ON THE CROSS-CORRELATION OF GALAXIES WITH UVX OBJECTS AND QSOS

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ABSTRACT

Recent measurement of UK Schmidt plates have yielded interesting results on the cross-correlation of galaxies with QSOs and ultra-violet excess (UVX) objects. We find that in all Schmidt fields so far analysed there appears to be a significant anti-correlation (at angular scales less than 5') between the positions of galaxies and QSOs and between the positions of galaxies and UVX objects. This anti-correlation appears to be restricted to those galaxies that are found in clusters. These observations can very naturally be explained using a model in which dust within clusters of galaxies obscures the QSOs lying at cosmological distances behind them. This hypothesis may be further corroborated by tentative evidence that the UVX objects and the QSOs appear to be reddened close to clusters of galaxies.

INTRODUCTION

For many years controversy has reigned over the proposed association of low redshift galaxies with high redshift QSOs (Arp 1970, Sulentic 1983). The overwhelming problem with recent statistical tests to assess the significance of these associations has been to find unbiased QSO catalogues. For example, one criticism levied at the recent study of Seldner and Peebles (1979) was that the Burbidge Crowne and Smith (1978) QSO catalogue may well have contained 'ringers'; QSOs that were detected only through their proximity to bright galaxies.

The appearance, in the last five years, of many new unbiased QSO catalogues (at positions of bright galaxies in the field) has now made it possible to test objectively these claims for galaxy/QSO associations, resulting in a far greater degree of confidence in the final results. A great deal of the work done in procuring these new catalogues has focussed on eyeball searches of UK Schmidt objective prism plates for emission-line objects. The area of sky covered by these plates produces catalogues of QSOs whose membership range up to a few hundred, at the limiting magnitude of the search. These large unbiased catalogues are

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therefore ideally suited for correlation analysis.

We describe here the results of cross correlating these QSO catalogues with the positions of faint galaxies found over the same areas using COSMOS machine measurements of UK Schmidt J plates. A more detailed discussion of these results can be found in Shanks et al. (1983) and Boyle, Fong and Shanks (1984).

RESULTS

Following Seldner and Peebles (1979) we use the 2 point cross-correlation function in analysing the data. The galaxy-QSO cross-correlation function is obtained by centering on each QSO in the catalogue in turn and counting the number of galaxies in an annulus of width, $\Delta\theta$, and angular distance θ from the central QSO. The counts are then compared to those found from a random distribution of test points around the QSO. The 2 point function w_{qg} is then

$$w_{qg} = \frac{\text{average number of galaxies in range } (\theta, \theta + \Delta\theta)}{\text{average number of random points in range } (\theta, \theta + \Delta\theta)} - 1$$

where w_{qg} will be zero from a Poissonian distribution of galaxies around QSOs, positive if galaxies cluster around QSOs and negative if galaxies and QSOs avoid each other.

We have now analysed one field centred at (00h 53,-28°) which contains the South Galactic Pole (SGP), and two other fields at (22h, -18°55') and (1h 12 -35°) for all of which we have both a complete QSO catalogue and a list of galaxy positions from the COSMOS measurement of

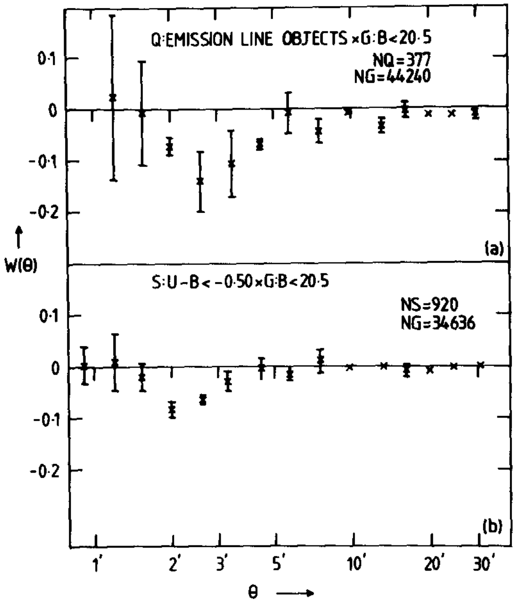

Fig. 1a. Cross correlation of QSOs with galaxies (B<20.5).

