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Data from 14,577 cosmological objects and 14 FRBs confirm the predictions of new tired light (NTL) and lead to a new model of the IGM

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Abstract

Predictions by New Tired Light were tested using 14,577 objects from the NED-D compilation of redshift-independent distances. These objects give an electron number density of $n_e = 0.499\, m^{-3}$ compared to the predicted one of $n_e = 0.5\, m^{-3}$. In NTL the Hubble constant is given by $H = 2n_e hr_e/m_e$ and, using this value for n_e gives 62.5 $km/s\, per\, Mpc$ which is very close to the accepted values. NTL predicts a linear relationship between distance and $\ln(1+z)$ with gradient ($m_e c/2n_e\, hr_e = 1.46x10^{26}\, m$). Plotting all the 14,577 points gives a straight line with gradient $1.40x10^{26}\, m$ – just 4% off the predicted value. Using distances from the compilation the redshift is calculated by NTL and a graph of predicted versus observed redshift is drawn. This has a gradient of 0.9756 close to the value '1.0' expected in a 1:1 relationship between prediction and expected. Both graphs are linear up to redshifts of '9' with no hint of relativistic effects.

In NTL, there is a delay between an electron in the IGM absorbing and re-emitting a photon whereby the electron recoils (leading to the redshift). Data from FRB 121102 gives the time lag between two frequencies arriving and using the extra number of photon-electron interactions made by the longer wavelength the time delay is found. This tells us the length of the delay at each interaction as $\approx 10^{-10} s.$ Using NTL and DM the redshift of the host galaxy was calculated and found to be $z = 0.143$ compared to the measured value of $z = 0.19$ – the difference lying well within the uncertainty in DM.

In NTL, DM and redshift are produced by the electrons in the IGM and so there is a direct relation between them. $DM_{IGM} = (m_e c/2hr_e)\{\ln(1+z)\}$ or $DM_{IGM} = 2470\{\ln(1+z)\}$. Plotting data from 14 localised FRBs on a graph of DM versus $\{\ln(1+z)\}$ does give a straight-line graph but a selection of eight from the fourteen are colinear with a gradient of $1244 \pm 147\ pc\ cm^{-3}$ much closer t that predicted. Several hosts are said to be tentative and so we will continue to plot this graph as more and more FRBs are located.

Often tired light models are discounted on the basis of an old model of the IGM as having a neutral plasma at high temperature and/or they are using Compton scatter. In NTL, recoil takes place along the line of sight so there is no blurring. Several mainstream papers show that every dust particle in the IGM is positively charged with an excess of protons due to photoionisation. This means an equal number of electrons have been released into the intervening space. On this basis the IGM is a 'dirty plasma' with the protons trapped on dust particles and a sea of electrons inbetween. When a group of electrons come together in this way, they will arrange themselves onto a BCC lattice (Wigner-Seitz crystal). Calculations show that if we use dust density restricted by considerations of an expanding Universe there is not enough to give the $n_e = 0.5\, m^{-3}$ found by observation but would need a dust density of $\rho_{IGM} \approx 3x10^{-25} kgm^{-3}$. A previous paper looked at the photoionisation of Hydrogen clouds surrounding a galaxy with the protons staying behind and forming dark matter whilst the electrons went off into

the IGM to form on their crystal lattice held by mutual repulsion. The mass of dark matter surrounding the Milky Way galaxy is known and so, if this is all protons, we can find the number of protons there. An equal number of electrons will have been released into the IGM and dividing this by the average volume occupied by a galaxy gives us the $n_e = 1\,m^{-3}$ and agrees with observation.

1. Introduction

In the cosmology of the Universe, the evidence is that photons of light have a longer wavelength on arrival then when those same photons set off. That is the experimental evidence – everything else is an interpretation of that result in terms of some idea.

In the Big Bang theory, the increase was initially thought to be a Doppler effect and later by space itself expanding and carrying the galaxies along with it. I have yet to see a paper start with the idea of expansion, use it to predict a value for the Hubble constant and then compare that predicted value to the one from observation. That is how real science works.

There is the CMBR, an omnipresent microwave radiation and claimed as the afterglow of the Big Bang. It may be linked or it may just be a coincidence that it is there.

In New Tired Light we believe that the Universe is static and probably infinite. Photons of light from distant galaxies interact with electrons in the IGM as they travel. The photons are absorbed and after a slight delay, re-emitted as a new photon. Since the IGM is sparsely populated these electrons recoil on absorption and again on re-emission and so some of the original energy has been transferred to the kinetic energy of the recoiling electron. The new photon has less energy than the original one, a lower frequency and therefore a longer wavelength – it has been redshifted. The Hubble law becomes. 'Photons of light from a galaxy twice as far away, travel twice as far through the intergalactic medium, make twice as many interactions with the electrons in the IGM, lose twice as much energy, undergo twice the reduction in frequency and twice the increase in wavelength.' Much simpler than all this expanding space. Isn't it?

The recoiling electron emits the kinetic energy as a secondary photon each time it recoils and this radiation is in the microwave region. Thus, we have both the redshift and CMBR with New Tired Light and the New Tired Light theory can predict values for both and compare them to observation.

In this paper we will use the New Tired Light (NTL) theory to make numerical predictions and compare them to observation throughout. There is no 'new physics.' everything here is based on published, accepted physics – though the outcomes may be surprising!

Firstly, we will take the NED-D online compilation of redshift independent extragalactic distances and use data from 15,930 cosmological objects having both redshift and distance. This along with NTL theory is used to determine the electron number density ($n_e = 0.499m^{-3}$) compared to the NTL prediction of ($n_e = 0.5m^{-3}$) that has been seen in published papers, books and online for over twenty years. We will use this value and NTL theory to predict a value for the Hubble constant giving $H = 62.5\,kms^{-1}\,per\,Mpc$ which compares favorably with observed values of $H = 67 - 74\,kms^{-1}\,per\,Mpc$ and lies well within uncertainties. NTL predicts a linear relationship between distance and ln $(1 + z)$ with a gradient consisting of a combination of the electron number density and several universal constants relating to the electron and the speed of light. When we use the data from these cosmological objects, we see that it is linear up to a redshift of nine with no hint of relativistic effects and the gradient is to within 8% of that predicted by NTL. Dispersion Measure (DM) is caused by radio signals interacting with electrons in the IGM and so we would expect (in NTL) a relationship between redshift and DM from Fast Radio Bursts (FRBs). We use NTL theory and data from an FRB to determine the delay suffered at each photon-electron interaction and we will see that it is of the order$1x10^{-10}s$. We then use NTL and derive the redshift of the host galaxy and will see that the predicted value is close to that measured. We will then derive a relationship between DM and redshift and test it using data from all known localised FRBs (at the time of writing) and we will see that they are in good agreement with that predicted.

Lastly, we will confront the elephant in the room with tired light theories. The main objection is that a photon cannot interact with a free electron and continue in a straight line ie the image would be blurred. The problem here is that these objectors are basing their ideas on an old model of the IGM whereby the IGM consists of a neutral plasma of electrons and protons acting independently. This is known not to be true. Several papers have looked at the charging of dust particles by the photoelectric effect and shown that every dust grain in the IGM has a positive charge. This means the protons are fixed on the dust grains with the electrons filling the IGM. When there is a group of electrons where their electric potential energy is greater than their kinetic energy, they will arrange themselves on a BCC crystal lattice held apart by their mutual repulsion – a Wigner-Seitz crystal or 'electron glass.' This allows photons to interact with the electrons in the IGM and continue in a straight line – with no blurring of the image. Order of magnitude calculations on the charges on dust grains and surrounding galaxies show this to be feasible.

2. New Tired Light (NTL)

In this paper we need to refer to several of the equations used to derive the NTL relationship of $z = \exp{(Hd/c)} - 1$ and thus, in order to make this a 'standalone' paper without the reader having to refer to several other papers, we will briefly go over the derivation in this section. A full derivation, with complete explanations is given here [1,2]

When light travels through a transparent medium it does so by being constantly absorbed and re-emitted by the electrons in the atoms of that medium [3,4]. The energy of the photon is transferred to the atomic oscillating system, there is a delay and then the energy is re-emitted as a new photon. Since there is a delay between absorption and re-emission the speed of light in a medium is less than that in a vacuum. In a transparent medium such as glass the electrons are 'fixed' in the atoms which are in turn 'fixed' in the block of glass and so any recoil of the electrons is negligible since it is the whole block of glass that recoils. There is no energy loss to the photon and hence no redshift. Since electrons in the plasma of the Intergalactic medium (IGM) can perform SHM [5,6] they too can absorb and re-emit photons of light. However, since the IGM is sparsely populated, the electrons in the plasma absorb the photon, the energy of the photon is transferred to the oscillating electron but here it recoils as well. The energy transferred to the recoiling electron is 'lost' to the photon and is emitted as a secondary photon (we shall see later that it is these secondary electrons that form the CMB – Appendix A). The energy stored in the oscillating electron is re-emitted as a 'new' photon – but not all of it as the electron recoils again on re-emission. This recoil energy is also emitted as a secondary photon and since two photons are emitted in the process the photon is able to continue in a straight line. There will be no blurring of an image, since in NTL, the recoil acts along the line of sight and not at some angle.

