MOIRCS UPGRADE PROJECT: FINAL IMAGING AND SPECTROSCOPIC PERFORMANCE

ICHI TANAKA (SUBARU TELESCOPE), MAXIMILIAN FABRICIUS (MPE), JOSH WALAWENDER (KECK TELESCOPE), YASUHITO HASHIBA (MITSUBISHI ELECTRIC), IKURU IWATA, TETSUO NISHIMURA, KOJI OMATA, NOBUO ARIMOTO (SUBARU TELESCOPE), YEN-SANG HU, SHIANG-YU WANG (ASIAA), MARK WEBER, DAVID COOK, PHILIP TAIT ET AL. INSTRUMENT DIVISION IN SUBARU TELESCOPE

MOIRCS is Subaru's wide-field near-infrared camera and MOS spectrograph. Since its first light in 2004, MOIRCS has been one of the most popular instrument in Subaru. To keep its competitiveness, we have started the upgrade project which includes the replacement of the old detector to the new Hawaii-2 RGs. The engineering work for the instrument was started in May 2015, and then was back on sky with new detectors since December 2015. The improvement of the sensitivity is significant especially in the shorter wavelength (imaging efficiency of 30-40%). The faster readout with much lower read noise realized by the efficient multi-sampling gives much benefit to the spectroscopic performance. The system efficiency for spectroscopic observation is >25% over all YHJK observable window thanks to our high-throughput VPH grisms. The wide wavelength coverage by our two low-resolution (R=500) grisms is unique among other similar instruments for large telescopes. Here we present some highlights of the engineering observations, with demonstration imaging/spectroscopy results in the presentation. We note that the next MOIRCS upgrade plan is currently TBD, due to the limitation of the resources.

1. MOIRCS Upgrade Project ("nuMOIRCS" Project)

MOIRCS is Subaru's wide-field near-infrared camera and MOS spectrograph. At the time of its first light in 2004 MOIRCS was the instrument with the widest-FOV and the only NIR MOS capability among 8-10m class telescope. However, nowadays some more powerful instruments such as Keck MOSFIRE, KMOS and Hawk-I on VLT are available to the community. To keep its competitiveness, we have started the upgrade project which includes the replacement of the old detector to the new Hawaii-2 RGs (the "nuMOIRCS Project: KAKAENHI 23224005). The engineering work for the instrument was started in May 2015, and then was back on sky with new detectors since December 2015.

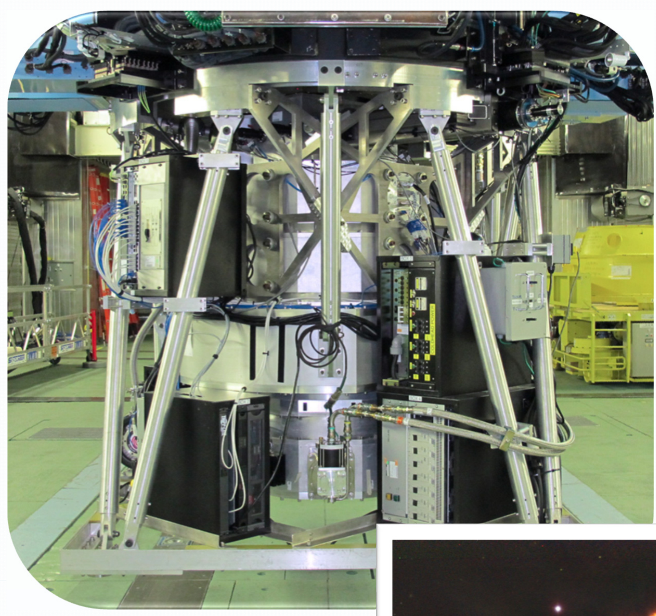
Upgrade Works in FY2015

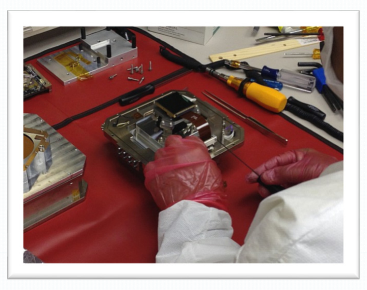
During the FY2015, we have done the following items as the "in-house" project.

