

Prime Focus Spectrograph (PFS) Instrumentation status report

Naoyuki Tamura (Subaru Telescope, NAOJ)
On behalf of PFS collaboration

Engineering First Light in Sep 2022

Successfully observed many stars simultaneously by intentionally positioning the fibers on the targets.

Wavelength
(630-970nm)



~600 fibers

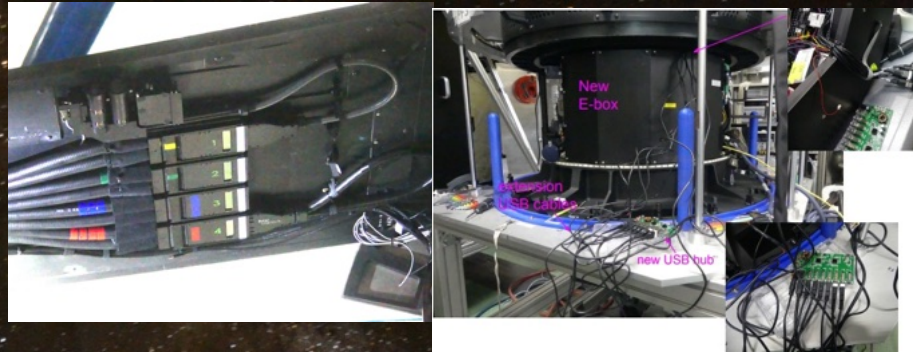
300s exposure of stars
in an NGC 1980 field
w/ SM1 red camera

The observation in Nov 2022 with
doubled multiplicity: $\sim 600 \rightarrow \sim 1200$

Two more modules to come for the full multiplicity of ~ 2400

300s exposure of stars
in an NGC 1980 field
w/ SM1 & SM3 blue cameras

3rd (02/2023) & 4th (05/2023) on-telescope fiber cables installation completed.



PFI E-box stabilization campaign (6-7/2023)

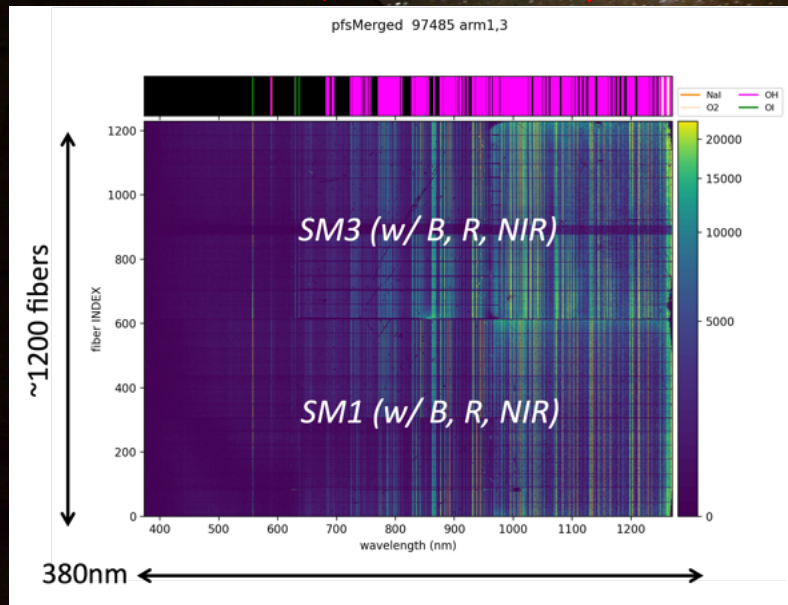
3rd SM (SM2) arrived at Summit and works begun (08/2023)

NIR camera 1st (03/2023), 2nd (07/2023) were installed on SM1 & 3.



NIR First Light (04/2023)

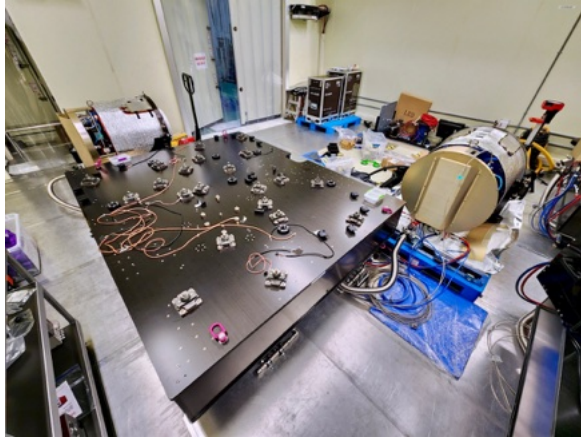
Both SM1 & SM3 now cover 380-1260nm (07/2023)



