

The MOSAIC/TIFKAM User's Manual

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1. Introduction

The MDM/Ohio State Array Infrared Camera (MOSAIC) is a multi-purpose infrared imager and spectrometer. The instrument was built as collaboration between MDM and Ohio State and was designed to work at the $f/7.5$ focus of the Hiltner 2.4-m telescope at 1-2.5 micron wavelengths. The instrument currently uses a 512x1024 InSb array supplied by NOAO. Internal optics allow for two plate scales and a variety of spectroscopic resolutions. Internal mechanisms control the selected filter, focal plane mask, pupil mask alignment, and optical arrangement. All mechanisms are user controlled and can be used to rapidly reconfigure the instrument, which allows for substantial observing flexibility.

Because MOSAIC is also the name of the 8K X 8K CCD imager at KPNO, the present instrument is referred to as TIFKAM or ONIS (Ohio State/NOAO Imaging Spectrograph) while in use at KPNO.

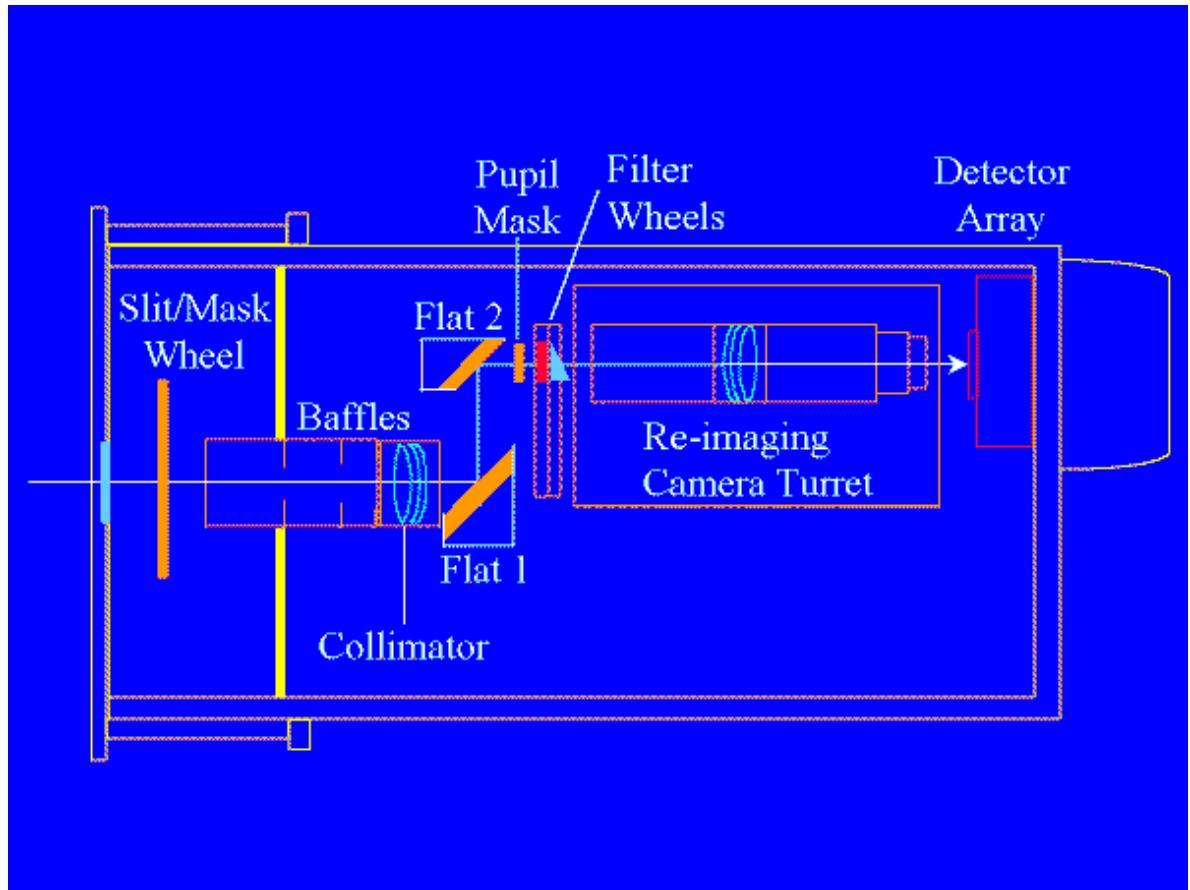
2. System Overview

TIFKAM is a general-purpose 1-2.5 micron imager and moderate-resolution spectrometer built as collaboration between Ohio State and the MDM (Michigan-Dartmouth-MIT) Observatory. The instrument was

designed to fully illuminate a 1024x1024 InSb array, but currently has a 512x1024 InSb array (supplied by NOAO and the USNO). The instrument can be used at any telescope with a beam slower than $f/7.5$ and includes cameras for two plate scales (approximately $f/7.5$ and $f/16.5$) and pupil viewing. Grisms provide spectroscopic dispersion with resolutions of ~ 600 to ~ 1200 (assuming a two-pixel slit) depending on the camera and grism used. All configurations of the instrument are under user control and can be selected rapidly (i.e. within a few minutes), so many different observational programs can be accommodated during a single night.

TIFKAM was designed to work at the $f/7.5$ cassegrain focus of the MDM 2.4-m Hiltner telescope, but has also been used at the MDM 1.3-m and KPNO 2.1-m and 4-m telescopes. In exchange for the large detector array, the instrument is available for community use at KPNO.

The [population](#) of the instrument filter, slit, and camera wheels changes occasionally, but generally includes standard broad band imaging filters (i.e. JHK) and a selection of grisms and slits.



The Light Path Through the Instrument

The control interface for the instrument is the *Prospero* package written at OSU. More information on *Prospero* can be found on the Web at

www.astronomy.ohio-state.edu/~prospero

Please note that *Prospero* is not an image processing package, but an interactive instrument control system. Simple commands for inspecting images are included in the *Prospero* command suite, but the observer is expected to use their favorite package to fully reduce and analyze their data (e.g. VISTA, IRAF, IDL, FIGARO, MIDAS, ZODIAC, HP-65, ABACUS, FINGERS). A useful summary of the *Prospero* commands pertinent to TIFKAM is provided in the form of a 2-page quick-reference card, copies of which may be obtained from:

www.astronomy.ohio-state.edu/~prospero/instcards.html

Or via our anonymous ftp server ([ftp.astronomy.ohio-state.edu](ftp://ftp.astronomy.ohio-state.edu), directory pub/prospero/instcards). A separate document, the [Prospero Observer's Guide](#), describes how to use the *Prospero* package.

Pictures of the instrument can be seen [here](#) along with a gallery of sample astronomical data on associated pages.

The instrument has many operational modes and has not been extensively tested in each. In particular, we have had very little photometric weather (thanks to El Nino) and have measured the throughput in the various spectroscopic modes only on the KPNO 2.1-m telescope. There are several known problems with the instrument which we note below. Our intent is to work on them as soon as possible, usually the next available opportunity to warm up and open the dewar. For historical interest, we also provide a list of problems the instrument has had in the past.

- [Reported Problems with TIFKAM](#)
- [Problems with TIFKAM in the past](#)

3. System Characteristics and Performance

Imaging

TIFKAM was designed for good image quality over the entire field of a 1024x1024 detector array. The optical design has a relatively small number of surfaces, so the instrumental throughput should be quite good. The terrible weather conditions during late 1997 and early 1998 has delayed accurate measurement of the actual throughput. One set of measurements at the KPNO 2.1-m suggest a total throughput (including the atmosphere and telescope optics) of approximately 0.25 in the J and H filters and 0.30 at K. More recent measurements in June 1998 at the KPNO 4-m under excellent conditions yield values 0.03 to 0.05 higher.

Feb 1999. The Ks filter previously in TIFKAM has been replaced. The new filter has significantly higher throughput, yields good images, and does **not** require a blocking filter.

TIFKAM has two camera lens sets ($f/7$ and $f/16.5$). The table below summarizes the possible plate scales:

Camera	Telescope			
	MDM 2.4m	MDM 1.3m	KPNO 2.1m	KPNO 4m
$f/7$	0.30"/pixel	0.55"/pixel	0.34"/pixel	0.18"/pixel
$f/16.5$	0.14"/pixel	0.26"/pixel	0.16"/pixel	0.08"/pixel

Here are representative photometric results.

Telescope	signal from 10th mag star (ADU/sec)				typical sky brightness (ADU/sec/pixel)			
	J + PK50	H	K	Ks	J + PK50	H	K	Ks
MDM 1.3m	...	...	...	...	...	...	...	...
KPNO 2.1m	61500	56500	30000	37300	30	130	250	125
MDM 2.4m	83000	63000	33000	...	...	...	...	...
KPNO 4m	220000	196000	100000	...	...	...	...	...

