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David C. Koo

Richard G. Kron

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SPACE TELESCOPE SCIENCE INSTITUTE
3700 San Martin Drive Baltimore, MD 21218

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David C. Koo
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

and

Richard G. Kron
Yerkes Observatory
University of Chicago
Williams Bay, WI 53191

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David C. Koo
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

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A Deep Redshift Survey of Field Galaxies

David C. Koo
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218 U.S.A.

Richard G. Kron
Yerkes Observatory
University of Chicago
Williams Bay, WI 53191 U.S.A.

ABSTRACT. A spectroscopic survey of over 400 field galaxies has been completed in three fields for which we have deep UBVI photographic photometry. The galaxies typically range from B = 20 to 22 and possess redshifts z from 0.1 to 0.5 that are often quite spiky in distribution. Little, if any, luminosity evolution is observed up to redshifts $z \approx 0.5$. By such redshifts, however, an unexpectly large fraction of luminous galaxies has very blue intrinsic colors that suggest extensive star formation; in contrast, the reddest galaxies still have colors that match those of present-day ellipticals.

1. INTRODUCTION

Over the past six years, we have been undertaking a deep redshift survey of field galaxies. Our original and still primary goal is to measure directly, with redshifts and multicolor photometry, the evolution in the luminosity function and color distributions of field galaxies. Adding the use of spectral features that relate to age, abundance, and star-formation rate (such as emission line strengths, the amplitude of the 4000Å break, or the relative strength of various absorption lines), we track evolution through several other parameters and thereby better understand the nature of any detected changes. Furthermore, our high quality imaging data yield limited, but still useful, information on the morphology and sizes of distant galaxies; both the angular positional data and redshifts probe evolution in the clustering behavior of galaxies; and finally, with an understanding of distant galaxies, even the geometry of the universe is in principle, measureable (cf. talk by Loh). At this time, our data are still being reduced, but we are able to report some preliminary results that do place interesting constraints on the clustering and evolution of field galaxies up to redshifts $z \sim 0.5$.

2. OBSERVATIONS

The spectroscopic data have been acquired with the Cryogenic Camera spectrograph system on the 4m telescope at Kitt Peak National Observatory. The detector is a TI 800 x 800 CCD chip. By using a mask with multiple slits at the focal plane, about 10 objects can be observed simultaneously over a 5 arcmin field of view. Our typical setting uses a 15Å FWHM spectral resolution at 4Å per pixel; a wavelength range of ~3000Å centered near 6000Å; and exposures as short as 10 min for very bright galaxies to several hours for very faint objects. Between 5 to 10 of these 5 arcmin fields were observed in each of three 0.3 deg^2 regions of the sky where we already have deep 4m plates taken with UBVI filters: Selected Area 57 (1305+30), SA 68 (0015+15), and Hercules No. 1 (1720+50).

The main reason our redshift survey has taken so long has been our attempt to achieve completeness, not in the sense of measuring redshifts of all galaxies to a given magnitude limit over a specified area, but rather in having subsamples in both magnitude and area that are representative so that the selection function is well defined, i.e. unbiased by color or strength of spectral features. This sample can then be legitimately used for statistical analysis and for direct comparisons to our models of galaxy spectral evolution. For galaxies that were faint or which did not have strong spectral features, repeat exposures for several years were often required. At present, we have measured redshifts for over 400 field galaxies, but only 300 of these constitute the statistically complete sample. Another similar and yet complementary project is the AAT faint galaxy survey of Ellis, Broadhurst, and Shanks (Ellis 1987, talk by Ellis), which differs from ours in that we have selected our sample using red (6100Å) magnitudes rather than blue; their spectra cover a wider wavelength range from 3700Å to 10,000Å with higher resolution; we possess multicolor photometry whereas their galaxies have mainly blue photometry; and their ~200 galaxies are divided among five fields, thus averaging 40 galaxies per field, while we have about 100 in each of SA 68 and Hercules and over 200 in SA 57.