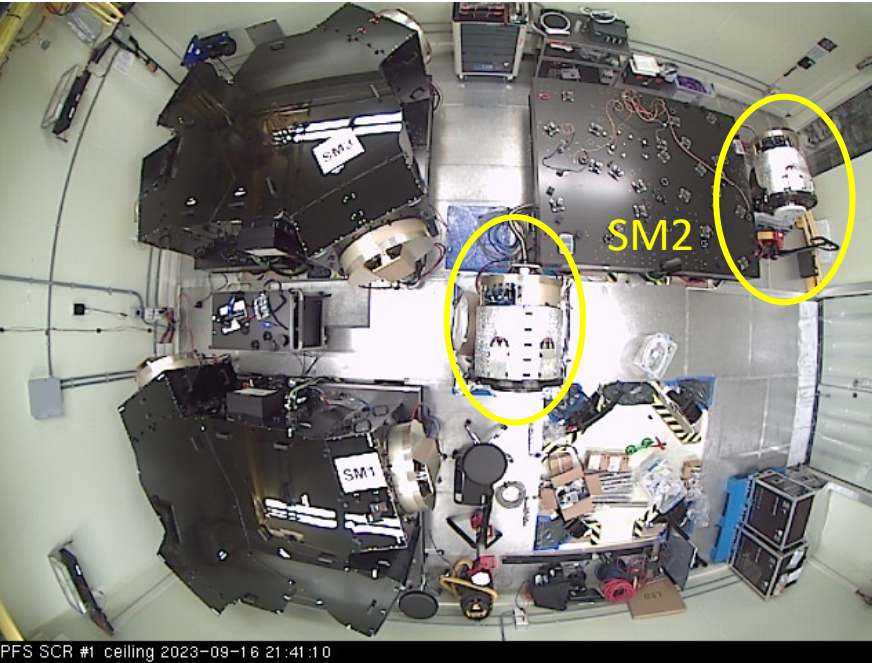
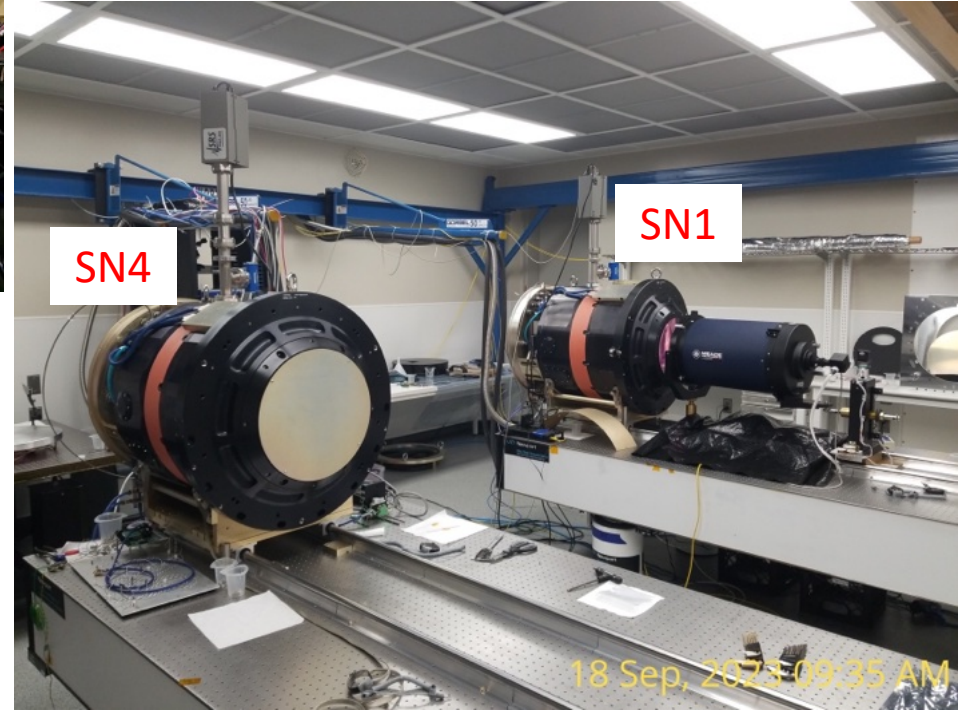
10/3-9 12/14-20

After the October run, SM2 & SM4 installation and tests works will be carried out with the few members from LAM.
 → Observation with the full set of hardware at the December run.

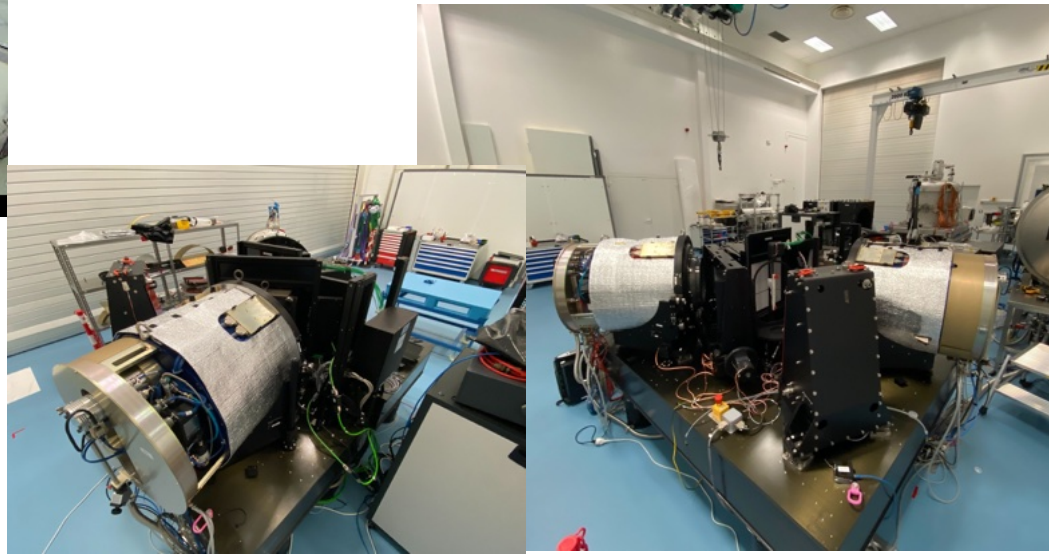
SM2 camera functional tests ongoing at Subaru summit



