Phoenix High-Resolution Infrared Spectrograph

User's Guide
KPNO 4-m Telescope

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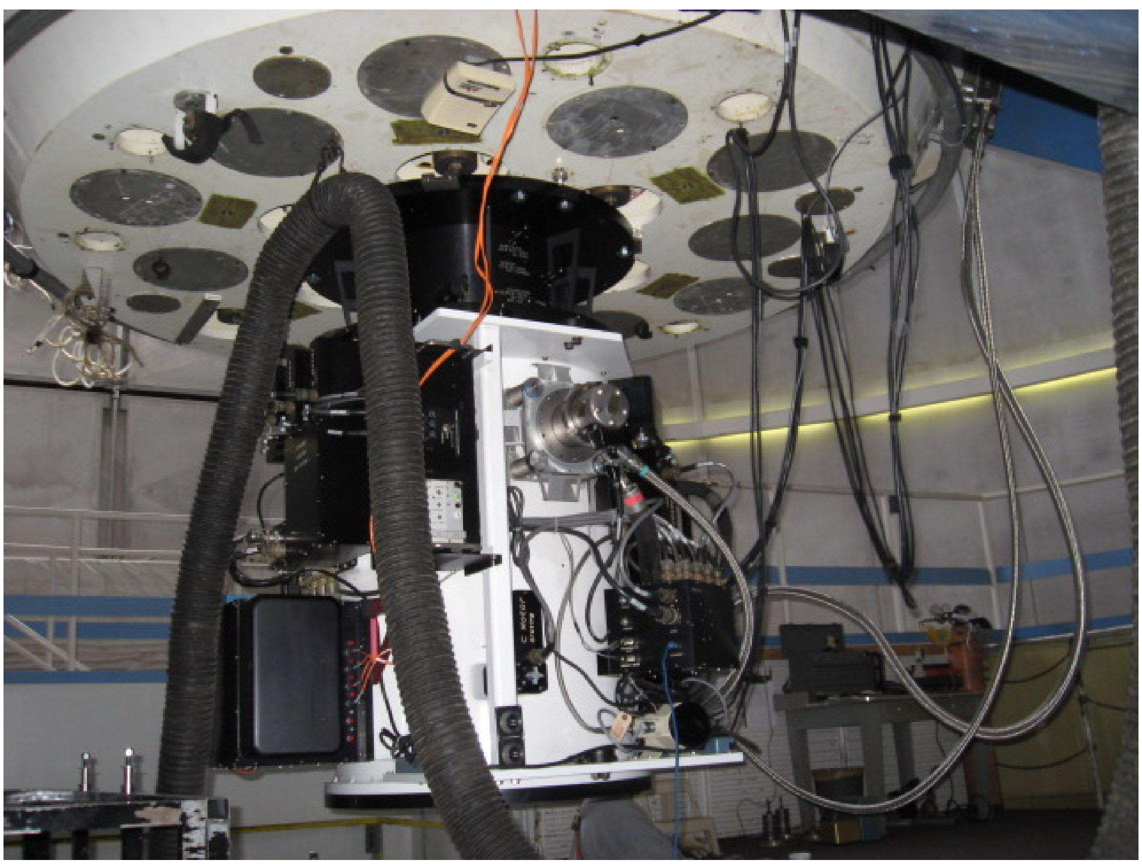

Contents

Phoenix User Guide for the Kitt Peak 4-m Telescope

1. General Description

Phoenix is installed at the 4-m on the rotator/guider used with other Cassegrain instruments (with the exception of NEWFIRM). The instrument itself is mounted to the Interface Unit, which is bolted directly to the back of the guider. The Interface Unit provides the proper back spacing for the f/15 telescope focus to the instrument and also contains the calibration sources.

With the rotator at the "nominal" position angle of 90°, the Instrument Power box is located on the east side of the instrument (to the left as one enters the Cassegrain Cage) and the motor controller box on the NW side of the instrument. There are two AC power lines which connect to the UPS power outlets in the cage, a set of four optical fibers from the Instrument Power to a fiber interface box on the telescope, and an Ethernet cable running from the motor controller box to a media converter box in the Cage and then through the fiber interface box to the computer room; this provides motor control through a private network.

- The power switch for the Instrument Power is a toggle switch on the top of the electronics box. This should be the *only* control (other than the mechanical slides on the Interface Unit) which the observer may have to operate.

The Interface Unit has three mechanisms which must be manually operated by the observer.

- The top slider controls an environmental cover which should be moved in during the daytime to protect the instrument window and out while observing at night. Calibrations may be done with the cover in.
- The middle slider moves a mirror directing the light from the tungsten flat field lamp into the instrument. The mirror should be out of the way when observing.
- The bottom slider has three positions
    - In – moves a ThAr emission line source into the beam
    - Middle – open, used while observing
    - Out – moves a CO gas absorption cell into the beam

Figure 1 shows Phoenix installed on the 2.1-m telescope, where the various mechanisms are easier to see than in the 4-m Cassegrain cage.

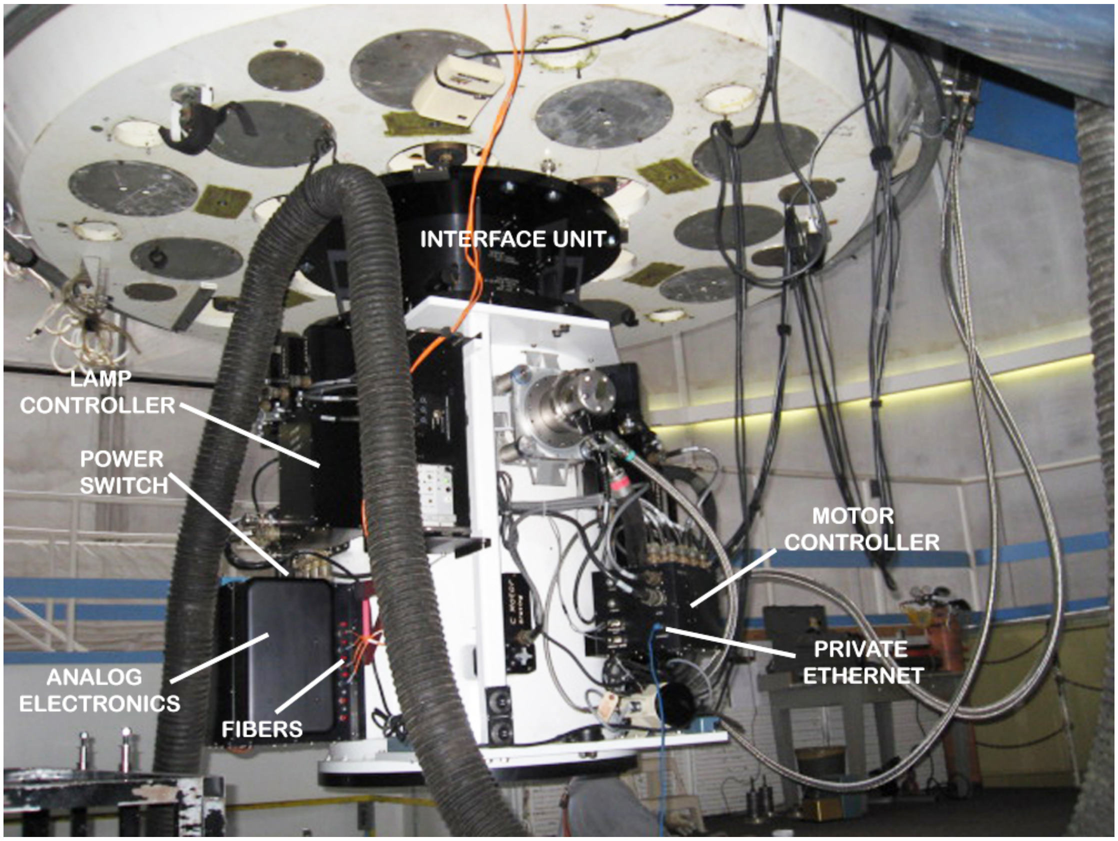

Figure 1: View of Phoenix installed on the 2.1-m telescope, showing the main components. The three manual slides on the Interface Unit are not easily visible in this image. The power switch to the Instrument Power (Analog Electronics) is on top, next to the power cord.

2. Computer Room

Phoenix is the last instrument running on the WildFire architecture, which runs on a Sun SparcStation 20 (named khaki) located in the computer room. There is a local monitor and keyboard in that room, but the observer runs Phoenix from the control room through a VNC session to royal running on the MacMini named mayall-2 (a second MacMini, mayall-3, may also be used). An Ethernet cable from the second port on khaki provides the private network connection to the Phoenix motor controller.