3. LARGE-SCALE CLUSTERING

One of the most striking results is displayed in Figure 1. Very strong fluctuations can be seen in the redshift distribution of galaxies in SA 57, over scales of up to 100 Mpc. These include not only strong peaks but also very large regions in which the densities of galaxies are low. For example, in the gap centered on redshift $z = 0.15$, about 15 galaxies are expected and yet at most 1 galaxy is found. As an example in the opposite sense, i.e. strong clustering, over 50% of all galaxies over the entire 0.3 deg^2 with $B < 20$ congregate at the same redshift of 0.125! Our other two fields also show fluctuations, but not as dramatically (Koo, Kron, and Szalay 1987; see also Ellis 1987).

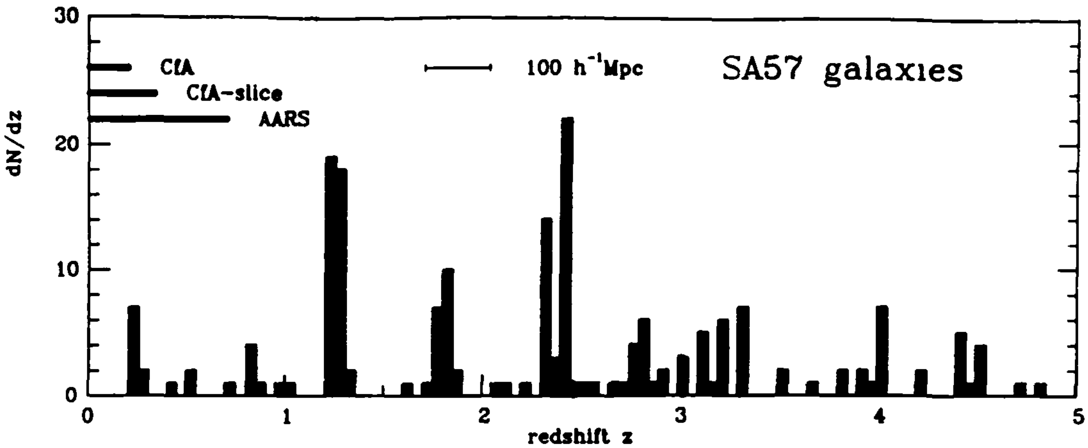

Figure 1. The distribution in redshift bins of 0.005 of the 204 galaxy redshifts at the North Galactic Pole over an area of 0.3 deg^2. Note the extreme clumpiness. CFA shows the depth of the B = 15 Center for Astrophysics redshift survey; the slice reaches B = 15.5; AARS shows the depth of the B = 17 Anglo Australian Redshift Survey.

4. FIELD GALAXY EVOLUTION

Of more interest to this workshop are the clues to galaxy evolution. In general, the preliminary results of our red-selected survey (Koo and Kron 1987) are in good agreement with those from the blue-selected one of the faint AAT survey (Ellis 1987). Some of the data is shown in Figure 2a. The model predictions given in Figure 2b fully account for photometric errors and the decreasing effective area of the redshift survey at fainter magnitudes and are otherwise similar to those of Bruzual and Kron (1980) that give good fits to faint galaxy counts and colors.

One surprise was that, on average, the distribution of higher redshifts is most consistent with little or no luminosity evolution among galaxies observed to redshifts $z \sim 0.5$. Evidence for this is partially seen in the near equality between the total observed numbers for $z > 0.25$ and those of the no-evolution model. There is some evidence for red galaxies being brighter in the past, but clustering (note clump at $z \sim 0.4$) makes this a marginal result. More secure is the evidence that luminous galaxies with extremely blue (Im type) colors were more common at higher redshifts, perhaps by a factor of two (Fig. 2b). This evidence for color evolution is substantiated by the presence of strong emission lines in many of the faint galaxies (Ellis 1987). In contrast to this trend, the reddest field galaxies have colors consistent with those of ellipticals found today.

