

## ARE SOME QUASI-STELLAR OBJECTS ASSOCIATED WITH CLUSTERS OF GALAXIES?

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### ABSTRACT

Five small-redshift quasi-stellar objects are listed that are within the approximate geometrical boundaries of catalogued clusters of galaxies. Spectra of four galaxies in one of the clusters show the same redshift as the associated quasi-stellar object B264.

A systematic search for clusters of galaxies associated with quasi-stellar objects (QSOs) with redshifts less than 0.3 has been started by Bahcall and Gunn. The observational problems in such a program have been discussed by Sandage and Miller (1966) in connection with their unsuccessful search for a cluster of galaxies near 3C 48. The present search is being carried out with the Palomar 48-inch Schmidt telescope and makes use of exposures of approximately  $2\frac{1}{2}$  hours' duration on Eastman IIIaJ plates behind a Wratten 4 filter.

Bahcall discovered at the outset of this investigation that five QSOs with redshift  $z < 0.2$  lie within the approximate geometrical boundaries of known clusters of galaxies (Abell 1958; Zwicky, Herzog, and Wild 1961; Zwicky and Herzog 1963, 1966). The discovery was made primarily by comparing the published positions of the QSOs with the geometrical outlines of clusters of galaxies in the catalogue of Zwicky *et al.* We list in Table 1 the six QSOs with definitive redshifts  $z < 0.2$  and for five objects the catalogue numbers of the clusters of galaxies with which they are geometrically associated. Observations of the continuum energy distribution, including infrared and radio, and possible variations of the QSOs in Table 1 will be of interest.

The first QSO that was found to be associated with a cluster of galaxies was B264 ( $z = 0.095$ ; Braccesi, Lynds, and Sandage 1968). The initial recognition of the association came, in this case only, from an inspection of a 48-inch Schmidt plate taken by Bahcall. Figure 1 (Plate L1) shows that the QSO is within the outline given in the Zwicky-Herzog catalogue, in the northwest part of the cluster.

Spectra of the galaxies indicated in Figure 1 (Plate L1) have been obtained by Schmidt with the Cassegrain image-tube spectrograph at the 200-inch telescope. Table 2 gives the redshifts and the spectral features from which they were primarily derived. Four galaxies show a late-type absorption spectrum with the Ca II K-line at 3933 Å and the G-band at 4303 Å. The weaker Ca II H-line at 3969 Å is seen in galaxies 2 and 3, but

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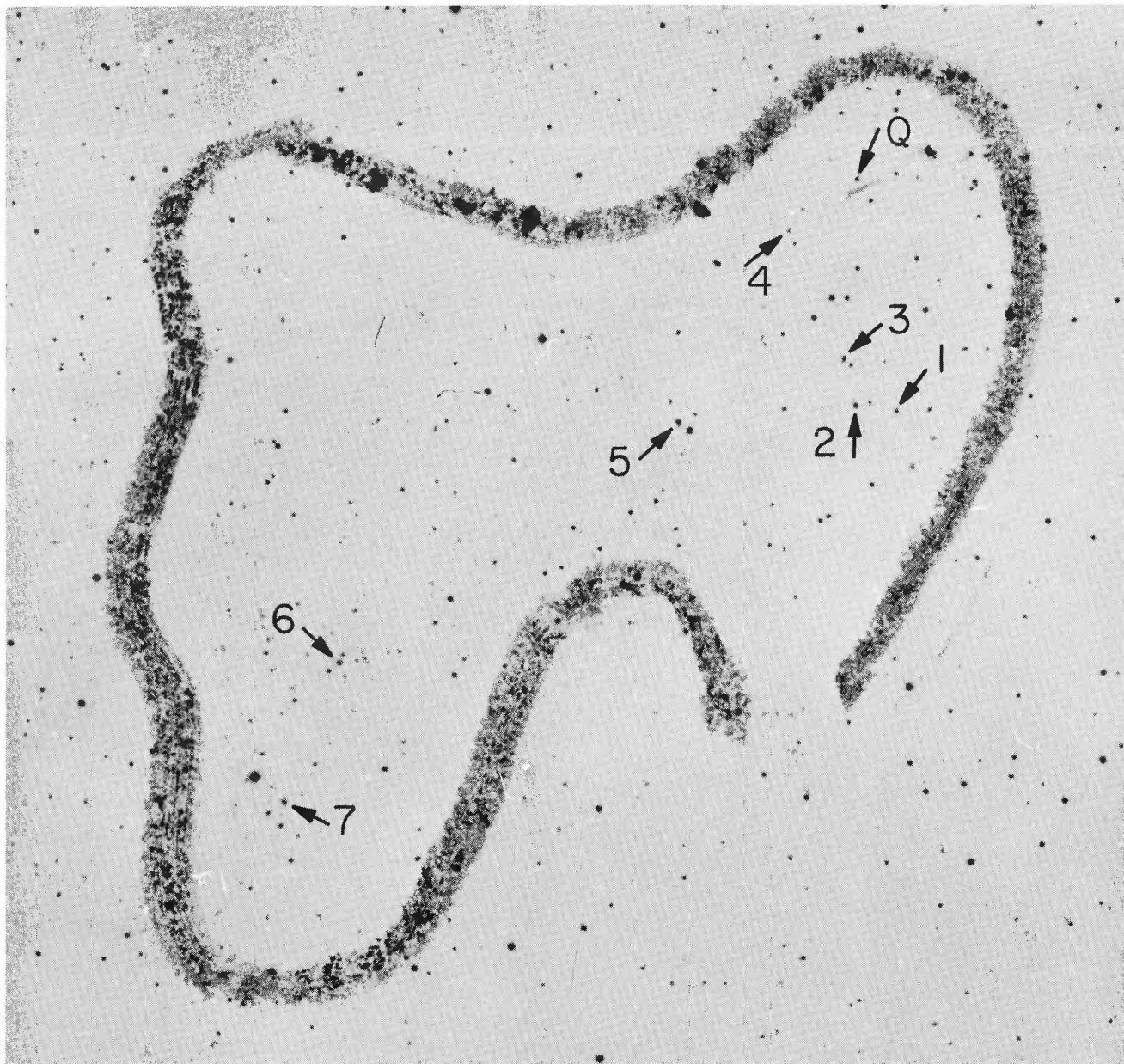


