The Universe We See

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Introduction

NASA missions like the Opportunity rovers and Mariner 2 provide extraordinary insight to astronomers because they provide us with data that is not light. Astronomy is unique among the sciences because what we are able to learn about the universe around us is greatly tied to the nature of light. This unit introduces both optics and astronomy concepts together in a truly integrated unit. Students often have a greater interest in astronomy than optics, and in teaching the two together should help students to have a greater understanding of both. Students could gain a better understanding of the electromagnetic spectrum by exploring data from different types of telescopes. Students will also be able to tie luminosity, spectroscopy, intensity, black body radiation and other physical concepts to their astronomical uses.

My School

William Penn High School is a traditional public high school in the Colonial School District. The Colonial School District mainly serves the community around the town of New Castle, but also reaches into some of the southern most parts of Wilmington, and reaches into a much more rural community of Port Penn. New Castle is a working class community that developed around large manufacturing hubs including an oil refinery and a car manufacturing plant that has shut down. The Colonial School District is a part of a range of choices students have to attend. New Castle County has a large amount of charter schools and vocational and technical schools that students are able to choice into; 14% of students that live in the district choice out of the traditional school system in some way. The district received its odd shape due to court ordered desegregation that evenly dispersed the majority black students of Wilmington into the predominantly white suburbs of New Castle County. The suburbs surrounding Wilmington have become increasingly diverse since this time. A lasting effect of this order is that William Penn, Colonial School District's lone high school, is a diverse integrated space.[1]

36% of the students attending William Penn are considered low income, as defined by eligibility for SNAP, TANF, Medicaid or guardian income below or near the poverty line. William Penn has begun implementing restorative practices as an effort to provide needed support for communities that experience the traumas that come with poverty. The student population is roughly half African American, one-quarter Hispanic, and about one-fifth White. Despite the student demographics, the staff of William Penn is overwhelmingly white, a disparity that is being addressed by the district through a number of diversity initiatives. William Penn also has a disproportionately large segment of its student population, 18%, who receive special education accommodations. 29% of students are assessed as meeting standards in science. [2]

William Penn has implemented an innovative school model that offers students different degree programs, which are organized into three colleges: STEM, Humanities, and Business. These degree programs give students specialized classes that allow them to gain valuable work and collegiate experience before graduation. Some of the degree programs provide rare work based experience like becoming a certified phlebotomy technician, receiving a paid internship with the school district to provide IT support, and art students having the opportunity to sell their work in a public store. These work focused opportunities are paired with a large selection of Advanced Placement courses that help to prepare students for college.

The Colonial School District has recently made a massive investment in reopening the districts old planetarium space. This space has been equipped with state of the are projection equipment that can be manipulated by computers. The districts goal is to use this space to spark greater interest in science from all ages, and the push students to better understand the world around them. The space has only recently been opened, but it has already been used for multiple different grade levels, and community education opportunities.

The Course

This unit is designed for an eleventh grade integrated science course, which serves academically lower achieving students. These are students that are placed in the integrated science course instead of chemistry. The integrated course also serves all of the special education students in the school. These students will hopefully take either chemistry, physics, anatomy and physiology, or paramedical sciences as twelfth graders, though they are not required to take any addition science courses. One of the main goals of the course is to inspire more students to take an additional science course despite them not being required to. The units in this course are: chemical reactions, mechanics, electricity, sound, optics, astronomy and environmental science. This unit will be the first step away from teaching these subjects as isolated units and beginning to make this a truly integrated course. This unit will be taught after the unit on sound, and before the unit on environmental science.

Rationale

This unit is designed to utilize student engagement to help them to access the curriculum. In the past, students have been the most interested in astronomy as a concept. This unit should use that interest for students to both understand astronomy and optics better as concepts. The unit lessons are designed to have students use optical data and concepts to explain astronomical phenomenon. This is a method is part of the practices utilized in the Next Generation Science Standards.

Background Content

In order for students to make a meaningful and lasting connection between the cosmos and the nature of light it important that they see how deeply integral understanding light is to understanding the cosmos. The appropriate Next Generation Science Standards are listed.

Physical Nature of Light HS-PS4-3

Though light is something that all people interact with continuously through every day, it is something that is often misunderstood. The Sun is our main light source on Earth, and for much of recorded history it was one of the only sources of light. As any cold blooded animal well understands, this light that we receive from our Sun is deeply connected to another necessity for life, energy, specifically energy in the form of heat. Students already understand that these two things come as a package deal; sunlight, lamp, and fires both come with both heat and light connected, but students must understand that these are not two different things that travel together but that light is a manifestation of energy. The different energies that are contained within the electromagnetic spectrum will be addressed later in the unit, with blackbody radiation following later. When human skin and other objects interact with light it is absorbed by individual atoms, and some of energy of the individual photons is lost to the atom. Because all energy must be conserved this lost energy is not simply lost, but it is converted to a different form of energy. This simply understanding will be sufficient for the beginning of the unit, as the lessons progress students will be introduced to the quantum theory of this process, and how different colors are absorbed and reflected.

Light, oddly enough does not just exist as one thing, but as two things at the same time. When you look at the way that light can be diffracted and the way it bends, lights behave exactly the way you would expect due to wave theory. But as Einstein would discover, the way light can both be absorbed and reemitted from individual atoms would lead you to believe that light is particulate like mater. In reality, it is both. Light exists as a strange marriage of opposites, referred to as the wave-particle duality.[3]

Students will also be introduced to the physical components of light, and how they differ from sound waves. This unit follows a unit that explicitly teaches about the characteristics of unspecific physical waves, and waves as they relate to sound. I plan to take time to explicitly contrast the differences between these types of waves. Students will have an understanding that the amplitude of a sound wave has an effect on the volume of sound, and will likely be able to deduce that the amplitude of a light wave relates to its relative brightness. The same logic will apply to students understanding that the pitch of a sound wave is created by its frequency, and the color of light is also determined by frequency. It will be important to note early that light behaves like both a wave and a particle. This will be discussed by talking about what photons are, and how they are like a particle, but also exist as a packet of energy. We will not dig into this topic very much, but it should be noted.