Provided the frequency of the photon is well away from the resonant frequency of the electron in the plasma (which is the same as the plasma frequency [7,8]) then the photon will always be re-emitted and since the plasma frequency in the IGM is less than 30Hz [9] this is the case. Since the photon loses energy at each interaction with the electrons in the plasma, the frequency of the photon is reduced and the wavelength increased. It has been redshifted.

The energy transferred to an electron by recoil is known [10] and equal to $Q^2/2m_ec^2$ where Q is the photon energy $m_e$the electron rest mass and c the speed of light. Since energy is lost on both absorption and re-emission, we must apply this twice so:

$$\text{total energy lost per interaction} = Q^2/m_ec^2 = \frac{h^2c^2}{\lambda^2c^2{m_e}^2} = \frac{h^2}{\lambda^2{m_e}^2} \tag{1}$$

or:

$$\frac{hc}{\lambda} - \frac{hc}{\lambda'} = \frac{h^2}{\lambda^2 m_e} \qquad (1)$$

Where λ is the initial wavelength of the incoming photon, λ' the wavelength of the re-emitted photon and h the Planck constant.
Solving this equation gives:

$$\delta\lambda(\lambda m_e c - h) = h\lambda \qquad (2)$$

Since $h \ll \lambda m_e c$

$$\delta\lambda = \frac{h}{m_e c} = 2.42x10^{-12}m \qquad (3)$$

As the photons travel through the IGM they are constantly absorbed and re-emitted and on each interaction their wavelength increases by $h/m_e c$. The Hubble Law becomes: 'Photons from galaxies twice as far away, travel twice as far through the IGM, make twice as many interactions and thus suffer twice the redshift.' Note that this calculation has been performed classically and is only valid for wavelengths above $\lambda \approx 10^{-11}m$ as for shorter wavelengths the recoil velocity approaches the speed of light.

However, it is not as simple as that since the number of collisions depends upon the collision cross-section and this in turn depends upon the wavelength of the photon. The collision cross-section, σ for a photon – electron interaction where the photon is absorbed and then re-emitted is found from low energy X-rays interacting with matter [2,11,12,13].

$$\sigma = 2r_e\lambda \qquad (4)$$

The mean free path of the photons is $(n_e\sigma)^{-1}$ or $(2n_e r_e\lambda)^{-1}$ where n_e is the number density of electrons in the IGM and since the photon is redshifted at each interaction the mean free path will get shorter and shorter as it travels through space

If the initial wavelength is λ, it will be $(\lambda + h/m_e\mathrm{c})$ after one interaction, $(\lambda + 2h/m_e\mathrm{c})$ after two interactions, $(\lambda + 3h/m_e\mathrm{c})$ after three and so on.

The sum of the mean free paths is equal to d, the total distance travelled.

$$\mathrm{d} = [2n_e r_e\lambda]^{-1} + [2n_e r_e(\lambda + h/m_e\,\mathrm{c})]^{-1} + [2n_e r_e(\lambda + h/m_e\,\mathrm{c})]^{-1} + \dots\dots\dots + [2n_e r_e(\lambda + (\mathrm{N}-1)\,h/m_e\,\mathrm{c})]^{-1} \qquad (5)$$

Or

Multiplying through by $2n_e r_e$ and summing:

$$\sum_{x=0}^{N-1}\left\{\lambda + x\left(\frac{h}{m_e c}\right)\right\}^{-1} = 2n_e r_e d \qquad (6)$$

And since N is large and $h/m_e\mathrm{c}$ is small this approximates to:

$$\int_0^{N-1}\left\{\lambda + x\left(\frac{h}{m_e c}\right)\right\}^{-1} dx = 2n_e r_e d \qquad (7)$$

Giving:

$$N = \lambda((m_e c/h)\exp(2n_e h r_e d/m_e c) + 1 - \lambda(m_e c/h) \qquad (8)$$

The total increase in wavelength, $\Delta\lambda = N\delta\lambda \; ie \; Nh/m_e c$

$$\Delta\lambda = \lambda\exp(2n_e h r_e d/m_e c) + h/m_e c - \lambda \qquad (9)$$

The redshift, z is $z = \Delta\lambda/\lambda$

$$z = \exp(2n_e h r_e d/m_e c) + h/(m_e c/\lambda) - 1 \qquad (10)$$

As $h/(m_e c/\lambda)$ is small compared to the other values ($= 2.42x10^{-12}\lambda$) for all wavelengths below X ray we can neglect it.

N.B. for X ray and above this classical approach fails as the recoil approaches the speed of light and so relativistic effects need to be considered.

$$z = \exp(2n_e h r_e d/m_e c) - 1 \qquad (11)$$

Since v=cz and in the Hubble Law v=Hd

$$H = (c/d)\{\exp(2n_e h r_e d/m_e c) - 1\} \qquad (12)$$

For small astronomical distances we use the approximation $e^x \approx 1 + x$

$$H = 2n_e h r_e/m_e \qquad (13)$$

Or:

$$z = \exp(Hd/c) - 1 \qquad (14)$$

Which has the same exponential form as the relationship proposed by Zwicky in 1929 [41] – but a totally different mechanism.

3. The NED-D compilation

One of the problems in testing Tired Light theories is that the data is often corrupted by expansion. Often, the observations such as distance measurements are adjusted for '*expansion*' with a '*stretch factor of usually (1+z)*' included before publication. This is no longer the case as we now have the '*NED-D:A Master List of redshift-independent extragalactic distances*' [14] (NASA Extragalactic Database (NED)) and I must thank Sahil Gupta [G2] for not only bringing this master list to my attention but also for converting it into a Google docs form (Excel) for easy access with 15,930 galaxies having both redshift and associated independently measured **actual** distances (and not corrupted by the expansion idea).

We are going to reduce the number of cosmological objects that we are to use. As we will see when we look at FRB the host galaxy may not be the host at all but just something on the same line of sight. So, we are removing all data that has a redshift of a '*host*' galaxy. That gives us 14,597 cosmological objects to test NTL predictions with. We will also remove a further 20 objects for the simple reason that their distance is far too great for their redshift and these would take up over the top half the chart space! All future predictions will be tested with the remaining 14,577 cosmological objects. Using normal statistical methods to remove outliers would have given more precise results but too often we see workers selecting ten or twenty objects out of hundreds or even thousands to make a cosmological point. I am using them all so as not to be accused of bias.

3.1 Mean electron number density

We reject that the Universe is expanding since the Universe is static. The redshift of these galaxies is caused purely by a photon-electron interaction ie New Tired Light. We saw in eq^n 11 that the distance – redshift relationship is:

$$d = \frac{m_e c}{2n_e h r_e}\{ln(1+z)\} \qquad (15)$$

Rearranging this to make n_e the subject gives:

$$n_e = \frac{m_e c}{2d h r_e}\{ln(1+z)\} \qquad (16)$$

We will now calculate the mean electron number density predicted by all 14,577 galaxies of known redshift and independent distances and find the average value.

$$\text{Mean electron number density} = 0.499\, m^{-3} \qquad (17)$$
$$\text{Standard deviation} = 0.20\, m^{-3}$$

It has to be said that in NTL a mean electron number density of $n_e = 0.5\, m^{-3}$ has been predicted throughout its entire life – from internet posts in 1998, to a book in 2003 [15] and in several peer reviewed journals continuously since 2006 [1]. This data confirms these NTL predictions fully. It also shows that the electrons are evenly distributed throughout the entire Universe.

3.2 The Hubble constant

In New Tired Light, the expression for the Hubble constant is (see eq^n 13):

$$H = \left(\frac{2n_e h r_e}{m_e}\right) \qquad (18)$$

We can use the mean electron number density found from our 15,930 galaxy sample to predict a value, by New Tired Light, for the Hubble constant itself. The result is:

$$H = 2.05x10^{-18}s\ or\ 62.5\ km/s\, per\ Mpc \qquad (19)$$

We see that this is in good agreement with recent values in the range $H \approx 67 - 74\ km/s\, per\ Mpc$ [16] . These values would require mean electron number densities of $n_e = 0.52 - 0.56\, m^{-3}$ – all within one standard deviation from $n_e = 0.499\, m^{-3}$.