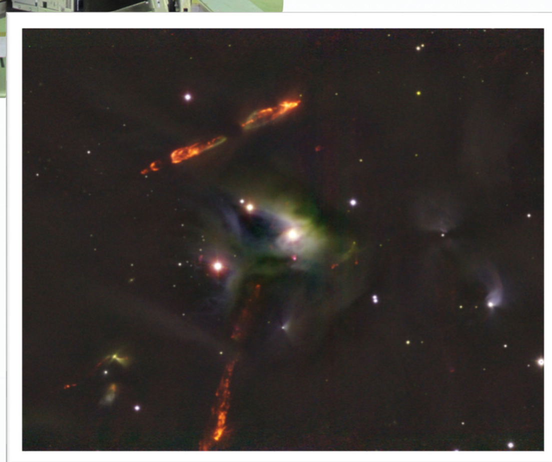
- ❑ **Replace detector system: Hawaii2+TUFPAC to Hawaii-2 RG + SIDECAR ASIC.**
- ❑ **Fully replace the MOIRCS control system to the in-house system.**
- ❑ **Replace the system hardware (sensors, switches, etc) to the most recent one.**

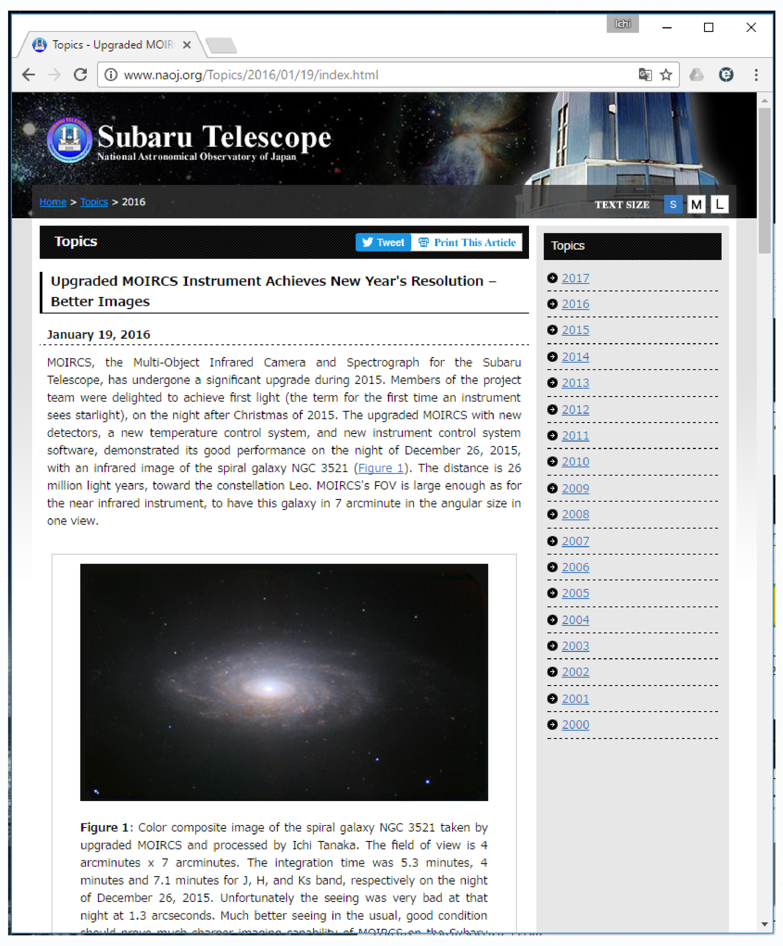
In short, we have upgraded the "eyes", "brain", "nerve system" of MOIRCS.

