THE PROBLEM OF THE REDSHIFTS

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It is my intention in this brief paper to present once again some of the evidence which appears to show that a major contribution to the redshifts of QSOs and perhaps some galaxies is not associated with the expansion of the universe. The evidence continues to grow and it is of four kinds:

(a) Evidence concerning galaxies with discrepant redshifts.

(b) Connections between QSOs and galaxies.

(c) Statistical information concerning the association of QSOs with galaxies.

(d) Individual and very striking examples of pairings between QSOs and bright galaxies.

If any part of this evidence is accepted it means that we cannot trust the redshifts of QSOs and perhaps some galaxies as distance indicators. It would suggest that the majority of the QSOs at least are no further away than ~ 100 Mpc. In turn this means that:

(1) Evidence for the strong evolution of QSOs as a function of epoch evaporates.

(2) Absorption in QSOs cannot be due to intervening galaxies and intergalactic clouds.

(3) Gravitational lenses as explanations of pairs of QSOs with identical redshifts cannot be correct.

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(4) Superluminal motions and certainly those requiring highly relativistic velocities don't occur.

Three years ago at the IAU Symposium No. 92 in Los Angeles (1) I discussed much of the evidence that I shall describe today. More evidence is available, but as far as I am aware none of the evidence given there and elsewhere (2,3) has been refuted. Consequently while I shall describe some of it again I shall be brief.*

GALAXIES WITH DISCREPANT REDSHIFTS

In this category of evidence we have small groups of galaxies such as Stefan's Quintet and VV172 where one object has a redshift very different from the others. There is extensive literature on this subject going back at least a decade. The statistical arguments underlying such evidence have often been discussed. Each case must be accidental if non-cosmological interpretations of the redshift differences are to be avoided.

More recently a number of galaxies with very different redshifts and luminous bridges between them have been shown (4,5). As far as I am aware no one has provided any evidence which disproves the existence of these bridges.

CONNECTION BETWEEN QSOs AND GALAXIES

The pre-eminent case of this kind is NGC 4319 and Markarian 205 (6). When Arp first claimed to show that a luminous connection existed, his paper was followed by a series of papers in which authors either argued that the connection did not exist, or was due to isophotal overlap between the two images (7,8,9). More recently Stockton, Wyckoff and Wehinger (10) claim to have detected a background galaxy which has MK 205 as its nucleus. Most recently Sulentic (11) has carried out a detailed study using digital image processing on the best photographic plates available of NGC 4319 and MK 205, and has concluded that there is indeed a connection with a continuous spectrum between the two systems which can be traced into the nuclear region of NGC 4319.

While this investigation will undoubtedly be subjected to more scrutiny, I conclude that it provides prima facia evidence that the connection is real.

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*Illustrations of many of the more striking objects appear in (3) and will not be repeated here.

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A second case of a similar kind is that of the radio galaxy 3C 303 where an N system with a redshift z = 0.141 gives rise to a radio structure which contains three faint optical objects one of which is a QSO with a redshift z = 1.57 (12).

STATISTICAL INFORMATION CONCERNING THE ASSOCIATION OF QSOs WITH GALAXIES

The statistical evidence is of several kinds. It is of:

(a) QSOs with $z \leq 0.45$ and galaxies at the same redshift.

(b) QSOs at all redshifts with bright galaxies which all have very small redshifts.

(c) QSOs and lists of both bright and faint galaxies.

We discuss these in turn.

(a) Stockton (13) chose all known QSOs with redshifts $z \lesssim 0.45$ and looked for galaxies lying within 45 arcsec of them. He reported that 13 galaxies in 8 fields (out of 27 fields) have redshifts within 1,000 km/sec of the QSO redshift. He estimated that the probability that this could occur by chance is $< 1.5 \times 10^{-6}$. This is the primary evidence that some QSOs at least have redshifts of cosmological origin.

(b) Many QSOs have been found either by accident, or by searching close to bright galaxies with redshifts less than a few thousand kilometers a second. Many but not all of these were found by Arp. Approximately 100 of the QSOs in the catalogue of Hewitt and Burbidge (14) are in this category. I have carried out a statistical study from this sample of the QSOs lying within 10' of bright galaxies (3) and a table giving the results is reproduced below.

TABLE 1

A COMPARISON BETWEEN THE NUMBERS OF QSOs FOUND NEAR BRIGHT GALAXIES (N_0) AND THE NUMBER EXPECTED BY CHANCE (<n>)

Apparent Magnitude	$\theta \lesssim 180''$		$\theta \lesssim 600''$	
	N_0	<n>	N_0	<n>
$\lesssim 17$	5	0.69	11	7.8
$\lesssim 18$	14	2.38	28	25.9
$\lesssim 19$	30	6.93	58	77.9
$\lesssim 20$	45	23.2	83	259

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The surface density of QSOs used in this study is based on surveys which are not in dispute. As can be seen from Table 1 the result is highly significant for $\theta \leqslant 3'$. The fact that far fewer QSOs are seen beyond 3' from the galaxies than are expected by chance, either means that in making the calculations the surface density in the field was overestimated (i.e., there are far fewer QSOs in the field in general than the surveys would suggest), in which case the significance of the results for QSOs close to the galaxies is increased; or that the fields far out around galaxies have not been well searched. It is possible that there is no such thing as a field density of QSOs, but that they all originate in the galaxies, and fade before they move far away from them.