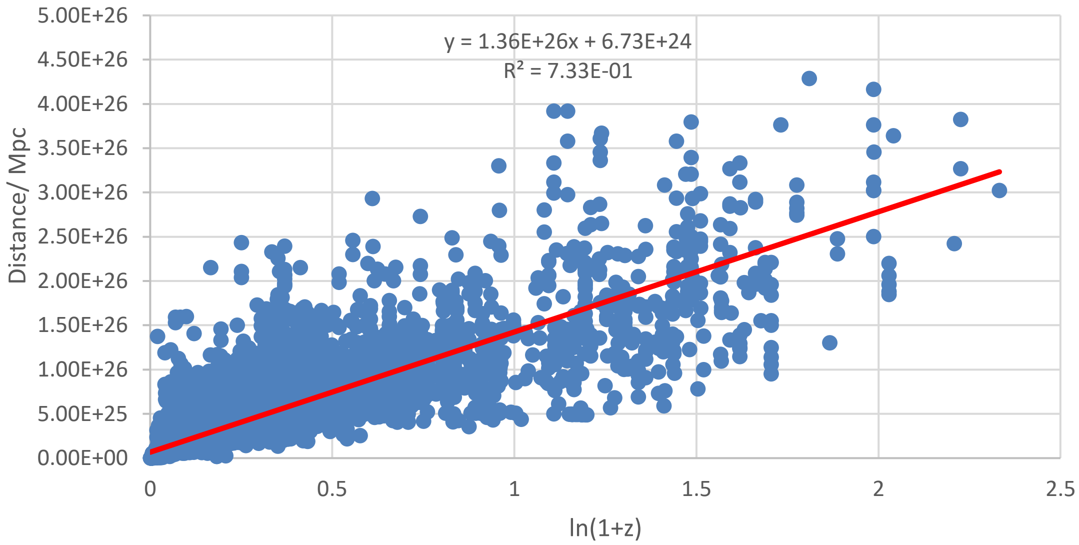
3.3 The New Tired Light Hubble diagram

We saw earlier in equation eq^n 15 that:

$$d = \frac{m_e c}{2n_e h r_e}\{ln(1+z)\} \qquad (20)$$

This is the equation of a straight line with intercept of 0 and gradient $m_e c/2n_e\, hr_e$. Using our sample of 14,577 galaxies of known redshift and independent distances taken from the '*NED-D: A Master List of redshift-independent extragalactic distances'* we can plot a scatter graph, compare it with the predicted equation of the straight lines and determine the gradient. This to be compared with that predicted of $m_e c/2n_e\, hr_e$. Substituting values for the constants gives a numerical value for the gradient of $1.46x10^{26}\ m$.

Figure 1. Hubble diagram for 14,577 cosmological objects. using NTL. Distance versus ln(1+z)



The graph of distance to galaxy versus ln(1+z) is a straight line and passes close to the origin. The R^2 value is 0.733 showing good correlation and importantly, the gradient of $1.36x10^{26}\ m$ is close to the predicted $'m_e c/2n_e\, hr_e'$ which has the value $1.46x10^{26}\ m$. A difference of just 7%.

Notice too, that the line is linear beyond $\ln(1+z) = 2.3$ or beyond redshifts of 9 whilst in the Big Bang theory one would have expected relativistic effects to have kicked in long before. Some say relativistic effects and time dilation of supernovae light curves are noticeable at redshifts of [17] but there to be no evidence for this here.

4. Comparing predicted redshift to observed redshift

With the mean electron number density, $n_e = 0.499\ m^{-3}$ found from our 14,577 cosmological objects, we can use the New Tired Light theory to predict the redshift of each one and compare it to the observed redshift. Fig 2 does just that.

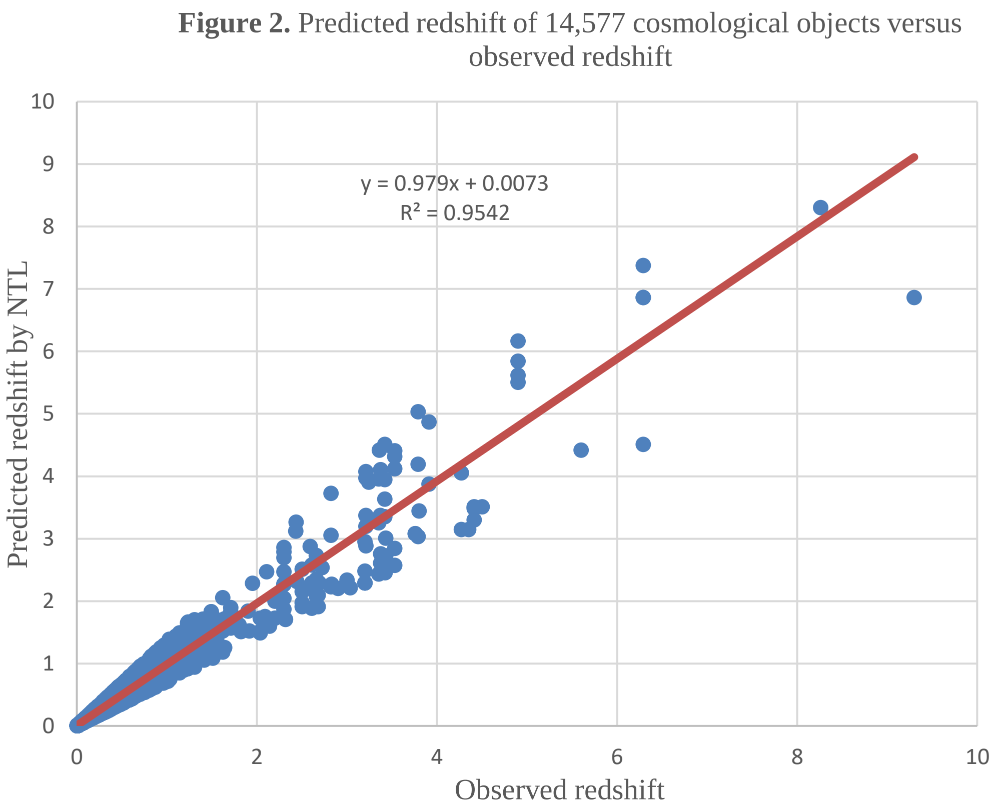


Fig 2 Fig. 2.
The predicted redshifts versus observed redshift for the 14,577 cosmological objects. We expect a 1:1 relationship between predicted and observed ie the gradient should be '1.0'. It is actually 0.979 a difference of just 2.8% and the R^2 value is 0.9542 showing very good correlation between observed and predicted redshifts.

5 Estimating the time delay between absorption and re-emission of a photon by an electron

We have seen many times over that in NTL, a photon is absorbed by an electron and the energy of the photon is transferred to vibrational energy of that electron as it performs SHM in the plasma of the IGM. There is a delay between absorption and re-emission and so the electron recoils on both absorption and re-emission. Some of the energy of the photon has been transferred to kinetic energy of the recoiling electron and so the newly emitted photon has less energy, a smaller frequency and a longer wavelength. It is this delay that separates New Tired Light from Compton scatter. In Compton scatter the absorption and re-emission occur simultaneously as there is no mechanism to store the energy. The new photon has to be scattered and thus blurs the image. In New Tired Light, there is a mechanism that stores the energy and so the new photon continues in the original direction. There is no 'blurring' of the image with NTL.

It is this delay that is responsible for the dispersion measure (DM) in the radio signals from FRBs. As the photons of radio wavelengths travel through the plasma of the IGM they are constantly absorbed and re-emitted by the electrons in that plasma. Lower frequencies of the signal take longer to travel the same distance than higher ones since the lower the frequency, the longer the wavelength and the greater the collision cross-section. Lower frequencies make more interactions than higher ones where they are delayed and thus take longer to travel the same distance. Hence the Dispersion Measure, DM.

This total time offset Depends upon:
How many interactions the photons make with the electrons in the IGM
The relaxation time between absorption and re-emission (Presumed to be frequency dependent?)

