Photometric Redshifts for DPOSS Galaxy Clusters at 
\( z < 0.4 \)

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Abstract. We report on the creation of an unbiased catalog of galaxy 
clusters from the galaxy catalogs derived from the digitized POSS-II 
(DPOSS). Utilizing the g-r color information, we show that it is possible 
to estimate redshifts for galaxy clusters at \( z < 0.4 \) with an rms accuracy of 
0.01.

1. Introduction

There are many cosmological uses for rich clusters of galaxies. They provide 
useful constraints for theories of large-scale structure formation and evolution, 
and represent valuable (possibly coeval) samples of galaxies to study their evolu-
tion in dense environments. Studies of \( \xi_{cc} \), the cluster two-point correlation 
function, are a powerful probe of large-scale structure, and the scenarios of its 
formation. Until recently, it has been impractical to obtain large numbers of 
redshifts for galaxy clusters, forcing cosmologists to deproject their distribution 
mathematically. We show that it is feasible to generate a catalog of galaxy 
clusters at \( z < 0.4 \) with accurately estimated photometric redshifts.

2. Observations

Our data is taken from the Digitized Second Palomar Observatory Sky Survey 
(DPOSS). The digitization, star-galaxy separation, and photometric calibration 
procedures are described in Weir et al. (1995). We have improved star-galaxy 
classification using a much larger training set.

We use a simple color selection of candidate cluster galaxies, coupled with 
the adaptive kernel method (Silverman, 1986) to generate galaxy surface density 
maps. A bootstrap technique is then used to generate the statistical significance 
map associated with a given surface density map. This map is then used to detect 
overdensities of galaxies on the sky which indicate candidate galaxy clusters. In 
our test fields, we recover all of the known Abell clusters, and find a large number 
of new clusters.
3. Redshift Estimation

Because the 4000Å break is shifting through the blue bandpass of DPOSS at $z < 0.4$, the $g - r$ color changes rapidly with redshift. We make the crude assumption that all cluster galaxies are a single-age, early-type population, and use a k-correction model to estimate redshifts from the $g - r$ color alone. We simply use the mean $g - r$ color of the galaxies in a cluster, after a background correction, to estimate the redshift. In Figure 1, a $g - r$ vs. $r - i$ diagram for galaxies to $M_r = 19.6$ in a typical DPOSS field (36 sq. deg.) is shown. Also shown are the k-correction tracks for Scd and E galaxies. The rapid change in $g - r$ between $z = 0$ and $z = 0.4$ for early type galaxies allows us to estimate redshifts for galaxy clusters.

A separate redshift estimate, from the magnitude of the n-th brightest galaxy, can also be made, but it is much more sensitive to errors in the correction for field galaxies.

3.1. Technique

In practice, the redshift estimation must be done iteratively. First, we detect-candidate clusters in our galaxy density maps. From those areas in our maps where there are no clusters, we estimate the background galaxy density and $g - r$ color distribution. This background correction is then applied to each cluster candidate in a fixed radius, corresponding to an Abell radius at $z = 0.15$, the expected median redshift of our clusters.

The redshift of each cluster is then estimated from the mean $g - r$ color of the galaxies inside this radius. Using this redshift estimate, we recalculate $R_{Abell}$, and estimate the redshift using the mean color in this radius. This procedure is repeated until the estimated redshift converges.

In Figure 2, we show the mean $g - r$ color for galaxies in 36 Abell clusters with spectroscopic redshifts. The line shown is a theoretical k-correction track for E-type galaxies. It is NOT a fit to the data. The mean deviation of the data from the theoretical curve is $\Delta z = 0.004$. This suggests that we can estimate
redshifts for our candidate clusters in an accurate, unbiased way, directly from calibrated plate photometry.

This result relies on the large number of same age and type galaxies in clusters at low redshift. As the cluster galaxy population changes with redshift, this technique will eventually fail. For $0.4 < z < 0.8$, the $r - i$ color could be used; unfortunately, our $i$ plate data are not deep enough for this purpose. We have obtained deeper CCD imaging of our low-$z$ candidates, where we will attempt to detect and estimate redshifts for more distant clusters.

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References

Dressler, A. and Gunn, J.E., (1992) Ap. J., Vol. no. 78, 1

Picard, A. 1992, Ph.D Thesis, Caltech

Silverman, B.W. 1986, *Density Estimation for Statistics and Data Analysis*, (London: Chapman & Hall)

Weir, N., Djorgovski, S., Fayyad, U., 1995 AJ, 110, 1