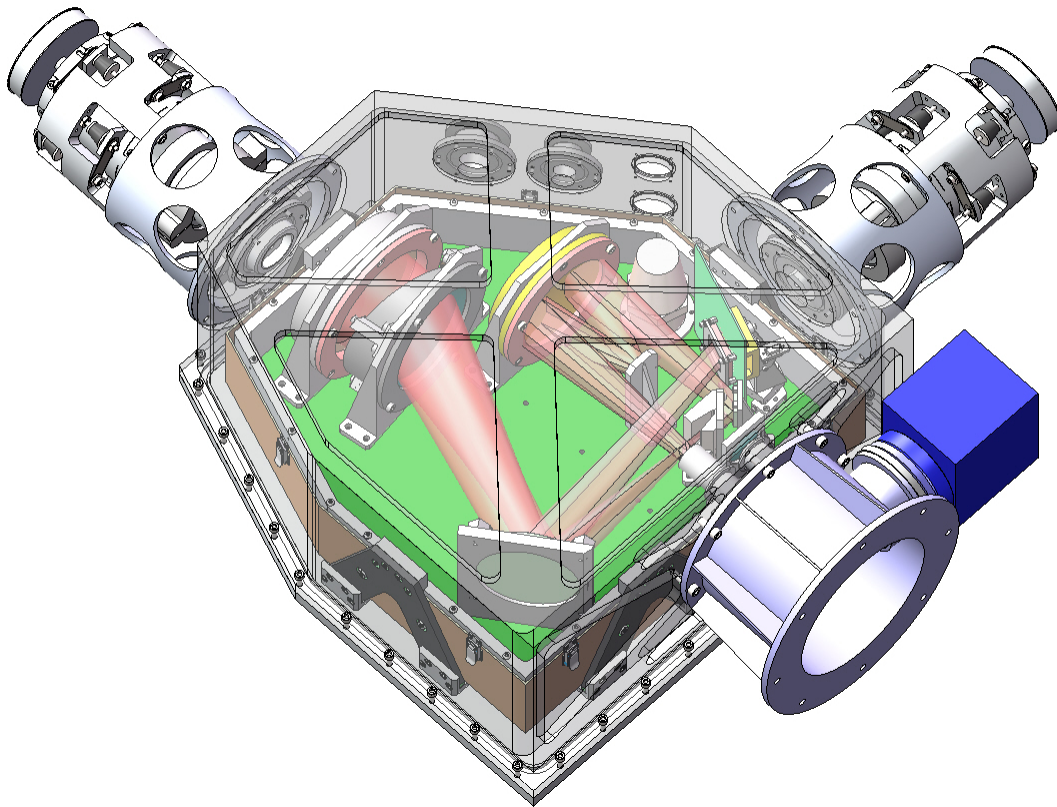


The Near Infrared High Throughput Spectrograph NIHTS User Manual

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V. 0.1



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Cameras

NIHTS: Spectrographic channel, Rockwell Hawaii-1 array

XCAM: Slit Viewing/Acquisition Camera, Xenics XEVA IR camera

LMI: Large Monolithic Imager (Visible)

Fun Facts

| | NIHTS | XCAM | LMI (binned 2×2) |
|-----------------------|---|----------------------------|-------------------|
| Gain | 24 e-/ADU | | 2.89 e-/ADU |
| Read noise | 100 e- | | ~6 e- |
| Readout Time | 0.001504 sec (Row Time) | | 24 sec |
| Minimum Exp. Time | 0.77 sec | | 0.1 sec |
| Maximum Exp. Time | | 5 sec | |
| Detector Size | 1024×1024 | 320×256 | 1564×1540 |
| Pixel Scale | 0.13 arcsec/pixel | 0.326 arcsec/pixel | 0.24 arcsec/pixel |
| Slit Widths (") | 4.03, 1.61, 1.34, 1.07, 0.81, 0.54, 0.26 | | |
| Field of View | 10" spatial length | 60" × 90" | 4' × 6' |
| 0° Field Orientation | | N:right (along slit), E:up | N:up, E:left |
| Dichroic Transmission | | | 0.4 - 0.7 μm |
| Operating Temperature | 75 K | 201 K | 153 K |

A0 and G2 Standard Stars:

http://irtfweb.ifa.hawaii.edu/cgi-bin/spex/find_a0v.cgi

Closure Limits

Humidity: ambient $\geq 85\%$, M1 $\geq 80\%$

Wind: sustained $\geq 11m/s$, gusts $\geq 16m/s$

Temperature: $> 30^\circ C$ or $< -20^\circ C$

Precipitation/Dust/Smoke: Any form, but Telescope Operator's judgment call

Data Directories

NIHTS: `dct-obs1.lowell.edu:/nihts/YYYYMMDDa` (or b or c ...)

XCAM: `xcam.lowell.edu:/Users/user/xcam/xenics-data/YYYY-MM-DD`

LMI: `dct-obs1.lowell.edu:/LMI/YYYYMMDDa` (or b or c ...)

Quick Start

1. Setup (§2):
 - (a) Start up LOIS and the NIHTS LOUI on dct-obs1 (or dct-obs2).
 - (b) Set Observer and Path Information.
 - (c) Start up XCAM/ZTV through the Mac Mini screen share.
 - (d) Take nihts test image using `nihts.go` command.
2. Calibrations (§3):
 - (a) Arcs: run `-i NIHTS_arcs.py` using the Xenon Arc Lamps
 - (b) Dome Flats: run `-i NIHTS_flats.py` using the Deveny 6V Lamps
 - (c) Note: Don't forget to turn the Dome Lamps Off!
3. Observing (§4):
 - (a) Telescope operator performs Wavefront
 - (b) Focus: run `-i NIHTS_focus.py xpos ypos -filter -seeing -x_exptime -step`
 - (c) Acquisition
 - i. Create a difference image of the target.
 - ii. [Click to Home]
 - iii. `tcs.current_target_pt = tcs.home_pt`
 - iv. `tcs.move_to_slit_position(tcs.slits['slit']['A/B/Cen'])`
 - v. Nudge with small offsets to refine pointing in ZTV if needed.
 - vi. run `-i NIHTS_ABBA.py target slit n_exptime -nseq -x_exptime -gdr_str`
 - vii. Clear offsets before moving to a different target.
 - (d) Real Time Analysis in LOUI:
 - i. Pixel Dump
 - `p` = pixel dump
 - ii. Line Profile
 - Type 1 = display line and column plots for the part of the image displayed in the LOUI image display.
 - Type L = display line and column plots of the entire image, regardless of what portion is actually displayed.
 - iii. LINE CUT
 - Horizontal Spectrum
 - Vertical Spectrum
4. Shut Down (§5):
 - (a) dct-obs1 (or dct-obs2)
 - i. Do NOT [Exit LOIS], simply click the red [X] in the upper left to close the LOUI.
 - ii. Do NOT close the `obsnihts@nihts` terminal window.
 - (b) Mac Mini Screen Share
 - i. Exit ZTV and XCAM terminal windows
 - ii. In the white "PWR USB" terminal window type: `python NIHTS_shutdown.py`
 - iii. Close screen sharing window.

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1 Introduction to NIHTS

The Near-Infrared High-Throughput Spectrograph (NIHTS, pronounced “nights”) is a low-resolution ($R \sim 200$) near-infrared prism spectrograph, covering 0.86-2.4 microns in a single order. NIHTS achieved first light in November 2015. NIHTS contains no moving parts and employs a single slit mask with 7 different slit widths (4.03, 1.34, 0.81, 0.27, 0.54, 1.07 and 1.61 arcseconds), each approximately 10 arcseconds in length. During early commissioning NIHTS was fed by a fold mirror in the instrument cube, which was replaced by a dichroic on 13 December 2017 to allow for simultaneous LMI imaging and NIHTS spectroscopy. Current instrumentation plans have NIHTS available on the telescope every night.

NIHTS commissioning will continue through the 2018A semester with the instrument operating in shared risk mode. Shared risk implies that best efforts will be made to deliver data of sufficient quality to meet scientific objectives, however this is not guaranteed. If the instrument is not fully ready for operations then some of the shared risk time may be needed for commissioning. The instrument will be available for normal science observing beginning 01 July 2018.

Software Systems

Presently there are four fundamental software systems of which the astronomer should be aware. Each system runs on a different server, though the astronomer interfaces with them through the standard observing computer, a dual-screen iMac named **dct-obs1 (or dct-obs2)**.

- **LOIS** (Lowell Observatory Instrument System) is the guts-level system that actually runs the CCD controller, setting the micro-code, generating the FITS header, and doing all the heavy lifting. It runs on the computer **nihts**.
- **xcam** is a Mac Mini accessed through VNC screen sharing and is the primary interface for controlling the NIHTS slit viewing camera and NIHTS spectral channel. There are two primary interfaces on **xcam**: an active iPython session in a terminal window labeled **XCAM**, and a GUI panel called **ZTV**. The observer issues commands in the **XCAM** iPython session to control exposures on the slit viewing camera and the NIHTS spectral channel (e.g. defining the type of exposure, exposure time, setting the desired slit). The **ZTV** GUI is an astronomical image viewer originally designed by Henry Roe that has been adapted to display and analyze images from the NIHTS slit viewing camera.
- **LOUI** (Lowell Observatory User Interface) acts as a status summary system for the user. In the case of NIHTS where **ZTV** is used for instrument control, we simply use the **LOUI** to monitor instrument and telescope subsystem processes. You can see real time image display, perform limited image analysis, and view the facility summary. However, different from other DCT instruments, the NIHTS **LOUI** is generally not used to take exposures. It runs on **dct-obs1 (or dct-obs2)**.
- **JOE** (Java Operator Executive) is a software “controller” (and is also a server that runs the activeMQ broker) that needs to be running. Generally the astronomer doesn’t have to worry about this, other than to be aware that **JOE** needs to be alive for control of all of the moving parts needed to take an exposure. Control of **JOE** is handled by the Telescope Operator at the beginning of the night. The status of **JOE** is indicated in the bottom status bar of the **LOUI**.

2 Beginning of the Night

1. Starting Up LOUI:

- (a) Log on to **dct-obs1** (or **dct-obs2**) as observer. The password is on the whiteboard.
- (b) Open the NIHTS LOUI by double clicking on the [LOUI_NIHTS] icon on the desktop.
- (c) LOIS is left running to monitor the instrument temperature. At the start of an observing session, it is highly recommended the LOIS be re-started to avoid any possible lingering side effects of earlier use.
- (d) Kill LOIS by clicking on the red [EXIT LOIS] in the upper right corner of the NIHTS LOUI (Figure 1). When the pop up appears, click okay to continue with the Kill LOIS.



Figure 1: The top menu bar allows you to Initialize and Exit LOIS. The top menu bar is located in the top right of the NIHTS LOUI.

- (e) You should see “LOIS Exiting Normally” in the LOIS log window in the lower left corner of the LOUI (Figure 2). Wait 15 seconds for this process to complete.