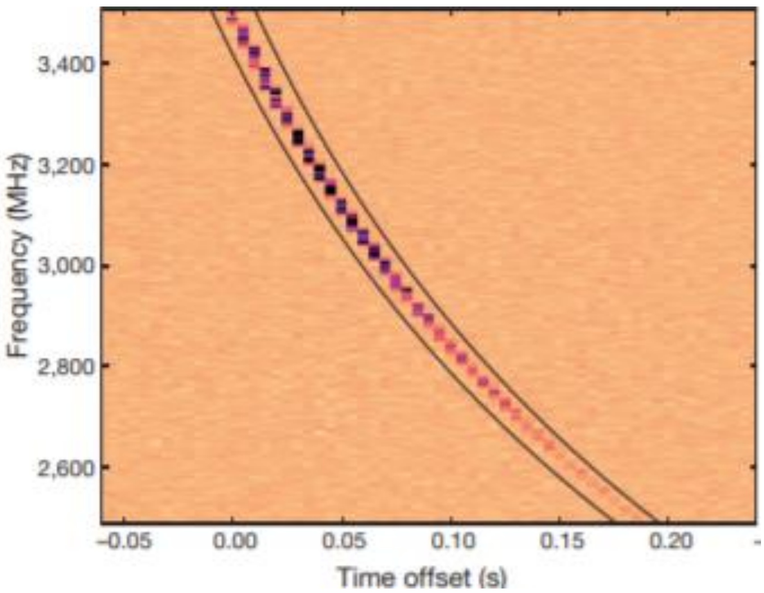
$$\text{Total Time Delay, } \Delta T = N\Delta t \tag{22}$$

Where N, is the total number of interactions between a photon of radio wavelengths and the electrons in the IGM and Δt, the relaxation time between absorption and re-emission of that photon.
Using NTL to determine, N, and time-frequency data from an FRB, we can determine an approximate value for Δt, the time delay at each interaction.

5.1 FRB121102

In the Chatterjee, et al. paper, 'A direct localization of a fast radio burst and its host,' [18] the time – frequency data from the VLA detection of FRB 121102 [Fig. 3] is given.

Figure 3. Time-frequency data from the VLA detection of FRB121102. Chatterjee et al. [T1]



5.2 Number of interactions

From this data we can see that the time offset between photons of frequency $3400MHz$ arriving and those of frequency $2600MHz$ arriving is $0.14s$.
We now need to calculate how many a times a photon of each wavelength interacts with the electrons in the IGM. Photons at the lower frequency, longer wavelength will make more interactions than photons of the higher frequency, shorter wavelength do – since the longer the wavelength, the greater the collision cross-section and the shorter the mean free path. Subtracting one from the other will tell us how many extra interactions photons of the longer wavelength make with the electrons of the IGM and it is these 'extra' interactions' that account for the delay of 0.14 seconds between the signals arriving – thus we can calculate the single time delay between an electron in the IGM absorbing a photon in the radio and then re-emitting it.

5.3 How long is the delay at each photon-electron interaction?

In NTL, when a photon interacts with an electron in the IGM some of the energy of the photon is transferred to the recoiling electron. The energy of the photon is reduced and Its wavelength increased

– it is redshifted. Since the wavelength has been increased the collision cross-section is also increased and the mean free path reduced. It is like skimming a stone across the smooth surface of a lake. The distance between successive 'bounces' becomes shorter and shorter as the stone travels further and further. Since the wavelength and hence collision cross-section increases with each interaction, the distance between each interaction becomes shorter and shorter. The number of interactions increases exponentially as the photon travels further and further. At the distance of FRB121102 the exponential term has not really 'kicked in,' and so we can find an approximate value of the number of interactions made by the photons by ignoring the increases in wavelength at each interaction for now and assume the wavelength remains constant for the entire journey.

The collision cross-section, σ, for a photon electron interaction is given by eq^n 4:

$$\sigma = 2r_e\lambda \tag{23}$$

Where r_e is the classical electron radius, $2.818x10^{-15}m$ and λ is the wavelength of the radio photon.

The mean free path, l, is given by:

$$l = (1/n_e\sigma) = (1/2n_e r_e\lambda) \tag{24}$$

The mean number of photon- electron interactions, N_i in travelling a distance, d, is:

$$N_i = (d/l) = 2n_e r_e\lambda d \tag{25}$$

FRB 121102 is a repeating FRB and so its host galaxy is known. We have a complete set of data consisting of the distance redshift of the host galaxy along with the Dispersion Measure [18,19,20].

Table 3. Data for FRB 121102

DM (measured)	$558.1 \pm 3.3\ pc\ cm^{-3}$
DM_{2001}	$\approx 188\ pc\ cm^{-3}$
DM_{Halo}	$\approx 30\ pc\ cm^{-3}$
DM_{host}	?
DM_{IGM}	$\approx (340 - DM_{host})\ pc\ cm^{-3}$
D_A	$\approx 683\ Mpc$
D_L	$\approx 972\ Mpc$
$host\ redshift, z$	0.19273 ± 0.00008

There are no standard candles in the host galaxy and so the distances are found using cosmological principles. We could use the value of $n_e = 0.499\ m^{-3}$ found earlier but I believe it best not to mix models and so we will find n_e from the DM and distance, d from the above table.

$$DM = n_e d \tag{26}$$

Making d the subject of this equation and then substituting for d in eq^n 25 gives:

$$N_i = 2r_e\lambda DM \tag{27}$$

Where DM is in SI units. One can see that regardless of which distance (D_A or D_L) we take we will have the same predicted number of interactions since DM is closely linked to n_e and d.

Table 5. Number of interactions at each frequency

Frequency/MHz	Wavelength/m	N_i
3400	0.088	$5.20x10^9$
2600	0.115	$6.80x10^9$

We see that a photon of frequency, $2600MHz$ make $1.60x10^9$ more interactions than those of $3400MHz$ in travelling the same distance – and arrive 0.14 seconds later.

The time Δt, between absorption and re-emission of a photon by an electron is therefore ($\Delta t = 0.14/1.60x10^9$) or $\Delta t = 0.88x10^{-10}\ s$, ie:

$$\Delta t \approx 1x10^{-10} \text{ seconds} \tag{28}$$

Note: we assumed that the relaxation time was the same for both frequencies. This should be a good approximation as they are fairly close when compared to the wide range of wavelengths across the electro-magnetic spectrum.

If we use the exponential redshift – distance function (eq^n 8) for a more precise calculation we still achieve the same result for an order of magnitude ie: $\Delta t \approx 1x10^{-10}$ seconds.

6 Calculating the redshift of the host galaxy

Knowing the number of interactions each photon makes with the electrons in the IGM allows us to calculate the redshift of the host galaxy by the NTL theory. In NTL, the photon undergoes an increase in wavelength of $2.42\text{x}10^{-12}\ m$ on each photon-electron interaction.

The total increase in wavelength, $\Delta\lambda = \text{N}\delta\lambda\ ie\ Nh/m_e\text{c}$

For our time delay calculation, we looked at frequencies of $2600\ and\ 3400\ MHz$ and so for our redshift calculation let us look at the average of these two frequencies, $3000\ MHz$. Substituting values for this frequency into eq^n 27shows there are $5.91x10^9$ interactions and so the total increase in wavelength, $\Delta\lambda$ suffered by our photon is:

$$\Delta\lambda = (5.91x10^9)\text{x}(2.42\text{x}10^{-12}) = 0.0143m \tag{29}$$

The redshift, z is $z = \Delta\lambda/\lambda$

$$z = (0.0143)/(0.100) \tag{30}$$

Or

$$z = 0.143 \tag{31}$$

This compares favourably with the measured value of 0.19 [[18,19,20] – a difference of just 25% between the calculated value by NTL and the measured value. It must be remembered that the measured DM was $558.1 \pm 3.3\ pc\ cm^{-3}$ and $218 \pm 3.3\ pc\ cm^{-3}$ was removed as estimates for other factors. To give the measured redshift of 0.19 would need a $DM_{IGM} = 450pc\ cm^{-3}$ which is still far less than the measured one. Perhaps we need to look again at the estimates of DM from other sources.

7 Relationship between dispersion measure (DM) and redshift revisited

"The dispersion measure (DM) is the column density of free electrons (total electron content) — i.e. the number density of electrons n_e (electrons/cm^3) integrated along the path travelled by the photon …" [21]. In New Tired Light, redshift is caused by photons interacting with these same electrons in the IGM (as to whether these electrons are actually 'free' is open to conjecture (see section 8) and so we would expect there to be a relationship that can be tested between DM and redshift. A paper on this subject was published by this author in 2016 [22]. At the time there was only one FRB with published host galaxy redshift and some extra galactic pulsar data. Pulsars are known to be troublesome as they have large intrinsic redshifts and this FRB is no longer included in lists of FRBs with known host galaxies [23]. At the time of writing there are thirteen known FRB with known redshifts of their host galaxy and so it would seem a good time to revisit this relationship using this new data. Note reference [23] has one FRB not used here since the redshift is not know precisely.

7.1 The relationship between DM and z

The distance to FRB is found from cosmological relationships as there are no cepheid variables to be seen at these distances. This direct relationship between DM and z alleviates us of the problem, as we do not need the distance in our relation.

$$DM = n_e d \tag{32}$$

where n_e is the average electron number density in cm^{-3} along line of sight and d is the distance from the source to observer in parsec.