Two NIR cameras (SN1 for SM2 & SN4 for SM4) under testing at JHU



SM4 integration & test with the blue & red cameras at LAM

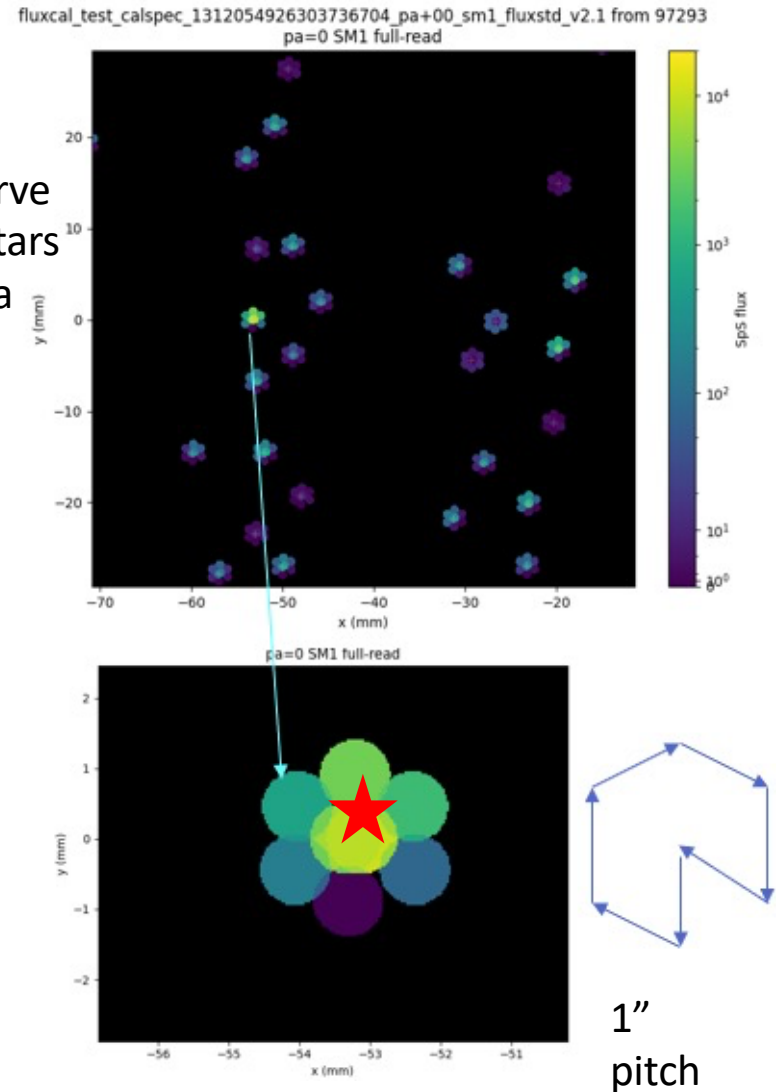


Engineering run

- Performance evaluation
 - Fiber positioning accuracy
 - Sensitivity (e.g. S/N reaches N after one-hour integration)
 - Throughput
 - Whether S/N increase with time as expected
 - Sky subtraction accuracy
 - Stability
- Optimizing operation efficiency
 - Minimizing overheads
 - Implementing automation
 - Minimizing risks of operation errors
- Validations of operation processes

Configure the fibers to observe many bright stars and then run a raster scan.

Raster scan



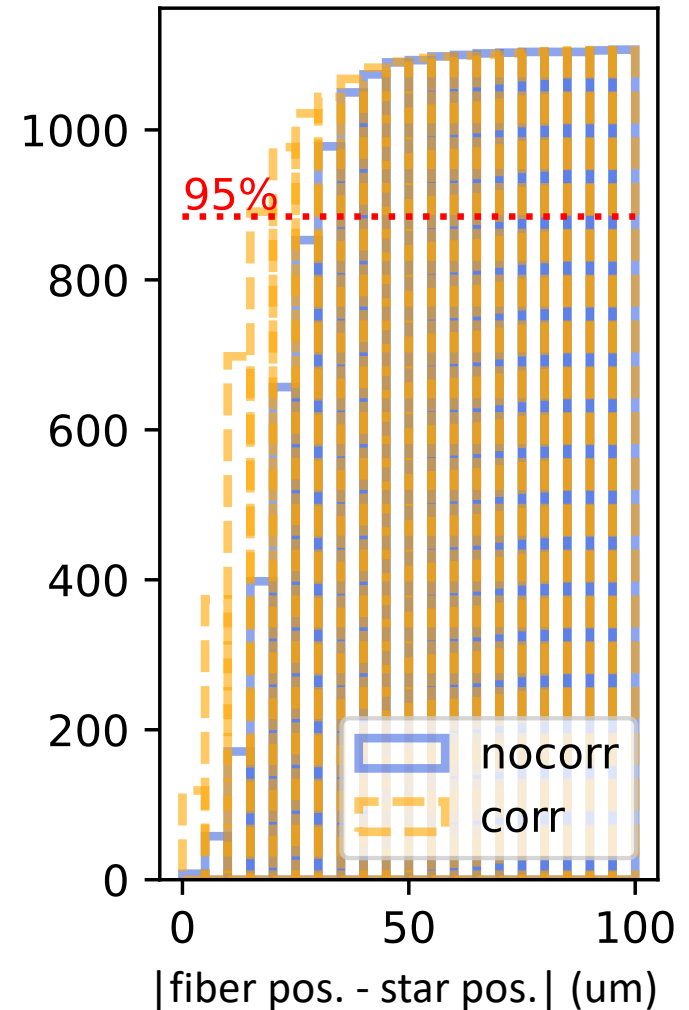
A spectrograph exposure is taken at each dither position keeping fiber positions the same,

Fiber positioning accuracy

- The on-sky difference between fiber pos. and star pos. is measured by the so-called raster scan operation.
- Still systematic errors remain in translation, rotation, and scale.
 - But the rotational offset has been greatly improved this time (i.e. in the July run) down to $\sim 0.001\text{deg}$ i.e. $\sim 4\mu\text{m}$ at the field edge.
 - A scale error seems to persistently exist, so its removal should be possible by updating the parameter in the model. Will be confirmed next time.
 - Lateral offset exists at a $10\mu\text{m}$ level. More data are needed to characterize it for removal. Perhaps the removal of scale error will ease visualizing how the lateral offset looks.
- $20\mu\text{m}$ error in total is quite reasonable: Most of the fibers within $\sim 10\mu\text{m}$ to target (x,y) @PFI, plus a few to several microns from each of sky->PFI projection, astrometry, and field acquisition & auto guiding.

"nocorr": Result directly from data
"corr": Result after the systematics are moved by hand

95%: 29.2 μm (nocorr)
17.7 μm (corr)