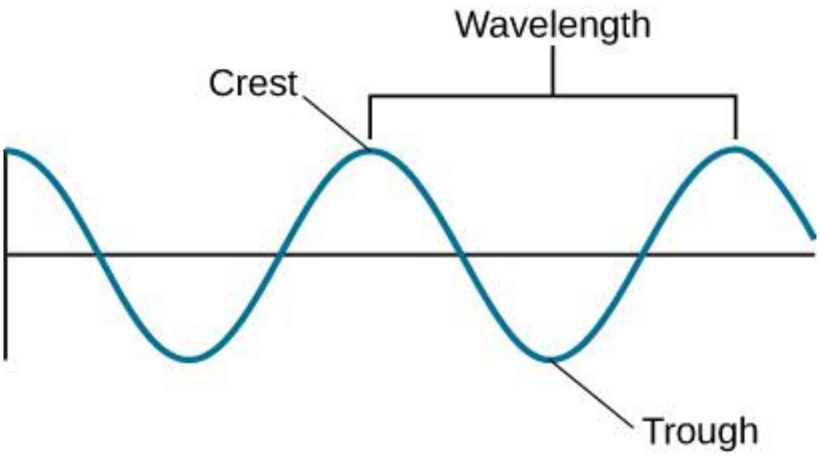

Figure 1: This figure shows a transverse wave and depicts the different vocabulary terms for characteristics of a wave.[4]

By this point the class has already drifted too far from the cosmos, and an introduction to the speed of light will bring us back. This is concept that students may already have an intuitive hunch about, but when the logic is applied to the enormity of space things get more interesting. It takes eight minutes for us to see the light from our own star the Sun; it takes four whole years for the light from our closest neighboring star, Alpha Centauri, to reach our planet. This means that viewing stars that are great distances away is viewing not what the star looks like today, but what it looked like many years ago. This will bring students to understand the very useful unit of distance, the lightyear, which is defined as the distance that light can travel in one Earth year. Students will also be introduced to the mathematical relationship between the speed of light, frequency, and wavelength. No object is able to travel faster than rays of light in a vacuum, and scientists say this today with a great degree of confidence that this will always hold true. [5]

$$C = \lambda * v$$

Equation 1: This equation shows the relationship between the speed of a wave and the waves wavelength and frequency. The speed of light in a vacuum is $3.0*10^8$m/s. C is the speed of light in a vacuum. λ is the wavelength. v is the frequency.

It is important to understand intensity of light in order to understand how astronomers can determine the distance of stars. This centers on astronomers determining what type of star it is to determine a baseline, but that will go beyond the scope of this unit. As light travels from a source it continually becomes less and less concentrated. This happens because when light is emitted form a source light is sent out in every direction. As the light travels over greater and greater distances light waves begin to spread out more and more from one another. This is best explained with a model. Imagine covering a light bulb so that light can only escape out of a hole that is 1cm x 1cm. If you hold a piece of graph paper 1 cm away from the hole you will find that that light has now spread to region that is 2cm x 2cm. If you move the paper back another centimeter the light will spread to a region that is 3cm x 3cm. This will be done with students in class using a lightbulb with a cover, and graph paper. Students will be able to easily see the trend that is discussed by this relationship.

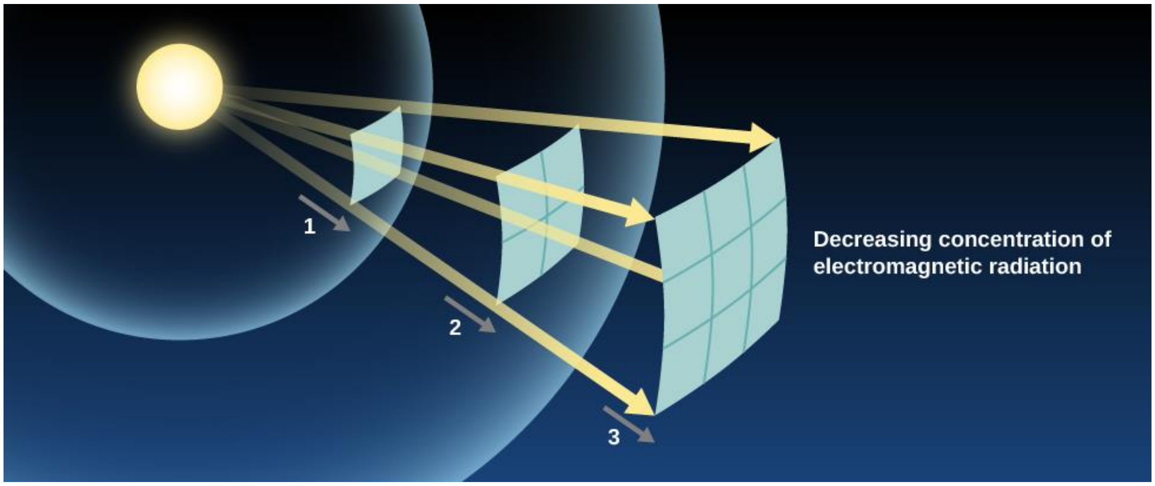

Figure 2:This figure depicts how light spreads over a larger area as the light moves farther and farther from its source. [6]

As we move farther and farther from the light source the light will take up a greater area of the paper, and therefore the brightness of light at any point on the paper will be diluted as well. This relationship is described in the inverse squares law. Students can use this equation to determine the distance between a star and Earth, if they know the initial light brightness (called "Luminosity" in astronomy). Students can also use this relationship to determine the correct brightness if the true distance is already known.

$$B = \frac{L}{4\pi d^2}$$

Equation 2:This equation shows the relationship between the brightness of the observed light (B) in relationship to the lights initial brightness (L) and the distance the light has traveled (d).

