Astron. Astrophys. 136, L9–L10 (1984)

ASTRONOMY AND ASTROPHYSICS

Letter to the Editor

The clustering of quasars

P. A. Shaver

European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-8046 Garching bei München, Federal Republic of Germany

Received May 14, accepted May 17, 1984

Summary. A new method of studying the clustering of quasars is applied to a large sample of quasars with known redshifts. Tentative first results reveal possible clustering, which may be comparable to that of galaxies at the current epoch.

Key words: Quasars - Clusters - Cosmology

Conclusive evidence regarding the physical clustering of quasars has so far proven elusive, largely because of the low space density of these objects. Previous attempts were based on small but homogeneous samples of quasars (Osmer, 1981; Webster, 1982; Chu and Zhu, 1983), or large samples of UVX objects of which some fraction are quasars of unknown redshifts (Shanks et al., 1983; Boyle et al., 1983). No evidence was found for physical clustering, beyond some groupings of quasars in position and redshift which may conceivably be physical entities (e.g. Osmer, 1981; Margon et al., 1981; Oort et al., 1981; Webster, 1982; Woltjer and Setti, 1982; Oort, 1983). In the present work a new method is applied to a large sample of over 2000 quasars with published redshifts.

Clustering is expected to show up amongst pairs or groups of quasars which are close to each other in both redshift and position on the sky. By contrast, pairs which have large differences in either redshift or position are expected to be physically unassociated with each other, and should exhibit no clustering. The search for clustering can then be done by comparing these two groups. This has the great advantage that selection effects (survey areas, redshift ranges, limiting magnitudes, sensitivity variations, edge effects, etc.) should cancel out, making possible the use of large quasar catalogues for this purpose. The present sample was obtained from the Véron catalogue (Véron-Cetty and Véron, 1984), which contains 2251 quasars with published redshifts.

Round-off and uncertainties in the quoted redshifts can be largely eliminated by excluding quasars with redshifts $z = 0.05n$ $(n = 0,1,2,...)$. Alternatively, one may exclude quasars for which the quoted redshifts were obtained from slitless spectroscopy, or quasars with redshifts quoted to less than two decimal places; there is some overlap, and the results are similar. Many of the redshifts are quoted to two decimal places; an uncertainty of 0.01 in redshift corresponds to 1000 km s^{-1} at $z = 2$, and 2000 km s^{-1} at $z = 0.5$. Further uncertainty arises from the fact that many of the broad, high-excitation lines of quasars, from which the redshift is normally determined, are displaced relative to the systemic redshift; these deviations can exceed 1000 km s^{-1} and go either way (Gaskell, 1982). Such uncertainties will tend to dilute any real clustering in redshift.

It is necessary to assume a cosmological model in computing the projected separations of the quasar pairs, and some sort of evolutionary model must be adopted in order to bring them to a common epoch, which is necessary for intercomparison. Two extremes have been used in both cases: a universe which is open (asymptotically empty, $q_o = 0$) or flat ($q_o = 1/2$), and cluster sizes which are comoving [$(1+z)$ dependence] or constant with time.

Figure 1 shows the results for an open universe and comoving linear separations. There appears to be an excess of quasar pairs of small separation ($< 5\ h^{-1}$ Mpc, where $H_o = 100\ h$ km s^{-1} Mpc^{-1}) and redshift difference (< 2500 km s^{-1}), relative to those of large separation and redshift difference. Only 2.4 such pairs would be expected if there were no clustering (in which case the ratios in Fig. 1 should be constant as a function of separation or redshift difference), whereas 12 were found. These are listed in Table 1. Two of them may be gravitationally lensed quasars, which are irrelevant for clustering, but the others have angular separations which are too great for gravitational imaging by intervening galaxies or clusters. The only obvious possible selection effect would be the inclusion of close pairs which were published preferentially because they also had similar redshifts. This certainly applies to the gravitational lens quasar 2345+006A,B, and possibly also to the 0952,3+698 group (see comments in Table 1). Finally, improving the uncertain redshifts may remove the 1254,5+370 pair from this table, depending on whether or not the quasars are actually clustered, but the 0103-294A,B and 1258+285,6 pairs would almost certainly remain. Thus, the final number of unbiased pairs of distinct quasars in Table 1 probably lies between 6 and 10, an excess of 2.3 - 4.9σ.

Whatever the actual excess may be, the sensitivity achieved with this technique is sufficient to permit a meaningful comparison with galaxy clustering. Figure 2 shows that the quasar-quasar correlation function, generated from the data in Figure 1, is (at most) consistent with the galaxy-galaxy correlation function and considerably less than the cluster-cluster correlation function. If one assumes $q_o = 1/2$, or non-evolving cluster sizes, the linear scale of the excess is reduced or increased by about 25% respectively. It is noteworthy that there is no hint of clustering on scales larger than about 5 h^{-1} Mpc; the larger pairs and groups which have been cited in the past as possible examples of quasar clustering are not commonplace.

1984A&A...136L...9S

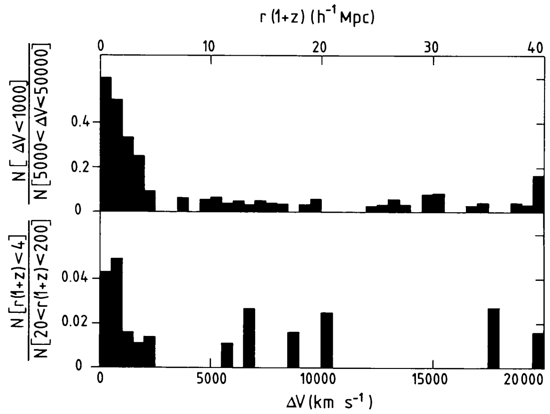

Figure 1. Top: Ratio of the number of quasar pairs with small redshift difference (ΔV <1000 km s^{-1}) to the number with large redshift difference, against projected linear separation. Bottom: Ratio of the number of quasar pairs with small projected linear separation [$r(1+z)$ <4 h^{-1} Mpc] to the number with large separation, against velocity difference.