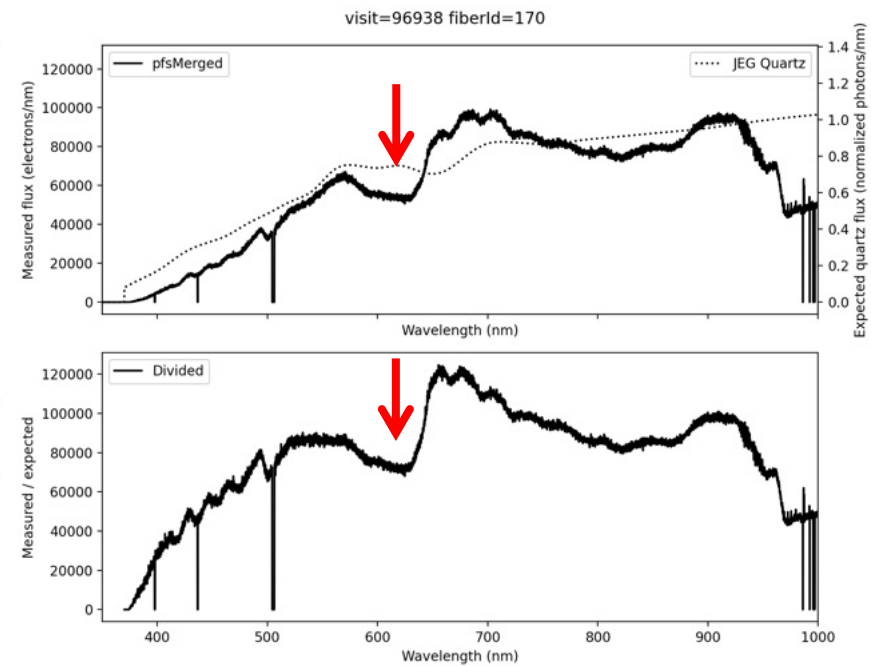
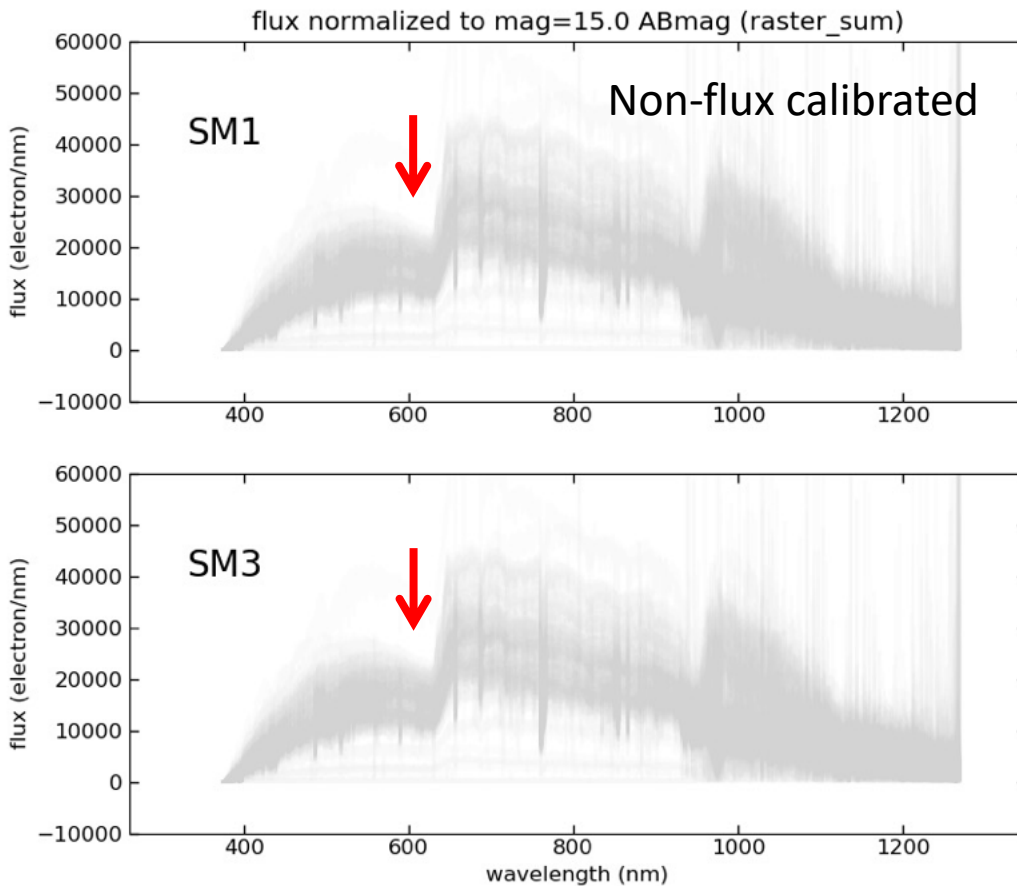


Moritani (Subaru)

Throughput measurement

Flux standard (spectral-type-known) stars

Quartz lamp

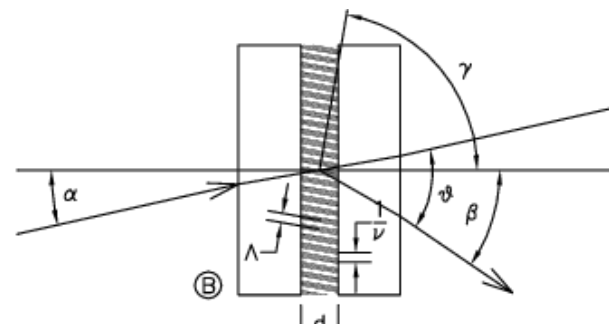
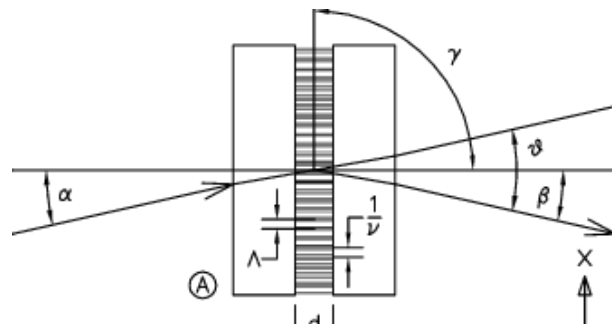


Confirmed this is not due to a pipeline error.

Something fundamental is amiss on the instrument ...??

