Astron. Astrophys. 327, 479–482 (1997)

ASTRONOMY
AND
ASTROPHYSICS

Research Note

Concentration of quasars around the active extragalactic object 3C 345

Halton Arp

Max-Planck-Institut fur Astrophysik, Karl-Schwarzschild-Strasse 1, D-85740 Garching, Germany

Received 11 March 1997 / Accepted 24 June 1997

Abstract. It is shown that there is an over density of about a dozen fainter, generally higher redshift quasars around the bright,strongly variable 3C 345. The associated quasars are generally aligned through 3C 345 with an accuracy that is highly improbable to occur by chance. There is a Seyfert 1 galaxy (NGC6212) within 4.7 arc min of 3C 345, as in many other significant associations of quasars with low redshift galaxies. The excess of quasars around 3C 345 and the Seyfert (a factor of 15) is similar to the excess of quasars around the jet Seyfert NGC1097 (a factor of 20) which was found in 1984. It is noted that at a redshift of z= .59, 3C 345 is like a number of other bright apparent magnitude quasars of medium redshift which fall significantly close to low redshift, active galaxies and exhibit alignments of X-ray sources and X-ray BSO's and quasars.

Key words: quasars: individual: 3C 345 – galaxies: NGC 6212 – X-rays: galaxies – quasars: general

1. Introduction

The bright radio source 3C 345 was optically identified in 1965, only two years after the first quasars were discovered (Goldsmith and Kinman 1965). It quickly became noted for its extreme variability in all wavelengths (see references in Hewitt and Burbidge 1993 p.797). It is also a VLBI jet object which shows superluminal motion when placed at its redshift distance.

A number of other active objects were known to be in its vicinity but it was not until G. Burbidge pointed out to me that a low redshift galaxy, NGC6212, lay very close to 3C 345 that I investigated further and found that the region had been included in two extended fields which had been uniformly searched for quasars with CHFT slitless spectra plates (Crampton et al. 1988). It was immediately apparent that the most conspicuous concentration of quasars in the 8 sq. deg. region which included 3C 345 was centered on this famous, active object. The analysis in the following paper concentrates on the nature and significance of the association and compares it with a number of similar associations.

Send offprint requests to: H. Arp

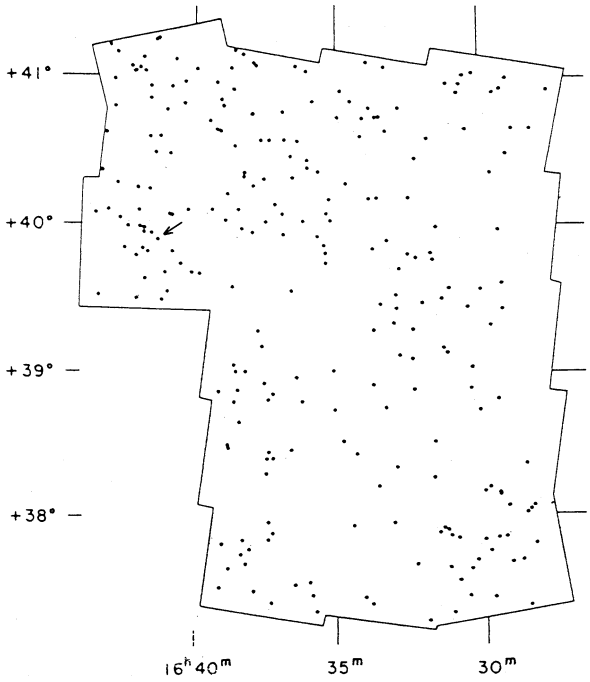

Fig. 1. Quasar candidates discovered in an 8 sq. deg. area by Crampton et al. (1988). The concentration around 3C 345 can be seen at about 16h39m and +40 deg (arrow). This region is shown enlarged in Fig. 2.

2. The density enhancement around 3C 345

Fig. 1 shows the quasars found in the grens search of about 8 sq. deg. by Crampton et al. One conspicuous concentration is at R.A. = 16h 41m 18s Dec. = +39deg 41′ 11″ (1950). The concentration is in the form of a rough line running from NE

