Integration and Commissioning of the new UH Hilo Hoku Ke‘a Observatory

Final Report

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Summary:

The project which Dr. Pierre Martin and I worked on involved the integration and testing of the different hardware and software components for the new UH Hilo Hōkū Ke‘a Observatory. This includes assembling the PlaneWave 0.7-meter telescope, evaluating its control software environment for classical, remote, and robotic observing modes, characterizing the CCD imaging camera and its suite of Astrodon filters, and starting installation and commissioning of the fiber-fed echelle spectrograph. It is imperative for all systems and sub-systems within the observatory to be completely integrated to ensure efficient operations, reliability and flexibility during future operations.

Dome:

The AstroHaven 18-foot clamshell dome arrived at UH Hilo on July 20th and has been in storage. Beforehand, an area had to be cleared so that there would not be any obstacles to maneuver around when moving it to its current location on the UHH campus. It came on two large pallets which required 2 forklifts to get it out of the shipping container. The process took half-a-day and was considerably difficult. I contributed in the preparation of storage place and by bringing the pallets from the delivery truck to the storage location. Installation of the dome has been delayed until a suitable site for a temporary observatory is selected.

Telescope:

UH Hilo has purchased a PlaneWave Instrument CDK700 0.7-meter telescope. The manufacturing company built and tested the telescope several months earlier than expected. Working with the new telescope was not in the original plan for my internship but we refocused my work when it was delivered to UH Hilo in early September.

Preparation: In preparation for the arrival of the telescope, we had to first rearrange the room to ensure that the telescope would be able to move freely without hitting the walls or other obstacles. The room was cleaned to get rid of the dust and dirt that was left by the last users of the lab. It was important to ensure that the telescope and instruments stay in pristine condition. After cleaning and arranging the room, we set up the computers that control the telescope, dome, and instruments and connected them to the Smart-UPS in case of power outages and surges. For the large amount of data we expect to collect during the lifetime of the observatory, we implemented a Buffalo TeraStation hard drive raid system providing 64 terabytes of data storage.

<u>Arrival:</u> When the telescope arrived, it was in three large crates which had to be taken off the truck with a fork lift. The crates were delivered in the machine shop on the first floor of STB. We inspected their condition for any dampness or outward cosmetic damage. It was important to check the outer shipment monitors on the crates to ensure they were kept upright, there wasn't too much turbulence that shook the crates, and the accelerometer to make sure there wasn't too much g-force on their journey over. All areas on the crates showed no damage on the outside. Pictures were taken of notices and sensors on the outside of the boxes as documentation. The crates were open for an initial inspection of the main parts of the telescope (body, secondary mirror truss, and system control panel) and no damage was found.

Accelerometer to measure the g-force

Indicator for any Turbulance or shaking of the crate

<u>Full Inspection:</u> The lower-section (fork mount, primary, and tertiary mirrors) of the telescope was fully removed from the crate so we could walk around and inspect all the components. An inventory was taken of all parts delivered with the telescope from a checklist of parts ordered and pictures were taken for documentation. We found all parts were accounted for. The primary mirror was inspected by taking off the cardboard covers and shining a flashlight onto it. We saw a few blue "smudges" on the mirror which look as they could be finger smudges. Pictures were taken and the manufacturer was notified. When PlanWave visits the Big Island to help set up the primary mirror cover, they will also take a look at the smudges but we are not worried about them. The secondary mirror was checked in the same fashion and no problem was seen. Lastly, we check the corrective refractive optics on either port side of the telescope where the instrumentation will go. There is some dust in and around the whole telescope but it is in good condition.


Blue smudges on the primary mirror

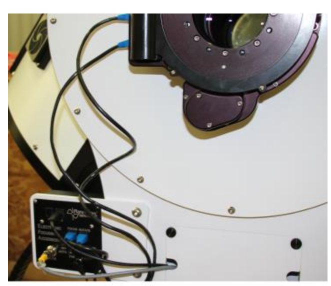
<u>Installation:</u> We moved the telescope into the desired location so that its complete motion would not be obstructed. The alt-az reference position was aligned with the correct southern direction as to get the correct encoder positions and optimized limits when the telescope is powered on. We

purchased large bolts and cut pieces of 2x4 wood to hold the telescope base up from the pallet so that cables could be threaded through the telescope fork. Then, we began to assemble the telescope following the provided instructions. The secondary mirror truss was put onto of the lower-section of the telescope using 4 people to lift and carefully place it over the telescope being careful to align the reference holes and reference pins between the lower-section and the truss. Bolts were put into place to secure the secondary mirror to the main body. One bolt was missing so the manufacturer was notified. We then removed the orange straps which stabilize the telescope for shipping. The metal braces bolted to each side of the fork mount which supported the weight of the telescope were removed. This left the full weight of telescope supported by only the base bolts and wood; the telescope is very well balanced so the configuration is very stable. The azimuth locking mechanism (locked for shipping) was released using a long screwdriver tool provided by the manufacturer and the support ring above the primary mirror was also released. This allowed us to move the telescope in all directions. The telescope was so well balanced and unobstructed that we were able to move the entire structure with the force of a single finger.

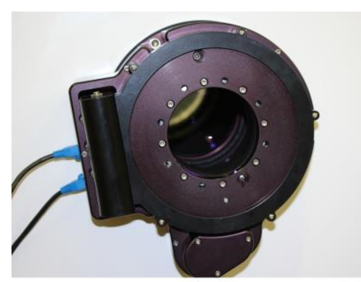
Bolts and wood holding telescope off the platform

Installation of the Secondary Mirror Truss

We had to remove the control box from the crate with the help of two people. The 6 cords (from left to right: DC Power, Altitude motor power, azimuth motor power, Altitude Encoder, Azimuth Encoder, and CAN I/O) were then attached to the control box and threaded through the bottom of the telescope into the fork cord area in the base of the telescope. We also installed the rotator-focuser system on both ports of the telescope. The rotator and focus mechanisms were attached to the power box located beside the ports.



Power box for the rotator-focuser system



Rotator-focuser system (Nasmyth Port) for attaching the instumenation.

Calibration and Alignment: Using the PlaneWave Interface software manual, we enabled the telescope motors and were able to move it minimally due to the telescope not knowing it was in Hawaii instead of California where it was built. To calibrate and align the telescope we sent it to its home position (az=180d) with the telescope and lowest elevation (alt=+10d). Using the PlaveWaves software we adjusted the coordinates of our location and moved the telescope to its hard stops by pushing on in manually. This process is necessary for defining the software limits which will be used by pointing software. The mount can move 660 degrees in azmuth and from

10 to 90 degrees in elevation. After calibrating the telescope, we were able to move it to its full extent while using the PlaneWave software. We learned that if we turn off the power in the control box we will have to recalibrate it every time we turn it back on. We also controlled both focuser/rotators on both ports of the telescope as well as the tertiary rotation. Fan and temperature sensors were also tested which showed that the telescope could be cooled down quickly and efficiently.

