Resubmission of 09A-0110

NOAO Observing Proposal *Longterm proposal* **Panel:** *For office use.*
Date: March 24, 2009 **Category:** Cosmology

Normalization and scatter of the mass-temperature relation for supermassive galaxy clusters

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Abstract of Scientific Justification *(will be made publicly available for accepted proposals)*:
We propose a high-accuracy survey of the 20 most massive clusters in the northern hemisphere at $0.15 < z < 0.3$, to yield a uniform catalog of X-ray, galaxy, and dark-matter properties (from weak gravitational lensing, WL). All quantities will be determined with high S/N and low systematic errors. The major scientific goals are to (a) determine the normalization *and scatter* in the mass-temperature relation for massive clusters, which is essential for the use of clusters to constrain cosmological parameters, and (b) use the relations between WL mass, X-ray temperature, and other structural variables to validate numerical models of cluster evolution. There has to date been no cluster lensing survey with sufficiently large sample size and sufficiently low random and systematic errors to infer the intrinsic component of the M-T scatter. We expect to determine the scatter in the M-T relation to ±5%. All targets have existing Chandra, XMM, and ASCA X-ray data, HST strong-lensing imaging, and good-seeing WL imaging from Subaru or MMT, or scheduled observation time at MMT. Our project will, with this proposal, obtain multiband Mosaic observations for photometric redshifts. Uniform photo-z's are essential to properly calibrate the WL data and isolate the (unlensed) cluster member galaxies.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	KP-4m	MOSA	2.5	darkest	Nov - Dec	Oct - Jan
2	KP-4m	MOSA	2.5	dark	Nov - Dec	Oct - Jan
3	KP-4m	MOSA	1	grey	Nov - Dec	Oct - Jan
4						
5						
6						

Scheduling constraints and non-usable dates *(up to four lines).*

15 of 18 target fields are in the 7-16h RA range. Nov-Dec are the most productive months in 2009B (Oct-Jan acceptable); since we are requesting long-term status, we have suggested splitting the observing time into 6 nights in 2009B and 3 in 2010A (Feb-Apr preferred). It would be possible to adjust this split somewhat.

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

The abundance of galaxy clusters is a key measure of dark energy (Albrecht et al. 2006), and the properties of massive clusters provide very stringent tests of theories of gravitational collapse. We have designed a survey to obtain the most precise and accurate measures to date of galaxy-cluster projected masses, X-ray properties, and galaxy contents, to facilitate new tests of cluster models and to evaluate the suitability of galaxy clusters as a dark-energy test.

Survey summary: The targets are the 20 most massive galaxy clusters in the northern hemisphere with $0.15 < z < 0.3$, selected by X-ray temperature to have $M > 10^{15}h^{-1}M_{\odot}$. Focusing on the most massive clusters gives the most precise tests of models because it maximizes the S/N level of the observations, particularly the weak gravitational lensing (WL) mass determinations. The X-ray surveys and pointed followups are complete in this mass-redshift range, so we can select a complete sample and conduct meaningful statistical studies.

This proposal is to obtain multi-color imaging of all galaxies in the cluster fields from the Mayall 4-meter, for determination of photometric redshifts that reliably identify cluster members and determine the redshift distribution of the source galaxies in the weak-lensing study. Many cluster catalogs and WL measurements exist, but this survey will be unique in its precise and accurate calibration of the WL masses for a sizable, fair sample.

Scatter in the M-T relation: The primary quantitative goal of our proposed survey is to carry out the first precision measurement of the normalization *and scatter* between cluster X-ray observables and the true projected mass of galaxy clusters, determined via WL. Knowledge of this scatter is essential for the use of galaxy cluster abundances to constrain dark energy with upcoming cluster surveys (Albrecht et al. 2006, Lima & Hu 2005), such as Planck, ACT (Kosowsky 2006) and SPT. Mandelbaum & Seljak 2007 shows that without knowing the size of the lognormal mass-observable scatter when determining σ_8 from abundance measurements of clusters at $M > 5 \times 10^{14}h^{-1}M_{\odot}$, it is impossible to constrain σ_8 to within ~ 0.1. Past halo-abundance studies have had to assume a mean relation *and* scatter between halo mass and X-ray observable to extract cosmological information (*e.g.*, Ikebe et al. 2002).

