A Review of Anomalous Redshift Data

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Abstract

One of the greatest challenges facing astrophysics is derivation of remoteness in cosmological objects. At large scales, it is almost entirely dependent upon the well-established Hubble relationship in spectral redshift. The comparison of galactic redshifts with distances arrived at by other means has yielded a useable curve to an acceptable confidence level, and the assumption of scale invariance allows the adoption of redshift as a standard calibration of cosmological distance. However, there have been several fields of study in observational astronomy that consistently give apparently anomalous results from ever-larger statistical samples, and would thus seem to require further careful investigation. This paper presents a review summary of recent independent work, primarily (for galaxies and proto-galaxies) by teams led by, respectively, D. G. Russell, M. Lopez-Corredoira, and H. C. Arp, and for galaxy clusters and large-scale structures, those of N. A. Bahcall, J.C. Jackson, and N. Kaiser. Included also are several other important contributions that will be fully cited in the text. The observational evidence is presented here *per se* without attempting theoretical conclusions or extrapolating the data to cosmology.

PACS: 95.10 –a; 95.30 –k; 97.10.Ri; 98.

Key words: redshift, quasars, galaxies, expansion, cosmology, anomalous, peculiar.

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1. Introduction

It is not my intention in this summary to present all the evidence, or to include the detail. There is simply too much of it. It is a broad review using selected examples, and I would be happy if it were to do no more than provide some pointers to those of you who may be inspired to investigate further.

The first question that needs to be answered in a review of anomalous redshift data is, *"What is the statistical significance of the samples being cited?"* Put another way; are anomalous redshift associations not in fact just extremely rare events that can be written off to chance alignments and optical illusion? This was for decades the criticism levelled particularly at the observational work of Halton Arp, so I will let him answer it (from his paper with Chris Fulton, 2008):

*"Fulton & Arp have analyzed the positions, redshifts, and magnitudes of ~**118, 000 galaxies** and ~**25, 000 quasars** in the 2dF deep field. The examination of individual samples revealed concentrations of high z galaxies and quasars near galaxies. A natural extension of the analysis was to determine the average densities of objects over the survey area as a whole."* [1]

Redshift is an extremely important quantity in astrophysics, and supports a large body of theory. In cosmology, it gives us the radial calibration along line-of-sight that determines almost exclusively the depth in 3-D representation of structure. In 1929, Edwin Hubble discovered that for galaxies in his field of view, that is, fairly local, the fainter they are, the higher the redshift. From the outset, data patterns were indistinct and tenuous. Hubble's original redshift data were described by Weinberg [2] as leaving him *"perplexed how he (Hubble) could reach such a conclusion—galactic velocities seem almost uncorrelated with their distance, with only a mild tendency for velocity to increase with distance."* Hubble himself remained unconvinced that the Doppler effect correctly explained his observations. Hoyle, Burbidge, and Narlikar, in <u>*A Different Approach to Cosmology*</u> [3], recount Hubble's uncertainty: *"In his last discussion of the observations, Hubble in the George Darwin lecture at the Royal Astronomical Society in 1953, a few months before he died, gave the first results obtained using the 200-inch telescope…Sandage has pointed out that using the 'no recession factor' (meaning no correction for the number effect), Hubble was still doubtful if the expansion was real."* In the same book (pages 32—33), we learn that, *"In the case of the redshifts it had been accepted that they must be corrected for solar motion with respect to the centroid of the Local Group, since it had been realised since 1936 that the systematic redshift does not operate within the Local Group."* The crucial implication of this was that it was impossible to test redshift-expansion against parallax distance measures, the most reliable method for quantifying celestial remoteness, albeit within the limits of achievable baseline scale. Given that uncertainty increases dramatically with remoteness on all axes, it would appear that ***the Hubble relationship fits best where it is tested least.***

Historically, galaxy counts compiled by Abell (*Catalogue of Rich Clusters*, 1958), Zwicky *et al* (*Catalogue of Galaxies and Clusters of Galaxies*, 1961—1968), and Arp (*Atlas of peculiar Galaxies*, 1966) made no attempt to reconcile redshift values with other properties in space, but the data were invaluable to later analysts constructing 3-D interpretations. The *Sloan Digital Sky Survey* (SDSS) and the *Centre for Astrophysics* (CfA) survey, as two examples of modern works, have given us 3 dimensional interpretations of pie slices of the universe that rest, or fall, with redshift distance. All these mentioned surveys produced peculiar patterns when arranged spatially according to redshift, and even more obvious anomalies where resolution permitted detection of material connections between bright objects.

M.B. Bell, of Herzberg Institute of Astrophysics in Canada, sums it up, *"Because the belief that the redshift of quasars is cosmological has become so entrenched, and the consequences now of it being wrong are so enormous, astronomers are very reluctant to consider other possibilities. However, there is increasing evidence that some galaxies may form around compact, seed objects ejected with a large intrinsic redshift component from the nuclei of mature active galaxies."* [4]

2. Phenomenology

Anomalous redshifts, defined as quantities significantly at variance with the Hubble Law, present in two ways: Either the redshift value itself is inconsistent with other known properties of the object, or the redshift is taken as the benchmark and doubt is cast on the verity of other measured properties of the object. To assess whether the arrangement in an apparent system is or is not anomalous, we would look for *"properties of nearness, alignment, disturbances, connections"* (Arp, Burbidge, Burbidge [5]).

Thus, we may assume that there is something anomalous about the redshift of an astrophysical object if:

1.1. There is a prevalence of high redshift objects near the nucleus of nearby galaxies, or high redshift galaxy-like systems associated with low redshift clusters;

1.2. Physical connections are seen between objects with significantly varying redshifts;

1.3. Apparent proximity of high redshift objects is given by non-redshift distance indicators;

1.4. Radial alignment suggests ejection and common origin of objects with excessively varying redshifts;

1.5. Absorption lines (or lack thereof) of higher redshift objects places them in the foreground of lower redshift background systems;

1.6. Morphological associations, for example asymmetries in rotation curves or overall shapes, in contradiction of redshift distance. This evidence, although documented in the literature, is not included in this review.