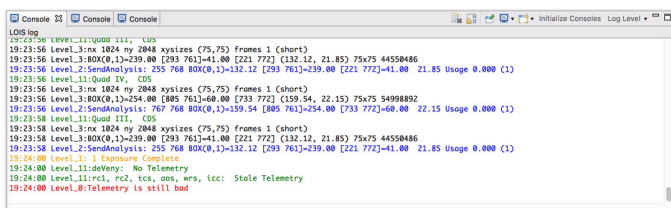


Figure 2: The NIHTS console, located in the bottom left of the LOUI, populates with status information, including image exposures, and errors.

- (f) There should be a terminal window already open connected to **nihts**. If not, open one and connect with `ssh obsnihts@nihts` using the password listed on the whiteboard.
- (g) Type `st` to check the status of LOIS.
 - i. When status is “Not Running” type `lois &` to restart LOIS.
 - ii. If LOIS is still “Running”, try to exit LOIS again by clicking the red [EXIT LOIS]. If LOIS is *still* “Running”, perform a kill LOIS in the terminal window. Ask the telescope operator how to do this.
 - iii. *Note:* NIHTS terminal window should always remain open, so please do not close it.
- (h) Click on the green [Initialize LOIS] in the upper right corner of the NIHTS LOUI shown in Figure 1. A stream of messages will go by in the LOIS log window in the lower left corner for about six seconds. Among the last half dozen messages or so, in orange, it should say “LOIS Successfully Initialized”. You can ignore the red telemetry error.
- (i) In the lower right of the LOUI (Figure 3), you will see the “Information View” exposure time counter marked in blue (“exposure 1/1 - 0.0/0.0 seconds (100%)”). Within this panel, scroll down until you can enter the Observer Name and Observer Affiliation (Figure 4). Fill these out and click [Set Standard Image Path & Observer]. Note that if you do not do a “Set Standard Image Path & Observer” at the start of your observations, LOIS remembers the last entries and will use those. When you click [Set Standard Image Path & Observer], this will create the data directory where the data will be stored; it

will have a name like 20170820a, where 20170820 corresponds to the UT date for that night. If you are the second (or third or...) observer for the night, first click the box labeled [New Rundate Directory]. This will change the “a” to “b” or “c” or....

- (j) You can have sounds initiated at the end of a science exposure and/or at the end of the read-out and/or at the end of a series of exposures. Open [Sound Effects] (Figure 5) below the data path to change the sound feature. By default the LOUI is silent.

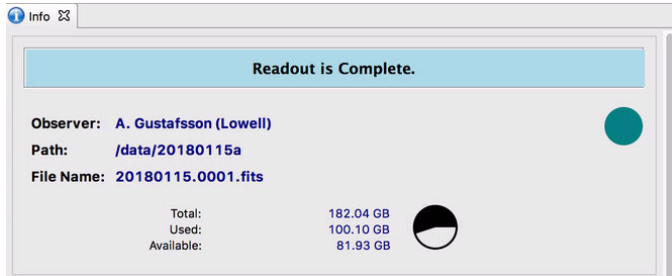


Figure 3: The info view is located in the bottom right hand panel of the NIHTS LOUI. Here, you can view the exposure and sequence status.



Figure 4: The observer information is entered in the panel below the Info View. This sets the path and observer information for headers.

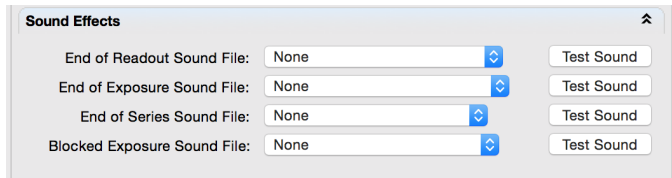


Figure 5: Sound effects are available for exposure readout notifications at the bottom of the Info View panel.

- (k) Grab the tab that says [Facilities Summary] (Figure 6) in the upper left and pull it out to somewhere on the desktop.
- (l) All of the tabs can be individually pulled out and re-positioned on the desktop. If the user makes a mistake and winds up with an unexpected window configuration, they can reset everything to the default using the “Reset Perspective” option in the Window menu.

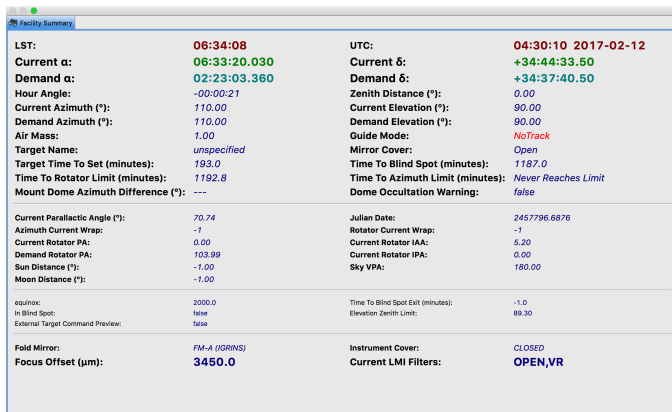


Figure 6: The Facility Summary contains all useful information regarding the telescope information. This includes pointing, UT time, target name, pointing, offsets, and more.

- (m) The LOUI provides some very valuable guidance to you as to whether or not the telescope is ready. Note at the bottom of the LOUI screen (Figure 7) the words GDR, JOE, TCS, AOS, and DOME are color coded to indicate the status of those sub-systems. First, check that JOE is on. If JOE is not on, ask your telescope operator how JOE is doing.
- (n) Wait for TCS, AOS, and DOME to all turn green before starting a science exposure. These indicate, respectively, that the telescope is in position, that the secondary mirror is in position and the primary mirror supports are tweaked and stable, and that the dome is in position. If you are using the guider, and the guider is currently guiding, GDR will be green. (The AOS light may occasionally flicker; this is just due to the secondary being adjusted for temperature and elevation changes; don't worry about it.)

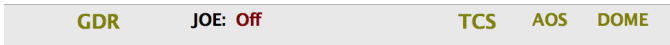


Figure 7: The Status Bar is located across the bottom of the NIHTS LOUI. Here, you can see the status of TCS, AOS, the dome, JOE, and the guider.

2. Starting Up **xcam**:

- (a) Open a VNC connection to the Mac Mini.
 - i. From Finder on **dct-obs1 (or dct-obs)**, type `cmd-K` to open the “Connect to Server” window.
 - ii. Enter server address `vnc://xcam.lowell.edu` and click [Connect].
 - iii. Enter the username (`xcam`) and password listed on the whiteboard.
- (b) Double click on the NIHTS desktop icon. This will open two terminal windows. The window in the lower left (white text, black background; Figure 8) is labeled XCAM and is where you will enter commands for both the slit viewing and spectral cameras. The window in the upper right (black text, grey background; Figure 9) is labeled ZTV and is a status window for the ZTV interface. Wait 30 seconds for the ZTV GUI to open.

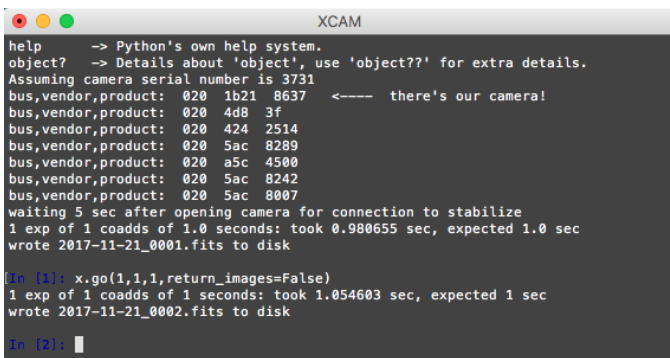


Figure 8: XCAM Terminal Window

- (c) Select [Auto-load file] radio button on the ZTV GUI under the default [Source] tab (Figure 10) to auto display the most current image from the slit viewing camera in the display window.
- (d) You will need to take a test image of the spectral channel which you will see displayed in the NIHTS LOUI. Use the `nihts.go` command in the XCAM terminal to take your exposure. The syntax is shown below:


```

ZTV
Last login: Tue Nov 21 14:53:34 on ttys002
sleep 20 && source activate xcam-python-ztv-dev && ztv
discarding /Users/xcam/anaconda2/bin from PATH
prepending /Users/xcam/anaconda2/envs/xcam-python-std/bin to PATH
(xcam-python-std)xcam:~ xcam$ sleep 20 && source activate xcam-python-ztv-dev &&
ztv
discarding /Users/xcam/anaconda2/envs/xcam-python-std/bin from PATH
prepending /Users/xcam/anaconda2/envs/xcam-python-ztv-dev/bin to PATH
Python 2.7.10 [Continuum Analytics, Inc.] (default, Oct 19 2015, 18:31:17)
Type "copyright", "credits" or "license()" for more information.

IPython 4.0.0 -- An enhanced Interactive Python.
?                -> Introduction and overview of IPython's features.
%quickref        -> Quick reference.
help             -> Python's own help system.
object?         -> Details about 'object', use 'object??' for extra details.

In [1]: 

```

Figure 9: ZTV Status Terminal Window

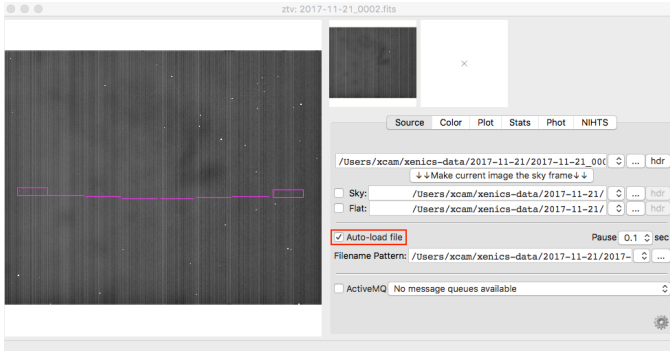


Figure 10: ZTV GUI: Source Tab

- `nihts.go(nexp=1, exptime=1, target='test', frame_type='object', comment1='Slit: None, Position: None', aborterror=False)`
- (e) For the first exposure you should see a note about bad telemetry in the LOIS log window and no image displayed in the viewer. Take another test image for the display to appear. The data will now begin saving to the new directory. You will need to click the [CURRENT] button in the NIHTS LOUI to see the display.
- (f) **IMPORTANT NOTE:** If you start up a ZTV session before the UT date has switched (5pm MST), you will need to redo the entire Mac Mini NIHTS Startup (starting at Step 2b above) when the UT date changes. This is a known bug that will eventually get fixed.

3 Calibration

Calibrations for NIHTS include arc line spectra from a Xenon lamp mounted inside the instrument cube and dome flat field exposures. The dispersion solution for NIHTS is very stable ($\Delta\lambda < 0.0005 \mu m$) across the full range of pointing geometries (see Section 8.6), thus in most use cases calibrations will only be required at the beginning of the night. This stability has only been tested under temperature ranges $\sim 2-6^\circ$. Batch scripts are provided to collect relevant calibration frames for all available slits. Setting up for and running these scripts takes approximately 30 minutes and can be completed before twilight.

