The aim is to investigate the region of the sky around NGC4410/Mrk1325 for objects which are physically associated with this active, double nucleus galaxy. We use archived data to study the placement, brightness, X-ray properties and redshifts of objects within 60’ of the bright, central galaxy. It is found that pairs of quasars are aligned across NGC 4410 which, if ejected from it, have equal and opposite ejection velocities and fall very close to the quantized Karlsson redshift peaks for quasars. X-ray sources and Abell galaxy clusters at higher redshifts appear elongated along directions away from NGC4410.

**Key words.** galaxies: active - galaxies: peculiar - galaxies individual (NGC 4410)- quasars: general - galaxies: clusters: individual: Abell 1541
Quasars and Galaxy Clusters Paired Across NGC 4410

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Abstract.

1. Introduction

NGC 4410 is a disturbed galaxy classified as Sab interacting. It appears to contain two nuclei, 4410 A and B, separated by about 20 arcsec. A is more compact, an X-ray source and probably the source of the ultraviolet continuum which caused NGC 4410 to be catalogued as Markarian 1325 (Markarian et al. 1980).

Radio measures by Beverly J. Smith (2000) show that A has abundant molecular gas. There is HI coincident with faint optical tails to the SE and NE. To the NE there is a longer X-ray structure and optical bridge along which lie a second and third galaxy. Optical measures (B. Smith et al. 2003) indicate a redshift of \(cz = 7440 \text{ km/sec}\) for A and 7500 for B. The HI redshift for A + B is listed as 7350 km/sec.

The above reference shows there are 8 point x-ray sources around the active Markarian nucleus, A. Because they are in the Ultra Luminous class (ULX), it has been speculated that they are black hole binaries or background sources. There has been no attempt to measure their redshifts nor any reason advanced as to why they are closely situated around the component which is the Markarian galaxy. X-ray observations are discussed by (Tschöke, et al 1999) among others.

2. Quasar Pairs Associated With NGC 4410

Among the closest objects to NGC 4410 there are two optically bright quasars at 17.5' and 23.6' distance which are very exactly aligned NE-SW across the galaxy center. They are the closest pair shown in Fig. 1. The exact alignment and close centering of these two inner quasars across the active galaxy nucleus is strong evidence for them to be associated with NGC 4410. Moreover, X-ray observations of this region reveal that both of these quasars are exceptionally bright and similar at \(C = 23.8\) and 27.9 counts/kilosec (ROSAT PSPC).

Quasar redshifts have long been found to favor certain periodic values of which the pairs in Table 1 are an example (Karlsson 1971; Arp et al. 1990):

Karlsson Periodicities : .06, .30, .60, .96, 1.41, 1.96, 2.64, ...

We have to note, however, that, even when their redshifts are transformed to the frame of the central galaxy \((z_0)\)'s, that the innermost pair of quasars \(z_0\)'s are not close to a Karlsson, preferred redshift peak. What is the reason for this deviation? It turns out that when we average the two \(z_0\)'s we obtain \(|z_0| = .59\) which is almost exactly the expected intrinsic redshift peak of \(z_K = .60\). We then see that the individual deviations from the preferred peak are \(z_v = -.064\) and +.050. In other words the ejection velocity is away from us for one of the pair and towards us for the other in the pair.

Another trio of catalogued quasars, somewhat more separated but closely matching each other in redshift are located NW and SE of NGC 4410. They are shown in Fig. 1. In Table 1 these quasars are shown to have mean \(|z_0|\)'s close to the Karlsson peak \(z_K = 1.41\). These quasars are apparently ejected more across the line of sight because they are more separated and have smaller projected components of ejection velocity (as computed in table 2).

3. All Catalogued Quasars within 60' of NGC 4410

The disposition of all catalogued quasars within a degree of the central galaxy are listed in Table 2. On studying these 25 quasars within 60’ of the central galaxy it becomes apparent that the quasars with the smallest residual \((z_v)\)' from periodic \(z_0\) values involve brighter quasars and are generally at greater distances from NGC 4410. This is precededent since paper III of “The 2dF Redshift Survey” (Arp and Fulton 2006) showed

\[ z_v = \frac{1 + z_0}{1 + z_K} = (1 + z_v)\]

\(^1\) \(z_v\) is the residual from the Karlsson value which can be interpreted as a peculiar velocity: \((1 + z_0)/(1 + z_K) = (1 + z_v)\)
shells of quasars vacant for radii of 10' - 20' around some active parent galaxies. This was viewed as ejected quasars hitting a boundary shell, slowing and completing their evolution at some distance from the parent galaxy.