1.7. The redshift is systematically quantised in discrete values along preferred peaks (the Karlsson Effect).

3. Overview

3.1 Galaxies. Our descriptive knowledge of galaxies increased exponentially from the time of Hubble's first foray into extra-galactic astronomy in the late 1920s. However, our definitive *understanding* of these systems seems to have simultaneously gone backwards.

Edwin Hubble designed his Tuning Fork classification system around his belief that galaxies were stable and symmetrical, reducible to a linear hierarchy of just a handful of distinct species. By the 1950s, it was obvious that Hubble's galaxy classes were woefully inadequate, and that galaxies were indeed behaving mysteriously. A decade earlier (in 1941), Erik Holmberg had modelled tidal disturbances apparent in *"stellar systems which pass one another at small distances"* [6]. In 1956, Fritz Zwicky was the first astronomer to describe large-scale tidal effects characterising galaxies, in the form of *"clouds, filaments, and jets of stars"* [7]. He attributed these phenomena to *ejection*, caused by *galaxy collisions*. Viktor Ambartsumian tendered a very important alternative view, theorising the *fissioning* of celestial objects. This raised the possibility that galaxy-galaxy interactions and consequent tidal disturbances described by Zwicky, could well be caused primarily by the ejection of one object by another without their prior *merging* necessarily. Either way, they were definitely peculiar.

In the paper *Large Scale Structure in the Universe Indicated by Galaxy Clusters* [8], Neta Bahcall, widow of the late John Bahcall and professor of astronomy at Princeton, summarises it thus, *"Still, despite the great effort and many ingenious ideas, no single theory for the formation of galaxies and large-scale structure can yet satisfactorily match all observations"*. Thus, it would appear, at super-galactic scales at least, redshift-distance correlations are always in some or other respect anomalous when tested against the body of theory.

3.2. Quasars. Alan Sandage and Thomas Matthews, in a landmark fusion of optical and radio astronomy, identified Quasi-Stellar Objects (QSOs, hereafter *quasars*) in 1963. They were properly described in terms of their spectral signature, and presented an unusual defining characteristic: Redshifts significantly higher than other objects seen on the sky. This created difficulties for physical theory because at their redshift-implied remoteness, they would by known physics be impossibly bright. Quasars are very compact objects, typically only ~1 LY across. If they really are at their redshift distance, they would be so energetic that their luminosity enters the realm of metaphysics.

If one plots quasars' redshift against apparent brightness, as Hubble did for galaxies, one gets a wide scatter, as compared with a smooth curve for the same plot done for galaxies. This seems to indicate that quasars do not follow the Hubble law, and there is no direct indication that they are at their proposed redshift distance. In fact, it is argued if Hubble had been given the plot for quasars first, he and other astronomers would not have concluded the Universe was expanding.

Furthermore, the calculated charge density of quasars is in some cases so high that it would appear that photons could not likely escape the interior, meaning that quasars should be radio- and X-ray-quiet. They obviously were not. Even more onerous was the precision measurement of radial expansion rate by very long baseline radio interferometry. Quasars appeared to be expanding at up to ten times the speed of light, with obviously serious implications for underlying theory and Einsteinian physics. All of these quandaries about quasars were real only at their redshift-implied remoteness, and would tend to disappear if the objects were in fact closer to our point of observation. It was clear that quasars were peculiar enough to warrant further investigation to establish observationally *what* they actually were in the scheme of things, and *where* they might be located in space.

3.3. Observations and Catalogues. It would be fair to say that the controversy surrounding quasars and the implied phenomenon of intrinsic redshift may be attributed mainly to the early observational work of Dr Halton C. Arp, then a professional astronomer working at the major West Coast observatories of the USA. His interest in the astronomical distance ladder, stemming from his doctoral work with Edwin Hubble and subsequent 2-year stint observing Cepheids in South Africa, brought redshift into focus. In 1965, two oddities caught his interest: Galaxies appeared to be in turmoil, showing signs of great internal stress and presenting themselves in ways that could not neatly be accommodated on Hubble's Tuning Fork; and an unusual prevalence of quasars, in pairs or more, aligned closely across active (Seyfert-like) galaxies. Sandage collaborated with de Vaucouleurs in 1958 to try to accommodate the wildly varying structural types of galaxies, and in 1966, Arp published a collection of these images in his classic *Atlas of Peculiar Galaxies*.

The furore that followed split the astrophysical community, with most astronomers declaring that close alignment of quasars with AGN was just chance, line-of-sight coincidence with no statistical or physical significance. A small minority took an alternative view, however, amongst them (besides Arp) Margaret and Geoff Burbidge, Fred Hoyle, Jayant Narlikar, and Jack Sulentic. After his banning from the West Coast observatories in the early 1980s, Dr Arp took up employment at the *Max Planck Institut für Extraterrestrische Physik* (MPE) in Germany, where he was able to continue acquiring images in X-ray of objects he had previously observed optically. Ironically, the enforced migration from optical to X-ray dealt Arp an unexpected trump—previously unseen linking structures were thereby revealed, and the great value of composite images in various wavebands was obvious. The MPE's cutting-edge X-ray telescope, says Arp, *"picked out the most energetic objects with ease, and the telescope was still small enough so that it had sufficiently large field to include the crucial objects which were related to the central progenitor galaxies"*[9]. Those seeking to suppress his research had shot themselves squarely in the foot.