In the computer rack to the left of khaki is the black Heurikon Digital Signal Processor (DSP) electronics. The DSP is connected through four fibers to the Instrument Power box on Phoenix. During the initial installation and setup of Phoenix, it is important to ensure that there is two-way communication through all fibers. This can be verified by checking the red receiver status error LEDs on both the DSP and the Phoenix Instrument Power box. If all four lights are out, the communications should be good. If one or more error lights are lit, this condition must be rectified before the instrument can be run.

During a normal nightly startup, when the instrument has been running, the observer should not have to interact with any of the electronics on the instrument or in the computer room. When the instrument is first installed or if it suffered a software crash while observing, a more comprehensive startup procedure will be required. This manual will cover these two situations in separate sections.

3. Normal Startup

3.1 WildFire Startup

When all is well during an observing run, the observer need only carry out a few tasks at the end and beginning of the night. See Section 3.2 for a summary. On the first night of a run the instrument support person will take the observer through a startup of the WildFire program, since this may be necessary if the system crashes or needs to be restarted for other reasons.

The 4-m control room contains three MacMini computers with large flatscreen displays. One of these, mayall-1, is located at the Operator's station and is used by the OA only for controlling the telescope operation. The other two, located on the long Observer's station, are mayall-2 and mayall-3; these are used for operating the various instruments used on the 4-m. Mayall-2 is generally preferred for instrument operation, since it has additional monitors displaying the telescope status information (VDU) and guider camera field, while mayall-3 is generally used for off-line data inspection/analysis if there are multiple observers.

NOTE: The instructions in this section assume that a previous session of WildFire has been shut down gracefully and not as a result of a serious software crash, power interruption to the Instrument Power or Digital Processors, or loss of communication over the fiber network. These situations call for a more comprehensive recovery which will be described in Section 4.

3.1.1 WildFire

WildFire is a command-line control system based on transputer technology, which was thought in the late 1980s to be the Next Great Design in computing. This technology combines integrated memory and serial communications and can run at Kitt Peak only on the Sun Workstations, which have been superseded by newer generations of instrumentation control. Fortunately, it has been possible to incorporate some technology advances into the Observer Interface, such as running WildFire through a VNC session on the MacMinis with their dual monitors and incorporating GUIs to hide some of the startup details from the user.

Figure 2 shows the left-hand monitor of mayall-2 from which one initiates the WildFire startup. Any of the windows can be moved seamlessly from one monitor to the other. In addition, there are four "spaces" on which one may run ancillary processes (Web interfaces, etc.) and keep clutter under control. These may be selected by the "spaces" icon on the task line at the bottom of the monitor screen.

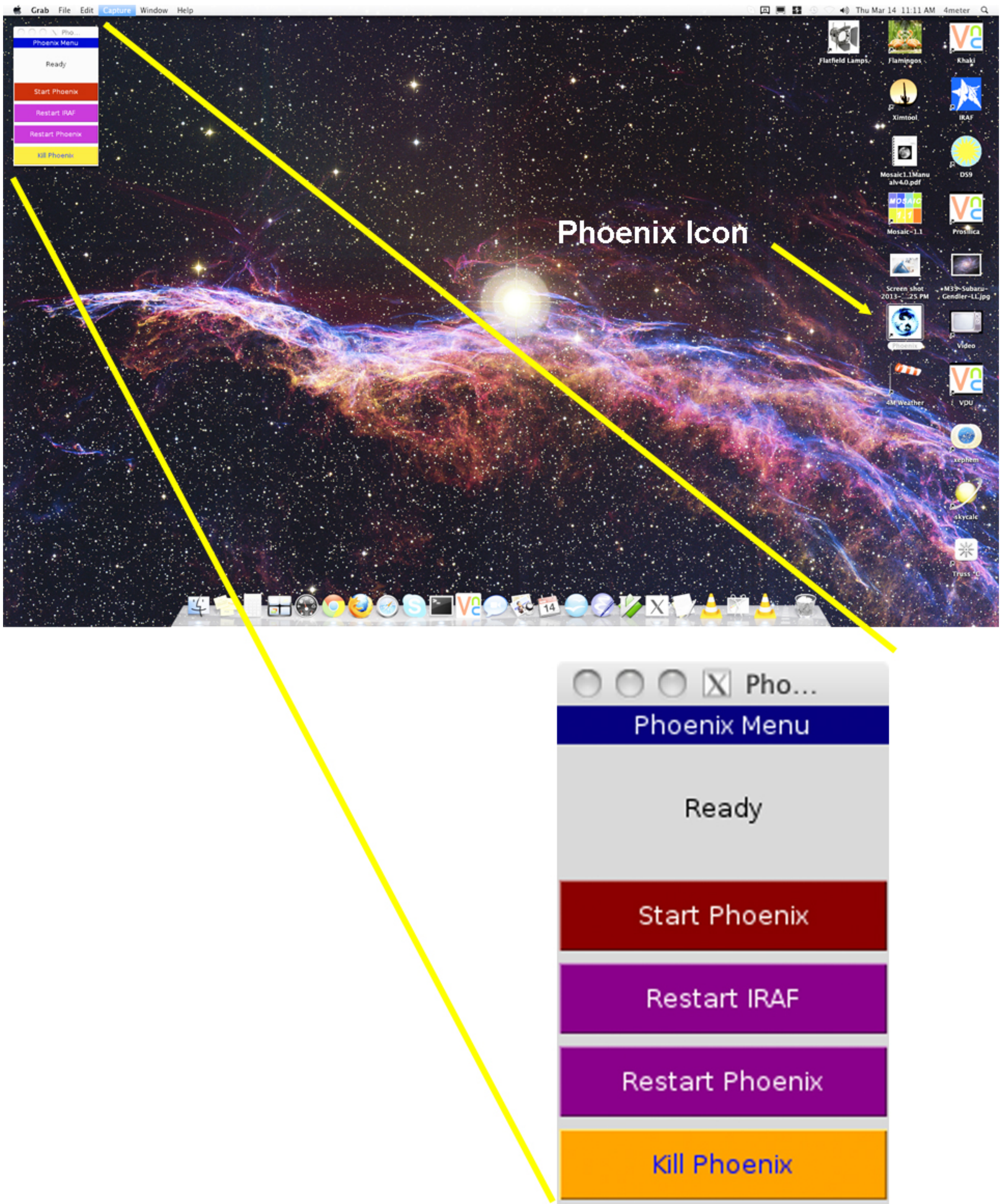

Figure 2: View of the left-hand monitor of mayall-2. Double-clicking on the "Phoenix" icon has brought up the Phoenix Menu GUI.

1. Starting with mayall-2 logged in as "4meter", locate the "Phoenix" icon on the right side of the screen and double-click to open. This will bring up the Phoenix Menu, which consists of four selections:

- Start Phoenix – this opens a VNC session to royal and brings up the initial startup screens which allow for a full startup of WildFire.
- Restart IRAF – this will restart the IRAF session which normally comes up with the Start Wildfire without exiting from WildFire (in case the xgterm or ds9 has been inadvertently closed).
- Restart Phoenix – this will restart the Phoenix WildFire session if it has been terminated gracefully and not as a result of a power or communications failure.
- Kill Phoenix – this will exit WildFire in a graceful manner and shutdown any background processes. In theory, this should allow an efficient restart using the Restart Phoenix button.

2. Click on the "Start Phoenix" button. This will bring up four windows, as shown in Fig. 3. (Note: these windows have been resized and arranged to fit onto a single screen on the Mayall-2 monitor for clarity).

