

ORIGINS OF QUASARS AND GALAXY CLUSTERS

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The distribution on the sky of clusters of galaxies shows significant association with relatively nearby, large, active galaxies. The pattern is that of clusters paired equidistant across a central galaxy with the apparent magnitudes and redshifts of their constituent galaxies being closely matched. The clusters and the galaxies in them tend to be strong X-ray and radio emitters and their redshifts occur at preferred redshift values. *The central, low redshift galaxies often show evidence of ejection in the direction of these higher redshift clusters and the clusters often show elongation along these lines.* In most of these respects the clusters resemble quasars which have been increasingly shown for the last 34 years to be similarly associated with active parent galaxies. It is argued here that, empirically, the quasars are ejected from active galaxies. They evolve to lower redshift with time, fragmenting at the end of their development into clusters of low luminosity galaxies. The cluster galaxies can be at the same distance as their lower redshift parents because they still retain a component of their earlier, quasar intrinsic redshift.

1 Introduction

The distribution on the sky of clusters of galaxies started to be catalogued about 40 years ago by George Abell and collaborators. The cores of these clusters were predominantly old stellar population E galaxies which were believed to be mostly gas free and inactive. With the advent of X-ray surveys, however, it became evident that many clusters of galaxies were strong X-ray emitters. This evidence for non-equilibrium behavior was not easily explained. In these active properties, however, the clusters joined AGN's and quasars as the three principal kinds of extragalactic X-ray sources. Evidence then developed that quasars, and now some galaxy clusters were physically associated with much lower redshift galaxies. Surprisingly, the cluster redshifts were sharply peaked at the preferred quasar redshifts of $z = .061$, $.30$ etc. (This evidence has been discussed principally in Arp 1997; 1998a; Arp and Russell 2001).

It was possible to explore these properties further by plotting the distribution of galaxy clusters on other, larger areas on the sky. Some appeared projected along the spine of the Virgo Cluster. It turned out that the Abell clusters which were located in that part of the sky in the direction of Fornax fell in the same distinctively elongated area as the large, low redshift Fornax Cluster. (The Abell clusters reach to about $z = .2$ limit and the brightest galaxy in the Fornax cluster is $z = .0025$.) On the sky, in the direction of the giant, low redshift galaxy CenA/NGC5128, the Abell clusters fell almost exclusively along a broadening extension of the X-ray, radio jet going northward from this active galaxy. This is the same line occupied by a number of active, higher redshift galaxies which have been previously associated with ejection of radio plasma from CenA (Arp 1998a)

2 Abell Clusters A3667 and A3651

Abell 3667 is a rich cluster of galaxies studied in radio and X-rays by Rottgering et al. (1997) and Knapp, Henry and Briel (1996). It emits copious X-rays. (Grandi et al. 1999 estimate a total of 2,440 ct/ks in the hard band.) Its galaxies are bright, with the tenth brightest having an apparent magnitude of $m_{10} = 15.3$ mag. As Fig.1 shows, there is only one other rich cluster of bright galaxies for a wide area around. That second cluster is A3651, a cluster with almost identically bright galaxies, $m_{10} = 15.4$ mag. A3651 also is a bright X-ray emitter with a total of 430 ct/ks. The two form an obvious pair of galaxy clusters.

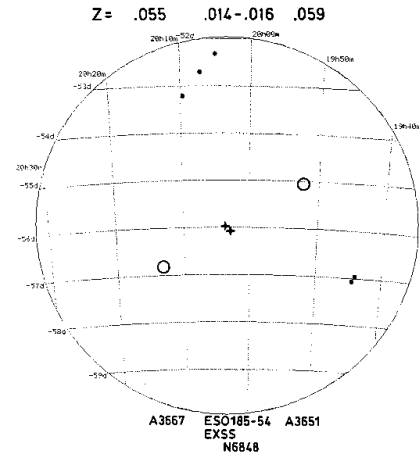


Figure 1: A particularly conspicuous pair of bright galaxy clusters with closely the same redshift is shown. Abell clusters with $m_{10} \leq 15.4$ mag are plotted as open circles. The remaining clusters in the field are designated as small filled circles and have $m_{10} \geq 17.3$ mag. The plus signs indicate the two brightest galaxies in a group with redshift near $z = .015$. The two paired clusters have redshifts near $z = .06$.

As Fig. 2 shows, A3667 is a very elongated cluster and points directly at A3651. The latter, in turn, is elongated back toward A3667. Almost exactly at the center between these two clusters are located some very bright galaxies.

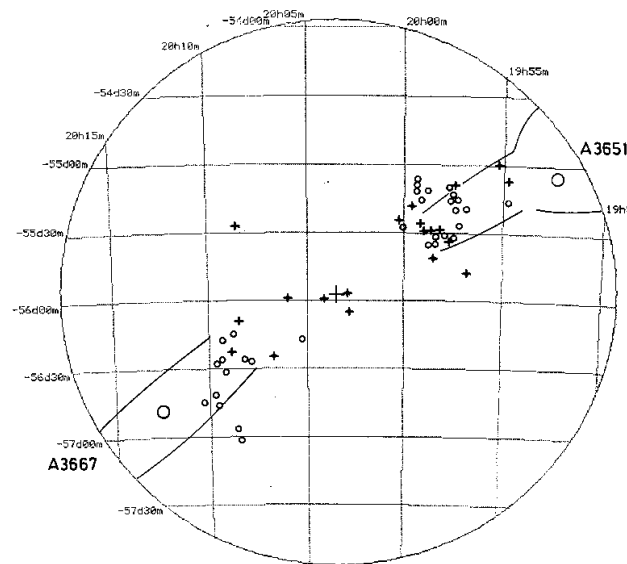


Figure 2: An enlarged plot of Fig. 1 shows the two clusters Abell 3667 and 3651 elongated toward the central group. The shape of these two clusters is indicated by boundary lines and their centers by large circles. On the inner edges individual galaxies belonging to the $z = .06$ clusters are indicated as small open circles. Individual galaxies belonging to the $z = .015$ group are shown as plus signs.

