Major Optical/Infrared Instrumentation Projects in ASIAA

王　祥　宇

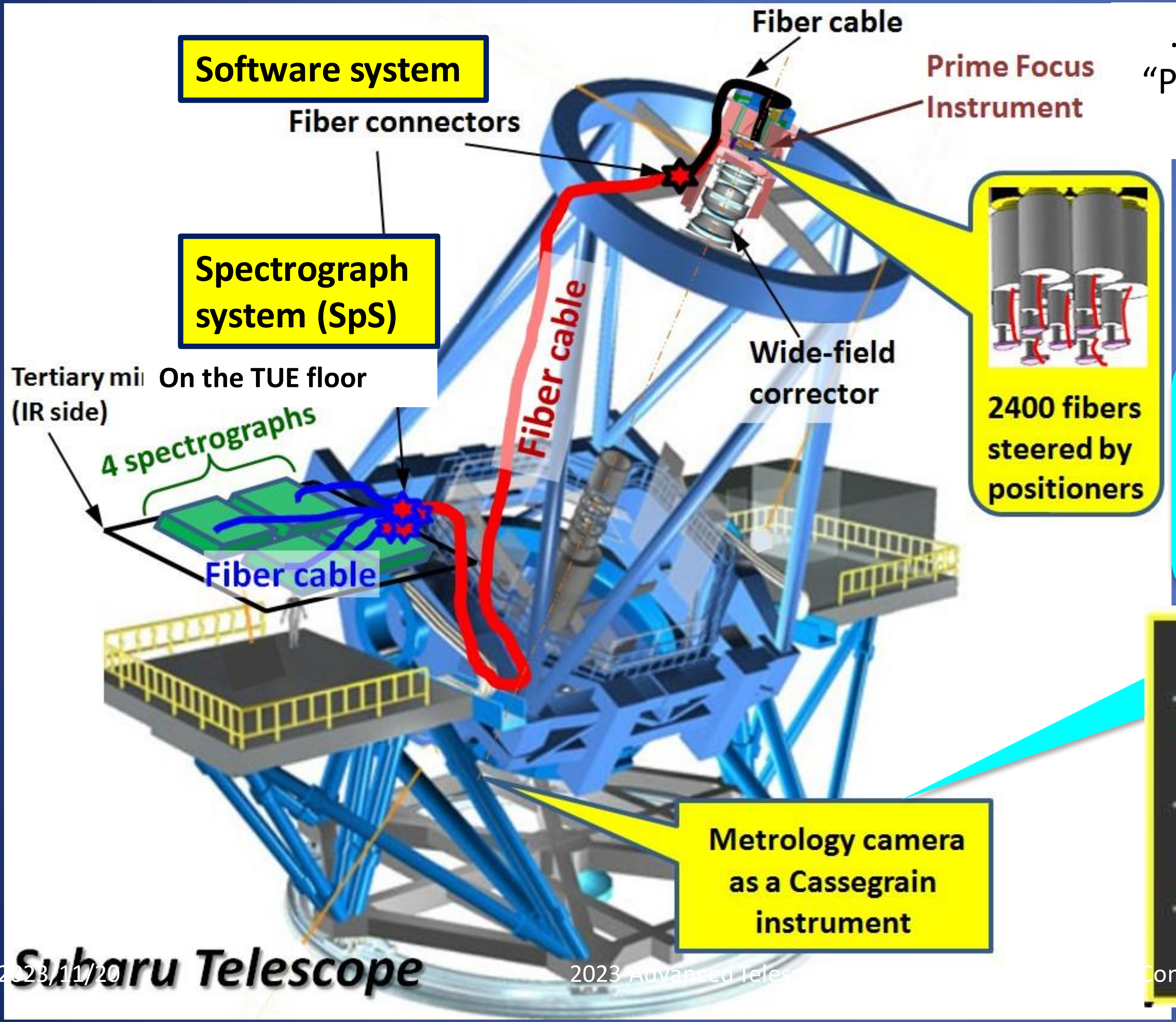
Academia Sinica

Institute of Astronomy and Astrophysics

Development Strategy

- Develop the instrumentation capability rather than building large telescopes considering the budget and community size
- Collaborate with advanced telescopes of large apertures
  - CFHT (4m): WIRCam(2005), Flyeyes(2009), SPIRou(2018)
  - Subaru (8m): HSC(2013), PFS(on going)
  - ELT (39m): METIS (on going)
  - GMT (24m):G-CELF, GMACS (under discussion)
- Build small telescope systems
  - TAOS I (2005) & TAOS II (on going)
- Provide the access to the advanced optical/IR telescopes

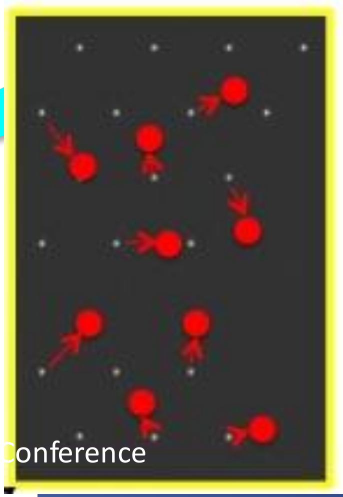
Subaru Prime Focus Spectrograph

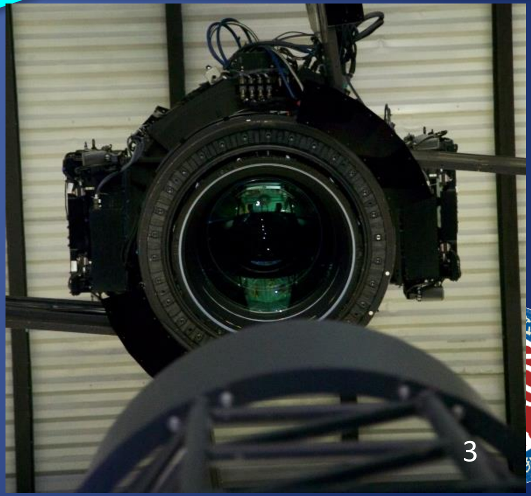


… in Prime focus unit “POpt2” with Wide Field Corrector “WFC”.

Calibration system

This takes an image of the prime focus with the fibers “backlit” and measure their current positions: *Key part of iterative fiber positioning process.*

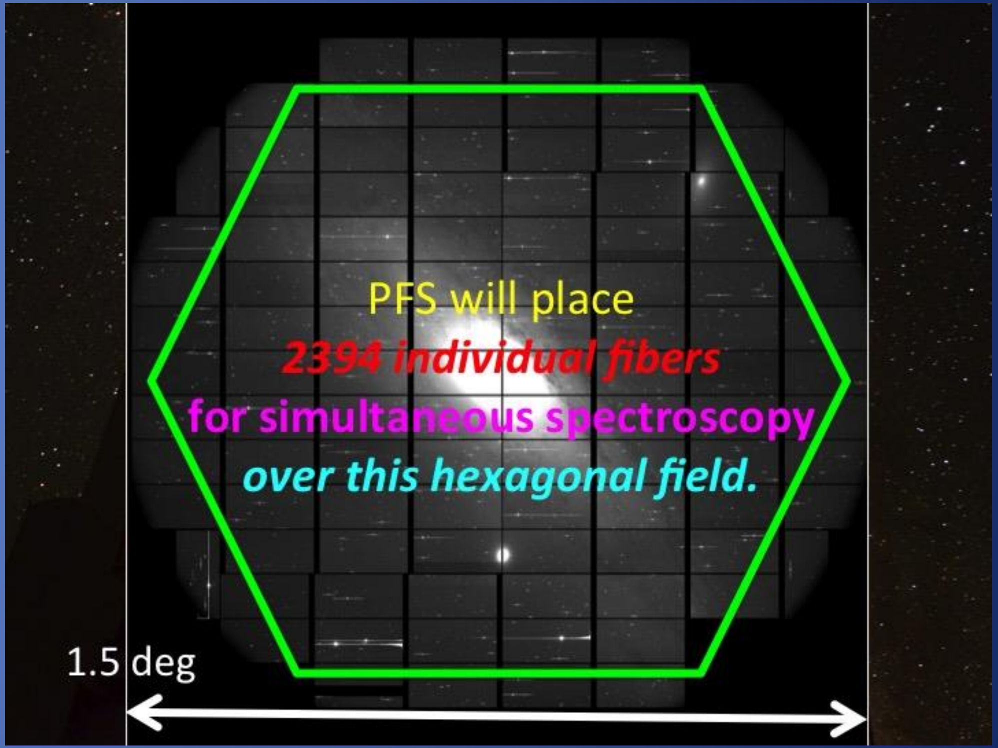




PFS Partners

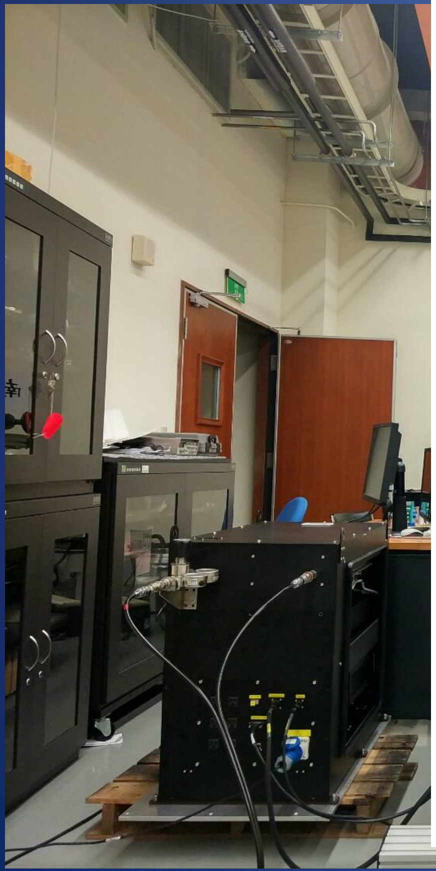
PFS - Fast facts

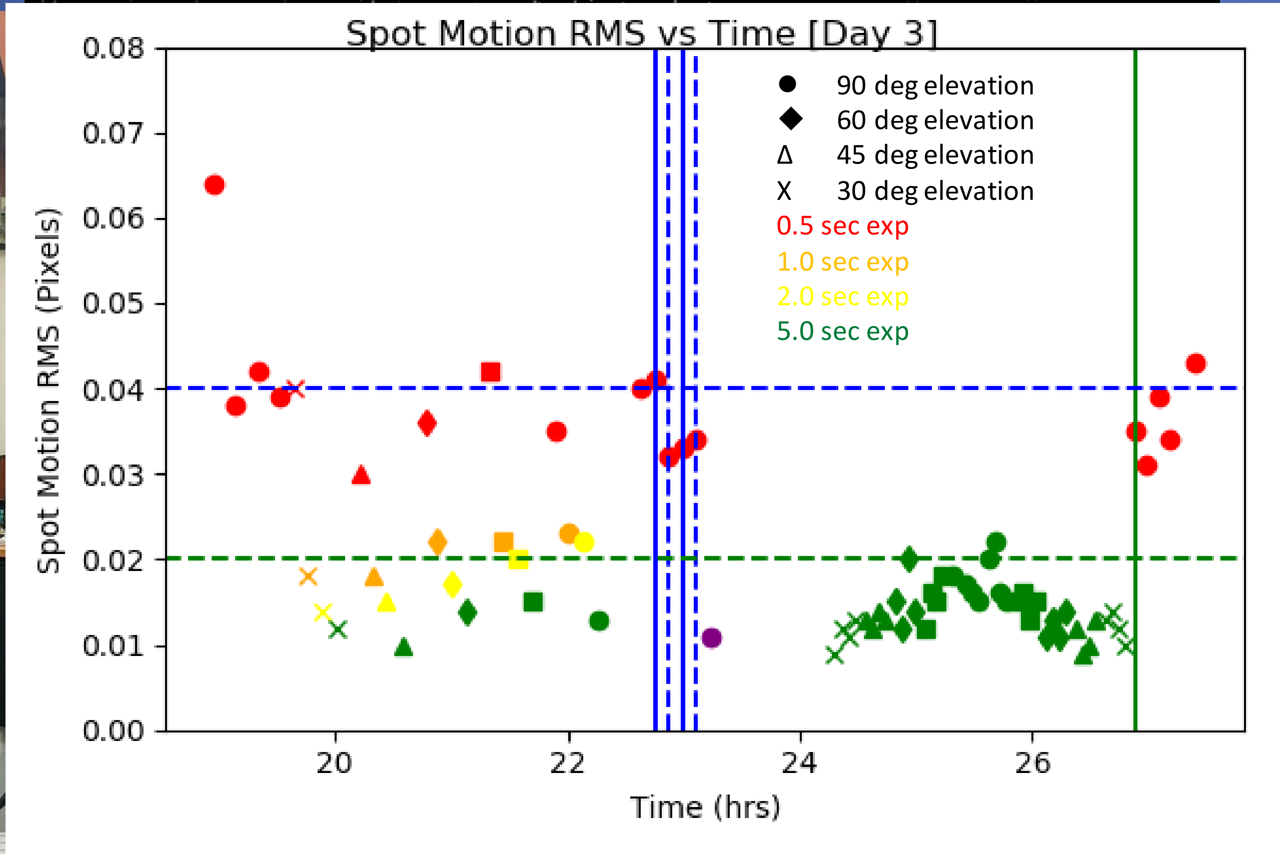
- *Prime Focus Spectrograph*: *Spectroscopic exploitation of the Subaru's prime focus (complementarily to HSC)*
  - Wide field: ~*1.3 deg* diameter
  - High multiplicity: *2394 fibers*
    - Fiber diameter: ~1.05 arcsec
    - Fiber positioner pitch: ~85 arcsec
    - Minimum fiber separation: ~30 arcsec
  - Quick fiber reconfiguration: ~*2 min* (TBC)
    - *Dynamic* survey strategy/operation is allowed.
  - VIS-NIR coverage: *380-1260nm simultaneously*
    - Low resolution mode: ~2.5 A resolution
    - Medium resolution mode (around 800nm): ~1.6 A resolution

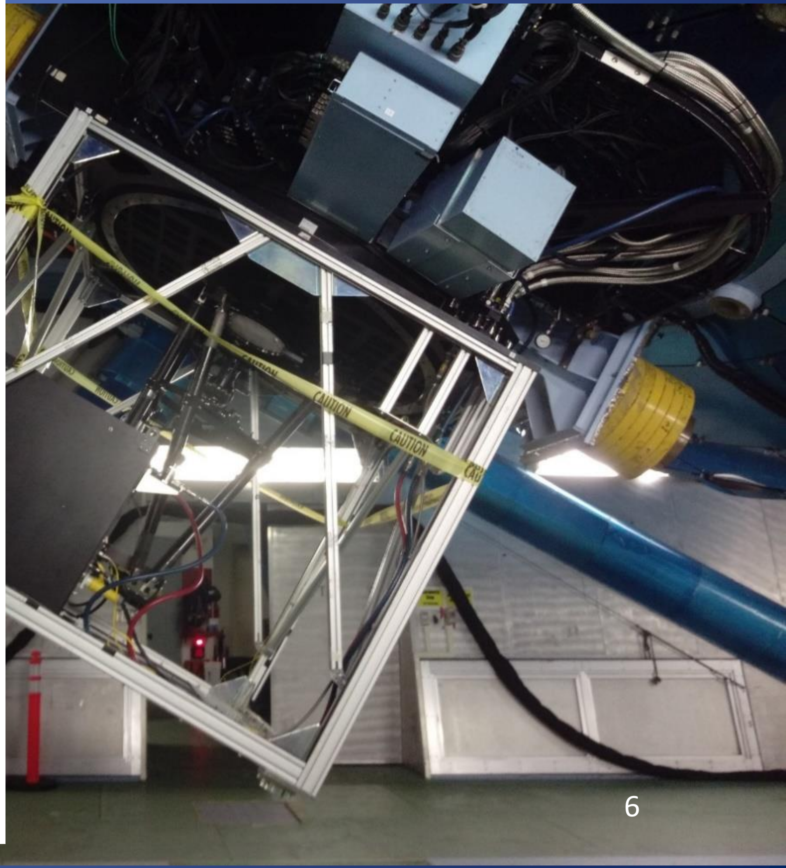


MCS delivered in June 2018

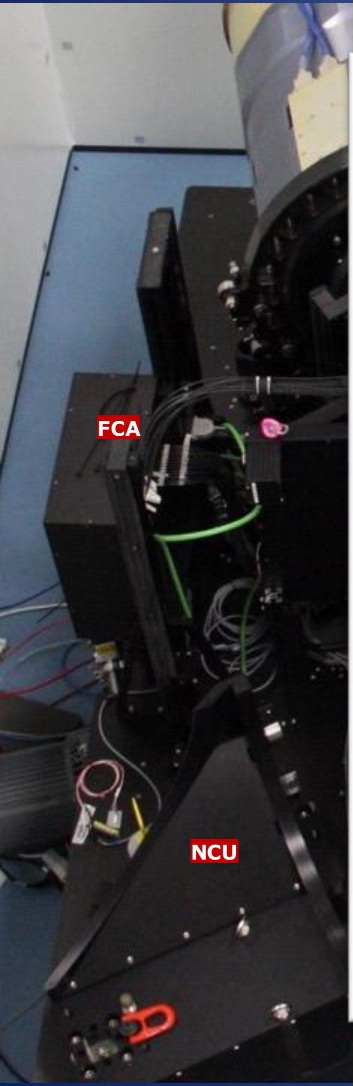
- 380mm aperture Schmidt telescope
- Measure all fiber positions with 5 microns error in 5 sec
- Test result shows the accuracy is around 4 microns and the acquisition + analysis time is about 3.7s.