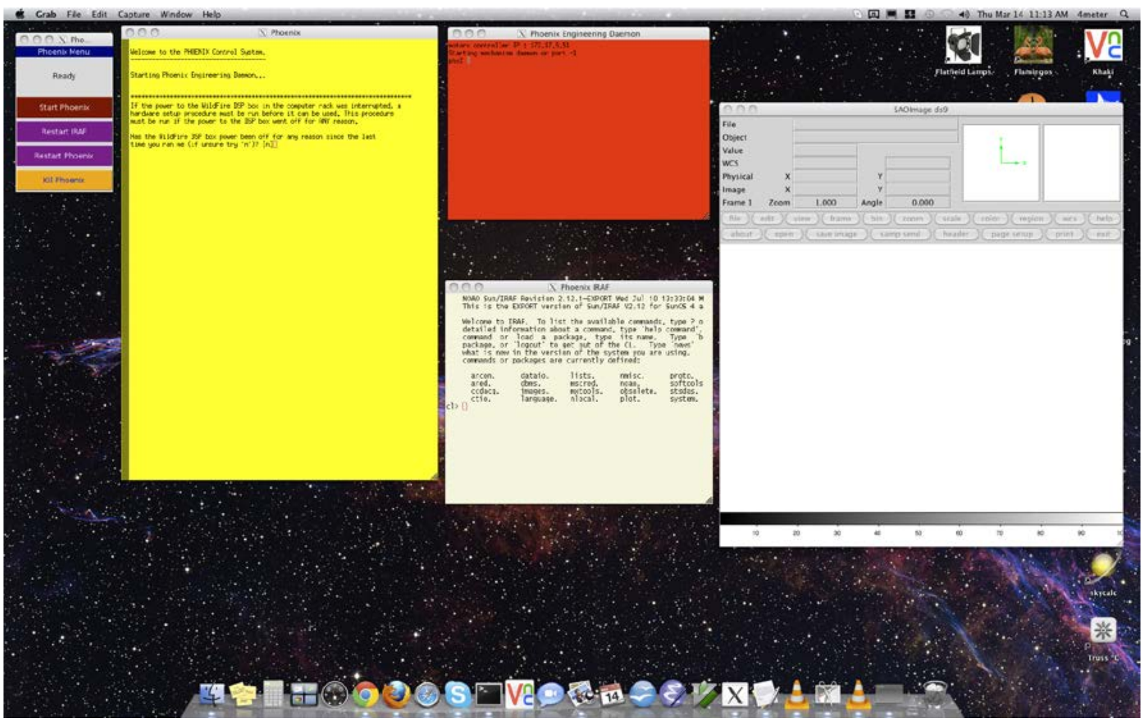

Figure 3: Mayall-2 monitor after commanding Start Phoenix from the Menu GUI

- Phoenix IRAF – this is an IRAF xgterm running on khaki and can be used for accessing and quick-look examination of the data.
- SAOimage ds9 – this is actually running on mayall-2, but will display images from khaki over a network once initialized
- Phoenix – this distinctive yellow window is the command line interface for all of the Phoenix commands.
- Phoenix Engineering Daemon – this red window can be used for executing low-level commands in the event that the system requires extensive diagnostics. This window is not for use by general observers.

3. Follow the directions on the startup menu in the Phoenix window. You will be asked a number of questions which must be read carefully. Simply hitting a <cr> will return the default answer, which may not be appropriate.

This example assumes that the DSP and Instrument Power have not been interrupted or communications through the fibers have been lost. These more dramatic cases will be covered in the next section.

a. Enter <cr> to continue from the initial startup window
b. "Has the DSP been turned off since the last time you ran startwf? n
c. "Has the instrument power been off since the last time you ran startwf? n

At this point, the system will bootstrap the network. You should see a series of ten nodes being bootstrapped; these are the fiber optic transceivers and network connections from the DSP to khaki. The system will then download four WildFire programs specific to running Phoenix and open up two more windows labeled Phoenix Status and Phoenix Saver, which will display the instrument mechanism/temperature status and the file saver updates as images are taken. The program will then ask if these windows have been initialized (Figure 4):

d. "Do you see engineering, saver, and status windows" y

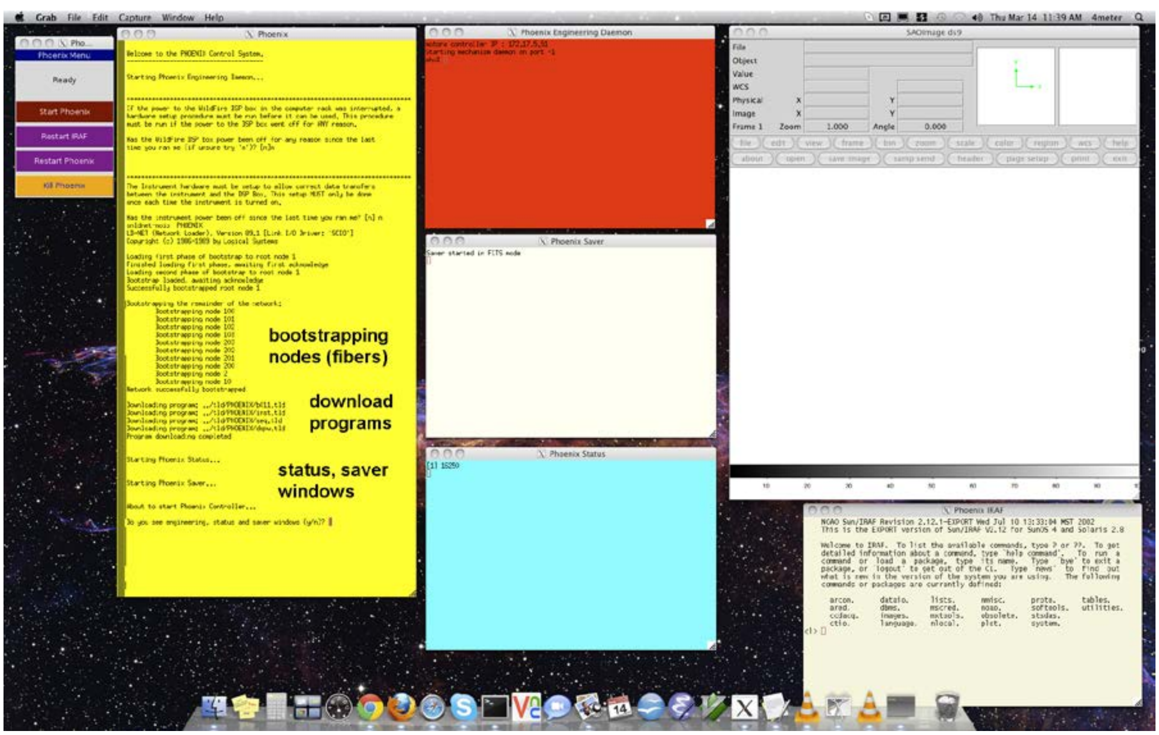

Figure 4: Mayall-2 monitor after opening the Saver and Status (blue) windows. The windows have been resized and shifted to fit onto a single screen for clarity.

If the answer to the question is “y”, the program will go through an internal initialization, then download five voltages. It will then return a final question:

e. “Do you want to activate the array?” Normally, you will answer “y” if planning to observe. **Do not answer ‘y’ unless the instrument and detector are cold.**

The program will then query the location of the mechanisms, open up a second Phoenix Daemon window and end with the message “Initialization complete” and the WildFire “%” prompt.

The end result is shown in Figure 5.

NOTE: Error messages (shown in Fig. 5) referring to the xterm are normal, vestiges of the earlier use of xterm windows for running WildFire. The final error message about expecting a Boolean value but getting “” refers to a dark slide mechanism which was used on the Gemini South telescope but is not used at Kitt Peak.

At this point, you may wish to redistribute the windows among the two monitors to reduce clutter. You should now be ready to set up the mechanisms and parameters for observing, as described in the step-by-step operations section of this manual (Section 5).

One may also iconify the phxDaemon windows, as they are used only for diagnostic or low-level commands.

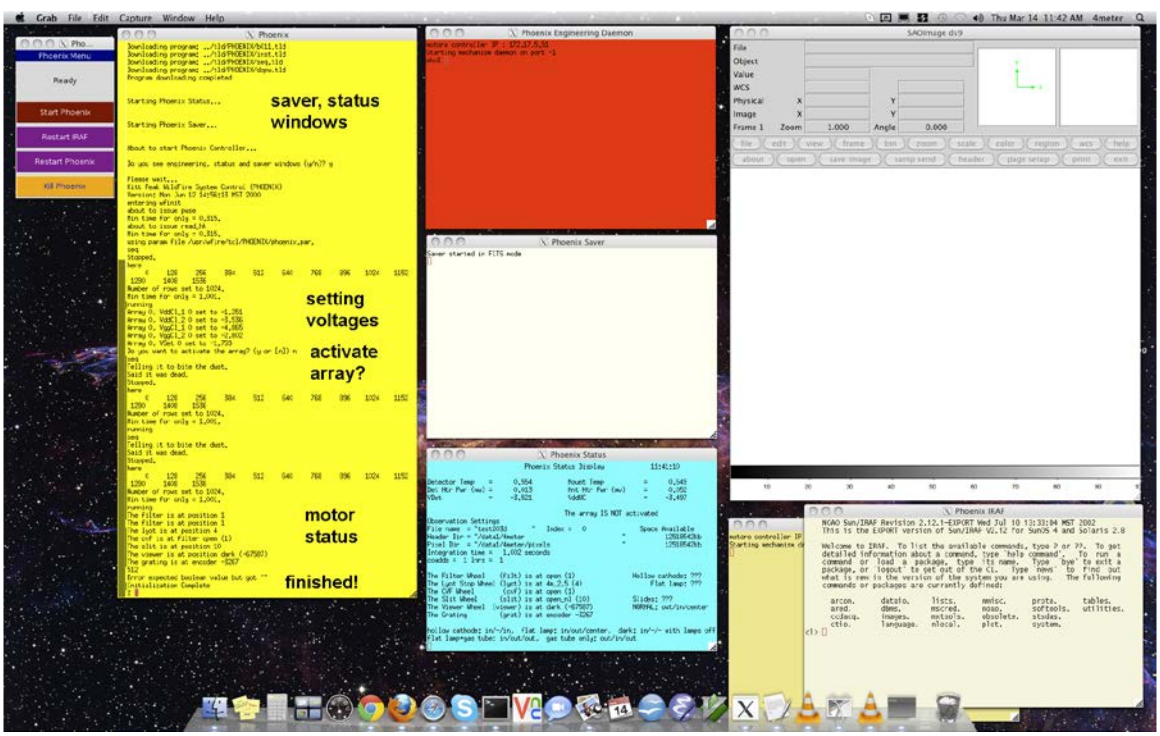

Figure 5: Mayall-2 monitor after a successful WildFire startup. The various steps are annotated on the yellow WildFire command line window.

