How Does Light Travel?

By Chris Deziel; Updated April 24, 2017

The question of how light travels through space is one of the perennial mysteries of physics. In modern explanations, it is a wave phenomenon that doesn't need a medium through which to propagate. According to quantum theory, it also behaves as a collection of particles under certain circumstances. For most macroscopic purposes, though, its behavior can be described by treating it as a wave and applying the principles of wave mechanics to describe its motion.

Electromagnetic Vibrations

In the mid 1800s, Scottish physicist James Clerk Maxwell established that light is a form of electromagnetic energy that travels in waves. The question of how it manages to do so in the absence of a medium is explained by the nature of electromagnetic vibrations. When a charged particle vibrates, it produces an electrical vibration that automatically induces a magnetic one -- physicists often visualize these vibrations occurring in perpendicular planes. The paired oscillations propagate outward from the source; no medium, except for the electromagnetic field that permeates the universe, is required to conduct them.

A Ray of Light

When an electromagnetic source generates light, the light travels outward as a series of concentric spheres spaced in accordance with the vibration of the source. Light always takes the shortest path between a source and destination. A line drawn from the source to the destination, perpendicular to the wave-fronts, is called a ray. Far from the source, spherical wave fronts degenerate into a series of parallel lines moving in the direction of the ray. Their spacing defines the wavelength of the light, and the number of such lines that pass a given point in a given unit of time defines the frequency.

The Speed of Light

The frequency with which a light source vibrates determines the frequency -- and wavelength -- of the resultant radiation. This directly affects the energy of the wave packet -- or burst of waves moving as a unit -- according to a relationship established by physicist Max Planck in the early 1900s. If the light is visible, the frequency of vibration determines color. The speed of light is unaffected by vibrational frequency, however. In a vacuum, it is always 299,792 kilometers per second (186, 282 miles per second), a value denoted by the letter "c." According to Einstein's Theory of Relativity, nothing in the universe travels faster than this.

Refraction and Rainbows

Light travels slower in a medium than it does in a vacuum, and the speed is proportional to the density of the medium. This speed variation causes light to bend at the interface of two media -- a phenomenon called refraction. The angle at which it bends depends on the densities of the two media and the wavelength of the incident light. When light incident on a transparent medium is composed of wave fronts of different wavelengths, each wave front bends at a different angle, and the result is a rainbow.

Chris Deziel holds a Bachelor's degree in physics and a Master's degree in Humanities, He has taught science, math and English at the university level, both in his native Canada and in Japan. He began writing online in 2010 with the goal of exploring scientific, cultural and practical topics, and at last count had reached over a hundred million readers through various sites.

- 07.28.11

Scientists Discover The Oldest, Largest Body Of Water In Existence–In Space

Around a black hole 12 billion light years away, there's an almost unimaginable vapor cloud of water–enough to supply an entire planet's worth of water for every person on earth, 20,000 times over.

BY CHARLES FISHMAN 3 MINUTE READ

Scientists have found the biggest and oldest reservoir of water ever–so large and so old, it's almost impossible to describe.

The water is out in space, a place we used to think of as desolate and desert dry, but it's turning out to be pretty lush.

Researchers found a lake of water so large that it could provide each person on Earth an entire planet's worth of water–20,000 times over. Yes, so much water out there in space that it could supply each one of us all the water on Earth–Niagara Falls, the Pacific Ocean, the polar ice caps, the puddle in the bottom of the canoe you forgot to flip over–20,000 times over.

The water is in a cloud around a huge black hole that is in the process of sucking in matter and spraying out energy (such an active black hole is called a quasar), and the waves of energy the black hole releases make water by literally knocking hydrogen and oxygen atoms together.

The official NASA news release describes the amount of water as "140 trillion times all the water in the world's oceans," which isn't particularly helpful, except if you think about it like this.

That one cloud of newly discovered space water vapor could supply 140 trillion planets that are just as wet as Earth is.

Mind you, our own galaxy, the Milky Way, has about 400 billion stars, so if every one of those stars has 10 planets, each as wet as Earth, that's only 4 trillion planets worth of water.

The new cloud of water is enough to supply 28 *galaxies* with water.

Truly, that is one swampy patch of intergalactic space.

Equally stunning is the age of the water factory. The two teams of astrophysicists that found the quasar were looking out in space a distance of 12 billion light years. That means they were also looking back in time 12 billion years, to when the universe itself was just 1.6 billion years old. They were watching water being formed at the very start of the known universe, which is to say, water was one of the first substances formed, created in galactic volumes from the earliest time. Given water's creative power to shape geology, climate and biology, that's dramatic.

"It's another demonstration that water is pervasive throughout the universe, even at the very earliest times," says Matt Bradford, an astrophysicist at NASA's Jet Propulsion Laboratory and leader of one of the teams that made the discovery. (The journal article reporting the discovery is titled, without drama, "The Water Vapor Spectrum of APM 08279+5255: X-Ray Heating and Infrared Pumping over Hundreds of Parsecs.")

It is not as if you'd have to wear foul-weather gear if you could visit this place in space, however. The distances are as mind-bogglingly large as the amount of water being created, so the water vapor is the finest mist–300 trillion times less dense than the air in a typical room.

And it's not as if this intergalactic water can be of any use to us here on Earth, of course, at least not in the immediate sense. Indeed, the discovery comes as a devastating drought across eastern Africa is endangering the lives of 10 million people in Somalia, Kenya, and Ethiopia. NASA's water discovery should be a reminder that if we have the sophistication to discover galaxies full of water 12 billion light years away, we should be able to save people just an ocean away from drought-induced starvation.

The NASA announcement is also a reminder how quickly our understanding of the universe is evolving and how much capacity for surprise nature still has for us. There's water on Mars, there's water jetting hundreds of miles into space from Enceladus, one of Saturn's moons, there are icebergs of water hidden in the polar craters of our

own Moon. And now it turns out that a single quasar has the ability to manufacture galaxies full of water.

But it was only 40 years ago, in 1969, that scientists first confirmed that water existed anywhere besides Earth.

Read the latest installment of this series: Americans Guzzling More Bottled Water Than Ever"