NONCOSMOLOGICAL REDSHIFTS

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ABSTRACT. Although the majority of astronomers interpret the redshifts of quasars according to Hubble's law, there are isolated cases as well as detailed studies indicating that the redshifts of quasars and even some galaxies may have noncosmological components. The evidence discussed here will be on two counts: (i) the periodicities in redshift distributions, (ii) the associations between discrepant redshifts objects. In addition, theoretical constraints on physical models based on the cosmological hypothesis will be briefly mentioned.

1. INTRODUCTION

The fact that a conference on quasars cannot find more than two percent of total available time for a discussion of the question as to how far these objects are located, indicates that most astronomers have already made up their minds about the answer. To many, questioning the cosmological hypothesis now is like questioning the validity of special relativity [1]. To a small minority, however, the issue still remains open; especially because fresh evidence keeps coming in, throwing doubt on the universal validity of the cosmological hypothesis. For some of the earlier reviews of the quasar distance controversy see Refs [2 - 5].

In the interest of brevity, the present review will concentrate mainly on the more recent evidence. This is not to say that all of the earlier evidence has gone away. Rather, there has always been a reluctance on the part of the astronomical community to face it on the curious grounds that 'the idea must be wrong because we have no respectable theory to explain it.' To avoid getting into such arguments the ground rules to be followed here are stated below.

1. The cosmological hypothesis (C.H. in brief) assumes that the redshift z of an extragalactic object is due entirely to the expansion of the universe. In other words, given a cosmological model there exists a unique Hubble relation

$$z = f(DH_0/c) \tag{1}$$

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between the redshift and the (luminosity) distance D of the object. In this relation c and H_o are respectively the speed of light and the present value of Hubble's constant. For example, the form of f in the standard dust-dominated Friedmann models is well known [4].

2. The C.H. may be granted a certain leeway through the formula

$$(1 + z) = (1 + z_C)(1 + z_{NC}), \tag{2}$$

where z is the total observed redshift, z_C the cosmological component obeying relation (1) and z_{NC} the 'noncosmological' part $\lesssim 3 \times 10^{-3}$. This limit on z_{NC} allows for random motions relative to the cosmological substratum, of upto $\sim 10^3$ km s^{-1}.

3. Evidence in support of the C.H. should ideally demonstrate the validity of relation (1) in which independent measures of D are used: that is measures not based on (1). Indirect evidence claiming that quasars are distant but not providing a measure for D can at best be considered consistent with (1) but not a proof of it.

4. If the C.H. is claimed to have universal validity, such as its applicability to galaxies and quasars then it is sufficient to produce one counter-example where (1) does not hold, in order to disprove it.

5. A counter-example should demonstrate that the z_{NC} in (2) is substantially greater than what could be attributed to random velocity Doppler shifts in clusters of galaxies. It is not necessary to show that the entire redshift is of noncosmological origin.

6. Finally, to accept the existence of a noncosmological redshift it is not essential that there should already be a theory available to explain it. Rather the reverse: if no existing theory can explain an established phenomenon the onus is on the theoretician to find a new theory.

Within the above framework I will present recent evidence indicating that the cosmological hypothesis may not apply to all extragalactic objects.

2. PERIODICITIES AND PEAKS IN REDSHIFT DISTRIBUTIONS

2.1 Groups of Galaxies

In 1976 Tifft [6] reported a peculiar result that there is a correlation between the nuclear magnitudes of galaxies in clusters and their differential redshifts Δz, and that the values of $c\Delta z$ appear to be bunched near multiples of 72 km s^{-1}. If CH holds for galaxies, then the bunching of Δz translates to bunching of ΔD and hence suggests some discrete quantized structure in the space distribution of galaxies.

It is hard to understand such a result within the conventional cosmology and it was hoped that the result would 'go away' as more accurate data accumulated. The opposite happened. By 1982 high quality 21cm redshift measurements became available for galaxies in small groups with cz values known to an accuracy of at least 9 km s^{-1}.

In 1983 Cocke and Tifft [7] analyzed the new data and found that the effect still holds quite unambiguously.

More recently Arp and Sulentic [8] have reported results of redshift measurements from over 260 galaxies. Of these over 100 galaxies in 40 different groups have redshifts measured at 21 cm with accuracy of $\lesssim 4$ km s^{-1} while over 160 others are taken from the Rood Catalogue [9] where the accuracy in cz is $\lesssim$ 8 km s^{-1}. The entire sample typically shows systems wherein a large central galaxy is surrounded by smaller fainter companions. Also, the companion galaxies tend to have systematically higher redshifts than the brightest galaxy in the group. The redshift differentials $\Delta z = \{z$ (companion) $- z$ (dominant)$\}$ for these galaxies show peaks for $c\Delta z$ at 70,140 and 210 km s^{-1}. The Tifft effect therefore persists.

