Intrinsic Plasma Redshifts Now Reproduced in the Laboratory: a Discussion in Terms of New Tired Light

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Recent developments in laser induced plasma have shown that the characteristic recombination lines from atoms within the plasma itself are redshifted. Importantly, the experimental results show that the redshift of these lines increases with the free electron density of the plasma. Long predicted by exponents of alternative theories to the Big Bang, these intrinsic redshifts produced by plasma in the laboratory give credence to such theories. This paper gives an overview of the laboratory results of Chen et al and relates them to the predictions previously made by the New Tired Light Theory. The plasma induced redshift, line broadening are all as predicted by New Tired Light. A further laboratory test is suggested whereby New Tired Light predicts the wavelength of the secondary radiation (λ = 0.1 mm) emitted by the plasma - should New Tired Light be responsible for the redshifts. If this relatively easy and inexpensive test is carried out then it could settle the matter once and for all. Regardless of this, now that it has been shown in the laboratory that plasma induce intrinsic redshifts, will this be incorporated into the Big Bang theory? The Universe is a big place filled with plasma and these laboratory results show that this plasma induces redshifts. Experience tells me that mainstream science will ignore good science.

1. Introduction

Chen et al [1] report that redshifts of spectral lines detected in a laboratory experiment are influenced by the free electron density of the surrounding plasma. In fact the lines are redshifted with the degree of redshift increasing with the surrounding free electron density.

Whilst this result has long been predicted it must be seen as a major development in terms of alternative theories to an expanding universe - since any test of a scientific theory must include reproduction under laboratory conditions.

2. The Experimental Procedure

A 1064 nm pulsed-laser with pulse duration of 10 ns and energy 1 J is focussed onto a $Hg_{0.8}Cd_{0.2}Te$ crystal such that the laser beam has a diameter of 0.66 mm and the high resolution time resolved emission spectra of the plasma formed obtained. The spectra are observed at a distance of 0.5 mm from the crystal target surface.

The plasma is 'cold' – approximately 10^4 K at the start and cooling from then on. Initially, the spectra consist of a continuum produced by bremsstrahlung as the interacting free electrons in the plasma lose their energy by the emission of photons of electro-magnetic radiation. This makes the plasma lose energy overall and the plasma temperature to drop. During this next stage, the free electrons recombine with the positive ions and recombination radiation is emitted. Indeed, for the first 100 ns the bremsstrahlung dies away and becomes invariant and the spectral lines due to recombination become dominant.

3. The Experimental Results

- The spectral lines are detected at different times in relation to their wavelength. The line of the Hg atom (435.83 nm) appears first after 50 ns whilst lines with a longer wavelength appear approximately 30 ns after this.
- The spectral lines are broadened and the Full Width at Half Maximum (FWHM) of the lines decreases as time passes and the free electrons density reduces. The 435.83 nm line has a FWHM value of just under 10nm.
- The lines are redshifted and the line shift increases with plasma free electron density – by 'eye' there is a linear relationship for all but one of the data points. The shift in the wavelength of the 435.83 line is approximately 1nm at an electron density of just over $1\text{x}10^{24}$ m^{-3} rising to just over 2.5 nm at an electron density of $3\text{x}10^{24}$ m^{-3}.

4. Possible Explanations Given

In the paper, Chan et al put forward the following explanations of the results:

- It is suggested that the spectral lines appearing at different times are due to the high plasma temperature and thus the occupation numbers of atoms or ions in the highly excited states is greater than that in the lower energy states. Thus higher energy electrons recombine first giving out higher frequency photons followed by the lower frequency, longer wavelengths appearing later.
- It is suggested that the spectral broadening is due to the 'Stark Effect.' This is the broadening of lines due to a 'splitting' of spectral lines caused by an external field. That is, the ions in the plasma set up an electric field which causes the energy levels in the atoms to split. When recombination takes place, a range of wavelengths is emitted and hence the lines broaden.
- It is suggested that the Redshift is explained as being due to the free electrons '*shielding the nucleus*.' Quote: '*the electronic fields generating from free electrons compressed inside an atom screen the Coulomb potential of the atomic nucleus. Then the nu-*

cleus' forces to the bound electrons are diminished, whilst the repulsion of free to bound electrons is enhanced, so that the energy levels out of the nucleus are raised and the intervals of excited energy level … are diminished.'

In other words, the greater the free electron density, the more they shield the nucleus, the less effect it has, the lower the energy level difference, the lower the frequency of emitted photons and hence the longer their wavelength – emitted photons are redshifted.

