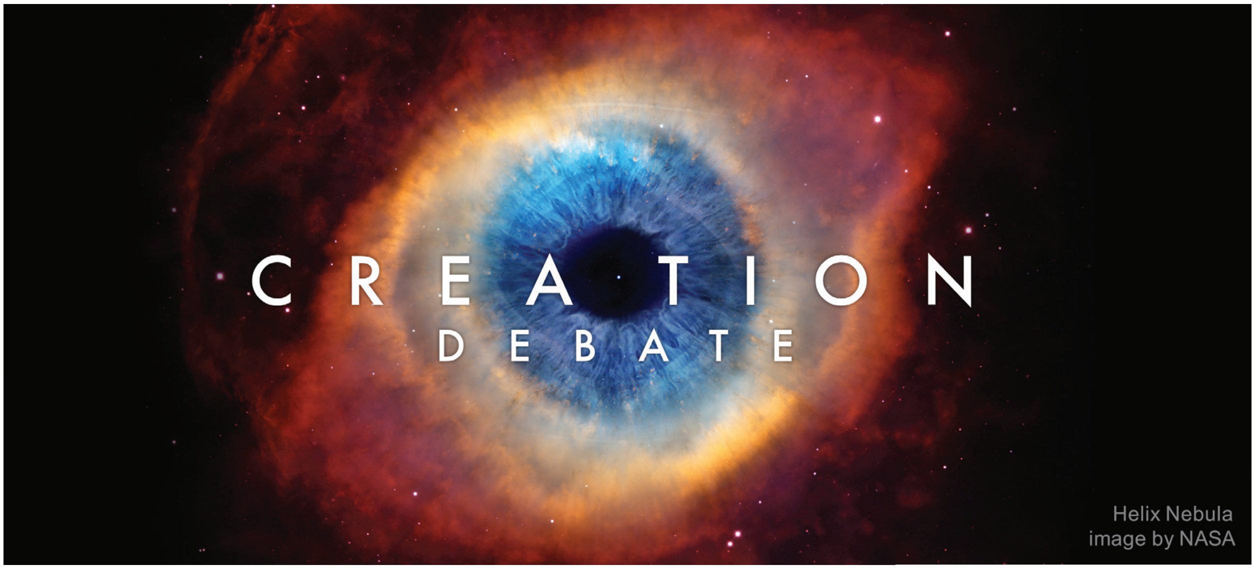


Leader Discussion Guide for *Cosmos: A SpaceTime Odyssey*

Episode 5: "Hiding in the Light"

The creators of *Cosmos: A SpaceTime Odyssey* state that their aim is to promote scientific literacy. Episode five, "Hiding in the Light," explains several properties of light, the speed of light having been addressed in episode four. "Hiding in the Light" reveals how those who discovered some of light's most interesting properties, even many centuries ago, did so by applying the principles of the scientific method. In this discussion guide we focus primarily on certain properties of light, the people who discovered them, and the principles of observational science that enabled them to discover scientific facts that ushered us into the modern age.

1. **Children of the 21st century are sometimes guilty of thinking that ancient people were ignorant savages. Yet from the Bible we know that, while man's savagery was evident as early as 6,000 years ago when Cain committed the first murder, the generations soon after Adam and Eve already understood how to work with metal and make musical instruments. After the global Flood and the dispersion of people from the Tower of Babel, many ancient people discovered or rediscovered scientific and technological principles.**

    A. **What fifth century BC philosopher does the program present as an example of an ancient discoverer of how light works? What country did he live**

in? What was going on in his land at the time? What sort of philosophy did he promote?

B. What did the philosopher invent?

C. Which of the philosopher's essays does Tyson describe as an early example of the scientific method? What principles does he say the essay recommends? How does that compare to the scientific method?

ANSWERS:

A. The philosopher Mozi (also spelled Mo-Tzu and several other ways) lived in what is now China before it became a unified nation. He lived in a time characterized by frequent wars between feudal-type warlords. Like Confucius, who lived during the same period, he opposed war. He was a military genius who focused on defensive tactics and encouraged peace and cooperation between warring kings. While Confucius taught that people had a responsibility to their family members, Mozi said that people had a responsibility to try to make things better for everybody. Therefore *Cosmos* host Neil deGrasse Tyson says that he promoted "universal love" and opposed oppression.

Images produced in a camera obscura are upside down like this projection of the New Royal Palace at Prague Castle produced on an attic wall by light rays entering through a hole in the tile roofing.