The remarkable result which appears is that the low redshift galaxies reach out from the center and actually intermingle with the higher redshift galaxies of both clusters

For example NGC6848 is 13.1 mag. An even brighter galaxy, however, which surprisingly, was missed by early cataloguers is ESO 185-54 at $m_B = 11.9$ mag. The latter is the dominant galaxy in a group of galaxies which is called MdCL 15 (Maia et al. 1989). Ramella, Focardi and Geller (1996) give a mean redshift of $z = .0157$ for this group.

The most startling result, however, is shown in Fig. 2 where the galaxies of redshift near 5,000 km/sec extend out on both sides of the central group and join and intermingle with the

galaxies of around 17,000 km/sec. The configuration is striking even when all the galaxies in the area are plotted (e.g. in SIMBAD) regardless of whether their redshifts are known or not. *The two elongated X-ray clusters appear to be continuous, linear extensions of the bright galaxies surrounding the central ESO 185-54 galaxy.*

Such a coincidence seems extremely unlikely to occur by chance. Since there is a strong precedent for pairing of higher redshift objects such as quasars and higher redshift companions across active galaxies, it is natural to ask whether the low redshift galaxy in the center is active. It turns out that ESO 185-54 is an early type galaxy with bright emission lines (da Costa et al. 1988; Sairava, Ferrari and Pastoriza 1999).

By good fortune the field was also observed for 5752 seconds with the ROSAT PSPC because of the presence of a white dwarf. That observation shows that ESO 185-54 is an extended X-ray source of about 27 ct/ks (broad band). Reduction of that exposure reveals that there is indeed a line of bright X-ray sources across the central X-ray galaxy, NW and SE, closely along the line to either of the two strong X-ray clusters. These sources are respectively double, triple and double. X-ray sources ejected from active galaxies are often double or triple (Arp 2001) suggesting that these are incipient quasars in the process of fragmenting and evolving into groups and clusters of lower redshift galaxies.

It can also be seen in the full PSPC broad band exposure that the majority of the fainter X-ray sources in both the central group around ESO 185-54 and the rich X-ray cluster A3667 are elongated toward each other in the same way the galaxies are in Fig. 2. The lines of X-ray sources 1, 2 and 3 in Fig. 5 are at p.a. = 137 and 305 deg. whereas the directions to the X-ray clusters are at about 125 and 300 deg. respectively. There is also a high redshift cluster of $z=.710$ along the line to A3667. Further details are given in Arp and Russell 2001.

Note Added. After the submission of this manuscript a preprint appeared by Vikhlinin, Markevitch and Murray (2001) reporting that Chandra observations of Abell 3667 showed a bow shock indicating that it was moving through the intergalactic medium with a speed of about 1400 km/sec. They state "The edge is . . . almost perpendicular to the line connecting subclusters A and B." that would place it at p.a. = 122 to 127 degrees. But it has just been noted in the closing paragraph above that the inferred line of SE ejection from the central ESO 185-54 is about p.a. = 125 deg. **We therefore now have direct evidence for Abell 3667 moving accurately out along this line of ejection which had been previously predicted.**

3 Recent Results on the Surroundings of M101

In addition to the case discussed above, the recent investigation by Arp and Russell (2001) reported a number of other cases of galaxy clusters paired across large, nearby galaxies. For example, an elongated cluster Abell 2256 pointing toward NGC 6217 (Atlas of Peculiar Galaxies No. 185) with quasars of $z = .380, .376$ and $.358$ closely around this X-ray jet galaxy. A pair of 3C radio quasars across another Atlas object, No. 227 had a probability of only about 2×10^{-9} of being accidental. This pair defined an ejection direction which ended on a total of 11 bright Abell clusters. A number of other cases were presented which had colinear strings of quasars and galaxy clusters emerging from large, low redshift galaxies which had negligible chance of being coincidences.

One of the cases presented in the above reference was that of two bright clusters of $z = .070$ and $z = .071$ aligned diametrically across the nearby, bright apparent magnitude, ScI spiral, M101. I had known that Markarian 273, regarded as one of the extreme "ultra luminous" infrared galaxies, was relatively close to M101 on the side toward the $z = .070$ galaxy cluster. But then I happened to notice the Hickson Compact Group No. 66 at $z = .070$. It turned out to be in the direction of M101 from the cluster with $z = .070$. While considering this development, an astronomer with a wider overall awareness, Amy Acheson, sent me a question: "Why do the