The Electromagnetic Spectrum HS-PS4-4

Light exists over a wide range of wavelengths and frequencies. As we have discussed these differences lead to the waves having differences in energy as well. This spectrum of light is referred to as the electromagnetic spectrum. This spectrum has been divided into different regions. Each of these regions have different general characteristics.

The electromagnetic spectrum is broken into the following regions, organized in order from smallest to largest frequency: Radio, Microwave, Infrared, Visible, Ultraviolet, X-ray, and Gamma (γ) ray. Each region of the spectrum reveals something different to us about the cosmos around us, and also have great uses in technology and medicine. Connecting the used in astronomy to fields that are more concrete to students can help students to build a greater understanding of the nature different types of light.

Radio waves are the longest waves of the spectrum, with wavelengths ranging from just under a centimeter, to well over a mile. Radio waves, as its name suggests, is used extensively in radio and television communication. They are also used in cell phone communications, and no it does not have enough energy to cause damage to your body's cells. Radio waves are one of the few regions of the electromagnetic spectrum that can penetrate the Earth's atmosphere easily, and have become a large part of astronomy. Radio waves show evidence of pulsars and quasars, these specific astronomical objects fall beyond the scope of this unit, but they are very important in determining the distances of other galaxies. These telescopes look greatly different than what students would expect a telescope looks like, and it is important for students to see the diversity of different types of telescopes. Radio telescopes are massive instruments that are on the Earth's surface, and interestingly do not need a mirror as we know them to reflect radio light. Radio waves are also used in the medical field for magnetic resonance imaging.

Microwaves are perhaps the most easily identifiable region of the spectrum because of their wide use in heating food. They are often used in communications in radar. They are also used in cell phone communications, and no it does not have enough energy to cause damage to your body's cells, that does not occur until you get to the ultraviolet region. Microwaves are central to our understanding of the Big Bang through the discovery of the Cosmic Microwave Background, which will be discussed more in-depth later in the unit. Radio waves and microwaves are produced in great numbers by humans on Earth, and do not occur as frequently on other planets. The fact that Earth emits so many of these low frequency waves shows that there is something weird happening on our planet. If we are to be discovered by other lifeforms these are likely to be the clue that gave away our location, though of course, they will take a long time to spread through the universe.

Next as we approach the visible region of light we reach the Infrared region of light. This region is known popularly by its ability to allow people to see heat, and this use will be discussed as it related to blackbody radiation later in the unit. Infrared light was the first “invisible light” to be discovered in 1800 by astronomer William Herschel on accident. He was measuring the different temperatures of the rainbow as split by a prism and had laid a control thermometer next to the red light, and to his surprise it had exceeded all of the visible temperatures. Herschel described this as rays coming from the sun that were unfit for vision, and named his discovery invisible light.[7] This discovery of something that had been around us all of this time was a monumental discovery in the world of physics at the time. In astronomy infrared light is used to determine the temperature of cold objects.

By far the smallest region of the electromagnetic spectrum is light that is visible to the human eye. It is incredible to ponder on the fact that only we can only see one ten billionth of the of the electromagnetic waves that pass through our bodies every day. No one needs to be told of the applications of visible light, and its importance in life. In astronomy visible light was for a long time the only way that we had to see the universe around us, and it still has important uses today in the world of technologically advanced instruments.

Ultraviolet light also referred to as black light is the beginning of the spectrum that is dangerous to human beings, and for some reason the first one that children find exciting. Ultraviolet light was discovered just a year after Herchel discovered Infrared light. Johann Wilhelm Ritter conducted an experiment very similar to Herschel’s, but using a material that is similar to objects that glow in the dark today. He placed a region just beyond violet light, and this region glowed the greatest of all of the colors. We then learned that the light that we knew was far from the complete picture.[8] Exposure to ultraviolet light, specifically UVB light, causes neighboring thymine base pairs in DNA to bond together, leaving that segment to become damaged and need repair. This causes an increased production of melanin and a perceived darker skin tone, but when the DNA strands are repaired there is a chance for error which can cause damage to the cell, and over time can lead to cancer. UVB does also have its health benefits, a lack of any exposure to UVB light is linked to a deficiency of vitamin D, which can lead to prostate, colon or breast cancer. A simple ten minutes of exposure is believed to be sufficient. Aside from cancer, ultraviolet light is also important in imaging in astronomy and understanding the lifecycle of distant hot stars.