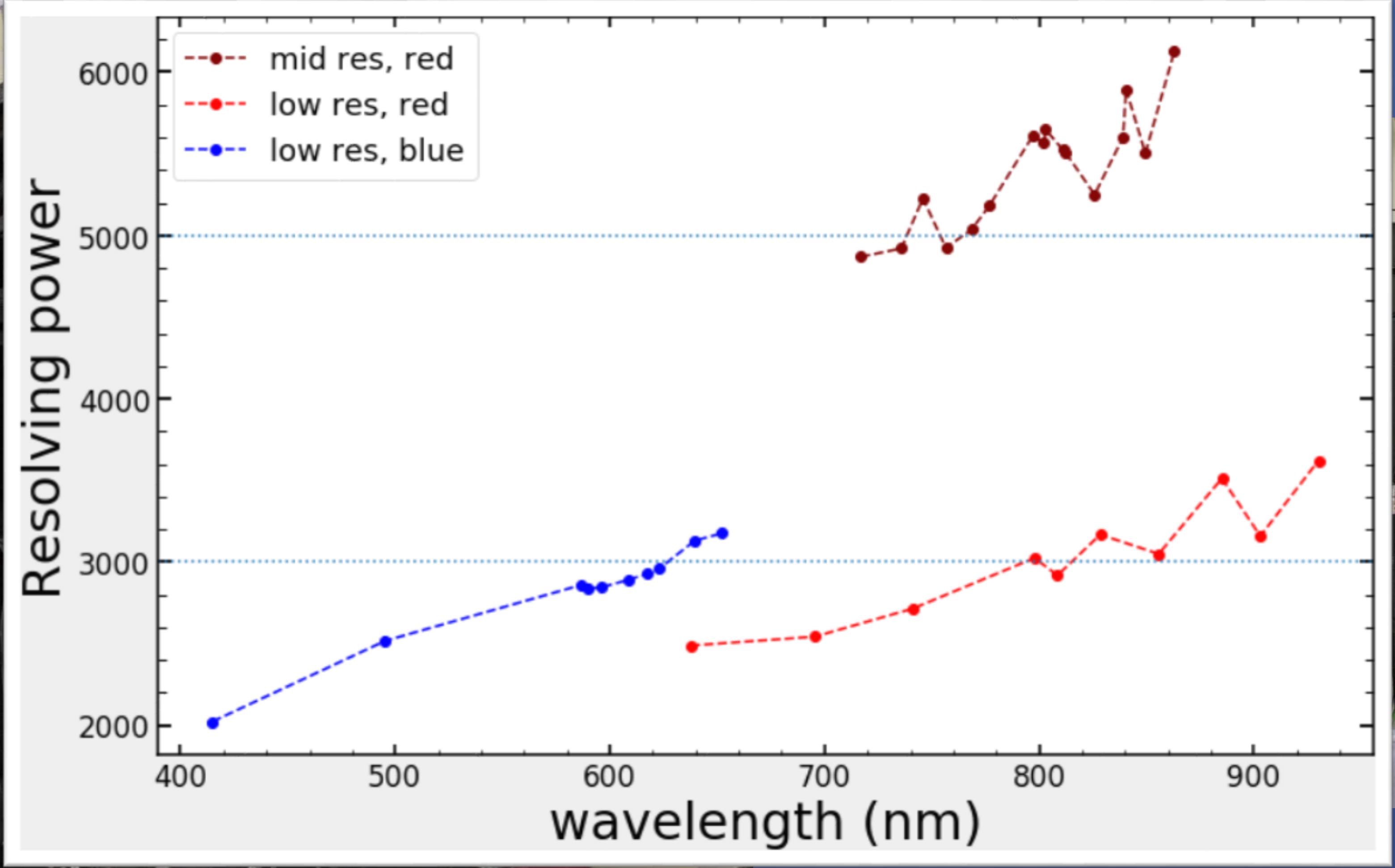




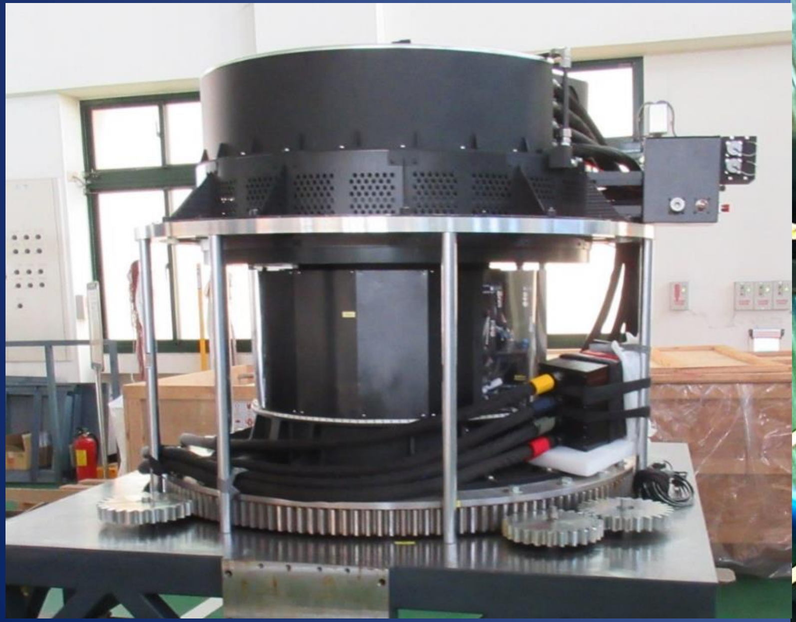


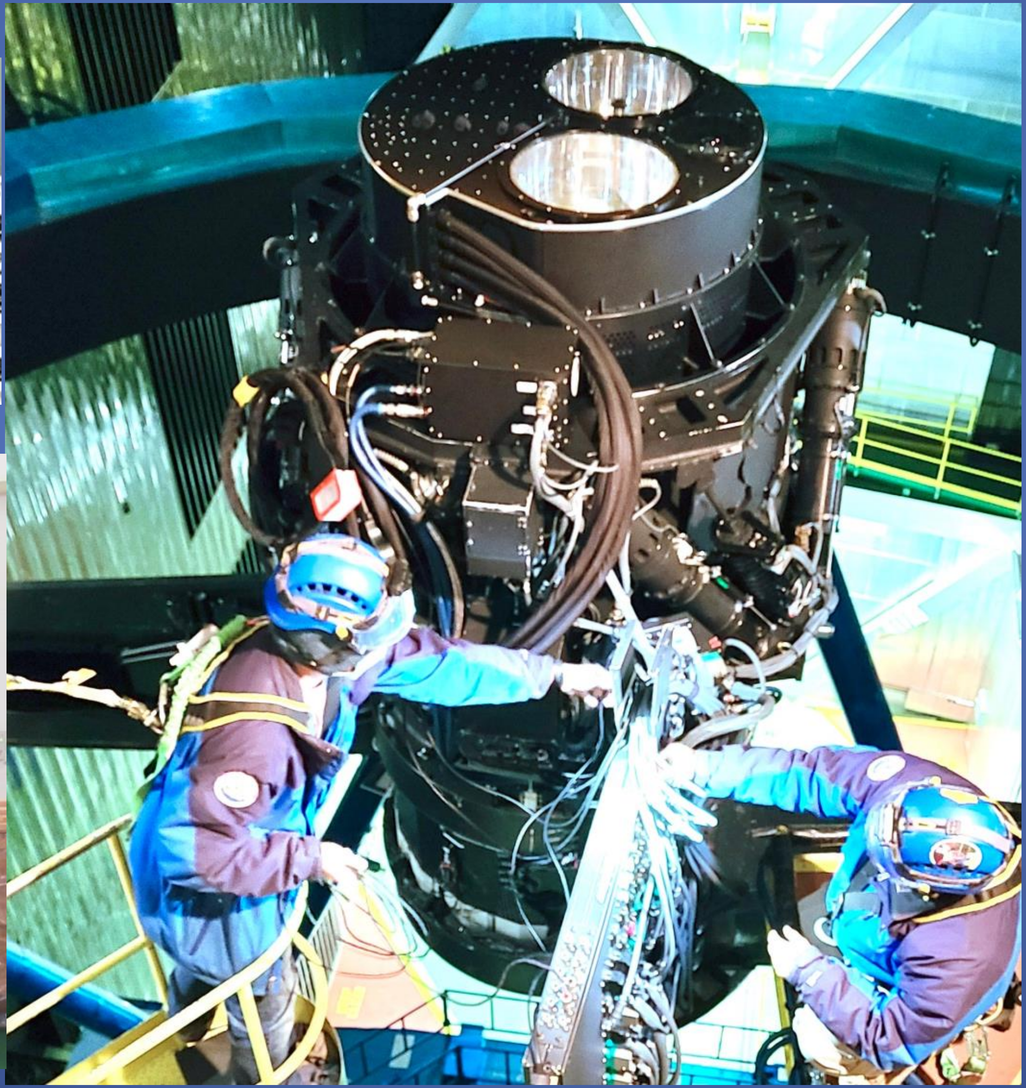
1st Spectrograph Module was installed in Dec 2019

