“A review of redshift and its interpretation in cosmology and astrophysics”

R. Gray and J. Dunning-Davies,
Department of Physics,
University of Hull,
Hull HU6 7RX,
England.

email: j.dunning-davies@hull.ac.uk

Abstract

The interpretation of redshift in cosmology and astronomy yields a great deal of information about the universe in which we live, but much controversy surrounds the correct interpretation of the phenomenon. This article discusses the history of the redshift, and how its interpretation varies between different cosmological theories, including the Big Bang theory and some of its most famous rivals, the Steady State theory and Tired Light theory, and aims to highlight a few of the problems still existing. Some notions not normally associated with astronomy and astrophysics are mentioned also in the hope that a somewhat broader view of this important topic may be investigated.

Introduction

Redshift is a very important, and somewhat controversial, phenomenon with respect to cosmology and astronomy. The phenomenon occurs when the electromagnetic radiation that is emitted or reflected from an object is shifted toward the less energetic (higher wavelength) end of the spectrum. Using this phenomenon allows a start to be made on attempting to understand features of our galaxy and even of the universe as a whole.

However, there is a large number of interpretations of the observed redshift and this brings into question the true nature of the observations and their meaning. One particular case where this is especially relevant is in the theories surrounding the origins of our universe. Nowadays, the Big Bang model for the origin of the universe often appears to be accepted as established fact[1], its popularity in the scientific community apparently overshadowing all other theories. But, is this model necessarily correct? What evidence truly supports this theory over others? Is it, in fact, fair for this theory to receive so much acclaim, when rival theories seem to be dismissed without being afforded the same privileges of additions and corrections to their problems?

These questions are amongst those to which this article aims to draw attention; there may not be a definite known answer, but a broader view of the problems surrounding these topics may allow an open-minded reader the opportunity their own decision as to whether or not to believe “conventional wisdom”. It is intended to discuss the history of redshift and its astronomical and cosmological interpretations, including the origins of the redshift-distance relationship theory and Hubble’s Law, making mention of the Doppler effect and how the two are related. This should cover the “relativistic Doppler Effect”, Einstein’s general relativity equations, their solution by Schwarzschild, Friedmann’s equations and gravitational redshift. Discussion will follow of some of the views of our universe and, more specifically, of the theories for the origins of the universe and how the interpretation of the cosmological redshift is important to these theories. In particular, due to its popularity in the scientific community, the Big Bang theory will be considered in some detail, drawing comparisons between this theory and its rivals, such as the Steady State theory. A brief discussion of one or two alternative theories for the cause of the cosmological redshift will also be included. These may be linked with the theories of the origins of the universe, but will be discussed in more detail afterwards, and include the Compton effect, “intrinsic redshifts” and tired light theory.

History and Origins of “Redshift”

Theories regarding cosmological redshifts began with the development of wave mechanics in the 19th Century, and the exploration of phenomena associated with the Doppler effect. This effect is named after Christian Andreas Doppler, who offered the first known physical explanation for the phenomenon in 1842.[2] The Doppler effect is one encountered on a day-to-day basis, though the average person may not understand fully what it is, or that they are even experiencing it. It is commonly attributed to sound waves, as these are involved in the most commonly encountered occurrences of the effect.

Doppler predicted that this effect should apply to all waves. This prediction turns out to be correct. The first Doppler redshift was described in 1848 by French physicist Armand-Hippolyte-Louis Fizeau, who pointed to the shift in spectral lines seen in stars as being due to the Doppler Effect. In 1868, British astronomer William Huggins was the first to determine the velocity of a star moving away from the earth by this method[3]. In 1871, optical redshift was confirmed when the phenomenon was observed in Fraunhofer lines using solar rotation, about 0.1 Å in the red[4]. Optical redshift was also verified in 1901 by Aristarkh Belopolsky in the laboratory using a system of rotating mirrors[5].

The earliest occurrence of the term “red-shift” in print (in this hyphenated form), appears to be by American astronomer Walter S. Adams in 1908, where he mentions "Two methods of investigating that nature of the nebular red-shift"[6]. The word doesn't appear unhyphenated, perhaps indicating a more common usage of its German equivalent, *Rotverschiebung*, until about 1934 by Willem de Sitter[7].