Another clear result is that the intrinsically faint galaxies at low redshifts predicted by the models are not observed, and since these do not involve any evolution, the input parameters of our models must be in error at some level. We hope to improve the models by, e.g., using different shapes of the luminosity function for

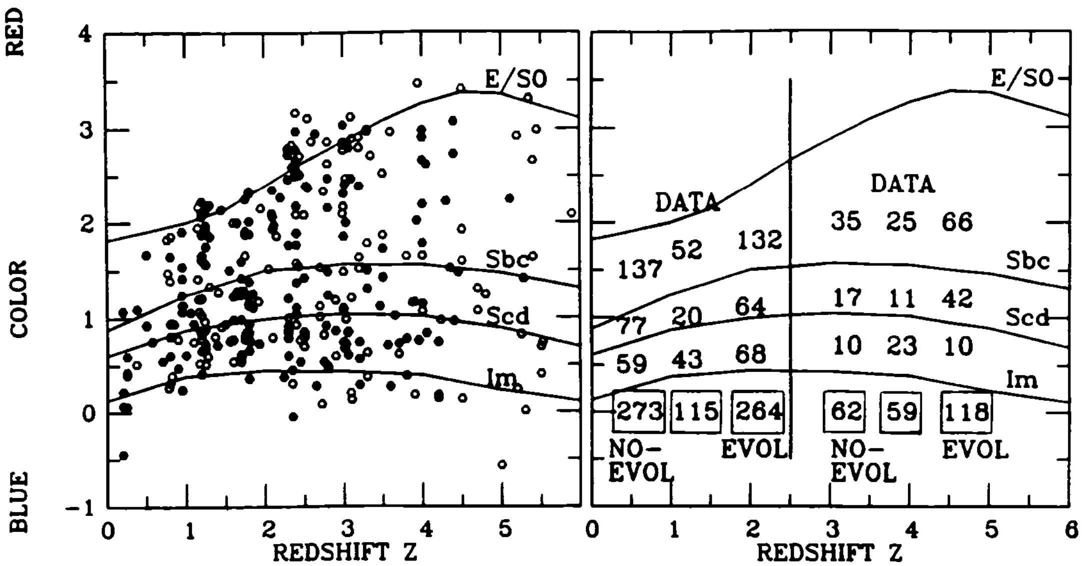

Figure 2 (a) Color (U - F) versus redshift for ~230 field galaxies in SA 57 and SA 68, where U is our ultraviolet band (3600Å) and F is our red band (6150Å); filled circles are those constituting the statistically complete sample. The tracks taken by various types of galaxies are also shown. (b) Observed numbers (statistically complete sample only) versus predictions of models with mild and without evolution in the regions bounded by the Sbc and Scd galaxy types and divided at z = 0.25. The boxed numbers are totals.

galaxies of different colors (Sandage et al. 1985). As suggested by Ellis (1987), however, perhaps our picture of evolution, and thus our model, needs more substantial revision.

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COMMENTS ON THE REALITY OF THE BUTCHER-OEMLER EFFECT

David C. Koo
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218 U.S.A.

ABSTRACT. We propose that some of the evidence, especially recent spectroscopic data, for evolution in the properties of galaxies in the central cores of high redshift clusters remain questionable. Problems include biased selection of the clusters, contamination by extraneous galaxies, and non-inclusion of several corrections including the expansion of the universe. In particular, we suggest that clusters viewed approximately in the plane of flattened superclusters will preferentially be selected, thus magnifying the contamination by other clusters and "field" galaxies. The ratio of the accepted volume to that of the cluster core may easily reach beyond 400 for redshifts z greater than 0.3. Reasonable assumptions on the density structure of clusters and superclusters predict 10% or more contamination as observed.

1. INTRODUCTION

For nearly a decade since the classic paper by Butcher and Oemler (1978a), their claim for more blue galaxies in the cores of rich compact clusters at higher redshifts has fired the imagination of observers and theorists. Recently, attention has shifted from deep photometric towards spectroscopic surveys. Exciting results from such surveys include not only confirmation that many of the blue galaxies apparently in the cluster center have redshifts close to that of the cluster itself, but also evidence for unexpectedly large numbers of galaxies with unusual spectra, including "E+A", strong emission lines, or Seyfert 1 or 2 type features (see conference articles by Gunn, Ellis, Mellier, Henry, etc.). Before we accept these results as evidence for cluster evolution, however, we need to establish the extent to which the effects are unique to clusters rather than to the general field population (or to the outer parts of clusters) and the extent of possible contamination problems.

