Current status of PFS DRP development

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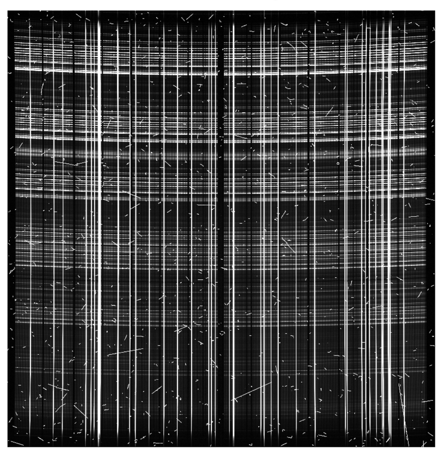
Abstract

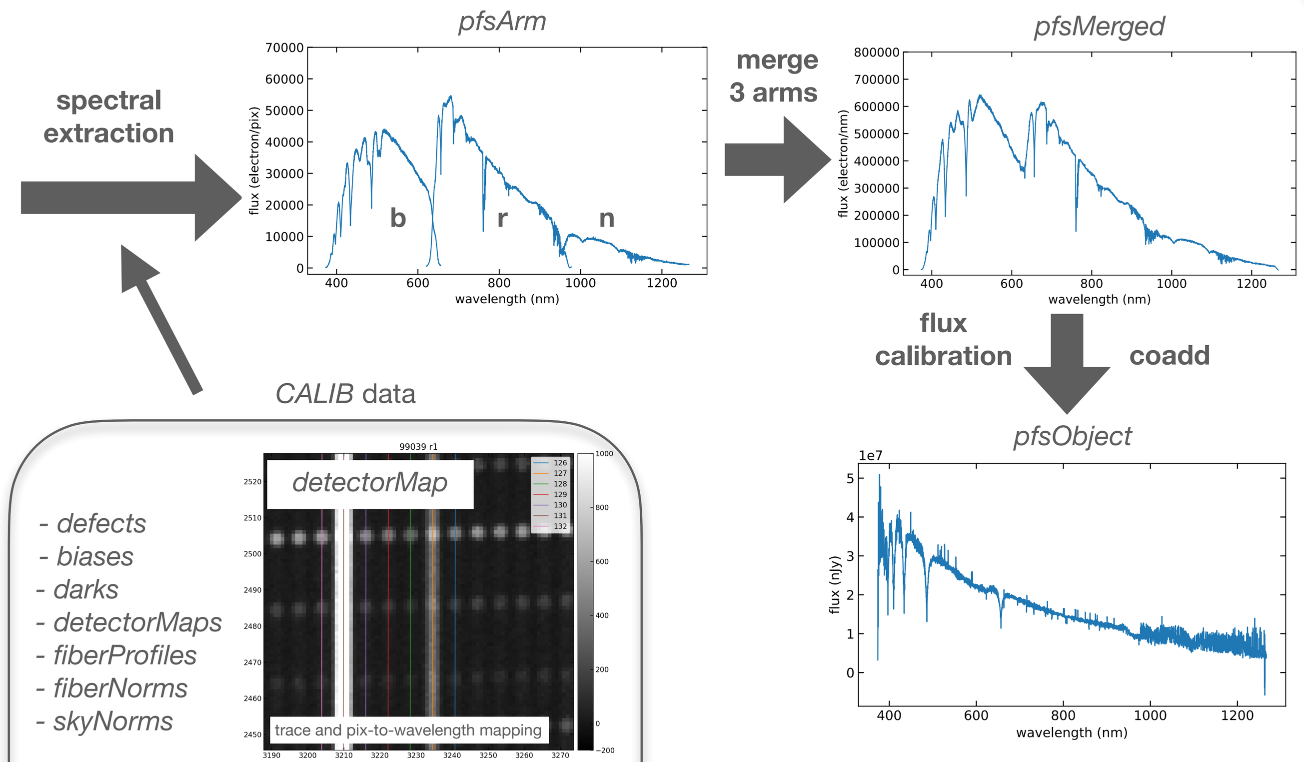
The PFS DRP is undergoing improvements using engineering and open-use data. Catastrophic variations in fiber throughput have been resolved using index-matching gel, and spatial variations of several percent across the focal plane have been empirically corrected. To address the remaining few percent of variation caused by temporal changes in the fiberProfiles during a single run, we are implementing a correction that applies measured image kernels in the spectral extraction, reducing this variation to ~1%. For NIR data reduction, we improved dark subtraction by updating nirDark cubes per run. Updates to the non-linearity correction have also been made, and quality checks are ongoing. Finally, we are testing a simple and quick correction of the image persistence. Although still a proof-of-concept, it already yields better spectra than uncorrected data. We will continue to work on refining these modeling in the future.