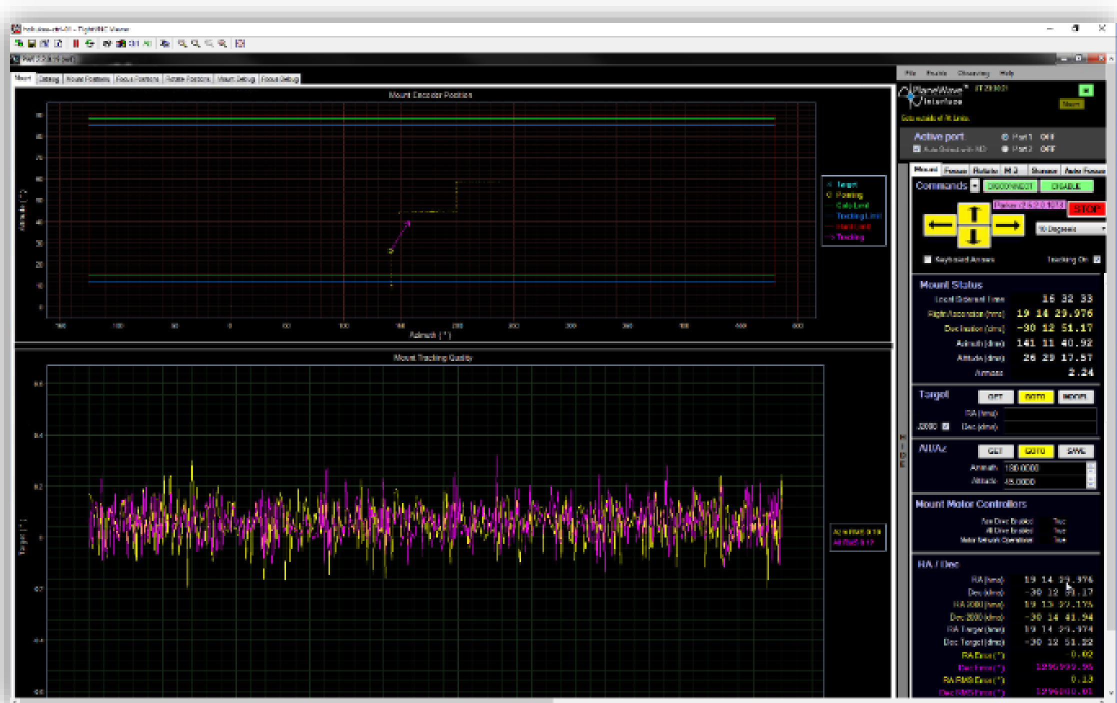
Software Installation:

There are many different software programs we use in which to operate our observatory system. Some software controls specific instruments such as the CCD camera, spectrograph, and telescope. Others control the telescope and dome through the classical, remote, or robotic operations. Because we have software from many different manufactures, they all have to be carefully interacting together for the operations of our observatory.

<u>Software:</u>

ASCOM (Astronomy Common Object Model) – This is a suite of drivers for astronomy software and instruments to ensure communication between all components in the system.

PlaneWave Interface 2 – This software is the direct link between the CDK700 telescope and the user. In this program, you can control the telescope and the accessory ports on the side and monitor the status of the telescope such as the temperature, location, tracking motions, focus, pointing position, etc.



UCAC4 Catalog for CDK700 (PlateSolver) – This program will establish the pointing model for the telescope. It has a list of objects which can be used or the user can use the RA and DEC of an object they would like to view instead.

TeraStation – This software connects the computer to the Buffalo TeraStation hard drive which has 32 terabytes of memory. It will store the data collected by the telescope.

Finger Lakes Instrumentation (FLI) software – This software controls the CCD Camera and the filter wheels. It tells camera to take a picture (e.g. bias or dark) with details such as how long it should expose for. With this software, we can also change the filter in front of the camera.

ACP (Observatory Control Software) – For future robotic operations of the telescope, dome and instrumentation.

MaximDL – Software for collecting and analizing data from observations, spectroscopy, and imaging

SkyX – Control software with a planetarium for use when finding objects required to the observing run.

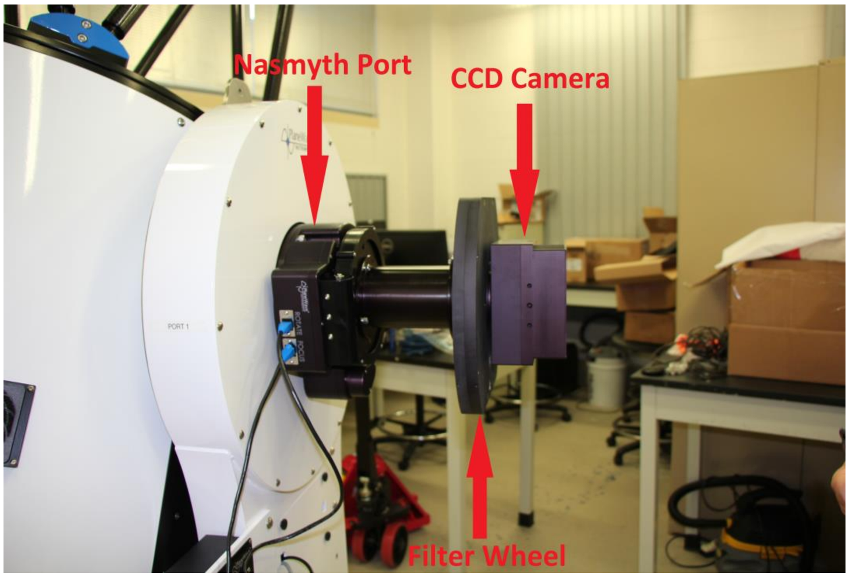
VNC – Allows for remote access of computer and system. This has already been tested out during the presentation in Oahu by controlling the telescope system remotely.

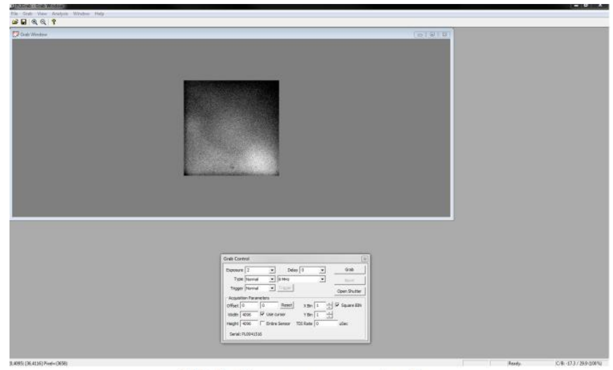
Shelyak ISIS – For controlling the Shelyak Instruments eShel spectrograph, with its autoguider.

Instrumentation:

We have started to test and characterize the instruments for the Hōkū Ke‘a Observatory.

<u>Camera:</u> The CCD camera was attached to port 1 (west side of telescope when in home position) with the CenterLine filter wheel in front of it using a set of adapters bought from PlanWave Instruments. It was then connected to the telescope and computer. Using the PlaneWave software, we rotated the camera and moved its focus to ensure that the camera was fully attached and would not fall off in the future.