B. Mozi invented what is best described as a camera obscura. Tyson says, "He is said to have observed that light could be made to paint a picture inside a locked treasure." In its simplest form, the camera obscura admits light through a pinhole to project an image onto a screen inside.

C. In an essay titled "Against Fate," Mozi advises evaluating ideas using three questions. Tyson lists these in the episode:

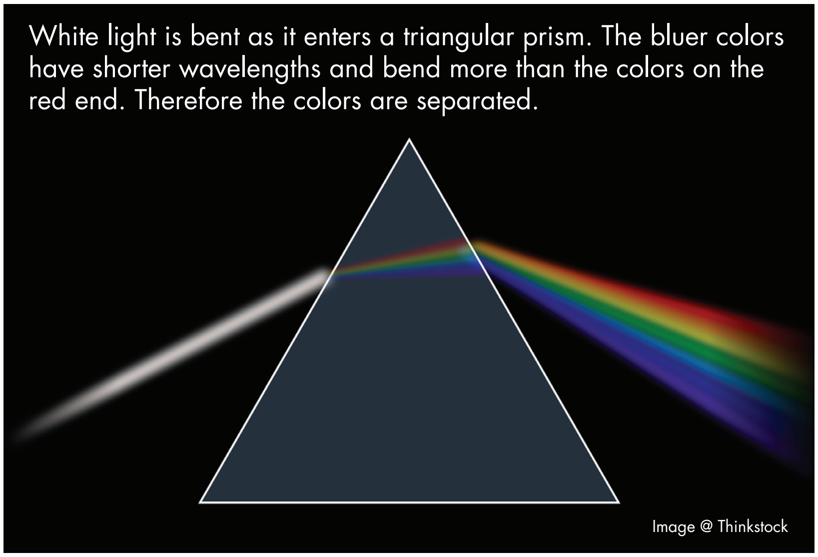
1. Question its basis.
2. Ask if it can be verified by the sights and senses of the common people.
3. Ask how it is to be applied and how it will benefit the greatest number.

The first two questions embody the essence of the scientific method, which is the basis of observational, experimental science. When we have an idea about how something works—a *hypothesis*—we should question whether it is true. To test a hypothesis scientifically we should test it in ways that we can observe and verify.

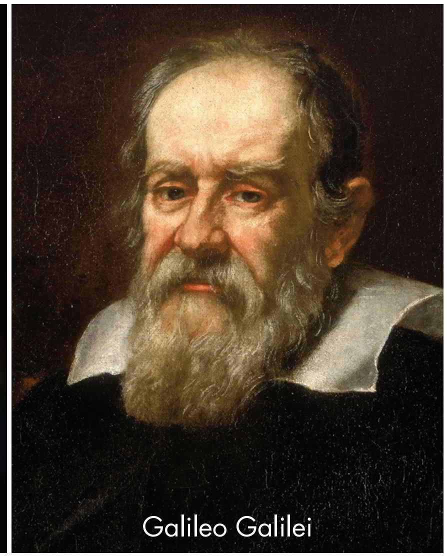
Ironically, molecules-to-man evolution and the big bang idea of how the universe originated are beliefs that Tyson accepts but that cannot be verified by observations or experiments. Even more ironically, in the *Cosmos* series, Tyson often mocks those who "question the basis" of the evolutionary ideas that he declares to be factual.

2. **What 11th century Arabian scientific genius learned a lot about how light moves? How did he test his idea about how light moved?**

ANSWER: According to Tyson, people once thought that rays from our eyes went out to touch the things we see and bounced back. Ibn Alhazen (Ibn al-Hasan, Ibn al-Haytham) reasoned that the stars were too far away for that process to happen and instead reasoned that light bounced off of objects and carried the image of those objects to our eyes. By observing light coming through a pinhole in a tent, he discovered that light moved in a straight line. He also invented a camera obscura. He discovered that the image was sharper when a smaller pinhole was used. Alhazen did much experimental work with lens and optics and was a pioneer in the field of optics. He also refined the scientific method by his insistence on discarding ideas that did not stand up to objective tests.



White light is bent as it enters a triangular prism. The bluer colors have shorter wavelengths and bend more than the colors on the red end. Therefore the colors are separated.



