



## Application Form for Telescope Time

### 1. Title of Proposal

Subaru lensing survey of dark matter in supermassive galaxy clusters

### 2. Principal Investigator

Name: NAKAJIMA Reiko  
Institute: University of Pennsylvania  
Mailing Address: David Rittenhouse Lab (4N7), 209 South 33rd St., Philadelphia, PA 19104-6396, USA  
E-mail Address: reiko3@sas.upenn.edu  
Phone: +1-215-898-6250 Fax: +1-215-898-2010

### 3. Scientific Category

- |  |  |   |   |
|--|--|---|---|
| <input type="checkbox"/> Solar System                    | <input type="checkbox"/> Normal Stars            | <input type="checkbox"/> Extrasolar Planets   | <input type="checkbox"/> Star and Planet Formation    |
| <input type="checkbox"/> Compact Objects and SNe         | <input type="checkbox"/> Milky Way               | <input type="checkbox"/> Local Group          | <input type="checkbox"/> ISM                          |
| <input type="checkbox"/> Nearby Galaxies                 | <input type="checkbox"/> Starburst Galaxies      | <input type="checkbox"/> AGN and QSO Activity | <input type="checkbox"/> QSO Absorption Lines and IGM |
| <input checked="" type="checkbox"/> Clusters of Galaxies | <input type="checkbox"/> Gravitational Lenses    | <input type="checkbox"/> High- $z$ Galaxies   |   |
| <input type="checkbox"/> Large-Scale Structure           | <input type="checkbox"/> Cosmological Parameters | <input type="checkbox"/> Miscellaneous        |   |

### 4. Abstract (*approximately 200 words*)

We request 1 night of imaging in S08A for a complete Subaru Suprime-Cam weak gravitational lensing survey of the 20 most massive clusters of galaxies in the northern hemisphere (X-ray temperature selected, with  $M \gtrsim 10^{15} h^{-1} M_{\odot}$  at redshifts  $0.15 < z < 0.3$ ). The Subaru telescope is the best available instrument for weak-lensing measurements to the virial radius. The primary goal is to measure the mass-temperature relation for massive clusters and its *scatter*, which is essential to the use of clusters for cosmological constraints, and is a strong test of models of cluster formation. Measuring the intrinsic  $M - T$  scatter requires a fair sample and the minimization of random and systematic errors. When combined with pre-existing Chandra X-ray imaging, space-based strong lensing data, and multi-band photometry from KPNO to obtain source photometric redshifts (proposal pending), the Subaru data will permit many tests of galaxy-cluster physics to high statistical precision with minimal systematic error on a large, fairly-selected cluster sample. We expect to determine the scatter in the  $M - T$  relation to  $\pm 5\%$ .

### 5. Co-Investigators

| Name              | Institute                    | Name               | Institute                 |
|-------------------|------------------------------|--------------------|---------------------------|
| Rachel Mandelbaum | Institute for Advanced Study | Charles R. Keeton  | Rutgers University        |
| Gary Bernstein    | University of Pennsylvania   | Neta Bahcall       | Princeton University      |
| Satoshi Miyazaki  | NAOJ                         | Nikhil Padmanabhan | LBNL                      |
| Tim Schrabback    | Universitaet Bonn            | Kenneth Cavagnolo  | Michigan State University |
| Megan Donahue     | Michigan State University    | Andrey V. Kravtsov | University of Chicago     |

### 6. List of Applicants' Related Publications (*last 5 years*)

**Mandelbaum R.**, Hirata C. M., Seljak U., Guzik J., **Padmanabhan N.**, Blake C., Blanton M. R., Lupton R., Brinkmann J., 2005, MNRAS, 361, 1287  
**Mandelbaum R.**, Seljak U., Cool R. J., Blanton M., Hirata C. M., Brinkmann J., 2006, MNRAS, 372, 758  
**Mandelbaum R.**, Seljak U., 2007, JCAP, 6, 24  
**Mandelbaum R.** et al., 2007, preprint (arXiv:0709.1692)  
Massey R., ..., **Bernstein G.**, ... **Mandelbaum R.**, ... **Nakajima R.**, ... **Schrabback T.** et al., 2007, MNRAS, 376, 13  
**Nakajima R.**, **Bernstein G.**, 2007, AJ, 133, 1763  
**Schrabback T.** et al., 2007, A&A, 468, 823

information for these purposes. The entire proposal including scientific justification will be passed to support astronomers for preparation of observations upon acceptance.

