Quasars and the Hubble Relation

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ABSTRACT

If active galaxies are defined as extragalactic objects with appreciably non thermal spectra then a continuity exists in redshift from the highest redshift quasars to low redshift Seyferts, AGNs and allied galaxies.

Evidence is discussed for this sequence to be an evolutionary track with objects evolving from high to low intrinsic redshift with time. At the end of this evolution the objects are nearly the same age as our own galaxy and they come to rest on the traditional Hubble relation.

Introduction

In 1963 some blue, stellar appearing objects in the sky were found to have high redshifts. They had been observed initially because they were radio sources, but then radio quiet and finally X-ray, stellar appearing sources were found with even higher redshifts. They were called Quasi Stellar Objects, soon shortened to QSOs or quasars. The main interest lay in their high redshifts which were interpreted as requiring great distances and therefore much higher luminosities than previously derived for any extragalactic objects.

Spurred on by the promise of learning about far reaches of the Universe, researchers of that day competed in discovering and analyzing more of these high redshift quasars. A disappointing result, however, soon became evident. These supposedly most distant objects showed no redshift - apparent magnitude (Hubble) relation. In the z - m diagram the clump of quasar points showed too much dispersion in redshift over a small range in apparent magnitude.

But in all the attention given to the high redshift objects little notice had been taken of objects that looked like QSOs except they had intermediate to low redshifts. They had been given various names such as N galaxies, compact galaxies, compact and radio nuclei, emission line and/or Seyfert spectra. All of them shared properties with quasars and formed a link between quasars and nearby galaxies. When these were plotted in the z - m diagram it became apparent that there was a broad relation between redshift and apparent magnitude.

This relation can be seen here in Fig. 1, the diagram of QSO and QSO-like objects which were known at that time (Arp 1968). Most recently Morley Bell (2007) has plotted all currently known quasars and active galaxies (106,958) in the diagram which is shown here in Fig. 2. This important result shows the large number of current points confirms the earlier seen sharp rise in redshifts between apparent magnitude 16 and 20. The problem is still, however, that the relation is broader and overall shows a different slope than the standard Hubble Relation.

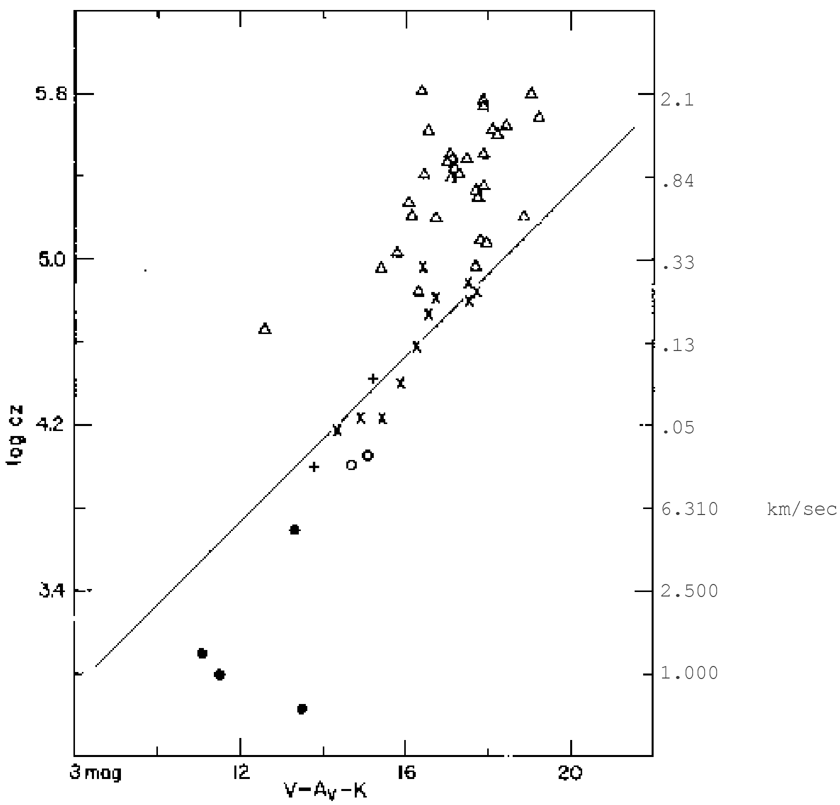

Fig. 1.— Redshift-apparent magnitude diagram for QSOs (*triangles*) compact Seyfert spectra (*plus signs*), radio galaxies with compact nuclei (*crosses*), two Zwicky compact galaxies (*open circles*) and Seyfert galaxy nuclei (*filled circles*). The Hubble relation line is for radio E galaxies. (Diagram from Arp 1968).