In any case NGC 4410 is a large bright galaxy and one would expect its quasars to be brighter and at greater separation than from smaller, fainter parents that happen to be in the area. In order to make this a quantitative statement we plot in Fig. 2 the frequency distribution of $z_r$ for radii greater than 30'. One sees the characteristic double peak around $z_r = 0$ for quasars with small positive and negative ejection velocities. The open circles represent quasars within 30' radius and are rather evenly spread throughout the $z_r$ range.

In order to establish that the small $z_r$'s systematically belong to the bright NGC 4410 we show Fig. 3 where they average about 0.7 mag. brighter than quasars with $z_r \geq 0.03$

### 4. X-ray Sources Related to NGC 4410

We have seen two strong X-ray sources aligned NE - SW across the central, active galaxy. Are there more X-ray sources in the vicinity? Fig. 4 shows the fainter X-ray sources in a 1 degree radius around NGC 4410 as catalogued in the ROSAT PSPC Source Browser. It is apparent that there is a strong cluster about 18' SE from the galaxy.

Within ~ 15' radius directly around NGC 4410 there is a relative vacancy of sources (similar to cases referenced earlier in Paper III of Arp and Fulton 2006). But most important of all, Fig. 4 shows, from the thickest part of the bounding arc, a dense concentration of points streaming away to the SE from just the direction which leads back to the galaxy. That elongation of X-ray sources is mostly due to galaxies in a cluster. Not just diffuse X-rays within a cluster volume but in this case probably individual X-ray sources of objects within a cluster.

#### 4.1. Abell Clusters 1541, 1541A and 1541C

The most surprising result now comes from the measures of the redshifts of galaxies in this region It turns out there are three clusters, all listed at exactly the same position in this concentration of X-ray sources:

| Quasar | $d'$ | mag. | $z$ | $z_o$ | $<z_o>$ |
|--------|------|------|-----|-------|---------|
| 2E 1224+0930 | 17.5' | 18.5g | .722 | .681 mean .590 |
| LBQS 1222+0901 | 23.6 | 17.3 | .535 | .498 |
| LBQS 1222+0928 | 25.4 | 18.5g | 1.466 | 1.407 mean 1.410 |
| LBQS 1225+0836 | 49.1 | 17.83 | 1.471 | 1.412 |
| SDSS 1225+0955 | 58.6 | 18.8g | 1.429 | 1.371 |

| Object | $z$ | $z_o$ | $d'$ | mag. |
|--------|-----|-------|------|------|
| NGC 4410 | .0244 | —— | 0.0 | 13.6 |
| SDSS | 2.237 +.067 | 9.6 | 19.4g |
| SDSS | .622 +.014 | 13.3 | 18.9g |
| SDSS | 1.903 -.043 | 14.4 | 19.3g |
| HB89 | .722 +.050 | 17.5 | 18.5g |
| LBQS | .535 -.064 | 23.6 | 17.3 |
| SDSS | 1.776 -.085 | 25.2 | 19.1g |
| LBQS | 1.466 -.002 | 25.4 | 18.5g |
| HB89 | .084 -.007 | 26.9 | 16.8 |
| SDSS | 1.590 +.049 | 29.0 | 20.0g |
| SDSS | 1.502 +.013 | 30.9 | 18.6g |
| SDSS | .628 -.007 | 34.8 | 19.0g |
| SDSS | 1.043 +.017 | 39.5 | 18.5g |
| SDSS | 1.363 -.043 | 43.0 | 19.1g |
| PSS | 4.340 | —— | 48.9 | —— |
| LBQS | 1.471 +.000 | 49.1 | 17.83 |
| SDSS | 1.076 +.033 | 49.7 | 18.7g |
| SDSS | 1.345 -.051 | 49.8 | 19.1g |
| SDSS | 1.090 +.040 | 50.3 | 19.0g |
| SDSS | 1.715 +.100 | 51.3 | 19.1g |
| LBQS | .681 +.025 | 52.0 | 17.6 |
| SDSS | 2.649 -.022 | 54.2 | 19.9g |
| SDSS | .773 +.081 | 56.3 | 18.5g |
| 2MASX | .064 -.025 | 56.3 | 16.7g |
| LBQS | .397 +.049 | 56.4 | 18.2g |
| SDSS | 1.429 -.017 | 58.6 | 18.8g |

