TESTS OF THE LAS CAMPANAS DISTANT CLUSTER SURVEY FROM CONFIRMATION OBSERVATIONS FOR THE ESO DISTANT CLUSTER SURVEY

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ABSTRACT

The ESO Distant Cluster Survey (EDisCS) is a photometric and spectroscopic study of the galaxy cluster population at two epochs, \( z \approx 0.5 \) and \( z \approx 0.8 \), drawn from the Las Campanas Distant Cluster Survey (LCDCS). We report results from the initial candidate confirmation stage of the program and use these results to probe the properties of the LCDCS. Of the 30 candidates targeted, we find statistically significant overdensities of red galaxies near 28. Of the ten additional candidates serendipitously observed within the fields of the targeted 30, we detect red galaxy overdensities near 6. We test the robustness of the published LCDCS estimated redshifts to misidentification of the brightest cluster galaxy (BCG) in the survey data, and measure the spatial alignment of the published cluster coordinates, the peak red galaxy overdensity, and the brightest cluster galaxy. We conclude that for LCDCS clusters out to \( z \approx 0.8 \), 1) the LCDCS coordinates agree with the centroid of the red galaxy overdensity to within \( 25" (\sim 150 h^{-1} \text{kpc}) \) for 34 out of 37 candidates with 3 times galaxy overdensities, 2) BCGs are typically coincident with the centroid of the red galaxy population to within a projected separation of \( 200 h^{-1} \text{kpc} \) (32 out of 34 confirmed candidates), 3) the red galaxy population is strongly concentrated, and 4) the misidentification of the BCG in the LCDCS causes a redshift error \( > 0.1 \) in 15-20\% of the LCDCS candidates. These findings help explain the success of the surface brightness fluctuations detection method.

1. INTRODUCTION

Observations of the distant galaxy cluster population are being driven by a new generation of catalogs that provide statistically significant samples of hundreds to thousands of candidate clusters between redshifts 0.5 and 1. These catalogs can either serve as large statistical samples without appealing to any further observations, for example to measure the cluster-cluster correlation function (\(?\)), or as input for follow-up studies of selected subsamples. The European Southern Observatory Distant Cluster Survey (EDisCS) is a detailed follow-up study of 20 clusters, 10 at \( z \approx 0.5 \) and 10 at \( z \approx 0.8 \), drawn from the 1073 candidate clusters cataloged by the Las Campanas Distant Cluster Survey (LCDCS; \(?\), thesis.gon2001). This paper describes results from the preliminary effort to confirm the set of cluster candidates that will be the focus of the more extensive observations of the EDisCS.

The value of a cluster catalog is greatly enhanced for any application if the catalog includes measurements of the redshift and mass of each candidate cluster. Due to the size of recent catalogs, it is impractical to obtain spectroscopic redshifts or masses for a significant fraction of the catalog. Most catalogs now provide an estimate of these properties drawn solely from the survey data (\(?\), see)post96.gon2001. Superior survey data, for example deeper images or multiple colors, should improve the reliability of the estimated parameters, but they decrease the observing efficiency. The optimum balance between the fidelity of the cluster catalog and observational efficiency is not evident, and will depend on the scientific aims. \(?\) provided a catalog from what is arguably the most observationally efficient method (10 nights at a 1m telescope produced a catalog of \( \sim 1000 \) cluster candidates out to \( z \approx 1 \) over an area covering 130 sq. degrees), but which might in turn provide the least robust estimates of the cluster redshifts and masses, and which, even more importantly for some potential uses of the catalogs, may include a larger fraction of false detections. Using observations in multiple filters that are \( \sim 3 \) magnitudes deeper than original survey data, we examine whether the false positive rate quoted originally for the LCDCS is valid and whether the LCDCS cluster coordinates and estimated redshifts are confirmed using deep, multicolor data.

The LCDCS generated a catalog of concentrations of photons on the sky rather than galaxies (\(?\)). Significant fluctuations in the background sky are classified into various categories, including high redshift clusters. The cluster redshift is estimated using the magnitude of the brightest galaxy near the surface brightness fluctuation, which is presumed to be the brightest cluster galaxy (BCG). The redshift-magnitude relationship for BCGs is calibrated using spectroscopy of a sample of \( \sim 20 \) clusters. The cluster mass is estimated using the peak brightness of the convolved surface brightness map, calibrated using a sample of \( \sim 10 \) clusters with X-ray temperature and velocity dispersion measurements. The uncertainties in each of these estimators, and of the false positive and negative rates, are discussed by \(?\) in their presentation of the LCDCS. Our examination of these issues here utilizes multifilter images of 30 targeted fields, which contain 40 LCDCS candidate clusters, obtained with ESO’s Very Large Telescope (VLT) as part of the

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The format of this paper is as follows. In §2 we present the data utilized in this analysis and details of the reduction procedure. We then examine the two-color photometry in §3 to confirm or reject the cluster candidates observed by EDisCS and test whether the fractional contamination is consistent with that given by ?. In §4 we test the robustness of the estimated redshifts quoted for the LCDCS, which are based upon the magnitude of the brightest cluster galaxy, with particular emphasis on the potential problem of BCG misidentification. In this section we also quantify the offsets between the LCDCS coordinates, the locations of the brightest cluster galaxies, and the peak of the projected galaxy distribution. Next, we briefly comment upon the LCDCS mass estimates in §5 and compare the peak of the projected galaxy distribution. Finally, a summary of the results and brief discussion of forthcoming work are presented in §5. For all physical distances in this paper we assume a flat, \( \Lambda \) CDM cosmology with \( \Omega_0 = 0.3 \).