Table 1. Quasar Pairs of Small Separation and Redshift Difference

QSO	z	θ (')	r(1+z) (h^{-1}Mpc)	ΔV (km s^{-1})	Comments
0103-294A 0103-294B	2.18* 2.17*	2.0	2.5	944	objective prism survey
0307-195A 0307-195B	2.144 2.122	0.9	1.1	2105	objective prism survey
0952+698 0953+698A	2.048 2.054	2.0	2.4	590	3 of 6 quasars found on grism plate of the M82 field; these 3 published first because of small angular separations (and redshift differences?)
0952+698 0953+698B	2.048 2.040	3.6	4.2	788	
0953+698A 0953+698B	2.054 2.040	2.1	2.5	1377	
0957+561A 0957+561B	1.390 1.390	0.1	0.1	0	gravitational lens
1146+111 1146+110	1.011 1.010	2.6	1.7	149	close group of quasars from objective prism survey
1254+370 1255+370	0.28 0.283	3.1	0.7	702	UVX survey 4C 36.22
1258+285 1258+286	1.38* 1.374	4.6	3.9	757	objective prism survey 5C 4.127
1641+399A 1641+399B	0.594 0.594	8.4	3.6	0	3C 345 serendipitous X-ray source
2203-187 2203-188	0.627 0.618	6.8	3.0	1663	objective prism survey PKS 2203-18
2345+006A 2345+006B	2.147 2.152	0.1	0.1	476	gravitational lens

* redshifts from slitless spectra

The projected separations were calculated using the average of the two redshifts.

In conclusion, the present results reveal possible clustering of quasars, which may be similar to that of galaxies at the current epoch both in linear size and velocity dispersion. Further evidence for clustering at high redshift comes from absorption-line observations of pairs of quasars of very different redshifts which happen to be located close to each other on the sky. The probability of finding absorption in the spectrum of the background quasar at the redshift of the foreground quasar is relatively high, as expected if quasars are located in clusters of galaxies (Shaver and Robertson, 1983).

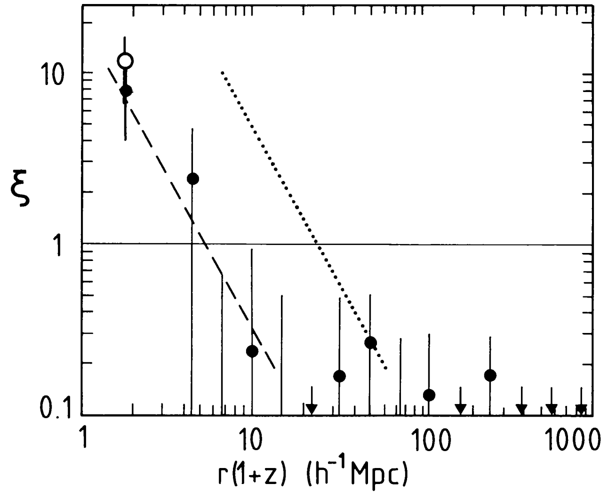

Figure 2. (Projected) spatial correlation function from the data in Figure 1, plotted in logarithmic bins. The open circle includes the two possible gravitational lens quasars indicated in Table 1. Error bars are ±1σ. The dashed and dotted lines represent the galaxy-galaxy and cluster-cluster (3-D) spatial correlation functions respectively (Bahcall and Soneira, 1983) (the mean difference between true and projected scale is small, ~15%, and has not been applied here).

This method can readily be applied to the extensive new objective-prism surveys now being undertaken, which should be unbiased with respect to small angular separations and redshift differences. If accurate measurements are then made of the redshifts of those close pairs with similar redshifts, a more reliable global correlation function for quasars will be obtained. Eventually it should be possible to study the properties of the correlation function as a function of cosmic epoch.

I am grateful to a number of colleagues, particularly Guido Chincarini, Colin Norman, Bob Sanders, and Philippe Véron, for stimulating discussions on this subject.

References

Bahcall, N.A., Soneira, R.M. 1983, Astrophys. J. 270, 20.
Boyle, B.G., Fong, R., Shanks, T. 1983, Quasars and Gravitational Lenses, Proc. 24th Liège Astrophysical Colloquium, p. 368.
Chu, Y., Zhu, X. 1983, Astrophys. J. 267, 4.
Gaskell, C.M. 1982, Astrophys. J. 263, 79.
Margon, B., Chanan, G.A., Downes, R.A. 1981, Nature 290, 480.
Oort, J.H., Arp, H., de Ruiter, H. 1981, Astron. Astrophys. 95, 7.
Oort, J.H. 1983, Quasars and Gravitational Lenses, Proc. 24th Liège Astrophysical Colloquium, p. 301.
Osmer, P.S. 1981, Astrophys. J. 247, 762.
Shanks, T., Fong, R., Green, M.R., Clowes, R.G., Savage, A. 1983, Mon. Not. Roy. astr. Soc. 203, 181.
Shaver, P.A., Robertson, J.G. 1983, Nature 303, 155.
Véron-Cetty, M.-P., Véron, P. 1984, ESO Scientific Report No. 1.
Webster, A. 1982, Mon. Not. Roy. astr. Soc. 199, 683.
Woltjer, L., Setti, G. 1982, Astrophysical Cosmology, eds. H.A. Bruck, G.V. Coyne, M.S. Longair, Pontificia Academia Scientarium, p.315.