Taking perhaps an extreme viewpoint, I would like to propose that many of the effects attributed to the cluster-core galaxies represent a more general phenomenon occurring in less dense environments and that much of the apparent evolution is the result of how clusters were selected, of contamination of the core area by galaxies outside, and of not including corrections such as the expansion of the universe. Indeed, Butcher and Oemler (1984b) themselves suggested the possibility that the evolution seen in clusters may be largely independent of environment, based upon their spectroscopic survey of a non-compact cluster at $z = 0.38$. Using multicolors as crude estimators of redshift, I find that even field galaxies appear to have larger fractions (~70% at $z \sim 0.4$ versus ~45% today) of intrinsically very blue galaxies (Koo 1986), but this conclusion relies on models of galaxy evolution and needs confirmation from a spectroscopic survey. Although analysis of the deep field-galaxy redshift surveys have yet to be completed for such a confirmation, preliminary results suggest that larger fractions of field galaxies at moderate redshifts $z > 0.3$ did undergo enhanced star formation, as seen in the distribution of either emission-line strengths (Ellis 1987) or bluer colors (see talk by Koo and Kron). At present, however, the fraction of "E+A" type field galaxies still appears low but a quantitative comparison has yet to be made, so that perhaps the frequency of such galaxies seen in cluster cores is giving direct conclusive evidence for cluster evolution (see talk by Gunn or Dressler 1987). In the meantime, let me continue with my concerns.

2. SICILIAN PIZZA MODEL

The picture I have is shown in Figure 1. Based upon strong hints of flattened extended distributions of galaxies (like a Sicilian pizza) seen in the redshift surveys of Haynes and Giovanelli (1986), or De Lapparent et al. (1986), I simply imagine that the types of galaxies seen within an apparent cluster core (1 Mpc diameter where Ho = 50 km s^{-1} Mpc^{-1} has been used throughout this paper) depend on the vantage point. Viewed face-on (Fig. 1-I), a sausage clump (cluster) may NOT be contaminated much by bits of pepper (blue galaxies) or anchovies ("E+A"); viewed in the plane of the pizza (supercluster), one may see increased contamination along the line of sight (Fig. 1-III); and in the extreme case, one may see two or more sausage clumps superimposed (Fig. 1-II) along with substantial contamination. The following sections describe a number of what I call anti-Butcher-Oemler effects, all of which may contribute to the illusion of high-redshift cluster cores containing more unusual galaxies, if such galaxies are common outside of cluster cores.

3. ANTI-BUTCHER-OEMLER EFFECTS

3.1. Moving-Target Effect

Before describing the anti-BO effects, a bit of history shows how slippery the target can be. The original BO effect was the claim that the central cores of two rich compact clusters at high redshift,

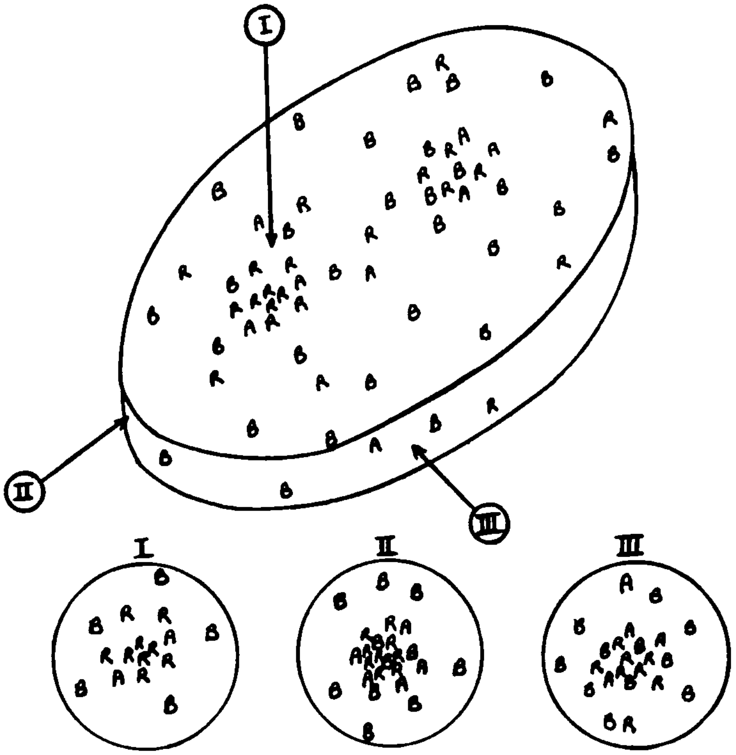

Figure 1. Several views of a flattened supercluster of galaxies are shown within the circular frames, where R's (sausage bits) represent red early-type galaxies usually found in high density environments, A's (anchovies) represent unusual "E+A" type galaxies, and B's (pepper bits) represent blue galaxies.