Another statistical survey of QSOs close to bright galaxies was that made in 1971 of the 3C QSOs and galaxies in the Shapley-Ames catalogue (15). This also showed a strong positive effect, but some later studies using other samples of radio QSOs failed to confirm it.

(c) More recently Seldner and Peebles (16) carried out a statistical analysis applying the cross correlation technique to the QSOs in the Burbidge, Crowne, and Smith catalogue (17), and galaxies in the Lick Catalogue (18). They have found statistically significant evidence of a correlation between the QSOs and the Lick counts of galaxies. Nieto and Seldner (19) have done a similar analysis using the bright galaxy catalogue of de Vaucouleurs et al (20) and have concluded that the only effect which may be real is due to a sub-class of QSOs.

Most recently Chu, Zhu, Burbidge and Hewitt (21) have done an extensive analysis using the cross-correlation technique on the QSO sample in (14) and galaxies in (20). They have found a strong positive result.

From all of these investigations I believe that the fairest statement which can be made is that there is strong statistical evidence that some QSOs are physically associated with galaxies at the same redshifts, but there is equally good evidence that many are physically associated with QSOs at very different redshifts.

INDIVIDUAL AND VERY STRIKING EXAMPLES OF PAIRINGS AND ALIGNMENTS BETWEEN QSOs AND GALAXIES

While statistical evidence is very important the primary evidence which often persuades scientists to rethink their ideas is evidence of individual events (in particle physics) or pictures (in astronomy). A good example with parallels for today is Wegener's original thinking about continental drift, which stemmed from simply noticing that the

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continents of the earth looked as though they could be fitted together and thus were probably once physically associated.

Particularly striking examples which bear on the redshift arguments are:

(1) It has been pointed out by Arp that 3 QSOs lie within 2' of the center of the bright spiral galaxy NGC 1073 (3). The fact that they each have redshifts at the peaks of the redshift distribution discovered long ago (22) i.e., z = 0.6, 1.4, and 1.95 is even more remarkable.

(2) The discovery by Hazard, et al. (23) of a very close (within 5") pair of QSOs (1548 + 114 a,b) with very different redshifts (1.901 and 0.436) close to a group of galaxies with redshift 0.432.

(3) Two triple systems of QSOs each exactly aligned, with the lines nearly parallel (24). The redshifts in each triplet are very different namely 2.1, 0.51 and 1.7 in the northern triplet, and 2.1, 0.54 and 1.6 in the southern triplet. "Pairs" in the sense that they have approximately the same redshifts, lie in approximately the same positions relative to the other members of the triplet.

As I have stated before it does seem that the large body of evidence for the existence of non-cosmological redshifts requires us to rethink many of our basic concepts in extragalactic astronomy.

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DISCUSSION

Chincarini: Is there any possibility that the correlation between angular separation and the distance from the galaxy is due to bias in the evaluation of the selected areas? (Their envelope runs parallel to the correlation line.)

G. Burbidge: Selection effects are present, as Browne and others have pointed out. However, I do not believe that they can account for the effect.

Nieto: About the specific question of QSO-galaxy associations, I would like to mention two contributions in collaboration with M. Seldner (Astronomy and Astrophysics, to be published) and with R. Bacon (submitted preprint) that are presented in this symposium as posters. The second one suggests a possible interpretation in terms of gravitational lenses due to individual stars in galactic haloes.

About "abnormal" associations between galaxies, the use of conventional distance criteria from a surface photometry study in collaboration with L. Tiennot of NGC 4156 (claimed to be associated by Arp with NGC 4151, whose redshift is much smaller) suggests that NGC 4156 is at its cosmological distance, and is in fact physically associated with a faint compact galaxy having the same redshift.

G. Burbidge: Your results are interesting. However, I feel that alignments of QSOs across bright galaxies make gravitational lens explanations very doubtful.

R. Ellis: Regarding Chincarini's comment, such a controlled experiment to test the significance of the angular separation-redshift effect you present has been performed. Several years ago Ian Browne (M.N.R.A.S.) showed that using a technique similar to that employed by Arp, one could derive a similar relationship between normal

galactic stars and galaxies. The effect is entirely due to the selection procedure as he has repeatedly stressed to you.

G. Burbidge: Browne has certainly argued that the relation between θ and the distances of the bright galaxies is due to observational selection. However, I think the precision of the selection and its recent extension by Arp make this very unlikely.

Abell: I am unaware of any complete survey about a randomly selected sample of galaxies chosen, before knowledge of quasars near them in direction, and in which quasars have been searched for to a given limiting magnitude and to a given radial distance from the galaxies, both specified in advance. Until this is done, statistics of quasars near galaxies, I think, should be regarded with caution.

G. Burbidge: You are correct. However, Arp, A. Hewitt, and M.H. Ulrich are now doing such a study with us. Also, I believe that the analysis that I carried out, comparing all known QSOs within 10' of galaxies with those expected by chance, is a conservative study, as was the original study of 3 CR QSOs and bright galaxies carried out by Burbidge et al. in 1972.

I might add that Arp seems to have a knack of finding QSOs near galaxies. Since he finds far more than are present in the field according to all other workers, this, in effect, is evidence that the effect is real.

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