The first volume, The Atlas of Peculiar Galaxies, originally a supplement to ApJ, is currently out of print, so I reference here Kanipe and Webb's version [10], which contains all the images. It lists 338 disturbed galaxies. They are known as the *Arp galaxies*, and have *Arp numbers* from 1 to 338 in the order presented in the atlas. Arp's subsequent publications continued to display observational evidence of these associations, now improved by advanced instrumentation to include more detail than just tight angular spread, and led ultimately to his *Catalogue of Discordant Redshift Associations*, [11] published in 2003.

Up to then, the samples available to Dr Arp had been limited in scope, but contemporary large-scale cosmic surveys, prominently the *Sloan Digital Sky Survey*

(SDSS), immediately introduced millions of objects to the field of study. Amongst them were more than 40 000 positively identified quasars. The two deep field surveys are also invaluable sources of redshift data. The 2dF Galaxy Redshift Survey (2dFGRS) lists ~250 000 galaxies, and the 2dF Quasar Redshift Survey (2QZ) examines ~25 000 quasars. In the words of Arp and Fulton, *"The resulting collection of objects can be analysed to obtain the average numbers of galaxies and quasars per square degree as shown in Table 1. The subject count records the occurrence of galaxies and quasars inside a circle of radius 30′ around each galaxy and the background count records the occurrence of galaxies and quasars in a concentric annulus of equal area enclosing the subject circle."* [1]

In *Analysis of possible anomalies in the QSO distribution of the Flesch & Hardcastle catalogue* [12], Martin Lopez-Corredoira and colleagues give the scope of that collection: *"Flesch & Hardcastle present an all-sky catalogue with 86 009 optical counterparts of radio/X-ray sources as QSO candidates…"*

Again, in *A Catalogue of M51 type Galaxy Associations* [13], David G Russell and his colleagues discuss the need for further investigation:

"A catalogue of 232 apparently interacting galaxy pairs of the M51 class is presented. Catalogue members were identified from visual inspection of multi-band images in the IRSA archive…[]… It was found that only 18% of the M51 type companions have redshift measurements in the literature. There is a significant need for spectroscopic study of the companions in order to improve the value of the catalogue as a sample for studying the effects of M51 type interaction on galaxy dynamics, morphology, and star formation. Further spectroscopy will also help constrain the statistics of possible chance projections between foreground and background galaxies in the catalog. The catalog also contains over 430 additional systems which are classified as 'possible M51' systems."

4. Fields of study

4.1. Statistical distribution. Halton Arp and colleagues found that three aspects of quasar distribution were anomalous: Their distribution amongst other objects, that is, the 2-D density of quasars on the sky, showed an inordinate prevalence of quasars paired in close (angular) proximity across Active Galactic Nuclei; objects apparently physically associated in space had significantly varying redshifts; and the asymmetrical concentrations of isophotes on AGN/quasar maps indicated that the quasars were moving away from the AGN, suggesting ejection. Dr Arp has to date published 4 volumes besides his many papers and articles, 3 in book form [9, 11, 14, 15]. All are in effect catalogues of his observations, and they contain hundreds of examples. It is not practicable to present here an analysis of each case, so I have selectively chosen three examples to illustrate the principles being put forward. It is interesting to note Arp's use of the collective noun "family" in his recent work; it emphasises the important increase in power and resolution of modern surveys. From the first tentative observed alignments of pairs of quasars in the 1960s, we are now introduced to groups of ten or more closely gathered around active galaxies.

4.1.1. NGC 3516: The Rosetta Stone. In 1997, Halton Arp, together with a team of Chinese astronomers, published a landmark paper: *Quasars around the Seyfert Galaxy NGC3516* [16] Arp has described this system as the "Rosetta Stone" of Intrinsic Redshift. He says, *"We report redshift measurements of 5 X-ray emitting blue stellar objects (BSOs) located less than 12 arc min from the X-ray Seyfert galaxy, NGC 3516. We find these quasars to be distributed along the minor axis of the galaxy and to show a very good correlation between their redshift and their angular distance from NGC 3516. All of the properties of the high redshift X-ray objects in the NGC 3516 field confirm the body of earlier results on quasars associated with active galaxies. We conclude that because of the number of objects in this one group, the evidence has been greatly strengthened that quasars are ejected from nearby active galaxies and exhibit intrinsic redshifts."*

4.1.2. AM 2230-284 large quasar family. This striking example of a family of 14 quasars (reduced to 7 by magnitude constraints) gathered around the central galaxy AM 2230-284 is examined in one of Arp's most recent studies (Arp and Fulton 2008) [1]. Arp: *"In order to work with a manageable number of cases…I was asked to excerpt from the most constrained test a list of the families with the largest number of detected companions. The list supplied 44 galaxies with 7 − 9 such companions. Glancing through these associations revealed the surprising appearance of families in which many of the quasar companions were strikingly similar in redshift. In one case the redshifts of all 7 quasars within a radius of d = 30 were closely the same…The fact that there are so many quasars all of nearly the same redshift around this galaxy marks them as being associated with a high degree of probability.(…)*

"There are specific properties of this association that are predicted from the ejection model for quasars by Narlikar & Arp (1993). Briefly summarized they are:

- *QSOs are ejected in opposite directions conserving linear momentum. Figure 2 shows 7 QSOs with positive (presumably Doppler) velocity shifts and 7 with negative shifts.*
- *The mean approaching and receding ejection velocities are very much the same. Extension along the lines of ejection can be slowed or deviated by moving individual QSOs around but the average usually stays closely balanced.*
- *The parent galaxy is an Arp/Madore peculiar galaxy. It is moderately bright at B = 17.33 mag. Its peculiarity is its compactness (high surface brightness) usually an indicator of active physical processes.*
- *(Karlsson Periodicity)."*

The peculiarity of this system typically extends also to the rate at which it expands intrinsically. Radial expansion at 3600 km s^{-1} is measured, which includes a significant ejection component. Conservatively, we may say that $V_{exp} << 3600$ km s^{-1}. We may then check to see if it matches the expansion rate expected if it really were at its redshift-supposed distance. Arp says, *"It is interesting to calculate what the rate of expansion would be if the cluster were at its conventional redshift distance. First of all,* *how far away would it be? If the velocity of light is taken to be 300, 000 km/s, then the redshift z = 2.149 is v/c = .817   v = 245, 100 km/s*

Using the Hubble constant H0 = 55 km/s/Mpc r = 4, 456 Mpc = the distance to the cluster. D = 181 Mpc = the diameter of the cluster. Hence the cluster should be expanding with 9, 955 km/s. But only 3, 600 km/s is measured and most, if not all, of that is deemed ejection velocity. At the conventional redshift distance, however, just the expansion of space should imprint nearly 3 times as much front to back expansion velocity than actually measured for this quasar cluster."