Although Byrd and Valtonen [10] have attempted to explain the observed values of Δz in the above work in terms of expansion of companions away from the main galaxy, the morphology of the groups, the preponderance of positive z-values and the observed peaking effect remain unexplained.

2.2 Quasars

Geoffrey Burbidge has highlighted the peaks in the redshift distribution of quasars [3]. In fact the peaks have also shown persistance in spite of the conventional expectation that with bigger and bigger samples of quasars, newer methods of their detection the supposed effect will disappear. In this conference Hewitt and Burbidge [11] have presented histograms showing the numbers of quasars in different redshift ranges, for the largest known compilation of data on quasars - the revised Hewitt-Burbidge catalogue containing about 3000 sources.

For these quasars sharp peaks are present at $z \simeq 0.3$, 1.4, 1.95 as in earlier smaller samples. To counter the criticism that a selection effect is responsible for it, Hewitt and Burbidge have also given separate histograms for quasars discovered by the objective prism method as well as for quasars discovered by other methods. The peaks persist in spite of such a separation.

Power spectrum analysis of the data by Depaquit et al [12] shows clear indication of periodicity in the values $\ln(1+z)$.

I leave you with these findings to figure out how they could be explained in conventional terms.

3. ASSOCIATIONS BETWEEN DISCREPANT REDSHIFT OBJECTS

The main approach here is to demonstrate that two extragalactic objects with very different redshifts are physical neighbours. Note that if two objects are shown to be real neighbours it is not necessary to know their actual distance D from us. That two different values of z are found at the same D is sufficient to invalidate the Hubble relation (1).

3.1 Galaxy-Galaxy Associations

Although it is commonly assumed that only quasars (if at all) may be accused of noncosmological redshifts, even galaxies are not immune! Indeed, I have already discussed the findings of Arp and Sulentic [8] that companion galaxies have larger redshifts than the dominant galaxies. Even if one discounts periodicities in $c\Delta z$, the observation that $c\Delta z > 0$ remains unexplained. Although I have described the 1985 paper, Arp has been reporting such results from earlier surveys also [13, 14, 15]. In a recent study Sulentic [16] finds statistically significant excess redshifts in a sample of 196 companion galaxies in 60 groups where the dominant galaxies are spirals. (A sample of 62 companions in 21 E/SO dominated groups, however, shows no such excess.) As discussed by Sulentic, the effect, if real, cannot be explained in conventional terms.

One conventional defence is to discount the companionship of the companion galaxies and to argue that they are considerably father away as required by (1) and just happen to be projected near the dominant galaxies. There are cases, however, where luminous filamentary connections have been demonstrated between a pair of galaxies of discrepant redshifts. In 1982 Arp [17] has discussed four such cases, with $c\Delta z$ ranging from 4,800 km s^{-1} to 26,200 km s^{-1}. However, Sharp [18] has pointed out that in the case of 0213-2836 discussed earlier by Arp [15] there is no dynamical evidence of interaction between the main galaxy and its excess redshift companion.

More recently Sulentic and Arp [19] have found two pairs of galaxies 4030-11 and 4151-46 with luminous connections and perturbations in the form of asymmetric internal structures of the higher redshift companions. Both the direct and spectroscopic studies indicate that the pair members are dynamically interacting. Yet the $c\Delta z$ values in the two cases are 4859 km s^{-1} and 28661 km s^{-1} - too large for the pair members to be neighbours according to the conventional view.

3.2 Quasar-Galaxy Associations

Taking the conventional view that bright galaxies are nearby and quasars with their larger redshifts farther away, we do not expect any correlation between their respective distributions. Correlations have, however, been found in several studies, ranging from isolated groups to large populations.

3.2.1. Large associations. The most recent study was done by Chu et al [20] who compared the quasars in the Hewitt-Burbidge catalogue of 1980 [21], with the bright galaxies in the Second Reference Catalogue of de Vaucouleurs et al [22]. Using the statistical techniques of cross-correlation function and the nearest neighbour separation these authors find that quasars and bright galaxies are associated. For example, there are $0.36 \pm .09$ more bright galaxies within 40 arc min of quasars than would be expected under the cosmological hypothesis.