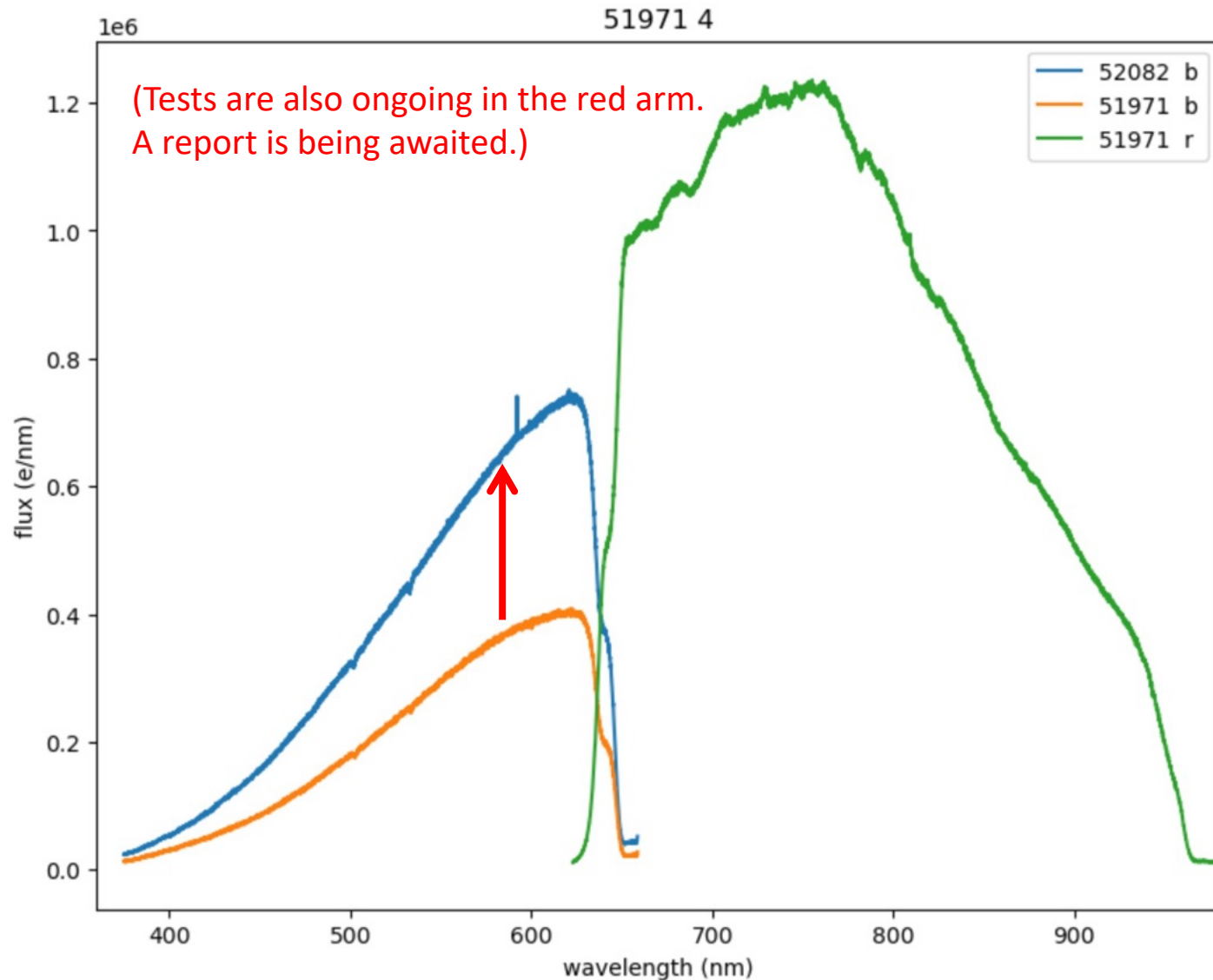
Taskforce (“tiger team”) was formed ...

- ~15 items were immediately listed as what might be wrong and what could be done to isolate problem(s).
- Visual inspections of the real hardware at LAM and at Subaru summit, document checks, data analyses, and discussions.
- **VPHG has been found wrongly mounted:**
 - The orientation is rotated by 180 degree around the optical axis
 - The efficiency curve becomes different due to the slant.
 - The red end of the blue is especially impacted in the way we are seeing on the data.



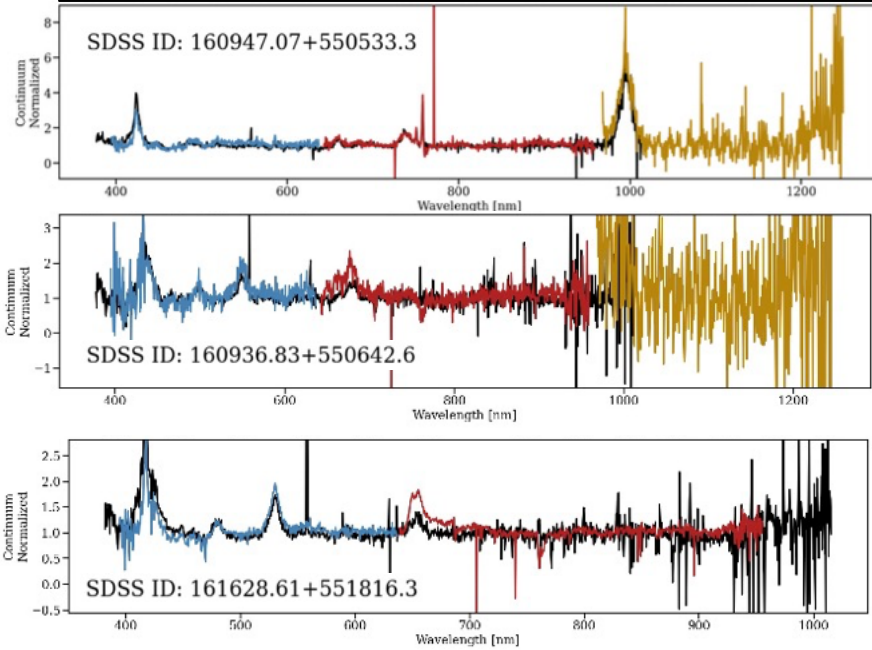
(Barden 1999)

Quartz spectrum from SM4 at LAM after VPHG orientation correction



2D Data Reduction Pipeline (2D DRP)

900s in 04/2023, whitened galaxy spectra

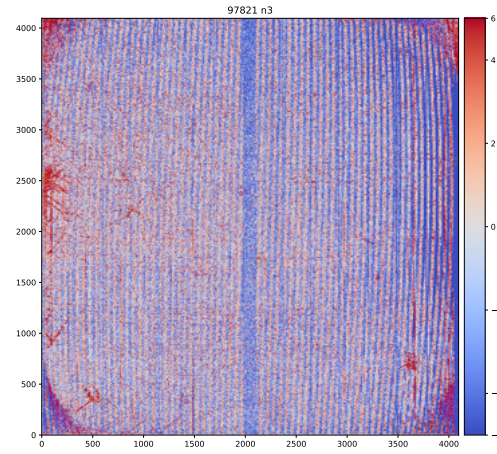
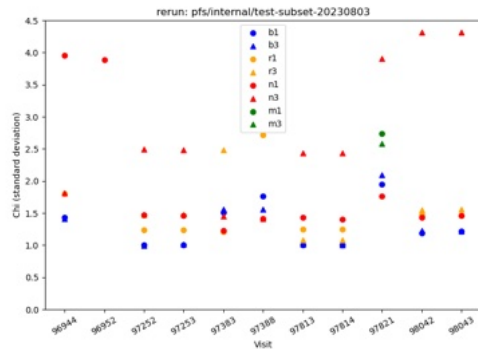


Processing data from engineering observations for:

