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ORIGINAL ARTICLE

Quasars Associated with NGC 613, NGC 936 and NGC 941

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Abstract The association of low redshift, active galaxies with high redshift quasars is here tested in two regions uniformly surveyed for quasars to faint limits. Three active galaxies in these regions all show significant association with nearby quasars. Radio, optical and X-ray data available for these galaxies give new information on the processes which accompany the proposed ejection of the quasars. It is concluded that the quasars are originally relatively compact compared to the galactic medium through which they exit but can be slowed. It is argued that effects of ejection can be seen on the galaxies and may be connected with spiral structure. Evidence for periodicity of the redshifts is discussed.

Keywords Galaxies: active · Galaxies: individual (NGC 613, NGC 936, NGC 941) · Quasars: general · Radio continuum: general

1. Introduction

In the Catalogue of Southern Peculiar Galaxies and Associations (Arp and Madore, 1987) the galaxy NGC 613 appears as a striking example of the class of multi-armed spirals (Figure 1). NGC 613 (AM0132-294) is bright ($B_T = 10.75$), barred (SBb(rs)II) and has a redshift of $z = 0.005$. High-resolution images show a narrow, high brightness bar extending from the nucleus out on either side, roughly NW and SE.

The strong, flocculent spiral arms drew attention from some of the earliest investigators of internal motions. Spectra by E.M. Burbidge et al. (1964) revealed assymmetric velocities ranging up to 250 km/s with respect to the nucleus. Later spectra by Hummel et al. (1987) indicated outflow in the nuclear emission lines. But already in 1964 E.M. Burbidge et al. had remarked that "For such a galaxy, the estimate of the total mass is highly uncertain."

Radio maps established the galaxy as a strong radio source (PKS 0131-296) and later Very Large Array, VLA maps, catalogued radio sources and extensions along the bar within the inner regions of the galaxy. It is also an X-ray source, infrared, IRAS source, and was listed as morphologically peculiar (Vorontsov-Velyaminov 824).

2. Ejection of radio sources?

The VLA maps at 1.49 GHz (Condon et al., 1998) identified four radio sources within NGC 613 whose distances from the center of NGC 613 are listed later. The contour plot with a beam size of 45″, however, does not show conspicuous point sources (Figure 2). The 2″ resolution map at 1.49 MHz by Hummel et al. (1992), however, shows the inner two radio sources of Table 1 and also the general extension along the line of the bar, variously estimated as p.a. = 110–115°.

The latter authors show the innermost nucleus is ejecting a jet of radio material and they suggest it is coming out along the minor axis of a ring in the plane of the galaxy. But their 0.8″ resolution, 1.49 MHz map, shows the ring extended on either end and seemingly with narrow punctures along the p.a. = 110° of the bar. Whether the current, innermost ejection is along the minor axis or in the plane, or both, is perhaps moot at this point. In the discussion which follows, however, we will assume these NVSS catalogued positions represent sources of some degree of compactness and the pairing and extension along the position angle of the bar (see Figure 3) represents ejection from the nucleus.

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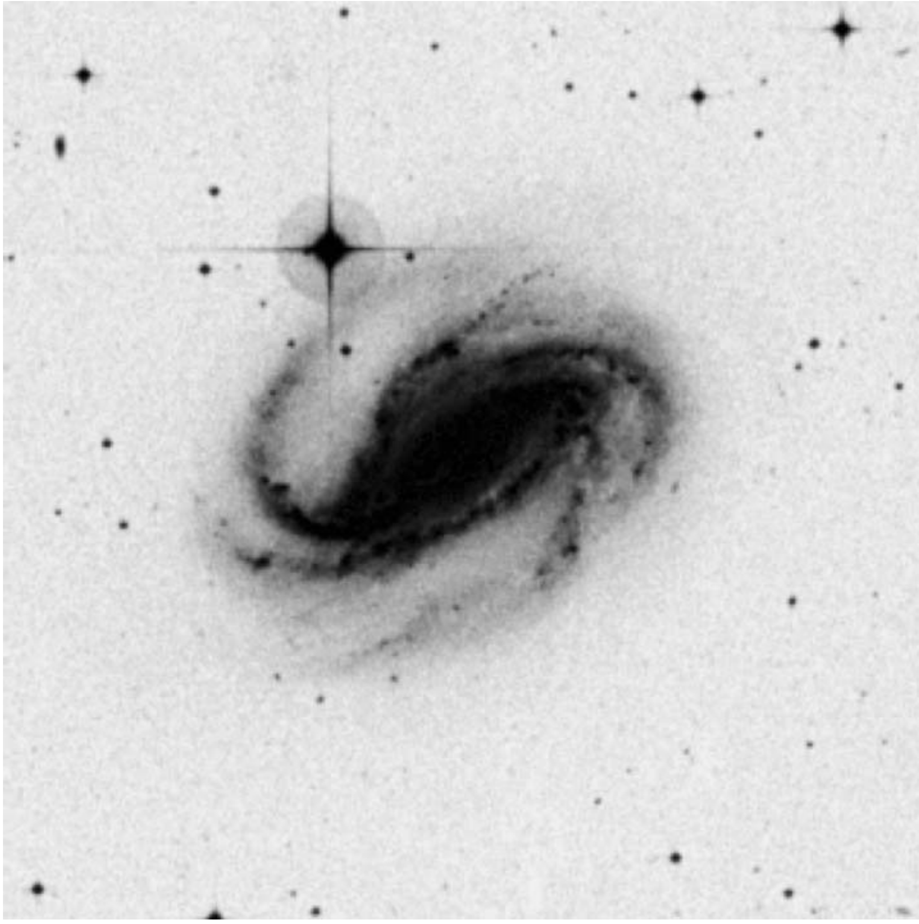

Fig. 1 UK Schmidt photograph of NGC 613, classified as a multi-armed spiral, AM 0132-294. The frame is 9′ × 9′

3. Alignment of quasars and radio sources

Tables 1 and 2 show the distances and alignments of the radio sources and QSOs as measured from the center of NGC 613. Figure 4 shows that the nearest quasar to NGC 613 ($z = 2.222$) at p.a. = 299° is accurately along the radio line. The next nearest quasar ($z = 2.059$) is at p.a. = 121°.