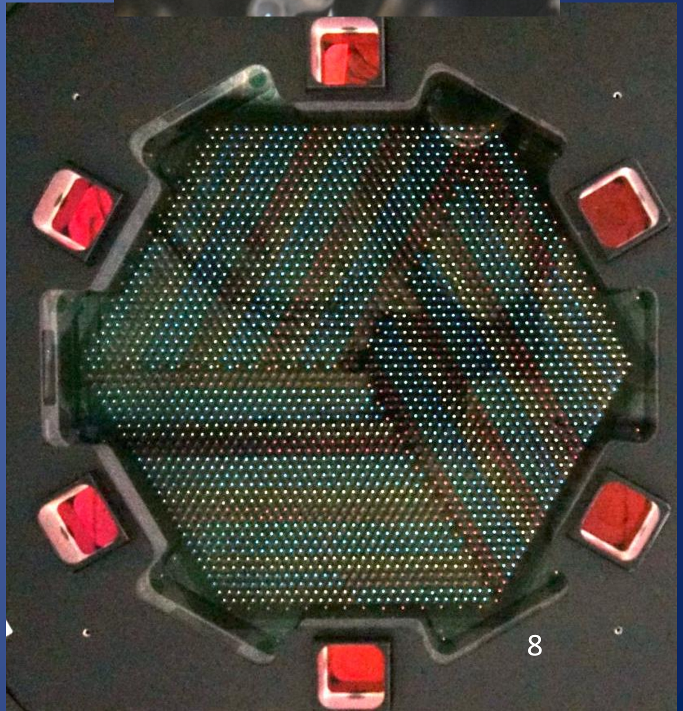




Prime Focus Instrument was delivered in Jun-2021

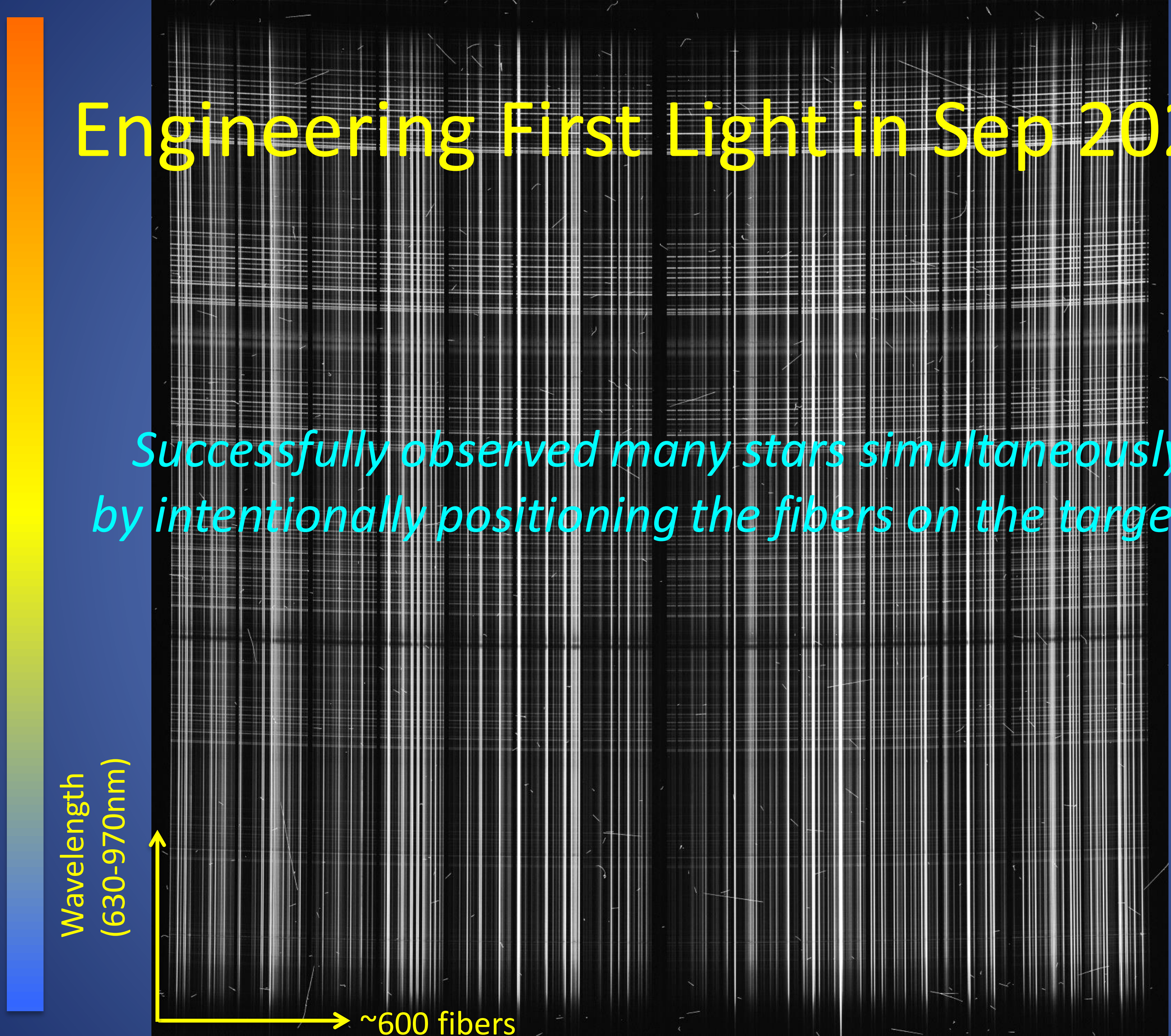






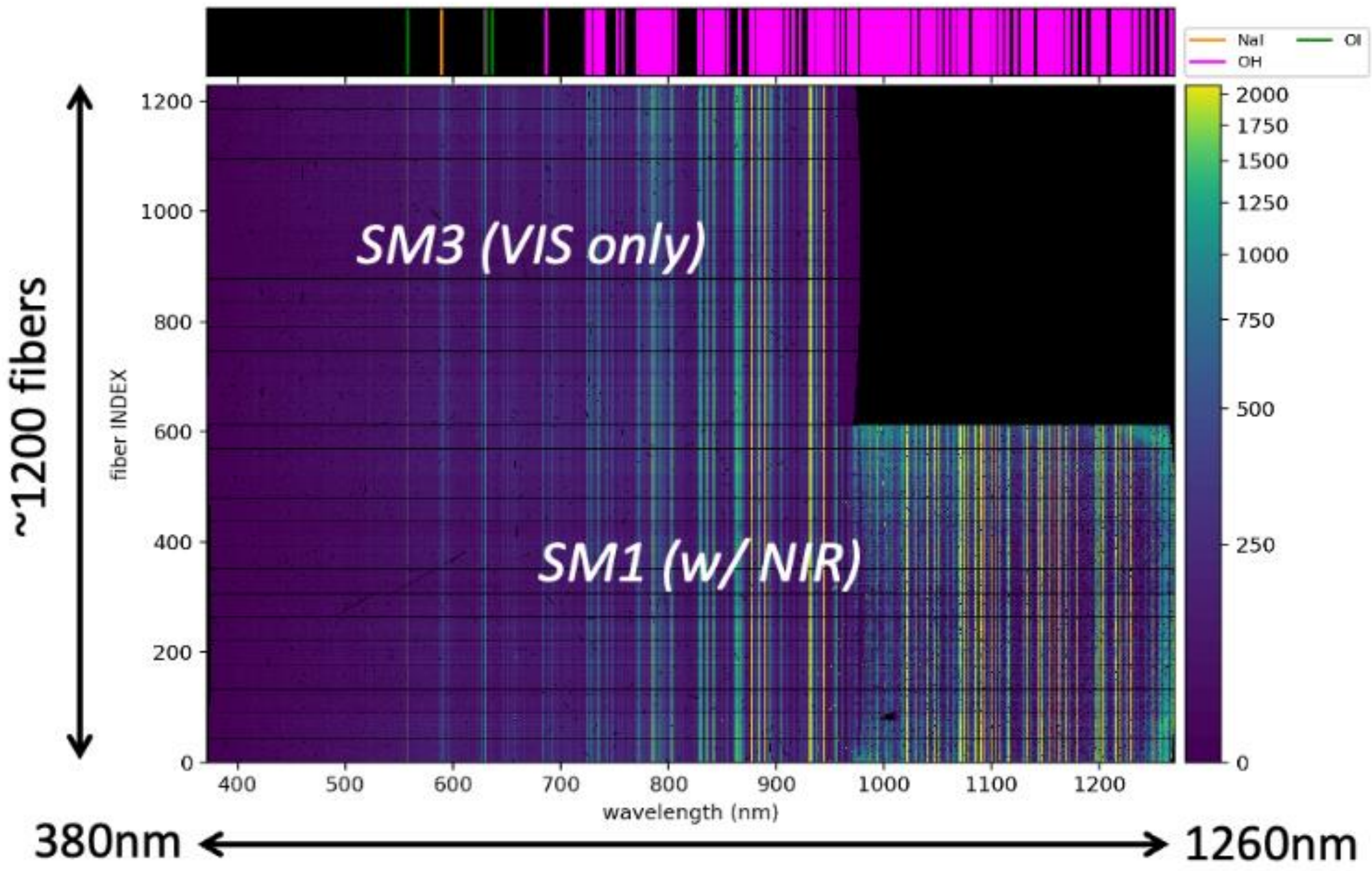
Engineering First Light in Sep 2022

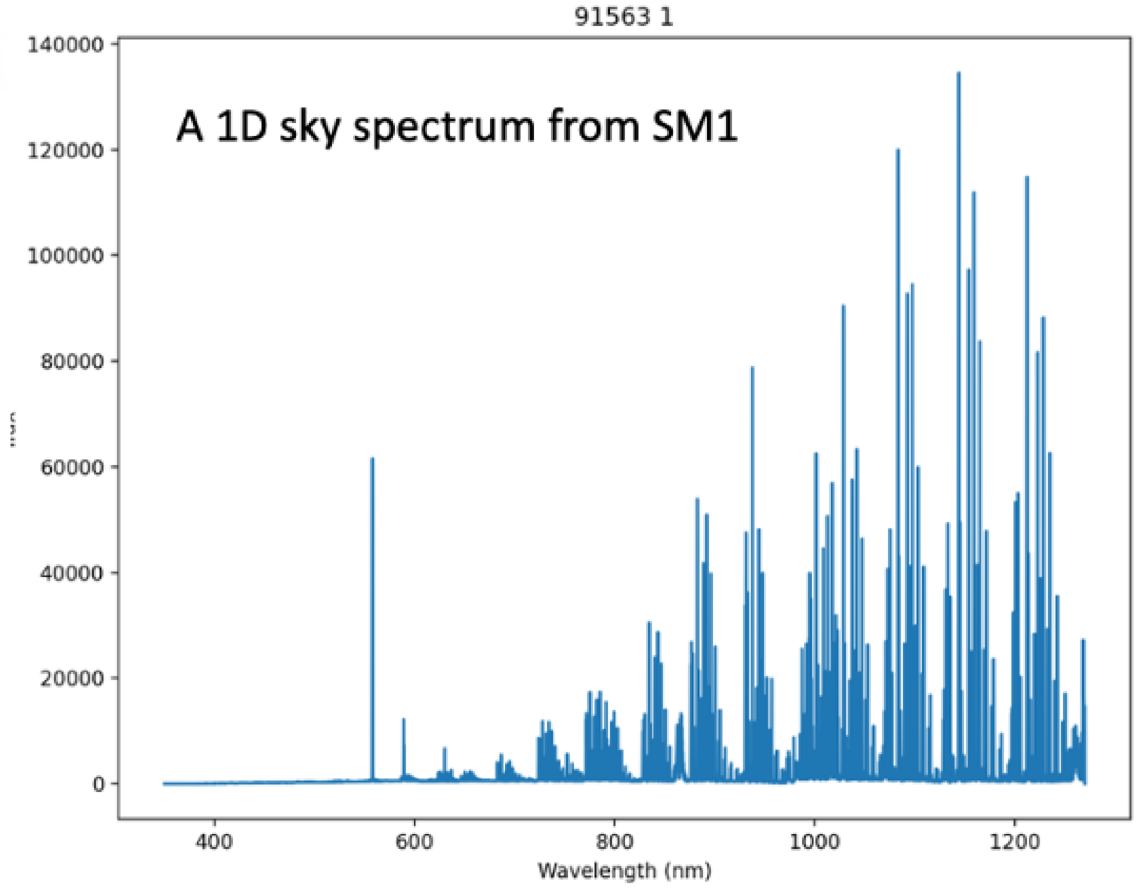
Successfully observed many stars simultaneously by intentionally positioning the fibers on the targets.



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

Engineering run of April 2023





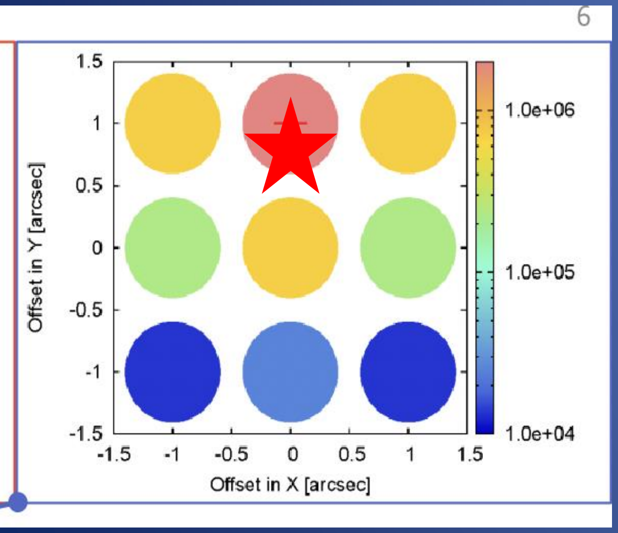
Fiber positioning accuracy

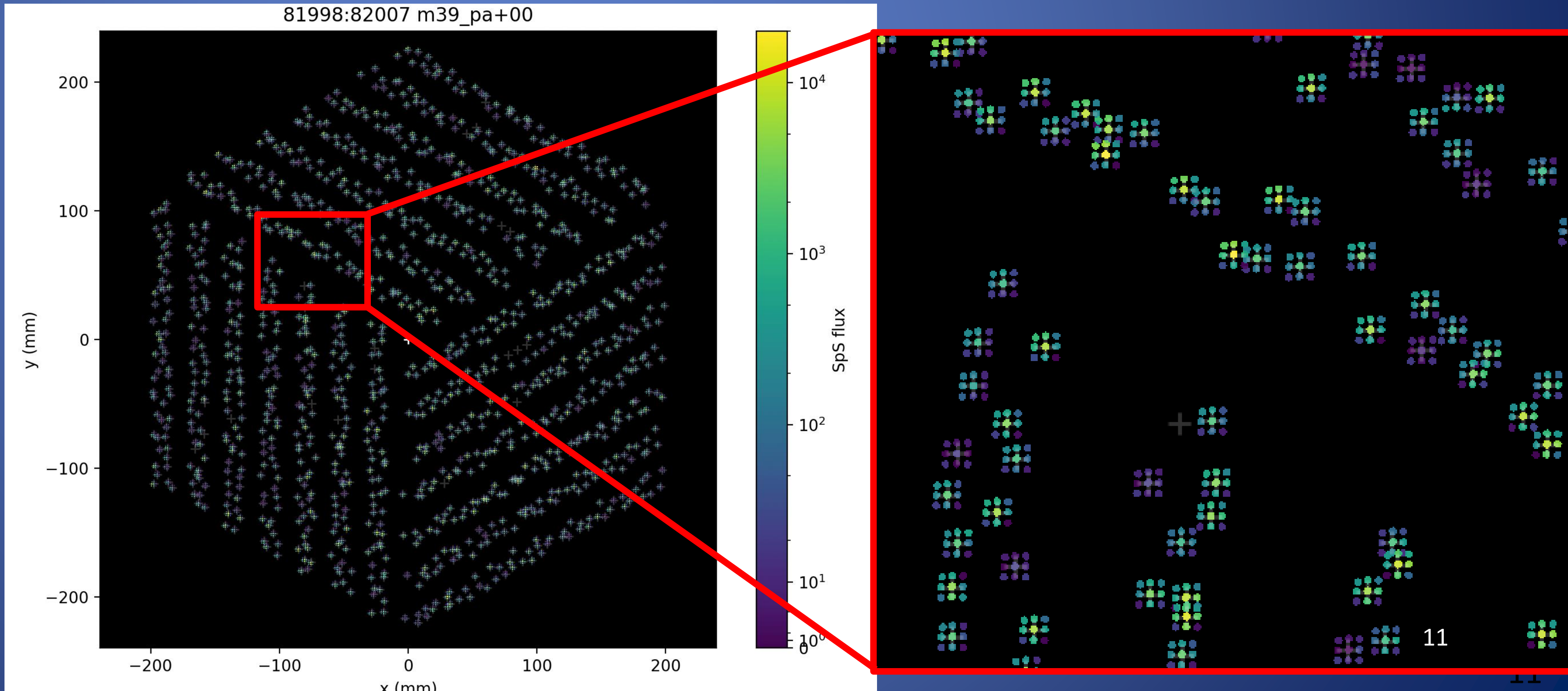
Accurately predict (x,y) from (α, δ).
Accurately move the fiber to requested (x.y).

Raster scan

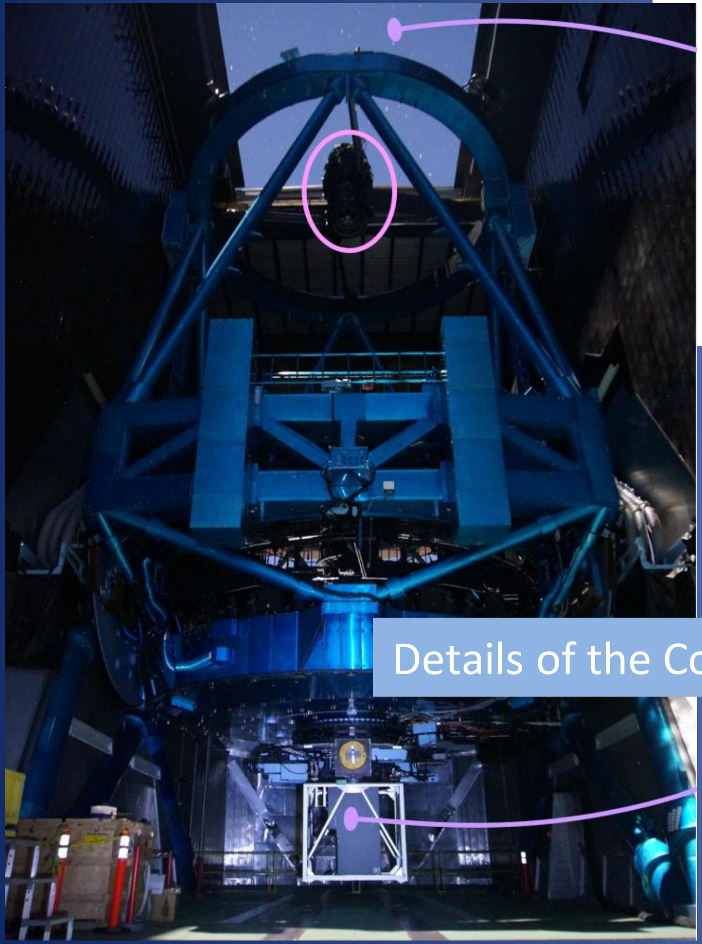
- To generate a 2D map of flux coming into the instrument around each fiber.