Galileo Galilei

3. **Galileo's telescope gathered in more light from the night sky than a person's eyes can. How? And why is that important? How do modern telescopes do the same thing, but even better?**

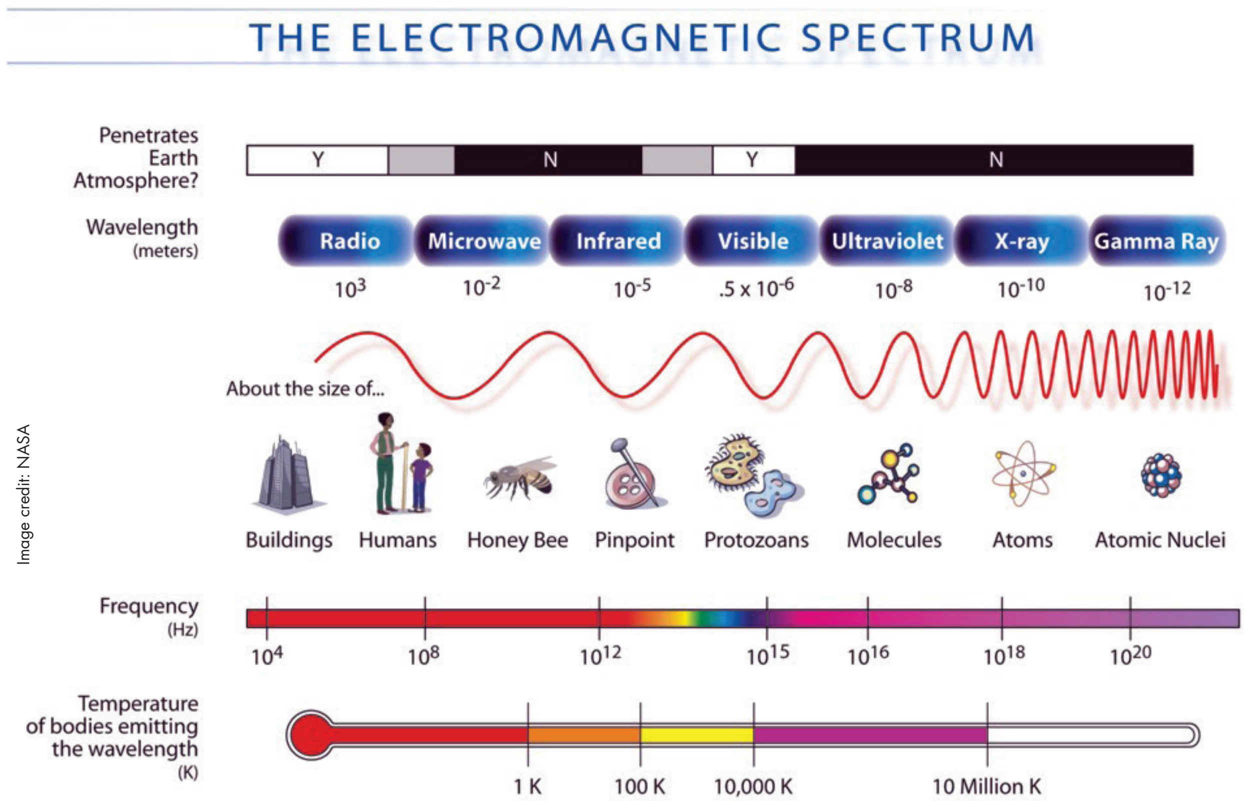
   ANSWER: A lens gathered and focused the light. That made it possible to see more objects in the sky than can be seen with the naked eye. Large modern telescopes can collect a lot of light from a given object in space because they track the object for many hours, moving as the earth moves and gathering enough light to produce a viewable image.

4. **What do Isaac Newton and the rainbow have in common?**

   ANSWER: Newton discovered that sunlight is composed of a mixture of colors of light. Those are the colors we see in the rainbow. Before Newton's discovery people thought that prisms created the rainbow light that came out of them. To prove that all the colors were already present in the white light that entered a prism, he passed the red light emerging from one prism through a second prism and found that it did not change. He also used a lens to recombine all the colors from a prism rainbow to make a beam of white light.

5. **What "new" kind of light did William Herschel discover? How did he do it?**

   ANSWER: William Herschel, known as the father of stellar astronomy, placed a thermometer in the colored light beams from light split into colors by a prism. His "control" thermometer was in a place beside the little rainbow. The thermometer that was sitting beside the little rainbow, *below the red end*, registered the highest temperature, however. He had discovered *infrared* light, which is invisible to the naked eye but carries heat. (The prefix *infra* means "below.")