3.1 Xenon Arc Lamp

1. Ask the telescope operator to put the dichroic in place for NIHTS (nominal position: 237.9 mm). The instrument cover should be closed at this time.

2. On the command line in the XCAM terminal window type the following:

(a) `run -i NIHTS_arcs.py`

- i. This script will turn on the Xenon lamps and take 5 exposures at 120 seconds each. There is no required warm-up time for the lamps. The script will then turn the lamps off and take 1 exposure at 120 seconds to capture the thermal background. A background subtracted arc line spectrum is shown in Figure 11.

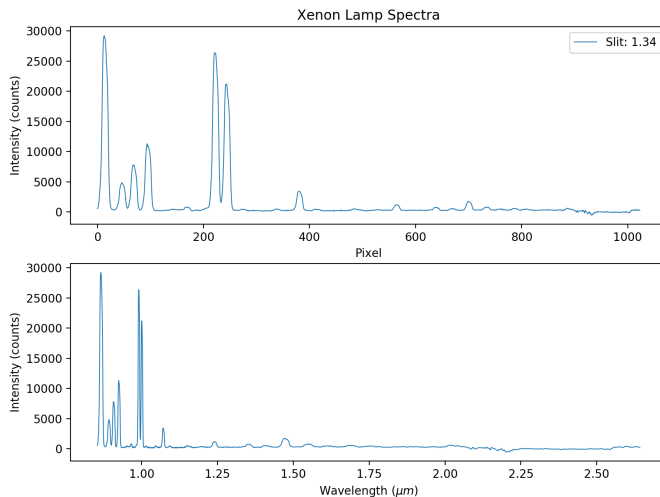


Figure 11: Five co-added arc lamp exposures at 120-sec each. Background subtraction from a 120-sec image without the lamps on has been applied. Faint lines are detectable to ~ 2 microns. On sky observations of planetary nebulae have provided an extended wavelength calibration out to 2.166 microns. This spectrum was taken with the 1.34 arcsec slit on 2017-12-18.

3.2 Dome Flats

1. Ask the telescope operator to move the telescope to the Dome Flat Screen. The dichroic should still be in place. You will need to ask the operator to open the instrument cover and mirror cover. At this point, no flat lamps are on.
2. On the command line in the XCAM terminal window type the following:

(a) `run -i NIHTS_flats.py`

- i. This script takes 1 exposure for each slit width starting with the Flat Lamps OFF. These exposure times are listed below in Table 1.
- ii. Once these exposures are complete, the script will prompt you to ask the telescope operator to turn the Deveny Flat Lamps ON at an intensity of 6V.
- iii. The script will then take 10 exposures for each slit width with the Flat Lamps ON. Example flat field spectra for each slit are shown in Figure 12. Exposure times for these flats were chosen to produce sufficient counts across the spectrum without saturating due to thermal background at long wavelengths.

4 Observing Procedure

4.1 Observing Logs

Many astronomers like to take logs as a backup to image header information. We have created a NIHTS Observing Log (pdf) which you can locate on the **dct-obs1** (or **dct-obs2**) desktop

| Slit # | Slit Width (") | Exposure Time (s) | # Exposures |
|--------|----------------|-------------------|-------------|
| 1 | 4.03 | 1 | 10 |
| 2 | 1.34 | 3 | 10 |
| 3 | 0.81 | 6 | 10 |
| 4 | 0.27 | 15 | 10 |
| 5 | 0.54 | 7 | 10 |
| 6 | 1.07 | 4 | 10 |
| 7 | 1.61 | 2 | 10 |
| 8 | 4.03 | 1 | 10 |

Table 1: Deveny 6V Lamp Dome Flat exposure times for each slitlet.

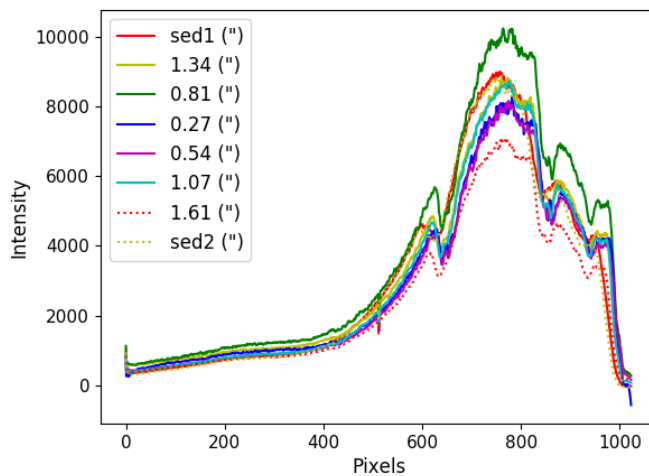


Figure 12: Slice along the dispersion axis of flat field exposures for each slit. Exposure times have been set to achieve peak counts $\sim 6000 - 8000$.

available for printing, or to adopt electronically (xls). There is currently one version of the log, but in the near future, two versions of the log will be available -one for NIHTS only observing, and the second for simultaneous NIHTS-LMI observing. See Appendix D.

4.2 Wavefront Solution

Ask the telescope operator to perform a Wavefront Solution at the beginning of your observing run. This will remove any higher order aberrations in the system. It will take about 15-20 minutes and can be performed in twilight. Note: If the conditions have changed significantly across the night, you may want to do more than one Wavefront Solution.

4.3 Focus Loop

1. Ask the telescope operator to point to a nominal NIHTS focus star (J=12-13) from the UCAC4 catalogue by referencing the 2MASS magnitudes.
2. Acquire the star by creating a background subtracted image. First, take a 3-second exposure of the star on the NIHTS slit viewing camera using the `x.go(exptime_sec, coadds, nexp return_images=False)` command.

```
> x.go(3,1,1,return_images=False)
```

- In the ZTV Source tab, set this image to be the background image by clicking [Make Current Image the Sky Frame].
- Select the ZTV NIHTS Tab (Figure 13) and use the hand paddle to offset 20" in any direction. Take another 3-second exposure. You should now see the focus star very clearly.

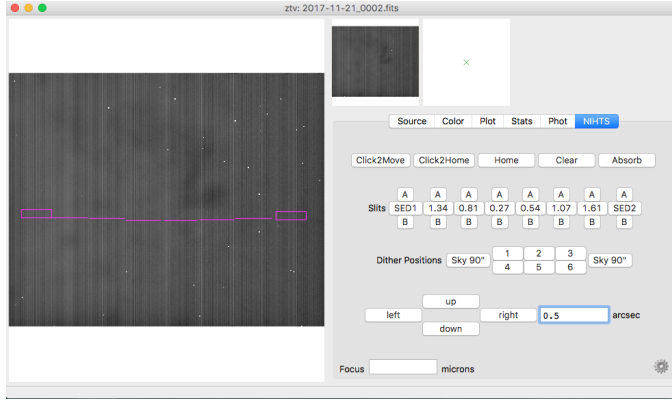


Figure 13: ZTV GUI NIHTS Tab

- Select the ZTV Phot tab. Then, change cursor mode by right-clicking in the image with your mouse and selecting “Phot” from the pull-down menu. The Phot Panel is shown in Figure 14.
- Click on your focus star. You will see a gaussian profile fit in the ZTV PHOT window where the blue annulus contains the focus star and the red annulus defines the background. You want a focus star with ~ 6000 - 8000 peak counts with a three second exposure. You can use the FWHM (pix) to estimate the current seeing (plate scale = $0.32''$).

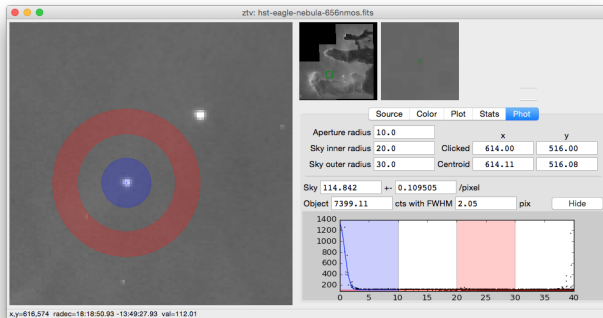


Figure 14: ZTV GUI PHOT Tab

- At this point, you can either run a focus script from the XCAM iPython environment or perform a focus sequence manually:
 - **Focus Script** (see Appendix A for more details on this script):


```
> run -i NIHTS_focus.py xpos ypos -filter -seeing -x_exptime -step -gdr_str
```

 - Note the x, y position of the focus star using the centroid in the ZTV GUI Phot tab.
 - Specify the LMI filter *only* if using LMI and NIHTS simultaneously.

- **Manual Focus:**

- (a) The nominal NIHTS M2 focus offset at the current dichroic position of 237.9 mm is 1000 microns.
- (b) If you are not using LMI, then proceed to Step f. If you are planning to use LMI simultaneously, proceed to Step c.
- (c) Have the telescope operator move the NIHTS dichroic fold mirror stage to the appropriate position corresponding to the LMI filter of choice (see Table 2 for the dichroic positions defined for each LMI filter).
- (d) Set the LMI filter position to OPEN/OPEN. Confirm the focus offset is set to the nominal LMI OPEN filter value of 810 microns. If not, set the focus with the following command in the XCAM terminal window:

```
> tcs.send_focus_microns(810)
```
- (e) Then, move the LMI filter wheel to the desired filter in the LMI LOUI. This will apply an M2 offset.
- (f) Focus on the NIHTS slit viewing camera:
 - i. Confirm the ZTV scaling is set to “linear” by right-clicking with your mouse and checking the scaling settings.
 - ii. Check the FWHM fit from the centroid photometry in the PHOT tab (Figure 14). Photometry parameters such as object aperture and sky annulus can be changed as needed in the ZTV Phot tab.
 - iii. Change the focus value from the XCAM terminal in 50 micron steps in both directions away from the nominal focus specific to the LMI filter. Note that if you set the focus offset to 810 microns before selecting the LMI filter, then you will already be at the correct nominal focus. Confirm this by referencing the values in Table 2 where 810 microns is the initial focus offset for the LMI OPEN filter position. Use the following command in the XCAM terminal window to change the focus:

```
> tcs.send_focus_microns('focus')
```

 for an integer focus offset.
 - iv. Take at least 3 exposures at each focus offset to get a sense of the variability and average FWHM.
 - v. Refine your best focus with 20 micron steps if the seeing is 1" or better. Increase the step size to greater than 50 microns if seeing conditions are poor.