4.1.3. The Quasars around NGC5985. Halton Arp *Redshifts of New Galaxies* [17]*"(It) shows one of the most exact alignments of quasars and galaxies known. Attention was drawn to this region when it was discovered that a very blue galaxy in the second Byurakan Survey had a quasar of redshift z = 0.81 only 2.4 arcsecs from its nucleus. Even multiplying by 3 x 10^4 galaxies of this apparent magnitude or brighter in their survey they estimated only a chance proximity of 10^{-3}.* **(Nevertheless they took this as proof that it was a chance projection! Also it was not referenced that G. Burbidge, in 1996 in the same Journal, had published extensive list of other quasars improbably close to low redshift galaxies)**. *A combined numerical probability of the configuration gives a chance of around 10^{-9} to 10^{-10} of being accidental. Nevertheless several peer reviewers recommended against publication on the grounds that the accidental probability was 'greater' than this. But, of course, several dozens of cases of anomalous associations had been reported since 1966 with chance probabilities running from 10^{-4} to 10^{-5}. What is the combined probability of all these previous cases? And what is the motivation to claim each new case is 'a posteriori'?"*

4.2. Physical association in specific systems. Meanwhile, the original observations catalogued by Dr Arp had prompted open enquiry by a number of astronomers in various fields of study. At the *Instituto de Astrofisica de Canarias*, Martin Lopez-Corredoira and Carlos Gutierrez (hereafter L-C & G), both professional astronomers at the *Instituto*, studied individual systems to try to establish the presence of evidence supporting or refuting physical associations and material connections between objects in apparent proximity incompatible with their respective redshifts.

In their classic 2005 paper, *Research on Candidates for Non-Cosmological Redshifts*, [18], L-C & G hint at their uphill battle for telescope time: *"A surprising fact regarding our observations is that we have observed only about a dozen systems. The reason is mainly because we obtained only a few nights of observation time on 2 to 4 metre telescopes. In subsequent applications, no time was obtained despite our having published several papers in major astronomical journals on the topic."* It is worth adding that of the 12 they were permitted to observe, fully half were found to contain definite anomalies, clearly justifying their research.

L-C & G had set themselves the target of trying to investigate, by close observation, the discordant redshift associations listed in Arp's Atlas—a daunting task given the sheer numbers involved. They say, *"The sample of discordant redshift associations given in Arp's* *atlas is indeed quite large, and most of the objects remain to be analysed thoroughly. For about 5 years, we have been running a project to observe some of these cases in detail, and some new anomalies have been added to those already known; For instance, in some exotic configurations such as NGC 7603 or NEQ3, which can even show bridges connecting four objects with very different redshifts, and the probability for this to be a projection of background sources is very low."*

4.2.1. Markarian 205. The classic case, featured on the covers of all Arp's books, is the famous "invisible" bridge linking NGC 4319 and the quasar Mrk 205. Arp published the original images in 1972. In the early 1980s, Dr Jack Sulentic soundly debunked two much-cited papers that claimed the observed bridge simply did not exist, and in 2007, he reacted again to similar claims, this time in a press release from Hubble Heritage. *"The papers H. Arp and I wrote have never been refuted in the literature. Did we make a mistake no one told us about?"* In the HST image, Sulentic says, *"You can see the narrow core in the connection, which HST is able to detect because of its excellent resolution. It is seen exactly where we found it in the earlier studies…Hubble Space Telescope has in fact, confirmed our earlier work."*

The case of Mrk 205 has been discussed *ad nauseum*, and in my opinion, we can be as certain as we are of anything in cosmology that the bridge is a real physical connection between these two objects. Anyone not yet convinced is unlikely to change his mind now. Markarian 205 rests.

4.2.2. NGC 7603. In 2002, these two astronomers applied for telescope time to study the field surrounding NGC 7603 [19]. It is particularly interesting because it is one of the cases where filamentary connections appear between objects of different redshift. In 2004, they revisited the study, and published a comprehensive summary paper in *Astronomy & Astrophysics*, entitled *The Field Surrounding NGC 7603: Cosmological or non-cosmological redshifts?* [20]. The authors presented in this review new evidence from this specific set of observations, particularly concerning two knots in the filament connecting NGC 7603 (z = 0.029) and the QSO NGC 7603B (z = 0.057).

"The angular proximity of both galaxies and the apparently luminous connection between them makes the system an important example of a possible anomalous redshift association. Arp has claimed that the compact member, NGC 7603B, was somehow ejected from the bigger object. Moreover, there are also two objects overimposed on the filament apparently connecting both galaxies. We identified several emission lines in the spectra of the two knots, and…we determined their redshifts to be 0.394±0.002 and 0.245±0.002 for the objects closest to and farthest from NGC 7603 respectively…According to the line ratios, these objects are HII-galaxies but are quite peculiar…However, if we consider an anomalous intrinsic redshift case…they would be on the faint tail of the HII-galaxies; they would be dwarf galaxies, 'tidal dwarfs', and this would explain the observed strong star formation ratio...Of course, this would imply that we have non-cosmological redshifts."