$Abell 1541 z = .089$

$Abell 1541A z = .0244$

$Abell 1541C z = .0035$

The redshift $z = .0244$ is exactly the redshift of NGC 4410. So the companion galaxies of NGC 4410 are shown to be spatially contiguous with the much higher redshift cluster Abell 1541 at $z = .089$.

Supporting evidence that the $z = .089$ cluster Abell 1541 was ejected from the NGC 4410/Mrk 1325 active galaxy is to be found in Fig. 5. Here we have plotted all galaxies catalogued in NED within ~ 60' of NGC 4410. It turns out that about 26' NW from NGC 4410 is an elongated group of galaxies with $z_{ave} = .091$. They are strikingly paired with the Abell custer 1541 at $z = .089$ on the opposite side of NGC 4410. This is the canonical pattern of elongated clusters paired on either side of an active galaxy.

The physical nature of the pairing is further supported by Fig. 6 where the X-ray sources of Fig. 4 are now superposed onto the galaxy distribution of Fig. 5. One can better see the circular boundary from East to South of sources around NGC 4410. One can see evidence of connection NW to the $z = .091$ elongated cluster of galaxies. But most strongly of all, the increasing density and elongation of sources to the SE from NGC
4410. The ejection argument for X-ray sources would be hard to argue against.

5. Previous Associations of Higher Redshift Galaxy Clusters with Active Galaxies

It should be emphasized that the NGC 4410 pairing is closely the same result that was obtained for the Abell X-ray clusters Abell 3667 and 3651 (Arp and Russell 2001). Abell 3667 was later shown to be moving away from its lower redshift parent at a speed of 1400km/sec (Arp 2003 pp 178 -186). Other examples were shown in the 2003 reference including NGC 7131 with an elongated cluster of $z = .088$ pointing back to the $z = .018$ parent (page 194). In another case, from Arp 220 ($z = .018$), there emerges a group of X-ray galaxies at $z = .09$ (Arp et al. 2001, Arp 2003). An elongated X-ray cluster showed near perfect pairing with the X-ray ejecting NGC 720 (Arp 2005, Burbidge et al 2006). As shown here in Fig. 7 the Arp 220 case is a particularly clear demonstration of the NGC 4410 ejection interpretation because the X-ray group is right along the line of the quasar pair All the redshifts are strikingly similar between NGC 4410 and Arp 220.

It should also be noted that Abell 1541, here associated with NGC 4410, is a strong X-ray cluster. In the SHARC Survey for X-ray clusters it was one of the 37 brightest detected (Romero et al. 2000). Among bright X-ray cluster it is noted that they tend to occur in elongated, non-equilibrium forms. In addition to the ones cited above there is the elongated X-ray cluster which appears like a jet coming out of the Seyfert Galaxy NGC 5548 (Arp 1998 p 145).

6. The Origin of NGC 4410

Considering the active nature of NGC4410/Mrk1325 discussed in the Introduction it is natural to ask: “Where is its lower redshift parent?” Actually the answer is immediately present in the Abell Clusters catalogued SE of NGC 4410. Abell 1541C has $z = .0035$ and contains large galaxies any one of which could be the parent of NGC 4410. The redshift $z = .0035$ is a little over 1000 km/sec and, in position and redshift, places these galaxies in the conventional Virgo Cluster. Within a cluster like Virgo the intergalactic medium would presumably furnish a resisting force which would string out the clusters in the direction of ejection. The NVSS radio map presently suggests that there is roughly a ring of radio sources around NGC 4410 which represents the major onset of interaction of the ejecta with the medium.