The success of the first on-sky test (2015-12-26) was reported via the Subaru Website, as well as the last Users Meeting.









http://www.naoj.org/Topics/2016/01/19/index.html

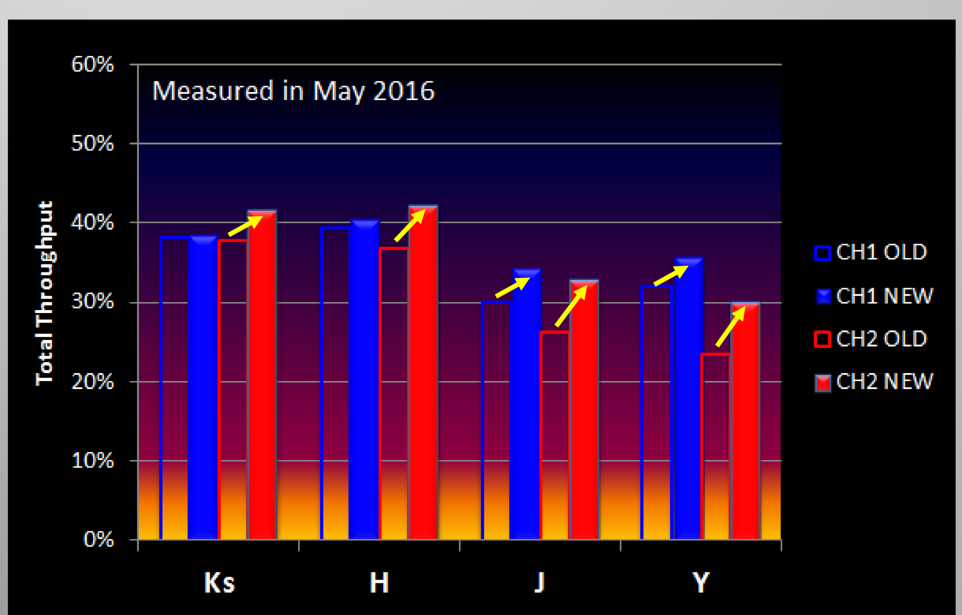
3. Engineering Observations

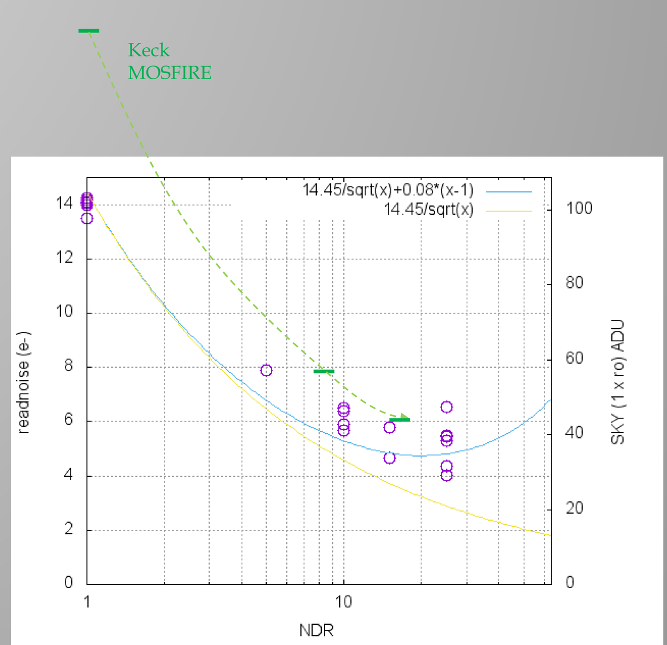
In total 4 (S16A)+1.5 (S16B) nights. Detail is below (Poor Weather!)

