MNRAS **000**, 1– 3 (2017) Preprint 18 June 2017 Compiled using MNRAS LATEX style file v3.0

Planck Cluster Paper

Steven Boada,[1★] JPH,[1], Felipe

[1]*Physics and Astronomy Department, Rutgers University, Piscataway, NJ 08854-8019, USA*

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT

We propose to continue our program of optical imaging to unveil all of the most massive clusters in the observable Universe. We start from the all-sky Planck Sunyaev-ZelâĂŹdovich (SZ) catalogs, which contain several hundred high significance (signal-to-noise ratio, SNR > 5) unconfirmed cluster candidates. Since SZ selection favors high mass clusters and the Planck confirmation process favored low redshift systems, the highest significance unconfirmed candidates are, therefore, likely massive clusters ($M_{500} > 5 \times 10^{14}$ M$_\odot$) at relatively high redshift ($z > 0.5$). Our proposed observations, using MOSAIC-3 on Mayall, are designed to confirm the presence of a brightest cluster galaxy (to $z \sim 1$) and red sequence of accompanying cluster members (to $z \sim 0.7$). Preliminary results from our observations over the past two years have validated our approach by the detection of optical clusters in a number of Planck candidates, including the discovery of rich systems at $z = 0.553$ and $z = 0.830$ that rival the most massive clusters known. The proposed observations represent the first step required to provide a complete all-sky census throughout the observable Universe of the most massive, high redshift clusters. Their expected high redshift and high mass make the unconfirmed Planck clusters, arguably, the most important available sample for probing deviations from ΛCDM and defining the high-mass end of the cluster mass function.

1 INTRODUCTION

Throughout this paper, we adopt the following cosmological model from the Buzzard simulations: $\Omega_\Lambda = 0.714$, $\Omega_M = 0.286$, and $H_0 = 70$ km s^{-1}Mpc^{-1}, assume a Chabrier initial mass function (IMF; Chabrier 2003), and use AB magnitudes (Oke 1974).

2 DESIGN

lorem

2.1 Observations

The proposed observing strategy consists of targeted *riz* observations of individual candidates with exposure times of 350 s, 1100 s and 1100 s (assuming dark conditions) to provide 5σ detections limits of $r = 24.5$, $i = 24.5$, $z = 24.2$ ensuring the unambiguous detection of the faint galaxies (i.e., 0.4L★) in the red cluster sequence up to $z \sim 1.0$ (see Fig. 3) and of BCGs to higher redshifts. The choice of filters in our program is driven by the need to segregate early-type galaxies in the cluster through their colors (or photometric redshifts) by sampling blue-ward and red-ward of the 4000Å break

For these observations we will follow the successful setup we used before. We obtained an hour on each target in the Ks band using 1 minute exposures (5 coadded 12 s exposures) taken at 60 different dither positions distributed quasi-randomly over a square 100” ÃŮ 100” region. This produced reduced images with uniform exposure and sky level. The large FOV of the dithered NIR images (approximately 28’ ÃŮ 28’) comfortably matches the MOSAIC observations proposed for Run 1. Based on our experience over the last two years, an hour of integration on NEWFIRM will allow us to reach a magnitude limit of Ks ∼ 22.0 (AB, 3σ). This magnitude limit corresponds to $\sim M_\star + 2$ in the cluster luminosity function at $z = 1.0$ as measured by De Propris et al. (1999), and assuming K AB = K Vega +1.86. This surface brightness limit corresponds to $\sim M_\star + 1.0$ at $z = 1.5$, sufficient for detecting sub $L_\star$ at this limit. This allows for confident detection of the BCG and associated red cluster sequence.

The narrow-band observations were made with the Mosaic cameras mounted at the prime foci of the KPNO and CTIO 4-m telescopes. The instruments and basic reduction procedures are given in detail in Paper I. Here we note that each camera consists of a 2x4 array of 2048x4096 SITe CCDs. The field of view is 36âĂŹx36âĂŹ, and the plate-scale of the final reduced images is 0.27âĂİ pixelâĹŠ1 The target galaxies were imaged using the Mosaic camera on the KPNO Mayall 4 m telescope. The Mosaic camera consists of eight 2048ÃŮ4096 CCDs separated by a small gap (âĹij50 pixels). On the Mayall telescope, the imager has a 36’ ÃŮ 36’ field of view with 0.26” pixels.

the near-IR with the National Optical Astronomy Observatory (NOAO) Extremely Wide-Field Infrared Imager (NEWFIRM)

The NEWFIRM camera, designed to quickly map large areas of the sky, contains four InSb 2048 ÃŮ 2048 pixel arrays arranged in a 2 ÃŮ 2 pattern with a 28' field of view and an approximately 1' gap between the CCDs. The detector has a pixel scale of 0.4" pixelâĹŠ1. (Probst et al. 2004)

