The Doppler Effect: What Are Redshift and Blueshift?

By Elizabeth Howell, Space.com Contributor | May 02, 2014

Redshift and blueshift describe how light changes as objects in space (such as stars or galaxies) move closer or farther away from us. The concept is key to charting the universe's expansion.

Visible light is a spectrum of colors, which is clear to anyone who has looked at a rainbow. When an object moves away from us, the light is shifted to the red end of the spectrum, as its wavelengths get longer. If an object moves closer, the light moves to the blue end of the spectrum, as its wavelengths get shorter.

To think of this more clearly, the European Space Agency suggests, imagine yourself listening to a police siren as the car rushes by you on the road.

"Everyone has heard the increased pitch of an approaching police siren and the sharp decrease in pitch as the siren passes by and recedes. The effect arises because the sound waves arrive at the listener's ear closer together as the source approaches, and further apart as it recedes," ESA wrote.

Sound and light

This sound effect was first described by Christian Andreas Doppler and is called the Doppler effect. Since light also emanates in wavelengths, this means that the wavelengths can stretch or crunch together depending on the relative position of objects. That said, we don't notice it on daily-life-sized scale because light travels so much faster than the speed of sound — a million times faster, ESA noted.
American astronomer Edwin Hubble (who the Hubble Space Telescope is named after) was the first to describe the redshift phenomenon and tie it to an expanding universe. His observations, revealed in 1929, showed that nearly all galaxies he observed are moving away, NASA said.

"This phenomenon was observed as a redshift of a galaxy's spectrum," NASA wrote. "This redshift appeared to be larger for faint, presumably further, galaxies. Hence, the farther a galaxy, the faster it is receding from Earth."

The galaxies are moving away from Earth because the fabric of space itself is expanding. While galaxies themselves are on the move — the Andromeda Galaxy and the Milky Way, for example, are on a collision course — there is an overall phenomenon of redshift happening as the universe gets bigger.

The terms redshift and blueshift apply to any part of the electromagnetic spectrum, including radio waves, infrared, ultraviolet, X-rays and gamma rays. So, if radio waves are shifted into the ultraviolet part of the spectrum, they are said to be redshifted — shifted toward the lower frequencies.

The redshift of an object is measured by examining the absorption or emission lines in its spectrum. These lines are unique for each element and always have the same spacing. When an object in space moves toward or away from us, the lines can be found at different wavelengths than where they would be if the object were not moving (relative to us).

Redshift is defined as the change in the wavelength of the light divided by the wavelength that the light would have if the source was not moving — called the rest wavelength:

Three Types of Redshift

At least three types of redshift occur in the universe — from the universe's expansion, from the movement of galaxies relative to each other and from "gravitational redshift," which happens when light is shifted due to the massive amount of matter inside of a galaxy.

This latter redshift is the subtlest of the three, but in 2011 scientists were able to identify it on a universe-size scale. Astronomers did a statistical analysis of a large catalog known as the Sloan Digital Sky Survey, and found that gravitational redshift does happen — exactly in line with Einstein's theory of general relativity. This work was published in a Nature paper.

"We have independent measurements of the cluster masses, so we can calculate what the expectation for gravitational redshift based on general relativity is," said University of Copenhagen astrophysicist Radek Wojtak at the time. "It agrees exactly with the measurements of this effect."

The first detection of gravitational redshift came in 1959, after scientists detected it occurring in gamma-ray light emanating from an Earth-based lab. Previous to 2011, it also was found in the sun and in nearby white dwarfs, or the dead stars that remain after sun-sized stars cease nuclear fusion late in their lives.

http://www.space.com/25732-redshift-blueshift.html