Our survey will measure the mass scatter to $\pm 5\%$ (see Fig. 1), assuming intrinsic scatter in $M(T_x)$ of 20–30% (Kravtsov et al. 2006). This project will be the first to produce WL masses with measurement error below the intrinsic scatter, for a sample large and complete enough to determine the scatter.

Cluster model validation: The mean and scatter in $M(T_x)$ are of intrinsic interest aside from their utility for cosmology. N-body+hydrodynamics models of galaxy clusters are quite advanced and make definitive, testable predictions for $M(T_x)$. Right now, there are still $\sim$ 20% normalization discrepancies between scaling relations in simulations and observations (Arnaud et al. 2007, Nagai et al. 2007). Since WL is the only path to accurate mass estimates for the unrelaxed clusters, there is substantial motivation for highest-quality data on a fairly-selected sample of clusters.

Our survey will also enable many new tests of models by determining distributions of other observables (e.g., concentration parameters and multipole moments of the X-ray and dark matter distributions), measurable at useful S/N in supermassive clusters (without stacking).

An important subtlety is that most models refer to cluster 3d virial masses whereas WL measures a 2d mass, which includes the cluster virial core, local nonvirialized structure (Metzler et al. 2000), and projected large-scale structure (Hoekstra 2003). We have a new $1/h$ Gpc N-body simulation that can determine the two projection effects with much greater statistical power than before, so we can remove their contribution and estimate the intrinsic scatter in virial $M(T_x)$ to high precision.

References

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Dahle H., Kaiser N., Irgens R. J., Lilje P. B., Maddox S. J., 2002, ApJS, 139, 313

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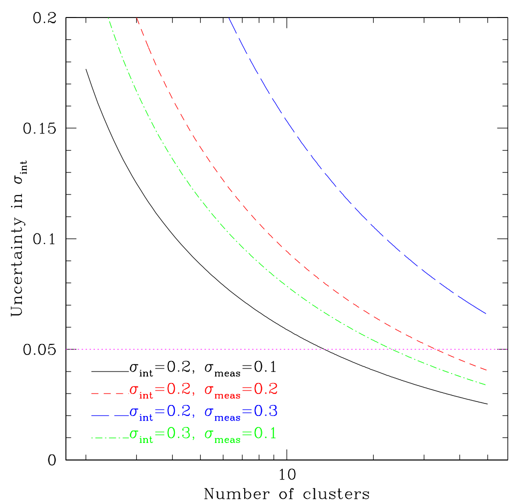

Figure 1: Given intrinsic scatter σ_{int} in the $\ln M - T_x$ relation, and a measurement error σ_{meas} in $\ln M$ per cluster, we show the expected measurement uncertainty in σ_{int} ($= (\sigma_{int}^2 + \sigma_{meas}^2)/\sqrt{2(N-1)\sigma_{int}^2}$) as a function of the number of clusters N. Our survey, with its low $\sigma_{meas} <\sim 0.1$, can measure σ_{int} with $N = 20$ clusters to within an uncertainty of ± 0.05 (dashed horizontal line), given typical values of σ_{int}. In contrast, surveys with higher σ_{meas} (typically 0.2–0.3) would require several times more clusters to achieve this level of accuracy.