X-rays have their well-known applications in medical imaging, but they are also have enough energy to be very dangerous to humans. The medical field takes great care to minimize people’s exposure to X-rays for good reason, they are known to cause cancer do to their ability to rip apart chemical bonds, leaving behind dangerous free radicals. Though low doses are unlikely to cause lasting damage, medical professionals who use X-rays must be extremely careful due to their increased exposure. X-ray astronomy is a more resent development, because X-rays are unable to pass through the Earth’s atmosphere in any significant quantity. Due to this X-rays were unable to be looked at until we were able to develop telescopes that could function in orbit. X-rays are often the result of the violent explosions of massive stars, thought they are emitted in smaller amounts in other processes. Though to us this may seem like a rarity these explosions, known as supernova, are frequent occurrences. They release a generous amount of X-rays mostly, and can only be seen for a limited amount of time after the occurrence.[9]

γ rays were discovered long before they were understood, and were named after the third Greek letter because they were the third byproduct of nuclear decay to be identified. It was not discovered until later that γ rays were an extremely energetic form of light, and would be the cause of death of many of the pioneering physicists, such as Marie Curie. To this day every single scientific notebook that Curie kept, and even her cook book, are considered to be too dangerous for human exposure.[10] Aside from nuclear decay, γ rays are produced only by the most violent events in the universe, such as the merging of stars and the supernova death of large stars, and also from violent events on Earth, like thunderstorms. Like X-rays, γ rays can best be directly observed from outside the Earth's atmosphere. Because they are so difficult to capture NASA"s Explorer XI Telescope detects γ rays when they interact with an electrical component, and emits electrically charged particles.[11] Evidence of γ rays can be best seen from the Earth's surface, because when the γ rays hit atoms in the atmosphere the atoms can often "break apart," and the pieces it is broken into can be observed on the Earth's surface. Recently these "pieces" have begun being used as a surprisingly accurate way to observe γ rays.[12]

Spectra HS-PS1-8

We perceive sunlight as white, because it is a combination of all of the different forms of light, as discovered by Isaac Newton. Why stars emit white light is a matter we will address later, but for now we will take it at face value. When this sunlight is reflected off of my white dress shirt all of the different colors of light are all reflected together. If red light or green light were to be reflected off of the same white shirt, then the shirt would appear to be red or green. When light is reflected off of my black tie the opposite occurs. All of the different colors of light are absorbed and converted into heat. Therefore, when we perceive the color black, we are really perceiving the lack of any color at all. This is also why wearing a black t-shirt on a hot summer day is a recipe for disaster, the black shirt absorbs more light than any other color, and will become hotter. My red sweater will absorb all colors of light except for red, which it will reflect. The same would occur with any other color.

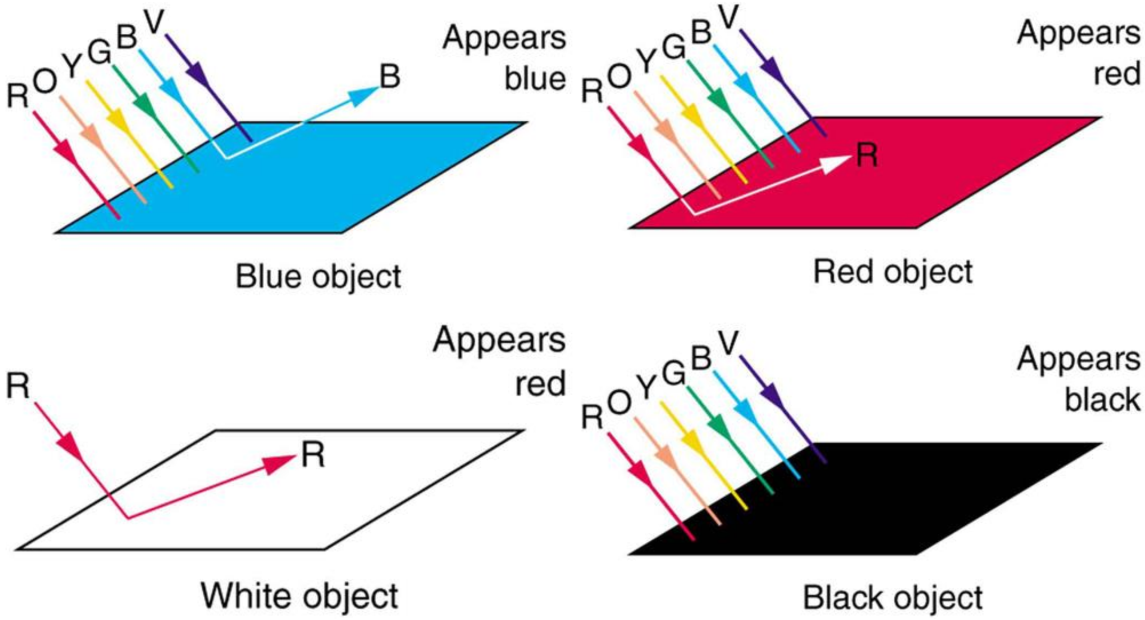

Figure 3:This figure shows how white light interacts with blue, red, and black objects, it also shows how pure red light interacts with a white object. [13]

In a similar fashion when white light passes through disperse gasses, like the exterior regions of the sun, not all light passes by. Different atoms will absorb very specific wavelengths, and will allow others to go past. The very specific wavelengths of light that are absorbed become missing from the light. Because each element absorbs different very specific wavelengths, this can be used to identify what elements make up the surface of not only our Sun, but of other stars as well. Elements are also able to emit the same very specific bands of light when their gaseous forms are heated.

The spectrums of lights that stars emit allow us to see a sample of what they are made up of, without ever having to visit. The same is true with planetary bodies. This spectrum data has allowed us to identify all of the elements within the Sun, and has even allowed us to discover an element before it was isolated on Earth. Evidence of Helium was first discovered from spectral observations of the sun and the element is named after the Greek word for the Sun, helios.