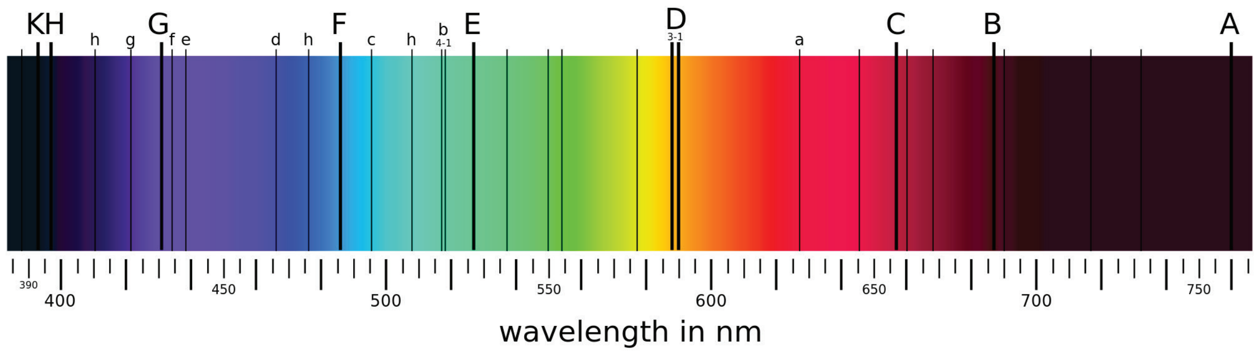


This depicts the electromagnetic spectrum. Visible light is the light we associate with the rainbow image produced by a prism. Various kinds of electromagnetic radiation are arranged left to right in order of decreasing wavelength and increasing frequency. This illustration shows the approximate scale of the wavelengths, which are dramatically long to the left of the visible spectrum and very short to the right of the visible spectrum. Ultraviolet light is the invisible light we associate with sunburn.

Additional explanatory information relating to Herschel's experiment as shown in the historical cartoon: Herschel was trying to find out whether all the colors of the rainbow had the same temperature. The thermometer exposed to red light registered a higher temperature than the thermometer exposed to blue light, but that was due to the much greater amount of red light over blue light in sunlight. Actually, the energy content of blue light is a little greater than that of red light.

6. **What 18th–19th century Bavarian who made many advances in optical science started out life as an apprentice not even allowed to read? How do the principles of light that he discovered enable us to know what stars are made of? How does that work?**

ANSWER: Joseph von Fraunhofer lived long before Einstein. He was allowed to read and get an education after he came under the patronage of Maximilian Joseph, the Prince Elector of Bavaria. He not only discovered how to make very fine optical glass, but he also discovered dark absorption lines in the sun's spectrum. These lines are still called Fraunhofer lines. Each element, because of the



This absorption spectrum shows black Fraunhofer lines, named in honor of their Bavarian discoverer. They represent the wavelengths of light absorbed by the atoms and molecules in a substance. Each element has a characteristic pattern determined by the quantum differences in the energy levels electrons can occupy. Spectrographic examination of stars makes it possible to determine the elements of which they are made.

characteristic pattern of energy levels in its electron cloud, absorbs a different pattern of wavelengths and therefore produces its own signature spectrum. By examining the spectrum of light produced by stars, scientists can pick out the elements in it. This is the science of *spectroscopy*.