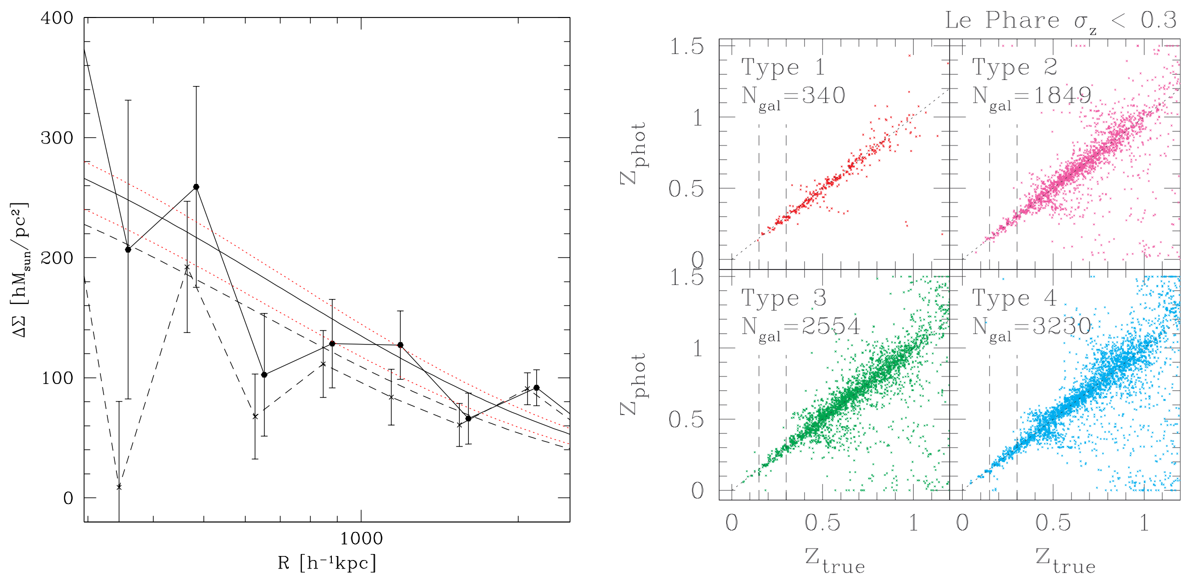

Figure 2: **Left:** Preliminary analysis of Abell 2219 based on KPNO photometry obtained May/Jun 2008 and Subaru archival data. This figure plots the azimuthally-averaged weak lensing mass profile $\Delta\Sigma$, with (solid points and lines) and without (crosses and dashed lines) a crude photo-z based on 5-band photometry. Contamination from cluster member galaxies significantly degrades signal below 2 Mpc/h. The solid curve shows the best-fit signal for the sample when we use photo-z, with $M = 1.4 \times 10^{15} h^{-1} M_{\odot}$, and the dotted curves surrounding it show the 1σ allowed region in mass. The dashed curve shows the best-fit signal when we do not have the photo-z, which lowers the mass outside the 1σ allowed region and makes NFW generally a poor fit. **Right:** Simulation of comparison of true redshift to photo-z, estimated using LePhare photo-z code (Ilbert et al., 2006) with our chosen filters and limiting magnitudes. Type 1 represents the red elliptical galaxies, while Type 4 represents the blue star-forming galaxies, and Types 2 and 3 are intermediate types. The simulated source sample is dominated by faint blue galaxies with $0.8 < z < 1.2$. The vertical dashed-lines represents the target cluster redshift range, $0.15 < z < 0.3$; as shown, we can easily identify and remove cluster members, yielding $< 3\%$ contamination to the lensing signal.

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science. (limit text to one page)*

Our survey is carefully designed to meet our goal of precisely measuring the normalization and scatter of the $M(T_x)$ relation at high mass. We use the most massive clusters to maximize S/N, to attain a low mass measurement error per cluster. We also require low *systematic* errors in WL measurement; Co-I's on this proposal have developed *three* of the best-performing WL pipelines ($\sim 2\%$ accuracy) in STEP2 (Massey et al. 2007), which were modeled on the deep, wide-field data that we use for our WL analysis. We reduce the calibration uncertainty in WL cluster mass due to ignorance of the source dN/dz; the multi-band photo-z data will reduce calibration uncertainty from 20% to $< 3\%$. The photo-z data will also reliably identify cluster galaxies, which would otherwise contaminate the source sample, suppressing the lensing signal in the inner cluster regions (Limousin et al. 2007 and our Fig. 2). What makes our survey unique is the deep, homogeneous photo-z data, which allows for a precise determination of the high-mass $M(T_x)$ relation.