3C 295 (z = 0.46) and 0024+16 (z = 0.39), exhibited a large fraction (50%-60%) of blue galaxies that were presumed to be spirals (Butcher and Oemler 1978a), whereas comparable clusters like Coma or others do not (Butcher and Oemler 1978b). Soon after, DeGioia and Grasdalen (1980) criticized the work by pointing out that the effect could be explained by the lack of corrections for the known correlation between intrinsically fainter non-spiral (i.e. gE or S0) galaxies being bluer (color-mag effect) and the possibility of poor background subtraction. Mathieu and Spinrad (1981) gave further support to the latter suggestion when their independent photometry of 3C295 did not show an excess of blue galaxies. In addition, the lack of any blue excess in an even higher redshift cluster 0016+16 at z = 0.54 (Koo 1981) demonstrated that the BO effect could not be universal. Moreover, Kron (1982) argued that the apparent excess of blue galaxies in a well-studied, nearby, rich compact cluster, A2199, would mean either more problems at larger redshifts if not real, or that some nearby clusters also have blue excesses. Wirth and Gallagher (1980) found that spiral fractions in two nearby clusters are much greater than previously measured, a result that may also diminish differences between the low and high redshift clusters.

Couch and Newell (1984) later claimed confirmation of the classic BO effect by expanding the sample of clusters with deep photographic color photometry, including corrections for the color-mag effect and improvements in the background field subtraction.

Then Butcher and Oemler (1984a) changed their definition of blue to include only **very** blue (rest frame B-V < 0.7) galaxies within a central area containing 30% of the cluster galaxies (typically 1-2 Mpc diameter) to quite faint absolute magnitudes ($M_V < -20$). They strengthened their conclusion of rapid cluster evolution by showing that nearby clusters had very-blue-galaxy fractions of $\lesssim$ 5%, field had 44%, and distant clusters (z ~ 0.5) had 25%. Cluster 0016+16, however, with 2% and still at the largest redshift in their sample, remained an anomaly in their picture. Furthermore, the presence of both high and low fractions is a phenomenon that appears to extend below redshifts of z ~ 0.3, thus placing further doubt to the homogeneity of the cluster sample and to the suggested evolution with redshift.

Spectroscopy had already begun in full force by this time, with Dressler and Gunn (1982, 1983) leading the way and claiming for 3C295 extreme evolution in the number of active-galactic-nuclei. They also discovered the presence of unusual "E+A" type galaxies which were relatively red but best explained as a combination of a normal gE type spectrum with an "A" type spectrum (strong Balmer lines) as seen from a stellar population 1 Gyr after a burst of star formation, but with no strong emission lines, unlike equally blue spirals today. Moreover, since many of the blue galaxies were not cluster members, the original BO effect could be questioned as resulting from poor background subtraction. A new effect was thus born. A similar study of 0024+16 (Dressler et al. 1985), however, showed a genuine excess of spiral-like blue galaxies centered at the cluster redshift, thus supporting the original BO effect.

As previously mentioned, Butcher and Oemler (1984b) showed that unusual "E+A" and active galaxies could be found even in non-compact distant clusters, putting into some question the extent to which the effects were unique to dense environments. More recently, Dressler and Gunn (Dressler 1987, talk by Gunn) found that the anomalously red cluster 0016+16 contains a high number of "active" galaxies, where active is now defined as non-passive, i.e., not like that of normal early-type galaxies. They did confirm, however, the small number of very blue galaxies as did Ellis et al. (1985), who restudied the cluster using multiple intermediate band CCD photometry. Thus 0016+16, which remains a cluster that has no excess of blue or very blue galaxies, is now cited as showing strong evolution on the basis of an excess of "E+A" spectra. To complicate further the issue of what exactly is meant by the BO effect and cluster evolution, Dressler and Gunn report the detection of a significant shift of the distribution of 4000Å breaks to smaller amplitudes among otherwise RED galaxies in clusters at redshifts z > 0.5. This is an important result that provides direct evidence for evolution, but its relationship to the BO effect, if any, remains unclear.