The NGC 4410 galaxies at $z = .0244$ ($cz = 7320$ km/sec) are then part of that over density of higher redshift galaxies in the Virgo direction which are conventionally believed to form a background cluster.(see Arp 1998 p 69). But they are like Stephan's Quintet at 5700 - 6700 km/sec which is connected to NGC 7331 (Arp 1987 p 99) and the Cartwheel galaxy and companions which are associated with NGC 134. Also the 6400 - 6700 km/sec companions to NGC 4151 (Seeing Red, page 78).

A final comment on periodicity is to note that the Abell 1541 cluster at $z = .089$ when referenced to its parent NGC 4410 has $z_0 = .063$. The lowest Karlsson period is $z_K \sim .06$ to $z_0 .065$ for active galaxies approaching AGN/quasar properties. (see G. and E.M. Burbidge 1967 and Arp et al. 1990 for the discovery of this lowest periodicity). Of course this periodicity would apply to the associations of $z = .09$ galaxies with $z = .02$ active parents mentioned in the last paragraph of the previous section. As for secondary ejections, two of the faintest quasars in Table 2 (19.4g and 20.0g) fall $z_0 = +.004$ and -.013 from the $z = .089$ cluster redshift.

7. Summary and Conclusions

Investigation of the field around the very active galaxy NGC4410/Mrk1325 reveals pairings of quasars and higher redshift galaxies including clusters of galaxies. The patterns are supported in detail by many previous investigations. The fit of the redshifts with the long standing Karlsson periodicity relation confirms again the reality of the numerical values of that series and at the same time the reality of the physical associations of the higher redshift objects.

The suggested model is that high redshift quasars are ejected and evolve in steps to lower redshifts. Either initially or as they grow in luminosity and mass they can divide into smaller objects which can evolve into groups or clusters of smaller companion galaxies. The elongated distribution of clusters implies that the evolving low mass plasmoids can be disrupted by passing out through the intergalactic medium which is often observed to be blown partially clear around the ejecting parent.

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Fig. 1. The most conspicuous pairs of quasars within 60' of the active galaxy NGC4410/Mrk1325 are shown. See Tables 1 and 2.

Fig. 2. The residuals from the Karlsson redshift periodicities, $z_v$, are $d > 30'$ pluses, and $< 30'$ circles. Histogram is for +’s.

Fig. 3. Plot showing that periodicity residuals $z_v \leq .03$ average brighter in apparent magnitude than $z_v \geq .03$.

Fig. 4. The dense elongation of X-ray sources SE of NGC 4410 (plus sign at center) coincides with the Abell Clusters A1541, A 1541A and A1541C (12h27m27s+08d50m24s). From Rosat source browser.
Fig. 5. All galaxies with $0.077 \leq z \leq 0.097$ within square 120' on a side around NGC 4410. Circle shows location of Abell 1541 with $z = 0.089$.

Fig. 6. The same field as Fig. 5 with X-ray sources added as X symbols. Data from ROSAT Web Browser.
Fig. 7. An X-ray picture of the ultra luminous, active galaxy Arp220. Note the emergence of the group of X-ray galaxies on the line to the $z = 1.25$ quasar and the many redshift similarities to the NGC4410 association.

8. Paper submitted 9 May. Report received 10 May from Astronomy and Astrophysics

We have read attentively your paper "Quasars and Galaxy Clusters Paired Across NGC 4410" and conclude unfortunately that we cannot accept it on the grounds that its scientific content is not sufficient to warrant publication in A&A.

Indeed, the heart of the paper is to investigate all alignment effects around a precise location on the sky, around a precise galaxy. This is not original, since your group has claimed alignment for many objects in the past, so there is nothing new. In addition, it is quite easy to find such alignments in the sky, given the spatial distribution of galaxies, distributed in a fractal structure of filaments, great walls, and non-uniform structure, that has now been even better revealed and precised by large surveys such as the SDSS. So many remarks of alignment could be noticed like that, and this would be purely by chance, as can be simulated in numerical simulations of cosmic filaments. No new observations are reported here, no new physics is involved either, and this short note only emphasizes some more numbers and coincidences, that can appear purely by chance.

We regret to inform you that we shall be unable to give any further consideration to this paper.

We are sorry to disappoint you on this occasion.

Yours sincerely,

The Editors