L-C & G conclude in [18]:

"Therefore, some facts, although not conclusive, seem to suggest that there is an interaction between the four galaxies of different redshift: the existence of the filament itself, the strong Hα emission apparently observed in the HII galaxies typical of dwarf galaxies, and the low probability of having three background sources projected on to the filament. As a speculative hypothesis, we might think that the three galaxies were ejected by NGC 7603…it seems extremely unlikely that objects 1–4 at different distances can, by chance, give a projection in the way these figures show up."

4.2.3. MGC 7-25-46, NGC 7319, and Stephan's Quintet. In 2004, Margaret Burbidge presented to the annual meeting of the American Astronomical Society a paper that created alarm in the world of cosmology. It was called *The Discovery of a High Redshift X-Ray Emitting QSO Very Close to the Nucleus of NGC 7319* [21]. In it, the authors presented observational evidence that a strong X-ray source (an *Ultraluminous X-ray Source* or ULX) with relatively high redshift ($z = 2.114$) lay in the *foreground* of NGC 7319, an active galaxy with relatively low redshift ($z = 0.022$). Several tests were conducted to determine whether or not it lay in the foreground, for if it were, beyond reasonable doubt, the case would be conclusive.

Is the QSO behind the galaxy? *"It is not surprising that interstellar sodium D1 and D2 absorption are seen in the spectrum of the QSO. If the ejected gas and the QSO lie near the plane of the disk, however disrupted that may be, we would still expect about half the possible optical depth of gas between the QSO and the observer. But we have no way of knowing whether the amount of gas observed here represents the total column of gas through the system, half, or even less. One obvious question suggests itself, namely: Does the colour of the QSO indicate that it is inordinately reddened and therefore obscured as if it were a background object? Of course that would require smooth conditions in the galaxy and a precise value for the unreddened colour. But we can make an empirical test by selecting 32 QSOs in a large sample region of the Hewitt-Burbidge Catalogue (Hewitt & Burbidge 1993) which have redshifts $2.0 \leq z \leq 2.2$. The average redshift is $z = 2.09$ and the average $(B\text{-}V)ave = 0.26 \pm .18$ (mean deviation). So we see the measured $B\text{-}V = 0.43$ for the QSO is somewhat reddened but within the average deviation. But if we compare the B-V of this ULX with fainter apparent magnitude QSOs from the Hewitt-Burbidge Catalogue we find that it is about 0.1 to 0.2 mag. bluer than average."*

It seemed at the time that the case was so strongly made that urgent revision of the redshift distance ladder would follow. It did not, and publication in the Astrophysical Journal (ApJ) was made conditional upon the inclusion of a contrived argument suggesting that it was in fact a background object. The authors had no option but to accede.

Notwithstanding the issue of foreground or not, Burbidge et al insist that the close alignment of so many ULXs with host galaxies cannot be written off to chance. *"In the last few years observations from Chandra and XMM-Newton have shown that there are many discrete, powerful X-ray-emitting sources which lie close to the nuclei of spiral galaxies, often, apparently inside the main* *body of the galaxy (Foschini et al. 2002a, 2002b; Pakull and Mirioni 2002; Roberts et al. 2001; Goad et al. 2002). Typical separations are from ~ 1′ to 5′. Since they are emitting at power levels above about 1038.5 erg sec*$^{-1}$*, they cannot be normal X-ray binaries. They have been called ULX (Ultraluminous X-ray sources) or IXO, intermediate luminosity X-ray sources (Colbert and Ptak 2002). It has been concluded that they are either binary systems with black hole masses in the range 102 – 104* $M_{\odot}$ *or they are X-ray emitting QSOs. Last year Burbidge et al. (2003) suggested that they were likely to be QSOs with a wide range of redshifts. If this is the case, the fact that they are all very close to the centres of the galaxies suggests strongly that they are physically associated with these galaxies and are in the process of being ejected from them. This is a natural conclusion following from the earlier studies by Radecke (1997) and Arp (1997), who showed that there is a strong tendency for QSOs to cluster about active spiral galaxies. Many cases of this kind have been found (eg. near the AGN galaxies NGC 1068, 2639, 3516, 3628). The typical separations between these QSOs and the galaxies in these cases are ~ 15′ - 20′. It is clear that if the separations are smaller than this, as is the case in general for the ULXs, there will be an even greater likelihood that the QSOs and galaxies are physically associated."*

They conclude, "*We have clearly demonstrated that the ULX lying 8 arc sec from the nucleus of NGC 7319 is a high redshift QSO. This is to be added to the list of more than 20 ULX candidates which have all turned out to be genuine QSOs. Since all of these objects lie within a few arc minutes or less of the centres of these galaxies, the probability that any of them are QSOs at cosmological distance, observed through the disk of the galaxy, is negligibly small."*[21]

In Research on candidates for non-cosmological redshifts [18], L-C & G point out the connections linking elements in the system:

"MCG 7-25-46 (or UGC 7175) was also analysed by Arp: a system with two galaxies connected by a bridge and with different redshift: z = 0.003 for the main galaxy and z = 0.098 for the small one. From our analysis, it is relevant that the bridge has the same redshift as the main galaxy…and we could produce a 2D map of the Hα emission…also observed perturbation, due possibly to interaction, in the higher redshift object. As in NGC 7603, one could ask why MCG 7-25-46 ejects a filament/bridge in the direction of the discordant redshift companion and not in other directions. There is the further interesting observation that the Hα emission at z = 0.003 finishes exactly where the Hα emission of the galaxy with z = 0.098 begins (which is supposed to be in the background), there is no overlap in the two emissions. Is it not a strange coincidence? This coincidence reminds us of the case in Stephan's Quintet, and the Hα bridge connecting NGC 7320 to the other galaxies that we have analysed with the same technique: it also happens in this case that the Hα with discordant redshift begins exactly where the major component redshift finishes in the bridge connecting NGC 7320 to the rest of the group; in such a case, there was no overlapping of both Hα emissions with different velocities. A coincidence? Perhaps. There are also other coincidences in Stephan's Quintet, such as

radio emission isophotes with 6600–6700 km/s tracing quite exactly the shape of NGC 7320 (≈ 800 km/s) and connecting it with the rest of the Quintet."

