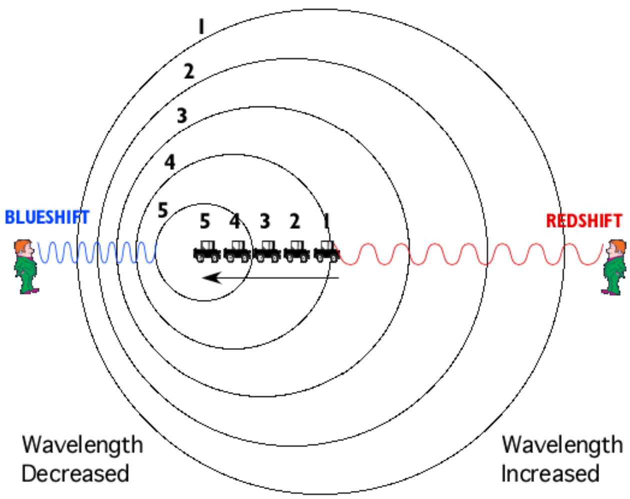
Lunar CRater Observation and Sensing Satellite

The Doppler Effect

Christian Andreas Doppler, also known as Christian Johann Doppler, was born in Salzburg, Austria, in 1803. At the age of 39, the professor of mathematics and physics published his most notable work, "On the coloured light of double stars and certain other stars of the heavens." In this work, Doppler discovered the apparent change in frequency and wavelength of electromagnetic radiation[1] as perceived by an observer when the source emitting the radiation is moving along the direction between the source and the observer. Spectral lines from the spectra of light emitted by objects in space moving toward or away from the Earth will differ in wavelength from their spectra if the objects were stationary.

Christian Doppler

The Doppler Effect for all parts of the electromagnetic spectrum[2] of radiation has a close analogy to sound waves, which need a medium, such as air, to travel through. Most people have experienced the Doppler Effect of sound when emergency vehicles, such as police cars with sirens blaring, travel along a direction toward them or away from them. The sound the siren makes seems to change dependent upon whether the police car is traveling toward you or away from you.



The Doppler Effect of Sound Waves from a Police Car's Siren: When the car is at location 1, the sound it emits moves outward in all directions, as indicated by the circle labeled 1. Similarly, sound emitted when the car is at locations 2 through 5 move outward as well, but note that the center of the circle is shifting with the car.

Look at the illustration above. The wavelength of the sound waves are compressed by the motion of the emergency vehicle toward the observer. Because the wavelength and the frequency of the waves are inversely related, as the wavelength decreases, the frequency increases.

For sound waves, the higher frequency is manifested as a higher pitch. The siren on the police car moving toward the observer sounds higher in pitch than it would if it were not traveling toward the observer.

On the other hand, the wavelength of the sound waves emitted by the police car which is moving away from the observer is "stretched" by the motion of the police car relative to the observer.

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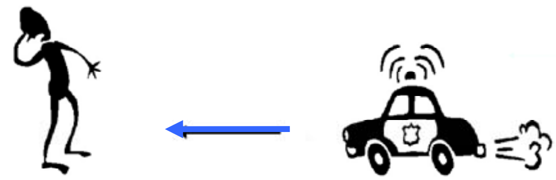
The Doppler Effect (continued)

A longer wavelength means that the frequency is decreased and the pitch of the siren is lower. The siren on the police car moving away from the observer sounds lower in pitch than it would if it were not moving away from the observer.

Blue Shifted
When the radiation given off by an object moving toward an observer is compressed by the motion toward the observer, its frequency appears to increase and we express that it shifts toward the blue end of the electromagnetic spectrum. Scientists say that the radiation is **blueshifted**.



Red Shifted
When radiation given off by an object moving away from an observer is stretched by the motion away from the observer, its frequency appears to decrease and we express that it shifts toward the red end of the electromagnetic spectrum. Scientist say that the radiation is **redshifted**.

The use of the terms redshift and blueshift came about in the early days of spectroscopy[3] when only the visible portion of the electromagnetic spectrum was observable. Spectral lines[4] in the spectra[5] of electromagnetic radiation emitted by objects moving toward or away from an observer will be blueshifted or redshifted compared to the spectrum of the radiation if there were no relative motion along the line of site between the source and the observer. Motion across the observer's field of view which is not along the line of site does not cause a Doppler shift.

The Doppler Effect is used by scientists to determine if stars in our galaxy or even entire galaxies are moving toward us or away from us. Scientists can determine information about the orbits of stars which exist in pairs through the Doppler Effect and can find new planets orbiting other stars by the Doppler shift they cause in the light we receive from a star. Students working on NASA's LCROSS mission to the Moon may use the Doppler Effect to determine the velocity of the spacecraft towards or away from their tracking station. This will be compared to the predicted orbit of LCROSS to determine whether or not the spacecraft is on target.

1: Electromagnetic radiation - radiation consisting of waves propagated through the building up and breaking down of electric and magnetic fields; include radio, infrared, light, ultraviolet, x-rays, and gamma rays. 2: Electromagnetic spectrum - the entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to the longest radio waves and including visible light. 3: Spectroscopy - the study of spectral lines from different atoms and molecules. Spectroscopy is an important part of studying the chemistry that goes on in interstellar clouds. 4: Spectral lines - light given off at a specific frequency by an atom or molecule. Every different type of atom or molecule gives off light at its own unique set of frequencies; thus, astronomers can look for gas containing a particular atom or molecule by tuning the telescope to one of its characteristic frequencies. For example, carbon monoxide (CO) has a spectral line at 115 GHz (or a wave length of 2.7 mm). 5: Spectra - a plural of *spectrum*, the plot of the intensity of light at different frequencies.