Beginning with observations in 1912, Vesto Slipher discovered that most spiral nebulae had considerable redshifts[8]. Then, in 1915, Albert Einstein developed his equations of General Relativity. These equations

$$G^{\mu\upsilon} = -(8\pi G/c^2)T^{\mu\upsilon}$$

connect matter and energy with the geometry of spacetime. Each superscript stands for one of the 4 coordinates of spacetime; so what looks like one equation is actually 16 equations (since some are repeated, there are really 10 equations)[9]. In essence, these formulae describe the laws of conservation, e.g. conservation of energy and momentum. These equations were solved by Karl Schwarzschild in 1916. The metric found by Schwarzschild is commonly given in the vast majority of textbooks as

$$ds^2 = c^2\left(1 - \frac{2MG}{c^2 r}\right)dt^2 - \left[\frac{dr^2}{\left(1 - \frac{2MG}{c^2 r}\right)}\right] - r^2(d\theta^2 + sin^2\theta d\varphi^2) \qquad [1]$$

It describes the spacetime geometry surrounding a spherically symmetric object of mass M, situated at the spatial coordinate r = 0. This metric gives an excellent description of the spacetime geometry around objects like the sun and the earth, that are, to a good approximation, spherical and forms the basis for an examination of the three classic tests of Einstein's theory of general relativity: 1) the perihelion advance of Mercury, 2) the bending of starlight by the sun and 3) the “gravitational redshift”.

Later, Edwin Hubble discovered an approximate relationship between the redshift of nebulae, such as those observed by Slipher, and the distance to them, with the formulation of his Hubble’s Law[10]. This law is simply a statement that the redshift in light coming from a distant astronomical entity (for example, a galaxy) is proportional to its distance. These observations corroborated Alexander Friedmann’s work from 1922, in which he derived the famous Friedmann equations[11], a set of equations that governs the expansion of space in homogeneous and isotropic models of the universe within the context of general relativity. This is considered to be the first observational basis for the expanding space paradigm and today serves as one of the most often cited pieces of evidence in support of the Big Bang theory. However, it may be interesting to note that Hubble, even up to his final lecture before the Royal Society, always held open the possibility that the redshift did not mean velocity of recession but might be caused by something else[1].

Doppler Shift: A Little More Detail

As explained above, the Doppler shift is a phenomenon in which the frequency and wavelength of a wave change for an observer moving relative to the source of the waves. If a source of light is moving away from an observer, then a redshift can be observed; conversely, if a source of light is moving toward an observer, a “blueshift” is observed. If the source moves away from the observer with velocity v, then, ignoring relativistic effects, the redshift is given by

$$z \cong v/c$$

where c is the speed of light in a vacuum. In the classical Doppler effect, the frequency of the source is not modified, but the recessional motion causes the illusion of a lower frequency.

However, for a more complete view of the effect, one must consider relativistic effects associated with motion of sources close to the speed of light. This “relativistic Doppler effect” is different from the non-relativistic Doppler effect as the equation includes the time dilation effect of special relativity and does not involve the medium of propagation as a reference point. They describe the total difference in observed frequencies and possess the required Lorentz symmetry. The revised expression for the redshift is

$$1 + z = \left(1 + \frac{v}{c}\right)\gamma$$

This phenomenon was first observed in a 1938 experiment performed by Herbert E. Ives and G.R. Stilwell, called the Ives-Stilwell experiment[12].

Since the Lorentz factor is dependent only on the magnitude of the velocity, this causes the redshift associated with the relativistic correction to be independent of the orientation of the source movement. However, in contrast to this, the classical part of the formula is dependent on the projection of the movement of the source into the line of sight which yields different results for different orientations. Consequently, for an object moving at an angle θ to the observer (zero angle is directly away from the observer), the full form for the relativistic Doppler effect becomes

$$1 + z = \frac{1 + v\cos(\theta)/c}{\sqrt{1 - v^2/c^2}}$$

and for motion solely in the line of sight ($\theta = 0°$), this equation reduces to

$$1 + z = \sqrt{\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}}$$

For the special case when the source is moving at right angles (θ = 90°) to the detector, the relativistic redshift is known as the “transverse redshift”, and a redshift

$$1 + z = \frac{1}{\sqrt{1 - v^2/c^2}}$$

is measured, even though the object is not moving away from the observer. In the cases where there is a transverse component to the motion, even if the source is moving toward the observer, then there is some speed at which the dilation just cancels the expected blue shift, and at even greater speeds, the approaching source will be redshifted[13].