Table 1 Radio sources across NGC 613

Source	Distance (′)	p.a. (°)
NVSS J013418-292513	0.2	127
NVSS J013416-292456	0.3	298
NVSS J013412-292430	1.4	296
NVSS J013423-292551	1.4	123

Table 2 Quasars along radio ejection lines

Quasar	Distance (′)	p.a. (°)	z
2QZ J013356.8-292223	5.4	299	2.222
2QZ J013445.8-292842	7.0	121	2.059
2QZ J013454.8-292523	8.0	94	2.062
2QZ J0I3448.0- 292015	8.2	304	1.855
2QZ J013345.0-291608	10.8	317	1.413
2QZ J013508.4-293023	12.2	117	1.482

It is surprising to find a quasar so close to NGC 613 and also so closely along the line of postulated radio ejection at p.a. = 298°. But given that, it is even more unlikely to find the next closest quasar lying at p.a. = 121°, closely along the line of opposite radio ejection.

If we take the density of 2 dF quasars as 17 degree^{-2} down to 20th magnitude (Croom et al., 2004, and the fit presented by López-Corredoira and Gutiérrez, 2004 to the Boyle et al., 2000 data) then there should be 3.3 quasars around NGC 613 in Figure 4. There are 11 quasars, an overdensity of almost four times, or a 4.2σ deviation from the number expected. The chance of finding the two nearest quasars aligned within 2° out of a possible 90° times the accuracy of NGC 613's centering (13%) is additionally $P = 2.9 \times 10^{-3}$. (Or normalized to random occurrences $P_{\rm N} = 1.2 \times 10^{-2}$.) In addition to this well-known pairing configuration (Arp, 2003), we must also consider the probability that this alignment could accidentally match the alignment of the four NVSS radio sources within NGC 613.

As for the quasars further out, they also tend to be placed along this direction, particularly the $z = 1.86$ and

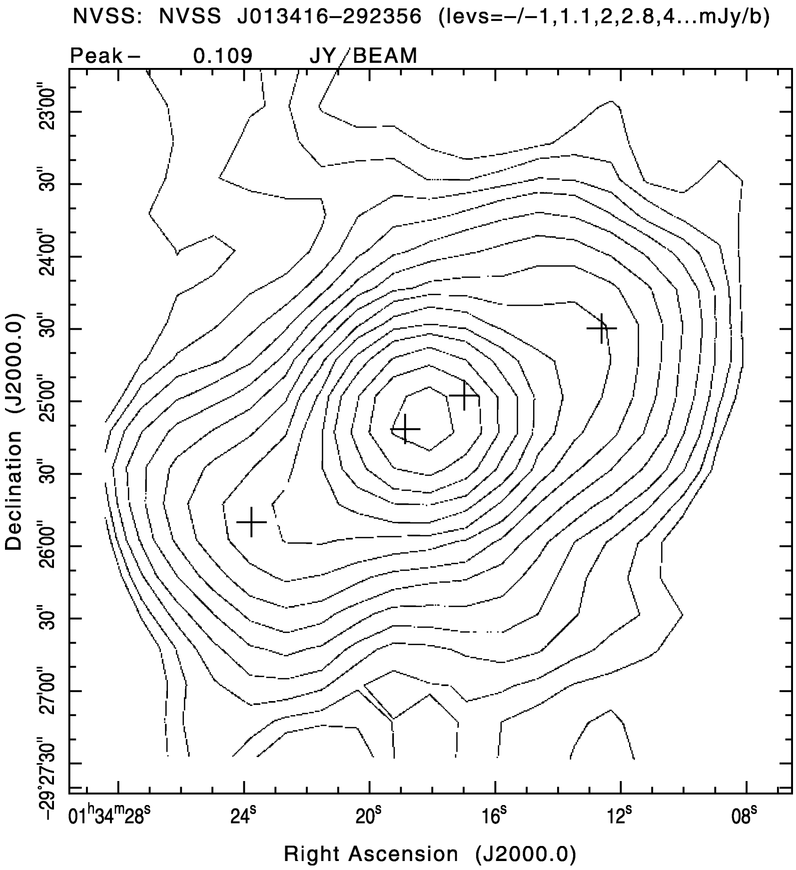

Fig. 2 VLA map of central $5' \times 5'$ of NGC 613. The plus signs indicate the four catalogued NVSS radio sources. Distances and position angles of these sources are given in Table 1. The frame is $5' \times 5'$

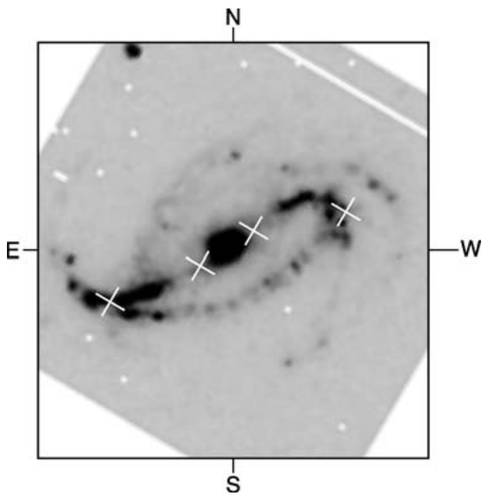

Fig. 3 Infrared 7 μm image showing narrow bar in the interior of NGC 613. Plus signs indicate positions of radio sources from Figure 2