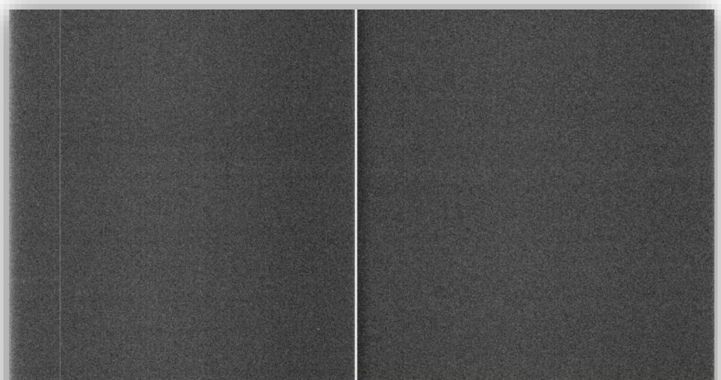




FLI Camera control

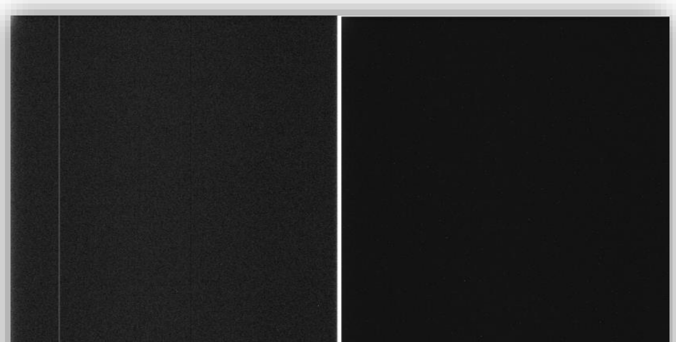
<u>Characterization of Camera</u>: We characterized the FLI Camera using the Finger Lakes Instrumentation software to take bias and darks with the following data obtained:

- Total readout time: To get the readout time we took a series of exposures while timing how long it took. We found that for 1MHz it took 18s and for 8MHz it took 2.5s.
- Temperature Behavior: We originally set the CCD temperature to -40C but it was not able to go that low and instead stayed around -32.8C and would fluctuate by < +/- 1C. This means it would stay around -50C from the room ambient temperature. All other temperatures set (-20C, -10C, and 0C) stayed within .1C of the set temperature. As we changed between each temperature, we saw that it would change quickly so we did not have to wait long to take our next data set.
- Bias Levels: We took a series of biases at 8Mhz and temperatures ranging from -32.5C – 0C. From this we found that the bias levels were around 1000ADUs.



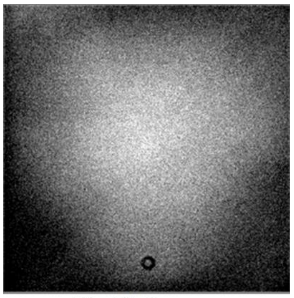
1Mhz bias 8Mhz bias

- EM (electromagnetic) environment of telescope: We wanted to see if there was any electromagnetic interference on the camera when we were rotating the camera, changing filters, or slewing the telescope. We expected to see wave patterns within the bias if there was a lot of electromagnetic interference especially as we moved parts telescope closer to the cameras. There was no obvious EM interference seen in are biases taken at 1Mhz.
- Dark Level: We tested this by having the lights off and taking darks of different exposure times (10s, 30s, 60s, 120s, 180s) at 1Mhz and with the temperature at -33.8C. We then took darks while moving the focus on the camera for 300s, a dark while the telescope was tracking with and without the lights on for 300s, and a dark with no light while the focus was moving for 180s. Afterwards we found that the dark



10s Dark 180s Dark

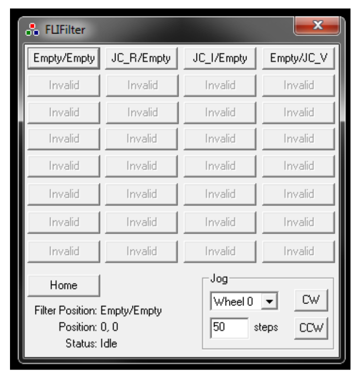
current was less than .005⁻/pix/second at the temperature of -33.8C. This is a very good result but also means that if we take darks at exposures of >300s, we will get a lot of electrons in our images.


First Flat Image

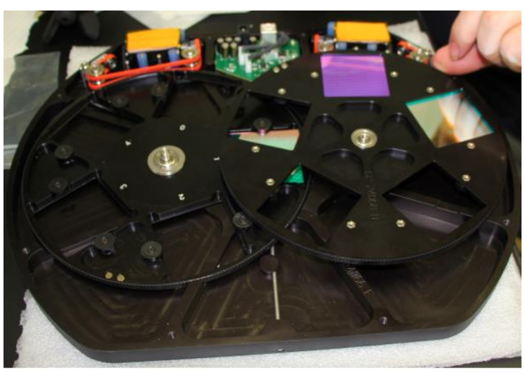
After working with the filter wheel, we were able to get our first flat field view while pointing the telescope at the slightly open window blinds and exposing for <2s. The image which we got shows a spot of dust which we expect is on the camera lens itself. While taking these exposures, we realized that the shutter speed on the camera was not as fast as we would like which means if you take an exposure <1s you will get a spiral pattern in your image. This isn't a huge concern since the exposures should be longer for most data collection in the future.

<u>Filters:</u> The filters which we will be using in the filter wheel came from Astrodon who sent us information on the filter transmission curves. While the data they sent were precise, we decided to scan the filters ourselves and compare the data to Astrodon's. To do this we went to CFHT headquarters and used their Spectral Photometer and UVProbe software. An initial measurement without a filter in place was taken to see how the instrument was running. It came back with a less that 0.5% error. Adding in the filters one by one, they were scanned and the information was saved. For the next couple months, the information was reduced to what was needed and graphed to see the transmission compared to the wavelength. Our data are on par with what Astrodon sent. All transmission curves are shown on Figures A-O in Appendix 1.

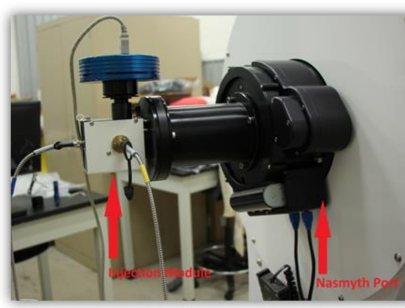
Three filters we put into the filter wheel (Johnson-Cousins IC, Johnson-Cousins V, and Johnson-Cousins B) as a test for the FLI software. We did not want to add more as when we took the camera off of the filter wheel, we noticed the metal where the two were in contacted was warped. We did not see any indication of damage on either instrument of than the warped metal but we did not want to add in all filters in case it caused damage to them. We suspect that the problem comes from the connection between the filter wheel and camera being too tight. After we replaced the filter wheel back on the telescope, we used the FLI software to move the filters in and out or their positions to get a sense of how they move. Once we saw that no damage was being done, we added the CCD camera back on to take our first flats.



