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# The measurement of the Speed of Light.

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Abstract. Preamble: In order that a measurement of one item against another item is significant it must be verified that these items ARE INDEPENDENT of each other. It can readily be shown that the unit of m/s is proportional to the speed of light and hence measurements of the speed of light in units of m/s are basically flawed. Some aspects of the speed of light not being a constant are discussed.

Introduction. Measurements of the speed of light c, such as carried out by Fizeau, Foucault [1] and Michelson [2] at various times in the past, always need a length and a clock. The standard length is the meter m, which length can be quietly assumed to be proportional to the Bohr radius $a_0$. We regard here of course the "classical" meter and not the one that is defined by the speed of light. We also assume that the measurements are carried out in a world at rest in which relativistic effects are negligible. The standard time is the second, which can be expressed in units of $t_0$. This is the time it takes for the electron in its ground state to orbit the proton. The unit of 1m/s is therefore equal to $2.872\ 10^{-6}\ a_0/t_0$ or equal to $4.571\ 10^{-7}\ v_o$. Where $v_o$ is the speed of the electron in the ground state around the proton. Of course $v_o$ equals the speed of light c multiplied with the fine-structure constant $\alpha$. Essentially the speed of light is measured against the speed of the electron orbiting the proton. The measurement of the speed of light in units of $a_0$ over $t_0$ will therefore be proportional to: $c.\alpha$. And since the fine-structure constant is practically a constant [3,4], the measurement of the speed of light against the m/s is basically flawed. A constant value of the speed of light in meters per second does not necessarily mean that the speed of light is a constant.

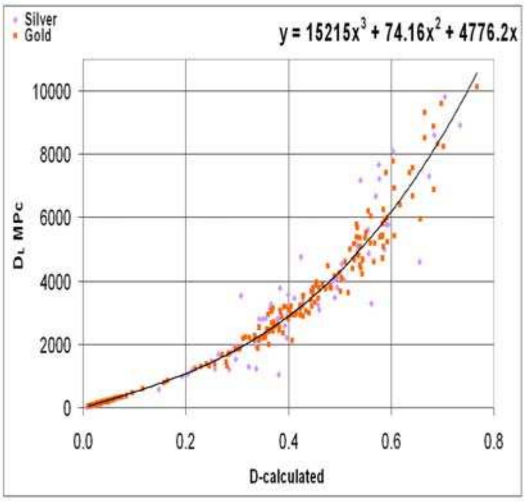
What parameters depend on the Speed of Light. The reason that the unit of 1m/s is proportional to the speed of light is that the Bohr radius is proportional to that speed. The Bohr radius is defined as: $a_0 = \varepsilon_0 h^2/\pi m_e e^2 = \hbar/(m_e c\alpha) = c.\hbar/(m_e c^2\alpha)$. The Planck constant $\hbar$ is connected to the angular momentum ($a_{0.}\ m_e v_o$) of the electron in orbit in its ground state for the hydrogen atom. This angular momentum is conserved and hence the Planck constant $\hbar$ must be a constant independent of the speed of light if the latter would happen to vary in the course of time. And of course the energy of the electron is conserved and hence it too must

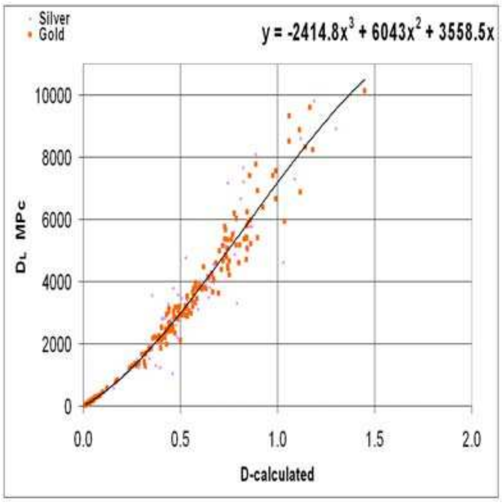
be independent of the speed of light. This makes the Bohr radius proportional to the speed of light apart from perhaps small changes in the fine-structure constant over time.
The Planck constant also converts time or frequency into energy and vice-versa ($E=h\nu=\hbar\omega$). And hence time and our clock $\omega$ defined by the Rydberg energy $E_R$ [5], should also be conserved and be independent of changes in the speed of light. Indeed our clock is: $t_0 = h/E_R = 2\pi a_0/v_o = h/(m_e c^2 \alpha^2)$. So apart from perhaps small changes in $\alpha$ the clock in a non-relativistic world is independent of the speed of light. One comes then to an important conclusion: the world around us, its size is set by the speed of light. And hence any variation of the speed of light over time (or space) will NOT be directly apparent.