Expansion of the Universe

Initial interpretations of the redshifts and blueshifts of interstellar objects beyond the Milky Way were based exclusively on the idea of the shift being due to the Doppler effect. However, after Hubble discovered a rough correlation between the increasing redshift and the increasing distances of galaxies, theorists almost immediately realised that these observations could be explained by a different mechanism for producing redshifts. Hubble's law of the correlation between redshifts and distances is required by models of cosmology derived from general relativity that have a metric expansion of space[14]. This idea is different from that of the Doppler effect theory of redshift in that the photons increase in wavelength and redshift as the space through which they are travelling expands, as opposed to the velocity boost between the source and the observer being due to classical momentum and energy transfer[15]. This effect is described by the current cosmological model as an observable manifestation of the time-dependent cosmic scale factor (*a*) in the following way

$$1 + z = \frac{a_{\mathrm{now}}}{a_{\mathrm{then}}}.$$

This type of redshift is known as the cosmological redshift, or sometimes the “Hubble Redshift”. These galaxies are not receding simply by means of a physical velocity in the direction away from the observer; instead, the intervening space is expanding, which accounts for the large-scale isotropy of the effect demanded by the cosmological principle[16]. For cosmological redshifts of $z < 0.1$ the effects of spacetime expansion are minimal and observed redshifts are dominated by the peculiar motions of the galaxies relative to one another that cause additional Doppler redshifts and blue shifts.

Despite the distinction between redshifts caused by the velocity of objects and the redshifts associated with the expanding universe, astronomers sometimes refer to “recession velocity” in the context of the redshifting of distant galaxies from the expansion of the Universe, even though it is only an apparent recession[17]. As a consequence, popular literature has a tendency to use the expression "Doppler redshift" instead of "cosmological redshift" to describe the motion of galaxies dominated by the expansion of spacetime, despite the fact that a "cosmological recessional speed" when calculated will not equal the velocity in the relativistic Doppler equation[18]. In particular, Doppler redshift is bound by the laws of Einstein's special relativity, which dictates that an object cannot travel faster than the speed of light through a vacuum; thus $v > c$ is impossible. On the other hand, in the case of cosmological redshift, $v > c$ is possible because the space which separates the objects (e.g. a quasar from the Earth) can expand faster than the speed of light; this is because space, not being composed of any material, can grow faster than the speed of light since, not being an object, it is not bound by the speed of light upper bound. More mathematically, the viewpoint that "distant galaxies are receding" and the viewpoint that "the space between galaxies is expanding" are related by changing coordinate systems. Expressing this precisely requires working with the mathematics of the Friedmann-Robertson-Walker metric[19].

Gravitational Redshift

In the theory of general relativity, there is time dilation within a gravitational well. This is known as the gravitational redshift or "Einstein Shift"[20]. The gravitational redshift of spectral lines is often held to be one of the "crucial tests" of general relativity. However, the result may also be derived with no recourse to the general theory of relativity whatsoever, nor even to the principle of equivalence[21], as has been shown on several occasions.

Redshift in Cosmology

Redshift, and its many interpretations and variations, is a very important phenomenon to consider with respect to cosmology. Its implications are far reaching, from the very beginnings of our universe, to how it is behaving now, and even to the future of our universe, or possibly its end! There is a wide array of different cosmological views and theories, many of which focus on different interpretations of the redshift phenomenon, covering a very diverse spectrum of ideas. A few of these will be covered shortly.

The redshift's interpretation is crucial for many, if not all of the cosmological theories, as much of the important evidence for these theories is derived and explained starting with the interpretation of redshift. How redshift has been historically discovered and interpreted has been considered, but other views, which will be mentioned later, have also been put forward, and evidence for and against each interpretation has been presented. If the nature of our universe is to understood correctly, a more generally acceptable interpretation for the cosmological redshift must be found.

Before discussing any specific cosmological theories, the fundamental assumptions and general features that these cosmological theories make about the universe must be considered. Several theories may be based upon similar assumptions, but in most cases, the differences between the theories may be as little as a single difference in opinion about a certain feature of the universe, or as much as a complete disagreement about all the fundamental assumptions made by another theory.

Historically, cosmology has been in existence as a discipline for thousands of years, though the original cosmological theories were not known as such. Some cosmological theories date back to around 500BC, for example the "Atomist Universe" theory proposed by Greek philosophers Democritus and Leucippus[22]. These early theories, though flawed by the "limited" understanding of physics in that age compared with today, paved the way for the theories used today. Einstein's general theory of relativity was used as a mathematical starting point for most of the current cosmological theories, including the popular Big Bang theory and arguably its biggest competitor, the Steady State theory. In order to arrive at a cosmological model, however, theoreticians needed to make assumptions about the nature of the largest scales of the universe.