1. Evolution in the Hubble Diagram

The standard Hubble line in Fig. 1 is delineated by E galaxies which are the brightest in their clusters. The objects which fall above this line can be loosely referred to as "active". We will use in the following discussion the fact that their underlying spectra comprise non

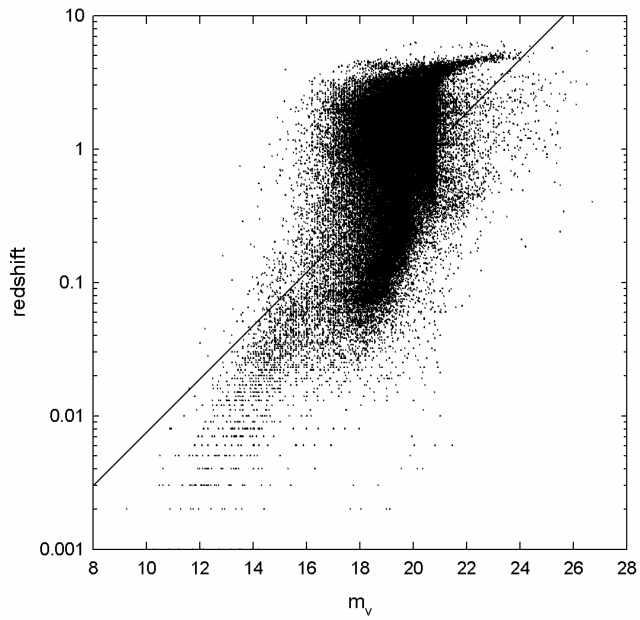

Fig. 2.— A plot by M. Bell (2007) of 106,958 quasars and active galaxies in the VCV Catalog. The solid line indicates Hubble relation for first ranked cluster galaxies.

thermal radiation which cuts off further to the red as they age. Observationally they span the extremes between the strong synchrotron continuum of the quasars to the far red cut off of the radio galaxies and finally to the oldest E galaxies which define the accepted Hubble line in Figs.1 and 2.

At this point we invoke the analyses of individual galaxy - quasar associations which establish that the quasars start out their life at very small luminosity and very high redshift (Arp 1998a, 2003). The general solution of the field equations then show that the particles near zero mass in recently created proto quasars increase as t^2 (t being the age of the created particles in the variable mass hypothesis; Narlikar 1977; Narlikar and Das 1980). In order to conserve momentum the particles slow down, lowering the temperature and helping the growing gravity to condense the plasma into a coherent proto galaxy (Actually the effect for which "dark matter" was invented.) After this rapid wringing out of the synchrotron energy, low mass atoms form and, because of increasing mass of the electrons in energy level transitions, the intrinsic wavelengths of emissiion and absorption, the redshifts, decrease. (Narlikar and Arp 1993.)

The resultant evolution in the z - m diagram is to brighten apparent magnitude initially followed by a deep decline of intrinsic redshift. Then a slower brightening of the object as star formation sets in. Looking at the distribution of objects in Fig. 2 would suggest a fast evolution in luminosity from about z = 6 to 4, then a long decline in intrinsic redshift from z= 5 to 0.1 and finally a slow approach to the Hubble line for high mass AGNs and somewhat below the Hubble line for low mass progenitors.

As they near the end point of their evolution (when their intrinsic redshift has stabilized near zero) they have ended up somewhat under the standard Hubble line (because most of them finish as intermediate bright galaxies). If one were to shut off the galaxy creating mechanism one would see the active galaxies disappearing with time leaving only the standard Hubble line.