3 DATA REDUCTION AND CALIBRATION

Standard processing of dark frame subtraction, flat fielding, sky-subtraction, and bad pixel masking was performed by the NEWFIRM Science Pipeline (Dickinson & Valdes 2009; Swaters et al. 2009) to produce five stacked composite images for each near-IR band. The final stacked images retain the detector pixel scale of 0.4" pixelâĹŠ1. Variable seeing conditions caused the final observed point source FWHM in the stacked images to range from approximately 0.9âĂŞ1.5". The H-band observations were taken during the best seeing conditions and have the smallest FWHM, and the Ks images have the largest FWHM. Even in the most crowded portions of the region observed, however, the difference in effective resolution at the different NEWFIRM bands has a minimal effect on later source matching.

3.1 Mosaicking

Mosaics are created with SWARP (Bertin et al. 2002).

3.2 Astrometric Calibration

Images are calibrated with SCAMP (Bertin 2006) and PHOTOMETRYPIPELINE (PP; Mommert & M. 2017).

3.3 Photometric Calibration

Sloan Digital Sky Survey (SDSS; York et al. 2000). We use the SDSS Data Release 12 (Alam et al. 2015) We use The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) Data Release 1 (Chambers et al. 2016; Flewelling et al. 2016).

4 ANALYSIS

lorem

4.1 Source Extraction

We used SExtractor (Bertin & Arnouts 1996).

4.2 Photometric Redshifts

We determine photometric redshifts from the four-band optical images using BPZ (Benitez 2000) following the same procedure as in Menanteau et al. (2008).

4.3 Cluster Finding

We create RGB images using STIFF (Bertin & Emmanuel 2011). We use MaxBCG (Koester et al. 2007).

5 RESULTS AND DISCUSSION

lorem

6 SUMMARY

lorem

ACKNOWLEDGEMENTS

This research made use of APLpy, an open-source plotting package for Python hosted at http://aplpy.github.com; the IPython package (Perez & Granger 2007); MATPLOTLIB, a Python library for publication quality graphics (Hunter 2007). IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy under cooperative agreement with the National Science Foundation (Tody 1993). PyRAF is a product of the Space Telescope Science Institute, which is operated by AURA for NASA. Funding for the SDSS and SDSS-II has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, the U.S. Department of Energy, the National Aeronautics and Space Administration, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. The SDSS Web Site is http://www.sdss.org/. The SDSS is managed by the Astrophysical Research Consortium for the Participating Institutions.

REFERENCES

Alam, S., Albareti, F. D., Prieto, C. A., et al. 2015, The Astrophysical Journal Supplement Series, 219, 12

Benitez, N. 2000, The Astrophysical Journal, 536, 571

Bertin, E. 2006, in Astronomical Society of the Pacific Conference Series, Vol. 351, Astronomical Data Analysis Software and Systems XV, ed. C. Gabriel, C. Arviset, D. Ponz, & S. Enrique, 112

Bertin, E., & Arnouts, S. 1996, Astronomy and Astrophysics Supplement Series, 117, 393

Bertin, E., & Emmanuel. 2011, Astrophysics Source Code Library, record ascl:1110.006

Bertin, E., Mellier, Y., Radovich, M., et al. 2002, in Astronomical Society of the Pacific Conference Series, Vol. 281, Astronomical Data Analysis Software and Systems XI, ed. D. Bohlender, D. Durand, & T. Handley, 228

Chabrier, G. 2003, Publications of the Astronomical Society of the Pacific, 115, 763

Chambers, K. C., Magnier, E. A., Metcalfe, N., et al. 2016, eprint arXiv:1612.05560, arXiv:1612.05560

Flewelling, H. A., Magnier, E. A., Chambers, K. C., et al. 2016, eprint arXiv:1612.05243, arXiv:1612.05243

Hunter, J. D. 2007, Computing in Science & Engineering, 9, 90

Koester, B. P., McKay, T. A., Annis, J., et al. 2007, The Astrophysical Journal, 660, 221

Mommert, M., & M. 2017, Astronomy and Computing, 18, 47

Oke, J. B. 1974, The Astrophysical Journal Supplement Series, 27, 21

Perez, F., & Granger, B. E. 2007, Computing in Science & Engineering, 9, 21

Probst, R. G., Gaughan, N., Abraham, M., et al. 2004, in Ground-based Instrumentation for Astronomy. Edited by Alan F. M. Moorwood and Iye Masanori. Proceedings of the SPIE, Volume 5492, pp. 1716-1724 (2004)., Vol. 5492, 1716

Tody, D. 1993, Astronomical Data Analysis Software and Systems II, 52

York, D. G., Adelman, J., Anderson, John E., J., et al. 2000, The Astronomical Journal, 120, 1579

This paper has been typeset from a TEX/LATEX file prepared by the author.