Recently published WL cluster studies demonstrate that our overall methodology is reasonable, but that a new survey is required: Bardeau et al. (2007) state explicitly that their sample is too small, with uncertainties in individual masses σ_{meas} that are too large to determine intrinsic scatter σ_{int}. Okabe et al. (2009, LoCUSS survey) present WL mass estimates for 22 clusters, which will constrain the mean $M(T_x)$ normalization and slope. These clusters span 1–$10\times10^{14}h^{-1}M_\odot$, however, and each cluster has $\sigma_{meas} > \sigma_{int}$, unlike for our survey.

Sample selection and size: Our Fisher matrix analysis suggests that with $M_{180\overline{\rho}} \sim 10^{15}h^{-1}M_\odot$ we can achieve a statistical error on the projected cluster mass of $< 10\%$ per cluster. This measurement error is far below the other sources of scatter discussed in the scientific justification, so the ensemble mean value of M can be determined to 9%, and the total scatter in the 2d mass at fixed X-ray temperature can be determined to within $\pm 5\%$ with 20 clusters (Fig. 1). When combined with the N-body simulations to determine the scatter due to large-scale structure and the 2d-to-3d projection, we can subtract off those contributions to determine the scatter in the $M(T_x)$ relation to high precision (5% out of an expected 20%, or one part in four).

The X-ray temperature is more highly correlated with the cluster mass than the X-ray luminosity; we require $T_x > 6.5$ keV to obtain virial masses $> 10^{15}h^{-1}M_\odot$ (Dahle et al. 2002, Smith et al. 2005). We choose the redshift range $0.15 < z < 0.3$, which gives the optimal combination of high lensing efficiency and X-ray flux. Our selection criteria lead to an unbiased sample of supermassive clusters, because we do not eliminate complex or merging systems.

Photo-z calibration: Besides the 20 clusters (19 targets, since one double cluster fits in a single pointing), we must also observe 2 photo-z calibration fields, the DEEP2 Extended Groth Strip (EGS) and 02h30m+00 00 (02h) in $Cg'r'i'z'$. In the DEEP2 02h field, a single pointing can image up to ~ 2700 galaxies with high-quality spectroscopic redshifts (spectro-z with $0.7 < z < 1.2$), using ~ 1000 Prism Multi-object Survey (PRIMUS) redshifts at $R < 23.3$ to complement this color cut. We also use 1200 DEEP2 EGS redshifts, which are approximately flux-limited to $R < 24$.

Required exposure depths: We have used the Le Phare photo-z code (Ilbert et al. 2006) to simulate a realistic photo-z sample given our exposure times and limiting magnitudes in each band with the COMBO-17 spectral type-dependent R-band luminosity function (Wolf et al. 2003). **We have found that our limiting magnitudes provide photo-z accuracy that reduces contamination from cluster member galaxies to the 2–3% level at the minimum scale used for WL; and reduces redshift-related calibration error to $< 1\%$ (see Fig. 2).**

Proprietary Period: None

Use of Other Facilities or Resources *(1) Describe how the proposed observations complement data from non-NOAO facilities. For each of these other facilities, indicate the nature of the observations (yours or those of others), and describe the importance of the observations proposed here in the context of the entire program. (2) Do you currently have a grant that would provide resources to support the data processing, analysis, and publication of the observations proposed here?"*

The NOAO photo-z data proposed herein will be supplemented by single-band wide-field imaging with seeing $0\farcs9$ or better for WL purposes. Suitable data is publicly available in the Subaru archive for 5 of the 20 clusters; we have observed 12 clusters in good conditions with MMT Megacam; and we have been given time to observe the remaining 3 at MMT in April, 2009.