Spectroscopy

Spectroscopic capability is provided by grisms inserted into the beam by the filter wheel. Below is a table that summarizes the resolutions and wavelength coverages of the various possibilities. Note that the actual wavelength coverage will depend on the filter selected in the other filter wheel (i.e. if using the J/K grism and the K filter as a blocker, the wavelength coverage will only be 2000 to 2400 nm due to the transmission of the filter); we are currently trying to obtain special filters to use specifically as spectroscopic blockers. The table gives the resolution assuming the 50 micron slit is also inserted into the beam; this corresponds to roughly two pixels FWHM for unresolved lines. There is also a 100 micron slit that will give four pixels per resolution element and correspondingly lower spectral resolution. Note that this slit is recommended when the seeing is poor or when observing spectroscopically on the KPNO 4-m (where the 50 micron slit is only 0.36" wide).

grism	blocking filter	resolution (2 pixels)	full array wavelength coverage (nm)	illuminated rows
J/K	J	1450	1110 - 1360 (2 nd order)	400 - 982
J/K	K	1325	1970 - 2420 (1 st order)	160 - 704
H	H	1150	1480 - 1800 (2 nd order)	470 - 918
J+H	IJH	720	950 - 1910 (1 st order)	1 - 900
JHK	JHK	750	1220 - 2490 (usable to 2290; limited by blue leak)	1 - 1024

Signal Levels

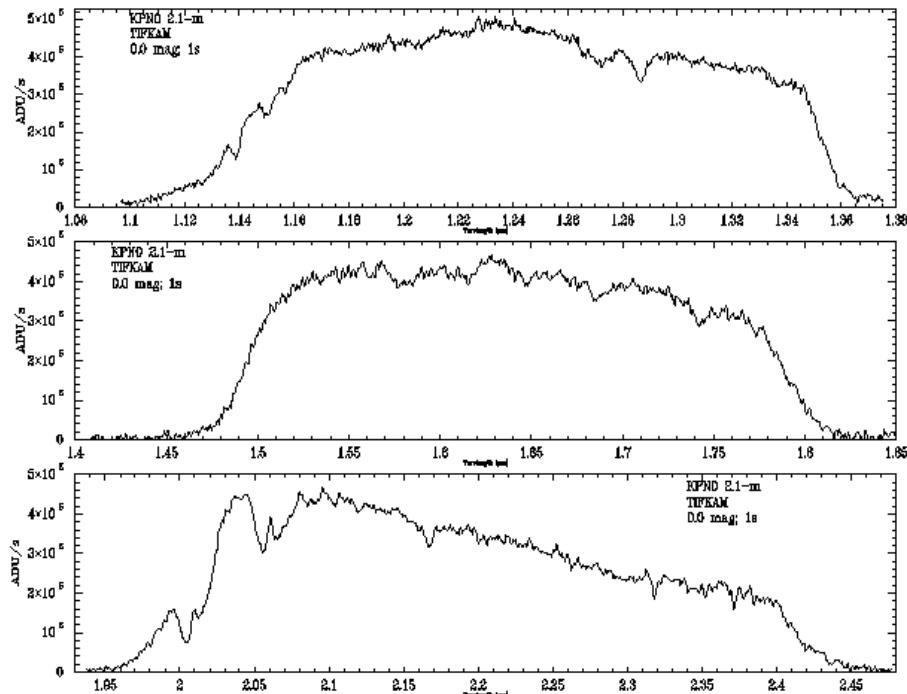
In order to estimate the spectroscopic throughput, we obtained slitless spectra of the Elias standard HD84800 in April 1998 at the KPNO 2.1-m telescope under clear but rather poor (1.5-2 arcsec) seeing conditions. The latter factor is not important in the throughput measurement, but it made

an estimate of the typical slit losses impractical. The three primary configurations (J filter, J/K Grism; H filter, H/L Grism; K filter, J/K Grism) all yielded approximately the same maximum signal ($\sim 5 \times 10^5$ ADU/s) referenced to a 0.0 mag star and an integration time of 1 s. These are the signals integrated through the spatial profile. The peak signal on a given row, which is an important consideration with regard to possible saturation, will naturally depend on the seeing. These spectra have been bias subtracted, but *not* flatfielded, as they are intended to be a guide to the raw signal level.

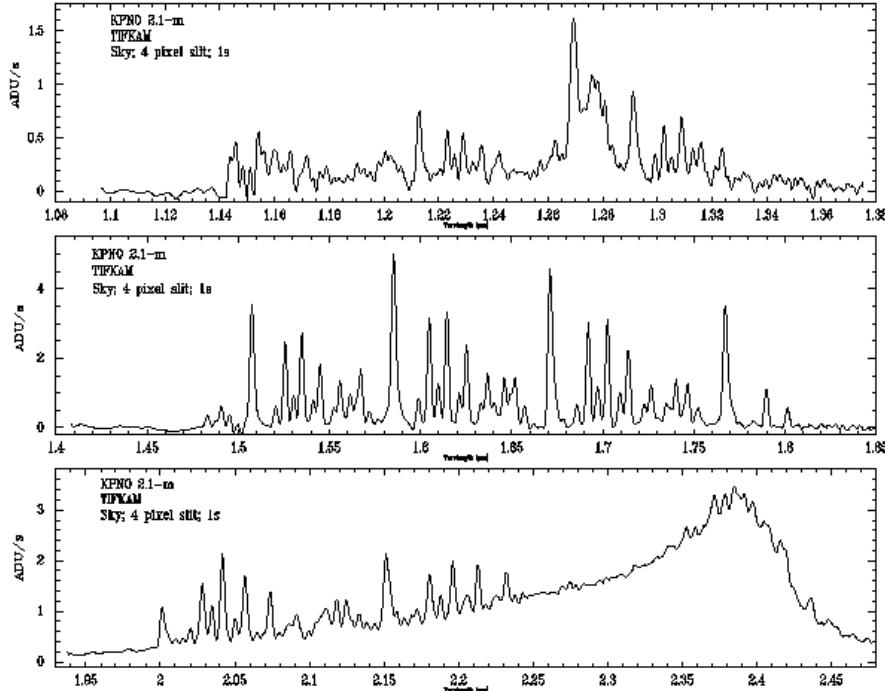
Sky Background Levels

On the same night, we measured the sky background through the 4 pixel slit, using the same three configurations. An equivalent dark exposure was used to subtract the bias, but the baseline subtraction may not be perfect. The plots, however, give a representation of the expected background. Use of a narrower slit will decrease the continuum in the K band proportionally, but will not affect the height of the OH emission lines, as they are unresolved.

- [Signal Levels for 0.0 mag star on KPNO 2.1-m](#)



- [Sky Background on KPNO 2.1-m](#)



4. The InSb Detector Array

Introduction

The infrared array currently in TIFKAM is a 512 X 1024 InSb array on loan from NOAO/USNO. The array is a product of the NOAO/USNO *Aladdin* development project and is one of the largest format infrared detectors in routine use. The array is a hybrid of a silicon multiplexer and an array of infrared sensitive detectors. The two pieces are pressed together, with indium bumps on each piece making the electrical connection. The multiplexor is an array of discrete read-out transistors and is unlike an optical CCD. In particular, the array can be read non-destructively and each pixel can be read separately and in any order. Although these differences do not matter for typical observing programs, future upgrades could permit additional observational flexibility. For example, designated sub-arrays could be read-out at high frequency, then shifted and added later to create diffraction limited images.

The band gap energy of InSb is ~5 times smaller than that of Si, so the detector array is sensitive to radiation out to wavelengths around 5500 nm. The relatively small band gap energy also causes high dark current at

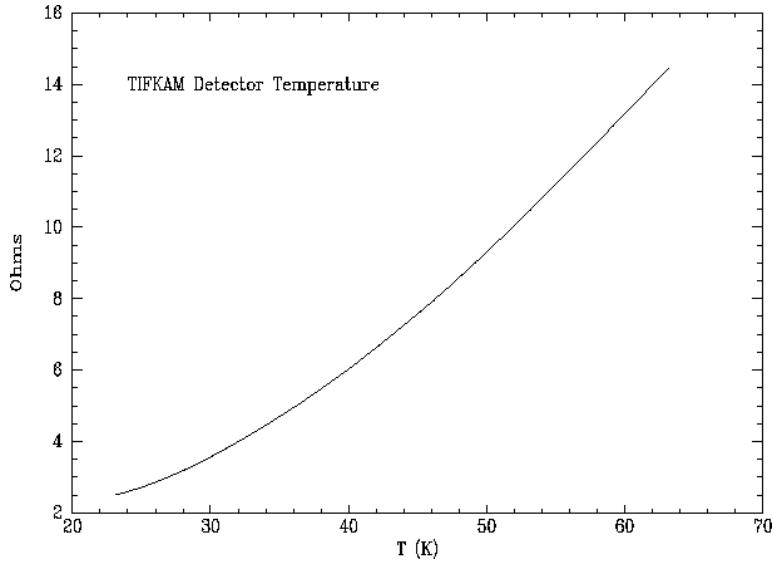
relatively high temperatures. If this array is operated at 77 K, for example, the dark current would be $\sim 1 \times 10^6$ e⁻/sec. Consequently, the array must be operated at a temperature significantly colder than LN₂. TIFKAM has a small mechanical refrigerator (a Split-Sterling Cycle cryo-cooler) that cools the detector and its mount to ~ 35 K.

