Roman CCS White Paper

Subaru-Roman Synergetic Galaxy Survey IV: HSC 16 Medium Band Filters survey

Roman Core Community Survey: *High Latitude Wide Area Survey*

Scientific Categories: *galaxies; large-scale structure of the universe*

Additional scientific keywords: *Cosmology; Gravitational Lensing; High-redshift galaxies*
Suggestions for each of the above categories can be found here.

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Abstract:
We propose a 25 square degree imaging survey of Subaru Hyper Suprime-Cam (HSC) with a set of medium band filters ranging from 400 to 1000 nm in four distinct deep regions of HSC Subaru Strategic Program (SSP), COSMOS, XMM-LSS, DEEP2-F3, and ELAIS-N1 regions. The region selection is essential to combine the medium band filter data with the existing deep broad and narrow bands data. The sample depth is 26 mag at r-band equivalent wavelength range and the expected photometric redshifts will deliver a performance of 1% outlier rate and 1% scatter. For the robust calibration of the Roman photometric redshift sample, especially for the WL sample, the observation of the overlapped sky region is of great importance.

1. Subaru HSC strategic survey

As part of the Subaru Strategic Program (SSP), Hyper Suprime-Cam (Miyazaki et al., 2018; Aihara et al., 2018) survey started observation in Feb. 2014, lasting five years with additional few years for completion. The survey consists of three different depth layers, wide deep and ultra-deep, covering a large portion of the sky, 1100, 30, and 5 square degrees, respectively. With the high capability of collecting the lights using the 8m primary mirror and the CCD camera of high sensitivity, the HSC offers unique photometric data in the depth-area parameter space compared to the other competitive photometric surveys, such as DES, KiDS, and CFHTLS.

The photometric redshift (photo-z) catalog (Tanaka et al., 2018) combined with the compilation of the spectroscopic redshift catalog enables us to measure the photo-z performance. The performance depends on the different codes, but the broad width of the filters mostly limits the accuracy by causing broad scatter and outliers due to the degeneracy between breaks.

2. Filter design

According to the observation log, we realize that it takes 30 minutes to replace one filter with another, which will lead to a 5% loss of the observation time. In addition, the HSC filter exchange unit (FEU) can hold six different filters in a single observation run. An efficient observation will be required since our complete dataset will consist of 16 different filters.

We propose a multicolor filter to minimize the overheads due to the filter exchange. The multicolor filter is compounded from four sectors of a circle. Each has different wavelength transmission (see Fig. 1). Taking the one observation exposure enables us to obtain four different color images. By rotating the position angle of the telescope, which is relatively fast, we can take another shot with different combinations of colors. We are going to finalize the filter's mechanical and optical design. However, we still have some possibility to reduce the number of filters depending on the results from the simulation and actual data from medium band filters from supreme-Cam data in the COSMOS field.

To properly process this complex filter design, a different pipeline will be needed to handle the raw image data. This is necessary because the current software pipeline only handles single-band images across the entire field. Additionally, it is important to keep track of the filter's orientation to ensure that the observed area remains consistent with the filter's name.

3. Data specification and survey strategy

To combine our data with the existing HSC deep broadband data, it is of great importance to cover the sky area matched to the HSC deep regions. Those regions comprise approximately 6 square degree fields, each centered at COSMOS (150.2, +2.5), XMM-LSS (35.5, -4.7), DEEP2/3 (352, -0.2), and ELAIS-N1 (243, +55). Therefore, to calibrate the photo-z of the Roman photometric sample, the survey field should have fully overlapped with those sky regions. The entire target region is 25 square degrees down to the same limiting magnitude of the HSC deep survey. It requires 3600 sec exposure for twelve bluer medium bands and 4000 sec for four redder medium bands. Approximately the limiting magnitude at 650nm is 26th AB magnitude.

4. Simulation study

The photo-z obtained by combining the existing broadband filter and proposed medium band filters may offer a unique calibration sample for the upcoming deep imaging survey. We assume the photo-z's from such a dataset will be accurate enough for calibration purposes. To evaluate the expected photo-z accuracy, we use a set of synthetic galaxy spectral energy density (SED) fitted to the COSMOS 30 band photo-z called EL-COSMOS (Saito et al., 2020). We generate the mock data by convolving the SED with filter optical transmission and adding the random Gaussian sky noise corresponding to the exposure time.

We measure the photometric redshift using machine learning (DNNz: Nishizawa et al. in prep.) Fig. 2 compares the photometric redshift estimates based on only five broadband data (left) and 16 medium band filters in addition to the five broadbands (right). We see that the overall scatter and outlier rates are significantly improved; they are σ=0.01, η=0.01 respectively. Moreover, in the HSC deep region, we have u-band data from CFHT and near-infrared J, H, and K bands from UKIDSS to further improve the photo-z (Despez et al., 2023).