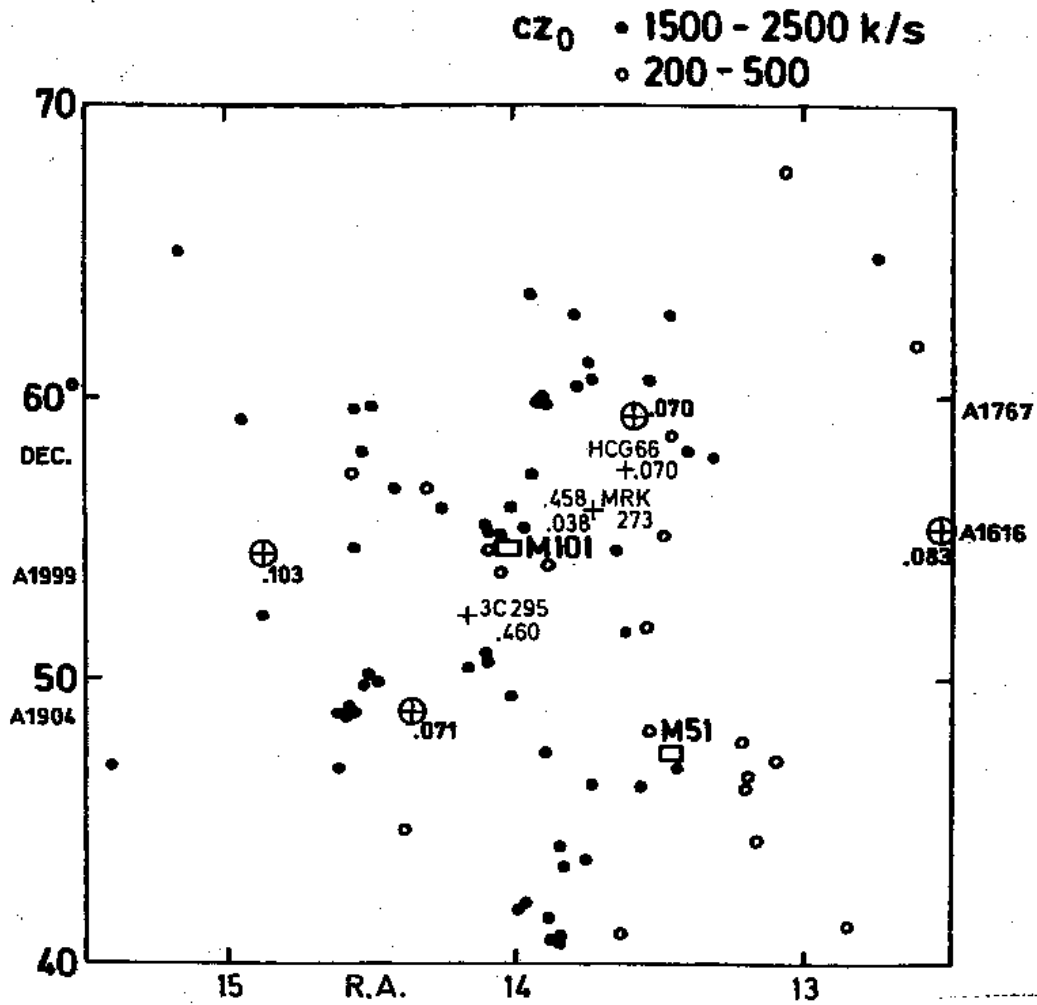


Figure 3: Over a wide area are plotted companions around the nearby galaxy, M101 (200 - 500 km/sec). Also galaxies of redshift 1500 - 2500 km/sec appear concentrated around M101, some in a predominantly NW - SE line. The circled plus signs represent all Abell clusters with m_{10} brighter than 16.3 mag. The clusters which pair NW -SE across M101 have mean redshifts of $z = .070$ and $.071$. The plus signs designate special objects described in text.

famous, active objects like 3C295 tend to fall close to bright galaxies?" I plotted the position of 3C295 as in Fig. 1 here and thereupon decided that I had to investigate in detail all the various kinds of objects around this particularly large, nearby galaxy.

The filled circles in Fig. 1 show a plot of all galaxies between $cz = 1500$ and 2500 km/sec over a large area around M101. They are very sparse on the edges of the region but increase steadily toward the center, to the position where M101 is located. It is difficult to see how this concentration toward M101 could be a selection effect since galaxies of both higher and lower redshift are scattered more or less uniformly throughout the area. (See Arp 1990 for details of this analysis.) Moreover, these galaxies form lines radiating from the position of M101 outwards. The line radiating NW - SE from M101, however, is the most populated. The open circles show low redshift companions of M101 reaching out into the same areas - demonstrating that physical association with M101 reaches out to this distance.

The latest update in Fig. 1, shown here, has marked the positions of the brightest Abell Clusters (As in the earlier Fig. 7 of Arp and Russell 2001). But also added are three plus signs showing the positions of Mrk 273, HCG 66 and 3C295. These three objects, along with

two bright Abell clusters fall roughly in the filament of galaxies which extend in the NW - SE direction which was identified in 1990.

Mrk 273 is one of the three major, ultra luminous infrared galaxies known (Arp 2001). It is remarkable that it falls this close to, and with this orientation with respect to M101. It is a strong X-ray and radio source and in this respect is similar to higher redshift, active objects ejected from more distant central galaxies. In the present case, however, the apparent brightness of both the central galaxy and the AGN imply a closer distance and account for the larger apparent separation (~ 3 deg.).

Further along in this direction we encounter HCG 66 (Hickson 1994). This is a compact chain of six galaxies four of which have redshifts which average to $z = .070$. As a group it is like a small, or sub cluster (albeit in a non equilibrium configuration). With its identical redshift it would seem to be related to Abell 1767 just to the NNW. In this respect it would seem to be an extension of Abell 1767 in the general direction of the filament of objects leading back to M101. This will be an important property, of the galaxy clusters which appear to be involved in the alignments with the central galaxy. More elongations of clusters along the line back to their galaxy of origin will be shown later in this paper. As for the long apparent extension on the sky across M01 (see also Arp 1984), the only longer line of apparent separation known is the line of higher redshift galaxies extending along the minor axis of M31 in the Local Group of galaxies, which is obviously much closer to us (see Arp 1998b).