FLI Filter Control


Inside of FLI Filter Wheel with 3 filters for testing

<u>Spectrograph:</u> We have begun to set up the Shelyak Instruments fiber-fed echelle spectrograph. We hit a snag in our process when we found that the manufactured had not sent us American adapters for the power supply. We were able to connect the fiber injection guiding unit onto port 2 (East side of the telescope when in home position). And



Port 2 with Shelyak Fiber Injection Guiding Unit connect the fiber optic cables which will connect to the spectrograph on a table elsewhere in the observatory.

Appendix 1

Narrow-Band Filters

Figure A: HKO_151 Halpha_2. Slit width = 0.2nm. Wavelength 636-676nm

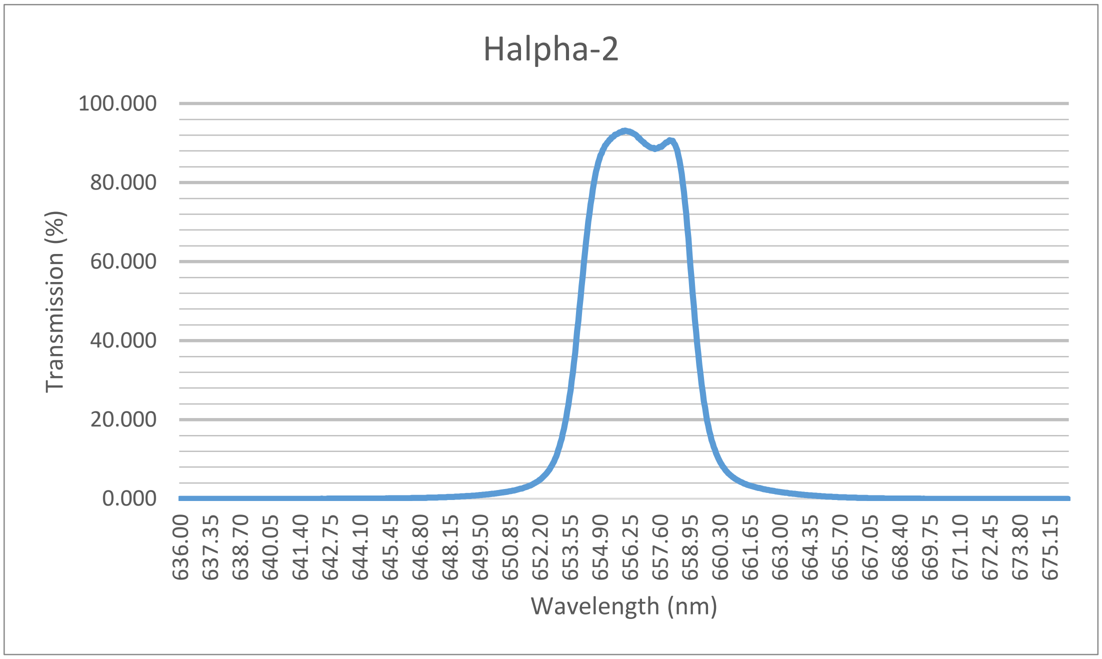


Figure B: HKO_150 Halpha_1. Slit width = 0.2nm. Wavelength 636-676nm

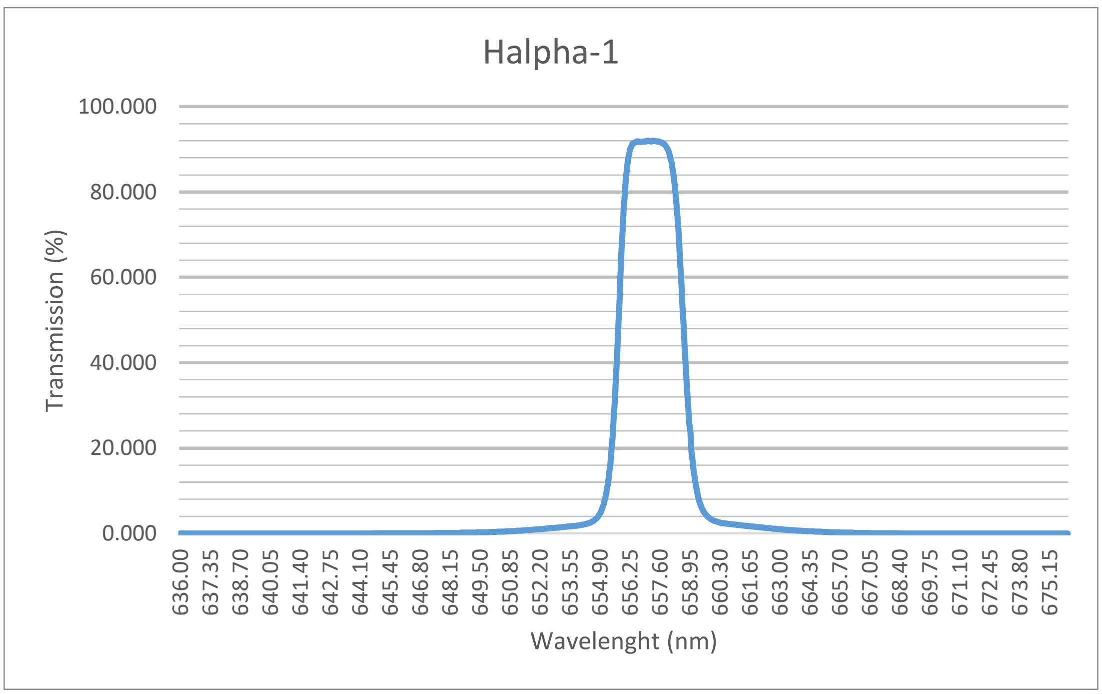