TIFKAM Detector Characteristics

Pixel Size	27 microns
Operating Temperature	35 K
Detector bias	300 mV
System gain	4.0 electrons/ADU
Read noise	35 electrons RMS
Dark current	Approximately 1.2 electrons/s
Full well capacity	Approx 10^5 electrons
Minimum integration time	1.7 s

Dark Current and Read Noise

The dark current in the array is low. We currently measure ~ 0.3 ADU/sec dark current, some of which may be due to background radiation in the dewar. The dark current can be higher if the array cryo-cooler has lost power (the array is warming up) or if the instrument has been cold for less than ~ 36 hours. The [temperature of the array](#) is given on an LCD on the side of the large aluminum box (the unanodized, silver one). At the nominal detector temperature of 35 K, the LCD should read 4.5, with a slope of about 0.3/K. Values between 4.0 and 5.0 indicate a normal detector temperature. If you measure dark current significantly higher than 1 ADU/sec, please check the LCD and report the problem to Dick Joyce (rjoyce@noao.edu), Mike Merrill (mmerrill@noao.edu), or Darren DePoy (depoy@astronomy.ohio-state.edu). The read noise of the array is ~ 9 ADU. The effective read noise of the detector can be reduced by reading each pixel's signal non-destructively many times; factors of 2-3 improvement are possible. Note, however, that a read noise of 9 ADU is low compared to the shot noise for signals greater than ~ 1000 ADU, which happens quickly in most imaging and low-resolution spectroscopic observations. If your observations are read-noise limited, please contact Darren DePoy (depoy@astronomy.ohio-state.edu) for more information.



Maintenance

The only maintenance task required during an observing run is to keep the LN₂ topped off. Our experience is that filling the instrument once per day is sufficient. This task is handled by the OT, usually prior to opening up in the evening. The OT has been requested to log each fill of LN₂, along with the ambient temperature, detector temperature LCD readout, and power setting of the cryocooler into the logbook which is kept with the instrument.

Linearity and Saturation

The array becomes significantly non-linear before the well capacity of the detector is reached. Further, an accurate non-linearity correction depends on the signal rate as well as the total signal collected. However, non-linearity is <1% for <11,000 ADU at signal rates ranging up to ~600 ADU/sec (about the background rate at K on a warm night with the f/7 camera). We are working on obtaining more information about the reproducibility and signal-rate-dependence of the non-linearity; we currently suggest that interesting signals be kept to <8000 ADU so that non-linearity corrections should be <0.2%.

There may be a small offset between the integration time requested by the observer (and entered in the image header) and the actual time interval between the two reads of the double-correlated sampling cycle. This will result in an apparent non-linearity in the measurement of a constant signal as a function of integration time. Until we understand this better, we advise against the use of bright standard star observations at very short

integration times to photometrically calibrate object fields at much longer integration times.

Hard saturation of the detector array occurs at about 25,000 ADU. The array becomes seriously non-linear (>5%) at about 17,000 ADU.

Bad Pixels

There are many dead, hot, unresponsive, and just plain bad pixels on the array. There is a large group of essentially dead pixels in the upper left corner of the array (referred to as the "fingerprint" region for obvious morphological reasons) and many scattered bad pixels in the upper right corner of the detector. The large number of bad pixels makes it important to "dither" images so that all pieces of the sky are measured by a good pixel. We have a [bad pixel mask](#) dating from November 1998 stored here for convenience, although it is possible that this may become outdated in time.

After Image or Residual Charge

The detector array in TIFKAM exhibits a residual signal from bright sources. The magnitude of the residual image seems to depend on the brightness of and total signal recorded from the source. For typical observations the residual will be 0.5-2% of the originally detected signal. Reading the array several times reduces the magnitude of the residual image to <<1% of the original signal.

We do not know if the cause of the residual is our particular read-out electronics (reset voltages, bias level, etc.) or if it is intrinsic to the detector array. Other InSb arrays operated by KPNO do not seem to show this level of residual, but the particular detector in TIFKAM was not carefully evaluated using a KPNO system.

We suggest that if a 1% residual image will seriously compromise your results, you dither the telescope faithfully and, perhaps, read the array several times (set the exposure time to 0 seconds, do an `mgo 3`, and throw those images away) between each science exposure.

System Sensitivity

One may use the NOAO [Exposure Time Calculator](#) to estimate the performance of TIFKAM for imaging programs. However, it is very

important to understand the assumptions and limitations of this tool, and we strongly suggest reading the background material on [Signal-to-Noise Calculations](#).

5. Observing Setup

Unix Workstation Startup

Details of how to use the *Prospero* program for observing are described in detail in the *Prospero Observer's Guide* (available in the control room or on-line from the OSU anonymous ftp site, see [section 8](#) below). This section describes the setup procedures you need to follow on the first day of your observing run (or to do a full-dress recovery after a major system crash).

KPNO Startup

At the very beginning of your run at Kitt Peak, you need to configure the observing account for running the *Prospero* data-taking package, and delete the previous observer's data. This is accomplished for you by running the **osuinit** script. The procedure is as follows:

- Login to the workstation using the observer login name and password posted next to the machine (e.g., at the 2.1-m, this will be the machine named *lapis*, and at the 4-m it will be *khaki*).
- If there are any *IRAF* windows running, shut them down by typing the `logout` command at the **cl>** prompt in each window.
- Open a **Unix Xgterm** window using the console's mouse menu (via the right-hand mouse button).
- Enter `ps ax` and look for any *ariel* or *caliban* processes. If any are running, the **osuinit** script will not execute properly. You must exit them using the `kill -9 [PID]` command.
- In this xgterm window, type the `~osu/bin/osuinit` command. This script will ask you a series of questions designed to step through the re-initialization procedure. Answer them appropriately for your observing run. Among other things you will be asked to provide the names of the observers and the proposal ID number assigned by the TAC for your project. These two pieces of information are used to help track data from this run in the observatory's [Save-The-Bits Archive](#).

- When *osuinit* is done, it will ask you to logoff and log back in again. When it comes back, it will automatically run the *Prospero* program and some related tools (e.g., *IRAF*, etc.).

Among other things, *osuinit* will delete the previous observer's data files and reset the data storage directory used by the data-taking system for your images. You have to make sure that *IRAF* is closed and that the *ariel* and *caliban* daemons are not running before starting the *osuinit* script, as these will not be correctly reset if left running while *osuinit* is executing.

Note: When answering questions such as the desired data directory, it is necessary to enter the value (e.g., */data1/4meter/data*) explicitly. Even though the default value is given in square brackets, entering a carriage return is not sufficient!

Starting Prospero

At Kitt Peak, *Prospero* should startup automatically when you log back in after running the *osuinit* script. If you need to restart *Prospero* during an observing run, use the workstation menu (left mouse button) and select the option labeled **Data Acquisition (Prospero)** from the menu.

You should be presented with two windows: an xterm labeled "**Prospero Command**", and a second window labeled "**Prospero Status**" located immediately above the command window. The status window will be mostly blank until you have connected *Prospero* to the data-taking PCs and started an observing session.

Other programs needed on startup

Before *Prospero* can be connected to the data-taking PCs, you need to make sure that two other support programs are running: *ariel* and *caliban*.

ariel

The *ariel* program mediates communications between *Prospero* and the PC computers running the *ICIMACS* system. Under ideal circumstances, *ariel* should be executed automatically when the WC is started up, although in practice, it is usually necessary to manually start the *ariel* program by entering *ariel* at the keyboard of the WC.

caliban

The *caliban* program is responsible for transferring images in FITS format from the data-taking PCs to the Sparcstation. Before starting *caliban*, the *ICIMACS* system has to be turned on and the WC computer started and connected.

At KPNO, *caliban* is supposed to be started automatically upon login to the workstation after completing the *osuinit* process. If *caliban* is not running (or has crashed), it needs to be restarted by typing **in an xterm window on the workstation**

```
caliban fits
```

This appends the ".fits" extension to FITS files created by the system to enable reading them with the FITS kernel which became a standard feature with version 2.11 of *IRAF* in summer 1997.

The *caliban* setup at KPNO is also responsible for archiving all data taken with the instrument using the observatory's [Save-the-Bits](#) Archive. [Archive Status Reports](#) are available on-line via the Web.

Caliban will start up as an icon labeled "**Caliban**" and automatically connect to the WC and mount the two data transfer disks. Normally *caliban* is left as an icon to save on workstation screen space, and is only opened if you need to interact directly with *caliban* to investigate problems. Typing the ? in the *caliban* window will give a list of interactive commands. Be aware that careless use of the *caliban* command window could shut down the data transfer system and lead to loss of data (if you don't have a good reason to mess with it, you probably shouldn't).

prospero

Once *ariel* and *caliban* are running, go to the Prospero command window and enter

```
startup
```

There will be a bunch of chatter between *Prospero* and the various processes, and you will see the Prospero Status window begin to fill up with detector, instrument, and system status information. A detailed startup example is given in Appendix C of the *Prospero Observer's Guide*, along with discussion of possible error situations.