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8. Observing Run

| Instrument  | # Nights | Moon      | Preferred Dates | Acceptable Dates | Observing Modes  |
|-------------|----------|-----------|-----------------|------------------|------------------|
| Suprime-Cam | 1        | Dark/Grey | early Apr       | Mar/Apr          | Imaging ( $r'$ ) |

Total Requested Number of Nights  Minimum Acceptable Number of Nights

9. List of Targets (*Use an additional sheet if this space is not sufficient*)

☐ I do **not** want observatory staff to see the target names for the technical review.

| Target Name | RA          | Dec        | Equinox | Magnitude (Band)         |
|-------------|-------------|------------|---------|--------------------------|
| ABELL0665   | 08:30:45.20 | 65:52:55.3 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ABELL0773   | 09:17:59.39 | 51:42:23.1 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ZwCl3146    | 10:23:39.63 | 04:11:10.4 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ABELL1576   | 12:36:49.12 | 63:11:30.2 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ABELL1682   | 13:06:49.72 | 46:32:58.9 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ABELL1763   | 13:35:17.20 | 40:59:58.0 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ABELL2111   | 15:39:38.34 | 34:24:20.5 | J2000   | $r'_{\text{lim}} = 25.2$ |
| ABELL2218   | 16:35:53.99 | 66:13: 0.2 | J2000   | $r'_{\text{lim}} = 25.2$ |

10. Scheduling Requirements ☒ Request Remote Observation

As shown from the target list (sorted in order of right ascension), there are 8 targets that are visible in the spring semester. Since they are between RA = 08 – 17h, we request observation in the early part of the semester, March/April, to achieve the lowest possible airmass. These observations will take 1 night, and we will propose to observe for another 1 hour for the remaining single cluster without pre-existing WL quality data (ABELL68 at RA = 0h) in S08B when it is easily visible. A lunar phase  $\leq 7$  is required to meet the  $S/N$  requirements in the  $r'$ -band imaging.

11. Instrument Requirements

N/A

12. Experience

The likely observers (Nakajima and Mandelbaum) have not observed at Subaru before, and have minimal observation experience.

13. Backup Proposal in Poor Conditions (*specify object names*)

If seeing is poor, imaging of the same targets will be obtained but will be used for photo- $z$ 's (in  $g'$ ,  $r'$ ,  $i'$  or  $z'$ ), not weak lensing.

*Please describe in detail about instrument configuration, exposure time, required sensitivity, and so on.*

Lensing-quality images (sufficiently deep and well-resolved) in various bands are either publicly available in SMOKA for 11 of the 20 targets, or will be publicly available within  $\sim 9$  months from now. We therefore propose to observe the remaining 9 only, of which 8 are observable in the spring.

We propose single-band ( $r'$ ) imaging of a single pointing of each of the eight cluster targets. With an exposure time of 1800s, we can reach a limiting magnitude of 25.2 ( $S/N = 10$  for  $2''$  aperture at lunar phase 7) which will allow us to measure shapes of source galaxies to  $z \sim 1$ . We require high imaging quality for weak lensing measurements (seeing  $< 0.9''$  FWHM). We split the integration time up into  $4 \times 450$ s observations, and when including overhead of 60s per exposure, we obtain a total time this semester of  $8 \times 4 \times (450 + 60)$ s, or  $\sim 5$  hours. The RA distribution of the 8 clusters, however, requires a full night's observation. If the seeing is sufficiently good ( $< 0.7''$  FWHM), the remaining time can be used to image a few of the other 10 clusters that are visible during this semester, and which may not have as good quality images in SMOKA. These clusters are: ABELL0611 (seeing  $0.8''$ ), ABELL1689 ( $0.9''$ ), ABELL1758 ( $0.8''$ ), and ABELL1835 ( $0.9''$ ).

## 15. Condition of Closely-Related Past Observations

*Please fill in here, if this proposal is a continuation of (or inextricably related with) the previously accepted proposals. This is to describe what kind of relevant/similar proposals have existed in the past and how such previous observations were carried out.*

| Proposal ID | Title (may be abbreviated) | Observational condition | Achievement (%) |
|-------------|----------------------------|-------------------------|-----------------|
|-------------|----------------------------|-------------------------|-----------------|

## 16. Post-Observation Status and Publications

*Please report the status or outcome of your main Subaru observations carried out in the past. All observations relevant to this proposal (e.g., those enumerated in the above entry 15) must be included here; otherwise, only those within last 3 years suffice.*

| Year/Month | Proposal ID | PI name | Status: data reduction/analysis | Status: publication |
|------------|-------------|---------|---------------------------------|---------------------|
|------------|-------------|---------|---------------------------------|---------------------|

## 17. Thesis Work

☐ This proposal is linked to the thesis preparation of \_\_\_\_\_

## 18. Subaru Open Use Intensive Programs

☐ This is a proposal for Intensive Programs.