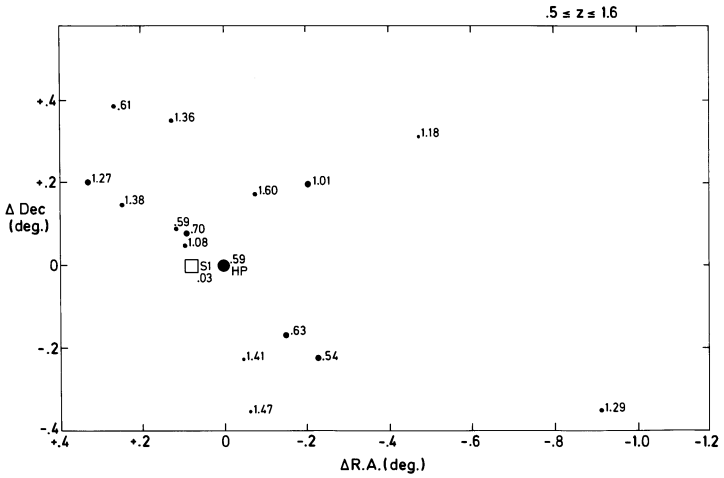

Fig. 2. Quasars of redshift $.5 < z < 1.6$ in a homogeneously searched area around 3C 345 and an equal area to the west. Redshifts are written to the upper right of each quasar. 3C 345 is identified HP (for high polarization) and the Seyfert galaxy NGC6212 is marked S1.

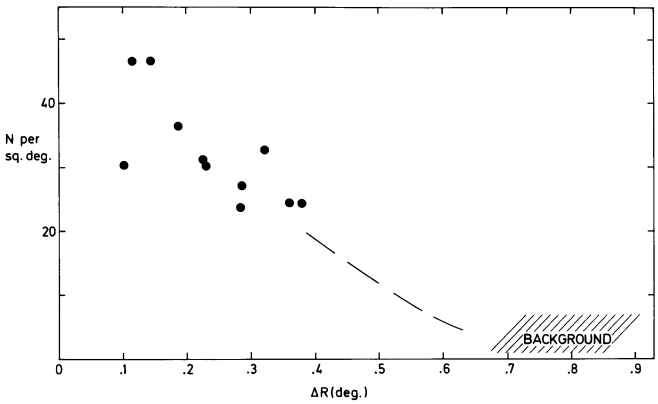

Fig. 3. Density of quasars in Fig. 2 in concentric circles around 3C 345. Background value discussed in text.

to SW exactly through the position of 3C 345. Most of these quasars can be identified in the enlarged plot of Fig. 2

The first question that poses itself is whether the quasars in the concentration around 3C 345 are different from the quasars in the rest of the field. The answer is yes. The quasars in the rest of the field are fainter and generally of much higher redshift. This is illustrated in Fig. 2 where only the quasars of $.5 < z < 1.6$ are plotted and the symbol size varies as their apparent magnitude. In this case we can see by inspection that an equal area west of 3C 345, analyzed in exactly the same way, shows almost no similar quasars.

This result can be quantified by calculating the quasar density within concentric circles centered on 3C 345. Fig. 3 plots the density per sq. deg. at different radii from 3C 345. The background density which the 3C 345 group is obviously approaching at large radii is very interesting. Taking the background density as that in the western half of Fig. 3 one obtains 2.5 background objects per sq. deg. How does this correspond to background densities in the rest of the sky? As summarized by Arp (1981), down to 20th apparent magnitude various determinations yield about 6 quasars per sq. deg. Conservatively assuming half are in the $.5 < z < 1.6$ redshift range we would expect a background of 3, agreeing almost exactly with the background derived from Fig. 2 and plotted in Fig. 3. Alternatively we can use the density of quasars $.5 < z < 1.0$ from the CHFT survey as determined by Arp (1990). That also comes out to be a background level of about 3 per sq. deg.

What this means is that we have a very good determination of the expected background density in Fig. 3 Therefore we can confidently compute that the over density close to 3C 345 reaches a factor of 15, falling away at greater distances to an indicated group diameter of the order of a degree. If we estimate the standard deviation of the background density as a maximum of 3, we have a minimum of 5 sigma density enhancement at this particular position in the sky.

We note that a similar density enhancement of quasars (a factor of 20) was found around the active, jet Seyfert NGC1097 (Arp, Wolstencroft and He 1984). Morever the three brightest quasars, one of which was extremely variable, were situated just between the two brightest jets of NGC1097 and had redshifts of z= .34, .53 and 1.00.

3. The X-ray identifications

Because 3C 345 is bright in X-rays and variable, a number of short exposures (up to 4 ks) were taken with ROSAT. Those optically identified quasars listed in Table 1 and shown in Fig. 2 which are detected in the archived ROSAT X-ray exposures are plotted in Fig. 4. Their broad band counts per kilosecond (cts ks^{-1}) are listed in the last column of Table 1 and written to the upper right of each quasar in Fig. 4.

Fig. 4 shows that the quasars close to 3C 345 are very bright X-ray sources and are well aligned across it. We can roughly compute the probability of finding such bright X-ray sources so close to 3C 345 by halving the broad band fluxes listed in Table 1 and consulting the average background density for (.5 to 1.0 keV) X-ray sources from Hasinger et al.(1993) or Hasinger et al. (1997 unpublished).