Some of the popular assumptions and features that cosmological theories tend to rely upon are as follows:

The Universality of Physical Laws – this assumption states that the laws of physics don't change from one place and time to another

The Cosmological Principle – as mentioned earlier in this report, this principle states that the universe is roughly homogenous and isotropic in space, but not necessarily in time

The Perfect Cosmological Principle – similar to the standard cosmological principle, although this states that the universe is not only homogenous and isotropic in space, but also in time

The Copernican Principle – this assumes that we are not observing the universe from a preferred locale.

Some of the current cosmological theories will be considered next, together with the relevance of redshift and the above assumptions, together with possible problems faced by the various theories.

Big Bang Theory

Galileo Galilei once said: "in questions of science, the authority of a thousand is not worth the humble reasoning of a single individual"[23]. It seems taken for granted that the Big Bang theory best explains cosmological observations and the origins of the universe. The average layman often readily accepts the theory because it's the only one he knows; children are taught about the Big Bang theory at a young age, with little or no mention of the existence of alternatives. People also have a tendency to follow popular trends; therefore, it is easy for the non-physicist to fall into the trap of blindly accepting the Big Bang theory without question. After all, if so many highly intelligent, well-known scientists believe in the theory, then surely it must be correct?

The aforementioned quote from Galileo gives an important message; simply because it's a popular theory that most physicists believe, that doesn't make it the correct theory. It still has its faults, and is not necessarily any more truthful than any of the other theories available today. But, it does seem to receive an unfair amount of acclaim for just a theory, being afforded such luxuries as being able to simply alter the theory conveniently whenever a question is raised against it, or invoking hypothetical "dark energy" ideas to explain away discrepancies with the theory; such luxuries are not so readily afforded to alternatives. However, before becoming too wrapped up in what's wrong with the Big Bang theory, consider what the theory actually entails, how it came to be, the evidence that is considered to support it, and finally, the issues that bring its validity into question.

The Big Bang theory operates on the primary assertion that the universe started as a singularity of infinite density and temperature at some finite time in the past (observational evidence suggests this to be approximately 13.7 billion years ago)[24]. It relies upon the assumptions that the universe adheres to the cosmological principle, the Copernican principle, and the universality of physical laws (as mentioned above). By analysing the spectrum of light from distant astronomical entities, and applying Hubble's law to the observed shift towards the longer wavelengths proportional to the object's distance, it becomes apparent that the universe itself is expanding. This is considered to be among the "proofs" of the validity of the Big Bang theory.

According to the most common models of Big Bang theory, the universe was originally filled homogeneously and isotropically with an incredibly high energy density, huge temperatures and pressures, and was very rapidly expanding and cooling. Approximately 10^{-35} seconds into the expansion, a phase transition caused a "cosmic inflation", during which the universe grew exponentially[25]. After this inflation stopped, the universe consisted of a quark-gluon plasma (a phase of quantum chromodynamics (QCD) which exists at extremely high temperature and/or density; this phase consists of (almost) free quarks and gluons which are the basic building blocks of matter), as well as all other elementary particles[26] (an elementary particle is one which does not appear to have substructure; quarks, leptons and gauge bosons fit into this category). Temperatures were so high that the random motions of particles were at relativistic speeds (i.e. speeds approximating to the speed of light, requiring special relativity for a scientific analysis for such particles), and particle-antiparticle pairs of all kinds were being continuously created and destroyed in collisions. At some point an unknown reaction (termed "baryogenesis") violated the conservation of baryon number, leading to a very small excess of quarks and leptons over anti-quarks and anti-leptons—of the order of 1 part in 30 million. This resulted in the predominance of matter over antimatter in the present universe[27].

The universe continued to grow in size and fall in temperature, hence the typical energy of each particle was decreasing. Symmetry-breaking phase transitions put the fundamental forces of physics and the parameters of elementary particles into their present form[31]. After about 10^{-11} seconds, the picture appears to become less speculative, since the energies of the particles drop to values that can be attained in particle physics experiments. At about 10^{-6} seconds, quarks and gluons combined to form baryons such as protons and neutrons. The small excess of quarks over anti-quarks led to a small excess of baryons over anti-baryons. The temperature was now no longer high enough to create new proton-antiproton pairs (similarly for neutrons-antineutrons), so a mass annihilation immediately followed, leaving just one in 10^{10} of the original protons and neutrons, and none of their antiparticles. A similar process happened at about 1 second for electrons and positrons. After these annihilations, the remaining protons, neutrons and electrons were no longer moving relativistically and the energy density of the universe was mainly dominated by photons.