4.4 Moving the Telescope

There are currently two ways for the astronomer to move the telescope into position:

1. Give the operator your coordinates (either on paper or by shouting across the room).
2. Construct a simple text file ahead of time and load it into the Target Observing List Tool (opened from the icon on the **dct-obs1** (or **dct-obs2**) Desktop) in order to select coordinates to send to the telescope. This process is detailed in Appendix F.
3. Edit one item at a time manually into the Target Observing List Tool.

| LMI Filter | Focus Offset (μm) | Dichroic Position (mm) |
|--------------------------------|--------------------------|----------------------------|
| <i>Miscellaneous Filters</i> | | |
| Open | 0 | 239.95 |
| VR | +185 | 237.84 |
| <i>Johnson-Cousins Filters</i> | | |
| B | +105 | 238.76 |
| V | +105 | 238.76 |
| R | +140 | 238.36 |
| <i>Sloan (SDSS) Filters</i> | | |
| g' | +180 | 237.90 |
| r' | +180 | 237.90 |
| i' | +180 | 237.90 |
| <i>Narrow Band Filters</i> | | |
| [OIII] | +205 | 237.62 |
| H α -On | +155 | 238.19 |
| H α -Off | +155 | 238.19 |
| <i>Wolf-Rayet Filters</i> | | |
| WC | +165 | 238.07 |
| WN | +160 | 238.13 |
| CT | +170 | 238.01 |
| <i>Comet Filters</i> | | |
| Blue Continuum (BC) | +175 | 237.96 |
| Green Continuum (GC) | +175 | 237.96 |
| Red Continuum (RC) | +175 | 237.96 |

Table 2: Focus offset and dichroic positions for LMI filters which can be used simultaneously with NIHTS. Note the nominal focus value for the Open filter is 810 microns. See Section 8.1 for the dichroic transmission curves.

4.5 Target Acquisition

**** IMPORTANT NOTE **** *The ZTV GUI and the XCAM command line are separate ipython environments and do NOT communicate with one another. As a result, we do not recommend moving to slitlets from **Home** using the ZTV GUI. The scripts handle the separate ipython environments, but if you are doing the moves by hand, this can get messy very quickly.*

1. Send your target coordinates through the Target List tool or ask the telescope operator to slew to the RA/DEC location of your target.
2. Take a test exposure on the Slit Viewing Camera from the XCAM terminal window:

```
> x.go(1,1,1,return_images=False)
```

3. You need to Home your target in the slit viewing camera by using the [Click to Home] button in the ZTV NIHTS tab. Click the [Click to Home] button then click on your target. This moves the target to the **Home** location. (You can [Click to Home] multiple times for better accuracy because there is currently no centroiding.) Take an exposure to confirm the location of your target is actually at **Home** defined as the center of the

chip (160,128). Once at home, on the XCAM command line enter the following command:
`tcs.current_target_pt = tcs.home_pt`

Now both interfaces (ZTV and XCAM terminal) know that the target is at **Home** and you can send offsets to move your object to the desired slit position.

****IMPORTANT NOTE**** *The **Home** location is critical. All slit positions are defined relative to this **Home** location. If you forget to send your target to **Home** before trying to access a slit location, then the pointing will not be where you expect. The **Home** location needs to be set separately in ZTV and the XCAM terminals.*

4. If you would like to guide, ask the telescope operator to setup guiding. Once guiding is running you may want to confirm on ZTV that object is still at **Home**.

5. Move the target to the desired slit and position (A or Cen) using the `tcs.move` command:

```
> tcs.move_to_slit_position(tcs.slits['slit']['A/Cen'])
```

6. Confirm the target has moved to the correct position by taking an xcam exposure. Note that the A/B positions are noted as hatch marks on each slit outline on the ZTV display.

```
> x.go(exptime_sec, coadds, nexpt, return_images=False)
```

7. Collect spectra of your target by executing nod sequences on the command line in the XCAM terminal window. There are currently three scripted nod sequences, all of which expect the pointing to begin with the object on the slit at either the A or Center position. See Section [A](#) for more details on these scripts:

- (a) AB: nods the target from the A beam position to B beam position. The target can be returned to the A beam position with a call to `tcs.move_object_on_xcam`

```
> run -i NIHTS_AB.py target slit n_exptime -x_exptime -x_coadds -gdr_str
```

- (b) ABBA: takes 1 exposure at A beam position, 2 at B, and 1 at A.

```
> run -i NIHTS_ABBA.py target slit n_exptime -nseq -x_exptime -x_coadds -gdr_str
```

- (c) Center/off: takes 1 exposure at the Center position, dithers off slit at a specified distance in arcseconds and direction (RA, DEC, LEFT, RIGHT, UP, DOWN).

```
> run -i NIHTS_CO.py target slit n_exptime -nseq -x_exptime -x_coadds -direction -offset -gdr_str
```

8. You can also take exposures with the science camera individually . To take a single exposure, use the `nihts.go` command where you can specify the target name, slit, and position, or take a test image.

```
> nihts.go(nexpt=1, exptime=1, target='test', frame_type='object',  
comment1='Slit: None, Position: None', aborterror=False)
```

9. If you think ZTV and the command line are out of sync, reset both ZTV and XCAM to **Home** as described in step 3 above.

- ZTV: [Click to Home]
- XCAM: `> tcs.current_target_pt = tcs.home_pt`

10. **Don't forget!** Clear your offsets before moving to the next target! This can be done in the Target List, on the command line, in the ZTV GUI, or by asking the telescope operator.

4.6 Rotator Frame

The telescope can operate in two different rotator modes: *Target* mode which maintains field orientation during exposures, and *Fixed* mode which keeps the focal plane fixed relative to alt-az coordinates, typically set to the parallactic angle (i.e. perpendicular to the horizon). These modes are set by the telescope operator and need to be specified when setting up on a target. Confirm the current rotation angle by referencing the ‘ROTIPA’ keyword in the Facility Summary.

- **Target Mode:** With the rotatorFrame=“Target”, the default angle of 0° results in the NIHTS slit viewing camera oriented with N to the right and E up (LMI orientation will be N up, E left). Setting the rotator PA to 30° will change this orientation by 30° from north through east. We recommend you use Target Mode for situations when you are observing at low airmasses (roughly <1.5). The telescope can more easily keep your target fixed on the slit.
- **Fixed Mode:** In rotatorFrame=“Fixed” mode, the rotator PA is the mechanical angle of the instrument cube and stays constant relative to the horizon. We recommend you use Fixed Mode when you are at high airmass (roughly >1.5). As you move to lower airmass, it can be difficult to keep your target on the slit in Fixed mode.

4.7 Telescope Offsets

The telescope control supports both relative and absolute offsets (described below). These can be applied in a number of ways including through the ZTV, with the XCAM terminal, and by the telescope operator. It is important to note that these control interfaces do not necessarily communicate with one another, which can lead to confusion regarding the current pointing state of the telescope. The best way to recover from this is to zero the pointing by clearing the offsets and reacquire the target.

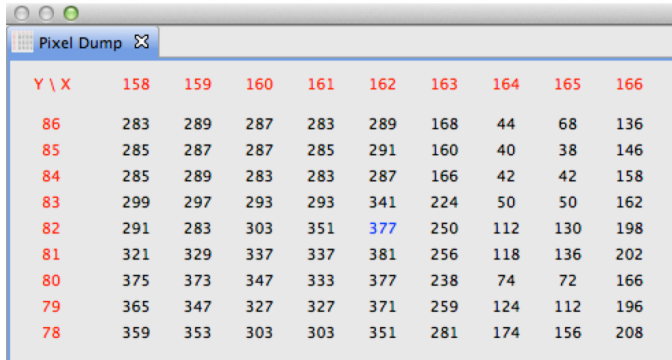
- **Relative:** These offsets can be applied in the ZTV and XCAM terminal. These offsets are applied relative to the current pointing location and can be repeatedly applied to accumulate net offsets relative to a reference zero point, often the original target pointing. In the ZTV NIHTS tab, pressing the [Clear] button will return the telescope to its reference zero point position. The [Absorb] button will define a new zero point at the current pointing. You can select the [Clear] and [Absorb] buttons in the ZTV or send offsets via the XCAM command line. Any cumulative offsets you’ve applied will continue to be applied to every new pointing until explicitly cleared by hitting [Clear].
- **Absolute:** These offsets are currently only available to the telescope operator. Absolute offsets are applied relative to the pointing zero point. Repeatedly applying the same absolute offsets will not move the telescope. Whatever you have applied here will continue to be applied to every new pointing until explicitly cleared by hitting [Clear] in ZTV. To reset the pointing zero point to the current location, use the [Absorb] button in ZTV.

4.8 Real Time Image Analysis

Real time image analysis tools for the NIHTS spectral channel images (i.e. in the LOUI, not in ZTV) include image differencing, pixel dump, single column/row line profiles, and averaged column/row line cuts. There are four image display options: Current, Previous, Reference, and Diff. The Reference image is selected using the NIHTS menu on the image viewer toolbar. The difference

image (Diff) is created by subtracting the reference image from the currently selected image – Current, Previous or Reference. For example, if the Current image is displayed, then clicking Diff will display Current - Reference. Image analysis can be performed on any of the images.

- Pixel Dump: This displays a text version of the pixel counts in a 9x9 region in the Pixel Dump tab. This function is toggled on and off by placing the cursor in the image, and typing p. But, be warned: these are “sampled” values because of the under-sampling that LOUI does for image display, so the peak intensity of a star may not be correct, and similarly a bad column or other defect may escape notice. An example of the Pixel Dump tab is shown in Figure 15.



| Y \ X | 158 | 159 | 160 | 161 | 162 | 163 | 164 | 165 | 166 |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 86 | 283 | 289 | 287 | 283 | 289 | 168 | 44 | 68 | 136 |
| 85 | 285 | 287 | 287 | 285 | 291 | 160 | 40 | 38 | 146 |
| 84 | 285 | 289 | 283 | 283 | 287 | 166 | 42 | 42 | 158 |
| 83 | 299 | 297 | 293 | 293 | 341 | 224 | 50 | 50 | 162 |
| 82 | 291 | 283 | 303 | 351 | 377 | 250 | 112 | 130 | 198 |
| 81 | 321 | 329 | 337 | 337 | 381 | 256 | 118 | 136 | 202 |
| 80 | 375 | 373 | 347 | 333 | 377 | 238 | 74 | 72 | 166 |
| 79 | 365 | 347 | 327 | 327 | 371 | 259 | 124 | 112 | 196 |
| 78 | 359 | 353 | 303 | 303 | 351 | 281 | 174 | 156 | 208 |

Figure 15: Pixel Dump

- Line Profile: The Line Profile tool allows the user to make line and column plots: typing 1 in the image display will display just the region that spans the image view, while an L will provide line and column plots of the whole image. An example of the Line Profile tab is shown in Figure 16. Typing 1 or L a second time will turn the Line Profile tool off. Before switching images for analysis, you must turn the tool off. Once the new image is displayed, you are then able to turn the tool back on by typing 1 or L.