Let us pick the two brightest X-ray quasars across 3C 345 at C = 37 cts/ks and C = 62 cts/ks. This represents the same kind of pairing of X-ray quasars as reported across active Seyfert galaxies by Pietsch et al. (1994), E.M. Burbidge (1995) and Arp (1996;1997). The chance of accidently finding such bright

Table 1. Quasars near NGC 6212/3C345

object	z	V	R.A. (2000)	Dec.	ΔX	ΔY	$X-ray$
quasar	1.75	20.4mag.	$16^h36^m51^s.3$	$+39°56'05''$	-1'.175	'.125	$ctsks^{-1}$
"	1.83	19.8	16 37 01.4	39 38 43	-1.147	-.165	
"	2.0	19.4	16 37 49.5	39 55 48	-.989	.120	
"	1.29	19.2	16 38 15.3	39 27 29	-.911	-.352	
"	1.864	19.6	16 38 81.6	39 50 30	-.855	.032	
"	2.010	20.1	16 38 32.8	39 58 46	-.849	.169	
"	1.898	19.6	16 38 48.1	40 02 46	-.800	.236	
"	1.965	19.2	16 39 53.7	40 14 06	-.589	.425	
"	1.183	19.7	16 40 29.5	40 07 14	-.476	311	
" HP	1.666	16.5	16 40 29.7	39 46 46	-.477	-.031	
"	1.625	18.5	16 40 34.2	39 56 22	-.462	.129	
"	2.253	19.2	16 41 02.5	40 00 45	-.371	.203	
"	2.614	19.2	16 41 30.7	39 34 36	-.283	-.233	
"	.540	18.3	16 41 47.5	39 35 03	-.229	-.226	62
"	1.005	17.1	16 41 54.2	40 00 33	-.206	.199	13
"	.625	18.0	16 42 11.2	39 38 36	-.153	-.167	24
"	2.529	19.7	16 42 28.2	39 58 30	-.098	.165	
"	1.860	18.6	16 42 28.5	39 43 43	-.097	-.081	
"	1.595	19.3	16 42 34.1	39 58 53	-.079	.171	4
"	1.466	20.2	16 42 39.2	39 27 19	-.063	-.355	
"	1.414	19.8	16 42 43.9	39 35 02	-.048	-.226	(7)
3C345 HP	.594	16.0	16 42 58.8	39 48 37	.000	.000	365
quasar	2.0	20.9	16 43 11.5	39 51 11	special field		
"	2.0	21.2	16 43 19.5	39 43 39	"	"	
NGC6212 S1	.030	15.	16 43 23.1	39 48 24	.078	-.003	6
quasar	.443	18.0	16 43 25.7	39 32 34	.086	-.267	
"	.704	16.8	16 43 26.2	39 53 14	.088	.077	13
"	1.083	18.6	16 43 27.2	39 51 25	.091	.047	12
"	.594	19.3	16 43 34.9	39 53 47	.115	.086	37
"	2.113	18.9	16 43 36.6	40 00 23	.121	.196	
"	1.358	19.5	16 43 38.7	40 09 35	.127	.350	24
"	2.179	20.5	16 44 06.7	39 45 05	.218	-.059	
"	1.377	19.7	16 44 15.7	39 57 15	.246	.144	9
"	.608	19.3	16 44 20.8	40 11 28	.261	.381	
"	1.268	18.8	16 44 40.3	40 00 37	.324	.200	
"	2.145	19.1	16 45 01.8	39 25 48	.396	-.380	
"	1.88	18.0	16 45 07.4	39 59 18	.410	.178	

X-ray sources this close to a given point in the sky is .06 and .2, giving a probability of finding two such sources so close as p = .01. But now we have to multiply by the chance they would be accidently aligned to within 7 deg. out of 180 or p = .04. This gives a total accidental probability that two such bright sources would be so well aligned across 3C 345 as $P = 4 \times 10^{-4}$. This is quite in line with the probabilities of the pairs of X-ray sources aligned across the Seyfert galaxies mentioned above. But we have more X-ray quasars aligned in this case, and considering just the three of C = 13, 12 and 24 cts/ks we have three more cases of $p \sim .04$ which produces an overall probability of the alignment of the five strongest X-ray quasars of $P \sim 3 \times 10^{-8}$. This partial calculation of probability would seem to strongly confirm the visual conclusion that these quasars are physically associated with the central, active 3C 345.

4. Preferred redshifts

Further confirmation of the physical reality of the association comes from the similarity of redshifts of the quasars in the alignment. In Fig. 2, five of the six quasars in the alignment (counting 3C 345 at z = .59) average to z = .61. It is very unlikely, on the assumption that these are unrelated background quasars, that they would be so closely the same redshift.

