Source of a Fast Radio Burst identified: implications for some tired-light redshift theories

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First detected in 2001, Fast Radio Bursts (FRBs) were discovered six years later in archival data. Since then, fewer than 30 FRBs have been detected by radio telescopes. Because they occur so infrequently and only last a few milliseconds, these radio bursts are very difficult to study. In an effort to understand how FRBs are produced, a network of radio and optical telescopes was set up to locate and photograph the progenitor system from which they originate. In a paper published in Nature [1] a team of astronomers reported that they have located the source of FRB 150418 detected by the Parkes radio telescope on April 18th, 2015. This burst was followed by a fading radio signal which gave the astronomers enough time to obtain its celestial coordinates. Using optical telescopes the host of the FRB was identified as being a massive elliptical galaxy, giving an important clue to the kind of mechanism responsible for the generation of these powerful bursts. The FRB originated from an old galaxy where the star formation rate is low. Contrary to what was hypothesized, this FRB is not likely to have anything to do with star birth. Instead, the FRB would have been produced by a type of event involving old stars, such as the collision of neutron stars.

More matter found in the universe

Of the 4% of the content of the universe that is "normal matter" - not dark energy nor dark matter - only half of it is actually seen in stars, galaxies and hydrogen gas. More mass could exist as a plasma in the form of free protons and electrons, but these particles are difficult to detect. The observation of FRB 150418 provides an important tool to determine the density of electrons present in the intergalactic medium (IGM). This observation can confirm that the mass of the normal matter is in agreement with the predictions of the current cosmological model, the Lambda-CDM model.

The density of electrons in the IGM is obtained from the *dispersion measure* of the detected radio bursts. Dispersion is caused by the interaction of the radio burst with electrons which cause the high frequency components of a radio burst to travel faster than the low frequency components. After a long journey through the IGM, these frequency components reach Earth at different times. By measuring the delay between the different frequency components, the number of electrons encountered by the burst can be obtained. This number of electrons is called the *column density* by analogy with the shape of a well collimated light beam projected up into the sky. In the case of FRB 150418, a dispersion of about one second was measured [1]. The theory of radio wave propagation provides a simple equation which relates the measured delay with the column density. The measured dispersion for FRB 150418 is found to be produced by a column density S = 776.2(5) electrons parsec/cm^3 [1].

The quantity of interest here, the density of electrons, is simply derived from the ratio of the column density to the distance traveled by the radio burst. The distance traveled by FRB 150418 is the distance to the host galaxy which is known, from its redshift z = 0.492, to be d_C = 1.88 gigaparsecs or 6.14 billion light-years away [1-3]. In the Lambda-CDM model, the current model of the expanding universe, it is important to use the *comoving distance* d_C which is a distance measured with rulers which stretch with the expansion of space.

The electron density (D_e) in the IGM, calculated from the column density and the comoving distance, is:
$D_e = S / d_C = 776.2 \pm 0.5$ cm^{-3} parsec/1.88 ± 0.03 Gparsec = 0.41 ± 0.01 electron/m^3.

Since the IGM is assumed to be neutral, the density of protons is the same as the density of electrons. When the mass of these protons is added to the mass of stars, galaxies and hydrogen gas, the calculated total mass of normal matter is in agreement with the value given by the Lambda-CDM model.

Redshift mechanisms based on energy loss in electrons

A number of theories do not rely on the expansion of space to explain the cosmological redshift. Some of these theories propose that the redshift is caused by a tired-light (T-L) mechanism where photons lose energy through an interaction with electrons and predict the density of electrons that should be found in the IGM. The electron density derived from FRB measurements provides a value to invalidate T-L theories which make predictions that are not in agrement with the measured value. Table 1 lists some of the T-L mechanisms with their prediction of the electron density required to produce the cosmological redshift.

For the comparison between theory and experiment, care must be taken in the interpretation of "distance" in the calculation of the electron density. Because T-L mechanisms do not require the expansion of space, distance calculations have to be done without using the Lambda-CDM model. The comoving distance is not appropriate for this calculation because there is no expansion of space. Instead, the distance d_L, given by the "light travel time" [3] multiplied by the speed of light, gives a better value for the distance traveled by light through the IGM. Using the galaxy's redshift z = 0.492 ± 0.008, this gives a distance d_L = 1.54 ± 0.03Gparsec. The electron density in a non-expanding universe is then:
$D_e = S / d_L = 0.50 \pm 0.01$ electron/m^3.
This is the value which should be predicted by T-L mechanisms.

Table 1. Tired-light redshift mechanisms based on an interaction of light with electrons. The mechanisms are listed in increasing order of predicted density.