4.2.4 Double radio source 3C343.1. Dr Arp and the Doctors Burbidge published the results of their study in 2004: *The Double Radio Source 3C343.1: A galaxy-QSO pair with very different redshifts*. [5] They summarise the case as follows: *"The strong radio source 3C343.1 consists of a galaxy and a QSO separated by no more than about 0.25''. The chance of this being an accidental superposition is conservatively ~1 × 10^{-8}. The z = 0.344 galaxy is connected to the z = 0.750 QSO by a radio bridge. The numerical relation between the two redshifts is that predicted from previous associations. This pair is an extreme example of many similar physical associations of QSOs and galaxies with very different redshifts... We have discussed this pair of objects from the standpoint of whether there could be any 'a posteriori quality' to their extraordinarily small probability of being an accidental configuration. In fact we have found that this pair has properties very similar, but more extreme than most of the other associations of QSOs and galaxies which have been discovered earlier — properties of nearness, alignment, disturbances, connections. Since there are very few cases that have been examined this closely, the possibility is raised that there are more such associations to be discovered."*

4.2.5. NEQ 3. This is a system of 3 compact objects with angular spread < 6 arcsecs, aligned with the minor axis of a lenticular galaxy at ~17 arcsecs. Although it is an intriguing astronomical system, the only prior study of NEQ3 had been by Arp, some 27 years previously. He had noted a filament connecting the galaxy and the 3 outriggers, and L-C & G studied the system in some detail. L-C & G: *"A filament is situated along the optical line connecting the main galaxy and the three compact objects. We have obtained a better image of the filament (previously noted by Arp) along the line of the minor axis of object 4…again, as in NGC 7603, we have seen that the system is even more anomalous than previously thought: we now have three different redshifts instead of two. Also as in NGC 7603, the origin of the filament is a mystery; it is supposed to be due to the interaction of the pair 1,2 with some other galaxy to the south-west. Where is this object? It seems that object 4 is the galaxy concerned, and this would imply anomalous redshift."*[22]

4.3. Redshift survey of local galaxies. David G Russell (as distinct from David M Russell of the University of Southampton, who publishes also in astrophysics) is engaged in an ongoing, novel study of spiral galaxies in the Virgo Cluster, using the Tully-Fisher Relationship (TFR) to identify those galaxies that were physically bound in the cluster, and then comparing their mean redshift values. TFR describes an empirically derived correlation between the spin rate and luminosity of certain classes of spiral galaxy. It is an extremely robust ratio, remaining tight over at least 7 magnitudes, which represents a factor of 600 in luminosity. It follows the simple theorem that spin rates are proportional to mass; mass in galaxies translates into stellar population; and stars are what give a galaxy its shine. If the intrinsic luminosity of the galaxy is known, comparison with apparent luminosity will give distance from point of observation via the inverse square law for light dissipation. Doppler shifts measured at the approaching and departing limbs of sufficiently oblique galaxy disks deliver a reliable value for rotation rate, and then intrinsic surface brightness can be estimated via the TFR.

In 60 years of use, the TFR principle has entrenched itself as a major component in the extragalactic distance scale, and is widely regarded as the second most reliable measure of remoteness at that scale, or, to put it another way, it the most important secondary measure of cosmological distance. A detailed exposition of the Tully-Fisher Relationship may be obtained in reference [23]. Dr Russell's initial publication in this field was 2003, Intrinsic Redshifts in Normal Spiral Galaxies [24]. It formed the launch pad for a series of papers on TFR calibrations of both B-band and I-band in spiral galaxies in the Virgo cluster. Assuming a (then) commonly agreed upon Hubble Constant of 72 km sec^{-1} Mpc^{-1}, Russell identified excess redshifts in normal ScI galaxies that were clearly non-cosmological and consistent with Arp's intrinsic redshift hypothesis. In addition, he found that giant Sab/Sb galaxies in the same cluster showed evidence of intrinsic redshift expressed as extreme negative motion. This was consistent with Arp's 1988 observation that Sbs commonly show redshift deficits relative to other species in a cluster [25]. Russell followed with two more papers expanding the same theme [26,27].

In his 2003 paper Intrinsic Redshifts in Normal Spiral Galaxies [24], Russell states, *"The Tully-Fisher (TF) relation calibrated in both the B-band and the I-band indicates that*

(1) "The redshift distribution of Virgo Cluster spirals has a morphological dependence that is inconsistent with a peculiar velocity interpretation.

(2) *"Galaxies of morphology similar to ScI galaxies have a systematic excess redshift component relative to the redshift expected from a Hubble Constant of 72 km s^{-1} Mpc^{-1}.*

(3) *"Pairs and groups of galaxies exist for which the TF relation provides excellent agreement among individual members, but for which the group redshift deviates strongly from the predictions of the Hubble Relation.*

"It is again found that morphology plays a role as these galaxies are all of Hubble types Sbc and Sc. The overall results of this study indicate that normal Sbc and Sc galaxies have a systematic excess redshift component relative to the predictions of the standard Hubble relation assuming a Hubble Constant of 72 km s^{-1} Mpc^{-1}. The excess redshifts identified in this analysis are consistent with the expectations of previous claims for non-cosmological (intrinsic) redshifts.