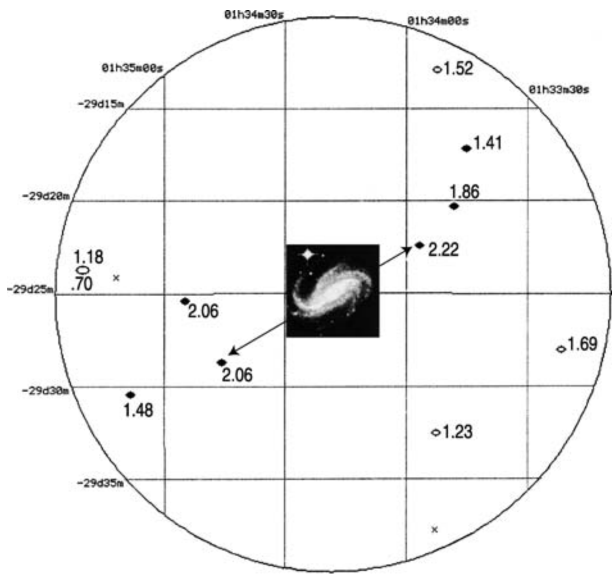

Fig. 4 Simbad map inside 15′ radius around NGC 613. Quasars from the 2 dF Survey are labeled with their redshifts. Arrows indicate the direction of the radio sources pictured in Figures 2 and 3

1.48 quasars. So there are two sets of quasars suggesting a match with the two inner pairs of radio sources. In all, the six nearest quasars have similar apparent brightness, around 20th magnitude.

The numerical value of the quasar redshifts also argue against their being accidental background projections. We note particularly the average redshift of the nearest two on the NW as being $z = 2.04$ closely matching the $z = 2.06$ of the ones on the SE. The two in the outer most pair are also very similar at $z = 1.41$ and 1.48. These redshifts are close to the Karlsson values of the periodicity peaks (see Table 3).

Table 3 Summary of associations

Galaxy	z QSO	d'	Remarks	z_0	$z_K(12^h)$
NGC 613	2.22	5.4	First of pair	2.20	2.05
	2.06	7.0	Second	2.04	2.05
	2.06	8.0		2.04	2.05
	1.86	8.2		1.85	2.05
	1.41	10.8	First of pair	1.40	1.48
	1.48	12.2	Second	1.47	1.48
NGC 936	2.18	4.5	First of pair	2.16	2.05
	2.04	9.9	Second PKS	2.02	2.05
	2.23	11.9		2.21	2.05
	0.69	50.3	Strong PKS	0.68	0.65
NGC 941	1.13	1.7	Radio connection	1.12	1.02
RBS 0218	1.18	0.3	Parent $z = 0.70$	0.28	0.34

4. Pairing across NGC 936

An amazing coincidence is shown in Figure 5 where there is an almost identical configuration to that just discussed in NGC 613. Even the redshifts of the quasars and the galaxies are very closely the same! Figure 5 shows the SE quasar is $z = 2.04$ in NGC 936 compared to $z = 2.06$ for NGC 613. The NW quasar is $z = 2.18$ compared to $z = 2.22$ for NGC 613. Both central galaxies have $z = 0.005$ and the separation of the pair across NGC 936 is 14.5′ compared to 12.5′ across NGC 613. NGC 936 is classified SB0 with a short bar running almost E–W (Sandage and Tamman, 1981). The pairing across NGC 936 is not only almost exactly aligned but the two quasars are unusually bright and similar at 18.2 and 18.8 magnitudes (values from NED). The probability of accidental pairing across NGC 936 is $P = 0.05 \times 0.26 \times 0.02 \times 0.34 = 9 \times 10^{-5}$ (nearness$_1$ × nearness$_2$, ×alignment × centering).

This should be normalized by an accidental chance of 0.5^4 or

$$P_N = 1.4 \times 10^{-3}$$

4.1. Is NGC 936 an active galaxy?

Figure 6 shows an Einstein, IPC X-ray image of NGC 936 and the neighboring region. The most prominent feature is X-ray emission running along the bar in NGC 936 and extending out to the ESE of the galaxy. *The nucleus of the galaxy is a point source on the high resolution FIRST radio map.* At the very least this marks it as an active galaxy. From the point radio nucleus the outer contours extend to the SE toward the strong radio quasar (Figure 7).

The strongest additional X-ray source in Figure 6 coincides with the strong radio quasar with $z = 2.04$. On the other side of NGC 936 is the quasar $z = 2.18$ which is near a smaller X-ray source. Within the positional accuracy of the IPC this could represent a pair of X-ray quasars across NGC 936 or perhaps a quasar with an X-ray source about an arcminute further out along the ejection line.