3.1 3C295

To the SW of M101 in Fig. 1 is plotted the famous radio galaxy 3C295. The remarkable properties of this location are that it is closely the same separation and on the other side of M101 from Mrk 273. Most striking, however, it is almost exactly on a line to the SE Abell cluster, at $z = .071$. I remember the excitement at Mt. Wilson and Palomar observatories when the redshift of 3C295 was first measured. Among the strongest radio sources discovered in initial radio surveys, Minkowski's 1960 redshift of $z = 0.46$ remained the highest redshift measured until past 1975 (see Sandage 1999 for history of major events over 50 years at Palomar).

The most recent observation of 3C295 is in X-rays by Chandra (Harris et al. 2000). It shows a pair of X-ray condensations coming out of the nucleus at a position angle of about $\text{p.a.} = 144$ deg. This is the same alignment as the radio lobes shown as overlaid contours. Since the ejection origin of radio lobes has long been accepted, and X-ray jets often are found at their core, the X-ray sources in 3C295 are indicated to be in the process of ejection. Surprisingly, at a very small scale, between 3C295 at $z = .461$ and its closest major companion at $z = .467$, there is a much brighter galaxy at $z = .285$. The two higher redshift galaxies are almost perfectly aligned across the lower redshift galaxy at only 11 arcsec on either side of it. There is a only very small a priori chance of a galaxy this bright accidentally occurring at this exact spot. This of course is the quintessential pattern of AGN's ejected from a larger galaxy (often interpreted as gravitational lensing). There is some hint of luminous material connecting from the central galaxy to 3C295 and deeper, high resolution images should be obtained to check the possibility that this brighter, low redshift galaxy is the origin of 3C295 and its similar redshift companion.

4 The Distribution of Bright Markarian Galaxies

Because of the provocative location of Mrk 273 it seemed interesting to see if there were similar objects within the extended field of M101. A Simbad screen was set up to tabulate objects brighter than about 15.5 mag. with redshifts between 0.35 and 0.41. A field of radius 10 degrees was arbitrarily set. Fig. 4 shows that a total of five Markarian galaxies were found. Unexpectedly the exceptionally active Mark 231 showed up near the NW edge of the field. Mrk 231 is the second of what are believed to be the three most luminous infrared galaxies in the sky (Arp 2001). To find it here, close to Mrk 273, and in the same NW direction from M101 appears by chance to be quite unlikely.

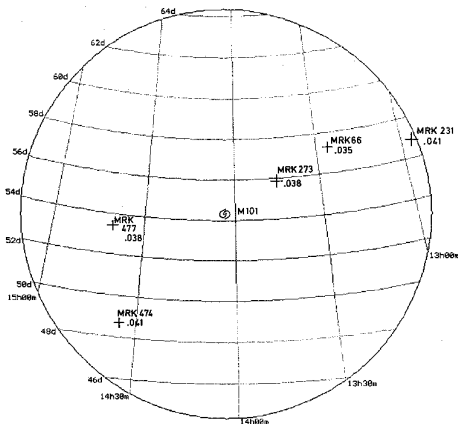


Figure 4: Around the very bright nearby galaxy M101 it is shown that five of the brightest and most intensively studied Markarian (active) galaxies are strung out in a direction roughly NW - SE. Within a radius of 10 deg. All Markarian galaxies brighter than 15.3 magnitude and z between .035 and .045 are plotted.

The second point Fig. 4 illustrates is that the five Markarian galaxies are distributed roughly along a line NW - SE which, as we shall continue to see, is where most of the galaxies and active objects are situated. But these Markarian galaxies are all exceptional objects. The intensity with which they have been studied attests to their importance - for example the number of literature references for Mrk 231 is 509, for Mrk 273, 274; for Mrk 477, 126; for Mrk 474, 60 and even for the least, Mrk 66, there are 32 references.

Perhaps even more impressive, however, is that this is a general alignment over almost 20 degrees in the sky of exceptionally active objects with nearly the same redshift: $z = .041, .041, .038, .038, .035$. In terms of conventional redshift distance this would represent a narrow filament of physically related galaxies spanning an enormous distance in space. The tendency would be to say that these were all galaxies at one particular time in their evolution. Associated with M101, however, they could have an origin in a single ejection event. Such events are recurrent and could later furnish different lines of objects at different discrete stages in their evolution.

5 The Distribution of Bright Quasars

In order to separate background quasars from candidates for association with M101 another Simbad screen was set at the relatively bright apparent magnitude of $V = 17.1$ mag. The search was supplemented by visual search of the Veron and Veron Catalog and checks with NED lists of high redshift quasars. The quasars found are plotted in Fig. 5. The first impression is that these brightest quasars are distributed along the same general line of Markarian galaxies as just discussed. In detail, there are quasars near each of the plus signs which represent the Markarian galaxies from Fig. 4, suggesting that these quasars may have originated more recently from these lower redshift, active Markarian galaxies and not necessarily as direct ejections from M101 itself.