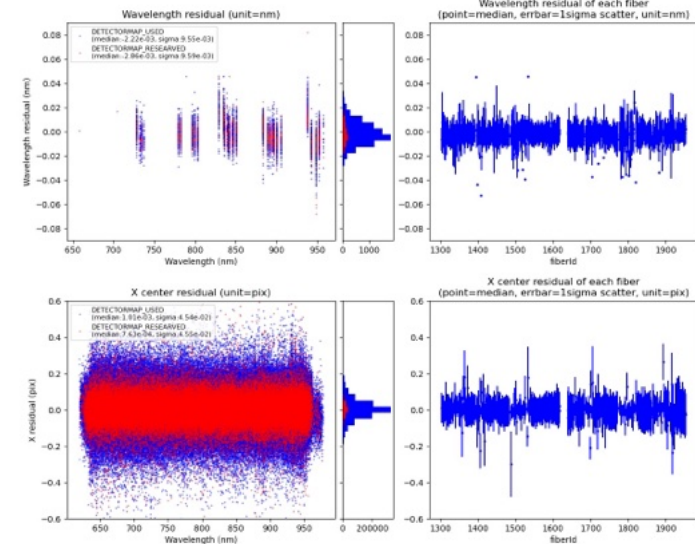
- Developments of the pipeline itself
- Developments of QA tools and metrics for diagnostics and decisions

detectorMap (Hamano, Gee [NAOJ]+)

Fiber extraction (Hamano [NAOJ]+)



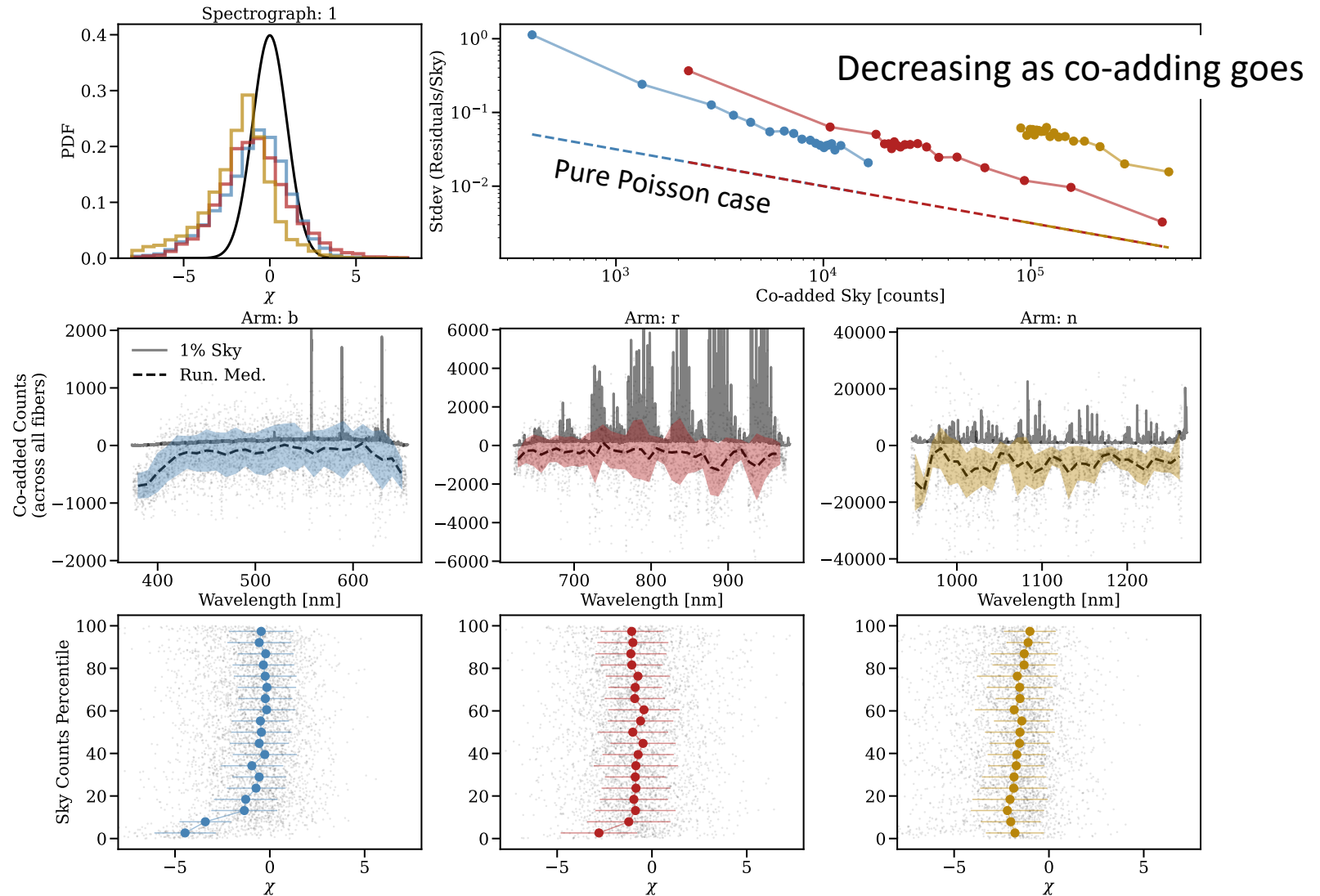
Detector map residual (visit=82596, arm=r, spectrograph=3)