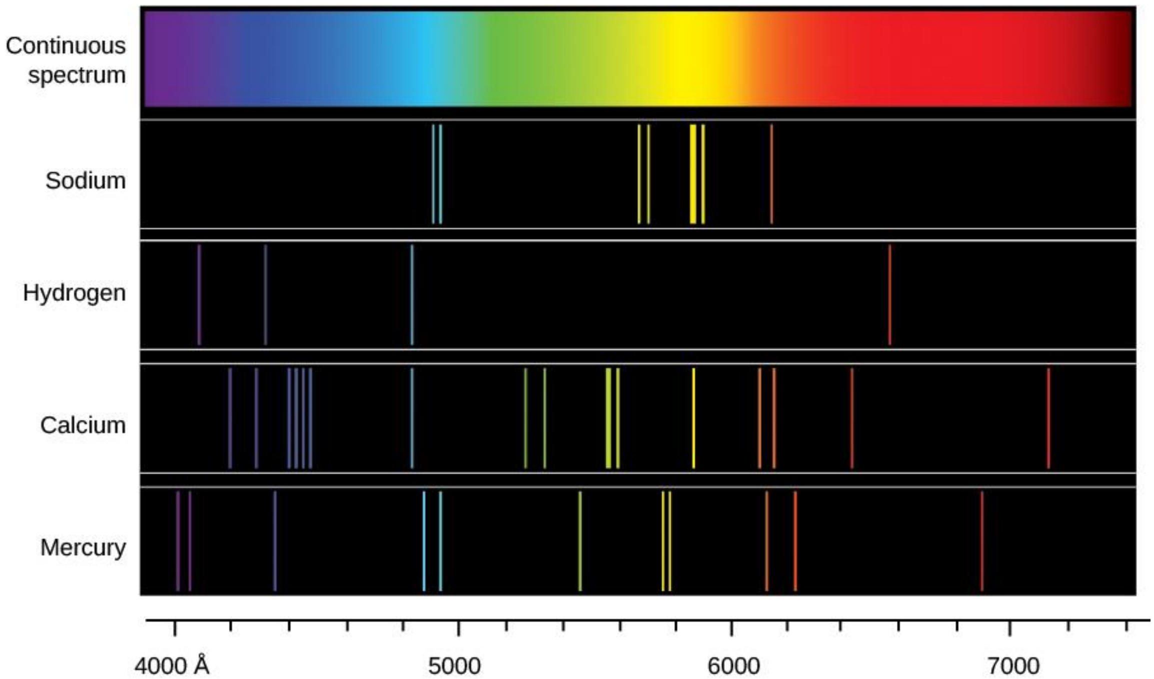

Figure 4: This figure shows the different emission spectrums from a few different elements. Each emission line is representative of different transitions in electron energy levels.[14]

Students should be able to be given emission data for different gas discharge lamps and be able to identify what element is in the gas lamp.

Telescopes HS-PS4-5

Telescopes have been used in astronomy since the time of Galileo Galilei, and have been an integral part in learning so much about the universe around us. Telescopes have mostly been designed around two main optical tools, lenses and mirrors.

Lenses bend parallel beams of light so that they will converge to a central point called a focus. How far the focus is from the lens depends on the curvature of the lens. A combination of two lenses are used in refracting telescopes to both magnify images and take in more light

Later telescopes were created with the use of both mirrors and lenses in more modern reflector telescopes. These telescopes have a large opening that lead to a concave mirror. This mirror reflects the parallel light rays onto a second mirror, which reflects to the lens for magnification. There are more variations in the design of these telescopes depending upon what they are being used for.

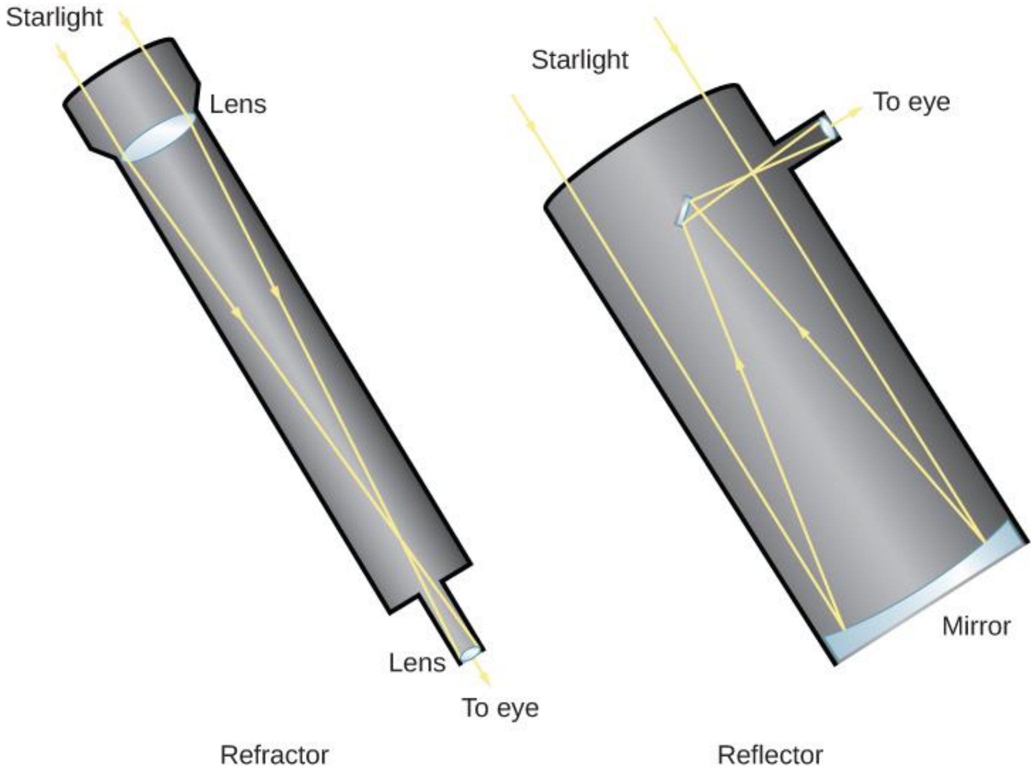

Figure 5:This figure shows both a refactor telescope (left) and a reflector telescope (right). [15]

A major benefit to the reflector telescopes is that mirrors ca be made much larger than lenses, allowing reflector telescopes to take in more light. Collecting light in a telescope is like collecting water in a bucket, a larger bucket opening will collect more water, and the same applies for telescopes. A larger amount of light allows a telescope to see objects that cannot be seen by the human eye because they do not emit enough light. This has allowed astronomers to see far more objects than the ancients could have ever imagined in the clearest nights.