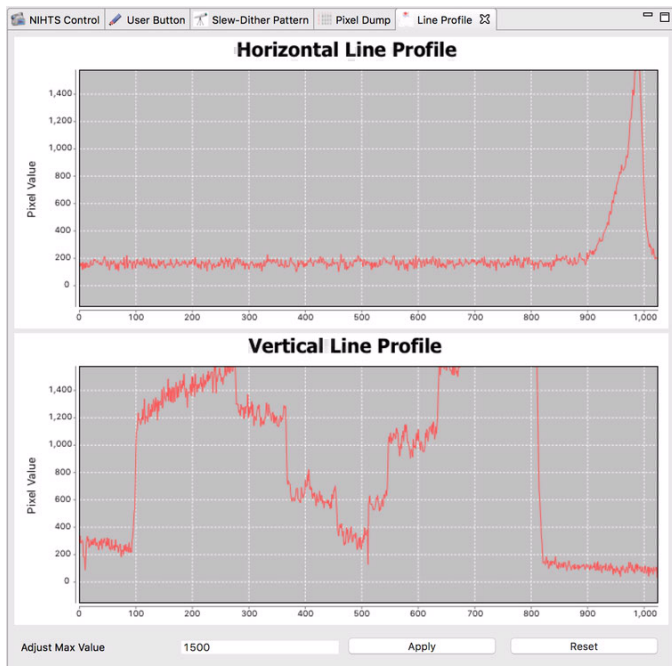
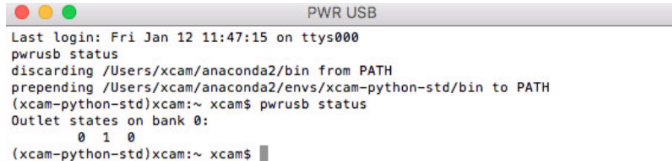


Figure 16: Line Profile

- Line Cut: This feature allows you to create horizontal and vertical cuts by drawing a rectangle around a region of interest. The Horizontal Line Cut averages the rows in the box, while the Vertical Line Cut averages the columns. The vertical cut is useful to monitor the current seeing, as the tool will fit a 1-D Gaussian profile to the average across the columns.

5 End of the Night

1. dct-obs1 (or dct-obs2):
 - (a) Exit out of LOUI by clicking the red [X] in the upper left corner.
 - (b) Do NOT [Exit LOIS].
 - (c) Do NOT close the `obsnihts@nihts` terminal window.
2. Close the Target List if you have it open.
3. Mac Mini:
 - (a) Exit ZTV and the corresponding terminal window.
 - (b) Exit the XCAM terminal window.
 - (c) In the white terminal window (“PWR USB”) located in the top right corner of the Mac Mini screen share (Figure 17 below), turn off XCAM by typing the command:
`> python NIHTS_shutdown.py`
 Leave this terminal window open.



```

PWR USB
Last login: Fri Jan 12 11:47:15 on ttys000
pwrusb status
discarding /Users/xcam/anaconda2/bin from PATH
prepending /Users/xcam/anaconda2/envs/xcam-python-std/bin to PATH
(xcam-python-std)xcam:~ xcam$ pwrusb status
Outlet states on bank 0:
  0 1 0
(xcam-python-std)xcam:~ xcam$
  
```

Figure 17: PWRUSB Terminal Window

- (d) Close Mac Mini Screen Sharing Window.

4. Fill out the End of Night Report found on the dct-obs1 (or dct-obs2) Desktop.

6 Taking Your Data Home

dct-obs1 (or dct-obs2):

- NIHTS: `/nihts/YYYYMMDDa` (or `b` or `c` or ...)
- LMI: `/LMI/YYYYMMDDa` (or `b` or `c` or ...)

MacMini:

- XCAM: `/Users/user/xcam/xenics-data/YYYY-MM-DD`

7 Important Tips and Troubleshooting

1. ZTV can be closed and restarted without problems.
2. Restarting the XCAM terminal requires a full NIHTS_Startup reboot. See Section 2 for restart instructions.
3. Every time you restart XCAM, you must take a test image on both the slit camera and NIHTS before running any scripts. See Section 2d.
4. Starting before UT turnover in ZTV, requires you to restart ZTV because the date directory changes at turnover. Terminal→New Window→ZTV. Here you would also need to take test images on both the slit viewing camera and NIHTS. See Section 2.
5. When starting up XCAM, if an ipython environment is not active in the XCAM terminal window, try restarting XCAM. See Section 2.
6. If a nod script fails partway through but the ipython environment is still active, then you will need to re-Home your target in ZTV and on the XCAM command line. If the failed script backs out of ipython, you need to do an XCAM restart. See Section 4.5.
7. The two environments ZTV and XCAM can get confused and have different values for the current telescope pointing (`tcs.current_target_pt`). Correct this by sending the target to Home in the ZTV window and forcing the current target point to equal **Home** on the XCAM command line. See Section 4.5.

```
> tcs.current_target_pt = tcs.home_pt
```
8. If you get images of zero value (i.e. they show up all black with no data in them), you will need to restart LOIS and re-initialize in the LOUI. This is a symptom of an instrument controller crash (instrument LEDs are in a two-light state) which requires reestablishing connection with the instrument through a LOIS restart. LOIS can be restarted within restarting the LOUI. See 2.
9. If you see the error “missing tcsStatus and/or tcsTelemetry or unable to figure out posang, so no move sent”, try to resend your target. Otherwise, check the broker status.

8 Instrument Overview

The Near-Infrared High-Throughput Spectrograph (NIHTS, pronounced “nights”) is a low-resolution (R200) near-infrared prism spectrograph, covering 0.86-2.4 microns in a single order. NIHTS contains no moving parts and employs a single slit mask with 7 different slit widths (4.03, 1.34, 0.81, 0.27, 0.54, 1.07 and 1.61 arcseconds), each approximately 10 arcseconds in length. An instrument schematic is shown in Figure 18 where light enters from the telescope on the lower right, is redirected twice off of an Offner relay, passes through the slit mask, out to a large fold mirror and a ZnSe prism, and then back through the fold mirror to be imaged onto a HAWAII-1 array. The entire assembly is chilled with two Sunpower closed-cycle Stirling cryocoolers. NIHTS is fed by a dichroic at the center of the instrument cube (Figure 19) which enables simultaneous LMI imaging and NIHTS spectroscopy.

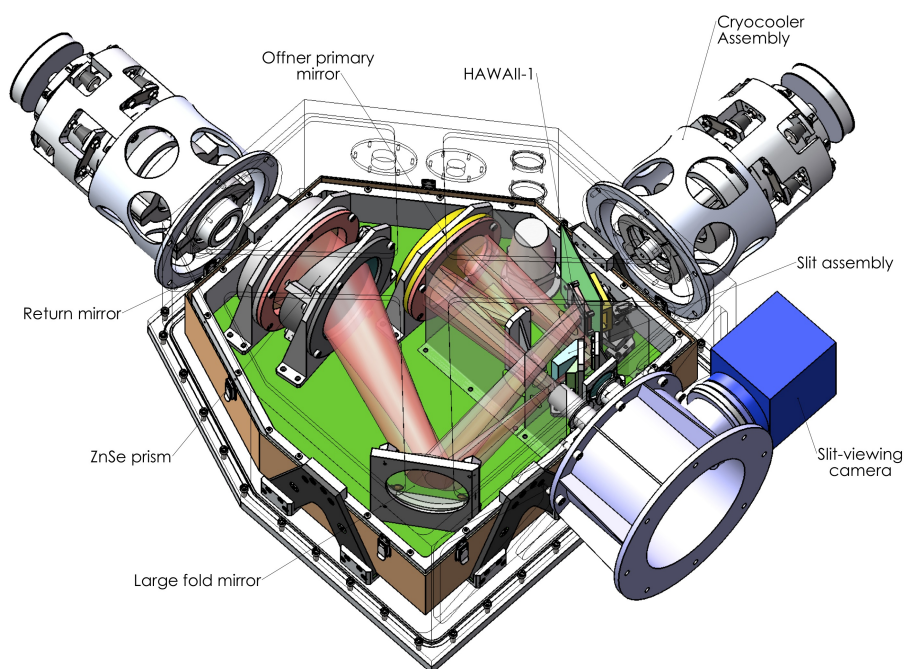


Figure 18: NIHTS Layout

8.1 Dichroic Mirror

The NIHTS dichroic sits in the Fold Mirror D location in the instrument cube. The dichroic transmits visible wavelengths and reflects the near-infrared, allowing for simultaneous observing with LMI and NIHTS. The visible wavelength transmission of the dichroic is about 90% between 0.4 and 0.7 microns. The LMI filters with transmission profiles that overlap the dichroic transmission are given in Table 2.

8.2 LMI Field of View

The full LMI field of view is reduced during simultaneous NIHTS/LMI observing due to obstruction by the dichroic. Changing the LMI filter automatically causes offsets of the secondary mirror to

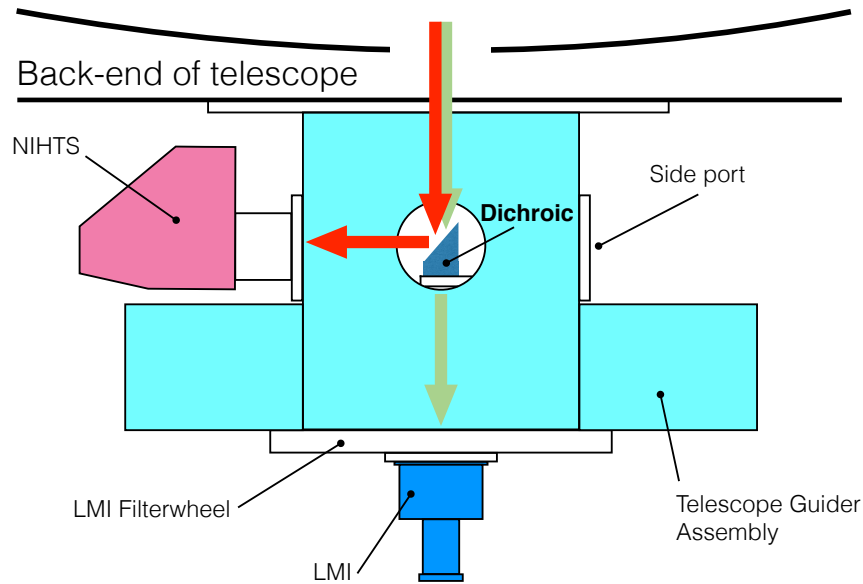


Figure 19: NIHTS lightpath through the instrument cube with the dichroic for simultaneous LMI and NIHTS observing.

accommodate for filter-dependent focus. The dichroic has to be offset to compensate for this change in light path to keep NIHTS in focus. As a result the unobstructed region on LMI will shift with these dichroic offsets. Figure 21 is an LMI flat in SDSS r' with the NIHTS dichroic inserted into the light path. The dichroic was inserted to full extension (242.1 mm) and then retracted 4.2mm (237.9mm) to achieve focus on NIHTS. The central region in grey is roughly 6×4 arcmin in size and throughput drops off steeply outside of that region. Table 2 provides computed dichroic positions for each filter.