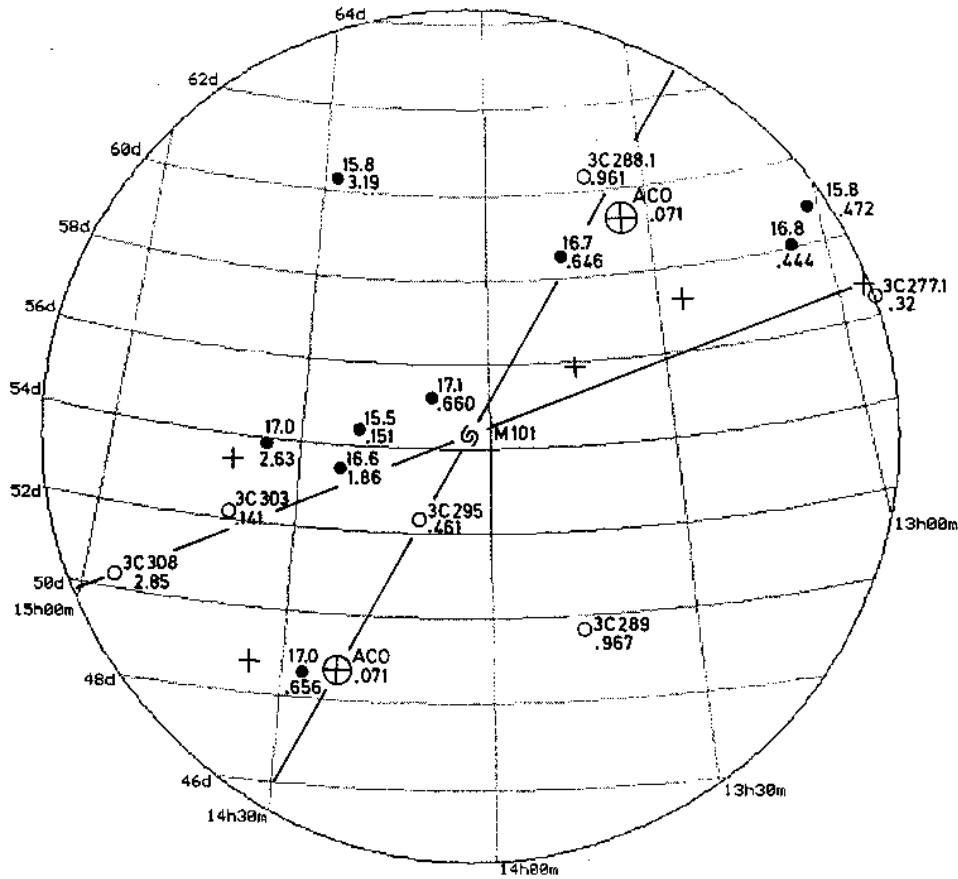


Figure 5: The plus signs are the same Markarian galaxies from Fig. 4 with now all QSO's less than $z = 17.1$ mag added as filled circles. All known 3C radio objects in the area are represented by open circles. The two circled plus signs are Abell Clusters from Fig. 1.

Some of the high redshift quasars here have such bright apparent magnitudes that whatever the average luminosity for this redshift may be, they are certainly among the closest of this class - if the red shift does not indicate distance (Arp 1999). Examples are redshifts of $z = 2.63$ at 17.0 mag., $z = 1.86$ at 16.6 mag. and $z = 3.19$ at 15.8 mag. (We should remark that while the $z = 3.19$ quasar is not near a Markarian galaxy it is quite near an infrared, IRAS, galaxy of 15.3 mag. and $z = .037$ and therefore similar to the Markarian galaxies plotted here.) The 15.5 mag. object is a BL Lac type quasar, OQ 530, very bright in apparent magnitude for its class and agreeing with the close association of BL Lac's with nearby galaxies as reported in Arp (1997, Table 2 and 1998a).

5.1 Numerical Coincidences of Redshifts

There are some remarkable numerical agreements in redshifts of a number of objects in Fig. 5. The quasars at $z = .646$, $.660$ and $.656$ stand out. It should be remarked that there is an additional quasar at 17.7mag., slightly below the cut off of 17.1 mag., which has a $z = .646$ and falls just SW of M101. The latter makes a close apparent pair with the $z = .660$ quasar across M101 directly. As remarked in the previous section Quasars at greater distances from M101 may arise from secondary ejections from earlier ejected, still active galaxies such as the Markarian objects.

The numerical coincidence of the 3C quasars at $z = .961$ and $.967$ also stands out. Even more strikingly, these redshifts agree very closely with peak values of redshifts in the Karlsson formula which expresses the empirical relation found for many years for quasar redshifts:

$$z = .06, .30, .60, .96, 1.41, 1.96, 2.64, 3.48\dots$$

The agreement between these predicted values and the values for the majority of quasars in Fig. 5 is evident. Recently Burbidge and Napier (2001) have demonstrated a very significant extension of the Karlsson series to the highest redshifts.

6 The 3C Radio Sources

Again in Fig. 5 we see the brightest, earliest discovered, 3C radio sources falling mostly along the line of objects which passes through M101 from NW to SE. Apparently 3C277.1 is associated with Mrk 231 and 3C295 apparently with M101 itself. Some of the others may also be associated with nearby active galaxies such as Mrk 477.

3C303 is a particularly well studied object because of it has a prominent one sided radio jet pointing from a compact radio galaxy of $z = .141$ toward its double radio lobe, the northern component of which is at p.a. = 280 deg. (Lonsdale et al. 1983). The direction to M101 is about 289 deg. The ROSAT PSPC observation shows X-ray sources mildly extended in the NW -SE direction.