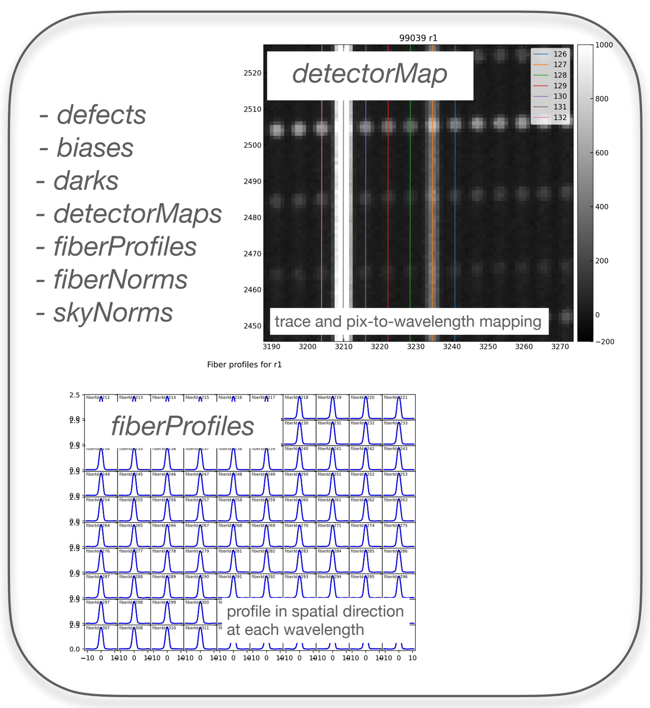
Overview of the PFS Data Reduction Pipeline (DRP)

"2D-DRP"

2D raw images







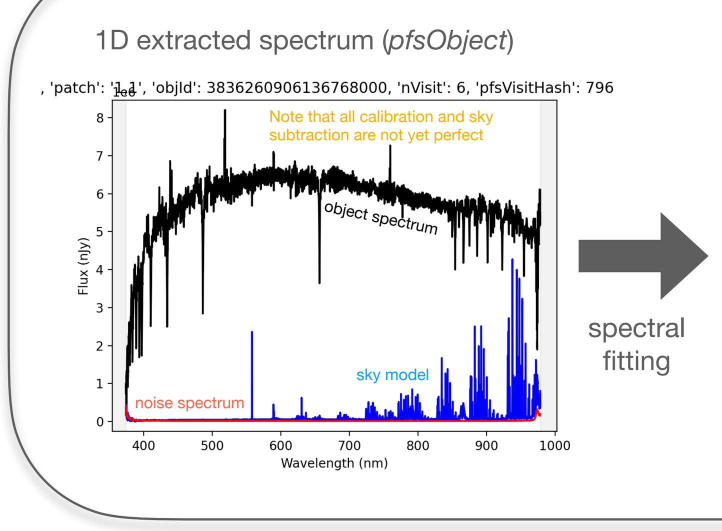
Reduction of 2D raw images to 1D calibrated spectra
- Basic instrumental signature removal (ISR)
- Wavelength calibration
- Spectral extraction
- Merge 3 arms
- Sky subtraction
- Flux calibration
- Coadd multiple visits

(work by mainly Princeton 2D DRP team)

Basic ISR and spectral extraction are carried out to generate wavelength calibrated 1D spectra (*pfsArm*) in each camera using calibration data set (*CALIB*). *pfsArms* of 3 cameras are merged into a single spectrum (*pfsMerged*). Flux calibration is done and coadd multiple spectra into a single flux-calibrated spectrum (*pfsObject*).