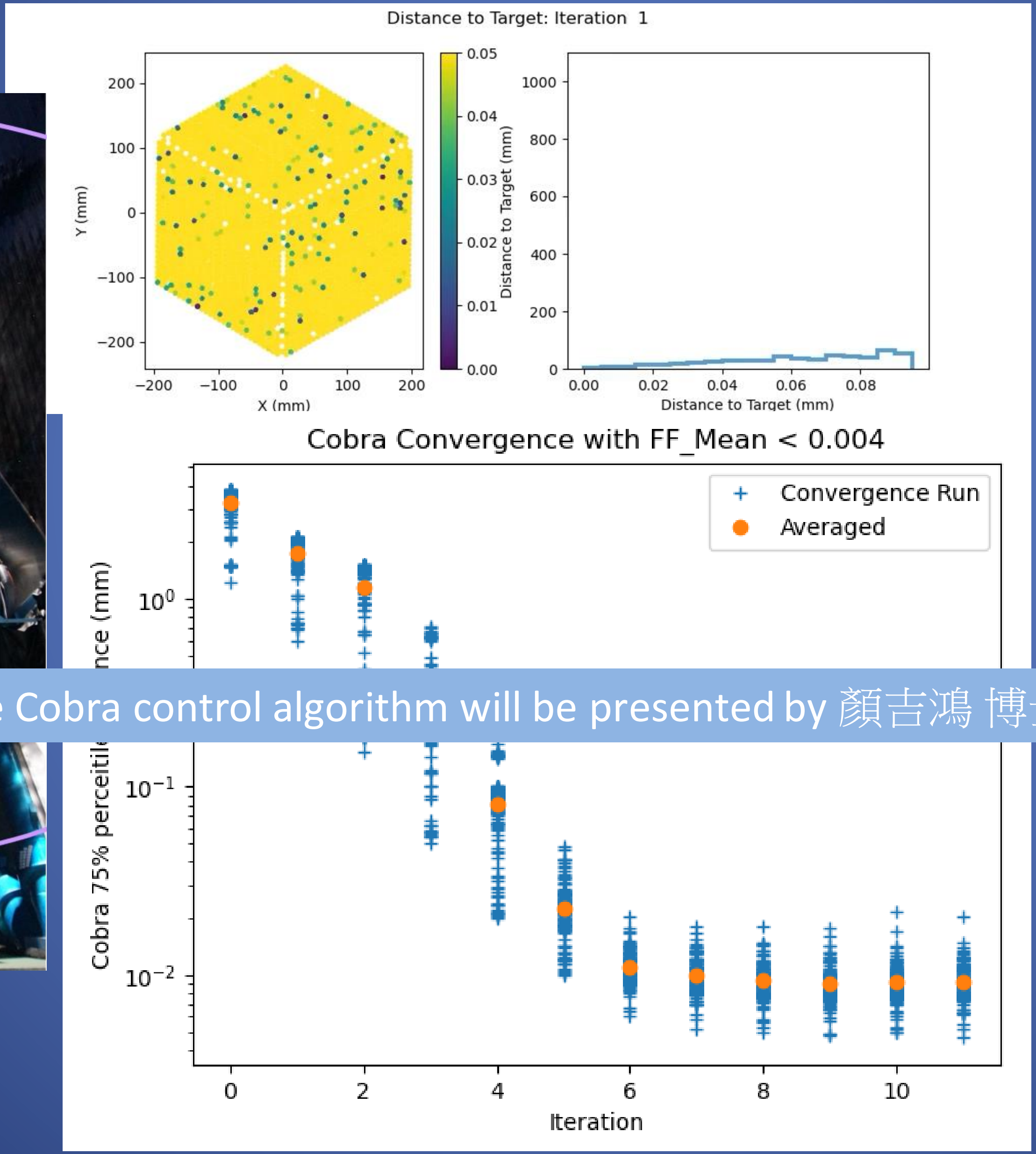
The offset of flux peak from the middle is a fiber positioning error.





Accurately move the fiber to requested (x.y)

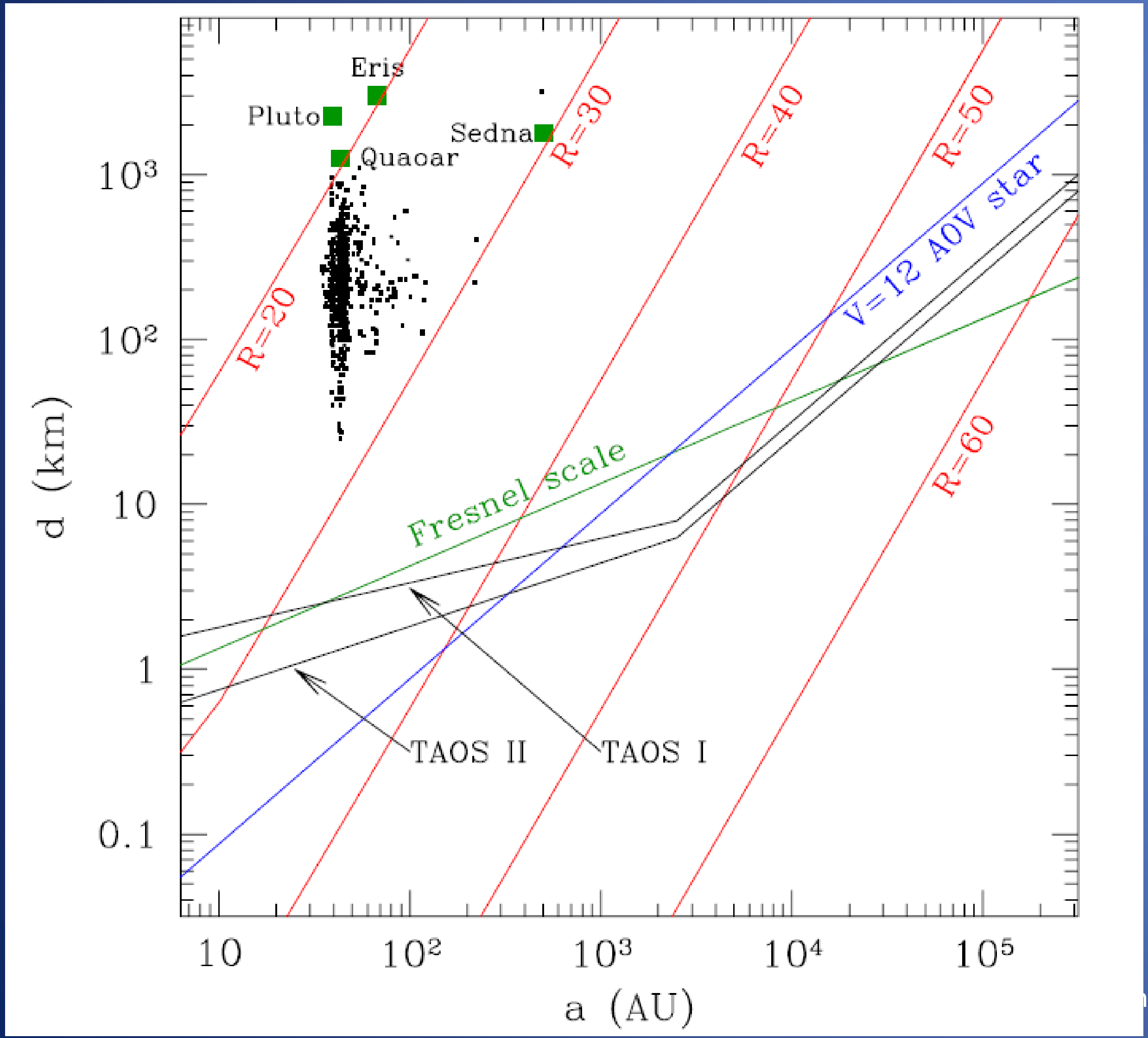




- 12 iterations are applied but improvement seems little after ~8th iteration.
- ***>95% success rate*** is now stably achieved with 4.8s MCS exposure.
- Optimizing the processing time is one vital engineering item:
  - ~330s/~220s by 12/8 iterations, respectively.
  - profiling & optimization are needed, reducing the MCS exposure time for the first few iterations can easily improve it

Details of the Cobra control algorithm will be presented by 顏吉鴻 博士 this afternoon

TransNeptunian Automatic Occultation Survey (TAOS II)



TAOS II partners

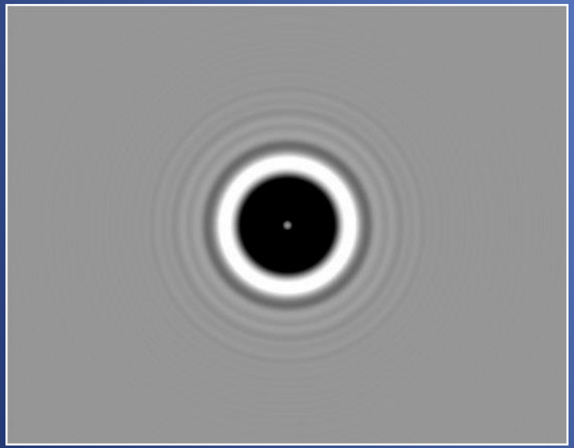
ASIAA

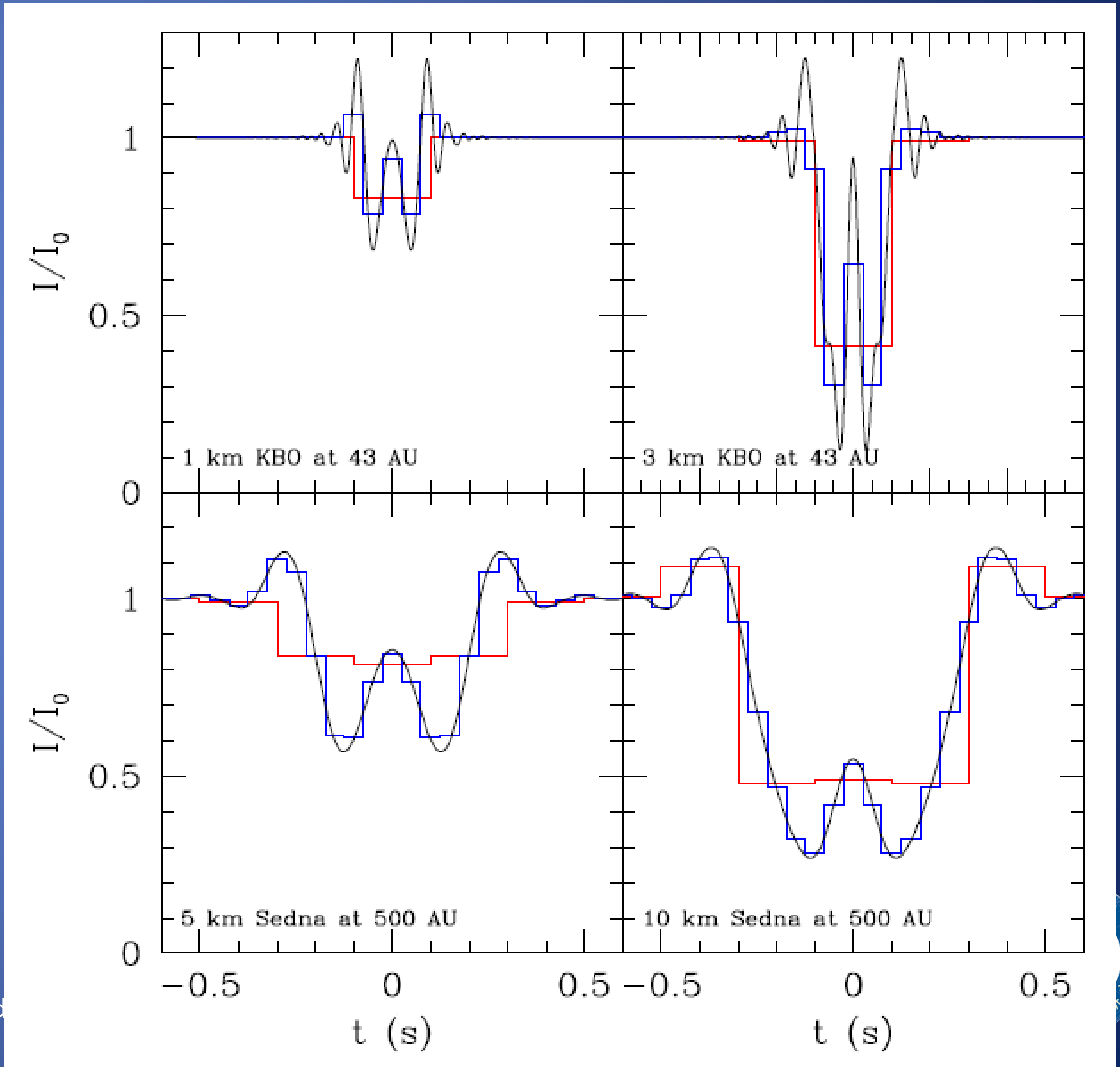
CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

Canada NRC·CNRC

Diffraction shadow of TNO occultation events

- The duration of the occultation event is around 0.2ms for objects smaller than 5 km at opposition.
- High speed photometry is required to sample the brightening part of the lightcurves.





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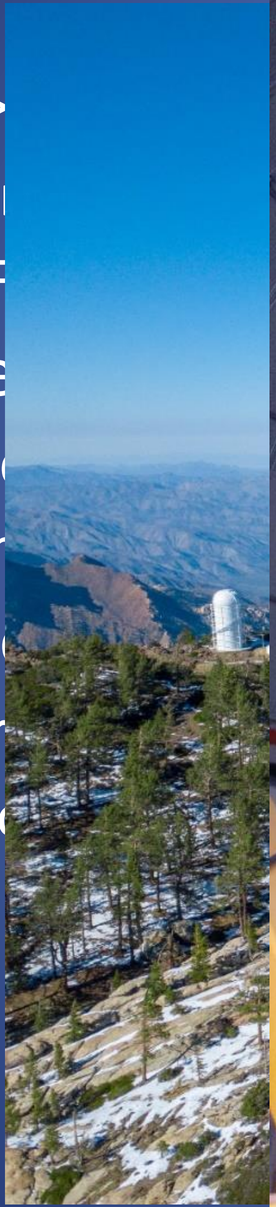
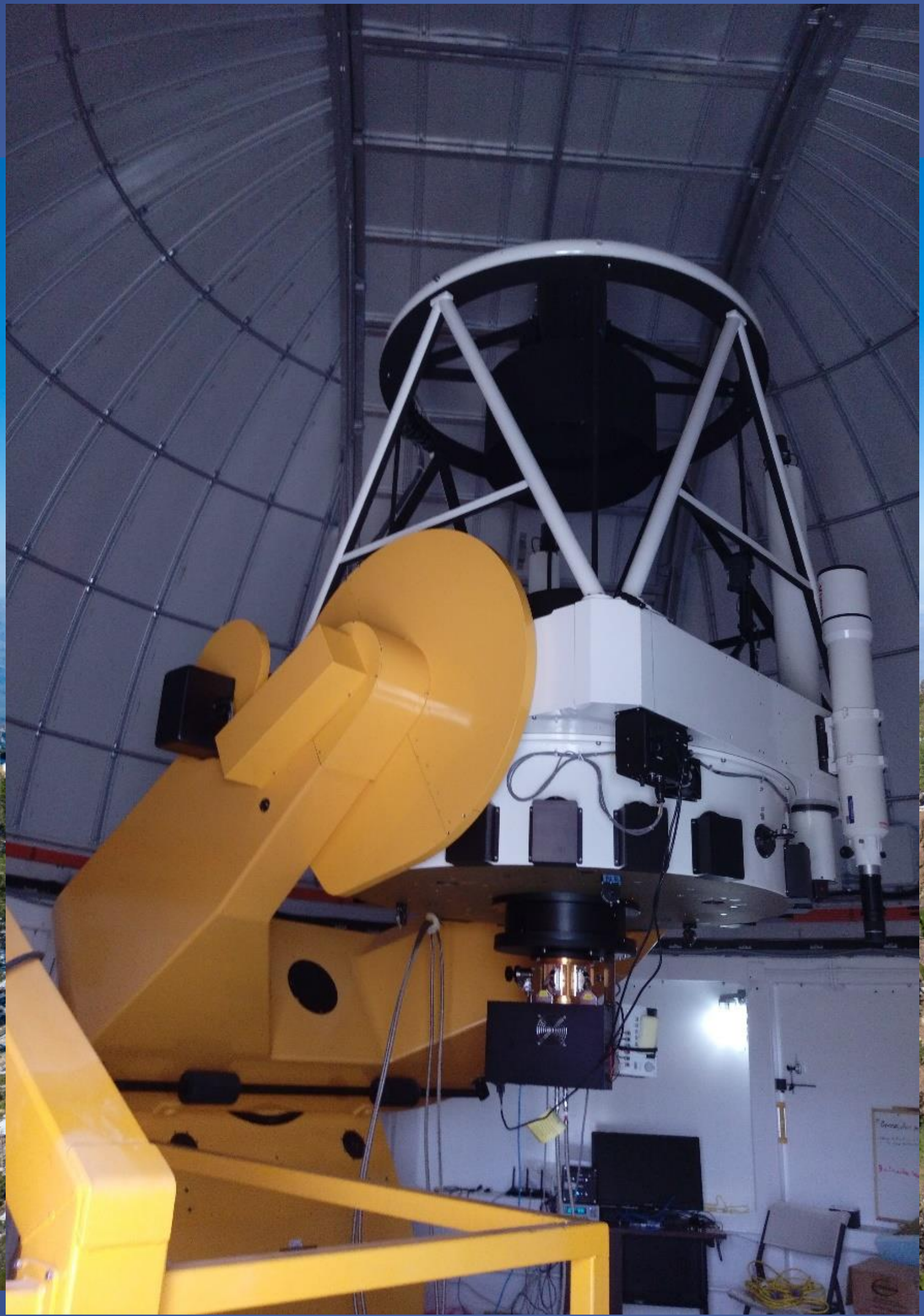
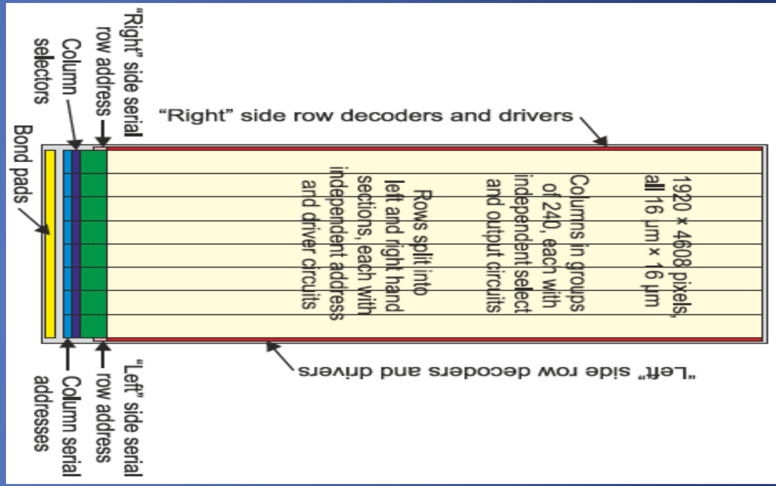
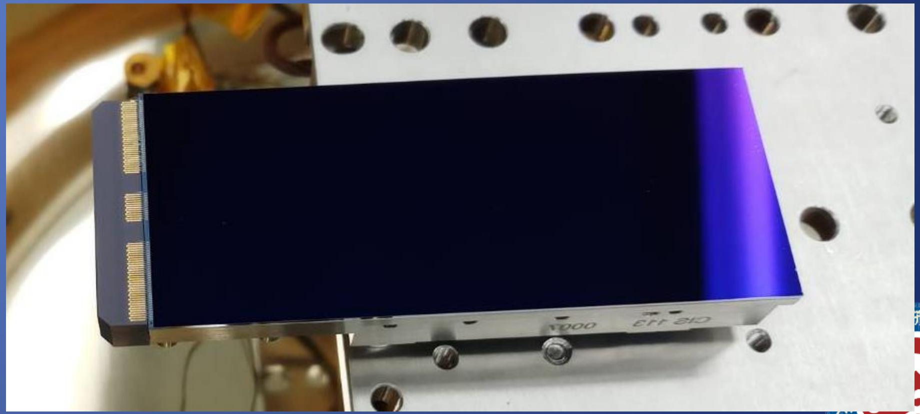