Of particular importance, however, are three ultraviolet excess objects apparently associated with the western lobes of 3C303 (Kronberg et al. 1977). Margaret Burbidge obtained from the spectrum of one a redshift of $z = 1.57$. In spite of the fact that this association was discussed as a possible conclusive proof of the near distance of quasars, no further time has been assigned to obtain the spectra of the remaining two candidates.

With the plot in Fig. 5 now complete, we could propose that there was a cone of ejected objects from M101 in the NW - SE direction. Or we could interpret the distribution of objects as two rather narrow lines, one at p. a. = 110 and the other at p.a. = 147 deg. We will prefer the latter interpretation because we now wish to examine the possible connection of the Abell galaxy clusters with these lines of objects.

7 Elongation of Clusters Toward M101

From previous evidence we have some expectation of galaxy clusters being elongated along the line of their apparent ejection. In Arp and Russell (2001) the clusters Abell 3667 and 3651 were paired across the central galaxy ESO 185-54. The clusters were strongly elongated along this connecting line and later Chandra observations actually showed a bow shock indicating motion outward along just this line at 1400 km/sec. The famous gravitational arc cluster, Abell 370 showed elongation back toward its purported galaxy of origin, the bright Seyfert NGC1068. Several other similar examples were also noted in the above reference.

Cataloged galaxies within a radius of 60 arcmin around the cluster Abell 1904 show that the cluster is noticeably elongated in a direction leading back to 3C295, and hence very closely along the line back to M101. Another cluster of somewhat fainter galaxies, Abell 1738, which is just N of Mrk 66 has relatively few cluster members with measured redshifts but they are aligned very accurately back toward M101.

Not much can be said about Abell 1767 except that it gives some impression of being aligned back toward M101 at about 140 deg. The PSPSC X-ray sources around 3C303 appear inclined at about p.a. = 110 deg toward M101. These last two clusters, however, would require

quantitative determination of their optical galaxy isopleths and/or X-ray contours of their smoothed distribution.

The shapes of the clusters, however, in conjunction with similar data referenced, would seem to furnish compelling evidence for the origination of the cluster from a point near the present M101. In the conventional view, constraints which give spontaneously forming, linear, non equilibrium configurations in deep space would seem to difficult enough. But to have them pointing back to a large galaxy would seem to require their connection with generally linear, recurrent ejections from that galaxy.

7.1 An Additional Example of Aligned, Connected Clusters of Different Redshift

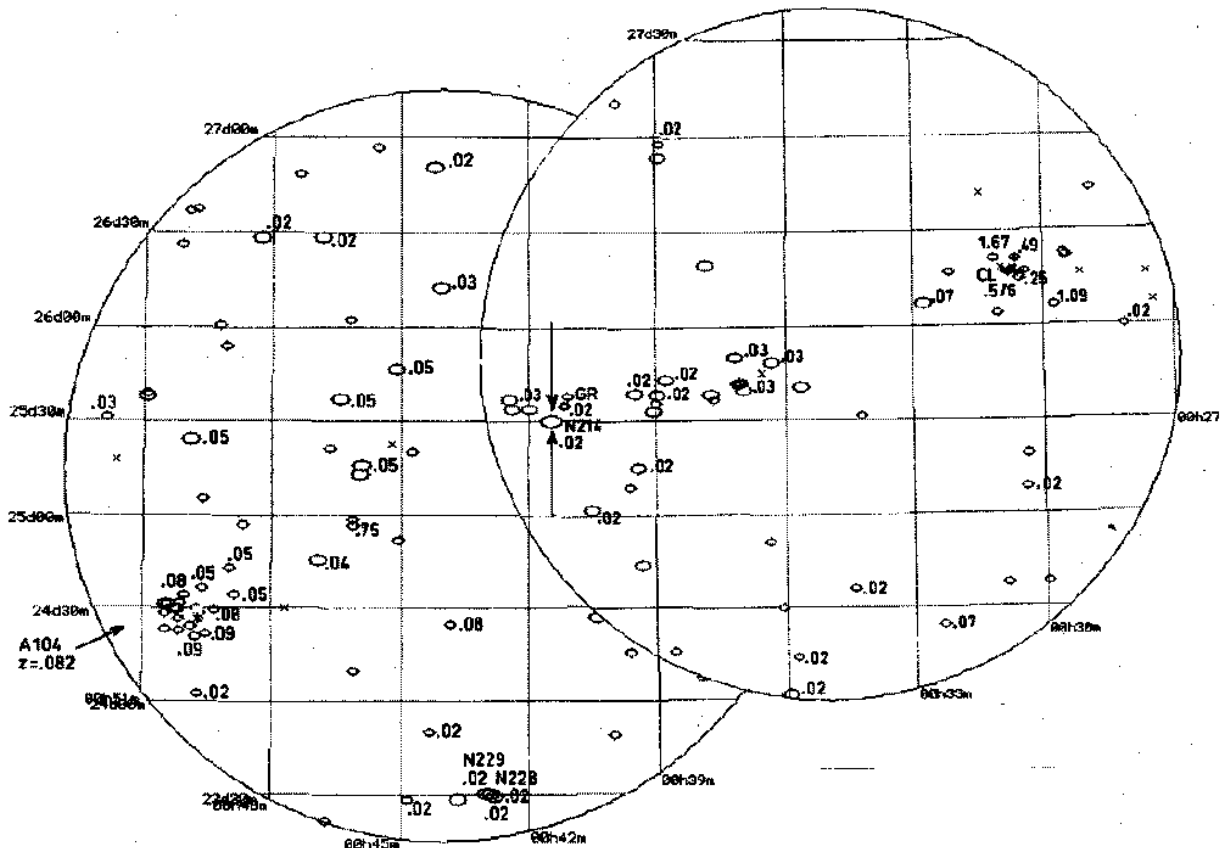


Figure 6: All catalogued galaxies from SIMBAD centered on the ScI galaxy NGC 214. Known redshifts are labeled. The redshifts increase as the line extends toward the galaxy cluster at $z = .516$ about 2.5 degrees to the WNW and also in the opposite direction about 2 degrees toward the Abell cluster 104 at $z = .082$.