Date	Main Engineering Items	Issue/achievement
2016-04-17	Software Function Tests, Alpha Particle Blocker, Adjusting Cold Stop Position, Efficiency Measurement (Spec: R500 & VPH; Imaging), Basic spectroscopic data characterization (1).	Window Fogging by High Humidity! 50%.
2016-05-19 (2nd), 22(2nd)	Software Function Tests (cont.), Efficiency Measurement (Spec: R500 & VPH; Imaging; cont.), Basic spectroscopic data characterization (2), Demonstration Data.	100%
2016-06-14,17	Software Improvement, Upgrade, and Stability Tests, Basic spectroscopic data characterization (3), Noise Test, Demo Data Acq., Non-Sidereal Tracking and nodding obs Tests for Spec, Imaging Consistency,	Bad Weather. 20%
8/22, 9/24, 10/29,30 (1.4 nights total.)	All the remaining items from S16A.	Bad Weather, <10%

4. Results of On-sky Tests: Imaging Obs.

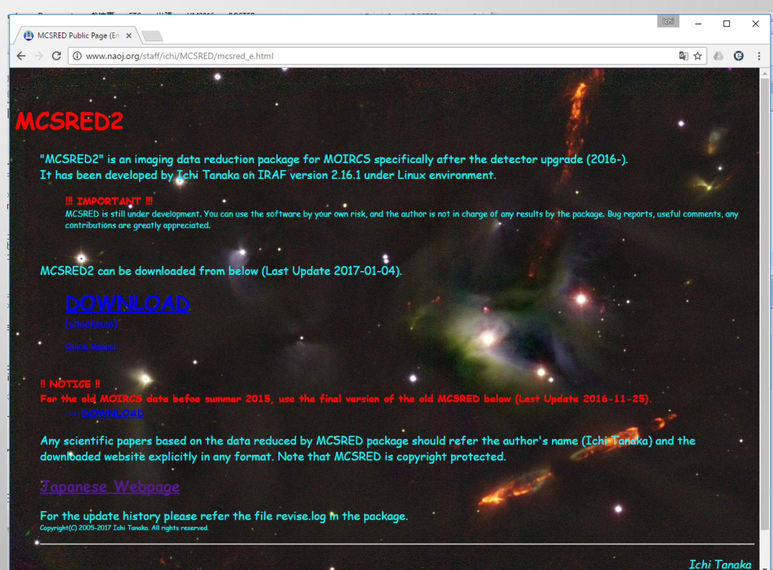
- The improvement of the sensitivity is significant especially in the shorter wavelength (**imaging efficiency of 30-42%**)!
- On-telescope measurement of **the readnoise is 14e-** in CDS readout. It goes down to 6e- after 10 times multi-sampling. This is better than the measurement by Keck MOSFIRE. However, the effect of multi-sampling has **bottomed around 5e-** level at 20 times multi-sampling.
- Overall performance of detector seems **better for channel-1**. The bias drift of channel-2 detector is significant (see 7 below). Thus we recommend to put higher-priority target on channel-1 side.



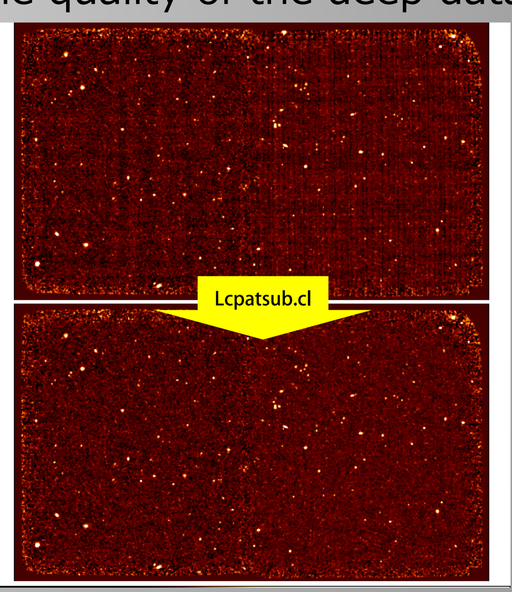


7. Data Reduction Pipeline

MCSRED2, the imaging data reduction pipeline, is now released in Jan 4, 2017. The correction of the bias drift greatly enhances the quality of the deep data.