8.3 Slit Mask

The slit mask contains a single slit broken up into 7 different slit widths – referred to as slitlets – in a configuration with the widest slitlets near the edge of the mask, and the narrowest slitlets in the middle. Each slitlet is $10''$ long. The slit widths from left to right in the slit viewing camera (top to bottom on the spectrographic detector) are $4.03''$, $1.34''$, $0.81''$, $0.27''$, $0.54''$, $1.07''$, $1.61''$, and $4.03''$. Figure 22 shows a cartoon schematic of what is visible on the slit viewing camera. The two widest slits ($4.03''$) are referred to as SED1 and SED2 where SED stands for spectral energy distribution. These slits are designed to eliminate slit losses to enable spectro-photometric calibration. The approximate pixel locations of each slit on the slit viewing camera are detailed in Table 3. The pixel location of the narrowest slitlet ($0.27''$) is not well constrained. There are other factors, including the location of the amplifier boundaries on the spectral channel, that make the $0.27''$ slitlet difficult to use. As such, we do not recommend the use of this slitlet at this time. The measured per pixel resolution and resolving power of each slitlet at 1, 1.5, and 2 microns are defined in Table 4.

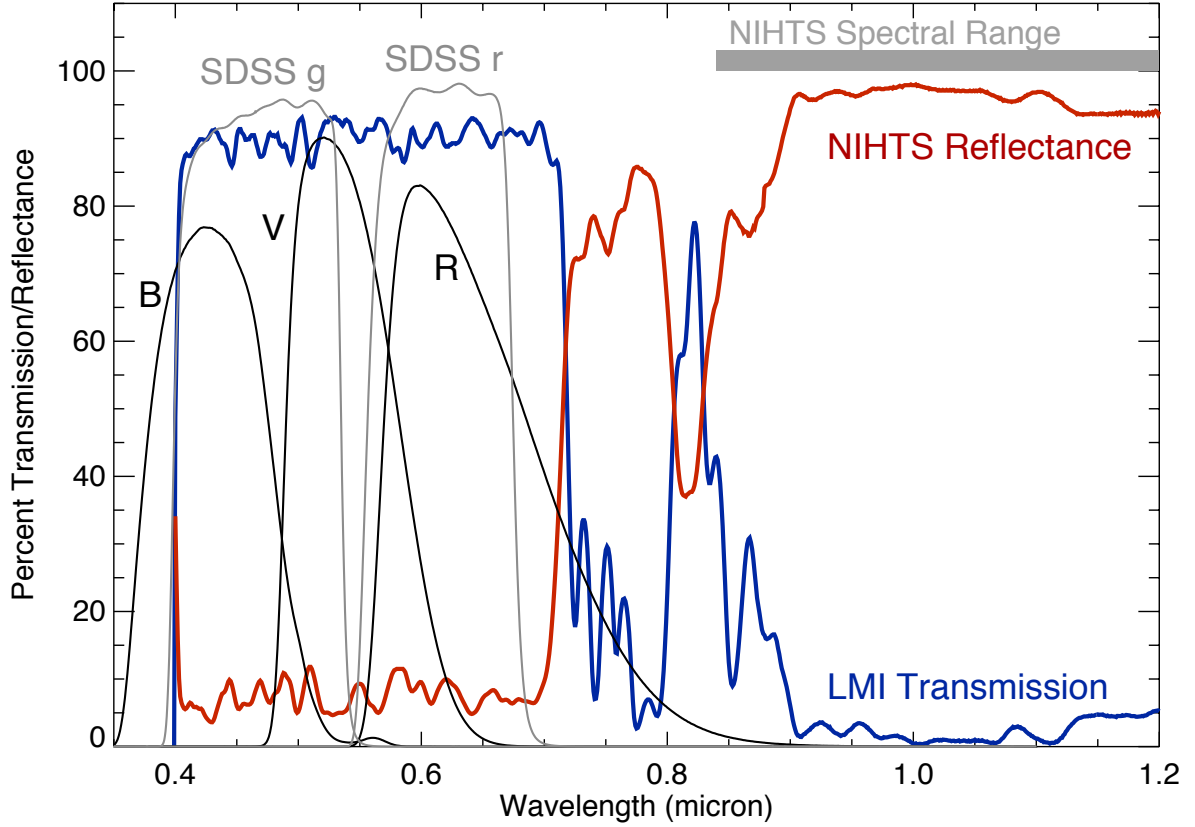


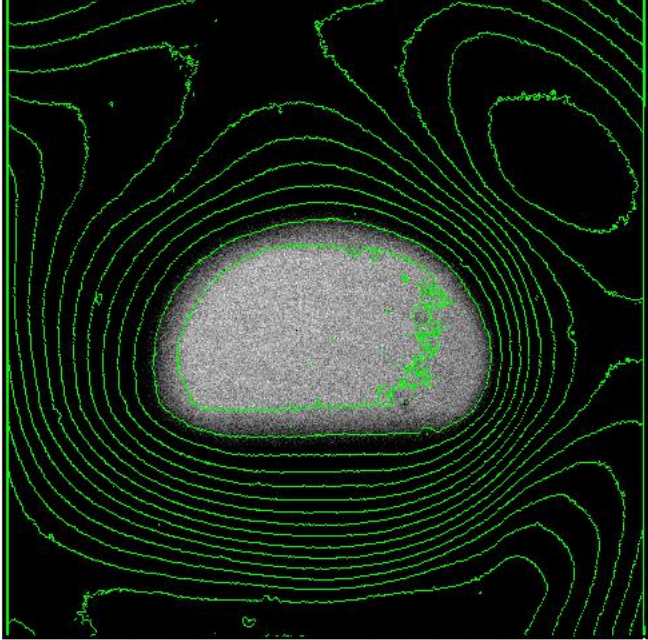
Figure 20: Dichroic transmission through to LMI and reflectance to NIHTS. The spectral range of NIHTS is shown. These curves are roughly constant longwards of 1.0 micron out to 2.4 microns. The transmission through to LMI spans wavelengths that overlap Johnson-Cousins BVR and SDSS g'r' filters.

| Slit # | Slit Width (") | Y Center | A Position | B Position | Center |
|--------|----------------|----------|------------|------------|--------|
| 1 | 4.03 | 122 | 15.3 | 30.7 | 23 |
| 2 | 1.34 | 117.8 | 49.8 | 65.2 | 57.5 |
| 3 | 0.81 | 116.9 | 87.8 | 103.2 | 95.5 |
| 4 | 0.27 | 114.3 | 125.2 | 140.7 | 133 |
| 5 | 0.54 | 115.1 | 162.8 | 178.2 | 170.5 |
| 6 | 1.07 | 116.9 | 198.3 | 213.7 | 206 |
| 7 | 1.61 | 116.8 | 234.3 | 249.7 | 242 |
| 8 | 4.03 | 122 | 273.3 | 288.7 | 281 |

Table 3: Slit Positions on the Slit Viewing Camera

8.4 Coadds

Currently NIHTS only supports coadds on the slit viewing camera. NIHTS does not support coadds at the time of data acquisition on the spectral channel. The observer can coadd by stacking spectral images post-observing.



20171219a/lmi.0061.fits - r' flat, NIHTS dichroic retracted 4.2mm from full

Figure 21: Observable field of view on LMI with dichroic deployed. The unobstructed field size is $6.4' \times 4.1'$. The green contours are at 500 ADU intervals between 15,000 and 25,000 counts. Image courtesy of Stephen Levine (Lowell).

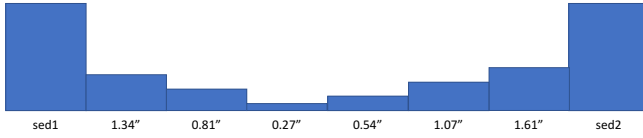


Figure 22: Schematic of the NIHTS slit mask with 8 slitlets of 7 different widths, each $10''$ long.

| Slit # | Slit Width ($''$) | R= $\lambda/\delta\lambda$ (per pix) | | | R' = R/slit_width | | |
|--------|---------------------|--------------------------------------|------------|----------|-------------------|------------|----------|
| | | $1\mu m$ | $1.5\mu m$ | $2\mu m$ | $1\mu m$ | $1.5\mu m$ | $2\mu m$ |
| 1 | 4.03 | 2125 | 675 | 546 | 69 | 22 | 18 |
| 2 | 1.34 | 2194 | 667 | 535 | 196 | 60 | 48 |
| 3 | 0.81 | 1813 | 680 | 525 | 271 | 101 | 78 |
| 4 | 0.27 | 1283 | 682 | 502 | 583 | 310 | 228 |
| 5 | 0.54 | 2087 | 663 | 521 | 464 | 147 | 116 |
| 6 | 1.07 | 2152 | 667 | 531 | 242 | 75 | 60 |
| 7 | 1.61 | 2311 | 645 | 513 | 172 | 48 | 38 |
| 8 | 4.03 | 2113 | 680 | 548 | 68 | 22 | 18 |

Table 4: Measured resolution per pixel and effective resolving power of each slit at three reference wavelengths

8.5 Detector Linearity and Saturation

To first order, the NIHTS detector is linear up to about 17,500 counts in all wavelengths (Figure 23). The detector saturates earlier in the longer wavelengths. We will be performing a more detailed pixel by pixel linearity mapping. Coming soon...

Table 5 below shows the maximum wavelength reached prior to saturation in each of the slits with respect to a given exposure time. The NIHTS detector is sensitive up to $2.45 \mu m$.

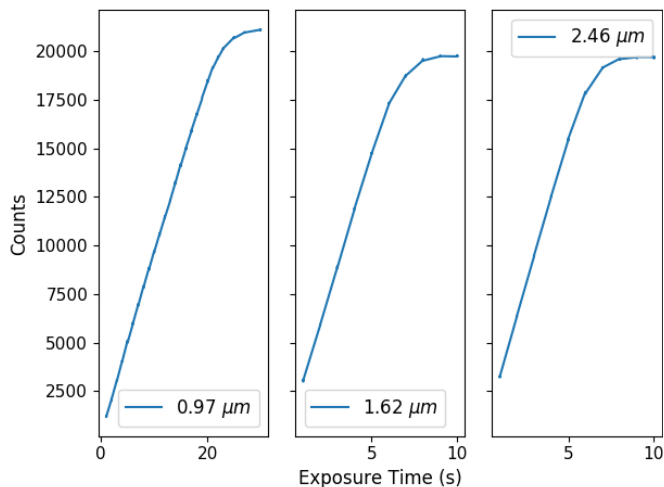


Figure 23: Linearity test with increasing exposure time vs counts at $0.97 \mu m$, $1.62 \mu m$, and $2.46 \mu m$.

| Slit (") | sed1 | 1.34 | 0.81 | 0.27 | 0.54 | 1.07 | 1.61 | sed2 |
|-------------|------|------|------|------|------|------|------|------|
| ExpTime (s) | | | | | | | | |
| 3 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 |
| 4 | 2.40 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.40 |
| 5 | 2.35 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.35 |
| 10 | 2.30 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.40 | 2.30 |
| 20 | 2.20 | 2.30 | 2.45 | 2.45 | 2.45 | 2.40 | 2.30 | 2.20 |
| 30 | 2.20 | 2.30 | 2.35 | 2.45 | 2.35 | 2.30 | 2.25 | 2.20 |
| 45 | 2.15 | 2.25 | 2.30 | 2.30 | 2.30 | 2.30 | 2.20 | 2.15 |

Table 5: Maximum accessible wavelength (in microns) for a given slit and exposure time. NIHTS is sensitive to a maximum wavelength of $2.45 \mu m$. Note that the wider slits saturate in the longer wavelengths much quicker than the smaller slits.