"The most dramatic result in Table IV is the extreme excess redshifts of the ScI/Seyfert group. Since three of these galaxies (NGC 4321, NGC 4535, NGC 4536) have Cepheid distances it is unlikely that this phenomenon results from inaccurate distances (see also Arp 2002). The result cannot be attributed to the morphological density relation (Dressler 1980) because the redshift excess is systematically positive and the galaxies in question are on both the front and backside of the mean cluster distance. ***Adopting a strict velocity interpretation of***

galaxy redshifts requires that as a group the giant Sb galaxies are approaching the Milky Way with a mean velocity of -898 km s^{-1} while the giant ScI galaxies are receding from the Milky Way with a mean velocity of +824 km s^{-1}.”

The implication of Russell’s last sentence is crucial—the standard redshift interpretation of velocity would have us believe that galaxies migrate peculiarly by *type!* The notion of species-dependent universal expansion is an exceptionally strong argument against the Hubble Law.

In *Intrinsic Redshifts and the Tully-Fisher Distance Scale* [24], Dr Russell summarises thus, *“The Tully-Fisher relationship (TFR) has been shown to have a relatively small observed scatter of ~ +/-0.35 mag implying an intrinsic scatter < +/-0.30 mag. However, when the TFR is calibrated from distances derived from the Hubble relation for field galaxies scatter is consistently found to be +/-0.64 to +/-0.84 mag. This significantly larger scatter requires that intrinsic TFR scatter is actually much larger than +/-0.30 mag, that field galaxies have an intrinsic TFR scatter much larger than cluster spirals, or that field galaxies have a velocity dispersion relative to the Hubble flow in excess of 1000 km s^{-1}. Each of these potential explanations is contradicted by available data and the results of previous studies. An alternative explanation is that the measured redshifts of galaxies are composed of a cosmological redshift component predicted from the value of the Hubble Constant and a superimposed intrinsic redshift component previously identified in other studies. This intrinsic redshift component may exceed 5000 km s^{-1} in individual galaxies.”*

More recently (2008), Russell switched to K-band analysis, and found that distances changed. In private correspondence with this author, Dr Russell stated, *“The basic results haven’t changed, are improved actually…the tests that indicate that deviation is real are much more compelling.”*[28]

4.4. Large-scale structure: The “Finger of God” and Kaiser Effect anomalies in galaxy clusters. J. C. Jackson [29] in 1972 found an observational effect in galaxy distribution data that caused clusters of galaxies to appear elongated when expressed in redshift space, taking on the appearance of “fingers” pointing towards Earth. The virial association of high velocities in clusters with their gravitation distorts the Hubble redshift relationship, and consequently, distance measurements are inaccurate, that is, anomalous according to the model.

N. Kaiser [30] in 1987 revealed a related but smaller effect occurring in even larger structures. These *“Pancakes of God”* are attributed to line-of-sight distortion unrelated to distributions predicted by the virial theorem. They are thought to arise instead from infall motions of galaxies as the cluster forms, based on the assumption that high-redshift objects are nascent. Notwithstanding the evolutionary explanation and the somewhat arbitrary scalar cut-off of virial distribution, the redshift/structure relationship is anomalous.

Furthermore, redshift-mapped large structures give anomalous results in terms of the Cosmological Principle, a fundamental requirement of the Standard Model of Cosmology, and the mathematical bedrock of universal expansion theory. In the paper *Large*

Scale Structure in the Universe Indicated by Galaxy Clusters, [8], Neta Bahcall states *"The results imply the existence of very large-scale structures with scales of ~100—150h^{-1} Mpc…[] …The cosmological principle states that the Universe is homogeneous and isotropic. Observations of galaxies and clusters, however, show inhomogeneities and structure on all scales studied so far…When does the Universe become homogeneous? How does the clumpy distribution of luminous matter fit with the highly isotropic distribution of the microwave background radiation on the largest scales? The answers are not known yet."* Either the redshift data are anomalous, or the implied spatial properties do not fit, or both.

They are anomalous also for the λ-CDM model. Bahcall: *"The large scale structure results discussed in this review, however, constitute a difficulty for CDM. Considerable evidence for structure on scales ≥ 30h^{-1} Mpc has now been accumulated by a number of investigators; this large-scale structure (and velocity) cannot be matched by unadorned CDM models…If these largest scale results are confirmed by new and deeper observations, it will be damaging to the simplest CDM models."* [8].

5. Periodicity

In 1967, Burbidge and Burbidge detected what appeared to be a quirky statistic in the redshifts of quasars: A preferred value of z = 1.95. In 1971, by which time the quasar database had expanded significantly, J. G. Karlsson established that quasar redshifts do indeed have preferred peaks, given by the formula $(1 + z_2)/(1 + z_1) = 1.23$, and tend to fall into the series z = 0.061, 0.30, 0.60, 0.91, 1.41, and 1.96. This phenomenon was verified by W. G. Tifft in a series of studies from 1976 to 1997, referenced in the supporting paper *Discrete Components in the Radial Velocities of ScI galaxies* by Bell, Comeau, and Russell [31]. Burbidge and Napier found in 2000 in their paper *The Distribution of Redshifts in New Samples of Quasi-Stellar Objects* [32] that, *"The redshift distributions of the samples are found to exhibit distinct peaks…identical to that claimed in earlier samples but now extended out to higher redshift peaks…predicted by the formula but never seen before."* In March 2006, M. B. Bell and D. McDiarmid of the National Research Council of Canada published a paper entitled *Six Peaks Visible in Redshift Distribution of 46,400 Quasars…* [33]. They find, *"The peak found corresponds to a redshift period of Δz = ~0.70. Not only is a distinct power peak observed, the locations of the peaks in the redshift distributions are in agreement with the preferred redshifts predicted by the intrinsic redshift equation."* Most recently (2008), Arp and Fulton published their findings *The 2dF Redshift Survey II: UGC 8584 – Redshift Periodicity and Rings* [34]: *"UGC 8584 was selected by a computer program as having a number of quasars around it that obeyed the Karlsson periodicity in its reference frame…9 of the nearest 10 quasars turned out to be extremely close to the predicted values."*

6. Notes

6.1. Instrument time. Fortunately for science, redshift is, as we have seen, a defining property of celestial objects, and is often included in the array of measurements taken from observation. These data are then usually available to succeeding analysts who may not have been in the team that commissioned the observations in the first place. In terms of research into cluster populations (Russell), the denial of instrument time based on the "consensus status" of the researcher and/or the objects under investigation has little or no impact. However, in the cases of investigations into the specific density on the sky of quasars and AGN, and physical connections between objects (Arp, Burbidge, Lopez-Corredoira), these restrictions are onerous indeed.