In NTL, the redshift distance formula is (eq^n 14)

$$z = \exp\,(2n_e h r_e d/m_e c) - 1 \tag{33}$$

where n_e is the electron number density, h is the plank constant, r_e is the classical electron radius, d is the distance in metre, $m_e$the electron rest mass, c the speed of light in a vacuum and z the redshift as before. Rearranging this equation to make d the subject gives:

$$d = \frac{m_e c}{2n_e h r_e}\{ln(1+z)\} \tag{34}$$

Equating equations 32 & 34 gives:

$$DM_{IGM} = \left(\frac{m_e c}{2hr_e}\right)\{\ln(1+z)\} \tag{35}$$

Notice that the relationship is independent of the electron number density, n_e since it is the same electrons in the IGM that are responsible for both Dispersion Measure and redshift, z.
Notice also that the relationship between DM and ln $(1+z)$ is one of direct proportion since the first bracket consists of universal constants.

In SI units the relationship is:

$$DM_{IGM} = (7.32x10^{25})\{\ln(1+z)\} \tag{36}$$

DM is quoted in units of $pc\ cm^{-3}$ and so we must divide the right-hand side by a unit conversion factor of $3.086x10^{22}$ to ensure that DM can remain in $pc\ cm^{-3}$ whilst the right-hand side can remain in SI units.

Our relationship becomes:

$$DM_{IGM} = (2370)\{\ln(1+z)\} \tag{37}$$

Whilst the DM data for the FRB has been adjusted to account for localised DM from the Milky Way galaxy, it has not been adjusted for the host galaxy. Consequently, our final relation is:

$$DM_{IGM} = (2370)\{\ln(1+z)\} + \ mean\ DM_{host} \tag{38}$$

A graph of DM versus ln $(1 + z)$ will be a straight line having a gradient of $2370\ pc\ cm^{-3}$ and an intercept equal to the mean DM_{host}. Whilst this will vary from FRB to FRB, they are often found on the extremities of galaxies so should not be too great [24]

7.2 Testing all the Data

Table 4 Lists all known FRBs with corresponding redshifts of their host galaxy (at time of writing) and so we can test our relationship by plotting a graph of DM versus $\ln(1+z)$ $(Fig. 4)$

Figure 5. DM versus ln $(1 + z)$ all the 14 localised FRBs - at time of writing.
FRBs (at the time of writing)

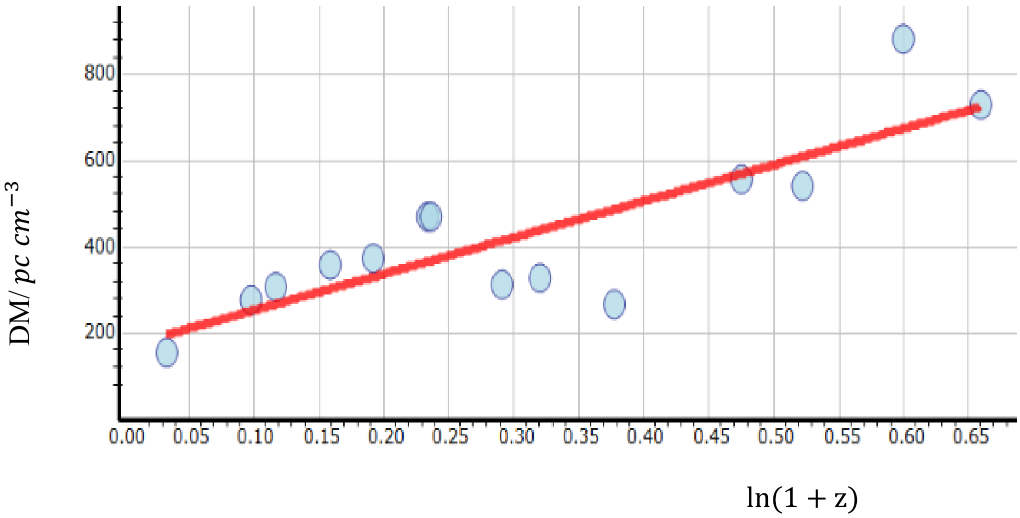


Table 6. List of data for all known FRB (at time of writing)

N^0.	Name	z_{host}	DM_{obs} [$pc\ cm^{-3}$]	DM_{MW} [$pc\ cm^{-3}$]	$DM_{IGM+host}$ [$pc\ cm^{-3}$]	Ref
1	FRB 180916	0.034	348.8	199	149.8	[25,26]
2	FRB 20201124A	0.098	414	140	274	[27,28,29]
3	FRB 190608	0.118	339.5	37.2	302.3	[30,31]
4	FRB 200430	0.160	380.0	27.2	352.8	[32,33]
5	FRB 121102	0.193	557.0	188	369	[25,34]
6	FRB 191001	0.2340	507.9	44.2	463.7	[33,36]
7	FRB 190714	0.2365	504.1	38.5	465.6	[32,36]
8	FRB 190102	0.291	364.5	57.3	307.2	[30,31]
9	FRB 180924	0.321	361.4	40.5	320.9	[31,37]
10	FRB 190611	0.378	321.4	57.8	263.6	[30,31,32]
11	FRB 181112	0.476	589.3	40.2	549.1	[38,39]
12	FRB 190711	0.522	593.1	56.5	536.6	[30,40]
13	FRB 20119061AD	≈0.60	959.19	83.5	875.7	[41]
14	FRB 190523	0.660	760.8	37.0	723.8	[42]

The equation of the line of regression is:

$$DM = 843 \ln(1+z) + 165 \qquad (39)$$

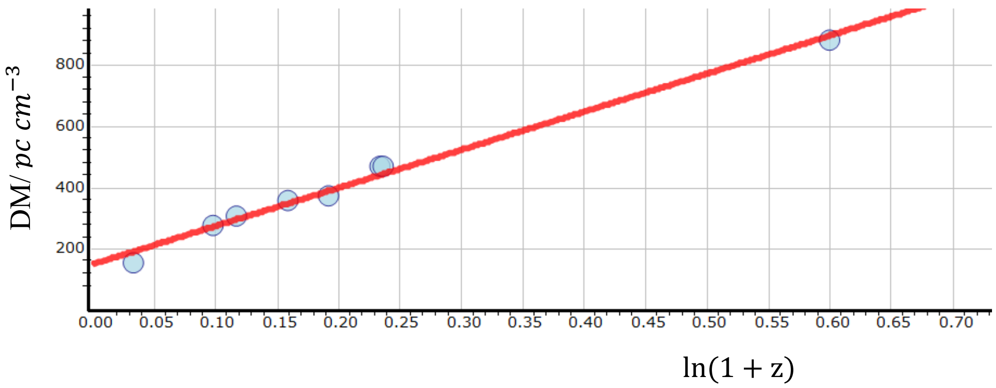
Giving a gradient of $843 \pm 346\ pc\ cm^{-3}$ and an intercept DM of $165\ \pm 125 pc\ cm^{-3}$. Note that whilst the gradient from the data is of the same order of that predicted by NTL ($2370\ pc\ cm^{-3}$) – it is not as convincing as one would like!

It should also be noted that there is some uncertainty into the '*host*' galaxy actually being the '*host*' galaxy. Researchers detect a FRB, assume that the photons travel in a straight line (even though they are interacting with '*free*' electrons on the way!) and an optical search is mounted to find a galaxy in this position. But there is no guarantee that the object found is the actual host. The galaxy may just be in the optical path and the FRB being some distance behind this galaxy, or the FRB may be hosted by a small galaxy in front of a large one behind which is thought to be the host.

7.3 A closer look at eight of the FRBs

FRB numbered 1,2,3,4,5,6,7, and 13 in Table look interesting so let us just look at them separately.

Figure 5. DM versus ln $(1+z)$ for eight of the 14 localised FRBs - at time of writing.



We can see here that all eight points lie either on or close to the line of best fit (notice that two of the points almost lie on top of one another).

The equation of the line of regression is:

$$DM = 1244 \ln(1 + z) + 147 \quad (40)$$

With the gradient at $1244 \pm 147\ pc\ cm^{-3}$ and an intercept with the 'y' axis of $+147\ \pm 34\ pc\ cm^{-3}$.

These are in better agreement with the predicted value of the gradient by NTL of 2370 $pc\ cm^{-3}$– and we must remember that this predicted gradient is just a combination of universal constants involving the electron and photons of light. It should be noted that a small change in one data point makes a large difference to the gradient since there are not enough data points. We need to continue with these graphs as more and more FRBs are located.

8 The Intergalactic Medium (IGM)

8.1 Dispersion Measure

The IGM is often thought of as a neutral plasma at a very high temperature (50,000K) [43] It is on this basis that Tired Light theories are discounted since, it is argued that the light would be scattered and the image blurred. However, signals from fast radio bursts (FRB) at cosmological distances have been received and these are undisturbed. Even when these signals pass through the known plasma around the extremes of galaxies they arrive in pristine conditions [44]. The plasma did not scatter them or affect them in any way. These radio signals are emitted with a very high total energy over a very short time duration. As this pulse travels towards Earth, theory tells us that they interact with 'free electrons' [21] in the IGM with the result that dispersion takes place were high frequencies travel the fastest and arrive first with the slower, lower frequencies arriving later.