Finally, in the Prospero command window, enter

```
runinit
```

This will set up specific information for a night's run, such as the observers, proposal ID, data directory, filename, etc. It is a good idea to execute *runinit* at the beginning of each night, as it preserves various state variables and permits a quick recovery in case of a crash. In addition, the IC and WC configurations will also be saved for the same reason.

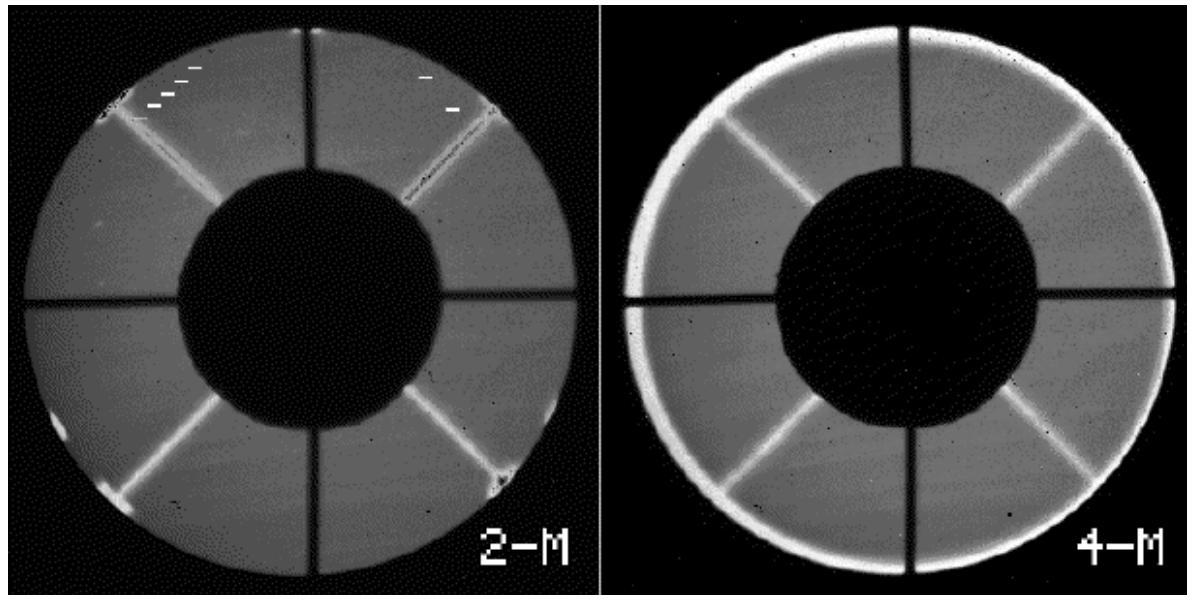
Setup Checklist

Pupil Mask Alignment

There is a silicon lens in the instrument that focuses the telescope pupil onto the detector array. There is also a cold pupil mask in the dewar that can be moved (using the `xpupil` and `ypupil` commands) to align the mask with the pupil to reject the thermal emission from the telescope secondary support and mirror cell. The procedure for aligning the mask is to insert the silicon lens and the K filter into the beam (see the list of wheel [populations](#) for the instrument to determine which turret and filter position is appropriate), set the camera focus to 2000 (`camfocus 2000`), and then issue the `ie campupil` command. The `ie campupil` is a direct command to the instrument electronics (hence the "ie" prefix) which offsets the camera turret to a position where the entirepupil can be seen on the detector array (note that this is not a legitimate location for the camera turret, but is between detented camera locations).

A short exposure against the night sky (clouds will do, but the interior of the dome is probably too bright) ideally should look like the figure below. The bright areas are the telescope, secondary, support structure, etc. that should be masked off by the cold stop. Adjust the values of `xpupil` and `ypupil` until the dark areas obscure as much of the bright as possible (the current mask is a compromise choice; it is not optimal for any particular telescope but includes a large central obscuration for the KPNO 2.1-m, an outer diameter for the MDM 2.4-m and KPNO 2.1-m, and secondary support vanes for MDM telescopes). Note that at the KPNO telescopes, the secondary support vanes are not aligned with the mask vanes and will always be bright. Because the KPNO 4-m primary is

masked down, the TIFKAM pupil stop is somewhat oversize and one will see a bright rim to the pupil image.



Pupil images at KPNO 2.1-m and 4-m

Note that this procedure need only be done once per run.

Focusing

Both the internal optics and the telescope should be in focus for the most optimal images.

The internal optics can be focussed by inserting one of the spectroscopic slits into the beam and then running the camera focus through a range of values. Steps of 50-100 in the camera focus are appropriate. Approximate values (March 1998) are `camfocus 100` for the $f/7.5$ camera, `camfocus 1100` for the $f/16.5$ camera, and `camfocus 2000` for the pupil viewing silicon lens. The best focus for the coronagraphic mask was determined to be approximately `camfocus 350`, but we recommend that potential users of this feature run through a focus sequence to verify this value. For spectroscopy, we recommend that the optimum camera focus be determined using a calibration line source. We found that the JHK grism yielded the optimum resolution at `camfocus 250`, even though the slit was focused at `camfocus 100` in direct imaging. The value of the the various camera foci do not change unless the detector array is removed or the optics are realigned, both of which require opening the dewar.

The telescope can then be focused in the normal manner. We generally find a rough focus by starting `movie` (which reads out the array continuously) and rapidly running the telescope focus in and out until the image looks good, then taking a series of images at different focus settings. There is no analog to the CCD command that reads out a single frame with multiple images of a star at various telescope foci. At the KPNO 2.1-m, the $f/8$ secondary readout at focus is approximately 15000.

Note that all the filters and prefilters are in collimated light, so there is no change of optimal focus with wavelength.

6. Observing Techniques

Imaging Observations

There are 5 mechanisms that you control from within the Prospero program: a slit/focal plane mask wheel ("slit"), two filter wheels (called "filter" and "prefilt"), the choice of camera ("camera"; which sets the imaging plate scale and spectral resolution), and the internal focus position of the camera ("camfocus"). The slit, filter, and camera selections can be most conveniently found by typing `print slit` or `print prefilt` etc., which then lists out the populations of that particular mechanism.

The syntax for moving these mechanisms is of the form `[mechanism] [value]`. To set up for J band imaging with the PK-50 blocker, for example, one would execute `prefilt 2` and then `filter 6`.

The plate scale at the KPNO 2.1-m was measured to be 0.341" per pixel in both the J and K filters by observations of NGC 7790 in September 1996, equivalent to a total field of view 175 X 349 arcsec. The scale at the 4-m telescope was measured to be 0.178" per pixel in June 1998. Based on the signals observed at the 2.1-m, the total (instrument + telescope) throughput is approximately 0.25 at J and H (both of which require a PK-50 blocker) and 0.30 at K. The slits are roughly 480 pixels long. The 2 pixel slit is slightly rotated with respect to the array, by about 2 pixels over the length of the slit. The 4 pixel slit appears aligned with respect to the array to within 1 pixel.

There are three ways of taking exposures: `go`, `mgo [n]`, and `avego [n]`. `go` takes a single exposure; `mgo [n]` takes **n** integrations and

writes **n** frames to the disk; `avego [n]` takes **n** integrations and writes 1 averaged frame to the disk. The array becomes significantly non-linear beyond ~8000 ADU, so it is advisable to keep the integration times sufficiently short to keep the background less than this level. At this point the background shot noise overwhelms the read noise anyway. The upper right quadrant seems to become non-linear at a somewhat lower level than the rest of the array.

Tmove

Mike Merrill's provisional IRAF script *tmove* may be used for centering stars on the array, using an image displayed in the `ximtool` window. Because this is not yet a standard IRAF task, it will probably have to be manually installed for an observing run.