Fig. 6 shows a serendipitously discovered association which well illustrates the elongation of clusters back toward a central galaxy. It was discovered because I was interested in the unusual galaxy cluster CRSS J0030.5 +2618 . The cluster has $z = .516$ and an order of magnitude excess of Chandra X-ray sources (Brandt et al. 2000). It also has two galaxies of redshift $z = .247$, one of $z = .269$ and three quasars of $z = .492$, 1.665 and 1.372 all within 5 arcmin and a further quasar $z = 1.094$ within 8 arc min.

I asked the question : "Where is the bright galaxy from which all this was ejected?" I found it about 2.5 degrees away. It was NGC 214, an ScI galaxy of $B_T^{0,i} = 12.48$ mag. and a redshift of $v_o = 4757$ km/sec or $z = .016$. This redshift indicates it is associated with the ubiquitous

Perseus-Pisces filament (Arp 1990). But the striking feature was that bright companion galaxies at $z = .02$ and $.03$ stretched away to the WNW directly toward the cluster of high red shift objects centered around the CRSS cluster.

Naturally I then asked: "What is on the other side of NGC 214?" As Fig. 6 shows there is an Abell Cluster, ACO 104 about 2 degrees away and nearly opposite NGC 214 with a red shift of $z = .082$. The striking feature of this cluster is that it is clearly elongated back toward NGC 214. Also interesting is the fact that galaxies of $z = .04$ and $z = .05$ lead into the cluster from the direction of NGC 214. (There are even two galaxies of $z = .03$ seen inside the cluster at higher resolution.)

In all these cases all the galaxies and optical objects in these areas should be completely measured. But even at this stage it seems clear that there are strings of objects extending in opposite directions from the central galaxy NGC 214 *and their redshifts continually increase as we approach galaxy clusters at either terminus.*

8 Sunyaev-Zeldovich Effect

The calculations of the distances of galaxy clusters from their scattering of microwave background in conjunction with measurements of their X-ray surface brightness seems to rest on such proven physical principles that it is difficult to see how anyone could accept much closer distances as the observations in the present paper claim. If we are, however, to give the observations even equal consideration we must face the apparent discordance of nearby galaxy clusters with S-Z distance determinations.

Perhaps the first point to be made is that with galaxy clusters which are nearby we would be dealing with strongly non-equilibrium physical conditions. If they are formed in more recent ejections from active galaxies and they themselves are ejecting secondarily and in non equilibrium configurations, perhaps it is incorrect to assume equilibrium temperature, radiation and energy densities. A strong indication of this situation comes from consideration of cooling flows. In many clusters the densities near the center are so high that the cooling flows would exhaust the available heat in much less than a cosmic time scale. The situation is so severe that suggestions have been made for merging or accretion of companion objects to resupply the energy in the center (A. Fabian, Moriond Conference).

Actually the situation in many clusters, especially those dominated by a large central galaxy, is that powerful ejections take place which must intermittently add bursts of energy into the surrounding cluster medium. (See for e.g. 3C295 pictured in Harris et al. 2000) The question then becomes: Do observations of the cluster medium at any given time represent an equilibrium physical state on which the conventional physical calculations can be made?

To make this suggestion more specific, consider that in order to account for the intrinsic redshifts of the objects of various ages associated with an active galaxy it has been necessary to make a more general solution of the general relativistic field equations where particle masses are a function of time (Narlikar and Arp 1993). In the beginning this requires a plasma of low mass particles to be ejected near light velocity. Because of their low mass the newly ejected particles can have large scattering cross sections, enabling microwave photons to be efficiently boosted. The synchrotron/bremstrahlung jets however are observationally well collimated and must mean relatively low temperatures orthogonal to the direction of travel. Their energy is mostly converted to temperature only at the interaction surface of the jet cocoon with the surrounding medium. Both of these, the strong scattering and low temperature effects would tend to give large distances in the SZ equation for distances of a small total mass cluster.

Put in a possibly observable way, even if there were a nearby cluster in temporary temperature equilibrium with a well determined X-ray surface brightness, but no measurable SZ microwave depression, would there be an upper limit calculated for the distance of this cluster?

9 An On-site Demonstration of the Origin of Galaxies

A recently announced observational result on the ultra luminous infrared galaxy Arp 220 serves to illustrate the formation origin of groups and clusters of galaxies. This ULIRG is reputed to be one of the most luminous galaxies known and extremely active both optically and in X-rays. Investigation of the brighter X-ray sources immediately around the galaxy have identified quasars and quasar candidates (Arp et al. 2001). Most striking are a pair of quasars shown here in Fig. 7 which are exactly aligned across the central active galaxy. By now many such pairs have been identified across active galaxies and they tend to have similar redshifts. But the striking result in Fig. 7 is that this pair have almost identical redshifts of $z = 1.26$ and 1.25 .