Figure 7 shows an NVSS radio map around NGC 936. It is apparent that the galaxy has radio isophotes elongated along the direction of the close by pair of $z \sim 2$ quasars. The elongation is greater in the direction of the $z = 2.04$ quasar which is a very strong PKS radio source seen at the SE edge of Figure 7. The radio extension from NGC 936 is at

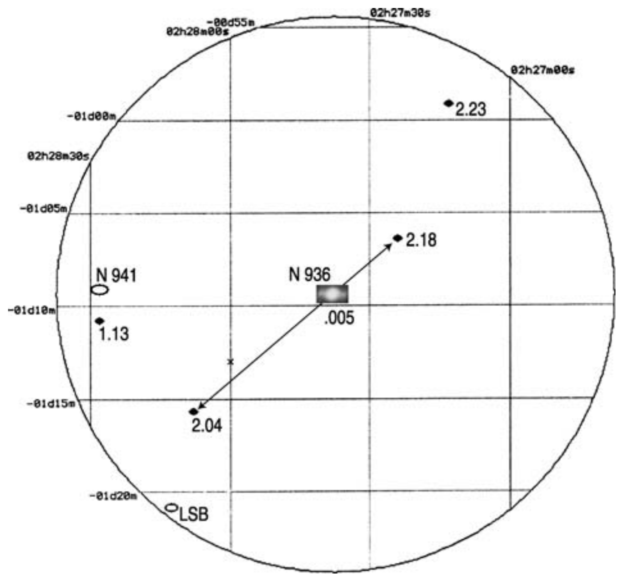

Fig. 5 Simbad map inside 15′ radius around NGC 936. Quasars from the SDSS and PKS Survey are labeled with their redshifts. Arrows indicate the direction of the radio sources pictured in Figure 10

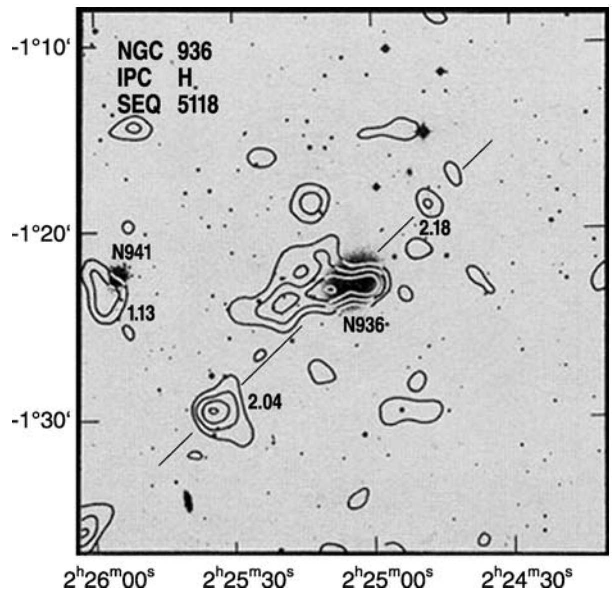

Fig. 6 X-ray contours from Einstein IPC superposed on POSS I survey image. Optical bar in NGC 936 shows X-ray extensions to the ESE. FIRST shows unresolved radio nucleus

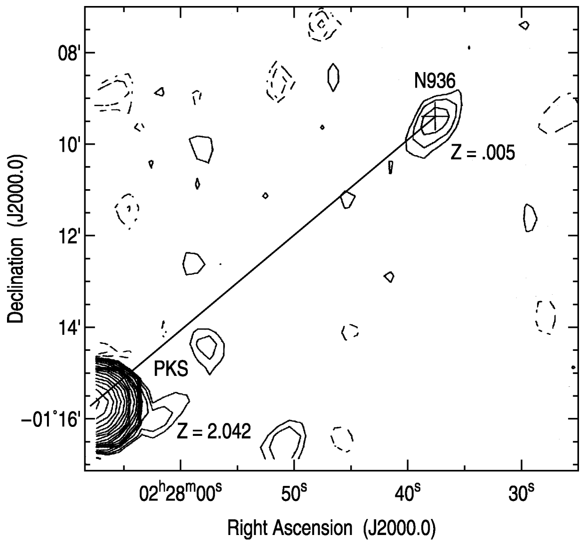

Fig. 7 The NVSS map showing radio extension from NGC 936 along the line of adjacent quasars. The extension from the radio point nucleus is stronger in the SE direction toward the PKS quasar of $z = 2.04$

p.a. = 145° and the X-ray extension is at p.a. = 110° which gives a mean p.a. = 128°. Considering the uncertainties of definition, this is remarkably close to the p.a. = 129° to the X-ray/radio quasar.

There is an alternative interpretation, however, which would invoke a clockwise rotation of the ejecting nucleus in NGC 936. In that case the radio ejection would be the oldest and the X-ray the most recent with the innermost jet joining the bar with an even slightly greater rotation.

Overall it seems reasonable to consider NGC 936 a radio and X-ray active galaxy showing signs of ejecting along the line of the pair, most strongly toward the strong PKS quasar at $z = 2.04$.

The previous case of NGC 613 has ROSAT HRI X-ray observations which give $C = 10.6$ cts/ks for the nucleus. The HRI X-ray contours in NGC 613 (W. Pietsch, private communication) do not show any conspicuous concentration along the bar, but clearly, both NGC 613 and NGC 936 have very active nuclei and one might expect compact radio sources emerging from the nucleus if high enough resolution was available as in Zensus (1977).

4.2. NGC 941, the companion to NGC 936

Figure 5 also shows NGC 941, an ScdIII companion galaxy to NGC 936 at 204 km/s greater redshift. A quasar ($z = 1.130$) 1.7′ south of NGC 941 was found by Arp (1981) in a systematic search for UV excess objects near companion galaxies. (The working hypothesis at that time was that companion galaxies were more active than parents. This may be true since there was a very strong association of quasars with companion galaxies found – but in the ensuing years it has become clear that parent galaxies also can be very active.)