- If the file "tmove.cl" is not found in the [telescope] or [tclSamples] directory.

```
# TMOVE: 23AUG95 KMM
# TMOVE: 12DEC95 KMM
# TMOVE: 16FEB95 KMM
# TMOVE: 23MAR94 KMM
# TMOVE: 23JUN94 KMM
# TMOVE: 04JUN99 RRJ
# TMOVE: 04JUN99 RRJ; MODIFIED FOR N-S TIFKAM ORIENTATION OPTION

procedure tmove ()

# Edit instrument and telescope string below for your configuration.
# Default orientation for TIFKAM is E-W slit. If slit is N-S, then
# set 'rotate = yes' in line 76 and uncomment lines 160,161

# You may wish to edit the "center" coordinates for the particular
# detector configuration for use with the 'c' key

# Install edited file in data directory and identify as an IRAF task
# with 'task tmove=tmove.cl'. Enter 'tmove' to execute

string instrument {"TIFKAM",
                   prompt="IR instrument
(SQIID|PHX|IRIM|CRSP|TIFKAM|none)?",
                   enum="SQIID|PHX|IRIM|CRSP|TIFKAM|none"}
string telescope {"2.1m", prompt="KPNO telescope
(1.3m|2.1m|4m|none)?",
                   enum="1.3m|2.1m|4m|none"}
bool verbose {yes, prompt="Verbose reporting"}

imcur *starco

begin
```

```

int      stat, nin, nout, slen, wcs, rid, prior
real     xin, yin, xref, yref, xshift, yshift, dist, adist, foo
real     xscale, yscale, xcenter, ycenter
bool    xinvert, yinvert, rotate
string   uniq, sjunk, sname, key
struct   command = ""

# Get offset between master reference and reference frames

if (instrument == "SQIID") {
    xcenter = 128.; ycenter = 128.
    xinvert = no; yinvert = yes; rotate=no
    if (telescope == "2.1m") {
        xscale = 0.76; yscale = 0.76 # K channel
    } else if (telescope == "4m") {
        xscale = 0.43; yscale = 0.43
    }
} else if (instrument == "PHX") {
    xcenter = 128.; ycenter = 512.; rotate=no
    if (telescope == "2.1m") {
        xscale = 0.25; yscale = 0.25 # Viewer Scale
        xinvert = yes; yinvert = no
    } else if (telescope == "4m") {
        xscale = 0.125 ; yscale = 0.125
        xinvert = no; yinvert = yes
    }
} else if (instrument == "IRIM") {
    xcenter = 128.; ycenter = 128.; rotate=no
    if (telescope == "2.1m") {
        xinvert = no ; yinvert = yes
        xscale = 1.09; yscale = 1.09
    } else if (telescope == "4m") {
        xinvert = no ; yinvert = yes
        xscale = 0.60; yscale = 0.60
    }
} else if (instrument == "CRSP") {
    xcenter = 85.; ycenter = 128.; rotate=no
    if (telescope == "2.1m") {
        xinvert = no ; yinvert = yes
        xscale = 0.61; yscale = 0.61
    } else if (telescope == "4m") {
        xinvert = yes ; yinvert = no
        xscale = 0.36; yscale = 0.36
    }
}

} else if (instrument == "TIFKAM") {
    xcenter = 200.; ycenter = 502.7; rotate=no
# Set rotate=yes if slit is N-S and uncomment lines 160, 161
    if (telescope == "2.1m") {
        xscale = 0.341 ; yscale = 0.341
        xinvert = yes; yinvert = yes
    } else if (telescope == "4m") {
        xscale = 0.178 ; yscale = 0.178
        xinvert = no; yinvert = yes
    }
} else if (instrument == "none") {
    xinvert = no ; yinvert = no ; rotate=no

```

```

}

if (!xinvert && !yinvert)
    print ("NORTH at top and EAST at left in frame XY system")
else if ( !xinvert && yinvert)
    print ("NORTH at bottom and EAST at left in frame XY system")
else if ( xinvert && !yinvert)
    print ("NORTH at top and EAST at right in frame XY system")
else if (xinvert && yinvert)
    print ("NORTH at bottom and EAST at right in frame XY system")

print ("Use image cursor to indicate current position...")
print ("Allowed keystrokes: |c(to center)|spacebar(here)|q(skip)|")
while (fscanf(starco,xin,yin,wcs,command) != EOF) {
    if (substr(command,1,1) == "\\\"")
        key = substr(command,2,4)
    else
        key = substr(command,1,1)

    if (key == "c") {
        xref = xcenter; yref = ycenter
        print ("")
        print ("==> Offset position: ",xin,yin," to frame center:
",xref,yref)
        break
    } else if (key == "040") {                      # 040 == spacebar
        print ("Current position is = ",xin,yin)
        print ("Indicate where you want to be...")
        while (fscanf(starco,xref,yref,wcs,command) != EOF) {
            if (substr(command,1,1) == "\\\"")
                key = substr(command,2,4)
            else
                key = substr(command,1,1)

            if (key == "c") {
                xref = xcenter; yref = ycenter
                print ("Desired position is frame center = ",xref,yref)
                break
            } else if (key == "040") {          # 040 == spacebar
                print ("Desired position is = ",xref,yref)
                break
            } else if (key == "q") {
                print ("Safe exit!")
                goto err
            } else {
                print("Unknown key: ",key," allowed =
|c|f|spacebar|q|")
                beep
            }
            break
        }
        print ("")
        print ("==> Offset position: ",xin,yin," to: ",xref,yref)
        break
    } else if (key == "q") {
        print ("Safe exit!")
        goto err
    }
}

```

```

    } else {
        print("Unknown key: ",key," allowed = |f|spacebar|q|")
        beep
    }
}

# Eastward motion of telescope is defined as positive
xshift = 0.1*real(nint(10.0*(xscale * (xref - xin))))
# Northward motion of telescope is defined as positive
yshift = -0.1*real(nint(10.0*(yscale * (yref - yin)))))

print(xinvert,yinvert, rotate)
if (xinvert)
    xshift = -1.0 * xshift
if (yinvert)
    yshift = -1.0 * yshift
# if (rotate)
#     foo = yshift; yshift = -1.0 * xshift; xshift = foo

dist = sqrt(xshift ** 2 + yshift ** 2)
adist = 0.01*real(nint(100.0*dist))
dist = adist/((xscale+yscale)/2.)
print ("Separation = ",dist," pixels : ", adist," arcsec")

if (xshift >= 0)
    print (xshift, " east")
else
    print (-1.0*xshift, " west")

if (yshift >= 0)
    print (yshift, " north")
else
    print (-1.0*yshift, " south")

print ("Within the instrument control window type: toffset
",xshift,yshift)

err:

xref = 0.0

end

```

- The script is defaulted for TIFKAM at the 2.1-m. If you are at the 4-m, it will be necessary to edit the telescope string parameter in the file "tmove.cl".
- The script is also defaulted for E-W slit orientation. If the instrument has been rotated so the slit is N-S, you must edit the file as noted in the file comments.
- In the data directory, identify the task to IRAF by entering the full path name of the file; e.g,

```
task tmove      =      /data1/4meter/tmove.cl
```

- To execute, enter `tmove`. You will be prompted to put the cursor on the star in the ximtool display. Entering `c` will compute the offset to the nominal slit center (200:502.7) on the best part of the array; entering [spacebar] will prompt you to move the cursor to the target position and enter another [spacebar], in the event the actual slit image center is different from the default. In either case, the computed offsets will be displayed in the IRAF window. You may also edit the 'xcenter' and 'ycenter' fields in the file "tmove.cl".

Spectroscopic Observations

Use imaging mode to acquire spectroscopic targets, offset the telescope to move the target onto the array location of the slit (which can be found by taking an image of the slit against the night sky; without the grism in place of course), acquire a guide star to "lock" the telescope onto the object, put in the slit, check that the telescope did not move while acquiring a guide star by taking another image (and correct the position if it did move), put in the grism, and start taking data. Note that the first few spectra may have residual image artifacts due to the previous imaging observations.

Executing several short "dummy" observations prior to taking science data will greatly reduce the magnitude of these artifacts. We recommend taking spectra of point sources at several positions along the slit to provide sky measurements and to aid in removal of systematic effects such as bad pixels which may occur in any one spectrum. Because the slit is so narrow, we strongly recommend the use of the autoguider at both the 2.1-m and 4-m telescopes.

NOTE: Although the grisms are in the nominally collimated beam, we have observed that the lines from a comparison source are in best focus at a camfocus value of approximately 250, whereas a direct image of the slit is best focused at a value of approximately 100. *We recommend that the optimum camera focus for spectroscopy be empirically determined using a source such as a comparison lamp or the atmospheric OH lines.*

Telescope Focus

There is a fairly strong focus dependence on temperature at both the 2.1-m and 4-m telescopes; in addition, the 2.1-m shows a pronounced effect with zenith distance. Once you have a good focus, the coefficients below will guide you in refocusing as the temperature and airmass changes.

Focus Change (F) with		T(°C) and	X
	F/ T	F/	X
4m	-90	0	
2.1m	-75	-130	

Prospero Scripts

Although *Prospero* commands are normally entered from the terminal, it is possible to execute a list of commands stored in an external text file. These scripts make it possible to execute complex or repetitive observing sequences, including loops and conditional branching from the vocabulary of individual *Prospero* commands. These may be written and stored on disk prior to observing. The [Prospero Command Procedure Scripts](#) Manual provides comprehensive coverage of this subject.