Mechanism	Ref.	Predicted density	Comment
Forward Scattering by Relativistic Electrons	[4]	D_e ~ 0.04 to 0.4 electron/m^3	The redshift is proportional to the product of temperature and density $< T_e D_e > = 4 \times 10^{-4}$ K cm^{-3}. The theory predicts that the average density is most likely within the given range.
Electronic Secondary Emission	[5]	$D_e = 0.54$ electron/m^3	
Spectral Transfer Red-Shift	[6]	D_e ~ 0.6 electron/m^3	The mechanism predicts a redshift which depends on light irradiance and the geometry of the light sources. The density is given for isotropic light and cold electrons.
Smid's plasma Red-Shift theory	[7]	D_e ~ 1 electron/m^3	
Shelton Head-on Collisions on Electrons	[8]	D_e ~ 100 electron/m^3	
Compton Effect Interpretation	[9]	D^* ~ 100 particles/m^3	The redshift is caused by an interaction with a free particle, which could be an electron, positron, or a neutrino if they have a small mass.
Deep Space Electrons	[10]	D_e ~ 116 electron/m^3	
Brynjolfsson's Plasma Red-Shift	[11]	$D_e = 205$ electron/m^3	The redshift occurs in a hot plasma T ~ 2×10^6 K.

A comparison of the density in non-expanding space with the numbers in Table 1 shows that if the cosmological redshift is produced by an interaction of light with electrons, four mechanisms make predictions which are incompatible with experiment by a factor of more than 200, therefore reducing the number of possible "candidate theories".

Challenges: Identification of the host galaxy and redshift in the Milky Way and its halo

Soon after Keane et al. [1] published their results, the origin of the FRB was disputed by Williams and Berger [12]. They argue that there is a high probability to find an active galactic nucleus (AGN) at the location of the proposed host galaxy. Since AGNs are known for their luminous variability, the claimed transient in the detection of FRB 150418 may in fact just come from a normal change in the AGN luminosity. Therefore the exact identification of the host galaxy may not be justified which affects two conclusions: the origin of the FRB may still be unknown and the precise distance to the source of the radio burst could remain uncertain. This puts some doubt on the kind of mechanism involved in the production of FRBs. A mistake in the identification of the host galaxy would also result in a different estimation for the density of matter in the universe. A precise identification of the host galaxy might be very difficult since a new FRB identification [14] gives an electron density in the IGM lower by a factor of three. This latter estimate is, however, less reliable since the paper does not rely on the exact value of D_e For the final conclusion.

For T-L mechanisms in electrons, the conclusion remains the same since it is unlikely that the calculated distance is incorrect by a factor 200. Four mechanisms make predictions which are incompatible with experiment. However, there is another problem which arises for T-L redshifts mechanisms in electrons. This problem becomes clear if one considers the location of the electrons contributing to the total column density. Four regions are identified [1]:
- electrons near the host contribute S_{host} = 37 cm^{-3} parsec,
- electrons in the intergalactic medium contribute S_{IGM} = 520 cm^{-3} parsec,
- electrons in the halo of the Milky Way contribute S_{halo} = 30 cm^{-3} parsec, and
- electrons in the disk of the Milky Way contribute S_{MW} = 189 cm^{-3} parsec.

These contributions are shown schematically in Fig. 1. As light escapes the host galaxy, the electrons of the host produce a redshift. Then, light gets further redshifted as it travels through the electrons of the IGM. Finally, in the neighbourhood of the Milky Way, the electrons in the halo and the disk contribute 219 cm^{-3} parsec to the column density. The mathematical relationship between redshift and column density for T-L theories predicts that the electrons of the Milky Way disk and halo alone contribute a redshift $z = 0.12$. This implies that even for the closest galaxies, a minimum redshift $z = 0.12$ should be observed. This is clearly not in agreement with observations: a large number of galaxies have been observed with much smaller redshifts than $z = 0.12$. From this argumentation, it is clear that T-L redshift theories in electrons need some refinements in order to explain observations.