All of the target clusters have pre-existing Chandra and/or XMM X-ray data with well-determined ASCA temperatures, and HST WFPC2 and/or ACS imaging of the cluster cores to reveal any strongly lensed features. The X-ray data are sufficient not just to obtain average temperatures, but also mass profiles. Twelve clusters also have publicly-available Spitzer IRAC data in the cluster center that will supplement the KPNO data to get photo-z's for $z > 1$ sources.

Existing computational resources at the investigators' institutions will suffice to store and reduce these data. The code for the weak lensing data reduction and analysis, for the production of X-ray data products (surface brightness maps, mass profiles, etc.), and for photometric redshift computation already exists.

Long-term Details *If you are requesting long term status, list the observing runs (telescope, instrument, number of nights) requested in subsequent semesters to complete the project.*

Due to the range of right ascension of our targets, they cannot all be observed in one semester, so we are requesting long-term status to observe in S2010A as well. We are requesting 6 nights for observation in S2009B and 3 in S2010A, but it would be possible to adjust this split somewhat. The observing runs in S2010A will be the same as for S2009B, except that in each we attempt to observe fewer clusters.

Previous Use of NOAO Facilities *List allocations of telescope time on facilities available through NOAO to the PI during the last 2 years for regular proposals, and at any time in the past for survey proposals (including participation of the PI as a Co-I on previous NOAO surveys), together with the current status of the data (cite publications where appropriate). Mark with an asterisk those allocations of time related to the current proposal. Please include original proposal semesters and ID numbers when available.*

We were awarded 4 nights (May30–June2) during the 2008A semester (2008A-0356*), with all nights either clear or photometric. The 26 hours worth of observation allowed us to obtain full 5-band photometry for one of the calibration fields, as well as for 3.5 of the 20 cluster targets. We were awarded 4 nights in late June during the 2009A semester (2009A-0110*), at which point we expect to observe 4.5 more clusters.

We have reduced the KPNO raw images from 2008A to the point that we have photometric information, and are able to define color cuts that allows us to select background galaxies (defined as $z > 0.3$) at an estimated purity of $\sim 90\%$ and efficiency of $\sim$70%. These estimation are based on the calibration field with known spectroscopic redshifts. This is a huge improvement over past WL cluster studies that use, at best, two passbands, which can only reliably identify red-sequence galaxy redshifts, and hence only give a 10 to 30% reduction in cluster member contamination (*e.g.,* Hoekstra 2007). In contrast, we have explicitly used five passbands in our preliminary analysis of Abell 2219 (Fig. 2, left panel) to achieve a much more efficient exclusion of cluster member galaxies, which with further work to improve purity and efficiency will be sufficient for precision weak lensing measurements. We expect to improve upon the WL mass estimate through the use of (1) true photo-z, which will further reduce cluster member galaxy contamination and improve the accuracy of WL signal normalization, and (2) better image reduction (higher source number density) on both the WL and photometry images.

Observing Run Details for Run 1: KP-4m/MOSA

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

We request darkest-time (lunar phase < 3) observation in Washington C and SDSS g' bands with the KPNO-4m telescope (Mosaic imager). For each target, we require 60 minutes of integration time split into 6 exposures in C band, and 30 minutes of integration time split into 4 exposures in g' band, to reach limiting magnitudes of 24.8 and 25.3 (point source $S/N = 10$) respectively. For these bands, we restrict observations to airmass< 1.3. 9 out of the 18 targets are observable in mid December. Including integration+readout time, with 30 minutes for observing photometric standards each night, and based on our past observing run, we require 3.5 nights total for this observation across 2 semesters. We request 2.5 nights in 2009B and 1 in 2010A. For this and all other observing runs, the target table shows targets visible in both semesters, with those that we would observe in 2009B if we are given our optimal time marked. We exclude those targets for which we have obtained the necessary KPNO data in a previous observation, and mark those scheduled to be observed in June 2009.