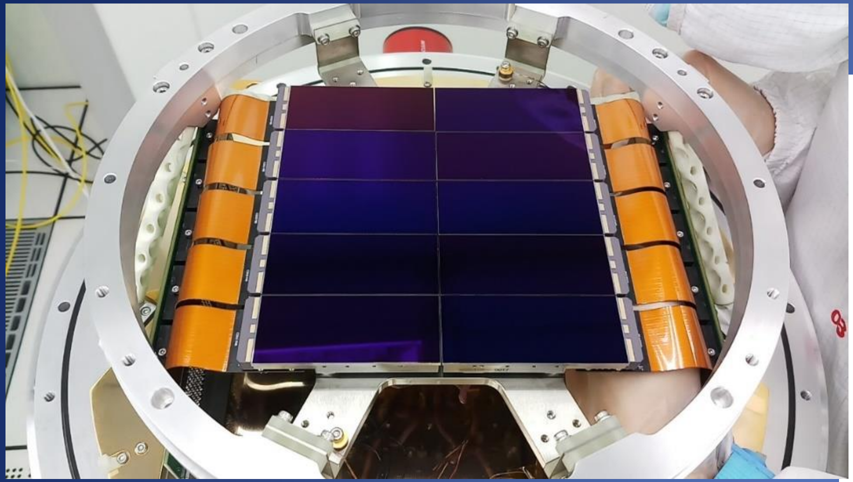
Camera requirements

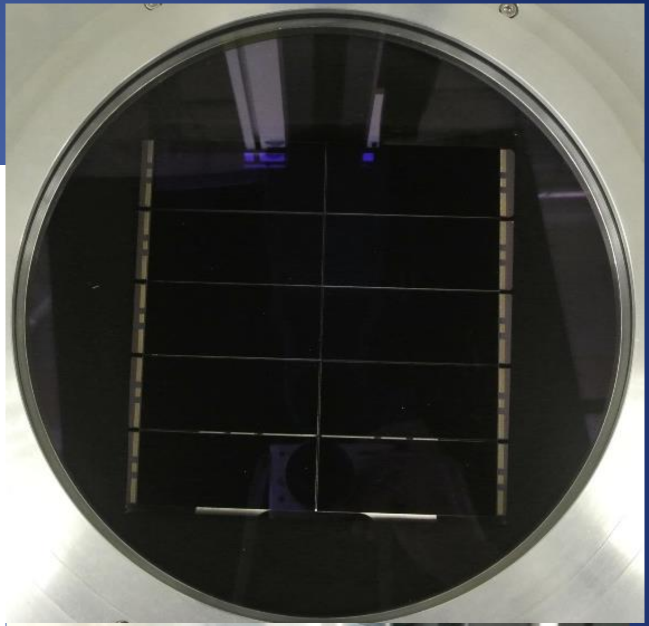
- Covering 154mm focal plane with reasonable psf sampling
- High speed readout with low noise
- High sensitivity as CCDs
- Custom CMOS from Teledyne e2v
  - 16 micron pixels, 0.63”/pix
  - 1920×4608 3-edge buttable
  - Back illuminated
  - 8 outputs and 2 row registers
  - Sub-aperture readout, reference output

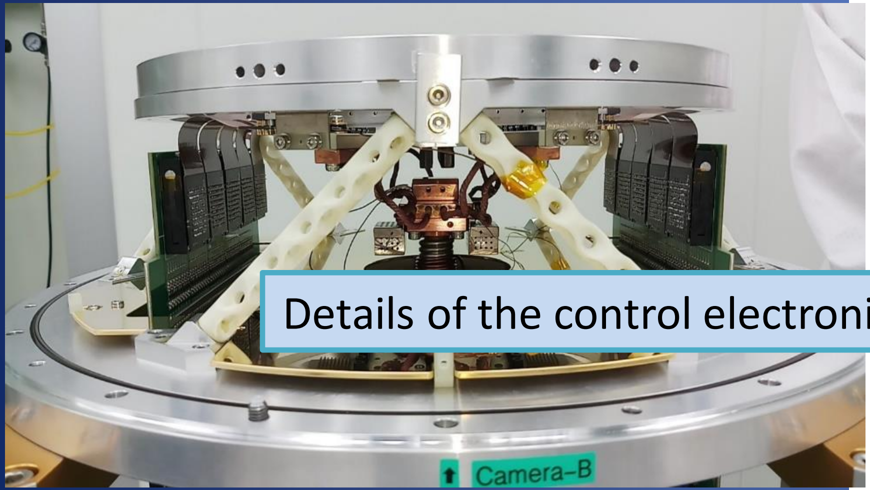


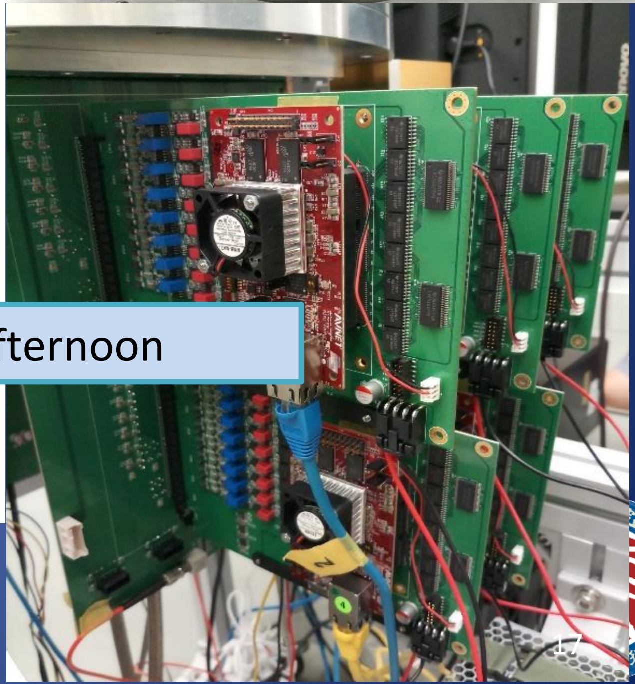


Camera design





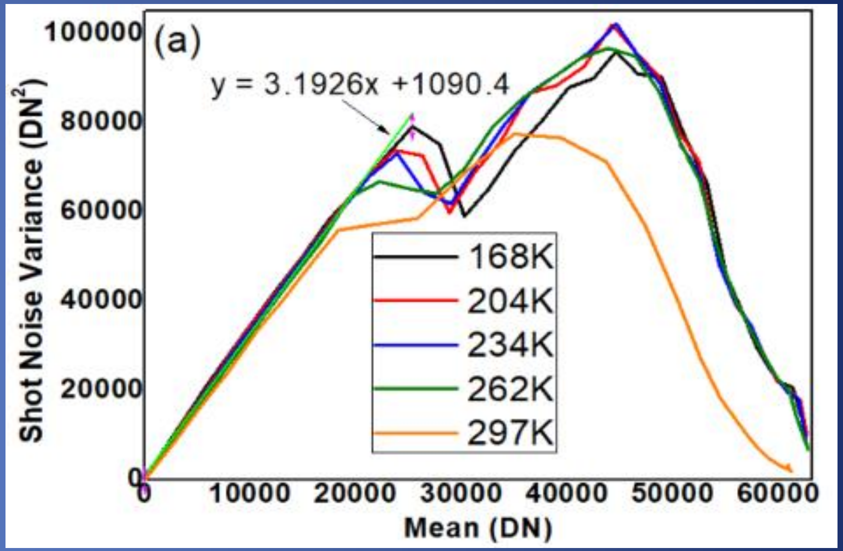




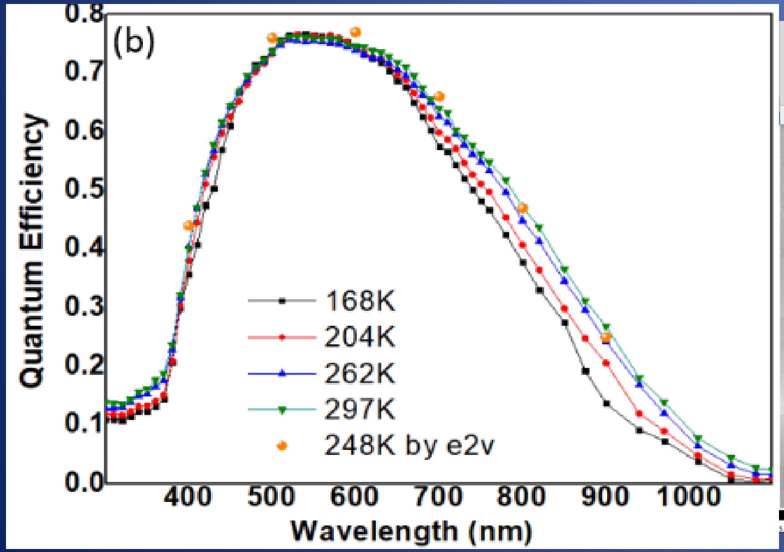
Details of the control electronics will be presented by 王伯洲博士 tomorrow afternoon

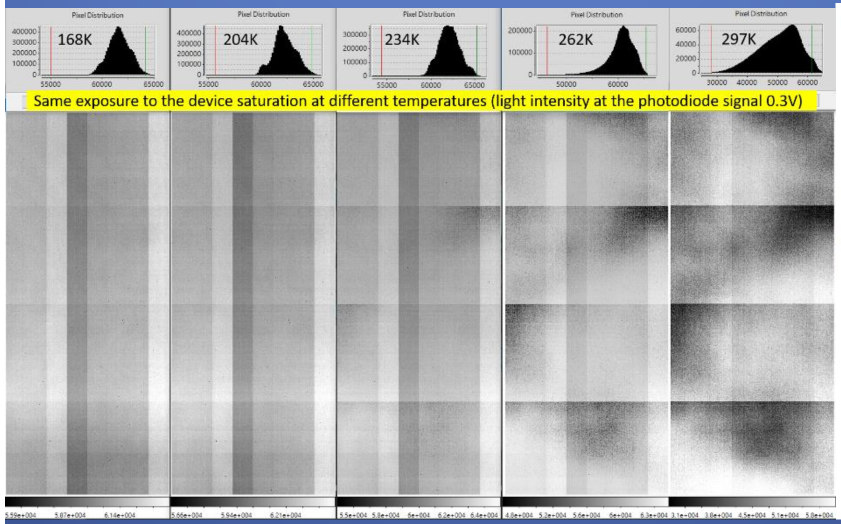
Teledyne e2v CIS 113

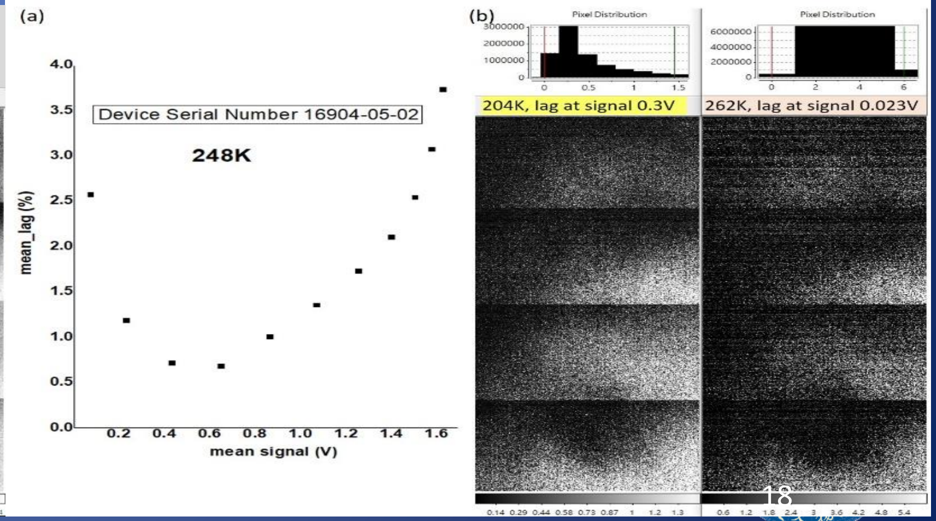
- peak QE about 77% in 500-600 nm, readout noise around 3e$^-$ and dark current lower than 2 e$^-$/s/pix at 230K.
- The linear full well is about 14400 e- at 210K.
- Image lag around 2~3%
- Fixed pattern noise has to be removed