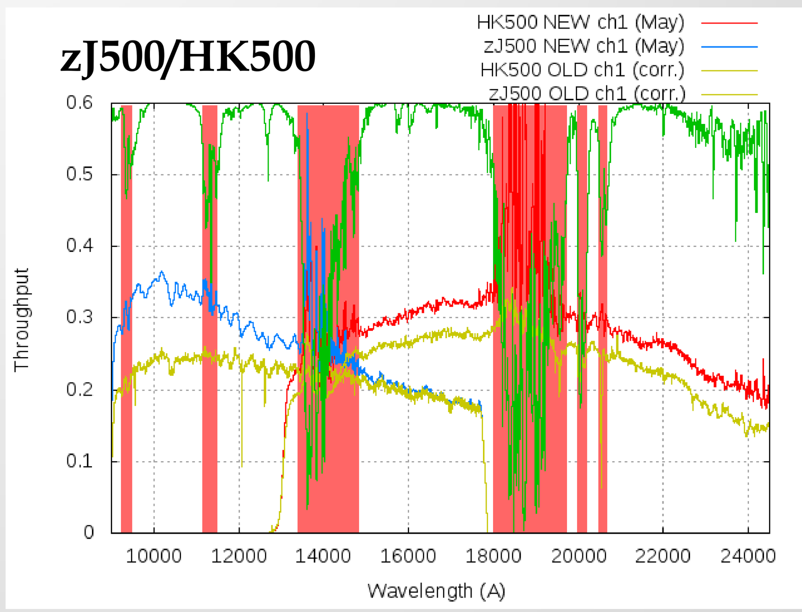
The MCSRED2 Website:
http://subarutelescope.org/staff/ichi/MCSRED/mcsred.html

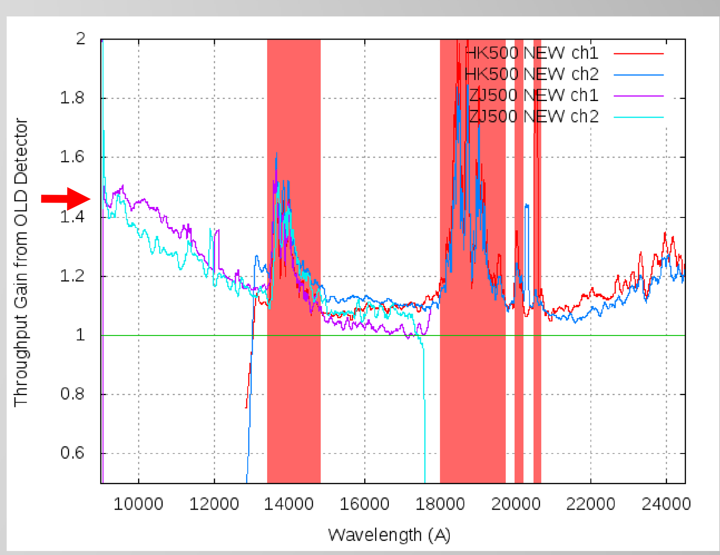


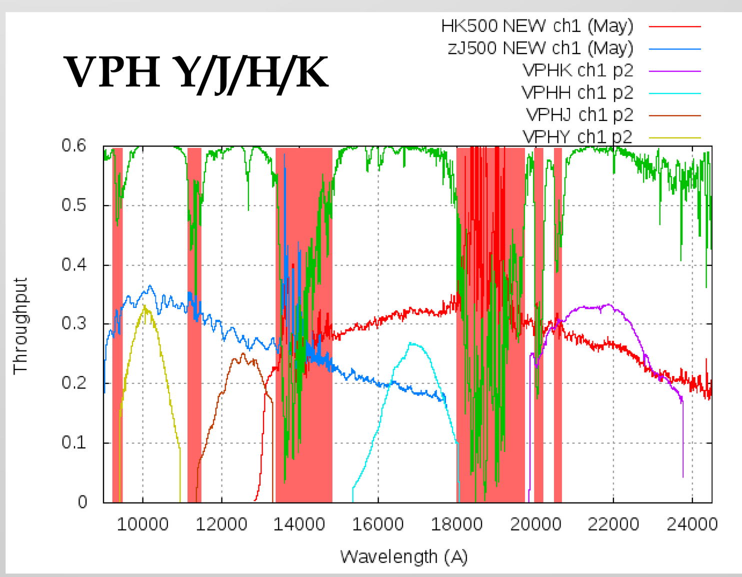
The effect of the bias drift elimination task.
NB 2.16um deep imaging data (by courtesy of Dr. T. Kodama)