The key to this is the solution of the generalized field equations based on the Hoyle Narlikar Machian gravitation theory as described by Narlikar (1977). For a constant mass approximation the theory reduces to the standard Einstein theory. However, the input from Mach's principle, suggests that the inertia of a newly created particle starts off as zero and grows with its age as it begins to get Machian contributions from more and more remote matter in the universe. The typical wavelengths emitted by a particle (such as the electron in a hydrogen atom) would reduce as its mass grows. Thus newly created matter would exhibit high intrinsic redshift. In such a framework, the intrinsic redshift of all galaxies created at the same time as our own will always give a perfect Hubble line because the look back time to a distant galaxy will always reveal it at a younger age when its intrinsic redshift was exactly that predicted by the Hubble law, cz = d x Ho.

In other words the Hubble line is the the line of repose, the evolutionary end for all galaxies of the age of our own galaxy. Younger galaxies have higher intrinsic redshifts which do not signal their velocity or distance but only their age and their luminosity at that time which can be much fainter than our own, contrary to the tenants of current astronomy.

2. Definition of active galaxy and QSO/AGN

The observational properties of the the quasars are their spectral characteristics and their mainly stellar images. But in my opinion an error in taxonomy was made when the term QSO was arbitrarily *defined* as an object more luminous than, $M_V \leq$ -23 mag. (For example, as listed in the Cetty-Véron and Véron Catalogue).

This meant that the definition depended on a theory about redshifts, not an observational property. The Nobelist Percy Bridgeman (1936) stressed the necessity for science to use operational definitions. If we follow that principle here we would suggest a definition along the following lines:

A QSO/AGN is A high surface brightness object with a non thermal energy spectrum.

Surface brightness is a quantity which does not depend on distance so we are not in the embarassing position of calling an object stellar at low resolution then a galaxy at higher resolution. As to the second criterion: If an object is composed of stars the spectral continuum falls off in the blue and red as bodies do when radiating at their effective temperature. If the energy spectrum is flatter the object is not dominated by stars. The flat continua in QSOs have long been identified as radiation from accelerating or decelerating charged particles (e.g. synchrotron radiation). Therefore we can empirically classify an object as active from its energy spectrum alone. Also, of course, by the presence of strong, broad, emission lines.

What to call the objects which look like QSOs but have moderate to low redshift? As Fig. 1 shows they go by a variety of names but usage required some blanket term and active galaxy nuclei (AGN) came to be used for galaxies with compact energetic nuclei and AGN galaxy for objects where the whole compact body appeared active (including therefore QSOs).

Fig. 3 shows these active QSO/AGN galaxies in the redshift - color plot. It emphasizes the fact that regardless of whether non thermal or thermal radiation is dominant, the evolution from QSO towards lower z active galaxies is accompanied by evolution to redder colors right up to the older galaxies of the kind which define the Hubble line.

2.1. Evolution of thermal and non thermal radiation

The defining characteristics of active galaxies can vary in relative amount. For example, if we utilize the fact that high energy particle radiation will decay faster than the low energy radiation we can arrange QSOs in order of the age of their energy burst by their blue cut