A sixth quasar in the close alignment is at z = 1.08 and the outer quasars in the group are at redshifts which agree closely with the quantized redshifts found in all analyses of quasar redshifts, namely:

z = .60, .91, 1.41 (see Arp et al. 1990)

5. The role of the Seyfert and ejection

The Seyfert NGC6212 at redshift z = .03 falls only 4.7 arc min from 3C 345 (z = .59). This is very similar to the associations of

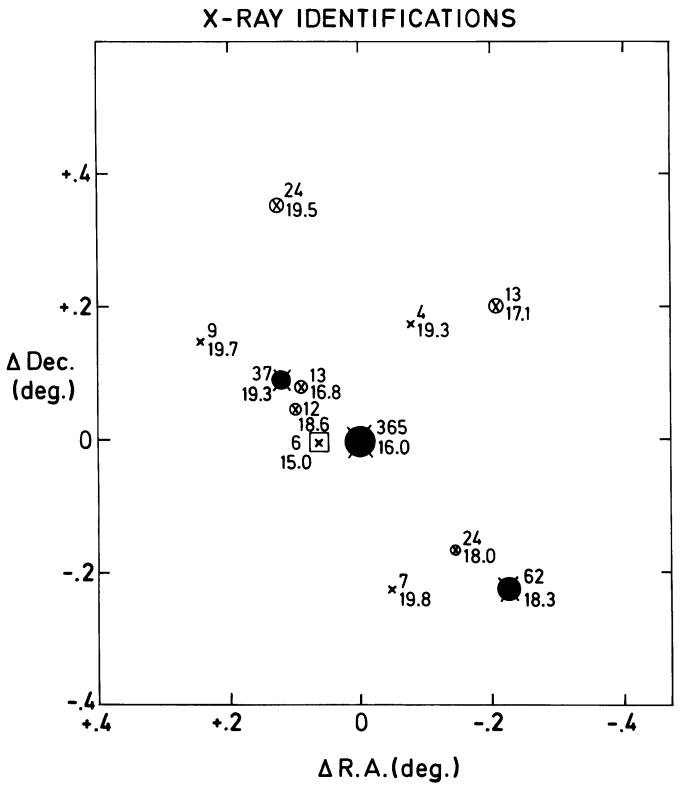

Fig. 4. Those quasars which are detected as X-ray sources in archived ROSAT observations are marked with cts ks^{-1} written to upper right. Apparent V magnitude is written below.

low redshift NGC galaxies with bright radio quasars found by Burbidge et al. (1971). In two of these cases even the redshifts of the the radio quasars were similar (3C275.1 at z = .56 and 3C232 at z = .53). In the latter two cases, elongated X-ray extensions or jets, from what turned out to be active NGC galaxies, were found to be pointing to the the quasars in ROSAT PSPC observations (Arp 1996).

My conclusion from these previous cases was that the bright radio quasars originated from the adjacent Seyfert and that they were in turn ejecting generally higher redshift quasars in opposite directions. In the configuration shown here in Fig. 2 it is not clear whether the quasars of z = 1.36 and 1.38 and z = 1.41 and 1.47 originated in ejection from the Seyfert or 3C 345. But the stronger X-ray quasars of lower redshift are very well aligned with 3C 345 and indicate origin from that source as in the lines of X-ray sources originating from 3C275.1 and 3C232.

It is also noticeable that the quasar redshifts on one side of the 3C 345/NGC6212 center, fall systematically higher than the quantized values, and those on the other side fall systematically lower. This effect is to be expected if quasars at quantized values are ejected toward and away from the observer from the center with projected velocities of some hundredths of c.

6. Summary

It is reported here that an over density of optically as well as X-ray selected quasars exists around the famous radio AGN, 3C 345. Alignment and other properties of the quasars support the conclusion that this represents another example of a group of physically related active objects of various redshifts.

References

Arp H., 1981, ApJ **250**, 31.
Arp H., 1990, A& A **229**, 93.
Arp H., 1996, A& A **316**, 57.
Arp H., 1997, A& A **319**, 33.
Arp H., Wolstencroft R.D., and He X.T., 1984, Ap.J. **285**, 44.
Arp H., Bi H.G., Chu Y. and Zhu X., 1990, A& A **239**, 33.
Burbidge E. M., 1995, A& A **298**, L1.
Crampton, D., Cowley A.P., Schmidtke P. C., et al., 1988, AJ **96**, 816.
Goldsmith D.W., and Kinman, T.D., 1965, ApJ **142**, 1693.
Hasinger G., Burg R., Giacconi R., et al., 1993, A& A **275**, 1.
Hewitt. A., and Burbidge, G., 1993, ApJS **87**, 797.
Pietsch W., Vogler A., Kahabka P. et al. 1994, A& A **284**, 386.

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.