5. Results of On-sky Tests: Spectroscopy

The improvement of the system throughput is again significant in the shorter wavelength (**spectroscpic efficiency of 20-35%**)! The 40% increase of the relative gain in efficiency is observed in channel-1 Y-band wavelengths.





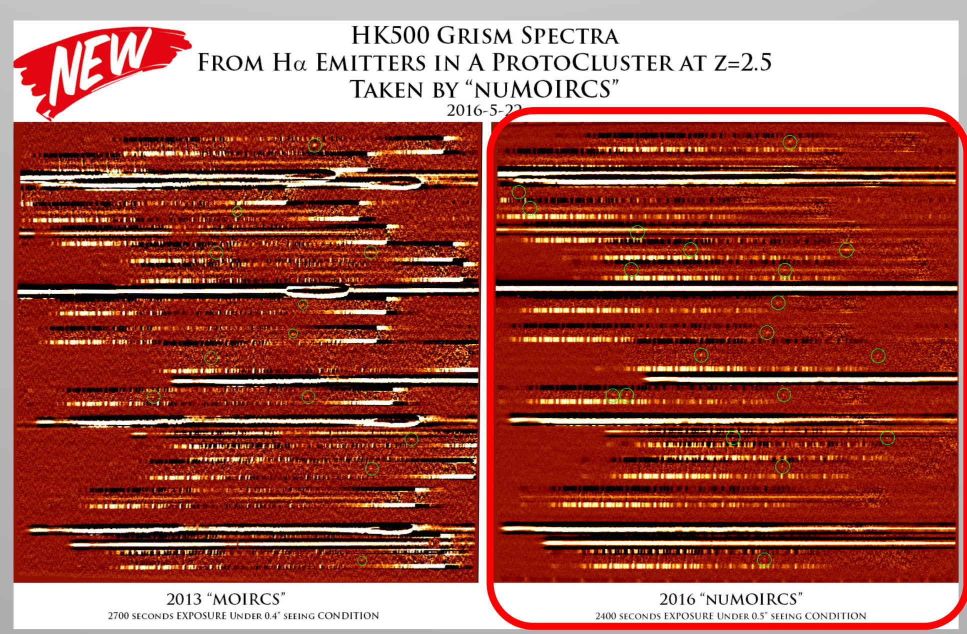


(Left) Total system throughput of the VPH grisms. In VPHK it is better than HK500. Though VPHY and VPHJ has similar throughput to zJ500, the wider areas between the OH night lines for these grisms is the immediate advantage for faint object spectroscopy.

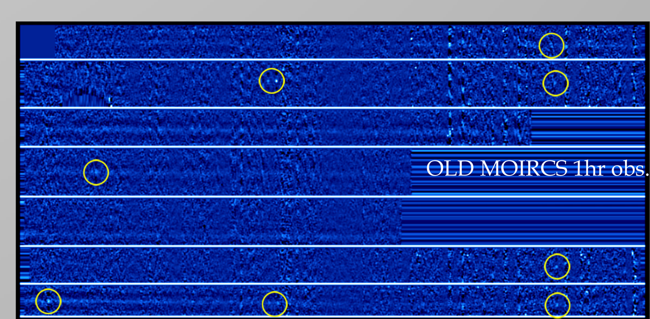
We note that now all grisms (VPHs and R500s) have the same dispersion direction.