6.2. Gravitational lensing. *"Weak gravitational lensing by dark matter has also been proposed as the cause of the statistical correlations between low and high redshift objects, but this seems to be insufficient to explain them, and cannot work at all for the correlations with the brightest and nearest galaxies. More recently, Scranton et al. have contradicted these results and have claimed that the correlation between QSOs and galaxies from the SDSS-survey is due to weak gravitational lensing. Indeed, what they have found was an ad hoc fit of the halo distribution function to an angular cross-correlation with very small amplitude of faint galaxies with QSO candidates selected photometrically (5% of this sample are not QSOs). Who knows what the origin is of this very small cross correlation? In any case, as said, no explanation of gravitational lensing for correlations with the brightest and nearest galaxies is possible in terms of gravitational lensing, for instance for the high amplitude angular correlation found by Chu et al. (and) Scranton et al., even if they were right, have not solved the question of the correlation of galaxies and QSOs, because cross-correlations with bright and nearby galaxies, which are the most significant, are still without explanation in standard cosmological terms."* M. Lopez-Corredoira and C. M. Gutierrez, *Research on candidates to non-cosmological redshifts* [18] (in E. J. Lerner and J. B. Almeida, Eds., 1st Crisis in Cosmology Conference, CCC-1, AIP Conference Proceedings, Vol 822, 2006 [59]).

7. Discussion & Conclusion:

The physical association between objects with different redshifts has been made abundantly clear in observation. In the documentary programme *Universe—the Cosmology Quest* [37], Geoff Burbidge puts it most succinctly: *"If you see two objects close together with very different redshifts, you only have one of two explanations. One is that a large part of the redshift has nothing to do with distance. The other is that it's an accident. So the real issue…is* ***how frequently do you expect to see accidents?****"*

If we find in observation that the Hubble redshift relationship is subject to notable exceptions, which certainly appears to be the case, I would hope that we would take a healthy interest in them. Just one such exception, reasonably verified, would suffice to cast doubt upon the reliability of redshift/distance theory, with far reaching consequences for astrophysics.

High-resolution galaxy images acquired by powerful telescopes, and statistically significant samples from contemporary deep space surveys tell us clearly that we have a challenging situation. Galaxies are troubled, displaying morphological dynamics that defy convenient, simple classification into distinct species. We have seen images of galaxies giving vent to their inner turmoil by spewing matter into the close environment, in the form of clouds, filaments, jets, and compact objects, probably including quasars.

Whichever way we treat quasars in cosmological modelling, they are peculiar. If they are distant, they are too bright to be true, and if they are nearby, they call for extraordinary physics to explain ejection. The holographic map of galaxy clusters in redshift space produces fingers and pancakes that point towards us in a way that exaggerates our significance in the scheme of things, and in any event are unlikely to exist in real space. Additionally, the possibility of super-galactic-scale structure weighs against the Cosmological Principle. Measurements of the macro universe are odd, revealing exceptions more than the rule.

How we react to anomalous results is going to be crucial to the future of cosmology, the empirical foundation of astrophysics, and indeed, possibly the importance of scientists to the progress of society generally. How we incorporate discordant results into our knowledge base and theoretical structures will in my view define the relationship between astronomy and cosmology, and may well determine whether such a link can exist at all. This paper asks the questions, without implicitly stating answers, *"Do quasars present a compelling case that some additional cause of cosmological redshift, other than velocity, is prevalent in the Universe? Does the implied presence of relatively high-redshift galaxies in clusters with lower redshift objects not support this contention? Do redshift-defined large scale structures impinge upon the notion of an expanding, isotropic Universe?"*

The anomalies result always, and exclusively, from our comparison of the data with theoretical models. The data and images are not in and of themselves anomalous, and cannot be intrinsically peculiar. Prof Bahcall puts it neatly: *"The advantages of 'What you see is what you get' (i.e. $\Omega \cong 0.2$ as observed, and only baryons, with no unknown particles) may be more important than the elegance of the solution."* (Neta Bahcall, [8]).

The signs indicating that the standard redshift/distance relationship model is critically flawed are numerous and varied, and only one piece of evidence speaks in favour: The Hubble Law itself. Whether we continue to pursue the mysteries of the larger-scale cosmos with our eyes wide shut, or instead with due circumspection take notice of the measurable reality surrounding us, time will tell.

8. Acknowledgements:

None of those mentioned here necessarily agrees or disagrees with any argument or inference made in this paper. I do not wish to imply that those who graciously offered me help are thereby indelibly stamped with the same philosophical and scientific persuasion as I am.

As always, Martin Lopez-Corredoira has taken time to share his experience with me, and review my work with a friendly, critical eye. Dave Russell is ever courteous, never too busy to swap data and ideas. Chip Arp has been magnanimous as usual, giving me free rein with his published work. Geoffrey Burbidge offered some incisive advice of a more general nature, which was gratefully received.

I received help also from Tom Van Flandern, Eric Lerner, Paul Jackson, Oliver Manuel, Tony Bray, and Sir Patrick Moore. I am sincerely grateful for their unstinting efforts to propagate real science. This paper is dedicated to my late mentor and teacher, South African solar astronomer Robert Bennett Blore, to whom my debt is incalculable

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