Other investigations of large scale inhomogeneities of quasar populations have been carried out by Arp [23, 24]. To avoid the usual criticism of 'selection effect' Arp looked for inhomogeneity of distribution in the Parkes and 3CR quasars. These are complete samples of radio loud quasars. Shastri and Gopal Krishna [25] had also earlier reported inhomogeneity in the distribution of these quasars with redshifts $z > 2$. Arp found that quasars in the redshift range $1.4 < z < 2.7$ and magnitude range $17.5 < V < 19$ are distributed in a non-random fashion. The distribution of these quasars looks like an elongated jet extending from R.A. $\sim 1^h\ 30^m$, $\delta \sim 30°$ to R.A. $\sim 23^h$, $\delta = 0°$. Arp noticed that the companion galaxy M33 in the Local Group lies at one end of this line. Are these quasars ejected from the galaxy? If they are distant background quasars then the above anisotropy implies inhomogeneities in the universe on the scale of $\sim 10^3$ Mpc. Subsequently Arp [26] has reported jets and filaments in the distributions of low redshift quasars as well as high velocity hydrogen clouds associated with galaxies in the Sculptor Group, NGC 55 and NGC 300.

Before one worries about a theory of ejection of objects from galaxies in jets and filaments one has to be convinced that the observed anisotropy is statistically significant. The usual statistical tests of nonrandomness are not applicable to such distributions where the claim is for an elongated large scale structure. Narlikar and Subramaniam [27] have devised new tests and applied them to these radio samples. It is found that Arp's claim for M33 is significant although for quasars in other redshift or magnitude ranges there is no significant nonrandomness on a large scale.

3.2.2. Quasars lying close to galaxies. I wish to highlight three recent investigations.

a) NGC 4319 and Markarian 205. This pair with redshifts 0.006 and 0.071 has a long history dating back to 1971 when Arp [28] announced a luminous connection between the spiral galaxy with the higher redshift object. The existence of the connecting filament was finally accepted (I hope!) after Sulentic's detailed study of the plates [29], although conventional interpretation of it was not long to follow! Cecil and Stockton,[30] while admitting the reality of the connection, have argued that the filament connects M 205 with a companion galaxy at the same redshift. Recently Sulentic has claimed (private communication) that the optical spectroscopy of the connection by him with Arp invalidates this conventional interpretation.

Sulentic [31] has also studied NGC 4319 and its surrounding region by VLA and finds that there is no corresponding radio connection. However, NGC 4319 is a double lobed radio source. Thus the fact that it is an active galaxy capable of ejecting matter lends circumstantial evidence that M 205 may also have been ejected from NGC 4319.

b) 1E 0104.2 + 3153 and the neighbouring elliptical galaxy. This example was reported in 1984 by Stocke et al [32] in connection with the optical identification of the above X-ray source arising from the Einstein Observatory Medium Sensitivity Survey. It has a quasar with $z = 2.027$ about 10 arc sec away from a giant elliptical galaxy at z = 0.111. The authors chose to describe this as a gravitational lens.

In earlier times such a pair would have been dismissed as chance coincidence even though its probability were small. Multiple imaging with same redshifts which is the hallmark of gravitational lensing is absent in this case, however. However, the next case is even more striking.

c) The galaxy 2237 + 0305 and the neighbouring quasar. If I were to pick up only one counter example to CH, I would pick up this one. Not only does it provide strong evidence for noncosmological redshifts - it also illustrates the present sociology of science. The quasar with redshift z = 1.695 was discovered by Huchra et al [33] within 0.3 arc sec of the centre of the galaxy 2237 + 0305, with z = 0.0394. The probability of a 17^m background quasar lying by chance within 0.3 arc sec of the centre of the galaxy is $\sim 10^{-5}$, while if one allows the quasar to be anywhere within the larger slit area used in observing galaxies then the probability is $\sim 10^{-3}$.

By standard statistical practice a hypothesis leading to an outcome of low probability (- even 10^{-3} is normally considered low!) would be rejected and the conclusion should be that the quasar and galaxy are associated. Indeed a number of low redshift quasars have been found with fuzz around them which are conventionally interpreted as galaxies hosting the quasars in their nuclei. Following this line of argument one could have concluded that 2237 + 0305 was hosting the quasar. However, such a conclusion would clearly have been embarrassing for CH. So some argument had to be found to get round the difficulty.

The argument involves gravitational lensing. Make the quasar a background quasar and fainter than the observed 17^m, and then amplify its brightness by invoking the galaxy as a lens. The lensing argument apparently increases the probability of the observed event to 2×10^{-4} from 10^{-5} and to 3×10^{-2} from 10^{-3} (in the case of the larger slit area). However, as pointed out by M. G. Edmunds [34] these probabilities are further reduced if one takes into account the dimming of the quasar light by 3^m through interstellar extinction as implied by its $\nu^{-3.5}$ spectrum.