However, overall, plasma is electrically neutral. If, as Chen et al suggest, the redshifts are caused by free electrons 'compressed inside an atom' then there must be regions where there is an excess of positive ions for overall neutrality to be maintained – should this not produce a blue shift? None detected. That is, the redshift occur for all photons from atoms of a particular element and it appears unlikely that every single atom under investigation is packed with extra free electrons when we remember that plasma is overall electrically neutral.

The experimental results from the laboratory are that photons are redshifted and the degree of redshift increases with free electron density and so we must look at alternative explanations.

In cosmology, the mainstream idea is that cosmological redshift is produced by expansion effects. However, several theories have already been put forward explaining redshift as being an interaction between photons and the plasma in Intergalactic Space (IG Space). Could it be that the experiment carried out by Chen et al is a lab test of these theories? If so, these results take on a particular importance in cosmology thinking. The 'New Tired Light' (NTL) theory has previously predicted the results of this experiment [2, 3] and this paper now goes on to examine how this data fits those predictions.

5. New Tired Light Revisited

In order to compare these experimental results with the predictions of the 'New Tired Light' theory we need to remind ourselves of the predictions [2]. Electrons in the plasma can perform SHM and any electron that can perform SHM can absorb and reemit photons of light. [4, 5]. To quote, "*The electron just has a natural oscillation frequency equal to the local plasma frequency, and we get a simple picture of resonance absorption in terms of the driving field being in resonance with this natural frequency….*" [6]. The plasma in these experiments has a free electron density of approximately $2\text{x}10^{24}$ m^{-3} and thus a plasma frequency of the order of 10^7 Hz and so the driving field, i.e. the photon of light, has a driving frequency far above resonance. In consequence, resonance absorption will not take place and the photon will always be re-emitted. The electron will not only absorb and reemit the photon but will recoil each time. The energy lost to the recoiling absorbing/emitting system is well known [7] and given by:

$$E_{\text{lost}} = \frac{Q^2}{2m_e c^2}$$

where Q is the energy of the incoming photon, m_e the rest mass of the electron and c the speed of light.

This must be applied twice for absorption and reemission. Hence, total energy lost by photon = $Q^2 / m_e c^2 = h^2c^2 / \lambda^2 m_e^2$

(energy before interaction) – (energy after) = $h^2c^2 / \lambda^2 m_e^2$.

$$hc / \lambda - hc / \lambda' = h^2 / \lambda^2 m_e \tag{4}$$

λ = initial wavelength of photon, λ' = wavelength of the reemitted photon.

Multiplying through by $\lambda^2\lambda' m_e$ and dividing by h, gives:

$$\lambda\lambda' m_e c - \lambda^2 m_e c = h\lambda' \tag{5}$$

Increase in wavelength $\delta\lambda = \lambda' - \lambda$, so:

$$\lambda(\delta\lambda + \lambda)m_e c - \lambda^2 m_e c = h(\delta\lambda + \lambda) \tag{6}$$

=> $$\lambda m_e c\delta\lambda + \lambda^2 m_e c - \lambda^2 m_e c = h\delta\lambda + h\lambda \tag{7}$$

=> $$\delta\lambda\left(\lambda m_e c - h\right) = h\lambda \tag{8}$$

since $h \ll \lambda m_e c$

$$\delta\lambda = h / m_e c \tag{9}$$

On their journey through plasma, the photons will make many such collisions and undergo an increase in wavelength of $h / m_e c$ each time. On this basis red shift becomes a distance indicator and the distance - red shift relation becomes: photons of light from sources twice as far away will travel twice as far through the plasma, make twice as many collisions and thus undergo twice the red shift. Conservation of linear momentum will ensure the linear propagation of light.

6. The Hubble Law

The process whereby a photon interacts with an electron and gives all its energy to the electron is known as photoabsorption and the photoabsorption cross section σ is known from the interaction of low-energy x-rays with matter [8, 9, 10].

$$\sigma = 2r_e\lambda f_2 \tag{10}$$

where r_e is the classical radius of the electron and f_2 is one of two semi-empirical atomic scattering factors depending, amongst other things, on the number of electrons in the atom. For 10 keV to 30 keV x-rays interacting with Hydrogen f_2 has values approximately between 0 and 1. '1' means that the photon has been absorbed and the atom remaining in an excited state, and '0' means that the photon was absorbed and an identical photon reemitted [11].

Collision cross sections have the units of area and represent a probability that the interaction will take place. In a photon-electron interaction there are only two possible outcomes. Either the photon is absorbed and not re-emitted (resonance absorption, $f_2 = 1$, and probability of re-emission = 0) or the photon is absorbed and a '*new*' photon is emitted (transmission, $f_2 = 0$ and probability of re-emission = 1). Consequently when the photon frequency is well off resonance the probability of absorption is zero and the probability of re-emission is 'one'. For conditional probability were we need the photon absorbed AND re-emitted, $2r_e\lambda$ is the probability of absorption and f_2 is the probability of re-emission, and so we multiply the two separate probabilities. Since f_2 has the value of unity the collision cross-section for transmission is $2r_e\lambda$. The atomic scattering factor, f_2, only modulates the collision cross-section $2r_e\lambda$ and so this is the term we need.