FIG. 1.—Print of *Sky Survey* E-plate in the vicinity of the QSO B264. North is at the top, east at left. Cluster outline is that given by Zwicky and Herzog (1963). Galaxies studied spectroscopically are numbered in order of increasing right ascension. The QSO is indicated as *Q*.

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accurate measurement is made impossible by mercury emission at 4358 Å. Both the K-line and the G-band in the faint galaxy 3 are weak, making its redshift less certain than those of the other galaxies. The emission line observed in galaxy 4 is identified as [O II]  $\lambda 3727$  emission. Weak emission at the same wavelength may be present in the spectra of galaxies 1 and 3. For the galaxies with few spectral features the observed wavelengths are given in Table 2. All wavelengths fit the identifications and redshifts to within 3 Å. The redshifts of galaxies 5 and 7 are well established by a larger number of spectral lines. The redshift of the QSO B264 was determined from the narrow [O III] lines (the

TABLE 1  
CLUSTERS OF GALAXIES GEOMETRICALLY ASSOCIATED WITH QSOs

QSO	Redshift*	Zwicky Cluster†	Abell Cluster‡	Remarks§
PKS 0736+01.....	0.191	0737.5+0108 (0.05-0.1)	.....	
3C 273.....	.158	.....	.....	1
B264.....	.095	1300.4+3213 (0.1-0.15)	1667 (0.18)	
B234.....	.060	1308.2+3531 ( $\leq 0.05$ )	.....	2
B340.....	.184	1304.4+3430 ( $\geq 0.2$ )	.....	
Ton 256.....	0.131	1612.7+2624 (0.15-0.2)	2165 (0.18)	

\* For references see Burbidge (1967) and Braccesi, Lynds, and Sandage (1968).

† Zwicky, Herzog, and Wild (1961) and Zwicky and Herzog (1963, 1966). Estimated redshifts are given in parentheses.

‡ Abell (1958). Estimated redshifts, given in parentheses, are taken from Table 8 of this reference.

§ Remarks: (1) Cf. Sandage and Miller (1966). (2) One 17-mag galaxy and several fainter ones are within 30".

TABLE 2  
SPECTROSCOPIC DATA FOR GALAXIES NEAR B264

Object	Main Spectral Features	Redshift
QSO B264.....	[O II], [O III], and Balmer emission	0.0953
Galaxy:		
1.....	K-line, G-band (obs. $\lambda\lambda 4305, 4714$ )	.0950
2.....	K-line, G-band (obs. $\lambda\lambda 4307, 4718$ )	.0958
3.....	K-line, G-band (obs. $\lambda\lambda 4302, 4702$ )	.0933
4.....	[O II] emission (obs. $\lambda 4083$ )	.0954
5.....	[O II], [O III], and H $\beta$ emission	.0631
6.....	K-line, G-band (obs. $\lambda\lambda 4576, 5005$ )	.1634
7.....	Balmer absorption lines	0.1661

Balmer lines are broad); our value (0.0953) is in excellent agreement with that (0.095) given by Braccesi *et al.* (1968).

The redshifts given in Table 2 suggest that there are, in fact, two clusters of galaxies within the Zwicky-Herzog outline: a western cluster with a redshift of 0.095 and an eastern cluster with a redshift of 0.165. Galaxy 5 is apparently a foreground galaxy. The occurrence of a foreground galaxy among the observed objects is not surprising, since we chose the brighter galaxies for spectroscopic observation.

The average redshift of the four galaxies in the western cluster is 0.0949. The mean deviation of the individual redshifts is  $\pm 0.0011$ , corresponding to a velocity dispersion of  $\pm 330$  km sec $^{-1}$ . The redshift of B264 is 0.0953, practically identical to that of the western cluster.

The excellent agreement in direction and redshift of B264 and the western cluster suggests strongly that they are physically associated. Since there are no reasonable

doubts about the cosmological nature of the redshifts exhibited by clusters of galaxies, the redshift of B264 is most probably cosmological.

Since B264 is about 1 mag fainter than the typical brightest cluster galaxies at the same redshift, it might be argued that B264 is an N-type galaxy with an unusually bright nucleus. It is, however, bluer than any of the N-type galaxies measured by Sandage (1967). Further work on the nature of B264 will be of interest.

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