This is the most commonly accepted interpretation of the origin of the universe. The three most direct kinds of observational evidence that are claimed to support the Big Bang theory are the Hubble-type expansion seen in the redshifts of galaxies, the abundance of light elements due to the "Big Bang nucleosynthesis"[31] (where, after a few minutes into the expansion, when the temperature was about a billion Kelvin and the density was about that of air, neutrons combined with protons to form the universe's deuterium and helium nuclei), and the often cited "cosmic microwave background radiation". This was rediscovered in 1965[28], filling out the entire universe, with a thermal black body spectrum at a temperature of 2.725 K. This radiation, according to Big Bang theorists, is supposed to date back to approximately 379,000 years after the Big Bang, when the electrons and first-formed nuclei combined together to form atoms; according to the Big Bang theory the radiation decoupled from matter and continued through space largely unimpeded. At this point, it is important to mention that the Big Bang theory is not the only theory that is capable of providing an explanation for the cosmic background radiation; in fact, all three pieces of evidence can be applied to the Steady State theory also.

There are, of course, some problems with the theory. During the 1970s and 1980s, various observations showed that there is not sufficient visible matter in the universe to account for the apparent strength of gravitational forces within and between galaxies. In order to make up for these observations, Big Bang theorists whimsically invented "dark matter", which supposedly makes up around 90% of the matter in the universe, but does not emit light or interact with normal baryonic matter. The supposed evidence for the existence of dark matter is that the universe is far more "lumpy" and contains far less deuterium than can be accounted for without it, and that it has a gravitational influence on other matter. However, to the sceptic, this sounds very much like a convenient way to force the physics to fit with the figures, as opposed to being actual evidence for its existence. No dark matter particles have ever been observed.

Also, measurements of the redshifts of type Ia supernovae indicate that, if the assumptions that the Big Bang theory relies upon are true, then the universal expansion is in fact accelerating. To explain this acceleration, general relativity requires that much of the energy in the universe consists of a component with large negative pressure. This has been named "dark energy", another whimsical invention of Big Bang theorists in an attempt to explain away something that clearly contradicts their theory. Dark energy is allegedly indicated by several "other" lines of evidence. Measurements of the cosmic microwave background indicate that the universe is very nearly spatially flat, and therefore, according to general relativity, the universe must have almost exactly the critical density of mass/energy. But the mass density of the universe can be measured from its gravitational clustering, and is found to have only about 30% of the critical density[29]. Since dark energy does not cluster in the usual way it is the best explanation for the "missing" energy density. Dark energy is also said to be required by two geometrical measures of the overall curvature of the universe, one using the frequency of gravitational lenses, and the other using the characteristic pattern of the large-scale structure as a cosmic ruler.

Both of these problems appear to have been solved by the convenient creation of new, undetectable forms of matter and energy. When so many alternative theories are available, ones which aren't afforded so much as an opportunity to adapt the theories to correct for new discoveries in astronomy and physics, it seems utterly ridiculous that Big Bang theorists are allowed to get away with simply explaining away their problems in such a way.

It is also interesting to note that the dark energy is said to be given by the cosmological constant, an idea originally created by Einstein in order to achieve a theory for a stationary universe (one that is not expanding or contracting but is dynamically stable), but eventually abandoned, in light of Hubble's observations, as his "greatest blunder". Now it is being invoked again to explain away problems for the Big Bang theory. It is amusing that an idea is abandoned for not supporting the theory of an expanding universe, yet is now being called upon in an attempt to support the theory as it flounders.

There is a very large number of problems with the Big Bang theory; too many, in fact, to realistically mention.[30] Even several of the premises that are often held to "prove" the Big Bang theory are held by some to be evidence against it, including the background radiation, which (according to new evidence) has "cool spots", which are said to possibly bring the Big Bang's interpretation of the CMBR into question since the size of the average cool spot is around the size of that which had been forecast for a flat, smooth universe, and that "not only is the average about right, but far too many of the spots themselves are 'just right' with too little variation in sizes. Given the uneven distribution of matter in an expanding universe, (Dr. Richard Lieu) says, we should see a broader size distribution among the cool spots by the time that radiation reaches Earth"[31].