Fig. 1b. Cross correlation of UVX objects with galaxies (B<20.5).

FIG 1

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UK Schmidt plates. The positions for the QSOs were found from Clowes and Savage (1983), Savage and Bolton (1979), and Savage et al. (1983).

On cross-correlating the samples (Figure 1a) we find a somewhat surprising result. Rather than finding an excess of QSOs around galaxies as Seldner and Peebles had done we see a deficiency of QSOs near the galaxies at the 3σ level. At yet smaller scales <1', there may also be the suspicion of an upturn, but the statistics here are poor and w_{qg} is very noisy. This anti-correlation was originally found on the SGP alone (Shanks et al. 1983). The result was verified on the 22h and 1h 12 fields. The combined result for all 3 fields is shown here, the error bars are derived from the field-to-field variation in the estimator for $w_{qg}(\theta)$ on each field.

On obtaining this result we were immediately concerned that a selection effect was responsible for the observed anti-correlation. One can easily imagine a situation in which emission line objects lying near to galaxies would be rejected from an 'eyeballed' QSO catalogue in case they were merely overlapped galaxy spectra.

To test for this selection effect we procured an automatically detected sample of QSOs. This was achieved by obtaining U and B magnitudes from COSMOS measurements of 50000 stars with $B < 20^{m}.5$ in three fields; the SGP and 22h fields as previously analysed and one new field centred at (12h 30, 0°).

From Sandage and Luyten (1969) it is well known that, at high galactic latitudes and faint magnitudes, many UVX stars are QSOs. We thus defined a sample of stars with UVX. The criterion for inclusion in the UVX sample was $17.5<B<20.0$ and $U-B<-0^{m}.50$, giving a surface UVX star density of 25 deg^{-2}. It is generally accepted that at $B<20^{m}.0$ the density of QSOs is 10-15 deg^{-2} (Veron and Veron 1982). We expect, therefore, that this UVX sample will be contaminated by ordinary galactic stars. This contamination will only serve to decrease any apparent clustering or anti-clustering as galactic stars are Poisson distributed with respect to faint galaxies. From a slit spectrum survey (see Shanks 1983, it appears that the proportion of QSOs in the UVM samples is, indeed, about 40-45%, the remainder being halo stars and white dwarfs.

The cross-correlation of the UVX stars with the galaxies is shown in Fig. 1b. We see a similar result to that found with the QSO sample, although at a lower amplitude (due to the presence of galactic stars). Again this result was first seen on the SGP and was reported in Shanks et al. (1983). It has now been substantiated by the inclusion of two new fields.

Although the same selection effect could not cause both the anti-correlation seen in the QSO/galaxy cross-correlation and in the UVX/galaxy cross-correlation, it is still conceivable that some selection effect in the COSMOS measurement process could be responsible for the observed anti-correlation seen in this case. The cross-correlation of

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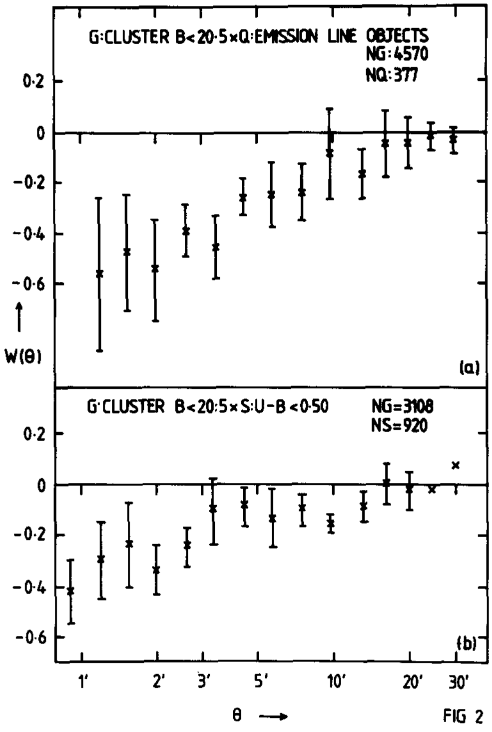

Fig. 2a. Cross correlation of QSOs with duster members

Fig. 2b. Cross correlation of UVX objects with cluster members.

a large control sample of non-UVX, ordinary galactic stars as detected by the COSMOS machine from their broadband colours did, however, produce a Poissonian result at all scales (Shanks et al. 1983).