3.2 Nightly Startup and Shutdown (Summary)

Here we summarize the nightly startup and shutdown. See section 5 for the detailed step-by-step version.

During the course of a normal observing run, the instrument and all of the control screens may be left running during the day. At the end of each night, the observer should only need to:

- Deactivate the array by entering **deactivate**
- Close the dark slide (top slider on the Interface Unit)

Upon starting up the following evening, the observer must:

- Open the dark slide on the Interface Unit
- Activate the array by entering **activate**; enter a bias value near 0.320 to give 0.300
- Create a new data directory for the night on /data1/4meter in terminal
- Execute **ped** to enter the new data directory into WildFire
- After the telescope has been started up, enter **tcpon** to establish communications with the telescope

These instructions and the commands are described in more detail in the Step-by-step Operations section of the Manual (Section 5).

NOTE: At the end of a Phoenix observing block, before the instrument is powered off, the viewer should be moved to the 'dark' position and the filter, CVF, and slit wheels to the 'open' position to protect the detector and filters from condensation (see Section 5).

4. Startup in Special Circumstances

Because of the complex organization between the Sun computer khaki, the DSP, and the Instrument Power, it is necessary to establish communications between these in the proper order. Once this has been done, restarting WildFire is fairly straightforward, as described in Section 3. However, there are situations in which the simple startup will not work, such as:

- The computer software has crashed for some reason. If this happens, first try using the "Kill Phoenix" button on the Phoenix menu to close all of the processes, then "Start Phoenix" as described above. Depending on the cause and severity of the crash, this might work.
- There has been a significant power failure which affected the Instrument Power, DSP, or khaki, or any of them has been turned off for any reason.
- Communication through the fibers has been lost for some reason. If this is suspected, check the red Error LEDs on both the DSP and the Instrument Power. If any of them is red, there is a hardware communication problem which must be repaired before attempting to run WildFire.
- The instrument has just been installed on the telescope, since the Instrument Power will have been powered off.

1. Before starting the procedure, particularly if the instrument has just been installed, make sure that khaki, the DSP box, and the Instrument Power are all turned on. Visually check the red fiber LEDs on both the Instrument Power and DSP. If any of them is red, WildFire will not run, and the fiber hardware situation must be repaired.

2. If the fibers are OK, turn the Instrument Power OFF.

3. Go down to the computer room and turn the power on the Heurikon DSP box OFF for about 30 seconds, then ON. Alternatively, the operator can do this remotely through 4m-power-4, where the IR DSP power is outlet 7.

4. Reboot khaki. This requires superuser permission, and must be carried out by the OA, Electronic Maintenance, or the Instrument Scientist.

NOTE: Since WildFire is run as an ssh session on khaki, the "Start Phoenix" button on the mayall-2 monitor will automatically log in, so it is not necessary to specifically log into khaki after the reboot. Periodically "ping khaki" from a window on mayall-2 until you get a response indicating that khaki is alive.

5. Once the reboot is completed, click the "Start Phoenix" button on the Phoenix GUI (NOTE: the Instrument Power should still be OFF). This will bring up the normal startup configuration displayed in Figure 3.

6. Go through the startup sequence as in Section 3. However, the answers to the questions will be different, and there will be more of them.

a. Enter <cr> to continue from the initial startup window
b. "Has the DSP been turned off since the last time you ran startwf?" y
c. "Was the computer rebooted with the DSP power on and the instrument
power off?" y

You should then see a short flurry of activity ending with a message about configuring the C004 being complete.

d. "Is the instrument power on now" n
e. "Turn on the instrument power and enter <cr> when it is on"

Now go out the Instrument Power box and switch on the power (or have the Instrument Scientist do this if logged in remotely), then: <cr>

This should initiate another flurry of activity, after which the startup should proceed as during the normal startup.

At this point, the system will bootstrap the network. You should see a series of ten nodes being bootstrapped; these are the fiber optic transceivers and network connections from the DSP to khaki. The system will then download four WildFire programs specific to running Phoenix and open up two more windows labeled Phoenix Status and Phoenix Saver, which will display the instrument mechanism/temperature status and the file saver updates as images are taken. The program will then ask if these windows have been initialized (Figure 4):

f. “Do you see engineering, saver, and status windows”

If the answer to the question is “y”, the program will go through an internal initialization, then download five voltages. It will then return a final question:

g. “Do you want to activate the array?” Normally, you will answer “y” if planning to observe. **Do not answer “y” unless the instrument and detector are cold.**

The program will then query the location of the mechanisms, open up a second Phoenix Daemon window and end with the message “Initialization complete” and the WildFire “%” prompt.

The end result is shown in Figure 5.

5. The Step-by-Step Phoenix Operation Guide

5.1 New Feature – countdown clock

Throughout the history of IR array operation with WildFire, an annoying aspect of the operating system was that the software architecture did not permit any estimate of the time remaining in an exposure. The microcode would send out an initial read command and wait for the data to come back when the exposure was completed. Although this is still the case, it has been possible to program a countdown clock on mayall-2 which is initiated by the start of an integration and gives the *approximate* time until the end of the exposure. While not precise, it should be a very useful guide to the observer.

5.2 Setting up the detector and the mechanisms

In Wildfire window (Note that the Wildfire window is the same as the yellow Phoenix window):

> **activate**
> Turns on the array. Use the default 0.320 bias. The echoed back bias should be 0.300. If it is not, then use
> **setbias {value}**
> Normally {value} should be 0.320 in order to get an echoed back bias of 0.300. Adjust up and down to get to a read back of 0.300.

In a terminal window:

> ssh to khaki
> Check that you are in data directory (should be /data1/4meter)
> **df**
> Check that there is sufficient disk space on /data1 to store your data. Each image is 1.05 MB in size.

In IRAF window:

> **mkdir** {label}
> For {label} use a directory name using the date, for example 2012nov23.
> **cd** {label}
> **pwd**

In Wildfire window:

> **ped**
> Stands for Parameter EDitor. You should leave most parameters as default. However, you will want to change the header and pixel directory to match the IRAF data directory. If the IRAF directory was, for instance /data1/4meter/2012nov23, you should type in /data1/4meter/2012nov23 in Wildfire.
> **eask**

This sets the parameters that whose values will be requested before each observation. Set with “la” the parameters to be shown/requested by ask. Other parameters get “l”, and will not be shown or requested before an observation. You can always rerun **eask** if you change your mind. Note that while “picture number” is automatically incremented by the software, you may want to set this to “la” so that you see the frame number before beginning an observation, and can mark this on your observing log.
ask
To get started make sure the integration time is set to a small value, pictures to 1, lnrs to 1, coadds to 1.

<u>The following commands involve mechanisms</u>.

status s displays the current position of all of the instrument mechanisms in the status window. The status display automatically updates when you move mechanisms.

help {mechanism name} tells about the command and the position options.

IMPORTANT – make sure the mechanism command has finished; i.e., that you get a prompt back, before typing anything else. This is the main cause of lost time with Phoenix. If you type in a new command before the previous one finishes you can hang the computer.

IMPORTANT – at the beginning of a run, the instrument scientist will initialize the mechanisms (except for the collimator focus), which have home switches to define the zero position using the command **init <mechanism>**. This command may be done by the user if for some reason one of the mechanisms seems to have become lost. However, the order of the words is important! For some reason, the software interprets the word “init” as a position, so reversing the order of the two words will attempt to move the mechanism to a position which is impossible for some of the mechanisms.