Steady State Theory

The "Steady State" theory for the origins of the universe is a rival of the Big Bang theory. It was proposed in 1948 by Fred Hoyle, Thomas Gold and Hermann Bondi, working on the assumption that the universe adheres to the perfect cosmological principle (as opposed to the Big Bang theory's reliance on the cosmological principle). It has similarities to the Big Bang theory in that it also predicts a universe that is expanding, as it still follows the interpretations of Hubble's law and Doppler redshift, but the Steady State theory explains that, although the universe expands, its overall density does not change[32]. One of the big problems many people had with this theory is that an expanding universe cannot maintain the same density at all times, as everything would be "thinned out". The theory therefore supposed that there was a constant generation of matter (mostly hydrogen) that allowed the average density of matter to remain equal over time.

The Steady-State theory started to encounter more serious problems, as far as most cosmologists are concerned, when observations apparently supported the idea that the universe was, in fact, changing: quasars and radio galaxies, having extremely high redshifts, can be seen to be only at very large distances, and not in closer galaxies (please note, this is only if we interpret the redshift as being solely due to the redshift-distance relationship; more on this later). The Steady-State theory predicted that such objects should be found everywhere in the universe, not just at the far reaches, where Big Bang theory is supposed to have predicted the very thing that was observed. The discovery of the cosmic microwave background radiation was, as Steven Hawking put it, “the final nail in the coffin of the Steady-State theory”. The Steady-State theory explains that the background radiation is the result of light from ancient stars which has been scattered by galactic dust. However, most cosmologists seem to have been unconvinced by this idea, as the cosmic microwave background is very smooth, making it difficult to explain how it arose from point sources, and the microwave background shows no evidence of features such as polarization which are normally associated with scattering. Furthermore, its spectrum is so close to that of an ideal black body that it could hardly be formed by the superposition of contributions from dust clumps at different temperatures as well as at different redshifts[36].

A quasi-Steady State model for the origins of the universe was proposed by Fred Hoyle, Geoffrey Burbidge, and Jayant V. Narlikar in 1993, as a new incarnation of the Steady-State theory designed to take into account the new discoveries that the old model failed to predict. However, “mainstream” cosmologists who have reviewed the QSS model have disregarded it due to “flaws and discrepancies” with observations left unexplained by the proponents[33].

Tired Light Theories and the Compton Effect

The tired light theories are very different from the aforementioned theories, in that they don’t operate on the premise of the redshift being due to the Doppler Effect, nor to the expansion of the universe. The concept was first proposed in 1929 by Fritz Zwicky, who suggested that photons lose energy over time via interaction with matter or other photons, or by some novel physical mechanism[34]. One of the successes of this theory was that it predicted the cosmic background radiation temperature to be around 2.8°K, during a time when the Big Bang theory was predicting temperatures anywhere between 5°K and 50°K[35]. A tired light model was also proposed in the 1950’s by Finlay-Freundlich to explain the redshift of solar lines and anomalous redshifts of stars as well as the cosmological redshift.

One of the remaining problems with the tired light theories is the identification of the physical process through which the energy loss of the photons is brought about. Scientists are still searching for this mechanism, and in 1988 Pecker and Vigier came up with a possibility[36], drawing attention to the possibility of photons interacting with vacuum particles, which would result in the loss of energy.

Another apparently major problem encountered when considering questions about light is the erroneous belief that Einstein’s special theory of relativity precludes any variation in the speed of light. However, it is important to bear in mind that Einstein's assumption referred to the speed of light in a vacuum, and that it is well known experimentally that the speed of light actually varies according to the medium through which it travels[35]. In a 1985 article, Thornhill[37] showed that the speed of light varies with the square root of the background temperature, which implies that it varies in time and would, in fact, slow down with the passage of time.

Another idea used to explain the cosmological redshift is the idea that the redshift is due to the Compton Effect, and has nothing to do with the Doppler Effect or universal expansion at all. The Compton Effect was observed by Arthur Holly Compton in 1923, and explains that photons lose energy when they interact with matter, thus causing an increase in the wavelength of the photon. Compton scattering usually refers to the interaction involving only the electrons of an atom, although nuclear Compton scattering does exist.