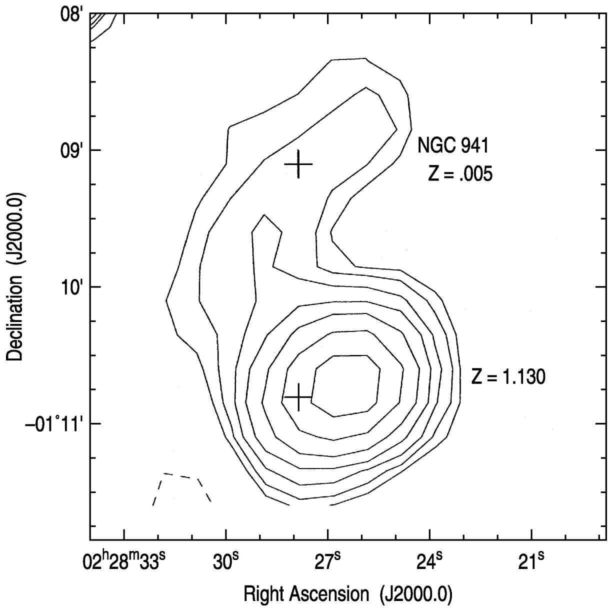

Fig. 8 This NVSS map shows radio extension from NGC 941 down to, and enveloping the $z = 1.130$ quasar about 2′ to the south

In any case, NGC 941 is a radio source and Figure 8 shows it has a strong plume of radio material reaching down and enclosing the quasar. The quasar appears offset by 30′ to the east from the center of the NVSS radio lobe. In order to interpret this configuration, it is fortunate that there is a high-resolution, FIRST map of this region.

The FIRST extract in Figure 9 shows the quasar at the center of the radio lobe is itself a radio source, slightly resolved. The stronger source about 30′ WNW of the quasar is also compact but definitely extended toward the quasar. This would indicate that the stronger source (not optically identified to the limit of the dss plates) had been ejected from the quasar. That the quasar is ejecting radio material is supported by Figure 9, which is a contrast-enhanced FIRST extract which shows a small pair of radio sources aligned across the quasar image. (Plus some fainter possible sources.) A lower contrast FITS image makes it clear that the strong source to the NW has been ejected by the quasar.

These observations suggest that we may be seeing details of secondary ejections involved in the evolution of quasars. It would therefore be an important group of radio sources to investigate with the highest resolution to the faintest isophote levels. As it stands at present, however, it seems likely that the $z = 1.130$ quasar is physically involved with ejection of radio material from NGC 941.

Further support for the association of NGC 941 with the quasar $z = 1.13$ is shown in the X-ray map of Figure 6. On the E edge of the figure is shown NGC 941 with the quasar about 2′ south of it. Apparently, there is a scaling or fitting error and the X-ray contour has slipped slightly to the east of the optical objects. But it is clear that the X-ray contours extend

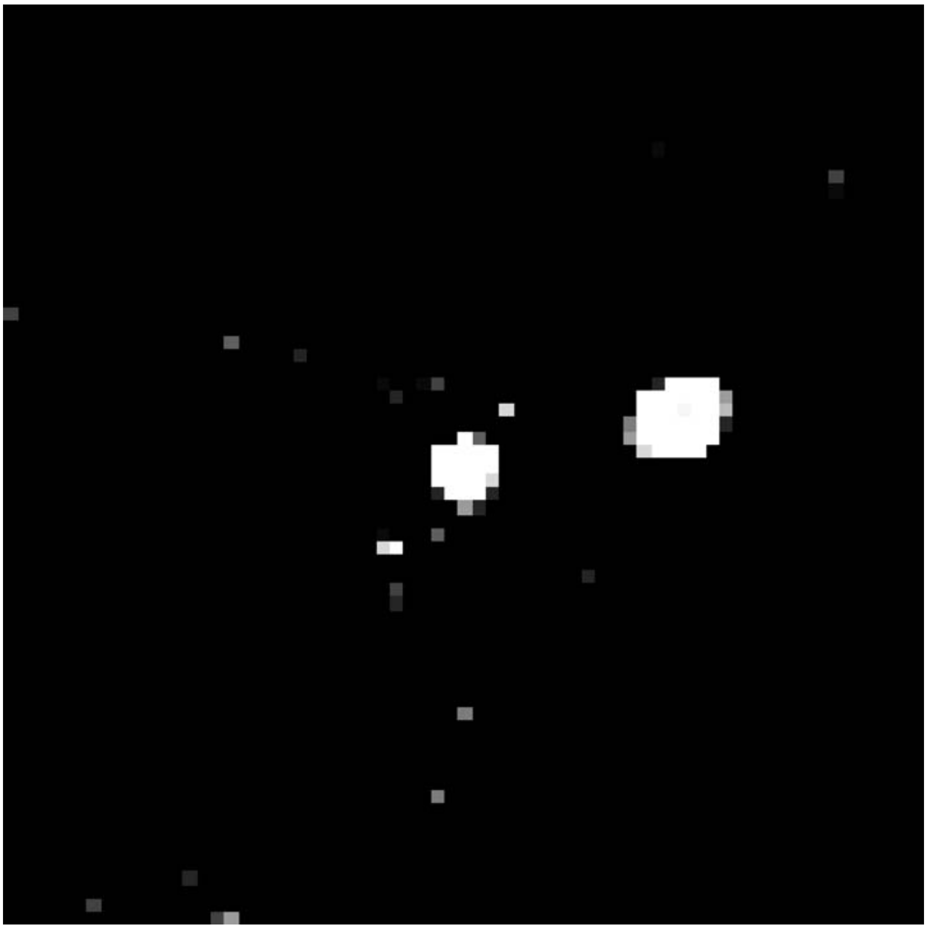

Fig. 9 This high-resolution, FIRST map has been contrast enhanced to show the extension of the brightest radio component back to the quasar and the small radio sources on either side of the quasar

from NGC 941 to the quasar in much the same fashion as the NVSS radio contours do. This means that in all three of the associations considered here between galaxies and quasars, the galaxies are active in both radio and X-rays and there is evidence in both wavelengths for ejection from them.