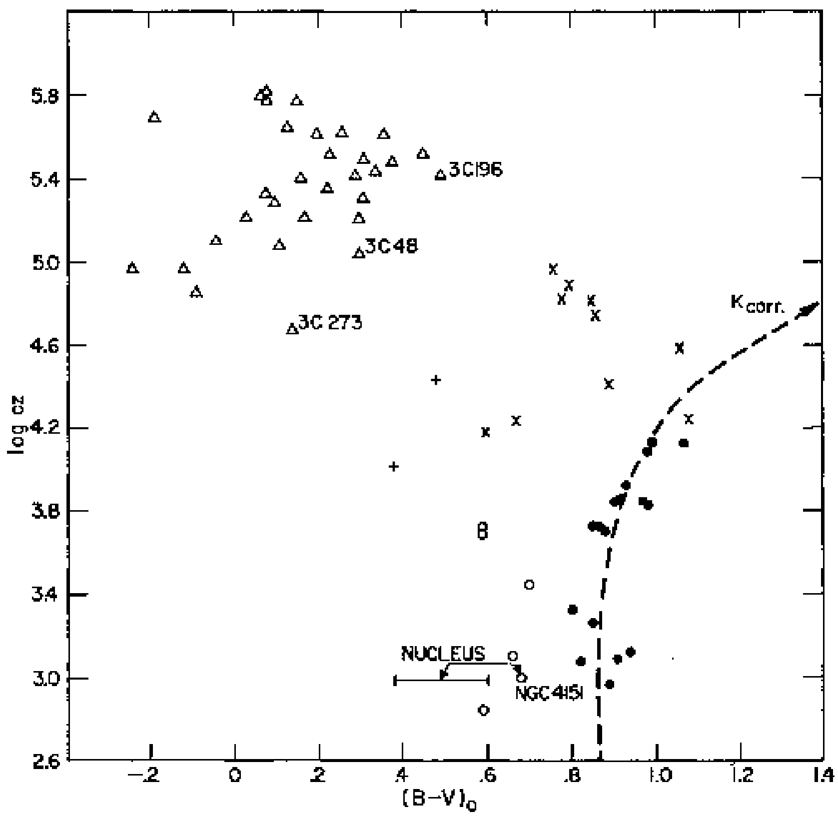

Fig. 3.— Color evolution in the redshift - color plane. Triangles are QSOs, crosses are radio galaxies with compact nuclei, two plus signs are compact galaxies with Seyfert spectra, open circles represent Seyfert galaxies and filled circles represent old E galaxies.

off. The high energy gamma and X-ray continua will quickly age into ultraviolet excess QSOs which in turn will age into infra red excess and finally into the longest lived, radio radiation. It is strongly suggested here that QSOs are evolving proto galaxies. They pass from a higher energy state of an ionized gas to beginning formation of atoms - from optical entities called Quasi Stellar Objects through compact radio galaxies and finally to normal, quiescent appearing galaxies.

How does this fit with the observations? A very few QSO's are strong gamma ray sources, more are X-ray sources, then UV excess QSO's and finally radio QSO's (originally called QSR's). Emphasis on the non thermal energy source enables an empirical model of the QSO phenomenon from the most energetic to the quietest extra galactic objects. It is interesting that this picture looks much like the conventional one of a QSO as the nucleus of a host galaxy. And indeed the nucleus of an active galaxy (AGN) would fit a QSO as we have defined it. If smaller in luminosity, however, a QSO could also be considered a smaller portion of an active nucleus with an initially higher redshift

2.2. Evolution of stellar content

Once star production has started in a QSO/AGN galaxy the spectrum can come to be dominated by thermal radiation. In such cases, however, the blueness of the optical spectrum still reflects bright, hot stars and a stellar population which is younger than, say a quiescent galaxy. Evolved red giant stars can be conversely used as an indicator of an old stellar population. This evolutionary continuity is well illustrated here in Fig.4.

