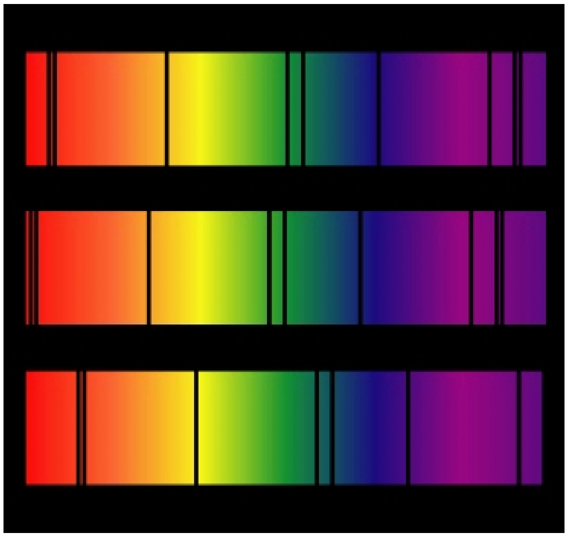
Top: Normal 'dark' spectral line positions at rest.
Middle: Source moving away from observer.
Bottom: Source moving towards observer.

We have all heard the sound of an ambulance siren as it passes-by. The high-pitch as it approaches is replaced by a low-pitch as it passes-by. This is an example of the Doppler Shift, which is a phenomenon found in many astronomical settings as well, except that instead of the frequency of sound waves, it's the frequency of light waves that is affected.

The figure to the left shows how the wavelength of various atomic spectral lines, normally found in the top locations, are shifted to the red (long wavelength; lower pitch) for a receding source, and to the blue (short wavelength; higher pitch) for an approaching source of light.

For very distant galaxies, the effects of curved space causes the wavelengths of light to be increasingly red-shifted as the distance to Earth increases. This is a Doppler-like effect, but it has nothing to do with the speed of the galaxy or star, but on the c hanging geometry of space over cosmological distances.

Just as in the Doppler Effect, where we measure the size of the Doppler 'red'-shift in terms of the speed of the object emitting the sound waves, for distant galaxies we measure their redshifts in terms of the cosmological factor, z. Close-by galaxies have z-values much less than 1.0, but very distant galaxies can have z=6 or higher.

Observing distant galaxies is a challenge because the wavelengths where most of the light from the galaxy are emitted, are shifted from visible wavelengths near 500 nanometers (0.5 microns) to much longer wavelengths. This actually makes distant galaxies very dim in the visible spectrum, but very bright at longer infrared wavelengths. For example, for redshifts of z = 3, the maximum light from a normal galaxy is shifted to a wavelength of L = 0.5 microns x (1+z) = 2.0 microns!

Problem 1 - The Webb Space Telescope, Mid-Infrared Instrument (MIR) can detect galaxies between wavelengths of 5.0 and 25.0 microns. Over what redshift interval can it detect normal galaxies like our Milky Way?

Problem 2 - An astronomer wants to study an event called Reionization, which occurred between 5.0 < z < 7.0. What wavelength range does this correspond to in normal galaxies?

Problem 3 - The NIRcam is sensitive to radiation between 0.6-5.0 microns, the MIR instrument range is 5.0 to 25.0 microns, and the Fine Guidance Sensor-Tunable Filter Camera detects light between 1 to 5 microns. Which instruments can study the Reionization event in normal galaxies?

Problem 1 - The Webb Space Telescope, Mid-Infrared Instrument (MIR) can detect galaxies between wavelengths of 5.0 and 25.0 microns. Over what redshift interval can it detect normal galaxies like our Milky Way?

Answer: L = 5.0, so 5.0 = 0.5 x (1+z) and so z = 9.0
L = 25, so 25 = 0.5 x (1+z), and so z = 49.0
The redshift interval is then z = [9,49]

Problem 2 - An astronomer wants to study an event called Reionization, which occurred between 5.0 < z < 7.0. What wavelength range does this correspond to in normal galaxies?

Answer: Z=5.0 corresponds to L = 0.5 x (1 + 5) so L = **3.0 microns**
Z = 7.0 L = 0.5 x (1 + 7) = **4.0 microns**.

Problem 3 - The NIRcam is sensitive to radiation between 0.6-5.0 microns, the MIR instrument range is 5.0 to 25.0 microns, and the Fine Guidance Sensor-Tunable Filter Camera detects light between 1 to 5 microns. Which instruments can study the Reionization event in normal galaxies?

Answer: The Reionization event can be detected between 3.0 and 4.0 microns ,which is within the observing ranges of both the NIRcam and the FGS-TFC instruments, but not the MIR camera.

Note: The Reionization event is believed to be the result of an intense period of supernova activity in millions of galaxies across the universe, which caused intense amounts of ultraviolet radiation sufficient to ionize hydrogen gas clouds. The first time the universe was ionized to this degree ended about 400,000 years after the Big Bang when the universe cooled down during its expansion. The term 're' ionization indicates that the expanding cooled hydrogen gas clouds once again became ionized about 100 million years after the Big Bang in a second ionization event.