Electrons in plasma behave in the same way as those in an atom. Since the photon frequency of light in this experiment is far removed from the resonant frequency of the free electrons in the plasma, the photons will always be reemitted.

On their journey through the plasma, photons of radiation at the red end of the spectrum will encounter more collisions than photons at the blue end of the spectrum and thus undergo a greater total shift in wavelength. For a particular source, the ratio $\Delta\lambda/\lambda$ will be constant.

For large distances in IG Space, the collision cross-section increases as the photons are redshifted and this leads to an exponential Hubble diagram and the prediction of effects usually put down to '*acceleration*.' However, for this experiment it is a good approximation to assume that it is constant as the percentage redshifts are small.

We have $\sigma = 2r_e\lambda$. The mean free path is given by $(n_e\sigma)^{-1}$ or $(2n_e r_e d\lambda)^{-1}$, where n_e is the mean electron density. The total number of interactions N suffered by the photon in traveling a distance d is simply the distance divided by the mean free path.

$$N = \frac{d}{(2n_e r_e \lambda)^{-1}} \quad \text{or} \quad N = 2n_e r_e d\lambda \tag{11}$$

The total shift in wavelength suffered by the photon, $\Delta\lambda$, is $N\delta\lambda$ and since redshift z is given by $z = \Delta\lambda / \lambda$ we have:

$$z = \left(\frac{2n_e h r_e}{m_e c}\right) \tag{12}$$

We have $v = cz$ and $v = Hd$ where v is a term attributed to velocity in the Big Bang theory and H is the Hubble constant. This leads to an expression for H as:

$$H = \frac{2n_e h r_e}{m_e} \tag{13}$$

Published values of the Hubble constant are around H = 64±3 km/s per Mpc or, in SI units, 2.1x10^{-18} s^{-1}. An estimated value of n_e in the IG space can be achieved from the WMAP data [12] and gives n_e = 2.2x10^{-7} cm^{-3} or an average of 0.22 electrons per metre cubed. Thus this *New Tired Light* theory gives a predicted value of H as 0.9x10^{-18} s^{-1} or 27 km/s per Mpc. Thus the theory's predicted value of H from first principles is in good agreement with the observational value.

7. Cosmic Microwave Background (CMB)

Of particular interest to us here is that, New Tired Light also predicts the CMB. The recoiling electron will be brought to rest by Coulomb interactions with all the electrons contained within a Debye sphere of radius λ_D. The decelerating electron will emit transmission radiation (TR) i.e. bremstrahlung. There are two emission channels of the system, 'intrinsic emission' by the decelerating electron, and 'emission by the medium' where the background electrons radiate energy.

The interactions between light and the electrons are non-relativistic and the initial and final states of the electron belong to the continuous spectrum. The photon frequency of the transmission radiation f_{CMB} is given by:

$$hf = (1/2m_e)(p^2 - p'^2) \tag{14}$$

where $p = m_e v$ and $p' = m_e v'$ are the initial and final momentum of the electron [13]. The electron returns to rest after absorption and reemission and so the wavelength of the transmission radiation λ_{CMB} is given by:

$$\lambda = 2m_e\lambda^2 c / h \tag{15}$$

Light of wavelength 5x10^{-7} m gives rise to TR of wavelength 0.21 m. In IG space, the dominant background photons are microwaves, having peak energy of 6x10^{-4} eV and a photon density of about 400 per cm^{-3} [16, 17]. In this theory, these background photons (λ = 2.1x10^{-3} m) would be given off as TR by a photon of wavelength 5x10^{-8} m (i.e. Ultra Violet radiation) interacting with an electron.

Interestingly, the CMB has a black body form of radiation and it is known that plasma emit Black Body radiation as the clouds will be in thermal equilibrium. To quote, "when every emission is balanced by an absorption by the same physical process – this is the 'principle of detailed balance'. The radiation spectrum must have a black body form in thermodynamic equilibrium." That is when the emission of a photon is due to the absorption of a photon, the emission will be black body [14].

8. Matching Predictions to Lab Results

In the NTL theory, statistical line broadening takes place on emission lines as the photons travel through plasma. Since the number of collisions is determined statistically there will be a spread in the number of collisions suffered by the photons on their journey through the plasma. This results in a broadening of the lines.