Students will look at these different types of visual light telescopes and learn of the advantages and disadvantages of them. They will also use small lenses to build small telescopes to see that the technology is relatively simple.

Doppler Effect

When you are in the city and a car drives past you laying on the horn you hear a very distinct change in pitch. As the car get closer to us the sound of the horn raises in frequency until the car is next to you. And them as the car flees away you hear the pitch quickly drop in pitch. Dispute what you hear the driver hears a constant pitch the whole time. When an object is approaching you the sound waves get “bunched up” causing the pitch to rise, and when an object is moving away from you the sound waves get “spread out” causing the pitch to drop. And of you had a great ear, you could use the sound of the car as it is driving away and compare that to the true pitch of the horn and determine how fast the car was going.[16]

More importantly for astronomy, the same thing occurs with light waves. As an object that emits light moves towards the observer the light it emits produces shorter wavelengths. Astronomers call this a blue shift, because the light is shifted in the blue direction of the electromagnetic spectrum. When objects are moving away from the observer, the light has longer than expected wavelengths. This is called the red shift.

This can be paired with what we know about spectra to draw many conclusions about the motion of stars. Elements emit light at very specific wavelengths, and create easily identifiable patterns. Astronomers can see the pattern in spectra that matched hydrogen, but notice that all of the wavelengths are a few wavelengths longer than would be expected. They are able to infer that the object has been red shifted, and is therefore moving away from the Earth. The magnitude of the shift can also be used to calculate the speed at which the object is moving away from the Earth.

When this was discovered scientists observed the effects on as many galaxies and stars as possible. They quickly began to see a trend that almost all of the visible objects that are far from us are moving away from us. They found out that not only were all of these distant galaxies light redshifted, but the galaxies that were farther away had been redshifted to a greater degree.[17] This is a critical piece of evidence that the universe is expanding. It is very important to note that they are all not moving away from us at constant velocities from body to body, if this were the case we would be the center of the universe.

Blackbody Radiation

When you turn on your toaster you can tell right away if is working, not only by the heat that is emitted, but you will begin to see a red glow of the heating elements. This light is due to the kinetic vibration of the individual molecules. All molecules are vibrating all of the time, this is what temperature is an average measure of, and these vibrations are constantly emitting light usually well below the visible band of the spectrum.

When objects are heated they emit light across a broad range of the electromagnetic spectrum. This is why the sun, or a good old-fashioned light bulb, all emit white light, as we perceive it. But that is emitted is not uniformly distributed, it peaks in different regions depending upon the temperature. Both toasters and traditional incandescent lightbulbs peak in the infrared region, meaning the bulk of their light is emitted in this region. This is why incandescent bulbs are so ineffective, they are emitting a great deal of light that the human eye cannot even see. As objects are heated they peak in regions of the electromagnetic spectrum that have greater energy.[18] This constant emission of light is referred to as blackbody radiation. Blackbody radiation is infrared goggles can see heat, the range of temperatures that are experienced by the human body emit light in the infrared region.

Blackbody radiation is how stars give off their light. Because every individual atom has slight variations in temperature the light is emitted as a large band of wavelengths, but there is a much larger concentration of photons with a wavelength that correlates with the average temperature of a star. As that average is shifted more towards blue light the temperature of the star increases. This is very accurate way of determining the temperature of a star (bluish stars are hotter than reddish stars), and gaining more insight into the lifespan of the star.

The Big Bang HS-PS3-1

In the beginning, nearly fourteen billion years ago, all the space and all the matter and all the energy of the known universe was contained in a volume less than one-trillionth the of the period that ends this sentence. Conditions were so hot, the basic forces of nature that collectively describe the universe were unified. Though still unknown how it came into existence, this sub-pinpoint-size cosmos could only expand. Rapidly. In what today we call the big bang. [19]

If took a few minutes after the Big Bang, and an incredible amount of cooling before mater began to come into existence in the form of protons, neutrons, and electrons coming together to make atoms like we know them today. These early second of the universes history are almost incomprehensible at first because the universe at this time is almost unrecognizable to what we see around ourselves today. Despite it's complexity, the effects of the Big Bang are still evident, and the evidence is all around us.

As astronomers began to take better microwave and radio wave measurements they started to see a constant interference no matter where they pointed their telescopes. This was discovered by scientists employed by a phone company in the 1960's who were hoping to identify the source of interference in their communications. There were very few instruments that could be used to detect microwaves and radio waves at the time, but communication companies were pioneering the technology.[20] There was a narrow range of microwaves that seems to be coming from everywhere. We now know that this Cosmic Microwave Background. To simplify things, as the universe was expanding it passed a threshold to become the transparent world we know, from essentially a cloud that encompassed all of the universe. Before this cloud became transparent it was glowing with heat due to blackbody radiation, like a toasters heating element. Just before the universe became transparent it emitted a last burst of light, which is still scattering around today. 14 billion years ago this light was almost a visible orange but as the universe has expanded the wavelengths have increased to well below what they human eye can see. The only plausible explanation for the Cosmic Microwave Background is that it was emitted from the immediate aftermaths of the Big Bang.