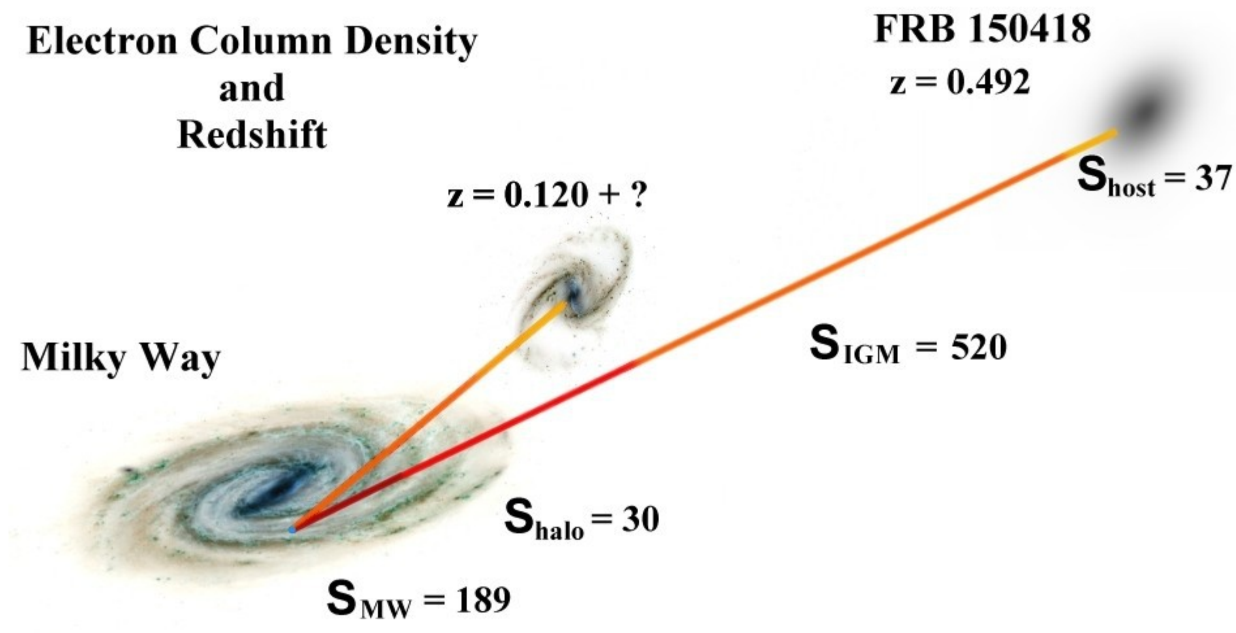

Fig. 1: Contributions to the electron column density when observing FRB 150418 and a nearby galaxy. The units used for the column density are: electrons cm^{-3} parsec.
(This image is constructed from two images taken from Wikimedia Commons: 1) NGC 1365: credit Lars Lindberg Christensen, and 2) an artist's conception of the Milky Way: credit Nick Risinger. The images were modified - e.g. negative and stretched. FRB 150418 is the author's own "artist's representation" based on the images of the host galaxy photographed by the Subaru telescope.)

Many additional precise measurements of redshift and distance of FRB hosts will be necessary to establish a good set of experimental data. Already, multiple detections of FRBs from the same direction as an older FRB have been obtained [13], but no host was identified and the production mechanism remains speculative. However the repeating FRB's all have the same dispersion measure, indicating that the same source can produce several FRBs within a short time interval. It will be interesting to see if future measurements, when associated with a host having a known redshift, will give the same electron density value for the intergalactic medium. A challenge remains for T-L theories to explain why the electrons of the Milky Way do not contribute to the redshift.

References:

[1] E. F. Keane *et al.*, “The host galaxy of a fast radio burst,” Nature, vol. 530, no. 7591, p. 453, Feb. 2016; or: E. F. Keane et al. "A Fast Radio Burst Host Galaxy," arXiv:1602.07477 [astro-ph.HE]

[2] Enrico de Lazaro, "Astronomers Detect Host Galaxy of Fast Radio Burst for the First Time," sci-news.com, http://www.sci-news.com/astronomy/host-galaxy-fast-radio-burst-03657.html, Feb 25, 2016.

[3] E.L. Wright, "A Cosmology Calculator for the World Wide Web", The Publications of the Astronomical Society of the Pacific, Volume 118, Issue 850, p. 1711, Dec. 2006. The web site is http://www.astro.ucla.edu/~wright/CosmoCalc.html.

[4] R.F. Bonn, "Cosmological Effects of Scattering in the Intergalactic Medium," Vaughan Publishing, 2008, p. 502.

[5] L. Ashmore, "Tired Light: an explanation of redshifts in a static universe", CreateSpace Independent Publishing Platform, ISBN-13: 978-1539070375, September 28, 2016.

[6] L. Marmet, “Optical Forces as a Redshift Mechanism: the ‘Spectral Transfer Redshift’,” in CCC-2, 2009, vol. 413, p. 268.

[7] T. Smid, "Research Proposal 'Cosmological Redshifts'," http://www.plasmaphysics.org.uk/research/#A11

[8] H.S. Shelton, "The red shift in the spectra of distant nebulae," The Observatory, 73:84, April 1953.

[9] J. Kierein, "Why the Big Bang is Wrong," http://www.angelfire.com/az/BIGBANGisWRONG/index.html

[10] D.L. Mamas, "An explanation for the cosmological redshift." Physics Essays, 23:326-329, 2010.

[11] A. Brynjolfsson, "Redshift of photons penetrating a hot plasma," arXiv:astro-ph/0401420, January 2004.

[12] P. K. G. Williams, E. Berger, "Cosmological Origin for FRB 150418? Not So Fast," arXiv:1602.08434 [astro-ph.CO]

[13] L. Papadopoulos *et al.*, "New Twists Add More Mystery to the Fast Radio Burst Enigma," AmericaSpace, http://www.americaspace.com/?p=92046. Also: L. G. Spitler et al., "A repeating fast radio burst," Nature 531, p. 202, 10 March 2016; or: L.G. Spitler et al., "A Repeating Fast Radio Burst," arXiv:1603.00581 [astro-ph.HE]

[14] Ravi et al., "The magnetic field and turbulence of the cosmic web measured using a brilliant fast radio burst," arXiv:1611.05758 [astro-ph], Nov. 2016

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