(Wang, S.-Y. et al. Proc. SPIE 11454, 114542P (2020))



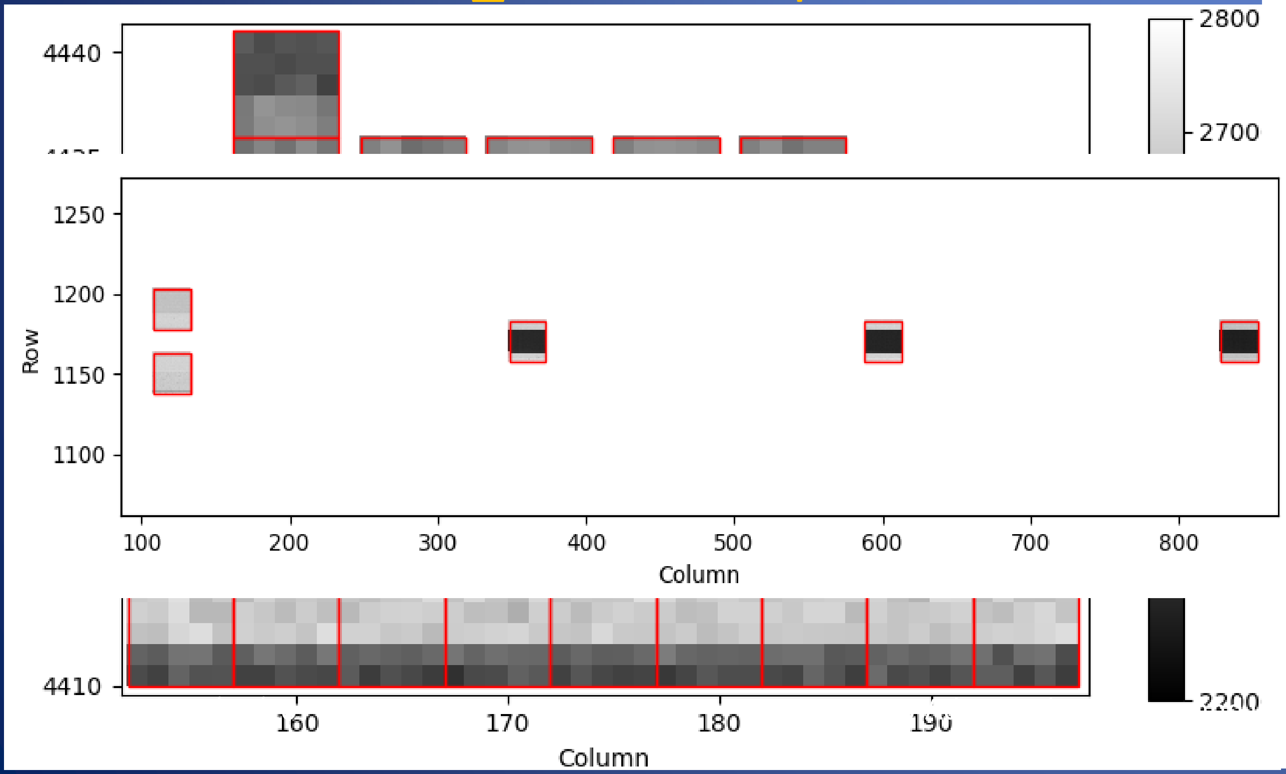




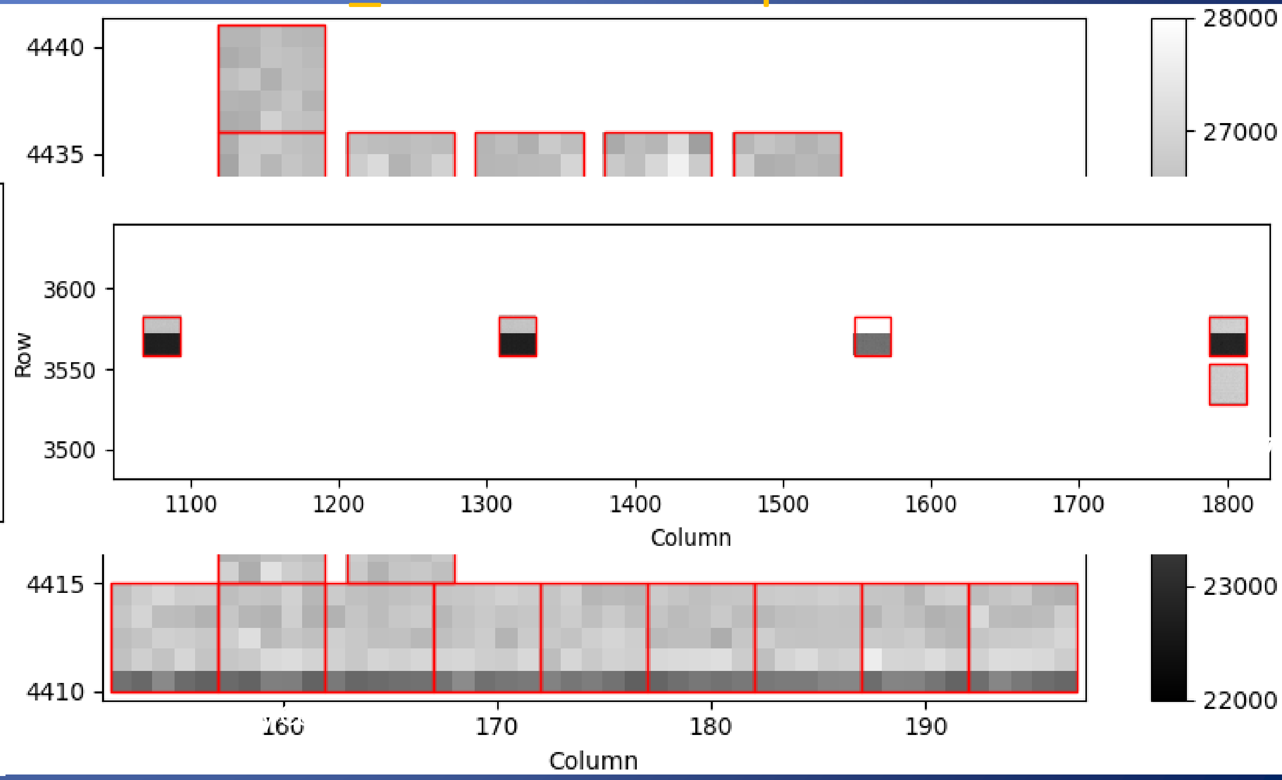
Window mode anomalies

- The row sampling time has to be longer than 13 µs to have correct output level
- The first output channel has to read pixels so that other outputs can have correct signal level

PIX_SEL low 10µs

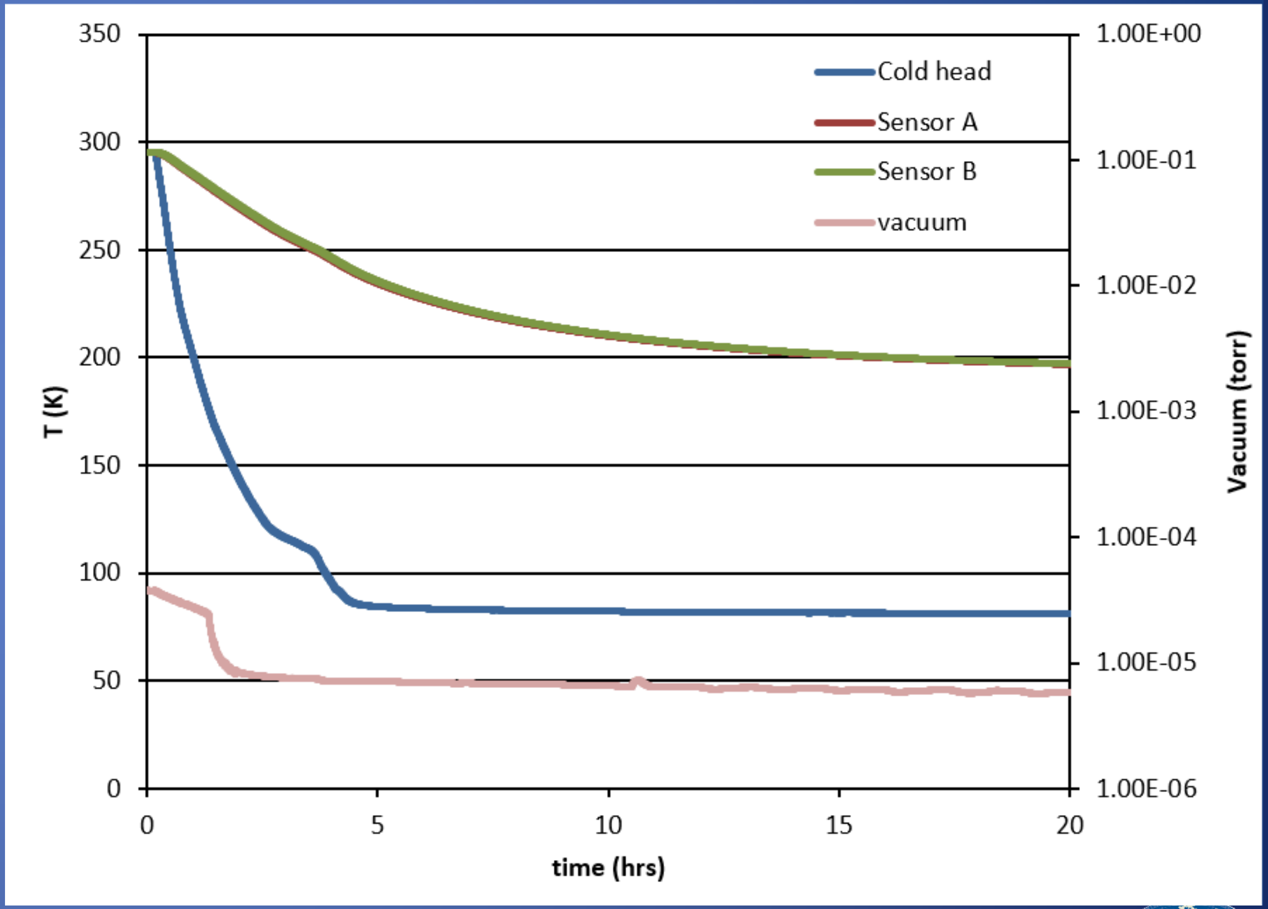


PIX_SEL low for 15 µs



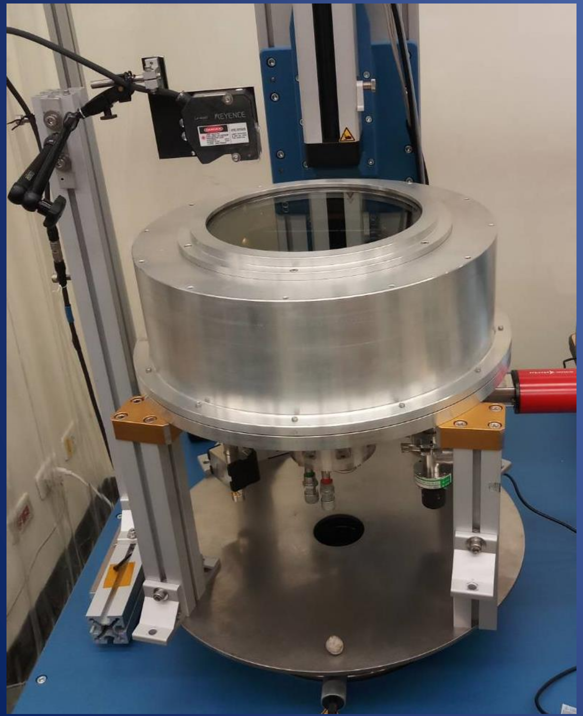
Cryostat performance

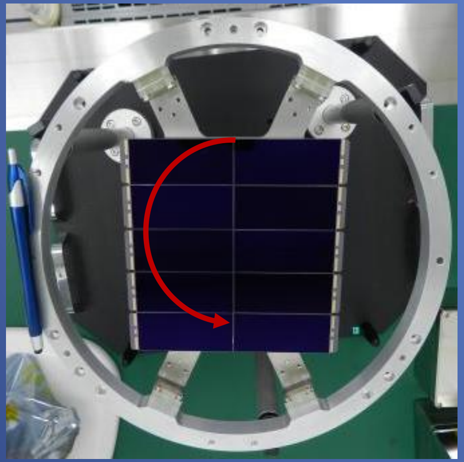
- With a single Polycold Compact Cooler, the cool down time is around 12 hours which is close to our expectation.
- The sensor temperature variation is around 0.5K.
- The vacuum can be maintained to be lower than 5×10^{-6} mbar during the normal operation with the ion pump.

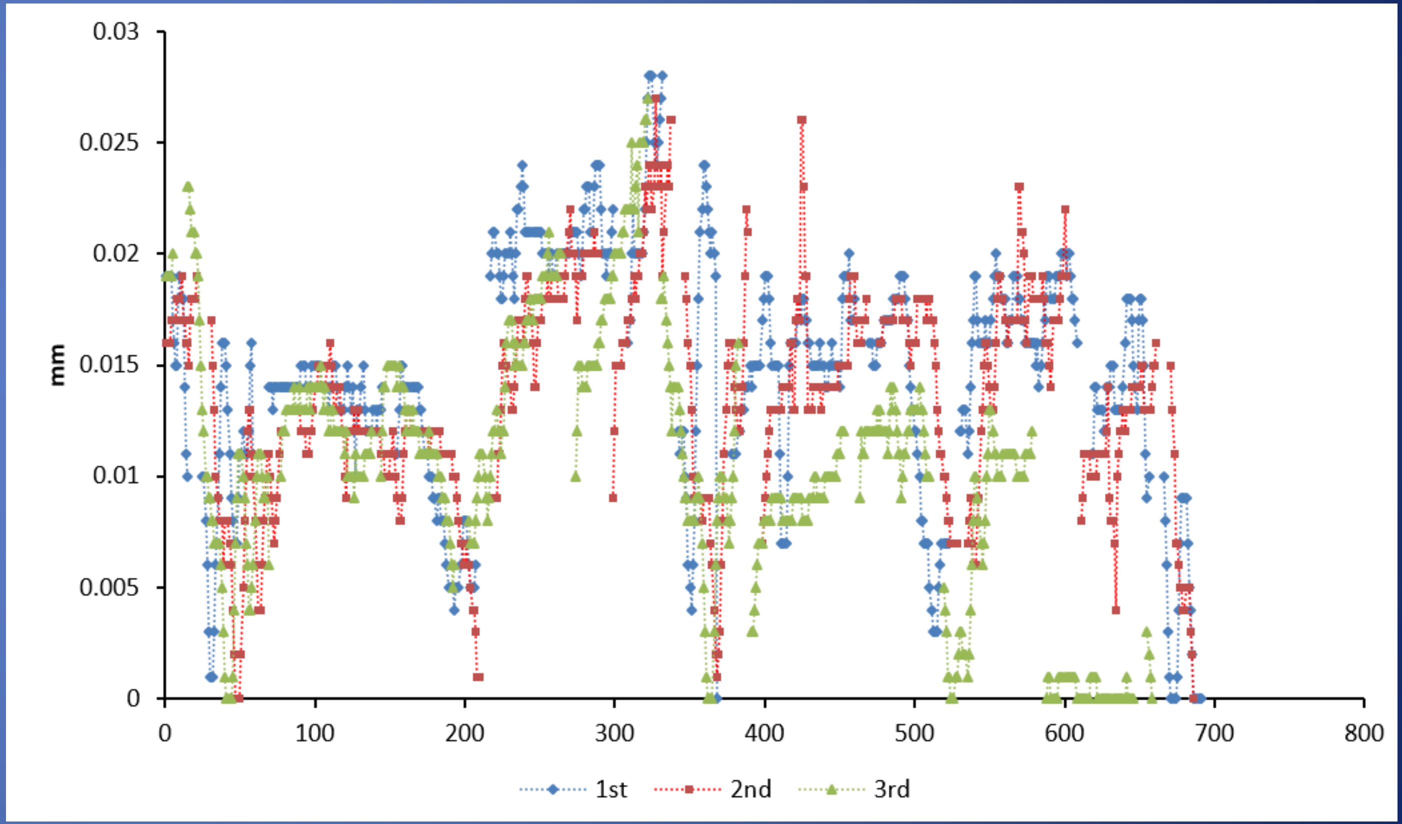


Sensor surface flatness

- The sensor surface height was measured by a Keyence laser probe LK-H085
- The measured height is within 30 µm < 40 µm requirement