Other spectroscopic surveys of distant clusters can be found among the proceedings of this conference with a general consensus that cluster evolution has been detected. Note that the criteria for evolution is no longer confined to the presence of very blue galaxies but also includes not only the findings of Dressler and Gunn above but also slight ultraviolet excesses among the reddest galaxies as described by MacLaren, Ellis, and Couch (1987) or larger numbers of close, probably interacting, pairs of galaxies as suggested by Henry. The diversity by which distant clusters appear to be signaling evolution is itself quite compelling and opens exciting doors of opportunity to understand better the evolution of galaxies. But before attributing all these phenomenon to be clues to the evolution of cluster galaxies, I believe closer attention to problems of contamination is needed to separate how much of each evidence belongs to the dense cluster core, to the less dense outer parts of clusters, to perhaps overlapping but less compact clusters in the same supercluster, or to galaxies belonging to the general field or small groups, all residing in a supercluster around the rich cluster.

3.2. Tail-Does-Not-Wag-the-Dog Effect

Tails of distributions, i.e., extreme examples of any class, are expected to be peculiar. Among the four compact clusters studied by Butcher and Oemler (1984a) with redshifts $z > 0.3$, A370 at $z = 0.37$ has the highest known redshift among Abell clusters, 0024+16 at $z = 0.39$ has the highest known redshift among Zwicky clusters, 3C295 at $z = 0.46$ stood as the highest known redshift among galaxies for over a decade (and is a strong emission line radio galaxy of course), and 0016+16 at $z = 0.54$ was noticed by Kron and observed by Spinrad because its appearance was so extreme in richness, redness, and faintness among clusters visible over an area covered by about a dozen deep 4m plates. As emphasized in this conference by Chincarini, Ellis, and Gunn, a sample of distant clusters is needed whose selection is well understood. The distant clusters of Gunn and colleagues are certainly an improvement and the best available, but until some simulations, as suggested by Chincarini, are made using realistic spatial distributions and colors of galaxies, groups, clusters, and superclusters, an accurate assessment of the selection biases and contamination problems of the sample would remain difficult.

3.3. Rich-Get-Richer Effect

Very rich clusters are known to be strongly correlated with other clusters, groups, and galaxies (Bahcall and Soneira 1983). This correlation will certainly aggravate any contamination problems, especially in spectroscopic surveys where the background is generally not defined by control samples in nearby fields but rather by redshifts alone. Such large-scale aggregations may even preclude accurate "background" galaxy-surface-density estimates in photometric surveys, which tend to use controls within at most a few tens of Mpc away. This strong tendency for other rich structures to be nearby greatly increases the probability that the selection of the clusters at high redshift are often due to or at least affected by chance projections of non-rich-cluster galaxies. In the case of the BO clusters with z > 0.3, I would surmise that the two very blue clusters, A370 and 0024+16, are the result of two overlapping clusters (Fig. 1-II), one that is compact, rich, and quite red with a looser one quite blue, or the result of an elongated structure viewed pole-on; cluster 0016+16, on the other hand, is perhaps being viewed as in Fig. 1-I, and hence shows mainly red galaxies (but the 9 "E+A" galaxies out of 33 cluster members observed by Dressler and Gunn remains unusual); finally 3C 295 is uncertain but could be a cluster viewed projected into the plane of a flattened supercluster and hence has an apparent excess of non-early-type galaxies (Dressler and Gunn 1983). Though more time consuming, some spectroscopic control samples should be included in future work. Such control fields might be taken adjacent to the cluster core region if the effects within the core are to be distinguished from non-core regions, or further away if the effects of the supercluster are to be discriminated against that of the cluster itself. In the end, without any known method for accurate spatial positioning along the radial direction, only statistical analysis of many clusters combined with realistic simulations of their selection will provide solid evidence for evolution within the cluster core (unless a large fraction of the cluster core galaxies undergo similar changes). The field galaxy samples will also provide crucial clues of what effects are unique to clusters.