Companion quasars are usually found in the 10′–50′ range from their parent galaxy. If there is interaction with the material in the ejecting galaxy, however, it would be expected that the quasar would be slowed in its velocity and be observed at a closer distance from it. The drawn out radio connection between NGC 941 and the $z = 1.13$ quasar would furnish the reason then for the quasar to be found so unusually close (1.7′) to its galaxy.

5. Relation to previous associations of quasars with low redshift galaxies

The pattern of quasars of similar redshift paired across active and ejecting galaxies of much lower redshift has been recorded many times now (Arp, 1967, 1998, 2003; Burbidge, 1997; Radecke, 1997; Arp et al., 2001, 2002). Quasars also have been associated with radio and X-ray ejections from the beginning. In the three cases presented here, however, the alignment of radio emission coinciding so closely with the alignment of the pairs of quasars is further striking evidence that quasars, like radio sources, are ejected from galaxy nuclei.

In order to emphasize the significance of the patterns which are repeated in the association of the aforementioned quasars with NGC 613, NGC 936 and NGC 941, we outline a possible scenario as follows:

(1) Ejection of high intrinsic redshift plasmoids from the nucleus.
(2) The radio emitting plasma is less dense and is stripped from the proto quasar as it travels outward.

This could result from a radio burst in the quasar while moving through the galactic medium or by encountering a cloud as it exits into the intergalactic medium. Examples of this process have been discussed previously (Arp, 1999a, 2001). It would furnish a physical model for why the quasar and radio sources are coincident and/or aligned in the early stages. Since the low-density radio cloud would subsequently move under different forces, this model would also account for the paucity, in general, of radio-loud quasars compared to X-ray and optical quasars.

It was concluded in the earlier references that the ejection of quasars or proto quasars through the disk disrupts the ejecting galaxy and slows their ejection velocities. In the case of NGC 613 this would explain both the non-equilibrium disturbances in the disk and why the quasars are found so unusually close the galaxy of origin. (It is striking that the six quasars fall within a radius of from 5 to 12′ from NGC 613, whereas in most cases of association with large low redshift galaxies their quasars are distributed out to radii of 50′.)

(3) The redshifts decrease going away from nucleus and are quantized at the Karlsson peaks.

For 33 years the evidence has been accumulating that quasar redshifts occur at certain preferred values (Karlsson, 1971, 1990; Arp and Chu, 1990; Arp, 2003). Recently, it has been claimed that analysis of the faint 2dF quasar survey does not show these peaks (Hawkins et al., 2002). Later analysis finds strong periodicity evidence when the redshifts are transformed into the rest frames of the proper parent galaxies (Napier and Burbidge, 2003; Arp et al., 2005).

The redshifts of the six quasars around NGC 613 fall from $z = 2.22$ to 1.41 as they go away from the center. This decreasing redshift with separation has been observed in the best defined lines of quasars coming from the Seyfert galaxies NGC 3516 and NGC 5985 (Arp, 1999b). The obvious interpretation has been that the most recently ejected quasars are the youngest and therefore have the highest intrinsic redshift (Narlikar and Arp, 1993; Arp, 1998). Moreover, the NGC 613 quasars are obviously quantized in redshift also. Two of the most populated Karlsson peak redshifts for quasars in general are $z = 1.96$ and 1.41. The four innermost quasars average to $z = 2.05$ and the two outer ones to $z = 1.45$. For some regions of the sky, for example the 12 h, NGH region where the peaks are at $z = 2.05$ and 1.48 (Arp et al., 1990), an even closer match results (see Table 3).

(4) The redshifts tend to be numerically equal at equal distances on either side of the galaxy.

It has been observed previously that there is a strong tendency for quasars to occur in equidistant, aligned pairs with the two quasars resembling each other closely in redshift. We see that again in the NGC 613 case, but exceptionally there are now two aligned pairs. The first pair consist of quasars of $z = 2.22$ and 2.06. The second pair consists of $z = 1.48$ and 1.41. It is interesting to note that close to the $z = 2.059$ quasar lies a similar quasar of $z = 2.062$ – an unlikely coincidence if at cosmological distances. Next to the $z = 2.22$ quasar lies the $z = 1.86$ quasar. In both these cases, it might be proposed that the original quasar had split, and one pair is separating across the line of sight and the other with a component of velocity along the line of sight.

5.1. Ejection and the long standing problem of spiral arms

The most unusual morphological feature of NGC 613 is the strong, multiple spiral arms emerging from the end of a narrow, straight internal bar. Even more striking is the double nature of the major arms emerging from either end of the bar (Figure 1). It is very tempting to identify this pair of double arms with a double ejection event which has taken place in the interior of the galaxy.

The justification would be as follows: In an article in *Scientific American* in 1963, Arp suggested that ejections from galaxy interiors under the influence of rotation were the cause of spiral features. In 1964, Lin and Shu proposed a mathematical model where spiral arms were the result of density waves in a disk. Arp (1969a,b) argued again that the empirical morphology of spirals favored an ejection origin for the arms. (Arms narrowing instead of spreading at their ends, straight and broken arms, multiple and odd numbers of arms – see Arp (1986) and references therein.) In fact, Arp and Madore (1987) reported that a survey of more than 77,000 galaxies in the "Catalogue of Southern Peculiar Galaxies and Associations" showed that about 0.5% of peculiar galaxies have as many as three arms. This would be counter evidence against symmetrical density waves and at the same time positive evidence that the rare spiral arm configuration in NGC 613 was connected to the rare double pairs of ejected radio sources.