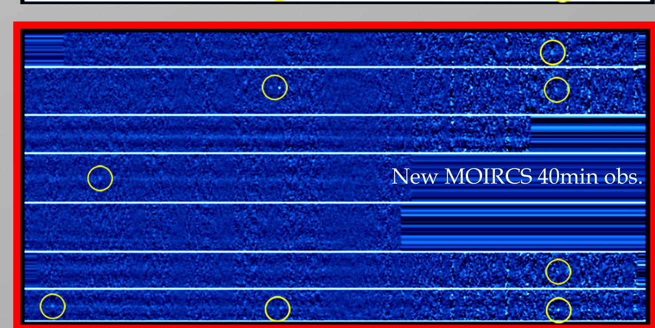
6. Demonstration Spectroscopy

These demo spectroscopy are for the search of the best exposure parameters under real situation. To do this, we observed the fields using the same mask as we used previously by the old detector. We acknowledge Dr. Y. Koyama for permission to use his science mask for the purpose.

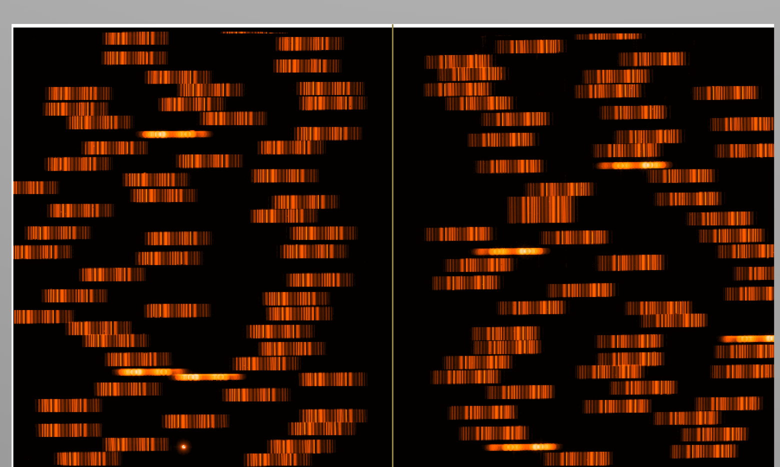


The comparison of the HK500 data (right = new detector). Thanks to the faster exposure we can use, we have less sky residual, which significantly improves the resulting quality of the data.

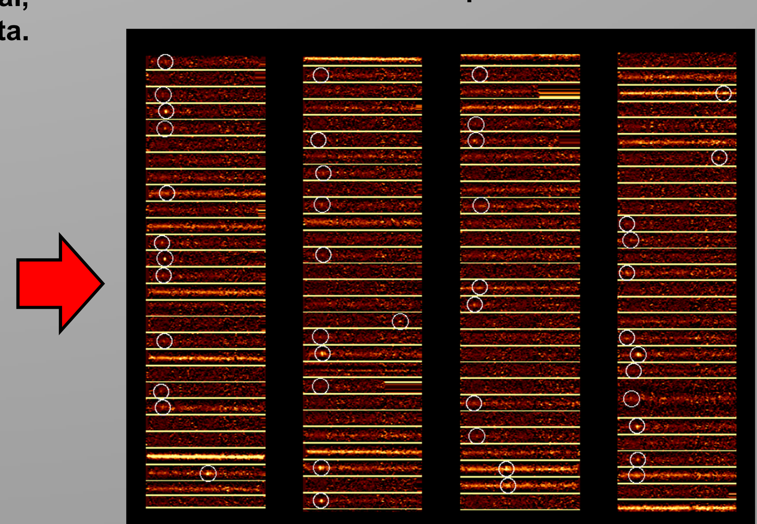




The comparison of the zH500 data (bottom is new). We can achieve the similar quality data in only 60% exposure time.



An example of zJ500+J-band filter for more multiplicity.
We have140 slits in a mask!



In only 45 minutes exposure (0.8" FWHM, EL=35deg!) we detected >40 emission line from z~0.8 cluster galaxies.