3.4. Sad-Giant Effect

As was emphasized by Osterbrock (1984), the bluest (i.e., saddest) and brightest (i.e., most giant) galaxies are most likely to be Seyfert 1 or 2 active galaxies. Thus if a large volume of space is included as being part of the cluster, and if the bluest and brightest objects in such a volume are selected for spectroscopic followup, there will be a bias towards finding relatively more such objects than in comparable volumes in nearby surveys that reach fainter luminosities. As for strong but narrow emission lines in distant galaxies, it is worth noting that, with the exception of the work on 32 galaxies near clusters by Dressler et al. (1985) and a few others many years ago (e.g. by D. Wells as compiled by Pence 1976), virtually no large-aperture spectroscopy is available for a wide variety of galaxies. Thus considerable care must be taken to intercompare the emission line strengths seen from a small aperture enclosing the red bulge of an otherwise very blue disk galaxy in nearby surveys to that from apertures that cover such disks at large redshifts. An extension of the Dressler et al survey would certainly be a worthy thesis topic.

3.5. Tuck-in-Your-Tummy Effect

As mentioned above, two relatively nearby clusters in projection would pose serious contamination effects. Yet these two clusters may not even be discriminated by spectroscopy, e.g. as two partially overlapping Gaussians in redshift space. In fact they may appear to have the same redshift if they are infalling fast enough towards each other in an expanding universe. The amplitude of such an effect is not negligible, perhaps 500 km sec^{-1} or more (i.e., many Mpcs worth of separation) between clusters, as suggested recently from the work on large-scale motions of nearby galaxies (see talk by Burstein). Indeed, coherent motions in general aggravate the problem of ambiguity between spatial positions and redshifts. Kaiser (1987) estimates that rich clusters themselves have infall-turnaround radii near 1500 km sec^{-1}; Bingelli et al (1987) suggest infall motions by late-type galaxies around Virgo. A fundamental assumption in the studies of distant rich compact clusters is that they are fully virialized and can be compared to clusters of similar structure nearby. But if even the best example of a relaxed cluster, Coma, has sub-structure today (Fitchett and Webster 1987), choosing the equivalent progenitors at high redshifts would indeed be difficult. Moreover, even the use of a metric diameter (typically 1 or 2 Mpc) for studying distant clusters may be a questionable practice. In fairness to those claiming detection of spectral changes in cluster galaxies with time, corrections for evolution in the structure of clusters are likely to exaggerate the observed effects (Gunn 1987).

3.6. FOG Effect

One of the most serious contamination problems occurs as a result of the so called "Finger-of-God" effect. This effect produces an apparent elongation of a cluster in redshift space due to the large cluster velocity dispersion and obscures (fogs) what is or is not a cluster-core member by a very large factor. For example, for a cluster core of 1 Mpc diameter (i.e., 50 km sec^{-1} worth), the FOG effect, in the case of say ±3 sigma, where sigma is a velocity dispersion of 1500 km sec^{-1}, encompasses a total volume (assuming a cylinder to first order) about 9000/50 or 180 times larger or nearly 140 Mpc^3! This is the volume which the spectroscopists would include as being part of the cluster core itself, and to my knowledge, has NOT been corrected for in published discussions of blue or active galaxies in distant clusters. Since 100 Mpc^3 would usually contain less than one field galaxy on average, field contamination appears to be negligible. Projected onto a rich cluster, however, this volume may not only include the outer parts of the cluster itself but also a volume with a density much higher than the typical field, depending upon the viewing angle and selection biases, as discussed above. In support of this probable contamination, the distributions of bluer galaxies of the "cluster" are less compact, not only in the plane of the sky (Butcher and Oemler 1984a), but also in redshift space (Dressler 1987).