Sky subtraction coadding test with “all-sky” data

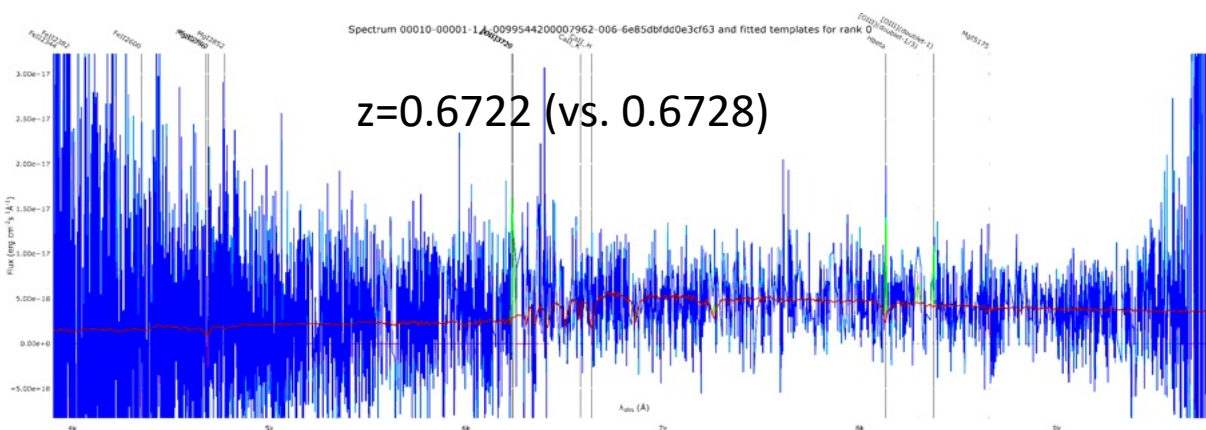
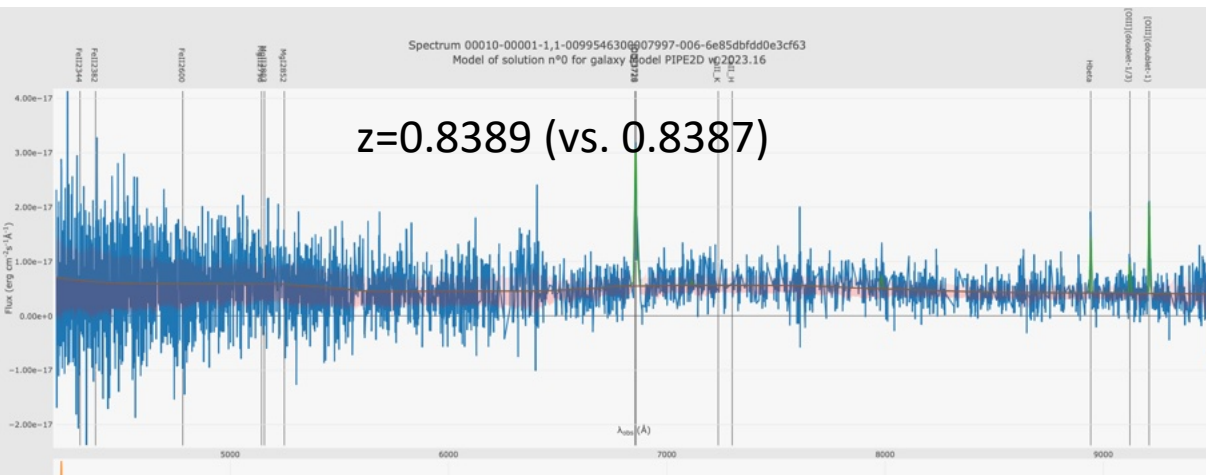
Siegel (Princeton)+

Residuals & scatters on sky-subtracted sky spectra and how they evolve with co-adding.



1D Data Reduction Pipeline (1D DRP)

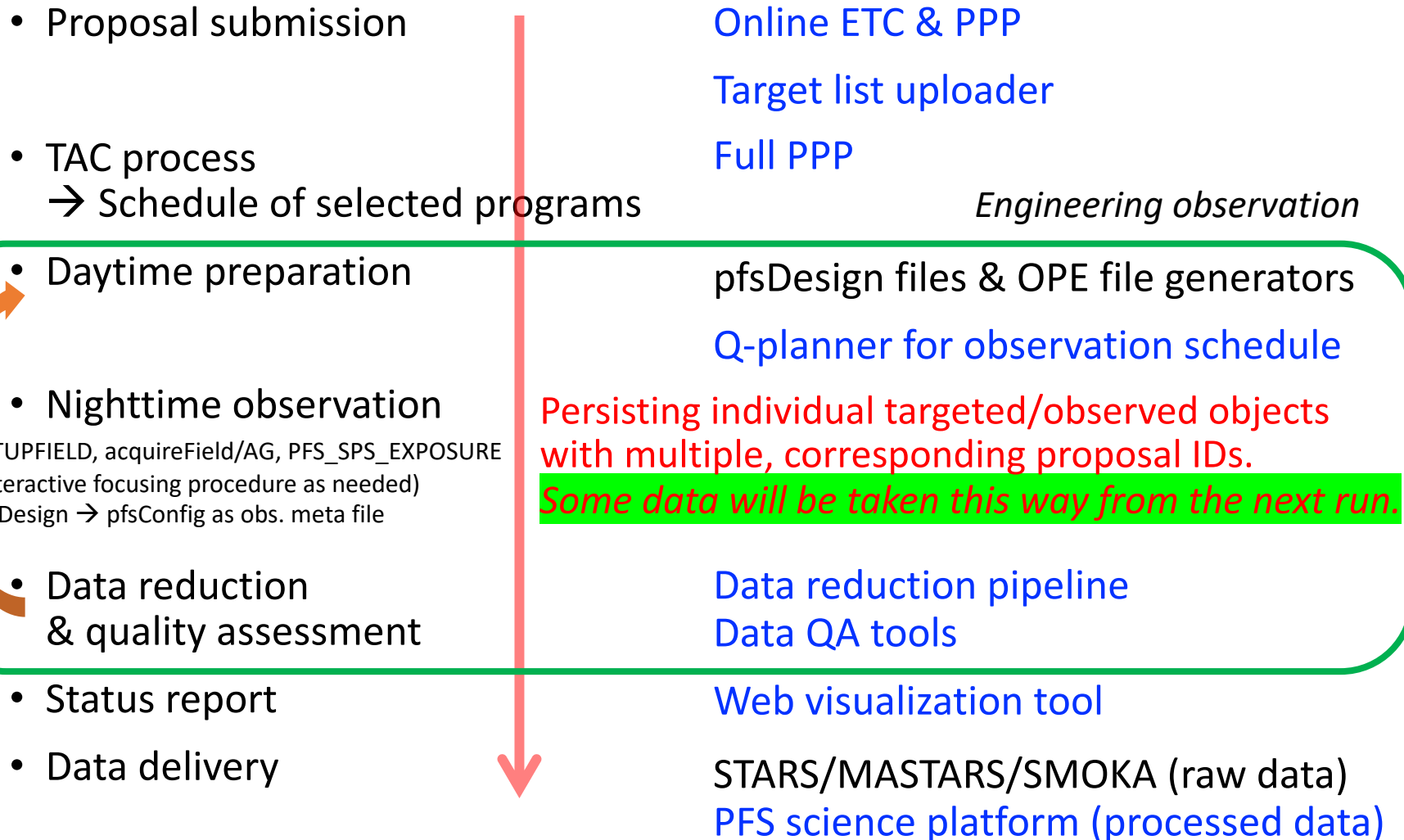
(5400s in 11/2022)



- 1D pipeline is to apply classification and various measurements to fully reduced and calibrated 1D spectra from 2D DRP.
- Updated version of LAM 1D DRP is released every a few months.
- Simulated spectra are still mainly used for developments and tests but some real spectra from engineering runs are also being processed.
- There is also so-called GA 1D pipeline specialized for radial velocity and abundance measurements on stellar spectra developed by PFS GA (Galactic Archaeology) WG.