The farther away the source, the greater the lag time between the arrival of the various frequencies. Dispersion Measure (DM) is a measure of this lag time and from the DM the mean 'free' electron number density,n_e, can be found ($n_e \approx 0.5\ m^{-3}$) [45] and compares favourably with the $0.4999m^{-3}$ from our cosmological objects in the NED-D compilation. The farther away the FRB, the greater the number of free electrons the photons interact with, the greater the delay in the arrival of these photons and the greater the DM. But if the IGM consists, allegedly, of this hot neutral plasma, how can the 'free' electrons within it slow the photons down? At the date of writing, we know the host galaxies of thirteen FRBs and we know their source because, just as the light travels in straight lines, the radio signals also travel in straight lines even though they interacted with 'free' electrons in the IGM - and yet there is no blurring of the pulses. Mainstream cosmology tells us that the photons from the FRB interact with 'free' electrons, suffer a delay in doing so and yet travel in straight lines with no blurring. If this is true for FRBs why cannot it be true for tired light theories - since both involve a photon interacting with an electron in the IGM? This, begs the question, "*is our model of the IGM, well … to put it bluntly, wrong?*"

8.2 The history of the IGM

In order to find where this idea of the IGM being a 'hot' neutral plasma originated we need to look at the history and for that, where better than the 'Encyclopaedia Britannica?' [46]. Here we see that having been unable to find any form of matter in the IGM, all that was left was to propose a very hot plasma. This view was reinforced in the 1970's with the discovery of a uniform extragalactic X-ray background similar to that emitted if a plasma at a temperature of $10^8 K$ occupying the entire IGM.

However, this residual X-ray background is now believed to be caused by active galactic nuclei at high redshift. So, this begs the question, "*why do we still believe the IGM to be a 'hot' neutral plasma when it has been shown that the original assumption was wrong and there is now no evidence for this*?"

Furthermore, it begs the question, if the IGM does consist of separate protons and electrons, why don't they just recombine?

8.3 A new model of the IGM

Freed of the historical (and wrong) notion of an IGM made up of a hot neutral plasma, in this paper we will develop the photoelectric/ionisation model whereby electrons are separated from their protons by photo-ionisation. The protons remain on the dust particles in the IGM or surrounding Hydrogen clouds or galaxies whilst the ejected electrons move off into the IGM and form an 'electron sea.' The IGM is not a neutral plasma with electrons and protons roaming feely and separately through the vast expanses of the IGM, but more of a 'dirty plasma' where the protons are held firm on the dust particles whilst the electrons fill the spaces in-between.

The electrons and protons in Hydrogen atoms are separated with the protons left behind on the dust particles whilst the electrons move off to fill the IGM. The IGM is still overall neutral but the protons and electrons separated and in dynamic equilibrium.

When we have an IGM with an excess of electrons, the electrons will arrange themselves into a Body Centered Cubic (BCC) crystal structure held in place by their mutual repulsion. These are known as Wigner-Seitz crystals. Neutral plasma can, under certain conditions, crystalise but these need extreme densities and very low temperatures so that the electrical potential energy between charges is greater than their kinetic energy. With only electrons present (or even a region of excess protons) these extreme conditions are not necessary. The Electrical potential energy of the electrons readily outweighs the kinetic energy. The charges arrange themselves into an 'electron glass' of BCC crystals held together, not by their mutual attractive forces but by their mutual repulsion. In these crystal structures charges can and do perform Simple Harmonic Motion (SHM) and so can, and do, absorb and re-emit photons of light.

Consequently, these electrons on their Wigner- Seitz crystal lattice will form a coherent set of scatterers and can explain why the signals from an FRB interact with 'free' electrons, become delayed, and yet travel in a straight line [47, 48]. It will also explain why, in tired light theories, photons can be redshifted and the light not scattered since the electrons are not 'free' but arranged on a crystal lattice.

8.4 Intergalactic dust and photoelectric effect

The proposals put here are not new. Indeed, the whole subject of photoelectric heating of dust particles in the IGM has been studied widely and has been published in several illustrious mainstream journals. It is true. It happens. High energy photons strike a dust particle in the IGM and liberate electrons from it – leaving every dust particle in the IGM positively charged. What is new in this paper is that no-one seems to have asked, 'what happened to the electrons?' This paper will answer that question but firstly, let us review these papers.

To emphasize, Physics, published in mainstream, peer reviewed journals state that every dust particle in the IGM is positively charged. The question not asked, but answered in this paper is 'where are the corresponding electrons?'

8.5 Amount of intergalactic dust

Akio K. Inoue and Hideyuki Kamaya [49] looked at the constraints on the amount of dust in the IGM from supernovae and the history of the IGM. The dust grains are thought to consist of graphite or silicates and found that the dust density in the IGM increases from $\approx 10^{-34} g\ cm^{-3}$ at $z = 0$ to $\approx 10^{-33} g\ cm^{-3}$ at $z \approx 1$, '*and keeps a constant value or slowly increases toward higher redshift.*'

It is known that the dust can be responsible for IG extinction and reddening but the amount of IGM dust was previously thought to be negligible because significant reddening has not been seen. The reddening by dust in the IGM is uncertain and could possibly be 'grey' or independent of wavelength

[50] – in which case a large extinction is possible with no reddening. Furthermore, the dimming of distant supernovae presently attributed to the cosmological constant can be explained in terms of IG extinction without the need for a cosmological constant if there is more dust in the IGM!

One of the parameters included in the determination was, '*we constrain the amount of the IG dust in order that the IG dust should not affect the determination of the cosmological parameters from distant SN Ia.*'

In other words, the amount of dust in the IGM may be much higher than the figures cited above – but we would have to say the Big Bang is wrong. We will go along with this density for now.

Akio K. Inoue and Hideyuki Kamaya [51] looked at how the electrical potential of the dust grains varied with grain size. They studied the effects of collisional charging by electrons '*bumping*' into the grains and '*sticking to them,'* and photoelectric charging whereby a photon of high enough energy can release an electron into the IGM. They found that an equilibrium charge would be reached where the rate at which an electron from the IGM collides with a grain and sticks is equal to the rate at which an electron is ejected by the photoelectric effect. The time to reach equilibrium where the charge and electrical potential are constant is $6x10^{-3}year$, or $2.2\ day$. As a result, all the grains are positively charged and in equilibrium. For a hard spectrum background radiation dominated by QSO's, the electrical potential varies slightly with grain size and varies from $\approx +20V$ for large and small grains sizes ($1\ and\ 10^{-3}\mu m$) and peaking at $\approx 30V$ for grain sizes $\approx 10^{-2}\ \mu m.$

8.6 To sum up

The density of dust in the IGM is . $\approx 10^{-33}g\ cm^{-3}$ but may be much more since one of the constraints put on it is that it must not contradict the Big Bang Theory – even though IG dust can explain away observations that require a cosmologic constant without it! The grain size has ranges between $1\ and\ 10^{-3}\mu m$ and the grains reach a dynamic equilibrium in positive charge within two days with an electrical potential of $\approx 25V.$

Mainstream, peer reviewed papers in highly respected journals are telling us that every dust particle in the IGM is positively charged because of the photoelectric effect. What these papers do not tell us or ask is, '*what happened to the ejected electrons*?'

So, we now begin **this** paper which will answer that question and consequently show why New Tired Light can predict redshifts without scatter or blurring of the image.

9. Calculating the electron number density of the IGM from the equilibrium charge on the dust grains

Dust grains in the IGM are thought to consist of graphite and silicate having densities of:

$$\text{Density graphite} = 2260\ kg\ m^{-3} \text{ and silicate} = 2648\ kg\ m^{-3} \qquad (41)$$

We will do this algebraically since the density of dust in the IGM stated earlier had the constraint that it must not go against the Big Bang and the expanding Universe. Let ρ_{IGM} be the density of dust in the IGM.

