The Subaru PFS/Roman (SuPR) Deep Survey

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Subaru Instrument: PFS

Number of nights (hours): 50 nights

Condition of nights (moon phase, airmass, seeing): Moon < 30%, airmass < 1.5, seeing < 1 arcsec

Time critical (year, season, date, time): Two fields: COSMOS (10h) and XMM-LSS (2h23m).

Relevant CCS/other Roman programs: Unknown

Category (exoplanet, galaxies, large scale structure, solar system, stellar physics, stellar population/ISM, supermassive blackhole/AGN, IGM/CGM): Large-scale structure, galaxies

Keywords: Redshifts, calibration, shear, galaxy evolution, photometric redshifts, spectroscopy

Basic goals and strategy

- Roman Weak Lensing/3x2pt and cluster cosmology analyses will require photometric estimates of redshifts for individual objects and characterization of redshift distributions for subsamples (e.g., tomographic shear bins)
- These photometric redshift (photo-z) estimates rely critically on having a set of objects with known redshifts spanning color-magnitude space:
  - 1) for optimizing template-based algorithms or training ML/AI methods
  - 2) for precision characterization of redshift distributions
- To optimize HLIS cosmology, we want to obtain **highly-secure redshift determinations over as much of the color space used for weak lensing analyses as feasible**
  - **Thanks to its high multiplex, full optical-IR coverage, and large aperture, PFS will be the best instrument in the world for this!**
- Want to survey broadly down to limits of Roman weak lensing sample: $H_{AB} \sim 24.5$
  - Target *H*-limited sample, subsampled to have flatter (but not flat) mag. distribution
  - Long exposures will be required to achieve high redshift success rates (90%+)
    - Tests have shown that DESI (with PFS-like design but optical-only coverage) exhibits background-limited scaling in integrations as long as 8 hours (Biprateep Dey et al. 2024, in prep.); no reason to expect this shouldn't be true for PFS too

Proposed Observations

- Based on simple analytic scalings, tests of ML algorithms, and Fisher forecasts, we want a total sample size of 20k–30k objects (cf. Newman & Gruen 2023 and refs. therein)
  - **Potentially** 10–20k of these could come from other programs that would obtain *i*–limited (not *H*–limited) spectroscopy, in support of Rubin and/or Euclid observations
    - E.g.: proposed repeated spectroscopy of Rubin deep drilling fields (DDFs) with DESI, with supernovae and hosts as primary targets and repeated observations of mag–limited sample as secondary
- To mitigate sample/cosmic variance, want to separate PFS pointings as much as possible; distributing them over two 10 sq. deg. fields is sufficient based on new tests by our team (Yin et al.)
  - Proposal: conduct spectroscopy in the two equatorial Rubin Observatory deep drilling fields (DDFs), COSMOS and XMM–LSS
    - We have recommended that Roman also use these fields as DDFs within HLIS
    - Using fields with deeper imaging available for photo–z calibration has substantial benefits (cf. Buchs et al. 2019; Myles, Alarcon et al. 2021)
- Net result: 5 – 15 PFS pointings, w/ exposure times of 60–20 hours each, yielding 10k–30k spectra
  - Total **50 dark nights**
  - If e.g. DESI deep campaigns occur, would do fewer/longer pointings; if PFS is only option, more/shorter. Would evaluate actual environment/trades before observations begin

Strategy considerations

- Targeting strategy could be flexible; examples:
  - favor sources outside of *i*-limited selections (or that fail to yield z with optical spectrographs)
  - switch fibers to new, bright sources once secure redshifts are obtained for objects
    - or instead continue, get higher-S/N spectroscopy for galaxy evolution studies for them
- Why do we most urgently want PFS spectroscopy, not many-band imaging?
  - Even a 1% incorrect redshift rate is too high for the precision characterization needed for Roman weak lensing science (cf. Newman & Gruen Fig. 8)
    - Medium-band surveys are much worse; e.g., ~5% for fainter objects in COSMOS2020
  - PFS represents a unique capability; other facilities could potentially attain medium-band imaging by adding filters, but no other instrument combines PFS' high multiplex with full optical + IR coverage
    - IR arm will be more important for Roman than other surveys: IR-selected lensing sample
  - Deep medium-band imaging still is useful; e.g. for training photo-z algorithms via higher-quality photo-z's, or for assessing the nature of objects with failed redshifts
    - We would make use of the currently planned medium-band HSC imaging for this
    - If new methods robust to incorrect redshifts can be developed, medium-band could also contribute to precision characterization, but such methods not currently available
  - Because of this, PFS spectroscopy is the most urgent need for us, with no good alternatives

Summary

- We propose to obtain PFS spectroscopy of faint objects for training photo-z's and characterizing redshift distributions, thus enabling the success of the cosmology science programs undertaken by the HLIS PIT (including weak lensing, large-scale structure, and galaxy cluster measurements)
  - Total request is 50 dark nights distributed over 5-15 PFS pointings

Significance of Synergy:

- The proposed observations would play a key role in all High Latitude Imaging Survey cosmology studies with Roman, filling one of the most urgent needs for the HLIS cosmology program.
- They would also enhance Roman galaxy evolution science, both by enabling improved photometric redshift estimates and by mapping the relationships of other galaxy properties (e.g., specific star formation rate or stellar population history) to observed galaxy SEDs.
  - Would also complement the planned PFS/Sumire galaxy evolution survey via broad selection and deeper spectroscopy; color cuts for Sumire greatly limit utility for photo-z calibration
- The observations could potentially be performed in conjunction with spectroscopy of Type Ia supernovae or their hosts, as those targets would have a low surface density, leaving most fibers available for spectroscopy to enhance photo-zs.
  - Could split up exposure time over multiple years to enable greater numbers of transient targets to get spectroscopy (adding new targets each year)