End to end observing process: Simulation, implementation & validation

ETC: Exposure Time Calculation
PPP: PFS Pointing Planner



PFS community meeting

9/19 (Tue) 9:00-12:00 JST
~60 participants

Walking through proposed procedures

プロポーザル準備 (観測時間の見積り)

- もともとは fiber hour + target completeness で時間要求するやり方でしたが、そ

観測時 (Classical)

- 通常の classical のやり方ですが、ターゲットリストは提出済み(その場で作らない)。

観測時 (Queue)

- 観測時は queue 方式で、ターゲットリストは提出済み(その場で作らない)。
- Proposal 提出時に target list が全て揃っている。TAC から Grade が届いている。

観測時 (ToO)

- 通常の ToO と同様、当日の9時までにトリガーをかける。
- 時間は半夜単位である必要はありません。
- ただし、ToOポリシーは改訂が予定されていて、hour単位の要求もあるところまでできるようになるかもしれません。
- トリガー時にターゲットリストを提出。
- classical modeでの実行になります。
- 余剰ファイバーには filler が入ります。他の共同利用観測のターゲットは当面入りません。

Demos

ETC/Spectrum simulator



PFS Pointing Planner



Working meeting at Tufts Univ. 8/30-9/1

PFS science WG co-chairs got together to share the status of instrumentation and discuss how the SSP survey plan and proposal document should be developed further accordingly.

Cosmic Evolution & the Dark Sector

DRAFT VERSION MARCH 23, 2022
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COSMIC EVOLUTION AND THE DARK SECTOR: A PFS SSP FOR THE SUBARU TELESCOPE

THE SUBARU PRIME FOCUS SPECTROGRAPH (PFS) COLLABORATION
The full author list is given in the Appendix
Draft version March 23, 2022

ABSTRACT

We propose a large-scale survey with PFS to address fundamental and important questions in the dark sector (dark matter and dark energy) with significant implications for cosmology, galaxy evolution and the origin of the Milky Way Galaxy. The unique wide-field and massively-multiplexed spectroscopic capability of PFS will maintain and strengthen Subaru's world-leading role in cosmology and astronomy for the next decade. Our experienced team of astronomers from Japan and the international community has developed an ambitious 360 night survey to be undertaken over 5 years which fully exploits the unique capabilities of PFS to address outstanding questions relating to the history and fate of the Universe as well as the physical processes and role of dark matter in governing the assembly of galaxies including our Milky Way. We commit to fully reducing the data from this landmark survey and making it available to the global astronomical community in a timely manner.



Timeline of planned works

- 9/27 (tomorrow): SM4 preship review
- 10/3-9: Engineering observation
 - Clean data sets for throughput measurements
 - Validation of data acquisition along procedures expected at open-use
- 10/16-20: SM1 upgrade works with a JHU member
- 10/23-11/30: SM2 and SM4 works with a few LAM members
 - Re-integration
 - VPHG rotation correction
 - Pumping & cooling the cameras, and carrying out validation tests
- 12/1-13: Preparation
- 12/14-20: Engineering observation
 - With the full hardware set

PFS subsystems distribution

The two spectrograph modules have been fully assembled and in operation, and the 3rd one is being installed.

All four on-telescope fiber cable have been installed on the telescope and two of them are in operation with SM1 and SM3.

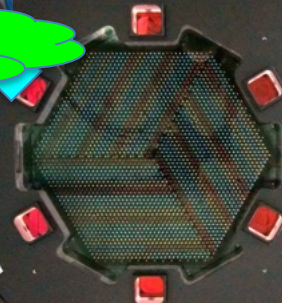
Fiber c

Prime Focus Instrument (PFI) arrived at Subaru in June 2021.

OPERATING!



2400 fibers steered by positioners



Wide-field corrector

Two are ... **OPERATING!**

Two others are ...

READY!

1st & 2nd ones are ...

OPERATING!

3rd & 4th ones are ...

COMING!

Metrology came as a Cassegrain instrument

OPERATING!

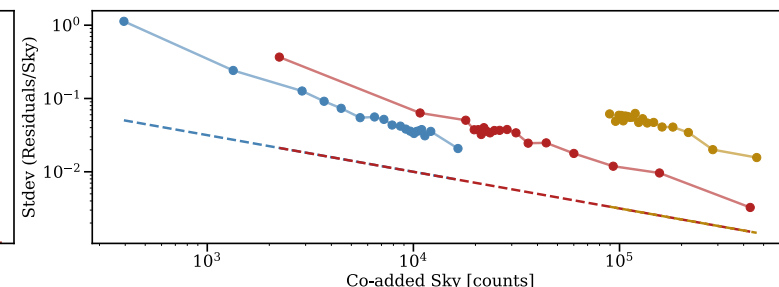
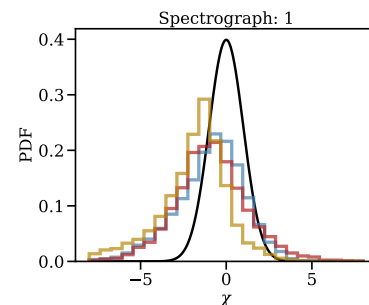
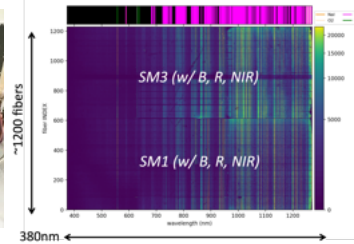
The metrology camera was fully integrated and tested on the telescope by 2019.

Subaru Telescope

Summary



p4Merged 97485 am1.3



- Successful installations of 2 more on-telescope fiber cables in Feb & May 2023 → All cables are complete.
- Successful implementations of 2 NIR cameras in Mar and July 2023 → SM1 and SM3 are in operation generating data from 380nm to 1260nm.
- SM2 arrived at the Subaru summit in Aug. SM4 will also be delivered soon.
- SM2 and SM4 will be reintegrated and tested in Oct-Nov. The VPHG orientation will be corrected during this period.
- Developments of the pipelines and QA tools & metrics are progressing through the processing of engineering observation data.
- Developments and validations of observation preparations and data acquisition, and observation procedures for open-use observations are underway.
- Aiming at the full hardware testing at the engineering observation in December.