7. Why does a prism split ordinary light into a rainbow?

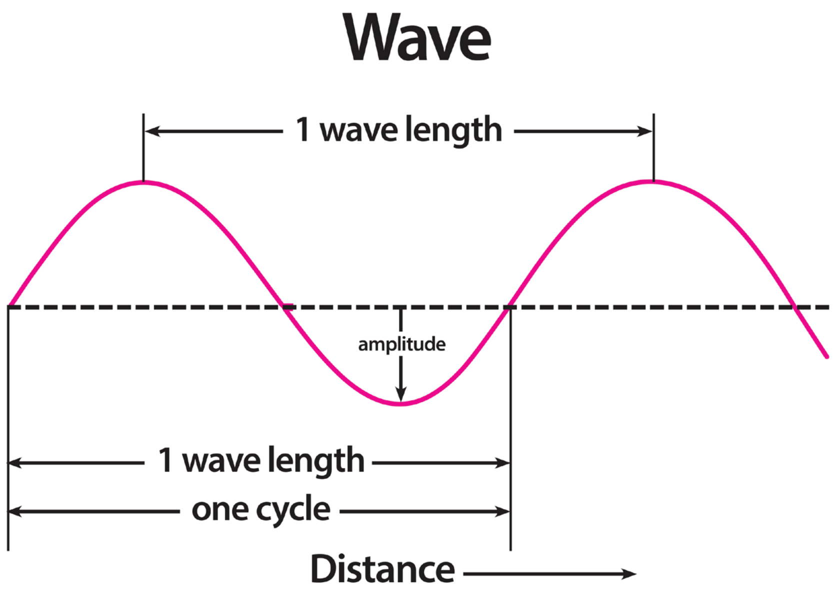
ANSWER: When light enters the prism glass, it slows down. This causes the direction of the light beam to bend. (A common misconception is that this would violate Einstein's theory of special relativity, that the speed of light is constant. However, the Einstein's theory does allow for different speeds in different medium. What the theory of special relativity refers to is that the speed of light does not depend upon the velocity of the source of light nor upon the velocity of the observer of the light.) Different wavelengths, or colors, of light bend by different amounts. Colors with shorter wavelengths—the bluer colors—bend more than colors with longer wavelengths—on the red end of the spectrum. Thus the colors separate. Therefore when the light emerges from the prism, the colors are each aimed in a slightly different direction and appear as a rainbow.

For further study:

http://en.wikipedia.org/wiki/File:Light_dispersion_conceptual_waves.gif (an animation that demonstrates this)

8. What is wavelength? What is frequency? Compare the wavelength and frequency of the various colors in the visible spectrum.

ANSWER: Wavelength is the distance between identical points on two successive waves. Frequency is the number of waves that pass a point during a second.



Wavelength is the distance between identical spots on two successive waves.

If waves are shorter, then more of them can pass a point in a second. Thus, high frequency waves have shorter wavelengths and low frequency waves longer wavelengths. The colors in the visible spectrum are red, orange, yellow, green, blue, indigo, and violet. The wavelength determines the color we see. Colors on the red end of the spectrum have longer wavelengths and lower frequencies. Colors on the blue end of the spectrum have shorter wavelengths and higher frequencies.

9. How do sound waves differ from light waves? How can you tell the difference between a high frequency and low frequency sound? On a pipe organ, which pipes make what kind of sound?

ANSWER: Sound waves need matter to travel, as they travel by causing matter to vibrate. Sound cannot travel through a vacuum. Light waves—or *electromagnetic radiation*—does not require matter to travel. That's why the light from the sun can reach earth through the vacuum of space. Sound waves also travel much, much slower; that is why you can see lightning before you hear the thunder it causes.

Just as the wavelength of light determines the color we see, so the wavelength of sound waves determines the pitch we hear. Higher pitched sounds are associated with high frequency sound waves. Higher frequency waves have shorter wavelengths. On a pipe organ, shorter wavelengths—and therefore higher pitched sounds—are produced by the shorter pipes.

10. **Name the various kinds of light (electromagnetic radiation).**

    ANSWER: Radio waves, microwaves, and infrared light have longer wavelengths and lower frequencies than visible light. Ultraviolet light (which gives you a suntan), X-rays, and gamma rays have shorter wavelengths and higher frequencies that visible light.

Reaching Beyond

11. **Why do evolutionists consider cosmic microwave background radiation to be strong evidence for the big bang model? What is wrong with that claim?**

    ANSWER: Evolutionary scientists believe the existence of cosmic microwave background (CMB) radiation is their best evidence for the big bang model because the big bang model was used to predict its existence. However, the existence of cosmic microwave background radiation does not mean it could have only come to exist through the big bang. Furthermore, the fact that CMB viewed from opposite parts of the sky has exactly the same temperature creates significant difficulties for the big bang model. This is called the horizon problem.

    For further study:

    http://www.answersingenesis.org/articles/cm/v25/n4/light-travel-time

    http://www.answersingenesis.org/articles/2014/03/17/has-cosmic-inflation-been-proved

    http://www.answersingenesis.org/articles/2006/03/29/cosmologists-evidence-inflation

    http://www.answersingenesis.org/articles/arj/v7/n1/cosmic-microwave-background

    http://www.answersingenesis.org/articles/ud/problems-with-big-bang

12. **Investigate some properties of light for yourself by building your own camera obscura, the forerunner of the modern camera. A number of Internet sites offer instructions. (You will need adult supervision or assistance in acquiring instructions and handling sharp cutting tools.)**

    Example of instructions:

    http://www.getty.edu/education/teachers/classroom_resources/tips_tools/downloads/aa_camera_obscura.pdf