3.7. Stuff-the-Sausage Effect

To compound problems from the FOG effect, the expansion of the universe multiplies the sausage-like contaminating volume by $(1+z)^{1.5}$ with $q_0 = 0.5$ or $(1+z)^2$ with $q_0 = 0$, where I have taken account of the change in velocity dispersion with redshift, but not any dynamics such as infall. This effect results from the adoption of a single metric diameter within which the contents of clusters at different redshifts are compared, since the cores of compact, rich clusters are presumed to be virialized and thus stable in size as the universe expands. Some galaxies in the very outer parts of clusters or in the field, but otherwise projected onto the same metric diameter in a large-redshift cluster, would partake in the expansion and lie beyond the metric diameter at lower redshifts. Together with the FOG effect, the ratio of contaminating volume to cluster core volume, using the above values, is about 500 by z = 0.5.

4. SUMMARY

To put the variety of anti-BO effects into perspective, a very rough estimate of the amplitude of various effects can be derived by adopting the recent results of the CFA redshift slice (as reported by Huchra 1987) where flattened structures of 10 Mpc in thickness, about 50 Mpc in size, and volume densities five times average were measured. To first order then, if a rich cluster were imbedded within such structures, there is about 10% chance that it would be viewed close to the plane of the supercluster. If so, we can estimate the contamination by the supercluster as well as by cluster members outside the core. For the cluster, we adopt spherical symmetry, a constant density to a radius of 0.25 Mpc, and a r^{-3} density drop beyond to the presumed edge of 3 Mpc. Furthermore, we assume that the spectroscopists include a ±3 sigma volume within a cylinder of 1 Mpc metric diameter, independent of z, containing about 50 cluster galaxies (44% of the total cluster), where the sigma of the cluster's intrinsic velocity dispersion is 1500 km sec^{-1}. We find that about 25% of these visible cluster members lie outside the core of 1 Mpc, thus resulting in substantial contamination to begin with, assuming that our interest is in cluster core galaxies alone. If 40% of these are E+A galaxies, then the observed fraction of 10% by z ~ 0.5 (Dressler 1987) would be fully accounted for, though admittedly, evolution has occurred but not in the core of clusters. To this possible source of contamination should be added the supercluster galaxies occupying the cylinder of 1 Mpc diameter, where we assume a uniform filling of the entire FOG sausage by the enhanced supercluster volume density, (about 0.015 Mpc^{-3} to reach $M_V < -20$) and that the stuff-the-sausage effect is applicable to superclusters. The results are presented in Table 1, where the contaminating volumes can be compared to the cluster's spherical core-volume of 0.52 Mpc^3.

Table 1
Supercluster Contamination
of Distant Clusters (% of total = 50)

Redshift	$q_o = 0$ Volume (Mpc³)	No. Gal.	(%)	$q_o = 0.5$ Volume (Mpc³)	No. Gal.	(%)
0.015	140	2.0	(4)	140	2.0	(4)
0.30	240	3.4	(7)	210	2.9	(6)
0.50	315	4.4	(9)	260	3.7	(7)
0.75	425	6.0	(12)	330	4.6	(9)
1.0	560	7.9	(16)	400	5.6	(11)

These numbers (or fractions) alone do not quite account for the average observed fractions of emission-line galaxies in distant clusters (15% at z ~ 0.5 according Dressler 1987) by about a factor of two, but could easily be underestimated by such factors if these clusters are biased by having another cluster or moderately rich group be in projection and within the FOG cylinder.

In summary, we find that if distant clusters are frequently projections of rich clusters and superclusters, the resulting contamination by non-cluster-core galaxies in spectroscopic surveys may be significant at the 10% level or more. To explain all the observations, especially the large number of E+A galaxies, with this simple idea appears far-fetched at the moment, especially without more detailed knowledge of the true distribution of galaxies and better simulations, but contamination must be a problem at some level. Since only a few, if any, of the anti-BO effects have been accounted for, the burden of proof lies on the shoulders of those in favor of cluster-core evolution to demonstrate (or more precisely define! or redefine!!) their claims.

5. ACKNOWLEGEMENTS

The chairman, R. Kron, is to be blamed for encouraging my provocative stance, but I take responsibility and offer my apologies for any, though unintended, disrespect or harshness in tone expressed. I am sincerely impressed, fascinated, and challenged by the high-quality, exciting results of my colleagues that represent years of difficult observations, and have purposely taken an extreme viewpoint to highlight areas which need more attention. A. Dressler, R. Ellis, J. Gunn, and R. Kron are all thanked for helpful discussions.

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