Thus, even prima facie, gravitational lensing does not improve the situation for CH, it only adds more epicycles. In a comment on the paper by Huchra et al Burbidge [35] has rightly called the title of the paper '2237 + 0305: A New and Unusual Gravitational Lens', a little unfair.

Tyson and Gorenstein have since claimed that they have indeed found other images of the quasar produced by the lens [36]. It is my prediction that these claims would be accepted readily and uncritically while Arp's 1971 claim of a connection had to wait fourteen years for a grudging acceptance. I will therefore base my remaining comments on the assumption that the claim is correct.

The observed image configuration imposes certain limitations on the lens. For example, the lensing galaxy must have a bar-component or it must be a highly eccentric spheroid. Neither possibility belongs to a common category of galaxies. Further, the anisotropy of the lens means it has to be suitably oriented. K. Subramanian (private communication) who has studied the diferent aspects of this lensing system finds that the probability of the lensing configuration is as low as $\sim 2 \times 10^{-5}$.

Schneider [37] has argued that it is improbable that gravitational amplification can sufficiently account for the puzzling observations of quasar galaxy associations. If further observations rule out the lens alternative, or if the lensing probability remains embarrassingly small then the conventional defence would fall back on the oft-expressed view that it is dangerous to calculate a-posteriori probabilities.

3.3 Close Pairs of Quasars

Another test of the cosmological hypothesis comes from the observed occurrence of close pairs of quasars. If the test is to be applied fairly and ideally, we should first decide whether the members of the pair are physical neighbours. If the answer is in the affirmative we should then measure their redshifts. If the redshifts are equal then the CH survives. If the pair has discrepant redshifts the CH is falsified.

How do we decide if the pair members are really physical neighbours? Since we are not permitted to use (1) to estimate their distances we have to rely on other indirect means. These methods are statistical. Given the rules under which the sample of close pairs is to be selected can we estimate the probability of their occurrence by chance?

Burbidge et al [38] in 1974 outlined this procedure soon after two close pairs Ton 155, 156 and 1548 + 114 A, B were found. The aim of this paper was to lay down a formula for computing probabilities that did not have the label 'a-posteriori' attached to it. Simply stated, the expected number of quasars lying within θ arc sec of an arbitrary search centre is given by

$$\langle n \rangle = 2.4 \times 10^{-7}\, \Gamma(<m)\theta^2 \qquad (3)$$

where $\Gamma(<m)$ is the sky density of quasars brighter than magnitude m expressed in (arc deg)$^{-2}$.

In practice the situation is usually inverted. Observers tend to classify close pairs after measuring their redshifts. Thus those with identical redshifts are supposed to be gravitationally lensed images of a single object. Those with nearly equal redshifts are supposed to belong to the same supercluster, while those with discrepant redshifts are considered to be chance projections without any significance. Thus according to this point of view, the CH is taken to be valid no matter how many and how close are the pairs of the third kind.

Burbidge et al [39], however, have attempted to compute the probability of occurrence of close pairs. They have carefully laid down the values of the parameters that go into the formula (3) and found that the probability of finding the observed number of 6 close pairs with one member a radio source, both brighter than V = 18.5 and lying within 2 arc min of one another to be $\sim 10^{-4}$. As these authors admit, the values of the parameters chosen by them are open to modification as the data on quasars improve. But if their values are accepted the close pairs are occurring much too frequently to be ascribed to chance.

4. THEORETICAL CONSIDERATIONS

I end with three brief theoretical comments. The first is that there are severe theoretical constraints on quasar models if the cosmological hypothesis is accepted. Burbidge has outlined some in a recent review [5]. The general difficulty is as follows. At cosmological distances the quasars must be very luminous objects. At the same time the apparent superluminal motions and rapid flux variations require these objects to be very compact. Whatever energy machine (including the omnipotent massive black hole) is thought of as the source of quasar's energy, it has to function with extremely high efficiency ($\gtrsim$ 10%) in delivering the observed luminosity of a quasar. Further, the models require large scale relaativistic bulk motions in a highly ordered form, a concept that has not yet been put on sound theoretical footing [40]. Both these aspects are novel so far as the rest of astrophysics is concerned. Those who insist on conventional physics being applicable throughout the universe are already stretching the limit of conventionality beyond what is familiar elsewhere.