7. Calibration

Standard Stars

Photometric Standards

The best near-infrared standards are those defined by Elias et al (1982, AJ, 87, 1029), but these stars are all too bright to observe with TIFKAM without neutral density filters (i.e. they saturate the detector array in the minimum available exposure time). There are several sets of fainter standards including those measured by Carter & Meadows, the UKIRT Faint Standards, and a set of stars being measured to support NICMOS. The Carter & Meadows measurements appear to be excellent quality, but the stars are relatively bright (e.g. K = 9-10 mag) and may not be observable with TIFKAM without a neutral density (ND) filter. Since we do not know how "neutral" an ND filter is in the near infrared, this makes this set of standards somewhat problematic. Note, however, that an ND filter is currently installed in TIFKAM . The UKIRT standards are probably fine for measurements requiring no better than 5% accuracy or so.

We suggest that the list of [standards prepared for NICMOS](#) (Persson et al. 1998, A.J., 116, 2475) be used when the most accurate photometry is desired.

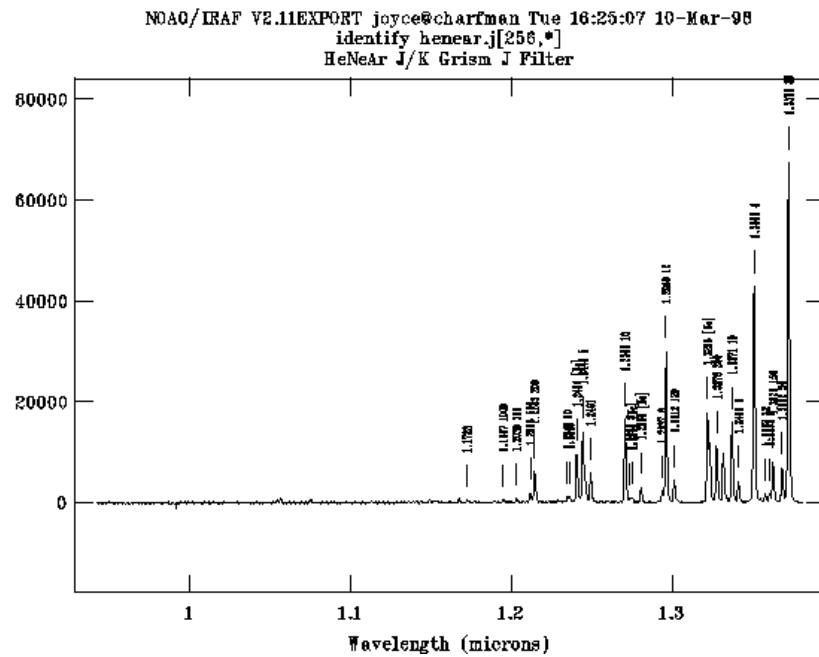
Spectroscopic Standards

The near-infrared region has many strong absorption features due to various molecules in the atmosphere. One of the best ways to remove these features is to ratio the spectrum of the target object with the spectrum of a featureless source observed with the same instrumental setup and airmass. In the J and K band, A stars provide good atmospheric standards, since they have only H absorption features at 2.17 microns (Br-gamma) and 1.28 microns (Pa-beta). In the H band, A stars have many Br-series absorption features that make them somewhat problematic. Note that Kurucz models of A stars actually seem to reproduce the near-infrared spectrum of these stars reasonably well, so these may be used to correct for the intrinsic absorption in the stellar atmosphere.

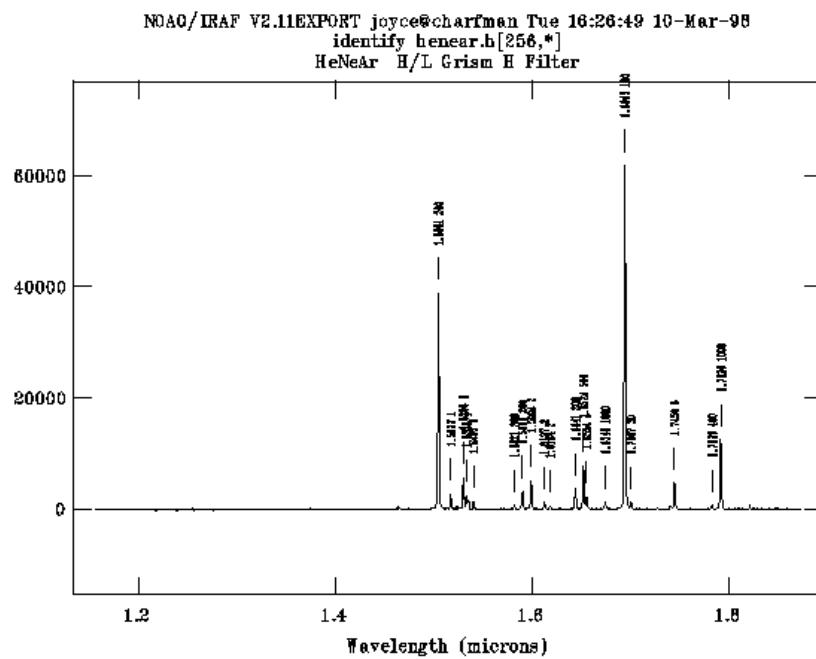
Wavelength Calibration

In the JHK region, the OH airglow lines which are such a nuisance do provide a useful grid for spectral calibration. However, at both the 2.1-m and 4-m telescopes, the spectral comparison sources built into the guiders provide an excellent Ar spectrum, with a few He and Ne lines thrown in. One may obtain a high S/N calibration spectrum with a 30 - 60 sec exposure (followed by an equal dark observation for bias subtraction) using the HeNeAr source, so this technique is recommended. Plots of HeNeAr spectra for the five presently available configurations are given below. These were obtained on the KPNO 2.1-m telescope with the 2 pixel slit.

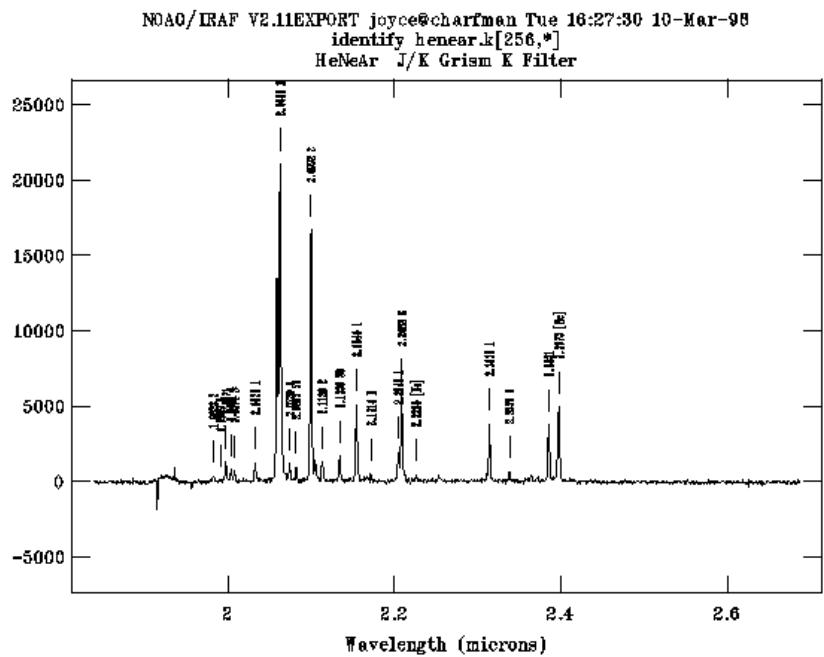
- [HeNeAr; J filter; J/K Grism](#)