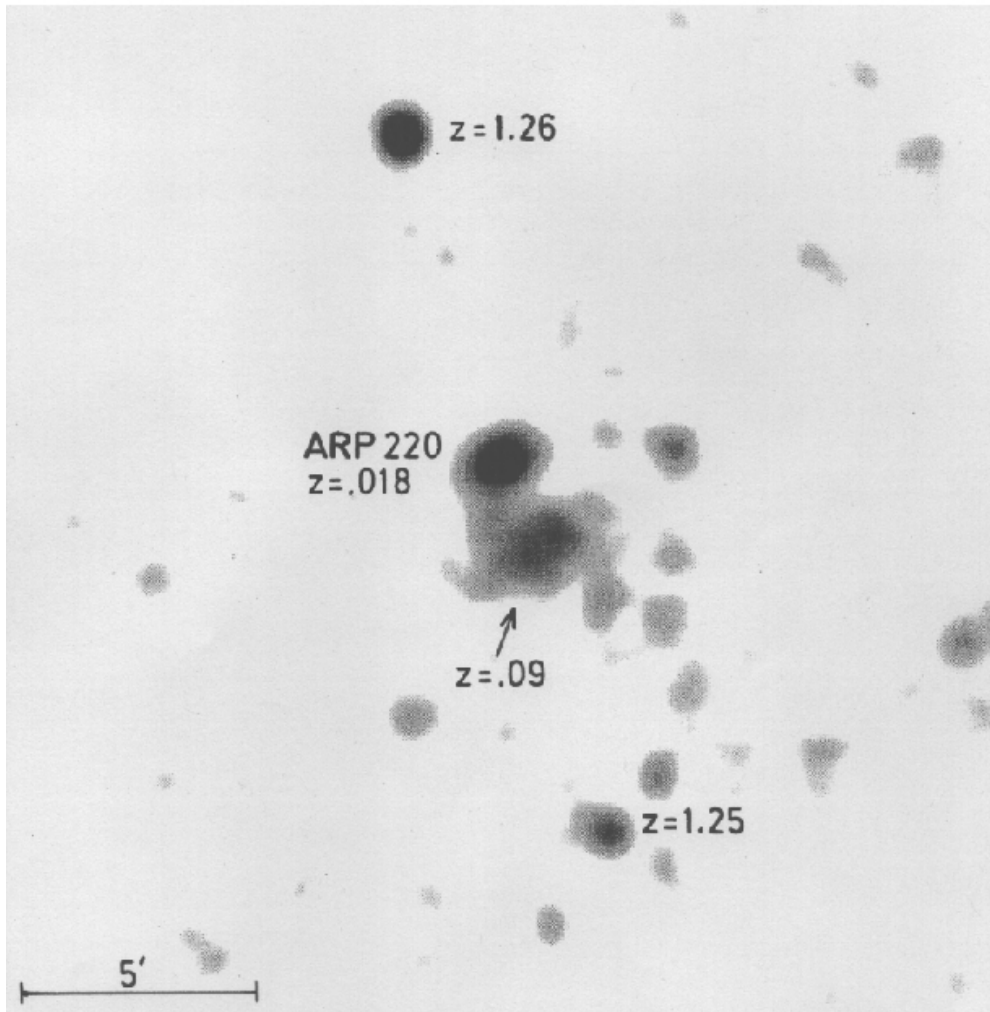


Figure 7: Hard X-ray band (.5 to 2.4 keV) from ROSAT PSPC, showing pair of strong sources across Arp 220. Note curved string of sources leading down to the SSW quasar. Known redshifts are labeled.

Normally such a pair would differ from their mean by of the order of 0.1 in redshift, rep-

representing an ejection velocity toward and away from the observer from about 10,000 to 30,000 km/sec. There are too many close matches in redshift, however to be explained by an ejection origin which was occasionally closely across the line of sight. These very close matches are more plausibly explained by the interaction of the ejected proto quasars with the material in the ejecting galaxy and the immediately surrounding medium. This robs the ejecta of their outward velocity, stops them close to their galaxy of origin and leaves only the intrinsic redshift to be observed (Arp 1999). Interaction with the body of Arp 220 would furnish a natural explanation for the spectacular disruption of this galaxy.

But the pertinence of Fig. 7 for the discussion in the present paper is that there are three galaxies emerging from the SW end of Arp 220, all three of which have redshifts about $z = .09$. These galaxies are fairly normal looking but are connected back to Arp 220 by both radio (see Arp 2001) and X-ray material as can be seen so clearly in the Figure. They are strong X-ray sources on their own and clearly cannot be unconnected background galaxies. In fact they are so bright in apparent magnitude that if they were at their conventionally believed redshift distance they would have the supposed luminosities of quasars. They instead appear to be quasars that were severely impeded on their exit from Arp 220, broke into separate pieces and evolved to their present size and redshift while still in the edge of the parent galaxy. Unlike most of the cases we have seen where the quasars do not evolve into lower redshift galaxies until they are at extreme separations from their origin, the present group represents the rarer case where they have been trapped near the galaxy that they have disrupted.

This picture is further reinforced by the trail of X-ray sources coming out of Arp 220 to the SSW quasar. This is on the side of the exit of the $z = .09$ galaxies and suggests that the trail of X-ray sources represents material stripped off the fainter of the two quasars as it passed through the region where the incipient cluster of galaxies is emerging. Regardless of the details, however, this image seems to show directly from observation how quasars, galaxy groups and galaxy clusters originate from nearby, low redshift, active galaxies.

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