My second comment is that the generally held belief that gravitational lensing has demonstrated that quasars are distant is not quite correct. The lensing configuration can be scaled down without difficulty. In fact in a recent paper Chitre and Padmanabhan [41] have shown that Population III stars or other units of dark matter with masses $\sim 10^6_\odot$ in the halo of our Galaxy can act as lenses for distant as well as local quasars, reproducing all the observed features.

Finally, if noncosmological redshifts are present, what is the physics behind them? Conventional physics offers two alternatives, gravitational and Doppler redshifts. Do viable and detailed models exist with these redshifts in which the quasars are considerably closer than implied by CH?

To some extent this is a chicken and egg problem. Because it is generally believed that there is no need for noncosmological redshifts detailed models are not many. At the same time because there are no detailed investigations of noncosmological models it is assumed that there are no serious alternatives to CH. Just to draw attention of this community to recent models of noncosmological redshifts I mention the gravitational model of Hoyle [42] and the Doppler model of Narlikar and Subramanian [43].

Should the conventional alternatives to CH also fail then 'new physics' will have to be invoked. In the last analysis, it is fear of this prospect that, I suspect, makes most astronomers hold on tenaciously to the cosmological hypothesis and to ignore the contrary evidence. This attitude is surprising from workers in a subject that contributed such new physics as the law of gravitation, spectroscopy and thermonuclear fusion. Personally, I find the opposite more dreadful - that astronomy will make no more fundamental contributions

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DISCUSSION

Lawrence : I hope we all recognise the importance of counter examples in science. But the Universe is a messy place, and there will always be puzzles. In the spirit of a question earlier in the week, I would like to ask on the basis of what evidence would you accept the cosmological hypothesis as a working hypothesis ?

Narlikar : Like any scientific hypothesis the CH is also subject to scientific tests. A more valid question therefore should be posed to the supporters of CH : "What observational test, in your opinion would constitute a disproof of CH ?"

However, in the spirit of the question asked, I may mention that CH for galaxies emerged as a tight Hubble relationship in a natural way. I would have taken CH as a natural working hypothesis if a Hubble law had emerged for quasars. After two decades we still have a scatter diagram.

Burbidge : In reply to the question just asked I would be more inclined to believe in cosmological redshifts if much of the evidence for non-cosmological redshifts had been shown to be wrong. Infact, this has not happened in any critical case.

Birkinshaw : To take up the challenge, I would accept as proof of the non-cosmological nature of quasar redshifts an example of a low-redshift quasar being lensed by a substantially higher redshift object, or showing absorption features from the higher-redshift object in its spectrum.

Narlikar : So far as lensing is concerned a supporter of CH would dismiss the high redshift galaxy as a 'chance coincidence' and he would argue that lensing (if at all) is being done by a faint massive object between the quasar and the observer. The absorption features would be harder to explain away but given sufficient ingenuity, I am sure somebody will find an explanation for it too - because so much is at stake !

Peacock : Do you believe that any quasar has a cosmological redshift ? One quasar in (say) 1000 with a discrepant redshift would not affect conventional statistical studies.

Narlikar : In my talk I have taken the view that there are some genuine counter examples to CH, i.e., a few cases wherein a part of the redshift (say $>> 10^3$ kms^{-1}) is noncosmological. Rather than statistical studies, a genuine point of fundamental importance is involved here. For, if, noncosmological components are present in the redshifts of a few quasa-rs, then one automatically becomes suspicious about all quasars. The suspicion is reinforced because prima-facie no tight Hubble relationship is seen for quasars.

Leahy : I disagree with your ground rule that "no new theory is requi-red". In the history of science no widely successful theory has been rejected on the basis of a counter-example until a new theory was avai-lable which accounted both for the counter-example and for the success of the old theory. (For instance, Maxwellian electrodynamics was not abandoned after it was apparently undermined by the Michelson-Morley experiment.)

Narlikar : I was objecting to the fact that many physicists doubt the evidence against CH on the grounds of lack of theory for the evidence. It was not Maxwellian electrodynamics but the ether theory that was threatened by the Michelson-Morley experiment. Attempts were made, e.g. by Lorentz and Fitzgerald to patch up - but these did not succeed. A new theory came eventually, but nobody doubted the Michelson-Morley result till then.

There can be such a situation that no theory is available to explain observed phenomena. Spectral lines discovered in the last cent-ury had no theory to explain them : but this did not make physicists doubt their existence. The situation here is the reverse : physicists doubt the existence of counter examples to CH because there is no alter-native theory for them. I consider this attitude unscientific.