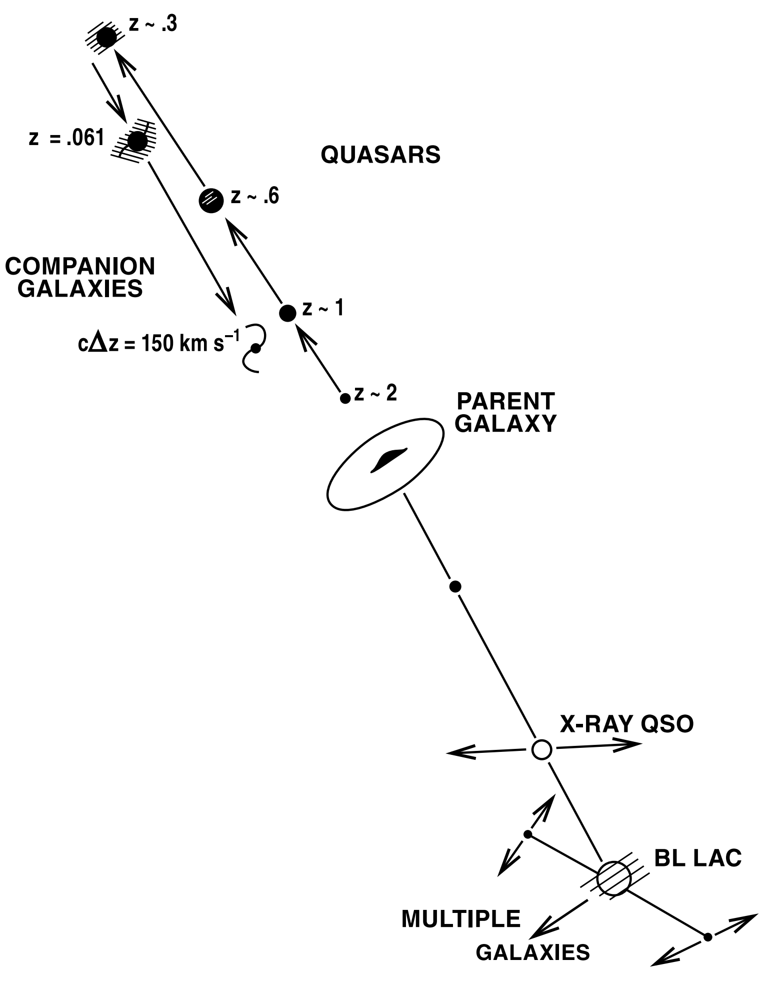

Fig. 4.— Summary of empirical data on evolution from high redshift quasar to low redshift companion galaxy. From Arp (1998b).

2.3. Luminosity of QSOs

In our operational definition of QSO we have not included the property of luminosity because the meaning of redshift has not been agreed on. QSO's do not obey a redshift-apparent magnitude relation. In order to obey a redshift-distance relation their luminosity range would have to be enormous. At present therefore the only way we could estimate distances to QSOs is by association with other extragalactic objects whose distances we accept.

Associations of high redshift quasars with low redshift galaxies have been accumulating for more than 40 years. But the majority of astronomers still firmly believe that QSO redshifts measure greater distances and hence have much greater luminosities. Instead of redshifts caused by recessional velocities in an expanding universe, however, we try to review here the evidence that they are intrinsic redshifts caused by younger matter in the QSOs.

In spite of General Relativity's assumption that matter in the Universe is homogeneously distributed, the galaxies are conspicuously grouped on the sky in clusters and super clusters. QSOs are more widely spread but also show clustering (although the somewhat similar redshifts differ too much to be velocity.) Denied for many years, current measures show a correlation with QSO's on the scale of about 1 degree. This is now interpreted as gravitational lensing of background QSOs by foreground galaxies. In a discussion of their own and 23 other analyses J. Nollenberg and L. Williams (2005) appear to accept correlations of galaxies and higher redshift quasars. But in commenting on possible gravitational lensing effects they note that greater amounts of cold dark matter are needed than in currrent models. Of course the alignments, pairings and connections of companion quasars to much lower redshift galaxies which are observed would exclude lensing. (Arp and Crane 1992; Arp 1998a, p177)

In the real world, however, galaxies are almost never isolated. The typical group consists of a dominant, lowest redshift galaxy with increasingly fainter and higher redshift companions up to and including QSOs. More and brighter QSO's are found around galaxies which have active (strong, non thermal) nuclei. The question is what is different about the companions compared to the dominant galaxy? The answer is the smaller galaxies tend to have younger stars, are less dynamically relaxed and more active. What more obvious conclusion could be made other than that they are younger? Add to this the fact that Erik Holmberg found as long ago as 1969 that companion galaxies tended to lie along the minor axes of disk galaxies. Is there any alternative to the their having originated in the nuclei of these larger galaxies and escaped along the line of least resistance? The evolution of quasars into companion galaxies was then strongly supported when it was shown that: "Pairs of quasars tend to lie even more closely along minor axis of ejecting galaxies."(Arp 1998a) The quasar result was confirmed by López-Corredoira and Gutiérrez (2006) with a larger sample of quasars.