Instrument Configuration

Filters: C, g'	Slit:	Fiber cable:
Grating/grism:	Multislit:	Corrector:
Order:	λ_{start}:	Collimator:
Cross disperser:	λ_{end}:	Atmos. disp. corr.:

R.A. range of principal targets (hours): 0 to 16

Dec. range of principal targets (degrees): -2 to 67

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

Target Table for Run 1: KP-4m/MOSA

Obj ID	Object	α	δ	Epoch	Mag.	Filter	Exp. time	# of exp.	Lunar days	Sky	Seeing	Comment
	ABELL0068	00:36:59.402	+09:08:30.05	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0267	01:52:41.960	+01:00:25.59	J2000		C	600	6	2	phot	1.1	2009B
	DEEP02h	02:30:00.000	+00:00:00.00	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0586	07:32:20.593	+31:38:14.60	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0611	08:00:56.816	+36:03:23.59	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0665	08:30:45.195	+65:50:34.67	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0697	08:42:57.557	+36:21:59.26	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0773	09:17:53.426	+51:43:37.32	J2000		C	600	6	2	phot	1.1	2009B
	ABELL0963	10:17:03.637	+39:02:49.39	J2000		C	600	6	2	phot	1.1	2009B
	ZWCL3146	10:23:39.636	+04:11:10.65	J2000		C	600	6	2	phot	1.1	
	ABELL1576	12:36:59.242	+63:11:11.70	J2000		C	600	6	2	phot	1.1	
	ABELL1682	13:06:49.999	+46:33:33.38	J2000		C	600	6	2	phot	1.1	
	ABELL1689	13:11:29.499	-01:20:27.91	J2000		C	600	6	2	phot	1.1	
	ABELL1758	13:32:35.817	+50:28:55.02	J2000		C	600	6	2	phot	1.1	(2009A Jun)
	ABELL1763	13:35:20.094	+41:00:04.13	J2000		C	600	6	2	phot	1.1	(2009A Jun)
	ABELL1835	14:01:02.073	+02:52:42.48	J2000		C	600	6	2	phot	1.1	(2009A Jun)
	ABELL1914	14:26:03.887	+37:49:53.36	J2000		C	600	6	2	phot	1.1	(2009A Jun)
	ABELL2111	15:39:40.494	+34:25:27.31	J2000		C	600	6	2	phot	1.1	(2009A Jun)
	ABELL0068	00:36:59.402	+09:08:30.05	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0267	01:52:41.960	+01:00:25.59	J2000		g'	450	4	3	phot	1.1	2009B
	DEEP02h	02:30:00.000	+00:00:00.00	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0586	07:32:20.593	+31:38:14.60	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0611	08:00:56.816	+36:03:23.59	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0665	08:30:45.195	+65:50:34.67	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0697	08:42:57.557	+36:21:59.26	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0773	09:17:53.426	+51:43:37.32	J2000		g'	450	4	3	phot	1.1	2009B
	ABELL0963	10:17:03.637	+39:02:49.39	J2000		g'	450	4	3	phot	1.1	2009B
	ZWCL3146	10:23:39.636	+04:11:10.65	J2000		g'	450	4	3	phot	1.1	
	ABELL1576	12:36:59.242	+63:11:11.70	J2000		g'	450	4	3	phot	1.1	
	ABELL1682	13:06:49.999	+46:33:33.38	J2000		g'	450	4	3	phot	1.1	
	ABELL1689	13:11:29.499	-01:20:27.91	J2000		g'	450	4	3	phot	1.1	
	ABELL1758	13:32:35.817	+50:28:55.02	J2000		g'	450	4	3	phot	1.1	(2009A Jun)
	ABELL1763	13:35:20.094	+41:00:04.13	J2000		g'	450	4	3	phot	1.1	(2009A Jun)
	ABELL1835	14:01:02.073	+02:52:42.48	J2000		g'	450	4	3	phot	1.1	(2009A Jun)
	ABELL1914	14:26:03.887	+37:49:53.36	J2000		g'	450	4	3	phot	1.1	(2009A Jun)
	ABELL2111	15:39:40.494	+34:25:27.31	J2000		g'	450	4	3	phot	1.1	(2009A Jun)