Make sure the mechanism went where you wanted. The new position is echoed back.
filt {pos value} – selects the filter. There is a second set of filters in the cvf wheel, which is now effectively a second filter wheel. To use these first do **filt open** and then **cvf** {pos value}. Otherwise, set cvf to open.
lyot {pos value} – sets the lyot stop for the telescope and wavelength
slit {pos value} – sets the slit. The commonly used 4 pixel slit is number 8.
viewer {pos value} The viewer positions are “open”, “dark”, or “image”. Typically we will want “image” to start. The choice for spectroscopy is “open”. (Note that for the viewer, unlike for the other mechanisms, you cannot type “viewer 1” or “viewer 2”, etc. You must use “viewer image”, “viewer open” or “viewer dark”.)

grat {pos in cm^{-1}} **K** {offset} The **grat K** command moves the grating to a given frequency. The offset parameter is necessary to account for the encoder zero point. An offset of 800 works well as of May 2013.
grat {encoder position} – moves the grating to a given encoder position

If a mechanism fails to move, then try
kick {mech. Name} {pos value} -- this commands applies extra torque

<u>When the telescope is running</u>

tcpon
This starts communication between the telescope and the Phoenix computer. It is sometimes needed at the start of the night. It should not be necessary after that.

5.3 Locating and marking the position of the slit

1. Acquire a V ~ 9 SAO star that is close to overhead. If you are observing in the 4-5 micron region use a bright star.

In Wildfire:

Check that the viewer is set to "image"
ask
Enter the title = target name, filename and the exposure time. Filename is just the start of the filename, for example, "image" or "setup" for imaging the slit, or "data" if you want all files to have the same file start. A 3-digit extension will be appended to the end of this filename. Typically the exposure time should be about 10 sec.
go

This takes an image of the sky through the slit.

NOTE: Initially, images may not display automatically on the ds9. If this is the case, change to the current data directory in the IRAF window and display an image using the IRAF "display" command: **display <imagename> 1**. If the image displays properly on the ds9, succeeding images should autodisplay as they are taken.

In IRAF:

Measure position of the middle of the slit and write down the coordinates. If all is well this should be close to x=128 and y= 510. This position will be different for each filter. Mark down this position (xcenter, ycenter), and then

In Wildfire:

zcenter {xcenter}{ycenter} {pa} 0.123
This will orient the software for the slit geometry. <xcenter> and <ycenter> are the slit center coordinates measured above. <pa> is the position angle of the 4-m instrument rotator and 0.123 is the scale in arcsec per pixel at the 4-m.

NOTE: You must run **zcenter** prior to running either **recenter**, **abba** or **ab** for the first time, or after any change in the rotator angle, since these routines require the coordinate and scale information.

In Wildfire:

> **slit open**
> **ask**
> Set the time for an image of the star, typically about 1 sec.
> **go**

In IRAF:

> Measure position (xpos, ypos) of the center of the star.

In Wildfire:

> **recenter** {xpos} {ypos}
> This will move the telescope so that the star is at the (xcenter, ycenter) coordinates of the center of the slit.
>
> If you encounter any trouble with these routines, you can always do the recentering yourself. Compare your measured position to that of the slit center, multiply by 0.123 arcsec per pixel (at the 4-m), and move the telescope by the right amount to center the star at the slit center using the commands below.

In Wildfire:

> **north** {arcsec} or south {arcsec}
> **east** {arcsec} or **west** {arcsec}
> **go**
> go takes another image. Make sure star is at the slit center location or iterate the adjustments until the star is there.

On TV guider monitor, mark position of center with wax pencil. NOTE -- Each filter will have a different position.

On the first night of an observing block, the instrument scientist will focus the star on the array and then adjust the focus of the TV so the image is in focus. Afterwards, it should only be necessary to adjust the secondary focus to maintain a sharply focused image on the TV. If you wish to check the focus, use **imexam** and the ‘r’ key to generate a radial plot of the star image. Iterate, using small focus motions, until the best image is obtained.

2. Acquire a relatively bright K giant or A star, move to marked spot on TV

In Wildfire:

> **slit** {number of your science slit}
> **viewer open**
> **ask**

Enter name of source, set time to some small amount appropriate for the spectrum of this bright star (use ITC). If star is very bright, multiple coadds can be used to average several very short exposures.
east 5
This moves the star to the bottom of the slit.
go

In IRAF:
Measure signal using **imexam** and the 'j' key.

In Wildfire:
north 0.5
go
Then measure signal, repeat these steps moving the star small amounts north and south (perpendicular to the slit) and recording signal. When you find the best signal move back to this position, confirm reading, and mark on TV screen. Then move **west 10** and repeat the process. When done move **east 5** and re-mark point at the middle of the slit. The middle point is just used for acquisition so there is no need to peak up the signal here.

NOTE: Remember, the slit position will be different for each filter.

5.4 Fine Tuning the Grating Position

Using the best pair of bright star spectra obtained during the above peaking procedure (or by observing a new pair of spectra) with the star at the east and west ends of the slit.

In IRAF:
imar {east spectral image} – {west spectral image} {diff image}
twodspec
apextract
apall {diff image}

Apall is the IRAF spectral extraction task. It will begin by asking a number of questions about finding apertures. Answer "yes" to all, "1" to number of apertures to extract. You will then get a display of a row cut across the image, showing the negative and positive spectral sections. There should be an aperture marked on the peak of the positive feature. If the centering is good, enter "q" and "yes" to the questions about tracing and fitting the apertures. The display will show a plot of the fit to the spectral aperture sampled at intervals (typically 10 pixels) along the spectrum. If the fit looks good, enter "q" again and answer "yes" to the questions about storing the apertures and extracting the spectra. You will finally get a spectral plot; answer "y" to the question about saving the spectrum. The result will be a spectrum named "diff image.0001.fits" (or "diffimage.ms.fits") in the data directory. The command "help apall" will bring up a more comprehensive explanation for the task.

Display the spectrum using **splot** {diffimage.0001}.

Compare the spectrum to the Arcturus Atlas and figure out the central wavenumber. Frequency increases with pixel number, so the orientation of the spectrum should be the same on the display as in the Arcturus Atlas. Note how many wavenumbers off the desired center the spectrum is. Add the opposite of this difference to your original wavenumber and rerun **grat** with the corrected value. Re-observe the spectrum and repeat the above analysis to converge on the desired central wavenumber.

During the November 2012 observing run, we found it necessary to adjust the wavenumber setting in **grat** by -2 cm^{-1} in the K band.

5.5 Observing

It would be best to start with a bright star, perhaps a hot star for removing the telluric lines. Observing a bright star, with a short integration time, minimizes time lost if anything is not set up correctly.

NOTE: The array will saturate at approximately 9000 ADU. For the minimum integration time of 1.002 sec, the saturation occurs at about 5000 ADU. We recommend keeping the maximum signals to no more than half of these values to avoid nonlinearity effects.

In Wildfire:

At the start of the night after the telescope has gone to the first star it might be necessary to type:

> **tcpon**
> This starts communication between the telescope and the Phoenix computer. tcpon should only be needed when the telescope is started.

For the first observation only the position angle and plate scale must be entered:

> **zcenter {xcenter} {ycenter} {pa} 0.123**
> <xcenter> and <ycenter> are the X and Y values of the slit image center on the detector which were measured in the last section. These numbers will be close to 128 and 510, but will differ slightly for each filter. <pa> is the position angle of the 4-m instrument rotator. 0.123 is the 4-m plate scale in imaging mode.

For all observations:

> **ask**
> this command sets up the observing parameters for this observation. **eask** determines which parameters are set by ask.
> **abba 10 {number of repeats}**
> 10 is the nod (A-B separation) in arcseconds. This corresponds to the **east 5** and **west 5** that were used above. This is a good value for the 4-m. **abba** will take four spectra. The default number of repeats for the **abba** script is 1.

The command **ab {nod} {number of repeats}** is similar to **abba**, except that it just does one observation at each point.

5.5.1 Observing infrared bright, visually very faint objects

If objects can not be seen on the guide TV they must be acquired in the IR using the imaging mode. Tracking on the slit can be done using an offset star and the guide camera (provided one is visible in the field).

In the near-IR:

In Wildfire:

viewer image
slit {your science slit}
ask
go

This images the slit. Record the mid point. This needs to be done once.

slit open
ask
If the exposure time is very short coadds =10 will average over 10 exposures.
go
east 5
go
west 5

In IRAF:

imar {image1} **–** {image2} {some name for the difference image}
displ {name of difference image} **1** This displays the difference in the ds9 window. Measure the position of the positive star image.

In the thermal IR:

The sky will likely saturate the images. Use the neutral density filter in the cvf wheel to reduce the flux. This filter is not intended to be used in spectroscopy mode so make sure it is removed prior to science observing.