It is clear from our observations of other stars and galaxies that our universe is expanding from a given point. We are able to determine this from observing the red shift in different stars.

Another important piece of evidence for the Big Bang is the concentration of hydrogen and helium in the universe. During these first few minutes of the universes existence hydrogen nuclei and helium were forming at a 10: 1 ratio. Some of these element would later fuse to form the beautiful array of elements that we now see across the Periodic Table. The fact that hydrogen and helium make up 75% of the universe today is further proof of the Big Bang. [21]

It is important for students to not just understand what we know about the beginning of our universe, it is imperative that they understand the evidence that has allowed scientists to draw that conclusion. Our ever-changing universe had a beginning, and it has put all of history we know of into motion.[22]

Teaching Strategies

Process Oriented Guided Inquiry Learning (POGIL)

This is a teaching method that is student centered and has the teacher acting as a facilitator guiding student to a clearer understanding of the concepts. POGIL activities focus on teaching students how to address problems, and this focus on the process leads to students having a deeper and more lasting understanding of concepts. In my class students complete POGIL activities in groups of two or three students, preferably three when possible. While students are working on the activity I go from group to group asking probing questions the gauge students understanding and to challenge what they feel are adequate explanations. It is important to break the activities into chunks and reconvening as a class to be sure that everyone is on the same page, and some students are not building any misconceptions.

Blended Learning

Learning management systems have become an integral component of teaching in the modern error. This unit will use the learning management system Schoology to help all students to understand the material. These systems allow for differentiated instruction for all students who are at different achievement levels. Some students need to have the opportunity to preview material before engaging in a grade level text. This approach also allows for immediate feedback on assignments via quizzes that automatically grade themselves. This is important because in science if a misconception sits with a student for too long it will be very difficult for them to move past it.

Inquiry Labs

One of the largest changes with science education with the implementation of the Next Generation Science Standards is how lab activities are done. Inquiry labs move away from traditional lab activities which came with a set of instructions, like a recipe for a cake. Inquiry labs give students all of the needed materials, and has them think about the problem at hand, and do their best to develop their own research. Student then utilize any data that they may have collected and draw their own conclusions. This process allows students to act as scientist themselves, and gain a much better understanding of the scientific method. This unit will use inquiry labs to help students gain an understanding of astronomy.

Activities

Intensity of Light

This lesion is designed to give students a greater understanding of how light disperses over time as it travels a greater distance from a star, and should address the lesson essential question: What changes about light as it travels through space away from a star the emitted the light? An important takeaway is that students understand that is that stars that are farther away will appear less bright, when they are the same type of star. This lesson is a hands on activity that demonstrates the relationship between brightness and distance.

Instruction

This activity will be introduced with a discussion that follows instruction of the speed of light. The class will begin with a discussion, “how old is the light we see?” after discussing the students’ different ideas I will inform them that the sunlight that we see on a day to day basis has taken 8 minutes flying through space at incredible speeds to reach the Earth’s surface. This will likely surprise many students, but others will be unimpressed. I will then move to our closest neighboring star, Alpha Centauri, “How long does it take light to travel to us from our nearest neighboring star?” Four years is a staggering amount of time, and the time frames get so much larger. Once students have a grasp on these time frames I will pose the next question, “What happens to all of that light on such a large journey?”

The lab activity will be centered around an old lamp that has the light bulb almost completely covered. The light bulb will be enclosed in a cardboard container, that has a one square centimeter hole cut in opposite sides of the container. Cutting two holes will allow for two student groups to share a light without getting cluttered. Students will also be working with: large graph paper with a 1 cm x 1 cm grid, and a meter stick. Students will be holding the graph paper up to the light at multiple different distance to see how the light disperses over greater distances. It will be clear to them that the light is both taking up a greater area as the distance increases, and that the intensity of the light diminishes as the distance increases.

As students move through this simple activity they will be able to record data on the area the light spreads out to cover. Students will be able to use this data to see the inverse square law, and will be able to extrapolate their data.

We will end with discussing the light bulbs we have worked with. These lightbulbs can only be seen from a few miles away, which is nothing on astronomical distance scales. We will lastly talk about how bright stars must be so that we can see them from such astounding distances. As an exit ticket students will write a letter to a younger family member and explain to them what happens to light as it travels through space.

The Sky Through Different Eyes

This lesson will be given in a planetarium. The use of a planetarium is not essential, but does make the lesson a more immersive experience for students. The idea of this lesson is to put students in the shoes of telescopes that can see different regions of the spectrum, and be able to get a better understanding to what astronomers can “see” with the assistance of telescopes. By the end of the lesson students should be able to address the lesson essential question: What would the night sky look like if our eyes could see different regions of the electromagnetic spectrum, not just visible light?

Instruction

The lesson will begin with a quick tour of the night sky as we see it. I will give students time to identify things the remember learning about in the past, and ask questions about things they are unsure about. These students have learned in the past about how the night sky changes over time, and how it is different in different hemispheres. We will spend some time reviewing these concepts as well to help ease students into the planetarium.

Once students have a good understanding of the night sky as we see it, we will look at the sky in only each of the different regions of the electromagnetic spectrum. In each region they will see different objects and events as discussed in the electromagnetic spectrum section above. As they begin to see the different regions of the spectrum, they will be able to appreciate that light from the highest regions of the spectrum occur in events that are highly energetic.

Spectral Lines of Different Atmospheres

This lesson will have them gain real experience taking spectral data from hand spectrometers and using that to make identifications. They will also use the observations to infer what effect the different atmospheres have on the planets. The lesson should address the lesson essential question: How can we use spectra observations to determine the chemical composition of different planetary atmospheres?