For photo-z calibration, a ladder of color-redshift relations can be used (Buchs et al., 2019). First, the relation between Roman color and HSC medium band deep color can be trained. Then in each HSC medium band color, we derive a tight redshift distribution function.

5. Summary

We propose to take a medium band filter data using Subaru HSC over 25 square degrees sky at the sky area of HSC SSP deep regions, COSMOS, XMM-LSS, DEEP2/3, and ELAIS-N1. The simulation study reveals that the photometric redshift accuracy goes ~1% scatter and outlier rate. The observation at the overlapped regions is essential to fully utilize the data as a photometric redshift calibration sample of Roman. It is further expected to have better accuracy of the photo-z at a broader range of the redshift if our medium band data is combined with the Ultimate WFI medium band survey in the future.

Reference

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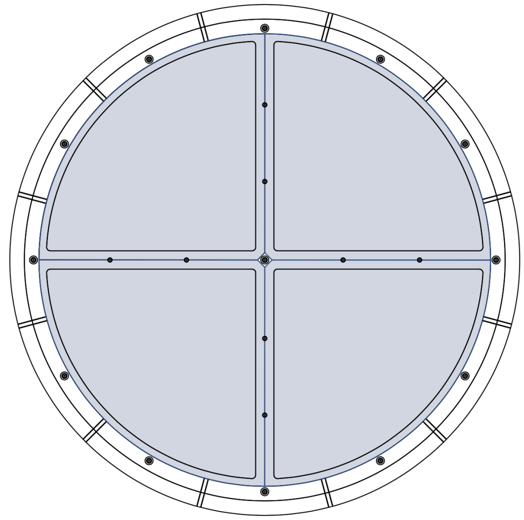

Fig. 1 Mechanical design of the filter separated into four distinct sectors of a circular field of view of HSC. We must add a cross-shaped support rod to rigidly hold the filter glass.

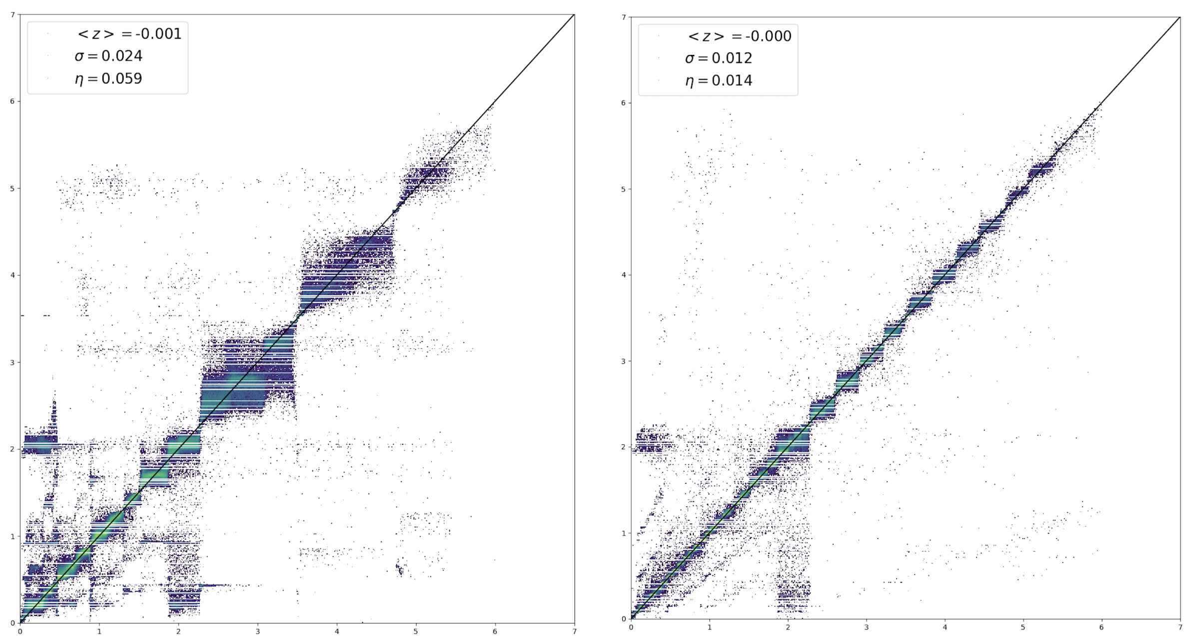

Fig. 2 Accuracy improvement of the photo-z using EL-COSMOS sample. (Left) The photo-z performance for HSC 5 broad band filters, while (Right) the HSC broadband filter combined with 16 medium band filters. The outlier rate and scatter reach to ~1%.