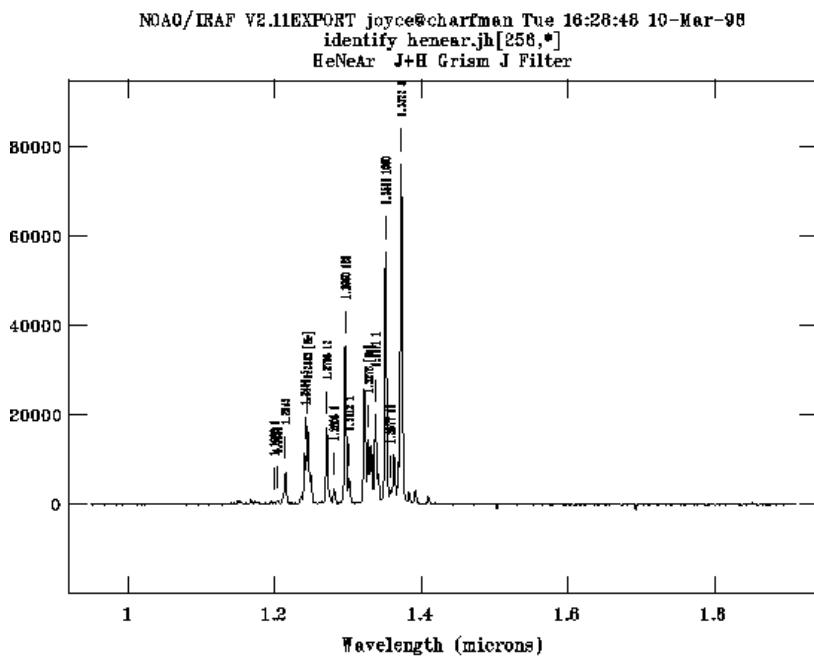
- HeNeAr; H filter; H/L Grism



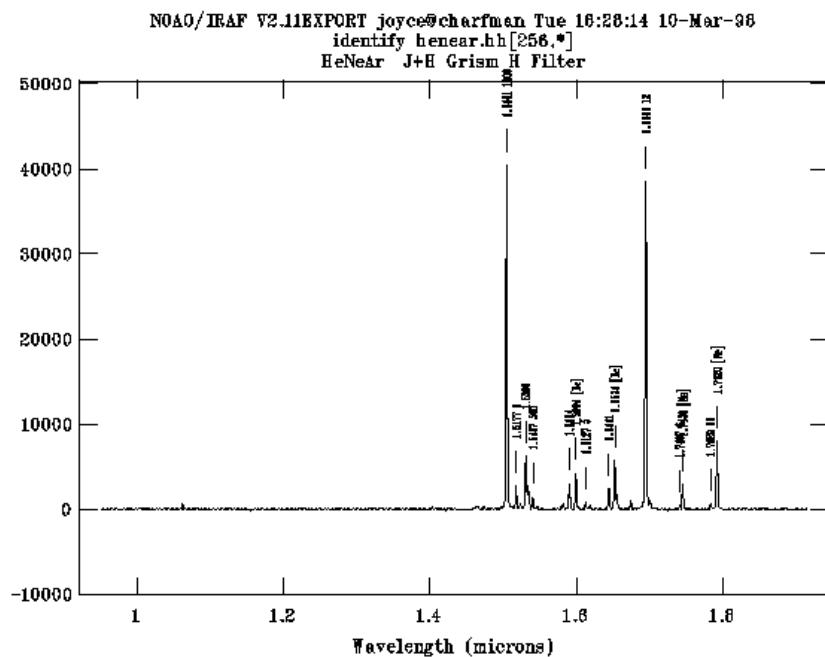
- HeNeAr; K filter; J/K Grism



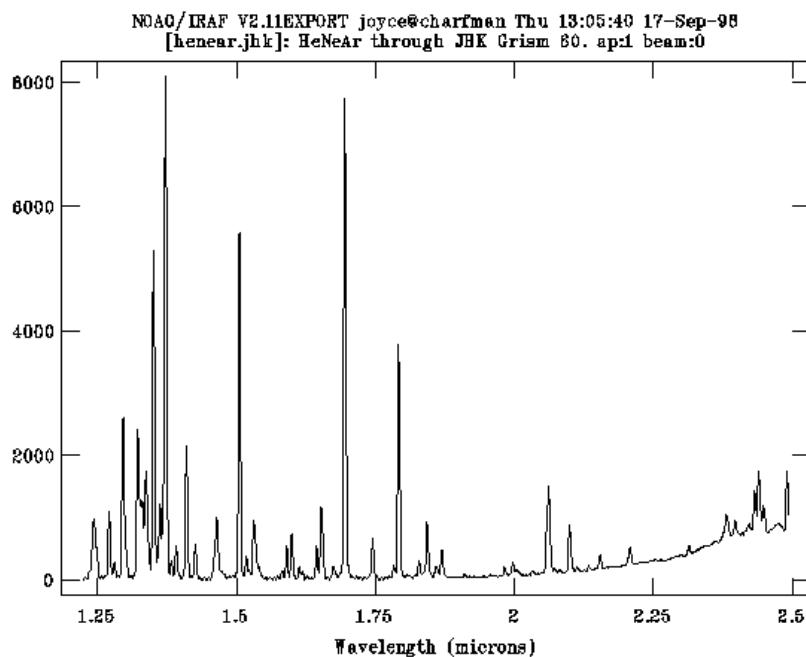
- HeNeAr; J filter; J+H Grism



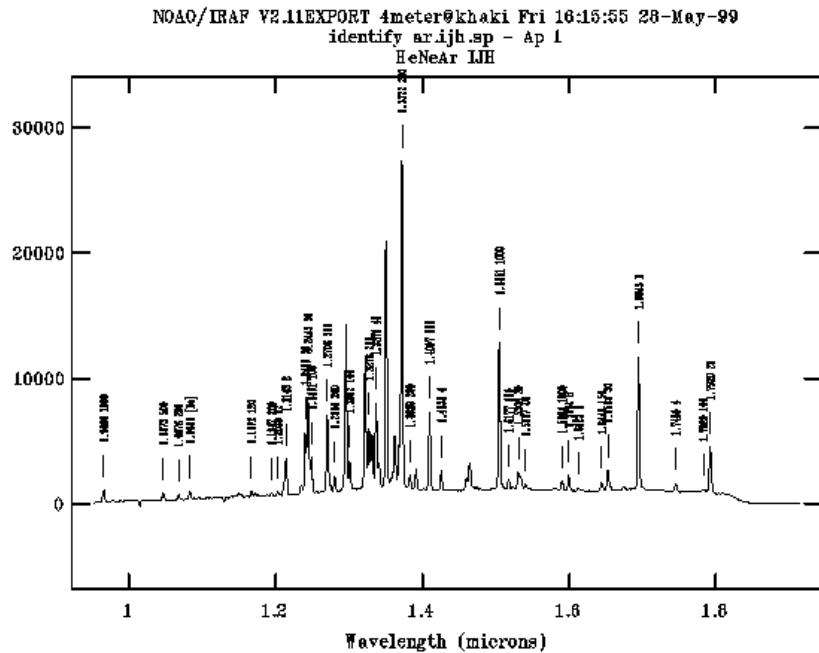
- HeNeAr; H filter; J+H Grism



- HeNeAr; JHK filter; JHK Grism



- HeNeAr; IJH filter; J+H Grism



Flat Fielding

The InSb detector array is reasonably flat; we have measured ~2% photometric accuracy for standard stars (at K) without flat-fielding the data. At the KPNO telescopes, the best flat fields seem to be made by observing the dome flat field screen with the lights on (at a low level in imaging mode) and with the lights off, forming the flat from the difference of the two. This technique seems to remove any significant scattered light or thermal emission component from the resulting flat.

HST/NICMOS Faint Standards

This page contains information on standard stars currently being used at CTIO with our facility imagers. The photometry data are from the lists compiled for the new faint HST/NICMOS standards on the Las Campanas (LCO) system. An additional set of RED stars has been observed on the LCO system. We are grateful to Eric Persson, and his collaborators David Murphy, Wojciech Krzeminski, Miguel Roth, and Marcia Rieke for making these data available for the CTIO www pages.

n	HST	RA(J2000)	Dec(J2000)	J	+/-	H	+/-	K	+/-	Ks	+/-
9101	P525-E	00:24:28.3	07:49:02	11.622	0.005	11.298	0.005	11.223	0.008	11.223	0.005