For both near-IR and thermal IR:

In Wildfire:

recenter {x pos} {y pos} Note that **recenter** requires a previous use of **zcenter**. If you have not yet executed **zcenter** you must do so before using **recenter**. This must also be done whenever the rotator position angle is changed. **Recenter** moves the star to the **zcenter** position. It may be necessary to do this twice.

When the star is centered up a final image can be taken by putting the slit back in and imaging through the slit.

5.5.2 Integration time and data quality

The data quality will naturally depend on conditions. Each observation should be checked. It is the observer's responsibility to do this and to talk to the start up person about the data quality.

The starting point for setting the integration time is the Phoenix ITC. Using the ITC tool, compute integration times for the planned observations. Most observations require four separate frames (abba) so the total integration time should be divided by four.

After taking an observation the spectral image will appear on the ds9 display.
In IRAF:

imexam
This allows measurements of the spectral image, 'j' takes a horizontal cross cut of the image and carries out a Gaussian fit; 'k' does the same in a vertical cut; 'e' provides a contour map.

Roughly integrate the number of ADU in the cross cut using the peak signal and FWHM provided on the graphics terminal. Multiply this by 9.2 (the gain in e/ADU) and take the square root. This is the approximate S/N in this observation (ignoring the read noise of the detector). Multiply by two to get the final S/N for four frames. The integration times from the ITC can then be scaled.

A more detailed assessment of the data quality can be made by extracting a spectrum using the following commands.

In IRAF:

imar {aperture a spectrum} – {aperture b spectrum} {some name for difference spectrum}
twodspec
apextract
apall
onedspec
splot {name for difference spectrum.ms}

The spectrum can be smoothed if required and S/N measured on specific regions using the tools in **splot**. The ‘s’ key will smooth the spectrum to a desired pixel resolution; ‘a’ will redefine the display window; ‘c’ will reset to the full display, and ‘m’ will calculate the S/N between two cursor positions on the spectrum.

5.6 Flats and darks

Every time the grating is moved a new set of flats must be observed. To do this the sliders on the interface unit are used. The sliders must be moved by hand. Pull the mirror (middle mechanism) into the beam. The dark slide (top) can be open or closed. The reference slide (bottom) should be at the middle (open) position.

For the near-IR (1-2.5 microns)

In Wildfire:

flamp on
This turns on the flat lamp.

Lamp flats require roughly 4 second exposures in the K band. We recommend using **ask** to set up a test image. Execute this with **go**. Then measure the signal with the ‘l’ command in IRAF imexam. The maximum signal level should be between 1000 and 2000.

ask
Set the number of pictures to 10.
go
flamp off
This turns off the lamp.
ask
Type in a comment saying these are dark. The exposure time must be unchanged from those taken with the lamp on.
go

When done remember to remove the mirror in the Interface Unit from the beam.

For the thermal IR (3-5 microns)

In the thermal IR, the ambient background is brighter than the flat field lamp, so the flat exposures can be taken without turning on the lamp. Take a test exposure to set the exposure time. Then as above

ask
Set the number of pictures to 10.
go

There are two schools of thoughts about darks at 4.6 microns, they are worthless or you should take them. If you want darks it is necessary to move a mechanism within Phoenix to the dark position. Then take 10 exposures with the same integration time as for the flat.

When done remember to remove the mirror in the Interface Unit from the beam.

5.7 Hollow cathode lamp

The hollow cathode lamp works only in the 1-3 micron region. Using the bottom slider on the Interface Unit, move the hollow cathode lamp into the beam (slider in).

In Wildfire:

hlamp on
ask
Generally it will take a minute or more to see hollow cathode lines.
go
hlamp off

IMPORTANT – you must turn the lamp off after taking data. It has a limited lifetime and is impossibly difficult to change.

When done remove the hollow cathode lamp from the beam (slider to middle position).

5.8 End of night

At the Interface Unit move the dark slide into place (top slider in).

In Wildfire:

deactivate

NOTE: At the end of a Phoenix observing block, before the instrument is powered off, the viewer should be moved to the 'dark' position to protect the detector from condensation with the command 'viewer dark'. Also move the filter, CVF, and slit wheels to the 'open' position.

5.9 Saving your data

While at Kitt Peak, **scp** can be used to copy your data to your laptop. It is highly recommended that you copy your data to your laptop and take the data away with you.

From your laptop:
scp –rp 4meter@khaki:{data directory} **.**
You can get the data directory using **pwd** in the IRAF window.

All data also goes into the Kitt Peak data archive.

6. Operation Guide

6.1 Temperature Calibration

The temperatures are measured as the forward bias voltage on a temperature-sensitive diode operated at a current of 100 μa. Most of the diodes in Phoenix are 1N914 diodes, which are relatively inexpensive; those on the detector and mount are factory-calibrated Lakeshore diodes, which have a slightly different dependence from the 1N914. The calibration curve for both diodes is presented in Figure 6. The status readbacks (Figure 7) are in voltages, so one may refer to this curve to convert to temperature.

In general, the 1N914 diodes read approximately 0.400 volts at room temperature and 1.000 volts at ~ 70K. The behavior in between is roughly linear with a slope of about 3 mv/K. Below 40 K (30K for the Lakeshore diode), the behavior becomes highly nonlinear.

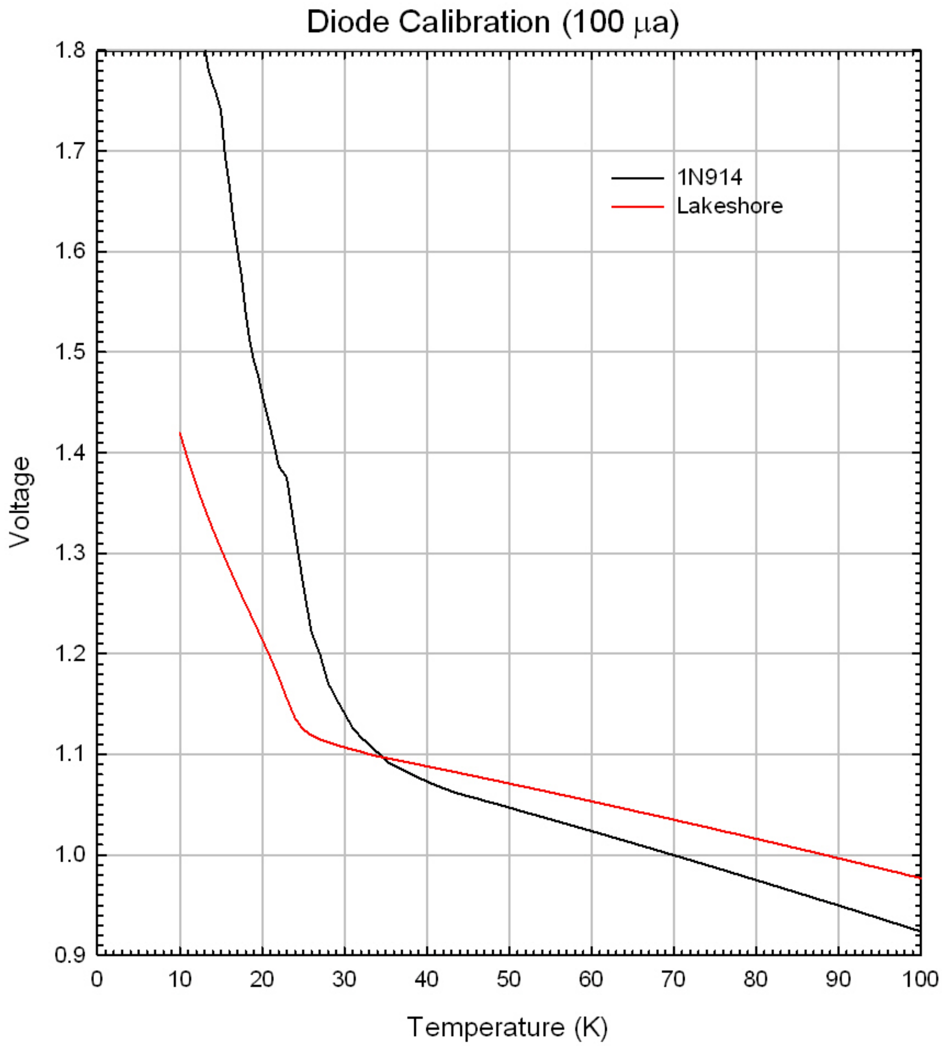

Figure 6: Calibration curves for the 1N914 and Lakeshore temperature diodes.