Figure C: HKO_120 OIII. Slit width = 0.2nm. Wavelength 480-520nm

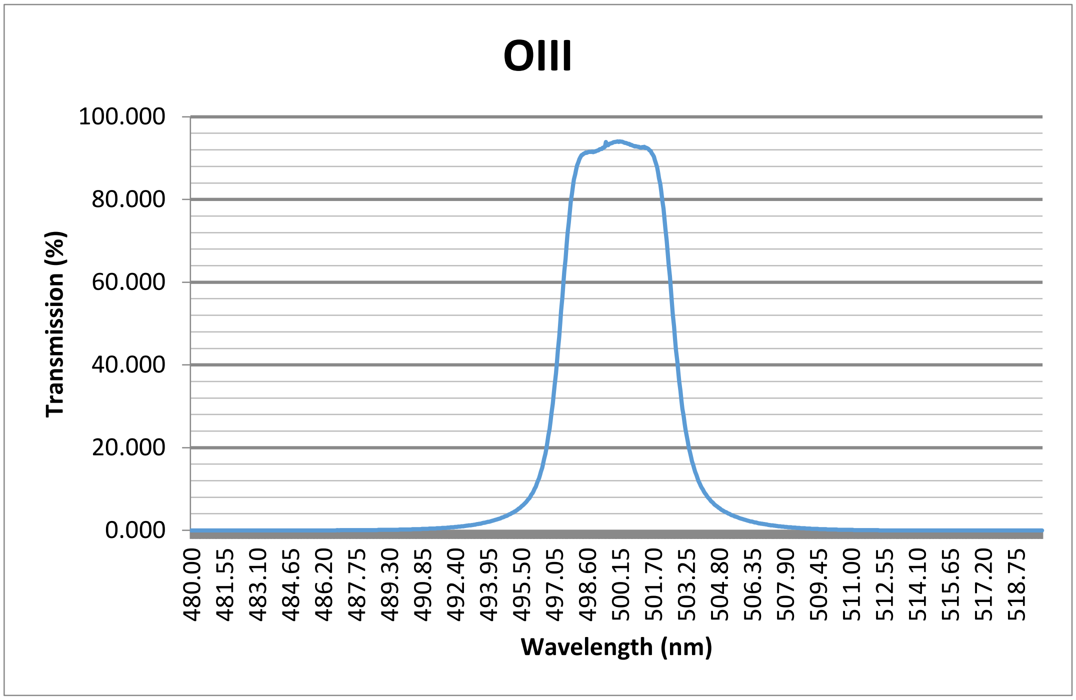


Figure D: HKO_180 SII. Slit width = 0.2nm. Wavelength 651-691nm

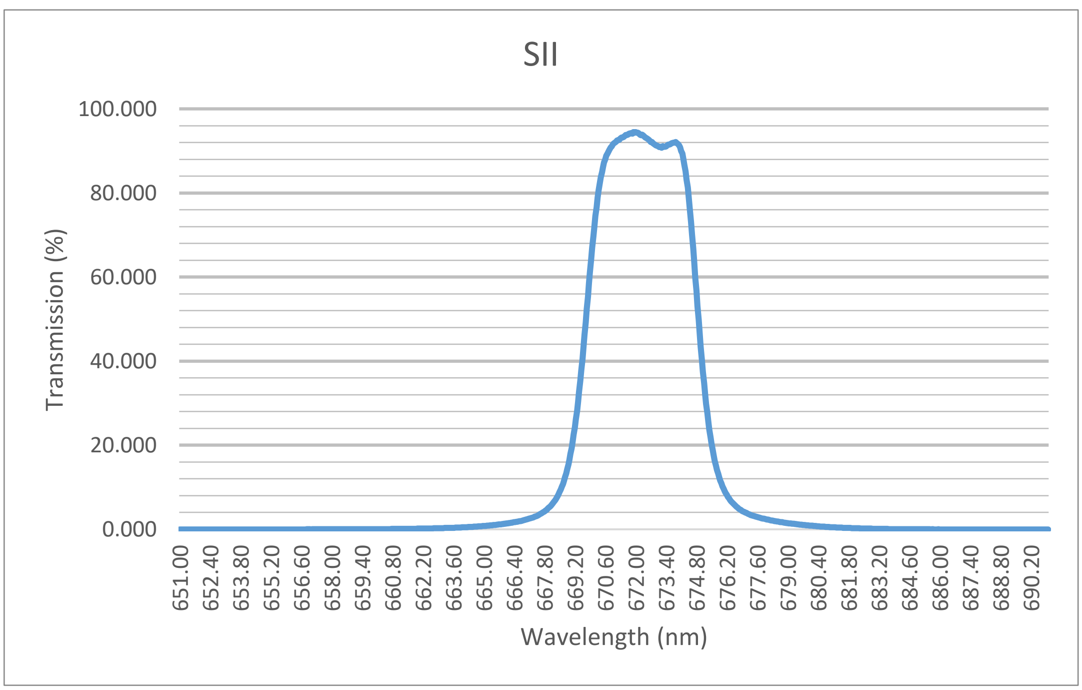


Figure E: HKO_170 NII. Slit Width = 0.2nm. Wavelength 638-678nm

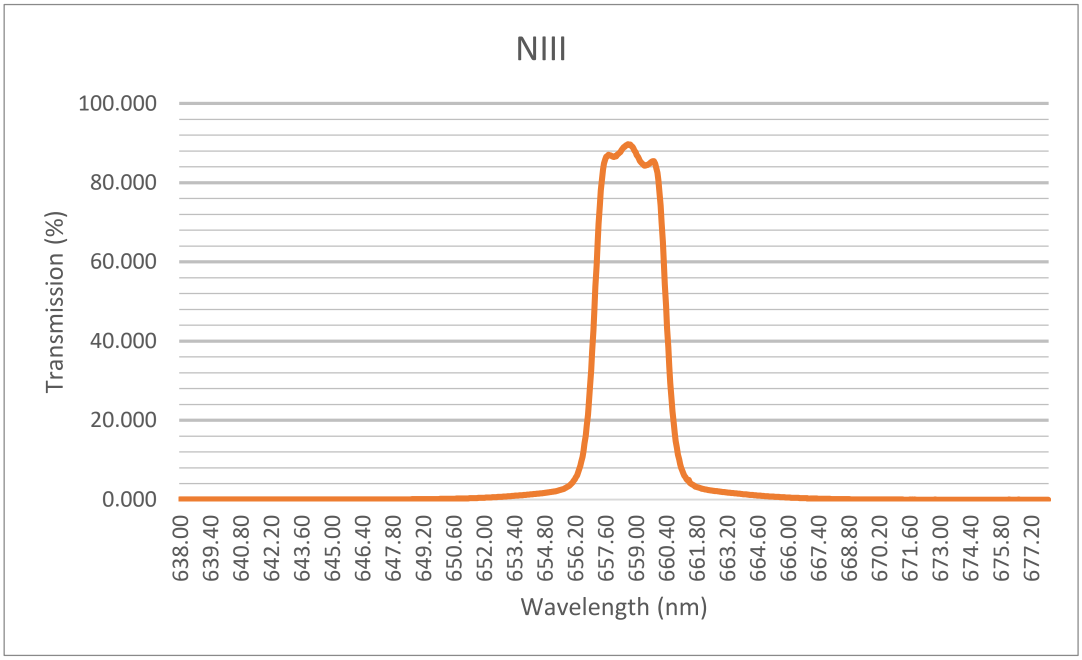
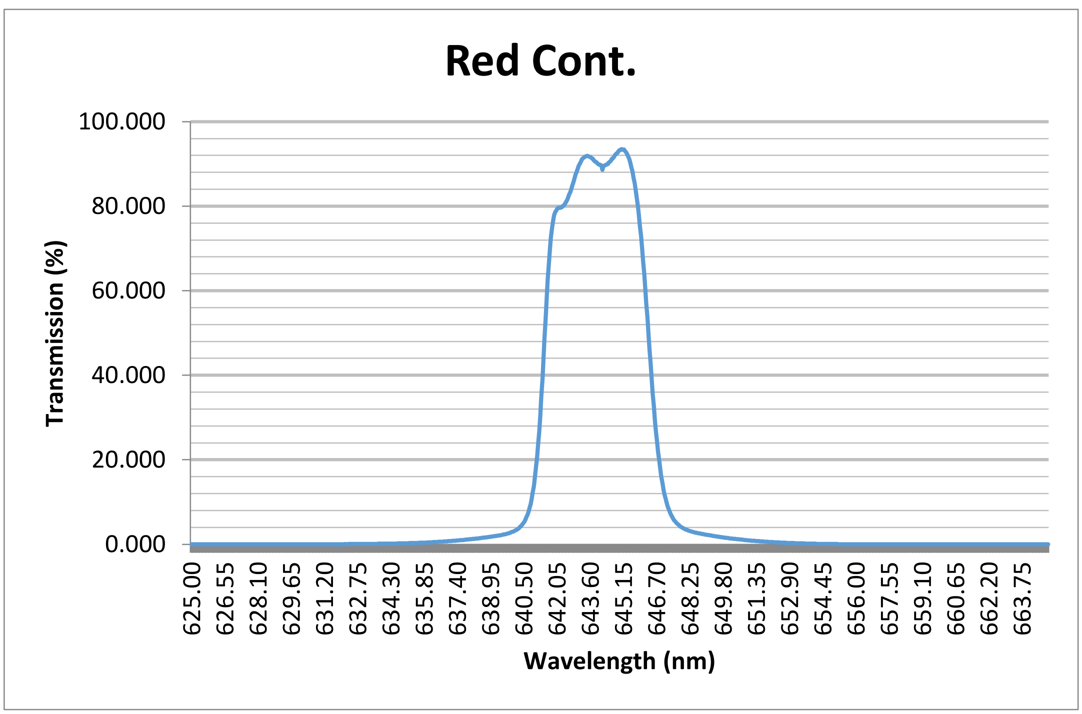
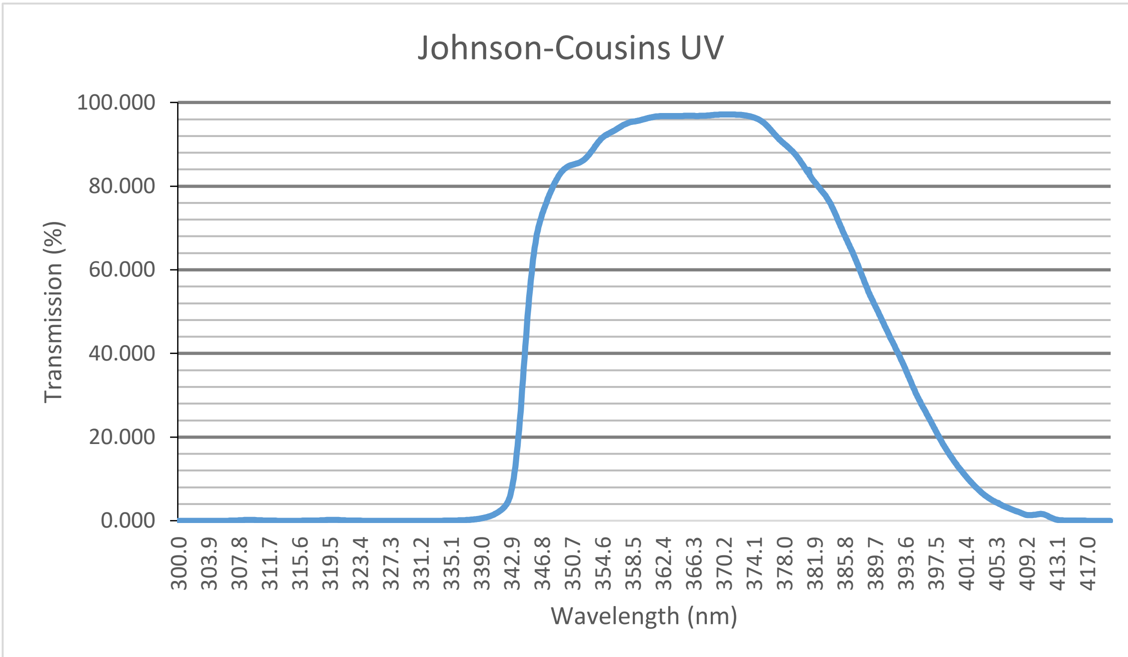