"1D-DRP"

1D extracted spectrum (*pfsObject*)



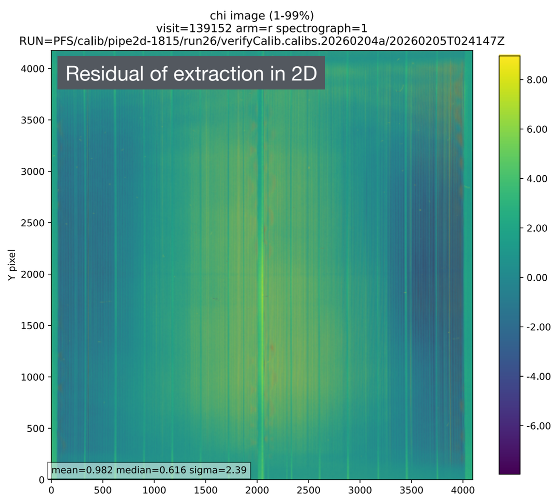
Measurement of physical quantities
- Object classification (stars/gals/QSO)
- Redshift of galaxies
- Emission line fluxes
- Radial velocity of stars
- etc.

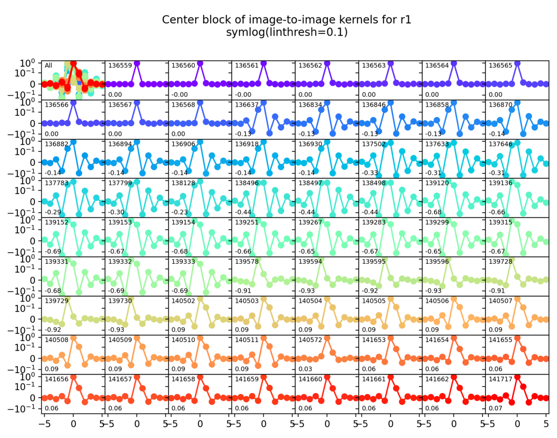
(work by mainly LAM 1D DRP team)

The PFS DRP consists of two distinct pipelines: the reduction of raw 2D images to extract 1D spectra (2D-DRP) and the fitting of the 1D spectra to extract physical information (1D-DRP). The basic processing functionality has been mostly developed, and various tests with on-sky data are currently ongoing. In this poster, we mainly focus on the 2D-DRP. We have been working on improving the DRP, addressing issues such as suboptimal sky subtraction in some cases, wavelength calibration, and the reduction of NIR data. Here, we highlight some recent progress in its development.

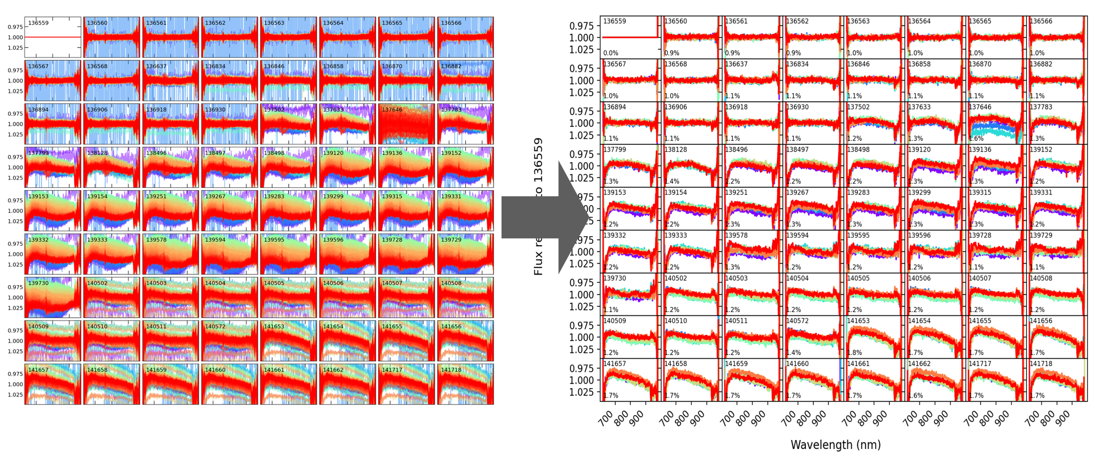
Improvement of the fiberProfiles variation

