QUASARS IN RICH GALAXY CLUSTERS

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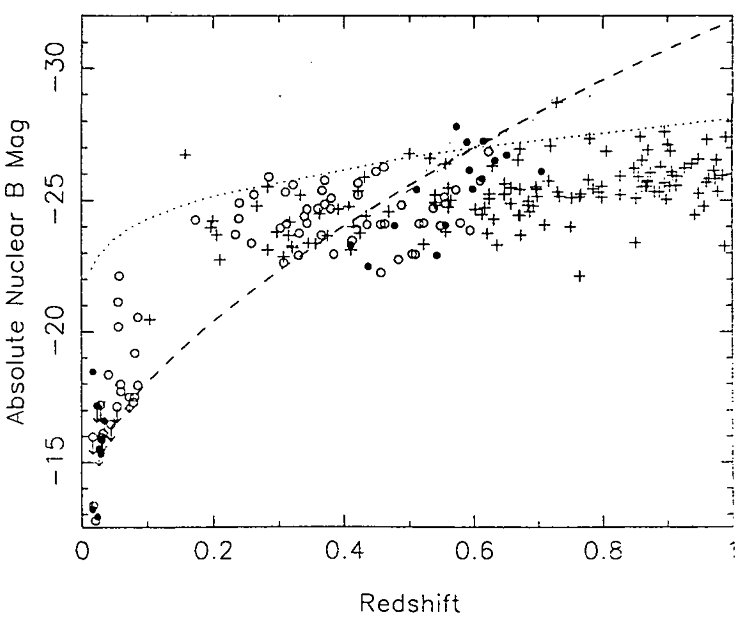
ABSTRACT

The evolution of AGN activity in rich clusters of galaxies is found to be approximately 5 times more rapid than that in poor clusters. This rapid evolution may be driven by evolution in the dynamics of galaxy cluster cores. Results from our spectroscopic studies of galaxies associated with quasars are consistent with this scenario, in that bright AGN are preferentially found in regions of lower velocity dispersion. Alternately, the evolution may be driven by formation of a dense intra-cluster medium (ICM). Galaxies close to quasars in rich clusters cores are much bluer (presumably gas rich) than galaxies in the cores of other rich clusters, in support of this this model.

Rapid Evolution of AGN in Rich Galaxy Clusters

Figure 1 shows the absolute nuclear B magnitudes versus redshift for samples of quasars and radio galaxies ($z < 0.1$) from the 3C, 4C and Parkes radio samples. Nuclear magnitudes for the latter were determined spectroscopically (e.g. DeRobertis and Yee 1990). The quasar-galaxy spatial covariance amplitude, B_{gq}, was determined for many objects in order to quantify the richness of the galaxy cluster environment. Objects with environments richer than Abell class 0 clusters ($B_{gq} > 500$ Mpc$^{-1.77}$) and are denoted by closed dots, and objects in poorer environments with open dots, and those without information as crosses.

Assuming a luminosity function (LF) for AGN and its evolution, we construct models predict the brightest that will be included in our samples, as a function of redshift. The dotted line in Figure 1 represents a model using the standard quasar LF and evolution determined by Boyle *et al.* (1989). This model matches the upper envelope for objects in poor environments well. The dashed line represents a model using the same LF form, but which requires evolution 5 times faster in order to match the behavior of AGN in rich clusters of galaxies. The e-folding timescale for this evolution are approximately 1 Gyr, similar to dynamical timescales in these environments.



The model describing the evolution of AGN activity in rich clusters, drastically overpredicts the density of quasars for $z > 0.7$. A possible explanation for this abrupt change in the evolution of AGN in rich environments is that the formation rate of galaxy clusters declines at $z \sim 0.7$. In this scenario, AGN activity is primarily associated with young, unevolved clusters (see below for evidence supporting this possibility). At $z \sim 0.7$, however, a decline in the supply of new rich sites means that the AGN activity in rich environments would decline on timescales similar to evolutionary timescales of the cores of rich galaxy clusters, as is seen.

Dynamics of AGN Environments

Dynamical evolution in the cluster core may be responsible for this rapid evolution of AGN activity in rich clusters. Much evidence suggests that quasar activity is linked with galaxy–galaxy interactions and that these interactions are most efficient at low relative velocities (DeRobertis 1985, Roos 1985). In this scenario, young, unevolved clusters might also have low velocity dispersions, but as they virialize, the velocities in their cores increase, causing the observed AGN activity to decline.

Multi-object spectroscopic observations of faint galaxies in quasar fields with $0.4 < z < 0.6$ have been taken at KPNO and the CFHT in order to examine the dynamics of quasar environments. A large sdample of galaxies associated with quasars have now been identified (Ellingson, Green and Yee 1991, Ellingson and Yee 1992). For a sample of high-redshift quasars in rich clusters, 59 galaxies yield a composite velocity dispersion of 580 (+50 -70) km/sec. For comparison, the velocity dispersions of clusters of similar richness which are associated with the radio galaxies at low redshift are usually 700-900 km/sec (Zabludoff *et al.* 1990), significantly higher. These results are consistent with the scenario where increasing velocity dispersions are linked with decreasing AGN activity in the cores of rich clusters.

The ICM in Clusters Associated with Quasars

A second possible mechanism responsible for the rapid evolution of AGN activity in rich galaxy clusters, may be that it is in response to evolution in the intra-cluster medium (ICM). The presence of a dense ICM may be able to strip gas from either the AGN host galaxy or from companion galaxies, depriving the central engine of a necessary fuel source (Stocke and Perrenod 1981). Recent results of X-ray observations of distant galaxy clusters (Gioia *et al.* 1990, Edge *et al.* 1990) do indeed suggest that the ICM has evolved significantly since $z \sim 0.5$, in agreement with this scenario.

Observed g–r colors of galaxies in the cores of clusters associated with quasars at $z \sim 0.5$ indicate a very high fraction of blue galaxies located within only 10–15 $''$ of the centers of rich galaxy clusters. A lower limit of 60% is found, in comparison with ~20% found in other clusters at similar redshifts (e.g. Butcher and Oemler 1984). This result implies that the near environments of quasars contain many gas-rich galaxies, despite their location in the cores of rich galaxy clusters. This results is therefore consistent with, but not necessarily indicative of the evolving ICM model.

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