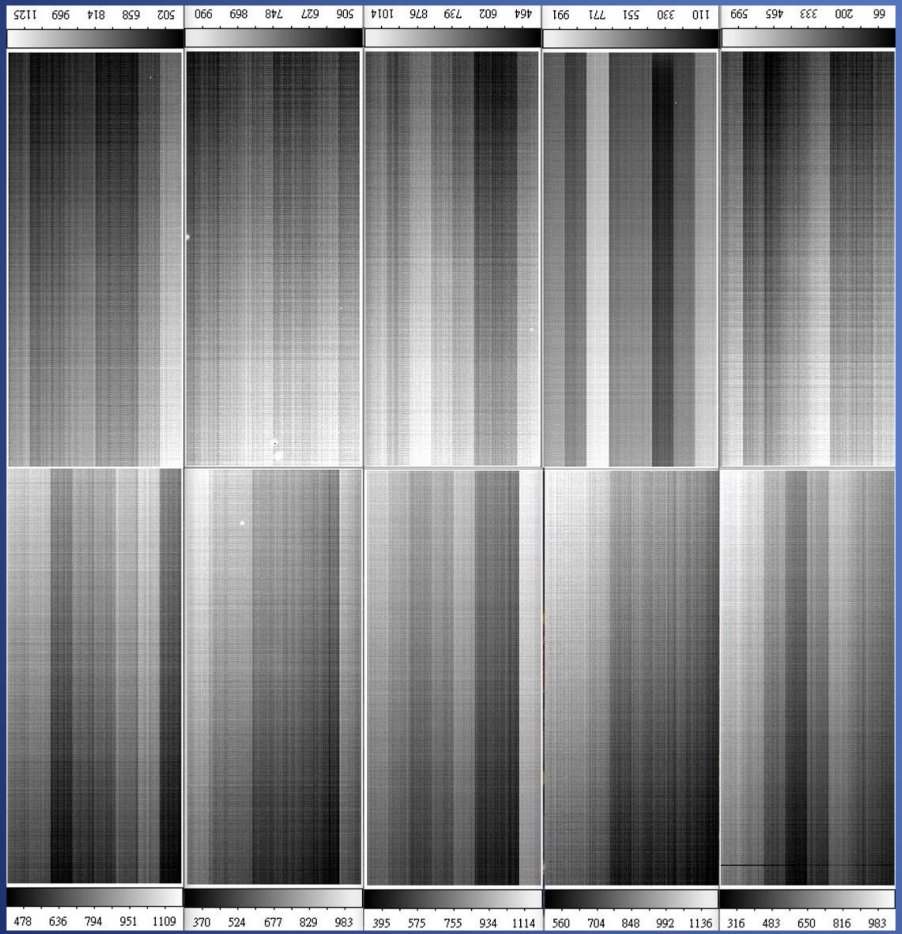




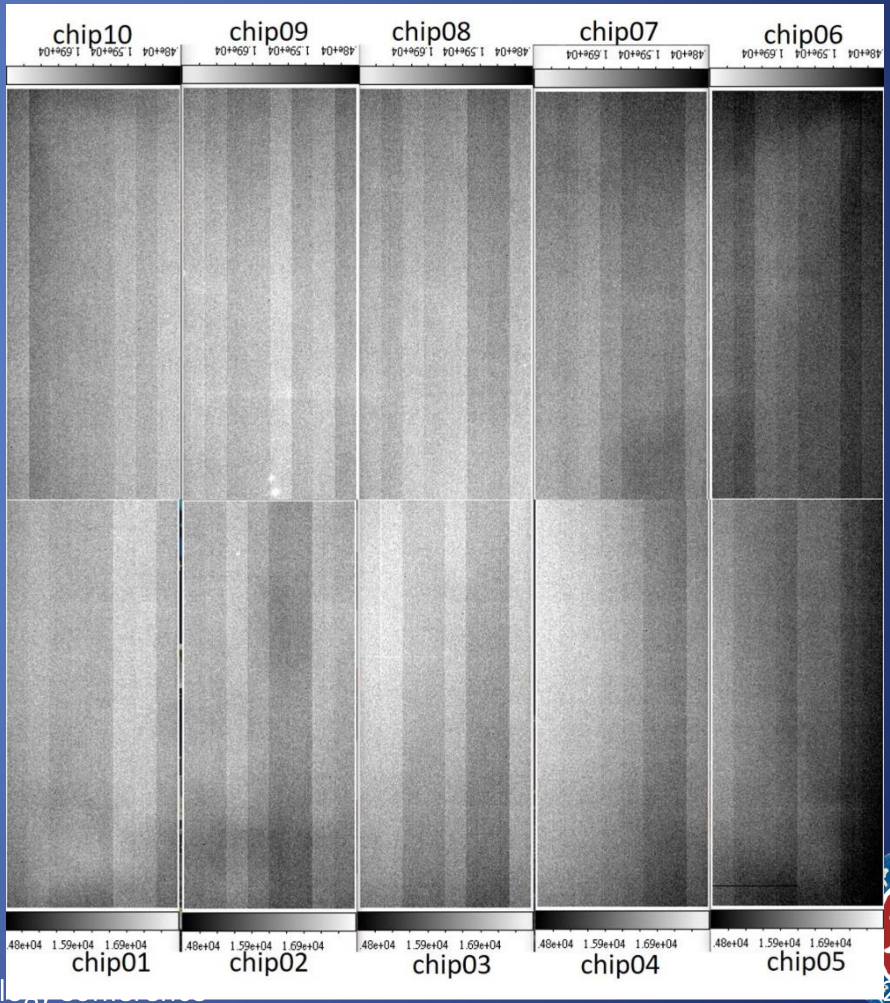


Camera characteristics

Bias frame

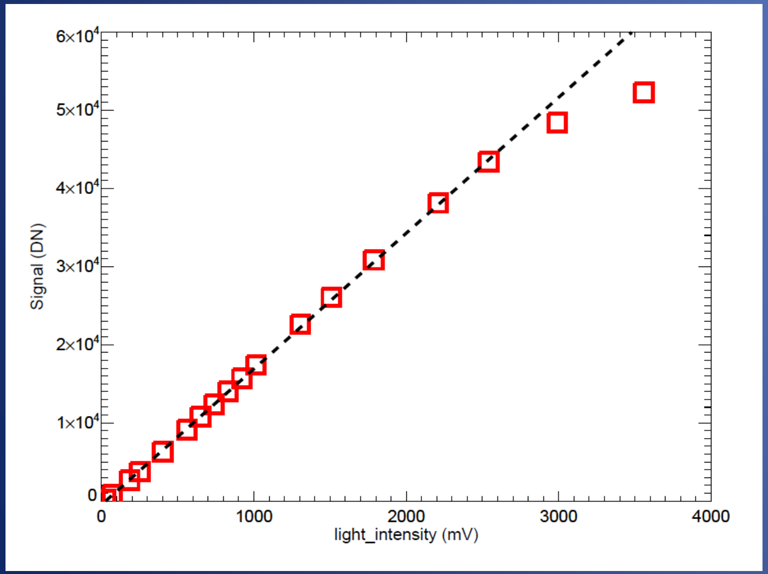


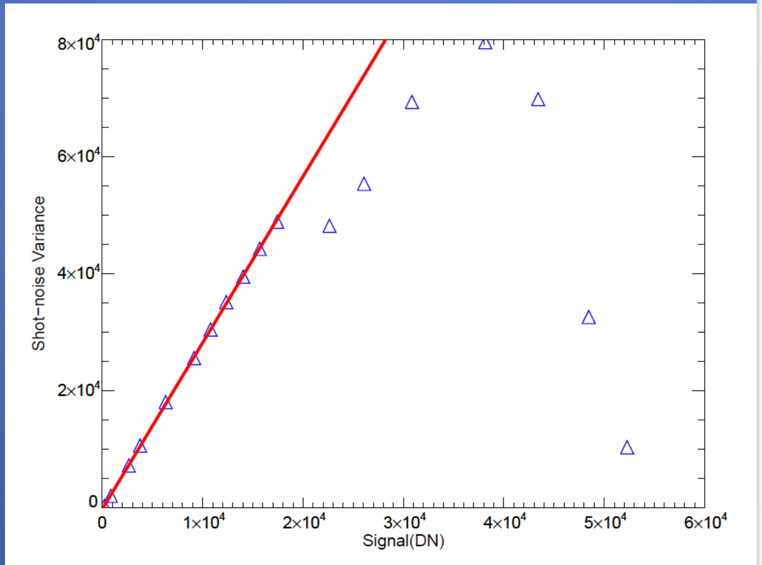
illuminated frame

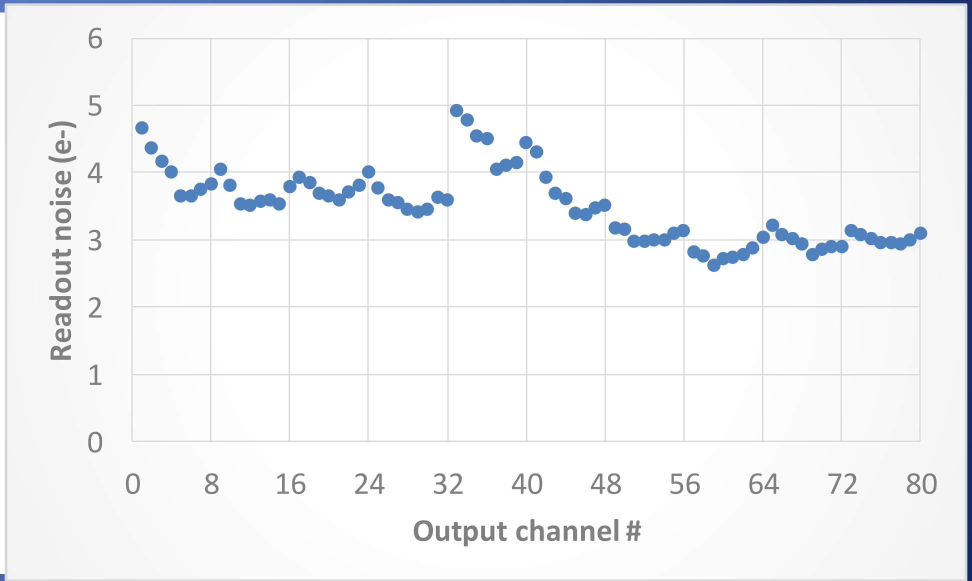


Camera characteristics

- The average gain is around 2.75 DN/e- and the variation of each channel is around 5%, i.e. from 2.62 ~2.85 DN/e^-
- The linear full well is around 45000DN ~ 16000 e^-
- The readout noise is around 3-5 e^-, it is similar to the noise (3~4 e^-) with single chip.