Figure F: HKO_190 Red Cont. Slit Width = 0.2nm. Wavelength 625-665nm



Broad-Band Filters

Figure G: HKO_001 Johnson-Cousins UV. Slit width = 2.0nm. Wavelength 300-420nm



HKO_002 Johnson-Cousins B. Slit width = 2.0nm. Wavelength 330-510nm

No Data

Figure H: HKO_003 Johnson-Cousins V. Slit width = 2.0nm. Wavelength 420-680nm

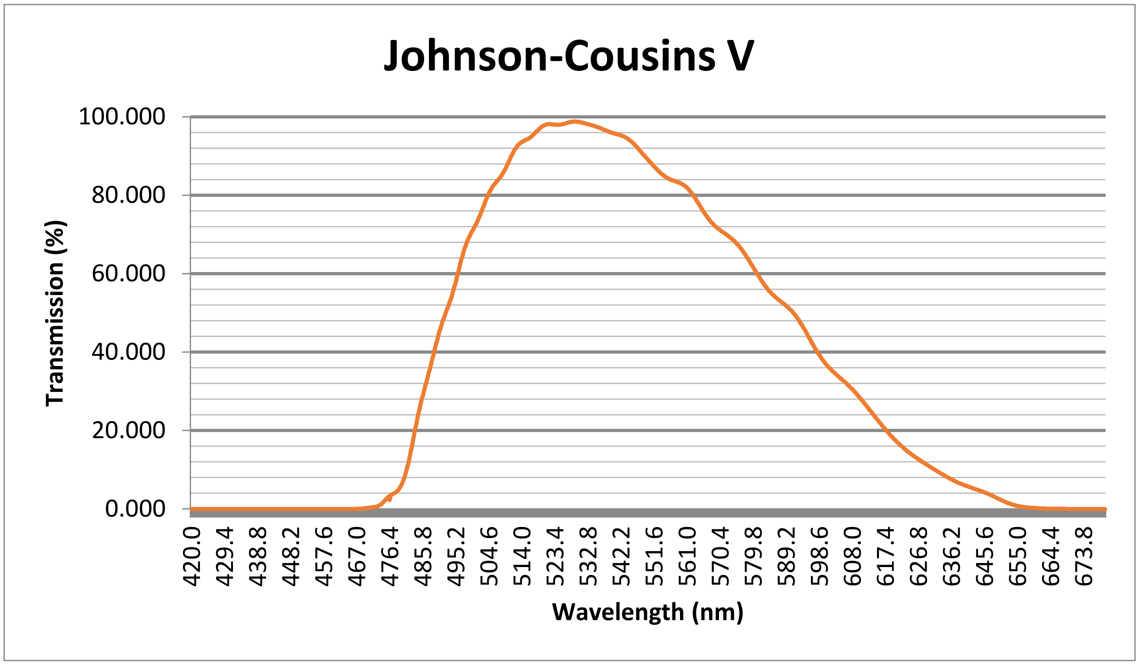


Figure I: HKO_004 Johnson-Cousins RC. Slit width = 2.0nm. Wavelength 420-880nm

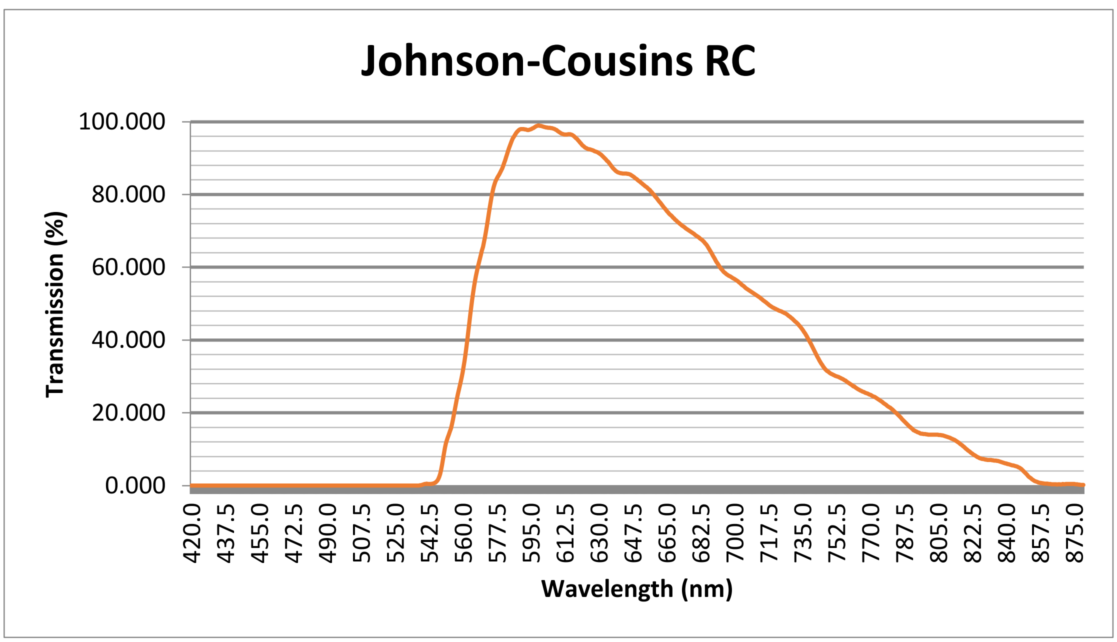


Figure J: HKO_005 Johnson-Cousins IC. Slit width = 2.0nm. Wavelength 660-980nm