It is intriguing to note that in the infrared, 7 μm image (Figure 3), the inner bar is very narrow and straight and ends on dense knots of what are presumably intense star forming regions. If the two NVSS sources are real, they would be associated with these two regions. The two inner radio sources would be associated with slight bulges of the nucleus along this same direction. This could be construed as outflow of ejected material at this point causing the star formation. In another barred spiral, NGC 1672, there are strong X-ray sources at a similar point which may mark the exit of ejected quasars (Arp, 1998, Figure 3-29).

In the present paper, we have seen evidence for strong activity in galaxy nuclei. Since it has been long known that there are compact X-ray sources and extended radio sources outside galaxies, it poses the question as to how did such sources get there? They must have tunneled out through the material in the galaxy. It is probable that they would have left a wake or entrained material from the inner galaxy regions which then condenses into a young star population characteristic of young spiral arm population.

If the ejection model is correct it offers intriguing opportunities to learn about the properties of the quasars and the spiral arms which either guide their ejection or are caused by their ejection. Since the generally accepted optical synchrotron radiation of the quasars requires magnetized plasma it is suggestive that measures show magnetic fields running along spiral arms. On the observational side an object of $z = 0.1$ has been observed near a disturbance in the spiral arm of the spectacular face-on spiral NGC 1232 (Arp, 1987, 1998). More recently two quasar-like objects of $z = 0.24$ and 0.39 have been observed in the spiral–arm-like connection between the Seyfert NGC 7603 and its >8400 km/s higher redshift companion (Lopez-Corredoira and Guitierrez, 2002).

6. Additional objects possibly associated with NGC 613

There is a quasar 13.6′ east of NGC 613 in Figure 4 which is very bright at 15.7 apparent magnitude and is a very strong X-ray source. Quite closely aligned on the other side of NGC 613 is a gamma ray burster, 4b 940216 (located 17.2′ west, just beyond the $z = 1.69$ quasar in Figure 4). This pair of unusual objects fits the distance and alignment criteria of ejected objects from bright galaxies. Association of GRBs with active, low redshift galaxies has been pointed out by Burbidge (2003), and Arp (2003).

It is also notable that the bright quasar has $z = 0.699$ and only 17″ north of it there is a quasar of $z = 1.177$. If the bright quasar has had an ejection origin then the fainter companion which is unusually close would represent a more recent, secondary ejection. When the higher redshift is transformed into the rest frame of the brighter object it becomes $z_0 = 0.28$ – very close to the Karlsson preferred redshift peak of $z_K(0^h) = 0.30$.

7. The more distant pair across NGC 936

In Figure 10 it is seen that about 50′ northwest of NGC 936 there is a very bright Parks radio source (PKS 0222-00). *It is exactly aligned with bright PKS quasar SE across NGC 936.* This quasar (PKS 0222-00) is a strong X-ray source of 70 cts/ks and $z = 0.687$. It also has a bright apparent magnitude of 18.4 which places it with the aligned inner pair which are at 18.2 and 18.8 magnitude.

Interestingly, only 1′ from the aforementioned quasar, there is a galaxy optically elongated back toward the quasar with a faint but definite jet pointing in the opposite direction. The galaxy is UGC 01876 at 15.2 magnitude (NED). It is an X-ray source (WGA) and lies within the strong NVSS radio extension from the quasar. Perhaps most interesting of all, the high radio resolution of FIRST shows two compact nuclei in the quasar aligned approximately back to the compact radio nucleus of the galaxy. (Or possibly the radio source is a few arcsecond west of the position of the galaxy.)

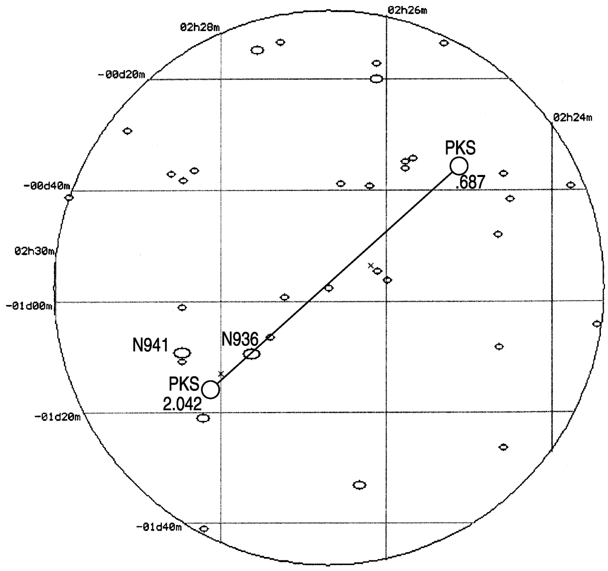

Fig. 10 All Simbad objects within a 50′ radius are plotted. The two bright PKS quasars are seen to be aligned across NGC 936

If we correct the observed redshift of the quasar, $z_Q = 0.687$ to that of the galaxy $z_G = 0.041$ its intrinsic redshift becomes $z_0 = 0.620$. This is very near the redshift periodicity peak of $z_p = 0.60$. As a consequence, every indication is that the active UGC galaxy is associated with this extremely powerful and active quasar.

The UGC galaxy is then indicated to be an active companion to NGC 936. In addition, we now discuss a very unusual string of quasars in the vicinity of this pair of objects.

