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Editorial Article

How Far Visual Light Can Travel

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Abstract

As light travels extreme distances through space, its frequency slowly diminishes (attenuates). We observe this phenomenon as a redshift, the tendency of visible light to drop toward the red end of the spectrum. This study explains the true nature of redshift and provides a formula for estimating the rate at which light attenuates over extreme distances. When redshift is properly understood, it can tell us how far light travels before it drops beneath the visible spectrum.

Keywords: *Light; Attenuation; Redshift; Frequency*

Redshift is Attenuation

Over extreme distances, light attenuates according to the following equation $c = \lambda f$

where c = speed of light; λ = wavelength of light; and f = frequency of light wave.

The farther light travels, the greater the degree to which its frequency slowly diminishes as its wavelength correspondingly increases. We observe this phenomenon as a *redshift*, i.e., the tendency of visible light to drop toward the red end of the spectrum. The farther away a galaxy is, the more its light shifts toward the red end of the spectrum.

If a distant source emits light in the middle of the spectrum, it can be in the red end of the spectrum by the time we receive it. If, however, that source emits light in the blue end of the spectrum, it will have redshifted but could still be in the blue range by the time we receive it. There is no such thing as a "blueshift" whereby wavelengths shorten and frequency increases. All light is redshifted. Light cannot behave in any other way.

Because the surface temperature of the Sun is 5, 5000 C, it emits light in the yellow range of the spectrum. A star with a surface temperature of $12{,}000^0$ C emits light in the blue end of the spectrum, and one with a surface temperature of $3{,}000^0$ C emits light in the red end of the spectrum.

If Star ***X*** at a temperature of $7{,}000^0$C and Star ***Y*** at $12{,}000^0$C are the same distance from Earth, we could simultaneously be receiving light from ***X*** in the red end of the spectrum and light from ***Y*** in the blue end of the spectrum. The temptation is to conclude that light from ***X*** is redshifted and light from ***Y*** is blueshifted, but that would be a mistake. The light from both ***X*** and ***Y*** is being attenuated (redshifted) at the same rate. It is only because light from ***Y*** started out at a much higher frequency that it has not yet dropped into the red range of the spectrum.

Rate of Attenuation

Galazy GN-z11 enables us to estimate rate of attenuation over its distance of 13.39 billion light-years. Light from GN-z11 is dull red, and its frequency is documented by NASA as being in the low red range of the spectrum [1, 2].

Suppose that GN-z11's frequency at source (f_s) is 590 THz (mid spectrum) and its frequency received (f_{obs}) is 410 THz (low red). This would mean that over 13 billion light-years (Gly), frequency from GN-z11 has dropped by 180 THz. This is equivalent to frequency dropping every billion light-years by 2.75% of the frequency of the previous billion light-years. We can thus express redshift attenuation ($\mathbf{R_A}$) by the following equation in which distance (D) is in incremental units of one billion light-years (Gly).

$$R_A = f_{obs} = f_s (0.9725)^D$$

When its frequency drops below 400 THz, light is no longer visible. It continues at the speed of light but as electromagnetic energy that cannot be seen. This would happen for GN-z11 at 14.6 Gly – which means that an observer located 2 Gly from Earth in the opposite direction would not be able to see GN-z11 at all.

Unseen Galaxies

At distance 10 Gly the frequency of light from a sun-like star emitting at 525 THz (yellow range) drops below the visual threshold of 400 THz. Thus, we have no way of knowing how many stars farther than 10 Gly away may be invisible to us.

The Hubble Space Telescope creates for us a spherical horizon with radius of 13.4 Gly. We have no way of knowing how many galaxies there may be at or beyond 15 Gly because their light will have dropped below the visual threshold of 400 THz some 400 million light-years before it reaches us.

It is a convenience of nature that there should be a maximum distance that visible light can travel. If this were not so, the night sky would be ablaze with a patchwork blanket of light rendering us incapable of distinguishing one celestial object from another. We would never be able to understand the cosmos or our place in it [3].

Conclusion

Over extreme distances through space, the energy of light gradually diminishes (attenuates). As its frequency slowly reduces, its wavelength correspondingly increases. We observe this phenomenon as a redshift, the tendency of visible light to drop toward the red end of the spectrum. Redshift measurements suggest that the energy of light emitted from far distant galaxies may drop beneath visibility within a range of from 10 to 14 billion light-years from us, depending on its frequency at source [3].

References

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