2. DATA

2.1. Sample Selection

The data presented here are part of the ESO Distant Cluster Survey, an ongoing ESO large program to examine a set of \( \sim 10 \) massive clusters in each of two distinct redshifts regimes, \( z \simeq 0.5 \) and \( z \simeq 0.8 \). The cluster candidates for this study are drawn from the Las Campanas Distant Cluster Survey (Gonzalez et al. 2001), with candidate selection constrained by the published redshift estimates and surface brightness corrected for Galactic absorption, \( \Sigma_{cor} \). Candidates are selected to be among the highest surface brightness detections at each redshift in an attempt to recover some of the most massive clusters at each epoch. Because some of the brightest detections, especially at higher estimated redshifts, turn out to be spurious (for example, scattered light or tidal material around nearby galaxies) and because there is a factor of two scatter in the relationship between \( \Sigma_{cor} \) and mass (as measured from \( T_k \) or \( L_X \)), we visually classify all of the candidates that satisfy our initial criteria (RA constraints, \( \Sigma_{cor} > 8 \times 10^{-3} \) counts s\(^{-1}\) arcsec\(^{-2}\), \( 0.45 \leq z \leq 0.55 \) or \( 0.75 \leq z \leq 0.85 \)) to select the most probable, massive clusters. The distribution in \( \Sigma_{cor} \) of the observed list of candidates (not all visually approved candidates were observed) is shown in Figure 1. A second set of criteria, based on the data presented here, are applied to select the final 20 clusters that will be the focus of the EDiCS and will be discussed in the presentation of the deeper photometry of the EDiCS clusters (?). The final sample represents our best effort to select a subsample of the most massive clusters at the two epochs, but is neither complete within the survey volume nor necessarily unbiased with respect to the LCDCS catalog.

Using the estimated contamination rate for the LCDCS from ? of \( \sim 30\% \), we targeted thirty candidates in an effort to obtain twenty confirmed clusters. We initially observed 11 at \( z \simeq 0.5 \) and 13 at \( z \simeq 0.8 \); the final 6 candidates were selected to replace false detections, poor systems, and clusters with galaxy colors inconsistent with the desired redshift intervals. Images of four candidates, two at each epoch, are shown in Figure ?? These thirty fields also serendipitously contain ten additional cluster candidates from the LCDCS catalog, yielding imaging for a total of 40 LCDCS candidates. The ten serendipitous clusters are a more representative selection from the LCDCS catalog, although some may be at the same redshift as the target cluster and therefore be part of a larger association of clusters and groups.

2.2. Observations and Image Analysis

Preliminary imaging for the EDiCS was carried out in service mode during January and February of 2001 and in visitor mode on March 19, 2001 using the FOCal Reducer/low dispersion Spectrograph 2 (FORS2) in direct imaging mode on the UT2/Kueyen telescope on Paranal, Chile. The field of view is \( 6.8^\prime \times 6.8^\prime \), with corresponds to a physical extent of \( \sim 1.7 \times 2.2 h^{-1} \) Mpc for the clusters in our sample. In total, thirteen \( z \simeq 0.5 \) candidate fields and seventeen \( z \simeq 0.8 \) candidate fields were observed for 20 minutes in each of two passbands: \( I_B \) and \( R_B \) for the \( z \simeq 0.8 \) sample and \( I_B \) and \( V_B \) for the \( z \simeq 0.5 \) sample. In each passband, the observing time was split into 4 exposures of 5 minutes each, dithered by \( 10'' \) between exposures. The service observing was only performed in photometric conditions with seeing better than \( 1'' \); the conditions on March 19 were \( 0.7^\prime \) seeing and thin cirrus. Comparison of the images for the three clusters observed on March 19, which were selected for the EDiCS final sample, to images taken later in photometric conditions shows that the extinction varied between 0 and 0.15 magnitudes during the night.

The images had the bias removed by first subtracting a medianed master bias frame, taken each night, and then performing and subtracting a linear fit to the overscan strip residuals. Because the data was taken in 4-port readout mode, this step was done separately for each quadrant. Medianed nightsky flats were then constructed for each week’s data and used to flatfield the images. Our visual inspection of the flatfielded data did not find any evidence for dust spots or other large-scale fluctuations, suggesting that the flatfield did not change over the course of a week. The images were then aligned using integer pixel offsets and averaged with 3\( \sigma \) clipping to remove cosmic rays.

For each cluster candidate field, the images taken in the