring the earth, which is in principle the same as many modern methods.
3. Galileo: Through his telescope discovered that the Milky Way consists of a myriad of faint stars.
4. Harlowe Shapley: Recognized the importance of Cehpeids as distance indicators and pioneered the work of determining distances to some of them in our own galaxy.
5. Herschel: Explained why the Milky Way appeared as a band all the way around the sky and demonstrated the nature of the stellar system..
6. Jacobus C. Kepteyn: First measured the size of the Milky Way. Kepteyn measured the distances to nearby stars by parallax and then estimated the distanced to more remote stars by their motion. He came closer to the accepted size of our galaxy.
7. Sir Isaac Newton: Discovered the Laws of Motion.
9. Claudius Ptolemy: Measured the distance to the moon.

10. Charles Messier: Placed on record 103 objects that might be mistaken for comets.
11. Thomas Wright: Developed the idea that the sun is a part of a large system of stars.
12. Immanuel Kant: The nebulous appearing luminous objects are referred by him are found in all directions in the sky.

LESSON PLAN I

Objective: Students will calculate, using the distance formula, how many kilometers are in one light-year.

Solution

Given the speed of light: 300,000 km/s

year: 365 days

Solution: Distance = Speed x Time

Light year = Speed of light x One year =

= 300,000 km x 365 days
S Year
= 24 hours x 60 minutes x 60 seconds
day hour minute
= 9,467,280,000,000 km
= 9,500,000,000,000 km approximately

LESSON PLAN II

Objective: By listening and following directions, students will:

1. Develop a pattern using numbers
2. Review graphing techniques
3. Review several types of graphs

Activity: Students will develop patterns of their own and then make a graph, using Bode's law.

As part of this activity, students will write down the numbers 0 and 3, then successive numbers by doubling the preceding number until them have nine numbers. (0, 3, 6, 12, 24, 48, 96, 192, 384)

Then they will add 4: (4, 7, 10, 16, 28, 52, 100, 196, 388)

Then they will divide by 10: (.4, .7, 1, 1.6, 2.8, 5.2, 10, 19.6, 38.8)

Using the data and numbers, students will create a graph.

LESSON PLAN III

Objective: Students will demonstrate correct use of mathematical scale to draw and graph a representation of our solar system.

There is always an artist in every group of students, sometimes sitting at the back of the classroom waiting to be discovered, and perhaps wondering how his or her talent will be used in our study of the Milky Way. Integrating art and humanities into the mathematics curriculum will involve the artists in the group and will include the following activities:

- First draw our galaxy, placing the solar system in scale, as one sees it.
- Then develop a mathematically scaled representation, using 1"= x amount of light-years.
- Finally, create a graph to represent distances and relative positions.

STUDENT READING LIST

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3. Drantz, Les, What the Odds Are, Harper Collins Publishers, NY, 1992.

4. Ferris, Timothy, Coming of Age in the Milky Way, Anchor, 1989. Shows how the model of the universe has been altered at various times in history.

5. Hamblin, Kenneth, Exploring the Planets, 1992.

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7. Morrison, Philip and Phyllis; the Office of Charles and Ray Eames, Powers of Ten. This book explains and shows the relative size of planets and objects in the universe.

TEACHER READING LIST

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