Instruction

This inquiry lab will begin with students taking spectral observations of a few different spectrum tubes that they will use for comparisons. The discharge tubes that will be used will be carbon dioxide, nitrogen, oxygen, argon, and any others that are available. As they take the spectral observation for these lights they will also take note of the different chemical properties for each compound. They will note that carbon dioxide is a greenhouse gas and would contribute to planetary warming. Nitrogen is relatively unreactive, but will hold some heat. Oxygen is highly reactive with most planetary materials, and also hold some heat. Argon is inert, and does not hold very much heat.

Students will then go to four different stations each with one of the four gas lamps listed above, each gas will be the sample atmosphere of a planet. Students will use their hand spectrometers to determine which gas they are observing. Once the gas has been determined students will be able to make inferences about each of the planets that correlates with each of the gasses.

Once students have made their inferences we will discuss the effect of even relatively small gasses in atmospheres. This will center at first with discussing carbon dioxide in the Earths atmosphere. Even though it is only currently at a concentration of 400 parts per million, it is having a major effect on the Earth’s global climate. Students will then reflect on the possibilities of obtaining spectra data with such a small relative concentration.

Notes

[1] "Penn (William) High School." Delaware School Profile. Summer 2018. http://profiles.doe.k12.de.us/SchoolProfiles/School/Default.aspx?checkSchool=490&districtCode=34.

[2] "Penn (William) High School." Delaware School Profile. Summer 2018. http://profiles.doe.k12.de.us/SchoolProfiles/School/Default.aspx?checkSchool=490&districtCode=34.

[3] Sagan, Carl. *Cosmos*. New York: Ballsntine Books, 1980.

[4] Fraknoi, Andrew, David Morrison, and Sidney C. Wolff. *OpenStax: Astronomy*. Rice University. https://cnx.org/contents/LnN76Opl@14.31:t5W09zMY@11/Preface.

[5] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[6] Fraknoi, Andrew, David Morrison, and Sidney C. Wolff. *OpenStax: Astronomy*. Rice University. https://cnx.org/contents/LnN76Opl@14.31:t5W09zMY@11/Preface.

[7] Herschel, Willaim. "Experiments on Solar and on the Terrestrial Rays That Occasion Heat." *Philosophical Transactions of the Royal Astronomical Society*, 1800, 17.

[8] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[9] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[10] Bryson, Bill. *A Short History of Nearly Everything*. London: Black Swan, 2016.

[11] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[12] Park, Naheen. "Status of Ground Based Gamma-ray Observations." *Cornell University Library*, August 30, 2018. https://arxiv.org/abs/1808.10495.

[13] Dirks, Kim, and Manjula Sharma. *OpenStax: College Physics*. Rice University. https://cnx.org/contents/Ax2o07Ul@14.4:pFeekPiU@20/Preface.

[14] Fraknoi, Andrew, David Morrison, and Sidney C. Wolff. *OpenStax: Astronomy*. Rice University. https://cnx.org/contents/LnN76Opl@14.31:t5W09zMY@11/Preface.

[15] Fraknoi, Andrew, David Morrison, and Sidney C. Wolff. *OpenStax: Astronomy*. Rice University. https://cnx.org/contents/LnN76Opl@14.31:t5W09zMY@11/Preface.

[16] Sagan, Carl. *Cosmos*. New York: Ballsntine Books, 1980.

[17] Sagan, Carl. *Cosmos*. New York: Ballsntine Books, 1980.

[18] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[19] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[20] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[21] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

[22] Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

Bibliography

Bryson, Bill. *A Short History of Nearly Everything*. London: Black Swan, 2016.

Though it may sound like a history book, this book looks at the history of our universe, and of us, through a scientific viewpoint. This book discusses all aspects of science and does so in a way that highlights individual antidotes about scientists through the years.

Dirks, Kim, and Manjula Sharma. *OpenStax: College Physics*. Rice University. https://cnx.org/contents/Ax2o07Ul@14.4:pFeekPiU@20/Preface.

OpenStax is a great organization that has a collection of open source textbooks of a number of subjects. They encourage these books to be used as primary texts for course work, and to be adjusted however necessary. They also supply additional materials with the text that are helpful to the learner.

Fraknoi, Andrew, David Morrison, and Sidney C. Wolff. *OpenStax: Astronomy*. Rice University. https://cnx.org/contents/LnN76Opl@14.31:t5W09zMY@11/Preface.

See above.

Herschel, Willaim. "Experiments on Solar and on the Terrestrial Rays That Occasion Heat." *Philosophical Transactions of the Royal Astronomical Society*, 1800, 17.

This is the original text of Herschel’s discovery of infrared light through experimentation with a prism and different thermometers laid out in the different color regions.

Park, Naheen. "Status of Ground Based Gamma-ray Observations." *Cornell University Library*, August 30, 2018. https://arxiv.org/abs/1808.10495.

This talk discussed the ways that you can observe gamma-rays indirectly by observing the highly accelerated particles that are emitted when the gamma rays interact with matter in the Earth's atmosphere.

Sagan, Carl. *Cosmos*. New York: Ballsntine Books, 1980.

Carl Sagan's 1980 book Cosmos is written for the general audience, and is designed to give them insight to the advanced workings of the cosmos. This book reads like a conversation, and represents scientific finding in a concise and presentable manner, and is a great introduction to astronomy.

Tyson, Neil DeGrasse. *Astrophysics for People in a Hurry*. New York: W.W. Norton & Company, 2017.

This book is in many ways model after, and inspired by Sagan's Cosmos. This series of essays read like a collection of stories, and not like textbook chapters. Each chapter in this book will leave you looking at the world around you with a different perspective.