Grote Reber[38] proposed that this effect was responsible for the cosmological redshift, in order to explain the observations of bright, very long wavelength, extragalactic radio waves. John Kierein[39] applied the Compton Effect explanation to explain quasars and the redshift of the sun, which cannot be explained using Doppler shift, or expansion of the universe. These ideas also suggest that quasars might be much closer than their redshift would indicate if they have an "intrinsic redshift" due to being surrounded by a "fuzzy" atmosphere containing free electrons and other material. This concentration of electrons produces the unusual red shift as the light travels through it and loses energy to these electrons by the Compton Effect. If quasars are nearby, they may even exhibit proper motion in the sky as the Earth travels around the sun. Such a proper motion has apparently been seen[40]. There is other evidence in support of the notion that the redshift may be due to the Compton Effect, which, along with more arguments against the validity of the Big Bang theory, is illustrated by Kierein[41].

Intrinsic Redshifts

The idea of intrinsic redshift is the hypothesis that a significant portion of the observed redshift of extragalactic objects, such as quasars and distant galaxies, may be caused by a phenomenon other than the traditionally accepted ideas of Doppler shift and gravitational redshift. The most reputable proponent of this hypothesis is Halton Arp, who noted that many of the astronomical radio sources close to radio galaxies are quasars – high redshift objects of which some are radio-loud. Arp proposed the hypothesis that the quasars might be associated with the radio galaxies which themselves somehow ejected the quasars from the galactic nucleus. Quasars which followed this model are described as "local" and by extension their redshifts would not follow Hubble's law[1].

Possible evidence for this includes the case of two conspicuous X-ray sources paired across the nucleus of the galaxy NGC4258. Both of these sources were confirmed to be quasars, and there is strong evidence to imply that they are related to the galaxy (such as photographs showing tails of excited gas emerging from the nuclear regions of the galaxy in the directions of the quasars). It has also been calculated that the probability of this pairing of quasars across NGC4258 being accidental is only 5 in a million[1].

Other similar cases have been noted, many of which are mentioned in Arp's book[1], and if such evidence is correct, this shows that the redshift of the quasars, which is significantly higher than that of the galaxy itself, cannot be due solely to recession velocities; there must be an intrinsic part to the redshift. The nature of this intrinsic redshift is unknown, although as previously mentioned, a suggestion for the intrinsic redshift in the form of a Compton shift has been suggested.

However, Arp's hypothesis that quasars are local and contain large intrinsic redshifts has never gained any significant support in the astronomical research community. This is because Arp's work is, according to most astronomers, "based on a limited number of quasar-galaxy associations"[1], and that these associations are merely the result of chance. This opinion is unfortunate as, with the vast majority of astronomical and cosmological research being devoted to Big Bang theory and its ideals, very little can be done observationally in the way of further proving or assisting Arp's, and others', hypotheses regarding intrinsic redshifts, making it all the more difficult for their ideas to be heard.

More modern ideas concerning redshift.

Although there is little, or no, mention of it in main-line astronomical literature, a mechanism for optical redshifts being due, at least in part, to correlations among radiating sources and classical interference was first proposed in 1986 by Emil Wolf[42]. This basic concept has been developed extensively and also verified experimentally. It has been pointed out recently[43], that there is a possibility that this mechanism could account, at least in part, for the redshift observed in quasars. This point is important due to Arp's observations as noted earlier and is one which needs to be cleared up openly. Gallo[44] has drawn attention to the fact that a Doppler and/or space-expansion effect will yield similar photon and neutrino redshifts, whereas a non-Doppler mechanism arising from an energy-loss interaction with intervening matter will result in totally different redshifts for the two cases. On the basis of this observation, an experiment is suggested which, if performed, might settle this question once and for all.

Current literature indicates further that astronomers and astrophysicists might learn much of use from those interested in plasma science. Looking back to the work, both theoretical and experimental, of such as Birkland and Alfvén raises many interesting questions which are deserving of carefully considered answers. Considering the strength of the electromagnetic force in comparison with that of gravity surely indicates a need for the two basic schools of thought concerned with problems of astronomy and astrophysics to come together for open-minded consideration of the problems facing those disciplines today. In the end, all we have are theories; theories which, in many cases such as the life history of a star, can never be completely proved or disproved to the satisfaction of all. Therefore, open-minded collaboration and discussion are essential if satisfactory progress is ever to be made. A complete re-examination of the redshift problem could prove a important beginning.

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