The standard deviation in the number of interactions and hence 'line width' should increase with distance and redshift - as the square root of N to be precise, i.e. the greater the number of interactions the wider the line.

$$\sigma_{tot} = \sigma_{th}\sqrt{N} \tag{16}$$

where σ_{tot} is the total standard deviation due to statistical and thermal line broadening and σ_{th} is that due to thermal effects alone whilst N is the number of interactions. The NTL theory predicts that the lower the plasma density, the fewer the number of photon-electron interactions, the narrower the lines. This is what Chen et al found experimentally, that as time went on, the plasma density reduced and the line width narrowed.

In the NTL theory, as the photons are absorbed and re-emitted by the free electrons in the plasma the electrons recoil and some of the energy of the photon is transferred to the electrons. The energy of the photon has been reduced, the frequency of the photon has been reduced and the wavelength has been increased, i.e. redshifted. In the experimental results of Chen et al the atoms are within the plasma itself and the photons emitted due to recombination have to pass through the plasma in order to reach the detector. It is proposed that on their way through the plasma they are redshifted as per NTL theory. The experimental results support this.

In the NTL theory, for large increases in the free electron density the effective mass of the electron also increases and the increase in wavelength on each interaction reduces. This is why we do not get large redshifts when photons travel through dense plasma in space. However, for small increases in plasma density, the effects on redshift due to increased collisions outweigh those due to increased effective mass. The shift in wavelength will increase with plasma density on the small scale.

As we saw in Eq. (11), $N = 2n_e r_e d\lambda$, so if r_e , d, and λ are constant, the number of collisions and hence shift in wavelength is proportional to the free electron density. In the experimental results of Chen et al, on inspection by eye, only the data point at the lowest density fails to fall on a linear relation between shift in wavelength and electron density. The shift in the wavelength of the 435.83 line is approximately 1 nm at an electron density of just over $1\text{x}10^{24}$ m^{-3} rising to just over 2.5 nm at an electron density of $3\text{x}10^{24}$ m^{-3}.

9. Laboratory Test for New Tired Light

As stated in section 5, the NTL theory predicts the CMB. On absorption and re-emission the recoiling electrons in the plasma emit this recoil energy as two secondary photons and it is this secondary radiation that forms the CMB. If the redshifts produced in this laboratory experiment are caused by the New Tired Light theory then secondary radiation will also be emitted as the incident photons are redshifted. The wavelength of this secondary radiation can be predicted by the NTL theory and so this forms a basis for testing NTL in the lab.

From the paper we see that the shifts in the 435.83 nm line are in the region of 2 nm. This represents an increase of 0.46% in wavelength and therefore a reduction of 0.46% in energy – energy which, according to the NTL theory will be emitted as two secondary photons. The 435.83 nm line photons have energy $4.6\text{x}10^{-19}$ J and so the two secondary photons will have energies of $2.1\text{x}10^{-21}$ J and wavelengths of 0.1 mm.

The laboratory test of NTL is thus:

- Place a microwave detector tuned to 0.1mm near the target crystal.
- Fire the laser with no crystal present.
- Check the microwave detector for background.
- Put the target crystal in place.
- Fire the laser again.
- If the microwave detector records a greater reading than background, it's New Tired Light.
- It's as simple as that.

Unfortunately the Chen et al paper gives line intensities in arbitrary units. If the actual intensities are available in SI units we can use the NTL theory to determine the intensity of the secondary radiation and add to our predictions.

10. Conclusion

The Chen et al paper is an extremely important paper with regard to cosmology and, in particular, to proponents of alternative cosmologies. It gives the creators of alternative cosmologies the opportunity to try out their theories on actual laboratory data – something that has been lacking until now. The New Tired Light Theory (circa 1995) predicted that photons travelling through plasma would be redshifted. It predicted the relationship between redshift and plasma density and also emission line broadening. All of which are now verified in the laboratory thanks to Chen et al. However, we must remember that this is not ultimate proof of alternative theories. The atoms producing the characteristic recombination lines that are redshifted lie within the plasma itself. It could well be that the charges in the plasma are affecting the energy levels in the atoms producing the lines. To explain expansion effects, the sources must lie outside the plasma. Redshift must increase with distance and that is not investigated in the Chen paper. That said, the lab results plasma does induce redshifts and thus gives credence to all theories that have been relating redshift to plasma interaction - and not expansion and, in particular, to intrinsic redshifts. This paper proposes a simple, inexpensive, test to discriminate between theories and test if the redshifts are a result of the New Tired Light theory. Hopefully this will be carried out. What remains to be seen is that now we have laboratory results showing that plasma does produce intrinsic redshifts, will these laboratory proven results be included in mainstream theories? The Universe is a big place filled with plasma. Now that we have lab tests to show that plasma induces intrinsic redshifts, will these effects be included in the Big Bang Theory? Experience tells me, no.

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