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Cosmological Redshift of the Hydrogen (Lyman) Alpha-Line and the Principle of Energy Conservation

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"It doesn't matter how beautiful your theory is ...
If it doesn't agree with the experiment, it's wrong."
Richard Feynman

According to the standard cosmology, nearby and distant galaxies[1] recede from the Earth because the Universe is expanding at a constant rate. This theory states that the wavelength of light coming from these galaxies increases or shows cosmological redshift. If this shift is denoted as z can be defined by the following equation

$$1 + z = \lambda_E/\lambda_G \quad \dots (1)$$

where λ_G is the wavelength of light emitted by a galaxy (or any astronomical object) and λ_E is the wavelength of this light measured by an Earth observer.

Bohr's equation for energy levels of the hydrogen (H) atom is

$$E_n = 1/n^2(-2\pi^2e^4m/h^2) \dots (2)$$

where n (= 1, 2, 3,) is the quantum number, m is the mass of the electron, e (= 1.6×10^{-19} C) is its charge and h (= 6.63×10^{-34} J sec) is Planck's constant.[2]

The spectrum of H atoms is dominated by a series of lines, the highest in energy being the Lyman series from 121.6 nm - 92.1 nm in the far-ultraviolet (UV) region. The hydrogen (Lyman) alpha-line or Ly-α at 121.6 nm is of utmost importance in many fields of astrophysics. For the sake of simplicity, we will mainly deal in this communication with the Ly-α line.

The energy of the photon emitted by the H atom during its transition from the higher (excited) energy level with $n = 2$ to the ground level with $n = 1$ is

$$h\nu = 3/2(\pi^2e^4m/h^2)$$

[1] We define nearby galaxies as those galaxies whose redshift z is from 0.001 to 0.1 (or $0.001 \leq z \leq 0.1$) and distant galaxies those having $z > 0.1$. Of course, there is no sharp boundary between nearby and distant galaxies.
[2] It is often considered that the Schrödinger equation is superior to Bohr's equation in describing the H atom. In most cases, the results of both approaches coincide or are very close.

where ν is the frequency of the emitted photon. This is the equation for the energy of the Ly-α line: 10.2 eV. This energy is more than enough to ionize all alkali metals whose first ionization potential ranges between 3.89 eV (cesium) to 5.39 eV (lithium).

EGSY8p7 is a distant galaxy, with a spectroscopic redshift of $z = 8.68$ [Wikipedia EGSY8p7]. EGSY8p7 is the most distant known detection of the Lyα emissions. This detection is surprising because the early Universe was full of atomic H clouds which should absorb these emissions.

We know that the frequency equals the speed of light divided c by the wavelength. Multiplying the reciprocal of eqn. (1) with c/h and after a bit of algebra we arrive at

$$h\nu_E = h\nu_G/(1 + z) = 10.2 \text{ eV}/9.68 = 1.05 \text{ eV}$$

where c ($\approx 3 \times 10^8$ m sec^{-1}) is the speed of this light and $h\nu_G$ is the energy of light emitted by EGSY8p7 and $h\nu_E$ is the energy of this light received by the Earth's observer and ν_G and ν_E are the corresponding frequencies. The received energy is far less than the first ionization potential of alkali metals and, therefore, it will not be able to ionize them. Moreover, this energy is by a factor $(1 + z)$ lower than the energy of the light emitted by EGSY8p7. This violates the Principle of energy conservation which is one of the basic laws of physics. As far as we are aware, no violation of this law has ever been experimentally observed.

If we adopt the conservation law then

$$h\nu_G = h\nu_E = h\nu$$

or

$$\nu_G = \nu_E = \nu.$$

As we noted above, the frequency equals the speed of light divided by the wavelength then combining this equation and eqn. (1) we find that

$$c_G = c/(1 + z)$$

where c_G is the speed of light emitted by a galaxy (or any astronomical object) and c ($\approx 3 \times 10^8$ m sec^{-1}) is the speed of this light observed by an Earth observer. In other words, the speed of light emitted by EGSY8p7, c_G, is lower for a factor $(1 + z)$ than the speed of this light received by the Earth's observer or the current speed of light c.