Background Microwave Radiation. Since the speed of light may vary over time, one could imagine a scenario in which the speed of light would be infinite. It is easily seen that then particles do not exist, since they will extend to infinity (using the Heisenberg uncertainty principle). All particles are everywhere all the time. There is only energy in a very homogeneous primordial soup indeed. If then for what ever reason somewhere in space this speed of light would relax to finite values, all particles would appear there and then. An event that would look like what we call now the Big Bang. An important detail is that the universe would emerge from a very homogeneous medium. Perhaps this is a good explanation of the observed homogeneity of the Background Microwave Radiation.

The expansion. The expansion of the universe is also under scrutiny, because this is measured as a Doppler shift of particular emission spectral lines. What is really then measured, is the ratio of the real expansion and the true speed of light. The “observed” recent acceleration of the expansion is based on the assumption that the speed of light is a constant and indeed the speed of light has a constant value in meters per second. However it is not necessarily a constant. So that readily enough, one can also postulate that the increase of the Doppler shift is in fact due to a speed of light diminishing in time in a world that in the same time becomes smaller too. It will therefore look from the outside similar as an accelerating expansion because of the shrinking of the world, but we could be wrong in believing that we are living in a phase of an accelerating expansion. Evidence brought forward to demonstrate an accelerating expansion is from the supernovas.
Supernovas further away are dimmer than can be expected from their distance. See for instance, the supernova data presented by S. Perlmutter [6] and the more recent data by A.

Riess [7]. However the distance becomes larger if the speed of light was higher in the past (this could well turn out to be a good way to deduce the evolution of the speed of light). Using the distances defined by E.Wright [8], one can compare the distances calculated based on a constant speed of light with those assuming a varying speed of light using a simple model which puts $c(t)= c_0.t_0/t$. The data obtained from A. Riess show indeed a marked improvement (fig.1 and 2) in the linear relationship between the distances deduced from the brightness of the supernova’s and the calculated one and therefore a compelling need for an acceleration of the expansion seems to have gone.




The speed of light defines the wavelength of an emission line. We know that the impulse moment of the photon equals h/λ and that this is conserved throughout. Hence, if at times, that the red shift Z=1, the speed of light was exactly a factor of two higher than today, indeed the wavelength of the emitted photon would have been precisely twice that of the same photon emitted today and this will be the photon arriving on the earth today if there are no Doppler shifts. So how much of the observed red shift is due to expansion of the universe ($1+Z=a_{NOW}/a_{THEN}$) and how much is due to a possible variation in the speed of light.

Discussion. Can one find other arguments against the variation or in favour of it? We have seen that the fine-structure constant remains unchanged simply because it can be defined by the ratio of $v_o/c$. Are there other fundamental constants that should change with c, but are known not to vary in time? What we have used up to now is, that energy, angular impulse moment and impulse moment are conserved throughout, no more and no less. Also it looks as if the General Relativity remains valid too: nothing can travel faster then the speed of light even if the speed itself is not a constant. Simply because the speed of light defines the objects we see. In any case, if the dimensions of the world change with c the Lorentz transform seems to be unaffected. Also the levels in the hydrogen atom can all be written in units of $m_e c^2$, so these to are unaffected when c changes but $m_e c^2$ remains constant.

Now if the speed of light would change so would the mass of the objects in question but in the opposite direction of course, following Einstein's equation of $E=mc^2$ , which remains perfectly valid.

Finally a systematic decrease of the speed of light in time would also make the arrow of time going in one direction only.

Conclusions. The true speed of light is in principle an unknown quantity. Variations of the speed of light can best be deduced from the measured brightness of the supernovas as function of their apparent distance. Already it looks from this data that the speed of light is diminishing in time, but not in meters per second, unless the latter unit is defined in our time and place.

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*Fig.1. Luminosity distance versus distance calculated (* $D_C = \frac{(1+Z)^2-1}{(1+Z)^2+1}$ *) for a flat expanding universe and constant c. The non-linear relationship is explained by an acceleration of the expansion.*

*Fig.2 Luminosity distance versus distance calculated for an expanding universe at critical density and a speed of light that falls as 1/t.* $D_C = \frac{3}{2}((1+Z)^{\frac{2}{3}}-1)$.