9103	S294-D	00:33:15.2	-39:24:10	10.932	0.006	10.657	0.004	10.596	0.005	10.594	0.004
9104	S754-C	01:03:15.8	-04:20:44	11.045	0.005	10.750	0.005	10.693	0.010	10.695	0.005
9105	P530-D	02:33:32.1	06:25:38	11.309	0.010	10.975	0.006	10.897	0.006	10.910	0.005
9106	S301-D	03:26:53.9	-39:50:38	12.153	0.007	11.842	0.005	11.772	0.010	11.788	0.006
9107	P247-U	03:32:03.0	37:20:40	11.934	0.005	11.610	0.004	11.492	0.011	11.503	0.005
9108	P533-D	03:41:02.4	06:56:13	11.737	0.009	11.431	0.006	11.337	0.008	11.336	0.005
9109	S055-D	04:18:18.9	-69:27:35	11.552	0.002	11.326	0.002	11.255	0.027	11.269	0.002
9111	S361-D	04:49:54.6	-35:11:17	11.246	0.006	11.031	0.006	10.992	0.033	10.980	0.006
9113	S252-D	05:10:25.6	-44:52:46	11.059	0.005	10.766	0.005	10.708	0.034	10.713	0.005
9115	S363-D	05:36:44.8	-34:46:39	12.069	0.007	11.874	0.005	11.826	0.007	11.831	0.005
9116	S840-F	05:42:32.1	00:09:04	11.426	0.009	11.148	0.009	11.077	0.014	11.058	0.008
9118	S842-E	06:22:43.7	-00:36:30	11.723	0.011	11.357	0.009	11.264	0.016	11.261	0.010
9119	S121-E	06:29:29.4	-59:39:31	12.114	0.006	11.838	0.005	11.765	0.009	11.781	0.005
9121	S255-S	06:42:36.5	-45:09:12	11.719	0.004	11.434	0.004	...	...	11.372	0.004
9122	P161-D	07:00:52.0	48:29:24	11.680	0.006	11.408	0.006	11.356	0.013	11.352	0.006
9123	S427-D	06:59:45.6	-30:13:44	10.833	0.007	10.499	0.007	10.431	0.015	10.442	0.009
9125	S005-D	07:19:38.6	-84:35:06	10.885	0.007	10.598	0.006	10.514	0.013	10.522	0.008
9126	P309-U	07:30:34.5	29:51:12	11.876	0.013	11.522	0.014	...	...	11.450	0.022
9129	S209-D	08:01:15.4	-50:19:33	10.914	0.007	10.585	0.006	10.487	0.021	10.496	0.009
9131	P035-R	08:25:43.8	73:01:18	10.819	0.008	10.546	0.007	10.499	0.010	10.515	0.008
9132	S312-T	08:25:36.1	-39:05:59	11.949	0.006	11.669	0.005	11.608	0.004	11.609	0.004
9133	S495-E	08:27:12.5	-25:08:01	11.521	0.007	11.048	0.008	10.965	0.016	10.960	0.010
9134	P545-C	08:29:25.1	05:56:08	11.881	0.007	11.624	0.005	11.575	0.005	11.596	0.006
9135	S705-D	08:36:12.5	-10:13:39	12.362	0.010	12.098	0.011	...	...	12.040	0.014
9136	S165-E	08:54:21.7	-54:48:08	12.489	0.008	12.214	0.008	12.138	0.018	12.142	0.011
9137	S372-S	09:15:50.5	-36:32:34	11.153	0.007	10.891	0.007	10.830	0.019	10.836	0.010
9138	S852-C	09:41:35.8	00:33:12	11.354	0.006	11.041	0.006	10.981	0.015	10.982	0.008
9139	P091-D	09:42:58.7	59:03:43	11.683	0.008	11.338	0.007	11.276	0.011	11.282	0.010
9140	S262-E	09:45:42.8	-45:49:40	11.409	0.011	11.085	0.008	...	...	11.022	0.012
9141	S708-D	09:48:56.4	-10:30:32	11.081	0.008	10.775	0.008	10.715	0.035	10.718	0.010
9142	P212-C	10:06:29.0	41:01:26	11.993	0.006	11.729	0.005	11.686	0.009	11.697	0.007
9143	P550-C	10:33:51.8	04:49:05	12.344	0.007	12.121	0.005	12.067	0.006	12.081	0.005
9144	S264-D	10:47:24.1	-44:34:05	11.642	0.009	11.335	0.008	11.263	0.018	11.280	0.010
9145	P064-D	12:13:12.0	64:28:56	11.958	0.009	11.711	0.008	11.664	0.011	11.675	0.009
9146	S217-D	12:01:45.2	-50:03:10	11.323	0.007	11.002	0.005	10.931	0.003	10.936	0.004
9147	S064-F	12:03:30.2	-69:04:56	12.111	0.007	11.803	0.007	11.722	0.013	11.724	0.007
9148	P266-C	12:14:25.4	35:35:55	11.642	0.009	11.378	0.008	11.324	0.011	11.343	0.008

9149	S860-D	12:21:39.3	-00:07:13	12.213	0.007	11.917	0.006	11.861	0.005	11.865	0.005
9150	S791-C	13:17:29.6	-05:32:37	11.661	0.008	11.310	0.007	11.250	0.014	11.267	0.008
9152	P133-C	13:58:40.2	52:06:24	11.149	0.009	10.878	0.007	10.831	0.011	10.839	0.010
9153	P499-E	14:07:33.9	12:23:51	11.947	0.008	11.605	0.008	11.560	0.013	11.540	0.008
9154	S008-D	14:23:45.5	-84:09:58	11.232	0.007	10.990	0.007	10.904	0.009	10.915	0.008
9155	S867-V	14:40:58.0	-00:27:47	12.045	0.008	11.701	0.005	11.622	0.005	11.633	0.005
9156	P041-C	14:51:57.9	71:43:13	10.873	0.008	10.588	0.006	10.523	0.009	10.530	0.007
9157	S273-E	14:56:51.9	-44:49:14	11.341	0.007	10.924	0.005	10.851	0.004	10.849	0.004
9158	P272-D	14:58:33.1	37:08:33	11.640	0.008	11.277	0.006	11.210	0.008	11.223	0.007
9160	S870-T	15:39:03.5	00:14:54	10.914	0.008	10.701	0.008	10.649	0.010	10.659	0.009
9162	P177-D	15:59:13.6	47:36:40	12.258	0.012	11.924	0.008	11.857	0.013	11.868	0.012
9164	P565-C	16:26:42.7	05:52:20	12.180	0.007	11.895	0.006	11.842	0.007	11.844	0.006
9166	P330-E	16:31:33.6	30:08:48	11.816	0.007	11.479	0.005	11.419	0.007	11.429	0.006
9169	P138-C	17:13:44.5	54:33:21	11.355	0.007	11.118	0.005	11.075	0.008	11.080	0.007
9170	S875-C	17:27:22.2	-00:19:25	11.132	0.005	10.835	0.005	10.739	0.006	10.744	0.005
9172	S279-F	17:48:22.6	-45:25:45	12.477	0.009	12.118	0.006	12.026	0.006	12.031	0.006
9173	S024-D	18:18:46.2	-80:06:58	11.039	0.007	10.778	0.007	10.693	0.009	10.711	0.008
9175	S071-D	18:28:08.9	-69:26:03	12.252	0.006	11.916	0.007	11.834	0.011	11.839	0.007
9177	P182-E	18:39:33.7	49:05:38	12.104	0.005	11.764	0.004	11.688	0.006	11.696	0.005
9178	S808-C	19:01:55.4	-04:29:12	10.966	0.007	10.658	0.008	10.566	0.014	10.575	0.008
9181	S234-E	20:31:20.4	-49:38:58	12.464	0.011	12.127	0.008	12.095	0.007	12.070	0.007
9182	S813-D	20:41:05.1	-05:03:43	11.479	0.005	11.142	0.005	11.082	0.010	11.085	0.005
9183	P576-F	20:52:47.3	06:40:05	12.247	0.004	11.940	0.004	11.873	0.007	11.880	0.005
9185	S889-E	22:02:05.7	-01:06:02	12.021	0.005	11.662	0.004	11.586	0.012	11.585	0.005
9186	S893-D	23:18:10.0	00:32:56	11.403	0.009	11.120	0.006	11.045	0.006	11.055	0.006
9187	S677-D	23:23:34.4	-15:21:07	11.857	0.003	11.596	0.003	11.538	0.009	11.542	0.003
9188	P290-D	23:30:33.4	38:18:57	11.634	0.005	11.337	0.004	11.257	0.008	11.262	0.006

In addition, we are assembling [finding charts](#) for all the standards listed in these tables. These will be useful at the telescope.

please mail questions or comments to: Bob Blum (rblum@noao.edu). rev 31 July 1998.

8. Additional Information

World-Wide Web Services:

MOSAIC/TIFKAM Web Page:

<http://www.astronomy.ohio-state.edu/~isl/mosaic.html>

This site includes descriptions of the instrument (with pictures), and access to copies of all of the documentation.

Prospero Support Web Page:

<http://www.astronomy.ohio-state.edu/~prospero>

This web site includes a searchable online manual for the *Prospero* package, and copies of all of the documentation. A help line and other services will be included in the future.

Documents available via Anonymous FTP:

Connection info:

ftp site: [ftp.astronomy.ohio-state.edu](ftp://ftp.astronomy.ohio-state.edu)

login: anonymous

password: your full email address

MOSAIC/TIFKAM Documents:

PostScript format copies of all MOSAIC/TIFKAM documents are available online at our anonymous ftp site as well as through our WWW sites above:

```
cd pub/MOSAIC
```

Documents are available as either gzip compressed PostScript (.gz) files or uncompressed PostScript (.ps) files. For example:

```
binary  
get mosaic.gz
```

or

```
ascii  
get mosaic.ps
```

and print using

```
zcat mosaic.gz | lpr
```

for gzip compressed files.

To download the complete document package (compressed tar archive):

```
binary  
get mosdocs.tar.Z
```

and unpack using

```
zcat mosdocs.tar.Z | tar xvf -
```

See the **README** file for the list of available documents.

Prospero Documents:

PostScript format copies of the various Prospero manuals and reference guides are available online at our anonymous ftp site as well as through our WWW sites above:

```
cd pub/prospero
```

Individual files are available as either gzip compressed PostScript (.gz) files or uncompressed PostScript (.ps) files. For example, to retrieve the observer's guide, you would type either:

```
binary  
get obsguide.gz
```

or

```
ascii  
get obsguide.ps
```

To retrieve all documents (Unix tar file):

```
binary  
get prdocs.tar
```

and unpack using

```
tar xvf prdocs.tar
```

A gzip-compressed archive is available as **prdocs.tgz**. See the **README** file for the list of available documents.

KPNO Support Staff

The TIFKAM support scientists for KPNO are Mike Merrill mmerrill@noao.edu and Dick Joyce rjoyce@noao.edu.

*rjoyce@noao.edu
14 Sep 1999*