Although index-matching gel is applied, there is a variation in the normalized quartz spectra during a single run, which has been prominent especially in recent runs since Jan. 2026. We found that this is due to the time variation of the PSF (fiberProfiles) on the detectors. We are now developing a method to evaluate image kernels to adjust the fiberProfiles and apply them to the spectral extraction. Preliminary results show a significant improvement in the scatter (~1%) of the normalized quartz spectra.





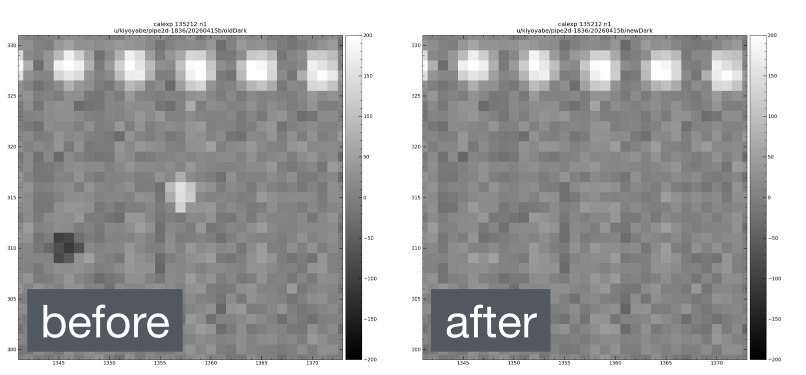
(**Left**) A chi map of the residuals in spectral extraction. A closer look shows that the residual occurs due to the difference of fiberProfiles. There is also a spatial pattern on the detector. (**Right**) A kernel to fit the observed profiles for each visit. The kernel measurement is done in the center block section of the detector.



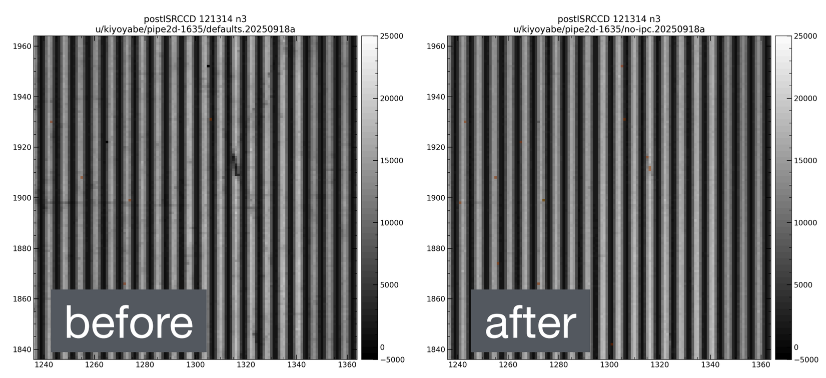
The normalized quartz spectra in each visit divided by the first quartz. **Left** shows the normalized spectra without any correction and **right** shows those with the correction. With this correction, the scatter in the normalized spectra is decreased significantly.

Improvement of NIR reduction (dark/linearity)

nirDarks appear to significantly change over time, and many pixels are poorly corrected. We will generate a nirDark cube every run and apply it to the science data, which significantly improves the correction of bad and problematic pixels. Linearity is modeled with Chebyshev polynomials, but the code is being updated to apply the correction before the UTR reduction process so that we can detect and track BAD, SAT, and CR pixels more accurately.