Observing Run Details for Run 2: KP-4m/MOSA

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

We request dark-time (lunar phase < 7) observation in the SDSS r' and i' bands with the KPNO-4m telescope (Mosaic imager). For each target, we require 30 minutes of integration time split into 4 exposures in r' band; and 60 minutes of integration time split into 6 exposures in i' band. We can then expect to reach a limiting magnitude of 24.8 in r' and 24.7 in i' (point source $S/N = 10$). For these bands, we restrict observations to airmass$<$ 1.6. Including integration+readout time, with 30 minutes for observing photometric standards each night, we request 2.5 nights of observation in S2009B and 1 night in S2010A.

Instrument Configuration

Filters: r', i'	Slit:	Fiber cable:
Grating/grism:	Multislit:	Corrector:
Order:	λ_{start}:	Collimator:
Cross disperser:	λ_{end}:	Atmos. disp. corr.:

R.A. range of principal targets (hours): 0 to 16

Dec. range of principal targets (degrees): -2 to 67

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

Target Table for Run 2: KP-4m/MOSA

Obj ID	Object	α	δ	Epoch	Mag.	Filter	Exp. time	# of exp.	Lunar days	Sky	Seeing	Comment
	ABELL0068	00:36:59.402	+09:08:30.05	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0267	01:52:41.960	+01:00:25.59	J2000		r'	450	4	5	phot	1.1	2009B
	DEEP02h	02:30:00.000	+00:00:00.00	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0586	07:32:20.593	+31:38:14.60	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0611	08:00:56.816	+36:03:23.59	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0665	08:30:45.195	+65:50:34.67	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0697	08:42:57.557	+36:21:59.26	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0773	09:17:53.426	+51:43:37.32	J2000		r'	450	4	5	phot	1.1	2009B
	ABELL0963	10:17:03.637	+39:02:49.39	J2000		r'	450	4	5	phot	1.1	2009B
	ZWCL3146	10:23:39.636	+04:11:10.65	J2000		r'	450	4	5	phot	1.1	
	ABELL1576	12:36:59.242	+63:11:11.70	J2000		r'	450	4	5	phot	1.1	
	ABELL1682	13:06:49.999	+46:33:33.38	J2000		r'	450	4	5	phot	1.1	
	ABELL1689	13:11:29.499	-01:20:27.91	J2000		r'	450	4	5	phot	1.1	
	ABELL1758	13:32:35.817	+50:28:55.02	J2000		r'	450	4	5	phot	1.1	(2009A Jun)
	ABELL1763	13:35:20.094	+41:00:04.13	J2000		r'	450	4	5	phot	1.1	(2009A Jun)
	ABELL1835	14:01:02.073	+02:52:42.48	J2000		r'	450	4	5	phot	1.1	(2009A Jun)
	ABELL1914	14:26:03.887	+37:49:53.36	J2000		r'	450	4	5	phot	1.1	(2009A Jun)
	ABELL2111	15:39:40.494	+34:25:27.31	J2000		r'	450	4	5	phot	1.1	(2009A Jun)
	ABELL0068	00:36:59.402	+09:08:30.05	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0267	01:52:41.960	+01:00:25.59	J2000		i'	600	6	5	phot	1.1	2009B
	DEEP02h	02:30:00.000	+00:00:00.00	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0586	07:32:20.593	+31:38:14.60	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0611	08:00:56.816	+36:03:23.59	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0665	08:30:45.195	+65:50:34.67	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0697	08:42:57.557	+36:21:59.26	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0773	09:17:53.426	+51:43:37.32	J2000		i'	600	6	5	phot	1.1	2009B
	ABELL0963	10:17:03.637	+39:02:49.39	J2000		i'	600	6	5	phot	1.1	2009B
	ZWCL3146	10:23:39.636	+04:11:10.65	J2000		i'	600	6	5	phot	1.1	
	ABELL1576	12:36:59.242	+63:11:11.70	J2000		i'	600	6	5	phot	1.1	
	ABELL1682	13:06:49.999	+46:33:33.38	J2000		i'	600	6	5	phot	1.1	
	ABELL1689	13:11:29.499	-01:20:27.91	J2000		i'	600	6	5	phot	1.1	
	ABELL1758	13:32:35.817	+50:28:55.02	J2000		i'	600	6	5	phot	1.1	(2009A Jun)
	ABELL1763	13:35:20.094	+41:00:04.13	J2000		i'	600	6	5	phot	1.1	(2009A Jun)
	ABELL1835	14:01:02.073	+02:52:42.48	J2000		i'	600	6	5	phot	1.1	(2009A Jun)
	ABELL1914	14:26:03.887	+37:49:53.36	J2000		i'	600	6	5	phot	1.1	(2009A Jun)
	ABELL2111	15:39:40.494	+34:25:27.31	J2000		i'	600	6	5	phot	1.1	(2009A Jun)