6.2 Operating Temperatures

In normal operation, one will see a status screen shown in the top panel of Figure 7, showing the detector temperatures, detector activation status, observation parameters, and mechanism status. The lamps and sliders are not encoded at Kitt Peak as they were at Gemini, so they will normally return "???" The detector temperature should be approximately 1.11 v (28 K) and the detector heater power should read a nonzero value, indicating that the temperature control is active.

This screen updates automatically, so it will record changes in temperatures, mechanisms, etc. One may update manually by entering **status s**. A more detailed temperature status screen (bottom of Figure 7) can be displayed by entering **status t.**

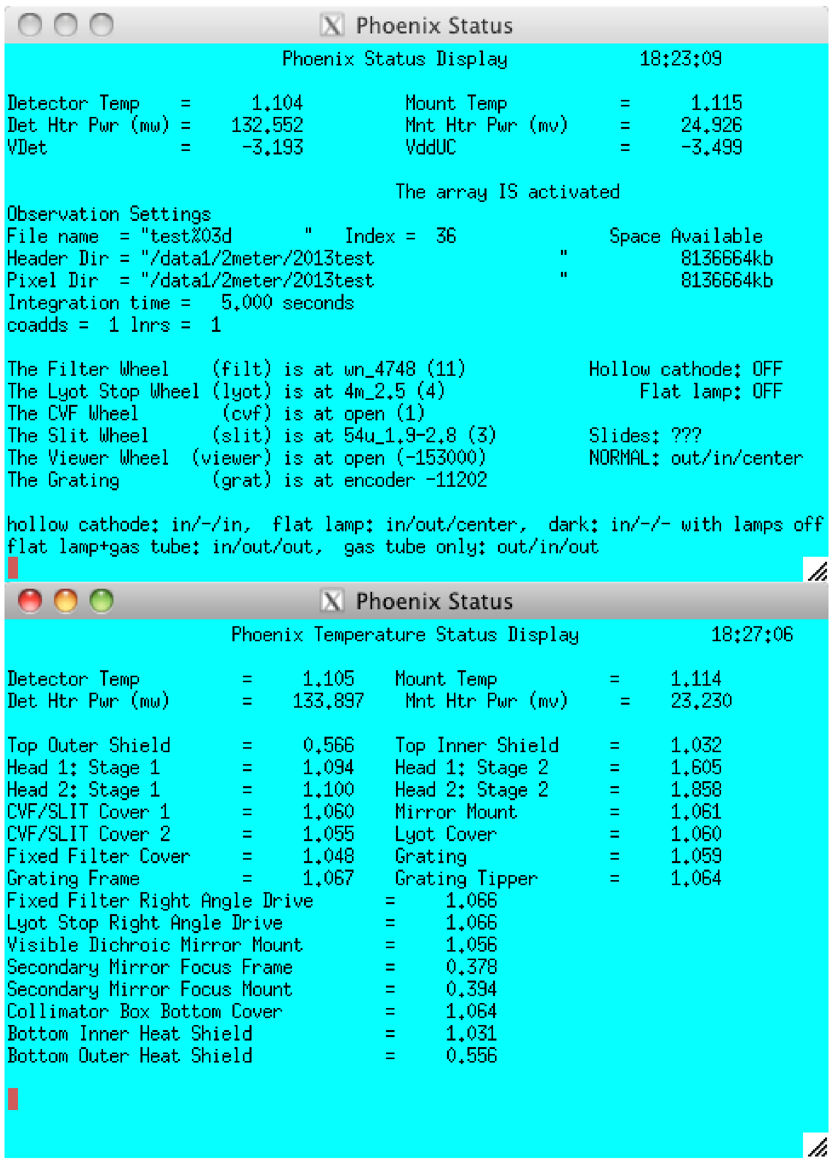

Figure 7: Screens for **status s** (top) and **status t** (bottom), with the instrument cold.

6.3 Typical Images

Figures 8 and 9 show some typical images under normal operation.

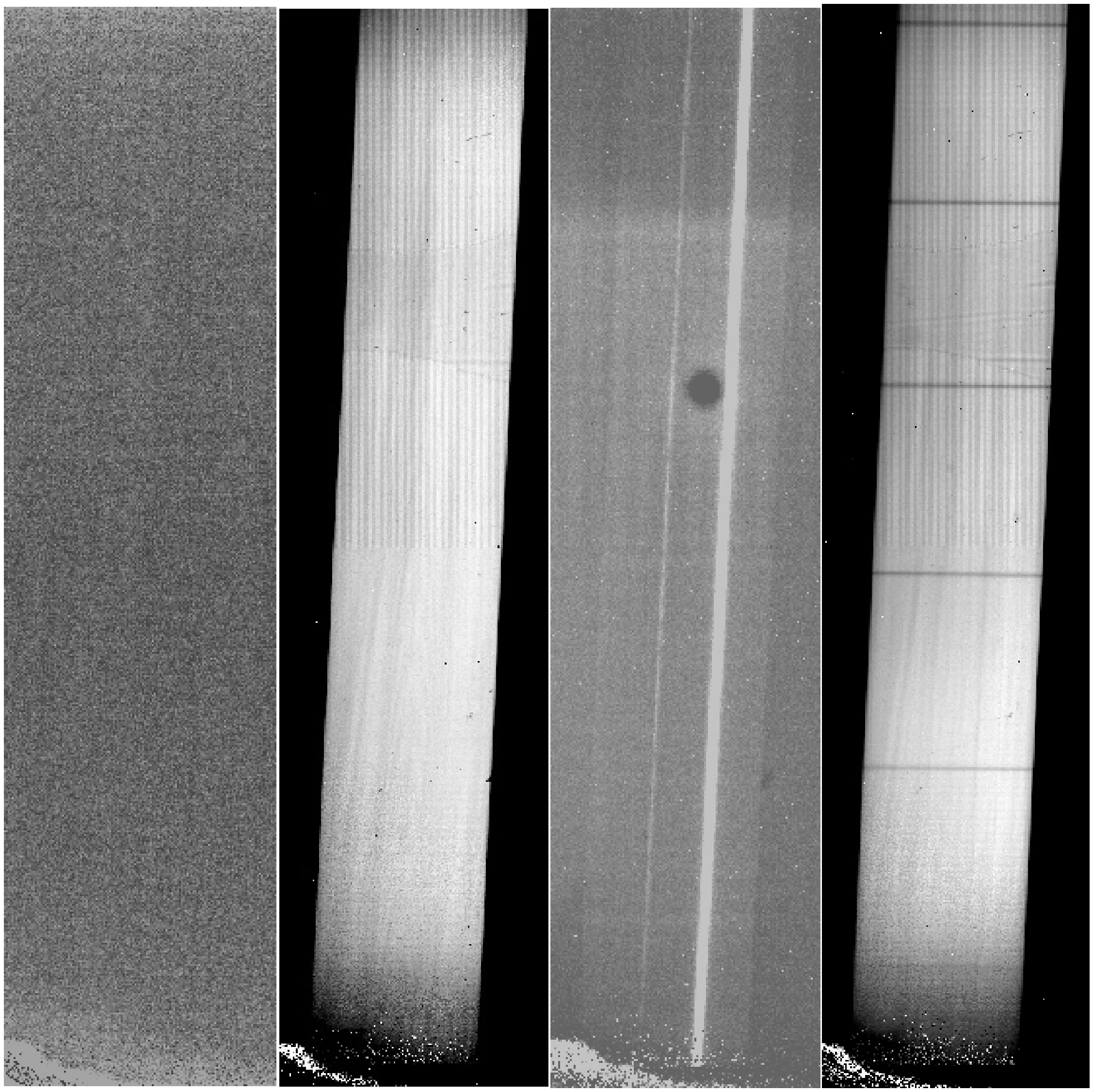

Figure 8 (from left): a. Dark frame. There are some noisy and/or high dark current pixels in the image, which is normal. The crack in the lower left is an array defect. b. Flat field image; the striped pattern in the upper half of the array is a normal property of the detector/controller. c. A frame showing an unusual "Phobos" event. These are believed to be electrical discharges within the array introduced by stresses and are more frequent during the first few days after the instrument has been cooled. The dark current in the lower 75% of the array is evident in this 900 s exposure is at a level ~ 350 e. Some of this may result from very low level thermal background. d. Spectrum of the flat field lamp at 4275 cm^{-1} with the CO cell in the beam. Only six of the low-J 2-0 lines are visible.

