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Fine Structure Constant and the Minimum Speed of Light

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When I die my first question to the Devil will be:
What is the meaning of the fine structure constant?
Wolfgang Pauli

Adopting *a priori* the Principle of energy conservation, Premović [1] proposed that the speed of light c_t emitted by the nearby or distant galaxy (hereinafter the galaxy) at time t in the cosmological past is lower than the (current) speed of this light c reaching the Earth. He derived the following expression which relates c_t and c

$$c_t = c/(1 + z_G) \quad \ldots (1)$$

where z_G is the cosmological redshift of the light emitted by the galaxy in the past but measured by an Earth observer at present time.

The fine structure constant, denoted by α, is a measure of the strength of electromagnetic interaction between light (or photons) and electrons (or charged elementary particles). This constant is considered one of the most fundamental constants in physics. Moreover, cosmologists consider this constant to be one of the fundamental constants that describe the Universe.

The fine structure constant includes four of nature's fundamental constants: the permittivity of the free space ε_0, the electric charge of electron e, Planck's constant h and the speed of light c. This can be formulated by

$$\alpha = e^2/2\varepsilon_0 hc = 1/137$$

where α is dimensionless, ε_0 (= 8.85×10^{-12} F m^{-1}), e (= 1.60×10^{-19} C), h (= 6.63×10^{-34} J sec^{-1}) and c (= 2.99792×10^8 m sec^{-1}).

Multiplying the left and right ends of this equation with c, we get

$$\alpha c = c/137.$$

Obviously, αc represents "some" speed of light. In view of the eqn. (1), the product αc represents a minimum speed of light emitted by the galaxy with redshift $z_G = 136$ in the distant cosmological past. In the equation form,

$$\alpha c = c_{min} = c/137 = c/(1 + z_G) = c/(1 + 136) \quad \ldots (2).$$

Thus, we suggest that the exact formula for the fine structure constant is

$$\alpha = c_{min}/c.$$

When the light was emitted from the galaxy with $z_G = 136$ the speed of this light was 1/137th of its present speed c.[1,2] As the current speed of light c, the minimum speed of light c_{min} is also independent of the frame of reference. In other words, we define the minimum speed of light c_{min} as a low-speed limit of the speed of light in the past of our Universe.

Let us denote by λ_{min} and λ the wavelengths corresponding to c_{min} and c. We know that the ratio of the speed of light to the wavelength is equal to the frequency. In this case

$$c_{min}/\lambda_{min} = c/\lambda = \nu.$$

Combining this equation with $\alpha c = c_{min} = c/137 =$ and after a bit of algebra we get

$$\lambda_{min} = \alpha\lambda = \lambda/137.$$

In other words, the Earth's observer measures the wavelength of the light emitted by the nearby or distant galaxy redshifted for the factor 1/137.

We know that light (or better a stream of photons) carries the momentum p = h/wavelength. So, the light with c_{min} carries the maximum momentum

$$p_{max} = h/\lambda_{min} = 137h/\lambda = 137p.$$

This momentum is related to the energy by the simple equation

$$E = p_{max}c_{min} = hc/\lambda = h\nu.$$

When the galaxy with $z_g = 136$ emitted light, the size of the Universe was 1/137th of its current size or its radius was about 0.1 % of its current radius.[3] The age of this ancient Universe of course

[1] It can be easily calculated that $\alpha c = c_{min} \approx 2.2 \times 10^6$ m sec^{-1}.
[2] From the frame of reference **of galaxy**, the speed of light on the Earth is c/137.
[3] The currently highest redshift observed is $z_G = 11.01$ (the galaxy GNz-11), the Universe was about 1/12th of its present size or its radius was about 1 % of its present radius.

depends on the dynamics of the space expansion. With the current concordance cosmology of a flat Universe with a matter density $\Omega_m \approx 0.25$, a cosmological constant $\Omega_\Lambda \approx 0.75$ and a Hubble constant $H_0 = 72$ km sec^{-1} Mpc^{-1}, $z_G = 136$ corresponds to an age of about 11 My or roughly 0.1 % of current cosmological time. At that age, most of the molecular hydrogen (H_2) in the present-day Universe was already formed. This form of hydrogen is the predominant gas constituent in this Universe. Simultaneously, the photons were probably completely decoupled from matter spreading through the Universe to form the cosmic microwave background (CMB) radiation. The Wilkinson Microwave Anisotropy Probe (WMAP) combined with other measurements reveals that the redshift of this decoupling is 1091, implying that the size of the Universe or its radius at the time when the light was emitted was 1/1092th of its present size or radius.

As we noted above, we interpret the fine structure constant as the ratio between the minimal speed of light c_{min} to current this speed c. This constant was initially formulated by Sommerfeld in 1916 as the ratio of the speed υ of the electron in the first Bohr's orbit of a hydrogen atom to the speed of light: $\alpha = \upsilon / c$. However, these two speeds are completely different in physics and completely independent from each other. Therefore, this ratio has nothing to do with the nature of the fine structure constant.

Numerous physicists and mathematicians have tried to find the most accurate mathematical formula for the experimental value of fine structure constant α. Excellent reviews of these theories are presented by Sherbon [2, and references therein] and Pellis [3, 2021, and references therein]. The most recent inverse value of this constant α^{-1} determined theoretically and experimentally is 137.036 [3]. Einstein was the first to propose in 1909 a mathematical formula for a fine constant structure. His formula is

$$\alpha = 7\pi/10^3$$

with numerical value $\alpha^{-1} = 136.426$. If we multiply by 10^5 both the numerator and the denominator of the right-hand side of this equation we obtain

$$\alpha = 7\pi \times 10^5/3 \times 10^8.$$

At first glance, it can be seen that the denominator represents the approximate current value of the speed of light $c \approx 3 \times 10^8$ m sec^{-1}. Using the mathematical constant π to be approximately equal to 3.142 we estimate that $7\pi \times 10^5$ is approximately equal to the minimum speed of light $c_{min} \approx 2.2 \times 10^6$ m sec^{-1}. The numerical value of α^{-1} is approximately equal to 136.400.

References

[1] P. I. Premović, *The Speed of Light and the Principle of Energy Conservation.* The General Science Journal, April 2022.
[2] M. A. Sherbon, *Fine structure constant from Sommerfeld to Feynman.* J. Adv. Phys. 16, 335-343 (2019).

[3] S. Pellis, *Exact expressions of the fine structure constant* α. https://vixra.org/abs/2110.0117, pdf, 2.021.