Observing Run Details for Run 3: KP-4m/MOSA

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

We request grey-time observation in the SDSS z' band with the KPNO-4m telescope (Mosaic imager). For each target, we require 60 minutes of integration time split into 6 exposures to reach a limiting magnitude of 23.1 (point source $S/N = 10$). For this band, we restrict observations to airmass< 1.8. Including observation+readout time, with 30 minutes for observing photometric standards each night, we require 1 night of observation in S2009B and 1 night in S2010A.

Instrument Configuration

Filters: z'
Grating/grism:
Order:
Cross disperser:
Slit:
Multislit:
λ_{start}:
λ_{end}:
Fiber cable:
Corrector:
Collimator:
Atmos. disp. corr.:

R.A. range of principal targets (hours): 0 to 16

Dec. range of principal targets (degrees): -2 to 67

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

Target Table for Run 3: KP-4m/MOSA

Obj ID	Object	α	δ	Epoch	Mag.	Filter	Exp. time	# of exp.	Lunar days	Sky	Seeing	Comment
	ABELL0068	00:36:59.402	+09:08:30.05	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0267	01:52:41.960	+01:00:25.59	J2000		z'	600	6	9	phot	1.1	2009B
	DEEP02h	02:30:00.000	+00:00:00.00	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0586	07:32:20.593	+31:38:14.60	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0611	08:00:56.816	+36:03:23.59	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0665	08:30:45.195	+65:50:34.67	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0697	08:42:57.557	+36:21:59.26	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0773	09:17:53.426	+51:43:37.32	J2000		z'	600	6	9	phot	1.1	2009B
	ABELL0963	10:17:03.637	+39:02:49.39	J2000		z'	600	6	9	phot	1.1	2009B
	ZWCL3146	10:23:39.636	+04:11:10.65	J2000		z'	600	6	9	phot	1.1	
	ABELL1576	12:36:59.242	+63:11:11.70	J2000		z'	600	6	9	phot	1.1	
	ABELL1682	13:06:49.999	+46:33:33.38	J2000		z'	600	6	9	phot	1.1	
	ABELL1689	13:11:29.499	-01:20:27.91	J2000		z'	600	6	9	phot	1.1	
	ABELL1758	13:32:35.817	+50:28:55.02	J2000		z'	600	6	9	phot	1.1	(2009A Jun)
	ABELL1763	13:35:20.094	+41:00:04.13	J2000		z'	600	6	9	phot	1.1	(2009A Jun)
	ABELL1835	14:01:02.073	+02:52:42.48	J2000		z'	600	6	9	phot	1.1	(2009A Jun)
	ABELL1914	14:26:03.887	+37:49:53.36	J2000		z'	600	6	9	phot	1.1	(2009A Jun)
	ABELL2111	15:39:40.494	+34:25:27.31	J2000		z'	600	6	9	phot	1.1	(2009A Jun)

NOAO observing proposal LaTeX macros v2.14.