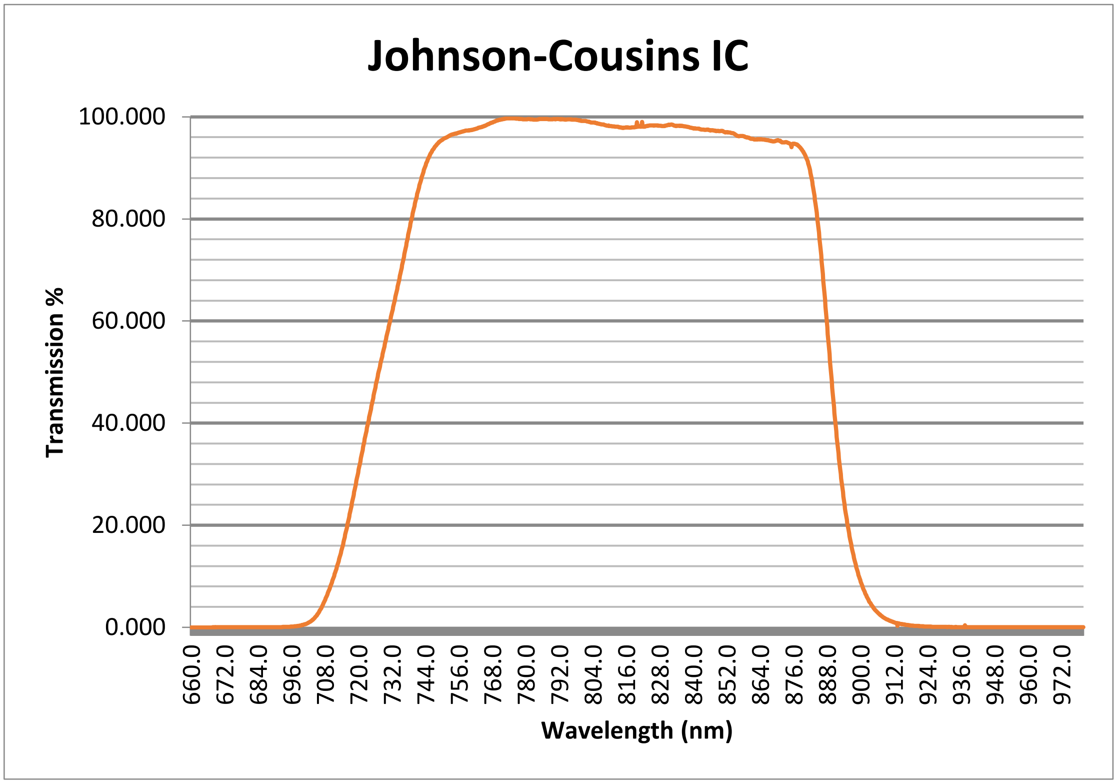


Figure K: HKO_010 Sloan u’. Slit width = 2.0nm. Wavelength 300-420nm

Figure L: HKO_011 Sloan g'. Slit width = 2.0nm. Wavelength 580-380nm

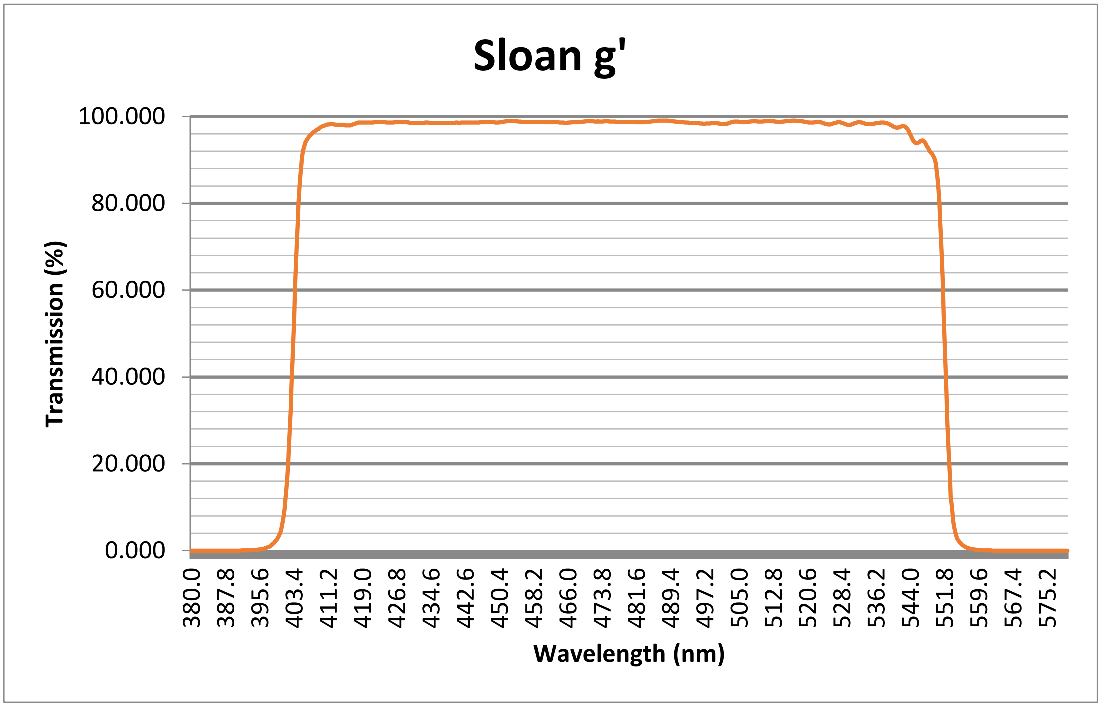


Figure M: HKO_012 Sloan r'. Slit width = 2.0nm. Wavelength 530-720nm

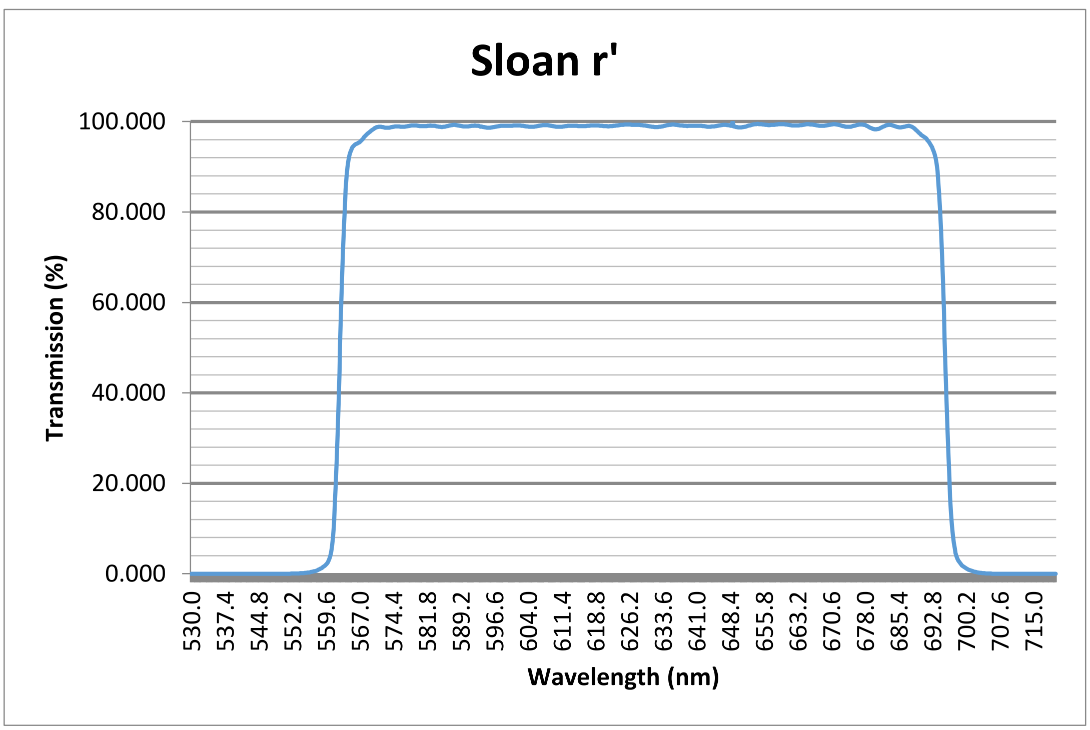


Figure N: HKO_013 Sloan i’. Slit width = 2.0nm. Wavelength 650-900nm

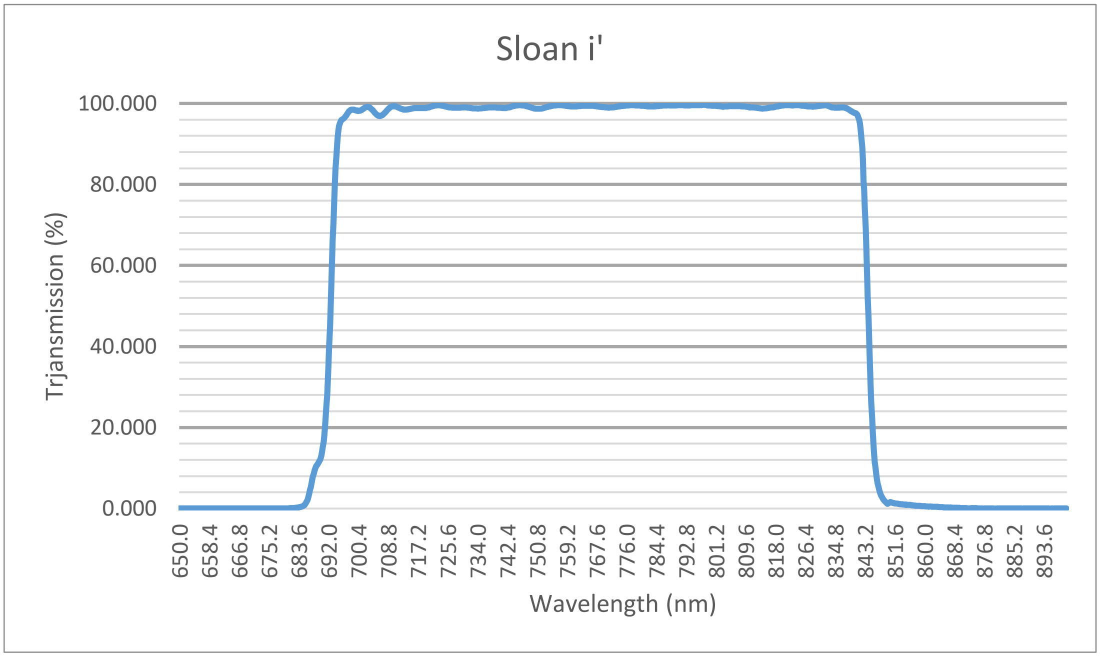


Figure O: HKO_014 Sloan z’. Slit width = 2.0nm. Wavelength 780-1100nm.