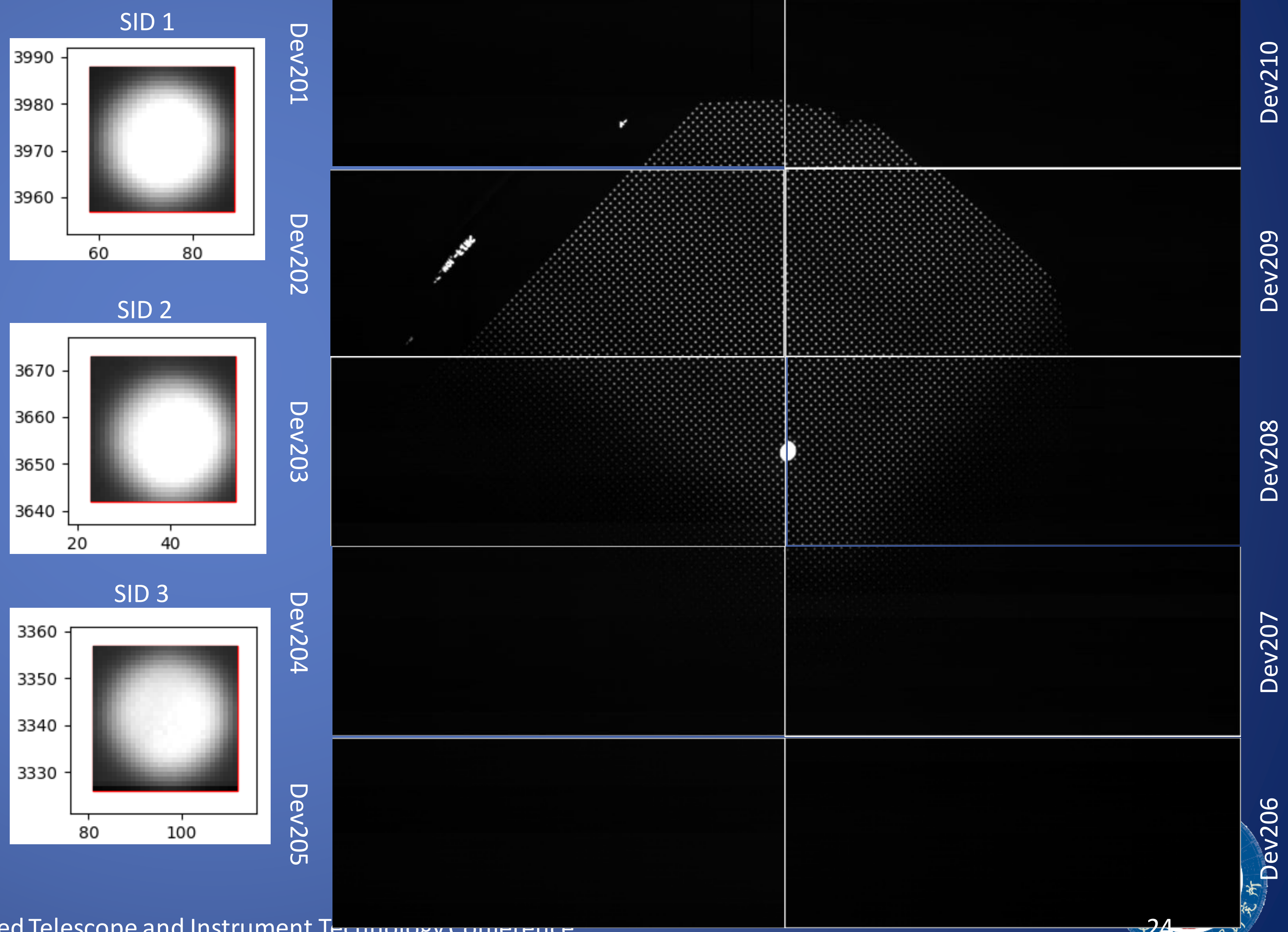


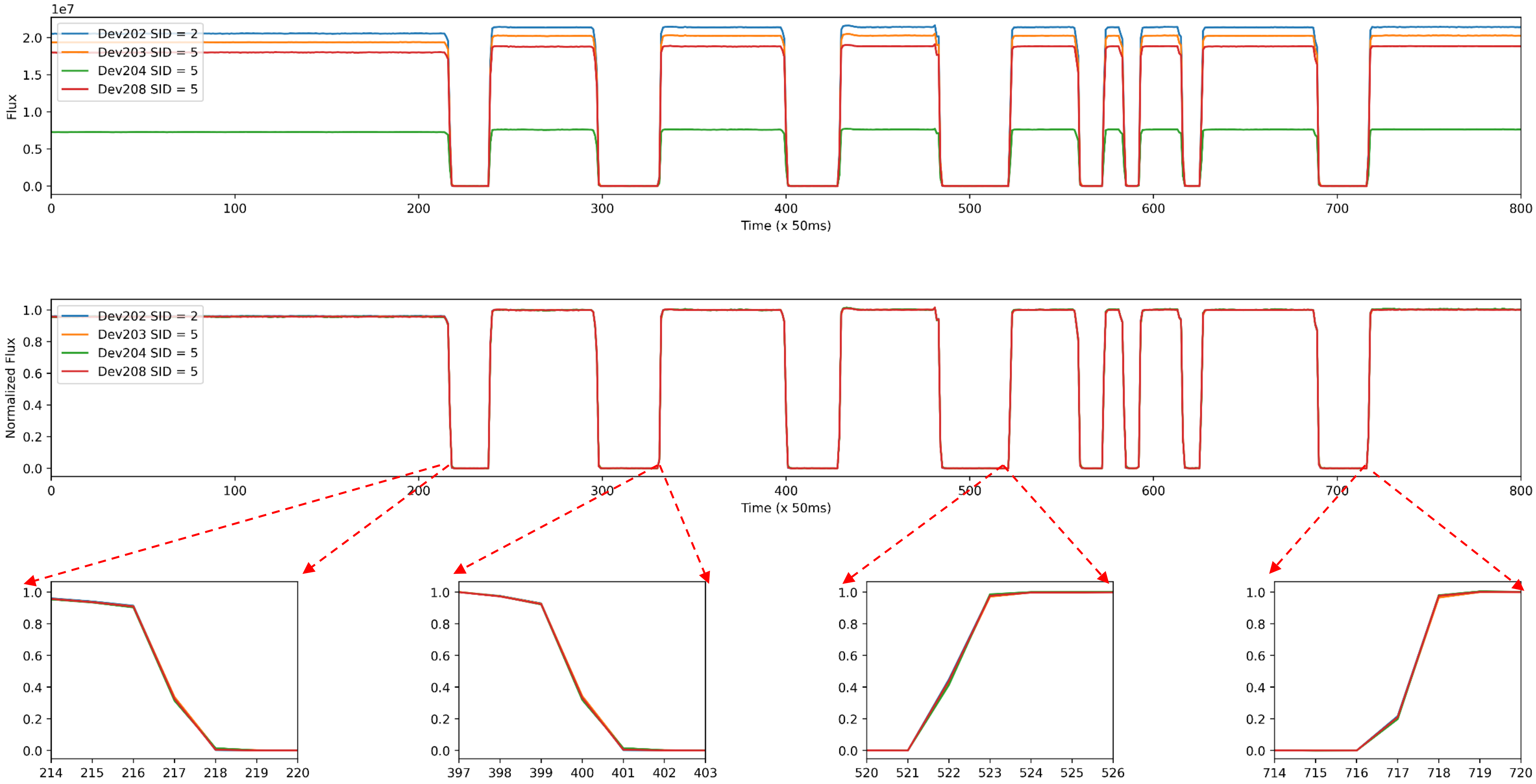




Synchronization tests

- The synchronization between different cameras and sensors is critical to the occultation event detection and interpretation.
- We setup an pin hole mask in front of the focal plane and illuminated it to generate spots
- We turn on and off the LED to generate time dependence signal for synchronization tests
- 20Hz 31x31 star boxes were sampled

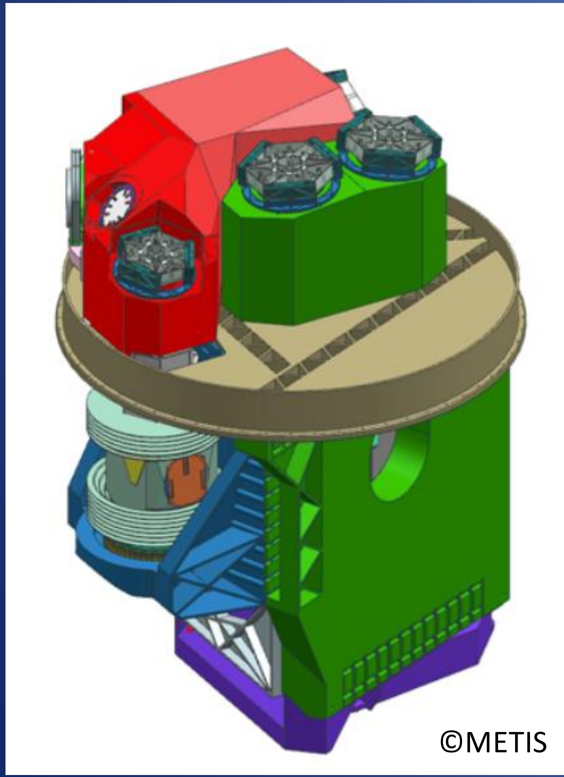


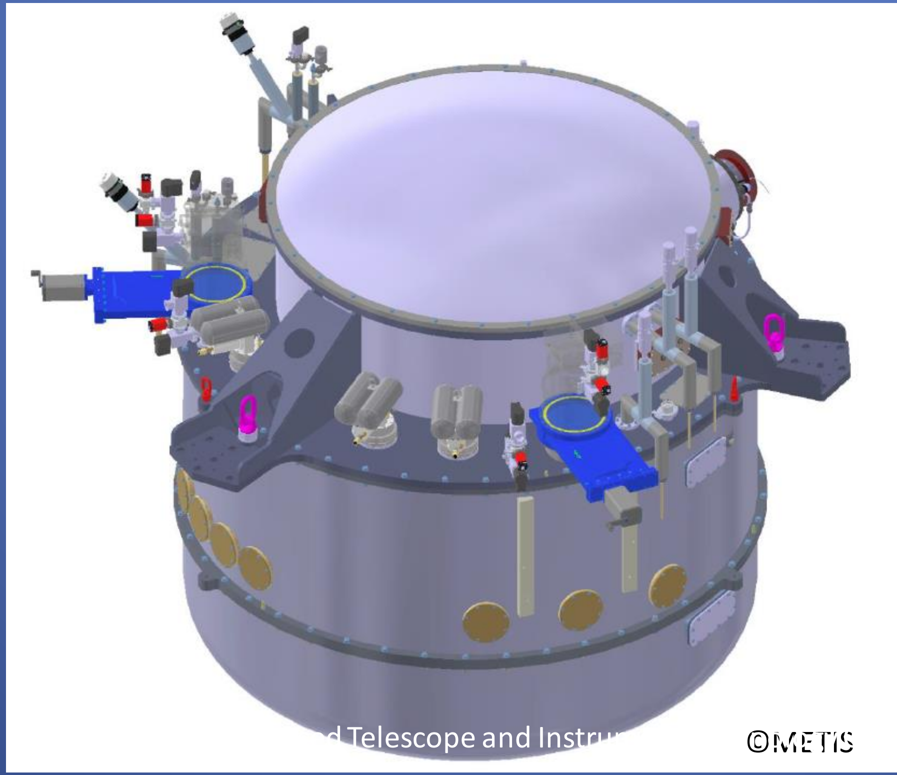


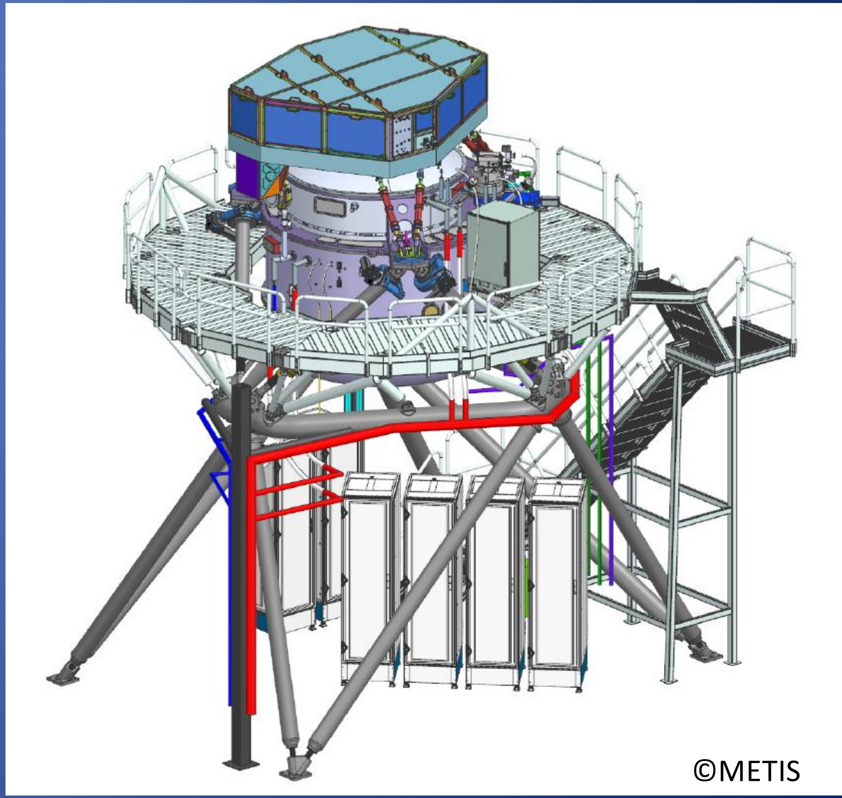
1e7
Flux
Dev202 SID = 2
Dev203 SID = 5
Dev204 SID = 5
Dev208 SID = 5
Time (x 50ms)
Normalized Flux
Dev202 SID = 2
Dev203 SID = 5
Dev204 SID = 5
Dev208 SID = 5
Time (x 50ms)

Mid-infrared ElT Imager and Spectrograph (METIS)

- Imaging at 3 – 19 μm over a field of view of ~10″×10″.
  - low resolution (R ~ few hundreds) long-slit spectroscopy,
  - coronagraphy for high contrast imaging.
- High resolution (R ~ 100,000), integral field (IFU) spectroscopy at 3 – 5 μm over a field of view of ~1.0″×0.5″ and coronagraphy for high contrast IFU spectroscopy.

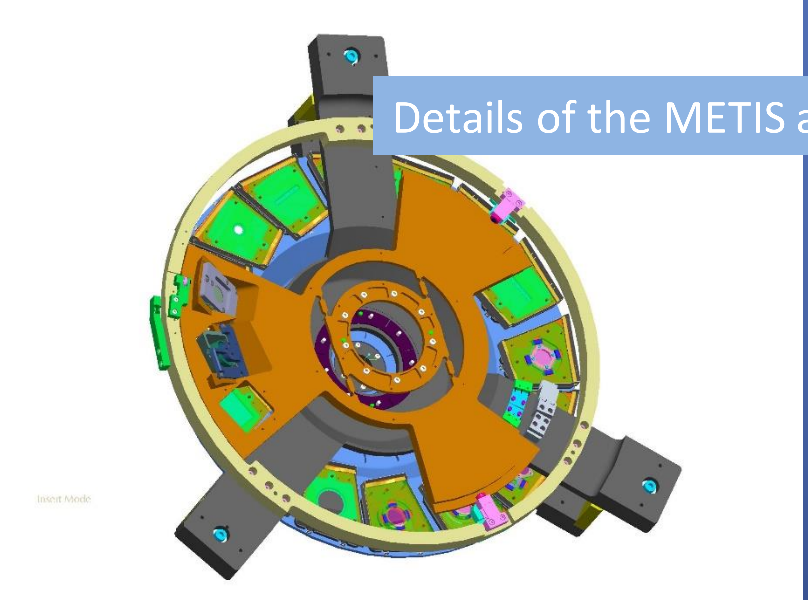


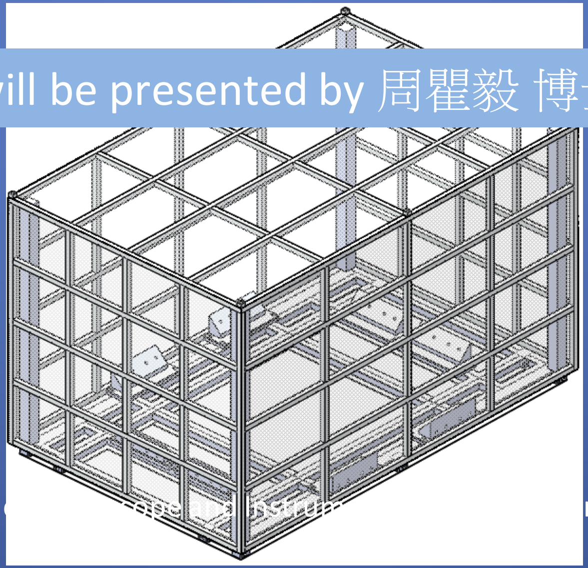


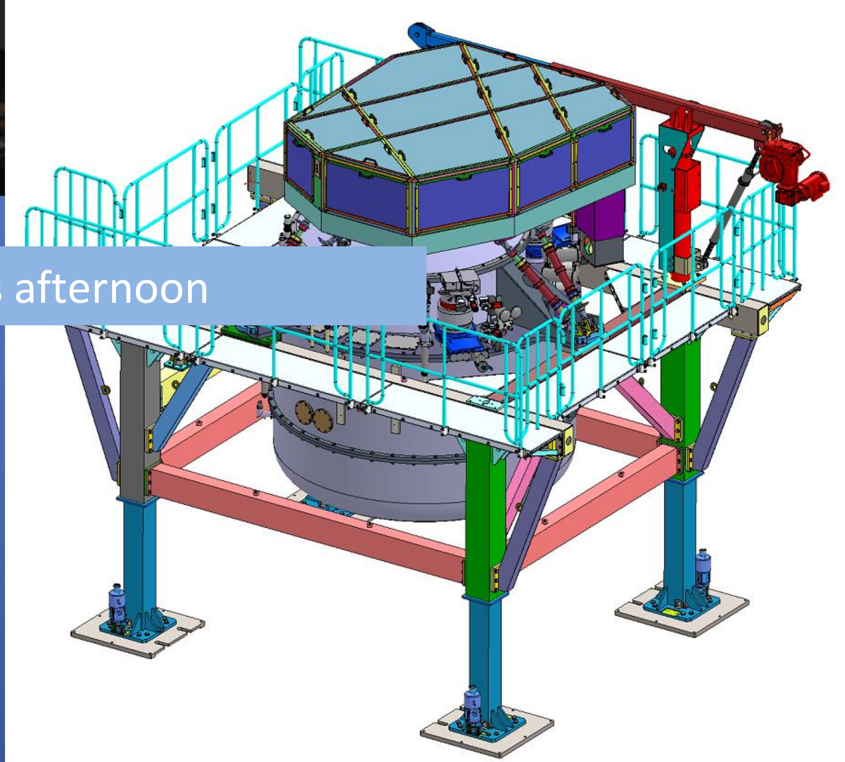


Mid-infrared ElT Imager and Spectrograph (METIS)

- ASIAA work items
  - Pupil plane wheel
  - Focus plane wheel
  - Chopper control
  - Assembly Integration and verification







Details of the METIS activities will be presented by 周瞿毅 博士 this afternoon

Giant Magellan Telescope

GMT instrument development

- We have been talking to CfA for the possible instrumentation contribution from Taiwan, including
  - The detector readout electronics for G-CLEF and GMACS
  - The detailed detector characterization of G-CLEF
  - The calibration spectral source for G-CLEF
  - The mask cutting machine for GMACS
  - The binary etched grating for the GMACS
- Taiwanese industry will be able to bid for certain infrastructure of the telescope, such as the telescope enclosure and other supporting facilities

Summary

- The overview of the current OIR instrumentation development in ASIAA is presented
- We have developed a solid group for astronomical OIR instrumentation covering various capabilities
- We look forward to possible collaborations