To investigate the origin of the anti-clustering in the galaxy sample we divided the galaxies into field and cluster subsamples, using the cluster detection algorithm of Gott and Turner (1977). The clusters were chosen to have a density contrast 8 times that of the background density and to have a membership of at least 6 galaxies. The clusters thus detected ranged in size from small groups to rich Abell-type clusters.

The cross-correlation of these clusters with the UVX stars and the QSOs is shown in Figs. 2a and 2b. The anti-correlation seen at all scales less than 5' in the UVX sample and at scales less than 8' in the QSOs is far more marked than before, (3.5σ with the QSOs and 3σ with the UVX objects) and clearly shows that the clusters are the major cause of the anti-clustering. In contrast the results found with the field galaxies (not shown) are consistent with a Poissonian distribution of QSOs and UVX stars around them.

INTERPRETATION

The simplest explanation of the observed anti-correlation between clusters of galaxies and QSOs is that dust lying in line of sight

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clusters obscures the QSOs lying at cosmological distances behind them. Evidence for reddening of QSOs in the vicinity of galaxy clusters has recently been claimed by Boyle et al. 1984 who found that QSOs and UVX objects which lay within 2' of a cluster were on average $0^m.1$ redder in U-B than those found elsewhere. If this tentative result is confirmed then it would be a strong indication that the dust absorption model is correct.

On this assumption, we can estimate the amount of absorption needed to produce the observed amplitude of the cluster/QSO cross-correlation w_{qc}. We assume that the dust resides entirely in the galaxy clusters and that, at the faint magnitude limit for the detection of these QSOs the QSOs follow a number magnitude relation of the form

$$n(m_B) \propto 10^{0.6m_B} \quad \text{(Veron \& Veron 1982)}$$

If we have A_B magnitudes of absorption associated with each cluster then it can easily be shown that

$$w_{qc} + 1 = 10^{-0.6A_B}$$

giving an A_B of $0^m.35$ for $w_{qc} = -0.40$.

From this value of A_B we derive a reddening of $E(U-B) \simeq 0.1$. This agrees well with the values found from the colours of UVX stars and QSOs close to cluster galaxies, though caution must be urged lest we read too much into the significance of these results. Bogart & Wagoner (1973), again from cross-correlation techniques, proposed an absorption of $A_B = 0^m.5$ associated with Abell clusters, in good quantitative agreement with our results considering our clusters are not as rich as those used by Bogart & Wagoner. The mass of dust associated with this absorption can easily be calculated (Salpeter 1979). Given that our clusters have a typical angular diameter of 6' and are located at redshifts $\simeq 0.15$, we find, on average, $10^{10} M_\odot$ of dust in each cluster.

CONCLUSIONS

It has been shown that, in all fields so far studied QSOs and UVX objects are significantly anti-clustered with respect to galaxies that are members of clusters. Additional evidence from the reddening of QSOs and UVX stars around galaxy clusters, indicates that the most natural and simplest model for explaining these results is one in which QSOs distributed at cosmological distances are obscured by the dust located in intervening, foreground clusters of galaxies.

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DISCUSSION

J.-L. NIETO: The effect found by Seldner and Peebles (1979) does not hold any longer since Seldner himself and myself have redone the study and showed that the effect was just due to observational biases toward QSOs near galaxies. In our study, however, we found an excess of $m \leqq 19$ Lick galaxies at 2° from the QSO, at a quite significant level. Could this be explained by your absorption hypothesis? In addition, what is the meaning of the error bars?

B.J. BOYLE: There is no explanation in the dust model for this excess of galaxies at 2° that you have observed. We have not investigated the properties of the cross correlation function at such large angular scales so I can make no further comment. The error bars used are the r.m.s. field-to-field variation in the values for $\omega(\theta)$ obtained on each field.

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