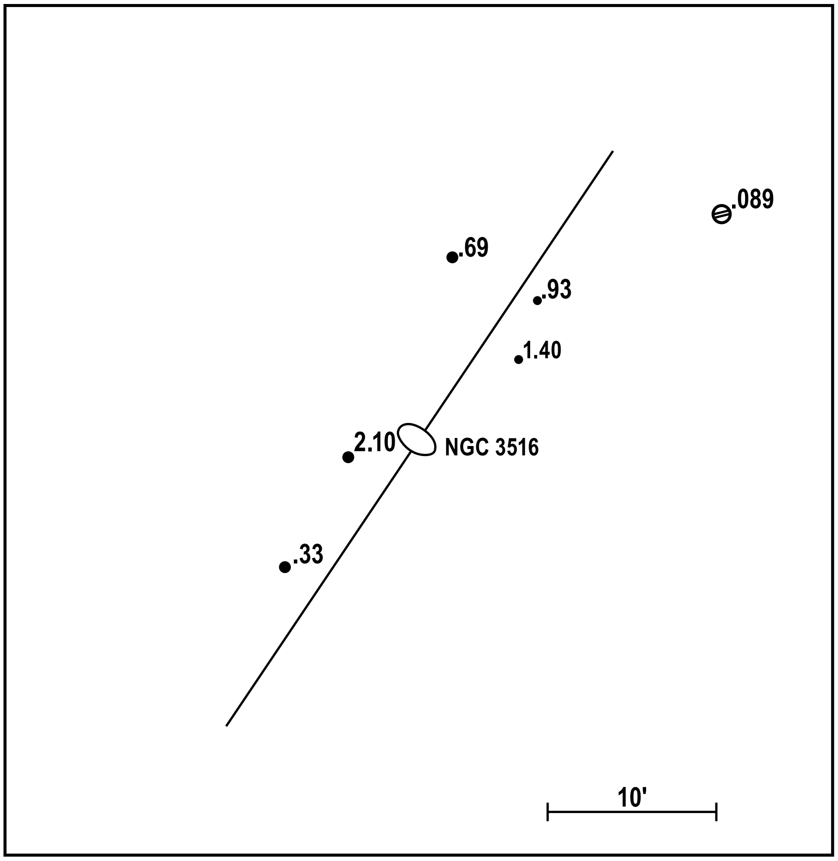

Fig. 5.— Rosetta stone of ejected quasars. The brightest X-ray sources in the field are quasars coming out along the minor axis of the Seyfert which is NGC 3516 at z = .009

One of the most striking cases is shown here in Fig. 5. The Chinese astronomers Chu and Xu realized the position of these six strong X-ray sources warranted their taking spectra of each optical identification. The closeness brightness and alignments identified them clearly as belonging to the central active galaxy. They turned out to be have apparent magnitudes from 18.5 to 20.2 mag. and if NGC 3516 has an absolute magnitude of M_V = -20.5 the five quasars would have luminosities of M_V -13 to -14. So the absolute magnitudes of the quasars are not in the range above -23 as they are supposed by current definition to be but instead are only three or four magnitudes brighter than the brightest stars in a low redshift spiral galaxy. The brighter, outer, X-ray compact galaxy (z = .089) is M_V = -18.2 which empirically confirms the evolution from quasar into active companion galaxy. Because of the commonly accepted M_V -23mag. lower limit in the definition of a quasar, however, it makes it very difficult to now relinquish the picture of a QSO as a super luminous galaxy and switch to the observational evidence for it being a small seed with its redshift as a parameter of evolution.

Summary

Quasars and active galaxies form a broad, continuous track in the Hubble diagram. It is argued that the evolution of QSOs must be along this sequence in both intrinsic redshift and apparent magnitude. If so, the evolution comes to rest near the age of our galaxy on the conventional Hubble redshift - apparent magnitude relation. It is considered highly significant that the more general solution of the Einstein field equations by Narlikar predicts evolution in intrinsic redshift and also exactly the Hubble relation for all galaxies created at the same time as our own galaxy.

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