8. Six similar redshift quasars in a string from PKS 0222-00

Figure 11 shows the distribution of all cataloged quasars (including SDSS) within a 50′ radius of a center about 32′ west of PKS 0222-00. There are six quasars with $1.651 \leq z \leq 1.706$. They are circled and labeled in Figure 9. It is clear that these six quasars form a filament or arc leading across the field from the active AGN PKS 0222-00. Quasars with redshifts such as these ($\langle z \rangle = 1.686$) are quite rare as can be seen by noting their absence in the rest of the field.

The most remarkable property of these six quasars, however, is that if we take the active AGN PKS 0222-00 as the origin of this string and transform the redshifts in the string to $z_{AGN} = 0.687$ we get six z_0s with an average $z_0 = 0.592$. Only 0.008 away from the Karlsson periodicity peak of $z_p = 0.60$!

This certainly appears as if the very powerful and active PKS AGN had ejected this string of quasars all of the same age (and hence the same intrinsic redshift). Unfortunately, the origin of this string of quasars has an alternative which leaves its identification somewhat uncertain.

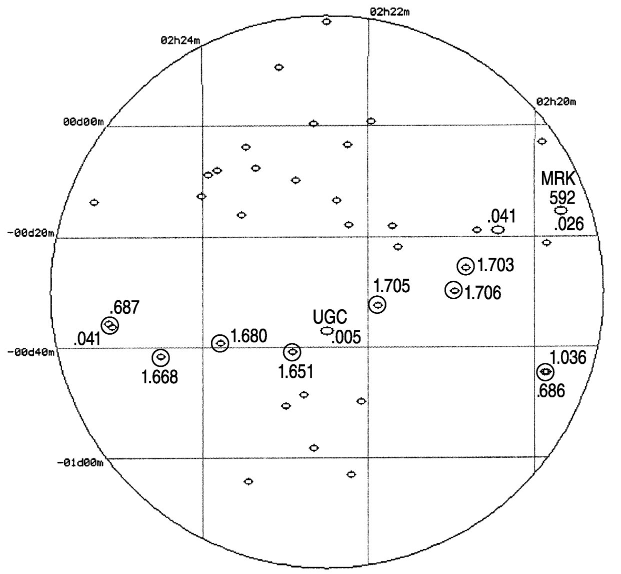

Fig. 11 All catalogued quasars (including SDSS) within 50′ radius of a center about 32′ west of PKS 0222-00. The six quasars with $1.651 \leq z \leq 1.706$. are circled plus two others

8.1. Another possible origin

As shown in Figure 11 there is a galaxy of $z = 0.005$ (UGC 01839) at the center of the string of $z \sim 1.7$ quasars. The six quasars are situated three on each side, pair wise across the galaxy and, if ejected, with slight rotation as they become more separated from the galaxy.

There are two arguments, however, against UGC 01839 as the origin: (1) It is classified as a 15.2 magnitude, edge on spiral with no observable nuclear bulge but does not appear active in radio or X-rays. The second argument is (2) that transforming the $z \sim 1.7$ quasars to $z = 0.005$ does not place them on a periodic redshift as an origin in the PKS object would. As a result, we prefer the PKS origin for the string but recognize that then the $z = 0.005$ galaxy either is accidental in its position or there is more to the story than we presently understand.

9. Summary

NGC 613 (AM 0132-294) is a multi-armed spiral with an active nucleus. Four radio sources paired along the narrow inner bar suggest a line of ejection from this nucleus. Four high redshift quasars from the 2 dF survey are paired further out along this same line.

In NGC 936 there is an X-ray extension along the bar and outwards from an unresolved radio source in its nucleus. In separation, redshifts and other properties the pair of $z \sim 2$ quasars paired across this radio, ejecting barred galaxy are an almost exact duplicate to those across NGC 613.

One of the pair across NGC 936, a strong Parks quasar, is also accurately aligned with another strong Parks quasar further away. NGC 941, a companion to NGC 936, has a quasar apparently connected to it by a radio bridge which shows structure at high resolution.

Possible relationships between other quasars and low redshift galaxies in a broader region around NGC 936 are discussed.

The redshifts of the quasars which are near NGC 613 and NGC 936 are remarkably concentrated near $z = 2$. This conforms to previous results (Arp, 2003) in which the redshifts of the associated quasars drop as they reach further away from the parent galaxy. They are also near the classical Karlsson peaks 0.30, 0.60, 0.96, 1.41 and 1.96. But when transformed to their parent galaxies (z_0) they are even closer to the Karlsson series when it is phase shifted by about 3%, i.e., 0.34, 0.65, 1.02, 1.48, 2.05, ... This is illustrated in the last two columns of Table 3. This latter Karlsson series is the fit found for quasars in the R.A. = 12 h region of the sky (Arp et al., 1990). It is called $z_K(12^h)$ in the last column of Table 3.

10. Conclusion

There are three major aims of this paper. One is to report an X-ray nucleus and radio extensions which suggest ejection of material along the narrow bar in NGC 613. Since the adjacent, high redshift quasars are found in the same line, an ejection origin for these quasars is strongly supported. The multiple arms of this barred spiral are attributed to multiple ejections.

The second aim is to show a completely different but confirming example of another barred spiral, NGC 936, active in both radio and X-rays, which appears to be ejecting a pair of quasars of similar redshift in nearly the same configuration as in NGC 613.

Thirdly, a strong radio connection between NGC 941 and the nearby $z = 1.130$ quasar is displayed. This supports the interaction of the ejected quasars with the material of the parent galaxy.

Other connections between low redshift objects and quasars in the general region of NGC 936 are also discussed. I hope these cases demonstrate that more information on the physical nature of galaxy–quasar associations and the periodicity of the quasar redshifts is to be had by further multiwavelength analyses of the new, large area 2dF and SDSS surveys.

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