The densities of graphite and silicate are very close so let us use a mean density of dust particle of $2450\ kg\ m^{-3}$. In $1\ m^3$ of the IGM, the total mass of grains is $\rho_{IGM}\ kg$. Dividing this by our mean grain density of $2450\ kg\ m^{-3}$ gives the volume of graphite in each cubic metre of the IGM.

$$\text{Volume of graphite in } 1\ m^3 \text{ of the IGM} = (\rho_{IGM}/2450)m^3 \qquad (42)$$

Let a be the radius of the dust grain such that the volume of the grain is $(4\pi a^3/3)$. Dividing the total volume of our grains in the IGM by the volume of a single grain will give us the number of grains in $1\ m^3$ of the IGM.

$$\text{Number of grains in } 1\ m^3 \text{ of the IGM} = (9.7x10^{-5}x\ \rho_{IGM})/a^3 \tag{43}$$

We saw earlier that the equilibrium potential of the grains was $\approx 25V$. Assuming them to be spherical we can calculate just how much charge there is on each by using the formula for capacitance of a sphere of radius, a.

$$\text{Capacitance of a sphere} = 4\pi\varepsilon_0 a \tag{44}$$

Using $Q = CV$ and $V \approx 25V$ gives the charge on the grain as:

$$\text{Charge on each grain} = 100\pi\varepsilon_0 a \tag{45}$$

Dividing the charge on each grain by the electronic charge, e gives the number of excess protons on the grain.

$$\text{Number of excess protons on each grain} = 100\pi\varepsilon_0 a/e \tag{46}$$

And this will equal the number of electrons sent off into the IGM by that grain. Multiplying the number of electrons released by each grain by the number of grains in each cubic metre gives the electron number density per cubic metre in the IGM.

$$\text{Number of electrons in each } m^3, n_e = (1.7x10^6\rho_{IGM}/a^2) \tag{47}$$

Inserting value for $n_e = 0.5\ m^{-3}$ from Fast radio bursts (my ref) and the near 15,000 cosmological objects earlier, $\rho_{IGM} = 10^{-30}kgm^{-3}$ gives a value of dust particle radius as $a \approx 2x10^{-12}m$ – which is clearly impossible as the dust particle would be much smaller than an atom!

In determining this value for the density of dust in the IGM, one of the constraints placed on it was that, '*the IG dust should not affect the determination of the cosmological parameters from distant SNIa.*' Removing this constraint will lead to higher density of dust in the IGM and could reach that needed for the grains – and perhaps do away with the cosmological constant at the same time.

So, what density would we need? Substituting $n_e = 0.5\ m^{-3}$ and a radius of $a \approx 10^{-9}m$ (a known dust radius) gives a density of dust in the IGM of $\rho_{IGM} \approx 3x10^{-25}kgm^{-3}$ – which seems high until we remember that the critical density and the density parameter, Ω are only relevant if one believes that the universe is expanding – which in New Tired Light, we don't! [49] discusses the possibility of large grains of 'grey' dust (wavelength independent) which would add to the photoelectric emission of electrons into the IGM but would be very difficult to detect since there would be no reddening of distant galaxes – they would just 'dim' the galaxy or supernova, making it look further away.

10. Galaxies Boiling off electrons

In a previous paper, 'Galaxies "*Boiling off" Electrons Due to the Photo-Electric Effect Leading to a New Model of the IGM and a Possible Mechanism for "Dark Matter*,"' [52] I looked at, not dust, but galaxies being responsible for the electrons in the IGM.

Here photons of UV and baryons from solar winds emerging from galaxies, ionise the Hydrogen atoms in the clouds surrounding the galaxy. The electrons move off to fill the IGM leaving the protons behind.

When we have a cloud of electrons, they will spread themselves out so as to be evenly spaced - held apart by their mutual repulsion on a BCC lattice. Here their electrical potential energy is greater than their kinetic energy and so the charges just oscillate about their equilibrium position ie we have an 'electron glass' or Wigner – Seitz crystal. This allows then to absorb a photon; the photon energy is transferred to vibrational energy of the electron (with some to the electron recoil energy) and then re-emit a new photon. Hence New Tired Light. As we saw before, the natural frequency of oscillation of the electrons is $\approx 30Hz$, it is well below the frequency of the photons of radio or light, there is no resonance absorption and so every frequency is absorbed and then re-emitted. The photons will continue in a straight with no blurring of image since recoil occurs along the line of sight.

It is the same with the protons left surrounding the galaxies. They too will arrange themselves on a BCC crystal lattice and they too can absorb and re-emit photons of light (though recoil will be much less due to the much larger mass of the particles. The proton cloud is transparent. We will not see it. It is 'dark.'

As anyone who has walked into a closed glass door knows, we cannot see anything that is clear and transparent and it was proposed in that paper that this was a possible mechanism for 'dark matter.' We only 'see' objects because of the light that they reflect or absorb and our Wigner- Seitz crystals will transmit light without either. It is 'dark.'

10.1 The way forward

Knowing that there are $n_e \approx 0.5\ m^{-3}$ electrons in the IGM from observations, in this model each of these electrons will have left behind a proton surrounding a galaxy somewhere in the Universe since they were produced by photoionisation of Hydrogen atoms surrounding a galaxy. A recent paper [53] has given us an, "accurate determination of the mass profile of the Milky Way galaxy.' The total mass of the MW galaxy is $3.0x10^{42}kg$. Dark matter is thought to make up approximately 84% of the total mass.

That is, having the mass of the dark matter surrounding the Milky Way (MW), we assume that it is made up solely of protons. Knowing the mass of a proton we can determine how many protons are in it and this will give us the number of electrons released by the MW galaxy into the IGM. There are several ways to determine the average distance between galaxies and so we can find the average distance between them and hence the average volume of the IGM occupied by that galaxy. Dividing the total number of electrons 'boiled off,' by the MW by the average volume of space occupied by it will give us the predicted electron number density, n_e. The question then is, '*does it equal* $n_e \approx 0.5\ m^{-3}$?'

10.2 Number of electrons contributed by the MW

From '*section 10.1,'* the mass of dark matter surrounding the MW is $2.5x10^{42}kg$. Dividing this by the rest mass of a proton, $1.67x10^{-27}kg$ tells us that in this model of dark matter there are $1.5x10^{69}$protons surrounding the MW as dark matter and hence $1.5x10^{69}$ electrons emitted into the IGM.

10.3 Average volume occupied by a galaxy in space

The volume of the observable universe is $2.85x10^{81}m^3$ and contains $2x10^{12}$galaxies [54]. Dividing the volume of the observable universe by the number of galaxies in it gives us the average volume occupied by a galaxy, which is $1.4x10^{69}m^3$.

10.4 Predicted mean electron number density, n_e of the IGM

So, we have $1.5x10^{69}$ electrons contributed by the MW into the average volume occupied by a galaxy of $1.4x10^{69}m^3$ giving a mean electron number density of $1.1\ m^{-3}$ - which compares very favourably with that from observation of $n_e \approx 0.5\ m^{-3}$. Whilst this does not prove the model correct (especially as the author accepts, there is a great deal of work yet to be done and problems to be solved). It does however show that numerically, it is a perfectly feasible model of dark matter surrounding galaxies and of the electrons in the IGM.

11. Evidence for crystallization of electrons from the lab and chemistry

It may seem odd this idea of the electrons in the IGM arranging themselves into a crystal lattice or indeed the protons surrounding our galaxy forming on a crystal lattice as dark matter, transmitting the light through them. That said plasma dust crystallization has been performed in the lab. Micron sized spheres were suspended in a charge-neutral plasma gained a negative charge as electrons collided with them. And it was found ,'*a two-dimensional non-quantum lattice forms through the Coulomb interaction of these spheres. Microgravity is thought to be required to observe a three-dimensional structure.*' [55]. That is, in the IGM, they would have formed in a three-dimensional lattice. Consequently, the positively charged dust grains must also arrange themselves on a three-dimensional crystal lattice in the IGM.

In chemistry we often think of electrons whizzing around in their orbits or sharing as they move between nuclei to form molecules. In VSEPR models this is not the case [56]. The electrons in the valence shell of an atom keep as far apart from each other as they can. Whilst this appears to be due to electrostatic repulsion, it is actually due to the Pauli exclusion principle. That said the electrons arrange themselves at the vertices of regular shapes such as tetrahedrons etc. The positioning of the electrons can not only predict the shape of a molecule but even the bond angles.

So, is it surprising that the electrons in the IGM, once separated from the protons left behind, arrange themselves on a lattice? Held apart by their mutual attraction, oscillating about their mean position.

12 Discussion and conclusions

12.1 Using the NED-D compilation

This compilation gives the redshift-independent distances to cosmological objects ie they are from direct measurements only and have not been adjusted to take into account for '*expansion effects*.' There are 15,930 of these objects which have both distance and redshift and 14,577 of these have actual redshift from the object and not a 'host.' We took the data from these along with NTL theory to determine the mean electron number density in the IGM. This gave us a number of $n_e = 0.499m^{-3}$ which compares well with the predicted value from NTL of $n_e = 0.5m^{-3}$. This predicted value has been seen in published papers, books and online for over twenty years. The standard deviation was $0.2\ m^{-3}$ but it must be noted that the data had not been 'cleaned up' by removing outliers as I did not want to be accused of selecting data. Had outliers been removed the standard deviation would be much less.