8.6 Dispersion Stability

We have quantified the dispersion stability in Y and J bands up to $1.4 \mu m$. Figure 24 shows sub-pixel stability at all rotation angles and elevations. We suggest that for most science cases, arc line calibrations at the beginning of the night will be sufficient for determining the dispersion solution.

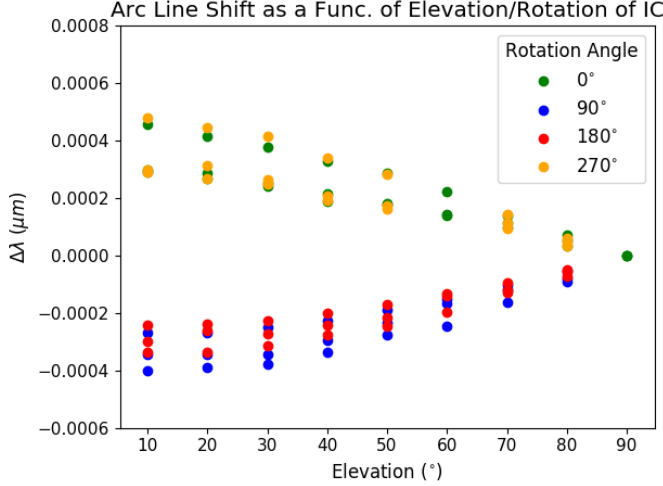


Figure 24: Wavelength shift ($\Delta\lambda$) of 3 different arc lines with rotation of the instrument cube and elevation changes from 10° to 90° .

8.7 NIHTS Efficiency

We determined the sensitivity of the NIHTS detector using spectrophotometric standard star Feige 110, observed through the SED1 ($4.03''$) slitlet. The results for the total flux measurements are outlined in Table 6. These data were used to derive the overall system throughput which is plotted as efficiency curves in Figure 25.

| Band | Wavelength (μm) | Mag. | Catalog Flux ($\text{erg s}^{-1}\text{cm}^{-2}\text{\AA}^{-1}$) | Integrated Counts | | | Mean Eff. (%) |
|------|---------------------------------|-------|--|-------------------|----------------------------|-------------------------|------------------|
| | | | | # pixels | Object (s^{-1}) | Sky (s^{-1}) | |
| Yish | 0.96 - 1.1 | 12.94 | 1.32×10^{-12} | 3640 | 29900 | 29500 | 44.8 |
| J | 1.1 - 1.4 | 12.55 | 2.54×10^{-13} | 2400 | 23000 | 36000 | 45.3 |
| H | 1.5 - 1.8 | 12.63 | 7.33×10^{-14} | 1140 | 16500 | 81000 | 36.5 |
| K | 2.0 - 2.4 | 12.77 | 2.18×10^{-14} | 970 | 10700 | 560000 | 30.4 |

Table 6: Measured counts integrated over different band passes for spectro-photometric standard star Feige 110. The resulting mean efficiency of the instrument and telescope is given in the last column.

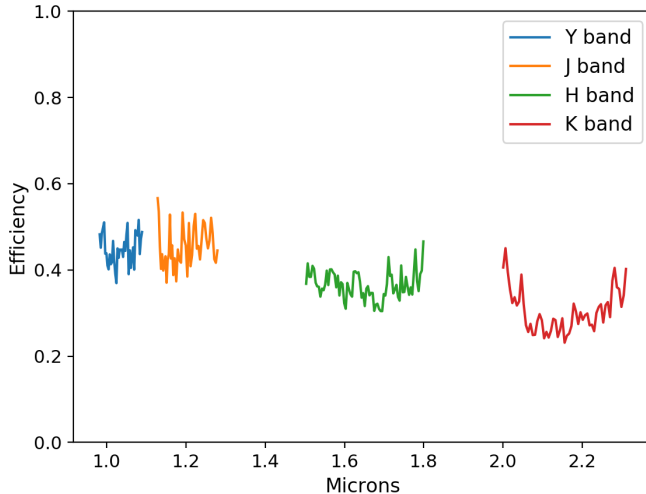


Figure 25: Measured NIHTS efficiency which accounts for telescope, dichroic, and detector throughput in Y, J, H, and K bands. Regions of telluric absorption, which can have highly variable transmission, have been excluded.

Acknowledgements

The overall system design and optical design of NIHTS was performed by Ted Dunham. Ted Dunham and Rich Oliver did the electrical design and construction of the instrument. Mechanical design was done by James French, Tomas Chylek, Frank Cornelius, Tom Binda, and Ted Dunham. Most of the NIHTS instrument parts were made by Steve Lauman and Jeff Gehring or by Boston University. The control software and user interface for the NIHTS ZTV was written by Henry Roe, while the NIHTS LOUI was written by Peter Collins, Saeid Zoonemat Kermani, and Dyer Lytle. Saeid also provided the Observer Target List application described in Appendix F.

Funds for the construction of the instrument were obtained from NASA's Planetary Astronomy and Planetary Major Equipment programs (PI: Henry Roe). The MANOS grant (PI: Nicholas Moskovitz), funded by the NASA Near-Earth Object Observations Program, has provided important support for finishing many of the commissioning tasks. The Mt. Cuba Foundation purchased the NIHTS dichroic coatings for which simultaneous observing with NIHTS and LMI is now possible. Phil Massey has provided documentation and figures used in the LMI Manual which have been critical in putting together a complete NIHTS manual. Stephen Levine has provided useful feedback, edits, and comments to improve the manual for the convenience of our observers.

A NIHTS Scripts

Until our NIHTS GUI is available, we operate the spectral channel and slit viewing camera with python based command lines. The scripts are designed to be run in the ipython environment with a `run -i` precursor. Following the script name are required and optional arguments. optional arguments are denoted with a dash (-) in front. Ex: `-nseq 2`.

> NIHTS_arcs.py

- *Description:* Take arc lamp exposures.
- Turns on the Xenon Arc lamp. Takes 5 exposures at 120-sec. Turns the Xenon Arc lamp off. Takes 1×120 -sec exposure to capture the thermal profile.

> NIHTS_flats.py

- *Description:* Take a sequence of flat field exposures for each of the slits.
- Takes 1 exposure at each slit-defined exposure time with flat lamps off to account for the thermal profile. The script prompts you to have the telescope operator turn on the Deveny 6V lamps. It then takes 10 exposures at each slit-defined exposure time with the flat lamps on.

> NIHTS_focus.py *xpos ypos* [-*filter*] [-*seeing*] [-*x.exptime*] [-*step*]

- *Description:* Take a focus sequence with the slit viewing camera.
- Move to a nominal NIHTS focus target of J=12-13. Note the x,y position of the star in ZTV, as you will need that in the script. If you are not using LMI, the LMI filter entry value in the script will be OPEN. Note that each LMI filter will require a different NIHTS dichroic position. The script handles this by prompting you to move the dichroic to a given location depending on the LMI filter you request. The script will take a total of 7 different focus steps with 4 exposures taken at each step. The images are copied to a folder entitled focus_0 (focus_1, focus_2, etc). $30'' \times 30''$ thumbnails are extracted around the star for each image. Gaussian fits are performed in both x and y directions. The FWHM of each fit is calculated and plotted against focus values for the final fits. The best focus for x and y are printed to the terminal screen. Once a focus is found in one LMI filter, you should be able to switch between filters and stay in focus, as long as you move the dichroic accordingly.

- Parameters:

- * **xpos** - x position of the star of interest
- * **ypos** - y position of the star of interest
- * **-filter** - (optional) LMI filter you will be using for simultaneous observations. If not using LMI, the default filter is 'SDSSr'. Choices for other filters are: 'OPEN', 'B', 'V', 'R', 'VR', 'SDSSg', 'SDSSr', 'SDSSi', 'OIII', 'Ha_on', 'Ha_off', 'WC', 'WN', 'CT', 'BC', 'GC', 'RC'. See Table 2 for more details on these filters.
- * **-seeing** - (optional) estimated sky seeing in arcseconds. The default is 2 arcsecond seeing. This value holds well for actual seeing between 1 and 2 arcseconds.
- * **-x.exptime** - (optional) slit viewing camera exposure time (s). The default is 3 second exposures.

- * **-step** - (optional) step size in microns. The default step size is 50 microns which is well suited for a well sampled focus curve. We recommend larger step sizes when the seeing is poor ($> 2''$). Smaller step sizes of 20 microns may be needed when seeing is better than 1 arcsecond, however step sizes less than 10 microns generally are not meaningful.

> **NIHTS_AB.py** *target slit n_exptime [-x_exptime] [-x_coadds] [-gdr_str]*

- *Description:* Two-exposure sequence with target nodded between A and B slit positions.
- Begin by placing your target in the A position of your desired slit in ZTV. The script will take one exposure at the A position. It will nod the telescope to the B position and take one exposure. You can monitor your target’s position on the slit with the slit viewing camera in ZTV. At any time, you can apply a small offset in the ZTV GUI to nudge your target back onto the center of the slit.
- **Parameters:**
 - * **target** - target name
 - * **slit** - slit width in arcseconds. Choices: SED1, 1.34'', 0.81'', 0.27'', 0.54'', 1.07'', 1.61'', and SED2.
 - * **n_exptime** - science detector exposure time (s)
 - * **-x_exptime** - (optional) slit viewing camera exposure time (s). The default is 1 second exposures.
 - * **-x_coadds** - (optional) the number of slit viewing camera coadds. The default is 1.
 - * **-gdr_str** - (optional) set this parameter to True if guiding. The default is False.

> **NIHTS_ABBA.py** *target slit n_exptime nseq [-x_exptime] [-x_coadds] [-gdr_str]*

- *Description:* Four-exposure sequence with target nodded between A and B slit positions.
- Begin by placing your target in the A position of your desired slit in ZTV. The script will take one exposure at the A position. It will nod the telescope to the B position and take two exposures. It will then nod back to A and take an exposure. The sequence of ABBA nods repeats for the number of sequences requested. You can monitor your target’s position on the slit with the slit viewing camera in ZTV. At any time, you can apply a small offset in the ZTV GUI to nudge your target back onto the center of the slit. This is extremely helpful if you are taking many sequences and your target is drifting slowly off slit.
- **Parameters:**
 - * **target** - target name
 - * **slit** - slit width in arcseconds. Choices: SED1, 1.34'', 0.81'', 0.27'', 0.54'', 1.07'', 1.61'', and SED2.
 - * **n_exptime** - science detector exposure time (s)
 - * **-nseq** (optional) the number of ABBA sequences you want. The default is 1 ABBA sequence.
 - * **-x_exptime** - (optional) slit viewing camera exposure time (s). The default is 1 second exposures.
 - * **-x_coadds** - (optional) the number of slit viewing camera coadds. The default is 1.
 - * **-gdr_str** - (optional) set this parameter to True if guiding. The default is False.