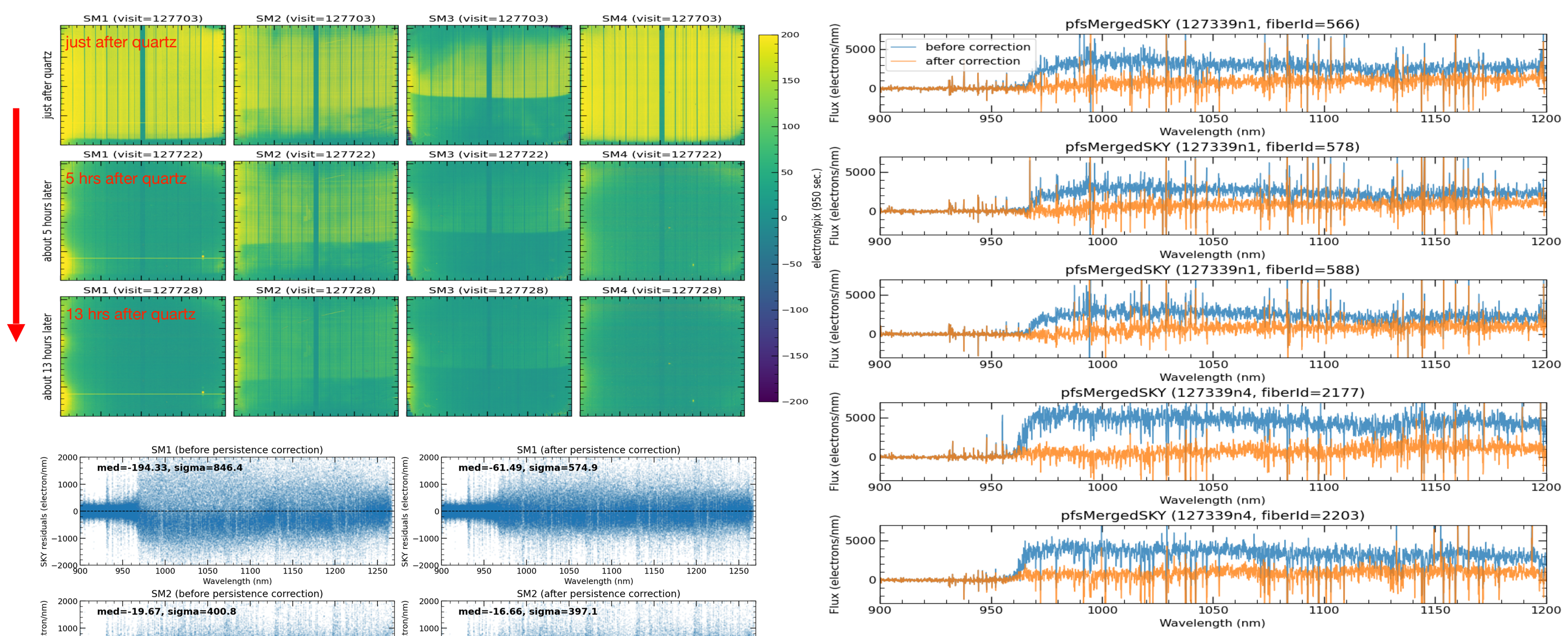
(**Left**) 2D detrended image of a science exposure processed with previous nirDark cube. There are pixels badly corrected for dark. (**Right**) The same image processed with the updated nirDark cube. The bad pixels are cleanly corrected.