We then used this electron number density to calculate the Hubble constant. NTL predicts that the Hubble constant shall be $H = (2n_e hr_e/m_e)$ which, with our electron number density from the 14,577 objects of $n_e = 0.499m^{-3}$ gives a value of $H = 62.5\ kms^{-1}\, per\ Mpc$ which compares favourably with observed values of $H = 67 - 74\ kms^{-1}\, per\ Mpc$ and lies within uncertainties in n_e. But just why should the Hubble constant have a value so close to a combination of constants involving the electron, Plank constant and the speed of light? If it is a coincidence then it is a very remarkable one!

NTL predicts a linear relationship between distance and $\ln(1+z)$ with a gradient consisting of a combination of the electron number density and several universal constants relating to the electron and the speed of light ($m_e c/2n_e\, hr_e$). When we use all data from all these objects, we see that it is linear up to a redshift of nine - with no hint of relativistic effects. The gradient of $1.40x10^{26}\ m$ is close to the predicted $m_e c/2n_e\, hr_e$ which has the value $1.46x10^{26}\ m$ – a difference of just 4%. Again, why is the observed value so close to the predicted value consisting of universal constants relating to the electrons and photons of light?

With true distances that have not been corrupted with the *'Big Bang idea'*, we can use NTL to take the distance for each object and predict the redshift of that object. A graph of predicted redshift plotted against observed redshift should be a straight line through the object with a gradient of one since if NTL is correct, there should be a $1\ to\ 1$ relationship between them. Fig2. Shows this and we see a straight line through the origin with gradient 0.9756 a difference of just 2.8% from unity and the R^2 value is

0.9557 showing very good correlation between observed and predicted redshifts. Again, numerical predictions by NTL are supported by observation.

12.2 Time delay between absorption and re-emission

The time-frequency data from the VLA detection of FRB121102 enables us to determine an average time, Δt between an electron absorbing a photon and re-emitting a '*new*' photon for photons in the radio band with a frequency of approximately $3000\ MHz$ and we see that this is $\Delta t \approx 1x10^{-10}$ seconds. This falls within expectation since it is very short – One would not expect a loosely bound electron in the IGM to hold onto the energy for very long. It is this delay that allows the electron to recoil on absorption and re-emission, for the photon to lose energy to the recoiling electron on absorption and re-emission and hence become redshifted. All this whilst the photon continues in a straight line. There is no 'blurring' of the image in New Tired Light.

12.3 Predicting the redshift of the host galaxy by New Tired Light

FRB 121102 has a complete set of z, D_L, D_L and DM and so it is an interesting thing to use the DM and wavelength to determine the number of interactions a radio photon makes on its journey to Earth. Multiplying this by the increase in wavelength at each interaction $(2.42x10^{-12}m)$ as predicted by NTL gives the total increase in wavelength $(\Delta\lambda)$. Dividing this by the wavelength $(\Delta\lambda)$ gave the redshift of the host galaxy as $z = 0.143$ compared to the measured value of $z = 0.19$ – a difference of 25%. The problem here is that we do not know the actual distance as there are no cepheid variables to be seen in the host galaxy so distances are determined cosmologically. The measured DM was $558.1 \pm 3.3\ pc\ cm^{-3}$ whilst the value attributed to the IGM was $340\ pc\ cm^{-3}$ – the difference removed as estimates of DM due to the MW and its halo. To achieve the measured value of the redshift $(z = 0.19)$ requires a $DM_{IGM} = 450 pc\ cm^{-3}$.

12.4 Relationship between DM and redshift

Since both DM and redshift (in NTL) are both caused by the same electrons in the IGM, then there should be a direct relationship between them. Taking the equations for NTL and DM and rearranging them to make distance d the subject then equating them gives us the expression.

$$DM_{IGM} = \left(\frac{m_e c}{2hr_e}\right)\{\ln(1+z)\} \tag{48}$$

We see that it is a linear expression with gradient equal to a combination of universal constants relating to the electron and the photon. Substituting values and including a conversion factor so that the right-hand side can remain in SI units with the left-side in $pc\ cm^{-3}$ gives:

$$DM_{IGM} = 2470\{\ln(1+z)\} \tag{49}$$

At the time of writing there are fourteen localised FRB with DM and host redshift. Plotting these data points gives a gradient of $843 \pm 346\ pc\ cm^{-3}$ and reasonable support for the prediction. Host galaxies are always a worry as one never knows if they are the host or just on the same line of sight with the FRB lying behind. The FRB could also lie in a much smaller galaxy at the front which is too small to be seen. By inspection there are seven FRB that stand out and when the data for these are plotted, they give much better support with all seven lying on or near the straight line of best fit and gradient of $1244 \pm 147\ pc\ cm^{-3}$– almost exactly one half of the predicted value. That said, we really need more data points in view of the uncertainties involved and we will continue to plot this graph as more and more FRBs are located. It must be remembered that the predicted gradient is equal to a combination of universal constants relating to the electron and the photon.

12.5 New Model of the IGM

Neither FRB or New Tired Light produce blurring of the object. In both cases the photons interact with electrons in the IGM to produce the DM or the redshift. Either they both travel in straight lines or neither does. The problem is in the old and false model of the IGM. This model had the electrons and protons acting separately but mixed together in a plasma. The reason for this model was to explain X-ray emission from a hot source. We now know that these X-rays are produced by active galactic nuclei at high redshift so there is no evidence for this neutral plasma in the IGM. Several workers have studied the charging of dust grains in the IGM and found that every dust grain has an equilibrium positive charge caused by a balance between photoelectric emission of electrons and electrons bumping in to the grain and sticking to it. But what these workers didn't ask was, '*what happened to the electrons?*'

This implies that the IGM is a 'dirty plasma' with positively charged dust grains holding the protons fast whilst the electrons move off to fill the IGM. When there are a group of electrons, they will arrange themselves on a BCC crystal lattice held there by their mutual repulsion. Since their electrical potential energy is greater than their kinetic energy they oscillate about their mean positions. Since they can perform SHM, they can absorb a photon and there is a delay whilst the photon energy is transferred to vibrational energy of the electron. It is this delay that produces Dispersion Measure since photons of greater wavelength have a greater collision cross-section and thus suffer more delays and arrive later. The delay also allows the electron to recoil, take up some of the energy of the photon and give us cosmological redshift.

Using published densities of IGM dust found by including parameters that insisted there should not be so much dust as to compromise the Big Bang Theory, then there is not enough dust to provide the necessary $n_e = 0.5m^{-3}$ found here. However, if we remove the constrains of the Big Bang theory there may well be enough. It can be shown that, if there is enough dust, then it could explain the dimming of distant supernovae and remove the need for the cosmological constant.

In a previous paper, this author proposed that photons and baryons escaping from the inside of a galaxy could ionise Hydrogen atoms in the clouds surrounding a galaxy releasing the electrons to go off to fill the IGM leaving the protons behind, surrounding the galaxy. The electrons form on a BCC lattice as discussed earlier and allow DM and redshift to take place.

The remaining protons will arrange themselves by their mutual repulsion and form onto a lattice structure. These will transmit light and so will not be seen – they will be dark. We now have a precise estimate of the mass of the Milky Way and hence the amount of dark matter surrounding this. With this model we assume it all to be protons and so dividing the mass of the dark matter by the proton mass gives us the number of protons making up the dark matter. For every proton here there must be an equal number of electrons in the IGM. There are good estimates of the size of the observable and the number of galaxies in it and so the average volume of the IGM occupied by each galaxy can be found – and this contains the number of electrons released by the galaxy. The predicted mean electron number density of the IGM is found to be $n_e \approx 1\ m^{-3}$ – almost exactly the same as that found from observation.

12.6 NTL – a robust theory

The New Tired Light theory has been in existence for over twenty years and still provides predictions that are confirmed by observational data. In the case of FRBs, these were not known about at the time the theory was first developed and yet these too provide confirmation of the predictions made. It remains a robust theory despite all this time and new discoveries that come along.

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Appendix A
The Cosmic Microwave Background Radiation

The recoiling electron will interact with the other charges in the plasma and the kinetic energy gained by recoil will be emitted in the form of secondary radiation. Since the interactions are non-relativistic it is a simple matter to find the wavelength of these secondary photons.

$$momentum\ of\ photon, mv = \frac{h}{\lambda} \tag{50}$$

From this we can find the recoil velocity, v. The kinetic energy gained is the energy 'lost' to the photon and the energy radiated as a secondary photon.

$$hf = \frac{mv^2}{2} \tag{51}$$

We see that an incident photon in the UV ($\lambda \approx 5x10^{-8}m$) emits a secondary photon of wavelength $\lambda_{CMBR} \approx 2x10^{-3}m$ which is at the peak of the CMBR.