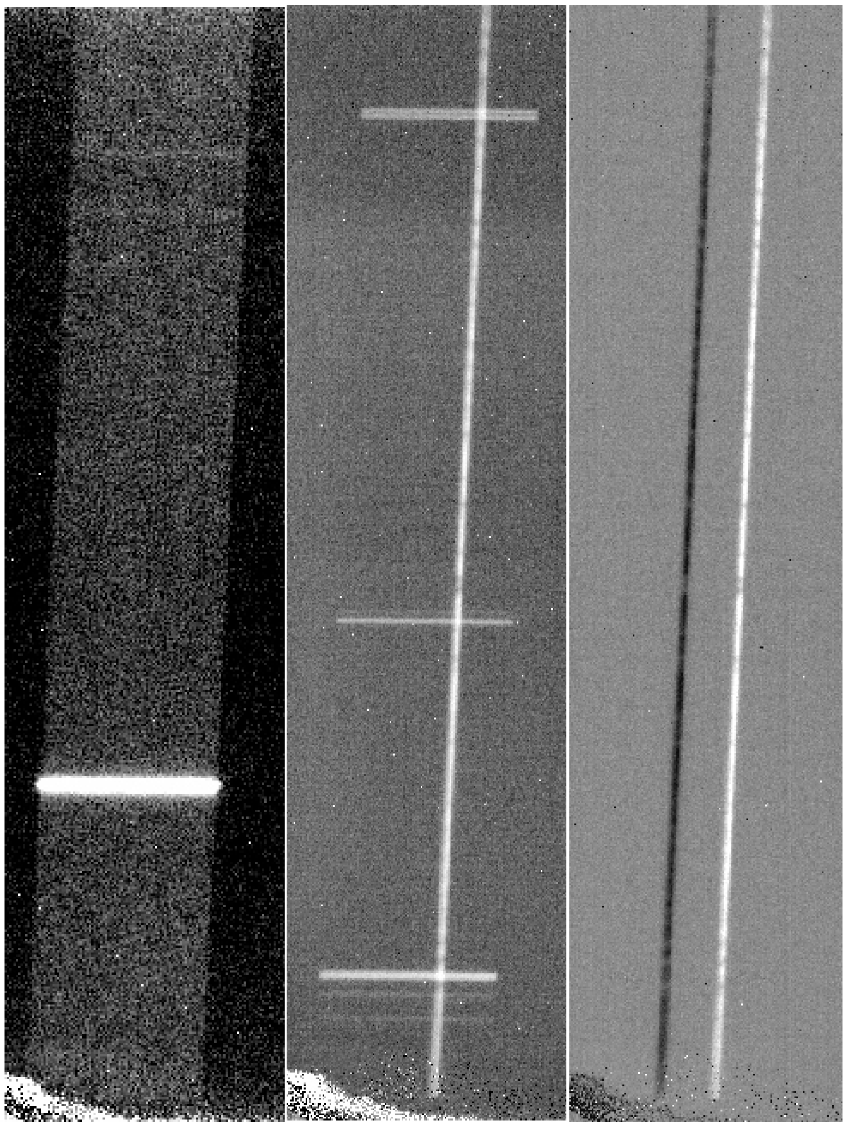

Figure 9 (from left): a. Image of ThAr hollow cathode lamp taken during the spectrograph focus procedure. b. Raw image of a star in the 6395 cm^{-1} band; note the OH emission lines from the atmosphere. c. Result of subtracting two images after dithering along the slit, demonstrating the removal of the sky features.

7. Mechanism Information

Of the seven mechanisms, five have discrete positions which can be commanded by number or name (Section 5). The grating and focus mechanisms can be moved continuously.

Filter: This wheel has 13 positions, including an open. The filter names are the photometric band and the central frequency in cm^{-1} (e.g., K4220 is at 4220 cm^{-1}).

CVF: This originally housed a continuously variable filter (CVF), but is now a second filter wheel. The naming convention is the same as for the filter wheel. Note that one of the Filter or CVF position must be open.

Slit: There are three slit widths: 2, 3, and 4 pixels. The 2 and 3 pixel slits have different lenses for three wavelength regions to focus the pupil on the cold (Lyot) stop. The open position is used for imaging the field.

Lyot: This wheel contains pupil stops for the 2.1-m and 4-m telescopes. Because the Phoenix foreoptics are transmissive, the pupil will be imaged at slightly different axial locations in the different wavelength regions, so there is a different Lyot stop for a particular photometric band. The masks are used for setup only.

Viewer: This can be used to image the slit or object directly on the detector (image), for darks (dark), or for normal spectroscopy (open). The Lyot position is used during setup.

Table 1 Phoenix Mechanism Positions

No.	Filter	CVF	Slit	Lyot	Viewer
1	**open**	**open**	**pinhole_n1**	**dark**	**image**
2	**M2150**	**ND**	**54µm_0.9-2.0**	**4m_1.1**	**dark**
3	**J9232**	**M1930**	**54µm_1.9-2.8**	**4m_1.5**	**open**
4	**L2734**	**L3010**	**54µm_3.0-5.0**	**4m_2.5**	**lyot**
5	**K4220**	**L2462**	**84µm_0.9-2.0**	**4m_3.6**	
6	**K4308**	**K4578**	**84µm_1.9-2.8**	**4m_5.1**	
7	**L3290**	**L2870**	**84µm_3.0-5.0**	**2m_1.1**	
8	**K4484**	**K4396**	**107µm_1.0-5.0**	**2m_1.5**	
9	**M2030**	**K4667**	**lyot_viewer**	**2m_2.5**	
10	**J7799**	**H6073**	**open**	**2m_3.6**	
11	**K4798**	**L3100**	**plus**	**2m_5.1**	
12	**H6420**		**dark**	**4m_mask_2.5mag_1.5**	
13	**J9440**			**4m_mask_2.5mag_3.0**	
14				**2m_mask_2.5mag**	
15				**mask_5mag**	
16				**secondary_mask**	

Table 2 Phoenix Order Sorting Filters

Name	**Filt**	**CVF**	**cm^{-1}**	**μm**	**Encoder**	**Order**	**Range (cm^{-1})**
M1930	1	3	1890-1970	5.076-5.291	-14764	11	1926.7-1934.3
M2030	9	1	1980-2030	4.808-5.050	7897	11	2024.3-2035.7
M2150	2	1	2105-2190	4.566-4.751	-5208	12	2144.7-2155.4
L2462	1	5	2410-2495	4.008-4.149	-13603	14	2456.4-2467.6
L2734	4	1	2680-2770	3.610-3.731	2131	15	2726.7-2741.3
L2870	1	7	2820-2910	3.436-3.545	-4716	16	2862.8-2877.2
L3010	1	4	2950-3050	3.279-3.390	-10368	17	3002.9-3017.1
L3100	1	11	3030-3145	3.180-3.300	2340	17	3091.7-3108.3
L3290	7	1	3240-3355	2.980-3.085	-22532	19	3283.2-3296.8
K4132	-	-	*4077-4156*	*2.406-2.452*	*-4064*	*23*	*4121.6-4142.4*
K4220	5	1	4188-4263	2.348-2.392	-13670	24	4210.4-4229.6
K4308	6	1	4258-4355	2.296-2.349	-4421	24	4297.2-4318.8
K4396	1	8	4355-4446	2.249-2.296	-13651	25	4386.0-4406.0
K4484	8	1	4429-4525	2.210-2.250	-4751	25	4472.8-4495.2
K4578	1	6	4525-4630	2.160-2.210	-12987	26	4567.5-4588.5
K4667	1	9	4617-4717	2.120-2.166	-4221	26	4655.3-4678.7
K4748	11	1	4704-4803	2.082-2.126	-13618	27	4737.2-4758.7
H6073	1	10	6017-6129	1.632-1.662	-6514	34	6058.1-6087.9
H6420	12	1	6377-6464	1.547-1.568	-7198	36	6404.4-6435.6
J7799	10	1	7750-7865	1.271-1.290	-9878	44	7780.6-7817.4
J8265	-	-	*8243-8360*	*1.196-1.213*	*-13620*	*47*	*8246.2-8283.7*
J9232	3	1	9183-9286	1.077-1.089	-9151	52	9210.0-9254.0
J9440	13	1	9397-9497	1.053-1.064		53	9424.2-9470.1
J9671	-	-	*9652-9709*	*1.030-1.036*	*-13662*	*55*	*9649.1-9692.9*

NOTE: Filters K4132, J8265, and J9671 are not currently installed in Phoenix

Name: Filter name. Photometric band and approximate center frequency
Filt, CVF: The 'filt' and 'cvf' settings for the filter
cm^{-1} : The approximate FWHM of the filter in cm^{-1}
μm : The approximate FWHM of the filter in microns
Encoder: The approximate 'grat' encoder setting of the center frequency with **no offset**
Order: The grating order at the center frequency
Range: The frequency coverage on the detector (in cm^{-1}) at the center frequency setting