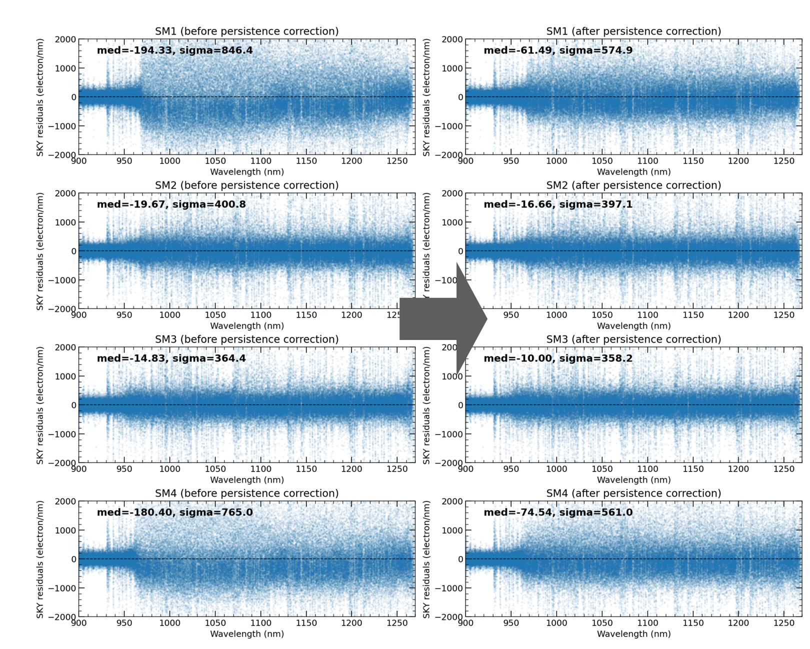


(**Left**) 2D detrended image of a quartz exposure processed without the linearity correction. (**Right**) The same image processed with the linearity correction. The image (and the extracted spectra) looks smooth and clean.

Improvement of NIR reduction (persistence)

Significant persistence remains in basically all n-arm cameras. Cameras n1 and n4 show intense persistence but a faster decay, while n2 and n3 show mild persistence but have a longer decay timescale than the other cameras (note that n2 was replaced recently). In the long run, we need to model the persistence accurately per pixel, but we are currently trying to correct it more quickly with a simple model. Although it is still in the conceptual design phase, by looking at SKY fibers that observed bright objects in the previous visit, we found that the spectra corrected with this simple model are better than without correction.

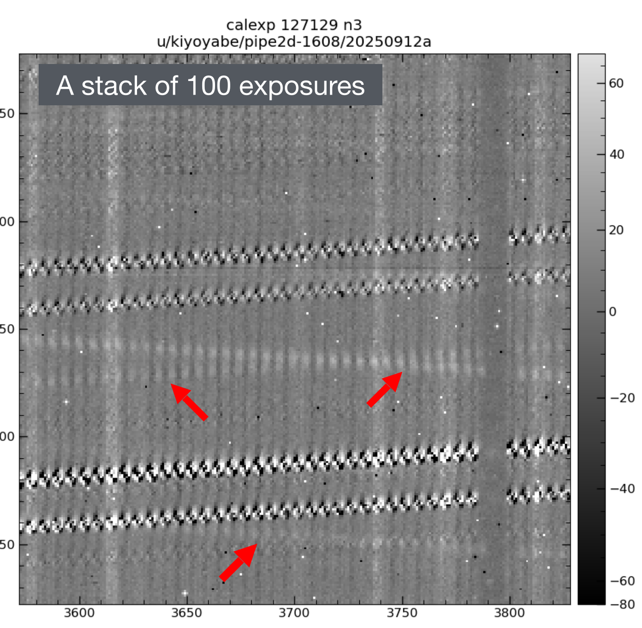




(**Top left**) The change of persistence on 900 sec. dark exposures (after quartz exposure) with time. (**Top right**) The extracted spectra without (blue) and with (orange) applying the correction. These are SKY fibers which observed very bright targets in the previous visit. (**Bottom**) The sky residual of SKY fibers without (left) and with (right) the correction.

Future prospects

Future tasks include refining the modeling of throughput variation as a function of cobra motor angles (theta - phi), refining the H4RG persistence modeling per pixel, and improving the coaddition of spectra. We will also improve wavelength calibration especially at bluer wavelengths. Faint but non-negligible ghosts are observed, especially in the n-arm, where there are many bright OH emission lines. Detailed ray-tracing of the optics may be needed to map the ghosts to the incident OH lines, but an empirical subtraction may be possible since their positions appear to be stable.



Example of faint ghosts on NIR detector. Emission lines from OH lines present as ghosts with normal and reverse curvature on the detector. The mapping between the location of the spots and the wavelength of the original OH lines is not yet done.

Contact pfs-data-analysis-help@ml.nao.ac.jp for questions and requests!