- > **NIHTS_CO.py** *target slit n_exptime nseq [-x_exptime] [-x_coadds] [-dir] [-offset] [-gdr_str]*
- *Description:* Exposure sequence with target nodded between slit center and off-slit positions.
 - Begin by placing your target in the Center position of your desired slit in ZTV. The script will take one exposure at the Center position. It will nod the telescope to the desired offset position requested in the command and take one exposure. The sequence of CO nods repeats for the number of sequences requested. You can monitor your target's position on the slit with the slit viewing camera in ZTV. At any time, you can apply a small offset in the ZTV GUI to nudge your target back onto the center of the slit.
 - **Parameters:**
 - * **target** - target name
 - * **slit** - slit width in arcseconds. Choices: SED1, 1.34", 0.81", 0.27", 0.54", 1.07", 1.61", and SED2.
 - * **n_exptime** - science detector exposure time (s)
 - * **-nseq** (optional) the number of ABBA sequences you want. The default is 1 ABBA sequence.
 - * **-x_exptime** - (optional) slit viewing camera exposure time (s). The default is 1 second exposures.
 - * **-x_coadds** - (optional) the number of slit viewing camera coadds. The default is 1.
 - * **-dir** (optional) the direction you want to offset your target. Choices are RA/DEC or UP/DOWN/LEFT/RIGHT. RA/DEC sends telescope offsets in arcseconds while UP/DOWN/LEFT/RIGHT moves the telescopes with pixel offsets. The default offset is UP.
 - * **-offset** (optional) the dither offset in the specified direction, either in arcseconds or pixels as defined in the direction. The default=20.
 - * **-gdr_str** - (optional) set this parameter to True if guiding. The default is False.

*Note: If there are scripts you need but don't see available, contact Nicholas Moskovitz and Annika Gustafsson at nmosko@lowell.edu and agustafsson@lowell.edu

B Useful iPython Commands

- `x.go(exptime_sec=None, coadds=None, nexp=None, return_images=False, save_every_Nth_to_currentfits=None)`
- `nihts.go(nexp=None, exptime=None, target=None, frame_type=None, comment1='Slit: None, Position: None', comment2=None, aborterror=False)`
- `tcs.absorb_target_offset`
- `tcs.clear_target_offset`
- `tcs.current_target_pt`
- `tcs.home_pt`
- `tcs.move_object_on_xcam(start_pt, end_pt, reset_current_target_pt=True)`
- `tcs.move_to_slit_position(tcs.slit['slit_width']['A/B/Cen'])`
- `tcs.send_focus_microns(focus_value_microns)`
- `tcs.target_offset(ra, dec, handset=False, simple=False, tplane=False)`

C PwrUSB

PwrUSB strip on NIHTS has 4 outlets. Three are controlled (numbered 1,2,3). The fourth is always on.

PwrUSB is controlled from the command line with the command `pwrusb`.

With no input parameters `pwrusb` provides documentation on itself. Examples:

- > `pwrusb status`
returns the current outlet states, in format: outlet states on bank BANK:
OUTLET1 OUTLET2 OUTLET3
where OUTLET state is 0=OFF, 1=ON
- > `pwrusb set OUTLET1STATE OUTLET2STATE OUTLET3STATE`
sets all 3 outlets to individually specified states where OUTLET[1-3]STATE— is 0=OFF, 1=ON
(anything except 0 is ON)
- > `pwrusb setall STATE`
sets all 3 outlets where STATE is 0=OFF, 1=ON (anything except 0 is ON)
- > `pwrusb setone OUTLETNUM STATE`
where OUTLETNUM is 1, 2, or 3 and STATE is 0=OFF, 1=ON (anything except 0 is ON)
- > `pwrusb current`
returns the total current being drawn (milliamp)

E Detailed Focus Procedure

This section describes the detailed process of focusing both NIHTS and LMI while confirming the expected M2 focus offset between these instruments. This procedure would not generally need to be run by the observer.

1. Move the NIHTS dichroic fold mirror stage to the fully deployed position.
2. Move the LMI filter wheel to the desired filter in the LMI LOUI.
3. Acquire the nominal NIHTS focus target (J=12-13) on the NIHTS slit viewing camera.
4. Focus on the NIHTS slit viewing camera per the usual focusing procedure.
5. Offset the M2 piston +370 microns from NIHTS M2 position determined in (3). If this or another offset is known to be correct, skip to step 6.
6. Acquire nominal LMI focus star on LMI. Offset telescope to place object near the center of the dichroic FOV, at pixel (1055, 950) for images binned 3x3.
7. Focus on LMI per standard procedure with the dichroic in position. Record final M2 position.
8. Calculate back-focus change:

$$\text{dBF } mm = 11.4 * [\text{M2-piston(LMI+dichroic)} - \text{M2-piston(NIHTS)}] mm$$

If LMI/dichroic focus was not redetermined in (4-5),

$$\text{dBF} = 11.4 * 0.370 mm = 4.22 mm$$

9. Read current position of fold mirror D

$$\text{FM-D-pos } mm$$

Calculate:

$$\text{FM-D-NIH-pos } mm = \text{FM-D-pos} - \text{dBF}$$

Enter result in FM-D Move field, and execute.

10. Offset telescope to reacquire target on NIHTS slit viewing camera. The offset should be along the NIHTS slit spatial direction, approximately:

$$\text{dA } (") = \text{dBF } (mm) * 8 ("/mm)$$

11. Verify image quality on NIHTS slit viewing camera.

F Observer Target List

There is an astronomer-friendly interface that allows one to construct an observing list and send the object coordinates to the operator. Full details can be found at <http://jumar.lowell.edu/confluence/display/DCTIC/Observer+Target+List>. A simple example is shown in Fig. 26.

```
#title=true ra=true dec=true epoch=false muRA=true muDec=true magnitude=true dRA=true dDec=true rotatorPA=true rotatorFrame=true comment=true
#
"Vega - Alpha Lyrae" 18:36:56.336 +38:47:01.28 200.94 286.23 0.03 1.0 2.0 3.0 Target "line 1"
"HR 173 - HD 3795" 00:40:32.809 -23:48:17.56 635.18 -363.56 6.14 1.0 2.0 3.0 Fixed "line 2"
```

Figure 26: Observer Target List text file format

The possible fields for inclusion are:

- **title:** This needs to be surrounded by double quotes and will be sent to the TCS as the science target name. The quotes have to be standard ASCII double quotes, they cannot be the dynamic paired double quotes used by word processors. You either need to use a simple text editor, or set your editor to not use matching quotes. It cannot be blank. **REQUIRED.**
- **ra:** The J2000 right ascension in hh:mm:ss.sss format. The seconds can be either an integer or a floating-point number. **REQUIRED.**
- **dec:** The J2000 declination in in +/-dd:mm:ss.ss format. The seconds can be either an integer or a floating-point number. The “+” is option. **REQUIRED.**
- **epoch:** the epoch for the proper motion. The only allowable value is J2000.0, leaving epoch=false is probably the best idea.
- **muRA:** proper motion in RA (mas/yr). Note that this is actually $\mu_\alpha \times \cos \delta$, which is what most catalogs (and SIMBAD) provide.
- **muDEC:** Proper motion in Dec (mas/yr).
- **magnitude:** Magnitude. The option to include magnitude is in case the observer wishes to sort the table based on brightness. It is not used by the TCS.
- **dRA:** non-sidereal tracking rate offset with respect to sidereal in RA in units of arcseconds/hour.
- **dDec:** non-sidereal tracking rate offset with respect to sidereal in DEC in until of arcseconds/hour.
- **rotatorPA:** The rotator position angle in degrees. With the rotatorFrame=“Target”, an angle of 0° results in the NIHTS slit viewing camera columns and rows aligned with the cardinal directions as given in the Fun Facts at the beginning of this guide, i.e., N is to the right and E is up. Setting the rotator PA to 30° will change this orientation by 30° from north through east. In rotatorFrame=“Fixed” mode this angle is instead the mechanical angle of the rotator, ignoring the sky orientation, and maintains the NIHTS slit perpendicular to the horizon.
- **rotatorFrame:** Valid choices are either “Target” or “Fixed,” without the quotes. The former maintains instrument orientation relative to sky during an exposure (i.e. the instrument cube rotates to follow the field on sky), the later fixes the instrument orientation relative to the horizon so that the slit can be fixed at the parallactic angle.

The fields should all be separated by at least one space. The columns do not have to line up but extra spaces can be inserted if it makes you happy.

Note: in constructing this file, make sure you use a text editor such as vi or emacs. Do *not* use TextEdit, as this doesn't use the standard ASCII double quote character. It will be helpful if you give the file the extension “.tls” (for target list), as this is what the program will look for.

To use the tool, do the following:

1. If you've brought the file with you on your laptop, sftp it over to `observer@dct-obs1` (or `observer@dct-obs2`). A convenient place to put it is the desktop, but please be sure to move the file to the trash at the end of your run.
2. Start the tool by double-clicking the [observerTargetListTool] icon on the desktop.
3. Once started, the “Observer Target List” menu will appear at the upper left on the screen. Go to File → Open Target List:
4. Open Target List will open a standard dialog box for selecting the input file. The default extension for the input file is “.tls” (for “target list”) and all other types are greyed out simply to make it easy to recognize the file among all the other files that might be in a directory. The input file has to be a standard ASCII text file but it can have any extension (or none at all). Binary files will not be read correctly.

The open file dialog box allows selection of other file extensions via a drop down menu. The user can choose “All Files (.)” from the file type drop down menu and that allows selection of any file in the directory. The files other than *.tls would still be grey but they can be selected and loaded into the app.

Multiple input files can be used during one session and each file would be loaded into a separate tab.

5. The process of sending the target to the TCS is a 2 step process. First a target is selected from the table. The data is loaded into the upper view for a final check by the observer. It can be sent to the TCS as a science target by pressing the button. Issuing this command can result in either the telescope moving immediately to the target, or simply loading the target into the preview pane for the telescope operator's approval. The behavior can be selected on the TCS's UI and cannot be controlled by the observer from the app. The selection is persistent until changed by the operator. You can check which mode the system is in by looking at the “External Target Command” label, which will either say “Preview” (the operator checks) or “Direct” (the telescope just goes there).

Note that we provide several observing lists in the **PhotStds** folder on the desktop.

- **AA2014_ubvri.tls**—Astronomical Almanac for 2014 list of UBVI standards (section H), which is basically the list from Landolt (2009). This is there in case you need it, but most observers will prefer landolt09.
- **clem07**—Clem, Vandenberg, & Stetson (2007): Secondary standard stars for the u'g'r'i'z' photometric system.
- **clem13.tls**—Clem & Landolt (2013): Faint UBVRi standard star fields
- **hbstand.tls**—Farnham, Schleicher, & A'Hearn (2000), The HB narrowband comet filters: standard stars and calibration.

G Data Reduction using SpeXTool

Coming Soon ...